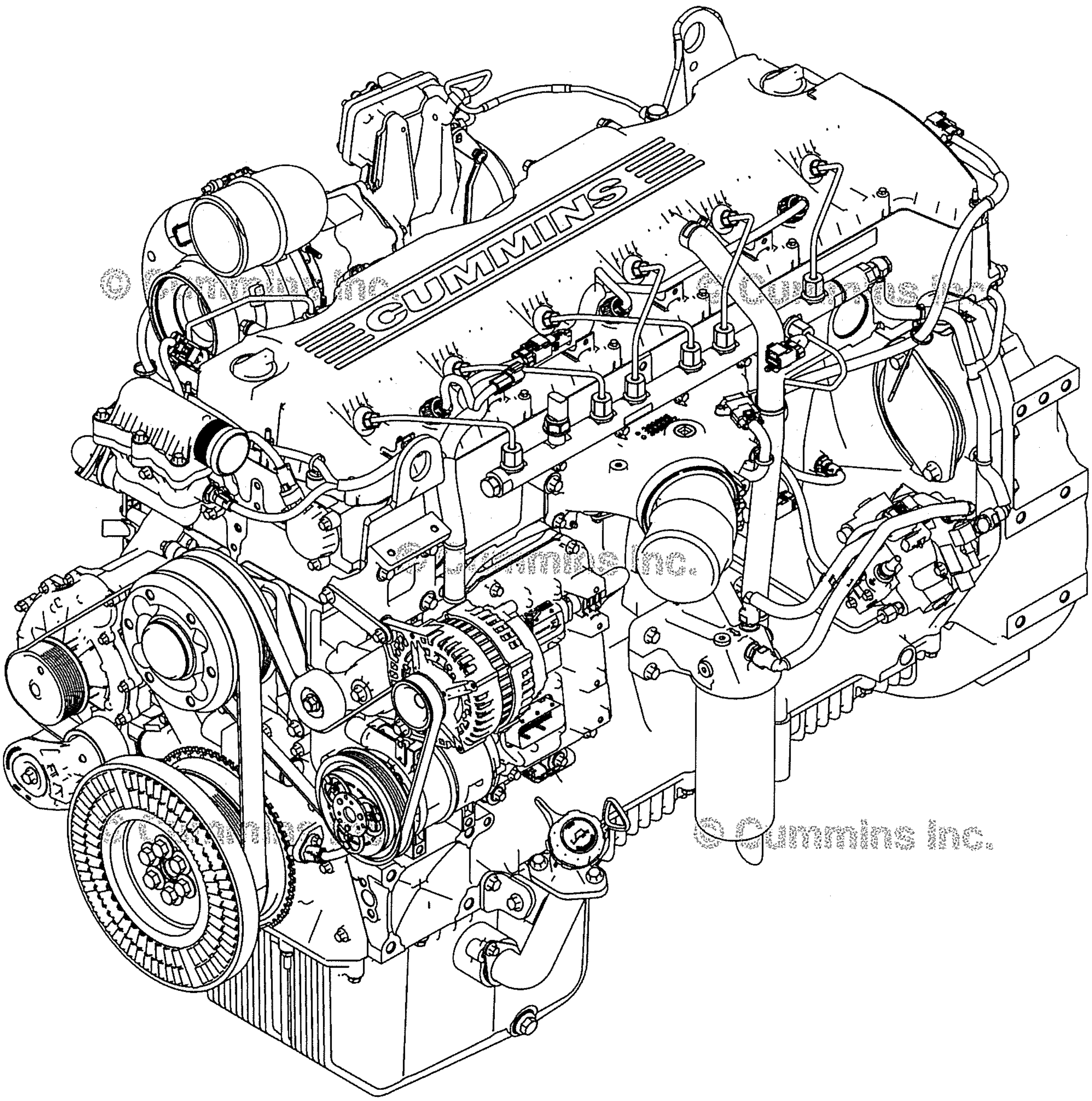
Service Manual
QSG12 CM2350 G110
Volume 1



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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

Introduction	i
System Identification	E
Familiarization	F
Troubleshooting Symptoms	TS
Troubleshooting Symptoms (New Format)	TT
Engine Disassembly - Group 00	DS
Engine Assembly - Group 00	AS
Product - Group 00	0
Cylinder Block - Group 01	1
Cylinder Head - Group 02	2
Rocker Levers - Group 03	3
Fuel System - Group 05	5
Back	back

Section i - Introduction

Section Contents

Page
About the Manual ... i-1
About ... i-1
General Information ... i-1
Acronyms and Abbreviations ... i-27
General Information ... i-27
General Cleaning Instructions ... i-22
Abrasive Pads and Abrasive Paper ... i-22
Definition of Clean ... i-22
Fuel System ... i-25
Gasket Surfaces ... i-23
Plastic Bead Cleaning ... i-24
Solvent and Acid Cleaning ... i-23
Steam Cleaning ... i-24
General Repair Instructions ... i-20
General Information ... i-20
Welding on a Vehicle with an Electronic Controlled Fuel System ... i-21
General Safety Instructions ... i-8
Aftertreatment ... i-13
Best Practices ... i-8
Common Hazards ... i-16
Common Substances ... i-14
Electrical Components ... i-16
Fuels ... i-10
Hazardous Substances ... i-15
Important Safety Notice ... i-8
Job Safety Assessment ... i-17
Personal Protective Equipment (PPE) ... i-9
Power Generation Applications ... i-13
Work Environment ... i-8
How to Use the Manual ... i-2
General Information ... i-2
Illustrations ... i-7
General Information ... i-7
Symbols ... i-3
General Information ... i-3

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About the Manual

General Information

Cummins Inc. manuals are created to support Cummins® products. For information on components or fault codes not supplied by Cummins Inc., contact the original equipment manufacturer or supplier.

The content of this manual is based on the information in effect at the time of publish. 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.

About

Cummins® manuals are divided into sections. Each section consists of procedures which are associated with the title of the section.

When viewing a manual online, the sections of the manual are displayed to the left of the procedure display. If a section is clicked, it will expand to show the procedures within that section. to view a procedure, click on the procedure title.

When viewing a printed manual, the table of contents provides the list of sections and their subsequent procedures, with page numbers located to the right.

How to Use the Manual

General Information

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

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

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

Each section contains the following in sequence:

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

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

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

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

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

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

Symbols

General Information

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

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

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

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

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

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

INSPECTION is required.

CLEAN the part or assembly.

PERFORM a mechanical or time **MEASUREMENT**.

LUBRICATE the part or assembly.

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

TIGHTEN to a specific torque.

PERFORM an electrical **MEASUREMENT**.

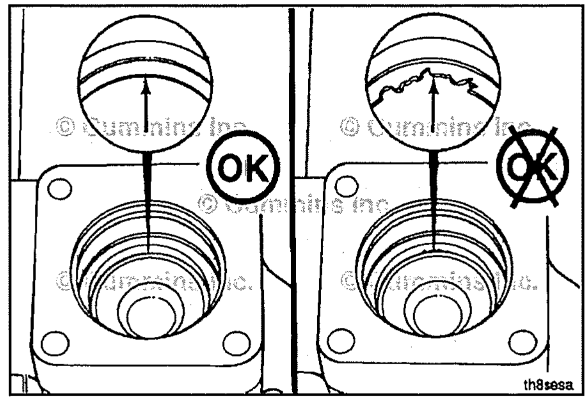
Refer to another location in this manual or another publication for additional information.

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

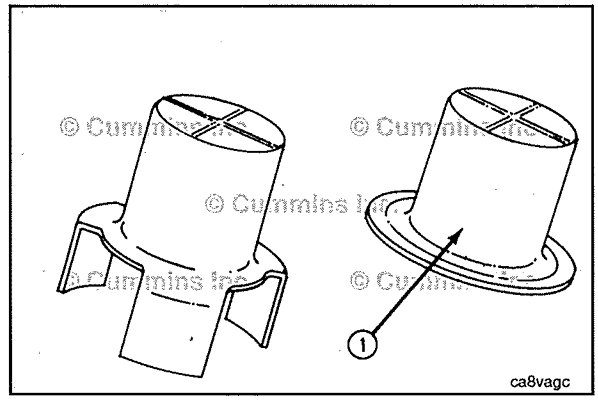
Illustrations

General Information

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



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



General Safety Instructions

Important Safety Notice

Read and understand the safety information and precautions before performing any repair or operating equipment. This procedure contains general safety precautions that **must** be followed to provide personal safety. **Always** follow procedures to mitigate safety concerns.

Work Environment

Follow these recommended practices when servicing products.

- **Always** follow on-site safety requirements.
- **Always** follow local training, certification, authorization, and specific customer requirements. Do **not** work on products unless proper training has been completed to allow safe repair completion. Do **not** operate equipment unless proper training has been completed to allow safe operation..
- Work in a well-ventilated area away from ignition sources.
- If adverse weather conditions are present, take appropriate safety precautions when performing work.
- **Always** be aware of hazardous conditions that may exist in the work environment.

Best Practices

Follow these recommended practices when servicing or operating equipment.

- **Always** wear protective glasses and protective shoes.
- Remove rings, watches, long jewelry, or metallic items.
- Do **not** wear loose fitting or torn clothing, jewelry, long hair, etc.. These increase the risk for personal injury.
- Do **not** perform any repairs, or operate equipment, when fatigued or impaired due to drugs or alcohol.
- **Always** use tools that are in good condition.
- Do **not** work on equipment that is running unless otherwise directed by troubleshooting procedures.
- If any work **must** be performed while the unit is running, use extreme caution around hot components, moving parts, etc..
- Exercise caution when working on products that have just been turned off. Hot parts may cause burns or ignite or melt common materials.
- Do **not** bleed the fuel system of a hot engine. Contact with hot manifolds or other components can cause a fire.
- Do **not** attempt to rotate the crankshaft by pulling or prying on the fan. **Only** use proper engine barring techniques.
- Do **not** lift components that weigh 23 kg [50 lb] or more. Use mechanical help or seek assistance.
- Exercise caution when working around rotating parts. Rotating parts can cause cuts, mutilation, or strangulation.
- Exercise caution when working on electrical components. High voltages can cause serious injury or death.
- Relieve system pressure as instructed before removing or disconnecting lines, fittings, or related items.
- **Always** test for pressure leaks as instructed.
- **Always** torque fittings and connections to the required specifications. Over or under tightening can damage threads and create leaks.
- **Always** use the same fastener part number, or equivalent, when replacing fasteners.

Perform the following prior to beginning work on any products.

- Shutdown the equipment unless otherwise directed by troubleshooting procedures.
- **Always** allow the product to cool.
- **Always** ensure the product is properly supported by blocks or stands. Do **not** work on a product supported **only** by lifting jacks or hoists.
- Disconnect the battery unless otherwise directed by troubleshooting procedures.
- Disconnect the starting motor, if equipped, unless otherwise directed by troubleshooting procedures.
- Place a "Do NOT Operate" tag in the operator area or near the product controls.
- Become familiar with the tools required for performing the task at hand and how to use those tools correctly.

- Use only genuine Cummins or Cummins Recon replacement parts as instructed.

Personal Protective Equipment (PPE)

To reduce the possibility of personal injury, personal protective equipment (PPE) should be utilized. Various types of PPE are listed below. Use proper judgment to determine which types of PPE are required for a given task. **Always** meet on-site safety regulations for required PPE. Proper maintenance of safety equipment **must** be practiced. Integrity of safety equipment **must** be checked to ensure equipment functionality is maintained.

Eye Protection

Eye protection **must always** be worn. Wear appropriate eye protection based on the task being completed. Types of eye protection to consider are listed below.

- Safety glasses. Exposure to flying particles or debris, chemicals or caustic liquids, gases or vapors.
- Polarized safety glasses. Working in outdoor or bright lighting environments.
- Over-the-glass safety glasses. Add protection to prescription glasses.
- Safety goggles. Handling caustic liquids or chemicals.
- Shade or arc rated eyewear. Exposure to welding. Use appropriate filter ratings.

Foot Protection

Protective shoes **must always**be worn. Wear appropriate foot protection based on the task being completed. Types of protective footwear to consider are listed below.

- Steel toed shoes. Exposure to falling or rolling objects. Working with or around parts, tools, and equipment.
- Chemical resistant. Exposure to chemicals and other fluids.
- Overshoes and overboots. Add protection to everyday work shoes.
- Foot, toe, and metatarsal guards. Add protection to everyday work shoes.
- Electrical hazard safety toe shoes. Exposure to electrical hazards.
- Leather footwear or shoe protectors. Exposure to welding or arc flash.
- Cold protection. Exposure to cold weather.

Head and Face Protection

Wear appropriate face protection based on the task being completed. Types of head and face protection to consider are listed below.

- Hard hats. Exposure varies. Consider welding, heat, or arc-rated.
- Visors. Exposure varies. Consider welding, heat, or arc-rated.
- Face liners. Exposure to cold weather.
- Face shields. Exposure to liquid splash. Handling caustic liquids or chemicals.

Hand Protection

Wear appropriate type and fit of gloves based on the task being completed. Types of protective gloves to consider are listed below.

- Heat resistant or insulated. Exposure to hot items.
- Flame resistant. Exposure to welding or arc flash.
- Impact resistant. Performing repetitive impact and vibration work. Using pneumatic tools.
- Impervious. Exposure to high pressure fluids.
- Chemical resistant. Exposure to chemicals, fluids, or batteries.
- Cut resistant. Handling sharp objects or tools.
- Cold weather. Exposure to cold weather.

Hearing Protection

When working around operating equipment, appropriately rated hearing protection should be worn. Types of hearing protection to consider are listed below.

- Single use ear plugs.

- Pre-formed ear plugs.
- Ear muffs.

Protective Clothing

Wear appropriate protective clothing based on the task being completed. Types of protective clothing to consider are listed below.

- Flame resistant. Exposure to electrical hazards. Exposure to oil and gas or generator set applications. Performing welding.
- Chemical resistant. Exposure to chemicals.
- High visibility. Exposure to reduced visibility working environments. Working on mining, oil and gas, or sites with large equipment.

Respiratory Protection

Wear appropriate respiratory protection based on the task being completed. Types of respiratory protection to consider are listed below.

- Disposable respirators. Exposure to dust and particles, welding fumes, nuisance odors, nuisance level acid gas.
- Reusable respirators. Exposure to cleaning, machining, welding, sanding, grinding, etc.

Fall Protection

Utilize fall protection if a task is being completed more than 1.2 m [4 ft] above a solid surface. Types of fall protection to consider are listed below.

- Fall harness and lanyard combinations.
- Safety nets.
- Guardrails.

Fuels

Follow these recommended practices when interacting with equipment that uses different fuel types. For information regarding proper handling of various substances, refer to the manufacturer's safety data sheet.

Diesel Fuel

- Protect eyes.
- Protect skin.
- **Always** test for fuel leaks as instructed.
- Do **not** dilute.
- Avoid sparks, arcing switches and equipment, cigarettes, pilot lights, flames, and other sources of ignition.
- Provide extra ventilation to the work area.
- Do **not** troubleshoot or repair fuel leaks while the engine is running.
- If material is spilled, avoid contact and dispersal with runoff, soil, waterways, drains, and sewers. Absorb with sand, clay, or commercial absorbent. Transfer to containers and neutralize the material. Flush spill area with soap and excess water.
- Report spills effecting water source contamination to local authorities immediately.
- Proper disposal is required. Dispose of in accordance with local and environmental regulations.
- **Always** torque fittings and connections to the required specifications. over or under tightening can damage threads and create leaks.

Gasoline

- Protect eyes.
- Protect skin.
- **Always** be alert for the smell of gas.
- **Always** test for fuel leaks as instructed.
- Do **not** dilute.
- Avoid sparks, arcing switches and equipment, cigarettes, pilot lights, flames, and other sources of ignition.

- Vapors accumulate near the floor. Check the work floor, sumps, and low lying areas for ignition sources before servicing equipment..
- Provide extra ventilation to the work area.
- Do **not** troubleshoot or repair fuel leaks while the engine is running.
- If material is spilled, avoid contact and dispersal with runoff, soil, waterways, drains, and sewers. Absorb with sand, clay, or commercial absorbent. Transfer to containers and neutralize the material. Flush spill area with soap and excess water.
- Report spills effecting water source contamination to local authorities immediately.
- Proper disposal is required. Dispose of in accordance with local and environmental regulations.
- **Always** torque fittings and connections to the required specifications. over or under tightening can damage threads and create leaks.

Biodiesel

- Protect eyes.
- Protect skin.
- **Always** test for fuel leaks as instructed.
- Do **not** dilute.
- Avoid sparks, arcing switches and equipment, cigarettes, pilot lights, flames, and other sources of ignition.
- Vapors accumulate near the floor. Check the work floor, sumps, and low lying areas for ignition sources before servicing equipment..
- Provide extra ventilation to the work area.
- Do **not** troubleshoot or repair fuel leaks while the engine is running.
- If material is spilled, avoid contact and dispersal with runoff, soil, waterways, drains, and sewers. Absorb with sand, clay, or commercial absorbent. Transfer to containers and neutralize the material. Flush spill area with soap and excess water.
- Report spills effecting water source contamination to local authorities immediately.
- Proper disposal is required. Dispose of in accordance with local and environmental regulations.
- **Always** torque fittings and connections to the required specifications. over or under tightening can damage threads and create leaks.

Compressed Natural Gas

- Protect eyes.
- Protect skin.
- **Always** be alert for the smell of gas. Compressed natural gas is typically treated with an odor producing chemical for leak detection. Non-refined sources of natural gas (landfill gas, biogas, coal bed gas, wellhead gas, etc.) can **not always** be detected by smell.
- **Always** test for fuel leaks as instructed. Odorant can fade.
- Upon entering a room or approaching a vehicle where the smell of gas is present, immediately shutoff all engines and ignition sources.
- Natural gas ignites when there is a 5% - 15% mixture in the air. Asphyxiation can occur when concentration reaches 21% or more.
- Do **not** start equipment or nearby equipment until a suspected gas leak is corrected and the area is ventilated.
- Avoid sparks, arcing switches and equipment, cigarettes, pilot lights, flames, and other sources of ignition.
- Work in areas that do **not** share common ventilation with areas containing ignition sources.
- Store and service natural gas fueled equipment in large, well-ventilated areas, or outside.
- Provide extra ventilation to the work area.
- Natural gas accumulates near the ceiling. Check the ceiling of the work area for ignition sources before servicing equipment.
- **Only** disconnect gas lines in a well-ventilated area.
- Do **not** troubleshoot or repair gas leaks while the engine is running.

- Natural gas ignition systems produce high voltage during operation. Do **not** touch ignition wiring or components while the engine is operating. If necessary, use **only** insulated tools.
- Natural gas exhaust systems operate at higher temperatures than similar diesel exhaust systems. Do **not** touch exhaust components. Do **not** route lines or hoses which deteriorate from heat exposure near exhaust components or in the flow path of the exhaust.
- **Always** torque fittings and connections to the required specifications. over or under tightening can damage threads and create leaks.

Liquefied Natural Gas

- Protect eyes.
- Protect skin.
- **Always** be alert for the smell of gas. Liquefied natural gas may **not** have an odor. Non-refined sources of natural gas (landfill gas, biogas, coal bed gas, wellhead gas, etc.) can **not always** be detected by smell.
- **Always** test for fuel leaks as instructed. Odorant can fade.
- Upon entering a room or approaching a vehicle where the smell of gas is present, immediately shutoff all engines and ignition sources.
- Natural gas ignites when there is a 5% - 15% mixture in the air. Asphyxiation can occur when concentration reaches 21% or more.
- Do **not** start equipment or nearby equipment until a suspected gas leak is corrected and the area is ventilated.
- Avoid sparks, arcing switches and equipment, cigarettes, pilot lights, flames, and other sources of ignition.
- Work in areas that do **not** share common ventilation with areas containing ignition sources.
- Store and service natural gas fueled equipment in large, well-ventilated areas, or outside.
- Provide extra ventilation to the work area.
- Natural gas accumulates near the ceiling. Check the ceiling of the work area for ignition sources before servicing equipment.
- **Only** disconnect gas lines in a well-ventilated area.
- Do **not** troubleshoot or repair gas leaks while the engine is running.
- Natural gas ignition systems produce high voltage during operation. Do **not** touch ignition wiring or components while the engine is operating. If necessary, use **only** insulated tools.
- Natural gas exhaust systems operate at higher temperatures than similar diesel exhaust systems. Do **not** touch exhaust components. Do **not** route lines or hoses which deteriorate from heat exposure near exhaust components or in the flow path of the exhaust..
- Liquefied natural gas is stored in vehicle tanks at extremely cold temperatures. If there is a liquefied natural gas spill, evacuate the area immediately and do not attempt to make contact with the liquid.
- **Always** torque fittings and connections to the required specifications. over or under tightening can damage threads and create leaks.
- Vapors accumulate near the floor. Check the work floor, sumps, and low lying areas for ignition sources before servicing equipment.

Liquefied Petroleum Gas

- Protect eyes.
- Protect skin.
- **Always** be alert for the smell of gas. Liquefied petroleum gas is typically treated with an odor producing chemical for leak detection.
- **Always** test for fuel leaks as instructed. Odorant can fade.
- Upon entering a room or approaching a vehicle where the smell of gas is present, immediately shutoff all engines and ignition sources.
- Do **not** start equipment or nearby equipment until a suspected gas leak is corrected and the area is ventilated.
- Avoid sparks, arcing switches and equipment, cigarettes, pilot lights, flames, and other sources of ignition.
- Work in areas that do **not** share common ventilation with areas containing ignition sources.
- Store and service natural gas fueled equipment in large, well-ventilated areas, or outside.

- Provide extra ventilation to the work area.
- Liquefied petroluem gas accumulates near the floor. Check the work floor, sumps, and low lying areas for ignition sources before servicing equipment.
- **Only** disconnect gas lines in a well-ventilated area.
- Do **not** troubleshoot or repair gas leaks while the engine is running.
- Liquefied petroleum gas ignition systems produce high voltage during operation. Do **not** touch ignition wiring or components while the engine is operating. If necessary, use **only** insulated tools.
- Liquefied petroleum gas exhaust systems operate at higher temperatures than similar diesel exhaust systems. Do **not** touch exhaust components. Do **not** route lines or hoses which deteriorate from heat exposure near exhaust components or in the flow path of the exhaust..
- Liquefied natural gas is stored in vehicle tanks at extremely cold temperatures. If there is a liquefied natural gas spill, evacuate the area immediately and do not attempt to make contact with the liquid.
- **Always** torque fittings and connections to the required specifications. over or under tightening can damage threads and create leaks.

Power Generation Applications

Follow these recommended practices when interacting with equipment in generator set applications.

Power generation applications produce high voltage during operation. When servicing a generator set, the following safety precautions **must** be taken.

- Remove any debris from the generator set.
- Keep the floor clean and dry throughout servicing
- Service access doors **must** be secured in the "open" position before working on enclosed generator sets.
- Use insulated or non-conducting tools.
- Prevent accidental or remote starting. Disconnect the starting battery cables. Disconnect the negative (-) terminal first.
- Isolate all auxiliary supplies.
- Switch the generator set control panel "off."
- Place a "Do **Not** Operate" tag on the control panel.
- Lock the generator set circuit breaker in the "Open" position.
- Activate the manual "Emergency Stop" device.
- Do **not** step on the generator set when servicing, entering, or leaving the generator room.

Aftertreatment

Follow these recommended practices when interacting with equipment that utilize aftertreatment systems. For information regarding proper handling of various substances, refer to the manufacturer's safety data sheet.

Diesel Exhaust Fluid

- Avoid breathing vapor or mist.
- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes.
- Protect skin. In case of contact with skin, wash with soap and water.
- Do **not** ingest. If ingested, contact a physician immediately.

Diesel Particulate Filter

- Protect eyes.
- Protect skin.
- Avoid stirring up exhaust particulate dust.
- Avoid inhalation of exhaust particulate dust. Wear a dust mask. If respiratory irritation or discomfort occurs, leave the dusty area. Utilize breathing assistance or oxygen if necessary.
- Elevated concentrations of metals in the form of dust, soot, and contaminants are contained in these filters. Health regulations may exist for the materials found in these filters such as Zinc, Molybdenum, polynuclear aromatic

hydrocarbons. Potentially toxic materials found in these filters are oxides of calcium, zinc, phosphorous, silicon, sulfur, and iron.

- Proper disposal of the exhaust dust and filter are required. Dispose of in accordance with local and environmental regulations.
- Diesel particulate filter maintenance **must** be completed by appropriately trained personnel.

Selective Catalytic Reduction (SCR) Catalyst

- Protect eyes.
- Protect skin.
- Avoid stirring up exhaust catalyst dust.
- Avoid inhalation of exhaust catalyst dust. Wear a dust mask. If respiratory irritation or discomfort occurs, leave the dusty area. Utilize breathing assistance or oxygen if necessary.
- Do **not** cut open exhaust catalyst assemblies.
- Proper disposal of the exhaust catalyst is required. Dispose of in accordance with local and environmental regulations.

Oxidation Catalysts

Types of Oxidation Catalysts may include, but are not limited to the following.

- Diesel Oxidation Catalyst (DOC)
- 3-way Oxidation Catalyst

When working with oxidation catalysts, perform the following.

- Protect eyes.
- Protect skin.
- Avoid stirring up exhaust catalyst dust.
- Avoid inhalation of exhaust catalyst dust. Wear a dust mask. If respiratory irritation or discomfort occurs, leave the dusty area. Utilize breathing assistance or oxygen if necessary.
- Do **not** cut open exhaust catalyst assemblies.

Common Substances

Follow these recommended practices when interacting with the following substances. For information regarding proper handling of various substances, refer to the manufacturer's safety data sheet.

Coolant

- Coolant is also referred to as antifreeze.
- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes. Receive medical attention immediately.
- Protect skin. In case of contact with skin, wash with soap and water. Remove contaminated clothing. If injection occurs, it is a medical emergency. Receive medical attention immediately.
- Do **not** ingest. If ingested, drink excess water for dilution and seek medical attention.
- Do **not** pour used antifreeze into containers that have been used to store other chemicals or products, such as oil or gasoline, unless they have been thoroughly cleaned.
- If material is spilled, avoid contact and dispersal with runoff, soil, waterways, drains, and sewers. Provide adequate ventilation to the area. Absorb with sand, clay, or commercial absorbent. Transfer to containers and neutralize the material. Flush spill area with soap and excess water.
- Report spills effecting water source contamination to local authorities immediately.
- Proper disposal is required. Dispose of in accordance with local and environmental regulations.

Liquid Nitrogen

- Work in a well-ventilated area.
- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes. Receive medical attention immediately.
- Protect skin. In case of contact with skin, receive medical attention immediately.

- Wear protective clothing and gloves that insulate.
- Handle items with tongs or wire hooks.
- Avoid prolonged breathing of liquid nitrogen vapors. Utilize breathing assistance or oxygen if necessary.

Lubricating Oil

See Lubricating Oil in the "Hazardous Substances" step.

Refrigerant

- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes. In case of frostbite, use lukewarm water, not hot. Seek medical attention if irritation continues.
- Protect skin. Wear leather or insulated gloves. In case of contact with skin, wash with soap and water. Seek medical attention if irritation continues.
- Proper disposal is required. Dispose of in accordance with local and environmental regulations.
- **Only** disconnect liquid refrigerant lines in a well-ventilated area. 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 refrigerant in the United States of America.

Solvents

- Follow the manufacturer's instructions for safe handling practices.
- Follow the manufacturer's recommendations for use.
- Some solvents are flammable and toxic..
- Protect eyes. In case of contact with eyes, follow manufacturer's recommendations.
- Protect skin. In case of contact with skin, follow manufacturer's recommendations.
- Dispose of in accordance with manufacturer's recommendations.

Starting Aids (Starting Fluid)

- Do **not** use starting fluid if the intake air heater option is used.
- Do **not** use volatile cold starting aids in underground mine or tunnel operations. The local United States Bureau of Mines inspector can provide more information and instructions.
- Avoid sparks, arcing switches and equipment, cigarettes, pilot lights, flames, and other sources of ignition.
- Work in a well-ventilated area.
- Avoid inhalation.

Hazardous Substances

Hazardous substances are known to some state and federal agencies to be carcinogenic and cause reproductive harm. Hazardous substances that may be encountered during service events are listed below.

Diesel Engine Exhaust

- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes.
- Protect skin. In case of contact with skin, wash with soap and water.
- Avoid inhalation.

Lubricating Oil

- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes.
- Protect skin. In case of contact with skin, wash with soap and water.
- Do **not** ingest. If ingested, contact a physician immediately..
- Proper disposal is required. Dispose of in accordance with local and environmental regulations.
- Do **not** allow water droplets to enter a container of hot oil. A violent reaction can result.

Mercury

- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes.
- Protect skin. In case of contact with skin, wash with soap and water.
- Do **not** ingest. If ingested, contact a physician immediately.

- Proper disposal is required. Dispose of in accordance with local and environmental regulations.

Vanadium Pentoxide

- Can be found in some selective catalytic reduction (SCR) catalysts.
- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes.
- Protect skin. In case of contact with skin, wash with soap and water.
- Do **not** ingest. If ingested, contact a physician immediately.
- Avoid inhalation of vapors or airborne particles.
- Proper disposal is required. Dispose of in accordance with local and environmental regulations.

Electrical Components

Follow these recommended practices when interacting with electrical components.

Batteries

- Protect eyes. Wear safety glasses or goggles. In case of battery acid contact with eyes, flush with water for a minimum of 15 minutes. Receive medical attention immediately.
- Protect skin. Wear rubber gloves and a chemical apron. In case of battery acid contact with skin or clothing, rinse with water for several minutes. Avoid spreading the acid. Receive medical attention immediately.
- Do **not** open the battery caps with your face over or near the battery.
- Remove rings, watches, long jewelry, or metallic items when working with or near batteries.
- Ventilate the battery compartment before servicing the battery.
- Work in a well-ventilated area.
- Avoid sparks, arcing switches and equipment, cigarettes, pilot lights, flames, and other sources of ignition.
- Use insulated or non-conducting tools.
- Neutralize static buildup by contacting the nearest ground surface before working on a battery.
- Do **not** lift batteries by the posts.
- Do **not** touch both battery terminals with your bare hands at the same time.
- Disconnect the negative (-) battery cable first.
- Attach the negative (-) battery cable last.

Common Hazards

Follow these recommended practices when interacting with equipment as the following hazards may exist.

High Temperature Area

Be alert for high temperature areas which may cause severe burns. High temperature areas may be encountered in the following situations.

- On products that have just been turned off.
- On or around exhaust related components (turbocharger, aftertreatment systems, etc).
- In exhaust gas flow paths.
- Contacting hot fluid lines, tubes, or compartments.

Recommended Practices:

- Allow components to cool before servicing. Verify the temperature of the component. Utilize an infrared gun, temperature sensor, temperature gauge, or other reliable method to determine component temperature. Take appropriate precautions before starting work.
- Protect eyes.
- Protect skin. Wear insulated gloves.
- Ensure surrounding items do not come in contact with hot components or exhaust. Contact may ignite or melt those materials.

Heavy Objects

Be alert when working with heavy objects.

- Do **not** lift components that weigh 23 kg [50 lb] or more. Use mechanical help or seek assistance.
- Use mechanical help to move items whenever possible. Make sure the load is securely fastened to the equipment.
- Make sure lifting devices, like chains, hooks, slings, etc., are in good condition and are rated for the correct capacity before use.
- Make sure lifting devices are positioned correctly before use.
- Use a spreader bar when necessary.
- If the item can be lifted manually, squat to lift and lower the item. Do **not** bend at the waist.
- Maintain balance when lifting items by keeping feet apart or staggered if possible.
- If the item must be carried, make sure the path is clear when carrying the item to, and placing the item in, the desired location.

Pressurized Areas

Be alert for pressurized areas. Pressurized areas may be encountered in the following situations.

- Air, Oil, Fuel, and Cooling systems.
- When disconnecting or removing lines, fittings, or related items.
- When disconnecting a device from a pressurized system.
- When removing or loosening caps on tanks or pressurized systems.

Injuries that may result when interacting with pressurized areas are listed below.

- High pressure spray can penetrate the skin. Serious injury or death may result.
- Hot fluid spray can cause burns. See "High Temperature Area."

Recommended Practices:

- Protect skin. Wear impervious gloves. If skin penetration from high pressure spray occurs, it is a medical emergency. Receive medical attention immediately.
- Check for pressure leaks as instructed. **Never** check for pressure leaks with your hand.
- Allow product to cool before accessing pressurized areas.
- Relieve system pressure as instructed.
- Slowly loosen fill caps to relieve pressure before servicing.

Job Safety Assessment

Completing a Job Safety Assessment (JSA) prior to performing work helps identify job safety hazards and prevent incidents. Use the guidelines below to assess if a situation is safe or at risk prior to performing designated work. If deteremined to be at risk, take appropriate precautions to prepare for, or eliminate, the hazard. If the risks are uncontrollable, consult a knowledgeable resource to find a safe practice solution. A knowledgeable resource may include, but is not limited to, one of the following:

- Site supervisor
- Customer
- Work supervisor

Always check with the site where work is being performed to determine if safety assessment documentation is required.

Work Practices

Job Safety Analysis.

- Assess the job to identify safety hazards that may occur during the repair event.

Ascending or Descending

- Maintain 3 points of contact when using steps, ladders, or entering and exiting a unit.

Communication

- When working with others, make sure you understand what each other is doing to safely complete the task.

Eyes On Hands and Work.

- Confirm if you will be able to maintain an unobstructed view of your hands at all times while performing the task.

Eyes On Path

- Watch for hazards in your path to avoid trip or slip hazards. Examples are pits, platform edges, etc.

Line Of Fire

- Position yourself so that you avoid striking against, or being struck by, anything that can swing, fall, or roll.

Pinch Point

- Prevent exposure of all parts of your body to a nip hazard or pinch point.

Rushing

- Take adequate time to safely perform the job. Do **not** rush or take short cuts.

Follow Procedures

- Utilize QuickServe® Online or other standard procedures when available.
- Make sure the procedures are correct and safe.

Ergonomics

Back-Bending and Twisting

- Avoid bending forward more than 45 at your waist.
- Avoid working with your back twisted with loads over 23 kg [50 lb].

Knee

- Avoid bending your knee more than 90.
- Avoid kneeling for more than 4 hours per day.

Lifting and Lowering

- Squat to pick up parts.
- Keep loads close to the body when lifting or carrying.
- Use a team lift or a lifting device if the object is more than 23 kg [50 lb].

Pulling or Pushing

- Pull with your arms.
- Push with your legs.
- Avoid exerting more force than necessary.
- Avoid moving heavy load(s) too quickly.

Tools and Equipment

Selection

- Select the correct tool or equipment to perform the task.

Condition

- Confirm the tool or equipment is free of defects before use.
- Confirm that safety devices are in place before use.

Use

- Use the tool or equipment as directed.
- Follow the manufacturer's instructions.

Personal Protective Equipment (PPE)

Eye, Face, and Head Protection

- Confirm the eye, face, or head protection you plan to use are adequate for performing the task at hand.

Foot Protection

- Confirm the foot protection you plan to use is adequate for performing the task at hand in the current environment.

Fall Protection

- Fall protection should be used if you are working more than 1.2 m [4 ft] above the floor.
- Use fall protection if you have been properly trained to do so. If you are not trained to use fall protection, allow someone who has received proper training to perform the task.

Hand Protection

- Avoid exposing hands to cuts or burns while completing the task.
- Confirm the proper glove type is being used for the task at hand. Examples are cut-resistant, chemical-resistant, electric shock-resistant, electric arc flash, welding, etc.

Hearing Protection

- Hearing protection should be worn when required or recommended.

Body Protection

- Body parts should be protected from work hazards.
- Avoid contact with sharp edges, hot surfaces, etc.

Work Prcedures

Training

- Confirm if you have received task and safety training for the job being performed.

Working Alone

- Avoid working alone.
- Avoid working where you are **not** able to be seen or heard by another person.
- If you **must** work alone, notify others of your location and schedule check-in times.

Lockout and Tagout

- Lock out or tag out energy sources before work. Examples are electrical, mechanical, hydraulic, and pneumatic.

Barricades and Warnings

- Mark overhead work areas with barricade tape or signs.
- Mark open floor hazards with barricade tape, signs, or cones.

Confined Space

- Confirm if a confined space entry permit is required.
- If required, confirm the permit is posted, signed, and dated correctly.

Hot Work

- Confirm a functional fire extinguisher is readily available.
- Maintain separation between ignition sources and fuel sources.

Place Wheel Chocks

- Place wheel chocks at either the front or back tire of the unit prior to starting the task.

Spotter

- Use a spotter when moving a customer's unit.
- Confirm the driver can see and hear the spotter when moving.

Housekeeping (The 5 S's - Scrap or Segregate, Set to Order, Spotless, Standardize, and Sustain)

- Remove parts, extension cords, air hoses, and liquids from the work area that may cause trip, slip, or fall hazards.

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
bhp	Brake Horsepower
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
CES	Cummins Engineering Standard
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
ESN	Engine Serial Number
°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 $H_2 0$	Inches of Water
ICM	Ignition Control Module
IEC	International Electrotechnical Commission
JSA	Job Safety Assessment
km/l	Kilometers per Liter
kPa	Kilopascal
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LTA	Low Temperature Aftercooler
MCRS	Modular Common Rail System
MIL	Malfunction Indicator Lamp

MPa	Megapascal
mph	Miles Per Hour
mpq	Miles Per Quart
N•m	Newton-meter
NOx	Nitrogen Oxides
NG	Natural Gas
O2	Oxygen
OAT	Organic Acid Technology
OBD	On-Board Diagnostics
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Administration
PID	Parameter Identification Descriptions
PPE	Personal Protective Equipment
ppm	Parts Per Million
psi	Pounds Per Square Inch
PTO	Power Takeoff
QSOL	QuickServe® Online
REPTO	Rear Engine Power Takeoff
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
TSB	Technical Service Bulletin
ULSD	Ultra Low Sulfur Diesel
VDC	Volts of Direct Current
VGT	Variable Geometry Turbocharger
VS	Variable Speed
VSS	Vehicle Speed Sensor

Section E - System Identification

Section Contents

	Page
Cummins® Product Technology	E-14
General Information	E-14
Cummins® Service Engine Model Identification	E-11
General Information	E-11
Engine Diagrams	E-4
Engine Views	E-4
Engine Identification	E-1
Air Compressor	E-3
Cummins® Engine Nomenclature	E-2
Engine Control Module Dataplate	E-2
Engine Dataplate	E-1
Fuel Injection Pump Dataplate	E-2
Turbocharger Dataplate	E-3

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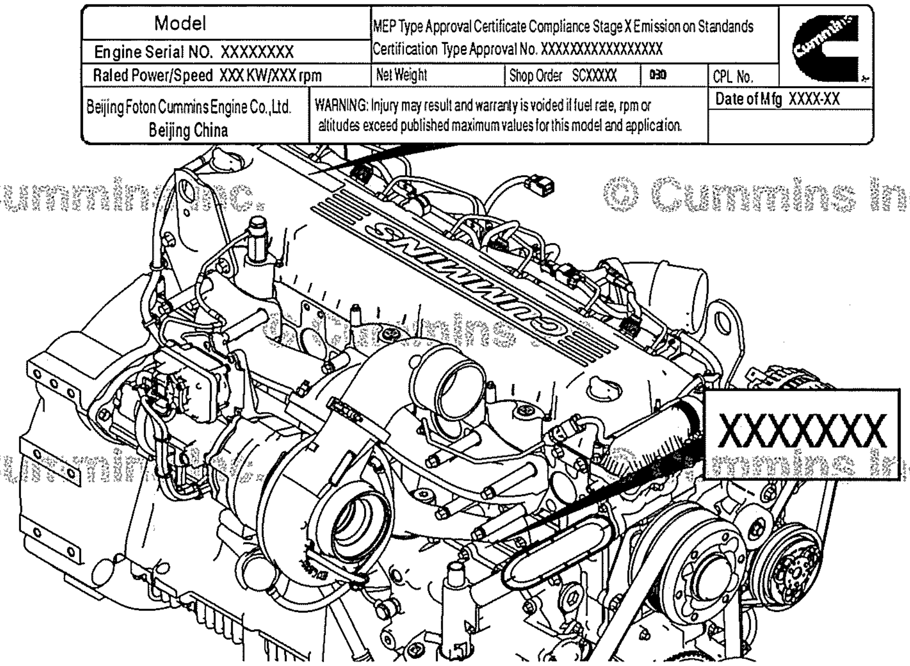
Engine Identification

Engine Dataplate



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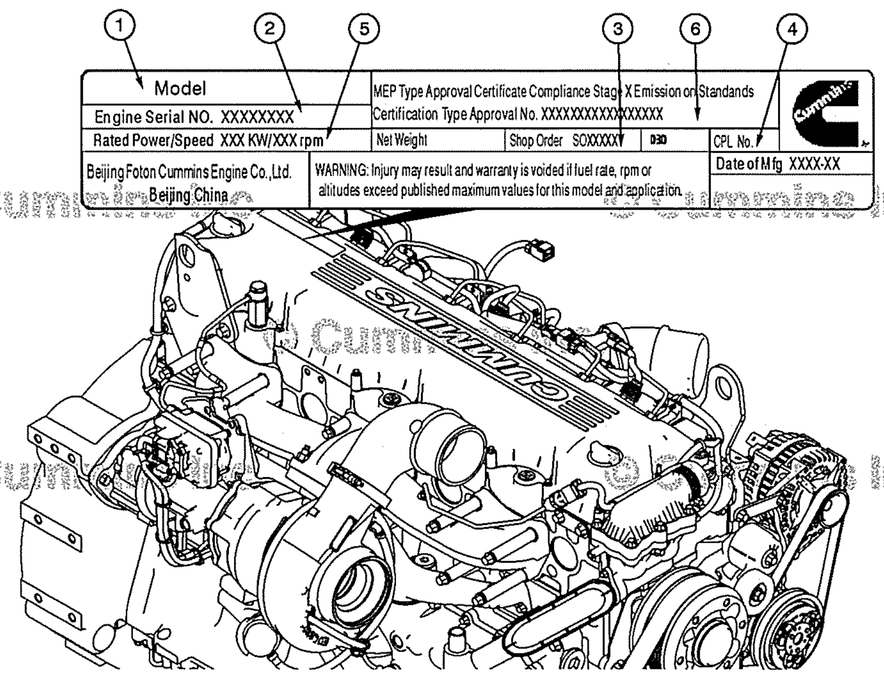
The engine dataplate provides important facts about the engine. The dataplate is typically located on the engine rocker lever cover, but may also be located on the side of the gear housing. The engine serial number (ESN) and control parts list (CPL) provide data for ordering parts and service. The engine dataplate **must not** be changed unless approved by Cummins Inc.

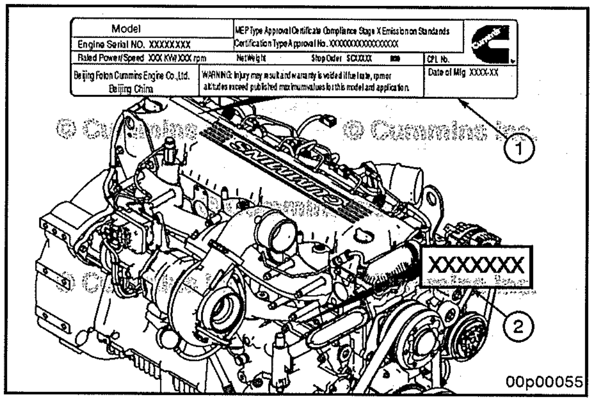
Have the following engine data available when communicating with a Cummins® Authorized Repair Location. The information on the dataplate is mandatory when sourcing service parts.



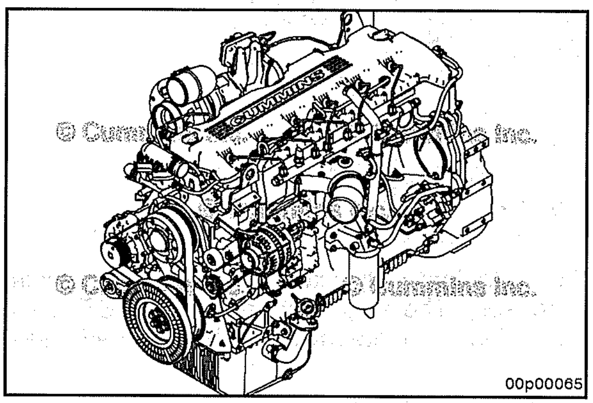
00p00054

1 Engine model information
2 Engine serial number (ESN)
3 Shop Order (SO)
4 Control parts list (CPL)

5 Horsepower and rpm rating
6 Emissions certification level.



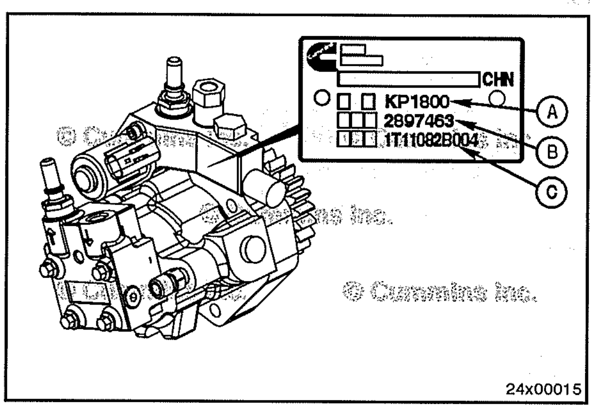
If the engine dataplate (1) is **not** legible, the ESN (2) can be found on the engine block next to the lubricating oil cooler housing. Additional engine information is on the engine control module (ECM) dataplate.



Cummins® Engine Nomenclature

The Cummins® Service Engine Model Identification procedure describes how to use the Cummins® Service Model Name to identify an engine. Refer to Procedure 100-005 in Section E.

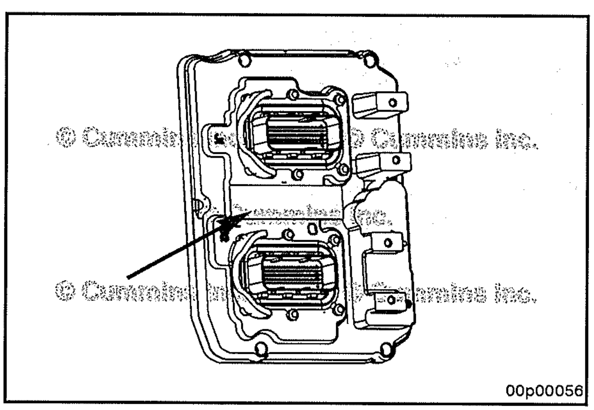
The Cummins® Product Technology procedure provides the Cummins® Service Model Name and describes the unique technology used by the engine covered by this manual. Refer to Procedure 100-006 in Section E.



Fuel Injection Pump Dataplate

The Cummins® Fuel System dataplate is located on the side of the high-pressure pump. The dataplate contains the following information:

A Model number
B Assembly part number
C Pump serial number.



Engine Control Module Dataplate

The ECM dataplate is located on the front of the ECM.

The following information is found on the ECM dataplate:

- ECM part number (PN)
- ECM serial number (SN)
- ECM date code (DC)
- Engine serial number (ESN)
- ECM code (identifies the software in the ECM).

Air Compressor

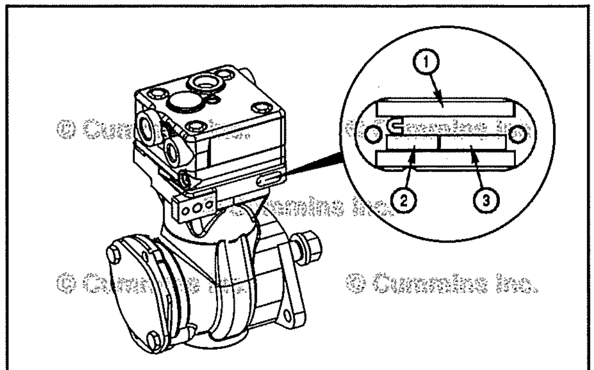
NOTE: Not all engines are equipped with an air compressor.

The Cummins® branded air compressor dataplate, identified by the Cummins Inc. logo on the dataplate, is typically located on the rear side of the air compressor. The dataplate contains the following information that assists in service or replacement.

1 Cummins® part number

2 Date code

3 Serial number.



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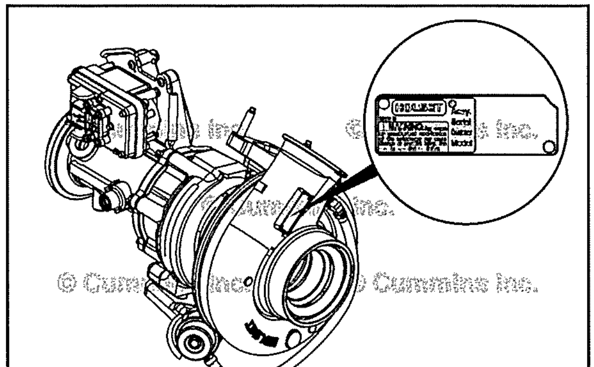
Turbocharger Dataplate

The Holset® turbocharger dataplate is located on the turbocharger inlet compressor housing. The dataplate contains the following information which will assist in servicing or replacement.

- Cummins® part number
- Serial number
- Customer number
- Model number.



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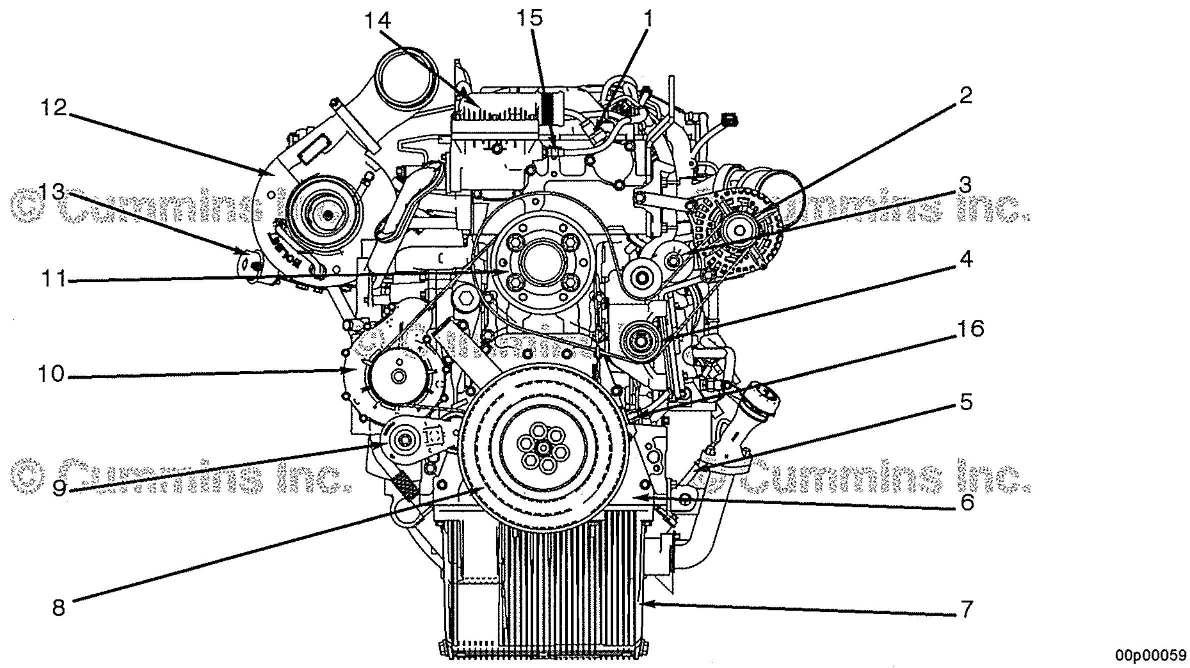
Engine Diagrams

Engine Views

The following illustrations show the location 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.

Engine Diagrams

Engine Views

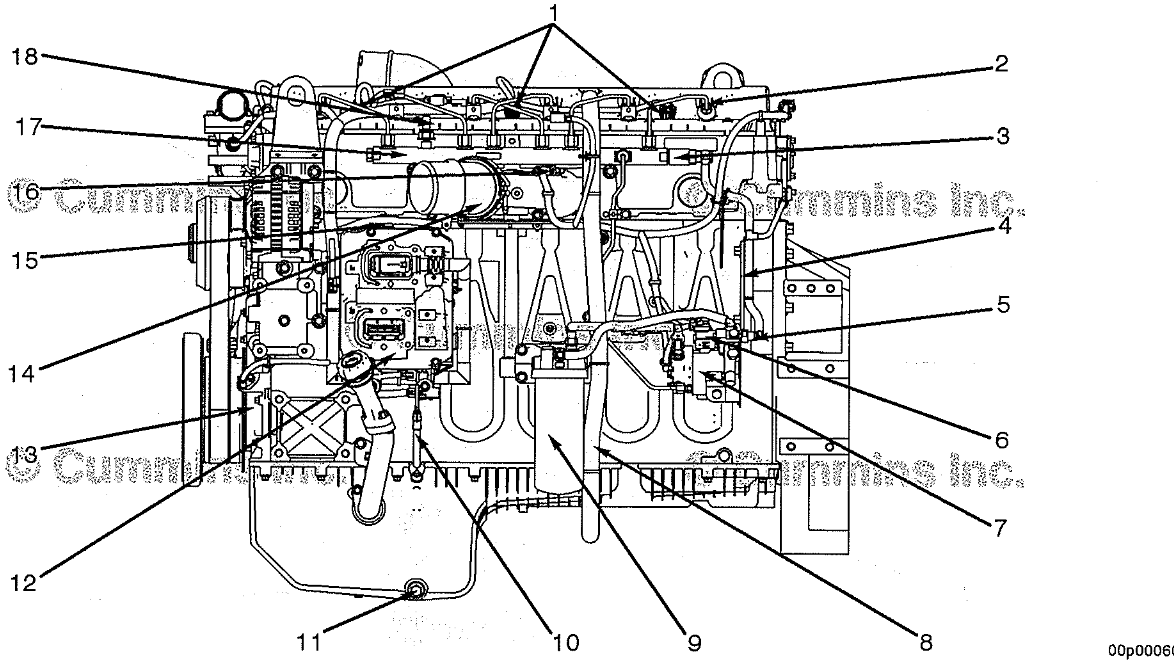


Front

1 Camshaft position sensor
2 Alternator
3 Alternator belt tensioner
4 Alternator idler pulley
5 Lubricating oil dipstick
6 Lubricating oil pump
7 Lubricating oil pan
8 Vibration damper
9 Water pump belt tensioner
10 Water pump
11 Fan pulley
12 Turbocharger
13 Turbocharger wastegate control valve
14 Dual thermostat housing
15 Coolant temperature sensor
16 Crankshaft position sensor.

Engine Diagrams

Engine Views

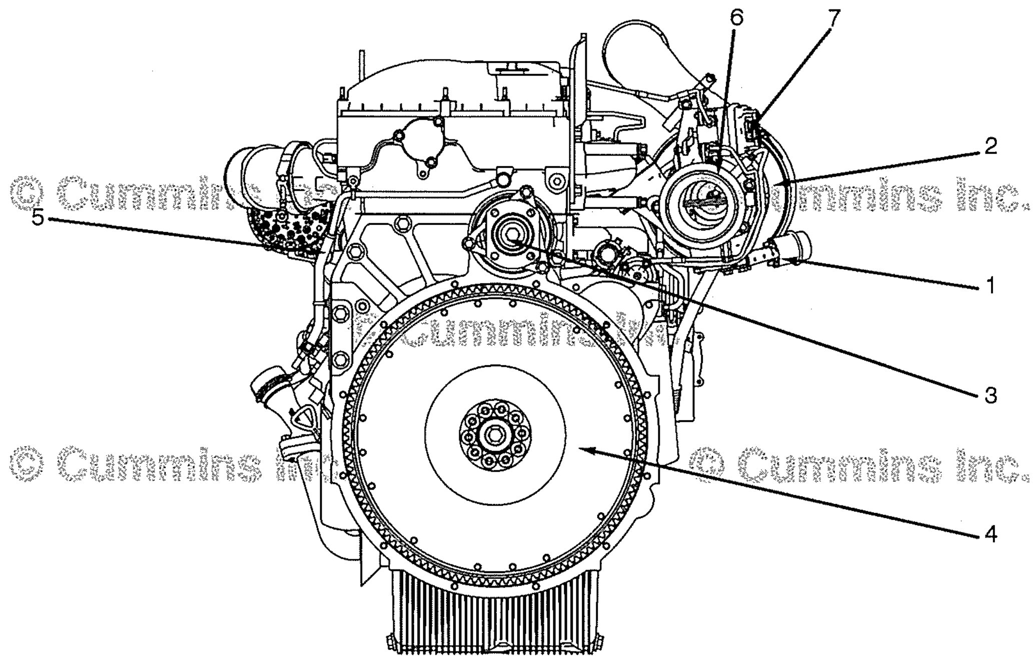


Left

1 Rocker lever cover wiring harness pass-through connector
2 High pressure fuel line
3 Fuel rail pressure relief valve
4 Hydraulic drive adaptor
5 Fuel return connection
6 Fuel pump actuator
7 Fuel pump
8 Crankcase breather tube
9 Fuel filter
10 Lubricating oil dipstick
11 Lubricating oil heater
12 Engine control module (ECM)
13 Lubricating oil pump
14 Air intake connection
15 Service datalink connector
16 Intake manifold temperature/pressure sensor
17 Fuel rail
18 Fuel rail pressure sensor.

Engine Diagrams

Engine Views

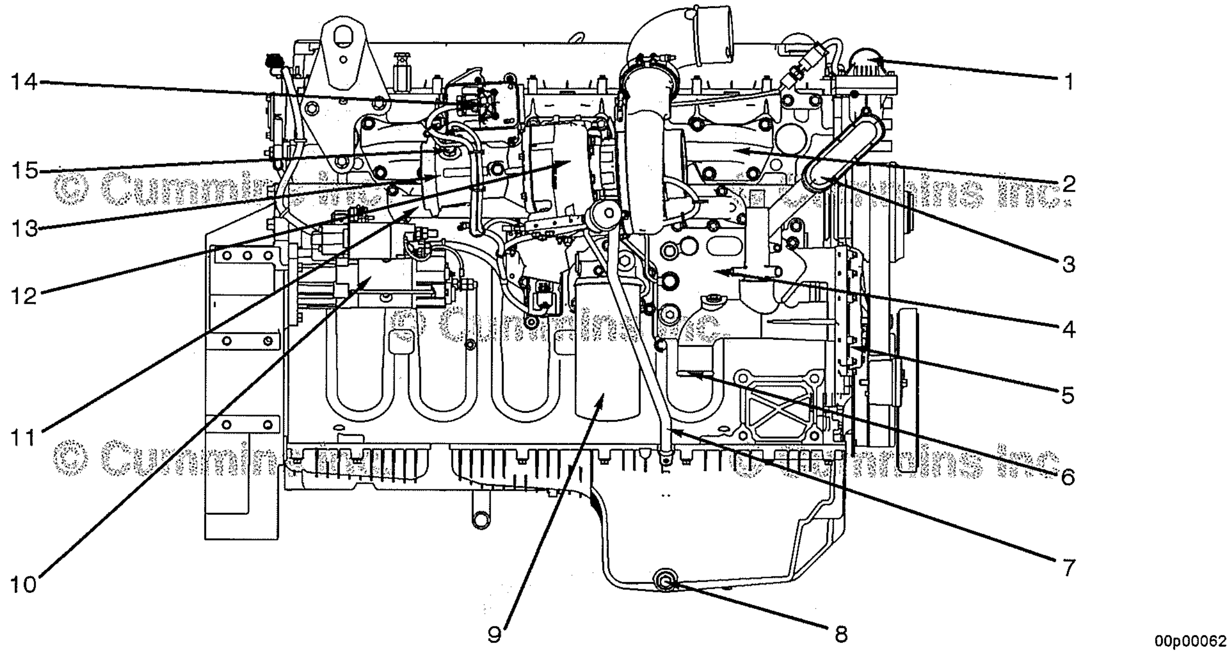


Rear

1 Turbocharger wastegate control valve
2 Turbocharger
3 Rear end power take off (REPTO)
4 Flywheel
5 Fuel return line.
6 Exhaust pressure regulator
7 Exhaust pressure regulator actuator

Engine Diagrams

Engine Views

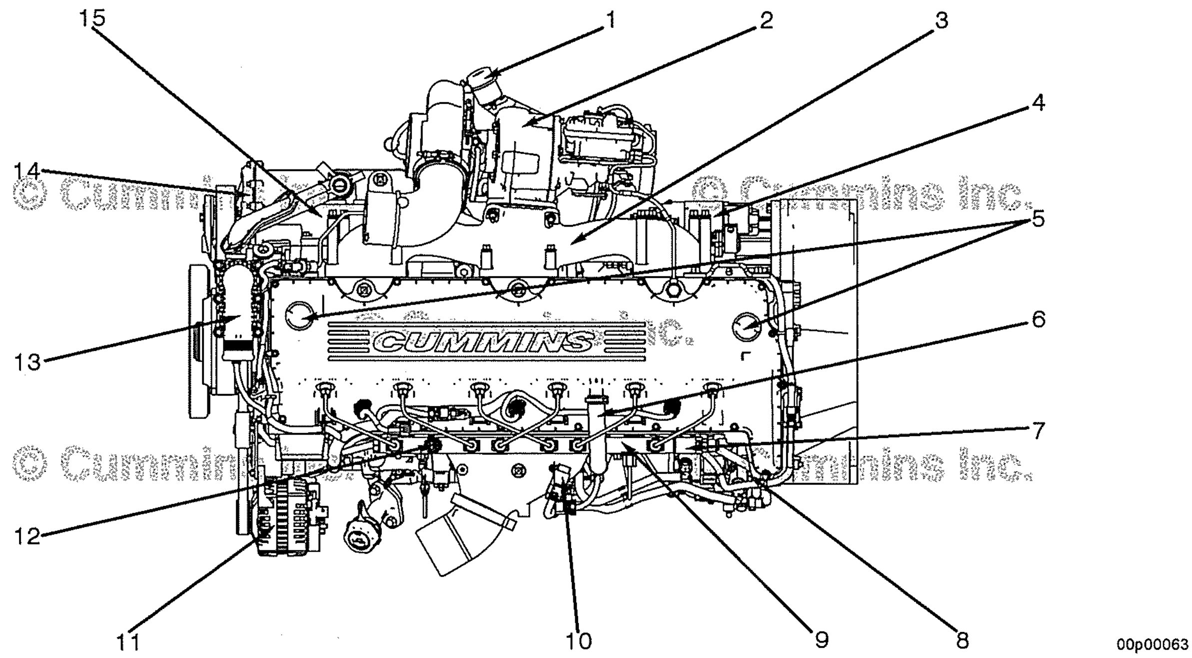


Right

1 Dual thermostat housing
2 Exhaust manifold
3 Coolant bypass tube
4 Lubricating oil cooler module
5 Water pump
6 Water pump inlet connection
7 Turbocharger oil drain line
8 Lubricating oil drain plug
9 Lubricating oil filter
10 Starter motor
11 Coolant manifold
12 Turbocharger.
13 Exhaust pressure regulator
14 Exhaust pressure regulator actuator
15 Aftertreatment intake NOx sensor

Engine Diagrams

Engine Views



Top

1 Turbocharger wastegate control valve

2 Turbocharger

3 Exhaust manifold

4 Starter

5 Oil fill cap

6 Crankcase breather tube

7 Fuel rail pressure relief valve

8 Hydraulic drive adaptor

9 Fuel rail

10 Intake manifold pressure/temperature sensor

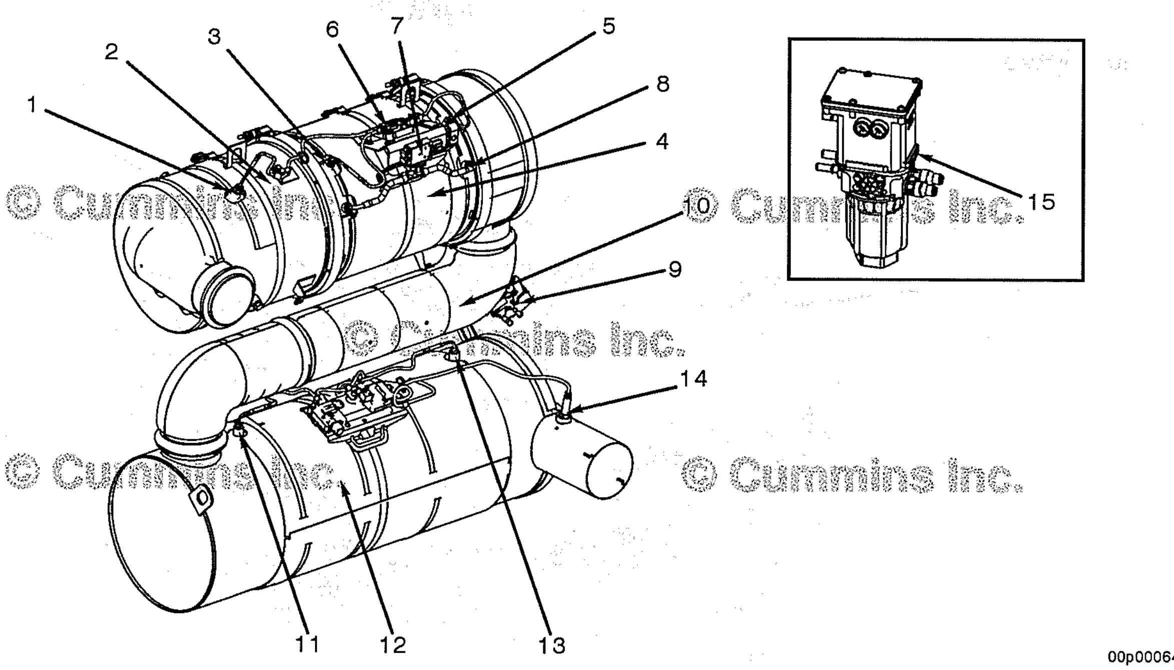
11 Alternator

12 Fuel rail pressure sensor

13 Dual thermostat housing

14 Water pump

15 Lubricating oil cooler module.



Aftertreatment Components

1 Aftertreatment diesel oxidation catalyst (DOC) intake temperature sensor
2 Aftertreatment DOC
3 Aftertreatment diesel particulate filter (DPF) intake temperature sensor
4 Aftertreatment DPF
5 Aftertreatment DPF outlet temperature sensor
6 Aftertreatment DPF temperature sensor interface module
7 Aftertreatment DPF differential pressure sensor
8 Aftertreatment diesel particulate filter (DPF) differential pressure tubes
9 Aftertreatment diesel exhaust fluid (DEF) dosing valve
10 Aftertreatment decomposition tube
11 Aftertreatment selective catalytic reduction (SCR) inlet temperature sensor
12 Aftertreatment SCR catalyst
13 Aftertreatment SCR outlet temperature sensor
14 Aftertreatment outlet NOx sensor
15 Aftertreatment DEF dosing unit.

