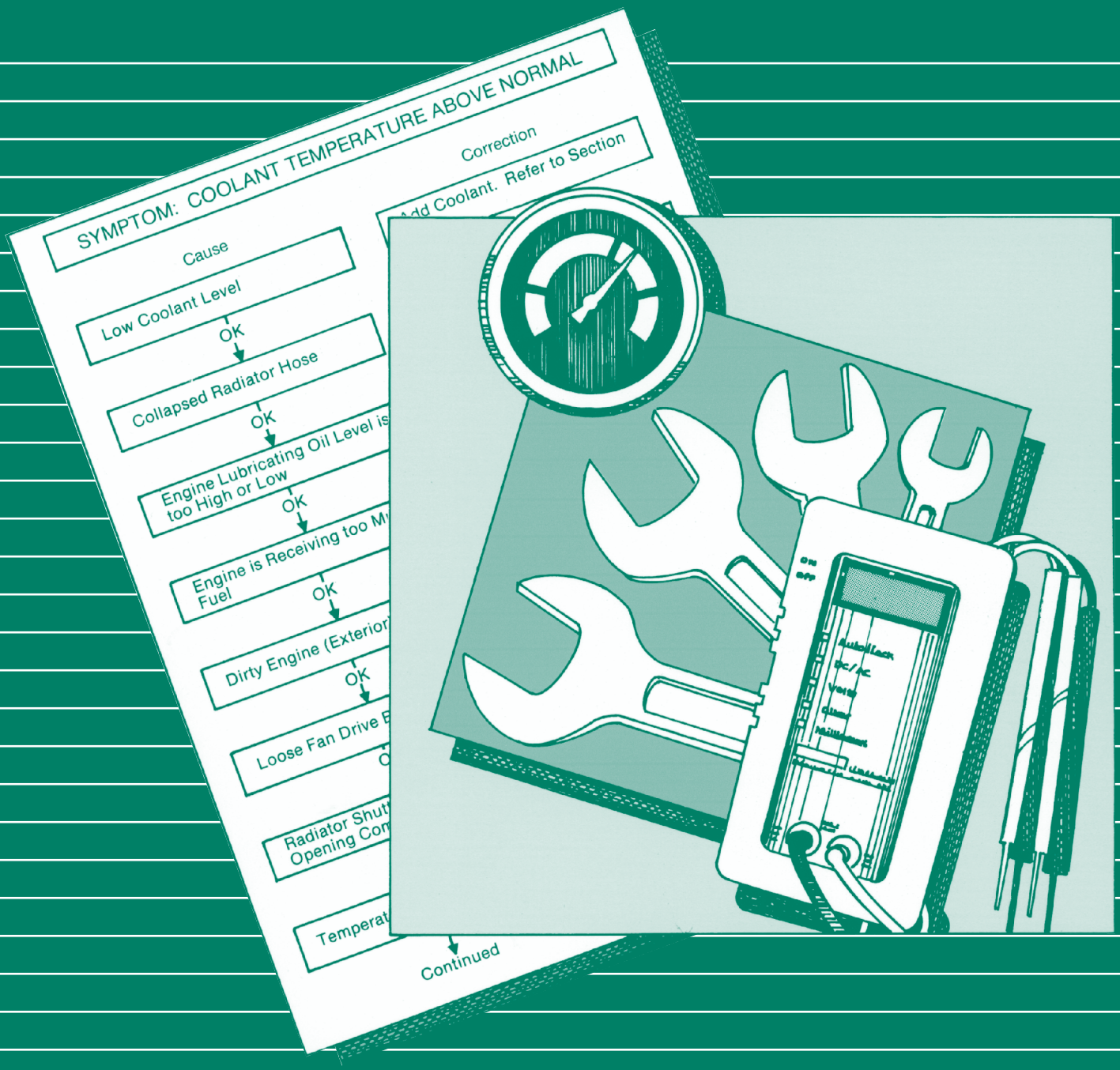
Service Manual
B3.9, B4.5, B4.5 RGT, and B5.9
Volume 1



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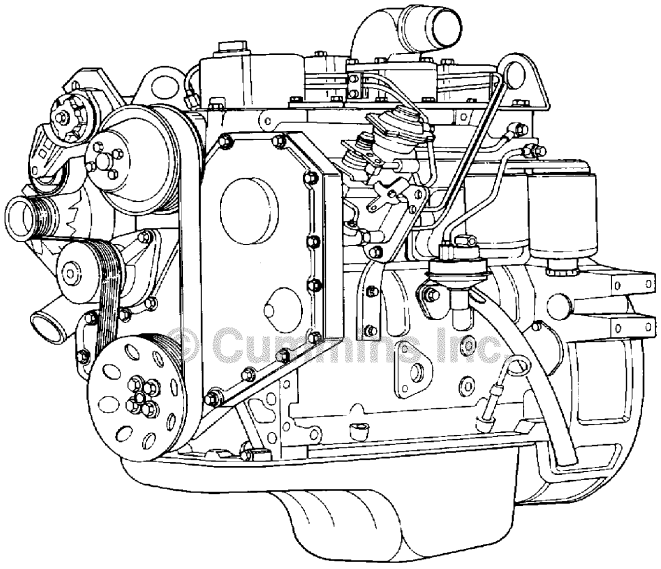
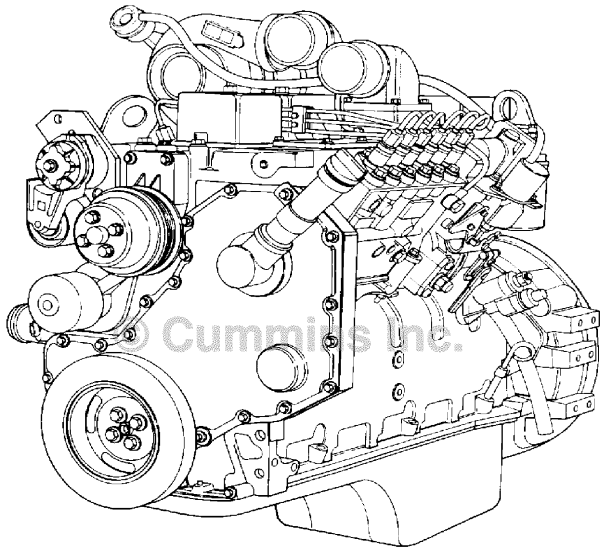


B3.9 and B4.5



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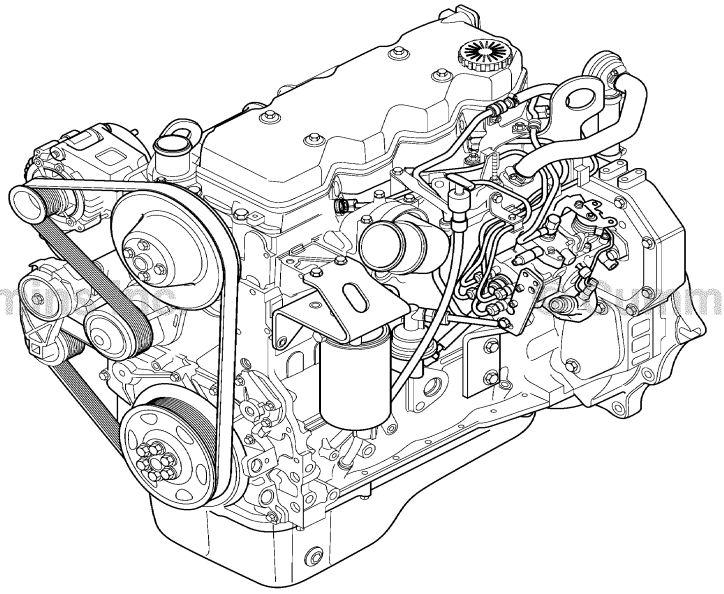

B4.5 RGT

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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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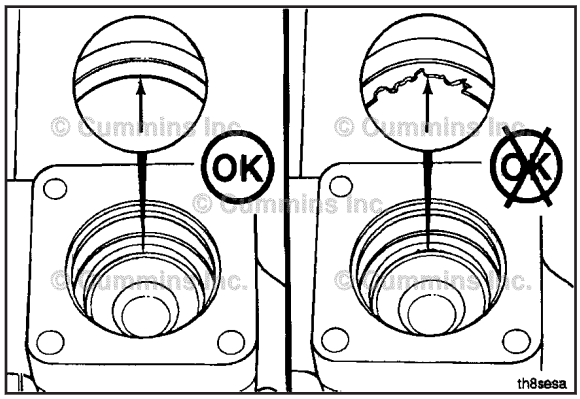
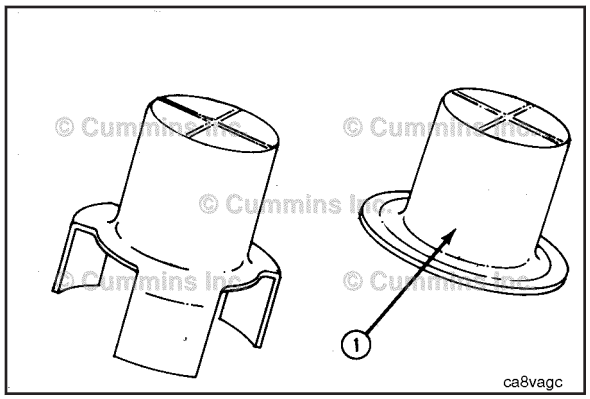


Illustrations

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 E - Engine and System Identification

Section Contents

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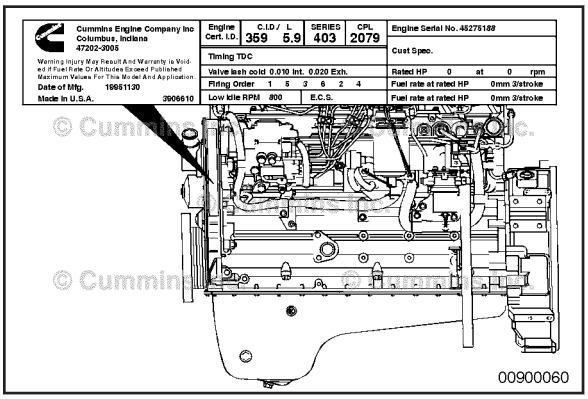
Engine Identification

Engine Dataplate

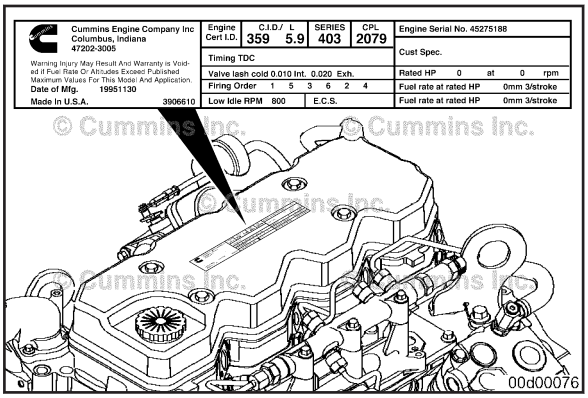
B3.9, B5.9, and B4.5 Engines

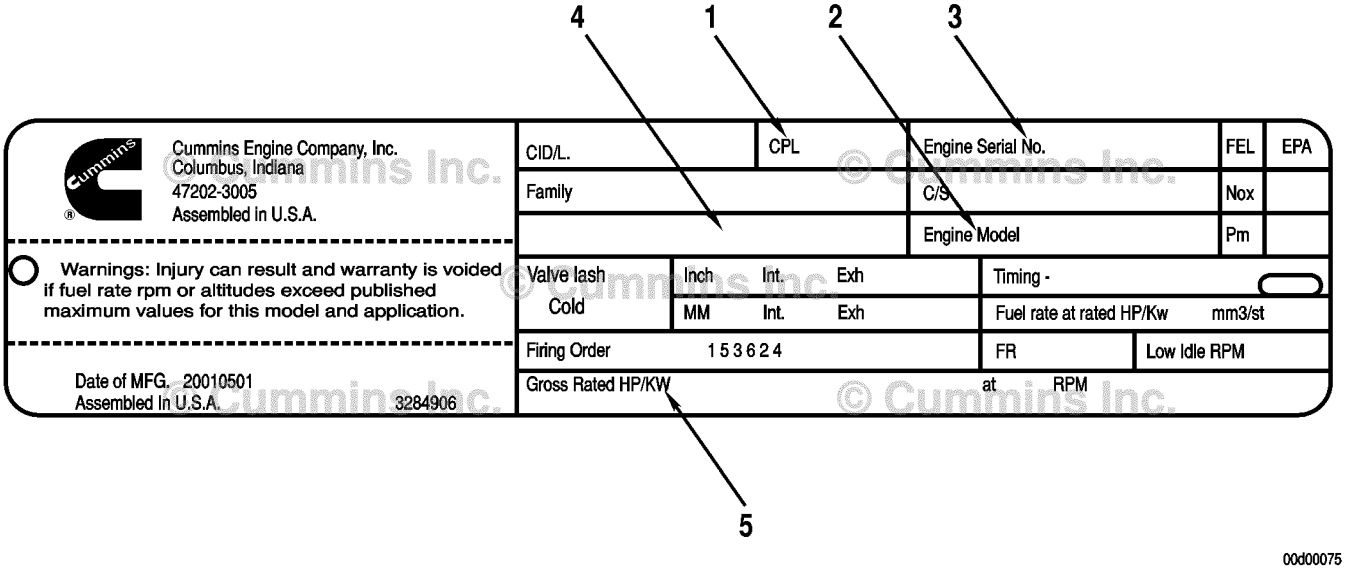
The engine dataplate shows specific facts about your engine. The engine serial number and Control Parts List provide information for ordering parts and for service. The engine dataplate **must not** be changed unless approved by Cummins Inc.



B4.5 RGT Engines

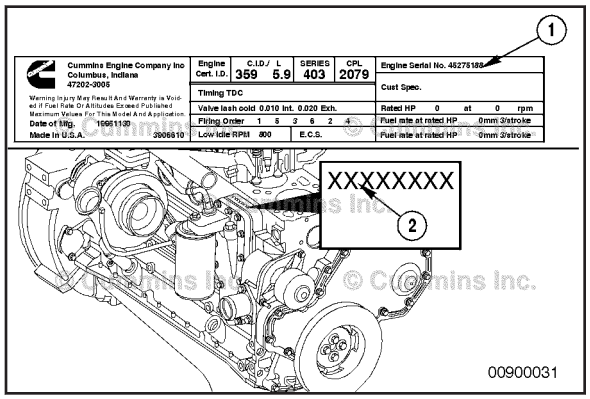
The engine dataplate shows specific facts about your engine. The engine serial number and Control Parts List provide information for ordering parts and for service. The engine dataplate **must not** be changed unless approved by Cummins Inc.



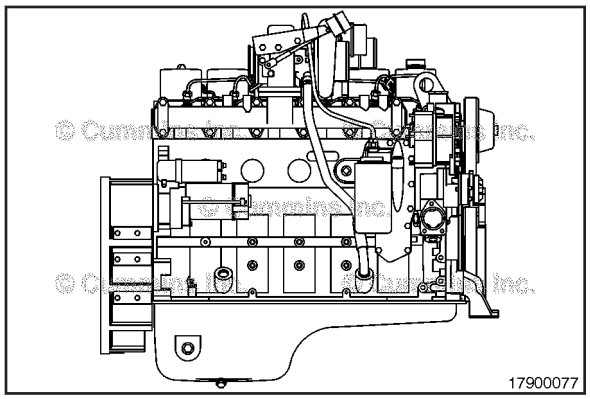


Have the following engine data available when communicating with a Cummins Authorized Repair Location. The information on the dataplate is **mandatory** when sourcing service parts.

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



NOTE: If the engine dataplate (1) is **not** readable, the engine serial number (2) can be identified on the engine block above the oil cooler.

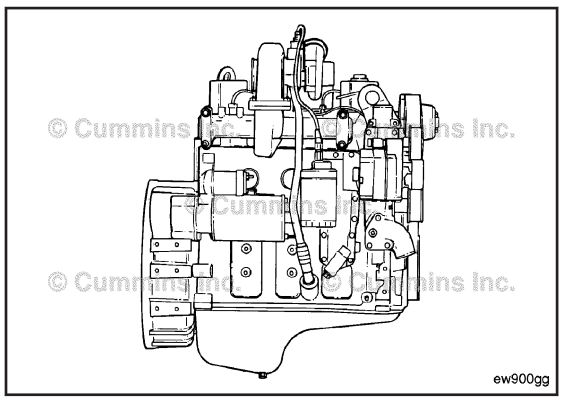


Cummins® Engine Nomenclature

B5.9

The model name provides the following engine data:

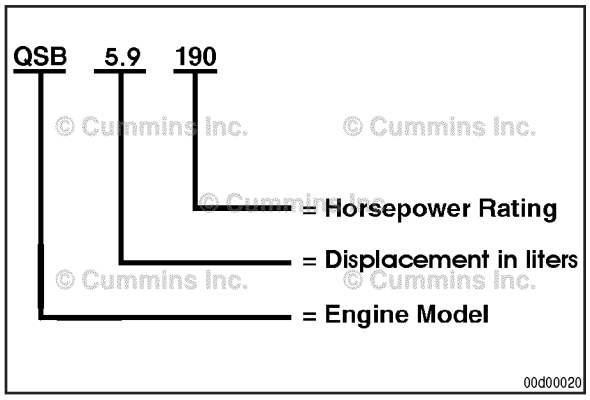
B = Engine series
5.9 = Displacement in liters.



B3.9

The model name provides the following engine data:

B = Engine series
3.9 = Displacement in liters.



The Cummins engine nomenclature provides the data as illustrated in the graphic.

The model name for engines in automotive applications provides the data shown below For example:

B3.9-105

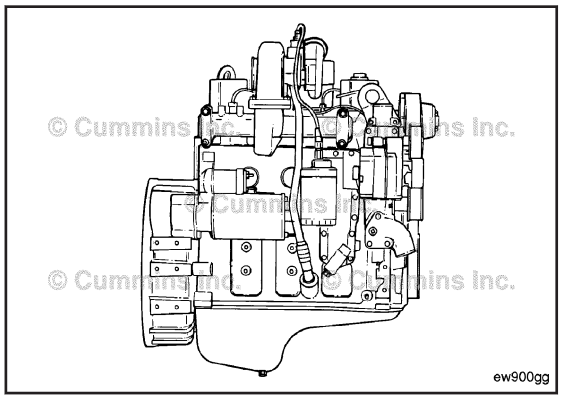
B = Engine series
3.9 = Displacement in liters
105 = Advertised horsepower.

The model name for engines in industrial applications provides the data shown below For example:

4BTAA-3.9

4 = Number of cylinders
B = Engine series
T = Turbocharged
AA = Charge air cooled
3.9 = Displacement in liters.

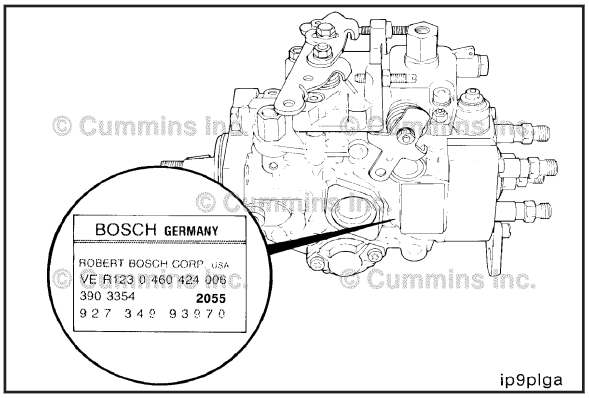
NOTE: The suffix RGT refers to “Rear Gear Train” engines.



Fuel Injection Pump Dataplate

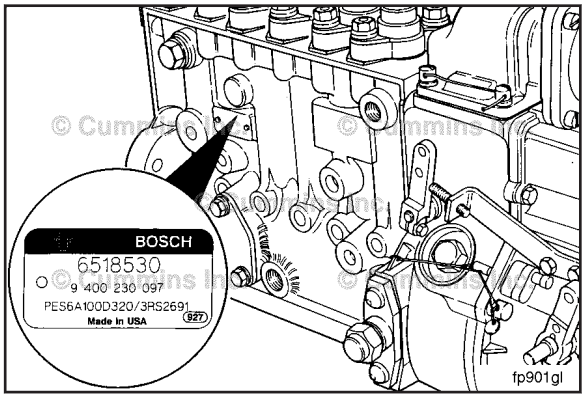
Bosch® Rotary

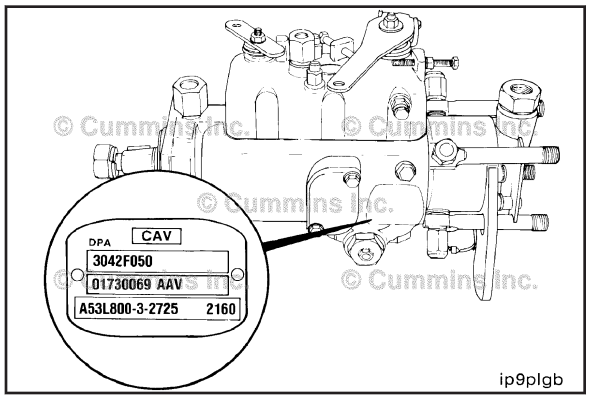
The injection pump dataplate for the Bosch® VE pump is located on the side of the injection pump. The dataplate provides information for fuel pump calibration.



Bosch® In-line

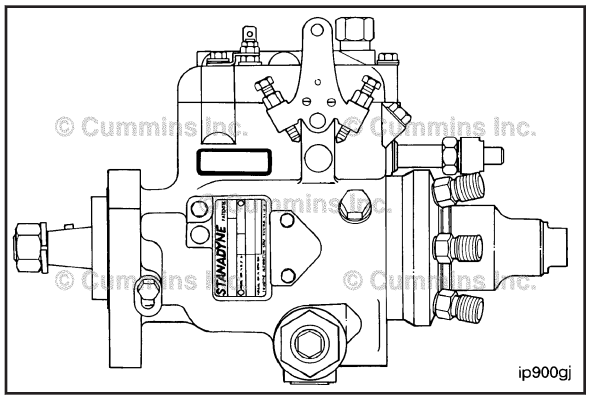
The injection pump dataplate for the Bosch® in-line pump is located on the side of the injection pump. The data plate provides information for fuel pump calibration.





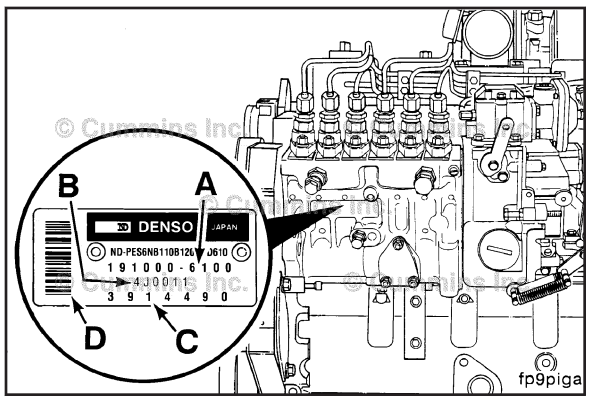
CAV Rotary

The injection pump dataplate for the Lucas DPA pump is located on the side of the injection pump. The dataplate provides information for fuel pump calibration.



Stanadyne Rotary

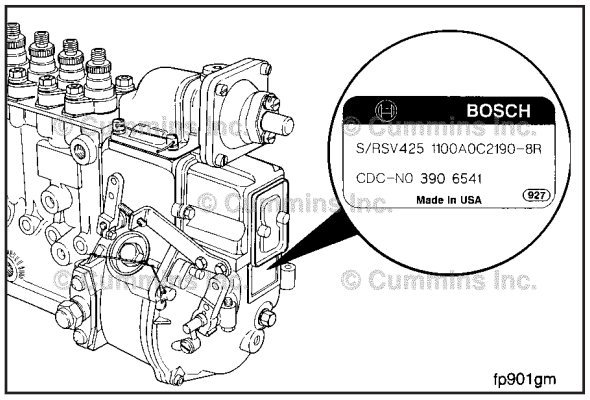
The injection pump dataplate for the Stanadyne DB4 is located on the side of the injection pump. The dataplate provides information for the fuel pump calibration.



Denso In-line

The Denso fuel injection pump dataplate contains the following information:

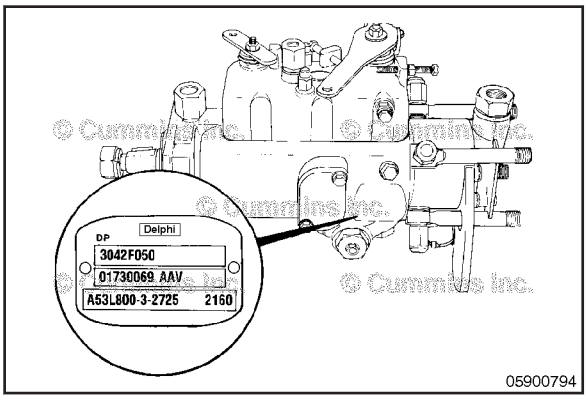
(A) Fuel injection pump part number
(B) Denso serial number
(C) Cummins part number
(D) Fuel injection pump bar code.



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

Delphi Rotary

The injection pump dataplate for the Delphi DP pump is located on the side of the injection pump. The dataplate provides information for fuel pump calibration.



Engine Diagrams

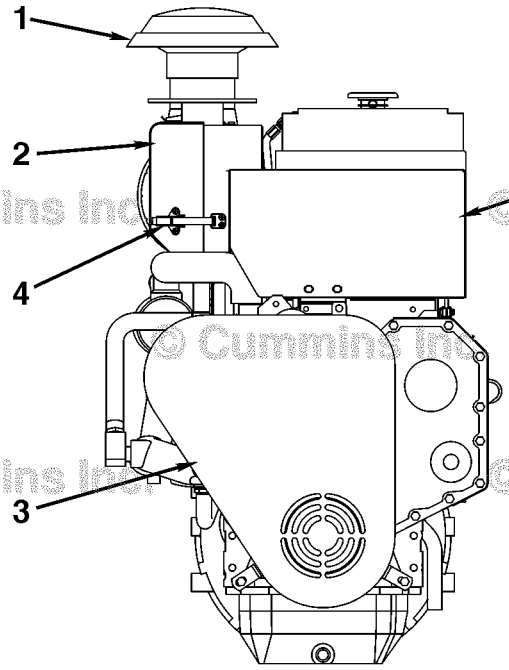
Engine Views

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

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

Engine Diagrams

Engine Views



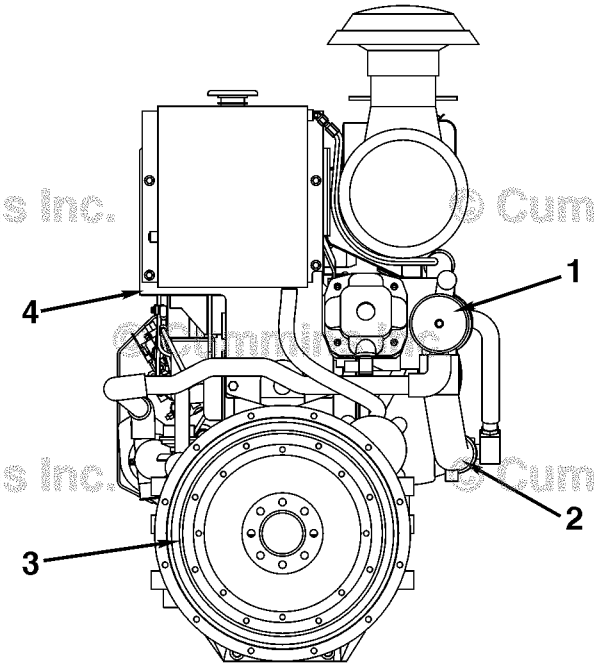
00900448

6BTA5.9-DM Front View

1. Air cleaner inlet
2. Heat shield
3. Belt and damper guard
4. Heat shield connector clamp

Engine Diagrams

Engine Views



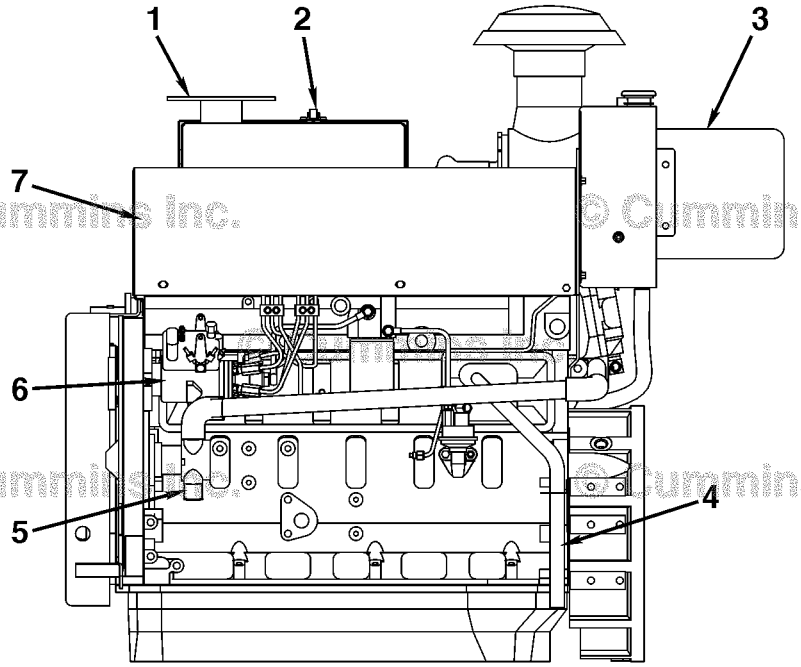
00900449

6BTA5.9-DM Rear View

1. Heat exchanger
2. Engine coolant out of heat exchanger
3. Flywheel
4. Expansion tank mounting bracket

Engine Diagrams

Engine Views



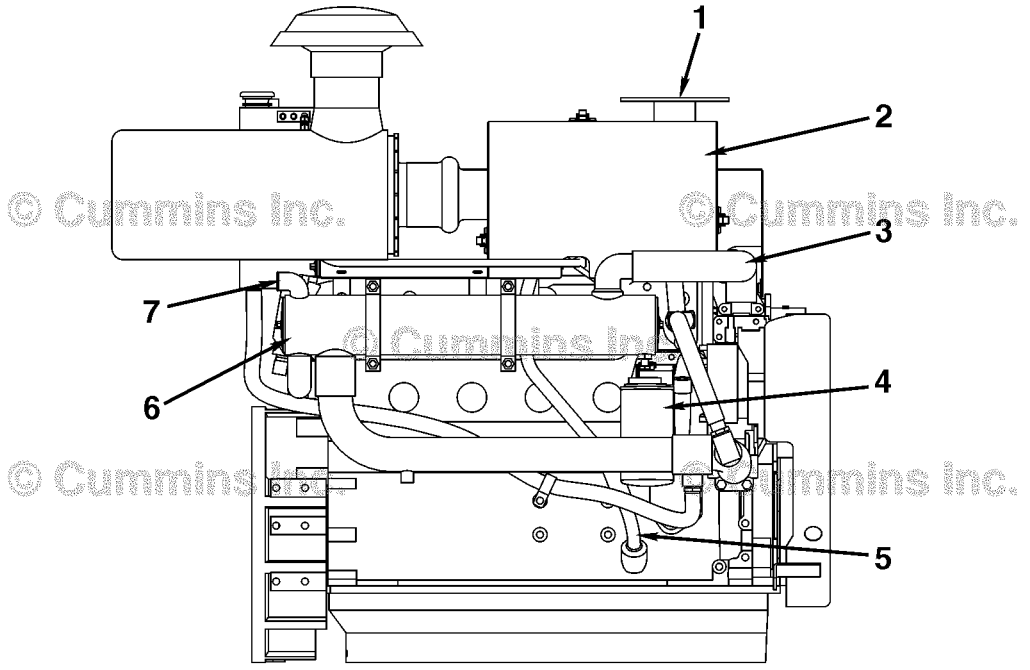
00900450

6BTA5.9-DM Fuel Pump Side

1. Exhaust outlet
2. Heat shield connector clamps
3. Air cleaner
4. Blowby outlet tube
5. Sea water inlet
6. Fuel pump
7. Heat shield

Engine Diagrams

Engine Views

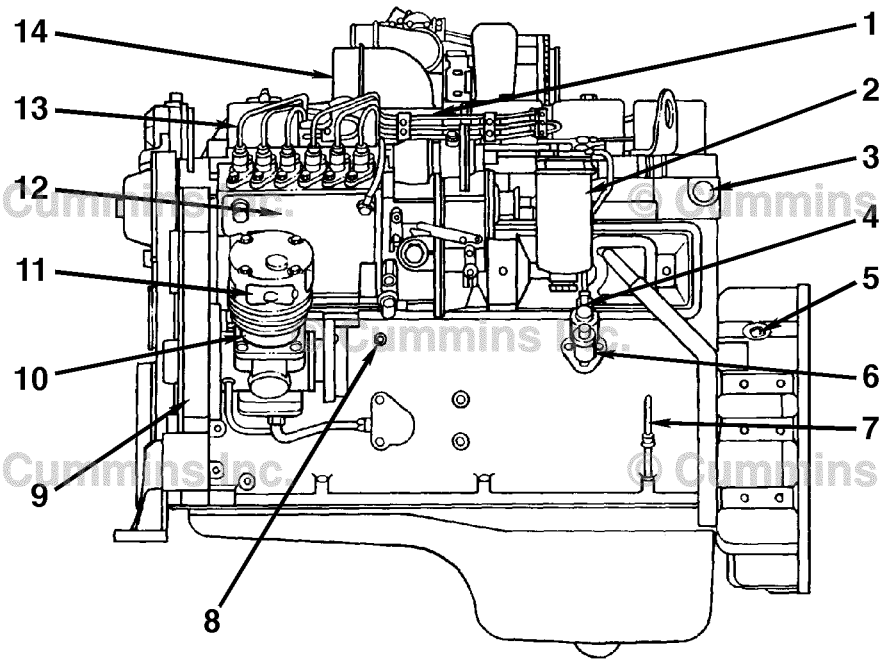


6BTA5.9-DM Exhaust Side

1. Exhaust outlet connection
2. Heat shield
3. Heat exchanger coolant inlet
4. Lubricating oil filter
5. Turbocharger oil drain connection
6. Heat exchanger
7. Heat exchanger sea water outlet

Engine Diagrams

Engine Views



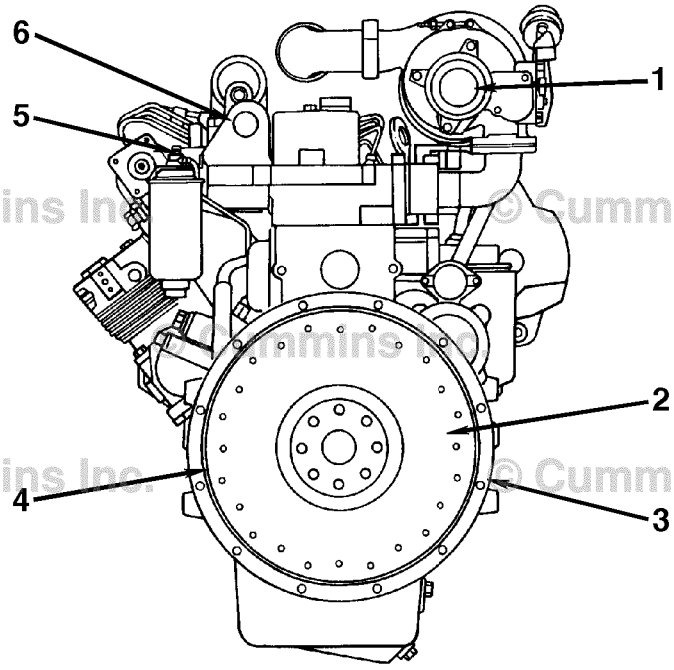
00900280

Automotive - Fuel Pump Side View

1. Intake air preheater (optional)
2. Fuel filter/water separator
3. Water heater supply (3/4-inch NPTF)
4. Fuel inlet connection (1/4-inch NPTF)
5. Magnetic pickup location (3/4-16 UNF)
6. Fuel lift pump
7. Dipstick
8. Oil pressure (1/8-inch NPTF)
9. Engine dataplate
10. Air compressor
11. Air compressor intake
12. In-line fuel injection pump
13. High pressure fuel lines
14. Engine air inlet.

Engine Diagrams

Engine Views



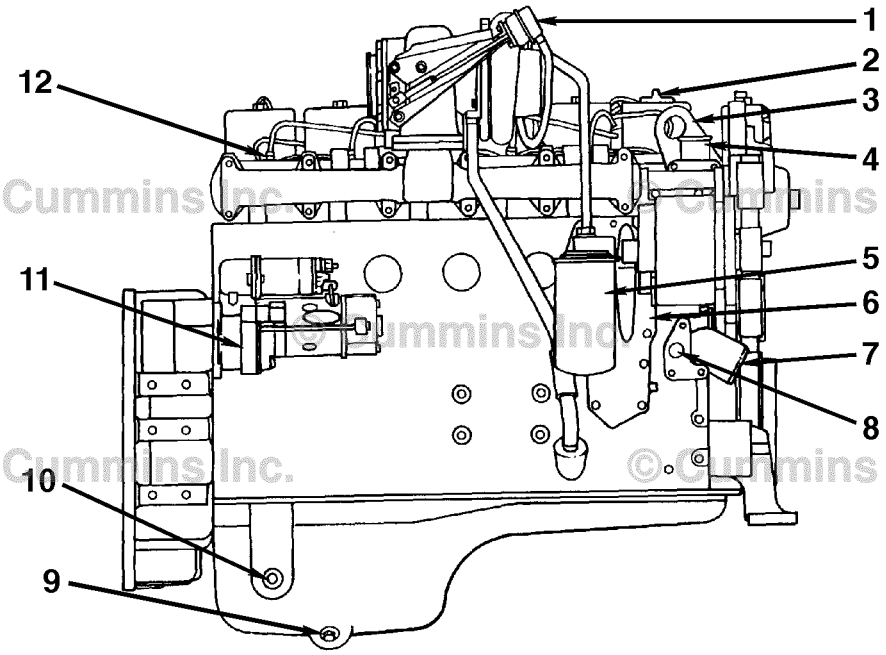
00900279

Automotive - Rear View

1. Turbocharger exhaust outlet
2. Clutch mounting plate
3. Flywheel housing
4. Flywheel flexplate
5. Fuel return connection
6. Rear engine lifting bracket.

Engine Diagrams

Engine Views



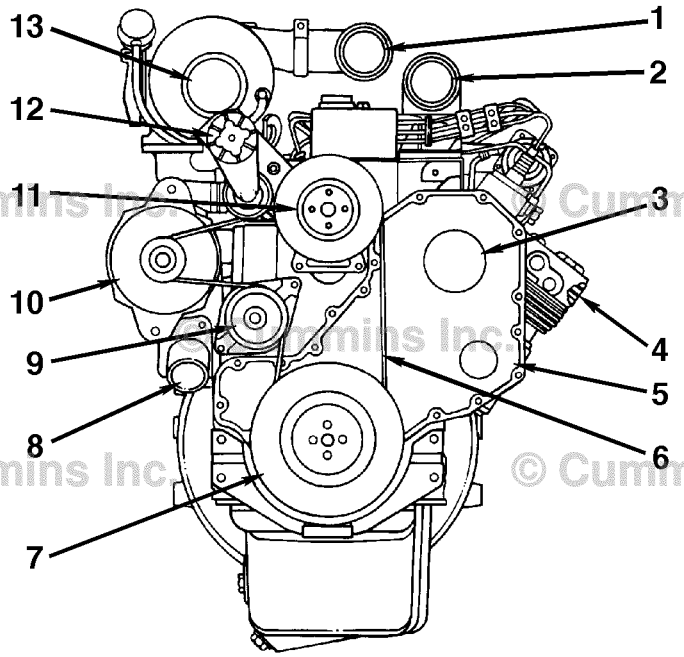
00900278

Automotive - Turbocharger Side View

1. Turbocharger wastegate actuator
2. Oil fill
3. Front engine lifting bracket
4. Water outlet
5. Lubricating oil filter
6. Lubricating oil cooler
7. Water inlet
8. Water heater return (1/2-inch NPTF)
9. Oil drain
10. Provision for oil immersion heater
11. Starter motor solenoid
12. Fuel injection nozzles.

Engine Diagrams

Engine Views



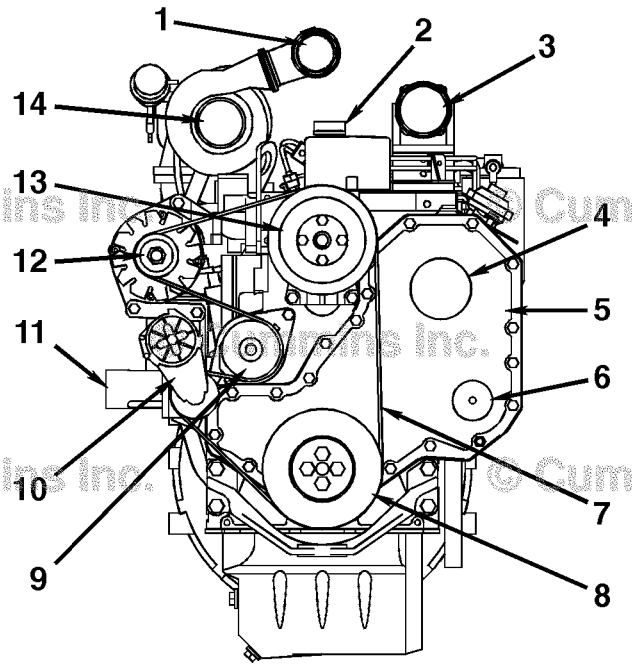
00900277

Automotive - Front View

1. Turbocharger air outlet
2. Engine air inlet
3. Fuel pump drive cover
4. Air compressor air outlet
5. Front gear cover
6. Fan drive belt
7. Vibration damper
8. Water inlet
9. Water pump
10. Alternator
11. Fan pulley
12. Automatic belt tensioner
13. Turbocharger air inlet.

Engine Diagrams

Engine Views



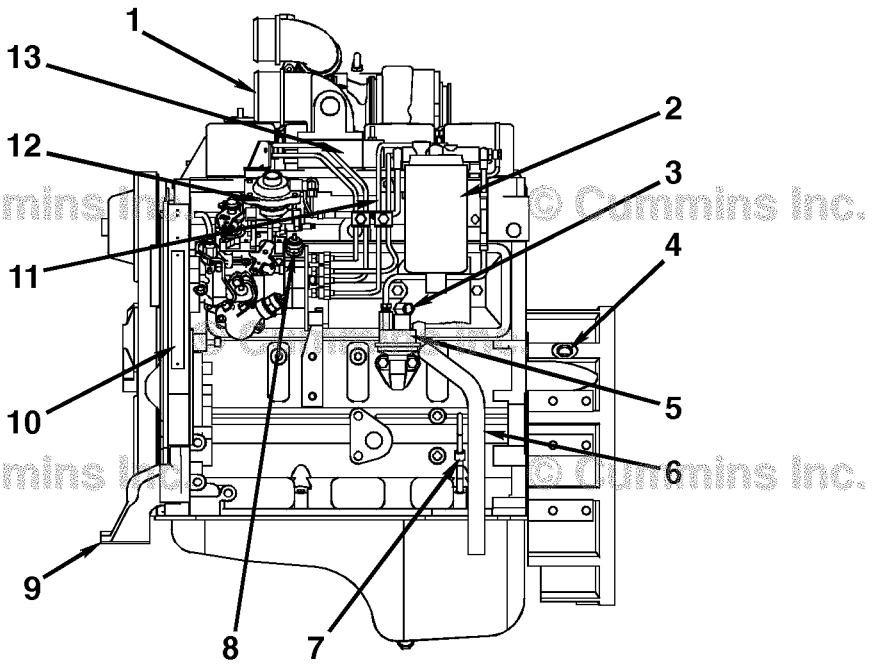
00900346

Front View - B3.9 Industrial

1. Turbocharger air outlet
2. Lubricating oil fill
3. Engine air inlet
4. Fuel pump drive cover
5. Front gear cover
6. Accessory drive cover (optional)
7. Fan drive belt
8. Front Pulley
9. Water pump
10. Automatic belt tensioner
11. Water inlet
12. Alternator
13. Fan pulley
14. Turbocharger air inlet.

Engine Diagrams

Engine Views

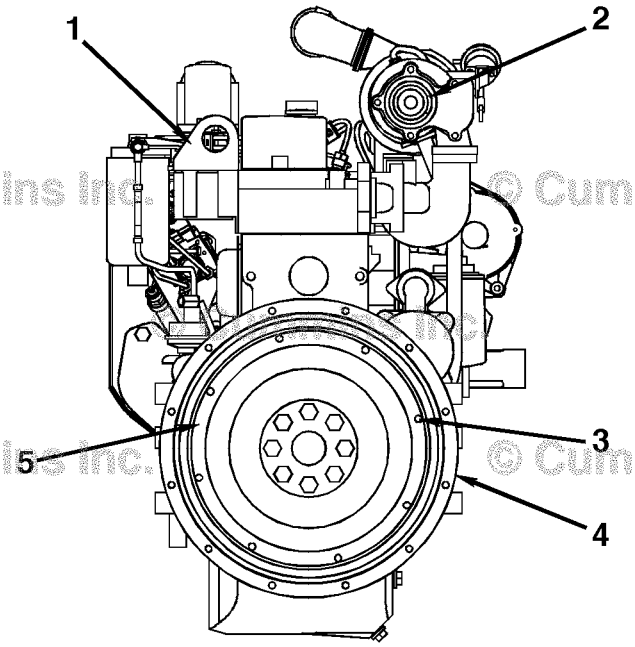


Left Side View - B3.9 Industrial

1. Engine air inlet
2. Fuel filter/water separator
3. Fuel inlet connection
4. Magnetic pickup location (3/4-16 UNF)
5. Fuel lift pump
6. Crankcase breather tube
7. Lubricating oil dipstick
8. Fuel drain connection
9. Front engine mounting bracket
10. Engine dataplate
11. High pressure fuel lines
12. Fuel injection pump
13. Intake air preheater (optional).

Engine Diagrams

Engine Views



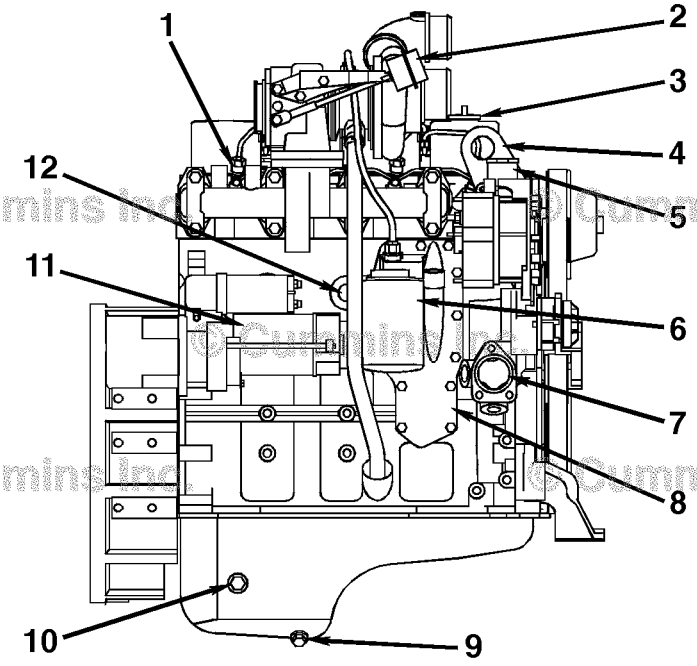
00900344

Rear View - B3.9 Industrial

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

Engine Diagrams

Engine Views



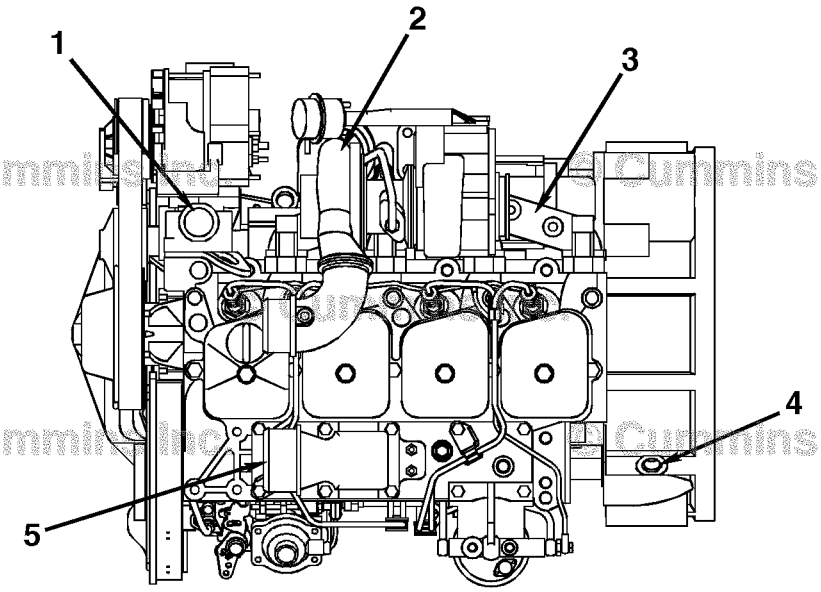
00900345

Right Side View - B3.9 Industrial

1. Fuel injection nozzles
2. Turbocharger wastegate actuator
3. Lubricating oil fill
4. Front engine lifting bracket
5. Water outlet
6. Lubricating oil filter
7. Water inlet
8. Lubricating oil cooler
9. Lubricating oil drain
10. Provision for lubricating oil immersion heater
11. Starter motor and solenoid
12. Provision for coolant heater.

Engine Diagrams

Engine Views



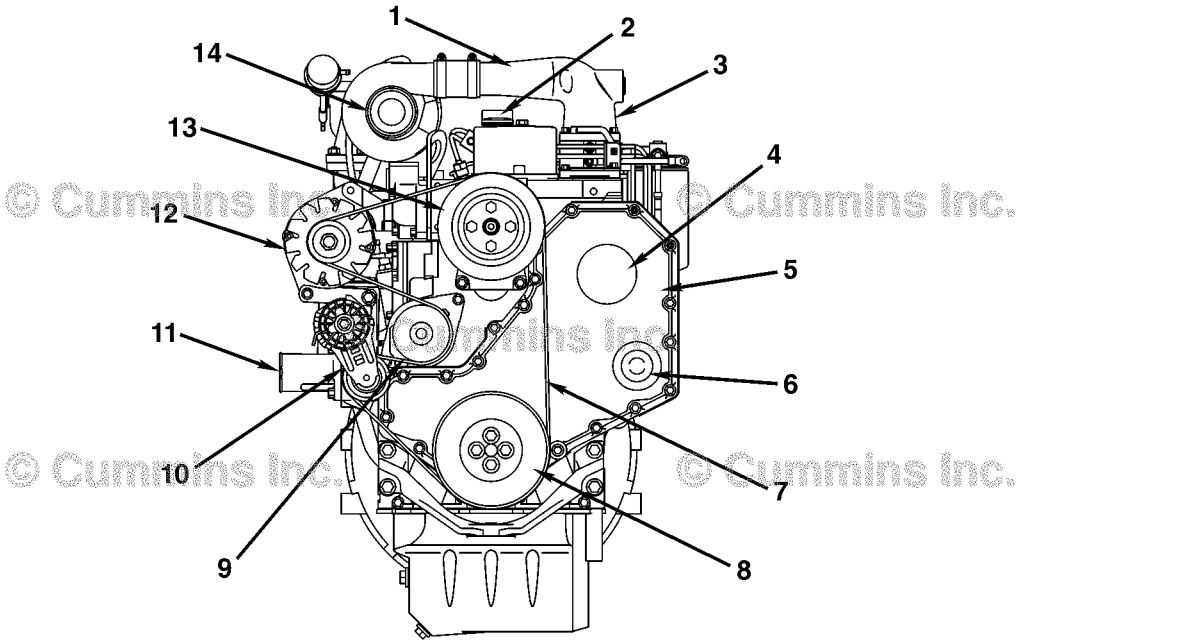
00900347

Top View - B3.9 Industrial

1. Water outlet
2. Turbocharger
3. Exhaust manifold
4. Magnetic pickup location (3/4-16 UNF)
5. Engine air inlet.

Engine Diagrams

Engine Views

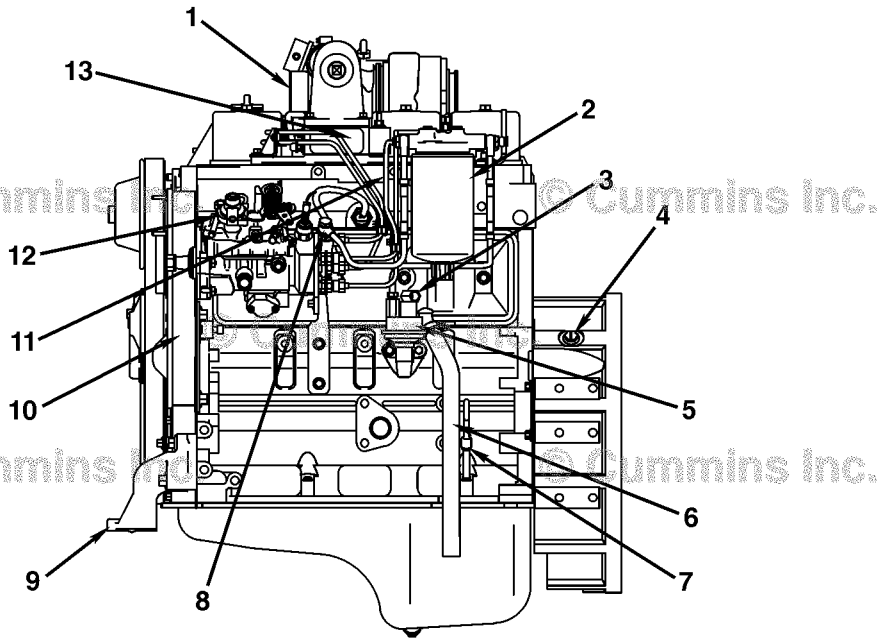


Front View - B4.5 Industrial

1. Turbocharger air outlet
2. Lubricating oil fill
3. Engine air inlet
4. Fuel pump drive cover
5. Front gear cover
6. Accessory drive cover (optional)
7. Fan drive belt
8. Front Pulley
9. Water pump
10. Automatic belt tensioner
11. Water inlet
12. Alternator
13. Fan pulley
14. Turbocharger air inlet.

Engine Diagrams

Engine Views



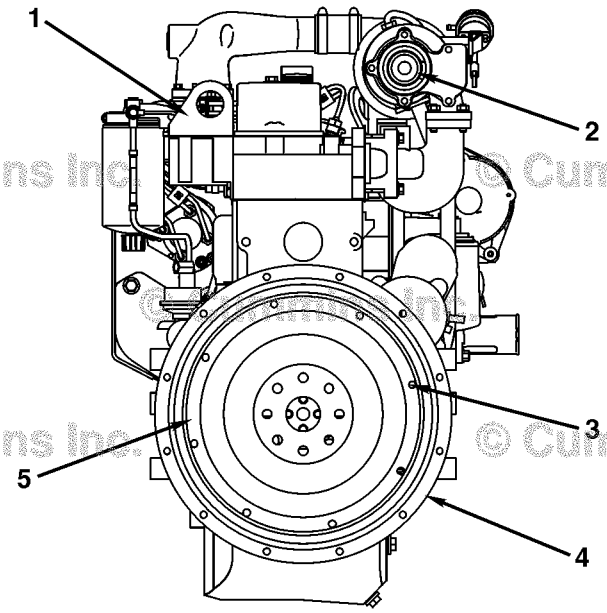
00900380

Left Side View - B4.5 Industrial

1. Engine air inlet
2. Fuel filter/water separator
3. Fuel inlet connection
4. Magnetic pickup location (3/4-16 UNF)
5. Fuel lift pump
6. Crankcase breather tube
7. Lubricating oil dipstick
8. Fuel drain connection
9. Front engine mounting bracket
10. Engine dataplate
11. High pressure fuel lines
12. Fuel injection pump
13. Intake air preheater (optional).

Engine Diagrams

Engine Views



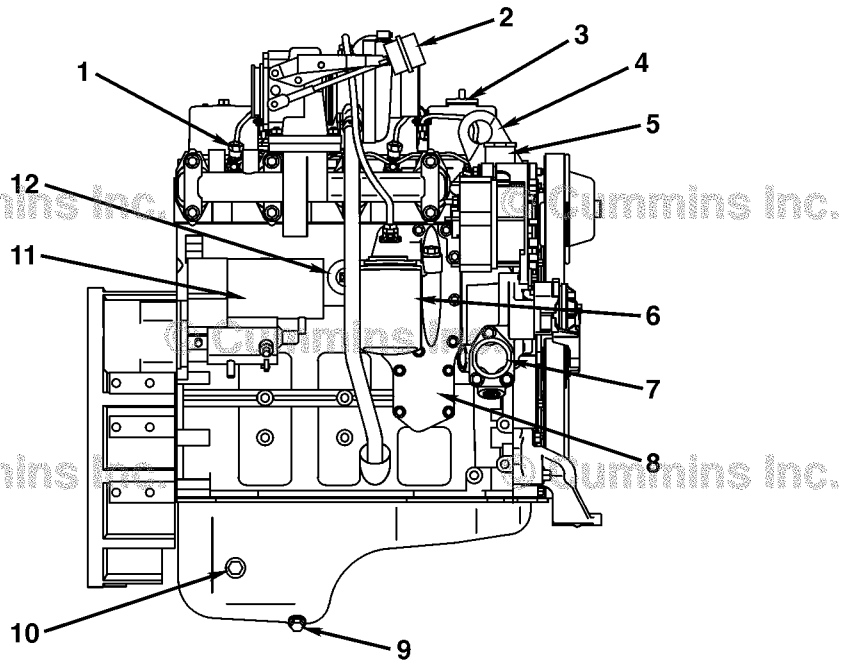
00900381

Rear View - B4.5 Industrial

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

Engine Diagrams

Engine Views

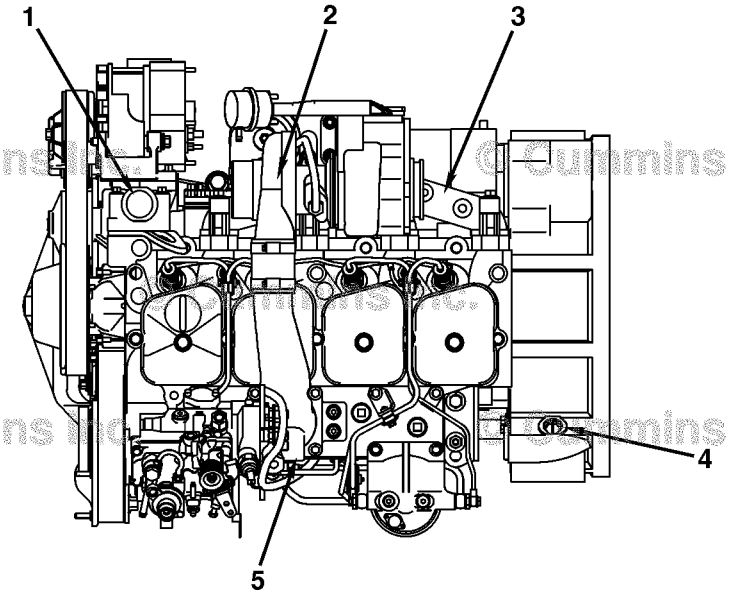


Right Side View - B4.5 Industrial

1. Fuel injection nozzles
2. Turbocharger wastegate actuator
3. Lubricating oil fill
4. Front engine lifting bracket
5. Water outlet
6. Lubricating oil filter
7. Water inlet
8. Lubricating oil cooler
9. Lubricating oil drain
10. Provision for lubricating oil immersion heater
11. Starter motor and solenoid
12. Provision for coolant heater.

Engine Diagrams

Engine Views



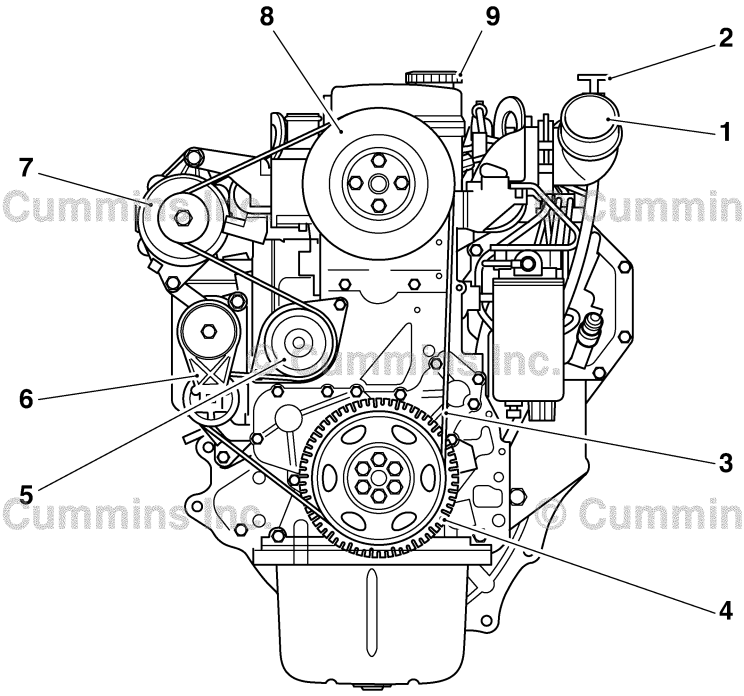
00900384

Top View - B4.5 Industrial

1. Water outlet
2. Turbocharger
3. Exhaust manifold
4. Magnetic pickup location (3/4-16 UNF)
5. Engine air inlet.

Engine Diagrams

Engine Views



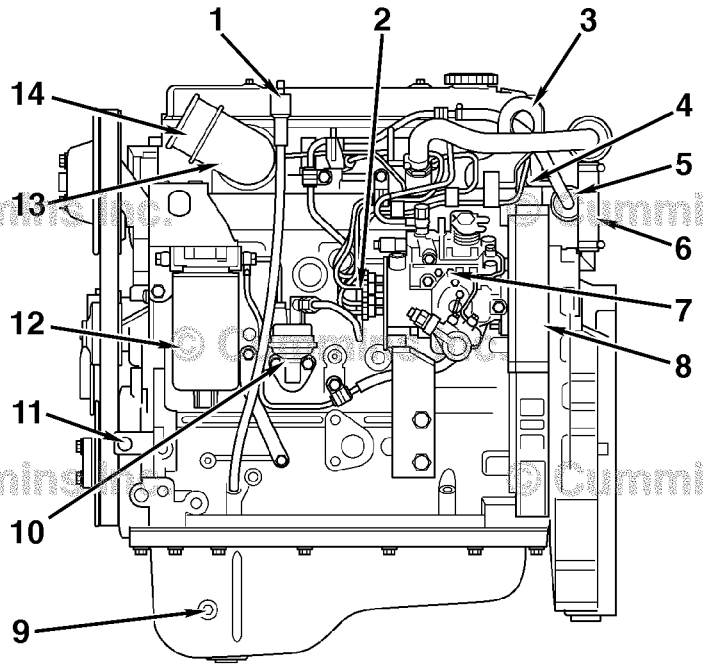
00d00242

Front View - B4.5 RGT

1. Engine air inlet
2. Lubricating oil dipstick
3. Fan drive belt
4. Front pulley
5. Water pump
6. Automatic belt tensioner
7. Alternator
8. Fan pulley
9. Lubricating oil fill.

Engine Diagrams

Engine Views



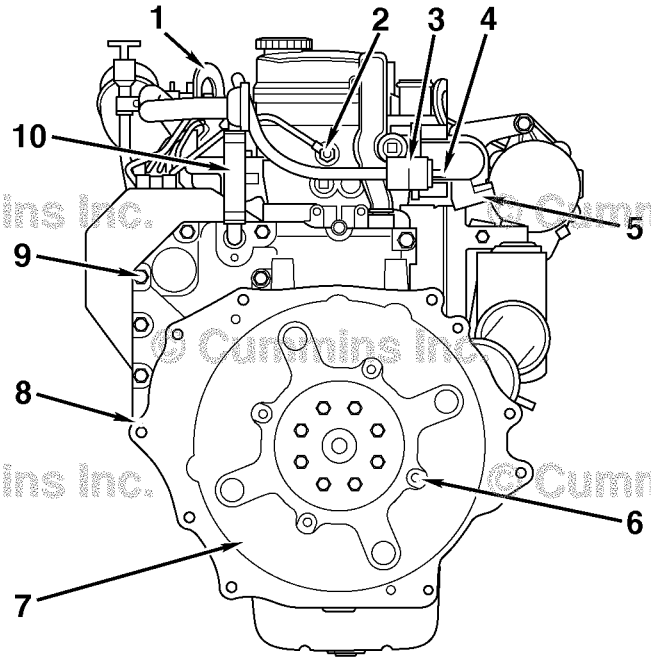
00d00243

Left Side View - B4.5 RGT

1. Lubricating oil dipstick
2. High pressure fuel lines
3. Rear engine mounting bracket
4. Fuel return line and fuel drain connection
5. Inlet fuel filter
6. Crankcase breather tube
7. Fuel injection pump
8. Engine dataplate
9. Provision for lubricating oil immersion heater
10. Fuel lift pump
11. Magnetic pickup location (3/4-16 UNF)
12. Fuel filter/water separator
13. Intake air preheater (optional)
14. Engine air inlet.

Engine Diagrams

Engine Views



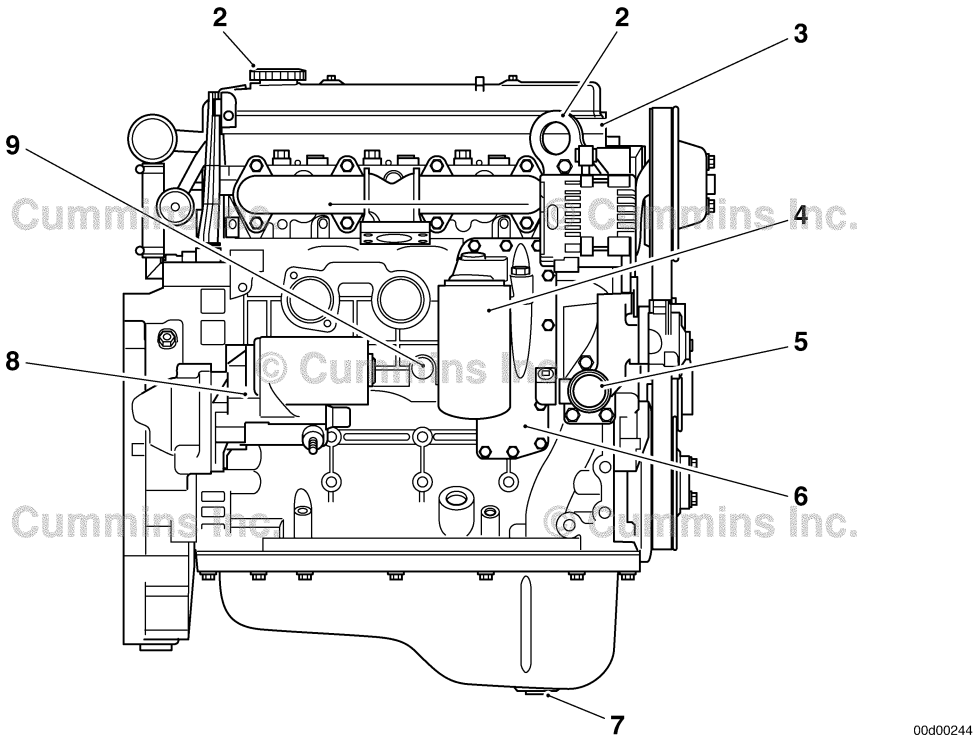
00d00241

Rear View - B4.5 RGT

1. Rear engine lifting bracket
2. Fuel return and fuel drain connection
3. Inline fuel filter
4. Fuel Inlet connection
5. Exhaust outlet
6. Flexplate mounting holes
7. Flywheel/flexplate
8. Flywheel housing
9. Rear gear train housing
10. Crankcase breather tube.

Engine Diagrams

Engine Views

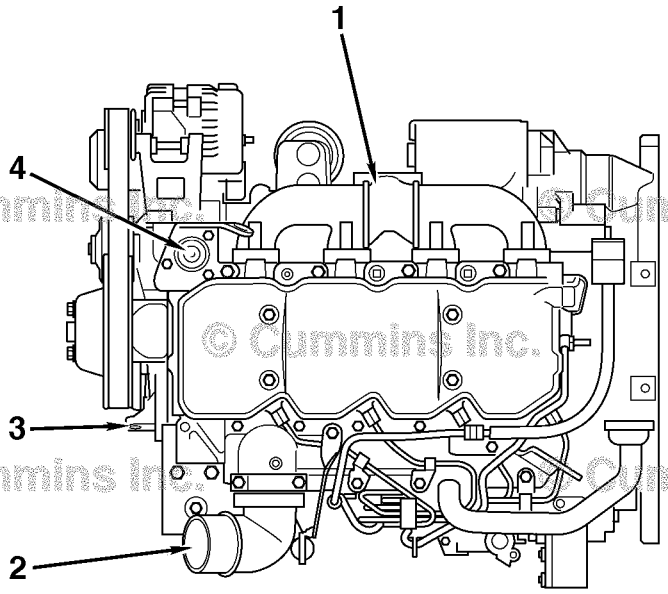


Right Side View - B4.5 RGT

1. Lubricating oil fill
2. Front engine lifting bracket
3. Water outlet
4. Lubricating oil filter
5. Water inlet
6. Lubricating oil cooler
7. Lubricating oil drain
8. Starter motor and solenoid
9. Provision for coolant heater.

Engine Diagrams

Engine Views



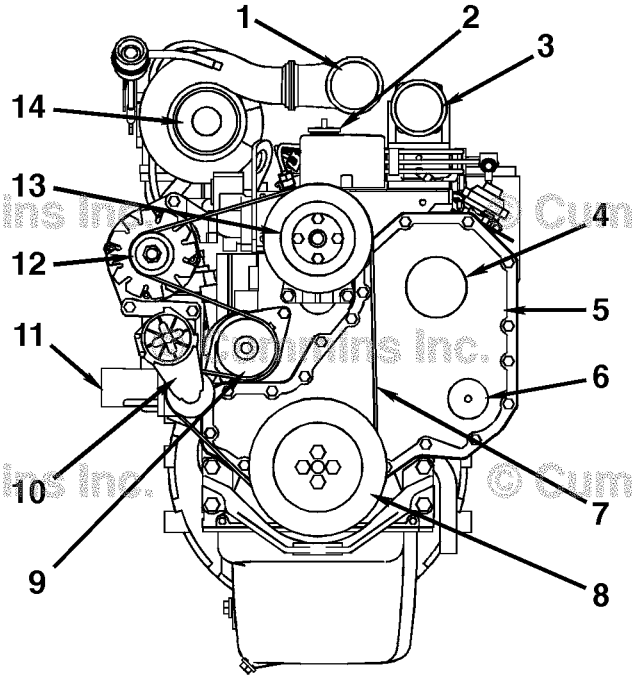
00d00245

Top View - B4.5 RGT

1. Exhaust manifold
2. Engine air inlet
3. Magnetic pickup location (3/4-16 UNF).
4. Water outlet

Engine Diagrams

Engine Views



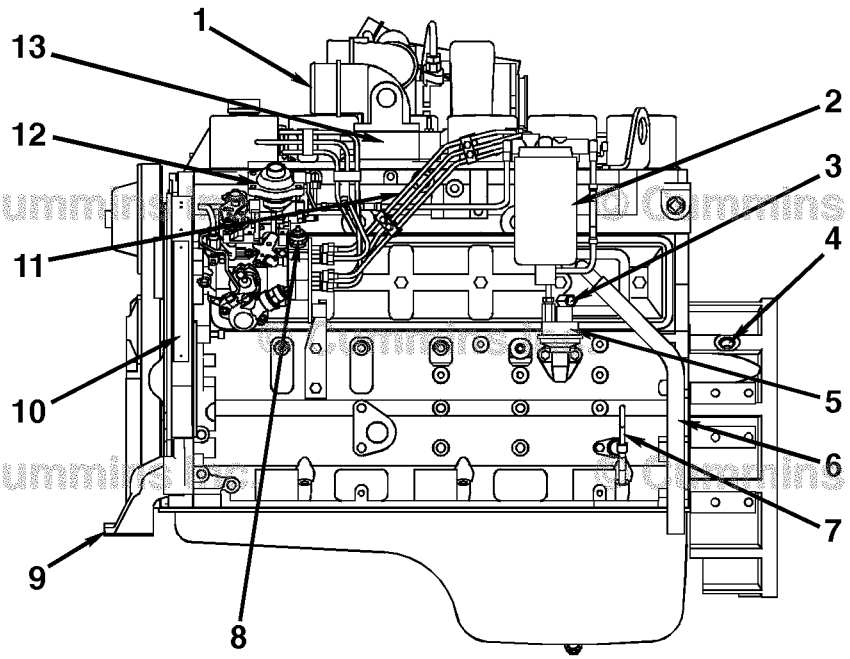
00900351

Front View - B5.9 Industrial

1. Turbocharger air outlet
2. Lubricating oil fill
3. Engine air inlet
4. Fuel pump drive cover
5. Front gear cover
6. Accessory drive cover (optional)
7. Fan drive belt
8. Vibration damper
9. Water pump
10. Automatic belt tensioner
11. Water inlet
12. Alternator
13. Fan pulley
14. Turbocharger air inlet.

Engine Diagrams

Engine Views



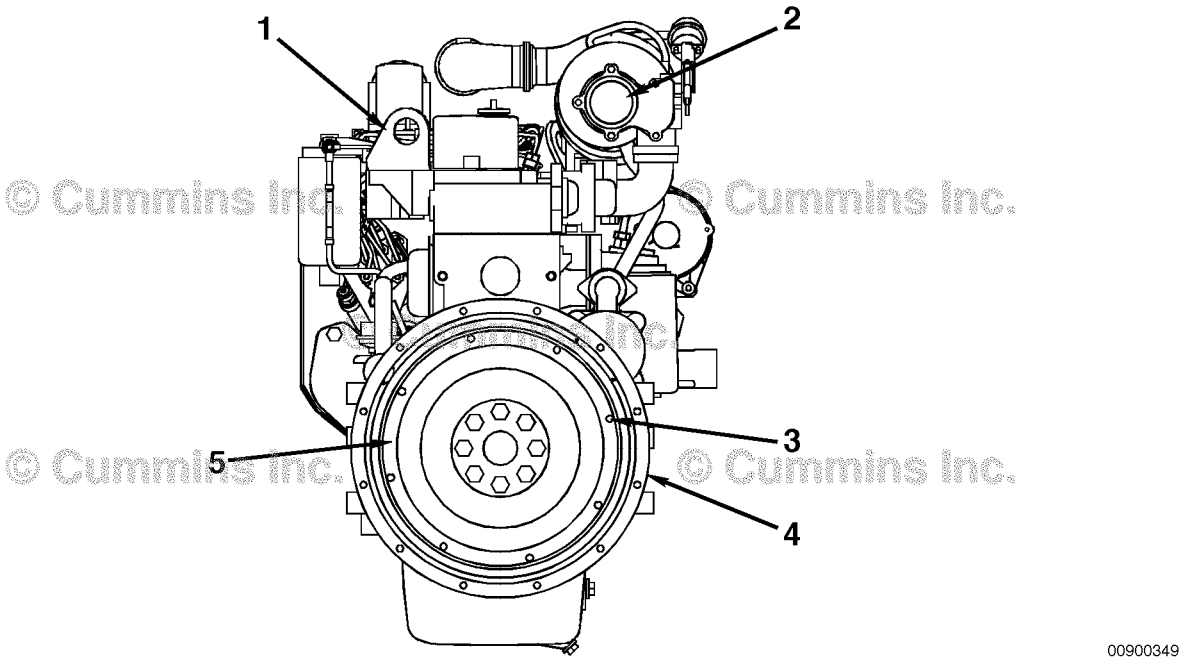
00900348

Left Side View - B5.9 Industrial

1. Engine air inlet
2. Fuel filter/water separator
3. Fuel inlet connection
4. Magnetic pickup location (3/4-16 UNF)
5. Fuel lift pump
6. Crankcase breather tube
7. Lubricating oil dipstick
8. Fuel drain connection
9. Front engine mounting bracket
10. Engine dataplate
11. High pressure fuel lines
12. Fuel injection pump
13. Intake air preheater (optional).

Engine Diagrams

Engine Views

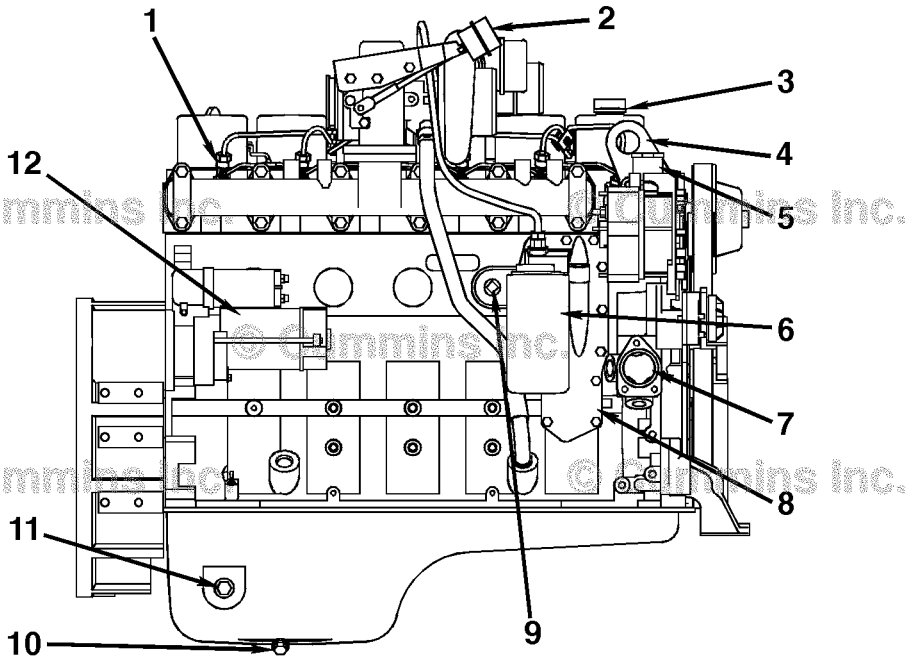


Rear View - B5.9 Industrial

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

Engine Diagrams

Engine Views

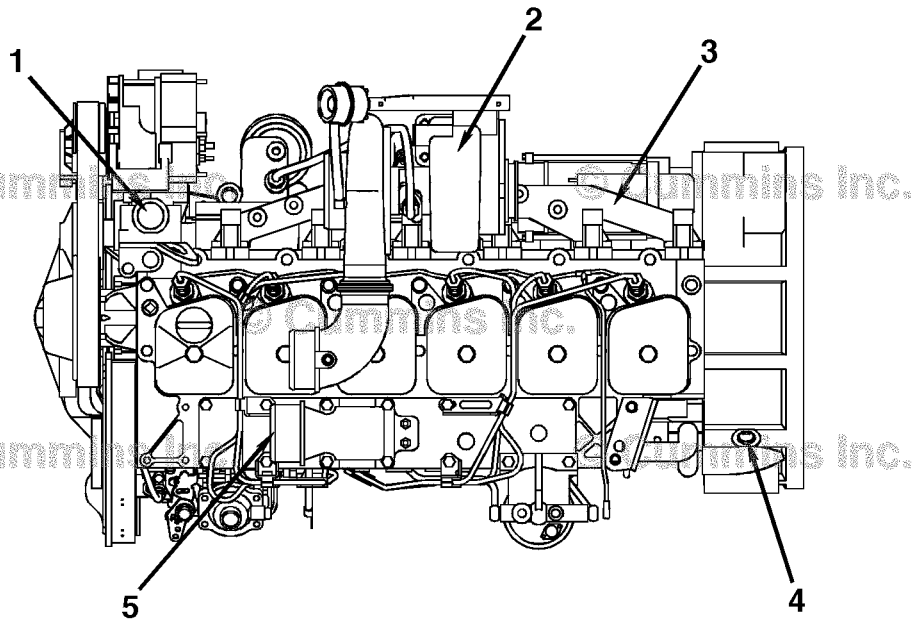


Right Side View - B5.9 Industrial

1. Fuel injection nozzles
2. Turbocharger wastegate actuator
3. Lubricating oil fill
4. Front engine lifting bracket
5. Water outlet
6. Lubricating oil filter
7. Water inlet
8. Lubricating oil cooler
9. Provision for coolant heater
10. Lubricating oil drain
11. Provision for lubricating oil immersion heater
12. Starter motor and solenoid.

Engine Diagrams

Engine Views



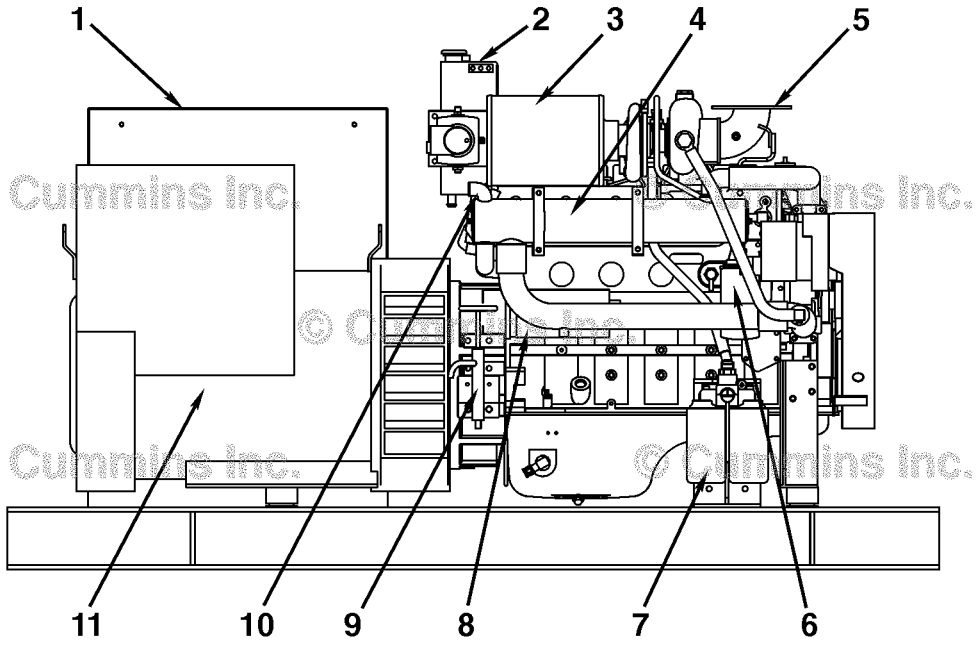
00900352

Top View - B5.9 Industrial

1. Water outlet
2. Turbocharger
3. Exhaust manifold
4. Magnetic pickup location (3/4-16 UNF)
5. Engine air inlet.

Engine Diagrams

Engine Views



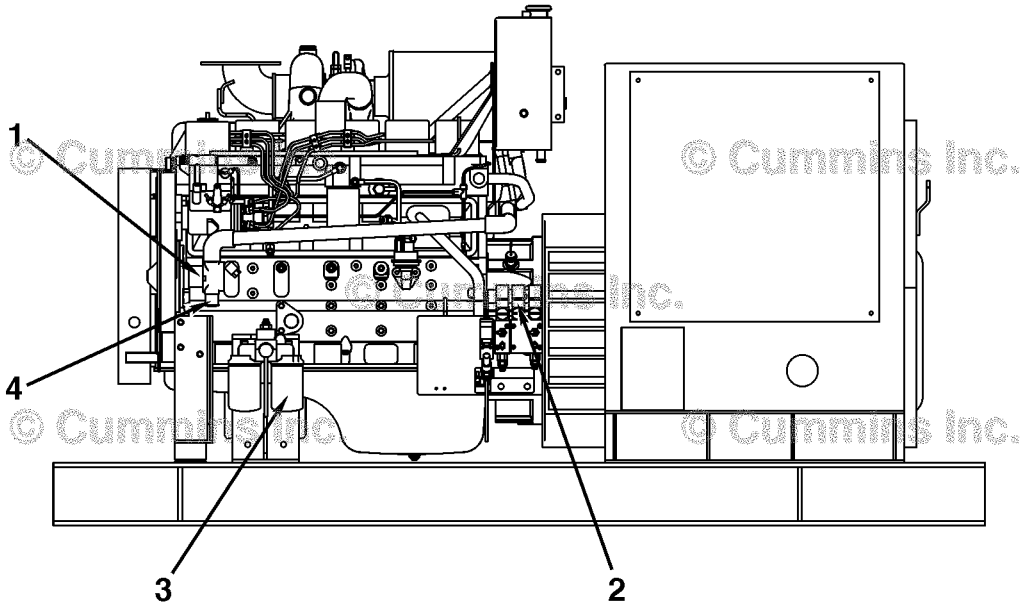
21900008

C Power Heat Exchanger Cooled - Exhaust Side View (B Series)

1. Local Control Panel
2. Coolant Expansion Tank
3. Air Cleaner
4. Heat Exchanger
5. Exhaust Connection
6. Coolant Filter
7. Duplex Lubricating Oil Filter
8. Starter
9. Lubricating Oil Sump Hand Pump
10. Sea Water Outlet Connection
11. Alternator.

Engine Diagrams

Engine Views



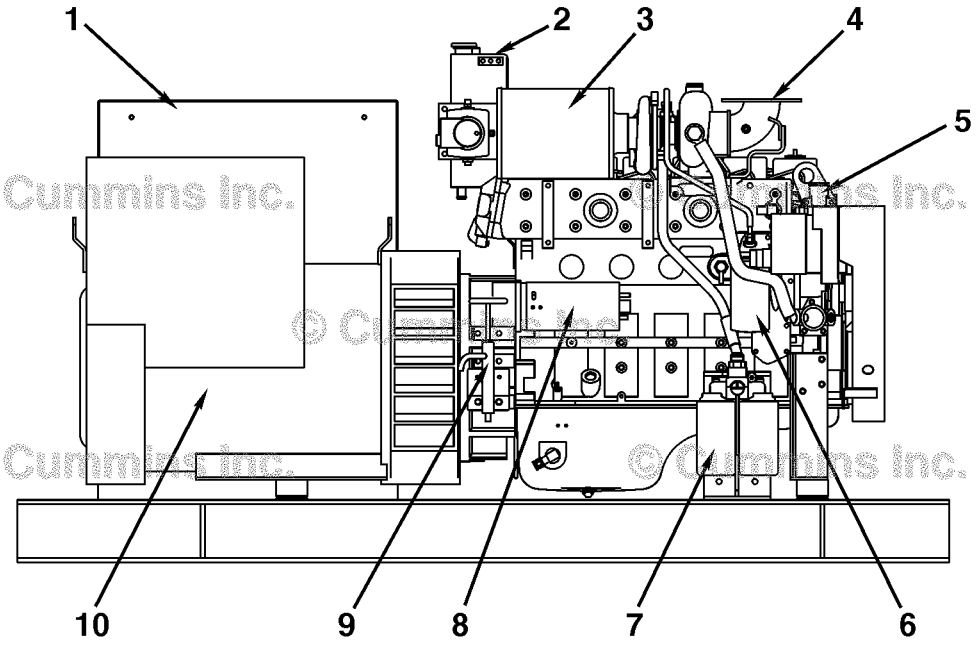
21900009

C Power Heat Exchanger Cooled - Air Intake View (B Series)

1. Seawater Pump
2. Emergency Shutdown Sensors
3. Fuel Filters
4. Seawater Inlet Connection.

Engine Diagrams

Engine Views



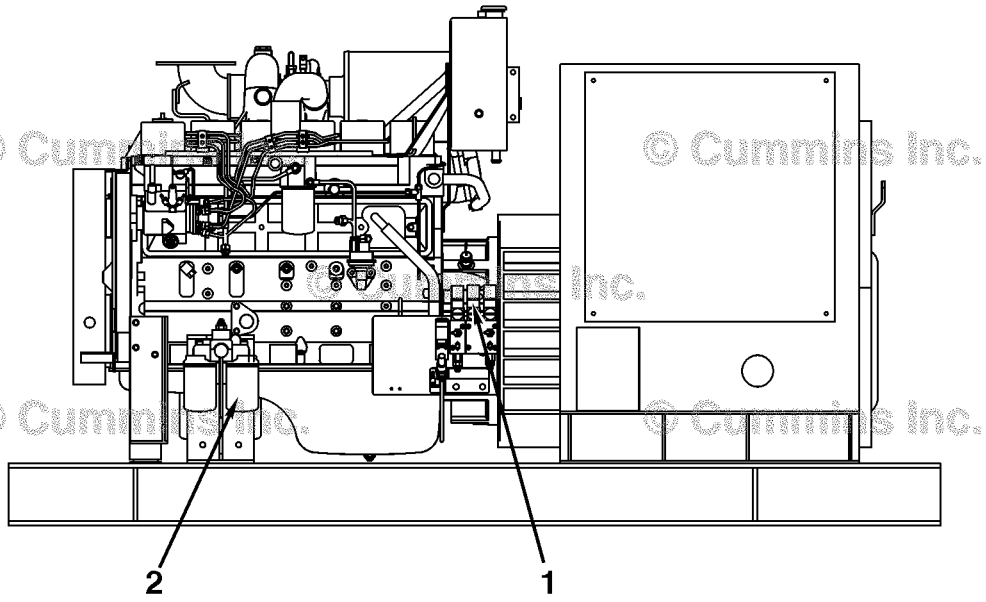
21900010

C Power Keel Cooler Cooled - Exhaust Side View (B Series)

1. Local Control Panel
2. Air Cleaner
3. Coolant Expansion Tank
4. Exhaust Connection
5. Coolant Thermostat Location
6. Coolant Filter
7. Duplex Lubricating Oil Filter
8. Starter
9. Lubricating Oil Sump Hand Pump
10. Alternator.

Engine Diagrams

Engine Views



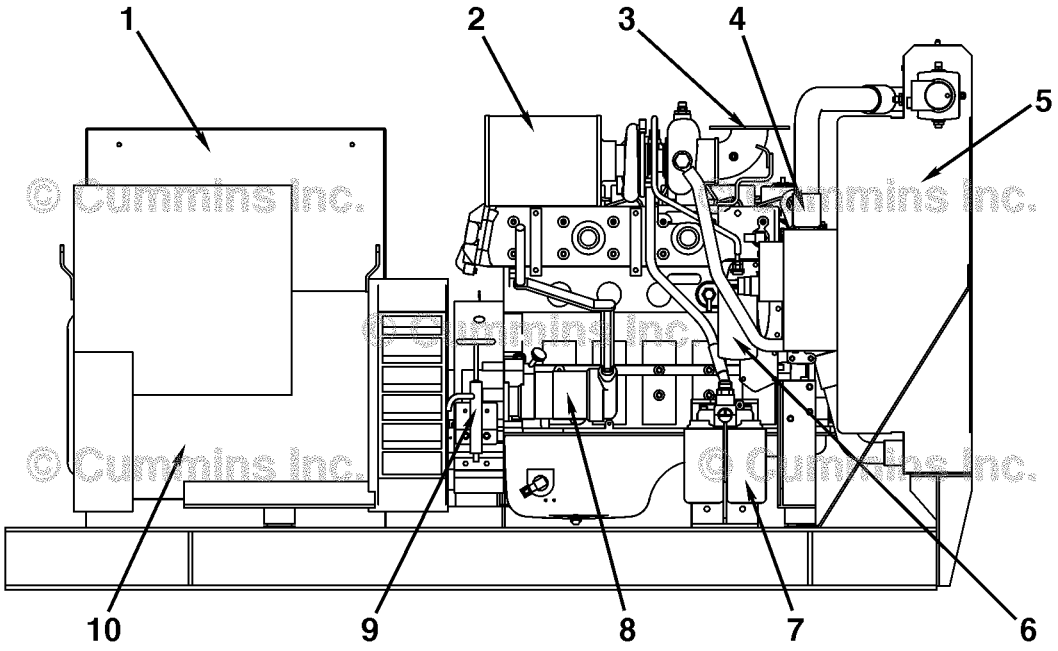
21900011

C Power Keel Cooler Cooled - Air Intake View (B Series)

1. Fuel Filters
2. Emergency Shutdown Sensors.

Engine Diagrams

Engine Views



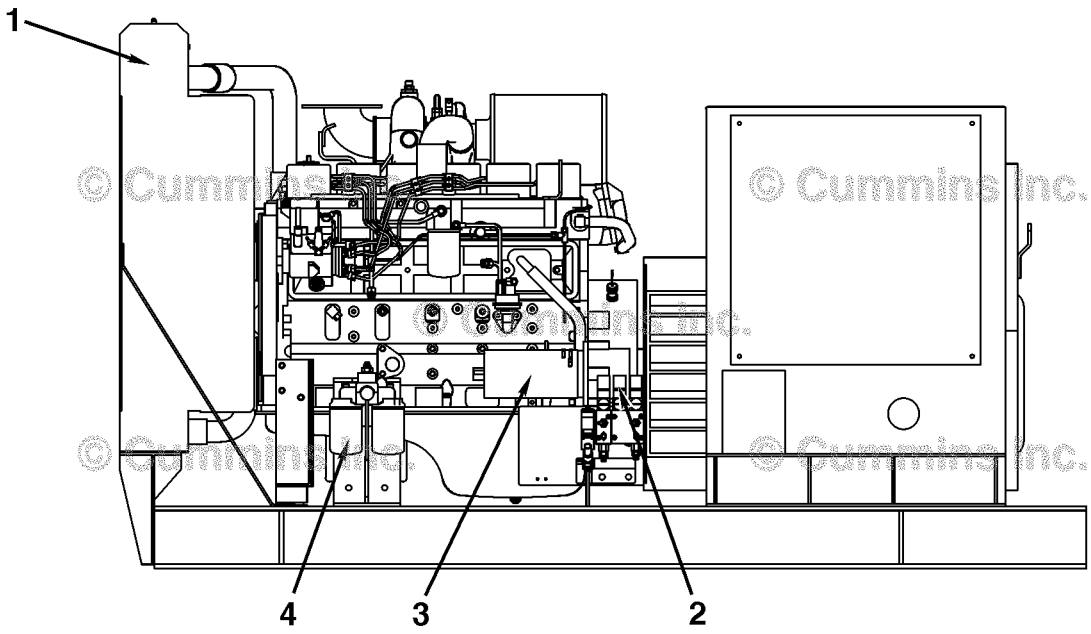
21900012

C Safe Radiator Cooled - Exhaust Side View (B Series)

1. Local Control Panel
2. Air Cleaner
3. Exhaust Connection
4. Coolant Thermostat Location
5. Radiator Fan Drive Shroud
6. Coolant Filter
7. Duplex Lubricating Oil Filter
8. Spring Starter
9. Lubricating Oil Sump Hand Pump
10. Alternator.

Engine Diagrams

Engine Views



21900013

C Safe Radiator Cooled - Air Intake Side View (B Series)

1. Radiator and Expansion Tank
2. Emergency Shutdown Sensors
3. Starter
4. Duplex Fuel Filters.

Section F - Familiarization

Section Contents

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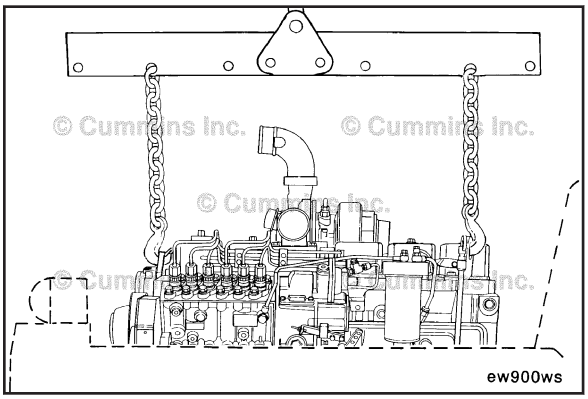
Complete Engine - Overview (000-999)

General Information

The procedures required to replace an engine will vary with different engine models, type of equipment, optional equipment, and shop facilities.

NOTE: Use the equipment manufacturer's recommendations and precautions for removal of chassis parts to gain access to the engine.



Cylinder Block - Overview (001-999)

General Information

Connecting Rods

This familiarization section helps to identify and orient the various styles of ISB connecting rods for installation. These details are important because some connecting rods are **not** marked with a part number and identification can be difficult. This section will also discuss the acceptability of mixing connecting rods with different part numbers to make a repair.

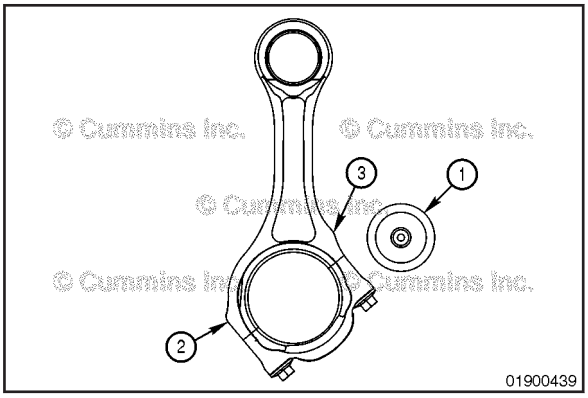
B Series engines use various connecting rods installed in different orientations, depending on where and when the engine was built. Generally, connecting rods should be installed in the same orientation as they were prior to removal. In special circumstances, this familiarization section may be referenced as a guideline.

The following information illustrates connecting rod styles and orientations for the Cummins® B Series 3.9 Liter (4 cylinder) and 5.9 Liter (6 cylinder) engines.

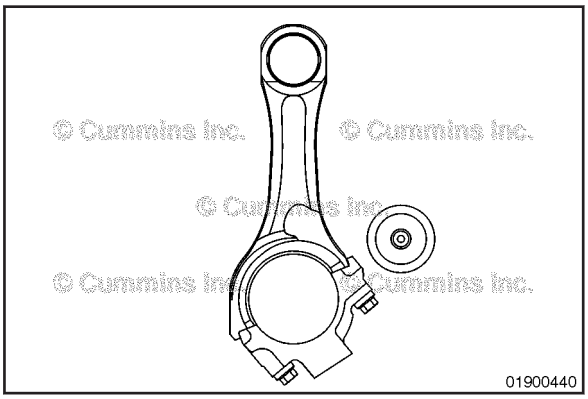
Each illustration shows the connecting rod and camshaft (1) as viewed from the front of the engine. The connecting rod capscrew holes help define the orientation of the connecting rod to the camshaft. One side of the rod has a through hole (2) and the other has a blind hole (3). The through hole is drilled through the rod. The blind hole is drilled into the rod and does not have an exit hole.

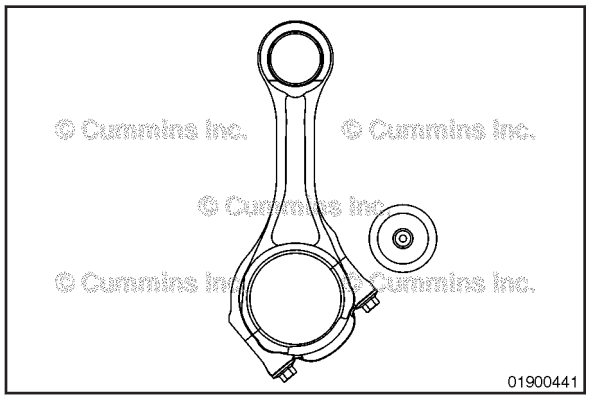
There are two possible orientations for the connecting rod:

- Through hole (2) toward the camshaft
- Blind hole (3) toward the camshaft.

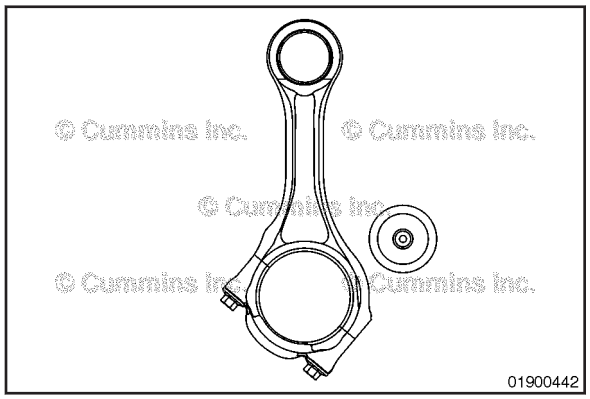


Connecting Rod Part Number:	3942581 (3942581 shown)
Cylinder Block:	ISB CM550, ISB CM850
Connecting Rod Joint:	Machined
Cylinder Bore:	102 mm [4.015 in]
Cylinder Stroke:	120 mm [4.724 in]
Orientation:	Blind hole toward camshaft

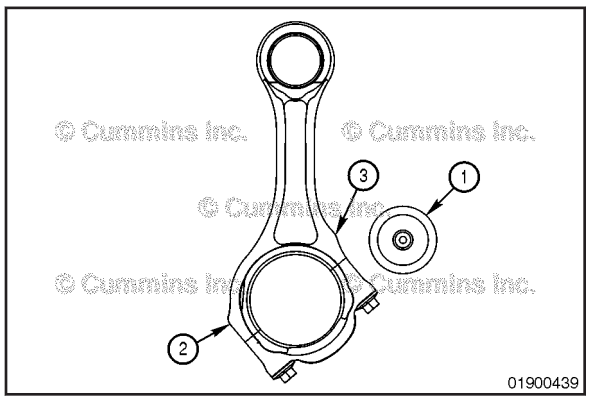




Connecting Rod Part Number:	3954658, 3971212, 4891176, 4935880, 4943979, 4989163, 5257364 (3954658 shown)
Cylinder Block:	ISB CM550
Connecting Rod Joint:	Fractured
Cylinder Bore:	102 mm [4.015 in]
Cylinder Stroke:	120 mm [4.724 in]
Orientation:	Blind hole toward camshaft



Connecting Rod Part Number:	3954658, 3971212, 4891176, 4935880, 4943979, 4989163, 5257364 (3954658 shown)
Cylinder Block:	ISB CM850
Connecting Rod Joint:	Fractured
Cylinder Bore:	102 mm [4.015 in]
Cylinder Stroke:	120 mm [4.724 in]
Orientation:	Through hole toward camshaft

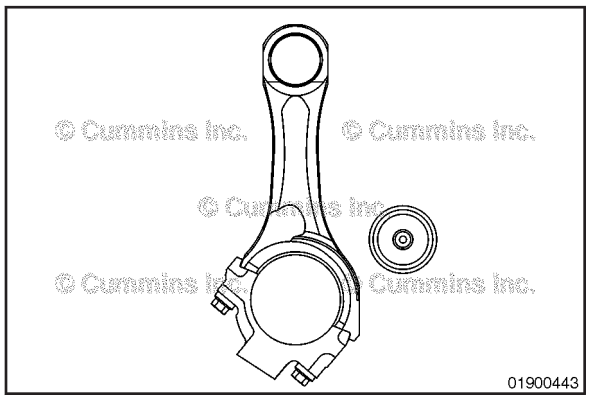


The following information illustrates connecting rod styles and orientations for the Cummins® B Series 4.5 Liter (4 cylinder) and 6.7 Liter (6 cylinder) engines.

Each illustration shows the connecting rod and camshaft (1) as viewed from the front of the engine. The connecting rod capscrew holes help define the orientation of the connecting rod to the camshaft. One side of the rod has a through hole (2) and the other has a blind hole (3). The through hole is drilled through the rod. The blind hole is drilled into the rod and does not have an exit hole.

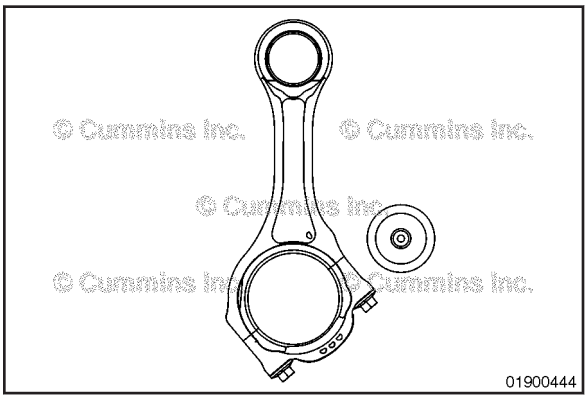
There are two possible orientations for the connecting rod:

- Through hole (2) toward the camshaft
- Blind hole (3) toward the camshaft.



Connecting Rod Part Number:	3942581 (3942581 shown)
Cylinder Block:	ISB 4.5, ISB 6.7
Connecting Rod Joint:	Machined
Cylinder Bore:	107 mm [4.212 in]
Cylinder Stroke:	124 mm [4.881 in]
Orientation:	Through hole toward camshaft

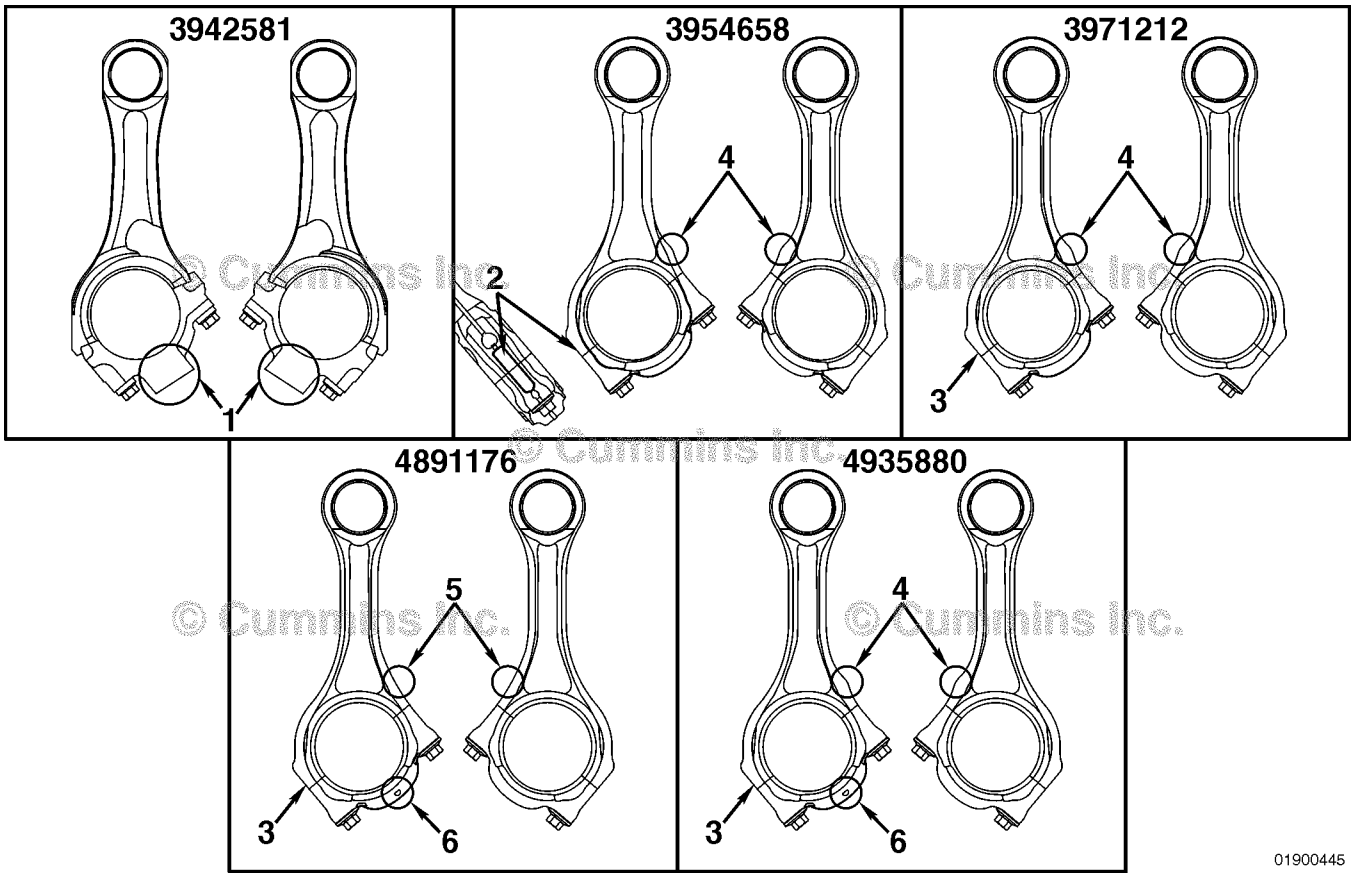
Connecting Rod Part Number:	3954658, 3971212, 4891176, 4935880, 4943979, 4989163, 5257364 (4943979 shown)
Cylinder Block:	ISB 4.5, ISB 6.7
Connecting Rod Joint:	Fractured
Cylinder Bore:	107 mm [4.212 in]
Cylinder Stroke:	124 mm [4.881 in]
Orientation:	Blind hole toward camshaft

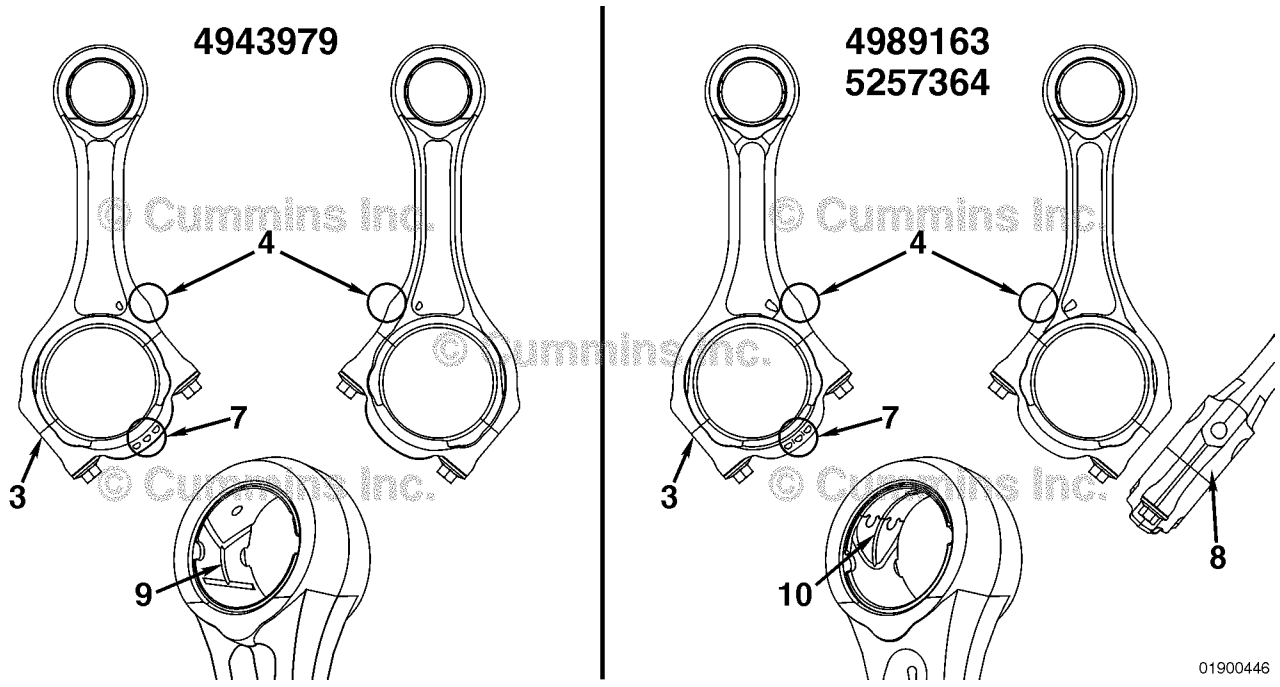


Cylinder Block - Overview (001-999)

General Information

Use the following illustrations to identify 3.9 Liter, 4.5 Liter, 5.9 Liter, and 6.7 Liter (6 cylinder) connecting rods.





Note: Lead-free bushings (10) Part Numbers 4983518 and 5257363 are not serviceable.

Connecting Rod Characteristics

1 Balancer

2 Machined surface

3 Non-machined surface

4 Bump or bulge

5 Smooth

6 Single dimple

7 Three dimple

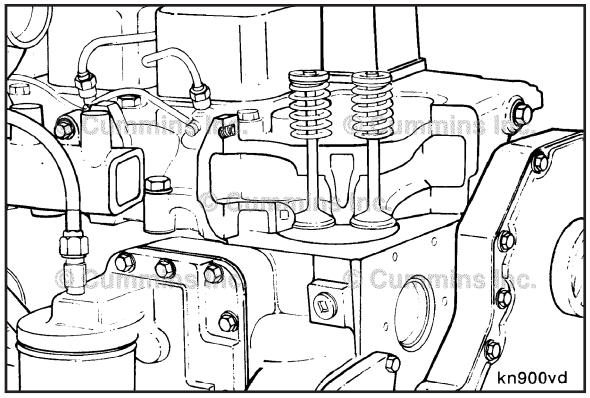
8 "TA LF" or "7364"

9 Oil grooves in leaded bushing Part Number 4891178

10 Oil grooves in lead-free bushings Part Numbers 4983518/5257363. (These bushings are **not** serviceable)

Due to weight differences that will result in engine vibration, special consideration **must** be given to mixing certain connecting rods in a single engine.

- In engines built before January 1, 2010, with connecting rod Part Numbers 4935880, 4943979, 4989163, and 5257364: these rods may **only** be mixed with each other.
- In engines built after January 1, 2010, with connecting rod Part Numbers 4989163, and 5257364: these rods may **only** be mixed with each other.
- Connecting rod Part Number 3954658 and 3971212 may **only** be mixed with each other.
- Connecting rod Part Number 4891176 **must never** be mixed with any other connecting rod.
- Connecting rod Part Number 3942581 **must never** be mixed with any other connecting rod.



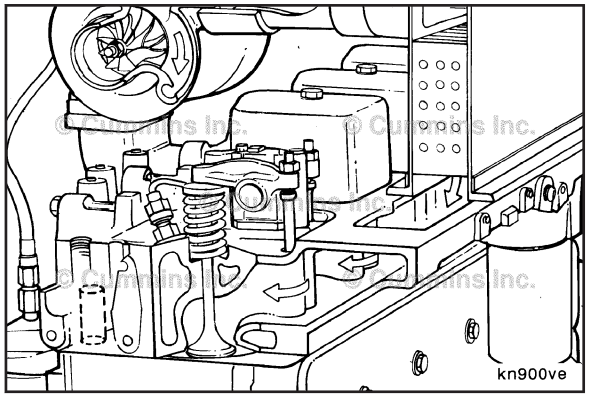
Cylinder Head - Overview (002-999)

General Information

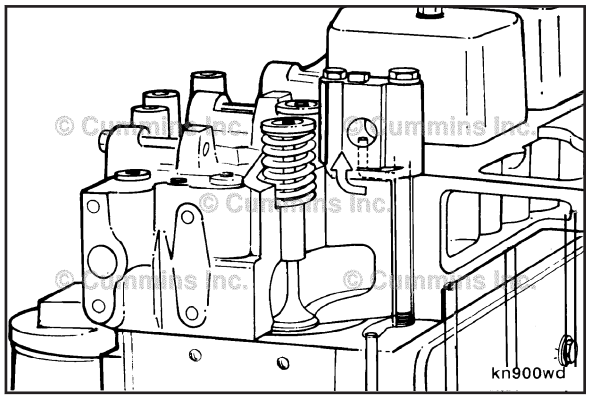
B3.9, B5.9, and B4.5 Engines

Cylinder Head and Valve Train

The cylinder head is a one-piece, cross flow design with two valves per cylinder. The head has integrally cast valve guides and hardened valve seat surfaces that can be repaired in a machine shop using the appropriate service parts.

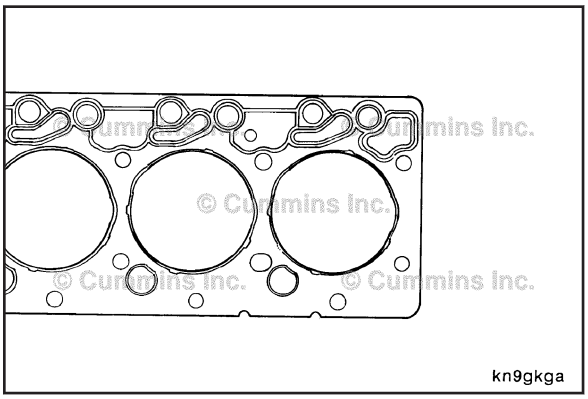


The cylinder head has a cast intake manifold, fuel filter head, thermostat housing and an internal water bypass. The injectors are mounted in the head for direct injection into the cylinders. Fuel filter head is remote for engines with in-line fuel injection pump.



Separate pedestals for each cylinder are to support and route oil to the rocker levers.

The cylinder head gasket is a specialized metal design with a printed o-seal on both sides around the water holes. An embossment in the gasket seals the cylinder bores. As discussed in the Cooling System, the gasket also provides orifices to control coolant flow.

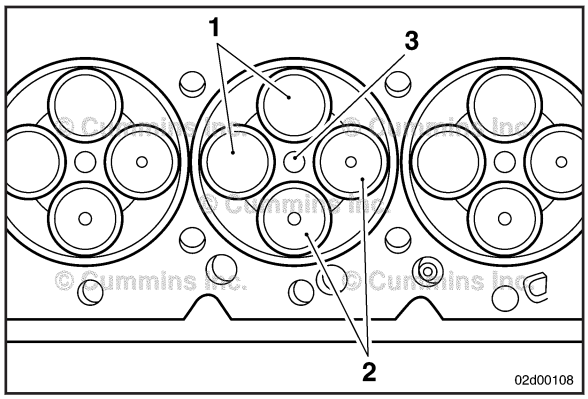


B4.5 RGT Engines

Cylinder Head and Valve Train

The cylinder head is a one-piece, cross flow design with four valves per cylinder. The cylinder head has an integral intake manifold, thermostat housing and an internal water bypass. The four valve per cylinder design allows for a center injector in the cylinder head (3).

The valves (1 and 2) are made of heat resistant steel, and have chrome plated stems to prevent scuffing. The intake and exhaust valves are both similar in head diameter and overall length, but they have unique face angles which makes them non-interchangeable. The valves are distinguished by unique dimples on the exhaust valve head (2).

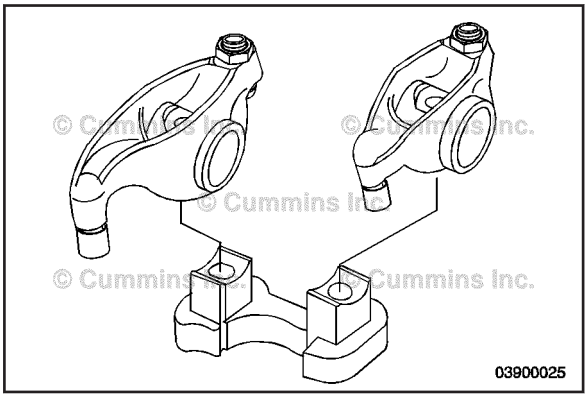


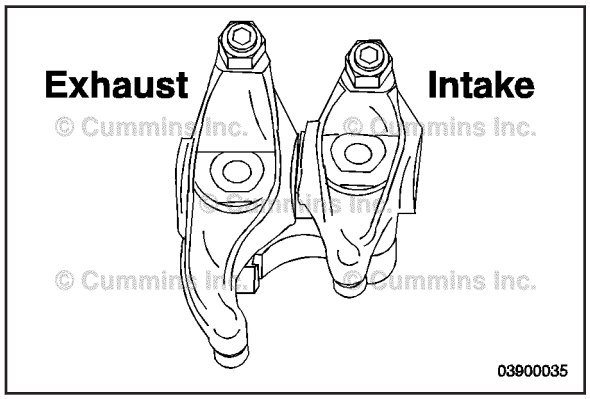
The exhaust valve springs are made from high strength, chrome silicon steel. The exhaust valve springs are also exhaust brake compatible.

The head has integrally cast valve guides which are **not** serviceable. The valve seats are inserts that can be serviced if damaged.

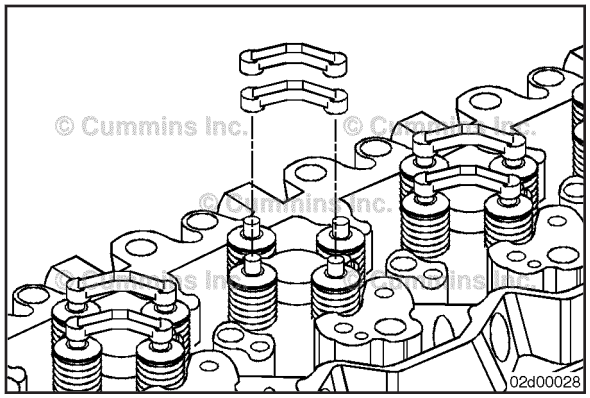
The exhaust and intake rocker levers are mounted on a common pedestal, but rotate on separate shafts.

Oil is supplied through a drilling in the cylinder head through the pedestals to supply oil to the rocker lever shafts, socket and an adjusting screw.



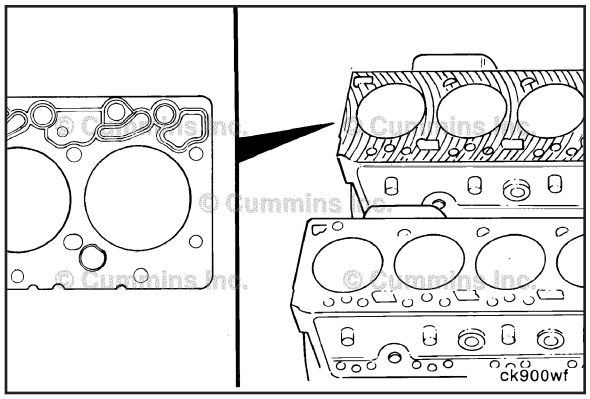


The exhaust and intake rocker levers are **not** interchangeable and **must** be located as shown.



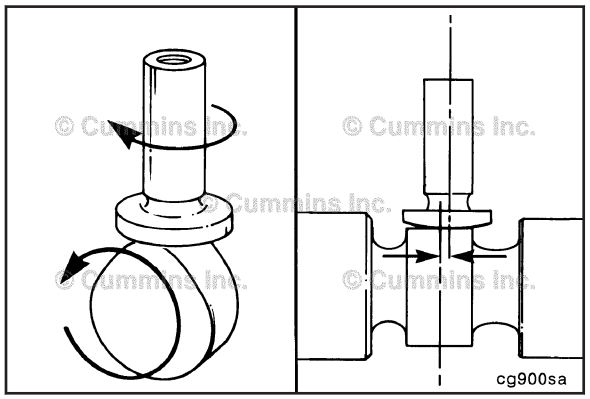
With the four valve per cylinder design, the rocker lever sockets do **not** directly contact the valve stem. With one rocker lever being required to operate two valves, a bridge, or crosshead, is needed to connect both intake and exhaust valves.

The socket on the rocker lever contacts the crosshead, which in turn contacts both corresponding valve stems.



The cylinder head gasket is a specialized metal design with a printed o-seal on both sides around the water holes. An embossment in the gasket seals the cylinder bores. As discussed in the Cooling System, the gasket also provides orifices to control coolant flow.

No specific head gasket with an increased thickness is available for cylinder head or block combustion deck resurfacing. If the combustion deck can **not** be resurfaced such that the piston protrusion, valve depth and injector protrusion specifications be maintained, the cylinder head and/or cylinder block **must** be replaced.



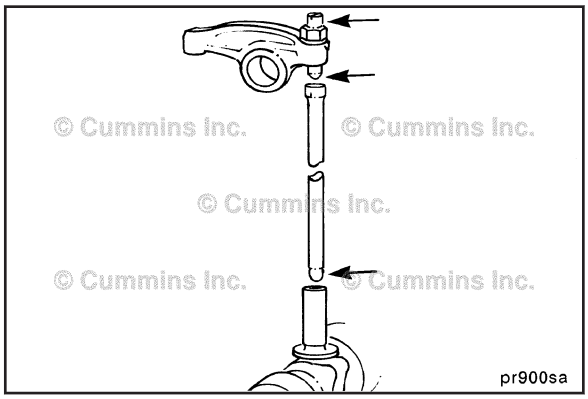
Cam Followers/Tappets - Overview (004-999)

General Information

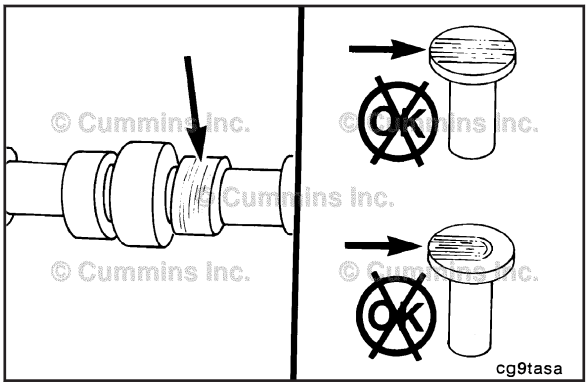
Valve Tappets and Push Tubes

The valve tappets are mushroom-shaped. The convex shape of the surface that contacts the camshaft lobe causes the tappets to rotate as it lifts the push tube.

The ball end of the push tube fits into a ball socket in the tappet. The other end of the push tube is fitted with a socket into which the ball end of the rocker lever adjusting screw operates.



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

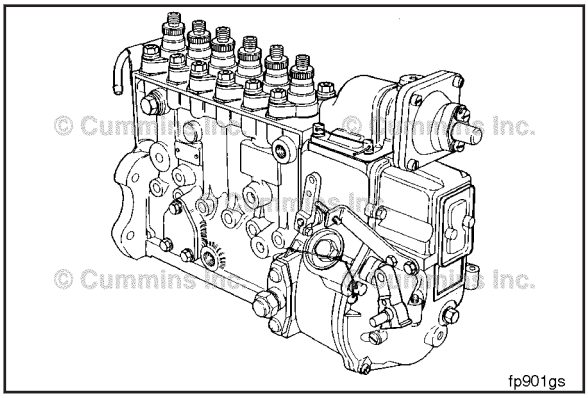


Fuel System - Overview (005-999)

General Information

Fuel System Components and Flow - Distributor-Type Fuel Injection Pump

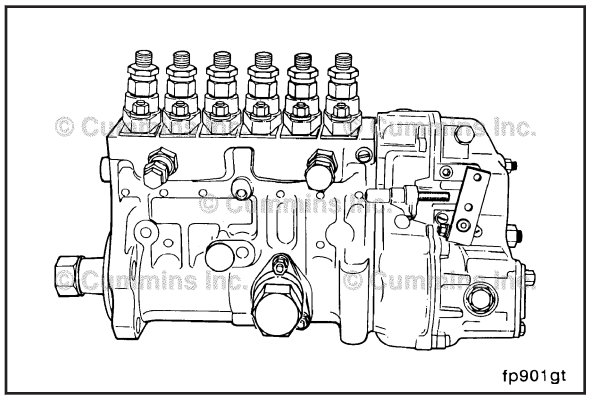
Most of the engines will be equipped with a cam actuated fuel transfer pump. Two types of fuel transfer pumps are available for distributor-type fuel injection pumps: 1) A diaphragm-style fuel transfer pump and 2) a piston-style fuel transfer pump. The piston-style fuel transfer pump is offered as an option. Fuel flow begins as the fuel transfer pump pulls fuel from the supply tank though a mandatory prefilter. The fuel transfer pump supplies low-pressure fuel to the fuel filter head, through the filter, and then to the distributor injection pump.



The distributor pump builds the high injection pressures required for combustion and routes the fuel through individual high-pressure fuel lines to each injector.

When the high-pressure fuel reaches the injector, the pressure lifts the needle valve against the spring tension to let the fuel enter the combustion chamber.

Any leakage past the needle valve enters the fuel drain manifold. The fuel drain manifold routes controlled venting from the distributor injection pump and leakage from the injectors back into the fuel tank.



Fuel System Components and Flow - In-Line Fuel Injection Pump

A cam-actuated piston-style fuel transfer pump provides positive fuel pressure to the fuel injection pump. Fuel flow begins as the fuel transfer pump pulls fuel from the supply tank. The system should have a prefilter or screen to remove larger contaminants from the fuel before reaching the fuel transfer pump. The fuel transfer pump supplies low-pressure fuel through the fuel filter head and filter, to the fuel injection pump.

The Bosch® in-line fuel injection pump is used on higher rated '91 and '94 B Series automotive engines and '96 marine engines. The Nippondenso EP-9 was used on pre-'96 higher horsepower marine B Series engines.

The Bosch® P3000 fuel injection pump is used on higher horsepower certified industrial engines and lower horsepower '91 to '93 automotive engines.

Bosch® “A”-type fuel injection pumps are used on lower horsepower certified industrial engines.

The fuel injection pump builds the high injection pressures required for combustion and routes the fuel through high-pressure fuel lines to each injector.

All B Series engines use closed-nozzle, hole-type injectors. When the high-pressure fuel reaches the injector, the pressure lifts the needle valve against the spring tension to allow fuel to enter the combustion chamber.

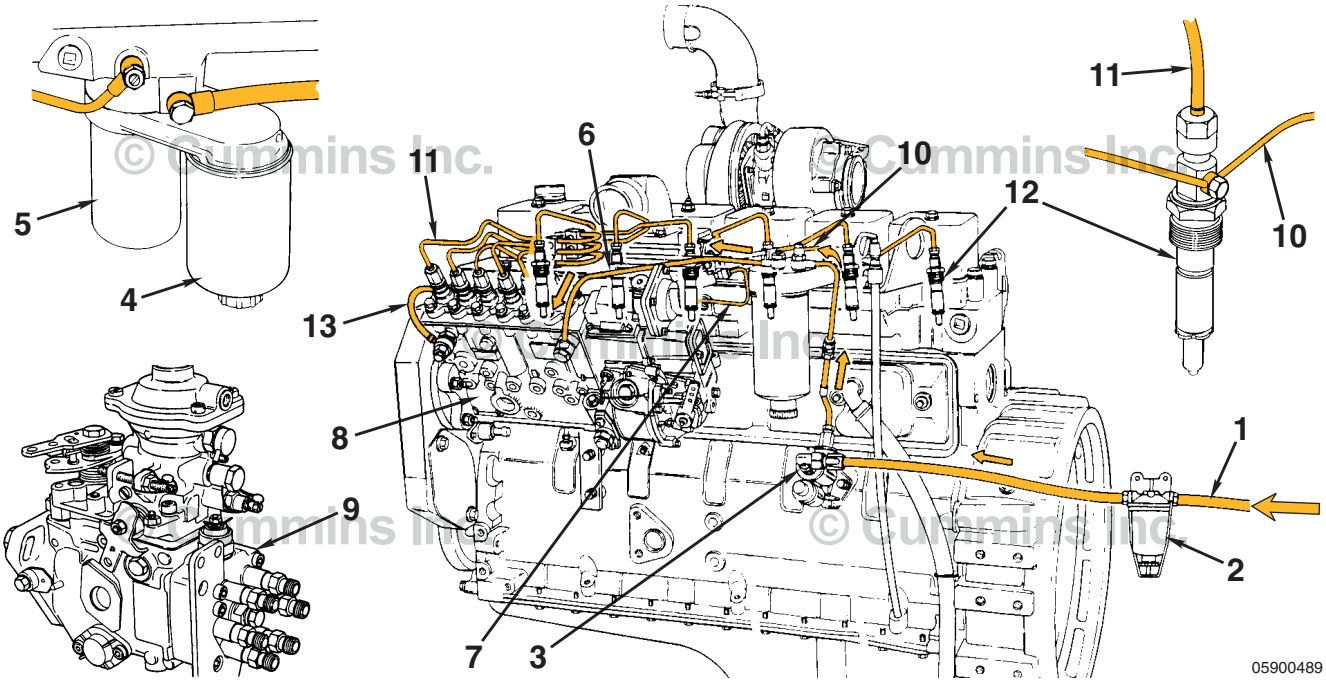
Any leakage past the needle valve enters the fuel drain manifold.

On engines equipped with the Bosch® in-line fuel injection pumps, the manifold routes leakage from the injectors to the inlet side of the fuel filter. On engines equipped with the Nippondenso EP-9 fuel injection pump, the manifold routes leakage from the injectors to the supply tank.

Flow Diagram, Fuel System (200-001)

Flow Diagram

Front Gear Train



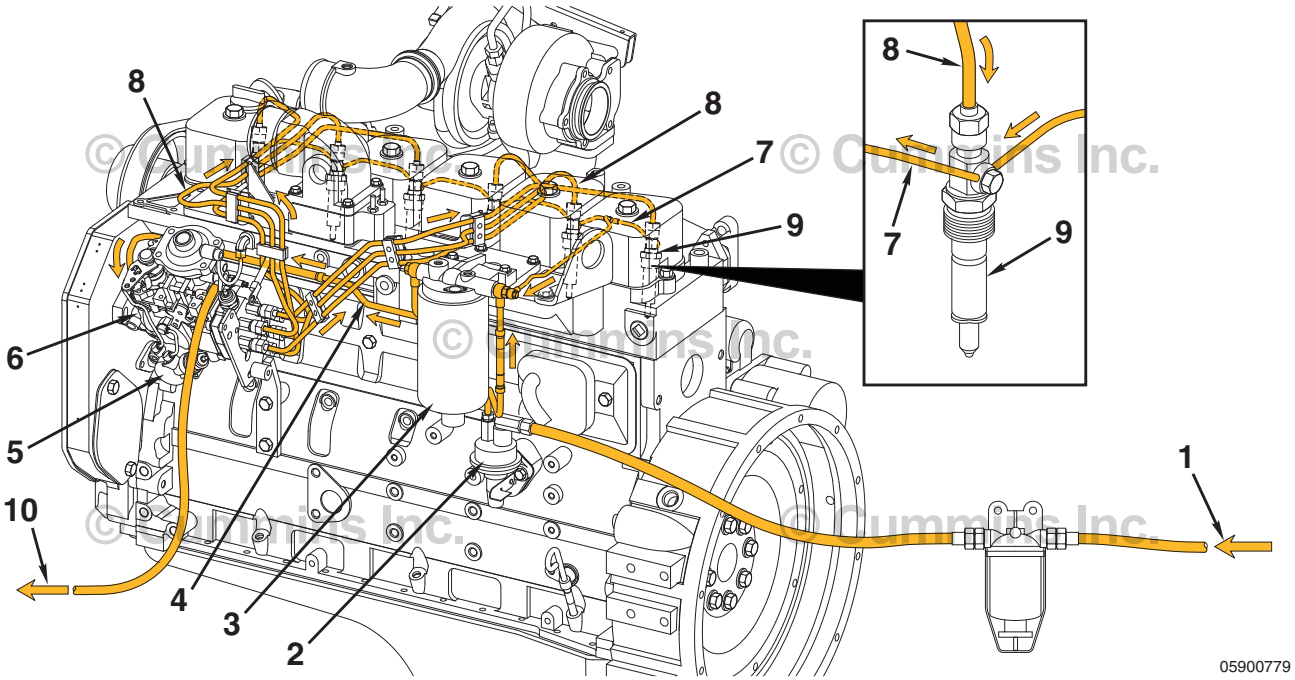
Automotive Applications

1. Fuel from supply tank
2. Prefilter or screen
3. Fuel lift pump
4. Fuel/water separator
5. Fuel filter
6. Low-pressure fuel line
7. Turbocharger boost control line
8. Bosch® P7100 injection pump
9. Bosch® rotary injection pump
10. Fuel drain manifold
11. High-pressure fuel line
12. Bosch® 7-mm closed-nozzle, hole-type injectors
13. Fuel return to supply tank.

Flow Diagram, Fuel System (200-001)

Flow Diagram

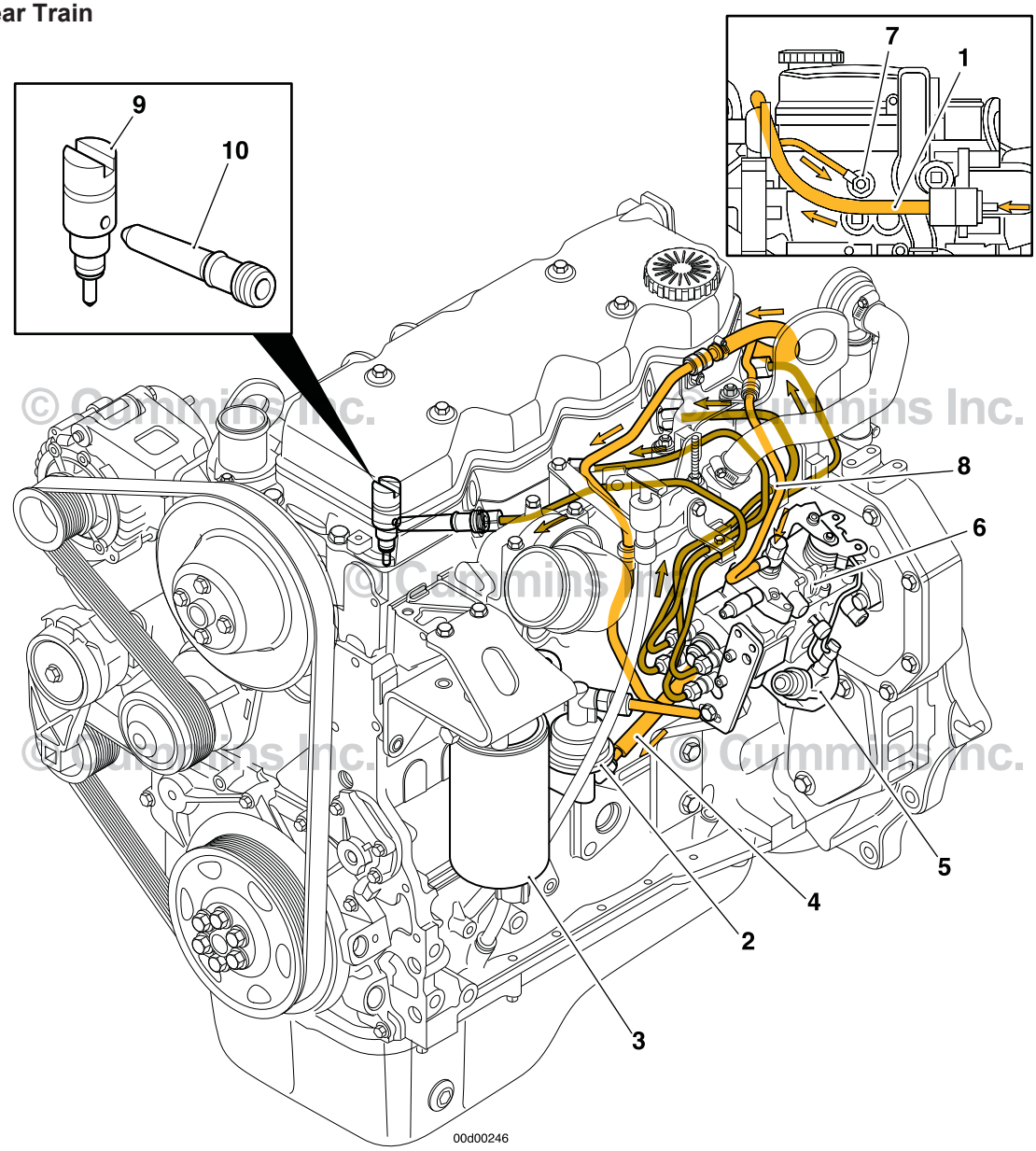
Front Gear Train



Industrial Applications

1. Fuel from supply tank
2. Fuel lift pump
3. Fuel filter/water separator
4. Low-pressure fuel supply lines
5. Bosch® KKSB cold start injection advance
6. Bosch® VE injection pump
7. Fuel drain manifold
8. High-pressure fuel supply lines
9. Bosch® closed nozzle injectors
10. Fuel return to supply tanks.

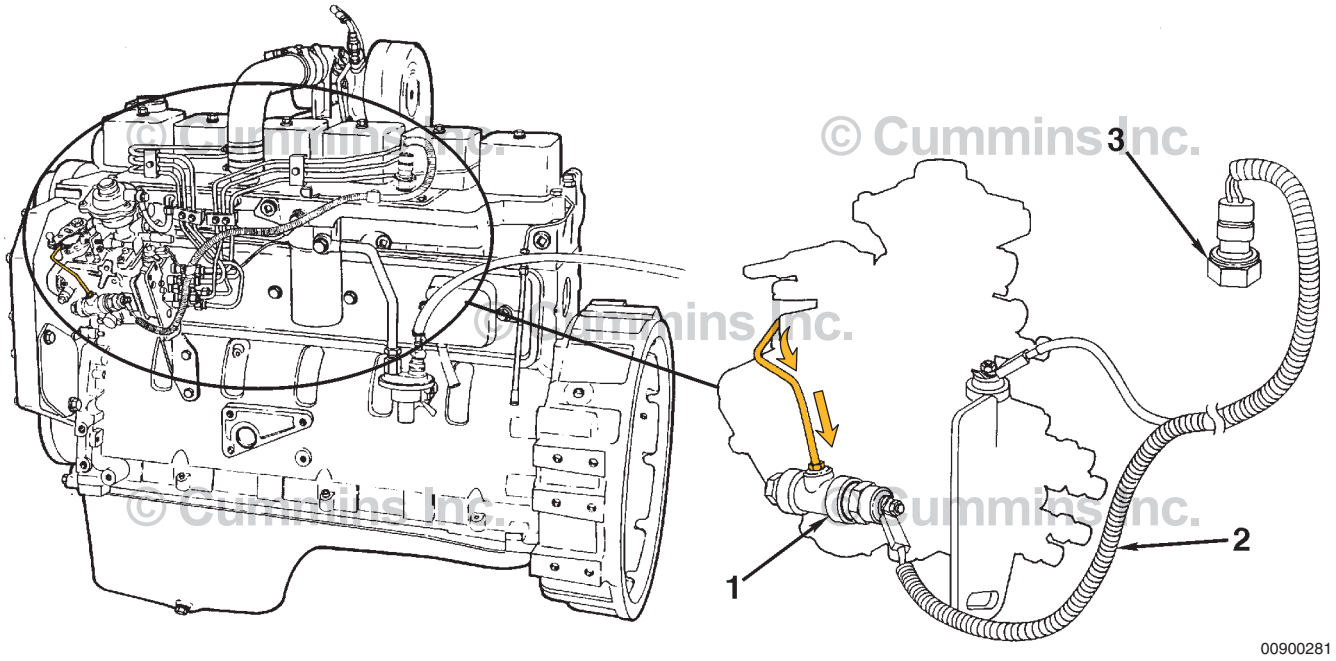
Rear Gear Train



Industrial Applications

1. Fuel from supply tank
2. Fuel lift pump
3. Fuel filter/water separator
4. Low-pressure fuel supply lines
5. Bosch® KKSB cold start injection advance
6. Bosch® VE injection pump
7. Fuel drain manifold and return to supply tanks
8. High-pressure fuel supply lines
9. Bosch® closed nozzle injectors
10. High pressure connector.

Industrial Applications



Hydraulic Cold Start Injection Advance (Rotary Pumps Only)

1. KSB valve
2. Wiring harness
3. Temperature switch.

Lubricating Oil System - Overview (007-999)

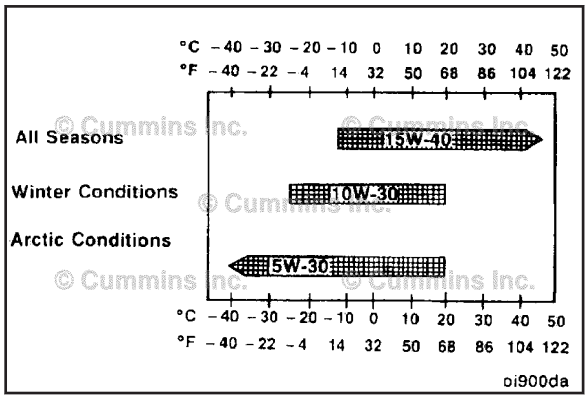
General Information

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

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

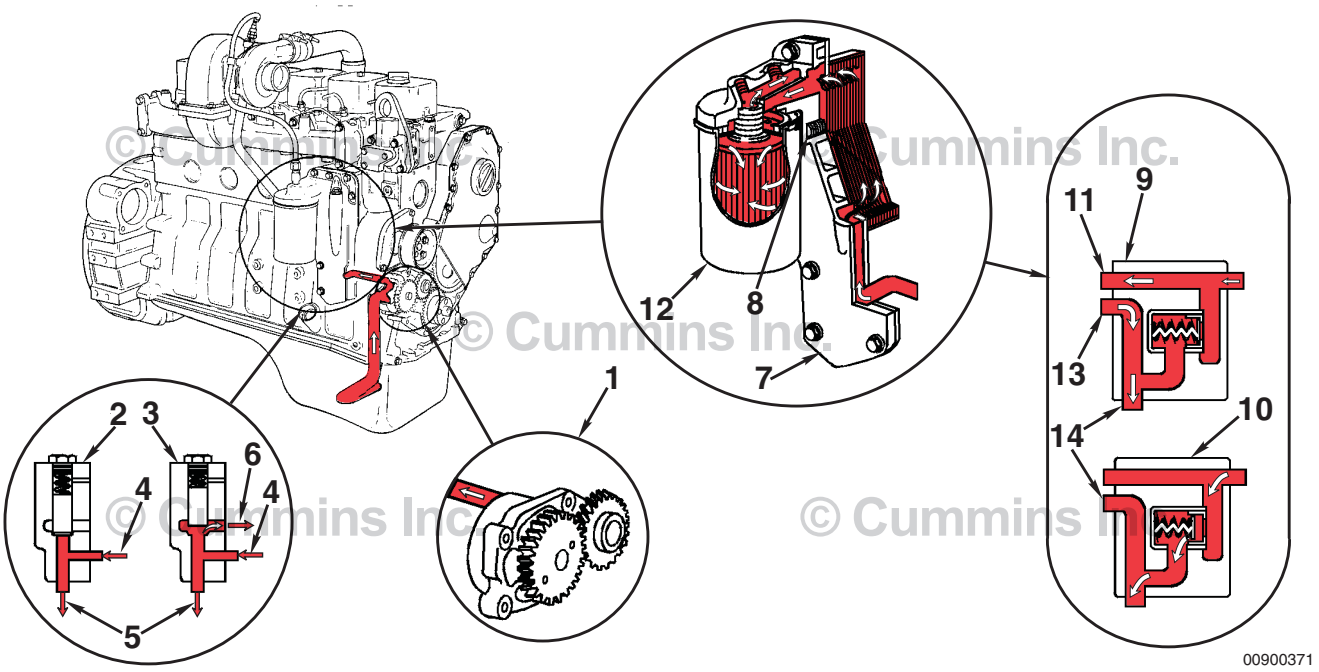
Cummins Inc, recommends the use of a high-quality SAE-40 heavy-duty engine oil, such as Cummins Premium Blue®, which meets the American Petroleum Institute (API) performance classification CF/SG.

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



Flow Diagram, Lubricating Oil System (200-002)

Flow Diagram



1. Gerotor lubricating oil pump
2. Pressure regulating valve closed
3. Pressure regulating valve open
4. From lubricating oil pump
5. To lubricating oil cooler
6. To lubricating oil pan
7. Lubricating oil cooler
8. Filter bypass valve
9. Filter bypass valve closed
10. Filter bypass valve open
11. To lubricating oil filter
12. Full-flow lubricating oil filter
13. From lubricating oil filter
14. Main lubricating oil rifle.

Flow Diagram, Lubricating Oil System (200-002)

Flow Diagram

Lubricating Oil Pump

The engine uses a gerotor-type lubricating oil pump (1). The machined cavity in the block is the same for all engines. A wider gerotor is used in the six-cylinder engine to increase the lubricating pump capacity. Consequently, the four-cylinder and six-cylinder lubricating pumps are **not** interchangeable.

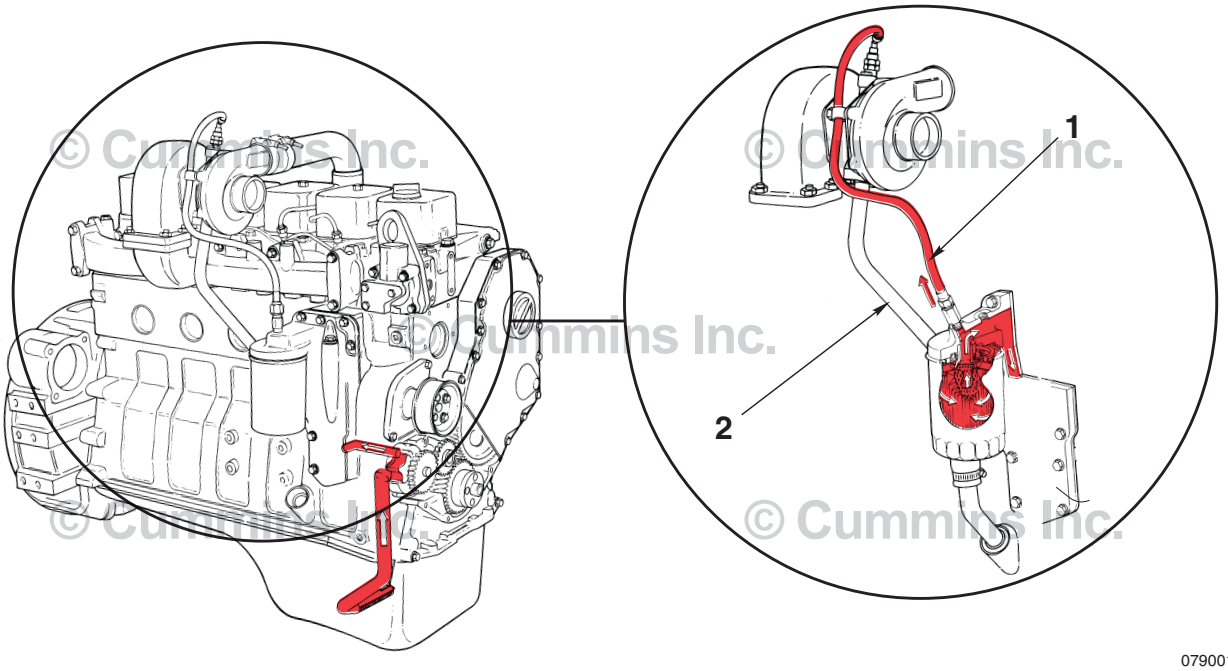
Pressure-Regulating Valve

The pressure-regulating valve (2) is designed to keep the lubricating oil pressure from exceeding 449 kPa [65 psi]. When the lubricating oil pressure from the pump is greater than 449 kPa [65 psi], the valve opens, uncovering the dump port, so part of the lubricating oil is routed to the oil pan. The minimum lubricating oil pressure limit is the same for the four-cylinder and the six-cylinder engine. Because of manufacturing tolerances of the components and the oil passages, the lubricating oil pressure can differ as much as 69 kPa [10 psi] between engines.

Lubrication for the Turbocharger

Flow Diagram, Lubricating Oil System (200-002)

Flow Diagram



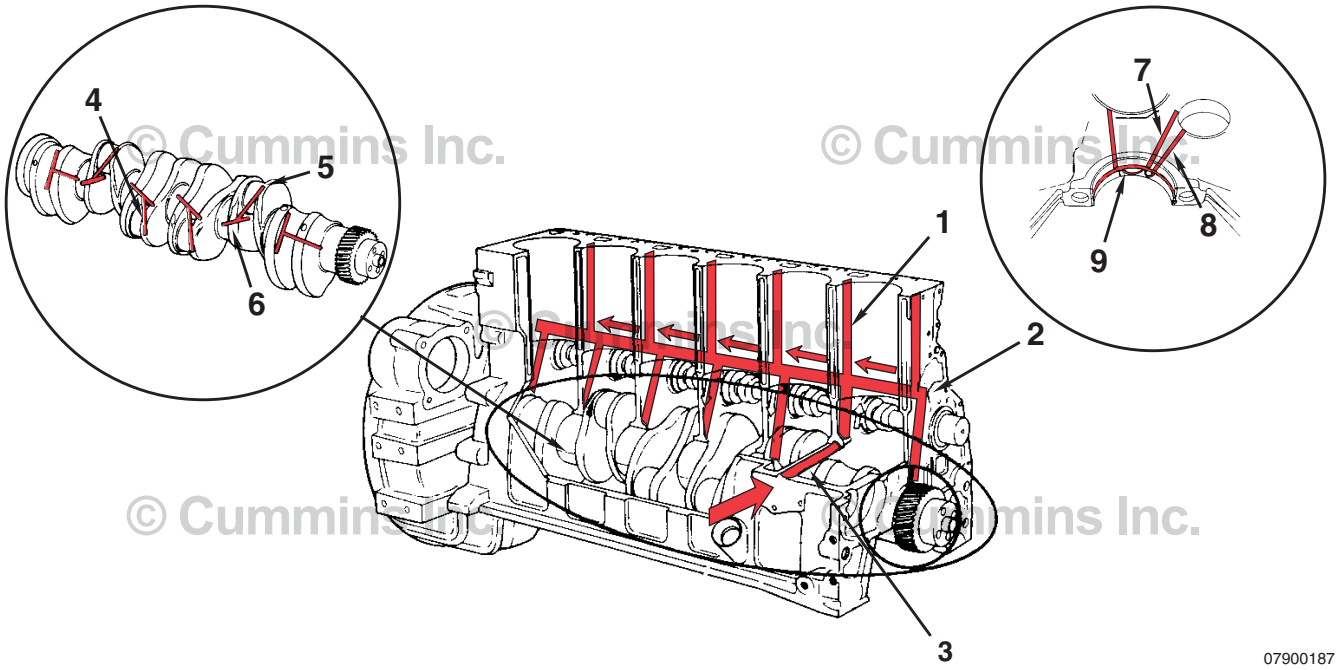
07900188

1. Oil supply
2. Oil drain.

The turbocharger receives filtered, cooled, and pressurized lubricating oil through a supply line from the filter head. A drain line connected to the bottom of the turbocharger housing returns the lubricating oil to the lubricating oil pan through a fitting in the cylinder block.

Flow Diagram, Lubricating Oil System (200-002)

Flow Diagram



Lubrication for the Power Components

1. To valve train
2. Main oil rifle
3. From oil cooler
4. Connecting rod journal
5. To connecting rod bearing
6. Crankshaft, main journal
7. From main oil rifle
8. To camshaft
9. To piston cooling nozzle.

The main bearings and the valve train are lubricated by pressurized oil directly from the main oil rifle. The other power components, connecting rods, pistons, and camshaft receive pressurized oil indirectly from the main oil rifle.

The drillings in the crankshaft supply oil to the connecting rod bearings. The oil is supplied to the camshaft journals through drillings in the main bearing saddle. Smaller drillings in the main bearing saddle supply oil to the piston cooling nozzles. The spray from the nozzles also provides lubrication for the piston pins.

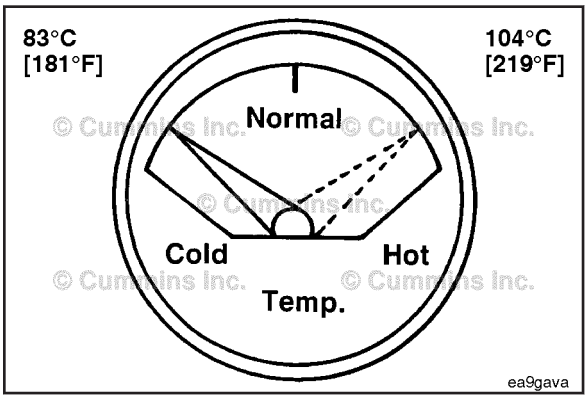
The Number 1 main bearing saddle does **not** contain a piston cooling nozzle. Cylinder Number 1 receives the lubricating and cooling spray from the nozzle located in the Number 2 bearing saddle. Cylinder Number 2 receives the spray from the Number 3 bearing saddle, etc.

Lubrication for the valve train is supplied through separate drillings in the cylinder block. The oil flows through the drillings and across the oil transfer slot in the cylinder head gasket. From the transfer slot, the oil flows around the outside diameter at the cylinder head capscrew, across a slot in the bottom of the rocker lever support, and up a vertical drilling in the support. From these drillings, oil flows through drillings in the rocker lever shaft to lubricate the rocker levers. Oil flows through a drilling in the rocker levers to fill a channel cast into the top of the levers. The oil from the channel lubricates the valve stems, push tubes, and tappets.

Cooling System - Overview (008-999)

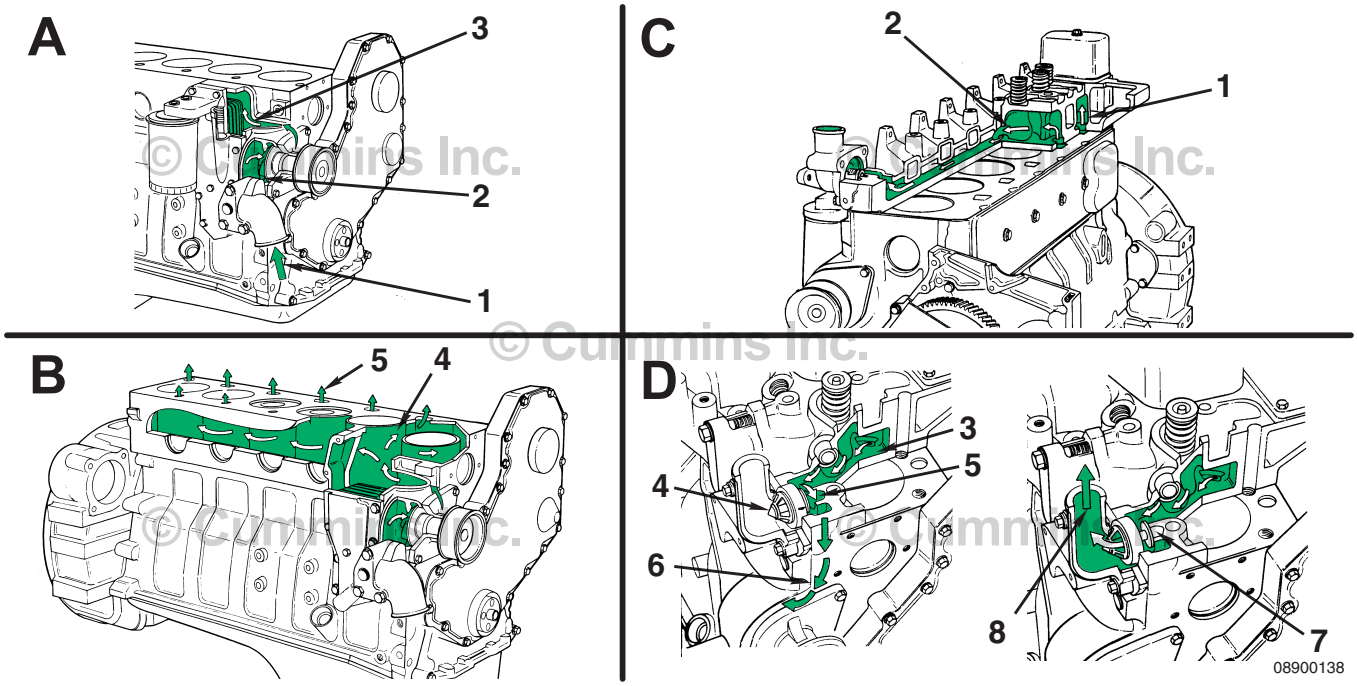
General Information

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



Flow Diagram, Cooling System (200-003)

General Information



⚠CAUTION⚠

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

The illustration identifies the significant features of the coolant system.

Sections A and B.

Coolant is drawn from the radiator by the integrally mounted water pump. The output from the water pump empties into the oil cooler cavity of the cylinder block.

The coolant then circulates around each cylinder and crosses the block to the fuel pump side of the engine.

1. Coolant Inlet
2. Pump Impeller
3. Coolant Flow Past Oil Cooler
4. Coolant Flow Past Cylinder Head
5. Coolant to Cylinder Head

Sections C and D.

Coolant then flows up into the cylinder head, crosses over the valve bridges, and down the exhaust manifold side of the engine to the integral thermostat housing.

As the coolant flows across the head toward the thermostat housing, it provides cooling for the injector. When the engine is below operating temperature, the thermostat is closed, and the coolant flow bypasses the radiator and goes to the water pump inlet through internal drillings in the block and cylinder head.

1. Coolant Flow from the Cylinder Head
2. Coolant to the Thermostat Housing
3. Coolant Flow Past Injector
4. Thermostat
5. Coolant Bypass Passage
6. Coolant Flow to Pump Inlet
7. Bypass Closed
8. Coolant Flow Back to Radiator

When operating temperature is reached, the thermostat opens, blocking the bypass passage to the water pump and opening the outlet to the radiator.

Air Intake System - Overview (010-999)

General Information

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

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

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

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

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

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

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

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

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

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

⚠CAUTION⚠

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

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

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

⚠CAUTION⚠

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

Theory of Operation

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

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

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

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

⚠ WARNING ⚠

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

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

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

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

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

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

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

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

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

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

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

- Intake heater grids
- Engine speed sensor
- Wiring.

The intake heater system operates in three modes as follows:

Preheat Cycle

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

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

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

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

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

Both elements heat during this cycle.

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

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

Post Heat Cycle

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

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

Battery voltage is monitored by the heater control module system.

The temperature sensor continues to monitor intake air temperature.

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

Both elements heat during this cycle.

Post Heat Recycle

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

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

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

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

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

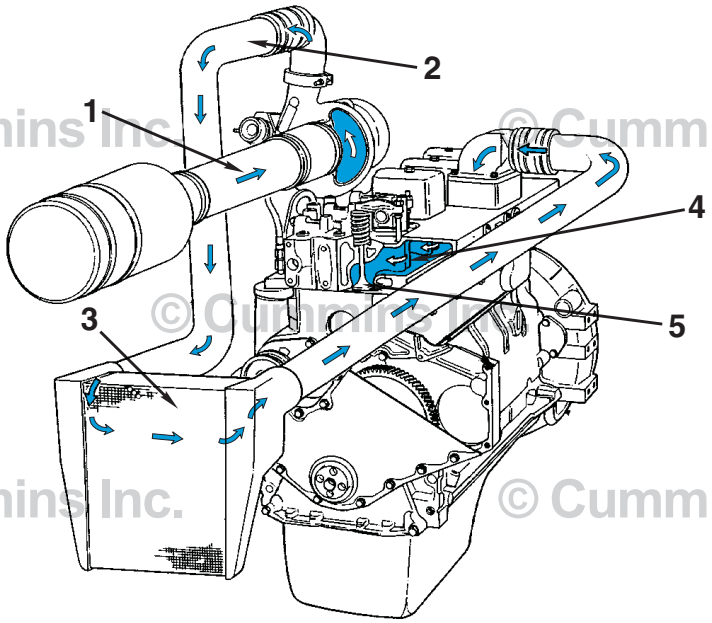
If the post heat recycle is interrupted during its 20-minute cycle, the cycle will restart, and reset for another 20 minutes if all of the following conditions occur:

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

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

Flow Diagram, Air Intake System (200-004)

Flow Diagram



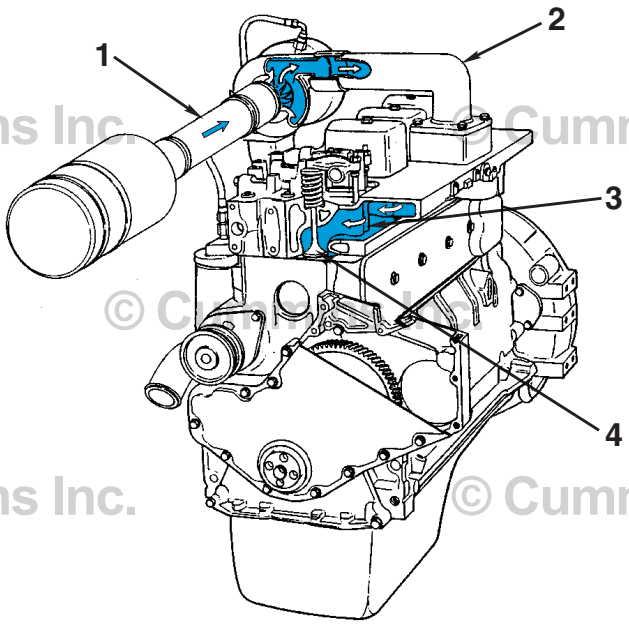
10900253

Turbocharged-Charge-Air-Cooled Engine

1. Intake air inlet to turbocharger
2. Turbocharger air to charge air cooler
3. Charge air cooler
4. Intake manifold
5. Intake valve.

Flow Diagram, Air Intake System (200-004)

Flow Diagram



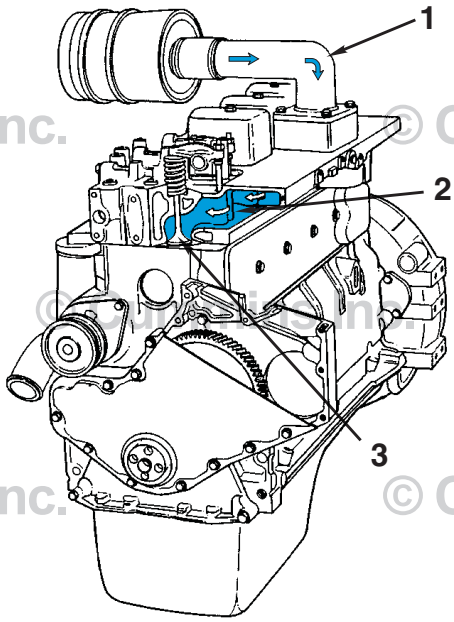
10900256

Turbocharged (only) Engine

1. Intake air inlet to turbocharger
2. Air to intake manifold
3. Intake manifold
4. Intake valve.

Flow Diagram, Air Intake System (200-004)

Flow Diagram



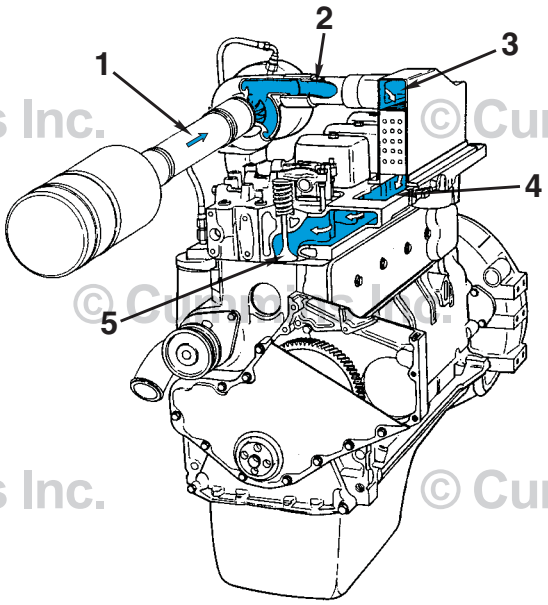
10900254

Naturally Aspirated Engine

1. Intake air inlet
2. Intake manifold
3. Intake valve.

Flow Diagram, Air Intake System (200-004)

Flow Diagram



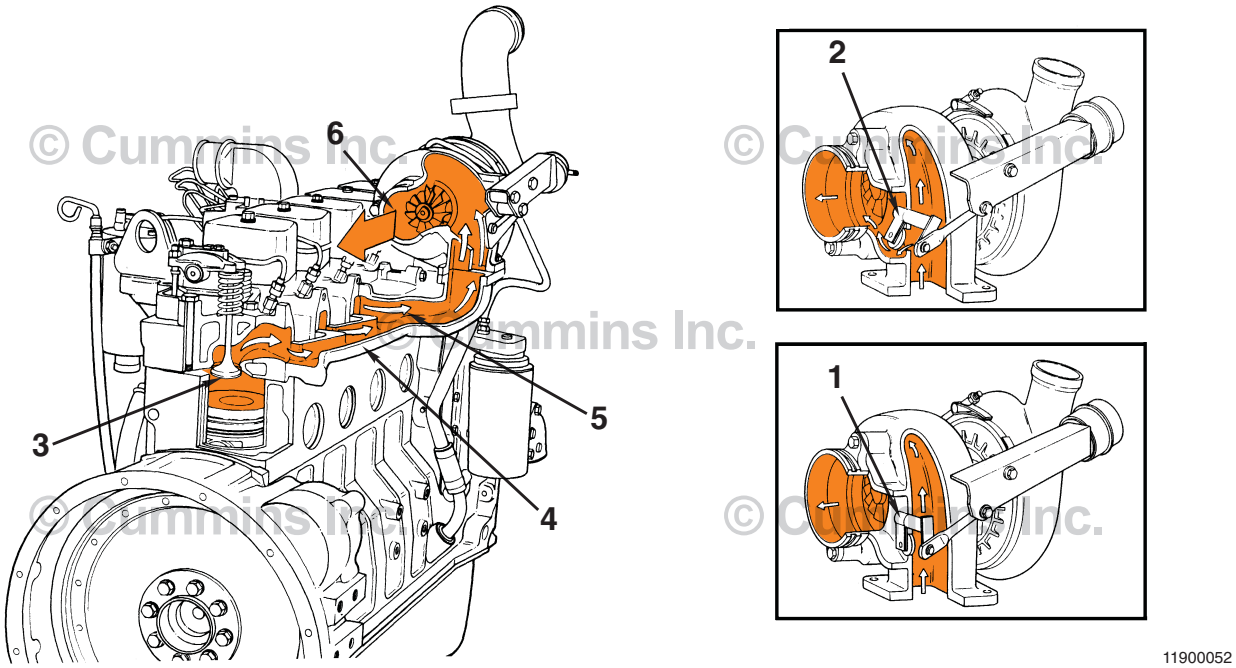
10900255

Turbocharged-Aftercooled Engine

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

Flow Diagram, Exhaust System (200-005)

Flow Diagram



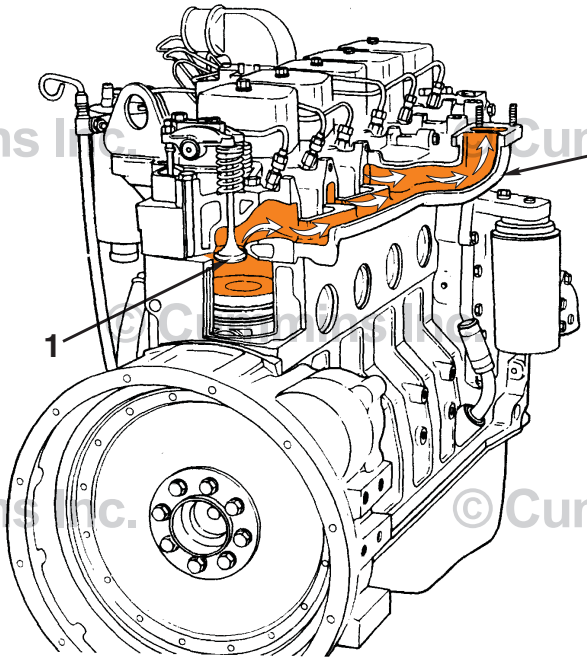
11900052

Turbocharged with Wastegate

1. Wastegate closed
2. Wastegate open
3. Exhaust valve
4. Exhaust manifold
5. Turbocharger exhaust inlet
6. Turbocharger exhaust outlet.

Flow Diagram, Exhaust System (200-005)

Flow Diagram



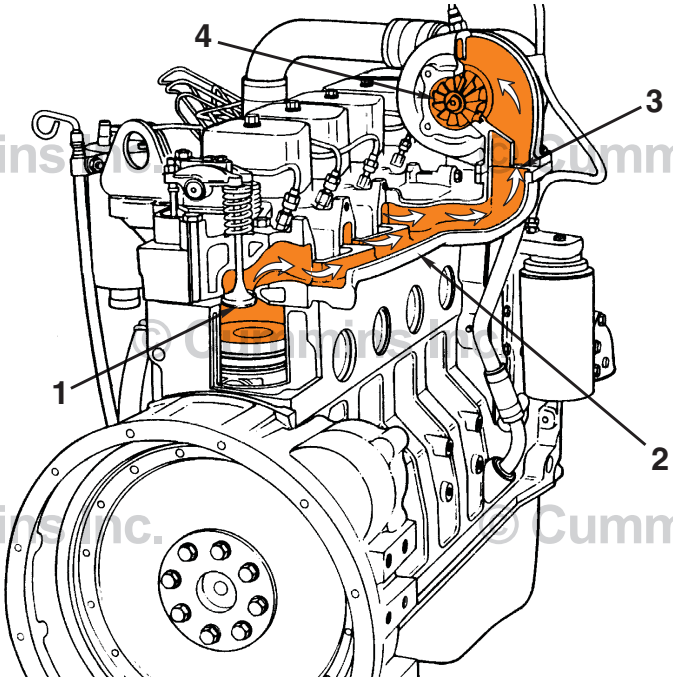
11900053

Naturally Aspirated Engine

1. Exhaust valve
2. Exhaust manifold.

Flow Diagram, Exhaust System (200-005)

Flow Diagram



11900054

Turbocharged Engine

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

Compressed Air System - Overview (012-999)

General Information

The Holset® SS191B air compressor is an engine-driven, piston-type compressor that supplies compressed air to operate air-activated devices. The compressor operates continuously but has a "loaded" and "unloaded" operating mode. The operating mode is controlled by a pressure activated governor and the compressor unloading assembly. When the air system reaches a predetermined pressure, the governor applies an air signal to the air compressor unloader assembly, causing the unloader valve to hold the compressor intake valve open and compressed air to stop flowing into the air system. As the air in the air system is used, the pressure drops. At a predetermined pressure, the governor exhausts the air signal to the compressor unloader assembly, allowing the compressor to again pump compressed air into the air system.

This air compressor is available in an air cooled or water cooled version, the **only** difference being changes to the cylinder head to incorporate a water passage.

This air compressor is also available with or without a power steering pump housing.

Other brands of compressors can be used on the B Series engine. Troubleshooting procedures are very similar for these air compressors compared to the Holset® SS191. Refer to the specific air compressor manufacturer's manual for detailed repair information, including torque values.

NOTE: The cylinder head and unloader components of the Holset® SS191 air compressor can be serviced without removal of the air compressor on many engine applications. This troubleshooting manual will cover servicing of the air compressor unloader components while the compressor is still on the engine. All other servicing of the air compressor internal components should be done after the compressor has been removed from the engine. Reference the Shop Manual, Bulletin 3810433, for detailed disassembly and assembly information on air compressor SS191.

The Holset® SS296 single-cylinder air compressor is an engine-driven, piston-type compressor that supplies compressed air to operate air-activated devices. The compressor runs continuously but has a loaded and unloaded operating mode. The operating mode is controlled by a pressure-activated governor and the compressor unloading assembly.

The SS296 air compressor used on B Series engines uses an (E-type) unloader. The economy (E-type) unloader system was designed to reduce pumping losses and engine boost pressure losses through the compressor intake valve while operating in unloaded mode.

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

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

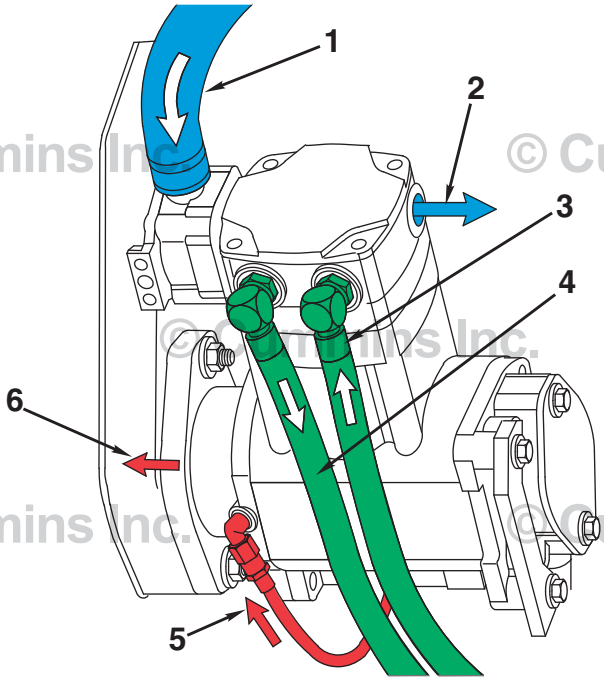
As the air in the air system is used, the pressure drops. At a predetermined pressure, the governor exhausts the air signal to the compressor unloader assembly, allowing the compressor to again pump compressed air into the air system.

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

Other brands of compressors can be used on B Series engines. Troubleshooting procedures are very similar for these air compressors compared to the Holset® SS296. Refer to the specific air compressor manufacturer's manual for detailed repair information and torque specifications.

Flow Diagram, Compressed Air System (200-006)

General Information



12900030

1. Air In
2. Air Out
3. Coolant In
4. Coolant Out
5. Lubricating Oil In
6. Lubricating Oil Out Is Internal to the Gear Housing.

Electrical Equipment - Overview (013-999)

General Information

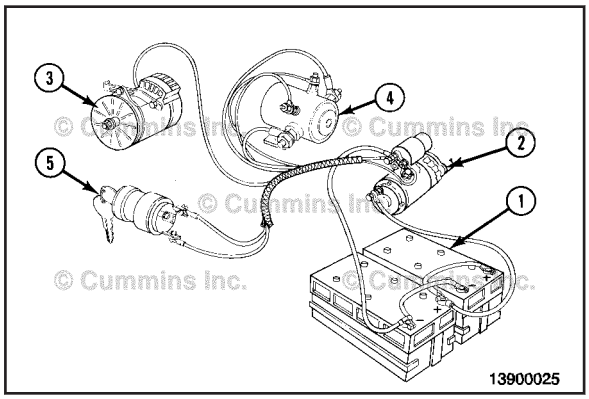
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first, and attach the negative (-) battery cable last.

⚠WARNING⚠
To reduce the possibility of personal injury, keep hands, long hair, jewelry, and loose-fitting or torn clothing away from fans and other moving parts.

The basic electrical system consists of:

- Batteries (1)
- A starter motor (2)
- An alternator (3)
- A magnetic switch (4)
- An ignition switch (5)
- All necessary wiring.

All components **must** be carefully matched.



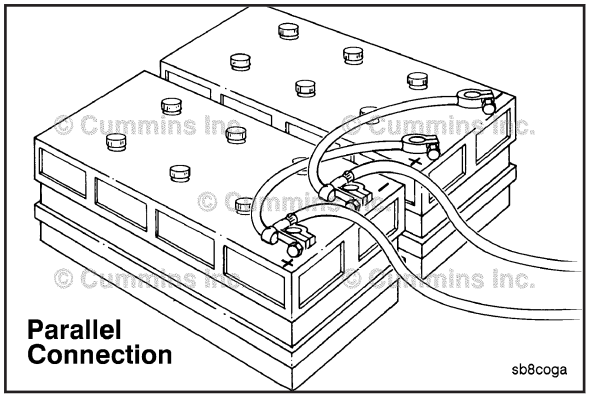
The rotary injection pump uses an electrical fuel shutoff valve. The in-line injection pump uses an electrically activated solenoid shutdown system. The function of the valve is discussed in the fuel system section.

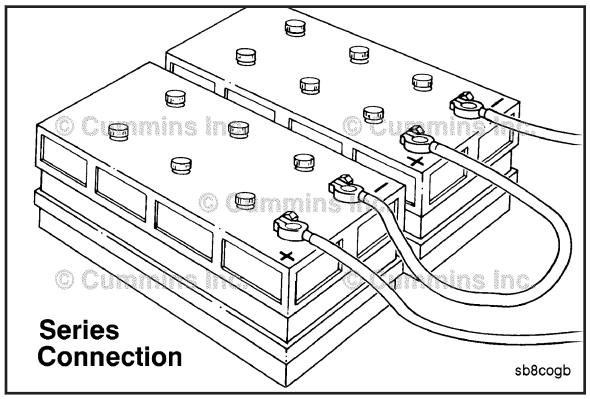
The engine will have temperature and oil pressure sensors connected to indicators or wired for automatic shutdown. The engine can also be fitted with a block heater, oil pan heater, or intake manifold air heater.

NOTE: When troubleshooting a Cummins B Series generator set, refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.

The accompanying illustrations show typical parallel and series connections:

- Parallel connection.





- Series connection.

Engine Testing - Overview (014-999)

General Information

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

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

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

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

Section TS - Troubleshooting Symptoms

Section Contents

Troubleshooting Procedures and Techniques

General Information

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

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

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

Follow these basic troubleshooting steps:

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

Troubleshooting Symptoms Charts

General Information

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

⚠ WARNING ⚠

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

Troubleshooting Overview

Engine Noise Diagnostic Procedures - General Information

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

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

Engine noise can sometimes be isolated by performing a cylinder cutout test. See Procedure 014-008 in the corresponding Troubleshooting and Repair Manual or Service manual for the engine being worked on. If the volume of the noise decreases or the noise disappears, it is related to that particular engine cylinder.

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

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

Main Bearing Noise

(Refer to Engine Noise Excessive - Main Bearing symptom tree)

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

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

An irregular noise can indicate worn crankshaft thrust bearings.

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

Connecting Rod Bearing Noise

(Refer to Engine Noise Excessive - Connecting Rod symptom tree)

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

Piston Noise

(Refer to Engine Noise Excessive - Piston symptom tree)

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

Driveability - General Information

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

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

Low power is a term that is used in the field to describe many different performance issues. However, in this manual low power is defined as the inability of the engine to produce the power necessary to move the vehicle at a speed that

can be reasonably expected under the given conditions of load, grade, wind, and so on. Low power is usually caused by the lack of fuel flow that can be caused by any of the following factors:

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

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

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

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

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

- Failed boost sensor, if equipped
- Excessive drainline restriction
- Accelerator deadband.

Driveability/Low Power - Customer Complaint Form

Customer Name/Company _____Date _____

- Describe Problem/Complaint_____
- Symptoms of the Problem/Complaint
- When cranking:
- ____Cranks too slowly
- ____Cranks OK but does not start easily
- ____Cranks OK but does not start
- ____Slow start; _____ seconds
- ____Starts then dies
- ____Idle RPM is rough when engine is cold
- ____Idle RPM is rough when engine is hot
- When driving
- ____Misses or hesitates during acceleration
- ____Misses or hesitates during deceleration
- ____Stalls (dies) during acceleration
- ____Stalls (dies) during deceleration
- ____Smokes: ___ black ___ white
- ____Low power
- ____Unusual engine behavior
- When do you notice the Problem/Complaint occuring?
- Engine conditions:
- When the coolant temperature for the engine is:
- ___ cold ___ normal ___ hot ___ all temperatures
- When the engine is ____ RPM on the tachometer
- Weather conditions:
- ___ cold (below 10°C [50°F]) ___ hot (above 27°C [80°F]) ___ humid or rainy ___ other _____
- When driving:
- ____Accelerating
- ____Decelerating
- ____Climbing a grade / hill
- ____Down hill
- ____Braking
- ____Unloaded
- ____Loaded
- How did the problem occur? Suddenly _____ Gradually _____
- At what hour/mileage did the problem begin? Hours _____ Miles_____ Since New _____
- After engine repair? Yes _____ No _____
- After equipment repair? Yes _____ No _____
- After change in equipment use? Yes _____ No _____
- After change in selected programmable parameters? Yes _____ No_____
- If so, what was repaired and when?_____
- Does the vehicle also experience poor fuel economy? Yes _____No _____

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Driveability/Low Power - Customer Complaint Form

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

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

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

- **A B C D E F**
- Can the vehicle obtain the expected road speed? Yes _____ No_____
- What is desired speed? rpm/mph _____
- What is achieved speed? rpm/mph _____
- Gross vehicle weight _____
- **A B C D E F**
- Has the vehicle's load changed? Yes _____ No _____
- Is the vehicle able to pull the load? Yes _____ No _____
- When?
- _____ On hilly terrain
- _____ With a loaded trailer
- _____ On flat terrain
- _____ Other _____

IF THE ANSWER WAS NO TO ONE OF THE PREVIOUS QUESTIONS, FILL OUT THE DRIVEABILITY/LOW-POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST AND GO TO THE LOW-POWER SYMPTOM TREE.

A B C D E F

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

When?

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

IF THE ANSWER WAS YES TO ONE OF THE PREVIOUS QUESTIONS, FILL OUT THE DRIVEABILITY/LOW-POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST, AND GO TO THE POOR ACCELERATION/RESPONSE SYMPTOM TREE.

Additional Comments:

- _____
  _____
  _____
  _____

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Driveability/Low Power/Excessive Fuel Consumption - Checklist

Vehicle/Equipment Specifications

Year, Type, and Model:
_____

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

Duty Cycle:_____,

Rear Axle Ratio, No. of Axles: _____, Application: Industrial ____, Marine ____, Genset ____, Automotive ____

Typical Gross Vehicle Weight: _____, Engine Rating:_____

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

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

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

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

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

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

Additional Comments:

_____
_____
_____

NOTE: Use this information for VE/VMS® run.

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Fuel Consumption - General Information

The cause of excessive fuel consumption is hard to diagnose and correct because of the potential number of factors involved. Actual fuel consumption problems can be caused by any of the following factors:

- Engine factors
- Vehicle factors and specifications
- Environmental factors
- Driver technique and operating practices
- Fuel system factors
- Low-power/driveability problems.

Before troubleshooting, it is important to determine the exact complaint. Is the complaint based on whether the problem is real or perceived, or does **not** meet driver expectations? The Fuel Consumption - Customer Complaint Form (on the next page) is a valuable list of questions that can be used to assist the service technician in determining the cause of the problem. Complete the form before troubleshooting the complaint. The following are some of the factors that **must** be considered when troubleshooting fuel consumption complaints.

1 **Result of a Low-Power/Driveability Problem:** An operator will change driving style to compensate for a low power/driveability problem. Some things the driver is likely to do are (a) shift to a higher engine rpm or (b) run on the droop curve in a lower gear instead of upshifting to drive at partial-throttle conditions. These changes in driving style will increase the amount of fuel used.

2 **Driver Technique and Operating Practices:** As a general rule, a 1-mph increase in road speed equals a 0.1 mpg increase in fuel consumption. For example, increasing road speed from 50 to 60 mph will result in a loss of fuel mileage of 1 mpg.

3 **Environmental and Seasonal Weather Changes:** As a general rule, there can be as much as a 1- to 1.5-mpg difference in fuel consumption depending on the season and the weather conditions.

4 **Excessive Idling Time:** Idling the engine can use from 0.5 to 1.5 gallons per hour depending on the engine idle speed.

5 **Truck Route and Terrain:** East/west routes experience almost continuous crosswinds and head winds. Less fuel can be used on north/south routes where parts of the trip are **not only** warmer, but also have less wind resistance.

6 **Vehicle Aerodynamics:** The largest single power requirement for a truck is the power needed to overcome air resistance. As a general rule, each 10-percent reduction in air resistance results in a 5-percent increase in mpg.

7 **Rolling Resistance:** Rolling resistance is the second largest consumer of power on a truck. The type of tire and tread design has a sizable effect on fuel economy and performance. Changing from a bias ply to low-profile radial tire can reduce rolling resistance by about 36 percent.

8 **Additional Devices Using the Same Fuel Source:** Additional devices may use the same fuel tank as the vehicle. For example, excessive use of generators or reefers can falsely indicate high fuel consumption.

Additional vehicle factors, vehicle specifications, and axle alignment can also affect fuel consumption. For additional information on troubleshooting fuel consumption complaints, see Troubleshooting Excessive Fuel Consumption, Bulletin 3387245.

Fuel Consumption - Customer Complaint Form

Customer Name/Company _____Date _____

Answer the following questions. Some questions require making an X next to the appropriate answer.

1 What fuel mileage is expected? _____ Expected mpg

2 What are the expectations based on? Original mileage _____, Other units in fleet _____, Competitive engines _____Previous engine owned_____, Expectations **only** _____, VE/VMS® report _____

3 When did the problem occur? Since New _____, Suddenly _____, Gradually _____

4 Did the problem start after a repair? Yes _____ No _____If so, what was repaired and when? _____

5 Is the vehicle also experiencing a driveability issue (low power or poor acceleration/response)? Yes _____ No _____

IF ANSWERED YES, FILL OUT THE DRIVEABILITY/LOW-POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST, AND GO TO THE ENGINE POWER OUTPUT LOW TROUBLESHOOTING SYMPTOM CHART.

1 Is the problem seasonal? Yes _____ No _____

2 Weather conditions during fuel consumption check? Rain _____, Snow_____, Wind _____, Hot temperatures _____, Cold temperatures _____

3 How is the fuel mileage measured? Tank _____, Trip _____, Month_____, Year _____Hubometer _____, Odometer _____

4 Are accurate records kept of fuel added on the road? Yes _____No _____

5 Do routes vary between compared vehicles? Yes _____ No _____

6 Have routes changed for the engine being checked? Yes _____ No_____

7 What are the loads hauled, compared to comparison unit? Gross Vehicle Weight _____Heavier _____, Lighter _____

8 What is the altitude during operation? Below 10,000 feet _____, Above 10,000 feet _____

9 How much of the time is the truck spent idling? Hours/day _____

10 Is the driver technique or operating practices affecting fuel economy?

- High road speed: mph _____
- Operate at rated speed or above: rpm _____
- Incorrect shift rpm: Shift rpm _____, Torque peak _____
- Operate at a cruise speed: rpm _____
- Compensating for low power: Yes _____ No _____

IF, AFTER FILLING OUT THIS FORM, IT APPEARS THAT THE ISSUE IS NOT CAUSED BY VEHICLE FACTORS, ENVIRONMENTAL FACTORS, OR DRIVER TECHNIQUE, FILL OUT THE DRIVEABILITY/LOW-POWER/ EXCESSIVE FUEL CONSUMPTION CHECKLIST, AND GO TO THE FUEL CONSUMPTION EXCESSIVE TROUBLESHOOTING SYMPTOM TREE.

This Page Can Be Copied for Your Convenience.

Oil Consumption

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

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

ACCEPTABLE OIL USAGE									
ANY TIME DURING COVERAGE PERIOD									
ENGINE FAMILY	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART
A - Series	-	-	-	-	-	-	10.0	10.6	12.0
B3.3/4B	400	425	475	650	675	775	10.0	10.6	12.0
ISF	400	425	475	650	675	775	10.0	10.6	12.0
6B/ISB/ QSB	400	425	475	650	675	775	10.0	10.6	12.0
6C/ISC/ QSC/ISL	400	425	475	650	675	775	10.0	10.6	12.0
V/VT-378	-	-	-	-	-	-	4.0	4.3	5.0
V/VT-504	250	265	310	400	425	485	4.0	4.3	4.8
V/VT-555	250	265	310	400	425	485	4.0	4.3	4.8
L10	500	530	620	800	850	970	7.0	7.4	8.4
M11/ISM	500	530	620	800	850	970	7.0	7.4	8.4
N14/NT	500	530	620	800	850	970	7.0	7.4	8.4
ISX/QSX/ Signature ™	500	530	620	800	850	970	7.0	7.4	8.4
V/VT/ VTA-903	250	265	310	400	425	485	4.0	4.3	4.8
KT/KTA19	200	210	250	320	340	390	3.0	3.2	3.6
V/VT/ VTA28	-	-	-	-	-	-	2.0	2.1	1.1
KT/KTA38	-	-	-	-	-	-	1.5	1.6	1.8
KTA50	-	-	-	-	-	-	1.1	1.2	1.3
QSK19	-	-	-	-	-	-	3.0	3.2	3.6
QST30	-	-	-	-	-	-	1.7	1.8	2.0
QSK23	-	-	-	-	-	-	1.7	1.8	2.0
QSK38	-	-	-	-	-	-	1.3	1.4	1.5
QSK45	-	-	-	-	-	-	1.25	1.3	1.5
QSK50	-	-	-	-	-	-	1.0	1.1	1.2
QSK60	-	-	-	-	-	-	0.9	0.95	1.1
QSK78	-	-	-	-	-	-	0.6	0.65	0.72

ACCEPTABLE OIL USAGE (Transit Bus, Shuttle Bus, and School Bus)									
ANY TIME DURING COVERAGE PERIOD									
ENGINE FAMILY	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART
B	10.0	10.6	12.0	200	210	240	320	340	385
C	8.0	8.5	10.0	150	160	180	240	255	290
L, M, N	4.0	4.3	5.0	100	105	120	160	170	195

Oil Consumption

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

15200020

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

Oil Consumption

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

15200020

OIL CONSUMPTION REPORT	
Customer Name:	D/r:
Engine Model:	Mi/Km/Hr:
Engine Serial Number:	CPL Number:
Vehicle Make/Model:	Date:
Signed: _____	

Air Compressor Air Pressure Rises Slowly

This is symptom tree t004

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

OK
Go To Next Step

STEP 2 Air system leaks	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.

OK
Go To Next Step

STEP 3 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.

OK
Go To Next Step

STEP 4 Carbon buildup is excessive in the air discharge line, check valve, or cylinder head	Check for carbon buildup. Replace the air compressor discharge line, if necessary. Refer to Procedure 012-003.

OK
Go To Next Step

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

OK
Go To Next Step

STEP 6 Unloader valve is malfunctioning	Check the unloader valve and unloader body seal. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.

OK
Go To Next Step

Air Compressor Air Pressure Rises Slowly

This is symptom tree t004

Cause	Correction
STEP 7 Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.

Air Compressor Cycles Frequently

This is symptom tree t005

Cause	Correction
STEP 1 Air compressor pumping time is excessive	Replace the desiccant cartridge on the Turbo/CR 2000 air dryer. Refer to the OEM service manual. Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.
OK Go To Next Step	
STEP 2 Air dryer outlet check valve is sticking	Lubricate or replace the air dryer outlet check valve assembly. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.
OK Go To Next Step	
STEP 4 Air system component is malfunctioning	Check the operation of check valves, alcohol evaporators, air dryers, and other OEM-installed air system components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Air system leaks	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.
OK Go To Next Step	
STEP 6 Carbon buildup is excessive in the air discharge line, check valve, or cylinder head	Check for carbon buildup. Replace the air compressor discharge line, if necessary. Refer to Procedure 012-003.
OK Go To Next Step	

Air Compressor Cycles Frequently

This is symptom tree t005

Cause	Correction
STEP 7 E-type system is **not** plumbed correctly	Install an Econ valve, a check valve, and system hoses. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.

Air Compressor Noise is Excessive

This is symptom tree t006

Cause		Correction
STEP 1 Carbon buildup is excessive in the air discharge line, check valve, or cylinder head	.....	Check for carbon buildup. Replace the air compressor discharge line, if necessary. Refer to Procedure 012-003.
OK Go To Next Step		
STEP 2 Ice buildup in the air system components	.....	For all models, check for ice in low spots of the air discharge line, dryer inlet, and elbow fittings. On Holset® models, also check the Econ valve (if equipped). Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.
OK Go To Next Step		
STEP 3 Air compressor mounting hardware is loose, worn, or broken	.....	Check air compressor mounting hardware. Refer to Procedure 012-101 or 012-104.
OK Go To Next Step		
STEP 4 Accessory drive is worn (axial end play is out of specification)	.....	Check the accessory drive axial end play. Inspect the shaft for wear. Refer to Procedure 009-001.
OK Go To Next Step		
STEP 5 Air compressor drive gear or engine gear train is worn or damaged	.....	Inspect the drive gears and gear train and repair as necessary. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.
OK Go To Next Step		
STEP 6 Air compressor timing is **not** correct	.....	Check the air compressor timing. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.
OK Go To Next Step		
STEP 7 Splined drive coupling or gear is excessively worn	.....	Check the coupling for wear. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.
OK Go To Next Step		

Air Compressor Noise is Excessive

This is symptom tree t006

Cause	Correction
STEP 8 Air compressor is excessively worn or internally damaged	Replace or rebuild the air compressor. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature. Replace the desiccant element on the Turbo/CR 2000 air dryer (if equipped). Refer to the manufacturer's instructions.

OK
Go To Next Step

STEP 9 Air compressor is sending air pulses into the air tanks	Install a ping tank between the air dryer and the wet tank and check discharge line size for the application. Refer to the manufacturer's instructions.

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree t007

Cause		Correction
STEP 1 Air intake system restriction to air compressor is excessive	.....	Replace the air compressor air cleaner (if installed). Check the air intake piping. Check engine air intake restriction if the air compressor inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031.
OK Go To Next Step		
STEP 2 E-type system is **not** plumbed correctly	.....	Install an Econ valve, a check valve, and system hoses. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.
OK Go To Next Step		
STEP 3 Lubricating oil drain line is restricted	.....	Remove the air compressor and check the oil drain holes in the air compressor and the accessory drive. Refer to Procedure 012-101 or 012-104.
OK Go To Next Step		
STEP 4 Carbon buildup is excessive in the air discharge line, check valve, or cylinder head	.....	Check for carbon buildup. Replace the air compressor discharge line, if necessary. Refer to Procedure 012-003.
OK Go To Next Step		
STEP 5 Air compressor runs hot	.....	If coolant temperature is above normal, refer to the Coolant Temperature Above Normal - Gradual Overheat symptom tree.
OK Go To Next Step		
STEP 6 Contaminants are building up in the system reservoirs	.....	Drain the reservoirs daily. Refer to the Operation and Maintenance Manual, B Series Engine, Bulletin 3810205.
OK Go To Next Step		
STEP 7 Crankcase pressure is excessive	.....	Check for excessive blowby. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.
OK Go To Next Step		
STEP 8 Engine angularity during operation exceeds specification	.....	Refer to the Engine Specifications data sheet.
OK Go To Next Step		

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree t007

Cause	Correction
STEP 9 Lubricating oil pressure is above specification	Check the oil pressure. Refer to Procedure 007-052 or the OEM service manual.

OK
Go To Next Step

STEP 10 Air compressor drive gear or engine gear train is worn or damaged	Inspect the drive gears and gear train and repair as necessary. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.

OK
Go To Next Step

STEP 11 Air compressor pumping time is excessive	Replace the desiccant cartridge on the Turbo/CR 2000 air dryer. Refer to the OEM service manual. Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.

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

This is symptom tree t008

Cause	Correction
STEP 1 Air system leaks	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.

OK
Go To Next Step

STEP 2 Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.

OK
Go To Next Step

STEP 3 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Refer to the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.

Air Compressor Will Not Pump Air

This is symptom tree t009

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

Air Compressor Will Not Stop Pumping

This is symptom tree t010

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

Alternator Not Charging or Insufficient Charging

This is symptom tree t013

Cause	Correction
STEP 1 Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009.
OK Go To Next Step	
STEP 2 Battery condition poor	Load-test the battery. If the battery charge is low, charge the battery. If battery fails the second load test, replace the battery. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Alternator belt is loose or missing	Check the alternator belt tension. Check pulleys in belt wrap, and repair, if necessary. Replace belt or belt tensioner, or both. Refer to Procedure 008-087.
OK Go To Next Step	
STEP 4 Alternator pulley is loose on the shaft	Tighten the pulley. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Alternator connection to ground is poor	Inspect the alternator mounting hardware for a proper electrical connection to the battery. Remove any paint and debris from the ground connection. Check mounting bracket bolts for proper torque. Refer to Procedure 013-001.
OK Go To Next Step	
STEP 6 Voltage regulator is malfunctioning	Check the voltage regulator. Replace the voltage regulator, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Alternator is malfunctioning	Test the alternator output. Refer to Procedure 013-001.

Alternator Overcharging

This is symptom tree t014

Cause	Correction
STEP 1 Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009.
OK Go To Next Step	
STEP 2 Battery condition poor	Load-test the battery. If the battery charge is low, charge the battery. If battery fails the second load test, replace the battery. Refer to Procedure 013-007.
OK Go To Next Step	
STEP 3 Alternator belt is loose	Check the alternator belt tension. Adjust as necessary. Refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.
OK Go To Next Step	
STEP 4 Alternator pulley is loose on the shaft	Tighten the pulley. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Alternator is malfunctioning	Replace the alternator. Refer to Procedure 013-001.

Coolant Contamination

This is symptom tree t018

Cause	Correction
STEP 1 Coolant mixture of antifreeze and water is **not** correct	Verify the concentration of antifreeze in the coolant. Add antifreeze or water to correct the concentration. Refer to to Procedure 008-018.
OK Go To Next Step	
STEP 2 Coolant is rusty and has debris	Drain and flush the cooling system. Fill with correct mixture of antifreeze and water. Refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.
OK Go To Next Step	
STEP 3 Transmission oil cooler or torque converter cooler is leaking	Check the transmission oil cooler and torque converter cooler for coolant leaks. Refer to to the manufacturer's instructions.
OK Go To Next Step	
STEP 4 Lubricating oil leaks from lubricating oil cooler, head gasket, head, turbocharger, and cylinder block	Refer to the Lubricating Oil Consumption Excessive symptom tree.

Coolant Loss

This is symptom tree t019

Cause	Correction
STEP 1 Coolant level is above specification	Check the coolant level. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 External engine leak	Inspect the engine and its components for seal, gasket, or draincock leaks. Inspect the radiator, heat exchanger, cab heater, hoses, and connections. Pressurize the cooling system if necessary to determine source of leak. Refer to to the OEM service manual.
OK Go To Next Step	
STEP 3 Cooling system hose are collapsed, restricted, or leaking	Inspect the cooling system hoses for restrictions, obstructions, and leaks. Refer to Procedure 008-045.
OK Go To Next Step	
STEP 4 Cooling system pressure cap is **not** correct, is malfunctioning, or has a low-pressure rating	Inspect the pressure cap. Refer to Procedure 008-047.
OK Go To Next Step	
STEP 5 Coolant loss through radiator overflow	Check and review OEM plumbing to make sure no high-pressure coolant can cause backflow. Check vent lines and fill line for restriction. Refer to the Application Engineering Bulletins, Midrange Cooling Requirements, AEB 90.24, and Coolant Recovery System, AEB 91.07.
OK Go To Next Step	
STEP 6 Transmission oil cooler or torque converter cooler is leaking	Check the transmission oil cooler and torque converter cooler for coolant leaks. Refer to the Application Engineering Bulletins, Midrange Cooling Requirements, AEB 90.24, and Coolant Recovery System, AEB 91.07.
OK Go To Next Step	
STEP 7 Wet exhaust manifold and turbine housing leaking coolant	Pressure-test the coolant system. Refer to Procedure 010-033.
OK Go To Next Step	

Coolant Loss

This is symptom tree t019

Cause	Correction
STEP 8 Coolant is leaking into the lubricating oil	Check for coolant in the oil. Refer to the Coolant in the Lubricating Oil symptom tree.

OK
Go To Next Step

STEP 9 Coolant is leaking into the combustion chamber	Remove the cylinder head, and inspect cylinder head, gasket, and pistons for evidence of coolant. Refer to Procedure 002-004, 002-021, or 001-043.

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause		Correction
STEP 1 Coolant level is below specification	.....	Inspect the engine and cooling system for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedure 008-018.
OK Go To Next Step		
STEP 2 Radiator and charge air cooling fins plugged (nonmarine **only**)	.....	Blow debris from fins.
OK Go To Next Step		
STEP 3 Airflow to the radiator is restricted (nonmarine engines **only**)	.....	Check and repair fan shroud, shutters, shutterstat, sensor, fan clutch, and viscous fan as required. Refer to the OEM service manual.
OK Go To Next Step		
STEP 4 Water pump is malfunctioning	.....	Check the water pump for correct operation. Replace the water pump if necessary. Refer to the OEM service manual.
OK Go To Next Step		
STEP 5 Fan drive belt is loose, tight, or **not** in alignment	.....	Check the fan drive belt. Refer to Procedure 008-002.
OK Go To Next Step		
STEP 6 Cooling system hose are collapsed, restricted, or leaking	.....	Inspect the cooling system hoses for restrictions, obstructions, and leaks. Refer to Procedure 008-045.
OK Go To Next Step		
STEP 7 Cooling system is contaminated with dirt, scale, or sludge	.....	Clean the cooling system. Refer to the OEM service manual.
OK Go To Next Step		
STEP 8 Coolant is contaminated with lubricating oil	.....	Refer to the Lubricating or Transmission Oil in the Coolant symptom tree.
OK Go To Next Step		
STEP 9 Fan shroud is damaged or missing or the air recirculation baffles are damaged or missing	.....	Inspect the shroud and the recirculation baffles. Repair, replace, or install, if necessary. Refer to the Lubricating or Transmission Oil in the Coolant symptom tree.
OK Go To Next Step		

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
STEP 10 Cooling system pressure cap is **not** correct, is malfunctioning, or has a low-pressure rating	Inspect the pressure cap. Refer to Procedure 008-047.
OK Go To Next Step	
STEP 11 Coolant mixture of antifreeze and water is **not** correct	Verify the concentration of antifreeze in the coolant. Add antifreeze or water to correct the concentration. Refer to Procedure 008-018.
OK Go To Next Step	
STEP 12 Temperature gauge malfunction	Check or replace the temperature gauge. Refer to the OEM service manual instructions on troubleshooting the gauge. Test the gauge and sensor. repair or replace, if necessary.
OK Go To Next Step	
STEP 13 Thermostat is **not** correct or is malfunctioning	Check the thermostat for the correct part number and for correct operation. Refer to Application Engineering Bulletin, AEB 90.24.
OK Go To Next Step	
STEP 14 Air or combustion gases are entering the cooling system	Check for air or combustion gases in the cooling system. Refer to to Procedure 008-019. Check fill rate to see if it not being exceeded.
OK Go To Next Step	
STEP 15 Sea water hose(s) collapsed	Check sea water system hose(s). Refer to Procedure 008-104.
OK Go To Next Step	
STEP 16 Plugged or restricted heat exchanger (marine engines **only**)	Clean the heat exchanger, both sea water and coolant passages. Refer to Procedure 008-053.
OK Go To Next Step	
STEP 17 Keel cooler is malfunctioning (marine engines **only**)	Inspect the keel cooler for proper operation. Refer to the vessel OEM service manual.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
STEP 18 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012 (Fuel Injection Pump, In-Line), or Procedure 005-014 (Fuel Injection Pump, Rotary).
OK Go To Next Step	
STEP 19 Fuel injection pump is malfunctioning	Replace the fuel injection pump. Refer to Procedure 005-037.
OK Go To Next Step	
STEP 20 Plugged cooling passages in the cylinder head, head gasket, or cylinder block	Pressure-test the cooling system. Refer to Procedure 008-020.
OK Go To Next Step	
STEP 21 Cooling system has insufficient capacity	Refer to the Application Engineering Bulletin (AEB) 90.24 for cooling system specifications.

Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

Cause		Correction
STEP 1 Coolant level is below specification	.....	Inspect the engine and cooling system for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedure 008-018.

OK
Go To Next Step

STEP 2 Fan drive belt is loose, tight, or **not** in alignment	.....	Check the fan drive belt. Refer to Procedure 008-002.

OK
Go To Next Step

STEP 3 Temperature gauge malfunction	.....	Check or replace the temperature gauge. Refer to the OEM service manual.

OK
Go To Next Step

STEP 4 Airflow to the radiator is restricted (nonmarine engines **only**)	.....	Check and repair fan shroud, shutters, shutterstat, sensor, fan clutch, and viscous fan as required. Refer to the OEM service manual.

OK
Go To Next Step

STEP 5 Cooling system hose are collapsed, restricted, or leaking	.....	Inspect the cooling system hoses for restrictions, obstructions, and leaks. Refer to Procedure 008-045.

OK
Go To Next Step

STEP 6 Thermostat is **not** correct or is malfunctioning	.....	Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013.

OK
Go To Next Step

STEP 7 Water pump is malfunctioning	.....	Check the water pump for correct operation. Replace the water pump if necessary. Refer to Procedure 008-062.

OK
Go To Next Step

STEP 8 Fill line or vent lines are restricted, obstructed, or **not** routed correctly	.....	Check the vent lines and the fill line for correct routing and for restriction. Refer to the OEM service manual.

OK
Go To Next Step

STEP 9 Air or combustion gases are entering the cooling system	.....	Check for air or combustion gases in the cooling system. Refer to Procedure 008-019.

OK
Go To Next Step

Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

Cause	Correction
STEP 10 Plugged cooling passages in the cylinder head, head gasket, or cylinder block	Pressure-test the cooling system. Refer to Procedure 002-004.
OK Go To Next Step	
STEP 11 Cooling system has insufficient capacity	Refer to AEB 90.24 for the cooling system specifications.

Coolant Temperature Below Normal

This is symptom tree t024

Cause	Correction
STEP 1 Engine is operating at low ambient temperature	Check the shutters and engine compartment air. Refer to Cold Weather Operation, Bulletin 3387266.
OK Go To Next Step	
STEP 2 Airflow across radiator is excessive (nonmarine engines **only**)	Check and repair shutters, fan clutch, and viscous fan as required. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Temperature gauge malfunction	Check or replace the temperature gauge. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Excessive coolant flow through OEM plumbing and heater cores	Close valves to heater cores. Run engine. If engine operates at normal temperature, refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Thermostat is **not** correct or is malfunctioning	Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013 and the OEM service manual.
OK Go To Next Step	
STEP 6 Fan drive or fan controls are malfunctioning (nonmarine engines **only**)	Check the fan drive and controls. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Coolant flow **not** correct to temperature sensor	Check and clean coolant passages.

Coolant in the Lubricating Oil

This is symptom tree t025

Cause	Correction
STEP 1 Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks and cracks. Refer to Procedure 007-003.
OK Go To Next Step	
STEP 2 Air compressor cylinder head is cracked or porous, or has a leaking gasket (nonmarine engines **only**)	Inspect the air compressor cylinder head and gasket. Refer to to Procedure 012-019 and the Master Repair Manual, Holset® Air Compressor, Bulletin 3666121 for Holset® air compressors; for other air compressors refer to the OEM service literature.
OK Go To Next Step	
STEP 3 Aftercooler is leaking	Inspect and pressure-test the aftercooler for leaks. Refer to Procedure 010-001.
OK Go To Next Step	
STEP 4 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to 002-021.
OK Go To Next Step	
STEP 5 Cylinder head is cracked or porous	Remove the intake and the exhaust manifolds. Check for evidence of coolant leak. If necessary, operate the engine at low idle. Pressure-test the cylinder head. Refer to Procedure 002-004.
OK Go To Next Step	
STEP 6 Cylinder head core and expansion plugs leaking or misassembled	Check cylinder head. Refer to Procedure 002-004.
OK Go To Next Step	
STEP 7 Cylinder block is cracked or porous	Inspect the cylinder block. Refer to Procedure 001-026.

Crankcase Gases (Blowby) Excessive

This is symptom tree t027

Cause	Correction
STEP 1 Air compressor is malfunctioning	Isolate the air compressor by disconnecting the air inlet and outlet lines. Refer to Procedure 012-003 in Section 12. Check blowby. If blowby is within specifications, rebuild or replace the air compressor.
OK Go To Next Step	
STEP 2 Cylinder head valve guides are excessively worn	Check the valve guides for wear. Replace the cylinder head, if necessary. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 3 Piston or piston rings are worn or damaged	Check for air intake system leaks. Refer to Procedure 010-024 in Section 10. Check the pistons and piston rings for wear or damage. For piston cleaning and reuse; Refer to Procedure 001-043 in Section 1. For cylinder block inspection and reuse; Refer to Procedure 001-026 in Section 1. For piston ring inspection; Refer to Procedure 001-047 in Section 1.
OK Go To Next Step	
STEP 4 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10.

Engine Acceleration or Response Poor

This is symptom tree t033

Cause	Correction
STEP 1 Engine duty cycle has changed	Verify the engine duty cycle with an electronic service tool. Refer to the appropriate electronic service tool manual or a Authorized Cummins Repair Facility.
OK Go To Next Step	
STEP 2 Operator technique is **not** correct	Explain correct engine operation to the operator. Refer to the Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, U.S.A., Canada, Australia, New Zealand, and Puerto Rico, Bulletin 3810205 or Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, Worldwide excluding U.S.A., Canada, Australia, New Zealand and Puerto Rico, Bulletin 3810464.
OK Go To Next Step	
STEP 3 Fuel level is low in the tank	Fill the supply tank. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Drivetrain is **not** correctly matched to the engine	Check for correct gearing and drivetrain components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Clutch is malfunctioning or is **not** correct	Compare the drivetrain specifications to Cummins recommendations. Check the clutch for correct operation. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Vehicle parasitics are excessive	Check the vehicle brakes for dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Fuel leak	Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines to the supply tanks. Refer to the OEM service manual.
OK Go To Next Step	

Engine Acceleration or Response Poor

This is symptom tree t033

Cause	Correction
STEP 8 Fuel inlet restriction	Check for fuel inlet restriction. Refer to the OEM service manual.
OK Go To Next Step	
STEP 9 Fuel lift pump is malfunctioning	Check the fuel lift pump for correct operation. Check the pump output pressure. Replace the fuel lift pump if necessary. Refer to Procedure 005-045.
OK Go To Next Step	
STEP 10 Fuel pump overflow valve is malfunctioning	Check the overflow valve. Refer to Procedure 006-044.
OK Go To Next Step	
STEP 11 Air in the fuel system	Check for air in the fuel system. Repair source of leak and bleed air from the system. Refer to Procedure 006-003.
OK Go To Next Step	
STEP 12 Air intake system restriction is above specification	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK Go To Next Step	
STEP 13 Charge air cooler is restricted or leaking	Inspect the charge air cooler for air restrictions or leaks. Refer to Procedure 010-027.
OK Go To Next Step	
STEP 14 Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK Go To Next Step	
STEP 15 Closed crankcase ventilation hoses are leaking or damaged	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step	
STEP 16 Close crankcase ventilation valve is leaking or malfunctioning	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.
OK Go To Next Step	

Engine Acceleration or Response Poor

This is symptom tree t033

Cause	Correction
STEP 17 Turbocharger is **not** correct	Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin number 3379133 or 4021327. Replace the turbocharger if necessary. Refer to Procedure 010-033.
OK Go To Next Step	
STEP 18 Turbocharger wastegate is malfunctioning (if equipped)	Check the wastegate for correct operation. Refer to Procedure 010-050.
OK Go To Next Step	
STEP 19 Exhaust brake adjustment is **not** correct	Check the exhaust brake adjustment. Refer to the OEM service manual.
OK Go To Next Step	
STEP 20 Exhaust system restriction is above specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK Go To Next Step	
STEP 21 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK Go To Next Step	
STEP 22 Injectors are **not** correct	Remove the injectors and compare the part numbers to the Control Parts List (CPL), Bulletin 3379133 or 4021327. Replace the injectors if necessary. Refer to Procedure 006-026.
OK Go To Next Step	
STEP 23 Injector is malfunctioning	Perform a pop test on the injector(s). Refer to Procedure 006-026.
OK Go To Next Step	
STEP 24 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of high-quality fuel. Refer to the Fuels For Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 25 Fuel inlet temperature to pump is above specification	Fill the fuel tank, turn off or bypass the fuel heaters, and check the fuel cooler. Refer to the OEM service manual.
OK Go To Next Step	

Engine Acceleration or Response Poor

This is symptom tree t033

Cause		Correction
STEP 26 Fuel supply line restriction between the fuel pump and the injectors	.....	Check the fuel supply line from the fuel pump to the cylinder head for sharp bends that can cause restrictions. Refer to Procedure 006-051.

OK
Go To Next Step

STEP 27 Internal engine damage	.....	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-013.

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

This is symptom tree t043

Cause	Correction
STEP 1 Starting procedure is **not** correct	Verify the correct starting procedure. Refer to the Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, U.S.A., Canada, Australia, New Zealand, and Puerto Rico, Bulletin 3810205 or Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, Worldwide excluding U.S.A., Canada, Australia, New Zealand and Puerto Rico, Bulletin 3810464.

OK
Go To Next Step

STEP 2 Engine cranking speed is too slow	Make sure all drive units are disengaged. Check the engine cranking speed with a handheld tachometer or electronic service tool. If the cranking speed is slower than 150 rpm, refer to the Engine Will Not Crank or Cranks Slowly symptom tree.

OK
Go To Next Step

STEP 3 Electrical or manual fuel shutdown binds	Check for loose wires and verify that the solenoid is functioning. Check to be sure manual shutoff lever is **not** binding at the injection pump. Refer to Procedure 005-043.

OK
Go To Next Step

STEP 4 Starting aid is malfunctioning	Check for correct operation of cold-starting aid. Refer to Cold Weather Starting Aids in the Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, U.S.A., Canada, Australia, New Zealand, and Puerto Rico, Bulletin 3810205 or Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, Worldwide excluding U.S.A., Canada, Australia, New Zealand and Puerto Rico, Bulletin 3810464.

OK
Go To Next Step

STEP 5 Intake air source is incorrect	If the vehicle is equipped with a valve to switch the intake source from under the hood to outside, position and set valve for the season.

OK
Go To Next Step

STEP 6 Intake air overheated	Inspect and clean any debris from the front of the charge air cooler. Refer to the OEM service manual.

OK
Go To Next Step

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

This is symptom tree t043

Cause	Correction
STEP 7 Closed crankcase ventilation hoses are leaking or damaged	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step	
STEP 8 Close crankcase ventilation valve is leaking or malfunctioning	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.
OK Go To Next Step	
STEP 9 Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003.
OK Go To Next Step	
STEP 10 Fuel filter or fuel inlet restriction	Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.
OK Go To Next Step	
STEP 11 Fuel quality is poor or diesel fuel grade number 1 is used above 0°C [32°F]	Number 1 diesel fuel and other light winter fuels are lower in heat content than number 2 diesel fuel and result in higher fuel consumption. Evaluate fuel consumption using number 2 diesel fuel. Fuel additives also result in lower heat content. Refer to Fuels For Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 12 Fuel pump return overflow valve is malfunctioning	Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.
OK Go To Next Step	
STEP 13 Fuel return line improperly plumbed	Make sure the fuel return line is plumbed to the bottom of the fuel tank.
OK Go To Next Step	
STEP 14 Fuel transfer pump malfunctioning	Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.
OK Go To Next Step	

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

This is symptom tree t043

Cause	Correction
STEP 15 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012 (Fuel Injection Pump, In-Line), or Procedure 005-014 (Fuel Injection Pump, Rotary).
OK Go To Next Step	
STEP 16 Charge air cooler restricted (if equipped)	Inspect the air cooler for internal and external restrictions. Replace the restricted cooler if necessary. Refer to Procedure 010-027.
OK Go To Next Step	
STEP 17 Valves are **not** sealing correctly	Check and adjust the valves. Refer to 002-020.
OK Go To Next Step	
STEP 18 Injectors worn or malfunctioning	Remove and test the injectors. Replace as necessary. Refer to Procedure 006-026.
OK Go To Next Step	
STEP 19 Engine compression is low	Perform the compression check to identify the malfunction. Correct as required. Refer to 014-008.
OK Go To Next Step	
STEP 20 Fuel injection pump is malfunctioning	Remove the fuel pump. Refer to Procedure 005-012 (Fuel Injection Pump, In-Line), or Procedure 005-014 (Fuel Injection Pump, Rotary). Calibrate the fuel pump.

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

This is symptom tree t044

Cause	Correction
STEP 1 Starting procedure is **not** correct	Verify the correct starting procedure. Refer to Operation and Maintenance Manual Automotive, Recreational Vehicle, Bus, and Industrial, B3.9 and B5.9 Bulletin 3810205, or 3810464.
OK Go To Next Step	
STEP 2 No fuel in supply tank	Check and replenish fuel supply. Check fittings and hose connections and hose conditions.
OK Go To Next Step	
STEP 3 Fuel shutoff valve is malfunctioning	Check for loose wires and verify that the fuel shutoff valve is functioning. Check to be sure manual shutoff lever is in the run position. Refer to Procedure 005-043.
OK Go To Next Step	
STEP 4 Fuel transfer pump malfunctioning	Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.
OK Go To Next Step	
STEP 5 Fuel filter or fuel inlet restriction	Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.
OK Go To Next Step	
STEP 6 Excessive water in the fuel filter	Drain the fuel water separator and replace the fuel filter. Refer to Procedure 006-015.
OK Go To Next Step	
STEP 7 Intake and exhaust system restricted	Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to Procedure 010-031 or 011-009.
OK Go To Next Step	
STEP 8 Closed crankcase ventilation hoses are leaking or damaged	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step	

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

This is symptom tree t044

Cause	Correction
STEP 9 Close crankcase ventilation valve is leaking or malfunctioning	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.
OK Go To Next Step	
STEP 10 Fuel injection pump **not** getting fuel or air in fuel	Check fuel flow or bleed fuel system. Refer to Procedure 006-003.
OK Go To Next Step	
STEP 11 Fuel return restriction excessive	Inspect the fuel return lines for restrictions. Refer to Procedure 006-012.
OK Go To Next Step	
STEP 12 Fuel pump return overflow valve is malfunctioning	Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.
OK Go To Next Step	
STEP 13 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-013, 005-014, or 005-037.
OK Go To Next Step	
STEP 14 Fuel injection pump is malfunctioning	Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012 or 005-014.
OK Go To Next Step	
STEP 15 Camshaft timing is **not** correct (after engine rebuild or repair)	Check the gear train timing alignment. Refer to Procedure 001-008.

Engine Noise Excessive

This is symptom tree t047

Cause	Correction
STEP 1 Fan drive belt is loose	Check the belt tension and tighten if necessary. Refer to Procedure 008-087.
OK Go To Next Step	
STEP 2 Fan is loose, damaged, or **not** balanced	Check the fan. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.
OK Go To Next Step	
STEP 4 Air intake or exhaust piping is contacting the chassis or cab	Inspect the air piping, chassis, and cab for contact points. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-025.
OK Go To Next Step	
STEP 6 Lubricating oil is thin or diluted	Refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205 for oil specifications. If the oil pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK Go To Next Step	
STEP 7 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, refer to Procedure 007-052.
OK Go To Next Step	
STEP 8 Vibration damper is damaged	Inspect the vibration damper. Refer to Procedure 001-052.
OK Go To Next Step	
STEP 9 Accessory drive is worn (axial end play is out of specification)	Check the accessory drive axial end play. Inspect the shaft for wear. Refer to Procedure 009-001.
OK Go To Next Step	

Engine Noise Excessive

This is symptom tree t047

Cause	Correction
STEP 10 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Gradual Overheat symptom tree.
OK Go To Next Step	
STEP 11 Drivetrain noise is excessive	Disconnect the drivetrain. Check for engine noise. Refer to the OEM service manual.
OK Go To Next Step	
STEP 12 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to the OEM service manual.
OK Go To Next Step	
STEP 13 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK Go To Next Step	
STEP 14 Overhead components are damaged	Inspect the rocker levers, rocker shafts, and valves for damage or excessive wear. Refer to Procedure 003-008.
OK Go To Next Step	
STEP 15 Injector is malfunctioning	Perform the single-cylinder cutout test. Replace the injectors as necessary. Refer to Procedure 006-026 or 014-008.
OK Go To Next Step	
STEP 16 Turbocharger noise	Refer to the Engine Noise Excessive - Turbocharger symptom tree.
OK Go To Next Step	
STEP 17 Combustion noise excessive	Refer to the Engine Noise Excessive symptom tree.
OK Go To Next Step	
STEP 18 Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-005.
OK Go To Next Step	

Engine Noise Excessive

This is symptom tree t047

Cause	Correction
STEP 19 Torque converter is loose	Check the torque converter. Refer to the OEM service manual.
OK Go To Next Step	
STEP 20 Main bearing or connecting rod bearing noise	Refer to Procedure 001-005 and 001-006.
OK Go To Next Step	
STEP 21 Piston or piston rings are worn or damaged	Check for air intake system leaks. Check the pistons and piston rings for wear or damage. Refer to Procedure 001-043 and 001-047.

Engine Noise Excessive — Combustion Knocks

This is symptom tree t048

Cause	Correction
STEP 1 Ether starting aid is malfunctioning	Repair or replace the ether starting aids. Refer to the manufacturer's instructions.
OK Go To Next Step	
STEP 2 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of high-quality fuel. Refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.
OK Go To Next Step	
STEP 3 Air in the fuel system	Check for air in the fuel system. Vent air from the system. Refer to Procedure 006-003.
OK Go To Next Step	
STEP 4 Coolant temperature is above specification	Check the coolant level. Refer to Procedure 008-018.
OK Go To Next Step	
STEP 5 Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedure 006-026.
OK Go To Next Step	
STEP 6 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.

Engine Noise Excessive — Connecting Rod

This is symptom tree t049

Cause	Correction
STEP 1 Lubricating oil level is below specification	Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-043 or the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.

OK
Go To Next Step

STEP 2 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, refer to Procedure 007-052.

OK
Go To Next Step

STEP 3 Lubricating oil is thin or diluted	Refer to Procedure 007-044 or Lubricating Oil Contaminated symptom tree.

OK
Go To Next Step

STEP 4 Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to Procedure 001-016.

OK
Go To Next Step

STEP 5 Connecting rod is bent or out of alignment	Remove and inspect the connecting rods. Refer to Procedure 001-014.

OK
Go To Next Step

STEP 6 Connecting rod capscrews are loose or **not** tightened correctly	Check the torque on the connecting rod capscrews. Refer to Procedure 001-014.

OK
Go To Next Step

STEP 7 Connecting rod and bearings are damaged or worn, are **not** assembled correctly, or are the wrong bearings	Inspect the connecting rod and bearings. Refer to Procedure 001-005 and 001-014.

Engine Noise Excessive — Main Bearing

This is symptom tree t050

Cause	Correction
STEP 1 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Lubricating oil level is below specification	Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-043.
OK Go To Next Step	
STEP 3 Lubricating oil is thin or diluted	Refer to Procedure 007-044 or Lubricating Oil Contaminated symptom tree.
OK Go To Next Step	
STEP 4 Main bearing capscrews are loose, worn or **not** tightened correctly	Check the torque on the main bearing capscrews. Inspect the capscrews for wear. Refer to Procedure 001-006.
OK Go To Next Step	
STEP 5 Main bearings are damaged or worn, or the wrong bearings are installed	Inspect the main bearings for damage, excessive wear, and the correct part number. Refer to Procedure 001-006.
OK Go To Next Step	
STEP 6 Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to Procedure 001-016.

Engine Noise Excessive — Piston

This is symptom tree t051

Cause	Correction
STEP 1 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of high-quality fuel. Refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.
OK Go To Next Step	
STEP 2 Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedure 006-026.
OK Go To Next Step	
STEP 3 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK Go To Next Step	
STEP 4 Connecting rod is bent or out of alignment	Remove and inspect the connecting rods. Refer to Procedure 001-014.
OK Go To Next Step	
STEP 5 Piston or piston rings are worn or damaged	Check for air intake system leaks. Check the pistons and piston rings for wear or damage. Refer to Procedure 001-043 and 001-047.
OK Go To Next Step	
STEP 6 Piston pin or bushing is loose, worn, or **not** installed correctly	Remove the pistons and inspect the piston pin and bushing for damage, wear, and correct installation. Refer to Procedure 001-043.

Engine Noise Excessive — Turbocharger

This is symptom tree t052

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

Engine Power Output Low

This is symptom tree t057

Cause	Correction
STEP 1 Engine under excessive load	Check for added loading from malfunctioning accessories or driven units, brakes dragging, and other changes in vehicle loading.
OK Go To Next Step	
STEP 2 Fuel shutoff lever (mechanical) partially engaged	Check for correct solenoid operation. Refer to Procedure 005-043 in Section 5.
OK Go To Next Step	
STEP 3 Engine will **not** reach full throttle	Make sure the throttle linkage is **not** misadjusted or damaged. Adjust and repair as necessary. Check the fuel lever for stop-to-stop travel. Refer to the OEM service manual or the Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, U.S.A., Canada, Australia, New Zealand, and Puerto Rico, Bulletin 3810205 or Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, Worldwide excluding U.S.A., Canada, Australia, New Zealand and Puerto Rico, Bulletin 3810464.
OK Go To Next Step	
STEP 4 Poor fuel quality or wrong fuel grade	Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to Fuels For Cummins® Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 5 Fuel temperature is above specification	Fill the fuel tanks. Verify the fuel heater is off during warm weather. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Fuel leak	Check the fuel lines, fuel connections, fuel delivery valve seals, and fuel filters for leaks. Check the fuel lines from the supply tank(s). Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Air in the fuel system	Check for air in the fuel system. Repair source of leak and bleed air from the system. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	

Engine Power Output Low

This is symptom tree t057

Cause	Correction
STEP 8 Fuel filter or fuel inlet restriction	Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015 in Section 6. Clean all prefilters and screens. Check the fuel suction line for restriction.
OK Go To Next Step	
STEP 9 Fuel drain line is restricted	Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012 in Section 6.
OK Go To Next Step	
STEP 10 Fuel transfer pump malfunctioning	Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045 in Section 5.
OK Go To Next Step	
STEP 11 Fuel pump return overflow valve is malfunctioning	Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044 in Section 6.
OK Go To Next Step	
STEP 12 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-043 in Section 7.
OK Go To Next Step	
STEP 13 Plugged air filter	Inspect the air cleaner element. Replace as needed. Refer to the OEM service manual.
OK Go To Next Step	
STEP 14 Intake air source is incorrect	If the vehicle is equipped with a valve to switch the intake source from under the hood to outside, position and set valve for the season.
OK Go To Next Step	
STEP 15 Air-fuel tube leaking, wastegate diaphragm ruptured, or wastegate plumbing damaged	Tighten the fittings, repair plumbing, replace wastegate diaphragm. Refer to Procedure 010-050 in Section 10.
OK Go To Next Step	

Engine Power Output Low

This is symptom tree t057

Cause	Correction
STEP 16 Intake air overheated	Inspect and clean any debris from the front of the charge-air cooler. Refer to Procedure 010-024 in Section 10.
OK Go To Next Step	
STEP 17 Aftercooler restricted (if equipped)	Inspect for plugged passages in the aftercooler. Refer to Procedure 010-001.
OK Go To Next Step	
STEP 18 charge-air cooler restricted (if equipped)	Inspect the air cooler for internal and external restrictions. Replace the restricted cooler if necessary. Refer to Procedure 010-024 in Section 10.
OK Go To Next Step	
STEP 19 Intake and exhaust system restricted	Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to Procedure 010-031 in Section 10 or Procedure 011-009 in Section 11.
OK Go To Next Step	
STEP 20 Closed crankcase ventilation hoses are leaking or damaged	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024 in Section 3.
OK Go To Next Step	
STEP 21 Close crankcase ventilation valve is leaking or malfunctioning	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023 in Section 3.
OK Go To Next Step	
STEP 22 Air leak between the turbocharger and the intake manifold	Check for leaks in the air crossover tube, charge-air cooler connections, hoses, or through holes in the manifold cover and repair or replace if necessary. Refer to Procedure 010-001, Procedure 010-027, and Procedure 010-023 in Section 10.
OK Go To Next Step	
STEP 23 Turbocharger is worn or malfunctioning	Check for the specified boost pressure. Inspect the turbocharger. Replace if necessary. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	

Engine Power Output Low

This is symptom tree t057

Cause	Correction
STEP 24 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-013, Procedure 005-014, or Procedure 005-037 in Section 5.
OK Go To Next Step	
STEP 25 Valves are **not** sealing correctly	Check and adjust the valves. Refer to Procedure 003-004 in Section 3 .
OK Go To Next Step	
STEP 26 Injector sealing washer **not** correct	Check to see if an extra sealing washer is installed under injector. Remove any additional sealing washer. **Only** one is required. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 27 Injectors worn or malfunctioning	Check the injectors and replace any malfunctioning injectors. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 28 Engine compression is low	Perform the compression check to identify the malfunction. Correct as required. Refer to Procedure 014-008 in Section 14 .
OK Go To Next Step	
STEP 29 Fuel injection pump is malfunctioning	Remove the fuel pump. Refer to Procedure 005-012 or Procedure 005-014 in Section 5. Calibrate the fuel pump.

Engine Runs Rough at Idle

This is symptom tree t061

Cause	Correction
STEP 1 Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal symptom tree.
OK Go To Next Step	
STEP 2 Idle speed is set too low for accessories	Check and adjust the low-idle screw. Refer to Procedure 005-029.
OK Go To Next Step	
STEP 3 Engine mounts are worn, damaged, loose, or **not** correct	Verify the condition of the mounts. Refer to Procedure 016-010 and the OEM service manual.
OK Go To Next Step	
STEP 4 Fuel leak	Check the fuel lines, fuel connections, fuel delivery valve seals, and fuel filters for leaks. Check the fuel lines from the supply tank(s). Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Air in the fuel system	Check for air in the fuel system. Repair source of leak and bleed air from the system. Refer to Procedure 006-003.
OK Go To Next Step	
STEP 6 Fuel filter or fuel inlet restriction	Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.
OK Go To Next Step	
STEP 7 Fuel transfer pump malfunctioning	Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.
OK Go To Next Step	
STEP 8 Fuel pump return overflow valve is malfunctioning	Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.
OK Go To Next Step	

Engine Runs Rough at Idle

This is symptom tree t061

Cause	Correction
STEP 9 Closed crankcase ventilation hoses are leaking or damaged	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step	
STEP 10 Close crankcase ventilation valve is leaking or malfunctioning	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.
OK Go To Next Step	
STEP 11 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-013, 005-014, or 005-037.
OK Go To Next Step	
STEP 12 Valves are **not** sealing correctly	Check and adjust the valves. Refer to 003-004.
OK Go To Next Step	
STEP 13 Engine compression is low	Perform the compression check to identify the malfunction. Correct as required. Refer to 014-008.
OK Go To Next Step	
STEP 14 Injector is malfunctioning	Perform a pop test on the injector(s). Refer to Procedure 006-026.
OK Go To Next Step	
STEP 15 Fuel injection pump is malfunctioning	Remove the fuel pump. Refer to Procedure 005-012 or 005-014. Calibrate the fuel pump.

Engine Runs Rough or Misfires

This is symptom tree t062

Cause	Correction
STEP 1 Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal symptom tree.
OK Go To Next Step	
STEP 2 Fuel leak	Check the fuel lines, fuel connections, fuel delivery valve seals, and fuel filters for leaks. Check the fuel lines from the supply tank(s). Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Fuel filter or fuel inlet restriction	Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.
OK Go To Next Step	
STEP 4 Air in the fuel system	Check for air in the fuel system. Repair source of leak and bleed air from the system. Refer to Procedure 006-003.
OK Go To Next Step	
STEP 5 Fuel contaminated	Verify by operating the engine with clean fuel from a temporary tank.
OK Go To Next Step	
STEP 6 Fuel pump return overflow valve is malfunctioning	Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.
OK Go To Next Step	
STEP 7 Fuel transfer pump malfunctioning	Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.
OK Go To Next Step	
STEP 8 Closed crankcase ventilation hoses are leaking or damaged	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step	

Engine Runs Rough or Misfires

This is symptom tree t062

Cause		Correction
STEP 9 Close crankcase ventilation valve is leaking or malfunctioning	.....	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.
OK Go To Next Step		
STEP 10 Fuel injection pump timing is **not** correct	.....	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-013, 005-014, or 005-037.
OK Go To Next Step		
STEP 11 Valves are **not** sealing correctly	.....	Check and adjust the valves. Refer to 003-004.
OK Go To Next Step		
STEP 12 Injectors worn or malfunctioning	.....	Check the injectors and replace any malfunctioning injectors. Refer to Procedure 006-026.
OK Go To Next Step		
STEP 13 Engine compression is low	.....	Perform the compression check to identify the malfunction. Correct as required. Refer to 014-008.
OK Go To Next Step		
STEP 14 Fuel injection pump is malfunctioning	.....	Remove the fuel pump. Refer to Procedure 005-012 or 005-014. Calibrate the fuel pump.
OK Go To Next Step		
STEP 15 Camshaft timing is **not** correct (after engine rebuild or repair)	.....	Check the gear train timing alignment. Refer to Procedure 001-008.
OK Go To Next Step		
STEP 16 Camshaft, tappets, or pushrods are damaged	.....	Inspect the camshaft and tappets. Refer to Procedure 001-008 or 004-015.

Engine Speed Surges at Low or High Idle

This is symptom tree t066

Cause	Correction
STEP 1 Fuel level is low in the tank	Fill the supply tank. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Engine under excessive load	Check for added loading from malfunctioning accessories or other engine-driven units, brakes dragging, or other changes in vehicle loading. Disengage engine-driven units.
OK Go To Next Step	
STEP 3 Idle speed is set too low for accessories	Check and adjust the low-idle screw. Refer to Procedure 005-029.
OK Go To Next Step	
STEP 4 Throttle linkage misadjusted or damaged	Adjust or repair the linkage. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Fuel leak	Check the fuel lines, fuel connections, and fuel filters for leaks. Refer to Procedure 006-024.
OK Go To Next Step	
STEP 6 Fuel filter or fuel inlet restriction	Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.
OK Go To Next Step	
STEP 7 Air in the fuel system	Check for air in the fuel system. Repair source of leak and bleed air from the system. Refer to Procedure 006-003.
OK Go To Next Step	
STEP 8 Injectors worn or malfunctioning	Check the injectors and replace any malfunctioning injectors. Refer to Procedure 006-026.
OK Go To Next Step	
STEP 9 High idle rpm is too low	Adjust high idle setting.
OK Go To Next Step	

Engine Speed Surges at Low or High Idle

This is symptom tree t066

Cause	Correction
STEP 10 Fuel injection pump is malfunctioning	Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012 or 005-014.

Engine Starts But Will Not Keep Running

This is symptom tree t072

Cause	Correction
STEP 1 Fuel level is low in the tank	Fill the supply tank. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Engine under excessive load	Check for added loading from malfunctioning accessories or other engine-driven units, brakes dragging, or other changes in vehicle loading. Disengage engine-driven units.
OK Go To Next Step	
STEP 3 Fuel shutoff valve malfunctioning	Inspect the fuel shutoff valve (FSOV) hold coil resistance and supply voltage. Refer to Procedure 005-043.
OK Go To Next Step	
STEP 4 Idle speed is set too low for accessories	Check and adjust the low-idle screw. Refer to Procedure 005-029.
OK Go To Next Step	
STEP 5 Air in the fuel system	Check for air in the fuel system. Repair source of leak and bleed air from the system. Refer to Procedure 006-003.
OK Go To Next Step	
STEP 6 Fuel filter or fuel inlet restriction	Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.
OK Go To Next Step	
STEP 7 Fuel is waxing due to cold weather	Check the fuel heater, if installed. Weather conditions sometimes require a fuel heater.
OK Go To Next Step	
STEP 8 Excessive water in the fuel filter	Drain the fuel water separator and replace the fuel filter. Refer to Procedure 006-015.
OK Go To Next Step	
STEP 9 Fuel contaminated	Verify by operating the engine with clean fuel from a temporary tank.
OK Go To Next Step	

Engine Starts But Will Not Keep Running

This is symptom tree t072

Cause		Correction
STEP 10 Fuel drain line is restricted	.....	Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012.
OK Go To Next Step		
STEP 11 Intake and exhaust system restricted	.....	Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to 010-031 or 011-009.
OK Go To Next Step		
STEP 12 Closed crankcase ventilation hoses are leaking or damaged	.....	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step		
STEP 13 Close crankcase ventilation valve is leaking or malfunctioning	.....	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.
OK Go To Next Step		
STEP 14 Injectors worn or malfunctioning	.....	Check the injectors and replace any malfunctioning injectors. Refer to Procedure 006-026.
OK Go To Next Step		
STEP 15 Fuel injection pump timing is **not** correct	.....	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-013, 005-014, or 005-037.
OK Go To Next Step		
STEP 16 Fuel injection pump is malfunctioning	.....	Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012 or 005-014.

Engine Will Not Crank — (Electric Starter)

This is symptom tree t074-005

Cause	Correction
STEP 1 Battery voltage is low	Check the battery connections. Refer to Procedure 013-007 in Section 13.
OK Go To Next Step	
STEP 2 Broken, loose, or corroded starting circuit connections	Inspect, clean, and tighten both the positive and negative connections between the starting motor and battery, including the magnetic switch. Refer to Procedure 013-009 in Section 13.
OK Go To Next Step	
STEP 3 Battery capacity is below specification	Refer to Procedure 013-007 in Section 13. Replace the batteries if necessary.
OK Go To Next Step	
STEP 4 OEM starter interlock devices engaged	Check the starter interlock devices. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Starting circuit component is malfunctioning	Check the starting circuit components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Starter solenoid does **not** make an audible sound	Check the magnetic switch and starter solenoid. Refer to Procedures 013-017 and 013-019 in Section 13.
OK Go To Next Step	
STEP 7 Battery cables are **not** the correct gauge or length	Replace the battery cables with larger gauge or shorter length cables. Refer to the OEM service manual.
OK Go To Next Step	
STEP 8 Engine-driven units are engaged	Disengage engine-driven units.
OK Go To Next Step	
STEP 9 Starter motor malfunction	Check the voltage drop at the starting motor. Refer to Procedure 013-020 in Section 13.
OK Go To Next Step	

Engine Will Not Crank — (Electric Starter)

This is symptom tree t074-005

Cause	Correction
STEP 10 Starting motor pinion or ring gear is damaged	Remove the starting motor, and inspect the gear. Refer to Procedure 013-020 in Section 13.
OK Go To Next Step	
STEP 11 Crankshaft rotation is impaired	Check the crankshaft for ease of rotation. Refer to Procedure 001-016 in Section 1.
OK Go To Next Step	
STEP 12 Hydraulic lock in a cylinder	Remove the injectors and rotate the crankshaft. Look for the source of fluid in the cylinder. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 13 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083 in Section 7.