Cummins® Service Engine Model Identification

General Information

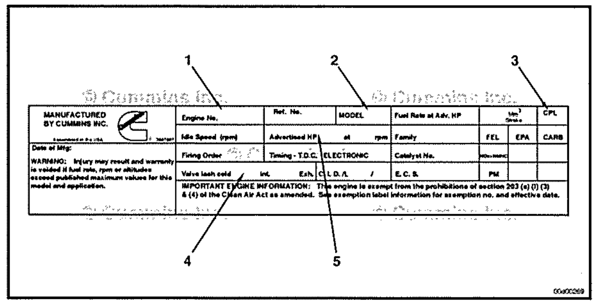
The Cummins® Service Engine Model Identification procedure describes:

- The purpose of the Cummins® Service Model Name.
- How to interpret a Cummins® Service Model Name to identify a Cummins® Engine.

This includes 2013 and later products.

The Cummins® Service Model Name differs from the Cummins® marketing model name. Service model names are more specific and help to match the correct Cummins® service information to the correct engine. Marketing engine model names are more generic and can capture multiple engine variations in the same model name.

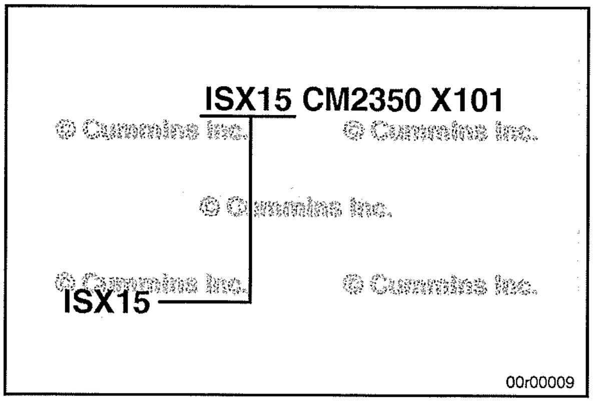
Marketing Engine Model Name	Service Model Name
ISX15	ISX15 CM2350 X101



Marketing engine model names (2) can be found on the engine dataplate, Cummins® brochures, and Cummins® promotional literature.

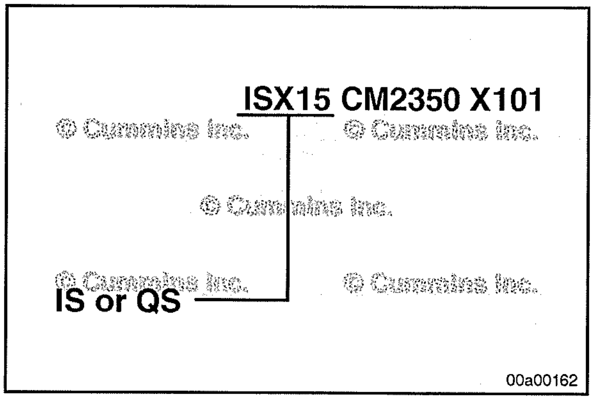
Examples of Cummins® service information and products that use service model names:

- QuickServe™ Online
- INSITE™ electronic service tool
- Owner's Manual
- Operation and Maintenance Manual
- Master Repair Manual
- Service Manual
- Wiring Diagram
- Fault Code Troubleshooting Manual
- Standard Repair Times
- Technical Service Bulletins
- Service Bulletins



The Cummins® Service Model Name begins with the marketing engine model name.

NOTE: For engines released specifically for the European market, marketing model names may include an "e" between the engine platform designation and the engine liter displacement. Service model names will not display this "e".



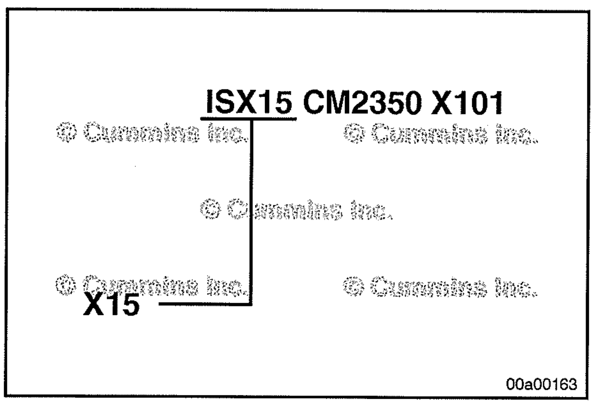
Typically, the first two letters of the marketing model name contain an "IS" or "QS" if the engine is an electronic engine.

"IS" prefix designates and On-Highway automotive engine.

"QS" prefix designates an Off-Highway industrial engine.

NOTE: Not all electronic engines use the "IS" or "QS" prefix. To verify if the engine is an electronic engine, check to see if an electronic control system is listed in the service model name. The control system that is identified as part of the service model name is referenced later in this procedure.

Non-electronic engines do not have an "IS" or "QS" prefix and do not have an electronic control system listed in the service model name.

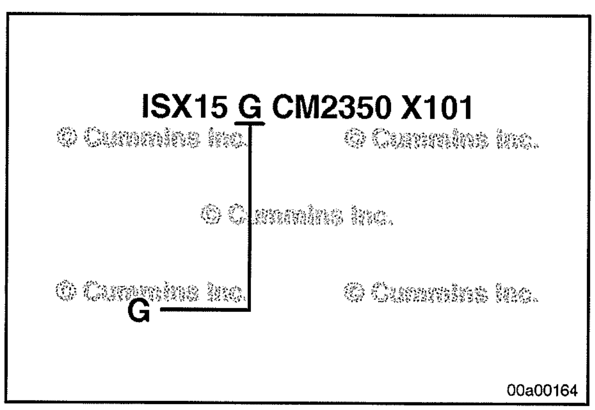


Typically, the third letter is the engine platform/series designation followed by the engine liter displacement. For the example shown in the graphic, the engine is a:

X Series engine

15 Liters in Displacement

NOTE: Some legacy engines will use the cubic inch rather than liter for engine displacement.



If a "G" indicator is located after the liter displacement, the engine is fueled by natural gas.

NOTE: Not all engines fueled by natural gas will have a "G" located after the displacement.

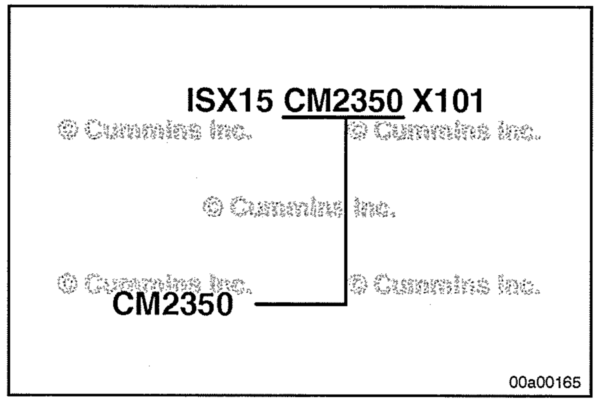
If a "M" is located after the liter displacement, the engine is in a marine application.

NOTE: Not all engines used in a marine application will have "M" located after the displacement.

If a "DF" is located after the liter displacement, the engine is a dual fuel application.

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

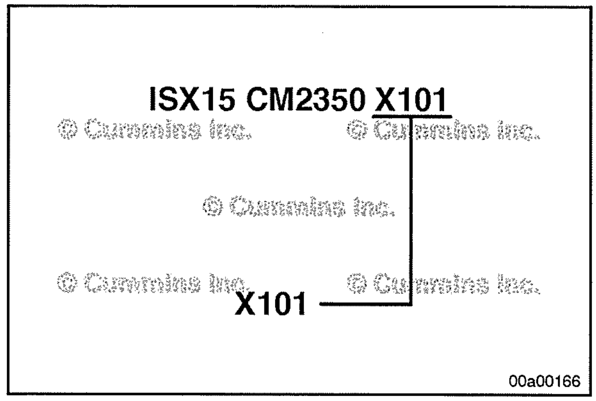
NOTE: Use of a parenthesis ( ) indicates that either engine control module (ECM) has been used on the product. Use of a slash "/" indicates that the product has multiple ECMs.



The identifier after the control system is a letter and number combination to identify variations between products.

The letter is the engine platform designation.

The number increments as new variations of the engine platform/series are released. The first number is 101.



Cummins® Product Technology

General Information

The service model name for this product is **QSG12 CM2350 G110**.

This engine is being released to meet the following emission regulation(s):

United States and Canada

- Tier 4 (EPA Final)

European Union

- Stage IV (Euro)

Korea (South)

EPA Product

This engine has the following Agency defined Emissions Control System (ECS) hardware, which can also be found on the engine dataplate. Use the following procedure for the location of theengine dataplate. Refer to Procedure 100-001 in Section E.

- Charge - Air Cooler (CAC)
- Direct Diesel Injection (DDI)
- Engine Control Module (ECM)
- Oxidation Catalyst (OC)
- Periodic Trap Oxidizer (PTOX)
- Selective Catalytic Reduction - Urea (SCR - U)
- Turbocharger (TC).

This engine uses the following product technology:

Engine

- Number of Cylinders - 6
- Engine Configuration - Inline
- Cylinder Block Material - Cast Iron
- Cylinder Head Material - Cast Iron
- Camshaft Location - Cylinder Head
- Engine Brake Option
- REPTO Option.
- Turbocharger (Single) - Wastegate
- Charge Air Cooler
- Intake Air Heater.

Electronic Control System

- Engine Control Module: CM2350
- Electrical System Voltage:
- 12 VDC
- 24 VDC
- Engine Coolant Level Sensor
- Engine Coolant Temperature Sensor
- Engine Oil Pressure Sensor
- Engine Oil Temperature Sensor
- Fuel Rail Pressure Sensor
- Fuel Pump Actuator

- Water in Fuel Sensor
- Camshaft Position Sensor
- Crankshaft Position Sensor
- Exhaust Gas Pressure Sensor
- Intake Manifold Pressure/Temperature Sensor
- Turbocharger Compressor Intake Pressure/Temperature Sensor
- Ambient Air Pressure Sensor
- Aftertreatment Diesel Particulate FilterDifferential Pressure Sensor
- Aftertreatment Exhaust Gas Temperature Sensor
- Diesel Exhaust Fluid Quality Sensor
- Aftertreatment Intake NOx Sensor
- Aftertreatment Outlet NOx Sensor.

Exhaust System

- Aftertreatment Fuel Injection
  - Internal
- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
  - Full Flow
- Selective Catalytic Reduction (SCR) Catalyst
- Aftertreatment Diesel Exhaust Fluid DosingSystem
  - Airless Diesel Exhaust Fluid Dosing Unit
  - Integrated Diesel Exhaust Fluid Controller(controlled by the engine's ECM).

Fuel System

- Diesel
- Common Rail Fuel System
  - Cummins XPI Common Rail Fuel System.

Market applications that will use this engine include, but **not** limited to:

Industrial

- Agriculture
- Construction
- Fire Pump
- Locomotive
- Power Unit
- Rail Car
- Oil and Gas
- Welding
- Air Compressor
- Underground Mining
- Track Maintenance.

Notes

Section F - Familiarization

Section Contents

Page
Air Intake System - Overview F-28
General Information....F-28
Complete Engine - Overview F-1
General Information....F-1
Compressed Air System - Overview F-47
General Information....F-47
Cooling System - Overview F-23
General Information....F-23
Cylinder Block - Overview F-3
General Information....F-3
Cylinder Head - Overview F-5
General Information....F-5
Electrical Equipment - Overview F-54
General Information....F-54
Engine Testing - Overview F-55
General Information....F-55
Exhaust System - Overview F-33
General Information....F-33
Flow Diagram, Air Intake System F-31
Flow Diagram....F-31
Flow Diagram, Compressed Air System F-50
Flow Diagram....F-50
Flow Diagram, Cooling System F-25
Flow Diagram....F-25
Flow Diagram, Exhaust System F-41
General Information....F-41
Flow Diagram, Fuel System F-10
Flow Diagram....F-10
Flow Diagram, Lubricating Oil System F-18
Flow Diagram....F-18
Fuel System - Overview F-8
General Information....F-8
Injectors and Fuel Lines - Overview F-11
General Information....F-11
Lubricating Oil System - Overview F-12
General Information....F-12
Rocker Levers - Overview F-7
General Information....F-7
Service Tools and Hardware - Overview F-56
General Information....F-56
Initial Check....F-56
INSITE™ Electronic Service Tool Description....F-56
Resistance Check....F-63
Setup....F-59

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Complete Engine - Overview (000-999)

General Information

Basic Engine Information and notable features:

- QSG CM2350
- Engine Control Module CM2350
- No Exhaust Gas Recirculation (EGR)
- Selective Catalytic Reduction (SCR) Catalyst
- Diesel Particulate Fitler (DPF)
- The engine uses two different pistons
- Fracture Split Connecting Rods
- Extra High Pressure Injection (XPI) Common Fuel Rail
- Rear Gear Train

Review the General Cleaning Instructions in this manual. Field shops are strongly encouraged to review these instructions with all technicians and to include general cleaning instructions in technician training programs and new technician orientation programs.

It is important that oil passages plugged and cavities are masked prior to scraping gaskets material and/or cleaning the joint surfaces. Good housekeeping that alleviates the amount of dust in the shop's atmosphere is needed. Washed parts that will **not** immediately be assembled into an engine, **must** be covered up to protect against contamination. Regularly clean sockets, wrenches, gauges and containers used for engine repairs. Clean the work surfaces of carts, tool boxes and tables regularly to prevent contaminations of parts.

Before servicing any fuel system components such as fuel lines, fuel pump, injectors, etc. which would expose the fuel system or internal engine components 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 and engine, resulting in damage to the fuel system and engine. See the engine steam cleaning procedure in the service manual.

The modern fuel system plays a major part in reducing diesel engine emissions. In order for the fuel system to meet these ever-increasing expectations, the fuel system **must** completely atomize injected fuel and the injection events **must** be precisely controlled. The internal drillings of a modern injector are often extremely small and very susceptible to plugging from contamination. Plugging of the injector on some diesel engine fuel systems can cause a continuous fueling event that can result in engine damage. Modern diesel fuel injection systems can operate at very high pressures. High pressure fuel can convert simple particles of dirt and rust into a highly abrasive contaminate that can damage the high pressure pumping components and fuel injectors. Many modern injectors are nonserviceable, with the exception of the nozzle and control solenoid. Some injectors are completely nonserviceable.

- Use Cummins recommended cleaning procedures 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.
- Be aware of compressed air. Avoid or limit the use of compressed air for cleaning if there is a fuel system or major engine repair underway in close proximity.
- 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 0.09 mm [0.0035 in] in diameter. One micron measures 0.001 mm [0.00004 in]. There are many Cummins® engines that require secondary fuel filtration at the 3 micron level. These contaminants are far 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 often overlooked as a potential source of contamination. Like fuel system parts, if tools are coated with oil or fuel they are a magnet for airborne contaminants. Because a tool looks clean does **not** mean that it is clean. Remember the following points regarding your fuel system tools:

- **Always** keep your fuel system tools as clean as possible.
- Clean and dry the tools before returning them to your tool box.
- If possible, store fuel system tools in sealed containers. This also helps to keep tools organized and ready for the next service event.
- Make sure fuel system tools are clean before use, especially if they are shared tools.

Keeping a fuel system clean is easier than cleaning up and repairing a contaminated system. Once a fuel system is contaminated, it is nearly impossible to know if you have successfully removed the contaminants. Cap and plug fuel lines, fittings, and ports whenever the fuel system is opened, even if the repair is **only** going to take a short time to complete. Airborne contaminants can come from the next bay, from bumping the hood, or even from your clothing.

Potential contaminants can be dislodged from other parts being removed from the engine (even after the engine has been thoroughly cleaned) from accidental contact like bumping an engine cover or wiring harness. The best practice is to **always** cap and plug openings in the fuel system as soon as possible.

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.

Before beginning repairs on a fuel system, be sure to understand the fuel flow of the particular engine. Information on engine fuel flows can be found in the service literature on QuickServe™ Online or in the printed service literature. Pay particular attention to the last point of filtration in the fuel system. After the last point of filtration, contaminants introduced into the fuel system have no possibility of being removed before entering contaminant-sensitive fuel system components.

Cleaning products recommended and available from Cummins Inc. are listed in the table below.

Cleaning Products Available From Cummins Inc.	
Description	**Part Number**
Parts cleaning soap	3823882
Solvent cleaner/engine degreaser	3824421
QD contact cleaner	3824510
Zvock engine degreaser	3825139

If the engine is found to be magnetized, the engine will need to be disassembled and examined for:

- Engine inspection for electrical pass-through damage.
- Magnetism of ferrous components.
- Debris through the lubrication system.
- Damage to bearings and bushings, including: crankshaft thrust bearings, main bearings, connecting rod bearings, and camshaft bushings.
- Component or wear damage.

The Disassembly and Assembly sections of this manual can be used to disassemble and assemble the engine.

Acceptable Magnetism Levels	
Injectors and Ferrous Injector Components	**All Other Ferrous Components**
5 or less gauss units	15 or less gauss units

Measure each ferrous component with a gauss meter and record the results. If the magnetism is out of specification, the engine **must** be treated in general as if debris (fine particles) have been traveling throughout the lubrication system, resulting in wear and damage to components.

Components with measured gauss units greater than specification **must** be demagnetized or replaced. A facility capable of magnetic testing of the engine components is capable of demagnetizing (degaussing) components.

Check components in the lubrication system closely and thoroughly clean the oil galleries.

Replace all main bearings, thrust bearings, connecting rod bearings, and camshaft bushings.

NOTE: Do **not** attempt to demagnetize sensors, engine control modules, or actuators.

There are two methods for demagnetizing components:

- Passing the part through an alternating current coil (50 or 60 cycles per second)
- Passing a reversing, 30 point step-down current through the part.

The alternating current coil is suggested for smaller parts.

For larger mass parts, the reversing 30 point step-down is suggested.

Parts with acceptable levels of magnetization **must** be cleaned and inspected for reuse.

It is recommended to have the alternating current coil just large enough for the parts to pass through. A small part passed through a large coil will **not** be demagnetized as well as if it were passed through a smaller coil.

The coil **must** be located so the longest part axis of the part is perpendicular to the coil when passing through. Parts **must** pass through a minimum of 457.2 to 609.6 mm [18 to 24 in] beyond the coil for the most effective demagnetization.

Do **not** attempt to demagnetize small parts by loading them into a basket and passing the basket through a coil. Do **not** attempt to demagnetize a whole engine assembly.

Direct current demagnetization can be accomplished by using the magnetizing unit. Clamp the part between the head and tail stock. Activate the demagnetization controls, and the reversing, step-down current passes through the part. Check all parts with the gauss meter.

When tiny pits occur in clearly defined patterns, or surfaces are fluted, electric current can be the problem. The patterns will vary with metals, sources, and movement.

For insert bearings, pitting is a chief indication. In anti-friction bearings, such as ball bearings, fluted surfaces or wavy lines of pitting in patterns differing with rotation, vibration, and current are the chief indications.

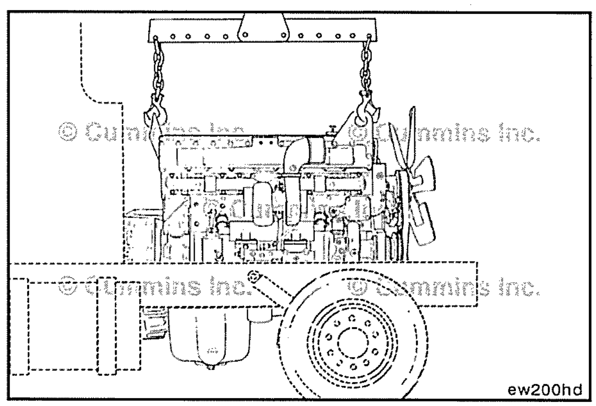
Sources of electrical damage are:

- Electrically actuated components (such as a clutch).
- Static current from belts or other moving parts.
- Grounding of electrical system through the crankshaft when some component such as the generator or engine block has **not** been grounded properly.
- An improperly grounded 24 volt system.

Engines that have experienced dust outs because of intake air system component damage that resulted in cylinder liner and piston ring wear, **must** be treated as if the lubricating oil system has been contaminated with debris. The engine **must** be disassembled and cleaned appropriately to remove debris from the oil galleries, block cavities, cylinder head, and air intake system. Camshafts, rocker lever pins, and rollers **must** also be thoroughly cleaned and examined for wear.

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

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



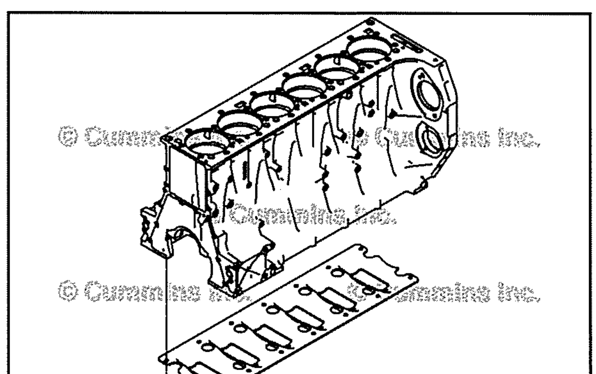
ew200hd

Cylinder Block - Overview (001-999)

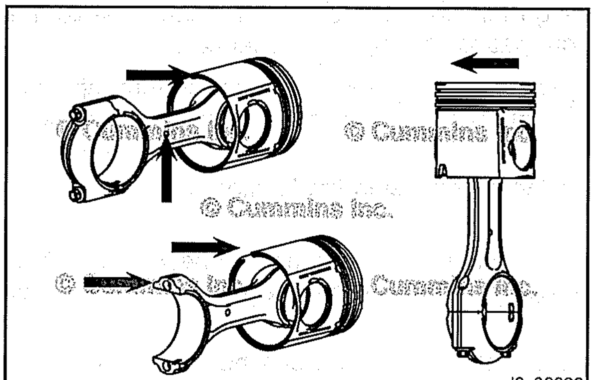
General Information

The cylinder block is an inline 6 cylinder made of grey cast iron. The cylinder block is designed to accommodate a rear gear train.

The block stiffener plate is a required component for all engines.

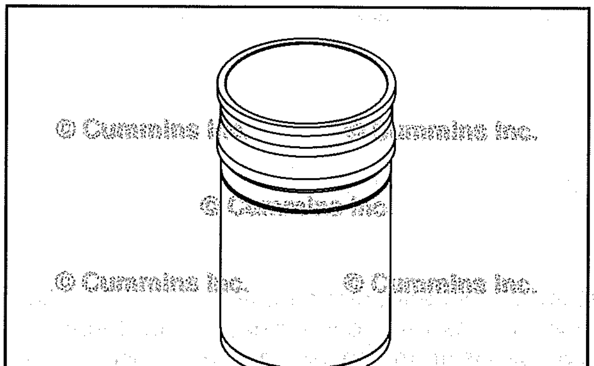


d3x00028


d3x00029

The connecting rod crankshaft bore is a fracture-split design with two capscrews.

The dimples on the connecting rod are located under the notch in the piston. The notch in the piston and the dimples on the connecting rod face the rear of the engine.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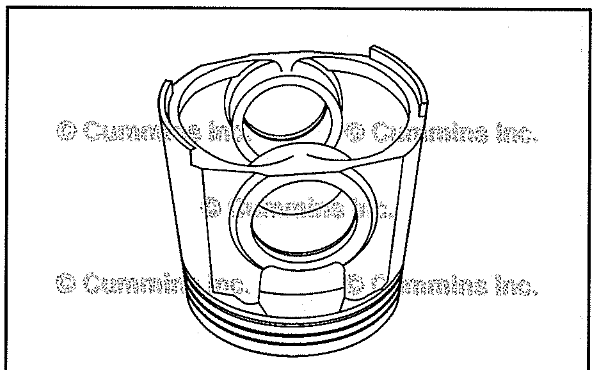
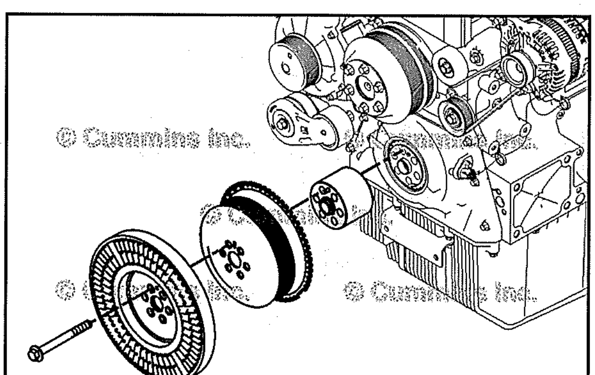
The cylinder liners are of a mid-stop cylinder liner design.


01400655

These engines use two different single piece steel pistons with target piston cooling nozzles.

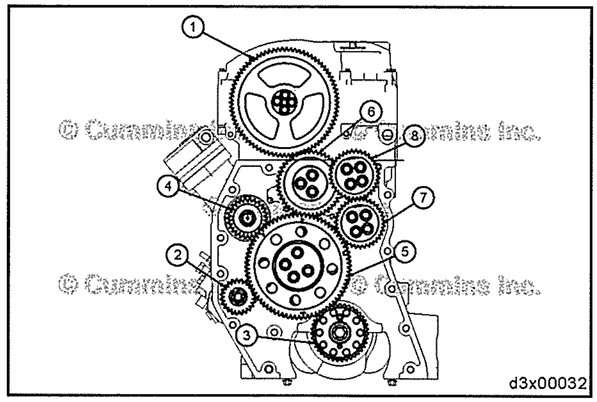
This engine uses two different pistons. One piston is used in cylinders 1,3,5 and the other is used in cylinders 2,4,6.


01x00027

The viscous vibration damper is a separate component from the crankshaft pulley.

The rear gear train uses the following components:

1 Camshaft gear
2 Fuel pump gear
3 Crankshaft gear
4 Air compressor gear
5 Crankshaft Idler gear
6 Camshaft Idler gear
7 If applicable, REPTO Idler gear
8 If applicable, REPTO gear.



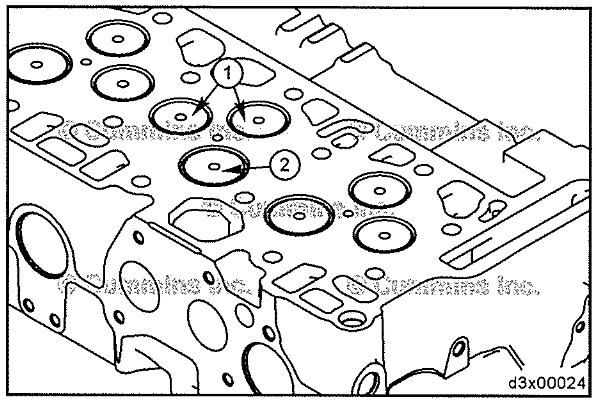
Cylinder Head - Overview (002-999)

General Information

Cylinder Head Assembly

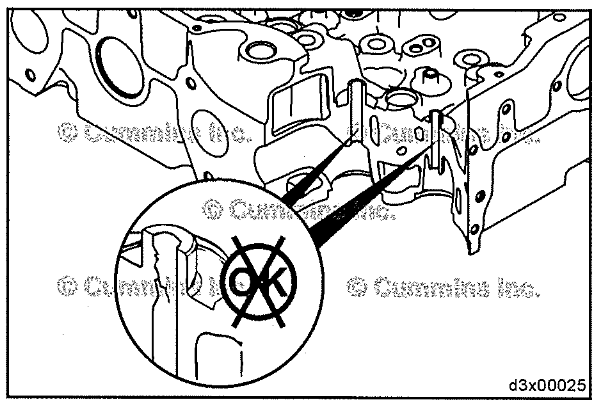
The cylinder head is a one-piece, cross flow design with three valves per cylinder. It contains an overhead camshaft directly in contact with the rocker levers.

The intake (1) and exhaust valves (2) are made of heat resistant steel. The intake and exhaust valves are different in head diameter and overall length, which makes them non-interchangeable.



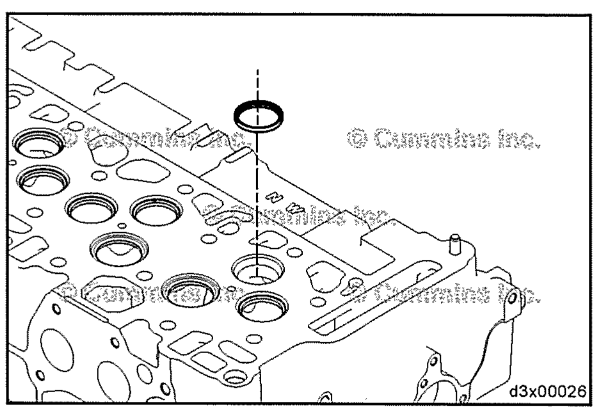
Valve Guides

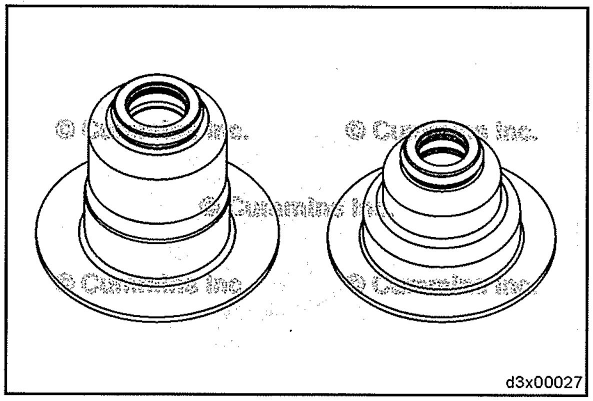
The cylinder head has integrally cast valve guides which are **not** serviceable. If the valve guides are damaged, the cylinder head **must** be replaced.



Valve Seat Inserts

The valve seat inserts can **not** be replaced if damaged. No oversize inserts are available if the valve seat bores are out of specification.

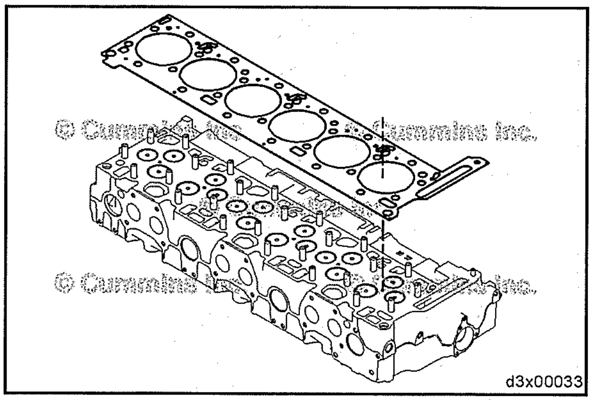




Valve Stem Seals

The valve stem seals have a "top hat" design that utilizes the valve spring to secure the valve stem seal in place.

The intake and exhaust have different top hat designs.

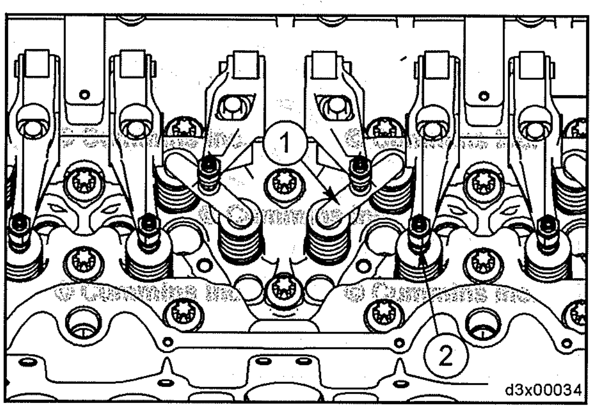


Cylinder Head Gasket

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. The gasket also provides orifices to control coolant flow from the cylinder block to the cylinder head.

Head gasket grading is **not** required for the engines covered by this manual.

No specific head gasket, with an increased thickness, is available for cylinder head or block combustion deck resurfacing. The cylinder head combustion deck can **not** be resurfaced. If out of specification, the cylinder head **must** be replaced.



Crossheads

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

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

For the single exhaust valve, the rocker lever contacts directly to the valve to operate.

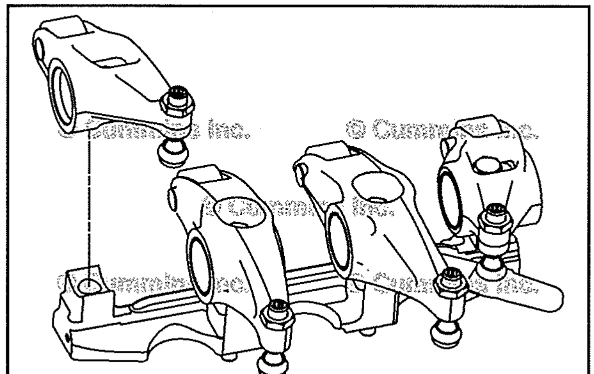
1 Intake Valve

2 Exhaust Valve.

Rocker Levers - Overview (003-999)

General Information

Rocker Levers



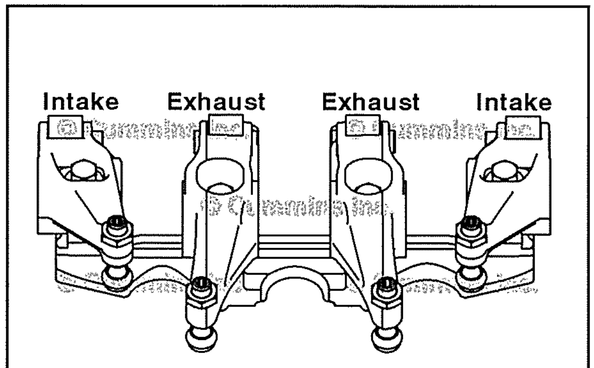
03x00009

The rocker levers transmit motion from the camshaft to either a crosshead or a valve. There are two intake valves that are compressed by a one rocker lever via a crosshead. There is one exhaust valve that is compressed directly from a rocker lever.

The exhaust and intake rocker levers are mounted on a common pedestal assembly, 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, sockets, and an adjusting screw.

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



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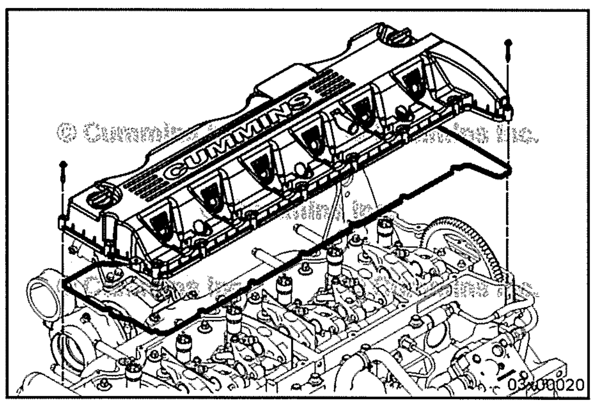
Rocker Lever Cover

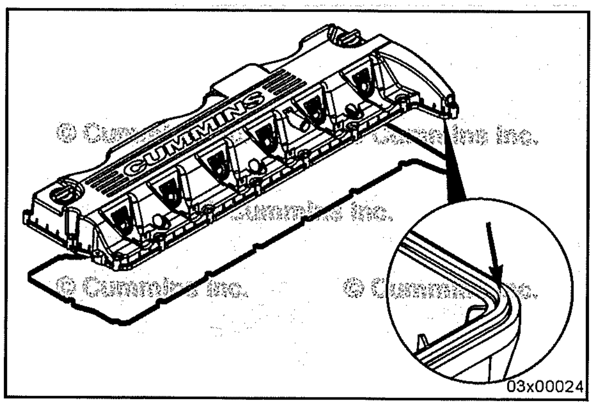


03x00020

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

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

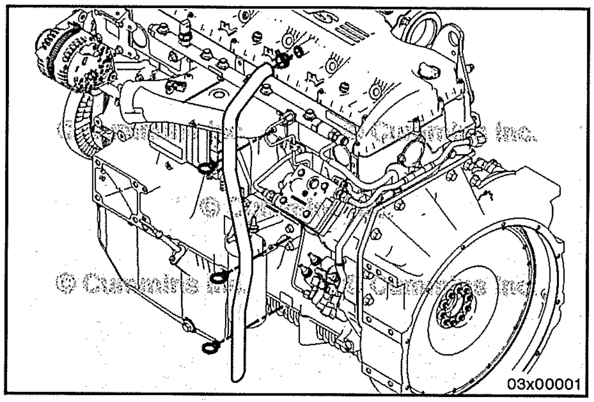
In order to remove a rocker lever cover, all high-pressure fuel lines need to be removed.



Rocker Lever Cover Gasket

The rocker lever cover uses a molded rubber gasket.

The molded gasket is inserted into a channel along the perimeter of the rocker lever cover.

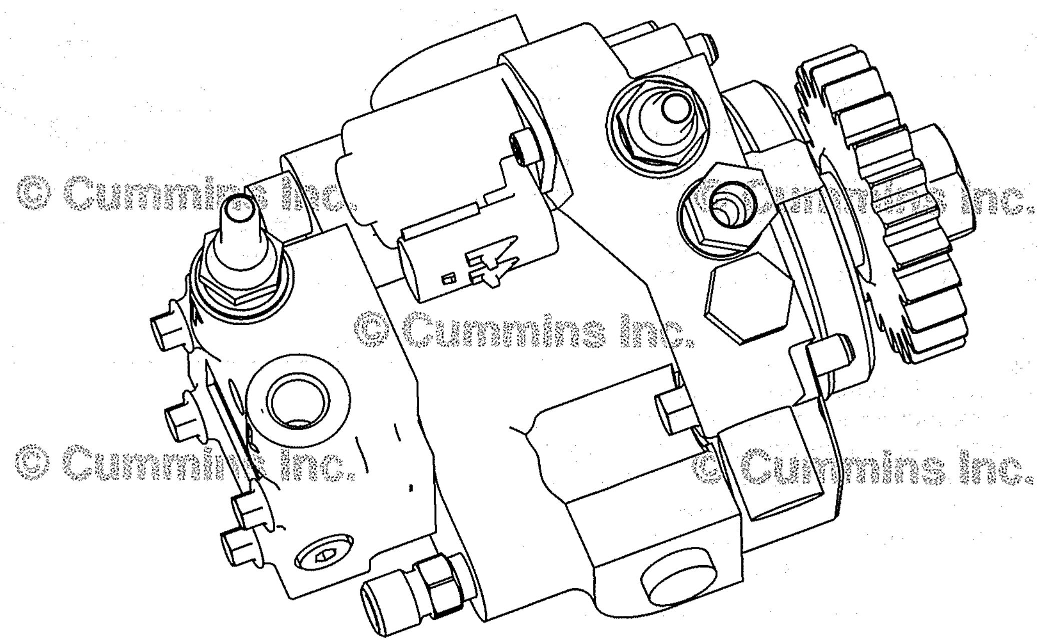


Crankcase Ventilation System

Open crankcase ventilation system gases are vented outside of the engine through the open crankcase ventilation hose mounted on the rocker lever cover.

Fuel System - Overview (005-999)

General Information



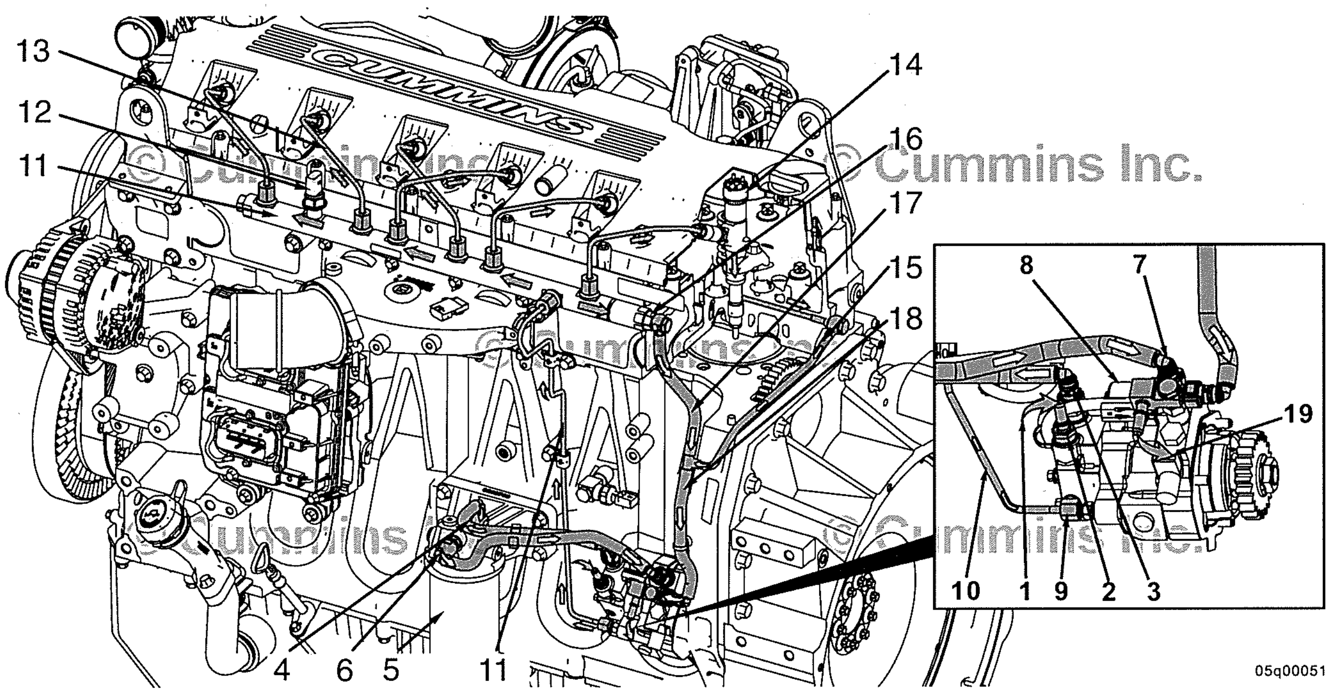
The fuel system is a high-pressure common rail electronically controlled fuel system. The high-pressure common rail system consists of five main components: fuel pump gear pump, pressure fuel filter, high-pressure pump, fuel rail, and injectors. The fuel pump gear pump supplies fuel to the pressure fuel filter, then to the high-pressure pump. The high-pressure pump supplies high-pressure fuel to the fuel rail independent of engine speed. The high-pressure fuel is then accumulated in the fuel rail. High-pressure fuel is constantly supplied to the injectors by the fuel rail. The electronic control module (ECM) controls the fueling and timing of the engine by actuating the injectors.

Fuel that enters the high-pressure fuel pump is pressurized between 250 and 1800 bar [3626 to 26107 psi] by two radial pumping chambers. A fuel pump actuator at the inlet to the two radial pumping chambers regulates the volume of fuel that is allowed to enter the pumping chambers. By regulating the volume of pressurized fuel, the fuel pump actuator uses signals from the ECM to maintain the pressure in the fuel rail. Fuel that is **not** allowed to enter the two radial pumping chambers is directed back to the inlet side of the pump via the regulator. A portion of this drain fuel is used to lubricate the high-pressure pump bearings and then returns the fuel to the fuel tank.

The fuel rail acts as a fuel manifold accumulating and distributing fuel to each of the injector supply lines. Within the fuel rail, there is a fuel rail pressure sensor that monitors the pressure provided to the fuel rail from the high-pressure fuel pump. Pressure measured by the fuel rail pressure sensor is used by the ECM to adjust the fuel output of the high-pressure pump. The fuel rail also contains a fuel rail pressure relief valve. The fuel rail pressure relief valve is a safety valve used to bleed off excess pressure if the rail pressure exceeds a preset threshold. Fuel bled off by the fuel rail pressure relief valve is returned to the fuel tank through a fuel drain line connected to the fuel rail.

Flow Diagram, Fuel System (200-001)

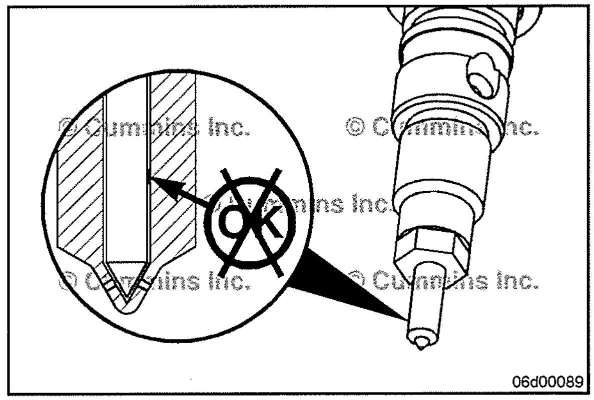
Flow Diagram



1 Fuel supply - from suction side filter
2 Fuel pump gear pump inlet
3 Fuel pump gear pump outlet
4 Pressure side fuel filter inlet
5 Pressure side fuel filter
6 Pressure side fuel filter outlet
7 High pressure fuel pump inlet
8 Fuel pump actuator
9 High pressure fuel pump outlet
10 Fuel rail supply line
11 Fuel rail
12 Fuel rail pressure sensor
13 Injector supply lines
14 Injectors
15 Fuel drain from injectors
16 Fuel pressure relief valve
17 Fuel pressure relief valve drain
18 Fuel drain line
19 Fuel return to OEM tank.

Injectors and Fuel Lines - Overview (006-999)

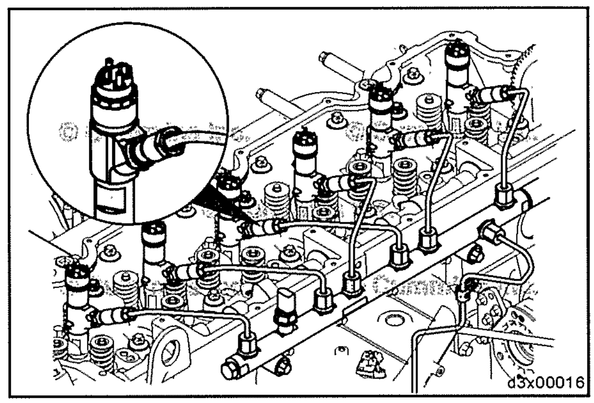
General Information



⚠WARNING⚠

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

High-pressure common rail fuel systems use solenoid-actuated injectors. High-pressure fuel flows into the side of the injector. When the solenoid is activated, an internal needle lifts and fuel is injected. The clearances in the nozzle bore are extremely small and any dirt or contaminants will cause the injector to stick. This is why it is important to clean around all fuel connections before servicing the fuel system. Also, cap or cover any open fuel connections before a fuel system repair is performed.

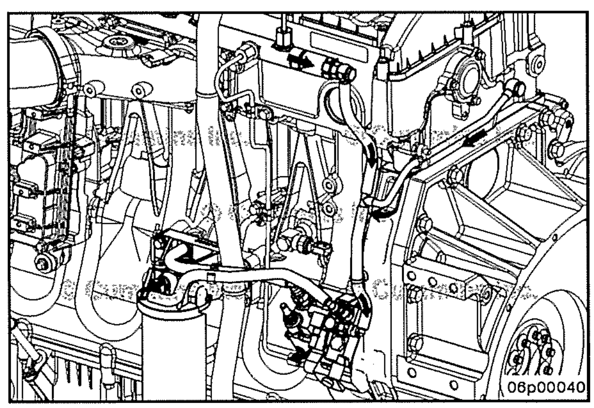


⚠CAUTION⚠

To reduce the possibility of engine damage, always use the proper torque on the high-pressure line nuts.

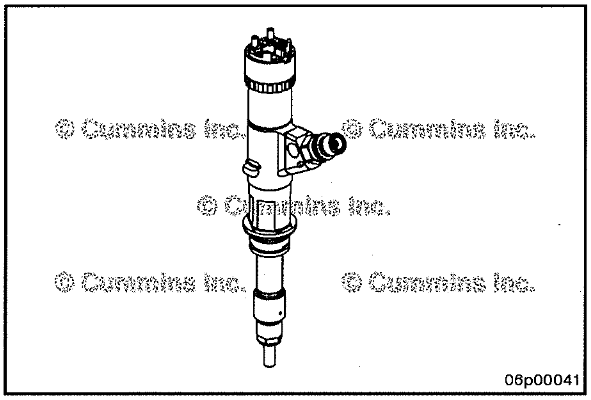
High-pressure fuel is supplied to the injector from the fuel rail by an injector supply line.

The torque on the injector supply lines is critical. If the nut or line is under tightened, the surfaces will **not** seal and a high-pressure fuel leak will result. If the nut is over tightened, the injector will deform and cause a high-pressure fuel leak. This leak will be inside the rocker cover and will **not** be visible. The result may be a fault code, low power, or no-start.

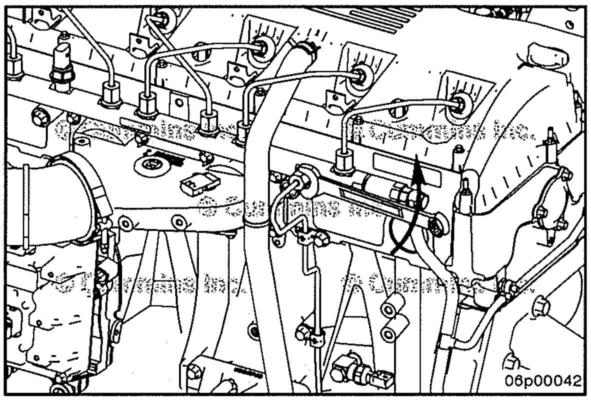


All injectors feed into a common return circuit contained within the cylinder head. Any excess fuel is returned to the tank via this drilling in the cylinder head and return line attached to the rear of the cylinder head. A back-pressure valve is located on the back of the cylinder head where the drain line attaches. The fuel drain lines may have either a quick-disconnect fitting or a banjo fitting at ends of the fuel drain lines.

Each of the fuel drain lines combine together at the fuel return manifold.


06p00041

The electronic control module (ECM) controls the fueling and timing of the engine by actuating the solenoids on the injector. An electronic pulse is sent to the solenoids to lift the needle and start the injection event. By electronically controlling the injectors, there is a more precise and accurate control of fueling quantity and timing. Also, multiple injection events can be achieved by electronically controlling the injectors.


06p00042

WARNING

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

d3x00001

Lubricating Oil System - Overview (007-999)

General Information

Lubricating Oil

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.

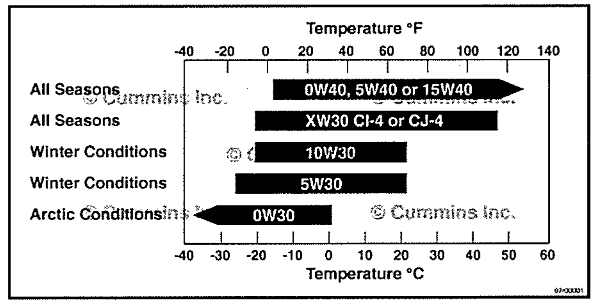
Cummins Inc. recommends the use of a high quality SAE 10W-30 heavy-duty engine oil which meets the American Petroleum Institute (API) performance classification CH-4.

NOTE: The oil grades CC, CD, CE, CF, and CF-4 have been obsoleted by API and **must not** be used. For detailed information on oil requirements and maintenance intervals, see the appropriate Operation and Maintenance and/or Owners manual for the engine being serviced. Refer to Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340 for more detailed information.

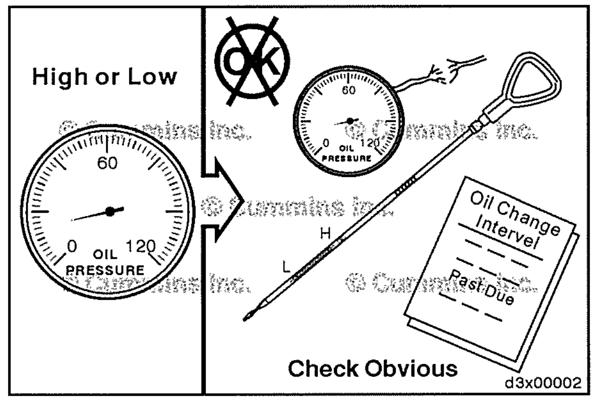
Arctic Operation Engine Oil

⚠CAUTION⚠

Limited use of low-viscosity lubricating oils, such as 0W-30, can aid in starting the engine and providing sufficient lubricating oil flow at ambient temperatures below -0°C [32°F] as shown in the illustration. However, the continuous use of low-viscosity lubricating oils can decrease engine life.

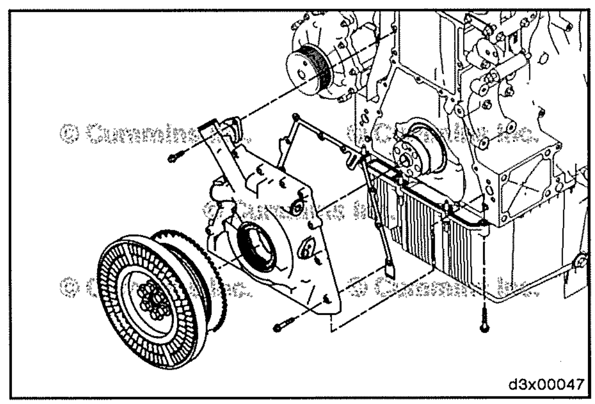


When diagnosing lubricating oil system malfunctions, check all obvious items related to oil pressure, such as gauges, high and low oil level, excessive oil contamination, and oil viscosity. Refer to Procedure 007-048 in Section 7.



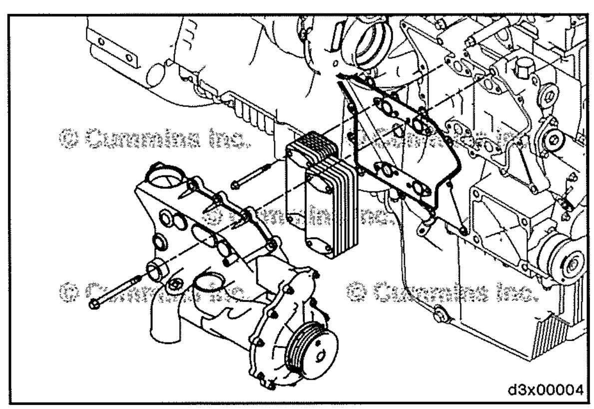
Lubricating Oil Pump

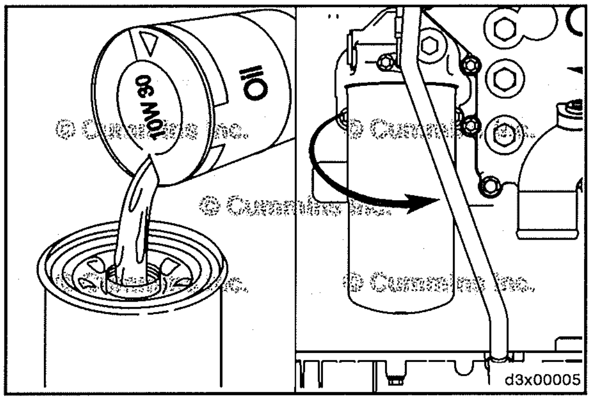
A gerotor type lubricating oil pump is used. The lubricating oil pump, located on the front of the engine behind the vibration damper, is driven directly by the crankshaft.



Lubricating Oil Cooler Module

A full-flow, plate-type lubricating oil cooler is used. The lubricating oil cooler is located on the exhaust side of the engine. Lubricating oil flows through the plates of the oil cooler, where it is cooled by engine coolant flowing past the plates. The lubricating oil cooler modules utilizes two cooling bundles.



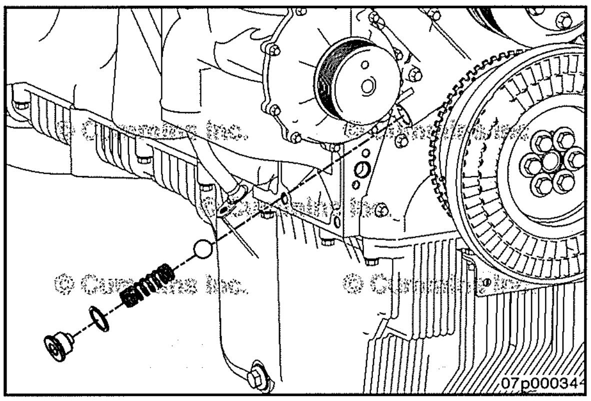


Lubricating Oil Filter

A full-flow oil filter is used for engine oil filtration. The oil filter is located on the exhaust side of the engine, toward the front. The lubricating filter head is part of the lubricating oil cooler module assembly.

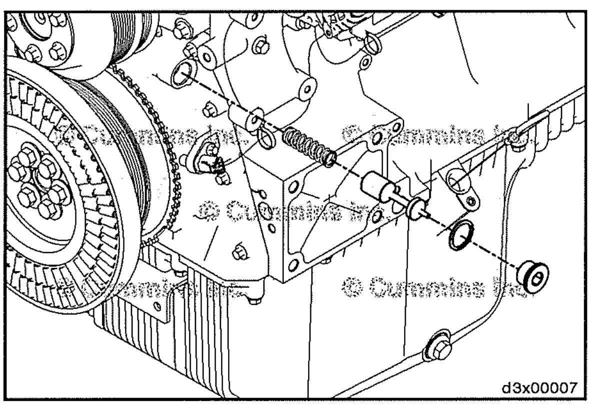
Cummins Inc. recommends that the oil filter be pre-filled when changed to prevent lubrication oil pressure delay at start-up.

NOTE: Be careful that debris is **not** allowed 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.



High Pressure Dump Valve

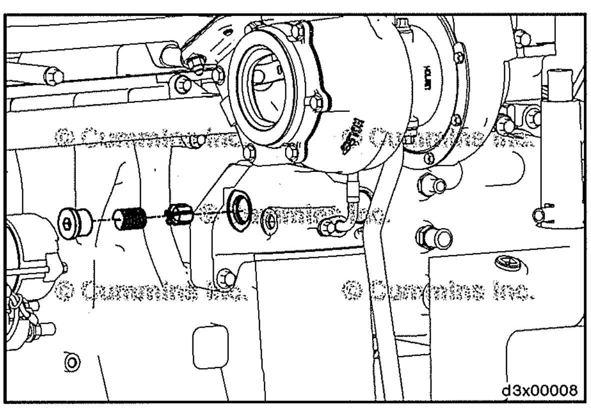
The lubricating oil high pressure dump valve is on the exhaust side of the lubricating oil pump. The high pressure dump valve is a ball check valve that prevents oil pressure from getting too high during cold start conditions.



Lubricating Oil Rifle Pressure Regulator

The lubricating oil rifle pressure regulator is located on the intake side of the engine. The rifle pressure regulator consists of a cap, spring, steel cup plug and plunger.

NOTE: Be careful that the steel cup plug is on the spring when reinstalling the lubricating oil pressure regulator.



Lubricating Oil Bypass Valve

Whenever the pressure drop across the lubricating oil filter exceeds 758 kPa [110 psi] the oil filter bypass valve opens and allows lubricating oil to bypass the lubricating oil filter.

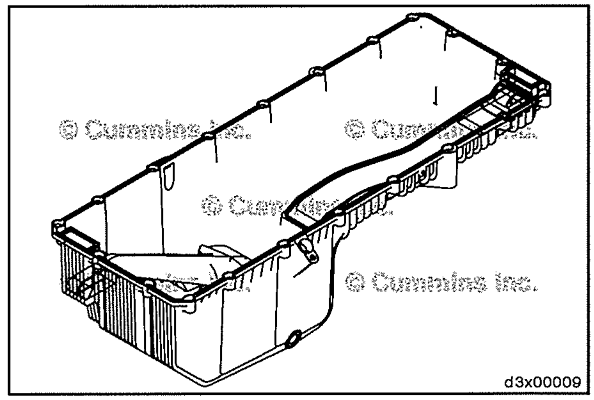
This condition can occur during cold ambient temperature (cold lubricating oil) engine start-ups.

The purpose of the bypass valve is to maintain lubricating oil flow to the engine and prevent an oil filter collapse.

Lubricating Oil Pan

The oil suction tube is integrated into the oil pan.

NOTE: This is a front sump engine. Care should be taken with installation to ensure that the pan orientation is correct.



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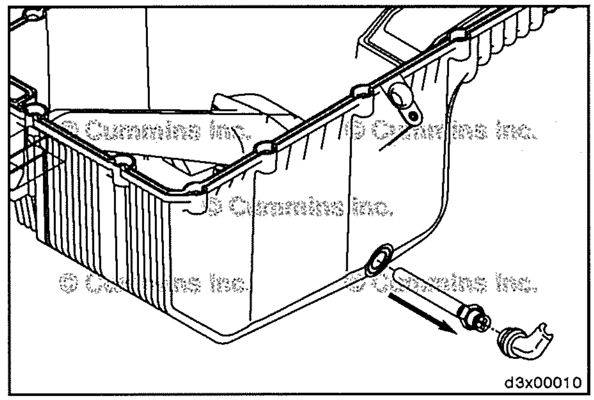
Engine Oil Heater

The engine oil pan allows for an optional lubricating oil heater to be installed to aid engines operating in cold climates.



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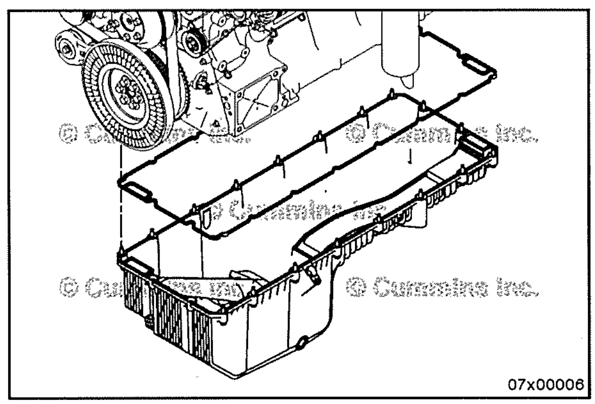
Suspended Oil Pan

A suspended oil pan is equipped with a reusable rubber gasket. Mounting fasteners are captured in the pan assembly.



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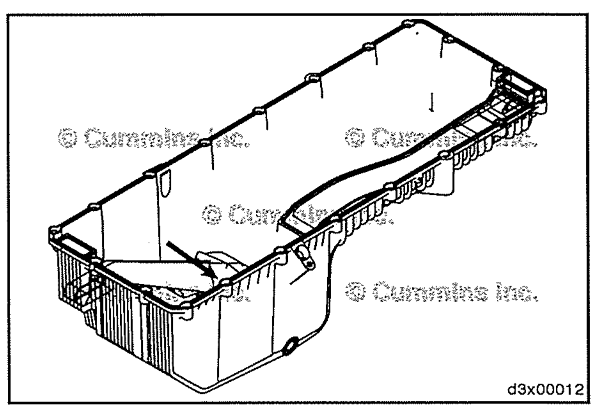
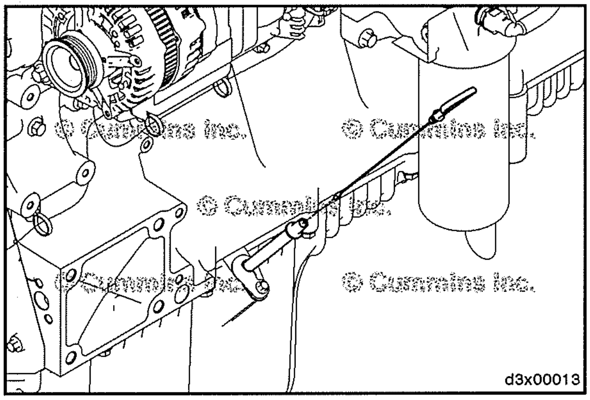
Lubricating Oil Suction

The lubricating oil suction tube is a formed plastic tube that is friction welded to the oil pan. There is a screen located at the bottom of the suction tube to prevent any large debris from entering the lubricating oil system.

The oil suction tube seals to the lube pump housing when the oil pan is installed.



d3x00012

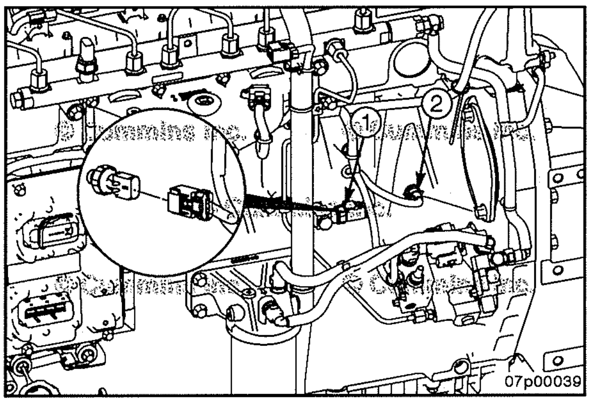


Lubricating Oil Dipstick

The lubricating oil dipstick for checking the engine oil level fit into the formed oil pan. It is held in place with a capscrew. The dipstick housing seals to the oil pan with an o-ring.

The dipstick seals to the dipstick housing with an o-ring.

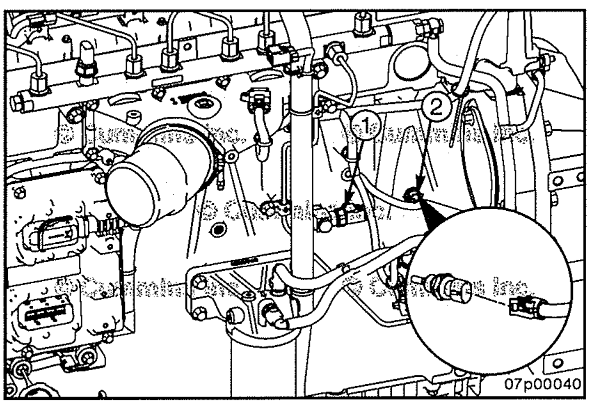
NOTE: Some engines/applications also have an optional oil level sensor to notify the operator when the lubricating oil level is low.



Lubricating Oil Pressure Sensor

To monitor oil pressure, an oil pressure sensor (1) is used.

The lubricating oil pressure switch is located on the intake side of the engine on the cylinder 5 main rifle.



Lubricating Oil Temperature Sensor

To monitor oil temperature an oil temperature sensor is used (2).

The lubricating oil temperature sensor is located on the intake side of the engine on the cylinder 6 main rifle.

Lubricating Oil Flow Description

Lubricating Oil Pump

The engine uses a gerotor-type lubricating oil pump. Lubricating oil in the oil pan travels through the suction tube and into the gerotor-type lubrication oil pump. The oil is then pressurized and passes up through the lube oil transfer tube into the lubricating oil cooler module.

High Pressure Dump Valve

The high pressure dump valve is designed to keep the lubricating oil pressure from exceeding 1034 kPa [150 psi] when in the lubricating oil pump. When the lubricating oil pressure from the pump is greater than 1034 kPa [150 psi], the high pressure relief valve opens, uncovering the dump port and allowing part of the lubricating oil to be routed back to the oil pan.

Lubricating Oil Rifle Pressure Regulator

The lubricating oil rifle pressure regulator allows oil to flow back to the pump if pressure in the main rifle exceeds 2.4 bar [35 psi].

Rifle regulated oil pressure

On the front, intake side of the block in the main rifle there is a sensing drilling for the rifle regulated oil pressure.

Oil Filter

Lubricating oil from the oil cooler flows through the full-flow lubricating oil filter. Oil exiting the full-flow oil filter is directed to the main oil gallery(s) of the cylinder block and the turbocharger.

Bypass Valve

The lubricating oil bypass valve is located in the lubricating filter head which is part of the lubricating oil cooler module. The lubricating oil bypass valve will open if the pressure differential across the lubricating oil filter exceeds 758 kPa [110 psi].

Lubrication for the Turbocharger

The turbocharger is the first component to receive filtered, cooled, and pressurized lubricating oil through a supply tube from the lube filter module. A drain tube, connected to the bottom of the turbocharger housing, returns the lubricating oil to the lubricating oil pan through a port in the pan. This tube is press fit into the pan and seals with o-rings.

Lubrication for the Power Components

Main Oil Rifle

Lubricating oil from the oil filter supplies oil to the piston cooling rifle and the main oil rifle in parallel from the exhaust side of the engine. The main oil rifle supplies oil to the overhead, crankshaft main bearings and rear gear train.

Vertical drillings in the block supply oil to the main bearings and overhead.

Lubrication for the Overhead Components

From the cylinder block, a vertical drilling provides oil to the cylinder head, rocker lever pedestal and camshaft journals.

Lubrication for the Rear Gear Train

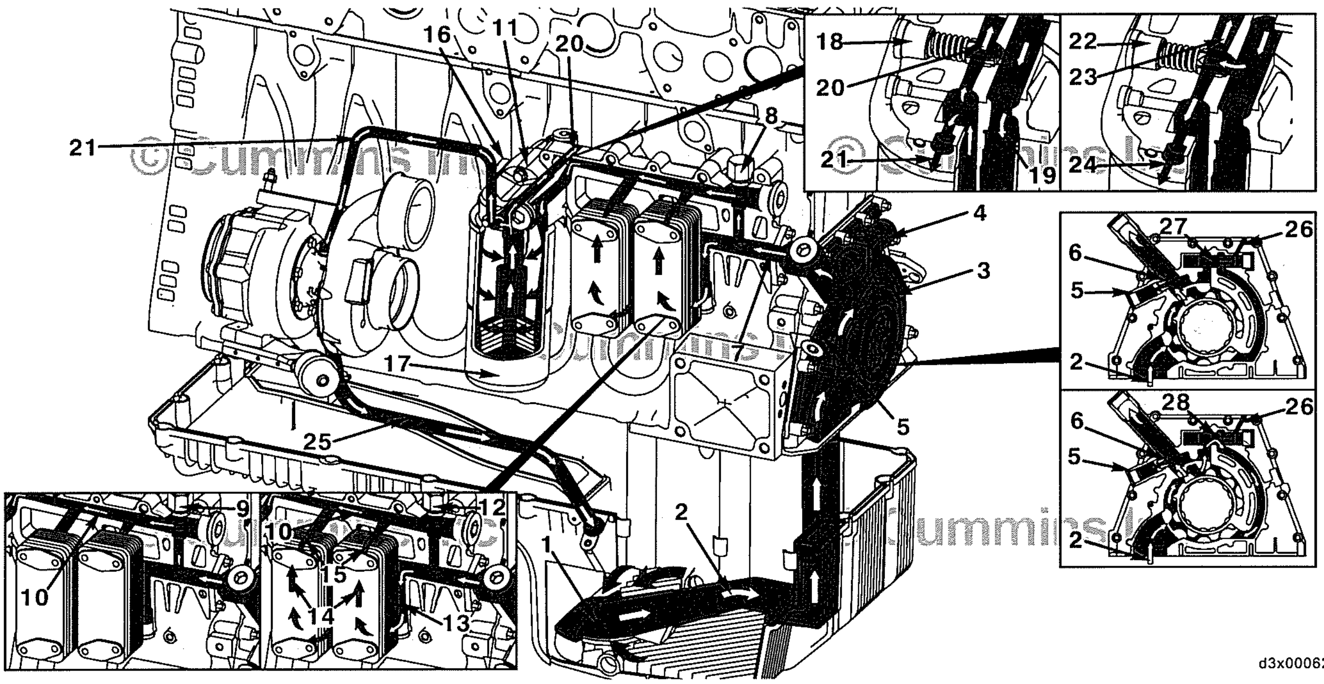
The rear gear train is supplied oil from a horizontal drilling to the main oil rifle.

Cylinder Head

The camshaft journal is supplied oil by vertical drilling in the head. The pedestals are also supplied oil from the vertical drilling to the cam journal. Internal drillings in the pedestal supply lubricating oil to the rocker shaft, rocker roller, and crosshead pad.

Flow Diagram, Lubricating Oil System (200-002)

Flow Diagram



1 Flow from oil pan through suction tube
2 Flow from suction tube to lubricating oil pump
3 Lubricating oil pump
4 Lubricating oil pressure regulator valve
5 Lubricating oil high-pressure relief valve
6 Lubricating oil return to oil pan
7 Lubricating oil flow from lubricating oil pump to lubricating oil cooler module
8 Lubricating oil thermostat
9 Flow with lubricating oil thermostat open
10 Lubricating oil flow from lubricating oil cooler module main oil rifle to lubricating oil filter head
11 Lubricating oil filter head
12 Flow with lubricating oil thermostat closed
13 Lubricating oil flow to oil cooler
14 Lubricating oil flow through oil cooler elements
15 Lubricating oil flow from lubricating oil cooler to lubricating oil cooler main oil rifle
16 Lubricating oil filter bypass valve
17 Lubricating oil filter
18 Flow with lubricating oil filter bypass valve closed
19 Lubricating oil flow from filter head to filter
20 Filtered lubricating oil flow to engine block main oil rifle
21 Filtered lubricating oil flow to turbocharger
22 Flow with lubricating oil filter bypass valve open
23 Unfiltered lubricating oil flow to engine block main oil rifle
24 Unfiltered lubricating oil flow to turbocharger
25 Lubricating oil drain from turbocharger

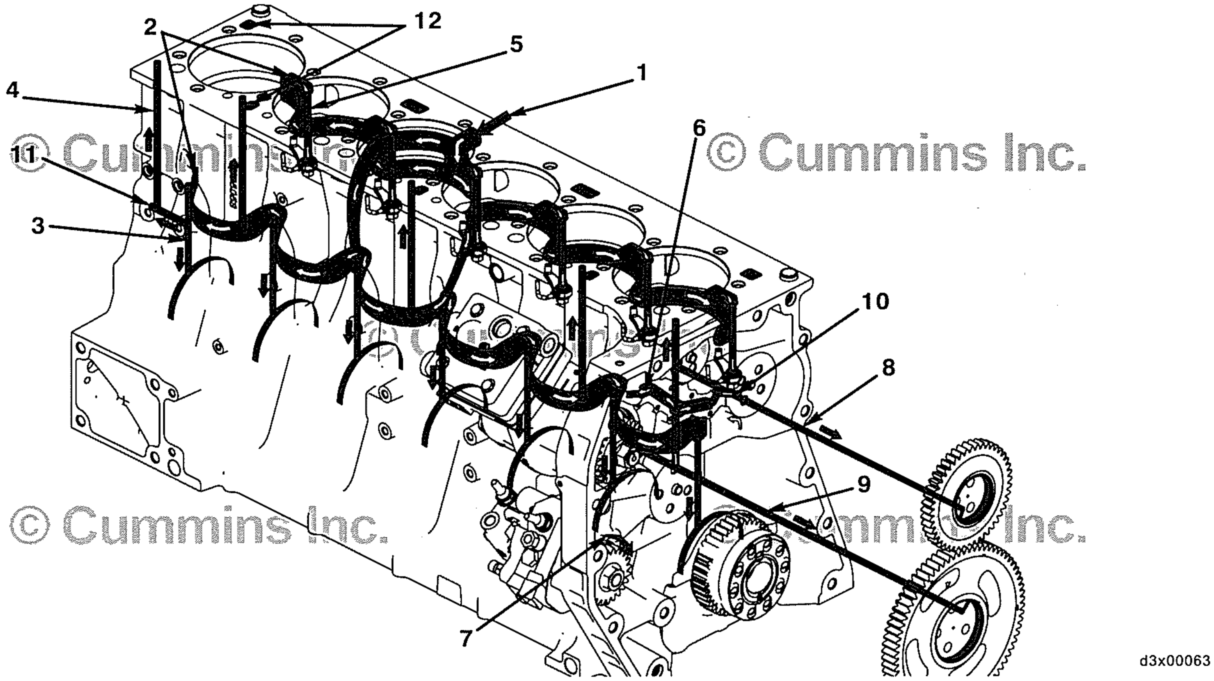
26 Block oil riffle pressure sensing channel

27 Flow with pressure regulator valve closed

28 Flow with pressure regulator valve open.

Flow Diagram, Lubricating Oil System (200-002)

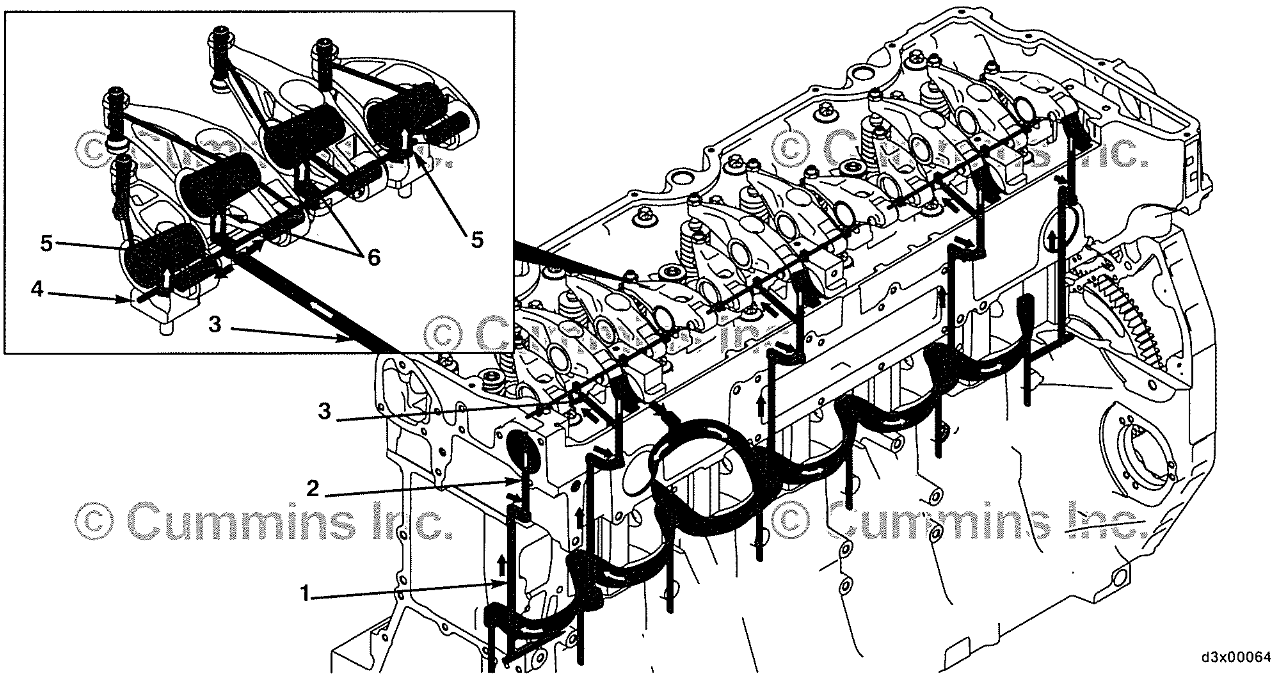
Flow Diagram



1 Lubricating oil flow from lubricating oil filter head to engine block main oil rifle
2 Main oil rifle
3 Flow to main bearings
4 Flow to cylinder head
5 Flow to piston cooling nozzle
6 Flow to air compressor
7 Flow to fuel pump
8 Flow to camshaft idler gear
9 Flow to crankshaft idler gear
10 Flow to REPTO idler gear (if applicable)
11 Block oil rifle pressure sensing channel
12 Oil drain to lubricating oil pan.

Flow Diagram, Lubricating Oil System (200-002)

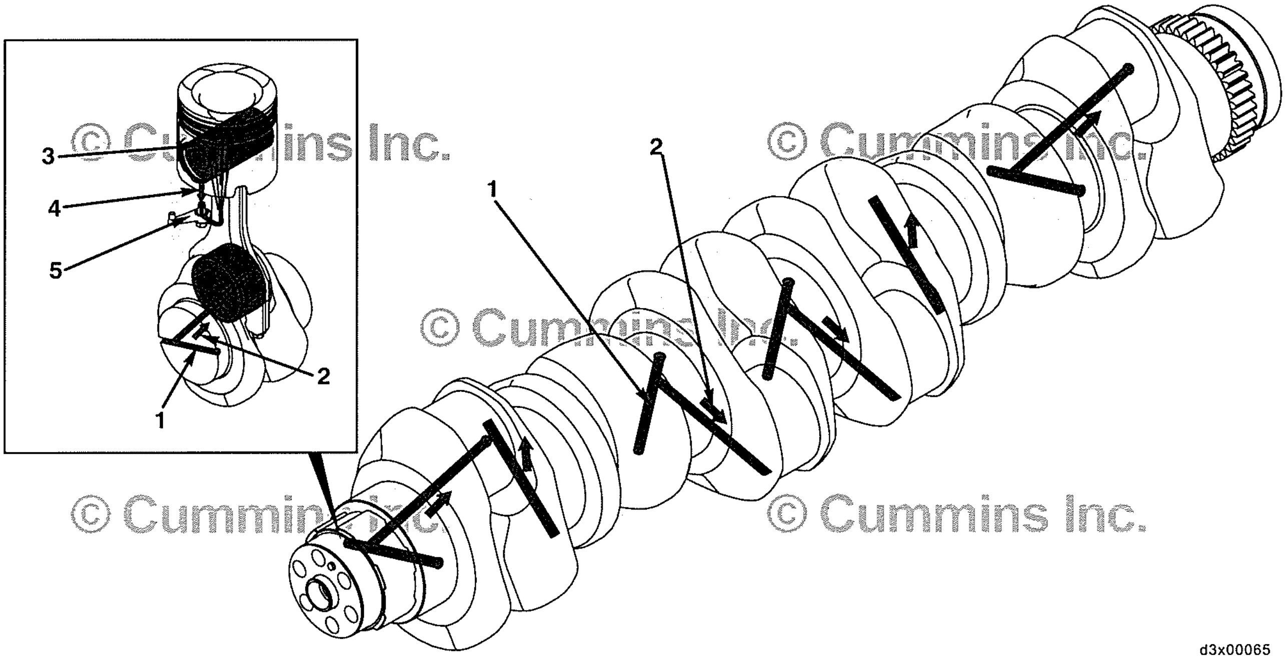
Flow Diagram



1 Flow from cylinder block to cylinder head
2 Flow to camshaft bushings
3 Flow to rocker lever shafts
4 Rocker lever shaft
5 Flow from rocker lever shaft to intake rocker levers
6 Flow from rocker lever shaft to exhaust rocker levers.

Flow Diagram, Lubricating Oil System (200-002)

Flow Diagram



1 Main bearing flow from oil rifle
2 Flow to crankshaft connecting rod bearing
3 Piston pin
4 Flow from oil rifle to piston cooling nozzle
5 Piston cooling nozzle.

Cooling System - Overview (008-999)

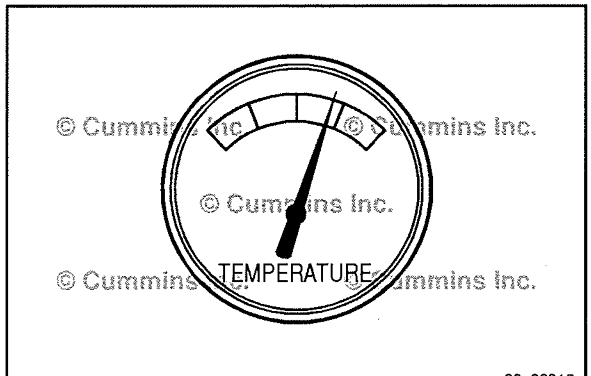
General Information

This engine is equipped with two thermostats. These thermostats open at different temperatures to improve cooling system efficiency. The low temperature thermostat opens between 82°C and 95°C [180°F to 203°F]. The high temperature thermostat opens between 88°C and 97°C [190°F to 207°F].

The functions of the cooling system are to:

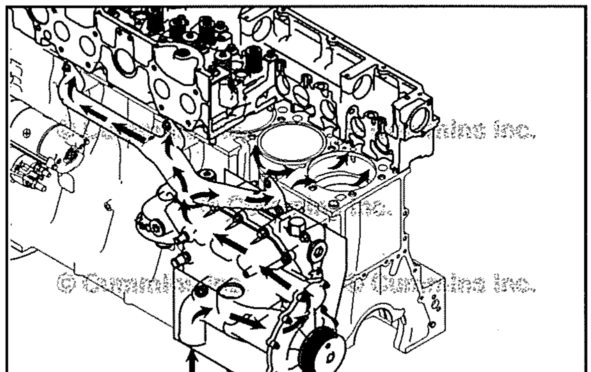
- Absorb heat from the engine components
- Circulate the coolant in the engine and aftertreatment components
- Dissipate the heat through the radiator and diesel exhaust fluid supply to prevent freezing
- Control coolant temperature by the thermostat.

The coolant **must** be made up of the correct proportions of water, antifreeze, and supplemental coolant additives (SCA) to perform these functions properly.



08c00015

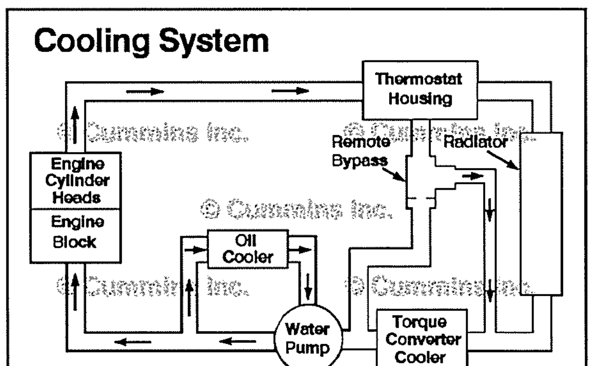
This illustrations shows the coolant flow through the engine. For more detail, see the following procedure. Refer to Procedure 200-003 in Section F.



d3x00042

Conventionally cooled engines with automatic transmissions typically use an oil-to-water transmission torque converter cooler plumbed between the radiator and the engine water pump.

A torque converter cooling system with a remote bypass allows the torque converter to receive coolant flow when the thermostat is closed (engine cold).



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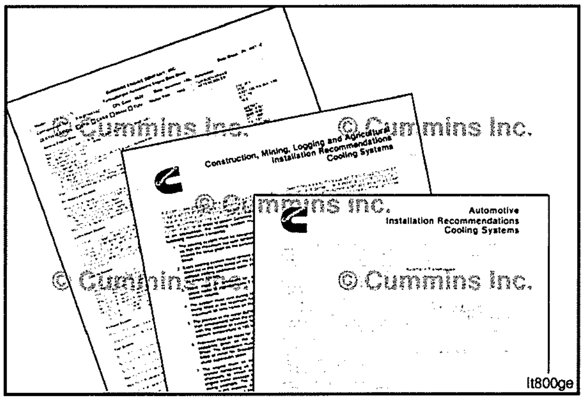
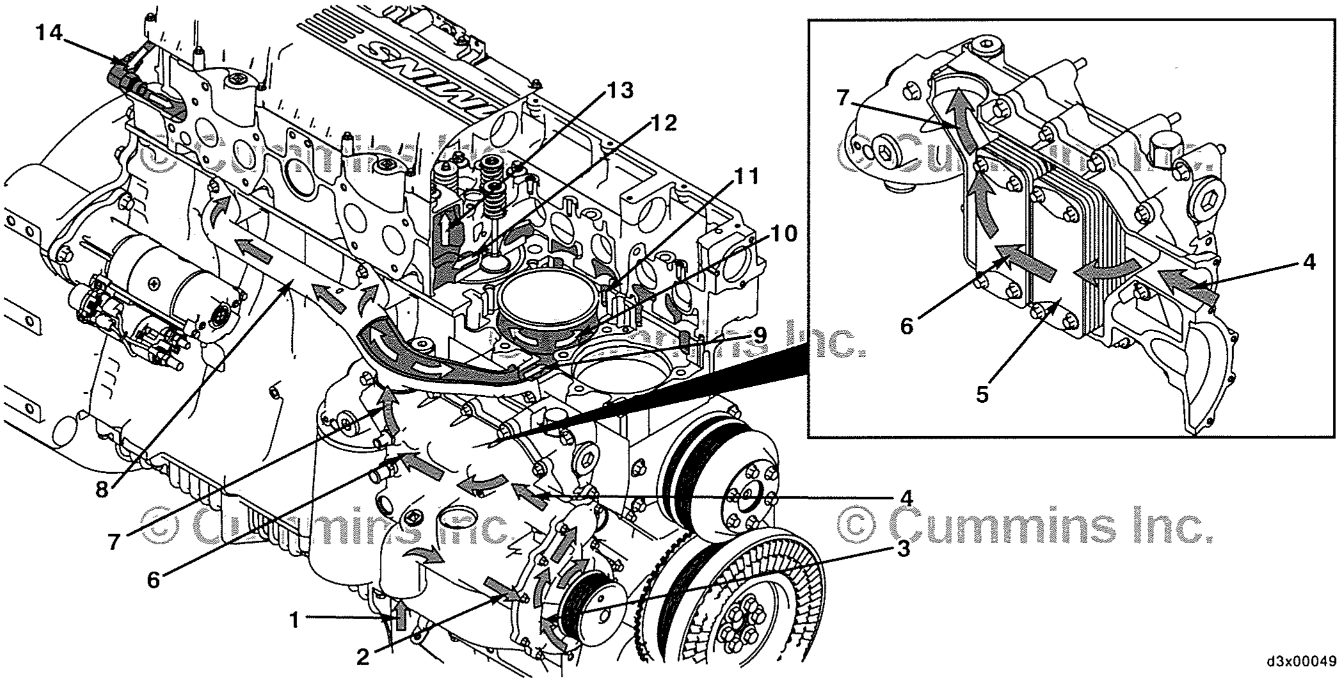


The following publications, available through a Cummins® Authorized Repair Location, provide cooling system installation recommendations and specifications approved by Cummins Inc:

- Data Sheets for specific engine models.
- Refer to Operation of Diesel Engines in Cold Climates, Bulletin 3379009.
- Refer to Cummins® Coolant Requirements and Maintenance, Bulletin 3666132.

Flow Diagram, Cooling System (200-003)

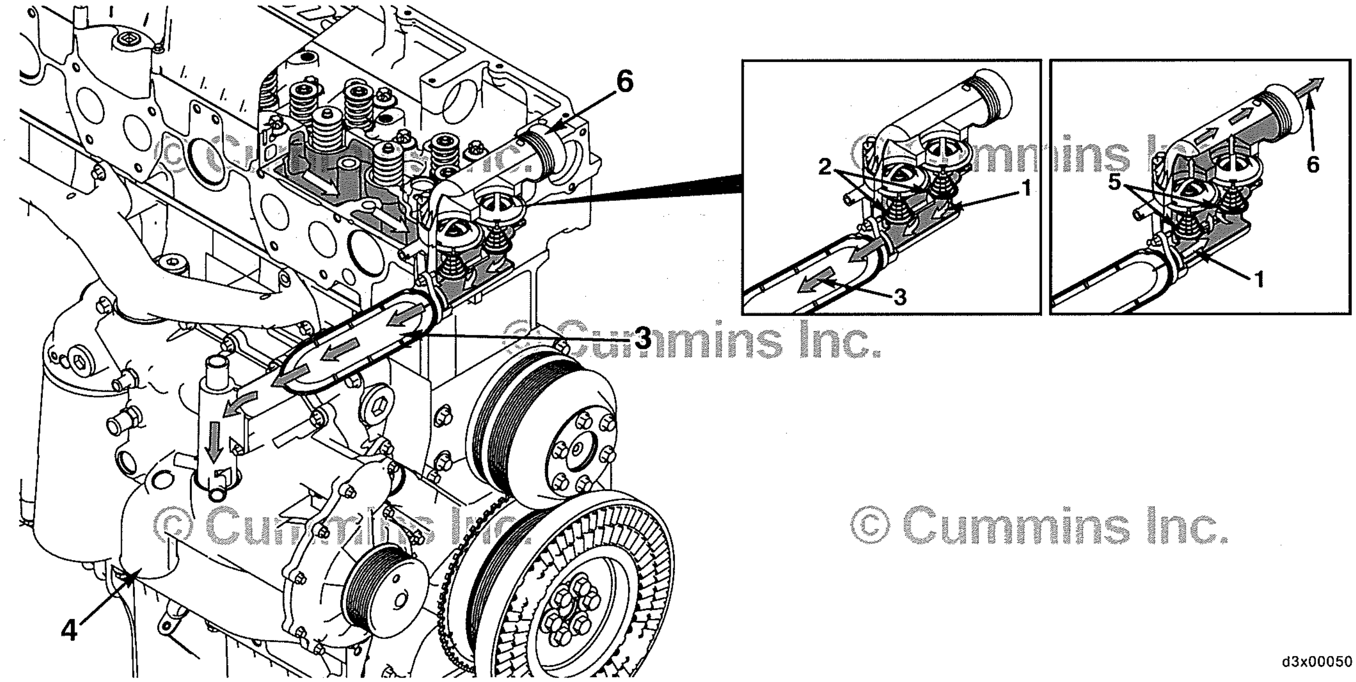
Flow Diagram



1 Coolant from radiator
2 Coolant flow to water pump
3 Water pump
4 Coolant flow from water pump to oil cooler module
5 Oil cooler element
6 Coolant flow around oil cooler element
7 Coolant flow from oil cooler module to coolant manifold
8 Coolant manifold
9 Coolant flow from coolant manifold to cylinder block
10 Coolant flow around cylinders
11 Coolant flow from cylinder block to lower cylinder head
12 Coolant flow to upper cylinder head
13 Coolant flow to rocker lever housing
14 Coolant flow from air compressor return line to cylinder head.

Flow Diagram, Cooling System (200-003)

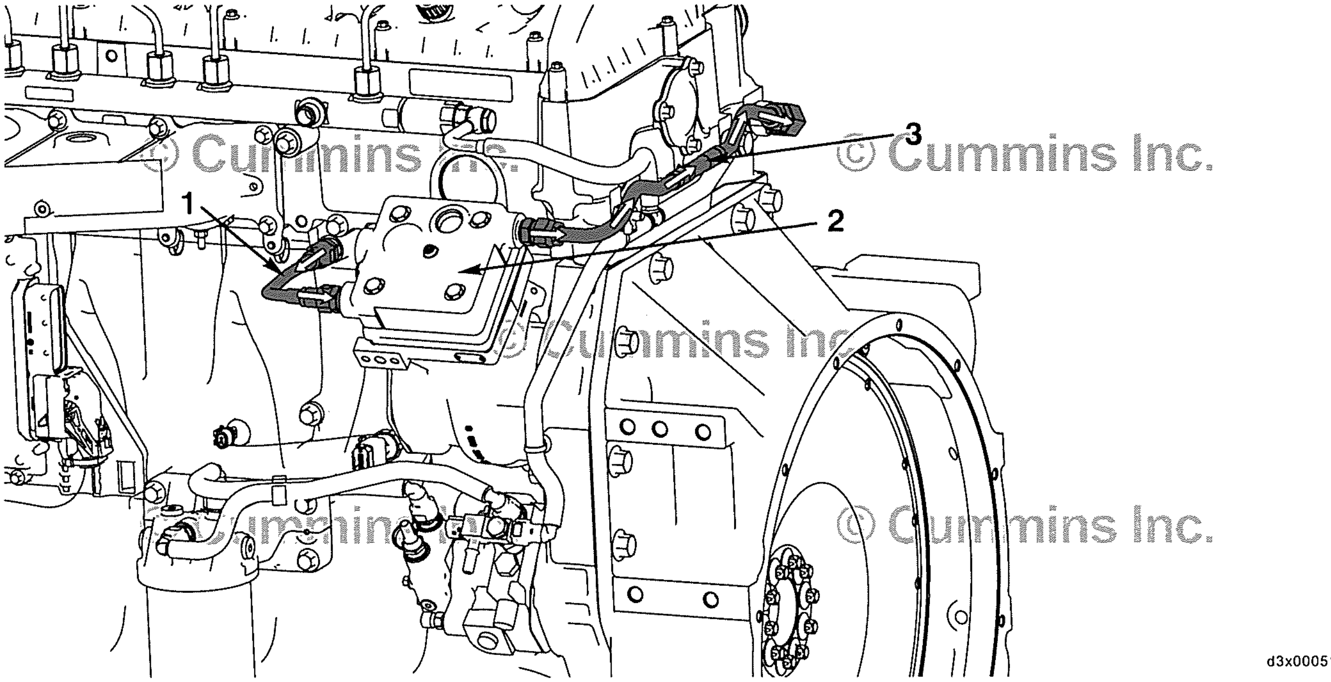
Flow Diagram



1 Coolant flow from rocker lever housing
2 Thermostat closed
3 Coolant flow through bypass tube to coolant inlet connection
4 Coolant inlet connection
5 Thermostat open
6 Coolant flow to radiator.

Flow Diagram, Cooling System (200-003)

Flow Diagram



1 Coolant flow from cylinder block to air compressor

2 Air compressor

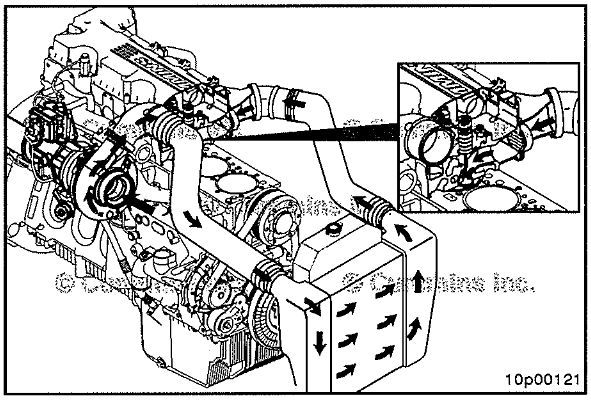
3 Coolant flow from air compressor to cylinder head.

Air Intake System - Overview (010-999)

General Information

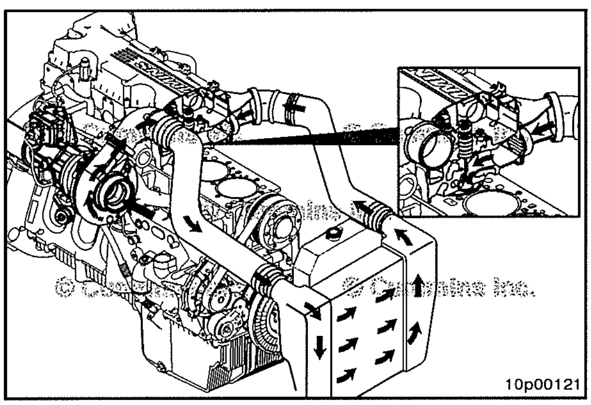
The air intake system **must** be air tight from the air filter to the turbocharger inlet. A loose clamp or hole in the air intake plumbing can lead to dust ingestion and ultimately worn power cylinders, evidenced by high crankcase blowby. Regular inspection of the air intake system plumbing is important for the durability of the engine. Replace malfunctioning or damaged components as soon possible to reduce the chance of engine damage.

The use of a high quality air filter with good maintenance practices is important for the durability of the engine. A plugged air filter will increase restriction in the air system that could result in high intake air temperature and combustion temperatures, black smoke, and premature engine wear. A plugged air filter can progress into a malfunctioning or ruptured filter that allows dust ingestion into the air intake system and power cylinders, resulting in worn power cylinders and high crankcase blowby. Make sure that a high-quality air cleaner is used and that it is periodically replaced according to the manufacturer's recommendations.

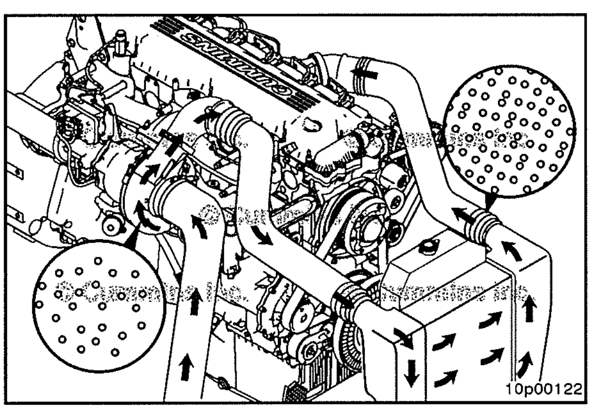


The combustion air system on this engine consists of the following:

- Air cleaner
- Intake air piping
- Turbocharger
- Exhaust pressure regulator
- Charge-air piping
- Charge-air cooler
- Air intake connection
- Cold starting aid (if applicable).

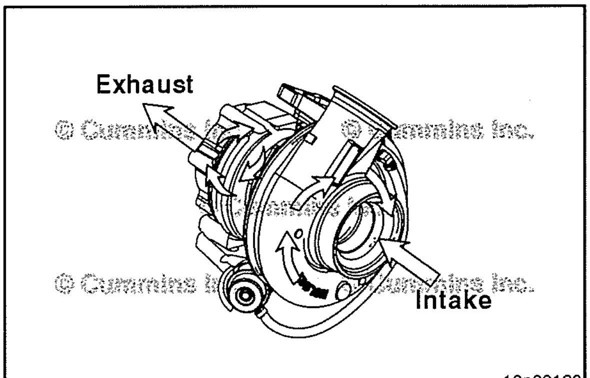


Air is drawn through the air cleaner into the compressor side of the turbocharger. The air is then forced through the charge-air cooler piping to the charge-air cooler, into the air intake connection, and through the cold starting aids (if applicable). Then air is forced into the cylinders and used for combustion.



As the intake air is compressed by the turbocharger, the air temperature increases. This heated air is then passed through the charge-air cooler, which cools it. Cool air is denser, which allows more air to be compressed into the cylinder, yielding a much greater combustion efficiency.

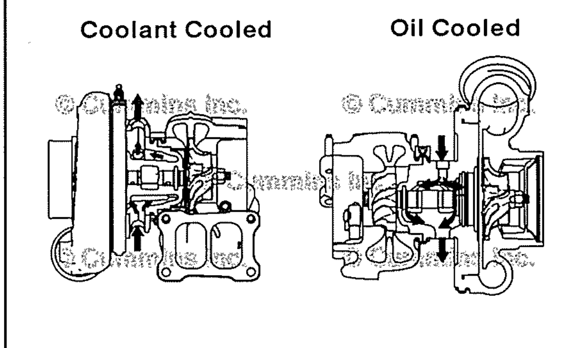
The turbocharger uses exhaust gas energy to turn the turbine wheel. The turbine wheel drives the compressor impeller, which provides pressurized air to the engine for combustion. The additional air provided by the turbocharger allows more fuel to be injected, to increase the power output from the engine.



10p00123

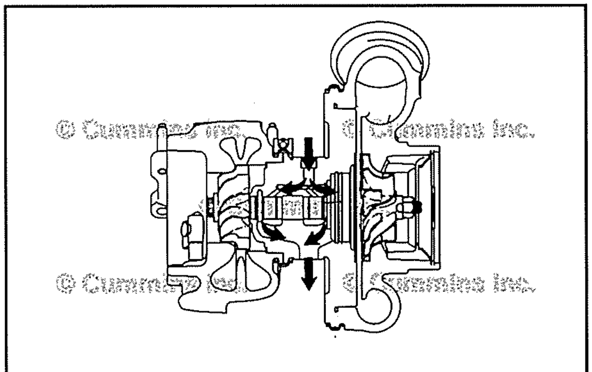
The turbine and compressor wheels share a common shaft (referred to as a rotor assembly), which is supported by two rotating bearings in the bearing housing. Passages in the bearing housing direct filtered, pressurized engine oil to the shaft bearings and thrust bearings. The oil is used to lubricate and cool the rotating components. Oil then drains from the bearing housing to the engine sump through the oil drain line.

An optional turbocharger also includes passages in the bearing housing that direct pressurized coolant to the rotating components. The coolant is used to cool the bearing housing. Coolant is supplied from a fitting in the lubricating oil cooler module and drains from the bearing housing to the cylinder head.



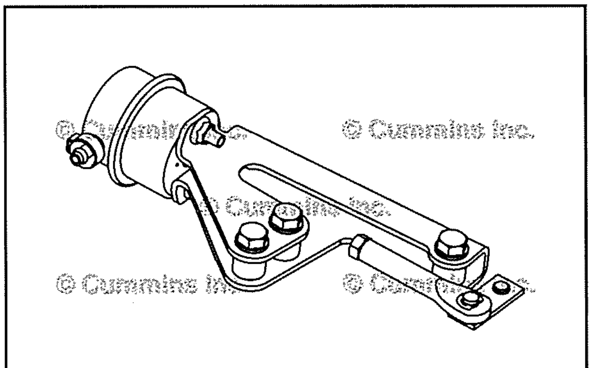
10p00124

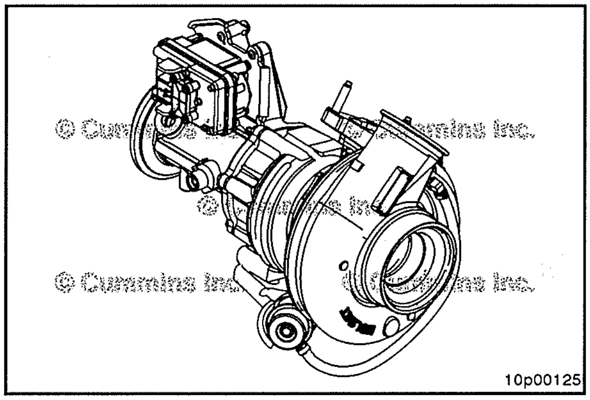
An adequate supply of good, filtered oil is very important to the operating life of the turbocharger. Make sure that a high-quality oil is used and that it and the oil filter are changed according to maintenance recommendations. Use the following procedure in the QSG12 CM2880 G110 Operation and Maintenance Manual, Bulletin 4367322. Refer to Procedure 102-002 in Section 2.


10p00127

⚠CAUTION⚠

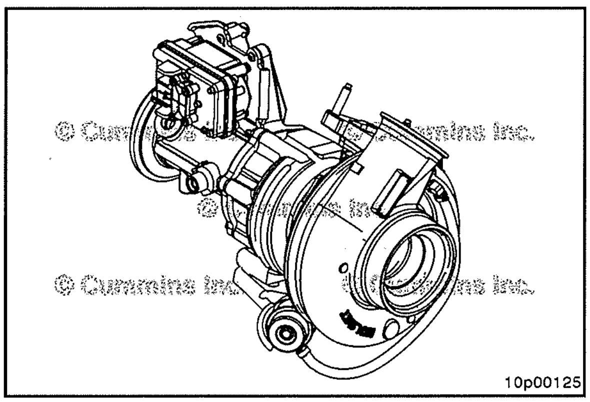
The turbocharger is a performance part and must not be tampered with. The wastegate bracket is an integral part of the turbocharger. Tampering with the wastegate components can reduce durability by increasing cylinder pressure and thermal loading, due to incorrect inlet and exhaust manifold pressure.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


d3x00038



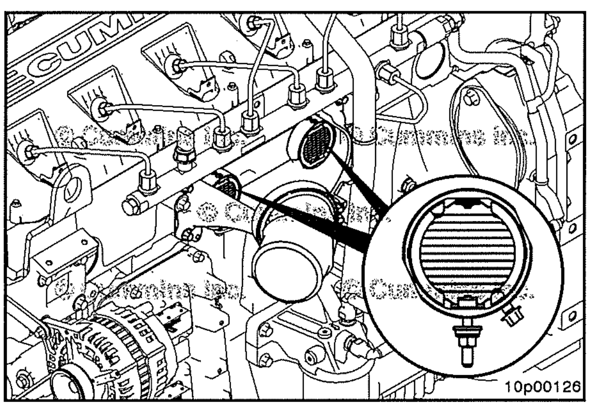
The wastegated turbocharger is comprised of a turbocharger, exhaust pressure regulator, wastegate actuator, control valve air line, and a wastegate valve in the turbine housing. A wastegated turbocharger provides improved response at low engine speeds without sacrificing turbocharger durability at high speeds. This is accomplished by allowing exhaust gases to bypass the turbine wheel during certain modes of engine operation. During low rpm operation, the turbocharger operates as a closed-system turbocharger, where the gas' energy is transferred to the compressor wheel and used to compress intake air. During high rpm operation, however, the turbocharger becomes an open-system turbocharger and allows exhaust gas to bypass the turbine. Since exhaust gas is gated around the turbine wheel, less energy is absorbed through the turbine and transferred to the compressor, reducing intake manifold pressures and turbine speeds.

NOTE: The wastegate design allows maximum boost to be developed quickly while making sure that the turbocharger does **not** overspeed at higher engine rpm.



Boost pressure enters the control valve via airflow from the turbocharger compressor housing.

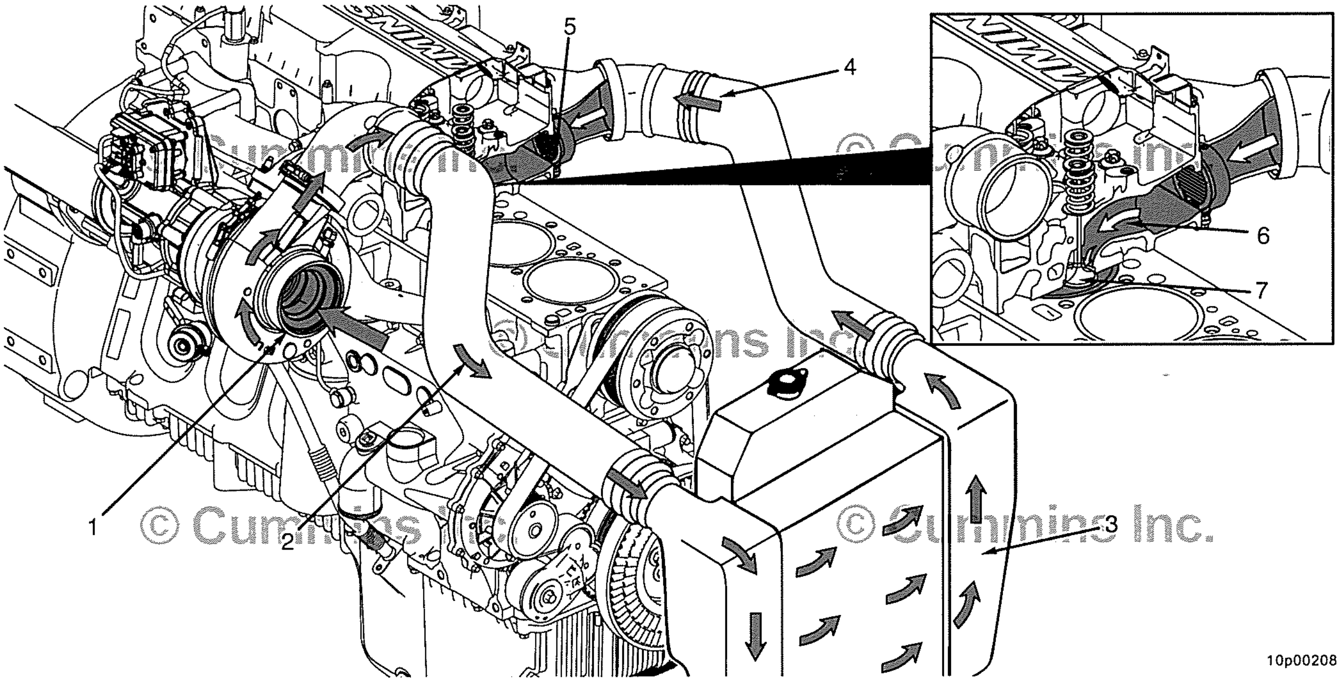
The control valve air line connects the control valve to the turbocharger compressor housing.



The cold starting aid is a duel-element intake air heater used to pre-heat air under cold ambient conditions. The ON/OFF operation of the cold starting aid is controlled by the engine ECM. The ECM controls the OEM supplied solenoid which provides power for the cold starting aid when commanded.

Flow Diagram, Air Intake System (200-004)

Flow Diagram



1 Intake air inlet to turbocharger.

2 Turbocharger air to charge-air cooler.

3 Charge-air cooler.

4 From charge-air cooler to intake air connection.

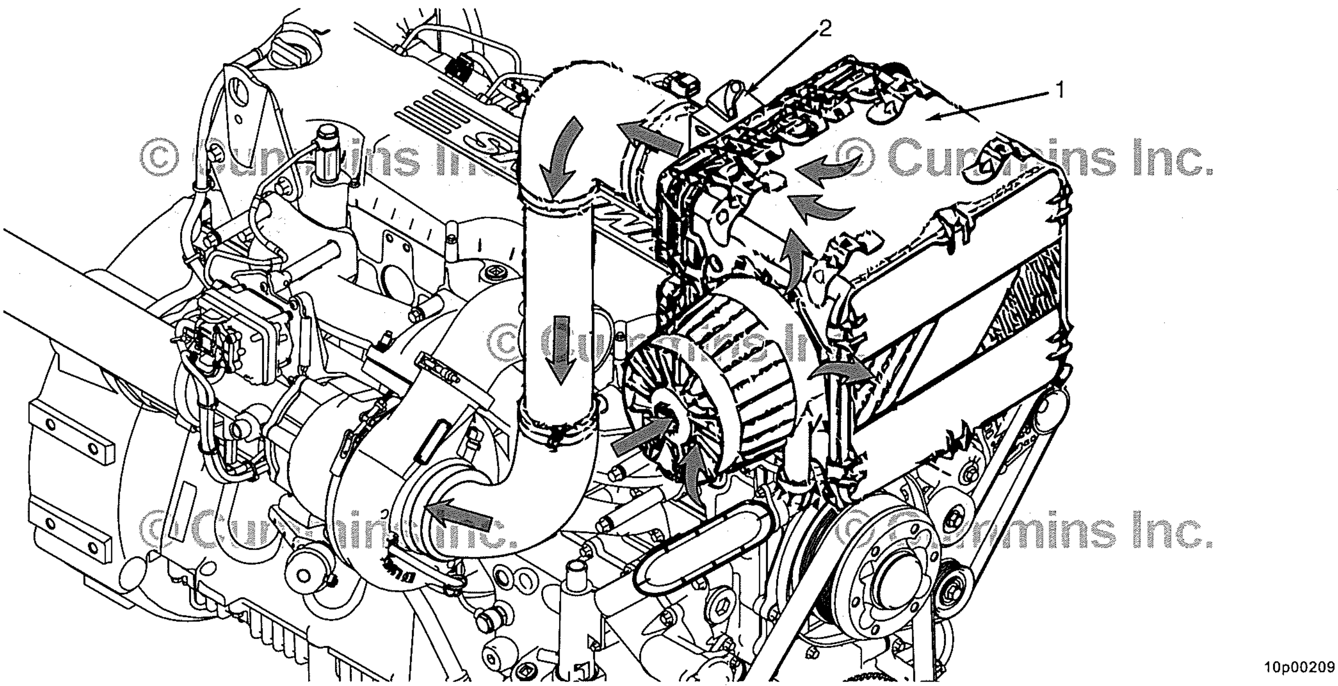
5 Cold starting aid.

6 Intake port.

7 Intake valve.

Flow Diagram, Air Intake System (200-004)

Flow Diagram



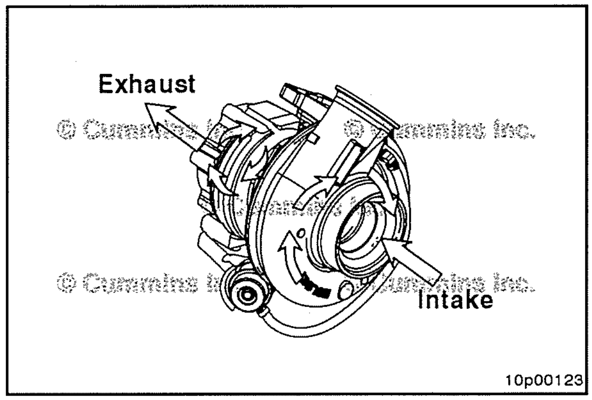
1 Direct Flow ™ air filter housing.

2 Engine turbocharger compressor intake temperature sensor.

Exhaust System - Overview (011-999)

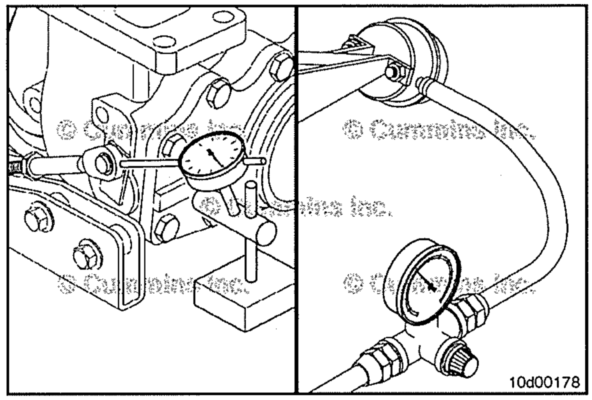
General Information

Turbocharger



- The turbocharger uses exhaust gas energy from the engine to turn the turbine wheel. The turbine wheel drives the compressor wheel through a common shaft. The impellers on the compressor wheel in turn draw intake air through the OEM air filter and inlet plumbing into the compressor housing of the turbocharger. The air is then pressurized by the compressor wheel before being delivered to the charge-air cooler.

Wastegate



- The wastegate actuator, located on the turbocharger, consists of a pressure canister, diaphragm, and rod. As the pressure changes in the canister the actuator rod adjusts the wastegate valve accordingly.
- The wastegate valve is mounted inside the turbocharger in the turbine housing. As the valve opens, exhaust gas is allowed to bypass the turbine wheel, lowering turbine speed to adjust the intake manifold pressure.

Wastegated Turbocharger

- The wastegated turbocharger is comprised of a turbocharger, wastegate actuator, wastegate actuator air line, and a wastegate valve in the turbine housing. A wastegated turbocharger provides improved response at low engine speeds without sacrificing turbocharger durability at high speeds. This is accomplished by allowing exhaust gases to bypass the turbine wheel during certain modes of engine operation. During low rpm operation, the turbocharger operates as a closed-system turbocharger, where the gas's energy is transferred to the compressor wheel and used to compress intake air. During high rpm operation, however, the turbocharger becomes an open-system turbocharger and allows exhaust gas to bypass the turbine. Since exhaust gas is gated around the turbine wheel, less energy is absorbed through the turbine and transferred to the compressor, reducing intake manifold pressures and turbine speeds.

Wastegate Actuator Air Line

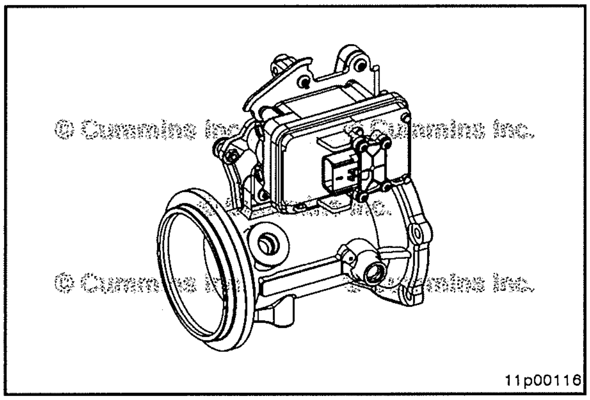
- Connects the turbocharger compressor housing to the wastegate actuator.

Wastegate Actuator

- The wastegate actuator is mounted on the turbocharger and consists of a pressure canister, diaphragm, and rod. As pressure changes in the canister, the actuator rod adjusts the wastegate valve accordingly.

Wastegate/Wastegate Valve

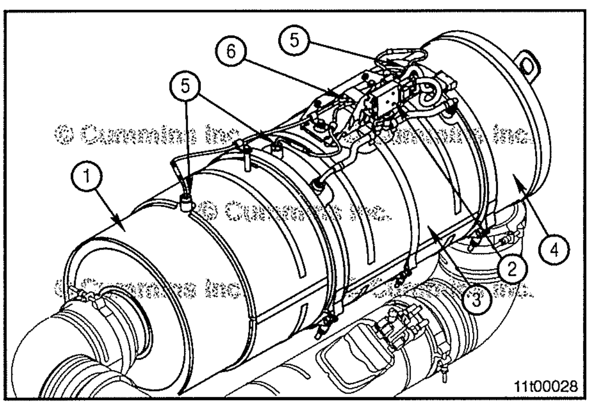
- The wastegate valve is mounted inside the turbocharger in the turbine housing. As the valve opens, via the actuator push rod, exhaust gas is allowed to bypass the turbine wheel, lowering turbine speed to adjust intake manifold pressure.



11p00116

Exhaust Pressure Regulator

- The exhaust pressure regulator is used to alter back pressure on the engine to control exhaust gas temperatures entering the aftertreatment system. During regeneration, the exhaust pressure regulator will actuate to increase the exhaust temperatures entering the aftertreatment system.



11t00028

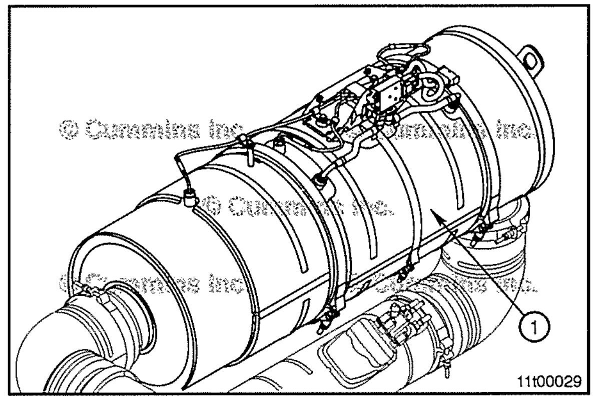
The aftertreatment diesel particulate filter (DPF) system is used to reduce particulate emissions and is composed of six main components:

1 Aftertreatment inlet and aftertreatment diesel oxidation catalyst (DOC)
2 Aftertreatment DPF differential pressure sensor
3 Aftertreatment DPF
4 Aftertreatment outlet
5 Aftertreatment exhaust gas temperature sensors
6 Aftertreatment DPF temperature sensor interface module.

Passive regeneration occurs when the exhaust temperatures are naturally high enough to oxidize the soot collected in the aftertreatment DPF (1) faster than the soot is collected.

Passive regeneration typically occurs when the temperature of the aftertreatment DPF is above 316°C [601°F]. This occurs during highway driving or driving with heavy loads.

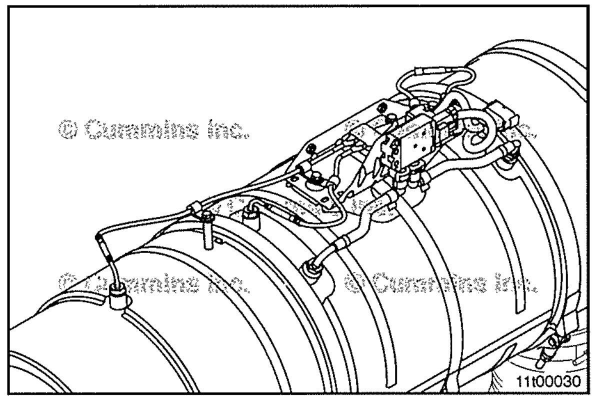
Since passive regeneration occurs naturally, it is considered to be normal engine operation. No fuel is added to the exhaust stream during passive regeneration.



Active regeneration occurs when the exhaust temperatures are **not** naturally high enough to oxidize the soot collected in the aftertreatment DPF faster than it is collected.

Active regeneration requires assistance from the engine in order to increase the exhaust temperature. This is typically done by injecting a small amount of diesel fuel into the exhaust stream (called aftertreatment injection) which is then oxidized by the aftertreatment DOC. The oxidation of this additional fuel creates the heat needed to regenerate the aftertreatment DPF.

For active regeneration to occur, the engine control module (ECM) **must** detect that the aftertreatment DPF restriction has reached a specified limit. Once this limit is reached, the engine will alter its operation in order to create exhaust temperatures high enough to actively regenerate the aftertreatment DPF.



Aftertreatment injection requires temperatures in the aftertreatment system to reach approximately 288°C [550°F]. At this temperature and above, the small quantities of fuel injected into the exhaust will properly oxidize across the aftertreatment DOC, creating the additional heat required to actively regenerate the aftertreatment DPF.

During active regeneration, the ECM monitors the exhaust temperatures before and after the aftertreatment DPF, and maintains the temperatures in a range of approximately 482 to 649°C [900 to 1200°F]. The quantity of fuel used for aftertreatment injection will vary as the temperature is controlled within these limits.

The temperatures achieved during active regeneration are typically higher than those achieved during passive regeneration. The conversion of soot to carbon dioxide occurs much faster as temperatures increase.

A typical active regeneration event will take approximately 20 to 40 minutes to complete while the equipment is operating. The equipment operator may notice additional turbocharger noise during this time, along with an illuminated High Exhaust Temperature Lamp, if equipped.

The frequency at which an engine will require an active regeneration varies greatly from application to application. In general, equipments with a low equipment speed, or a low-load duty cycle, will require more active regeneration events than heavily loaded equipment.

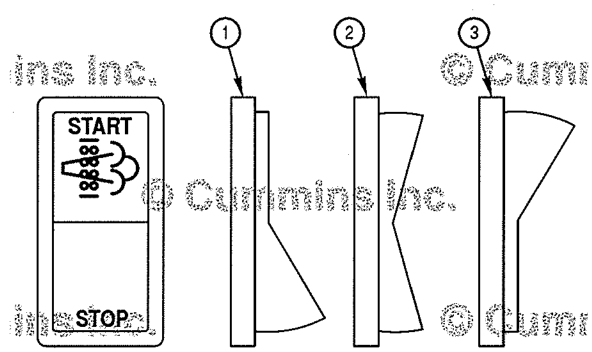
The ECM also contains a time-based feature for active regenerations that is used to verify correct aftertreatment operation when the equipment duty cycle is typically high enough that active regeneration events are **not** necessary.

If the engine has **not** completed an active regeneration within the last 100 hours of operation, the ECM will call for a time-based active regeneration event.

The 100-hour timer resets each time the ECM detects that an active regeneration event has completed.

Under some operating conditions, such as low speed, low load, or stop-and-go duty cycles, the engine may **not** have enough opportunity to regenerate the aftertreatment DPF during normal equipment operation. When this occurs, the engine illuminates the aftertreatment DPF lamp to inform the equipment operator that assistance is required, typically in the form of a stationary (parked or non-mission) regeneration.

Stationary (parked or non-mission) regeneration is a form of active regeneration that is initiated by the equipment operator when the equipment is **not** moving. Refer to Procedure 014-016 in Section 14.



11d00294

The equipment manufacturer has the option of installing two switches (the start switch and the permit switch) that control aftertreatment functions.