Engine Cranks Slowly — (Electric Starter)

This is symptom tree t074-010

Cause	Correction
STEP 1 Batteries are cold	Check the battery heater. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to Procedure 013-007 in Section 13.
OK Go To Next Step	
STEP 3 Broken, loose, or corroded starting circuit connections	Inspect, clean, and tighten both the positive and negative connections between the starting motor and battery, including the magnetic switch. Refer to Procedure 013-009 in Section 13.
OK Go To Next Step	
STEP 4 Battery capacity is below specification	Refer to Procedure 013-007 in Section 13. Replace the batteries if necessary.
OK Go To Next Step	
STEP 5 OEM starter interlock devices engaged	Check the starter interlock devices. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Lubricating oil pressure switch, gauge, or sensor is malfunctioning or is **not** in the correct location	Check the oil pressure switch, gauge, or sensor for correct operation and location. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Battery cables are **not** the correct gauge or length	Replace the battery cables with larger gauge or shorter length cables. Refer to the OEM service manual.
OK Go To Next Step	
STEP 8 Engine-driven units are engaged	Disengage engine-driven units.
OK Go To Next Step	
STEP 9 Starting circuit component is malfunctioning	Check the starting circuit components. Refer to the OEM service manual.
OK Go To Next Step	

Engine Cranks Slowly — (Electric Starter)

This is symptom tree t074-010

Cause	Correction
STEP 10 Starter motor malfunction	Check the voltage drop at the starting motor. Refer to Procedure 013-020 in Section 13.
OK Go To Next Step	
STEP 11 Starting motor pinion or ring gear is damaged	Remove the starting motor, and inspect the gear. Refer to Procedure 013-020 in Section 13.
OK Go To Next Step	
STEP 12 Lubricating oil level is above specification	Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-009 in Section 7.
OK Go To Next Step	
STEP 13 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 018-003 in Section V. This procedure can be found in the Owners Manual, Bulletin 4021391, to verify the correct lubricating oil is being used.
OK Go To Next Step	
STEP 14 Crankshaft rotation is impaired	Check the crankshaft for ease of rotation. Refer to Procedure 001-016 in Section 1.
OK Go To Next Step	
STEP 15 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083 in Section 7.

Engine Vibration Excessive

This is symptom tree t075

Cause	Correction
STEP 1 Engine **not** running smoothly	Refer to the Engine Runs Rough or Misfires symptom tree.
OK Go To Next Step	
STEP 2 Lubricating oil level is above specification	Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-025.
OK Go To Next Step	
STEP 3 Fan is loose, damaged, or **not** balanced	Check the fan. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Fan hub malfunctioning	Inspect or replace the fan hub. Refer to Procedure 008-036.
OK Go To Next Step	
STEP 5 Vibration damper malfunctioning (six cylinder **only**)	Inspect the vibration damper. Replace, if necessary. Refer to Procedure 001-052.
OK Go To Next Step	
STEP 6 Engine mounts are worn, damaged, loose, or **not** correct	Verify the condition of the mounts. Refer to 016-010 or the OEM service manual.
OK Go To Next Step	
STEP 7 Idle speed is set too low for accessories	Check and adjust the low-idle screw. Refer to Procedure 005-029.
OK Go To Next Step	
STEP 8 Alternator bearing worn or damaged	Clean and replace the alternator. Refer to Procedure 013-001.
OK Go To Next Step	
STEP 9 Power components loose or broken	Inspect the crankshaft and rods for damage that causes an unbalance. Refer to Procedure 001-016 or 001-014.
OK Go To Next Step	

Engine Vibration Excessive

This is symptom tree t075

Cause	Correction
STEP 10 Drivetrain components worn or unbalanced	Check or repair components if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 11 Flywheel housing is **not** aligned correctly	Check the flywheel housing alignment. Refer to Procedure 016-006.

Engine Will Not Reach High Idle

This is symptom tree t080-005

Cause	Correction
STEP 1 Tachometer is **not** calibrated or is malfunctioning	Compare the tachometer reading with a handheld tachometer or an electronic service tool reading. Calibrate or replace the tachometer as necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Engine under excessive load	Check for added loading from malfunctioning accessories or other engine-driven units, brakes dragging, or other changes in vehicle loading. Disengage engine-driven units.
OK Go To Next Step	
STEP 3 Airflow to the radiator restricted	Check and repair fan shroud, viscous fan as required. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Engine will **not** reach full throttle	Make sure the throttle linkage is **not** misadjusted or damaged. Adjust and repair as necessary. Check the fuel lever for stop-to-stop travel. Refer to Procedure 005-018.
OK Go To Next Step	
STEP 5 Fuel shutoff lever (mechanical) partially engaged	Check for correct solenoid operation. Refer to Procedure 005-043.
OK Go To Next Step	
STEP 6 Poor fuel quality or wrong fuel grade	Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to Fuels for Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 7 Fuel filter or fuel inlet restriction	Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.
OK Go To Next Step	
STEP 8 Fuel pump return overflow valve is malfunctioning	Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.
OK Go To Next Step	

Engine Will Not Reach High Idle

This is symptom tree t080-005

Cause		Correction
STEP 9 Manifold drain line restricted (Lucas CAV DPA **only**)	.....	Check and remove restriction. Refer to Procedure 006-021.
OK Go To Next Step		
STEP 10 Fuel transfer pump malfunctioning	.....	Check or replace the fuel transfer pump. Refer to Procedure 005-045.
OK Go To Next Step		
STEP 11 Closed crankcase ventilation hoses are leaking or damaged	.....	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step		
STEP 12 Close crankcase ventilation valve is leaking or malfunctioning	.....	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.
OK Go To Next Step		
STEP 13 Turbocharger wastegate is malfunctioning (if equipped)	.....	Check the wastegate for correct operation. Refer to Procedure 010-050.
OK Go To Next Step		
STEP 14 Fuel injection pump is malfunctioning	.....	Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012 or 005-014.

Engine Will Not Shut Off

This is symptom tree t081

Cause	Correction
STEP 1 Engine is running on fumes drawn into the air intake	Check the air intake ducts. Locate and isolate the source of the fumes. Repair as necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Fuel shutoff valve (FSOV) is malfunctioning	Stop the engine mechanically, by moving the manual shutoff lever to the STOP position. Check for correct solenoid operation. Refer to Procedure 005-043.
OK Go To Next Step	
STEP 3 Fuel injection pump is malfunctioning	Remove the fuel pump. Refer to Procedure 005-012 or 005-014. Calibrate the fuel pump.

Excessive Noise

This is symptom tree t081-001

Cause	Correction
STEP 1 Drive belt is loose or has high loading	Check the drive belt tension. Adjust the tension if necessary. Check the accessory drive belts. Refer to Procedure 008-087 and the OEM service manual.
OK Go To Next Step	
STEP 2 Intake air or exhaust leaks	Refer to the Exhaust Black Smoke - Excessive symptom tree.
OK Go To Next Step	
STEP 3 Turbocharger noise	Turbocharger fluttering noises can be heard during deceleration or quick throttle closing. This noise is normal.
OK Go To Next Step	
STEP 4 Valve lash excessive	Adjust valves. Make sure the push rods are **not** bent or rocker levers **not** severely worn. Refer to Procedure 003-004.
OK Go To Next Step	
STEP 5 Power knock	Inspect rod bearings. Replace if necessary. Refer to Procedure 001-014.

Fuel Consumption Excessive

This is symptom tree t087

Cause	Correction
STEP 1 Engine under excessive load	Check for added loading from malfunctioning accessories or other engine-driven units, brakes dragging, or other changes in vehicle loading. Disengage engine-driven units.
OK Go To Next Step	
STEP 2 Operator technique is **not** correct	Explain correct engine operation to the operator. Refer to the Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, U.S.A., Canada, Australia, New Zealand, and Puerto Rico, Bulletin 3810205 or Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, Worldwide excluding U.S.A., Canada, Australia, New Zealand and Puerto Rico, Bulletin 3810464.
OK Go To Next Step	
STEP 3 Fuel leak	Check the fuel lines, fuel connections, fuel delivery valve seals, and fuel filters for leaks. Check the fuel lines from the supply tank(s). Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Poor fuel quality or wrong fuel grade	Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to the Fuels For Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 5 Intake and exhaust system restricted	Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to 010-031 or 011-009.
OK Go To Next Step	
STEP 6 Closed crankcase ventilation hoses are leaking or damaged	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step	
STEP 7 Close crankcase ventilation valve is leaking or malfunctioning	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.
OK Go To Next Step	

Fuel Consumption Excessive

This is symptom tree t087

Cause	Correction
STEP 8 Injectors worn or malfunctioning	Remove and test the injectors. Replace as necessary. Refer to Procedure 006-026.
OK Go To Next Step	
STEP 9 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-013.
OK Go To Next Step	
STEP 10 Fuel injection pump is malfunctioning	Remove the fuel pump. Refer to 005-012 or 005-014. Calibrate the fuel pump.
OK Go To Next Step	
STEP 11 Valves are **not** sealing correctly	Check and adjust the valves. Refer to 003-004.

Fuel Knock

This is symptom tree t091-5

Cause	Correction
STEP 1 Starting aid is malfunctioning	Check for correct operation of cold-starting aid. Refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.
OK Go To Next Step	
STEP 2 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Gradual Overheat symptom tree.
OK Go To Next Step	
STEP 3 Air in the fuel system	Bleed the fuel system and check for suction leaks. Refer to Procedure 006-024.
OK Go To Next Step	
STEP 4 Poor fuel quality or wrong fuel grade	Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.
OK Go To Next Step	
STEP 5 Engine under excessive load	Check for added loading from malfunctioning accessories or other engine-driven units, brakes dragging, or other changes in vehicle loading. Disengage engine-driven units.
OK Go To Next Step	
STEP 6 Injectors worn or malfunctioning	Remove and test the injectors. Replace as necessary. Refer to Procedure 006-026.
OK Go To Next Step	
STEP 7 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-037.

Fuel in the Lubricating Oil

This is symptom tree t092

Cause	Correction
STEP 1 Fuel transfer pump malfunctioning	Check or replace the fuel transfer pump. Refer to Procedure 005-045.
OK Go To Next Step	
STEP 2 Fuel injection pump seal leaking (rotary)	Remove the fuel injection pump and repair if necessary. Refer to Procedure 005-014.
OK Go To Next Step	
STEP 3 Internal plunger seal leaking (inline)	Remove the fuel injection pump and repair if necessary. Refer to Procedure 005-012.
OK Go To Next Step	
STEP 4 Injector needle valve sticking	Check or replace the injector. Refer to Procedure 006-026.

Fuel or Lubricating Oil Leaking From Exhaust Manifold

This is symptom tree t093

Cause	Correction
STEP 1 Engine is operating for extended periods under light- or no-load conditions (slobbering)	Review the engine operating instructions in Section 1 in the Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, U.S.A., Canada, Australia, New Zealand, and Puerto Rico, Bulletin 3810205 or Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, Worldwide excluding U.S.A., Canada, Australia, New Zealand and Puerto Rico, Bulletin 3810464.

OK
Go To Next Step

STEP 2 Intake and exhaust system restricted	Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to 010-031 or 011-009.

OK
Go To Next Step

STEP 3 Closed crankcase ventilation hoses are leaking or damaged	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.

OK
Go To Next Step

STEP 4 Close crankcase ventilation valve is leaking or malfunctioning	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.

OK
Go To Next Step

STEP 5 Injector needle valve sticking	Check or replace the injector. Refer to Procedure 006-026.

OK
Go To Next Step

STEP 6 Turbocharger oil drain line is restricted	Remove the turbocharger oil drain line and check for restriction. Clean or replace the oil drain line. Refer to Procedure 010-045.

OK
Go To Next Step

STEP 7 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033.

OK
Go To Next Step

STEP 8 Worn piston rings	Check for excessive blowby. Refer to Procedure 014-010.

OK
Go To Next Step

Fuel or Lubricating Oil Leaking From Exhaust Manifold

This is symptom tree t093

Cause	Correction
STEP 9 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-037.

Intake Manifold Air Heater System Malfunctioning

This is symptom tree t097-25

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

Intake Manifold Air Heater System Malfunctioning

This is symptom tree t097-25

Cause	Correction
STEP 10 Heater control module malfunctioning	Check preheat, post heat, post heat recycle. Replace heater control module, if necessary. Refer to Procedure 010-125.

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause		Correction
STEP 1 External engine leak	.....	Inspect the engine and its components for seal, gasket, tappet cover, oil cooler, or draincocks leaks.
OK Go To Next Step		
STEP 2 Crankcase oil level above specification (dipstick calibration **not** correct)	.....	Verify that the dipstick is correctly marked. Refer to Procedure 007-009.
OK Go To Next Step		
STEP 3 Lubricating oil does **not** meet specifications for operating conditions	.....	Change the oil and filters. Refer to the Cummins Engine Oil Recommendations, Bulletin 3810340, Procedure 007-013 and 007-037.
OK Go To Next Step		
STEP 4 Closed crankcase ventilation hoses are leaking or damaged	.....	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step		
STEP 5 Close crankcase ventilation valve is leaking or malfunctioning	.....	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.
OK Go To Next Step		
STEP 6 Turbocharger leaking lubricating oil to the air intake or exhaust	.....	Inspect the air crossover tube for evidence of lubricating oil transfer. Refer to Procedure 010-019.
OK Go To Next Step		
STEP 7 Air compressor is pumping lubricating oil into the air system	.....	Check the air lines for carbon buildup and lubricating oil. Refer to Procedure 012-003.
OK Go To Next Step		
STEP 8 Piston rings **not** sealing (blue smoke)	.....	Perform a compression check and correct as required. Refer to Procedure 014-008.
OK Go To Next Step		
STEP 9 Valves are **not** sealing correctly	.....	Check and adjust the valves. Refer to 003-004.

Lubricating Oil Contaminated

This is symptom tree t103

Cause	Correction
STEP 1 Coolant in the lubricating oil, internal engine component leaks	Refer to the Coolant Loss and Coolant in Lubricating Oil symptom tree.
OK Go To Next Step	
STEP 2 Lubricating oil sludge is excessive	Refer to the Lubricating Oil Sludge in the Crankcase Is Excessive symptom tree.
OK Go To Next Step	
STEP 3 Lubricating oil is contaminated with coolant or fuel	Change the oil and filters. Refer to the Fuel in Oil symptom tree. If nothing is found, change the oil. Refer to Procedure 007-025. If the oil becomes diluted again, contact an Authorized Cummins Repair Facility.
OK Go To Next Step	
STEP 4 Metal in oil	Remove and cut filter open. Refer to Procedure 007-083.

Lubricating Oil Pressure High

This is symptom tree t104

Cause	Correction
STEP 1 Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to Coolant Temperature Below Normal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 2 Lubricating oil viscosity **not** correct	Make sure the correct lubricating oil is being used. Refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.
OK Go To Next Step	
STEP 3 Lubricating oil filter is **not** correct	Make sure the correct oil filter is being used. Refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.
OK Go To Next Step	
STEP 4 Lubricating oil pressure switch, gauge, or sensor is malfunctioning or is **not** in the correct location.	Check the oil pressure switch, gauge, or sensor for correct operation and location. Refer to Procedure 007-052.
OK Go To Next Step	
STEP 5 Lubricating oil pump installation **not** correct	Verify that the correct lubricating oil pump and o-rings are installed. Refer to Refer to Procedure 007-031 in Section 7.
OK Go To Next Step	
STEP 6 Pressure regulator valve stuck open	Replace the pressure regulator valve. Refer to Procedure 007-029.

Lubricating Oil Pressure Low

This is symptom tree t105

Cause		Correction
STEP 1 Lubricating oil level is low	.....	Check and replenish lubricating oil. Refer to Procedure 007-043.
OK Go To Next Step		
STEP 2 Cylinder head core and expansion plugs leaking or misassembled	.....	Check cylinder head. Refer to Procedure 002-004.
OK Go To Next Step		
STEP 3 Lubricating oil filter is diluted	.....	Refer to the Lubricating Oil Contamination symptom tree.
OK Go To Next Step		
STEP 4 Lubricating oil filter is plugged	.....	Change the oil and filter. Refer to the Lubricating Oil Contamination symptom tree. Verify the oil change interval is correct. Refer to the operation and maintenance manual.
OK Go To Next Step		
STEP 5 Lubricating oil pressure switch, gauge, or sensor is malfunctioning or is **not** in the correct location	.....	Check the oil pressure switch, gauge, or sensor for correct operation and location. Refer to Procedure 007-052.
OK Go To Next Step		
STEP 6 Lubricating oil filter is **not** correct	.....	Make sure the correct oil filter is being used. Refer to the Operation and Maintenance Manual, B Series Engines, Bulletin 3810205.
OK Go To Next Step		
STEP 7 Pressure regulator valve struck open	.....	Check and replace valve. Refer to Procedure 007-029.
OK Go To Next Step		
STEP 8 Lubricating oil cooler is plugged	.....	Check the oil cooler. Refer to Procedure 007-003.
OK Go To Next Step		
STEP 9 Lubricating oil cooler was replaced with shipping plugs left in cooler	.....	Check and remove shipping plugs.
OK Go To Next Step		

Lubricating Oil Pressure Low

This is symptom tree t105

Cause		Correction
STEP 10 Lubricating oil pump is malfunctioning	.....	Inspect the lubricating oil pump. Refer to Procedure 007-031.

OK
Go To Next Step

STEP 11 Lubricating oil suction or transfer tube is loose or broken, or the gasket or o-rings are leaking	.....	Remove and inspect the oil pan or suction tube. Refer to Procedure 007-025.

OK
Go To Next Step

STEP 12 Main bearing capscrews are loose, worn or **not** tightened correctly	.....	Check the torque on the main bearing capscrews. Inspect the capscrews for wear. Refer to Procedure 001-006.

OK
Go To Next Step

STEP 13 Main bearings are damaged or worn, or the wrong bearings are installed	.....	Inspect the main bearings for damage, excessive wear, and the correct part number. Refer to Procedure 001-006.

OK
Go To Next Step

STEP 14 Camshaft journals and number 1 bushing are severely damaged	.....	Inspect the camshaft journals and number 1 bushing for wear. Refer to Procedure 001-008 or 001-010.

Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree t106

Cause	Correction
STEP 1 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with noncontaminated oil. Replace the oil filter(s). Refer to Procedure 007-037 and 007-013.
OK Go To Next Step	
STEP 2 Coolant temperature is below specification	Refer to the Coolant Temperature Below Normal symptom tree.
OK Go To Next Step	
STEP 3 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-018.
OK Go To Next Step	
STEP 4 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of high-quality fuel. Refer to Fuels for Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 5 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Cummins Engine Oil Recommendations, Bulletin 3810340 and Procedures 007-013 and 007-037.
OK Go To Next Step	
STEP 6 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to the Operation and Maintenance Manual, Automotive, Recreational Vehicle, Bus, and Industrial B3.9 and B5.9 Series Engines, Bulletin 3810205 or 3810464.
OK Go To Next Step	
STEP 7 Lubricating oil is contaminated with coolant or fuel	Change the oil and filters. Refer to the Lubricating Oil Contaminated symptom tree.
OK Go To Next Step	
STEP 8 Crankcase pressure is excessive	Check for excessive blowby. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.
OK Go To Next Step	
STEP 9 Closed crankcase ventilation hoses are leaking or damaged	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step	

Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree t106

Cause		Correction
STEP 10 Close crankcase ventilation valve is leaking or malfunctioning	.....	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.

Lubricating Oil Temperature Above Specification

This is symptom tree t107

Cause	Correction
STEP 1 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Gradual Overheat symptom tree.
OK Go To Next Step	
STEP 2 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-043.
OK Go To Next Step	
STEP 3 Lubricating oil cooler is malfunctioning	Check the oil cooler. Refer to Procedure 007-003.
OK Go To Next Step	
STEP 4 OEM components cooled with engine lubricating oil are malfunctioning	Check OEM components. Refer to the OEM service manual.

Lubricating or Transmission Oil in the Coolant

This is symptom tree t108

Cause	Correction
STEP 1 Bulk coolant supply is contaminated	Check the bulk coolant supply. Drain the coolant and replace with noncontaminated coolant. Replace the coolant filters. Refer to Procedure 008-018.
OK Go To Next Step	
STEP 2 Lubricating oil cooler is malfunctioning	Check the oil cooler. Refer to Procedure 007-003.
OK Go To Next Step	
STEP 3 Torque converter cooler or hydraulic oil cooler is malfunctioning	Remove and inspect the cooler cores and o-rings. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Air compressor cylinder head is cracked or porous, or has a leaking gasket	Inspect the air compressor cylinder head and gasket. Refer to 012-104 and the Master Repair Manual, Holset® Compressors, Bulletin 3666121.
OK Go To Next Step	
STEP 5 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-004 or 002-021.
OK Go To Next Step	
STEP 6 Cylinder head is cracked or porous	Remove the intake and the exhaust manifolds. Check for evidence of coolant leak. If necessary, operate the engine at low idle. Pressure-test the cylinder head. Refer to Procedure 002-004.
OK Go To Next Step	
STEP 7 Cylinder block is cracked or porous	Inspect the cylinder block. Refer to Procedure 001-026.

Smoke, Black — Excessive

This is symptom tree t116

Cause	Correction
STEP 1 Engine is being lugged down	Use lower gear.
OK Go To Next Step	
STEP 2 Plugged air filter	Inspect the air cleaner element. Replace as needed. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Intake air source is incorrect	If the vehicle is equipped with a valve to switch the intake source from under the hood to outside, position and set valve for the season.
OK Go To Next Step	
STEP 4 Intake air overheated	Inspect and clean any debris from the front of the charge air cooler. Refer to Procedure 010-024.
OK Go To Next Step	
STEP 5 Aftercooler restricted (if equipped)	Inspect for plugged passages in the aftercooler. Refer to Procedure 010-001.
OK Go To Next Step	
STEP 6 Exhaust system restriction	Check the exhaust system for any restrictions. Refer to Procedure 011-009.
OK Go To Next Step	
STEP 7 Charge air cooler is restricted or leaking	Inspect the charge air cooler for air restrictions or leaks. Refer to Procedure 010-027.
OK Go To Next Step	
STEP 8 Air leak between the turbocharger and the intake manifold	Check for leaks in the air crossover tube, charge air cooler connections, hoses, or through holes in the manifold cover and repair or replace if necessary. Refer to Procedure 010-024.
OK Go To Next Step	
STEP 9 Exhaust leaks at the manifold or turbocharger	Check and correct any leaks in the exhaust manifold or turbocharger gaskets. Check for a cracked exhaust manifold. Refer to Procedure 011-007.
OK Go To Next Step	

Smoke, Black — Excessive

This is symptom tree t116

Cause		Correction
STEP 10 Closed crankcase ventilation hoses are leaking or damaged	.....	Inspect the closed crankcase ventilation system hoses and connections for leaks, obstruction, or damage. Refer to Procedure 003-024.
OK Go To Next Step		
STEP 11 Close crankcase ventilation valve is leaking or malfunctioning	.....	Inspect the closed crankcase ventilation valve for obstruction or damage. Refer to Procedure 003-023.
OK Go To Next Step		
STEP 12 Turbocharger wastegate is malfunctioning (if equipped)	.....	Check the wastegate for correct operation. Refer to Procedure 010-050.
OK Go To Next Step		
STEP 13 Turbocharger is worn or malfunctioning	.....	Check for the specified boost pressure. Inspect the turbocharger. Replace if necessary. Refer to Procedure 010-033.
OK Go To Next Step		
STEP 14 Injectors worn or malfunctioning	.....	Remove and test the injectors. Replace as necessary. Refer to Procedure 006-026.
OK Go To Next Step		
STEP 15 Injector sealing washer **not** correct	.....	Remove the injector. Check for extra sealing washer is installed under the injector. Check for proper sealing washer, and remove any additional sealing washer(s). **Only** one is required. Refer to Procedure 006-026.
OK Go To Next Step		
STEP 16 Fuel injection pump timing is **not** correct	.....	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-037.
OK Go To Next Step		
STEP 17 Fuel injection pump is malfunctioning	.....	Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012 or 005-014.
OK Go To Next Step		
STEP 18 Piston rings **not** sealing (blue smoke)	.....	Perform a compression check and correct as required. Refer to Procedure 014-008.

Smoke, White - Excessive

This is symptom tree t118

Cause	Correction
STEP 1 Starting procedure is **not** correct	Verify the correct starting procedure. Refer to the Operation and Maintenance Manual, Automotive, Recreational Vehicle, and Bus B Series Engines, Bulletin 3810205.
OK Go To Next Step	
STEP 2 Coolant temperature is below specification or the intake manifold air temperature is below specification	Refer to the Coolant Temperature Below Normal symptom tree.
OK Go To Next Step	
STEP 3 Poor fuel quality or wrong fuel grade	Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to the Operation and Maintenance Manual, Automotive, Recreational Vehicle, and Bus B Series Engines, Bulletin 3810205.
OK Go To Next Step	
STEP 4 Air in the fuel system	Check for air in the fuel system. Repair source of leak and bleed air from the system. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	
STEP 5 Fuel inlet pressure is low or excessive fuel inlet restriction	Check the fuel inlet restriction prior to the fuel lift pump, and test the output pressure of the fuel lift pump. Refer to Procedure 005-045 in Section 5.
OK Go To Next Step	
STEP 6 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-037 in Section 5 .
OK Go To Next Step	
STEP 7 KSB is malfunctioning (Bosch™ VE pump **only**)	Refer to the Master Repair Manual, Injector Pumps and Injectors, Bulletin 3666037.
OK Go To Next Step	
STEP 8 Injector sealing washer **not** correct	Check to see if an extra sealing washer is installed under injector. Remove any additional sealing washer. **Only** one is required. Refer to Procedure 006-026 in Section 6 .
OK Go To Next Step	

Smoke, White - Excessive

This is symptom tree t118

Cause	Correction
STEP 9 Injectors worn or malfunctioning	Remove and test the injectors. Replace as necessary. Refer to Procedure 006-026 in Section 6 .
OK Go To Next Step	
STEP 10 Coolant is leaking into the combustion chamber	Refer to the Coolant Loss - Internal symptom tree.
OK Go To Next Step	
STEP 11 Fuel injection pump is malfunctioning	Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012 in Section 5 or Procedure 005-014 in Section 5.

Notes

Section 0 - Complete Engine - Group 00

Section Contents

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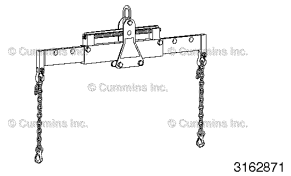
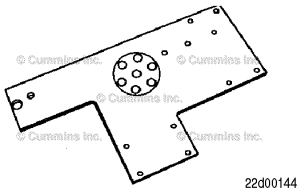
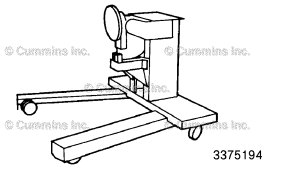
Service Tools

Engine Removal and Installation

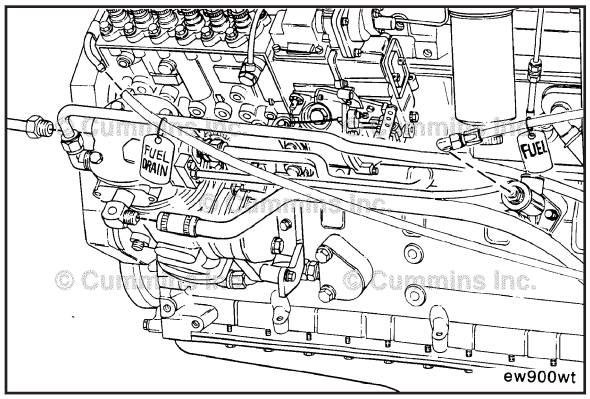
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3162871	**Engine Lifting Fixture** Used to remove and install the engine.	
3163625	**Engine Stand Adapter Plate** Used to mount the engine to the rebuild stand.	
3375194 or 3375193	**Engine Rebuild Stand** Tilt type of engine rebuild stand: 3375194 — Portable, 3375193 — Stationary	

Engine Removal (000-001)

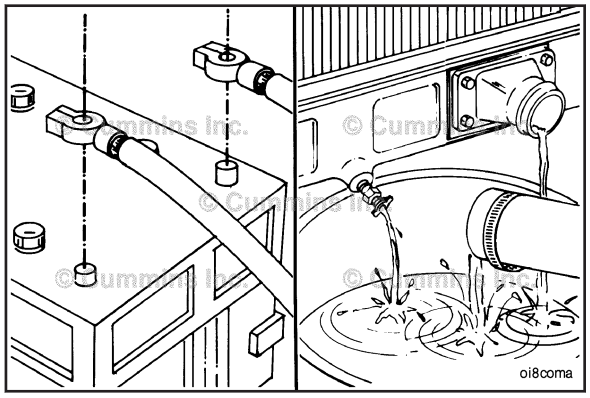
General Information

Installations can vary from OEM to OEM. Use the following steps as a guideline. Reference the OEM manual when necessary.



Remove

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



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

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

⚠WARNING⚠
Coolant is toxic. 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 battery cables.

Steam clean the engine. Refer to Procedure 000-009.

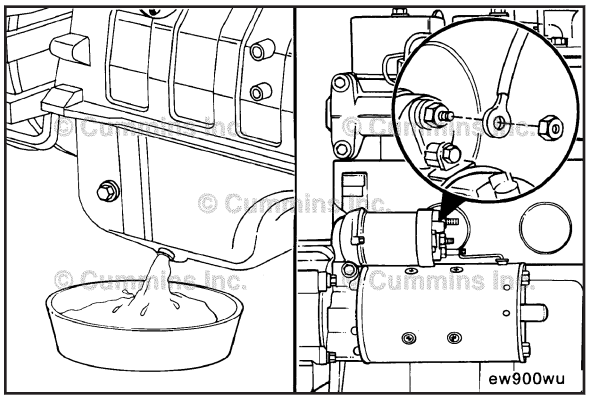
Drain the engine coolant. Refer to Procedure 008-018.

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

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

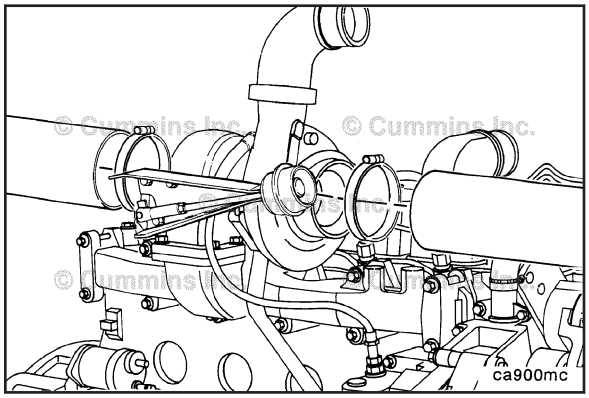
Drain the lubricating oil. Refer to Procedure 007-037.

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



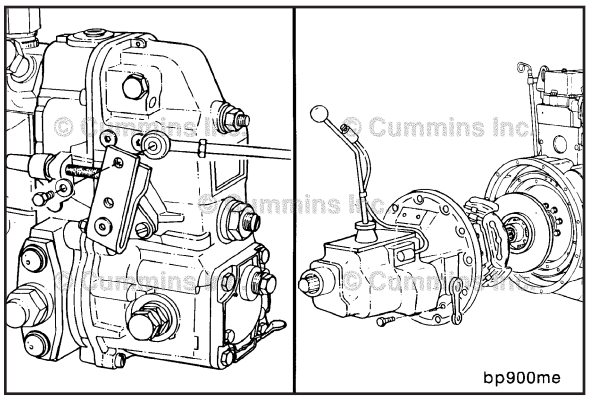
Disconnect the intake and exhaust pipes.

Disconnect all chassis-mounted, engine-driven accessories.



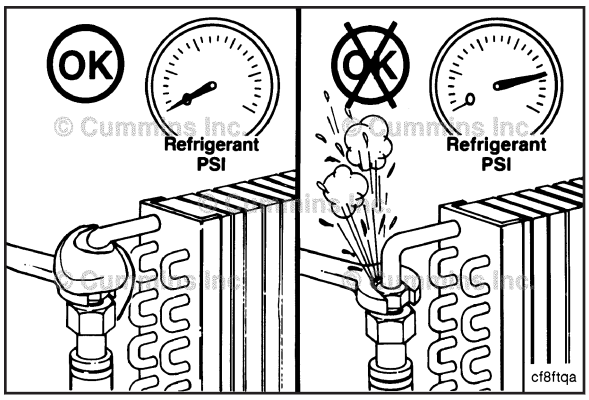
Disconnect the throttle linkage from the fuel injection pump control lever.

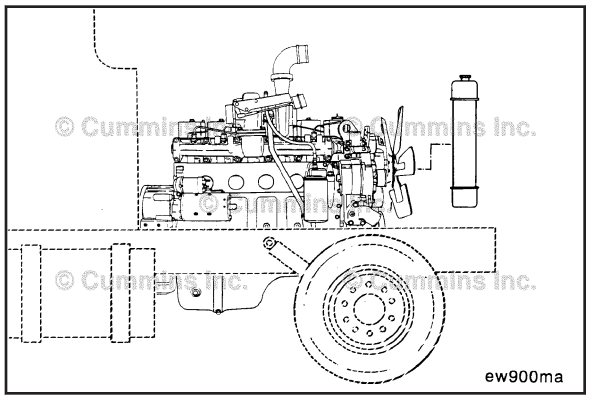
Disconnect the drive units from the flywheel.



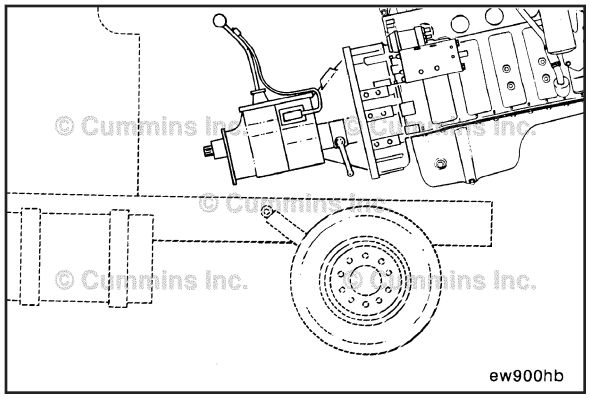
⚠WARNING⚠
If a liquid refrigerant system (air conditioning) is used, wear eye and face protection, and wrap a cloth around the fittings before removal. Liquid refrigerant can cause serious eye and skin injury.

⚠CAUTION⚠
To protect the environment, liquid refrigerant systems must be properly emptied and filled using equipment that prevents the release of refrigerant gas into the atmosphere. Federal law requires capturing and recycling the refrigerant.





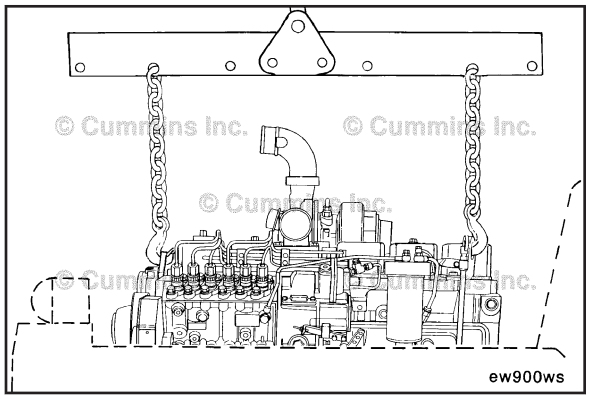
Remove all chassis components necessary to remove the engine from the equipment.



⚠WARNING⚠

The engine lifting equipment must be designed to lift the engine and transmission safely as an assembly without causing personal injury. For engine weight specifications refer to Procedure 018-015, General Engine Specifications in Section V. Refer to the equipment manufacturer's specifications for the transmission weight.

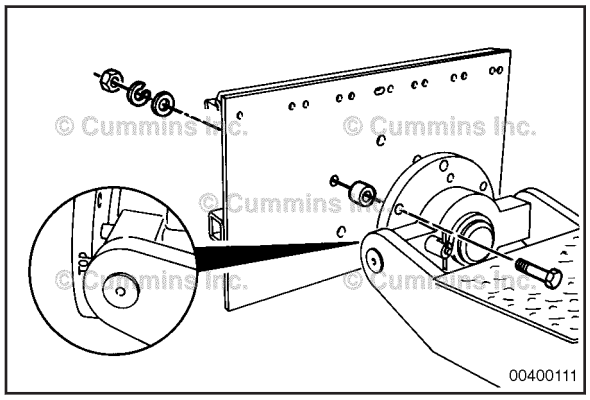
NOTE: On applications where the rear-engine mounts are attached to the transmission, it is often necessary to remove the engine and transmission as an assembly. Refer to the OEM service manual.



Use a properly rated hoist and engine-lifting fixture, Part Number 3822512, attached to the engine-mounted lifting brackets to remove the engine.

For engine weight specifications refer to Procedure 018-015, General Engine Specifications in Section V.

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



If the engine will be repaired, mount the engine stand adapter plate, part number 3163625, to the exhaust side of the engine.

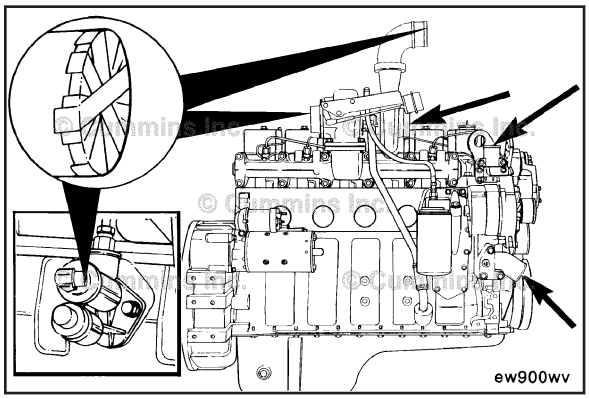
NOTE: If equipped, the turbocharger may need to be removed to install the engine stand adapter plate. Refer to Procedure 010-033.

Mount the engine stand adapter plate to the Portable tilt type of engine rebuild stand, Part Number 3375194 or 3375193.

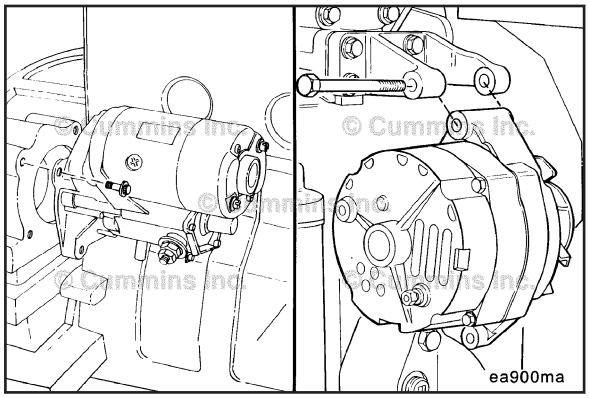
If the engine will be replaced, mount the engine on an appropriate shipping pallet.

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

Place the engine on suitable engine-support stands.



If the engine is to be replaced, remove all the remaining accessories, brackets, and drive units to use with the replacement engine.



Engine Installation (000-002)

General Information

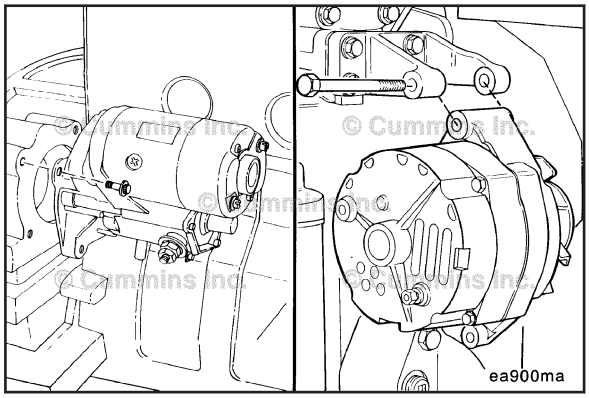
Installations can vary from OEM to OEM. Use the following steps as a guideline. Reference the OEM manual when necessary.

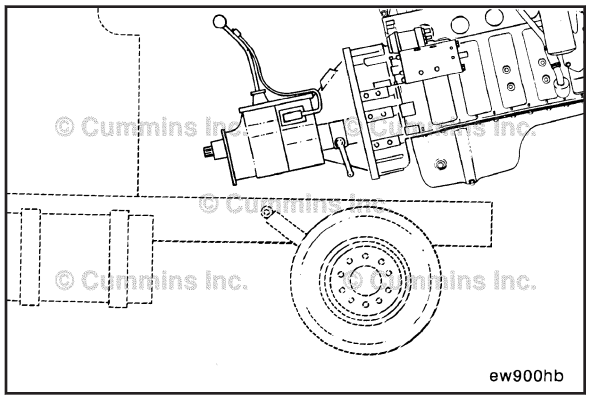
Install

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

For engine supplied components, reference the corresponding procedure in this manual.

For vehicle installed components, reference the corresponding OEM Manual.

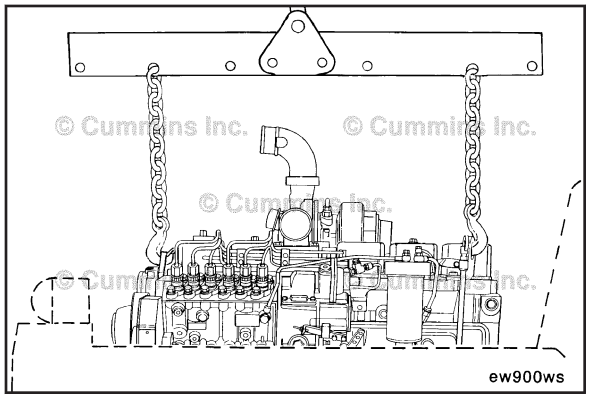




⚠WARNING⚠

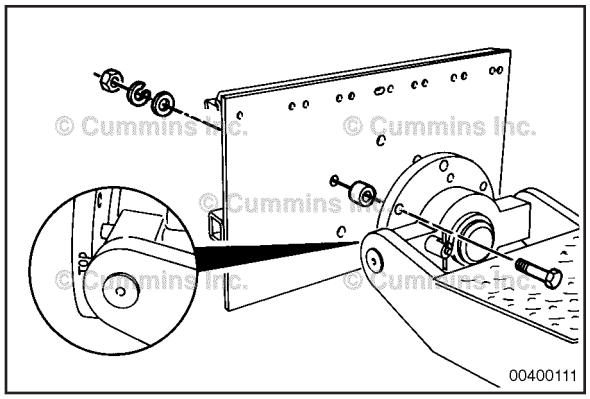
The engine lifting equipment must be designed to lift the engine and transmission safely as an assembly without causing personal injury. For engine weight specifications refer to Procedure 018-015, General Engine Specifications in Section V. Refer to the equipment manufacturer's specifications for the transmission weight.

NOTE: On applications where the rear-engine mounts are attached to the transmission, it is often necessary to install the engine and transmission as an assembly. Refer to the OEM service manual.



Use a properly rated hoist and engine-lifting bracket, Part Number 3822512, attached to the engine-mounted lifting brackets to install the engine.

For engine weight specifications refer to Procedure 018-015, General Engine Specifications in Section V.

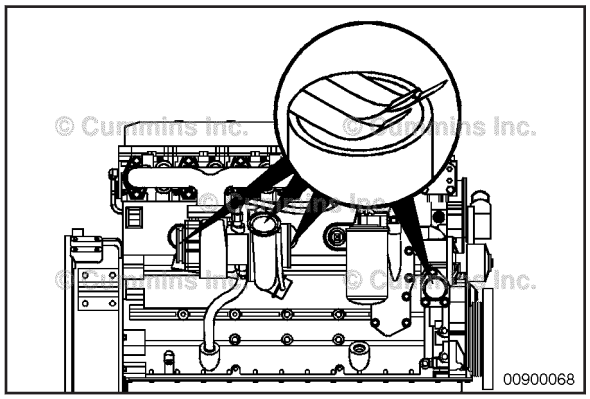


If the engine was repaired, lift the engine and engine stand adapter plate from the engine rebuild stand.

Remove the engine stand adapter plate.

NOTE: The turbocharger may need to be installed after the engine stand adapter plate is removed. Refer to Procedure 010-033.

If the engine was replaced, lift the engine from the shipping pallet.

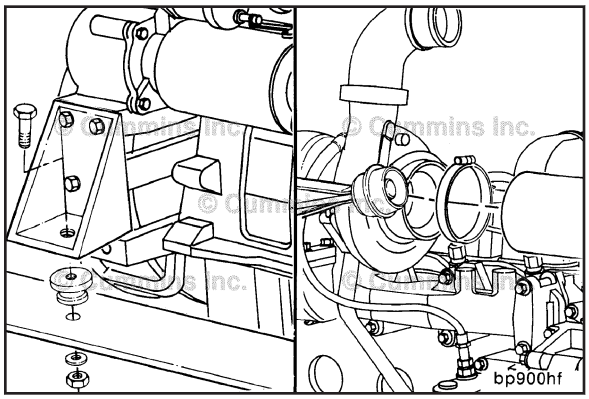


Remove the covers from all openings that were covered during removal.

Align the engine in the chassis, and tighten the engine-mounting capscrews. Refer to the equipment manufacturer's torque specifications.

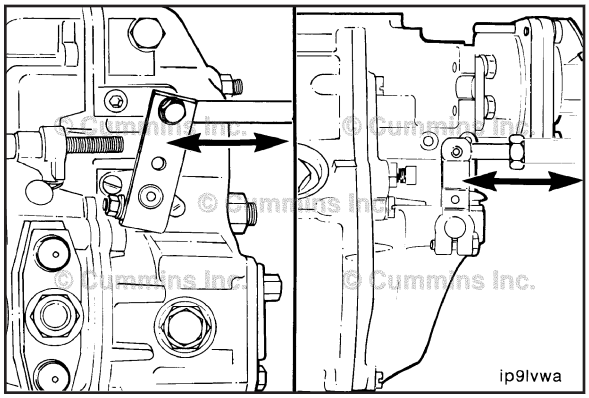
Connect all engine- and chassis-mounted accessories that were removed.

NOTE: Make sure that all lines, hoses, and tubes are properly routed and fastened to prevent damage. Make sure that the air intake and exhaust pipe connections are tight and free of leaks.

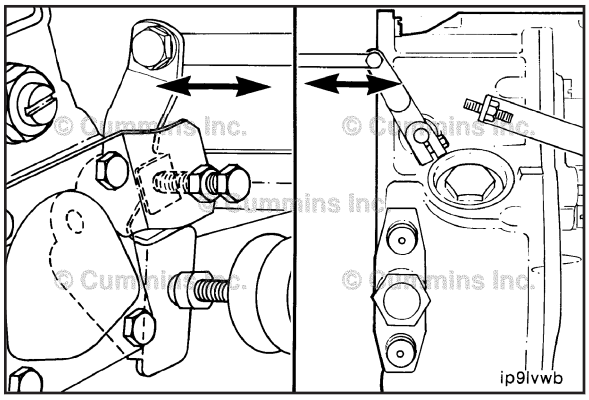


Throttle Control Lever Connection

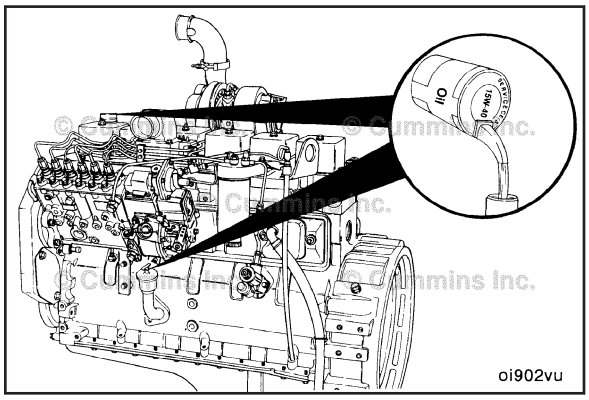
Install and adjust the throttle linkage to the injection pump control lever. Refer to the OEM service manual.

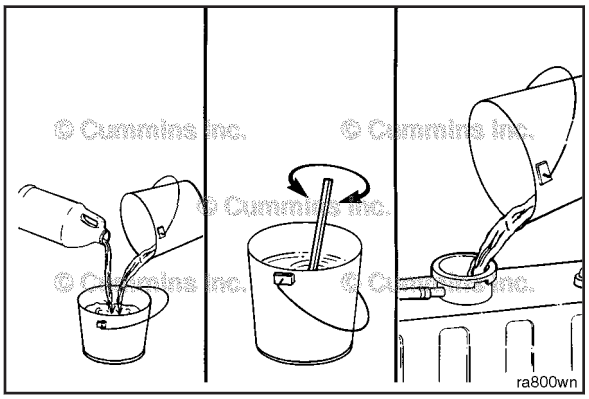


Adjust the length of the cable/rod to the mechanical shutdown lever so there is stop-to-stop movement. Refer to the OEM service manual.



Fill the engine with clean 15W-40 engine oil. Refer to Procedure 007-037.

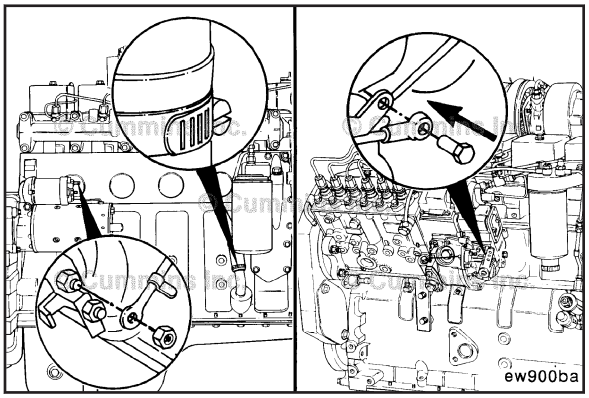




NOTE: The total coolant capacity of the engines varies. Refer to the original equipment manufacturer's instructions to determine the capacity of the whole cooling system.

Fill the cooling system with new coolant. Refer to Procedure 008-018.

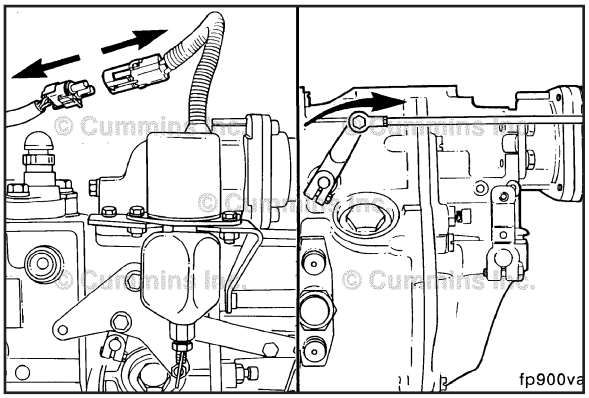
Refer to Procedure 018-018 for cooling system specifications.



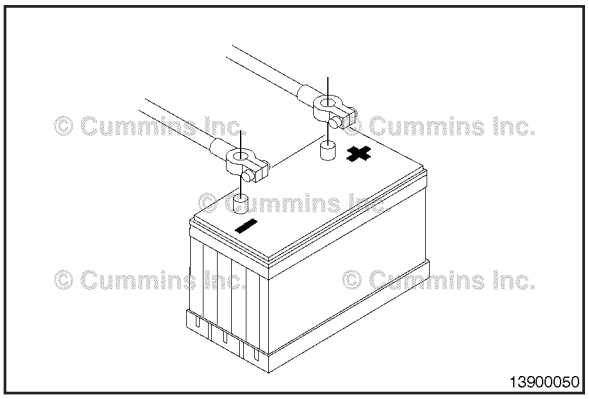
CAUTION

Installation of the radiator cap at this point is critical to proper purging of air trapped in the cooling system. Improper purging of air from the cooling system can result in engine damage from overheating.

Perform a final inspection to make sure that all hoses, wires, linkages, and components have been properly installed and tightened.



Make sure that the fuel is shut off by removing the wire from the fuel solenoid or by verifying that the mechanical fuel shutoff is in the OFF position. This is necessary to prevent the engine from starting during the lubricating oil rifle pressure charging operation.



WARNING

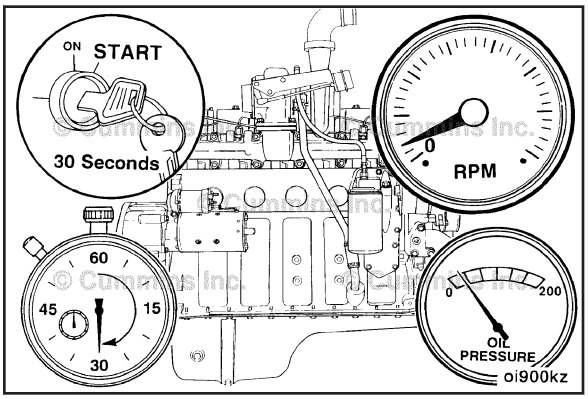
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Connect the batteries.

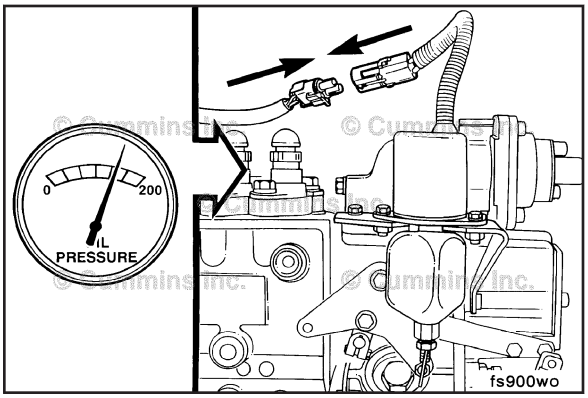
⚠CAUTION⚠

Do not engage the starting motor for more than 30 seconds. Wait 2 minutes between starter engagements to cool the starting motor.

Crank the engine until the lubricating oil pressure gauge indicates a positive pressure.



After pressure is observed, connect the wire to the fuel solenoid.

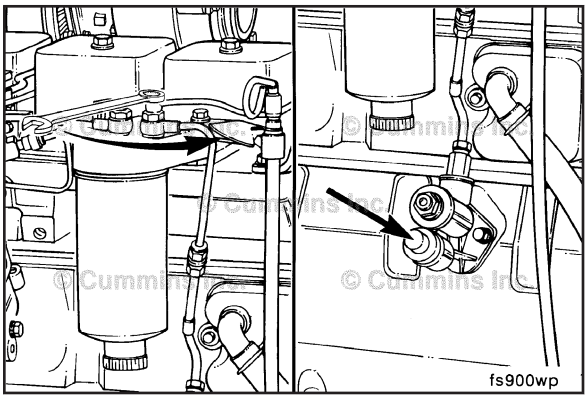


Prime the low-pressure fuel system by operating the plunger on the fuel transfer pump.

If equipped, open the bleed screw and operate the plunger until fuel flowing from the bleed screw is free of air.

Tighten the bleed screw.

Torque Value: 9 N•m [80 in-lb]

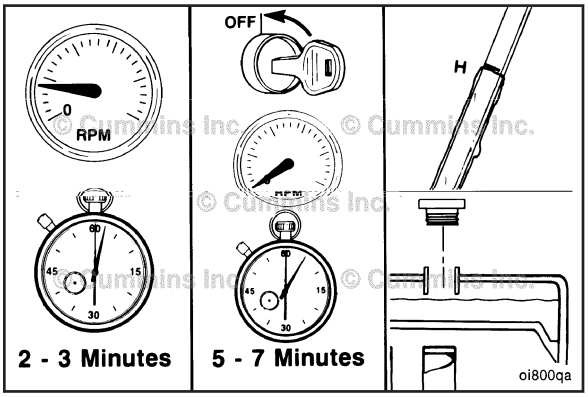


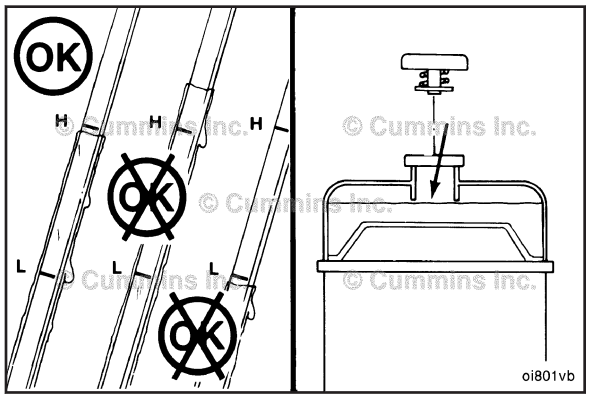
⚠WARNING⚠

Do not remove the radiator cap from a hot engine. Wait until the engine coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

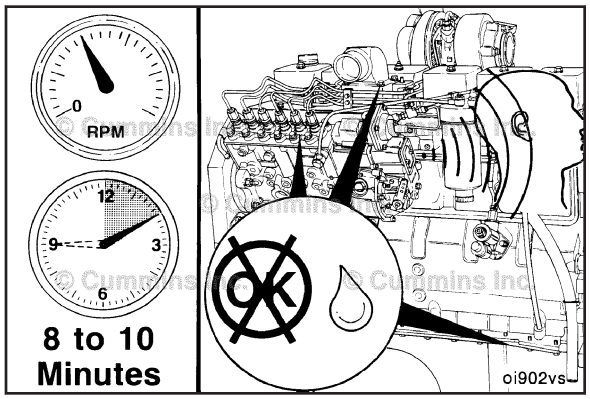
Operate the engine at low idle for 2 to 3 minutes.

Shut off the engine, and wait 5 to 7 minutes for the lubricating oil to drain to the lubricating oil pan, and check the lubricating oil and coolant levels again.





Fill the engine to the correct lubricating oil and coolant levels, if necessary.



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

Repair all leaks and component problems. See the appropriate procedures.

See Section 14 for the Engine Run-in and Test Procedures.

Engine Storage - Long Term (000-005)

General Information

⚠WARNING⚠

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

⚠WARNING⚠

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

△CAUTION△

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

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

Prepare the Engine for Long Term Storage

△CAUTION△

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

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

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

⚠CAUTION⚠

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

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

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

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

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

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

⚠CAUTION⚠

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

- If the engine is being stored as a loose engine, drain the engine coolant and cover all cooling system openings with plastic and tape.
- If the engine is **not** being removed from chassis and the engine has an extended life coolant with rust inhibitor, then coolant does **not** need to be drained.
- If the engine will remain in storage for over 24 months, the engine cooling system **must** be drained and flushed with a suitable solvent or a hot, lightweight mineral oil. Repeat after each 24-month period.
- Remove the intake and exhaust manifolds.
- Spray preservative oil into the intake and exhaust ports in the cylinder heads and in the exhaust manifolds **only**. Do **not** use preservative oil on the intake manifold or any fuel system components as this may permanently damage sensors or valves.
- Spray preservative oil in the inlet port on the air compressor (if applicable).
- Remove the rocker lever covers.
- Spray the rocker levers, the valve stems, the springs, the valve guides, the crossheads, and the push rods with preservative oil.
- Install the rocker lever covers, intake and exhaust manifolds.
- Brush or spray the preservative oil on all the exposed metal surfaces that are **not** painted. Preservative oil should **not** be applied to any plastic, rubber, or similar surfaces. Make sure to coat the flywheel, flywheel housing and all other unpainted machined surfaces with this preservative oil. Use a rust preservative oil compound that meets military specification MIL-C-16173C, type P-2, Grade 1 or 2.

- For components containing exposed bearings that are **not** easily accessible e.g. Fan Hubs, remove the component to aid access. Brush or spray preservative oil on all surfaces that are **not** painted and refit the component. Use a rust preservative oil compound that meets military specification, MIL-C-16173C, type P-2, Grade 1 or 2
- Cover all the openings (engine and components) with heavy paper and tape to prevent dirt and moisture from entering the engine. Cover the entire engine with plastic.
- Put a warning tag on the engine. The tag **must** indicate:
- Do **not** operate the engine.
- Do **not** bar the crankshaft.
- The engine has been treated with preservatives.
- The coolant has been removed.
- The date of treatment.
- The date of the 6 week inspection if required.

⚠CAUTION⚠

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

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

Remove the Engine from Long Term Storage

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

⚠CAUTION⚠

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

- Flush the engine preservative oil out of the engine by removing the plug from the main engine oil rifle and pumping a hot, lightweight mineral oil through it. Make sure that the engine crankshaft is barred at least three to four revolutions during this flushing procedure.
- Drain all the mineral oil that was used to flush the engine clean of the engine preservative oil.
- Install the drain plugs.
- Install new oil, fuel and coolant filters.
- Fill the engine to the high mark with engine oil.
    - If the engine has been in storage for less than 24 months and if the cooling system was drained, fill the cooling system with coolant. Refer to Procedure 018-004 in Section V for antifreeze, water, and SCA specifications.
    - If the engine has been in storage for 24 months, every 24 months the engine cooling system **must** be drained and flushed with a suitable solvent or a hot, lightweight mineral oil. Fill the cooling system with coolant. Refer to Procedure 018-004 in Section V for antifreeze, water, and SCA specifications.
    - If the engine has been in storage for less than 24 months and the engine has an extended life coolant with a rust inhibitor, drain the cooling system. Fill the cooling system with coolant. Refer to Procedure 018-004 in Section V for antifreeze, water, and SCA specifications.
- Adjust the engine brake (if applicable) and valve clearances. Reference the Overhead Set procedure in the corresponding base Troubleshooting and Repair Manual or Service Manual for the engine being serviced.
- Tighten the intake and exhaust manifold mounting capscrews.
- Prime the lubricating system.
- Reinstall any accessory drive belts that were removed.
- Replace all spark plugs. Reference the Spark Plugs procedure in the corresponding base Troubleshooting and Repair Manual or Service Manual for engine being serviced(if applicable).
- Make sure all fuel lines are securely tightened and all fuel shutoff valves are open prior to attempting to start the engine.
- Start the engine.

- Note that if might take multiple cranking attempts to start the engine. Do **not** crank the engine more than 30 seconds at a time as this might cause the starter to overheat and fail.
- Note that the engine might run rough until the fuel system is completely primed or until all residual fuel system preservative oil is completely flushed out of the fuel system (if the fuel has been treated with fuel system preservative oil).
- Install the exhaust aftertreatment components (if applicable).
- Force an active regeneration (if applicable).

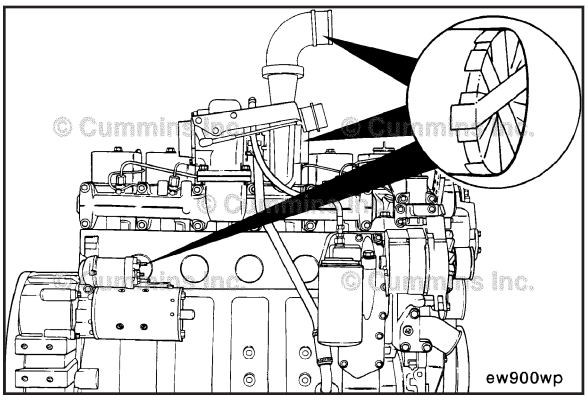
Engine Painting (000-007)

General Information

Remove all the belts from the engine.

Cover the following parts of the engine:

- All pulley belt surfaces
- Exhaust and intake openings
- Electrical components
- Fuel inlet and drain connections
- Any exposed fittings, threads, and electrical wire terminals.

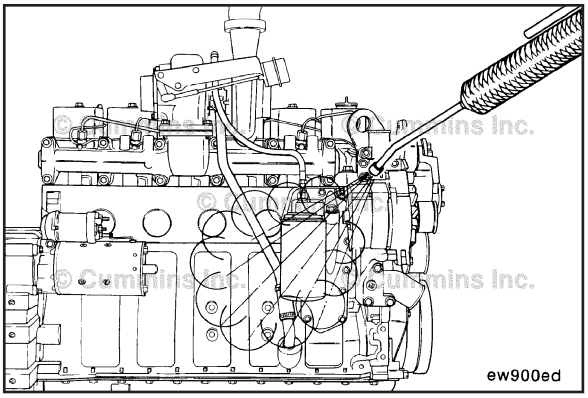


⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious injury.

Use steam to clean the engine, and dry with compressed air.

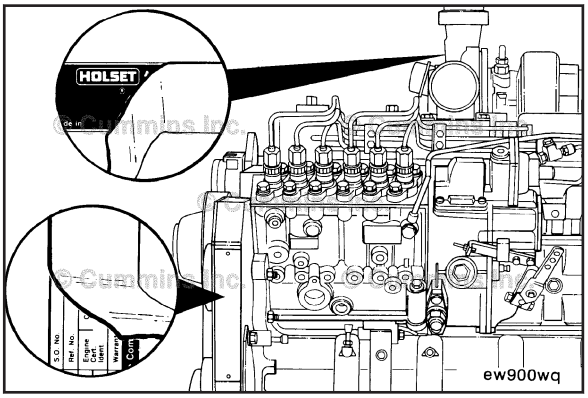
Avoid prolonged, direct steam or water spray on electrical components.

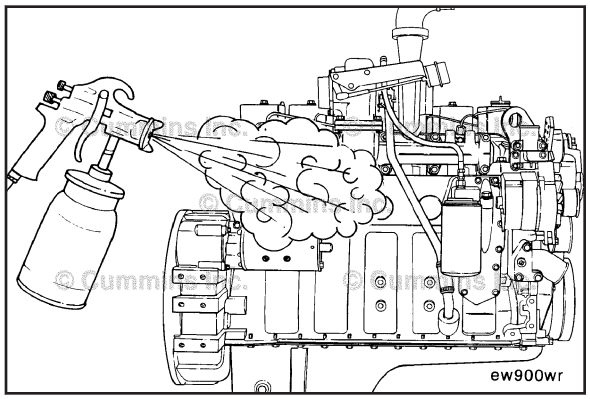
NOTE: Make sure that all engine surfaces are clean and dry before painting the engine.



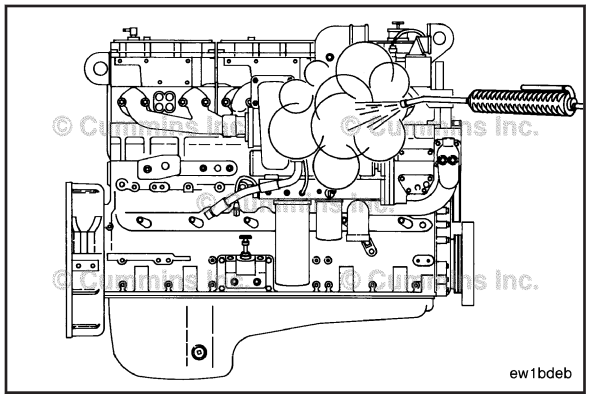
Protect the following components from the paint:

- All dataplates
- Valve and injector set marks
- Exhaust manifold
- Turbocharger turbine housing
- Flywheel
- Flywheel housing transmission mounting surface.





Paint the engine.



Engine Steam Cleaning (000-009)

Clean

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

Steam is the best method of cleaning a dirty engine or a piece of equipment. If steam is **not** available, use a solvent to wash the engine.

Protect all electrical components, openings, and wiring from the full force of the cleaner spray nozzle.

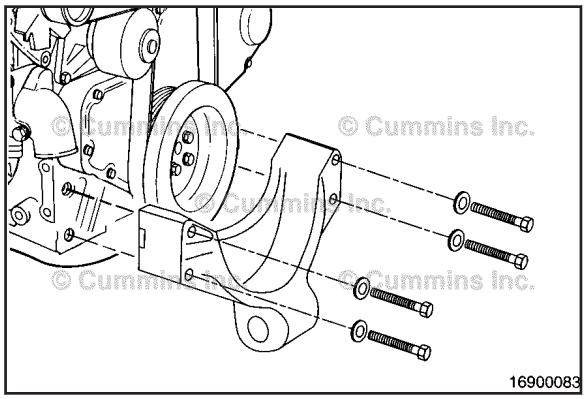
Section DS - Engine Disassembly - Group 00

Section Contents

Engine Support Bracket, Front (016-002)

Remove

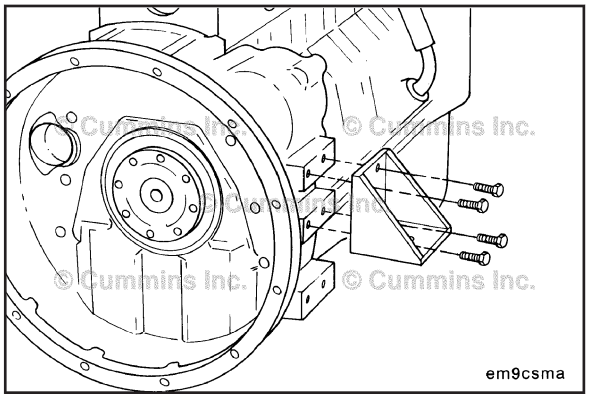
Remove the four mounting capscrews and the front engine support.



Engine Support Bracket, Rear (016-003)

Remove

Remove the four capscrews and rear support bracket.



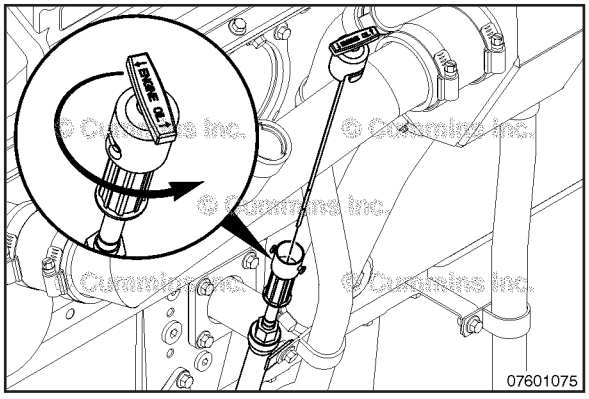
Lubricating Oil Dipstick Tube (007-011)

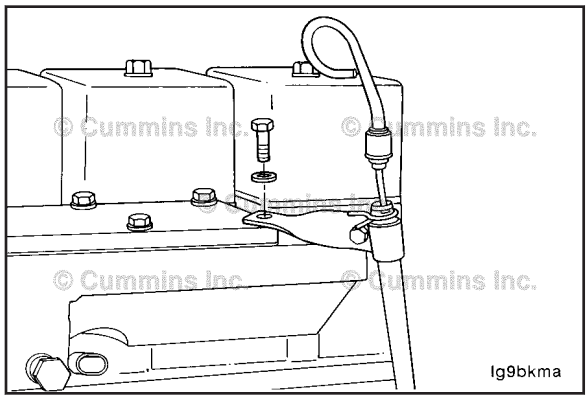
General Information

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.

Remove

If equipped with a locking dipstick, twist the handle counter-clockwise to unlock. Pull up to remove.

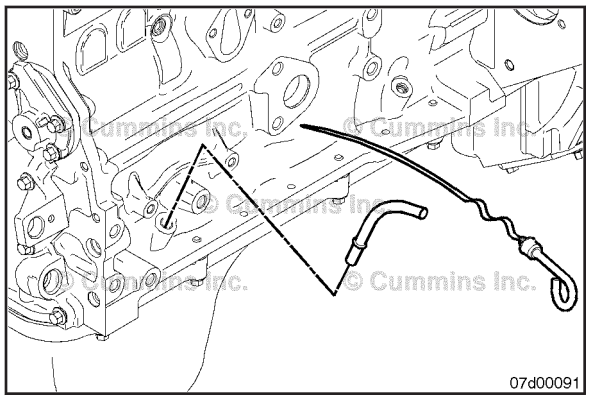




Remove dipstick from the dipstick tube.

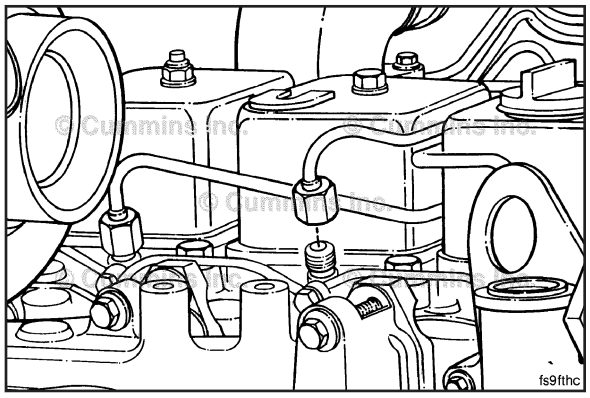
If equipped, remove any dipstick tube supports and clamps.

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.



Injector Supply Lines (High Pressure) (006-051)

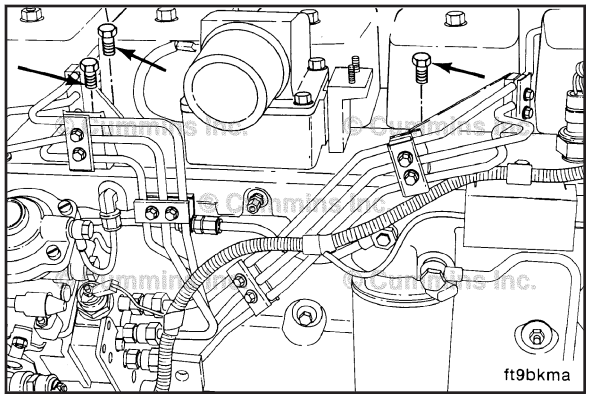
Remove

⚠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.

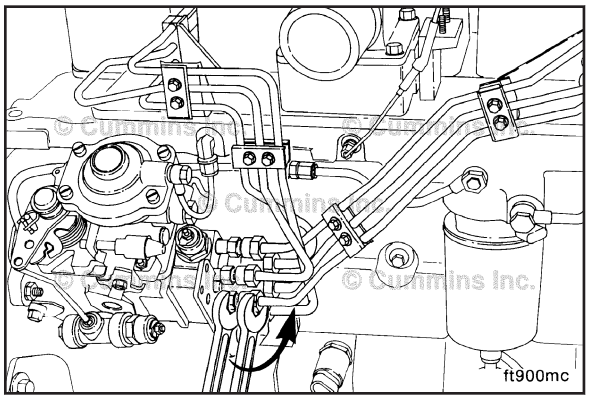
Disconnect the high-pressure fuel lines from the injectors, and complete the following steps:



Remove the fuel line clamp capscrews from the intake cover.

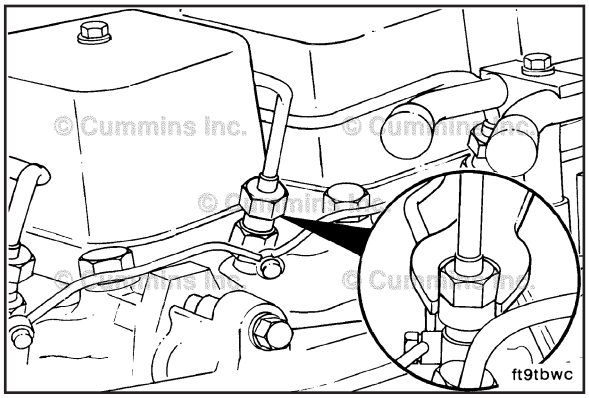
Remove the fuel lines from the fuel injection pump.

NOTE: Use two wrenches to prevent the delivery valve holder from turning.

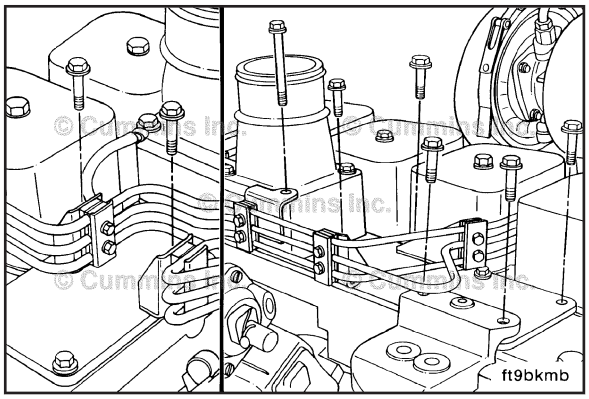


In-Line Pump

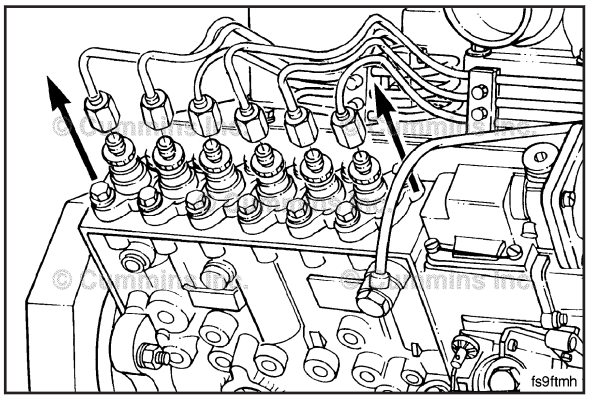
Disconnect the fuel line(s) from the injectors.

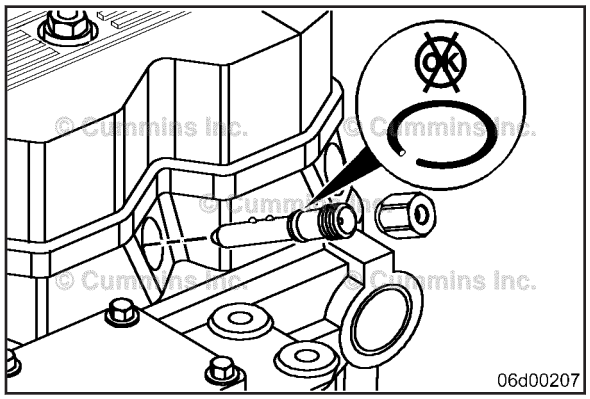


Remove the fuel line clamp capscrews from the intake cover.



Disconnect the fuel line(s) from the fuel injection pump.





Fuel Connector (Head Mounted) (006-052)

Remove

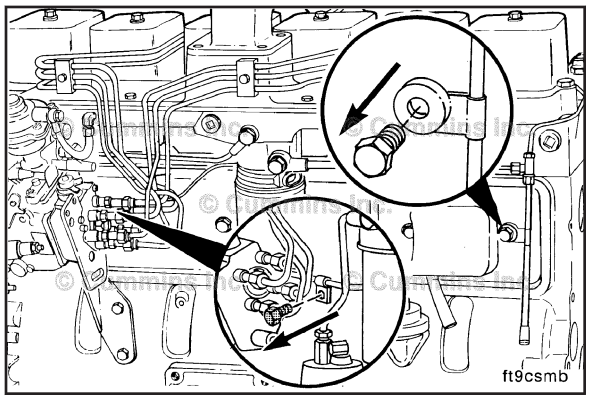
B4.5 RGT Engines

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.

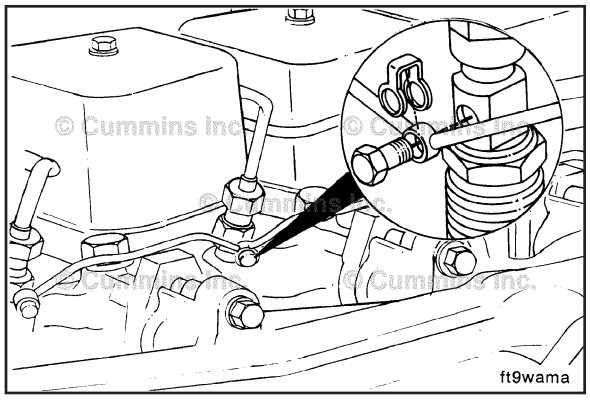


Fuel Manifold (Drain) (006-021)

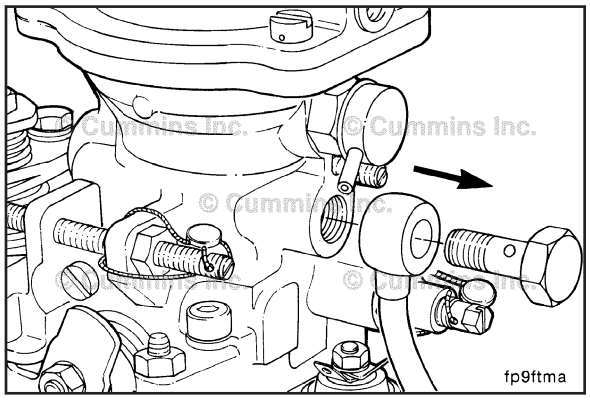
Remove

Distributor-Type Pump

Remove the capscrews from the hold-down clamps, and complete the following steps:



Remove the banjo fitting capscrews and washers.

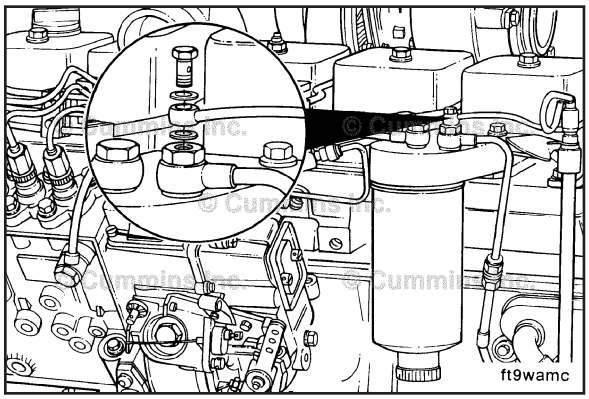


Disconnect the fuel drain line fittings.

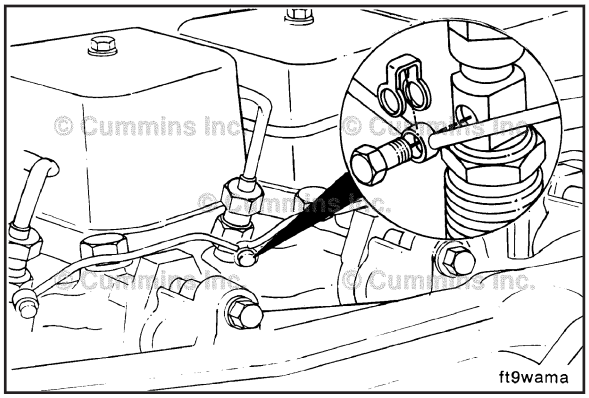
In-Line Pump

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.



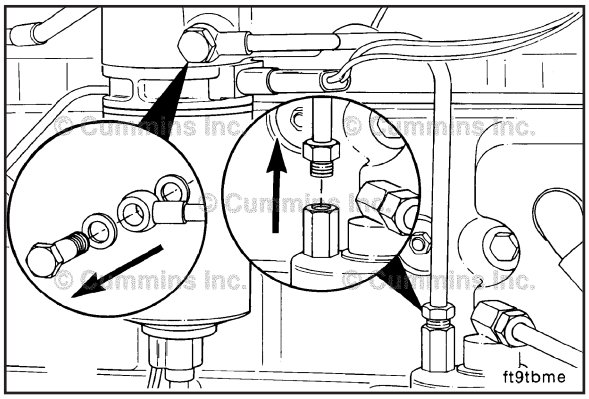
Fuel Supply Lines (006-024)

Remove

Low Pressure Fuel Line(s)

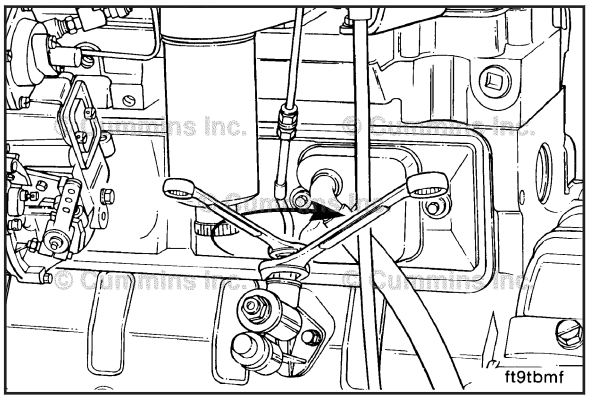
Low-Pressure Fuel Line Replacement - Distributor-Type Pumps

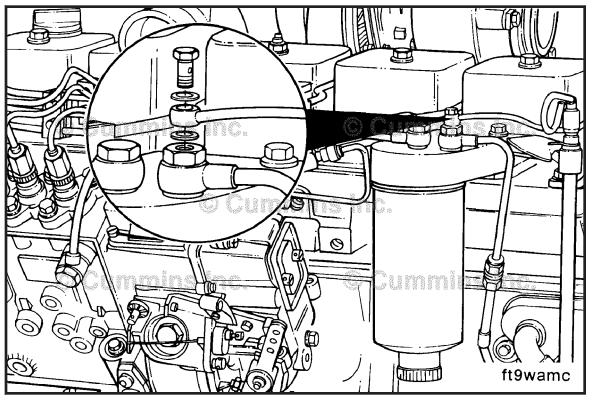
Remove the line from the fuel transfer pump and fuel filter head.



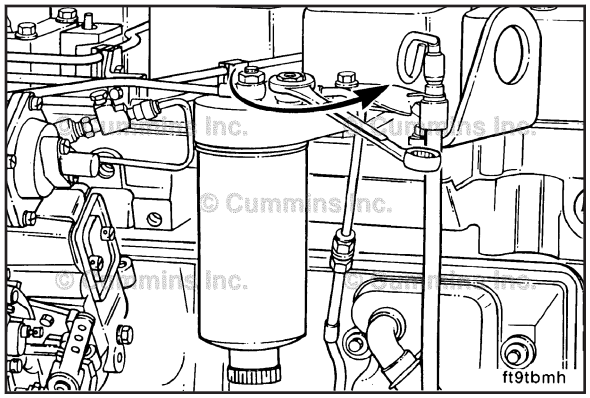
Bosch® In-Line Fuel Injection Pump Fuel Line

Remove the fuel line from the piston-style fuel transfer pump.

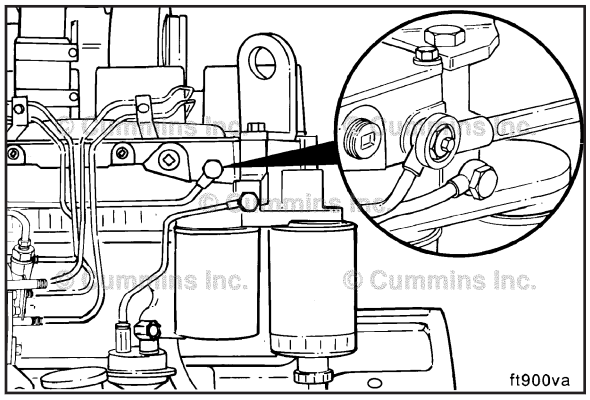




Remove the fuel drain manifold line at the filter head.

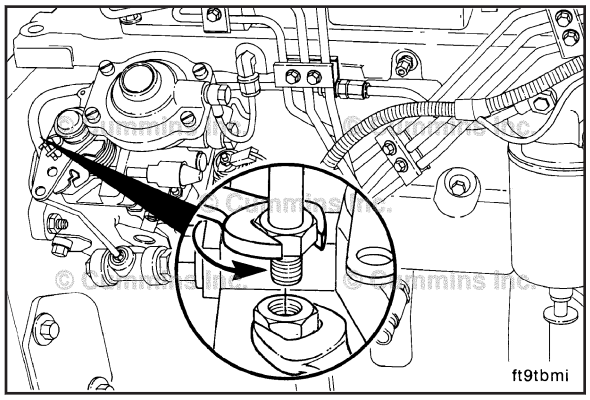


Remove the fuel line from the filter head.



Fuel Injection Pump Supply Line - Distributor-Type Pumps

Remove the bleed screw banjo fitting, and complete the following steps:

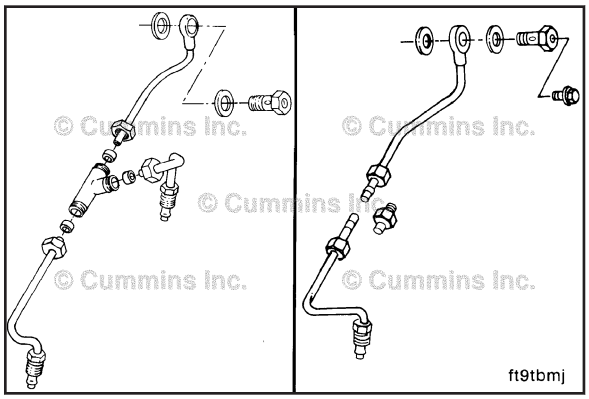


Remove the fuel line from the Bosch® fuel injection pump fitting.

NOTE: To prevent loosening the fuel injection pump inlet fitting, use two wrenches when removing the fuel supply line.

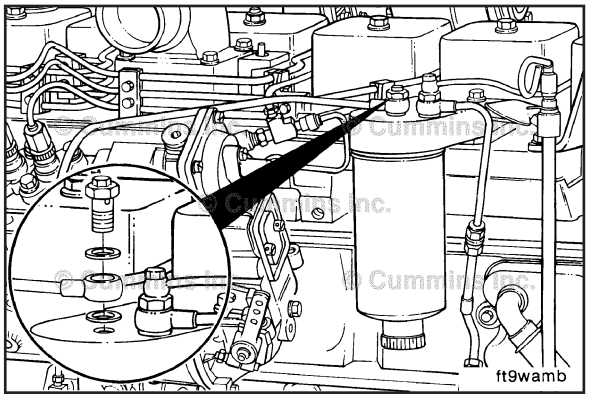
Remove the fuel supply line from the two Lucas CAV fuel injection pump fittings.

NOTE: Replace the seals in the fittings if the line is disassembled.

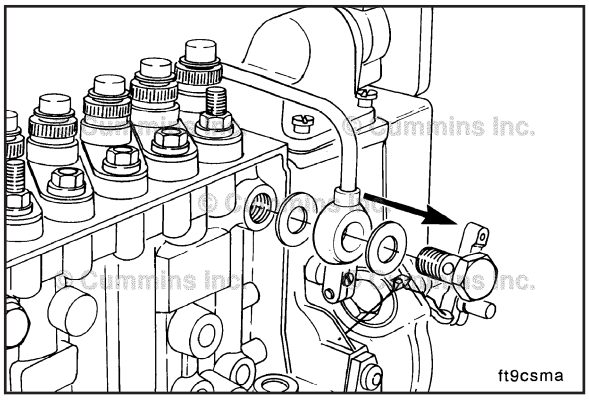


Pump Supply Line - Bosch® In-Line Pump

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.

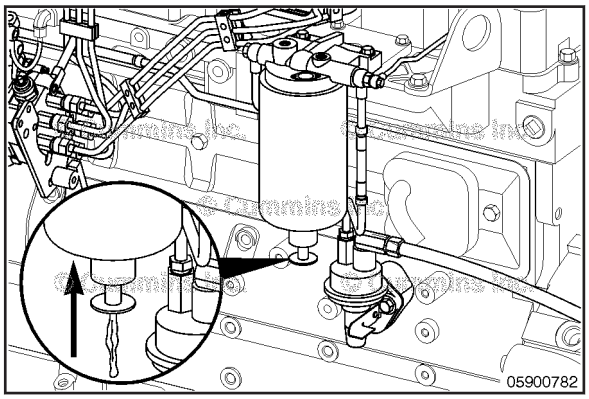


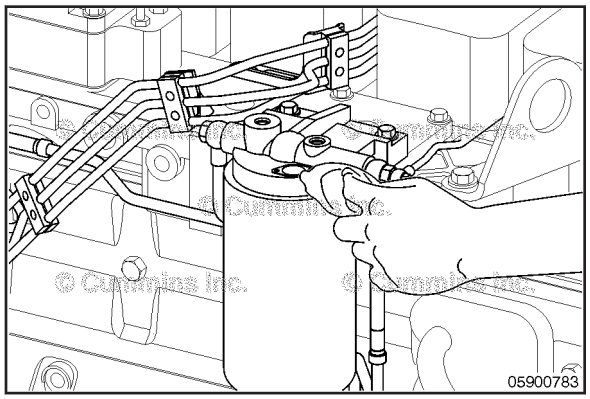
Fuel Filter (Spin-On Type) (006-015)

Drain

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

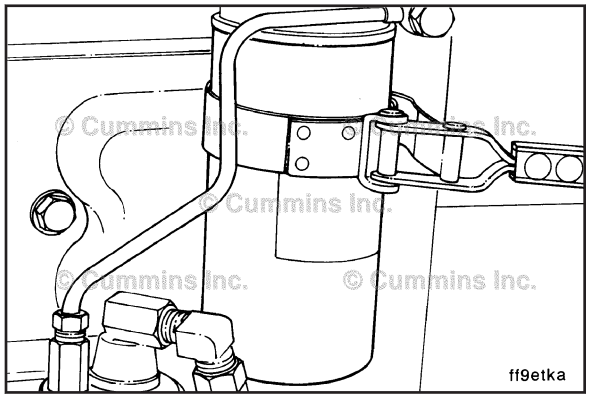
If equipped, use the filter drain valve to drain fuel out of the filter for approximately 5 seconds. This will eliminate fuel from running over the top of the filter upon removal.





Remove

Clean the area around the fuel filter head.

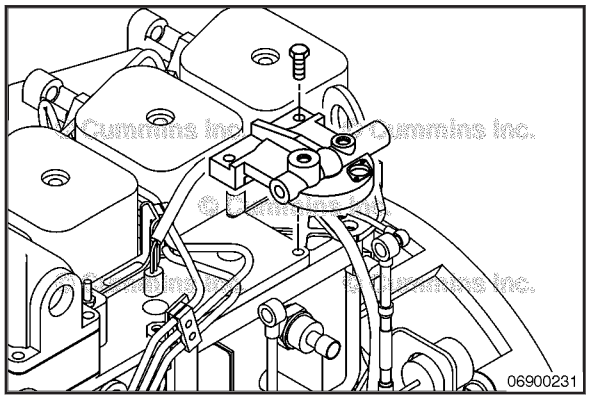


⚠WARNING⚠
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

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).



Fuel Filter Head (006-017)

Remove

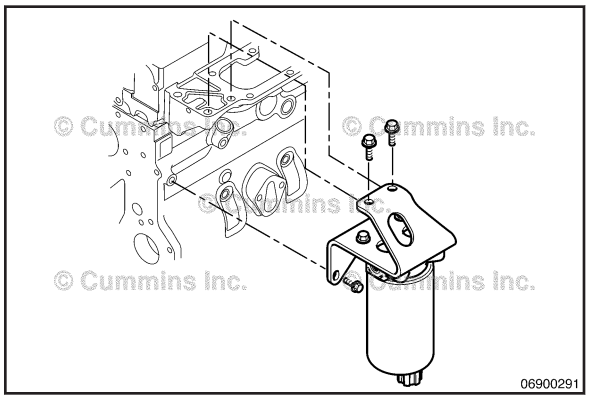
Front Gear Train

Remove the two capscrews retaining the filter head.

Remove the filter head from the engine.

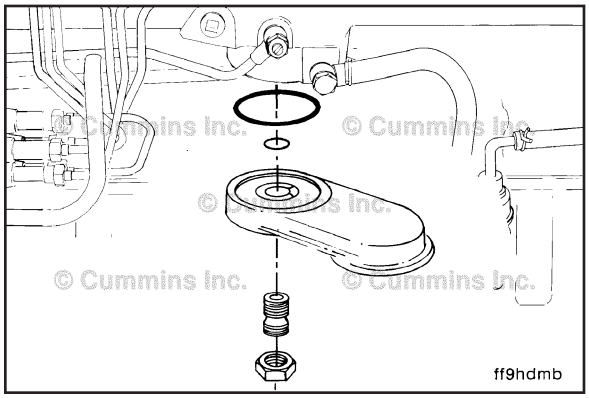
Rear Gear Train

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



Disassemble

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



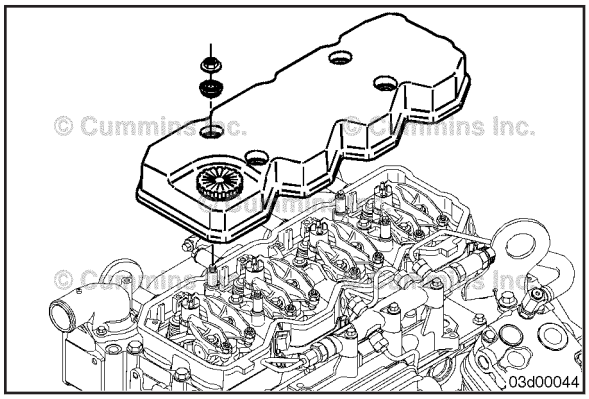
Rocker Lever Cover (003-011)

Remove

B4.5 RGT Engines

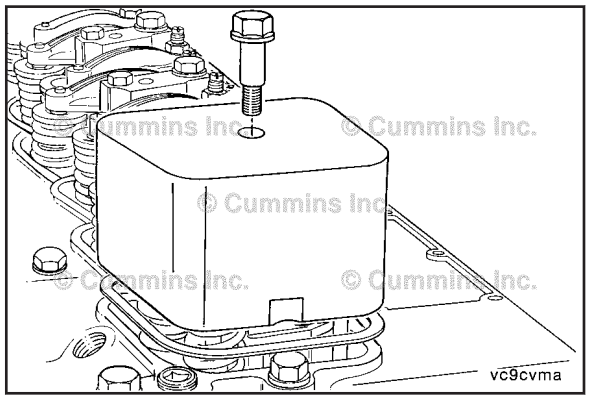
Remove the mounting nuts and isolators from the rocker lever cover.

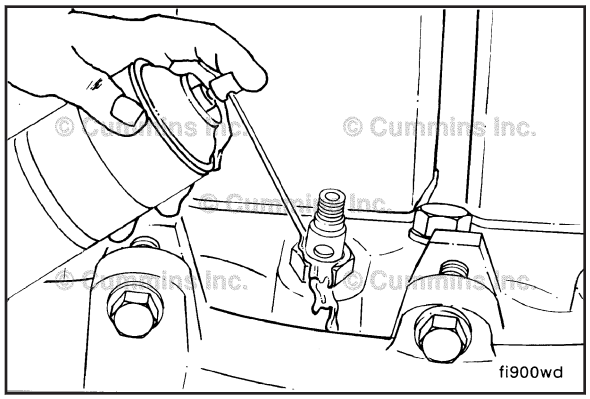
Remove the rocker lever cover.



B3.9, B5.9, and B4.5 Engines

Remove the capscrews, capscrew seals, rocker lever covers and rocker lever cover gaskets.





Injector (006-026)

Remove

Front Gear Train

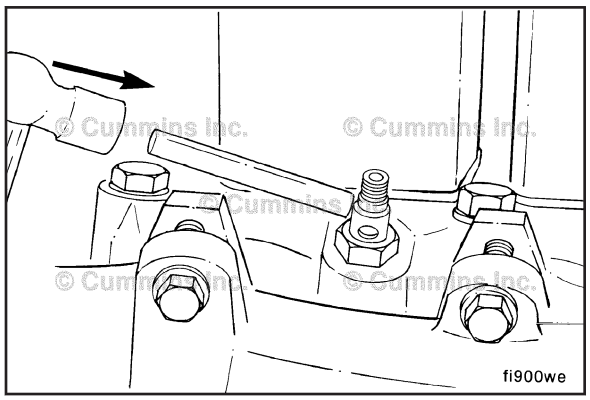
Rust-Penetrating Solvent

⚠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.

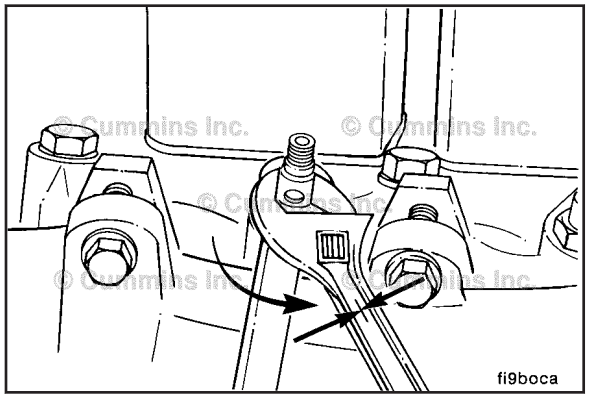
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

△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.

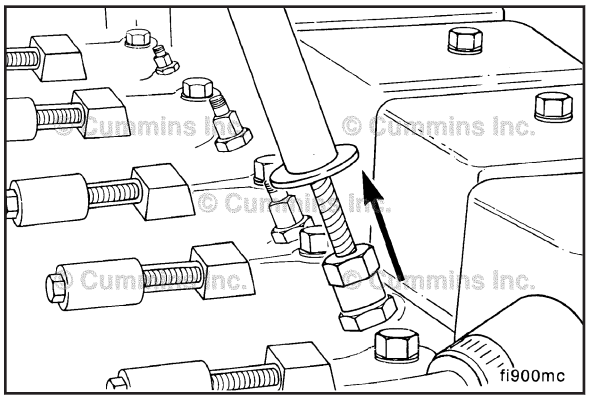


Hit the injector body with a drift pin to loosen any rust.

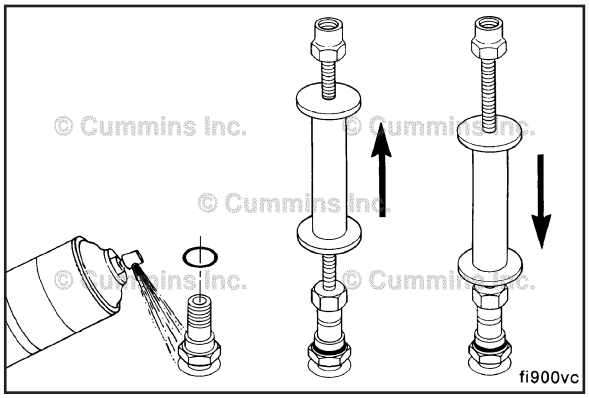


Hold the injector body with an adjustable wrench while loosening the hold-down nut with a 24-mm box wrench.

Use an injector puller, Part Number 3823276, to remove the injectors.



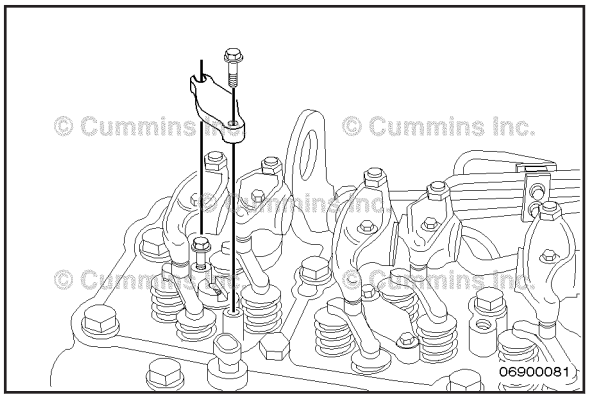
It is often necessary to tap the injector with the injector puller to work the injector up and down to remove it.



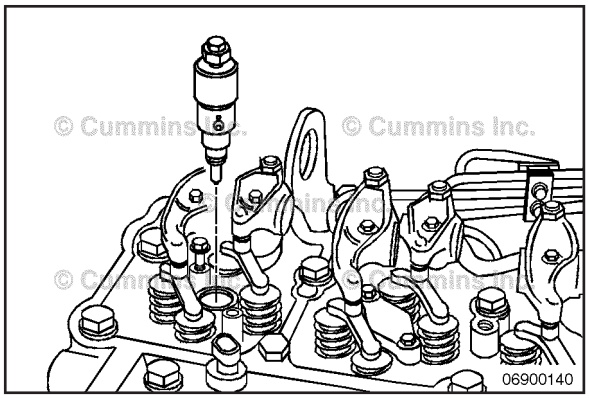
Rear Gear Train

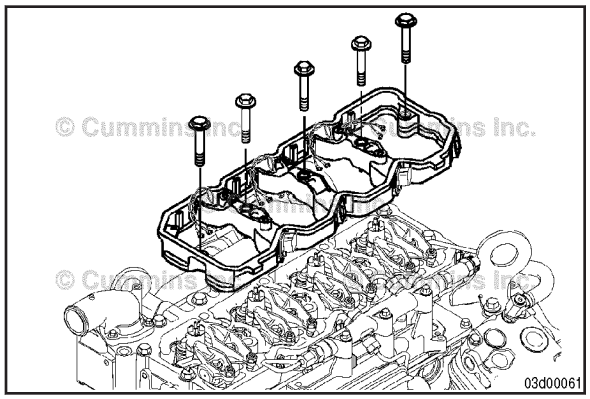
Remove the injector hold-down capscrews.

Tilt the hold-downs up, and slide them out.



Use an injector puller, Part Number 3825156, to remove the injectors from the head.





Rocker Lever Housing (003-013)

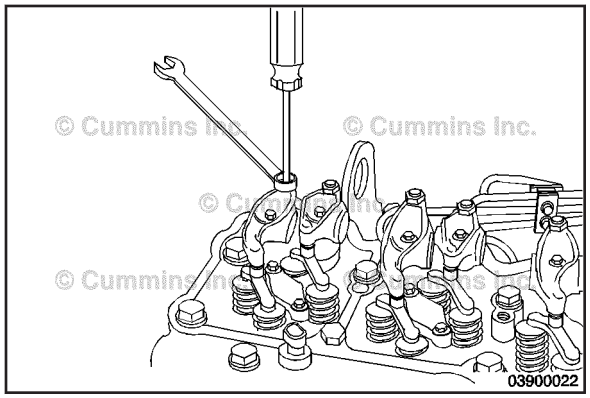
Remove

Rear Gear Train

NOTE: Check the gasket while it is installed in the rocker housing. Once the gasket is removed it **must** be replaced.

NOTE: Check for cracks in the rocker housing bridge area before removing the mounting capscrews.

Remove the rocker housing, capscrews, and gasket.



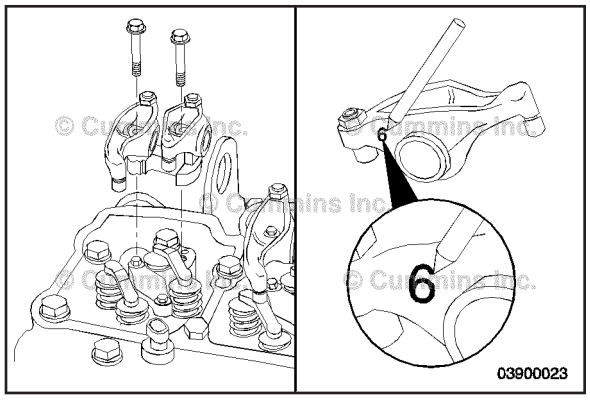
Rocker Lever (003-008)

Remove

B4.5 RGT Engines

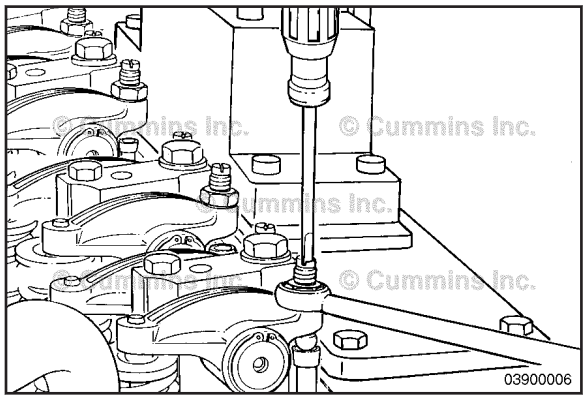
Loosen the adjusting screw locknuts.

Loosen the adjusting screws until they stop.



Remove the capscrews from the rocker lever pedestals.

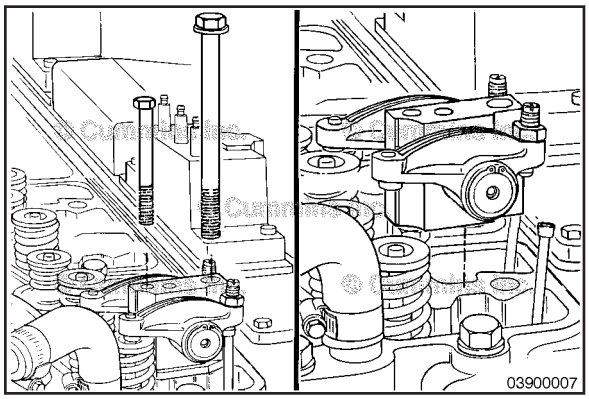
Remove and mark the pedestals and rocker lever assemblies one at a time as to their location and position.



B3.9, B5.9, and B4.5 Engines

Loosen the adjusting screw locknuts. Loosen the adjusting screws until they stop.

Remove the capscrews from the rocker lever pedestals. Remove the pedestals and rocker lever assemblies.

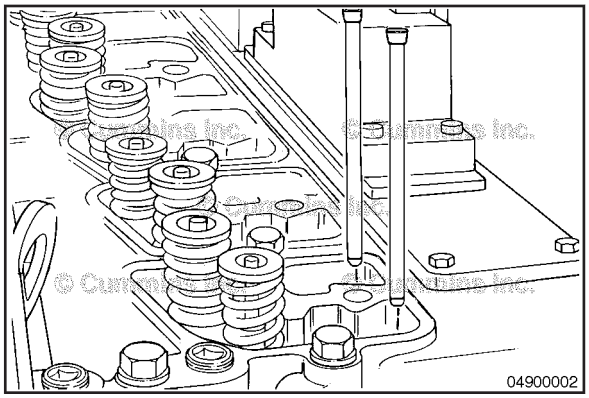


Push Rods or Tubes (004-014)

Remove

Remove the push rods.

NOTE: Mark the push rods to identify their location.



Crosshead (002-001)

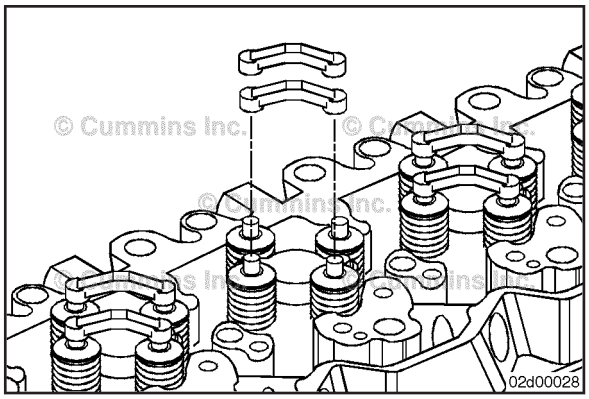
General Information

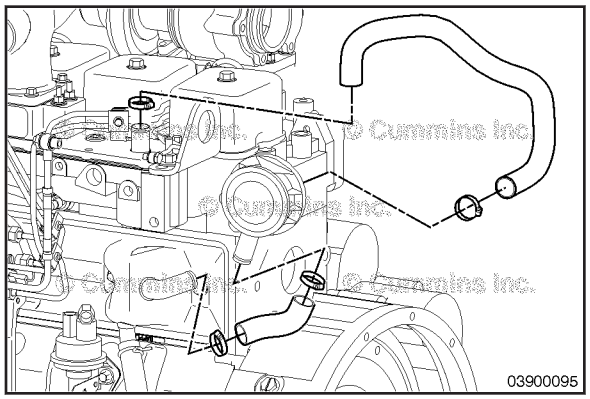
This procedure is for engines with 4 valves per cylinder only.

Remove

NOTE: Make note of the crosshead location and orientation. If the crossheads are reused, they **must** be installed in their original location and orientation.

Remove the crossheads.





Closed Crankcase Ventilation Hoses (003-024)

Remove

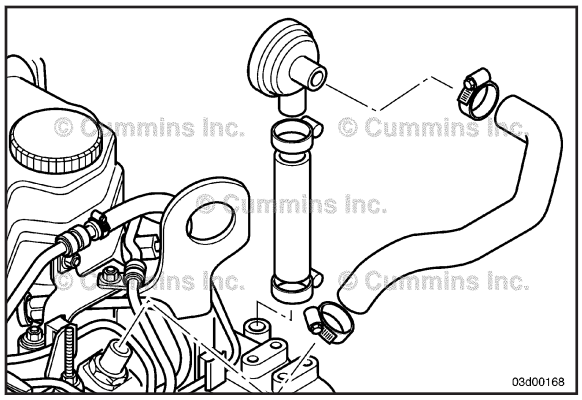
Front Gear Train

For front gear train engines, the closed crankcase ventilation valve is located between the tappet cover breather and intake manifold/cover of the engine.

The tappet cover closed crankcase ventilation valve is held in place by the molded closed crankcase ventilation hoses.

NOTE: Disconnecting and removing the hoses will also remove the valve.

Disconnect and remove the molded closed crankcase ventilation hoses and crankcase ventilation valve.



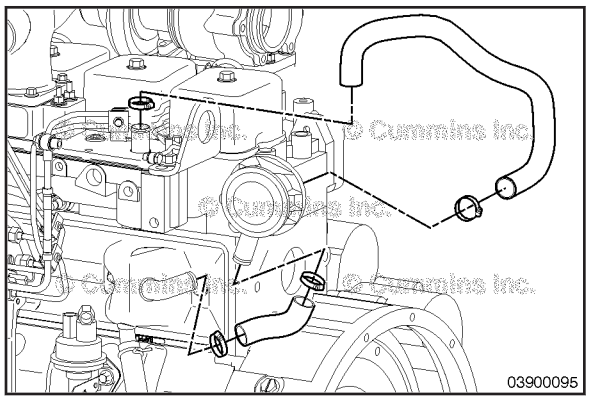
Rear Gear Train

For rear gear train engines, the closed crankcase ventilation valve is connected between the flywheel housing and intake manifold/cover of the engine.

The tappet cover closed crankcase ventilation valve is held in place by the molded closed crankcase ventilation hoses.

NOTE: Disconnecting and removing the hoses will also remove the valve.

Disconnect and remove the molded closed crankcase ventilation hoses and crankcase ventilation valve.



Closed Crankcase Ventilation Valve (003-023)

Remove

Front Gear Train

For front gear train engines, the closed crankcase ventilation valve is located between the tappet cover breather and intake manifold/cover of the engine.

The tappet cover closed crankcase ventilation valve is held in place by the molded closed crankcase ventilation hoses.

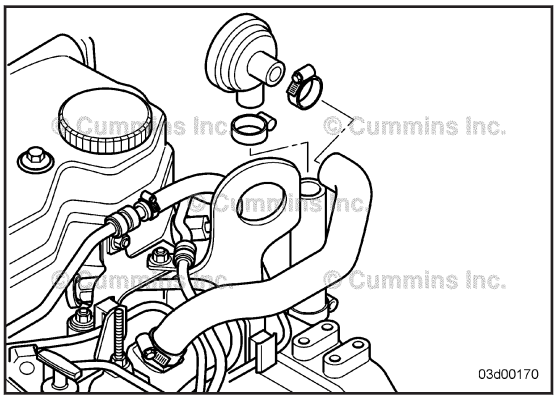
Removing the hoses will remove the valve.

Rear Gear Train

For rear gear train engines, the closed crankcase ventilation valve is connected between the flywheel housing and intake manifold/cover of the engine.

The tappet cover closed crankcase ventilation valve is held in place by the molded closed crankcase ventilation hoses.

Removing the hoses will remove the valve.

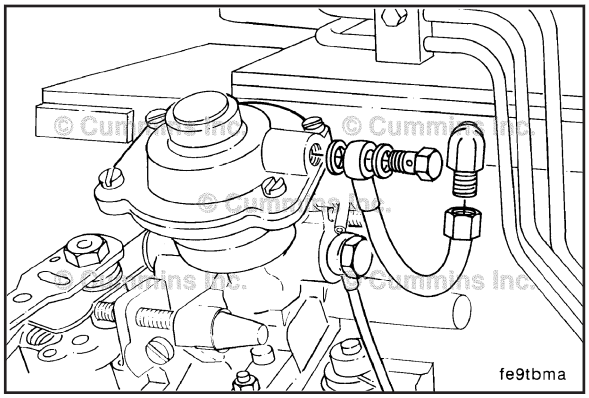


AFC Air Tube (006-001)

Remove

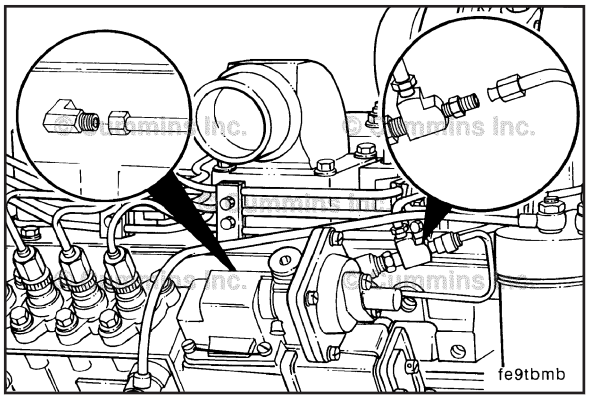
Distributor-Type Fuel Injection Pumps

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



In-Line Pumps

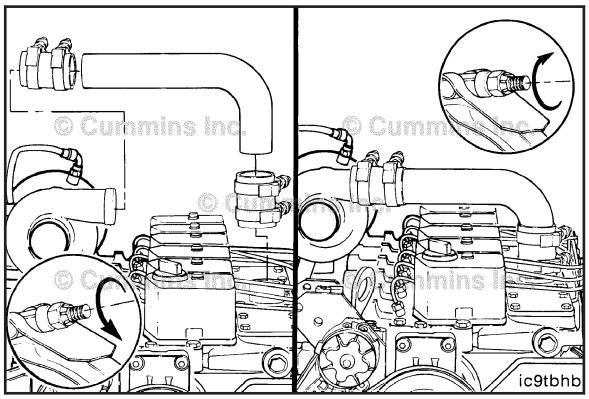
Remove the AFC tube.

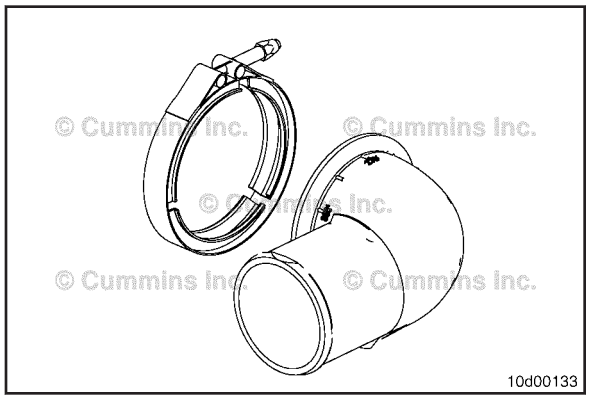


Air Crossover (010-019)

Remove

Loosen the hose clamps, and position the hose so the crossover tube can be removed.

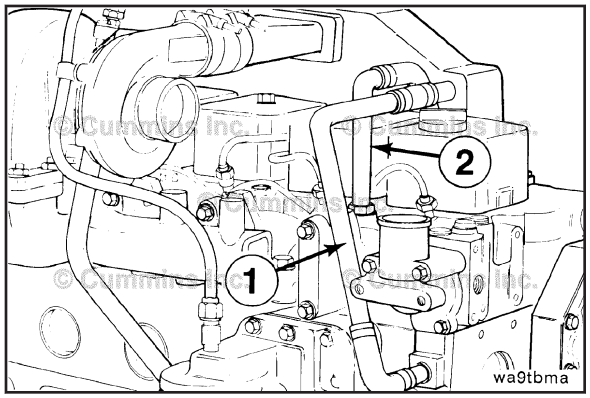




Air Intake Connection Adapter (010-131)

Remove

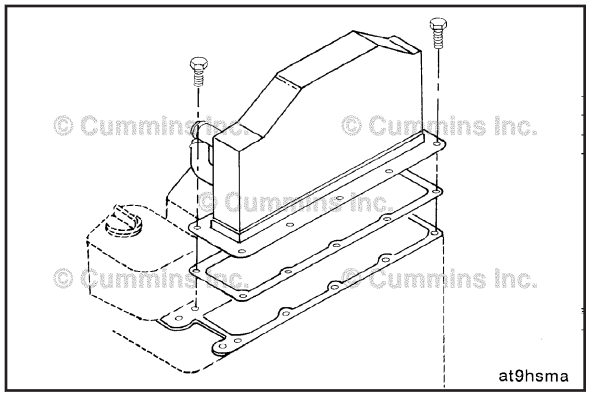
Remove the v-band clamp, the elbow piece of the air intake connection adapter, and the seal.



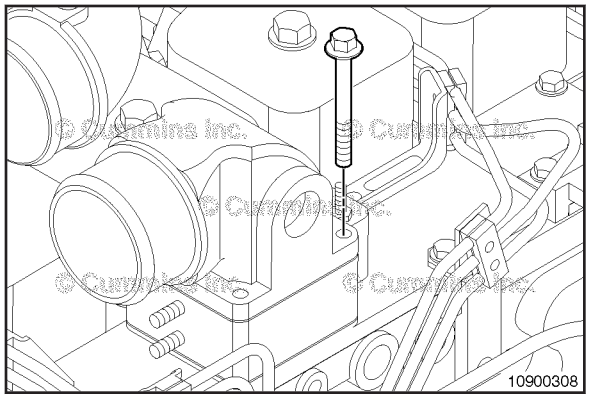
Aftercooler (010-001)

Remove

Remove the coolant supply tube (1) and the coolant return tube (2).



Remove the aftercooler housing and gasket.



Intake Manifold Air Heater Element (010-124)

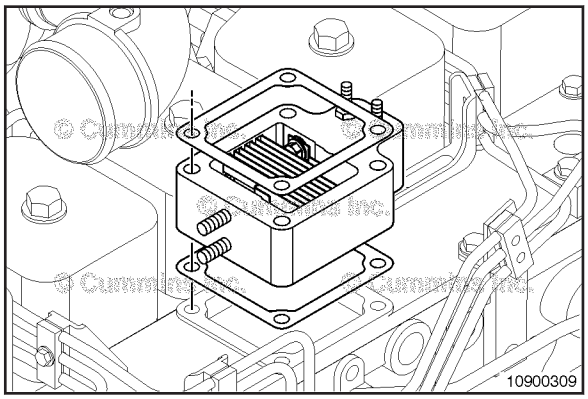
Remove

Brick Type

Remove the four capscrews that attach the air-crossover connection and heater.

Remove the heater and gaskets.

Clean the mounting surface.

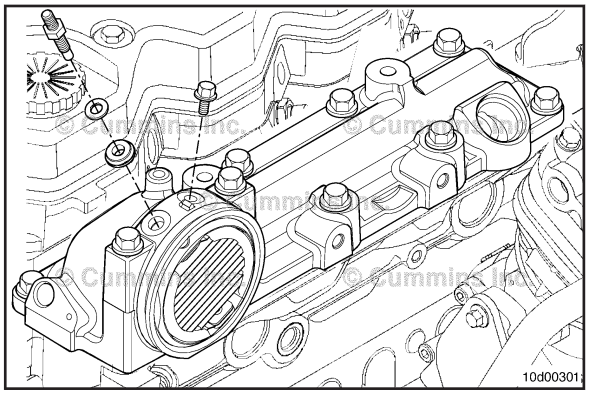


Cylindrical Type

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.

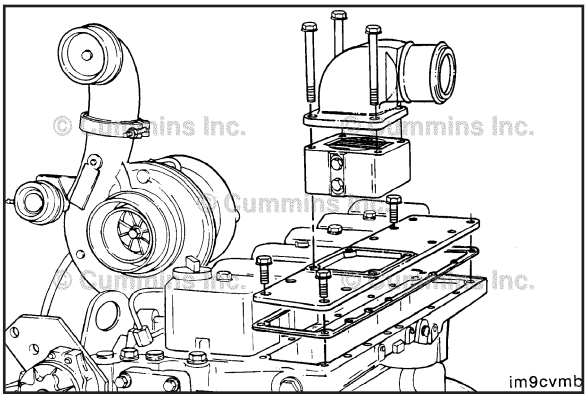


Air Intake Manifold (010-023)

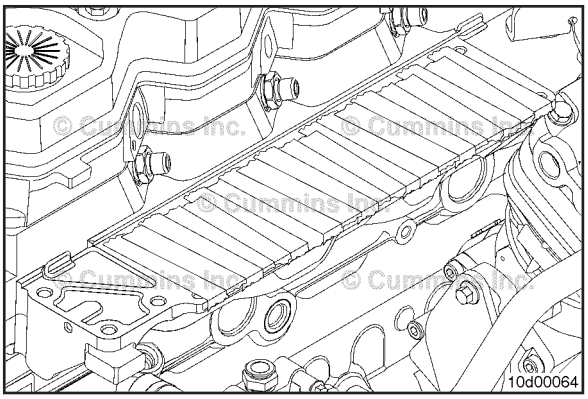
Remove

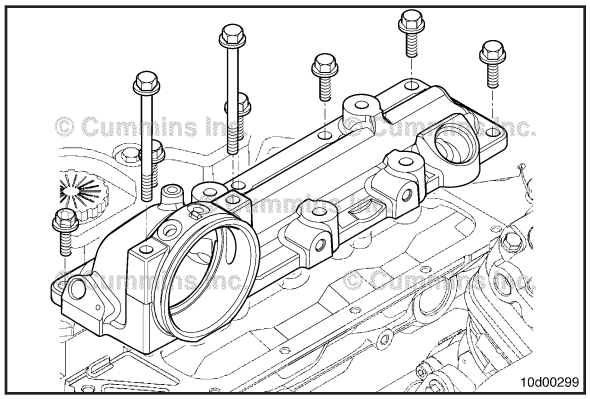
Front Gear Train

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.



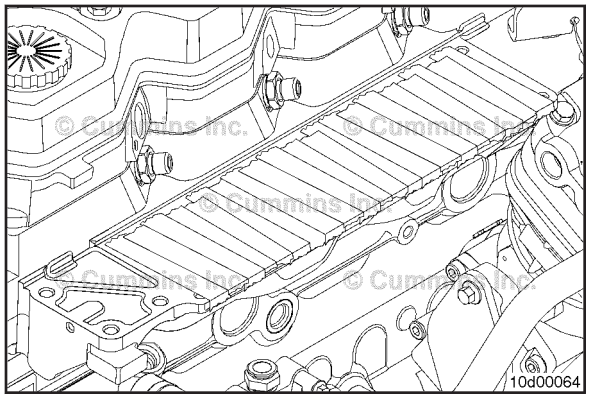


Rear Gear Train

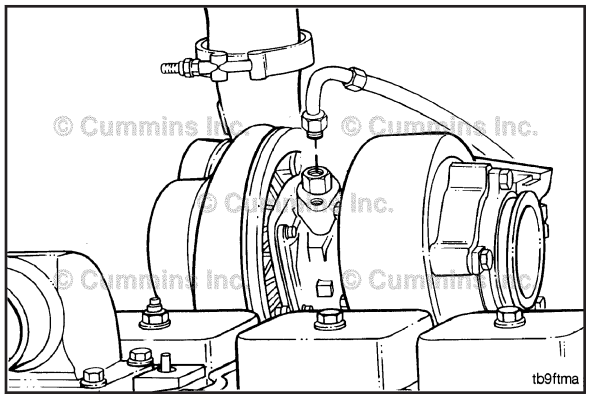
Remove the intake manifold mounting capscrews.

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.

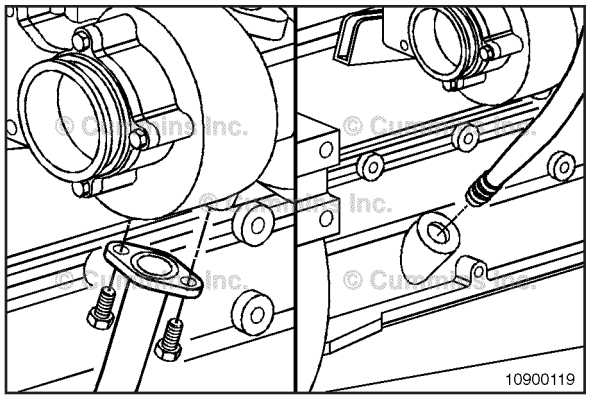


Turbocharger Oil Supply Line (010-046)

Remove

Remove the oil supply line from the oil filter head.

Remove the oil supply line from the turbocharger bearing housing.



Turbocharger Oil Drain Line (010-045)

Remove

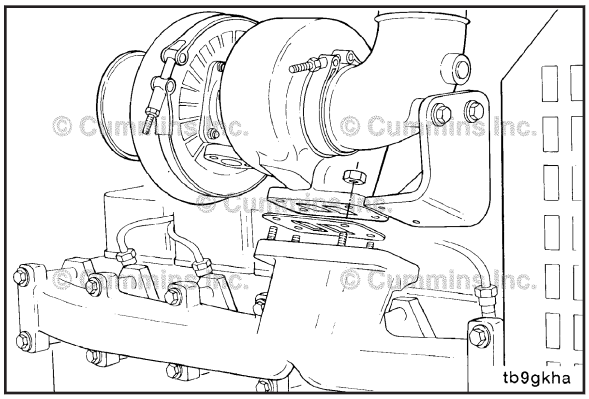
Remove the capscrews from the turbocharger oil drain tube.

Pull the drain line out of the drain line boss.

Turbocharger (010-033)

Remove

Remove the turbocharger mounting nuts, turbocharger, and gasket.



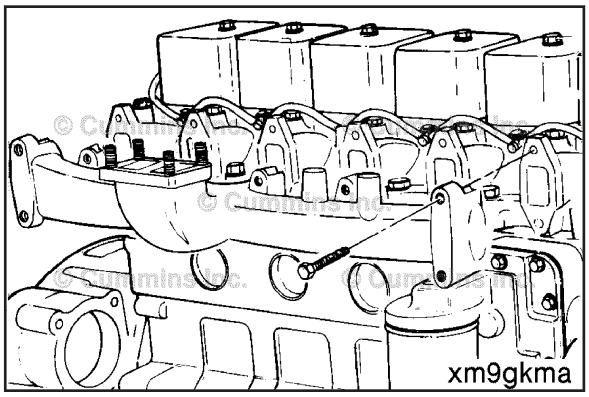
Exhaust Manifold, Dry (011-007)

Remove

For 6 cylinder engines, remove the exhaust manifold mounting capscrews and spacers.

Remove the exhaust manifold and gaskets.

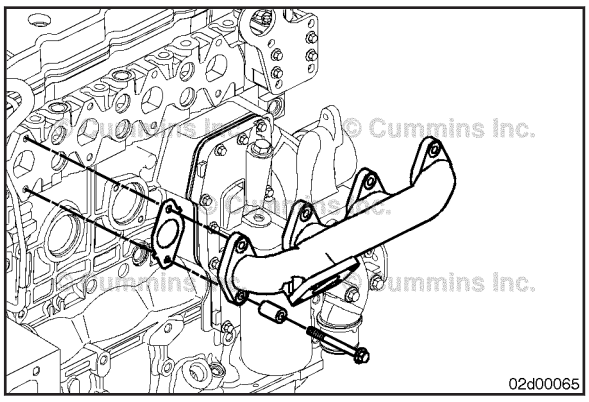
Discard the exhaust manifold gaskets.

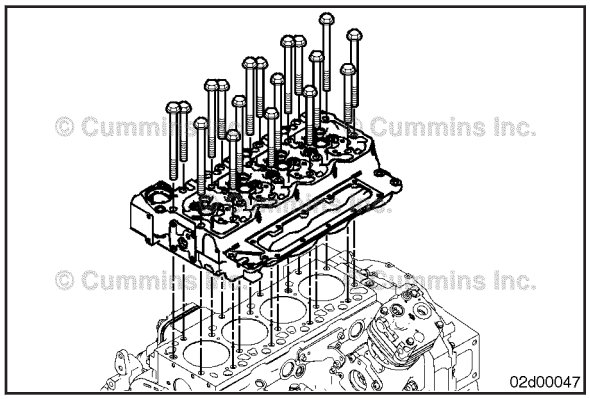


For 4 cylinder engines, remove the exhaust manifold mounting capscrews and spacers.

Remove the exhaust manifold and gaskets.

Discard the exhaust manifold gaskets.





Cylinder Head (002-004)

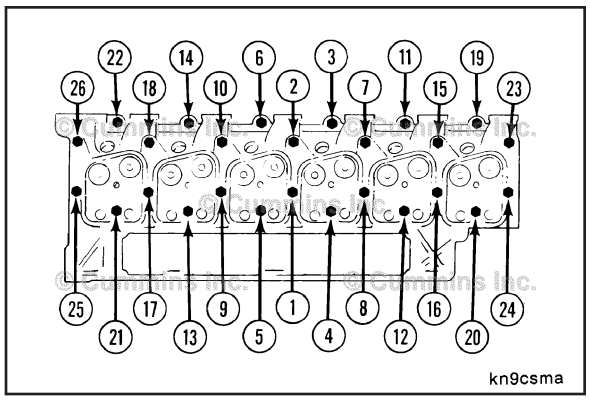
Remove

B4.5 RGT Engines

⚠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.

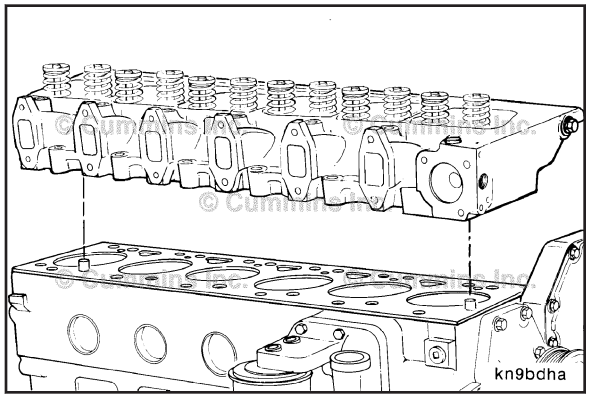
△CAUTION△
If removing the cylinder head with the injectors installed, be careful not to damage the tips of the injector. Do not set the cylinder head down on the combustion face with the injectors installed. Damage to the injector tips will result.

Remove the cylinder head capscrews and cylinder head.



B3.9, B5.9, and B4.5 Engines

Remove the cylinder head capscrews.



△CAUTION△
If removing the cylinder head with the injectors installed, be careful not to damage the tips of the injector. Do not set the cylinder head down on the combustion face with the injectors installed. Damage to the injector tips will result.

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

△CAUTION△
Do not lay the cylinder head on the combustion deck. This can cause damage to the cylinder head deck.

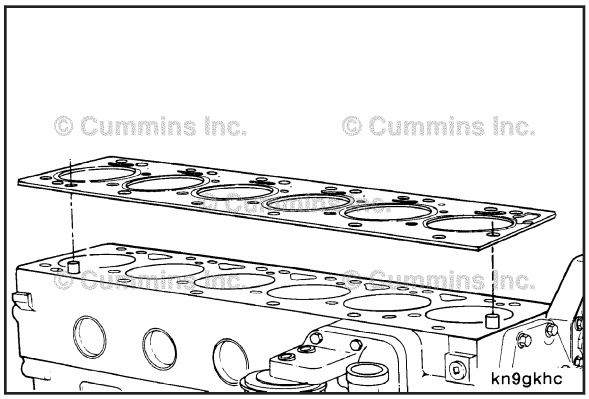
Remove the cylinder head from the cylinder block. Be sure the head is removed in a direct upward direction.

Cylinder Head Weight		
Cylinder Number	Kg	lb
4	36	79
6	51.3	113

Cylinder Head Gasket (002-021)

Remove

Remove the head gasket.



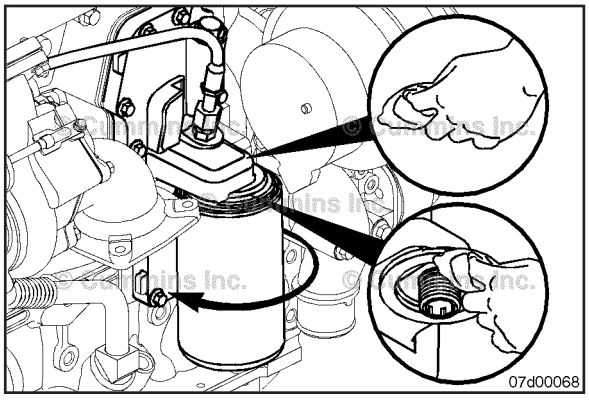
Lubricating Oil Filter (Spin-On) (007-013)

Remove

Clean the area around the lubricating oil filter head.

Use the oil filter wrench, Part Number 3400158, to remove the filter.

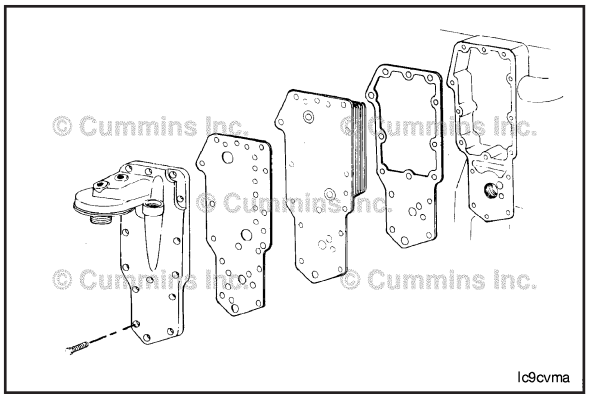
Clean the sealing surface of the filter head.



Lubricating Oil Cooler (007-003)

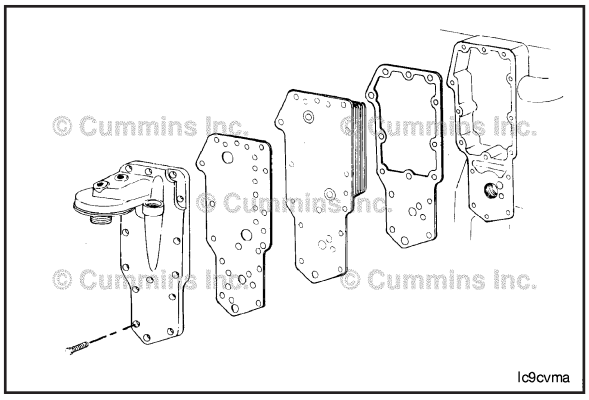
General Information

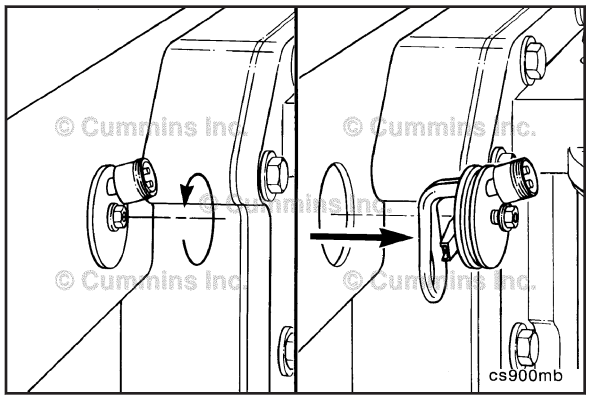
The lubricating oil cooler is mounted between the lubricating oil cooler cover and the cylinder block. Since neither the lubricating oil cooler or lubricating oil cooler cover can be removed without removing and installing the other, this procedure covers the removal and installation of both components.



Remove

Remove the lubricating oil cooler housing capscrews, housing, gaskets, and cooler element.





Coolant Heater (008-011)

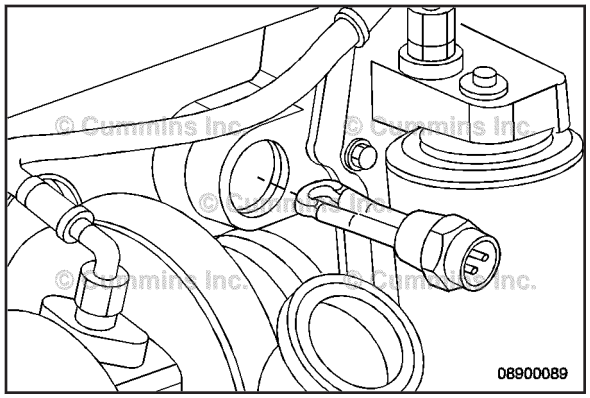
Remove

Front Gear Train

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.

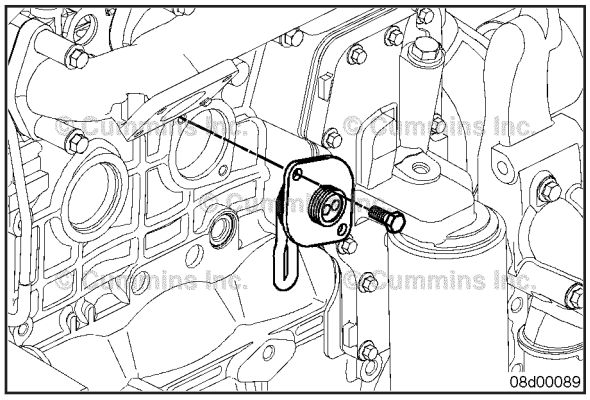
For bolted coolant heaters, loosen the block heater retaining nut.

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.

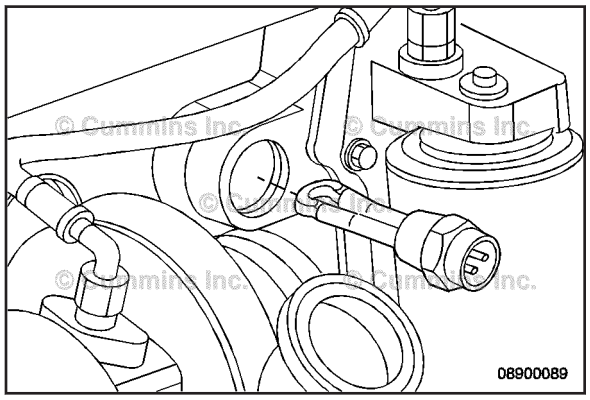


Rear Gear Train

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.

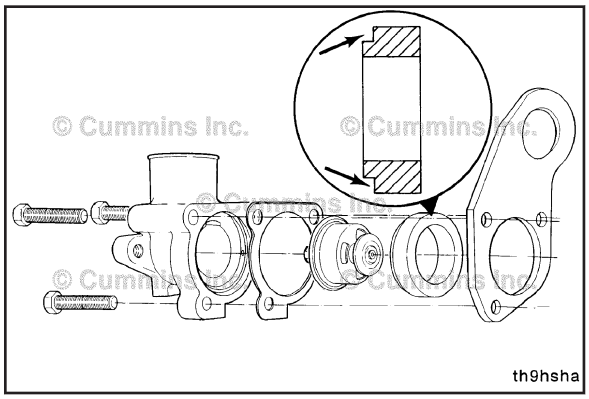
Remove the coolant heater from the block.

Coolant Thermostat (008-013)

Remove

Front Gear Train

Remove three capscrews, the thermostat housing, lifting bracket, thermostat, and thermostat seal.

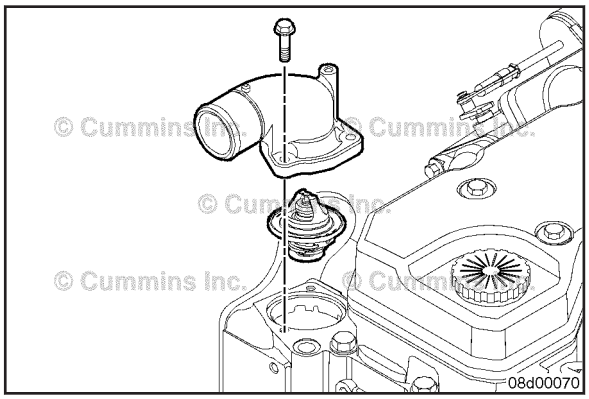


Rear Gear Train

Remove the water outlet connection capscrews.

Remove the water outlet connection.

Remove the thermostat.



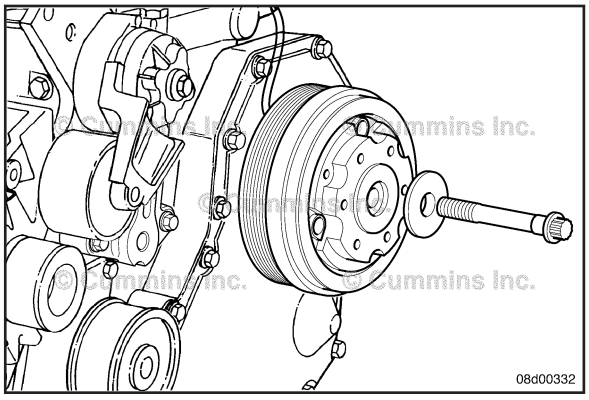
Fan Clutch, Electric (008-026)

Remove

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.

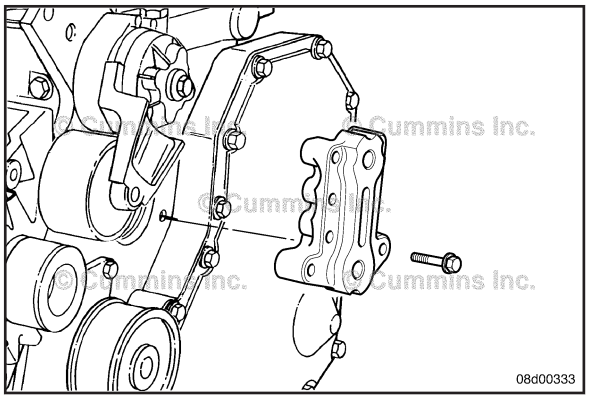
Remove the electric fan clutch mounting capscrew, washer and electric fan clutch.

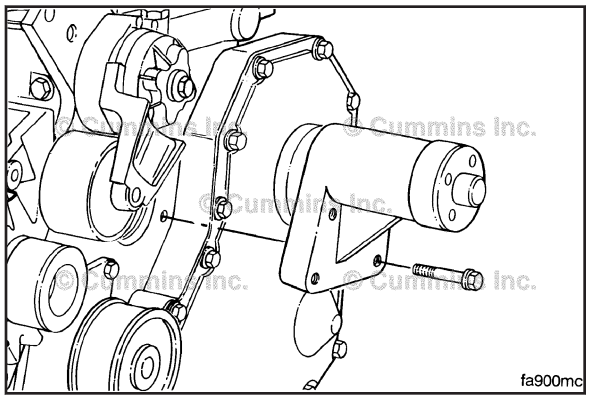


NOTE: Prior to removing the electric fan clutch support bracket, note the mounting location and orientation of the bracket. The mounting bracket can be installed in different orientations for different fan drive arrangements.

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.



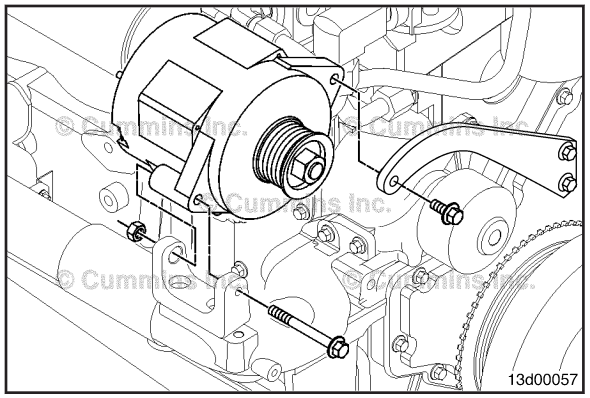


Fan Hub, Belt Driven (008-036)

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.



Alternator (013-001)

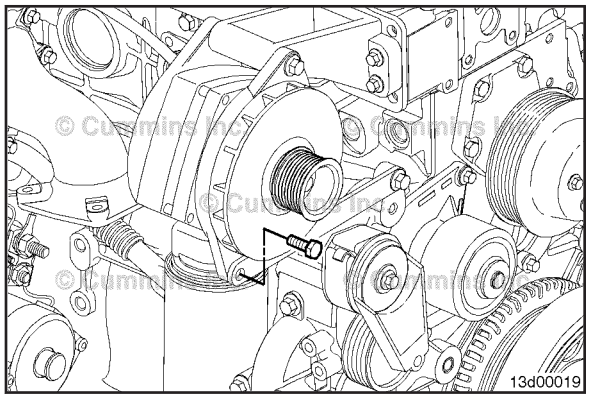
Remove

Spool Mount.

Remove the upper alternator link capscrew.

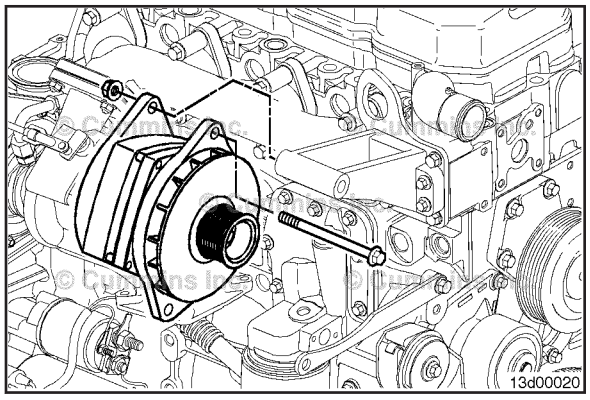
Remove the mounting capscrew and nut at the bottom of the alternator and alternator mounting bracket.

Remove the alternator.



Hinge Mount

Remove the alternator link capscrew.



Remove the alternator mounting capscrew.

Remove the alternator.

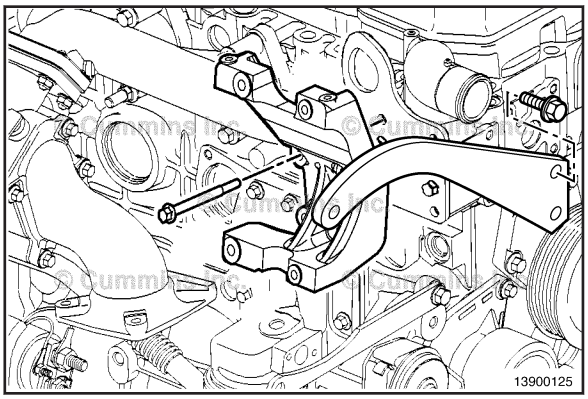
Alternator Bracket (013-003)

Remove

Spool Mount:

Remove the upper alternator bracket mounting capscrews.

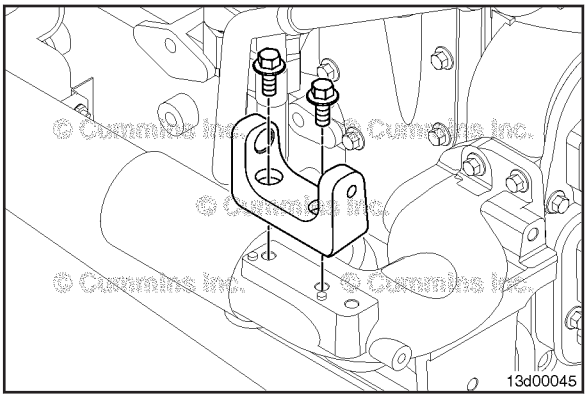
Remove the alternator bracket.



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.

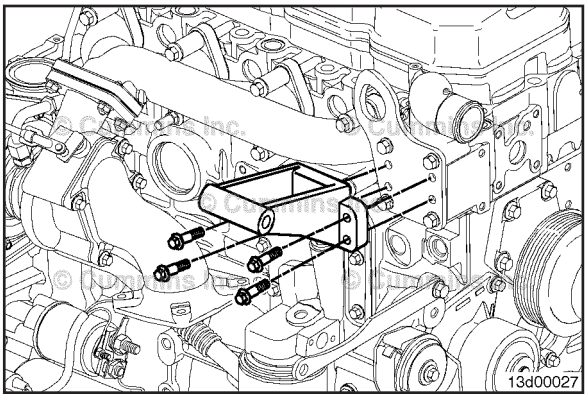


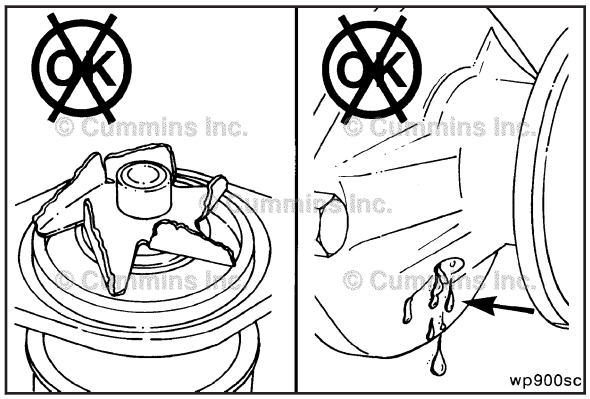
Hinge Mount:

Remove the upper alternator bracket mounting capscrews.

Remove the lower alternator bracket mounting capscrews.

Remove the alternator brackets.





Water Pump (008-062)

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.

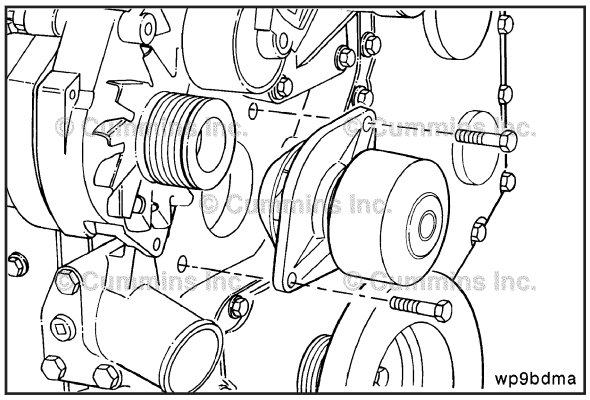
Use the following guidelines to determine if water pump replacement is necessary:

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.

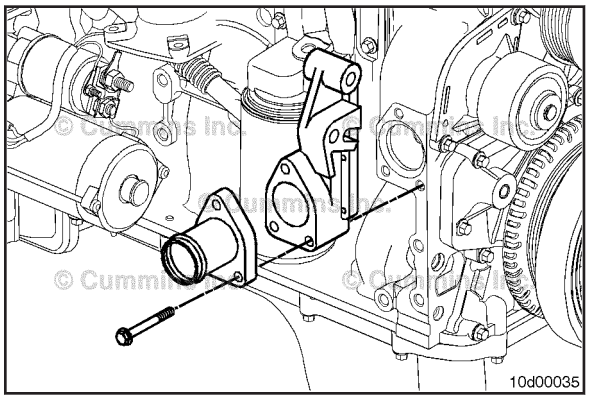
Water Inlet Connection (008-082)

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.

Remove

Remove the capscrews, water inlet connection, gasket, and rectangular sealing ring.

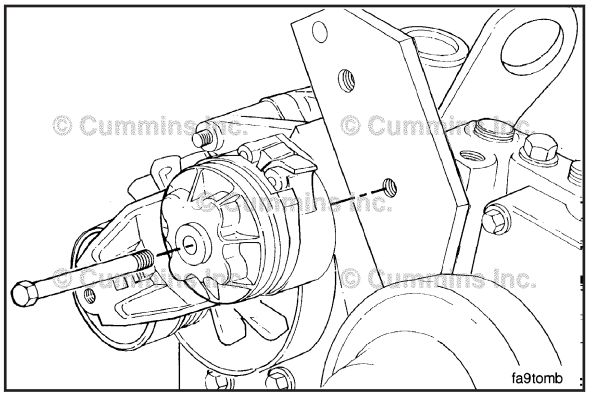


Cooling Fan Belt Tensioner (008-087)

Remove

Remove the capscrew and belt tensioner from the bracket.

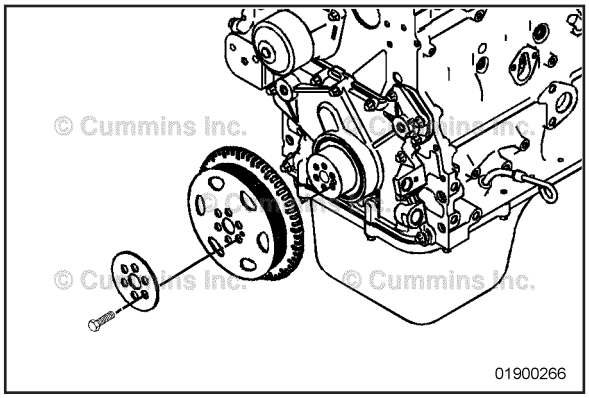
NOTE: Some belt tensioners are mounted to the water inlet connection.



Crankshaft Pulley (001-022)

Remove

Remove the six capscrews that hold the crankshaft pulley to the nose of the crankshaft.



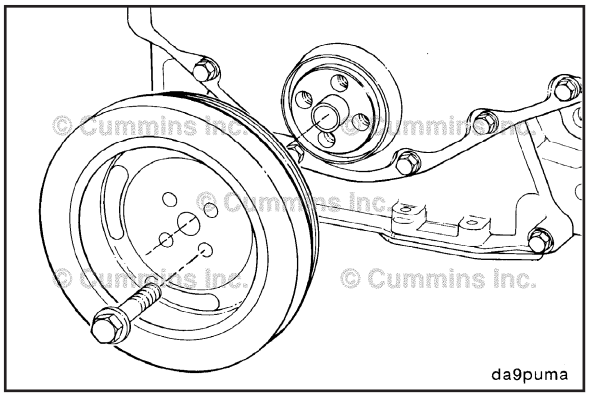
Vibration Damper, Rubber (001-051)

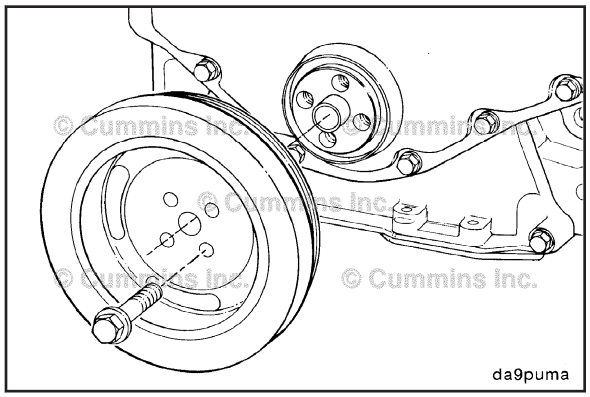
Remove

For front gear train engines, remove the four capscrews.

For rear gear train engines, remove the six capscrews.

Remove the vibration damper.





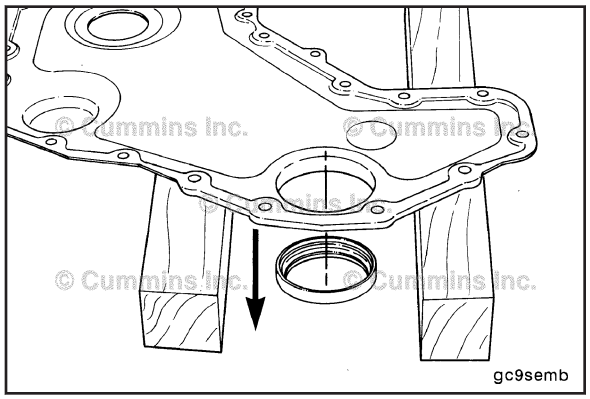
Vibration Damper, Viscous (001-052)

Remove

For front gear train engines, remove the four capscrews.

For rear gear train engines, remove the six capscrews.

Remove the vibration damper.



Crankshaft Seal, Front (001-023)

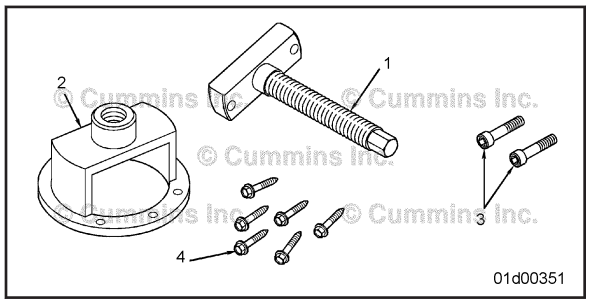
Remove

Front Gear Train

NOTE: For front gear train engines, the front gear cover **must** be removed in order to remove the front cranshaft seal. See the next disassembly step for removing the front gear cover.

Support the front gear cover on a flat work surface with wooden blocks. Using a suitable punch and hammer, drive the old seal out of the front gear cover from the back side of the cover to the front side.

NOTE: Some engines may have an addition dust seal installed in front of the front crankshaft seal.



Rear Gear Train

Use tool, Part Number 3164659, to remove the front crankshaft seal from the front gear cover.

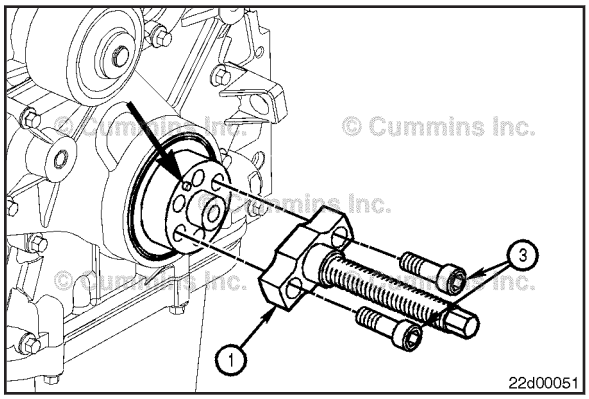
Table 1. Front Crankshaft Seal Replacer Kit, Part Number 3164659

Item Number	Part Number	Description	Quantity
1	3164667	Replace screw assembly	1
2	3164661	Crankshaft seal replacer	1
3	3164239	Socket head capscrew, M12 x 1.25 x 60 mm	2
4	3164217	Sheet metal screw, Number 10 x 25.4 mm [1 in] long	25 (6 shown)
Not shown	3164218	Drill. 3.57 mm [9/64 in]	1

NOTE: The front gear cover does **not** need to be removed to remove and install the crankshaft seal.

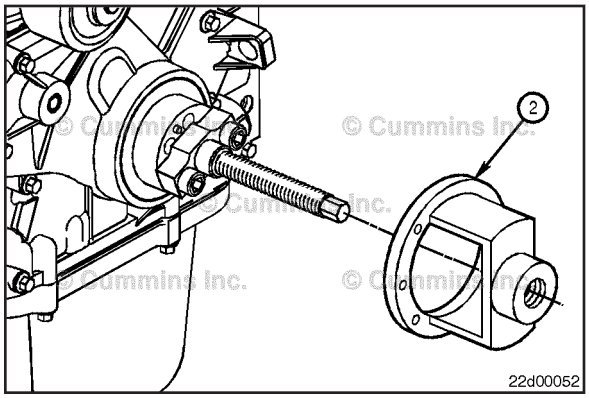
Mount the replacer screw assembly (1) onto the crankshaft nose.

Install the two M12 x 1.25 x 60-mm socket head capscrews (3).



Lubricate the replacer screw with anti-seize or a suitable grease.

Hold the replacer screw and install the crankshaft seal replacer (2) onto the replacer screw assembly. Advance the crankshaft seal replacer toward the seal by rotating it **clockwise** until it is positioned against the front gear cover.



⚠CAUTION⚠
Drill the hole carefully and straight to reduce the possibility of damage to the front cover or the crankshaft.

Service Tip: Because of space restrictions, it may be necessary to use a compact right angle drill. Also, it may be necessary to shorten the drill bit used to drill the sheet metal screw holes.

NOTE: The flange of the crankshaft seal replacer is 8 mm [0.32 in] thick.

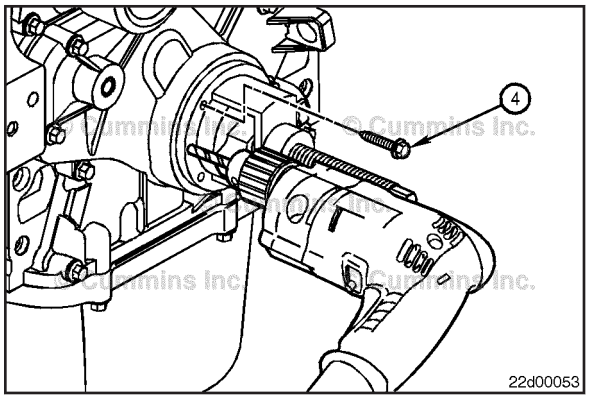
Mark the drill to a depth of 18 mm [0.71 in] with tape for drill depth control and apply grease to the drill to catch the chips. Stop frequently to remove the chips.

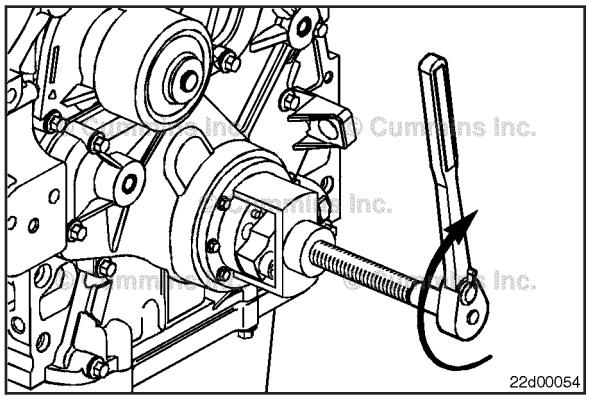
With the crankshaft seal replacer positioned against the front gear cover, drill one hole 10 mm [0.39 in] deep. Make sure the marking tape has **not** moved from the original position.

Install one sheet metal screw (4) into the seal to hold the crankshaft seal replacer in position.

Drill five additional holes 10 mm [0.39 in] deep and install the additional five sheet metal screws.

NOTE: Make sure all six sheet metal screws are threaded through both the inner and outer seal casings. The sheet metal screws need to be uniformly tightened in order to pull out the inner and outer casings of the seal together.





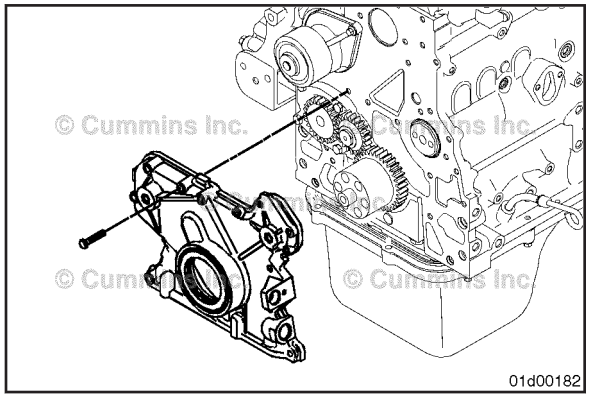
CAUTION
Do not use an impact wrench or air tools. Doing so can damage the tool.

Slowly rotate the replacer screw **clockwise** until the seal is removed. Do **not** exceed torque value.

Torque Value: 33 N•m [45 ft-lb]

NOTE: If the sheet metal screws pull out of the seal or **only** the inner casing pulls out, stop the removal operation. Rotate the replacer screw **counterclockwise** to force the inner casing back. Remove the sheet metal screws, slightly reorient the tool, drill new holes, and install the sheet metal screws in the new locations.

Complete the removal procedure, remove the tool, and discard the old seal.



Gear Cover, Front (001-031)

Remove

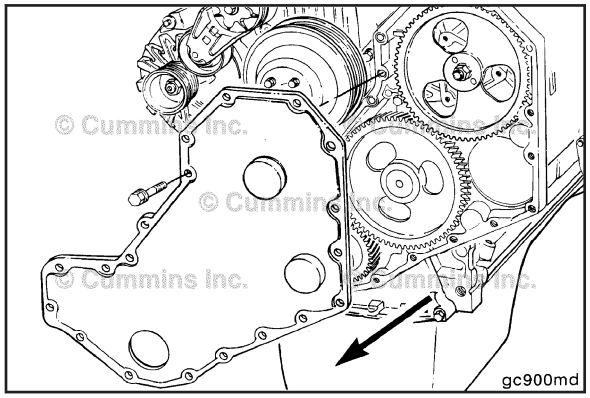
Rear Gear Train

CAUTION
Some rear gear train engines, with a cast aluminum front gear cover, have two threaded holes to aid in the removal of the front gear cover. When looking at the front of the front gear cover, there is a threaded through hole in the lower right-hand corner that can be used with a jackscrew. On the lower left-hand corner, there is a threaded blind hole. A capscrew can be inserted into that blind hole to be used with a slide hammer. Do NOT use the lower left-hand threaded blind hole as a jackscrew or the front gear cover will be damaged.

Remove the front gear cover mounting capscrews.

CAUTION
To break the seal, pry the front gear cover away from the front gear housing . Be careful NOT to damage the front gear cover when breaking the seal to the front gear housing.

Remove the front gear cover.



Front Gear Train

CAUTION
To break the seal, pry the front gear cover away from the front gear housing . Be careful NOT to damage the front gear cover when breaking the seal to the front gear housing.

Remove the front gear cover mounting capscrews.

Remove the front gear cover with the front crankshaft seal.

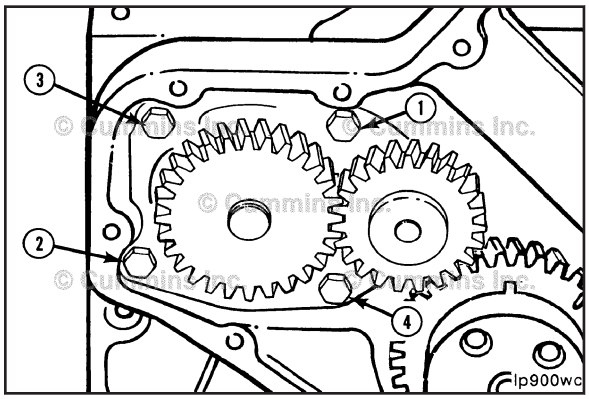
NOTE: Some engines have an additional dust shield installed in front of the front crankshaft seal.

Lubricating Oil Pump (007-031)

Remove

Remove the four mounting capscrews (1, 2, 3, and 4).

Remove the lubricating oil pump from the bore in the cylinder block.



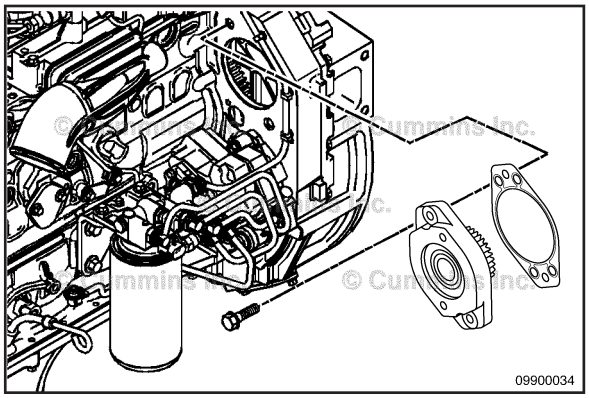
Accessory Drive (009-001)

Remove

Remove the two capscrews securing the accessory drive to the rear gear housing.

Remove the accessory drive and gasket.

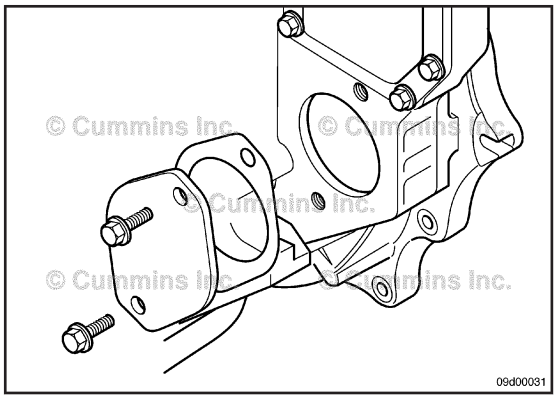
NOTE: For front gear train engines it may be necessary to remove the external oil supply tube.



Accessory Drive Cover (009-039)

Remove

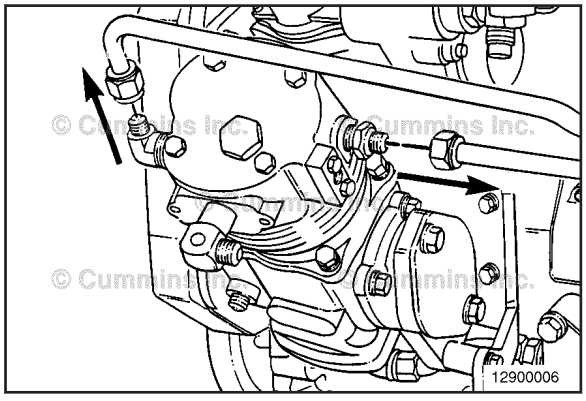
Remove the accessory drive cover, mounting capscrews and gasket.

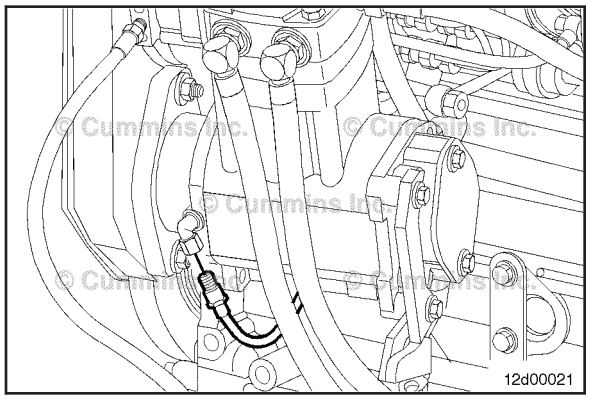


Air Compressor Coolant Lines (012-004)

Remove

Remove the coolant lines from the air compressor (does **not** apply to air cooled compressors).

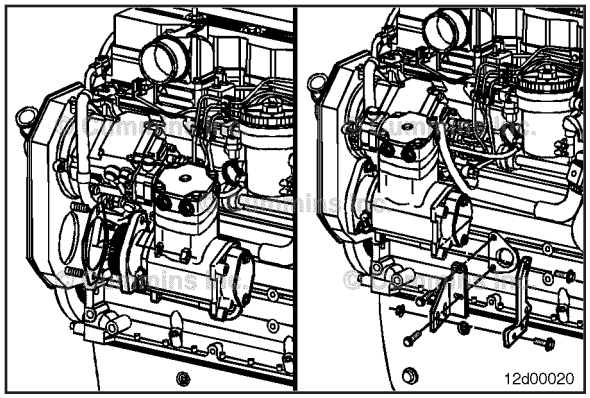




Air Compressor (012-014)

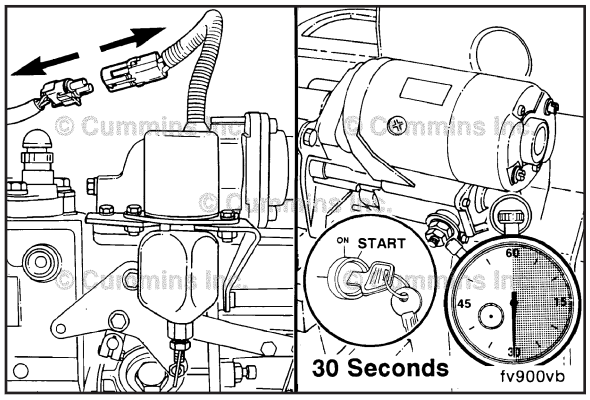
Remove

Remove the oil supply line.



Remove the air compressor support bracket and capscrews.

Remove the air compressor mounting capscrews and the air compressor.

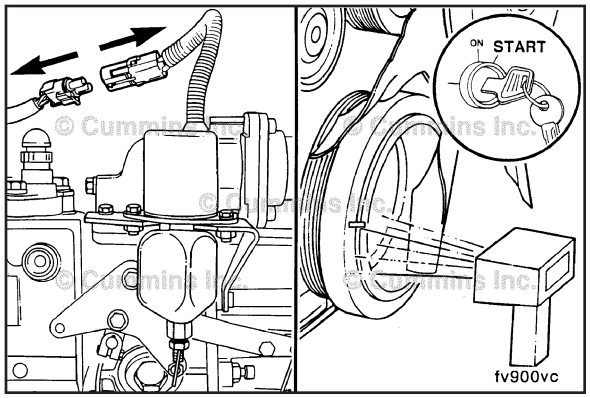


Fuel Lift Pump (005-045)

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.



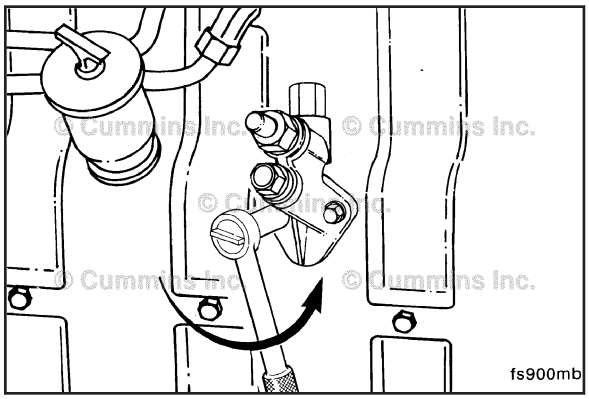
Disconnect the fuel shutdown solenoid wire.

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.



Fuel Pump Support Bracket (005-033)

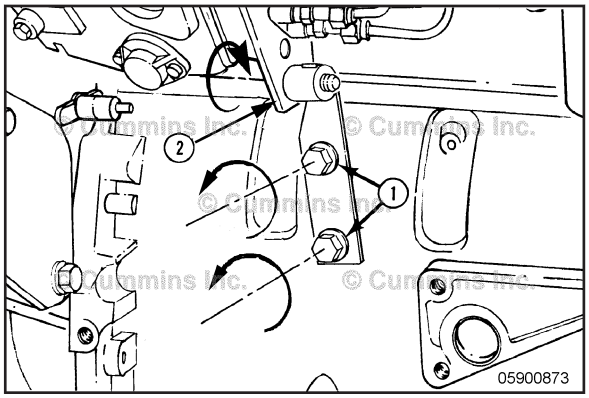
Remove

Front Gear Train

Bosch® and Stanadyne Rotary Pumps

10 mm

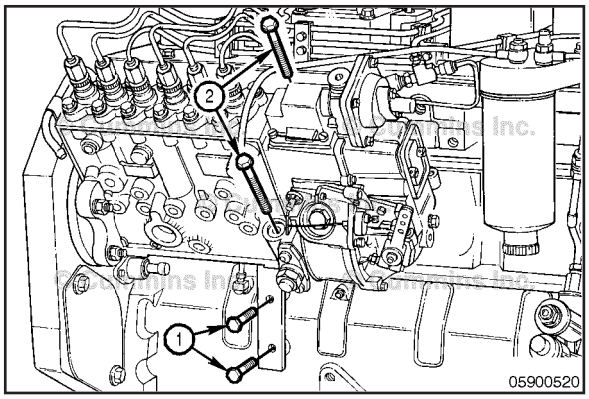
Remove the capscrew that is connected to the pump and the tail support bracket (2) first; then remove the capscrews from the bracket (1) and block.



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.

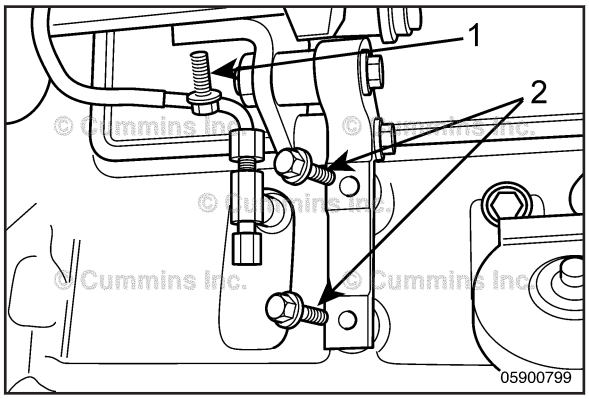


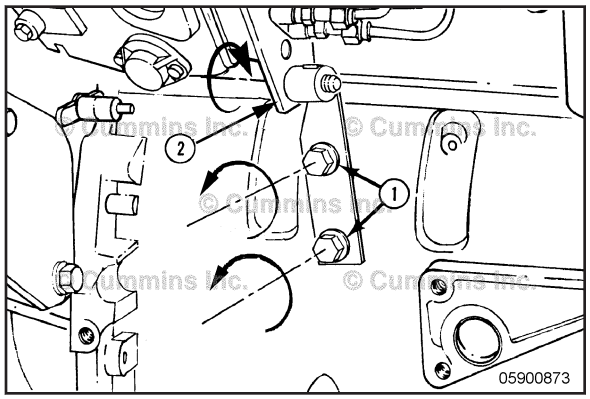
Four-Cylinder

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.

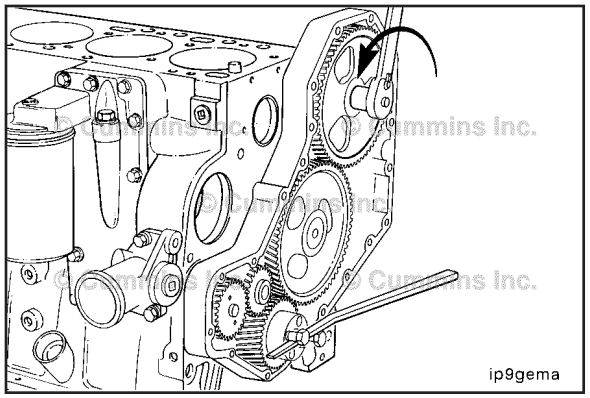




Rear Gear Train

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.



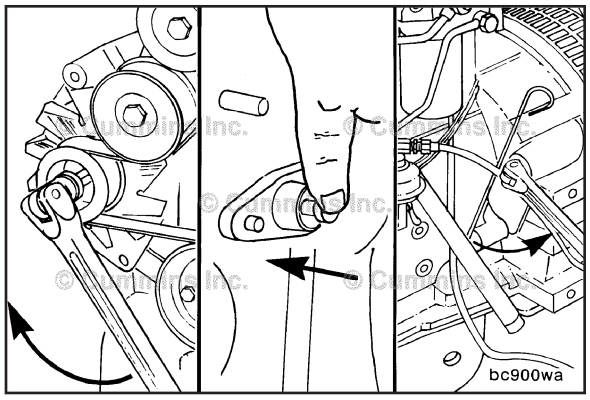
Fuel Injection Pump, Rotary (005-014)

Remove

Front Gear Train

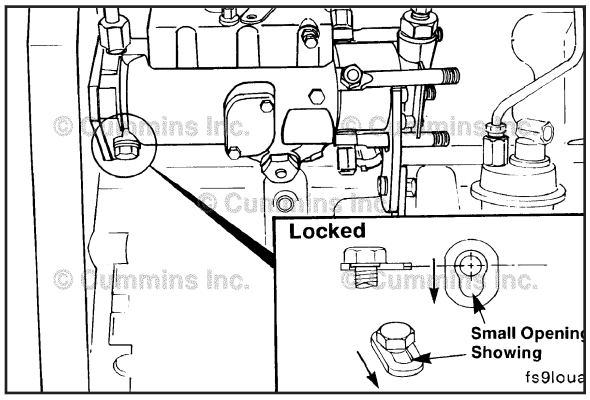
Remove the nut and washer from the fuel injection pump shaft.

NOTE: If necessary, insert two capscrews 180 degrees apart in the damper mounting locations in the nose of the crankshaft. Use an appropriate pry bar between the two capscrews to prevent the engine from turning when loosening the fuel pump gear mounting nut.



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

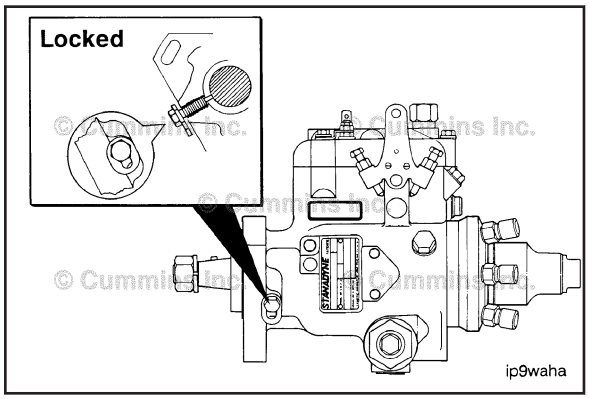
Loosen the CAV fuel injection pump lock screw and position the special washer; then tighten the lock screw against the pump drive shaft.

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]

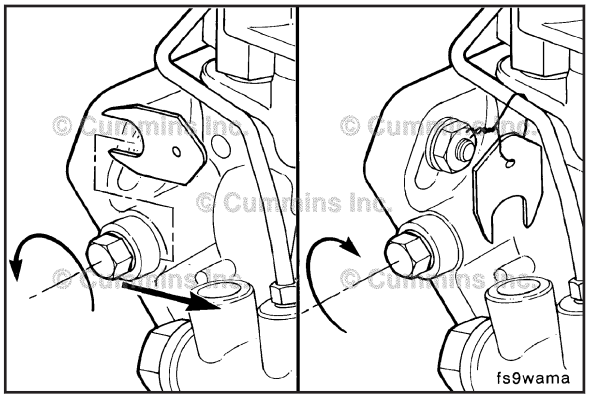


Bosch® VE

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

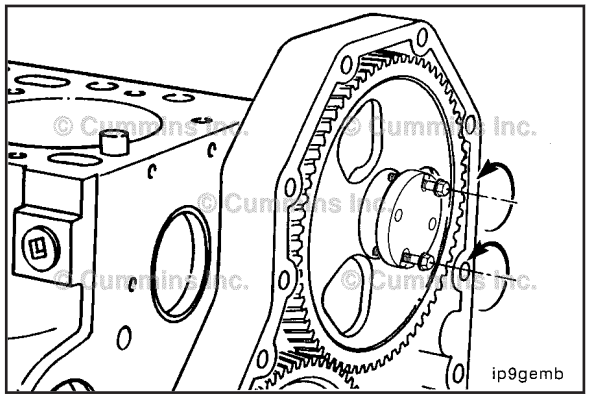
Torque Value: 30 N•m [22 ft-lb]

NOTE: Wire the washer to the pump.



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

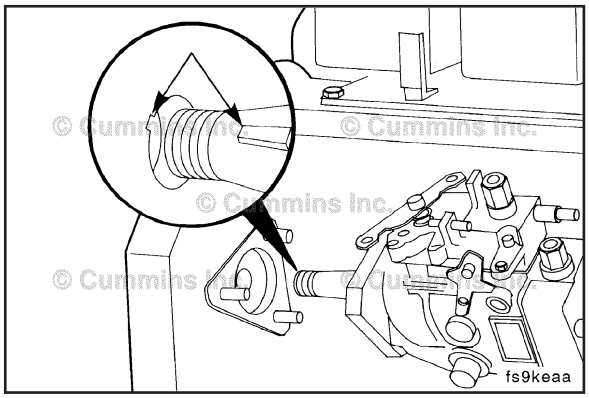
Use fuel pump gear puller, Part Number 3163381 or Part Number 3824469 with M8-1.25 x 50 capscrews, Grade 8.8 or equivalent.

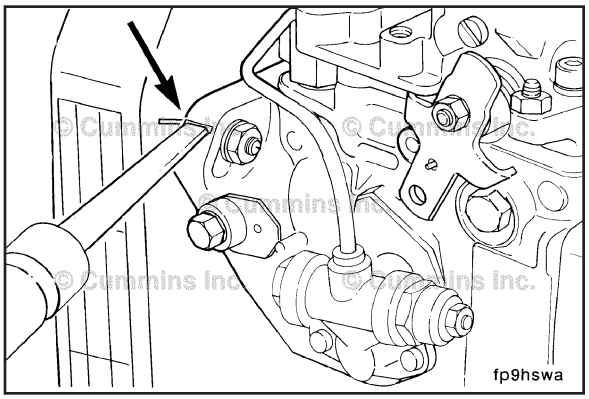


⚠CAUTION⚠
Do not drop drive gear key when removing the pump. Failure to do so can result in severe engine damage.

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

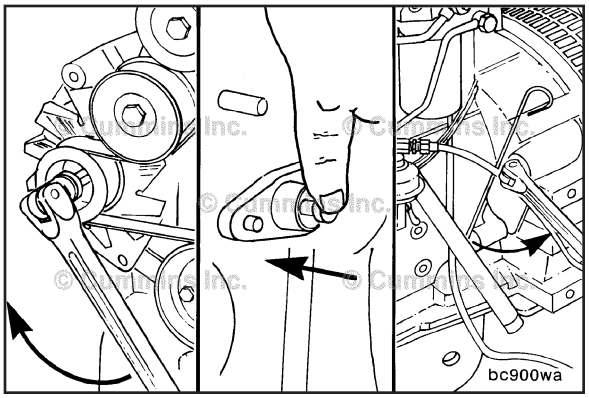
NOTE: Fuel pumps on engines designed to meet Tier 2/ Stage II Industrial emissions levels have straight holes (**not** kidney slots) and do **not** use a timing key.



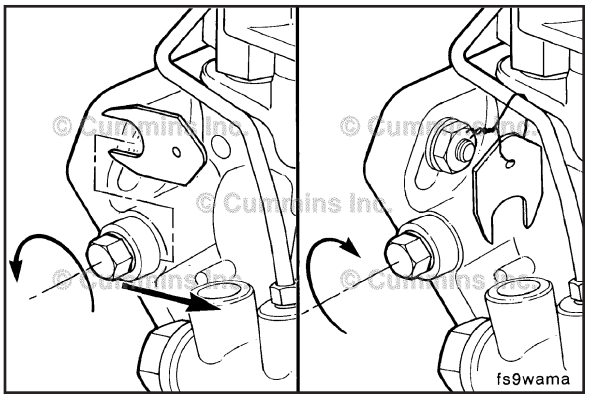


Rear Gear Train

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.

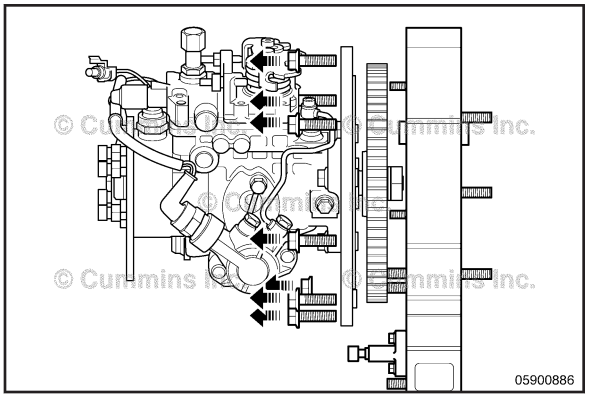
Bosch® VE

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.

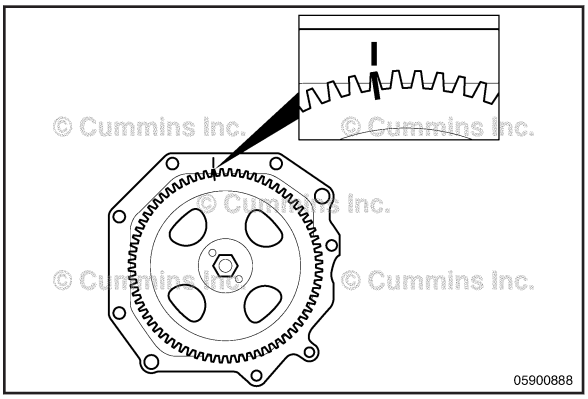


Remove the mounting nuts and bolts affixing the fuel pump mounting plate to the rear gear housing.

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.

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

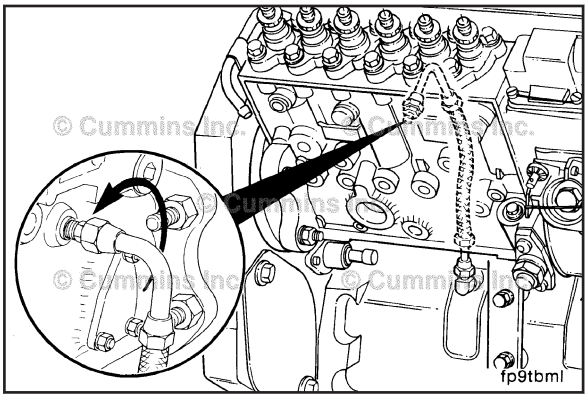


Fuel Injection Pumps, In-Line (005-012)

Remove

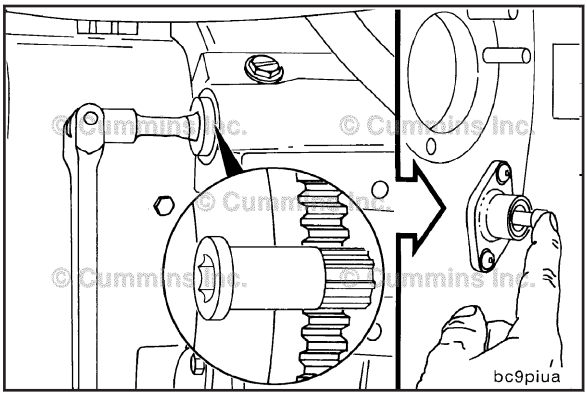
Disconnect the external oil feed line at the inboard side of the fuel injection pump (if applicable) and the main oil rifle.

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

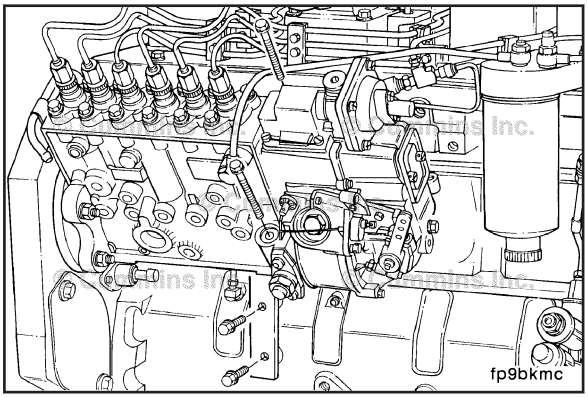


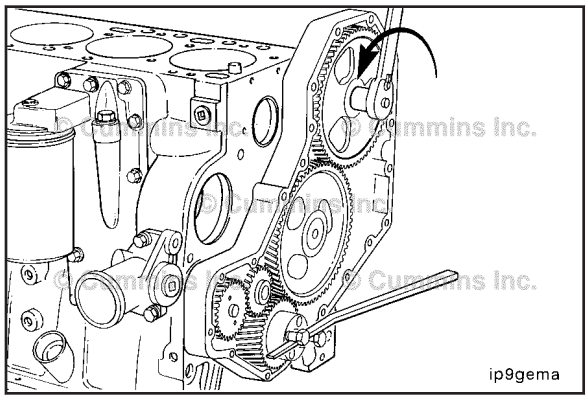
Locate top dead center for cylinder Number 1. Push the top dead center pin into the hole in the camshaft gear while slowly barring the engine.

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



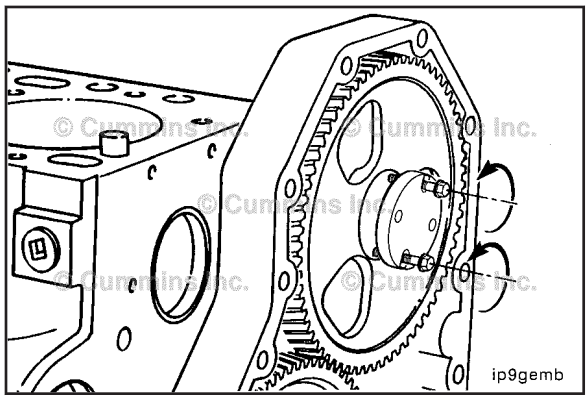
Remove the fuel injection pump mounting bracket, if applicable.





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

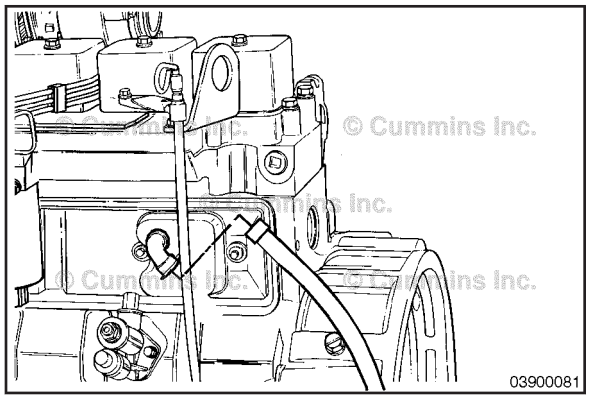
NOTE: If necessary, insert two capscrews 180 degrees apart in the damper mounting locations in the nose of the crankshaft. Use an appropriate pry bar between the two capscrews to prevent the engine from turning when loosening the fuel pump gear mounting nut.



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 fuel injection pump drive gear.

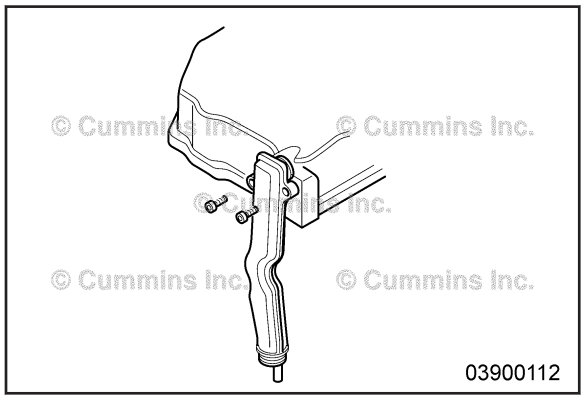


Crankcase Breather Tube (003-018)

Remove

Front Gear Train

Remove the crankcase breather tube from the tappet cover located on side of the engine block.



Rear Gear Train

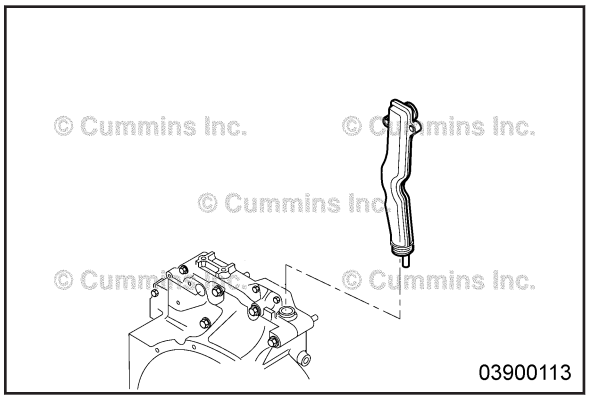
Disconnect the breather tube at the back of the rocker lever cover.

Two capscrews directly mount the breather tube to the rocker lever cover. Remove the capscrews to disconnect the breather tube from the rocker lever cover.

NOTE: Some breather tubes use internal Torx capscrews to secure the breather tube to the rocker lever cover.

Remove the breather tube from the rear gear housing.

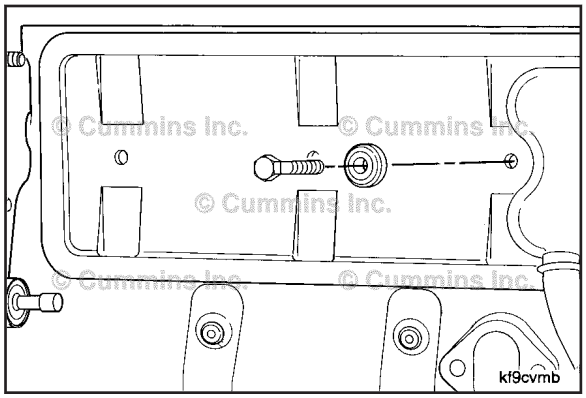
NOTE: There is an o-ring sealed connection to the rear gear housing. Remove the breather tube by pulling straight up.



Tappet Cover (004-017)

Remove

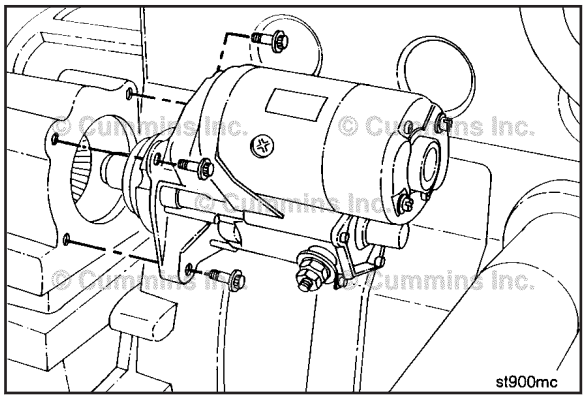
Remove the tappet cover, mounting capscrews, sealing washers, and gasket.



Remove

Remove the three capscrews and the starting motor.

NOTE: If equipped with a starting motor spacer, remove the spacer and clean all surfaces between the starting motor, starting motor spacer, and flywheel housing with a wire brush.

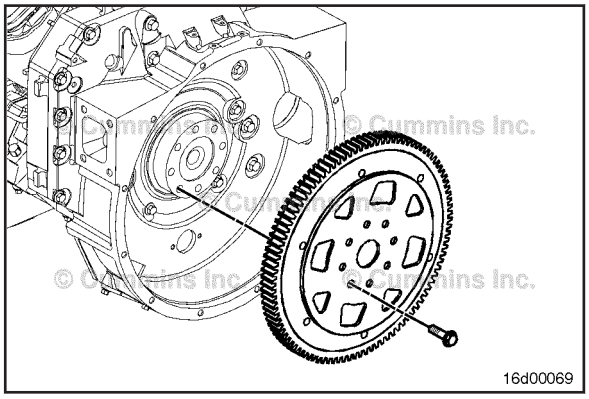


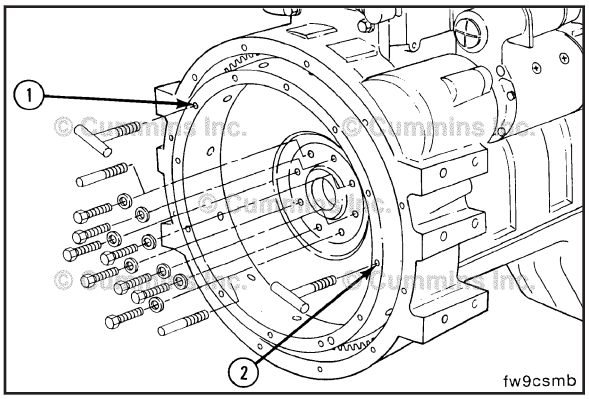
Flexplate (016-004)

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.





Flywheel (016-005)

Remove

NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

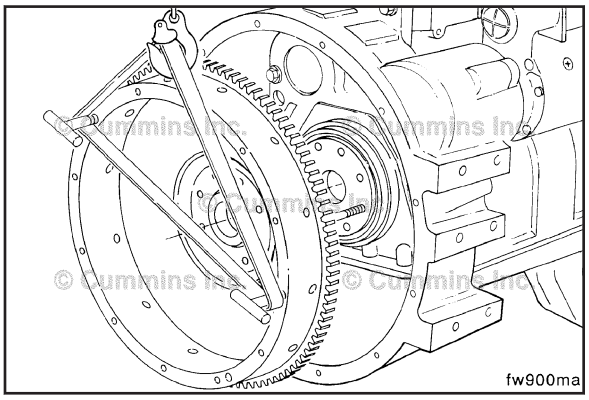
Remove two capscrews 180 degrees apart.

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.

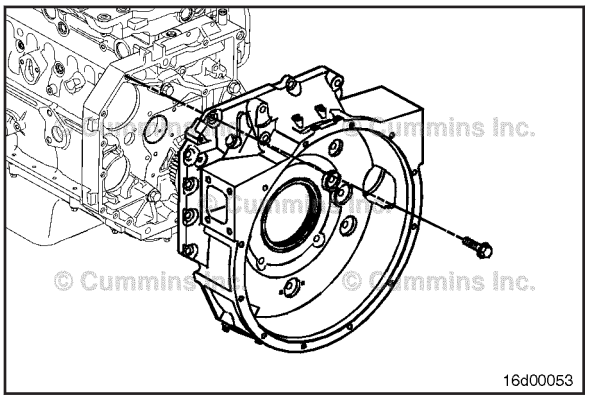
Determine the capscrew thread design and size, and install two T-handles in the flywheel at points (1 and 2).

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.



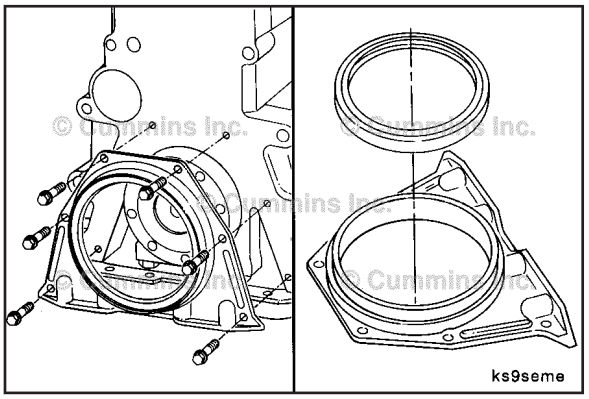
Crankshaft Seal, Rear (001-024)

Remove

Rear Gear Train

The rear crankshaft seal will be removed with the removal of the flywheel housing.

When the flywheel housing is removed, support the flywheel housing on a flat work surface with wooden blocks. Using a suitable punch and hammer, drive the old seal out of the flywheel housing.



Front Gear Train

The rear crankshaft seal will be removed with the removal of the rear crankshaft seal carrier.

With the rear crankshaft seal carrier removed, support the rear crankshaft seal carrier on a flat work surface with wooden blocks. Using a suitable punch and hammer, drive the old seal out of the rear crankshaft seal carrier.

Flywheel Housing (016-006)

Remove

Rear Gear Train

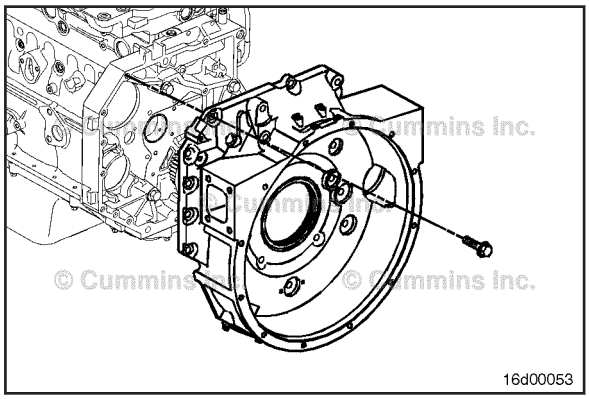
⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

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.

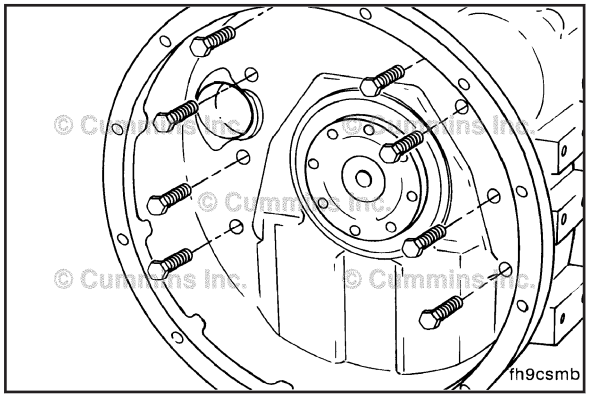
Note the location of the flywheel housing capscrews as removed. Some of the capscrews are different length/size fasteners and **must** be installed in the same location as removed.



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.

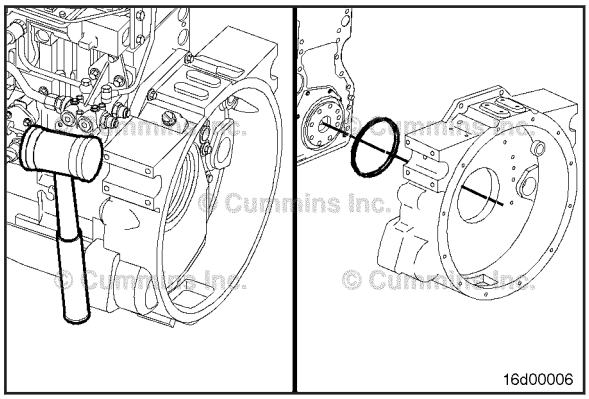


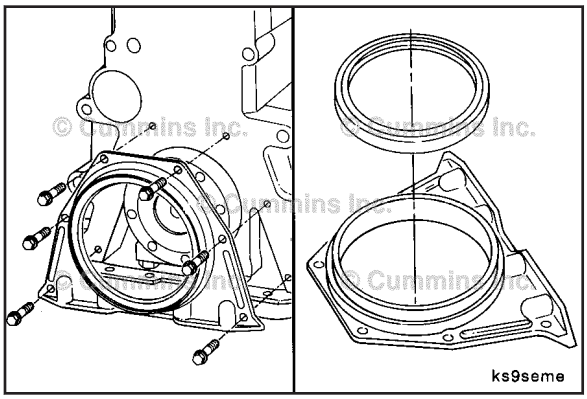
While supporting the flywheel housing, use a rubber hammer to loosen the flywheel housing.

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.



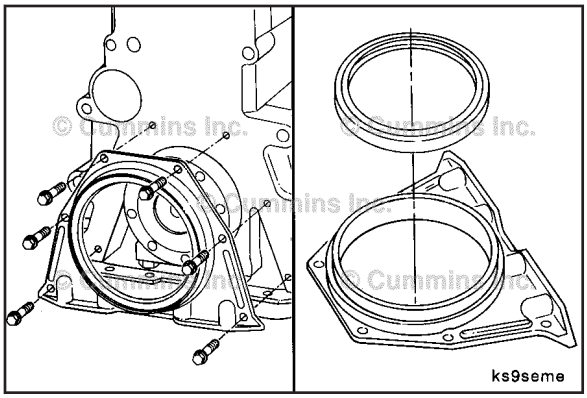


Crankshaft Seal Carrier, Rear (001-104)

General Information

NOTE: This procedure is for front gear train engines only.

For front gear train engines, a rear crankshaft seal carrier is mounted to the rear of the cylinder block to house the rear crankshaft seal. For rear gear train engines, the rear crankshaft seal is installed in the flywheel housing.

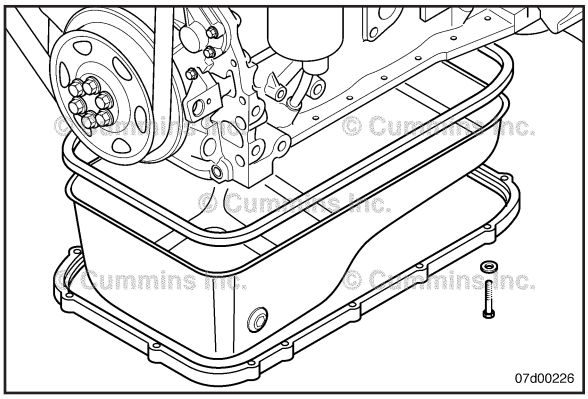


Remove

Remove the capscrews from the rear cover.

Remove the cover from the crankshaft flange.

Support the rear seal carrier on a flat work surface with wooden blocks. Use a suitable punch and hammer to drive the old seal out of the rear seal carrier.



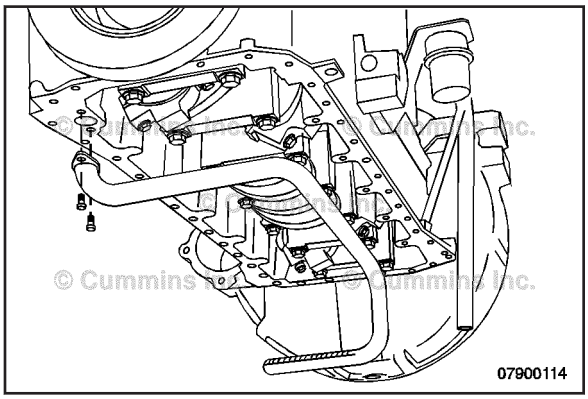
Lubricating Oil Pan (007-025)

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.

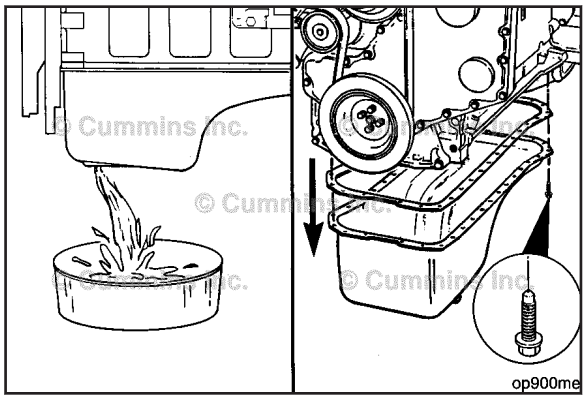
Remove the oil pan mounting capscrews, oil pan, mounting flange, and flexible gasket.



Remove the suction tube, if necessary. Refer to Procedure 007-035 in Section 7.

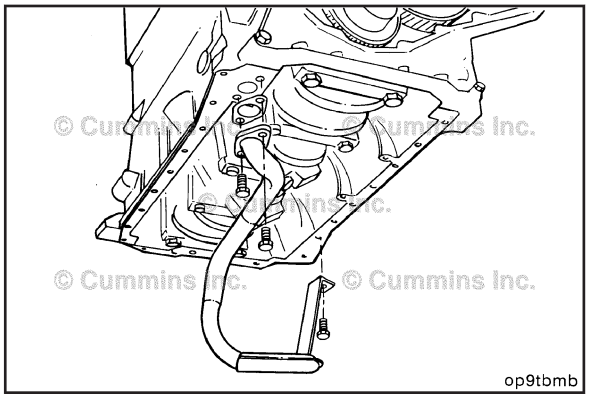
Front Gear Train

Remove the lubricating oil pan and gasket.



Remove the lubricating oil suction tube, if necessary. Refer to Procedure 007-035 in Section 7.

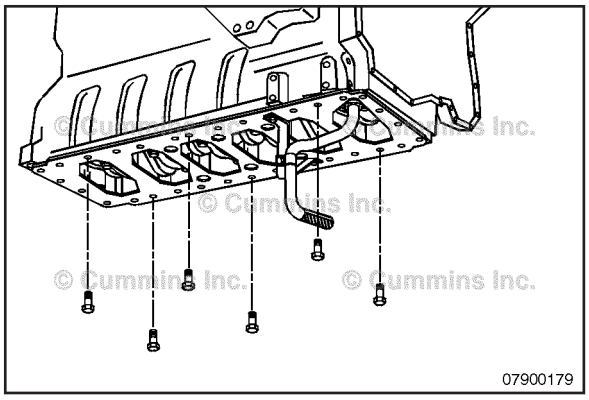
NOTE: For front gear train engines, the suction tube **must** be removed in order to remove the bedplate.



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.

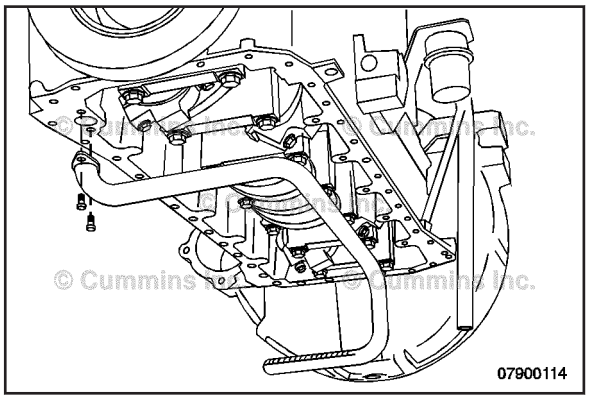


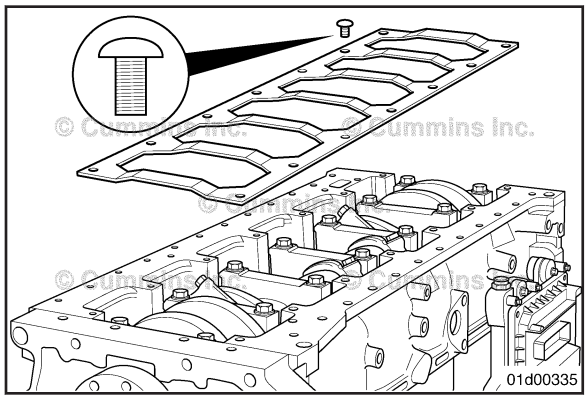
Lubricating Oil Suction Tube (Block-Mounted) (007-035)

Remove

Remove the suction tube mounting capscrews.

Remove the suction tube.



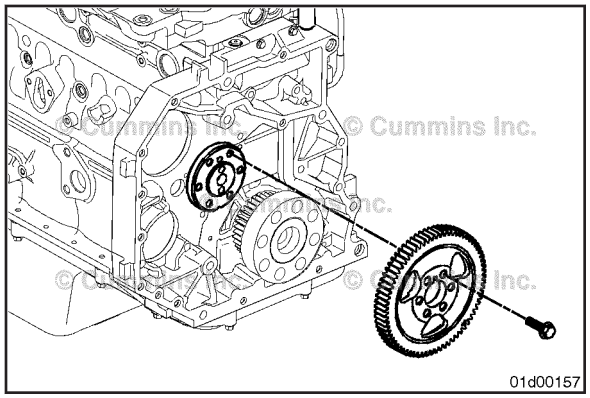


Block Stiffener Plate (001-089)

Remove

NOTE: For some oil pan/oil suction tube configurations, the block stiffener plate capscrew closest to the lubricating oil suction tube may be different than the rest. If equipped, note the capscrews location for installation. The low profile capscrew ensures in some applications that there is sufficient clearance between the oil suction tube and the block stiffener mounting capscrew.

Remove the capscrews and block stiffener plate.



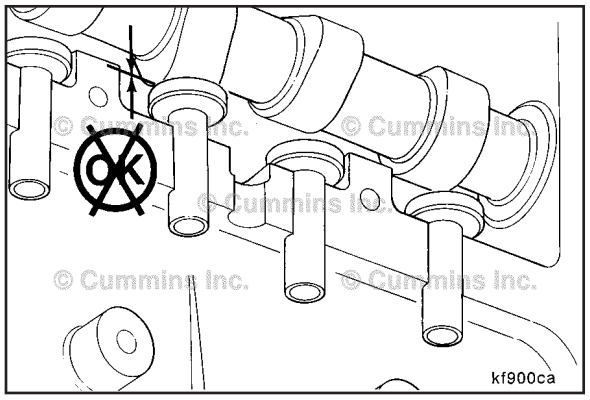
Camshaft Gear (Camshaft Installed) (001-012)

Remove

Remove the camshaft gear capscrews.

Remove the camshaft gear.

NOTE: For Front Gear Train Engines, the camshaft gear will be removed with the camshaft.



Camshaft (001-008)

Remove

Rear Gear Train

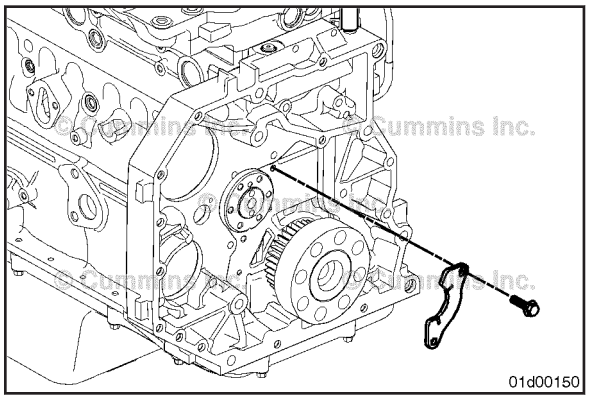
Before the camshaft can be removed, the tappets **must** be lifted off the camshaft lobes.

With the engine removed and on an engine stand, rotate the engine so that the oil pan side of the engine is up if the engine is **not** already in this position. This will allow the tappets to fall off the camshaft lobes prior to the camshaft being removed.

NOTE: Inspect the tappets to make sure they are no longer in contact with the camshaft lobes prior to removing the camshaft.

NOTE: The following illustrations will show the engine in the upright position for clarity.

Remove the thrust plate capscrews and remove the thrust plate.

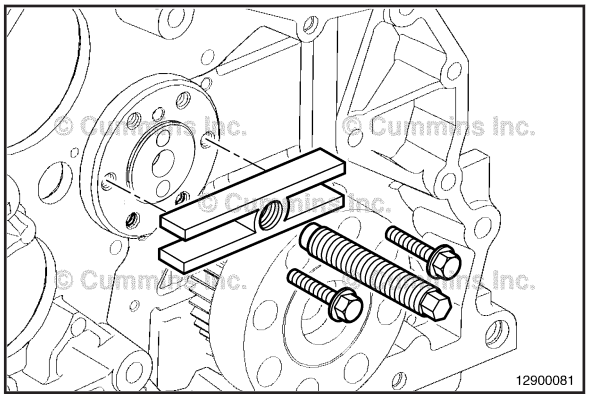


⚠CAUTION⚠

The camshaft will drop once the camshaft clears the last bushing if not supported. This can cause damage to the camshaft journal or, if equipped, the camshaft speed indicator ring.

Use a gear puller, service tool part number ST647 or equivalent, to attach to the end of the camshaft where the camshaft gear mounts, to act as a handle. This will give proper leverage and make it easier to remove the camshaft.

Slide the camshaft out of the bore using the installed gear puller.



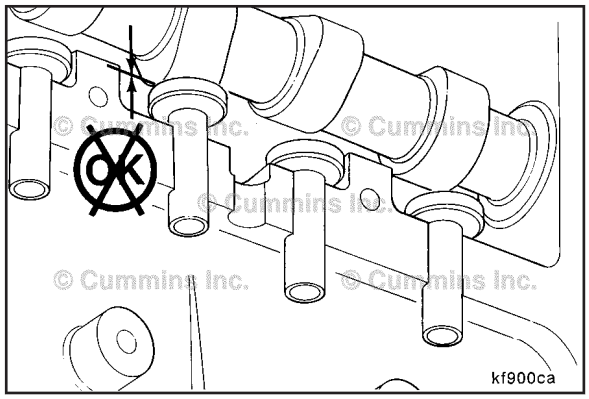
Front Gear Train

Before the camshaft can be removed the tappets **must** be lifted off the camshaft lobes.

With the engine removed and on an engine stand, rotate the engine so that the oil pan side of the engine is up if the engine is **not** already in this position. This will allow the tappets fall off the camshaft lobes prior to the camshaft being removed.

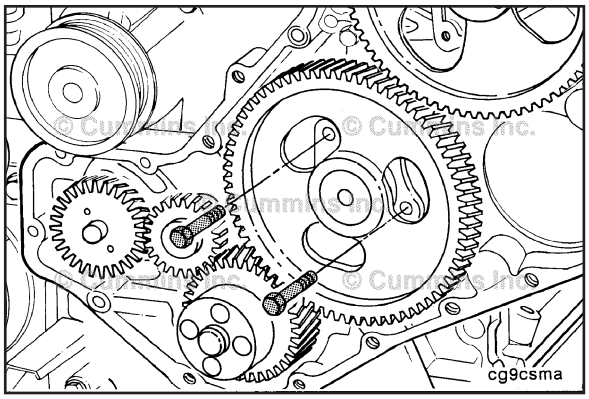
NOTE: Inspect the tappets to make sure they are no longer in contact with the camshaft lobes prior to removing the camshaft.

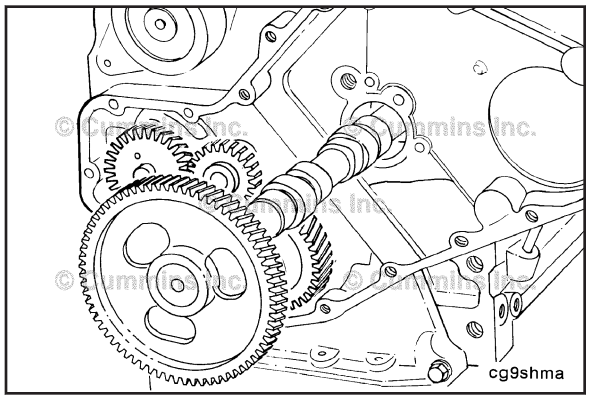
NOTE: The following illustrations will show the engine in the upright position for clarity.



Remove the capscrews from the thrust plate.

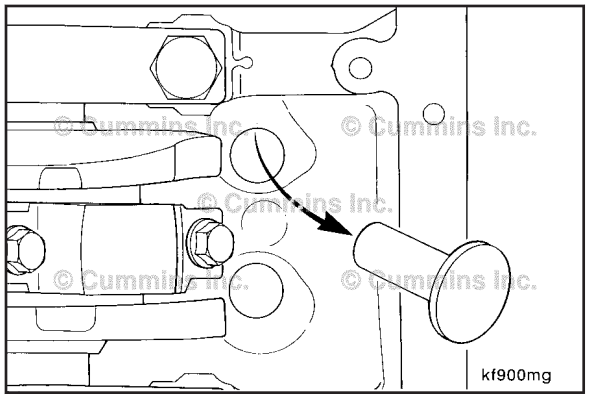
Remove the thrust plate.





Remove the camshaft and camshaft gear as an assembly.

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

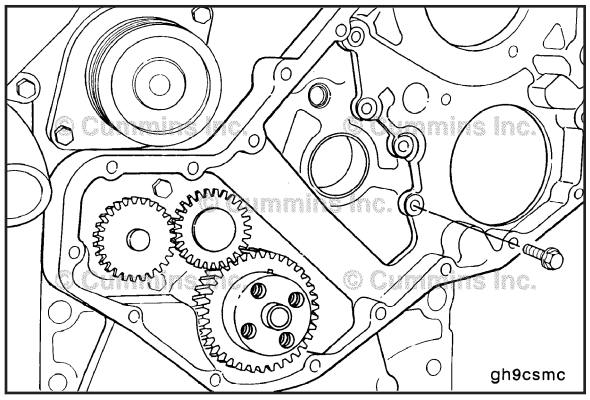


Tappet (004-015)

Remove

With the camshaft removed, remove the tappets through the bottom of the engine.

Mark the position of the tappets as they are removed. If reused, the tappets **must** be installed in the same position when the engine is assembled.

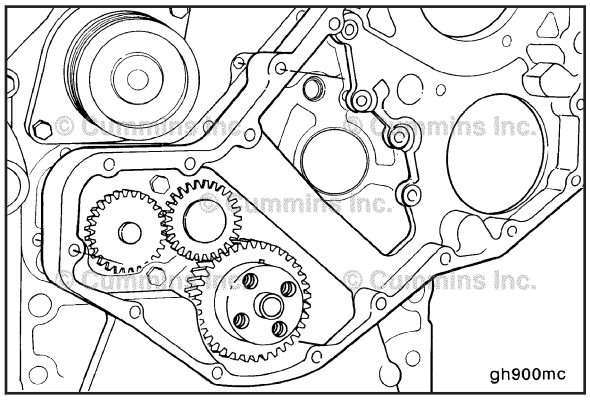


Gear Housing, Front (001-033)

Remove

Remove the gear housing capscrews.

Note the location of the gear housing capscrews as they are removed. Some of the capscrews are an internal torx fastener and **must** be installed in the same location as removed to ensure proper clearance.



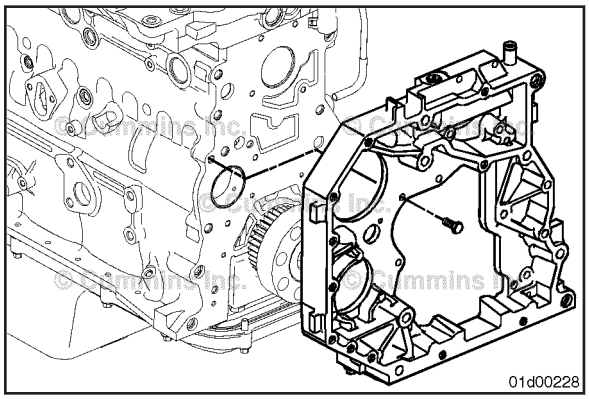
Use a plastic hammer to loosen the front gear housing.

Remove the gear housing.

Gear Housing, Rear (001-034)

Remove

Remove the rear gear housing capscrews and housing.



Piston Cooling Nozzle (001-046)

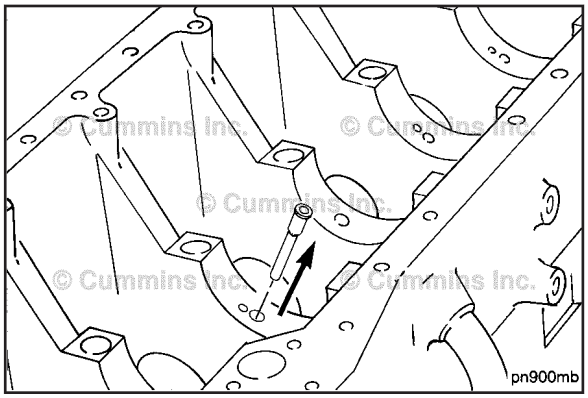
Remove

Saddle Jet Piston Cooling Nozzle

NOTE: The crankshaft **must** be removed before the saddle jet piston cooling nozzles can be removed.

Remove the piston cooling nozzles by pressing from the top with an appropriate size punch.

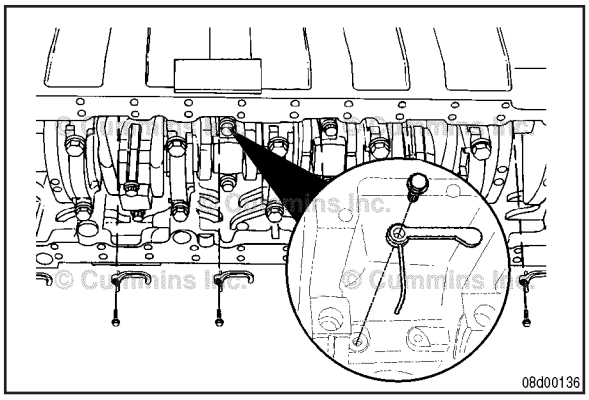
NOTE: Do **not** reuse the saddle jet piston cooling nozzles once removed.



J-Jet Piston Cooling Nozzle

Rotate the crankshaft to various positions to access each piston cooling nozzle.

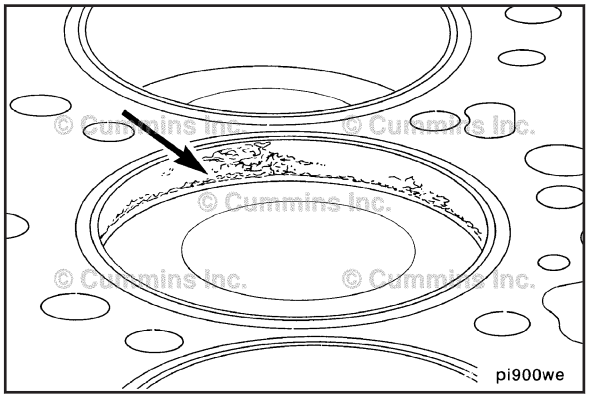
Remove the piston cooling nozzles.

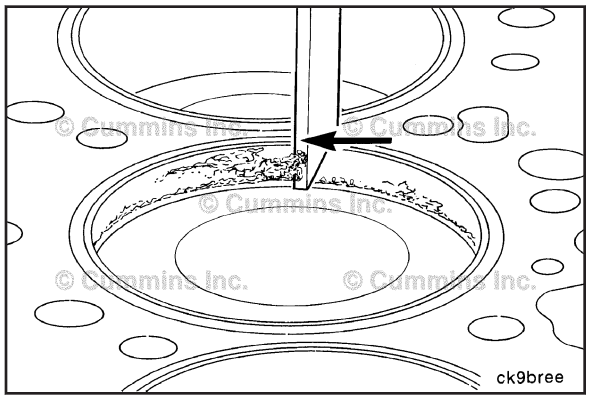


Piston and Connecting Rod Assembly (001-054)

Remove

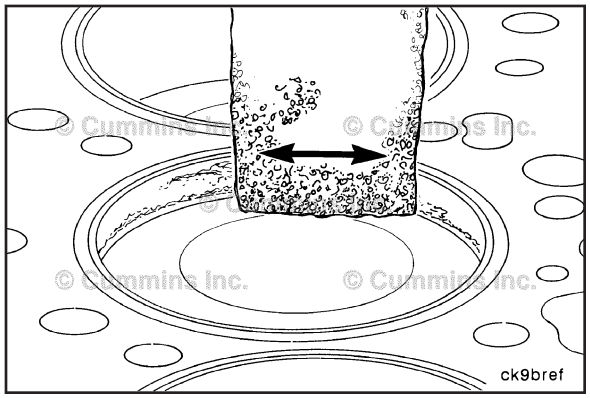
Rotate the crankshaft with engine barring tool, Part Number 3824591, until the pistons are below the carbon deposits, which are found above the ring travel area.



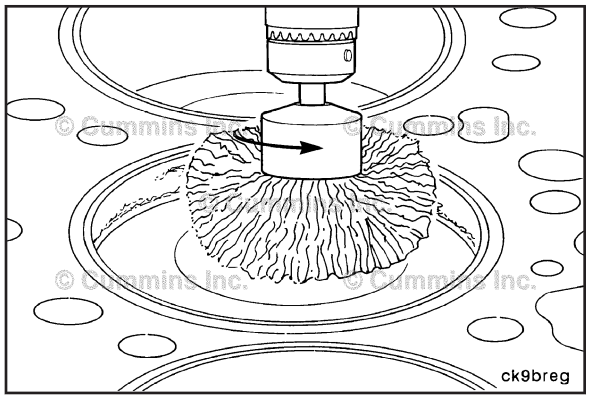


CAUTION
Do not use emery cloth or sandpaper to remove carbon from the cylinder bores. Aluminum oxide or silicon particles from these materials can cause serious engine damage.

Use a scraper or a blunt-edged instrument to loosen the carbon deposits. Do **not** damage the cylinder with the scraper.



Remove the remaining carbon with a Scotch-Brite™ cleaning pad, or equivalent.

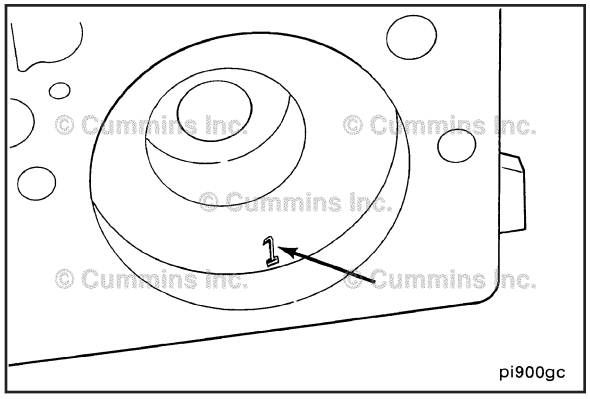


WARNING
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury

CAUTION
Do not use the steel wire wheel in the piston travel area. Operate the wheel in a circular motion to remove the deposits.

NOTE: An inferior quality wire wheel will lose steel bristles during operation, thus causing additional contamination.

An alternative method to remove the carbon ridge is to use a high-quality steel wire wheel installed in a drill or die grinder.

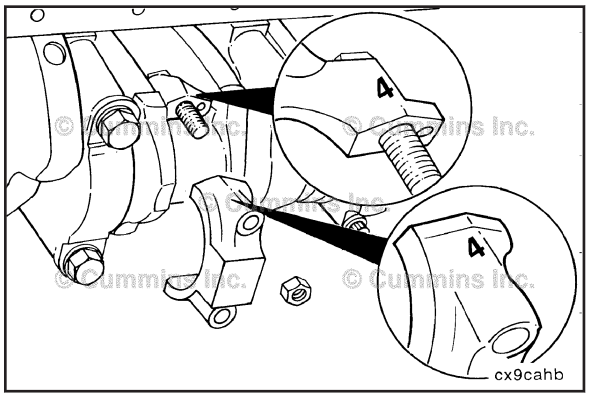


On pistons with anodized coatings, do **not** stamp the anodized coating on the outer rim.

Mark each piston according to the cylinder.

Rotate the crankshaft to position the connecting rod caps at bottom dead center for removal.

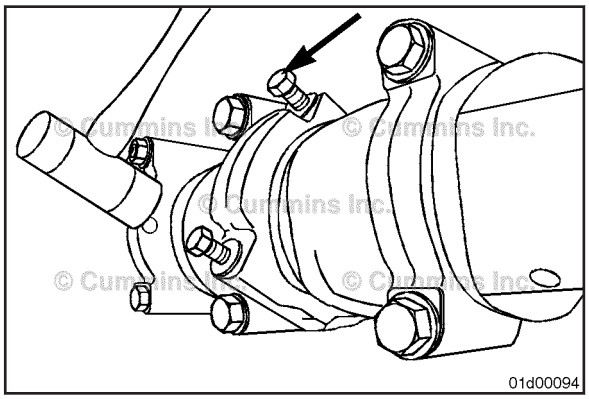
Mark each connecting rod and connecting rod cap according to the cylinder number location.



Loosen the connecting rod capscrews.

NOTE: Do **not** remove the capscrews from the connecting rods at this time.

Use a rubber hammer to hit the connecting rod capscrews to loosen the caps.

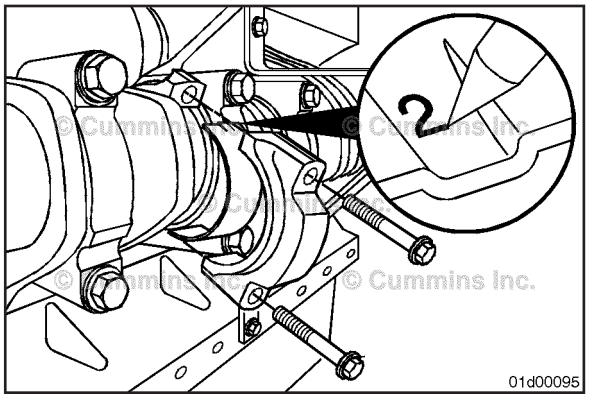


⚠CAUTION⚠
Do not damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod caps are removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage. Incorrect assembly can damage the rod.

⚠CAUTION⚠
When setting the connecting rod cap down do not set the cap down on the fractured split surface. Damage to the fractured split surface can result.

Remove the connecting rod capscrews.

Remove the connecting rod cap.

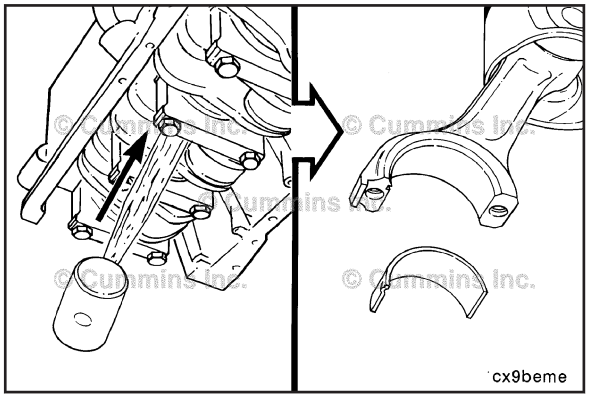


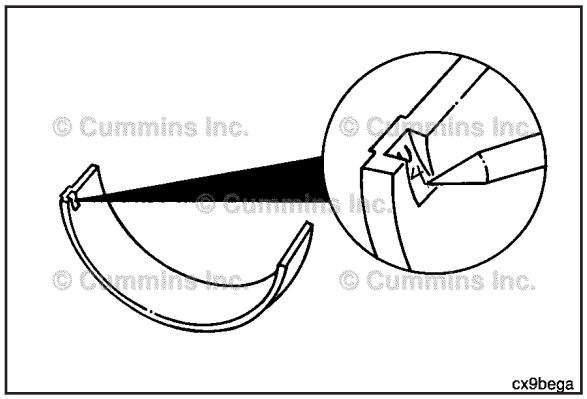
Remove the lower connecting rod bearing.

Mark the cylinder number and the letter “L” (lower) on the flat surface of the bearing tang.

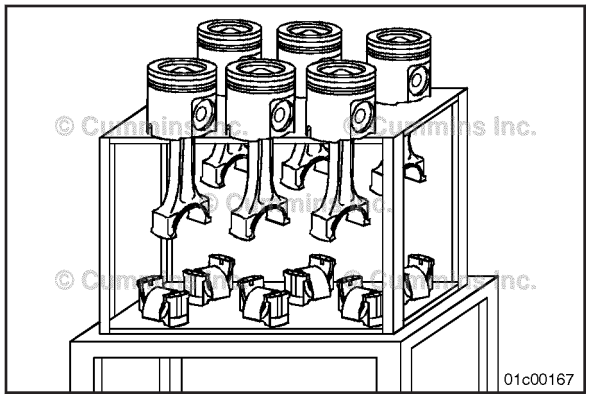
Push the connecting rod and piston assembly out of the cylinder bore. Care **must** be taken **not** to damage the connecting rod or bearing.

Remove the upper rod bearing.





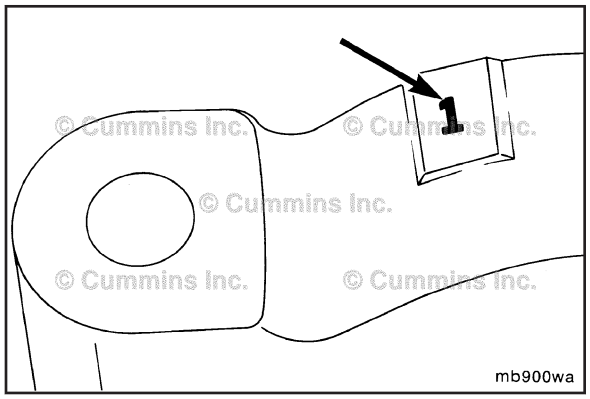
Mark the cylinder number and the letter “U” (upper) on the flat surface of the bearing tang.



The piston and connecting rod assemblies **must** be installed in the same cylinder number from which they were removed, to provide proper fit of worn mating surfaces, if parts are reused.

Use a tag to mark the cylinder number from which each piston and rod assembly were removed.

Place the rod and piston assemblies in a container to protect them from damage.

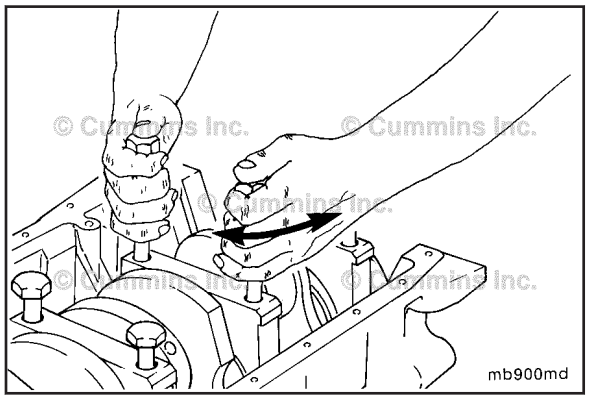


Crankshaft (001-016)

Remove

Before removing the main bearing caps, make certain that the caps are clearly marked for their location on the lubricating oil cooler side of the main bearing cap and cylinder block.

The number one cap is at the front of the engine.



Loosen the main bearing capscrews completely, but do **not** remove.

△CAUTION△
Do not pry on the main bearing caps to free them from the cylinder block. Damage to the main bearing caps and cylinder block can result.

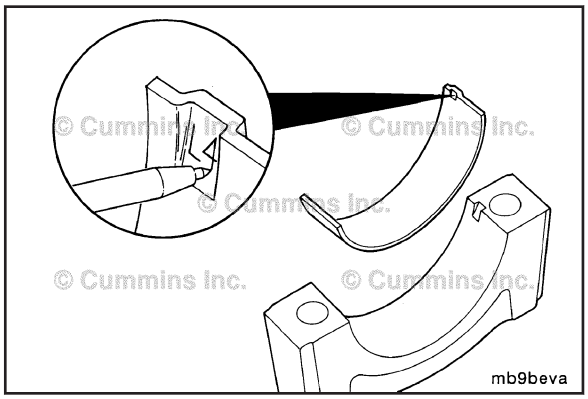
Use two of the main bearing cap bolts to “wiggle” the main bearing cap loose, being careful **not** to damage the bolt threads.