- The start switch (known as the Diesel Particulate Filter Regeneration Start Switch in INSITE™ electronic service tool) is used to start a stationary (parked or non-mission) regeneration. The equipment manufacturer can also see this switch as a stationary regeneration switch, start switch, or parked (non-mission) regeneration switch.
- The permit switch (known as the Diesel Particulate Filter Permit Switch in INSITE™ electronic service tool) is used to allow the equipment operator to disable active regeneration, if necessary. The equipment manufacturer can also see this switch as an inhibit switch, stop switch, or disable switch.

Refer to Procedure 011-056 in Section 11.

Active regeneration is a condition that occurs when there is **not** sufficient heat in the exhaust system to burn the carbon that accumulates in the DPF. During active regeneration, the exhaust temperatures are increased by adding small amounts of fuel to burn off the carbon build up in the DPF. This process is controlled by the ECM and is induced when certain conditions are seen. These conditions are application dependent.

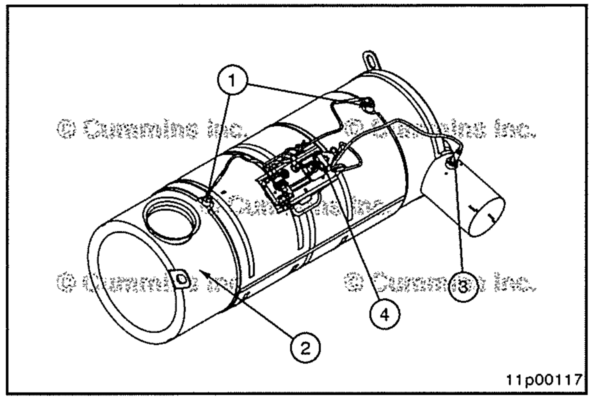
The aftertreatment selective catalytic reduction (SCR) is designed to reduce mono-nitrogen oxides (NOx) emissions from the engine using the following components:

1 Aftertreatment SCR intake/outlet temperature sensors

2 Aftertreatment SCR catalyst

3 Aftertreatment SCR outlet NOx sensor

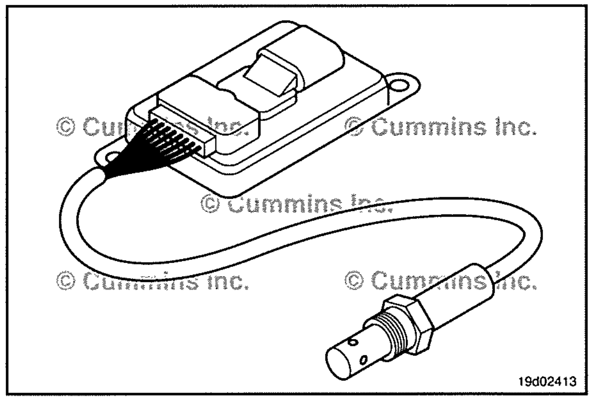
4 Aftertreatment SCR catalyst temperature senosr interface module



The SCR uses diesel exhaust fluid (DEF) in order to convert nitrogen oxides from the exhaust stream into nitrogen and water.

During an initial cold start, the engine will go into SCR warm-up condition. This condition will sound and act like an active regeneration. The SCR catalyst will need to have a temperature of over 150°C [302°F] in order to properly convert NOx in the exhaust stream.

The aftertreatment outlet NOx sensor at the outlet of the SCR will monitor the NOx output in the exhaust system and relay the information back to the ECM.



The SCR dosing system is composed of five main components to aid the SCR catalyst in the NOx conversion process.

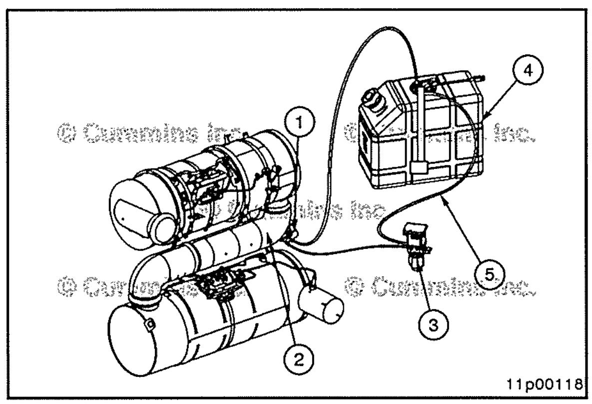
1 Aftertreatment DEF dosing valve

2 Aftertreatment decomposition tube

3 Aftertreatment DEF dosing unit

4 Aftertreatment DEF tank

5 Aftertreatment DEF lines



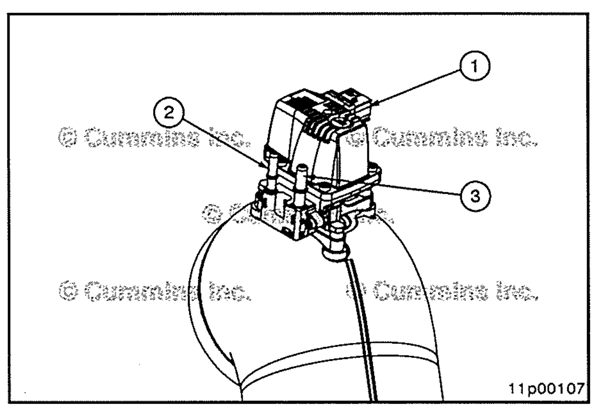
The aftertreatment DEF dosing control valve is controlled by the ECM. The ECM commands the correct amount of DEF to be sprayed into the exhaust stream. Because the dosing control valve is mounted directly to the exhaust system, it will encounter high temperatures. DEF is circulated through the DEF control valve to keep the valve cool and operable.

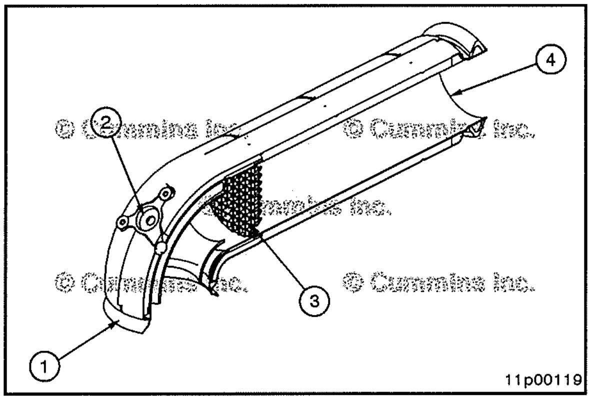
1 Electrical connection to the ECM

2 DEF Inlet Port

3 DEF outlet port

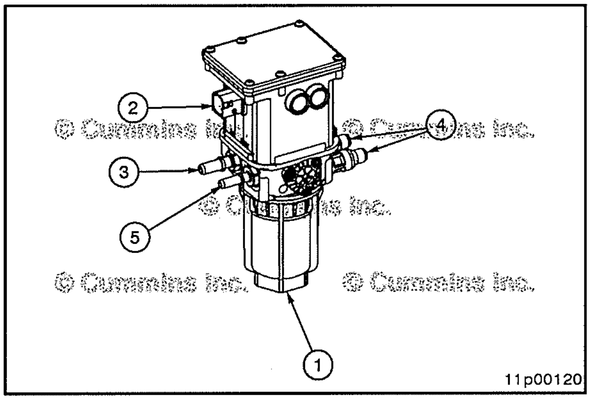
Use the following procedure for additional information. Refer to Procedure 011-059 in Section 11.





The DEF control valve is mounted to the aftertreatment decomposition tube. The aftertreatment decomposition tube contains a mixer to help the DEF mist distribute evenly in the exhaust stream.

1 Aftertreatment decomposition tube inlet
2 DEF control valve mounting
3 Aftertreatment decomposition tube mixer
4 Aftertreatment decomposition tube outlet.



When the aftertreatment DEF dosing unit is activated, it pulls DEF from the DEF tank, filters the DEF, and then pressurizes the DEF to the DEF control valve. Any DEF that is **not** used is returned to the DEF tank.

When a driver turns the key OFF, the dosing system will run a purge cycle during shutdown to prevent DEF from being left in the system and freezing in cold climates. An audible click and pumping sound will be heard from the DEF dosing unit when it is in the purge cycle. The DEF dosing unit will move its reverting valve, changing the direction of flow for the DEF. The DEF dosing unit will pull all of the DEF out of the DEF dosing control valve and line. This unused DEF is returned to the DEF tank. After a complete purge, the system will be free of any remaining DEF.

If ambient conditions are below -4°C [25°F], the ECM will turn ON the aftertreatment DEF tank heater control valve to flow coolant and defrost itself. The DEF dosing unit will **not** prime until it is completely defrosted.

The main components of the aftertreatment DEF dosing unit:

1 Aftertreatment DEF dosing unit filter cap
2 Electrical connector to the ECM
3 Inlet port
4 Coolant ports
5 Outlet port.

Use the following procedure for a more detailed description of the aftertreatment DEF dosing unit. Refer to Procedure 011-058 in Section 11.

Use the following procedure for a more detailed description of the aftertreatment DEF dosing unit filter. Refer to Procedure 011-060 in Section 11.

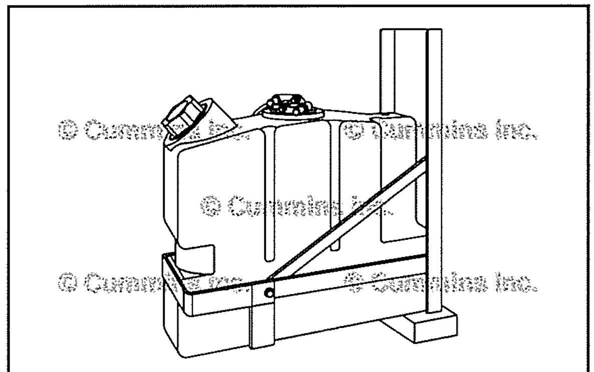
The aftertreatment DEF tank is designed to store DEF for the SCR aftertreatment. A sensor detects DEF tank level and DEF tank temperature and sends a signal to the ECM.

If the DEF tank level becomes too low, the ECM will register a fault and derate engine power.

If the DEF tank temperature drops below -5°C [23°F], the DEF tank coolant valve will be commanded open by the ECM. Hot engine coolant will flow though the tank to defrost the frozen DEF. The DEF dosing system will **not** prime until the DEF tank is defrosted.

If the DEF tank is filled with the incorrect fluid (anything other than DEF) the aftertreatment system will **not** operate correctly.

DEF tanks will vary in size and shape. See equipment manufacturer service information for additional information.



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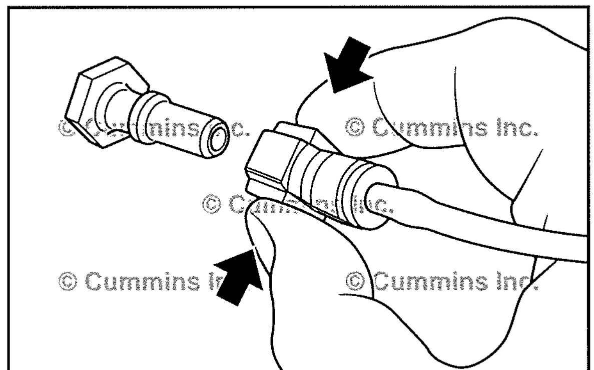
The aftertreatment DEF lines carry the DEF to and from the aftertreatment DEF tank as well as to the DEF control valve.

The aftertreatment DEF will fill the lines during a prime or operating state and be removed in a purge state to prevent freezing of the DEF.

If the ambient temperature is below -5°C [23°F], the fluid controller will command the heated lines ON. The dosing system will **not** prime until the DEF lines are completely defrosted.

DEF line connectors, length, and design will vary upon equipment manufacturer. See equipment manufacturer service information for additional information.



19d02324

The SCR system is comprised of many components but requires a minimal amount of servicing or driver intervention. The SCR system is comprised of four main states: priming, dosing, purging, and heating.

Priming State

- Once the SCR reaches a temperature of 150°C [302°F] the ECM will command the aftertreatment DEF dosing unit to start its priming process. The aftertreatment DEF dosing unit will draw DEF from the DEF tank, pressurize the DEF, and then filter the DEF to the aftertreatment DEF dosing valve. The aftertreatment DEF dosing valve will open and close to rid any air from the system. Once the system is able to build up pressure and has removed most of the air bubbles from the DEF lines, the aftertreatment DEF dosing system is capable of dosing.

Dosing State

- The aftertreatment DEF dosing valve will open and spray DEF in the exhaust stream when commanded by the ECM. The DEF will then be chemically altered by the aftertreatment SCR catalyst to clean the exhaust gases. As long as the dosing system is in the dosing state, the aftertreatment DEF dosing unit will continue to run regardless if the aftertreatment DEF dosing valve is or is **not** spraying DEF. DEF dosing rates are dependent on equipment duty cycle. The dosing rates are **not** necessarily constant under most duty cycles. The aftertreatment DEF dosing valve will pulse the demanded amount of DEF into the exhaust stream. Any DEF that is **not** used by the aftertreatment DEF dosing valve is returned to the DEF.

Purging State

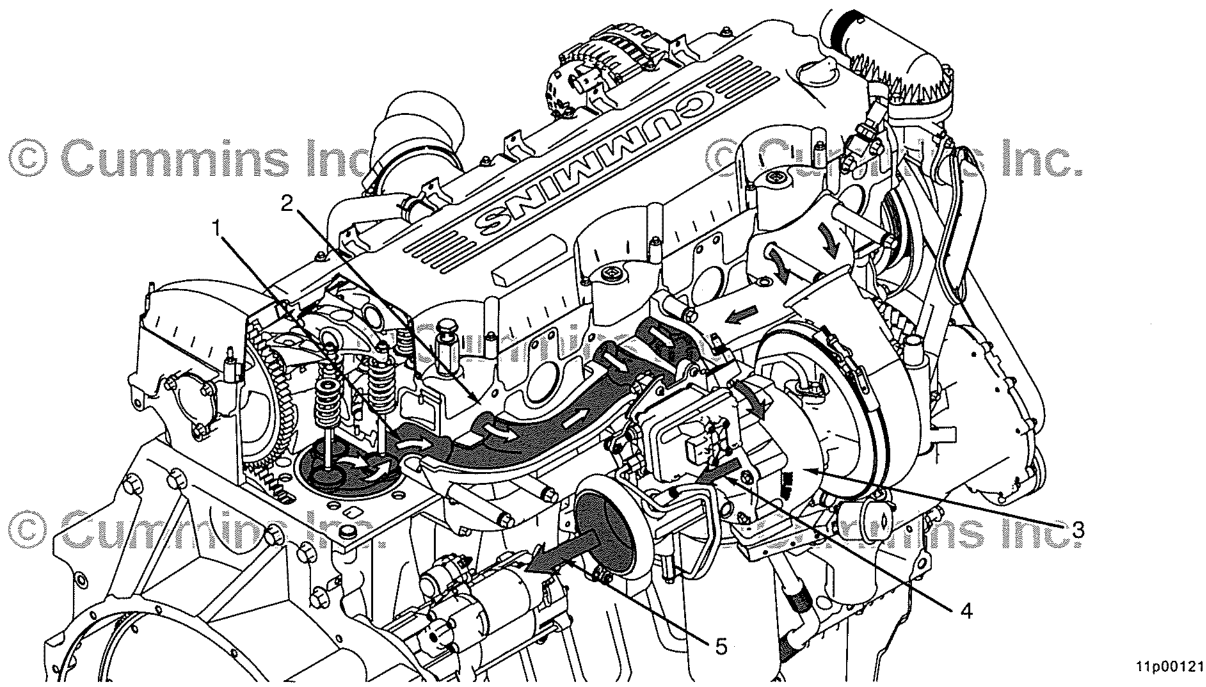
- When a driver keys OFF, the dosing system will shut itself down with a purge cycle to prevent DEF from being left in the system, and in cold climates, potentially freezing. An audible click and pumping sound will be heard from the DEF dosing unit when it is in a purge cycle. The DEF dosing unit will slide its internal reverting valve and cause a change in the flow direction of the DEF. The DEF dosing unit will pull all of the DEF out of the aftertreatment DEF dosing valve and pressure line, then return the unused DEF to the DEF tank. In this process the aftertreatment DEF dosing valve will open, eliminating the vacuum created in the lines for a more complete purge process. After a complete purge, the majority of the system will be free of any remaining DEF. If the main power to the ECM is removed, via battery cut off or other means before the purging state is completed, an internal fault will be logged in the ECM. The incomplete purge counter can be viewed in INSITE™ electronic service tool.

Heating State

- Diesel exhaust fluid freezes at -11°C [12°F]. If a driver starts the engine in a cold climate, the dosing heating state will be activated. If the ambient air temperature sensor reads ambient conditions are below -4°C [25°F] the ECM will command the dosing system to go into the defrost state. The aftertreatment dosing unit will turn on its internal heater to defrost any remaining DEF that still may be inside it. The heated DEF lines will also be commanded on. If the DEF tank temperature drops below -5°C [23°F] the DEF tank coolant valve will be commanded open by the ECM. Engine coolant will flow through the tank to defrost the frozen DEF. The DEF dosing system will **not** prime until every component is completely defrosted. If ambient conditions continue to be cold after the system has primed, the ECM will command a maintenance heating feature to prevent the DEF dosing system from refreezing. This feature will cycle the heating on and off to the DEF lines, DEF tank, and aftertreatment DEF dosing unit.

Flow Diagram, Exhaust System (200-005)

General Information

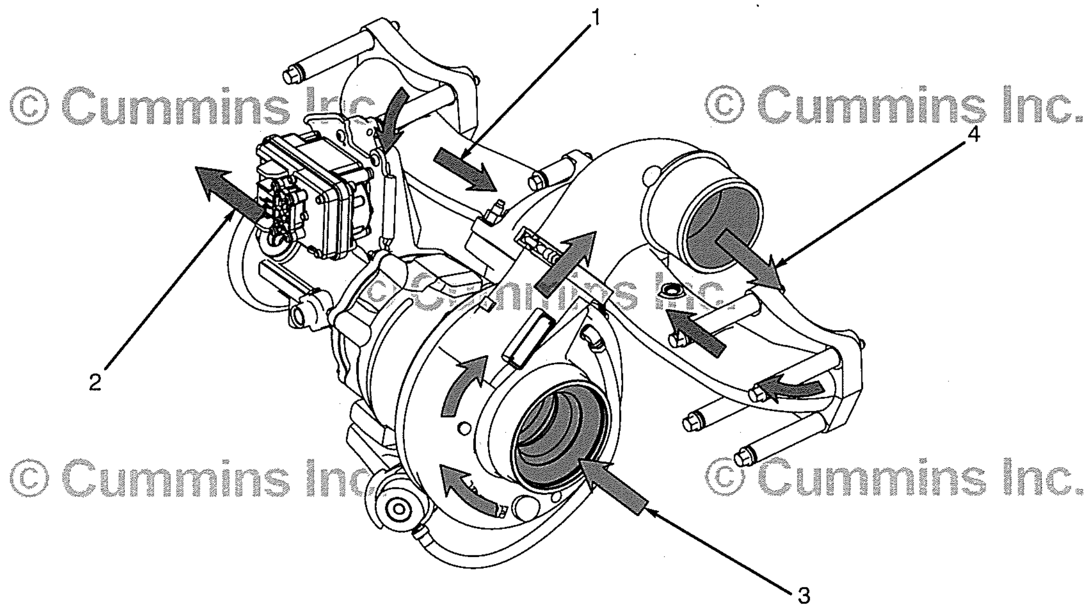


Exhaust Flow Through Engine

1 Exhaust flow from cylinder
2 Exhaust manifold (pulse type)
3 Dual-entry turbocharger
4 Exhaust pressure regulator
5 Flow from exhaust pressure regulator.

Flow Diagram, Exhaust System (200-005)

General Information

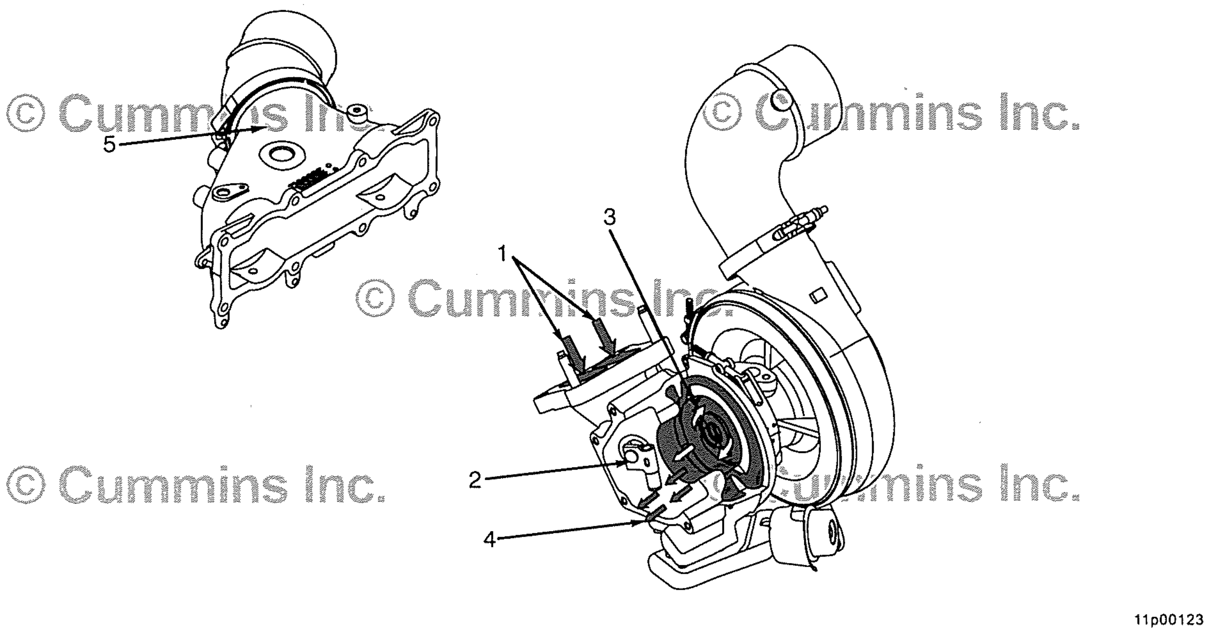


Flow Through Turbocharger

1 Exhaust gas inlet to turbocharger turbine housing
2 Exhaust gas outlet from exhaust pressure regulator
3 Intake air inlet to turbocharger compressor housing
4 Intake air outlet from compressor housing.

Flow Diagram, Exhaust System (200-005)

General Information



Wastegate Closed (Low Intake Manifold Pressure)

1 Exhaust flow from exhaust manifold

2 Wastegate closed

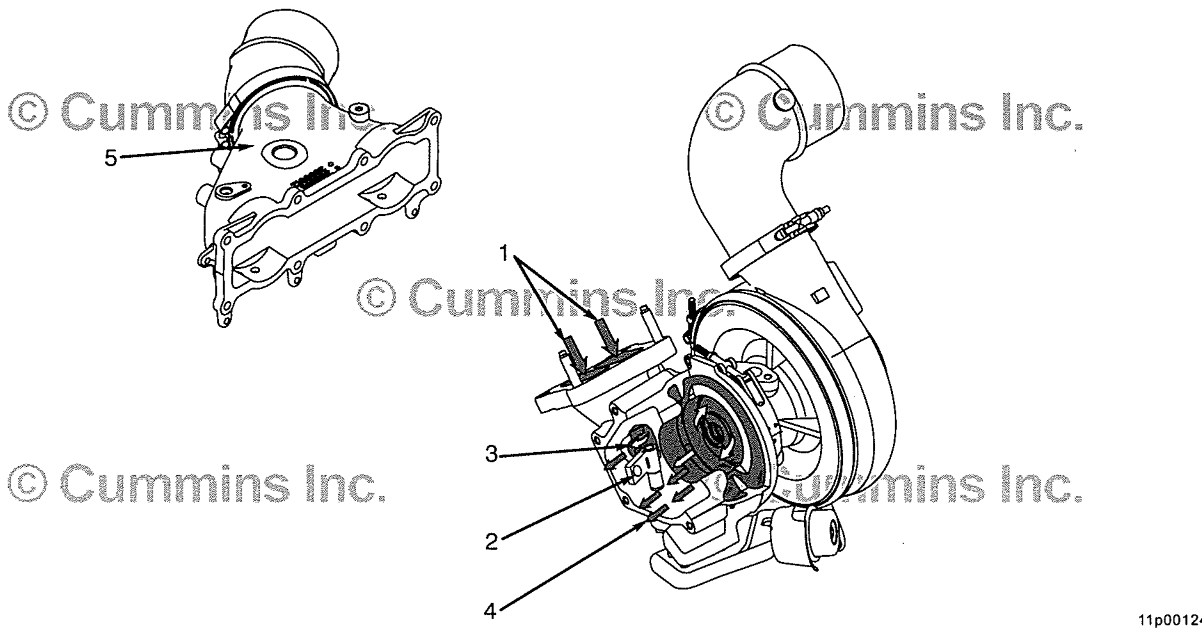
3 All exhaust flow through turbine

4 Turbocharger exhaust outlet

5 Intake manifold.

Flow Diagram, Exhaust System (200-005)

General Information

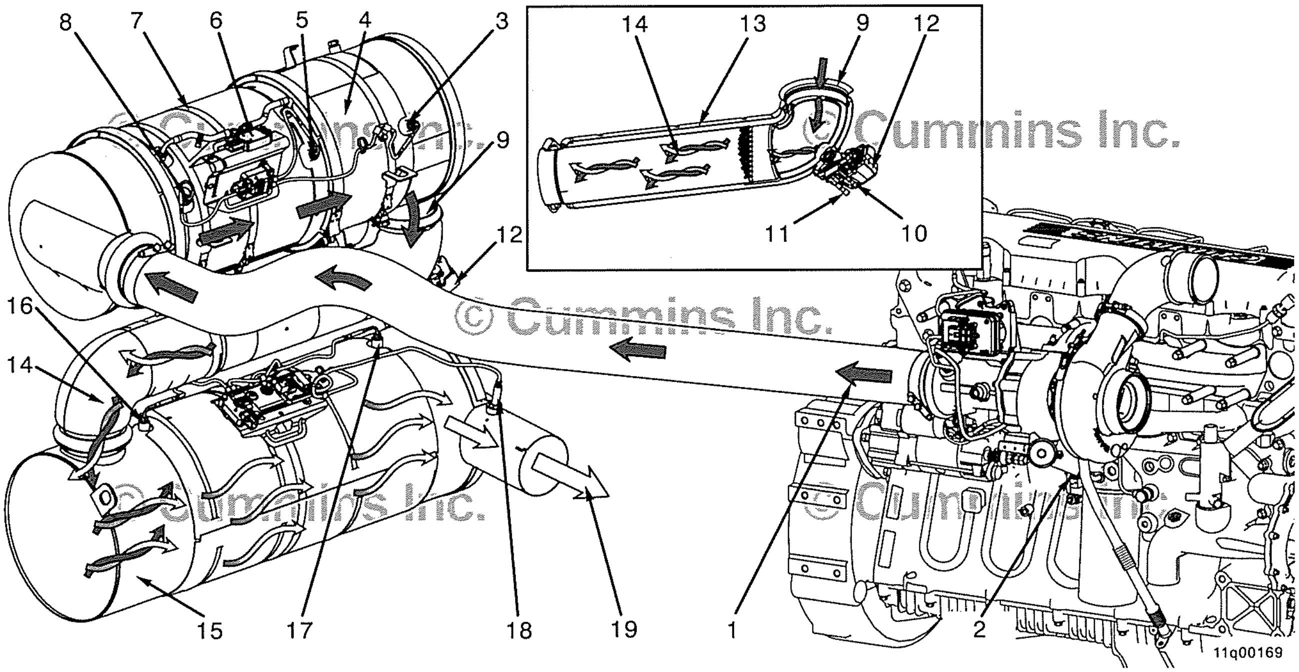


Wastegate Open (High Intake Manifold Pressure)

1 Exhaust flow from exhaust manifold
2 Wastegate open
3 Some exhaust flow bypassing the turbine
4 Turbocharger exhaust outlet
5 Intake manifold.

Flow Diagram, Exhaust System (200-005)

General Information

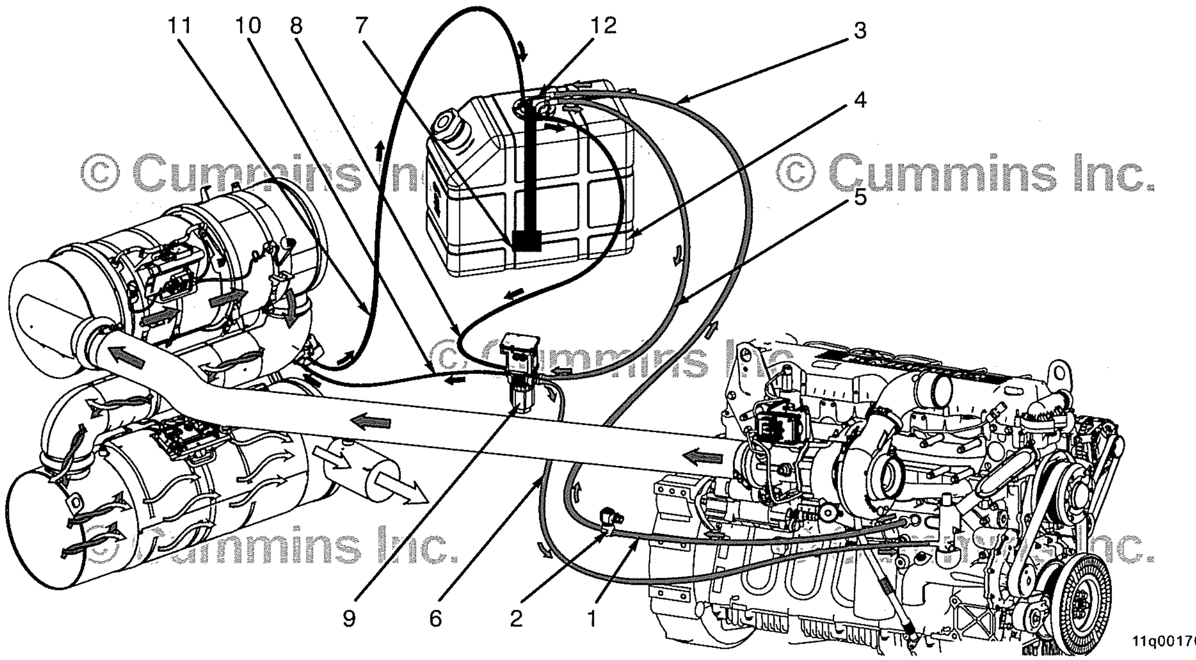


Aftertreatment System, Exhaust Flow – QSG12 CM2350 G110

1 Exhaust from exhaust pressure regulator
2 Aftertreatment intake NOx sensor
3 Aftertreatment diesel oxidation catalyst (DOC) intake temperature sensor
4 Aftertreatment DOC
5 Aftertreatment diesel particulate filter (DPF) intake temperature sensor
6 Aftertreatment DPF combination pressure sensor
7 Aftertreatment DPF
8 Aftertreatment DPF outlet temperature sensor
9 Exhaust gas flow from DPF
10 Aftertreatment diesel exhaust fluid (DEF) supply to aftertreatment DEF dosing valve
11 Aftertreatment DEF return to DEF tank
12 Aftertreatment DEF dosing valve
13 Decomposition tube
14 Exhaust and DEF mixture
15 Aftertreatment selective catalytic reduction (SCR) catalyst
16 Aftertreatment SCR intake temperature sensor
17 Aftertreatment SCR outlet temperature sensor
18 Aftertreatment outlet NOx sensor
19 Exhaust flow exiting aftertreatment system.

Flow Diagram, Exhaust System (200-005)

General Information



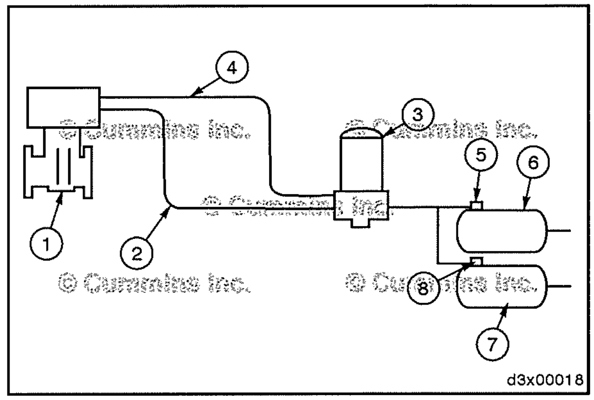
Aftertreatment System, Coolant and DEF Flow - QSG12 CM2350 G110

1 Coolant flow from engine to aftertreatment DEF tank heater control valve
2 Aftertreatment DEF tank heater control valve
3 Coolant flow to aftertreatment DEF tank (**only** when aftertreatment DEF tank heater control valve is open)
4 Aftertreatment DEF tank
5 Coolant flow to aftertreatment DEF dosing unit
6 Coolant return to engine
7 Aftertreatment DEF supply from aftertreatment DEF tank
8 Aftertreatment DEF flow to aftertreatment DEF dosing unit
9 Aftertreatment DEF dosing unit
10 Aftertreatment DEF flow to aftertreatment DEF dosing valve
11 Aftertreatment DEF return to aftertreatment DEF tank
12 Aftertreatment DEF temperature, level, and quality sensor(s).

NOTE: For additional information regarding DEF tank or DEF tank heater control valve, See equipment manufacturer service information.

Compressed Air System - Overview (012-999)

General Information



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

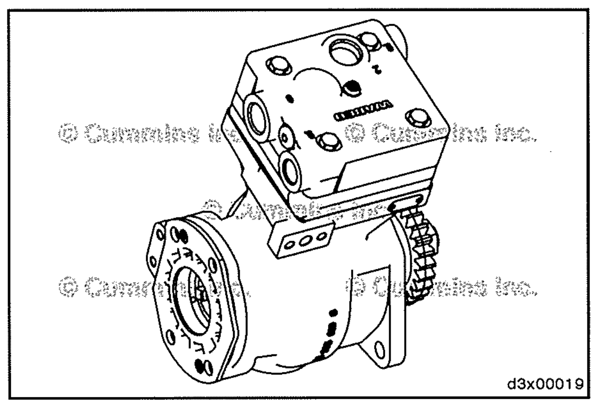
The components listed below are commonly used in a compressed air system:

1 Air compressor
2 Discharge line
3 Air dryer with integrated air governor
4 Air pressure signal from air governor to unloader port
5 Check valve
6 Primary air tank (dry tank)
7 Secondary air tank (dry tank)
8 Check valve.

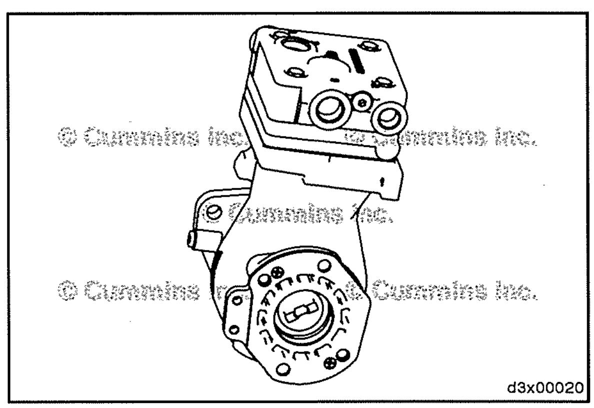
The engine is supplied with the air compressor and related intake air and coolant plumbing **only**. The remainder of the compressed air system is the responsibility of the vehicle manufacturer. See equipment manufacturer service information for more information.

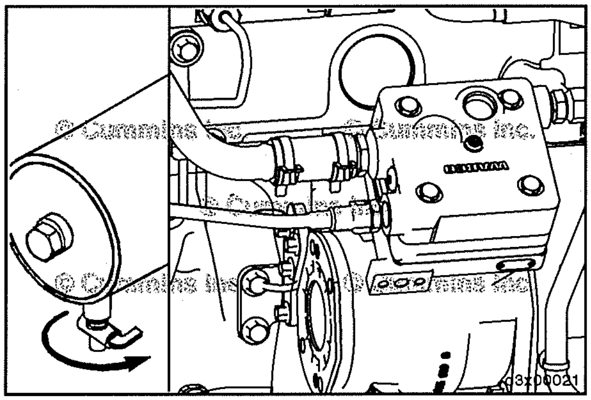
Air Compressor

- The air compressor is turbocharged, single cylinder.



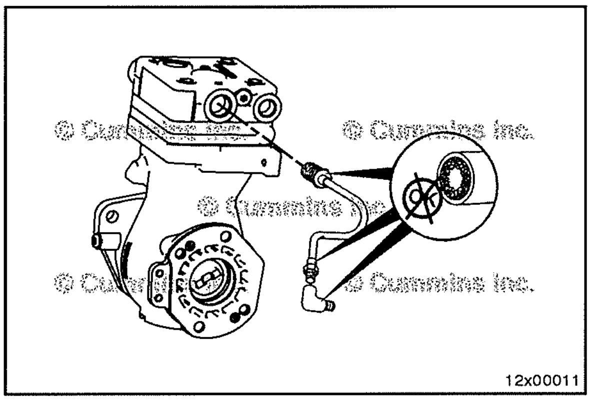
The air compressor has an SAE B rear flange with cruciform (DIN) drive.





The key factor which determines the reliability and durability of an air compressor in an application is the amount of time the air compressor is supplying air during the vehicle/machine operation, known as the duty cycle of the air compressor.

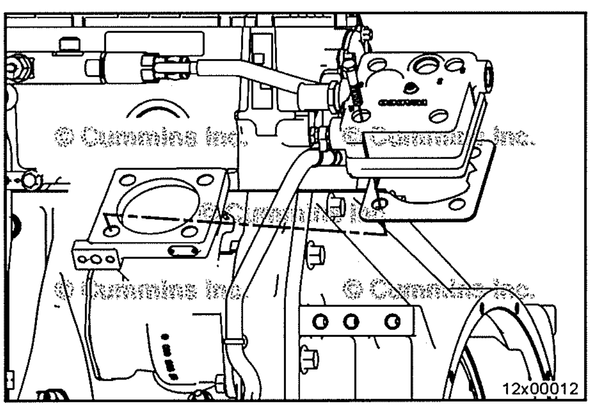
Air compressors are **not** designed to pump continuously and will generate a lot of heat when pumping, which is dissipated during the time the compressor is **not** pumping (called the unloaded operation).



Compressed air system maintenance/servicing can help minimize air compressor duty cycle and ensure reliability and durability of the air compressor. These item include but are **not** limited to:

1. Find and stop all leaks in the system. Air leaks can double or triple operating duty cycles. Close attention to correcting air system leaks is critical.
2. Checking the air compressor air outlet port, discharge line, and fittings for carbon build up. If the carbon buildup is greater than 1.6 mm [0.06 in], clean or replace as necessary.
3. Check the air lines and fittings between the outlet port of the air dryer and the first tank after the air dryer for any water or oil. The air tank should be dry. If oil is present, replace the dryer desiccant and clean the downstream system and components as required.

See equipment manufacturer service information for the vehicle for maintenance and service information for the compressed air system. For air compressor specific maintenance, see the Operation and Maintenance and/or Owner's manual for the engine being serviced.



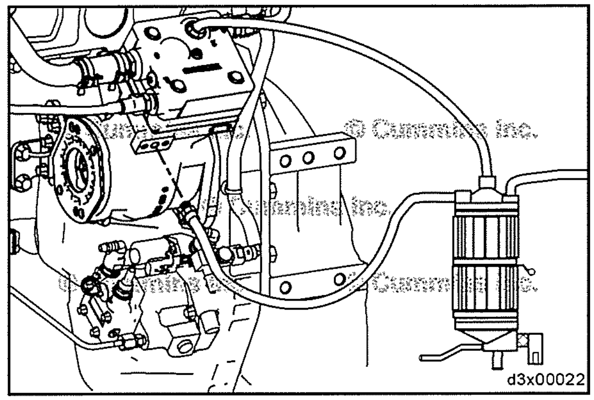
Air Compressor Cylinder Head

- The air compressor cylinder head is cooled by engine coolant. The cylinder contains intake and exhaust valves to regulate air flow into and out of the cylinder head.
- Most air compressor cylinder heads can be serviced without removing the compressor from the engine. This manual covers servicing of the cylinder head with the compressor installed on the engine. If there is internal damage to the air compressor, the air compressor **must** be replaced.
- Prior to removing the air compressor cylinder, make sure to check if replacement parts are available. Some air compressor cylinder heads may **not** be able to be serviced separately from the air compressor.

The compressor operates continuously, but has a "loaded" and "unloaded" operating mode. The operating mode is controlled by a pressure activated air governor and the air compressor unloader assembly. The air governor is integrated with the air dryer.

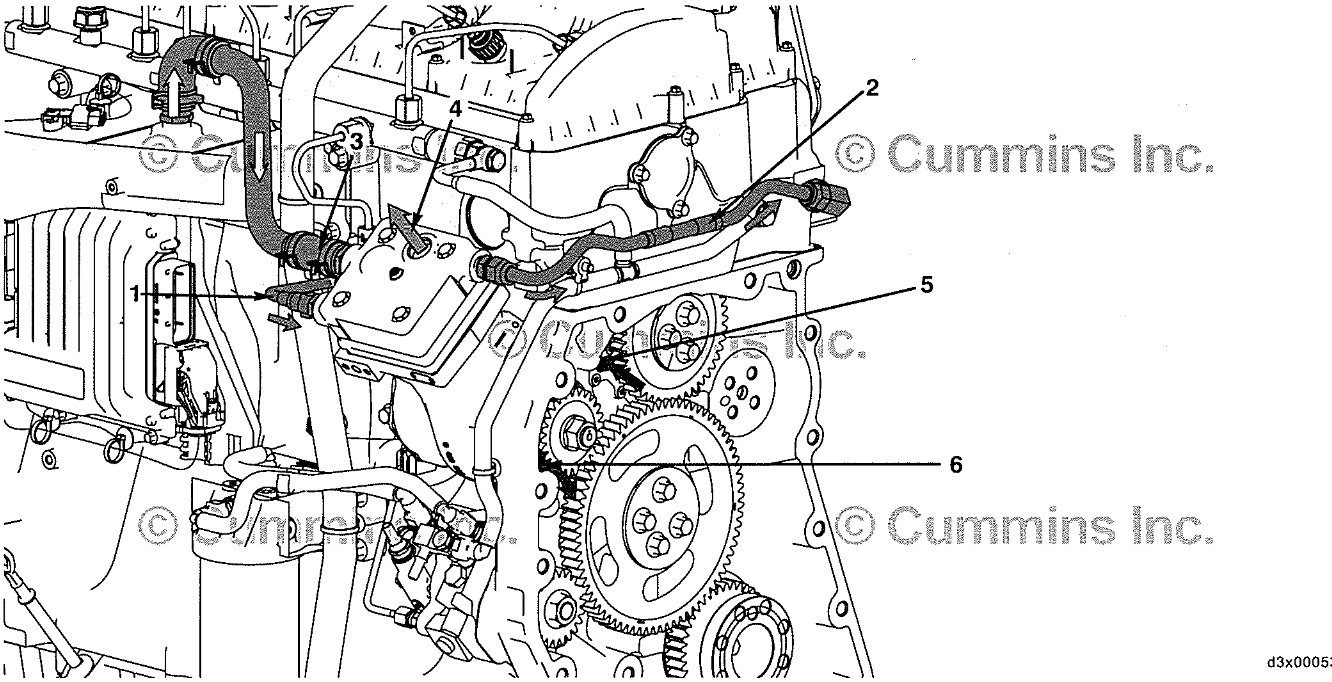
When the air system reaches a predetermined pressure, the governor applies an air signal to the unloader assembly, causing the unloader to either hold open or shutoff the compressor's intake valve. This causes compressed air to stop flowing into the compressed air system.

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



Flow Diagram, Compressed Air System (200-006)

Flow Diagram

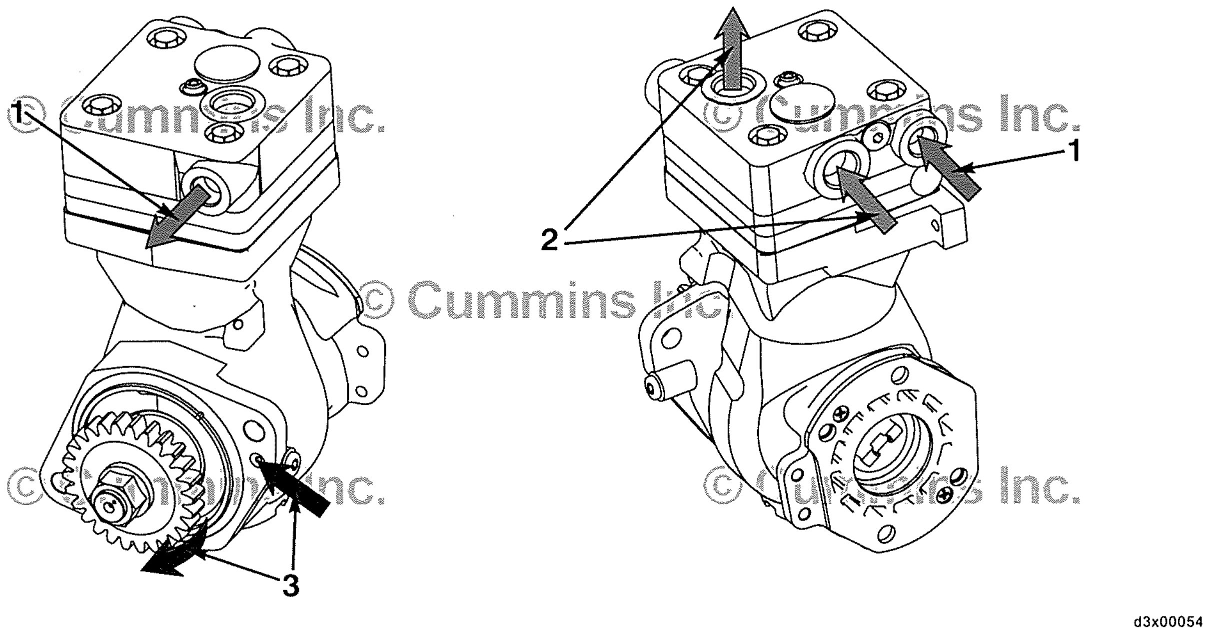


WABCO 318

1 Coolant supply from cylinder block
2 Coolant return to rocker lever housing
3 Air inlet
4 Air outlet
5 Lubricating oil supply from gear housing
6 Lubricating oil return to gear housing.

Flow Diagram, Compressed Air System (200-006)

Flow Diagram

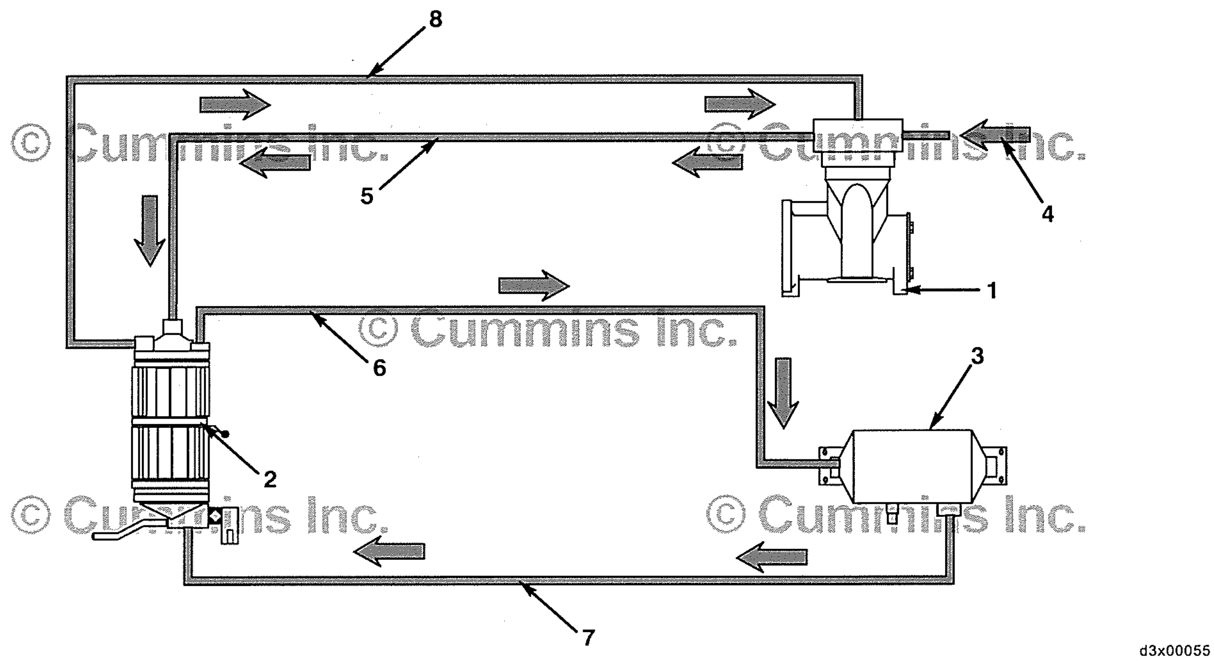


WABCO 318

1 Coolant flow
2 Air flow
3 Lubricating oil flow.

Flow Diagram, Compressed Air System (200-006)

Flow Diagram



WABCO - Type System with Air Dryer

1 Air compressor
2 Air dryer with integrated air governor
3 Air reservoir (dry tank)
4 Air intake
5 Air discharge
6 Air flow from air dryer to air reservoir
7 Air pressure signal from air reservoir to air governor
8 Signal from air governor to unloader valve.

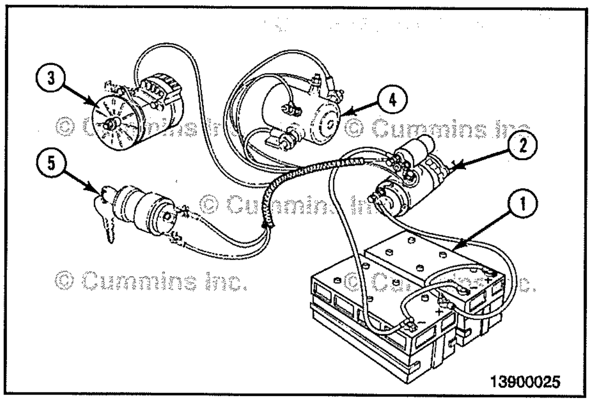
Flow Diagram, Compressed Air System (200-006)

Flow Diagram

NOTE: This diagram is generic and intended to convey the majority of systems. It may **not** be identical to every system. See equipment manufacturer service informatin for more information.

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.

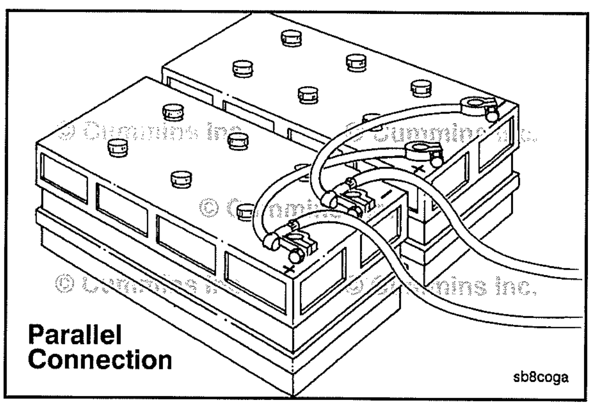
The basic electrical system consists of:

1 Batteries
2 Starter motor
3 Alternator
4 Magnetic switch
5 Keyswitch
6 All necessary wiring.

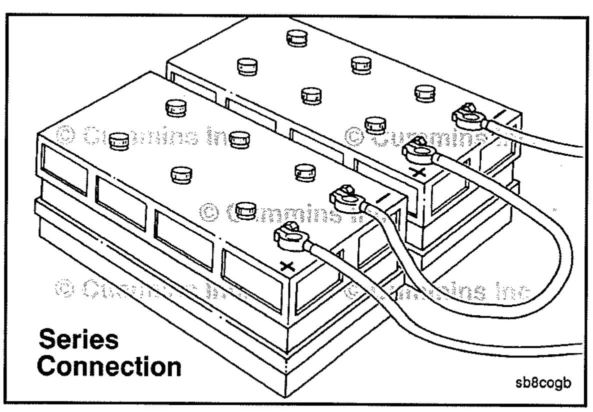
All components **must** be carefully matched.

The accompanying illustrations show typical parallel and series battery connections:

- Parallel connection.

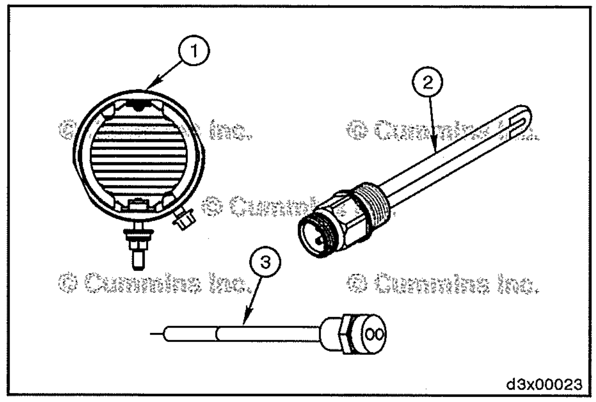


- Series connection.



Other electrical accessories available are:

1 Intake heater.
2 Engine coolant heater.
3 Oil pan heater.



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 horsepower range (full power).

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

Service Tools and Hardware - Overview

General Information

Cummins Inc. produces many engines that are electronically controlled. These engines have special diagnostic requirements for the engine control module (ECM) in the system. To interface with the ECMs, electronic service tools, such as INSITE™ electronic service tool, have been developed.

INSITE™ electronic service tool interfaces with the electronic engines via a data link. A data link provides a means of transmitting and sorting electric signals, and consists of special electronic circuitry and electrical harnesses. Connection points from electronic service tools are also part of the data link. An original equipment manufacturer (OEM) data link, if available, is provided by the OEM and consists of circuitry located in the OEM harness. An engine data link consists of circuitry located in the engine harness. Both engine and OEM data links alike are defined by standards written by the Society of Automotive Engineers (SAE). Cummins Inc. uses two such standards for electronic service tools. One is a combination of SAE J1587 and SAE J1708 and the other is SAE J1939. The J1939 data link is described in more detail in Procedure 019-165 in the appropriate engine service manual. The J1587/J1708 data link is described in more detail in Procedure 019-166 in the appropriate service manual, and is hereafter referred to as J1708 in this document. Engine data links (both J1939 and J1708) are discussed in more detail in Procedure 019-428 in the appropriate engine service manual.

INSITE™ Electronic Service Tool Description

INSITE™ electronic service tool is a Windows® based software application that works with Cummins® ECMs to diagnose and troubleshoot engine problems, store and analyze historical information about an engine, and to modify an engine's operating values. INSITE™ electronic service tool Professional also enables you to transfer calibrations to an ECM.

INSITE™ electronic service tool is used on an IBM® compatible personal computer (PC) that is attached to an ECM through an INLINE™, INLINE™ I, INLINE™ 2_1, INLINE™ 4, INLINE™ 5, or INLINE™ 6 data link adapter kit.

NOTE: 1. The INLINE™, INLINE™ I, INLINE™ 2, INLINE™ 4, and INLINE™ 5 adapter have become obsolete. It can be used with INSITE™, but technical support for these adapters is not available. These are 250k, and this requires 500k.

After registering a copy of INSITE™ electronic service tool and connecting to an ECM data source, INSITE™ electronic service tool enables you to retrieve present or recorded data about an engine, alter ECM settings, store data for viewing at a later time, analyze data to monitor and assess the operation of an engine, and view active or inactive engine fault codes.

INSITE™ electronic service tool is installed in the INTELECT™ folder on the hard drive of a personal computer. INSITE™ User's Manuals are available in the INTELECT™ and Manuals folder for specific Cummins® electronic engines. Additional information for service and support from a Cummins® distributor for INSITE™ electronic service tool questions is included in the front of the User's Manuals.

Different versions of INSITE™ electronic service tool may be available for use at one time, although some INSITE™ electronic service tool versions may **not** be compatible with some ECMs. ECM and INSITE™ electronic service tool compatibility information is available at the INSITE™ Product website. INSITE™ electronic service tool improvements are sometimes released as Feature Packs. The latest Feature Pack information for specific INSITE™ electronic service tool versions is also available at the INSITE™ Electronic Service Tool product website. It is important to maintain the INSITE™ electronic service tool with the latest versions and Feature Packs that become available.

INSITE™ electronic service tool can utilize either a communication port (COM port) or a Universal Serial Bus (USB) on the PC when communicating with an ECM. A COM port **must** be configured properly for INSITE™ electronic service tool to function correctly. It is possible for other software programs on the PC to take control of a COM port and prevent INSITE™ electronic service tool from accessing the COM port. Troubleshooting information for INSITE™ electronic service tool communication issues is available in the Base INSITE™ USER's Manual and also in the ECM No Communication Troubleshooting Tree on QuickServe™ Online or Intercept.

Initial Check

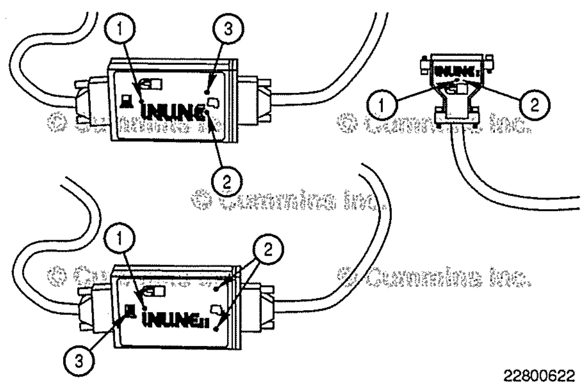
INSITE™

- In the main INSITE™ electronic service tool window, verify that the data link selected in the ECM Data Source Connection drop-down matches the data link hardware being used
- Verify that the correct INSITE™ version is installed. The INSITE™ version can be determined from the main INSITE™ electronic service tool window by selecting Help, About INSITE
- Verify that the infrared port is disabled so the serial port is **only** being used for ECM communications

- If you have the Palm Pilot Hot Sync Manager on a PC that **only** has one serial port, you **must** disable the Hot Sync Manager before connecting to an ECM.

Data Link Adapters

- Check the firmware version of the INLINE™ 2_1, INLINE™ 4, INLINE™ 5, or INLINE™ 6 data link adapter to make sure it is the latest firmware version available
- Verify that the data link adapter being used is compatible with the data link wiring available on the engine or vehicle.
- A data link adapter is a device that converts the J1708, or J1939 data link messages from the ECM into a message that a PC can process. Because INSITE™ electronic service tool is a PC based tool, a data link adapter is required to troubleshoot engines.
- Cummins® Service Products offer the following data link adapter kits:
- INLINE™ adapter kit, Part Number 3163099
- INLINE™ I adapter kit, Part Number 3163583
- INLINE™ 6 adapter kit, Part Number 2892092.
- The following illustration shows INLINE™ data link adapters.



Data Link Adapter Identification Diagram - INLINE™, INLINE™ I, and INLINE™ 2 (see note 1).

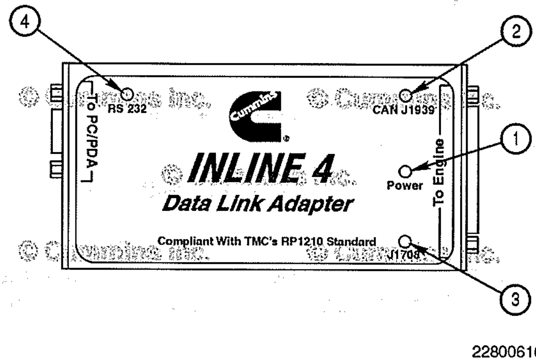
1 Power light
2 Communication light
3 To PC light.

Power for the INLINE™ I data link adapter is provided by the personal computer via the serial cable being used in the communication setup. In Windows XP™, Windows Vista™, and Windows™ 7, the power light will **only** be illuminated while INSITE™ electronic service tool has the COM port initialized and will **not** remain illuminated after exiting INSITE™ electronic service tool.

Power for the INLINE™, INLINE™ 2_1, INLINE™ 4, INLINE™ 5, and INLINE™6 data link adapters depends upon the communication setup in use. The 12-VDC power is supplied by the vehicle power system for the vehicle and engine communication setups. The 12 VDC power is supplied by an auxiliary power supply for the bench communication setup.

The INLINE™ and INLINE™ I data link adapters will **only** support J1708 data link protocols. The INLINE™ 2_1, INLINE™ 4, INLINE™ 5, or INLINE™ 6 data link adapter will support either J1708 or J1939 protocol. When connecting with INSITE™ electronic service tool using an INLINE™ 2_1, INLINE™ 4, INLINE™ 5, and INLINE™6, INSITE™ electronic service tool will attempt to establish communication with an ECM on J1939 first. If no communication is established on J1939, INSITE™ electronic service tool will then attempt to establish communication on J1708.

NOTE: 1. The INLINE™ 2 adapter has become obsolete. It can be used with INSITE™ electronic service tool, but technical support for this adapter is **not** available.



Data Link Adapter Identification Diagram - INLINE™ 4.

1 Power light
2 J1939 communication light
3 J1708 communication light
4 RS-232 to PC light.

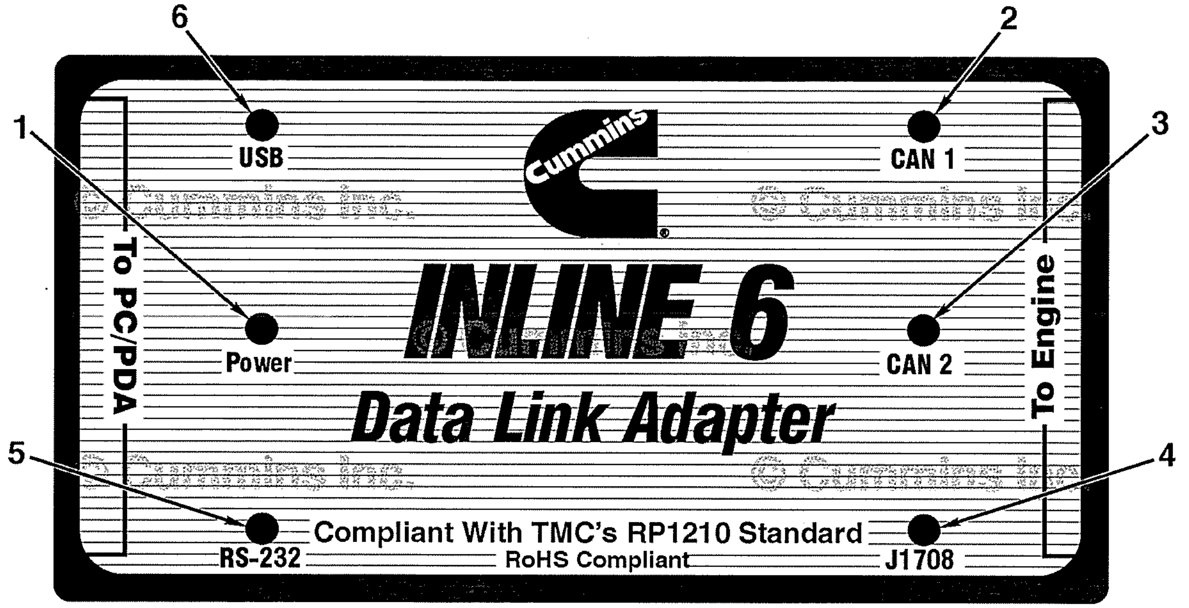
The INLINE™ 4 is an RP1210A compliant data link adapter that will support both J1708, and J1939 protocol. RP1210A is an industry wide standard that defines data link message format for service tools. The INLINE™ 4 **must** be configured correctly within INSITE™ electronic service tool to define the COM port being used on the PC and the type of data link protocol that is available, J1708, J1939, or autodetect.

Data Link Adapter Identification Diagram - INLINE™ 5.

1 Power light
2 J1939 communication light
3 J1708 communication light
4 RS-232 to PC light
5 USB to PC light.

The INLINE™ 5 is an RP1210A compliant data link adapter that will support both J1708, and J1939 protocol. It can be used with either a COM port or USB port. The INLINE™ 5 **must** be configured correctly within INSITE™ electronic service tool to define the COM or USB port being used on the PC and the type of data link protocol that is available, J1708, or J193, or autodetect.

NOTE: 1. The INLINE™ 2 adapter has become obsolete. It can be used with INSITE™ electronic service tool, but technical support for this adapter is **not** available.



Data Link Adapter Identification Diagram - INLINE™ 6

1 Power light
2 CAN 1 communication light (J1939)
3 CAN 2 communication light (J1939)
4 J1708 communication
5 RS-232 to PC light
6 USB to PC light.

The INLINE™ 6 is an RP1210A compliant data link adapter that will support both J1708 and J1939 protocols. It can be used with either a COM port or USB port. The INLINE™ 6 **must** be configured correctly within INSITE™ electronic service tool to define the COM or USB port being used on the PC and the type of data link protocol that is available, J1708, J1939, or autodetect.

The INLINE™2$_1$, INLINE™ 4, INLINE™ 5, and INLINE™ 6 data link adapters require firmware software in order to operate correctly. Firmware versions are updated periodically and **must** be uploaded into data link adapters when updates are released. The latest firmware version is always available on the most recent INCAL™ DVD-ROM as well as from the website http://inline.cummins.com.The firmware version for a data link adapter is displayed at the lower right corner on the main INSITE™ electronic service tool window when connected to an ECM. INSITE™ electronic service tool **must** be connected to an ECM in order for the firmware version to be displayed.

Setup

General Information

Communication with the ECM can be established at three basic locations:

- Bench communication setup
- Vehicle communication setup
- Engine communication setup.

The communication setups are described in more detail in the remainder of this procedure. Each location utilizes different data link adapter cables. All three locations require either a serial cable or USB cable (INLINE™ 5 **only**) to interface from the data link adapter to the PC.

The ECM on newer engines can support data link communication on the OEM data link through the OEM connector at the ECM. It can also support data link communication on the engine data link through the engine connector at the ECM. The wiring diagram for a specific engine and ECM **must** be consulted to determine if an ECM supports both OEM data link and engine data link communication.

For Midrange and Heavy Duty engines, the recommended communication setup, if available, is the Cummins Inc. bench communication setup which establishes communication directly to the ECM. The bench communication setup can support both J1708 and J1939 data link protocols, when used with ECMs that support both protocols.

For High Horsepower engines with multiple ECMs, the recommended communication setup is the engine communication setup through the 9-pin connector provided in the engine harness.

J1939 data link communication, if available, is preferred for transferring calibrations because of less interference from other data link devices such as traction control systems and electronic dashes. J1708 communication can require extra time to disable the OEM ECMs that are also communicating on the J1708 data link in order to avoid interference from those devices. Also, the J1939 information transfer rate is faster than J1708 and a calibration download will take less time to complete using J1939 communication compared to J1708 communication.

The functionality of a communication setup can be verified by testing the communication setup on a second ECM or vehicle, if available, or by completing the resistance checks defined for each setup type.

The following table summarizes the ECM communication setups.

Communication Setup	Data Link Connection Location	Engine ECM data link Source	Data Link Protocols Supported
Bench	ECM connector	OEM	J1708, J1939
Vehicle 6-pin	Dash 6-pin connector	OEM	J1708
Vehicle 9-pin	Dash 9-pin connector	OEM	J1708, J1939[1]
Engine	Engine harness 3-pin connector	Engine	J1939
Engine	Engine harness 6-pin connector	Engine	J1708[2]
Engine	Engine harness 9-pin connector	Engine	J1939[3]

Notes:

1 The 9-pin connector **must** be fully wired to support J1939 protocol.

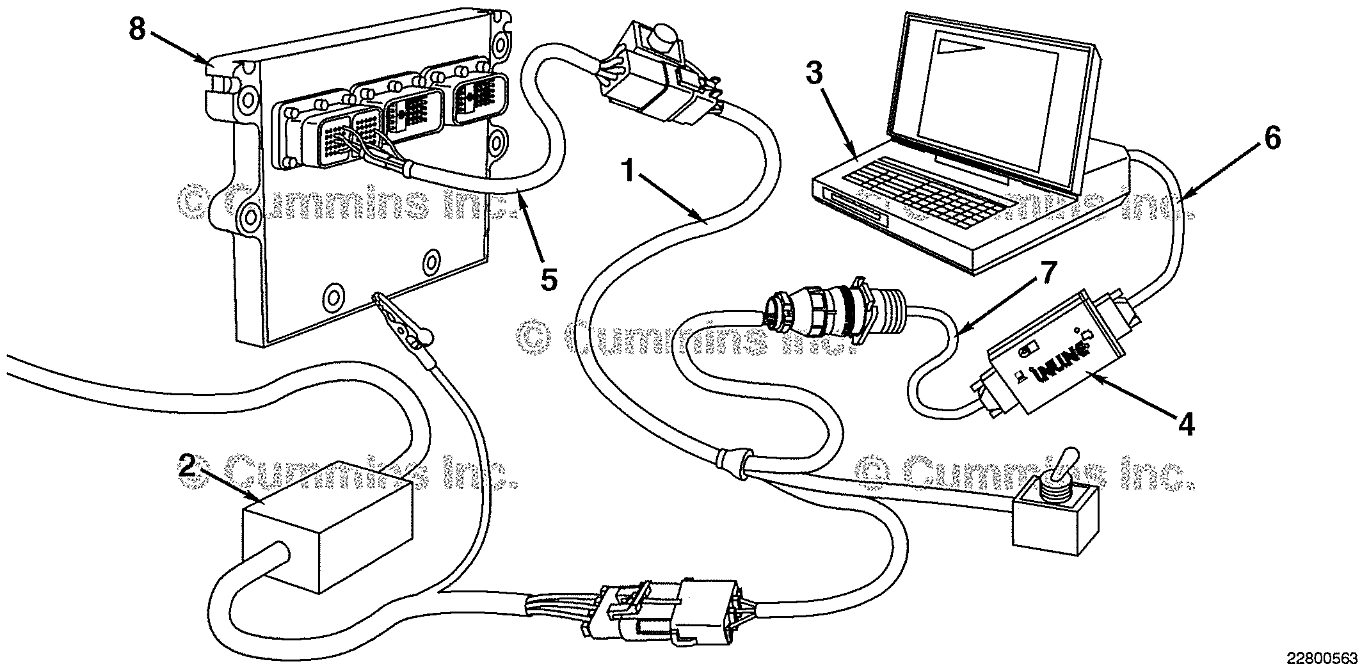
2 Available **only** on selected older engines.

3 Available **only** on selected High Horsepower engines.

Bench Communication Setup

The bench communication setup establishes communication directly with the ECM through the connector port on the ECM. An example of a bench communication setup is shown below.

The bench calibration harness (1) is common for most bench setups and can be used with the appropriate bench calibration cable (5) to communicate with various ECMs. A list of available bench calibration cables (5) for various ECMs is included in Bulletin 3377791, which is accessible on QuickServe™ Online. Proper function of the bench calibration harness (1) and bench calibration cable (5) can be verified by using the wiring diagrams provided to complete resistance checks.



Bench Communication Setup

1 Bench calibration harness, Part Number 3163151

2 Power supply$_1$

3 PC with INSITE™ electronic service tool

4 Data link adapter

5 CM570 bench calibration cable, Part Number 3164789

6 PC Serial cable$_2$, Part Number 4918418.

7 Data link adapter cable, Part Number 3165159

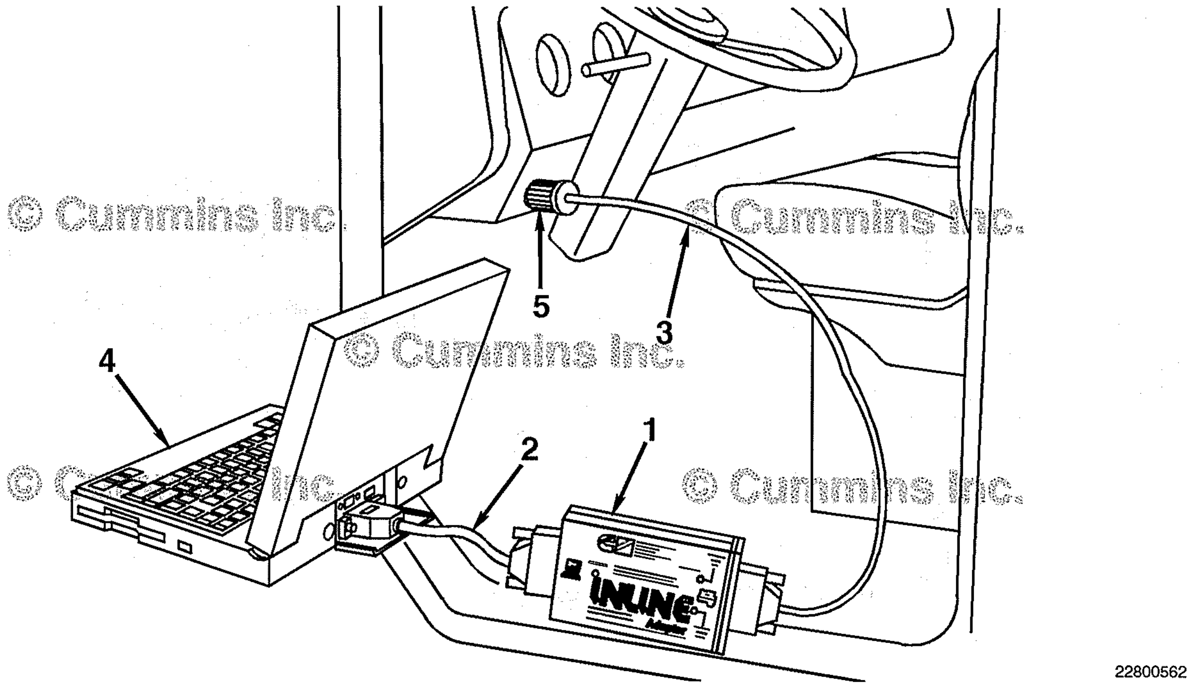
8 CM570 ECM (example).

NOTE: 1. See Bulletin 3377791 for part number.

NOTE: 2. USB cable, Part Number 4918591, can be used with the INLINE™ 4, INLINE™ 5, and INLINE™6.

Vehicle Communication Setup

An additional communication setup is a 9-pin or 6-pin Deutsch™ connection that is commonly located in the cab of a vehicle. The vehicle communication setup utilizes the OEM harness and connects to the ECM at the OEM connector port. A 9-pin connector in the cab, if fully wired, is capable of supporting both J1939, and J1708 protocol. Some OEMs place a 9-pin connector in the cab but do **not** provide wiring to support J1939 protocol. A 6-pin connector will **only** support J1708 protocol.



On Vehicle Communication Setup

1 Data link adapter
2 PC serial cable[2], Part Number 4918418.
3 Data link adapter cable[1]
4 PC with INSITE™ electronic service tool
5 Vehicle data link adapter connector[1].

NOTE: 1. See Bulletin 3377791 for part number.

NOTE: 2. USB cable, Part Number 4918591, can be used with the INLINE™ 4, INLINE™ 5, and INLINE™6.

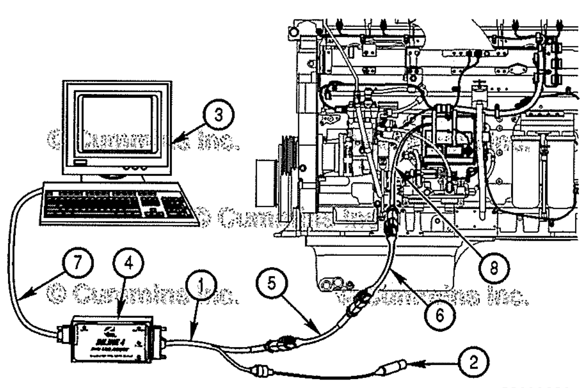
NOTE: Data link networks equipped to support 500K baud data link speeds require an adapter tool, Part Number 5299126, to connect to the 9-pin connector.

NOTE: Only the INLINE™ 6 is capable of supporting data link speeds of 500K baud. The INLINE™ 2, INLINE™ 4, and INLINE™ 5 do not support 500K baud data link speeds.

Engine Communication Setup

The engine communication setup utilizes the engine data link provided on the engine wiring harness. Depending upon the engine, the engine communication setup available on the engine harness can be a 3-pin Deutsch™ connector, a 6-pin Deutsch™ connector, or a 9-pin Deutsch™ connector.

A 3-pin Deutsch™ connector on the engine harness is available on newer engines and provides a connection point to the J1939 data link. A mini-backbone cable, which includes a 60 ohm resistor and a gender changer cable, may be required in order to connect to the ECM on the J1939 protocol. An auxiliary power supply is required for the data link adapter.



3-Pin Deutsch™ Connector

1 Data link cable$_1$

2 Power supply cable$_1$

3 PC with INSITE™ electronic service tool

4 Data link adapter

5 Gender changer cable, Part Number 3163597

6 Mini-backbone cable, Part Number 3163096

7 PC Serial cable$_2$, Part Number 4918418

8 Engine harness 3-pin connector, Part Number 3165141.

NOTE: 1. See Bulletin 3377791 for part number.

NOTE: 2. USB cable, Part Number 4918591, can be used with the INLINE™ 4, INLINE™ 5, and INLINE™6.

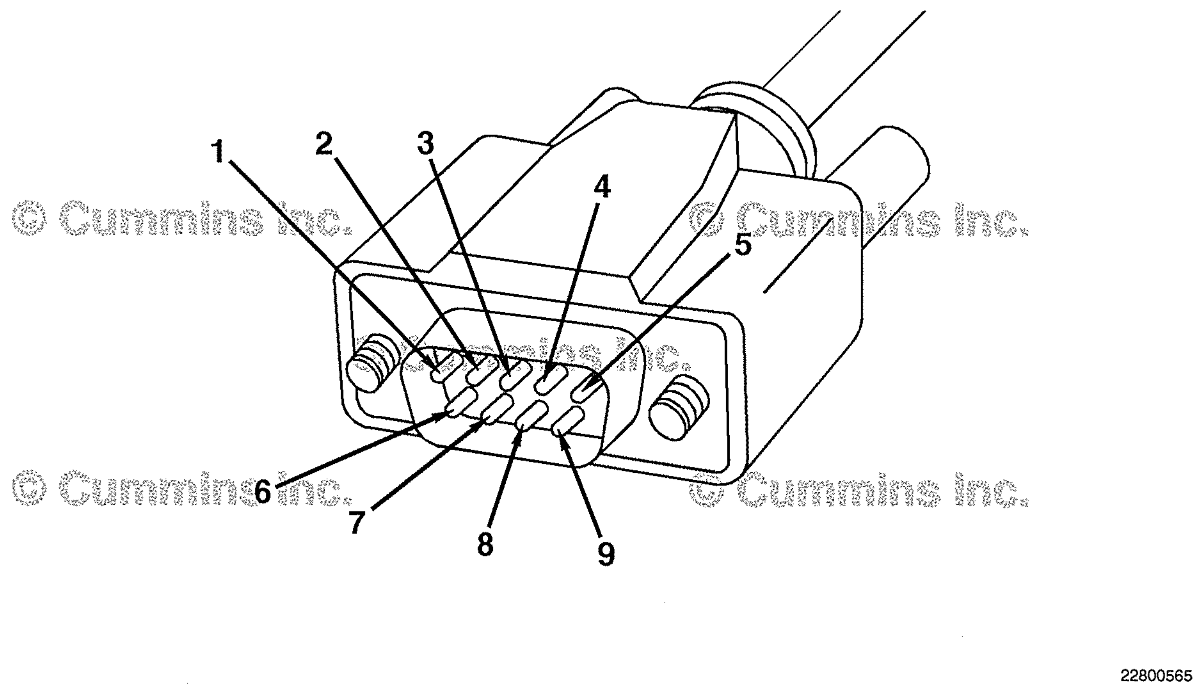
A 6-pin Deutsch™ connector is available on the engine harness for some older engines and provides a connection point to the engine J1939 data link. The 6-pin connector includes a power supply for the data link adapter.

Resistance Check

A serial cable is required to interface from the data link adapter to the PC, or a USB cable can be used with an INLINE™ 5/6 data link adapter.

⚠CAUTION⚠

Use test lead, Part Number 3822758, and test lead, Part Number 3822917, to avoid the possibility of damage to the serial cable pins.



Serial Cable, Part Number 4918418

1 Open

2 Transmit data

3 Receive data

4 Data terminal ready (+5 VDC)

5 Signal ground

6 Open

7 Request to send (+5 VDC)

8 Clear to send

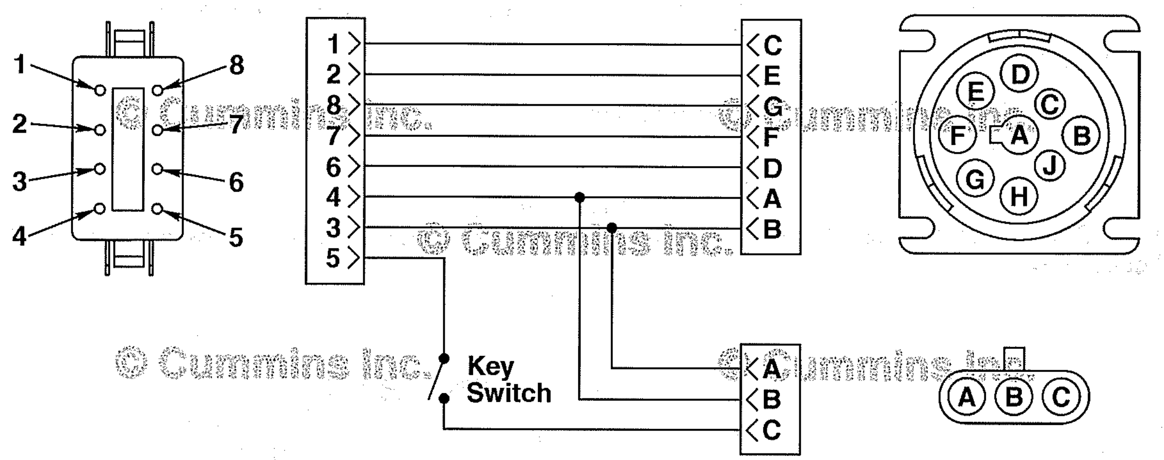
9 Open.

Insert a test lead into pin 1 of the female end of the serial cable, and connect it to the multimeter probe. Attach the other test lead to pin 1 of the male end of the serial cable, and connect it to the multimeter probe.

Measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less). Repeat the resistance measurement for pins 2 through 9. The multimeter **must** show a closed circuit (10 ohms or less) for each pin. If the circuit is **not** closed, replace the serial cable.

CAUTION

To avoid the possibility of damage to connector pins, use test lead, Part Number 3823993, on the 8-pin connector. Use test lead, Part Number 3823994, on the round 9-pin connector. Use test lead, Part Number 3824812, on the 3-pin connector.



Bench Calibration Harness, Part Number 3163151

1 J1939 data link (+)

2 J1939 data link shield

3 Battery (+)

4 Battery (-)

5 Keyswitch

6 J1939 data link (-)

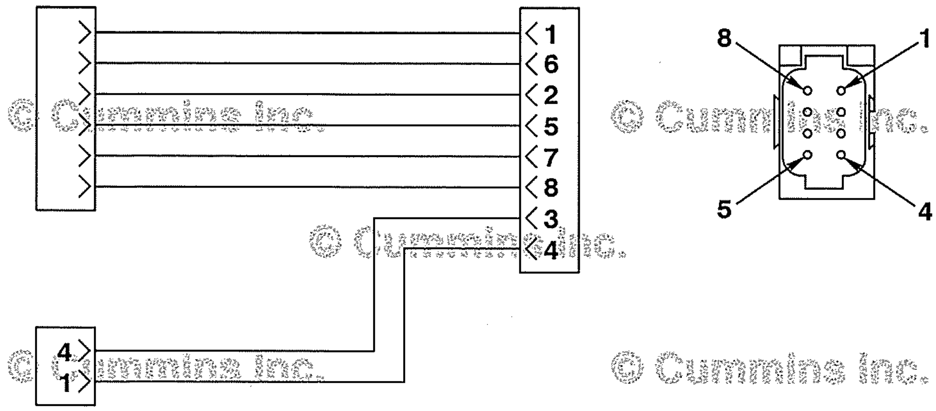
7 J1708 data link (+)

8 J1708 data link (-)

Measure the resistance from each pin in the 8-pin connector to the corresponding location in the 9-pin and/or 3-pin connector. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the bench calibration harness.

CAUTION

To avoid the possibility of damage to connector pins, use test lead, Part Number 382994, on the 8-pin connector. Determine the appropriate test lead needed for the ECM connector on the bench calibration cable.



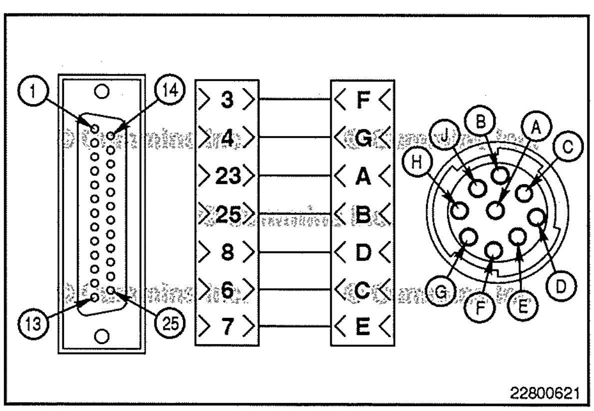
Bench Calibration Cable

1 J1939 data link (+)
2 J1939 data link shield
3 Battery (+)
4 Battery (-)
5 Keyswitch
6 J1939 data link (-)
7 J1708 data link (+)
8 J1708 data link (-).
9 ECM Connector (See wiring diagram for ECM connector pin identification).

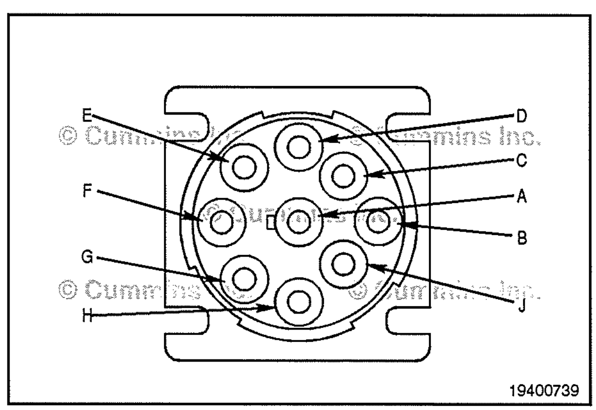
Measure the resistance from each pin in the 8-pin connector to the corresponding location in the ECM connector. See wiring diagram for the ECM for connector pin identification. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the bench calibration cable.

⚠CAUTION⚠

To avoid the possibility of damage to connector pins, use male test lead, Part Number 3823993, on the 9-pin Deutsch™ connector. Use male test lead, Part Number 3822758, on the 25-pin connector.



9-Pin Data Link Cable, Part Number 3165159



9-Pin In-Cab Data Link Connector

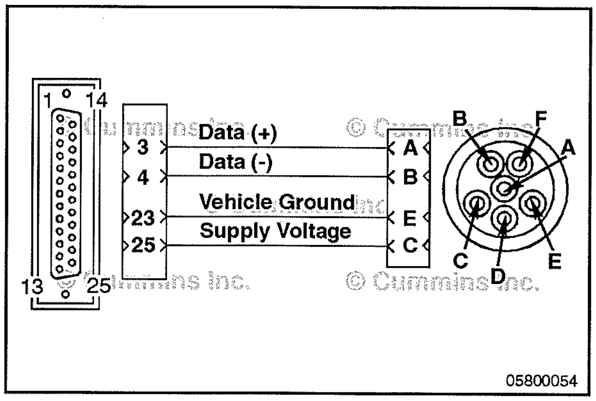
- A. Ground

- B. Battery (+)
- C. J1939 data link (+)
- D. J1939 data link (-)
- E. J1939 data link shield
- F. J1708 data link (+)
- G. J1708 data link (-)
- H. Open
- J. Open

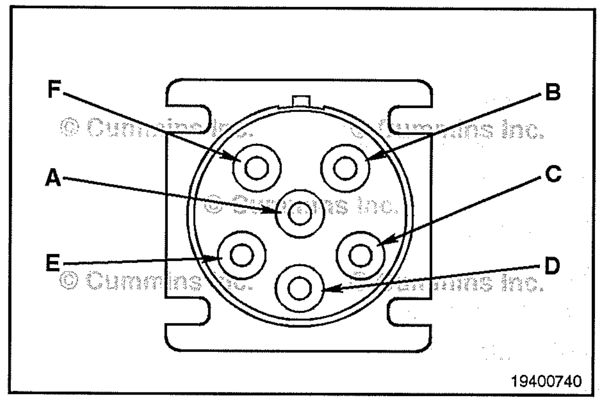
Measure the resistance from pins A, B, C, D, E, F, and G in the 9-pin connector to the corresponding location in the 25-pin connector, as shown. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the data link cable.

CAUTION

To avoid the possibility of damage to connector pins, use male test lead, Part Number 3824811, on the 6-pin Deutsch™ connector. Use male test lead, Part Number 3822758, on the 25-pin connector.



6-Pin Data Link Cable, Part Number 3165160



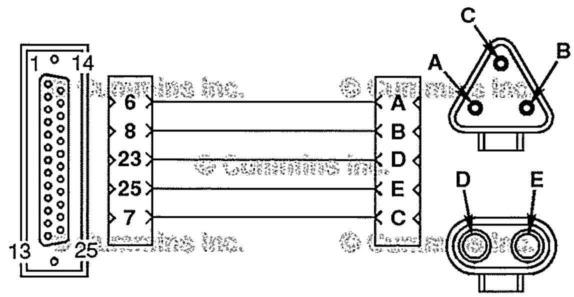
6-Pin In-Cab Data Link Connector

A J1708 data link (+)
B J1708 data link (-)
C Battery (+)
D Open
E Ground
F Open.

Measure the resistance from pins A, B, C, and E in the 6-pin connector to the corresponding location in the 25-pin connector, as shown. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the data link cable.

CAUTION

To avoid the possibility of damage to the connector pins, use male test lead, Part Number 3822758, on the 25-pin connector. Use female test lead, Part Number 3823994, on the 3-pin connector. Use male test lead, Part Number 3822995, on the 2-pin power connector.



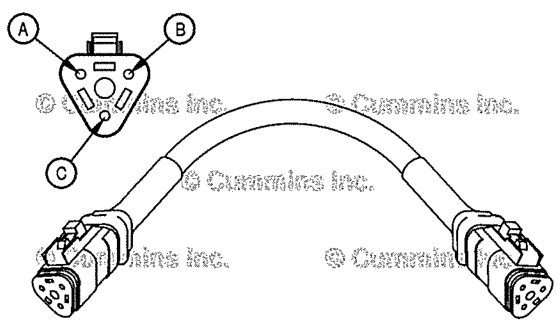
22800568

3-Pin Data Link Cable, Part Number 3165141

Measure the resistance from pins A, B, and C in the 3-pin connector to the corresponding location in the 25-pin connector, as shown. Measure the resistance from pins D and E in the 2-pin power supply connector to the corresponding location in the 5-pin connector, as shown. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the data link cable.

CAUTION

To avoid the possibility of damage to connector pins, use two male test leads, Part Number 3823993, on each 3-pin connector.



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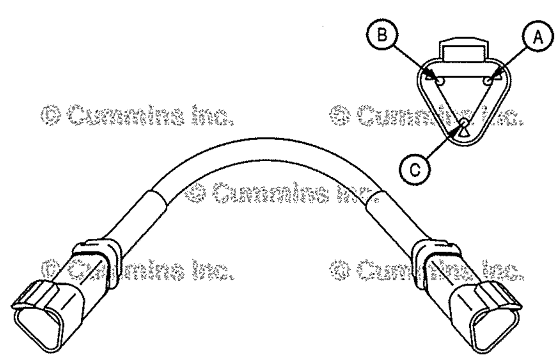
Mini Backbone Cable, Part Number 3163096

Measure the resistance from pin A in one end of the backbone cable to pin A in the opposite end of the backbone cable. Repeat for pins B and C. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the backbone cable. Measure the resistance across pins A and B at either end of the cable to measure the terminating resistance. The terminating resistance value **must** measure between 50-70 ohms.

CAUTION

To avoid the possibility of damage to connector pins, use two female test leads, Part Number 3823994, on each 3-pin connector.



19901672

Gender Changer Cable, Part Number 3163597

Measure the resistance from pin A in one end of the gender changer cable to pin A in the opposite end of the gender changer cable. Repeat for pins B and C. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the gender changer cable.

Section TS - Troubleshooting Symptoms

Section Contents

Page
Troubleshooting Procedures and Techniques TS-1
General Information....TS-1
Troubleshooting Symptoms Overview TS-2
General Information....TS-2
Aftertreatment Diesel Exhaust Fluid Not Pumping....TS-21
Aftertreatment Diesel Particulate Filter - Excessive Automatic and/or Stationary Regeneration....TS-105
Aftertreatment Diesel Particulate Filter - Excessive Soot Loading....TS-20
Air Compressor Air Pressure Rises Slowly TS-12
Air Compressor Cycles Frequently....TS-13
Air Compressor Noise is Excessive....TS-14
Air Compressor Pumping Excess Lubricating Oil into the Air System TS-15
Air Compressor Will Not Maintain Adequate Air Pressure (Not Pumping Continuously)....TS-17
Air Compressor Will Not Pump Air....TS-18
Air Compressor Will Not Stop Pumping....TS-19
Air Filter Plugging Frequent....TS-112
Aspirator Not Functioning....TS-114
Charging System Alternator Not Charging or Insufficient Charging....TS-24
Charging System Alternator Overcharging....TS-26
Coolant in the Lubricating Oil....TS-37
Coolant Loss - External....TS-27
Coolant Loss - Internal....TS-29
Coolant Temperature Above Normal - Gradual Overheat....TS-31
Coolant Temperature Above Normal - Sudden Overheat....TS-34
Coolant Temperature Below Normal....TS-36
Crankcase Gases (Blowby) Excessive....TS-38
Crystallization Buildup in the SCR Aftertreatment System....TS-23
Diesel Exhaust Fluid Contaminated....TS-109
Diesel Exhaust Fluid Usage - Abnormal....TS-102
Engine Cranks Slowly - (Electric Starter)....TS-69
Engine Decelerates Slowly....TS-39
Engine Difficult to Start or Will Not Start (No Exhaust Smoke)....TS-40
Engine Fan Does Not Operate, Operates Erratically, or Operates Continuously....TS-43
Engine Noise Excessive....TS-44
Engine Noise Excessive - Combustion Knocks....TS-47
Engine Noise Excessive - Connecting Rod....TS-48
Engine Noise Excessive - Drive Belt....TS-110
Engine Noise Excessive - Main Bearing....TS-49
Engine Noise Excessive - Piston....TS-51
Engine Noise Excessive - Turbocharger....TS-52
Engine Power Output Low....TS-53
Engine Runs Rough or Misfires....TS-55
Engine Shuts Off Unexpectedly or Dies During Deceleration....TS-57
Engine Speed Surges in PTO or Cruise Control....TS-62
Engine Speed Surges Under Load or in Operating Range....TS-59
Engine Starts But Will Not Keep Running....TS-65
Engine Will Not Crank - (Electric Starter)....TS-67
Engine Will Not Shut Off....TS-71
Fault Code Warning Lamps Do Not Illuminate....TS-73
Fault Code Warning Lamps Stay On (No Apparent Reason)....TS-72
Fuel Consumption Excessive....TS-74
Fuel in Coolant....TS-77
Fuel in the Lubricating Oil....TS-78
Intake Manifold Air Temperature Above Specification....TS-79
Intake Manifold Pressure (Boost) is Below Normal....TS-81
Low Idle Adjust Switch Does Not Work....TS-83
Lubricating Oil Consumption Excessive....TS-85
Lubricating Oil Contaminated....TS-87

Lubricating Oil Filter Plugged....TS-88
Lubricating Oil in the Fuel....TS-84
Lubricating Oil Pressure High....TS-90
Lubricating Oil Pressure Low....TS-91
Lubricating Oil Sludge in the Crankcase Excessive....TS-93
Lubricating Oil Temperature Above Specification....TS-95
Lubricating or Transmission Oil in the Coolant....TS-96
PTO or Cruise Control Does Not Operate....TS-97
Smoke, Black - Excessive....TS-98
Smoke, White - Excessive....TS-100
Stationary Regeneration - Will Not Activate....TS-103
Stationary Regeneration - Will Not Complete....TS-107
Turbocharger Leaks Engine Oil or Fuel....TS-101
Troubleshooting Overview....TS-3
Connecting Rod Bearing Noise....TS-3
Coolant Loss Pre-Troubleshooting Guide....TS-9
Driveability - General Information....TS-3
Driveability/Low Power - Customer Complaint Form....TS-5
Driveability/Low Power/Excessive Fuel Consumption - Checklist....TS-6
Engine Noise Diagnostic Procedures - General Information....TS-3
Fuel Consumption - Customer Complaint Form....TS-7
Fuel Consumption - General Information....TS-7
Main Bearing Noise....TS-3
Oil Consumption....TS-9
Piston Noise....TS-3

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 Overview

General Information

⚠ WARNING ⚠

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

This section utilizes Troubleshooting Symptoms as a guide to locate a problem and direct the end user to the correct procedure for making the repair.

Troubleshooting Symptom Trees are based on the following assumptions.

- The components have been installed according to the manufacturer's specifications.
- The easiest repairs are done first.
- All generic solutions are designed for the most common applications.

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

To utilize troubleshooting symptom trees, complete the following steps.

1 In Section TS - Troubleshooting Symptoms, locate the symptom that requires diagnosis.

- Locate the probable cause in the left column then navigate to the procedure referenced in the right column for a corrective action.
  - The left column of boxes in the Troubleshooting Symptom Tree indicates a probable cause of the problem, starting at the top with the simplest and easiest to repair, and continuing downward to the most difficult.
- The right column of boxes provides a brief description of the recommended corrective action for the associated probable cause, and provides a reference to the procedure that hosts those instructions.

3 Continue through the symptom tree until the issue has been resolved.

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 takeoff, 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 to 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 the Electronic Service Tool Manual. 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

(See 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

(See 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

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

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

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

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

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

Low power is **not** the inability of the vehicle to accelerate satisfactorily from a stop or the bottom of a grade. See the Engine Power Output Low symptom tree for the proper procedures to locate and correct a low power problem. The chart starts off with basic items which can cause lower power. It then breaks off into application specific items that can cause lower power. All of the application specific trees end with a step called "Fuel or air delivery problem". This step leads to an engine performance check which requires engine measurements. The last section of this chart is titled Performance Measurement. This leads the mechanic through the causes and corrections based on the outcome of the performance check.

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 gearing
- Improper engine application
- Worn clutch or clutch linkage.

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

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

See the Engine Acceleration or Response Poor symptom tree for the proper procedures to locate and correct a poor acceleration or response complaint.

Driveability/Low Power - Customer Complaint Form

Customer Name/Company ____ Date ____________

1 How did the problem occur? .... Suddenly ________ Gradually ________

2 Does the vehicle also experience poor fuel economy? .... Yes ____ No ____

3 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 selectable programmable parameters? .... Yes ____ No ____
- If so, what was repaired and when? ....

Answer questions 1 through 5 using selections (A through F) listed below. Circle the letter or letters that best describes the complaint.

A Compared to fleet

B Compared to competition

C Compared to previous engine

D Personal expectation

E Won't pull on hill

F Won't pull on flat

1 **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 ________ GVW ________________

2 **A B C D** Is the vehicle able to pull the load? .... Yes ____ No ____ When? In the hills ________ With a loaded trailer ________ On the flat ________ Other_______**IF QUESTION 4 OR 5 WAS ANSWERED NO, FILL OUT THE DRIVEABILITY/LOW POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST AND GO TO THE LOW POWER SYMPTOM TREE.**

3 **A B C D E F** Is the vehicle slow to accelerate or respond? .... Yes ____ No ____ From a stop? .... Yes ____ No ____ After a shift? .... Yes ____ No ____ rpm ________ Before a shift? .... Yes ____ No ____ rpm ________ No shift? .... Yes ____ No ____ rpm ________

4 **A B C D** Does the vehicle hesitate after periods of long deceleration or coasting? .... Yes ____ No ____ rpm _______**IF QUESTION 6 OR 7 WAS ANSWERED YES, FILL OUT THE DRIVEABILITY/LOW POWER/ EXCESSIVE FUEL CONSUMPTION CHECKLIST AND GO TO THE POOR ACCELERATION/RESPONSE SYMPTOM TREE.**

5 **A B C D E F** Additional Comments:

This Page Can Be Copied For Your Convenience.

Driveability/Low Power/Excessive Fuel Consumption - Checklist

Vehicle/Equipment Specifications				
Year/Type/Model:				
Wheel Base:		Vehicle Configuration (ex. 6 X 4 - 2S):		
Transmission Mfg:			Transmission Model:	
Rear Axle Model:			Rear Axle Ratio:	
Application:	On Highway:	Off Highway:	Genset:	Marine:
Typical GVW (kg [lbs]):				
Trailer Type (Van, round smooth, etc.):			Height:	Width:
Gap between Tractor and Trailer:				
Description of Vehicle aerodynamic aids:				
General Engine Information				
ESN:		CPL:	EPA Certification Year:	
ECM Code:		Engine Model:		
Engine Rating:			Rated Speed:	
Date in Service:			Mpg (average if multiple units):	
Engine Brake:	Yes		No	
Throttle Type:	Variable Speed		Automotive	
Tires				
Steer:	Tire Mfg		Tire Model	Rev/Mile
Drive:	Tire Mfg		Tire Model	Rev/Mile
Trailer:	Tire Mfg		Tire Model	Rev/Mile
Fan Type:	Direct Drive	Viscous	Clutch	Est. HP
Auxiliary Devices				
Power Steering:	Yes		No	
Air Conditioner:	None	Standard	Bus	High Capacity
Alternator:	Amps@Volts			
Road Speeds				
Maximum Cruise Control Speed:		Maximum Accelerator Vehicle Speed:		
Shift Technique:	Progressive Shift		Governed Speed Shift	
Electronic Features				
Gear Down Protection - Heavy Load:		mph		
Gear Down Protection - Light Load:		mph		
Cruise Control Upper Droop:		mph		
Cruise Control Lower Droop:		mph		
Road Speed Governor Upper Droop:		mph		
Road Speed Governor Lower Droop:		mph		
Typical Routes				
Route:				
Interstate	Dump	Rural	Urban	Bus
Grades:				
Level 1-2%	Short 1-5%		Long 1-5%	
Additional Comments:				
Recommended Literature:	Troubleshooting Driveability Complaints, Bulletin 3387137			

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 his 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 part 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. This means that 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 continual crosswinds and head winds. Less fuel can be used on north/south routes where parts of the trip are **not only** warmer, but see less wind resistance.

6 **Vehicle Aerodynamics:** The largest single power requirement for a truce 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 have a sizeable effect on fuel economy and performance. Changing from a bias ply to a low profile radial tire can reduce rolling resistance by about 36 percent.

Additional vehicle factors, vehicle specifications, and axle alignment can also affect fuel consumption.

Fuel Consumption - Customer Complaint Form

Customer Name/Company ______________________________ Date ____________

Customer Contact ______________________________ Customer Phone Number ____________

Describe the issue/complaint in detail, including current fuel economy being achieved:

____

____

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

1 What is the expected fuel mileage? ____________

2 What is the average GVW? ____________

3 What are the expectations based on? Original mileage ________ Other units in fleet ________ Competitive engines ________ Previous engine ________ Expectations **only** ________ VE/VMS report ________ **Note:** If the answer to number 3 is based on comparison (i.e. Other units in fleet, Competitive engines, Previous engine), the Customer Complaint Form and the Driveability/Low Power/Excessive Fuel Consumption - Checklist **must** be filled out for the comparison unit(s) in order to properly troubleshoot the complaint.

4 When did the problem occur? Since New ________ Suddenly ________ Gradually ________

5 Did the problem start after a repair? Yes ________ No ________ If so, what was repaired and why? ____

6 Is the vehicle also experiencing a Driveability problem (Low Power orPoor Acceleration/Response)? Yes ________ No ________ **If number 6 is answered Yes, fill out the Driveability/Low Power/Excessive Fuel Consumption Checklist.**

7 Is the problem seasonal? Yes ________ No ________

8 Weather conditions during fuel consumption check? Rain _____ Snow _____ Windy _____ Hot Temperatures _____ Cold Temperatures _____

9 How is the fuel usage measured? Tank _____ Trip _____ Month _____ Year _____Road Relay _____ ECM _____ Inspec _____

10 If number 9 is answered Road Relay, ECM, or Inspec, how do these fuel numbers compare to actual?Percent Difference ________

11 If tractor pulls a refrigerated trailer, are fuel tickets kept separate for tractor and trailer fuel?Yes ________ No ________

12 How is the distance measured?Hub _____ Odometer _____ Road Relay _____ ECM _____ Inspec _____ Map Miles _____ Dispatch/Paid Miles _____

13 If number 12 is answered Road Relay, ECM, Inspec, Map, or Dispatch/Paid, how do these distance numbers compare to actual? Percent Difference ___________

14 Are accurate records kept of fuel added on the road? Yes ________ No ________

15 Do routes vary between compared vehicles? Yes ________ No ________

16 Have routes changed for the engine being checked? Yes ________ No ________

17 Has driver changed for the engine being checked? Yes ________ No ________

18 Has typical load changed for the engine being checked? Yes ________ No ________

19 Has the fuel source changed? Yes ________ No ________

20 What are the loads hauled, compared to comparison unit? GVW _______________Heavier ________ Lighter ________

21 At what altitude is the truck operating? Below 10,000 feet ________ Above 10,000 feet ________

22 According to the driver, how many hours per day is the truck idling? Hours/day __________**The Service Location should fill out the remaining section** Distributor Name ____ Date __________________Distributor Contact ____ Distributor Phone Number __________________

23 Record the following parameters from Trip Information in INSITE™: Version of INSITE™ used ______________Percent Time in Top Gear ______________% Percent Time One Gear Down ______________% Percent Time in Cruise Control ______________% Percent Time at Idle ______________% PTO Time ______________hrs Trip Distance ______________mi/km Trip Fuel Used ______________gal/L Trip Gear Down Distance ______________mi/km Trip Top Gear Distance ______________mi/km Cruise Control Distance ______________mi/km Vehicle Overspeed 1 Distance ______________mi/km Vehicle Overspeed 1 Threshold ______________mph/kph Vehicle Overspeed 1 Time ______________hrs Vehicle Overspeed 2 Distance ______________mi/km Vehicle Overspeed 2 Threshold ______________mph/kph Vehicle Overspeed 2 Time ______________hrs

24 Is the driver technique or operating practices affecting fuel economy? Incorrect shift rpm? Yes ________ No ________ Rpm at cruise control speed? Yes ________ No ________ Is customer compensating for low power? Yes ________ No ________

25 Have fuel tank vents been verified to be working properly? Yes ________ No ________

26 Has vehicle been checked for brake drag? Yes ________ No ________

27 Has vehicle been checked for tractor and trailer alignment? Yes ________ No ________

28 Has vehicle been checked for fuel leaks? Yes ________ No ________

29 Does vehicle have either a fuel heater or cooler? Yes ________ No ________

30 Is customer using proper fuel for ambient conditions? Yes ________ No ________

31 Are all charge air cooler clamps present and tight? Yes ________ No ________

IF, AFTER FILLING OUT THIS FORM, IT APPEARS THAT THE PROBLEM IS NOT CAUSED BY VEHICLE FACTORS, ENVIRONMENTAL FACTORS, OR DRIVER TECHNIQUE, FILL OUT THE DRIVEABILITY/LOW POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST.

Oil Consumption

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

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				

Coolant Loss Pre-Troubleshooting Guide

Before troubleshooting, it is critical to know where the coolant is being lost. It is **not always** obvious where the missing coolant has gone.

Before troubleshooting, it is important to determine the exact complaint by interviewing the driver, looking at the service history, and looking at the ECM information.

Driver Interview Questions

Driver's Name:

ESN:

What is your complaint?

How is this engine used?

What sort of load factors?

Where is the vehicle driven?

1 How often do you add coolant?

1 How do you fill the radiator?
2 Do you fill to the High or Low mark when the engine is cold (less than 60°C [140°F])?
3 What type of coolant do you add?
4 Have you seen any coolant on the ground under your truck?
5 Have you seen green or white streaks on the engine or near the coolant overflow hose?

1 Is there any specific condition when you get indications of coolant loss (weather, altitude, or load)?
2 Does the engine ever overheat?
3 Does the warning light flash?
4 Under what condition?
5 At what temperature does the coolant run at normally?
6 Does the cooling fan operate correctly (fan on at 99°C [210°F])?

1 Have you seen any white smoke at operating temperature, or has anyone told you that white smoke is coming out of the exhaust?
2 Do you have oil analysis performed as part of your maintenance?
3 Are there elevated levels of sodium or potassium?
4 Have you noticed any increase in moisture condensation on the dipstick or oil fill cap, or moisture in the blowby?
5 Have you noticed a milky appearance in your lube oil that might indicate coolant is present?

1 What other comments do you have that might help us make the right repair?

Service History Review

Repeat cylinder head or cylinder head gasket repairs can indicate the problem is likely **not** the cylinder head or cylinder head gasket. Repeat problems can indicate a deeper problem in the engine. Keep this information in mind while going through the troubleshooting procedure.

Look at this engine's warranty claims history: who worked on the engine last and what did they do? How many miles/kilometers are on this engine? Has a cylinder head or cylinder head gasket been replaced before? At how many miles were the repairs made?

Engine Control Module Data Review

Print out an INSITE™ electronic service tool Image Report from the ECM. Look for high temperature alarms or low coolant level alarms. Either indication confirms a complaint of loosing coolant.

Are any fault codes logged in the Engine Protection Fault History?

- ECM Fault Code 235 - Low Coolant (how many times)?
- ECM Fault Code 151 - High Coolant Temperature (how many times)?

At this point, do you know where the coolant is going? If **not**, and the coolant loss is **not** severe, suggest mounting a catch bottle on the radiator overflow tube to catch any overflow that can possibly be blowing out and becoming lost while at speed. Send the vehicle out to collect more data about where the coolant is or is **not** going. If the catch bottle has some coolant in it, refer back to the Coolant Loss External (out the overflow) interview questions.

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 the engine air intake restriction if the air compressor air inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031 in Section 10.
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. Check for air system leaks in the catalyst dosing control unit. Refer to Procedure 012-019 in Section 12 and the OEM service manuals. Refer to Procedure 011-058 in Section 11 and the OEM service manual. Turn the keyswitch ON.
OK Go To Next Step	
STEP 3 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Some OEM installations may **not** utilize an air governor, therefore frequent cycling may be expected and normal. Refer to Procedure 012-017 in Section 12.
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 Unloader valve is malfunctioning	Check the unloader valve and unloader body seal. Refer to Procedure 012-013 in Section 12.

Air Compressor Cycles Frequently

This is symptom tree t005

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. Check for air system leaks in the catalyst dosing control unit. Refer to Procedure 012-019 in Section 12 and the OEM service manual, Procedure 011-058 in Section 11 and 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. Some OEM installations may **not** utilize an air governor, therefore frequent cycling may be expected and normal. Refer to Procedure 012-017 in Section 12.
OK Go To Next Step	
STEP 3 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 4 Air dryer outlet check valve is sticking	Lubricate or replace the air dryer outlet check valve assembly. Refer to the OEM service manual.

Air Compressor Noise is Excessive

This is symptom tree t006

Cause	Correction
STEP 1 Ice buildup in the air system components	Check for ice in low sections of the air discharge line.
OK Go To Next Step	
STEP 2 Carbon buildup is excessive in the air discharge line, downstream air valves, or cylinder head	Check for carbon buildup. Replace the air compressor discharge line, cylinder head, or air compressor, as necessary. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedure 012-003 in Section 12.
OK Go To Next Step	
STEP 3 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 OEM service manual.
OK Go To Next Step	
STEP 4 Air compressor mounting hardware is loose, worn, or broken	Check the air compressor mounting hardware. Refer to Procedure 012-014 in Section 12.
OK Go To Next Step	
STEP 5 Air compressor is excessively worn or internally damaged	Replace the air compressor. Replace the desiccant element on the air dryer, if equipped. Refer to Procedure 012-014 in Section 12 and the OEM service manual.
OK Go To Next Step	
STEP 6 Air compressor drive gear or engine gear train is worn or damaged	Inspect the drive gears and gear train. Repair as necessary. Refer to Procedure 012-014 in Section 12.

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree t007

Cause	Correction
STEP 1 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to Procedure 102-002 in Section 2 in the QSG CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 2 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 3 Air intake system restriction to air compressor is excessive	Replace the air compressor air cleaner, if installed. Check the air intake piping. Check the engine air intake restriction if the air compressor air inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 4 Contaminants are **not** being drained from the system on a regular basis	Drain the reservoirs daily. Refer to the equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Air compressor pumping time is excessive	Replace the desiccant cartridge on the air dryer (if equipped). Refer to the OEM service manual. Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to the equipment manufacturer service information.
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, cylinder head, or air compressor. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedure 012-003 and Procedure 012-007 in Section 12.
OK Go To Next Step	
STEP 7 Engine angularity during operation exceeds specification	Refer to the Engine Specification 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 8 Crankcase pressure is excessive	Check for excessive blowby. Refer to the Crankcase Gases (Blowby) Excessive troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 9 Lubricating oil pressure is above specification	Check the oil pressure. Refer to the Lubricating Oil Pressure High troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 10 Air compressor runs hot	If the coolant temperature is above normal, refer to the Coolant Temperature Above Normal - Gradual Overheat troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 11 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 012-014 in Section 12.
OK Go To Next Step	
STEP 12 Air compressor drive gear or engine gear train is worn or damaged	Inspect the drive gears and gear train. Repair as necessary. Refer to Procedure 012-014 in Section 12.
OK Go To Next Step	
STEP 13 Air compressor pumping too high air pressure	Check the air governor for correct operation. Refer to the equipment manufacturer service information.
OK Go To Next Step	
STEP 14 Air compressor is excessively worn or internally damaged	Replace or rebuild the air compressor. Refer to Procedure 012-014 in Section 12.

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. Check for air system leaks in the catalyst dosing control unit. Refer to Procedure 012-019 in Section 12 and the OEM service manuals. Refer to Procedure 011-058 in Section 11 and 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. Some OEM installations may **not** utilize an air governor, therefore frequent cycling may be expected and normal. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Air compressor intake or exhaust valve system leaks air	Replace the air compressor. Refer to Procedure 012-019 in Section 12.

Air Compressor Will Not Pump Air

This is symptom tree t009

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 the engine air intake restriction if the air compressor air inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 2 Unloader system is malfunctioning	Check the unloader system and head assembly system. Replace the head assembly if required. Refer to Procedure 012-003 in Section 12.
OK Go To Next Step	
STEP 3 Air compressor is excessively worn or internally damaged	Replace the air compressor. Replace the desiccant element on the air dryer, if equipped. Refer to Procedure 012-014 in Section 12 and the OEM service manual.

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. Check for air system leaks in the catalyst dosing control unit. Refer to Procedure 012-019 in Section 12, Procedure 011-058 in Section 11, and the OEM service manual.
OK Go To Next Step	
STEP 2 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. Check for air system leaks in the catalyst dosing control unit. Refer to Procedure 011-058 in Section 11.
OK Go To Next Step	
STEP 3 Air compressor intake or exhaust system leaks air	Replace the air compressor. Refer to Procedure 012-003 in Section 12.
OK Go To Next Step	
STEP 4 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Some OEM installations may **not** utilize an air governor, therefore frequent cycling may be expected and normal. Refer to the OEM service manual.

Aftertreatment Diesel Particulate Filter - Excessive Soot Loading

This is symptom tree t011

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in the Fault Code Troubleshooting Manual, QSG12 CM2350 G110, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Progressive damage from excessive black smoke caused from an earlier or present malfunction	Review the repair history of the engine to determine if the aftertreatment diesel particulate filter was replaced or needs to be replaced. Refer to Procedure 014-016 in Section 14.
OK Go To Next Step	
STEP 3 Extended operation of engine in low duty cycle, extended idling and/or low ambient temperatures	Perform a stationary regeneration with INSITE™ electronic service tool. Refer to Procedure 014-016 in Section 14.
OK Go To Next Step	
STEP 4 Engine is being lugged down	Use a lower gear.
OK Go To Next Step	
STEP 5 Intake air restriction is high	Check the air intake system for restriction. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 6 Excessive internal oil consumption	Refer to the Oil Consumption - Excessive troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 7 Excessive black smoke is observed	Refer to the Black Smoke - Excessive troubleshooting symptom tree in Section TS.

Aftertreatment Diesel Exhaust Fluid Not Pumping

This is symptom tree t012-1

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Aftertreatment diesel exhaust fluid level low	Fill the aftertreatment diesel exhaust fluid reservoir with aftertreatment diesel exhaust fluid. Refer to the OEM service manual for instructions on refilling the reservoir.
OK Go To Next Step	
STEP 3 Aftertreatment diesel exhaust fluid frozen in reservoir	Allow the aftertreatment diesel exhaust fluid reservoir to thaw. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Aftertreatment diesel exhaust fluid leak (external)	Inspect for external aftertreatment diesel exhaust fluid leaks or crystallization at exhaust joints, tailpipe exit, aftertreatment diesel exhaust fluid dosing valve, or associated plumbing. Repair as necessary. Refer to the OEM service manual for instructions on checking for leaks.
OK Go To Next Step	
STEP 5 Aftertreatment diesel exhaust fluid leak (internal)	Inspect for internal aftertreatment diesel exhaust fluid leaks or crystallization between the aftertreatment diesel exhaust fluid dosing valve and the exhaust catalyst. Repair as necessary. Refer to the OEM service manual for instructions on checking for leaks.
OK Go To Next Step	
STEP 6 Aftertreatment diesel exhaust fluid line is frozen or plugged	Replace the obstructed plumbing and inspect the aftertreatment diesel exhaust fluid reservoir filter for any small holes, tears or blockage. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Aftertreatment DEF dosing valve is plugged	Inspect the Aftertreatment DEF dosing valve. Refer to Procedure 011-059 in Section 11.
OK Go To Next Step	

Aftertreatment Diesel Exhaust Fluid Not Pumping

This is symptom tree t012-1

Cause	Correction
STEP 8 Engine control module (ECM) calibration is malfunctioning	Verify that the engine control module (ECM) calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. Refer to Procedure 019-032 in Section 19.

Crystallization Buildup in the SCR Aftertreatment System

This is symptom tree t012-2

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Exhaust leaks in the original equipment manufacturer (OEM) exhaust piping leading to the aftertreatment system or leaks in the aftertreatment system	Inspect the OEM exhaust piping and the aftertreatment system for exhaust leaks. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Aftertreatment diesel exhaust fluid leak (external)	Inspect for external aftertreatment diesel exhaust fluid leaks or crystallization at exhaust joints, tailpipe exit, aftertreatment diesel exhaust fluid dosing valve, or associated plumbing. Repair as necessary. Refer to Procedure 011-036 in Section 11.
OK Go To Next Step	
STEP 4 Aftertreatment diesel exhaust fluid volume and spray pattern from the aftertreatment DEF dosing valve incorrect	Measure the aftertreatment diesel exhaust fluid volume and spray pattern from the aftertreatment DEF dosing valve. Refer to Procedure 011-059 in Section 11.
OK Go To Next Step	
STEP 5 Engine operating for extended periods in low-duty cycle, extended idling, and/or low ambient temperatures	Interview the operator to understand the duty cycle, idling time, and operating temperatures of the vehicle. Shut off the engine rather than idle for long periods (greater than 10 minutes). If idle time is necessary, raise the idle speed. Refer to Procedure 008-028 in Section 8 if the fan is electronically controlled by the engine's ECM. If the fan is OEM controlled, refer to the OEM service manual. Refer to Cold Weather Operation, Bulletin 3387266.
OK Go To Next Step	
STEP 6 Exhaust gas flow before or after the aftertreatment diesel exhaust fluid dosing valve is restricted, causing aftertreatment diesel exhaust fluid crystallization	Inspect the exhaust piping. The piping must be straight and unobstructed before and after the aftertreatment diesel exhaust fluid dosing valve for proper distribution of diesel exhaust fluid.

Charging System 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 in Section 13.
OK Go To Next Step	
STEP 2 Batteries have failed	Check the condition of the batteries. Replace the batteries, if necessary. Refer to Procedure 013-007 in Section 13 and the OEM service manual.
OK Go To Next Step	
STEP 3 Batteries are cold	Check the battery heater. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Electrical system is "open" (blown fuses, broken wires, or loose connections)	Check the fuses, wires, and connections. Refer to the OEM service manual and the manufacturer's wiring diagrams.
OK Go To Next Step	
STEP 5 Alternator belt is loose	Check the alternator belt tension. Refer to Procedure 013-005 or Procedure 013-021 in Section 13.
OK Go To Next Step	
STEP 6 Vehicle gauge is malfunctioning	Check the vehicle gauge. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Alternator pulley is loose on the shaft	Tighten the pulley. Refer to the OEM service manual.
OK Go To Next Step	
STEP 8 Alternator or voltage regulator is malfunctioning	Test the alternator output. Replace the alternator or voltage regulator, if necessary. Refer to Procedure 013-001 in Section 13 and the OEM service manual.
OK Go To Next Step	
STEP 9 Alternator is overloaded, or alternator capacity is below specification	Install an alternator with a higher capacity. Refer to Procedure 013-001 in Section 13 and the OEM service manual.
OK Go To Next Step	

Charging System Alternator Not Charging or Insufficient Charging

This is symptom tree t013

Cause	Correction
STEP 10 Battery temperature is above specification	Position the batteries away from heat sources. Refer to the OEM service manual.

Charging System 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 the equipment manufacturer service information.
OK Go To Next Step	
STEP 2 Battery cell is damaged (open circuit)	Check the condition of the batteries. Replace the batteries, if necessary. Refer to the equipment manufacturer service information.
OK Go To Next Step	
STEP 3 Voltage regulator is malfunctioning	Check the voltage regulator. Replace the voltage regulator, if necessary. Refer to the equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Alternator is malfunctioning	Test the alternator output. Refer to Procedure 013-001 in Section 13 or the equipment manufacturer service information if the alternator was **not** manufactured by Cummins Inc.
OK Go To Next Step	
STEP 5 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in the Fault Code Troubleshooting Manual, Bulletin 4367324.

Coolant Loss - External

This is symptom tree t020

Cause	Correction
STEP 1 Excessive internal or external engine coolant loss	Before troubleshooting, it is important to determine the exact complaint by interviewing the driver, looking at the service history, and looking at the engine control module (ECM) information. Refer to the Coolant Loss Pre-Troubleshooting Guide at the end of Section TS.
OK Go To Next Step	
STEP 2 Coolant level is above specification	Check the coolant level. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 External coolant leak	Inspect the engine for coolant leaking from hoses, draincocks, water manifold, expansion and pipe plugs, fittings, radiator core, exhaust heat shield, heat exchanger and cylinder head gaskets, lubricating oil cooler, water pump seal, and OEM-mounted components that have coolant flow. If necessary, pressure-test the cooling system, exhaust heat shield, or heat exchanger. Refer to Procedure 008-018 in Section 8.
OK Go To Next Step	
STEP 4 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047 in Section 8.
OK Go To Next Step	
STEP 5 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 restrictions. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-045 in Section 8. Inspect all other cooling system hoses and connections.
OK Go To Next Step	
STEP 7 Air or combustion gases are entering the cooling system	Check for air or combustion gases in the cooling system. Refer to Procedure 008-019 in Section 8.
OK Go To Next Step	

Coolant Loss - External

This is symptom tree t020

Cause	Correction
STEP 8 Engine is overheating	Refer to the Coolant Temperature Above Normal - Gradual Overheat and Coolant Temperature Above Normal - Sudden Overheat troubleshooting symptom trees in Section TS.
OK Go To Next Step	
STEP 9 Exhaust pressure regulator is leaking coolant	Inspect the exhaust pressure regulator coolant lines for leaks.
OK Go To Next Step	
STEP 10 Turbocharger is leaking (if equipped with coolant cooled turbocharger)	Inspect the turbocharger coolant lines for leaks.
OK Go To Next Step	
STEP 11 Aftertreatment diesel exhaust fluid heating system leaking coolant	Check the aftertreatment diesel exhaust fluid heating system for leaks. Refer to the OEM service manual.
OK Go To Next Step	
STEP 12 Contact a Cummins® Authorized Repair Facility	

Coolant Loss - Internal

This is symptom tree t021

Cause	Correction
STEP 1 Excessive internal or external engine coolant loss	Before troubleshooting, it is important to determine the exact complaint by interviewing the driver, looking at the service history, and looking at the engine control module (ECM) information. Refer to the Coolant Loss Pre-Troubleshooting Guide at the end of Section TS.
OK Go To Next Step	
STEP 2 Pressure test the cooling system	After verifying the above step, pressure test the cooling system. Refer to Procedure 008-018 in Section 8. If this step was completed for the same complaint within the last 30 days (as per history), skip to the next step.
OK Go To Next Step	
STEP 3 Air compressor cylinder head is cracked or porous, or has a leaking gasket	Inspect the air compressor air inlet and outlet tubes for signs of coolant. Refer to Procedure 012-007 in Section 12.
OK Go To Next Step	
STEP 4 Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks. Refer to Procedure 007-046 in Section 7.
OK Go To Next Step	
STEP 5 Fuel heater is leaking coolant	Check the fuel heater for coolant leaks. Refer to the OEM service manual.
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 OEM service manual.
OK Go To Next Step	
STEP 7 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 8 Cylinder head is cracked or porous, or an injector sleeve is leaking	Pressure test the cylinder head and inspect the injector sleeves. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	

Coolant Loss - Internal

This is symptom tree t021

Cause	Correction
STEP 9 Cylinder liner is corroded or cracked, or the cylinder block is cracked or porous	Remove the oil pan. Pressure test the cooling system to check for leaks. Refer to Procedure 001-027 in Section 1 or Procedure 008-018 in Section 8.
OK Go To Next Step	
STEP 10 Exhaust pressure regulator is cracked or porous	Inspect the exhaust pressure regulator for signs of coolant.
OK Go To Next Step	
STEP 11 Turbocharger is cracked or porous (if equipped with coolant cooled turbocharger)	Inspect the turbocharger for signs of coolant.
OK Go To Next Step	
STEP 12 Aftertreatment diesel exhaust fluid heating system leaking coolant	Check the aftertreatment diesel exhaust fluid heating system for leaks. Refer to the OEM service manual.

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Coolant level is below specification	Check the coolant level. Check for an external leak. Refer to Procedure 008-018 in Section 8. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak).
OK Go To Next Step	
STEP 3 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Refer to Procedure 101-004 in Section 1 in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 4 Fan drive belt is loose	Check the automatic belt tensioner. Refer to Procedure 008-002 in Section 8 and Procedure 008-087 in Section 8.
OK Go To Next Step	
STEP 5 Charge-air cooler fins, radiator fins, or air conditioner condenser fins are damaged or obstructed with debris	Inspect the charge-air cooler, air conditioner condenser, and radiator fins. Clean, if necessary. Refer to Procedure 010-027 in Section 10, Procedure 008-042 in Section 8, and the OEM service manual.
OK Go To Next Step	
STEP 6 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-028 in Section 8.
OK Go To Next Step	
STEP 7 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047 in Section 8.
OK Go To Next Step	
STEP 8 Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge, if necessary.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
STEP 9 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-045 in Section 8. Inspect all other cooling system hoses and connections.
OK Go To Next Step	
STEP 10 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, as necessary. Refer to Procedure 008-038 in Section 8 and the OEM service manual.
OK Go To Next Step	
STEP 11 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 Procedure 008-017 in Section 8 and the OEM service manual.
OK Go To Next Step	
STEP 12 Thermostats are not correct or are malfunctioning	Check the thermostats for the correct part number and for correct operation. Refer to Procedure 008-013 in Section 8.
OK Go To Next Step	
STEP 13 Intake manifold air temperature is above specification	Refer to the Intake Manifold Air Temperature Above Specification troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 14 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-037 in Section 7. Check the dipstick calibration. Refer to Procedure 007-009 in Section 7.
OK Go To Next Step	
STEP 15 Water pump is malfunctioning	Check the water pump for correct operation. Replace the water pump, if necessary.
OK Go To Next Step	
STEP 16 Radiator core is internally obstructed or damaged, or the check valve or J-tube is malfunctioning	Inspect the radiator and clean, if necessary. Refer to Procedure 008-042 in Section 8.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
STEP 17 Check valve is damaged (with remote-mounted engine coolant heater)	Inspect the check valve. Replace if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 18 Air or combustion gases are entering the cooling system	Check for air or combustion gases in the cooling system. Refer to Procedure 008-019 in Section 8.
OK Go To Next Step	
STEP 19 Torque converter is malfunctioning	Check the torque converter. Refer to the OEM service manual.
OK Go To Next Step	
STEP 20 Vehicle cooling system is **not** adequate	Verify that the engine and vehicle cooling systems are using the correct components. Refer to the OEM service manual.

Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

Cause	Correction
STEP 1 Coolant level is below specification	Check the coolant level. Check for an external leak. Refer to Procedure 008-018 in Section 8. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak).
OK Go To Next Step	
STEP 2 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Troubleshooting Fault Code Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 3 Fan drive belt is broken	Check the fan drive belt. Replace the belt, if necessary. Refer to Procedure 008-002 in Section 8.
OK Go To Next Step	
STEP 4 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-028 in Section 8.
OK Go To Next Step	
STEP 5 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-045 in Section 8. Inspect all other cooling system hoses and connections.
OK Go To Next Step	
STEP 6 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047 in Section 8.
OK Go To Next Step	
STEP 7 Thermostats are not correct or are malfunctioning	Check the thermostats for the correct part number and for correct operation. Refer to Procedure 008-013 in Section 8.
OK Go To Next Step	
STEP 8 Water pump is malfunctioning	Check the water pump for correct operation. Replace the water pump, if necessary.
OK Go To Next Step	

Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

Cause	Correction
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 in Section 8.
OK Go To Next Step	
STEP 10 Torque converter cooler disc is **not** installed correctly	Check the disc for correct installation. Refer to the OEM service manual.

Coolant Temperature Below Normal

This is symptom tree t024

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Coolant temperature sensor is malfunctioning	Use an electronic service tool to check the coolant temperature sensor circuit. Refer to Procedure 019-019 in Section 19.
OK Go To Next Step	
STEP 3 Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge, if necessary.
OK Go To Next Step	
STEP 4 Engine is operating at low ambient temperature	Check the winterfront, and under-the-hood air. Use under-the-hood intake air in cold weather. Refer to the Operation of Diesel Engines in Cold Climates, Bulletin 3379009 and QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 5 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-028 in Section 8.
OK Go To Next Step	
STEP 6 Coolant fill line is **not** routed correctly	Check the routing of the coolant fill line. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Thermostat seal is damaged, missing, or **not** installed correctly	Check the thermostat seal. Check the thermostat for correct seating. Refer to Procedure 008-013 in Section 8.
OK Go To Next Step	
STEP 8 Thermostats are not correct or are malfunctioning	Check the thermostats for the correct part number and for correct operation. Refer to Procedure 008-013 in Section 8.
OK Go To Next Step	
STEP 9 Coolant flow through the radiator is **not** correct	Check for correct coolant flow through the radiator. Refer to Procedure 008-042 in Section 8.

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. Refer to Procedure 007-046 in Section 7.
OK Go To Next Step	
STEP 2 Air compressor cylinder head is cracked or porous, or has a leaking gasket	Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-003 in Section 12.
OK Go To Next Step	
STEP 3 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 4 Cylinder head is cracked or porous, or an injector sleeve is leaking	Pressure test the cylinder head and inspect the injector sleeves. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 5 Cylinder liner is corroded or cracked	Check the cylinder liners for corrosion and cracks.
OK Go To Next Step	
STEP 6 Cylinder block is cracked or porous	Inspect the cylinder block. Refer to Procedure 001-027 in Section 1.

Crankcase Gases (Blowby) Excessive

This is symptom tree t027

Cause	Correction
STEP 1 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 2 Air compressor is malfunctioning	Isolate the air compressor by disconnecting the air inlet and outlet lines. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 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 4 Piston, cylinder liner, or piston rings are worn or damaged	Check for air intake system leaks. Refer to Procedure 010-024 in Section 10. Check the pistons, piston rings, and liners for wear or damage. Refer to Procedure 001-043, Procedure 001-047, or Procedure 001-028 in Section 1.

Engine Decelerates Slowly

This is symptom tree t041

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Accelerator pedal or lever is restricted or malfunctioning	Check the percent accelerator pedal or lever reading with an electronic service tool. Verify that it reads 100 percent with the accelerator pedal depressed and 0 percent when released. Calibrate the accelerator, if possible. Replace the accelerator pedal, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	
STEP 4 Injector o-rings are damaged or missing	Remove and check the injectors. Replace the injector o-rings. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 5 Injector is malfunctioning	Perform the cylinder cutout test. Replace injectors as necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 6 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10.

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

This is symptom tree t044

Cause	Correction
STEP 1 Low fuel level in the fuel tank	Check the fuel level in the fuel tanks. Verify the fuel gauge is working properly.
OK Go To Next Step	
STEP 2 Low fuel rail pressure	Attempt to start the engine by engaging the engine starting motor for at least 30 continuous seconds. Use INSITE™ electronic service tool to monitor Fuel Rail Pressure (Measured) and Fuel Rail Pressure (Commanded). Use INSITE™ electronic service tool to read the fault codes. Attempting to start the engine for 30 continuous seconds allows the fault code logic time to run. If Fault Code 559 becomes active, fuel rail pressure is **not** being developed.
OK Go To Next Step	
STEP 3 Malfunctioning engine control module (ECM) power or ground circuit	Check the battery voltage of the ECM power supply and ground circuit. Refer to the corresponding wiring diagram for the engine being serviced for connector pin identification.
OK Go To Next Step	
STEP 4 Malfunctioning keyswitch circuit	Check the vehicle keyswitch circuit for intermittent connections. Refer to Procedure 019-064 in Section 19.
OK Go To Next Step	
STEP 5 Low battery voltage	Check the battery voltage. Measure the voltage from the positive (+) terminal to the negative (−) battery terminal while trying to start the engine.
OK Go To Next Step	
STEP 6 Slow cranking speed	The minimum cranking speed **must** be greater than 150 rpm.
OK Go To Next Step	
STEP 7 ROM-booted ECM	Connect INSITE™ electronic service tool. If the ECM is ROM-booted, either the ECM will **not** communicate or INSITE™ electronic service tool will indicate the ECM is ROM-booted and **must** be calibrated.
OK Go To Next Step	

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

This is symptom tree t044

Cause	Correction
STEP 8 Fuel drain-back to the fuel tanks	Verify all suction side fuel line connections are tight and air is **not** allowed to enter the fuel system. Verify the suction side fuel filter is tight. Refer to Procedure 006-024 and Procedure 006-066 in Section 6.
OK Go To Next Step	
STEP 9 Air in the fuel	Check for air in the fuel system. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	
STEP 10 Original equipment manufacturer (OEM) fuel drain line not routed to the bottom of the fuel supply tank	Verify the OEM fuel drain line is routed correctly to the bottom of the fuel tank. If the drain line is **not** routed to the bottom of the tank, air is allowed to enter the fuel system and the fuel will drain back to the tank on the suction side of the pump. This will cause a hard start condition after the engine is turned OFF for an extended period of time.
OK Go To Next Step	
STEP 11 Malfunctioning intake air heater	Connect INSITE™ electronic service tool. From the list of "ECM Diagnostic Tests", select "Grid Heater Override". Follow the instructions on the screen to determine if the cold starting aid is working properly. If the intake air heater is **not** functioning properly, troubleshoot the intake air heater wiring and relay circuits. Refer to Procedure 010-029 in Section 10.
OK Go To Next Step	
STEP 12 High exhaust restriction	Measure the exhaust restriction. Refer to Procedure 011-009 in Section 11.
OK Go To Next Step	
STEP 13 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 14 Stuck in-range or drifting fuel rail pressure sensor	Relieve the fuel pressure from the high-pressure fuel rail by loosening the pump-to-rail line at the rail. Use INSITE™ electronic service tool to measure fuel rail pressure. The fuel rail pressure should read 0 ± 43 bar [0 ± 624 psi]. Refer to Procedure 006-061 in Section 6.
OK Go To Next Step	

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

This is symptom tree t044

Cause	Correction
STEP 15 Plugged OEM fuel tank vent	Remove the fuel tank cap. If the engine starts properly with the fuel cap removed, inspect the fuel tank vent for plugging or restriction.

OK
Go To Next Step

Cause	Correction
STEP 16 Poor fuel quality or fuel additives	Operate the engine with a known high quality fuel supply and determine if the performance symptoms are eliminated. Verify if the customer is using any fuel additives that could cause white smoke complaints.

Engine Fan Does Not Operate, Operates Erratically, or Operates Continuously

This is symptom tree t046

Cause	Correction
STEP 1 Programmable parameters or selected features are **not** correct	Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again, if necessary. Refer to Procedure 019-078 in Section 19.
OK — Go To Next Step	
STEP 2 Manual fan ON/OFF switch and circuit is malfunctioning	Check the manual fan ON/OFF switch and circuit. Refer to Procedure 019-045 in Section 19.
OK — Go To Next Step	
STEP 3 Air conditioner sensor or circuit is malfunctioning	Check the air conditioner sensor and circuit. Refer to Procedure 019-262 in Section 19.
OK — Go To Next Step	
STEP 4 Fan clutch actuator or circuit is malfunctioning	Check the fan clutch actuator circuit. Refer to Procedure 019-045 in Section 19.
OK — Go To Next Step	
STEP 5 Engine electrical ground is malfunctioning	Check engine ground to chassis and chassis ground to battery negative (-) post. Refer to the OEM service manual and Procedure 013-009 in Section 13.

Engine Noise Excessive

This is symptom tree t047

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

Cause	Correction
STEP 1 Interview the operator to verify the complaint	Refer to Driveability-General Information, the Driveability/Low-Power Customer Complaint Form, and the Driveability Checklist at the end of Section TS. Follow the instructions on the forms before continuing with this tree.
OK Go To Next Step	
STEP 2 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 3 Lubricating oil level is below specification	Check the oil level. Refer to Procedure 007-037 in Section 7.
OK Go To Next Step	
STEP 4 Fan clutch, hydraulic pump, or refrigerant compressor noise is excessive	Isolate each component and check for noise. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Fan is loose, damaged, or **not** balanced	Check the fan. Refer to Procedure 008-040 in Section 8.
OK Go To Next Step	
STEP 6 Air intake or exhaust piping is contacting the chassis or cab	Inspect the air piping, chassis, and cab for contact points. Refer to Procedure 010-031 and Procedure 010-080 in Section 10.
OK Go To Next Step	
STEP 7 Engine mounts are worn, damaged, loose, or **not** correct	Verify the condition of the mounts. Refer to Procedure 016-010 in Section 16 and the OEM service manual.
OK Go To Next Step	
STEP 8 Air intake or exhaust leaks	Check for loose or damaged piping connections and missing pipe plugs. Check the turbocharger and exhaust manifold mounting. Refer to Procedure 010-024 in Section 10.
OK Go To Next Step	

Engine Noise Excessive

This is symptom tree t047

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

Cause	Correction
STEP 9 Turbocharger noise	Refer to the Engine Noise Excessive - Turbocharger troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 10 Vibration damper has failed	Remove the vibration damper and operate the engine at the rpm where the noise normally occurs. If the noise is still present, proceed to the next step. If the noise is eliminated, replace the vibration damper. Refer to Procedure 001-052 in Section 1.
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 Air compressor noise is excessive	Refer to the Air Compressor Noise Is Excessive troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 13 Valve lash adjustments are **not** correct	Measure and adjust the valve lash setting. Refer to Procedure 003-004 in Section 3.
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 003-009 in Section 3.
OK Go To Next Step	
STEP 15 Injector(s) are malfunctioning	Perform diagnostics to find the damaged injector(s). Replace the injector(s) as necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 16 Flywheel is loose or damaged	Check the flywheel. Refer to Procedure 016-005 in Section 16.
OK Go To Next Step	

Engine Noise Excessive

This is symptom tree t047

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

Cause		Correction
STEP 17 Friction shim damage	....	Check the friction shim. Refer to Procedure 016-005 in Section 16.
OK Go To Next Step		
STEP 18 Gear train backlash is excessive or the gear teeth are damaged	....	Check the gear backlash and the gear teeth for excessive wear. Refer to Procedure 001-118 and Procedure 001-119 in Section 1.
OK Go To Next Step		
STEP 19 Main bearing or connecting rod bearing noise	....	Refer to the Engine Noise Excessive - Main Bearing or Engine Noise Excessive - Connecting Rod troubleshooting symptom trees in Section TS.
OK Go To Next Step		
STEP 20 Piston, piston rings, or cylinder liner is worn or damaged	....	Refer to the Engine Noise Excessive - Piston troubleshooting symptom tree in Section TS.
OK Go To Next Step		
STEP 21 Rear engine power take-off (REPTO) noise is excessive	....	Disassemble and repair the REPTO as necessary. Refer to Procedure 009-022 in Section 9.
OK Go To Next Step		
STEP 22 Combustion knocks	....	Refer to the Engine Noise Excessive - Combustion Knocks troubleshooting symptom tree in Section TS.
OK Go To Next Step		
STEP 23 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 Noise Excessive - Combustion Knocks

This is symptom tree t048

Cause	Correction
STEP 1 Engine is operating at low ambient temperature	Check the winterfront, and under-the-hood air. Use under-the-hood intake air in cold weather. Refer to the Operation of Diesel Engines in Cold Climates, Bulletin 3379009.
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 known high quality fuel. Refer to Procedure 018-002 in Section V in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 3 Air in the fuel system	Check for air in the fuel system. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	
STEP 4 Vibration damper has failed	Remove the vibration damper and operate the engine at the rpm where the noise normally occurs. If the noise is still present, proceed to the next step. If the noise is eliminated, replace the vibration damper. Refer to Procedure 001-052 in Section 1.
OK Go To Next Step	
STEP 5 Coolant temperature is below specification	Refer to the Coolant Temperature Below Normal troubleshooting symptom tree.
OK Go To Next Step	
STEP 6 Injector(s) are malfunctioning	Perform diagnostics to find the damaged injector(s). Replace the injector(s) as necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 7 Valve lash adjustments are **not** correct	Measure and adjust the valve lash setting. Refer to Procedure 003-004 in Section 3.

Engine Noise Excessive - Connecting Rod

This is symptom tree t049

Cause	Correction
STEP 1 Interview the operator to verify the complaint	Refer to Driveability-General Information, the Driveability/Low-Power Customer Complaint Form, and the Driveability Checklist at the end of Section TS. Follow the instructions on the forms before continuing with this tree.
OK Go To Next Step	
STEP 2 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 3 Lubricating oil level is below specification	Check the oil level. Refer to Procedure 007-009 and Procedure 007-037 in Section 7.
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 019-066 in Section 19. If the readings from the engine sensors are suspect, use a master mechanical gauge of know accuracy to verify. Connect the line from the master gauge to the main oil rifle and compare the reading from the master gauge to the reading from INSITE™ electronic service tool.
OK Go To Next Step	
STEP 5 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.
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 in Section 1. If the capscrews are loose, check the connecting rod and cap for fretting. Replace the connecting rod bearings. Refer to Procedure 001-005 in Section 1.
OK Go To Next Step	
STEP 7 Connecting rod bearings are damaged or worn, are **not** assembled correctly, or are the wrong bearings	Inspect the connecting rod bearings. Refer to Procedure 001-005 in Section 1.

Engine Noise Excessive - Main Bearing

This is symptom tree t050

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

Cause	Correction
STEP 1 Interview the operator to verify the complaint	Refer to Driveability-General Information, the Driveability/Low-Power Customer Complaint Form, and the Driveability Checklist at the end of Section TS. Follow the instructions on the forms before continuing with this tree.
OK Go To Next Step	
STEP 2 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 3 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 007-009 and Procedure 007-037 in Section 7.
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 019-066 in Section 19. If the readings from the engine sensors are suspect, use a master mechanical gauge of know accuracy to verify. Connect the line from the master gauge to the main oil rifle and compare the reading from the master gauge to the reading from INSITE™ electronic service tool.
OK Go To Next Step	
STEP 5 Flywheel is loose or damaged	Check the flywheel. Refer to Procedure 016-005 in Section 16.
OK Go To Next Step	
STEP 6 Torque converter is loose	Check the torque converter. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 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 in Section 1. If the capscrews are loose, check the cylinder block and main bearing caps for fretting. Replace the main bearings and capscrews.
OK Go To Next Step	

Engine Noise Excessive - Main Bearing

This is symptom tree t050

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

Cause	Correction
STEP 8 Main bearings are damaged or worn, or the incorrect bearings are installed	Inspect the main bearings for damage, excessive wear, and the correct part number. Refer to Procedure 001-006 in Section 1.
OK Go To Next Step	
STEP 9 Thrust bearings are damaged	Inspect the thrust bearings for damage. Refer to Procedure 001-007 in Section 1.
OK Go To Next Step	
STEP 10 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083 and Procedure 007-013 in Section 7.

Engine Noise Excessive - Piston

This is symptom tree t051

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

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 known high quality fuel. Refer to Procedure 018-002 in Section V in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 2 Injector(s) are malfunctioning	Perform diagnostics to find the damaged injector(s). Replace the injector(s) as necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 3 Foreign object or debris inside the power cylinder	Inspect the turbocharger compressor blades for damage. Check the intake and exhaust valve lash for an open valve or valve beat-in that would indicate valve failure or damage. Refer to Procedure 010-033 in Section 10 and Procedure 003-004 in Section 3.
OK Go To Next Step	
STEP 4 Piston pin or bushing is loose, worn, or **not** installed correctly	Remove the pistons and inspect the piston pins and bushings for damage, wear, and correct installation. Refer to Procedure 001-043 in Section 1.
OK Go To Next Step	
STEP 5 Cylinder liner, pistons, or piston rings are worn or damaged	Check the pistons, piston rings, and cylinder liners. Refer to Procedure 001-043, Procedure 001-047, and Procedure 001-028 in Section 1.

Engine Noise Excessive - Turbocharger

This is symptom tree t052

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

Cause	Correction
STEP 1 Air intake or exhaust piping is contacting the chassis or cab	Inspect the air piping, chassis, and cab for contact points. Refer to Procedure 010-028 in Section 10 in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 2 Air intake or exhaust leaks	Check for loose or damaged piping connections and missing pipe plugs. Check the turbocharger and exhaust manifold mounting. Refer to Procedure 010-024 in Section 10.
OK Go To Next Step	
STEP 3 Air intake system restriction is above specification	Inspect the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 4 Exhaust system restriction	Check the exhaust system for restrictions. Refer to Procedure 011-009 in Section 11.
OK Go To Next Step	
STEP 5 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 6 Turbocharger is worn or damaged	Check the turbocharger for damage. Measure the turbine and compressor wheel clearances. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 7 Turbocharger is not correct	Check the turbocharger part number and compare it to the Control Parts List (CPL). Replace the turbocharger if necessary. Refer to Procedure 010-033 in Section 10.

Engine Power Output Low

This is symptom tree t057

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 known high quality fuel. Refer to the Fuels for Cummins® Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 2 Plugged air filter	Inspect the air cleaner element. Replace as needed. Refer to Procedure 010-031 in Section 10 .
OK Go To Next Step	
STEP 3 Fuel tank vents are plugged or damaged	Remove and clean the tank vents. Replace the vents, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020 in Section 6 .
OK Go To Next Step	
STEP 5 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Refer to Procedure 006-066 in Section 6. For engines with rotary mechanical fuel pumps, inspect and clean the fuel pump supply line banjo fitting. Refer to Procedure 006-024 in Section 6.
OK Go To Next Step	
STEP 6 Fuel leak	Inspect the fuel lines, fuel connections, and fuel filters for leaks. Inspect the fuel lines to and from the supply tanks for leaks. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Valve lash adjustments are **not** correct	Measure and adjust the valve lash setting. Refer to Procedure 003-004 in Section 3.
OK Go To Next Step	
STEP 8 Valves are **not** sealing correctly	Check and adjust the valves. Refer to Procedure 003-004 in Section 3.
OK Go To Next Step	
STEP 9 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	

Engine Power Output Low

This is symptom tree t057

Cause		Correction
STEP 10 Turbocharger is malfunctioning	....	Refer to Procedure 010-033 in Section 10.
OK Go To Next Step		
STEP 11 Clogged fuel injector nozzles	....	Clean the nozzles. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step		
STEP 12 Fuel injection pump is malfunctioning	....	Replace the fuel injection pump. Refer to Procedure 005-016 in Section 5.
OK Go To Next Step		
STEP 13 Worn piston rings	....	Check for excessive blowby. Refer to Procedure 014-010 in Section 14 to check for excessive crankcase blowby for turbocharged engines.

Engine Runs Rough or Misfires

This is symptom tree t062

Cause	Correction
STEP 1 Poor fuel quality or fuel additives	Operate the engine with a known high quality fuel supply and determine if the performance symptoms are eliminated. Verify if the customer is using any fuel additives that could cause white smoke complaints.
OK Go To Next Step	
STEP 2 Engine control module (ECM) calibration is malfunctioning	Verify the ECM calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. Refer to the calibration history spreadsheet on QuickServe™ Online internet website or the INCAL™ calibration CD-ROM. Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL) using the INCAL™ CD-ROM or QuickServe™ Online. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.
OK Go To Next Step	
STEP 3 Malfunctioning fuel injector	Perform INSITE™ electronic service tool Cylinder Cutout Test to determine if the misfire can be isolated to a single injector. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 4 Malfunctioning fuel pump actuator	Unplug the fuel pump actuator from the engine wiring harness while the engine is idling. Refer to Procedure 006-026 in Section 6. If the engine speed surge or rough idle stops, replace the fuel pump actuator.
OK Go To Next Step	
STEP 5 Belt driven accessories	Remove the drive belts and operate the engine under the conditions where the vibration occurs. Verify the vibration goes away with the drive belts removed.
OK Go To Next Step	
STEP 6 Plugged pressure-side fuel filter	Check for a plugged or restricted pressure-side fuel filter. Refer to Procedure 006-066 in Section 6.
OK Go To Next Step	
STEP 7 High fuel inlet restriction	Perform the Fuel Inlet Restriction Test. Refer to Procedure 006-020 in Section 6.
OK Go To Next Step	

Engine Runs Rough or Misfires

This is symptom tree t062

Cause	Correction
STEP 8 Air in the fuel	Check for air in the fuel system. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	
STEP 9 Incorrect overhead adjustments	Check the valve lash adjustment. If the valve seat insert is missing on a specific cylinder, the adjusting screw will be much higher than all other cylinders. Refer to Procedure 003-004 in Section 3.
OK Go To Next Step	
STEP 10 High fuel drain line restriction	Check for a blocked or restricted fuel drain line. Refer to Procedure 006-012 in Section 6.
OK Go To Next Step	
STEP 11 Damaged camshaft and/or tappets	Inspect the valve lobes and bearing journals for cracking, pitting, and scoring. Refer to Procedure 002-024 in Section 2.

Engine Shuts Off Unexpectedly or Dies During Deceleration

This is symptom tree t064

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Idle Shutdown or Power Take-Off (PTO) Shutdown features are activated	Check the time limit on Idle Shutdown and PTO Shutdown features with an electronic service tool. Refer to the electronic service tool manual.
OK Go To Next Step	
STEP 3 Engine will **not** restart	Refer to the Engine Starts But Will Not Keep Running troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 4 Keyswitch circuit is malfunctioning	Check the vehicle keyswitch circuit. Refer to Procedure 019-064 in Section 19.
OK Go To Next Step	
STEP 5 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 6 Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020 in Section 6.
OK Go To Next Step	
STEP 7 Fuel level is low in the tank or debris in the tank is blocking the fuel pickup tube screen	Inspect the fuel tank for debris. Fill the supply tank. Refer to the OEM service manual.
OK Go To Next Step	
STEP 8 Air in fuel system	Bleed the fuel system and correct the source of the leak. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	
STEP 9 Injector o-rings are damaged or missing	Remove and check the injectors. Replace the injector o-rings. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	

Engine Shuts Off Unexpectedly or Dies During Deceleration

This is symptom tree t064

Cause	Correction
STEP 10 Injector sealing washer is not sealing properly and allowing combustion gases to blow into the fuel drain	Remove and check the injector sealing washer (nozzle shield) for carbon buildup or damage. Replace the injector nozzle shield. Refer to Procedure 006-026 in Section 6.

Engine Speed Surges Under Load or in Operating Range

This is symptom tree t067

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 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-002 in Section V in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 3 Fuel tank vents are plugged or damaged	Remove and clean the tank vents. Replace the vents, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 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 5 Clutch is malfunctioning or is **not** correct	Compare the drivetrain specifications to Cummins Inc. recommendations. Check the clutch for correct operation. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 7 Engine control module (ECM) calibration is malfunctioning	Verify that the ECM calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.
OK Go To Next Step	
STEP 8 J1939 control devices are interfering with the engine controls	Alternately disconnect all other J1939 control devices from the data link circuit until communication or functionality is restored. Refer to the OEM service manual.
OK Go To Next Step	

Engine Speed Surges Under Load or in Operating Range

This is symptom tree t067

Cause	Correction
STEP 9 Accelerator pedal or lever is restricted or malfunctioning	Check the percent accelerator pedal or lever reading with an electronic service tool. Verify that it reads 100 percent with the accelerator pedal depressed and 0 percent when released. Calibrate the accelerator, if possible. Replace the accelerator pedal, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 10 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 the OEM service manual.
OK Go To Next Step	
STEP 11 Vehicle speed sensor (VSS) or circuit is malfunctioning	Use an electronic service tool to monitor the vehicle speed while the vehicle is **not** moving. Refer to the appropriate electronic service tool manual. If the monitor shows speed, check the sensor and the circuit. Refer to the OEM service manual.
OK Go To Next Step	
STEP 12 Moisture in the wiring harness connectors	Dry the connectors with Cummins electronic cleaner, Part Number 3824510.
OK Go To Next Step	
STEP 13 Fuel filter is plugged	Measure the fuel pressure before and after the fuel filter. Refer to Procedure 006-065 in Section 6.
OK Go To Next Step	
STEP 14 Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020 in Section 6.
OK Go To Next Step	
STEP 15 Air in the fuel system	Check for air in the fuel system. Vent air from the system. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	
STEP 16 Fuel drain line restriction	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	

Engine Speed Surges Under Load or in Operating Range

This is symptom tree t067

Cause	Correction
STEP 17 Fuel line is leaking fuel	Check for external fuel leak from the fuel lines. Check for fuel in the lubricating oil. Refer to Fuel in the Lubricating Oil troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 18 Injector sealing washer is **not** correct	Remove the injectors and verify the injector sealing washer thickness. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 19 Injector is malfunctioning	Perform the cylinder cutout test. Replace injectors as necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 20 Injectors are not correct	Replace the injectors if necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 21 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 22 Turbocharger is not correct	Replace the turbocharger if necessary. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 23 Fuel injection pump is malfunctioning	Replace the fuel injection pump. Refer to Procedure 005-016 in Section 5.
OK Go To Next Step	
STEP 24 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 Speed Surges in PTO or Cruise Control

This is symptom tree t068

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Cruise Control/power takeoff (PTO) ON/OFF switch or circuit is malfunctioning	Check the Cruise Control/PTO ON/OFF switch and circuit. Refer to Procedure 019-021 and Procedure 019-022 in Section 19.
OK Go To Next Step	
STEP 3 Engine control module (ECM) calibration is malfunctioning	Verify that the engine control module (ECM) calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.
OK Go To Next Step	
STEP 4 Crankshaft or Camshaft position sensors or circuits are malfunctioning	Check the Crankshaft or Camshaft position sensor and circuit. Refer to Procedure 019-363 and Procedure 019-365 in Section 19.
OK Go To Next Step	
STEP 5 Moisture in the wiring harness connectors	Dry the connectors with Cummins electronic cleaner, Part Number 3824510.
OK Go To Next Step	
STEP 6 Clutch is malfunctioning or is **not** correct	Compare the drivetrain specifications to Cummins Inc. recommendations. Check the clutch for correct operation. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 J1939 control devices are interfering with the engine controls	Alternately disconnect all other J1939 control devices from the data link circuit until communication or functionality is restored. Refer to the OEM service manual.
OK Go To Next Step	

Engine Speed Surges in PTO or Cruise Control

This is symptom tree t068

Cause	Correction
STEP 8 Accelerator pedal or lever is restricted or malfunctioning	Check the percent accelerator pedal or lever reading with an electronic service tool. Verify that it reads 100 percent with the accelerator pedal depressed and 0 percent when released. Calibrate the accelerator, if possible. Replace the accelerator pedal, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 9 Vehicle speed sensor (VSS) or circuit is malfunctioning	Use an electronic service tool to monitor the vehicle speed while the vehicle is **not** moving. Refer to the appropriate electronic service tool manual. If the monitor shows speed, check the sensor and the circuit. Refer to the OEM service manual.
OK Go To Next Step	
STEP 10 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 11 Turbocharger is not correct	Replace the turbocharger if necessary. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 12 Fuel filter is plugged	Measure the fuel pressure before and after the fuel filter. Refer to Procedure 006-065 in Section 6.
OK Go To Next Step	
STEP 13 Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020 in Section 6.
OK Go To Next Step	
STEP 14 Air in the fuel system	Check for air in the fuel system. Vent air from the system. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	
STEP 15 Fuel drain line restriction	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	

Engine Speed Surges in PTO or Cruise Control

This is symptom tree t068

Cause	Correction
STEP 16 Fuel line is leaking fuel	Check for external fuel leak from the fuel lines. Check for fuel in the lubricating oil. Refer to Fuel in the Lubricating Oil troubleshooting symptom tree.
OK Go To Next Step	
STEP 17 Injector sealing washer is **not** correct	Remove the injectors and verify the injector sealing washer thickness. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 18 Injector is malfunctioning	Perform the cylinder cutout test. Replace injectors as necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 19 Injectors are not correct	Replace the injectors if necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 20 Fuel injection pump is malfunctioning	Replace the fuel injection pump. Refer to Procedure 005-016 in Section 5.
OK Go To Next Step	
STEP 21 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 Starts But Will Not Keep Running

This is symptom tree t072

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Vehicle parasitics are excessive or starting off in wrong gear	Check for transmission malfunctioning, cooling fan operation cycle time, and engine-driven units. Check driving habits. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Keyswitch circuit is malfunctioning	Check the vehicle keyswitch circuit. Refer to Procedure 019-064 in Section 19.
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 known high quality fuel. Refer to Procedure 018-002 in Section V in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 5 Fuel level is low in the tank or debris in the tank is blocking the fuel pickup tube screen	Inspect the fuel tank for debris. Fill the supply tank. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to Procedure 019-087 in Section 19.
OK Go To Next Step	
STEP 7 Idle Shutdown or PTO Shutdown features are activated	Turn the keyswitch OFF for 5 seconds. Turn the keyswitch ON and check fault lamp operation. Use INSITE™ electronic service tool to check the Idle Shutdown and PTO Shutdown parameters.
OK Go To Next Step	
STEP 8 Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020 in Section 6. Check that the fuel inlet tubes are **not** collapsing inward when the engine is running.
OK Go To Next Step	

Engine Starts But Will Not Keep Running

This is symptom tree t072

Cause	Correction
STEP 9 Air in fuel system	Bleed the fuel system and correct the source of the leak. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	
STEP 10 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.

Engine Will Not Crank - (Electric Starter)

This is symptom tree t074-005

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF in the QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Battery voltage is low	Check the battery connections. 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	Replace the batteries, if necessary. Refer to Procedure 013-007 in Section 13.
OK Go To Next Step	
STEP 5 Original equipment manufacturer (OEM) starter interlock devices engaged	Check the starter interlock devices. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Starting circuit component is malfunctioning	Check the starting circuit components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Starter solenoid does **not** make an audible sound	Check the magnetic switch and starter solenoid. Refer to Procedure 013-017 and Procedure 013-019 in Section 13.
OK Go To Next Step	
STEP 8 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 9 Engine-driven units are engaged	Disengage any engine-driven units.
OK Go To Next Step	

Engine Will Not Crank - (Electric Starter)

This is symptom tree t074-005

Cause	Correction
STEP 10 Starter motor malfunction	Check the voltage drop at the starting motor. Refer to Procedure 013-020 in Section 13. Inspect the magnetic switch for proper installation. Refer to Procedure 013-017 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. Inspect the magnetic switch for proper installation. Refer to Procedure 013-017 in Section 13.
OK Go To Next Step	
STEP 12 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 13 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 14 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 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 3 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 4 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 5 Battery capacity is below specification	Replace the batteries, if necessary. Refer to Procedure 013-007 in Section 13.
OK Go To Next Step	
STEP 6 Original equipment manufacturer (OEM) starter interlock devices engaged	Check the starter interlock devices. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 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 8 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 9 Engine-driven units are engaged	Disengage any engine-driven units.
OK Go To Next Step	

Engine Cranks Slowly - (Electric Starter)

This is symptom tree t074-010

Cause	Correction
STEP 10 Starting circuit component is malfunctioning	Check the starting circuit components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 11 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 12 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 13 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 14 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filter(s). Refer to Procedure 018-003 in Section V. This procedure can be found in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322, to verify the correct lubricating oil is being used.
OK Go To Next Step	
STEP 15 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 16 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 Will Not Shut Off

This is symptom tree t081

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Keyswitch circuit is malfunctioning	Check the vehicle, equipment, or vessel keyswitch circuit. Refer to Procedure 019-064 in Section 19.
OK Go To Next Step	
STEP 3 Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 4 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 5 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10.

Fault Code Warning Lamps Stay On (No Apparent Reason)

This is symptom tree t083

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Diagnostic switch is in the ON position	Turn the diagnostic switch OFF.
OK Go To Next Step	
STEP 3 Diagnostic shorting plug is installed	Remove the diagnostic shorting plug.
OK Go To Next Step	
STEP 4 Diagnostic switch or circuit is malfunctioning	Check the diagnostic switch and circuit. Refer to Procedure 019-027 and Procedure 019-028 in Section 19.
OK Go To Next Step	
STEP 5 Fault code warning lamp circuit is malfunctioning	Check the fault code warning lamp circuit. Refer to Procedure 019-047 in Section 19.

Fault Code Warning Lamps Do Not Illuminate

This is symptom tree t084

Cause	Correction
STEP 1 Keyswitch is in the OFF position	Turn the keyswitch to the ON position.
OK Go To Next Step	
STEP 2 Fault code warning lamps are burned out	Check the warning lamps for voltage. Replace the bulbs, if necessary. Refer to Procedure 019-046 in Section 19.
OK Go To Next Step	
STEP 3 Fault code warning lamp circuit is malfunctioning	Check the fault code warning lamp circuit. Refer to Procedure 019-047 in Section 19.
OK Go To Next Step	
STEP 4 Keyswitch circuit is malfunctioning	Check the vehicle, equipment, or vessel keyswitch circuit. Refer to Procedure 019-064 in Section 19.

Fuel Consumption Excessive

This is symptom tree t087

Cause	Correction
STEP 1 Interview the operator to verify the complaint	Refer to Procedure t00-004 in Section TS. Follow the instructions on the form before continuing with this troubleshooting symptom tree.
OK Go To Next Step	
STEP 2 Operator technique is **not** correct	Explain correct engine operation to the operator. Refer to Procedure 101-015 in Section 1 in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 3 Equipment and environmental factors are affecting fuel consumption	Consider ambient temperatures, wind, tire size, axle alignment, routes, and use of aerodynamic aids when evaluating fuel consumption.
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 Vehicle parasitics are excessive	Check the vehicle for brakes dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Charge-air cooler is restricted or leaking	Inspect the charge-air cooler for air restrictions or leaks. Refer to Procedure 010-027 in Section 10.
OK Go To Next Step	
STEP 7 Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 8 Programmable parameters or selected features are **not** correct	Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again, if necessary. Refer to Procedure 019-078 in Section 19.
OK Go To Next Step	

Fuel Consumption Excessive

This is symptom tree t087

Cause	Correction
STEP 9 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.
OK — Go To Next Step	
STEP 10 Turbocharger is not correct	Check the turbocharger part number and compare it to the Control Parts List (CPL). Replace the turbocharger if necessary. Refer to Procedure 010-033 in Section 10.
OK — Go To Next Step	
STEP 11 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	
STEP 12 Hubometer or odometer is miscalibrated	Check the hubometer and odometer calibrations. Calibrate or replace the hubometer or odometer, if necessary. Calculate fuel consumption with new mileage figures.
OK — Go To Next Step	
STEP 13 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-002 in Section V in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK — Go To Next Step	
STEP 14 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 and Procedure 007-037 in Section 7.
OK — Go To Next Step	
STEP 15 Engine control module (ECM) calibration is malfunctioning	Verify that the ECM calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.
OK — Go To Next Step	

Fuel Consumption Excessive

This is symptom tree t087

Cause	Correction
STEP 16 Vehicle speed sensor (VSS) is **not** correct	Use an electronic service tool to monitor the vehicle speed while the vehicle is **not** moving. Refer to the appropriate electronic service tool manual. If necessary, install the correct VSS. Refer to Procedure 019-090 in Section 19.
OK Go To Next Step	
STEP 17 Vehicle speed sensor (VSS) or circuit is malfunctioning	Check the vehicle speed sensor and circuit. Refer to Procedure 019-090 in Section 19.
OK Go To Next Step	
STEP 18 Vehicle speed sensor (VSS) tampering has occurred	Check the vehicle speed sensor and circuit for tampering. Check for Fault Code 242. Repair the circuit as necessary. Refer to Procedure 019-093 in Section 19.
OK Go To Next Step	
STEP 19 Air intake system restriction is above specification	Check the air intake system for restriction. Replace the air filter and inlet piping as necessary. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 20 Exhaust system restriction is **not** within specification	Check the exhaust system for restrictions. Refer to Procedure 011-009 in Section 11.
OK Go To Next Step	
STEP 21 Injector(s) are malfunctioning	Perform diagnostics to find the damaged injector(s). Replace the injector(s) as necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 22 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004 in Section 3.
OK Go To Next Step	
STEP 23 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.

Fuel in Coolant

This is symptom tree t091

Cause	Correction
STEP 1 Bulk coolant supply is contaminated	Check the bulk coolant supply. Drain the coolant and replace with non-contaminated coolant. Replace the coolant filters. Refer to Procedure 008-018 in Section 8.
OK Go To Next Step	
STEP 2 Fuel heater is malfunctioning, if equipped	Check the fuel heater and replace, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Injector o-rings or sleeves are damaged. Injector o-rings are missing.	Remove and check the injectors. Check the o-rings and injector sleeves. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 4 Air or combustion gases are entering the cooling system	Check for air or combustion gases in the cooling system. Refer to Procedure 008-019 in Section 8.
OK Go To Next Step	
STEP 5 Cylinder head is cracked or porous	Replace the cylinder head. Refer to Procedure 002-004 in Section 2.

Fuel in the Lubricating Oil

This is symptom tree t092

Cause	Correction
STEP 1 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with non-contaminated oil. Replace the oil filter(s). Refer to Procedure 007-037 and Procedure 007-013 in Section 7.
OK Go To Next Step	
STEP 2 Engine idle time is excessive	Low oil and coolant temperatures can be caused by long idle times (greater than 10 minutes). Shut the engine OFF rather than idle for long periods. If idle time is necessary, raise the idle speed. Refer to QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 3 Fuel pump seal is leaking	Perform the fluorescent dye tracer test to confirm the fuel leak. Replace the fuel pump, if necessary. Refer to Procedure 005-016 in Section 5.
OK Go To Next Step	
STEP 4 Injector(s) are malfunctioning	Perform diagnostics to find the damaged injector(s). Replace the injector(s) as necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 5 Fuel drain line is restricted	Inspect the fuel drain lines for restrictions. Remove any restrictions found. Refer to Procedure 006-012 in Section 6.
OK Go To Next Step	
STEP 6 Cylinder head is cracked or porous	Perform the fuel passage leak test in the cylinder head. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 7 Base engine problem	Check the engine for high crankcase pressure, low compression, damaged pistons, camshaft, and other parts. Refer to Procedure 014-010 in Section 14, Procedure 001-043 in Section 1, Procedure 002-024 in Section 2 and other appropriate procedures.

Intake Manifold Air Temperature Above Specification

This is symptom tree t096

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Intake manifold temperature sensor is malfunctioning	Check the intake manifold temperature sensor. Refer to Procedure 019-159 in Section 19.
OK Go To Next Step	
STEP 3 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Refer to Procedure 101-015 in Section 1 in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 4 Charge-air cooler fins, radiator fins, or air conditioner condenser fins are damaged or obstructed with debris	Inspect the charge-air cooler, air conditioner condenser, and radiator fins. Clean, if necessary. Refer to Procedure 010-027 in Section 10, Procedure 008-042 in Section 8, and the OEM service manual.
OK Go To Next Step	
STEP 5 Fan drive belt is loose	Check the belt tension and tighten if necessary.
OK Go To Next Step	
STEP 6 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-028 in Section 8.
OK Go To Next Step	
STEP 7 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, as necessary. Refer to Procedure 008-038 in Section 8 and the OEM service manual.
OK Go To Next Step	
STEP 8 Fan is **not** an adequate size for the application	Verify that the fan is the correct size. Refer to the OEM service manual.
OK Go To Next Step	

Intake Manifold Air Temperature Above Specification

This is symptom tree t096

Cause	Correction
STEP 9 Intake air or exhaust leaks	Refer to Procedure 010-024 in Section 10 or the Engine Performance Troubleshooting Tree in Section TT.

Intake Manifold Pressure (Boost) is Below Normal

This is symptom tree t097

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Intake manifold pressure sensor is malfunctioning	Check the intake manifold pressure sensor. Refer to Procedure 019-159 in Section 19.
OK Go To Next Step	
STEP 3 Air intake or exhaust leaks	Check for loose or damaged piping connections and missing pipe plugs. Check the turbocharger and exhaust manifold mounting. Refer to Procedure 010-024 in Section 10.
OK Go To Next Step	
STEP 4 Charge-air cooler is restricted or leaking	Inspect the charge-air cooler for air restrictions or leaks. Refer to Procedure 010-027 in Section 10.
OK Go To Next Step	
STEP 5 Air intake system restriction is above specification	Replace the air filter and inlet piping as necessary. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 6 Turbocharger is worn or damaged	Check the turbocharger for damage. Measure the turbine and compressor wheel clearances. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 7 Air compressor connection is loose or damaged	Check the connection between the manifold and the air compressor. Repair or replace, if necessary.
OK Go To Next Step	
STEP 8 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 9 Turbocharger is not correct	Check the turbocharger part number and compare it to the Control Parts List (CPL). Replace the turbocharger if necessary. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	

Intake Manifold Pressure (Boost) is Below Normal

This is symptom tree t097

Cause	Correction
STEP 10 Exhaust system restriction	Check the exhaust system for restrictions. Refer to Procedure 011-009 in Section 11.
OK Go To Next Step	
STEP 11 Injector drain flow is excessive	Check injector drain flow. Refer to Procedure 006-012 in Section 6.
OK Go To Next Step	
STEP 12 Engine power output is low	Refer to the Engine Power Output Low troubleshooting symptom tree in Section TS.

Low Idle Adjust Switch Does Not Work

This is symptom tree t099

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK — Go To Next Step	
STEP 2 Engine idle speed is set at either the minimum or the maximum allowable value	The idle adjust switch will **not** adjust the idle speed outside the allowable range. Refer to Procedure 019-052 in Section 19.
OK — Go To Next Step	
STEP 3 Low-idle adjust switch feature is **not** enabled	Check the low-idle adjust switch feature with an electronic service tool. Refer to Procedure 019-078 in Section 19.
OK — Go To Next Step	
STEP 4 Low-idle adjust switch and circuit is malfunctioning	Check the idle adjust switch and circuit. Refer to Procedure 019-052 and Procedure 019-053 in Section 19.

Lubricating Oil in the Fuel

This is symptom tree t101

Cause	Correction
STEP 1 Asphaltines present	When asphaltines are present in diesel fuel, it appears black. To verify whether or not engine oil is present, take a fuel sample and perform an analysis to check for engine oil.
OK Go To Next Step	
STEP 2 Cylinder head is cracked or porous	Remove the intake and the exhaust manifolds. Check for evidence of coolant leaks. If necessary, operate the engine at low idle. Pressure test the cylinder head. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 3 Fuel pump plungers and barrels excessively scored and worn	Replace the fuel pump. Refer to Procedure 005-016 in Section 5.

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause	Correction
STEP 1 Verify the oil consumption rate	Check the amount of oil added versus the mileage.
OK Go To Next Step	
STEP 2 Lubricating oil leak (external)	Inspect the engine for external oil leaks. Tighten the capscrews, pipe plugs, and fittings. Replace gaskets, if necessary. Refer to Procedure 007-024 in Section 7.
OK Go To Next Step	
STEP 3 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-002 in Section 3.
OK Go To Next Step	
STEP 4 Air compressor is pumping lubricating oil into the air system	Check the air lines for carbon buildup and lubricating oil. Refer to the Air Compressor Pumping Excess Lubricating Oil into the Air System troubleshooting symptom tree.
OK Go To Next Step	
STEP 5 Lubricating oil dipstick calibration is **not** correct	Check the dipstick calibration. Refer to Procedure 007-009 in Section 7.
OK Go To Next Step	
STEP 6 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to Procedure 102-002 in Section 2 in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 7 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filter(s). Refer to the Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340 for lubricating oil specifications. Also, refer to Procedure 007-037 and Procedure 007-013 in Section 7. Use the oil type recommended in Section V.
OK Go To Next Step	
STEP 8 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause	Correction
STEP 9 Lubricating oil cooler is leaking	Check for lubricating oil in the coolant. Refer to the Lubricating or Transmission Oil in the Coolant troubleshooting symptom tree.
OK Go To Next Step	
STEP 10 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated symptom tree.
OK Go To Next Step	
STEP 11 Piston rings are **not** seated correctly (after an engine rebuild or piston installation)	Check blowby. Refer to Section 14. If blowby is excessive, check the piston rings for correct seating. Refer to Procedure 001-043 and Procedure 001-047 in Section 1.
OK Go To Next Step	
STEP 12 Piston, cylinder liner, or piston rings are worn or damaged	Check for air intake system leaks. Refer to Procedure 001-043, Procedure 001-047 and Procedure 001-028 in Section 1.

Lubricating Oil Contaminated

This is symptom tree t103

Cause	Correction
STEP 1 Identify lubricating oil contamination	Perform an oil analysis to determine the contaminants.
OK Go To Next Step	
STEP 2 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with non-contaminated oil. Replace the oil filter(s). Refer to Procedure 007-083 in Section 7. Also, refer to Procedure 007-037 or Procedure 007-013 in Section 7.
OK Go To Next Step	
STEP 3 Lubricating oil analysis indicates high silicon amounts in oil	Inspect the air intake system for damage that progressed to a power cylinder. Visually inspect the air intake system for leaks. Check the blowby. Refer to Procedure 014-010 in Section 14. If the blowby is excessive, refer to Procedure 001-043 and Procedure 001-047 in Section 1.
OK Go To Next Step	
STEP 4 Internal coolant leaks	Refer to the Coolant Loss - Internal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 5 Lubricating oil sludge is excessive	Change the oil and filters. Refer to the Lubricating Oil Sludge in the Crankcase Excessive troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 6 Fuel in the lubricating oil	Refer to the Fuel in the Lubricating Oil troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 7 Transmission or hydraulic fluid is in the lubricating oil	Refer to the OEM service manual.

Lubricating Oil Filter Plugged

This is symptom tree t103-56

Cause	Correction
STEP 1 Verify the plugged lubricating oil filter complaint	Measure the differential pressure drop across the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
OK Go To Next Step	
STEP 2 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filter(s). Refer to Procedure 007-037 and Procedure 007-013 in Section 7. Refer to the Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340 and Section V in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 3 Lubricating oil drain interval missed or is exceeded based on duty cycle or oil and filter combination	Change the oil and filters. Refer to Procedure 007-037 and Procedure 007-013 in Section 7. Refer to the Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340 and Section V in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 4 Lubricating oil is contaminated with coolant or fuel	Change the oil and filters. Refer to Procedure 007-037, Procedure 007-013, and Procedure 007-083 in Section 7. Refer to the Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340 and Section V in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 5 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-002 in Section V in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322. Refer to Fuels for Cummins® Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 6 Combustion gas contamination	Check for excessive engine blowby. Refer to Procedure 018-023 in Section V. Refer to the Crankcase Gases (Blowby) Excessive troubleshooting symptom tree, if crankcase gases are excessive.
OK Go To Next Step	

Lubricating Oil Filter Plugged

This is symptom tree t103-56

Cause	Correction
STEP 7 Injector is malfunctioning	Inspect the injectors for missing or damaged o-rings. Replace the o-rings or injector(s), as necessary. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 8 Engine timing incorrect	Check the engine base timing and adjust the overhead. Refer to Procedure 001-088 in Section 1 and Procedure 003-004 in Section 3.
OK Go To Next Step	
STEP 9 Base engine problem	Check the engine for damaged pistons, rings, liners, and other parts. Refer to Procedure 001-043, Procedure 001-047, and Procedure 001-028 in Section 1. Request additional Cummins® technical assistance.

Lubricating Oil Pressure High

This is symptom tree t104

Cause		Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	....	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step		
STEP 2 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 019-066 in Section 19 or the OEM service manual.
OK Go To Next Step		
STEP 3 Coolant temperature is below specification	....	Refer to the Coolant Temperature is Below Normal troubleshooting symptom tree.
OK Go To Next Step		
STEP 4 Lubricating oil does **not** meet specifications for operating conditions	....	Change the oil and filters. Refer to the Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340. Also, refer to Procedure 007-037 and Procedure 007-013 in Section 7. Use the oil type recommended in Section V of the operation and maintenance manual.
OK Go To Next Step		
STEP 5 Lubricating oil high-pressure relief valve, oil pressure regulator, or lubricating oil pump is malfunctioning	....	Remove and inspect the high-pressure relief valve, oil pressure regulator, or lubricating oil pump. Refer to Procedure 007-021, Procedure 007-029 and Procedure 007-031 in Section 7.

Lubricating Oil Pressure Low

This is symptom tree t105

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Lubricating oil pressure sensor or circuit is malfunctioning (electronic controlled fuel system)	Check the lubricating oil pressure sensor and circuit. Refer to Procedure 019-066 in Section 19.
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 and Oil Analysis Recommendations, Bulletin 3810340. Refer to Procedure 007-037 and Procedure 007-013 in Section 7. Use the oil type recommended in Section V of the operation and maintenance manual.
OK Go To Next Step	
STEP 4 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated troubleshooting symptom tree in Section TS.
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 007-037 in Section 7.
OK Go To Next Step	
STEP 6 Engine angularity during operation exceeds specification	Refer to the Engine Specification data sheet.
OK Go To Next Step	
STEP 7 Lubricating oil filter is plugged	Change the oil and filter(s). Refer to Procedure 007-037 and Procedure 007-013 in Section 7. Verify the oil change interval is correct. Refer to the operation and maintenance manual.
OK Go To Next Step	
STEP 8 Lubricating oil drain back from the overhead is restricted, preventing oil draining back to oil pan	Check the oil level with the engine running. Install a clear tube to the oil pan drain to measure a liquid column of lubricating oil during engine operation. The top of the column of lubricating oil should **not** be below the suction tube in the sump of the oil pan.
OK Go To Next Step	

Lubricating Oil Pressure Low

This is symptom tree t105

Cause	Correction
STEP 9 Lubricating oil pump is malfunctioning	Inspect the lubricating oil pump. Refer to Procedure 007-031 in Section 7.
OK Go To Next Step	
STEP 10 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 in Section 7.
OK Go To Next Step	
STEP 11 Lubricating oil high-pressure relief valve or lubricating oil pump is malfunctioning	Remove and inspect the high-pressure relief valve or lubricating oil pump. Refer to Procedure 007-021, Procedure 007-029 and Procedure 007-031 in Section 7.
OK Go To Next Step	
STEP 12 Lubricating oil temperature is above specification	Refer to the Lubricating Oil Temperature Above Specification symptom tree.
OK Go To Next Step	
STEP 13 Piston cooling nozzles are damaged or are **not** installed correctly	Check the piston cooling nozzles for damage and correct installation. Refer to Procedure 001-046 in Section 1.
OK Go To Next Step	
STEP 14 Lubricating oil cooler is plugged	Check the oil cooler. Refer to Procedure 007-046 in Section 7.
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. Contact a Cummins® Authorized Repair Location.

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 non-contaminated oil. Replace the oil filter(s). Refer to Procedure 007-083 and Procedure 007-013 in Section 7.
OK Go To Next Step	
STEP 2 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007-037 and Procedure 007-013 in Section 7. Use the oil type recommended in Section V of the operation and maintenance manual.
OK Go To Next Step	
STEP 3 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to Procedure 102-002 in Section 2 in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
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 known high quality fuel. Refer to Procedure 018-002 in Section V in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 5 Coolant temperature is below specification	Refer to the Coolant Temperature Below Normal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 6 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 7 Crankcase pressure is excessive	Check for excessive blowby. Refer to the Crankcase Gases (Blowby) Excessive troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 8 Crankshaft or Camshaft position sensors or circuits are malfunctioning	Check the Crankshaft or Camshaft position sensor and circuit. Refer to Procedure 019-363 and Procedure 019-365 in Section 19.
OK Go To Next Step	

Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree t106

Cause	Correction
STEP 9 Engine is out of time	Check base engine timing. Refer to Procedure 001-088 in Section 1.

Lubricating Oil Temperature Above Specification

This is symptom tree t107

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Lubricating oil temperature switch, gauge, or sensor malfunctioning or not in the correct location	Check the oil temperature switch, gauge, or sensor for correct operation and location. Refer to Procedure 019-067 in Section 19.
OK Go To Next Step	
STEP 3 Lubricating oil temperature sensor or circuit is malfunctioning (electronic controlled fuel system)	Check the lubricating oil temperature sensor and circuit. Refer to Procedure 019-067 in Section 19.
OK Go To Next Step	
STEP 4 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-037 in Section 7.
OK Go To Next Step	
STEP 5 Coolant temperature is above specification	Refer to the Coolant Temperature is Above Normal - Sudden Overheat or the Coolant Temperature is Above Normal - Gradual Overheat troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 6 Lubricating oil thermostat is malfunctioning	Check the oil thermostat. Refer to Procedure 007-039 in Section 7.
OK Go To Next Step	
STEP 7 Lubricating oil cooler is malfunctioning	Check the oil cooler. Refer to Procedure 007-046 in Section 7.

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 non-contaminated coolant. Replace the coolant filters. Refer to Procedure 008-018 in Section 8.
OK Go To Next Step	
STEP 2 Lubricating oil cooler transfer housing or lubricating oil cooler support is cracked or porous	Check the oil cooler transfer housing and the support. Refer to Procedure 007-046 in Section 7.
OK Go To Next Step	
STEP 3 Lubricating oil cooler is malfunctioning	Check the oil cooler. Refer to Procedure 007-046 in Section 7.
OK Go To Next Step	
STEP 4 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 5 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-004 in Section 2.
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 leaks. If necessary, operate the engine at low idle. Pressure test the cylinder head. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 7 Cylinder liner is corroded or cracked	Check the cylinder liners for corrosion and cracks.
OK Go To Next Step	
STEP 8 Cylinder block is cracked or porous	Inspect the cylinder block. Refer to Procedure 001-026 in Section 1.

PTO or Cruise Control Does Not Operate

This is symptom tree t112

Cause		Correction
STEP 1 Programmable parameters or selected features are **not** correct	....	Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again, if necessary. Refer to Procedure 019-078 in Section 19.
OK Go To Next Step		
STEP 2 Engine control module (ECM) calibration is malfunctioning	....	Verify that the engine control module (ECM) calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. Refer to Procedure 019-032 in Section 19.
OK Go To Next Step		
STEP 3 Vehicle speed sensor (VSS) or circuit is malfunctioning	....	Check the vehicle speed sensor and circuit. Refer to Procedure 019-090 and Procedure 019-093 in Section 19.
OK Go To Next Step		
STEP 4 Clutch switch or circuit is malfunctioning	....	Check the clutch pedal position switch adjustment, switch, and circuit. Refer to Procedure 019-009 and Procedure 019-010 in Section 19.
OK Go To Next Step		
STEP 5 Vehicle brake switch or circuit is malfunctioning	....	Check the vehicle brake pedal position switch and the circuit. Refer to Procedure 019-088 and Procedure 019-089 in Section 19.
OK Go To Next Step		
STEP 6 Cruise Control/power takeoff (PTO) ON/OFF switch or circuit is malfunctioning	....	Check the Cruise Control/PTO ON/OFF switch and circuit. Refer to Procedure 019-021 and Procedure 019-022 in Section 19.
OK Go To Next Step		
STEP 7 Cruise Control/PTO selector switch or circuit is malfunctioning	....	Check the Cruise Control/PTO selector switch and circuit. Refer to Procedure 019-023 and Procedure 019-024 in Section 19.

Smoke, Black - Excessive

This is symptom tree t116

Cause	Correction
STEP 1 Engine is overloaded	Check for added loading from malfunctioning accessories or driven units, brakes dragging, and other changes in vehicle, vessel, or equipment loading. Refer tothe OEM service manual.
OK Go To Next Step	
STEP 2 Plugged air filter	Inspect the air cleaner element. Replace as needed. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 3 Exhaust system restriction	Check the exhaust system for any restrictions. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Intake air leak between turbocharger and cylinder head	Inspect for air leaks.
OK Go To Next Step	
STEP 5 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 in Section 11.
OK Go To Next Step	
STEP 6 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 7 Turbocharger is malfunctioning	Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 8 Clogged fuel injector nozzles	Clean the nozzles. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 9 Worn piston rings	Check for excessive blowby. Refer to Procedure 014-010 in Section 14 to check for excessive crankcase blowby for turbocharged engines.
OK Go To Next Step	

Smoke, Black - Excessive

This is symptom tree t116

Cause	Correction
STEP 10 Valve lash adjustments are **not** correct	Measure and adjust the valve lash setting. Refer to Procedure 003-004 in Section 3.

Smoke, White - Excessive

This is symptom tree t118

Cause	Correction
STEP 1 Starting procedure is **not** correct	Verify the correct starting procedure. Refer to Procedure 101-014 in Section 1 in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
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 troubleshooting symptom tree in Section TS.
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 Fuels for Cummins® Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 4 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 5 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 6 Coolant is leaking into the combustion chamber	Refer to the Coolant Loss - Internal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 7 Fuel injection pump is malfunctioning	Replace as necessary. Refer to Procedure 005-016 in Section 5.

Turbocharger Leaks Engine Oil or Fuel

This is symptom tree t122

Cause	Correction
STEP 1 Engine is operating for extended periods under light- or no-load conditions (slobbering)	Review the engine operating instructions. Refer to Procedure 101-015 in Section 1 in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 2 Lubricating oil or fuel is entering the turbocharger	Remove the intake and exhaust piping, and check for oil or fuel.
OK Go To Next Step	
STEP 3 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 010-033 in Section 10.
OK Go To Next Step	
STEP 4 Crankcase pressure is excessive	Check for excessive blowby. Refer to Procedure 014-010 in Section 14.
OK Go To Next Step	
STEP 5 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 6 Air intake system restriction is above specification	Check the air intake system for restrictions. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 7 Exhaust system restriction is **not** within specification	Check the exhaust system for restrictions. Refer to Procedure 011-009 in Section 11.
OK Go To Next Step	
STEP 8 Turbocharger wheel clearance is out of specification	Check the radial bearing clearance and axial clearance. Inspect the turbocharger. Repair or replace the turbocharger, if necessary.

Diesel Exhaust Fluid Usage - Abnormal

This is symptom tree t128

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Aftertreatment diesel exhaust fluid leak (external)	Inspect for external aftertreatment diesel exhaust fluid leaks or crystallization at exhaust joints, tailpipe exit, aftertreatment diesel exhaust fluid dosing valve, or associated plumbing. Repair as necessary. Refer to Procedure 011-036 and Procedure 011-059 in Section 11.
OK Go To Next Step	
STEP 3 Engine operating for extended periods in low-duty cycle, extended idling, and/or low ambient temperatures	Extended operation of the engine in low-duty cycle, extended idling, and/or low ambient temperatures can result in reduced aftertreatment diesel exhaust fluid usage. Conversely, extended operation of the engine in high —duty cycle and/or high ambient temperatures can result in increased aftertreatment diesel exhaust fluid usage. Perform the Aftertreatment Diesel Exhaust Fluid Doser Pump Override Test with INSITE™ electronic service tool. Refer to Procedure 011-058 in Section 11.
OK Go To Next Step	
STEP 4 Aftertreatment diesel exhaust fluid leak (internal)	Inspect for internal aftertreatment diesel exhaust fluid leaks or crystallization between the aftertreatment diesel exhaust fluid dosing valve and the exhaust catalyst. Repair as necessary. Refer to Procedure 011-036 and Procedure 011-059 in Section 11.
OK Go To Next Step	
STEP 5 Exhaust gas flow before or after the aftertreatment diesel exhaust fluid dosing valve is restricted, causing aftertreatment diesel exhaust fluid crystallization	Inspect the exhaust piping. The piping must be straight and unobstructed before and after the aftertreatment diesel exhaust fluid dosing valve for proper distribution of diesel exhaust fluid.

Stationary Regeneration - Will Not Activate

This is symptom tree t146

The steps in this tree are intended to cover vehicles equipped with an on-vehicle method of activating a stationary regeneration. This troubleshooting tree can also be used if INSITE™ electronic service tool Aftertreatment Diesel Particulate Filter (DPF) Regeneration Test will not operate.

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324, for fault code troubleshooting information.
OK Go To Next Step	
STEP 2 Soot load of the aftertreatment diesel particulate filter is too low	A stationary regeneration can **not** be performed while the soot load is in the normal range. Refer to Procedure 014-016 in Section 14.
OK Go To Next Step	
STEP 3 The correct stationary regeneration procedure is **not** being followed	Refer to the original equipment manufacturer (OEM) service manual for instructions on how to perform a stationary regeneration via the drive/vehicle interface. Also refer to Procedure 014-016 in Section 14 for instructions on how to use INSITE™ electronic service tool. Note that some high idle applications may require an OEM switch to be pressed in order to lower the idle speed and allow a stationary regeneration to initiate. Refer to OEM service manual.
OK Go To Next Step	
STEP 4 OEM or customer-selected inhibit feature is preventing a stationary regeneration	Refer to the OEM service manual on Regeneration Inhibit features.
OK Go To Next Step	
STEP 5 Programmable parameters or selected features are **not** correct	Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again, if necessary. Refer to Procedure 019-078 in Section 19. Also refer to the service bulletin Multiplexing Troubleshooting, Bulletin 4021378.
OK Go To Next Step	
STEP 6 Vehicle brake switch or circuit is malfunctioning	Check the vehicle brake pedal position switch and the circuit. Refer to Procedure 019-088 and Procedure 019-089 in Section 19.
OK Go To Next Step	

Stationary Regeneration - Will Not Activate

This is symptom tree t146

The steps in this tree are intended to cover vehicles equipped with an on-vehicle method of activating a stationary regeneration. This troubleshooting tree can also be used if INSITE™ electronic service tool Aftertreatment Diesel Particulate Filter (DPF) Regeneration Test will not operate.

Cause	Correction
STEP 7 Vehicle speed sensor (VSS) or circuit is malfunctioning	Refer to the appropriate electronic service tool manual. If the monitor shows speed, check the sensor and circuit. Refer to Procedure 019-090 and Procedure 019-093 in Section 19.
OK Go To Next Step	
STEP 8 Clutch switch or circuit is malfunctioning	Check the clutch pedal position switch adjustment, switch, and circuit. Refer to Procedure 019-009 or Procedure 019-010 in Section 19. If available, use an electronic service tool to monitor the clutch switch status.
OK Go To Next Step	
STEP 9 Accelerator pedal or lever position sensor or circuit is malfunctioning	Check for foot pedal restriction. Check the accelerator pedal or lever position sensor and circuit. Refer to Procedure 019-085 in Section 19.
OK Go To Next Step	
STEP 10 Cruise Control/PTO selector switch or circuit is malfunctioning	Check the Cruise Control/PTO selector switch and circuit. Refer to Procedure 019-021 and Procedure 019-022 in Section 19.
OK Go To Next Step	
STEP 11 Vehicle parking brake is **not** set	Verify that the parking brake is set. Refer to the OEM service manual.
OK Go To Next Step	
STEP 12 Transmission is **not** in Park, if provided, otherwise in Neutral	Verify that the transmission is in Park, if provided, otherwise in Neutral. Refer to the OEM service manual.
OK Go To Next Step	
STEP 13 Engine control module calibration is malfunctioning	Verify the engine control module (ECM) calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.