Remove the main bearing cap.

Mark the lower main bearings for position and number as they are removed.

Use an awl to mark the bearing position in the tang area.

NOTE: Mark the bearing's position for future identification or possible failure analysis.



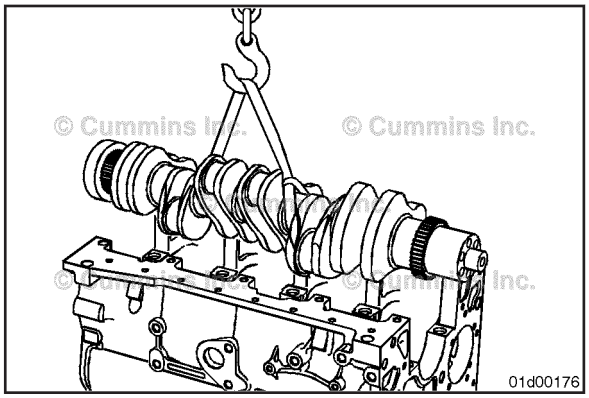
⚠WARNING⚠

This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

NOTE: Lift the crankshaft straight up to reduce the possibility of damage to the crankshaft and cylinder block.

Install nylon lift sling, Part Number 3375957, around Number 3 and Number 4 rod bearing journals.

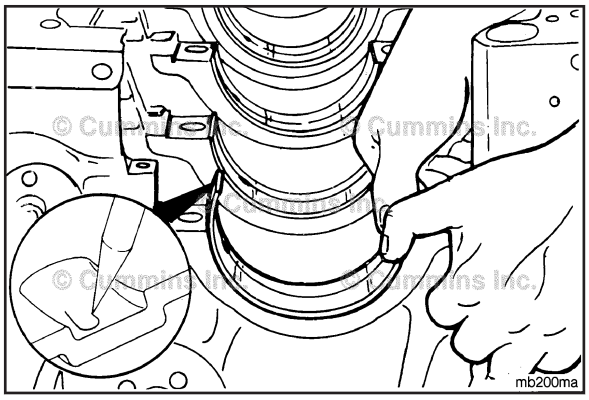
Attach the sling to a hoist and remove the crankshaft.



Remove the upper main bearings.

Use an awl to mark the bearing's position in the tang area.

NOTE: Mark the bearing's position for future identification or possible failure analysis.



Notes

Section AS - Engine Assembly - Group 00

Section Contents

Piston Cooling Nozzle (001-046)

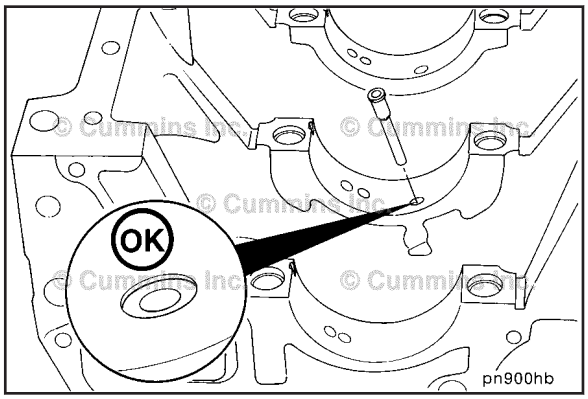
Install

Saddle Jet Piston Cooling Nozzle

⚠CAUTION⚠
Do not use a hammer to install the piston cooling nozzles. Use hand pressure only. Using a hammer can cause component damage.

Push the piston cooling nozzle into place by hand.

Use a flat punch to push the nozzle into the recess.



J-Jet Piston Cooling Nozzle

NOTE: The crankshaft **must** be installed before the J-jet piston cooling nozzle can be installed.

⚠CAUTION⚠
Slight bending of the piston cooling nozzles can result in severe engine damage. Replace piston cooling nozzle if it is bent or damaged during disassembly or assembly.

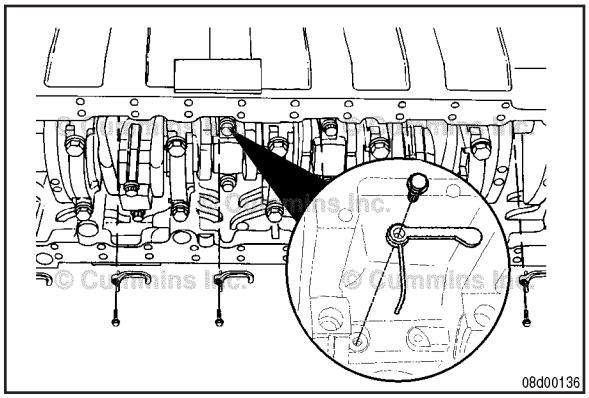
Install the piston cooling nozzle one cylinder at a time rotating the crankshaft as necessary for access.

Use a long extension to guide the capscrew and/or piston cooling nozzle into place.

NOTE: The locator pin on the J-jet piston cooling nozzle **must** engage the locating hole in the block for proper alignment.

Tighten the capscrew.

Torque Value:
J-Jet Capscrew 15 N•m [133 in-lb]



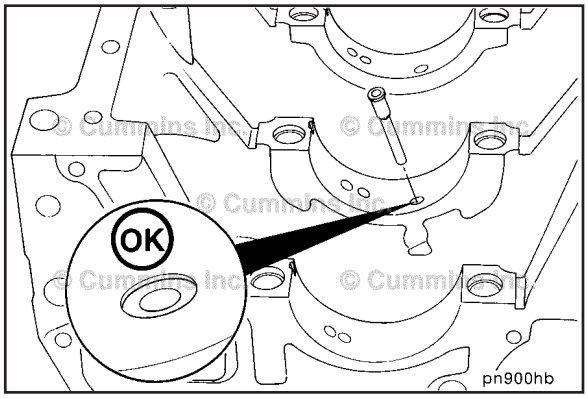
Crankshaft (001-016)

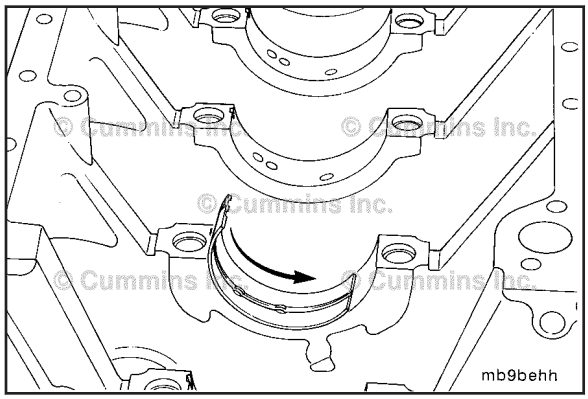
Initial Check

For engines equipped with drillings for saddle jet piston cooling nozzles/plugs, verify that:

- engines originally equipped with saddle jet piston cooling nozzles, the piston cooling nozzles are installed and free from debris/damage
- engines equipped with J-jet piston cooling nozzles, the saddle jet piston cooling nozzle drillings are plugged.

NOTE: Some engine do are **not** contain drillings for saddle jet piston cooling nozzles/plugs.

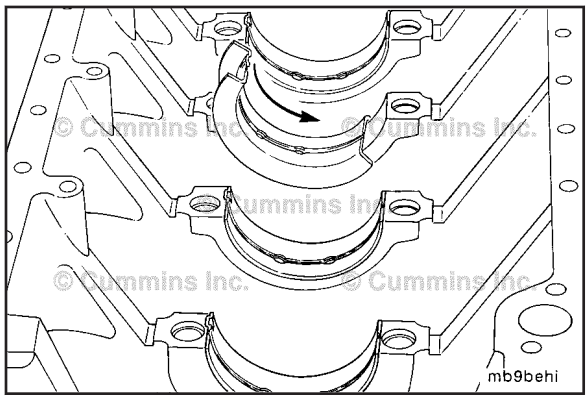




Install

Make sure the backsides of the bearings are clean and free of debris before installing the upper main bearings into the block.

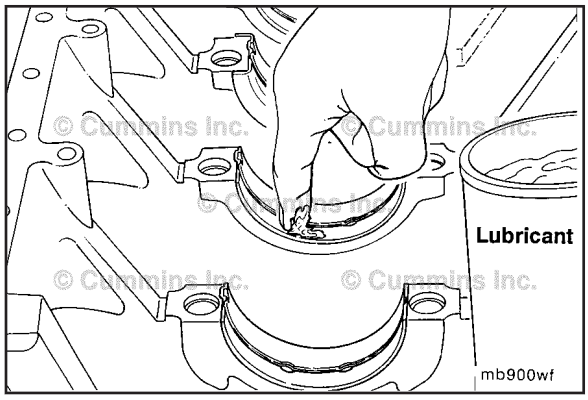
Make sure to align the tangs of the bearings with tangs on the main bearing block saddles.



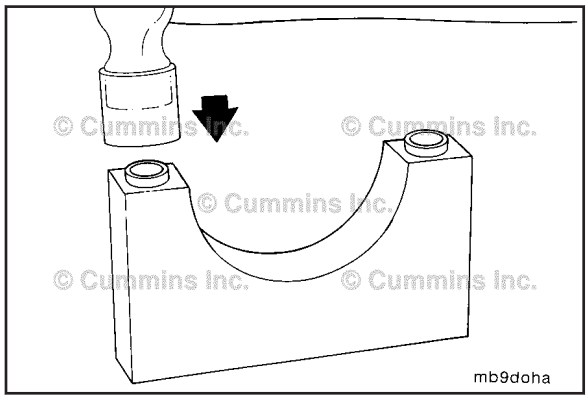
Install the upper crankshaft thrust bearing.

4 cylinder engines - The number 4 main bearing position.

6 cylinder engines - The number 6 main bearing position.



Apply a coat of assembly lube, Part Number 3163087, to the crankshaft side of the main bearings and thrust bearing surfaces.



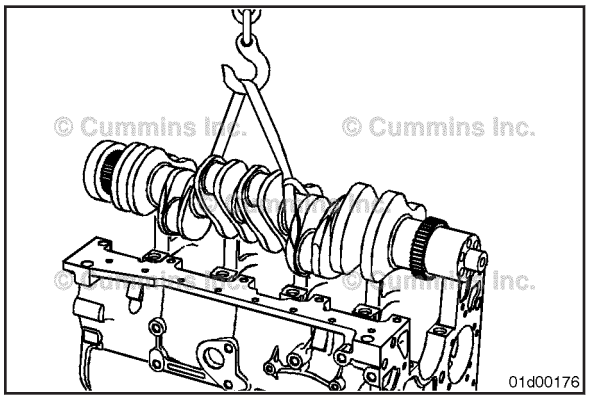
Check the main bearing caps to make sure the ring dowels are installed.

⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

△CAUTION△
Carefully install the crankshaft to avoid damage to the crankshaft main bearings, especially the thrust/main bearing journals. Engine life will be shortened if damage to the crankshaft occurs.

Install the crankshaft.

NOTE: When setting the crankshaft into the block, make sure the front crankshaft gear meshes with the lubricating oil pump gear (if not previously removed).



△CAUTION△
Do not lubricate the back side of the bearing that contacts the main bearing cap.

Make sure the backsides of the bearings are clean and free of debris before installing the lower main bearings into the main bearing caps.

Make sure to align the tangs of the bearings with tangs on the main bearing caps.

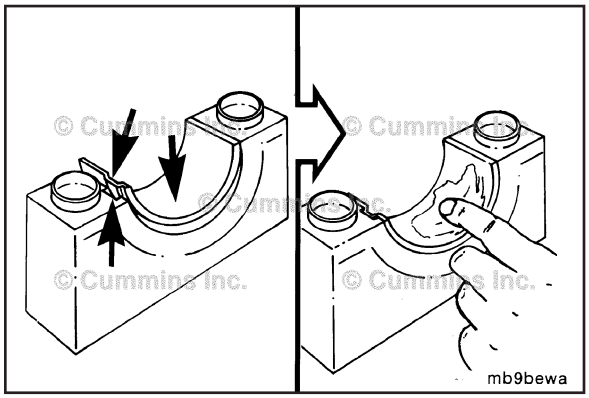
NOTE: Some engines use a thrust bearing for the upper and lower main bearing (360 degree), while other engines only have a thrust bearing for the upper main bearing (180 degree). **Always** replace like for like.

If equipped, install the lower crankshaft thrust bearing.

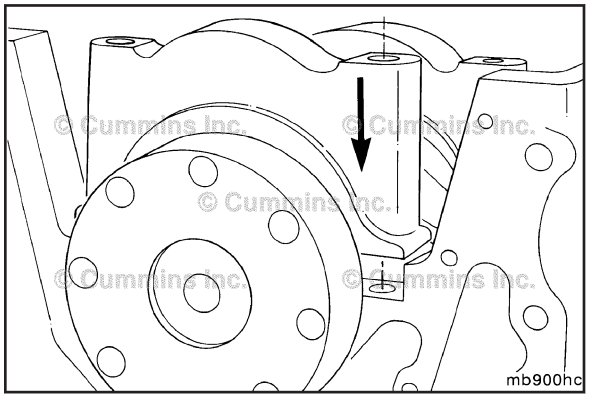
4 cylinder engines - The number 4 main bearing position.

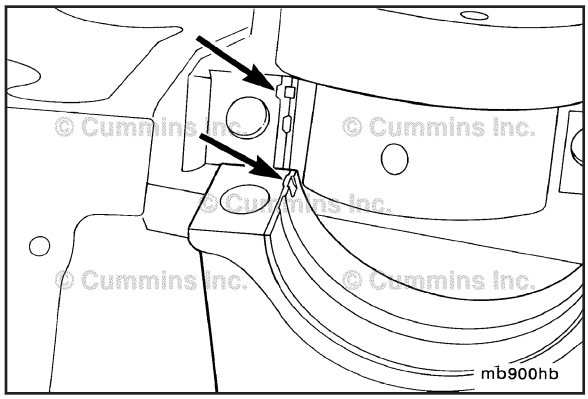
6 cylinder engines - The number 6 main bearing position.

Apply a coat of assembly lube, Part Number 3163087, to the crankshaft side of the main bearings and thrust bearing surfaces.



Make sure the main bear cap surfaces between the main bearing cap and block are clean and free of debris.

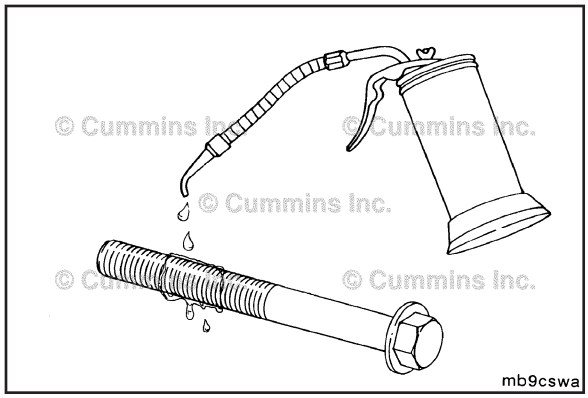




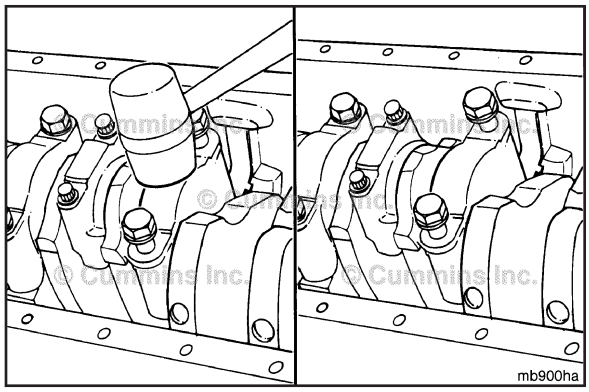
The main bearing caps are/were numbered during the removal process for their location. Number 1 starts with the front of the block.

NOTE: The caps **must** be installed so the numbers on the caps match the bearing saddle in the block. The lock tangs in the main bearing saddle and bearing cap **must** be on the same side.

Install the main bearing caps. Make sure to align the ring dowels on the main bearing cap with the corresponding drillings in the cylinder block.



Lubricate the main bearing capscrew threads and underside of the head with clean engine oil.



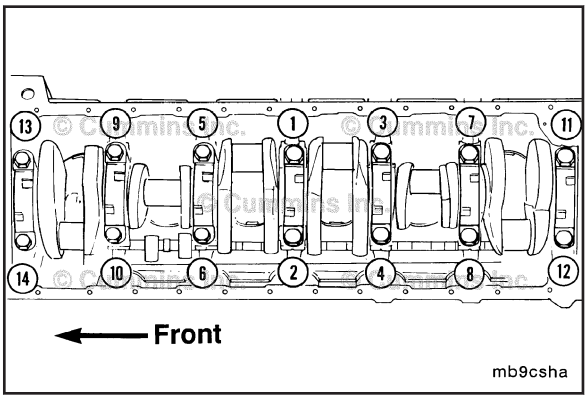
Gently tap the main bearing cap into position with a plastic or rubber mallet.

When seated, install the main bearing capscrews and tighten.

Torque Value: 50 N•m [37 ft-lb]

Do **not** tighten to the final torque value at this time. Final torque should be applied after all main bearing caps are installed.

NOTE: The sequence to the right is for a 6 cylinder engine. For a 4 cylinder engine, use the same sequence for the 5 main bearing caps.



Tighten the capscrews evenly and in sequence. Perform each step to all capscrews before performing the next step.

B3.9, B4.5, and B5.9 Engines:

Torque Value:

Step 1	60 N•m	[44 ft-lb]
Step 2	90 N•m	[66 ft-lb]
Step 3	Turn all capscrews through 90 degrees.	

⚠CAUTION⚠
For B4.5 RGT engines, there is a different torque procedure for new and previously installed main bearing capscrews. Failure to use the correct torque value can result in engine damage.

B4.5 RGT Engines:

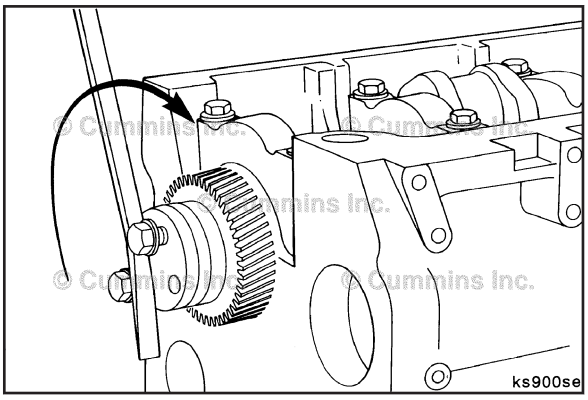
Torque Value:
Previously Installed Main Bearing Capscrews

Step 1	60 N•m	[44 ft-lb]
Step 2	80 N•m	[59 ft-lb]
Step 3	Rotate 90 degrees.	

Torque Value:
New Main Bearing Capscrews

Step 1	120 N•m	[89 ft-lb]
Step 2	Loosen completely.	
Step 3	60 N•m	[44 ft-lb]
Step 4	85 N•m	[63 ft-lb]
Step 5	Rotate 120 degrees.	

The crankshaft **must** rotate freely after installing the main bearing caps.



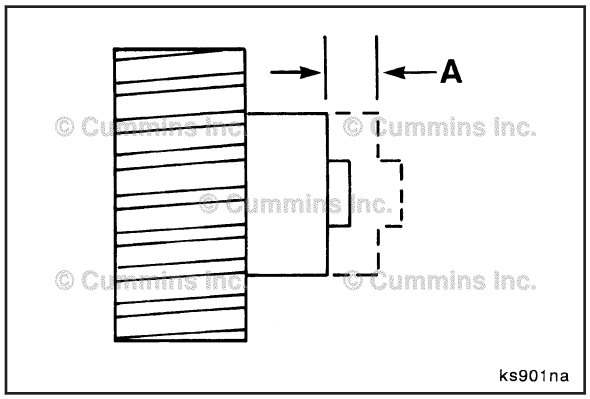
If the crankshaft does **not** rotate freely:

1 Check if the crankshaft is contacting one of the connecting rods

2 Check if the correct main bearing caps were installed correctly

3 Check if the main bearing cap ring dowels or mounting surfaces were damaged during installation

4 Check if the correct main bearings were installed.



NOTE: The dimensions of the thrust bearing and crankshaft journal determine end play.

Measure the crankshaft end play with a dial indicator assembly, Part Number 3824564 and magnetic base, Part Number 3377399.

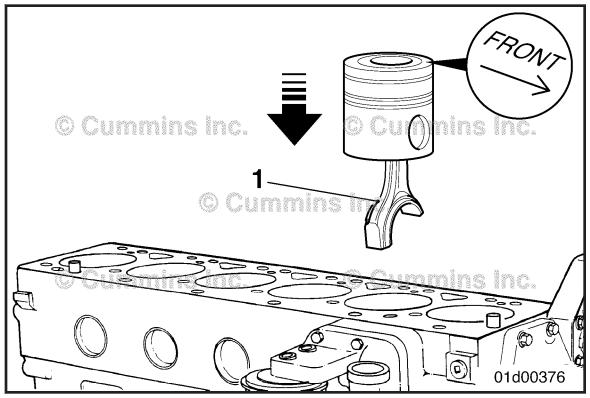
Crankshaft End Play		
mm		**in**
0.102	MIN	0.004
0.432	MAX	0.017

If the crankshaft end play is not within specification:

1 If the crankshaft end play is below specification, check if there are any obstructions limiting the crankshaft's travel (lubricating oil pump, connecting rod, etc.)

2 If the crankshaft end play is above specification, inspect the crankshaft thrust bearing surface. Also check if the correct thrust bearing(s) were installed.

NOTE: Oversize thrust bearings are available if the end play is **not** within specifications. Oversize thrust bearings of 0.25 to 0.51 mm [0.010 to 0.020 in] are available.



Piston and Connecting Rod Assembly (001-054)

Install

Front Gear Train

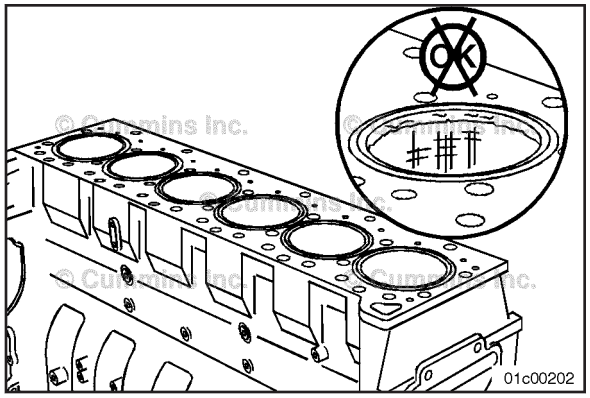
Piston Grading

NOTE: B4.5 RGT engines do **not** require piston grading.

When rebuilding an engine with the original cylinder block, crankshaft, and pistons, make sure the pistons are installed in the original cylinder.

If replacing the piston(s), make sure the replacement piston(s) are the same grade as the original piston.

If a new cylinder block or crankshaft is used, the piston grading procedure **must** be performed to determine the proper piston grade for each cylinder.



The cylinder block and all parts **must** be clean before assembly. Refer to Procedure 001-026 to inspect the cylinder walls of the cylinder block. Use a clean, lint-free cloth to clean the connecting rods and bearing shells.

CAUTION

The connecting rods and connecting rod caps are not interchangeable. The connecting rods and connecting rod caps are machined as an assembly. Failure will result if the connecting rods and caps are mixed.

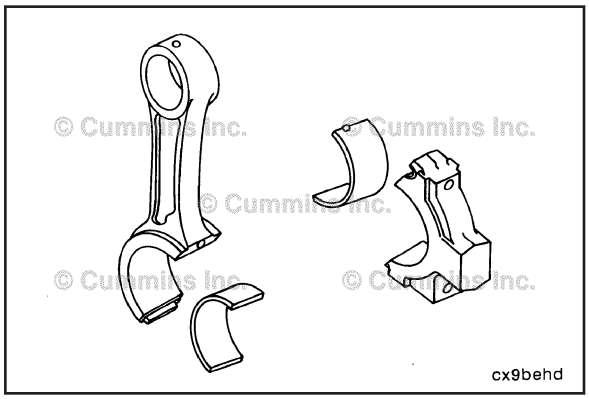
CAUTION

Make sure not to damage the mating surfaces of the fracture-split connecting rods and the rod caps.

NOTE: Fracture split connecting rods use a different upper and lower bearing.

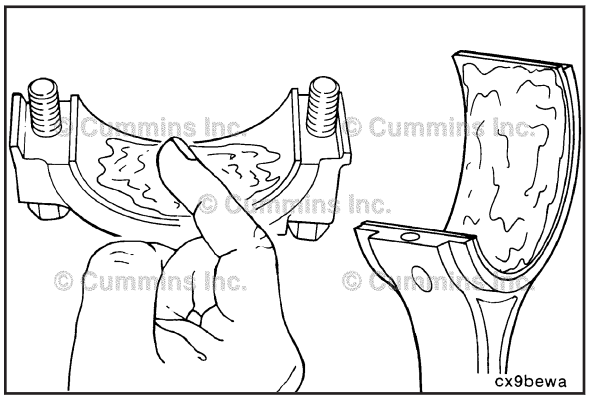
Install the bearing shells into both the connecting rod and the connecting rod cap.

Make sure the tang on the bearing shells is in the slot of the connecting rod cap and connecting rod.

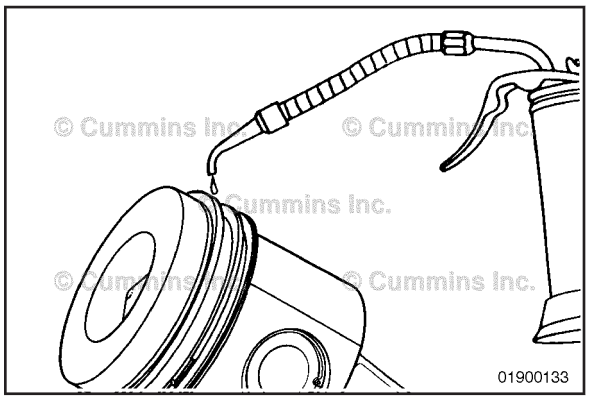


NOTE: The fracture surface on the fracture split connecting rod and connecting rod cap **must** be kept dry and clean to make sure proper mating of the two surfaces is maintained.

Lubricate the connecting rod bearings with a light film of assembly lubricant, Part Number 3163087.

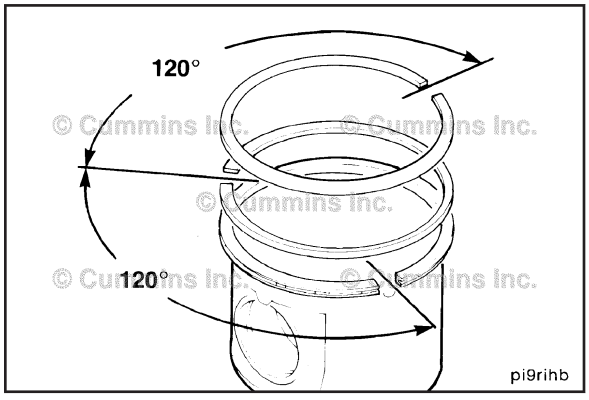


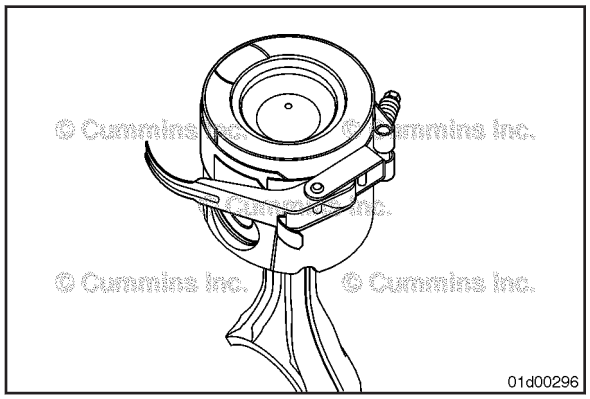
Lubricate the rings and piston skirts with clean engine lubricating oil.



Position the rings so that the ring gaps are 120 degrees apart.

NOTE: The ring gap of each ring **must not** be aligned with the piston pin, or any other ring. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.

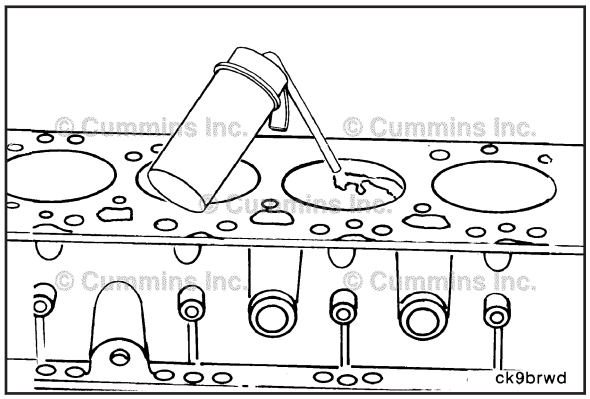




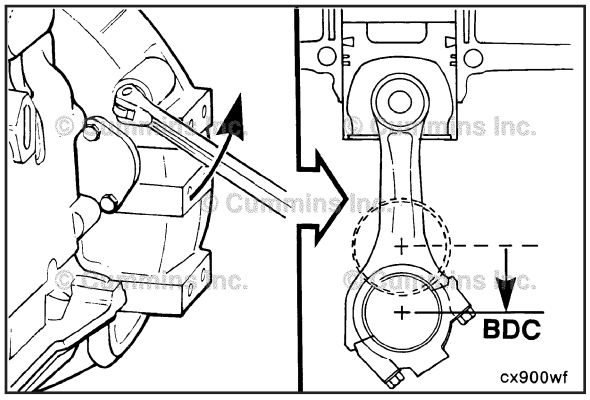
⚠CAUTION⚠
If using a strap type ring compressor, make sure the inside end of the strap does not hook on a ring gap and break the ring.

For B3.9, B4.5, and B5.9 engines, use piston ring compressor, Part Number 3164330, to compress the rings.

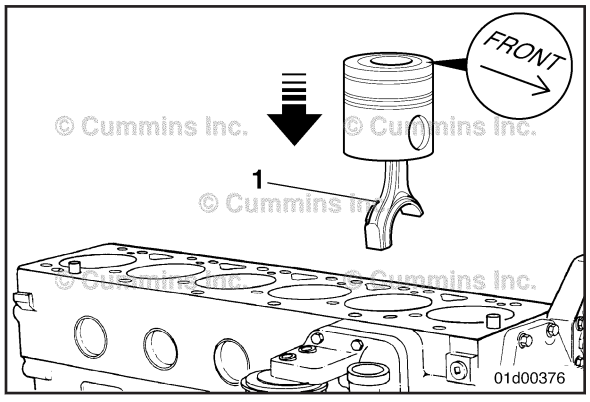
For B4.5 RGT engines, use piston ring compressor, Part Number 4918294, to compress the rings.



Lubricate the cylinder bore with clean 15W-40 lubricating engine oil.



Position the connecting rod journal for the piston to be installed to bottom dead center (BDC).



⚠WARNING⚠
Failure to follow this step will result in extensive engine damage.

Align the “front” marking and/or arrow on the top of the piston so that it points towards the front of the engine.

Insert the connecting rod through the cylinder bore until the ring compressor contacts the top of the cylinder block.

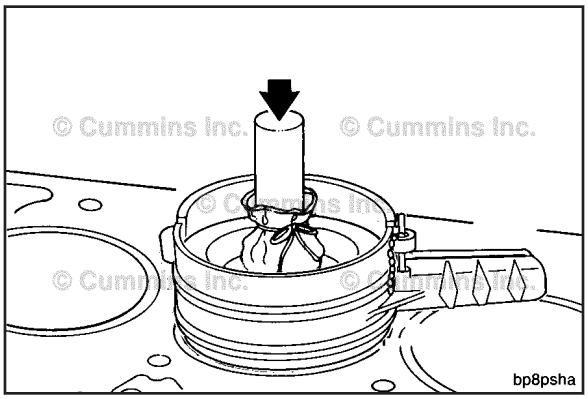
The long end of the connecting rod (1) will be on the exhaust side of the engine. If **not**, verify the piston is installed correctly onto the connecting rod.

Hold the ring compressor against the cylinder block.

Push the piston through the ring compressor and into the cylinder bore.

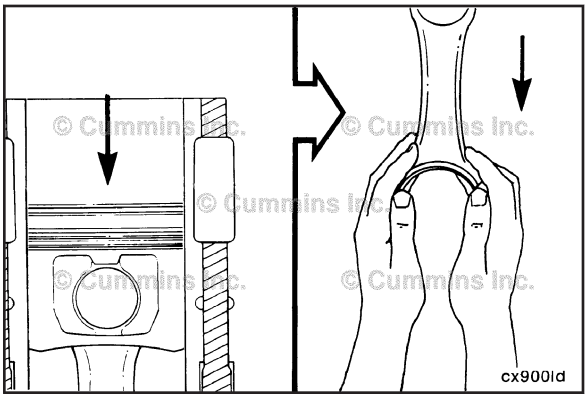
Push the piston until the top ring is completely in the cylinder bore.

NOTE: If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.



Take care to **not** damage the cylinder wall when inserting the connecting rod.

Carefully push the piston into the bore while guiding the connecting rod to the crankshaft journal.

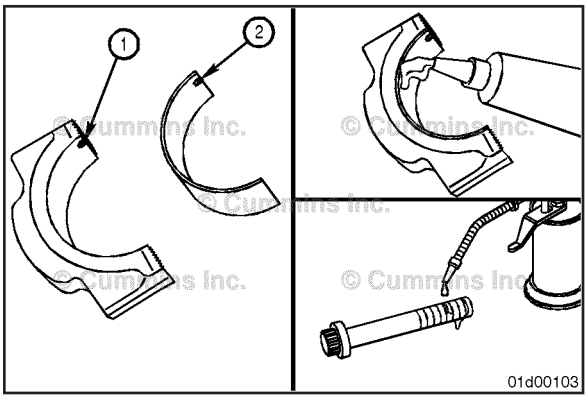


NOTE: The fracture surface on the fracture split connecting rod and connecting rod cap **must** be kept dry and clean to make sure proper mating of the two surfaces is maintained.

Verify the tang of the bearing (2) is in the slot of the cap (1).

Use assembly lube, Part Number 3163087, or equivalent to coat the inside diameter of the bearing shell.

Use clean 15W-40 oil to lubricate the connecting rod capscrew threads and underside of the connecting rod capscrew heads.

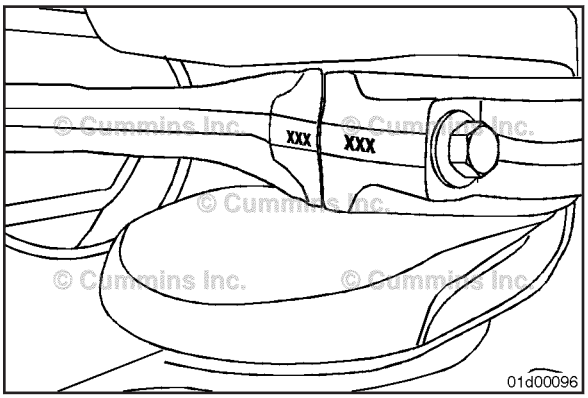


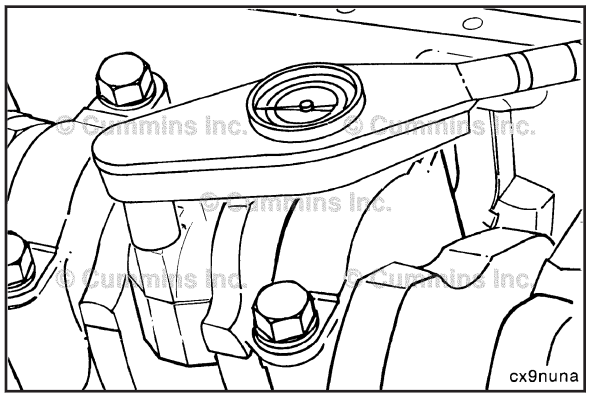
CAUTION

Do not damage the fractured split surface on the connecting rod or connecting rod cap when the connecting rod cap is installed. If the fracture split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage.

The connecting rod and cap **must** have the same number and **must** be installed in the proper cylinder. The connecting rod cap number and rod number **must** be on the same side of the connecting rod to prevent engine damage during engine operation.

Install the connecting rod and capscrews.



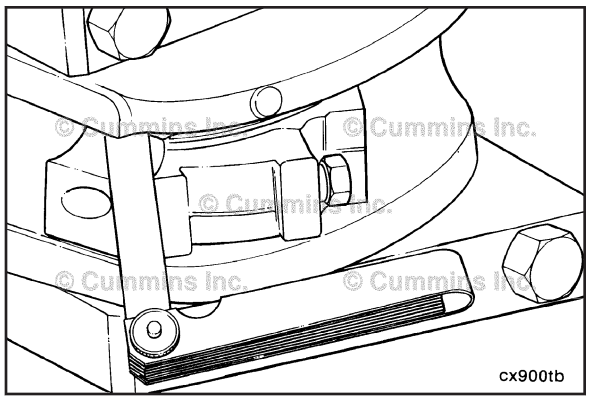


Use a marked socket and torque wrench to tighten the connecting rod capscrews.

Using the torque plus angle method, tighten the connecting rod capscrews in alternating sequence.

Torque Value:

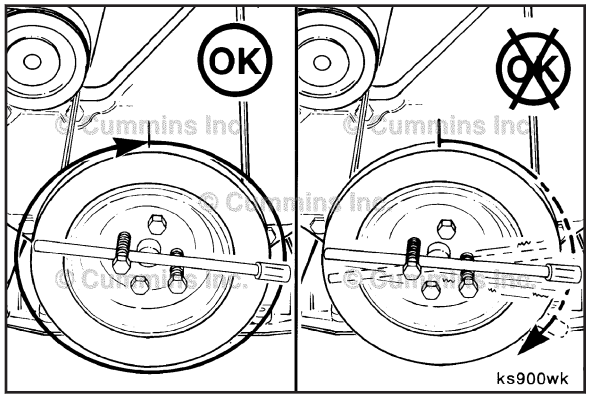
B3.9, B4.5 RGT and B5.9 Engines	Step1	30 N•m	[22 ft-lb]
	Step2	60 N•m	[44 ft-lb]
	Step3	Turn 60 degrees clockwise.	
B4.5 Engines	Step1	25 N•m	[18 ft-lb]
	Step2	Turn 60 degrees clockwise.	



NOTE: Do **not** measure the clearance between the connecting rod cap and crankshaft.

Measure the side clearance between the connecting rod and crankshaft.

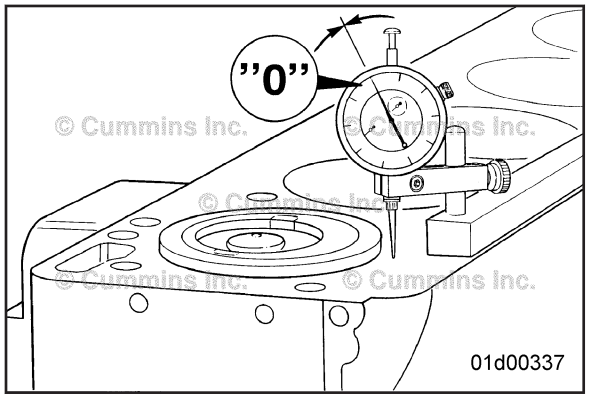
Side Clearance Limits		
mm		**in**
0.10	MIN	0.004
0.33	MAX	0.013



⚠CAUTION⚠
To reduce the possibility of engine damage, the crankshaft must rotate freely.

⚠CAUTION⚠
If the connecting rod is not properly oriented (tang opposite the camshaft), it will contact the camshaft and lock the engine.

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



Measure

Measure piston protrusion above the cylinder block combustion deck.

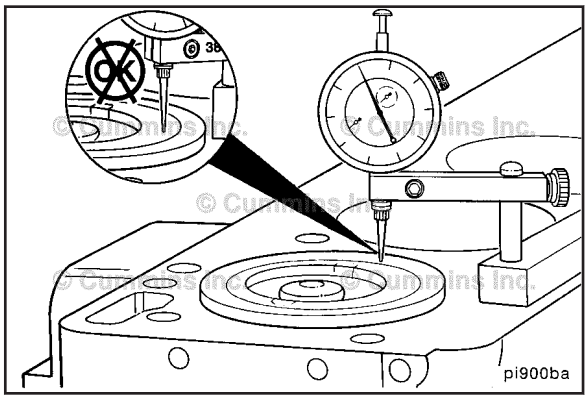
NOTE: For B3.9, B4.5, and B5.9 engines, if piston grading procedure was performed, this measure step is **not** required.

NOTE: For B4.5 RGT engines, this procedure is only required after a piston, crankshaft, connecting rod, or block modification/replacement.

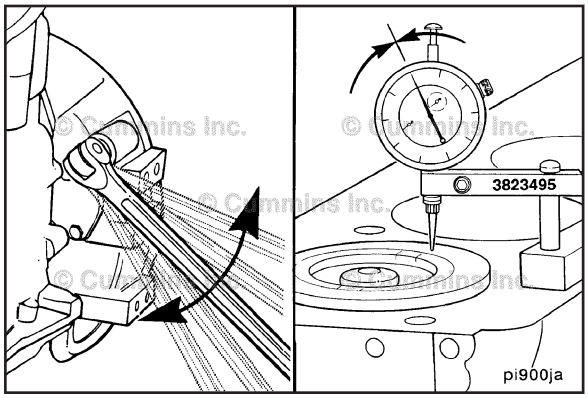
Measure the piston protrusion using depth gauge assembly part number 3823495. No piston or head gasket grading is required.

Install the dial indicator on the cylinder head and zero.

Move the dial indicator directly over the piston pin to eliminate any side-to-side movement. Do **not** place the indicator tip on the anodized area.



Rotate the crankshaft to top dead center. Rotate the crankshaft clockwise and counterclockwise to find the highest dial indicator reading. Record the reading.



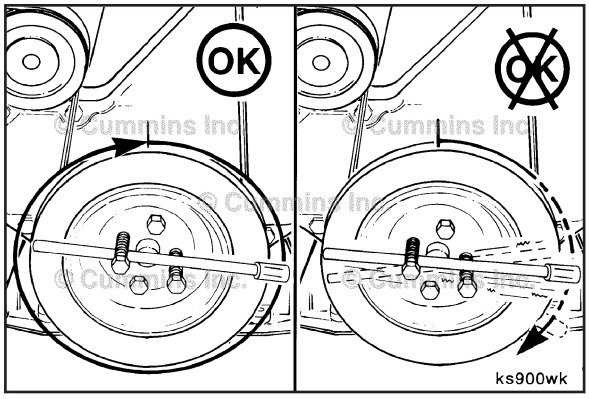
B4.5 RGT Piston Protrusion		
mm		**in**
0.151	MIN	0.006
0.485	MAX	0.019

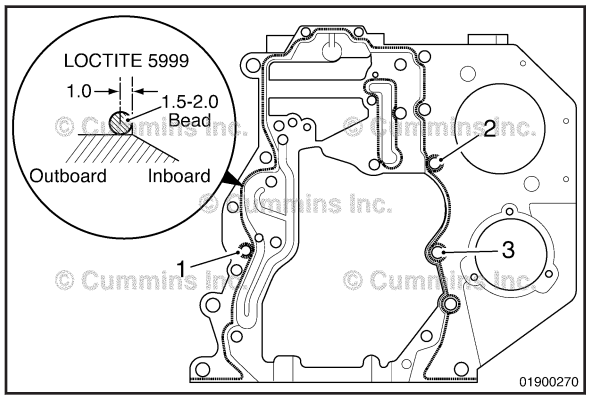
B3.9, B4.5, and B5.9 Piston Protrusion		
mm		**in**
0.609	MIN	0.024
0.711	MAX	0.028

If the piston protrusion is **not** within specification, verify that the correct parts are installed and/or the cylinder block combustion deck has been machined improperly. Refer to Procedure 001-026.

For B3.9, B4.5, and B5.9 engines verify the correct grade of piston is being used. See the Piston Grading section of this procedure.

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





Gear Housing, Rear (001-034)

Install

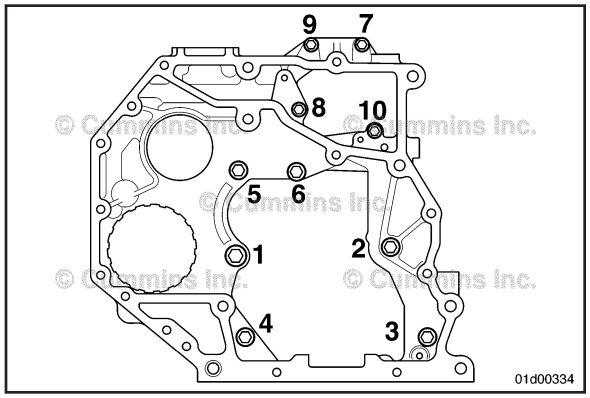
⚠CAUTION⚠
Make sure to only apply sealant to the areas specified. Failure to do so may block oil passages to the accessory drive and/or cause a loss of oil pressure. This will result in severe engine damage.

Apply a 1.5 to 2.0 mm [0.06 to 0.08 in] wide bead of sealant, Part Number 3164070, to the block side of the gear housing in the path illustrated and install the rear gear housing capscrews and housing.

NOTE: Make sure to apply a bead of sealant around the mounting capscrew holes shown, locations 1, 2 and 3.

Be sure there is a bead of sealant at the intersection joint of the cylinder block, oil pan, and gear housing.

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.

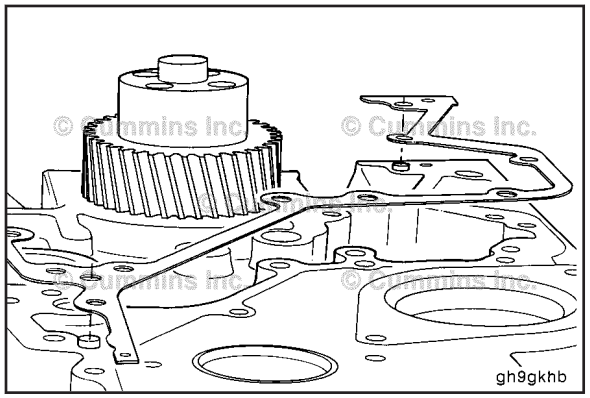


Tighten the capscrews as shown.

Torque Value:

M12	50 N•m	[37 ft-lb]
M10	47 N•m	[35 ft-lb]
M8	24 N•m	[212 in-lb]

NOTE: If a rear gear housing and/or timing pin assembly is installed, the timing pin **must** be accurately located. Refer to Procedure 001-049



Gear Housing, Front (001-033)

Install

Position the front gear housing gasket on the alignment dowels. Use guide pins, M8 x 1.25 x 50, to assist in aligning the gasket and gear housing. Make sure to remove the guidepins after alignment.

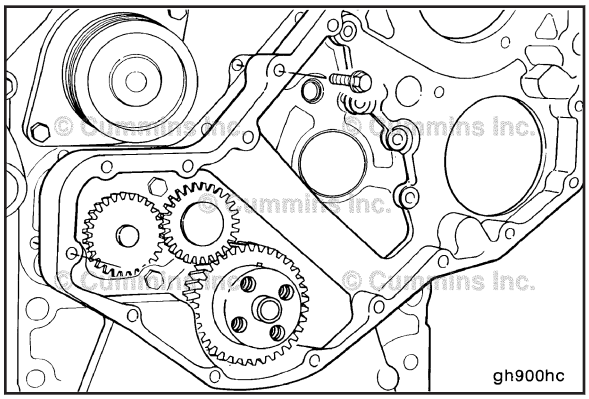
Carefully install the gear housing.

Make sure the gasket is still in place.

Install and tighten the mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]

NOTE: If a new front gear housing and/or timing pin assembly is installed, the timing pin assembly **must** be accurately located. Refer to Procedure 001-049.



Tappet (004-015)

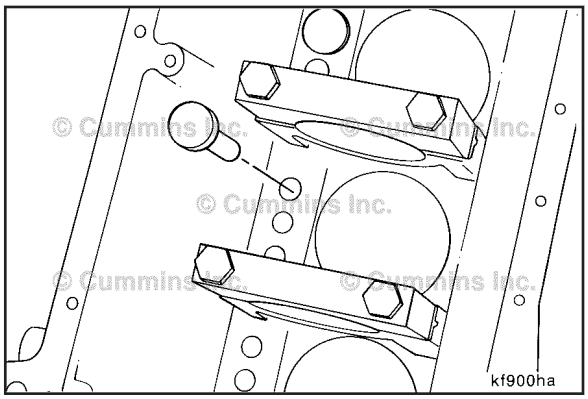
Install

Lubricate the tappets with assembly lubricant, Part Number 3163087, or equivalent.

Prior to installing the camshaft, install the tappets through the bottom of the engine.

If reusing the tappets, the tappets **must** be installed in the same location in which the tappets where removed.

NOTE: Anytime new tappets are used, the push rods **must** be replaced as well.

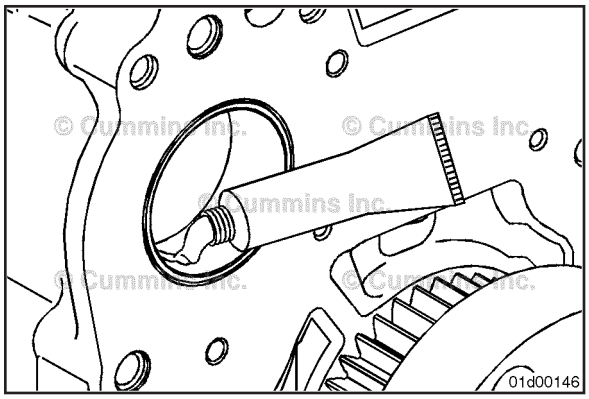


Camshaft (001-008)

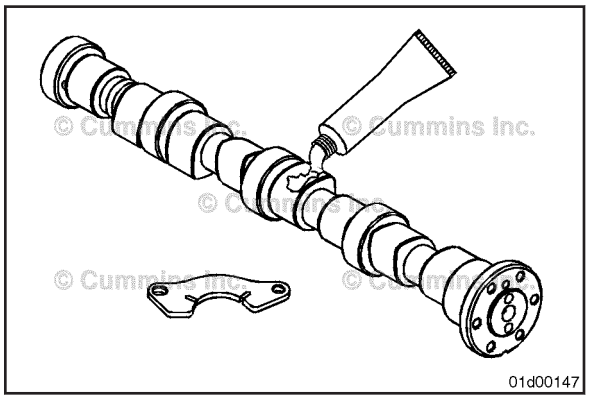
Install

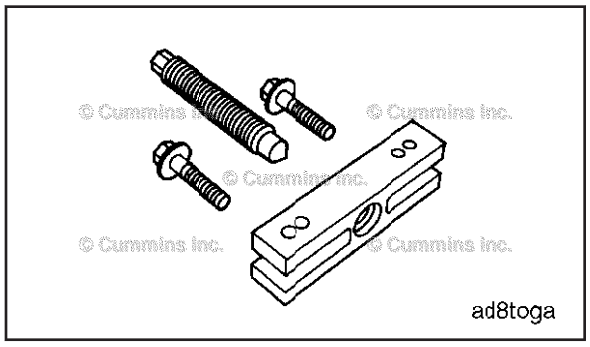
Rear Gear Train

Apply assembly lubricant, Part Number 3163087, to the rear camshaft bore.

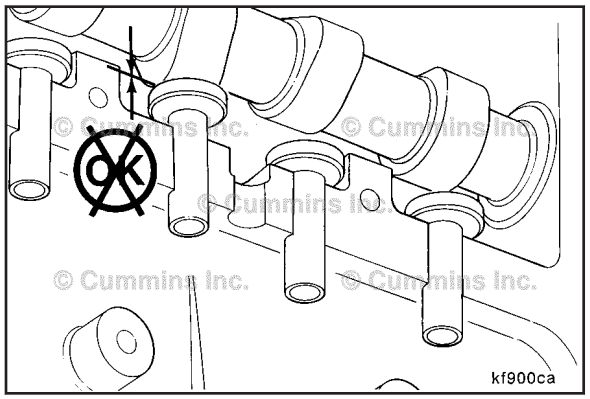


Lubricate the camshaft lobes, journals, and thrust washer with assembly lubricant, Part Number 3163087.



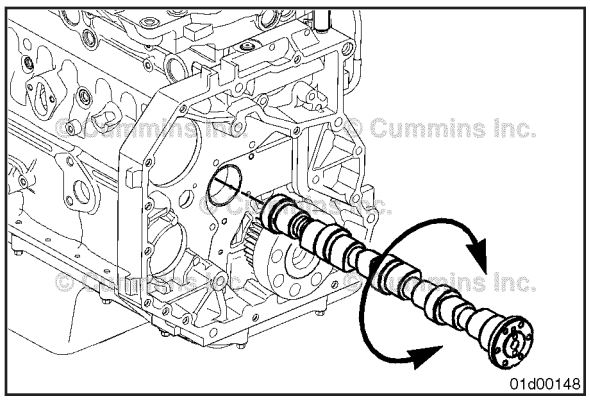


Use a gear puller, service tool Part Number ST647 or equivalent, to attach to the end of the camshaft where the camshaft gear mounts, to act as a handle. This will give proper leverage and ease installing the camshaft.



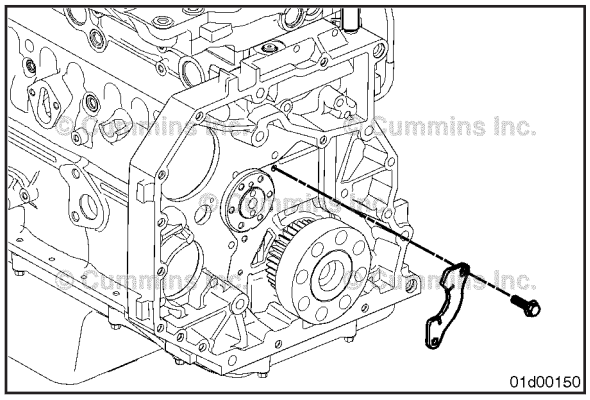
⚠CAUTION⚠
Before the camshaft is installed, verify the tappets are fully inserted into the tappet bores. If the tappets are not fully inserted, the camshaft and/or tappets may be damaged during installation.

NOTE: The following illustrations will show the engine in the upright position for clarity.



⚠CAUTION⚠
Do not force the camshaft into the camshaft bore as damage to the camshaft bushing can result.

Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the lobe from the bushing and allow the camshaft to be installed.



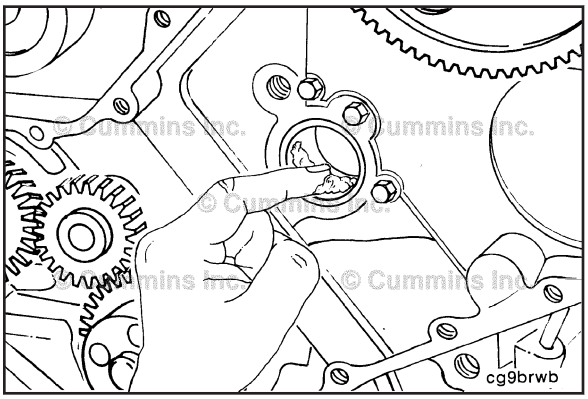
Install the thrust plate.

Install the thrust plate capscrews.

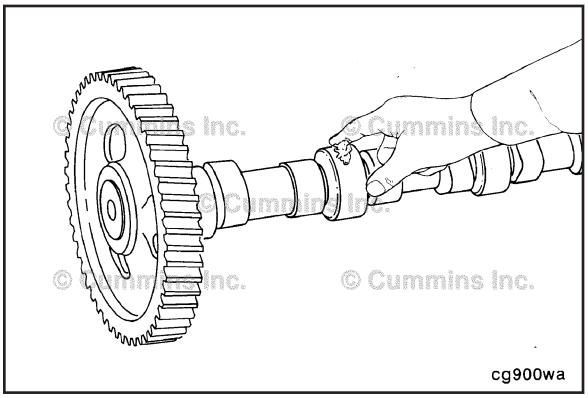
Torque Value: 24 N•m [212 in-lb]

Front Gear Train

Apply assembly lubricant, Part Number 3163087, to the front camshaft bore.

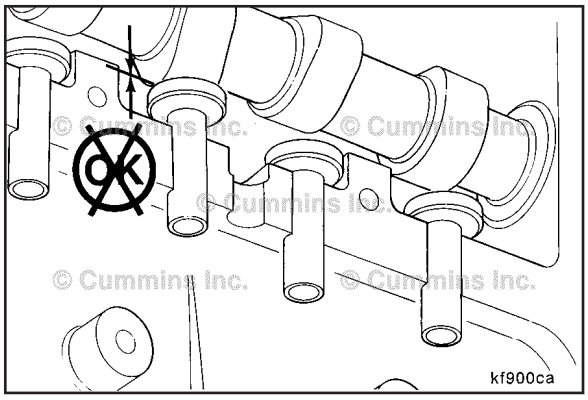


Lubricate the camshaft lobes, journals, and thrust plate with assembly lubricant, Part Number 3163087.



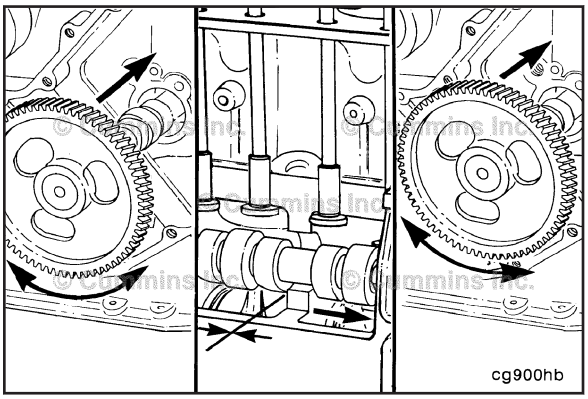
⚠CAUTION⚠
Before the camshaft is installed, verify the tappets are fully inserted into the tappet bores. If the tappets are not fully inserted, the camshaft and/or tappets may be damaged during installation.

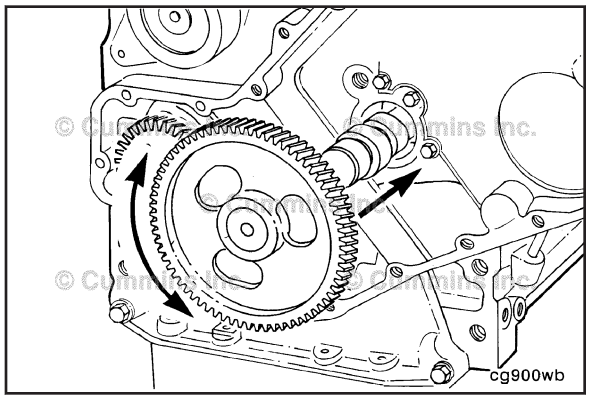
NOTE: The following illustrations will show the engine in the upright position for clarity.



⚠CAUTION⚠
Do not try to force the camshaft into the camshaft bore as damage to the camshaft bushing can result.

Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the lobe from the bushing and allow the camshaft to be installed.

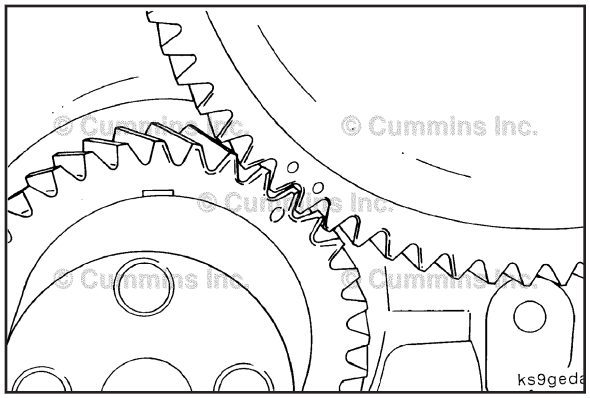




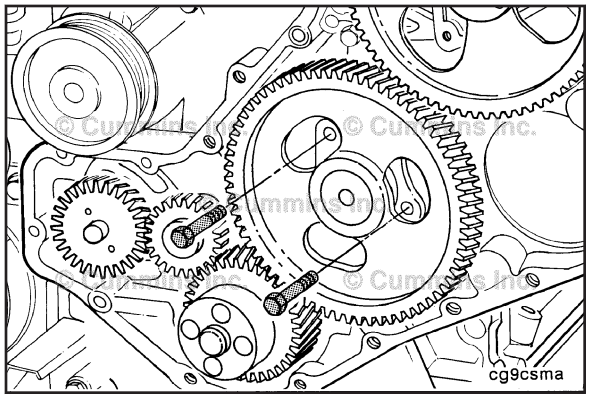
CAUTION

To reduce the possibility of engine damage, make sure the camshaft rotates freely.

Before the camshaft gear engages the crankshaft gear, check the camshaft for ease of rotation. When installed properly, the camshaft **must** rotate freely.



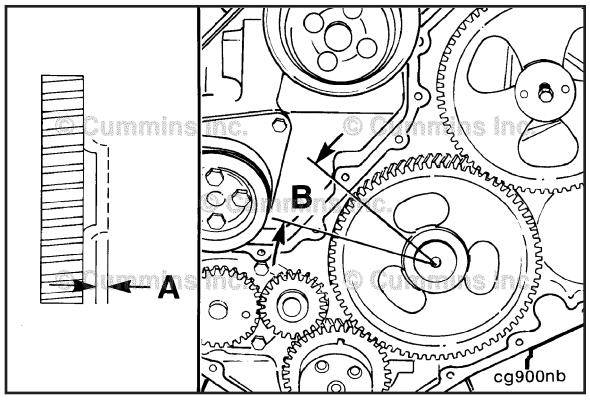
Align the timing marks as illustrated and finish installing the camshaft.



Install the thrust plate.

Install the thrust plate capscrews.

Torque Value: 24 N•m [18 ft-lb]



Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399, to verify the camshaft has proper backlash and end play.

Camshaft End Play (A)		
mm		in
0.12	MIN	0.005
0.47	MAX	0.018

Camshaft Gear Backlash Limits (B)		
mm		in
0.33	MIN	0.013
0.76	MAX	0.030

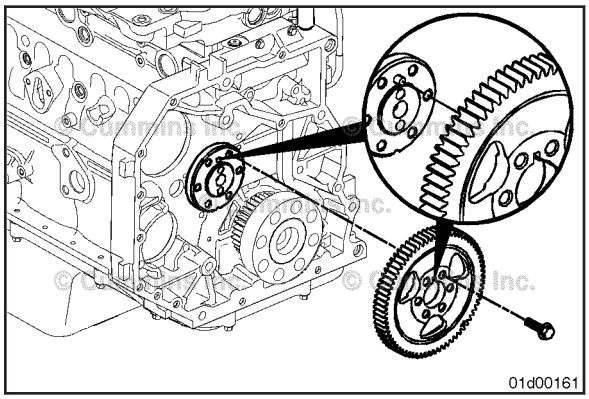
Camshaft Gear (Camshaft Installed) (001-012)

Install

NOTE: For Front Gear Train Engines, the camshaft gear will be installed with the camshaft.

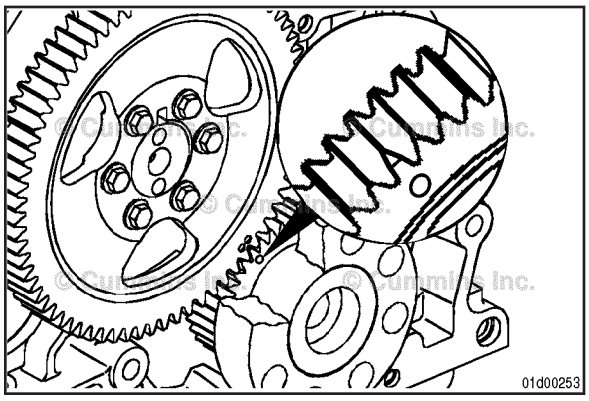
Align the camshaft gear with the pin in the camshaft and the mark on the crankshaft gear.

Install camshaft gear onto the camshaft.



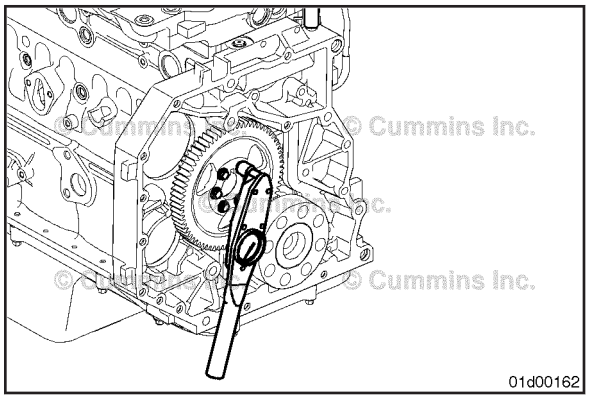
Check to make sure the timing marks on the camshaft gear align with the timing marks on the crankshaft gear.

NOTE: The engine can have a mark on the crankshaft gear or chamfered tooth.



Install camshaft gear capscrews and tighten.

Torque Value: 36 N•m [27 ft-lb]



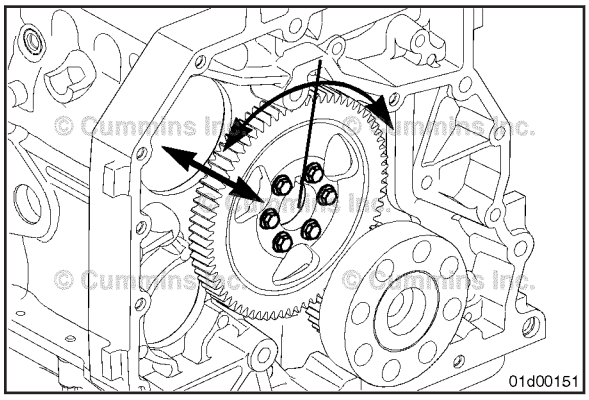
Measure

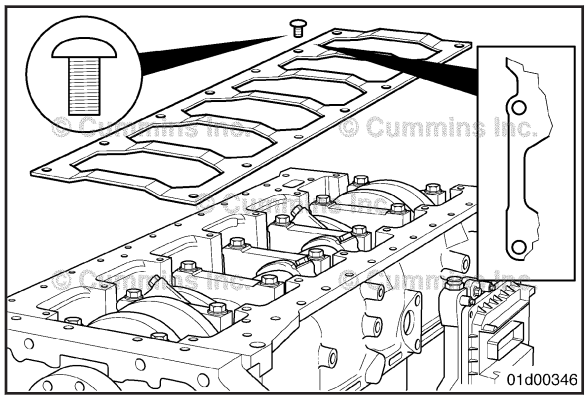
Using gauge, Part Number 3824564, and magnetic base, Part Number 3377399, check the camshaft end play.

Camshaft End Play		
mm		**in**
0.100	MIN	0.004
0.360	MAX	0.014

Check the camshaft backlash.

Camshaft Backlash		
mm		**in**
0.076	MIN	0.003
0.280	MAX	0.011





Block Stiffener Plate (001-089)

Install

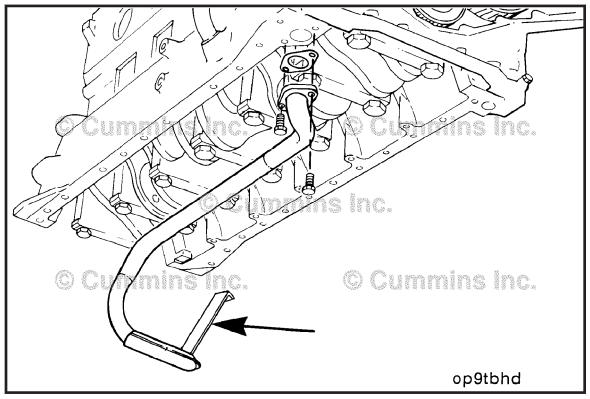
NOTE: The block stiffener plate **must** be installed so that the center ribs are bent away from the block, to ensure proper clearance from the block main caps.

NOTE: For some oil pan/oil suction tube configurations, one of the block stiffener mounting capscrews may be different than the rest. This capscrew, with a lower head profile, should be installed in the opening adjacent to the oil suction tube mounting location. The low profile capscrew ensures in some applications that there is sufficient clearance between the oil suction tube and the block stiffener mounting capscrew.

Install the block stiffener plate so that the exterior portion of the block stiffener plate with the recess is next to the oil suction tube mounting location at the front of the engine.

Install the block stiffener plate mounting capscrews.

Torque Value:
Block Stiffener Plate Capscrews 43 N•m [32 ft-lb]



Lubricating Oil Suction Tube (Block-Mounted) (007-035)

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.

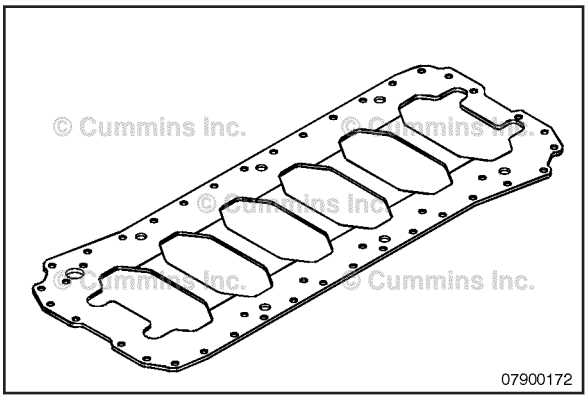
Lubricating Oil Pan (007-025)

Install

Front Gear Train

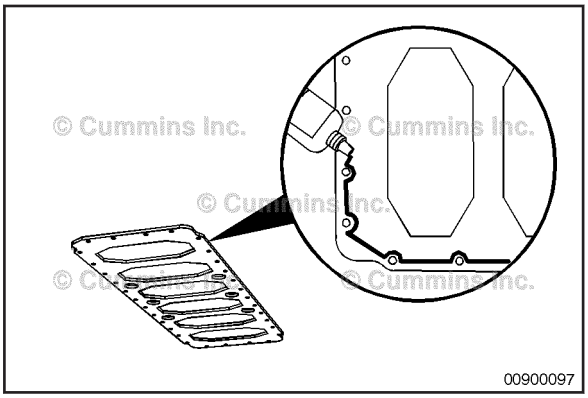
If the engine is equipped with a bedplate, install the bedplate first.

NOTE: The bedplate will **only** install one way. The center ribs are stamped offset to clear the main bearing caps.

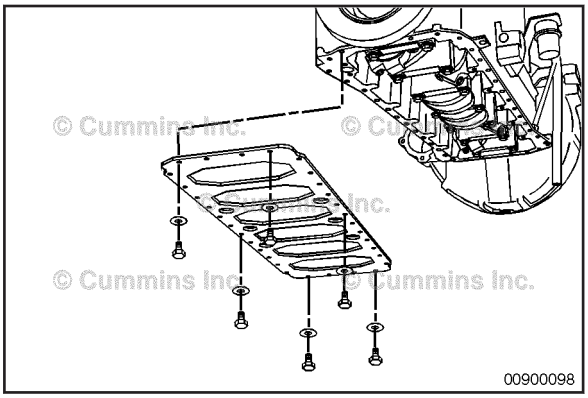


Apply a 1 to 2 mm [0.4 to 0.08 in] bead of RTV, Part Number 3164067, to the block side of the plate.

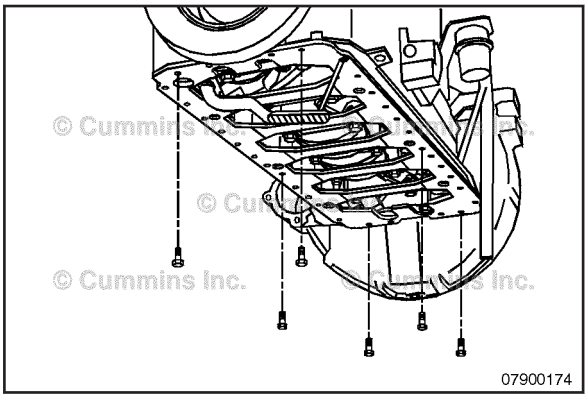
NOTE: The bedplate **must** be installed within 5 minutes of applying RTV sealant to obtain the proper seal.

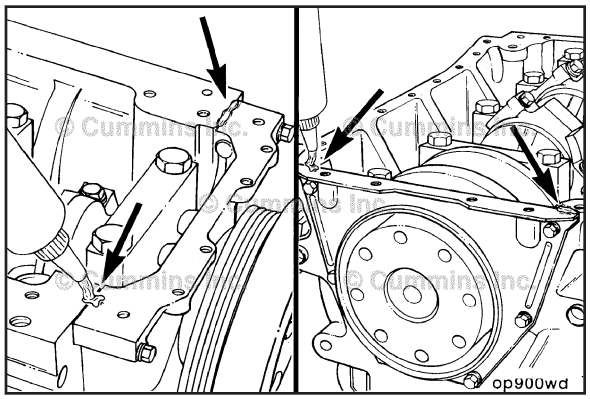


Install the bedplate to the block. Use six oil pan capscrews to hold the bedplate temporarily in place.

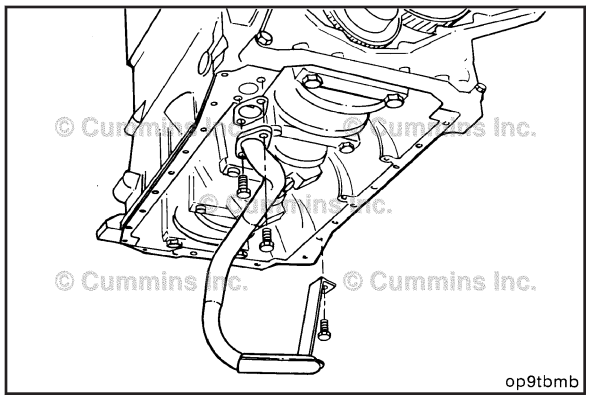


Remove the temporary capscrews.

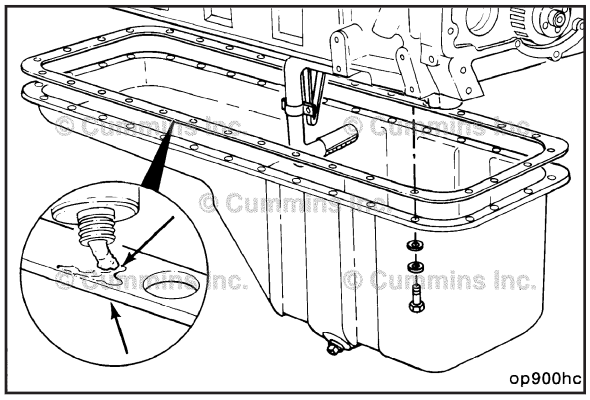




If the engine does **not** require a bedplate, use RTV sealant, Part Number 3164067, to fill the joints between the lubricating oil pan rail, gear housing, or the rear seal housing.



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.

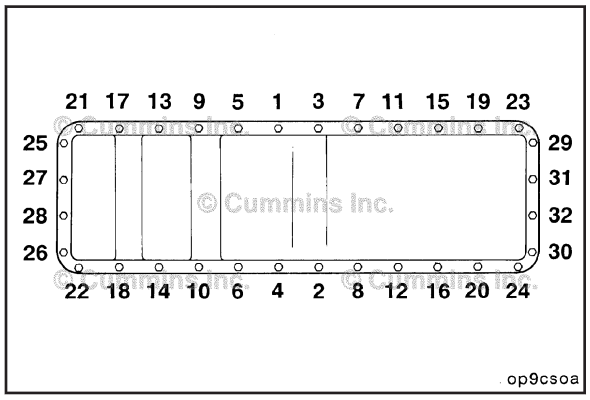


Apply a 2-mm [0.063-in] bead of RTV, Part Number 3164067, to both sides of the new lubricating pan gasket.

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.

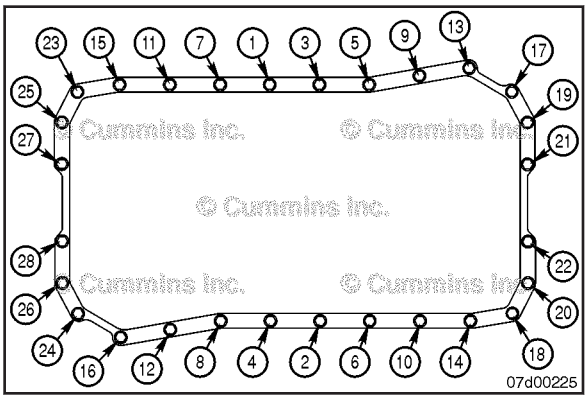
Torque Value: 24 N•m [212 in-lb]

Four-Cylinder

Assemble the washers and capscrews to secure the lubricating oil pan as illustrated.

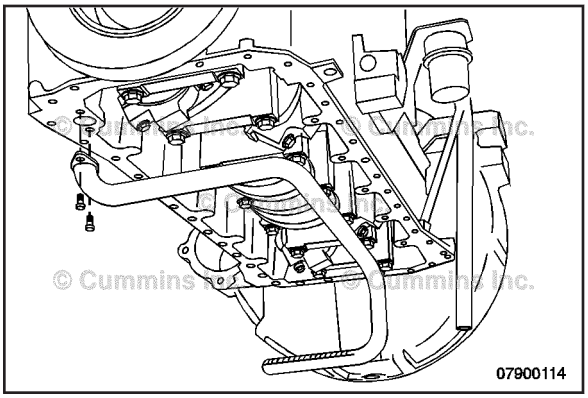
Tighten all capscrews in the sequence shown in the accompanying chart.

Torque Value: 24 N•m [212 in-lb]

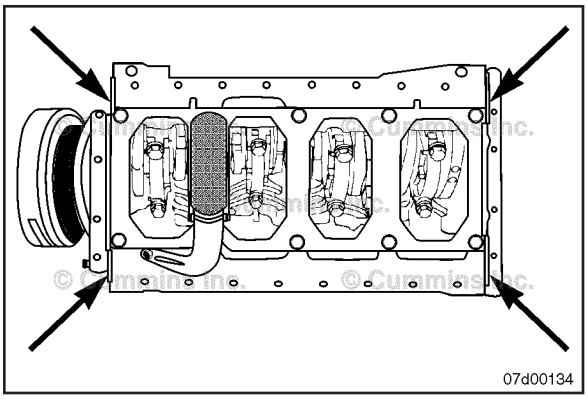


Rear Gear Train

Install the suction tube, if has been removed. Refer to Procedure 007-035 in Section 7.



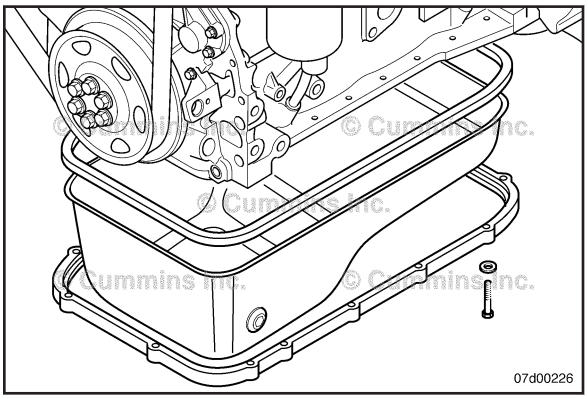
Prior to installing the oil pan, apply RTV sealant, Part Number 3164070, to the joints between the lubricating oil pan rail-rear gear housing, and the lubricating oil pan rail-front gear cover.

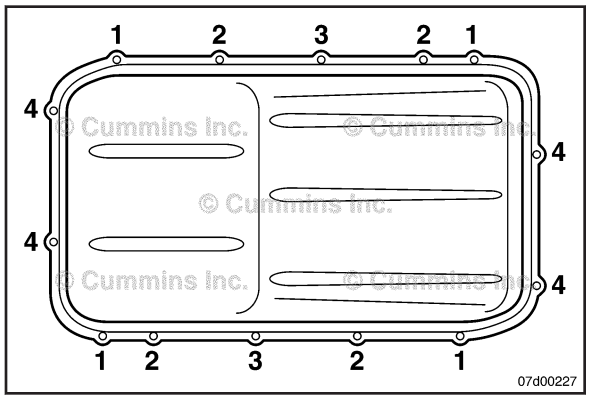


Assemble the new flexible gasket onto the oil pan.

Install the mounting flange over the oil pan/gasket assembly.

Install the oil pan assembly and mounting capscrews.

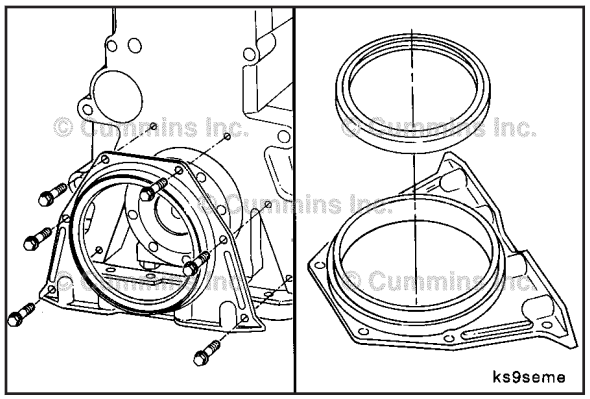




Tighten all capscrews in the sequence shown.

Torque Value:

Step 1	24 N•m	[212 in-lb]

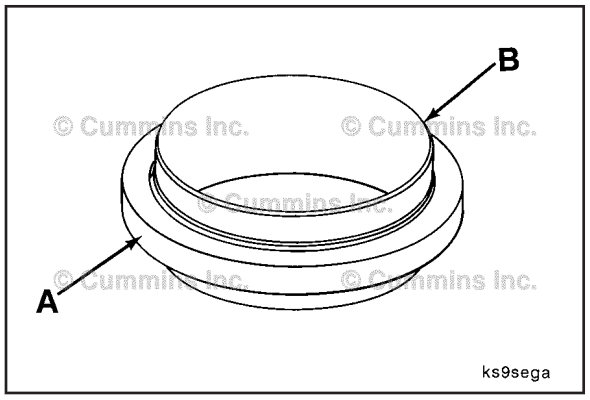


Crankshaft Seal Carrier, Rear (001-104)

General Information

NOTE: This procedure is for front gear train engines only.

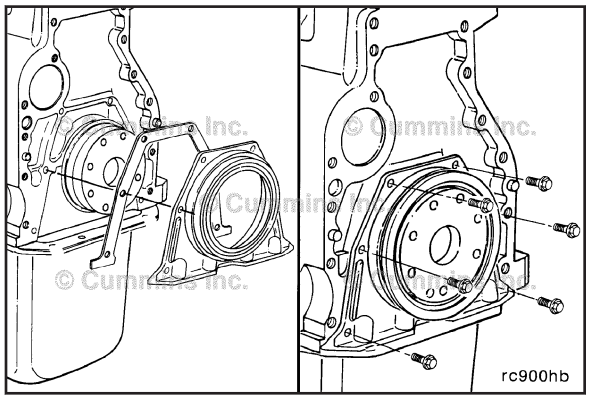
For front gear train engines, a rear crankshaft seal carrier is mounted to the rear of the cylinder block to house the rear crankshaft seal. For rear gear train engines, the rear crankshaft seal is installed in the flywheel housing.



Install

NOTE: For engines equipped with a wet flywheel housing, make sure to replace the rear crankshaft seal with the correct rear seal. Rear crankshaft seals for a wet and dry flywheel housings may **not** be the same.

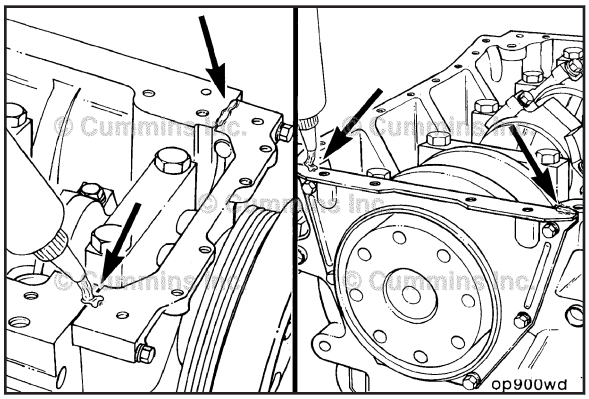
The new rear crankshaft seal (A) will come installed on a seal pilot (B). The seal **must** be left on the seal pilot while installing the seal onto the nose of the crankshaft. This will keep the lips of the seal from being damaged during installation.



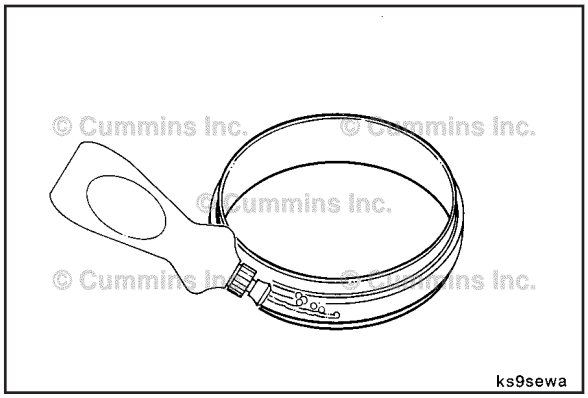
Install the rear crankshaft seal carrier and gasket. Apply Loctite™ 262 or 271 to the mounting capscrews and loosely tighten the rear seal carrier to the block.

NOTE: It may be necessary to trim the rear seal carrier gasket so that it is even with the oil pan mounting surface.

Apply a thin bead of sealant, part number 3164067, at this joint prior to installing the rear seal carrier. The rear seal carrier **must** be installed within 10 minutes of applying the sealant.



To aid in installation, the lubricating oil seal requires the application of a mild soap on the outside diameter of the seal case.



Place the new rear crankshaft seal, with the seal pilot, over the crankshaft nose and slide it by hand toward the flywheel housing.

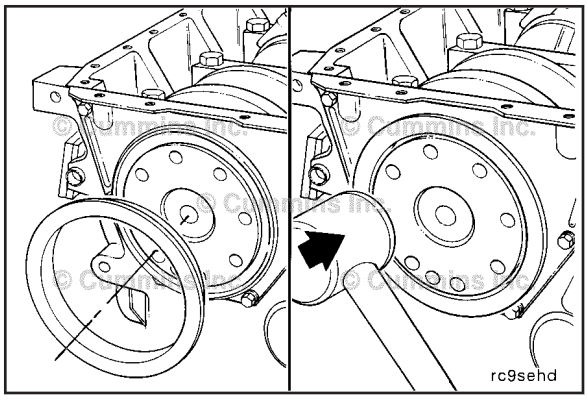
Remove the seal pilot.

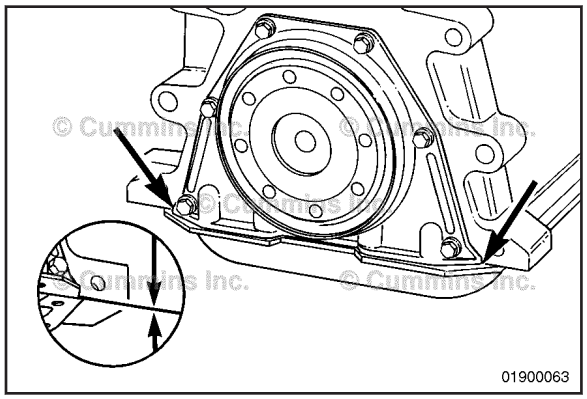
Use the disposable seal driver for front gear train engines to drive the rear crankshaft seal into the rear crankshaft seal carrier.

NOTE: Service tool, Part Number 3824078, used to install the rear crankshaft seal/wear sleeve assembly, can also be used to install the rear crankshaft seal.

Use a plastic hammer to drive the seal into the housing until the alignment tool stops against the housing.

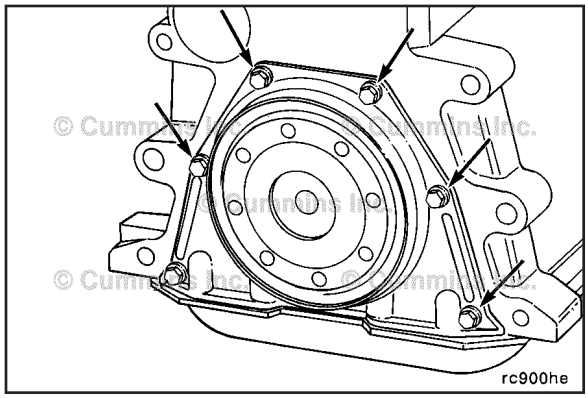
Hit the tool at the 12, 3, 6 and 9 o'clock positions to drive the seal evenly and to prevent bending the seal carrier. Hit the seal driver until contact is made with the rear crankshaft seal carrier.





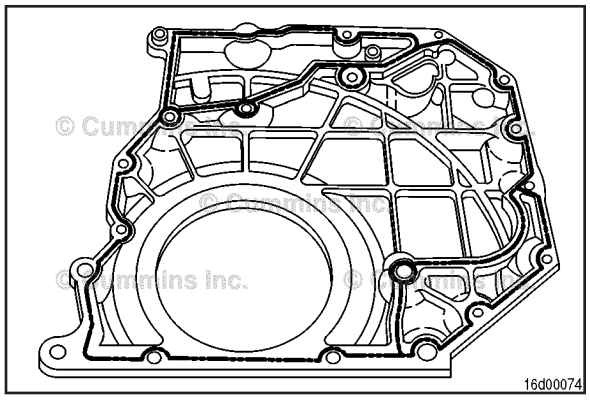
CAUTION
Do not push or force the cover in any direction. This may cause an irregular seal lip position after seal installation. An engine oil leak will result.

Align the rear cover even with both sides of the oil pan rail on the cylinder block.



Tighten the rear cover capscrews. The chart below shows the proper torque value when using either a 9.8 or 10.9 grade capscrew. The grade is embossed on the top of the capscrew.

Rear Seal Carrier				
Bolt Number	Bolt Size	Bolt Class	Torque	Dri-Loc™
3913638	M-6	9.8	10 N•m [89 in-lb]	Yes
3991306	M-6	10.9	13 N•m [115 in-lb]	Yes



Flywheel Housing (016-006)

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.

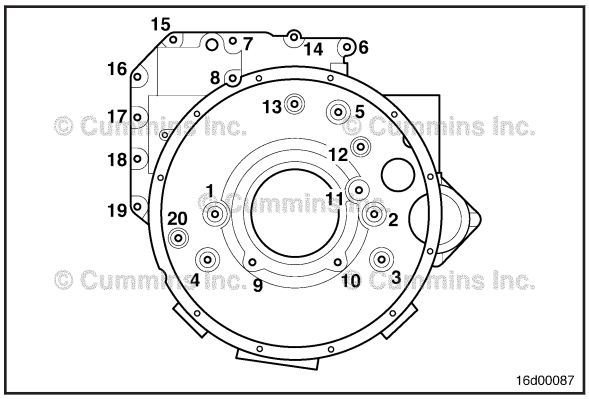
Install the flywheel housing and capscrews.

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:

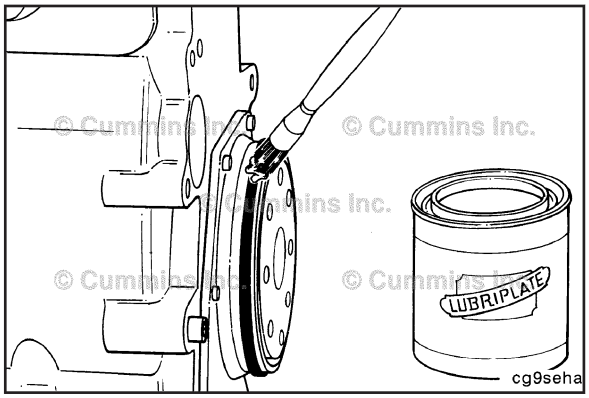
M10	49 N•m	[36 ft-lb]
M12	85 N•m	[63 ft-lb]



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.

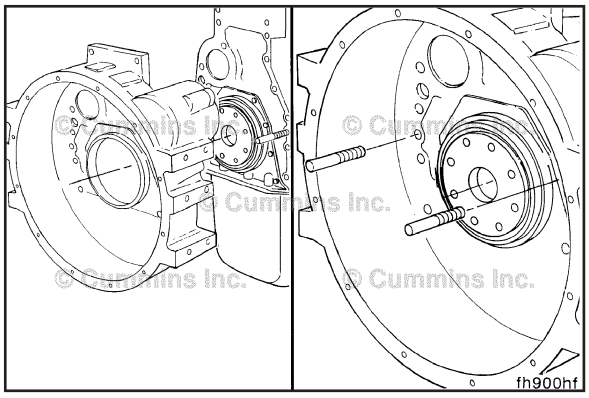


Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and raised nicks or burrs.

Install two guide pins. Part Number 3163934.

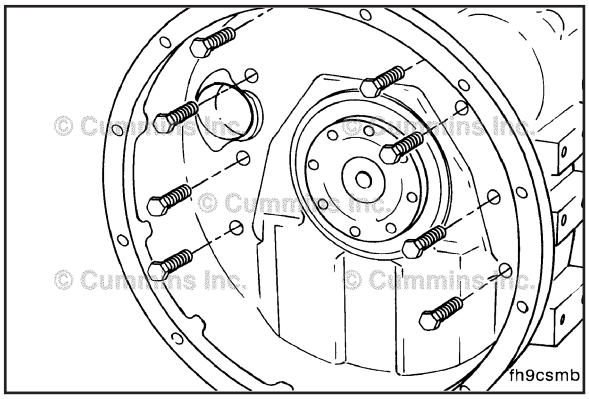
Install the flywheel housing over the guide pins, making sure the flywheel housing is located on the dowel rings.

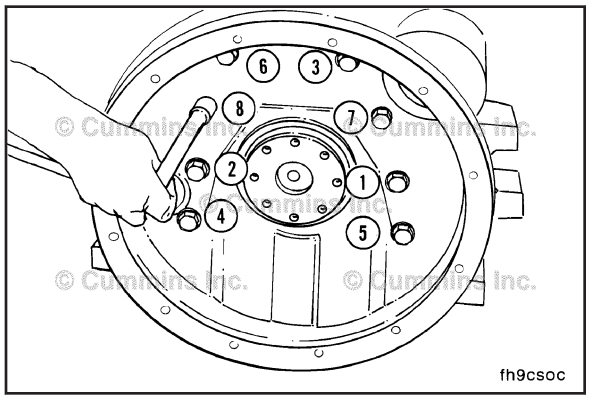
NOTE: Be sure the sealing ring is **not** damaged during installation.



Remove the guide pins.

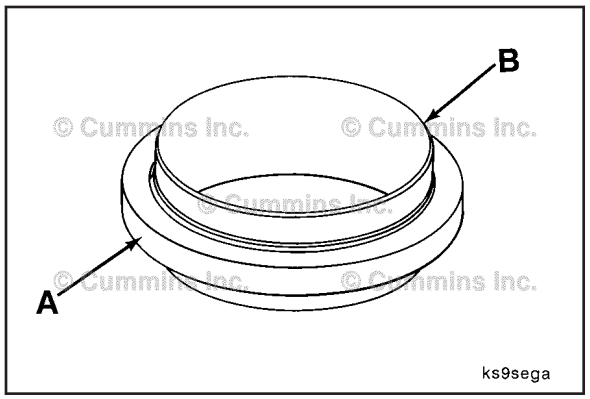
Install the mounting capscrews.





Tighten the flywheel housing capscrews in the sequence shown.

Torque Value: 77 N•m [57 ft-lb]



Crankshaft Seal, Rear (001-024)

Install

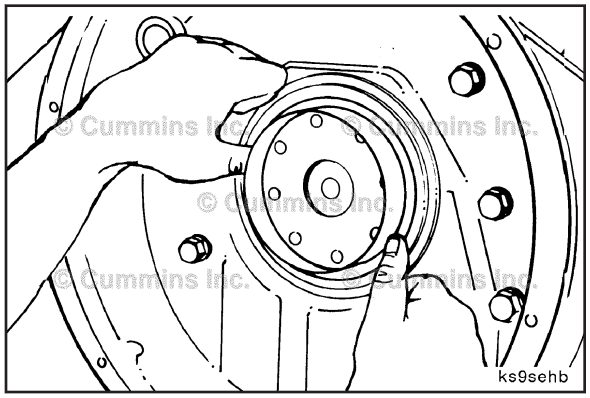
Rear Gear Train

⚠CAUTION⚠
Always replace the rear crankshaft seal with the same style as was previously installed. (wet flywheel housing seal, Lip Seal, Unitized, etc.). Engine oil leaks will result.

⚠CAUTION⚠
The seal lip/bore and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

To aid in installation, apply a mild soap to the outside diameter of the seal case (A).

NOTE: On engines equipped with a lip style rear crankshaft seal, a seal pilot (B) is provided with the new seal. The seal **must** be left on the seal pilot while installing the seal onto the nose of the crankshaft. This will ensure the lips of the seal do **not** get damaged during installation.



⚠CAUTION⚠
Always replace the rear crankshaft seal with the same style seal as was previously installed.

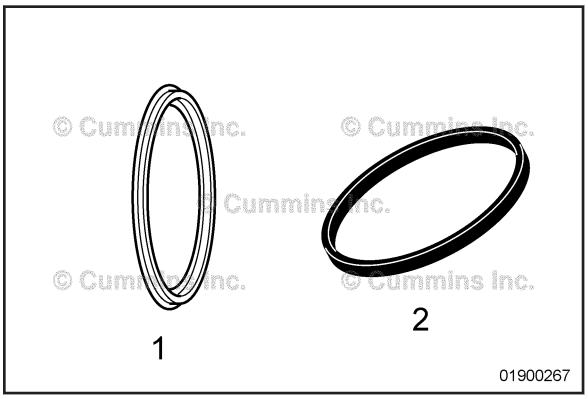
Place the new rear crankshaft seal, with the seal pilot, over the crankshaft nose and slide it by hand toward the flywheel housing.

NOTE: Make sure the seal is positioned squarely with the crankshaft.

Remove the seal pilot.

Each new lip style crankshaft seal comes with a disposable seal driver.

- The seal driver (1) for front gear train engines, which is typically a metal ring, will install the crankshaft seal to the proper depth in the rear seal carrier bore.
- The seal driver (2) for rear gear train engines, which is typically a plastic ring, will install the crankshaft seal to the proper depth in the flywheel housing bore.



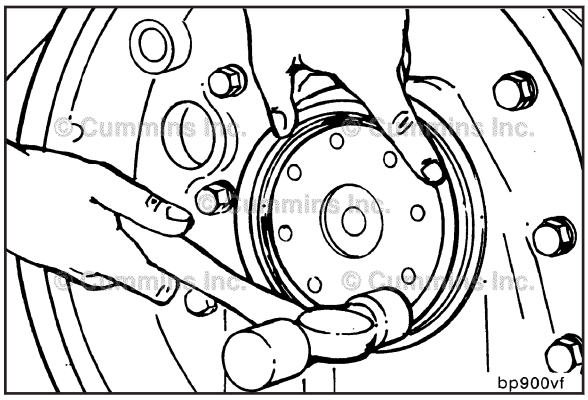
NOTE: For rear gear train engines, rear crankshaft seals for the wet flywheel housing applications do **not** come with a disposable seal driver. Service tool, Part Number 3824078, **must** be used to install the rear crankshaft seal for the wet flywheel housing. This is the same service tool used for installing the rear crankshaft seal and wear sleeve assembly. Refer to procedure 001-067. For front gear train engines, this service tool can be used in place of the disposable seal driver that comes with the crankshaft seal.

NOTE: It may be necessary to lightly tap the rear crankshaft seal with a plastic hammer without the disposable seal driver to help get the seal started.

Use the appropriate disposable seal driver that comes with each new rear crankshaft seal to install to the correct depth in the housing.

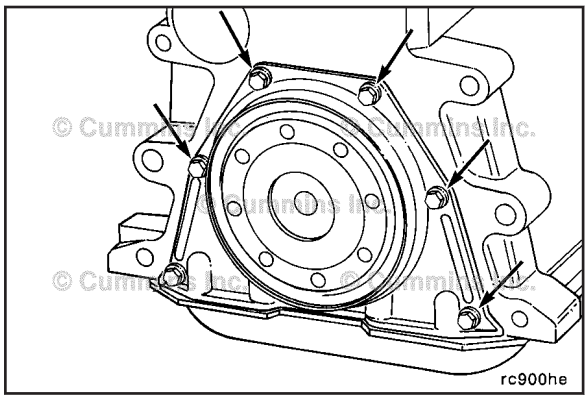
Use a plastic hammer to drive the seal into the housing until the alignment tool stops against the housing.

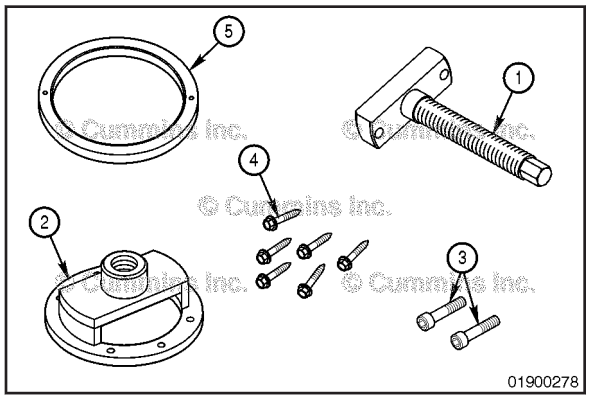
Hit the tool at 12, 3, 6 and 9 o'clock positions to drive the seal evenly and to prevent bending the seal carrier.



Front Gear Train

The rear crankshaft seal is installed when the rear crankshaft seal carrier is installed.



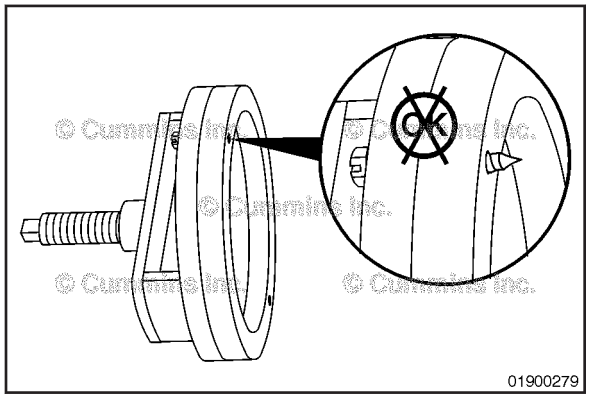


Optional Method

For rear gear train engines, the disposable plastic driver that comes with the new rear crankshaft seal has been designed with two holes in the outer ring. These holes are provided so that the driver can be used in conjunction with the Rear Crankshaft Seal Replacer Kit, Part Number 3164660.

Table 2. Rear Crankshaft Seal Replacer Kit, Part Number 3164660

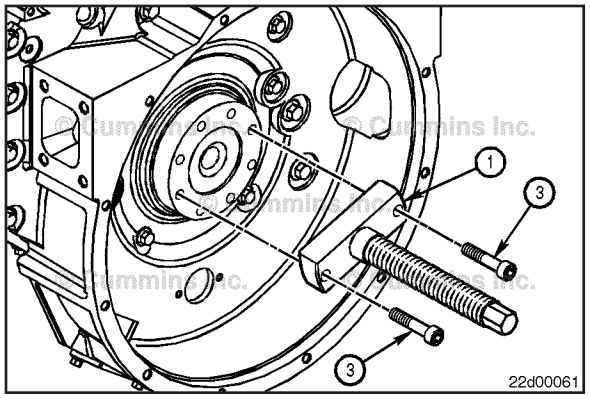
Item Number	Part Number	Description	Quantity
1	3164666	Replace screw assembly	1
2	3164664	Crankshaft seal replacer	1
3	3164174	Socket head capscrew, M12 x 1.25 x 25 mm	2
4	3164217	Sheet metal screw, Number 10 x 25.4 mm [1 in] long	25 (7 shown)
Not shown	3164218	Drill. 3.57 mm [9/64 in]	1
5	—	Disposable plastic driver (purchased with rear crankshaft seal kit)	1



⚠CAUTION⚠
Do not use the sheet metal screws that come with the Rear Crankshaft Seal Replacer Kit, service tool part number 3164660. The sheet metal screws are too long. When selecting the correct sheet metal screw, make sure the tip of the sheet metal screw does not protrude past the face of the driver. Damage to the crankshaft seal will result.

With the correct side of the disposable driver facing outwards for the type of seal that will be installed, center the disposable driver on the crankshaft seal replacer.

Attach the disposable driver to the crankshaft seal replacer using a number 2 sheet metal screw (number 10 by 19 mm [.75 in] long).



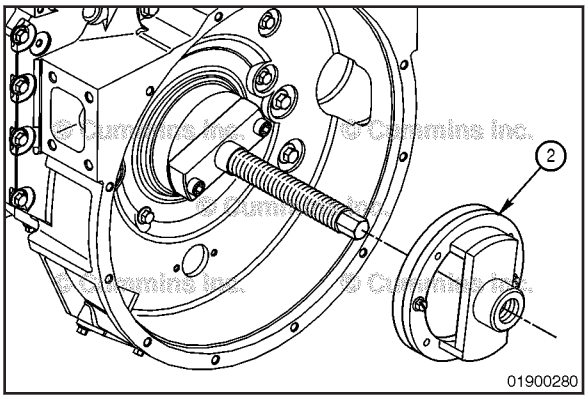
With the rear crankshaft seal installed onto the crankshaft flange as described earlier in this procedure, mount the replacer screw assembly (1) onto the rear of the crankshaft.

Install the two M12 x 1.25 x 60-mm socket head capscrews (3).

⚠CAUTION⚠
Do not use an impact wrench or air tools. Doing so can damage the tool.

Lubricate the replacer screw with anti-seize compound or a suitable grease.

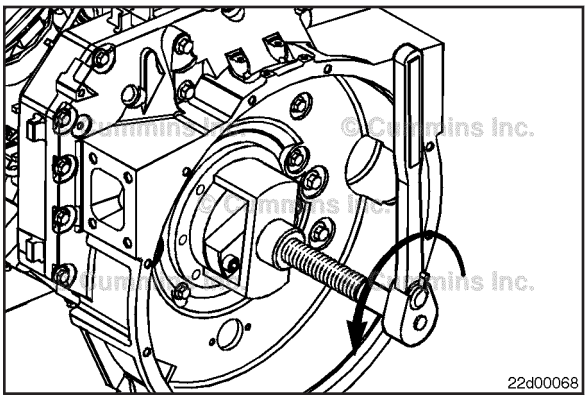
Hold the replacer screw and install the crankshaft seal replacer (2) onto the replacer screw assembly. Advance the crankshaft seal replacer toward the seal by rotating it **clockwise** until the attached disposable driver is positioned against the rear crankshaft seal.



⚠CAUTION⚠
Do not overtighten the replacer screw assembly after the crankshaft seal replacer contacts the flywheel housing. Doing so can damage the tool.

While holding the crankshaft seal replacer, rotate the replacer screw counterclockwise until the disposable driver attached to the crankshaft seal replacer makes contact with the flywheel housing.

Remove the service tools.



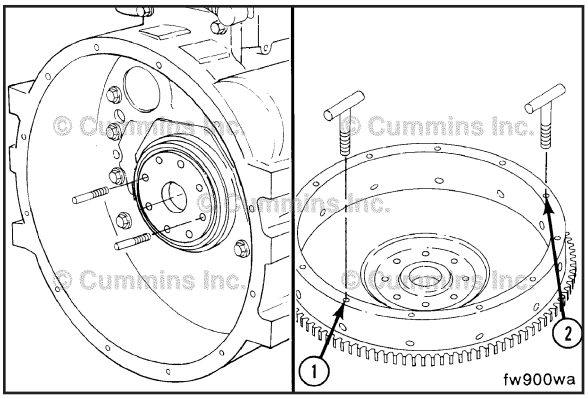
Flywheel (016-005)

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.

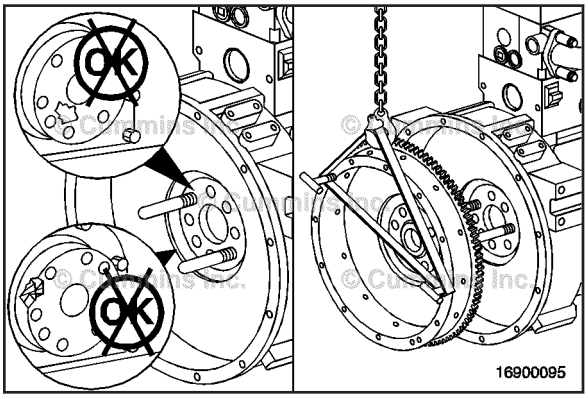
Determine the capscrew thread design and size, and install two T-handles into the flywheel (at points 1 and 2).

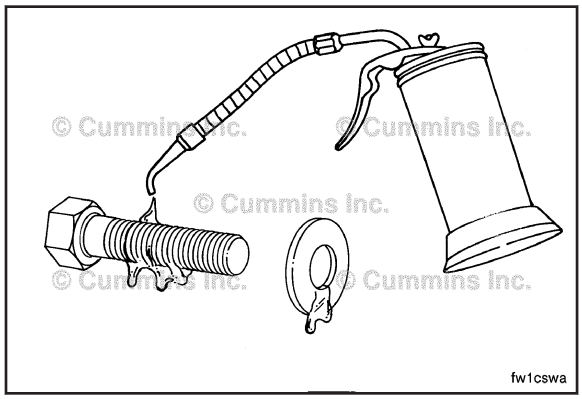


⚠WARNING⚠
The component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

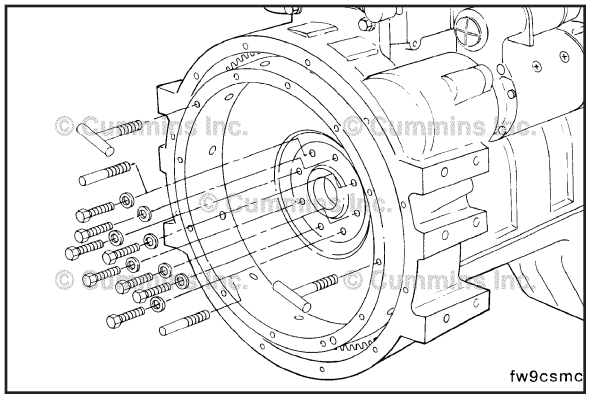
Inspect the rear face of crankshaft and flywheel mounting flange for cleanliness and raised nicks or burrs.

Install the flywheel on the guide pins.





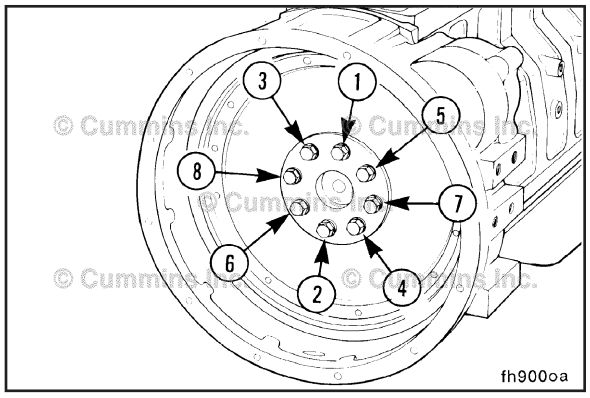
Lubricate the threads of the capscrews and the surface of the washers with clean lubricating engine oil.



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]

Flexplate (016-004)

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.

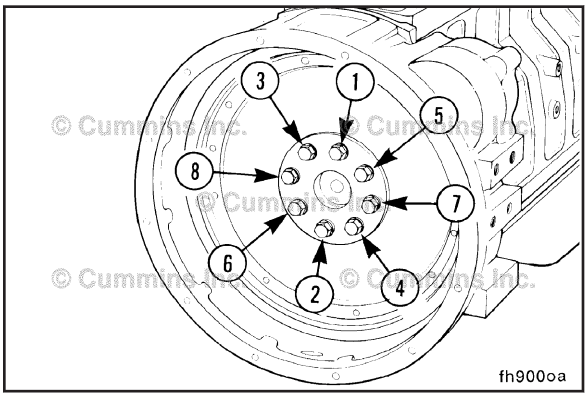
Install the flexplate capscrews, flexplate, and tighten.

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]



Starting Motor (013-020)

Measure

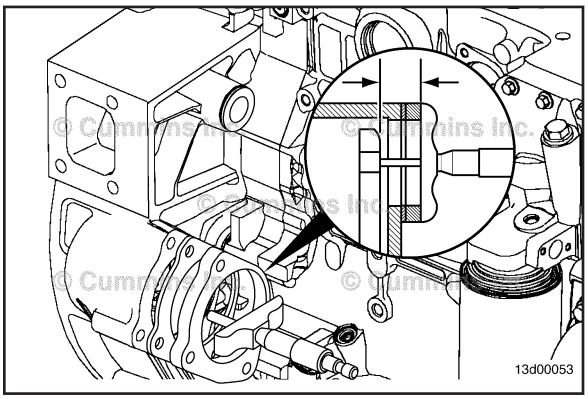
Using an inside micrometer or a vernier caliper, measure the distance from the starting motor mounting flange to the forward face of the front side of the flywheel ring gear.

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

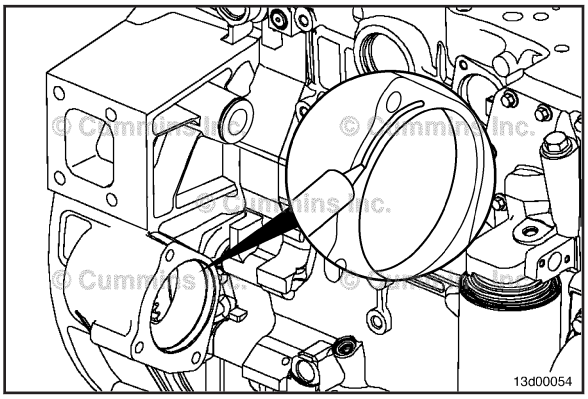
Add or remove spacers as necessary to achieve the correct starting motor spacing.

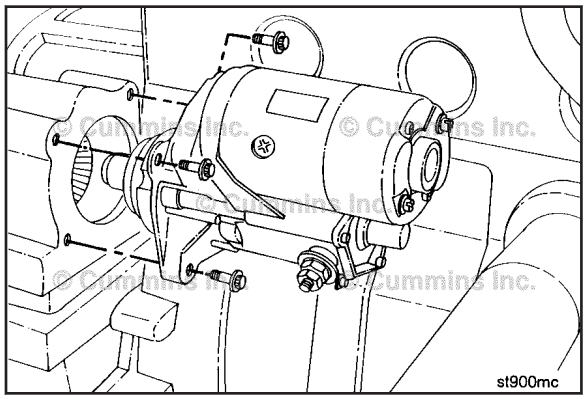


Install

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.

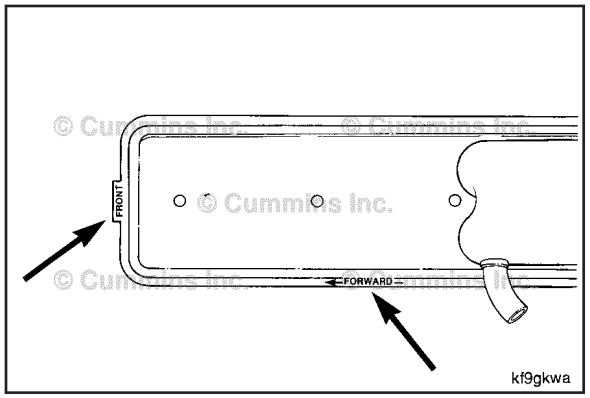
NOTE: If a starting motor spacer is required, make sure to apply sealant to the side of the spacer that contacts the starting motor.





Install the three capscrews, the starting motor, and starting motor spacer, if required.

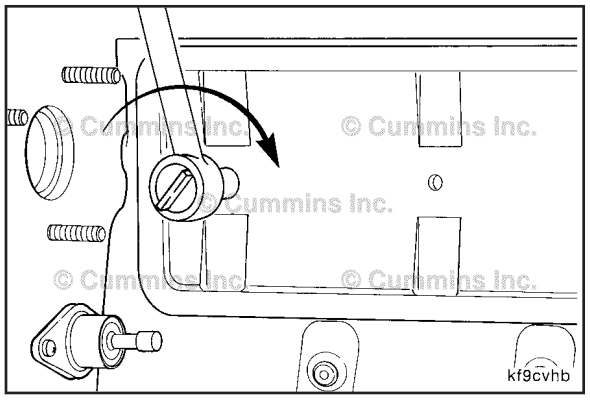
Torque Value: 43 N•m [32 ft-lb]



Tappet Cover (004-017)

Install

Install the tappet cover gasket onto the tappet cover. The tappet cover gasket **must** be installed as shown in the illustration.

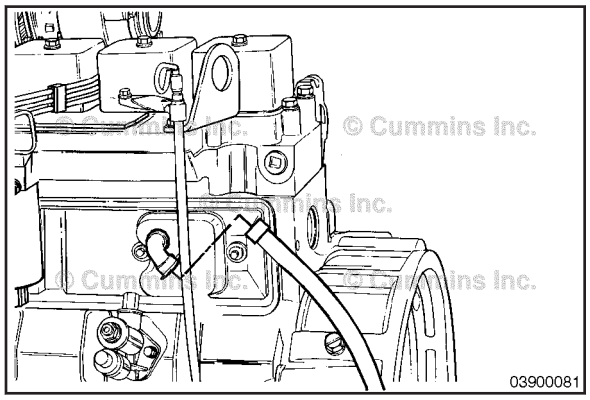


Install the tappet cover, gasket, sealing washers and mounting capscrews onto the engine block.

NOTE: Some of the tappet cover mounting capscrews also secure the fuel drain. It may be necessary to install the remaining mounting capscrews when the fuel drain is installed.

Tighten the tappet cover mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]



Crankcase Breather Tube (003-018)

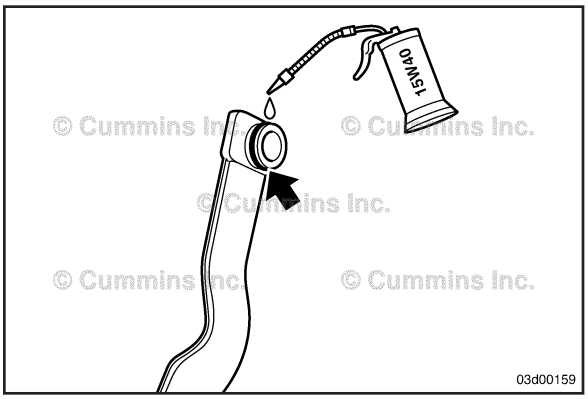
Install

Front Gear Train

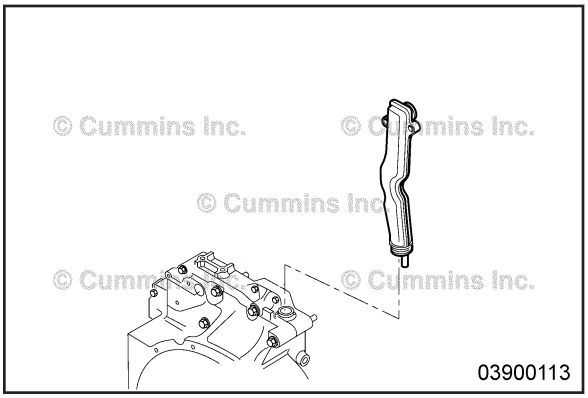
Connect the crankcase breather tube to the tappet cover on the side of the cylinder block.

Rear Gear Train

Prior to installing the breather tube, apply engine oil to the o-rings located on the breather tube.



Install the breather tube into the rear gear housing.



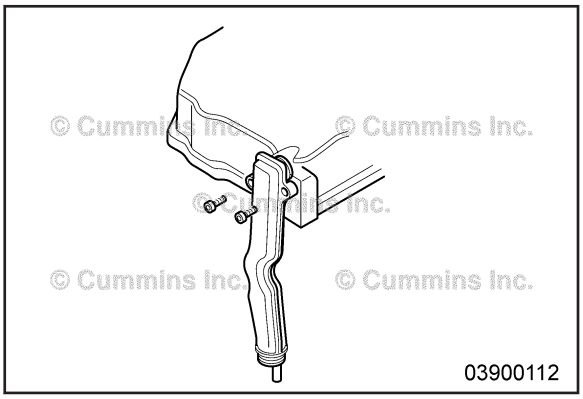
Connect the breather tube connection to the rocker lever cover.

Two capscrews directly mount the breather tube to the rocker lever cover. Install the capscrews to connect the breather tube connection to the rocker lever cover.

Tighten the capscrews.

Torque Value: 10 N•m [89 in-lb]

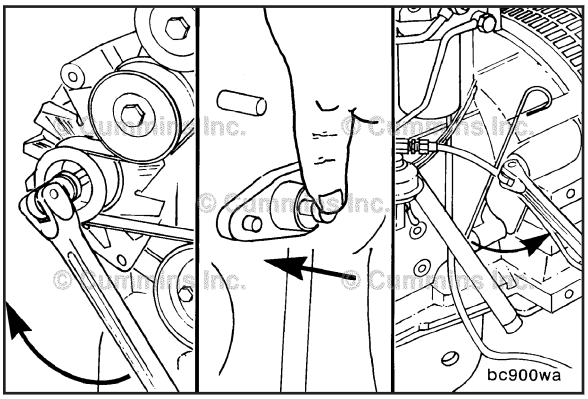
NOTE: Some breather tube connections use internal Torx capscrews to secure the breather tube to the rocker lever cover.

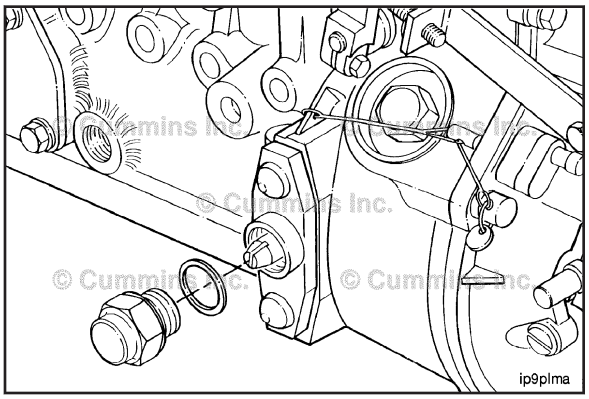


Fuel Injection Pumps, In-Line (005-012)

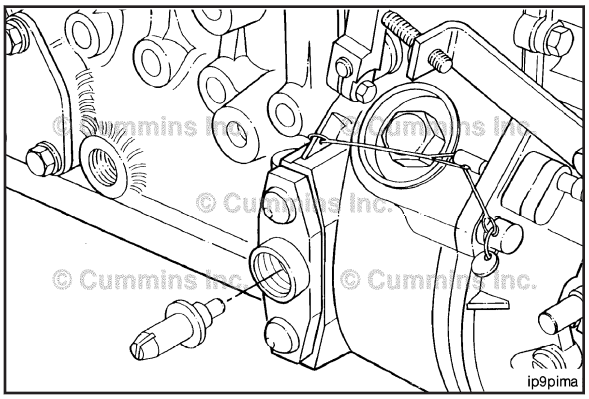
Install

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

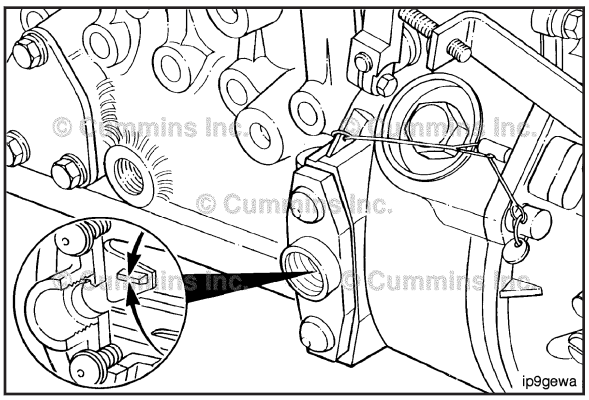




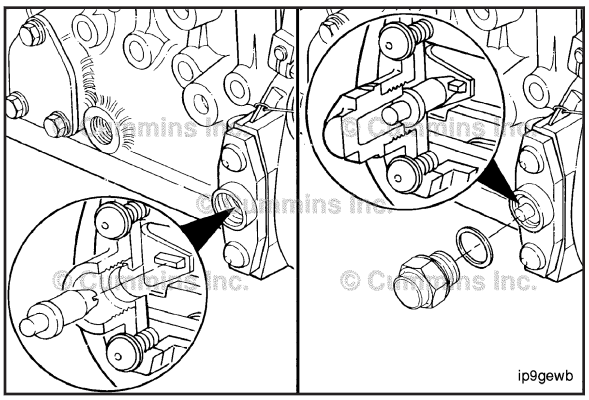
Remove the access plug.



Remove the timing pin.



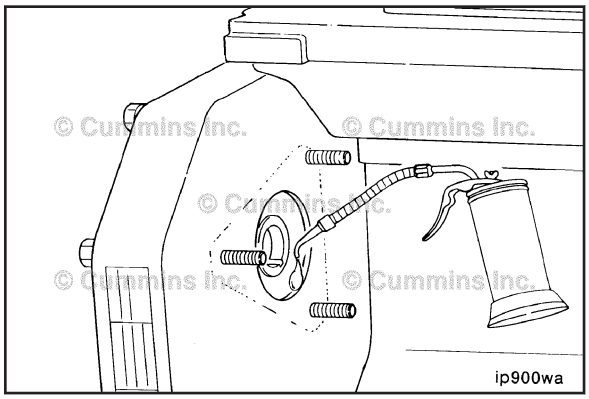
If the timing tooth is **not** aligned with the timing pin hole, rotate the fuel injection pump shaft until the timing tooth aligns.



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

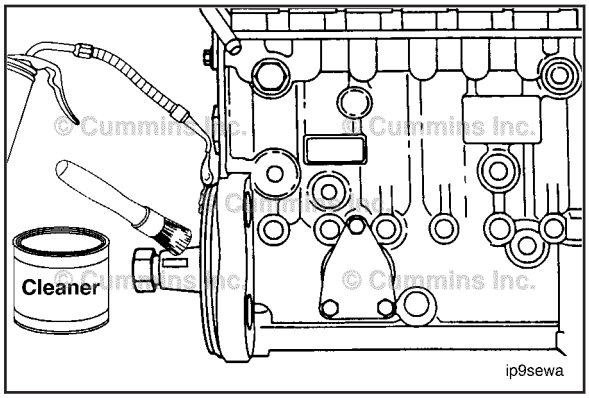
Install and secure the timing pin with the access plug.

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.

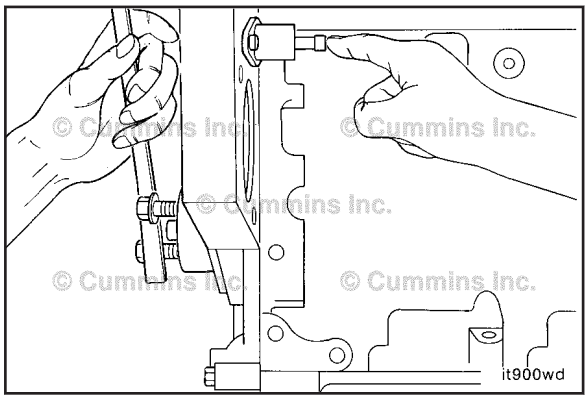
NOTE: Before installing the fuel pump drive gear, clean the injection pump shaft and gear tapers with residue-free cleaner, Part Number 3824510, by spraying into the gap between the shaft and the gear. Dry with compressed air.

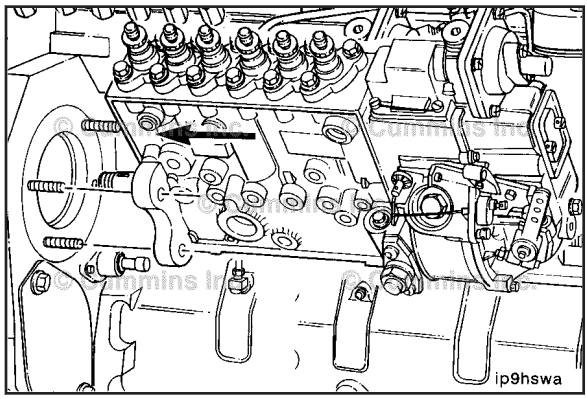
NOTE: The in-line fuel injection pump driveshaft has a provision for a Woodruff key: however, it is **not** required. Timing mark alignment is **not** required for the in-line drive gear.

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

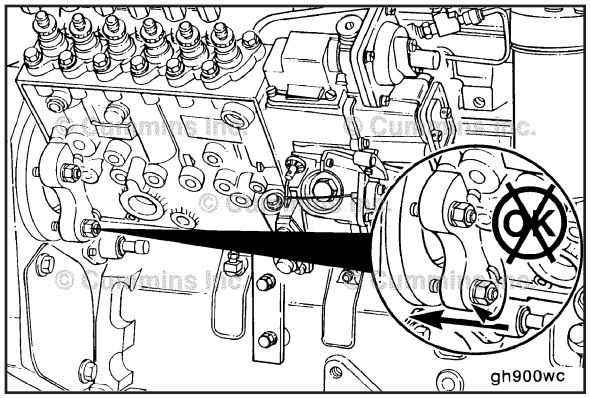
Make certain that the o-ring seals for the fill orifice and pilot are correctly installed and are **not** damaged.

Install new pilot o-ring.

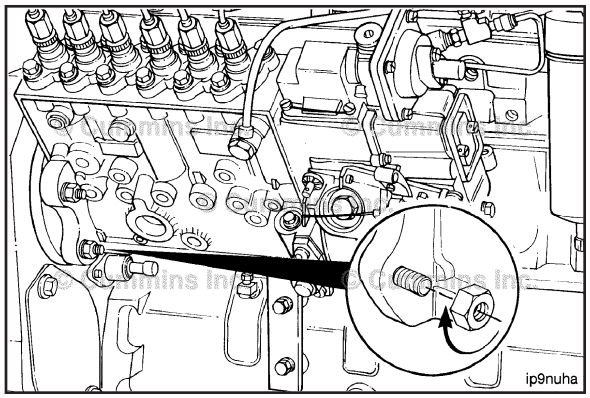




Push the pump forward until the mounting flange and o-ring are properly fitted into the gear housing bore.



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

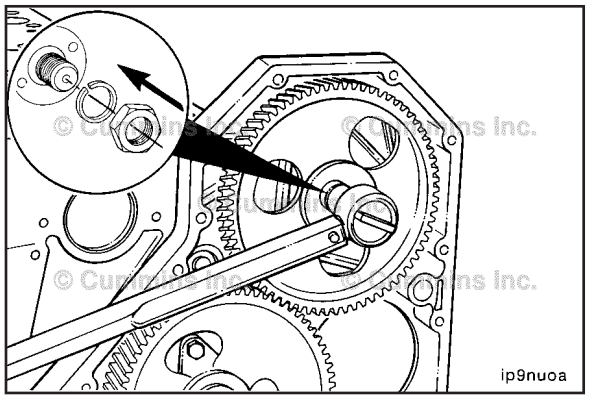


Install the mounting nuts.

Torque Value: 43 N•m [32 ft-lb]

Install the support bracket (if equipped).

Torque Value: 32 N•m [24 ft-lb]



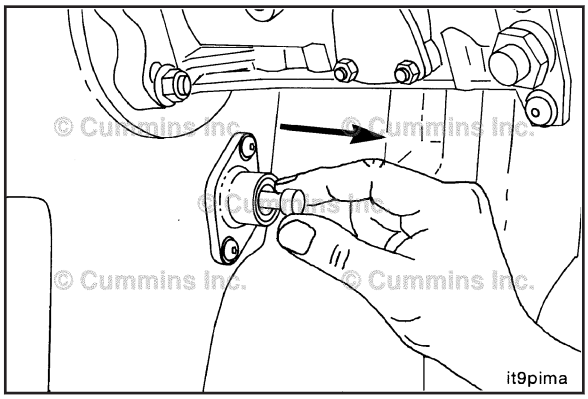
Install the fuel injection pump drive gear onto the fuel pump shaft.

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.

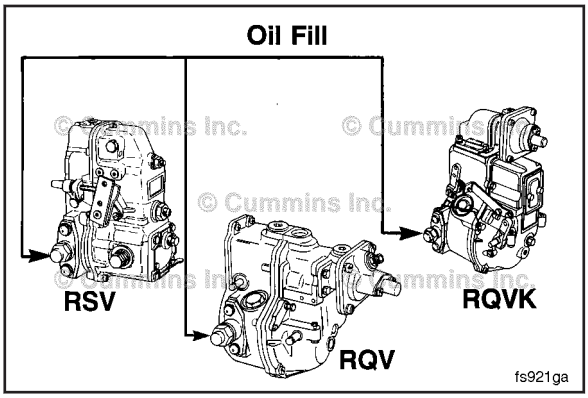


CAUTION
The governor housing must be prelubricated before engine operation. Failure to do so can result in premature governor wear.

Remove the access plug.

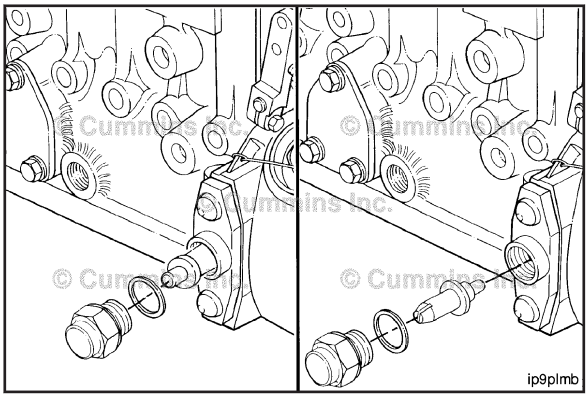
Add the following quantity of clean lubricating engine oil:

- 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.

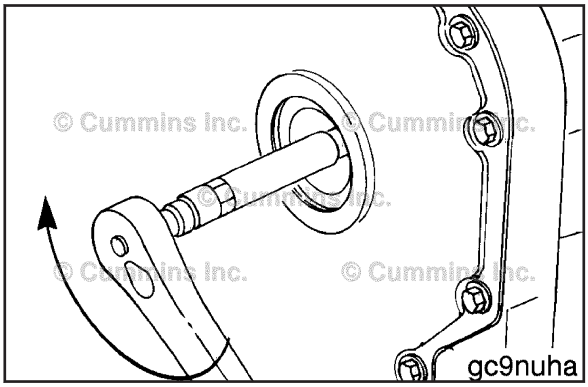
Torque Value: 27 N•m [20 ft-lb]

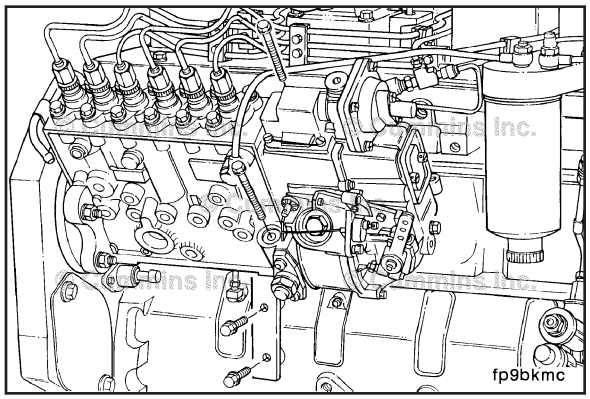


Tighten the fuel injection pump drive nut.

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]

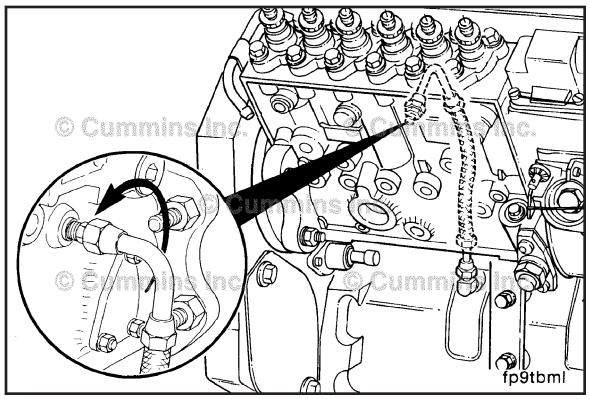




Install the fuel injection pump mounting bracket capscrews.

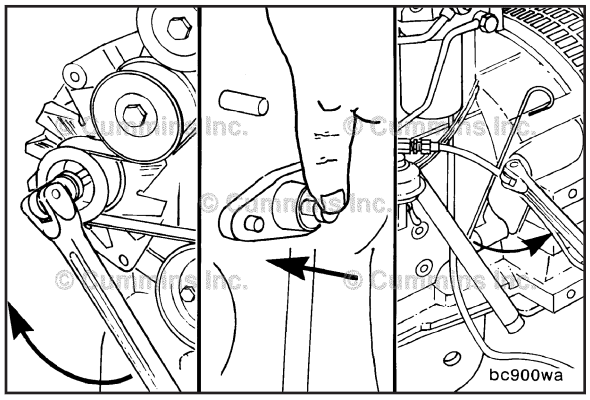
Tighten all capscrews by hand for proper alignment.

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.

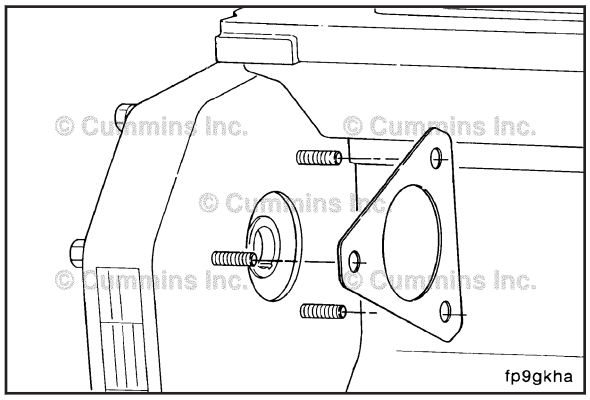


Fuel Injection Pump, Rotary (005-014)

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.

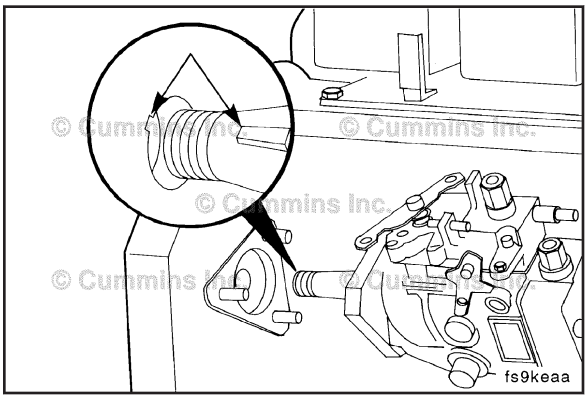


Install a new gasket.

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.

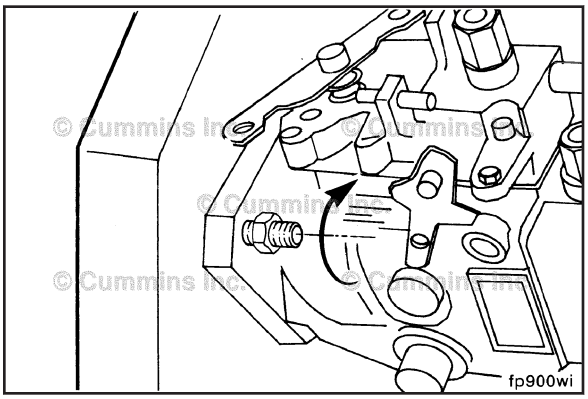
Install the pump.

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



Use your hands to 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).



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

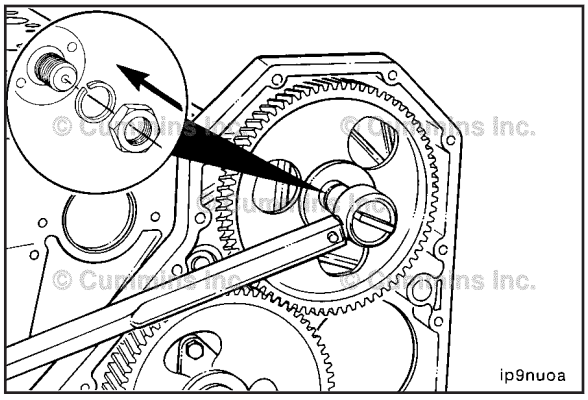
NOTE: The drive shaft and drive gear bore **must** be clean and free from all oil before installation. Failure to make certain the drive shaft is free of oil can result in the drive gear slipping on the shaft.

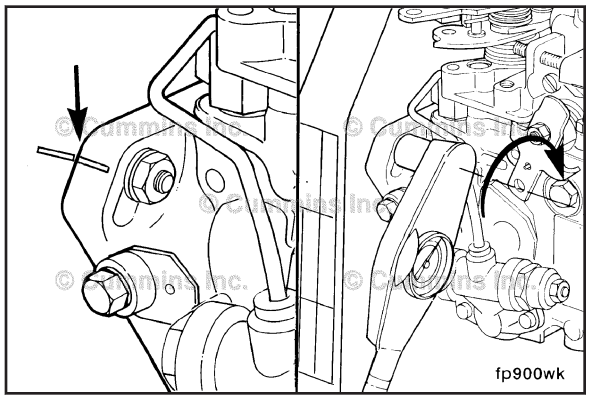
Install the fuel injection pump drive gear onto the fuel pump shaft.

If equipped, align the timing key on the drive shaft to the slot in the fuel injection pump drive gear.

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.

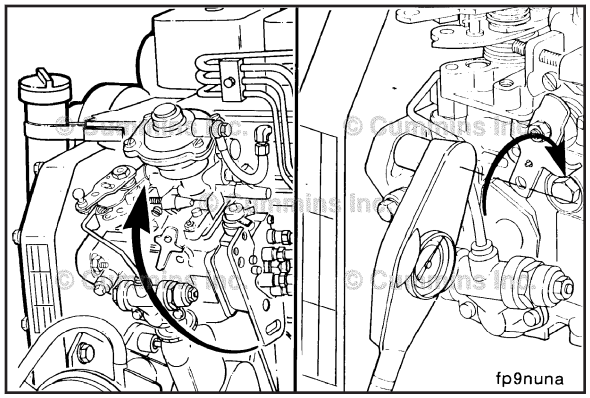
Torque Value: 15 to 20 N•m [11 to 15 ft-lb]





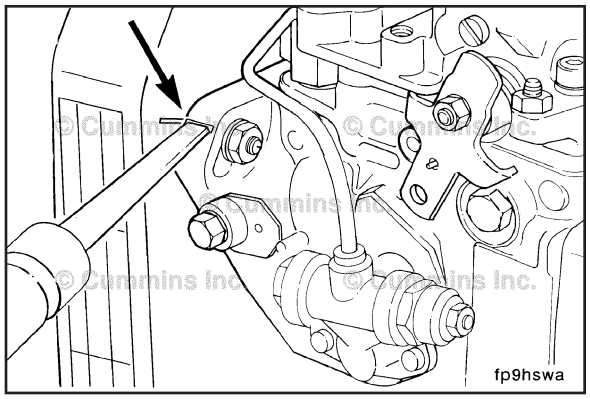
If installing the original pump, rotate the pump to align the scribe marks.

Torque Value: 24 N•m [18 ft-lb]

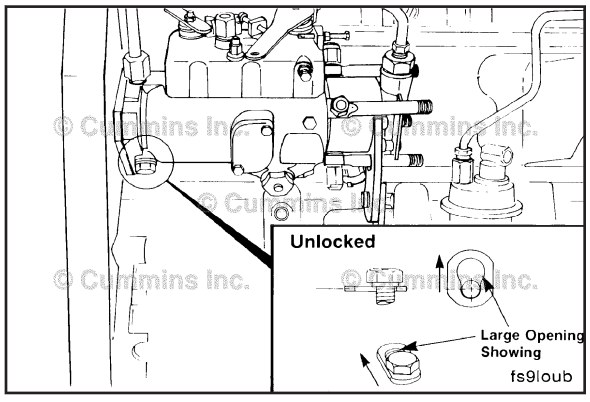


If installing a new or rebuilt pump without scribe marks, take up gear lash by rotating the pump against the direction of drive rotation. Tighten the flange mounting nuts.

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

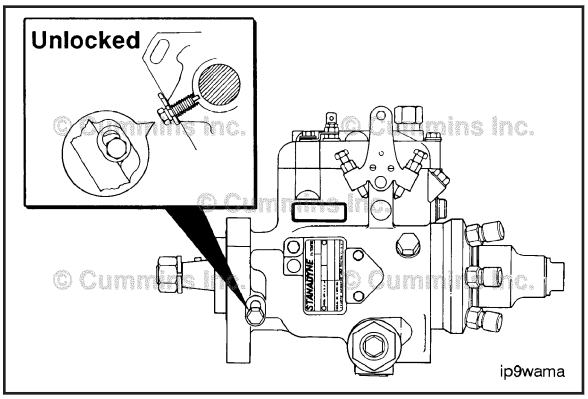
For CAV fuel injection pumps, loosen the lockscrew and position the special washer behind the lockscrew head.

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.

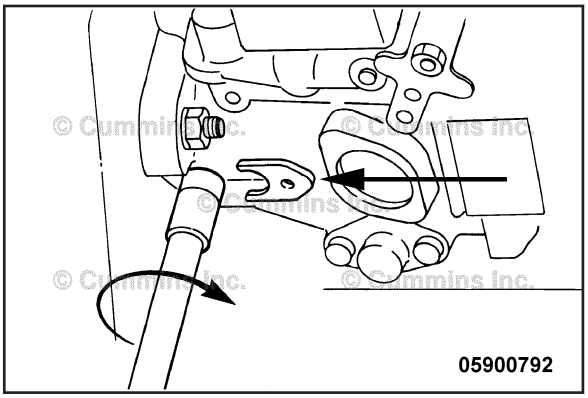


Bosch® VE

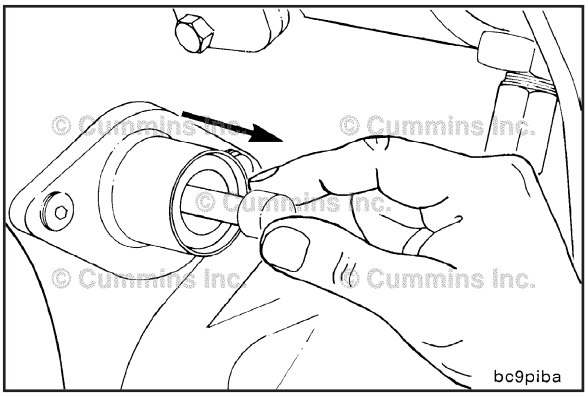
Loosen the Bosch® fuel pump lock timing screw and install the special washer that is wired to the fuel pump.

Tighten the Bosch® fuel pump lock timing screw.

Torque Value: 13 N•m [115 in-lb]



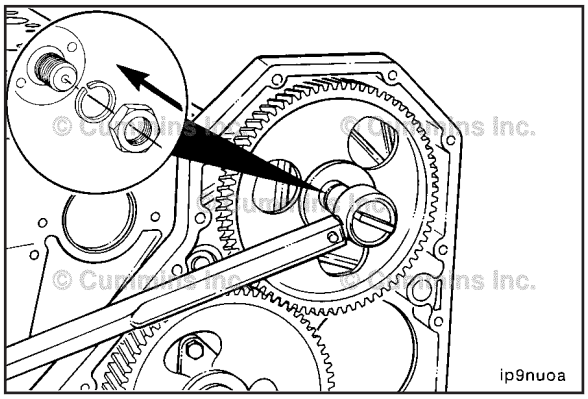
Disengage the timing pin before rotating the crankshaft.

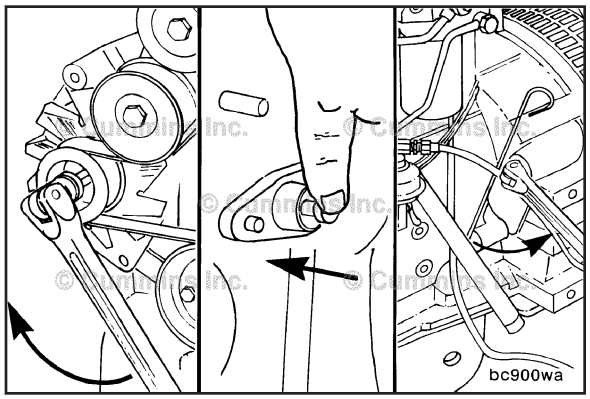


Tighten the pump gear retaining nut.

Torque Value:

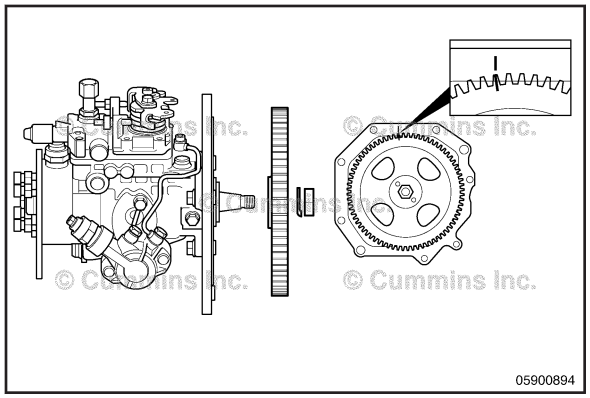
Bosch® VE (M14-1.5 nut)	98 N•m	[72 ft-lb]
Bosch® VE (M12 nut)	65 N•m	[48 ft-lb]
Lucas CAV/DPA	81 N•m	[60 ft-lb]
Stanadyne	65 N•m	[48 ft-lb]
Delphi DP21	93 N•m	[68 ft-lb]





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.

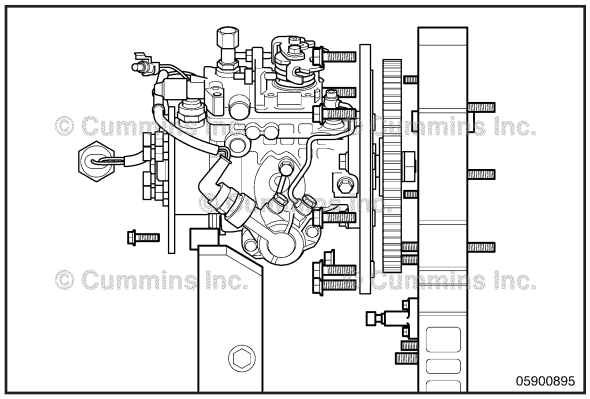


Verify the alignment mark on the fuel pump gear and the mark on the fuel pump mounting plate created during disassembly are aligned before installing the fuel pump assembly.

If the marks are **not** aligned, with the fuel injection pump locked, the fuel pump gear **must** be loosened and the marks aligned.

Tighten the pump retaining nut.

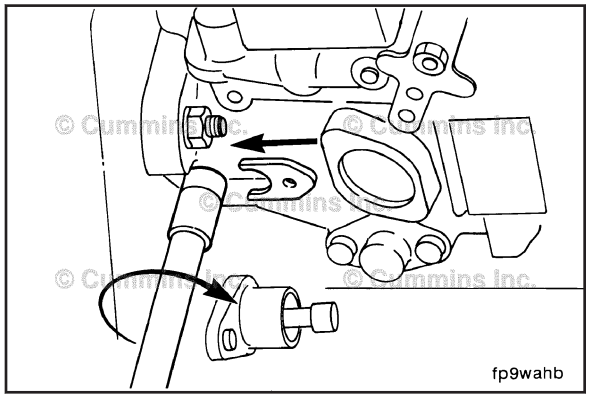
Torque Value: 98 N•m [72 ft-lb]



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]

Fuel Pump Support Bracket (005-033)

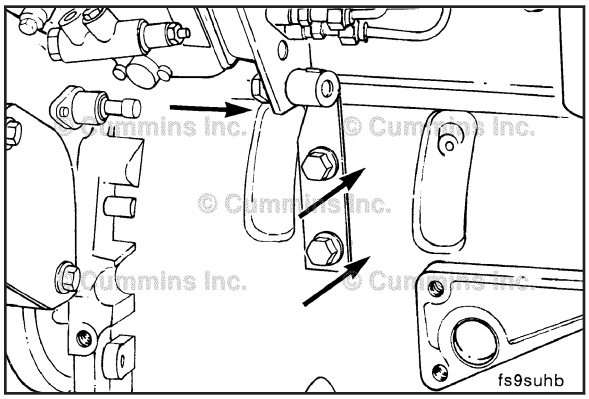
Install

Front Gear Train

Bosch®; and Stanadyne Rotary Pumps

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

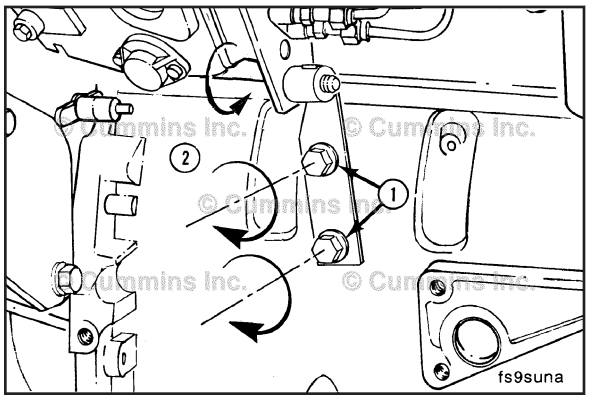
NOTE: Tighten bracket to block before tightening the bracket to the pump.



10 mm

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

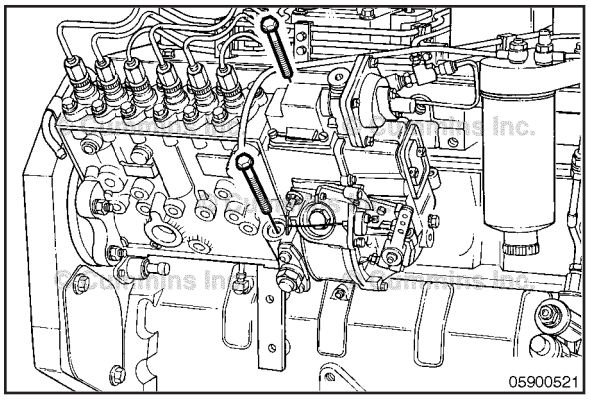
Torque Value: 24 N•m [18 ft-lb]



In-line Fuel Injection Pumps

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

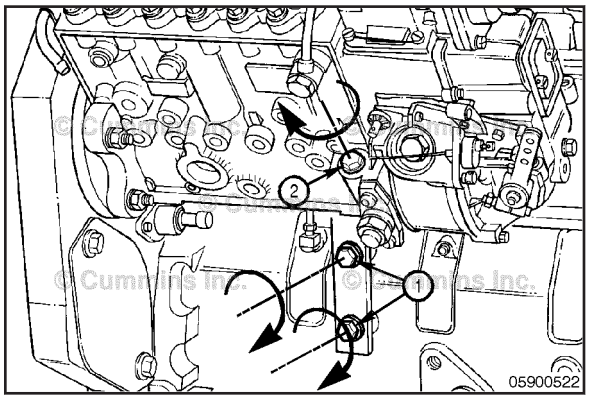
NOTE: Tighten bracket to block before tightening the bracket to the pump.

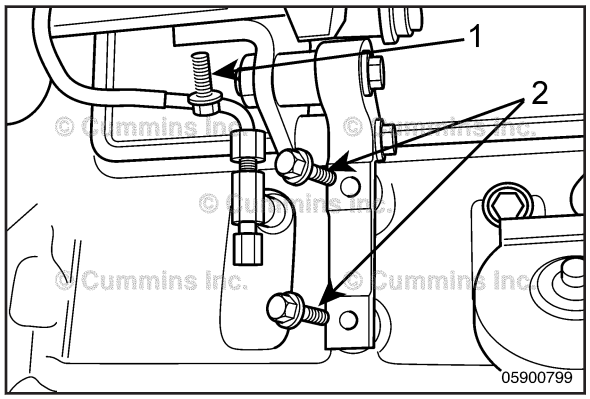


10 mm

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.

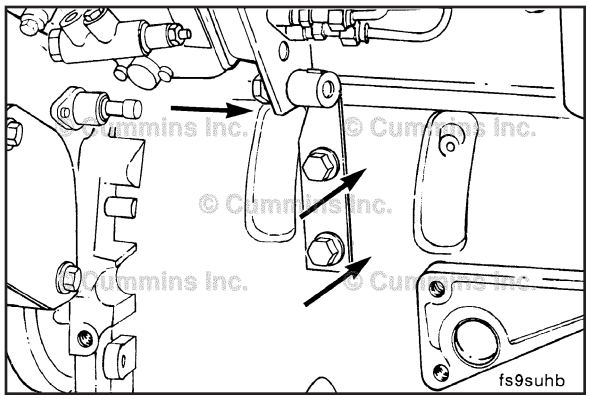
NOTE: Tighten bracket to block before tightening the bracket to the pump.

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]

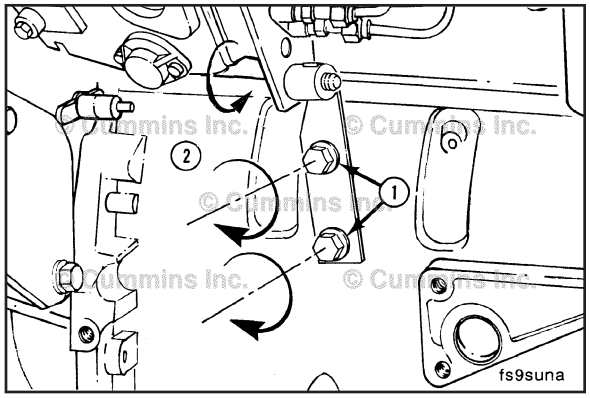
NOTE: Not all four cylinder engines are equipped with this style bracket. If the engine is equipped with a two piece bracket, install the bolts as depicted.



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

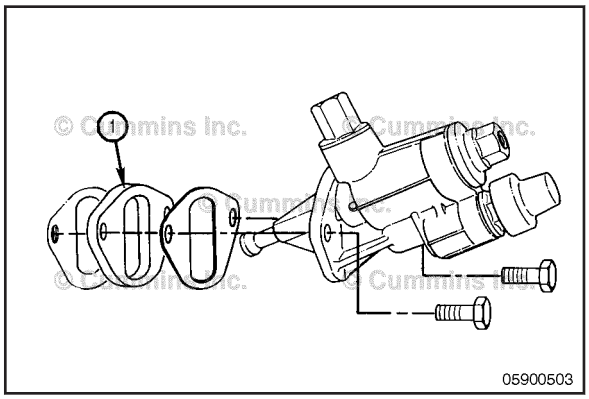
Tighten capscrew and bracket to the injection pump (2) first; then the capscrews to the bracket and block (1).

Torque Value: 24 N•m [18 ft-lb]

Fuel Lift Pump (005-045)

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.

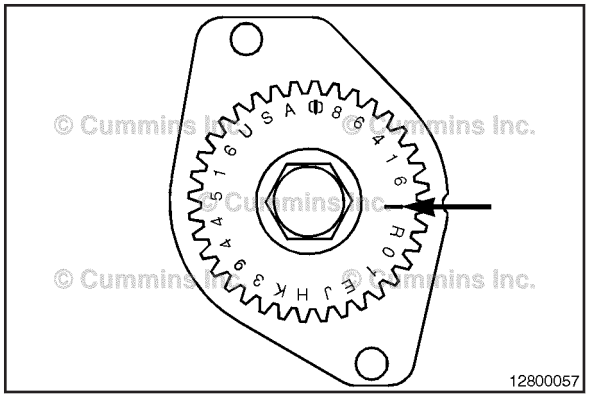
NOTE: For some applications, a bracket used for supporting other options will replace the 5 mm [0.20-in] spacer.

Air Compressor (012-014)

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.

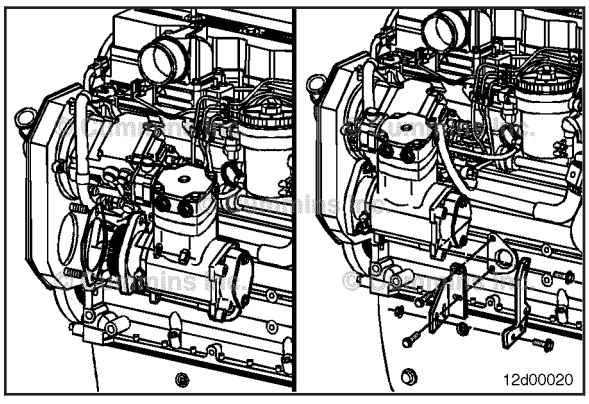
Torque Value:
Mounting Nuts 77 N•m [57 ft-lb]

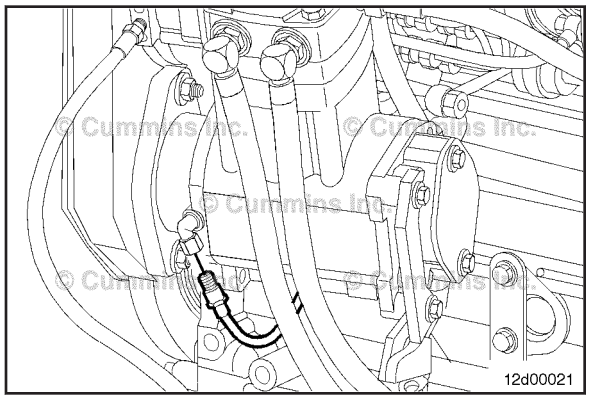
Torque Value:
Support Capscrews to Air Compressor Support 43 N•m [32 ft-lb]

Torque Value:
Capscrews to Block 57 N•m [42 ft-lb]

Compressor drive gear mounting nut torque:

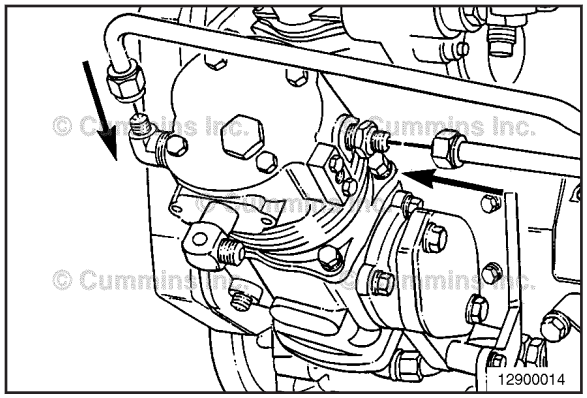
Torque Value:
Knorr-Bremse™ 165 N•m [122 ft-lb]





Install the oil supply line.

Torque Value: 15 N•m [133 in-lb]



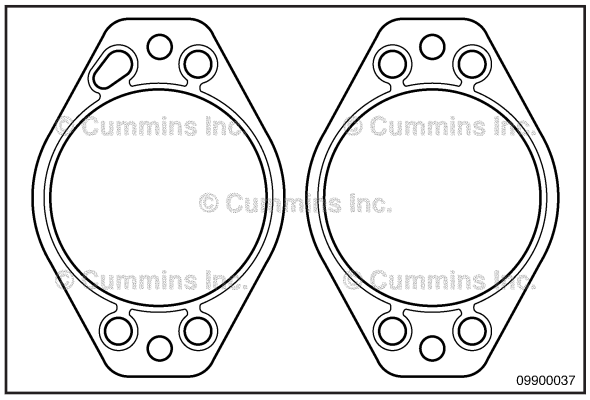
Air Compressor Coolant Lines (012-004)

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]



Accessory Drive Cover (009-039)

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:

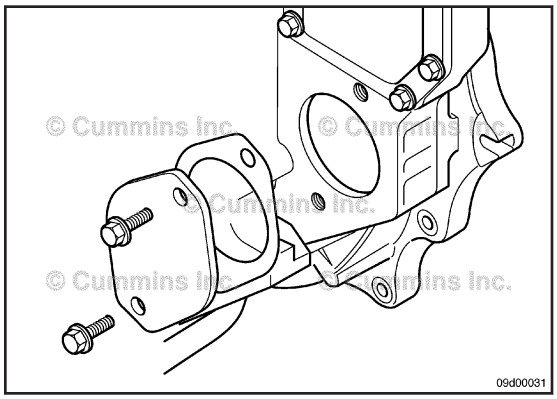
1. Three round oil supply passages and one elongated oil supply passage
2. Four round oil supply passages.

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]



Accessory Drive (009-001)

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.

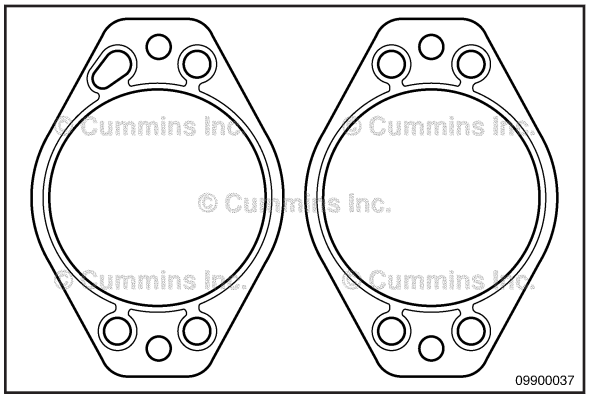
Prior to installing the accessory drive, identify which gasket is going to be installed so that, if necessary, the gasket can be properly oriented.

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

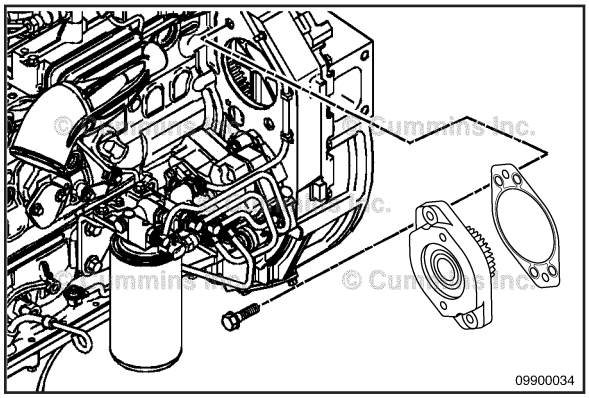
⚠CAUTION⚠
Failure to line up the oil supply hole to the accessory drive properly will result in accessory drive damage.

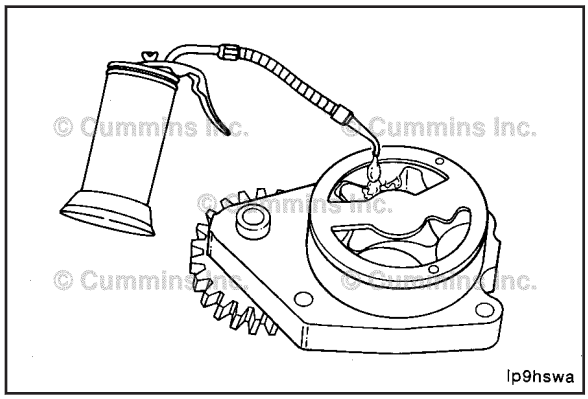
Install the accessory drive and new gasket.

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]



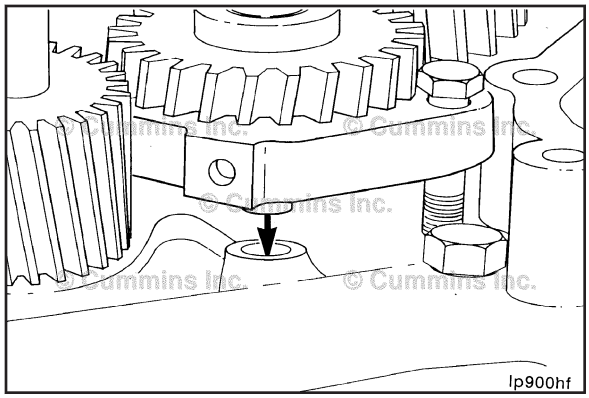


Lubricating Oil Pump (007-031)

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.

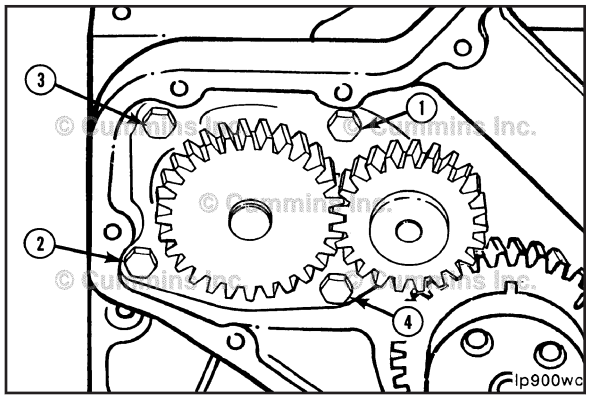
Lubricate the lubricating oil pump with clean 15W-40 engine oil.



⚠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.



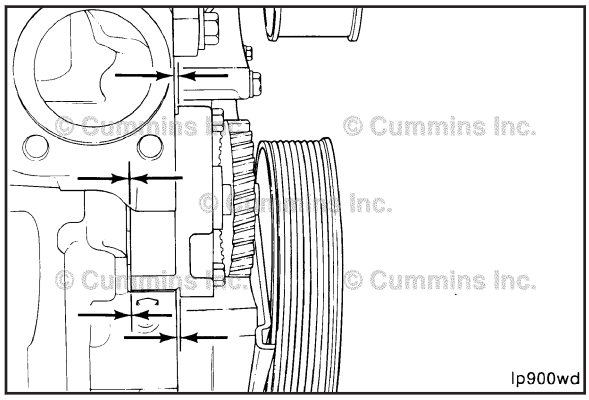
Using the sequence shown, torque the capscrews in the following sequence:

Initial Torque

Torque Value: 8 N•m [70 in-lb]

Final Torque

Torque Value: 24 N•m [212 in-lb]



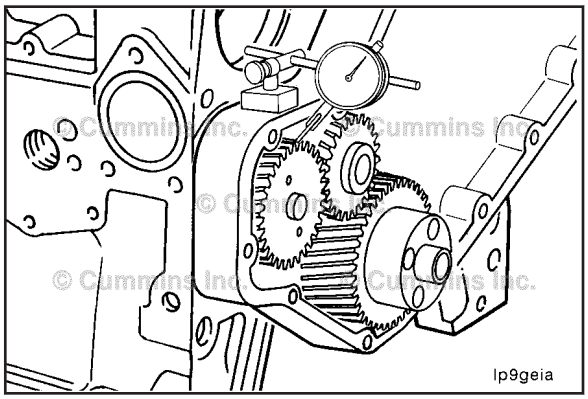
NOTE: The back plate on the pump seats against the bottom of the bore in the cylinder block. When the lubricating oil pump is correctly installed, the flange on the lubricating oil pump will **not** touch the cylinder block.

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

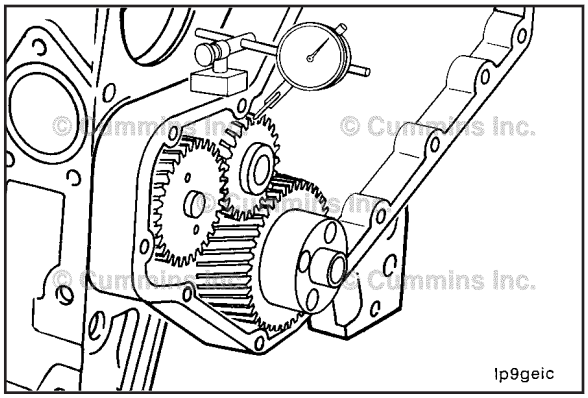
NOTE: If you are reinstalling a used pump and have already measured the backlash you do **not** need to complete this step.

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.

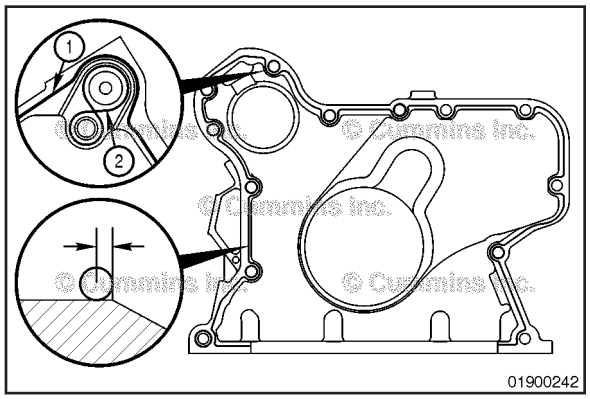
NOTE: If the adjoining gear moves when you measure the backlash, the reading will be incorrect.



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.



Gear Cover, Front (001-031)

Install

Rear Gear Train

NOTE: Install three guide pins, Part Number 3164977, to improve alignment of the front cover and front seal to the gear housing and crankshaft.

Apply a 1.5 to 2.0 mm [0.06 to 0.08 in] wide bead of sealant, Part Number 3164070, to the block side of the front gear cover in the path illustrated.

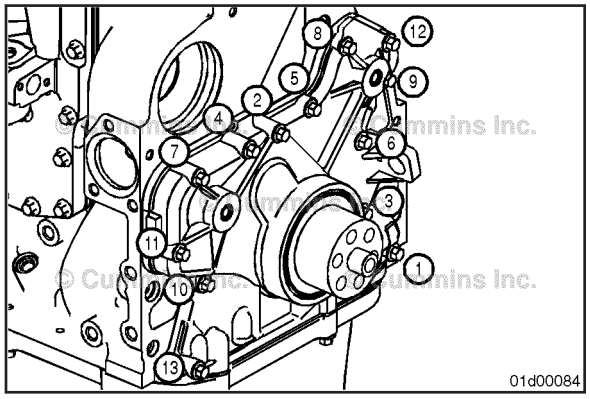
On engines equipped with an oil pressure sensor/switch located in the front gear cover, there are two critical sealant paths that **must** be followed:

1. In this area, the sealant **must** be applied towards the outer edge of the front gear cover to avoid an unused mounting hole in the cylinder block.

NOTE: To make sure the unused mounting hole in the cylinder block does not affect the sealing joint, fill the mounting hole with sealant, Part Number 3164070.

2. Sealant **must** be applied around both the mounting hole location and the oil supply hole in the front gear cover.

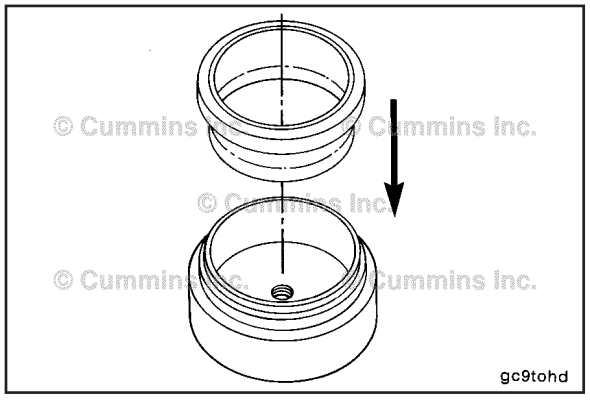
NOTE: Install the front cover within 10 minutes of applying the sealant, or the sealant will **not** seal correctly. Once installed, allow the sealant to dry for 30 minutes before operating the engine.



Use the dowel rings to locate the front gear cover and install the front gear cover onto the cylinder block.

Install the front gear cover to the cylinder block with mounting capscrews. Tighten the front gear cover to the cylinder block mounting capscrews in the order indicated.

Torque Value: 24 N•m [212 in-lb]



Front Gear Train

Install a new front crankshaft seal into the front gear cover prior to installing the front gear cover. Refer to Procedure 001-023 in Section 1.

Leave the plastic pilot installation tool in the front crankshaft seal.

⚠CAUTION⚠

The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

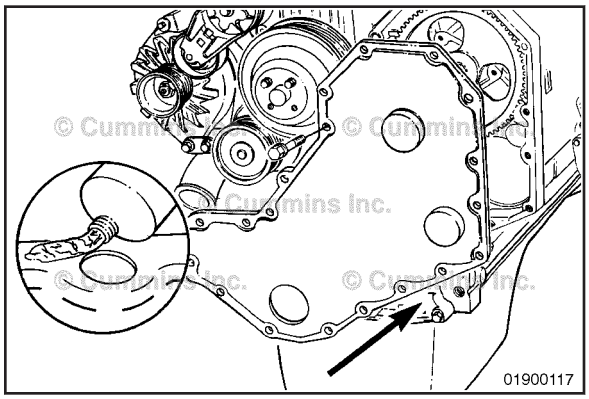
Stamped Steel Gear Cover - Apply a thin bead of sealant, Part Number 3164070, to the sealing surface of the front cover.

NOTE: Do **not** remove the plastic seal pilot tool from the front crankshaft seal at this time. Use the plastic seal pilot tool to guide the seal onto the crankshaft.

NOTE: Install the front cover within 10 minutes of applying the sealant, or the sealant will **not** seal correctly. Once installed, allow the sealant to dry for 30 minutes before operating the engine.

Cast Aluminum Gear Cover - Place the gasket, Part Number 3918673, between the gear cover and the gear housing.

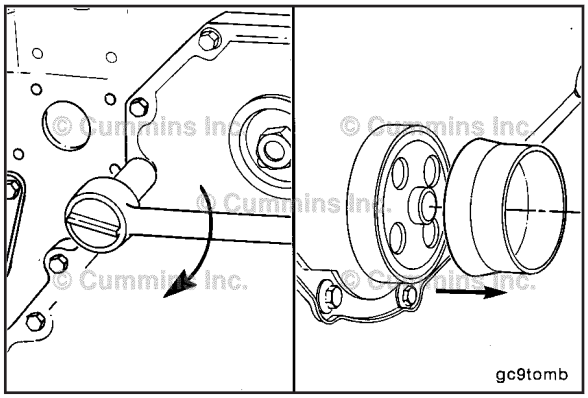
Install the front gear cover on the engine, with the plastic seal pilot tool to guide the front crankshaft seal onto the crankshaft.



Install and tighten the front gear cover capscrews.

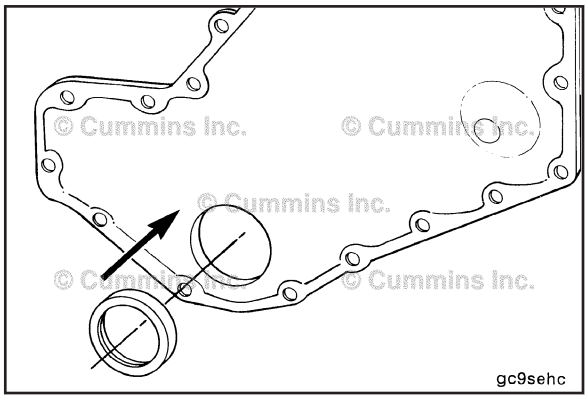
Torque Value: 24 N•m [212 in-lb]

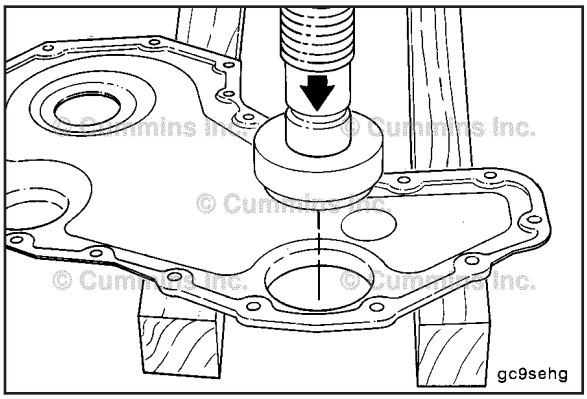
Remove the plastic pilot tool from the crankshaft.



If previously equipped, or if the engine operates in a dusty environment, install a dust shield.

A pilot tool is **not** necessary for the dust shield. Slide the dust shield over the nose of the crankshaft.



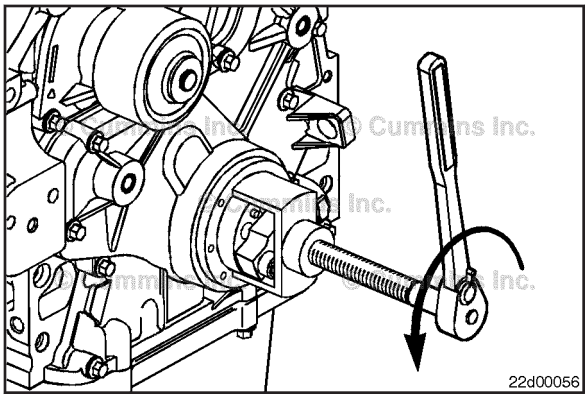


Crankshaft Seal, Front (001-023)

Install

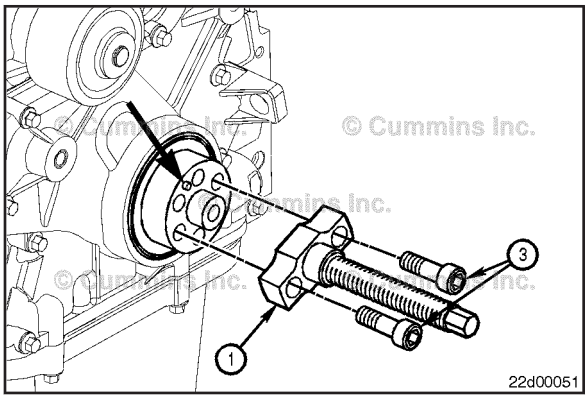
Front Gear Train

For front gear train engines, the front crankshaft seal is installed with the front gear cover removed. The front crankshaft seal is installed on the engine with the front gear cover.



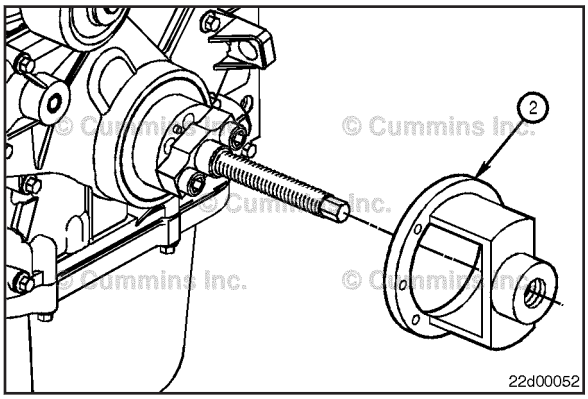
Rear Gear Train

Use tool, Part Number 3164659, to install the oil seal into the front gear cover.



Mount the replacer screw assembly (1) onto the crankshaft nose.

Install the two M12 x 1.25 x 60 mm socket head capscrews (3).



△CAUTION△
Do not use an impact wrench or air tools. Doing so can damage the tool.

Place the new front crankshaft seal over the crankshaft nose and slide it by hand toward the front gear cover as far as possible.

NOTE: Make sure the seal is positioned squarely with the crankshaft.

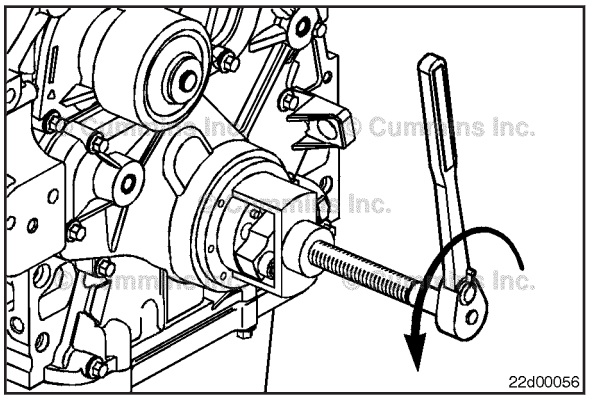
While holding the replacer screw, install the crankshaft seal replacer (2) onto the replacer screw assembly.

Advance the crankshaft seal replacer toward the seal by rotating it **clockwise** until it is positioned against the seal.

⚠CAUTION⚠
Do not overtighten the replacer screw assembly after the crankshaft seal replacer contacts the front cover. Doing so can damage the tool.

While holding the crankshaft seal replacer, rotate the replacer screw **counterclockwise** until the crankshaft seal replacer contacts the front gear cover.

Remove the service tools.



Vibration Damper, Viscous (001-052)

Install

Front Gear Train

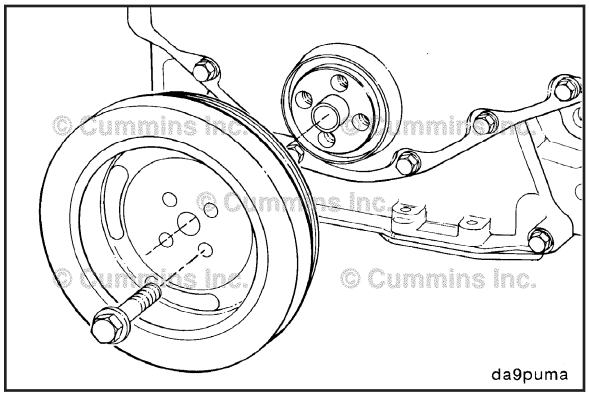
NOTE: The B Series engines have two configurations for the crankshaft pulleys and vibration dampers. Determine which configuration is used and use the appropriate steps in this procedure.

One Piece Pulley/Vibration Damper

Install the crankshaft vibration damper.

Install and tighten the crankshaft pulley/vibration damper capscrews.

Torque Value: 125 N•m [92 ft-lb]



Two-Piece Pulley/Vibration Damper

Install the vibration damper.

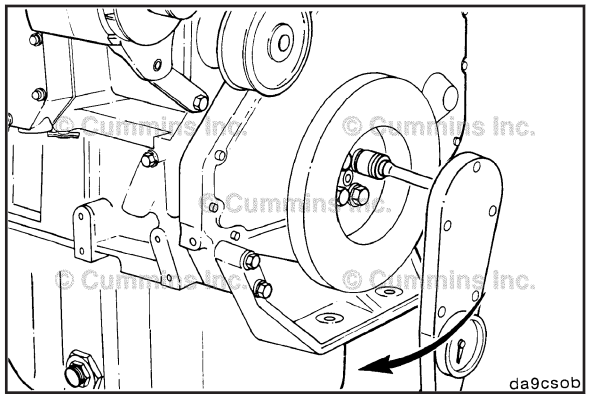
Install and tighten the vibration damper capscrews.

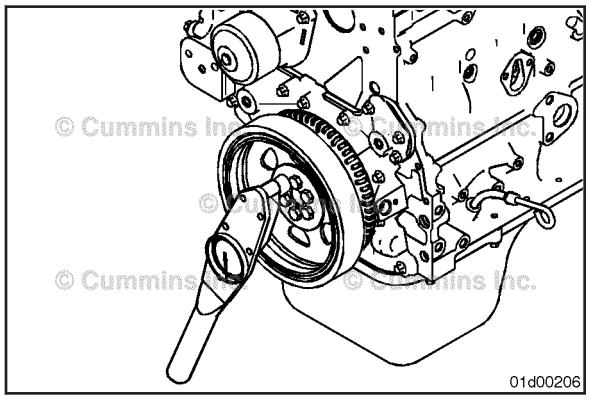
Torque Value: 200 N•m [148 ft-lb]

Install the crankshaft pulley.

Install and tighten the crankshaft pulley capscrews.

Torque Value: 77 N•m [57 ft-lb]





Rear Gear Train

Lubricate bolts with clean engine oil.

Install the vibration damper.

For rear gear train engines, tighten the six vibration damper capscrews in a criss-cross pattern.

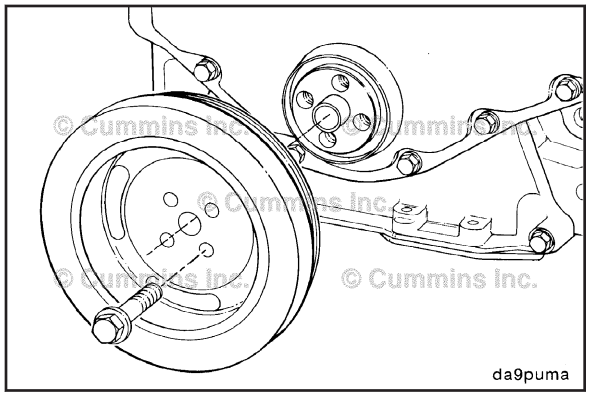
Torque Value: Step1 50 N•m [37 ft-lb]
Step2 Rotate 90 degrees

Vibration Damper, Rubber (001-051)

Install

Front Gear Train

NOTE: The B Series engines have two configurations for the crankshaft pulleys and vibration dampers. Determine which configuration is used and use the appropriate steps in this procedure.

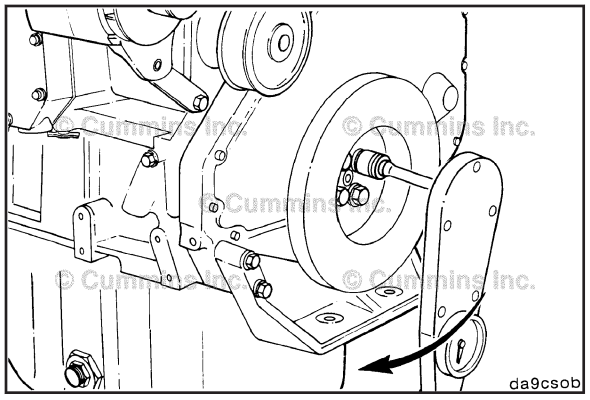


One Piece Pulley/Vibration Damper

Install the crankshaft vibration damper.

Install and tighten the crankshaft pulley/vibration damper capscrews.

Torque Value: 125 N•m [92 ft-lb]



Two-Piece Pulley/Vibration Damper

Install the vibration damper.

Install and tighten the vibration damper capscrews.

Torque Value: 200 N•m [148 ft-lb]

Install the crankshaft pulley.

Install and tighten the crankshaft pulley capscrews.

Torque Value: 77 N•m [57 ft-lb]

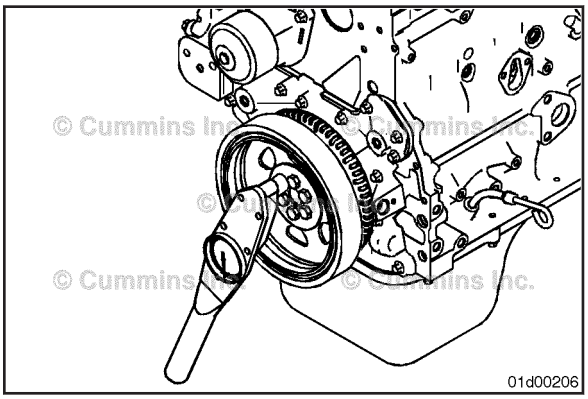
Rear Gear Train

Lubricate bolts with clean engine oil.

Install the vibration damper .

Tighten the six vibration damper capscrews in a criss-cross pattern.

Torque Value: Step1 50 N•m [37 ft-lb]
Step2 Rotate 90 degrees



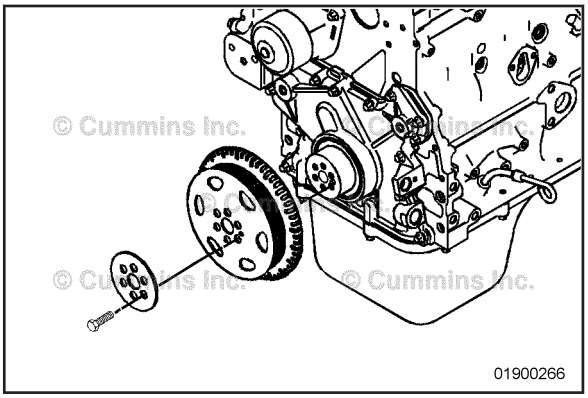
Crankshaft Pulley (001-022)

Install

Install the six capscrews that hold the crankshaft pulley to the nose of the crankshaft.

Tighten crankshaft pulley capscrews.

Torque Value: Step1 50 N•m [37 ft-lb]
Step2 Rotate 90 degrees

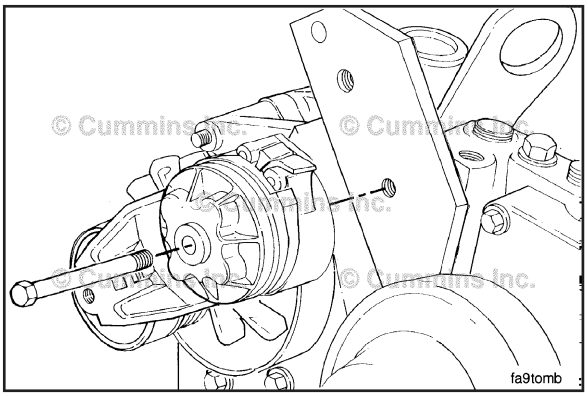


Cooling Fan Belt Tensioner (008-087)

Install

Install the tensioner and capscrew.

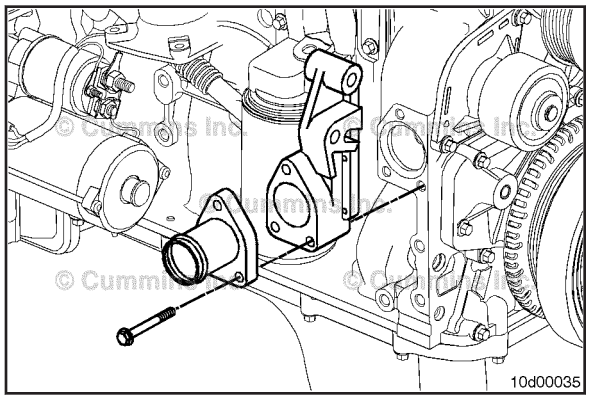
Torque Value: 43 N•m [32 ft-lb]



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.



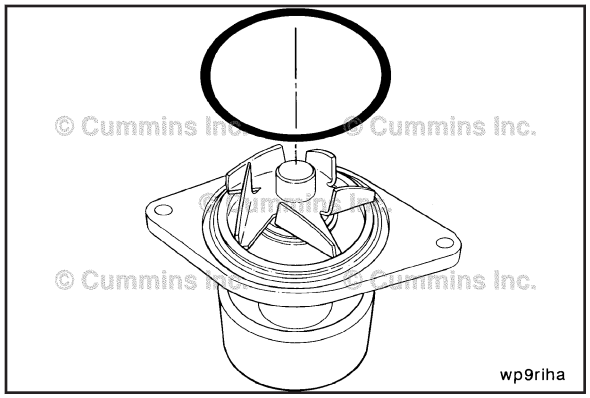
Install

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:

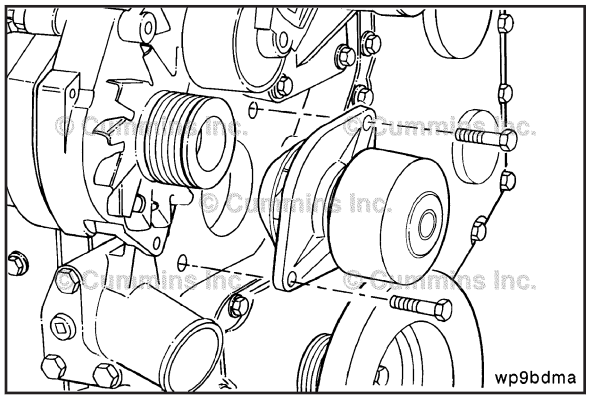
M10	43 N•m	[32 ft-lb]
M12	80 N•m	[59 ft-lb]



Water Pump (008-062)

Install

Install the new sealing ring into the pump groove.



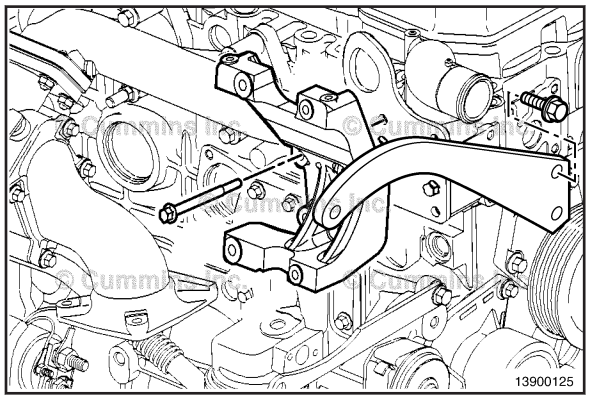
Install the water pump (with seal) and mounting capscrews.

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]



Alternator Bracket (013-003)

Install

Spool Mount:

Install the upper alternator bracket and mounting capscrews.

Tighten the upper and lower alternator bracket mounting capscrew.

Torque Value:

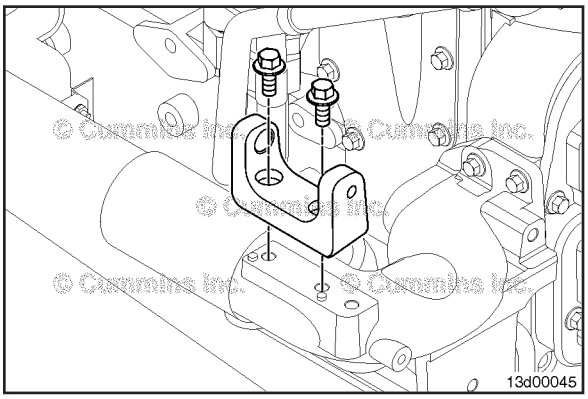
M8	24 N•m	[18 ft-lb]
M10	43 N•m	[32 ft-lb]

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.

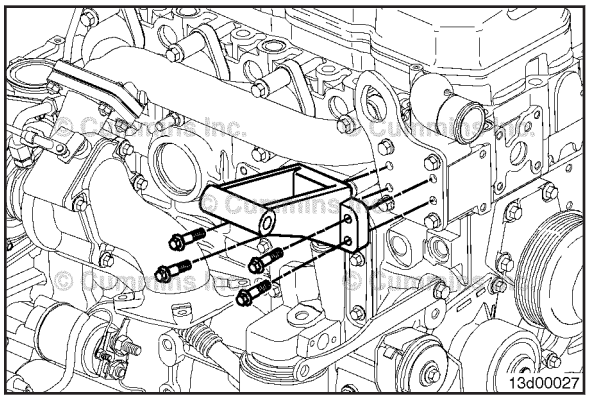
Install the lower alternator bracket and mounting capscrew.

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]



Alternator (013-001)

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.

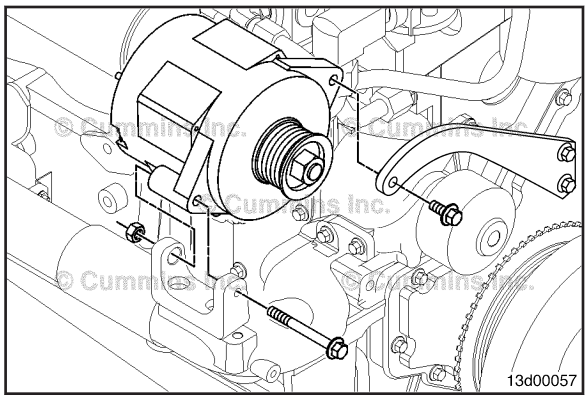
Tighten the capscrews.

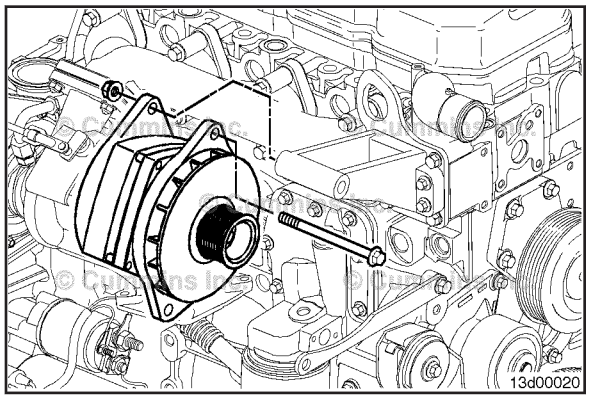
Torque Value:
Lower Mounting Capscrew

Step 1	40 N•m	[30 ft-lb]

Torque Value:
Upper Link Mounting Capscrew

Step 1	24 N•m	[212 in-lb]



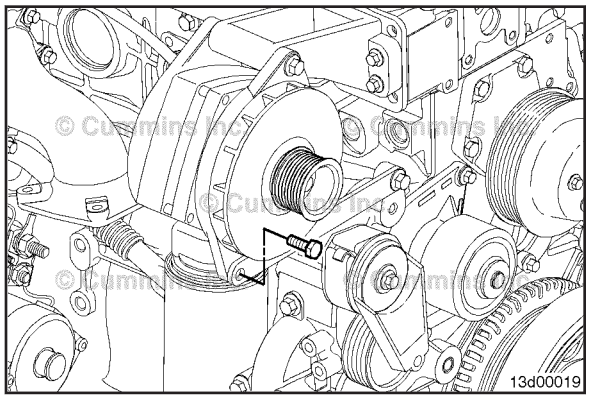


Hinge Mount

Install the alternator.

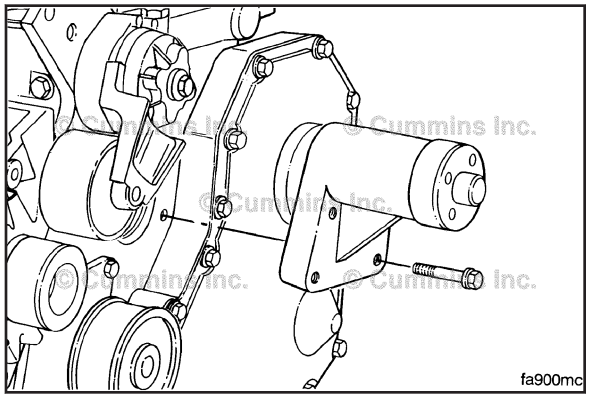
Install and tighten the alternator mounting capscrew.

Torque Value: 40 N•m [30 ft-lb]



Install the alternator link capscrew.

Torque Value: 24 N•m [212 in-lb]

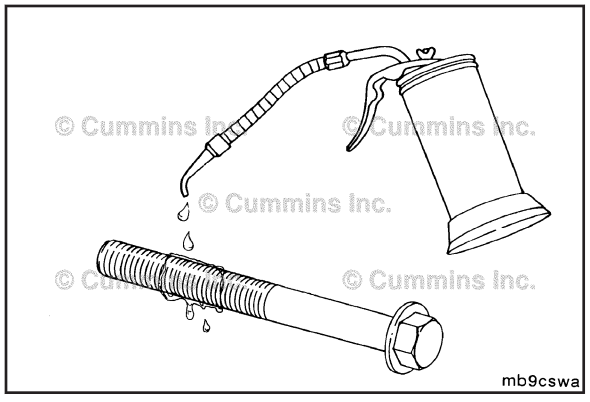


Fan Hub, Belt Driven (008-036)

Install

Install the fan hub and four capscrews.

Torque Value: 24 N•m [212 in-lb]



Fan Clutch, Electric (008-026)

Install

Do **not** use Loctite™ or any other thread locking compounds. Make sure capscrew head surface and threads are clean and free of debirs.

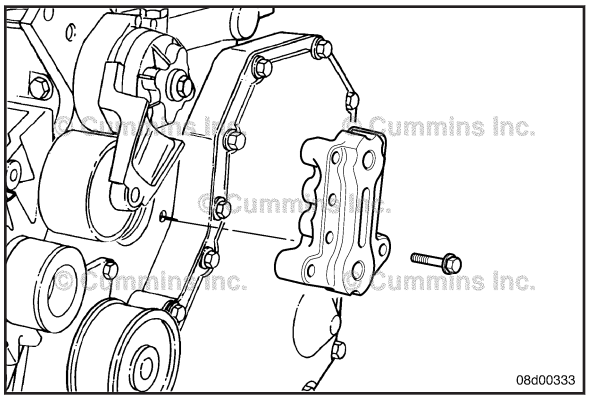
Use new capscrew if any damage is fouund.

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.

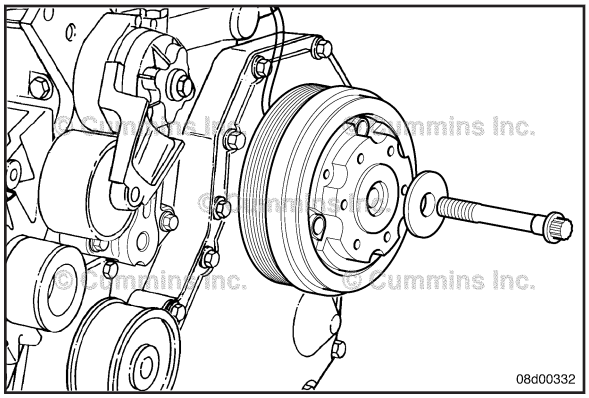
Prior to tightening the capscrew, rotate the fan clutch so that the wires coming out of the back of the fan clutch are captured by the P-clip. Bend the P-clip over by hand to secure the wires.

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	

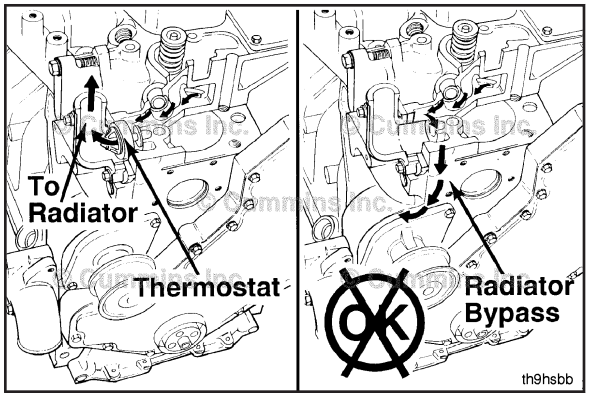


Coolant Thermostat (008-013)

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.

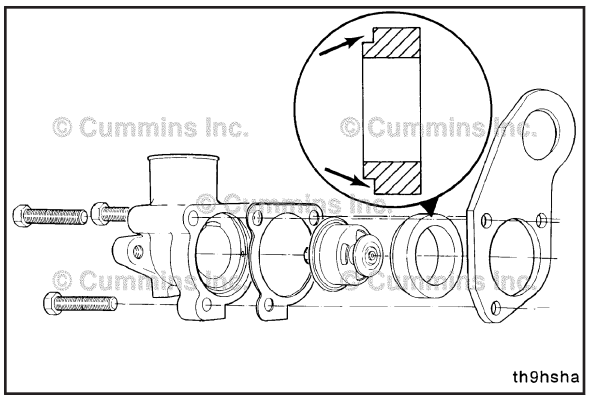


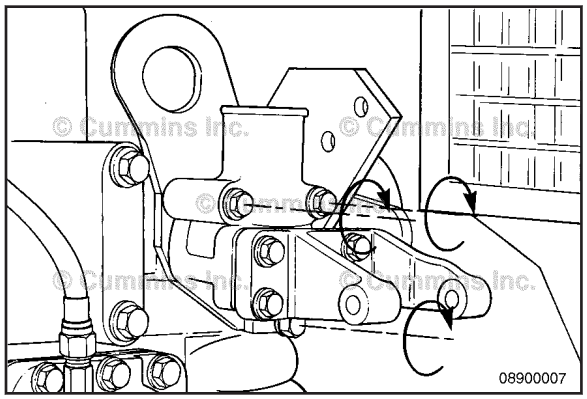
Position the thermostat as shown in the illustration.

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.

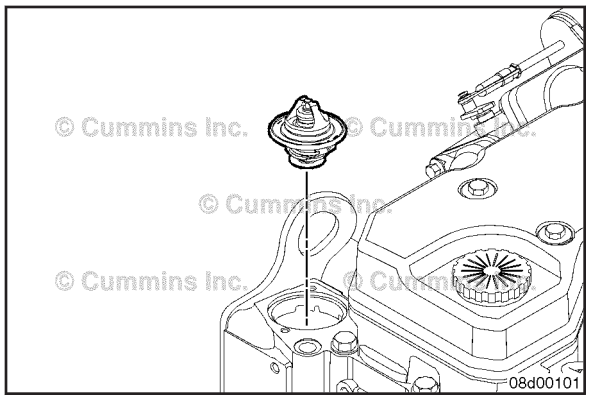




Install the removed parts in the reverse order of removal.

Install the thermostat, thermostat seal, thermostat housing, gasket, lifting bracket, and three capscrews.

Torque Value: 24 N•m [18 ft-lb]



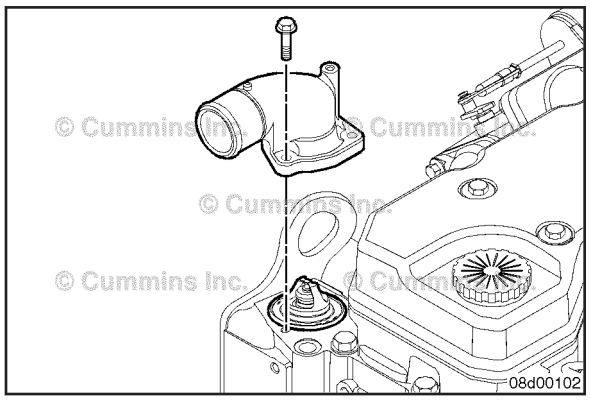
Rear Gear Train

⚠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.

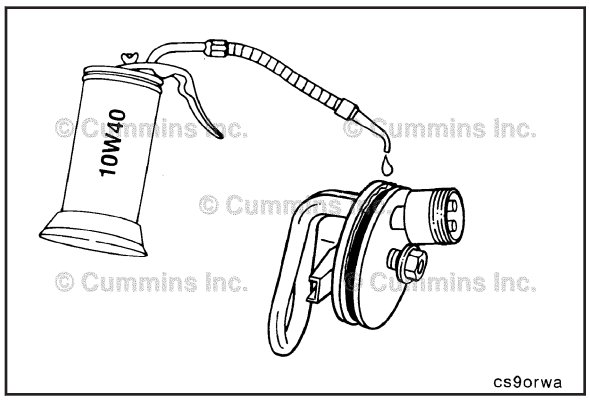
NOTE: Make sure a new thermostat seal is installed on the outer lip of the thermostat flange every time the thermostat is reinstalled.



Install the water outlet connection and mounting capscrews.

Tighten the capscrews.

Torque Value: 10 N•m [89 in-lb]



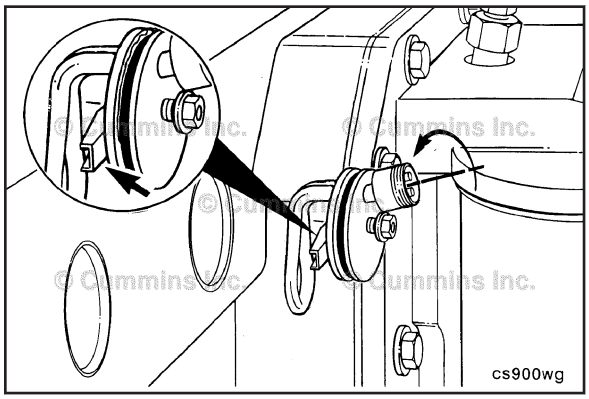
Coolant Heater (008-011)

Install

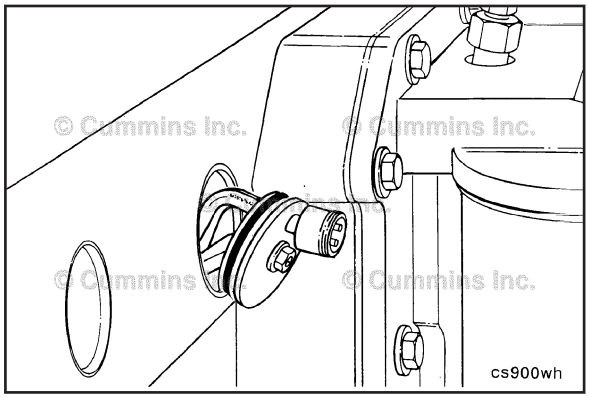
Front Gear Train

For bolted coolant heaters, lubricate the new heater o-ring with clean lubricating engine oil.

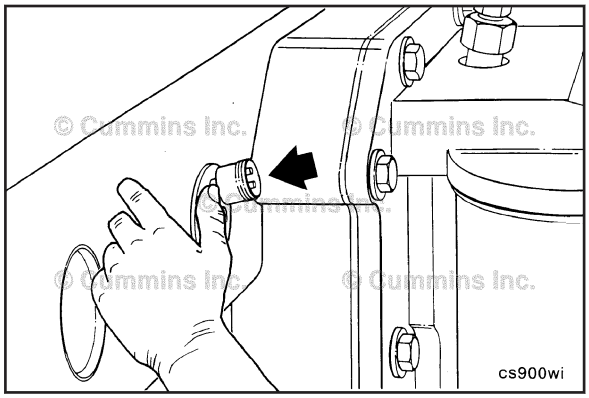
The locking channel (T-bar) should be threaded out to the end of the bolt. If so equipped, do **not** remove the retaining wire used to position the channel (T-bar).



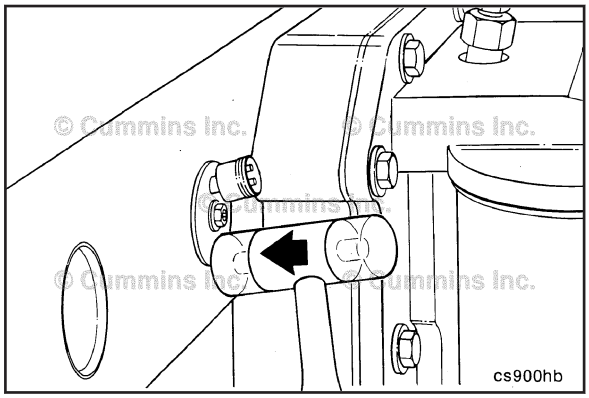
Hook the element and one leg of the channel (T-bar) into the hole as illustrated.

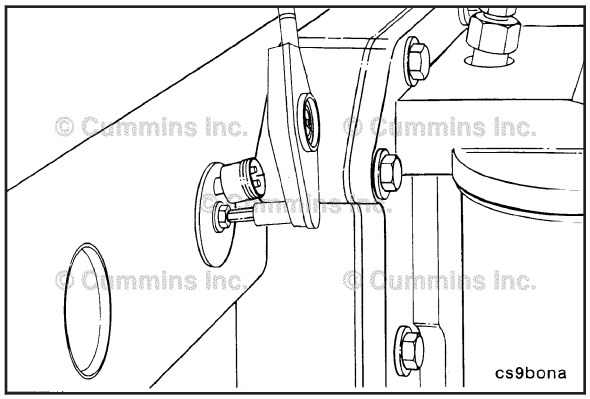


Hook the other leg of the channel in the hole, and push the heater into the hole as far as possible by hand.



If necessary, use a plastic hammer to tap the heater in until the shoulder contacts the block.

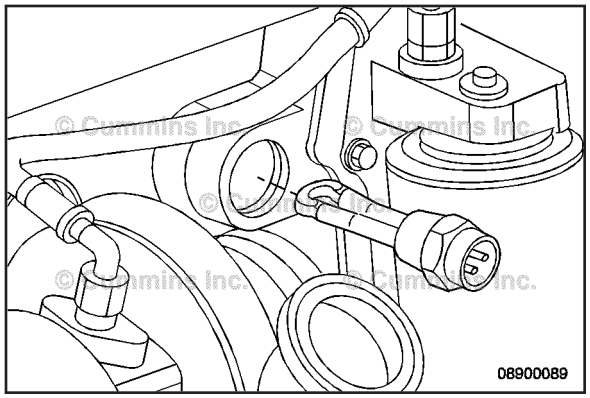




Torque Value:

Minimum:	1.3 N•m	[12 in-lb]
Maximum:	2.8 N•m	[25 in-lb]

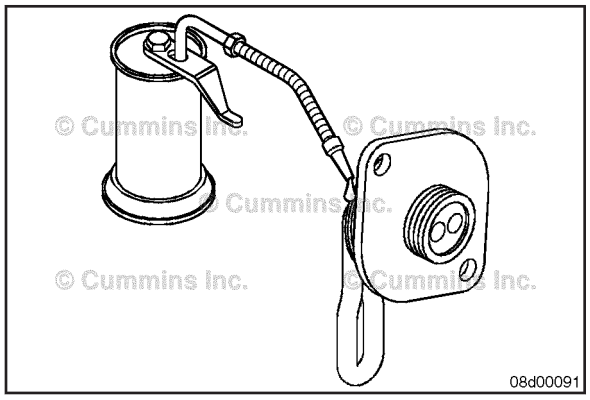
NOTE: Do **not** overtighten.



For threaded coolant heaters, apply pipe sealant, Part Number 3375066, to threads of the coolant heater.

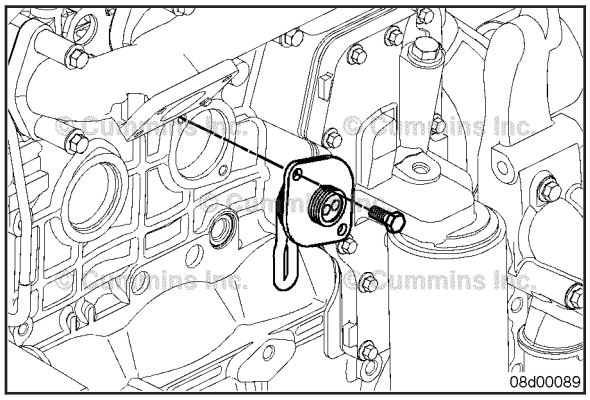
Install the coolant heater into the cylinder block and tighten.

Torque Value: 55 N•m [41 ft-lb]



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.

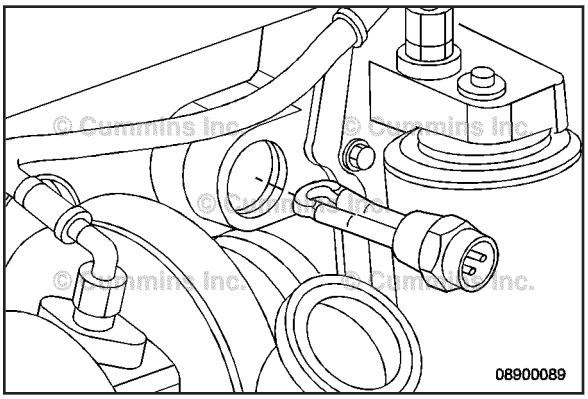
Tighten the two retaining capscrews.

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.

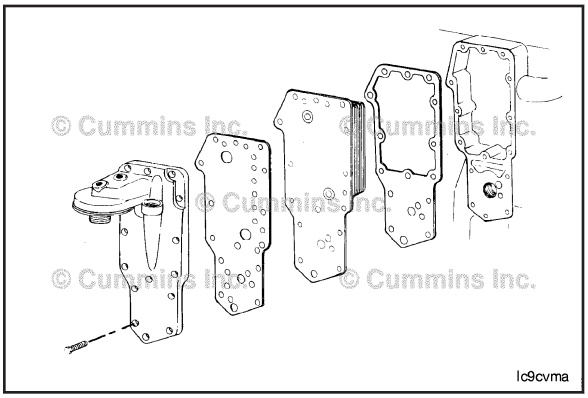
Torque Value: 55 N•m [41 ft-lb]



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.



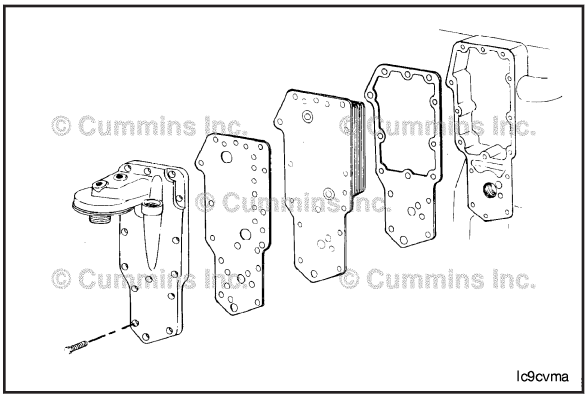
Install

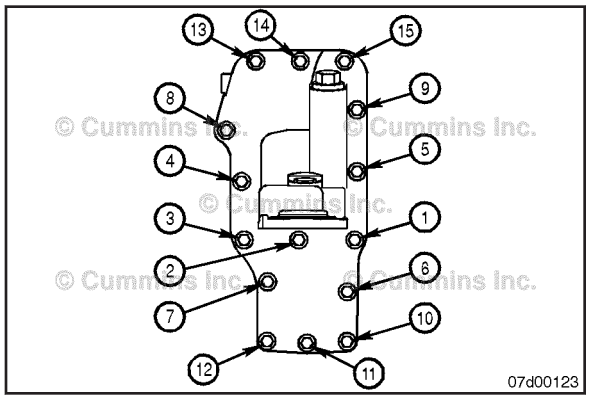
NOTE: Be sure to remove the shipping plugs from the oil cooler element.

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.

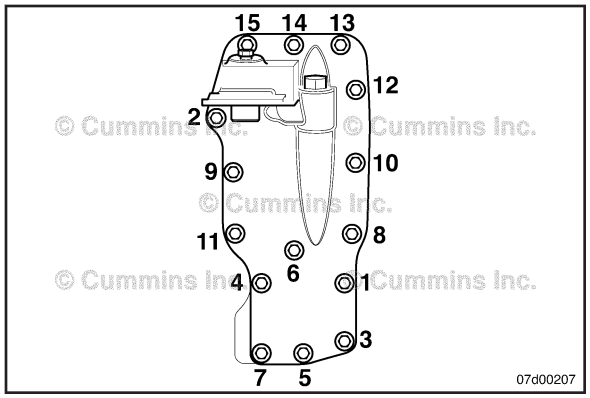




If the engine uses a lubricating oil cooler cover in which the lubricating oil filter is mounted low, use the torque sequence shown.

NOTE: Snug capscrew numbers six and eight, then tighten in the sequence shown.

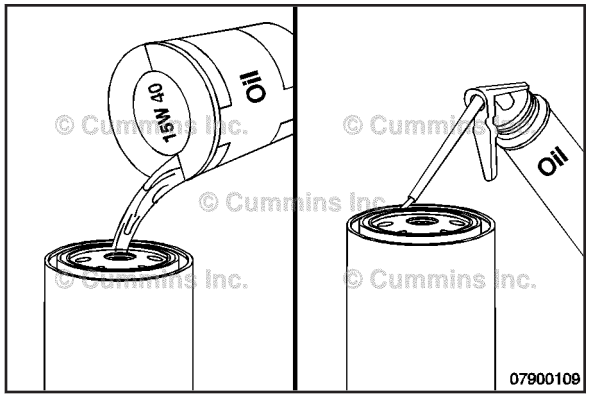
First Stage Torque Value	17 Nm	150 in-lb
Second Stage Torque Value	28 Nm	248 in-lb



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



Lubricating Oil Filter (Spin-On) (007-013)

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.

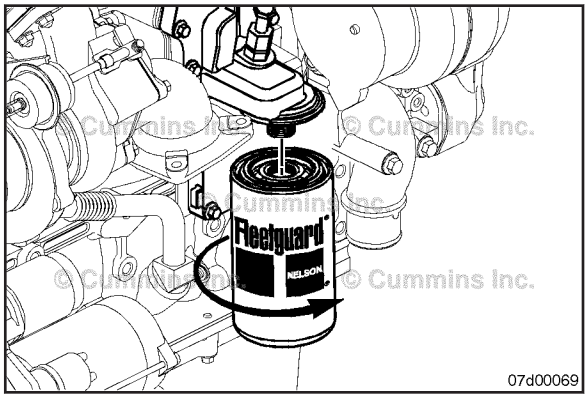
Fill the filter with clean 15W-40 oil.

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.



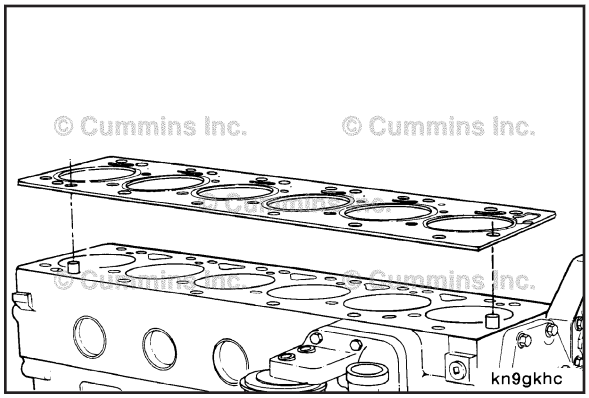
Cylinder Head Gasket (002-021)

Install

⚠CAUTION⚠
Be sure the gasket is correctly aligned with holes in the cylinder block. If the gasket is not correctly engine damage can result.

Install the new head gasket.

NOTE: Never reuse the old head gasket. **Always** use a new head gasket to prevent leakage.



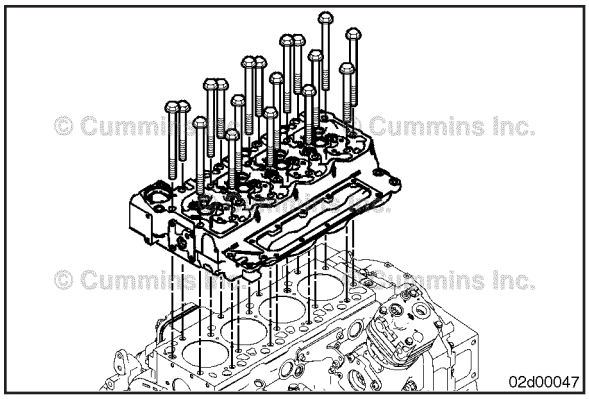
Cylinder Head (002-004)

Install

B4.5 RGT Engines

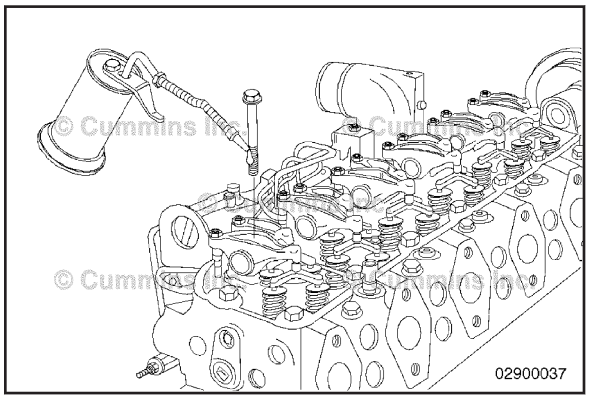
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

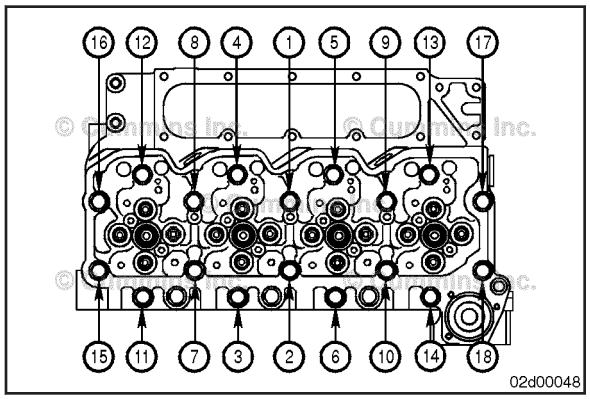
Carefully put the cylinder head on the cylinder block, and seat it onto the dowels.



Lubricate the threads and under the heads on the cylinder head mounting capscrews with clean engine oil.

Install the capscrews and tighten finger-tight.



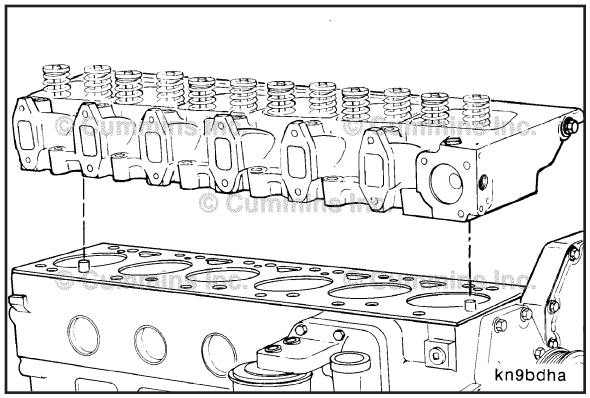


Use the illustrated sequence to tighten the cylinder head capscrews.

Tighten the capscrews.

Torque Value:

All Capscrews		
Step 1	90 N•m	[66 ft-lb]
Step 2	90 N•m	[66 ft-lb]
Step 3	Rotate 90-degrees clockwise.	



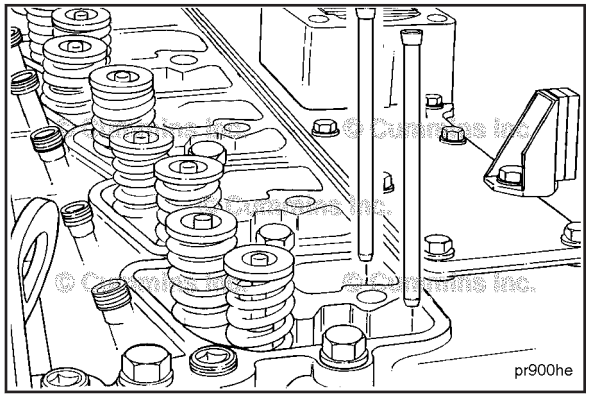
B3.9, B5.9, and B4.5 Engines

⚠WARNING⚠

This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Carefully put the cylinder head straight down onto the cylinder block, and seat it onto the dowels.

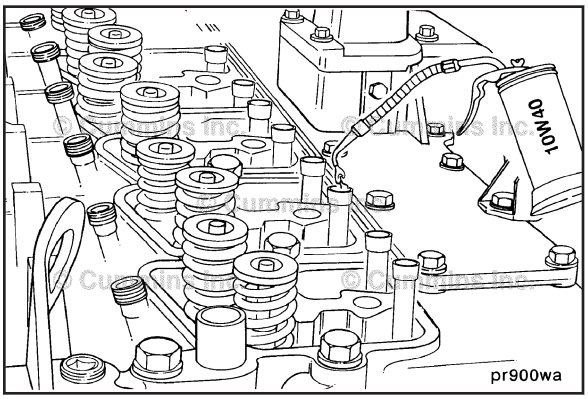
Cylinder Head Weight		
Cylinder Number	**Kg**	**lb**
4	36	79
6	51.3	113



Push Tubes - Installation

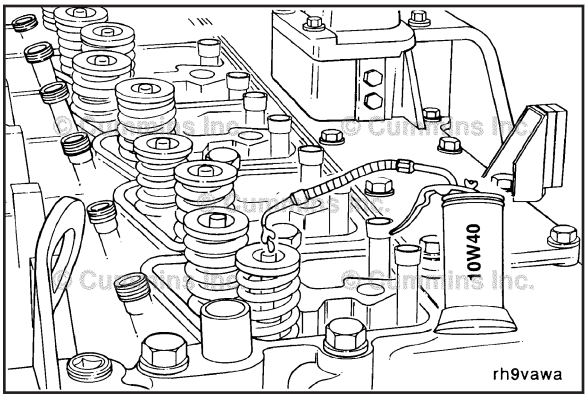
Position the push tubes into the valve tappets.

Lubricate the push tube sockets with clean lubricating engine oil.

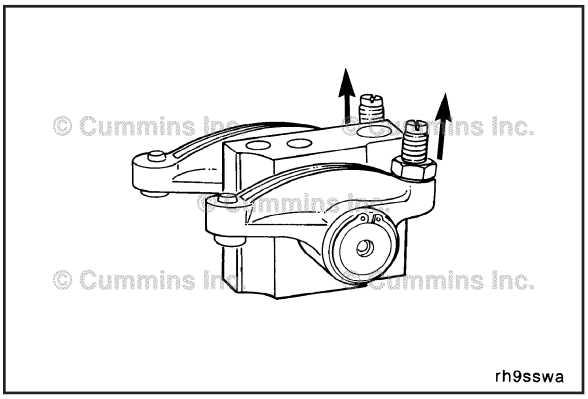


Rocker Levers - Installation

Lubricate the valve stems with clean lubricating engine oil.

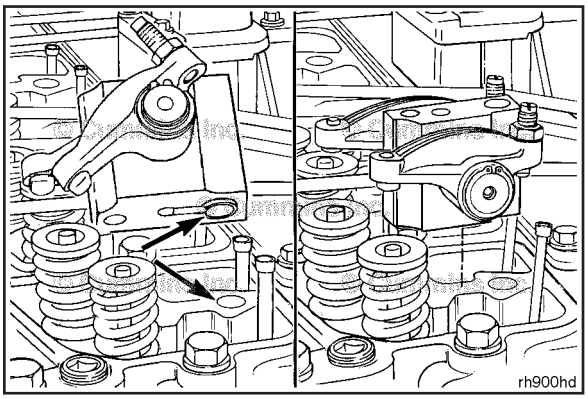


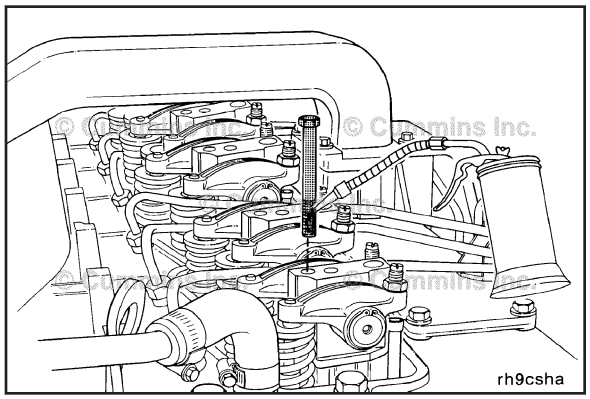
Completely loosen the rocker lever adjusting screws.



NOTE: The rocker lever pedestals are aligned with dowels.

Install the pedestals.

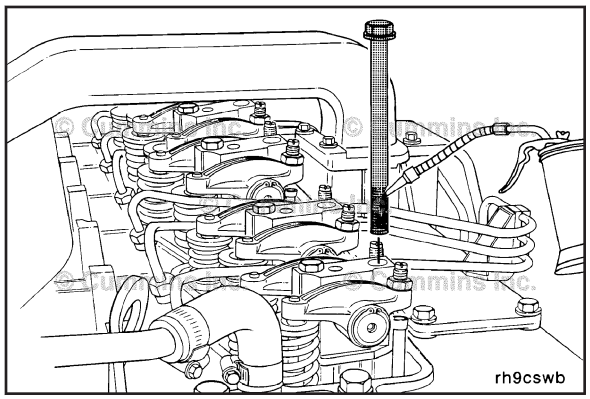




Use capscrew length gauge, Part Number 3823921, to inspect all cylinder head capscrews for proper length.

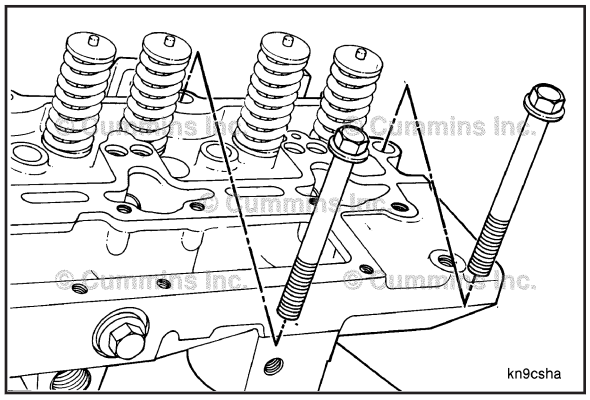
Lubricate the 8-mm pedestal capscrew threads and under the capscrew heads with clean lubricating engine oil.

Install the capscrews finger-tight.



Lubricate the 12-mm pedestal/head capscrew bolt threads and under the capscrew heads with clean lubricating engine oil.

Install the capscrews finger tight.



Lubricate the threads and under the heads on the remaining cylinder head capscrews with clean lubricating engine oil.

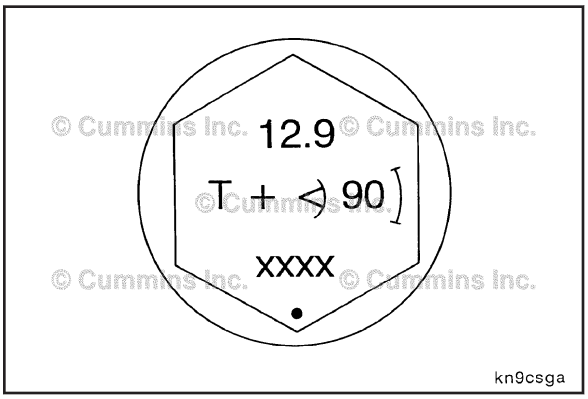
Install capscrews in the cylinder head and finger-tighten.

NOTE: Be sure to install the long capscrews into the holes underneath the injectors.

NOTE: Capscrews for the 1991 and later certification level engines are the same overall length, but have a longer threaded area.

⚠CAUTION⚠
Do not use pre-1991 certification level engine capscrews in a 1991 B Series or later certification level engine because pre-1991 capscrews do not have enough threads to provide enough thread engagement in the 1991 and later certification engines. Failure to do so can result in engine damage.

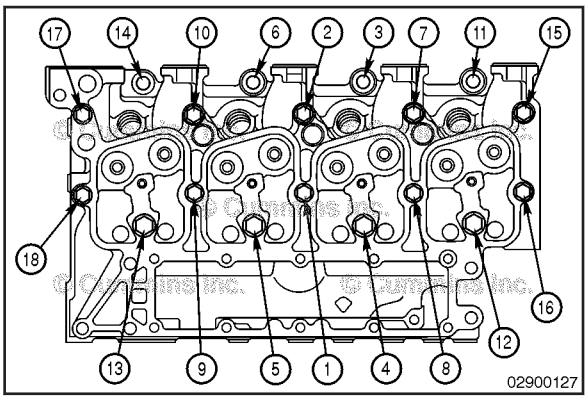
⚠CAUTION⚠
Capscrews for a 1991 B Series or later certification level engine can be used in a pre-1991 certification level engine because 1991 and later capscrews have enough threads to provide enough engagement in all certification level engines.



NOTE: The top of the cylinder head capscrew is identified with an angle marking. The cylinder head capscrews **must** be tightened by using the three-step “torque plus angle” method described as follows.

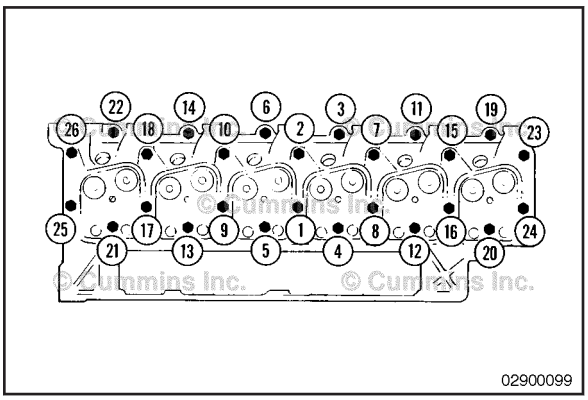
On a four cylinder engine, capscrew number 1 is located in between cylinders 2 and 3. The numbered sequence is the same as a six cylinder, but stops at capscrew number 18. Follow the numbered sequence for the four cylinder engine, and tighten all 18 capscrews.

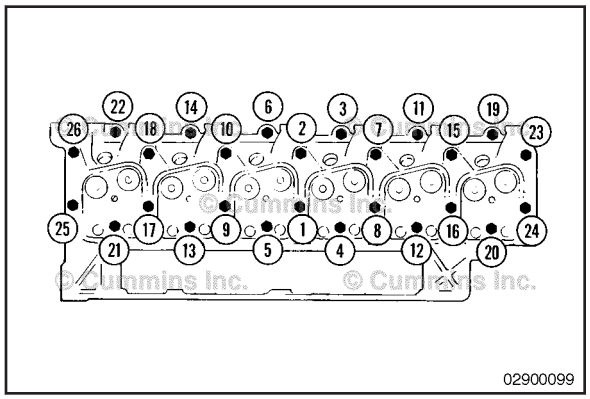
Torque Value: 90 N•m [66 ft-lb]



Follow the numbered sequence for the six cylinder engine, and tighten all 26 capscrews.

Torque Value: 90 N•m [66 ft-lb]





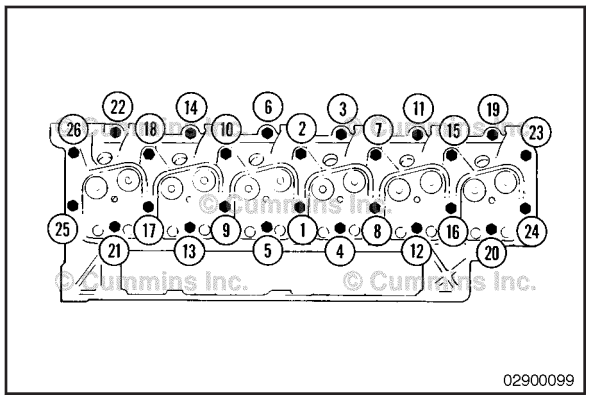
Four Cylinder

Follow the numbered sequence, and tighten the long capscrews **only** (numbers 4,5,12, and 13).

Six Cylinder

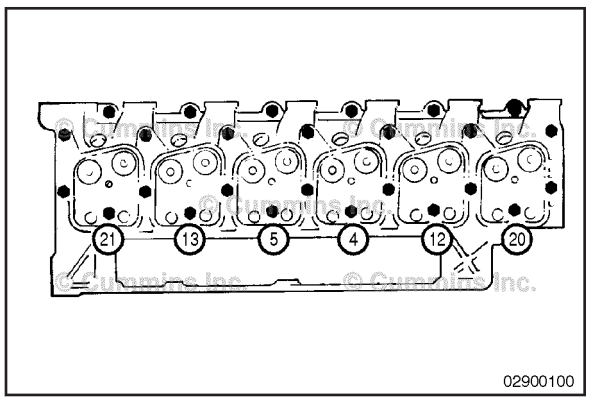
Follow the numbered sequence, and tighten the long capscrews **only** (numbers 4, 5,12, and 13, 20, and 21).

Torque Value: 120 N•m [89 ft-lb]



Tighten the short capscrews again (numbers 1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 18, 19, 22, 23, 24, 25, and 26) because of cylinder head relaxation and to obtain proper cylinder head torque requirements.

Torque Value: 90 N•m [66 ft-lb]



Tighten the long capscrews again because of cylinder head relaxation and to obtain proper cylinder head torque requirements.

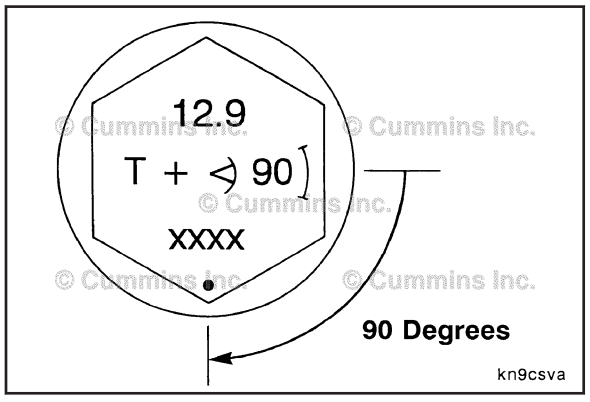
Four Cylinder

Follow the numbered sequence, and tighten the long capscrews **only** (numbers 4, 5, 12, and 13).

Six Cylinder

Follow the numbered sequence, and tighten the long capscrews **only** (numbers 4, 5, 12, and 13, 20, and 21).

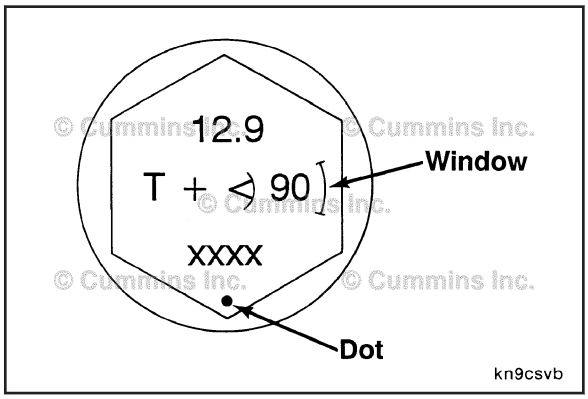
Torque Value: 120 N•m [89 ft-lb]



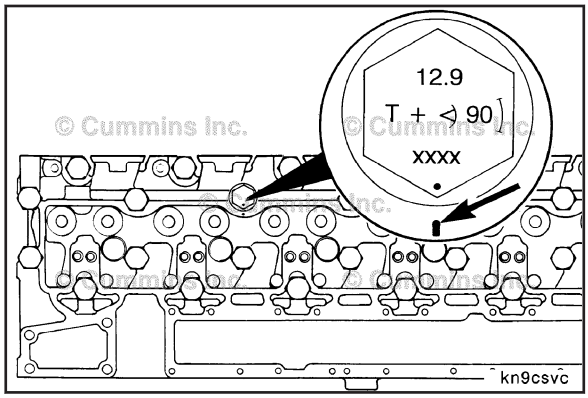
Follow the numbered sequence, and turn the capscrew 90 degrees as indicated on the capscrew head.

Torque Angle Gauge - 3/4-Inch Drive, Tool Number 3823878

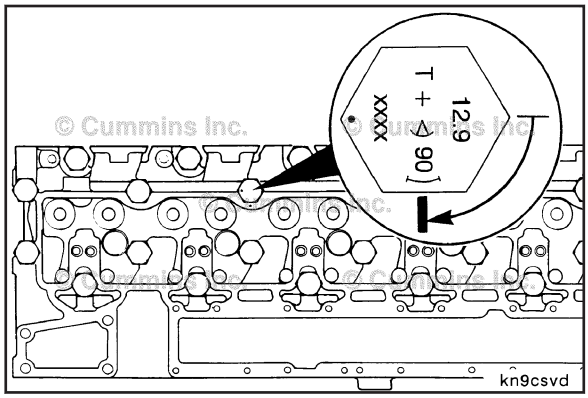
To turn the capscrew to the desired angle accurately, align the capscrew with the small “dot” and “window” that are marked on the capscrew head or use torque angle gauge - 3/4-inch drive tool, Part Number 3823878.



Mark the cylinder head adjacent to the dot on the capscrew head. This mark will serve as an indexing aid.

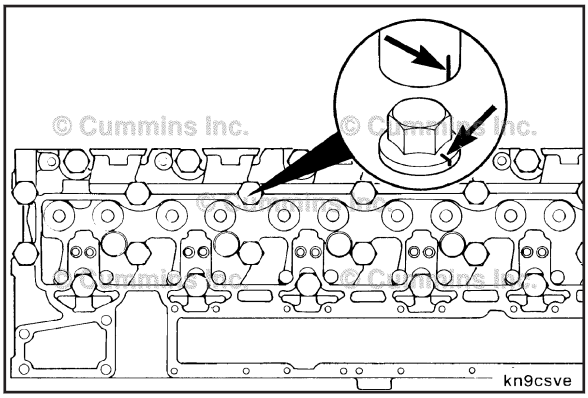


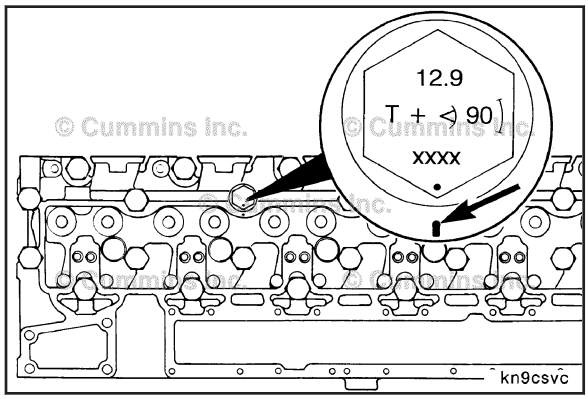
Rotate the capscrew until the mark that has been made on the cylinder head falls into the window on the capscrew head.



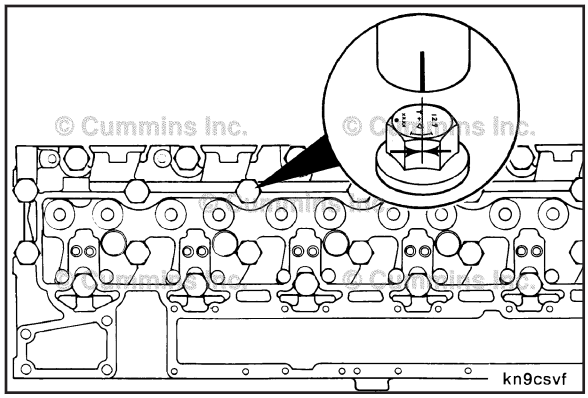
Service Tip:

Use a permanent marker to mark the socket corresponding to one of the flats of the socket hex.

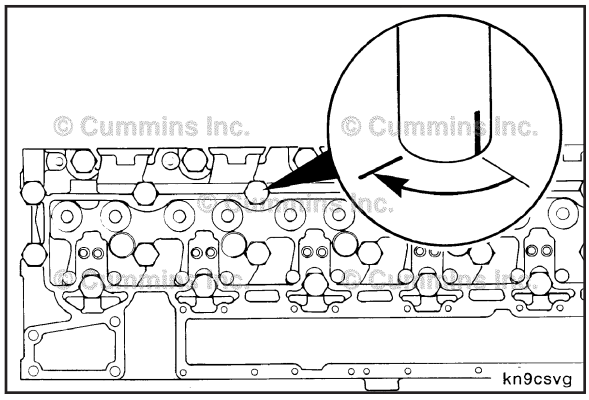




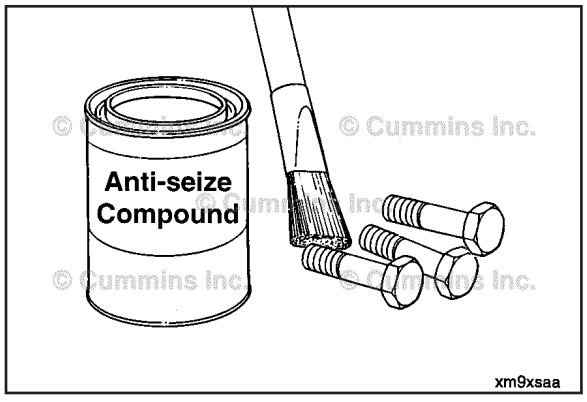
After the torque has been applied, mark the cylinder head at the location of the dot.



Position the socket on the capscrew such that the mark on the socket is at the same point as the window on the capscrew.



Turn the socket until the mark on the socket aligns with the mark on the cylinder head.



Exhaust Manifold, Dry (011-007)

Install

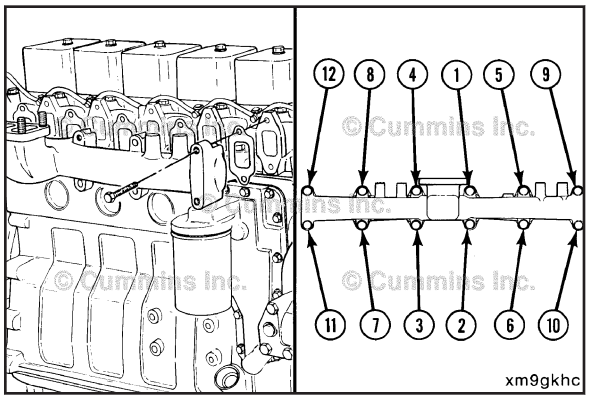
Coat all capscrew threads with an unleaded anti-seize compound.

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]

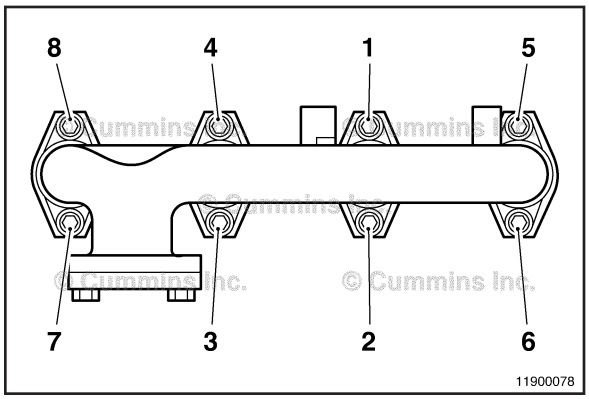


For 4 cylinder engines, install the exhaust manifold, new gaskets, spacers and mounting capscrews.

Follow the tightening sequence shown in the illustration.

Tighten the exhaust manifold mounting capscrews.

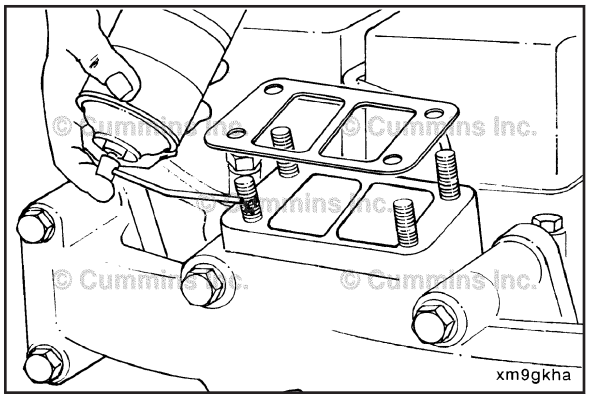
Torque Value: 43 N•m [32 ft-lb]



Turbocharger (010-033)

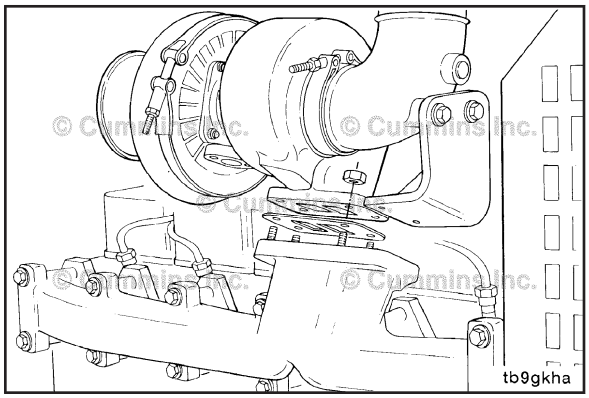
Install

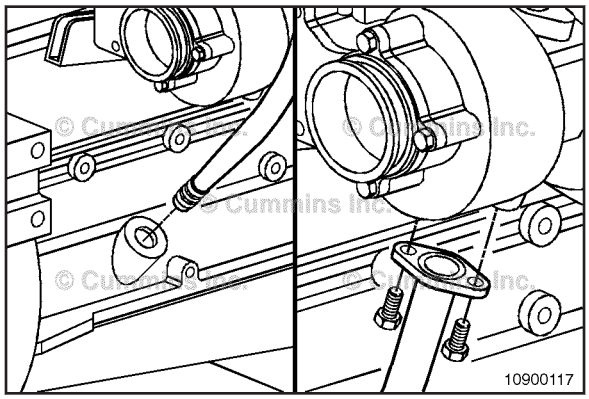
Install a new gasket, and apply anti-seize compound to the mounting studs.



Install the turbocharger.

Torque Value: 45 N•m [33 ft-lb]





Turbocharger Oil Drain Line (010-045)

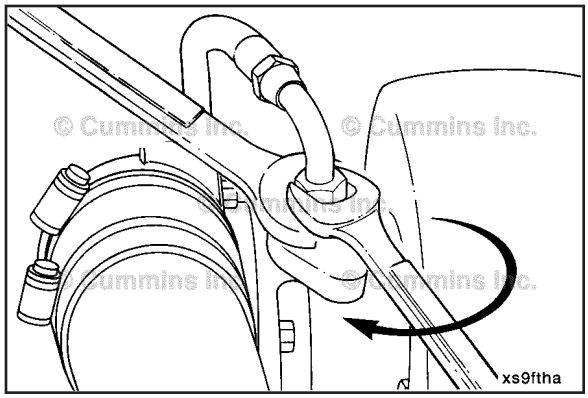
Install

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]



Turbocharger Oil Supply Line (010-046)

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.

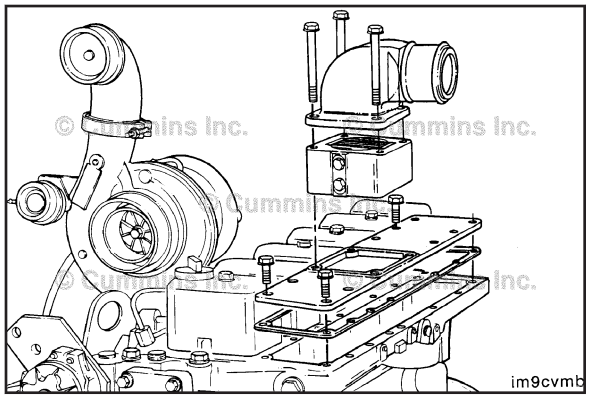
Apply a thin film of oil to the o-ring seals.

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]



Air Intake Manifold (010-023)

Install

Front Gear Train

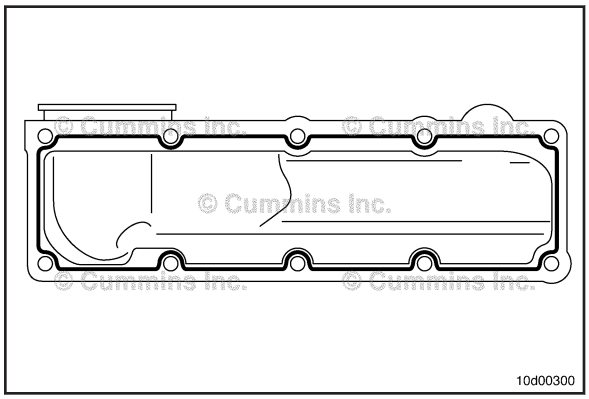
Install the cover and a new gasket.

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.

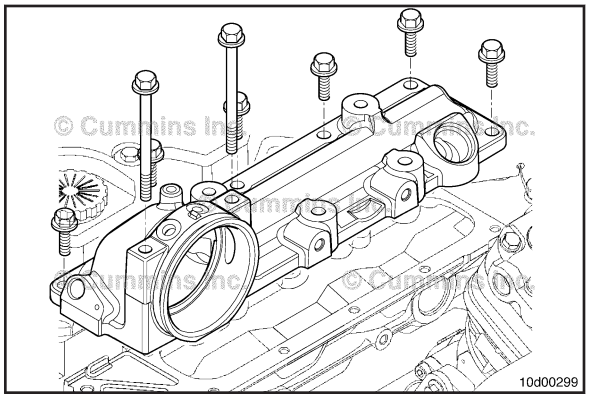
NOTE: Install the gear housing within 10 minutes of applying sealant or the sealant will **not** seal correctly. Once installed, allow the to dry for 30 minutes before running the engine.



Install the intake manifold and mounting capscrews.

Tighten the mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]



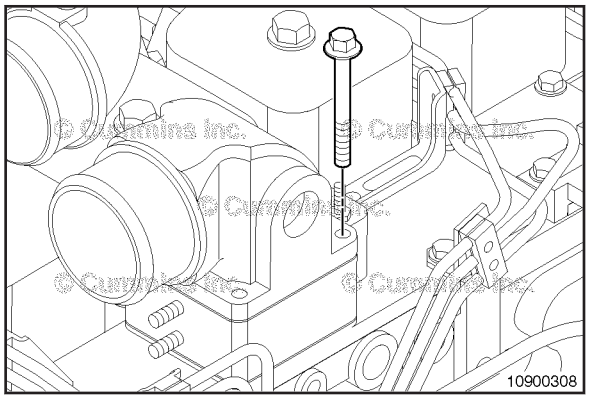
Intake Manifold Air Heater Element (010-124)

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.

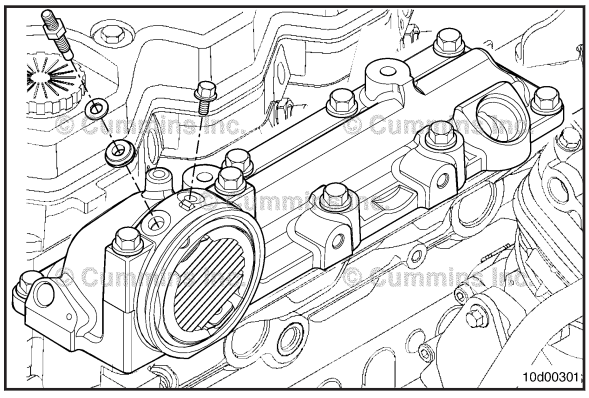
Install the electrical supply terminal (3), isolater/spacer (4) and washer (1) into air intake manifold heater element through the air intake manifold hole.

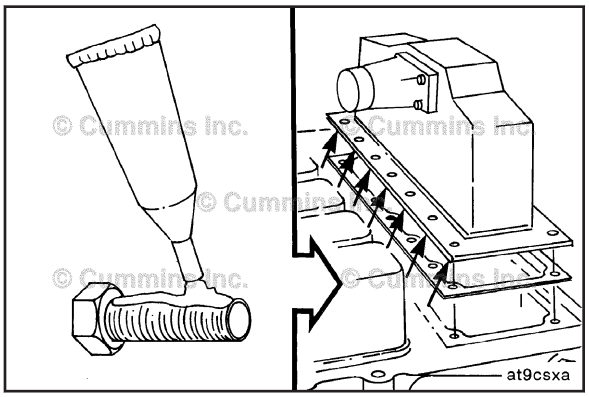
Tighten electrical supply terminal into the cold starting aid.

Torque Value: 8 N•m [71 in-lb]

Install the retaining capscrew (2) and tighten.

Torque Value: 8 N•m [71 in-lb]





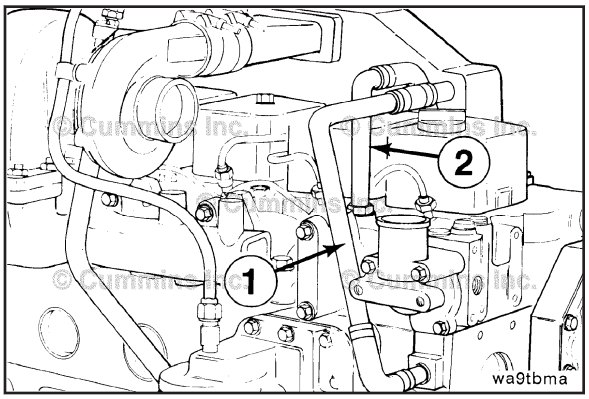
Aftercooler (010-001)

Install

NOTE: The holes shown in the illustration are drilled through. Apply liquid Teflon™ sealant to the capscrews.

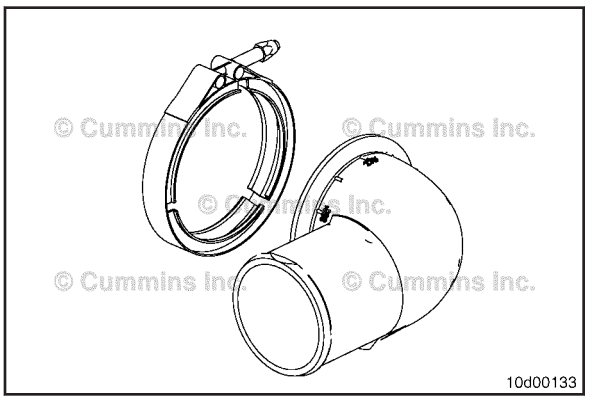
Install the aftercooler housing and a new gasket.

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]



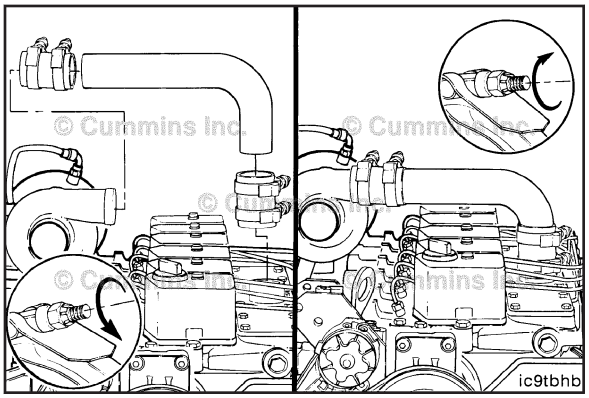
Air Intake Connection Adapter (010-131)

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]



Air Crossover (010-019)

Install

Install the crossover tube and clamps in the reverse order of removal.

Tighten the clamps.

Torque Value: 8 N•m [71 in-lb]

AFC Air Tube (006-001)

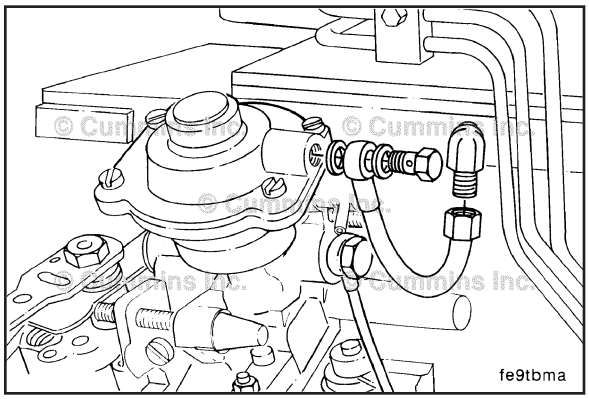
Install

Distributor-Type Pump

NOTE: Use new sealing washers when installing the tube.

Assemble in the reverse order of removal.

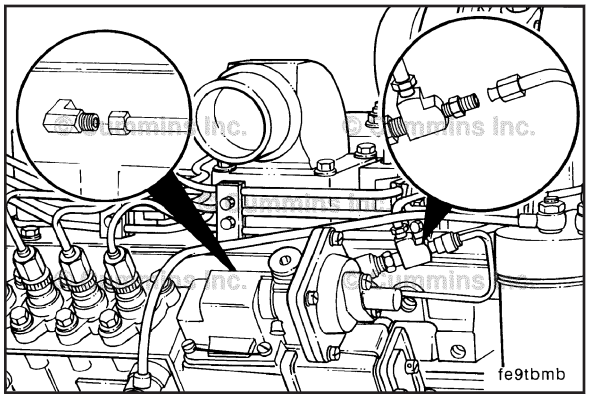
Torque Value: 9 N•m [80 in-lb]



In-Line Pump

Install the AFC tube in the reverse order of removal.

Torque Value: 24 N•m [18 ft-lb]



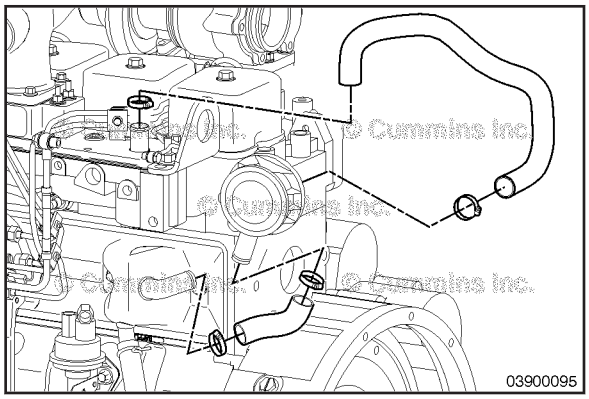
Closed Crankcase Ventilation Valve (003-023)

Install

Front Gear Train

Connect the tappet cover closed crankcase ventilation valve to the closed crankcase ventilation hoses and tighten the hose clamps.

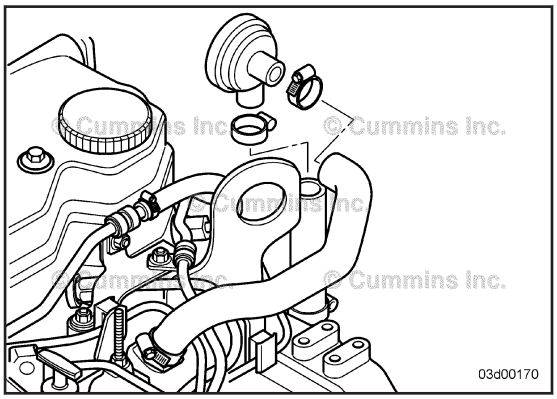
Torque Value: 8 N•m [71 in-lb]

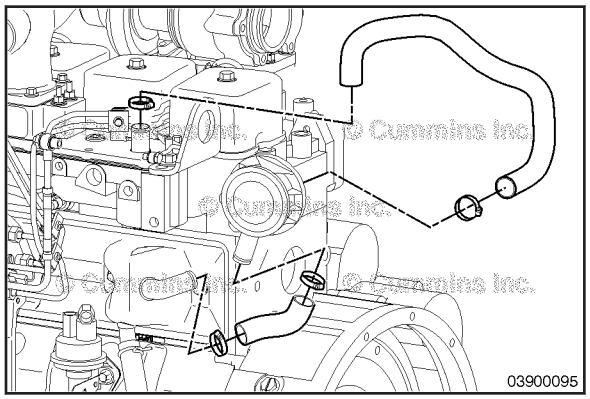


Rear Gear Train

Connect the closed crankcase ventilation valve to the closed crankcase ventilation hoses and secure the hose clamps.

Torque Value: 8 N•m [71 in-lb]





Closed Crankcase Ventilation Hoses (003-024)

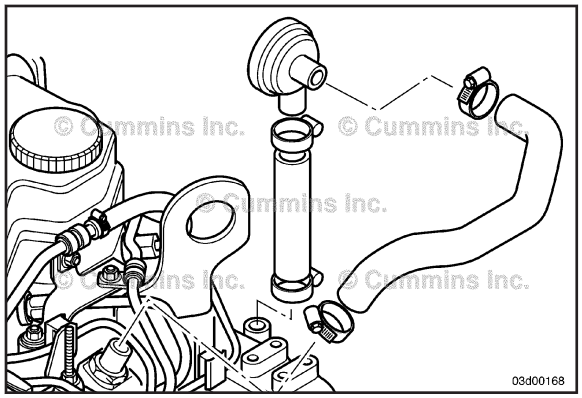
Install

Front Gear Train

Install the closed crankcase ventilation hoses and valve.

Tighten the hose clamps.

Torque Value: 8 N•m [71 in-lb]



Rear Gear Train

Install the closed crankcase ventilation hoses and valve.

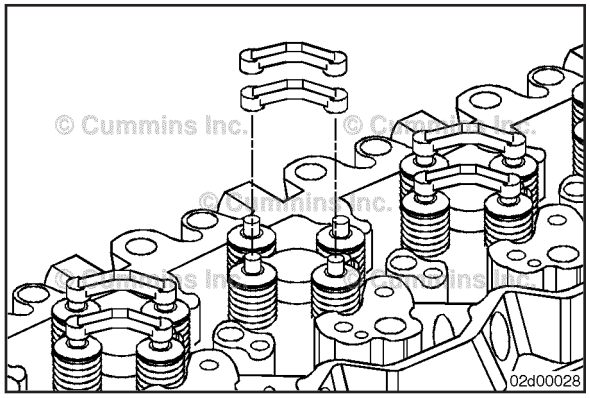
Secure the hose clamps.

Torque Value: 8 N•m [71 in-lb]

Crosshead (002-001)

General Information

This procedure is for engines with 4 valves per cylinder only.



Install

NOTE: The crosshead has a round and oval hole. If installing new crossheads, it is **not** required to place the holes in a particular position. If crossheads are being reused, make sure to install them in their original location and orientation.

Install the crossheads on the valve stems.

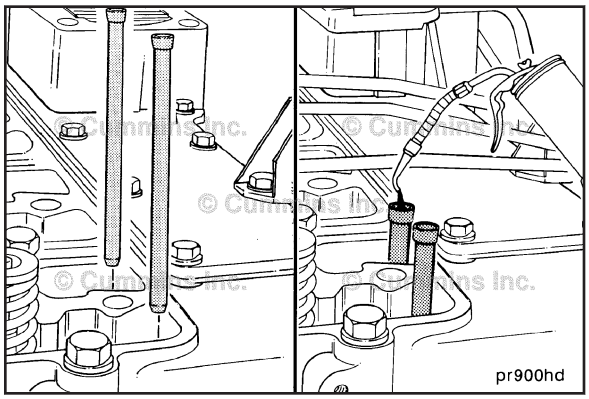
Push Rods or Tubes (004-014)

Install

Install the push rods into the sockets of the valve tappets.

Lubricate the push rods sockets with clean lubricating engine oil.

NOTE: The push rods and tappets **must** be installed in the same cylinder and intake or exhaust position from which they were removed.



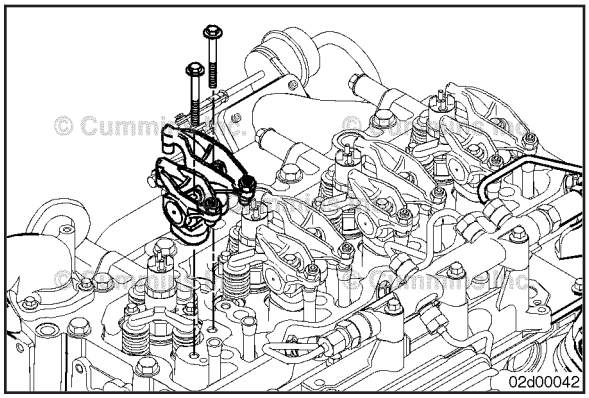
Rocker Lever (003-008)

Install

B4.5 RGT Engines

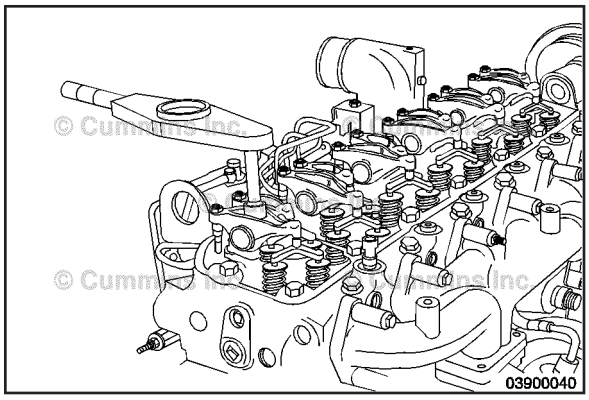
Install the rocker lever assemblies and pedestals in their original position.

Install the pedestal mounting capscrews.

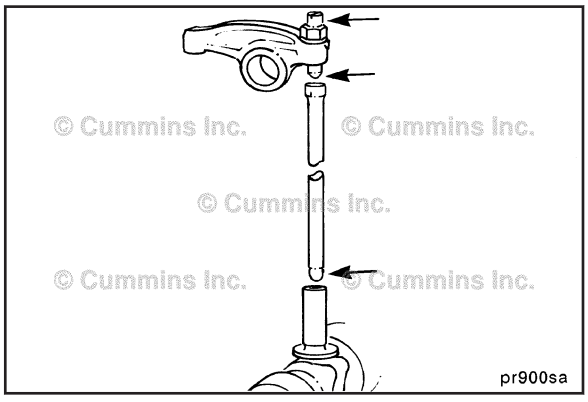


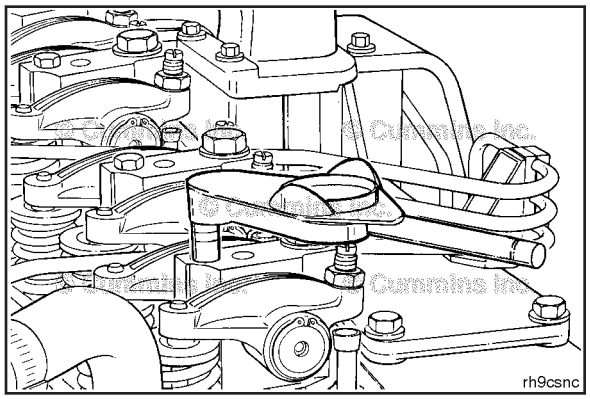
Tighten the pedestal mounting capscrews.

Torque Value: 36 N•m [27 ft-lb]



⚠CAUTION⚠
Rotate the adjusting screws until the adjusting screw contacts the socket of the push rod. This will ensure the push rod stays in contact with the tappet and adjusting screw when the engine is rotated to set valve lash. If not completed, the push rods may be bent or damaged.



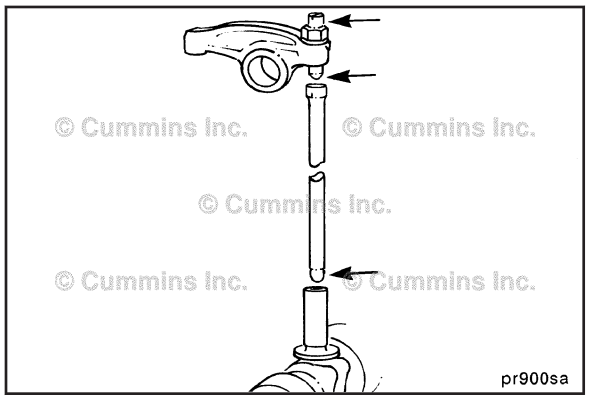


B3.9, B5.9, and B4.5 Engines

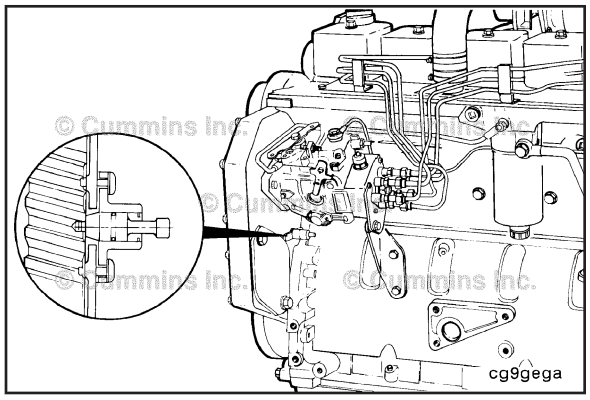
Because the rocker lever assemblies shares a mounting capscrew with the cylinder head, the initial rocker lever installation is a part of the cylinder head installation procedure. Refer to Procedure 002-004.

Tighten the remaining 8-mm rocker lever assembly pedestal capscrews.

Torque Value: 24 N•m [18 ft-lb]



⚠CAUTION⚠
Rotate the adjusting screws until the adjusting screw contacts the socket of the push rod. This will ensure the push rod stays in contact with the tappet and adjusting screw when the engine is rotated to set valve lash. If not completed, the push rods may be bent or damaged.

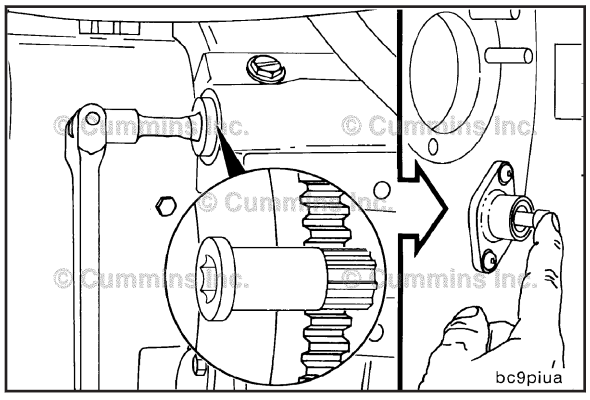


Overhead Set (003-004)

Preparatory Steps

NOTE: The timing pin is used to accurately locate TDC for setting the overhead. The timing pin is typically located below the fuel pump.

- for front gear train engines, in the front gear housing (shown)
- for rear gear train engines, in the rear gear housing (not shown)

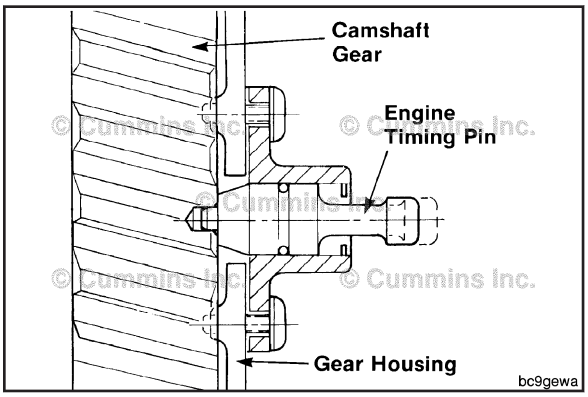


Locate top dead center (TDC) for cylinder number 1 by barring the crankshaft slowly while pressing on the engine timing pin. Barring the engine is recommended from the flywheel on the rear of the engine.

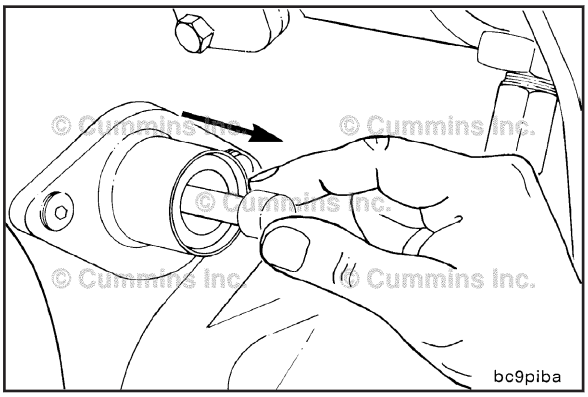
NOTE: Engine coolant temperature **must** be less than 60°C [140°F].

Using the barring tool Part Number 3824591, rotate the crankshaft slowly while pressing on the engine timing pin to locate TDC for cylinder number 1.

When the timing pin engages in the hole in the camshaft gear, cylinder number 1 is at TDC on the compression stroke.



⚠CAUTION⚠
To reduce the possibility of engine or timing pin damage, you must disengage the timing pin after locating top dead center.



Adjust

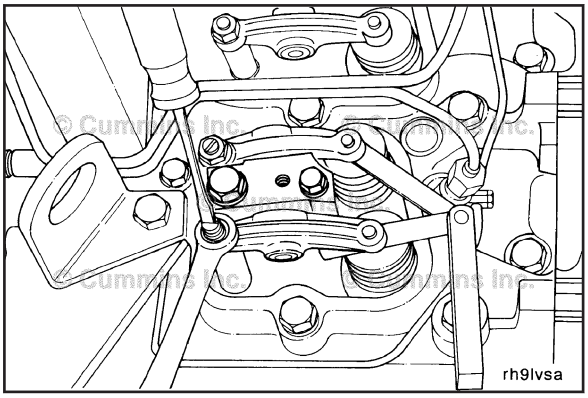
B3.9, B5.9, and B4.5 Engines

NOTE: The clearance is correct when some resistance is “felt” when the feeler gauge is slipped between the valve stem and the rocker lever.

NOTE: Caution **must** be used when setting the exhaust valve lash on marine cylinder heads with rotators. The top of the valve stem is slightly recessed below the top of the valve rotator.

Intake Clearance: 0.254 mm [0.010 in]

Exhaust Clearance: 0.508 mm [0.020 in]



Four-Cylinder Engine Adjustment

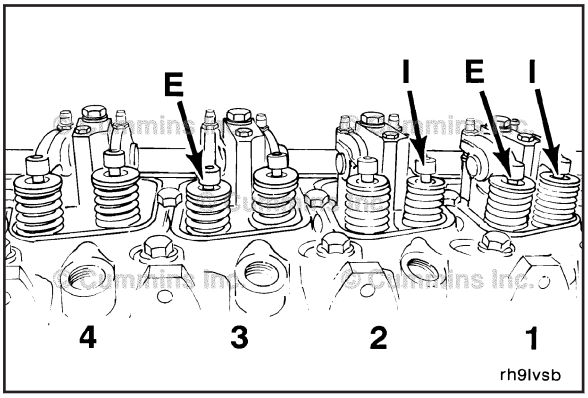
Make sure the engine is at top dead center (TDC) for cylinder number 1.

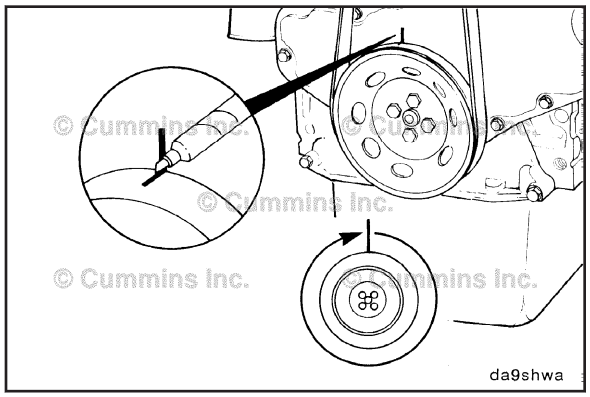
Set **only** valves indicated by the arrows (E = exhaust, I = intake). Do **not** set valves that are **not** indicated.

Holding the locknut steady with the wrench, adjust the valve clearance with the screwdriver or Allen wrench.

Tighten the locknut and measure the valve lash again.

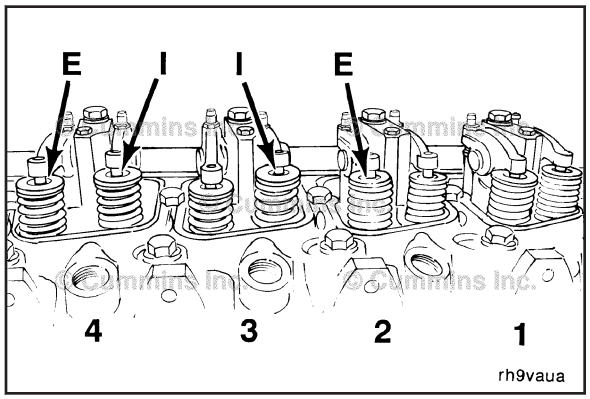
Torque Value: 24 N•m [18 ft-lb]





CAUTION
To reduce the possibility of engine or pin damage, be sure the timing pin is disengaged.

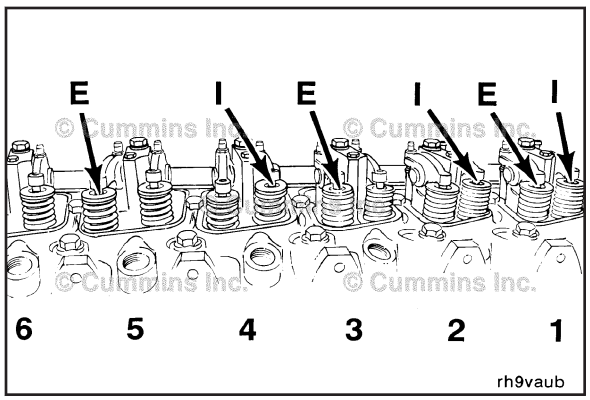
Mark the vibration damper and rotate the crankshaft 360 degrees.



Adjust the valves as indicated in the illustration.

Torque Value: 24 N•m [18 ft-lb]

Set **only** valves indicated by the arrows (E = exhaust, I = intake). Do **not** set valves that are **not** indicated.



Six-Cylinder Engine Valve Adjustment

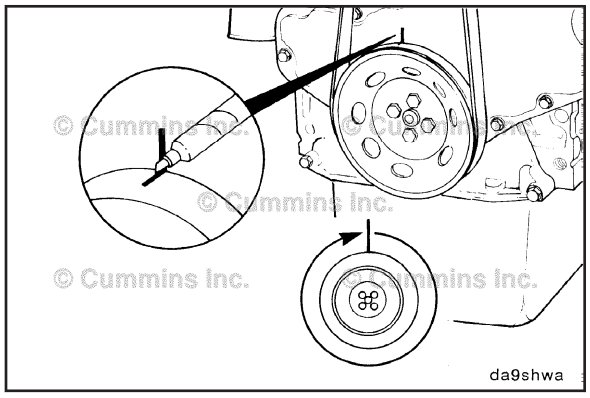
Make sure the engine is at top dead center (TDC) for cylinder number 1.

Set **only** the valves indicated by the arrows in the illustration (E = exhaust, I = intake).

Holding the locknut steady with the wrench, adjust the valve clearance with the screwdriver or Allen wrench.

Tighten the locknut, and measure the valve lash again.

Torque Value: 24 N•m [18 ft-lb]



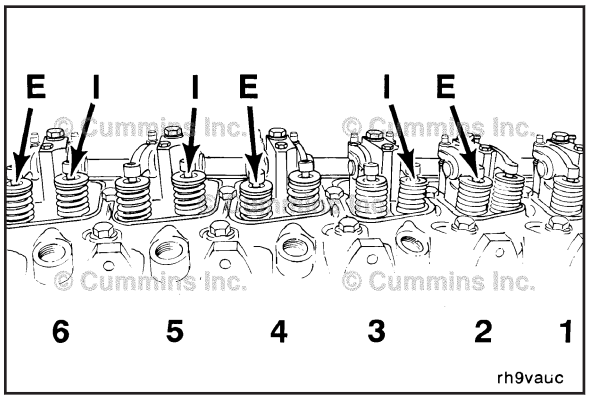
CAUTION
To reduce the possibility of engine or pin damage, be sure timing pin is disengaged.

Mark the pulley, and rotate the crankshaft 360 degrees.

Adjust the valves as indicated in the illustration.

Set **only** the valves indicated by the arrows in the illustration (E = exhaust, I = intake). Do **not** set valves that are **not** indicated.

Torque Value: 24 N•m [18 ft-lb]



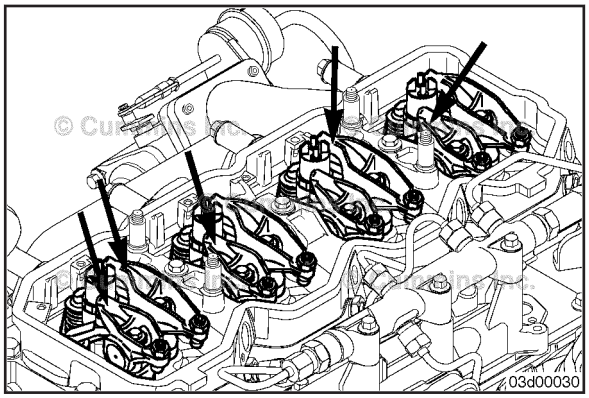
B4.5 RGT Engines

With the engine in this position, lash can be measured on the following rocker levers:

(E = exhaust, I = Intake)

Four-cylinder 1I, 1E, 2I, and 3E:

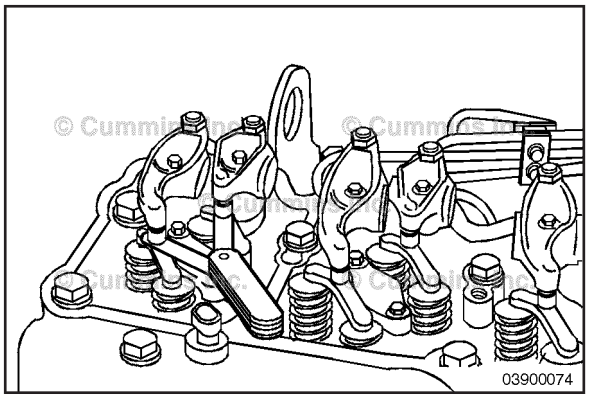
Six-cylinder 1I, 1E, 2I, 3E, 4I, and 5E.

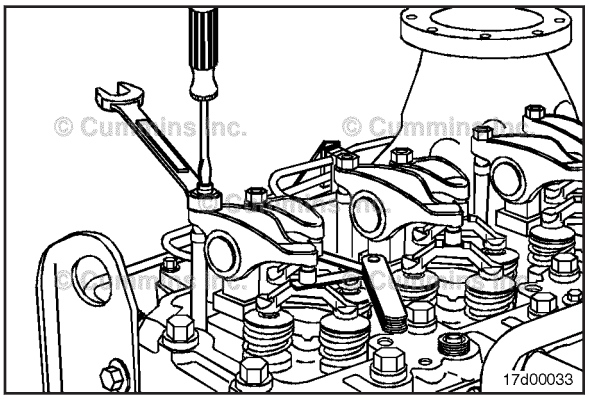


Lash Check Limits

	mm		in
Intake	0.152	MIN	0.006
	0.381	MAX	0.015
Exhaust	0.381	MIN	0.015
	0.762	MAX	0.030

NOTE: Checking the overhead setting is usually performed as part of a troubleshooting procedure, and resetting is **not** required during checks as long as the lash measurements are within the above ranges.





NOTE: The clearance is correct when some resistance is “felt” when the feeler gauge is slipped between the crosshead and the rocker lever socket.

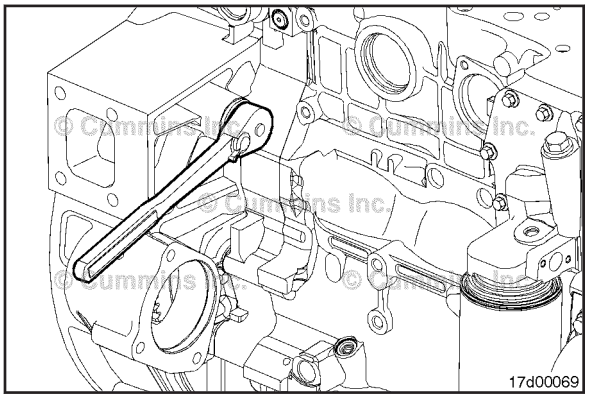
Measure lash by inserting a feeler gauge between the crosshead and the rocker lever socket. If the lash measurement is out of specification, loosen the locknut, and adjust the lash to nominal specifications.

Lash Specifications		
	mm	**in**
Intake	0.254	0.010
Exhaust	0.508	0.020

Tighten the locknut and remeasure.

Torque Value: 24 N•m [212 in-lb]

⚠CAUTION⚠
To reduce the possibility of engine or pin damage, be sure the timing pin is disengaged.



Using barring tool, Part Number 3824591, rotate the crankshaft 360 degrees.

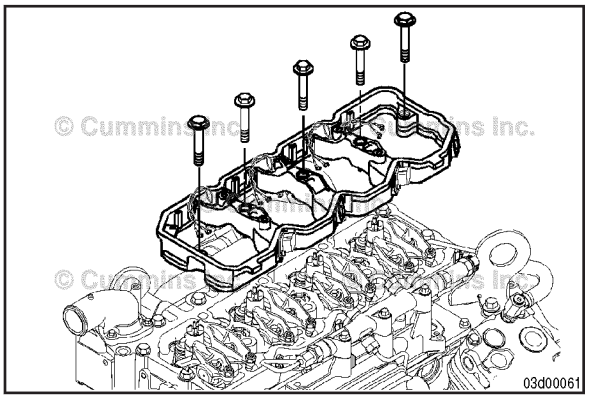
Following the same steps and specifications as previously stated, measure lash for the following rocker levers:

(E = exhaust, I = Intake)

Four-cylinder 2E, 3I, 4E, and 4I:

Six-cylinder 2E, 3I, 4E, 5I, 6I, and 6E.

Reset if out of specification.



Rocker Lever Housing (003-013)

Install

Rear Gear Train

⚠CAUTION⚠
Care must be taken when installing the gasket. Do not twist or stretch it. Failure to do so can result in an oil leak.

Install the rocker housing and a new rocker housing gasket, if removed.

Torque Value: 24 N•m [212 in-lb]

Injector (006-026)

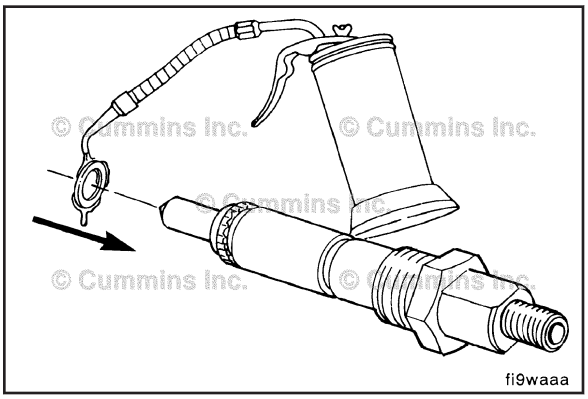
Install

Front Gear Train

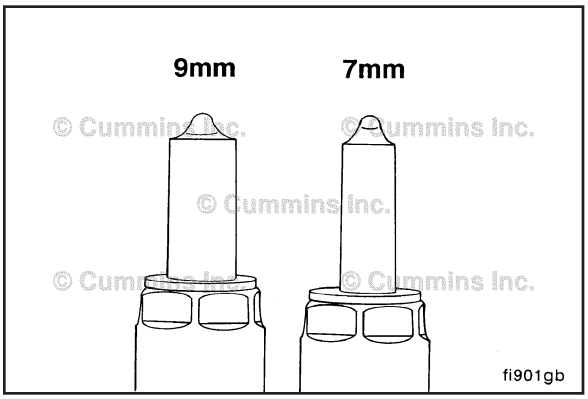
Assemble the injector and a new copper sealing washer.

Use **only** one copper washer.

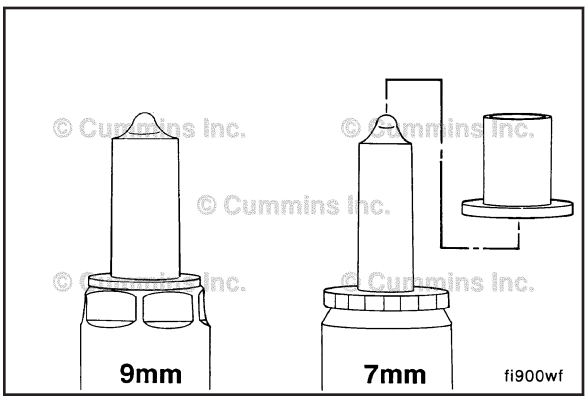
Service Tip: A light coat of clean lubricating engine oil between the washer and injector can help to keep the washer from falling during installation.



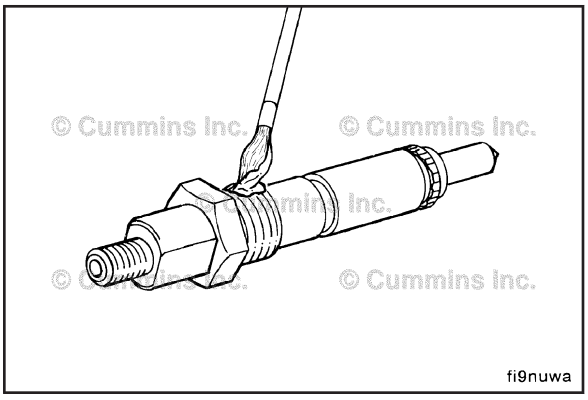
⚠CAUTION⚠
Early model injectors (pre-1991) have a 9-mm injector tip that can not be used in engines built in 1991 or later as these engines use a 7-mm injector tip.

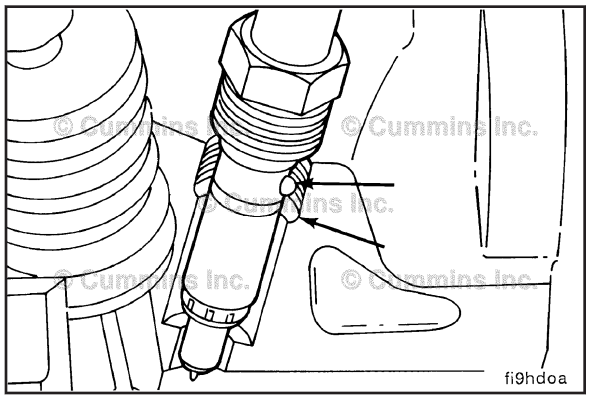


If the special adapter sleeve is installed onto the 7-mm injector tip, 7-mm injectors can be used in early model (9-mm) injector holes.



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.

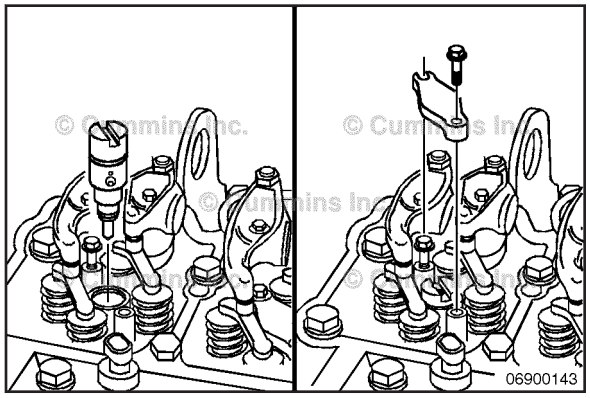




NOTE: Align the injector's protrusion with the notch in the bore.

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]

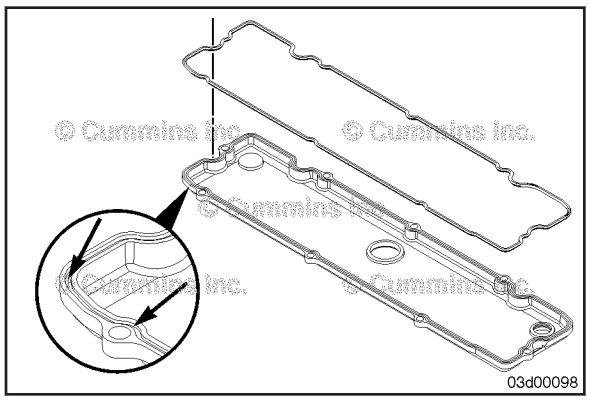


Rear Gear Train

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]



Rocker Lever Cover (003-011)

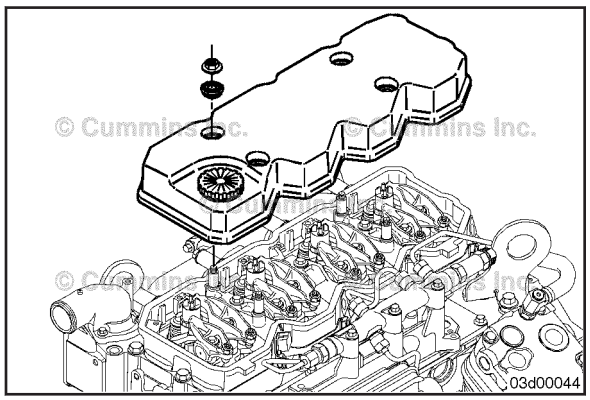
Assemble

B4.5 RGT Engines

NOTE: If the gasket has been removed from the rocker lever cover, a new gasket **must** be used.

If replacing the rocker lever gasket, the following installation procedure must be used when installing the press-in gasket.

1. Press the molded gasket into the corners of the rocker lever cover
2. Press the remaining gasket into the rocker lever cover.



Install

B4.5 RGT Engines

Install the rocker lever cover over the mounting capscrews.

Install the isolators and mounting nuts.

Tighten the mounting nuts.

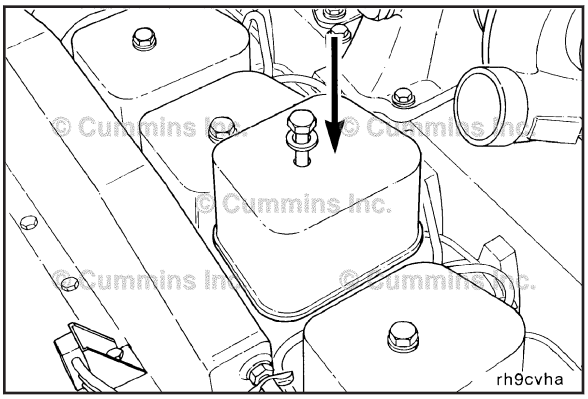
Torque Value: 24 N•m [18 ft-lb]

B3.9, B5.9, and B4.5 Engines

Install rocker lever cover(s).

Tighten the capscrews.

Torque Value: 24 mm [18 ft-lb]



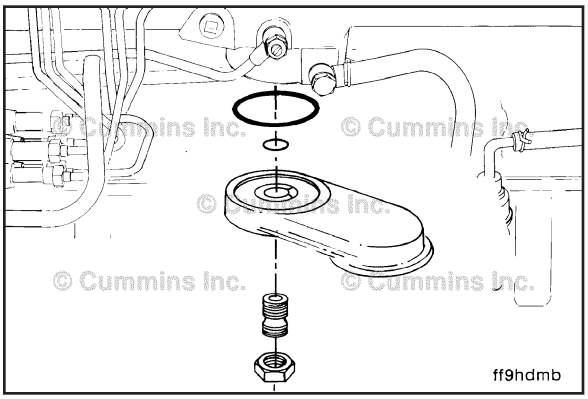
Fuel Filter Head (006-017)

Assemble

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]



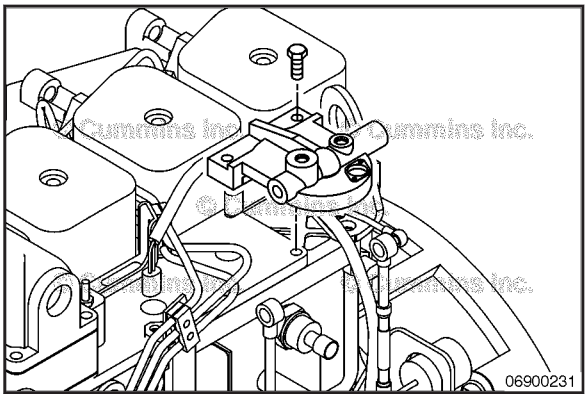
Install

Front Gear Train

Install the fuel filter head.

Tighten the two retaining capscrews.

Torque Value: 24 N•m [18 ft-lb]



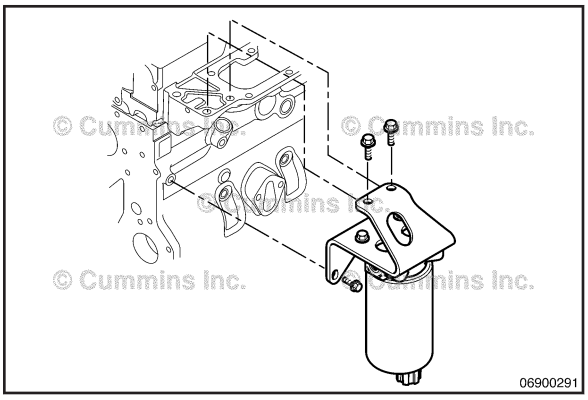
Rear Gear Train

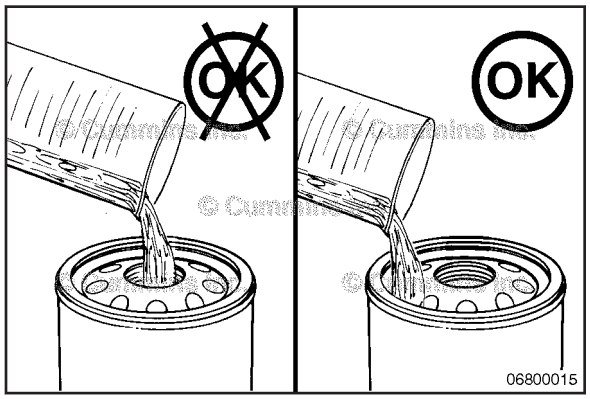
Install the fuel filter head bracket on the engine. Finger tighten the two M10 capscrews to the head and the remaining M8 capscrews into the cylinder block.

Tighten the fuel filter head bracket capscrews.

Torque Value:

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





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

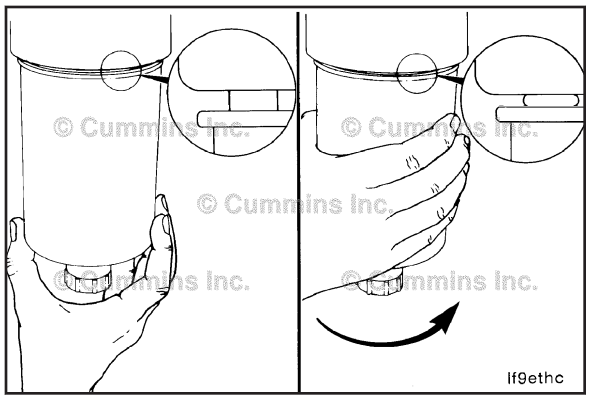
Install

⚠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.

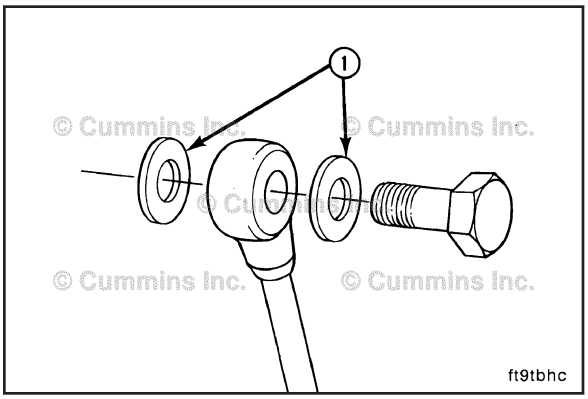
Tighten the fuel filter an additional ½ to ¾ of a turn after the gasket contacts the fuel filter head surface, or as specified by the fuel filter manufacturer.

Fuel Supply Lines (006-024)

Install

Low Pressure Fuel Line(s)

NOTE: When replacing the fuel lines, replace the banjo fitting sealing washers (1) each time they are removed.



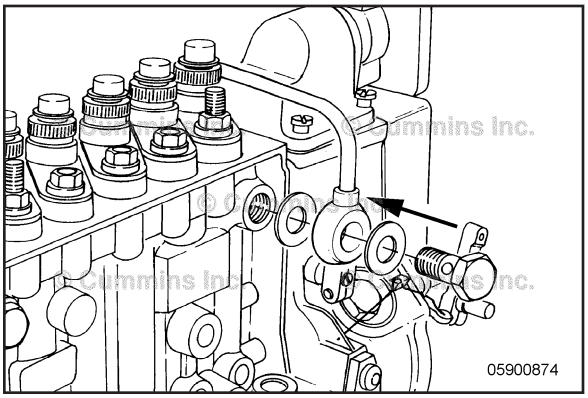
Fuel Pump Supply Line — Bosch® In-Line Pump.

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.

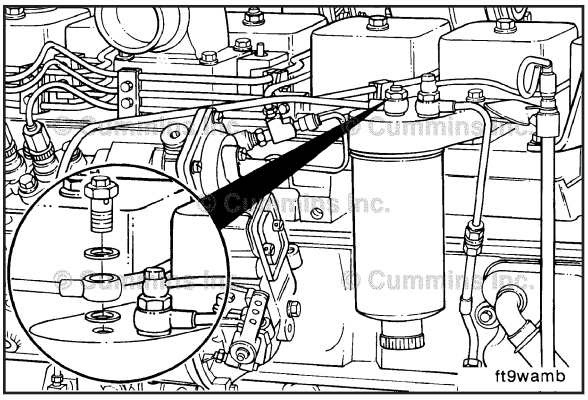
Install the fuel line and tighten.

Torque Value: 32 N•m [24 ft-lb]



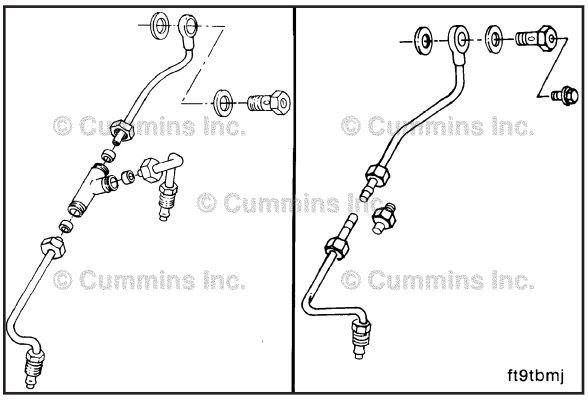
Install the banjo capscrew and sealing washers at the filter head.

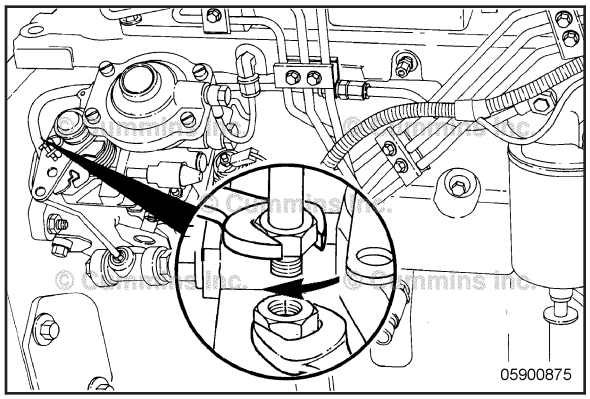
Torque Value: 24 N•m [18 ft-lb]



Install the fuel supply line to the two Lucas CAV fuel injection pumps.

Torque Value: 24 N•m [18 ft-lb]

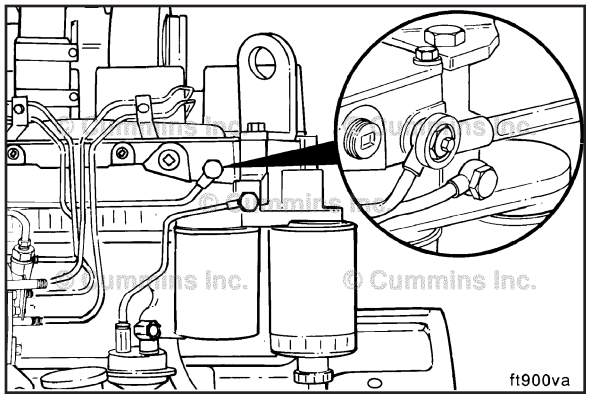




Install the fuel line to the Bosch® fuel injection pump fitting.

NOTE: To prevent overtightening the fuel injection pump inlet fitting, use two wrenches when installing the fuel supply line.

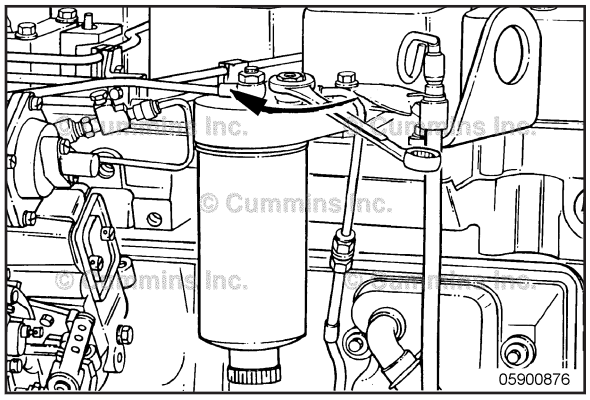
Torque Value: 32 N•m [24 ft-lb]



Fuel Injection Pump Supply Line — Distributor-Type Pumps.

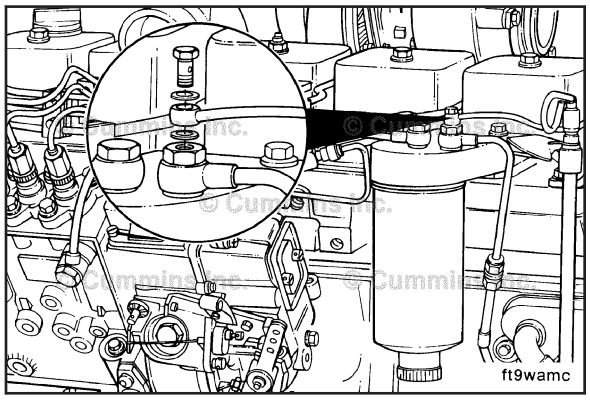
Install the bleed screw banjo fitting.

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.

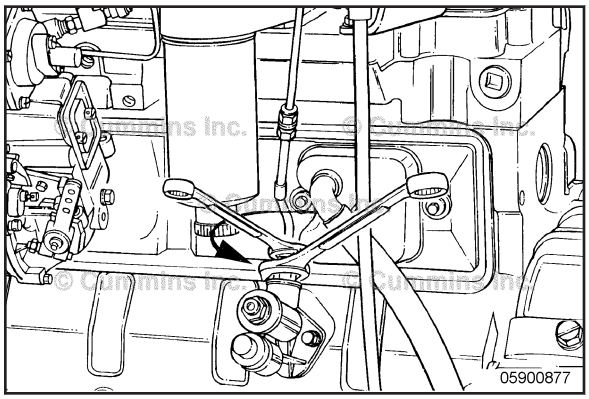
Torque Value: 13 N•m [10 ft-lb]

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]

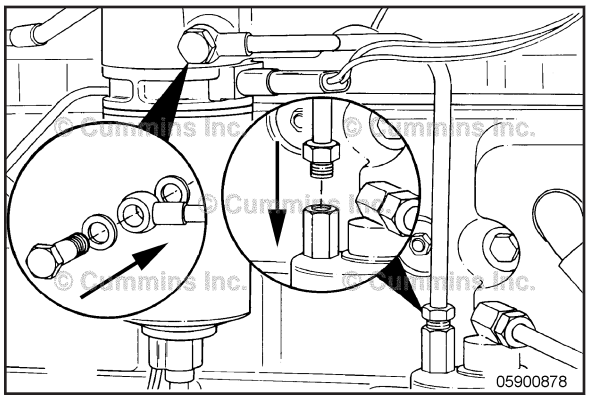
NOTE: To prevent overtightening the fuel injection pump inlet fitting, use two wrenches when installing the fuel supply line.



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]



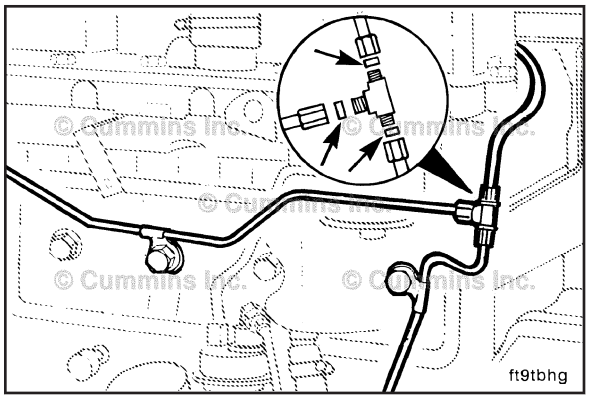
Fuel Manifold (Drain) (006-021)

Install

Distributor-Type Pump

Assemble the fuel drain line and fuel drain manifold in the reverse order of disassembly.

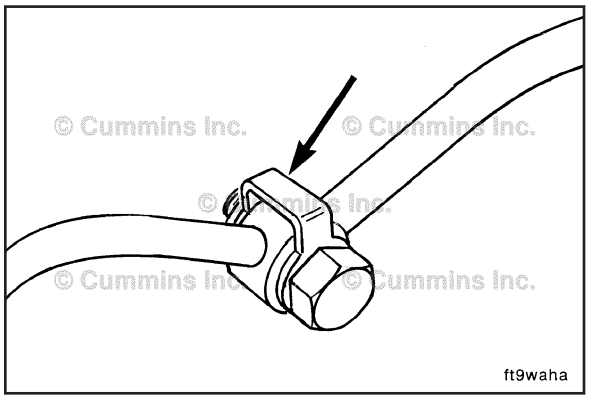
NOTE: Use new seals for the fittings.

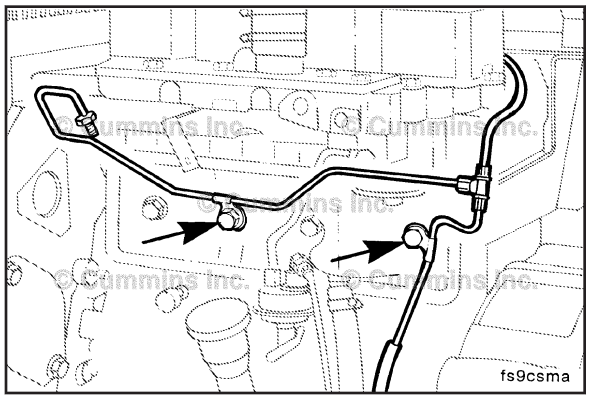


The installation torque for the banjo fitting screw is as follows:

Torque Value: 9 N•m [80 in-lb]

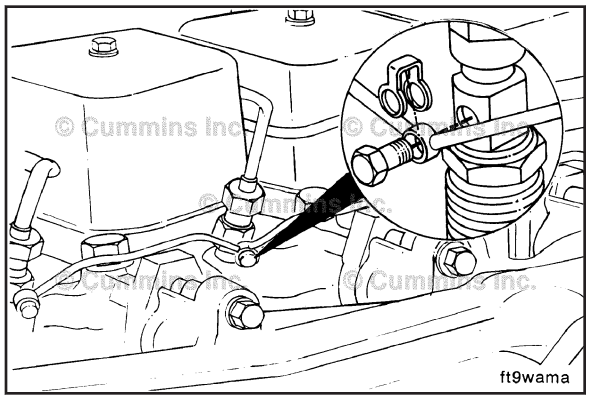
NOTE: Use new sealing washers for the fuel drain manifold.





Install the clamp capscrews.

Torque Value: 24 N•m [18 ft-lb]



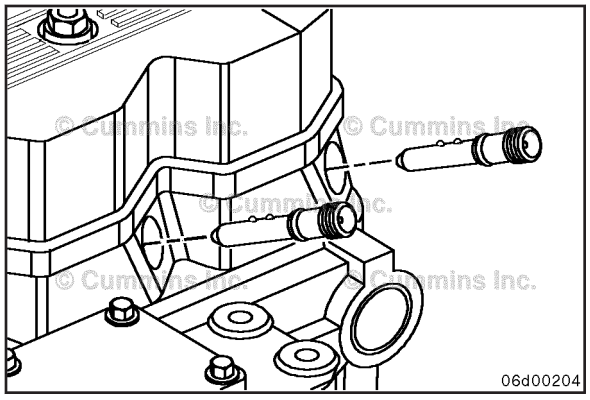
Bosch® In-Line pump

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.



Fuel Connector (Head Mounted) (006-052)

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]

Injector Supply Lines (High Pressure) (006-051)

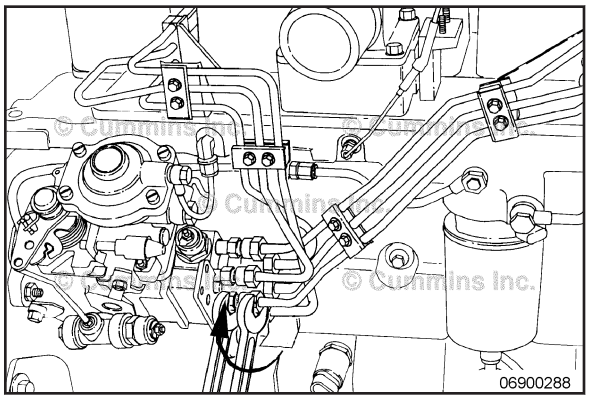
Install

Distributor-Type Pumps

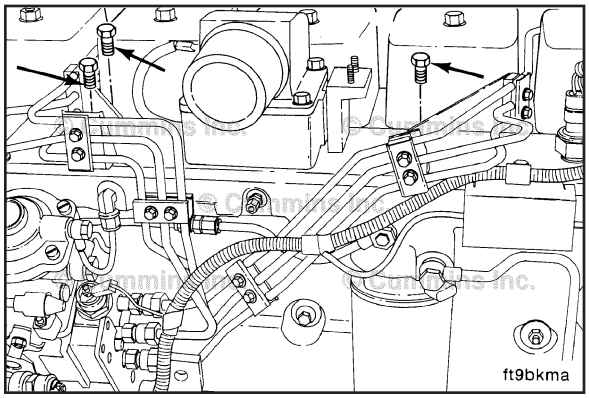
Install the fuel lines to the fuel injection pump.

NOTE: Use two wrenches to prevent the delivery valve holder from turning.

Torque Value: 24 N•m [18 ft-lb]

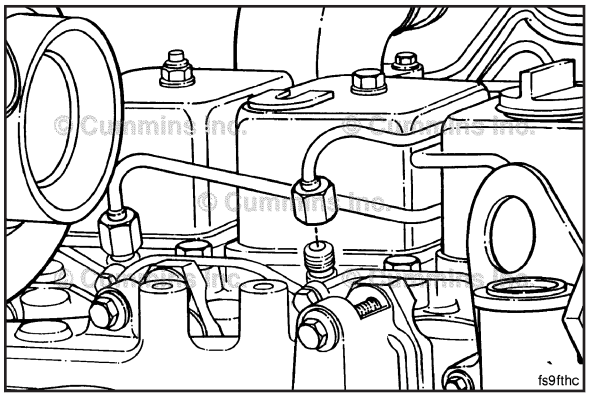


Install the fuel line clamp capscrews to the intake cover.



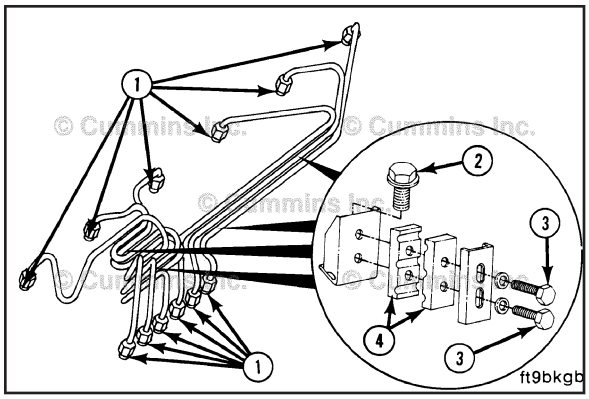
Connect the high-pressure fuel lines to the injectors.

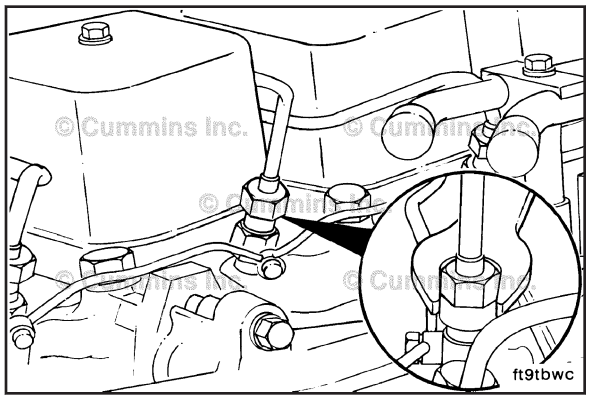
Torque Value: 38 N•m [28 ft-lb]



In-Line Pump

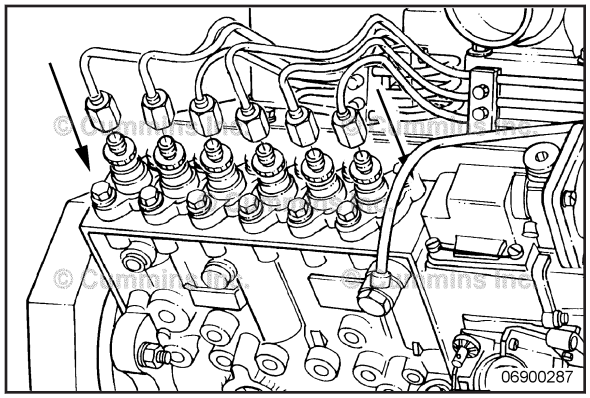
Install fuel line fittings (1), support bracket capscrews (2), vibration capscrew isolator (3), and isolators (4).





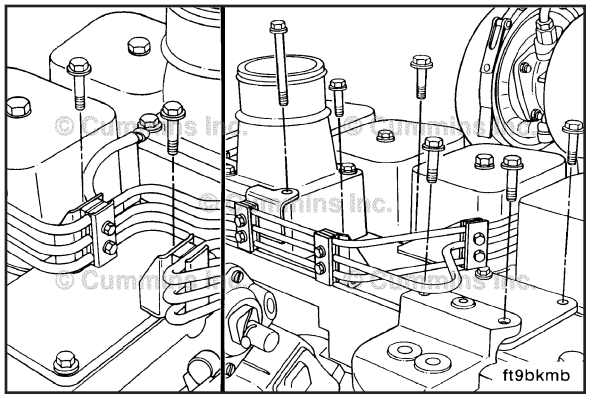
Connect the high-pressure fuel lines to the injectors.

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.

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.

Install

Apply a thin bead of thread sealant around the bottom of the knurled end of the tube.

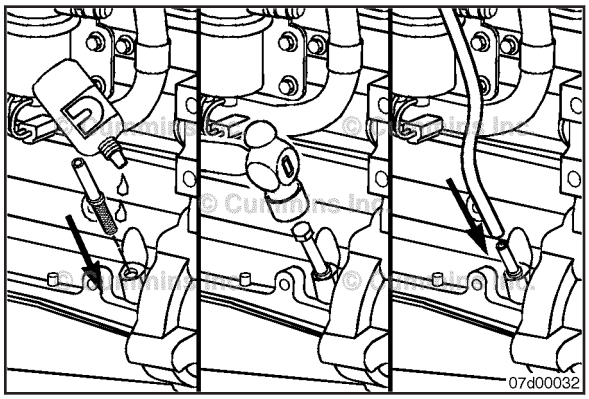
Place knurled end of tube into the dipstick tube bore in the cylinder block.

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.

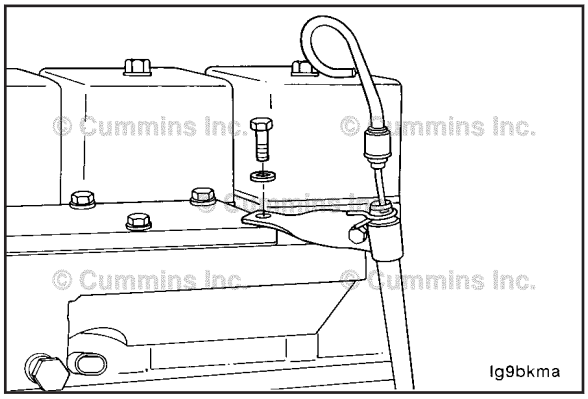
If equipped, install the flexible portion of the dipstick tube and secure with clamps.

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.

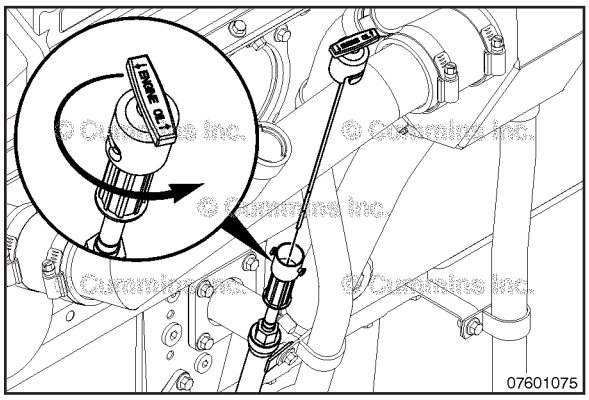
Install dipstick into the dipstick tube.



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.

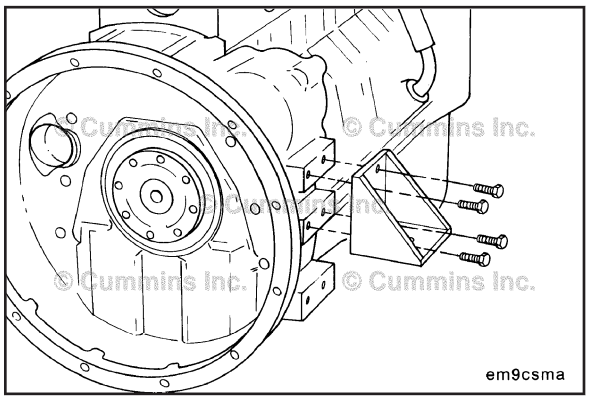


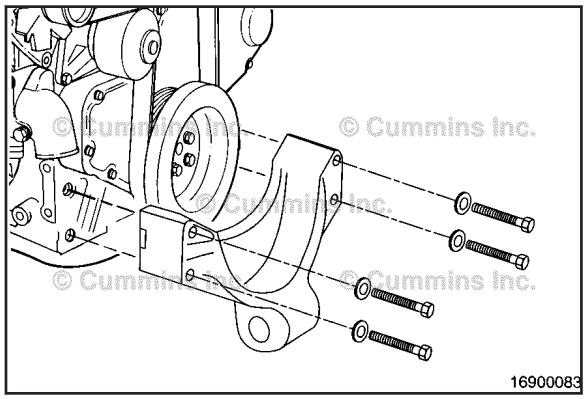
Engine Support Bracket, Rear (016-003)

Install

Install the support bracket and mounting capscrews.

Torque Value: 71 N•m [52 ft-lb]





Engine Support Bracket, Front (016-002)

Install

Install the front support and mounting capscrews.

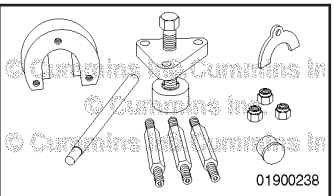
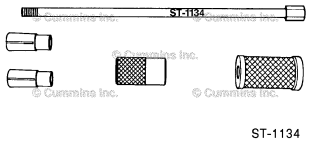
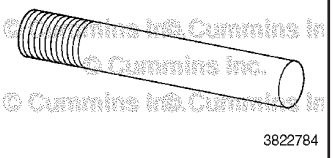
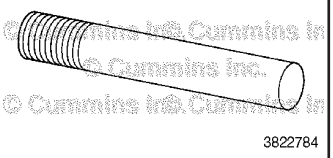
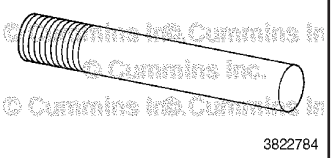
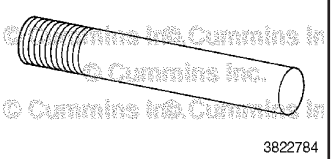
Torque Value: 68 N•m [50 ft-lb]

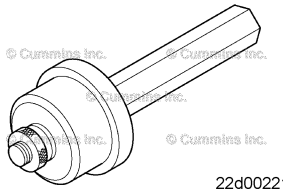
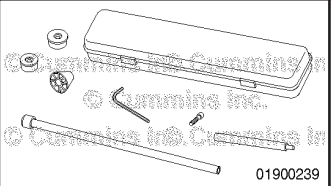
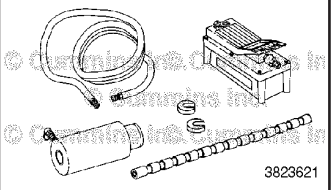
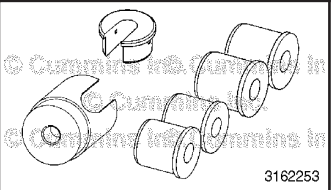
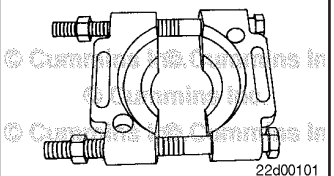
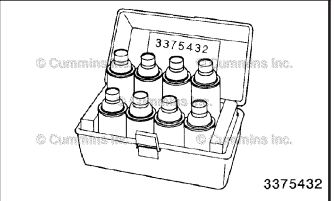
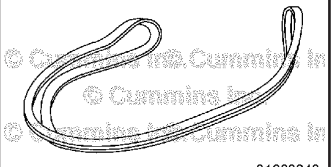
Section 1 - Cylinder Block - Group 01

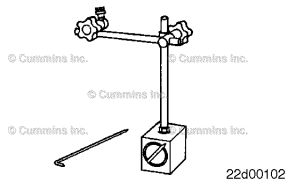
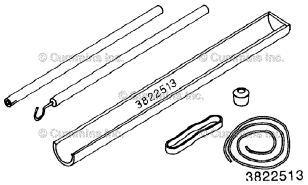
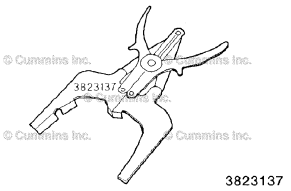
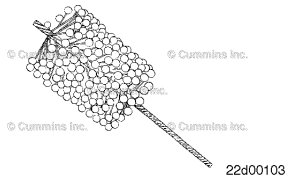
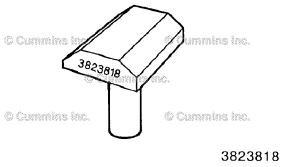
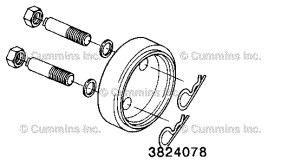
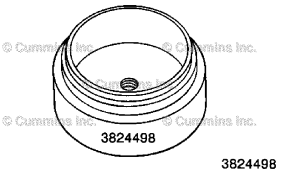
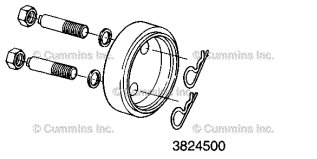
Section Contents

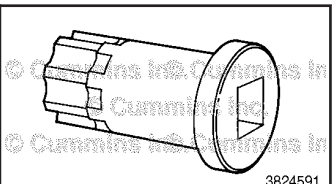
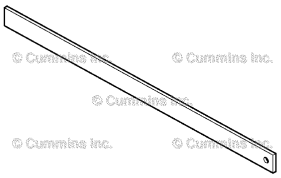
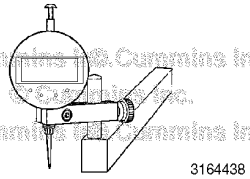
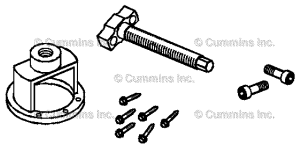
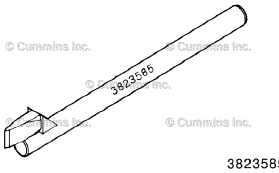
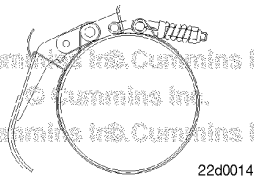
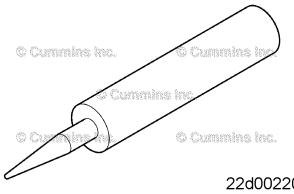
Service Tools

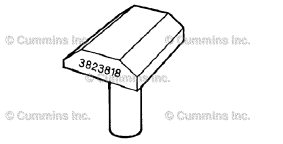
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

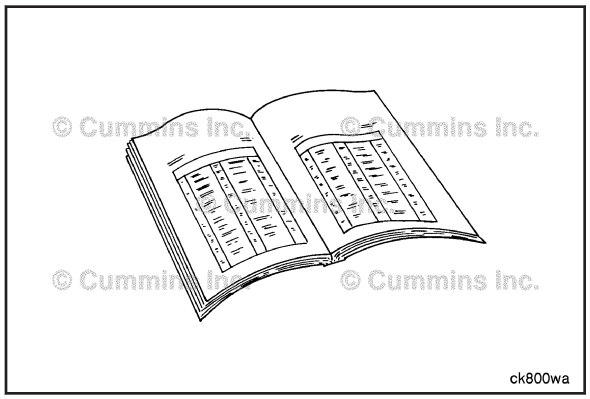
Tool No.	Tool Description	Tool Illustration
3163054	**Camshaft Gear Installation/Removal Tool** Used to install and remove the camshaft gear without removing the camshaft from the engine.	
3163720	**Dowel Pin Extractor** Used to remove solid locating pins from the cylinder block. Kit includes SAE and Metric sizes.	
3163934	**Assembly Guide Pin** M12 x 1.75	
3163935	**Assembly Guide Pin** M10 x 1.25	
3163936	**Assembly Guide Pin** M8 x 1.0	
3164977	**Assembly Guide Pin** M8 x 1.25	

Tool No.	Tool Description	Tool Illustration
3376488	**Assembly Guide Pin** M10 x 1.5	 3822784
3165035	**Cam Bushing Driver** Handheld driver can be used to replace the front or rear bushings **only**.	 22d00221
3165045	**Camshaft Bushing Tool** Used to remove and install camshaft bushings. NOTE: The following 2 kits are also available for this purpose.	 01900239
3823621	**Hydraulic Actuator Kit** Used to remove and install camshaft bushings.	 3823621
3162249	**Camshaft Bushing Installation/Removal Kit** Used to remove and install camshaft bushings.	 3162253
3375326	**Crankshaft Gear Remover** Used to pull the crankshaft gear without heating or damaging the gear.	 22d00101
3375432	**Crack Detection Kit** Used to locate cracks in cylinder blocks, cylinder heads; as well as in other engine components.	 3375432
3375957	**Nylon Lift Sling** Used to lift the crankshaft from the engine during installation and removal.	 01900240

Tool No.	Tool Description	Tool Illustration
3377399	**Magnetic Base Indicator Holder** Used in conjunction with dial indicator, Part Number 3824564 (metric); 4918289 (SAE).	
3822513	**Tappet Removal Tool Kit** Used to remove and install valve tappets.	
3823137	**Piston Ring Expander** Used to install piston rings onto pistons without damaging or distorting the rings.	
3823612	**Flexible Hone** Used to deglaze the engine block cylinder walls.	
3823818	**Main Bearing Rollout Tool** Used to remove and install the main bearings with the crankshaft installed.	
3824078	**Wear Sleeve Installation Tool** Used to install the rear crankshaft lubricating oil seal wear sleeve.	
3824498	**Oil Seal Installation Tool** Used to install the front crankshaft lubricating oil seal in the front cover to a specified depth.	
3824500	**Wear Sleeve Installation Tool** Used to install the front crankshaft lubricating oil seal wear sleeve.	

Tool No.	Tool Description	Tool Illustration
3824591	**Engine Barring Gear** Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591
4918219	**Precision Straightedge** Used to check cylinder blocks and cylinder heads for flatness.	 22d00222
3822709	**Threaded Insert Kit** Blind metric inserts can be used to repair different size cylinder block threads.	 22d00218
3164438	**Depth Gauge Assembly** Used to measure liner protrusion, cylinder block counterbore depths, and valve intrusion and/or protrusion. Equipped with a digital, electronic indicator.	 3164438
3164659	**Oil Seal Replacer (front)** Used to remove/install the front crankshaft seal. For rear gear train engines only.	 22d00086
3823585	**Gear Splitter** Used to separate cast iron gears.	 3823585
3164330, 4918294	**Piston Ring Compressor** Used to install piston with rings into the cylinder bore. 3164330 - 102 mm [4.02 in] bore engines. 4918294 - 107 mm [4.21 in] bore engines.	 22d00141
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 only.	 22d00220

Tool No.	Tool Description	Tool Illustration
3823818	**Main Bearing Rollout Tool** Used to remove and install main bearings with the crankshaft installed.	 3823818
3164067	**RTV Silicone Sealant** Used in most locations requiring RTV sealant.	 3823494



Balancer (001-004)

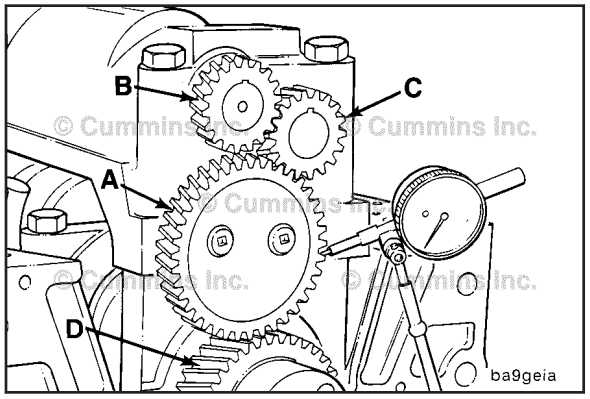
Preparatory Steps

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

⚠WARNING⚠
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.

- Disconnect the batteries. Refer to Procedure 013-009.
- Drain the lubricating oil. Refer to Procedure 007-037.
- Remove the lubricating oil pan. Refer to Procedure 007-025.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035.



Remove

Measure Backlash

Use an indicator to measure the backlash of the idler gear (A), upper shaft gear (B), and lower shaft gear (C).

NOTE: Do **not** allow the adjoining gear to move or the reading will be the total of both gears.

Balancer Gear Backlash

	mm		in
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

Record for use during inspection.

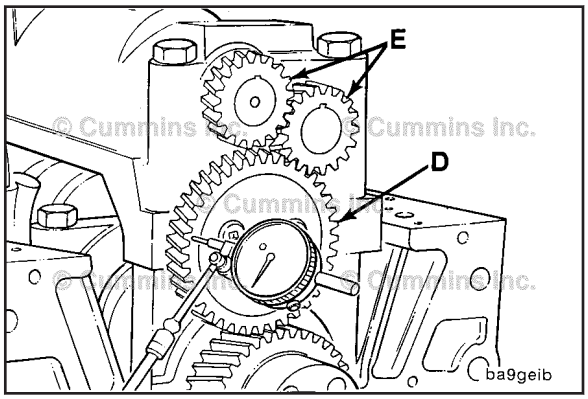
Measure End Play

Use an indicator to measure the end play of the idler gear (D) and shaft (E).

Balancer End Play

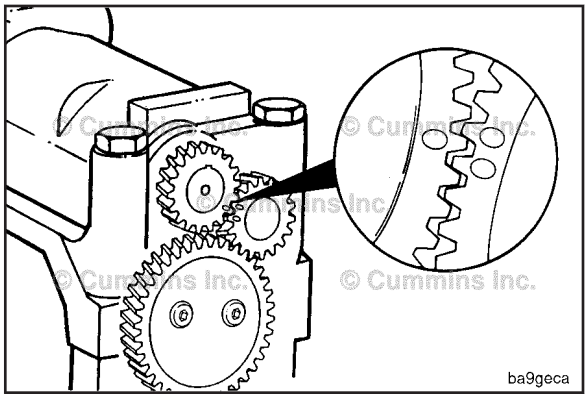
	mm		in
(D)	0.130	MIN	0.005
	0.630	MAX	0.024
(E)	0.075	MIN	0.003
	0.175	MAX	0.007

Record for use during inspection.

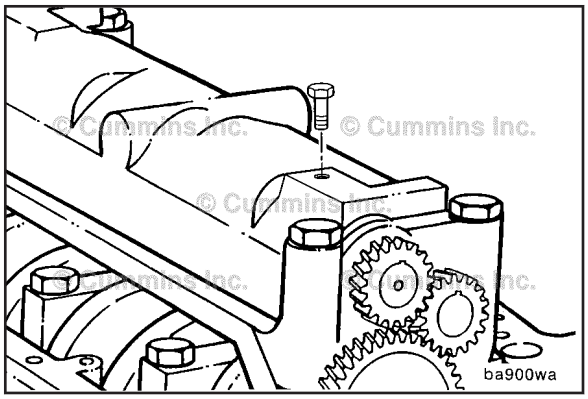


Lock Balancer

Rotate the balance gears until the timing marks are aligned.



If the balancer shaft has a tapped hole, the shaft can be locked in position by temporarily installing a M8 capscrew through the housing and into the shaft.

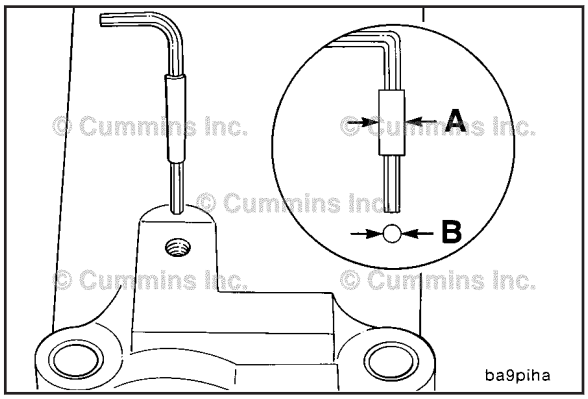


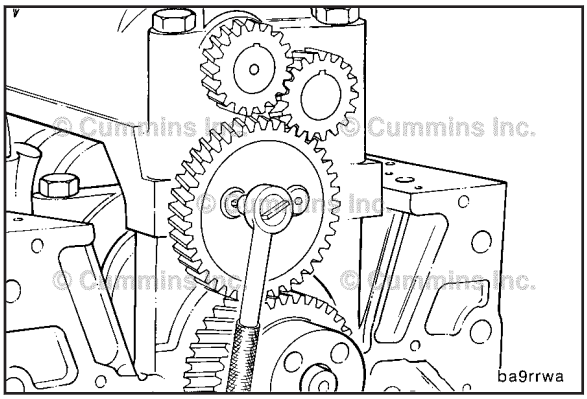
Follow this procedure if the shaft does **not** have a tapped hole.

Wrap the 4.5-mm Allen wrench with 1-inch wide masking tape until it has a snug fit in the hole in the balancer housing.

A = Approximately 10 mm [0.4 in]

B = 10 mm [0.4 in]

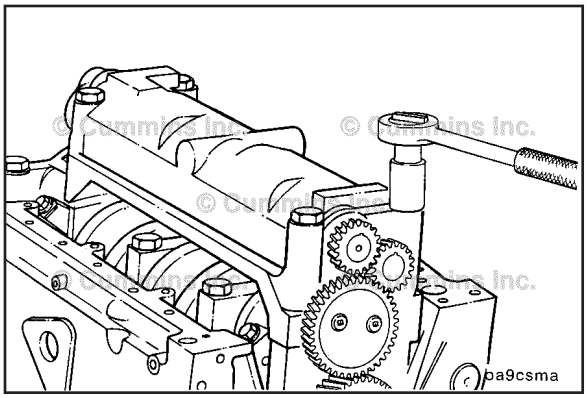




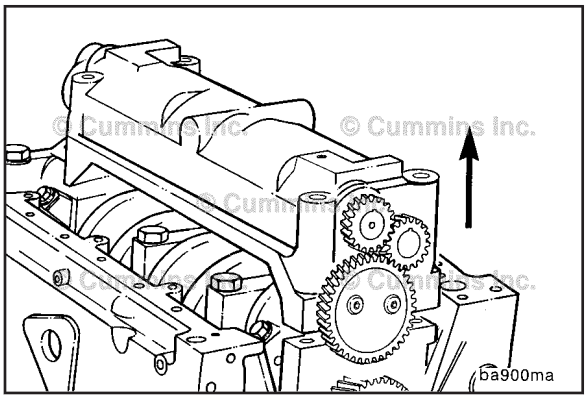
Remove Balancer

Loosen the socket head capscrew for the balancer idler gear retainer using an 8-mm Allen wrench.

Do **not** remove the capscrews.

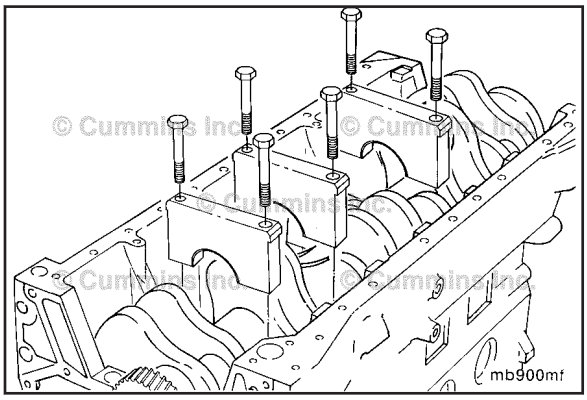


Remove the number 1 and number 4 main bearing capscrews.



Move the idler retainer until the pin in the number 1 cap disengages the slot in the retainer.

Remove the balancer assembly.



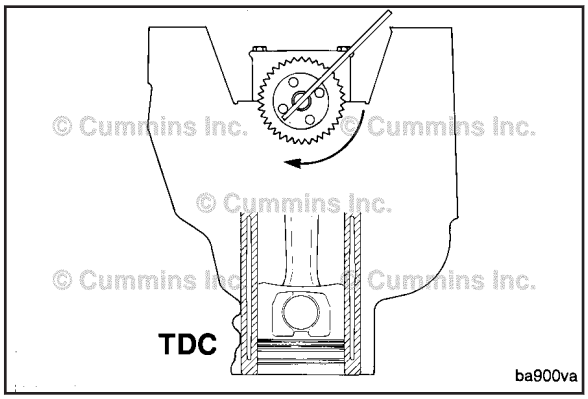
Install

Use a 23-mm wrench to rotate the cylinder block on the relaxed stand until the crankshaft is positioned at the top and parallel to the floor.

The number 1 and number 4 main bearing capscrews **must** be removed to install the balancer.

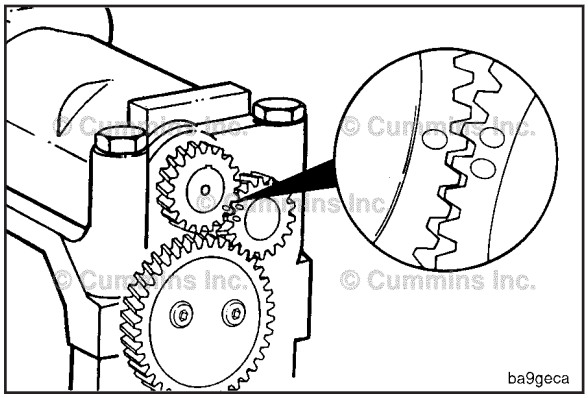
Rotate the crankshaft until the number 1 piston is at top dead center.

The engine **must** have a cylinder at top dead center for correct gear teeth alignment when the balancer is installed.



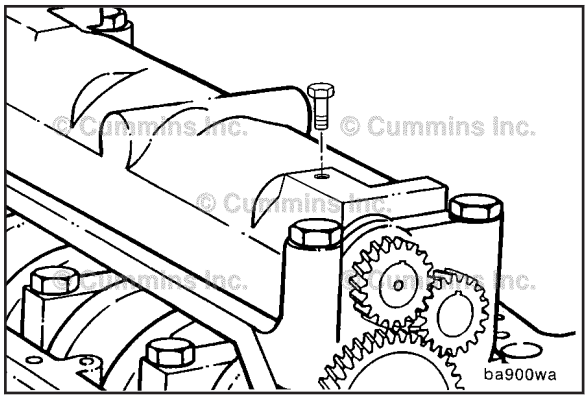
Rotate the balancer gears until the timing marks are aligned.

The balancer **must** be kept in this position for correct installation on the engine.



If the balancer shaft has a tapped hole, the shaft can be locked into position by temporarily installing an M8 capscrew through the housing and into the shaft.

Use a 13 mm wrench.



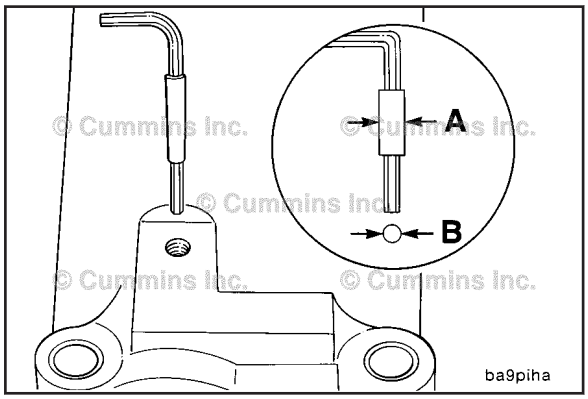
The idler gear retainer capscrews **must** be loose.

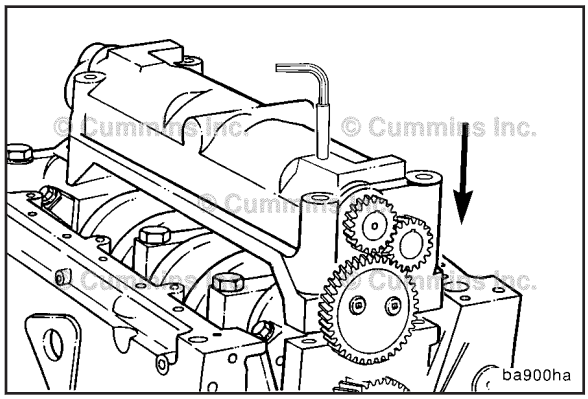
Follow this procedure if the shaft does **not** have a tapped hole.

Wrap the 4.5-mm Allen wrench with 1-inch wide masking tape until it has a snug fit in the hole in the balancer housing.

A = Approximately 10 mm [0.4 in]

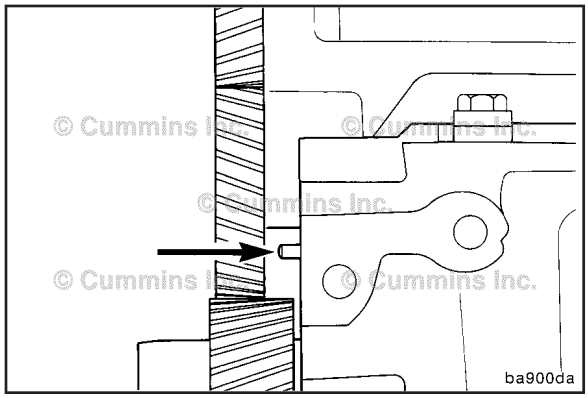
B = 10 mm [0.4 in]





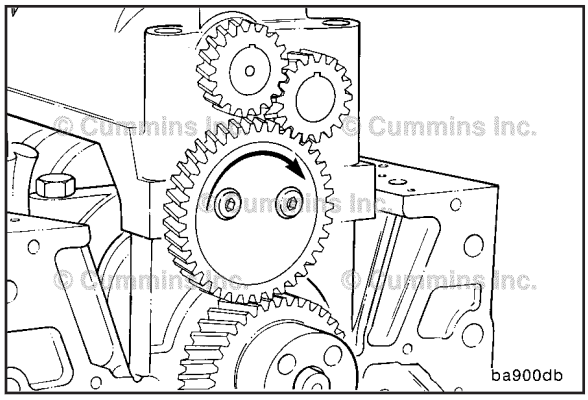
Position the locked balancer assembly onto the main bearing caps.

The assembly **must** be located squarely with the alignment ears against the side of the caps.

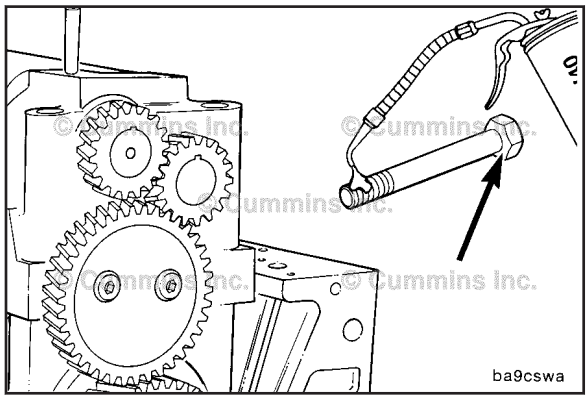


Align the slot in the idler gear retainer with the locating pin in the main bearing cap.

Slide the balancer into position.

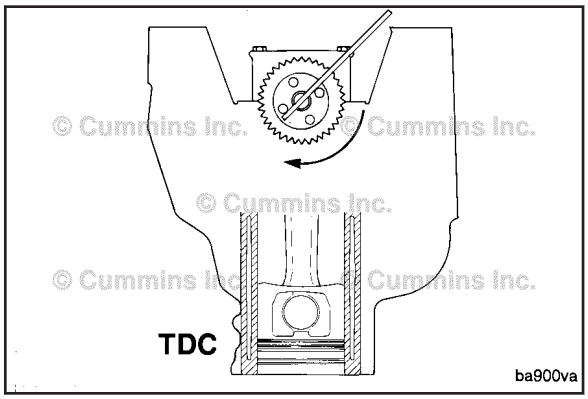


The idler gear can be slightly rotated to aid in alignment.



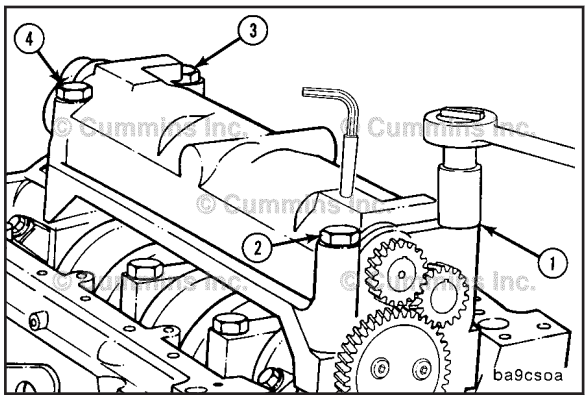
Lubricate the main bearing capscrew threads and the underside of the capscrew heads with clean engine oil.

If the capscrews do **not** install freely, check to be sure the engine has a piston at top dead center.

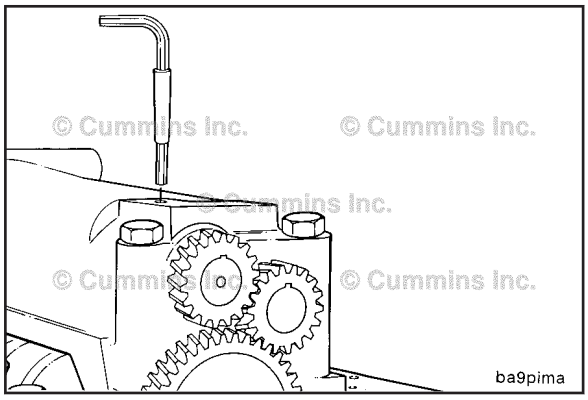


Tighten the capscrews evenly, use a 23 mm wrench, follow the illustrated sequence.

Torque Value: Step1 60 N•m [44 ft-lb]
Step2 119 N•m [88 ft-lb]
Step3 176 N•m [130 ft-lb]

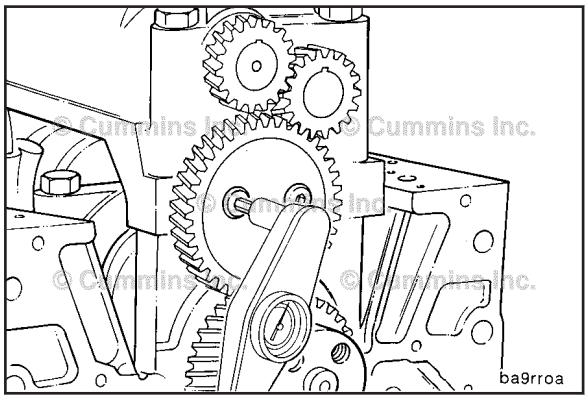


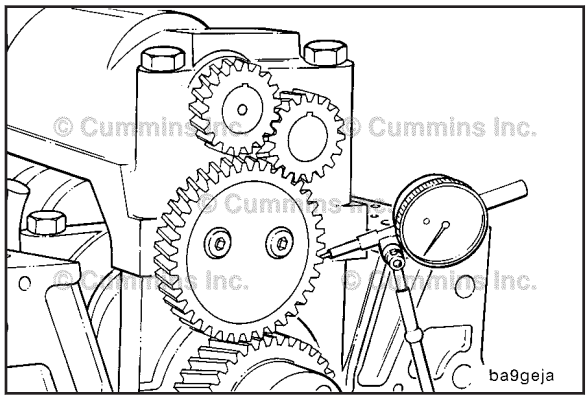
Remove the locking capscrew or Allen wrench from the balancer.



Tighten the idler gear retainer capscrews, use an 8-mm Allen wrench.

Torque Value: 57 N•m [42 ft-lb]





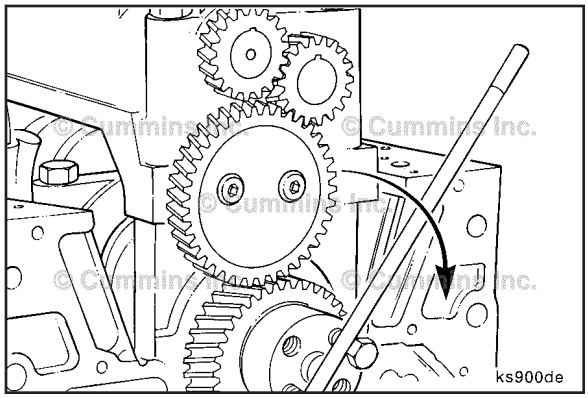
Measure the idler gear backlash.

Idler Gear Backlash		
mm		**in**
0.088	MIN	0.003
0.420	MAX	0.017

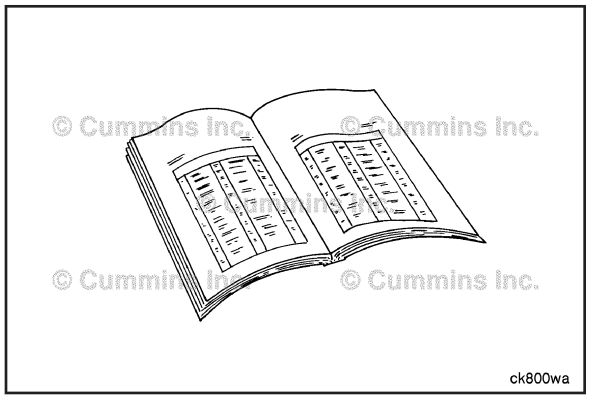
If the idler gear does **not** meet the specifications, loosen the idler gear retainer capscrews.

Position the idler gear and tighten the capscrews.

Torque Value: 57 N•m [42 ft-lb]



If the crankshaft does **not** rotate freely, make sure the balancer does **not** have an interference.

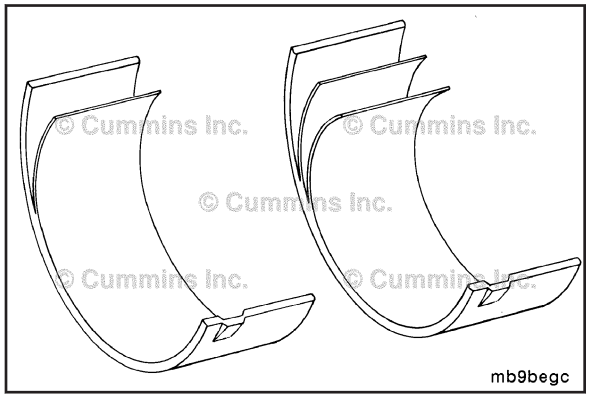


Finishing Steps

⚠WARNING⚠

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

- Install the lubricating oil suction tube. Refer to Procedure 007-035.
- Install the lubricating oil pan. Refer to Procedure 007-025.
- Fill the engine with lubricating oil. Refer to Procedure 007-037.
- Connect the batteries. Refer to Procedure 013-009.



Bearings, Connecting Rod (001-005)

General Information

In general, various types of connecting rod bearings have been used in B series engines:

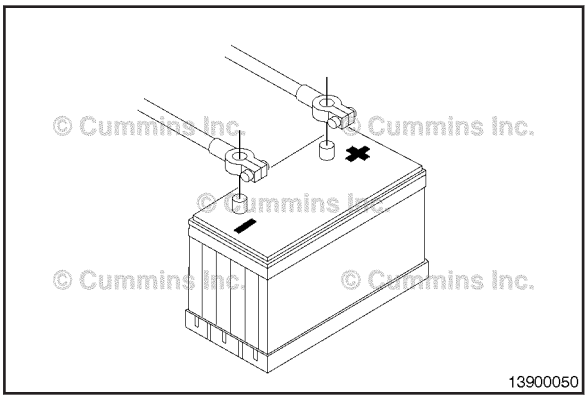
- Bi-Metal overlays
- Tri-Metal overlays
- Narrowed bearings (for some naturally aspirated engines).

Make sure to reference the appropriate part information resources when replacing the connecting rod bearings to ensure the correct connecting rod bearings are installed.

Preparatory Steps

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

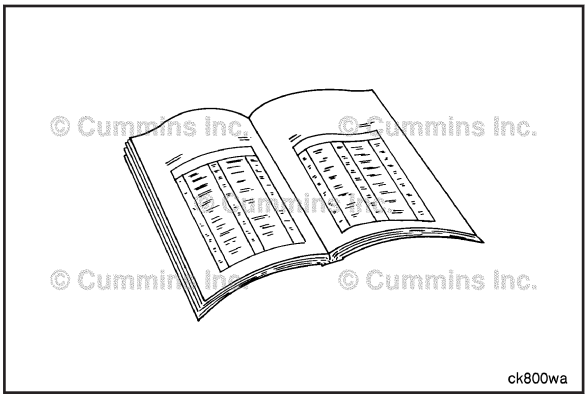
- Disconnect the batteries.



⚠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 oil pan and oil pan gasket. Refer to Procedure 007-025
- Remove the lubricating oil suction tube. Refer to Procedure 007-035
- If equipped, remove the block stiffener plate. Refer to Procedure 001-089.

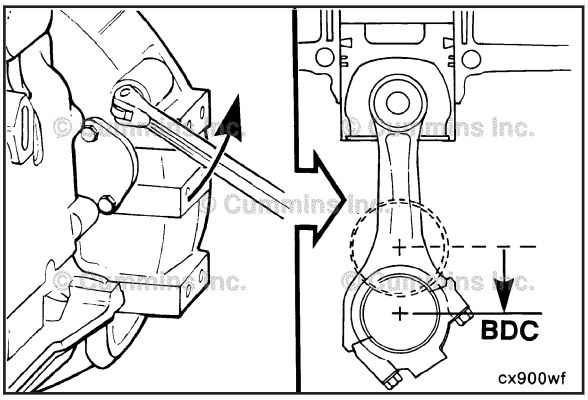


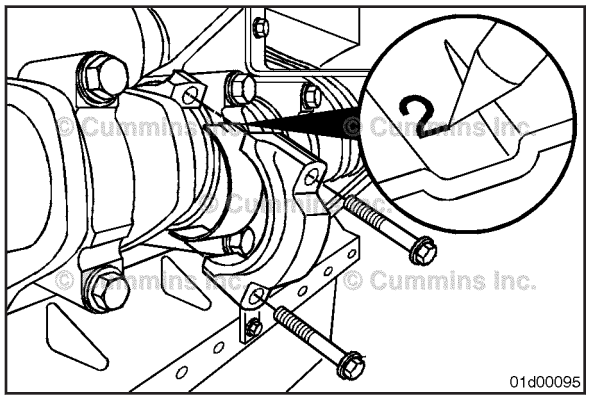
Remove

NOTE: The cylinder head does **not** need to be removed if the connecting rod bearings are being inspected or replaced.

⚠CAUTION⚠
If equipped with fracture split connecting rods, be careful not to damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod cap is removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage.

Using the barring tool, Part Number 3824591, bar the engine over to bottom dead center of the connecting rod bearing to be removed.





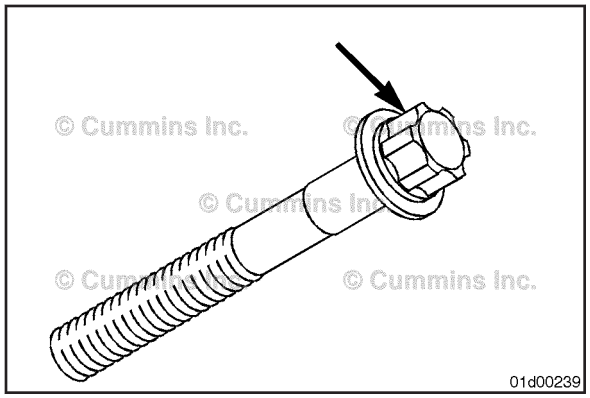
NOTE: Mark each connecting rod and cap to identify cylinder location.

Service Tip: Remove and install only one connecting rod cap at a time to avoid mismatching connecting rods with the wrong connecting rod cap.

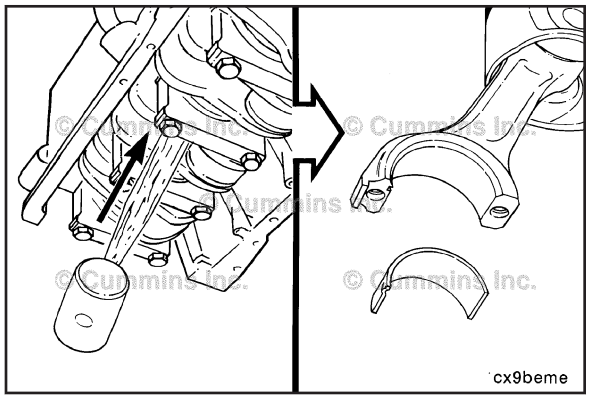
Remove the connecting rod bolts and connecting rod cap.

Remove the lower end bearing.

Mark the cylinder number and the letter ”L” (lower) on the flat surface of the bearing tang.



Some engines are equipped with an external Torx head.

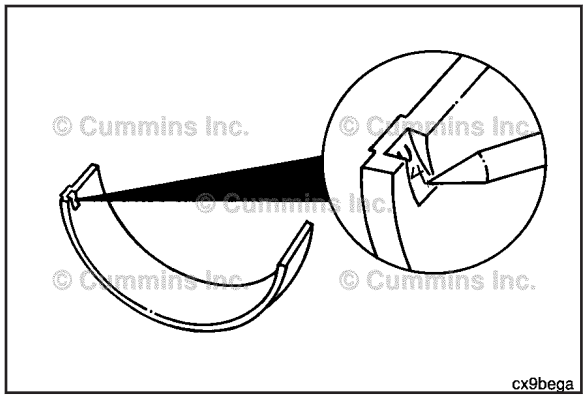


⚠CAUTION⚠
Do not damage the J-jet piston cooling nozzles when sliding the connecting rod into the cylinder away from the crankshaft. Engine damage can result.

NOTE: Slight bending of the j-jet piston cooling nozzles can result in severe engine damage. Replace piston cooling nozzles if any are bent or damaged during assembly or disassembly.

If equipped, remove the J-jet piston cooling nozzle for each cylinder that the connecting rod bearings will be removed. Refer to Procedure 001-046.

Push the connecting rod into the cylinder, away from the crankshaft, to allow the upper bearing shell to be removed.



Mark the connecting rod bearings for position and cylinder number as they are removed.

Example: U1 - upper rod bearing for cylinder number 1.

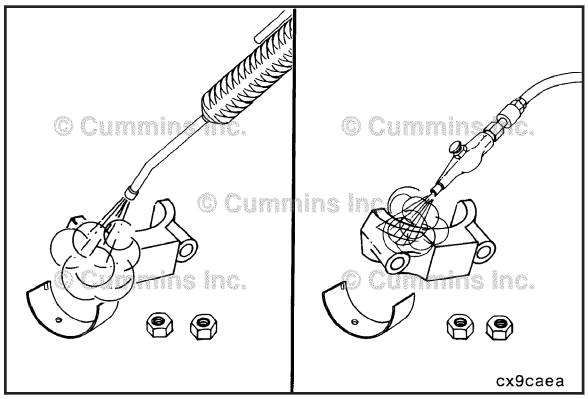
Clean and Inspect for Reuse

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

Wash the bearing and connecting rod caps.

Dry with compressed air.

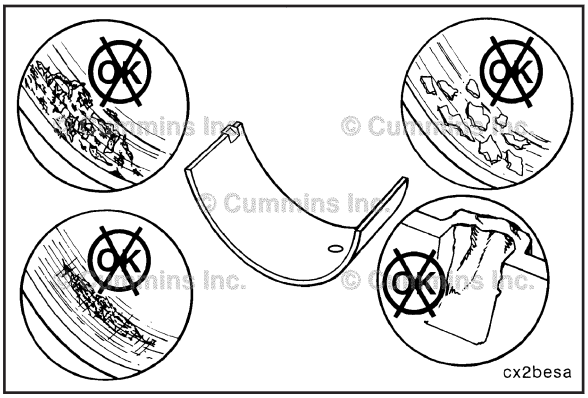
Inspect the connecting rod caps, connecting rod bearing saddles and capscrews for nicks, cracks, burrs, scratches, or fretting.



Inspect the bearings for damage.

Replace any bearings with the following damage:

- Pitting
- Flaking
- Corrosion
- Lock tang damage
- Scratches.

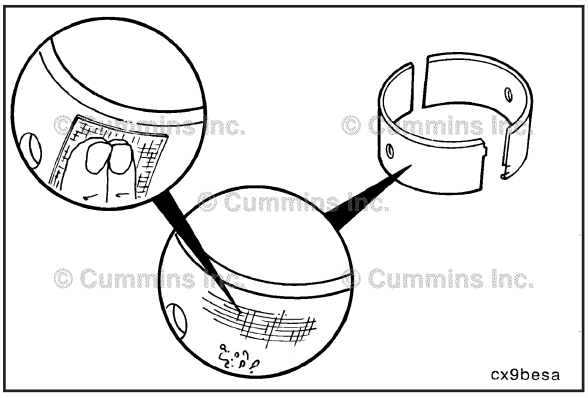


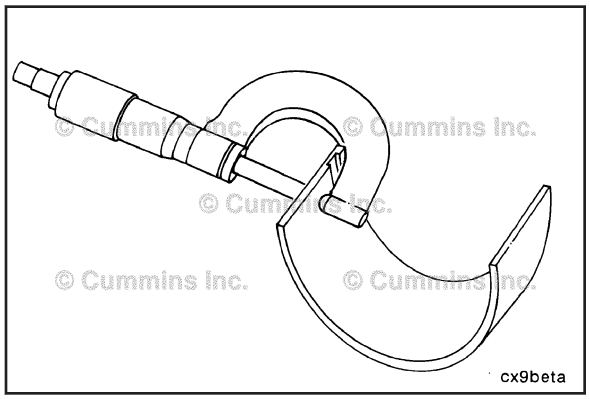
Inspect the bearing shell seating surface for nicks or burrs.

If nicks or burrs can **not** be removed with an abrasive pad, Part Number 3823258 or equivalent, the bearings **must** be replaced.

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

NOTE: For more detailed information of bearing damage, see “Analysis and Prevention of Bearing Failures” Bulletin No. 3810387.





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

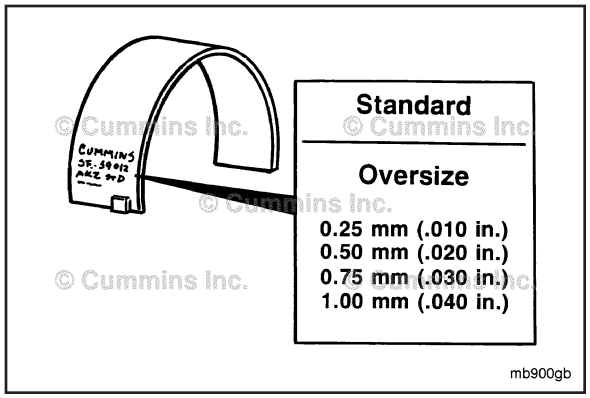
Connecting Rod Bearing Dimensions B3.9, B4.5 RGT, and B5.9 Engines

	mm		in
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

	mm		in
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

Discard a bearing shell if its thickness is below the minimum specification.

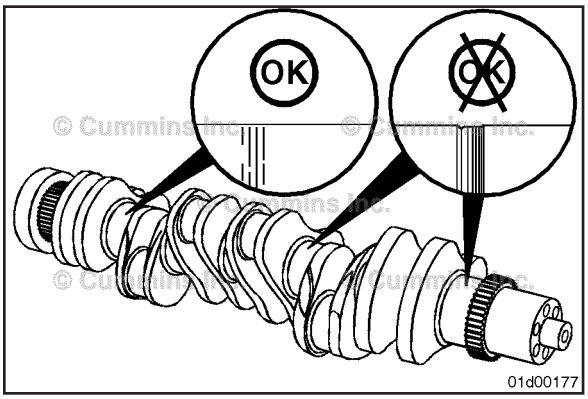


NOTE: Connecting rod bearings are identified with a part number and size stamped on the back side.

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

Oversize service rod bearings are available for use with crankshafts that have been machined undersized. See appropriate parts catalog.

Check the rod bearing journals for damage or excessive wear. Minor scratches are acceptable.



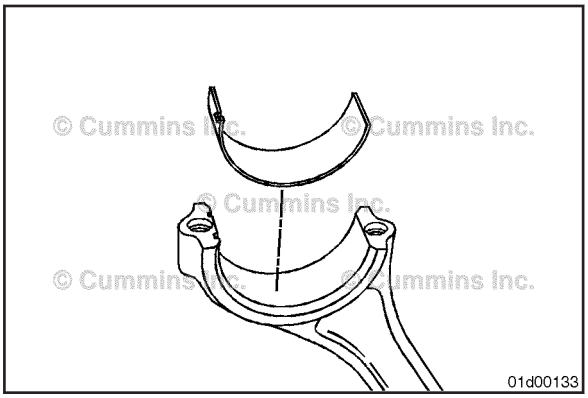
Install

NOTE: Used connecting rod bearings **must** be installed in their original locations.

NOTE: To help reduce the possibility of engine damage, make sure that the backside of the bearing, and connecting rod surface that the bearing contacts is clean and dry.

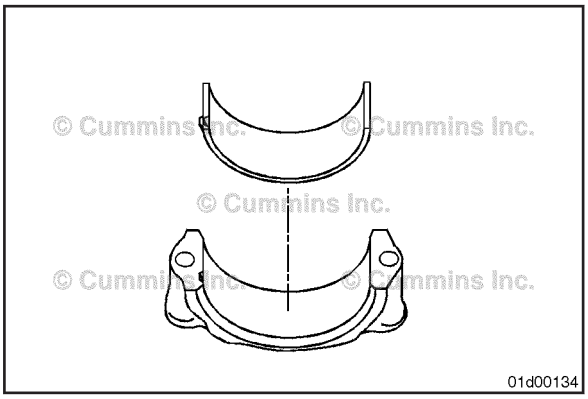
Install the upper bearings in the connecting rod. Make sure that the tang is aligned.

NOTE: Some B3.9 naturally aspirated engines use an upper connecting rod bearing narrower than the connecting rod mounting surface. The narrower bearing **must** only be installed in the upper location.



Install the lower bearings in the connecting rod caps. Make sure the tang is aligned.

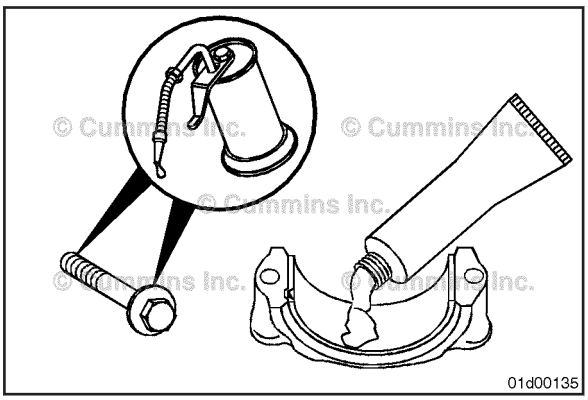
NOTE: For engines equipped with fracture split connecting rods, the upper and lower connecting rod bearing are **not** interchangeable.

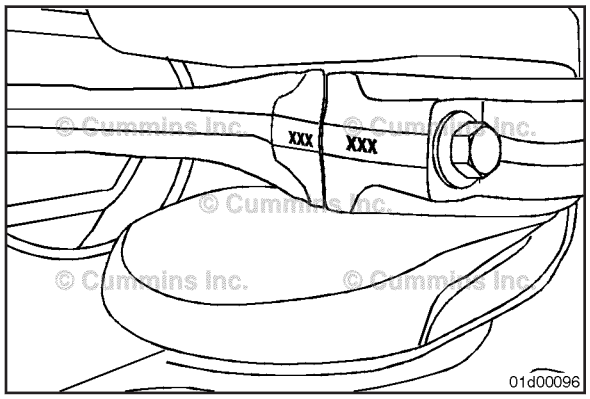


NOTE: For engines equipped with fracture split connecting rods, the fracture split surface on the connecting rod and connecting rod cap **must** be kept dry and clean to ensure proper mating of the two surfaces.

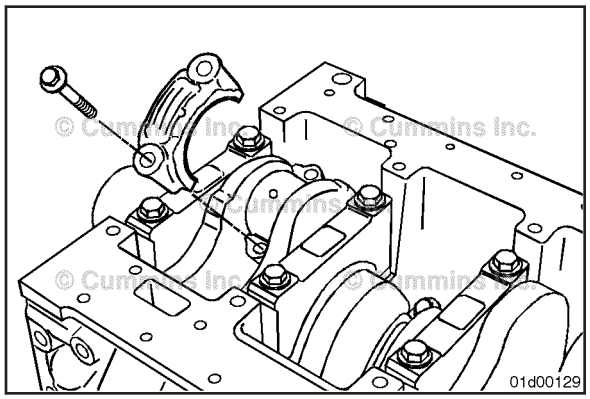
Lubricate the bearing surfaces with Assembly Lube, Part Number 3163087 or equivalent.

Lubricate the connecting rod bolt threads and under the heads with clean 15W-40 oil.





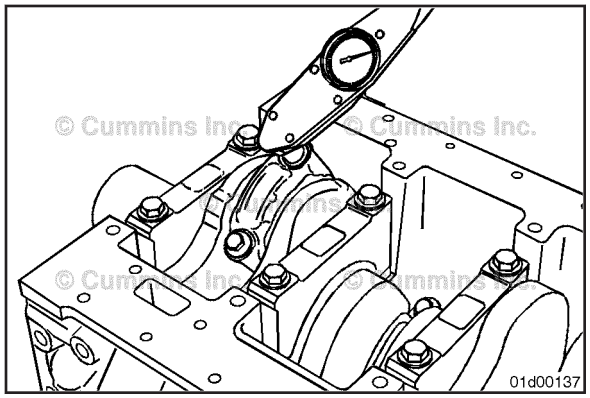
When installing the connecting rod cap, the numbers stamped on the connecting rod cap and connecting rod **must** match and be on the same side of the connecting rod, to prevent engine damage during engine operation.



Install the connecting rod caps on the corresponding connecting rod.

Install and hand-tighten the connecting rod capscrews.

NOTE: The long end of the connecting rod **must be** on the **exhaust** side of the engine.



Tighten the connecting rod capscrews.

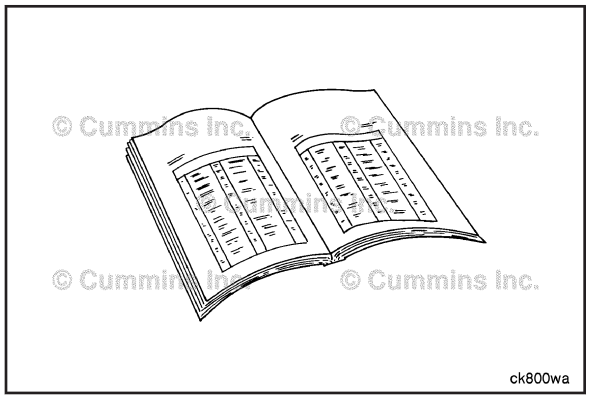
B3.9, B4.5 RGT and B5.9 engines

Torque Value:	Step1	30 N•m	[22 ft-lb]
	Step2	60 N•m	[44 ft-lb]
	Step3	Rotate 60 degrees.	

B4.5 engines

Torque Value:	Step1	25 N•m	[18 ft-lb]
	Step2	Rotate 60 degrees.	

NOTE: After tightening the capscrew for each connecting rod, rotate the crankshaft 360 degrees to make sure the crankshaft rotates freely.

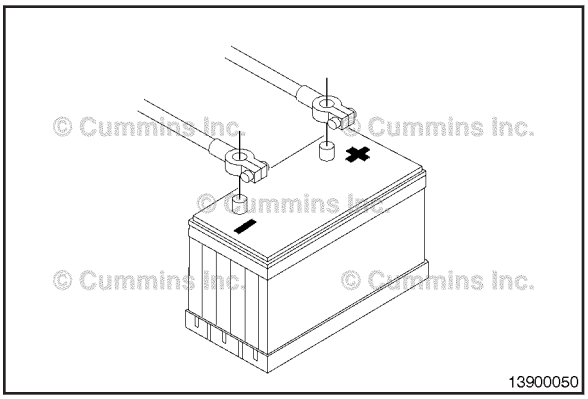


Finishing Steps

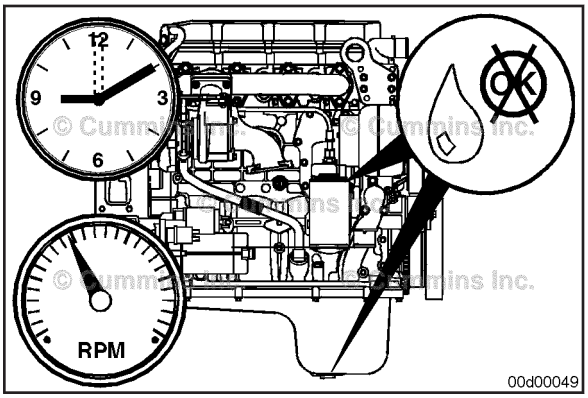
- If equipped and previously removed, install the J-jet piston cooling nozzles. Refer to Procedure 001-046
- If equipped, install the block stiffener plate. Refer to Procedure 001-089
- Install the lubricating oil suction tube. Refer to Procedure 007-035
- Install the oil pan and oil pan gasket. Refer to Procedure 007-025
- Fill the engine with clean 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 and proper oil pressure.

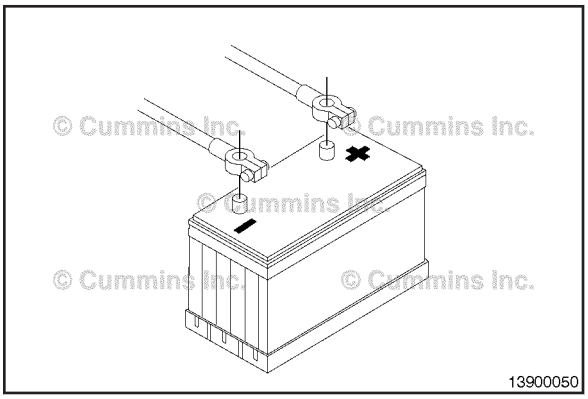


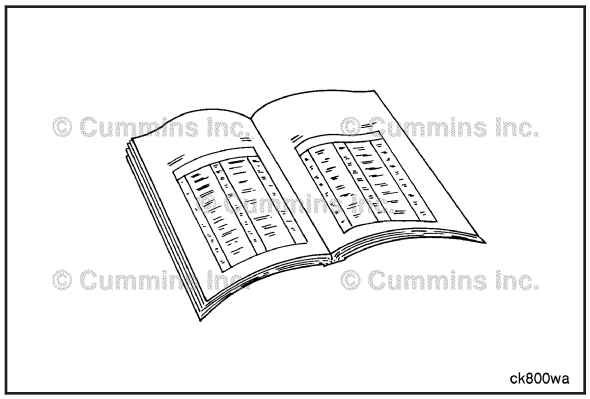
Bearings, Main (001-006)

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.





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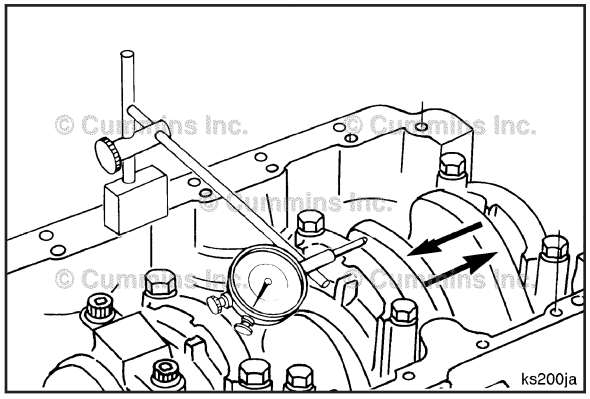
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

- Drain the lubricating oil. Refer to Procedure 007-037
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025
- Remove the lubricating oil suction tube. Refer to Procedure 007-035
- If equipped, remove the block stiffener plate. Refer to Procedure 001-089.



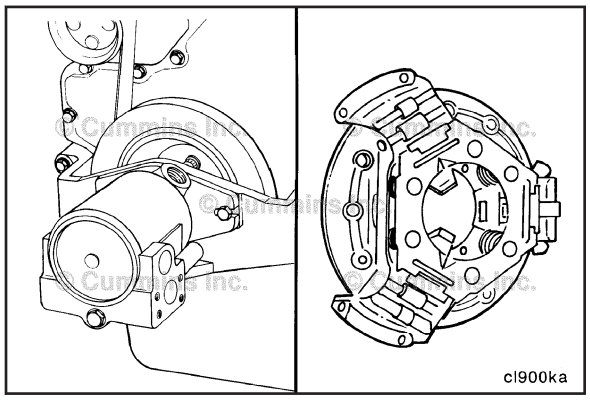
Initial Check

NOTE: The dimensions of the thrust bearing and crankshaft journal determine end play.

Measure the crankshaft end play using dial indicator, Part Number 3824564 and magnetic base, Part Number 3377399.

Crankshaft End Play		
mm		**in**
0.102	MIN	0.004
0.432	MAX	0.017

If the crankshaft end play is **not** within specification, make sure to inspect the crankshaft and thrust bearing surfaces for damage.



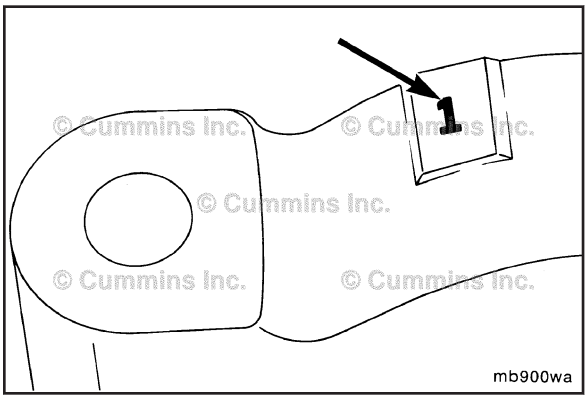
A common cause for increased crankshaft end play and thrust bearing damage is increased end-loading of the engine. The increased end-loading can be the result of driven units at the front or rear of the engine being:

- Incorrectly installed
- Incorrectly adjusted
- Incorrectly matched to the engine and exceeding the thrust load limits.

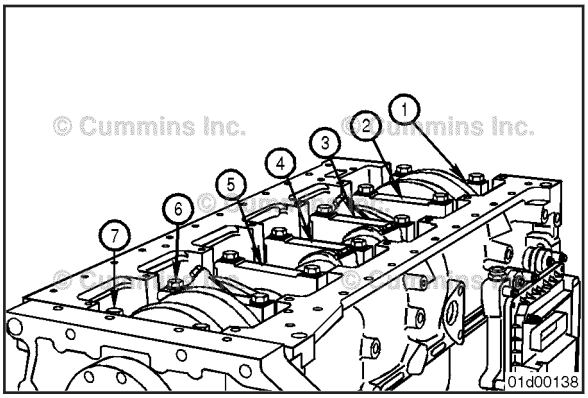
Remove

Before removing the main bearing caps, make certain that the caps are clearly marked for their location on the lubricating oil cooler side of the main bearing cap and cylinder block.

The number one cap is at the front of the engine.



NOTE: When replacing bearings in chassis: For four cylinder engines, replace number 2 through 4 while the number 1 and number 5 caps support the crankshaft. After replacing number 2 through number 4, replace number 1 and number 5. For six cylinder engines, replace number 2 through 6 while the number 1 and number 7 caps support the crankshaft. After replacing number 2 through number 6, replace number 1 and number 7.

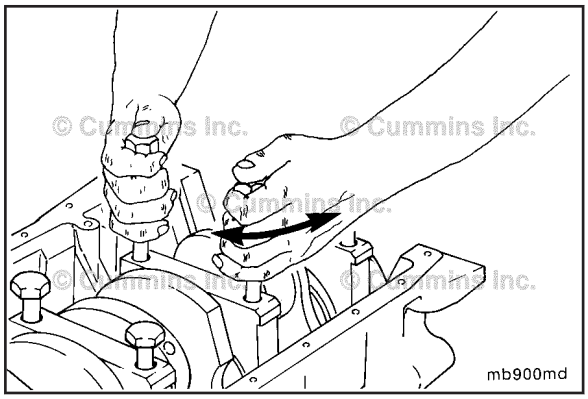


Loosen the main bearing capscrews completely, but do **not** remove.

⚠CAUTION⚠
Do not pry on the main bearing caps to free them from the cylinder block. Damage to the main bearing caps and cylinder block can result.

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

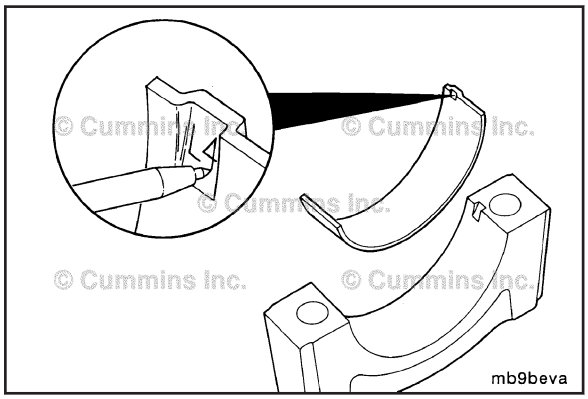
Remove the main bearing cap.

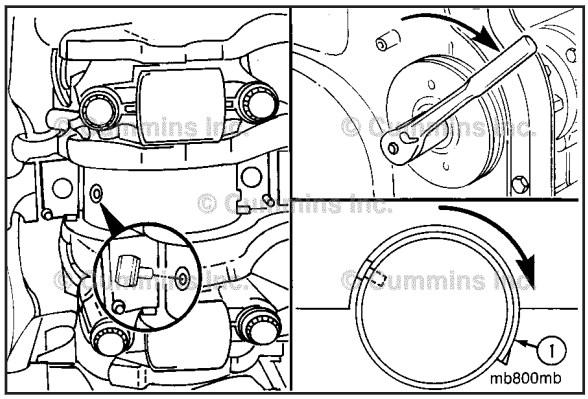


Mark the main bearings for position and number as they are removed.

Use an awl to mark the bearing's position in the tang area.

NOTE: Marking the bearing's position is for future identification or possible failure analysis.





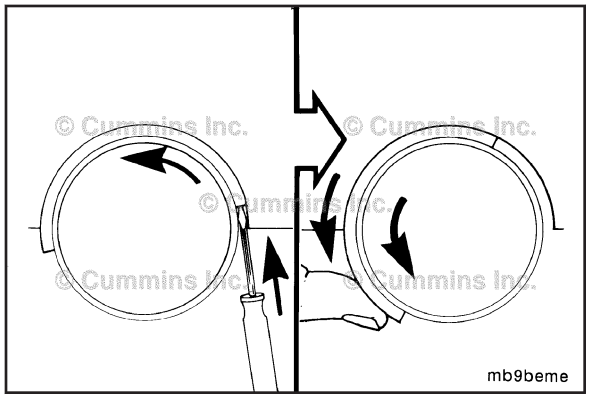
Follow this step to remove the upper main bearings, except for number 1 front main bearing.

To remove the upper main bearing, install the main bearing replacer, Part Number 3823818, in the oil hole of the crankshaft main bearing journal.

Using barring tool, part number 3824591, rotate the crankshaft so that the replacer contacts the upper main bearing on the side opposite the tang.

Continue to rotate the crankshaft in the direction that will remove the tang side (1) of the upper main bearing first.

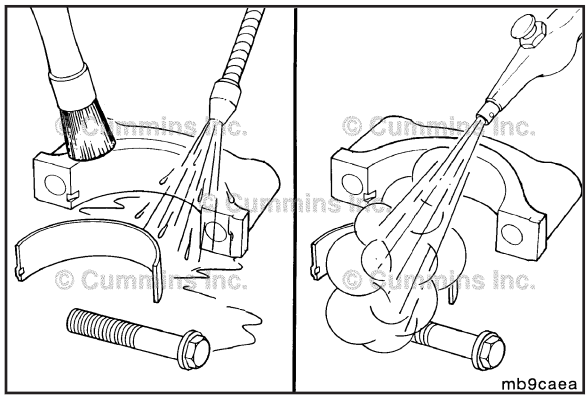
Remove the bearing.



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

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

Using a flat blade screwdriver, gently bump the end of the bearing to loosen it from the cylinder block. Then, use finger pressure against the main bearing shell and rotate the crankshaft to roll the main bearing out.



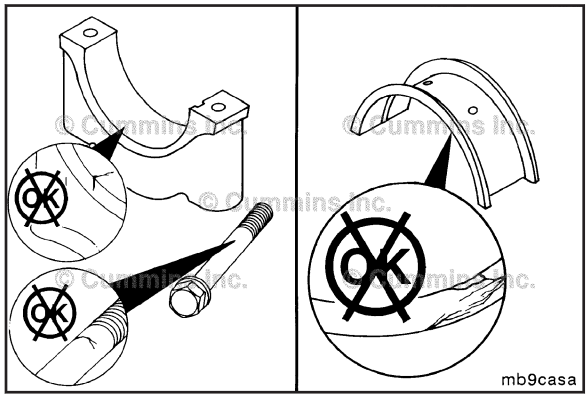
Clean and Inspect for Reuse

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

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

Steam-clean or use hot, soapy water to clean the main bearing caps.

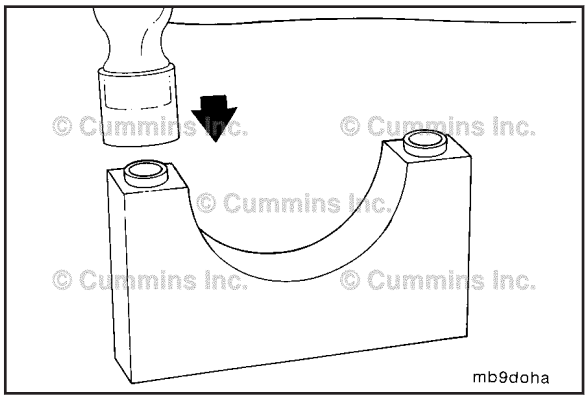
Dry with compressed air.



Inspect all main bearing caps, capscrews and thrust bearings for deep scoring, overheating, etc.

Replace any damaged components. If the main bearing cap is damaged, the block **must** be replaced.

Check the main bearing caps to make sure the ring dowels are installed.



Check the crankshaft main bearing journals for damage or excessive wear. Minor scratches are acceptable.

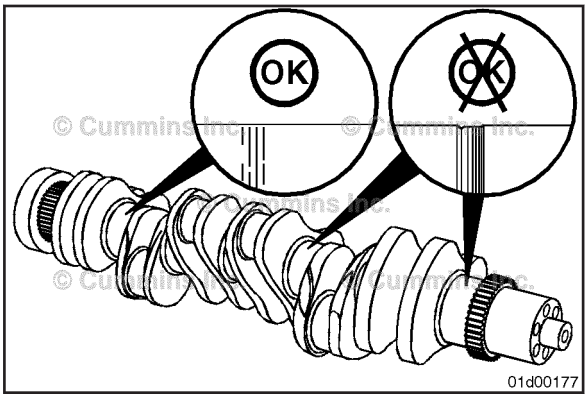
If crankshaft end play measured during the initial check was found to be out of specification, make sure to visually check the crankshaft thrust surface for excessive wear or damage. Minor scratches are acceptable.

Four cylinder engines — The number 4 main bearing journal.

Six cylinder engines — The number 6 main bearing journal.

If damage is found, the crankshaft will need to be removed. Refer to Procedure 001-016.

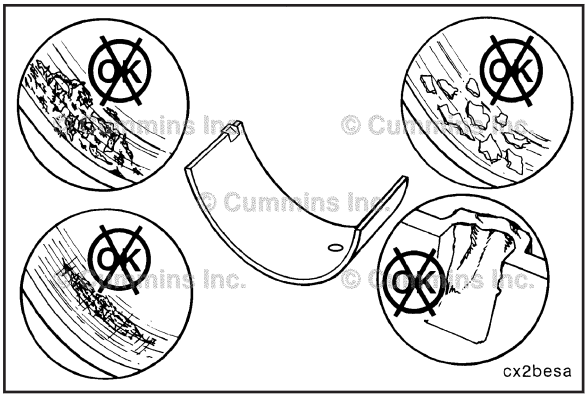
Also visually check the thrust bearing surfaces for excessive wear. Replace the thrust bearing(s) if excessive wear is found

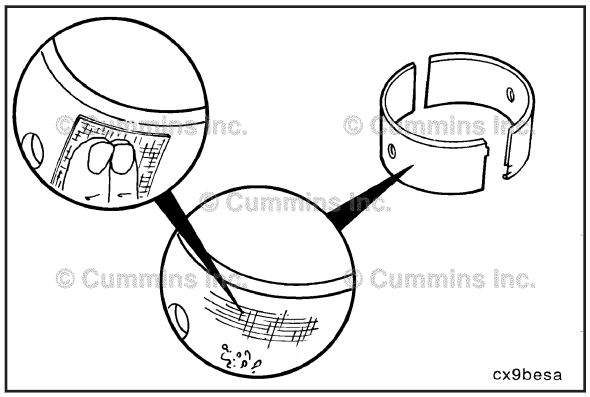


Inspect the bearings for damage.

Replace any bearings with the following damage:

- Pitting
- Flaking
- Corrosion
- Lock tang damage
- Scratches.

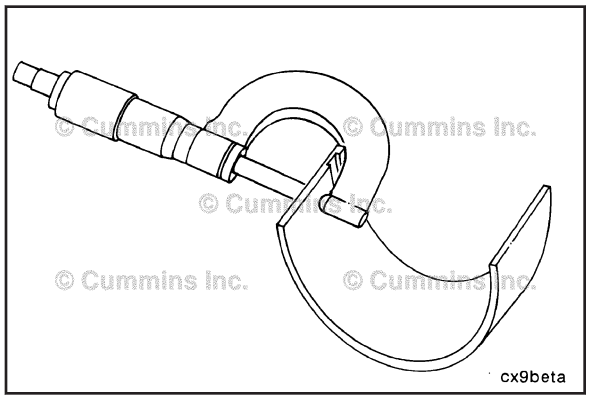




Inspect the bearing shell seating surfaces for nicks or burrs. If nicks or burrs can **not** be removed with an abrasive pad, Part Number 3823258 or equivalent, the bearings **must** be replaced.

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

NOTE: For more detailed information on bearing damage, see “Analysis and Prevention of Bearing Failures” Bulletin 3810387.



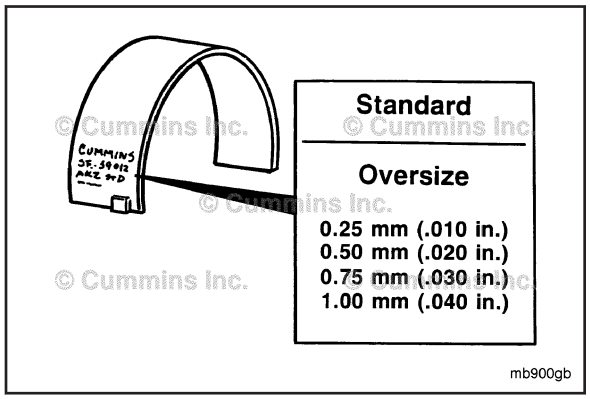
Measure

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

Main Bearing Dimensions

	mm		in
Standard	2.456	MIN	0.0967
	2.464	MAX	0.097
Oversize 0.25 mm [0.010 in]	2.706	MIN	0.1067
	2.714	MAX	0.117
Oversize 0.50 mm [0.020 in]	2.956	MIN	0.1167
	2.964	MAX	0.117
Oversize 0.75 mm [0.030 in]	3.206	MIN	0.1267
	3.214	MAX	0.127
Oversize 1.00 mm [0.040 in]	3.456	MIN	0.1367
	3.464	MAX	0.137

Discard a bearing shell if its thickness is below the minimum specifications.



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

If replacing the bearings, determine the size of the removed main bearings and obtain a set of the same size.

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

Main Bearing Capscrew Reuse Measurement

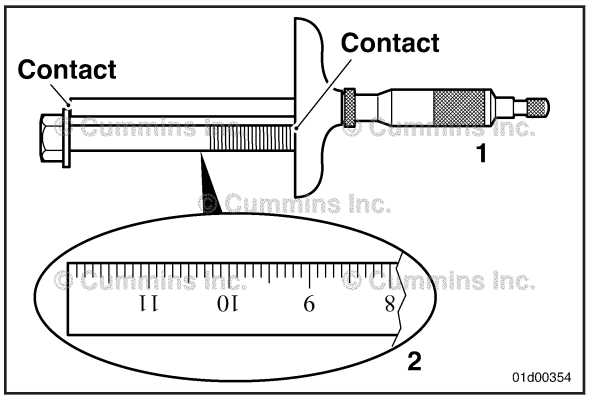
⚠CAUTION⚠
This step must be completed on B4.5 RGT engines. Failure to check the main bearing capscrew against reuse guidelines can result in severe engine damage.

To check if a main bearing capscrew can be reused, the length **must** be measured by performing the following:

For each main bearing capscrew that has been removed, measure the length from underneath the head of the capscrew to the tip of the capscrew, as illustrated, using one of two methods.

1. A depth micrometer (preferred method for accuracy)
2. A machinist's rule.

If the measurement is above the maximum specification, the main bearing capscrew **must** be replaced.



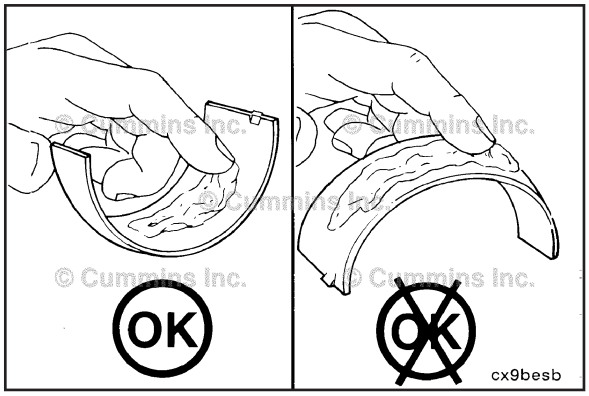
Main Bearing Underhead Capscrew Length		
mm		in
120.00	MAX	4.724

Install

Upper Main Bearing

NOTE: Make sure the main bearing being installed is the same size as the main bearing removed, if the crankshaft has not been machined. The size is engraved on the back of the main bearing.

NOTE: Install the upper main bearing cap after each upper main bearing is installed to keep the main bearing in place while the other upper main bearings are installed.



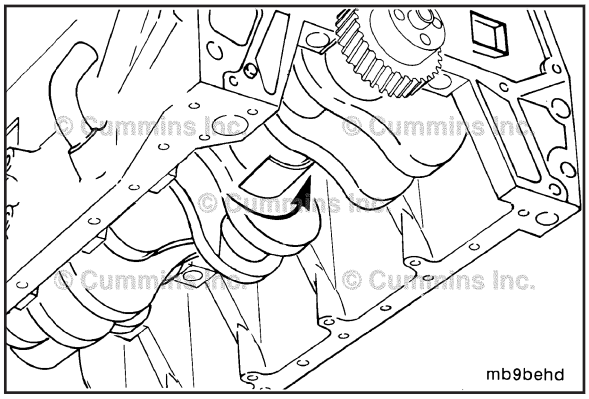
⚠CAUTION⚠
Do not lubricate the side that is against the cylinder block.

Apply assembly lube, Part Number 3163086, to the upper main bearings.

NOTE: The crankshaft thrust bearing **must** be installed in the: Four cylinder engines - The number 4 main bearing position. Six cylinder engines - The number 6 main bearing position.

NOTE: Some engines use a thrust bearing for the upper and lower main bearing (360 degree), while other engines only have a thrust bearing for the upper main bearing (180 degree). **Always** replace like for like.

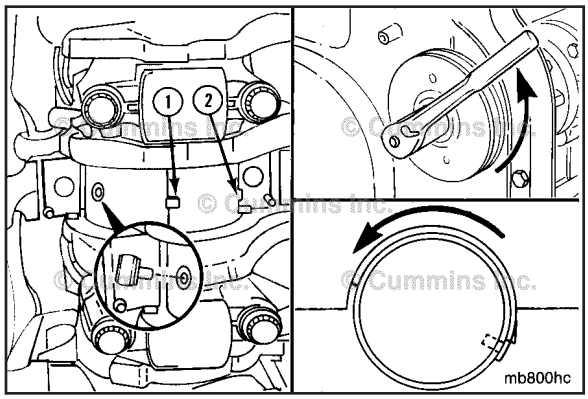
NOTE: The upper and lower main bearing shells are not interchangeable. The backs of the main bearings are marked with the proper orientation.



Install the upper main bearings.

Insert the side of the main bearing opposite the tang first in between the crankshaft journal and block. Install the bearing as far as possible by hand.

When installing the thrust bearing, it may be necessary to push the crankshaft to the front or rear of the cylinder block.

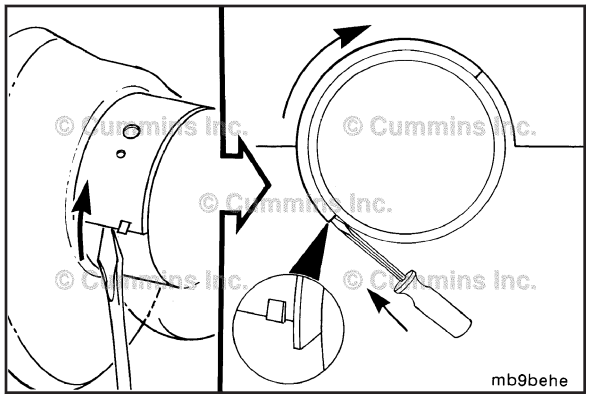


⚠CAUTION⚠
Make sure the pin does not slide under the bearing.

Follow this step to finish installing the upper main bearings, except for number 1 front main bearing.

Using the main bearing replacer, Part Number 3823818, finish installing the main bearing. Rotate the crankshaft, using the barring tool, part number 3824591.

Make sure the tang (1) on the main bearing is located in the notch (2) of the cylinder block. Finish pushing the main bearing into position.



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

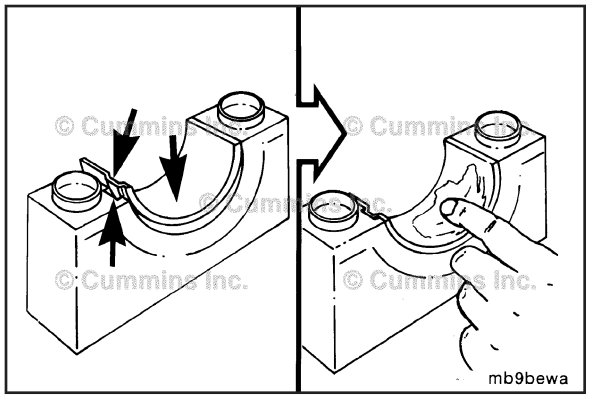
NOTE: The front main, number 1, does **not** have a hole in the journal so the pin can **not** be used to replace the bearing.

Install the number 1 main bearing.

Insert the side of the main bearing opposite the tang first and install as far as possible by hand.

Use a flat blade screwdriver to push the main bearing into position while rotating the crankshaft.

Make sure the tang on the main bearing is located in the notch of the cylinder block.



Lower Main Bearings

⚠CAUTION⚠
Do not lubricate the back side of the bearing that contacts the main bearing cap.

Making sure that the backside of the bearings are clean and free of debris, install the lower main bearings into the main bearing caps.

Make sure to align the tangs of the bearings with tangs on the main bearing caps.

NOTE: Some engines use a thrust bearing for the upper and lower main bearing (360 degree), while other engines only have a thrust bearing for the upper main bearing (180 degree). **Always** replace like for like.

If equipped, install the lower crankshaft thrust bearing.

Four cylinder engines - The number 4 main bearing position.

Six cylinder engines - The number 6 main bearing position.

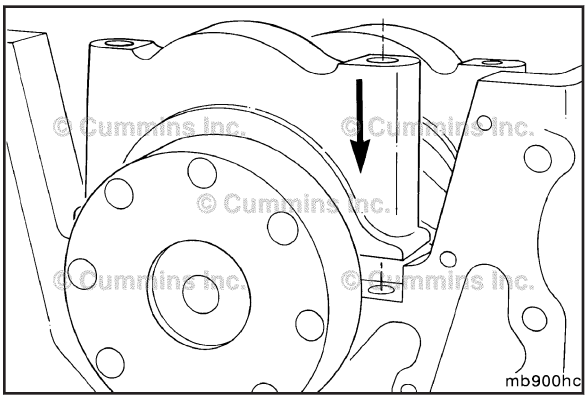
Apply a coat of assembly lube, Part Number 3163087, to the crankshaft side of the main bearings and thrust bearing surfaces.

⚠CAUTION⚠

Make sure the caps are correctly installed in the same position as removed, with the number towards the oil cooler side of the engine.

Make sure the main bear cap surfaces between the main bearing cap and block are clean and free of debris.

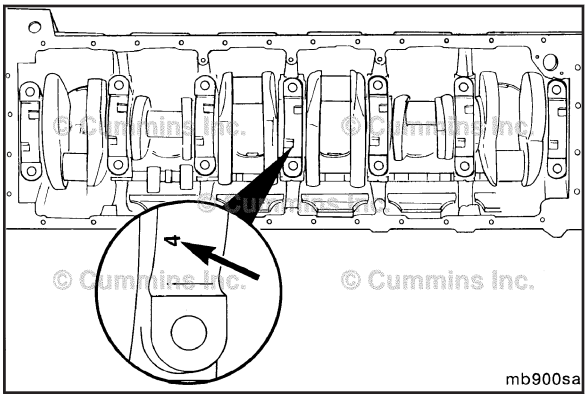
Install the main bearing cap into position, lining the main bearing cap dowel rings with the cylinder block.



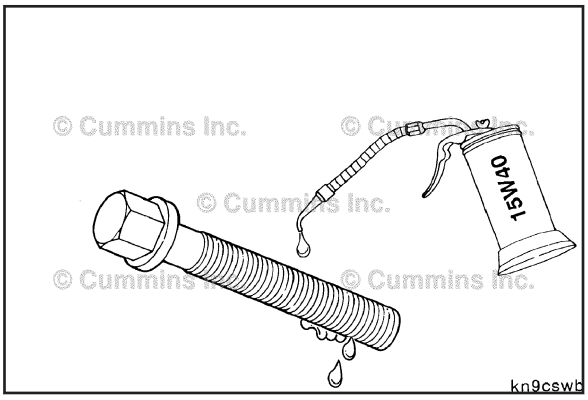
The main bearing caps are/were numbered during the removal process for their location. Number 1 starts with the front of the block.

NOTE: The caps **must** be installed so the numbers on the caps match the bearing saddle in the block. The lock tangs in the main bearing saddle and bearing cap **must** be on the same side.

Install the main bearing caps. Make sure to align the ring dowels on the main bearing cap with the corresponding drillings in the cylinder block.



Lubricate the main bearing capscrew threads and underside of the head with clean engine oil.

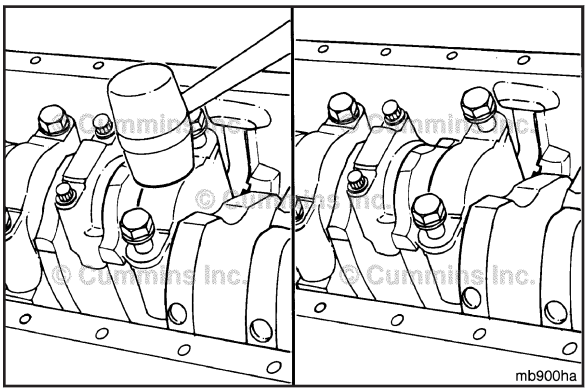


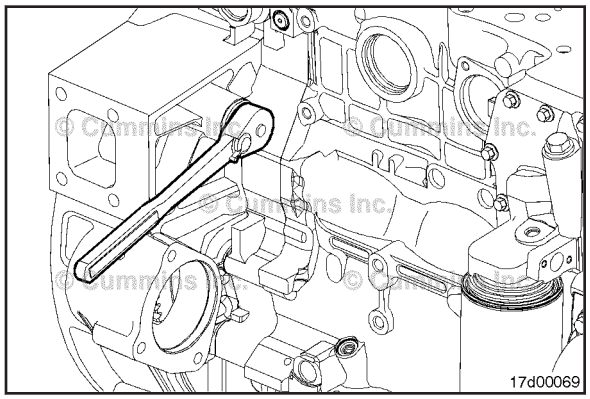
Gently tap the main bearing cap into position with a plastic or rubber mallet.

When seated, install the main bearing capscrews and tighten.

Torque Value: 50 N•m [37 ft-lb]

Do **not** tighten to the final torque value at this time. Final torque should be applied after all main bearing caps are installed.



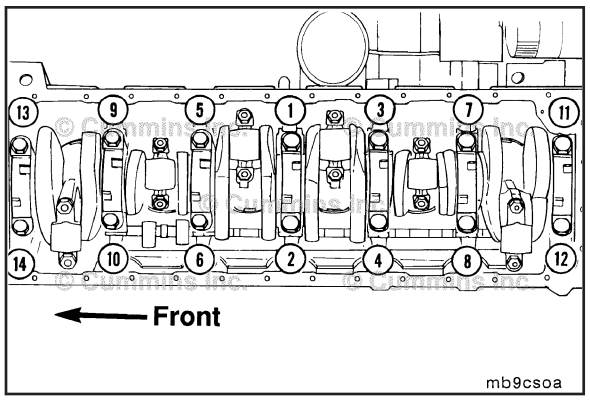


Using the barring tool, part number 3824591, the crankshaft **must** rotate freely after installing the main bearing caps.

While applying final torque to the main bearing capscrews, frequently check that the crankshaft rotates freely.

If the crankshaft does **not** rotate freely:

1. Check if the crankshaft is contacting one of the connecting rods
2. Check if the correct main bearing caps where installed correctly
3. Check if the main bearing cap ring dowels or mounting surfaces were damaged during installation
4. Check if the correct main bearings where installed.



NOTE: The sequence to the right is for a six cylinder engine. For a four cylinder engine, use the same sequence for the 5 main bearing caps.

Tighten the main bearing capscrews evenly and in sequence.

B3.9, B4.5 and B5.9 Main Bearing Capscrews

Torque Value:	Step1	60 N•m	[44 ft-lb]
	Step2	90 N•m	[66 ft-lb]
	Step3	Rotate 90 degrees.	

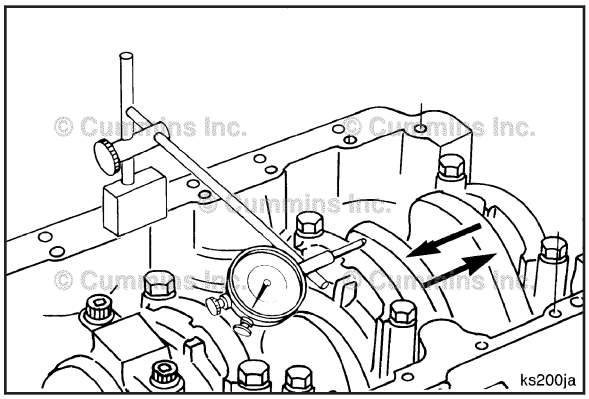
△CAUTION△
For B4.5 RGT engines there is a different torque procedure for new and previously installed main bearing capscrews. Failure to use the correct torque process can result in engine damage.

B4.5 RGT Main Bearing Capscrews

Torque Value:			
Previously Installed Main Bearing Capscrews	Step1	60 N•m	[44 ft-lb]
	Step2	80 N•m	[59 ft-lb]
	Step3	Rotate 90 degrees.	
New Main Bearing Capscrews	Step1	120 N•m	[89 ft-lb]
	Step2	Loosen completely	
	Step3	60 N•m	[44 ft-lb]
	Step4	85 N•m	[63 ft-lb]
	Step5	Rotate 120 degrees.	

NOTE: The dimensions of the thrust bearing and crankshaft journal determine end play.

Measure the crankshaft end play using dial indicator, Part Number 3824564 and magnetic base, Part Number 3377399.



Crankshaft End Play		
mm		in
0.102	MIN	0.004
0.432	MAX	0.017

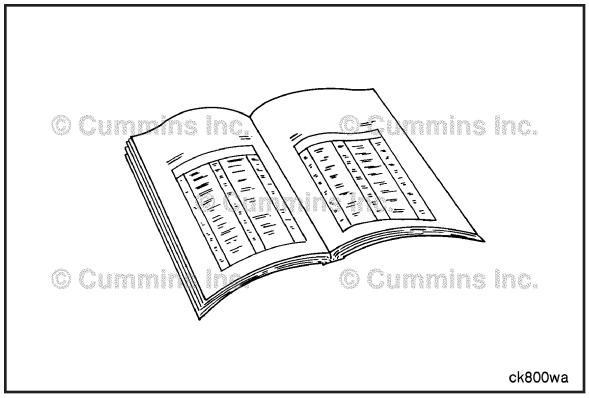
If the crankshaft end play is **not** within specification:

1. If the crankshaft end play is below specification, check if there are any obstructions limiting the crankshaft's travel (lubricating oil pump, connecting rod, etc.)
2. If the crankshaft end play is above specification, inspect the crankshaft thrust bearing surface. Also check if the correct thrust bearing(s) were installed.

NOTE: Oversize thrust bearings are available if the end play is **not** within specifications. Oversize thrust bearings of 0.25 to 0.51 mm [0.010 to 0.020 in] are available.

Finishing Steps

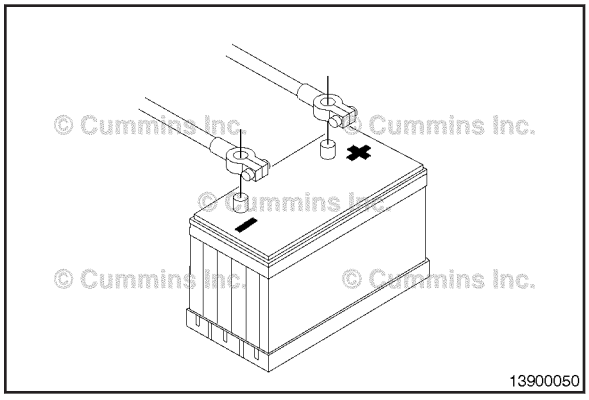
- If equipped, install the block stiffener plate. Refer to Procedure 001-089
- Install the lubricating oil suction tube. Refer to Procedure 007-035
- Install the lubricating oil pan and gasket. Refer to Procedure 007-025
- Fill the lubricating oil pan. Refer to Procedure 007-037.



⚠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 at idle for 5 to 10 minutes. Check for loose parts, leaks and proper oil pressure.



Camshaft (001-008)

Initial Check

This procedure covers both rear gear train engines and front gear train engines.

Prior to starting this procedure, make sure there is adequate clearance to remove the camshaft from the rear of the engine for rear gear train engines and from the front of the engine for front gear train engines.

Clearance from Front/Rear Gear Housing			
	mm		in
4 Cylinder	60.96	MIN	24
6 Cylinder	81.28	MIN	32

NOTE: It may be necessary to remove OEM components (radiator, charge air cooler assembly, etc.) for access. Refer to the OEM instructions.

If adequate clearance can **not** be obtained, the engine **must** be removed.

Preparatory Steps

Rear Gear Train

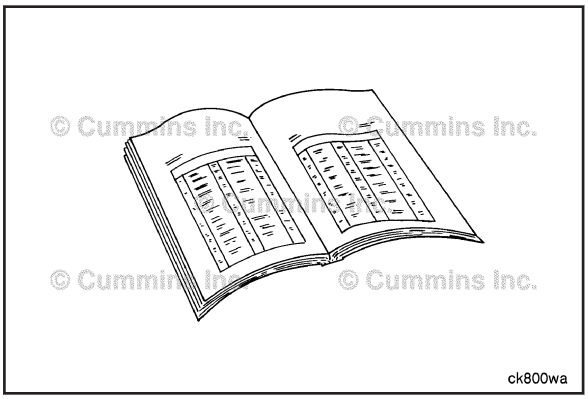
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

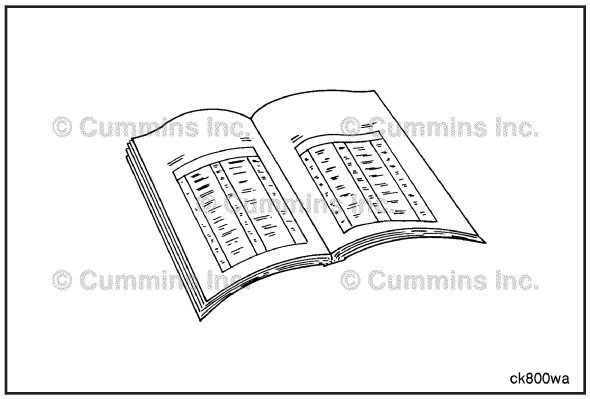
⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause personal injury.

NOTE: The camshaft **must** be removed from the flywheel end of the engine.

- Disconnect the batteries.
- Remove the transmission and all related components (if equipped). Refer to the OEM service manual.
- Remove the flywheel. Refer to Procedure 016-005 in Section 16.
- Remove the flexplate. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 Section 16
- Remove the fuel lift pump. Refer to Procedure 005-045 in Section 5
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3
- Remove the push rods. Refer to Procedure 004-014 in Section 4
- Raise the tappets. Refer to Procedure 004-015 in Section 4.
- Lock the fuel pump. Refer to Procedure 005-014 in Section 5.

NOTE: Failure to lock the fuel pump may result in improper fuel pump timing during reassembly.





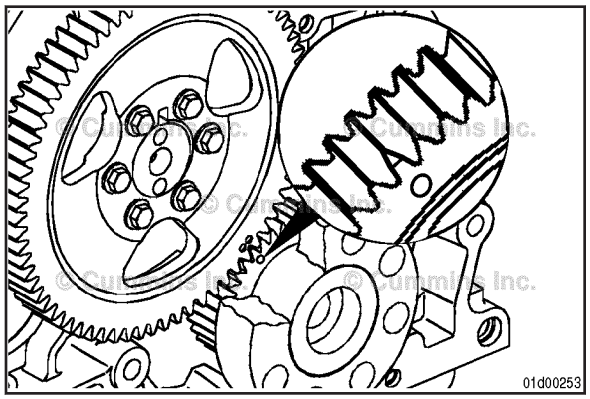
Front Gear Train

⚠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.

NOTE: The camshaft **must** be removed from the vibration damper end of the engine.

- Disconnect the batteries.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the fuel lift pump. Refer to Procedure 005-045 in Section 5.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the fan hub, if required. Refer to Procedure 008-039 in Section 8.
- Remove the vibration damper. Use the following procedure, if equipped with a viscous damper. Refer to Procedure 001-052 in Section 1.
- Remove the vibration damper. Use the following procedure, if equipped with a rubber damper. Refer to Procedure 016-004 in Section 16.
- Remove the front gear cover. Refer to Procedure 001-031 in Section 1
- Raise the tappets. Refer to Procedure 004-015 in Section 4



Remove

Rear Gear Train

NOTE: The engine can have either a mark on the crankshaft gear or a chamfered tooth.

Rotate the engine to align the timing marks on the camshaft and crankshaft gear.

Service Tip: The engine can be rotated by installing two of the flywheel/flexplate mounting capscrews half way. Then use a pry bar in between the two capscrews to rotate the engine.

Service Tip: Engines equipped with air compressors may require the air compressor be timed to the engine. Tomake suree that the air compressor is properly timed when the camshaft gear is later installed, scribe an alignment line on the air compressor and camshaft gear before removing the camshaft gear.

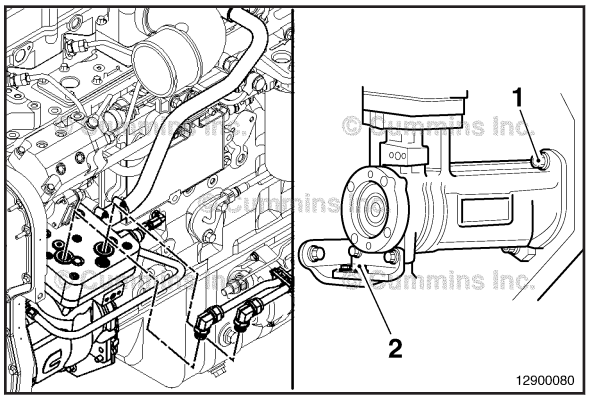
On engines equipped with an air compressor/accessory drive, it may be necessary to loosen/remove some of the air compressor/accessory drive mounting hardware in order to remove the camshaft gear. It is **not** necessary to remove the air compressor/accessory drive completely.

Loosening/removing some of the air compressor/accessory drive mounting hardware will give enough clearance to remove the camshaft gear.

Loosen the air compressor mounting fasteners (1).

Remove the two capscrews securing the air compressor support (2).

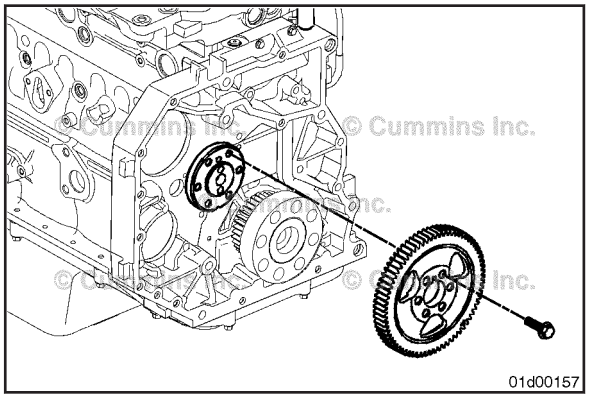
If equipped with a hydraulic pump driven off of the air compressor, it may be necessary to remove and/or loosen some or all of the mounting fasteners. Refer to the OEM Instructions.



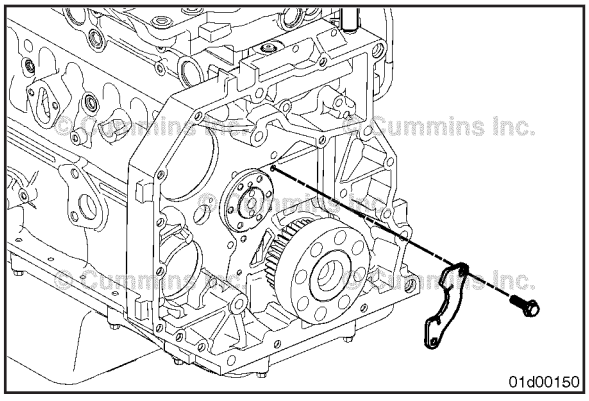
Remove the camshaft gear capscrews and remove the camshaft gear.

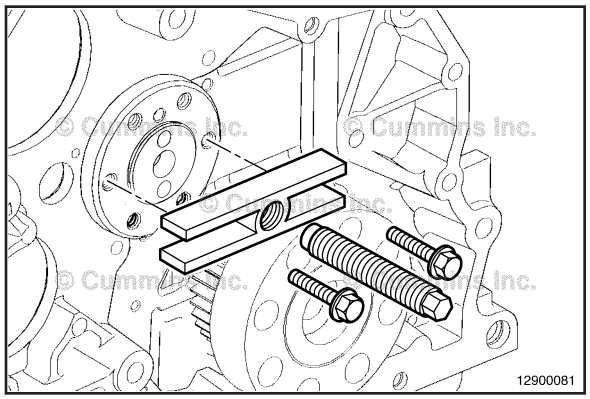
Refer to Procedure 001-012 in Section 1.

NOTE: On engines equipped with an air compressor/accessory drive, it could be necessary to remove the air compressor/accessory drive to gain clearance to remove the camshaft gear.



Remove the thrust plate capscrews and remove the thrust plate.



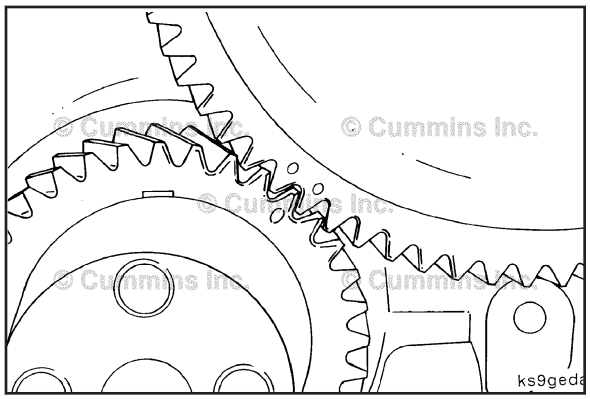


CAUTION

The camshaft will drop once the camshaft clears the last bushing if not supported. This can cause damage to the camshaft journal or, if equipped, the camshaft speed indicator ring.

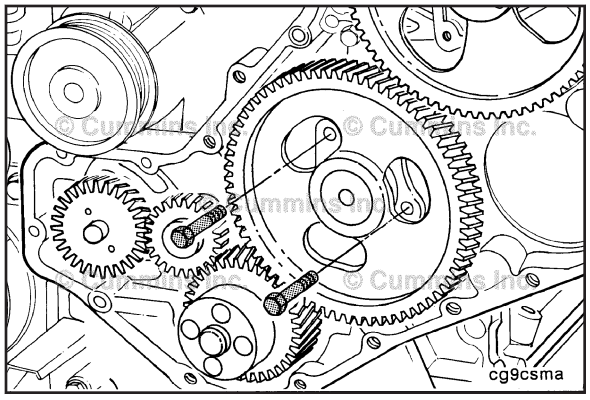
Use a gear puller, service tool part number ST647 or equivalent, to attach to the end of the camshaft where the camshaft gear mounts, to act as a handle. This will give proper leverage and make it easier to remove the camshaft.

Slide the camshaft out of the bore using the installed gear puller.



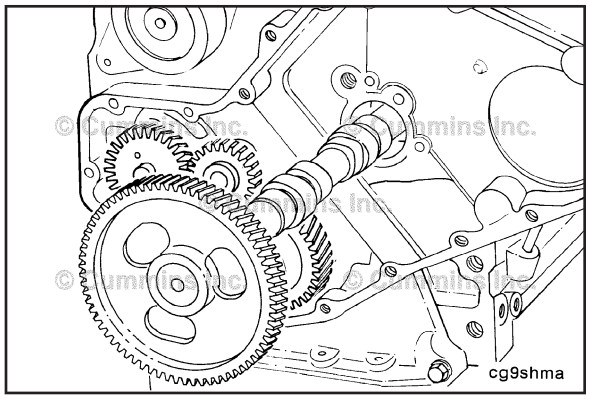
Front Gear Train

Use barring tool, Part Number 3824591, to rotate the crankshaft to align the crankshaft to camshaft gear timing marks.



Remove the capscrews from the thrust plate.

Remove the thrust plate.



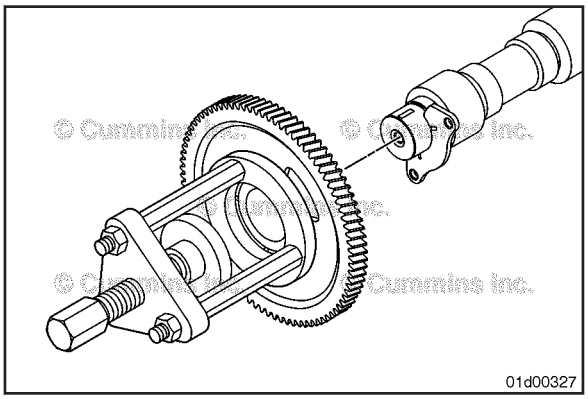
Remove the camshaft and camshaft gear as an assembly.

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

Disassemble

Front Gear Train

Remove the camshaft gear and locating key. Refer to Procedure 001-013 in Section 1.

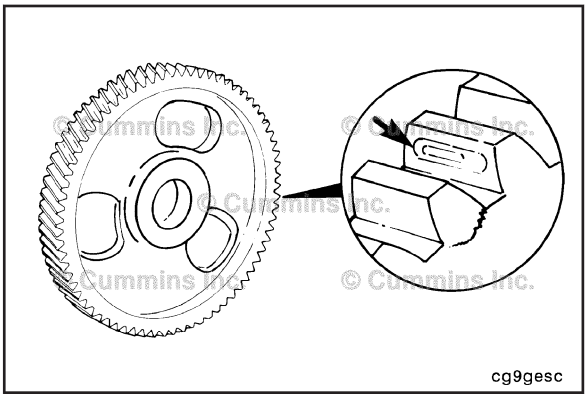


Clean and Inspect for Reuse

Inspect the camshaft gear.

For rear gear train engines, Refer to Procedure 001-012 in Section 1.

For front gear train engines, Refer to Procedure 001-013 in Section 1.

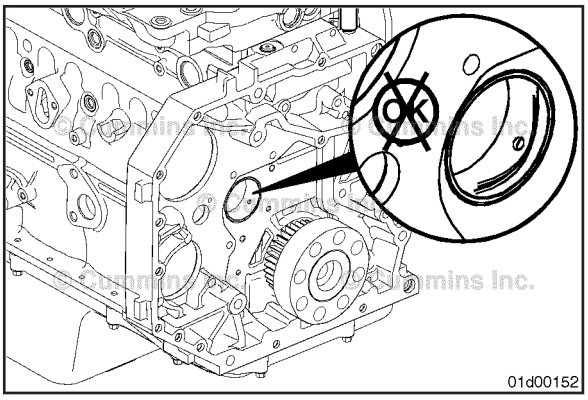


Inspect the camshaft bushing. Refer to Procedure 001-010 in Section 1.

NOTE: Front gear train engines will have a front camshaft bushing. Rear gear train engines will have a rear camshaft bushing. Some engines may be equipped with both.

Only inspect the camshaft bushing that is on the same end of the engine from which the camshaft was removed.

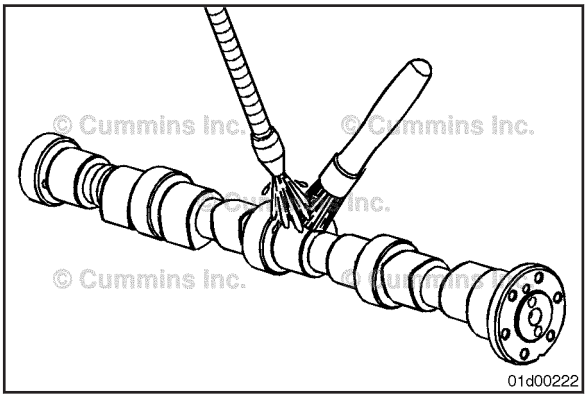
NOTE: Inspection of the rest of the camshaft bushings and camshaft block bores is **not** necessary unless, during the inspection of the camshaft, damage was noted on the camshaft journals.

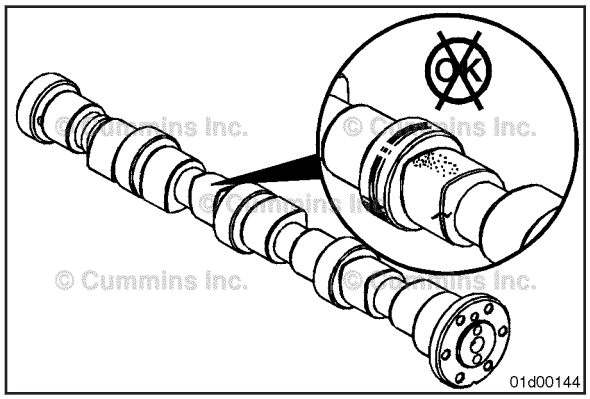


⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

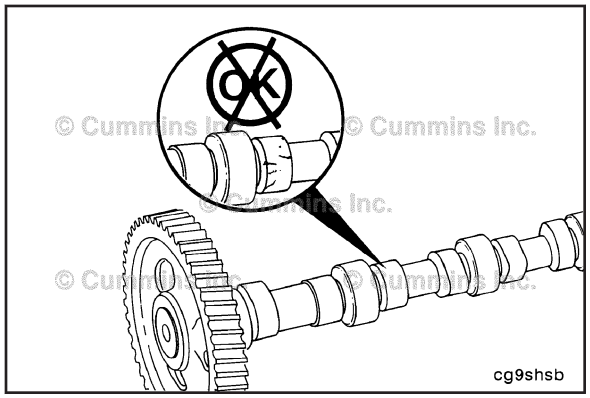
Clean the camshaft with solvents and dry with compressed air.



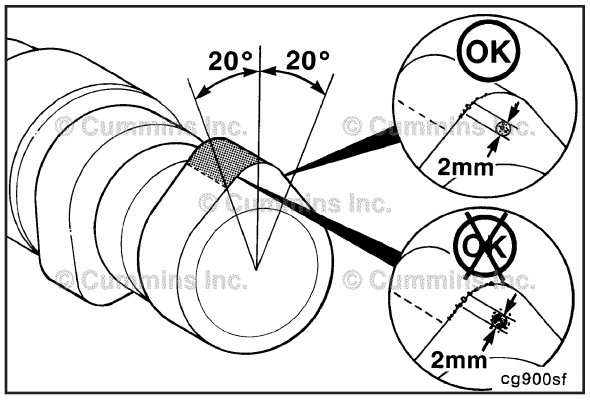


Inspect the valve lobes and bearing journals for cracking, pitting, or scoring.

Inspect the camshaft gear mounting surface on the camshaft to ensure the camshaft gear locating dowel pin is in place and **not** bent, sheared, or cracked.

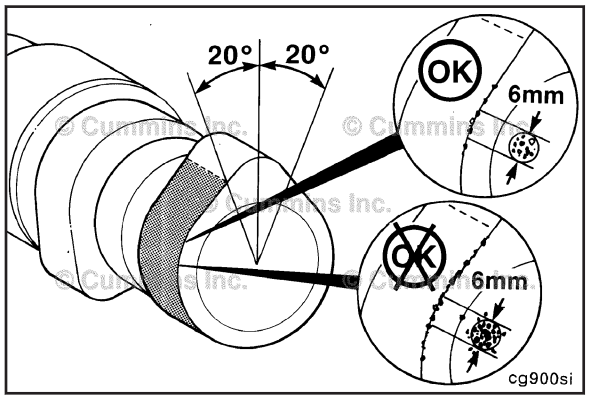


See Service Bulletin 3666475, Camshaft and Tappet Reuse Guidelines, for reuse guidelines for cast iron camshafts.



Edge Deterioration (breakdown) Criteria

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

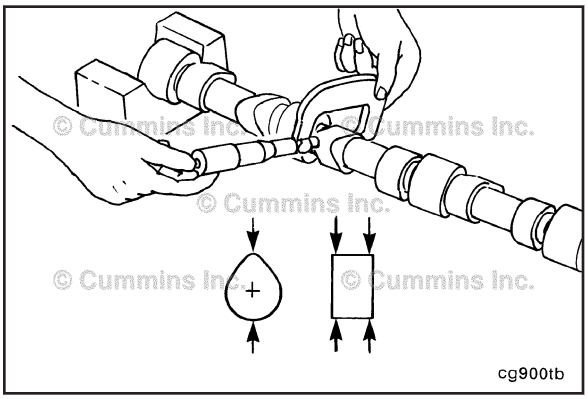


Outside of the ±20 degrees of the nose of the camshaft lobe, the areas of edge deterioration **must not** be greater than the equivalent area of a 6-mm [0.236-in] circle.

NOTE: If the camshaft shows any pitting or wear, remove and inspect the tappets before installing the camshaft. Refer to Procedure 004-015 in Section 4. If a new camshaft is installed, new tappets and push rods **must** also be installed.

Measure

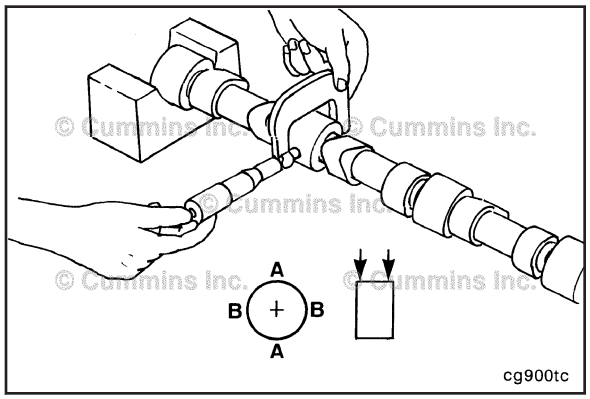
Measure the peak of the camshaft valve lobes.



4 Cylinder (Rear Gear Train) Diameter of Peak of Lobe			
	mm		in
Intake	46.132	MIN	1.8162
Exhaust	45.632	MIN	1.797

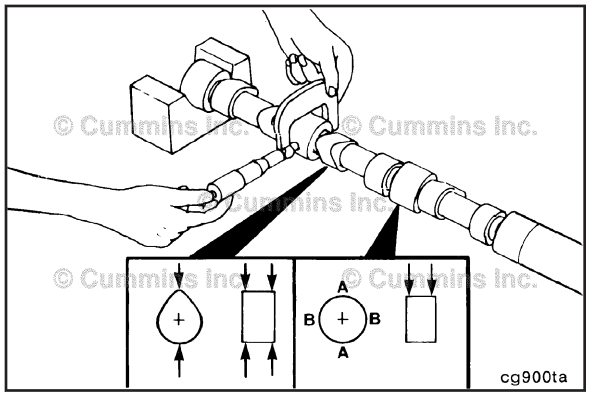
4 Cylinder (Front Gear Train) Engine Peak of Lobe Diameter by Camshaft Part Number		
Part Number	Minimum Intake	Minimum Exhaust
	mm [in]	mm [in]
3929039	45.400 [1.787]	45.141 [1.777]
3925582	45.400 [1.787]	45.141 [1.777]
3914638	45.400 [1.787]	45.141 [1.777]
3929885	45.795 [1.803]	44.649 [1.758]
3929038	45.795 [1.803]	44.166 [1.739]
3924574	45.795 [1.803]	44.166 [1.739]
3931281	45.400 [1.787]	44.649 [1.758]
3930346	45.400 [1.787]	44.649 [1.758]

6 Cylinder (Front Gear Train) Engine Peak of Lobe Diameter by Camshaft Part Number		
Part Number	Minimum Intake	Minimum Exhaust
	mm [in]	mm [in]
3283179	45.795 [1.803]	44.649 [1.758]
3929734	45.795 [1.803]	45.141 [1.777]
3929040	45.795 [1.803]	45.141 [1.777]
3926671	45.795 [1.803]	45.141 [1.777]
3924109	45.258 [1.782]	45.141 [1.777]
3929041	45.400 [1.787]	45.141 [1.777]
3921953	45.400 [1.787]	45.141 [1.777]
3930469	45.400 [1.787]	45.141 [1.777]
3919608	45.400 [1.787]	45.141 [1.777]
3929042	45.400 [1.787]	45.141 [1.777]
3914639	45.400 [1.787]	45.141 [1.777]
3929886	45.795 [1.803]	44.649 [1.758]
3930378	45.400 [1.787]	44.649 [1.758]
3283179	45.795 [1.803]	44.649 [1.758]



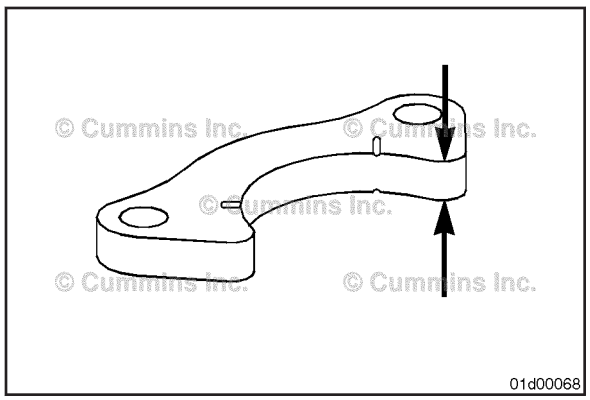
Measure the camshaft bearing journals.

Journal Diameter		
mm		**in**
53.962	MIN	2.1245
54.013	MAX	2.1265



Measure the fuel transfer pump lobe:

Fuel Transfer Pump Lobe Diameter		
mm		**in**
35.50	MIN	1.398
36.26	MAX	1.428



Measure the camshaft thrust plate thickness:

Rear Gear Train Camshaft Thrust Plate Thickness		
mm		**in**
5.25	MIN	0.207
5.35	MAX	0.211

Front Gear Train Camshaft Thrust Plate Thickness		
mm		**in**
9.40	MIN	0.370
9.60	MAX	0.378

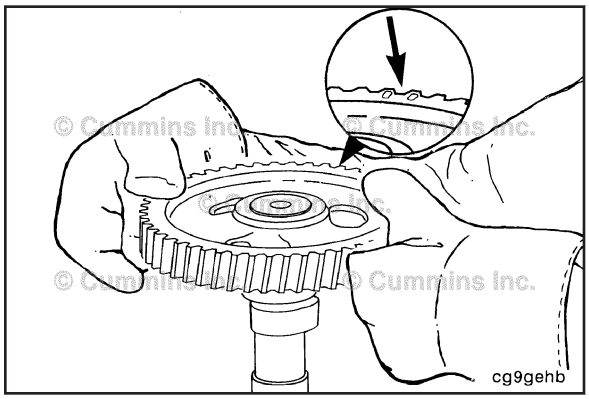
If the camshaft thrust plate is out of specification, replace the thrust plate.

NOTE: Front Gear Train and Rear Gear Train engines do **not** use the same camshaft thrust plate. The camshaft thrust plate thickness can also be verified by checking camshaft end play during installation.

Assemble

Front Gear Train

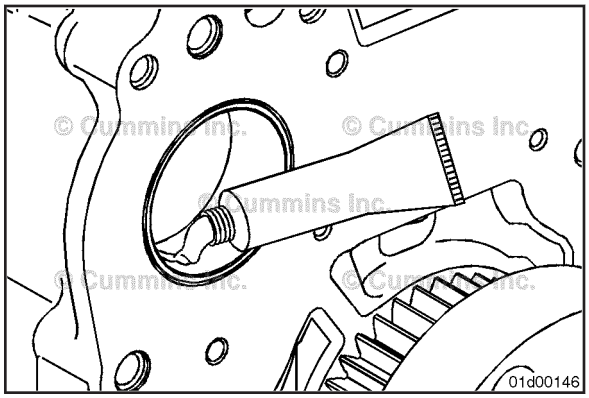
Install the camshaft gear locating key and camshaft gear. Refer to Procedure 001-013 in Section 1.



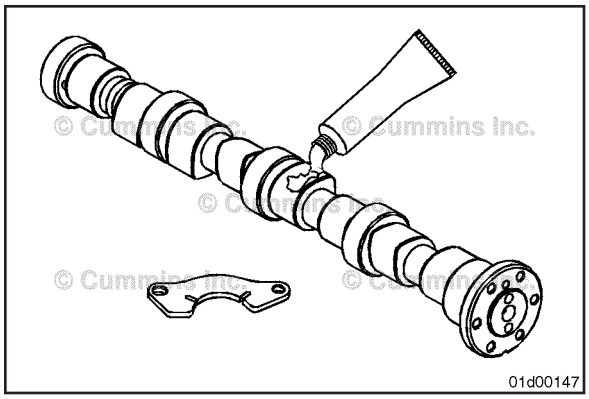
Install

Rear Gear Train

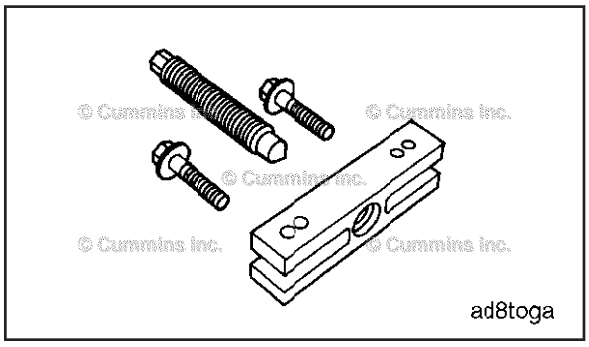
Apply assembly lubricant, Part Number 3163087, to the rear camshaft bore.

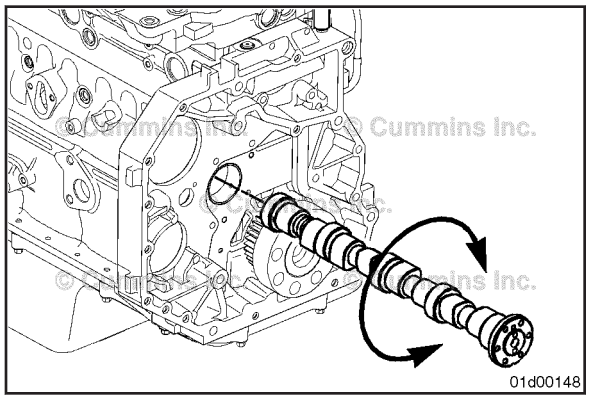


Lubricate the camshaft lobes, journals, and thrust washer with assembly lubricant, Part Number 3163087.



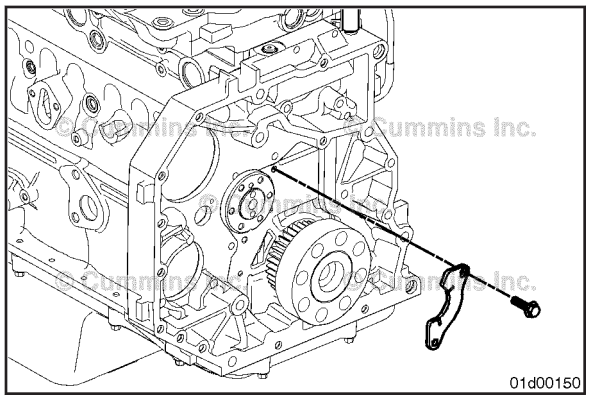
Use a gear puller, service tool Part Number ST647 or equivalent, to attach to the end of the camshaft where the camshaft gear mounts, to act as a handle. This will give proper leverage and ease installing the camshaft.





⚠CAUTION⚠
Do not force the camshaft into the camshaft bore as damage to the camshaft bushing can result.

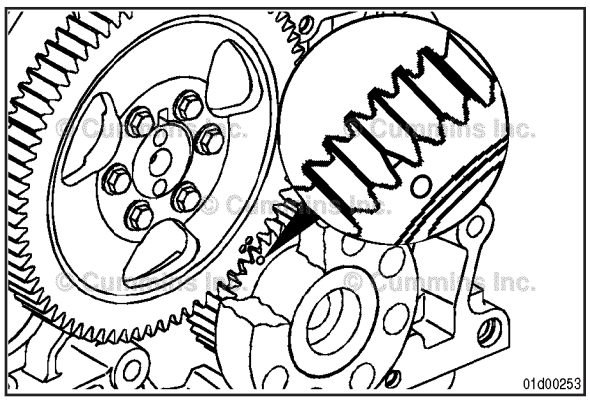
Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the lobe from the bushing and allow the camshaft to be installed.



Install the thrust plate.

Install the thrust plate capscrews.

Torque Value: 24 N•m [212 in-lb]

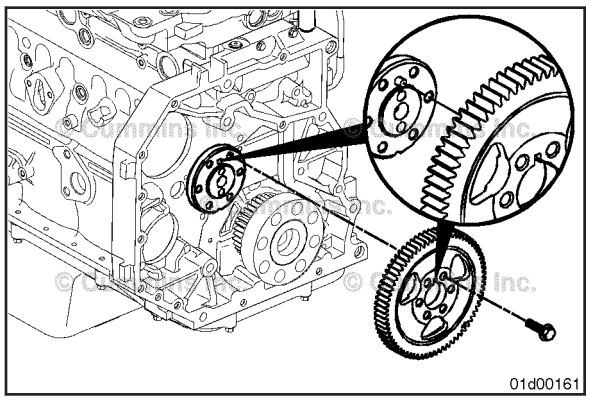


⚠CAUTION⚠
To reduce the possibility of engine damage, make sure the camshaft rotates freely.

NOTE: The engine can have either a mark on the crankshaft gear or a chamfered tooth.

Align the timing marks on the camshaft gear with the timing marks on the crankshaft gear.

NOTE: If equipped with an air compressor, make sure to align the line that was scribed on the camshaft gear and air compressor gear during the camshaft gear removal step. If this was **not** done, Refer to Procedure 012-014 in section 12.



Rotate the camshaft so that the camshaft dowel pin aligns with the slot on the camshaft gear. Install the camshaft gear and capscrews.

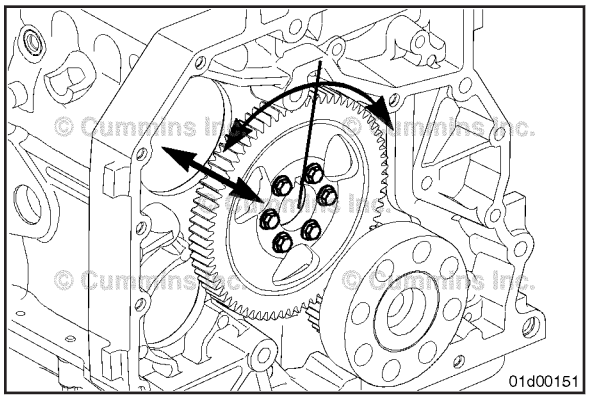
Tighten the capscrews.

Torque Value: 36 N•m [27 ft-lb]

Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399, to verify the camshaft has proper end play and backlash.

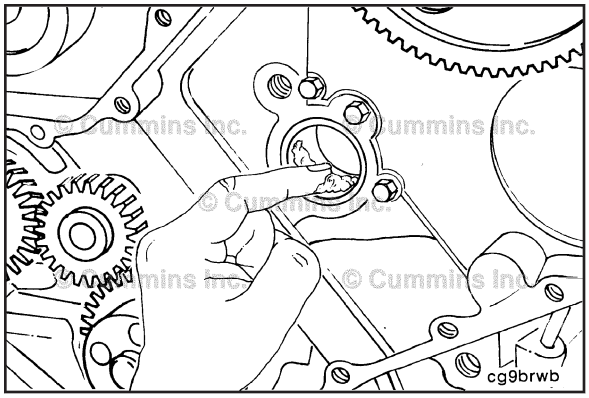
Camshaft End Play (A)		
mm		in
0.10	MIN	0.004
0.36	MAX	0.014

Camshaft Gear Backlash Limits (B)		
mm		in
0.076	MIN	0.003
0.280	MAX	0.011

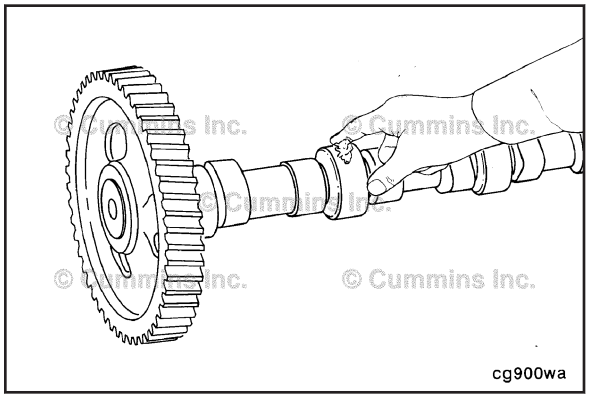


Front Gear Train

Apply assembly lubricant, Part Number 3163087, to the front camshaft bore.

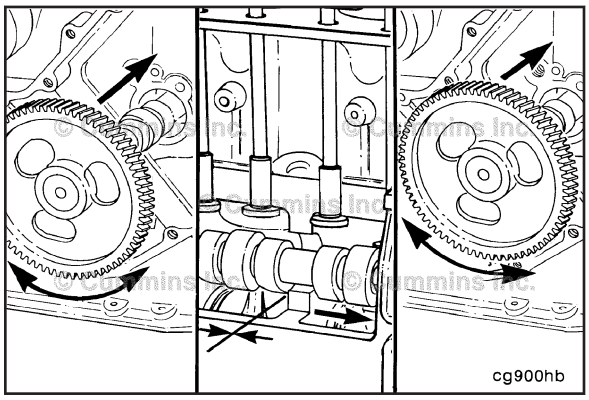


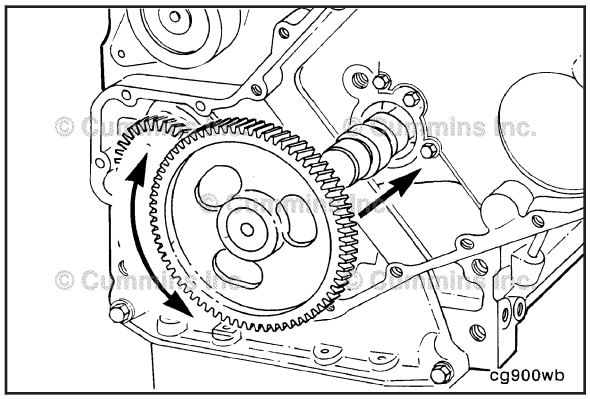
Lubricate the camshaft lobes, journals, and thrust plate with assembly lubricant, Part Number 3163087.



CAUTION
Do not try to force the camshaft into the camshaft bore as damage to the camshaft bushing can result.

Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the lobe from the bushing and allow the camshaft to be installed.

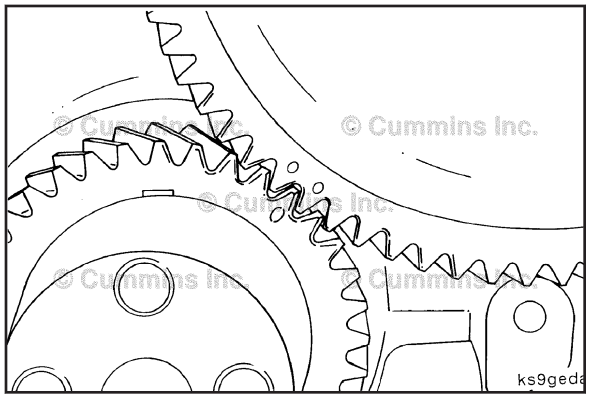




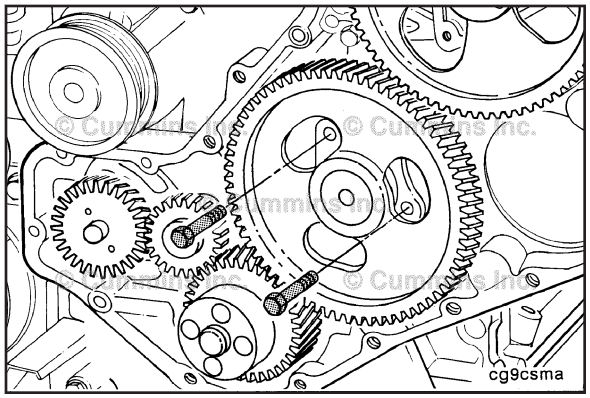
CAUTION

To reduce the possibility of engine damage, make sure the camshaft rotates freely.

Before the camshaft gear engages the crankshaft gear, check the camshaft for ease of rotation. When installed properly, the camshaft **must** rotate freely.



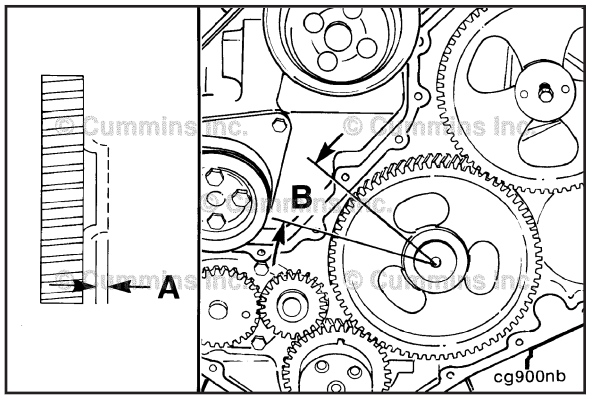
Align the timing marks as illustrated and finish installing the camshaft.



Install the thrust plate.

Install the thrust plate capscrews.

Torque Value: 24 N•m [18 ft-lb]



Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399, to verify the camshaft has proper backlash and end play.

Camshaft End Play (A)		
mm		in
0.12	MIN	0.005
0.47	MAX	0.018

Camshaft Gear Backlash Limits (B)		
mm		in
0.33	MIN	0.013
0.76	MAX	0.030

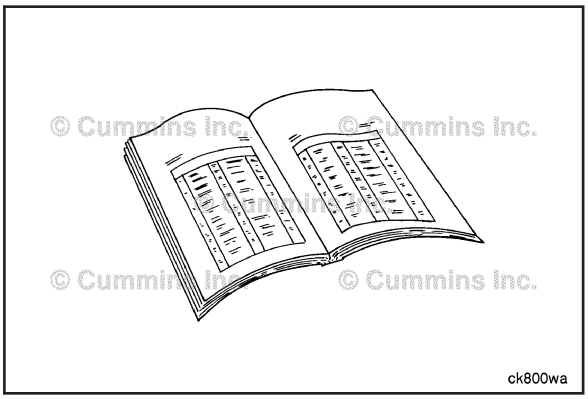
Finishing Steps

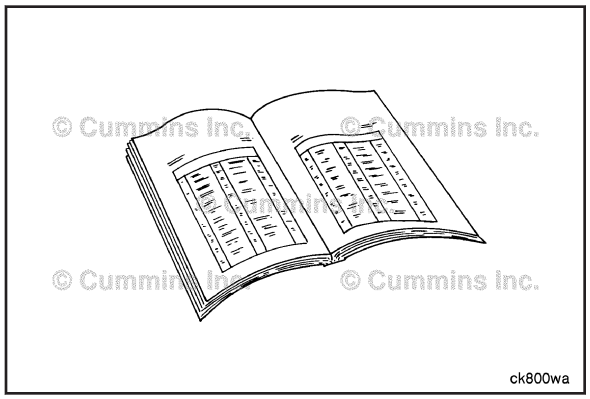
Rear Gear Train

⚠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.

- Unlock the fuel pump. Refer to Procedure 005-014 in Section 5.
- Lower the tappets. Refer to Procedure 004-015 in Section 4
- Install the push rods. Refer to Procedure 004-014 in Section 4
- Install the rocker levers. Refer to Procedure 003-008 in Section 3
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3
- Install the fuel lift pump. Refer to Procedure 005-045 in Section 5.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16
- Install the flywheel. Refer to Procedure 016-005 in Section 16
- Install the flexplate. Refer to Procedure 016-004 in Section 16.
- Install the transmission and all related components (if equipped). Refer to the OEM service manual.
- Install the air compressor. Refer to Procedure 012-014 in Section 12.
- Connect the batteries
- Operate the engine and check for leaks.





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 front gear cover. Refer to Procedure 001-031 in Section 1
- Install the vibration damper. Use the following procedure, if equipped with a viscous damper. Refer to Procedure 001-052 in Section 1.
- Use the following procedure, if equipped with a rubber damper. Refer to Procedure 016-004 in Section 1.
- Release the tappets. Refer to Procedure 004-015 in Section 4
- Install the push rods. Refer to Procedure 004-014 in section 4
- Install the rocker levers. Refer to Procedure 003-008 in Section 3
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3
- Install the fuel lift pump. Refer to Procedure 005-045 in Section 5.
- Install the fan hub, if required. Refer to Procedure 008-039 in Section 8
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the batteries
- Operate the engine and check for leaks.

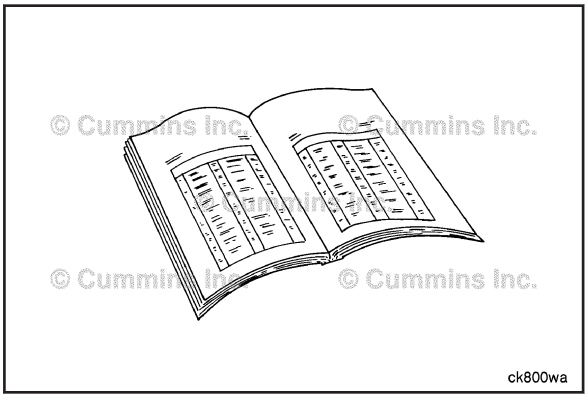
Camshaft Bushings (001-010)

General Information

Some engines are only built with a camshaft bushing installed in the first camshaft bore on the same side of the engine that the camshaft is removed and installed (front gear train engines, at the front of the engine and rear gear trains, at the rear of the engine). Some engines also have a second camshaft bushing at the opposite end of the engine from which the camshaft was removed and installed.

From production, there are no camshaft bushings installed in the inner block camshaft journal bores. If the inner block camshaft journal bores are damaged, the journal bores can be machined for camshaft bushings. See the Clean and Inspect for Reuse step of this procedure for specifications.

Preparatory Steps



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

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

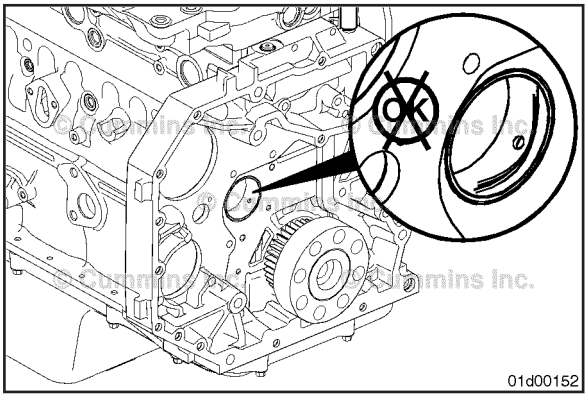
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

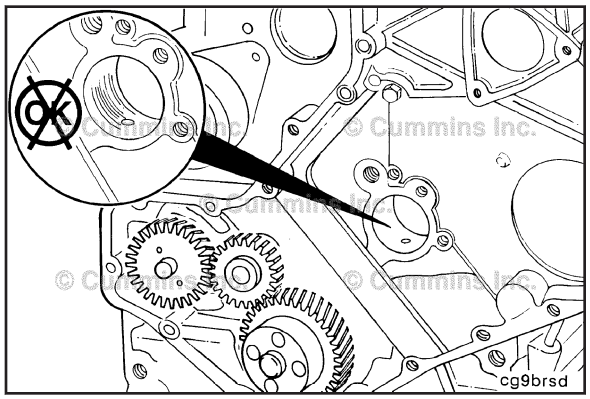
- Disconnect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Remove the camshaft. Refer to Procedure 001-008 (Camshaft) in Section 1.
- Drain the lubricating oil. Refer to Procedure 007-037 (Lubricating Oil System) in Section 7.
- Remove the oil pan and oil pan gasket. Refer to Procedure 007-025 (Lubricating Oil Pan) in Section 7.

Initial Check

Inspect the camshaft bushing at the end of the engine in which the camshaft was removed for scoring, scuffing or excessive wear.

If damage to the camshaft bushing is found, remove and replace the camshaft bushing.





From below the engine, inspect if a camshaft bushing is installed at the opposite end of the engine in which the camshaft was removed.

If a camshaft bushing is present, inspect the camshaft bushing for scoring, scuffing or excessive wear.

If damage to the camshaft bushing is found, remove and replace the camshaft bushing.

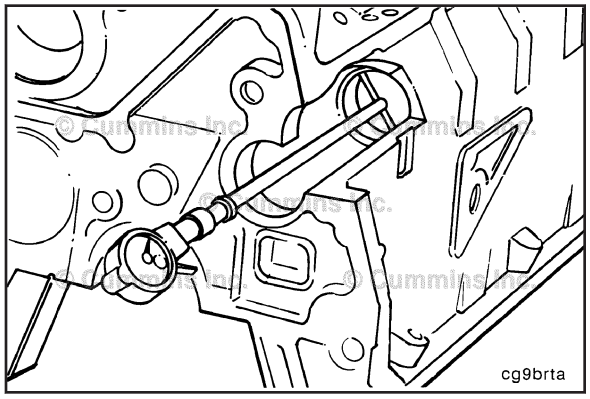
To replace the camshaft bushing, you must first:

For Rear Gear Train Engines:

Remove the front gear cover. Refer to Procedure 001-031 (Gear Cover, Front) in Section 1.

For Front Gear Train Engines:

Remove the flywheel housing. Refer to Procedure 016-006 (Engine Component Torque Values) in Section 16.



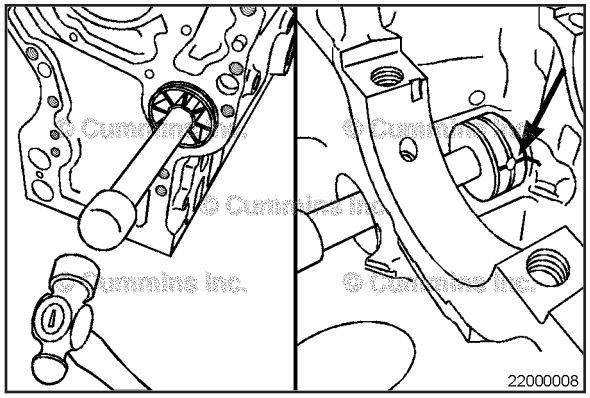
From below the engine, inspect the inner camshaft bores for scoring, scuffing or excessive wear.

NOTE: During a previous repair, camshaft bushings may have been installed.

For camshaft bore specifications see the Inspect for Reuse step of this procedure.

If damage to the inner camshaft bores is found, machine the camshaft bores oversize to install standard camshaft bushings. See the Inspect for Reuse step for specifications.

If the damage to the bore(s) is beyond machining, replace the block. Refer to Procedure 001-026 (Cylinder Block) in Section 1.



Remove

Remove the camshaft bushings, use the camshaft bushing replacer kit, Part Number 3165045. The tool will drive the camshaft bushing to the inside of the block. The camshaft bushing can be retrieved from the bottom of the engine.

The following kits are also available for camshaft bushing installation and removal:

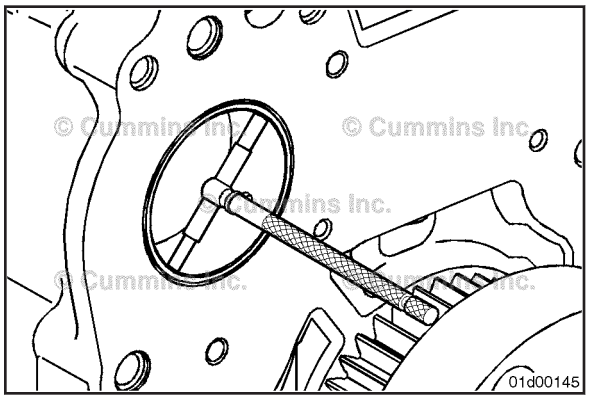
Hydraulic Actuator Kit, Part Number 3823621
Camshaft Bushing Kit, Part Number 3162249

NOTE: Once removed, camshaft bushings can **not** be reused.

Inspect for Reuse

Rear Gear Train

Measure the camshaft bores **without** the camshaft bushing installed.



Camshaft Bore Diameter without camshaft bushing (maximum)			
	mm		**in**
Camshaft Bore (Camshaft Bushing Previously Installed)	59.248	MAX	2.3326
Camshaft Bore (Camshaft Bushing not Previously Installed)	54.164	MAX	2.1324

If a camshaft bushing was previously installed and the camshaft bore is out of specification, the block **must** be replaced. Refer to Procedure 001-026 (Cylinder Block) in Section 1. No oversize cam bushings are available.

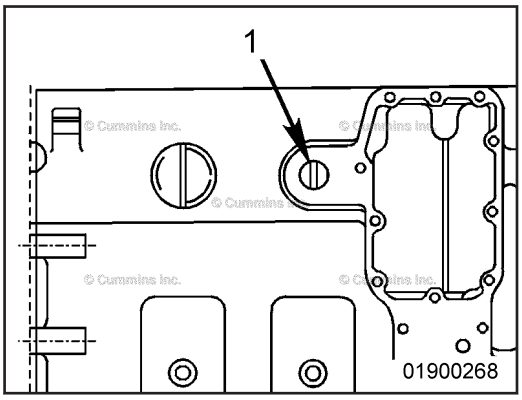
If a camshaft bore in which a camshaft bushing was **not** previously installed is damaged or out of specification, the camshaft bore can be machined oversize to install a standard camshaft bushing.

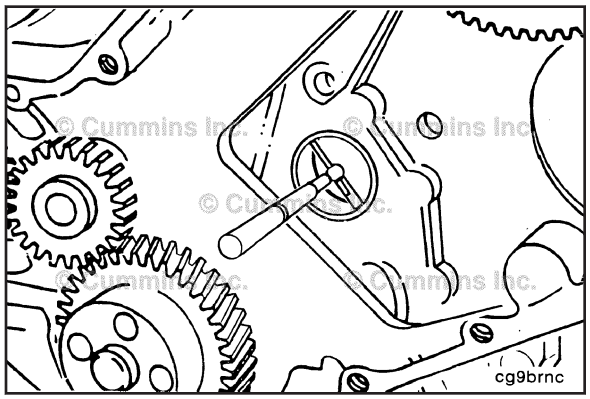
Machine the damaged bore to a maximum of 59.248 mm (2.3326 in) to accept a standard bushing.

Front Gear Train

With the introduction of the STORM block, the camshaft bushing bore increased by 2 mm [0.079 in] to accept a larger outer diameter camshaft bushing. The camshaft bushing inner diameter did **not** change.

NOTE: A STORM block will have a threaded port next to the oil cooler cavity in the cylinder block (1). A non-STORM block will **not** have this port.





Measure the camshaft bores **without** the camshaft bushing installed.

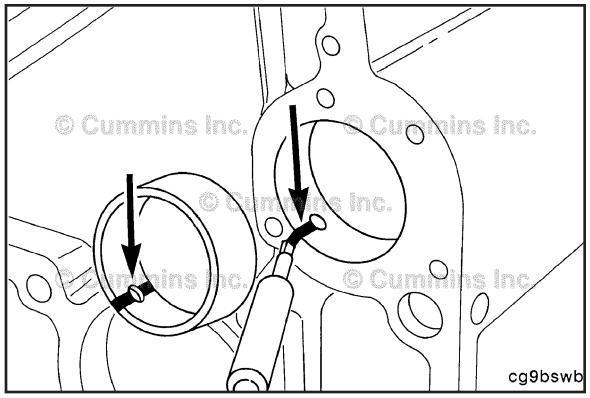
STORM Block Camshaft Bore Diameter without camshaft bushing (maximum)			
	mm		**in**
Camshaft Bore (Camshaft Bushing Previously Installed)	59.248	MAX	2.3326
Camshaft Bore (Camshaft Bushing not Previously Installed)	54.164	MAX	2.1324

Pre-STORM Block Camshaft Bore Diameter without camshaft bushing (maximum)			
	mm		**in**
Camshaft Bore (Camshaft Bushing Previously Installed)	57.248	MAX	2.2539
Camshaft Bore (Camshaft Bushing not Previously Installed)	54.164	MAX	2.1324

If a camshaft bushing was previously installed and the camshaft bore is out of specification, the block **must** be replaced. Refer to Procedure 001-026 (Cylinder Block) in Section 1. No oversize camshaft bushings are available.

If a camshaft bore in which a camshaft bushing was **not** previously installed is damaged or out of specification, the camshaft bore can be machined oversize to install a standard camshaft bushing.

Machine the damaged bore to a maximum of 59.248 mm (2.3326 in) to accept a standard bushing.

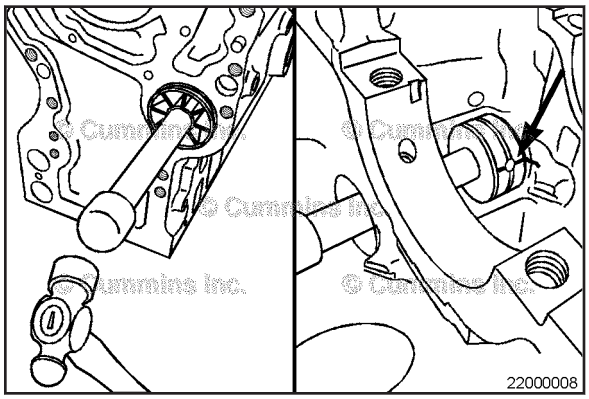


Install

Mark the camshaft bushing and cylinder block to aid in the alignment of the lubricating oil hole in the cylinder block with the large lubricating oil hole in the bushing.

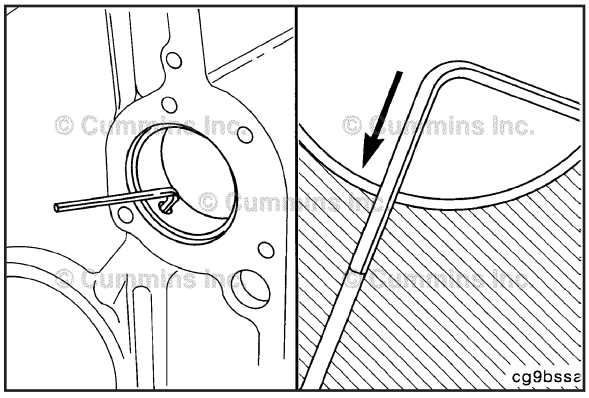
Slide the camshaft bushing on the replacer tool. Align the marks on the camshaft bushing and the cylinder block.

Drive the camshaft bushing to the correct installed depth. The correct installed depth is when the camshaft bushing end is flush with the machined face of the block and the oil hole aligns with the cylinder block oil hole.



Be sure the large lubricating oil hole is aligned.

A 3.2 mm [0.128 in] diameter rod **must** be able to pass through the lubricating oil hole.