Aftertreatment Diesel Particulate Filter - Excessive Automatic and/or Stationary Regeneration

This is symptom tree t147

For further information on vehicles that have the diesel particulate lamp illuminating frequently, high exhaust temperature lamp (if equipped) illuminating frequently, and/or require frequent automatic/stationary regenerations, use the following troubleshooting symptom tree.

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF in QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324.
OK Go To Next Step	
STEP 2 Applicable calibration fixes available	Check the calibration revision history on QuickServe™ Online for applicable fixes to the calibration presently installed. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.
OK Go To Next Step	
STEP 3 OEM or customer selected inhibit feature is preventing active regeneration during vehicle operation	Check the aftertreatment system inhibit features with INSITE™ electronic service tool. Change either the vehicle route and/or duty cycle such that the inhibit features do **not** prevent or interrupt active regeneration. Refer to Procedure 011-999 in Section F.
OK Go To Next Step	
STEP 4 Extended operation of engine in low duty cycle, extended idling and/or low ambient temperatures	Check the aftertreatment system trip information with INSITE™ electronic service tool. Low duty cycle applications generally require more active regeneration time to keep the aftertreatment system functioning properly. Change the vehicle route and/or duty cycle to increase the load on the engine, in order to decrease the amount of active regeneration time. Refer to Procedure 011-056 in Section 11 and Procedure 011-999 in Section F.
OK Go To Next Step	
STEP 5 Aftertreatment diesel particulate filter differential pressure sensor	Use the following procedure for instructions on how to check the aftertreatment diesel particulate filter differential pressure sensor. Refer to Procedure 019-443 in Section 19.
OK Go To Next Step	

Aftertreatment Diesel Particulate Filter - Excessive Automatic and/or Stationary Regeneration

This is symptom tree t147

For further information on vehicles that have the diesel particulate lamp illuminating frequently, high exhaust temperature lamp (if equipped) illuminating frequently, and/or require frequent automatic/stationary regenerations, use the following troubleshooting symptom tree.

Cause	Correction
STEP 6 Exhaust leaks in the OEM exhaust piping leading to the aftertreatment system or leaks in the aftertreatment system	Inspect the OEM exhaust piping and the aftertreatment system for exhaust leaks. Refer to Procedure 010-024 in Section 10. If an exhaust leak is discovered on the OEM exhaust plumbing, refer to the OEM service manual. In some instances, exhaust pipe gaskets are available.
OK Go To Next Step	
STEP 7 Aftertreatment diesel particulate filter is full of soot	The maintenance interval for ash cleaning has been reached. See the corresponding Owners or Operation and Maintenance manual for the engine being serviced. Refer to Procedure 102-002 in Section 2 of the Operation and Maintenance Manual, QSG12 CM2350 G110, Bulletin 4367322. Refer to the Aftertreatment Diesel Particulate Filter - Excessive Ash Cleaning troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 8 Engine produces excessive black smoke	Refer to the Smoke, Black - Excessive troubleshooting symptom tree in Section TS.

Stationary Regeneration - Will Not Complete

This is symptom tree t149

This tree is to be used when the engine speed changes after the stationary (parked) regeneration has been started and either stops after a short period of time or continues for an excessive period of time. If the engine speed does not increase when the stationary (parked) regeneration is started, refer to the Stationary Regeneration - Will Not Activate TS tree (t146).

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF of QSG12 CM2350 G110 Fault Code Troubleshooting Manual, Bulletin 4367324, for active fault code troubleshooting.
OK Go To Next Step	
STEP 2 Engine control module (ECM) calibration is malfunctioning	Verify that the engine control module (ECM) calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. Refer to Procedure 019-032 in Section 19.
OK Go To Next Step	
STEP 3 Stationary (parked) regeneration stops after a short period of time	Verify that all of the conditions that allow a stationary (parked) regeneration to activate are still valid. Refer to the Stationary Regeneration - Will Not Activate troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 4 Stationary (parked) regeneration **not** allowed to run to completion	Allow the stationary (parked) regeneration to run until completion, which can take up to 2.5 hours. Refer to Procedure 014-016 in Section 14. NOTE: The 2.5 hours is the maximum time that a regeneration will take to complete. If the diesel oxidation catalyst temperature is **not** at or above 316°C [600°F] and the aftertreatment fuel injector has **not** turned on within 1 hour, abort the regeneration and continue through this tree.
OK Go To Next Step	
STEP 5 Exhaust leaks in the original equipment manufacturer (OEM) exhaust piping leading to the aftertreatment system or leaks in the aftertreatment system	Inspect the OEM exhaust piping and the aftertreatment system for exhaust leaks. Refer to Procedure 010-024 in Section 10.
OK Go To Next Step	
STEP 6 Aftertreatment gas temperature sensors are not functioning properly	Monitor the aftertreatment gas temperature sensor values with INSITE™ electronic service tool during the stationary (parked) regeneration. Refer to Procedure 011-056 in Section 11.
OK Go To Next Step	

Stationary Regeneration - Will Not Complete

This is symptom tree t149

This tree is to be used when the engine speed changes after the stationary (parked) regeneration has been started and either stops after a short period of time or continues for an excessive period of time. If the engine speed does not increase when the stationary (parked) regeneration is started, refer to the Stationary Regeneration - Will Not Activate TS tree (t146).

Cause	Correction
STEP 7 Exhaust pressure regulator malfunctioning	Check the exhaust pressure regulator. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 8 Turbocharger is **not** functioning properly	Check for turbocharger related fault codes. If turbocharger related fault codes are present, follow the appropriate fault code troubleshooting tree.
OK Go To Next Step	
STEP 9 Aftertreatment diesel oxidation catalyst is **not** functioning properly or is damaged	Check the aftertreatment diesel oxidation catalyst for face plugging or other damage. Refer to Procedure 011-049 in Section 11.
OK Go To Next Step	
STEP 10 Aftertreatment diesel particulate filter is **not** functioning properly or is damaged	Check for cracks or other damage to the aftertreatment diesel particulate filter. Refer to Procedure 011-041 in Section 11.

Diesel Exhaust Fluid Contaminated

This is symptom tree t163

Cause	Correction
STEP 1 Diesel exhaust fluid tank has been filled or partially filled with fluid other than diesel exhaust fluid.	Drain the diesel exhaust fluid tank and replace with non-contaminated diesel exhaust fluid. Refer to Procedure 011-056 in Section 11.
OK Go To Next Step	
STEP 2 Diesel exhaust fluid tank is cracked or diesel exhaust fluid tank cap is leaking.	Repair or replace the diesel exhaust fluid tank or diesel exhaust fluid tank cap. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Bulk diesel exhaust fluid supply is contaminated.	Check the bulk diesel exhaust fluid supply. Drain the diesel exhaust fluid tank and replace with non-contaminated diesel exhaust fluid. Refer to Procedure 011-056 in Section 11.
OK Go To Next Step	
STEP 4 Diesel exhaust fluid tank heater coolant lines leaking coolant.	Repair or replace the diesel exhaust fluid tank heater coolant lines. Refer to the OEM service manual.

Engine Noise Excessive - Drive Belt

This is symptom tree t170

Cause	Correction
STEP 1 Verify which belt drive is producing noise	If the application uses an accessory belt drive, it is important to verify which belt is making noise. If the noise disappears when the accessory drive belt is removed, the source of the issue is the accessory drive. If it does not change, the source of the noise is the primary drive belt. Continue troubleshooting the drive that is making noise. Refer to Procedure 008-002 in Section 8 or Procedure 013-005 in Section 13.
OK Go To Next Step	
STEP 2 Determine the type of belt noise	There are two types of belt noise: chirping and squealing. A chirping noise is a symptom of misalignment in the system. A squealing noise is a symptom of a loss of tension in the system. Use a spray bottle of water to spray the groove side of the belt on the drive producing the noise. If the noise goes away, it is likely a belt chirp. If the noise did not change when water was sprayed on the groove side, spray the flat side of the belt. If the noise continues, or gets worse, it is likely a belt squealing.
OK Go To Next Step	
STEP 3 Determine the engine operating conditions that produce noise	Interview the driver to determine if the noise is continuous. If the noise is not continuous, determine the conditions when the noise is heard. Unique operating conditions could be the root cause of the belt noise.
OK Go To Next Step	
STEP 4 Isolate the source of the drive belt noise	Use a stethoscope, or equivalent device, to find the source of the noise. Refer to Procedure 008-002 in Section 8 or Procedure 013-005 in Section 13. Once the location of the noise has been identified, work in a direction opposite to belt travel (**counterclockwise**, for example) at the pulley where the noise originates and work upstream to determine which pulley is causing the noise.
OK Go To Next Step	

Engine Noise Excessive - Drive Belt

This is symptom tree t170

Cause	Correction
STEP 5 Drive belt incorrect, not routed correctly, or damaged	Verify the proper belt part number is installed on the drive producing the noise. Verify the belt tensioner arm stops are in the proper orientation with the drive belt installed. Inspect the belt for cracks, glazing, tears, cuts, and excessive wear. Inspect the belt grooves for debris, uneven or excessive rib wear, and exposed belt cords. Refer to Procedure 008-002 in Section 8, Procedure 013-005 in Section 13, or the OEM service manual.
OK Go To Next Step	
STEP 6 Loss of belt tension	For a fan drive belt, with the belt installed, verify that neither tensioner arm stop is in contact, or within 9.5 mm [3/8 in], of the spring case stop. If either of the stops are touching or within the specified range, replace the belt. Refer to Procedure 008-002 in Section 8. After replacing the belt, if the tensioner arm stops are still in contact, or within 9.5 mm [3/8 in] of the spring case stop, the tensioner **must** be replaced. Refer to Procedure 008-087 in Section 8. With the belt installed, pivot the belt tensioner away from the belt **counterclockwise** to check for smooth operation. For the accessory drive belt, verify the correct tension is applied. Refer to Procedure 013-005 in Section 13 or the OEM service manual.
OK Go To Next Step	
STEP 7 Belt tensioner is inoperative	With the belt removed, verify that the belt tensioner pulley bearing on the drive producing the noise is functioning properly. Also verify the belt tensioner moves smoothly throughout its travel. Refer to Procedure 008-087 in Section 8.
OK Go To Next Step	
STEP 8 Accessory drive components incorrect or inoperative	Verify that all accessory drive components and pulleys are correct. Refer to Procedure 008-002 in Section 8. Rotate all pulleys on the drive which are causing noise to make sure of smooth operation and bearing functionality.
OK Go To Next Step	
STEP 9 Accessory pulley is out of alignment	Verify the drive system pulley alignment with the belt alignment laser tool, Part Number 3163524 or equivalent. Refer to Procedure 008-002 in Section 8 or Procedure 013-005 in Section 13.

Air Filter Plugging Frequent

This is symptom tree t172

Cause	Correction
STEP 1 Dust ejector valve maintenance schedule not followed.	Determine if the inspection and maintenance schedules for the dust ejection valve are being followed. Refer to Procedure 102-002 in Section 2 in QSG12 CM2350 G110 Operation and Maintenance Manual, Bulletin 4367322.
OK Go To Next Step	
STEP 2 Dust ejector valve plugged.	Inspect the dust ejection valve for plugging. Clean and inspect the valve for reuse. Refer to Procedure 010-146 in Section 10.
OK Go To Next Step	
STEP 3 Dust ejector valve damaged or not installed correctly.	Inspect the dust ejection valve for damage and proper installation. Clean and inspect the valve for reuse. Refer to Procedure 010-146 in Section 10.
OK Go To Next Step	
STEP 4 Aspirator damaged or not operating correctly.	If equipped, inspect the aspirator for leaks or other damage. Refer to Aspirator Not Functioning troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 5 Air filter restriction indicator damaged or not operating properly.	Check the air filter restriction indicator for proper operation and damage. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 6 Large debris blocking precleaner.	Inspect the precleaner for large debris that can disrupt the air flow.
OK Go To Next Step	
STEP 7 Precleaner damaged or **not** installed correctly.	Inspect the precleaner for damage and proper installation. Refer to Procedure 010-015 in Section 10.
OK Go To Next Step	
STEP 8 Precleaner or dust ejection valve **not** oriented correctly	Inspect the precleaner for proper orientation. Refer to Procedure 010-015 in Section 10.
OK Go To Next Step	

Air Filter Plugging Frequent

This is symptom tree t172

Cause		Correction
STEP 9 Air filter media is excessively wet.	....	Inspect the air filter housing for cracks or other damage that would allow water into the housing. If equipped, inspect the rain cap and inlet piping for proper installation and damage. Refer to Procedure 010-014 in Section 10.
OK Go To Next Step		
STEP 10 Incorrect air filter elements installed.	....	Inspect the air filter elements for correct specifications. Refer to Procedure 010-014 in Section 10.
OK Go To Next Step		
STEP 11 Maintenance schedule for secondary air filter element was **not** followed.	....	Determine if the inspection and maintenance guidelines for secondary air filter elements are being followed. Refer to Procedure 010-014 in Section 10.
OK Go To Next Step		
STEP 12 Air filter housing damaged.	....	Inspect the air filter housing for damage. Inspect the air filter housing cover for proper installation. Refer to Procedure 010-014 in Section 10.
OK Go To Next Step		
STEP 13 Air filter inlet housing is located near the debris/ dust output of the vehicle or machine.	....	If the air filter air intake is ingesting contaminated air, filter replacement frequency will increase. Refer to the OEM service manual.

Aspirator Not Functioning

This is symptom tree t173

Cause	Correction
STEP 1 Aspirator hose, venturi, or check valve is plugged	Inspect the aspirator hose, venturi, and check valve for blockage. Refer to Procedure 010-015 in Section 10 .
OK Go To Next Step	
STEP 2 Aspirator hose is damaged or leaking	Inspect the aspirator hose for cracks, other damage, and loose connections. Refer to Procedure 010-015 in Section 10.
OK Go To Next Step	
STEP 3 Precleaner is damaged or obstructed	Inspect the air filter housing precleaner for damage and proper orientation. Be sure the precleaner is **not** obstructed. Refer to Procedure 010-015 in Section 10.
OK Go To Next Step	
STEP 4 Aspirator check valve is **not** functioning properly	Check the aspirator check valve for damage and proper operation. Refer to Procedure 010-015 in Section 10.
OK Go To Next Step	
STEP 5 Aspirator venturi is **not** functioning properly	Check the aspirator venturi for damage and proper operation. Refer to Procedure 010-015 in Section 10.
OK Go To Next Step	
STEP 6 Exhaust pipe is obstructed or back pressure is excessive	Check the exhaust pipe for obstructions and correct back pressure. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Light engine load causing reduced aspirator efficiency	Determine the average load of the engine. Excessive idle or light duty operation can reduce the efficiency of the aspirator.

Section TT - Troubleshooting Symptoms (New Format)

Section Contents

Page
ECM - No Communication Troubleshooting Tree TT-1
Vibration Excessive TT-20

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ECM - No Communication Troubleshooting Tree

This troubleshooting procedure should be followed for the following symptoms:

- No communication and engine will **not** start
- No communication and engine will start
- No communication related INSITE™ electronic service tool errors
- Communication with some ECMs but **not** all ECMs on a multi-module engine.

How to Use This Troubleshooting Procedure:

This troubleshooting procedure can be used to troubleshoot J1939 and J1587 data link communication issues between the electronic service tool and the ECM. There are four procedures that can be used to support this troubleshooting tree:

- Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, in the appropriate electronic control system troubleshooting and repair manual.
- Procedure 019-165 (Data Link Circuit, SAE J1939) in Section 19 in the appropriate electronic control system troubleshooting and repair manual.
- Procedure 019-166 (Data Link Circuit, SAE J1587) in Section 19 in the appropriate electronic control system troubleshooting and repair manual.

The troubleshooting steps in this procedure build upon information obtained in previous steps. The troubleshooting steps **must** be performed in the sequence specified in the troubleshooting procedure.

This troubleshooting procedure supports several engine families, therefore some instructions are stated in a general manner. Apply the requested procedures and actions to the specific engine family with the support of engine specific documentation that can be found in the Troubleshooting and Repair manuals for the specific engine family.

Shop Talk:

Three basic principles were used to define and sequence the troubleshooting steps that are listed in this tree.

- Verify high level system operation prior to troubleshooting individual components of the system. The purpose for this is to learn from the behavior of the system in order to direct the next steps for troubleshooting.
- Use the Bench Top Harness to separate the ECM from the vehicle so the ECM can be isolated from vehicle issues that could be causing no communication.
- Use a second vehicle or a second ECM to isolate high level system issues before troubleshooting individual components of the system.

TROUBLESHOOTING SUMMARY

STEPS		SPECIFICATIONS	SRT CODE
STEP 1:	**INSITE™ electronic service tool error code check**		
STEP 1A:	Check for INSITE™ electronic service tool error code 5023.	Is INSITE™ electronic service tool error code 5023 present?	
STEP 1B:	INSITE™ electronic service tool error code 5080 or 5081 check.	Is INSITE™ electronic service tool error code 5080 or 5081 present?	
STEP 1C:	INSITE™ electronic service tool other error code checks.	Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081?	
STEP 1D:	ECM password check	Does INSITE™ electronic service tool indicate the ECM is password protected?	
STEP 2:	**Initial data link adapter and INSITE™ electronic service tool check**		
STEP 2A:	Initial data link adapter check	Are the communication lights on the data link adapter flashing?	
STEP 2B:	data link adapter reset check	Does the ECM communicate?	
STEP 2C:	Initial INSITE™ electronic service tool check	Does the ECM communicate?	
STEP 2D:	data link adapter verification check	Is an Inline or Inline I being use to communicate with the ECM?	
STEP 2E:	data link adapter firmware check	Is firmware version compatible with ECM?	
STEP 3:	**Bench communication setup checks**		
STEP 3A:	Bench setup availability check	Is a bench setup available?	
STEP 3A-1:	Engine start check	Will engine start?	
STEP 3B:	Initial bench setup communication check	Does the ECM communicated using bench setup?	
STEP 3B-1:	Engine start check	Will engine start?	
STEP 3C:	Second vehicle or second ECM availability check for bench setup	Is second vehicle or second ECM available to connect to the bench setup?	
STEP 3D:	Initial bench setup functionality check	Does the second ECM communicate using bench setup?	
STEP 3E:	Troubleshoot bench setup	Does bench setup check OK?	
STEP 3F:	data link adapter replacement check	Does bench setup communicate with the second ECM using a replacement data link adapter?	
STEP 4:	**ECM power up circuit check**		
STEP 4A:	Engine configuration check	Is the engine equipped with a fuel shutoff valve?	
STEP 4A-1:	Check fuel shutoff valve voltage	Is the fuel shutoff valve voltage within 1-VDC of vehicle system voltage?	

STEP 4A-2:	Coolant temperature sensor signal voltage check	Is the coolant temperature signal voltage greater than 4.5-VDC?
STEP 4B:	ECM keyswitch voltage check	Is the keyswitch voltage within 1-VDC or vehicle system voltage?
STEP 4C:	Check the ECM power and ground	Is the ECM battery supply voltage equal to the battery voltage?
STEP 5:	**Initial electronic tool check**	
STEP 5A:	Bench setup previously used for troubleshooting check	In Step 3 checks, was bench setup used to successfully communicate with the ECM?
STEP 5B:	Second vehicle availability check for electronic tool	Is a second vehicle available to connect to the electronic tool?
STEP 5C:	Initial electronic tool functionality check	Does the second ECM communicate using electronic tool?
STEP 6:	**data link adapter power check**	
STEP 6A:	data link adapter determination check	Is an Inline I data link adapter being used to communicate with INSITE™ electronic service tool?
STEP 6B:	Check data link adapter power	Is the data link adapter power light on?
STEP 6C:	Determination if communication is being attempted at OEM dash connector	Is the communication being attempted at the OEM data link dash connector?
STEP 6D:	OEM data link dash connector voltage check	Is the voltage equal to or greater than 9-VDC?
STEP 6E:	Check voltage at data link adapter auxiliary power supply	Is the voltage equal to or greater than 9-VDC?
STEP 6F:	Check voltage at vehicle battery	Is the voltage equal or greater than 11-VDC?
STEP 6G:	Computer serial port voltage check	Is a minimum of 5 VDC available?
STEP 7:	**data link circuit check**	
STEP 7A:	Check J1939 or J1587 circuits	Does the circuit check OK?
STEP 8:	**Initial electronic tool check**	
STEP 8A:	Second vehicle availability check for electronic tool	Is a second vehicle available to connect to the electronic tool?
STEP 8B:	Initial electronic tool functionality check	Does the second ECM communicate using the electronic tool?
STEP 9:	**Detailed electronic tool check**	
STEP 9A:	Troubleshoot electronic tool hardware	Does the electronic tool hardware check OK?
STEP 10:	**Serial cable and computer check**	
STEP 10A:	Troubleshoot serial cable and computer	Do the serial cable and computer check OK?

STEP 11: ROM boot ECM

STEP 11A:	ROM boot tool availability check	Is the ROM boot tool available?
STEP 11B:	ROM boot ECM	Does the ECM communicate?

TROUBLESHOOTING STEP

STEP 1: INSITE™ electronic service tool error code check

STEP 1A: INSITE™ electronic service tool error code 5023 check

Condition:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Check for INSITE™ electronic service tool error code 5023. • Use INSITE™ electronic service tool to read the error codes.	Is INSITE™ electronic service tool error code 5023 present? **YES**	2A
	Is INSITE™ electronic service tool error code 5023 present? **NO**	1B

STEP 1B: INSITE™ electronic service tool error code 5080 or 5081 check

Condition:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Check for INSITE™ error code 5080 or 5081. • Use INSITE™ electronic service tool to read the error codes.	Is INSITE™ electronic service tool error code 5080 or 5081 present? **YES** **Repair:** Perform the ECM calibration download	Repair complete
	Is INSITE™ electronic service tool error code 5080 or 5081 present? **NO**	1C

STEP 1C: INSITE™ electronic service tool other error code checks.

Condition:
- Connect Is INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081? • Use INSITE™ electronic service tool to read the error codes.	Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081? **YES** **Repair:** See the INSITE™ Electronic Service Tool manual for troubleshooting guidelines.	Repair Complete
	Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081? **NO**	1D

STEP 1D: ECM password check

Condition:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Does INSITE™ electronic service tool indicate the ECM is password protected? • Use INSITE™ electronic service tool.	Does INSITE™ electronic service tool indicate the ECM is password protected? **YES** **Repair:** Enter correct password If password is unavailable, contact customer to request password information. If customer can **not** supply password information, see the INSITE™ electronic service tool manual for password removal information. Normal warranty guidelines will apply if ECM password removal is required.	Repair complete
	Does INSITE™ electronic service tool indicate the ECM is password protected? **NO**	2A

STEP 2: Initial data link adapter and INSITE™ electronic service tool check

STEP 2A: Initial data link adapter check

Condition:
- data link adapter connected to OEM data link connector in vehicle.
- INSITE™ electronic service tool computer **must not** be connected.
- Note: If connected to the 3 pin engine data link connector the communication lights will **not** blink, continue to Step 2B.

Action	Specification/Repair	Next Step
Turn keyswitch on.	Are the communication lights on the data link adapter flashing? • J1708 light for Inline • J1708 or J1939 for Inline II, Inline 4, and Inline 5. **YES** **Repair:** No Repair	2C
	Are the communication lights on the data link adapter flashing? • J1708 light for Inline • J1708 or J1939 for Inline II, Inline 4, and Inline 5. **NO**	2B

STEP 2B: data link adapter reset check

Condition:

INSITE™ electronic service tool connected to vehicle.

Action	Specification/Repair	Next Step
Data link adapter reset check • Disconnect power from the data link adapter. • Leave disconnected for 30 seconds • Connect power again to the Inline adapter • Turn keyswitch ON.	Does the ECM communicate? **YES**	Repair complete
	Does the ECM communicate? **NO**	3A

STEP 2C: Initial INSITE™ electronic service tool check

Condition:
- INSITE™ electronic service tool connected to vehicle
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Reboot INSITE™ electronic service tool PC. • Launch INSITE™ electronic service tool • Check for communication.	Does the ECM communicate? **YES**	Repair complete
	Does the ECM communicate? **NO**	2D

STEP 2D: data link adapter verification check

Condition:

None

Action	Specification/Repair	Next Step
Verify if an Inline or Inline I data link adapter is being used to communicate with ECM. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for General Information - data link Adapters, in the appropriate electronic control system troubleshooting and repair manual for data link adapter identification information.	Is an Inline or Inline I being used to communicate with the ECM? **YES**	8A
	Is an Inline or Inline I being used to communicate with the ECM? **NO**	2E

STEP 2E: data link adapter firmware check

Condition:

None

Action	Specification/Repair	Next Step
Verify data link adapter firmware version is compatible with ECM. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for General Information - data link Adapters, in the appropriate Electronic Control System Troubleshooting and Repair manual for data link adapter identification information.	Is firmware version compatible with the ECM? **YES**	8A
	Is firmware version compatible with the ECM? **NO** **Repair:** Load correct firmware version	2C

STEP 3: Bench communication setup checks

STEP 3A: Bench setup availability check

Condition:
- Bench setup available.

Action	Specification/Repair	Next Step
Verify bench setup is available.	Is a bench setup available? **YES**	3B
	Is a bench setup available? **NO**	3A-1

STEP 3A-1: Engine start check

Condition:
- None

Action	Specification/Repair	Next Step
Verify if engine will start.	Will engine start? **YES**	5A
	Will engine start? **NO**	4A

STEP 3B: Initial bench setup communication check.

Condition:
- Use the same INSITE™ electronic service tool PC as was used for the previous checks
- Bench setup connected to ECM
- Bench top calibration harness keyswitch ON.

Action	Specification/Repair	Next Step
Attempt to comunicate with the ECM using bench setup.	Does the ECM communicate with bench setup? **YES**	3B-1
	Does the ECM communicate with bench setup? **NO**	3C

STEP 3B-1: Engine start check

Condition:
- None

Action	Specification/Repair	Next Step
Disconnect the bench top calibration cable from the ECM. Reconnect the ECM to the original engine or OEM wiring harness connector. Verify if the engine will start.	Will the engine start? **YES**	5A
	Will the engine start? **NO**	4A

STEP 3C: Second vehicle or second ECM availability check for bench setup

Condition:
- Second vehicle or second ECM available for testing.

Action	Specification/Repair	Next Step
Verify if a second vehicle or second ECM is available to connect to the bench setup.	Is a second vehicle or second ECM available to connect to the bench setup? **YES**	3D
	Is a second vehicle or second ECM available to connect to the bench setup? **NO**	3E

STEP 3D: Initial bench setup functionality check

Condition:
- Use the same INSITE™ electronic service tool PC and bench setup tools that were originally used on the problem vehicle.
- Bench setup connected to second vehicle or second ECM
- Bench top calibration harness keyswitch ON.

Action	Specification/Repair	Next Step
Attempt to communicate with the ECM on the second vehicle or a spare ECM using bench setup.	Does the second ECM communicate using bench setup? **YES**	11A
	Does the second ECM communicate using bench setup? **NO**	3E

STEP 3E: Troubleshoot bench setup hardware

Condition:
- None

Action	Specification/Repair	Next Step
Troubleshoot bench calibration cable, bench calibration harness, and serial cable. • Perform troubleshooting procedures for evaluating the bench calibration cable, bench calibration harness, and serial cable. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for Resistance Check - Serial Cable, Benchtop Calibration Harness, Benchtop Calibration Cable, in the appropriate Electronic Control System Troubleshooting and Repair manual.	Does bench setup check OK? **YES**	3F
	Does bench setup check OK? **NO** **Repair:** Repair or replace bench calibration cable, bench calibration harness, or serial cable.	3B

STEP 3F: data link adapter replacement check

Condition:
- None

Action	Specification/Repair	Next Step
Try to communicate with the bench setup using a replacement datalink.	Does bench setup communicate with the second ECM using a replacement data link adapter? **YES** **Repair:** Use replacement data link adapter.	3B
	Does bench setup communicate with the second ECM using a replacement data link adapter? **NO** **Repair:** Issue with bench setup should have been found. Troubleshoot the bench setup again.	3E

STEP 4: ECM power up circuit check

STEP 4A: Engine configuration check

Condition:
- None

Action	Specification/Repair	Next Step
Determine if the engine is equipped with a fuel shutoff valve	Is the engine equipped with a fuel shutoff valve? **YES**	4A-1
	Is the engine equipped with a fuel shutoff valve? **NO**	4A-2

STEP 4A-1: Check fuel shutoff valve voltage

Condition:
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Measure the voltage from the fuel shutoff valve post to engine block ground. There are 12 and 24 volt systems, the fuel shutoff valve voltage needs to be within 1-VDC of the vehicle system voltage.	Is the fuel shutoff valve voltage within 1-VDC of vehicle system voltage? **YES**	5A
	Is the fuel shutoff valve voltage within 1 VDC of vehicle system voltage? **NO**	4B

STEP 4A-2: Coolant temperature sensor signal voltage check

Condition:
- Turn keyswitch ON.
- Disconnect the coolant temperature sensor connector.

Action	Specification/Repair	Next Step
Measure the voltage across the two pins of the coolant temperature sensor on the wiring harness connector. Reference the wiring diagram or circuit diagram for connector pin identification.	Is the coolant temperature signal voltage greater than 4.5-VDC? **YES**	5A
	Is the coolant temperature signal voltage greater than 4.5-VDC? **NO**	4B

STEP 4B: ECM keyswitch voltage check

Condition:
- Turn keyswitch OFF.
- Disconnect the wiring harness connector that contains the keyswitch signal from the ECM.
- Turn the keyswitch ON.

Action	Specification/Repair	Next Step
Measure the voltage from the keyswitch input SIGNAL wire of the wiring harness to engine block ground. Reference the wiring diagram or circuit diagram for connector pin identification.	Is the keyswitch voltage within 1-VDC of vehicle system voltage? **YES**	4C
	Is the keyswitch voltage within 1-VDC of vehicle system voltage? **NO** **Repair:** Repair or replace the wiring harness that contains the keyswitch signal, or repair or replace the keyswitch, or check the battery connection. Reference Procedure 019-064 (Key Switch Battery Supply Circuit) in Section 19 in the appropriate troubleshooting and repair manual. See the Engine Performance Troubleshooting Tree in the appropriate troubleshooting and repair manual, if the no start condition is still present.	Repair complete

STEP 4C: Check the ECM power and ground

Condition:

- Turn keyswitch OFF
- Disconnect from the ECM the wiring harness connector that contains the ECM battery SUPPLY (-) and SUPPLY (+) wiring.

Action	Specification/Repair	Next Step
Measure the voltage from each ECM battery SUPPLY (+) pin to all battery SUPPLY (-) pins in the wiring harness connector. Reference the wiring diagram or circuit diagram for connector pin identification.	Is the ECM battery supply voltage equal to the battery voltage? **YES** **Repair:** Call for authorization. Replace the ECM. Reference Procedure 019-031 (Electronic Control Module (ECM)) in Section 19 in the appropriate troubleshooting and repair manual.	Repair complete
	Is the ECM battery supply voltage equal to the battery voltage? **NO** **Repair:** Repair or replace the wiring harness that contains the ECM battery SUPPLY (+) and battery SUPPLY (-) wiring. See the Engine Performance Troubleshooting Tree if no start condition is still present.	Repair complete

STEP 5: Initial electronic tool check

STEP 5A: Bench setup previously used for troubleshooting check

Condition:

- None

Action	Specification/Repair	Next Step
In Step 3 checks, was bench setup used to successfully communicate with the ECM?	In Step 3 checks, was bench setup used to successfully communicate with the ECM? **YES** **Repair:** ECM is OK, repair complete if communication is **not** required through OEM data link connector or harness. If communication is required through the OEM data link connector or harness continue to Step 6A.	6A
	In Step 3 checks, was bench setup used to successfully communicate with the ECM? **NO**	5B

STEP 5B: Second vehicle availability check for electronic tool

Condition:
- Second vehicle available for testing

Action	Specification/Repair	Next Step
Verify a second vehicle is available to connect to the electronic tool.	Is a second vehicle available to connect to the electronic tool? **YES**	5C
	Is a second vehicle available to connect to the electronic tool? **NO**	6A

STEP 5C: Initial electronic tool functionality check

Condition:
- Electronic tool connected to a second vehicle.
- Keyswitch ON.

Action	Specification/Repair	Next Step
Attempt to communicate with the ECM on the second vehicle using the same electronic tool hardware used on the problem vehicle.	Does the second ECM communicate using electronic tool? **YES**	6A
	Does the second ECM communicate using electronic tool? **NO**	9A

STEP 6: data link adapter power check

STEP 6A: data link adapter determination check

Condition:
- None

Action	Specification/Repair	Next Step
Determine if an Inline I datalink adapter is being used to communicate with INSITE™ electronic service tool. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for General Information - data link adapter, in the appropriate electronic control system troubleshooting and repair manual.	Is an Inline I data link adapter being used to communicate with INSITE™ electronic service tool? **YES**	6G
	Is an Inline I data link adapter being used to communicate with INSITE™ electronic service tool? **NO**	6B

STEP 6B: Check data link adapter power

Condition:
- Do **not** use an Inline I
- Electronic tool hardware connected to the vehicle.
- INSITE™ electronic service tool launched
- Keyswitch ON.

Action	Specification/Repair	Next Step
Note: For all datalink adapters except Inline I. Attempt to communicate with INSITE™ electronic service tool and check to see if the data link adapter power light is on. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for General Information - data link Adapter, in the appropriate electronic control system troubleshooting and repair manual.	Is the data link adapter power light on? **YES**	7A
	Is the data link adapter power light on? **NO**	6C

STEP 6C: Determination if communication is being attempted at the OEM data link dash connector

Condition:
- None

Action	Specification/Repair	Next Step
Check to see if communication is being attempted at the OEM datalink dash connector.	Is communication being attempted at the OEM data link dash connector? **YES**	6D
	Is communication being attempted at the OEM data link dash connector? **NO**	6E

STEP 6D: OEM data link dash connector voltage check

Condition:
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Measure voltage across the SUPPLY and ground pins of the OEM datalink connector. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for In Cab data link Connector or 6-pin In Cab data link connector, in the appropriate Electronic Control System Troubleshooting and Repair manual for pin locations.	Is the voltage equal to or greater than 9 VDC? **YES** **Repair:** Replace data link adapter	Repair complete
	Is the voltage equal to or greater than 9 VDC? **NO**	6F

STEP 6E: Check voltage at data link adapter auxiliary power supply

Condition:
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Measure the data link adapter supply voltage at the datalink adapter harness connector. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for 3-pin data link Cable, in the appropriate Electronic Control System Troubleshooting and Repair manual for pin locations.	Is the voltage equal to or greater than 9-VDC? **YES** **Repair:** Replace data link adapter.	Repair complete
	Is the voltage equal to or greater than 9-VDC? **NO**	6F

STEP 6F: Check voltage at vehicle battery

Condition:
- None

Action	Specification/Repair	Next Step
Measure vehicle battery voltage in all cases except if using an Inline I. If using an Inline I measure data link adapter voltage supply from computer.	Is the voltage equal to or greater than 11-VDC? **YES** **Repair:** Repair or replace damaged wiring.	Repair complete
	Is the voltage equal to or greater than 11-VDC? **NO** **Repair:** Clean the battery connections or replace the batteries.	Repair complete

STEP 6G: Computer serial port voltage check

Condition:
- None

Action	Specification/Repair	Next Step
Note: For Inline I only. Measure voltage across the SIGNAL ground pin and the data terminal ready pin and the SIGNAL ground pin and the request to send pin on the computer serial port. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for Serial Cable, in the appropriate Electronic and Control System Troubleshooting and Repair manual for pin locations.	Is a minimum of 5 VDC available? **YES** **Repair:** Replace data link adapter	Repair complete
	Is a minimum of 5 VDC available? **NO** **Repair:** Contact PC administration support.	Repair complete

STEP 7: data link circuit check

STEP 7A: Check J1939 or J1587 circuits

Condition:
- None

Action	Specification/Repair	Next Step
Use the following procedures to perform J1939 or J1587 circuit checks depending on the datalink circuit being used. Reference Procedure 019-165 (Data Link Circuit, SAE J1939) in Section 19 in the appropriate troubleshooting and repair manual. This procedure gives information for a complete resistance check, check for short circuit to ground, and check for short circuit from pin-to-pin. Reference Procedure 019-166 (Data Link Circuit, SAE J1587) in Section 19 in the appropriate troubleshooting and repair manual. This procedure gives information for a complete resistance check, check for short circuit to ground, check for short circuit from pin-to-pin, and voltage check. Reference Procedure 019-428 (Engine data links) in Section 19 in the appropriate troubleshooting and repair manual. Complete resistance check, check for short circuit to ground, and check for short circuit from pin-to-pin.	Does the circuit check OK? **YES**	11A
	Does the circuit check OK? **NO** **Repair:** Repair or replace the harness with the data link problem, either the engine or OEM harness.	Repair complete

STEP 8: Initial electronic tool check

STEP 8A: Second vehicle availability check for electronic tool

Condition:
- Second vehicle available for testing

Action	Specification/Repair	Next Step
Verify if a second vehicle is available to connect to electronic tool?	Is a second vehicle available to connect to the electronic tool? **YES**	8B
	Is a second vehicle available to connect to the electronic tool? **NO**	10A

STEP 8B: Initial electronic tool functionality check

Condition:
- Electronic tool connected to second vehicle

Action	Specification/Repair	Next Step
Attempt to communicate with the ECM on the second vehicle using the electronic tool.	Does the second ECM communicate using the electronic tool? **YES**	11A
	Does the second ECM communicate using the electronic tool? **NO**	10A

STEP 9: Detailed electronic tool check

STEP 9A: Troubleshoot electronic tool hardware

Condition:
- None

Action	Specification/Repair	Next Step
Perform troubleshooting procedures for evaluating electronic tool hardware: • data link adapter cable • data link adapter power supply cable • data link adapter • Serial cable • Computer. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, in the appropriate troubleshooting and repair manual. Complete the following checks: • Initial Check - INSITE™ electronic service tool • Initial Check - data link Adapters • Resistance Check - Serial Cable • Resistance Check for data link adapter cable and data link adapter power supply cable.	Does the electronic tool hardware check OK? **YES** **Repair:** Communication issue found.	11A
	Does the electronic tool hardware check OK? **NO** **Repair:** Repair or replace damaged hardware.	Repair complete

STEP 10: Serial cable and computer check

STEP 10A: Troubleshoot serial cable and computer

Condition:
- None

Action	Specification/Repair	Next Step
Perform troubleshooting procedures for evaluating the serial cable and computer. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, in the appropriate troubleshooting and repair manual. Complete the following checks: • Initial Check - INSITE™ electronic service tool • Resistance Check - Serial Cable.	Do the serial cable and computer check OK? **YES** **Repair:** Communication issue found	11A
	Do the serial cable and computer check OK? **NO** **Repair:** Repair or replace damaged hardware.	Repair complete

STEP 11: ROM boot ECM

STEP 11A: ROM boot tool availability check

Condition:
- None

Action	Specification/Repair	Next Step
Verify if ROM boot tool is available for specific ECM.	Is the ROM boot tool available? **YES**	11B
	Is the ROM boot tool available? **NO** **Repair:** Call for pre-authorization Replace the ECM. Reference Procedure 019-031 (Electronic Control Module (ECM)) in Section 19 in the appropriate troubleshooting and repair manual.	Repair complete

STEP 11B: ROM boot the ECM

Condition:
- None

Action	Specification/Repair	Next Step
ROM boot the ECM. Reference Procedure 019-427 (ECM ROM Boot) in Section 19 in the appropriate troubleshooting and repair manual.	Does the ECM communicate? **YES** **Repair:** Calibrate the ECM again.	Repair complete
	Does the ECM communicate? **NO** **Repair:** Call for pre-authorization Replace the ECM. Reference Procedure 019-031 (Electronic Control Module (ECM)) in Section 19 in the appropriate troubleshooting and repair manual.	Repair complete

Vibration Excessive

This troubleshooting procedure should be followed for the following symptoms:

- Vibration excessive
- Cab noise due to vibration

How to Use This Troubleshooting Procedure:

This symptom tree can be used to troubleshoot all vibration-based symptoms listed above. Start by performing Step 1 troubleshooting. Step 2 will ask a series of questions and will provide a list of troubleshooting steps to perform, depending on the symptoms. Perform the list of troubleshooting steps in the sequence shown in the Specifications/ Repair section of the tree.

Shop Talk:

Vibration Troubleshooting Documentation Information Questions

1) What is the original equipment manufacturer (OEM) make/model?

2) What are the mileage/hours?

3) Has there been any recent repair and/or maintenance history?

- Any engine/clutch/transmission rebuild, removal, and installation?
- History of repeatedly broken brackets and/or capscrews (alternator, fan, exhaust, etc.)?
- Structural modifications to the vehicle from OEM built?

4) Description of vibration?

- What is shaking (mirror, seat, steering wheel, cab/dash, etc.)?
- Is there excessive noise in the cab during the vibration?

5) What are the conditions when the complaint occurs?

- Power take-off (PTO)?
- Power output (hard pull, during lug down, etc.)?
- During acceleration and/or deceleration?
- At idle?
- With or without a trailer?
- Does vibration increase with engine speed?
- Does vibration increase with road speed?
- Is the vibration at a certain engine revolutions per minute (rpm)?

6) Has the vibration been present since new? (From new, recent repair, modification to equipment)

7) Can the vibration be easily duplicated?

8) Do you have another piece of equipment with the same specification which exhibits the same complaint? (If yes, get the engine serial number (ESN) and possibly test the vehicle)

9) Are you the **only** operator of the equipment? (If no, are the symptoms noticed by other operators)?

General Information

Vibration complaints can be very difficult to troubleshoot and understand the root cause. This troubleshooting document was designed to help guide you through the logical steps of identifying the source. Vibration acceptance is very subjective; what is objectionable to one person can possibly be acceptable to another.

Vibration complaints can be caused by many parts in the system (system includes the engine, driven component, mounts, and equipment). The cause can be transmitted or generated from a remote point that is **not** readily apparent.

Cummins Inc. experience has shown that the engine is rarely the cause of an operator complaint. The majority of the time, it is the engine mounts or design of the various components on the equipment. The engine is **only** at fault if there is a misfire or an engine component that is out of balance.

Vibration complaints that occur **only** at idle speed are most likely caused by the engine mounts. If the engine mount natural frequency is close to the engine firing frequency, the engine will cause the mounts to amplify the normal vibration on an engine idling and cause the adjacent components to vibrate excessively.

Natural Frequency

- Natural frequency, as the name implies, is the frequency at which an object wants to naturally vibrate. The frequency is primarily dependent on mass and elasticity.

Types of Vibration

1) Linear

a) Rotating components

b) Torque reaction

- Caused by unbalanced rotating components and cylinder firing impulses.
- Can be felt and observed visibly.
- When excessive, can cause operator discomfort and destruction of components.

2) Torsional - twisting stresses

- Cyclic speeding and slowing of rotating components.
- Controlled by flywheel mass and vibration damper.
- Can **NOT** be felt by the operator.
- Can damage gears and splines.

3) Resonant - component excited at natural frequency

- Is actually linear vibration.
- Resonant vibration occurs when a system or component is excited by linear vibration at its natural frequency.
- Vibration will increase in amplitude as the system's natural frequency is approached. Amplitude will decrease as the exciting forces (engine firing frequency) increase in frequency beyond the system's natural frequency.
- Resonant vibration can be many times larger in amplitude than the exciting force.
- Vibration **must** be controlled by design of mounts (engine and cab) and components.

Engine and Cab Mounts

- The mounts **must** be designed to isolate or reduce the transmission of engine and equipment component vibrations.
- For maximum isolation, it is desired that the natural frequency of the mount be as low as possible.
- Good engine mounts will reduce the amount of engine vibration transmitted to the chassis frame by at least 50 percent at idle.
- Hard engine mounts will give little or no isolation, and can actually magnify the vibration transmitted to the chassis.
- Stiffness (durometer) and size of the isolator, along with the weight of the engine or component applied, are the determining factors when designing a mounting system. An isolator that is correct for one engine, can possibly **not** be right for another. Likewise, because of weight differential, a particular isolator designed for the rear of an engine, probably will **not** be ideal for the front.

TROUBLESHOOTING SUMMARY

STEPS		SPECIFICATIONS	SRT CODE
STEP 1:	**Perform the basic troubleshooting procedures.**		
STEP 1A:	Document the information questions in the Shop Talk section of this tree.	Documentation completed?	
STEP 1B:	Duplicate the complaint based on the customer description.	Customer's complaint be duplicated?	
STEP 1C:	Check for active fault codes or high counts of inactive fault codes.	Active fault codes or high counts of inactive fault codes?	
STEP 1D:	Perform the basic troubleshooting checks.	All steps verified to be correct?	
STEP 1E:	Determine if the engine is running rough.	Engine running rough?	
STEP 1F:	Perform a visual inspection of the engine mounts (without removal).	Visible engine mount damage?	
STEP 1G:	Check for an engine mounted component contacting the frame or body.	Engine mounted components touching the frame or body?	
STEP 1H:	Marine application.	Engine installed in a marine application?	
STEP 1I:	Do an engine rpm sweep.	Vibration present stationary below 1050 rpm?	
STEP 1J:	Do an engine rpm sweep.	Vibration present stationary above 1050 rpm?	
STEP 1K:	Check the vibration engine speed range.	Vibration speed range greater than 300 to 400 rpm?	
STEP 2:	**Perform low rpm checks.**		
STEP 2A:	Check that the accessory load is not excessive for the idle speed setting.	All steps verified to be correct?	
STEP 2B:	Check that the Fast Idle Warm-Up feature is activating (if applicable).	Fast Idle Warm-Up feature inactive?	
STEP 2C:	Check that the Alternator Failure Warning feature is activating (if applicable).	Alternator Failure Warning feature inactive?	
STEP 2D:	Check for malfunctioning belt driven accessories.	Vibration go away with the drive belts removed?	
STEP 2E:	Check for equipment structural modifications.	Any structural modifications to the equipment present?	
STEP 2F:	Check the engine mount transmissibility for the rear mount.	Vibration go away during the test condition?	
STEP 2F-1:	Check the engine mount transmissibility for all mounts.	Vibration go away during the test condition?	

STEP 2G:	Inspect the engine mounts.	All steps verified to be correct?
STEP 2H:	Complaint since new.	Problem been occurring since the equipment was new?

STEP 3: Perform higher rpm checks.

STEP 3A:	Inspect the engine mounts.	All steps verified to be correct?
STEP 3B:	Check for malfunctioning belt driven accessories.	Vibration go away with the drive belts removed?
STEP 3C:	Check for a damaged vibration damper.	Vibration damper damaged or out of specification?
STEP 3D:	Check the air compressor timing.	Air compressor timing correct?
STEP 3E:	Check the overhead adjustments.	Overhead adjustments correct?
STEP 3F:	Check for malfunctioning gear driven components.	Vibration go away?
STEP 3G:	Check for a damaged PTO.	Vibration go away?
STEP 3H:	Check for a malfunctioning engine internal balancer assembly (4 cylinder B-Series only).	Internal balancer meet specification?
STEP 3I:	Check the clutch or torque converter for vibration.	Engaging and disengaging the clutch affect the vibration?
STEP 3J:	Check for a loose or damaged flywheel or flex plate.	Flywheel meet specifications?
STEP 3K:	Check the flywheel housing for correct alignment.	Flywheel housing meet specifications?
STEP 3L:	Check to see if the crankshaft has been balanced.	Crankshaft balanced?
STEP 3M:	Check for internal engine damage.	Internal engine damage?

STEP 4: Operate the mobile equipment.

STEP 4A:	Perform a diagnostic road test.	Vibration present during a diagnostic road test?
STEP 4A-1:	Perform a diagnostic road test.	Vibration present with the transmission in neutral, under the road speed conditions, where the vibration was duplicated driving?
STEP 4B:	Inspect the engine mounts.	All steps verified to be correct?
STEP 4C:	Check for drive train components that are worn, unbalanced, malfunctioning, or are not correct.	All steps verified to be correct?

STEP 5: Marine applications.

STEP 5A:	Check the gear ratio and propeller configuration.	Gear ratio and the propeller incorrectly matched to the engine power?
STEP 5B:	Check for the correct engine mounting isolators and for	Engine mount isolators correct and installed correctly?

	proper installation requirements.	
STEP 5C:	**Check for damaged engine mounts and isolators.**	**Engine mounts and isolators in good condition?**
STEP 5D:	**Check the exhaust system.**	**Exhaust system deficient?**
STEP 5E:	**Check the engine driven accessories.**	**Engine driven accessory malfunctioning?**
STEP 5F:	**Check the shaft coupling to gear coupling alignment.**	**Shaft coupling to gear coupling misaligned?**
STEP 5G:	**Check the propeller shaft for proper installation.**	**Propeller shaft installed correctly?**
STEP 5H:	**Check the propeller shaft for straightness.**	**Propeller shaft straightness within the OEM specification?**
STEP 5I:	**Isolate the engine.**	**Engine vibration persist?**
STEP 5J:	**Check for strut/cutlass bearing misalignment.**	**Strut/cutlass bearing misaligned or strut mounting not secure?**
STEP 5K:	**Check the propeller.**	**Propeller out of balance or not fitted properly to the shaft?**
STEP 5L:	**Check the V-angle on the V-strut.**	**V-angle on the V-strut match the angle of the blade on the prop?**
STEP 5M:	**Check the propeller tunnels.**	**Entry and exit of the propeller tunnel match with the propeller blades?**
STEP 5N:	**Check the engine to transmission torsional coupling.**	**Torsional coupling incorrect or worn?**
STEP 5O:	**Check the rudder.**	**Rudder have excessive play in the rudder post?**
STEP 5P:	**Check the engine flywheel housing to cylinder block alignment.**	**Flywheel housing alignment incorrect?**

TROUBLESHOOTING STEP

STEP 1: Perform the basic troubleshooting procedures.

STEP 1A: Document the information questions in the Shop Talk section of this tree.

Condition:
- None

Action	Specification/Repair	Next Step
Perform the basic troubleshooting questionnaire. Complete the vibration troubleshooting documentation information questions contained in the Shop Talk section of this procedure.	Documentation completed? **YES**	1B
	Documentation completed? **NO** **Repair:** Complete the documentation.	1A

STEP 1B: Duplicate the complaint based on the customer description.

Condition:
- None.

Action	Specification/Repair	Next Step
Operate the equipment based on the description from the customer to duplicate the complaint. N/A	Customer's complaint be duplicated? **YES**	1C
	Customer's complaint be duplicated? **NO**	Repair complete

STEP 1C: Check for active fault codes or high counts of inactive fault codes.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
Check the fault codes. • Use INSITE™ electronic service tool to read the fault codes.	Active fault codes or high counts of inactive fault codes? **YES** **Repair:** See the corresponding Electronic Control System Troubleshooting and Repair manual for the engine being serviced.	Repair complete
	Active fault codes or high counts of inactive fault codes? **NO**	1D

STEP 1D: Perform the basic troubleshooting checks.

Condition:
- As required.

Action	Specification/Repair	Next Step
Check or verify the following items before continuing. • Battery voltage is low (engine running) • Lubricating oil level is above specification • External fuel leak • Engine idle speed is set too low • Engine idle speed is set too high • Throttle lever or pedal, return spring, or air throttle damaged or improperly adjusted (use INSITE™ electronic service tool for electronic engines) • Air in the fuel • Fuel pressure • Inlet restriction.	All steps verified to be correct? **YES**	1E
	All steps verified to be correct? **NO**	Repair complete

STEP 1E: Determine if the engine is running rough.

Condition:
- Operate engine at idle speed (less than 900 rpm).
- Turn accessories OFF(air conditioning, fan, PTO).
- Operate engine at operating temperature (greater than 170°C [70°F]).

Action	Specification/Repair	Next Step
Determine if the engine is running rough at engine idle. Refer to the Engine Runs Rough troubleshooting symptom tree in Section TS or the Engine Performance Troubleshooting Tree in Section TT.	Engine running rough? **YES** **Repair:** Refer to the Engine Runs Rough troubleshooting symptom tree in Section TS or the Engine Performance Troubleshooting Tree in Section TT.	Complete Engine Runs Rough troubleshooting tree
	Engine running rough? **NO**	1F

STEP 1F: Perform a visual inspection of the engine mounts (without removal).

Condition:
- Do **not** operate engine.
- Install engine mounts.

Action	Specification/Repair	Next Step
Perform a visual inspection of the engine mounts. Look for obvious damage or something shorting against the mounts, preventing isolation. A more detail inspection will be carried out later in the procedure.	Visible engine mount damage? **YES** **Repair:** Repair or replace the engine mounts. Refer to Procedure 016-010 in Section 16.	Repair complete
	Visible engine mount damage? **NO**	1G

STEP 1G: Check for an engine mounted component contacting the frame or body.

Condition:
- Do **not** operate engine.
- Install engine moun.

Action	Specification/Repair	Next Step
Check for an engine mounted component touching the frame or body. Inspect the engine and engine mounted components to make sure none of them are touching the frame and/or body. Including but not limited to the following: • Clamps • Mounting hardware • Exhaust system • Air intake piping • Cooling package support • Etc.	Engine mounted components touching the frame or body? **YES** **Repair:** Correct the mounting of the engine mounted component.	Repair complete
	Engine mounted components touching the frame or body? **NO**	1H

STEP 1H: Marine application.

Condition:

None

Action	Specification/Repair	Next Step
Engine in a marine application? N/A	Engine installed in a marine application? **YES**	5A
	Engine installed in a marine application? **NO**	1I

STEP 1I: Do an engine rpm sweep.

Condition:
- Operate engine
- Connect INSITE™ electronic service tool.
- Make sure of 0 vehicle speed.

Action	Specification/Repair	Next Step
Perform a slow (at 100 rpm per second) rpm sweep and observe where the vibration occurs. Record the engine speed at which any usual vibration or vibration related noise occurs (mirrors, panels, doors, seat, etc.). Record any speed points or ranges with excessive vibration. If a resonance is passed through quickly in getting up to the operating speed range and doesn't exist in the idle speed or peak operating range, it represents no major problem.	Vibration present stationary below 1050 rpm? **YES**	2A
	Vibration present stationary below 1050 rpm? **NO**	1J

STEP 1J: Do an engine rpm sweep.

Condition:
- Operate engine.
- Connect INSITE™ electronic service tool.
- 0 vehicle speed.

Action	Specification/Repair	Next Step
Perform a slow (at 100 rpm per second) rpm sweep and observe where the vibration occurs. Does the vibration increase progressively from idle to maximum speed? If so, rotating or reciprocating unbalance is the source. This can be caused by any rotating components or engine mount isolation.	Vibration present stationary above 1050 rpm? **YES**	1K
	Vibration present stationary above 1050 rpm? **NO**	4A

STEP 1K: Check the vibration engine speed range.

Condition:
- Operate engine
- Connect INSITE™ electronic service tool.
- Make sure of 0 vehicle speed.

Action	Specification/Repair	Next Step
Perform a slow (at 100 rpm per second) rpm sweep and observe where the vibration occurs. This step is to identify if the vibration progressively increases with engine speed or if it starts and stops within a slow engine rpm band. If the vibration progressively increases with engine speed and has a peak band greater than 300 rpm, this can indicate a rotating component that is out of balance. If the vibration peak is in a tight band of approximately 300 to 400 rpm or less, this indicates that a structural component of the engine or equipment is going into resonance because its natural frequency is close to or the same as the engine firing frequency.	Vibration speed range greater than 300 to 400 rpm? **YES**	3A
	Vibration speed range greater than 300 to 400 rpm? **NO**	2A

STEP 2: Perform low rpm checks.

STEP 2A: Check that the accessory load is not excessive for the idle speed setting.

Condition:
- Operate engine at idle speed (less than 900 rpm).
- Turn accessories off (air conditioning, fan, and PTO).
- Engine at operating temperature (greater than 77°C [170°F]).

Action	Specification/Repair	Next Step
Disable all engine driven accessories and PTOs to make sure they are **not** applying excessive load to the engine. N/A	All steps verified to be correct? **YES**	2B
	All steps verified to be correct? **NO** **Repair:** Repair as required.	Repair complete

STEP 2B: Check that the Fast Idle Warm-Up feature is activating, if applicable.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
Check the Fast Idle Warm-Up status. Use INSITE™ electronic service tool Data Monitor/Logger to check the status of the Fast Idle Warm-Up feature.	Fast Idle Warm-Up feature inactive? **YES**	2C
	Fast Idle Warm-Up feature inactive? **NO** **Repair:** Disable the Fast Idle Warm-Up feature and retest for the customer's complaint.	Repair complete

STEP 2C: Check that the Alternator Failure Warning feature is activating. if applicable.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
Check to see if the Alternator Failure Warning feature is active. Use INSITE™ electronic service tool Data Monitor/Logger to check that the Alternator Failure Warning feature is active.	Alternator Failure Warning feature inactive? **YES**	2D
	Alternator Failure Warning feature inactive? **NO** **Repair:** Disable the Alternator Failure Warning feature and retest for the customer's complaint.	Repair complete

STEP 2D: Check for malfunctioning belt driven accessories.

Condition:
- Remove drive belt(s).

Action	Specification/Repair	Next Step
Remove the drive belt(s) and operate the engine under the conditions where the vibration occurs. **Caution: For engines with a belt driven water pump, do not allow the engine to overheat during the test. Engine damage will occur.**	Vibration go away with the drive belts removed? **YES** **Repair:** Repair or replace the malfunctioning belt driven component.	Repair complete
	Vibration go away with the drive belts removed? **NO**	2E

STEP 2E: Check for equipment structural modifications.

Condition:
- Inspect.

Action	Specification/Repair	Next Step
Check for any structural modifications to the equipment. Check for any structural modifications to the equipment in the engine area that were completed by the OEM after equipment manufacture. • Snow plows, frame rail extensions, front bumpers, etc. Structural modifications can change the natural frequency of the frame and engine mounting system, which can result in a vibration complaint.	Any structural modifications to the equipment present? **YES** **Repair:** Contact the equipment manufacturer. If possible, remove or isolate the structural modification.	Repair complete
	Any structural modifications to the equipment present? **NO**	2F

STEP 2F: Check the engine mount transmissibility of the rear mount.

Condition:
- Loosen the front engine mount capscrews.
- Operate engine at the documented rpm where the complaint occurs.

Action	Specification/Repair	Next Step
Check the engine mounts. This step is checking to see if the engine mounts are amplifying the firing frequency of the engine, since the vibration **only** occurs in a low engine rpm range. • Loosen **only** the isolator capscrews for the front engine mount(s) and run the engine at idle.	Vibration go away during the test condition? **YES**	2G
	Vibration go away during the test condition? **NO**	2F-1

STEP 2F-1: Check the engine mount transmissibility for all mounts.

Condition:
- Loosen all engine mount capscrews.
- Operate engine at the documented rpm where the complaint occurs.

Action	Specification/Repair	Next Step
Check the engine mounts. This step is checking to see if the engine mounts are amplifying the firing frequency of the engine, since the vibration **only** occurs in a low engine rpm range. • Loosen the isolator capscrews for all of the engine mounts and run the engine at idle.	Vibration go away during the test condition? **YES**	2G
	Vibration go away during the test condition? **NO**	2G

STEP 2G: Inspect the engine mounts.

Condition:
- Do **not** operate engine.
- Remove engine mount isolators.

Action	Specification/Repair	Next Step
This step is a detailed inspection of the engine mount brackets, isolators, and mounting hardware. • Check the engine mount isolators for installation damage. • Check the alignment of the engine mount brackets. • Check for premature wear on the engine mount isolators and mounting hardware.	All steps verified to be correct? **YES**	2H
	All steps verified to be correct? **NO** **Repair:** Repair or replace the damaged components.	Repair complete

STEP 2H: Complaint since new.

Condition:
- Record the odometer/hour meter.
- Review the troubleshooting documentation information questions.

Action	Specification/Repair	Next Step
Check the equipment. Check the equipment mileage/hours and compare to the vibration customer interview form completed in Step 1A. • Low mileage is an indication that the complaint has been present since the equipment was new. • Complaints on new equipment are typically due to a manufacturing defect in the system or an inadequate engine mounting design.	Problem been occurring since the equipment was new? **YES** **Repair:** The engine mounts are **not** the right specification for the application, or a structural resonance exists.	Contact a Cummins® Technical Support Specialist or the OEM
	Problem been occurring since the equipment was new? **NO** **Repair:** Recheck for shorts, a rough running engine, or malfunctioning engine mounts.	Contact a Cummins® Technical Support Specialist or the OEM

STEP 3: Perform higher rpm checks.

STEP 3A: Inspect the engine mounts.

Condition:
- Do **not** operate engine.
- Remove the engine mount isolators.

Action	Specification/Repair	Next Step
Inspect the engine mount brackets, isolators, and mounting hardware. • Check the engine mount isolators for installation damage. • Check the alignment of the engine mount brackets. • Check for premature wear on the engine mount isolators and mounting hardware.	All steps verified to be correct? **YES**	3B
	All steps verified to be correct? **NO** **Repair:** Repair or replace the malfunctioning components. Refer to Procedure 016-010 in Section 16.	Repair complete

STEP 3B: Check for malfunctioning belt driven accessories.

Condition:
- Remove the drive belts.

Action	Specification/Repair	Next Step
Check the belt driven accessories. Remove the drive belts and operate the engine under the conditions where the vibration occurs. **Caution: For engines with a belt driven water pump, do not allow the engine to overheat during the test. Engine damage will occur.**	Vibration go away with the drive belts removed? **YES** **Repair:** Repair or replace the malfunctioning belt driven accessory.	Repair complete
	Vibration go away with the drive belts removed? **NO**	3C

STEP 3C: Check for a damaged vibration damper.

Condition:
- Do **not** operate engine.

Action	Specification/Repair	Next Step
Remove and visually inspect the vibration damper. Use Procedure 001-052 in Section 1 in the appropriate service manual for vibration damper inspection specifications.	Vibration damper damaged or out of specification? **YES** **Repair:** Replace the vibration damper. Reference the appropriate service manual.	Repair complete
	Vibration damper damaged or out of specification? **NO**	3D

STEP 3D: Check the air compressor timing.

Condition:
- Do **not** operate engine.
- Remove air compressor.

Action	Specification/Repair	Next Step
Check the air compressor timing. Reference Procedure 012-014 in Section 12 of the appropriate service manual.	Air compressor timing correct? **YES**	3E
	Air compressor timing correct? **NO** **Repair:** Correct the air compressor timing and retest for the vibration complaint. Reference Procedure 012-014 in Section 12 of the appropriate service manual.	Repair complete

STEP 3E: Check the overhead adjustments.

Condition:
- Do **not** operate engine.
- Remove rocker lever cover.

Action	Specification/Repair	Next Step
Measure and adjust the overhead settings. • Check the overhead components for damage. Reference Procedure 003-004 in Section 3 of the appropriate service manual.	Overhead adjustments correct? **YES**	3F
	Overhead adjustments correct? **NO** **Repair:** Repair or adjust the overhead. Reference Procedure 003-004 in Section 3 of the appropriate service manual.	Repair complete

STEP 3F: Check for malfunctioning gear driven components.

Condition:

None.

Action	Specification/Repair	Next Step
Check the hydraulic pump and air compressor. If possible, isolate any gear-driven accessories and check for vibration.	Vibration go away? **YES** **Repair:** Repair or replace the gear driven components.	Repair complete
	Vibration go away? **NO**	3G

STEP 3G: Check for a damaged PTO.

Condition:
- Disconnect the PTO.

Action	Specification/Repair	Next Step
Check the PTO for damage and correct installation. Refer to the OEM service manual.	Vibration go away? **YES** **Repair:** Repair the PTO. Refer to the OEM service manual.	Repair complete
	Vibration go away? **NO**	3H

STEP 3H: Check for a malfunctioning engine internal balancer assembly (4 cylinder B-Series only).