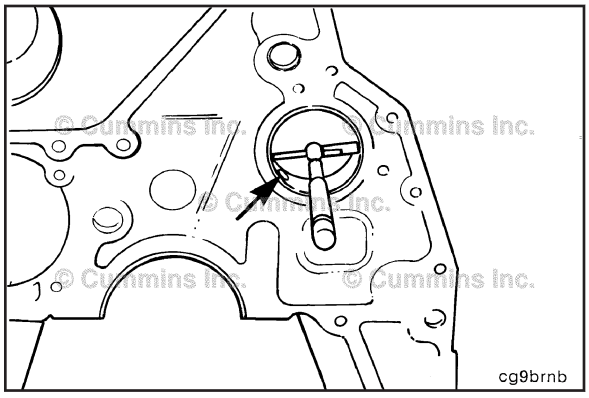


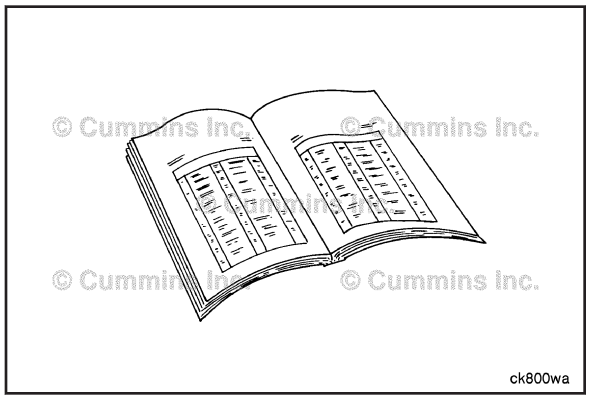
Measure

Measure the installed camshaft bushing.

Camshaft Bore (Bushing Installed)		
mm		**in**
54.083	MIN	2.1293
54.147	MAX	2.1318

If the camshaft bore with the camshaft bushing installed is out of specification, remove the camshaft bushing and inspect the camshaft bore.





Finishing Steps

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

⚠WARNING⚠
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.

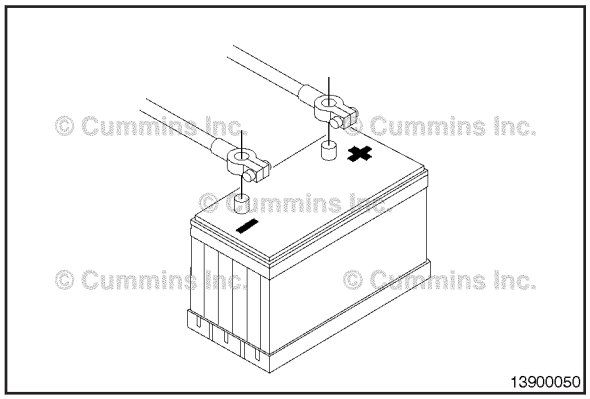
- Install the camshaft. Refer to Procedure 001-008 (Camshaft) in Section 1.
- Install the oil pan gasket and oil pan. Procedure 007-025 (Lubricating Oil Pan) in Section 7.
- Fill the engine with clean lubricating oil. Refer to Procedure 007-037 (Lubricating Oil System) in Section 7.
- Connect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Operate the engine and check for leaks.

Camshaft Gear (Camshaft Installed) (001-012)

General Information

This procedure applies to rear gear train engines only. For front gear train engines, the preferred method of removing the camshaft gear is to first remove the camshaft. Refer to procedure 001-008. Once the camshaft is removed, the camshaft gear can be removed. Refer to Procedure 001-013.

Camshaft gear removal/installation tool, Part Number 3823589, can be used to replace the camshaft gear with the camshaft partially installed. This method should **only** be applied to engines used in applications that prohibit the removal of the camshaft in chassis.



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.

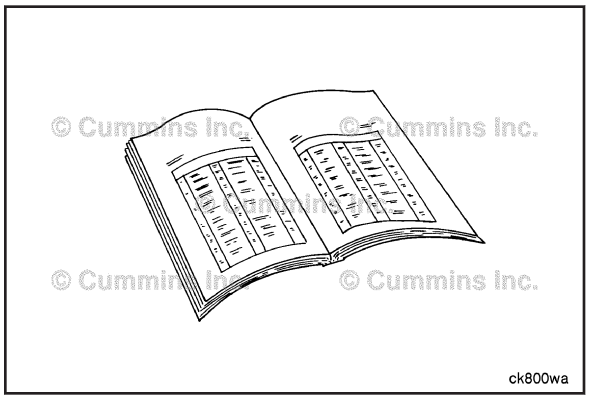
Disconnect the batteries.

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause serious personal injury.

⚠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. Refer to the original equipment manufacturer's instructions
- Remove the starting motor. Refer to Procedure 013-020
- Remove the flywheel or flexplate. Refer to Procedure 016-005 or Procedure 016-004
- Remove the flywheel housing. Refer to Procedure 016-006
- Lock the fuel pump. Refer to Procedure 005-014, Fuel Injection Pump, Rotary, or Procedure 005-012, Fuel Injection Pumps, In-Line.

NOTE: Failure to lock the fuel pump may result in improper fuel pump timing during reassembly.

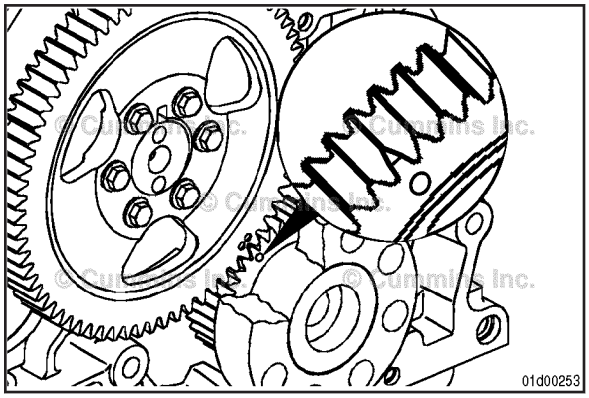


Remove

Rotate the engine to allow the camshaft timing marks to align.

NOTE: The engine can have a mark on the camshaft gear or chamfered tooth.

Service Tip: Engines equipped with air compressors may require that the air compressor be timed to the engine. To ensure that the air compressor is properly timed when the camshaft gear is later installed, scribe an alignment line on the air compressor and camshaft gear before removing the camshaft gear.



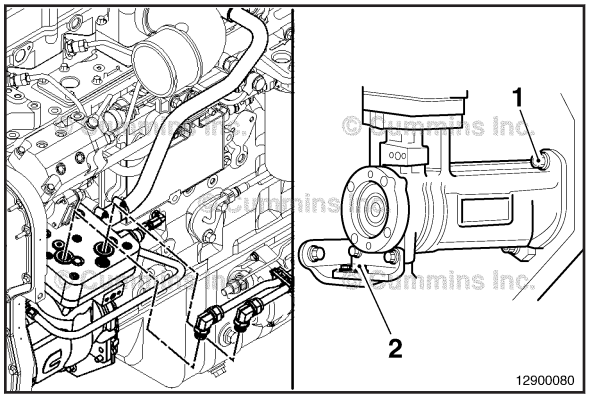
On engines equipped with an air compressor/accessory drive, it may be necessary to loosen/remove some the air compressor/accessory drive mounting hardware in order to remove the camshaft gear. It is **not** necessary to remove the air compressor/accessory drive completely.

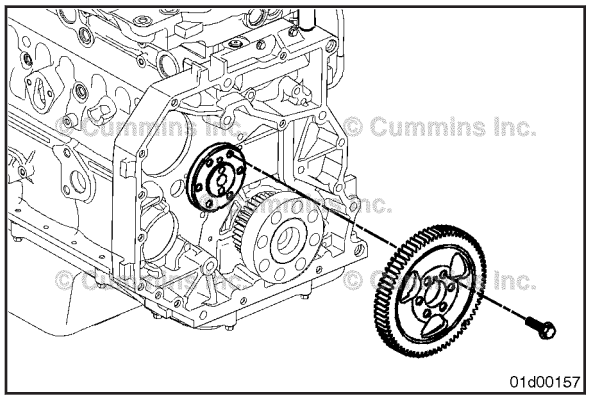
Loosening/remove some of the air compressor/accessory drive mounting hardware will give enough clearance to remove the camshaft gear.

Loosen the air compressor mounting fasteners (1).

Remove the two capscrew securing the air compressor support (2).

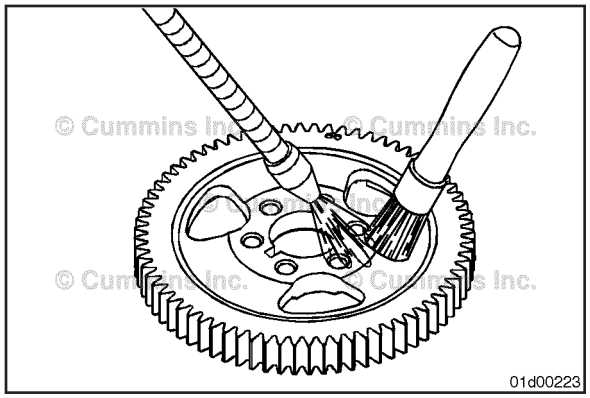
If equipped with a hydraulic pump driven off of the air compressor, it may be necessary to remove and/or loosen some or all of the mounting fasteners. Refer to the OEM Instructions.





Remove the camshaft gear capscrews.

Remove the camshaft gear.

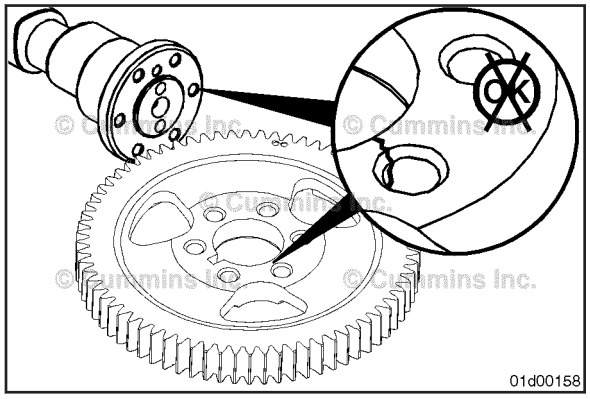


Clean and Inspect for Reuse

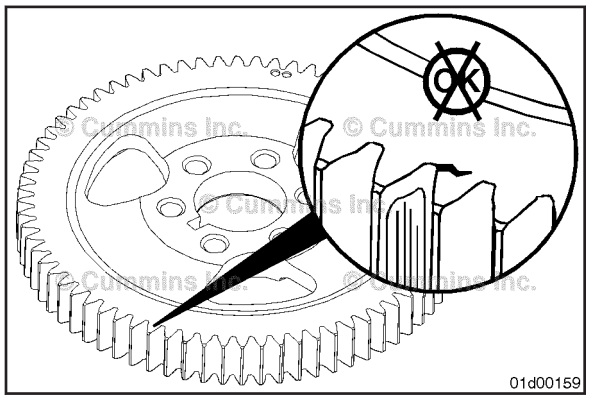
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Clean the camshaft gear. Dry with compressed air.



Inspect for cracks and fretting at the capscrew holes on the camshaft and camshaft gear.

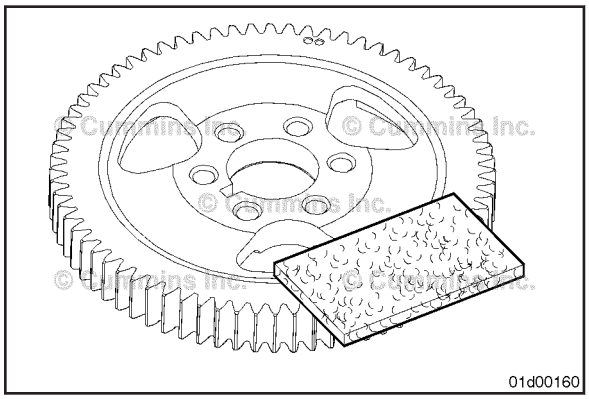


Inspect for fretting on the camshaft gear teeth.

Inspect for cracked or broken teeth on the camshaft gear.

Remove any frets, burrs, or raised metal with abrasive pad, Part Number 3823258.

If frets, burrs, or raised metal can **not** be removed with abrasive pad, Part Number 3823258, replace the gear.

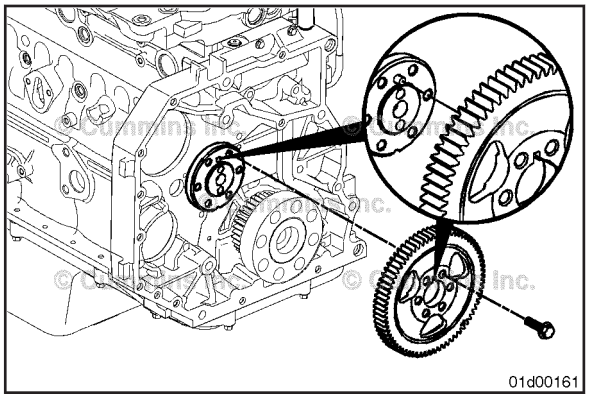


Install

⚠CAUTION⚠
To reduce the possibility of engine damage, make sure the camshaft rotates freely.

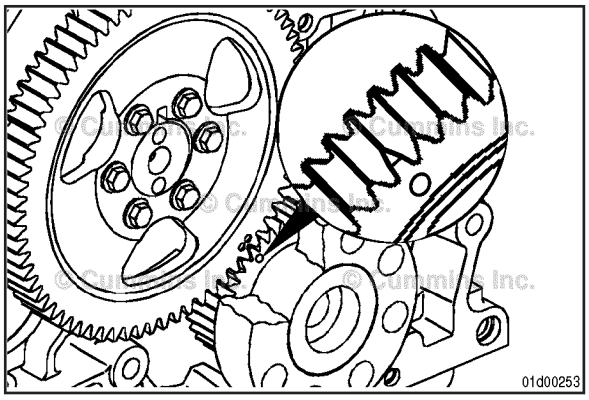
Align the camshaft gear with the pin in the camshaft and the mark on the crankshaft gear.

Install camshaft gear onto the camshaft.



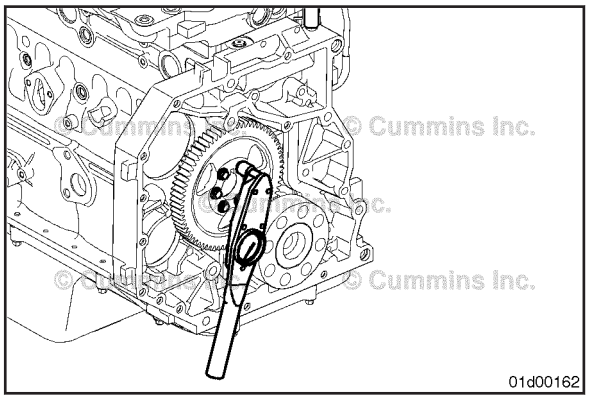
Check to make sure the timing marks on the camshaft gear align with the timing marks on the crankshaft gear. If equipped with an air compressor, make sure to align the line that was scribed on the camshaft gear and air compressor gear during the camshaft gear removal step. If this was **not** done, refer to Procedure 012-014 for air compressor timing procedures.

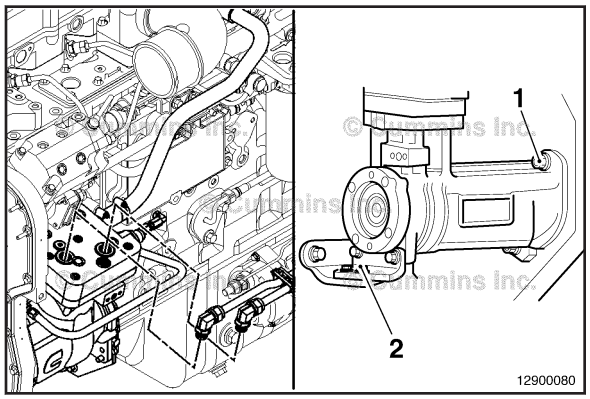
NOTE: The engine can have a mark on the crankshaft gear or chamfered tooth.



Install camshaft gear capscrews and tighten.

Torque Value: 36 N•m [27 ft-lb]





⚠CAUTION⚠
On engines equipped with an air compressor/ accessory drive, before tightening the air compressor mounting fasteners, inspect to see that the seals/ gaskets are in place. Failure to inspect may result in an oil leak or blockage of the air compressor oil passages, which will damage the air compressor.

Tighten the air compressor/accessory drive mounting fasteners (1).

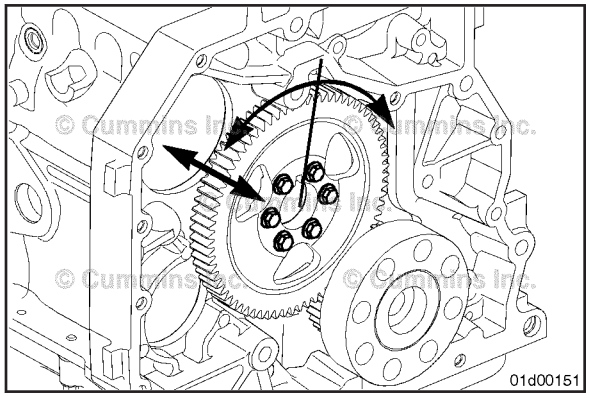
Torque Value: 77 N•m [57 ft-lb]

Install the two capscrew securing the air compressor support (2).

Torque Value:

M8	24 N•m	[18 ft-lb]
M10	43 N•m	[32 ft-lb]
M12	77 N•m	[57 ft-lb]

If equipped with a hydraulic pump driven off of the air compressor, install and/or tight any of the mounting fasteners removed. Refer to the OEM Instructions.



Measure

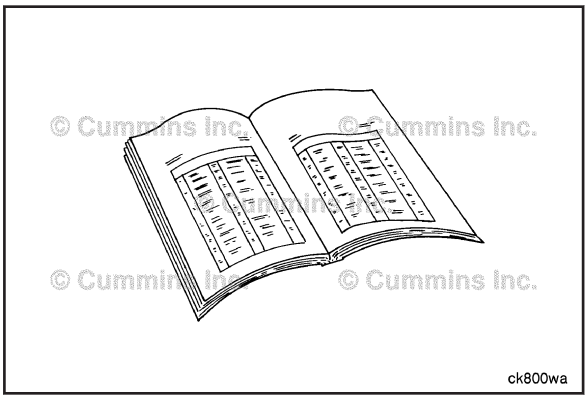
Using gauge, Part Number 3824564, and magnetic base, Part Number 3377399, check the camshaft end play.

Camshaft End Play		
mm		**in**
0.100	MIN	0.004
0.360	MAX	0.014

Check the camshaft backlash.

Camshaft Backlash		
mm		**in**
0.076	MIN	0.003
0.280	MAX	0.011

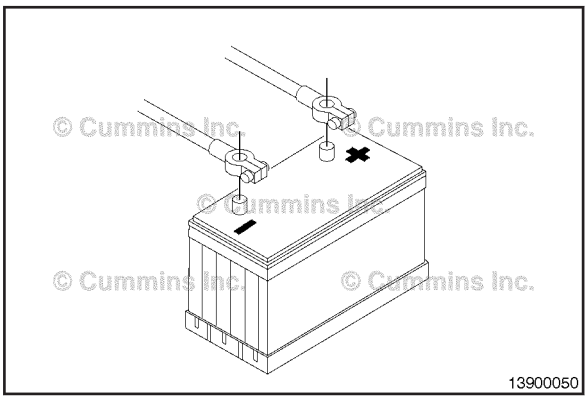
Finishing Steps



⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause serious personal injury.

⚠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.

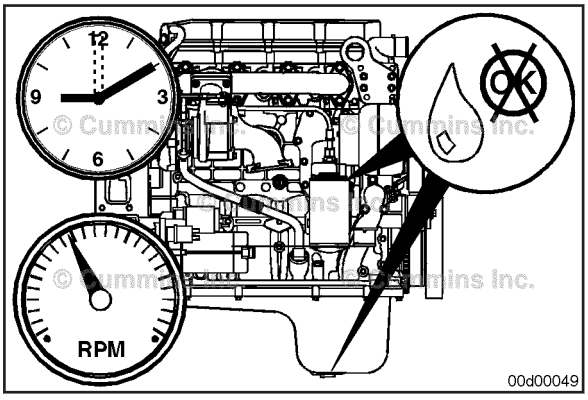
- Unlock the fuel pump. Refer to Procedure 005-014, Fuel Injection Pump, Rotary, or Procedure 005-012, Fuel Injection Pumps, In-Line
- Install the flywheel or flexplate. Refer to Procedure 016-005 or Procedure 016-004
- Install the flywheel housing. Refer to Procedure 016-006
- Install the starter motor. Refer to Procedure 013-020
- Install the transmission. Refer to the original equipment manufacturer's instructions.

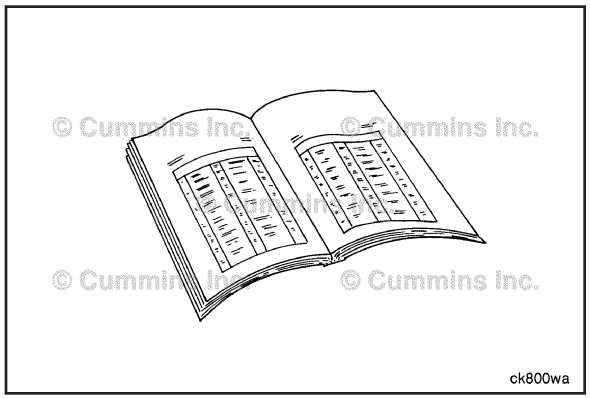


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Reconnect the batteries.

Operate engine and check for leaks.



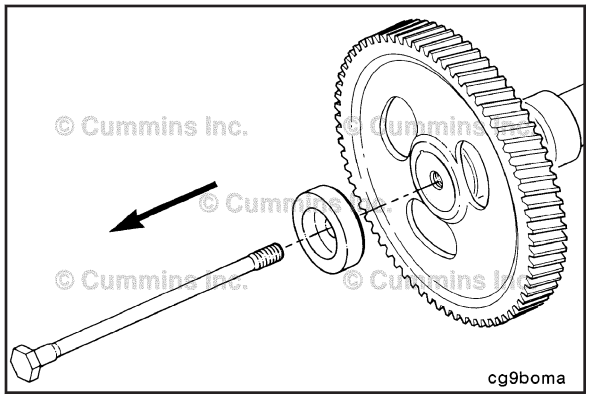


Camshaft Gear (Camshaft Removed) (001-013)

General Information

This procedure is for front gear train engines **only** in which the camshaft has already been removed. Refer to Procedure 001-008.

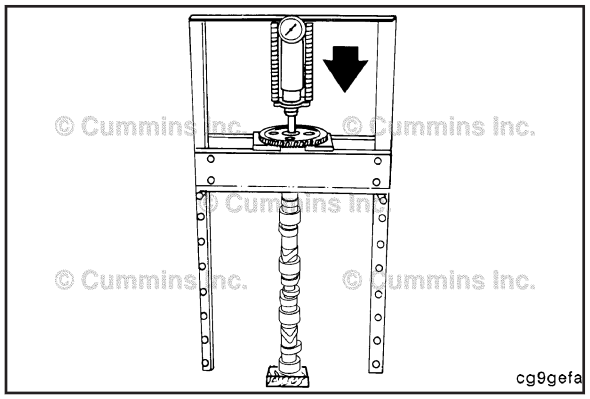
NOTE: For rear gear train engines, the camshaft gear **must** be removed to remove the camshaft. Refer to Procedure 001-012.



Remove

On bolted camshafts, remove the camshaft bolt and washer.

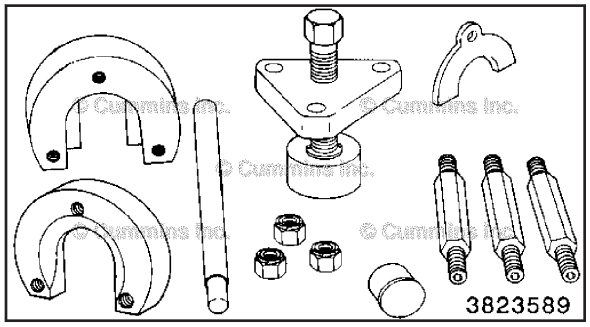
NOTE: Bolted camshafts are **only** used on 1991 engines with an inline injection pump.



The camshaft gear can be removed from the camshaft by the following methods:

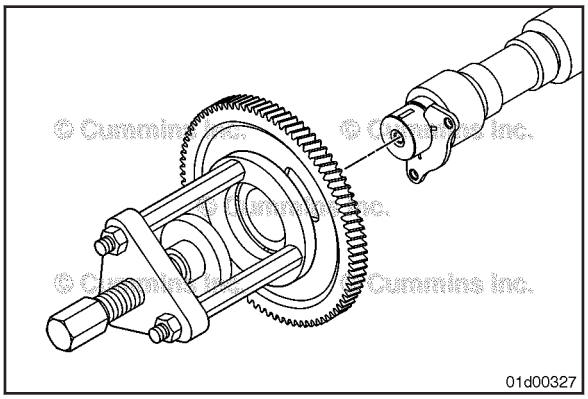
⚠CAUTION⚠
The camshaft gear must be fully supported when using a hydraulic press. Failure to properly support the camshaft gear will result in damage to the camshaft gear.

Use a hydraulic press

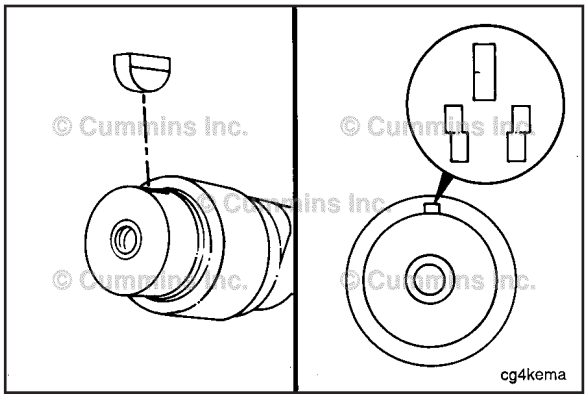


Use the camshaft gear removal and installation tool, Part Number 3823589.

Remove the camshaft gear from the nose of the camshaft.



Remove the camshaft gear locating key or dowel pin.



Clean and Inspect for Reuse

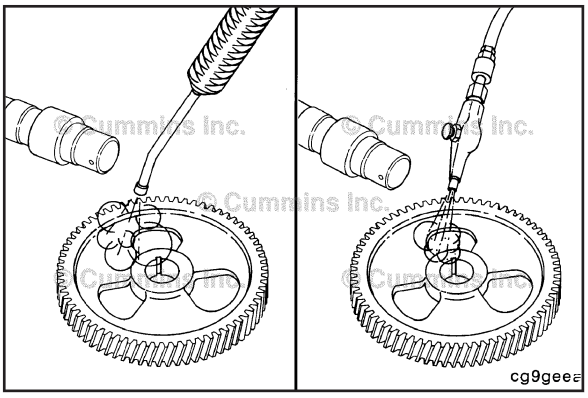
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

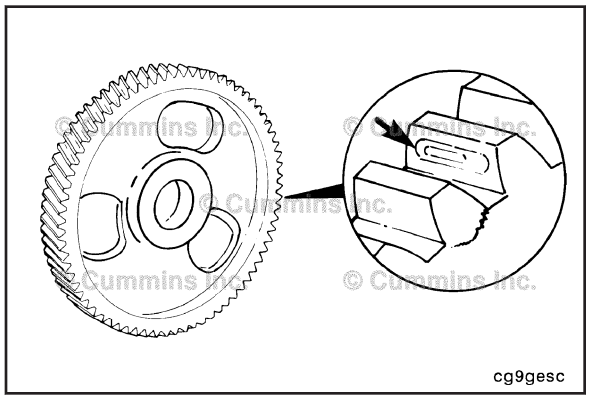
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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

Use solvent to clean the camshaft gear.

Dry with compressed air.



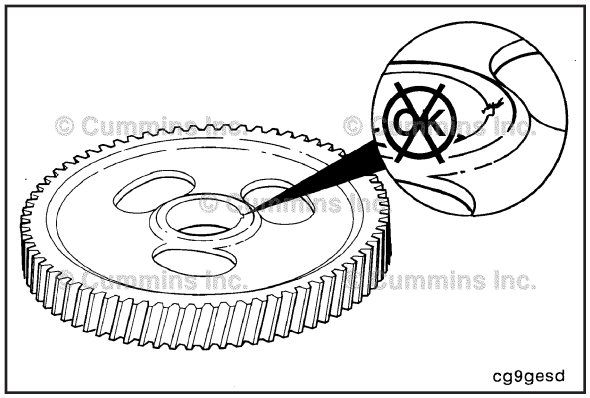


Inspect the camshaft gear teeth for pitting. Look for cracks at the root of the teeth.

Inspect the camshaft gear teeth for discoloration or signs of excessive heat (bluing).

If any damage is present, replace the camshaft gear.

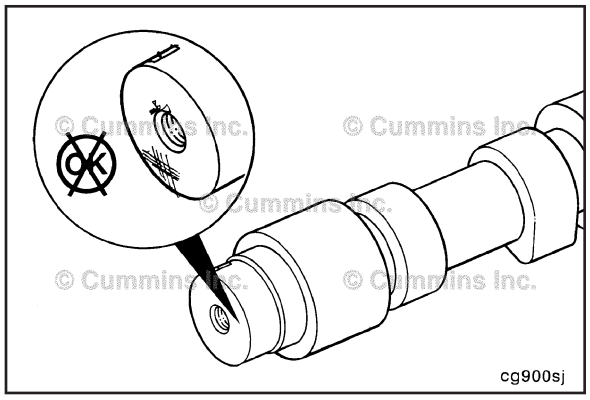
NOTE: If there is damage to the camshaft gear teeth or there are signs of excessive heat, make sure to inspect the associated crankshaft and fuel pump gears for damage. Measure camshaft gear backlash upon installation.



NOTE: If the fretting, burrs, or raised material burrs can **not** be removed, with abrasive pad, Part Number 3823258, replace camshaft gear.

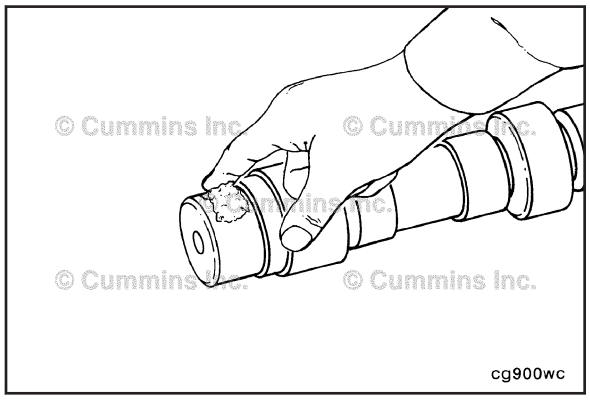
Inspect the camshaft bore for fretting or burrs.

Inspect the camshaft gear for burrs.



Inspect the camshaft nose for frets or burrs.

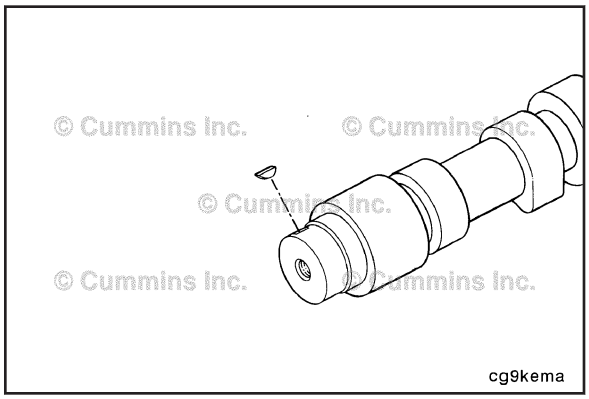
NOTE: If frets or burrs can **not** be removed with an abrasive pad, Part Number 3823258, or equivalent, replace the camshaft.



Install

Lubricate the camshaft nose with Lubriplate™ 105, or equivalent.

Install the camshaft gear locating key or dowel pin with a plastic mallet.



The camshaft gear can be installed by using the following methods:

CAUTION

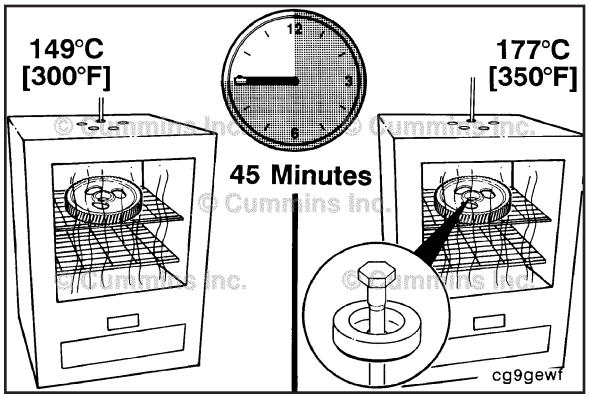
The camshaft gear will be permanently distorted if overheated. The oven temperature must never exceed, for the given camshaft gear type, the temperature specification given below.

Non-Bolted Camshaft Gears (1991 Engines only)

Heat the camshaft gear to 149°C [300°F] for 45 minutes.

All Other Camshaft Gears

Heat the camshaft gear to 177°C [350°F] for 45 minutes.

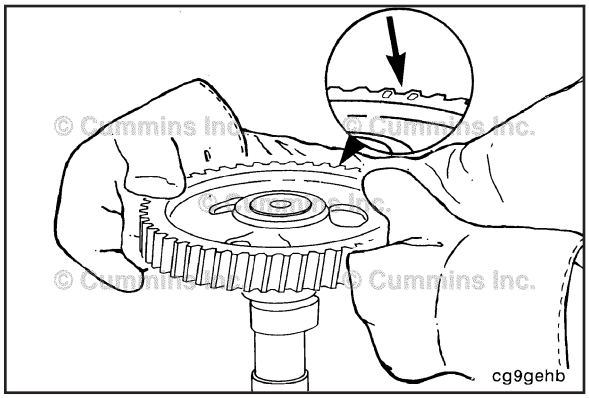


WARNING

To prevent personal injury, wear protective gloves to handle the hot gear.

Install the camshaft gear with the timing marks away from the camshaft.

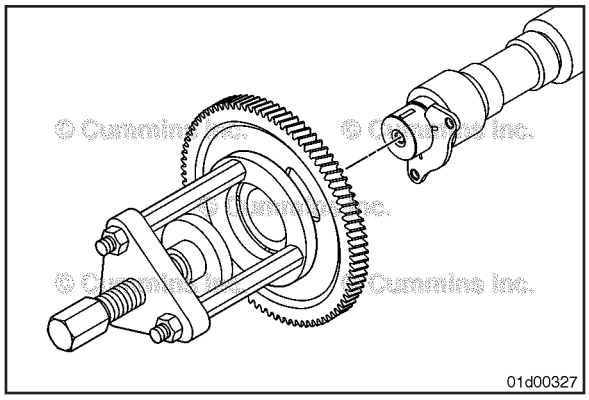
Install the camshaft gear onto the nose of the camshaft. Align the camshaft gear keyway with the camshaft locating key/dowel pin.

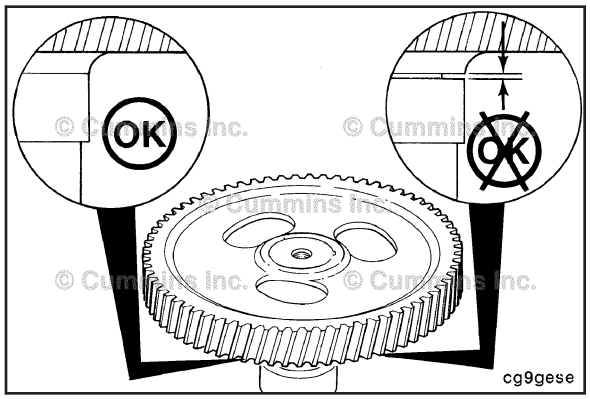


Using the camshaft gear removal and installation tool, Part Number 3823589.

NOTE: Install the camshaft gear with the timing marks away from the camshaft.

Install the camshaft gear onto the nose of the camshaft. Align the camshaft gear keyway with the camshaft locating key/dowel pin.

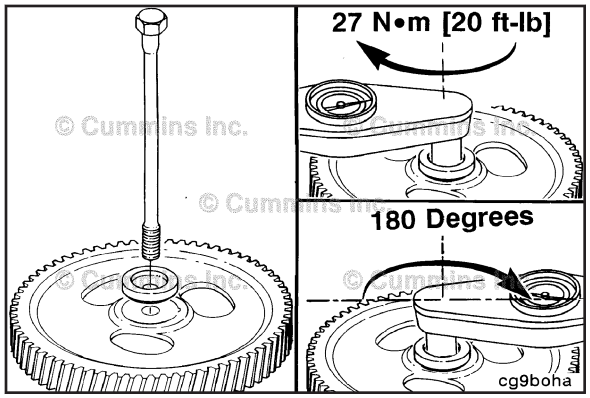




CAUTION

Make sure the gear is seated against camshaft shoulder.

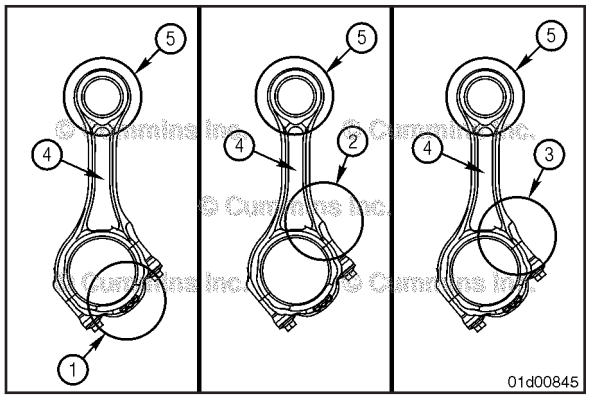
Use a 0.025 mm [0.001 inch] feeler gauge to see if the feeler gauge can be inserted between the camshaft gear and the shoulder on the camshaft. If the feeler gauge can be inserted, the camshaft gear is **not** properly seated.



For bolted camshaft gears, install the camshaft bolt and washer.

Tighten the bolt.

Torque Value: Step1 27 N•m [20 ft-lb]
Step2 Rotate capscrew 180 degrees.



Connecting Rod (001-014)

General Information

Different types of connecting rods are used in B series engines, depending on the producing plant and when the engine was built. **Not** all connecting rods are interchangeable. When replacing a connecting rod, use the following procedure for connecting rod identification and interchangeability. Refer to Procedure 001-999 in Section F.

1 Balance weight on the connecting rod cap

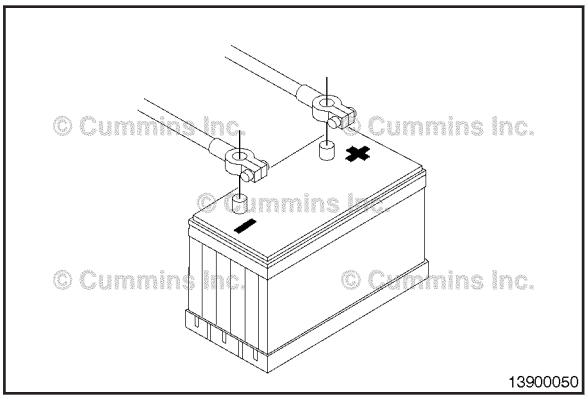
2 Protrusion on the short side of the connecting rod

3 Smooth edge on the short side of the connecting rod

4 I-beam design

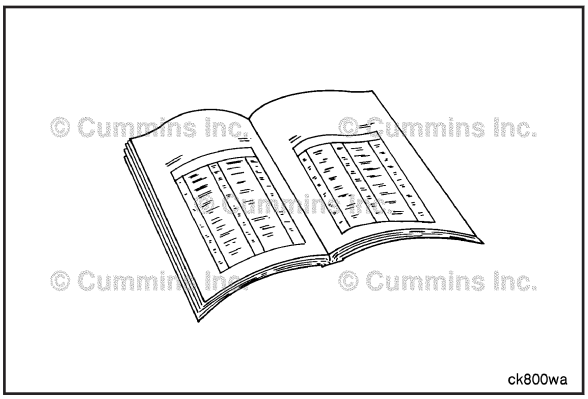
5 Oil grooves and thickness of connecting rod bushing.

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.

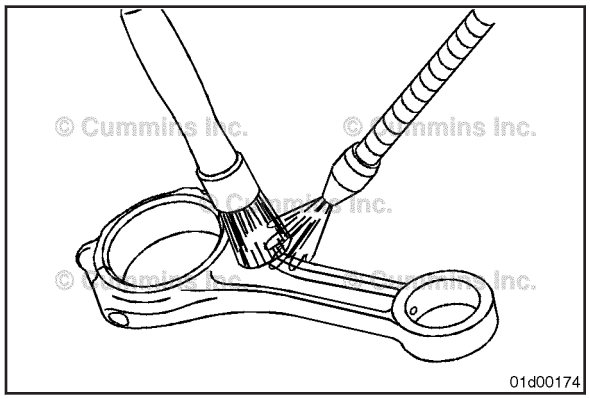
⚠WARNING⚠
Wait until the temperature is below 50°C [120°F] to reduce the possibility of personal injury from hot coolant.

- Drain the coolant. Refer to Refer to Procedure Procedure 008-018
- Remove the cylinder head. Refer to Refer to Procedure Procedure 002-004.

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

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

- Drain the lubricating oil. Refer to Refer to Procedure Procedure 007-037
- Remove the lubricating oil pan and gasket. Refer to Refer to Procedure Procedure 007-025
- Remove the lubricating oil suction tube. Refer to Refer to Procedure Procedure 007-035
- If equipped, remove the block stiffener plate. Refer to Refer to Procedure Procedure 001-089
- Remove the J-jet piston cooling nozzles (if equipped) to prevent damage during connecting rod removal. Refer to Refer to Procedure Procedure 001-046
- Remove the piston and connecting rod assemblies from the engine. Refer to Refer to Procedure Procedure 001-054
- Disassemble the pistons from the connecting rods. Refer to Refer to Procedure Procedure 001-054.



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⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Use only with protective clothing, goggles/shield, and gloves.

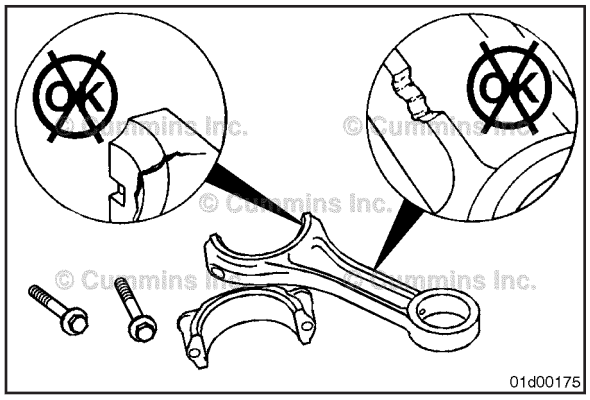
△CAUTION△
The contact surface between the connecting rod and connecting rod cap is not a machined surface. Care should be exercised so these parts are not damaged during handling.

Use solvent to clean the connecting rods.

NOTE: Unless cleaning the contact surface between the connecting rod and connecting rod cap, the rod and cap should be assembled together with the bolts tightened finger tight to prevent damage to the mating surfaces.

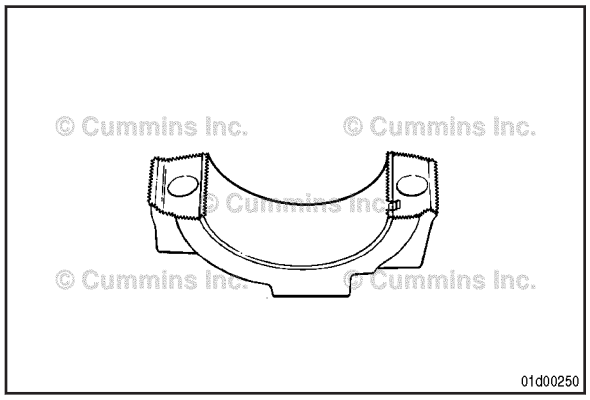
Use solvent and a nylon bristle brush to clean the contact surface between the connecting rod and connecting rod cap. Dry the contact surface with compressed air.

Dry the connecting rods with compressed air.



△CAUTION△
The connecting rod and rod cap must be replaced as an assembly if any fretting damage is visible on either piece.

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

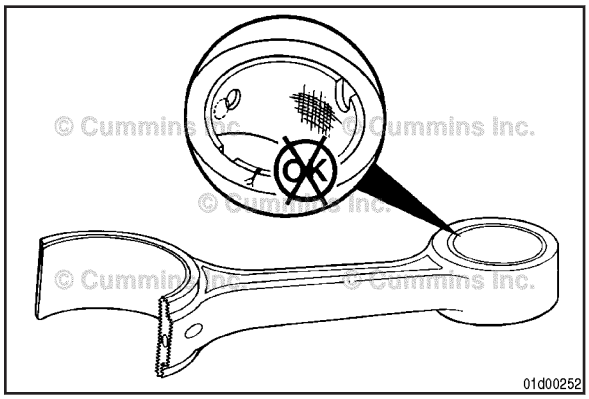


NOTE: On engines equipped with fracture split connecting rods, the contact surface between the connecting rod and the connecting rod cap is **not** a machined surface. This surface should **not** be considered damaged unless there are deep nicks or cracks across the surface.

Inspect the contact surface between the connecting rod and the connecting rod cap.

Inspect the connecting rod piston pin bore for damage.

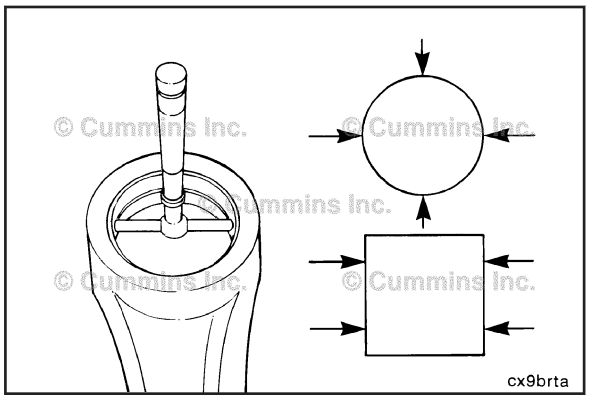
NOTE: Depending on when the engine was built, the connecting rod may or may **not** have an oil drilling in the top of the connecting rod small end. If replacing the bushing, the hole in the new bushing will **not** line up with the hole in the connecting rod. The hole in the bushing is for manufacturing purposes only and is no longer required to line up with the oil drilling in the connecting rod.



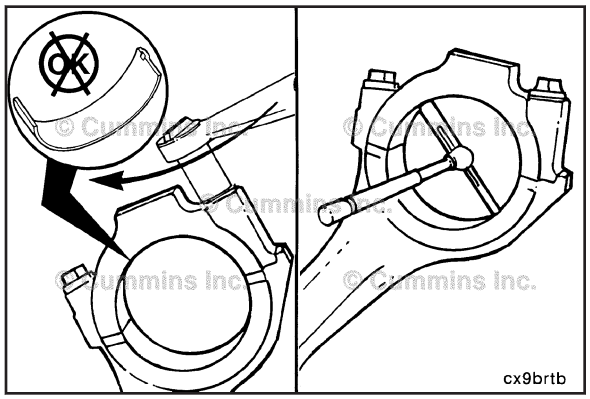
Measure the connecting rod piston pin bushing inside diameter.

B3.9, B4.5 RGT, and B5.9 Engines Connecting Rod Piston Pin Bushing Diameter		
mm		**in**
40.019	MIN	1.5756
40.042	MAX	1.5765

B4.5 Engines Connecting Rod Piston Pin Bushing Diameter		
mm		**in**
34.51	MIN	1.3586
34.54	MAX	1.3596



If the bushing is found to be damaged or out of specification, the bushing can be replaced. Use service tool Part Number 3823902 to remove and install the bushing.



⚠CAUTION⚠
Use a vise with brass jaws to hold the connecting rod. Notches, scratches, or dents in the I-beam area can cause engine damage.

⚠CAUTION⚠
The number on the connecting rod must be the same as the number on the rod cap. Connecting rods and caps are manufactured as an assembly and cannot be interchanged. Engine damage can result.

Use clean 15W-40 engine oil to lubricate the connecting rod capscrews.

Assemble the connecting rod, rod cap, and capscrews.

Tighten the capscrews.

B3.9, B4.5 RGT, and B5.9 Connecting Rod Capscrews

Torque Value: 100 N•m [74 ft-lb]

B4.5 Connecting Rod Capscrews

Torque Value: 70 N•m [52 ft-lb]

Use a dial bore indicator to measure the inside diameter within a 20-degree arc from each side of the parting line.

Measure the inside diameter at 90 degrees from the parting line.

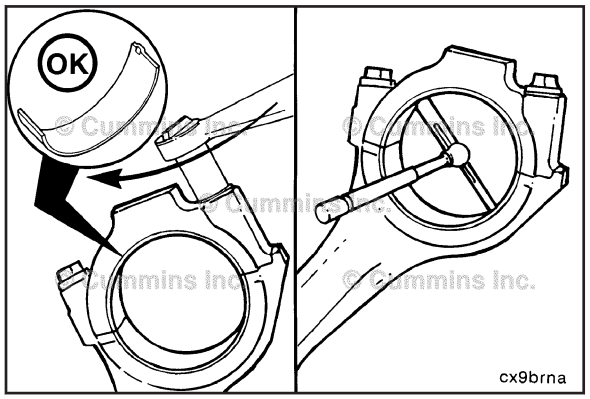
B3.9, B4.5 RGT, and B5.9 Connecting Rod Crankshaft Bore Diameter Bearings Removed

mm		in
72.99	MIN	2.873
73.01	MAX	2.875

B4.5 Connecting Rod Crankshaft Bore Diameter Bearings Removed

mm		in
69.675	MIN	2.7431
69.694	MAX	2.7439

NOTE: If the connecting rod crankshaft bore measurements are **not** within specifications, the connecting rod **must** be replaced.



Repeat the above inspection with the connecting rod bearings installed.

B3.9, B4.5 RGT, and B5.9 Standard Connecting Rod Crankshaft Bore Diameter with Bearings Installed

	mm		in
Standard	69.05	MIN	2.719
	69.10	MAX	2.720

B4.5 Standard Connecting Rod Crankshaft Bore Diameter with Bearings Installed

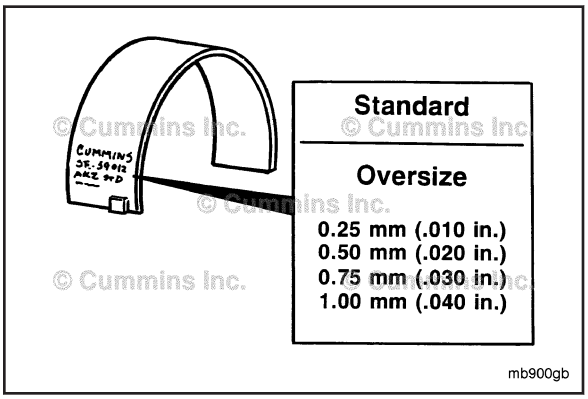
	mm		in
Standard	66.051	MIN	2.6004
	66.103	MAX	2.6025

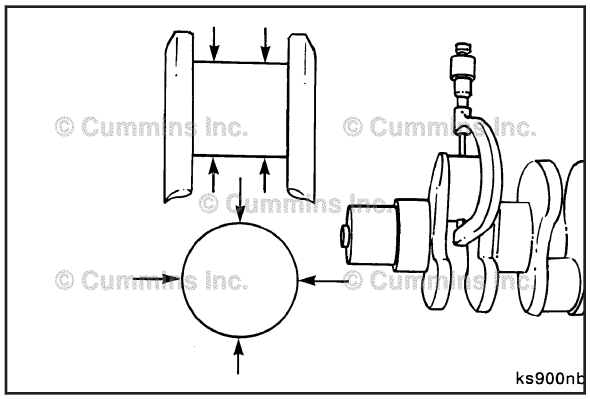
B3.9, B4.5 RGT, and B5.9 Oversize Connecting Rod Crankshaft Bore Diameter with Bearings Installed

	mm		in
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

B4.5 Oversize Connecting Rod Crankshaft Bore Diameter with Bearings Installed

	mm		in
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





Measure the diameter of the connecting rod journal on the crankshaft.

B3.9, B4.5 RGT, and B5.9 Standard Crankshaft Connecting Rod Journal Diameter

	mm		in
Standard	68.962	MIN	2.7150
	69.013	MAX	2.7170

B3.9, B4.5 RGT, and B5.9 Undersize Crankshaft Connecting Rod Journal Diameter

	mm		in
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

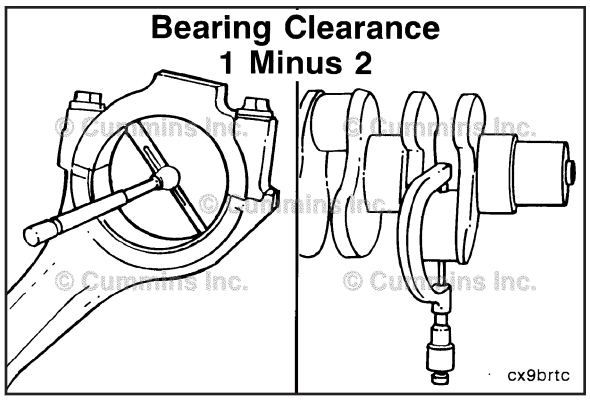
B4.5 Standard Crankshaft Connecting Rod Journal Diameter

	mm		in
Standard	65.987	MIN	2.5979
	66.103	MAX	2.5989

B4.5 Undersize Crankshaft Connecting Rod Journal Diameter

	mm		in
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

NOTE: If crankshaft connecting rod journals are **not** within the given specifications, the crankshaft **must** be reground.



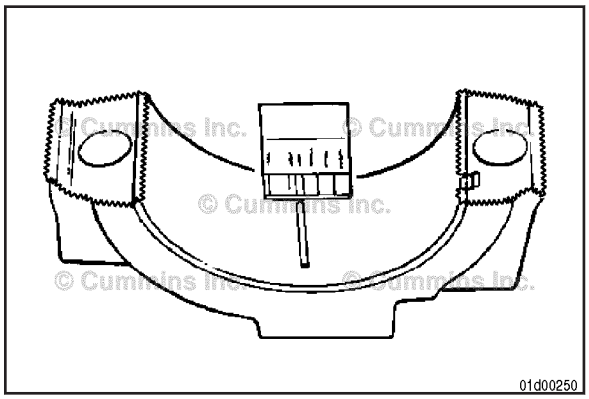
Bearing clearance equals the connecting rod crankshaft bore (with bearing) minus the crankshaft connecting rod journal diameter.

Connecting Rod to Crankshaft Bearing Clearance

mm		in
0.04	MIN	0.002
0.12	MAX	0.005

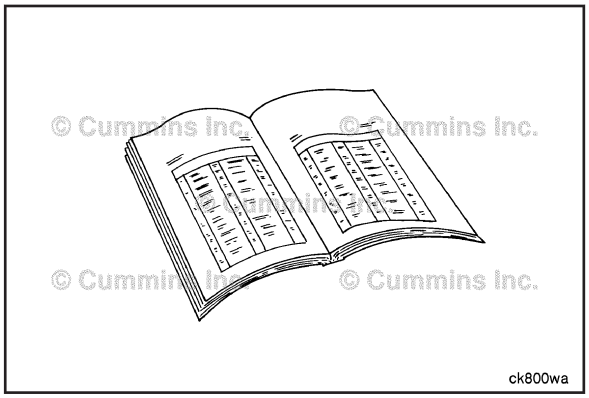
Bearing clearance can also be determined with a plastigauge during engine assembly.

NOTE: If the clearance is found to be out of specification, replace or try another set of connecting rod bearings.



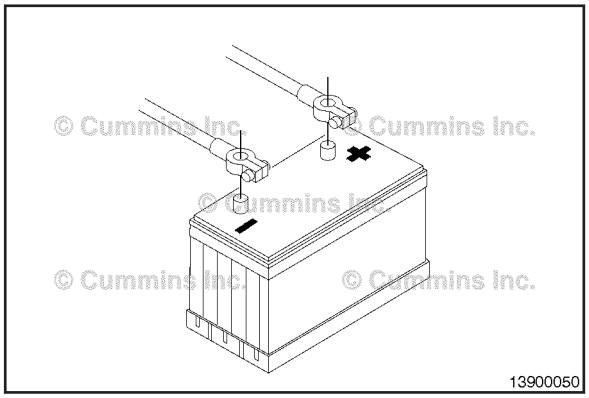
Finishing Steps

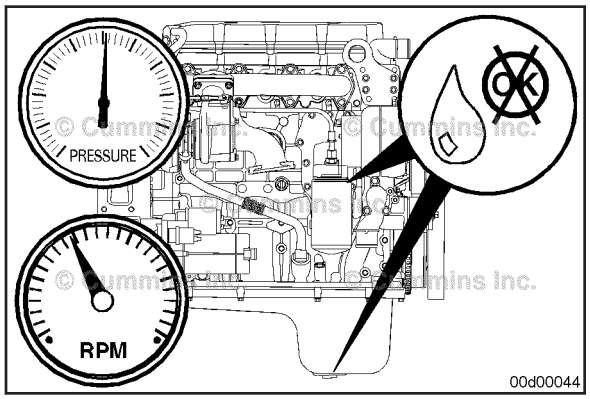
- Install the pistons on the connecting rods. Refer to Refer to Procedure Procedure 001-054
- Install the pistons and connecting rod assembly. Refer to Refer to Procedure Procedure 001-054
- Install the J-jet piston cooling nozzles (if equipped). Refer to Refer to Procedure Procedure 001-046
- If equipped, install the block stiffener plate. Refer to Refer to Procedure Procedure 001-089
- Install the lubricating oil suction tube. Refer to Refer to Procedure Procedure 007-035
- Install the lubricating oil pan and gasket. Refer to Refer to Procedure Procedure 007-025
- Install the cylinder head. Refer to Refer to Procedure Procedure 002-004
- Fill the lubricating oil pan. Refer to Refer to Procedure Procedure 007-037
- Fill the cooling 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.

Reconnect the batteries.

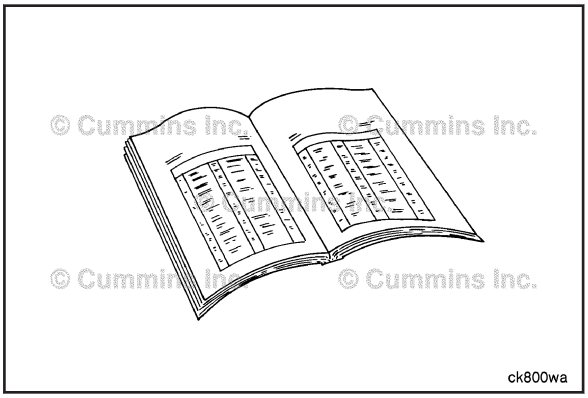




Operate the engine to normal operating temperature and check for leaks.

Crankshaft (001-016)

Preparatory Steps



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

WARNING
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

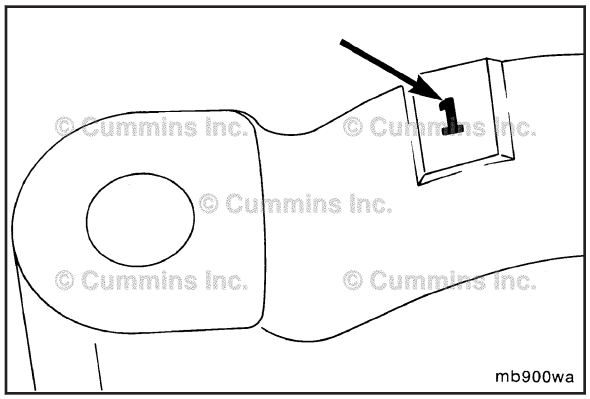
WARNING
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

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.

- Remove the engine and place on an engine stand. Refer to Procedure 000-001 in Section 00.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- If required, remove the fan hub pulley. Refer to Procedure 008-039 in Section 8.
- Remove the vibration damper/crankshaft pulley. If equipped with a viscous damper. Refer to Procedure 001-052 in Section 1. Use the following procedure if equipped with a rubber damper. Refer to Procedure 001-051 in Section 1. If equipped with a crankshaft pulley only. Refer to Procedure 001-022 in Section 1.
- Remove the front cover. Refer to Procedure 001-031 in Section 1.
- Remove the flywheel or flexplate. Refer to Procedure 016-005 or Refer to Procedure 016-004 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- For front gear train engines, remove the rear seal and rear seal carrier. Refer to Procedure 001-024 in Section 1. Refer to Procedure 001-104 in Section 1.
- For rear gear train engines, remove the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- If equipped, remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- If equipped, remove the balancer. Refer to Procedure 001-004 in Section 1.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Remove the fuel injection pump. Use the following procedure for rotary fuel injection pumps. Refer to Procedure 005-014 in Section 5. Use the following procedure for inline fuel injection pumps. Refer to Procedure 005-012 in Section 5.
- If equipped, remove or disconnect any driven accessories.
- If equipped, remove the air compressor. Refer to Procedure 012-014 in Section 12.
- Remove the fuel transfer pump. Refer to Procedure 005-045 in Section 5.

Service Tip: With the engine on the engine stand, rotate the engine so that it is upside down. This will allow the tappets to move off of the camshaft and eliminate the need to use tappet replacement kit, Part Number 3822513, to raise the tappets.

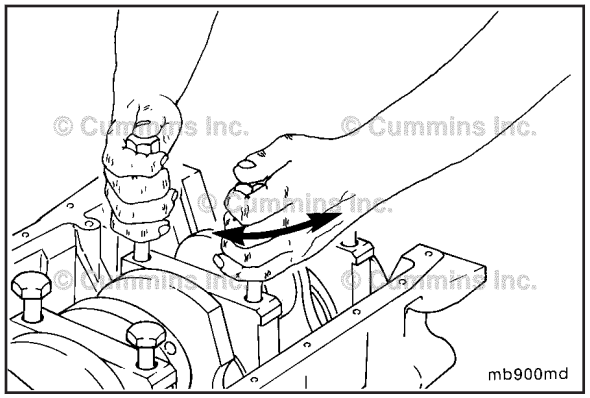
- Remove the camshaft. Refer to Procedure 001-008 in Section 1.
- For rear gear train engines, remove the rear gear housing. Refer to Procedure 001-034 in Section 1.
- For front gear train engines, remove the front gear housing. Refer to Procedure 001-033 in Section 1.
- For front gear train engines, remove the rear seal and rear seal carrier. Refer to Procedure 001-067 in Section 1.
- If equipped, remove the J-jet piston cooling nozzles. Refer to Procedure 001-046 in Section 1.
- Remove the connecting rod caps. Refer to Procedure 001-005 in Section 1.



Remove

Before removing the main bearing caps, make certain that the caps are clearly marked for their location on the lubricating oil cooler side of the main bearing cap and cylinder block.

The number one cap is at the front of the engine.

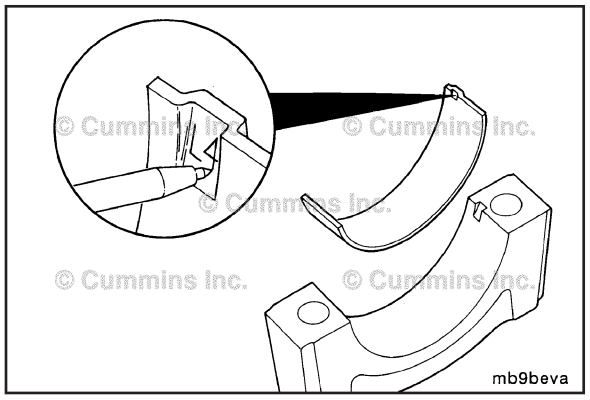


Loosen the main bearing capscrews completely, but do **not** remove.

CAUTION
Do not pry on the main bearing caps to free them from the cylinder block. Damage to the main bearing caps and cylinder block can result.

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

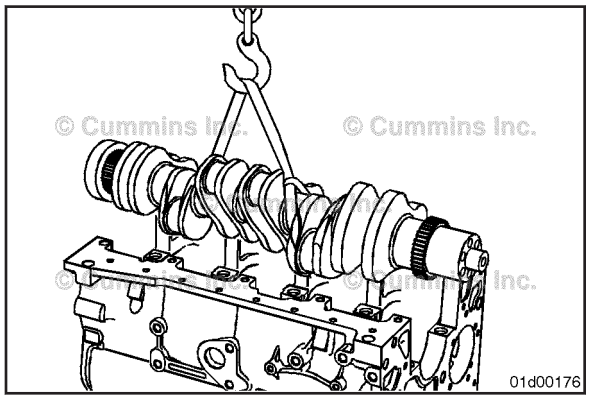
Remove the main bearing cap.



Mark the lower main bearings for position and number as they are removed.

Use an awl to mark the bearing position in the tang area.

NOTE: Mark the bearing's position for future identification or possible failure analysis.



WARNING
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

NOTE: Lift the crankshaft straight up to reduce the possibility of damage to the crankshaft and cylinder block.

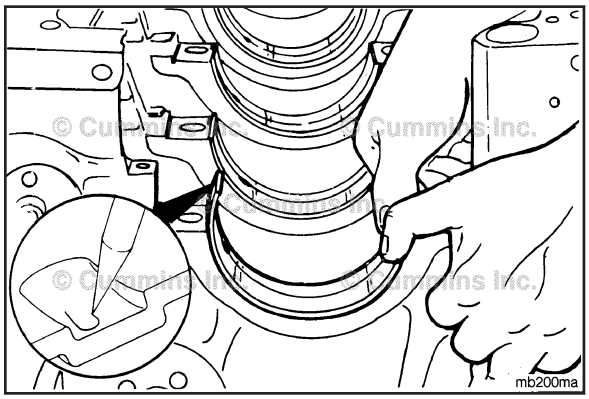
Install nylon lift sling, Part Number 3375957, around Number 3 and Number 4 rod bearing journals.

Attach the sling to a hoist and remove the crankshaft.

Remove the upper main bearings.

Use an awl to mark the bearing's position in the tang area.

NOTE: Mark the bearing's position for future identification or possible failure analysis.



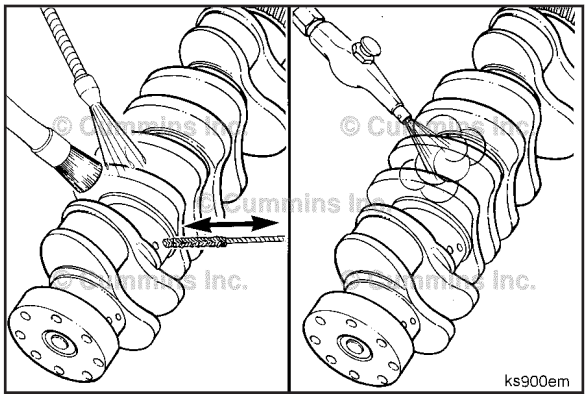
Clean

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

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

Steam clean or use hot, soapy water to clean the crankshaft and gear(s).

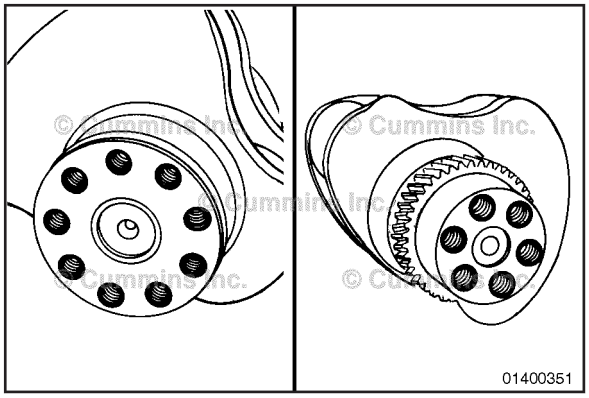
Use a non-metallic bristle brush to clean the oil drillings. Dry with compressed air. Make sure to blow out the threaded holes on each end of the crankshaft and the oil drillings.

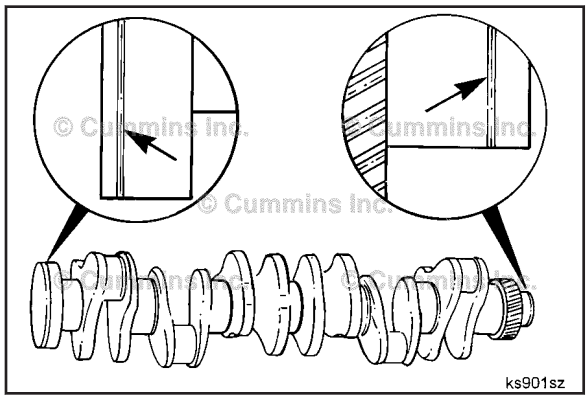


⚠CAUTION⚠
Do not chase threads on the crankshaft. Severe engine damage can occur.

Check the threads for damage at both ends of the crankshaft.

If damage is found, replace the crankshaft.





Use a fine crocus cloth to polish the machined surfaces.

Inspect the front crankshaft gear. Refer to Procedure 001-019 in Section 1.

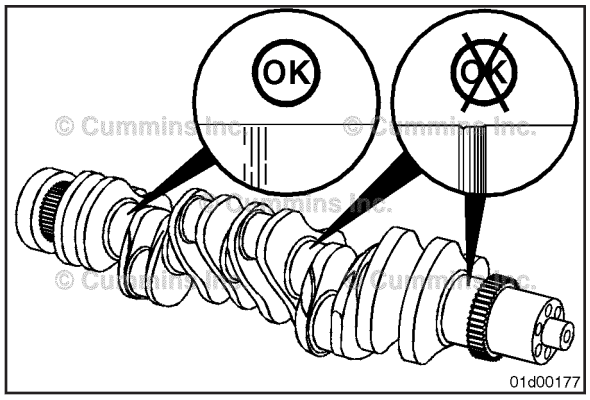
Inspect the front crankshaft seal contact area. Refer to Procedure 001-023 in Section 1.

Inspect the rear crankshaft seal contact area. Refer to Procedure 001-024 in Section 1.

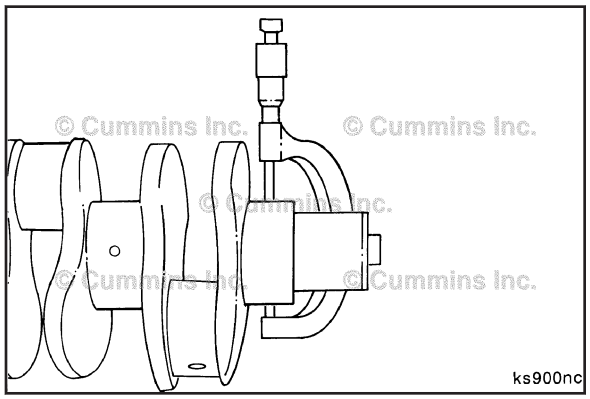
Inspect the connecting rod bearings. Refer to Procedure 001-005 in Section 1.

Inspect the main bearings. Refer to Procedure 001-006 in Section 1.

NOTE: For rear gear train engines, inspect the rear crankshaft gear. Inspect the crankshaft gear for pitting, fretting, or missing teeth. The rear crankshaft gear is not replaceable. If fretting can **not** be removed using abrasive pad, Part Number 3823258 or equivalent, the crankshaft **must** be replaced.



Check the main bearing journals and the rod bearing journals for damage or excessive wear. Minor scratches are acceptable.



Measure

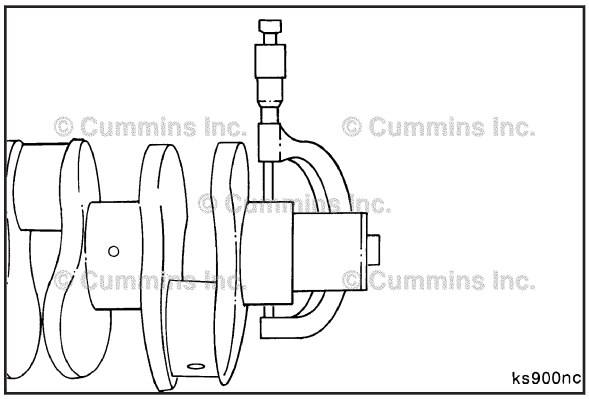
Measure the crankshaft main and connecting rod journals.

Out-of-Round: 0.050 mm [0.002 in].

Taper: 0.013 mm [0.0005 in].

NOTE: If crankshaft journals are **not** within the given specification, the crankshaft **must** be reground. **Always** grind **all** of the journals when one is **not** within specifications.

Measure and record the diameter of the connecting rod journal on the crankshaft.



B3.9, B4.5 RGT, and B5.9 Standard Crankshaft Connecting Rod Journal Diameter

	mm		in
Standard	68.962	MIN	2.7150
	69.013	MAX	2.7170

B3.9, B4.5 RGT, and B5.9 Undersize Crankshaft Connecting Rod Journal Diameter

	mm		in
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

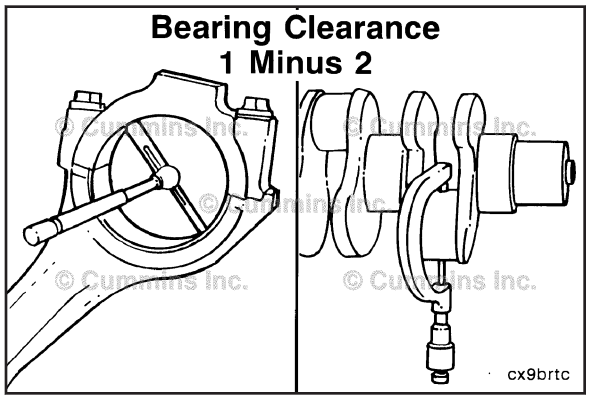
B4.5 Standard Crankshaft Connecting Rod Journal Diameter

	mm		in
Standard	65.987	MIN	2.5979
	66.013	MAX	2.5989

B4.5 Undersize Crankshaft Connecting Rod Journal Diameter

	mm		in
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

NOTE: If the crankshaft connecting rod journals are **not** within the given specification, the crankshaft **must** be reground. Select the target undersize journal diameter and its corresponding oversize bearing. Machine the crankshaft to the maximum journal diameter specified in the table above. Then finish the crankshaft to the target diameter. **Always** grind all of the journals when one is **not** within specifications.

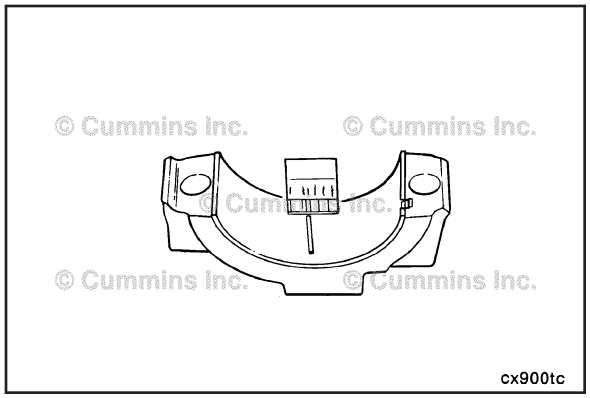


Measure and record the diameter of the connecting rod crankshaft bore with the bearings installed. Refer to Procedure 001-014 in Section 1 for measuring the connecting rod crankshaft bore (with bearing).

Calculate the connecting rod bearing to crankshaft journal clearance.

Bearing clearance equals the connecting rod crankshaft bore (with bearing) minus the crankshaft connecting rod journal diameter.

Connecting Rod to Crankshaft Bearing Clearance		
mm		in
0.04	MIN	0.002
0.12	MAX	0.005

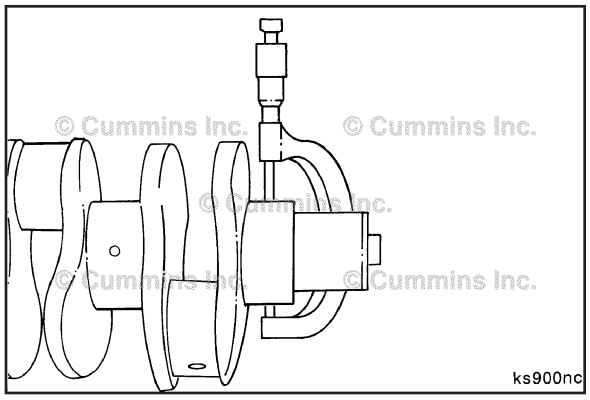


Bearing clearance can also be determined with a plastigauge during crankshaft installation.

NOTE: If the clearance is found to be out of specification:

1 Replace or try another set of connecting rod bearings

2 Measure and inspect the connecting rod crankshaft bore with the bearings removed. Refer to Procedure 001-014 in Section 1.



Measure and record the diameter of the main bearing journal on the crankshaft.

Standard Crankshaft Main Bearing Journal Diameter			
	mm		in
Standard	82.962	MIN	3.2662
	83.013	MAX	3.2682

Undersize Crankshaft Main Bearing Journal Diameter			
	mm		in
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

NOTE: If the crankshaft connecting rod journals are **not** within the given specification, the crankshaft **must** be reground. Select the target undersize journal diameter and its corresponding oversize bearing. Machine the crankshaft to the maximum journal diameter specified in the table above. Then finish the crankshaft to the target diameter. **Always** grind all of the journals when one is **not** within specifications.

Install the main bearing caps with the upper and lower main bearings. Refer to Procedure 001-006 (Bearings, Main) in Section 1 for main bearing cap installation.

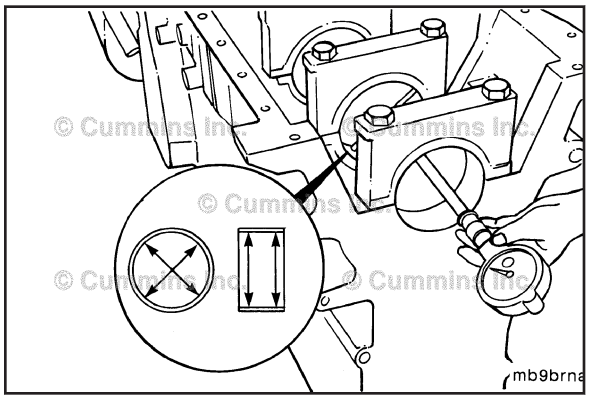
Tighten the main bearing cap capscrews.

Torque Value: 176 N•m [130 ft-lb]

Measure the main bearing bore with the bearings installed.

Calculate the main bearing to crankshaft journal clearance.

Bearing clearance equals the main bearing crankshaft bore (with bearing) minus the crankshaft main bearing journal diameter.



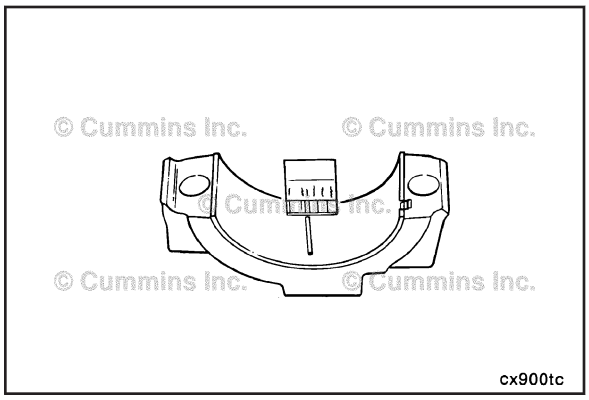
Main Bearing Bore to Crankshaft Bearing Clearance		
mm		**in**
0.04	MIN	0.002
0.12	MAX	0.005

Bearing clearance can also be determined with a plastigauge during engine assembly.

NOTE: If the clearance is found to be out of specification:

1 Replace or try another set of main bearings

2 Measure and inspect the main bearing bore with the bearings removed. Refer to Procedure 001-026 in Section 1.



Main Bearing Capscrew Reuse Measurement

⚠CAUTION⚠
This step must be completed on B4.5 RGT engines. Failure to check the main bearing capscrew against reuse guidelines can result in severe engine damage.

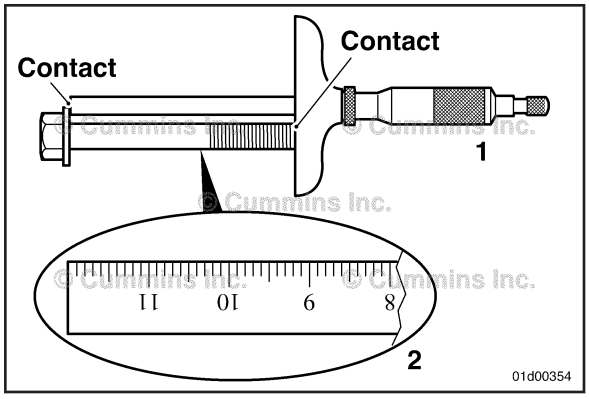
To check if a main bearing capscrew can be reused, the length **must** be measured by performing the following:

For each main bearing capscrew that has been removed, measure the length from underneath the head of the capscrew to the tip of the capscrew, as illustrated, using one of two methods.

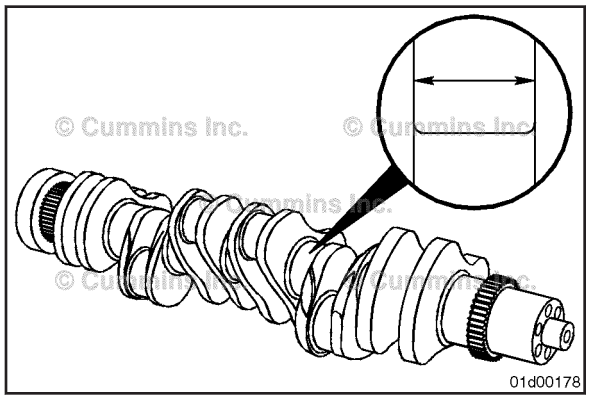
1 A depth micrometer (preferred method for accuracy)

2 A machinist's rule.

If the measurement is above the maximum specification, the main bearing capscrew **must** be replaced.



Main Bearing Underhead Capscrew Length		
mm		**in**
120.00	MAX	4.724



Check the thrust bearing surfaces for damage or excessive wear. Minor scratches are acceptable. Use a fine crocus cloth to polish the machined surfaces.

The thrust bearing surfaces are located at:

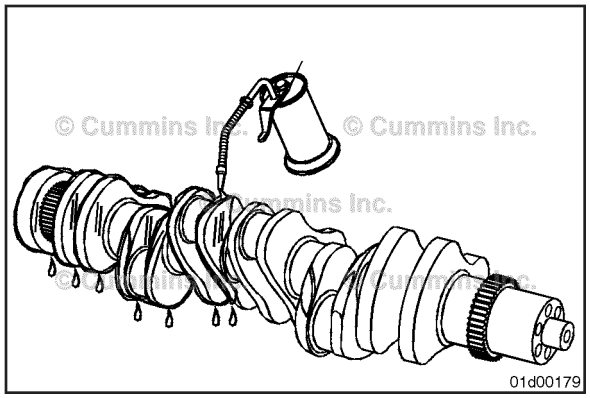
For 4 cylinder engines - The number 4 crankshaft main bearing journal.

For 6 cylinder engines - The number 6 crankshaft main bearing journal.

Measure the thrust distance.

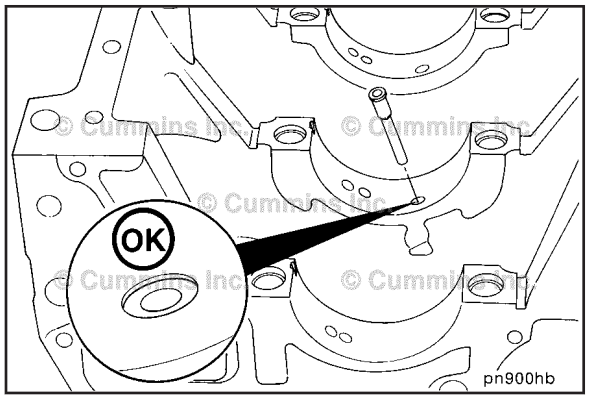
Thrust Distance		
mm		**in**
37.475	MIN	1.4754
37.576	MAX	1.4794

NOTE: Oversize thrust bearings are available if the thrust distance is **not** within specifications. Oversize thrust bearings of 0.25 and 0.50 mm [0.010 to 0.020 in] are available.



Use a light preservative oil to lubricate the crankshaft to prevent rust.

NOTE: If the crankshaft is **not** going to be used immediately, use a **heavy** preservative oil. Protect the crankshaft with a cover to prevent dirt from sticking to the oil.



Initial Check

For engines equipped with drillings for saddle jet piston cooling nozzles/plugs, verify that:

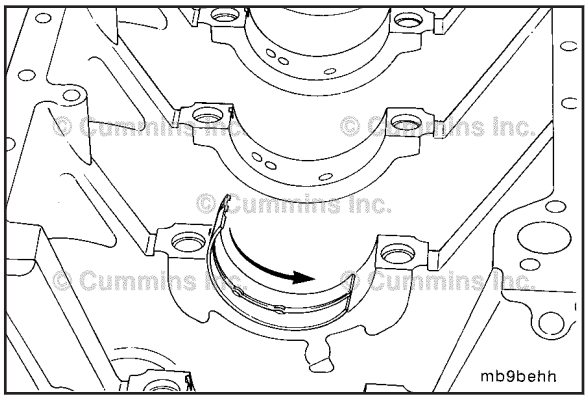
- engines originally equipped with saddle jet piston cooling nozzles, the piston cooling nozzles are installed and free from debris/damage
- engines equipped with J-jet piston cooling nozzles, the saddle jet piston cooling nozzle drillings are plugged.

NOTE: Some engine do are **not** contain drillings for saddle jet piston cooling nozzles/plugs.

Install

Make sure the backsides of the bearings are clean and free of debris before installing the upper main bearings into the block.

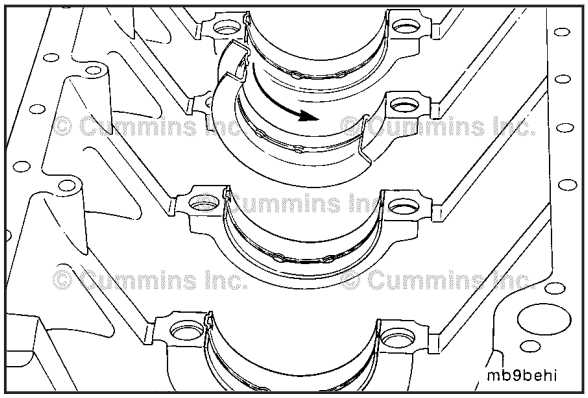
Make sure to align the tangs of the bearings with tangs on the main bearing block saddles.



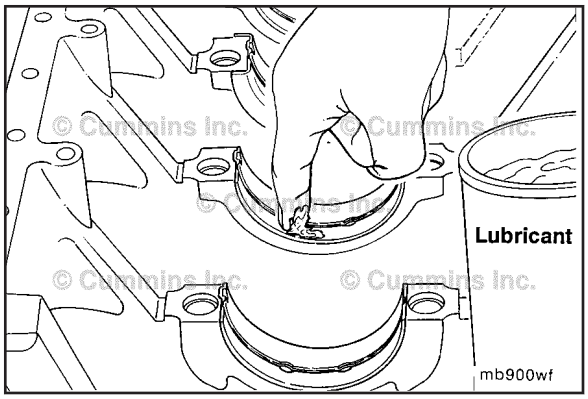
Install the upper crankshaft thrust bearing.

4 cylinder engines - The number 4 main bearing position.

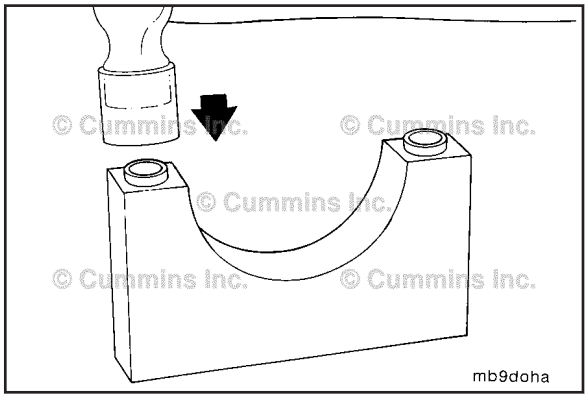
6 cylinder engines - The number 6 main bearing position.

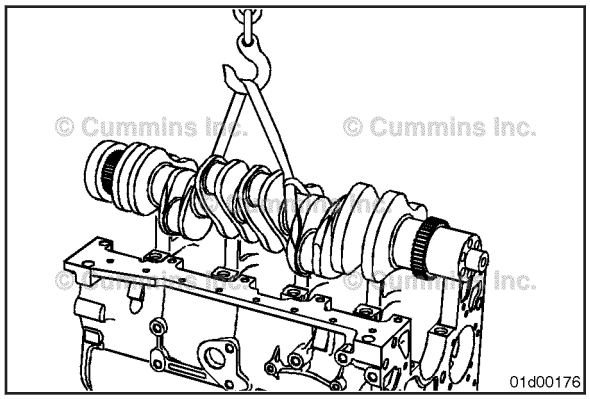


Apply a coat of assembly lube, Part Number 3163087, to the crankshaft side of the main bearings and thrust bearing surfaces.



Check the main bearing caps to make sure the ring dowels are installed.



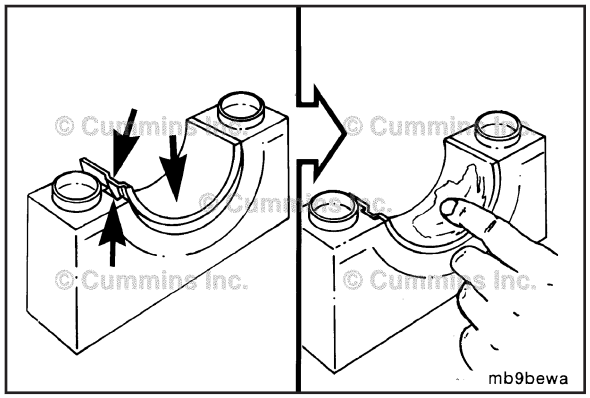


⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

△CAUTION△
Carefully install the crankshaft to avoid damage to the crankshaft main bearings, especially the thrust/main bearing journals. Engine life will be shortened if damage to the crankshaft occurs.

Install the crankshaft.

NOTE: When setting the crankshaft into the block, make sure the front crankshaft gear meshes with the lubricating oil pump gear (if not previously removed).



△CAUTION△
Do not lubricate the back side of the bearing that contacts the main bearing cap.

Make sure the backsides of the bearings are clean and free of debris before installing the lower main bearings into the main bearing caps.

Make sure to align the tangs of the bearings with tangs on the main bearing caps.

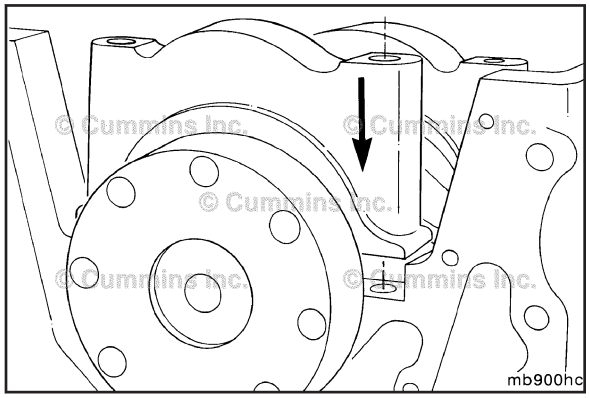
NOTE: Some engines use a thrust bearing for the upper and lower main bearing (360 degree), while other engines only have a thrust bearing for the upper main bearing (180 degree). **Always** replace like for like.

If equipped, install the lower crankshaft thrust bearing.

4 cylinder engines - The number 4 main bearing position.

6 cylinder engines - The number 6 main bearing position.

Apply a coat of assembly lube, Part Number 3163087, to the crankshaft side of the main bearings and thrust bearing surfaces.

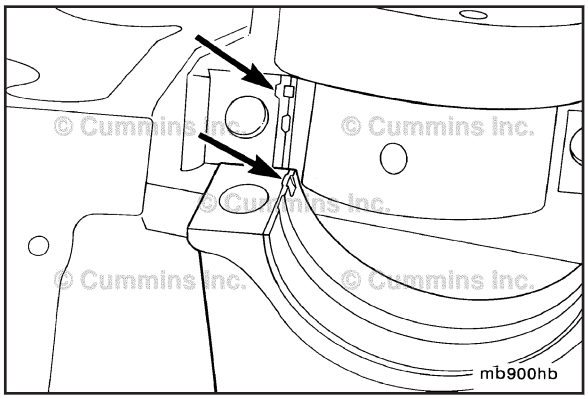


Make sure the main bear cap surfaces between the main bearing cap and block are clean and free of debris.

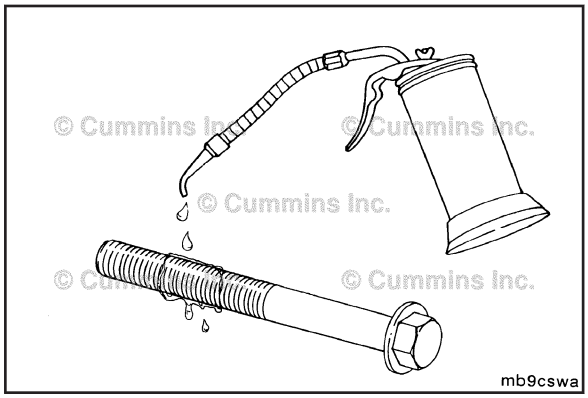
The main bearing caps are/were numbered during the removal process for their location. Number 1 starts with the front of the block.

NOTE: The caps **must** be installed so the numbers on the caps match the bearing saddle in the block. The lock tangs in the main bearing saddle and bearing cap **must** be on the same side.

Install the main bearing caps. Make sure to align the ring dowels on the main bearing cap with the corresponding drillings in the cylinder block.



Lubricate the main bearing capscrew threads and underside of the head with clean engine oil.

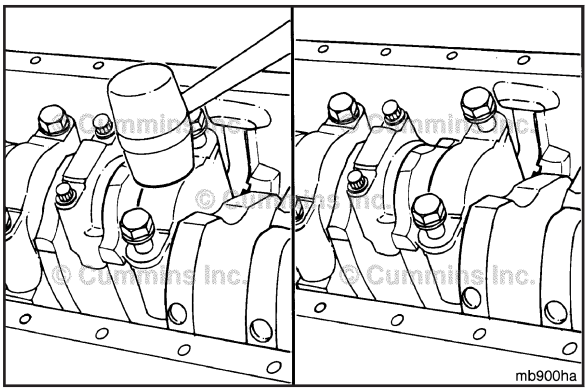


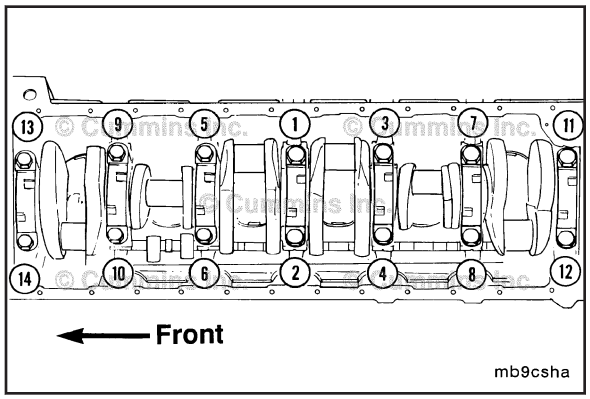
Gently tap the main bearing cap into position with a plastic or rubber mallet.

When seated, install the main bearing capscrews and tighten.

Torque Value: 50 N•m [37 ft-lb]

Do **not** tighten to the final torque value at this time. Final torque should be applied after all main bearing caps are installed.





NOTE: The sequence to the right is for a 6 cylinder engine. For a 4 cylinder engine, use the same sequence for the 5 main bearing caps.

Tighten the capscrews evenly and in sequence. Perform each step to all capscrews before performing the next step.

B3.9, B4.5, and B5.9 Engines:

Torque Value:

Step 1	60 N•m	[44 ft-lb]
Step 2	90 N•m	[66 ft-lb]
Step 3	Turn all capscrews through 90 degrees.	

CAUTION
For B4.5 RGT engines, there is a different torque procedure for new and previously installed main bearing capscrews. Failure to use the correct torque value can result in engine damage.

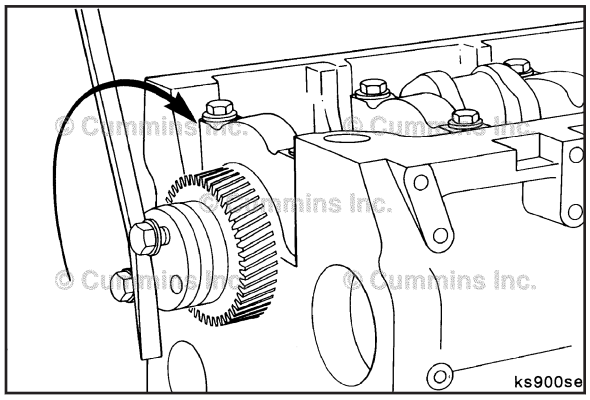
B4.5 RGT Engines:

Torque Value:
Previously Installed Main Bearing Capscrews

Step 1	60 N•m	[44 ft-lb]
Step 2	80 N•m	[59 ft-lb]
Step 3	Rotate 90 degrees.	

Torque Value:
New Main Bearing Capscrews

Step 1	120 N•m	[89 ft-lb]
Step 2	Loosen completely.	
Step 3	60 N•m	[44 ft-lb]
Step 4	85 N•m	[63 ft-lb]
Step 5	Rotate 120 degrees.	



The crankshaft **must** rotate freely after installing the main bearing caps.

If the crankshaft does **not** rotate freely:

1 Check if the crankshaft is contacting one of the connecting rods

2 Check if the correct main bearing caps were installed correctly

3 Check if the main bearing cap ring dowels or mounting surfaces were damaged during installation

4 Check if the correct main bearings were installed.

NOTE: The dimensions of the thrust bearing and crankshaft journal determine end play.

Measure the crankshaft end play with a dial indicator assembly, Part Number 3824564 and magnetic base, Part Number 3377399.

Crankshaft End Play

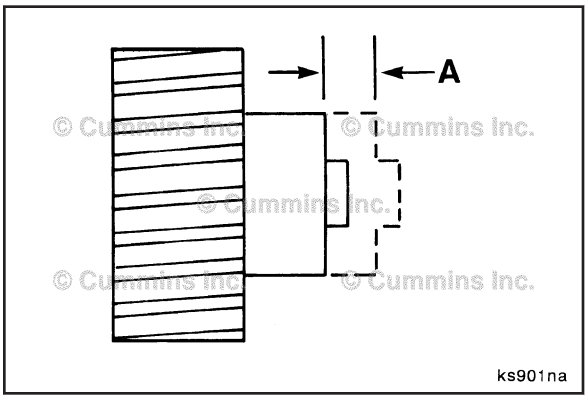
mm		in
0.102	MIN	0.004
0.432	MAX	0.017

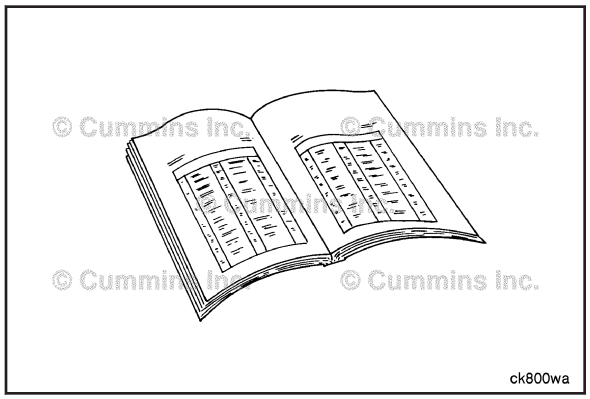
If the crankshaft end play is not within specification:

1 If the crankshaft end play is below specification, check if there are any obstructions limiting the crankshaft's travel (lubricating oil pump, connecting rod, etc.)

2 If the crankshaft end play is above specification, inspect the crankshaft thrust bearing surface. Also check if the correct thrust bearing(s) were installed.

NOTE: Oversize thrust bearings are available if the end play is **not** within specifications. Oversize thrust bearings of 0.25 to 0.51 mm [0.010 to 0.020 in] are available.





Finishing Steps

- Install the connecting rod caps. Refer to Procedure 001-005 in Section 1.
- If equipped, install the J-jet piston cooling nozzles. Refer to Procedure 001-046 in Section 1.
- For front gear train engines, install the front gear housing. Refer to Procedure 001-033 in Section 1.
- For rear gear train engines, install the rear gear housing. Refer to Procedure 001-034 in Section 1.

Service Tip: With the engine still on the engine stand and upside down, the camshaft should be installed. This will keep the tappets suspended so that the camshaft can be installed. This eliminates the need to use tappet replacement kit, Part Number 3822513, to raise the tappets. Once the camshaft is installed, rotate the engine upright so the tappets will contact the camshaft.

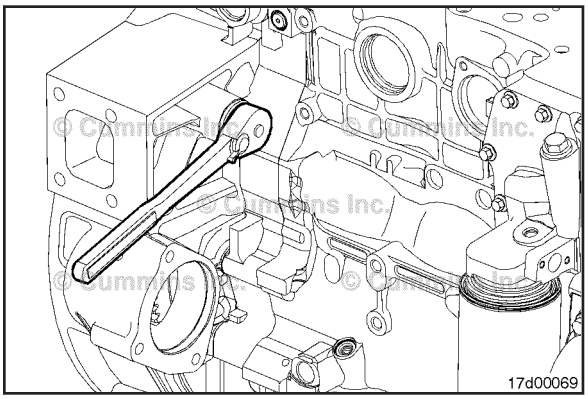
- Install the fuel transfer pump. Refer to Procedure 005-045 in Section 5.
- Install the camshaft. Refer to Procedure 001-008 in Section 1.
- For rear gear train engines, install the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Install the fuel injection pump. Use the following procedure for rotary fuel injection pumps. Refer to Procedure 005-014 in Section 5. For inline fuel injection pumps use the following procedure. Refer to Procedure 005-012 in Section 5.
- If equipped, install the air compressor. Refer to Procedure 012-014 in Section 12.
- If equipped, install or connect any driven accessories (i.e., hydraulic pump)
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- If equipped, install the balancer. Refer to Procedure 001-004 in Section 1.
- If equipped install the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- For front gear train engines, install the rear seal and rear seal carrier. Refer to Procedure 001-067 and Refer to Procedure 001-104 in Section 1.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- For rear gear train engines, install the rear seal. Refer to Procedure 001-024.
- Install the flywheel or flexplate. Refer to Procedure 016-005 or Refer to Procedure 016-004 in Section 16.
- Install the front cover. Refer to Procedure 001-031 in Section 1.
- Install the vibration damper/crankshaft pulley. Use the following procedure if equipped with a viscous damper. Refer to Procedure 001-052 in Section 1. If equipped with a rubber damper use the following procedure. Refer to Procedure 001-051 in Section 1. Use the following procedure if equipped with a crankshaft pulley **only.** Refer to Procedure 001-022 in Section 1.
- If required, install the fan hub pulley. Refer to Procedure 008-039 in Section 8.
- Install the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.

Rotation Check

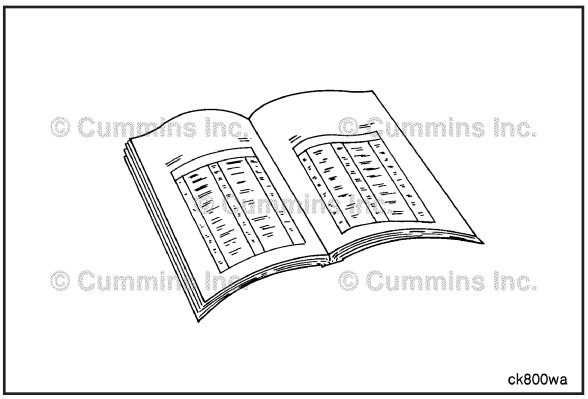
With the engine fully assembled, check that the engine rotates freely using barring tool, Part Number 3824591.

Insert the barring tool into the flywheel housing and engage the flywheel/flexplate ring gear. The crankshaft can then be rotated by hand, use a 1/2- inch drive ratchet or breaker bar.

If the engine does **not** rotate freely, check for any external obstructions. If no obstructions are found, remove the oil pan and look for internal damage.



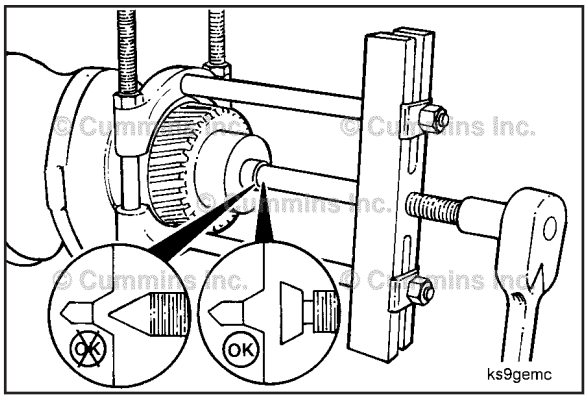
- Install the engine. Refer to Procedure 000-002 in Section 0.
- Fill the lubricating oil pan. Refer to Procedure 007-037 in Section 7.
- Operate the engine. Check for leaks and proper engine operation.

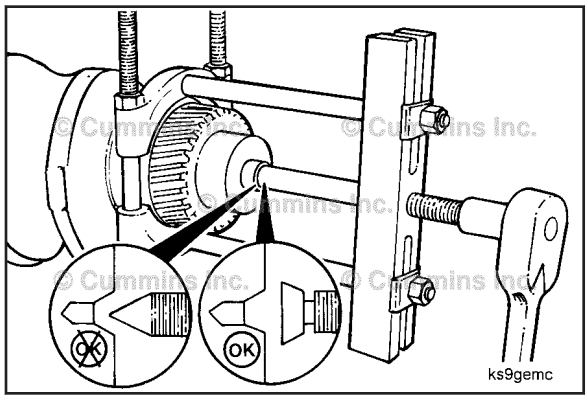


Crankshaft Gear, Front (Crankshaft Installed) (001-018)

General Information

The crankshaft gear can **not** be removed from the crankshaft with the crankshaft installed. Refer to Procedure 001-016 to remove the crankshaft and Procedure 001-019 to remove the crankshaft gear.





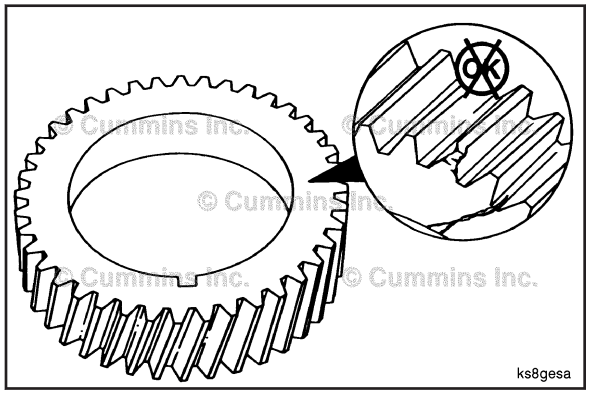
Crankshaft Gear, Front (Crankshaft Removed) (001-019)

Remove

⚠CAUTION⚠
Do not try to split the front crankshaft gear to remove. The gear is made out of steel and will not split. Damage to the to the tool and crankshaft can result.

NOTE: If a front crankshaft seal wear sleeve has been installed during a previous repair, it **must** be removed before removing the crankshaft gear. Refer to Procedure 001-025.

Use a heavy-duty bearing separator, Part Number 3162427, or a gear puller, as illustrated, to remove the crankshaft gear.

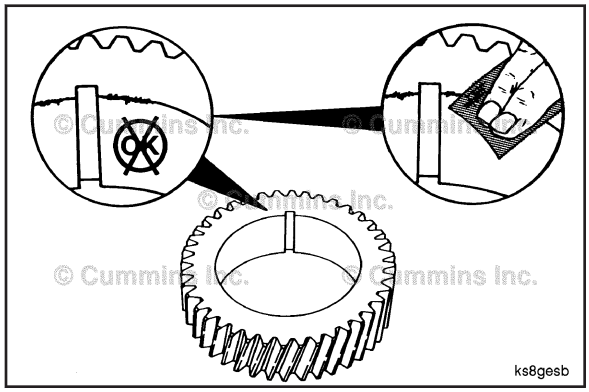


Clean and Inspect for Reuse

Visually inspect for cracks and broken or chipped teeth.

The gear **must** be replaced if it is damaged.

NOTE: If there is damage to the front crankshaft gear teeth or there are signs of excessive heat, make sure to inspect the associated lubricating oil pump and, for front gear train engines, the fuel pump and camshaft gears for damage.



Visually inspect the gear and, for front gear train engines only, the keyway for nicks or burrs.

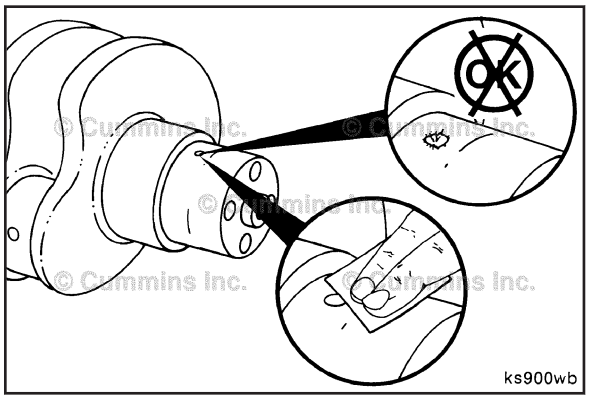
Use fine crocus cloth to remove nicks and burrs.

Visually inspect the crankshaft gear journal, gear alignment dowel pin and dowel pin hole for burrs or damage.

Use fine crocus cloth to remove burrs.

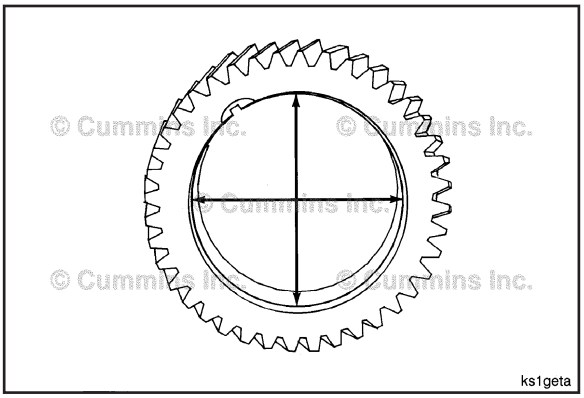
Replace the gear alignment dowel pin if damage is found.

NOTE: Rear gear train engines do **not** have any type of alignment pin for the front crankshaft gear.



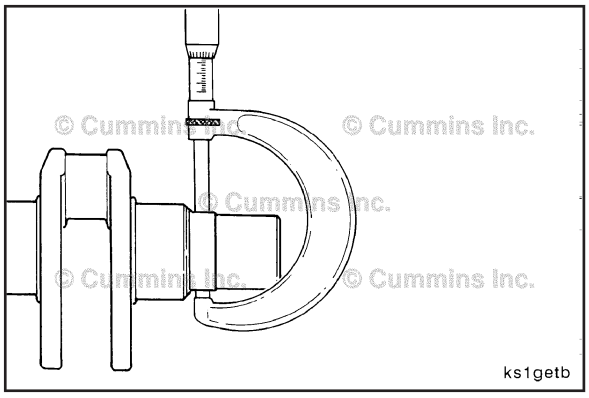
Measure the crankshaft gear bore inside diameter.

Crankshaft Gear Bore Inside Diameter		
mm		**in**
70.51	MIN	2.776
70.55	MAX	2.779



Measure the crankshaft gear journal outside diameter.

Crankshaft Gear Journal Outside Diameter		
mm		**in**
70.59	MIN	2.779
70.61	MAX	2.780

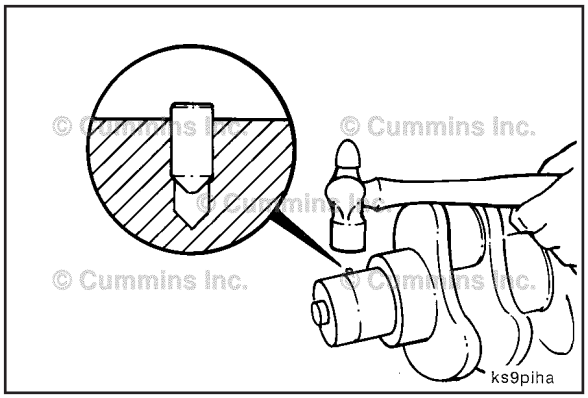


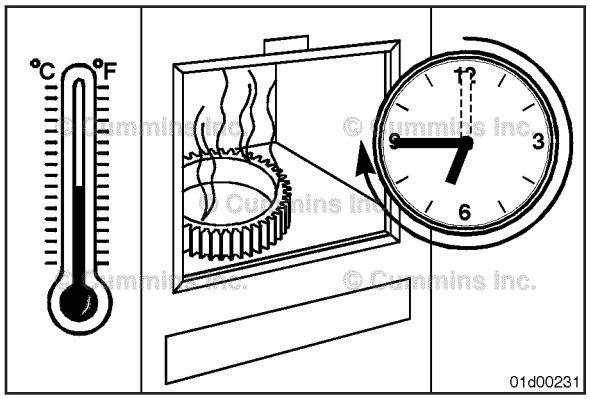
Install

Use a soft hammer to install the gear alignment dowel into the crankshaft.

The pin **must** be 1.02 mm [0.040 in] above the crankshaft surface.

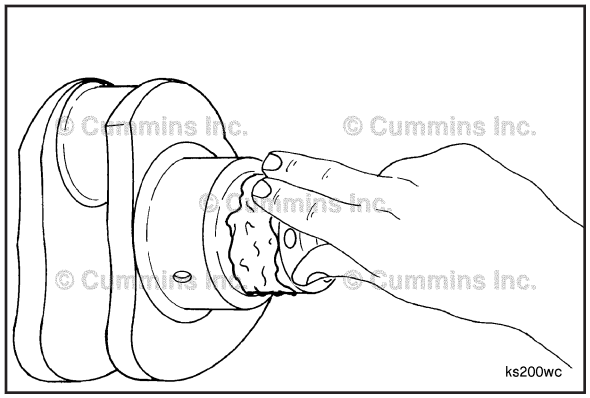
NOTE: Rear gear train engines do **not** have any type of alignment pin for the front crankshaft gear.



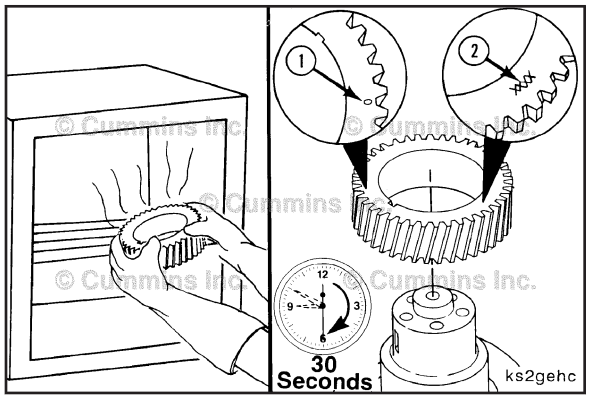


⚠CAUTION⚠
Do not exceed the specified heating time or temperature. The crankshaft teeth can be damaged.

Heat the gear in an oven for a minimum of 45 minutes, but **not** more than 2 hours at 177°C [350°F].



Use assembly lube, Part Number 3163087 or equivalent, to lubricate the outside diameter of the crankshaft gear journal.



⚠WARNING⚠
Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.

⚠CAUTION⚠
For front gear train engines the timing mark (1) and part number (2) on the gear must be facing away from the crankshaft after the gear is installed. Engine damage can result if the gear is installed backwards.

⚠CAUTION⚠
Do not use water or oil to reduce the cooling time. The gear can crack. Allow the gear to air cool.

NOTE: Rear gear train engines do not have any type of keyway or timing mark on the front crankshaft gear. The gear can be installed in any orientation.

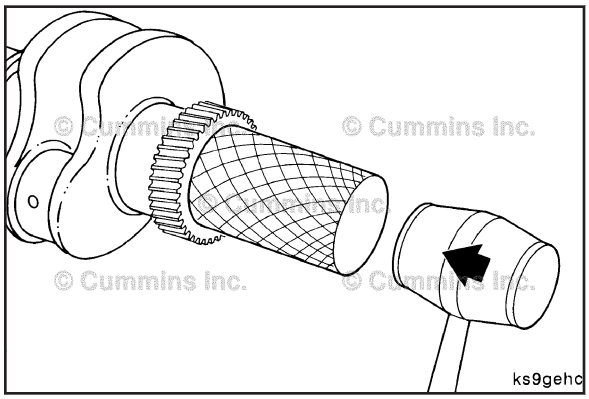
Remove the gear from the oven.

Align the keyway of the gear with the alignment dowel pin in the crankshaft and install the gear within 30 seconds.

For front gear train engines, align the keyway of the gear with the alignment dowel pin in the crankshaft. Install the crankshaft gear within 30 seconds of removing it from the oven.

If the gear cools and stops on the crankshaft before it is fully installed, use a driver to complete the installation.

Make sure the gear is seated against the crankshaft shoulder. Use a 0.02 mm [0.001 in] feeler gauge to check to see if the feeler gauge can be inserted between the crankshaft gear and the shoulder on the crankshaft. If the feeler gauge can be inserted, the crankshaft gear is **not** properly seated and **must** be removed and installed again.

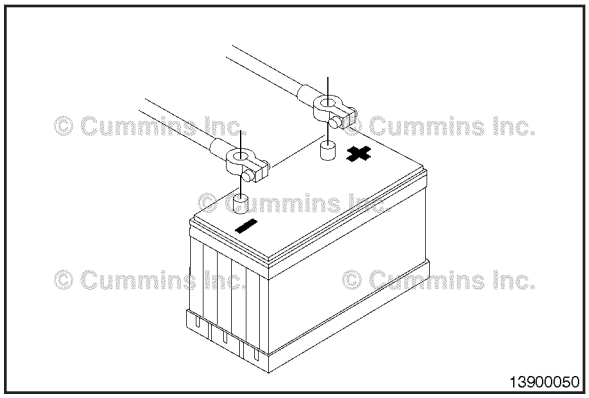


Crankshaft Pulley (001-022)

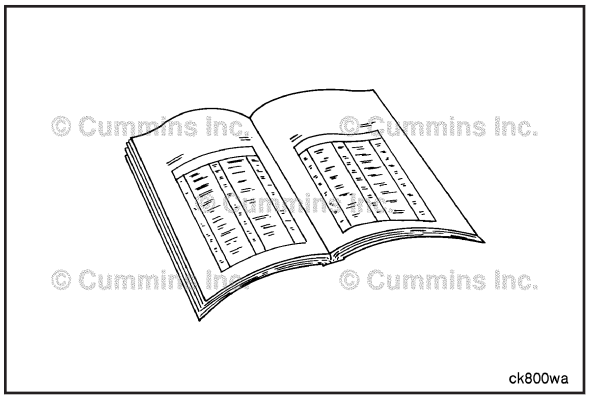
Preparatory Steps

⚠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.

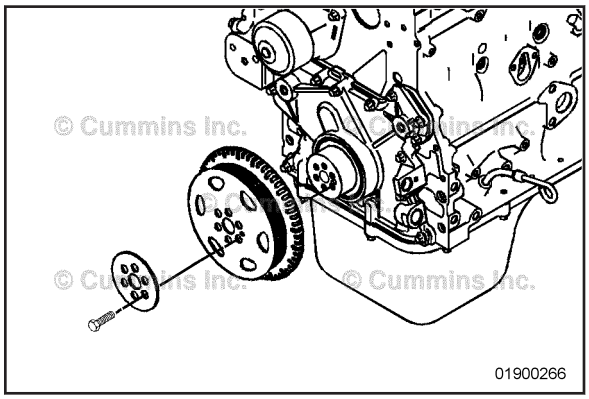


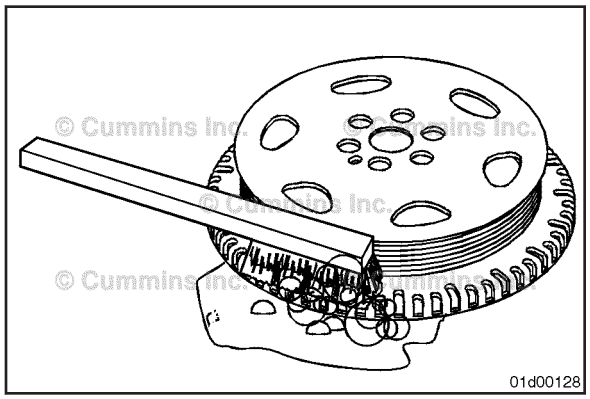
Remove the drive belt. Refer to Procedure 008-002.



Remove

Remove the six capscrews that hold the crankshaft pulley to the nose of the crankshaft.



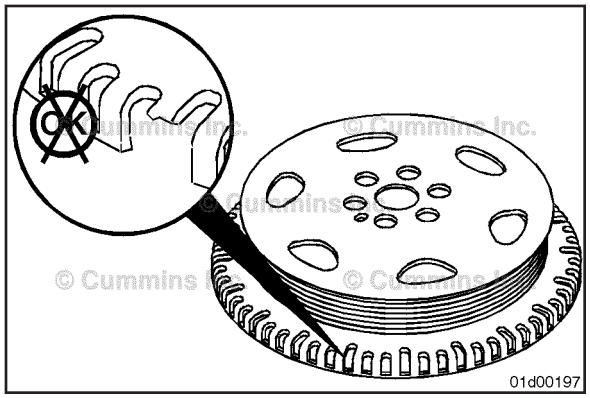


Clean and Inspect for Reuse

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear protective clothing, goggles/ shield, and gloves to reduce the possibility of personal injury.

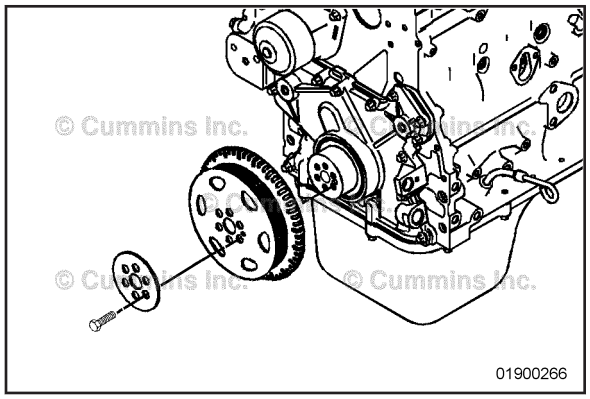
Using soapy water, clean any oil from the crankshaft pulley.

Dry the crankshaft pulley with compressed air.



Inspect the crankshaft pulley for cracks, or damaged surfaces.

If any damage is found, the crankshaft pulley **must** be replaced.

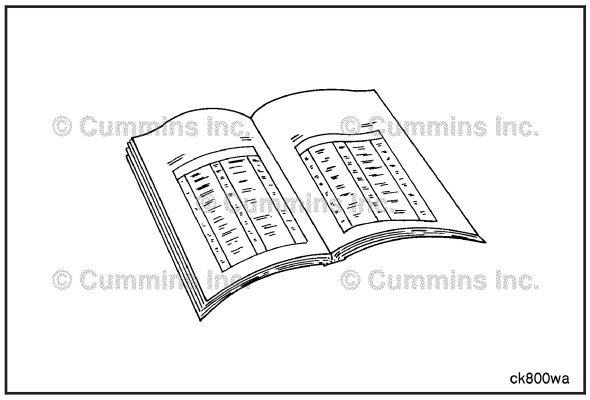


Install

Install the six capscrews that hold the crankshaft pulley to the nose of the crankshaft.

Tighten crankshaft pulley capscrews.

Torque Value: Step1 50 N•m [37 ft-lb]
Step2 Rotate 90 degrees

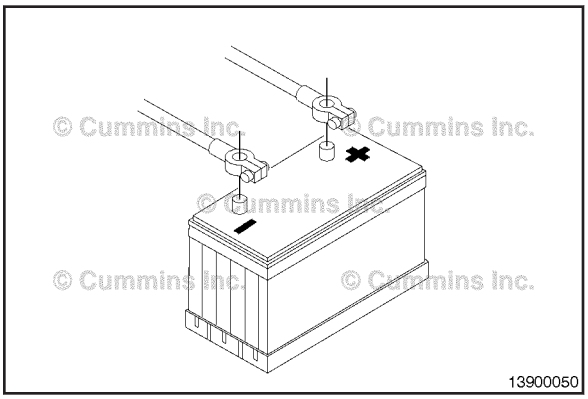


Finishing Steps

- 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.



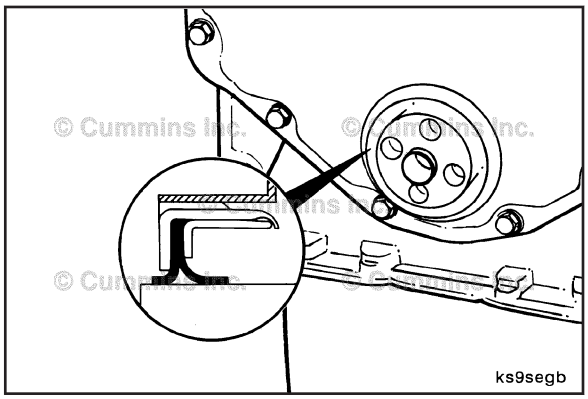
Crankshaft Seal, Front (001-023)

General Information

Lip Seal

Front gear train engines use a lip style front crankshaft Seal (shown) in which the rotating portion of the sealing occurs at the contact surface between the lip of the seal and the crankshaft.

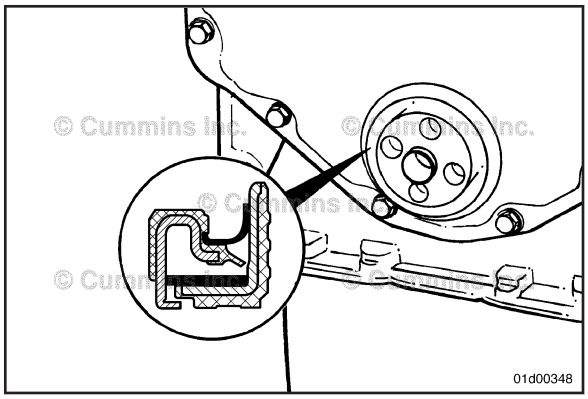
Always replace the front crankshaft seal with the same style seal as was previously installed.



Unitized Seal

Rear gear train engines use a dual or non-lip style seal which utilize a built in wear sleeve and a concealed sealing lip. The inner and out diameter are press-fit onto the crankshaft and the front gear cover respectively, requiring service tool, Part Number 3164659, to remove and install. The sealing point is internal to the seal.

Always replace the front crankshaft seal with the same style seal as was previously installed.

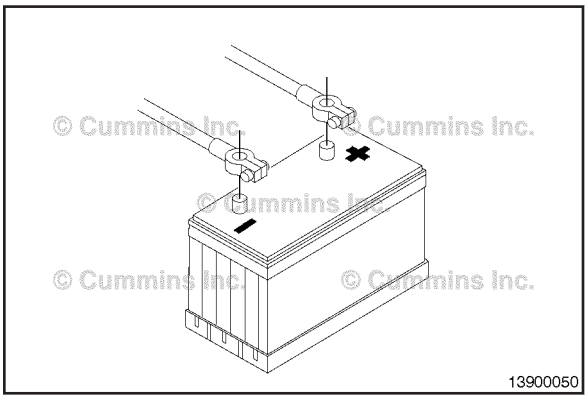


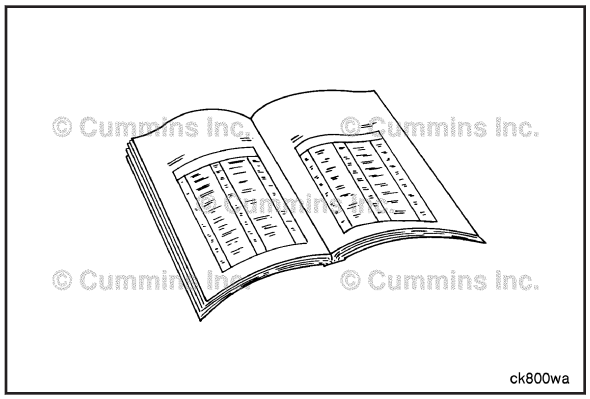
Preparatory Steps

Front Gear Train

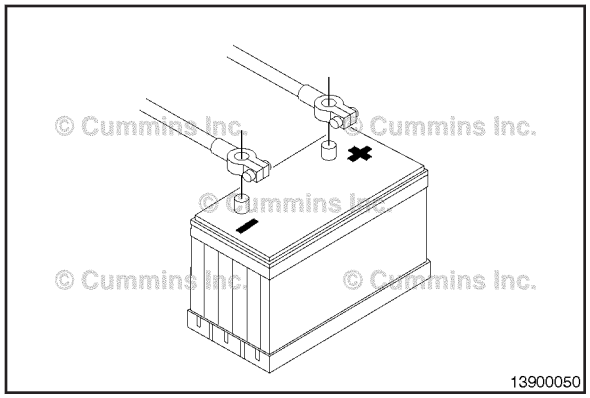
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the batteries.





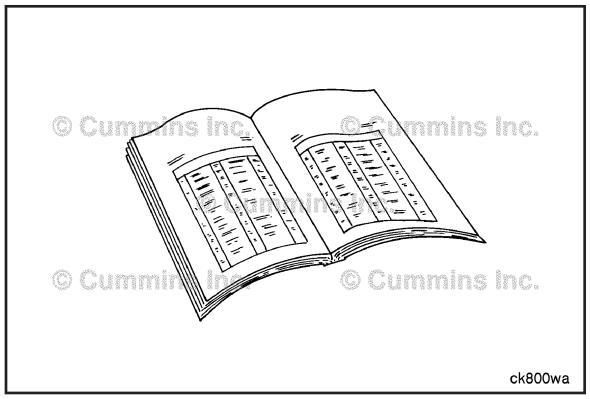
- Remove the engine water pump (cooling fan) drive belt. Refer to Procedure 008-002
- Remove the fan hub. Refer to Procedure 008-039
- Remove the vibration damper/crankshaft pulley. If equipped with a viscous damper, refer to Procedure 001-052, If equipped with a rubber damper, refer to Procedure 001-051. If equipped with a crankshaft pulley only, refer to Procedure 001-022
- Remove the front gear cover. Refer to Procedure 001-031.



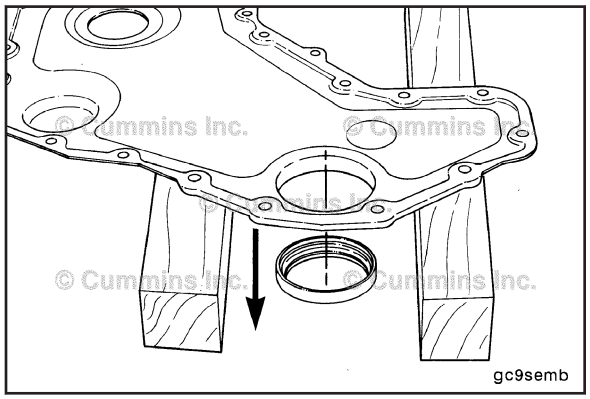
Rear Gear Train

⚠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 cooling fan 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 a crankshaft pulley only, refer to Procedure 001-022.



Remove

Front Gear Train

Support the front gear cover on a flat work surface with wooden blocks. Using a suitable punch and hammer, drive the old seal out of the front gear cover from the back side of the cover to the front side.

NOTE: Some engines may have an addition dust seal installed in front of the front crankshaft seal.

Rear Gear Train

Use tool, Part Number 3164659, to remove the front crankshaft seal from the front gear cover.

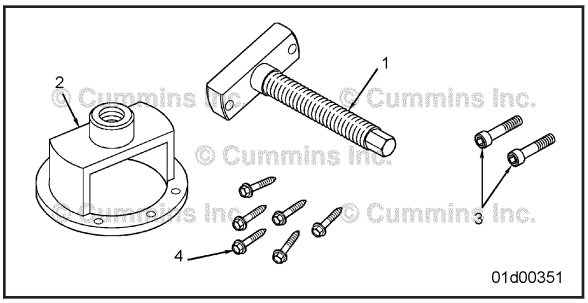
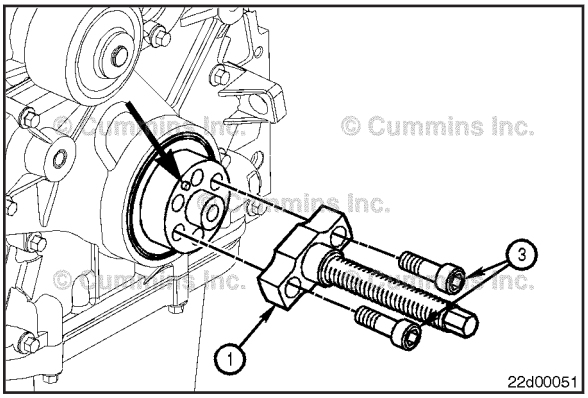


Table 1. Front Crankshaft Seal Replacer Kit, Part Number 3164659			
Item Number	**Part Number**	**Description**	**Quantity**
1	3164667	Replace screw assembly	1
2	3164661	Crankshaft seal replacer	1
3	3164239	Socket head capscrew, M12 x 1.25 x 60 mm	2
4	3164217	Sheet metal screw, Number 10 x 25.4 mm [1 in] long	25 (6 shown)
Not shown	3164218	Drill. 3.57 mm [9/64 in]	1

NOTE: The front gear cover does **not** need to be removed to remove and install the crankshaft seal.

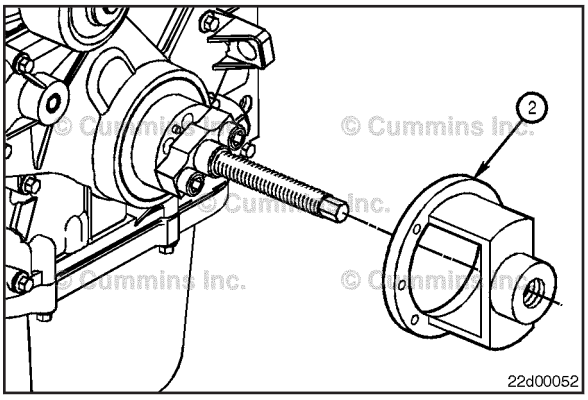
Mount the replacer screw assembly (1) onto the crankshaft nose.

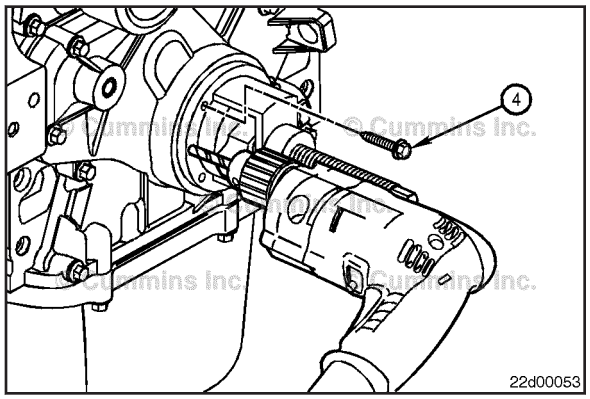
Install the two M12 x 1.25 x 60-mm socket head capscrews (3).



Lubricate the replacer screw with anti-seize or a suitable grease.

Hold the replacer screw and install the crankshaft seal replacer (2) onto the replacer screw assembly. Advance the crankshaft seal replacer toward the seal by rotating it **clockwise** until it is positioned against the front gear cover.





⚠CAUTION⚠
Drill the hole carefully and straight to reduce the possibility of damage to the front cover or the crankshaft.

Service Tip: Because of space restrictions, it may be necessary to use a compact right angle drill. Also, it may be necessary to shorten the drill bit used to drill the sheet metal screw holes.

NOTE: The flange of the crankshaft seal replacer is 8 mm [0.32 in] thick.

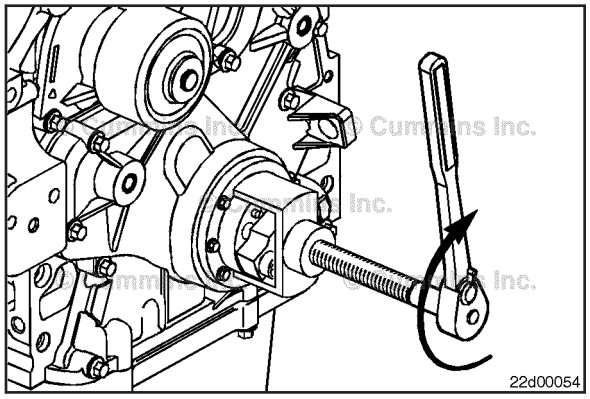
Mark the drill to a depth of 18 mm [0.71 in] with tape for drill depth control and apply grease to the drill to catch the chips. Stop frequently to remove the chips.

With the crankshaft seal replacer positioned against the front gear cover, drill one hole 10 mm [0.39 in] deep. Make sure the marking tape has **not** moved from the original position.

Install one sheet metal screw (4) into the seal to hold the crankshaft seal replacer in position.

Drill five additional holes 10 mm [0.39 in] deep and install the additional five sheet metal screws.

NOTE: Make sure all six sheet metal screws are threaded through both the inner and outer seal casings. The sheet metal screws need to be uniformly tightened in order to pull out the inner and outer casings of the seal together.



⚠CAUTION⚠
Do not use an impact wrench or air tools. Doing so can damage the tool.

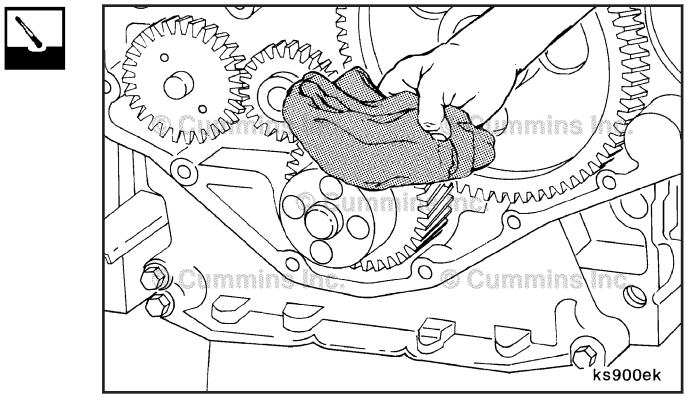
Slowly rotate the replacer screw **clockwise** until the seal is removed. Do **not** exceed torque value.

Torque Value: 33 N•m [45 ft-lb]

NOTE: If the sheet metal screws pull out of the seal or **only** the inner casing pulls out, stop the removal operation. Rotate the replacer screw **counterclockwise** to force the inner casing back. Remove the sheet metal screws, slightly reorient the tool, drill new holes, and install the sheet metal screws in the new locations.

Complete the removal procedure, remove the tool, and discard the old seal.

Clean and Inspect for Reuse



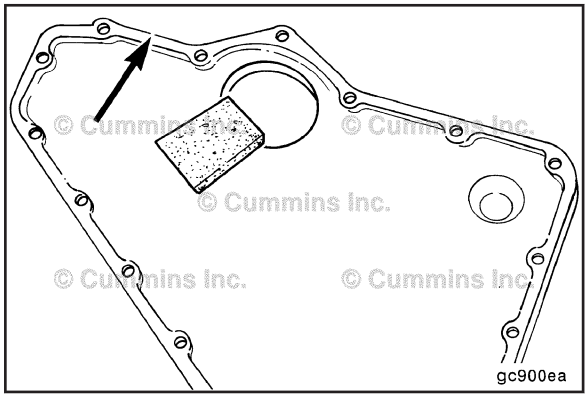
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

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

Using solvent, clean the oil and seal residue from the crankshaft surface.

Dry with compressed air.



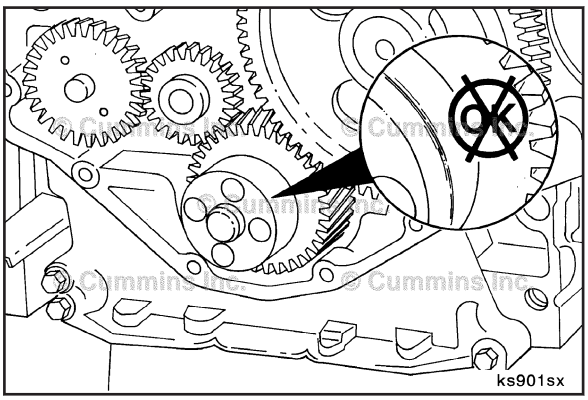
For front gear train engines, use a gasket scraper or abrasive pad, Part Number 3823258 or equivalent, to remove all sealant on the front gear cover and front gear housing.

Clean the gasket sealing surfaces and the surface between the oil seal and front gear cover.

Use solvent to clean the front gear cover.

For rear gear train engines, clean the front gear cover seal bore of any seal residue. Inspect the front gear cover seal bore for nicks or burrs. Use an abrasive pad, Part Number 3823258 or equivalent, to remove any minor damage.

Dry with compressed air.



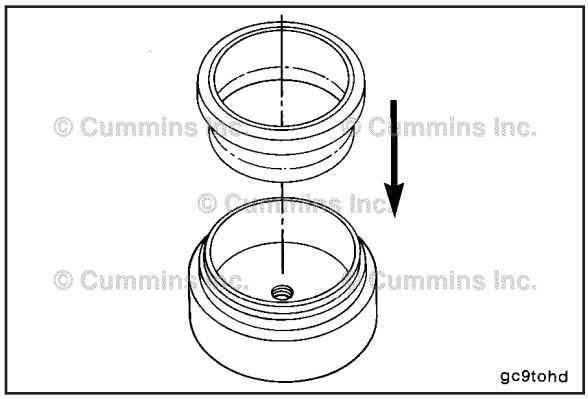
⚠CAUTION⚠
The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

NOTE: If the crankshaft has excessive wear, a service wear sleeve is available for engines that use a lip style front crankshaft seal.

Inspect the nose of the crankshaft for excessive wear.

For engines equipped with a non-lip style front crankshaft seal, use a fine crocus cloth to remove any nicks or burrs. No wear sleeve is available if the crankshaft nose sealing surface is damaged.

For engines equipped with a lip style front crankshaft seal, inspect the crankshaft seal contact area for a wear groove. If the groove is deeper than 0.25 mm [0.010 in], a wear sleeve and oversize seal **must** be used. Refer to Procedure 001-025.

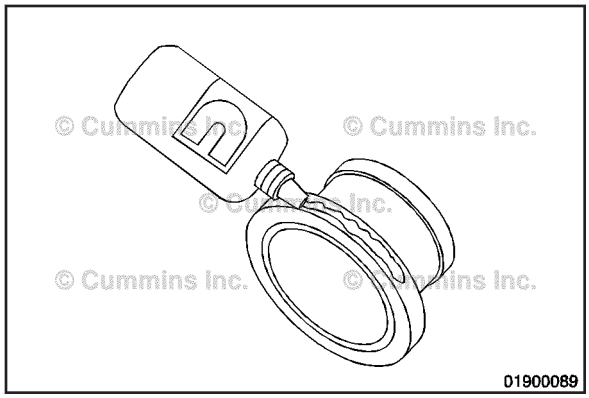


Install

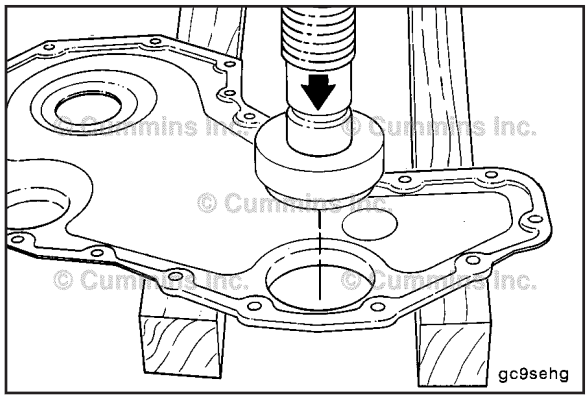
Front Gear Train

Leave the plastic pilot installation tool in the front crankshaft seal.

Position the seal on the seal installation tool, Part Number 3824498, with the seal dust lip facing outward.



Apply a bead of sealant, Part Number 3824498, to the outside circumference of the seal.



⚠CAUTION⚠
Properly support the front cover lubricating oil seal flange to prevent damage to the lubricating oil seal and front cover.

Press the lubricating oil seal into the front cover from the backside of the cover toward the frontside of the cover.

Press the lubricating oil seal until the oil seal installation tool, Part Number 3824498, bottoms against the front cover.

NOTE: Each front crankshaft seal kit comes with an installation tool. This tool can be used in place of front crankshaft seal installation tool, Part No. 3824498, if **not** available. Using a mallet, tap around the installation tool to drive the front crankshaft seal into the front gear cover until the installation tool bottoms against the front gear cover.

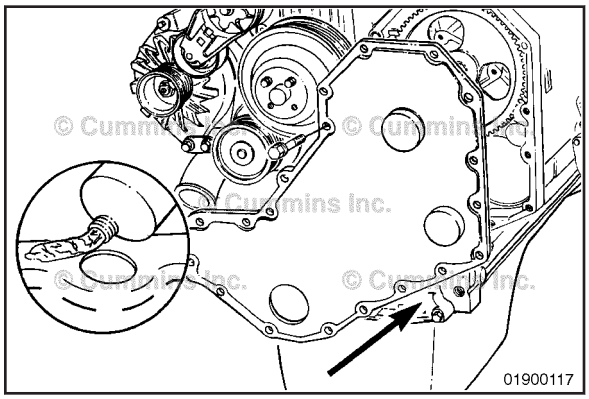
The seal lip and the sealing surface on the crankshaft **must** be free from all oil residue to prevent seal leaks.

Apply a thin bead of sealant, Part Number 3164070, to the sealing surface of the front cover.

NOTE: Do **not** remove the plastic seal pilot tool from the front crankshaft seal at this time. Use the plastic seal pilot tool to guide the seal on the crankshaft.

NOTE: Install the front cover within 10 minutes of applying the sealant, or the sealant will **not** seal correctly. Once installed, allow the sealant to dry for 30 minutes before running the engine.

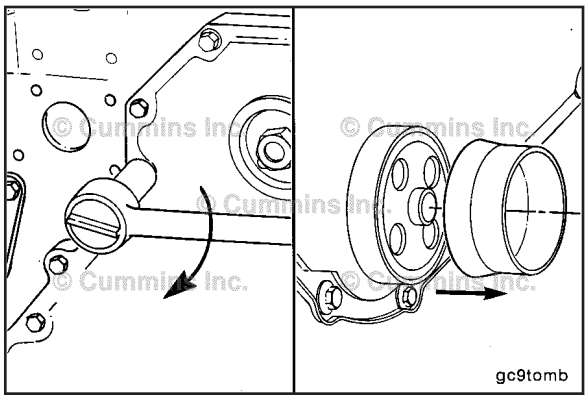
Install the front gear cover on the engine, using the plastic seal pilot tool to guide the front crankshaft seal onto the crankshaft.



Install and tighten the front gear cover capscrews.

Torque Value: 24 N•m [18 ft-lb]

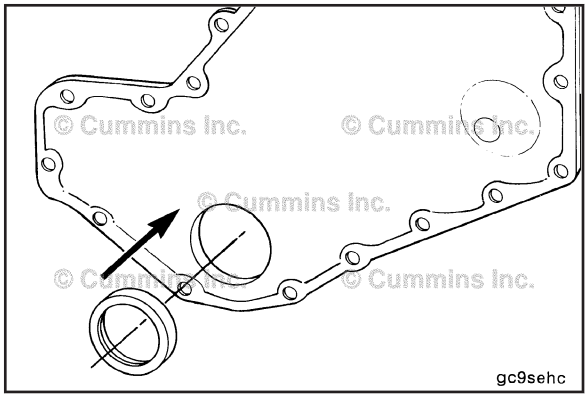
Remove the plastic pilot tool from the crankshaft.



If previously equipped or if the engine operates in a dusty environment, install a dust seal.

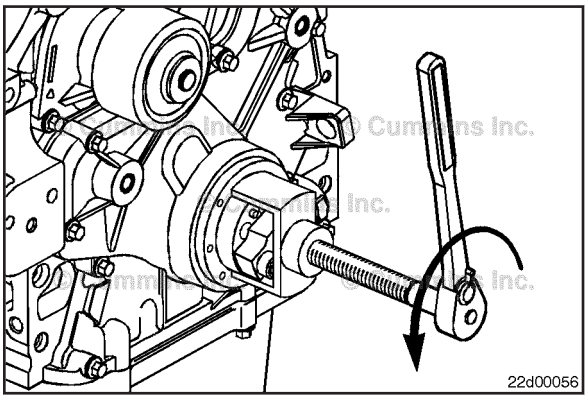
A pilot tool is not necessary for the dust seal. Slide the dust seal over the nose of the crankshaft.

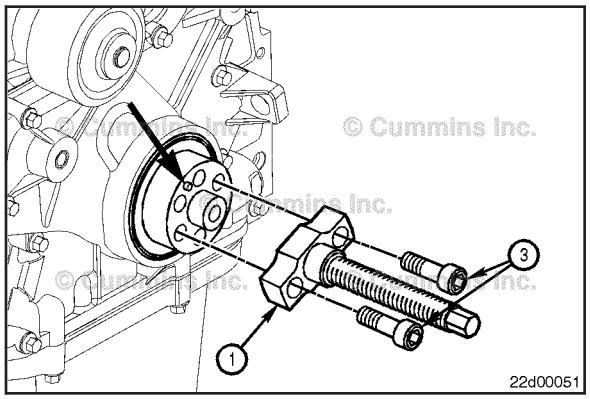
Use the installation tool that came with the new front crankshaft seal to install the dust seal into the front gear cover. Install the dust seal until it is even with the front gear cover.



Rear Gear Train

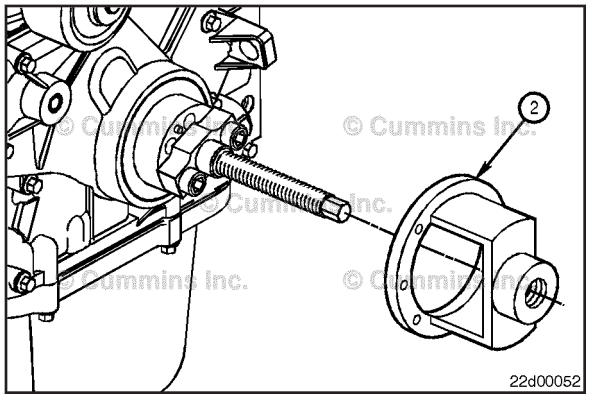
Use tool, Part Number 3164659, to install the oil seal into the front gear cover.





Mount the replacer screw assembly (1) onto the crankshaft nose.

Install the two M12 x 1.25 x 60 mm socket head capscrews (3).



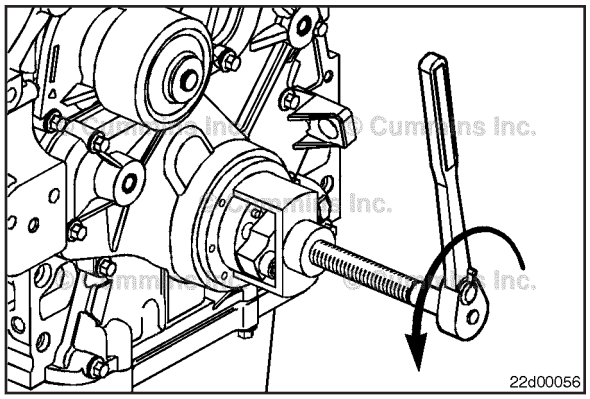
⚠CAUTION⚠
Do not use an impact wrench or air tools. Doing so can damage the tool.

Place the new front crankshaft seal over the crankshaft nose and slide it by hand toward the front gear cover as far as possible.

NOTE: Make sure the seal is positioned squarely with the crankshaft.

While holding the replacer screw, install the crankshaft seal replacer (2) onto the replacer screw assembly.

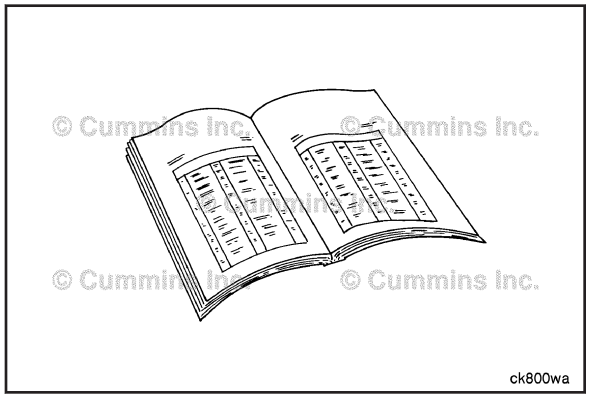
Advance the crankshaft seal replacer toward the seal by rotating it **clockwise** until it is positioned against the seal.



⚠CAUTION⚠
Do not overtighten the replacer screw assembly after the crankshaft seal replacer contacts the front cover. Doing so can damage the tool.

While holding the crankshaft seal replacer, rotate the replacer screw **counterclockwise** until the crankshaft seal replacer contacts the front gear cover.

Remove the service tools.



Finishing Steps

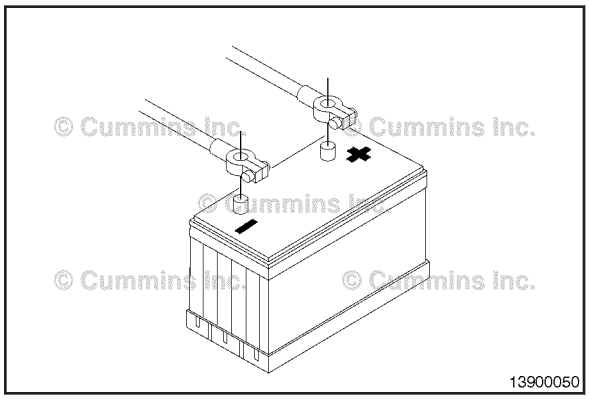
Front Gear Train

- 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 fan hub if removed. Refer to Procedure 008-039
- Install the engine water pump (cooling fan) 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.

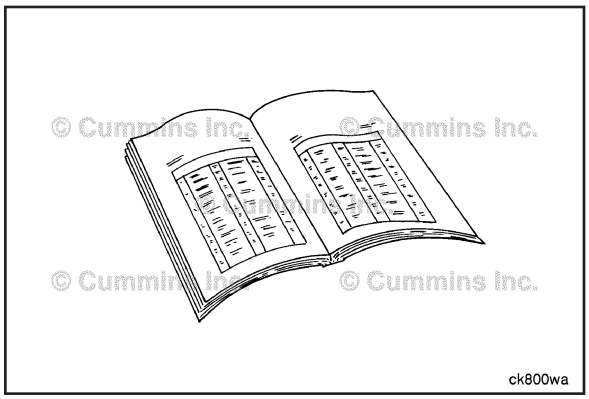
Connect the batteries.

Operate the engine and check for leaks.



Rear Gear Train

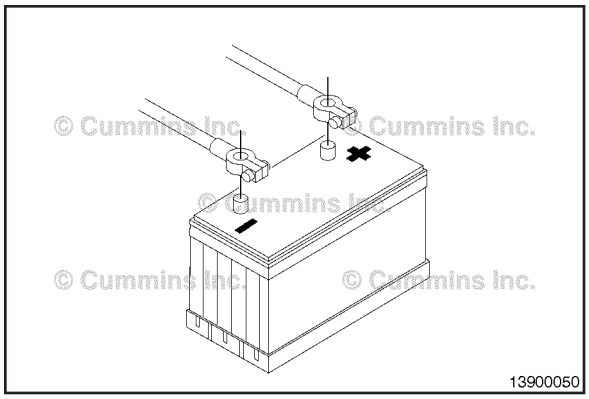
- Install the vibration damper pulley/crankshaft pulley. If equipped with a viscous damper, refer to Procedure 001-052. If equipped with a rubber damper, refer to Procedure 001-051. If equipped with a crankshaft pulley only, refer to Procedure 001-022
- Install the cooling fan drive belt. Refer to Procedure 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.

Operate the engine and check for leaks.



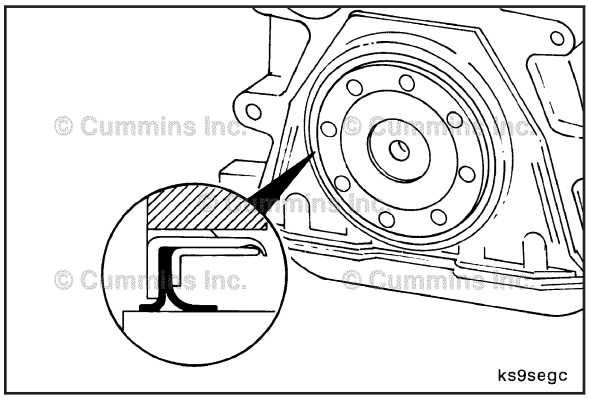
Crankshaft Seal, Rear (001-024)

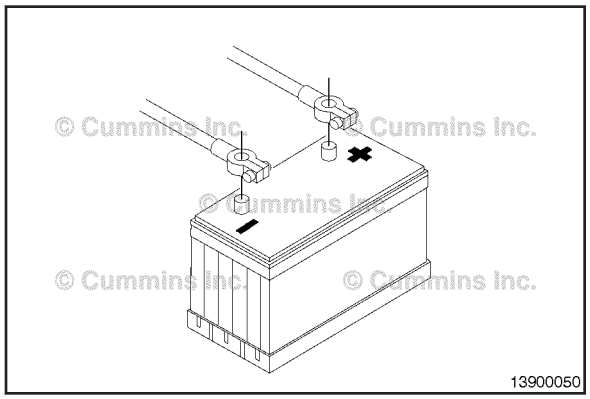
General Information

Lip Seal

Engines covered by this procedure use a lip style rear crankshaft seal (shown) in which the rotating portion of the sealing occurs at the contact surface between the lip of the seal and the crankshaft.

For front gear train engines, the rear crankshaft seal is mounted in a rear seal carrier that bolts to the rear of the cylinder block (shown). For rear gear train engines, the rear crankshaft seal is installed in the flywheel housing bore (not shown).



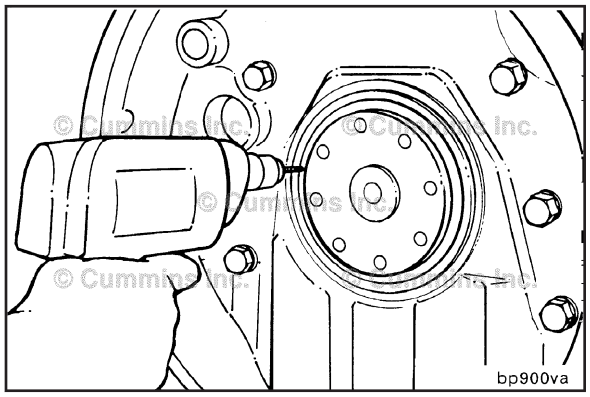


Preparatory Steps

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

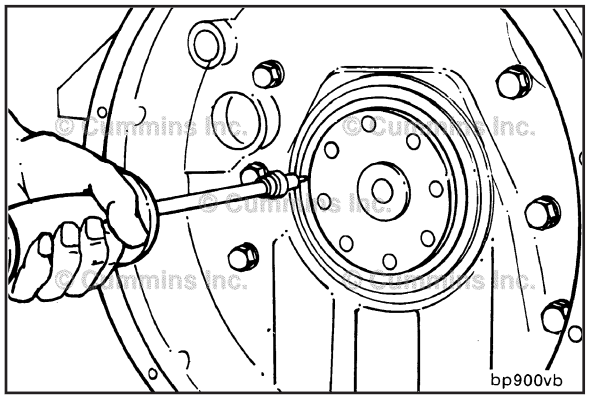
- Disconnect the batteries. Refer to Procedure 013-009

  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.
- Remove the flywheel/flexplate. Refer to Procedure 016-005 or Procedure 016-004.



NOTE: For engines equipped with a lip style rear crankshaft seal, the seal can also be removed using screws and a slide hammer.

Drill two holes 180-degrees apart into the seal carrier.



Install two coarse sheet metal screws in the holes just drilled. Use a slide hammer to remove the rear crankshaft seal.

Clean and Inspect for Reuse

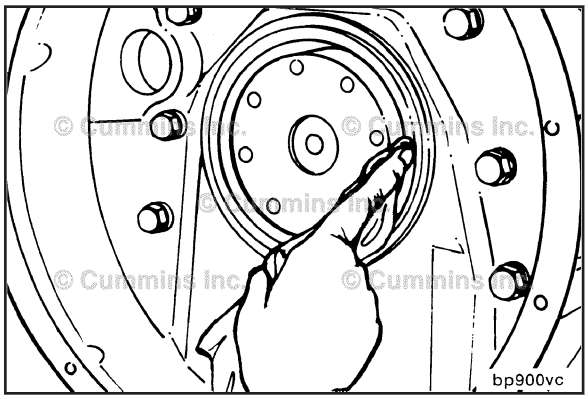
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Use only with protective clothing, goggles/shield, and gloves to reduce the possibility of personal injury.

△CAUTION△
The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

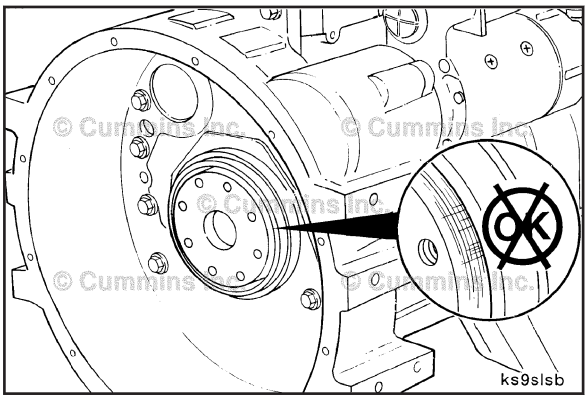
Clean the rear crankshaft sealing surface and bore with solvent.

Dry the surface with compressed air.



NOTE: If the crankshaft has excessive wear, a service wear sleeve is available.

For engines equipped with a lip style rear crankshaft seal, inspect the crankshaft seal contact area for a wear groove. If the groove is deeper than 0.25 mm [0.010 in], a wear sleeve and oversize seal **must** be used. Refer to Procedure 001-067.



Install

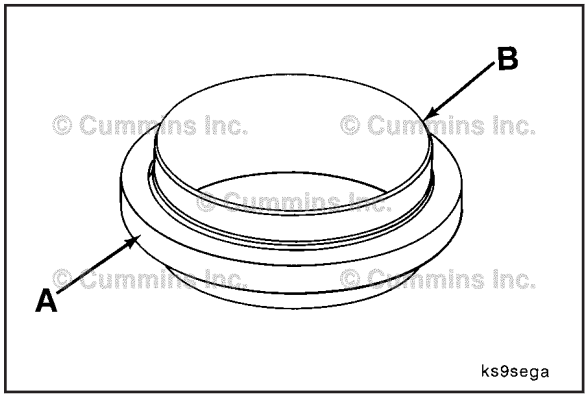
All Applications

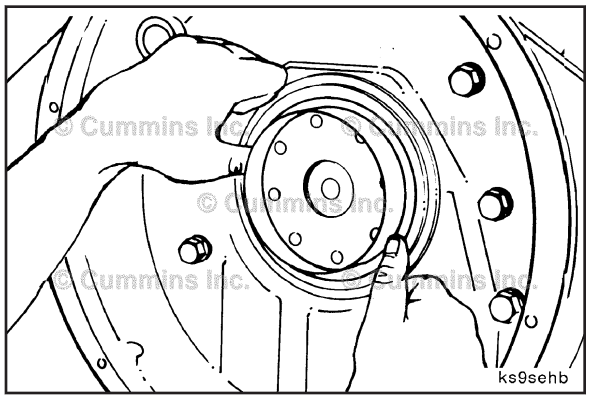
△CAUTION△
Always replace the rear crankshaft seal with the same style seal as was previously installed (wet flywheel housing seal, lip seal, unitized, etc.). Use of the incorrect rear crankshaft seal will result in an engine oil leak.

△CAUTION△
The seal lip/bore and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

To aid in installation, apply a mild soap to the outside diameter of the seal case (A).

NOTE: On engines equipped with a lip style rear crankshaft seal, a seal pilot (B) is provided with the new seal. The seal **must** be left on the seal pilot while installing the seal onto the nose of the crankshaft. This will make sure the lips of the seal do **not** get damaged during installation.



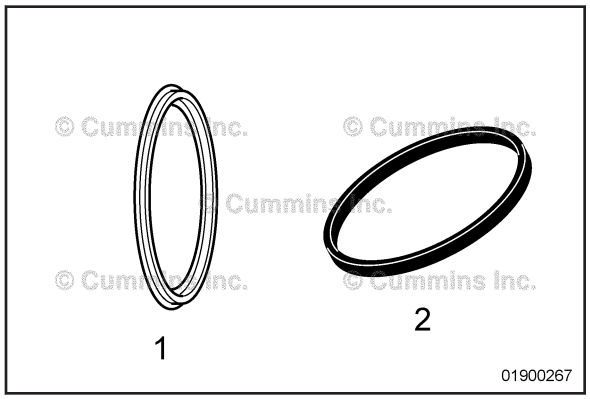


CAUTION
Always replace the rear crankshaft seal with the same style seal as was previously installed.

Place the new rear crankshaft seal, with the seal pilot, over the crankshaft nose and slide it by hand toward the flywheel housing.

NOTE: Make sure the seal is positioned squarely with the crankshaft.

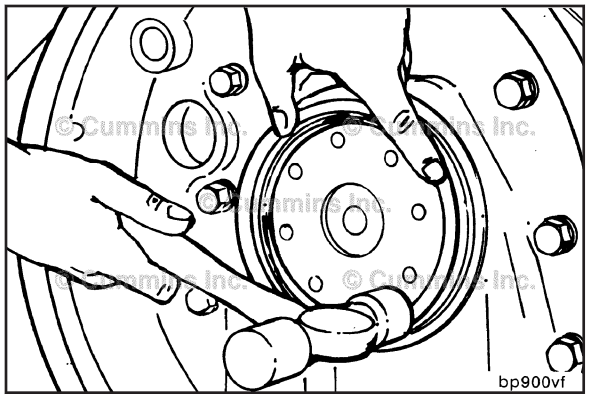
Remove the seal pilot.



Each new lip style crankshaft seal comes with a disposable seal driver.

- The seal driver (1) for front gear train engines, which is typically a metal ring, will install the crankshaft seal to the proper depth in the rear seal carrier bore.
- The seal driver (2) for rear gear train engines, which is typically a plastic ring, will install the crankshaft seal to the proper depth in the flywheel housing bore.

NOTE: For rear gear train engines, rear crankshaft seals for the wet flywheel housing applications do **not** come with a disposable seal driver. Service tool, Part Number 3824078, **must** be used to install the rear crankshaft seal for the wet flywheel housing. This is the same service tool used for installing the rear crankshaft seal and wear sleeve assembly. Refer to procedure 001-067. For front gear train engines, this service tool can be used in place of the disposable seal driver that comes with the crankshaft seal.



NOTE: It may be necessary to lightly tap the rear crankshaft seal with a plastic hammer without the disposable seal driver to help get the seal started.

Use the appropriate disposable seal driver that comes with each new rear crankshaft seal to install to the correct depth in the housing.

Use a plastic hammer to drive the seal into the housing until the alignment tool stops against the housing.

Hit the tool at 12, 3, 6 and 9 o'clock positions to drive the seal evenly and to prevent bending the seal carrier.

Optional Method

For rear gear train engines, the disposable plastic driver that comes with the new rear crankshaft seal has been designed with two holes in the outer ring. These holes are provided so that the driver can be used in conjunction with the Rear Crankshaft Seal Replacer Kit, Part Number 3164660.

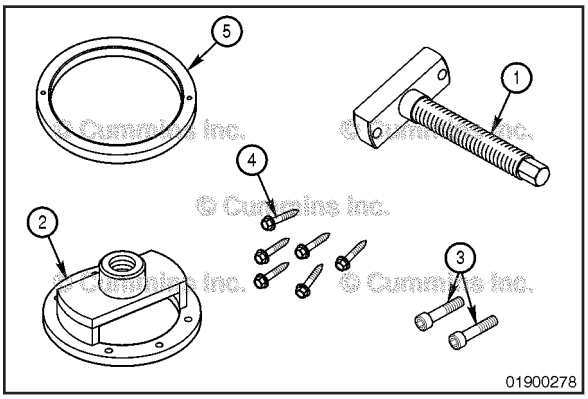
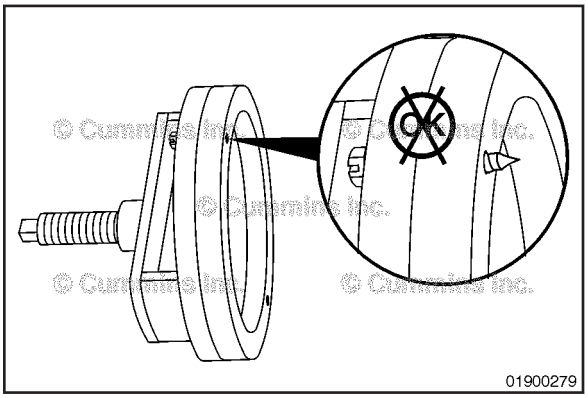


Table 2. Rear Crankshaft Seal Replacer Kit, Part Number 3164660

Item Number	Part Number	Description	Quantity
1	3164666	Replace screw assembly	1
2	3164664	Crankshaft seal replacer	1
3	3164174	Socket head capscrew, M12 x 1.25 x 25 mm	2
4	3164217	Sheet metal screw, Number 10 x 25.4 mm [1 in] long	25 (7 shown)
Not shown	3164218	Drill. 3.57 mm [9/64 in]	1
5	—	Disposable plastic driver (purchased with rear crankshaft seal kit)	1

⚠CAUTION⚠
Do not use the sheet metal screws that come with the Rear Crankshaft Seal Replacer Kit, service tool part number 3164660. The sheet metal screws are too long. When selecting the correct sheet metal screw, make sure the tip of the sheet metal screw does not protrude past the face of the driver. Damage to the crankshaft seal will result.

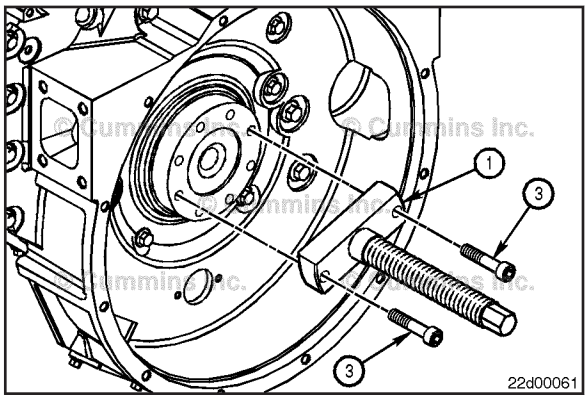


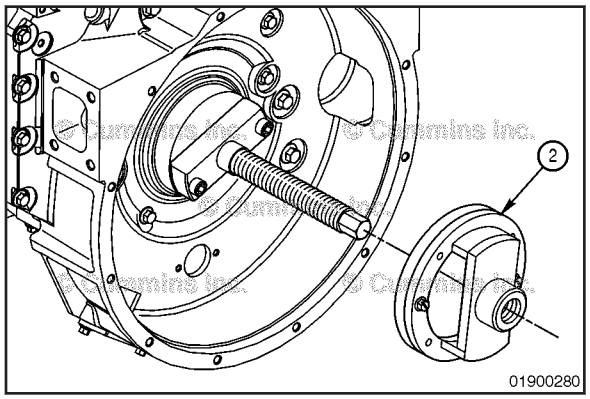
With the correct side of the disposable driver facing outwards for the type of seal that will be installed, center the disposable driver on the crankshaft seal replacer.

Attach the disposable driver to the crankshaft seal replacer using a number 2 sheet metal screw (number 10 by 19 mm [.75 in] long).

With the rear crankshaft seal installed onto the crankshaft flange as described earlier in this procedure, mount the replacer screw assembly (1) onto the rear of the crankshaft.

Install the two M12 x 1.25 x 60-mm socket head capscrews (3).

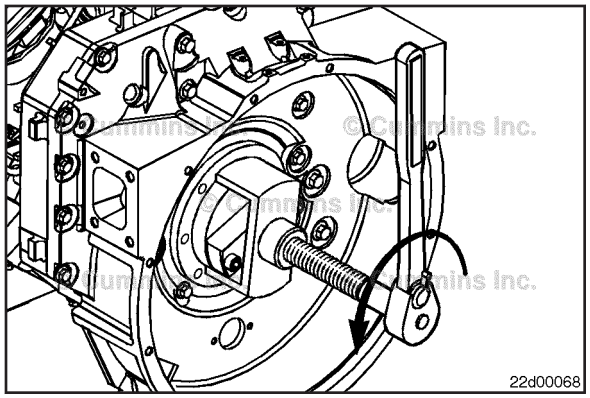




⚠CAUTION⚠
Do not use an impact wrench or air tools. Doing so can damage the tool.

Lubricate the replacer screw with anti-seize compound or a suitable grease.

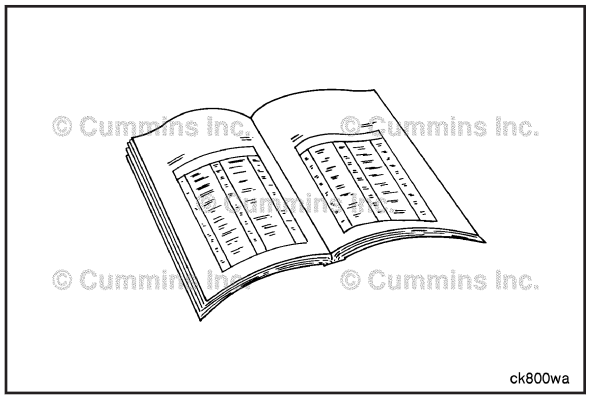
Hold the replacer screw and install the crankshaft seal replacer (2) onto the replacer screw assembly. Advance the crankshaft seal replacer toward the seal by rotating it **clockwise** until the attached disposable driver is positioned against the rear crankshaft seal.



⚠CAUTION⚠
Do not overtighten the replacer screw assembly after the crankshaft seal replacer contacts the flywheel housing. Doing so can damage the tool.

While holding the crankshaft seal replacer, rotate the replacer screw counterclockwise until the disposable driver attached to the crankshaft seal replacer makes contact with the flywheel housing.

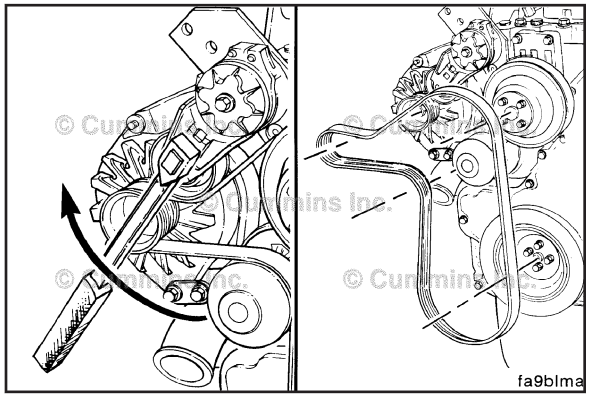
Remove the service tools.



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 flywheel/flexplate. Refer to Procedure 016-005 or Procedure 016-004
- Install the transmission and all related components (if equipped). Refer to the OEM instructions
- Connect the batteries. Refer to Procedure 013-009
- Operate the engine and check for leaks.

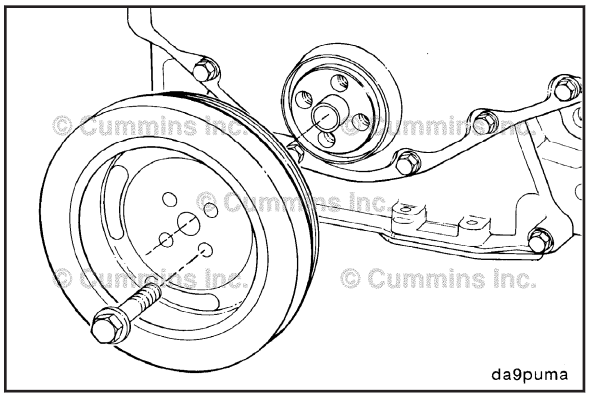


Crankshaft Wear Sleeve, Front (001-025)

Preparatory Steps

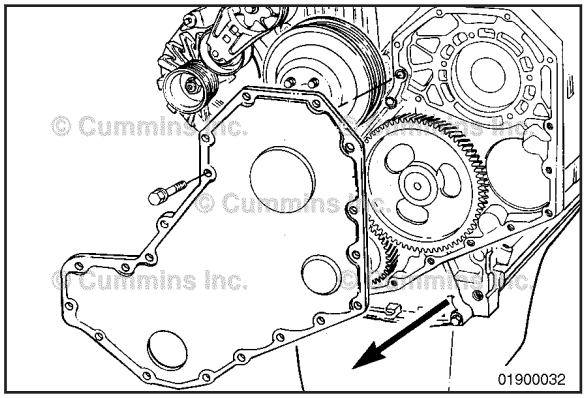
Remove the drive belt. Refer to Procedure 008-002.

Remove the vibration damper. Refer to Procedure 001-052.



Remove

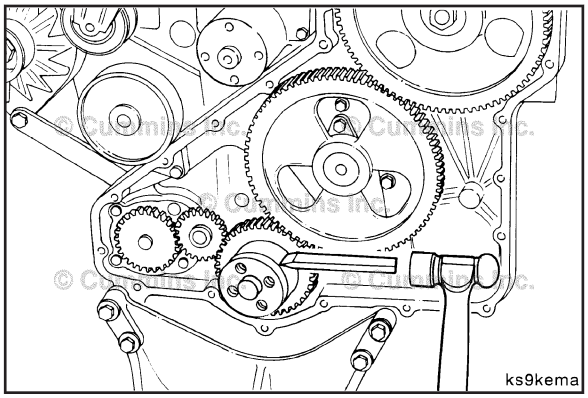
Remove the gear cover. Refer to Procedure 001-031.



⚠CAUTION⚠
Do not nick or gouge the crankshaft with the chisel. If the crankshaft is damaged, it must be replaced.

NOTE: Use a hammer and chisel that is **only** as wide as the wear sleeve.

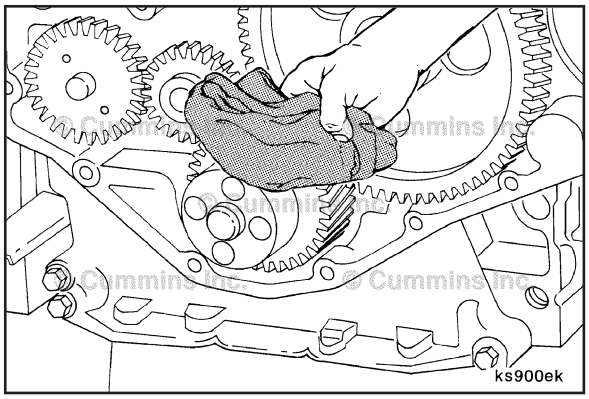
Make one or two chisel marks across the wear sleeve. This will expand the wear sleeve, allowing the sleeve to be removed.

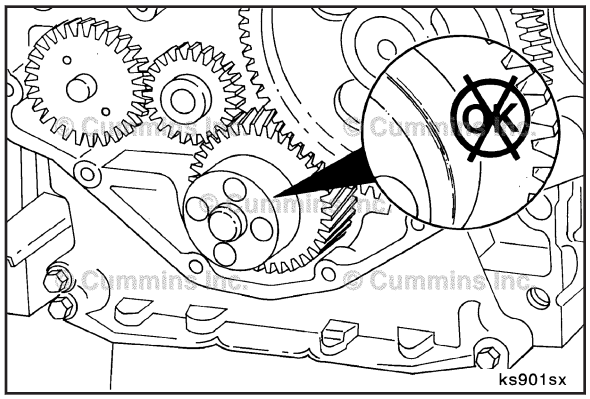


Clean

Use a crocus cloth to remove any rust or other deposits from the crankshaft flange.

Use a clean cloth to clean the crankshaft flange.

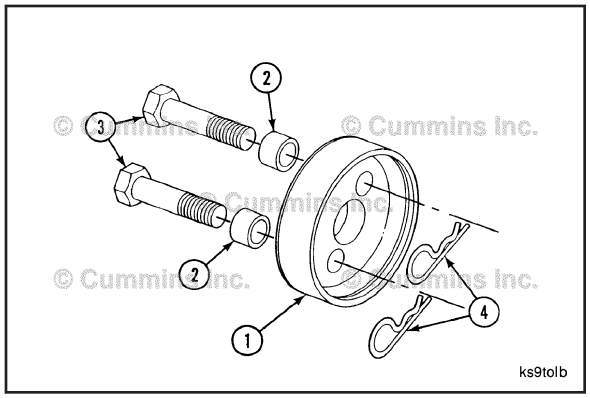




Inspect for Reuse

Inspect the seal contact area of the crankshaft for a wear groove. If the seal has worn a groove deep enough to be felt with a sharp object or fingernail, it will be necessary to install a wear sleeve to prevent an oil leak.

The oil seal used with the wear sleeve has a larger inside diameter than the standard seal. The two seals are **not** interchangeable. Refer to the appropriate B Series parts catalog for the correct part number.

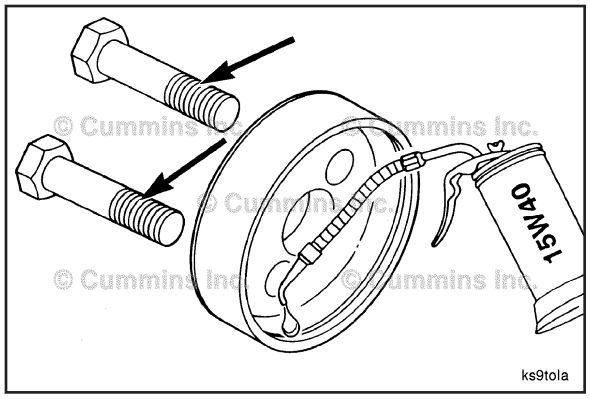


Install

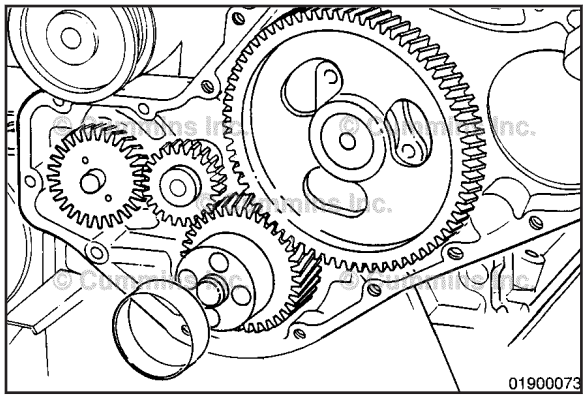
Crankshaft Front Wear Sleeve Installation Tool, Part Number 3824500

Use the driver to install the wear sleeve to the correct position on the crankshaft. The kit consists of the following:

Ref. Number	Description	Qty.
1	Driver	1
2	Spacer	2
3	Capscrew M14 x 1.5 x 60 mm	2
4	Hairpin Cotter	2



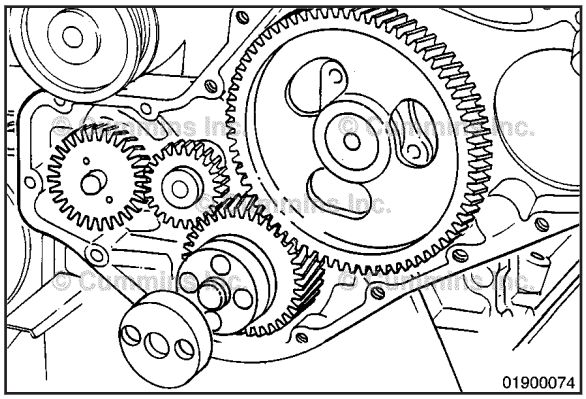
Apply a thin coat of clean lubricating engine oil to the inside diameter and capscrew threads.



Apply a thin coat of clean lubricating engine oil to the crankshaft flange.

Position the chamfered end of the wear sleeve onto the end of the crankshaft.

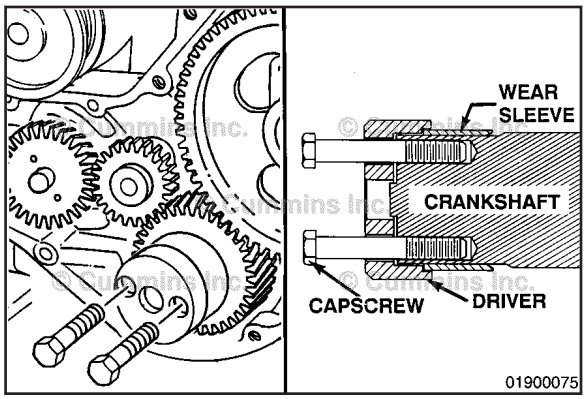
Position the counterbore end of the driver onto the wear sleeve.



Install two capscrews (without spacers or hairpin cotters) through the driver and into the crankshaft capscrew holes.

Align the wear sleeve and driver perpendicular to the crankshaft.

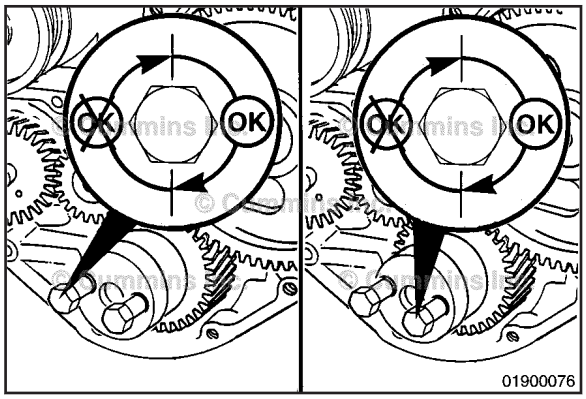
Tighten the capscrews finger-tight.



⚠CAUTION⚠
To prevent damage to the wear sleeve, do not exceed one-half revolution of each capscrew.

Alternately tighten the capscrews one-half turn until the sleeve is installed to a depth of approximately 16 mm [0.625 in].

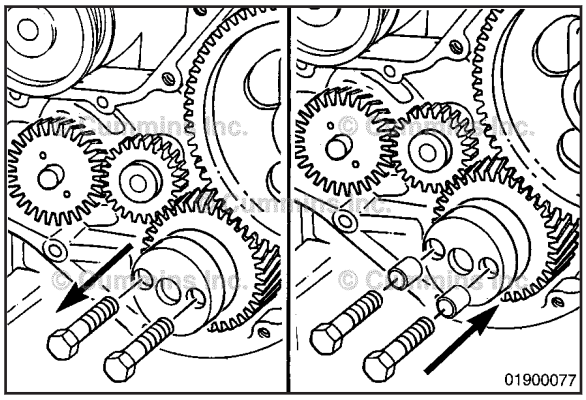
Torque Value: 20 N•m [15 ft-lb]

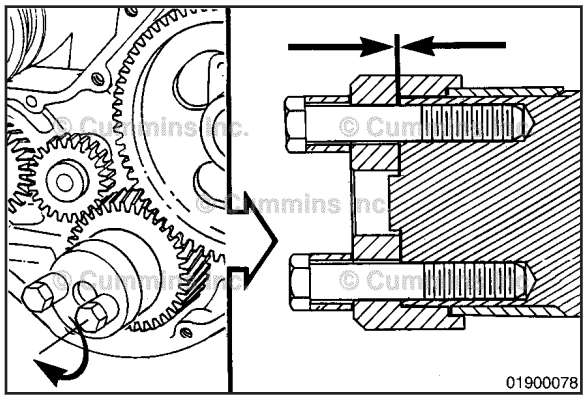


Remove the two capscrews.

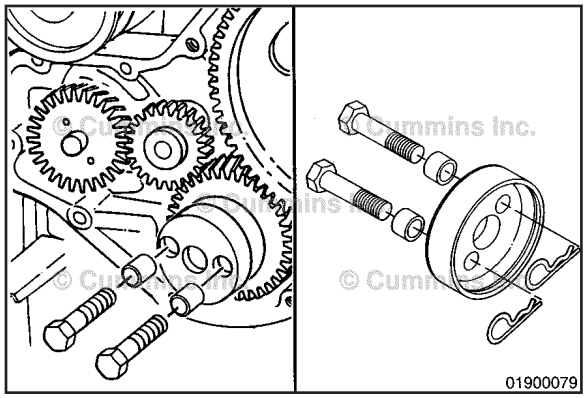
Install the spacer on each capscrew.

Install the two capscrews.

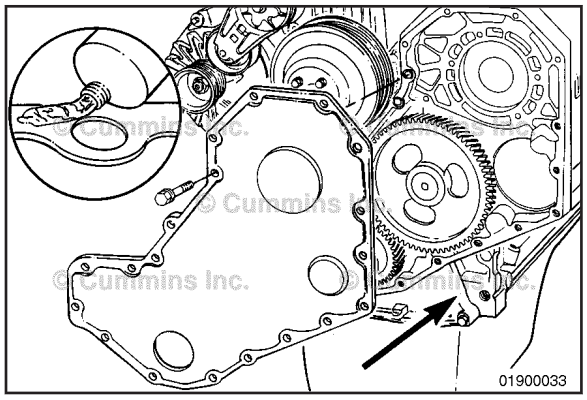




Continue to tighten the capscrews alternately until the bottom of the driver contacts the end of the crankshaft.



Remove the driver. Use the hairpin cotters to secure the capscrews and spacers to the tool during storage.

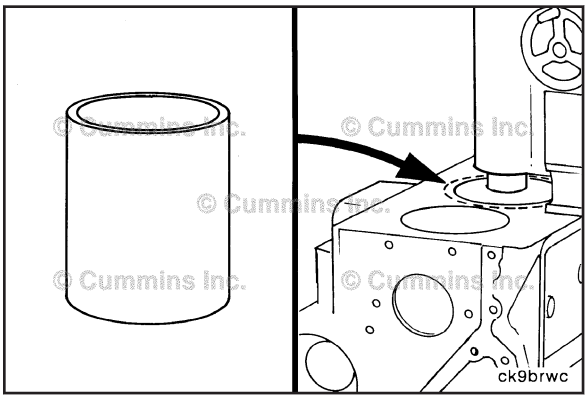


Install a new seal into the gear cover. Refer to Procedure 001-023.

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

Cylinder Block (001-026)

General Information

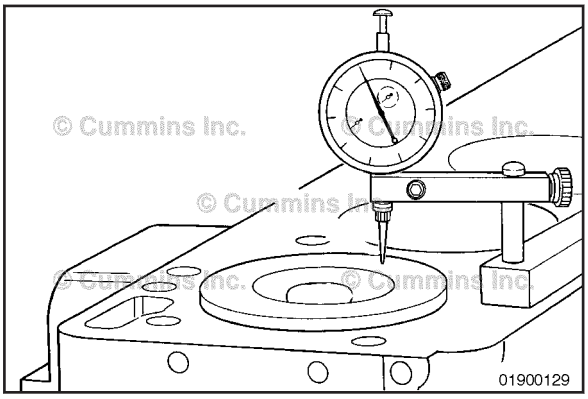


The cylinder block uses bored cylinders as opposed to liners. In the event of damage or wear out, the cylinders may be able to be repaired.

For B3.9, B4.5, and B5.9 engines, the cylinders can be bored oversize twice for the use of over size pistons and rings (0.5 mm [0.020 in]) and 1 mm [0.040 in] oversize). A repair sleeve can also be installed if the cylinder bore **must** be bored more than 1 mm [0.040 in] oversize. See the Overbore and/or Repair Sleeve section of this procedure.

For B4.5 RGT engines, the cylinders can **only** be bored oversize once for the use of oversize pistons and rings (0.5 mm [0.020 in] over size). A repair sleeve can be installed if the cylinder bore **must** be bored more than 0.5 mm [0.020 in] oversize. See the Overbore section in this procedure.

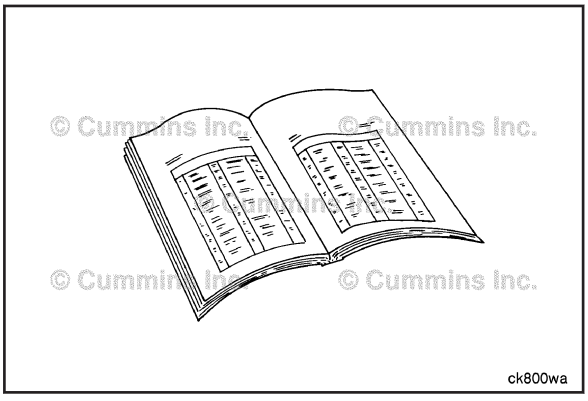
Initial Check



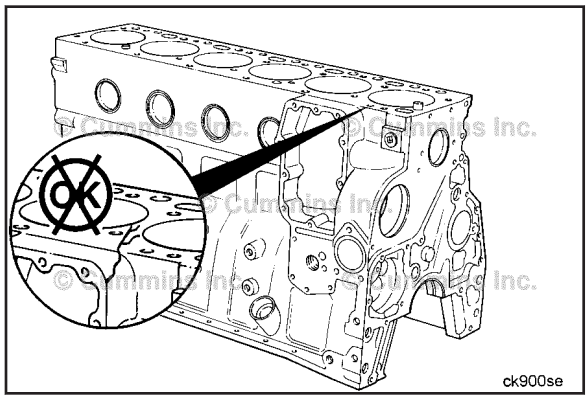
Prior to removing the piston and connecting rod assemblies, measure and record piston protrusion. Refer to Procedure 001-054 in Section 1.

Measuring piston protrusion prior to disassembly will aid in determining if the cylinder block, if required, can be resurfaced.

Preparatory Steps



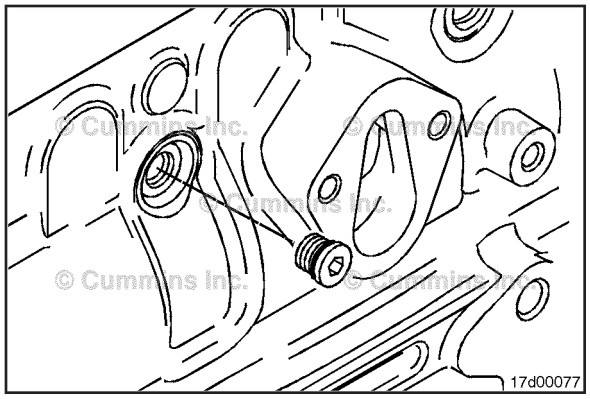
- Remove the engine and place on an engine stand. Refer to Procedure 000-001 in Section 0.
- Disassemble the engine. See Section DS - Engine Disassembly.



Initial Check:

Before cleaning or further disassembly of the block, perform a visual inspection to see if there is any damage (cracks, fretting, etc.) that would prohibit reuse. Paying close attention to areas of the block that include:

- Main bearing caps and bores
- Camshaft bores
- Cylinder bores
- Tappet bores
- Cylinder block combustion deck
- Oil pan mounting surface
- Lubricating oil pump mounting area
- Water pump mounting area
- Front and rear of block sealing surfaces
- Lubricating oil cooler cavity.

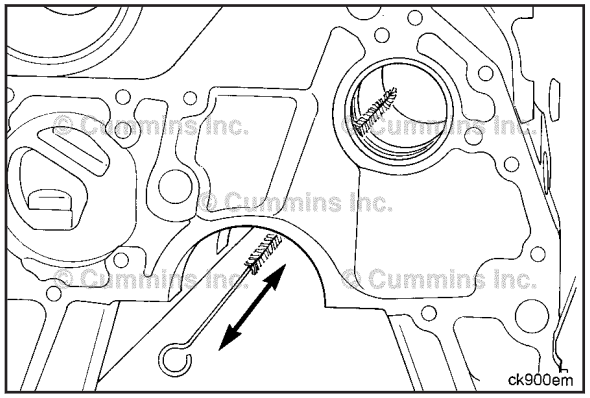


Clean and Inspect for Reuse

Inspect all pipe plugs, expansion plugs and straight thread plug for signs of damage or leaks.

If it is necessary to thoroughly clean the cylinder block for reuse due to excessive debris or contamination, remove all pipe plugs, expansion plugs and straight thread plugs as necessary. Make sure all oil and coolant passages are cleaned out.

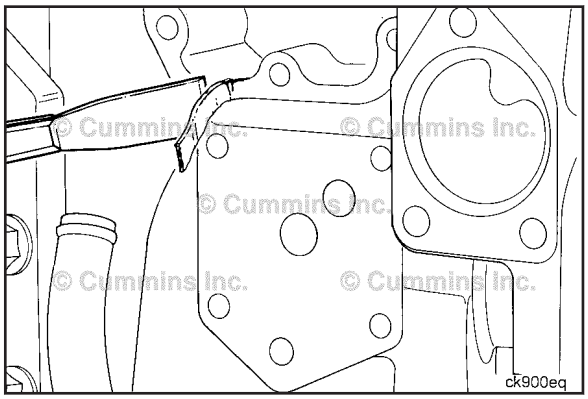
Use the following procedure for removal and installation of plugs. Refer to Procedure 017-002, Refer to Procedure Procedure 017-007, and Refer to Procedure 017-011 in Section 17.



⚠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.

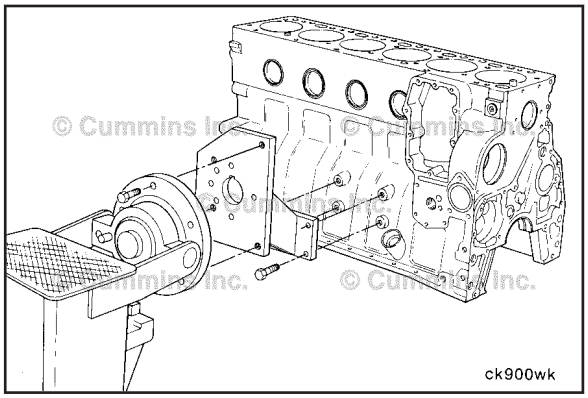
Use clean solvent and a nonmetallic brush to clean the block oil drillings.

Thoroughly clean all gasket sealing surfaces of any remaining gasket residue.



⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Remove the block from the engine stand.



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

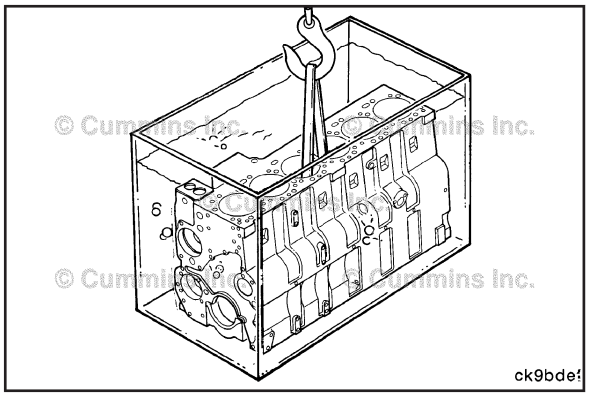
△CAUTION△
Use a cleaning solution that will not damage the camshaft bushings.

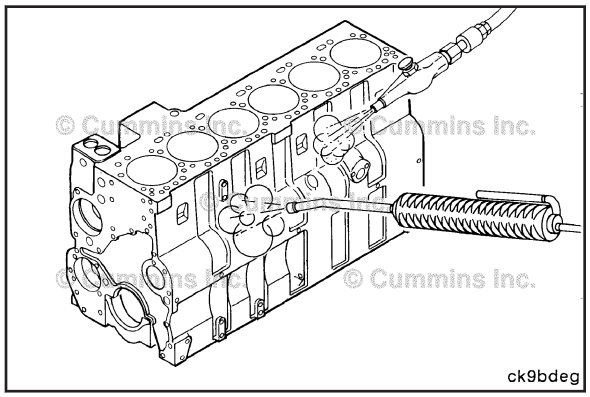
Follow the manufacturer's operating instructions for the cleaning tank.

Follow the solvent manufacturer's instructions for using the solvent.

NOTE: Cummins Inc. does **not** recommend any specific cleaning solution. Experience has shown that the best results are obtained by using a cleaning solution that can be heated from 80 to 95°C [176 to 203°F]. A cleaning tank that **will** mix and filter the cleaning solution will give the best results.

Clean the cylinder block in the cleaning tank.





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

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

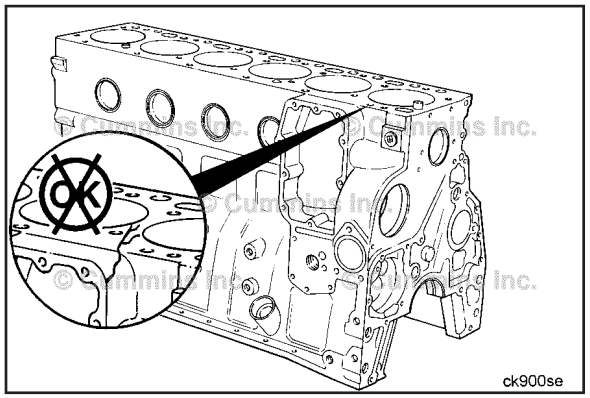
△CAUTION△
To reduce the possibility of engine damage, make sure all debris is removed from the capscrew holes and oil passages.

Remove the block from the cleaning tank.

Use steam to clean the cylinder block thoroughly.

Use compressed air to dry the block.

NOTE: If the cylinder block is **not** going to be used immediately, apply a coating of preservative oil to prevent rust. Cover the block to prevent dirt from sticking to the oil.

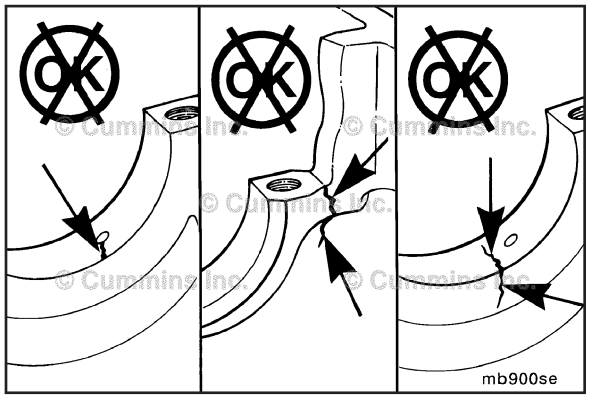


With the cylinder block cleaned, inspect the cylinder block again for signs of cracks, fretting, and discoloration that will prohibit reuse.

To help identify cracks in the cylinder block, use the Crack Detection Kit, Part Number 3375432.

Pay close attention to areas of the block that include:

- Main bearing caps and bores
- Camshaft bores
- Cylinder bores
- Tappet bores
- Cylinder block combustion deck
- Oil pan mounting surface
- Lubricating oil pump mounting area
- Water pump mounting area
- Front and rear of block sealing surfaces
- Lubricating oil cooler cavity.



Make sure to inspect the main bearing caps and main bearing saddle areas for cracks, fretting and signs of discoloration.

If any cracks are found, the cylinder block **must** be replaced.

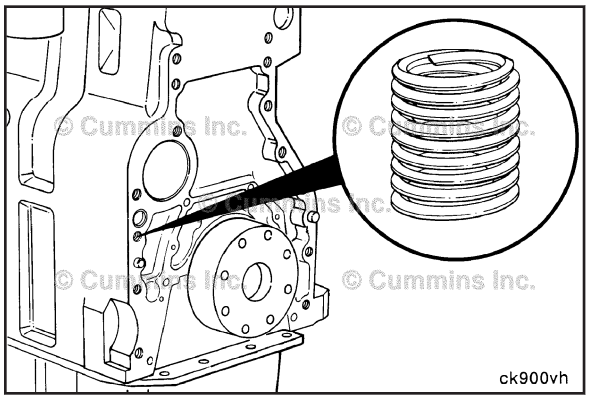
Inspect all threaded capscrew holes for damaged threads. Coiled thread inserts may be used to repair any damaged threads.

Service Tool threaded insert kits are available:

1 Part Number 3377905 for standard threads

2 Part Number 3377903 for metric threads.

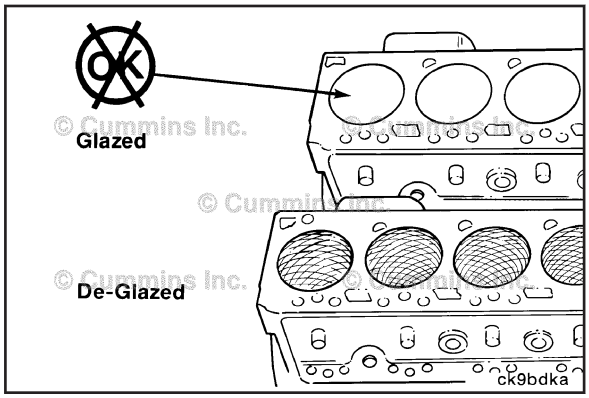
NOTE: Coiled thread inserts **must not** be used to repair main bearing saddle threaded capscrew holes. If damaged, the block **must** be replaced.



Inspect the cylinder bores for glazing.

A surface without glaze will have a crosshatched appearance with the lines at 25- to 30-degree angles with the top of the cylinder bore.

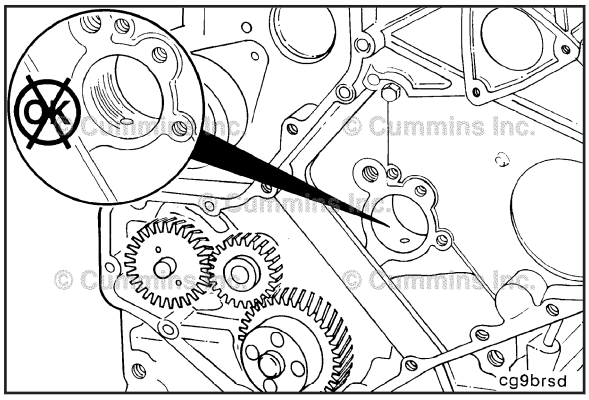
If deglazing is required, see the Deglazing section, located later in this section.



Inspect the camshaft bores for scoring, scuffing or excessive wear.

If damage to the camshaft bores is found and a camshaft bushing was **not** previously installed, machine the camshaft bores over size to install standard camshaft bushings. See the Measure step of this procedure for specifications.

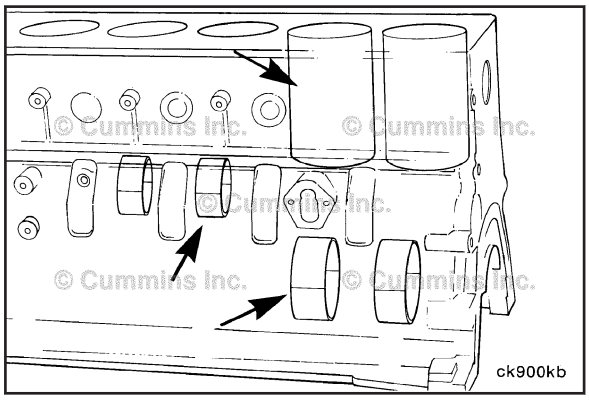
If the damage to the bore(s) is beyond machining, or if a camshaft bushing was previously installed, the block **must** be replaced. Oversize cam bushings are **not** available.

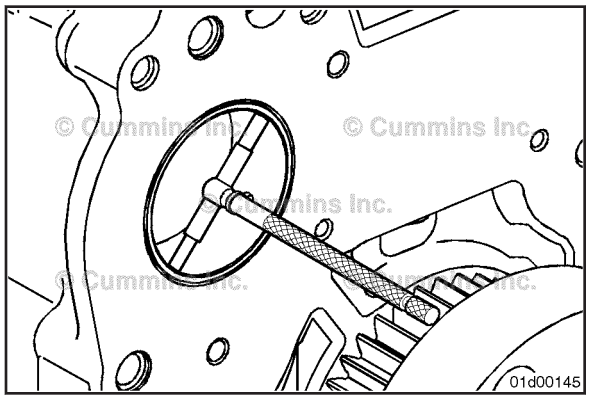


Measure

All measurements of the cylinder block **must** be made when the cylinder block is positioned on a flat surface with the main bearing caps installed, and torque plate installed.

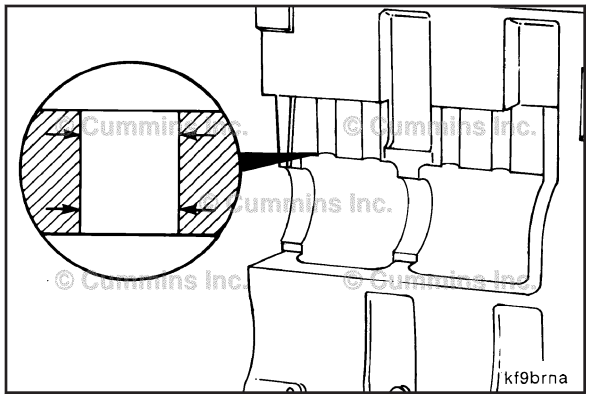
If the cylinder block is mounted on the engine stand and/ or the main bearing caps are **not** installed, the measurements can be incorrect because of distortion. (Cylinder bores, main bearing bores, camshaft bores, etc).





Inspect the camshaft bores without the camshaft bushing installed.

Use the following procedure for specifications. Refer to Procedure 001-010 in Section 1.

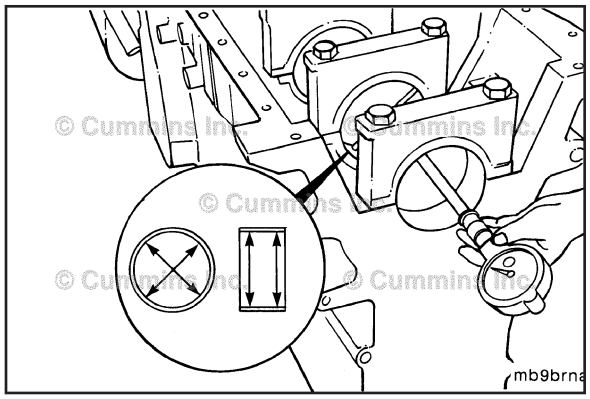


Inspect the tappet bores for scores or excessive wear.

Measure the tappet bores.

Tappet Bore Diameter		
mm		**in**
16.000	MIN	0.630
16.055	MAX	0.632

NOTE: If the tappet bores are out of specification, the block **must** be replaced.



Install the main bearing caps without the main bearings. Use the following procedure for main bearing installation. Refer to Procedure 001-006 in Section 1.

Tighten the main bearing cap capscrews.

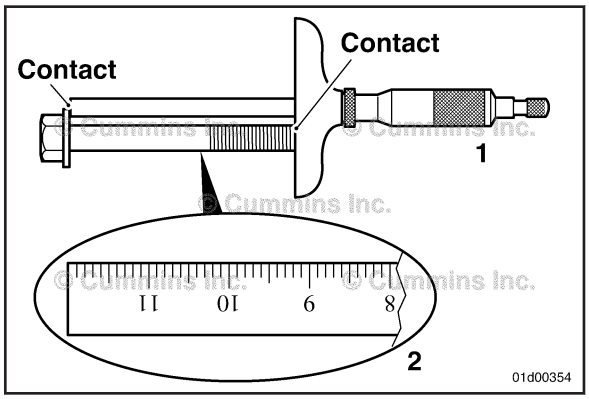
Torque Value: 176 N•m [130 ft-lb]

Measure the main bearing bore with the bearings removed.

Main Bearing Bore Diameter with Bearings Removed		
mm		**in**
87.983	MIN	3.4639
88.019	MAX	3.4653

NOTE: If the main bearing bore diameters are **not** within specification, check if the main bearing caps where installed in the proper location and orientation. If main caps are installed properly, the block **must** be replaced.

Main Bearing Capscrew Reuse Measurement



⚠CAUTION⚠
This step must be completed on B4.5 RGT engines. Failure to check the main bearing capscrew against reuse guidelines can result in severe engine damage.

To check if a main bearing capscrew can be reused, the length **must** be measured by performing the following:

For each main bearing capscrew that has been removed, measure the length from underneath the head of the capscrew to the tip of the capscrew, as illustrated, use one of two methods:

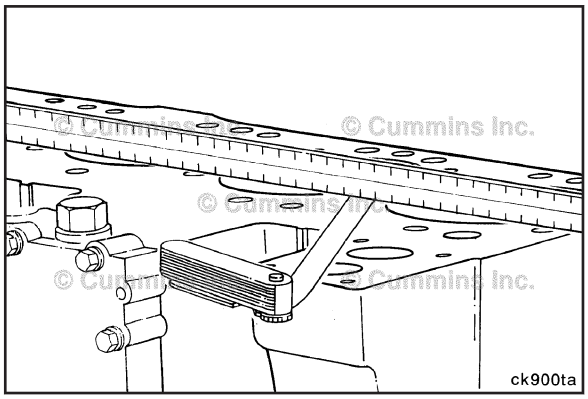
1 A depth micrometer (preferred method for accuracy)

2 A machinist's rule.

If the measurement is above the maximum specification, the main bearing capscrew **must** be replaced.

Main Bearing Underhead Capscrew Length		
mm		in
120.00	MAX	4.724

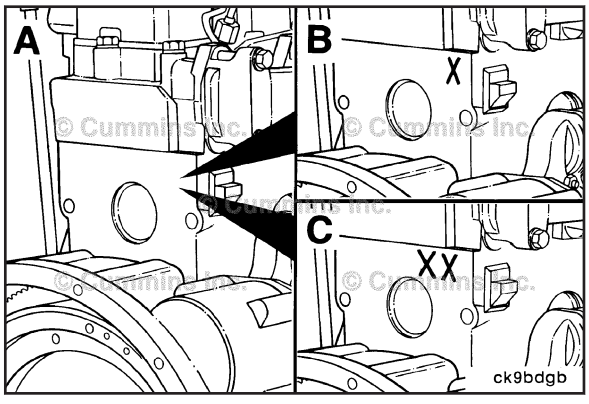
Measure the cylinder block's overall flatness.



Cylinder Block Flatness			
	mm		in
End-to-End	0.076	MAX	0.003
Side-to-Side	0.051	MAX	0.002

Inspect for any localized dips or imperfections. If present, the deck **must** be resurfaced.

For B3.9, B4.5, and B5.9 series engines, oversize head gaskets are available for resurfacing of the cylinder head and cylinder block combustion decks.



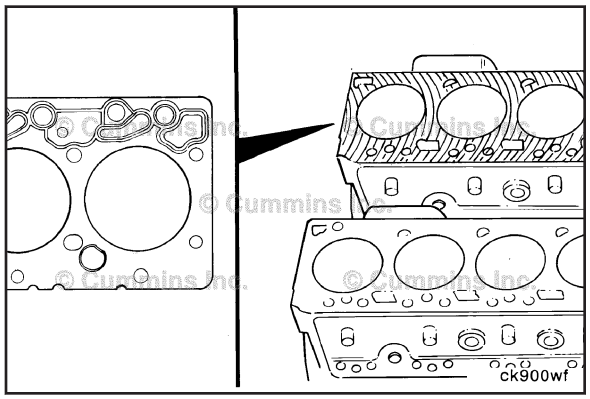
oversize head gaskets **must** be used to make sure the correct piston to cylinder head clearance can be maintained.

After machining, the cylinder block is stamped at the upper rear right corner surface of the cylinder block as follows:

A Standard none

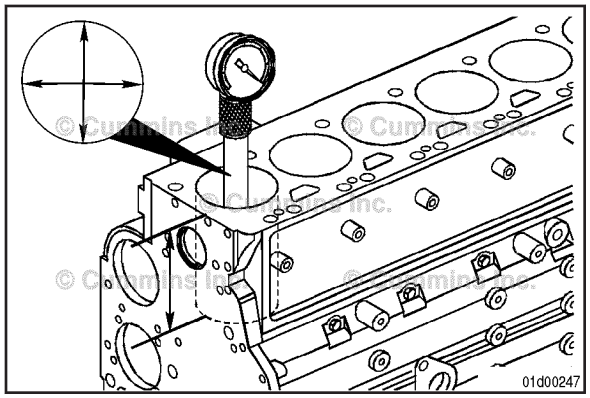
B 0.25 mm [0.010 in] machined for the first over size gasket X

C 0.50 mm [0.020 in] total for the second over size gasket XX.



For B4.5 RGT series engines, the combustion deck of the block can only be resurfaced if, after the resurface, the correct piston protrusion can be achieved.

A specific head gasket with an increased thickness is **not** available for combustion deck resurfacing. If the combustion deck can **not** be resurfaced such that the correct piston protrusion can be achieved, the cylinder block **must** be replaced.



B3.9, B4.5, and B5.9 Series Engines

⚠CAUTION⚠

Do not measure the bore diameter within 50 mm (1.97 in) of the block combustion deck. Inaccurate measurements will result.

NOTE: When measuring, deglazing, or boring a cylinder block, make sure all of the main bearing caps and torque plate are in place and properly torqued. Use the following procedure for proper torque values. Refer to Procedure 001-006 (Bearings, Main) in Section 1.

Inspect the cylinder bores for damage or excessive wear.

Use a dial bore gauge to measure the cylinder bore in four places, 90 degrees apart, at the top and bottom of the piston travel area.

Cylinder Bore Diameter - B3.9, B4.5, and B5.9 Series Engines Only (New Cylinder Block)		
mm		**in**
102.010	MIN	4.0161
102.030	MAX	4.0169

Cylinder Bore Diameter - B3.9, B4.5, and B5.9 Series Engines Only (Used Cylinder Block)		
mm		**in**
102.010	MIN	4.0161
102.050	MAX	4.0177

Out-of-Roundness		
mm		**in**
0.038	MAX	0.0015

Taper		
mm		**in**
0.076	MAX	0.003

NOTE: For B3.9, B4.5, and B5.9 Series Engines, the cylinders can be bored oversize twice for the use of oversize pistons and rings (0.5 mm [0.020 in] and 1 mm [0.040 in] over size). A repair sleeve can also be installed if the cylinder bore **must** be bored more than 1 mm [0.040 in] oversize. See the Overbore and/or Repair Sleeve section in this procedure.

B4.5 RGT Series Engines

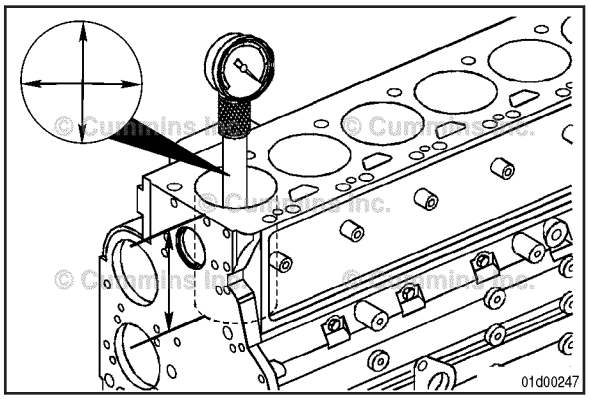
⚠CAUTION⚠

Do not measure the bore diameter within 50 mm (1.97 in) of the block combustion deck. Inaccurate measurements will result.

NOTE: When measuring, deglazing, or boring a cylinder block, make sure all of the main bearing caps are in place and properly torqued. Refer to Procedure 001-006 (Bearings, Main) in Section 1 for proper torque values.

Inspect the cylinder bores for damage or excessive wear.

Use a dial bore gauge to measure the cylinder bore in four places, 90 degrees apart, at the top and bottom of the piston travel area.



Cylinder Bore Diameter - B4.5 RGT Series Engines Only (New Cylinder Block)		
mm		**in**
106.990	MIN	4.2122
107.010	MAX	4.2130

Cylinder Bore Diameter - B4.5 RGT Series Engines Only (Used Cylinder Block)		
mm		**in**
106.990	MIN	4.2122
107.030	MAX	4.2138

Out-of-Roundness		
mm		**in**
0.038	MAX	0.0015

Taper		
mm		**in**
0.076	MAX	0.003

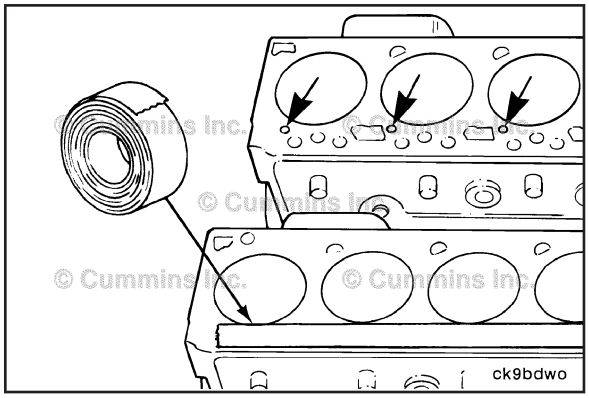
NOTE: For B4.5 RGT Series Engines, the cylinders can **only** be bored oversize **once** for the use of oversize pistons and rings (0.5 mm [0.020 in] oversize). A repair sleeve can be installed if the cylinder bore **must** be bored more than 1.5 mm [0.020 in] oversize. See the Overbore and/or Repair Sleeve section of this procedure.

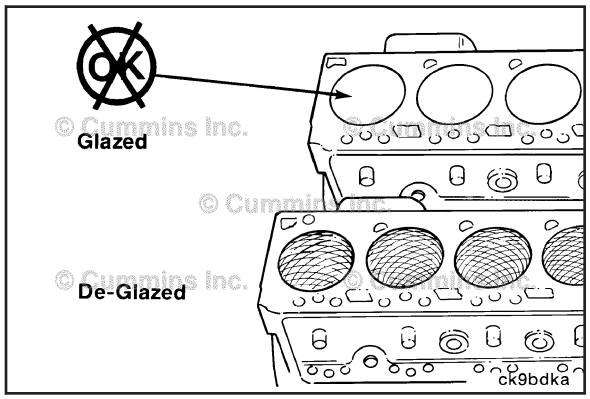
Repair

⚠CAUTION⚠

Precautions must be taken to prevent debris from any reconditioning operation from entering the lubricating oil passages of the engine. Engine damage will result.

Prior to any reconditioning of the cylinder bores, make sure to cover the lubricating holes and tappet holes in the top of the cylinder block with waterproof tape.

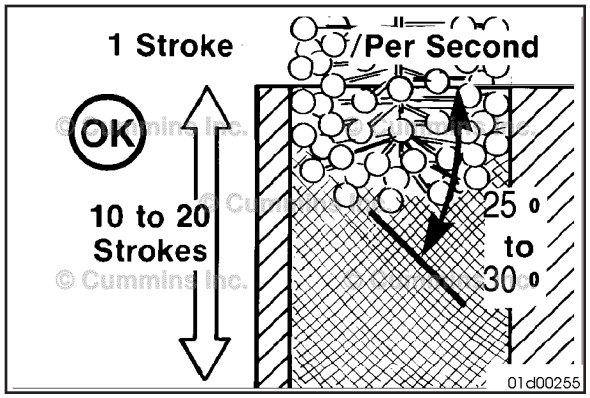




Deglaze:

Deglazing gives the cylinder bore the correct surface finish required to seat the piston rings. Deglazing **must only** be performed if the cylinder bores are still in specification.

NOTE: New piston rings will **not** seat in glazed cylinder bores.



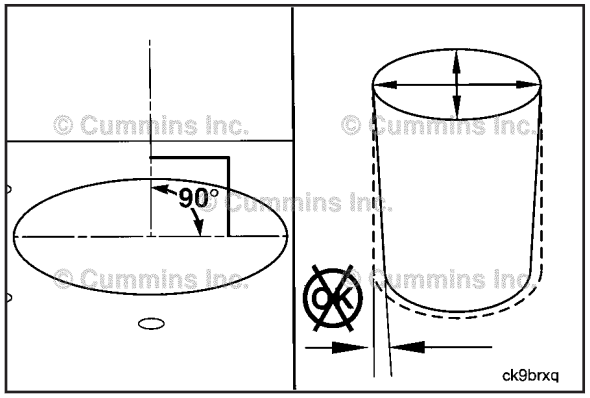
Use ball type hone and a rotational speed of 300 to 400 RPM with a stroke frequency of one stroke up and down per second. Make sure to use a good grade of honing oil or a mixture of equal parts SAE 30W engine oil and diesel fuel for a honing lubricant.

NOTE: Vertical strokes **must** be smooth, continuous passes along the full length of the cylinder bore.

Inspect the cylinder bore after 10 strokes.

NOTE: The crosshatch angle is a function of drill speed and how fast the hone is moved vertically. Moving too fast or too slow will give an incorrect crosshatch angle.

A correctly deglazed surface will have a crosshatched appearance with the lines at 25- to 30-degree angles with the top of the cylinder block.



Overbore:

If the cylinder bore was found out of specification or damaged, the cylinder bore can be refinished for oversize pistons and piston rings.

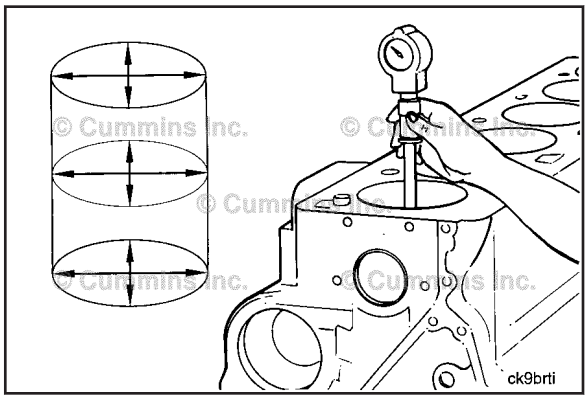
Boring **must** be done by qualified personnel on a suitable boring machine. Care **must** be taken to make sure the cylinders are perpendicular to the combustion deck and within taper and out-of-round specifications for the cylinder bore.

Follow the boring machine manufacturer's recommendations for machine setup to achieve the best quality bore.

NOTE: The boring diameters given below are **not** the finished cylinder bore dimensions. The finished cylinder bore diameter will be reached through the final honing operation.

The boring diameter dimensions are as follows:

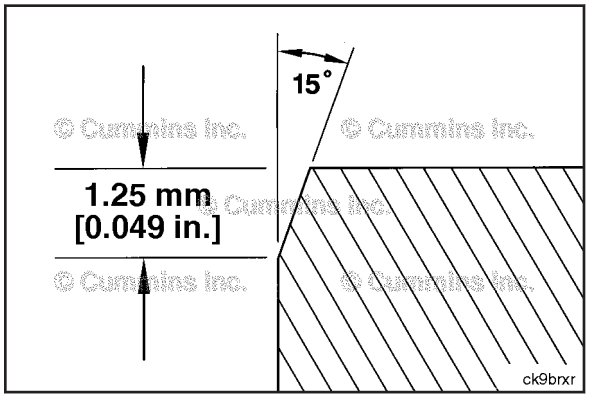
NOTE: Maximum cutting depth **must** be limited to 0.228 mm [0.009 in] per cut.



B3.9, B4.5, and B5.9 Series Engines Boring Diameter			
	mm		in
First Rebore	102.469	NOM	4.0342
Second Rebore	102.969	NOM	4.0539

B4.5 RGT Series Engines Boring Diameter			
	mm		in
Rebore	107.45	NOM	4.2303

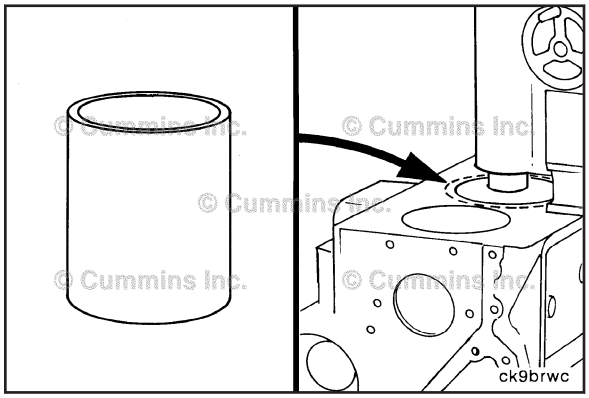
After boring, use a honing stone to break the edge of the bore to approximately 1.25 mm [0.049 in] at 15 degrees.

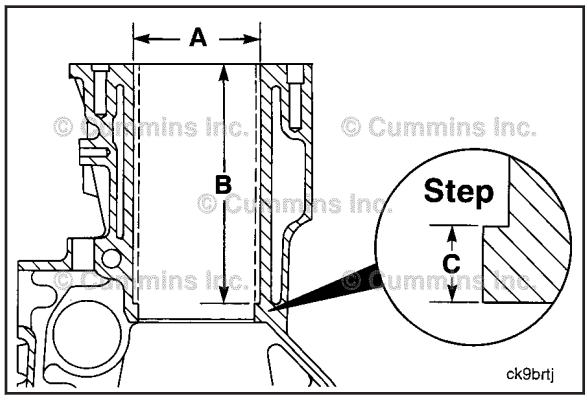


Repair Sleeve:

If more than 0.50 mm [0.020 in] in diameter oversize bore is required, the cylinder block **must** be rebored and a repair sleeve installed. The installation of a repair sleeve will allow for the use of standard size pistons and piston rings.

NOTE: Main bearing caps **must** be in place and properly torqued prior to any boring or measuring operations.





⚠CAUTION⚠

Boring must be done by qualified personnel on a suitable boring machine. Care must be taken to make sure that cylinders are perpendicular to the combustion deck and within taper and out-of-round specifications for the cylinder bore.

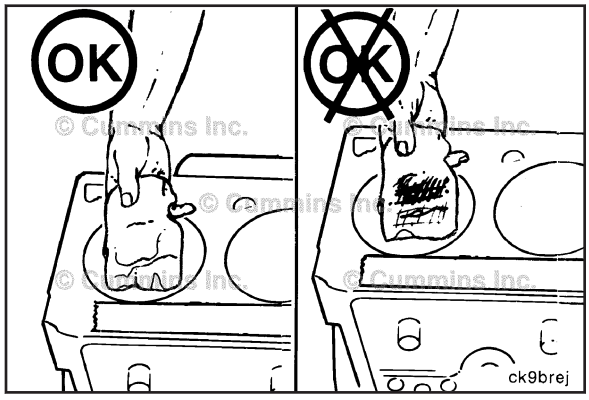
To prepare for repair sleeve installation, bore the cylinder(s) requiring a repair sleeve to:

Cylinder Bore Diameter (A)		
mm		**in**
109.700	MIN	4.3189
109.715	MAX	4.3195

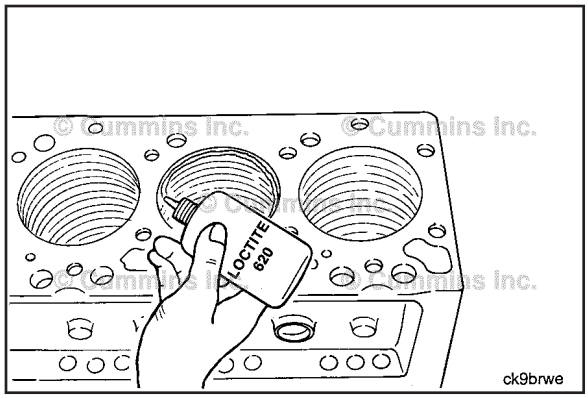
To a depth of:

Cylinder Bore Depth (B)		
mm		**in**
192.65	MAX	7.5846

This will result in a step at the bottom of the cylinder, approximately 6.35 mm [0.25 in] thick (C), against which the repair sleeve will sit.

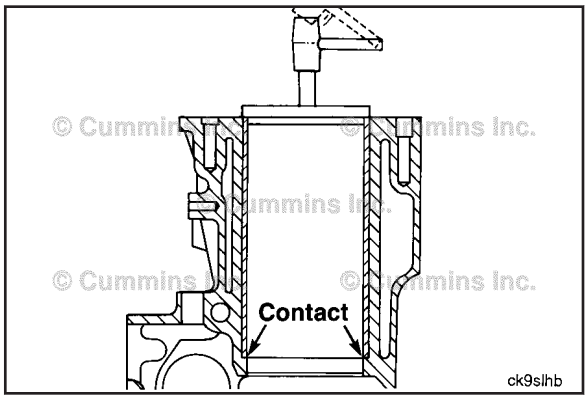


After boring, thoroughly clean the bore of all metal chips, debris and oil before installing the repair sleeve(s).

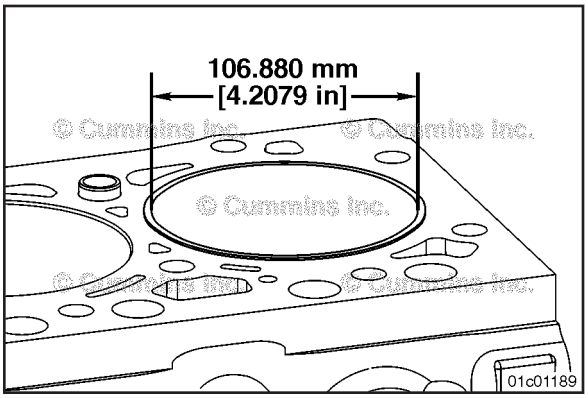


Apply a coat of Loctite 620 to the top of the cylinder bore, one at a time as the sleeve is installed.

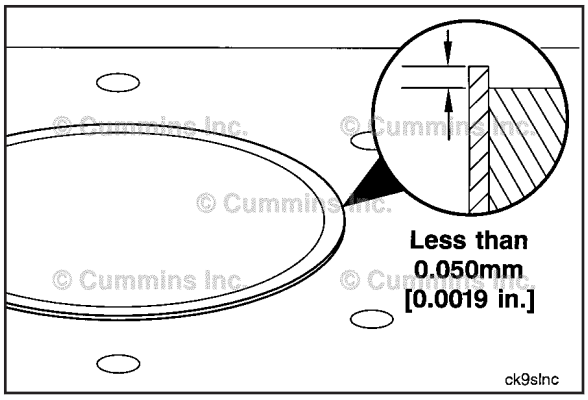
Use a sleeve driver, Part Number 3823230 for 102 mm [4.02 in], and Part Number 2892407 for 107 mm [4.21 in], to press or drive the repair sleeve into the cylinder bore until it contacts the step in the bottom of the bore.



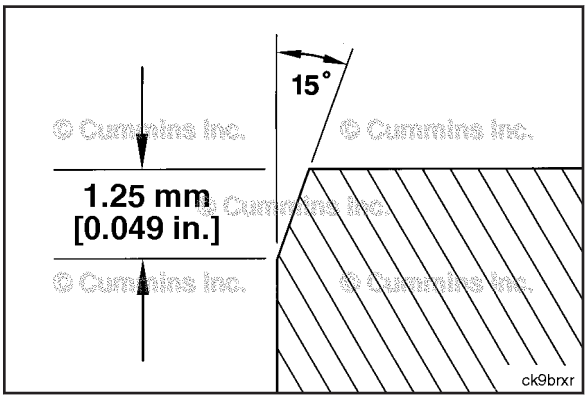
Bore the installed sleeve to 106.880 mm [4.2079 in].

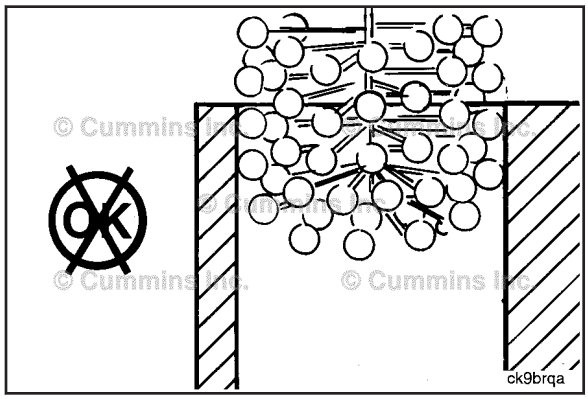


Machine the top of the sleeve to less than 0.050 mm [0.0019 in] protrusion above the combustion deck.



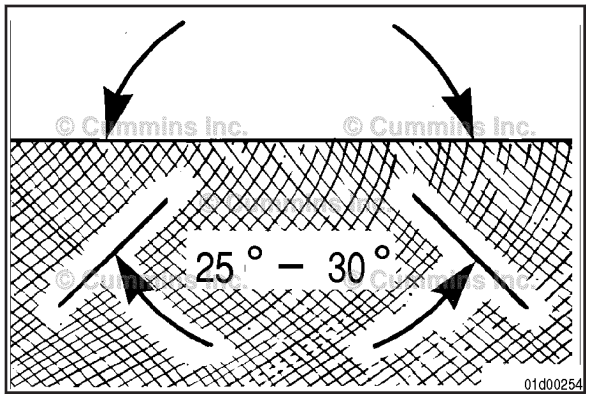
After boring, use a honing stone to break the edge of the bore to approximately 1.25 mm [0.049 in] at 15 degrees.



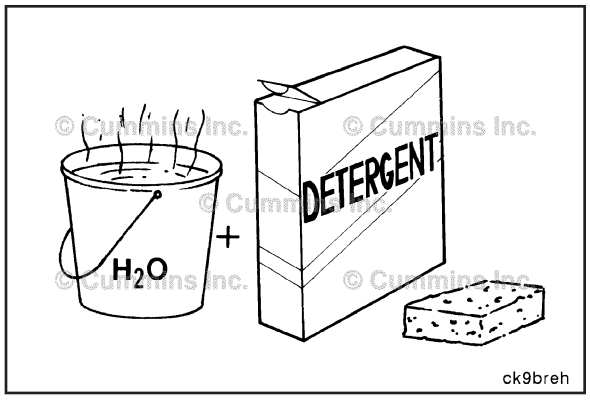


After boring a cylinder oversize or boring a repair sleeve, the cylinder requires a two stage honing process to finish the cylinder bores. It is recommended that quality equipment intended for honing engine cylinder bores be used.

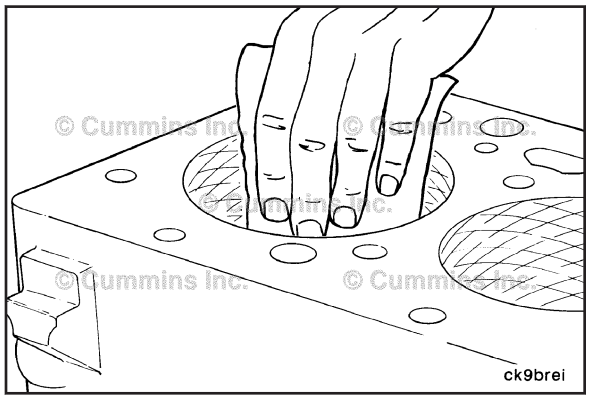
NOTE: Use of a ball-type hone is **only** recommended for refinishing cylinder walls that do need reboring and/or the installation of a repair sleeve.



A correctly finished cylinder bore surface will have a crosshatched appearance with the lines at 25- to 30-degree angles with the top of the cylinder block.



After Deglazing/Finishing Honing, use a strong solution of hot water and laundry detergent to clean the cylinder bores.



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

△CAUTION△
Clean the cylinder bores immediately after deglazing/ finish honing. Failure to do so can result in engine damage.

Rinse the cylinder bores until the detergent is removed.

Dry the cylinder block with compressed air.

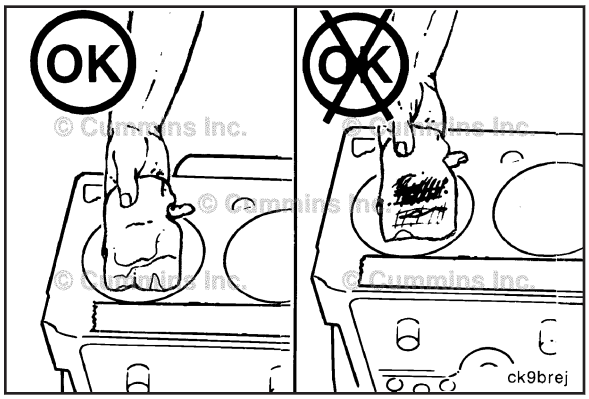
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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

△CAUTION△
Be sure to remove the tape covering the tappet holes after the cleaning process is completed. Failure to do so can result in engine damage.

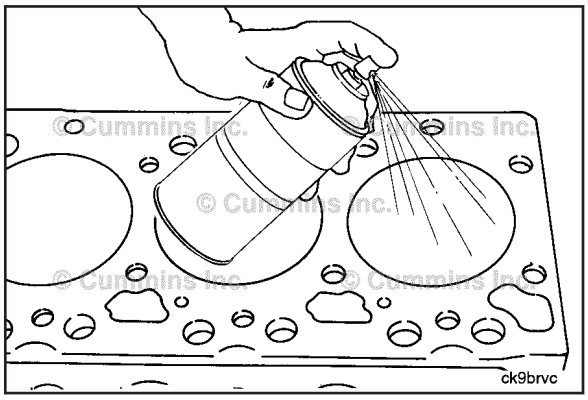
Check the cylinder bore cleanliness by wiping with a white, lint-free, lightly oiled cloth. If grit residue is still present, repeat the cleaning process until all residue is removed.

Wash the cylinder bores with solvent. Dry the cylinder block with compressed air.

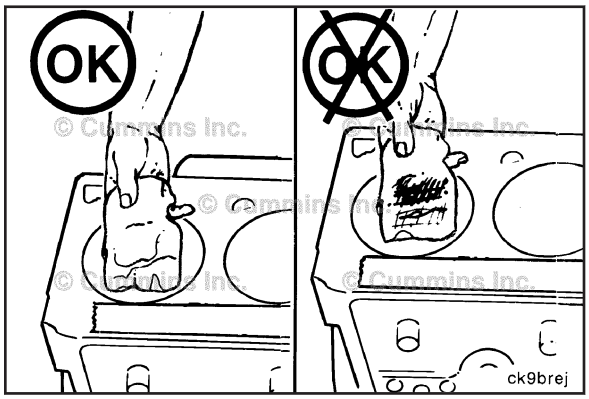


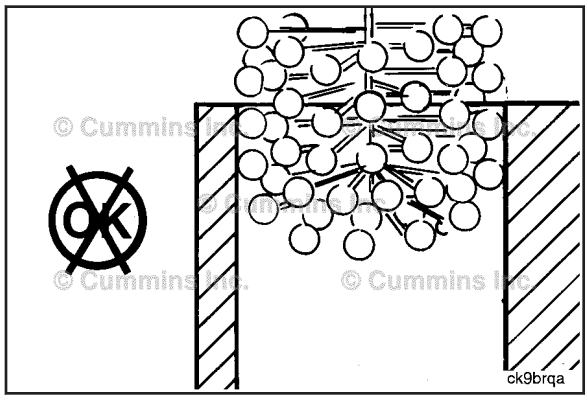
If the cylinder block is **not** to be used right away, coat all machined surfaces with a rust preventative solvent.

Make sure to cover the cylinder block to prevent dust and debris from collecting on and in the cylinder block.



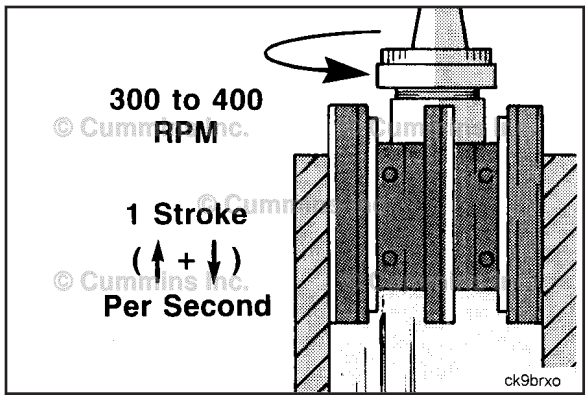
If replacing the cylinder block or using a previously stored cylinder block, make sure to clean any oil/rust preventative solvent from the cylinder bores, gasket sealing areas and main bearing bores prior to use.





After boring a cylinder oversize, the cylinder requires a two stage honing process to finish the cylinder bores. It is recommended that quality equipment intended for honing engine cylinder bores be used.

NOTE: Use of a ball-type hone is **only** recommended for refinishing cylinder walls that do need reboring and/or the installation of a repair sleeve.



Honing Process for B3.9, B4.5, and B5.9 Engines

Use a honing rotational speed of 300 to 400 RPM with a stroke frequency of 1 stroke up and down per second. Make sure to use a good grade of honing oil. For the first stage honing, or rough honing, use a soft (fast cutting) 80 grit silicone carbide stone. Hone the cylinders to their final size during this stage of honing.

For the second stage honing, or finish honing, use a medium hardness 285 grit silicone carbide stone. Hone the cylinder(s) for 15 to 20 strokes to apply the appropriate crosshatch.

Honing Diameter Dimensions B3.9, B4.5, and B5.9 Series Engines

	mm		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

Honing Diameter Dimensions B4.5 RGT and B6.7 Series Engines

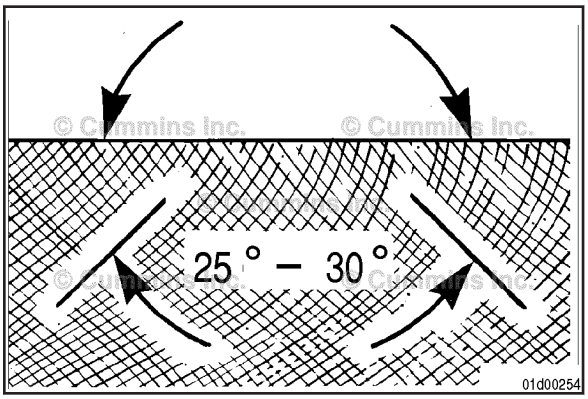
	mm		in
Standard Bore/Repair Sleeve	106.990	MIN	4.2122
	107.010	MAX	4.2130
Rebore	107.490	MIN	4.2319
	107.510	MAX	4.2327

Honing Process for B6.7 and B4.5 RGT Engines

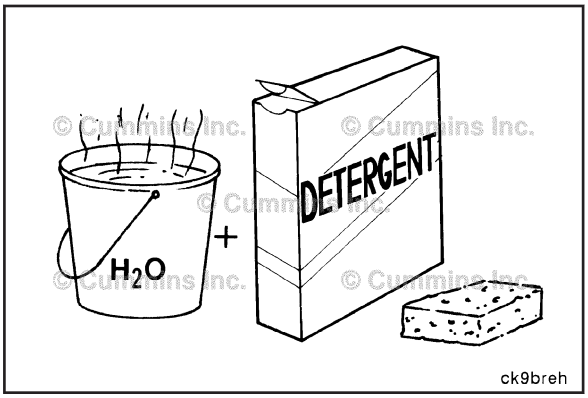
For the first stage honing, or rough honing, use a 160 grit diamond honing stone. Hone the cylinders to 106.9873 maximum.

For the second stage honing, or finish honing, use a 280 grit silicon carbide stone. Hone the cylinders to 106.990 minimum 107.000 maximum. Use a Plateau Honing Tools (PHT) brush for 10 to 12 strokes.

A correctly finished cylinder bore surface will have a crosshatched appearance with the lines at 25- to 30-degree angles with the top of the cylinder block.



After Deglazing/Finishing Honing, use a strong solution of hot water and laundry detergent to clean the cylinder bores.

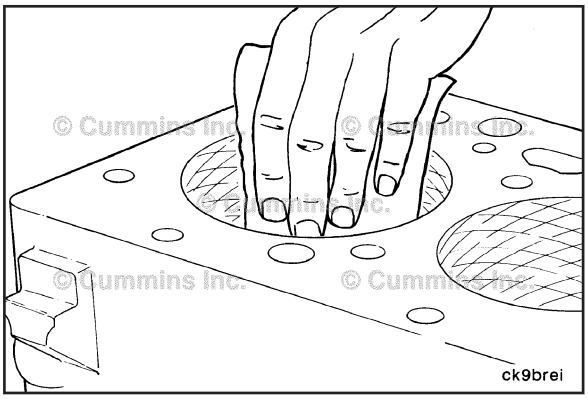


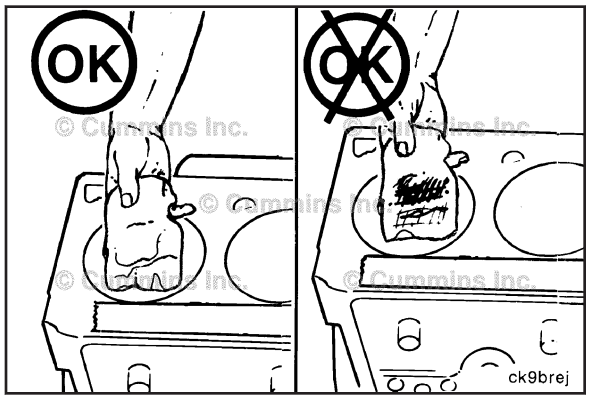
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Clean the cylinder bores immediately after deglazing/ finish honing. Failure to do so can result in engine damage.

Rinse the cylinder bores until the detergent is removed.

Dry the cylinder block with compressed air.





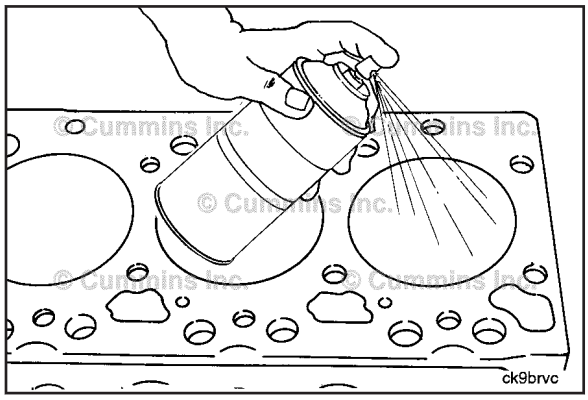
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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

△CAUTION△
Be sure to remove the tape covering the tappet holes after the cleaning process is completed. Failure to do so can result in engine damage.

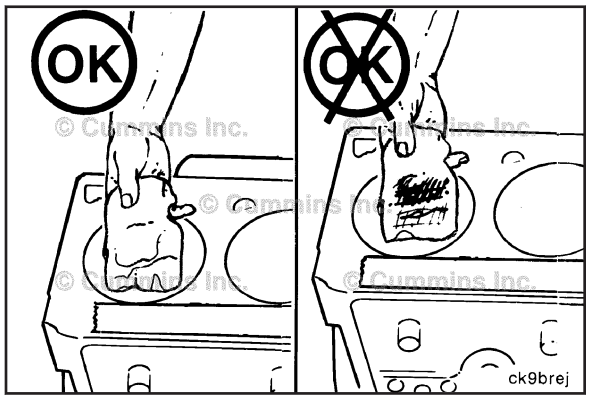
Check the cylinder bore cleanliness by wiping with a white, lint-free, lightly oiled cloth. If grit residue is still present, repeat the cleaning process until all residue is removed.

Wash the cylinder bores with solvent. Dry the cylinder block with compressed air.



If the cylinder block is **not** to be used right away, coat all machined surfaces with a rust preventative solvent.

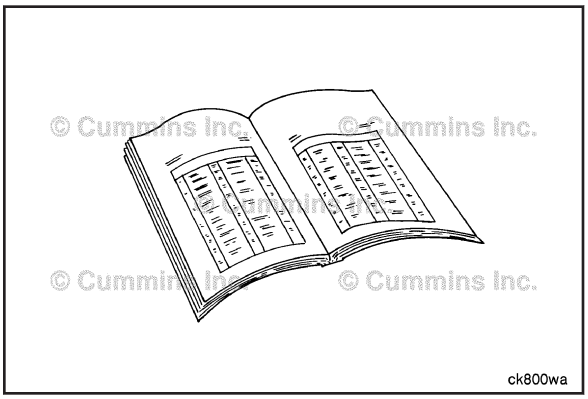
Make sure to cover the cylinder block to prevent dust and debris from collecting on and in the cylinder block.



If replacing the cylinder block or using a previously stored cylinder block, make sure to clean any oil/rust preventative solvent from the cylinder bores, gasket sealing areas, and main bearing bores prior to use.

Finishing Steps

- Assemble the engine. See Section AS - Engine Assembly
- Remove the engine from the stand and install the engine. Refer to Procedure 000-002 (Engine Installation) in Section 0.



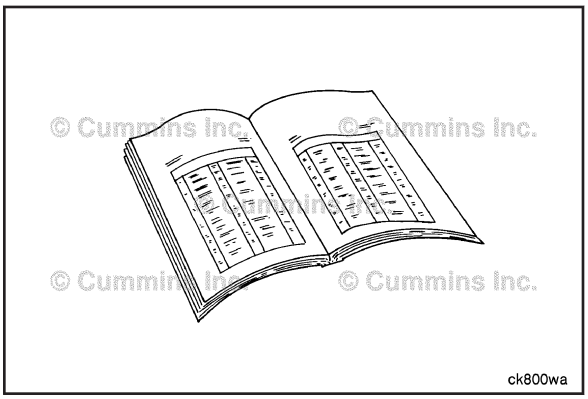
Gear Cover, Front (001-031)

Preparatory Steps

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. Refer to Procedure 013-009 in Section 013.
- Remove the engine water pump (cooling fan) drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the vibration damper/crankshaft pulley.
- If equipped, remove the viscous damper. Refer to Procedure 001-052 in Section 1.
- If equipped, remove the rubber damper. Refer to Procedure 001-051 in Section 1.
- If equipped, remove the crankshaft pulley **only**. Refer to Procedure 001-022 in Section 1.
- If required, remove the fan hub pulley. Refer to Procedure 008-039 in Section 8.
- Remove the front crankshaft seal. Refer to Procedure 001-023 in Section 1.

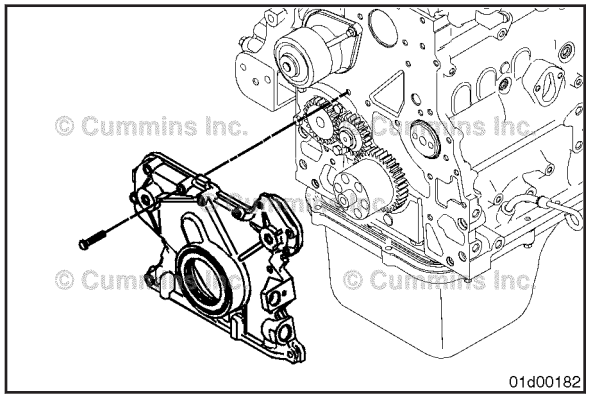


Front Gear Train

⚠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. Refer to Procedure 013-009 in Section 13.
- Remove the engine water pump (cooling fan) drive belt. Refer to Procedure 008-002 in Section 8.
- If required, remove the fan hub pulley. Refer to Procedure 008-039 in Section 8.
- Remove the vibration damper/crankshaft pulley.
- If equipped, remove the viscous damper. Refer to Procedure 001-052 in Section 1.
- If equipped, remove the rubber damper. Refer to Procedure 001-051 in Section 1.
- If equipped with a crankshaft pulley **only**. Refer to Procedure 001-022 in Section 1.



Remove

Rear Gear Train

△CAUTION△

Some rear gear train engines, with a cast aluminum front gear cover, have two threaded holes to aid in the removal of the front gear cover. When looking at the front of the front gear cover, there is a threaded through hole in the lower right-hand corner that can be used with a jackscrew. On the lower left-hand corner, there is a threaded blind hole. A capscrew can be inserted into that blind hole to be used with a slide hammer. Do NOT use the lower left-hand threaded blind hole as a jackscrew or the front gear cover will be damaged.

Remove the front gear cover mounting capscrews.

△CAUTION△

To break the seal, pry the front gear cover away from the front gear housing . Be careful NOT to damage the front gear cover when breaking the seal to the front gear housing.

Remove the front gear cover.

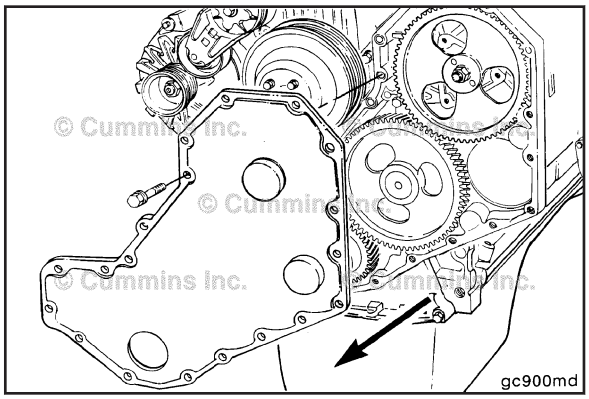
Front Gear Train

⚠CAUTION⚠
To break the seal, pry the front gear cover away from the front gear housing . Be careful NOT to damage the front gear cover when breaking the seal to the front gear housing.

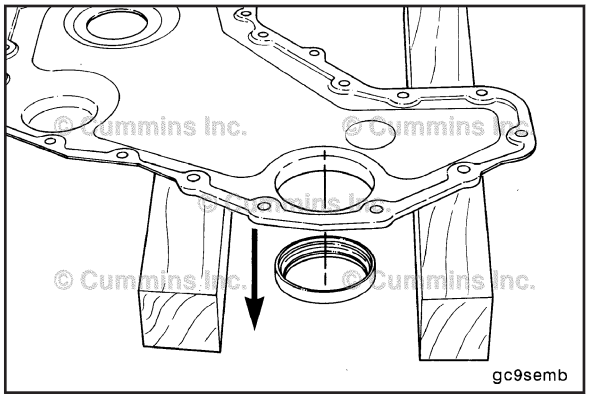
Remove the front gear cover mounting capscrews.

Remove the front gear cover with the front crankshaft seal.

NOTE: Some engines have an additional dust shield installed in front of the front crankshaft seal.



Remove the front crankshaft seal. Refer to Procedure 001-023 in Section 1.



Clean and Inspect for Reuse

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

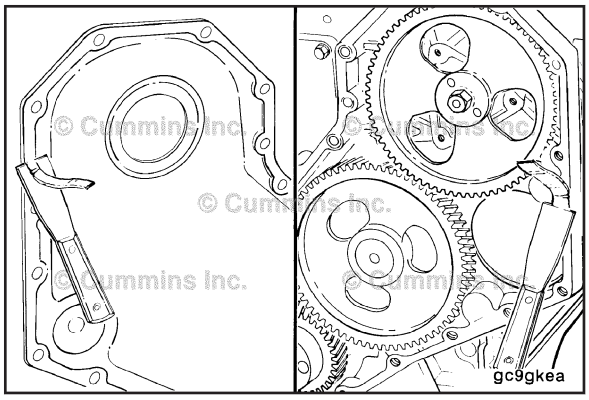
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

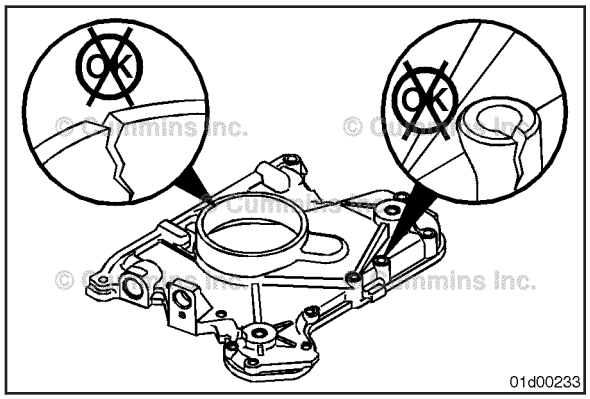
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Scrape the sealant from the front gear cover and gear housing surface for front gear train engines, or the cylinder block, for rear gear train engines.

Use solvent or steam to clean the front gear cover.

Dry the cover with compressed air.

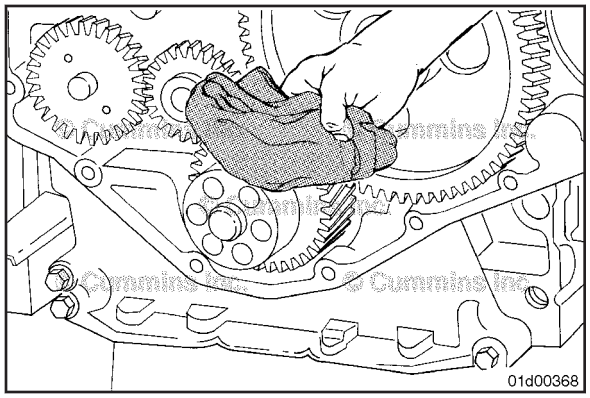




Inspect the gear cover for cracks or other damage.

Replace the front gear cover if **any** damage is found.

NOTE: Parts from the damaged front gear cover can be used again when replacing the front gear cover. Examples are the oil fill neck, fuel pump gear access plate, etc.

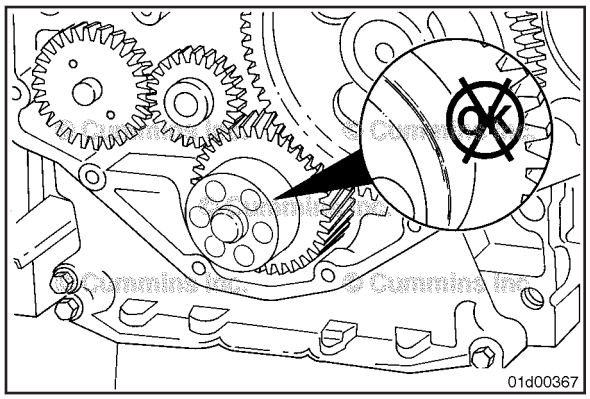


⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Use solvent to clean the oil and seal residue from the crankshaft surface.

Dry with compressed air.

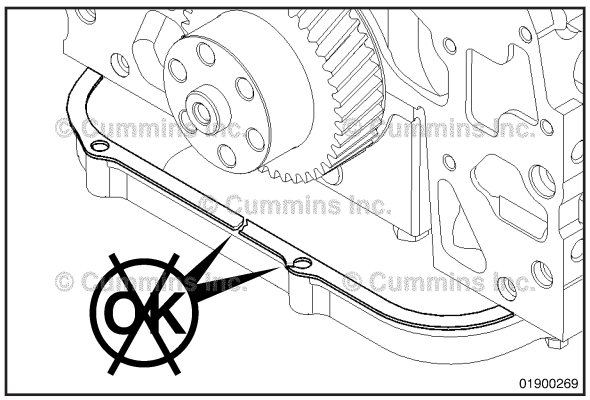


NOTE: If the crankshaft has excessive wear, a service wear sleeve is available for engines that use a lip style front crankshaft seal.

Inspect the nose of the crankshaft for excessive wear.

For engines equipped with a non-lip style front crankshaft seal, use a fine crocus cloth to remove any nicks or burrs. There is **no** wear sleeve available if the crankshaft nose sealing surface is damaged.

For engines equipped with a lip style front crankshaft seal, inspect the crankshaft seal contact area for a wear groove. If the groove is deeper than 0.25 mm [0.010 in], a wear sleeve and oversize seal **must** be used. Refer to Procedure 001-025 in Section 1.



For rear gear train engines, inspect the oil pan gasket for damage.

If the engine is equipped with a suspended oil pan with a rubber oil pan gasket, and the gasket is found to be damaged, the oil pan **must** be removed and the entire oil pan gasket replaced. Refer to Procedure 007-025 in Section 7.

Install

Rear Gear Train

NOTE: Install three guide pins, Part Number 3164977, to improve alignment of the front cover and front seal to the gear housing and crankshaft.

Apply a 1.5 to 2.0 mm [0.06 to 0.08 in] wide bead of sealant, Part Number 3164070, to the block side of the front gear cover in the path illustrated.

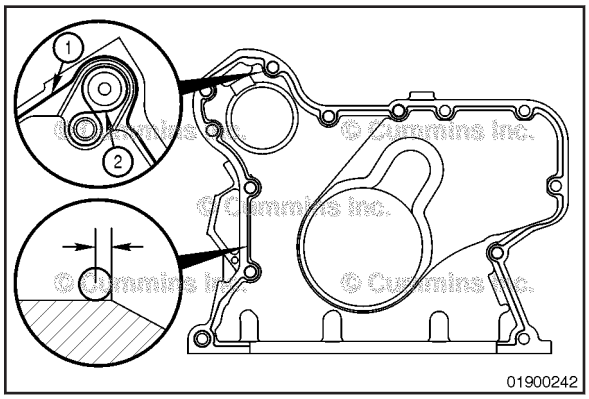
On engines equipped with an oil pressure sensor/switch located in the front gear cover, there are two critical sealant paths that **must** be followed:

1. In this area, the sealant **must** be applied towards the outer edge of the front gear cover to avoid an unused mounting hole in the cylinder block.

NOTE: To make sure the unused mounting hole in the cylinder block does not affect the sealing joint, fill the mounting hole with sealant, Part Number 3164070.

2. Sealant **must** be applied around both the mounting hole location and the oil supply hole in the front gear cover.

NOTE: Install the front cover within 10 minutes of applying the sealant, or the sealant will **not** seal correctly. Once installed, allow the sealant to dry for 30 minutes before operating the engine.

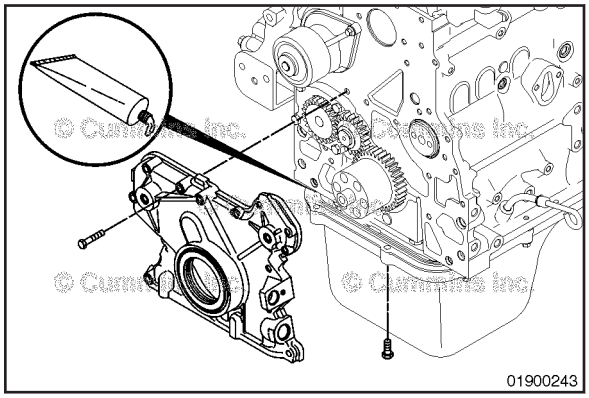


NOTE: Before installing the front gear cover, make sure sealant, Part Number 3164067, has been applied to the intersecting joint of the cylinder block, oil pan, and front gear cover.

Use the dowel rings to locate the front gear cover and install the front gear cover onto the cylinder block.

Install the front gear cover to the cylinder block using mounting capscrews and the oil pan to the front gear cover using mounting capscrews. Do **not** tighten the capscrews at this time.

If installed, remove the thread or wire holding the oil pan paper gasket in place.

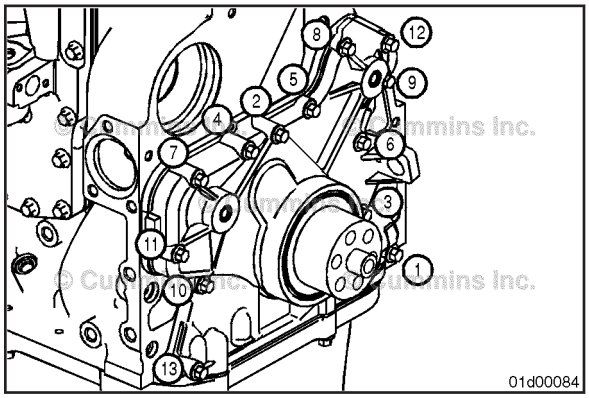


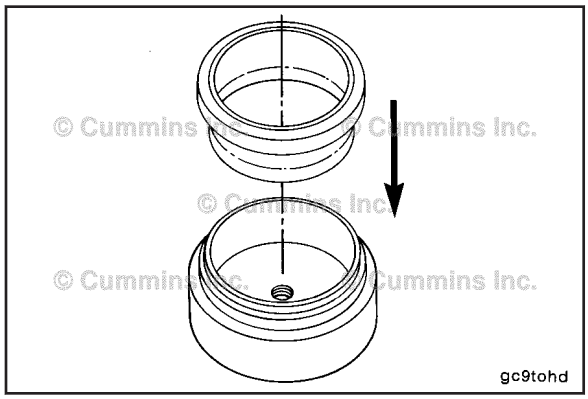
Tighten the front gear cover to the cylinder block mounting capscrews in the order indicated.

Tighten the oil pan-to-front gear cover mounting capscrews, starting with the inner capscrews first.

NOTE: Depending on the type of lubricating oil pan, there are two or four mounting capscrews.

Torque Value: 24 N•m [212 in-lb]

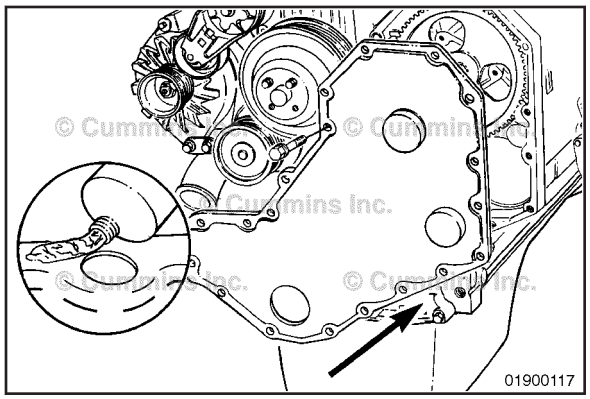




Front Gear Train

Install a new front crankshaft seal into the front gear cover prior to installing the front gear cover. Refer to Procedure 001-023 in Section 1.

Leave the plastic pilot installation tool in the front crankshaft seal.



⚠CAUTION⚠
The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

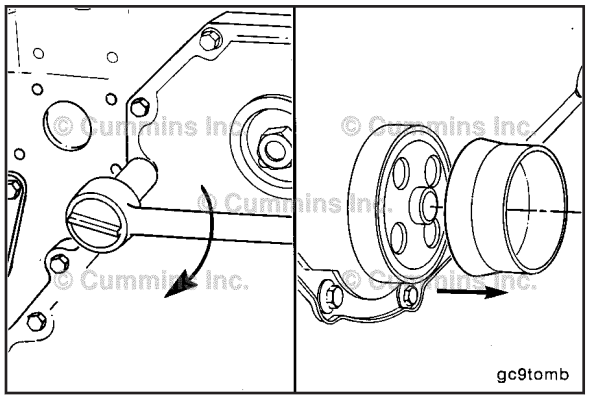
Stamped Steel Gear Cover - Apply a thin bead of sealant, Part Number 3164070, to the sealing surface of the front cover.

NOTE: Do **not** remove the plastic seal pilot tool from the front crankshaft seal at this time. Use the plastic seal pilot tool to guide the seal onto the crankshaft.

NOTE: Install the front cover within 10 minutes of applying the sealant, or the sealant will **not** seal correctly. Once installed, allow the sealant to dry for 30 minutes before operating the engine.

Cast Aluminum Gear Cover - Place the gasket, Part Number 3918673, between the gear cover and the gear housing.

Install the front gear cover on the engine, with the plastic seal pilot tool to guide the front crankshaft seal onto the crankshaft.



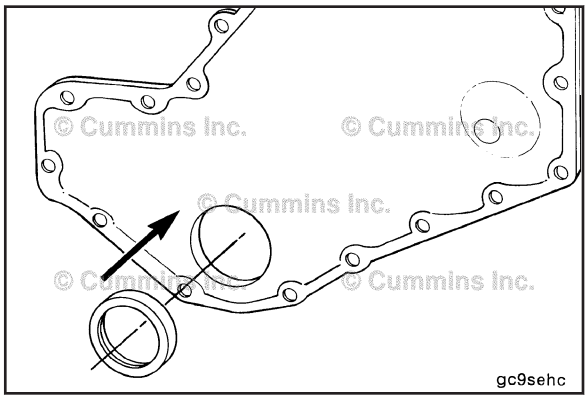
Install and tighten the front gear cover capscrews.

Torque Value: 24 N•m [212 in-lb]

Remove the plastic pilot tool from the crankshaft.

If previously equipped, or if the engine operates in a dusty environment, install a dust shield.

A pilot tool is **not** necessary for the dust shield. Slide the dust shield over the nose of the crankshaft.

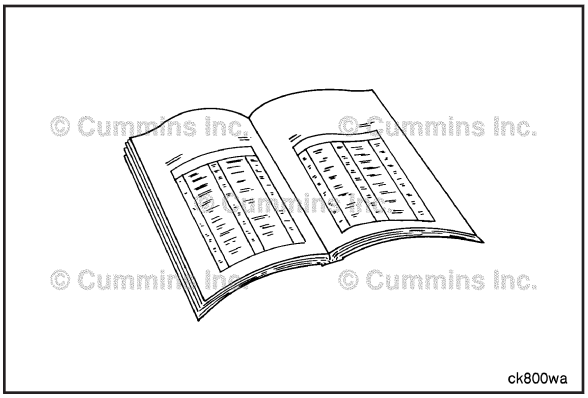


Finishing Steps

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.



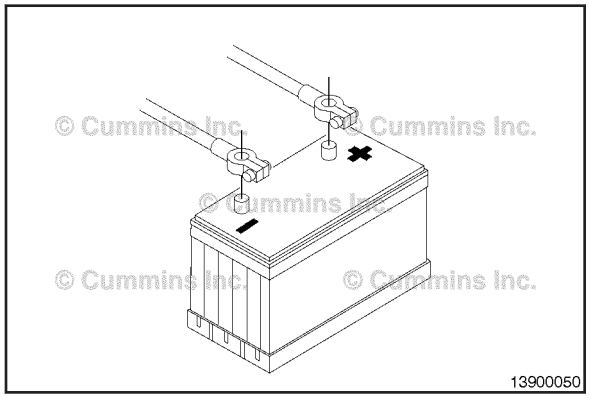
- If the oil pressure sensor/switch is located in the front gear cover, install and connect the sensor/switch. Refer to the OEM service manual.
- Install the crankshaft front seal. Refer to Procedure 001-023 in Section 1.
- If required, install the fan hub pulley. Refer to Procedure 008-039 in Section 8.
- Install the vibration damper/crankshaft pulley. Refer to Procedure 001-052 in Section 1.
- Install the vibration damper/crankshaft pulley. Refer to Procedure 001-051 in Section 1.
- If equipped with a crankshaft pulley **only** use the following procedure. Refer to Procedure 001-022 in Section 1.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate engine and check for leaks.

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 vibration damper/crankshaft pulley. Refer to Procedure 001-052 in Section 1.
- If equipped with a rubber damper. Refer to Procedure 001-051 in Section 1.
- If equipped with a crankshaft pulley **only**. Refer to Procedure 001-022 in Section 1.
- If removed, install the fan hub. Refer to Procedure 008-039 in Section 8.
- Install the engine water pump (cooling fan) drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



Gear Housing, Front (001-033)

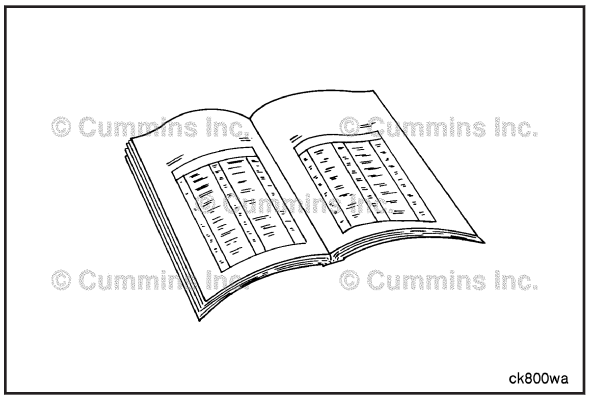
Preparatory Steps

⚠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.

⚠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.

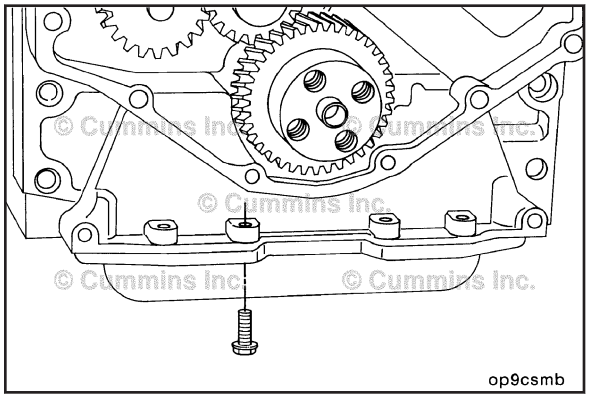


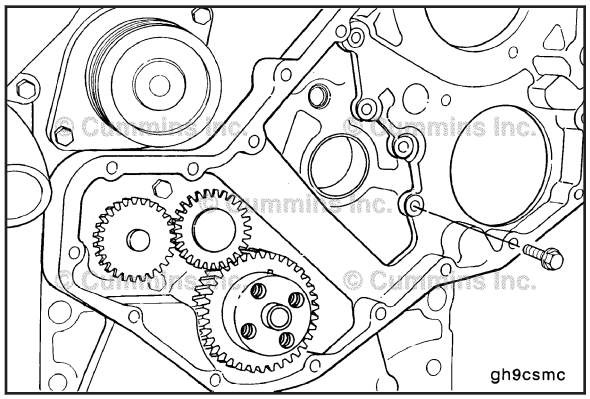
NOTE: The minimum clearance required from the front gear housing face to any obstruction in the camshaft area for camshaft removal is 81.28 cm [32 in]. If the required amount of clearance is **not** available, the engine **must** be removed from the vehicle. Refer to Procedure 000-001.

- Remove the engine water pump (cooling fan) drive belt. Refer to Procedure 008-002
- If required, remove the fan hub. Refer to Procedure 008-039
- Remove the vibration damper. If equipped with a viscous damper, refer to Procedure 001-052. If equipped with a rubber damper, refer to Procedure 001-051
- Remove the front gear cover. Refer to Procedure 001-031
- Remove the rocker lever cover. Refer to Procedure 003-011
- Remove the rocker levers. Refer to Procedure 003-008
- Remove the push tubes. Refer to Procedure 004-014
- Remove the fuel transfer pump. Refer to Procedure 005-045
- Use tappet replacement kit, Part Number 3822513, to raise the tappets. Refer to Procedure 004-015
- Remove the camshaft. Refer to Procedure 001-008
- Remove the fuel injection pump. For rotary fuel injection pumps, refer to Procedure 005-014. For inline fuel injection pumps, refer to Procedure 005-012
- Remove or disconnect driven accessories (i.e., hydraulic pump).

Remove

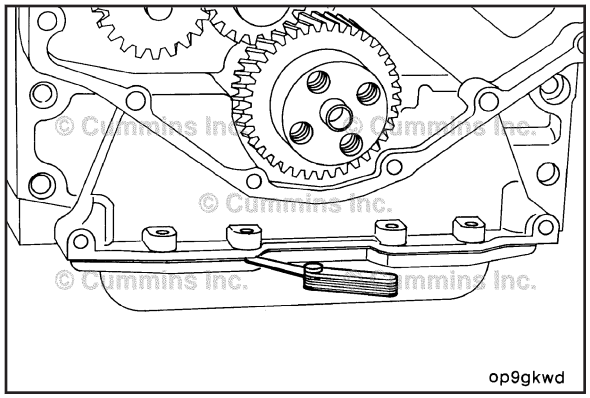
Remove the four front oil pan capscrews.



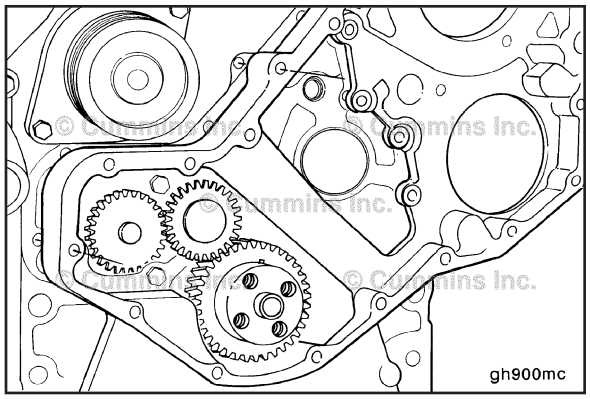


Remove the gear housing capscrews.

Note the location of the gear housing capscrews as they are removed. Some of the capscrews are an internal torx fastener and **must** be installed in the same location as removed to ensure proper clearance.

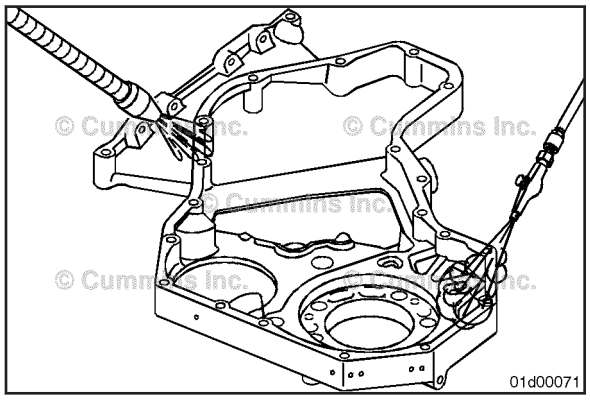


Using a feeler gauge, separate the lubricating oil pan gasket from the gear housing.



Use a plastic hammer to loosen the front gear housing.

Remove the gear housing.



Clean and Inspect for Reuse

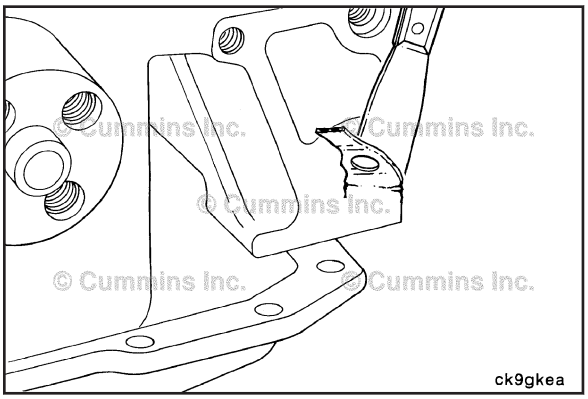
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear protective clothing and goggles to avoid personal injury.

Use solvent to clean the gear housing.

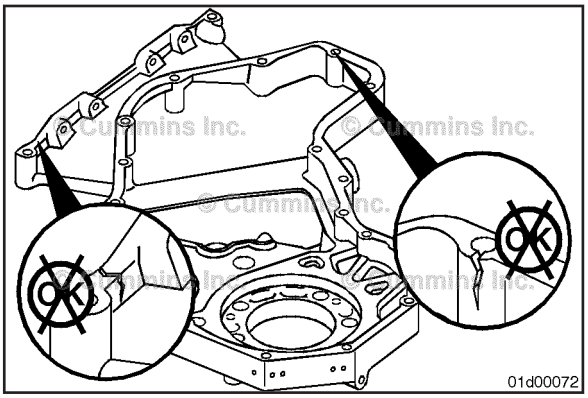
Dry the housing with compressed air.

Clean all gasket material from the cylinder block.

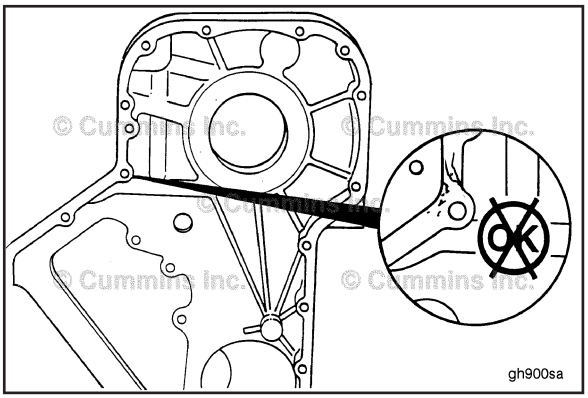


Inspect the gear housing for cracks or damage.

If any damage is found, replace the gear housing.

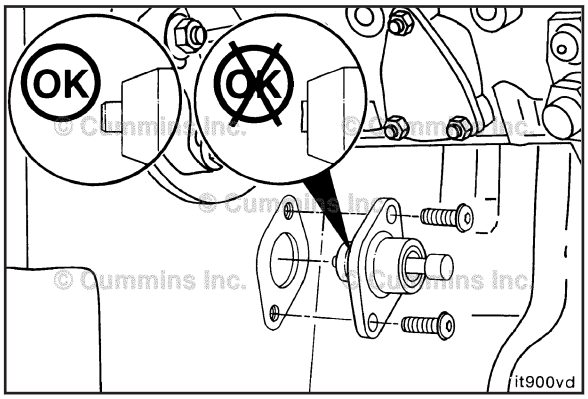


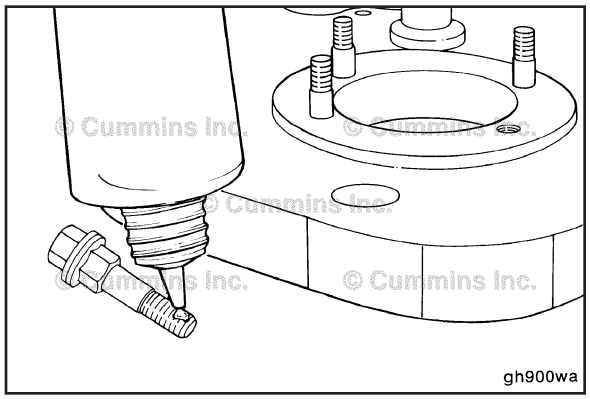
NOTE: If the front gear housing is cracked at the accessory drive hole or fuel injection pump mounting location, double check the mounting brackets, fasteners and component installation practices.



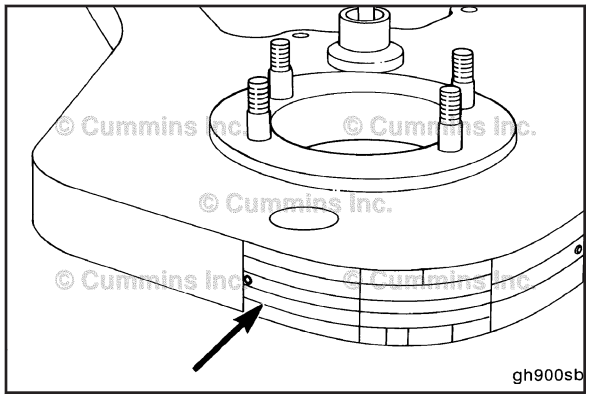
Inspect the timing pin housing and pin for damage.

NOTE: Do **not** remove the timing pin assembly unless it is damaged or leaking, or the gear housing is being replaced. Refer to Procedure 001-049.

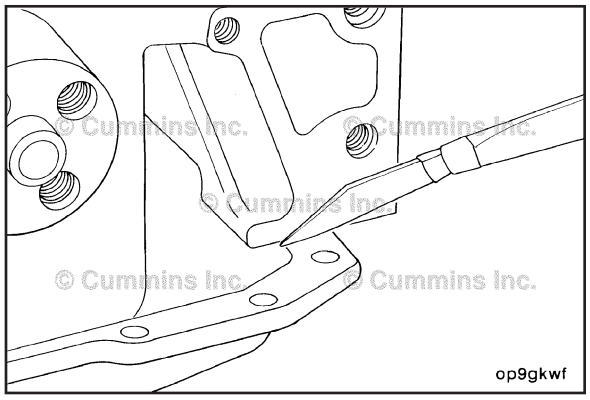




If the fuel injection pump studs are damaged or being installed in a new housing, coat the threads with Loctite 242. Use two nuts locked together to remove and install the studs.



If the gear housing is being replaced, remove the engine dataplate and install it on the new gear housing; refer to Procedure 001-057.



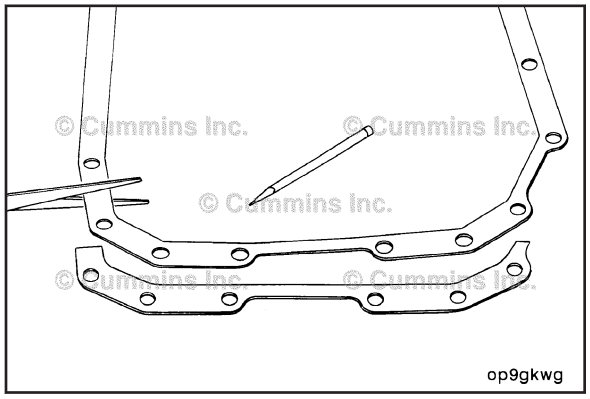
Install

For engines equipped with a paper gasket style oil pan, inspect the oil pan gasket for damage.

NOTE: If the engine is equipped with a suspended oil pan with a rubber oil pan gasket and the gasket is found to be damaged, the oil pan **must** be removed and the entire oil pan gasket replaced. Refer to Procedure 007-025. If the engine used sealant only between the gear housing and the oil pan, remove the old sealant and apply new sealant, Part Number 3164070, to the oil pan mounting flange.

If the pan gasket is torn, it can be repaired.

Cut the torn gasket off even with the front of the cylinder block.



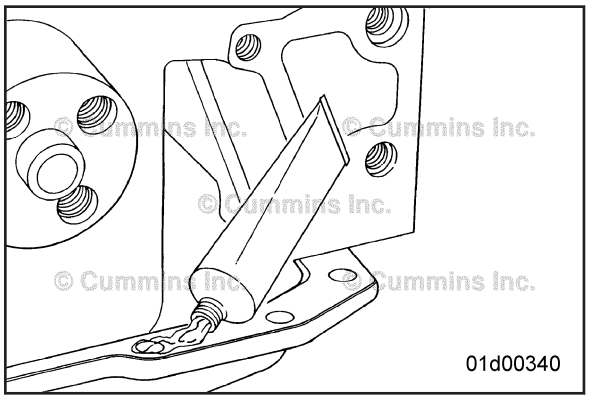
Using the old gasket as a pattern, cut the front section of a new gasket to the same size.

NOTE: The gear housing must be installed within 10 minutes of applying the sealant.

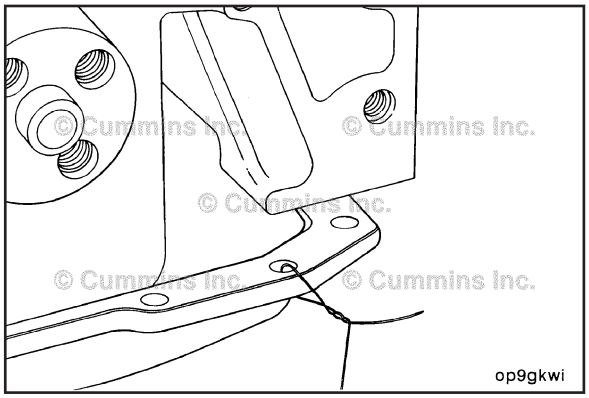
Clean the sealing surfaces.

Coat the new gasket on both sides with sealant, Part Number 3164067.

Be sure there is a bead of sealant at the intersecting joint of the cylinder block, oil pan, and gear housing.

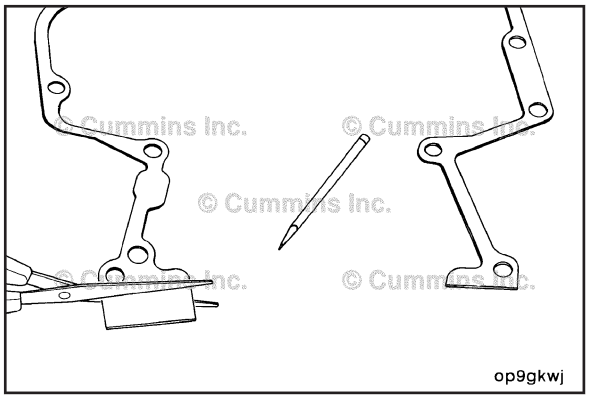


Use common thread or very fine wire to hold the new gasket splice in position as illustrated.



Check the fit of the new gear housing to cylinder block gasket. It may be necessary to trim the bottom edges of the gasket before installation.

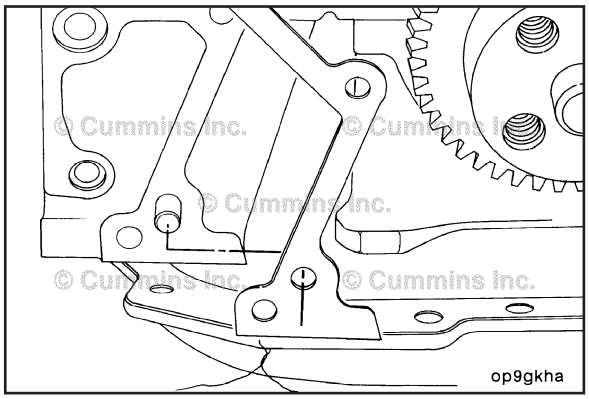
NOTE: When properly trimmed, the gear housing gasket **must** be even with the lubricating oil pan gasket when installed.

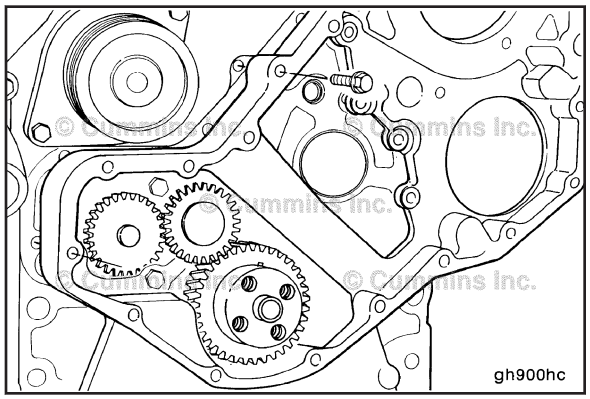


Position the gasket on the alignment dowels.

Use guide pins, M8 x 1.25 x 50, to assist in aligning the gasket and gear housing. Make sure to remove the guide pins after alignment.

Apply a bead of sealant, Part Number 3164067, at the intersecting joint of the cylinder block, oil pan, and gear housing.





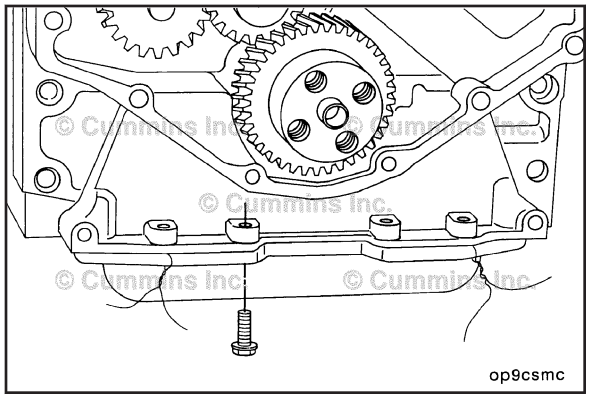
Carefully install the gear housing.

Make sure the gasket is still in place.

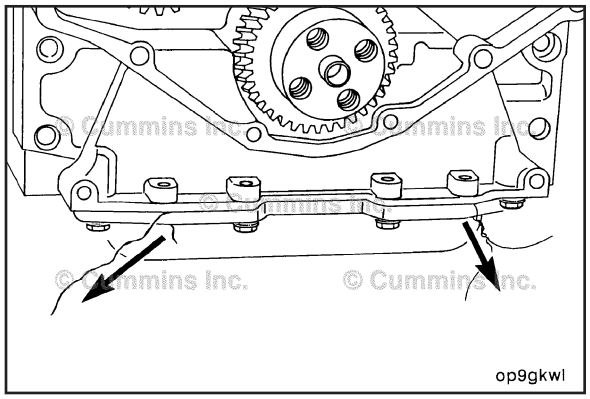
Install and tighten the mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]

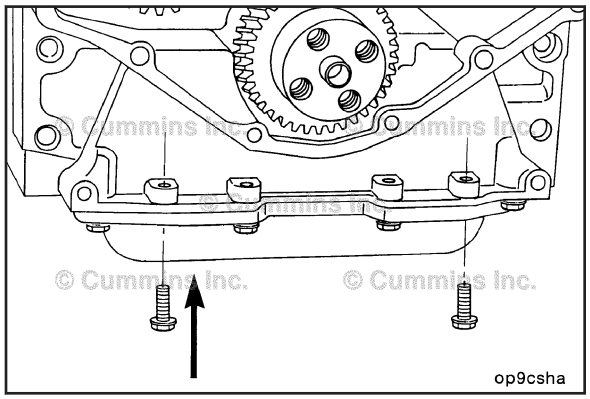
NOTE: If a new front gear housing and/or timing pin assembly is installed, the timing pin assembly **must** be accurately located. Refer to Procedure 001-049.



Start the oil pan capscrews into the holes **not** being used to tie the gasket in place.



Remove the thread or wire holding the gasket in place.

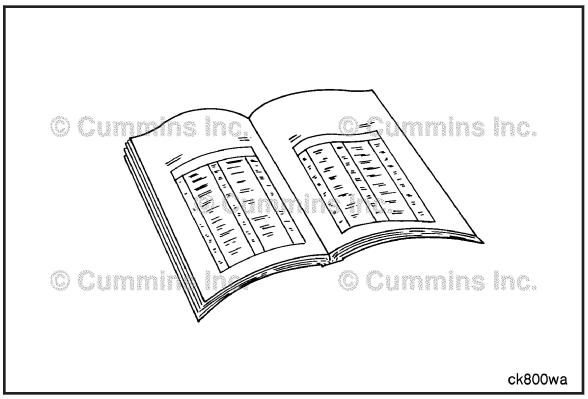


Install the remaining two capscrews.

Tighten the capscrews.

Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

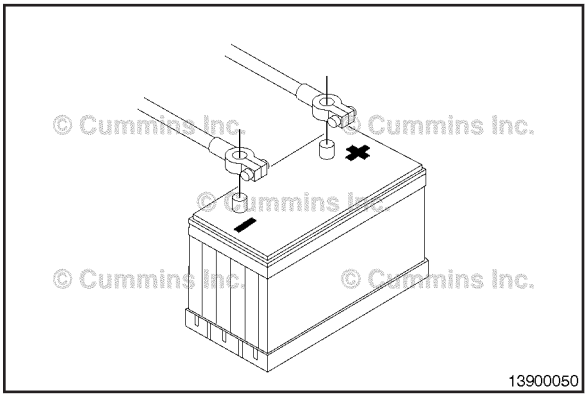


- Install the camshaft. Refer to Procedure 001-008
- Release the tappets. Refer to Procedure 004-015
- Install the push rods. Refer to Procedure 004-014
- Install the rocker levers. Refer to Procedure 003-008
- Adjust the valve lash. Refer to Procedure 003-004
- Install the rocker lever cover. Refer to Procedure 003-011
- Install the fuel transfer pump. Refer to Procedure 005-045
- Install the fuel injection pump. For rotary fuel injection pumps, refer to Procedure 005-014. For inline fuel injection pumps, refer to Procedure 005-012.
- Install or connect driven accessories (i.e., hydraulic pump)
- Install the front gear cover. Refer to Procedure 001-031
- Install the vibration damper. If equipped with a viscous damper, refer to Procedure 001-052. If equipped with a rubber damper, refer to Procedure 001-051
- If removed, install the fan hub. Refer to Procedure 008-039
- Install the engine water pump 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.

Operate the engine at idle for 5 to 10 minutes and check for leaks or loose parts.

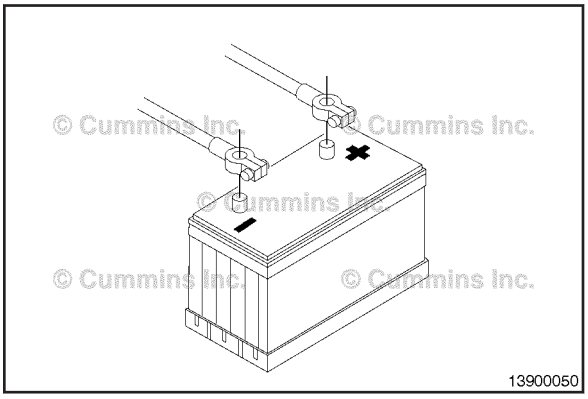


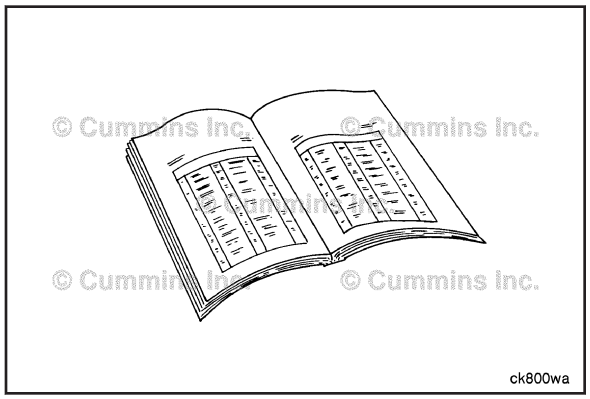
Gear Housing, Rear (001-034)

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.

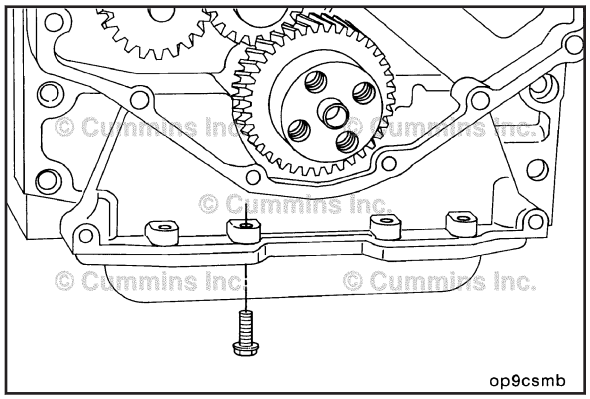
- Remove the transmission. Refer to the original equipment manufacturer's instructions
- Remove the flywheel or flexplate. Refer to Procedure 016-005 or Procedure 016-004
- Remove the rear crankshaft seal. Refer to Procedure 001-024

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause personal injury.

- Remove the flywheel housing. Refer to Procedure 016-006
- Remove the fuel transfer pump. Refer to Procedure 005-045
- Remove the fuel injection pump. For rotary fuel injection pumps, refer to Procedure 005-014. For inlne fuel injection pumps, refer to Procedure 005-012.
- If equipped, remove the hydraulic pump unit. Refer to Procedure 009-016.

Service Tip: Engines equipped with air compressors may require that the air compressor be timed to the engine. To ensure that the air compressor is properly timed when the camshaft gear is later installed, scribe an alignment line on the air compressor and camshaft gear before removing the camshaft gear or air compressor.

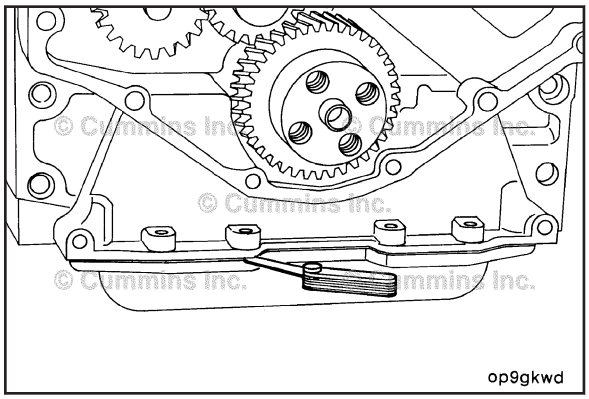
- If equipped, remove the air compressor. Refer to Procedure 012-014
- Remove the camshaft gear and camshaft. Refer to Procedure 001-008



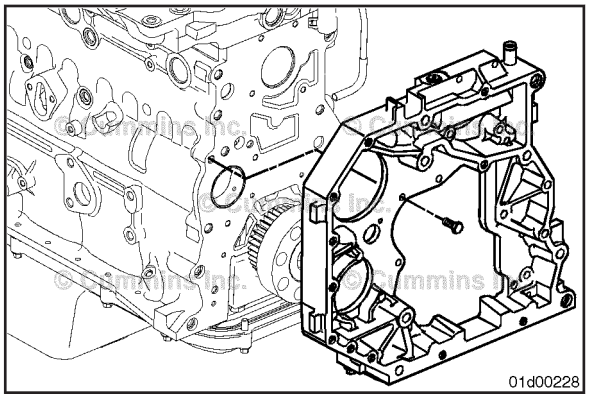
Remove

Remove the four (4) oil pan to rear gear housing capscrews.

Using a feeler gauge, separate the lubricating oil pan gasket from the gear housing.



Remove the rear gear housing capscrews and housing.



Clean and Inspect for Reuse

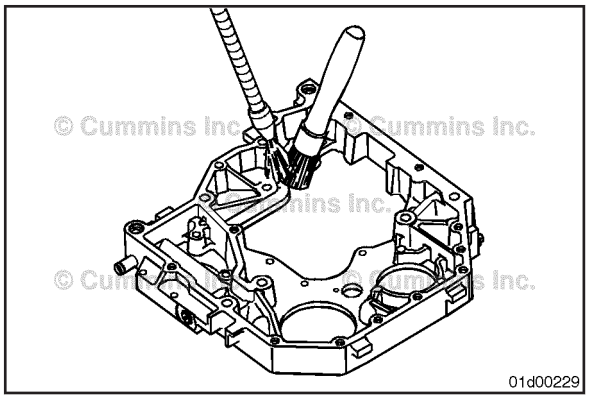
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

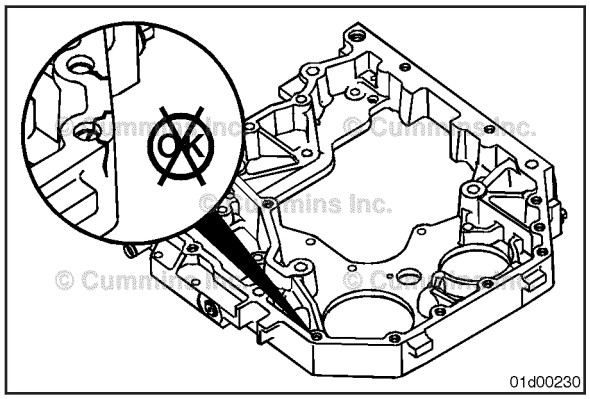
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the rear gear housing with solvent. Dry with compressed air.

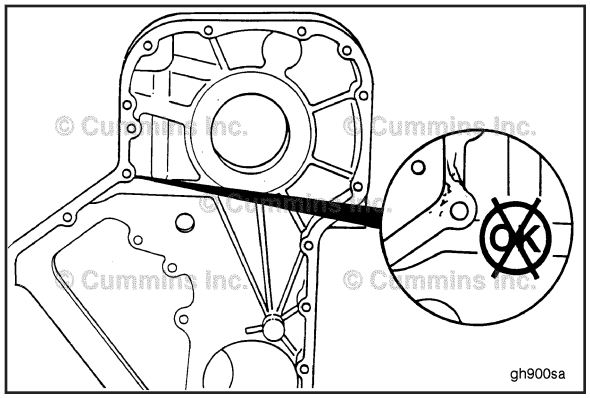
Clean the oil supply hole for the accessory drive.

NOTE: The rear gear housing has oil drain and supply passages designed into the housing. Make sure these passages are clean and free of debris.

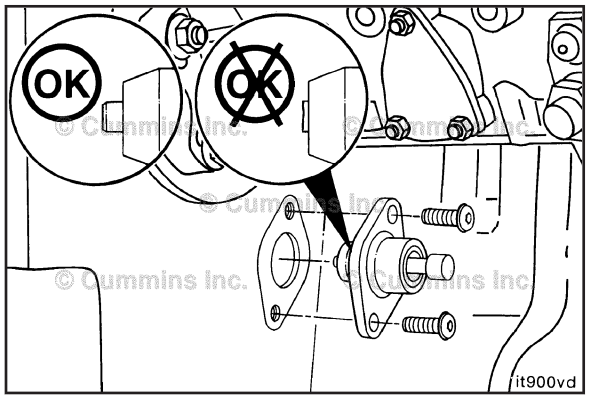




Inspect the rear gear housing for signs of leakage or any other damage.

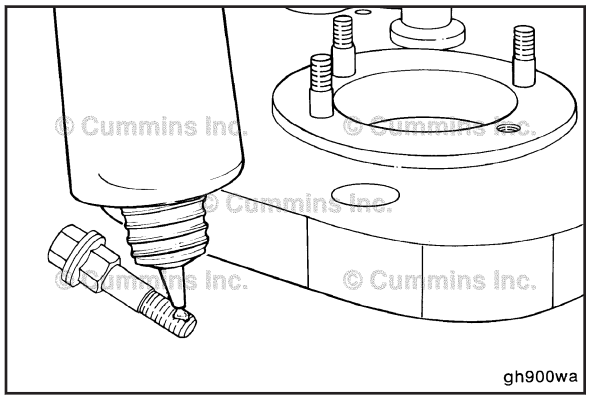


NOTE: If the rear gear housing is cracked at the accessory drive hole or fuel injection pump mounting location, double check the mounting brackets, fasteners and component installation practices.



Inspect the timing pin housing and pin for damage.

NOTE: Do **not** remove the timing pin assembly unless it is damaged or leaking, or the gear housing is being replaced. Refer to Procedure 001-049.



If the fuel injection pump studs are damaged or being installed in a new housing, coat the threads with Loctite 242. Use two nuts locked together to remove and install the studs.

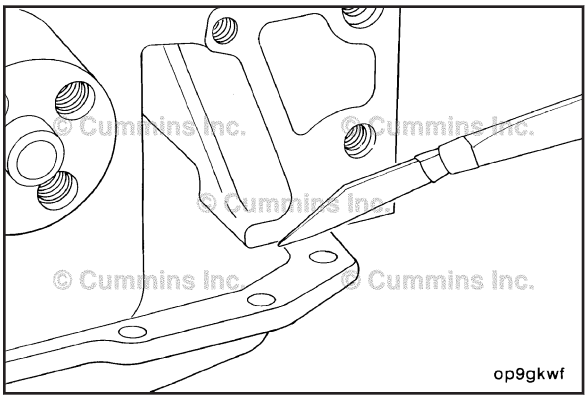
Install

For engines equipped with a paper gasket style oil pan, inspect the oil pan gasket for damage.

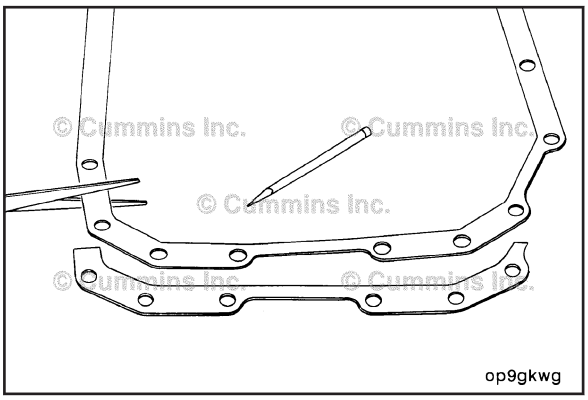
NOTE: If the engine is equipped with a suspended oil pan with a rubber oil pan gasket and the gasket is found to be damaged, the oil pan **must** be removed and the entire oil pan gasket replaced. Refer to Procedure 007-025. If the engine used sealant only between the gear housing and the oil pan, remove the old sealant and apply new sealant, part number 3164070, to the oil pan mounting flange.

If the pan gasket is torn, it can be repaired.

Cut the torn gasket off even with the front of the cylinder block.



Using the old gasket as a pattern, cut the front section of a new gasket to the same size.

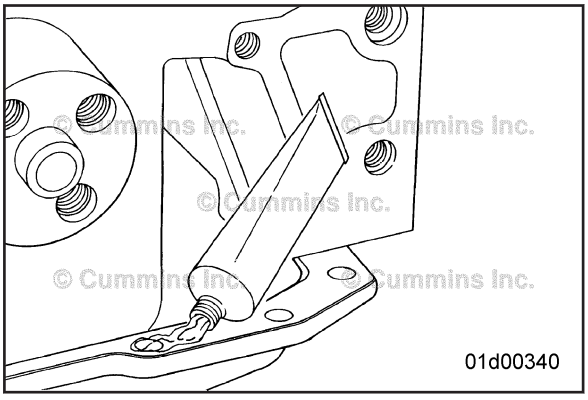


NOTE: The gear housing **must** be installed within 10 minutes of applying the sealant.

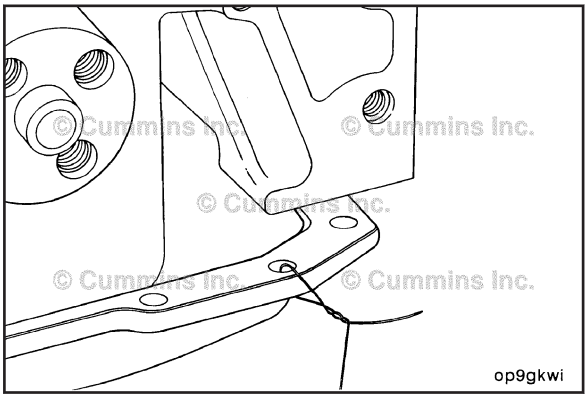
Clean the sealing surfaces.

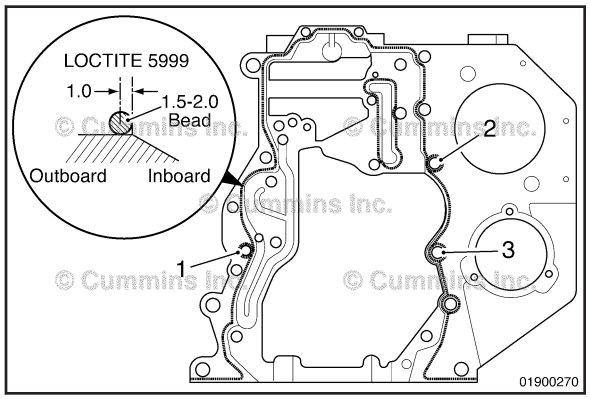
Coat the new gasket on both sides with sealant, Part Number, 3164067.

Be sure there is a bead of sealant at the intersecting joint of the cylinder block, oil pan, and gear housing.



Use common thread or a very fine wire to hold the new gasket splice in position as illustrated.





⚠CAUTION⚠

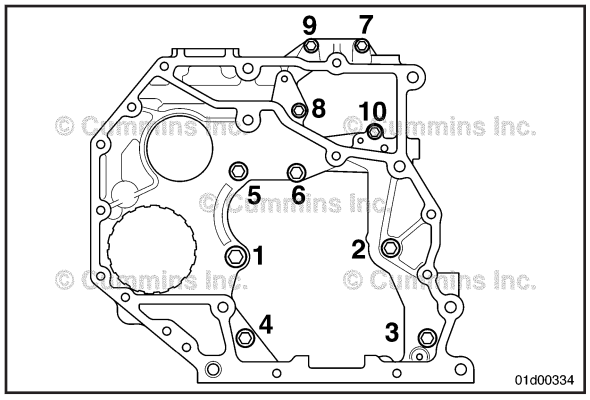
Make sure to only apply sealant to the areas specified. Failure to do so may block oil passages to the accessory drive and/or cause a loss of oil pressure. This will result in severe engine damage.

Apply a 1.5 to 2.0 mm [0.06 to 0.08 in] wide bead of sealant, Part Number 3164070, to the block side of the gear housing in the path illustrated and install the rear gear housing capscrews and housing.

NOTE: Make sure to apply a bead of sealant around the mounting capscrew holes shown, locations 1, 2 and 3.

Be sure there is a bead of sealant at the intersection joint of the cylinder block, oil pan, and gear housing.

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.

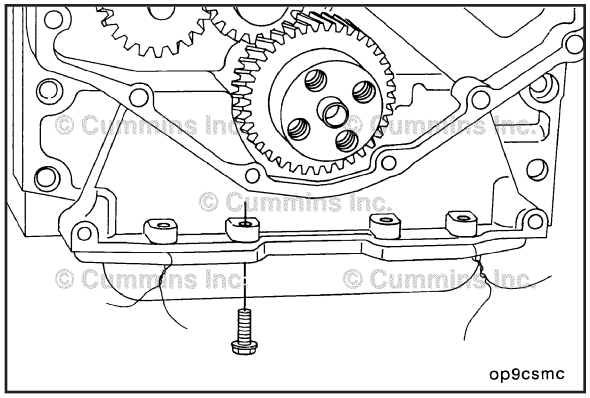


Tighten the capscrews as shown.

Torque Value:

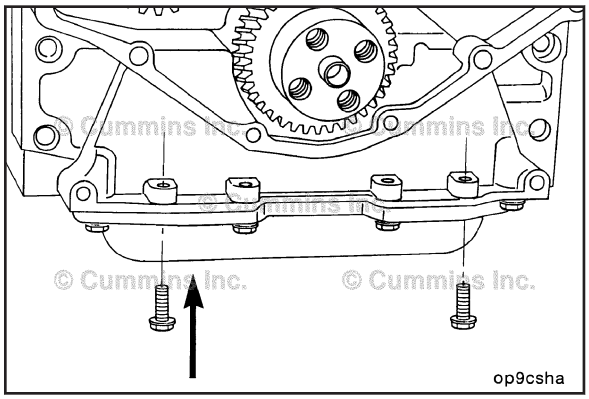
M12	50 N•m	[37 ft-lb]
M10	47 N•m	[35 ft-lb]
M8	24 N•m	[212 in-lb]

NOTE: If a rear gear housing and/or timing pin assembly is installed, the timing pin **must** be accurately located. Refer to Procedure 001-049



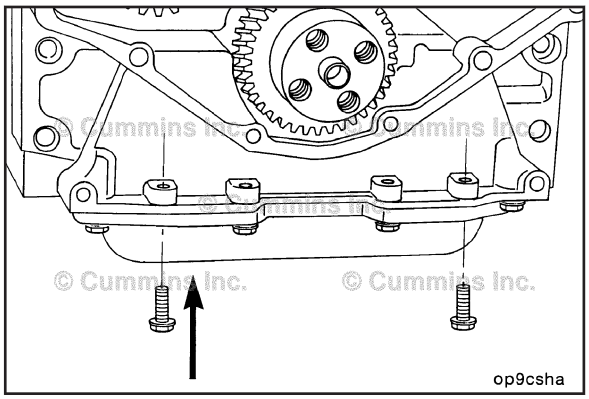
Start the oil pan capscrews in the holes **not** being used to tie the gasket in place.

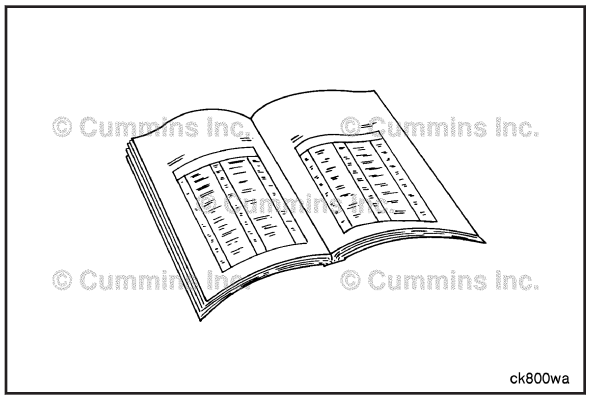
Remove the thread or wire holding the gasket in place.



Install the remaining two (2) oil pan capscrews and tighten.

Torque Value: 28 N•m [21 ft-lb]





Finishing Steps

- Install the camshaft gear and camshaft. Refer to Procedure 001-008.

Service Tip: Engines equipped with air compressors may require that the air compressor be timed to the engine. To ensure that the air compressor is properly timed when the camshaft gear is installed, a line should have been scribed during when removed. Align this line when installing the air compressor. If the line was **not** scribed or is no longer available, refer to Procedure 012-014.

- If equipped, install the air compressor. Refer to Procedure 012-014
- If equipped, install the hydraulic pump unit. Refer to Procedure 009-016
- Install the fuel transfer pump. Refer to Procedure 005-045
- Install the fuel injection pump. For rotary fuel injection pumps, refer to Procedure 005-014. For inline fuel injection pumps, refer to Procedure 005-012.

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause personal injury.

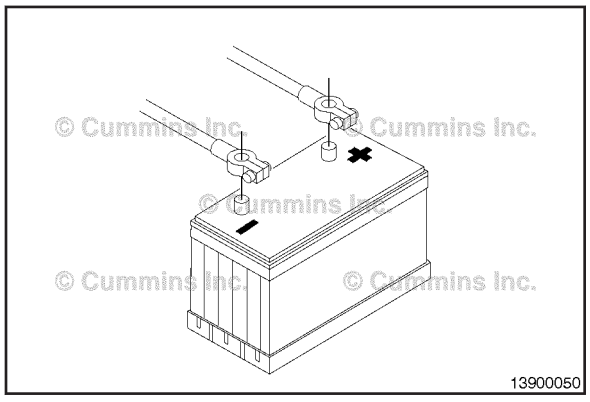
- Install the flywheel housing. Refer to Procedure 016-006
- Install the rear crankshaft seal. Refer to Procedure 001-024.

⚠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.

- Install the flywheel or flexplate. Refer to Procedure 016-005 or Procedure 016-004.

⚠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.

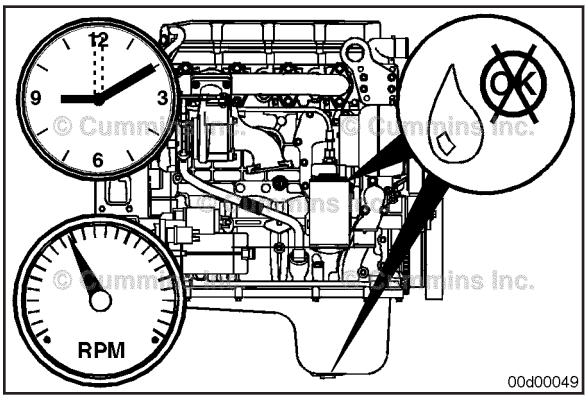
- Install the transmission. Refer to the original equipment manufacturer's instructions.



⚠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.

Reconnect the batteries.

Operate the engine and check for leaks.



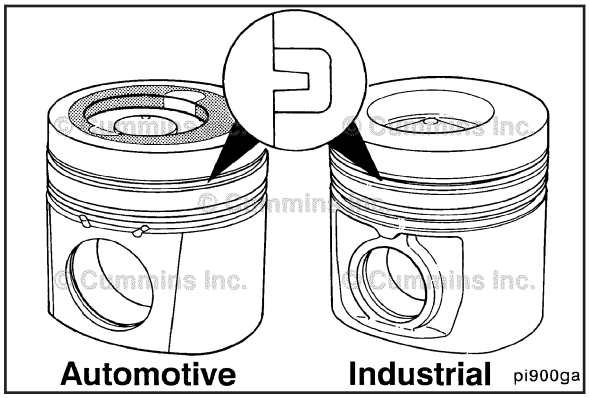
Piston (001-043)

General Information

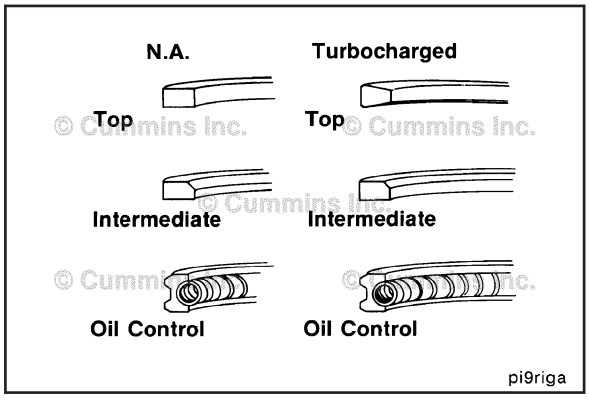
Front Gear Train

Piston features include high-swirl combustion bowl cast-aluminum body and three-ring grooves. The piston for turbocharged, turbocharged/aftercooled engines includes a Ni-resist insert with a keystone profile for the top piston ring. **Always** check the part number to be sure the correct configuration is used during piston replacement.

In addition to the ni-resist insert, automotive turbocharged engines also feature pistons with a hard-anodized combustion surface.

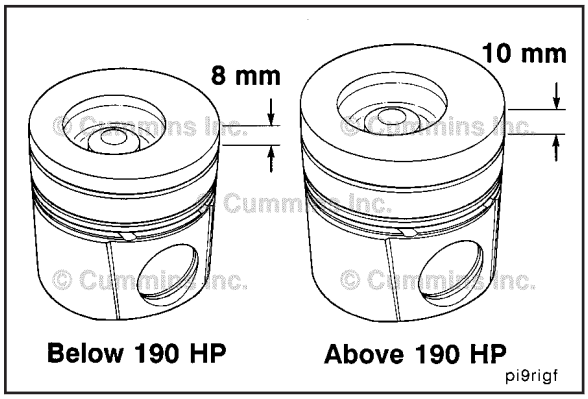


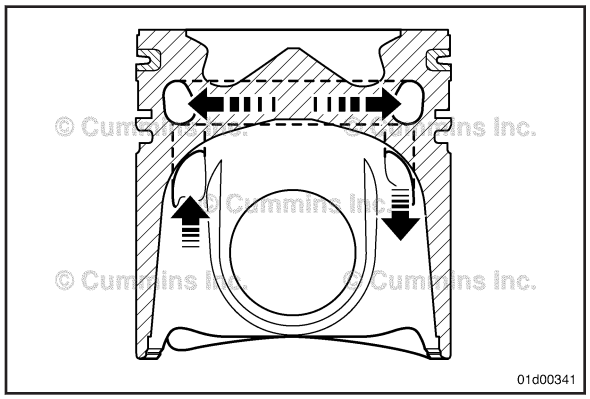
The piston ring sets are also different. While both sets consist of three rings, the top ring of the turbocharged/ aftercooled set has a keystone profile that operates in a ni-resist insert cast into the piston. The naturally aspirated top ring is square cut and operates in a groove machined into the aluminum piston.



The 1994 automotive pistons utilize different top ring locations. The 160-hp to 175-hp ratings use 8 mm crown to ring land pistons and 190 hp to 210 hp use 10 mm. The 1994 industrial pistons continue with the 14 mm ring position.

All Industrial two-valve pistons have a 6 mm top ring and a single Ni-resist insert, beginning in 2003.

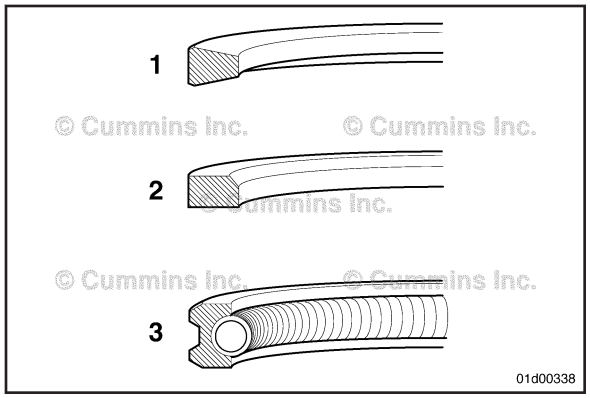




Rear Gear Train

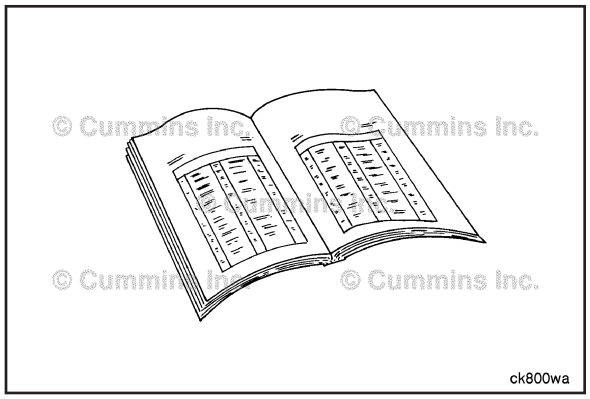
The piston features:

- A centered combustion bowl for more efficient combustion
- An offset piston pin for reduced combustion noise
- An internal oil gallery for piston cooling. Oil is sprayed at the underside of the piston by directed J-jet piston cooling nozzles. When the piston is near BDC, oil is sprayed through the internal oil gallery for maximum piston cooling.



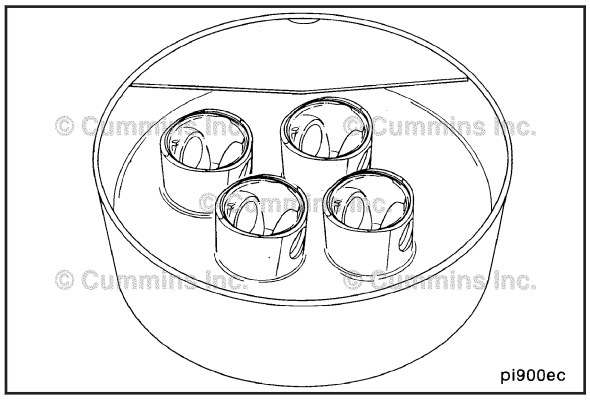
The piston rings set consists of three rings:

1. The Top Piston Ring — which has a keyway profile that operates in a Ni-resist insert cast into the piston
2. The Intermediate Ring (second ring)
3. The Oil Control Ring.



Preparatory Steps

- Remove the piston and connecting rod assembly. Refer to Procedure 001-054, Piston and Connecting Rod Assembly.



Clean and Inspect for Reuse

CAUTION
Do not use the bead-blast method to clean the pistons. The pistons will be damaged by blast material embedded in the aluminum.

CAUTION
Do not clean the pistons in an acid tank. Damage to the piston can occur.

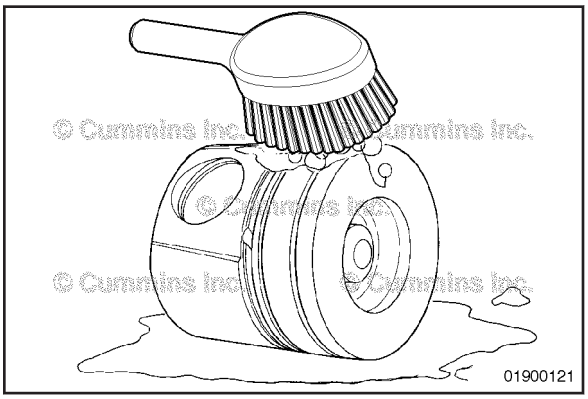
Soak the pistons in cold parts cleaner.

NOTE: Soaking the pistons overnight will usually loosen the carbon deposits.

⚠CAUTION⚠
Do not clean the pistons in an acid tank. Damage to the pistons can occur.

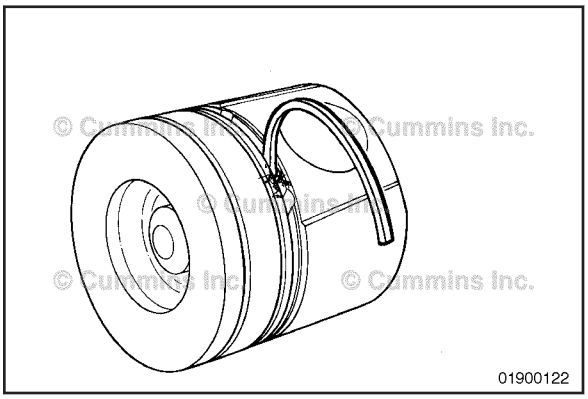
⚠CAUTION⚠
Do not use a metal brush. A metal brush will damage the piston ring grooves.

Wash the pistons in a strong solution of laundry detergent and hot water.



⚠CAUTION⚠
Do not use a ring groove cleaner and make sure not to scratch the ring sealing surface in the piston groove.

Clean the remaining deposits from the ring grooves with the square end of a broken ring.



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

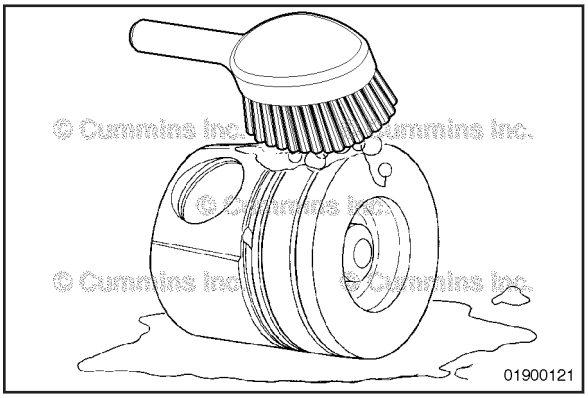
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

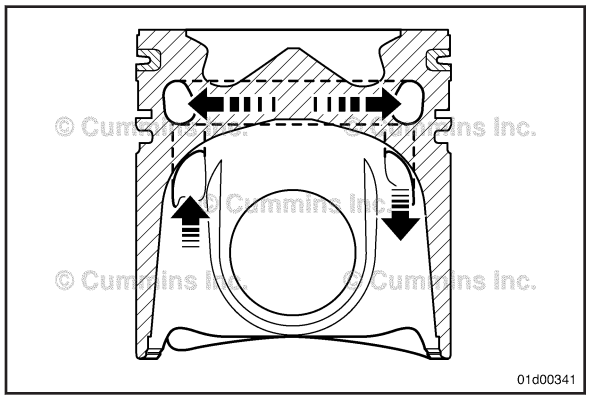
⚠CAUTION⚠
Do not clean the pistons and connecting rods in an acid tank. Damage to the pistons and connecting rods can occur.

Wash the pistons again in a detergent solution or solvent.

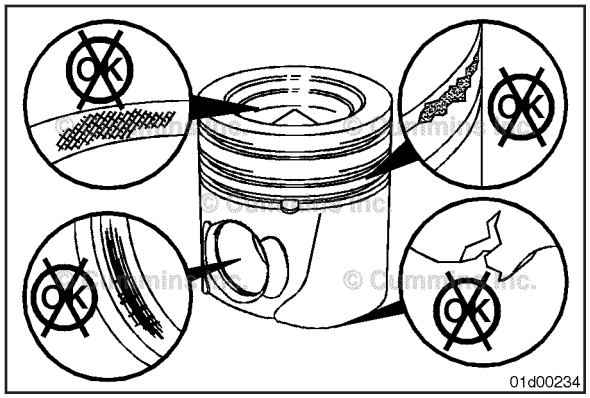
Rinse the pistons in clean, hot water.

Dry the pistons with compressed air.





NOTE: B4.5 RGT engines have an oil passage cast into the top of the piston for cooling purposes. When cleaning the pistons, make sure the oil passage is clean and free of debris.

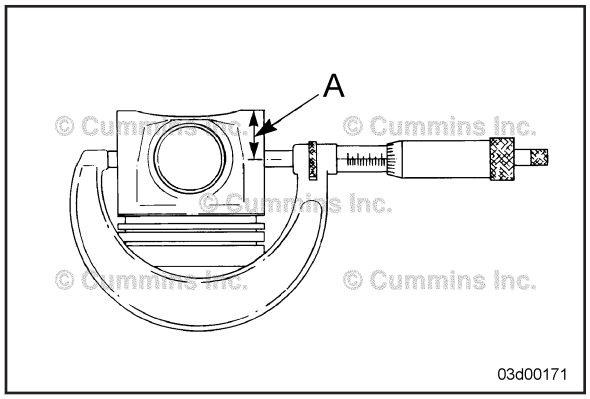


Failure Analysis Inspection

Rear Gear Train

Inspect the piston for damage and wear to the skirt, pin bore, top, and ring lands.

Inspect the piston pin for damage and wear.

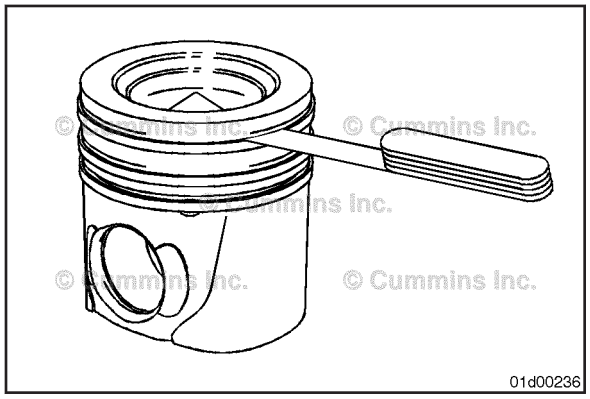


NOTE: To ensure accuracy, the following measurements should be completed with the components at room temperature, 20°C [68°F].

Measure the piston skirt diameter 21.4 mm [0.84 in] (A) from the bottom of the piston.

B4.5 RGT Standard Piston Skirt Diameter		
mm		in
106.878	MIN	4.2078
106.892	MAX	4.2083

B4.5 RGT Oversize Piston Skirt Diameter			
	mm		in
Oversize 0.5 mm	107.378	MIN	4.2275
	107.395	MAX	4.2280

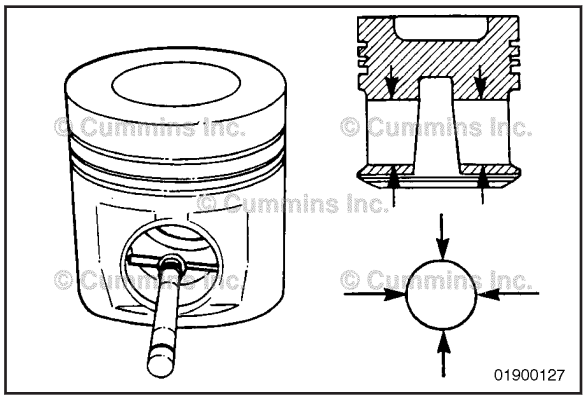


Measure the piston ring clearance. Use a new piston ring to measure the clearance in the ring groove.

B4.5 RGT Piston Ring Clearance			
	mm		in
Intermediate	0.040	MIN	0.0016
	0.110	MAX	0.0043
Oil Control	0.040	MIN	0.0016
	0.085	MAX	0.0033

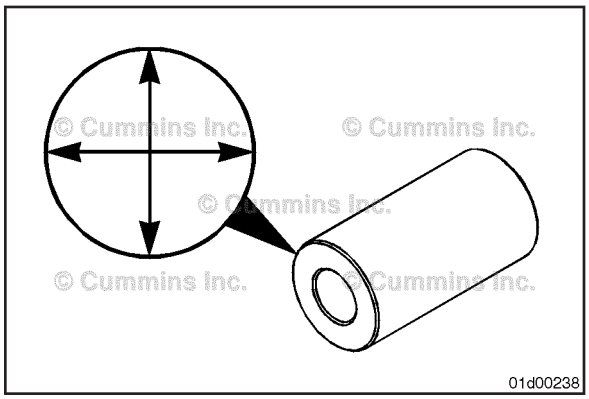
NOTE: The top piston ring clearance is **not** measured due to the type of piston ring used. The clearance can **not** be measured accurately with a typical feeler gauge.

Measure the piston pin bore.



B4.5 RGT Piston Pin Bore		
mm		in
40.006	MIN	1.5750
40.012	MAX	1.5753

Measure the piston pin diameter.

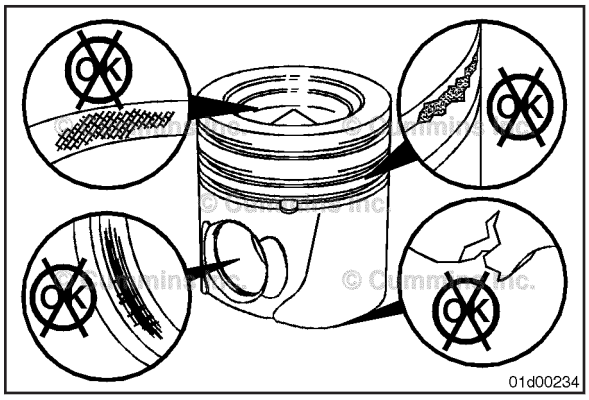


B4.5 RGT Piston Pin Diameter		
mm		in
39.997	MIN	1.5747
40.003	MAX	1.5749

Front Gear Train

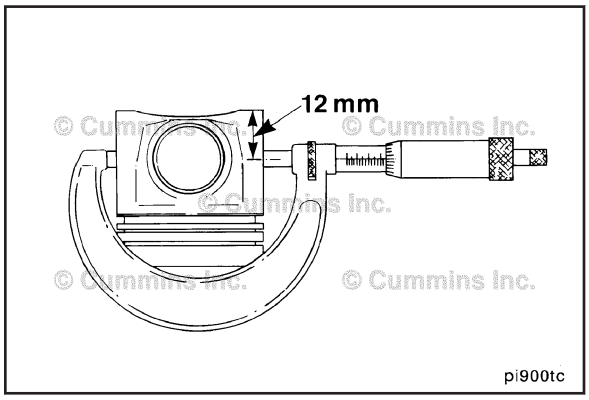
Inspect the piston for damage and wear to the skirt, pin bore, top, and ring lands.

Inspect the piston pin for damage and wear.



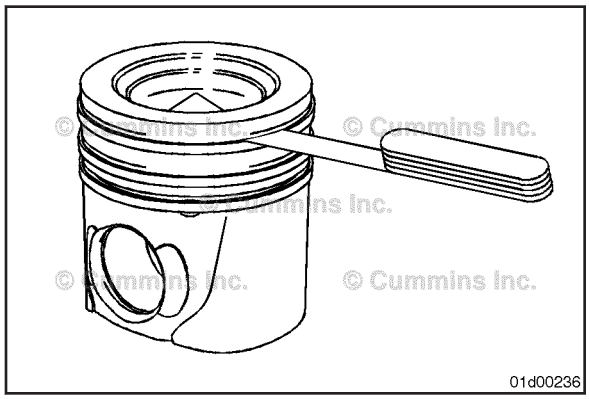
NOTE: To ensure accuracy, the following measurements should be completed with the components at room temperature, 20°C [68°F].

Measure the piston skirt diameter 12 mm [0.5 in] from the bottom of the piston.



B3.9 and B5.9 Piston Skirt Diameter		
mm		in
101.823	MIN	4.0088
101.887	MAX	4.0107

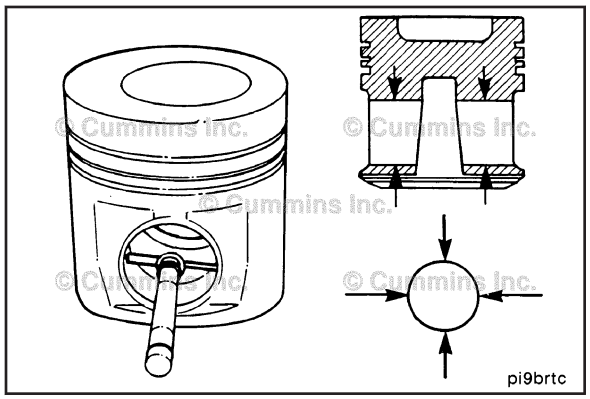
B4.5 Piston Skirt Diameter		
mm		in
101.833	MIN	4.0092
101.906	MAX	4.0120



Measure the piston ring clearance. Use a new piston ring to measure the clearance in the ring groove.

B4.5 Front Gear Train Piston Ring Clearance			
	mm		in
Intermediate	0.040	MIN	0.0016
	0.110	MAX	0.0043
Oil Control	0.040	MIN	0.0016
	0.085	MAX	0.0033

NOTE: The top piston ring clearance is **not** measured due to the type of piston ring used. The clearance can **not** be measured accurately with a typical feeler gauge.

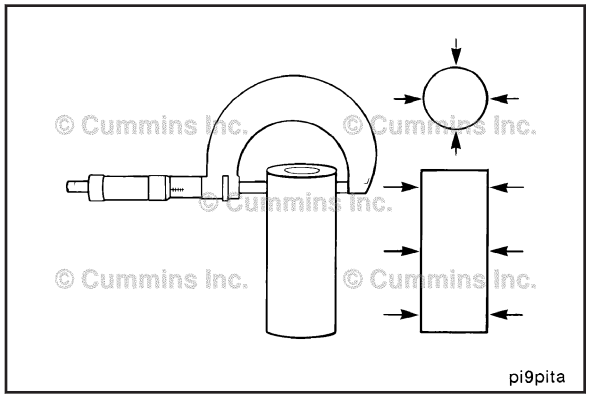


Measure the pin bore.

NOTE: Measure the pin bore in the center. The bore profile is tapered on the edges and will give incorrect measurements.

B3.9 and B5.9 Piston Pin Bore Diameter		
mm		in
40.006	MIN	1.5750
40.025	MAX	1.5758

B4.5 Piston Pin Bore Diameter		
mm		in
34.503	MIN	1.3584
34.522	MAX	1.3591



Piston Pin - Inspection

Inspect the piston pin for nicks, gouges, and excessive wear.

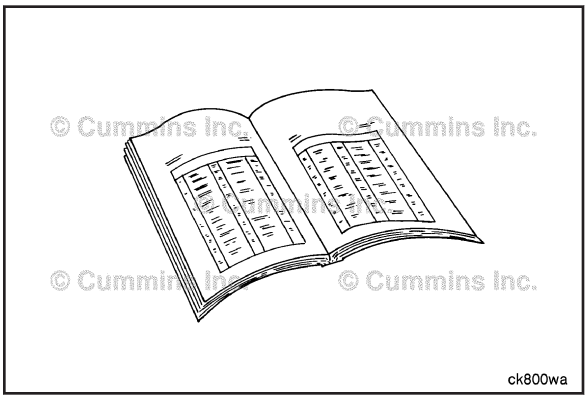
Measure the pin diameter.

B3.9 and B5.9 Pin Diameter		
mm		in
39.990	MIN	1.5744
40.003	MAX	1.5749

B4.5 Pin Diameter		
mm		in
34.483	MIN	1.3576
34.495	MAX	1.3581

Finishing Steps

- Install the piston and connecting rod assembly. Refer to Procedure 001-054, Piston and Connecting Rod Assembly.



Piston Cooling Nozzle (001-046)

General Information

Front Gear Train engines are equipped with:

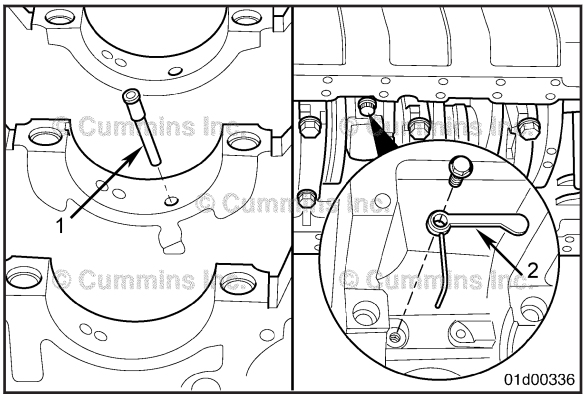
1. Saddle Jet Piston Cooling Nozzles

Rear Gear Train engines are equipped with:

2. J-jet Piston Cooling Nozzles

Saddle jet piston cooling nozzles are located in the main bearing saddle on the block side. Oil is supplied from the main bearing.

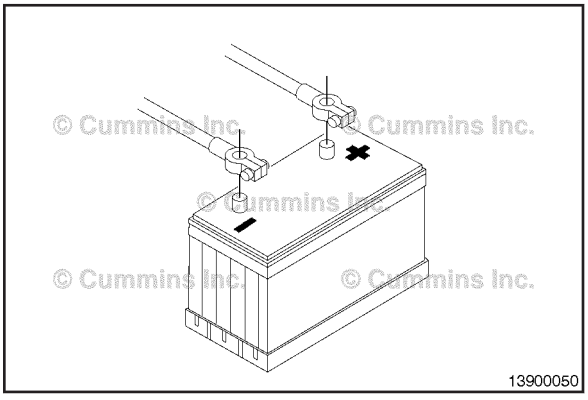
J-jet piston cooling nozzles are located in between the main bearing saddles on the exhaust side of the engine. Oil is supplied from an oil gallery in the block on the exhaust side of the engine.

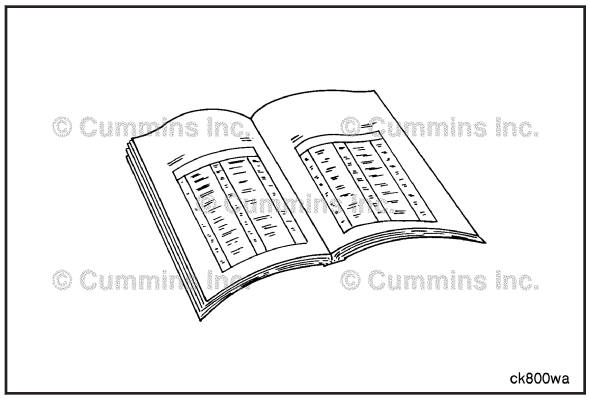


Preparatory Steps

⚠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.





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

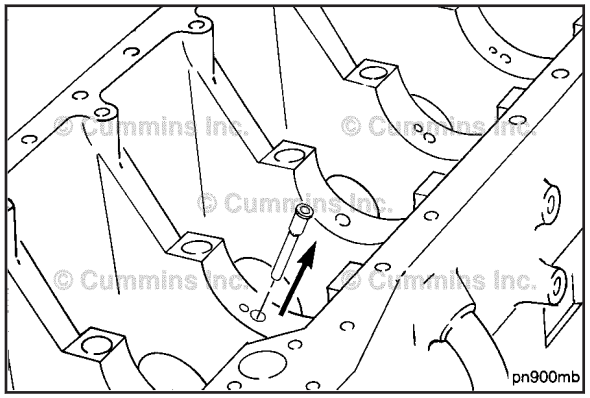
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

- Drain the lubricating oil. Refer to Procedure 007-037
- Remove the oil pan. Refer to Procedure 007-025
- Remove the lubricating oil suction tube. Refer to Procedure 007-035
- If equipped, remove the block stiffener plate. Refer to Procedure 001-089.

⚠WARNING⚠
This assembly weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this assembly.

NOTE: It is **not** necessary to remove the crankshaft if removing J-jet piston cooling nozzles.

- Remove the crankshaft. Refer to Procedure 001-016.

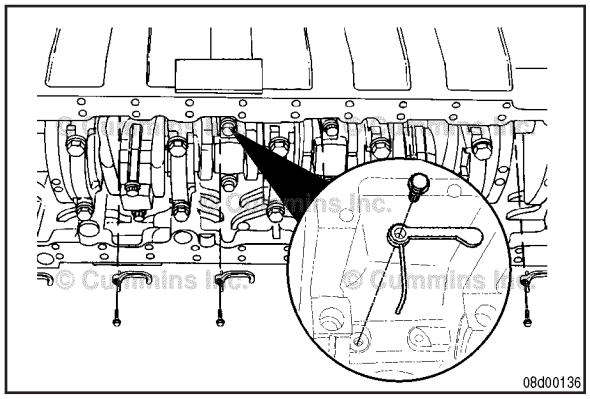


Remove

Saddle Jet Piston Cooling Nozzle

Remove the piston cooling nozzles by pressing from the top with an appropriate size punch.

NOTE: Do **not** reuse the saddle jet piston cooling nozzles once removed.

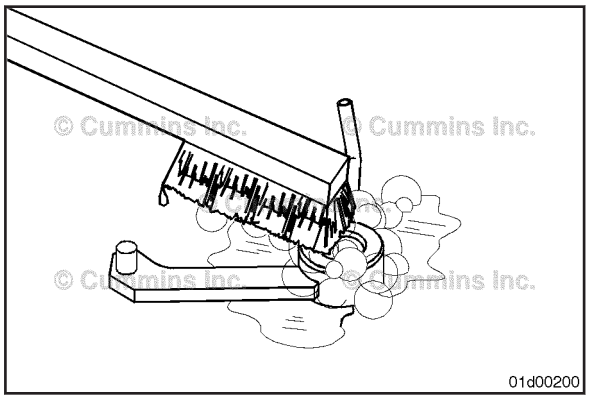


J-Jet Piston Cooling Nozzle

Rotate the crankshaft to various positions to access each piston cooling nozzle.

Remove the piston cooling nozzles.

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.

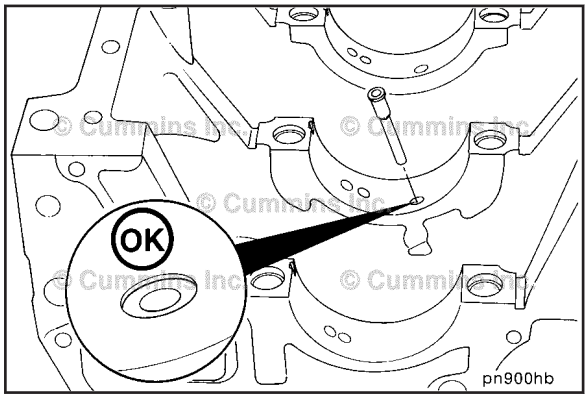
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: Do **not** reuse the saddle jet piston cooling nozzles or plugs once removed.

Clean the J-jet piston cooling nozzle and oil passage in the block using solvent. Dry with compressed air.

Inspect the capscrew and J-jet piston cooling nozzle for damage.

Install



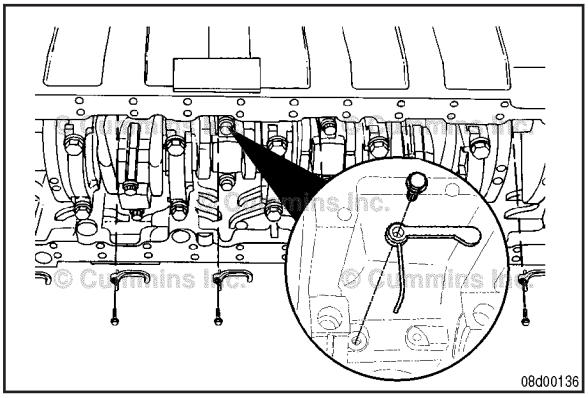
Saddle Jet Piston Cooling Nozzle

△CAUTION△
Do not use a hammer to install the piston cooling nozzles. Use hand pressure only. Using a hammer can cause component damage.

Push the piston cooling nozzle into place by hand.

Use a flat punch to push the nozzle into the recess.

J-Jet Piston Cooling Nozzle



△CAUTION△
Slight bending of the piston cooling nozzles can result in severe engine damage. Replace piston cooling nozzle if it is bent or damaged during disassembly or assembly.

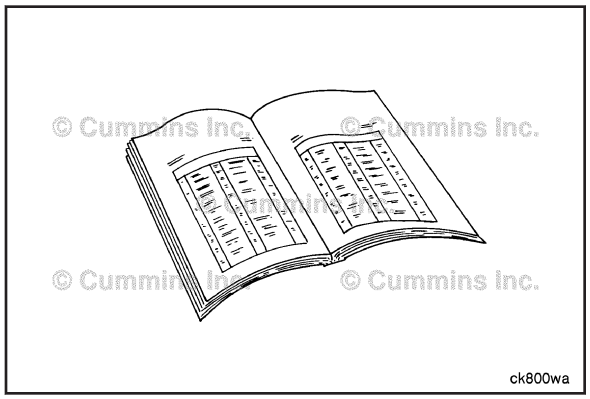
Install the piston cooling nozzle one cylinder at a time rotating the crankshaft as necessary for access.

Use a long extension to guide the capscrew and/or piston cooling nozzle into place.

NOTE: The locator pin on the J-jet piston cooling nozzle **must** engage the locating hole in the block for proper alignment.

Tighten the capscrew.

Torque Value:
J-Jet Capscrew 15 N•m [133 in-lb]

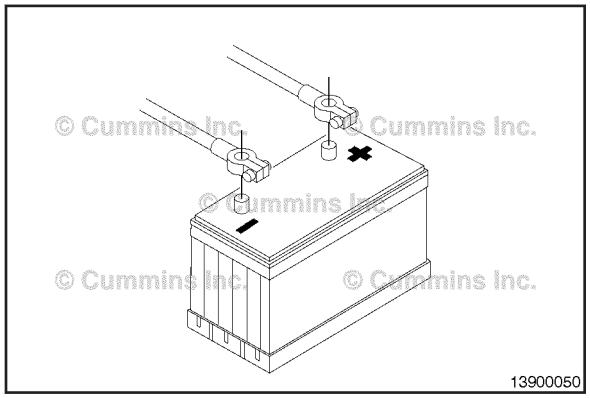


Finishing Steps

⚠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.

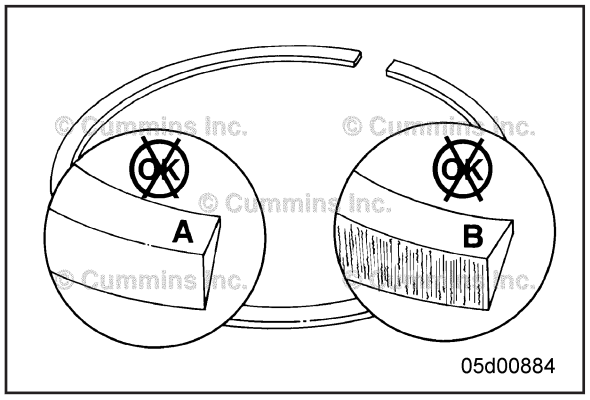
- If removed, install the crankshaft. Refer to Procedure 001-016
- If removed, install the block stiffener plate. Refer to Procedure 001-089
- Install the lubricating oil suction tube. Refer to Procedure 007-035
- Install the oil pan and oil pan gasket. Refer to Procedure 007-025
- Fill the engine with clean 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 and proper oil pressure.



Piston Rings (001-047)

Failure Analysis Inspection

Inspect the piston rings for the following:

- Abrasive wear.

NOTE: Abrasive wear of the intermediate ring can be indicated by a rapid reduction of the dark finish coating on the front face of the ring, in some cases, to the point where the dark finish coating is no longer visible (A). This is commonly referred to as full face ring wear. This rapid reduction will typically leave a sharp edge on the bottom of the intermediate ring. Abrasive wear can also be indicated by concentrated vertical scratches on the top ring (B).

Abrasive wear can be caused by:

1 Ingested abrasive material

2 Inadequate cleaning during a previous repair

3 Particles embedded in the bore

4 High soot content in the lubricating oil from extended oil drain intervals

5 Scuffing and scoring.

NOTE: Scuffing and scoring is indicated by heavy scratches, metal discoloration, and voids (B).

Scuffing and scoring can be caused by:

1 Engine overheating

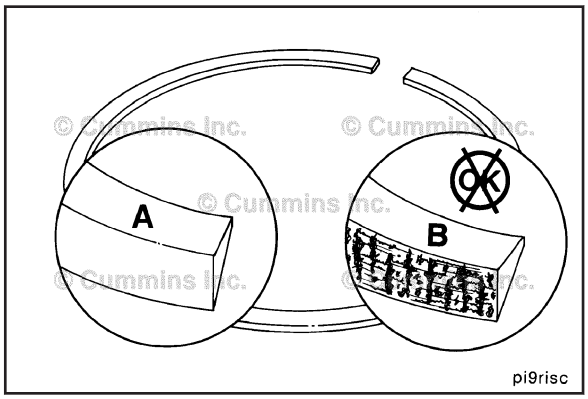
2 Oil dilution

3 Improper maintenance of the lubrication system

4 Piston cooling nozzle malfunction

5 Oil ring plugged by deposits.

NOTE: Scuffing and scoring on the piston rings indicates a breakdown of the oil film on the cylinder bore wall, causing transfer of material from the piston ring face to the cylinder bore.



NOTE: Oil ring plugging is indicated by deposits on the oil ring grooves (B).

Oil ring plugging can be caused by:

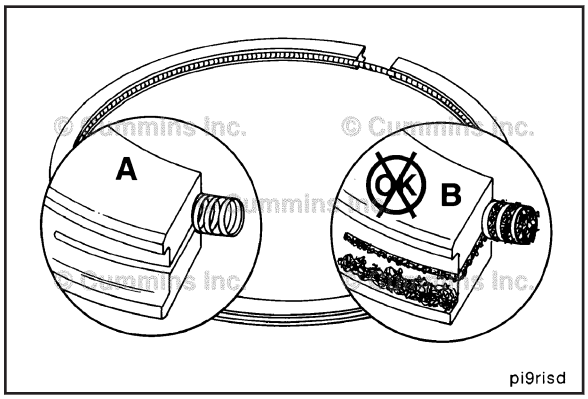
1 Low engine operating temperatures - long periods of idling or a cooling system malfunction

2 Extended oil change intervals

3 Use of the wrong grade of engine oil

4 Use of a poor quality engine oil.

NOTE: Plugging of the oil ring drains restricts oil drain back, which floods the piston ring belt area, resulting in a loss of oil control.



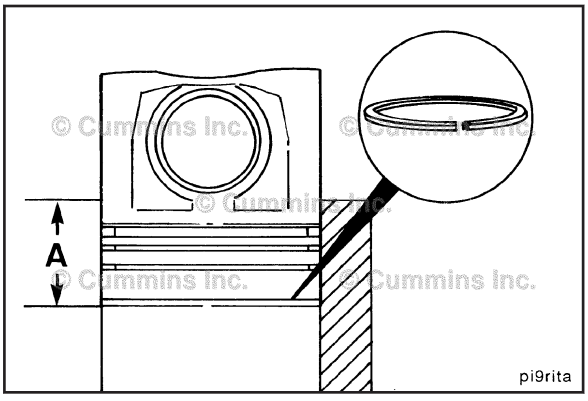
NOTE: The following measurements are intended for inspecting new piston rings.

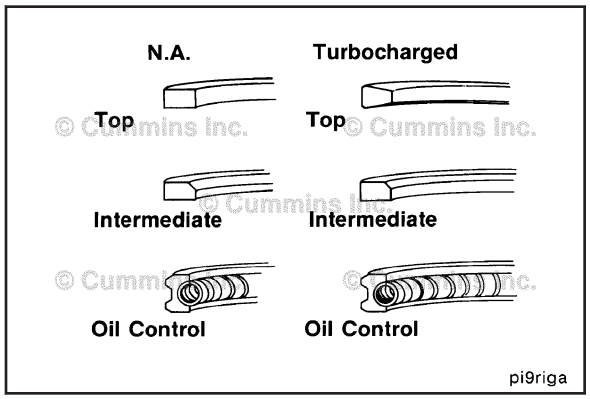
NOTE: Before completing this inspection, make sure the cylinder bore is within specification. Refer to Procedure 001-026 in Section 1.

Measure

Front Gear Train

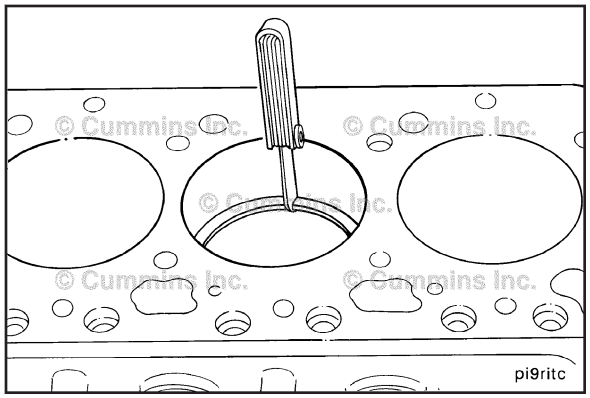
Measure the piston ring gap by installing the piston rings into the cylinder bore in which they will be used. Position the rings below the ring reversal area. Position each ring in the cylinder 89 mm [3.5 in] below the top deck (A), and using a clean piston to square it with the bore.





The piston ring sets are different. While both sets consist of three rings, the top ring of the turbocharged/aftercooled set has a keystone profile that operates in a ni-resist insert cast into the piston. The naturally aspirated (NA) top ring is square cut and operates in a groove machined into the aluminum piston.

NOTE: The top ring for a turbocharged engine is **not** the same as the top ring for a naturally aspirated engine.



Use a feeler gauge to measure the gap.

B3.9, B4.5, and B5.9 Ring Gap

	mm		in
Oil Control	0.25	MIN	0.010
	0.55	MAX	0.022

Piston Ring Gap Cross Referencing Tables

- To establish the correct top and intermediate piston ring gap, the part numbers of the piston rings must be known. If the engine has been rebuilt previously, then check for records of the parts used during the previous rebuild. If no records are present for the parts used during rebuild, then this table can't be used to determine the correct ring gap. If this is the case, then new piston rings should be used during the rebuild of the engine.
- The cross referencing tables are ordered by ring size (Standard, 0.5 mm oversize, then 1.0 mm oversize) and then by part number in descending order. First identify the correct bore / piston ring size, then find the part number of the rings in the appropriate table.

NOTE: Piston ring gap sizes are given in mm [inch].

Standard Size Piston Ring					
Top ring			Intermediate Ring		
Part Number	Minimum Gap	Maximum Gap	Part Number	Minimum Gap	Maximum Gap
4897899	0.22 [0.009]	0.38 [0.015]	4897900	0.60 [0.024]	0.86 [0.034]
3959079	0.26 [0.010]	0.42 [0.017]	3943544	0.85 [0.033]	1.21 [0.048]
3947678	0.26 [0.010]	0.42 [0.017]	3943544	0.85 [0.033]	1.21 [0.048]
3937392	0.35 [0.014]	0.51 [0.020]	3942265	0.25 [0.010]	0.61 [0.024]
3918315	0.40 [0.016]	0.76 [0.030]	3940777	0.25 [0.010]	0.61 [0.024]
3904529	0.40 [0.016]	0.76 [0.030]	3937393	0.55 [0.022]	0.90 [0.035]
3902401	0.40 [0.016]	0.76 [0.030]	3932519	0.25 [0.010]	0.61 [0.024]
2831144	0.30 [0.012]	0.46 [0.018]	3904531	0.25 [0.010]	0.61 [0.024]
			3904530	0.25 [0.010]	0.61 [0.024]
			3902400	0.25 [0.010]	0.61 [0.024]
			3902286	0.25 [0.010]	0.61 [0.024]

0.5 mm [0.02 in] Oversize Piston Ring					
Top ring			Intermediate Ring		
Part Number	Minimum Gap	Maximum Gap	Part Number	Minimum Gap	Maximum Gap
4898855	0.22 [0.009]	0.38 [0.015]	4898858	0.60 [0.024]	0.86 [0.034]
3957244	0.26 [0.010]	0.40 [0.016]	3943545	0.85 [0.033]	1.21 [0.048]
3937428	0.35 [0.014]	0.51 [0.020]	3942266	0.25 [0.010]	0.61 [0.024]
3919050	0.40 [0.016]	0.76 [0.030]	3937430	0.55 [0.022]	0.90 [0.035]
3902392	0.40 [0.016]	0.76 [0.030]	3933583	0.25 [0.010]	0.61 [0.024]
2831145	0.30 [0.012]	0.46 [0.018]	3904347	0.25 [0.010]	0.61 [0.024]
			3902393	0.25 [0.010]	0.61 [0.024]

1.0 mm [0.04 in] Oversize Piston Ring					
Top ring			Intermediate Ring		
Part Number	Minimum Gap	Maximum Gap	Part Number	Minimum Gap	Maximum Gap
4898856	0.22 [0.009]	0.38 [0.015]	4898859	0.60 [0.024]	0.86 [0.034]
3957245	0.26 [0.010]	0.40 [0.016]	3943546	0.85 [0.033]	1.21 [0.048]
3937429	0.35 [0.014]	0.51 [0.020]	3942267	0.25 [0.010]	0.61 [0.024]
3919051	0.40 [0.016]	0.76 [0.030]	3937431	0.55 [0.022]	0.91 [0.036]
3902441	0.40 [0.016]	0.76 [0.030]	3933585	0.25 [0.010]	0.61 [0.024]
2831146	0.30 [0.012]	0.46 [0.018]	3904348	0.25 [0.010]	0.61 [0.024]
			3902442	0.25 [0.010]	0.61 [0.024]

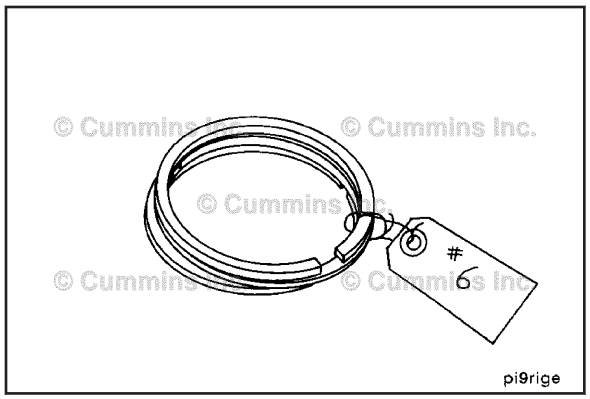
If the piston ring gap is **not** within specification:

1 Verify the correct type and part number piston ring is being used

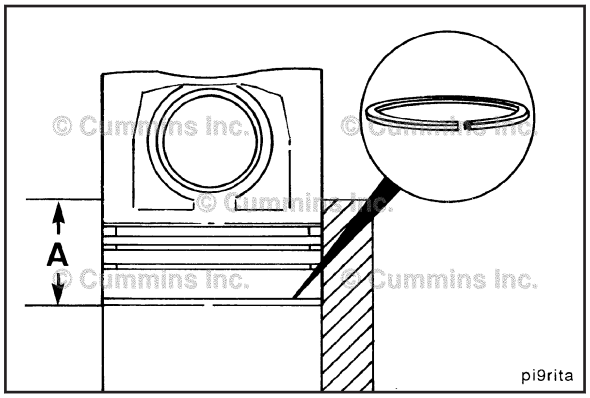
2 Verify the cylinder bore is within specification. Refer to Procedure 001-026 in Section 1.

3 Verify the piston ring gap measurement is being taken 89 mm [3.5 in] below the cylinder block deck

4 Try another set of piston rings.

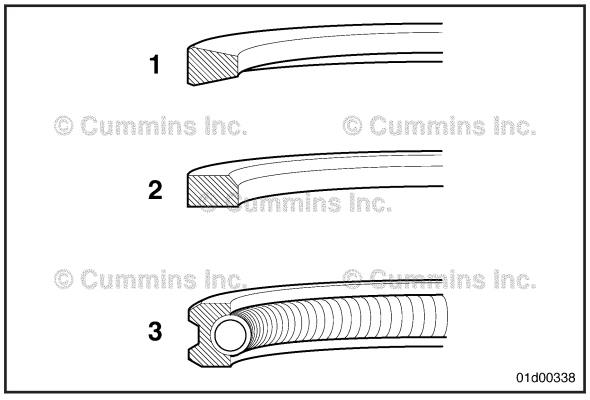


After each ring gap is checked and verified, identify the ring sets for installation in the cylinder bore where the end gap was measured.



Rear Gear Train

Measure the piston ring gap by installing the piston rings into the cylinder bore in which they will used. Position the rings below the ring reversal area. Position each ring in the cylinder 89 mm [3.5 in] below the top deck (A), and using a piston to square it with the bore.



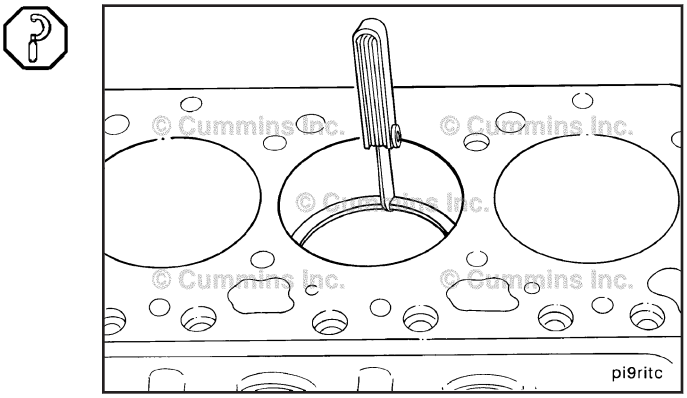
The piston ring type and location can be identified by piston ring profile.

1 Top piston ring

2 Intermediate piston ring

3 Oil control ring.

Use a feeler gauge to measure the gap.



B4.5 RGT Engines Ring Gap

	mm		in
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

If the piston ring gap is **not** within specification:

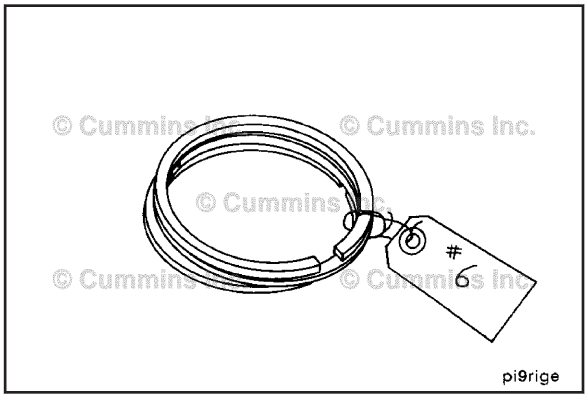
1 Verify the correct type and part number piston ring is being used

2 Verify the cylinder bore is within specification. Refer to Procedure 001-026 in Section 1.

3 Verify the piston ring gap measurement is being taken 89 mm [3.5 in] below the cylinder block deck

4 Try another set of piston rings.

After each ring gap is checked and verified, identify the ring sets for installation in the cylinder bore where the end gap was measured.



Timing Pin Housing (001-049)

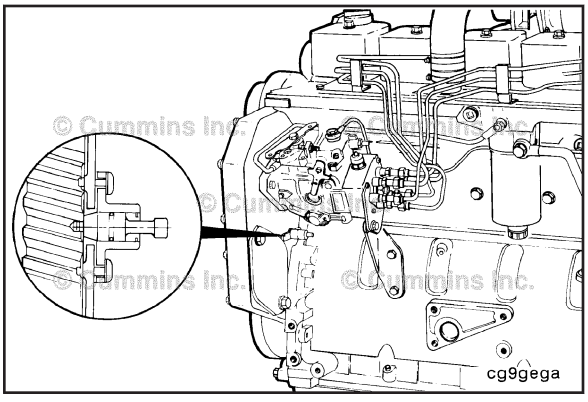
General Information

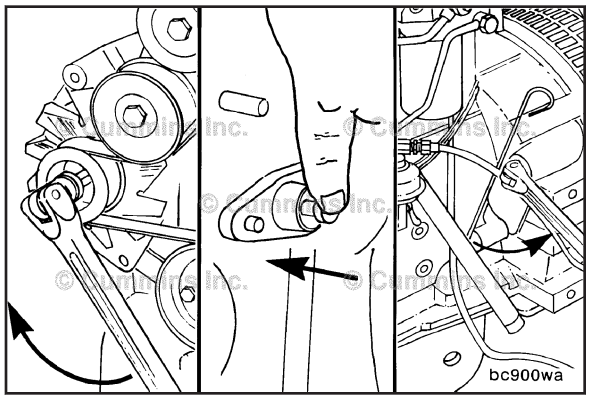
The timing pin is used to accurately locating TDC for:

- Fuel pump timing
- Overhead Set

The timing pin is typically located below the fuel pump:

- For front gear train engines, in the front gear housing (shown)
- For rear gear train engines, in the rear gear housing (**not** shown).

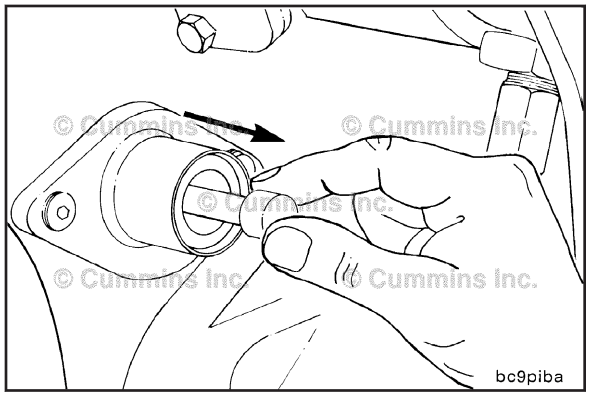




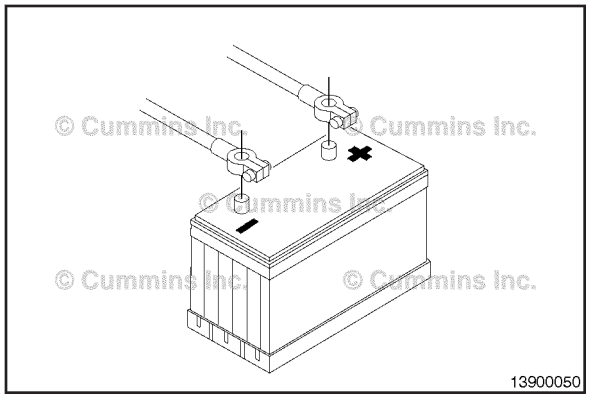
To use the timing pin to locate top dead center (TDC) for cylinder number 1, bar the crankshaft slowly while pressing on the engine timing pin. Use the barring tool, Part Number 3824591, to bar the engine.

Bar the engine over until the timing pin engages the notch in the camshaft gear.

Service Tip: If the barring tool is inaccessible, in some applications the alternator pulley can be used to bar the engine over.



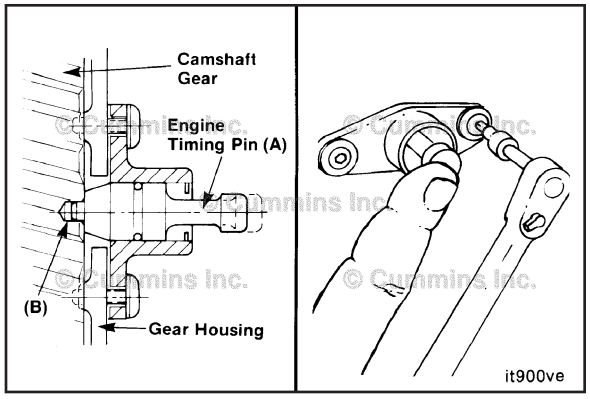
⚠CAUTION⚠
To reduce the possibility of engine or timing pin damage, you must disengage the timing pin before attempting to bar or crank the engine.



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: If the gear housing/gear train has **not** been removed, prior to removing the timing pin assembly, rotate the engine so that the timing pin engages the camshaft gear. See the General Information section of this procedure.

Remove the timing pin housing assembly.

NOTE: Most timing pin assemblies are mounted using internal Torx fasteners.

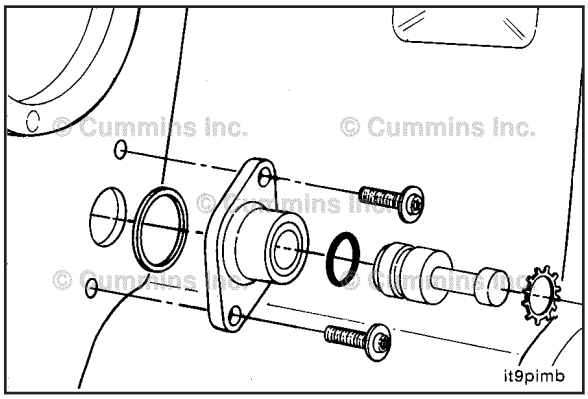
Install

The following steps **must** be performed before installing the timing pin assembly if one of the following has occurred:

- The gear housing was replaced
- The timing pin assembly was replaced with the gear housing removed
- The timing pin is suspected to be inaccurate.

The timing pins assembly is precisely located on the gear housing to correspond to TDC for cylinder number 1 on the compression stroke.

If only the timing pin assembly is being replaced, with the gear housing still installed, skip the following TDC locating steps.



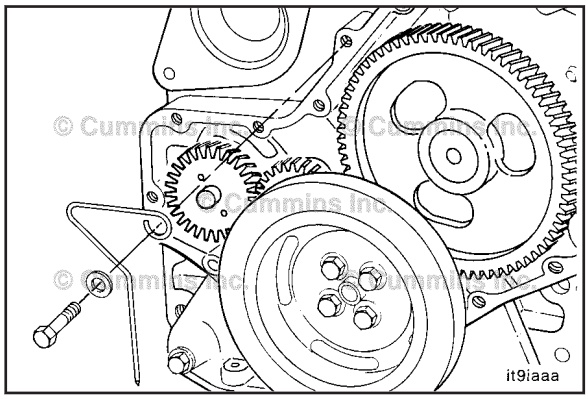
NOTE: The following steps have been generalized to cover both front and rear gear train engines. Some of the illustrations may differ from the engine being serviced.

TDC **must** accurately be located using one of the following two methods:

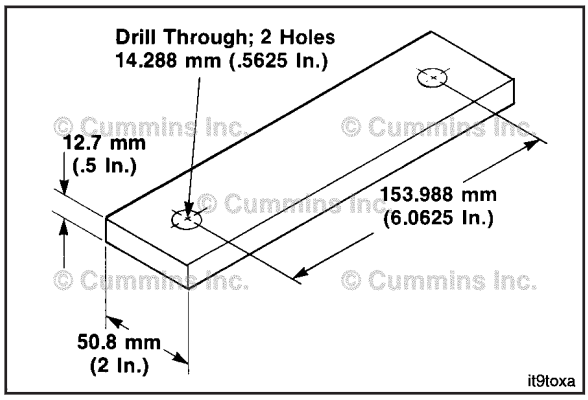
- If the cylinder head is removed, use a steel plate
- If the cylinder head is installed, use the engine's intake valve.

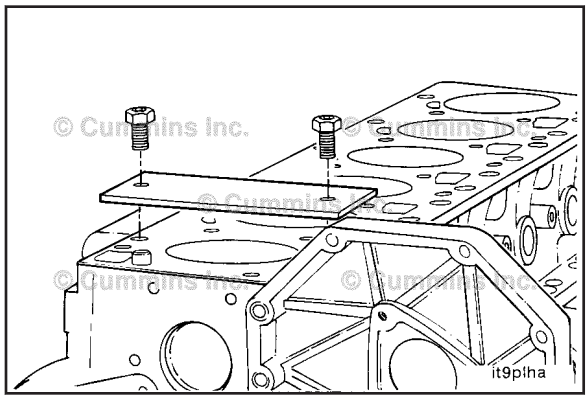
First, fabricate a pointer as illustrated. Attached the pointer to the front gear cover/gear housing using flat washers to prevent damage to the front gear cover/ housing.

NOTE: If the vibration damper/crankshaft pulley has been removed, the vibration damper/crankshaft pulley **must** be temporarily installed.

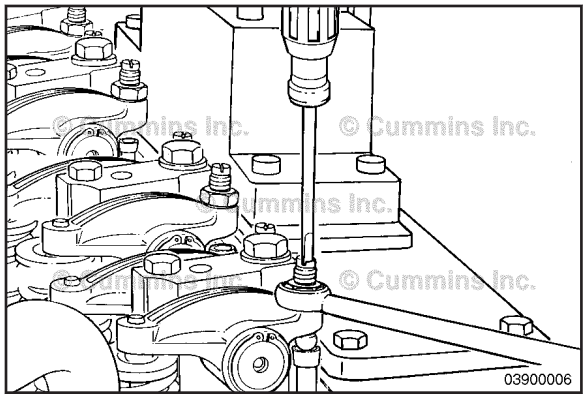


If the cylinder head is **not** installed, fabricate a steel plate as shown in the illustration.





Using two correct thread and pitch capscrews, attach the plate over cylinder number 1.



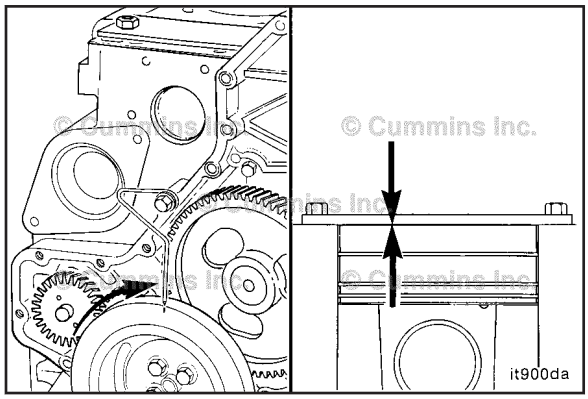
⚠CAUTION⚠
Once the intake valve(s) are protruding into the cylinder bore, bar the engine over with ease. Too hard of contact with the intake valve(s) will bend the valves and cause serious engine damage.

If the cylinder head is installed, remove the rocker lever cover to gain access to the number 1 cylinder intake and exhaust rocker levers. Refer to Procedure 003-011.

Use the barring tool, part number 3824591, rotate the engine over until cylinder number 1 exhaust valve(s) are fully open. The exhaust valve(s) are fully open when the exhaust valve spring(s) are compressed.

With the exhaust valve(s) fully open, set the overhead on the cylinder number 1 intake valve(s) so that the intake valve spring(s) are compressed.

NOTE: It may be necessary to bottom out the adjusting screw to achieve enough intake valve protrusion to contact the piston.



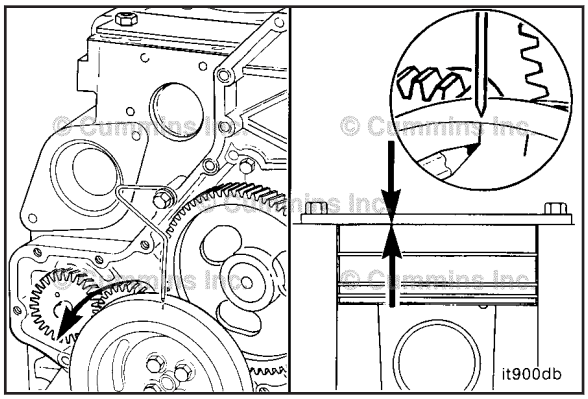
NOTE: The following steps will show illustrations of engines with the cylinder head removed. The following steps are the same for an engine with or without the cylinder head removed.

Use the barring tool, Part Number 3824591, rotate the engine clockwise until the piston makes contact with the steel plate or intake valve(s).

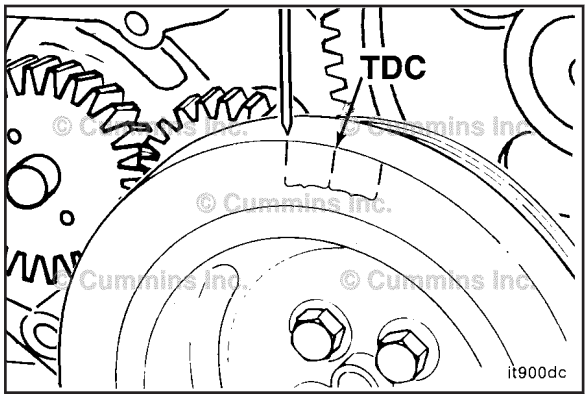
Mark the vibration damper/crankshaft pulley where the fabricated indicator points.

Use the barring tool, Part Number 3824591, rotate the engine counterclockwise until the piston makes contact with the plate or intake valve(s).

Mark the vibration damper/crankshaft pulley where the fabricated indicator points.



Place a mark on the vibration damper/crankshaft pulley at one-half the distance between the two marks. This is TDC for cylinder number one.

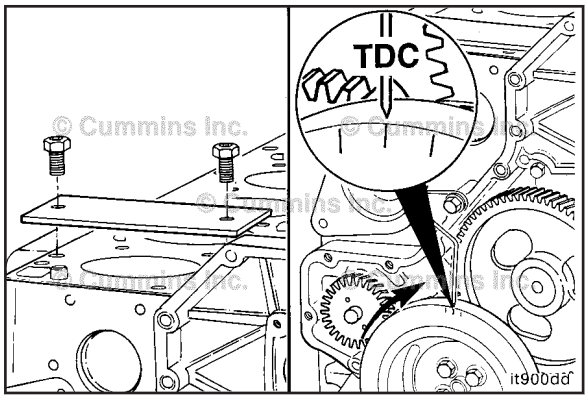


For engines with the cylinder head removed, remove the plate over cylinder number 1.

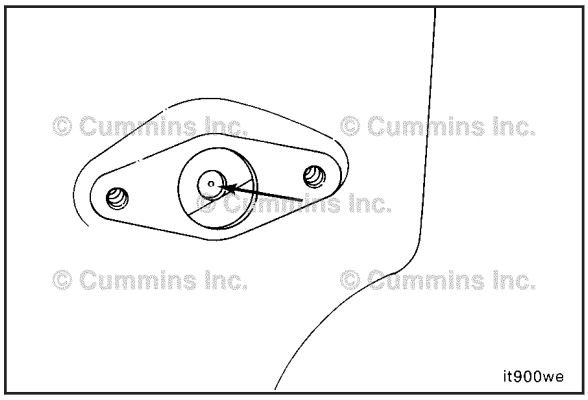
For engines with the cylinder head installed, adjust the intake valve(s) in order to close the valve(s).

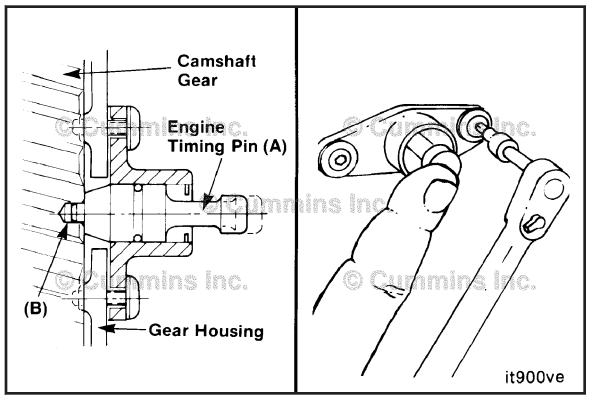
NOTE: When rotating the engine on engines with the cylinder head installed, carefully watch the rocker levers and push rods. The overhead is **not** set for the number one intake valve(s) which may cause the push rod to lose contact with the rocker lever.

Use the barring tool, part number 3824591, rotate the engine until the pointer aligns with the TDC mark on the vibration damper/crankshaft pulley.



Look through the timing pin hole in the gear housing. Look for the timing pin hole in the camshaft gear. If it is **not** visible, rotate the crankshaft 360 degrees and align the pointer with the TDC mark.



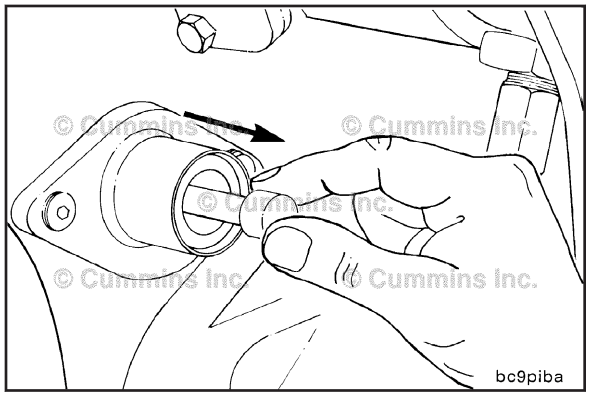


Install the timing pin assembly. Push the timing pin into the hole in the camshaft gear to align the housing.

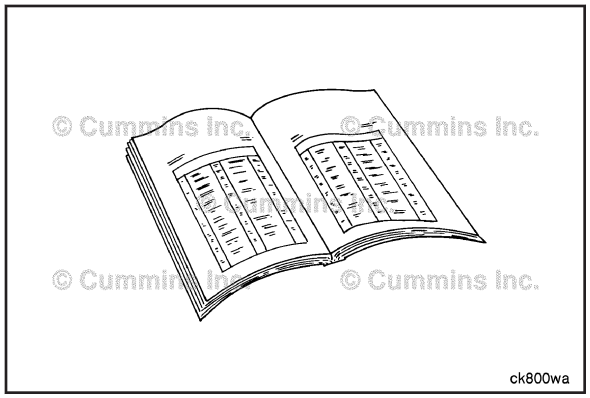
While holding the timing pin, tighten the mounting capscrews.

Torque Value: 5 N•m [48 in-lb]

NOTE: Most timing pin assemblies are mounted using internal Torx fasteners.

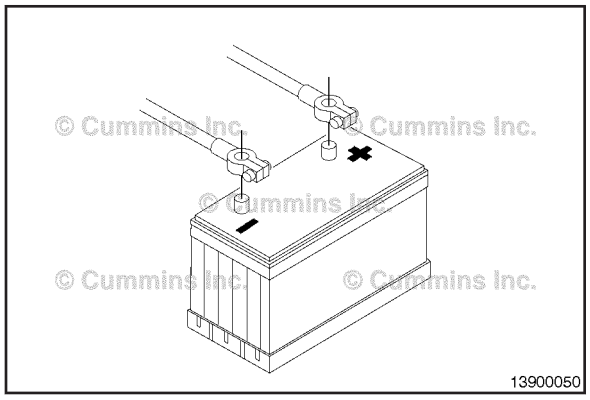


⚠CAUTION⚠
To reduce the possibility of engine or timing pin damage, you must disengage the timing pin before attempting to bar or crank the engine.



Finishing Steps

- For engines with the cylinder head installed, adjust the overhead for the intake valve(s) on cylinder number 1. Refer to Procedure 003-004.
- For engines with the cylinder head installed, install the rocker lever cover. Refer to Procedure 003-011.



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

Vibration Damper, Rubber (001-051)

General Information

The vibration damper controls the twisting or torsional vibration of the crankshaft. A vibration damper is engineered for use on a specific engine model.

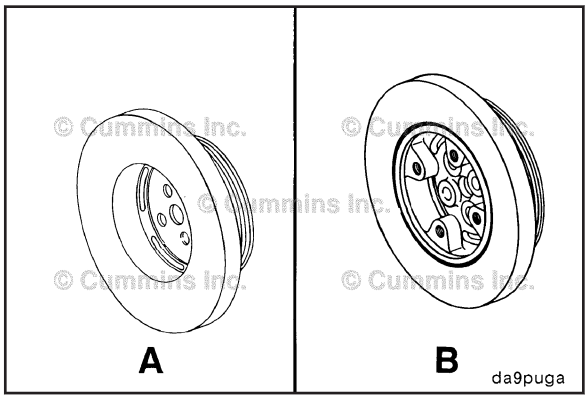
It is **not** economical to repair a vibration damper in the field. Install a new or rebuilt vibration damper if the inspection indicates that a damper is defective.

The viscous vibration damper has a limited service life. The damper **must** be replaced if worn or damaged.

There are two different design vibration dampers used on the B Series engines:

a. Viscous damper (A) for engines rated at speeds above 2500 rpm.
b. Rubber element damper (B) for engines rated at speeds below 2500 rpm.

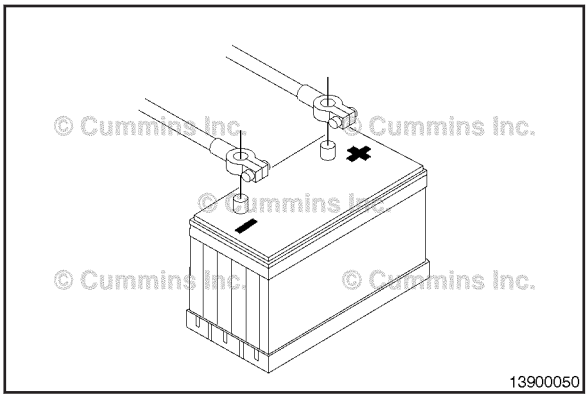
NOTE: The rubber vibration damper (B) is available either with or without the crankshaft adapter.



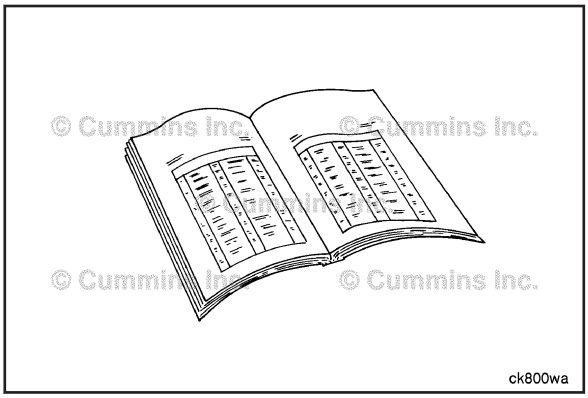
Preparatory Steps

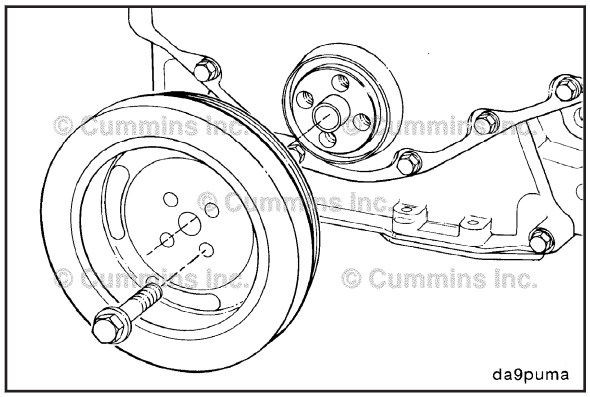
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



- Remove the drive belt. Refer to Procedure 008-002.



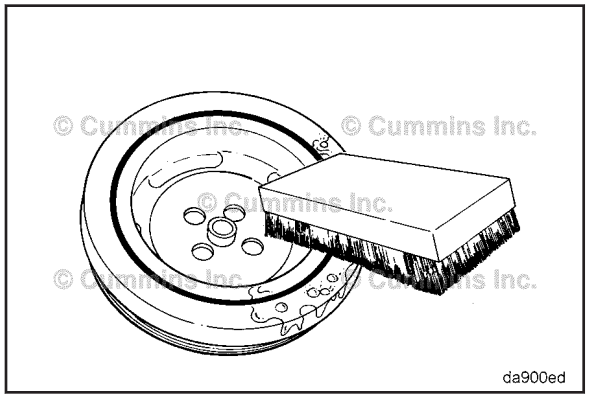


Remove

For front gear train engines, remove the four capscrews.

For rear gear train engines, remove the six capscrews.

Remove the vibration damper.

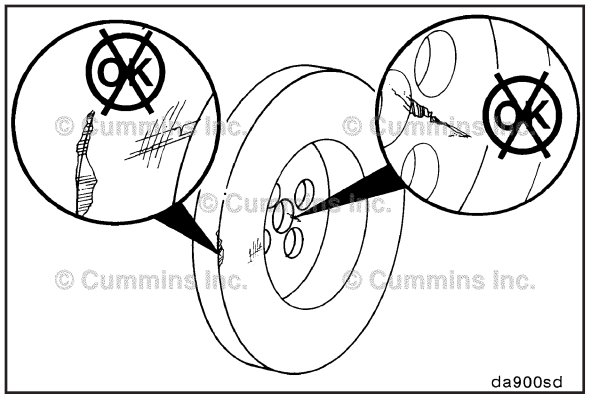


Clean and Inspect for Reuse

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear protective clothing, goggles/ shield, and gloves to reduce the possibility of personal injury.

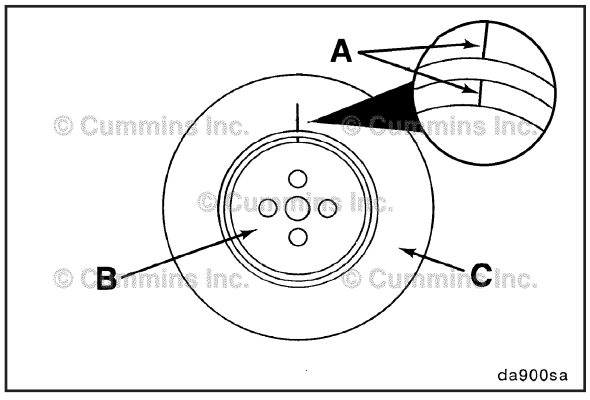
Using soapy water, clean any oil from the vibration damper.

Dry the vibration damper with compressed air.



Check the mounting web for cracks.

Check the alignment marks on the inner and outer rings.



Check the index lines (A) on the damper hub (B) and the inertia member (C).

If the lines are more than 1.59-mm [1/16-in] out of alignment, replace the damper.

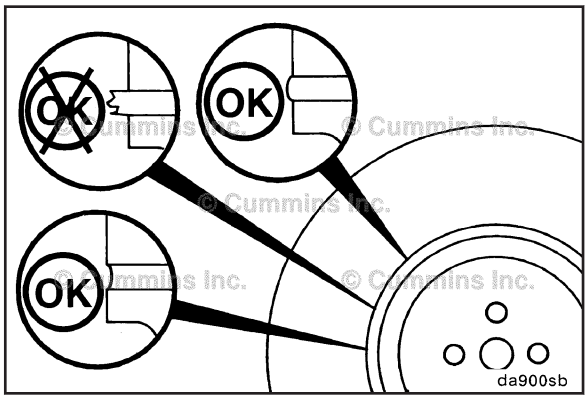
Inspect the vibration damper hub for cracks.

Replace the damper if the hub is cracked.

Inspect the rubber member for deterioration.

If pieces of rubber are missing or if the elastic member is more than 3.18 mm [1/8 in] below the metal surface, replace the vibration damper.

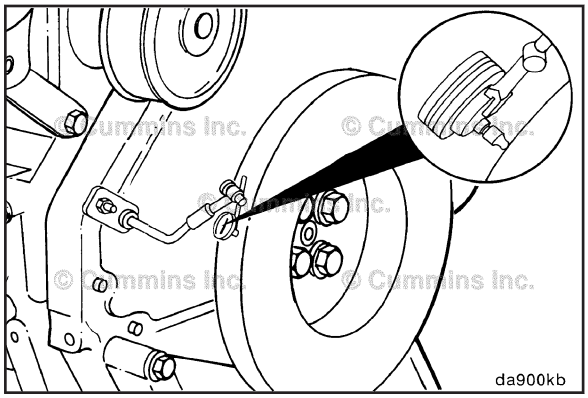
NOTE: Look for forward movement of the damper ring on the hub. Replace the damper if any movement is detected.



Measure

Measure the vibration dampers eccentricity.

Install a dial indicator as illustrated.

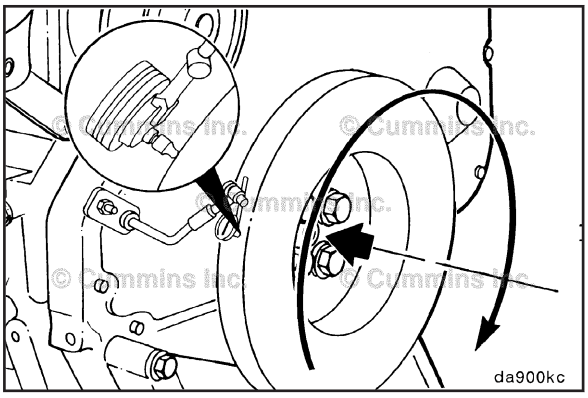


Rotate the crankshaft with engine barring tool, Part Number 3377371.

Record the dial indicators movement.

Vibration Damper Eccentricity per 25.4 mm [1.0 in] of Diameter		
mm		**in**
0.10	MAX	0.004

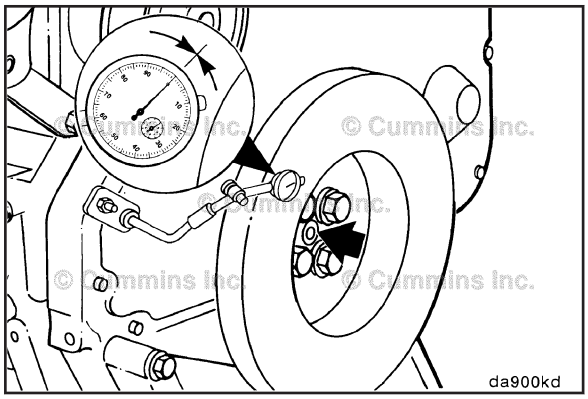
NOTE: If the eccentricity is **not** within specification the vibration damper **must** be replaced.

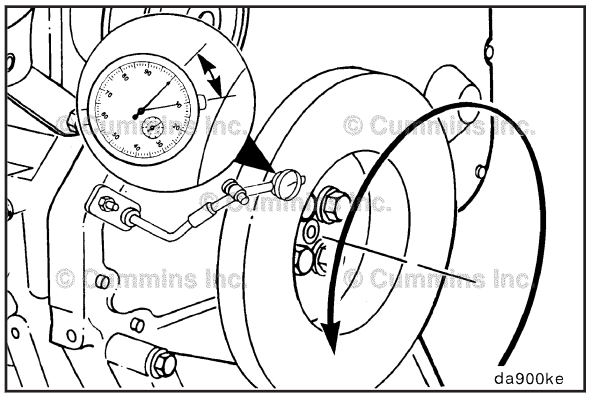


Measure the vibration damper wobble.

Install a dial indicator as illustrated.

Push the crankshaft to the front or rear and zero the dial indicator.





Rotate the crankshaft with engine barring tool, Part Number 3377371, 360 degrees, maintaining the position of the crankshaft.

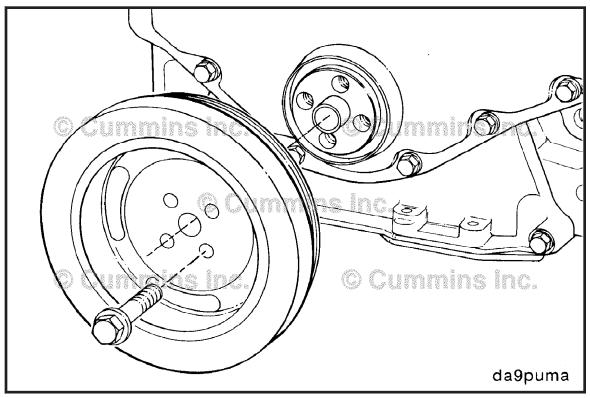
Record the dial indicator movement.

Vibration Damper Wobble per 25.4 mm [1.0 in] of Radius		
mm		**in**
0.18	MAX	0.007

Install

Front Gear Train

NOTE: The B Series engines have two configurations for the crankshaft pulleys and vibration dampers. Determine which configuration is used and use the appropriate steps in this procedure.

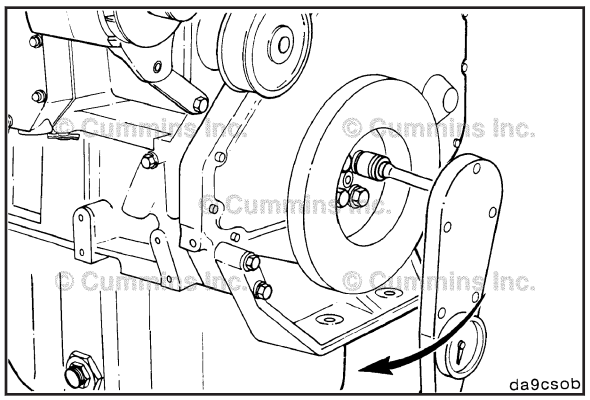


One Piece Pulley/Vibration Damper

Install the crankshaft vibration damper.

Install and tighten the crankshaft pulley/vibration damper capscrews.

Torque Value: 125 N•m [92 ft-lb]



Two-Piece Pulley/Vibration Damper

Install the vibration damper.

Install and tighten the vibration damper capscrews.

Torque Value: 200 N•m [148 ft-lb]

Install the crankshaft pulley.

Install and tighten the crankshaft pulley capscrews.

Torque Value: 77 N•m [57 ft-lb]

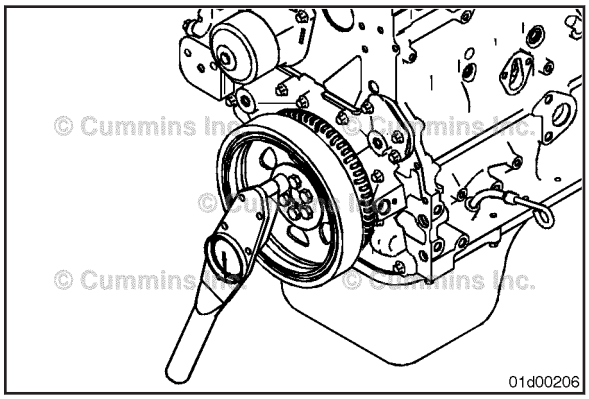
Rear Gear Train

Lubricate bolts with clean engine oil.

Install the vibration damper .

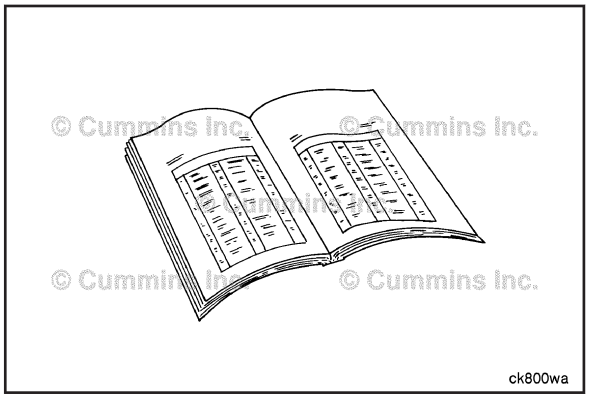
Tighten the six vibration damper capscrews in a criss-cross pattern.

Torque Value: Step1 50 N•m [37 ft-lb]
Step2 Rotate 90 degrees



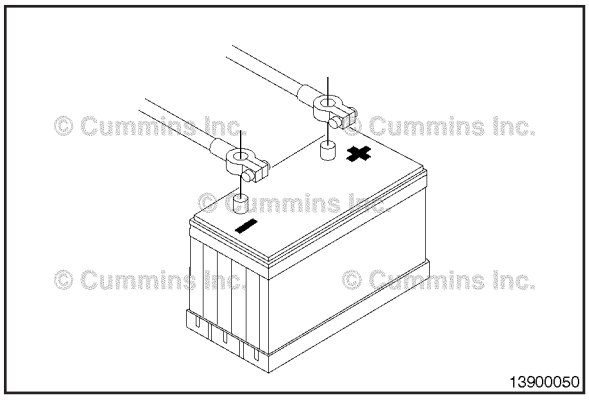
Finishing Steps

- 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.



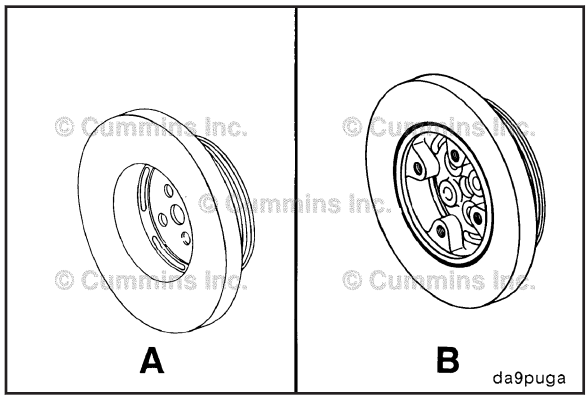
Vibration Damper, Viscous (001-052)

General Information

The vibration damper controls the twisting or torsional vibration of the crankshaft. A vibration damper is engineered for use on a specific engine model.

It is **not** economical to repair a vibration damper in the field. Install a new or rebuilt vibration damper if the inspection indicates that a damper is defective.

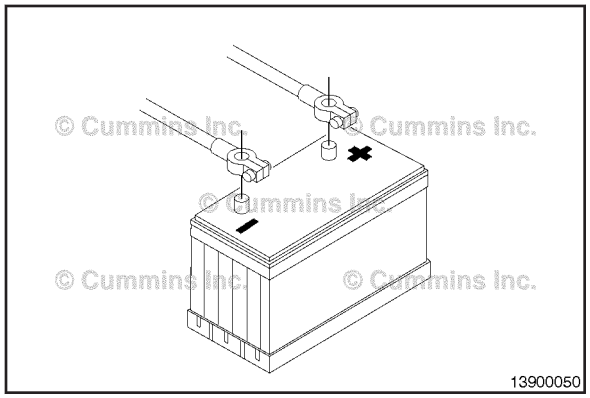
The viscous vibration damper has a limited service life. The damper **must** be replaced if worn or damaged.



There are two different design vibration dampers used on the B Series engines:

a. Viscous damper (A) for engines rated at speeds above 2500 rpm.
b. Rubber element damper (B) for engines rated at speeds below 2500 rpm.

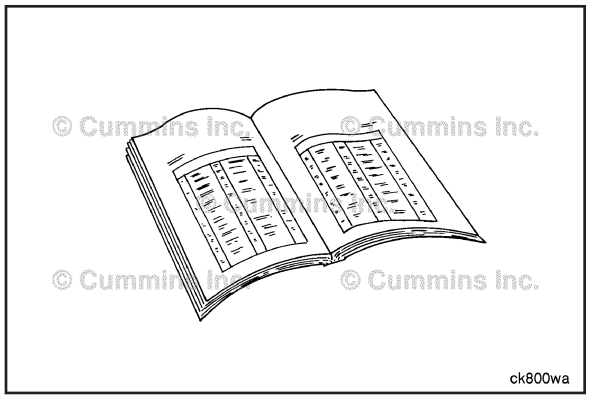
NOTE: The rubber vibration damper (B) is available either with or without the crankshaft adapter.



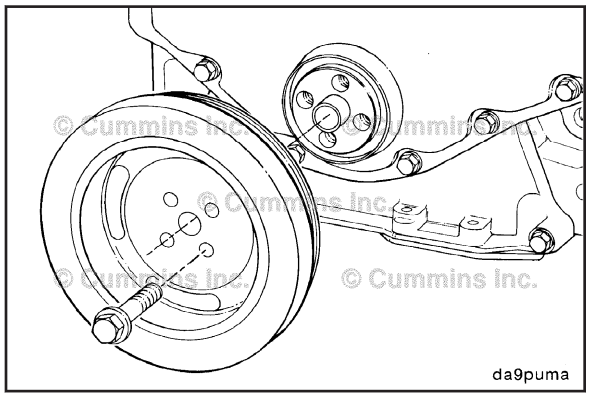
Preparatory Steps

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

- Disconnect the batteries.



- Remove the drive belt. Refer to Procedure 008-002.



Remove

For front gear train engines, remove the four capscrews.

For rear gear train engines, remove the six capscrews.

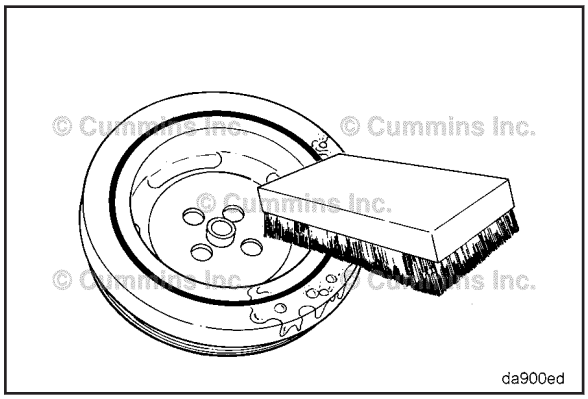
Remove the vibration damper.

Clean and Inspect for Reuse

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear protective clothing, goggles/ shield, and gloves to reduce the possibility of personal injury.

Using soapy water, clean any oil from the vibration damper.

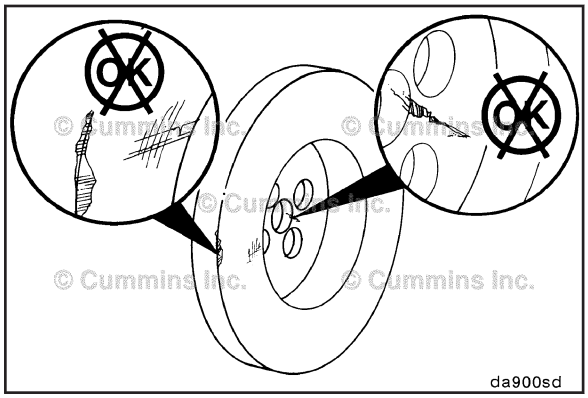
Dry the vibration damper with compressed air.



Check the mounting web for cracks.

Check the housing for dents or raised surfaces.

Replace the damper if any of these defects are identified

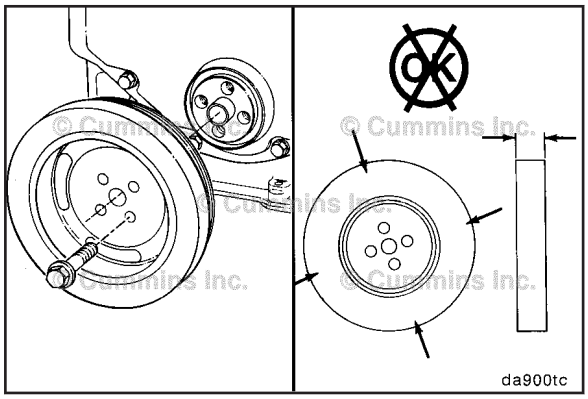


NOTE: The viscous damper is filled with a silicone fluid. After many hours of use, the silicone fluid can become thicker and expand.

To determine if the damper thickness is correct, remove the paint from the damper in four locations on either side of the damper.

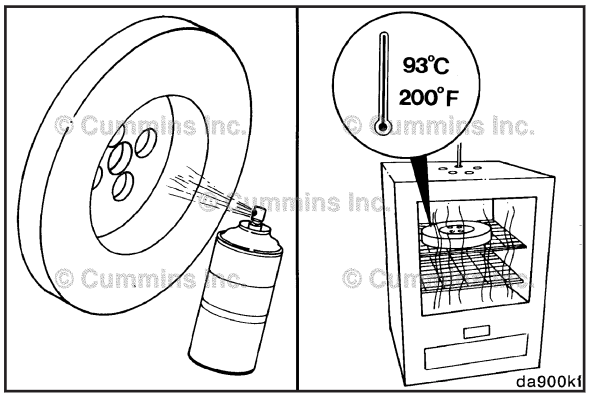
Measure and record the thickness of the damper in four places. Measure the thickness at 80.65 mm [3.175 in] from the outside of the damper.

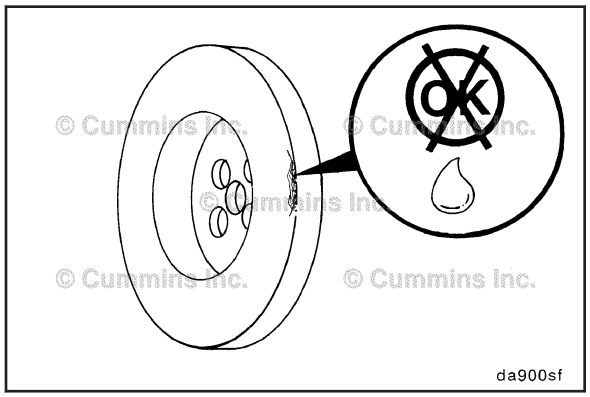
Replace the damper if its thickness varies by more than 6.35 mm [0.25 in].



Spray the damper with spot check developer, type SKD-NF, or its equivalent.

Heat the damper in an oven, rolled-lip side down, at 93°C [200°F] for 2 hours.

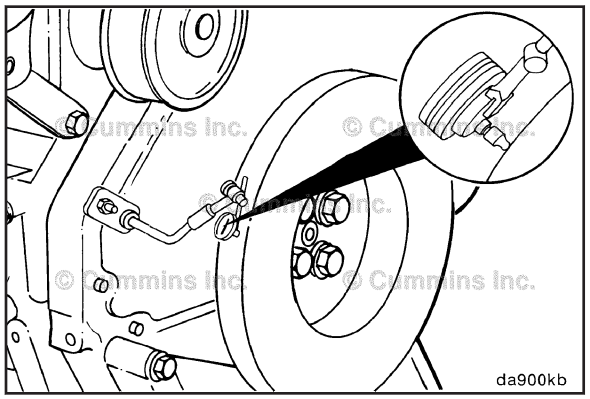




⚠WARNING⚠
Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.

Remove the damper from the oven and check for fluid leakage.

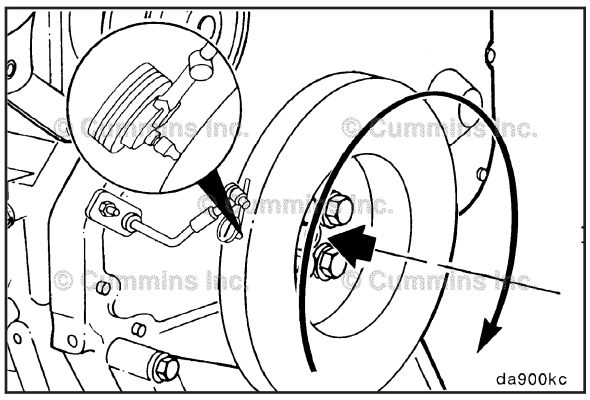
If there is leakage, the vibration damper **must** be replaced.



Measure

Measure the vibration dampers eccentricity.

Install a dial indicator as illustrated.

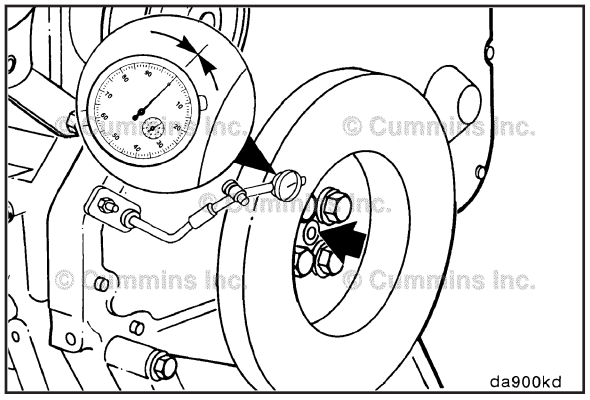


Rotate the crankshaft with engine barring tool, Part Number 3377371.

Record the dial indicators movement.

Vibration Damper Eccentricity per 25.4 mm [1.0 in] of Diameter		
mm		**in**
0.10	MAX	0.004

NOTE: If the eccentricity is **not** within specification the vibration damper **must** be replaced.



Measure the vibration damper wobble.

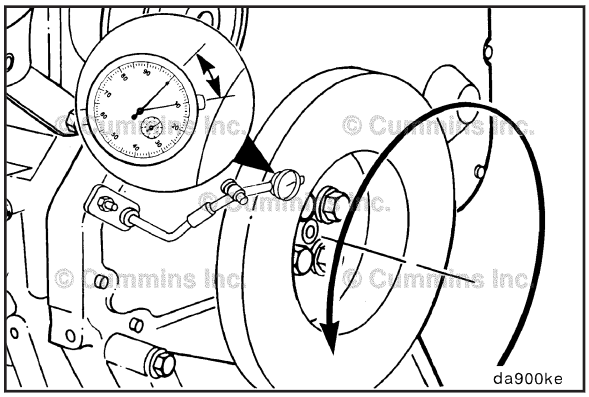
Install a dial indicator as illustrated.

Push the crankshaft to the front or rear and zero the dial indicator.

Rotate the crankshaft with engine barring tool, Part Number 3377371, 360 degrees, maintaining the position of the crankshaft.

Record the dial indicator movement.

Vibration Damper Wobble per 25.4 mm [1.0 in] of Radius		
mm		in
0.18	MAX	0.007



Install

Front Gear Train

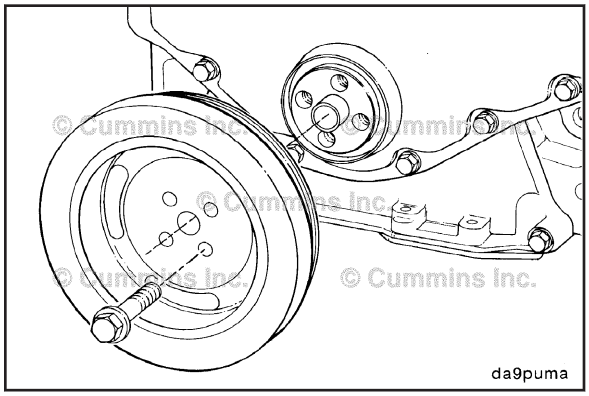
NOTE: The B Series engines have two configurations for the crankshaft pulleys and vibration dampers. Determine which configuration is used and use the appropriate steps in this procedure.

One Piece Pulley/Vibration Damper

Install the crankshaft vibration damper.

Install and tighten the crankshaft pulley/vibration damper capscrews.

Torque Value: 125 N•m [92 ft-lb]



Two-Piece Pulley/Vibration Damper

Install the vibration damper.

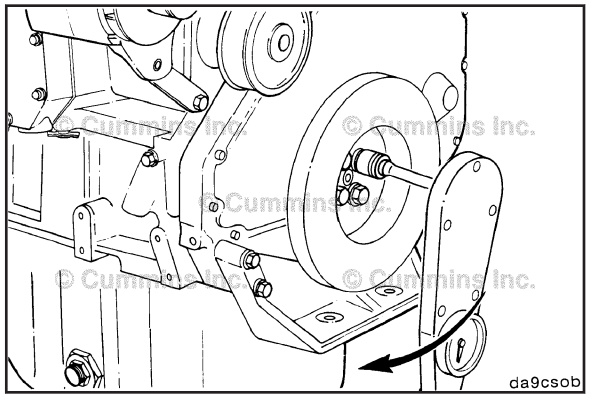
Install and tighten the vibration damper capscrews.

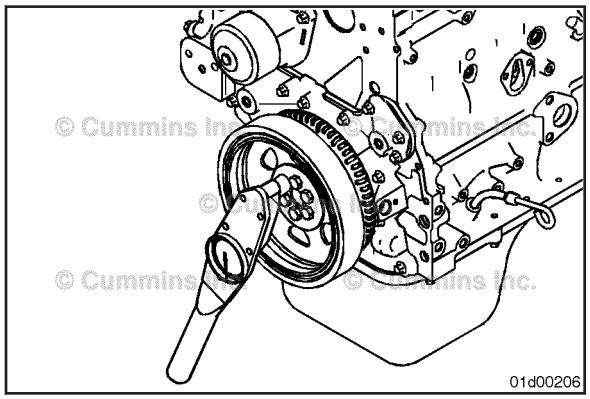
Torque Value: 200 N•m [148 ft-lb]

Install the crankshaft pulley.

Install and tighten the crankshaft pulley capscrews.

Torque Value: 77 N•m [57 ft-lb]





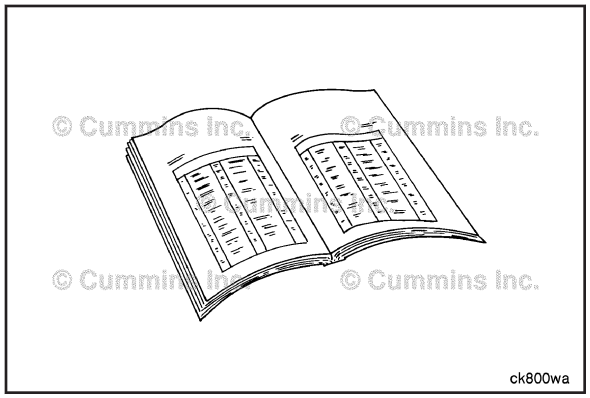
Rear Gear Train

Lubricate bolts with clean engine oil.

Install the vibration damper.

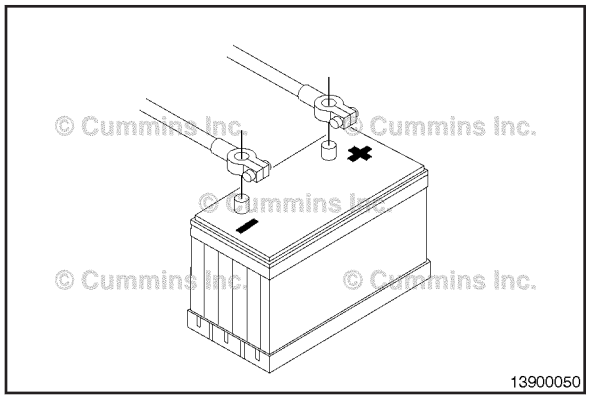
For rear gear train engines, tighten the six vibration damper capscrews in a criss-cross pattern.

Torque Value: Step1 50 N•m [37 ft-lb]
Step2 Rotate 90 degrees



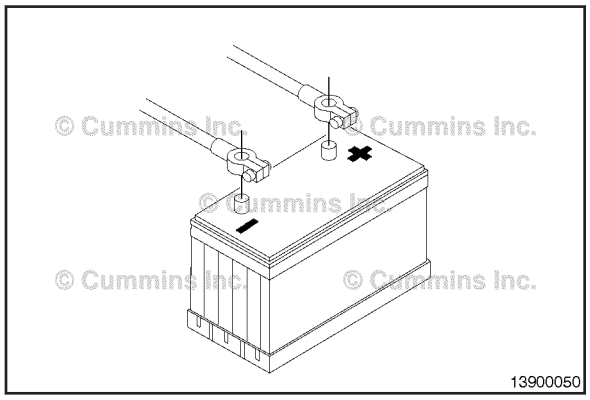
Finishing Steps

- 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.



Piston and Connecting Rod Assembly (001-054)

Preparatory Steps

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

- Disconnect the batteries.

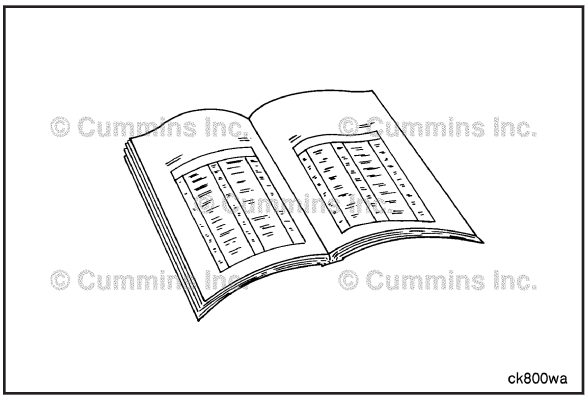
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠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.

⚠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 lubricating oil. Refer to Procedure 007-037
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025
- If equipped, remove the block stiffener plate. Refer to Procedure 001-089
- If the engine is equipped with J-jet piston cooling nozzles, they **must** be removed to prevent component damage. Refer to Procedure 001-046
- Drain the coolant. Refer to Procedure 008-018
- Remove the cylinder head. Refer to Procedure 002-004.



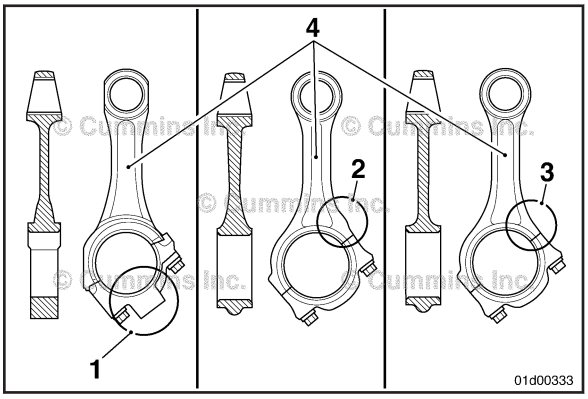
General Information

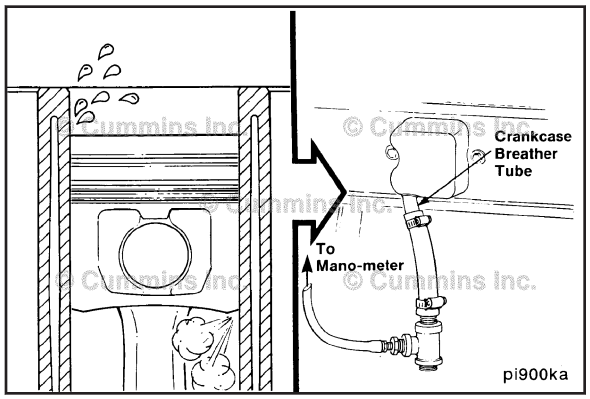
Different types of connecting rods are used in B Series engines, depending on the plant and time the engine was built. **Not** all connecting rods are interchangeable. When replacing a connecting rod, make sure it matches the other connecting rods. All connecting rods in the engine **must** be the same.

Not all connecting rods have the part number located on the connecting rod. It is necessary to identify physical characteristics of the connecting rod when matching it to existing connecting rods.

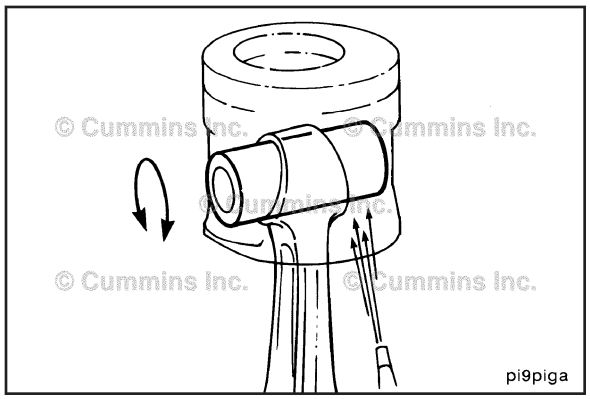
1. Balance weight on the connecting rod cap
2. Protrusion on short side of connecting rod
3. Smooth edge on the short side of the connecting rod
4. I-Beam design.

This procedure covers both the fracture-split (non-machined) and machined connecting rods. Cautions and notes are used throughout the procedure where special handling considerations **must** be followed for fracture split (non-machined) rods.

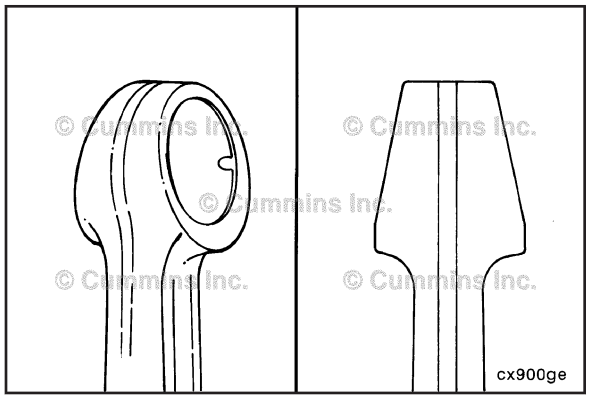




There are a number of power-related problems, including excessive lubricating oil consumption, smoke, blowby, and poor performance, that can be caused by inadequate sealing between the piston rings and the cylinder walls. A blowby measurement can help detect the problem.



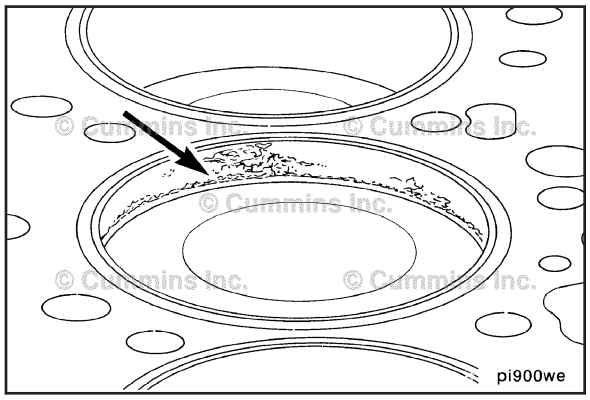
A free-floating, hollow piston pin is used to attach the piston to the connecting rod. Lubricating the pin and journal is accomplished by residual spray from piston cooling.



The piston pin end of the connecting rod is angle-cut to provide additional bearing surface. The connecting rod end is fitted with a bronze bushing.

Some engines have connecting rods which contain a hole in the piston pin end of the connecting rod and the bushing. The hole in the rod and bushing could possibly **not** line up. The hole is for manufacturing purposes **only**.

Some 4 cylinder naturally aspirated engines utilize a narrow lower connecting rod bearing.

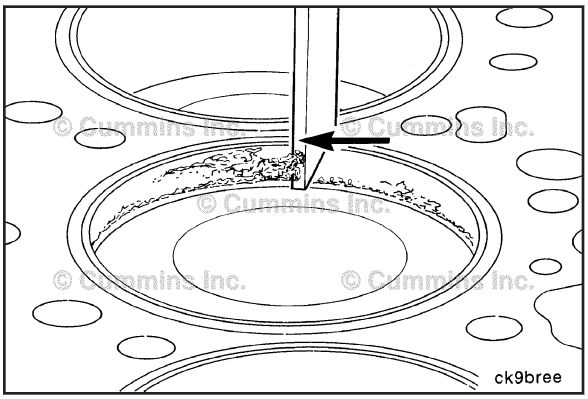


Remove

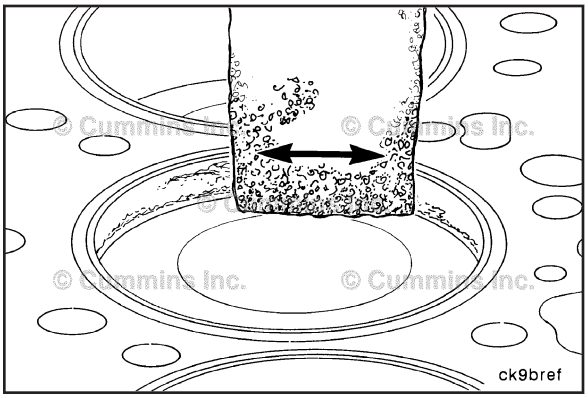
Rotate the crankshaft with engine barring tool, Part Number 3824591, until the pistons are below the carbon deposits, which are found above the ring travel area.

⚠CAUTION⚠
Do not use emery cloth or sandpaper to remove carbon from the cylinder bores. Aluminum oxide or silicon particles from these materials can cause serious engine damage.

Use a scraper or a blunt-edged instrument to loosen the carbon deposits. Do **not** damage the cylinder with the scraper.



Remove the remaining carbon with a Scotch-Brite™ cleaning pad, or equivalent.

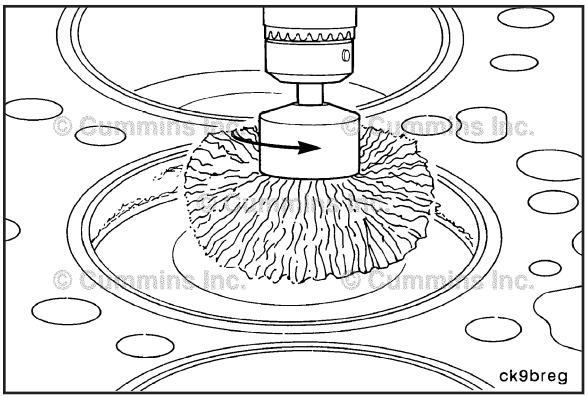


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury

⚠CAUTION⚠
Do not use the steel wire wheel in the piston travel area. Operate the wheel in a circular motion to remove the deposits.

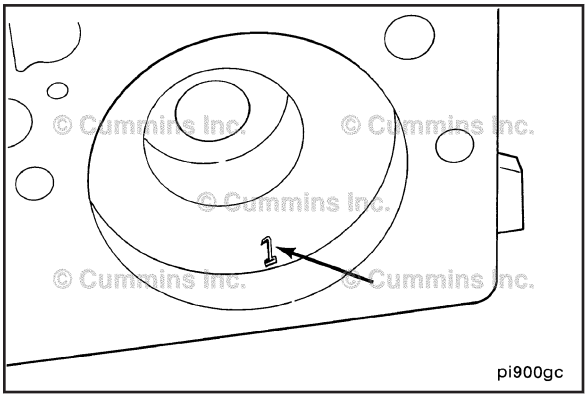
NOTE: An inferior quality wire wheel will lose steel bristles during operation, thus causing additional contamination.

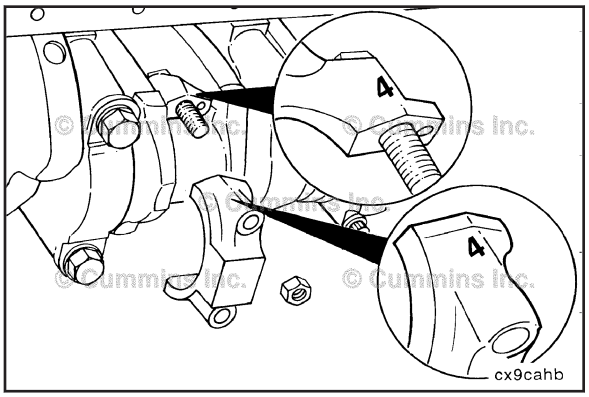
An alternative method to remove the carbon ridge is to use a high-quality steel wire wheel installed in a drill or die grinder.



On pistons with anodized coatings, do **not** stamp the anodized coating on the outer rim.

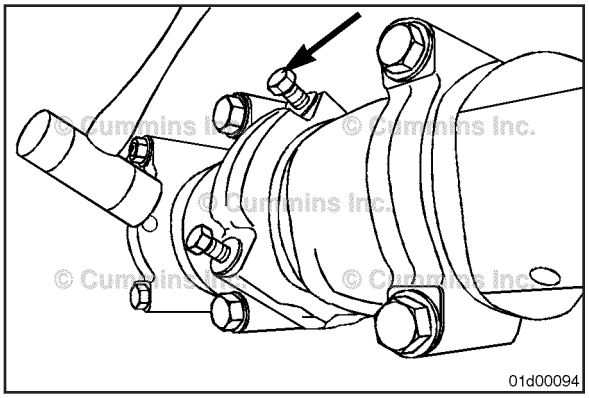
Mark each piston according to the cylinder.





Rotate the crankshaft to position the connecting rod caps at bottom dead center for removal.

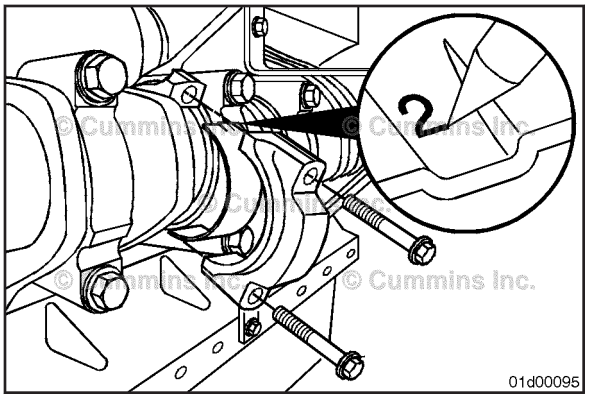
Mark each connecting rod and connecting rod cap according to the cylinder number location.



Loosen the connecting rod capscrews.

NOTE: Do **not** remove the capscrews from the connecting rods at this time.

Use a rubber hammer to hit the connecting rod capscrews to loosen the caps.

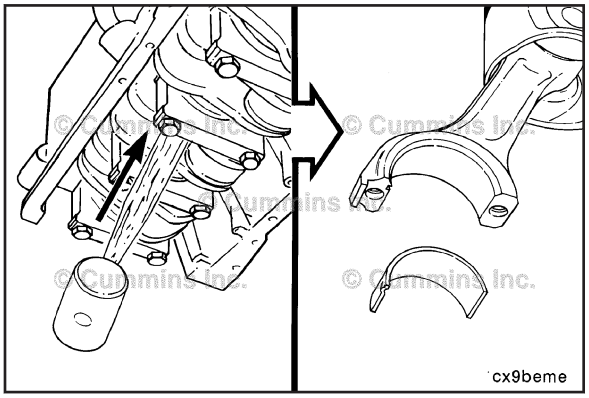


⚠CAUTION⚠
Do not damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod caps are removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage. Incorrect assembly can damage the rod.

⚠CAUTION⚠
When setting the connecting rod cap down do not set the cap down on the fractured split surface. Damage to the fractured split surface can result.

Remove the connecting rod capscrews.

Remove the connecting rod cap.



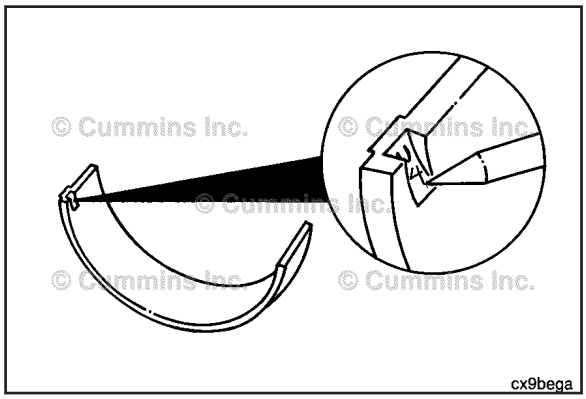
Remove the lower connecting rod bearing.

Mark the cylinder number and the letter “L” (lower) on the flat surface of the bearing tang.

Push the connecting rod and piston assembly out of the cylinder bore. Care **must** be taken **not** to damage the connecting rod or bearing.

Remove the upper rod bearing.

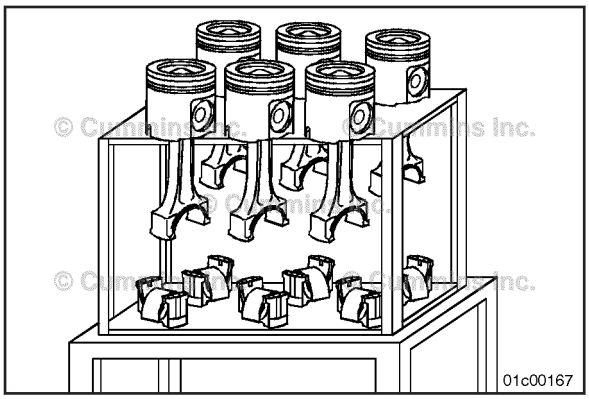
Mark the cylinder number and the letter “U” (upper) on the flat surface of the bearing tang.



The piston and connecting rod assemblies **must** be installed in the same cylinder number from which they were removed, to provide proper fit of worn mating surfaces, if parts are reused.

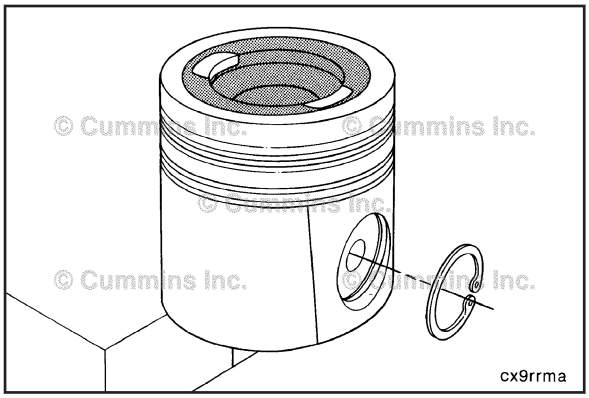
Use a tag to mark the cylinder number from which each piston and rod assembly were removed.

Place the rod and piston assemblies in a container to protect them from damage.



Disassemble

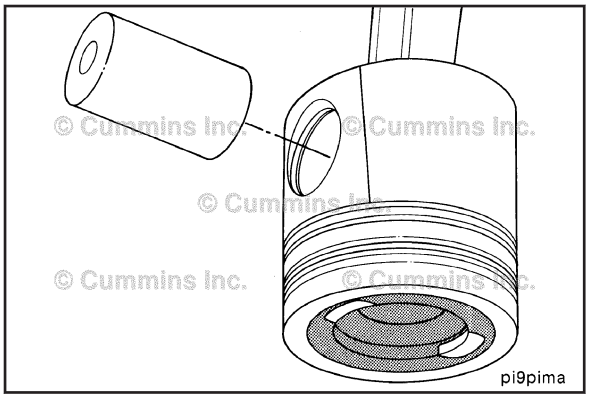
Remove the piston pin retaining rings.

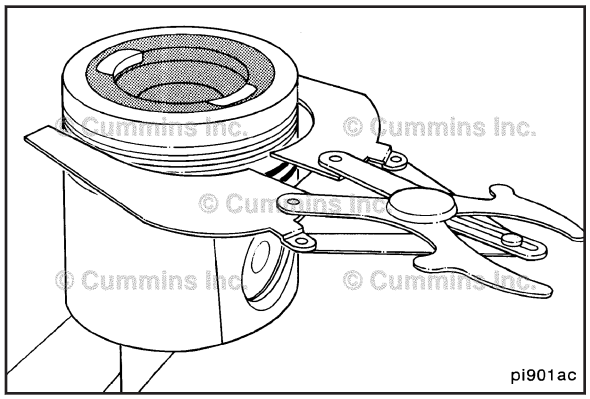


NOTE: Heating the piston is **not** required.

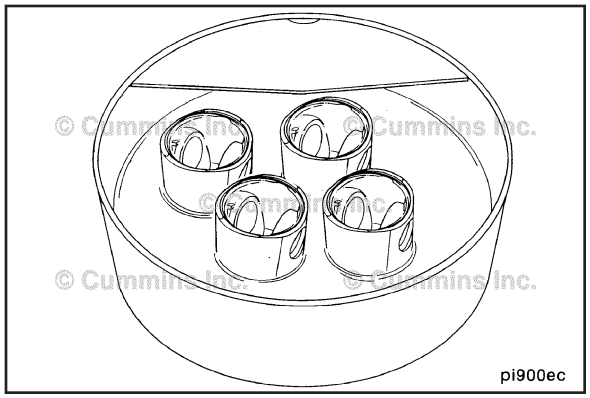
Remove the piston pin.

Remove the connecting rod from the piston.



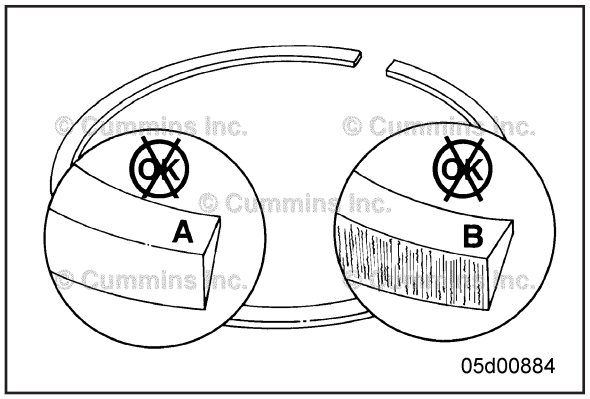


Remove the piston rings using piston ring expander, Part Number 3823137.

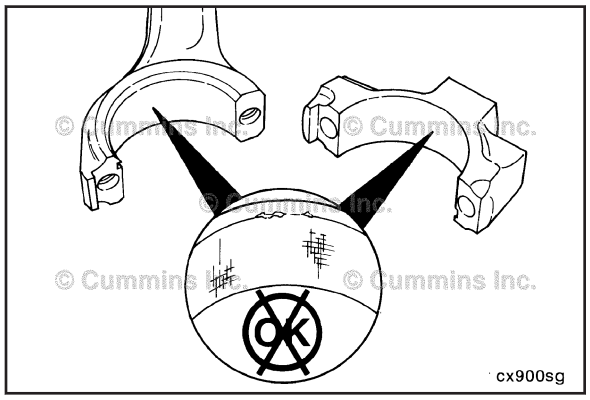


Clean and Inspect for Reuse

Clean and inspect the pistons and piston pins. Refer to Procedure 001-043.



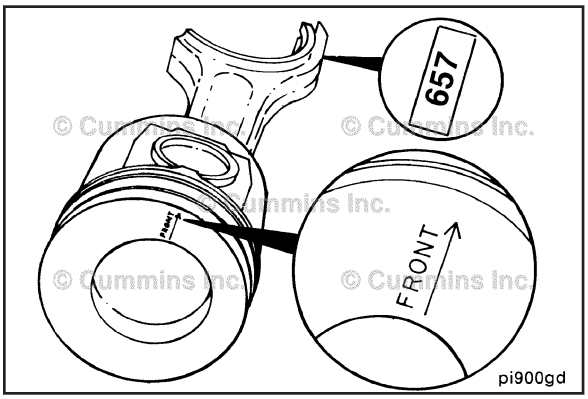
Inspect the piston rings. Refer to Procedure 001-047.



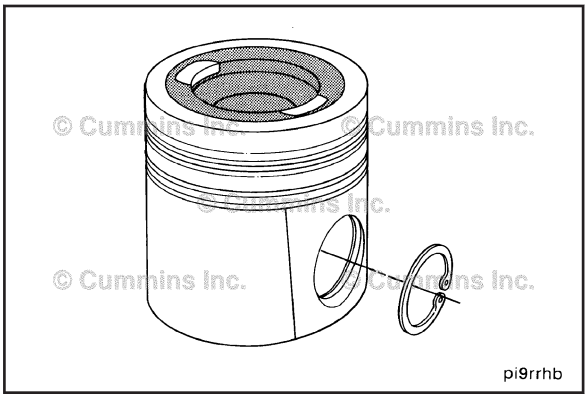
Inspect the connecting rod. Refer to Procedure 001-014.

Assemble

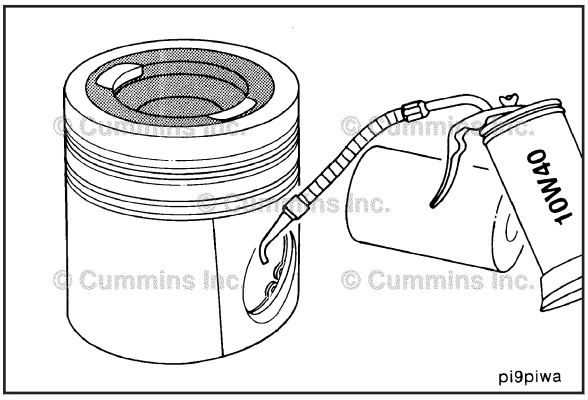
Be sure FRONT and/or arrow marking on the top of the piston and the numbers on the connecting rod and cap are positioned as illustrated.



Install the retaining ring in the pin groove on the front side of the piston.



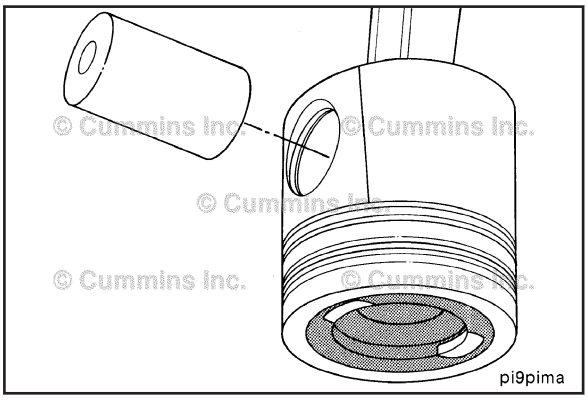
Lubricate the pin and pin bores with clean 15W-40 engine lubricating oil.

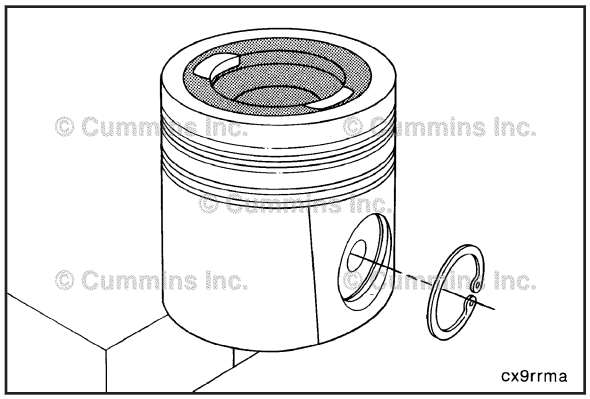


NOTE: Pistons do **not** require heating to install the pin; however, the pistons do need to be at room temperature or above.

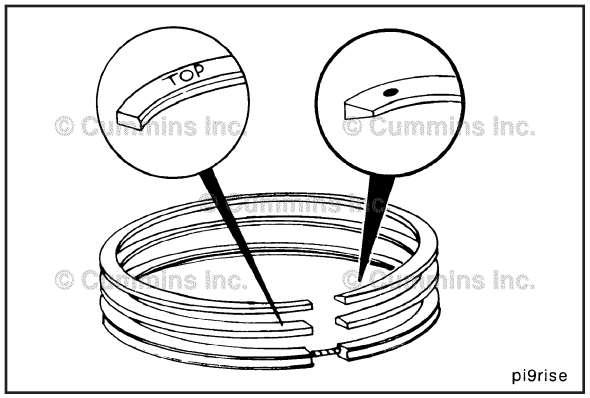
Install the connecting rod.

Install the piston pin.





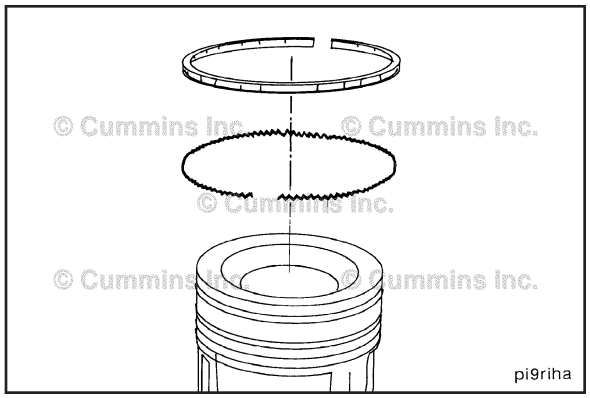
Install the second retaining ring.



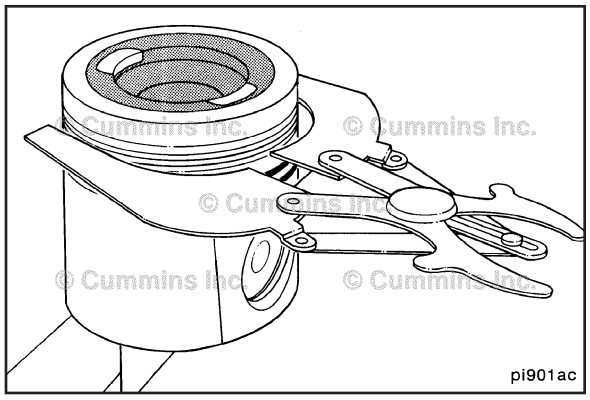
⚠CAUTION⚠
Most piston rings look similar but have significant differences. Make sure the correct part number is being used for the engine.

The top surface of the upper and intermediate rings are identified either with the word “TOP” or a supplier identification mark, such as a stamped dot. Assemble with the word “TOP” or the supplier mark facing upward.

The bottom, or oil control ring, can be installed with either side up.



NOTE: The two-piece oil control ring **must** be installed with the expander ring gap 180-degrees from the gap of the oil ring.

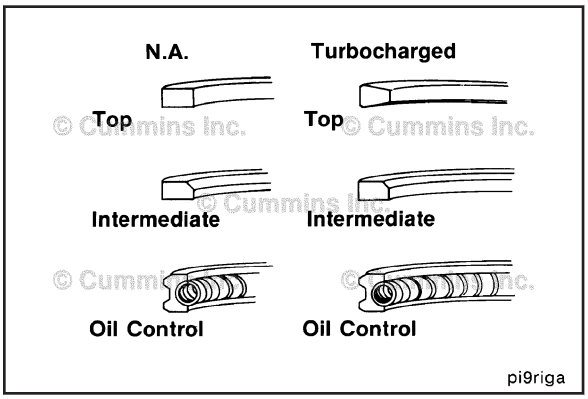


Using piston ring expander, Part Number 3823137, install the rings on the piston.

B3.9, B4.5, and B5.9 Engines

The piston ring type and location can be identified by piston ring profile.

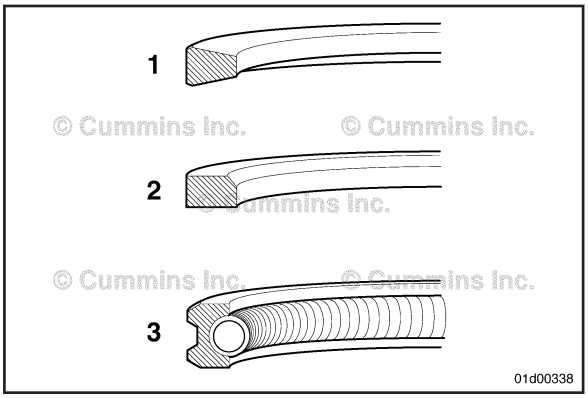
1. Top Piston Ring
2. Intermediate Piston Ring
3. Oil Control Ring.



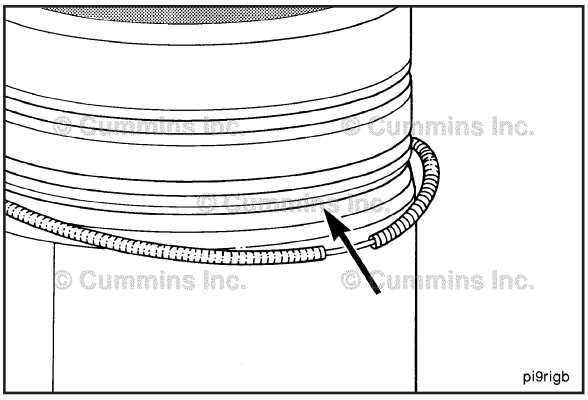
B4.5 RGT Engines

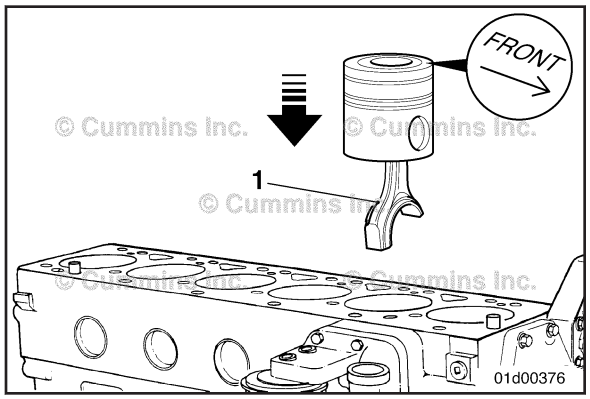
The piston ring type and location can be identified by piston ring profile.

1. Top Piston Ring
2. Intermediate Piston Ring
3. Oil Control Ring.



Start by positioning the oil ring expander in the oil control ring groove. Then install the oil control ring, followed by the intermediate ring and finally the top ring.





Piston Grading

NOTE: B4.5 RGT engines do **not** require piston grading.

When rebuilding an engine with the original cylinder block, crankshaft, and pistons, make sure the pistons are installed in the original cylinder.

If replacing the piston(s), make sure the replacement piston(s) are the same grade as the original piston.

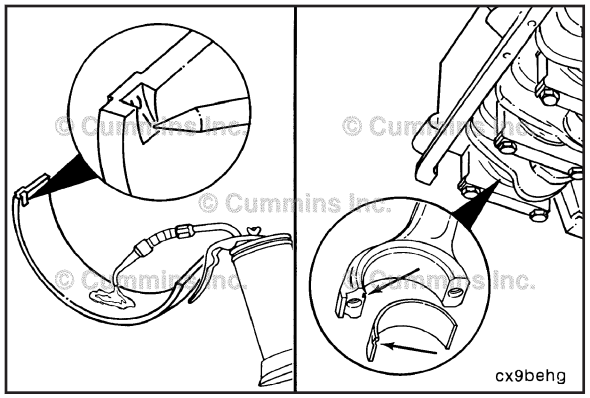
If a new cylinder block or crankshaft is used, the piston grading procedure **must** be performed to determine the proper piston grade for each cylinder.

Install the connecting rod and piston assembly into the Number 1 cylinder without the rings installed.

Align the “Front” marking and/or arrow on the top of the piston so that it points towards the front of the engine.

Insert the connecting rod through the cylinder bore.

The long end of the connecting rod (1) will be on the exhaust side of the engine.

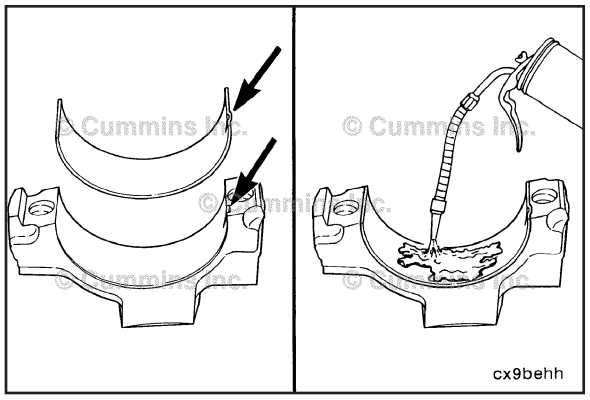


NOTE: The fracture surface on the fracture split connecting rod and connecting rod cap **must** be kept dry and clean to make sure proper mating of the two surfaces is maintained.

The connecting rod bearings **must** be installed in the original connecting rod and cap.

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

Use clean 15W-40 engine oil to coat the inside diameter of the connecting rod bearing shell.



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

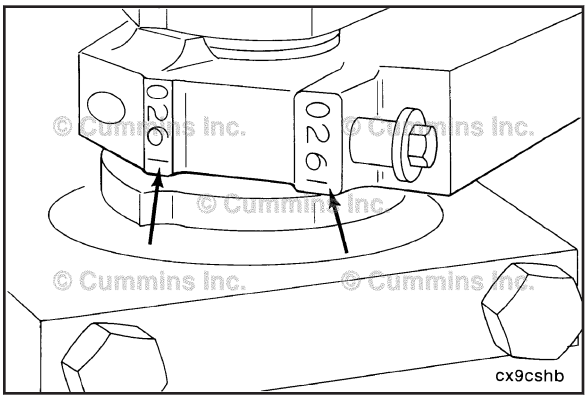
NOTE: The fracture split connecting rods use a different upper and lower bearing.

Use clean 15W-40 engine oil to coat the inside diameter of the connecting rod bearing shell.

NOTE: The fracture surface on the fracture split connecting rod and connecting rod cap **must** be kept dry and clean to make sure proper mating of the two surfaces is maintained.

The number stamped on the connecting rod and cap at the parting line **must** match and be installed on the oil cooler side of the engine.

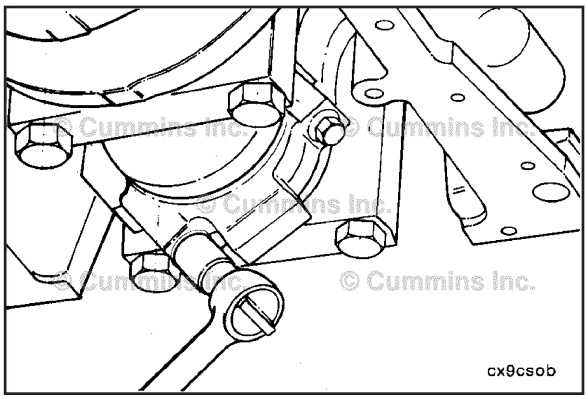
Install the connecting rod cap and capscrews to the connecting rod.



Tighten the two capscrews.

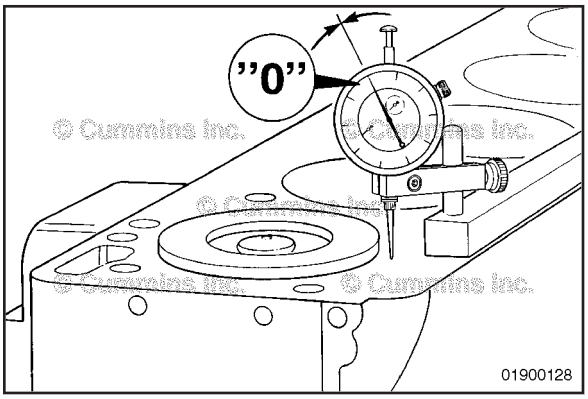
Torque Value:
Connecting rod cap capscrews 35 N•m [26 ft-lb]

Do **not** tighten to final torque value.



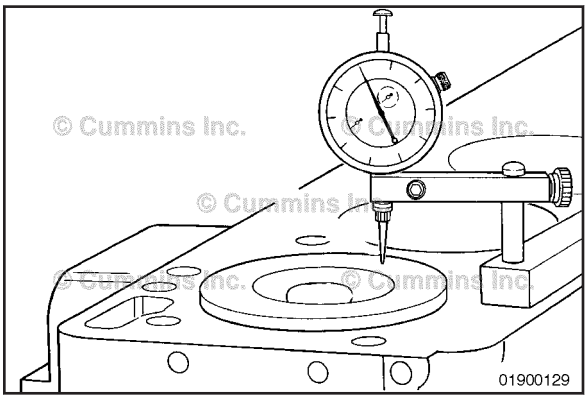
Use a fine-grit hone to remove any burrs from the cylinder block head deck.

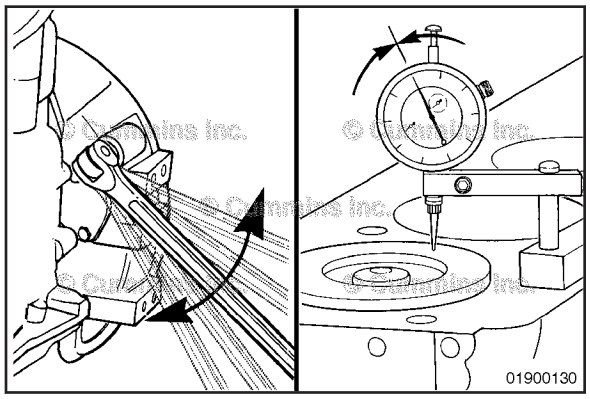
Zero the depth gauge, Part Number 3164438, to the cylinder block head deck.



NOTE: Do **not** place the indicator tip on the anodized area.

Move the depth gauge, Part Number 3164438, directly over the piston pin to eliminate any side-to-side movement.

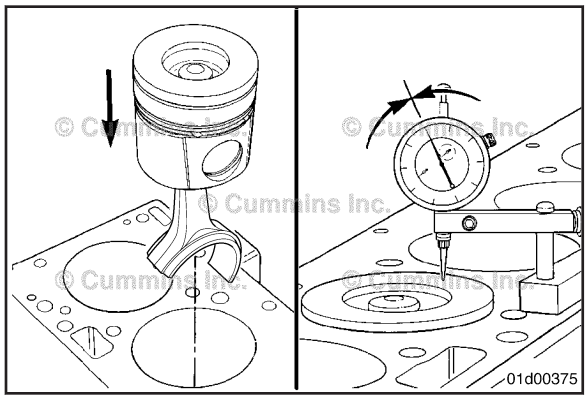




Rotate the crankshaft to top dead center (TDC).

Rotate the crankshaft **clockwise** and **counterclockwise** to find the highest dial indicator reading.

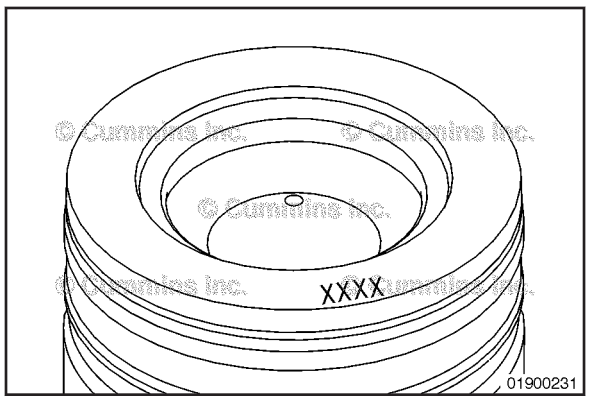
Record the reading.



Remove the piston and connecting rod assembly from the Number 1 cylinder.

Install the assembly into the Number 2 cylinder.

Repeat the procedure for every cylinder using the same piston and connecting rod assembly.



The four digits on top of the piston are the last four digits of the part number.

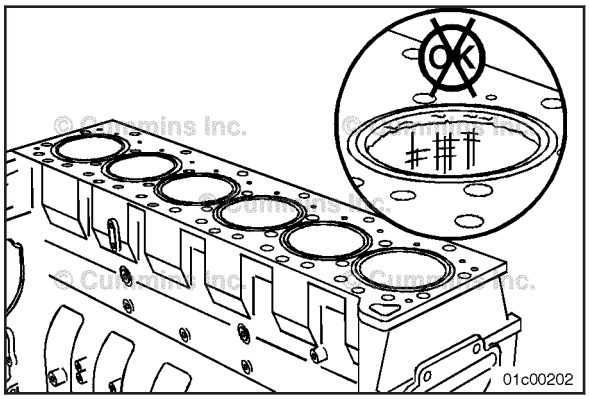
Using the measured piston protrusion and the grade of the piston, which was measured, determine the piston grade required to obtain protrusion from the following table.

The part number for each piston grade can be found by entering the engine serial number on QuickServe® Online Internet Website.

Piston Protrusion Chart			
Test Piston Grade	Protrusion		Use Grade
	mm	in	
A	0.609 to 0.711	0.024 to 0.028	A
A	0.508 to 0.609	0.020 to 0.024	B
A	0.406 to 0.508	0.016 to 0.020	C
B	0.711 to 0.813	0.028 to 0.032	A
B	0.609 to 0.711	0.024 to 0.028	B
B	0.508 to 0.609	0.020 to 0.024	C
C	0.813 to 0.914	0.032 to 0.036	A
C	0.711 to 0.813	0.028 to 0.032	B
C	0.609 to 0.711	0.024 to 0.028	C

Install

The cylinder block and all parts **must** be clean before assembly. Refer to Procedure 001-026 to inspect the cylinder walls of the cylinder block. Use a clean, lint-free cloth to clean the connecting rods and bearing shells.



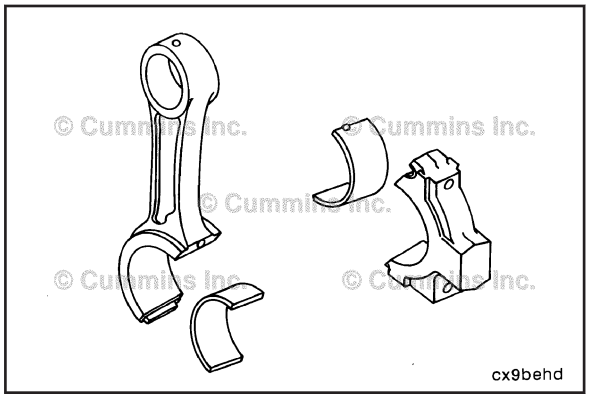
CAUTION
The connecting rods and connecting rod caps are not interchangeable. The connecting rods and connecting rod caps are machined as an assembly. Failure will result if the connecting rods and caps are mixed.

CAUTION
Make sure not to damage the mating surfaces of the fracture-split connecting rods and the rod caps.

NOTE: Fracture split connecting rods use a different upper and lower bearing.

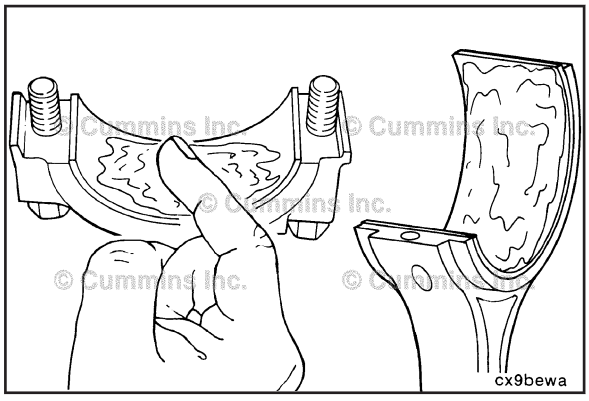
Install the bearing shells into both the connecting rod and the connecting rod cap.

Make sure the tang on the bearing shells is in the slot of the connecting rod cap and connecting rod.

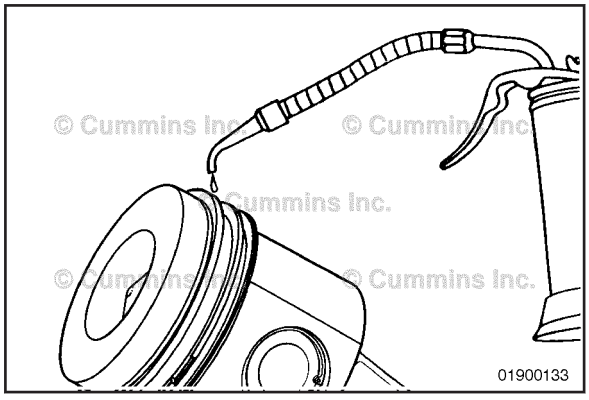


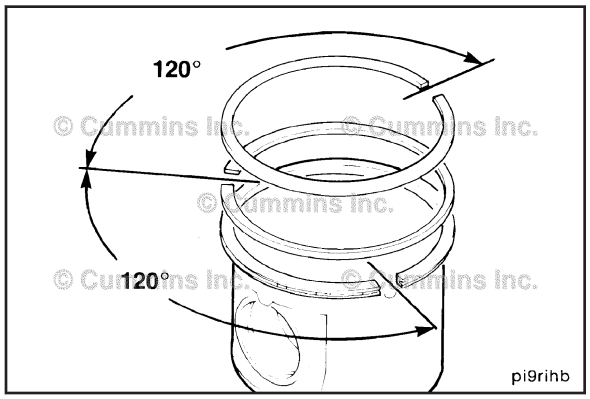
NOTE: The fracture surface on the fracture split connecting rod and connecting rod cap **must** be kept dry and clean to make sure proper mating of the two surfaces is maintained.

Lubricate the connecting rod bearings with a light film of assembly lubricant, Part Number 3163087.



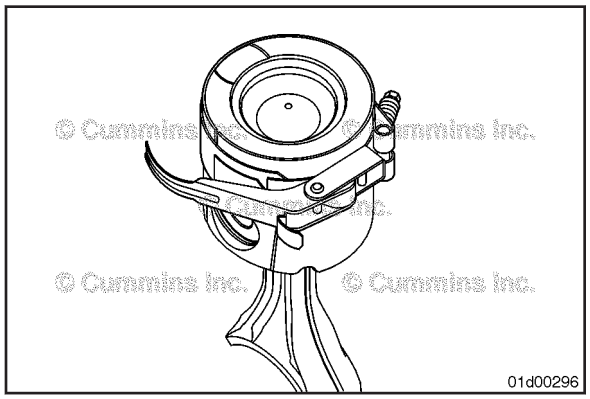
Lubricate the rings and piston skirts with clean engine lubricating oil.





Position the rings so that the ring gaps are 120 degrees apart.

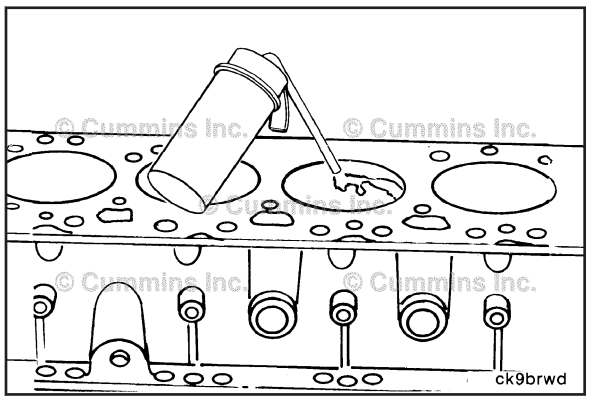
NOTE: The ring gap of each ring **must not** be aligned with the piston pin, or any other ring. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.



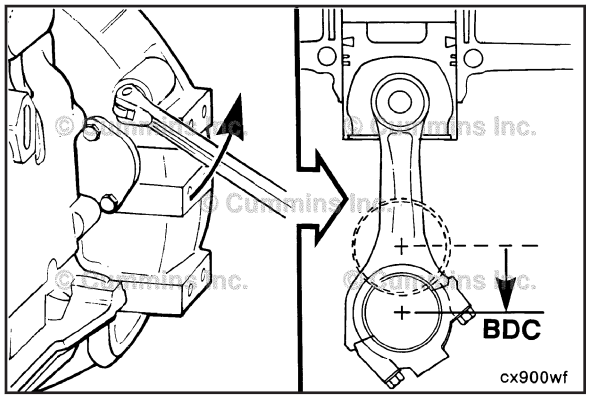
⚠CAUTION⚠
If using a strap type ring compressor, make sure the inside end of the strap does not hook on a ring gap and break the ring.

For B3.9, B4.5, and B5.9 engines, use piston ring compressor, Part Number 3164330, to compress the rings.

For B4.5 RGT engines, use piston ring compressor, Part Number 4918294, to compress the rings.



Lubricate the cylinder bore with clean 15W-40 lubricating engine oil.



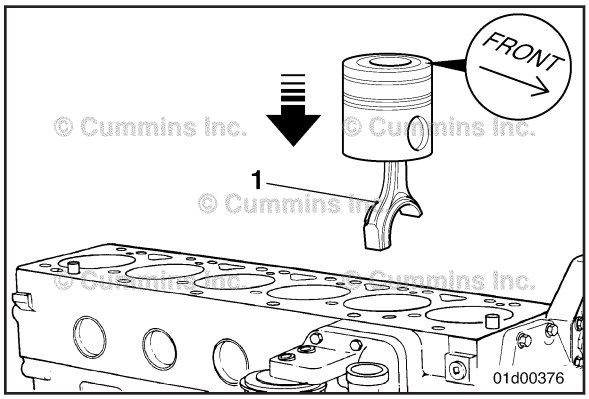
Position the connecting rod journal for the piston to be installed to bottom dead center (BDC).

⚠WARNING⚠
Failure to follow this step will result in extensive engine damage.

Align the “front” marking and/or arrow on the top of the piston so that it points towards the front of the engine.

Insert the connecting rod through the cylinder bore until the ring compressor contacts the top of the cylinder block.

The long end of the connecting rod (1) will be on the exhaust side of the engine. If **not**, verify the piston is installed correctly onto the connecting rod.

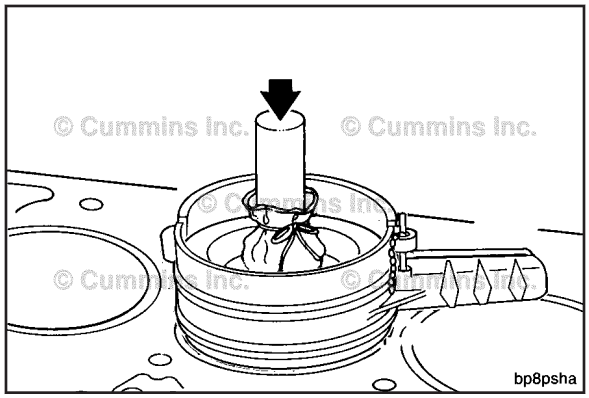


Hold the ring compressor against the cylinder block.

Push the piston through the ring compressor and into the cylinder bore.

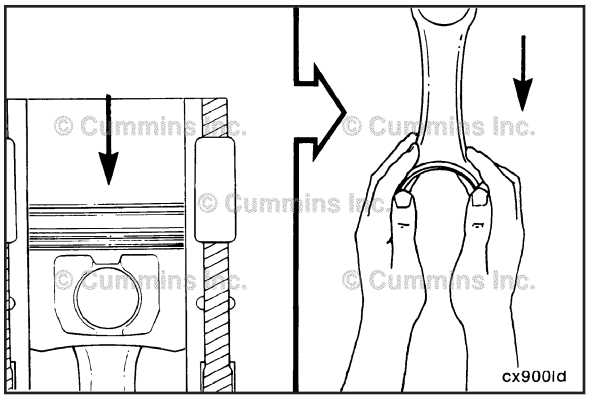
Push the piston until the top ring is completely in the cylinder bore.

NOTE: If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.



Take care to **not** damage the cylinder wall when inserting the connecting rod.

Carefully push the piston into the bore while guiding the connecting rod to the crankshaft journal.

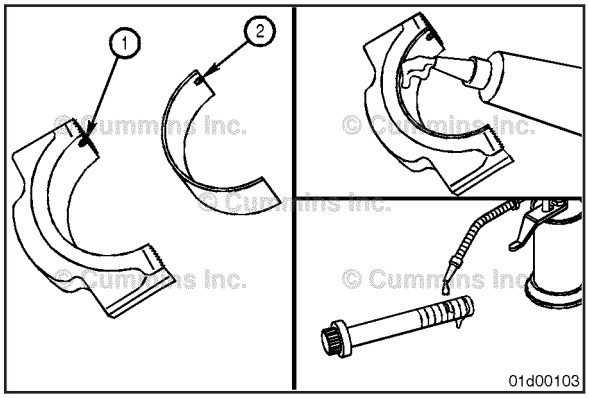


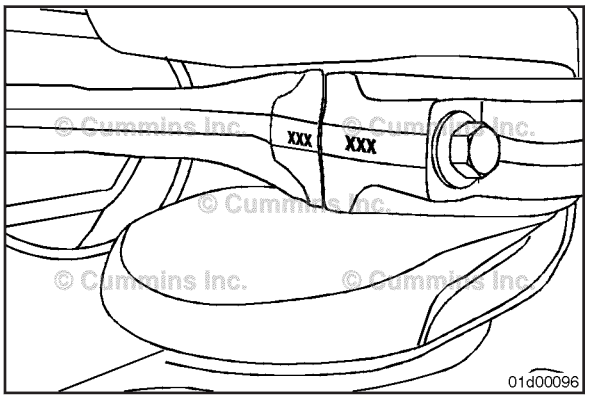
NOTE: The fracture surface on the fracture split connecting rod and connecting rod cap **must** be kept dry and clean to make sure proper mating of the two surfaces is maintained.

Verify the tang of the bearing (2) is in the slot of the cap (1).

Use assembly lube, Part Number 3163087, or equivalent to coat the inside diameter of the bearing shell.

Use clean 15W-40 oil to lubricate the connecting rod capscrew threads and underside of the connecting rod capscrew heads.

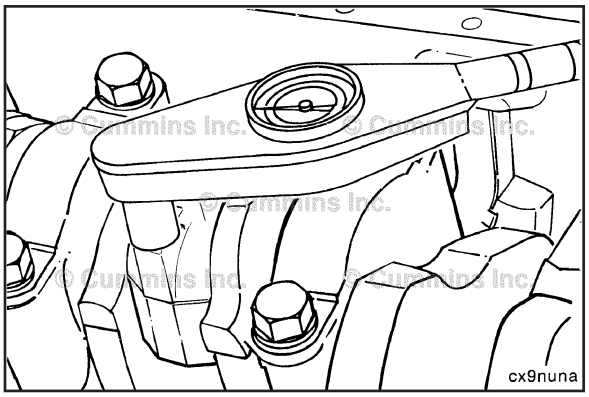




⚠CAUTION⚠
Do not damage the fractured split surface on the connecting rod or connecting rod cap when the connecting rod cap is installed. If the fracture split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage.

The connecting rod and cap **must** have the same number and **must** be installed in the proper cylinder. The connecting rod cap number and rod number **must** be on the same side of the connecting rod to prevent engine damage during engine operation.

Install the connecting rod and capscrews.

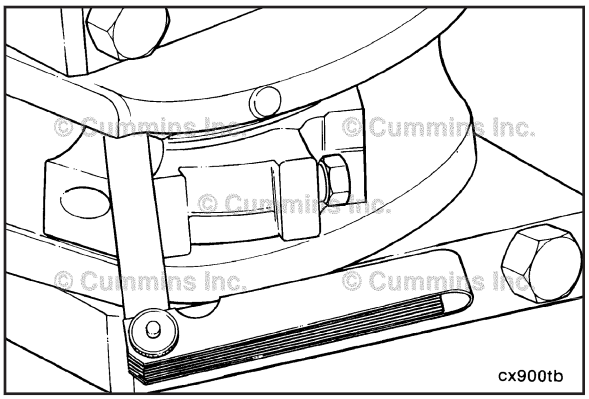


Use a marked socket and torque wrench to tighten the connecting rod capscrews.

Using the torque plus angle method, tighten the connecting rod capscrews in alternating sequence.

Torque Value:

B3.9, B4.5 RGT and B5.9 Engines	Step1	30 N•m	[22 ft-lb]
	Step2	60 N•m	[44 ft-lb]
	Step3	Turn 60 degrees clockwise.	
B4.5 Engines	Step1	25 N•m	[18 ft-lb]
	Step2	Turn 60 degrees clockwise.	

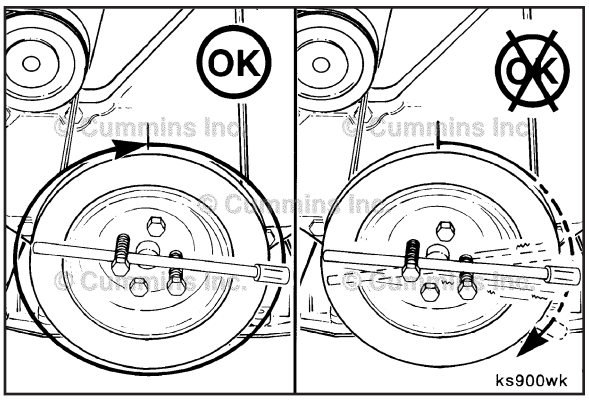


NOTE: Do **not** measure the clearance between the connecting rod cap and crankshaft.

Measure the side clearance between the connecting rod and crankshaft.

Side Clearance Limits

mm		in
0.10	MIN	0.004
0.33	MAX	0.013



⚠CAUTION⚠
To reduce the possibility of engine damage, the crankshaft must rotate freely.

⚠CAUTION⚠
If the connecting rod is not properly oriented (tang opposite the camshaft), it will contact the camshaft and lock the engine.

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

Measure

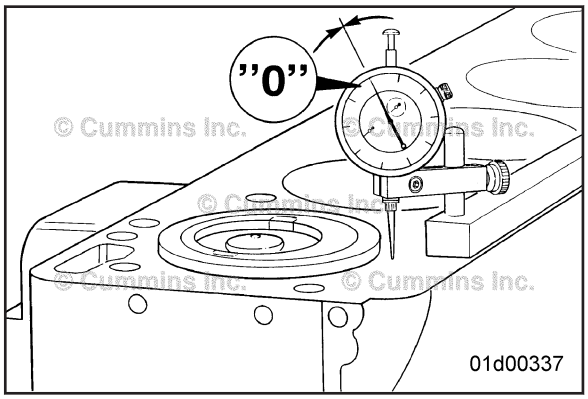
Measure piston protrusion above the cylinder block combustion deck.

NOTE: For B3.9, B4.5, and B5.9 engines, if piston grading procedure was performed, this measure step is **not** required.

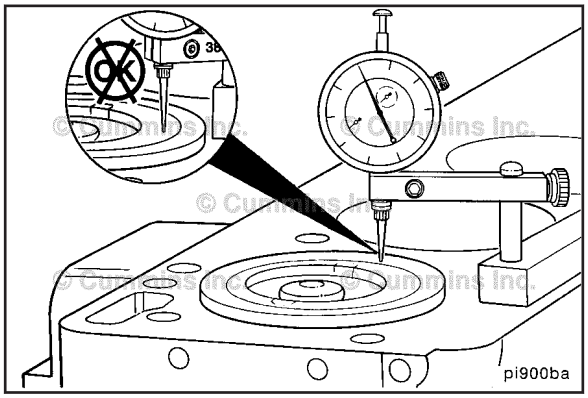
NOTE: For B4.5 RGT engines, this procedure is only required after a piston, crankshaft, connecting rod, or block modification/replacement.

Measure the piston protrusion using depth gauge assembly part number 3823495. No piston or head gasket grading is required.

Install the dial indicator on the cylinder head and zero.



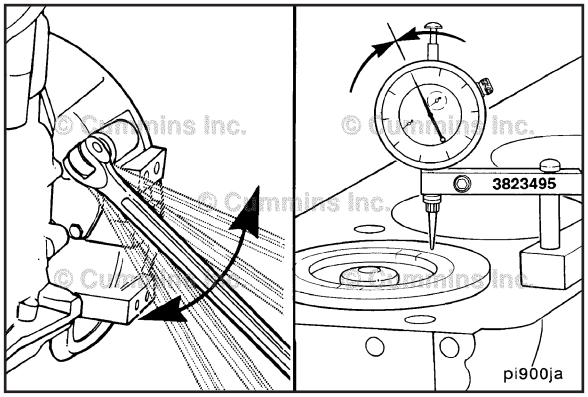
Move the dial indicator directly over the piston pin to eliminate any side-to-side movement. Do **not** place the indicator tip on the anodized area.



Rotate the crankshaft to top dead center. Rotate the crankshaft clockwise and counterclockwise to find the highest dial indicator reading. Record the reading.

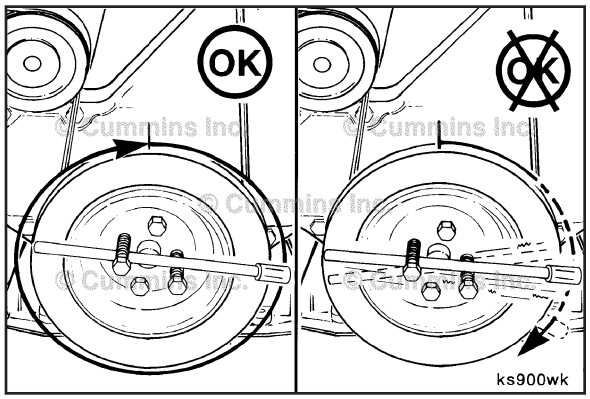
B4.5 RGT Piston Protrusion		
mm		**in**
0.151	MIN	0.006
0.485	MAX	0.019

B3.9, B4.5, and B5.9 Piston Protrusion		
mm		**in**
0.609	MIN	0.024
0.711	MAX	0.028

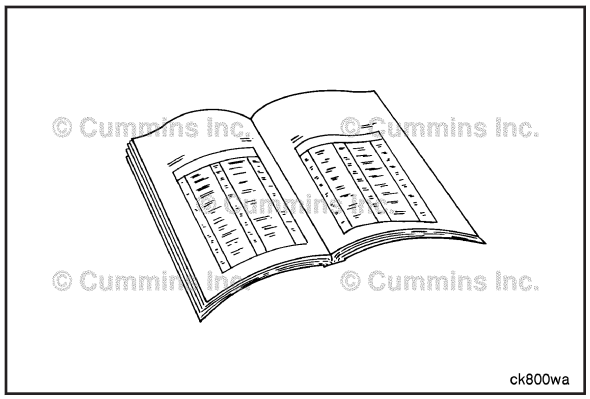


If the piston protrusion is **not** within specification, verify that the correct parts are installed and/or the cylinder block combustion deck has been machined improperly. Refer to Procedure 001-026.

For B3.9, B4.5, and B5.9 engines verify the correct grade of piston is being used. See the Piston Grading section of this procedure.

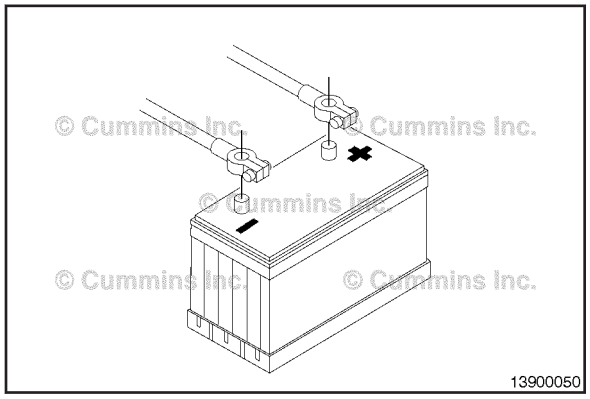


Check for freedom of rotation as the connecting rod caps are installed. If the crankshaft does **not** rotate freely, check the installation of the connecting rod bearings and the bearing size.



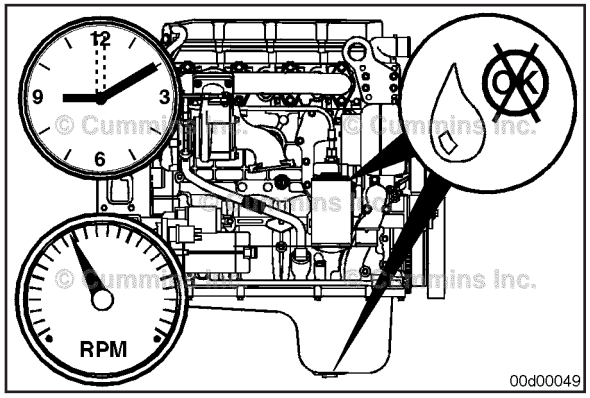
Finishing Steps

- If removed, install the J-jet piston cooling nozzles. Refer to Procedure 001-046
- Install the lubricating oil suction tube. Refer to Procedure 007-035
- If equipped, install the block stiffener plate. Refer to Procedure 001-089
- Install the lubricating oil pan. Refer to Procedure 007-025
- Install the cylinder head. Refer to Procedure 002-004
- Fill the engine with lubricating oil. Refer to Procedure 007-037
- Fill the engine with 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 to normal operating temperature and check for leaks.

Engine Dataplate (001-057)

General Information

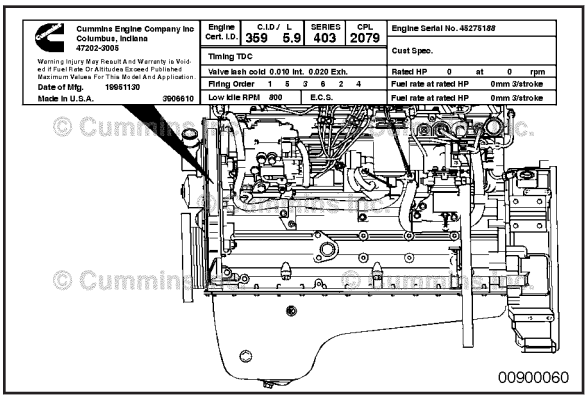
Front Gear Train

The engine data plate is typically located on the front gear housing next to the fuel injection pump.

Two types of data plates are typically used:

1. Metal stamped data plate which is riveted in place
2. A printed plastic data plate label adhered in place.

If the data plate is damaged, missing or incorrect, contact your local Cummins Inc. Service location to obtain a new data plate.



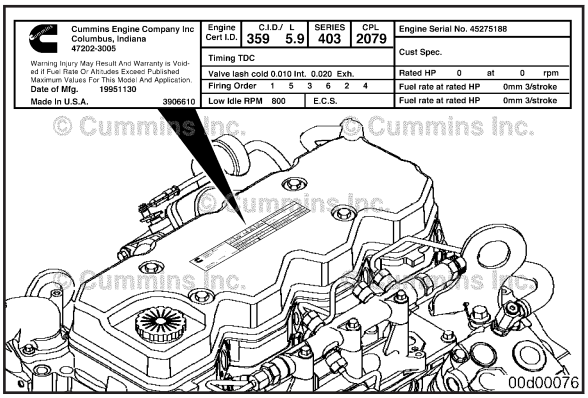
Rear Gear Train

The engine data plate is typically located on the rocker lever cover, but may be located on the gear housing.

Two types of data plates are typically used:

1. Metal stamped data plate which is riveted in place
2. A printed plastic data plate label adhered in place.

If the data plate is damaged, missing or incorrect, contact your local Cummins Inc. Service location to obtain a new data plate.

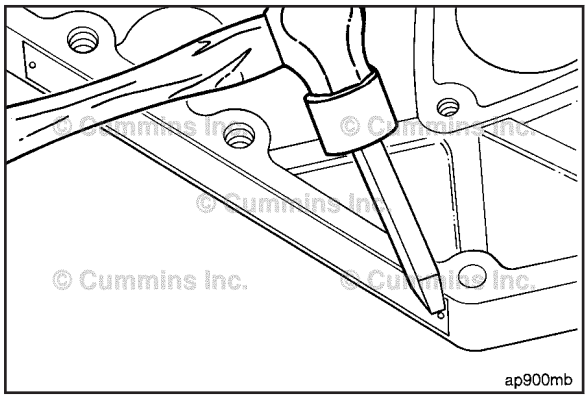


Remove

For metal stamped dataplates, remove the rivets securing the engine data plate.

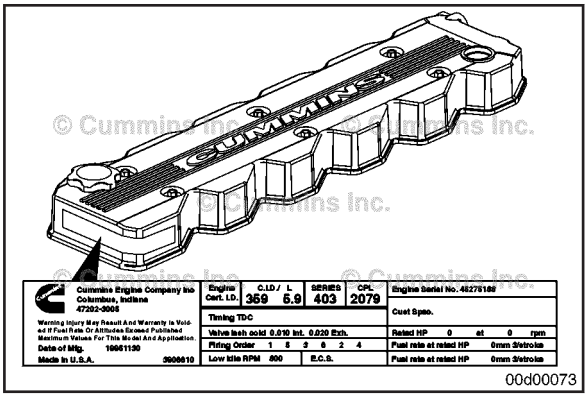
NOTE: If the data plate is to be reused, care **must** be taken **not** damage the data on the plate.

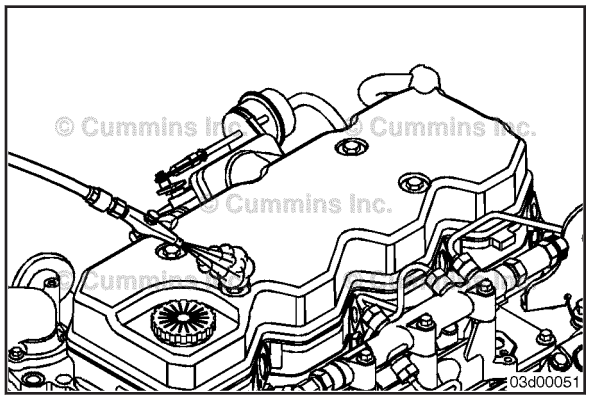
Using a flat chisel and hammer, drive the chisel under the head of the rivet to pry the rivet out.



For printed plastic dataplates, using the sharp edge of a gasket scraper, peel up a corner of the data plate. Then pull on the corner to remove the data plate.

NOTE: In most instances the data plate will be damaged during removal, contact your local Cummins Inc. Service location to obtain a new data plate.





Clean and Inspect for Reuse

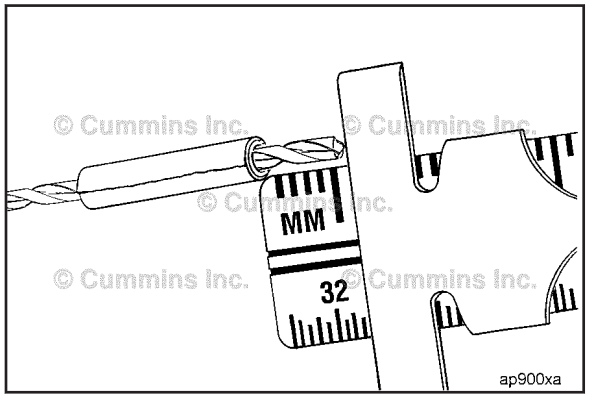
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Using solvent, clean the area where the data plate will be mounted.

Remove any left over adhesive from the printed plastic data plate. Use solvent with an abrasive pad, Part Number 3823258 or equivalent.

Dry with compressed air.

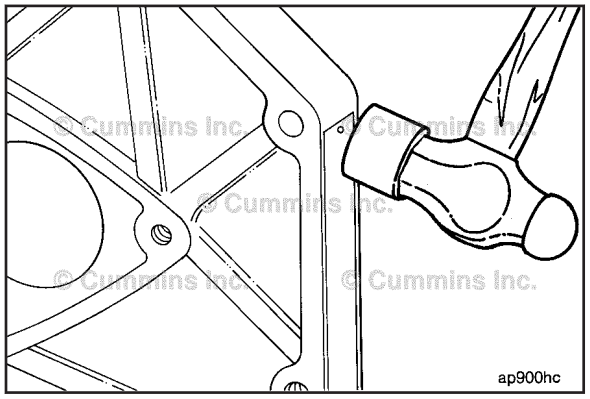


Install

△CAUTION△
When drilling holes for the data plate location, do not completely drill through the mounting location. Only drill deep enough to install the new blind rivets. Drill through will result in an oil leak.

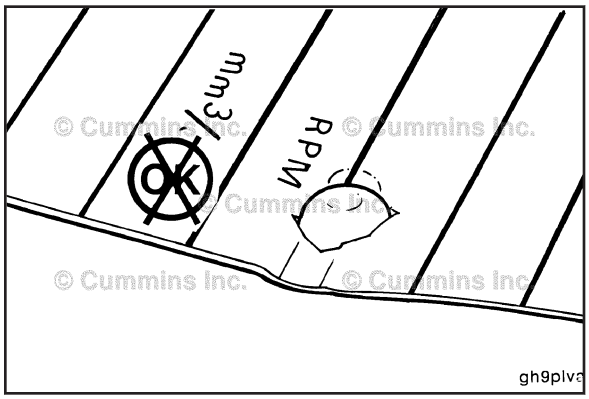
For metal stamped dataplates, if attaching the data plate to a new component or if the old rivet locations are damaged, drill new holes and attach with new blind rivets.

NOTE: The data plate should be located in the same area as it was previously installed.



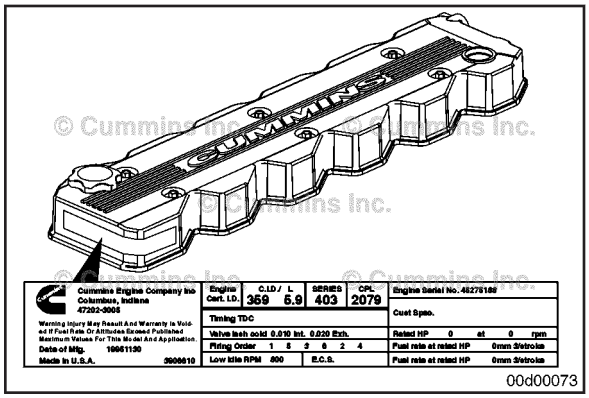
Install the data plate with new blind rivets. Drive the rivets until they contact the data plate.

⚠CAUTION⚠
Do not drive the rivets too far, they will cut through and damage the data plate.



For printed plastic dataplates, peel the backing off of the new data plate. Apply the new data plate to the appropriate mounting surface. Rub the data plate with a clean rag to work out any air bubbles and to adhere the data plate to the mounting surface.

NOTE: The data plate should be located in the same area as it was previously installed.

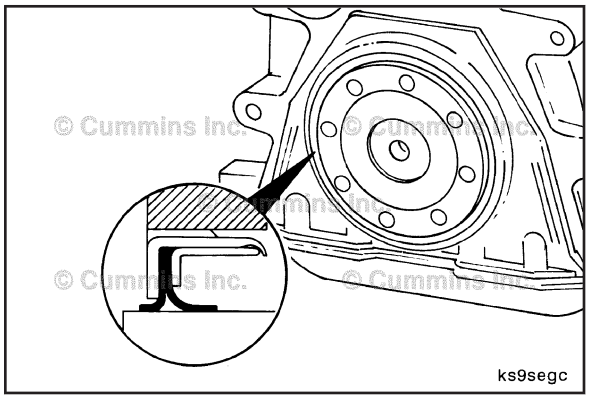


Crankshaft Wear Sleeve, Rear (001-067)

General Information

A lip style rear crankshaft seal (illustrated) is used, in which the rotating portion of the sealing occurs at the contact surface between the lip of the seal and the crankshaft.

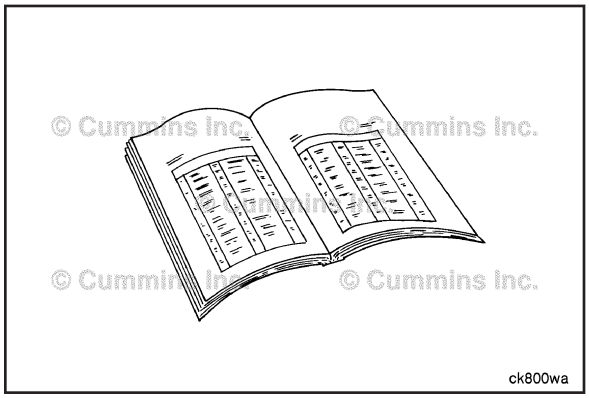
For front gear train engines, the rear crankshaft seal is mounted in a rear seal carrier that bolts to the rear of the cylinder block (illustrated). For rear gear train engines, the rear crankshaft seal is installed in the flywheel housing bore (**not** illlustrated).

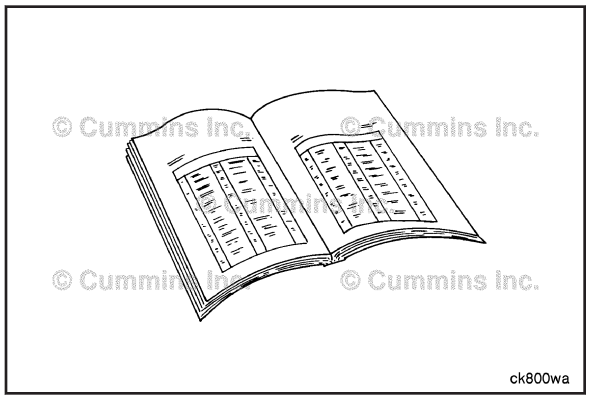


Preparatory Steps

⚠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.

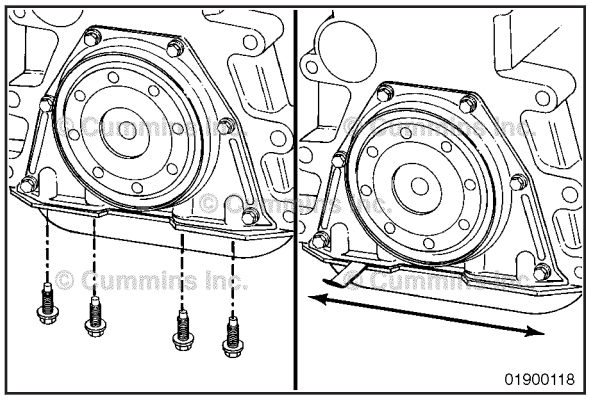
- Disconnect the batteries. Refer to the OEM service manual.





NOTE: Use a container that can hold at least 26 liters [27 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
- For front gear train engines, remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the transmission and all related components (if equipped). Refer to the OEM instructions
- Remove the flywheel/flexplate assembly. Refer to Procedure 016-005 in Section 16 or Refer to Procedure 016-004 in Section 16
- For rear gear train engines, remove the rear crankshaft seal. Refer to Procedure 001-024 in Section 1
- For some engines, it may be necessary to remove the crankcase breather tube. Refer to Procedure 003-018 in Section 3
- Remove any OEM attached components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. Refer to the OEM instructions
- For front gear train engines, remove the flywheel housing. Refer to Procedure 016-006 in Section 16.



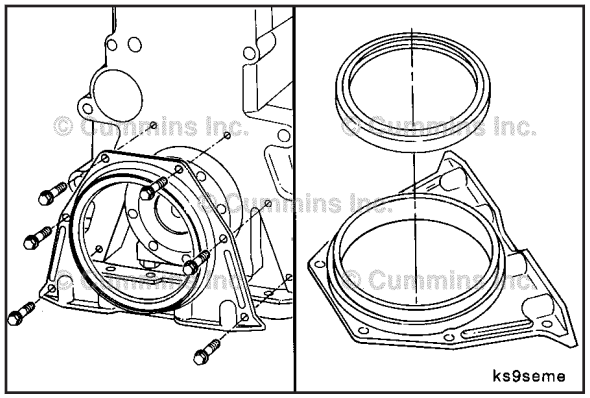
Remove

Front Gear Train

Remove the four oil pan mounting capscrews that secure the oil pan to the rear cover.

△CAUTION△
Use extreme care when releasing the oil pan gasket from the rear cover to prevent damage to the gasket.

Insert the feeler gauge or shim stock between the rear cover and the oil pan gasket. Move the feeler gauge back and forth to release the gasket from the rear cover.



Remove the capscrews from the rear cover.

Remove the cover from the crankshaft flange.

Support the rear seal carrier on a flat work surface with wooden blocks.Use a suitable punch and hammer to drive the old seal out of the rear seal carrier.

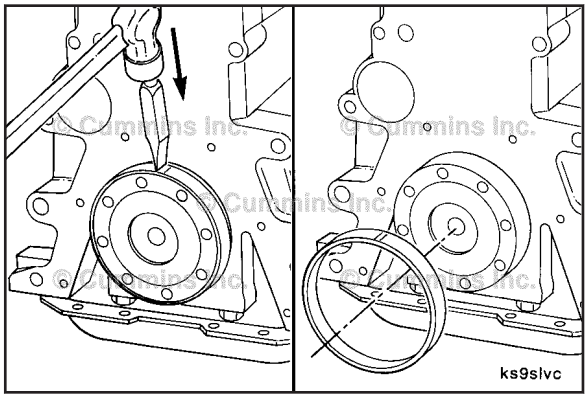
All Applications

⚠CAUTION⚠
Do not nick or gouge the crankshaft with the chisel. If the crankshaft is damaged, it must be replaced.

NOTE: For rear gear train engines, if a wear sleeve has previously been installed, the flywheel housing **must** be removed to remove the wear sleeve. After removing the wear sleeve, reinstall the flywheel housing. Refer to Refer to Procedure 016-006 in Section 16.

If a wear sleeve has previously been installed, use a dull chisel that is **only** as wide as the wear sleeve.

Make one or two soft blows with a hammer to make chisel marks across the wear sleeve. This will expand the wear sleeve, allowing the sleeve to be removed.



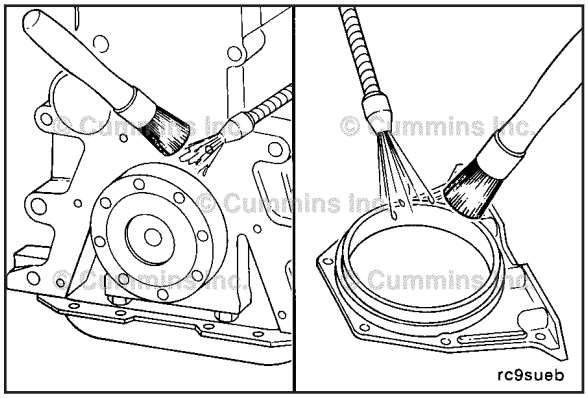
Clean and Inspect for Reuse

⚠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.

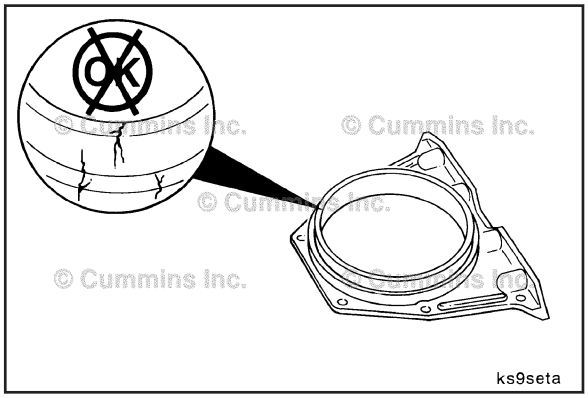
⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

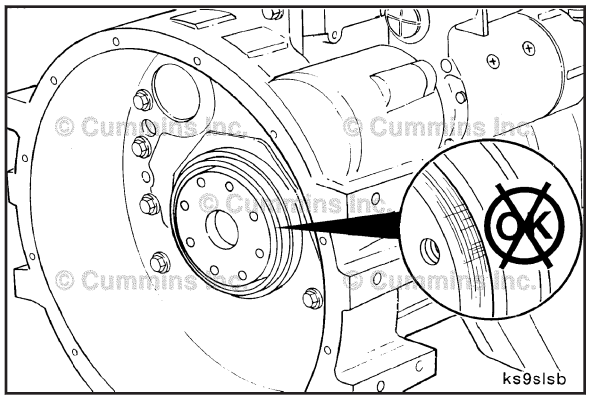
For front gear train engines, clean the gasket surface of the cylinder block and rear seal carrier.

Dry these areas with compressed air.



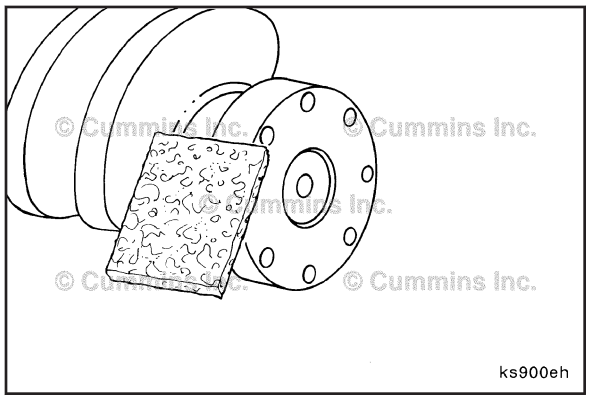
If equipped, inspect the rear seal carrier for cracks or other damage. Replace the rear seal carrier if any damage is found.





For rear gear train engines, clean the flywheel housing bore of any seal residue.

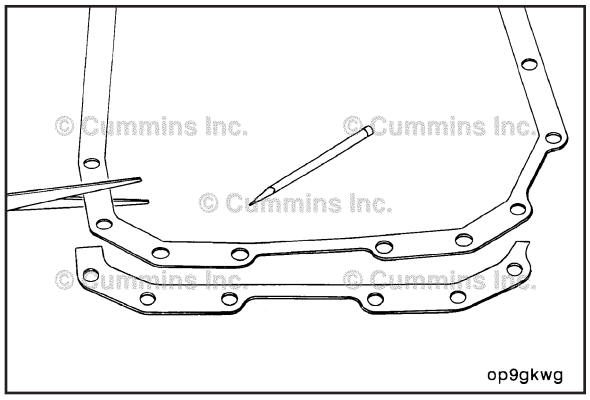
Inspect the flywheel housing bore for nicks or burrs. Use an abrasive pad, Part Number 3823258 or equivalent, to remove any minor damage.



Use a fine crocus cloth to remove any rust or other deposits from the crankshaft flange.

Use a clean cloth and solvent to clean the crankshaft flange.

Inspect the crankshaft flange for nicks or burrs. Use an abrasive pad, Part Number 3823258 or equivalent, to remove any minor damage.



Install

Front Gear Train

Service Tip: If the oil pan gasket was damaged during removal of the rear seal carrier, remove the damaged gasket and:

1 If previously equipped with a paper oil pan gasket, use the old gasket as a pattern and cut a section of a new gasket to the same size. Use a light coat of sealant, Part Number 3164067, to hold the gasket in place

2 If previously equipped with a sealant only oil pan gasket, apply a bead of sealant, Part Number 3164070, to the oil pan flange

3 If previously equipped with a suspended oil pan, the oil pan must be removed and a new gasket installed. Refer to Refer to Procedure 007-025 in Section 7.

NOTE: The rear seal carrier **must** be installed within 10 minutes of applying the sealant.

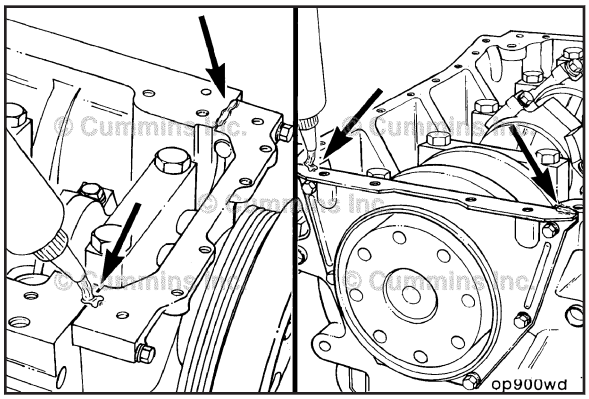
NOTE: If the oil pan is installed, it may be necessary to loosen additional oil pan capscrews to allow for rear seal carrier and gasket clearance.

NOTE: It may be necessary to trim the rear seal carrier gasket so that it is even with the oil pan mounting surface. Also, apply a thin bead of sealant, Part Number 3164067, at this joint prior to installing the rear seal carrier. The rear seal carrier **must** be installed within 10 minutes of applying the sealant.

Install the rear seal carrier, mounting capscrews, and gasket.

Apply Loctite™ 262 or 271 to the mounting capscrews and loosely tighten the rear seal carrier to the block.

NOTE: The seal installation will properly align the rear seal carrier.



All Applications

NOTE: For engines equipped with a wet flywheel housing, make sure to replace the rear crankshaft seal with the correct rear seal. Rear crankshaft seals for a wet and dry flywheel housings may **not** be the same.

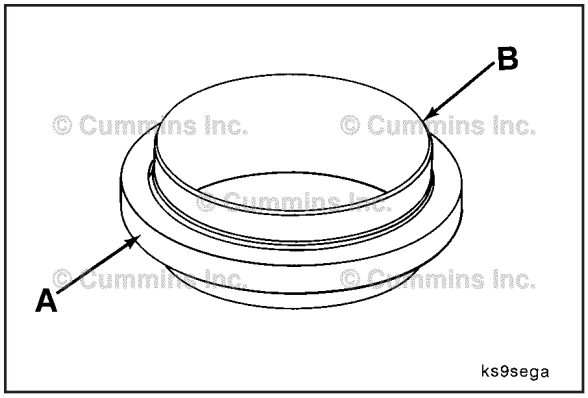
NOTE: The replacement oversize seal may appear different than the standard size seal.

⚠CAUTION⚠
The new rear crankshaft seal should not be removed from the crankshaft rear seal wear sleeve. Damage to the sealing lips may occur when reinstalling the seal onto the wear sleeve.

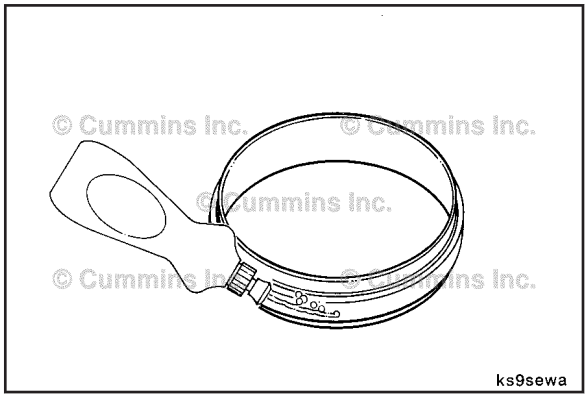
The new oversize seal and wear sleeve comes pre-assembled and will be installed on the crankshaft as an assembly.

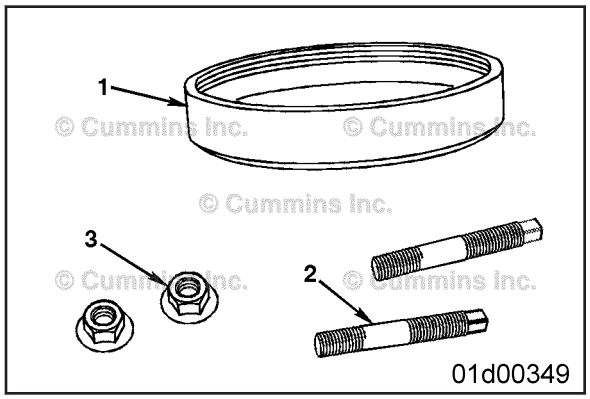
A Crankshaft oil seal

B Wear sleeve.



To aid in installation, the lubricating oil seal requires the application of a mild soap on the outside diameter of the seal case.



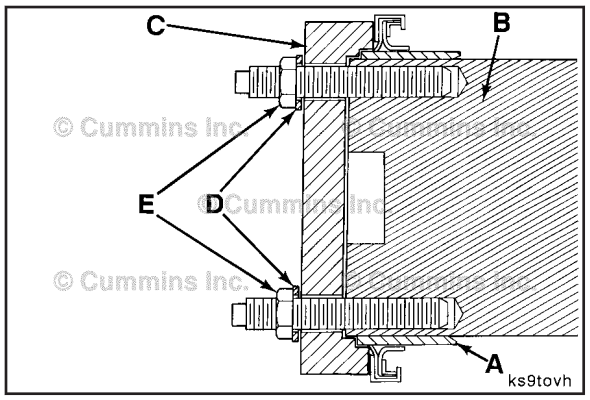


Use service tool, Part Number 3824078, to install the crankshaft seal/wear sleeve assembly.

Reference Number	Part Number	Description
1	3163734	Plate
2	3163628	Stud
3	3163741	Hex Nut

Install two (2) threaded studs into the crankshaft capscrew holes.

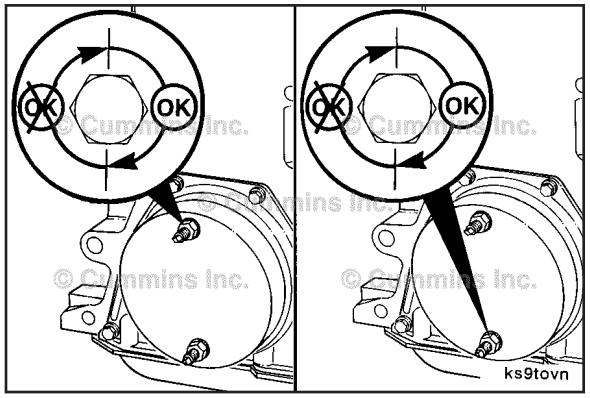
Apply a small amount of clean 15W-40 engine oil to the crankshaft, threaded studs, and the inside of the crankshaft rear seal/wear sleeve installation tool.



Position the chamfered end of the wear sleeve (A) onto the end of the crankshaft (B).

Position the counterbore end of installation tool (C) over threaded studs and align with the wear sleeve, perpendicular to the end of the crankshaft.

Install the washers (D) and nuts (E) onto the threaded studs.



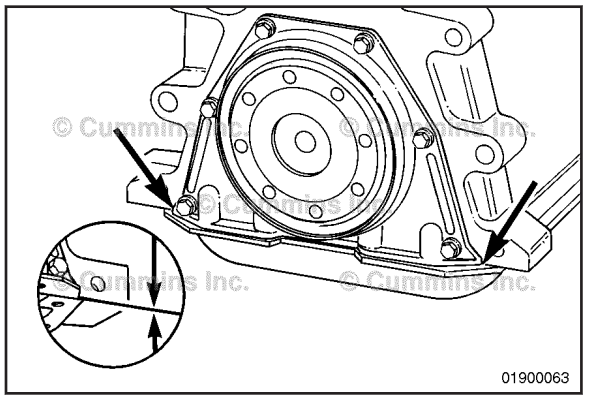
NOTE: The illustration shows a front gear train application with a rear crankshaft seal carrier. For rear gear train engines, the procedure for installing the crankshaft wear sleeve/seal into the flywheel housing bore is the same.

Alternately tighten the nuts ½ of a turn until the installation tool contacts the end of the crankshaft.

Do **not** exceed ½ of a turn of each nut to prevent wear sleeve binding and irregular stretch.

Torque Value: 20 N•m [177 ft-lb]

Remove the installation tool and the threaded studs.



Front Gear Train

⚠CAUTION⚠
Do not push or force the cover in any direction. This may cause an irregular seal lip position after seal installation. An engine oil leak will result.

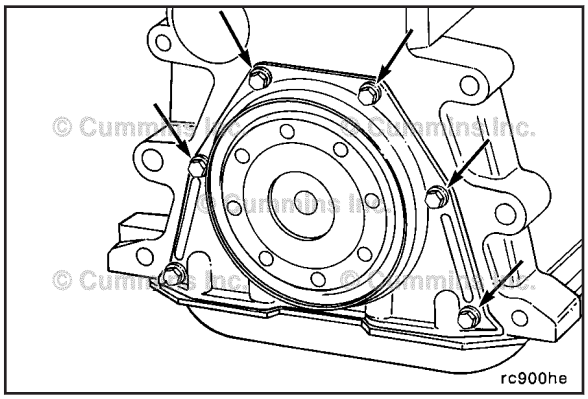
Align the rear cover even with both sides of the oil pan rail on the cylinder block.

Tighten the rear cover capscrews.

The chart below show the proper torque value when using either 9.8 or 10.9 grade capscrew. The grade is embossed on the top of each capscrew.

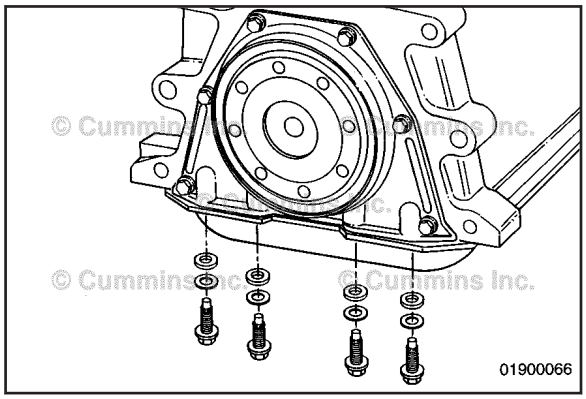
Apply Loctite™ 262 or 271 to both part numbers below during installation.

Rear Seal Carrier				
Bolt Number	**Bolt Size**	**Bolt Class**	**Torque**	**Loctite™**
3913638	M-6	9.8	10 N•m [89 in-lb]	Yes
3991306	M-6	10.9	13 N•m [115 in-lb]	Yes



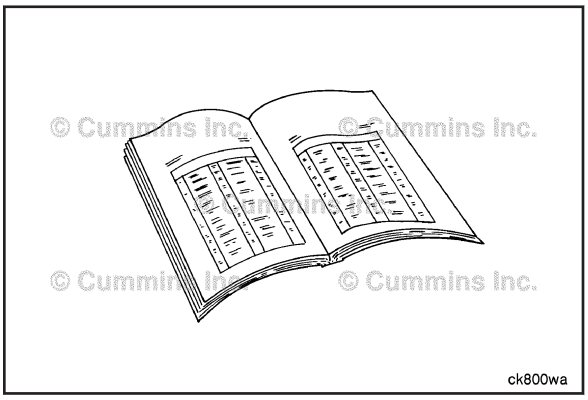
Install the four rear oil pan mounting capscrews into the pan.

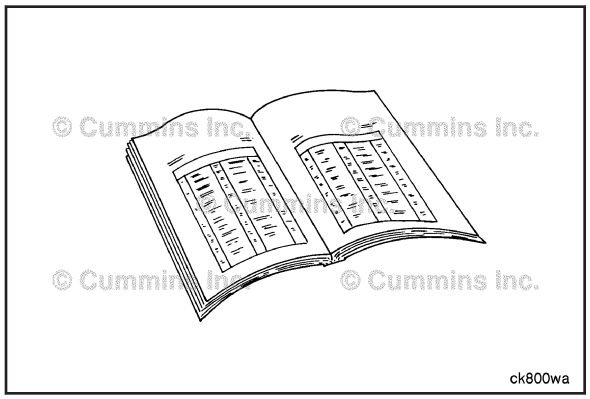
Torque Value: 24 N•m [212 in-lb]



Finishing Steps

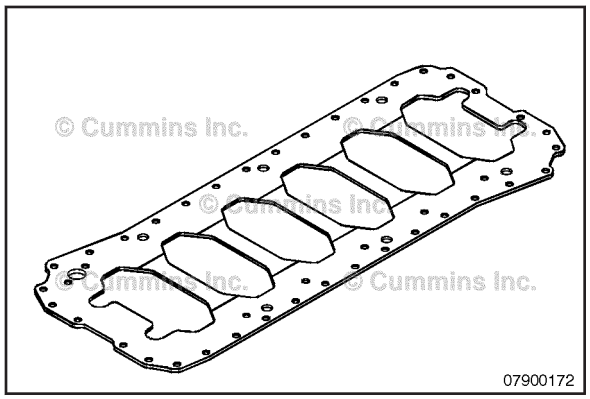
- If previously removed, install the crankcase breather tube. Refer to Procedure 003-018 in Section 18
- Install the flywheel/flexplate assembly. Refer to Procedure 016-005 in Section 16 or Refer to Procedure 016-004 in Section 16.
- For front gear train engines, install the starting motor. Refer to Procedure 013-020 in Section 13
- 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 OEM instructions
- If previously removed, attach any OEM attached components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. Refer to the OEM instructions.





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

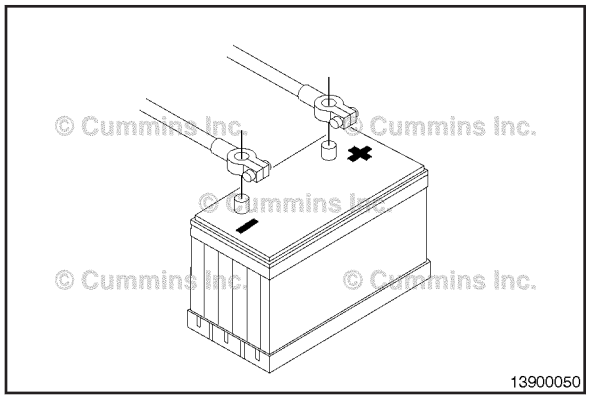
- Connect the batteries. Refer to the OEM service manual.
- Operate engine and check for leaks.



Block Stiffener Plate (001-089)

General Information

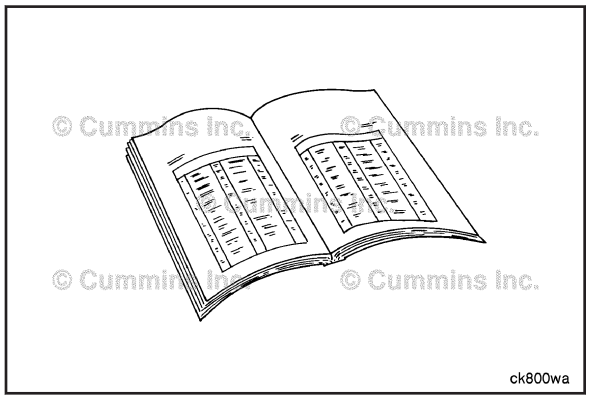
This procedure only covers bedplates that are attached to the cylinder block and **not** between the lubricating oil pan and cylinder block. If the bedplate is in between the lubricating oil pan and the cylinder block, refer to Procedure 007-025 for installation and removal procedures.



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.



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

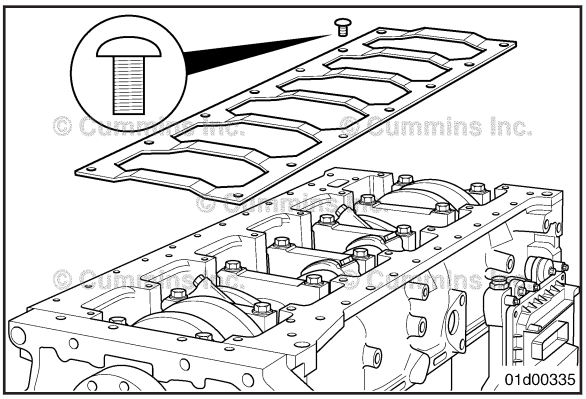
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

- Drain the lubricating oil. Refer to Procedure 007-037
- Remove the lubricating oil pan. Refer to Procedure 007-025
- Remove the lubricating oil suction tube. Refer to Procedure 007-035.

Remove

NOTE: For some oil pan/oil suction tube configurations, the block stiffener plate capscrew closest to the lubricating oil suction tube may be different than the rest. If equipped, note the capscrews location for installation. The low profile capscrew ensures in some applications that there is sufficient clearance between the oil suction tube and the block stiffener mounting capscrew.

Remove the capscrews and block stiffener plate.

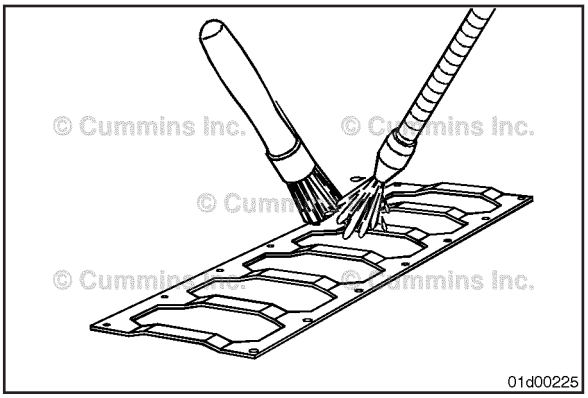


Clean and Inspect for Reuse

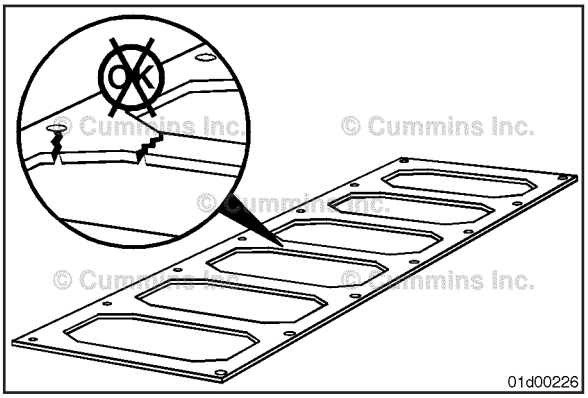
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

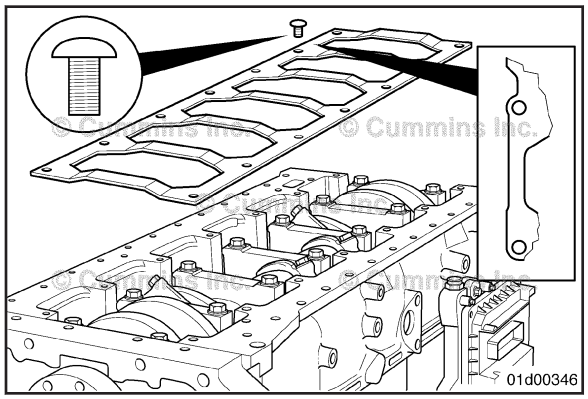
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the block stiffener plate with solvent. Dry with compressed air.



Check the block stiffener plate for cracks. Replace if damage is present.





Install

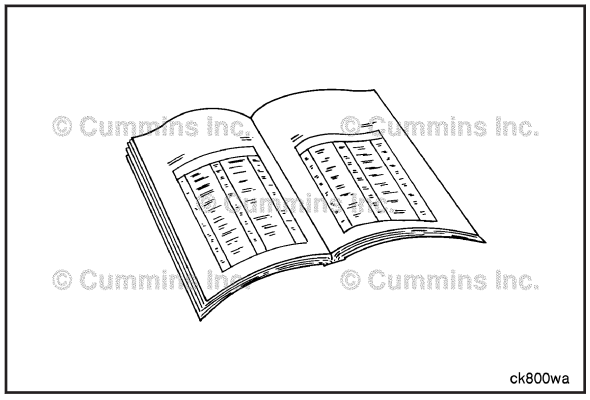
NOTE: The block stiffener plate **must** be installed so that the center ribs are bent away from the block, to ensure proper clearance from the block main caps.

NOTE: For some oil pan/oil suction tube configurations, one of the block stiffener mounting capscrews may be different than the rest. This capscrew, with a lower head profile, should be installed in the opening adjacent to the oil suction tube mounting location. The low profile capscrew ensures in some applications that there is sufficient clearance between the oil suction tube and the block stiffener mounting capscrew.

Install the block stiffener plate so that the exterior portion of the block stiffener plate with the recess is next to the oil suction tube mounting location at the front of the engine.

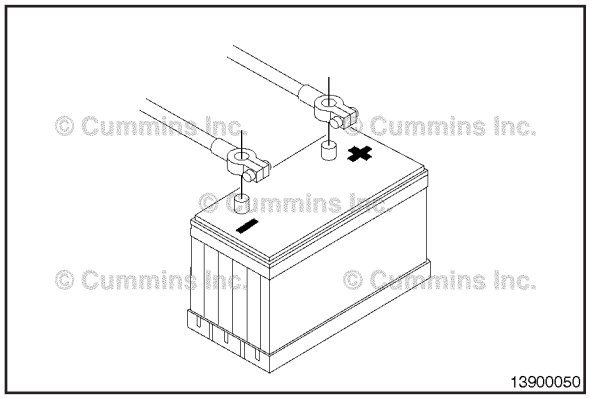
Install the block stiffener plate mounting capscrews.

Torque Value:
Block Stiffener Plate Capscrews 43 N•m [32 ft-lb]



Finishing Steps

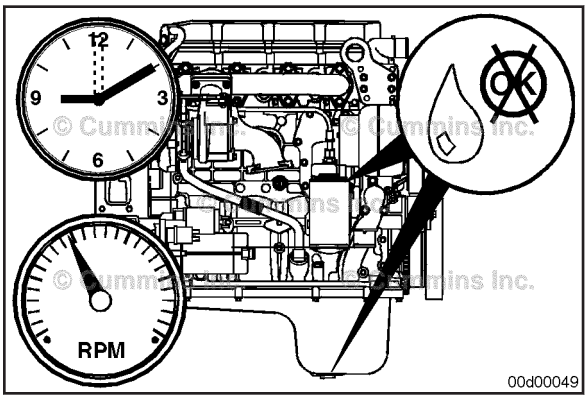
- Install the lubricating oil suction tube. Refer to Procedure 007-035
- Install the lubricating oil pan. Refer to Procedure 007-025
- Fill the engine with clean lubricating oil. Refer to Procedure 007-037.



⚠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.

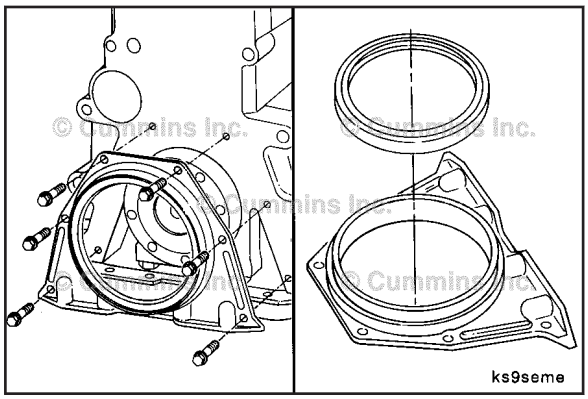


Crankshaft Seal Carrier, Rear (001-104)

General Information

NOTE: This procedure is for front gear train engines only.

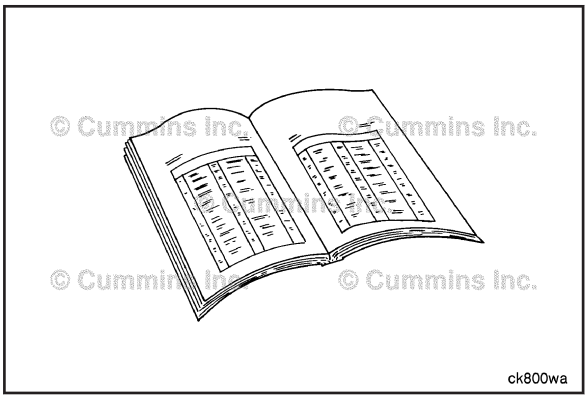
For front gear train engines, a rear crankshaft seal carrier is mounted to the rear of the cylinder block to house the rear crankshaft seal. For rear gear train engines, the rear crankshaft seal is installed in the flywheel housing.

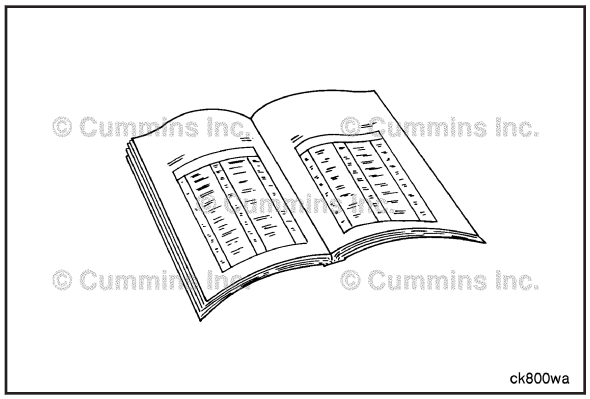


Preparatory Steps

⚠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.

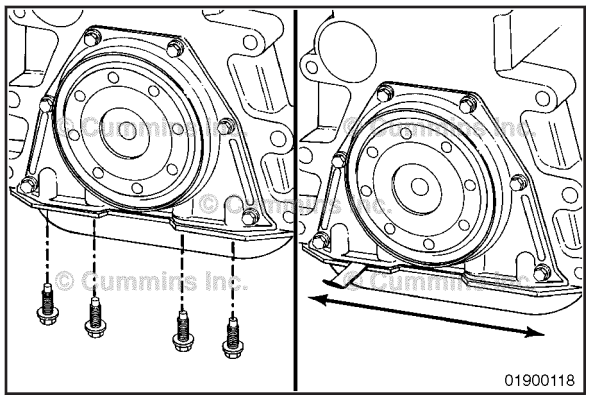
- Disconnect the batteries. Refer to the OEM service manual.





NOTE: Use a container that can hold at least 26 liters [27 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 in Section 13
- Remove the transmission and all related components (if equipped). Refer to the OEM instructions
- Remove the flywheel/flexplate assembly. Refer to Procedure 016-005 in Section 16 or Refer to Procedure 016-004 in Section 16
- Remove any OEM attached components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. Refer to the OEM service manual
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.

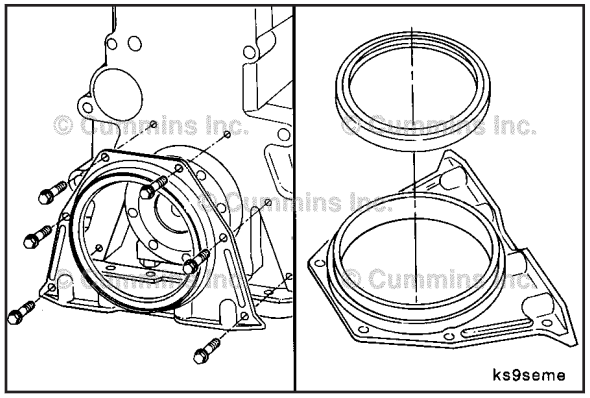


Remove

Remove the four oil pan mounting capscrews that secure the oil pan to the rear cover.

△CAUTION△
Use extreme care when releasing the oil pan gasket from the rear cover to prevent damage to the gasket.

Insert the feeler gauge or shim stock between the rear cover and the oil pan gasket. Move the feeler gauge back and forth to release the gasket from the rear cover.

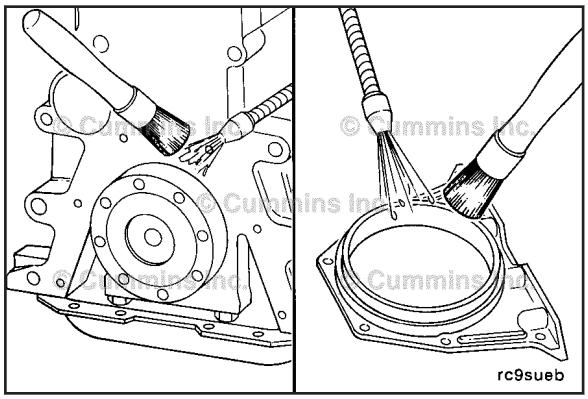


Remove the capscrews from the rear cover.

Remove the cover from the crankshaft flange.

Support the rear seal carrier on a flat work surface with wooden blocks. Use a suitable punch and hammer to drive the old seal out of the rear seal carrier.

Clean and Inspect for Reuse



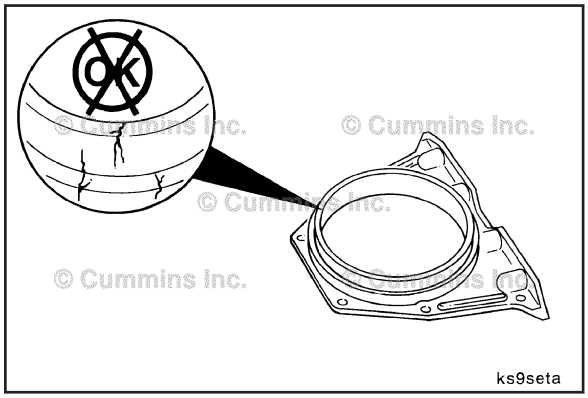
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Clean the gasket surface of the cylinder block and rear seal carrier.

Dry these areas with compressed air.

Inspect the rear seal carrier for cracks or other damage. Replace the rear seal carrier if any damage is found.



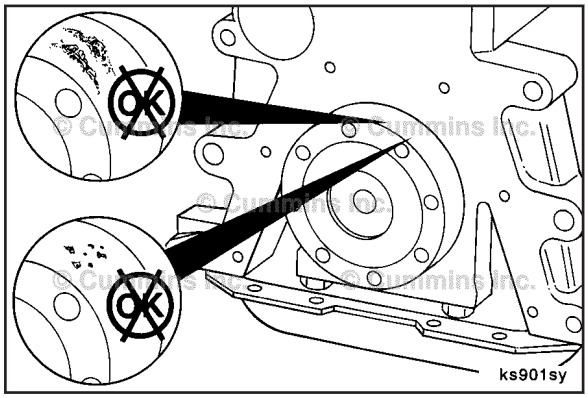
Use a fine crocus cloth to remove any rust or other deposits from the crankshaft flange.

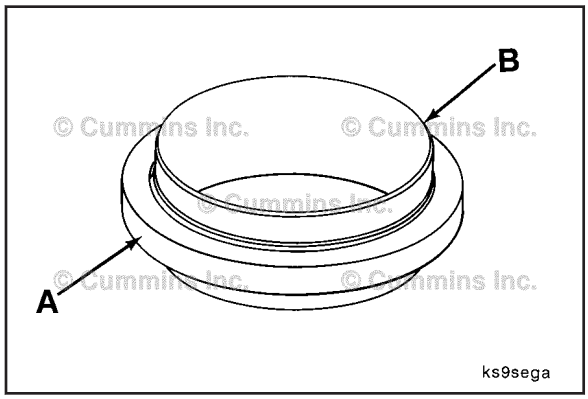
Use a clean cloth and solvent to clean the crankshaft flange.

Inspect the crankshaft flange for nicks or burrs. Use an abrasive pad, Part Number 3823258 or equivalent, to remove any minor damage.

NOTE: If the crankshaft has excessive wear, a service wear sleeve is available.

For engines equipped with a lip style rear crankshaft seal, inspect the crankshaft seal contact area for a wear groove. If the groove is deeper than 0.25 mm [0.010 in], a wear sleeve and oversize seal **must** be used. Refer to Procedure 001-067 in Section 1.

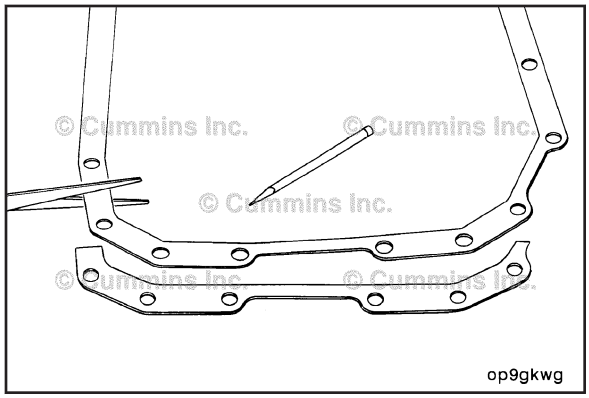




Install

NOTE: For engines equipped with a wet flywheel housing, make sure to replace the rear crankshaft seal with the correct rear seal. Rear crankshaft seals for a wet and dry flywheel housings may **not** be the same.

The new rear crankshaft seal (A) will come installed on a seal pilot (B). The seal **must** be left on the seal pilot while installing the seal onto the nose of the crankshaft. This will keep the lips of the seal from being damaged during installation.



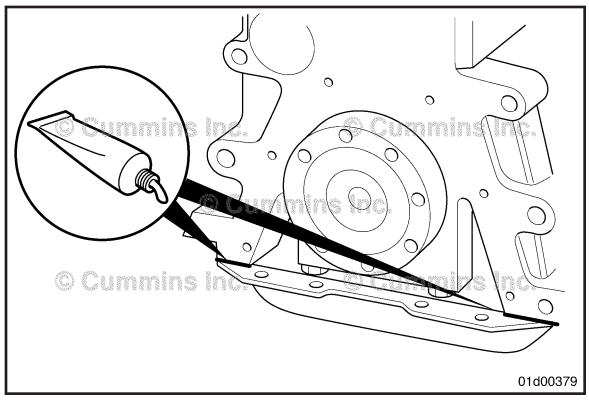
Service Tip: If the oil pan gasket was damaged during removal of the rear seal carrier, remove the damaged gasket and:

1 If previously equipped with a paper oil pan gasket, use the old gasket as a pattern and cut a section of a new gasket to the same size. Use a light coat of sealant, Part Number 3164067, to hold the gasket in place

2 If previously equipped with a sealant only oil pan gasket, apply a bead of sealant, Part Number 3164070, to the oil pan flange

3 If previously equipped with a suspended oil pan, the oil pan must be removed and a new gasket installed. Refer to Procedure 007-025 in Section 7.

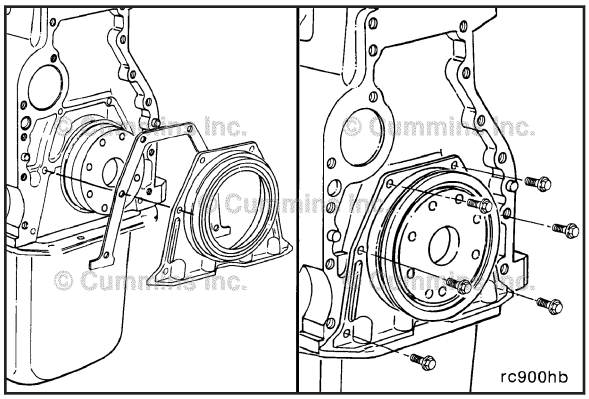
NOTE: The rear seal carrier **must** be installed within 10 minutes of applying the sealant.



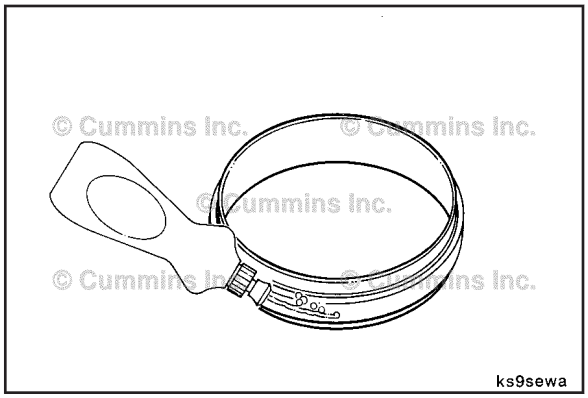
NOTE: It may be necessary to trim the rear seal carrier gasket so that it is even with the oil pan mounting surface. Test fit the gasket prior to installing.

Apply a thin bead of sealant, Part Number 3164067, at the intersecting joint of the oil pan and cylinder block prior to installing the rear crankshaft seal carrier. The rear crankshaft seal carrier **must** be installed within 10 minutes of applying the sealant.

Install the rear crankshaft seal carrier and gasket. Apply Loctite™ 262 or 271 to the mounting capscrews and loosely tighten the rear seal carrier to the block.



To aid in installation, the lubricating oil seal requires the application of a mild soap on the outside diameter of the seal case.



Place the new rear crankshaft seal, with the seal pilot, over the crankshaft nose and slide it by hand toward the flywheel housing.

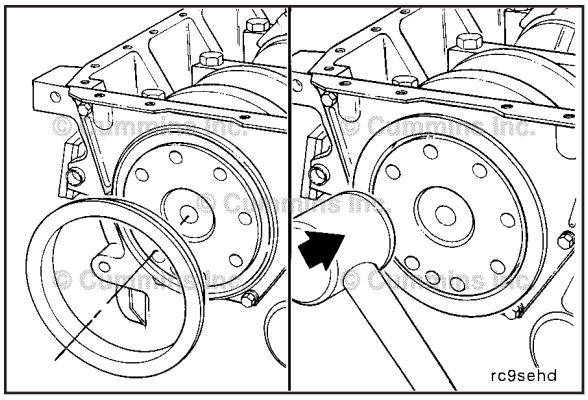
Remove the seal pilot.

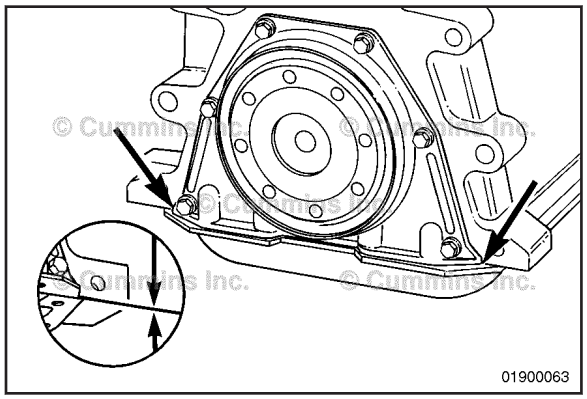
Use the disposable seal driver for front gear train engines to drive the rear crankshaft seal into the rear crankshaft seal carrier.

NOTE: Service tool, Part Number 3824078, used to install the rear crankshaft seal/wear sleeve assembly, can also be used to install the rear crankshaft seal.

Use a plastic hammer to drive the seal into the housing until the alignment tool stops against the housing.

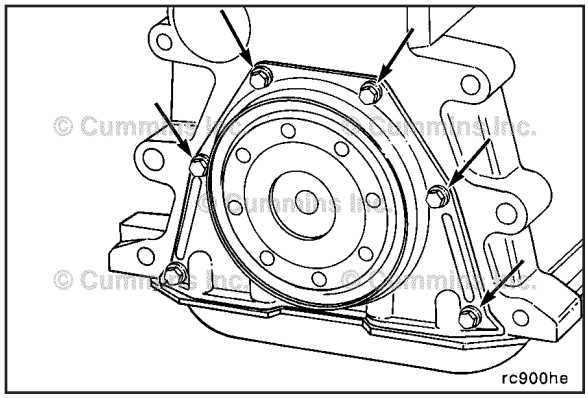
Hit the tool at the 12, 3, 6 and 9 o'clock positions to drive the seal evenly and to prevent bending the seal carrier. Hit the seal driver until contact is made with the rear crankshaft seal carrier.





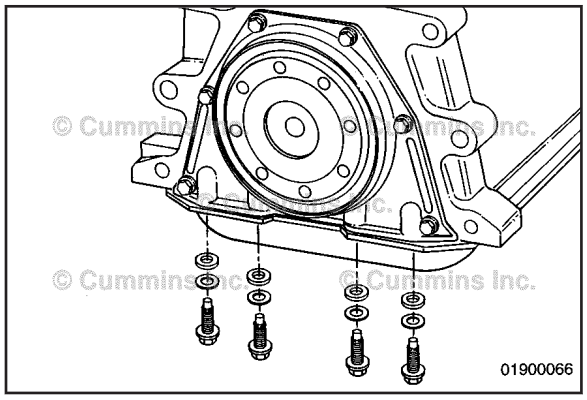
⚠CAUTION⚠
Do not push or force the cover in any direction. This may cause an irregular seal lip position after seal installation. An engine oil leak will result.

Align the rear cover even with both sides of the oil pan rail on the cylinder block.



Tighten the rear cover capscrews. The chart below shows the proper torque value when using either a 9.8 or 10.9 grade capscrew. The grade is embossed on the top of the capscrew.

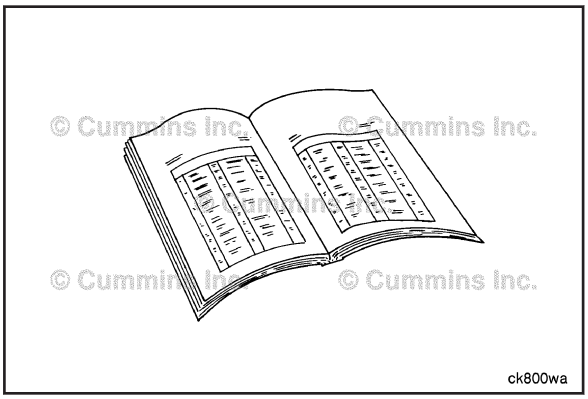
Rear Seal Carrier				
Bolt Number	**Bolt Size**	**Bolt Class**	**Torque**	**Dri-Loc™**
3913638	M-6	9.8	10 N•m [89 in-lb]	Yes
3991306	M-6	10.9	13 N•m [115 in-lb]	Yes



Install the four rear oil pan mounting capscrews into the pan.

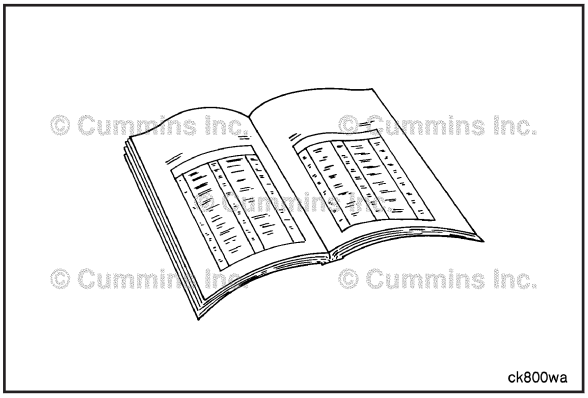
Torque Value: 24 N•m [212 in-lb]

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 flywheel/flexplate assembly. Refer to Procedure 016-005 in Section 16 or Refer to Procedure 016-004 in Section 16
- Install the starting motor. Refer to Procedure 013-020 in Section 13
- Install the transmission and all 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 OEM service manual
- If previously removed, attach any OEM attached components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. 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. Refer to the OEM service manual.
- Operate engine and check for leaks.

Notes

Section 2 - Cylinder Head - Group 02

Section Contents

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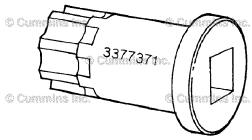
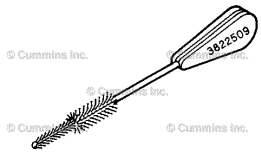
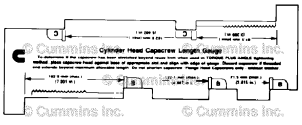
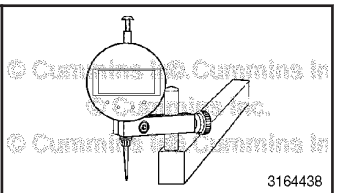
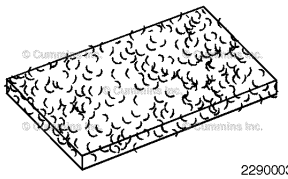
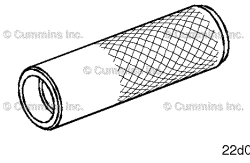
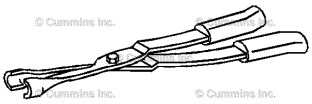
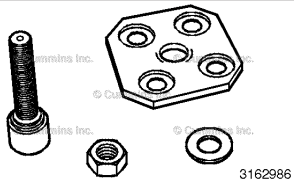
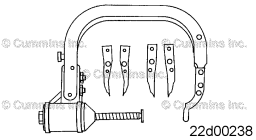
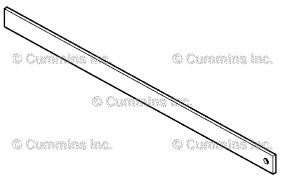
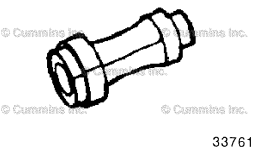
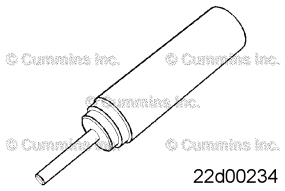
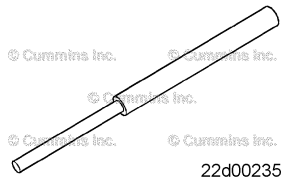
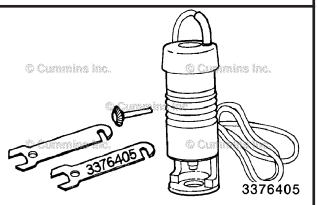
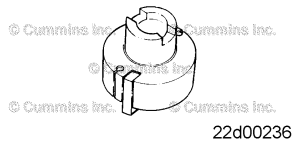
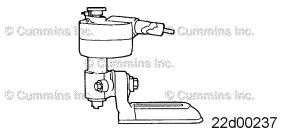
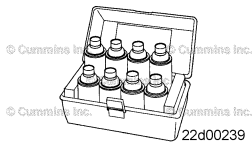
Service Tools

Cylinder Head

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

Tool No.	Tool Description	Tool Illustration
3824591	**Engine Barring Gear** Used to engage the flywheel ring gear to rotate the crankshaft.	
3822509	**Injector Bore Brush** Used to clean carbon from injector bores. For cylinder heads with 2 valves per cylinder.	 3822509
3822510	**Injector Bore Brush** Used to clean the injector bore in the cylinder head. For cylinder heads with 4 valves per cylinder.	 3822510
3823921	**Capscrew Length Gauge** Used to measure the length of the cylinder head capscrews. For cylinder heads with 2 valves per cylinder.	 3823921
3164057	**Capscrew Length Gauge** Used to measure the length of the cylinder head capscrews. For cylinder heads with 4 valves per cylinder.	 22d00085
3375182	**Valve Spring Tester** Used to check spring tension.	

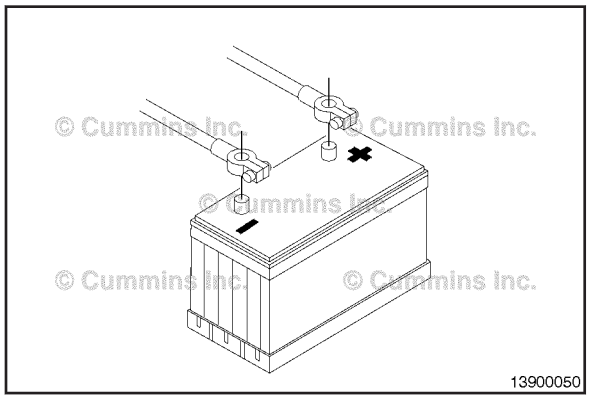
Tool No.	Tool Description	Tool Illustration
3164438	**Depth Gauge Assembly** Used to measure liner protrusion, injector protrusion, cylinder block counterbore depths, and valve intrusion and/or protrusion. Equipped with electronic digital indicator.	
3823258	**Abrasive Pad** Used to clean carbon from the upper liner bores, for removing rust and corrosion, and for scuffing surfaces.	
3164055	**Valve Stem Seal Installer** Used to install the valve stem seal.	
3163293	**Boot Plier** Used to remove the valve seal.	
3164329 and 3163292	**Valve Spring Compressor** 3164329 can be used to compress the all four valve springs at once for one cylinder on engines with 4 valves per cylinder. 3163292 can be used to compress both valve springs at once for one cylinder on engines with 2 valves per cylinder.	
3375960	**Valve Spring Compressor** Used with cylinder head removed. Quickly removes springs using shop air.	
4918219	**Precision Straightedge** Used to check cylinder head combustion deck for flatness.	
3165170	**Valve Seat Extractor Collet** Used with slide hammer, Part Number 3376617. Slide Hammer sold separately. For cylinder heads with 4 valves per cylinder.	

Tool No.	Tool Description	Tool Illustration
3165171	**Valve Seat Installer** Used for installing valve seats. For cylinder heads with 4 valves per cylinder.	
3165182	**Valve Guide Arbor** Use with Seat Cutter ST-257 to cut valve seat pockets for oversize seats. Can also be used with Gauge ST-685-4 to check valve seat concentricity. For cylinder heads with 4 valves per cylinder.	
3376405	**Valve Seat Grooving Tool** Cuts groove in valve seat. This is often required prior to use of valve seat extractor. Requires cutter bit Part Number 3376407. Cutter Bit is sold separately.	
3165183	**Valve Seat Cutters** 3165183 = .010 Oversize, 3165184 = .020 Oversize. Used with Valve Seat Cutter ST-257. For cylinder heads with 4 valves per cylinder.	
ST-257	**Valve Seat Cutter** Used to cut valve seat pockets for oversize seats. Valve Guide Arbor Part Number 3165182 and cutter bit Part Number 3165183 or Part Number 3165184 also required.	
3375432	**Crack Detection Kit (dye type)**	

Crosshead (002-001)

General Information

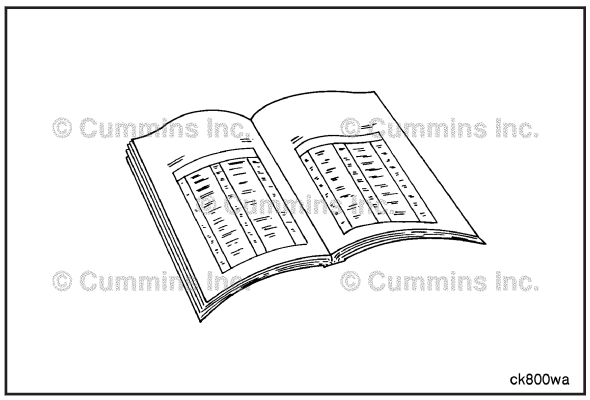
This procedure is for engines with 4 valves per cylinder only.



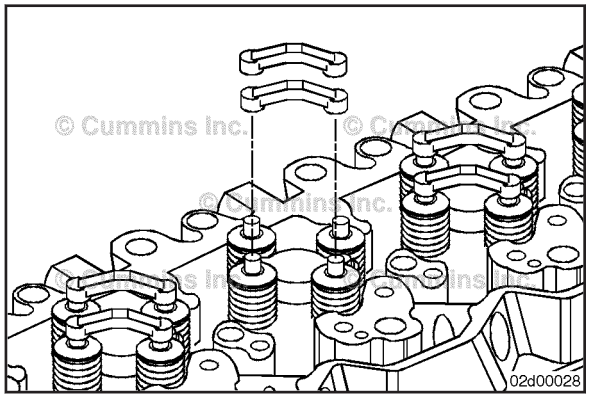
Preparatory Steps

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

- Disconnect the batteries.



- Remove rocker lever cover. Refer to Procedure 003-011
- Remove rocker lever. Refer to Procedure 003-008.



Remove

NOTE: Make note of the crosshead location and orientation. If the crossheads are reused, they **must** be installed in their original location and orientation.

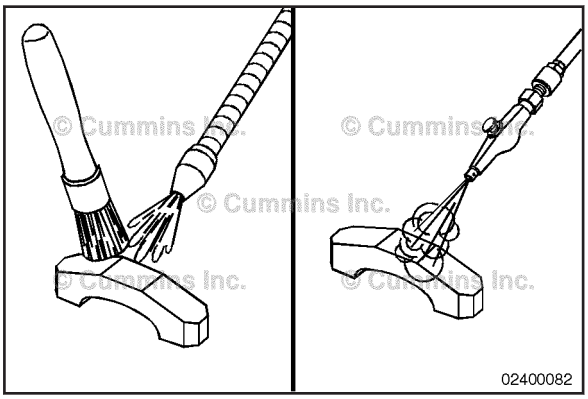
Remove the crossheads.

Clean and Inspect for Reuse

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

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

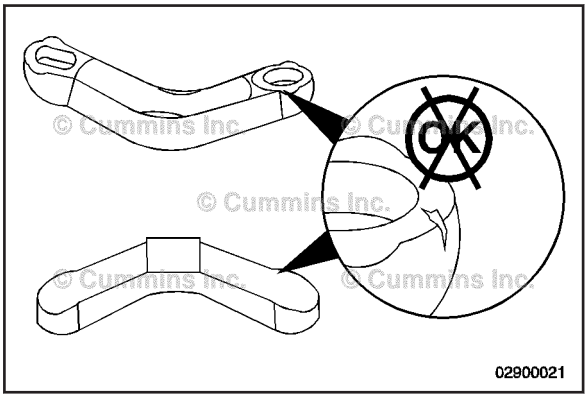
Clean the crossheads with solvent. Dry with compressed air.



Inspect the crossheads for cracks and/or excessive wear on rocker lever and valve tip mating surfaces.

Inspect the contact pads for cracks and other damage.

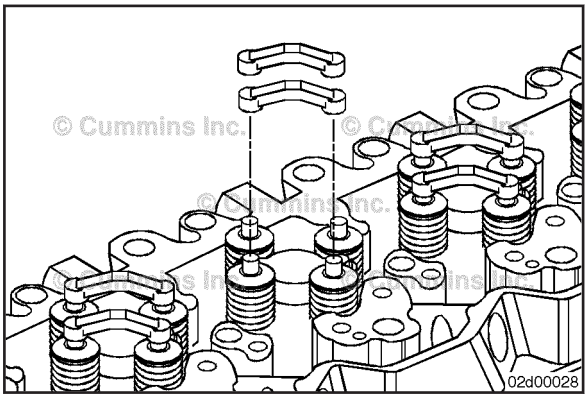
Replace the crossheads if any damage is found.



Install

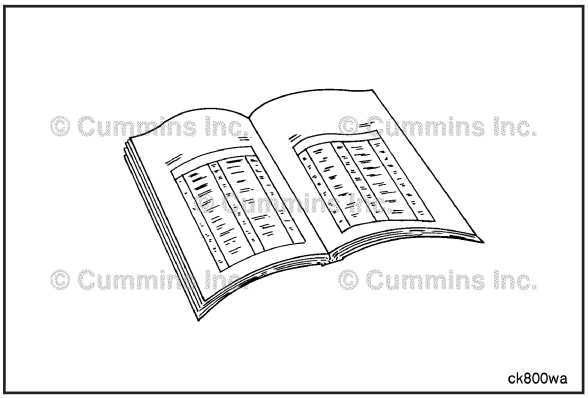
NOTE: The crosshead has a round and oval hole. If installing new crossheads, it is **not** required to place the holes in a particular position. If crossheads are being reused, make sure to install them in their original location and orientation.

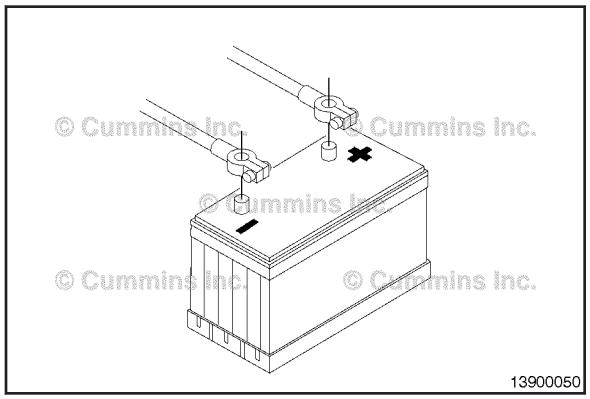
Install the crossheads on the valve stems.



Finishing Steps

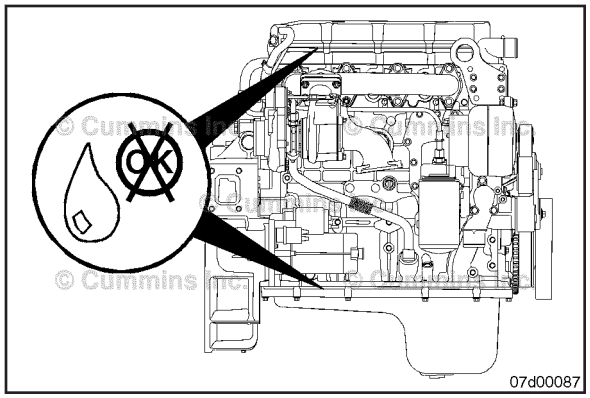
- Install rocker lever. Refer to Procedure 003-008
- Install rocker lever cover and gasket. Refer to Procedure 003-011.



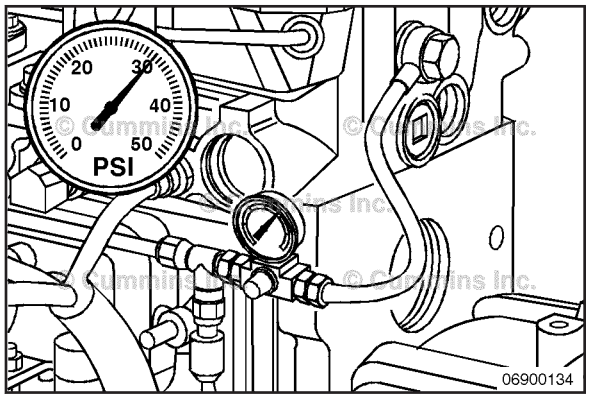


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries.



- Run the engine and check for leaks.



Cylinder Head (002-004)

Test

B4.5 RGT Engines

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

NOTE: This step **only** applies to B4.5 RGT engines. B3.9, B4.5 and B5.9 engines do **not** have an internal fuel drain line in the cylinder head.

If troubleshooting coolant in the fuel, fuel in the coolant, fuel in the oil, or oil in the fuel, pressurize the internal fuel drain line in the cylinder head and check for leaks.

Remove the fuel drain line at the back of the cylinder head. Refer to Procedure 006-021 in Section 6.

Connect a regulated air supply hose to the cylinder head fuel drain port with a shut off valve on the air supply side of the pressure gauge.

Apply air pressure.

Air Pressure		
kPa		psi
276	NOM	40

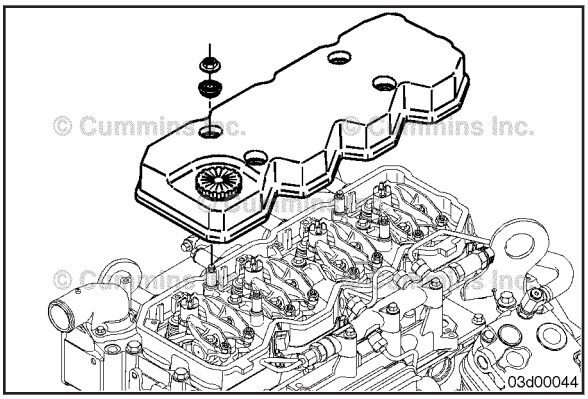
Shut off the air supply to the fuel drain port and monitor the pressure gauge reading. The pressure should hold steady. If the pressure drops rapidly, check for leaks around the:

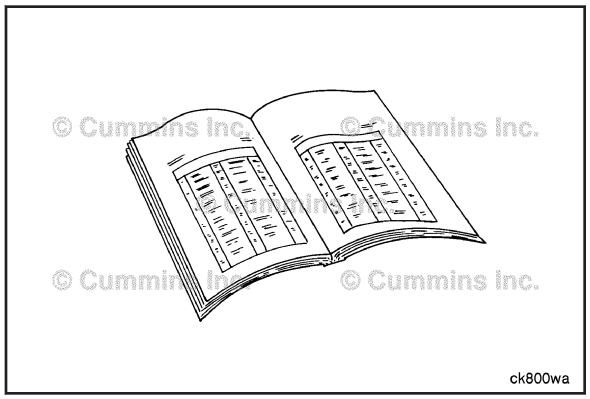
- Test fittings
- Fuel connectors at the cylinder head.

Remove the rocker lever cover and check for air bubbles around the injectors. Refer to Procedure 003-011 in Section 3.

Remove the radiator cap and check for air bubbles in the cooling system.

If the source of the leak can **not** be determined, remove the cylinder head and pressure test the complete cylinder head. See the Pressure Test step of this procedure. Replace the cylinder head, if 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.

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.

CAUTION
If removing the cylinder head with the injectors installed, be careful not to damage the tips of the injector. Do not set the cylinder head down on the combustion face with the injectors installed. Damage to the injector tips will result.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove any original equipment manufacturer (OEM) accessories attached to the cylinder head. Refer to the OEM service manual.
- Disconnect the air crossover connection. Refer to Procedure 010-019 in Section 10.
- Disconnect all water and heater hoses attached to the cylinder head. Refer to the OEM service manual.

NOTE: Omit the following steps if the engine is **not** equipped with the component or if it is **not** necessary to remove the component to remove the cylinder head. For some components, it is **only** necessary to remove the component if the cylinder head is being replaced or rebuilt.

- Remove the fuel filter. Refer to Procedure 006-015 in Section 6.
- Remove the fuel filter head. Refer to Procedure 006-017 in Section 6.
- Remove the air intake manifold. Refer to Procedure 010-023 in Section 10.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the fan hub pulley. Refer to Procedure 008-039 in Section 8.
- Remove the fan hub assembly. Refer to Procedure 008-036 in Section 8.
- Loosen the alternator link, mounting bolt, and water inlet connection capscrews. Remove the alternator bracket mounting capscrews and pivot the alternator away from the engine. Refer to Procedure 013-001 in Section 13.
- Remove the alternator bracket from the thermostat housing. Refer to Procedure 013-003 in Section 13.
- Remove the thermostat housing and thermostat from the engine. Refer to Procedure 008-013 in Section 8.

NOTE: The following components are required to be removed in order to remove the cylinder head.

- If equipped, remove the turbocharger. Refer to Procedure 010-033 in Section 10.
- Remove the exhaust manifold. Refer to Procedure 011-007 in Section 11.
- Remove the rocker lever cover(s). Refer to Procedure 003-011 in Section 3.
- Remove the rocker lever housing and gasket(s). Refer to Procedure 003-013 in Section 3.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the crosshead, if equipped. Refer to Procedure 002-001 in Section 2.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Remove the injector supply lines (high-pressure). Refer to Procedure 006-051 in Section 6.
- If B4.5 RGT engines, remove the fuel connectors (head-mounted). Refer to Procedure 006-052 in Section 6.

NOTE: For B4.5 RGT engines, do **not** remove the injectors at this time. Remove the cylinder head with the injectors installed so that injector protrusion can be checked.

- Remove the injectors. Refer to Procedure 006-026 in Section 6.

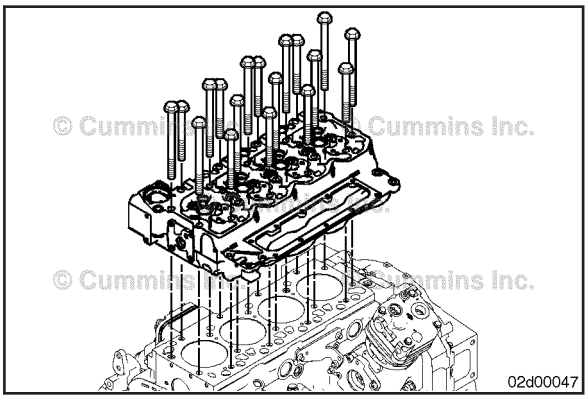
Remove

B4.5 RGT Engines

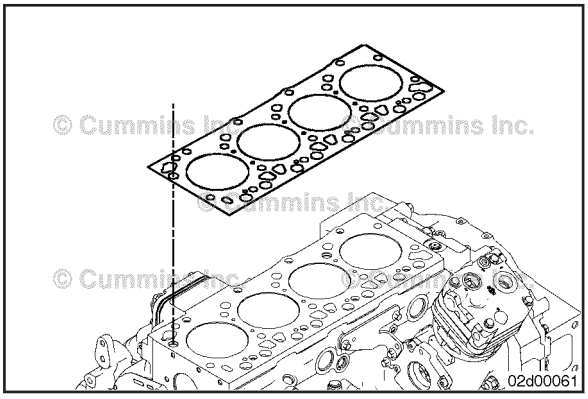
⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

△CAUTION△
If removing the cylinder head with the injectors installed, be careful not to damage the tips of the injector. Do not set the cylinder head down on the combustion face with the injectors installed. Damage to the injector tips will result.

Remove the cylinder head capscrews and cylinder head.

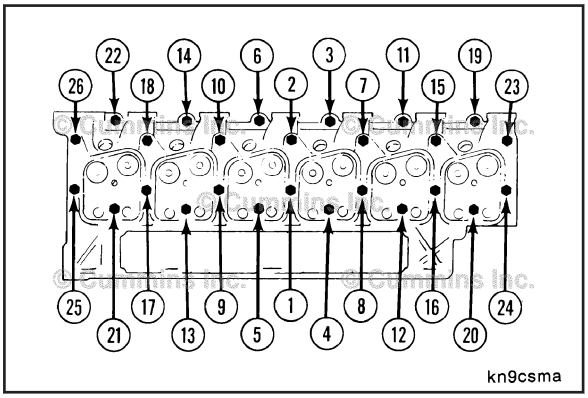


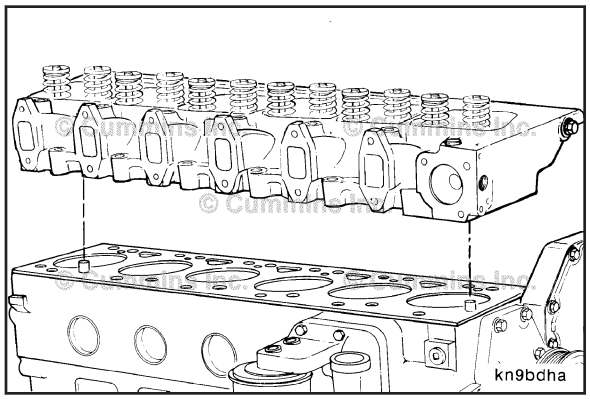
Remove the cylinder head gasket from the cylinder block.



B3.9, B5.9, and B4.5 Engines

Remove the cylinder head capscrews.





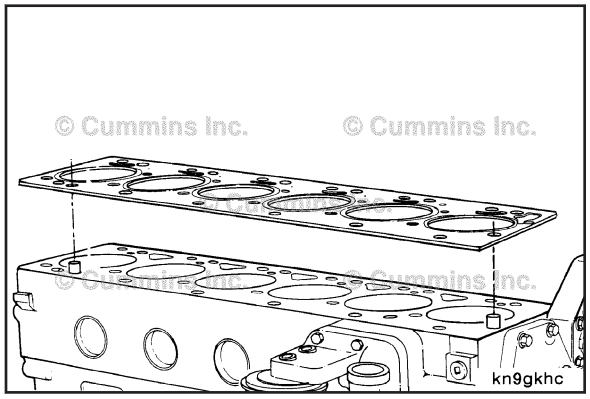
CAUTION
If removing the cylinder head with the injectors installed, be careful not to damage the tips of the injector. Do not set the cylinder head down on the combustion face with the injectors installed. Damage to the injector tips will result.

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

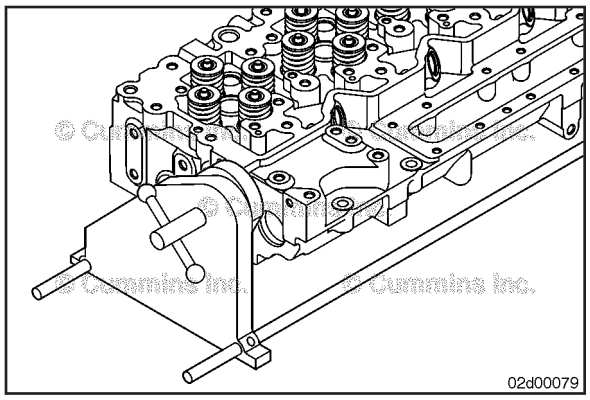
CAUTION
Do not lay the cylinder head on the combustion deck. This can cause damage to the cylinder head deck.

Remove the cylinder head from the cylinder block. Be sure the head is removed in a direct upward direction.

Cylinder Head Weight		
Cylinder Number	Kg	lb
4	36	79
6	51.3	113



Remove the cylinder head gasket.

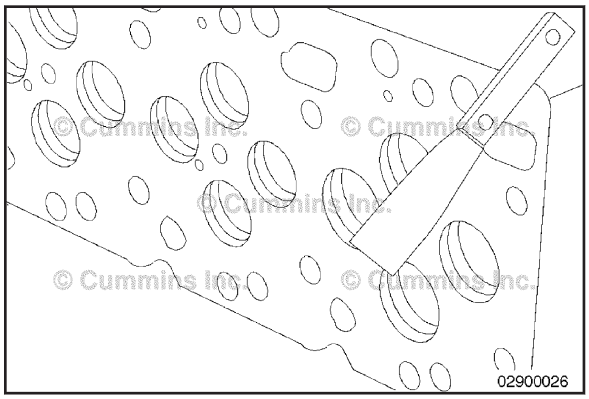


Initial Check

B4.5 RGT Engines

Install the cylinder head in the cylinder head holding fixture, Tool Number ST-583.

Scrape the gasket material and clean the combustion deck surfaces on the cylinder block and cylinder head.



Use a straightedge and a feeler gauge to inspect the cylinder head combustion surface for flatness.

Cylinder Head Flatness

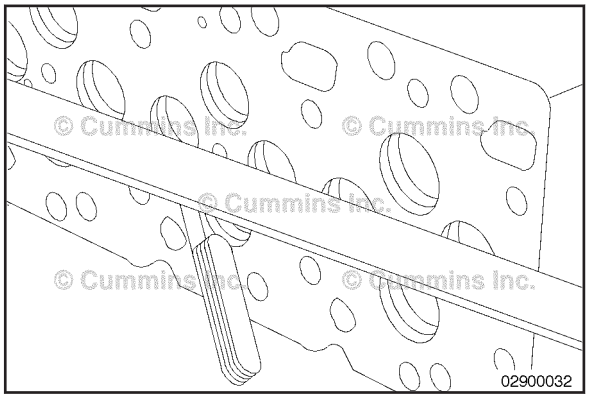
	mm		in
End-to-End	0.305	MAX	0.012
Side-to-Side	0.076	MAX	0.003

If out of specification, determine if the cylinder head can be resurfaced or if the cylinder head must be replaced by:

1 Measuring and recording valve depth

2 Measuring and recording injector protrusion.

If valve depth and injector protrusion specifications can be maintained, the cylinder head can be resurfaced. If the specifications can **not** be maintained, the cylinder head **must** be replaced.



Install depth gauge assembly, Part Number 3164438, on the cylinder head combustion deck and zero.

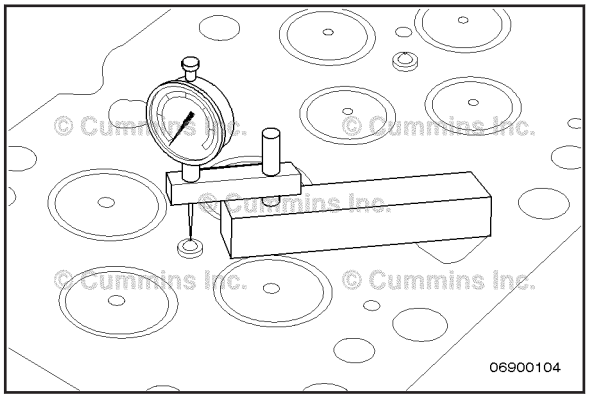
Rotate the depth gauge so that it is measuring the injector protrusion at the highest point on the injector.

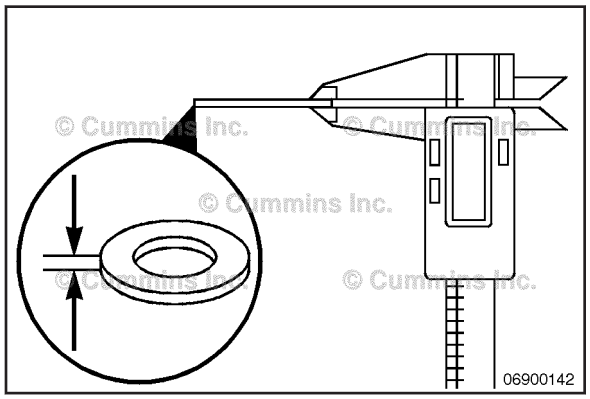
Record the injector protrusion for each injector.

Injector Protrusion

mm		in
2.45	MIN	0.096
3.15	MAX	0.124

NOTE: Do **not** use thicker or double stacked injector sealing washers to correct injector protrusion. This will cause misalignment of the high pressure fuel connector.

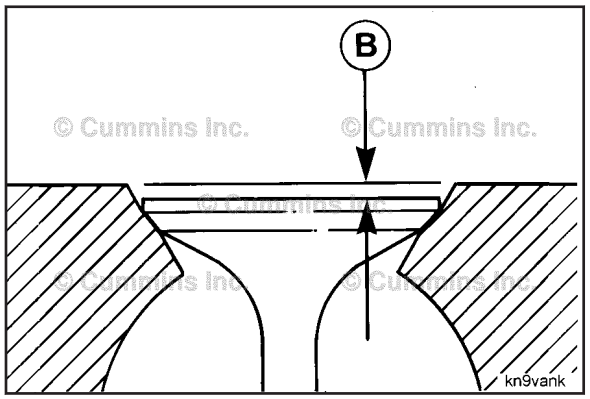




If the injector protrusion is out of specification, check the thickness of the injector sealing washer. Refer to Procedure 006-026 in Section 6.

If the sealing washer is the correct thickness, check to make sure the injector bore is clean and free of debris. Also make sure that sealing washers are **not** 'stacked' in the injector bore.

If the injector protrusion is within specification, remove the injector. Refer to Procedure 006-026 in Section 6.



Install depth gauge assembly, Part Number 3164438, on the cylinder head combustion deck and zero.

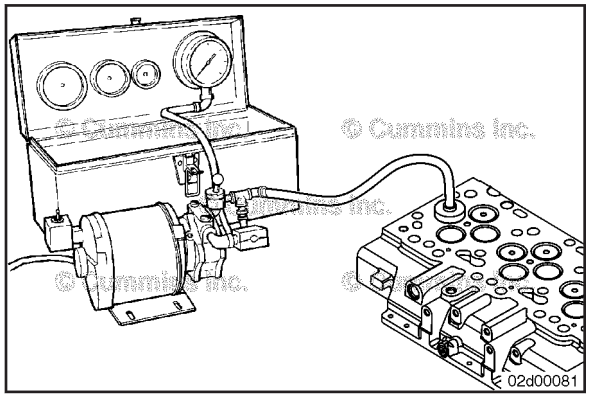
Rotate the depth gauge so that it is measuring the valve recession into the cylinder head (B).

Record the valve depth for each valve.

Intake Valve Depth (Installed)		
mm		**in**
0.584	MIN	0.023
1.092	MAX	0.043

Exhaust Valve Depth (Installed)		
mm		**in**
0.965	MIN	0.038
1.473	MAX	0.058

NOTE: Valve depth can be increased slightly for resurfacing of the cylinder head by lapping the valves.



If a leaking valve is suspected, or if the cylinder head was recently rebuilt, vacuum test the valves and valve seats using valve vacuum tester, Tool Number 3824277, and cup, Part Number ST-1257-6. The vacuum **must not** drop more than 25.4 mm Hg [1.0 in Hg] in five (5) seconds.

NOTE: If a vacuum tester is **not** available, with the valve removed, use a lead pencil or Dykem® marking pen to mark across the valve face. Install the valve in the valve guide. Hold the valve against the valve seat, and rotate the valve backward and forward three or four times. Correct contact against the valve seat will break the marks on the valve face.

Valve to Valve Seat Vacuum			
	kPa		**in Hg**
Used	51	NOM	15
New	69	NOM	20

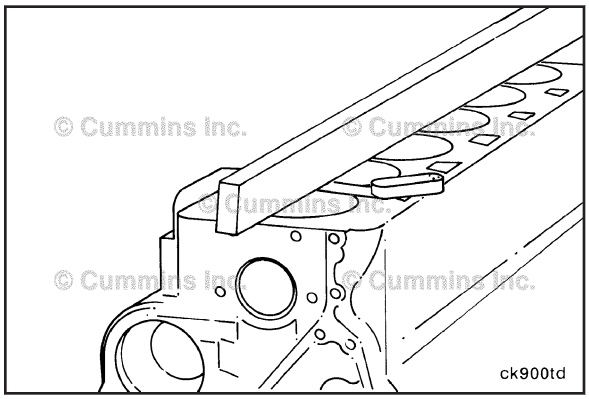
If out of specification, disassemble the cylinder head and inspect for damaged valves and/or valve seats. Repair as necessary:

1 Clean the valve/valve seat and lap the valves

2 Replace the damaged valve/valve seat, if available

3 Replace the cylinder head.

Use a straightedge and feeler gauge to measure the overall flatness of the cylinder block.



Cylinder Block Flatness

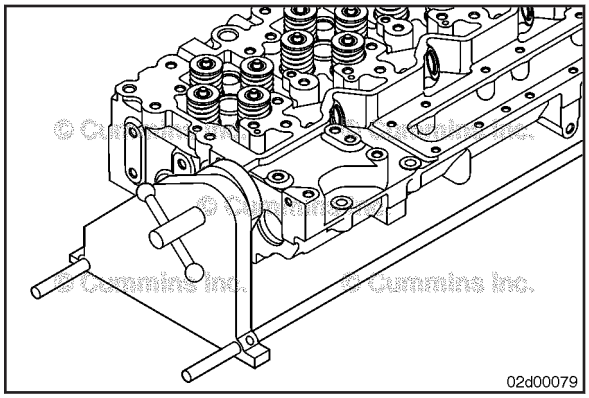
	mm		in
End-To-End	0.075	MAX	0.003
Side-To-Side	0.075	MAX	0.003

Inspect the combustion deck for any localized dips or imperfections.

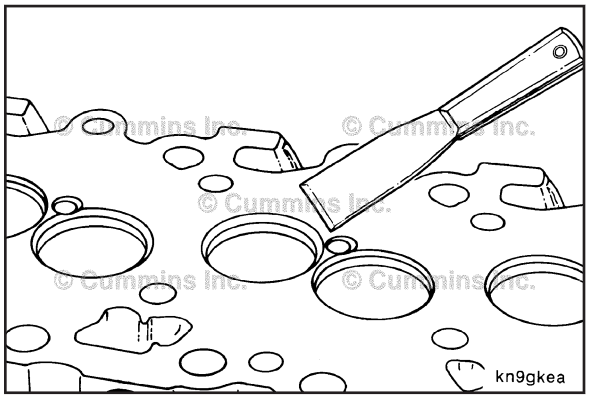
If out of specification, determine if the cylinder block can be resurfaced or if the cylinder block **must** be replaced. Refer to Procedure 001-026 in Section 1.

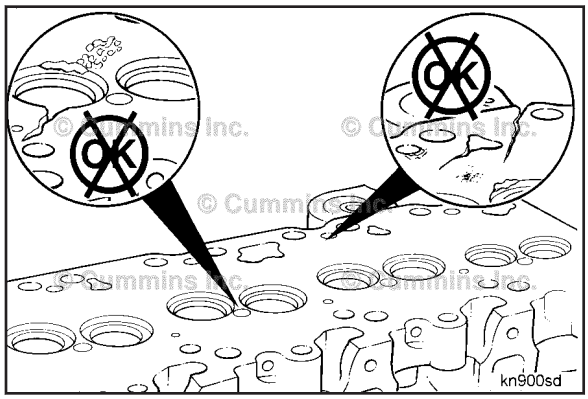
B3.9, B5.9, and B4.5 Engines

Install the cylinder head in the cylinder head holding fixture, Part Number ST-583.



Scrape the gasket material and clean the combustion deck surfaces on the cylinder block and cylinder head.





Use a straightedge and a feeler gauge to inspect the cylinder head combustion surface for flatness.

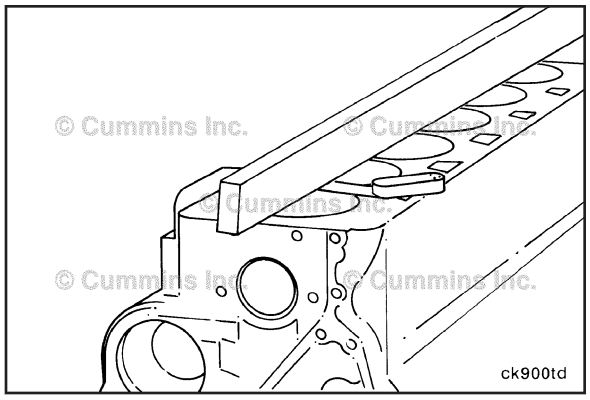
Cylinder Head Flatness (6 Cylinder)

	mm		in
End-to-End	0.305	MAX	0.012
Side-to-Side	0.076	MAX	0.003

Cylinder Head Flatness (4 Cylinder)

	mm		in
End-to-End	0.203	MAX	0.008
Side-to-Side	0.076	MAX	0.003

If the cylinder head combustion surface flatness is out of specification, the cylinder head can be resurfaced and an oversize head gasket used. Refer to Procedure 002-021 in Section 2.



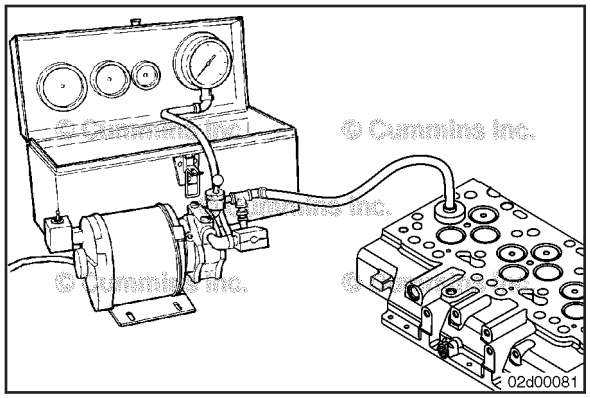
Use a straightedge and feeler gauge to measure the overall flatness of the cylinder block.

Cylinder Block Flatness

	mm		in
End-To-End	0.075	MAX	0.003
Side-To-Side	0.075	MAX	0.003

Inspect the combustion deck for any localized dips or imperfections.

If dips and/or imperfections are present, the cylinder head **must** be resurfaced. If resurfaced, an oversize head gasket **must** be used. Refer to Procedure 002-021 in Section 2.



If a leaking valve is suspected, use valve vacuum test kit, Part Number 3824277, to test the valves and valve seats. The vacuum **must not** drop more than 25.4 mm Hg [1.0 in Hg] in five (5) seconds.

NOTE: If a vacuum tester is **not** available, with the valve removed, use a lead pencil or Dykem® marking pen to mark across the valve face. Install the valve in the valve guide. Hold the valve against the valve seat, and rotate the valve backward and forward three or four times. Correct contact against the valve seat will break the marks on the valve face.

Valve to Valve Seat Vacuum

	mm Hg		in Hg
Used	457	MIN	18
New	635	MIN	25

If out of specification, disassemble the cylinder head and inspect for damaged valves and/or valve seats. Repair as necessary:

1 Clean and lap the valve/valve seat

2 Replace the damaged valve

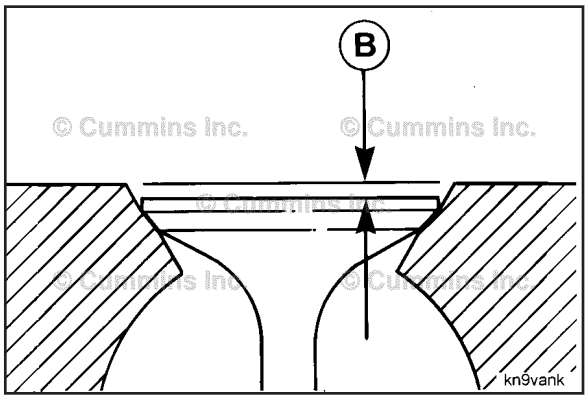
3 Install valve seat inserts, if available

4 Replace the cylinder head.

Install depth gauge assembly, Part Number 3164438, on the cylinder head combustion deck and zero.

Rotate the depth gauge so that it is measuring the valve recession into the cylinder head (B).

Measure the valve depth for each valve.



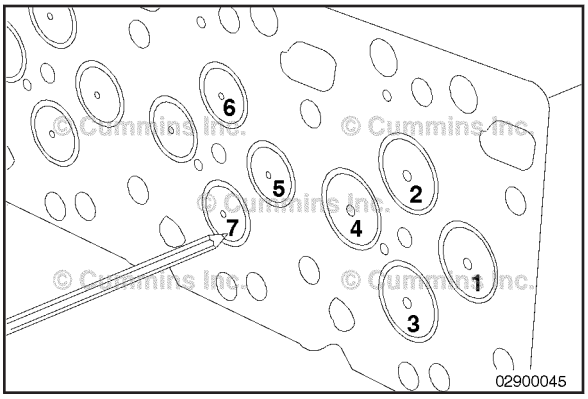
Valve Depth (Installed)		
mm		**in**
0.99	MIN	0.038
1.52	MAX	0.060

If the valve depth is **not** within specification during disassembly of the cylinder head, inspect the valve seats and valve for damage. If necessary, replace the valve and/or install valve seat inserts to achieve the correct valve depth. Information on valve seat insert installation is available in the Alternative Repair Manual, B and C Series Engines, Bulletin 3666109.

Disassemble

B4.5 RGT Engines

Mark the valves to identify their location.

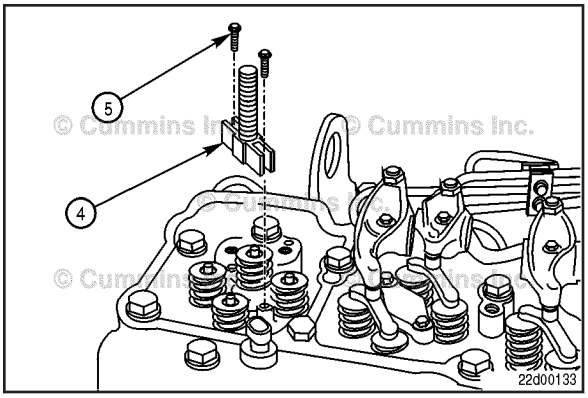


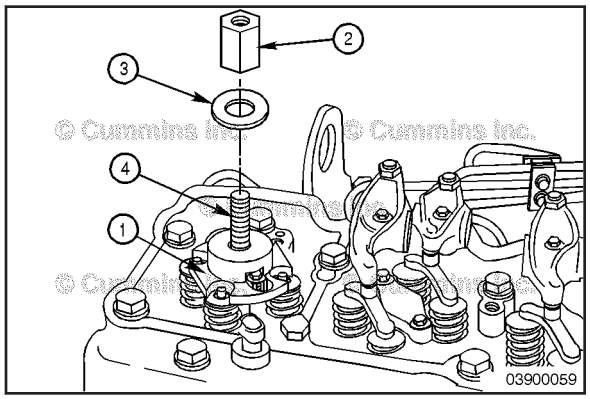
Compress the valve springs using the valve spring compressor service tool, Part Number 3164329.

Position the replacer screw (4) above the injector bore and install the two capscrews (5) in the cylinder head where the hold-down clamp screws were removed.

Tighten the capscrews (5).

Torque Value: 5 N•m [44 in-lb]



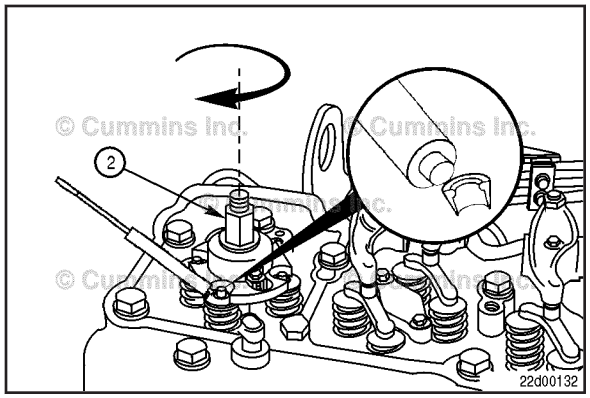


NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.

Apply anti-seize lubricant to the replacer screw (4) threads. Always read and follow label precautions.

Position the valve spring compressor plate (1) on the replacer screw (4) and align the slots in the valve spring compressor plate with the valve springs.

Install the washer (3) and nut (2) on the replacer screw (4).

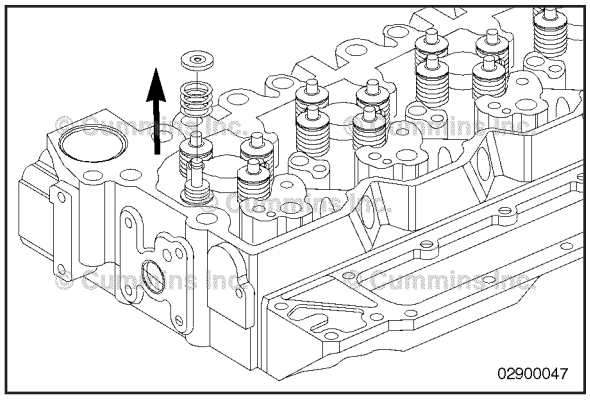


⚠WARNING⚠
Valve springs are under tension and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

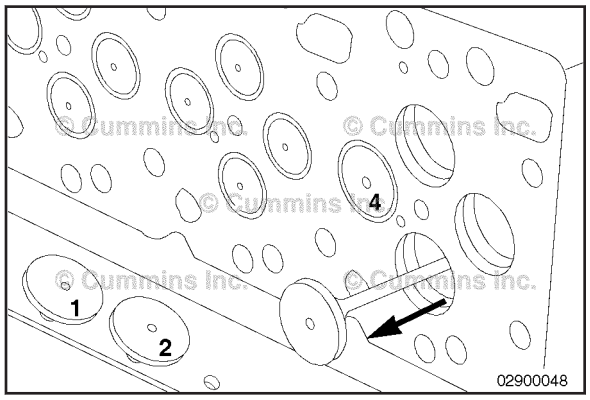
Turn the nut (2) **clockwise** to compress the valve springs.

Continue turning the nut (2) **clockwise** until the valve collets can be removed using a magnetic tool, such as the end of a magnetic screwdriver.

Remove the valve collets and the valve spring compressor service tool.



Remove the valve spring retainer and valve springs.



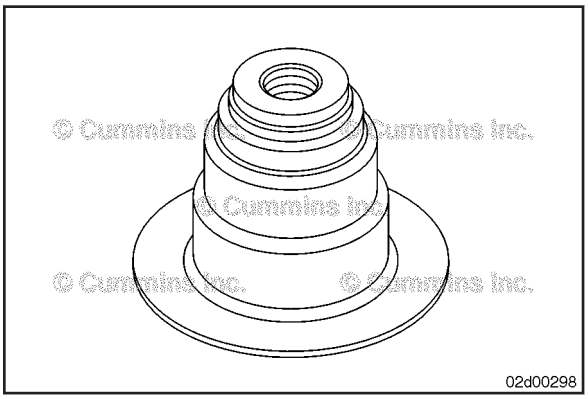
NOTE: Keep the valves in a labeled rack with the associated valve collets, spring retainers, and springs. This will aid in assembling the components as a matched set.

Remove the valves.

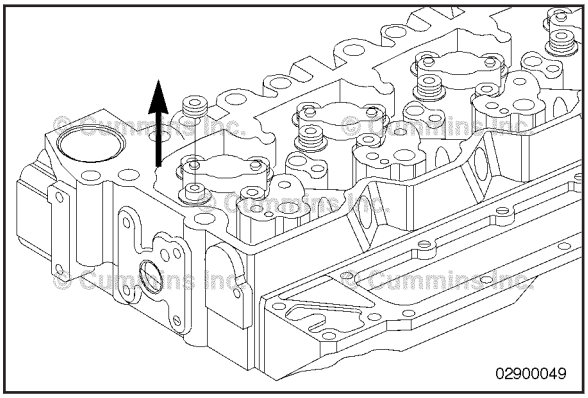
NOTE: Prior to removing the valve stems seals, note the color of the valve stem seal installed at each valve location. The same color valve stem seal **must** be installed when assembling the cylinder head.

Colors Used:

- Green (used for exhaust valves)
- Yellow (used for intake and exhaust valves).



Use boot pliers, Part Number 3163293, to remove the valve stem seals.



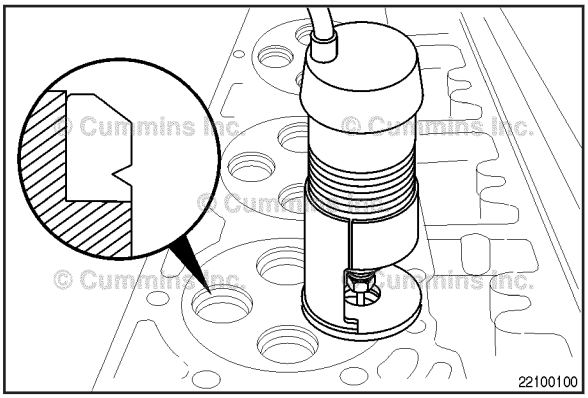
NOTE: Prior to removing the valve seat inserts, see the Initial Check and Clean and Inspect for Reuse sections in this procedure. The condition of the valve, the amount of recess, and the sealing of the valve on the seat insert all help determine whether or **not** a seat insert needs to be replaced.

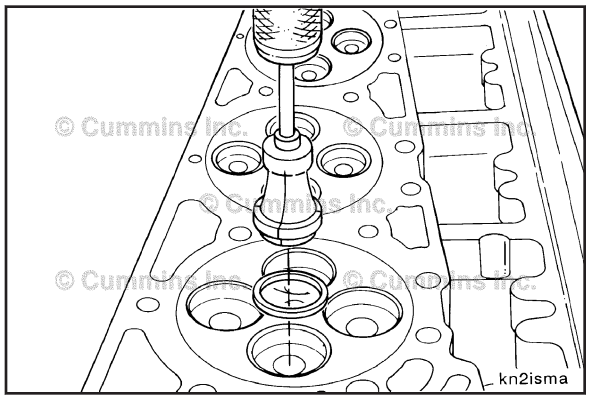
1 If required, remove the valve seat inserts.

2 Inspect the valve insert-to-cylinder head contact area. A sufficient groove for the remover **must** exist.

3 If there is sufficient valve insert groove area, proceed to the next step.

4 If the valve insert groove area is **not** sufficient, use the valve seat insert cutting kit, Part Number 3376405, to create a sufficient groove.





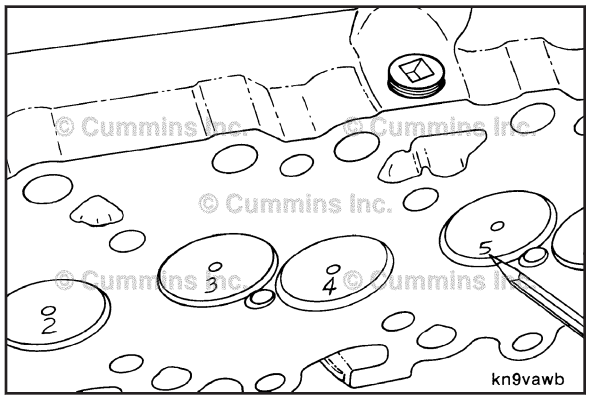
Use the slide hammer remover, Part Number 3376617, with valve insert remover, Part Number 3165170, to remove the valve seats.

NOTE: Make certain that the valve insert remover assembly is perpendicular to the cylinder head when installed.

Insert the valve insert remover assembly into the valve insert and rotate the T-handle **clockwise** until the remover loosely grips the valve insert.

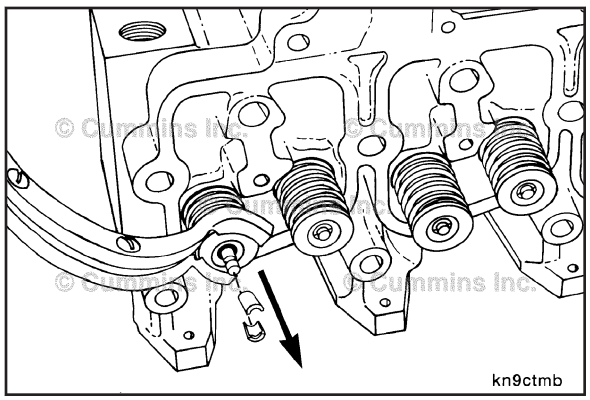
Position the valve insert remover assembly into the valve insert groove area. Tighten the T-handle firmly, allowing the remover to expand under the valve insert or into the cut groove.

Strike the slide hammer remover against the top nut until the valve insert is removed. Turn the T-handle **counterclockwise** to release the valve insert from the remover.



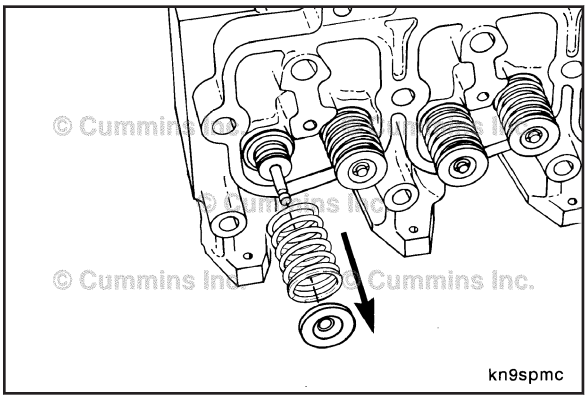
B3.9, B5.9, and B4.5 Engines

Mark the valves to identify their location.



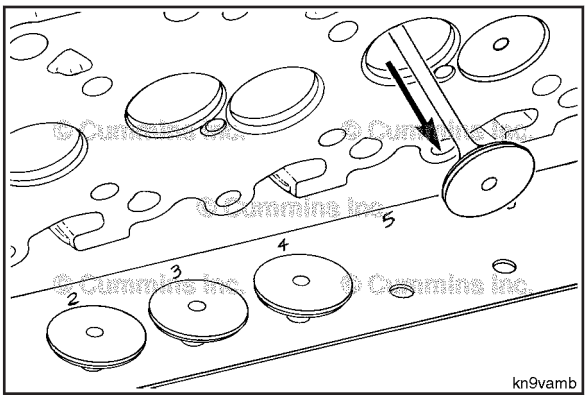
Compress the valve spring using the valve spring compressor, Part Number 3375960, and remove the valve stem collets. Discard the collets.

Release the valve spring and remove the spring retainer and spring.



Remove the remaining collets, retainers, springs, and valves.

NOTE: Keep the valves in a labeled rack for a correct match with companion seats while making measurements.

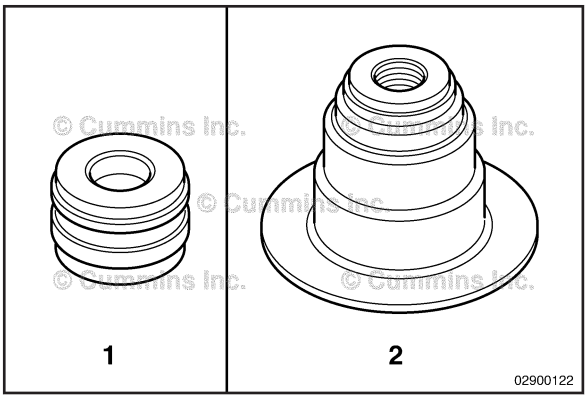


NOTE: Prior to removing the valve stem seals, note the type of valve stem seal installed at each valve location. The same type of valve stem seal **must** be installed when assembling the cylinder head.

There are two types of valve stem seals used:

1 “Drive-On” Seal

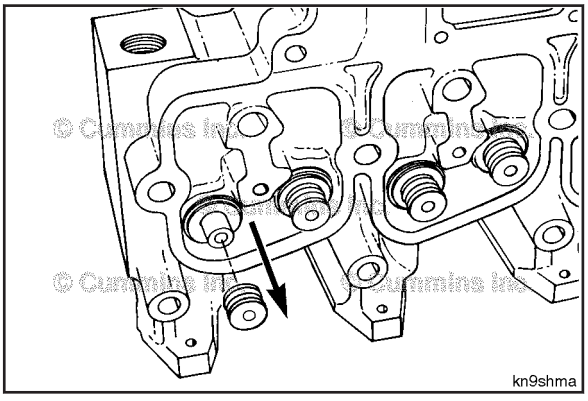
2 “Top-Hat” Seal

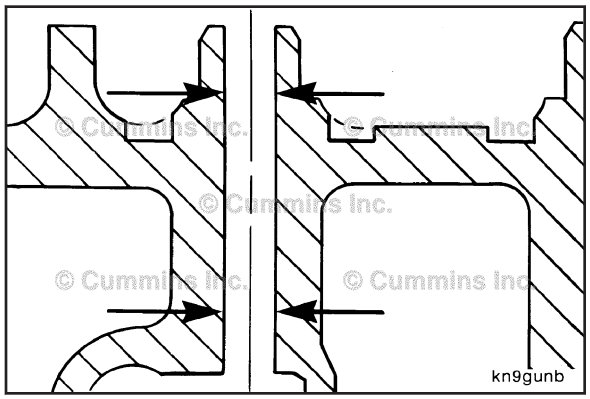


Remove the valve stem seals.

Use boot pliers, Part Number 3163293, to remove the valve stem seal.

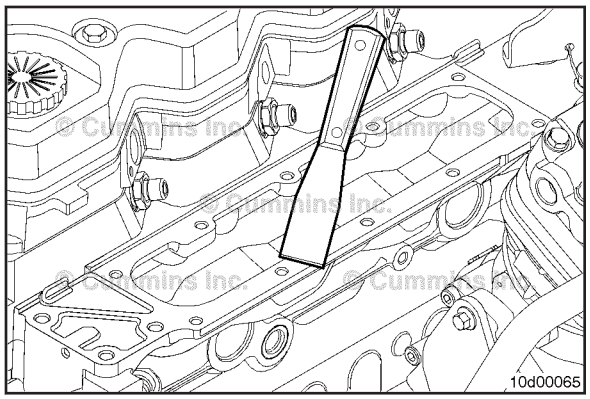
Remove and discard the valve stem seals.





From production, the cylinder head does **not** have valve guide inserts or valve seat inserts. The valve guides and valve seats are machined integral parts of the cylinder head.

If servicing an engine in which the cylinder head was previously repaired with valve guide inserts or valve seat inserts, information is available in the Alternative Repair Manual, B and C Series Engines, Bulletin 3666109.

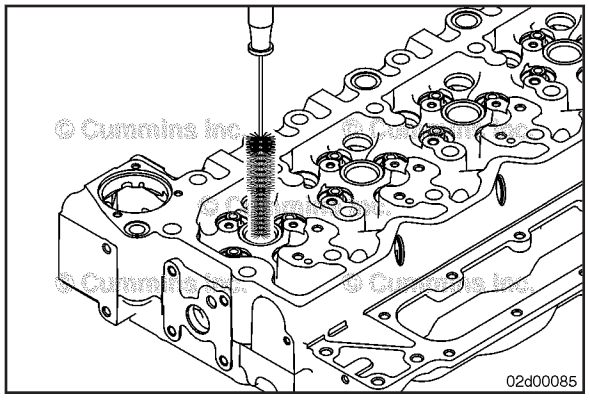


Clean and Inspect for Reuse

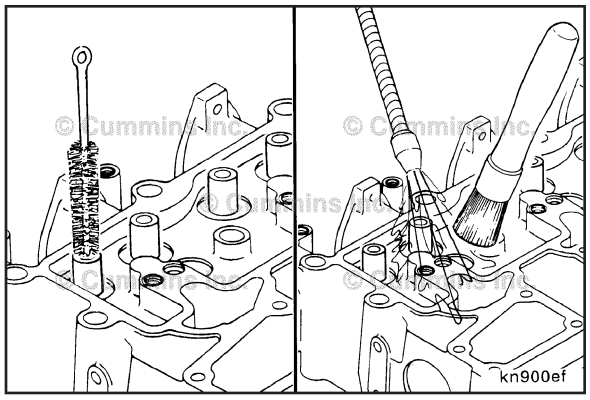
B4.5 RGT Engines

NOTE: Keep the gasket material and any other material out of the air intake.

If removed, clean the cylinder head sealing surfaces where the air intake manifold seals.



Use an injector bore brush, Part Number 3822510, or equivalent, to clean the carbon from the injector seat.

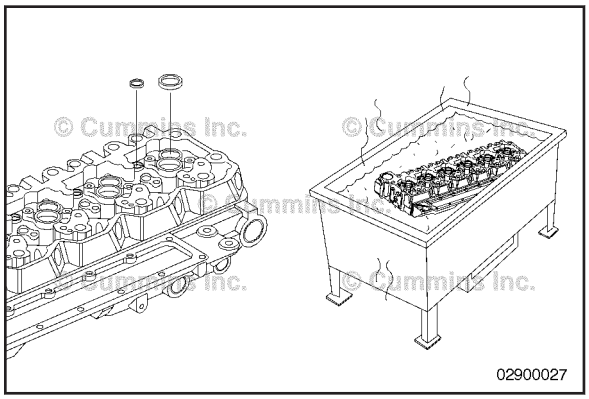


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use a bristle brush to clean the inside diameter of the valve guide bore and blow out with compressed air.

NOTE: Excessive deposits can be cleaned in an acid tank, but the expansion plugs **must** be removed first. Refer to Procedure 017-002 in Section 17.

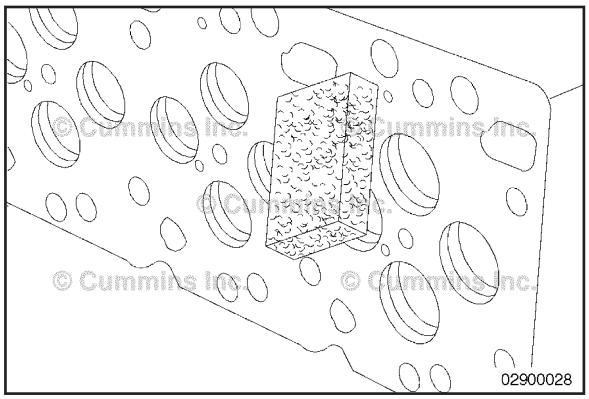
If required, clean the buildup of deposits in the coolant passages.



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

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

Clean the cylinder head combustion deck with an abrasive hand pad, Part Number 3823258, or equivalent, and solvent.



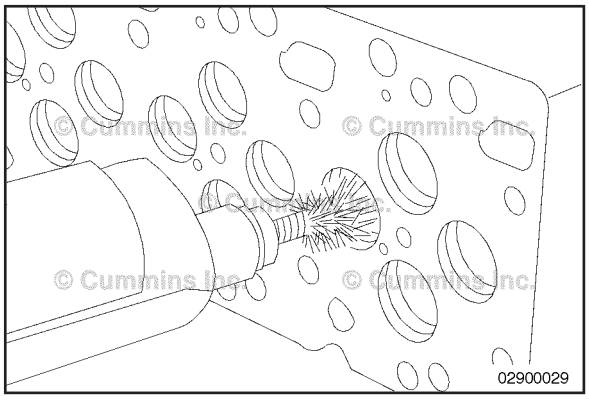
⚠WARNING⚠
Wear protective eye covering while cleaning carbon deposits to reduce the possibility of personal injury.

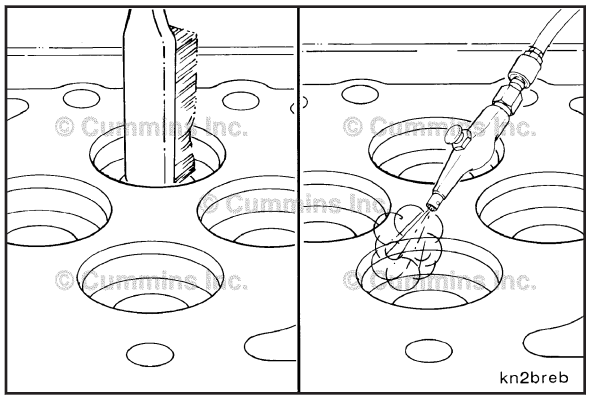
△CAUTION△
Contacting the valve seat with the wire wheel while it is spinning will damage the valve seat. If this occurs, new valve seats must be cut or new valve seat inserts must be installed.

Inspect the area within 1/8-inch of the firing ring diameter. Any wear that can be felt with a fingernail within the 1/8-inch area is unacceptable, making the cylinder head **not** reusable. Wear beyond this 1/8-inch area will have no effect on future combustion sealing and the usability of the cylinder head.

Clean carbon deposits from the valve pockets with a high-quality steel wire wheel installed in a drill or die grinder.

NOTE: An inferior-quality wire wheel will lose steel bristles during operation, causing additional contamination.



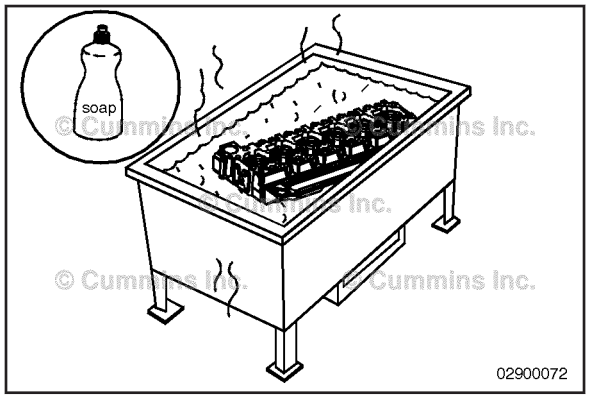


⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Use a wire brush and solvent to clean the deposits from the valve seat insert bores, if it was necessary to remove the valve seat inserts.

Dry with compressed air.

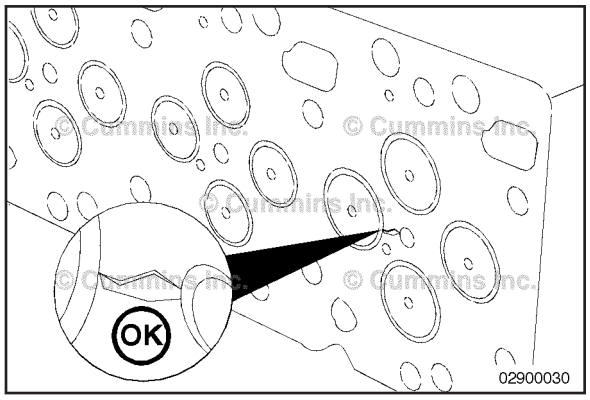


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Wash the cylinder head in a hot, soapy water solution.

Rinse the cylinder head with clean water.

Dry the cylinder head with compressed air.



Cylinder Head Cracks - Reuse Guidelines

With the cylinder head cleaned, re-inspect the cylinder head for signs of cracks, fretting, and discoloration that would prohibit reuse.

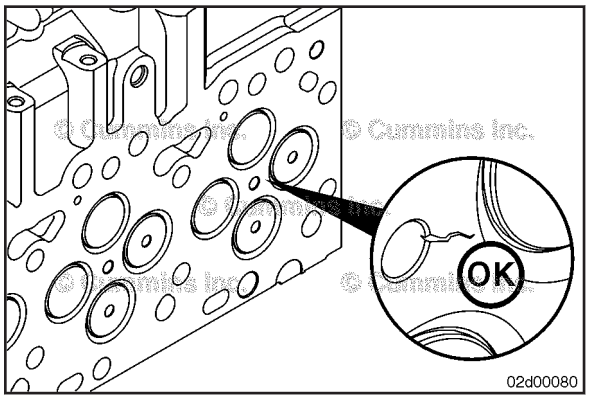
To help identify cracks in the cylinder block, use the crack detection kit, Part Number 3375432.

Pay close attention to areas of the cylinder head that include:

- Injector bore
- Combustion face
- Valve seats
- Valve guides.

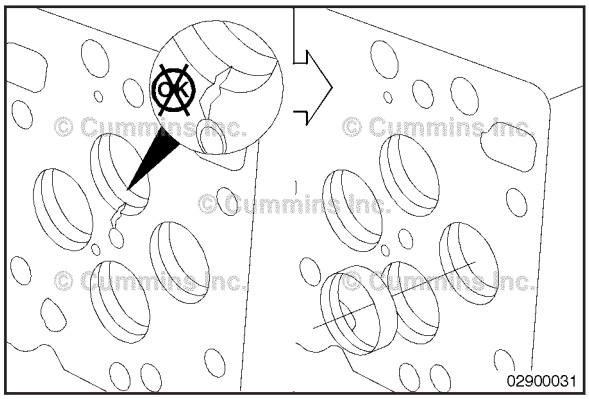
The reuse guidelines for a cylinder head with a crack extending from the injector bore to the intake valve seat are as follows:

- If the crack does **not** extend into the valve seat, the cylinder head is reusable.



- If the crack extends into or through the valve seat, the cylinder head **must** be replaced.

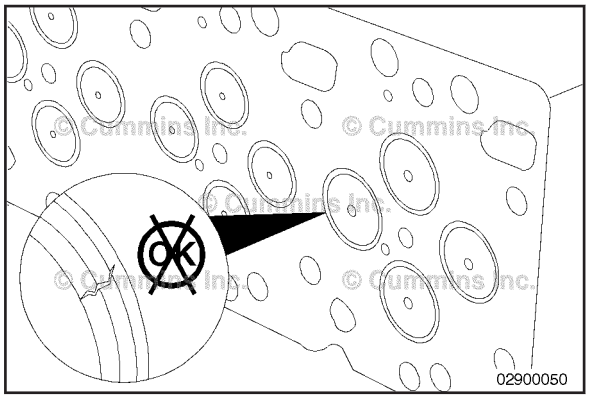
⚠CAUTION⚠
Failure to replace the cylinder head for a crack that extends into or through the valve seat bore will result in a valve seat insert falling out. Engine damage will result.

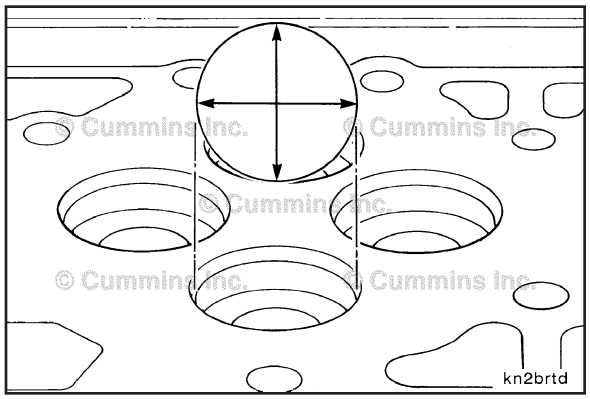


If still installed, inspect the valve seats for cracks or burn spots.

If the valve seat inserts are damaged for some cylinder heads, the valve seat inserts can be replaced.

1 Verify replacement valve seat inserts are available.
2 If available and require replacement, see the Disassembly Step for instructions on removing valve seat inserts.
3 If replacement valve seat inserts are **not** available, the cylinder head **must** be replaced.





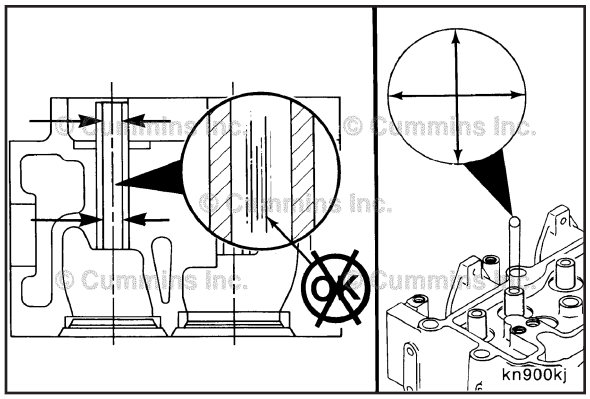
If the valve seat insert was removed in the Disassemble section, measure the inside diameter of the valve seat insert bore in the cylinder head.

Cylinder Head Insert Bore Inside Diameter (I.D.)		
mm		**in**
34.847	MIN	1.3719
34.863	MAX	1.3726

NOTE: Before cutting the cylinder head, verify valve seat inserts are available for the engine being serviced. If none are available, the cylinder head **must** be replaced.

If out of specification, the valve seat insert bore can be oversized .254 mm (.010 in) and/or .508 mm (.020 in).

Use valve seat insert tool kit, Part Number ST257, with valve guide arbor, Part Number 3165184, to the cut cylinder head to accept oversize valve seat inserts. Use valve seat cutter, Part Number 3165183 (.254 mm (.010 in) or Part Number 3165184 (508 mm (.020 in).



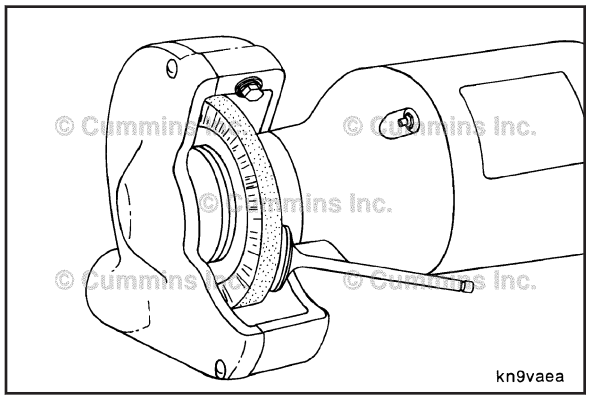
Valve Guide - Reuse Guidelines

Inspect the valve guides for scuffing or scoring.

Measure the valve guide inner diameter (I.D.)

Valve Guide Bore Diameter		
mm		**in**
7.027	MIN	0.2767
7.077	MAX	0.2786

If the valve guide bore is worn larger than the maximum specified or if inspection reveals damaged valve guides, the cylinder head **must** be replaced.



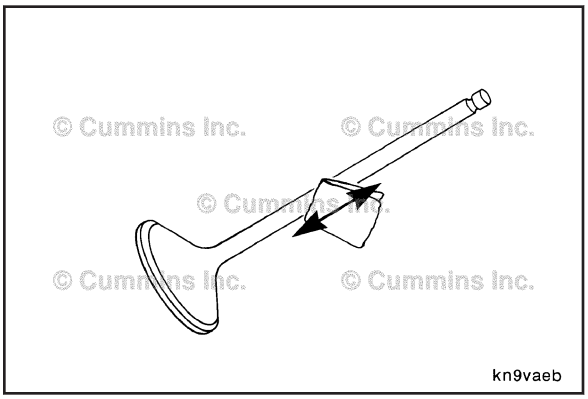
⚠WARNING⚠
Wear protective eye covering when cleaning the valves with a wire wheel to reduce the possibility of personal injury.

Clean the valve heads with a soft wire wheel.

NOTE: Keep the valves in a labeled rack to prevent mixing before taking measurements.

⚠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.

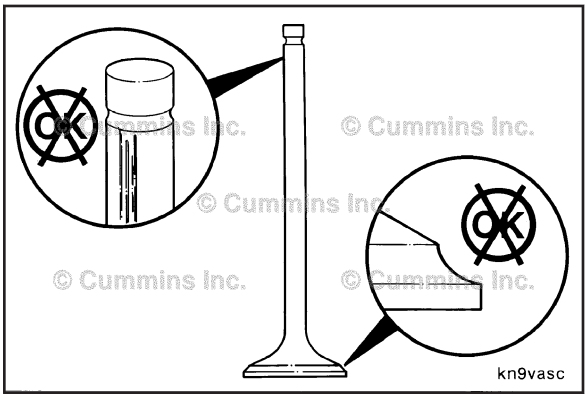
Polish the valve stems with an abrasive pad, Part Number 3823258, and solvent.



Valve - Reuse Guidelines

Inspect the valves for:

- excessive wear on the heads and stems
- excessive wear on the valve stem tips
- bends and distortion.



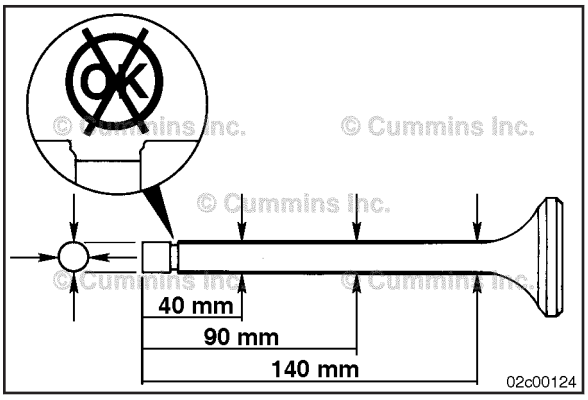
Inspect the valves for damage and the collet grooves for wear.

Measure the outside diameter of the valve stem.

Three measurements must be taken of each valve stem at 40 mm [1.57 in], 90 mm [3.54 in], and 140 mm [5.51 in] from the tip end.

Valve Stem Diameter		
mm		in
6.96	MIN	0.2740
7.01	MAX	0.2760

If the valves are damaged or the stems are worn smaller than the minimum specified, the valves **must** be replaced.



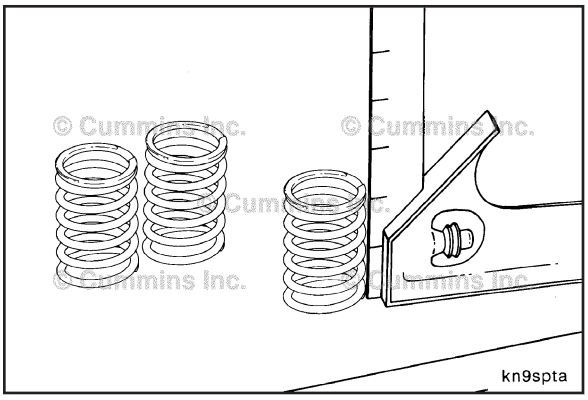
Valve Spring - Reuse Guidelines

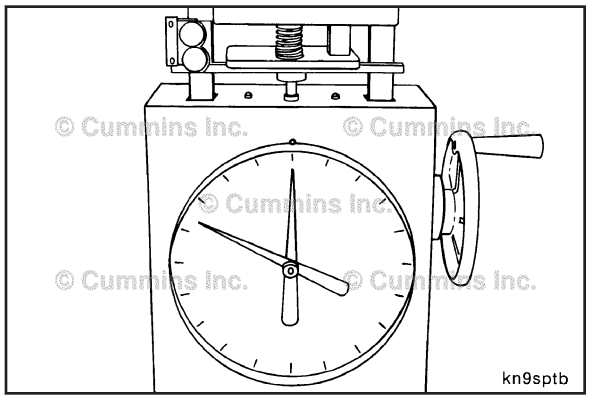
Inspect the valve springs.

Measure the valve spring. Place a square adjacent to the spring and use a feeler gauge to measure the clearance at the top spring coil.

Approximate Free Length (L): 47.75 mm [1.88 in]

Maximum Inclination: 1.5 mm [0.059 in]

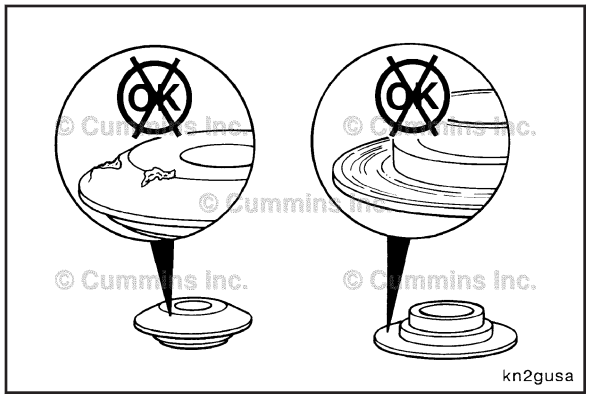




Use valve spring tester, Part Number 3375182, to compress the valve spring. A load of 320.8 to 358.8 N [72 to 80.7 lbf] is required to compress a spring to a height of 35.33 mm [1.39 in].

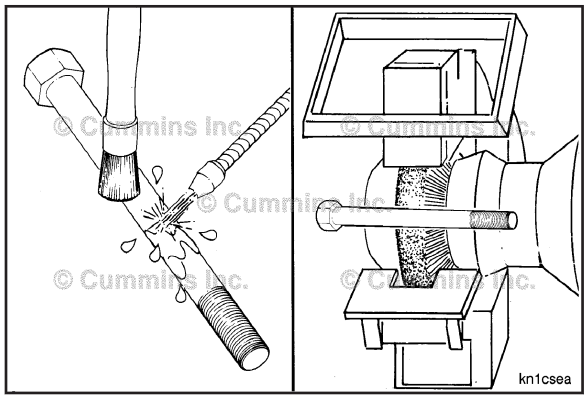
NOTE: If the valve spring is **not** within specification, a new valve spring **must** be used.

NOTE: Valve springs **must** be replaced in pairs under the same cross head. If one spring does **not** meet the specification, replace both valve springs under the same cross head.



Inspect the valve spring retainers and valve collets for damage or worn areas.

Discard and replace damaged and worn parts.



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

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

△CAUTION△
Do not use caustic or acid solutions to clean the cylinder head capscrews. Component damage can occur.

Use a petroleum-based solvent to clean the capscrews.

Clean the capscrews thoroughly with a wire brush, soft wire wheel, or nonabrasive bead blast to remove deposits from the shank and threads.

Cylinder Head Capscrew - Reuse Guidelines

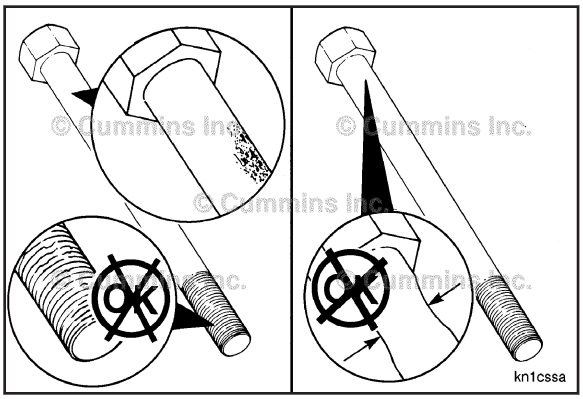
Inspect the cylinder head capscrews for damaged threads, corroded surfaces, or a reduced diameter (due to capscrew stretching).

Do **not** reuse cylinder head capscrews under the following conditions:

- Visible corrosion or pitting exceeding 1 sq cm [0.155 sq in] in area.

Example:

- Acceptable is 9.525 x 9.525 mm [3/8 x 3/8 in]
- Unacceptable is 12.700 x 12.700 mm [½ x ½ in]
- Visible corrosion or pitting exceeds 0.12 mm [0.005 in] in depth
- Visible corrosion or pitting is located within 3.2 mm [1/8 in] of the fillet or thread
- Stretched beyond "free-length" maximum. See the measurement procedure below:

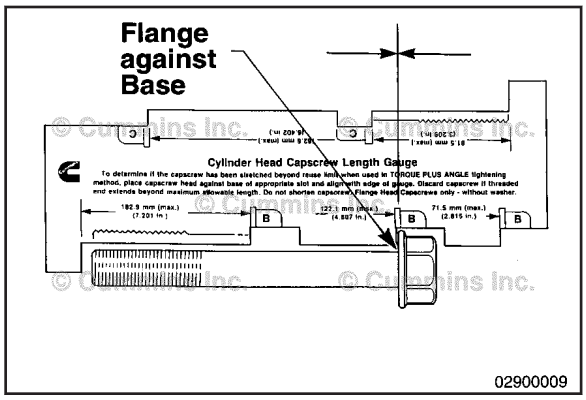


Free-Length Measurement

NOTE: If the capscrews are **not** damaged, they can be reused throughout the life of the engine, unless the specified free length is exceeded.

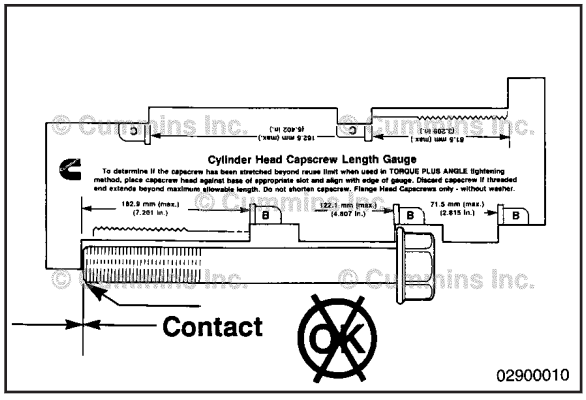
To check the capscrew free length, use capscrew length gauge, Part Number 316405. Place the head of the capscrew in the appropriate slot with the flange against the base of the slot.

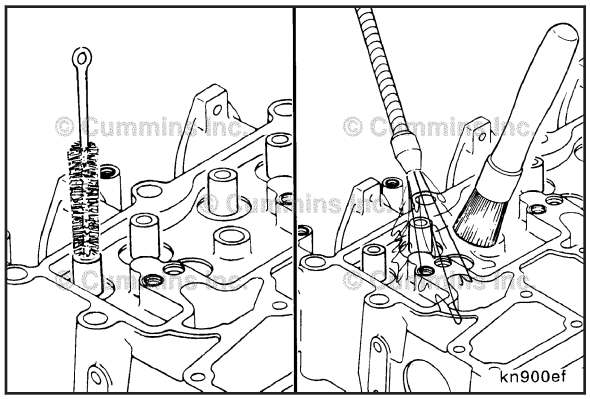
NOTE: Most new cylinder head gaskets and upper engine gaskets include the capscrew length gauge, Part Number 3164057.



If the end of the capscrew touches the foot of the gauge, the capscrew is too long and **must** be discarded.

Cylinder Head Capscrew Free Length		
mm		**in**
152.1	MAX	5.99



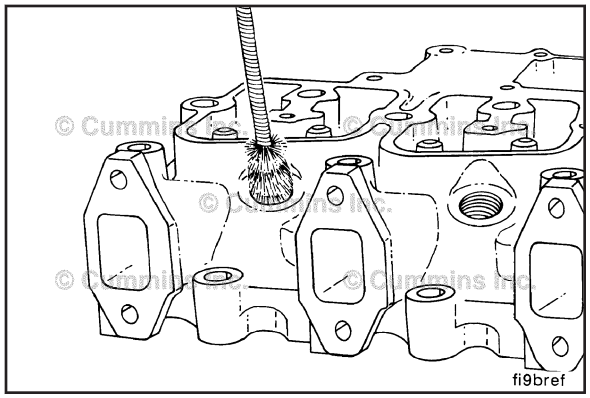


B3.9, B5.9, and B4.5 Engines

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

Clean the cylinder head with solvent.

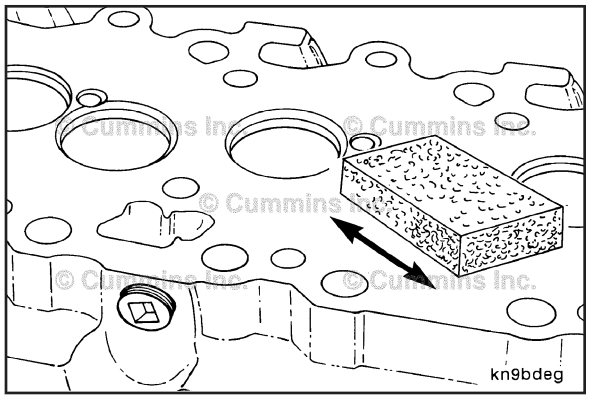
Use a bristle brush to clean the inside diameter of the valve guide bore.



Use an injector bore brush, Part Number 3822509, or equivalent, to clean the carbon from the injector seat.

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

Use compressed air to dry the cylinder head.



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

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

Clean the cylinder head combustion deck with an abrasive hand pad, Part Number 3823258, or equivalent, and solvent.

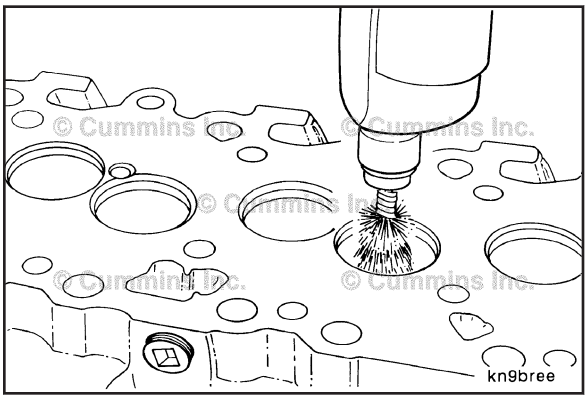
⚠WARNING⚠
Wear protective eye covering while cleaning carbon deposits to reduce the possibility of personal injury.

△CAUTION△
Contacting the valve seat with the wire wheel while it is spinning will damage the valve seat. If this occurs, new valve seats must be cut or new valve seat inserts must be installed.

Inspect the area within 1/8-inch of the firing ring diameter. Any wear that can be felt with a fingernail within the 1/8-inch area is unacceptable, making the cylinder head **not** reusable. Wear beyond this 1/8-inch area will have no effect on future combustion sealing and the usability of the cylinder head.

Clean carbon deposits from the valve pockets with a high quality steel wire wheel installed in a drill or die grinder.

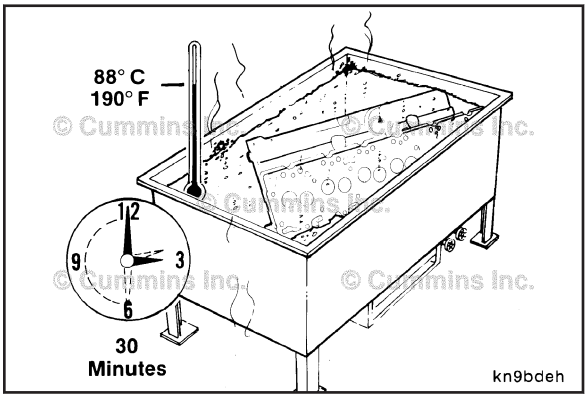
NOTE: An inferior-quality wire wheel will lose steel bristles during operation, causing additional contamination.



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

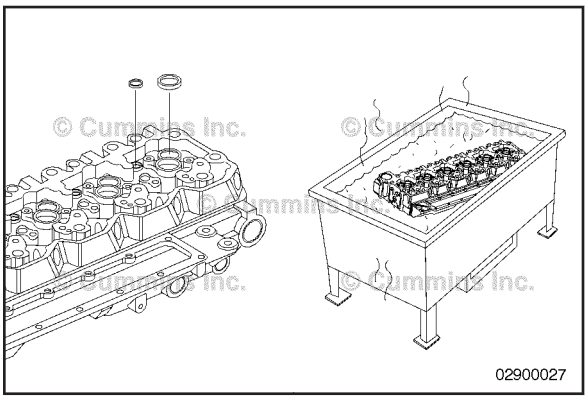
Wash the cylinder head in hot, soapy water solution.

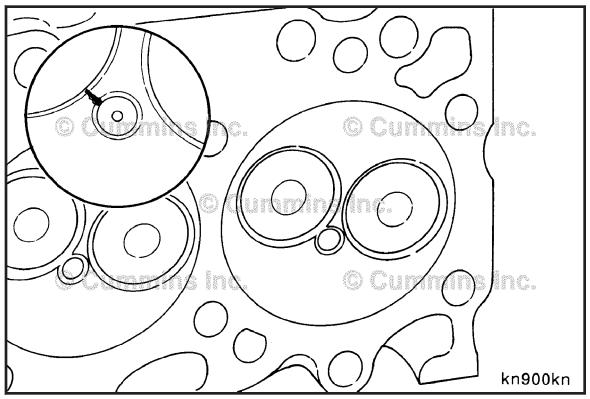
After rinsing, use compressed air to dry the cylinder head.



NOTE: Excessive deposits can be cleaned in an acid tank, but the expansion plugs **must** be removed first. Refer to Procedure 017-002 in Section 17.

Inspect the coolant passages for build up of deposits. If required, clean the coolant passages in an acid tank.





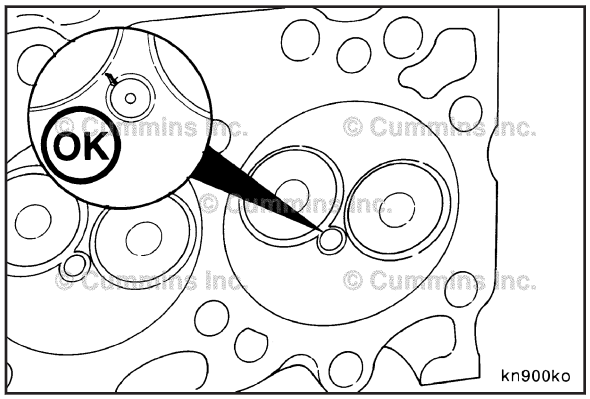
Cylinder Head Cracks - Reuse Guidelines

With the cylinder head cleaned, re-inspect the cylinder head for signs of cracks, fretting, and discoloration that would prohibit reuse.

To help identify cracks in the cylinder block, use the Crack Detection Kit, Tool Number 3375432.

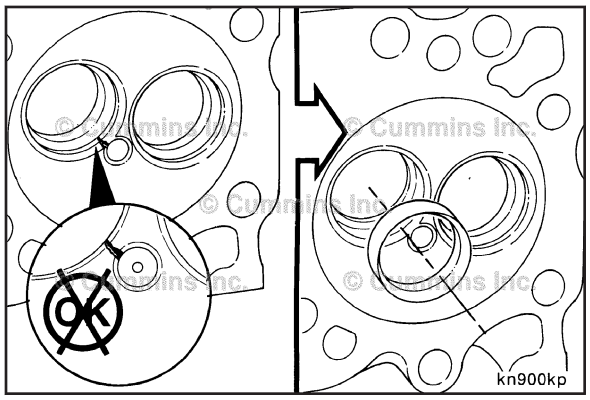
Pay close attention to areas of the cylinder head that include:

- Injector bore
- Combustion face
- Valve seats
- Valve guides.

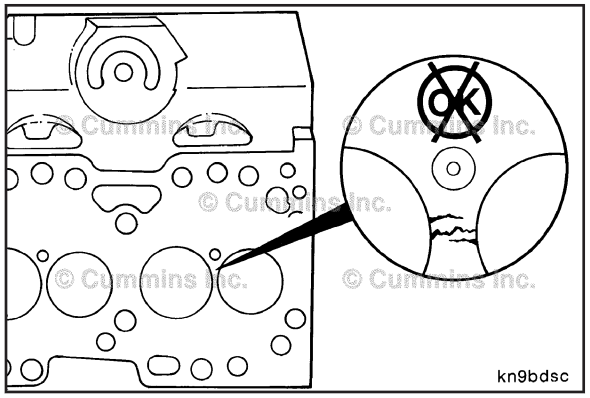


The reuse guidelines for a cylinder head with a crack extending from the injector bore to the intake valve seat are as follows:

- If the crack does **not** extend into the valve seat, the cylinder head is reusable.



If the crack extends into or through the valve seat, the cylinder head **must** be repaired by installing a valve seat insert. Refer to the Alternative Repair Manual, B and C Series Engines, Bulletin 3666109, for repair information.



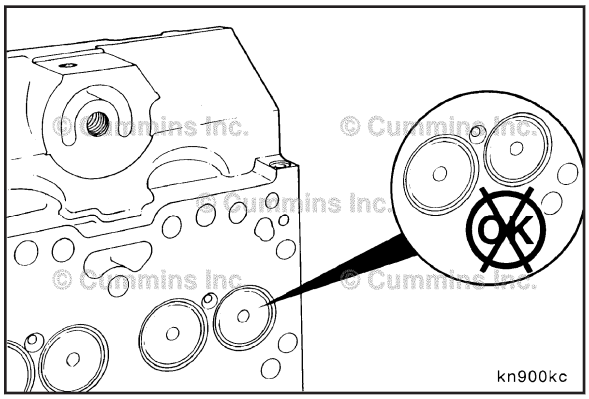
Cracks between the valve seats are **not** acceptable and the cylinder head **must** be replaced.

Inspect the valves for indications of leakage or burning.

Depending on the severity, lapping of the valves/valve seats will be a sufficient repair.

If **not**, installation of valve seat inserts will be required.

Information on valve seat insert installation is available in the Alternative Repair Manual, B and C Series Engines, Bulletin 3666109.



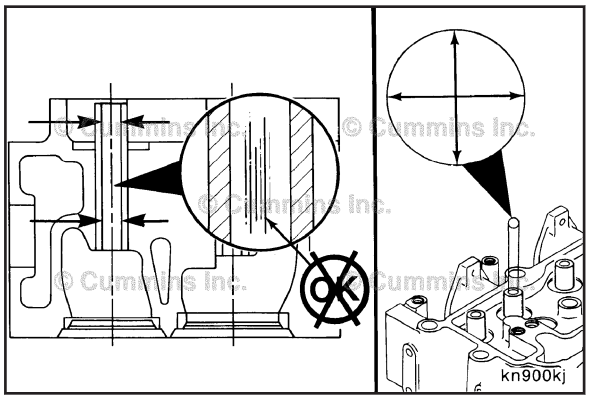
Valve Guide - Reuse Guidelines

Inspect the valve guides for scuffing or scoring.

Measure the valve guide inner diameter (I.D.)

Valve Guide Bore Diameter		
mm		**in**
8.01	MIN	0.315
8.10	MAX	0.319

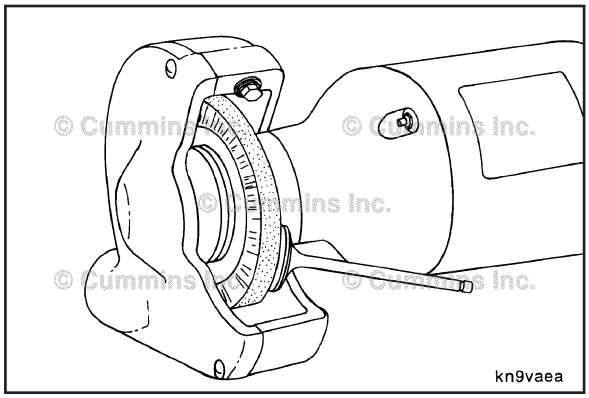
If the valve guide bore is worn larger than the maximum specified or if inspection reveals damaged valve guides, the cylinder head can be repaired with valve guide inserts. Information on valve guide insert installation is available in the Alternative Repair Manual, B and C Series Engines, Bulletin 3666109.



⚠WARNING⚠
Wear protective eye covering when cleaning the valves with a wire wheel to reduce the possibility of personal injury.

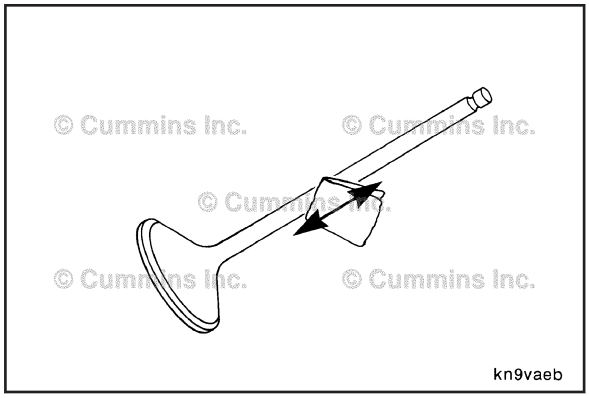
Clean the valve heads with a soft wire wheel.

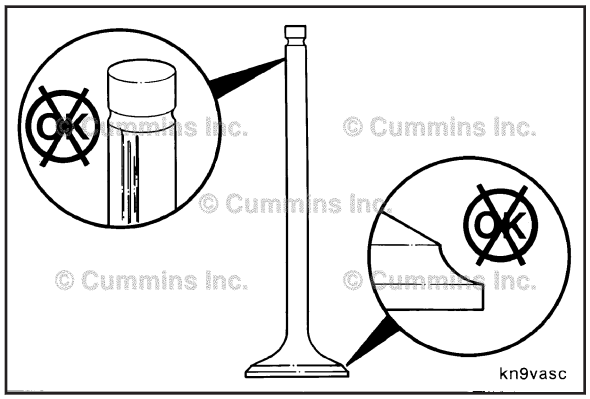
NOTE: Keep the valves in a labeled rack to prevent mixing before taking measurements.



⚠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.

Polish the valve stems with an abrasive pad, Part Number 3823258, and solvent.

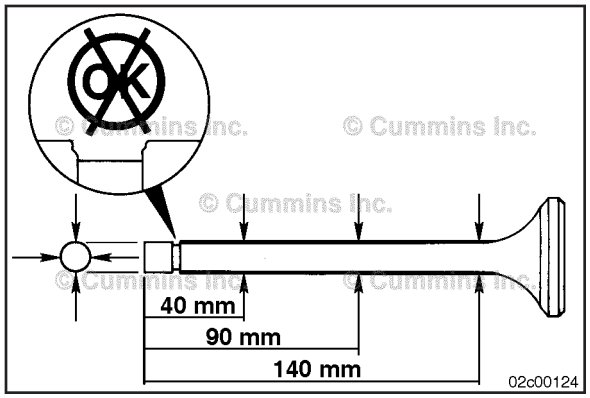




Valve - Reuse Guidelines

Inspect the valves for:

- excessive wear on the heads and stems
- excessive wear on the valve stem tips
- bends and distortion.



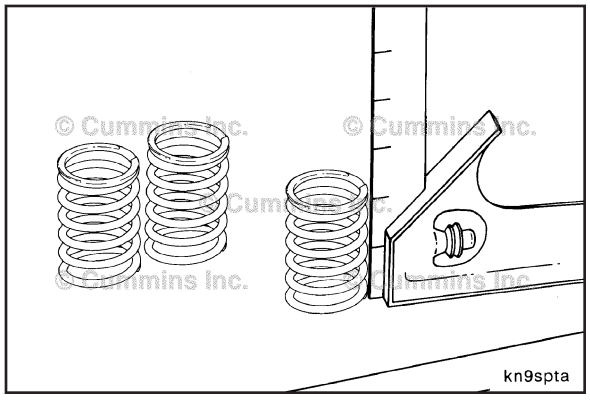
Inspect the valves for damage and the collet grooves for wear.

Measure the outside diameter of the valve stem.

Three measurements **must** be taken of each valve stem at 40 mm [1.57 in], 90 mm [3.54 in], and 140 mm [5.51 in] from the tip end.

Valve Stem Diameter		
mm		**in**
7.90	MIN	0.311
7.96	MAX	0.313

If the valves are damaged or the stems are worn smaller than the minimum specified, the valves **must** be replaced.



Valve Spring - Reuse Guidelines

Inspect the valve springs.

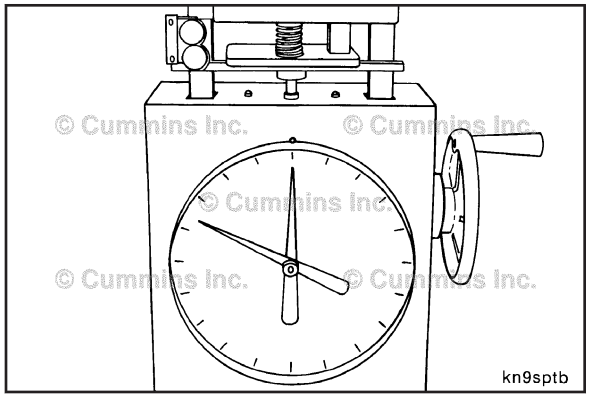
Measure the valve spring. Place a square adjacent to the spring and use a feeler gauge to measure the clearance at the top spring coil.

Approximate Free Length (L) 1991: 55.63 mm [2.190 in]

Maximum Inclination 1991: 1.00 mm [0.039 in]

Approximate Free Length (L) 1994: 60.00 mm [2.362 in]

Maximum Inclination 1994: 1.00 mm [0.039 in]

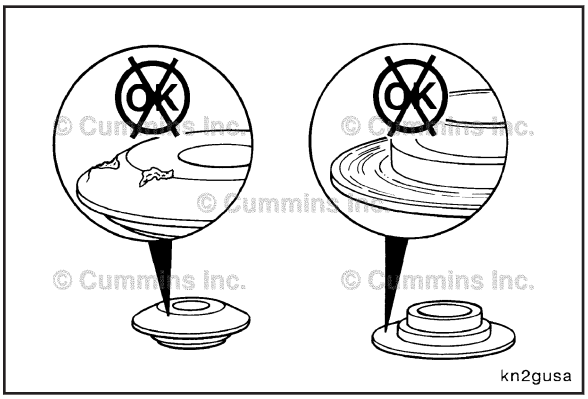


Use valve spring tester, Part Number 3375182, to compress the valve spring. A load of 289.13 to 321.16 N [65.0 to 72.2 lbf] (1991) and 359 to 397 N [80.7 to 89.2 lbf] (1994) is required to compress a spring to a height of 49.25 mm [1.94 in].

NOTE: If the valve spring is **not** within specification, a new valve spring **must** be used.

Inspect the valve spring retainers and valve collets for damage or worn areas.

Discard and replace damaged and worn parts.



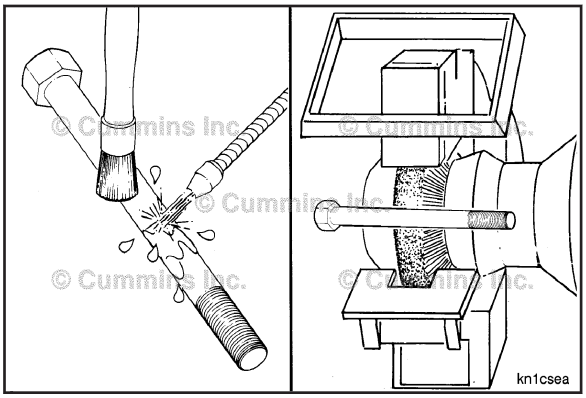
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

△CAUTION△
Do not use caustic or acid solutions to clean the cylinder head capscrews. Component damage can occur.

Use a petroleum-based solvent to clean the capscrews.

Clean the capscrews thoroughly with a wire brush, soft wire wheel, or nonabrasive bead blast to remove deposits from the shank and threads.



Cylinder Head Capscrew - Reuse Guidelines

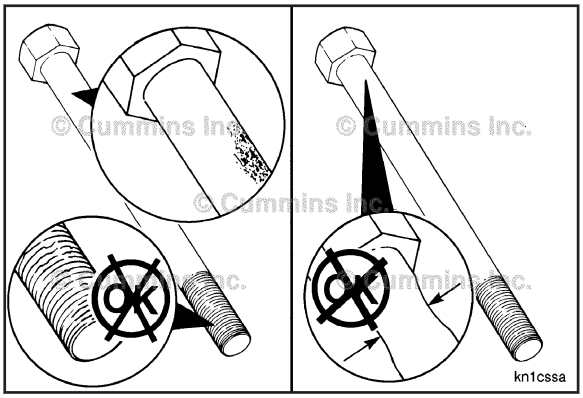
Inspect the cylinder head capscrews for damaged threads, corroded surfaces, or a reduced diameter (due to capscrew stretching).

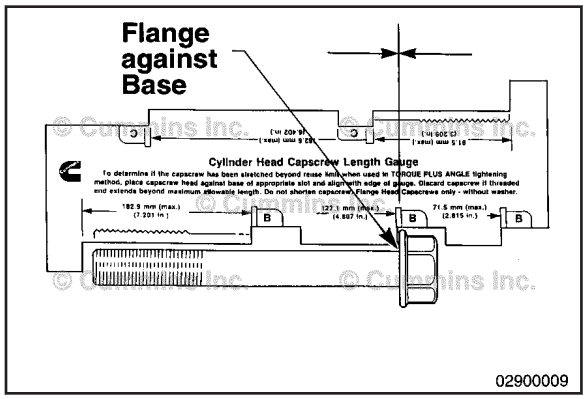
Do **not** reuse cylinder head capscrews under the following conditions:

- Visible corrosion or pitting exceeding 1 sq cm [0.155 sq in] in area.

Example:

- Acceptable is 9.525 x 9.525 mm [3/8 x 3/8 in]
- Unacceptable is 12.700 x 12.700 mm [½ x ½ in]
- Visible corrosion or pitting exceeds 0.12 mm [0.005 in] in depth
- Visible corrosion or pitting is located within 3.2 mm [1/8 in] of the fillet or thread
- Stretched beyond "free-length" maximum. See the measurement procedure below:





Capscrew Length Gauge, Part Number 3823921

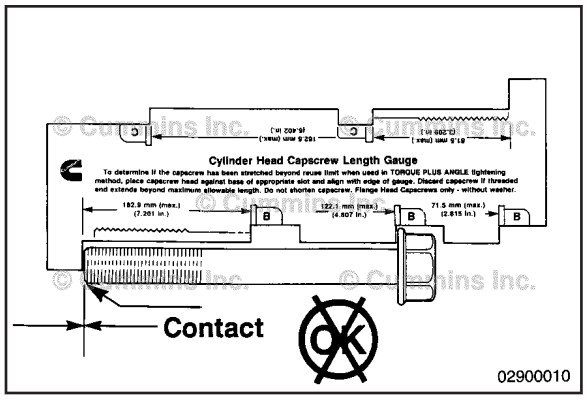
Free-Length Measurement

NOTE: If the capscrews are **not** damaged, they can be reused throughout the life of the engine, unless the specified “free length” is exceeded.

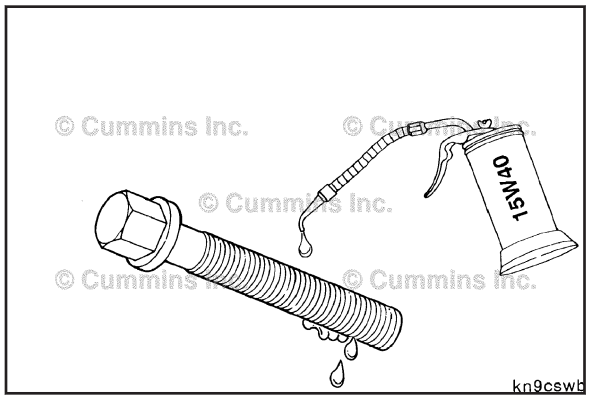
To check the capscrew free length, place the head of the capscrew in the appropriate slot with the flange against the base of the slot.

Capscrew Free Length

	mm		in
Short	71.5	MAX	2.815
Medium	122.1	MAX	4.807
Long	182.9	MAX	7.201



If the end of the capscrew touches the foot of the gauge, the capscrew is too long and **must** be discarded.



Immediately after cleaning and inspecting the capscrew, apply a film of clean engine oil to all capscrews that are to be reused.

Pressure Test

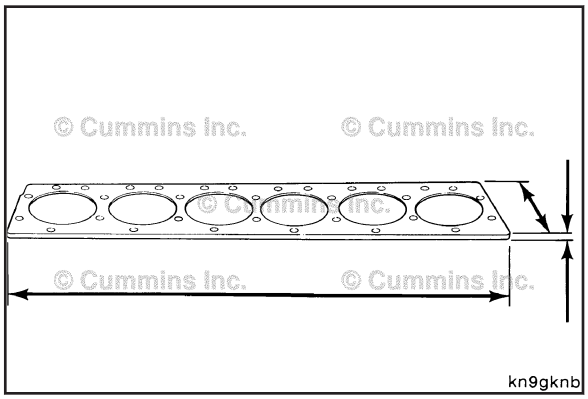
B4.5 RGT Engines

If troubleshooting an internal coolant leak or coolant loss symptom, a cylinder head test fixture can be fabricated from a flat piece of steel or aluminum to pressure test the cylinder head.

See the following table for test fixture dimensions.

16 mm	Thickness	0.630 in
749 mm	Length	29.5 in
193 mm	Width	7.6 in

NOTE: Use the old cylinder head gasket as a pattern for drilling the capscrew holes.



Install the thermostat, water outlet connection and mounting capscrews.

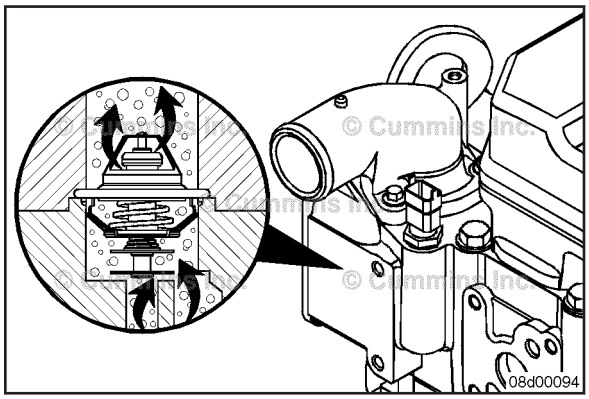
Tighten the capscrews.

Torque Value: 10 N•m [89 in-lb]

Install the engine coolant temperature sensor, located next to the water outlet connection.

Torque Value: 18 N•m [159 in-lb]

NOTE: The thermostat contains two check balls to vent air past the thermostat when closed. Install a rubber cap and hose clamp over the water outlet connection to prevent air from leaking through the check balls.



Install the cylinder head water test fixture.

1 Install a new head gasket.

2 Install the test plate.

3 Install the following:

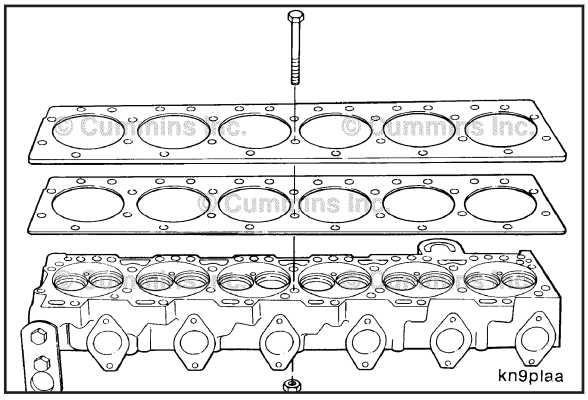
For four cylinder engines:

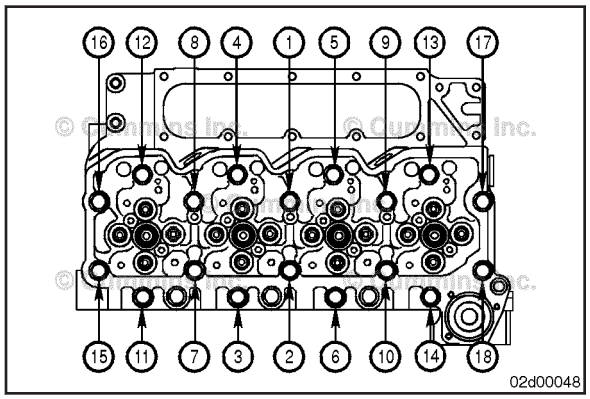
- 18 - 180-mm-long grade 12.9 flange head capscrews
- 18 - M12 x 1.75 hex flange nuts
- 36 - 12-mm washers

For six cylinder engines:

- 26 - 180-mm-long grade 12.9 flange head capscrews
- 26 - M12 x 1.75 hex flange nuts
- 52 - 12-mm washers

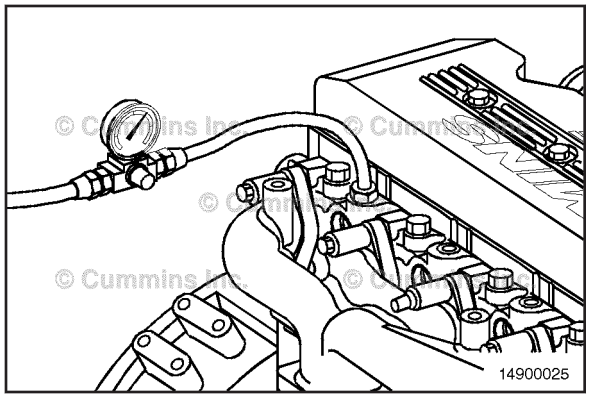
NOTE: Place a washer between each capscrew and the head, and between each nut and test plate. This will prevent mutilation on the surface of the cylinder head.



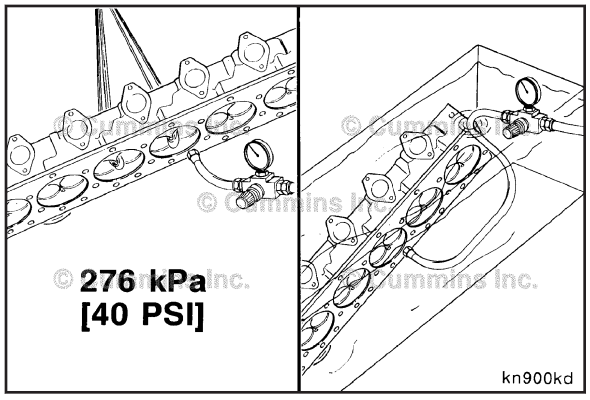


Use the illustrated sequence to tighten the four-cylinder nuts.

Torque Value: 80 N•m [59 ft-lb]



Service Tip: To apply air pressure to the cylinder head, remove one of the pipe plugs located on the exhaust side of the cylinder head. This is the same port used when the cylinder head is installed to check cylinder block coolant pressures.



⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly

NOTE: Make sure to plug or seal any open coolant ports before pressure testing the cylinder head.

Connect a regulated air supply hose, Part Number 3164231, to the cylinder head.

Apply air pressure.

Air Pressure: 276 kPa [40 psi]

Use a nylon lifting strap and a hoist to place the cylinder head in a tank of heated water.

Water Temperature: 60 °C [140 °F]

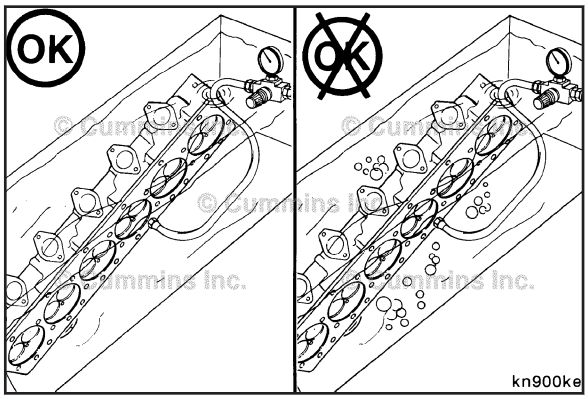
NOTE: The cylinder head **must** be completely submerged in the water.

Inspect the head. Bubbles indicate an air leak.

If any bubbles exist, verify that the air leak is not coming from:

- any cup plugs or fittings installed in the cylinder head
- the test fixture or air line fittings
- water outlet connection.

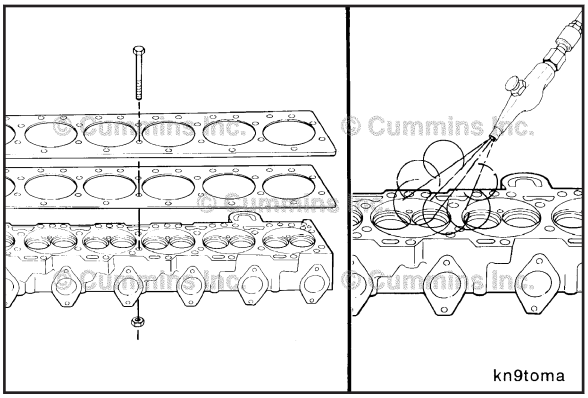
If the above checks out OK and bubbles are present, the cylinder head leaks and it **must** be replaced.



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

Remove the test fixture.

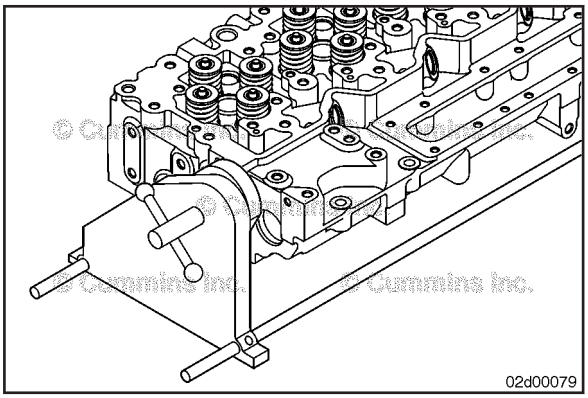
Use compressed air to dry the cylinder head.



Assemble

B4.5 RGT Engines

Install the cylinder head in the cylinder head holding fixture, Part Number ST-583.

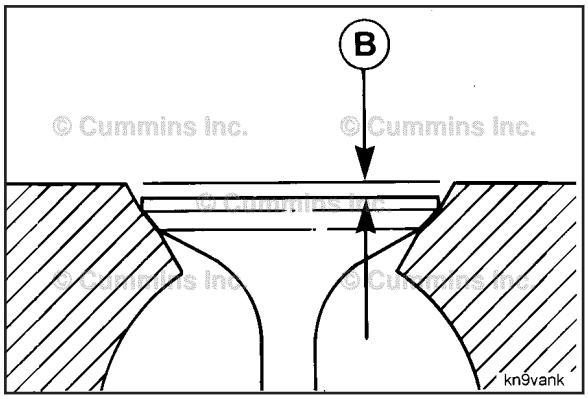


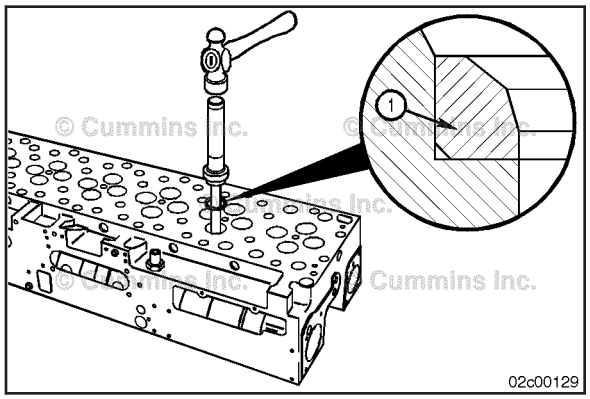
NOTE: When installing the valve seat inserts, the exhaust and intake valve seat inserts are **not** the same.

Valve seat angle:

- Intake 30-degrees
- Exhaust 45-degrees.

If new valve seat inserts are installed, check valve depth and perform a valve leak test. See the Initial Check of this procedure.



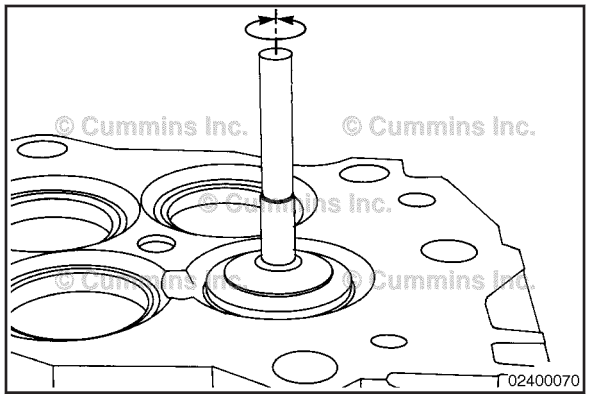


If the valve seat inserts were removed in the disassemble step, new inserts **must** be installed.

NOTE: The insert chamfer (1) **must** be installed toward the bottom of the counterbore.

Use valve seat installer, Part Number 3165171, to drive the intake and exhaust valve seat inserts into the counterbore.

Use a dead blow hammer with the seat drivers to install the new valve seat inserts.



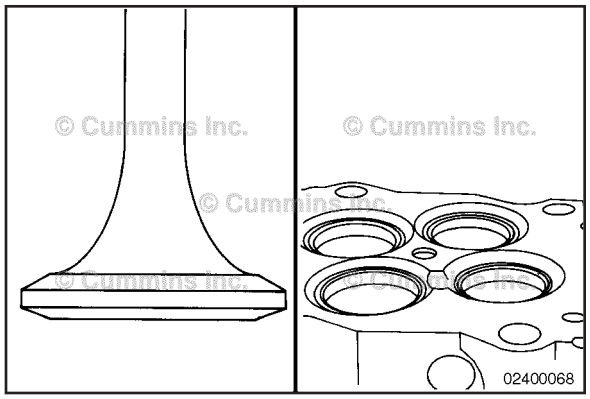
If new valve seat inserts were installed and/or the valve leakage was above specification, the valve seat/valve can be lapped.

NOTE: Lubricate the stems with 15W-40 engine oil before installing the valves.

Use a fine lapping compound, Part Number 3375805, or equivalent. Apply a thin and even coating on the valve.

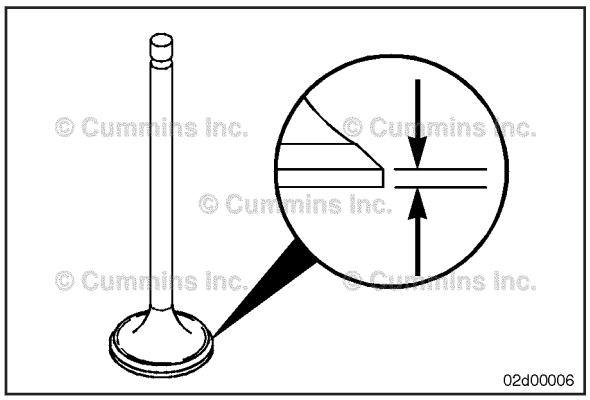
Use a power or a hand suction lapping tool to provide pressure in the center of the valve.

Turn the valve backward and forward. Continue lapping until the compound shows a continuous contact pattern on both the valve seat insert and the valve.



△CAUTION△
Lapping compound is an abrasive material. Failure will result if the cylinder head, the valves, and the valve seats are not cleaned thoroughly.

Clean the lapping compound from the parts.



If lapping of the valves was required, measure the rim thickness to determine if there is enough rim material left.

Valve Rim Thickness Limit		
mm		**in**
0.79	MIN	0.031

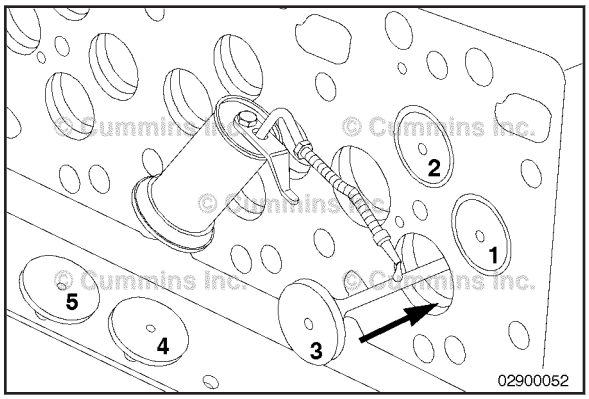
If the valve thickness is **not** within the limits, a new valve **must** be used.

⚠CAUTION⚠
Lubricate all the valve guide bores and valve stems with 15W-40 engine oil. Failure to lubricate the valve guides and valve stems can result in premature valve guide wear.

Lubricate the stems with 15W-40 engine oil before installing the valves.

NOTE: If installing the same valves as previously removed, make sure to install the valves in the same locations that the valves were removed.

NOTE: If the cylinder head will **not** be used right away, lubricate the valve stems with assembly lube, Part Number 3163087, or equivalent.



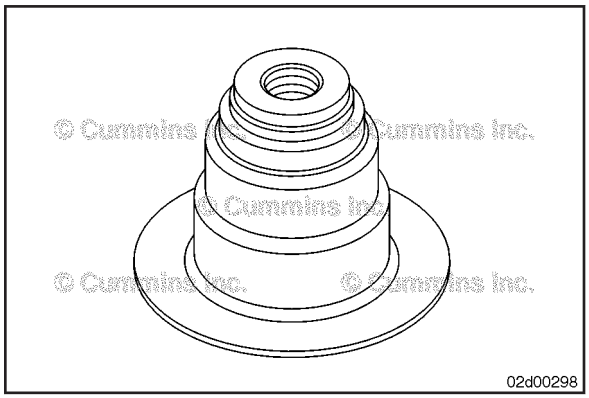
⚠CAUTION⚠
The same color valve stem seal must be installed in the same location as removed. Incorrect valve stem seals will result in excessive oil consumption and internal engine damage.

Install new valve stem seals of the same color as removed and in the same location.

There are two colors of valve stem seals used:

Colors Used:

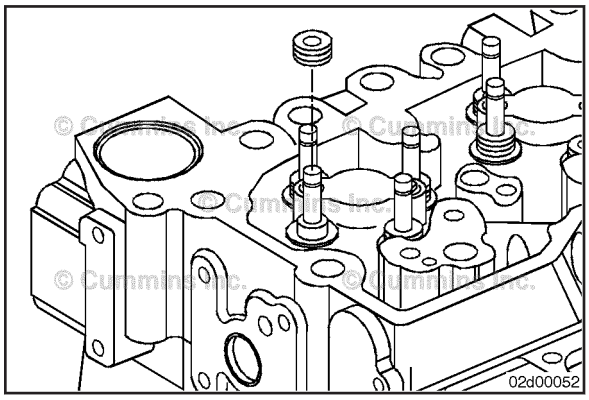
- Green (Used for exhaust valves)
- Yellow (Used for intake and exhaust valves).



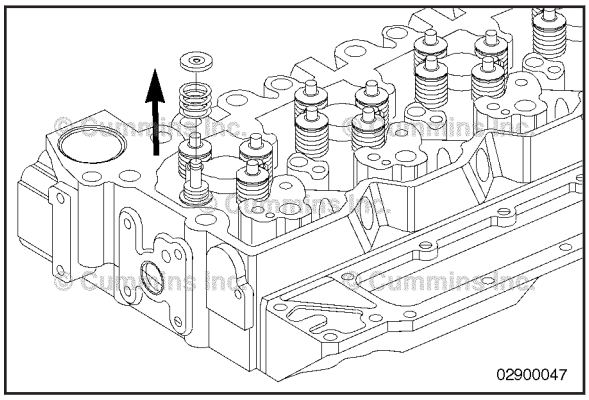
Install new valve stem seals using a valve stem installation tool, Part Number 3164055.

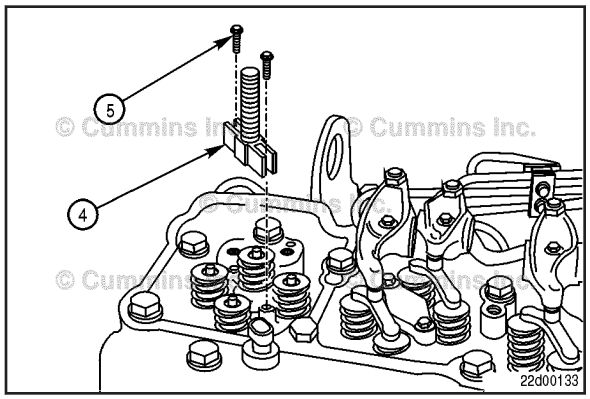
NOTE: The valve stem seals can be installed by hand. The installation tool will aid with installing the valve stem seals, but is **not** mandatory.

Use hand pressure to keep the valves from falling out during installation.



Install the valve spring retainer and valve springs.



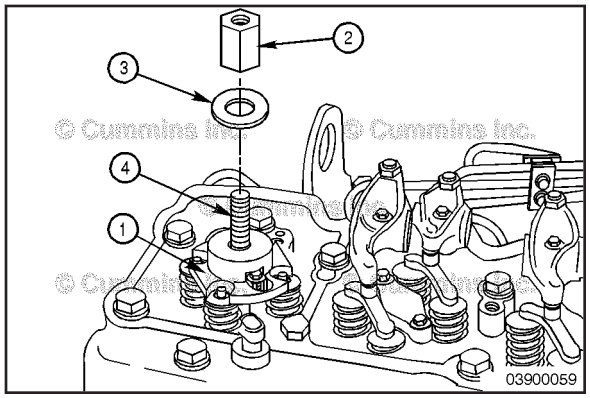


Compress the valve springs using the valve spring compressor service tool, Part Number 3164329.

Position the replacer screw (4) above the injector bore and install the two capscrews (5) in the cylinder head where the hold-down clamp screws were removed.

Tighten the capscrews (5).

Torque Value: 5 N•m [44 in-lb]

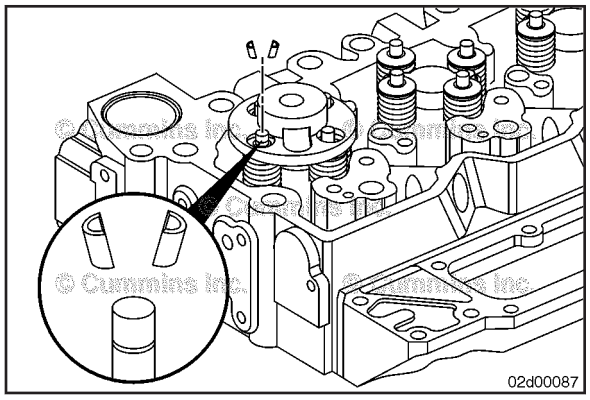


NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.

Apply anti-seize lubricant to the replacer screw (4) threads. **Always** read and follow label precautions.

Position the valve spring compressor plate (1) on the replacer screw (4) and align the slots in the valve spring compressor plate with the valve springs.

Install the washer (3) and nut (2) on the replacer screw (4).



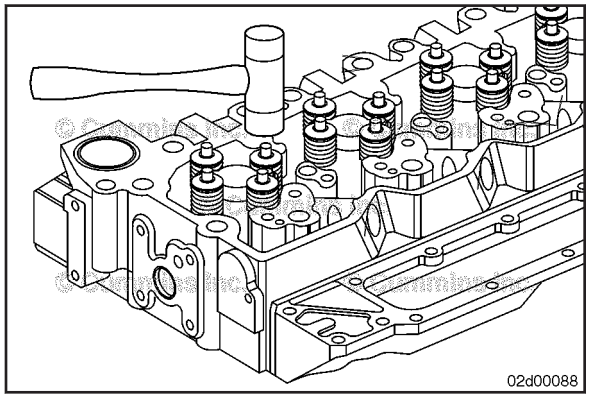
⚠WARNING⚠
Valve springs are under tension and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

Compress the valve springs until the valve collets can be installed.

Install the valve collets.

Service Tip: Use assembly lube, Part Number 3163087 or equivalent, on the valve collets to help hold them in place until the valve spring compressor is released.

Remove the valve spring compressor service tool.

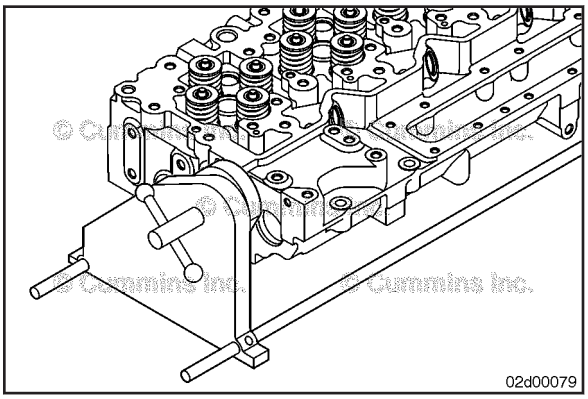


⚠WARNING⚠
To reduce the possibility of personal injury, wear eye protection. If the collets are not correctly installed, they can fly out when the stems are hit with a hammer.

After assembly, hit the valve stems with a plastic hammer to make sure the collets are seated.

B3.9, B5.9, and B4.5 Engines

Install the cylinder head in the cylinder head holding fixture, Tool Number ST-583.



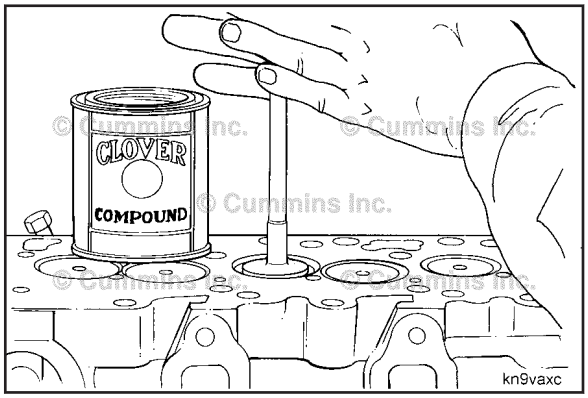
If during the inspection of the valve seats there were indications of leakage/burning and or the valve leakage during the leakage check was above specification, the valve seat/valve can be lapped.

NOTE: Lubricate the stems with 15W-40 engine oil before installing the valves.

Use a fine lapping compound, Part No. 3375805, or equivalent. Apply a thin and even coating on the valve.

Use a power or a hand suction lapping tool to provide pressure in the center of the valve.

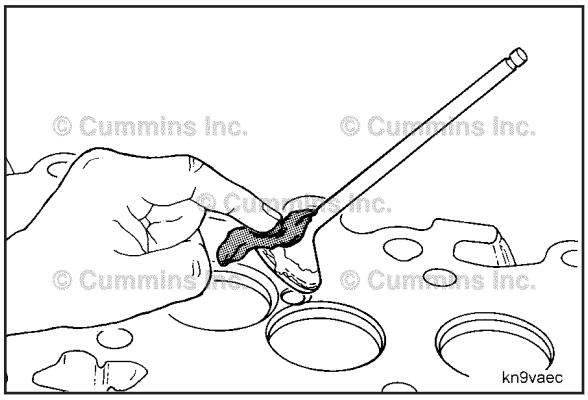
Turn the valve **backward** and **forward**. Continue lapping until the compound shows a continuous contact pattern on **both** the valve seat and the valve.



⚠CAUTION⚠
Lapping compound is an abrasive material. Failure will result if the cylinder head, the valves, and the valve seats are not cleaned thoroughly.

Clean the lapping compound from the parts.

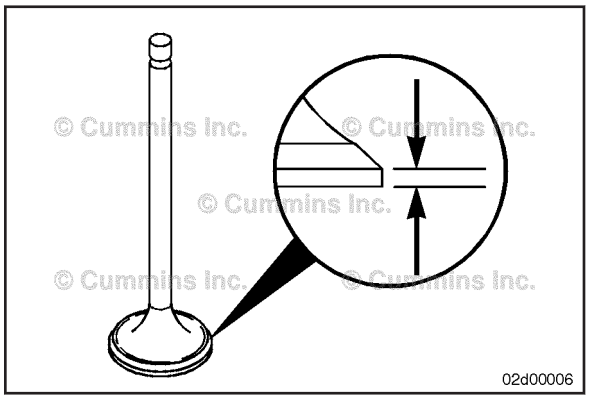
NOTE: If after lapping the valves/seats there are still indications of leakage or burning, the installation of valve seat inserts will be required. Information on valve seat insert installation is available in the Alternative Repair Manual, B and C Series Engines, Bulletin 3666109.

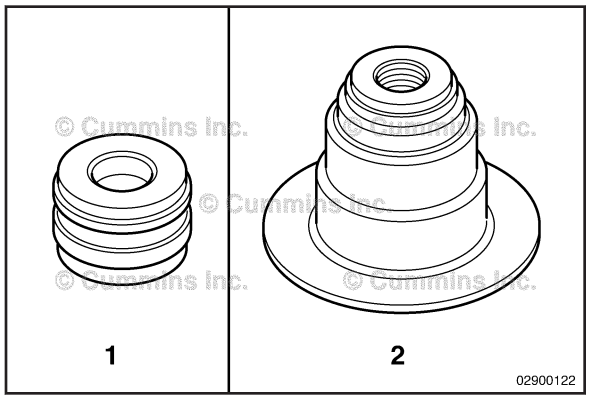


If lapping of the valves was required, measure the rim thickness to determine if there is enough rim material left.

Valve Rim Thickness Limit		
mm		**in**
0.79	MIN	0.031

If the valve thickness is **not** within the limits, a new valve **must** be used.



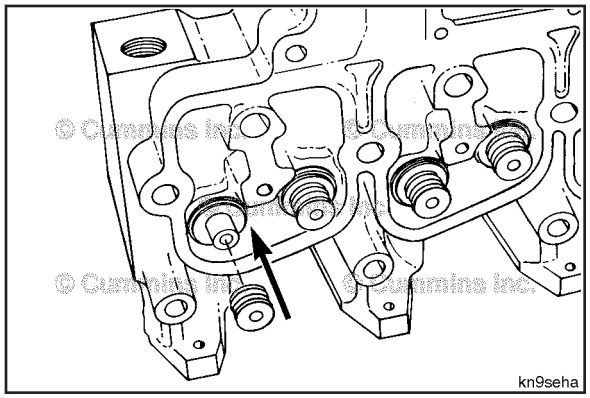


NOTE: Prior to installing the valve stem seals, make sure that the same type of valve stem seal is installed as was removed. The same type of valve stem seal **must** be installed when assembling the cylinder head.

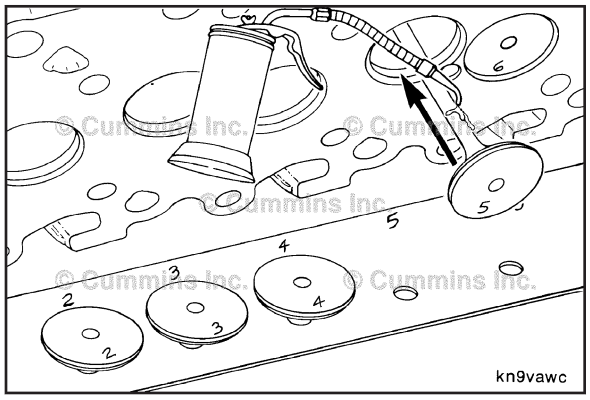
There are two types of valve stem seals used:

1 “Drive-On” Seal

2 “Top-Hat” Seal



Install new valve stem seals. Press the valve stem seal onto the valve guide support by hand.

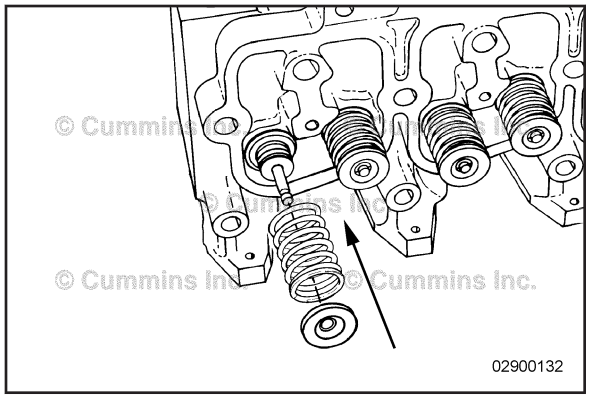


⚠CAUTION⚠
Lubricate all the valve guide bores and valve stems with 15W-40 engine oil. Failure to lubricate the valve guides and valve stems can result in premature valve guide wear.

Lubricate the stems with 15W-40 engine oil before installing the valves.

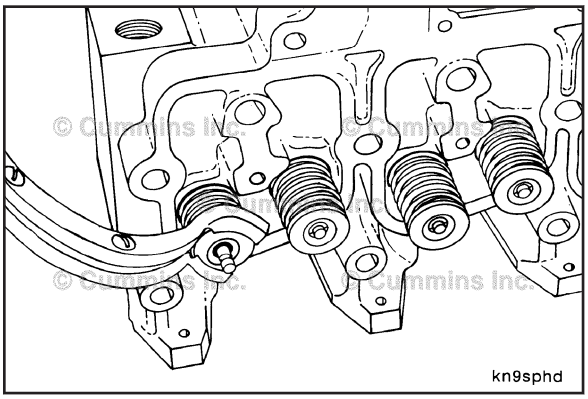
NOTE: If installing the same valves as previously removed, make sure to install the valves in the same locations that the valves were removed.

NOTE: If the cylinder head will **not** be used right away, lubricate the valve stems with assembly lube, Part Number 3163087, or equivalent.



Install the valve spring retainer and valve spring.

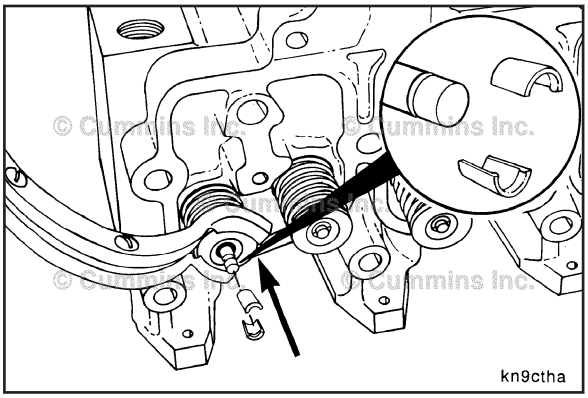
Use the valve spring compressor, Part Number 3375960, to compress the valve spring and retainer assembly.



Install new valve collets and release the spring tension.

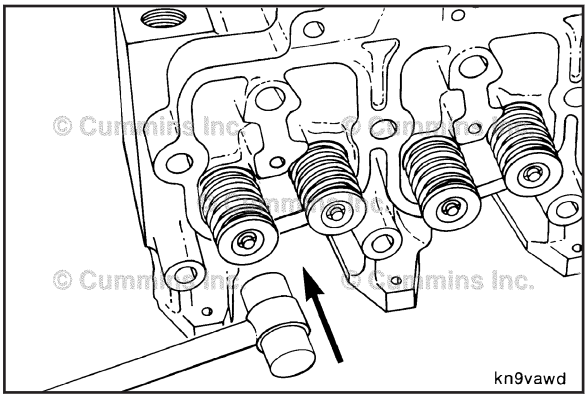
Service Tip: Use assembly lube, Part Number 3163087 or equivalent, on the valve collets to help hold them in place until the valve spring compressor is released.

Remove the valve spring compressor service tool.



⚠WARNING⚠
Wear eye protection. If the collets are not correctly installed, they can fly out when the stems are hit with a hammer.

After assembly, hit the valve stems with a plastic hammer to make sure that the collets are seated.



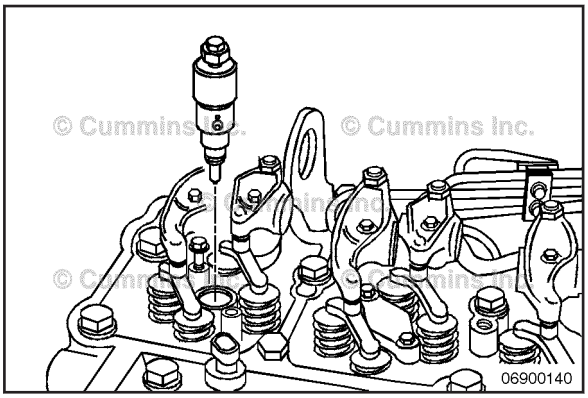
Measure

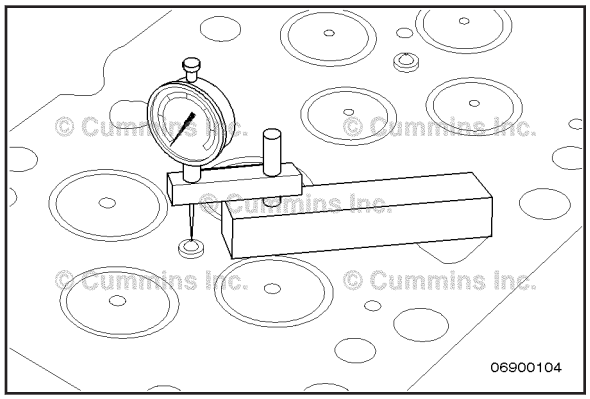
B4.5 RGT Engines

△CAUTION△
Improper injector protrusion can cause performance problems and high-pressure fuel leaks due to misalignment of the fuel connector.

Install the injectors with sealing washers into the cylinder head. Refer to Procedure 006-026 in Section 6.

Measure the injector protrusion.



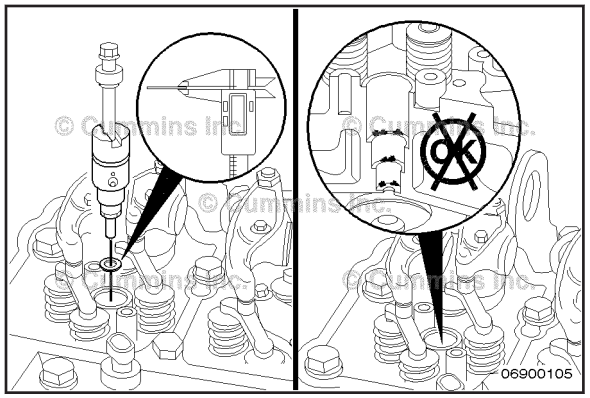


Install depth gauge assembly, Part Number 3164438, on the cylinder head combustion deck and zero.

Rotate the depth gauge so that it is measuring the injector protrusion at the highest point on the injector.

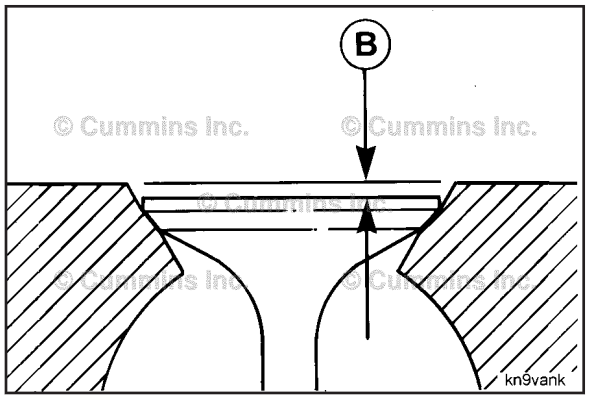
Measure the injector protrusion for each injector.

Injector Protrusion		
mm		**in**
2.45	MIN	0.096
3.15	MAX	0.124



If the injector protrusion is out of specification, check the thickness of the injector sealing washer. Refer to Procedure 006-026 (Injector) in Section 6.

If the sealing washer is the correct thickness, check to make sure the injector bore is clean and free of debris. Also make sure that sealing washers are **not** 'stacked' in the injector bore.



Install depth gauge assembly, Part Number 3164438, on the cylinder head combustion deck and zero.

Rotate the depth gauge so that it is measuring the valve recession into the cylinder head (B).

Measure the valve depth for each valve.

Intake Valve Depth (Installed)		
mm		**in**
0.584	MIN	0.023
1.092	MAX	0.043

Exhaust Valve Depth (Installed)		
mm		**in**
0.965	MIN	0.038
1.473	MAX	0.058

If the valve depth is **not** within specification, check if debris is preventing the valve from closing completely. If no debris is found, remove the valve and inspect the valve seat and valve face for damage.

B3.9, B5.9, and B4.5 Engines

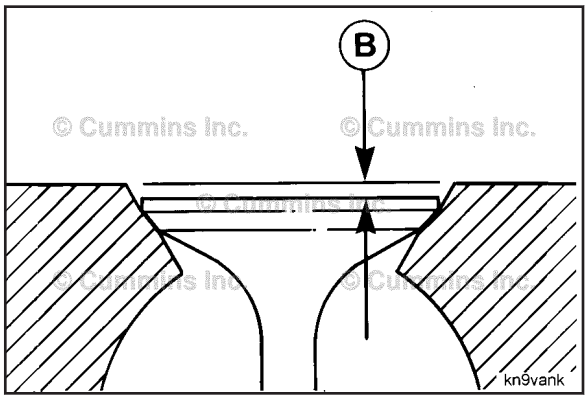
Install depth gauge assembly, Part Number 3164438, on the cylinder head combustion deck and zero.

Rotate the depth gauge so that it is measuring the valve recession into the cylinder head (B).

Measure the valve depth for each valve.

Valve Depth (Installed)		
mm		**in**
0.99	MIN	0.038
1.52	MAX	0.060

If the valve depth is **not** within specification, check if debris is preventing the valve from closing completely. If no debris is found, remove the valve and inspect the valve seat and valve face for damage.

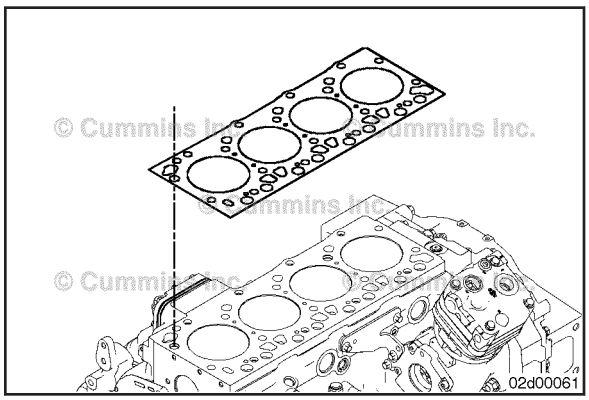


Install

B4.5 RGT Engines

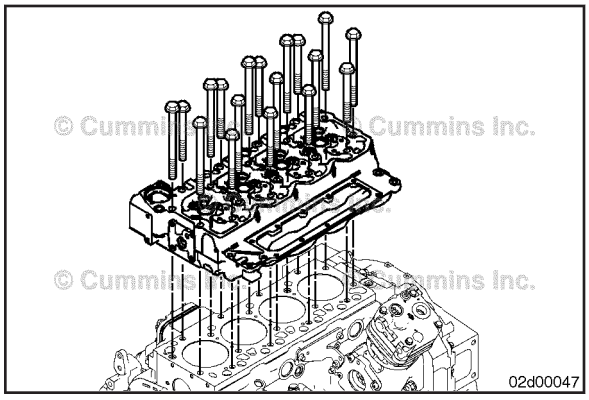
⚠CAUTION⚠
Make sure the gasket is correctly aligned with the holes in the cylinder block. Damage to the cylinder block can occur if the gasket is not aligned correctly.

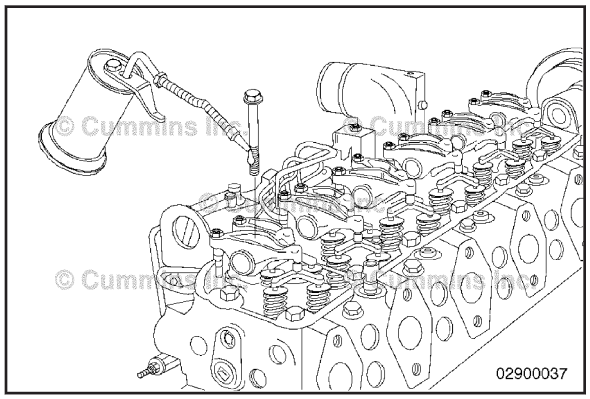
Install the cylinder head gasket. Refer to Procedure 002-021 in Section 2.



⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

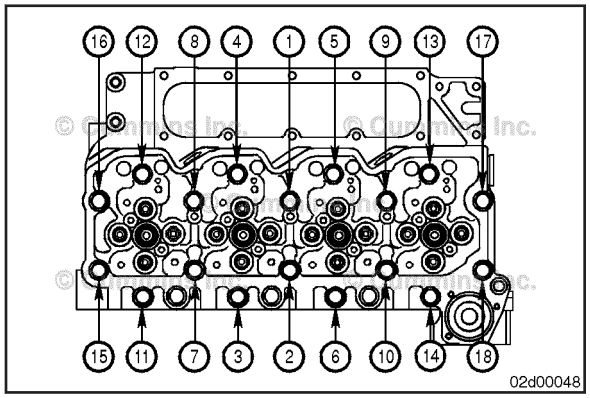
Carefully put the cylinder head on the cylinder block, and seat it onto the dowels.





Lubricate the threads and under the heads on the cylinder head mounting capscrews with clean engine oil.

Install the capscrews and tighten finger-tight.

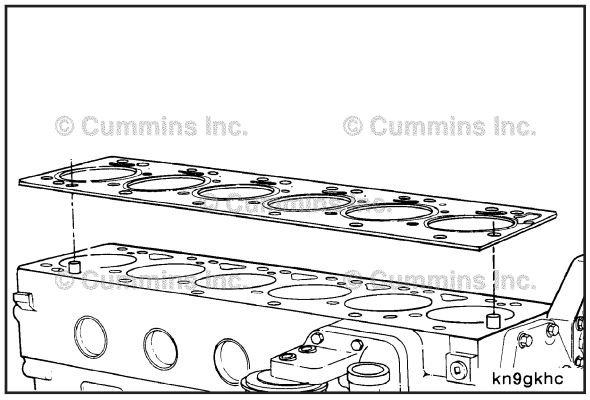


Use the illustrated sequence to tighten the cylinder head capscrews.

Tighten the capscrews.

Torque Value:

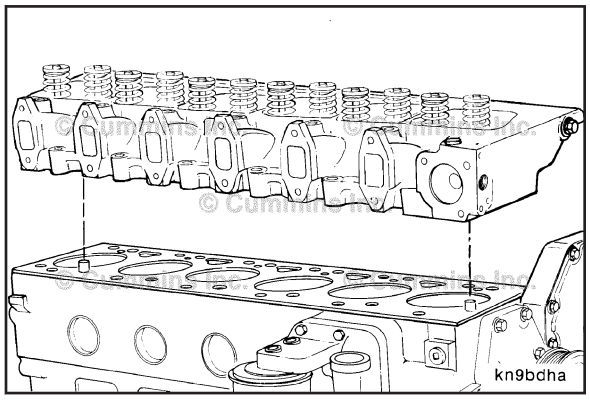
All Capscrews		
Step 1	90 N•m	[66 ft-lb]
Step 2	90 N•m	[66 ft-lb]
Step 3	Rotate 90-degrees clockwise.	



B3.9, B5.9, and B4.5 Engines

⚠CAUTION⚠
Be sure the gasket is correctly aligned with holes in the cylinder block. If the gasket is not aligned correctly engine damage can result.

Position a new cylinder head gasket over the dowels.



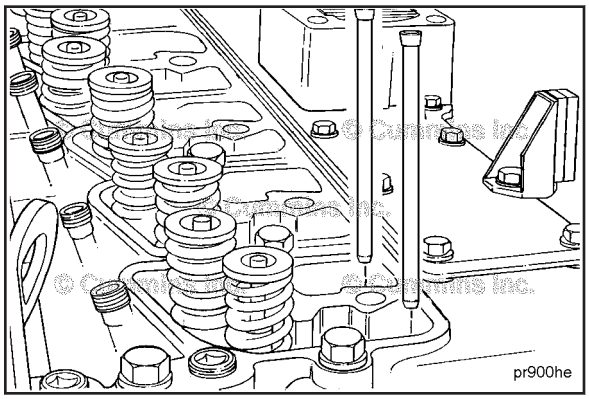
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Carefully put the cylinder head straight down onto the cylinder block, and seat it onto the dowels.

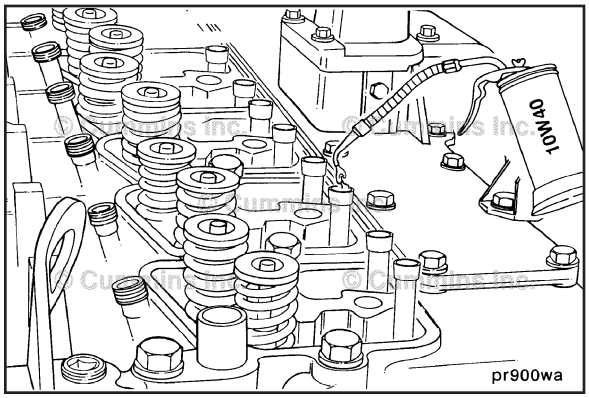
Cylinder Head Weight		
Cylinder Number	**Kg**	**lb**
4	36	79
6	51.3	113

Push Tubes - Installation

Position the push tubes into the valve tappets.

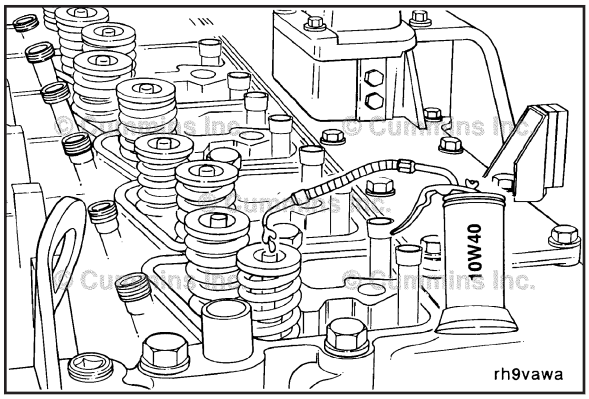


Lubricate the push tube sockets with clean lubricating engine oil.

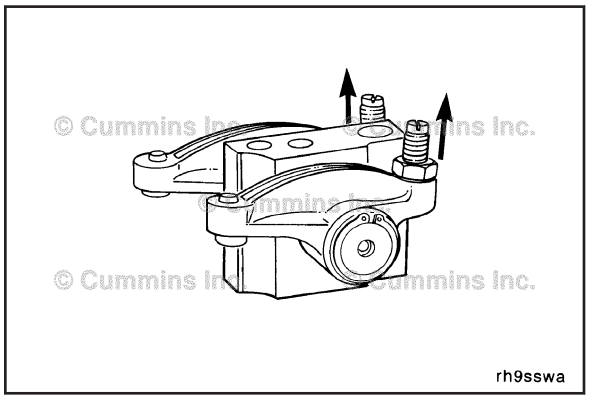


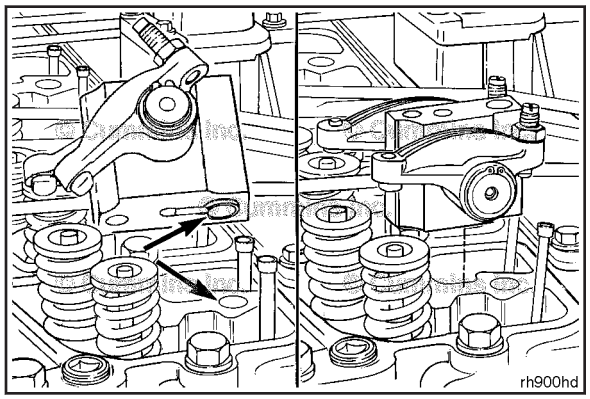
Rocker Levers - Installation

Lubricate the valve stems with clean lubricating engine oil.



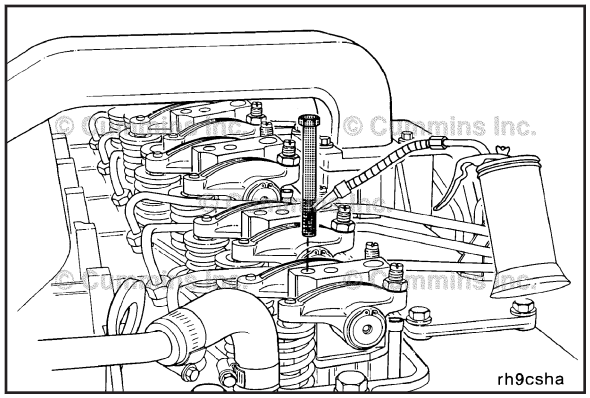
Completely loosen the rocker lever adjusting screws.





NOTE: The rocker lever pedestals are aligned with dowels.

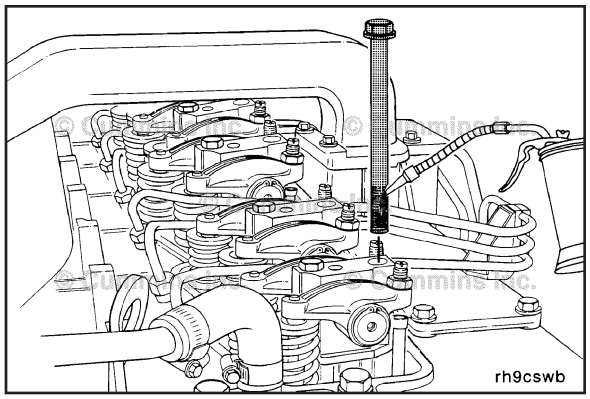
Install the pedestals.



Use capscrew length gauge, Part Number 3823921, to inspect all cylinder head capscrews for proper length.

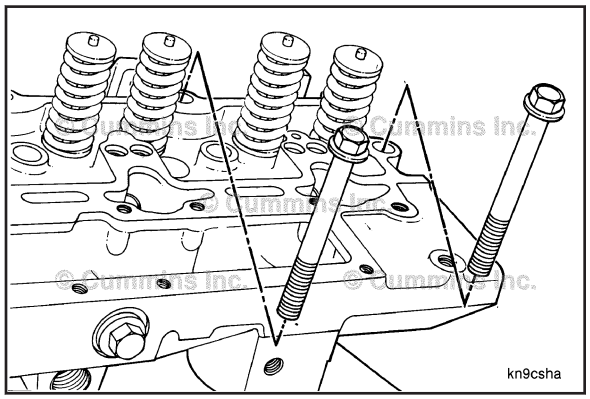
Lubricate the 8-mm pedestal capscrew threads and under the capscrew heads with clean lubricating engine oil.

Install the capscrews finger-tight.



Lubricate the 12-mm pedestal/head capscrew bolt threads and under the capscrew heads with clean lubricating engine oil.

Install the capscrews finger tight.



Lubricate the threads and under the heads on the remaining cylinder head capscrews with clean lubricating engine oil.

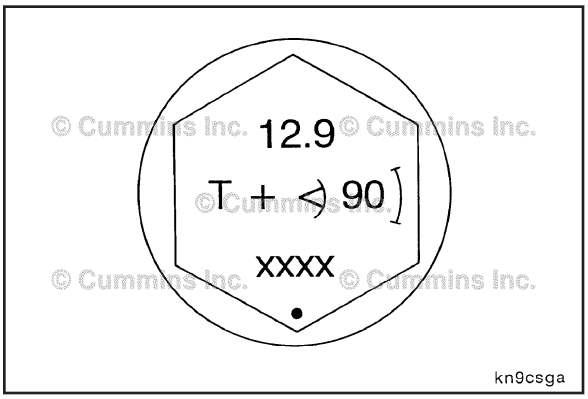
Install capscrews in the cylinder head and finger-tighten.

NOTE: Be sure to install the long capscrews into the holes underneath the injectors.

NOTE: Capscrews for the 1991 and later certification level engines are the same overall length, but have a longer threaded area.

⚠CAUTION⚠
Do not use pre-1991 certification level engine capscrews in a 1991 B Series or later certification level engine because pre-1991 capscrews do not have enough threads to provide enough thread engagement in the 1991 and later certification engines. Failure to do so can result in engine damage.

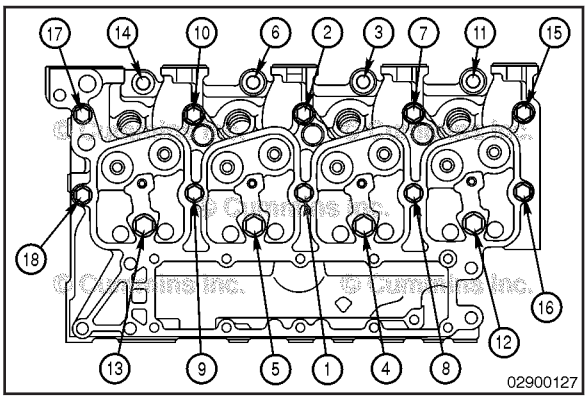
⚠CAUTION⚠
Capscrews for a 1991 B Series or later certification level engine can be used in a pre-1991 certification level engine because 1991 and later capscrews have enough threads to provide enough engagement in all certification level engines.



NOTE: The top of the cylinder head capscrew is identified with an angle marking. The cylinder head capscrews **must** be tightened by using the three-step “torque plus angle” method described as follows.

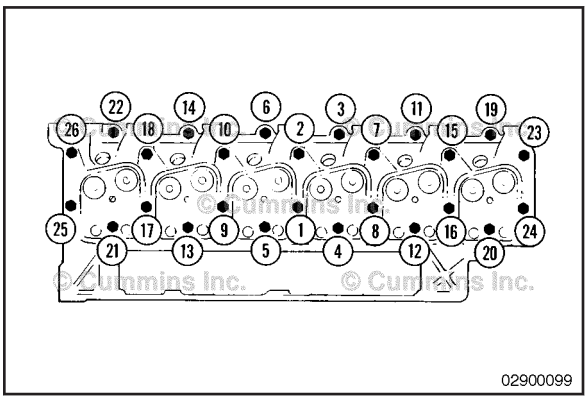
On a four cylinder engine, capscrew number 1 is located in between cylinders 2 and 3. The numbered sequence is the same as a six cylinder, but stops at capscrew number 18. Follow the numbered sequence for the four cylinder engine, and tighten all 18 capscrews.

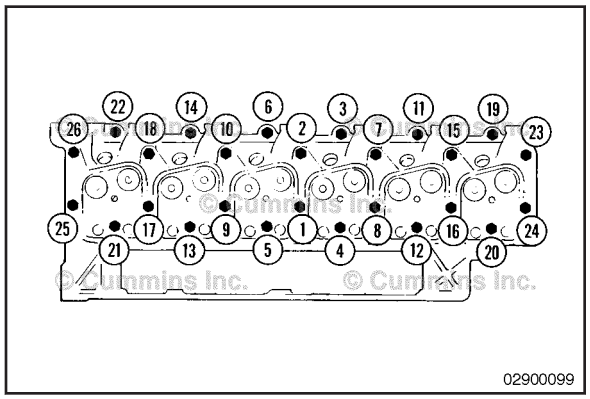
Torque Value: 90 N•m [66 ft-lb]



Follow the numbered sequence for the six cylinder engine, and tighten all 26 capscrews.

Torque Value: 90 N•m [66 ft-lb]





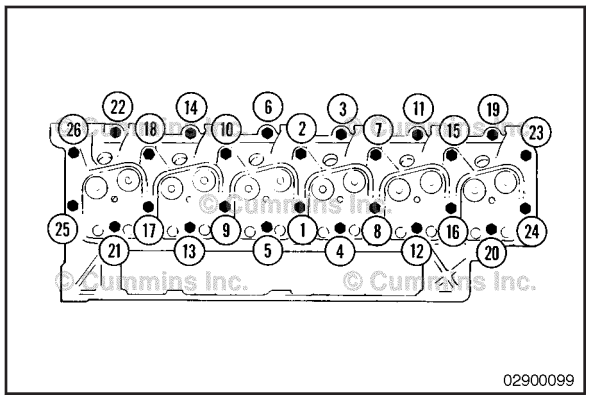
Four Cylinder

Follow the numbered sequence, and tighten the long capscrews **only** (numbers 4,5,12, and 13).

Six Cylinder

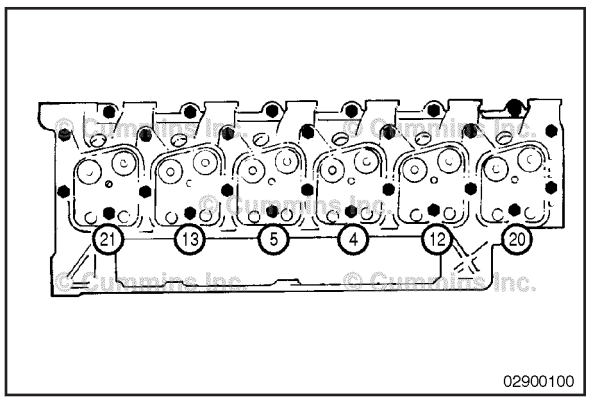
Follow the numbered sequence, and tighten the long capscrews **only** (numbers 4, 5,12, and 13, 20, and 21).

Torque Value: 120 N•m [89 ft-lb]



Tighten the short capscrews again (numbers 1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 18, 19, 22, 23, 24, 25, and 26) because of cylinder head relaxation and to obtain proper cylinder head torque requirements.

Torque Value: 90 N•m [66 ft-lb]



Tighten the long capscrews again because of cylinder head relaxation and to obtain proper cylinder head torque requirements.

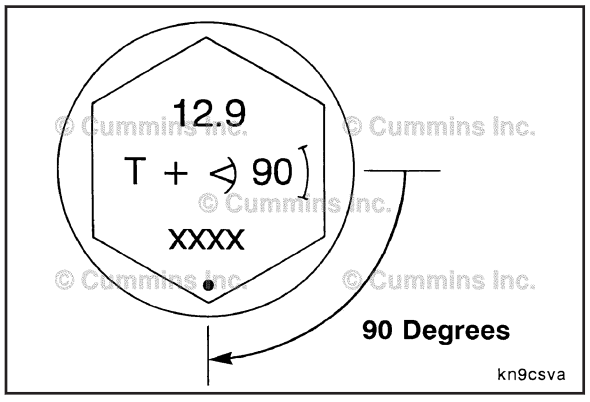
Four Cylinder

Follow the numbered sequence, and tighten the long capscrews **only** (numbers 4, 5, 12, and 13).

Six Cylinder

Follow the numbered sequence, and tighten the long capscrews **only** (numbers 4, 5, 12, and 13, 20, and 21).

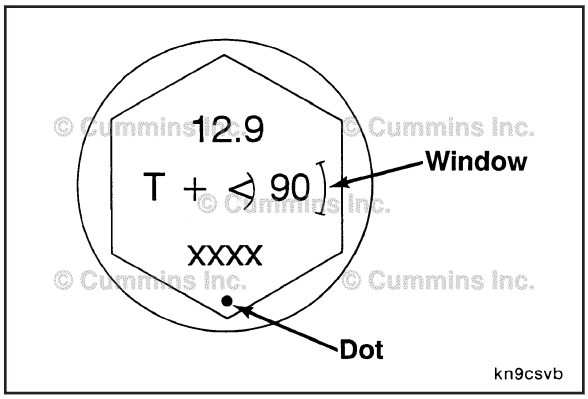
Torque Value: 120 N•m [89 ft-lb]



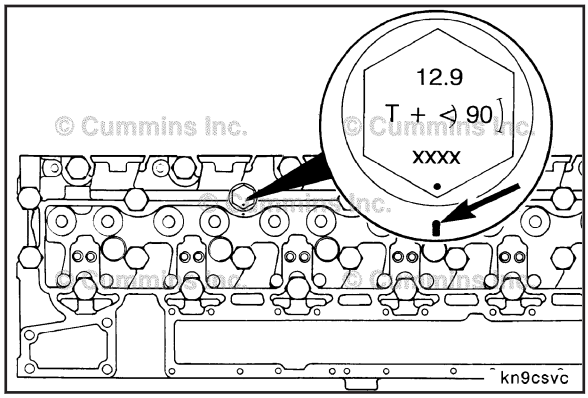
Follow the numbered sequence, and turn the capscrew 90 degrees as indicated on the capscrew head.

Torque Angle Gauge - 3/4-Inch Drive, Tool Number 3823878

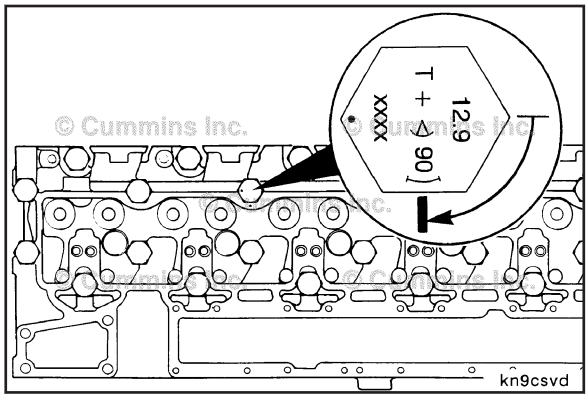
To turn the capscrew to the desired angle accurately, align the capscrew with the small “dot” and “window” that are marked on the capscrew head or use torque angle gauge - 3/4-inch drive tool, Part Number 3823878.



Mark the cylinder head adjacent to the dot on the capscrew head. This mark will serve as an indexing aid.

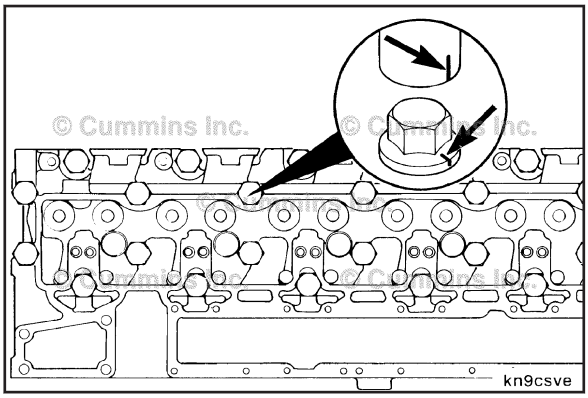


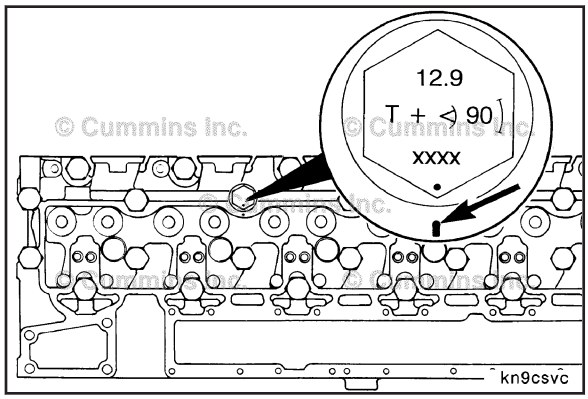
Rotate the capscrew until the mark that has been made on the cylinder head falls into the window on the capscrew head.



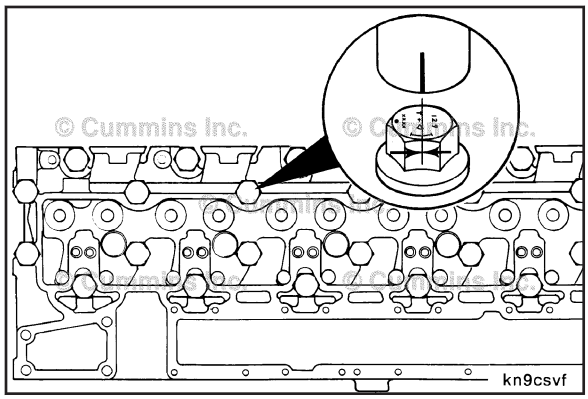
Service Tip:

Use a permanent marker to mark the socket corresponding to one of the flats of the socket hex.

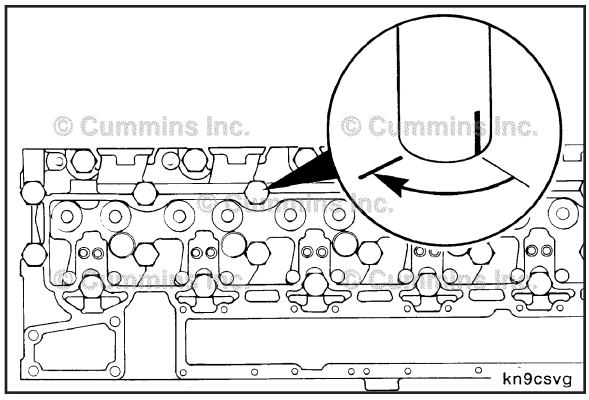




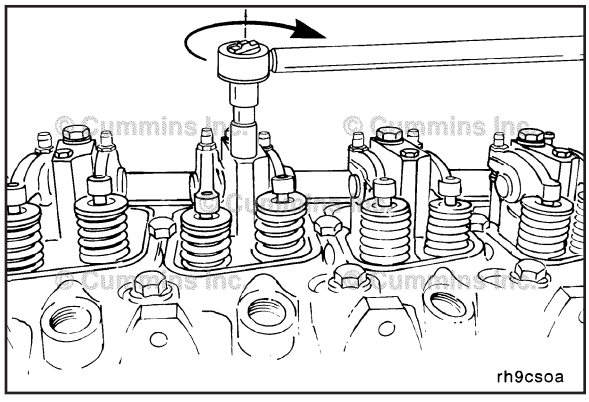
After the torque has been applied, mark the cylinder head at the location of the dot.



Position the socket on the capscrew such that the mark on the socket is at the same point as the window on the capscrew.



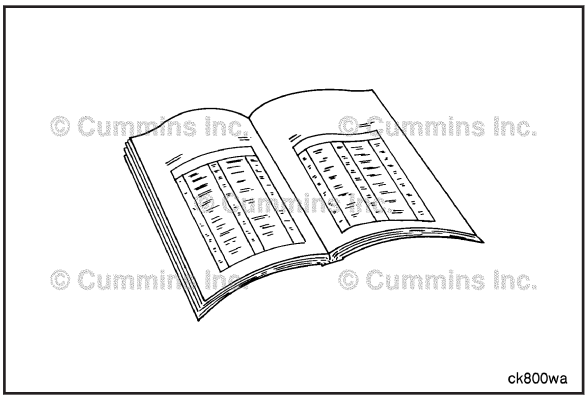
Turn the socket until the mark on the socket aligns with the mark on the cylinder head.



Tighten the 8-mm pedestal 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.

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

For B4.5 RGT engines, if the cylinder head was installed with the injectors installed, it may be necessary to loosen the injector to correctly install the fuel connectors. Failure to install the fuel connectors will result in excessive injector fuel leakage and poor engine performance.

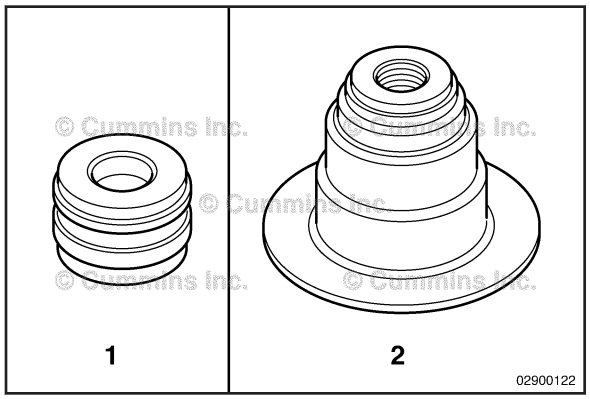
- If **not** already installed, install the injectors. Refer to Procedure 006-026 in Section 6.
- For B4.5 RGT engines, install the fuel connectors. Refer to Procedure 006-052 in Section 6.
- Install the injector supply lines (High Pressure). Refer to Procedure 006-051 in Section 6.
- Install the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- For B4.5 RGT engines, install the push rods. Refer to Procedure 004-014 in Section 4.
- For B4.5 RGT engines, install the rocker lever assemblies and crossheads. Refer to Procedure 003-008 in Section 3. Refer to Procedure 002-001 in Section 2.
- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- If equipped, install the rocker lever housing. Refer to Procedure 003-013 in Section 3.
- Install the rocker lever cover gasket and rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the exhaust manifold. Refer to Procedure 011-007 in Section 11.
- If equipped, install the turbocharger. Refer to Procedure 010-033 in Section 10.

NOTE: Omit the following steps if the engine is not equipped with the component or if it was **not** necessary to remove the component to remove the cylinder head.

- Install the thermostat housing and thermostat from the engine. Refer to Procedure 008-013 in Section 8.
- Install the alternator bracket to the thermostat housing. Refer to Procedure 013-003 in Section 13.
- Pivot the alternator towards the engine. Tighten the alternator link, mounting bolt, and water inlet connection capscrews. Refer to Procedure 013-001 in Section 13.
- Install the fan hub assembly. Refer to Procedure 008-036 in Section 8.
- Install the fan hub pulley. Refer to Procedure 008-039 in Section 8.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the air intake manifold. Refer to Procedure 010-023 in Section 10.
- Install the fuel filter and fuel filter head. Refer to Procedure 006-015 in Section 6. Refer to Procedure 006-017 in Section 6.

NOTE: The follow components are required to be installed in order to complete the installation of the cylinder head.

- Connect the air crossover connection. Refer to Procedure 010-019 in Section 10.
- Connect all water and heater hoses attached to the cylinder head. Refer to the OEM service manual.
- Install any OEM accessories attached to the cylinder head. Refer to the OEM service manual.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



Valve Guide Seal, Cylinder Head (002-016)

General Information

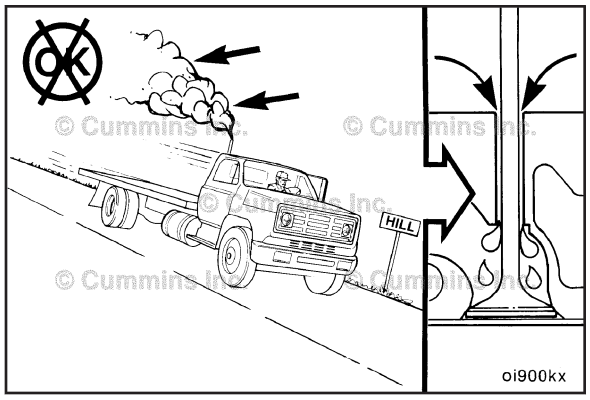
The following procedure is for removing the valve stems seals with the cylinder head installed. For removing the valve stem seals with the cylinder head removed, refer to Procedure 002-004.

NOTE: This procedure can also be used for removing valve springs, valve spring retainers and valve collets with the cylinder head installed.

For the engines covered by this procedure, different types and color valve stem seals are used. When replacing the valve stem seals, always replace like parts.

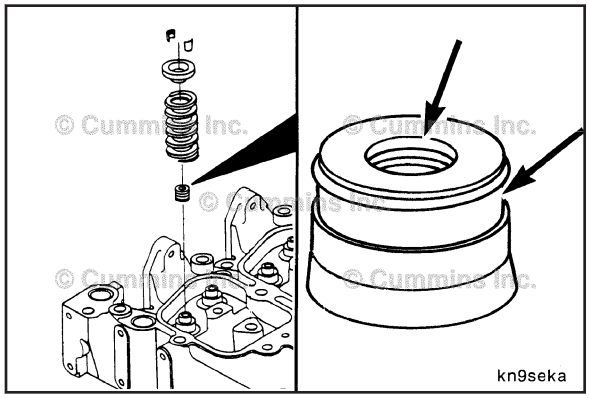
There are two types of valve stem seals used:

1. "Drive-On" Seal
2. "Top-Hat" Seal



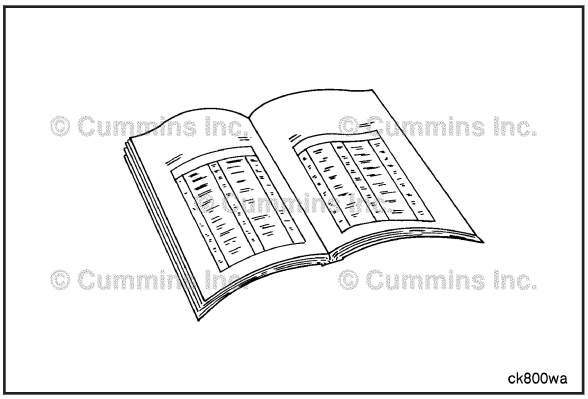
Valve Seal - Wear

Worn valve seals are typically detected by excessive smoke at idle or when the engine is unloaded when the vehicle is going downhill. Verify the condition by removing the valve spring and inspecting the valve seals.



Hardening of the material and wear or damage to the sealing surfaces will cause the valve seal to leak.

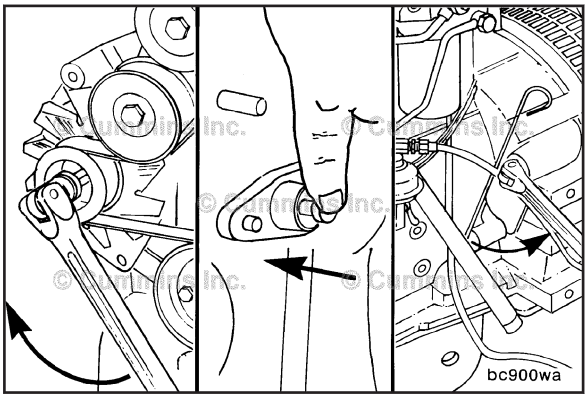
Preparatory Steps



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

- Disconnect the batteries. Refer to Procedure 013-009.
- Remove the rocker lever cover. Refer to Procedure 003-011.

Remove

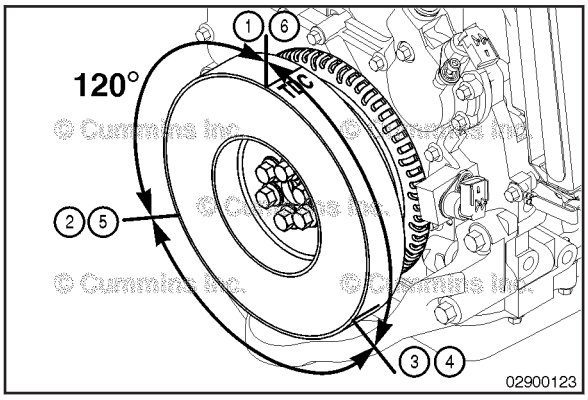


NOTE: In order to remove the valve springs with the cylinder head installed, the piston of the cylinder being worked on **must** be brought to TDC to support the valves.

Use the barring tool, Part Number 3824591. Locate top dead center (TDC) for cylinder number 1 by barring the crankshaft slowly while pressing on the engine timing pin.

Service Tip: If the barring tool is inaccessible, in some applications the alternator pulley can be used to bar the engine over.

When the timing pin engages in the hole in the camshaft gear, cylinder number 1 is at TDC on the compression stroke.



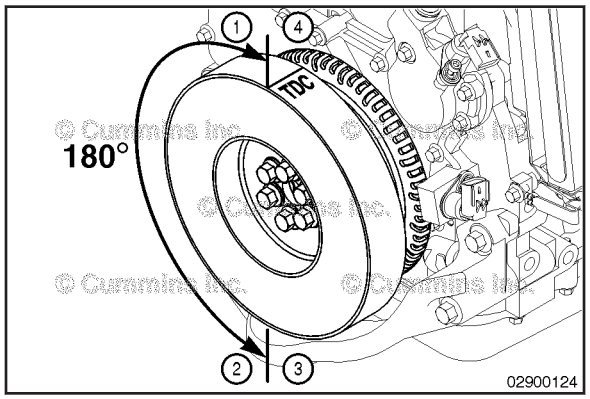
With the timing pin locked at TDC for the number 1 cylinder, mark the damper for the location of TDC for the other cylinders.

For six cylinder engines:

- Mark the vibration damper damper every 120 degrees with a marker directly on the damper or to a piece of masking tape applied directly around the damper.

Service Tip: A protractor, camshaft degree wheel or angle/level indicator, part number 3375855, can be used to locate 120-degree increments around the vibration damper.

- Mark the damper with the TDC indicator for each cylinder as shown. Two cylinders correspond to each 120-degree line.

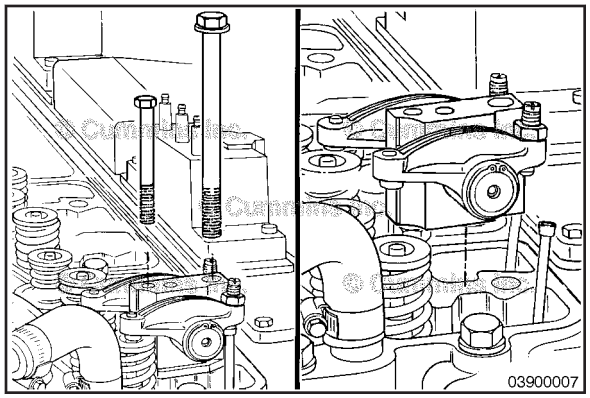


For four cylinder engines:

- Mark the vibration damper damper every 180 degrees with a marker directly on the damper or to a piece of masking tape applied directly around the damper.

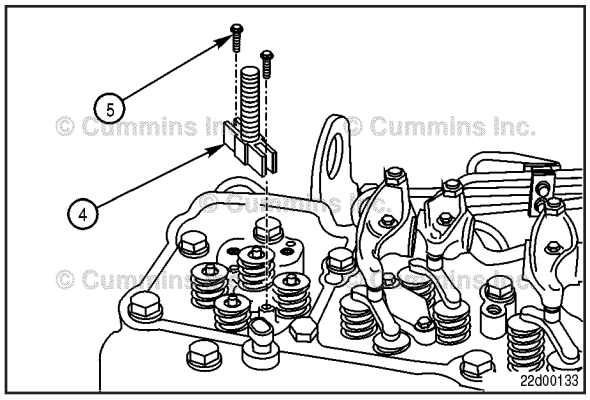
Service Tip: A protractor, camshaft degree wheel or angle/level indicator, part number 3375855, can be used to locate 180-degree increments around the vibration damper/crankshaft pulley.

- Mark the damper with the TDC indicator for each cylinder as shown. Two cylinder correspond to each 180-degree line.



For engines with 4 valves per cylinder, remove the rocker lever assemblies and crossheads. Refer to Procedure 003-008 and Procedure 002-001.

For engines with 2 valves per cylinder, remove the rocker lever assemblies. Refer to Procedure 003-008.



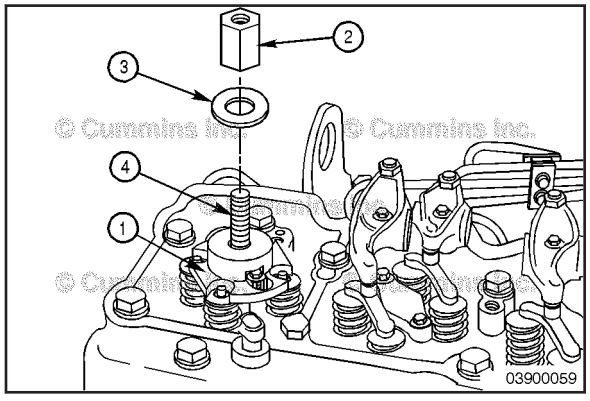
4 Valves per Cylinder:

Compress the valve springs. Use the valve spring compressor, Part Number 3164329.

Position the replacer screw (4) above the injector bore and install the two capscrews (5) in the cylinder head where the hold-down clamp screws were removed.

Tighten the capscrews (5).

Torque Value: 5 N•m [44 in-lb]



NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.

Apply anti-seize lubricant to the replacer screw (4) threads. **Always** read and follow label precautions.

Position the valve spring compressor plate (1) on the replacer screw (4) and align the slots in the valve spring compressor plate with the valve springs.

Install the washer (3) and nut (2) on the replacer screw (4).

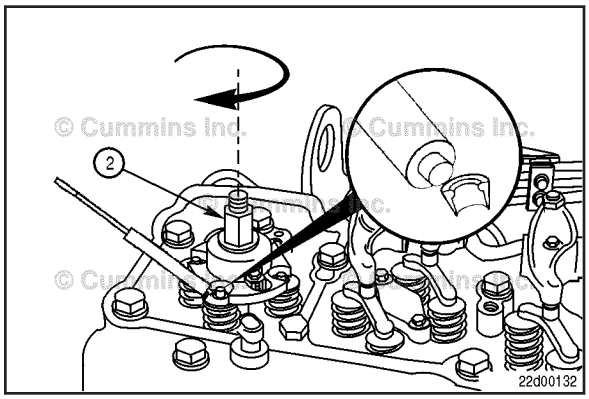
⚠WARNING⚠
Valve springs are under tension and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

Turn the nut (2) **clockwise** to compress the valve springs.

Continue turning the nut (2) **clockwise** until the valve collets can be removed. Use a magnetic tool, such as the end of a magnetic screwdriver.

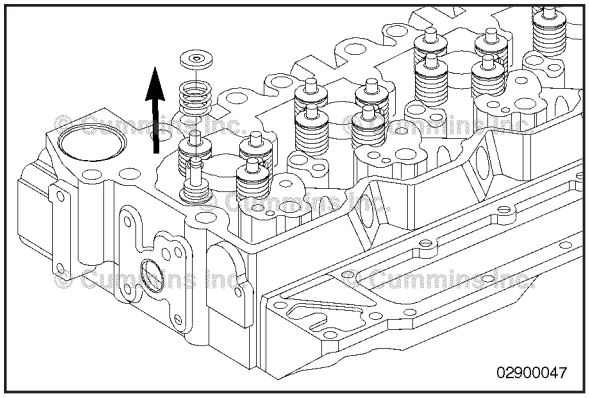
NOTE: Because there is a gap between the top of the piston and the valve face, it may be necessary to use a second magnet to hold the valve stem up to remove the valve collets.

Remove the valve collets and the valve spring compressor service tool.



⚠CAUTION⚠
With the valve collets, valve springs, and valve spring retainers removed, do not rotate the engine. Rotating the engine will allow the valves to drop into the cylinder requiring the cylinder head to be removed or possible engine damage.

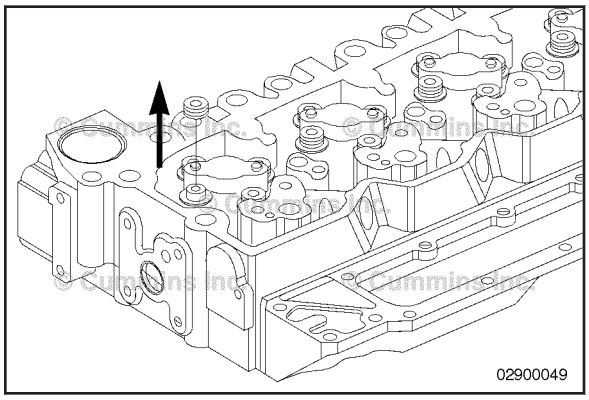
Remove the four valve spring retainers and valve springs.



Use boot pliers, Part Number 3163293, to remove the valve stem seals.

NOTE: The valve stem seals can be installed by hand. The installation tool will aid with installing the valve stem seals, but is **not** mandatory.

Note the type, and location of the seal, then discard the old seal.

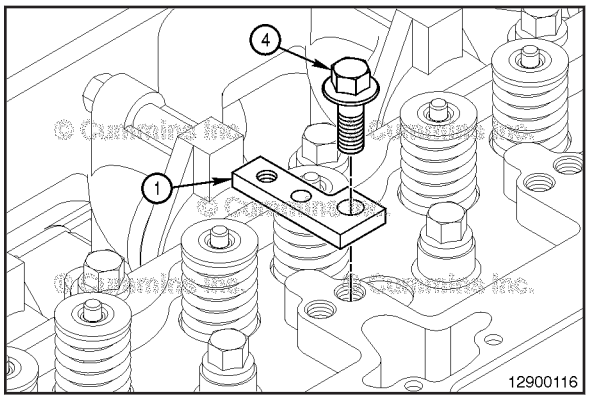


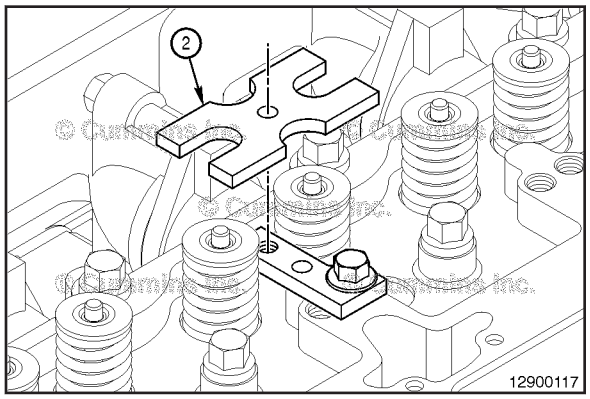
⚠CAUTION⚠
Do not use an impact tool for any part of this procedure. Doing so can damage the tool and/or the engine.

2 Valves Per Cylinder:

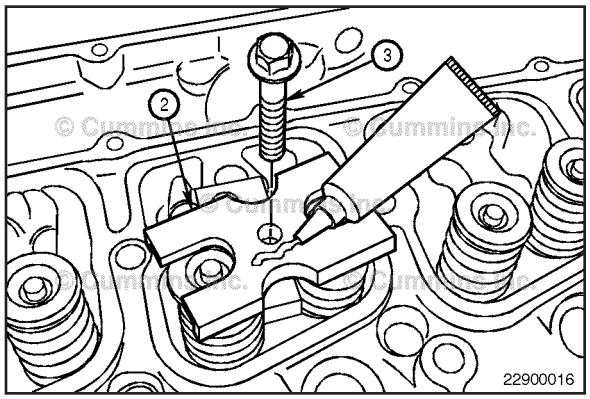
Compress the valve springs with valve spring compressor tool kit, Part Number 3163292.

Position the lower support plate (1) with the part number up, and install the 10-mm capscrew (4) through the plate and secure to the cylinder head. Tighten the capscrew finger-tight.



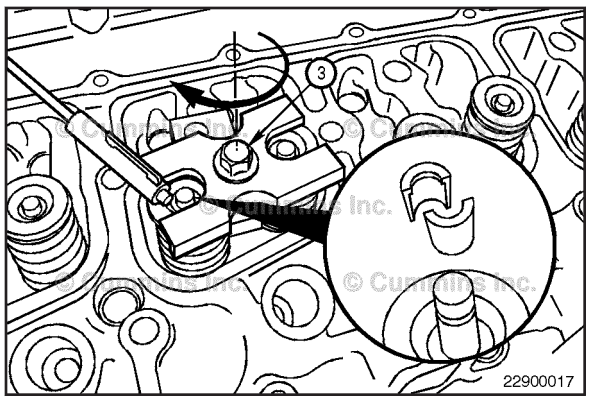


Position the spring compression plate (2) onto the valve springs with the part number up.



Apply grease to the top of the spring compression plate (2) and underneath of the capscrew (3) head and install the 10-mm (3) capscrew.

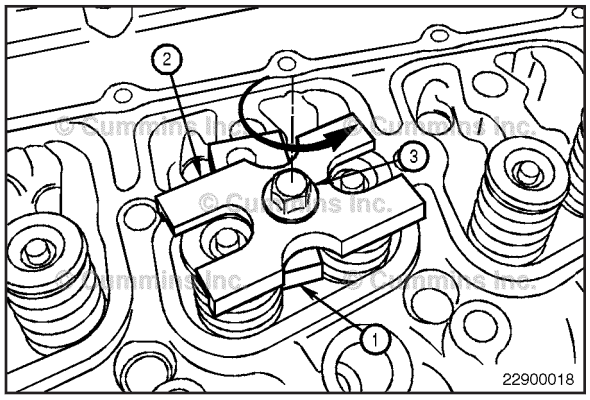
Tighten the capscrew finger-tight (3).



⚠WARNING⚠
Wear appropriate eye and face protection when performing this procedure. Springs are under tension and can act as a projectile if released, causing personal injury.

△CAUTION△
Do not overtighten the capscrew. Doing so can damage the tool and/or the engine.

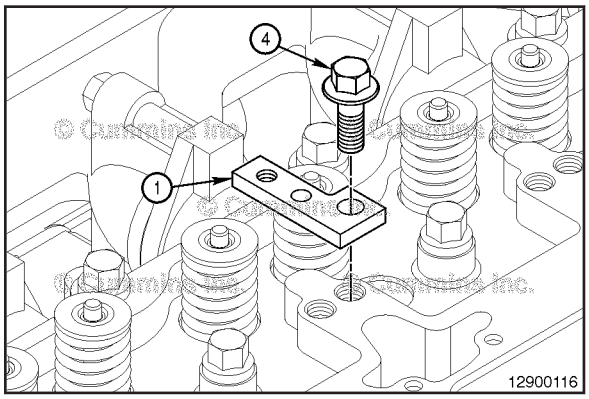
Turn the capscrew (3) **clockwise** until the collets can be removed. Use a magnetic tool.



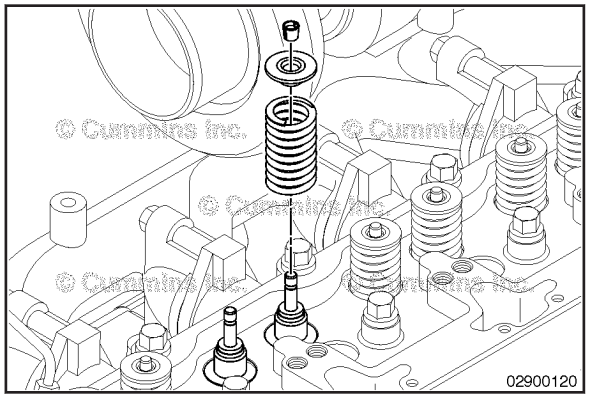
Carefully turn the capscrew (3) **counterclockwise** until the tension is released from the valve springs.

Remove the capscrew (3) and spring compression plate (2) from the lower support plate (1).

Remove the capscrew (4) and lower support plate (1).



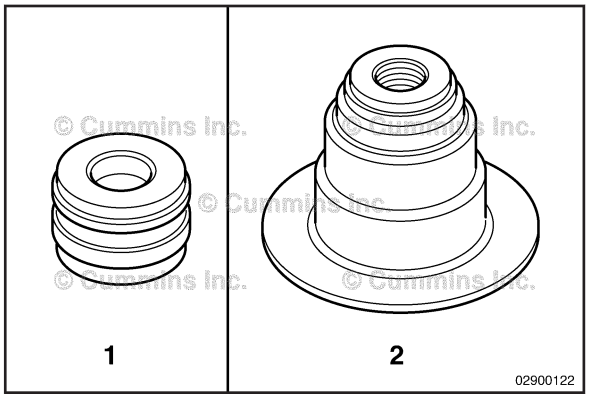
Remove the valve spring retainer and the valve spring.



NOTE: Prior to removing the valve stem seals, note the type of valve stem seal installed at each valve location. The same type of valve stem seal **must** be installed when assembling the cylinder head.

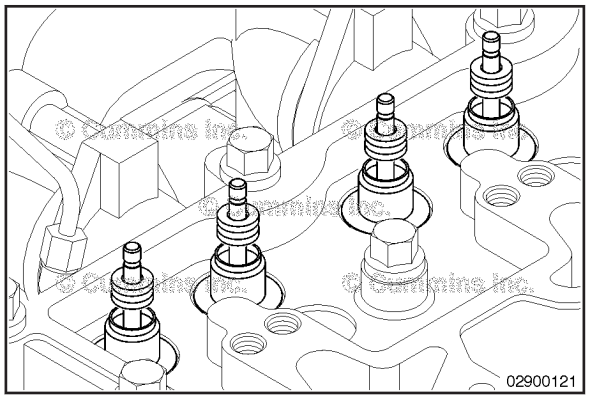
There are two types of valve stem seals used:

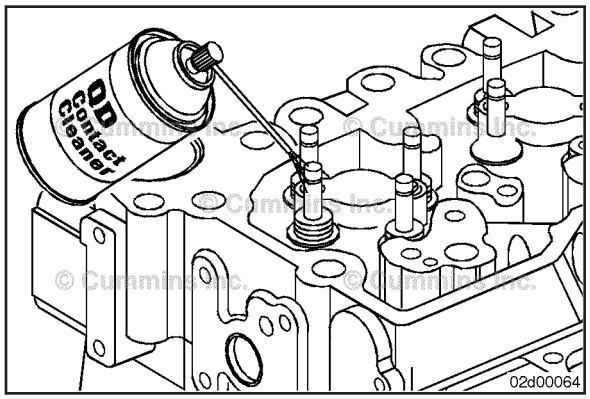
1. "Drive-On" Seal
2. "Top-Hat" Seal



Use boot pliers, Part Number 3163293, to remove the valve stem seal.

Remove and discard the valve stem seal.

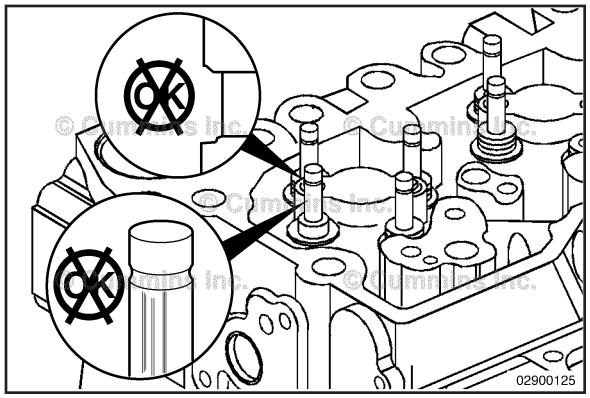




Clean and Inspect for Reuse

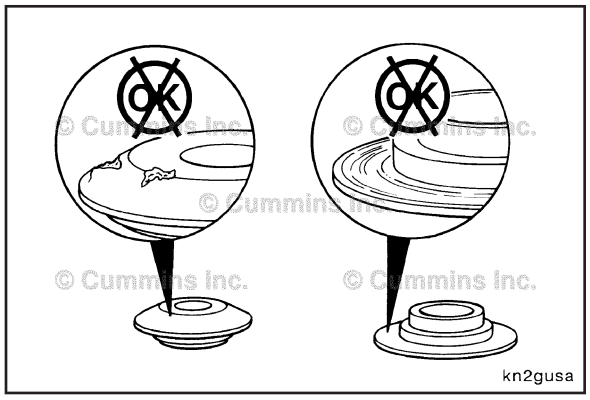
NOTE: The following Clean and Inspect for Reuse steps show illustrations of a 4 valve per cylinder head. The Clean and Inspect for Reuse steps for a 2 valve per cylinder are the same.

Clean the seal tower and valve stem with contact cleaner, Part Number 3824510.



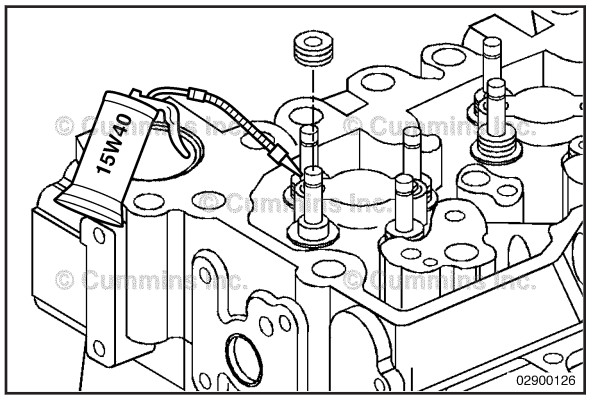
Inspect the exposed valve stem for scoring or heaving polishing. Inspect the valve collet grooves for wear.

If the valve stem is damaged, the cylinder head **must** be removed and the valve replaced. Refer to Procedure 002-004.



Inspect the valve spring retainers and valve collets for damage or worn areas.

Discard and replace damaged and worn parts.



Install

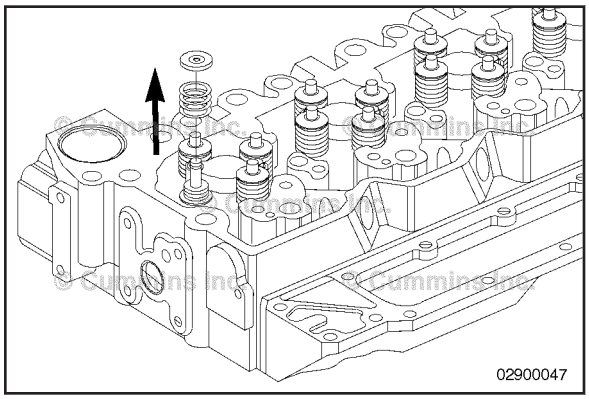
⚠CAUTION⚠
Lubricate all the valve guide bores and valve stems with SAE 15W-40 engine oil. Failure to lubricate the valve guides and valve stems can result in premature valve guide wear.

4 Valves Per Cylinder:

Lubricate the stems with SAE 15W-40 engine oil before installing the valve stem seals.

Install new valve stem seals. Use a valve stem installation tool, Part Number 3164055.

Install the valve spring retainer and valve springs.

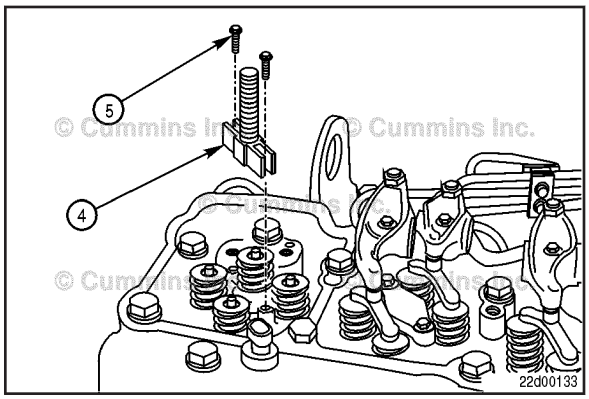


Compress the valve springs. Use the valve spring compressor, Part Number 3164329.

Position the replacer screw (4) above the injector bore and install the two capscrews (5) in the cylinder head where the hold-down clamp screws were removed.

Tighten the capscrews (5).

Torque Value: 5 N•m [44 in-lb]

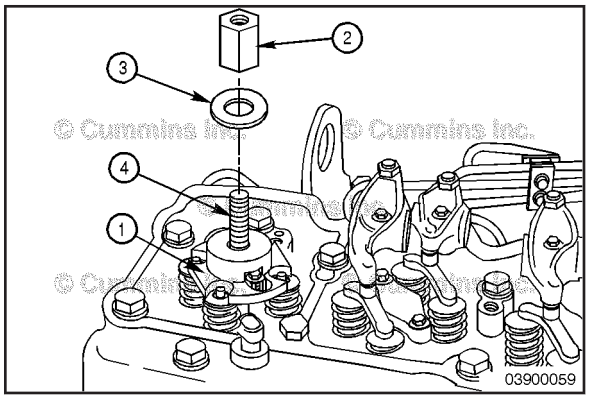


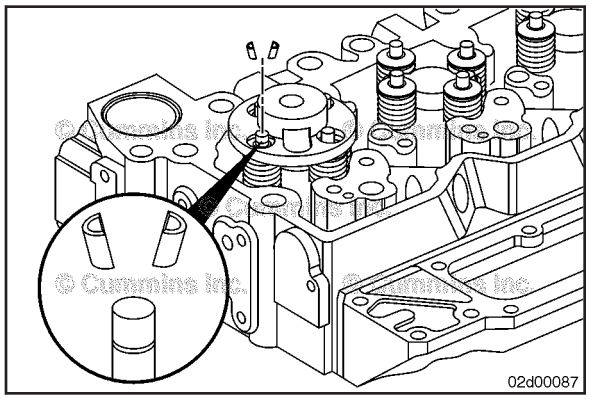
NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.

Apply anti-seize lubricant to the replacer screw (4) threads. **Always** read and follow label precautions.

Position the valve spring compressor plate (1) on the replacer screw (4) and align the slots in the valve spring compressor plate with the valve springs.

Install the washer (3) and nut (2) on the replacer screw (4).





⚠WARNING⚠
Valve springs are under tension and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

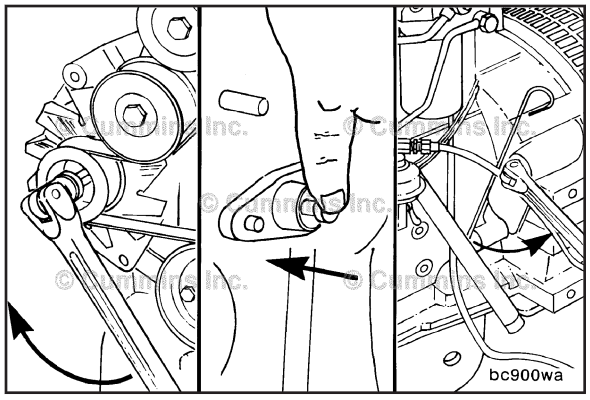
NOTE: Because there is a gap between the top of the piston and the valve face, it may be necessary to use a second magnet to pull the valve stem up to remove the valve collets.

Compress the valve springs until the valve collets can be installed.

Install the valve collets.

Service Tip: Use Assembly Lube, Part Number 3163087 or equivalent, on the valve collets to help hold them in place until the valve spring compressor is released.

Remove the valve spring compressor service tool.



NOTE: Make sure the timing pin is pulled out before the engine is barred over to avoid damaging the timing pin.

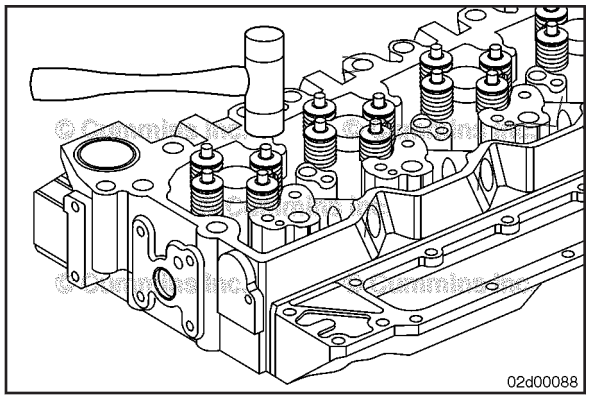
Use the marks made previously on the vibration damper/ crankshaft pulley, rotate the engine **clockwise** to the next cylinder in the firing order.

Service Tip: If the barring tool is inaccessible, in some applications the alternator pulley can be used to bar the engine over.

Firing Order:

Six cylinder engines - 1 5 3 6 2 4

Four cylinder engine - 1 3 4 2



⚠WARNING⚠
To reduce the possibility of personal injury, wear eye protection. If the collets are not correctly installed, they can fly out when the stems are hit with a hammer.

△CAUTION△
Rotate the engine to the next cylinder in the firing order before hitting the valve stem of the cylinder previously worked on. This will ensure that the valve does not contact the piston, resulting in a bent valve and internal engine damage.

After rotating the engine to the next cylinder in the firing order, hit the valve stems of the cylinder previously worked on with a plastic hammer to make sure the collets are seated.

Repeat the previous steps until all of the valve stem seals are replaced.

⚠CAUTION⚠
Failure to have the piston at top dead center will result in the valve dropping into the cylinder. If the valves drop into the cylinder, engine damage can result.

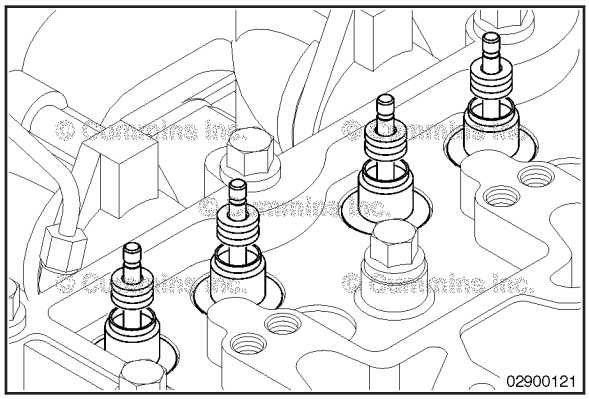
⚠CAUTION⚠
The same type of valve stem seal must be installed in the same location as removed. Incorrect valve stem seals will result in excessive oil consumption and internal engine damage.

⚠CAUTION⚠
Lubricate all the valve guide bores and valve stems with SAE 15W-40 engine oil. Failure to lubricate the valve guides and valve stems can result in premature valve guide wear.

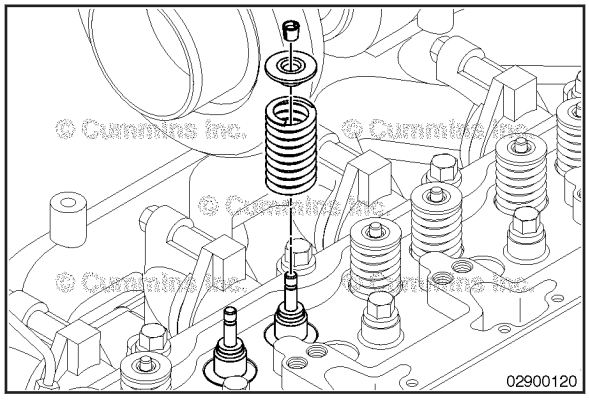
2 Valves Per Cylinder:

Lubricate the stems with SAE 15W-40 engine oil before installing the valve stem seals.

Install the new valve stem seals. Use a valve stem installation tool, Part Number 3164055.



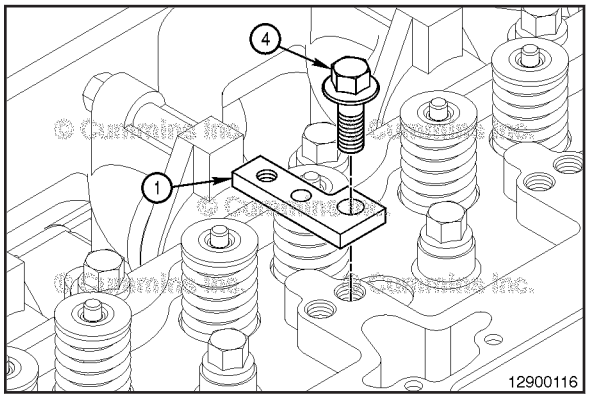
Install the valve springs and valve spring retainers.

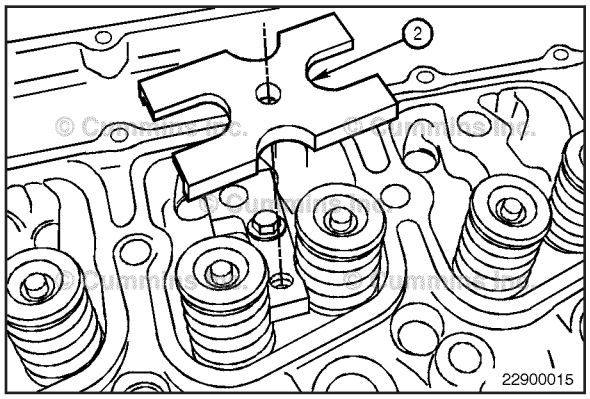


⚠CAUTION⚠
Do not use an impact tool for any part of this procedure. Doing so can damage the tool and/or the engine.

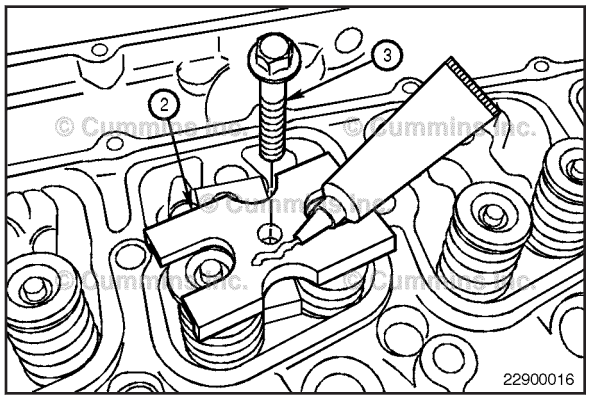
Compress the valve springs with valve spring compressor, Part Number 3163292.

Position the lower support plate (1) with the part number up, and install the 10-mm capscrew (4) through the plate and secure to the cylinder head. Tighten the capscrew finger-tight.



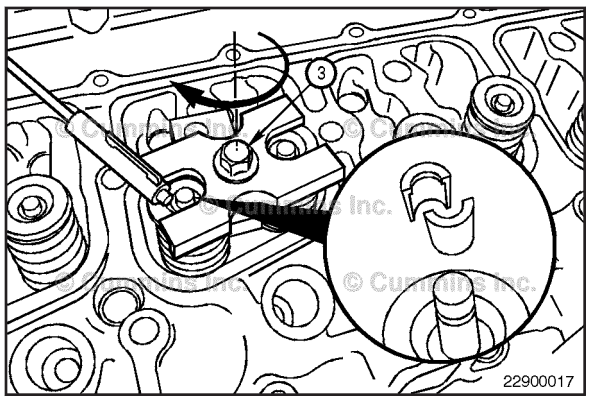


Position the spring compression plate (2) onto the valve springs with the part number up.



Apply shop grease to the top of the spring compression plate (2) and underneath of the capscrew (3) head and install the 10-mm (3) capscrew.

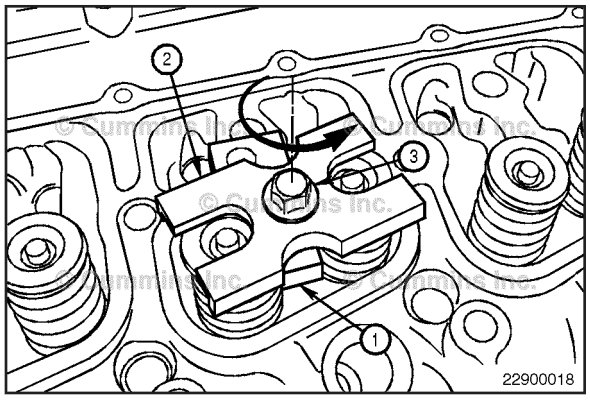
Tighten the capscrew finger-tight (3).



⚠WARNING⚠
Wear appropriate eye and face protection when performing this procedure. Springs are under tension and can act as a projectile if released, causing personal injury.

△CAUTION△
Do not overtighten the capscrew. Doing so can damage the tool and/or the engine.

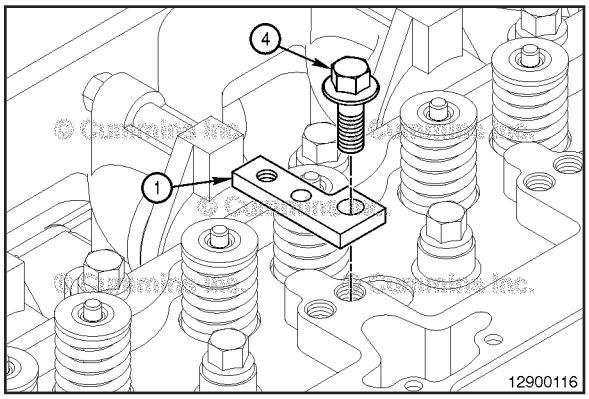
Turn the capscrew (3) **clockwise** until the collets can be installed. Use a magnetic tool.



Carefully turn the capscrew (3) **counterclockwise** until the tension is released from the valve springs.

Remove the capscrew (3) and spring compression plate (2) from the lower support plate (1).

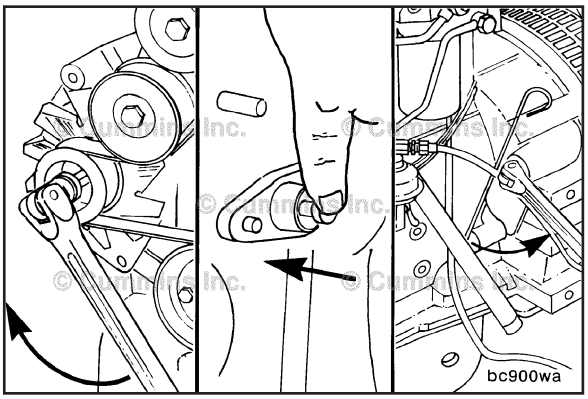
Remove the capscrew (4) and lower support plate (1).



NOTE: Make sure the timing pin is pulled out before the engine is barred over to avoid damaging the timing pin.

Use the marks made previously on the vibration damper/ crankshaft pulley, rotate the engine **clockwise** to put the next group of cylinders at TDC.

Service Tip: If the barring tool is inaccessible, in some applications the alternator pulley can be used to bar the engine over.

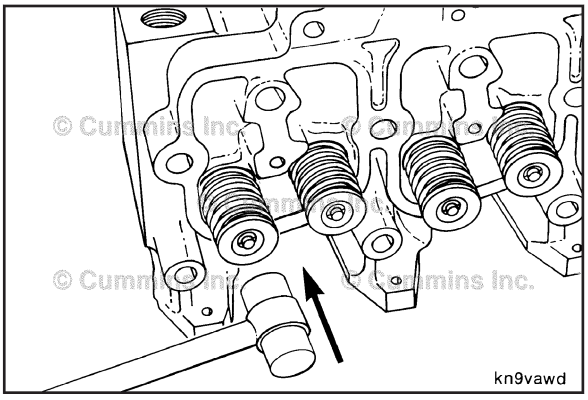


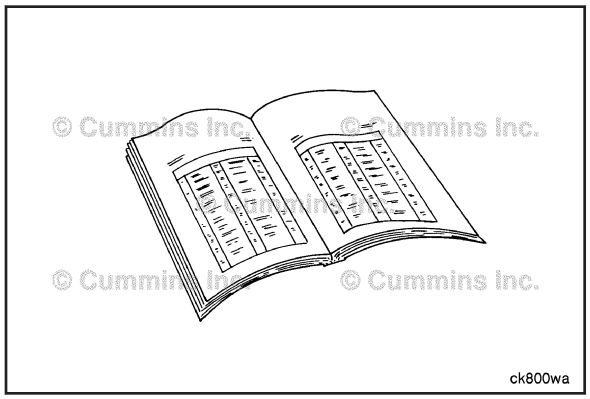
⚠WARNING⚠
To reduce the possibility of personal injury, wear eye protection. If the collets are not correctly installed, they can fly out when the stems are hit with a hammer.

△CAUTION△
Rotate the engine to the next cylinder in the firing order before hitting the valve stem of the cylinder previously worked on. This will ensure that the valve does not contact the piston, resulting in a bent valve and internal engine damage.

After rotating the engine to the next group of cylinders, hit the valve stems of the cylinders previously worked on with a plastic hammer to make sure the collets are seated.

Repeat the previous steps until all of the valve stem seals are replaced.



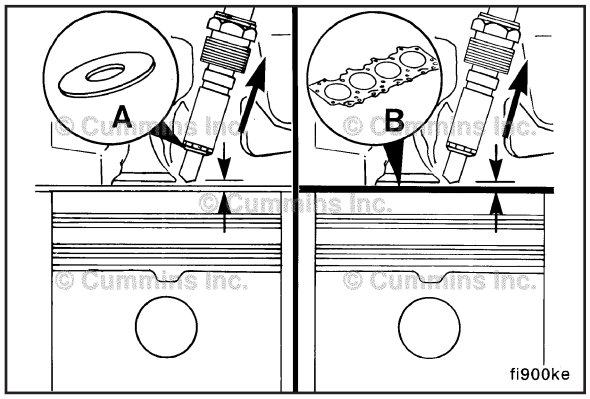


Finishing Steps

⚠WARNING⚠

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

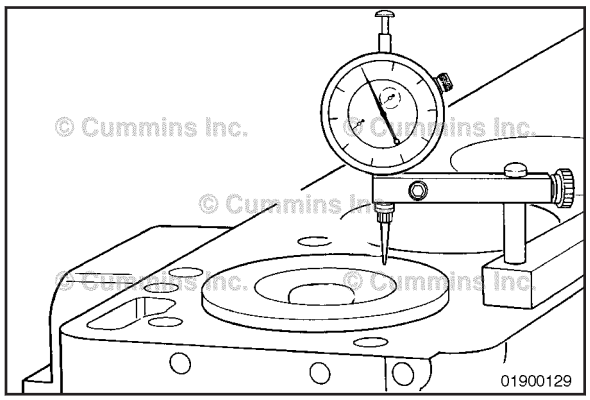
- For engines with 2 valves per cylinder, install the rocker lever assemblies. Refer to Procedure 003-008.
- For engines with 4 valves per cylinder, install the rocker lever assemblies and cross heads. Refer to Procedure 003-008 and Procedure 002-001.
- Adjust the overhead. Refer to Procedure 003-004.
- Install the rocker lever cover. Refer to Procedure 003-011.
- Connect the batteries. Refer to Procedure 013-009.
- Operate the engine and check for leaks.



Cylinder Head Gasket (002-021)

General Information

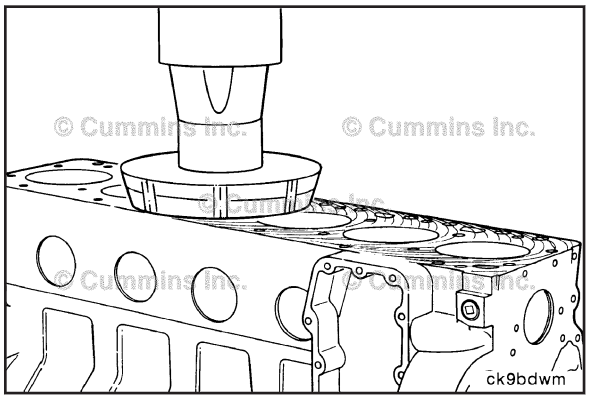
Injector protrusion can affect power from the engine. In addition to a single sealing washer (A) on the injector, the thickness (B) of the head gasket controls injector protrusion.



Piston protrusion can affect startabilty and engine smoke output. The cylinder head gasket helps to maintain correct piston protrusion.

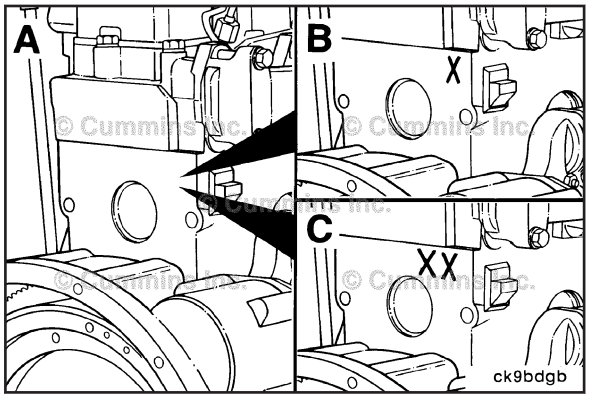
For B3.9, B4.5, and B5.9 series engines, oversize cylinder head gaskets are available for resurfacing of the cylinder head and cylinder block combustion decks to maintain correct:

1. Injector protrusion
2. Piston protrusion.

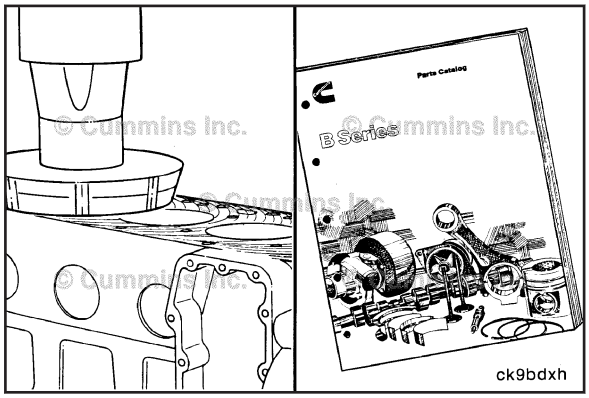


After machining, the cylinder is stamped in the upper rear right hand corner surface of the cylinder block (shown). The cylinder head is stamped on the rear of the cylinder head above where the cylinder block would be stamped (**not** shown).

Machining	Mark
A - Standard	None
B - 0.25 mm [0.010 in] machined for first oversize gasket.	X
C - 0.25 mm [0.010 in] machined (0.50 mm [0.020 in] total) for second oversize gasket.	XX

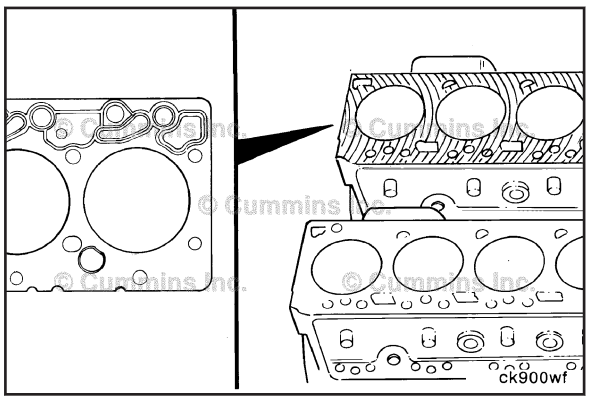


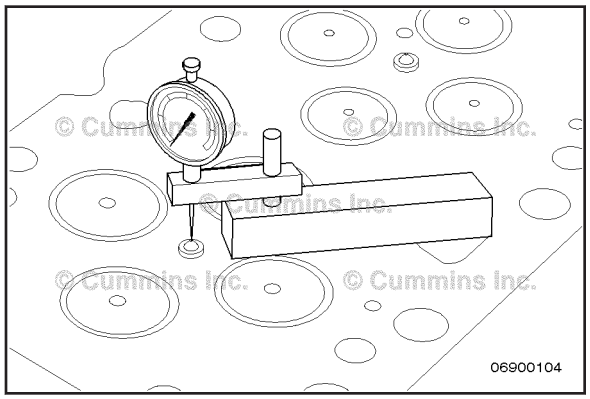
After determining the amount of machining that has been performed, see parts catalog for the proper oversize head gasket.



For B4.5 RGT series engines, the combustion deck of the block can only be resurfaced if, after resurface, the correct piston protrusion can be achieved. Refer to Procedure 001-054.

No specific head gasket with an increased thickness is available for combustion deck resurfacing. If the combustion deck can **not** be resurfaced such that the correct piston can be achieved, the cylinder block **must** be replaced.



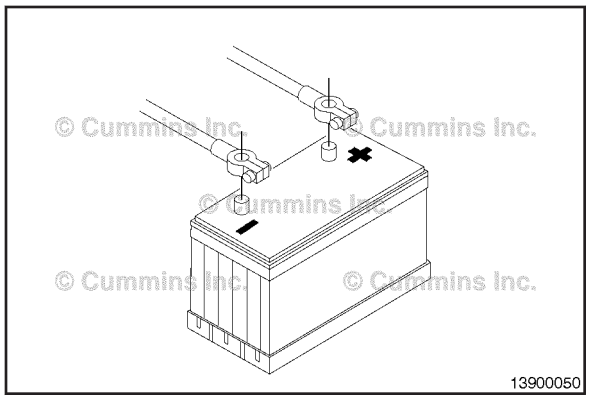


For B4.5 RGT series engines, the combustion deck of the cylinder head can only be resurfaced if both of the two following criteria are met:

1. Valve depth is kept in specification. Refer to Procedure 002-004 for specifications
2. Injector protrusion is kept in specification. Refer to Procedure 002-004 for specifications.

If valve depth and injector protrusion specifications can be maintained, the cylinder head can be resurfaced. If the specifications can **not** be maintained, the cylinder head **must** be replaced.

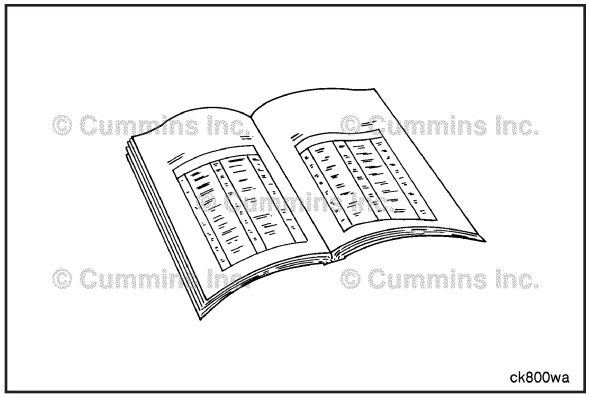
No specific head gasket with an increased thickness is available for cylinder head combustion deck resurfacing. If the combustion deck can **not** be resurfaced such that the valve depth and injector protrusion can be reached, the cylinder head **must** be replaced.



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.

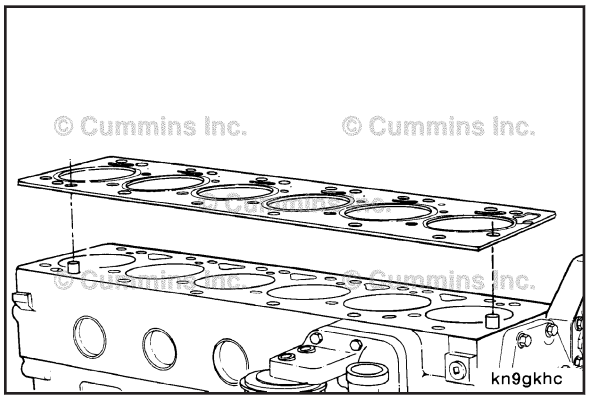


⚠WARNING⚠
This assembly weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this assembly.

- Remove the cylinder head. Refer to Procedure 002-004.

Remove

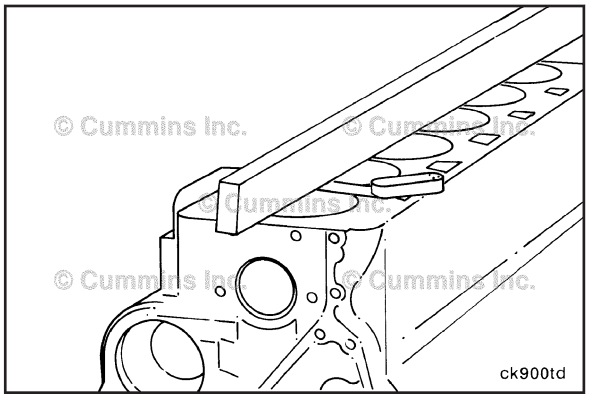
Remove the head gasket.



Clean and Inspect for Reuse

NOTE: Cylinder head gaskets can **not** be reused. A new cylinder head gasket **must** be used.

Clean the cylinder block and cylinder head combustion deck. Inspect and measure the cylinder block and cylinder head combustion deck flatness. Refer to Procedure 002-004.

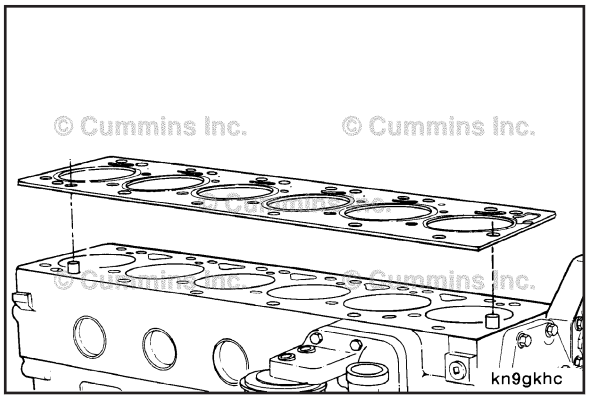


Install

⚠CAUTION⚠
Be sure the gasket is correctly aligned with holes in the cylinder block. If the gasket is not correctly engine damage can result.

Install the new head gasket.

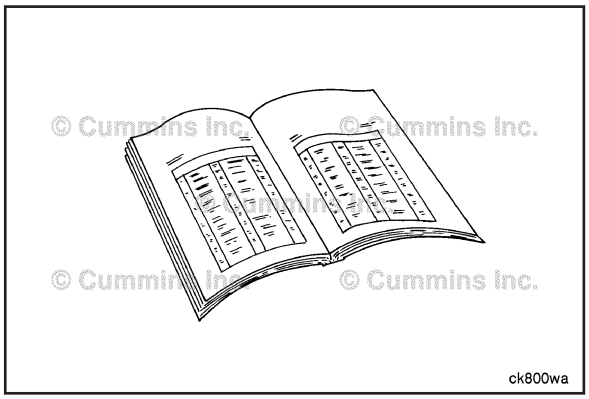
NOTE: Never reuse the old head gasket. **Always** use a new head gasket to prevent leakage.

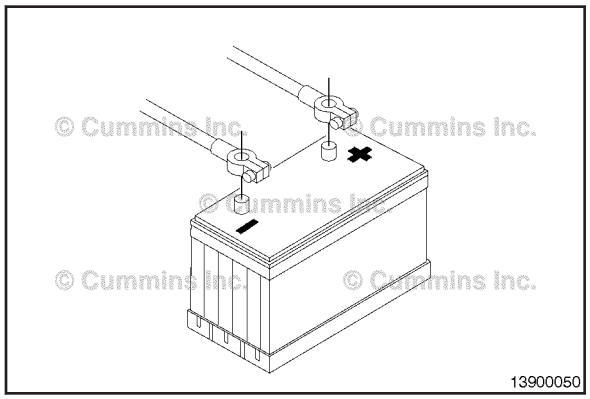


Finishing Steps

⚠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 cylinder head. Refer to Procedure 002-004.





⚠WARNING⚠

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

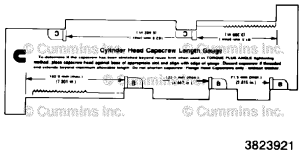
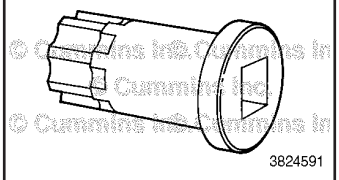
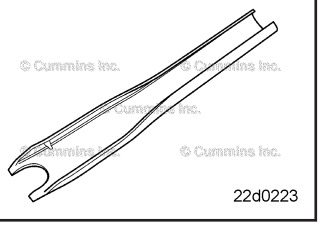
Section 3 - Rocker Levers - Group 03

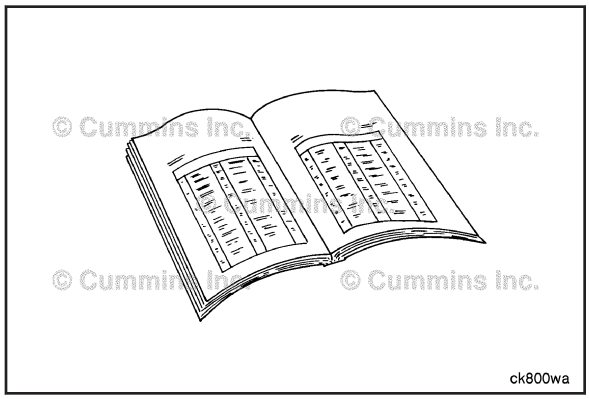
Section Contents

Service Tools

Rocker Levers

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

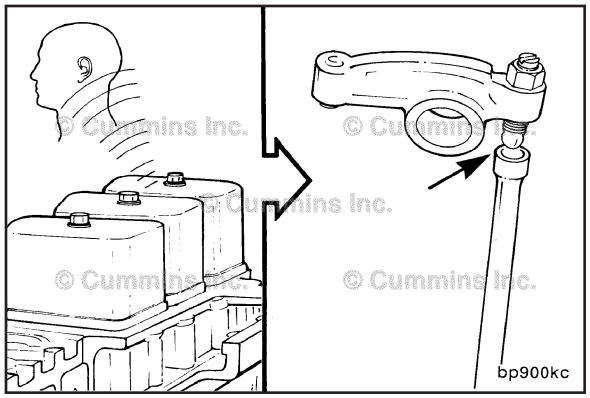
Tool No.	Tool Description	Tool Illustration
3823921	**Capscrew Length Gauge** Used to measure capscrew free length. For front gear train engines.	
3824591	**Engine Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
3165175	**Barring Plug Remover** Quickly removes stubborn barring plugs from flywheel housing.	



Overhead Set (003-004)

General Information

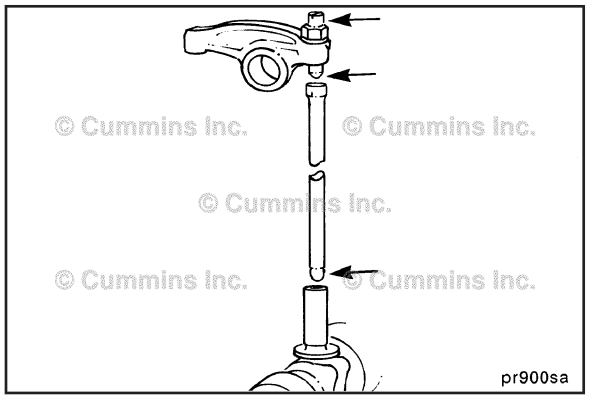
Overhead setting is only required at the interval specified in the appropriate Operation and Maintenance Manual/ Owners Manual or when engine repairs cause removal of the rocker levers and/or loosening of the adjusting screws.



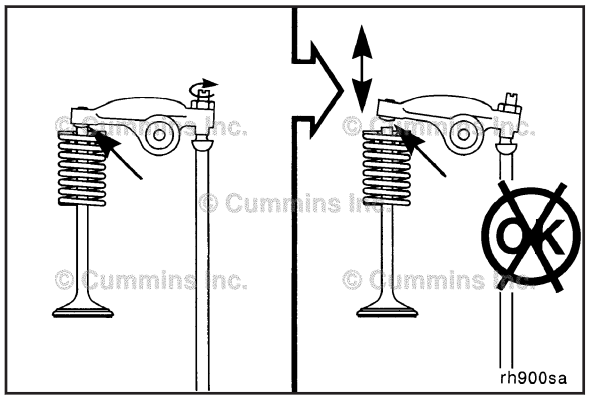
Diagnosing Component Malfunctions — Rocker Lever, Valve Stem, Push Rod, Tappet, and Camshaft.

Each cylinder of the engine has a separate rocker lever assembly. The pedestal support has drillings to route the oil flow to the shaft and levers.

The rocker levers are push rod actuated and use an adjusting screw to control the clearance between the rocker lever and valve stem (crossheads for four four valves per cylinder engines). The rocker levers do **not** use a bushing in the bore for the rocker lever shaft. The rocker lever **must** be replaced if the bore is damaged or worn beyond the specification limit.



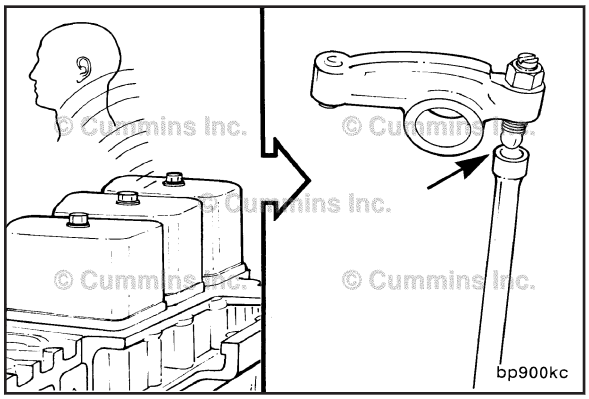
The ball end of the push tube fits into the ball socket in the tappet. The other end of the push rod has a ball socket in which the ball end of the rocker lever adjusting screw operates.



Excessive valve lash can indicate a worn valve stem, crosshead (for four valves per cylinder engines), push rod, valve tappet, or rocker lever.

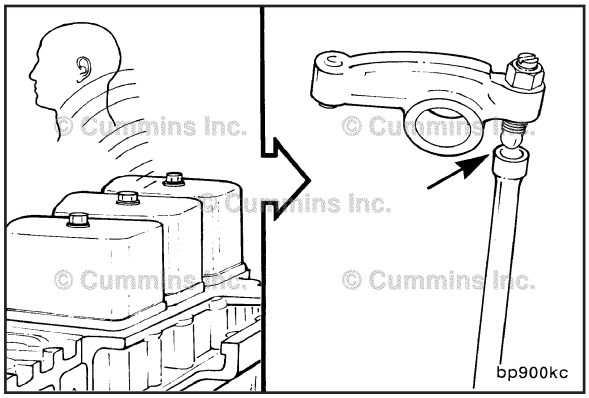
Loose rocker levers and the need to reset the valve clearance frequently can also indicate camshaft lobe or tappet wear. If an inspection of the rocker levers, valve stems, crosshead (for four valves per cylinder engines), and push rods does **not** show wear, then tappet and/or camshaft lobe wear can be suspected.

Refer to Procedures 001-008 and 004-015.



Loose rocker levers and the need to reset the valve clearance frequently can also indicate camshaft lobe or tappet wear. If an inspection of the rocker levers, valve stems, crosshead (for four valves per cylinder engines), and push rode does **not** show wear, then tappet and/or camshaft lobe wear can be suspected.

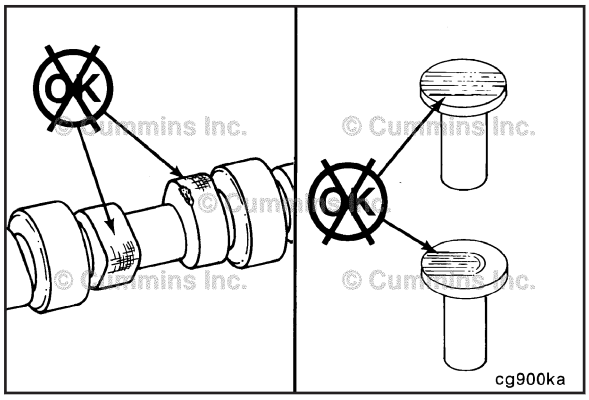
Contact a Cummins Authorized Repair Location.



⚠CAUTION⚠
Anytime a new camshaft is installed, new tappets and push tubes must also be installed. Failure to do so can cause severe engine damage.

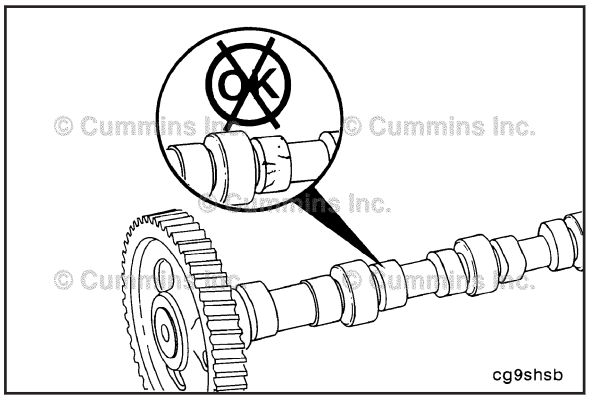
The camshaft lobes can be inspected after removing the lubricating oil pan.

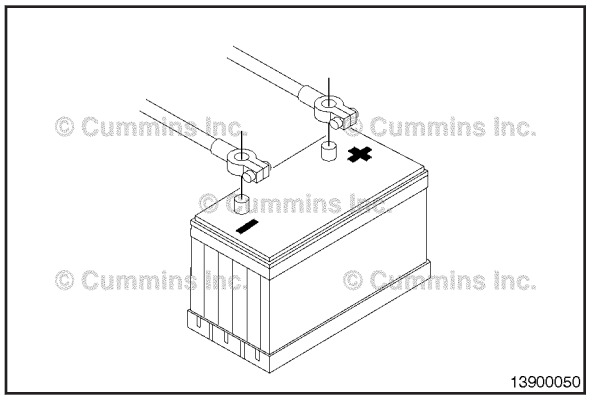
The tappets can also be inspected with the lubricating oil pan removed. Remove the push rods, lift the tappets, and inspect the tappet faces.



Severely damaged camshaft journal(s) can generate metal chips that will be found in the lubricating oil pan and oil filter.

NOTE: As the clearance between the camshaft bushing(s) and camshaft journal(s) increase, oil pressure and volume will decrease, causing damage to the camshaft and tappets.

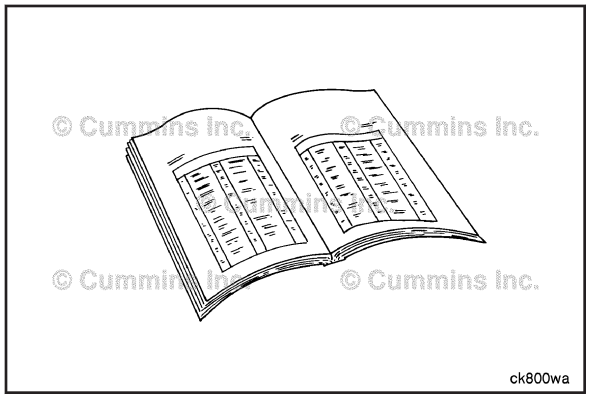




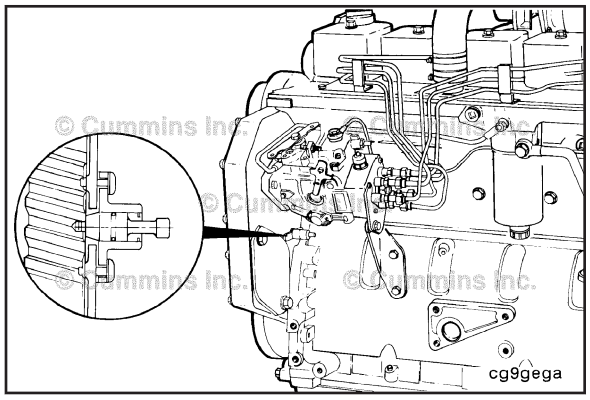
Preparatory Steps

⚠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.

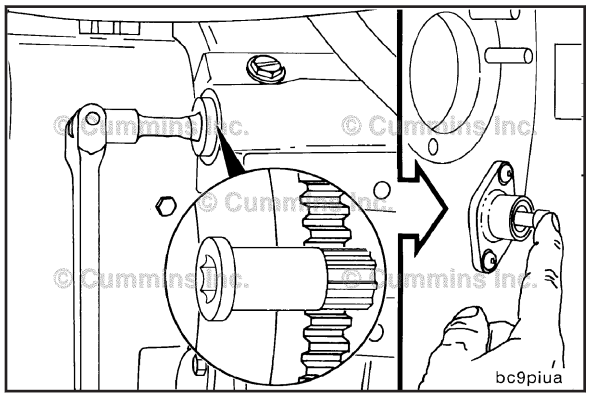


- Remove the rocker lever cover and gasket. Refer to Procedure 003-011.



NOTE: The timing pin is used to accurately locate TDC for setting the overhead. The timing pin is typically located below the fuel pump.

- for front gear train engines, in the front gear housing (shown)
- for rear gear train engines, in the rear gear housing (not shown)

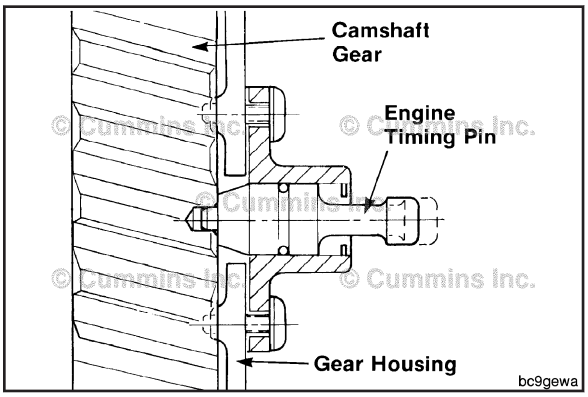


Locate top dead center (TDC) for cylinder number 1 by barring the crankshaft slowly while pressing on the engine timing pin. Barring the engine is recommended from the flywheel on the rear of the engine.

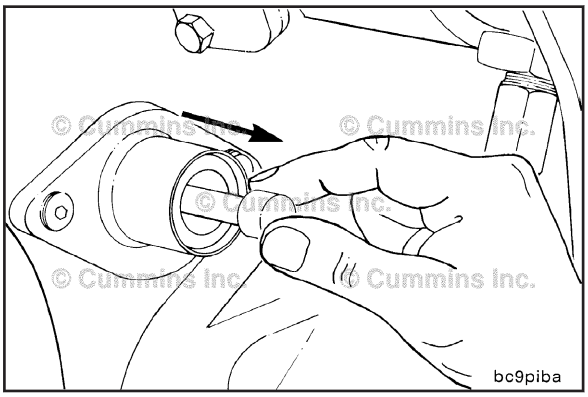
NOTE: Engine coolant temperature **must** be less than 60°C [140°F].

Using the barring tool Part Number 3824591, rotate the crankshaft slowly while pressing on the engine timing pin to locate TDC for cylinder number 1.

When the timing pin engages in the hole in the camshaft gear, cylinder number 1 is at TDC on the compression stroke.



⚠CAUTION⚠
To reduce the possibility of engine or timing pin damage, you must disengage the timing pin after locating top dead center.



Adjust

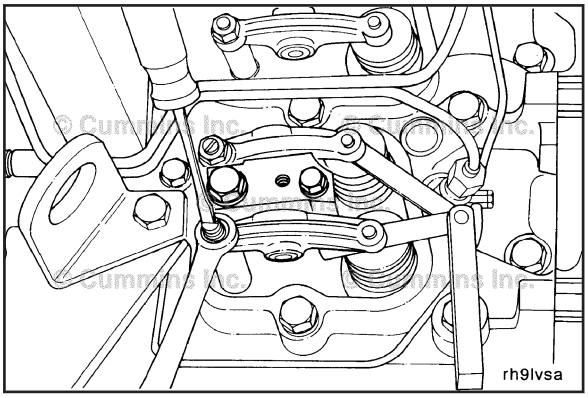
B3.9, B5.9, and B4.5 Engines

NOTE: The clearance is correct when some resistance is “felt” when the feeler gauge is slipped between the valve stem and the rocker lever.

NOTE: Caution **must** be used when setting the exhaust valve lash on marine cylinder heads with rotators. The top of the valve stem is slightly recessed below the top of the valve rotator.

Intake Clearance: 0.254 mm [0.010 in]

Exhaust Clearance: 0.508 mm [0.020 in]



Four-Cylinder Engine Adjustment

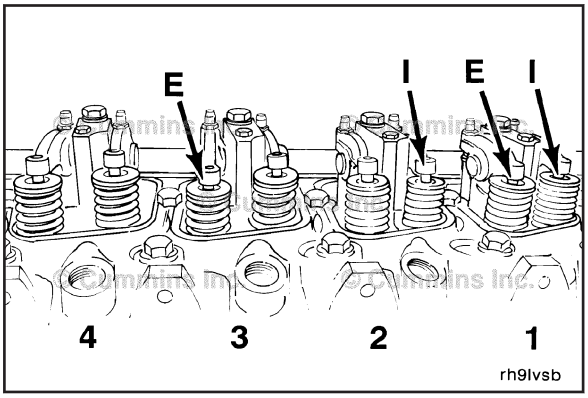
Make sure the engine is at top dead center (TDC) for cylinder number 1.

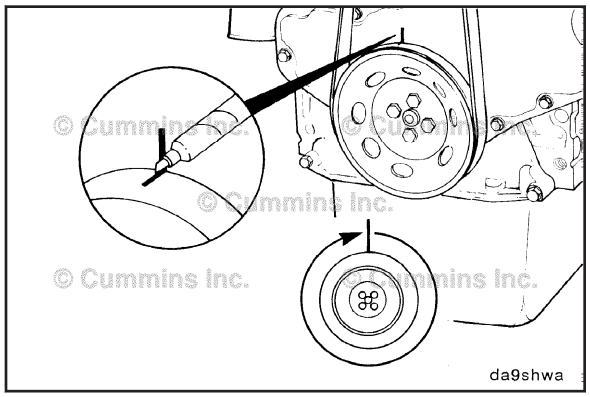
Set **only** valves indicated by the arrows (E = exhaust, I = intake). Do **not** set valves that are **not** indicated.

Holding the locknut steady with the wrench, adjust the valve clearance with the screwdriver or Allen wrench.

Tighten the locknut and measure the valve lash again.

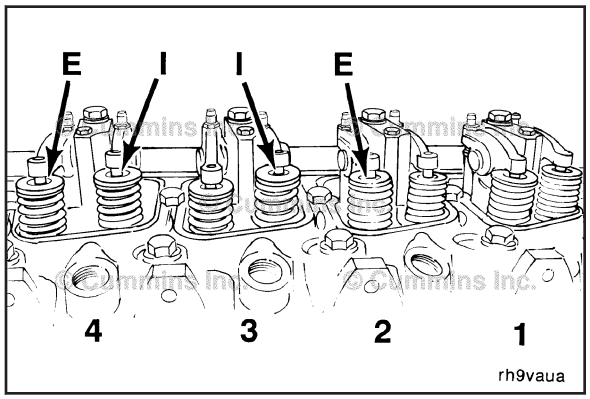
Torque Value: 24 N•m [18 ft-lb]





CAUTION
To reduce the possibility of engine or pin damage, be sure the timing pin is disengaged.

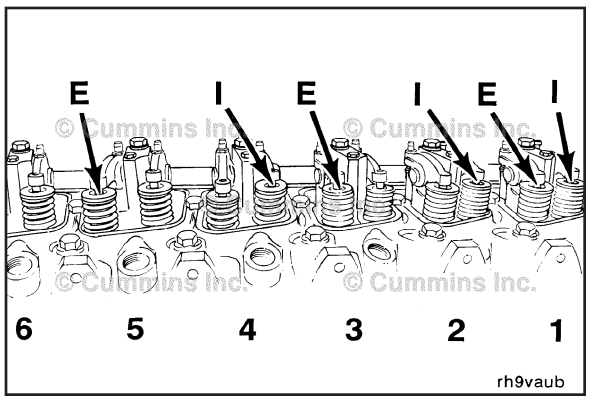
Mark the vibration damper and rotate the crankshaft 360 degrees.



Adjust the valves as indicated in the illustration.

Torque Value: 24 N•m [18 ft-lb]

Set **only** valves indicated by the arrows (E = exhaust, I = intake). Do **not** set valves that are **not** indicated.



Six-Cylinder Engine Valve Adjustment

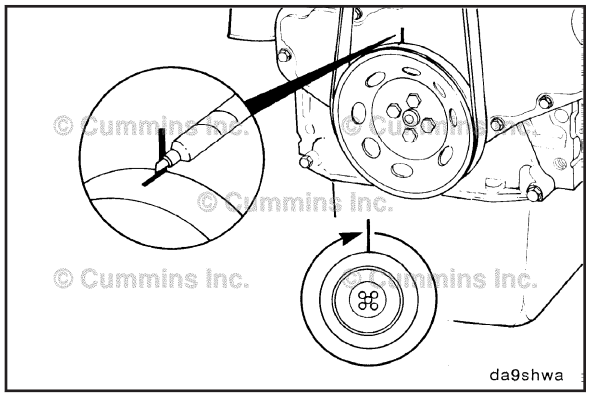
Make sure the engine is at top dead center (TDC) for cylinder number 1.

Set **only** the valves indicated by the arrows in the illustration (E = exhaust, I = intake).

Holding the locknut steady with the wrench, adjust the valve clearance with the screwdriver or Allen wrench.

Tighten the locknut, and measure the valve lash again.

Torque Value: 24 N•m [18 ft-lb]



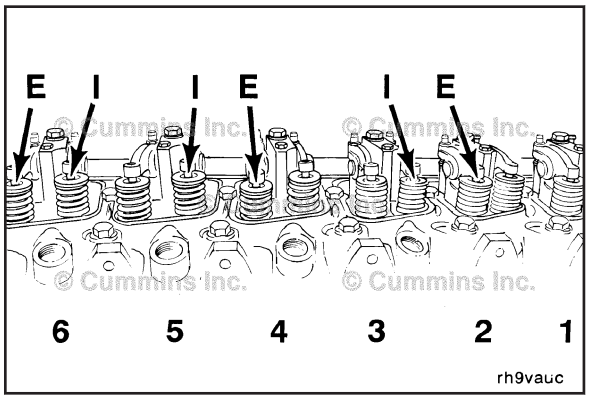
CAUTION
To reduce the possibility of engine or pin damage, be sure timing pin is disengaged.

Mark the pulley, and rotate the crankshaft 360 degrees.

Adjust the valves as indicated in the illustration.

Set **only** the valves indicated by the arrows in the illustration (E = exhaust, I = intake). Do **not** set valves that are **not** indicated.

Torque Value: 24 N•m [18 ft-lb]



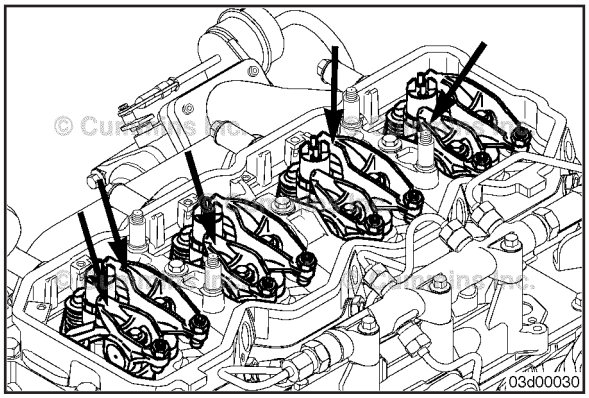
B4.5 RGT Engines

With the engine in this position, lash can be measured on the following rocker levers:

(E = exhaust, I = Intake)

Four-cylinder 1I, 1E, 2I, and 3E:

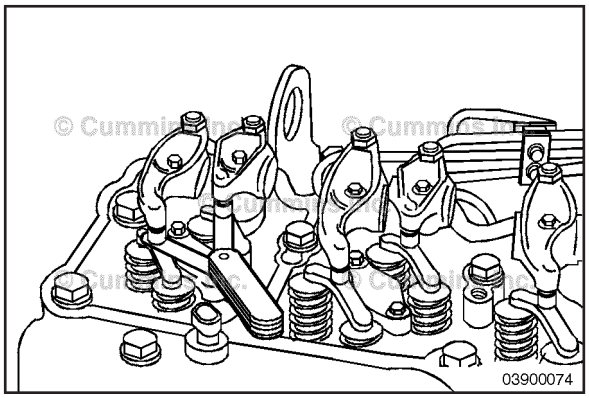
Six-cylinder 1I, 1E, 2I, 3E, 4I, and 5E.

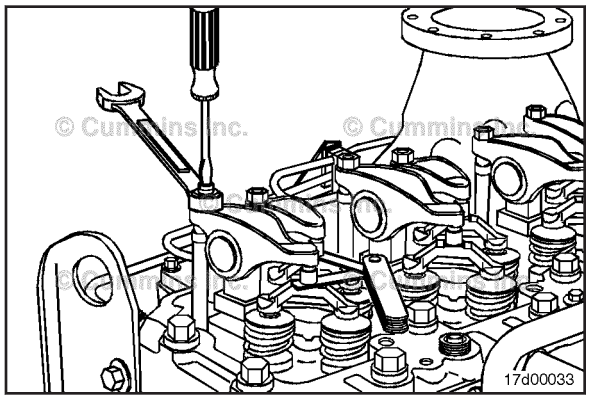


Lash Check Limits

	mm		in
Intake	0.152	MIN	0.006
	0.381	MAX	0.015
Exhaust	0.381	MIN	0.015
	0.762	MAX	0.030

NOTE: Checking the overhead setting is usually performed as part of a troubleshooting procedure, and resetting is **not** required during checks as long as the lash measurements are within the above ranges.





NOTE: The clearance is correct when some resistance is “felt” when the feeler gauge is slipped between the crosshead and the rocker lever socket.

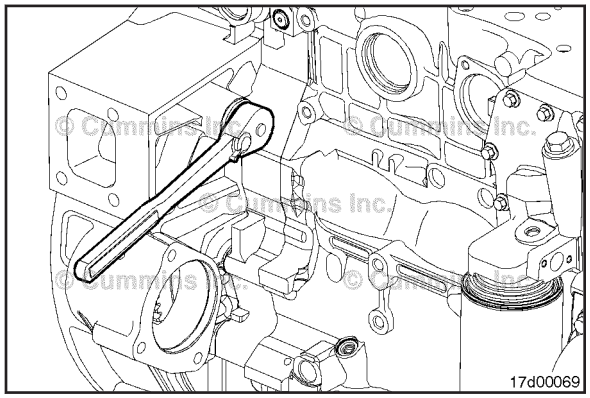
Measure lash by inserting a feeler gauge between the crosshead and the rocker lever socket. If the lash measurement is out of specification, loosen the locknut, and adjust the lash to nominal specifications.

Lash Specifications		
	mm	**in**
Intake	0.254	0.010
Exhaust	0.508	0.020

Tighten the locknut and remeasure.

Torque Value: 24 N•m [212 in-lb]

⚠CAUTION⚠
To reduce the possibility of engine or pin damage, be sure the timing pin is disengaged.



Using barring tool, Part Number 3824591, rotate the crankshaft 360 degrees.

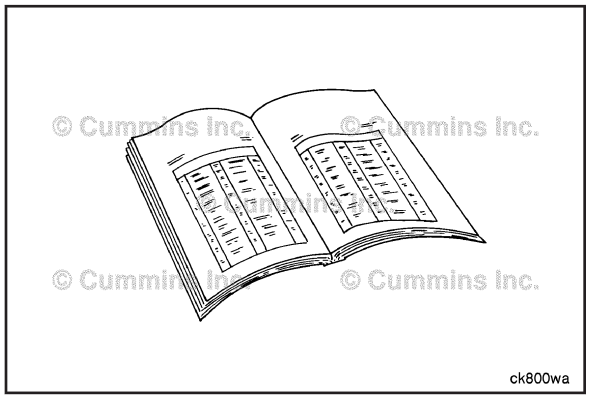
Following the same steps and specifications as previously stated, measure lash for the following rocker levers:

(E = exhaust, I = Intake)

Four-cylinder 2E, 3I, 4E, and 4I:

Six-cylinder 2E, 3I, 4E, 5I, 6I, and 6E.

Reset if out of specification.

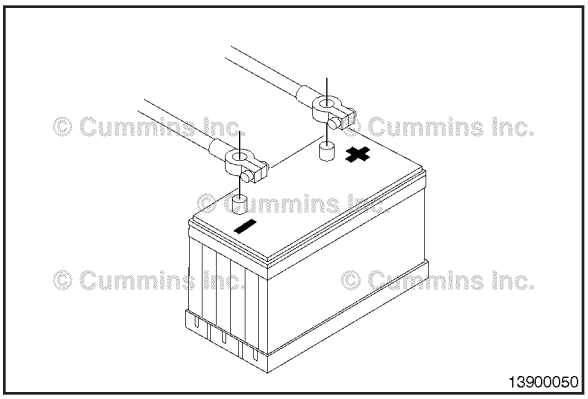


Finishing Steps

- Install the gasket and rocker lever cover. Refer to Procedure 003-011.

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

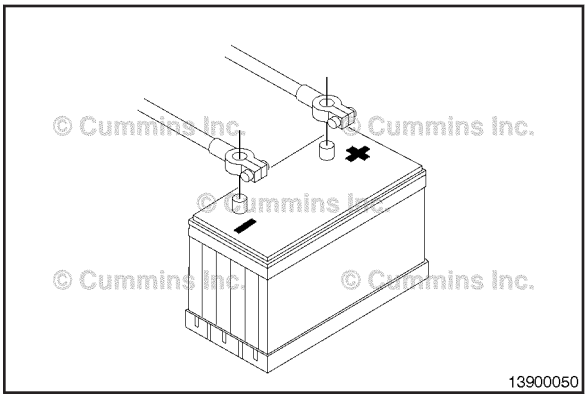


Rocker Lever (003-008)

Preparatory Steps

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

- Disconnect the batteries
- Remove the rocker lever cover and gasket. Refer to Procedure 003-011.

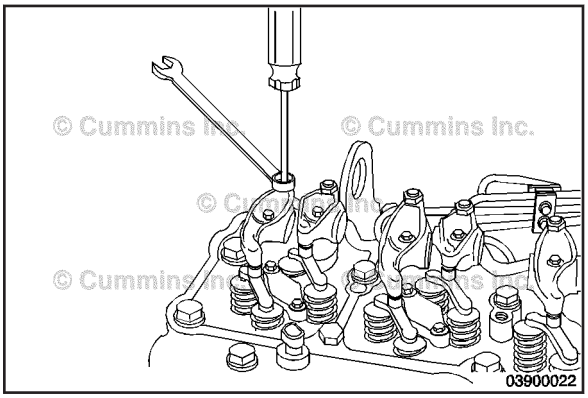


Remove

B4.5 RGT Engines

Loosen the adjusting screw locknuts.

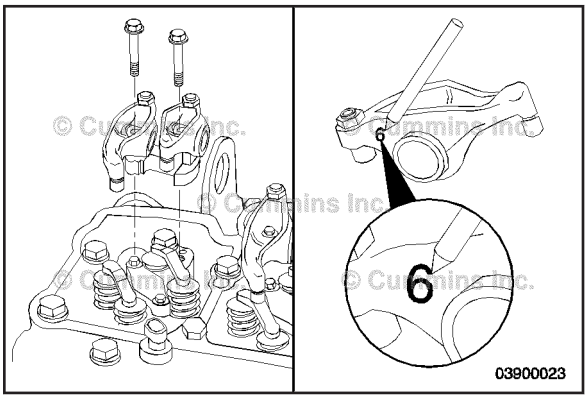
Loosen the adjusting screws until they stop.

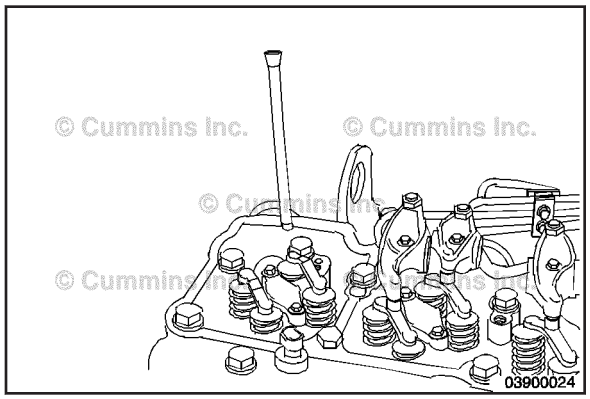


Remove the capscrews from the rocker lever pedestals.

Remove and mark the pedestals and rocker lever assemblies one at a time as to their location and position.

Remove and mark the crossheads one at a time as to their location and position. The crossheads and rocker assembly **must** be installed in their original location and position when reused.

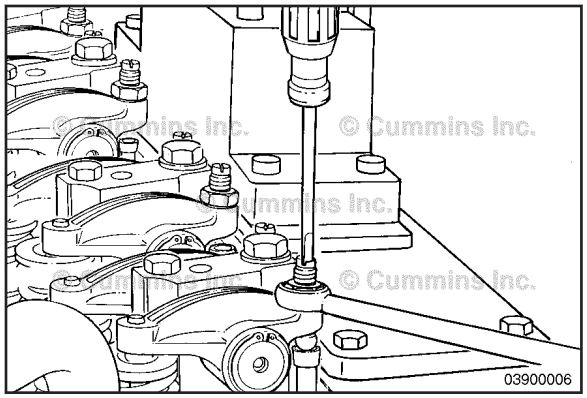




Mark the push rods to identify their location.

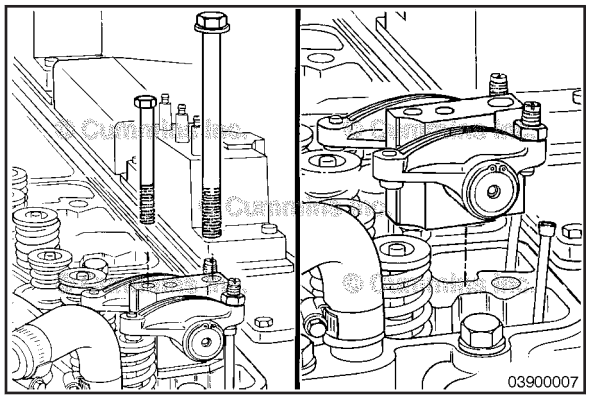
NOTE: The push rods **must** be installed in their original location and position.

Remove the push rods. Refer to Procedure 004-014.

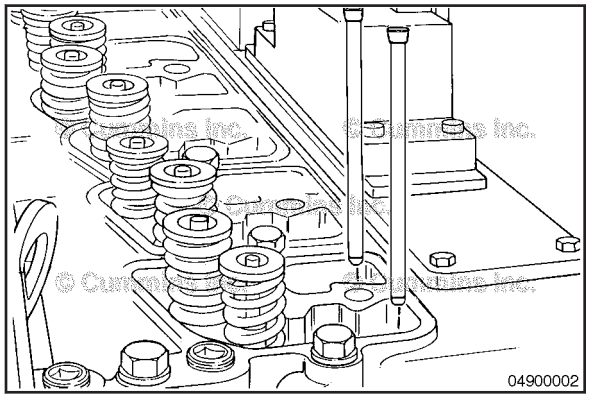


B3.9, B5.9, and B4.5 Engines

Loosen the adjusting screw locknuts. Loosen the adjusting screws until they stop.



Remove the capscrews from the rocker lever pedestals. Remove the pedestals and rocker lever assemblies.



NOTE: Mark the push rods to identify their location.

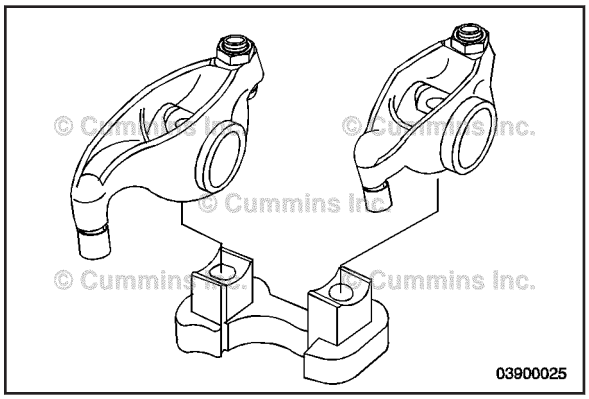
Remove the push rods.

Disassemble

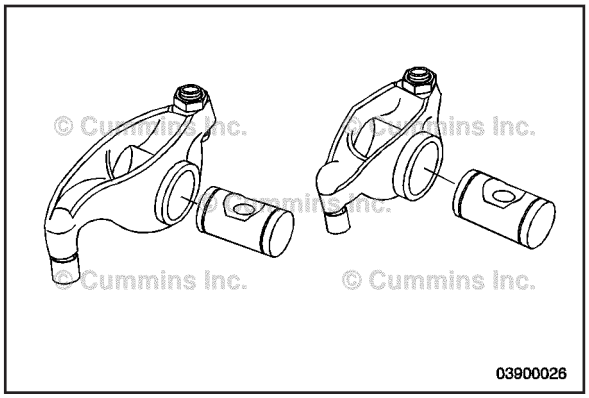
B4.5 RGT Engines

NOTE: All rocker lever components **must** be installed in their original location and position.

Remove the rocker levers from the pedestal.



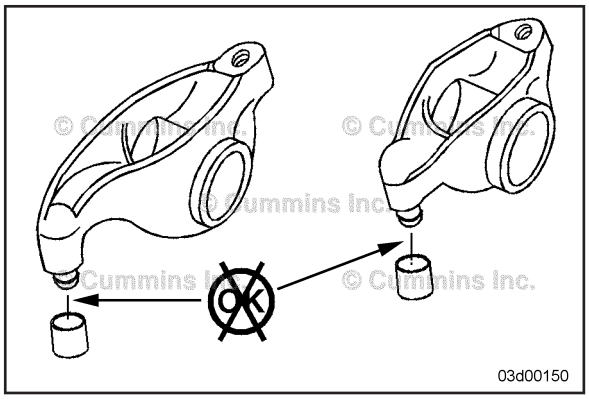
Remove the rocker lever shafts from the rocker levers.



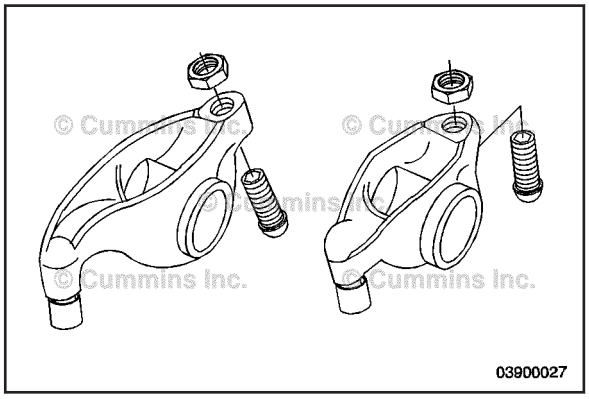
The socket at the tip of the rocker lever should **not** be removed.

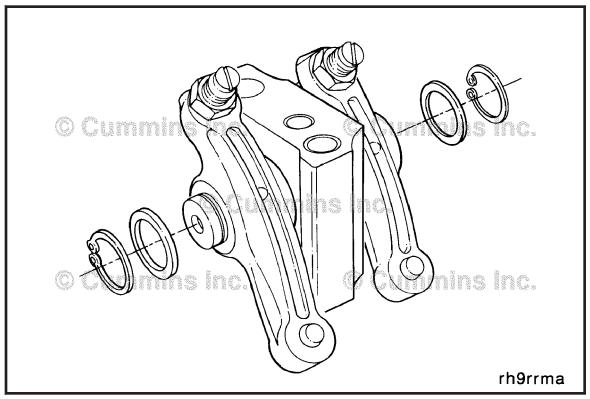
This part is **not** serviceable.

If damage to the socket is found the rocker lever **must** be replaced.



Remove the locknut and adjusting screw.

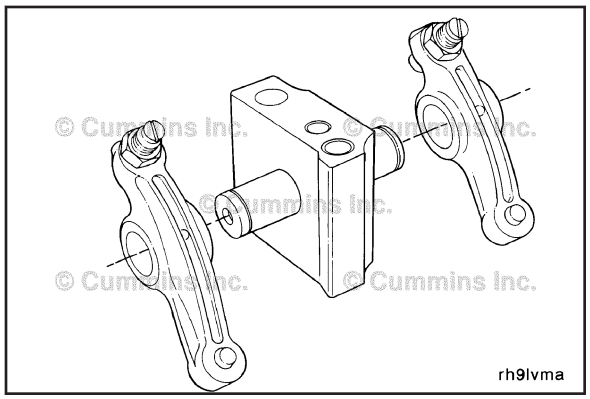




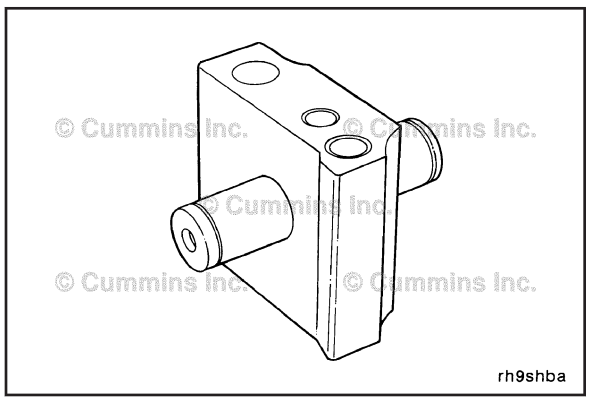
B3.9, B5.9, and B4.5 Engines

If the rocker lever and push tubes are to be inspected for reuse, follow these steps.

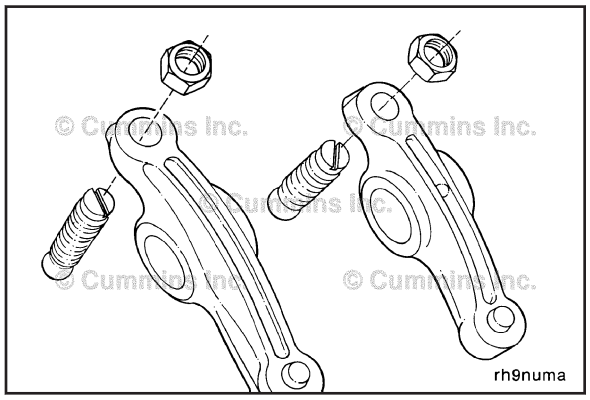
Remove the retaining rings and thrust washers.



Remove the rocker levers.



NOTE: Do **not** disassemble the rocker lever shaft and pedestal. The pedestal and shaft **must** be replaced as an assembly.

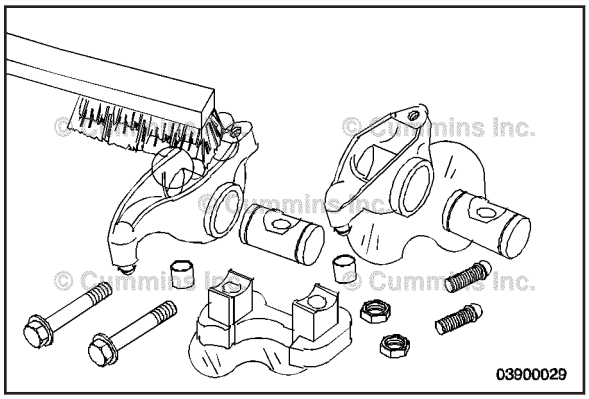


Remove the locknut and adjusting screw.

Clean and Inspect for Reuse

B4.5 RGT Engines

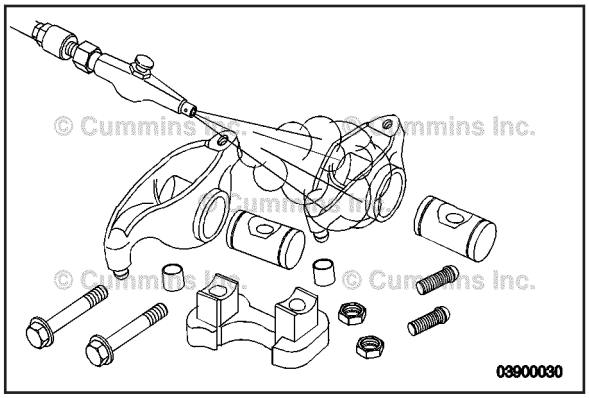
Clean all parts in a strong solution of laundry detergent and hot water.



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

Use compressed air to dry the parts after rinsing in clean, hot water.

NOTE: The pedestals are made from powdered metal and will appear wet even after they have been cleaned and dried.

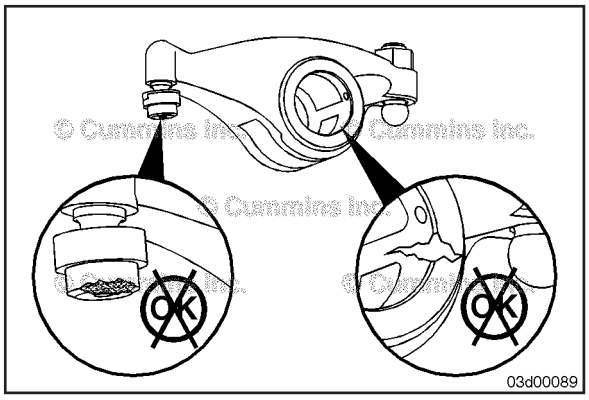


Inspect for cracks and excessive wear in the bore.

The socket should move freely on the rocker lever and the plastic socket retainer should be in place and not cracked.

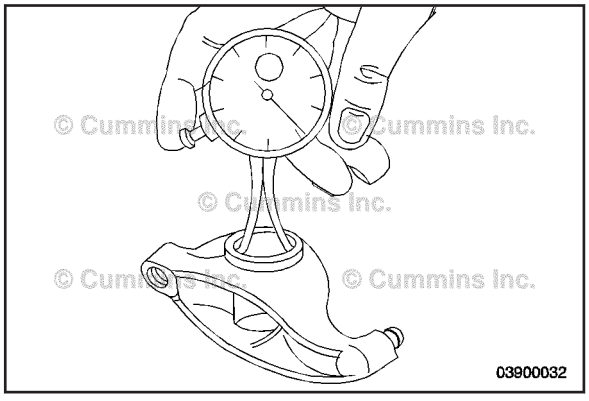
Inspect for wear on the nose of the socket.

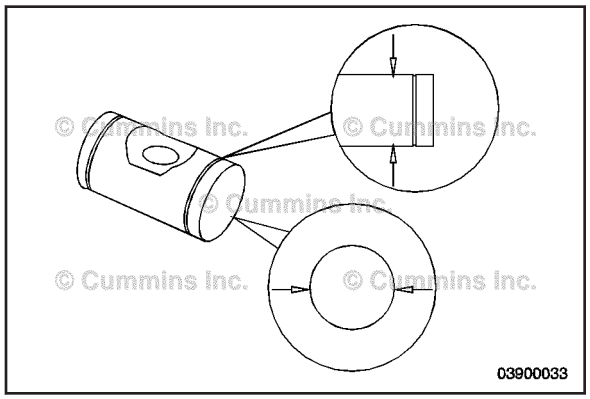
NOTE: The socket at the tip of the rocker lever should **not** be removed. This part is **not** serviceable. If damage to the socket is found the rocker lever **must** be replaced.



Measure the rocker lever bore.

Rocker Lever Bore		
mm		in
22.027	MAX	0.867



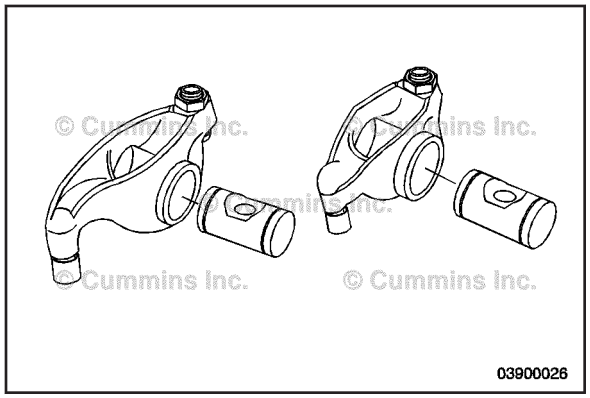


Inspect the rocker lever pedestal and rocker lever shaft.

It is **not** uncommon for the rocker lever shaft to have a polished appearance. Inspect for the following to determine rocker lever shaft reusability.

Measure the rocker lever shaft diameter.

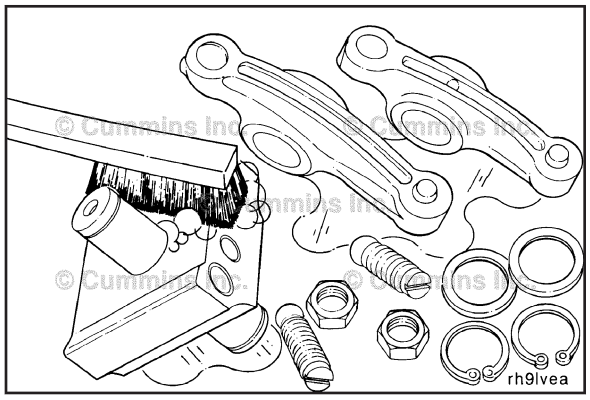
Rocker Lever Shaft		
mm		**in**
21.965	MIN	0.865



Lubricate the rocker lever shaft with clean 15W-40 engine lubricating oil.

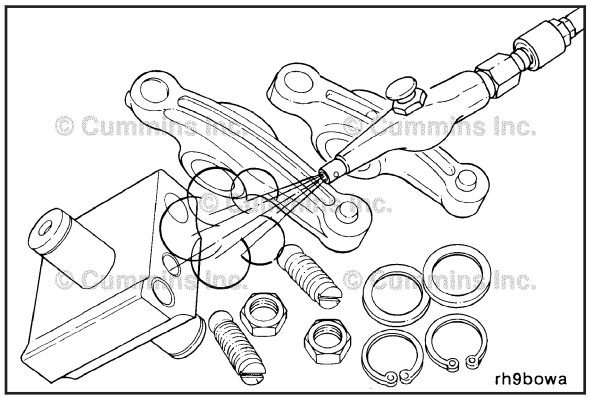
Install the rocker lever shaft into the rocker lever and rotate the rocker lever 180 degrees about the rocker lever shaft. The rocker lever should rotate freely without any binding.

If the rocker lever does **not** rotate freely, replace the rocker lever shaft and rocker lever.



B3.9, B5.9, and B4.5 Engines

Clean all parts in a strong solution of detergent in hot water.



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

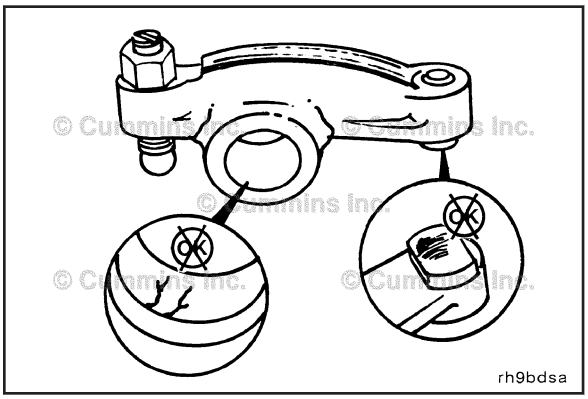
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Rinse parts with clean, hot water.

Dry with compressed air.

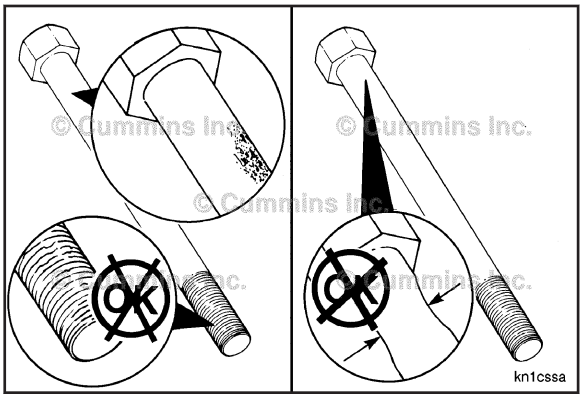
NOTE: The pedestals are made from powdered metal and will continue to show wetness after they have been cleaned and dried.

Inspect for cracks and excessive wear in the bore and the contact surface of the valve stem.



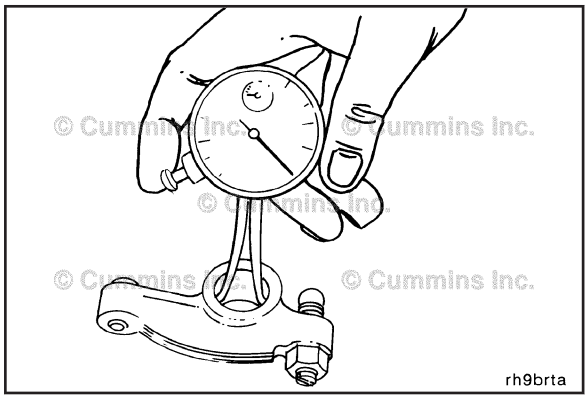
The longer rocker lever capscrew also joins the cylinder head to the cylinder block.

Inspect the cylinder head capscrew for damaged threads, corroded surfaces, reduced diameter and increased length (due to capscrew stretching). Refer to Procedure 002-004.



Measure the rocker lever bore.

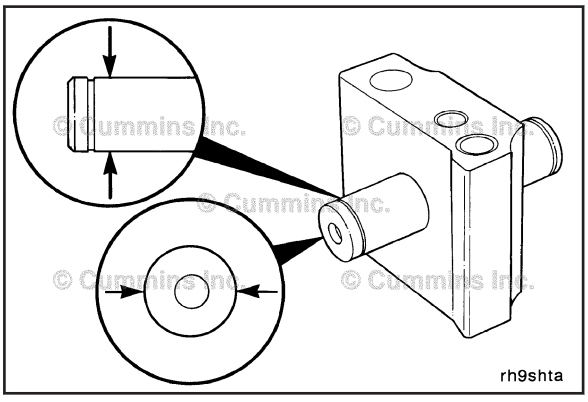
Rocker Lever Bore		
mm		in
19.00	MIN	0.748

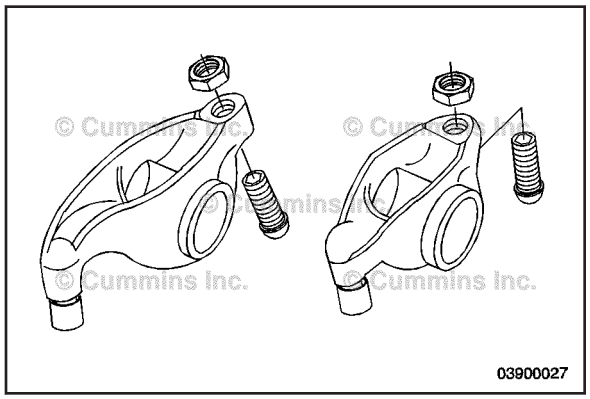


Inspect the pedestal and shaft.

Measure the shaft diameter.

Rocker Lever Shaft		
mm		in
18.98	MAX	0.747



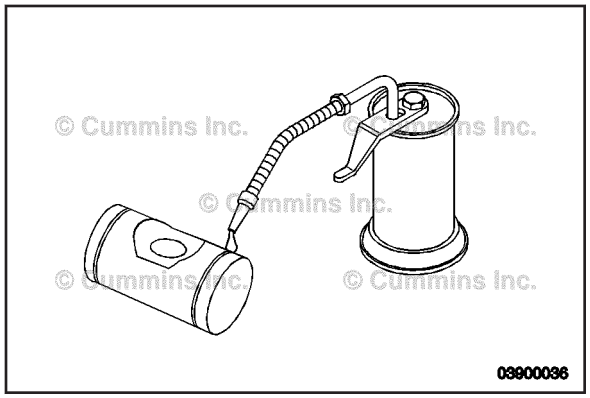


Assemble

B4.5 RGT Engines

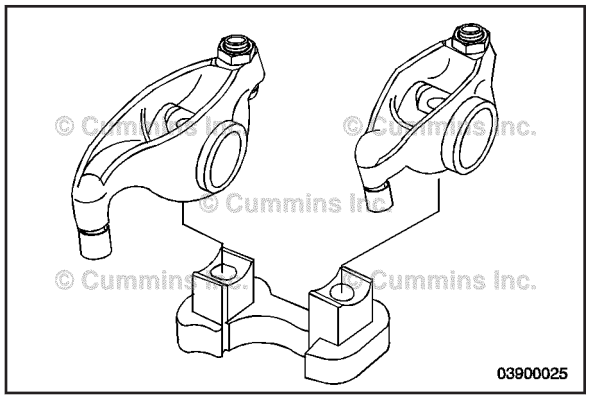
NOTE: All rocker lever components **must** be installed in their original location and position.

Install the adjusting screw until it stops and then install the locknut.

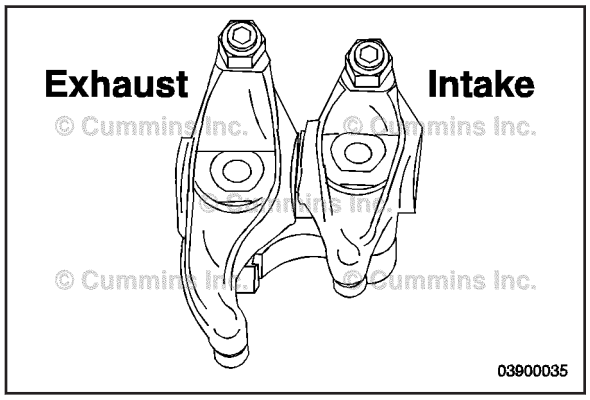


Lubricate the rocker lever shafts with clean 15W-40 engine lubricating oil.

Install the rocker lever shafts into the rocker levers.



Position the rocker levers on the rocker pedestal.

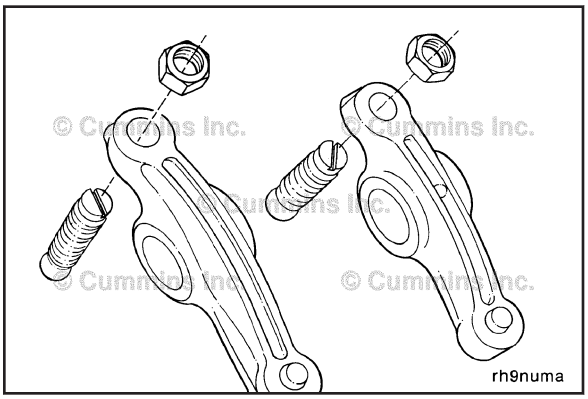


△CAUTION△

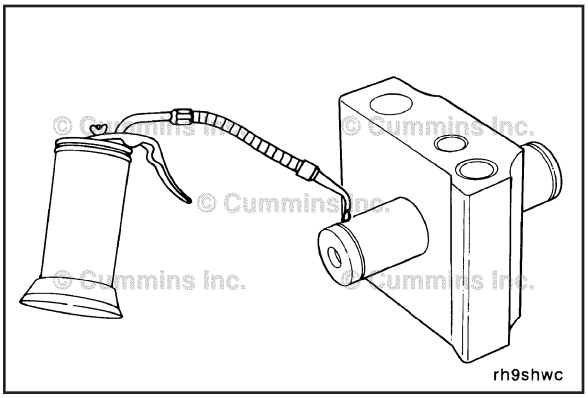
Be sure to assemble the intake and exhaust rocker levers in the correct location. Failure to do so will result in engine damage.

B3.9, B5.9, and B4.5 Engines

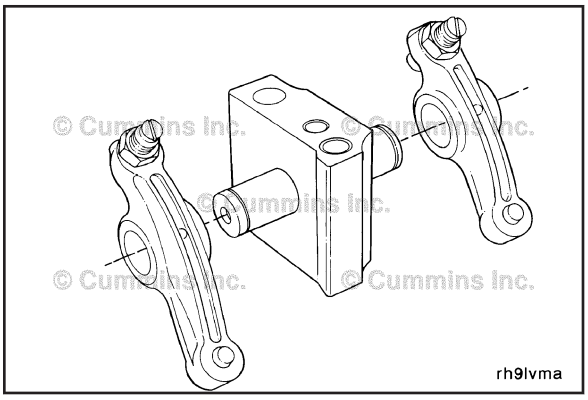
Install the adjusting screw and locknut.



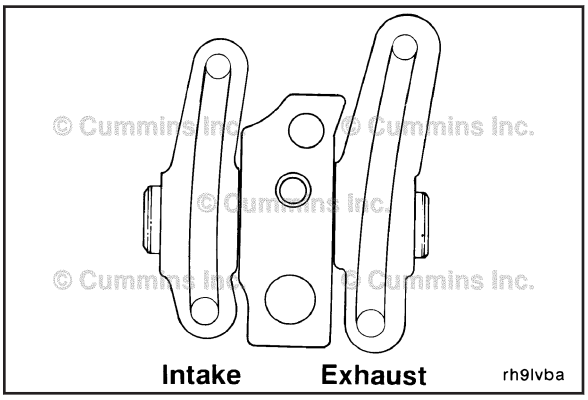
Lubricate the shaft with clean lubricating engine oil.

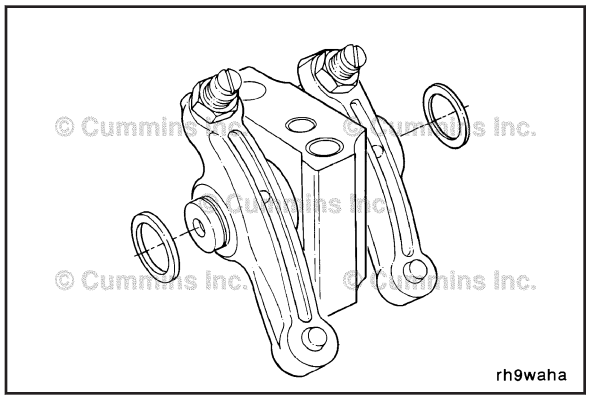


Position the levers on the rocker shaft.

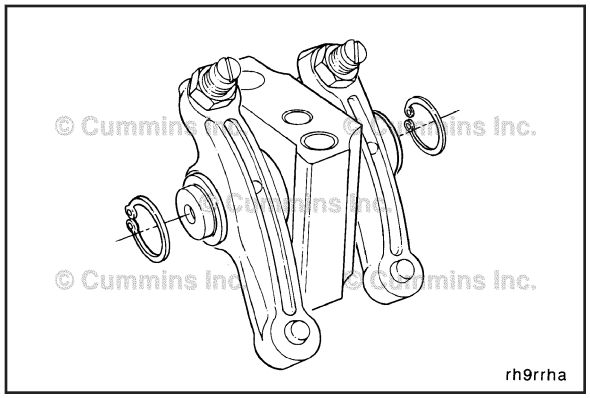


NOTE: Be sure to assemble the intake and exhaust rocker levers in the correct location.

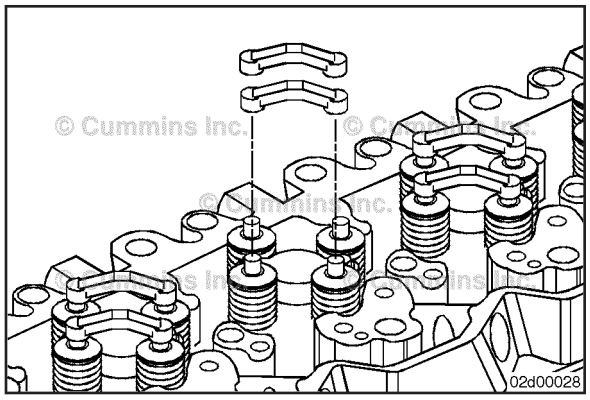




Install the thrust washers.



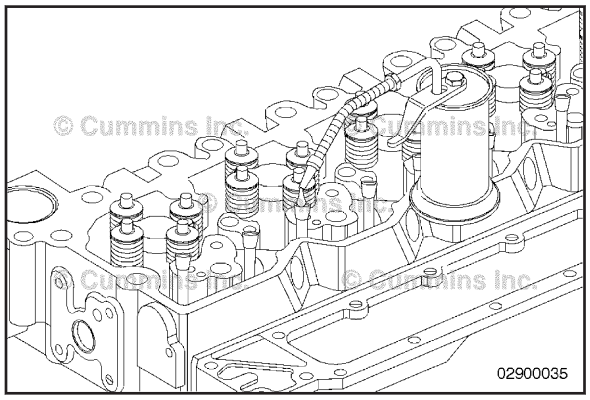
Install the snap rings.



Install

B4.5 RGT Engines

Install the crossheads in their original location and position.



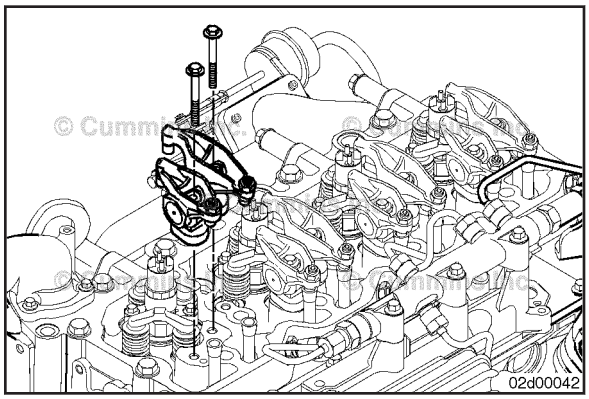
Install the push rods as marked during removal.

Install the push rods into the sockets of the valve tappets.

Lubricate the push rod sockets with clean 15W-40 lubricating engine oil.

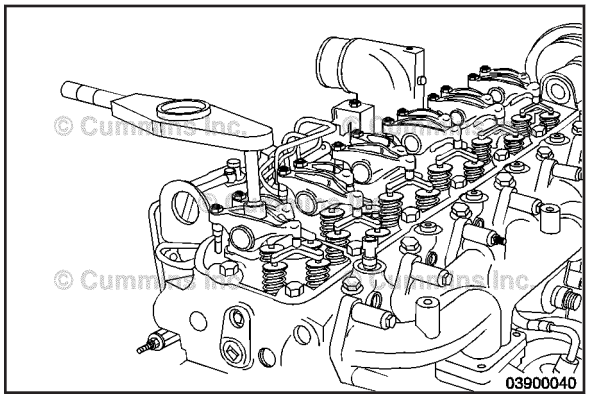
Install the rocker lever assemblies and pedestals in their original position.

Install the pedestal mounting capscrews.

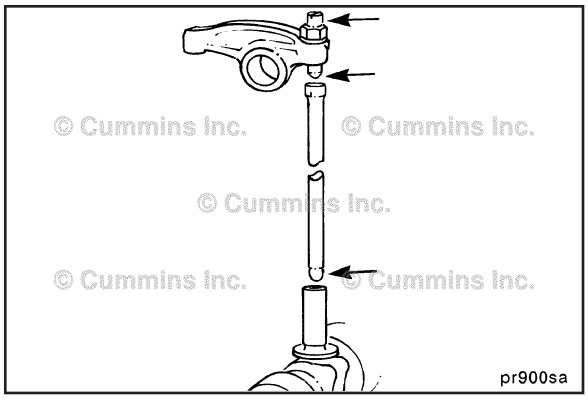


Tighten the pedestal mounting capscrews.

Torque Value: 36 N•m [27 ft-lb]

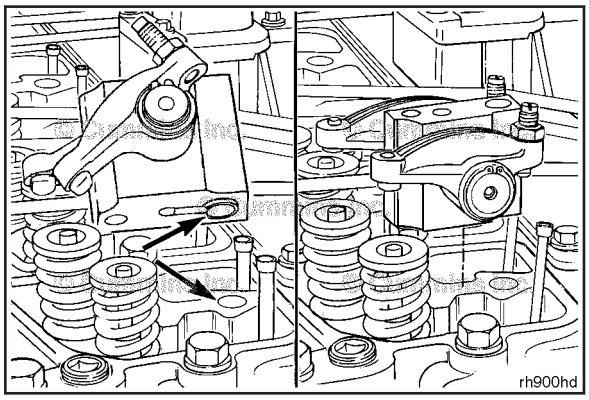


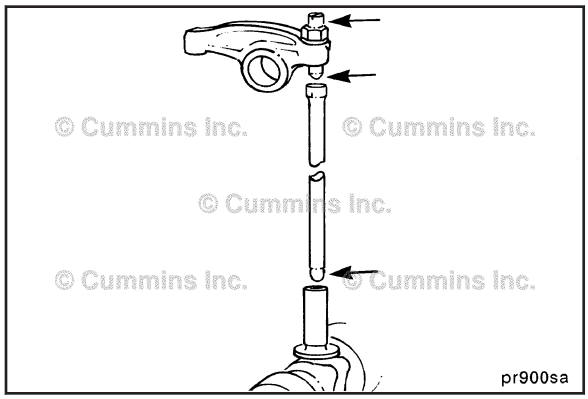
⚠CAUTION⚠
Rotate the adjusting screws until the adjusting screw contacts the socket of the push rod. This will ensure the push rod stays in contact with the tappet and adjusting screw when the engine is rotated to set valve lash. If not completed, the push rods may be bent or damaged.



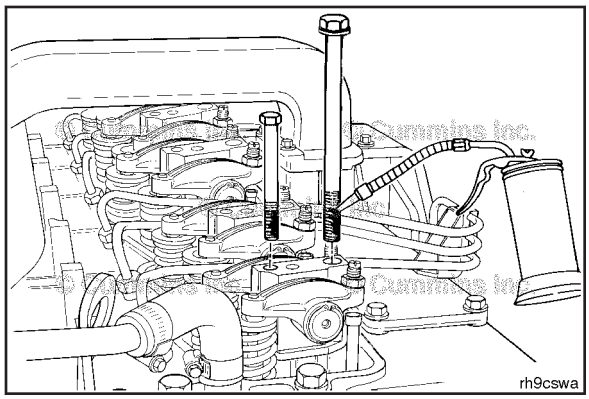
B3.9, B5.9, and B4.5 Engines

Make sure the dowel rings in the pedestals are installed into the dowel bores.



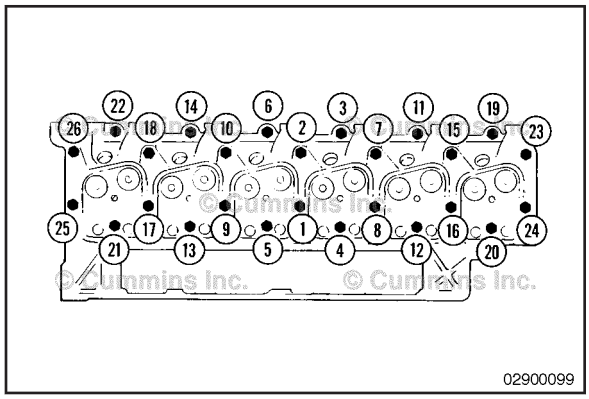


⚠CAUTION⚠
Rotate the adjusting screws until the adjusting screw contacts the socket of the push rod. This will ensure the push rod stays in contact with the tappet and adjusting screw when the engine is rotated to set valve lash. If not completed, the push rods may be bent or damaged.

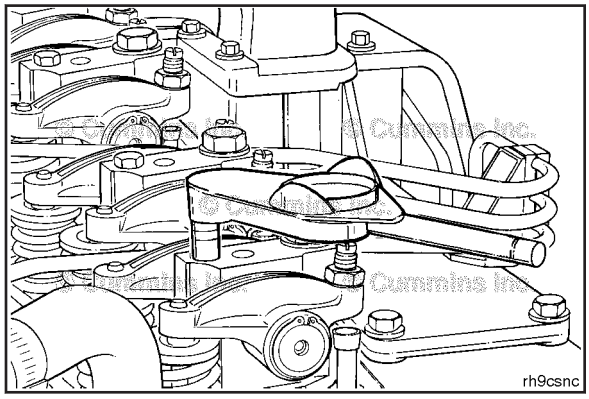


Use clean lubricating engine oil to lubricate the threads and under the heads of the capscrews.

Install the pedestal and cylinder capscrews into the pedestals.



Tighten all the cylinder head capscrews following proper torque order. Refer to Procedure 002-004.

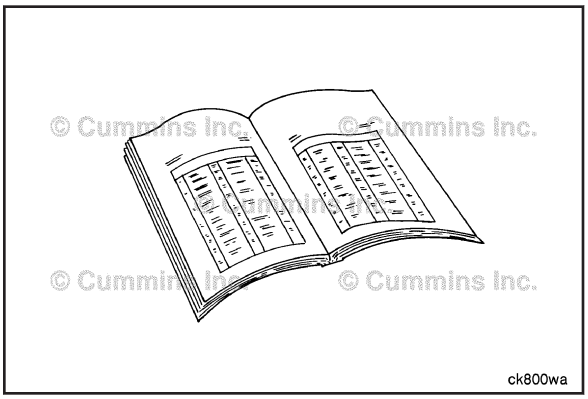


Tighten the 8-mm pedestal capscrews.

Torque Value: 24 N•m [18 ft-lb]

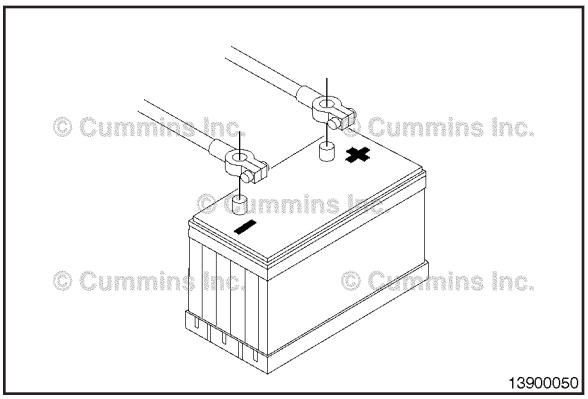
Finishing Steps

- Set valve lash for intake and exhaust valves. Refer to Procedure 003-004
- Install the rocker lever cover gasket and rocker lever cover. Refer to Procedure 003-011.



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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
- Run the engine and check for leaks.

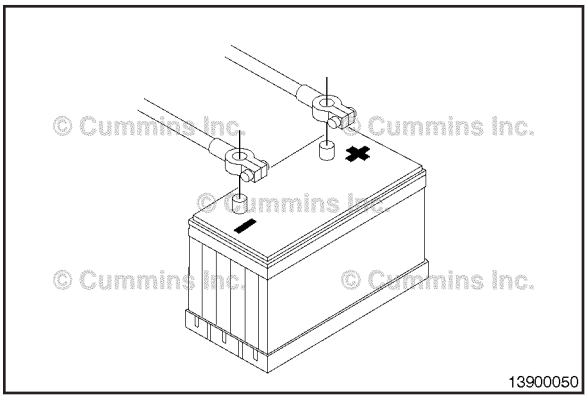


Rocker Lever Cover (003-011)

Preparatory Steps

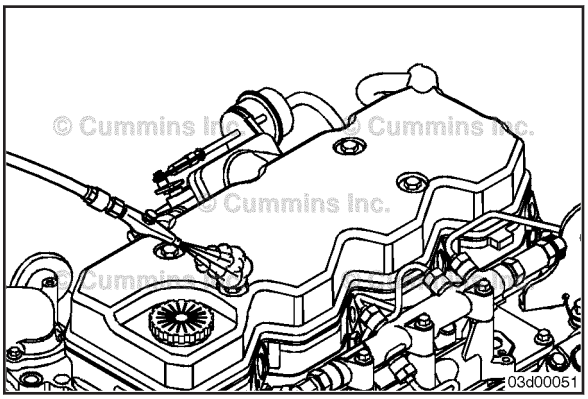
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

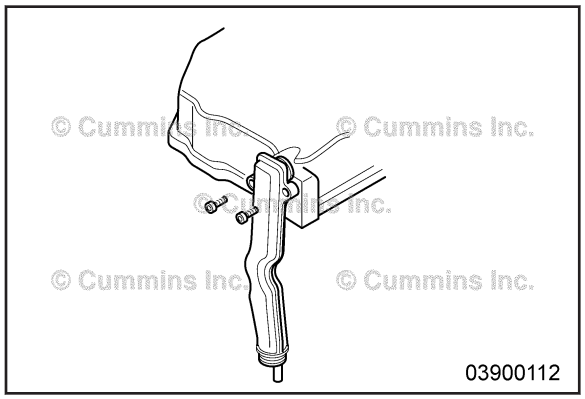
- Disconnect the batteries.



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

- Prior to removing any components, clean around the mounting fasteners and sealing joints with compressed air to remove any loose debris.





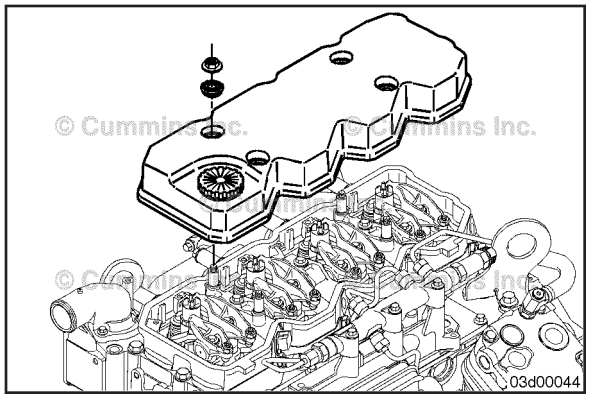
Remove

B4.5 RGT Engines

Disconnect the breather tube connection at the back of the rocker lever cover.

Two capscrews directly mount the breather tube connection to the rocker lever cover. Remove the capscrew(s) to disconnect the breather tube connection from the rocker lever cover.

NOTE: Some breather tube connections use internal Torx capscrews to secure the breather tube connection to the rocker lever cover.

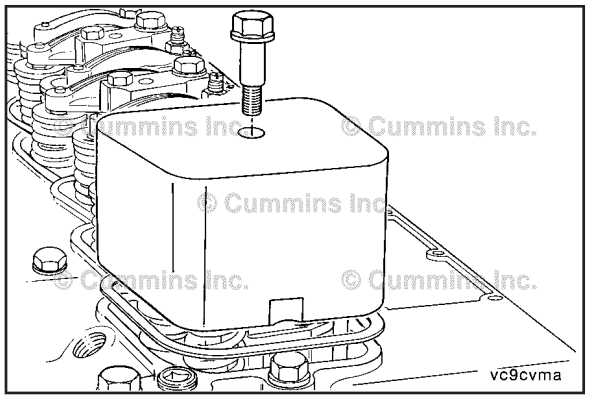


NOTE: Do **not** remove the rocker lever gasket on engines in which the rocker lever cover gasket is fit into a groove at the base of the rocker lever cover. The gasket is reusable. Once the gasket is removed from the rocker lever cover it **must** be replaced.

Remove the mounting nuts and isolators from the rocker lever cover.

NOTE: It may be necessary to gently pry the breather tube connection from the back of the rocker lever cover while removing.

Remove the rocker lever cover.



B3.9, B5.9, and B4.5 Engines

Remove the capscrews, capscrew seals, rocker lever covers and rocker lever cover gaskets.

Clean and Inspect for Reuse

B4.5 RGT Engines

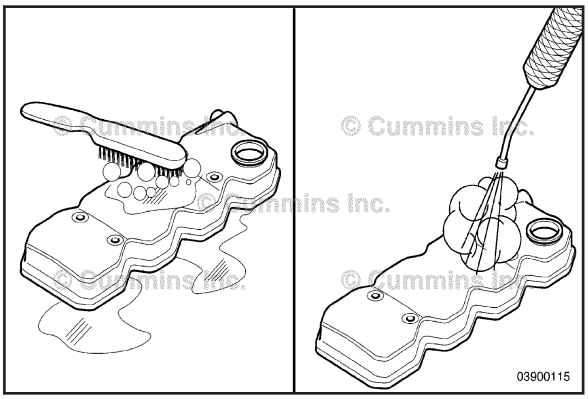
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

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

NOTE: When cleaning the rocker lever cover, if the rocker lever gasket is still installed in the base of the rocker lever cover, do **not** submerge the rocker lever cover in solvent. Limit the amount of exposure the gasket has to solvent. The gasket is reusable. Once the gasket is removed from the rocker lever cover it **must** be replaced.

Clean the rocker lever cover with solvent. Dry with compressed air.

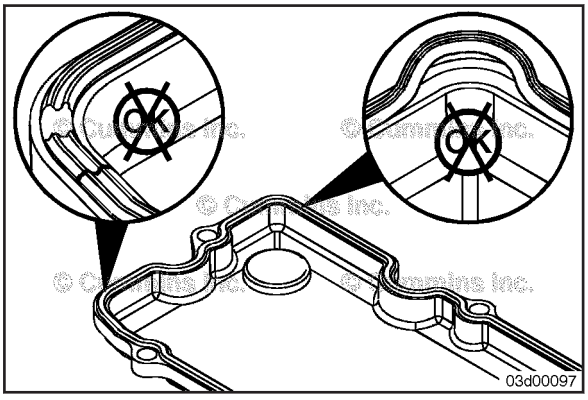


NOTE: Check the gasket while it is installed in the valve cover. Once the gasket is removed from the cover it **must** be replaced.

Check the gasket for cracks on the sealing surface.

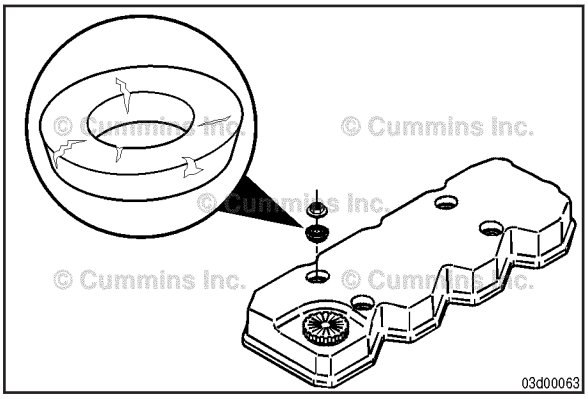
Replace the gasket if damage is present.

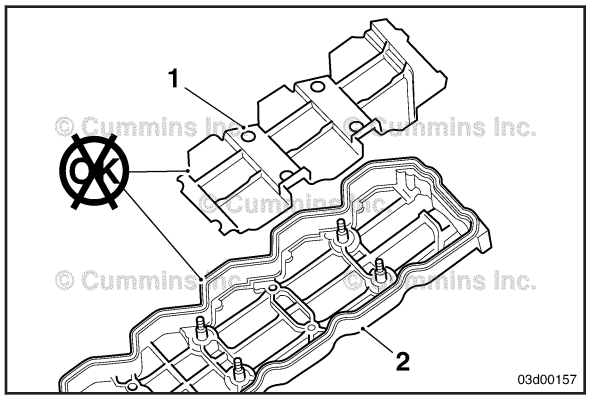
Replace the gasket if it is removed from the groove in the rocker lever cover.



Inspect the rubber isolators for cracks.

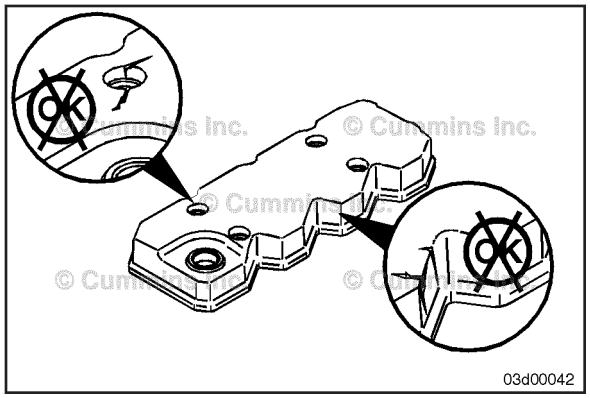
Replace if cracked or broken.





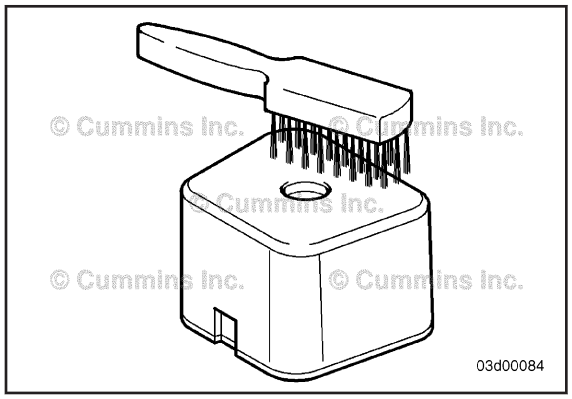
⚠CAUTION⚠
On engines equipped with an internal breather baffle (1), do not remove the baffle. Removal of the internal breather baffle mounting fasteners may damage the rocker lever cover (2).

It is **not** necessary to remove the baffle. There is no mesh or screening located internal to the breather baffle.



Inspect the rocker lever cover for cracks or other damage.

Replace the rocker lever cover if any damage is found.

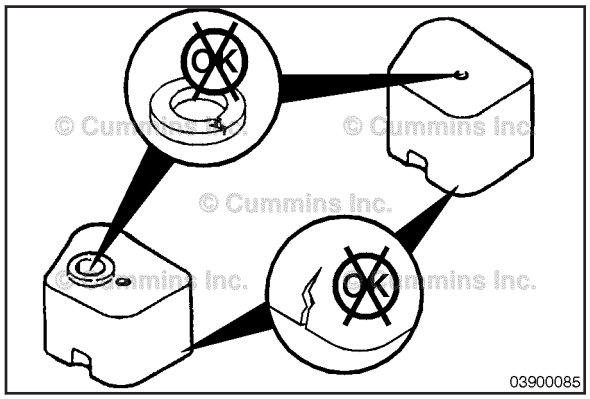


B3.9, B5.9, and B4.5 Engines

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

Clean the rocket lever cover(s) with a strong solution of detergent in hot water.

Dry with compressed air.



Inspect the capscrew seals, rocker lever covers and rocker lever cover gaskets for damage.

Replace any damaged components.

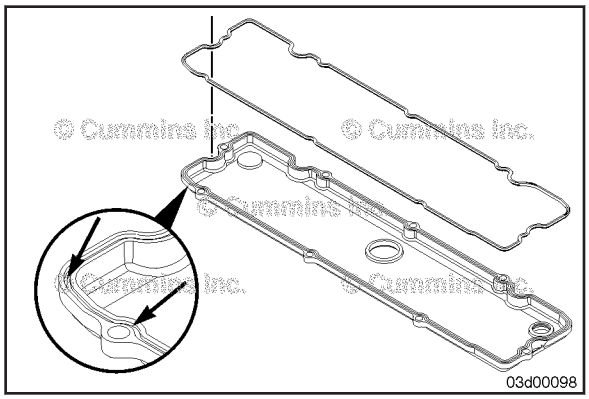
Assemble

B4.5 RGT Engines

NOTE: If the gasket has been removed from the rocker lever cover, a new gasket **must** be used.

If replacing the rocker lever gasket, the following installation procedure must be used when installing the press-in gasket.

1. Press the molded gasket into the corners of the rocker lever cover
2. Press the remaining gasket into the rocker lever cover.



Install

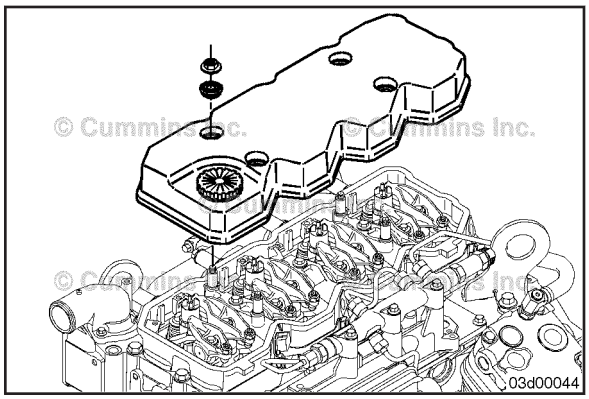
B4.5 RGT Engines

Install the rocker lever cover over the mounting capscrews.

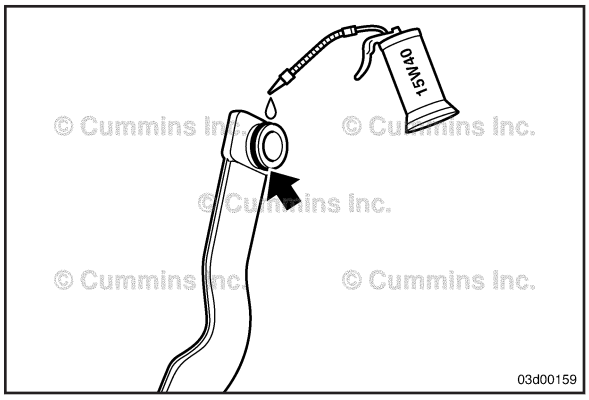
Install the isolators and mounting nuts.

Tighten the mounting nuts.

Torque Value: 24 N•m [18 ft-lb]



Prior to connecting the breather connection tube to the rocker lever cover, apply clean engine oil to the o'ring located on the breather tube connection.



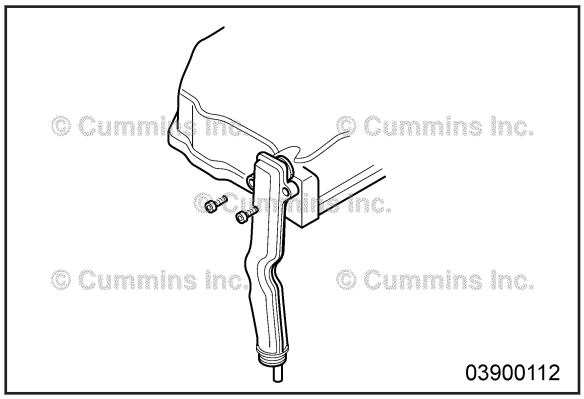
Connect the breather tube connection to the rocker lever cover.

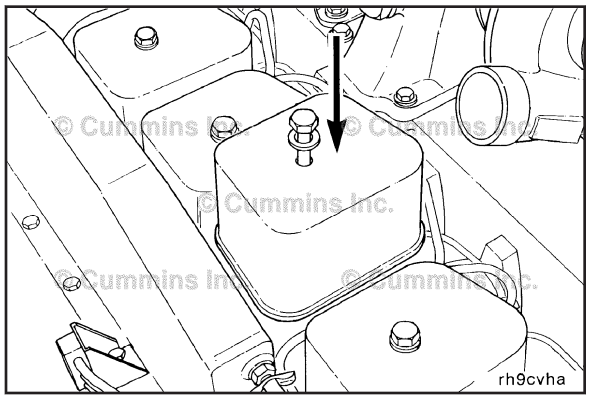
Two capscrews directly mount the breather tube connection to the rocker lever cover. Install the capscrew(s) to connect the breather tube connection to the rocker lever cover.

Tighten the Capscrew(s).

Torque Value: 10 N•m [89 in-lb]

NOTE: Some breather tube connections use internal Torx capscrews to secure the breather tube connection to the rocker lever cover.



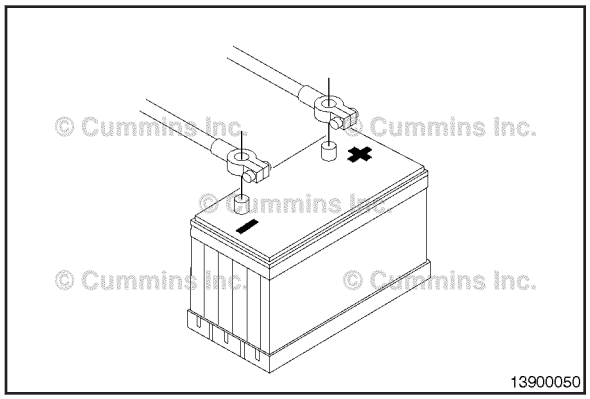


B3.9, B5.9, and B4.5 Engines

Install rocker lever cover(s).

Tighten the capscrews.

Torque Value: 24 mm [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.

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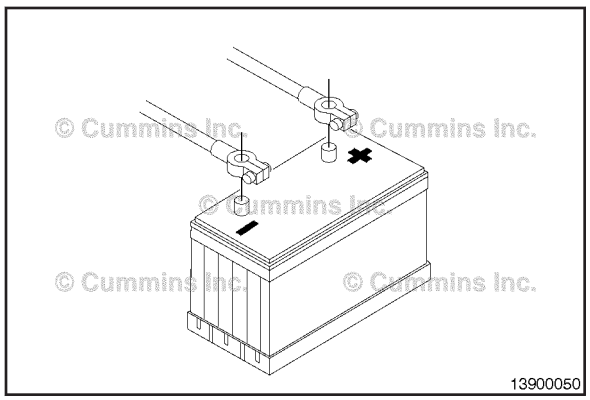
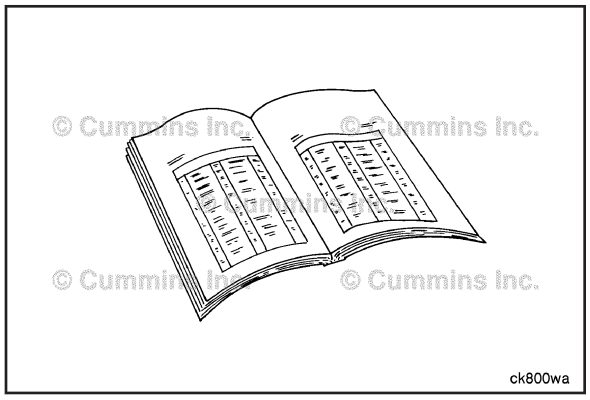


Rocker Lever Housing (003-013)

Preparatory Steps

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

- Disconnect the batteries.



- Remove the rocker lever cover. Refer to Procedure 003-011.

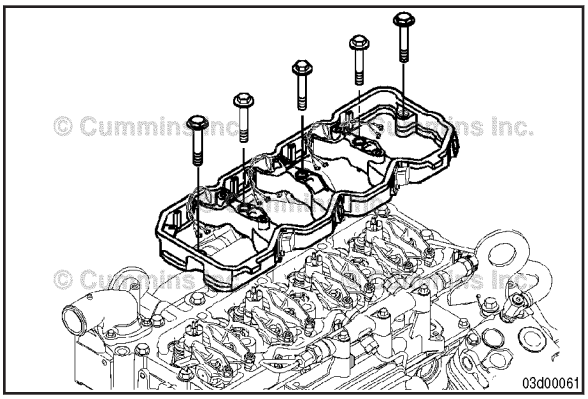
Remove

Rear Gear Train

NOTE: Check the gasket while it is installed in the rocker housing. Once the gasket is removed it **must** be replaced.

NOTE: Check for cracks in the rocker housing bridge area before removing the mounting capscrews.

Remove the rocker housing, capscrews, and gasket.



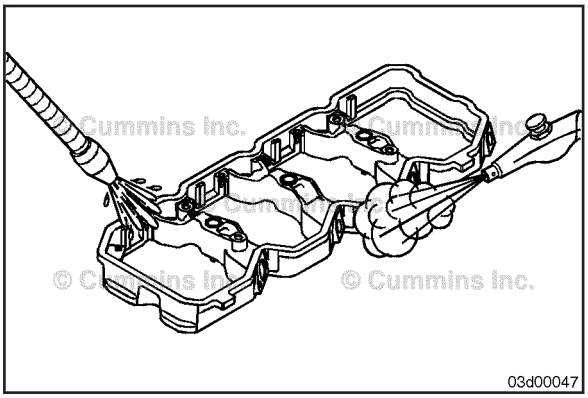
Clean and Inspect for Reuse

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

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

Clean the rocker housing with solvent.

Dry the rocker housing with compressed air.

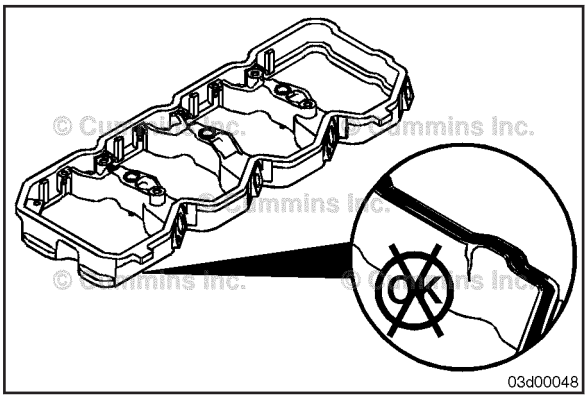


NOTE: Check the gasket while it is installed in the rocker housing. Once it is removed it **must** be replaced.

Inspect the rocker housing for cracks or any other damage, especially on the cylinder head mounting surface.

Check the gasket for cracks or is twisted in the groove.

Replace the gasket if it is torn, if cracks are present or it is twisted in the groove.



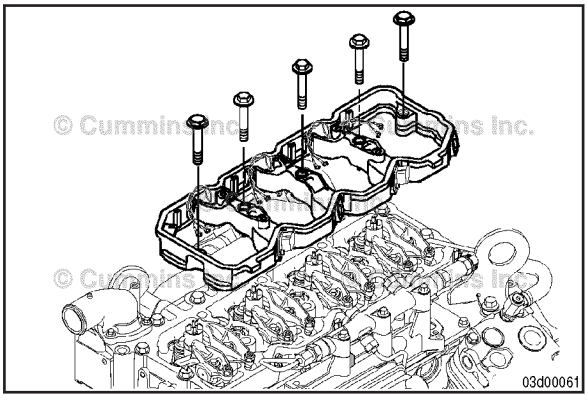
Install

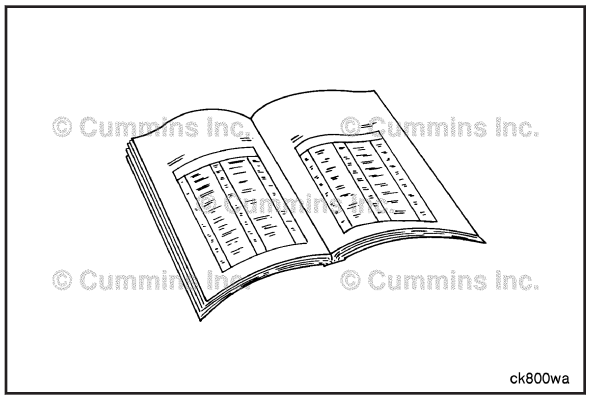
Rear Gear Train

⚠CAUTION⚠
Care must be taken when installing the gasket. Do not twist or stretch it. Failure to do so can result in an oil leak.

Install the rocker housing and a new rocker housing gasket, if removed.

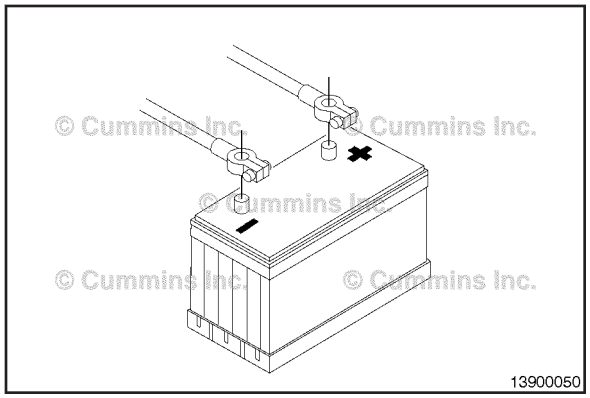
Torque Value: 24 N•m [212 in-lb]





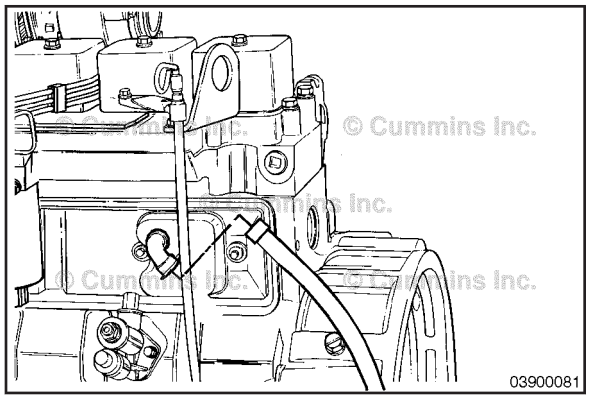
Finishing Steps

- Install the rocker lever cover and gasket. Refer to Procedure 003-011.



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

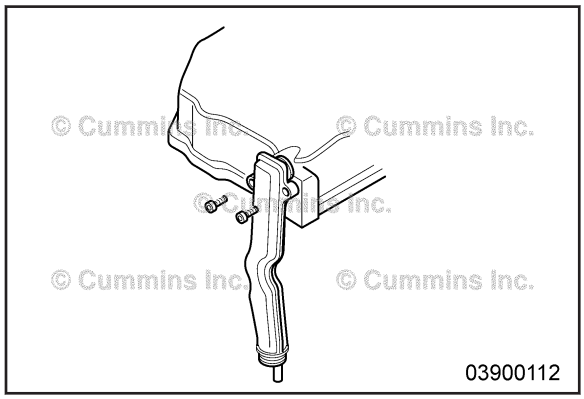


Crankcase Breather Tube (003-018)

Remove

Front Gear Train

Remove the crankcase breather tube from the tappet cover located on side of the engine block.



Rear Gear Train

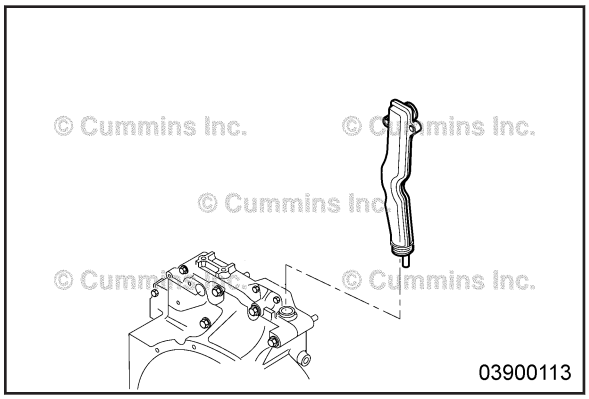
Disconnect the breather tube at the back of the rocker lever cover.

Two capscrews directly mount the breather tube to the rocker lever cover. Remove the capscrews to disconnect the breather tube from the rocker lever cover.

NOTE: Some breather tubes use internal Torx capscrews to secure the breather tube to the rocker lever cover.

Remove the breather tube from the rear gear housing.

NOTE: There is an o-ring sealed connection to the rear gear housing. Remove the breather tube by pulling straight up.



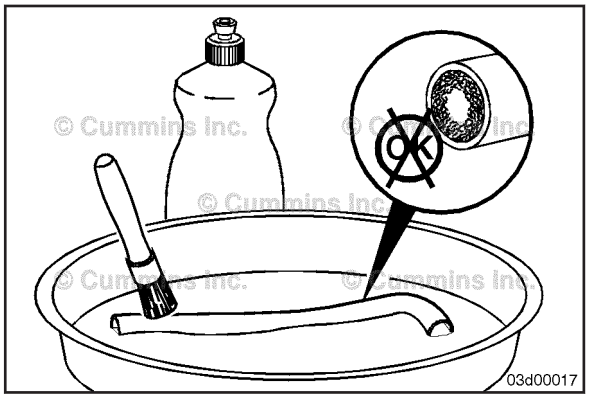
Clean and Inspect for Reuse

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

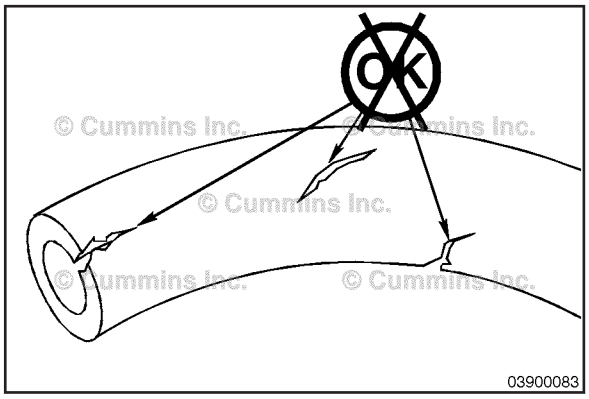
Inspect the crankcase breather tube internally for obstructions or sludge buildup.

If the tube is blocked, the crankcase breather tube **must** be cleaned with a strong solution of detergent or replaced to prevent excess crankcase pressure buildup.

Dry crankcase breather and tube with compressed air.

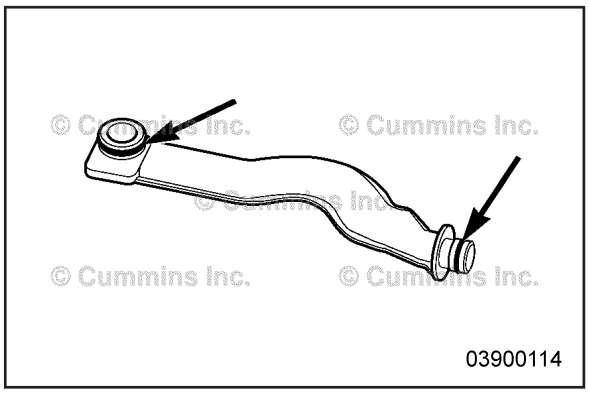


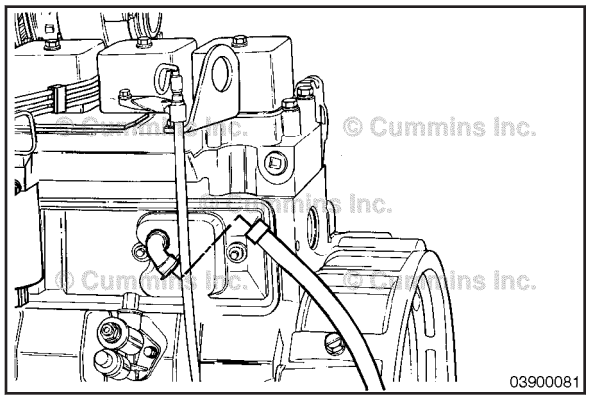
Check the crankcase breather tube for cracks or other debris, which could obstruct the tube.



For rear gear train engines, inspect the o-ring seals on the breather tube.

Make sure to inspect the o-ring for cracks, tears, or brittleness. If any damage is found, replace the o-ring.

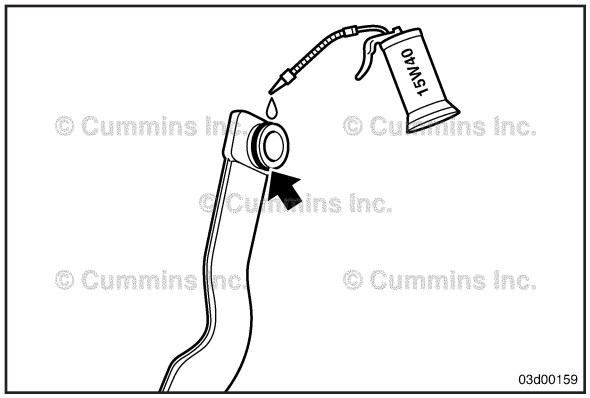




Install

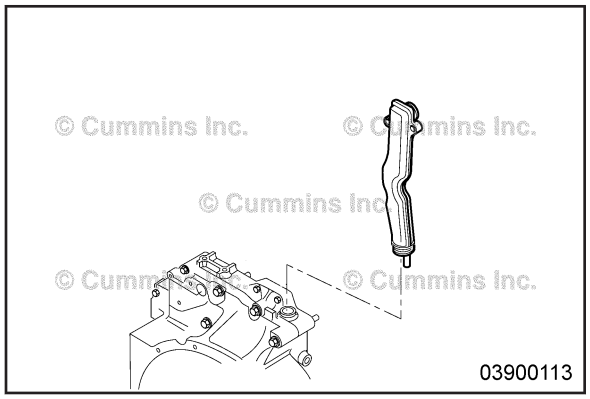
Front Gear Train

Connect the crankcase breather tube to the tappet cover on the side of the cylinder block.

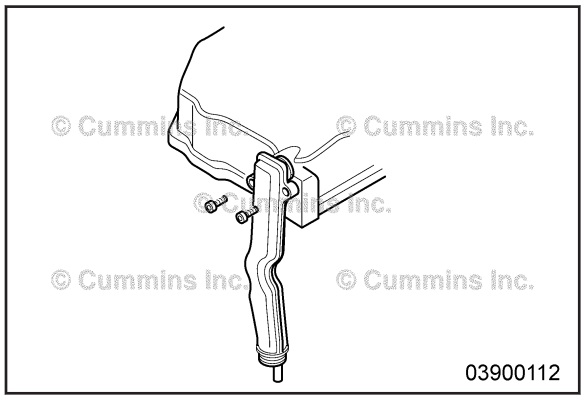


Rear Gear Train

Prior to installing the breather tube, apply engine oil to the o-rings located on the breather tube.



Install the breather tube into the rear gear housing.



Connect the breather tube connection to the rocker lever cover.

Two capscrews directly mount the breather tube to the rocker lever cover. Install the capscrews to connect the breather tube connection to the rocker lever cover.

Tighten the capscrews.

Torque Value: 10 N•m [89 in-lb]

NOTE: Some breather tube connections use internal Torx capscrews to secure the breather tube to the rocker lever cover.

Closed Crankcase Ventilation Valve (003-023)

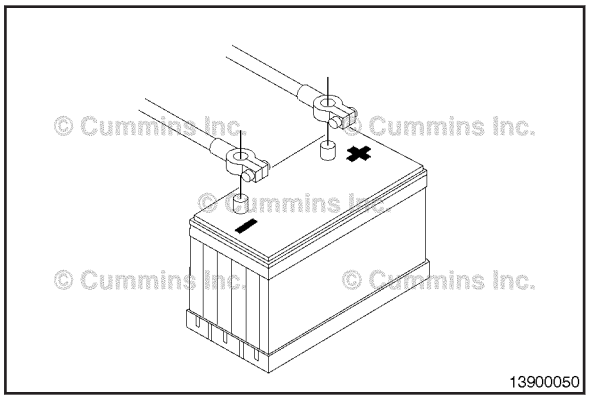
General Information

The closed crankcase ventilation valve is used on engines in which the crankcase gases are vented back into the intake of engine. The purpose of the valve is to aid in regulating crankcase gas flow to the intake of the engine. Under high intake vacuum situations, the closed crankcase ventilation will prevent the engine from syphoning crankcase gases/oil from the crankcase 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.



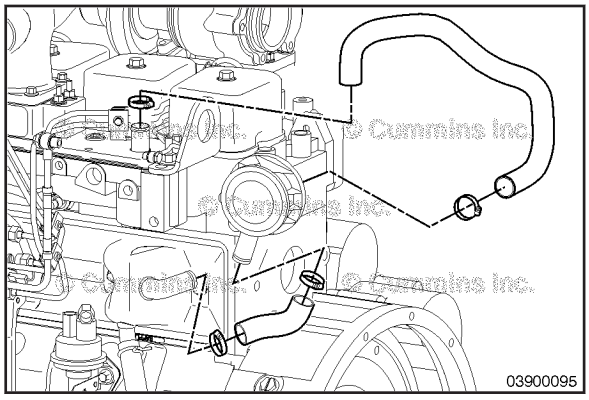
Remove

Front Gear Train

For front gear train engines, the closed crankcase ventilation valve is located between the tappet cover breather and intake manifold/cover of the engine.

The tappet cover closed crankcase ventilation valve is held in place by the molded closed crankcase ventilation hoses.

Removing the hoses will remove the valve.

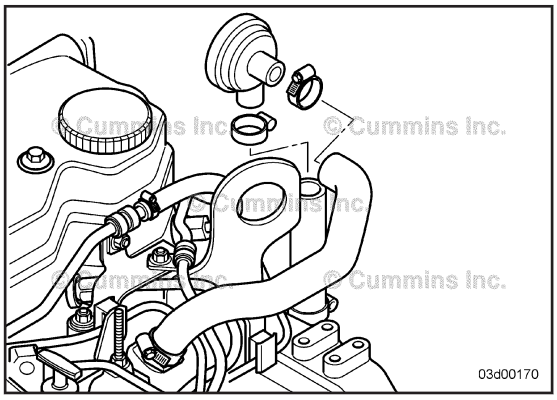


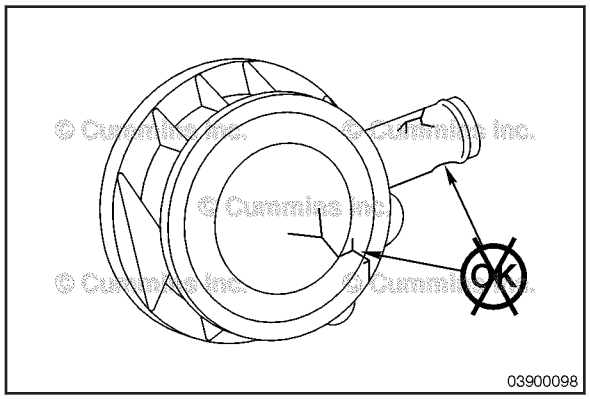
Rear Gear Train

For rear gear train engines, the closed crankcase ventilation valve is connected between the flywheel housing and intake manifold/cover of the engine.

The tappet cover closed crankcase ventilation valve is held in place by the molded closed crankcase ventilation hoses.

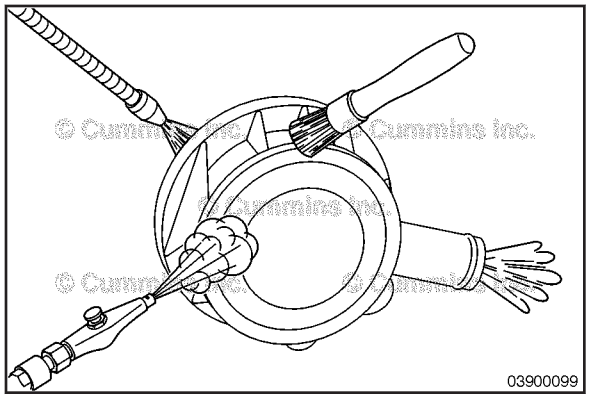
Removing the hoses will remove the valve.





Clean and Inspect for Reuse

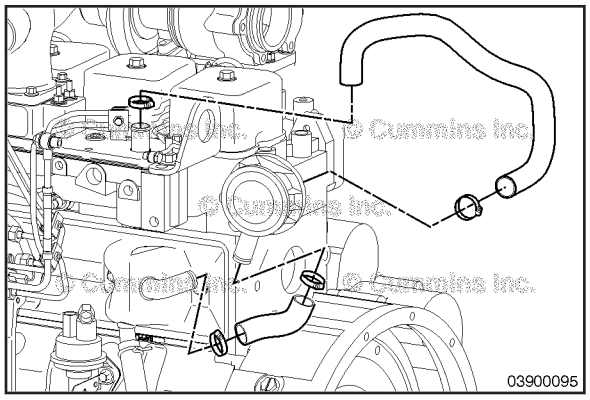
Inspect the valve for signs of damage or obstruction.



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

If the valve is obstructed it **must** be cleaned with a solution of detergent or replaced to prevent excessive crankcase pressure buildup.

Dry components with compressed air.

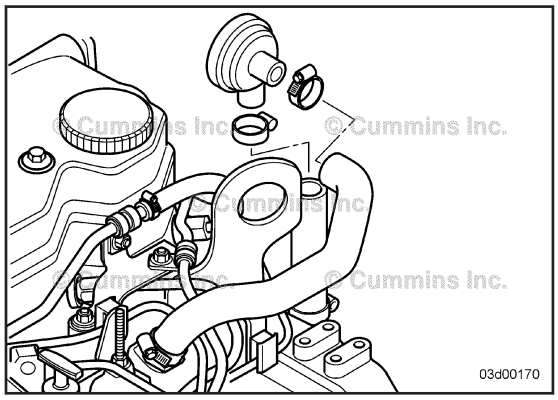


Install

Front Gear Train

Connect the tappet cover closed crankcase ventilation valve to the closed crankcase ventilation hoses and tighten the hose clamps.

Torque Value: 8 N•m [71 in-lb]



Rear Gear Train

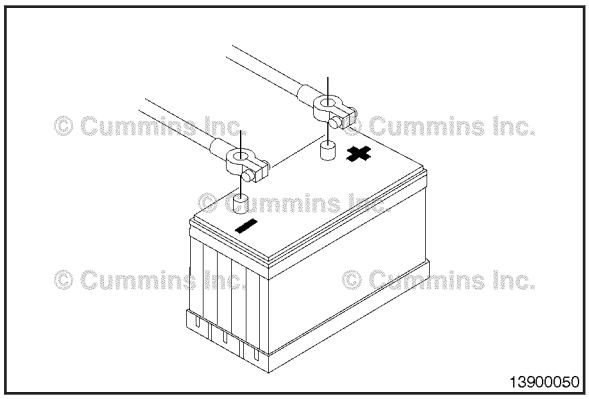
Connect the closed crankcase ventilation valve to the closed crankcase ventilation hoses and secure the hose clamps.

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.

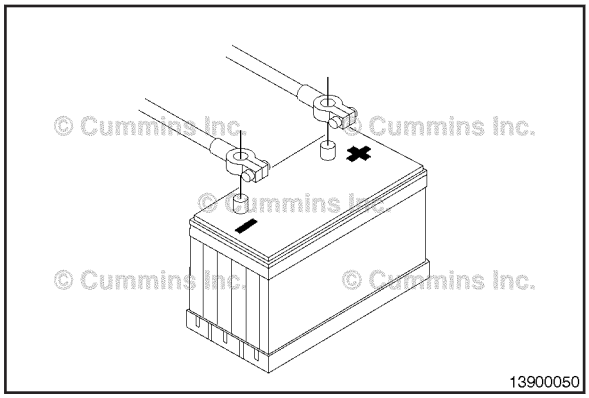


Closed Crankcase Ventilation Hoses (003-024)

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

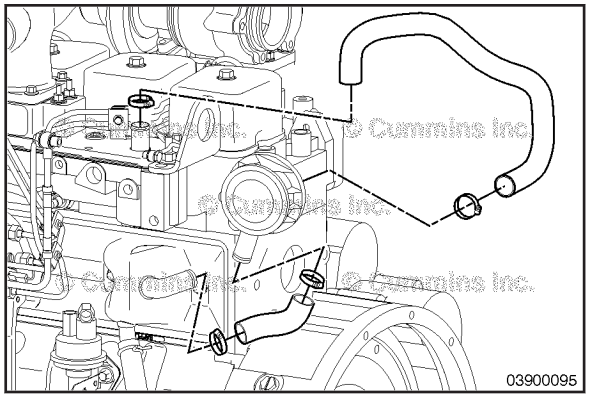
Front Gear Train

For front gear train engines, the closed crankcase ventilation valve is located between the tappet cover breather and intake manifold/cover of the engine.

The tappet cover closed crankcase ventilation valve is held in place by the molded closed crankcase ventilation hoses.

NOTE: Disconnecting and removing the hoses will also remove the valve.

Disconnect and remove the molded closed crankcase ventilation hoses and crankcase ventilation valve.



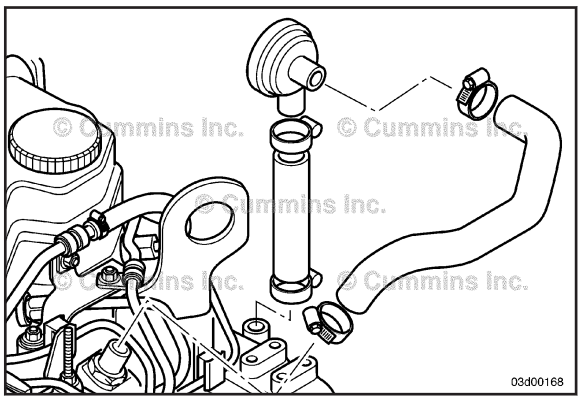
Rear Gear Train

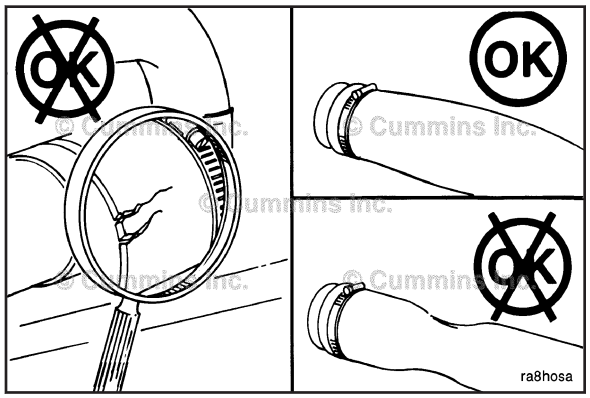
For rear gear train engines, the closed crankcase ventilation valve is connected between the flywheel housing and intake manifold/cover of the engine.

The tappet cover closed crankcase ventilation valve is held in place by the molded closed crankcase ventilation hoses.

NOTE: Disconnecting and removing the hoses will also remove the valve.

Disconnect and remove the molded closed crankcase ventilation hoses and crankcase ventilation valve.

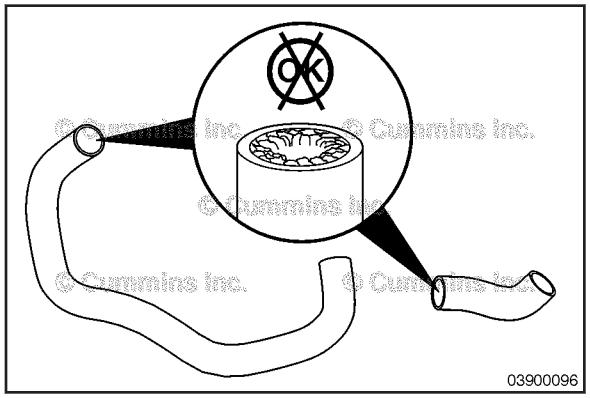




Clean and Inspect for Reuse

Inspect the hoses for cracks, cuts, or collapsing.

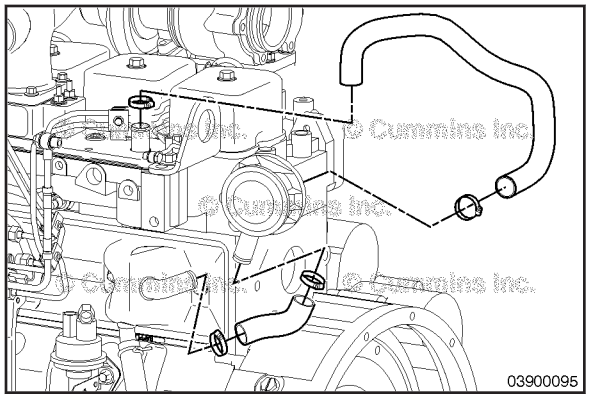
Inspect for debris or obstructions.



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

If the hoses are blocked they **must** be cleaned with a strong solution of detergent or replace to prevent excessive crankcase pressure buildup.

Dry components with compressed air.



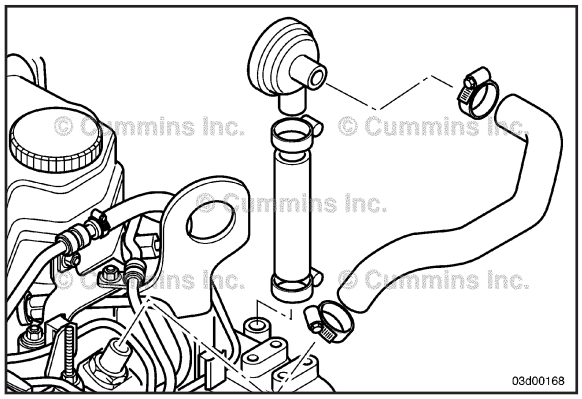
Install

Front Gear Train

Install the closed crankcase ventilation hoses and valve.

Tighten the hose clamps.

Torque Value: 8 N•m [71 in-lb]



Rear Gear Train

Install the closed crankcase ventilation hoses and valve.

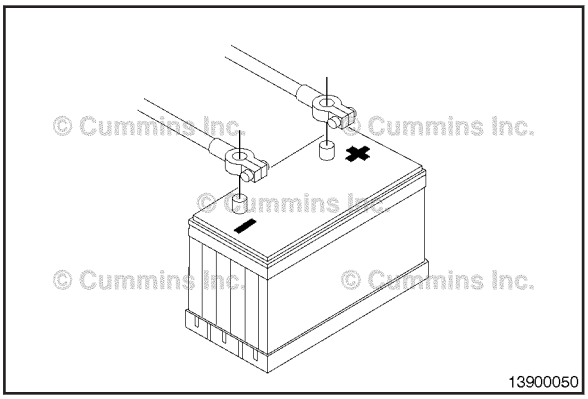
Secure the hose clamps.

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.



Notes

Section 4 - Cam Followers/Tappets - Group 04

Section Contents

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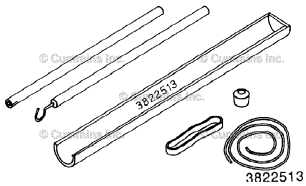
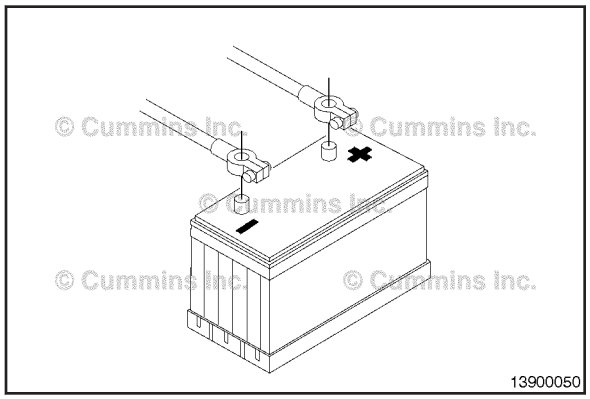
Service Tools

Cam Followers/Tappets

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

Tool No.	Tool Description	Tool Illustration
3822513	**Tappet Removal Tool Kit** Used to remove and install valve tappets.	

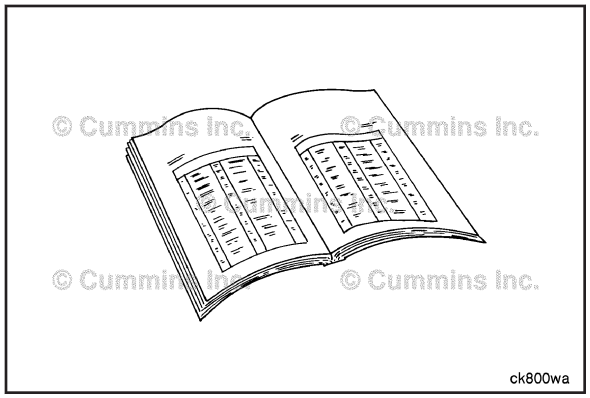


Push Rods or Tubes (004-014)

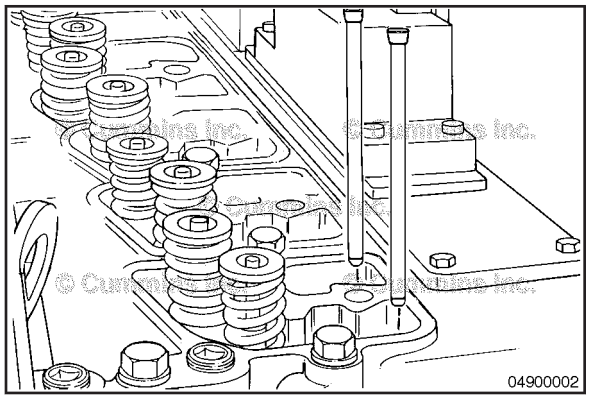
Preparatory Steps

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

- Disconnect the batteries.



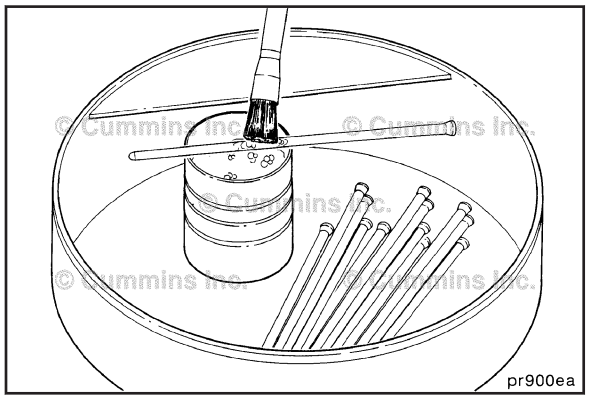
- Remove the rocker lever cover(s). Refer to Procedure 003-011.
- Remove the rocker levers. Refer to Procedure 003-008.



Remove

Remove the push rods.

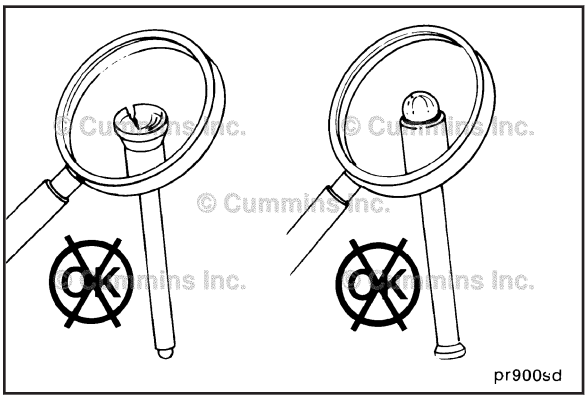
NOTE: Mark the push rods to identify their location.



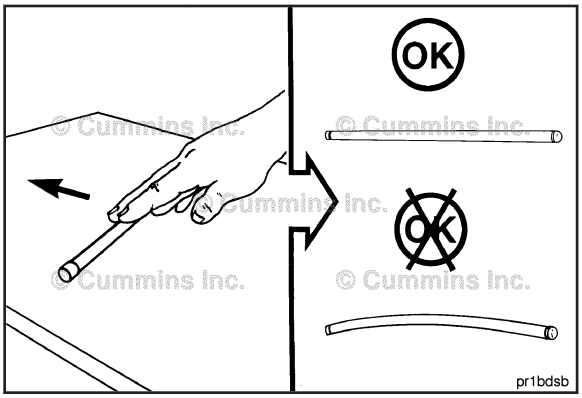
Clean and Inspect for Reuse

Clean the push rods in hot, soapy water.

Inspect the push rods ball and socket for signs of scoring. Check for cracks where the ball and the socket are pressed into the rod.



Check the push rods for roundness and straightness.

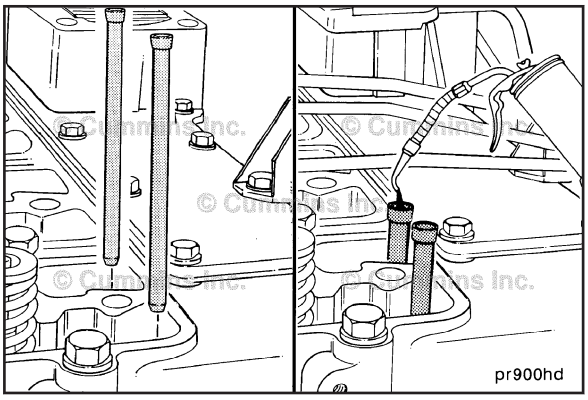


Install

Install the push rods into the sockets of the valve tappets.

Lubricate the push rods sockets with clean lubricating engine oil.

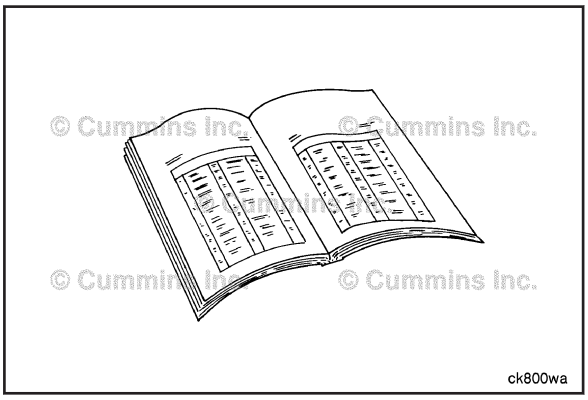
NOTE: The push rods and tappets **must** be installed in the same cylinder and intake or exhaust position from which they were removed.

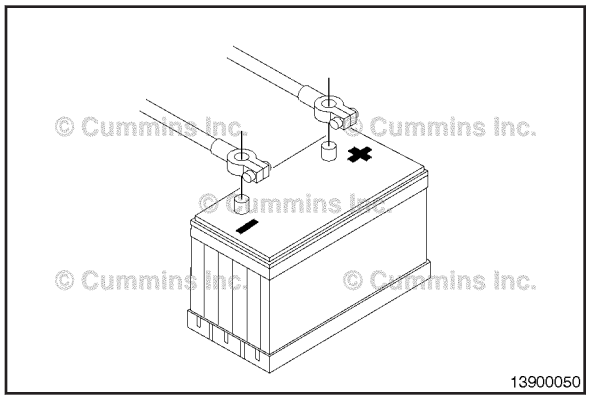


Finishing Steps

NOTE: Make sure the rocker lever adjusting screws are completely backed out.

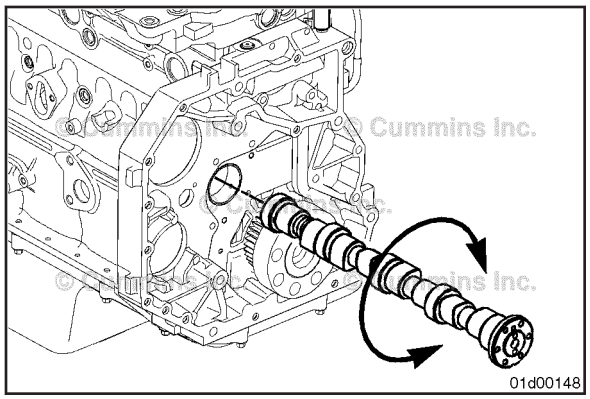
- Install the rocker levers. Refer to Procedure 003-008
- Adjust the valves. Refer to Procedure 003-004
- Install the rocker lever cover(s) and gasket(s). Refer to Procedure 003-011.





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

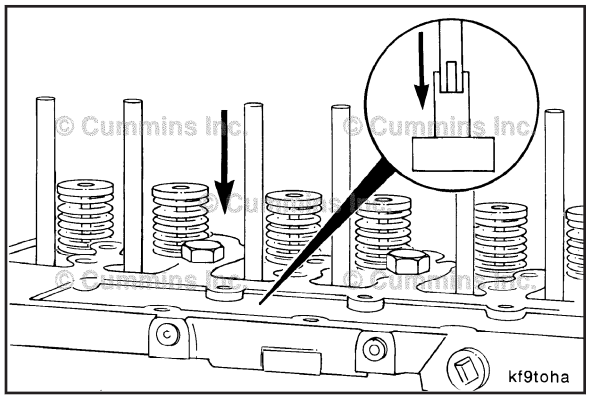


Tappet (004-015)

General Information

In order to remove the tappets from the engine, it is first necessary to start the removal process of the camshaft. Refer to the preparatory steps of the camshaft Procedure 001-008, before following this procedure.

NOTE: Some of the graphics shown in this procedure are for rear gear train engines. However, the remove and install steps are the same for both rear gear train engines and front gear train engines.

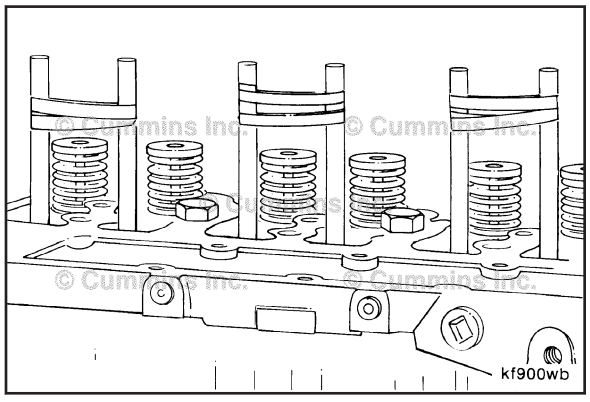


Remove

Use tappet removal tool kit, Part Number 3822513, to remove the tappets.

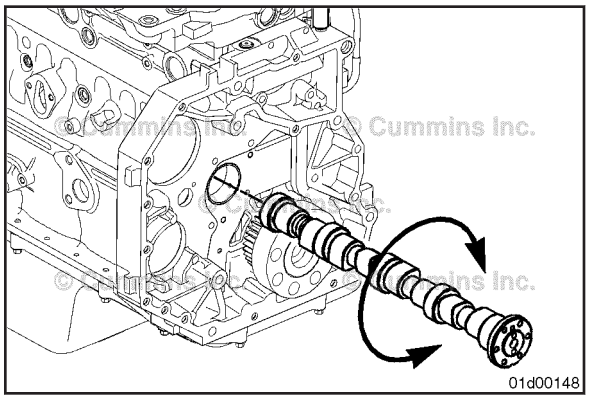
Push a wooden dowel rod into each tappet. It will probably be necessary to push the dowel into the tappet with a soft-face hammer.

NOTE: When properly installed, the dowels can be used to pull the tappets up and should require considerable effort to be pulled out.



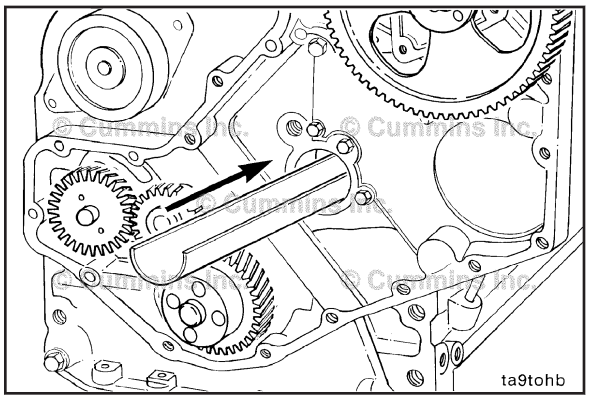
Pull each valve tappet up until it makes contact with the cylinder block. Put a rubber band around two dowels. This will hold the tappets up off the camshaft.

Remove the camshaft. Refer to Procedure 001-008.



Insert the trough from the tappet replacement kit, Part Number 3822513, to the full length of the cam bore.

NOTE: Make sure the trough is positioned so that it will catch the tappet when the wooden dowel is removed.

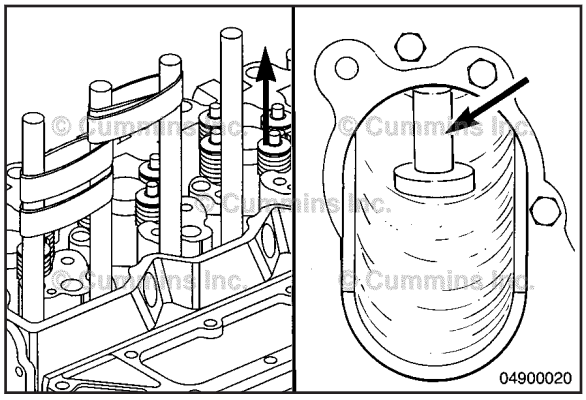


Only remove one tappet at a time.

Mark the position of the tappets as they are removed. The tappets **must** be installed in the same position when the engine is assembled.

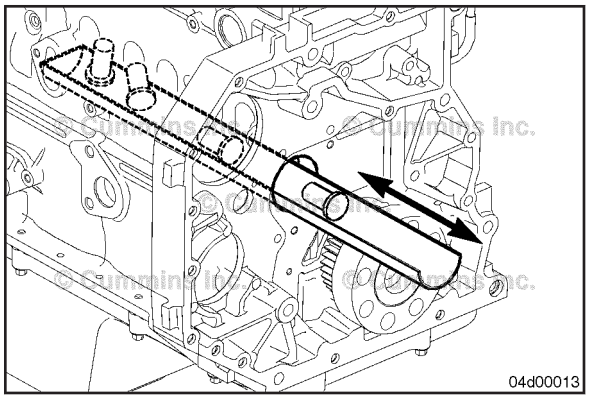
Remove the rubber band from the two companion tappets.

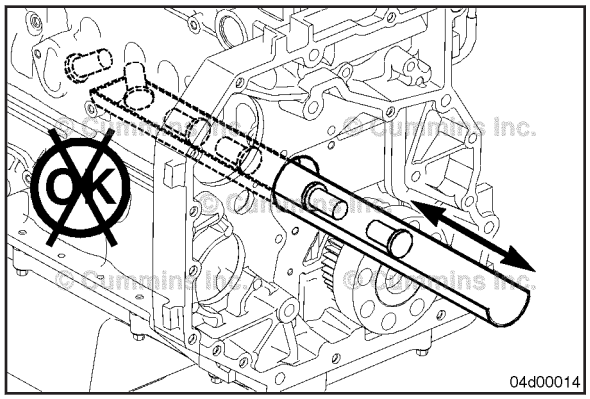
Secure the tappet that is **not** to be removed with the rubber band.



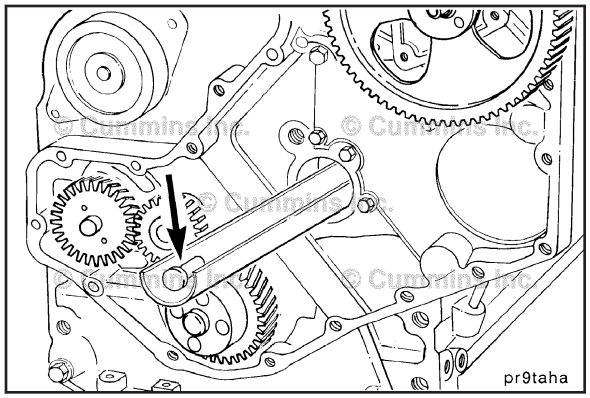
NOTE: When the tappet is dropped into the trough, most of the time it will fall over. However, if it does **not**, gently shake the trough just enough to allow the tappet to fall over before removing.

Pull the wooden dowel from the tappet bore, allowing the tappet to fall into the trough.

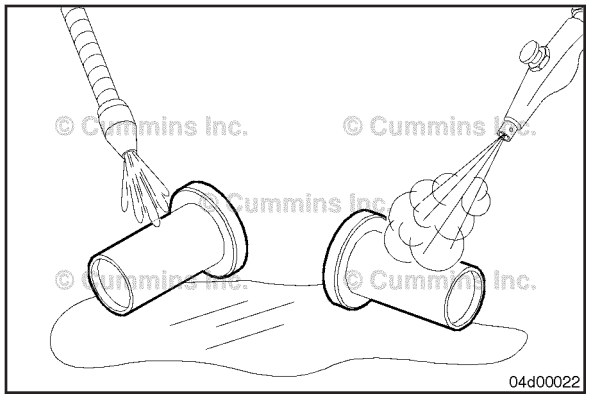




Take special care **not** to knock or shake the tappets over the end of the trough.



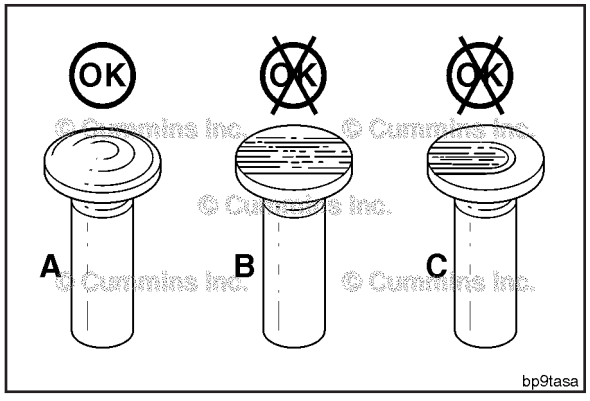
Carefully pull the trough and tappet from the cam bore, and remove the tappet. Repeat the process until all tappets are removed.



Clean and Inspect for Reuse

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

Clean the tappets with solvent.



Inspect the socket, stem, and face for excessive wear, cracks, and other damage.

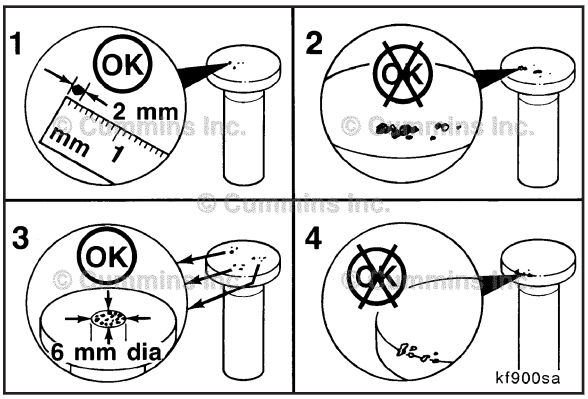
A. Normal contact (exaggerated)
B. Irregular contact - do **not** reuse
C. Irregular contact - do **not** reuse.

Pit marks on the tappet face are acceptable.

The following criteria define the size of the pits allowed.

- A single pit can **not** be greater than 2 mm [0.079 in].
- Interconnection of pits is **not** allowed.
- Total pits when added together should **not** exceed 6-mm [0.236-in] diameter or a total of 4 percent of the tappet face.
- No pitting is allowed on the edges of the wear face of the tappet.

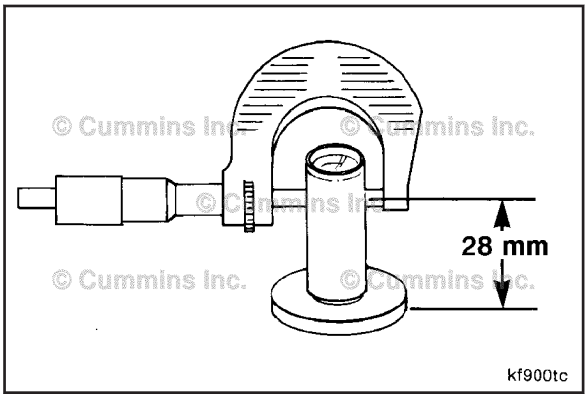
For detailed illustrations and reuse guidelines, refer to Service Bulletin 3666475, Camshaft and Tappet Reuse Guidelines.



Measure the valve tappet stem.

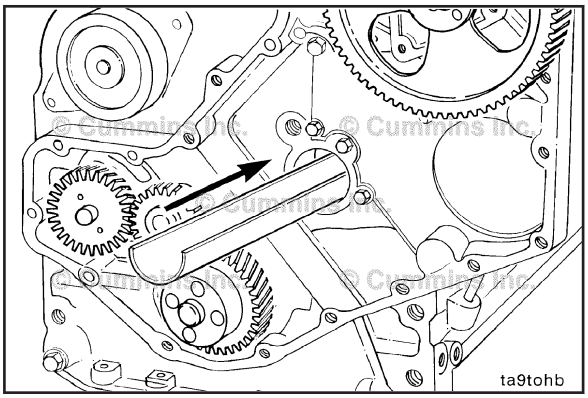
Valve Tappet Stem Diameter		
mm		**in**
15.936	MIN	0.627
15.977	MAX	0.629

If the tappet stem is **not** within specifications, replace the tappet. Make sure to inspect the tappet bore for wear. Refer to Procedure 001-026.

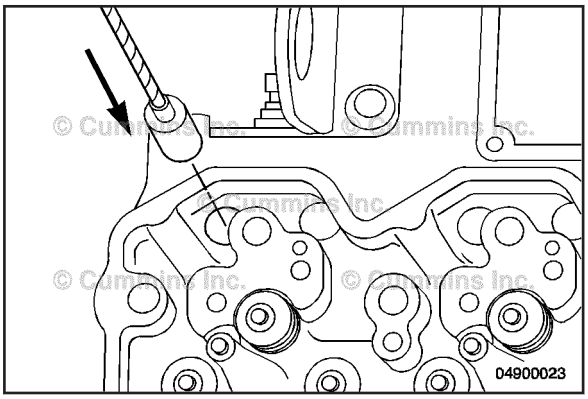


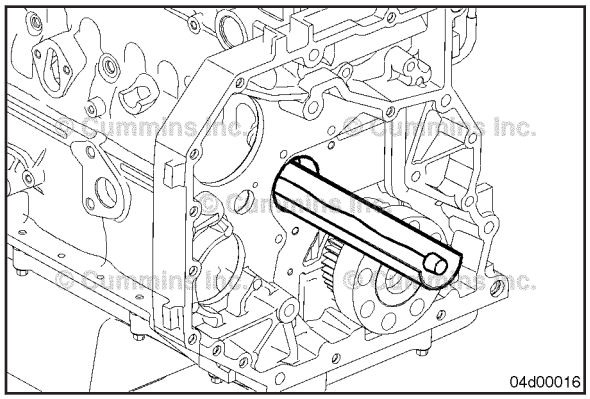
Install

Insert the trough from the tappet replacement kit, Part Number 3822513, the full length of the cam bore.

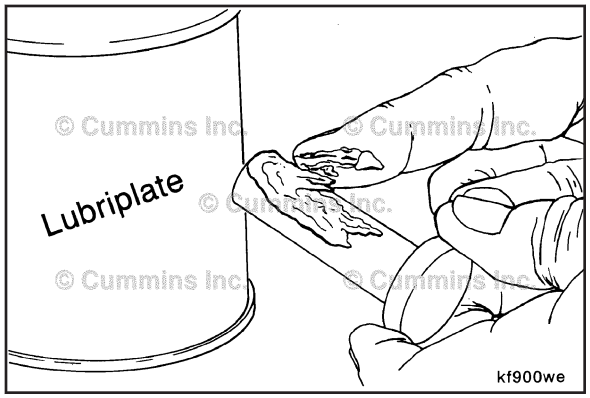


Lower the tappet installation tool down through the push tube hole, through the tappet bore, and into the trough.

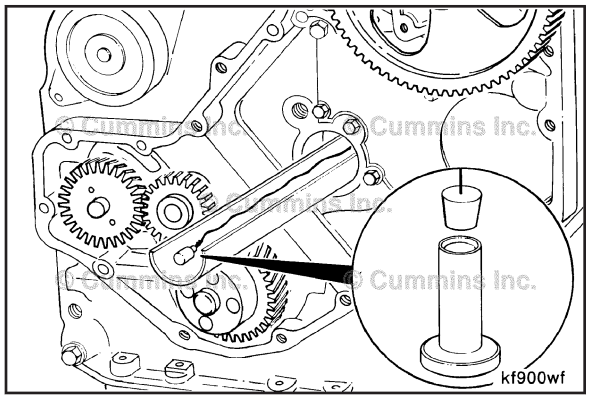




Feed the installation tool through the cam bores by carefully pulling the trough/installation tool out the front of the engine. The barrier at the rear of the trough will pull the tool out **most** of the time.

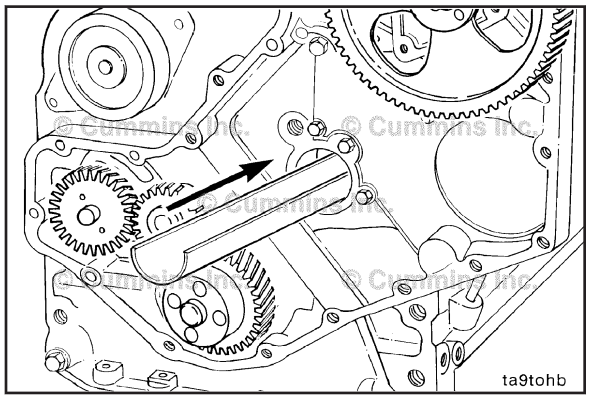


Lubricate the tappets with assembly lubricant, Part Number 3163087, or equivalent.



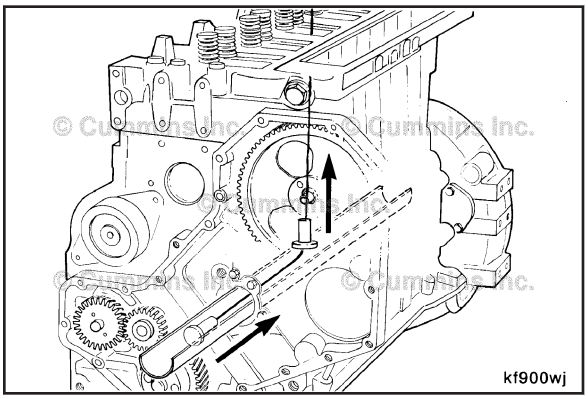
To aid in removing the installation tool after the tappet is installed, work the tool in and out of the tappet several times **before** installing the tappets.

Insert the installation tool into the tappet.



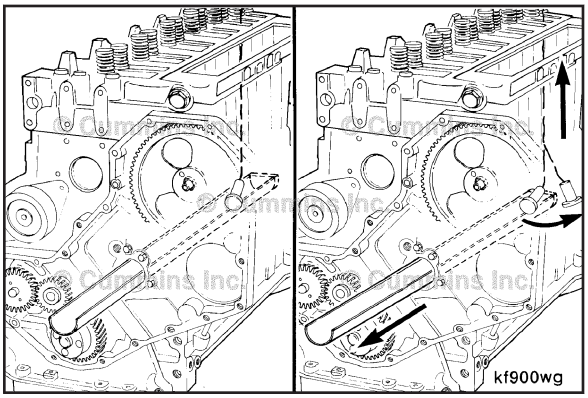
Slide the trough into the cam bore.

Pull the tool and tappet through the cam bore and up into the tappet bore.

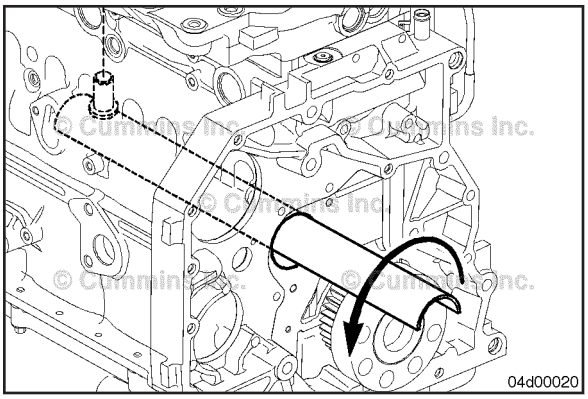


If difficulty is experienced in getting the tappet to make the bend from the trough up to the tappet bore, pull the trough out enough to allow the tappet to drop down and align itself.

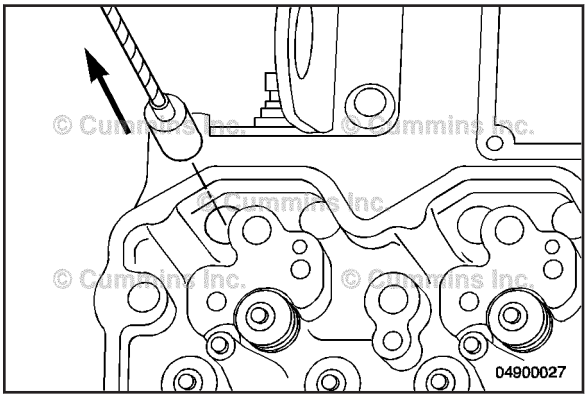
Pull the tappet up into the bore.

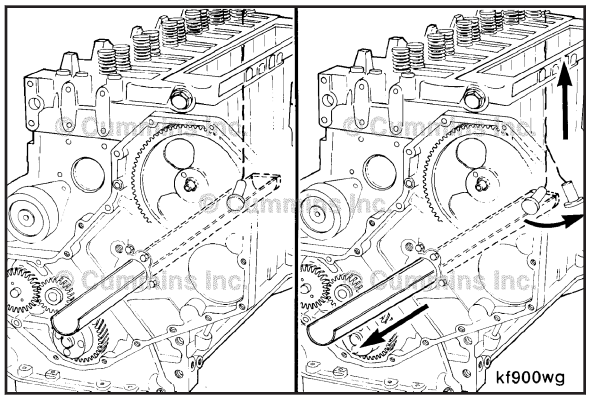


After the tappet has been pulled up into position, slide the trough back into the cam bore, and rotate it ½ of a turn. This will position the round side of the trough up, which will hold the tappet in place.



Remove the installation tool from the tappet.

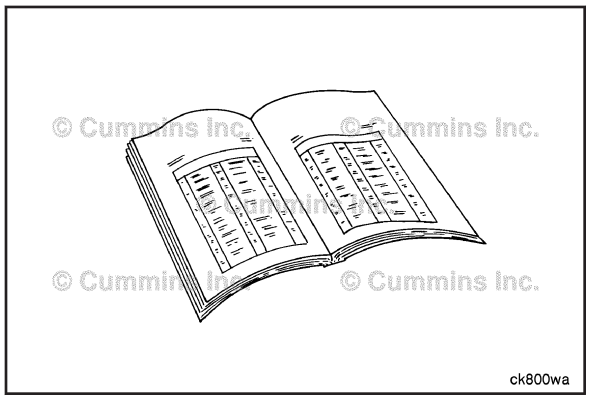




Install a wooden dowel into the top of the tappet.

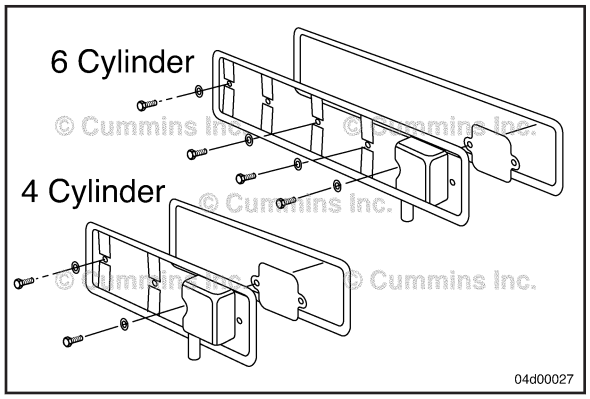
Wrap rubber bands around the wooden dowels to secure the tappets.

Repeat this process until all tappets have been installed.



Finishing Steps

- Install the camshaft. Refer to Procedure 001-008.



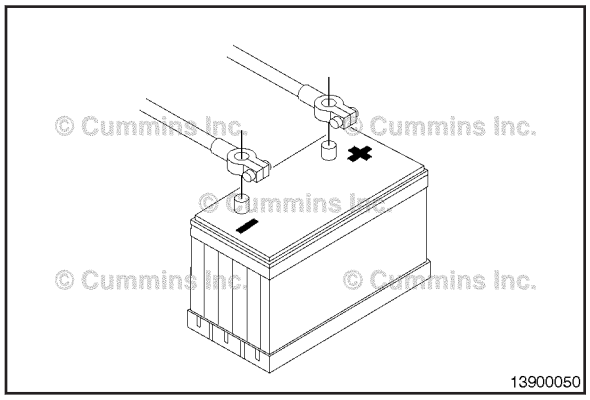
Tappet Cover (004-017)

General Information

The tappet cover is located on the intake side of the engine. For some engines, the tappet cover also contains the crankcase breather.

Removing the tappet cover will **not** allow for removal of the tappets. The tappets **must** be removed through the bottom of the engine with the lubricating oil pan removed.

NOTE: Rear Gear Train engines do **not** have a tappet cover.

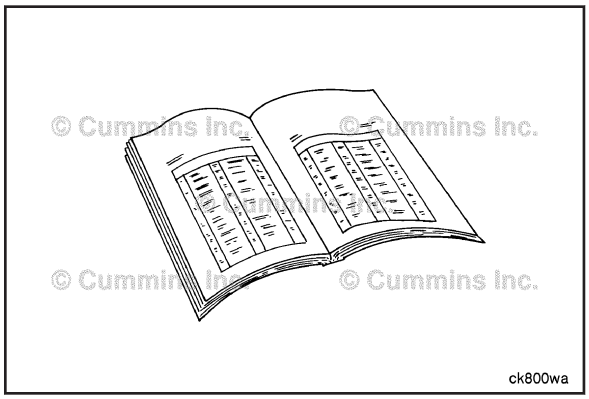


Preparatory Steps

⚠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.

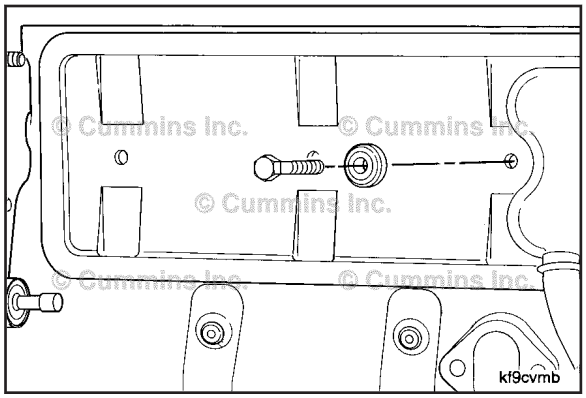
- Disconnect the batteries.

- If required, remove the fuel filter(s). Refer to Procedure 006-015
- If required, remove the fuel drain line. Refer to Procedure 006-021
- Remove the fuel injection pump. For rotary fuel injection pumps refer to Procedure 005-014. For inline fuel injection pumps refer to Procedure 005-012
- For open crankcase systems, disconnect and remove the crankcase breather tube. Refer to Procedure 003-018
- For closed crankcase system, disconnect the closed crankcase ventilation hoses. Refer to Procedure 003-024.



Remove

Remove the tappet cover, mounting capscrews, sealing washers, 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.

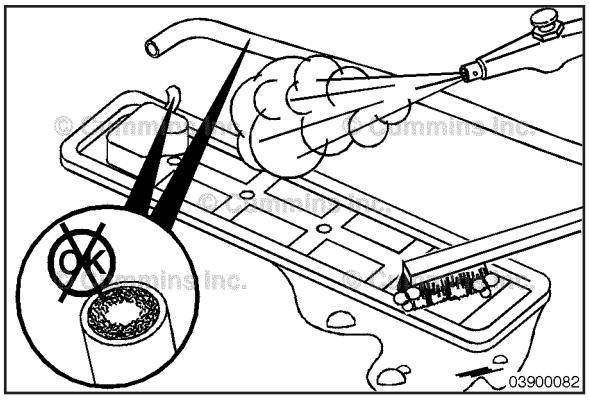
Clean the tappet cover and crankcase breather tube in a solution of detergent in hot water.

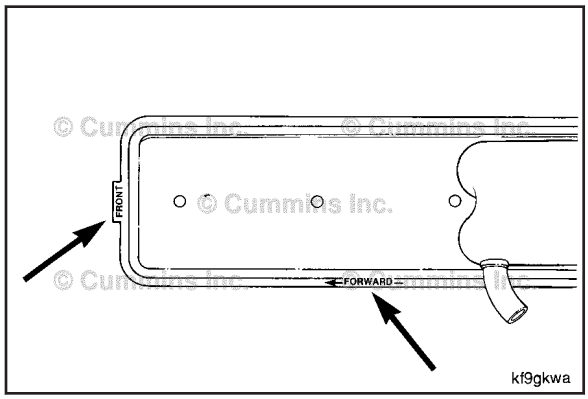
Dry the tappet cover and tube with compressed air.

Inspect the tappet cover/crankcase breather and tube internally for obstructions or sludge buildup.

If the tappet cover/crankcase breather and/or tube is blocked, the tappet cover/crankcase breather and/or tube **must** be cleaned with a strong solution of detergent or replaced to prevent excess crankcase pressure buildup.

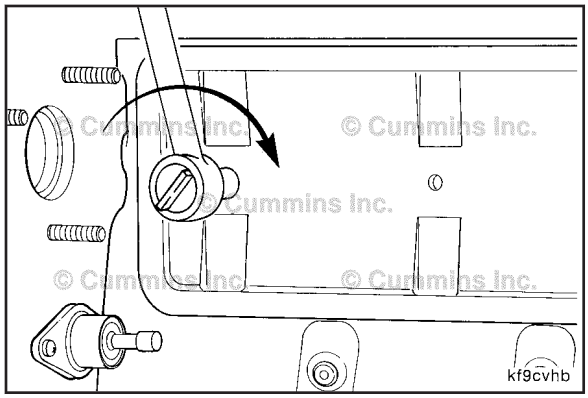
Dry tappet cover/crankcase breather and tube with compressed air.





Install

Install the tappet cover gasket onto the tappet cover. The tappet cover gasket **must** be installed as shown in the illustration.

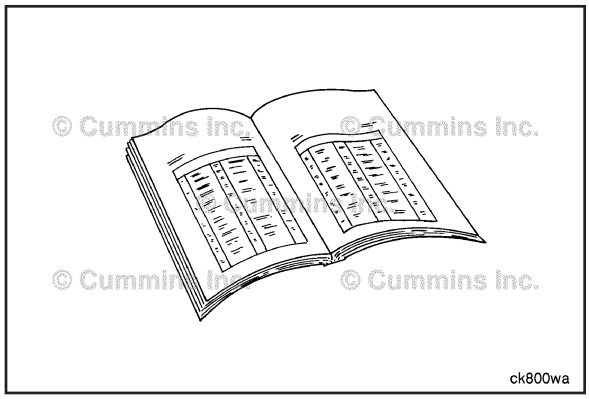


Install the tappet cover, gasket, sealing washers and mounting capscrews onto the engine block.

NOTE: Some of the tappet cover mounting capscrews also secure the fuel drain. It may be necessary to install the remaining mounting capscrews when the fuel drain is installed.

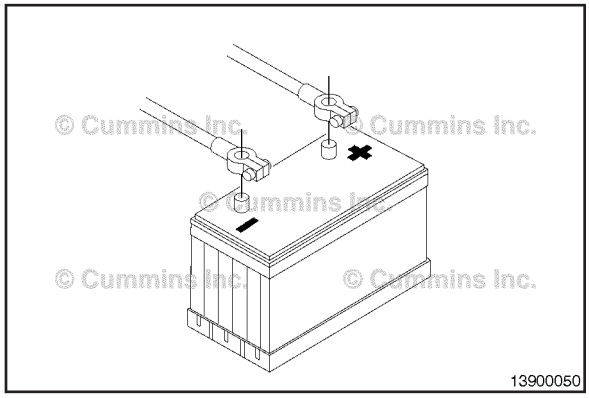
Tighten the tappet cover mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]



Finishing Steps

- For closed crankcase system, connect the closed crankcase ventilation hoses. Refer to Procedure 003-024
- For open crankcase systems, connect and install the crankcase breather tube. Refer to Procedure 003-018
- Install the fuel injection pump. For rotary fuel injection pumps refer to Procedure 005-014. For inline fuel injection pumps refer to Procedure 005-012
- If removed, install the fuel drain line. Refer to Procedure 006-021
- If removed, install the fuel filter(s). Refer to Procedure 006-015.



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

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