Condition:
- None.

Action	Specification/Repair	Next Step
Inspect the engine internal balancer assembly. Reference Procedure 001-004 in Section 1 of the appropriate service manual. This applies to 4 cylinder B-Series engines **only**.	Internal balancer meet specification? **YES**	3I
	Internal balancer meet specification? **NO** **Repair:** Repair the internal balancer. Reference Procedure 001-004 in Section 1 of the appropriate service manual.	Repair complete

STEP 3I: Check the clutch or torque converter for vibration.

Condition:
- Operate engine.

Action	Specification/Repair	Next Step
With engine running in the operating condition of the vibration, disengage and engage the clutch serval times. If there is a significant vibration reduction, clutch plate(s) balance is the source.	Engaging and disengaging the clutch affect the vibration? **YES** **Repair:** Repair or replace the clutch. Refer to the OEM service manual.	Repair complete
	Engaging and disengaging the clutch affect the vibration? **NO**	3J

STEP 3J: Check for a loose or damaged flywheel or flex plate.

Condition:
- Remove transmission.

Action	Specification/Repair	Next Step
Check the flywheel. • Check the flywheel bore and face run out. • Check the flywheel for damage. Reference Procedure 016-005 in Section 16 of the appropriate service manual.	Flywheel meet specifications? **YES**	3K
	Flywheel meet specifications? **NO** **Repair:** Repair or replace the flywheel or flexplate. Reference Procedure 016-005 in Section 16 of the appropriate service manual.	Repair complete

STEP 3K: Check the flywheel housing for correct alignment.

Condition:
- Remove transmission.
- Remove flywheel/flexplate.

Action	Specification/Repair	Next Step
Check the flywheel housing bore and face alignment. Reference Procedure 016-006 in Section 16 of the appropriate service manual.	Flywheel housing meet specifications? **YES**	3L
	Flywheel housing meet specifications? **NO** **Repair:** Repair or replace the flywheel housing. Reference Procedure 016-006 in Section 16 of the appropriate service manual.	Repair complete

STEP 3L: Check to see if the crankshaft has been balanced.

Condition:
- Do **not** operate engine.
- Remove lubricating oil pan.

Action	Specification/Repair	Next Step
Remove the lubricating oil pan. Reference Procedure 007-025 in Section 7 of the appropriate service manual. Check the crankshaft to see if it has been balanced. Reference Procedure 001-016 in Section 16 of the appropriate service manual. This step **only** applies if the complaint has been present since the engine was new or after a crankshaft replacement. ISX engines built after 01-November-2008 have a marking on the crankshaft to indicate if it passed the balancing step in the manufacturing process. Reference Procedure 001-016 in Section 1 of the appropiate service manual.	Crankshaft balanced? **YES**	3M
	Crankshaft balanced? **NO** **Repair:** Replace the crankshaft. Contact a Cummins® Technical Support/Warranty specialist before proceeding with the repair.	Repair complete

STEP 3M: Check for internal engine damage.

Condition:
- None.

Action	Specification/Repair	Next Step
Contact a support specialist. At this point, a significant amount of labor has been invested in the repair. Before disassembling the engine, seek troubleshooting assistance. Contact the appropriate Technical Support Channel for your facility. They will provide the necessary guidance and schedule on-site support, if deemed necessary. • Camshaft journals and number 1 camshaft bushing are severely damaged • Gear train backlash is excessive or the gear teeth are damaged • Idler gear bushing damaged or worn • Main or connecting rod bearing damage • Gears out of balance or gear bushing damage • Connecting rod damage.	Internal engine damage? **YES**	Contact Technical Support
	Internal engine damage? **NO**	Contact Technical Support

STEP 4: Operate the mobile equipment.

STEP 4A: Perform a diagnostic road test.

Condition:
- Preform diagnostic road test.

Action	Specification/Repair	Next Step
Perform a diagnostic road test, observing where the vibration occurs. If the vibration can be duplicated on the road, place the transmission in neutral and allow the engine speed to drop to idle under the road speed conditions of the vibration.	Vibration present during a diagnostic road test? **YES**	4A-1
	Vibration present during a diagnostic road test? **NO**	No repair

STEP 4A-1: Perform a diagnostic road test.

Condition:
- Perform diagnostic road test.

Action	Specification/Repair	Next Step
Perform a diagnostic road test, observing where the vibration occurs. If the vibration can be duplicated on the road, place the transmission in neutral and allow the engine speed to drop to idle under the conditions of the vibration.	Vibration present with the transmission in neutral, under the road speed conditions, where the vibration was duplicated driving? **YES**	4C
	Vibration present with the transmission in neutral, under the road speed conditions, where the vibration was duplicated driving? **NO**	4B

STEP 4B: Inspect the engine mounts.

Condition:
- Do **not** operate engine.
- Remove the engine mount isolators.

Action	Specification/Repair	Next Step
This step is a detailed inspection of the engine mount brackets, isolators, and mounting hardware. • Check the engine mount isolators for installation damage. • Check the alignment of the engine mount brackets. • Check for premature wear on the engine mount isolators and mounting hardware. • If the equipment is new, check for the proper mount specification. Reference Procedure 016-010 in Section 16 of the appropriate service manual.	All steps verified to be correct? **YES**	4C
	All steps verified to be correct? **NO** **Repair:** Repair or replace damaged components.	Repair complete

STEP 4C: Check for drive train components that are worn, unbalanced, malfunctioning, or are not correct.

Condition:
- None.

Action	Specification/Repair	Next Step
Compare the drive train components to the engine and equipment specifications. Isolate the drive train components and check for vibrations. Refer to the OEM service manual.	All steps verified to be correct? **YES**	Contact Cummins® Technical Support and the OEM
	All steps verified to be correct? **NO**	Contact Cummins® Technical Support and the OEM

STEP 5: Marine applications.

STEP 5A: Check the gear ratio and propeller configuration.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check for an incorrect matching of the gear ratio and propeller to the engine power. N/A	Gear ratio and the propeller incorrectly matched to the engine power? **YES** **Repair:** Contact a Cummins® Distributor or a Marine District Field Service Manager.	Repair complete
	Gear ratio and the propeller incorrectly matched to the engine power? **NO**	5B

STEP 5B: Check for the correct engine mounting isolators and for proper installation requirements.

Condition:
- None.

Action	Specification/Repair	Next Step
Check for the correct engine mount isolators and for propeller installation requirements. N/A	Engine mount isolators correct and installed correctly? **YES**	5C
	Engine mount isolators correct and installed correctly? **NO** **Repair:** Check for proper isolator installation requirements. Replace and repair vibration isolators as needed. Reference Procedure 016-026 in Section 16 of the appropriate service manual and the Engine Mounting/ Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649. If the isolators are **not** manufactured by Cummins Inc.; see the OEM service manual.	Repair complete

STEP 5C: Check for damaged engine mounts and isolators.

Condition:
- None.

Action	Specification/Repair	Next Step
Inspect the engine mount and isolators for damage. N/A	Engine mounts and isolators in good condition? **YES**	5D
	Engine mounts and isolators in good condition? **NO** **Repair:** Remove and replace the engine mount isolators. Reference Procedure 016-026 in Section 16 of the appropriate service manual and the Engine Mounting/Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649. If the isolators are **not** manufactured by Cummins Inc.; see the OEM service manual.	Repair complete

STEP 5D: Check the exhaust system.

Condition:
- None.

Action	Specification/Repair	Next Step
Check for exhaust system deficiencies. N/A	Exhaust system deficient? **YES** **Repair:** Repair or replace as needed. See the Exhaust System section in the Marine Recreational Installation Directions, Bulletin 3884649, and the OEM service manual.	Repair complete
	Exhaust system deficient? **NO**	5E

STEP 5E: Check the engine driven accessories.

Condition:
- Turn keyswitch ON.
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check for engine driven accessory malfunctions. • Isolate or disconnect the accessories and check for vibration. • Do **not** operate the engine if the sea water pump is disconnected.	Engine driven accessory malfunctioning? **YES** **Repair:** Determine the cause of the malfunctioning accessories and correct the problem. See the Exhaust System section in the Marine Recreational Installation Directions, Bulletin 3884649, and the OEM service manual.	Repair complete
	Engine driven accessory malfunctioning? **NO**	5F

STEP 5F: Check the shaft coupling to gear coupling alignment.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check the shaft coupling to gear coupling alignment. N/A	Shaft coupling to gear coupling misaligned? **YES** **Repair:** Repair or replace as needed. Reference Procedure 016-025 in Section 16 of the appropriate service manual and the Engine Mounting/Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649, and the gear manufacturer's recommendations.	Repair complete
	Shaft coupling to gear coupling misaligned? **NO**	5G

STEP 5G: Check the propeller shaft for proper installation.

Condition:
- None.

Action	Specification/Repair	Next Step
Check the propeller shaft for proper installation. N/A	Propeller shaft installed correctly? **YES**	5H
	Propeller shaft installed correctly? **NO** **Repair:** Repair or replace as needed. Reference Procedure 016-025 in Section 16 of the appropriate service manual and the Engine Mounting/Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649, and the gear manufacturer's recommendations.	Repair complete

STEP 5H: Check the propeller shaft for straightness.

Condition:
- None.

Action	Specification/Repair	Next Step
Check the propeller shaft for straightness. N/A	Propeller shaft straightness within the OEM specification? **YES**	5I
	Propeller shaft straightness within the OEM specification? **NO** **Repair:** Repair or replace the propeller shaft as needed. Contact an authorized OEM service location.	Repair complete

STEP 5I: Isolate the engine.

Condition:
- Disconnect the drive shaft.

Action	Specification/Repair	Next Step
Run the engine without the drive shaft attached at the coupler. N/A	Engine vibration persist? **YES** **Repair:** Check the engine vibration damper for damage. Repair or replace as needed. Reference Procedure 001-052 in Section 1 of the appropriate service manual.	Repair complete
	Engine vibration persist? **NO**	5J

STEP 5J: Check for strut/cutlass bearing misalignment.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check for strut/cutlass bearing misalignment or strut mounting **not** secure. N/A	Strut/cutlass bearing misaligned or strut mounting not secure? **YES** **Repair:** Check the strut for mounting stiffness. Repair or replace as necessary. Contact an authorized OEM service location.	Repair complete
	Strut/cutlass bearing misaligned or strut mounting not secure? **NO**	5K

STEP 5K: Is the propeller out of balance or not fitted properly to the shaft?

Condition:
- None.

Action	Specification/Repair	Next Step
Check for propeller out-of-balance or propeller not fitted properly to shaft. N/A	Propeller out of balance or not fitted properly to the shaft? **YES** **Repair:** Check the propeller for accuracy. Repair or replace as needed. Contact an authorized OEM service location.	Repair complete
	Propeller out of balance or not fitted properly to the shaft? **NO**	5L

STEP 5L: Check the V-angle on the V-strut.

Condition:
- None.

Action	Specification/Repair	Next Step
Check to see if the V-angle on the V-strut does not match the angle of the blade on the propeller. N/A	V-angle on the V-strut match the angle of the blade on the prop? **YES**	5M
	V-angle on the V-strut match the angle of the blade on the prop? **NO** **Repair:** Repair or replace as needed. Refer to an Authorized OEM Service Location.	Repair complete

STEP 5M: Check the propeller tunnels.

Condition:
- None.

Action	Specification/Repair	Next Step
Check if the propeller tunnels are properly matched with the propellers. N/A	Entry and exit of the propeller tunnel match with the propeller blades? **YES**	5N
	Entry and exit of the propeller tunnel match with the propeller blades? **NO** **Repair:** Repair or replace as needed. Contact an authorized OEM service location.	Repair complete

STEP 5N: Check the engine-to-transmission torsional coupling.

Condition:
- None.

Action	Specification/Repair	Next Step
Check the engine-to-transmission torsional coupling. N/A	Torsional coupling incorrect or worn? **YES** **Repair:** Replace the coupling. Contact an authorized OEM service location.	Repair complete
	Torsional coupling incorrect or worn? **NO**	5O

STEP 5O: **Check the rudder.**

Condition:

None.

Action	Specification/Repair	Next Step
Check the rudder for excessive play in the rudder post. N/A	Rudder have excessive play in the rudder post? **YES** **Repair:** Repair or replace as needed. Contact an authorized OEM service location.	Repair complete
	Rudder have excessive play in the rudder post? **NO**	5P

STEP 5P: **Check the engine flywheel housing-to-cylinder block alignment.**

Condition:
- None.

Action	Specification/Repair	Next Step
Check the engine flywheel housing-to-cylinder block alignment. N/A	Flywheel housing alignment incorrect? **YES** **Repair:** Align the flywheel housing to cylinder block. Reference Procedure 016-006 in Section 16 of the appropriate service manual.	Repair complete
	Flywheel housing alignment incorrect? **NO** **Repair:** The engine can possibly have internal damage that has **not** been detected. Analyze the oil and inspect the filters to locate an area of probable damage. Reference Procedure 007-083 in Section 7 of the appropriate service manual. The engine can possibly need to be rebuilt. Reference Procedure 000-001 in Section 0 of the appropriate service manual and the engine rebuild specifications in the appropriate service manual. If the engine is **not** damaged, the problem can possibly be the vessel design. Contact an authorized OEM service location.	Repair complete

Notes

Section DS - Engine Disassembly - Group 00

Section Contents

Page
Air Compressor DS-26
Remove....DS-26
Air Compressor Coolant Lines DS-25
Remove....DS-25
Air Compressor Inlet Tube DS-25
Remove....DS-25
Air Inlet Connection DS-26
Remove....DS-26
Air Intake Connection DS-26
Remove....DS-26
Camshaft Cover Plate DS-33
Remove....DS-33
Camshaft Position Sensor DS-12
Remove....DS-12
Charging System Alternator DS-17
Remove....DS-17
Charging System Alternator Automatic Belt Tensioner DS-16
Remove....DS-16
Charging System Alternator Bracket DS-17
Remove....DS-17
Charging System Alternator Drive Belt DS-15
Remove....DS-15
Coolant Thermostat DS-18
Remove....DS-18
Coolant Thermostat Housing DS-18
Remove....DS-18
Cooling Fan Belt Tensioner DS-16
Remove....DS-16
Crankcase Breather Tube DS-6
Remove....DS-6
Crankshaft Position Sensor DS-11
Remove....DS-11
Crankshaft Pulley DS-29
Remove....DS-29
Crosshead DS-32
Remove....DS-32
Cylinder Head DS-35
Remove....DS-35
Cylinder Head Gasket DS-36
Remove....DS-36
Drive Belt, Cooling Fan DS-15
Remove....DS-15
Engine Control Module DS-14
Remove....DS-14
Engine Control Module Mounting Bracket DS-14
Remove....DS-14
Engine Coolant Temperature Sensor DS-11
Remove....DS-11
Engine Lifting Brackets DS-23
Remove....DS-23
Engine Oil Pressure Sensor/Switch DS-12
Remove....DS-12
Engine Oil Temperature Sensor DS-12
Remove....DS-12
Engine Removal DS-1
Remove....DS-1
Engine Wiring Harness DS-7

Remove....DS-7
Exhaust Gas Pressure Sensor DS-13
Remove....DS-13
Exhaust Gas Pressure Sensor Tube DS-13
Remove....DS-13
Exhaust Manifold, Dry DS-23
Remove....DS-23
Exhaust Pressure Regulator DS-22
Remove....DS-22
Fan Hub, Belt Driven DS-18
Remove....DS-18
Fan Pulley DS-18
Remove....DS-18
Flywheel DS-37
Remove....DS-37
Flywheel Housing DS-37
Remove....DS-37
Fuel Drain Lines DS-27
Remove....DS-27
Fuel Filter Head DS-28
Remove....DS-28
Fuel Pump DS-28
Remove....DS-28
Fuel Rail DS-28
Remove....DS-28
Fuel Rail Supply Line (High Pressure) DS-3
Remove....DS-3
Fuel Supply Lines DS-27
Remove....DS-27
Idler Gear, Camshaft Rear DS-38
Remove....DS-38
Injector DS-31
Remove....DS-31
Injector Supply Lines (High Pressure) DS-28
Remove....DS-28
Intake Manifold Pressure/Temperature Sensor DS-11
Remove....DS-11
Internal Actuator Wiring Harness DS-30
Remove....DS-30
Lubricating Oil Cooler Housing DS-24
Remove....DS-24
Lubricating Oil Dipstick Tube DS-5
Remove....DS-5
Lubricating Oil Fill Tube DS-5
Remove....DS-5
Lubricating Oil Filter (Spin-On) DS-4
Remove....DS-4
Lubricating Oil Pan DS-29
Remove....DS-29
Lubricating Oil Pump DS-30
Remove....DS-30
Overhead Camshaft Gear, Valve DS-33
Remove....DS-33
Overhead Camshaft Timing Speed Ring DS-32
Remove....DS-32
Overhead Camshaft, Valve DS-34
Remove....DS-34
Pressure Fuel Filter DS-4
Remove....DS-4
Refrigerant Compressor DS-17
Remove....DS-17
Rocker Lever Assembly DS-32
Remove....DS-32
Rocker Lever Cover DS-30

Remove.....DS-30
Starting Motor.....DS-24
Remove.....DS-24
Turbocharger.....DS-23
Remove.....DS-23
Turbocharger Compressor Intake Pressure/Temperature Sensor.....DS-13
Remove.....DS-13
Turbocharger Coolant Hoses.....DS-20
Remove.....DS-20
Turbocharger Oil Drain Line.....DS-20
Remove.....DS-20
Turbocharger Oil Supply Line.....DS-19
Remove.....DS-19
Vibration Damper, Viscous.....DS-29
Remove.....DS-29
Water Pump Cartridge.....DS-19
Remove.....DS-19

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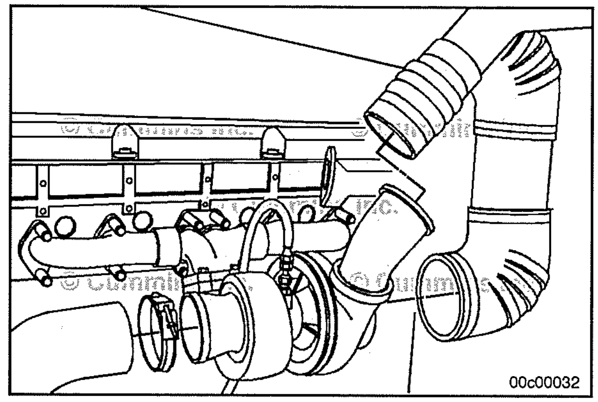
Engine Removal (000-001)

Remove

Disconnect the intake and the exhaust air pipes.

Disconnect all chassis-mounted, engine-driven accessories.



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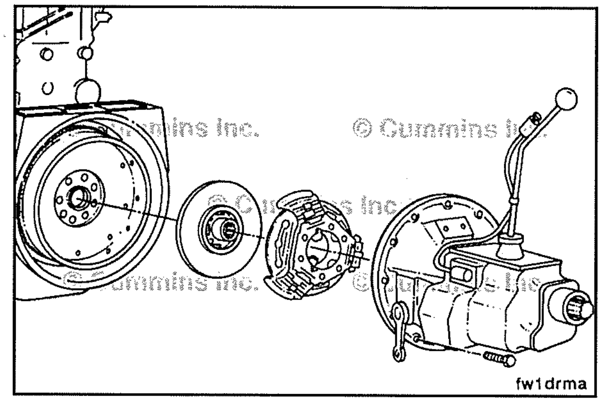
Disconnect the drive units from the flywheel.



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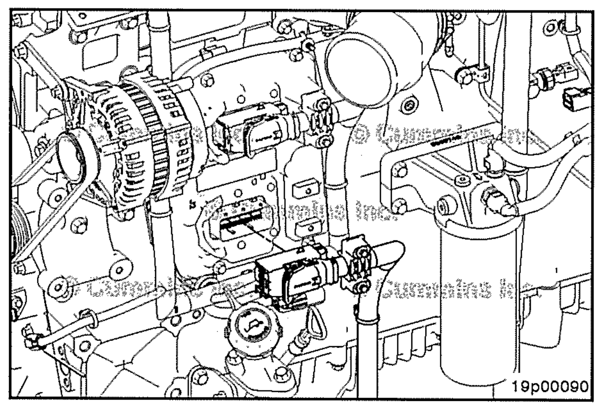
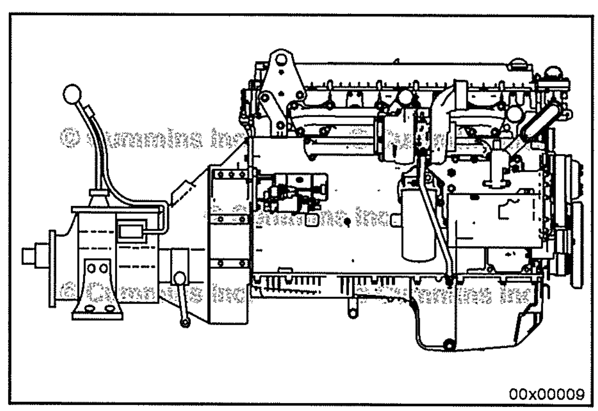
Disconnect the OEM wiring harness from the engine control module (ECM). Refer to Procedure 019-071 in Section 19.



19p00090

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

Most cab-over configuration vehicles will have the Cummins Inc. factory-installed rear engine lifting bracket still installed.



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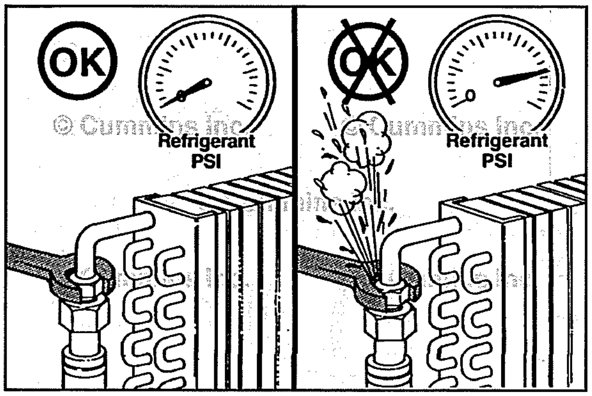
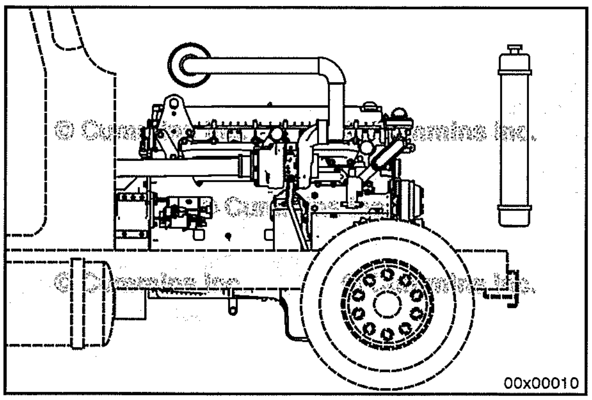
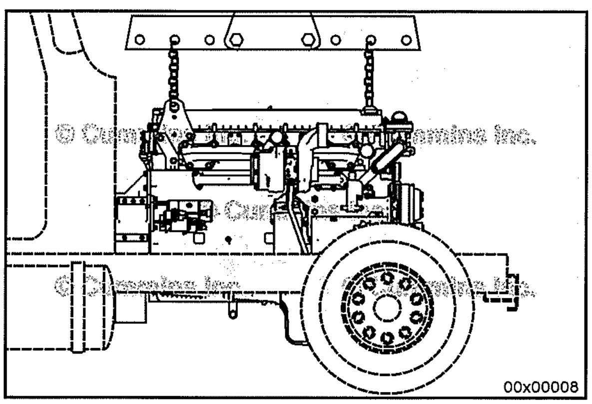


WARNING
If a liquid refrigerant system (air conditioning) is used, wear eye and face protection, and wrap a cloth around the fittings before removing. Liquid refrigerant can cause serious eye and skin injuries.

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



Remove all chassis components necessary to remove the engine.



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 [51 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

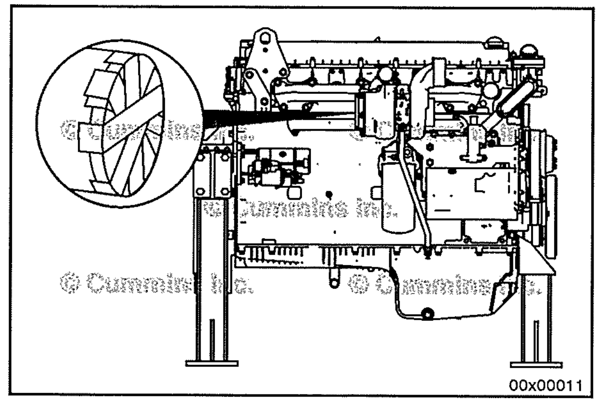
Use a correctly rated hoist, and attach the engine lifting fixture, Part Number 3162871, to the engine-mounted lifting brackets to remove the engine.

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

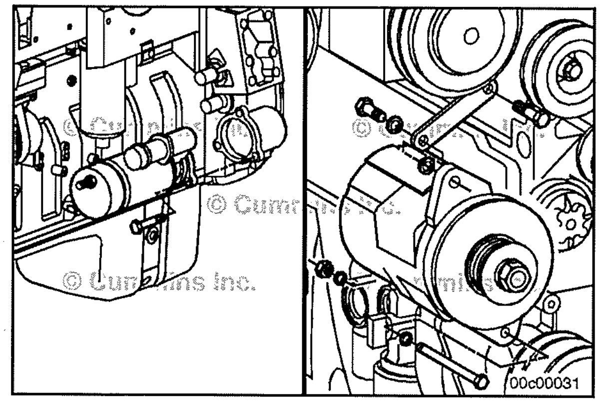
Remove the engine.

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

Place the engine on suitable engine support stands.



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

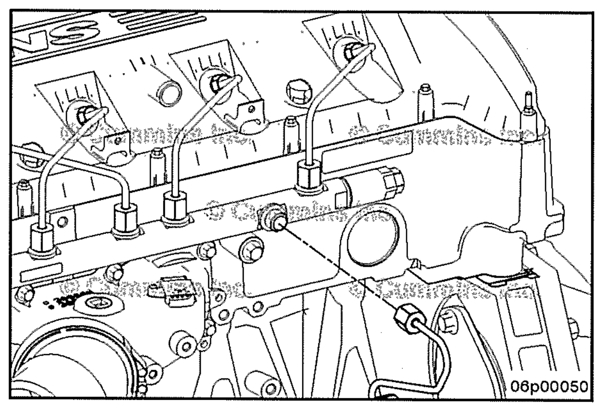


Fuel Rail Supply Line (High Pressure) (006-071)

Remove

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

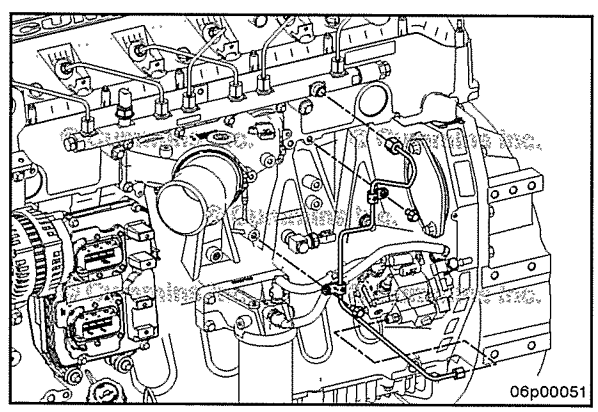
Disconnect the high-pressure fuel rail supply line.

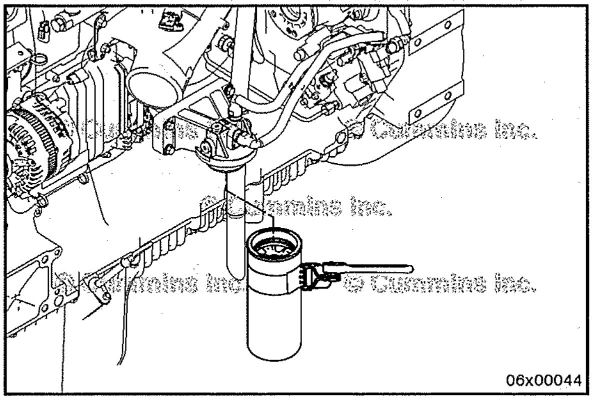


Remove the fuel rail supply line clamps.

NOTE: Do **not** bend, pry, or kink the fuel rail supply line during removal.

Remove the fuel rail supply line.





Pressure Fuel Filter (006-065)

Remove

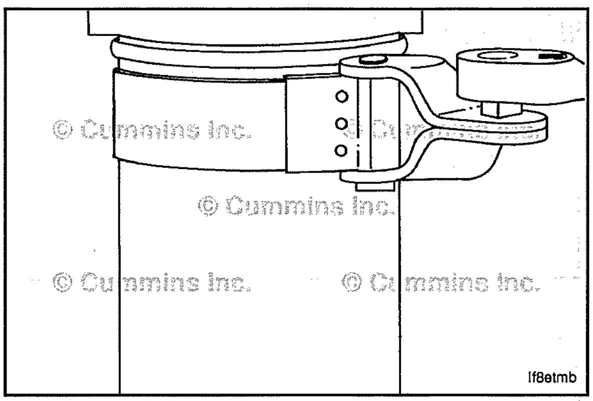
⚠WARNING⚠

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

Remove fuel filter with filter wrench, Part Number 3400157.

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

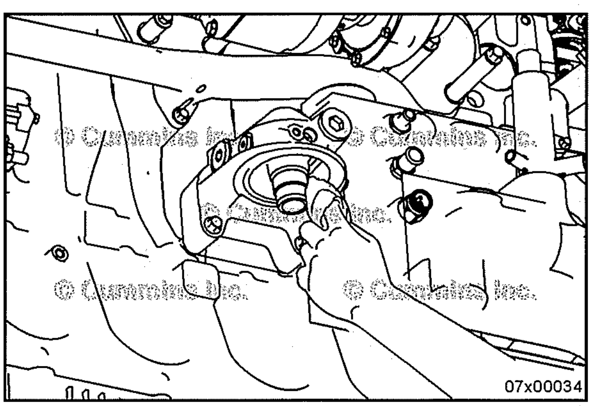
Remove the ring with an o-ring pick, if necessary.



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

Remove

Use an oil filter wrench, Part Number 3400157, to remove the oil filter.

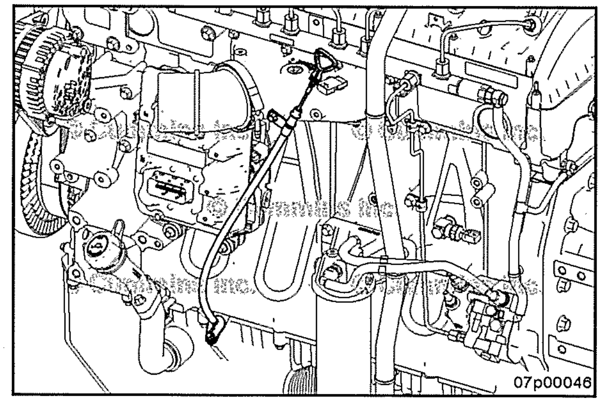


Clean the sealing surface of the filter head.

Lubricating Oil Dipstick Tube (007-011)

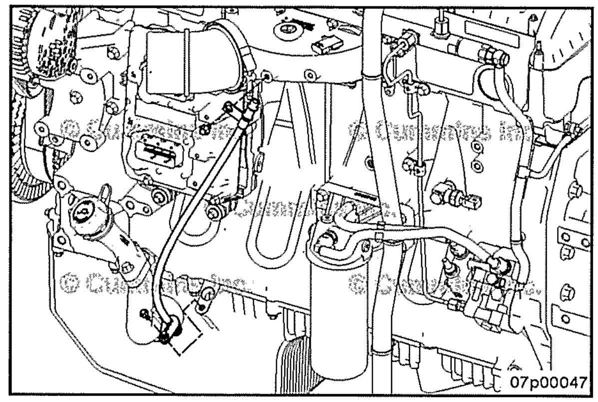
Remove

Remove the dipstick from the dipstick tube.

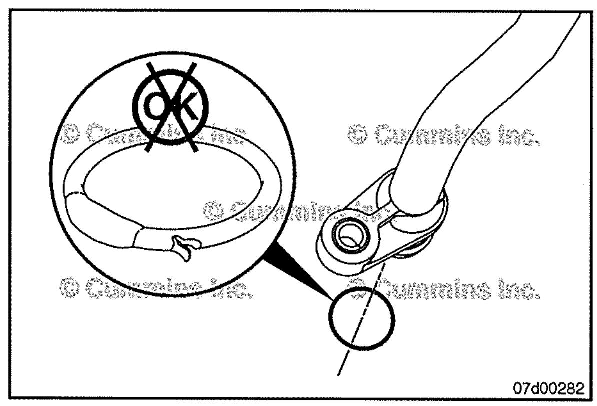


Remove the mounting capscrews that hold the dipstick tube to the oil pan and if necessary, the intake manifold.

Remove the dipstick tube.



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



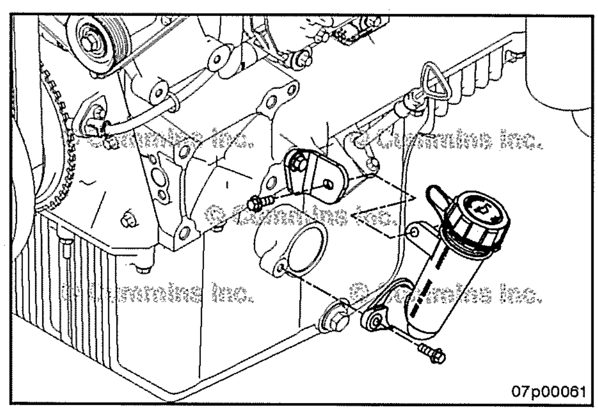
Lubricating Oil Fill Tube (007-065)

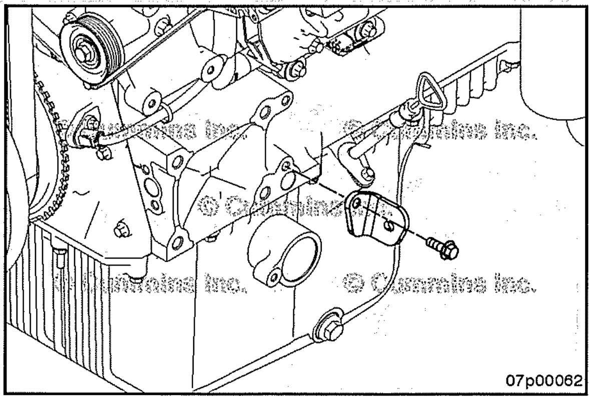
Remove

Remove the tube brace capscrew from the oil fill tube.

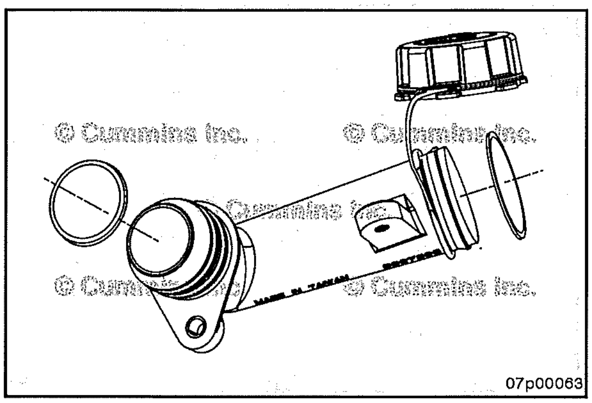
Remove the tube capscrew from the oil pan.

Remove the oil fill tube.





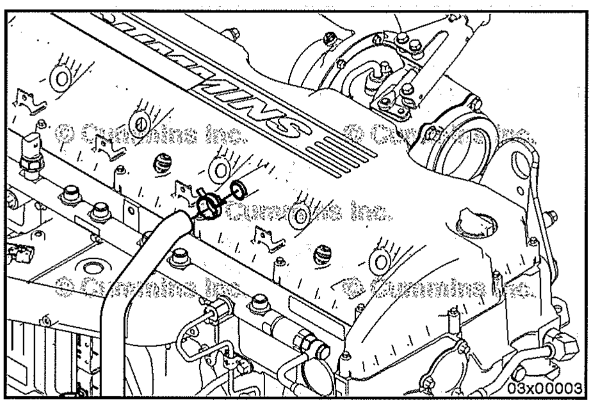
Remove the tube brace and capscrew from the block.



Remove the ring seals from the oil fill tube and the oil fill tube cap.

Discard the ring seals.

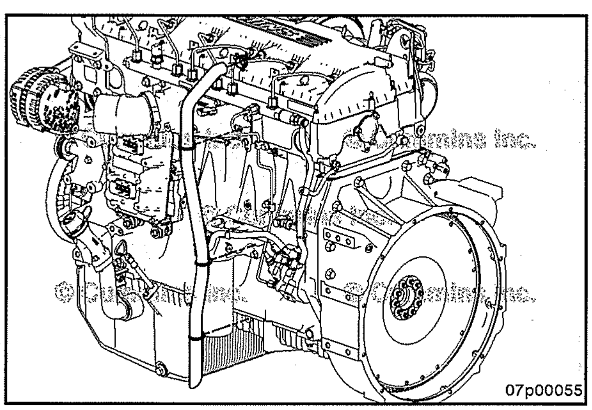
- Oil fill tube o-ring
- Oil fill cap seal



Crankcase Breather Tube (003-018)

Remove

Disconnect the crankcase breather vent tube from the rocker lever cover.



Remove the three fir tree clips securing the crankcase breather tube to the intake connection, cylinder block, and oil pan.

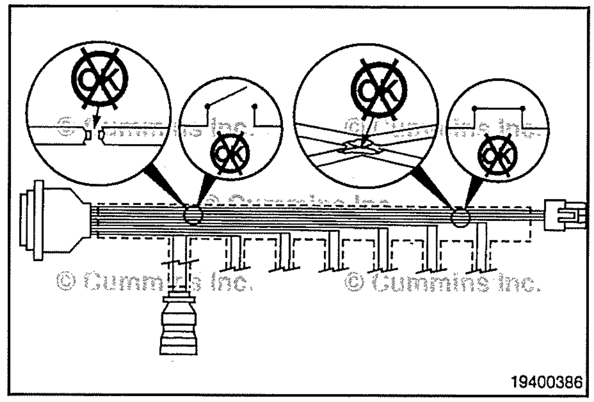
Remove the crankcase breather vent tube.

Engine Wiring Harness (019-043)

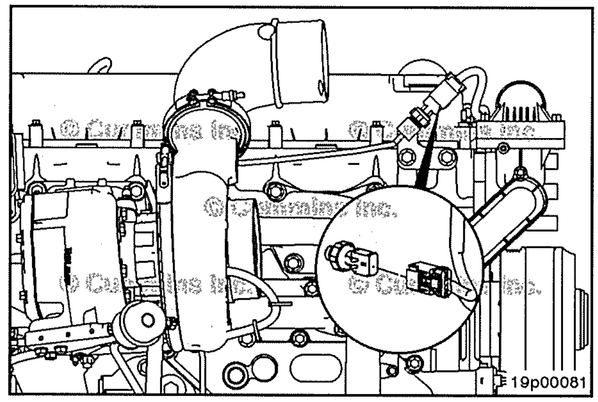
Remove

Replace the engine harness if there is an open or short circuit found under the protective covering of the harness body.

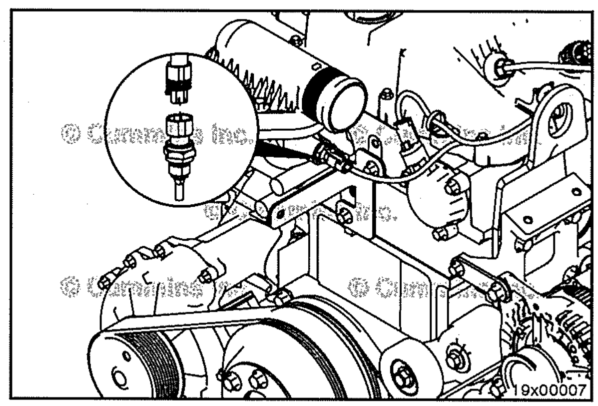
Damaged connectors can be replaced with service repair components.



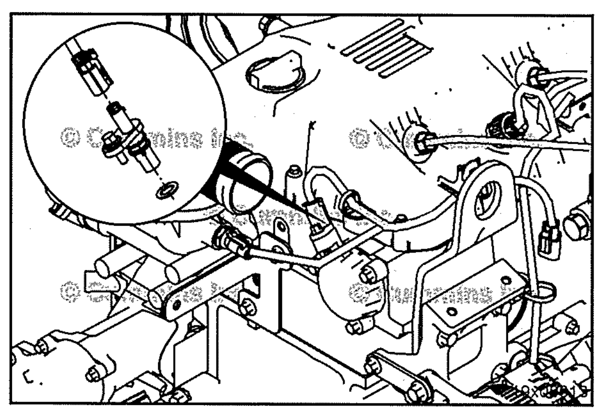
Disconnect the exhaust manifold pressure sensor electrical connector.

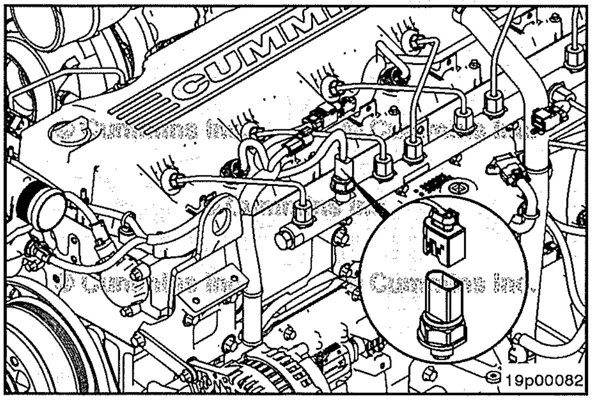


Disconnect the coolant temperature sensor electrical connector.

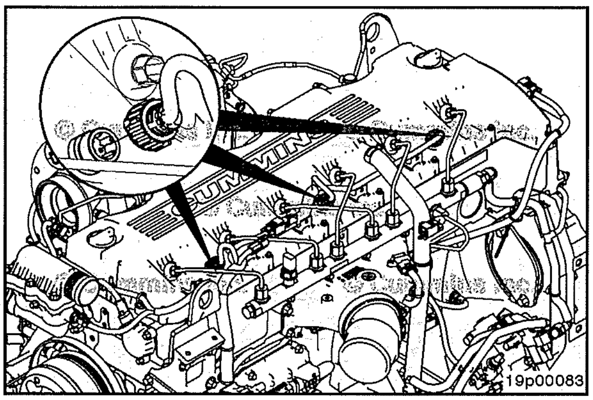


Disconnect the camshaft position sensor electrical connector.

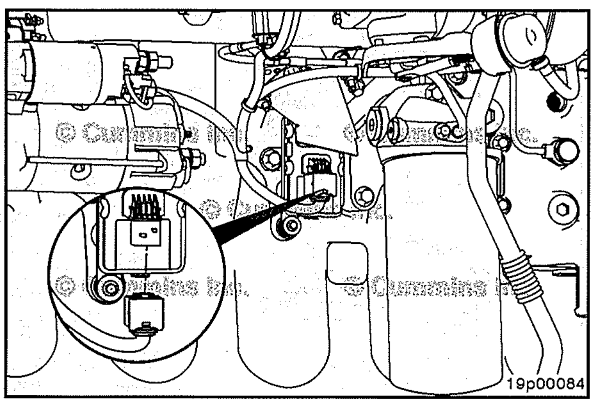




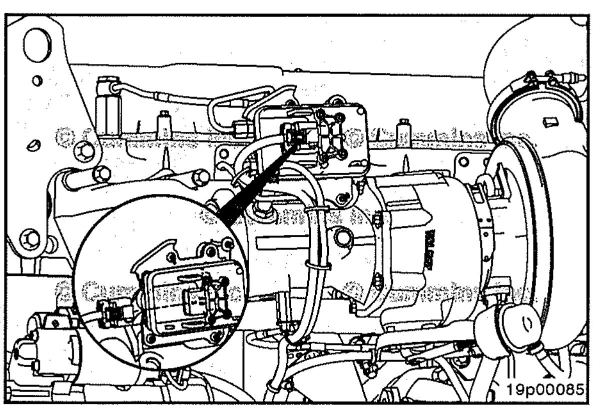
Disconnect the fuel rail pressure sensor electrical connector.



Disconnect the three injector passthrough electrical connectors.

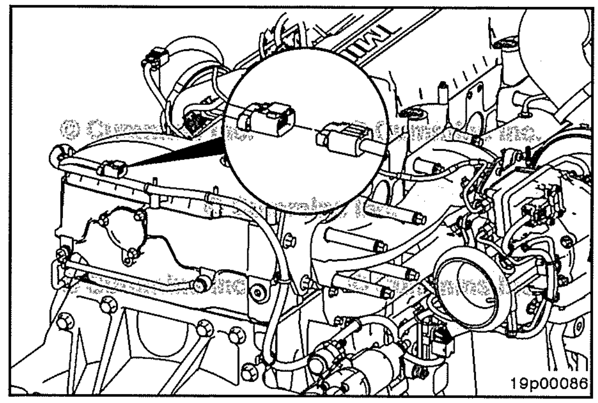


Disconnect aftertreatment intake NOx sensor electrical connector.

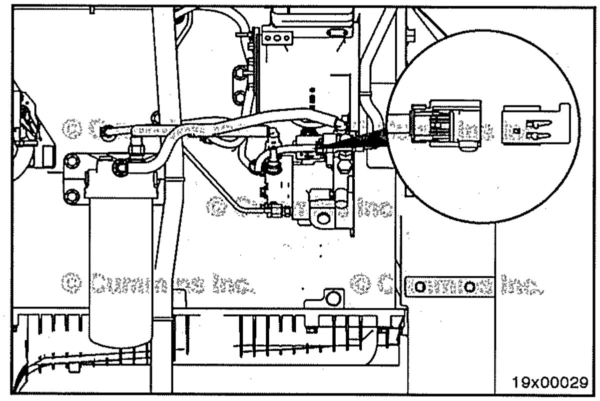


Disconnect exhaust pressure regulator electrical connector.

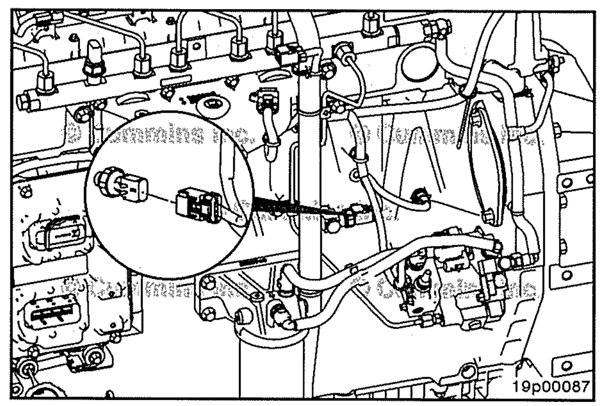
Disconnect temperature and barometric air pressure sensor at rear of head.



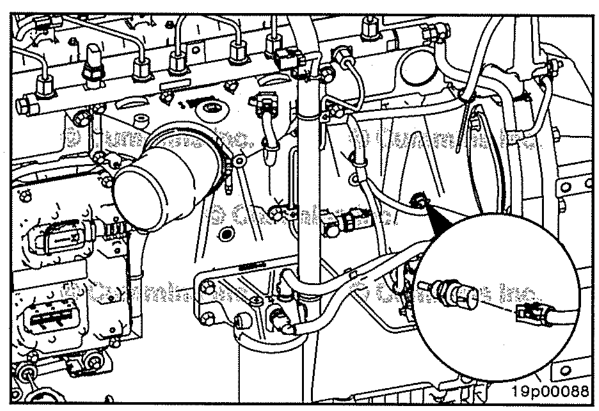
Disconnect the fuel pump actuator electrical connector.

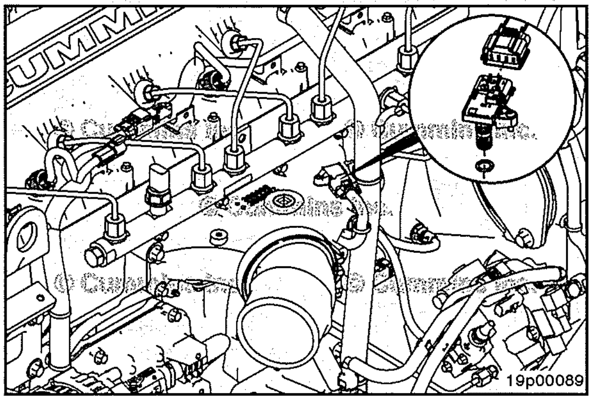


Disconnect the lubricating oil pressure sensor electrical connector.

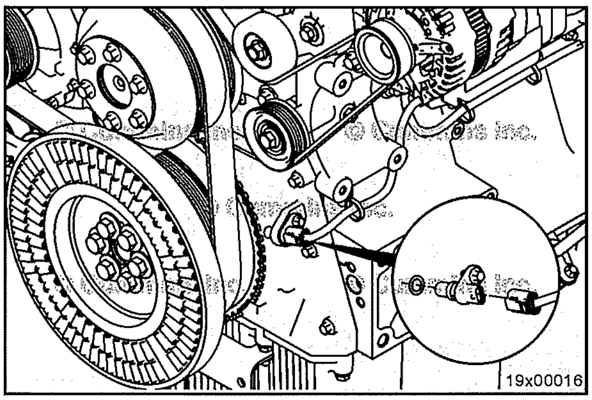


Disconnect the lubricating oil temperature sensor electrical connector.

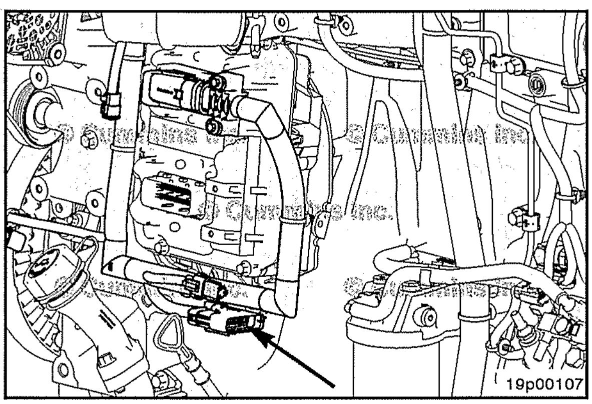




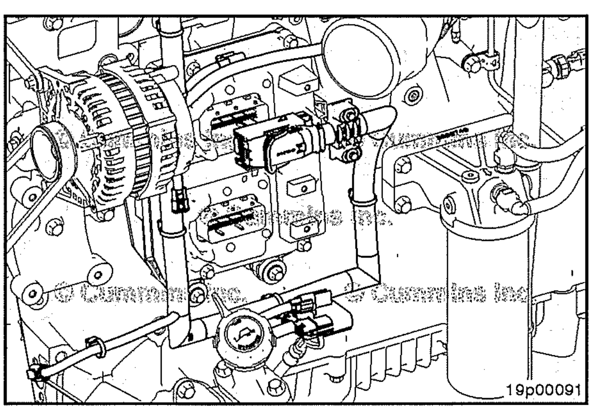
Disconnect the intake manifold temperature/pressure sensor electrical connector.



Disconnect the crankshaft position sensor electrical connector.



Disconnect OEM crossover connector.



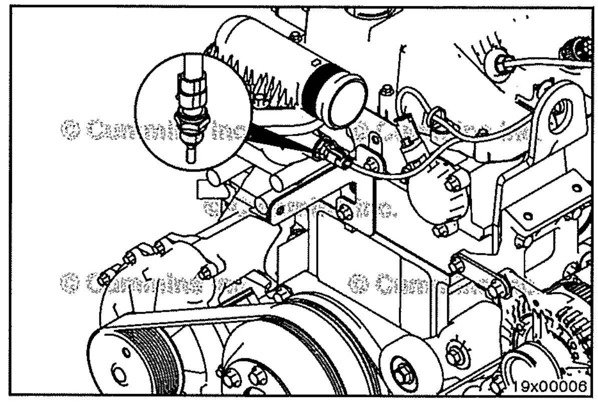
Disconnect engine wiring harness from ECM.

Remove the engine wiring harness from the engine.

Engine Coolant Temperature Sensor (019-019)

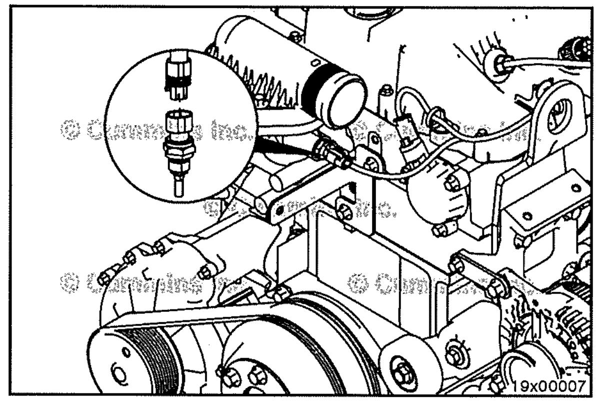
Remove

The coolant temperature sensor is located on the thermostat housing.



Lift up on the locking tab and pull the electrical connectors apart.

Remove the sensor.



Crankshaft Position Sensor (019-365)

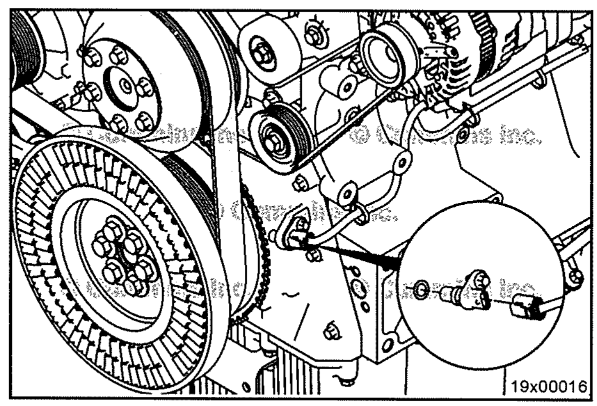
Remove

The crankshaft position sensor is located behind the vibration damper on the front of the engine.

Disconnect the sensor from the engine harness. Slide the locking tab to unlock the connector. Push down on the button toward the rear of the connector and disconnect it from the sensor.

Remove the capscrew that secures the sensor to the lubricating oil pump housing.

Remove the sensor from the mounting location.



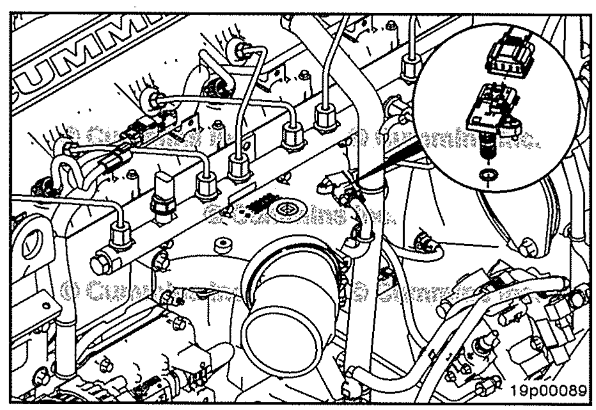
Intake Manifold Pressure/Temperature Sensor (019-159)

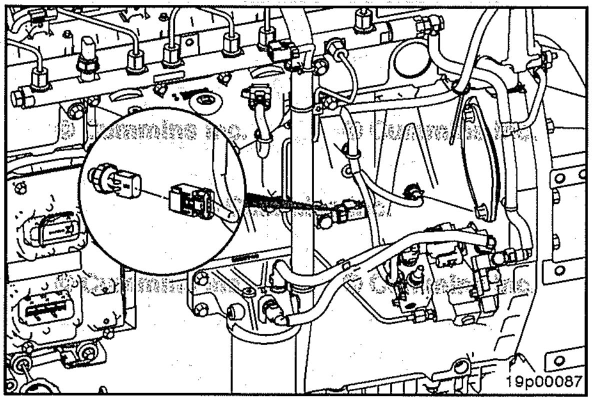
Remove

Lift up on the locking tab and pull the electrical connectors apart.

Remove the capscrew.

Remove the sensor from the engine by pulling straight up on the sensor. Be careful **not** to damage the o-ring seal or the plastic cage surrounding the sensor tip when removing the sensor. Do **not** pry the sensor, as damage to the plastic cage can occur.





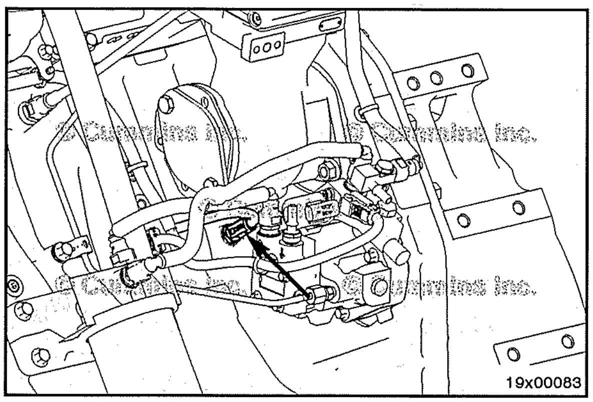
Engine Oil Pressure Sensor/Switch (019-066)

Remove

The engine oil pressure sensor is located on the left (intake) side of the engine near the fuel pump.

Disconnect the engine wiring harness from the engine oil pressure sensor.

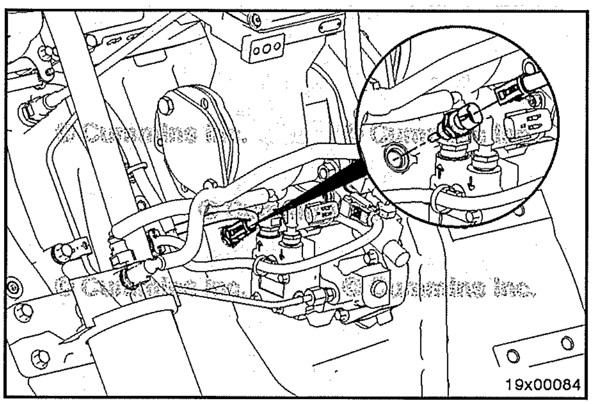
Remove the engine oil pressure sensor.



Engine Oil Temperature Sensor (019-067)

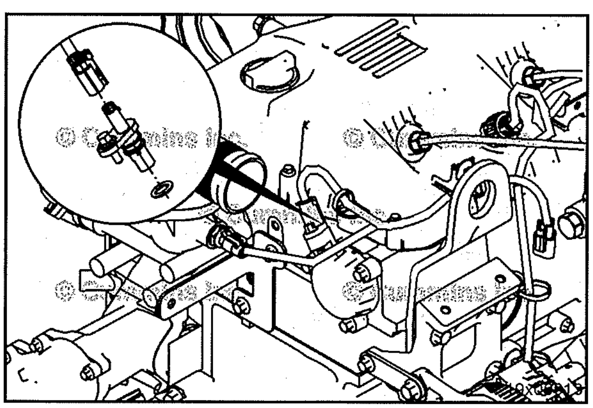
Remove

The engine oil temperature sensor is located on the left (intake) side of the engine. It is located on the engine block, between the fuel pump and the air compressor.



Disconnect the engine wiring harness from the engine oil temperature sensor.

Remove the engine oil temperature sensor.



Camshaft Position Sensor (019-363)

Remove

The camshaft position sensor is located on the front of the cylinder head in the timing speed ring cover.

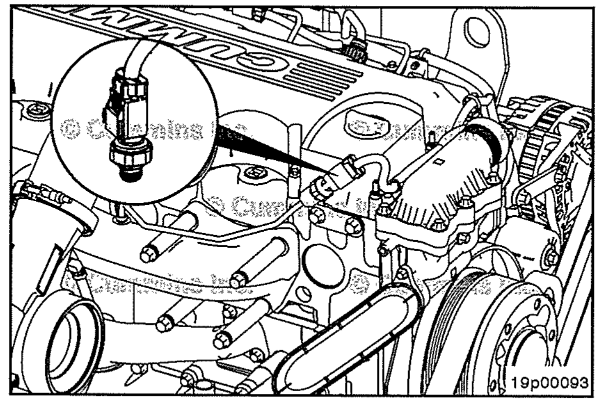
Disconnect the sensor from the engine harness.

Remove the camshaft speed sensor from the timing speed ring cover.

Exhaust Gas Pressure Sensor (019-376)

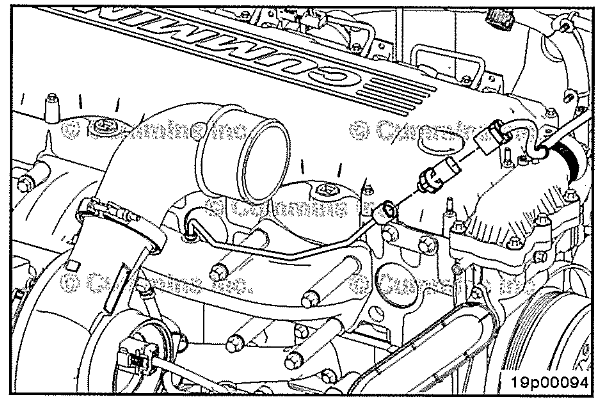
Remove

The exhaust gas pressure sensor is located near the thermostat housing.



Disconnect the wiring harness connector.

Remove the sensor.



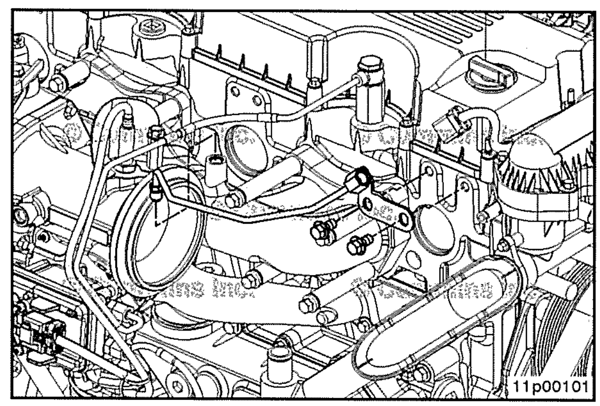
Exhaust Gas Pressure Sensor Tube (011-027)

Remove

Loosen the tube nuts at the exhaust manifold.

Remove capscrews at cylinder head.

Remove the tube.



Turbocharger Compressor Intake Pressure/Temperature Sensor (019-466)

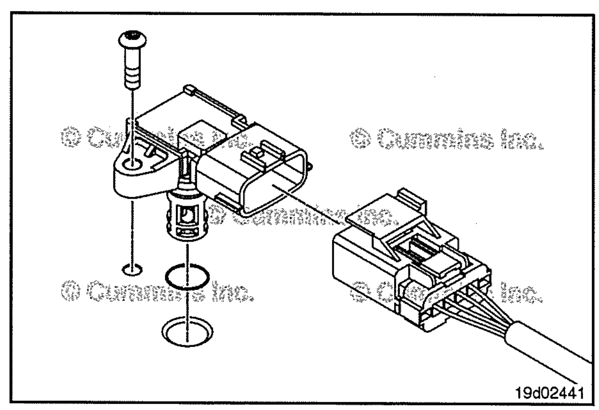
Remove

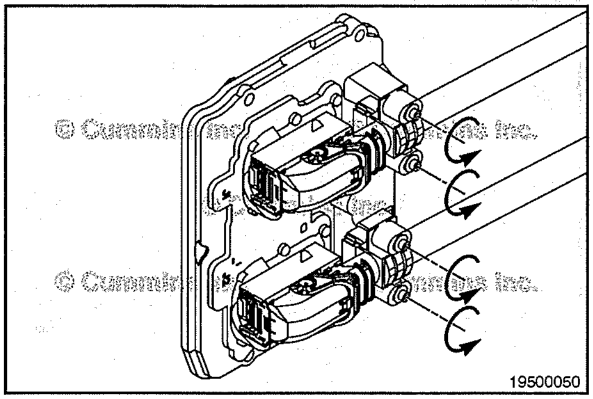
Disconnect the sensor connector from the engine harness.

Remove the mounting capscrew.

Remove the sensor from the engine by pulling straight up on the sensor.

Be careful **not** to damage the o-ring when removing the sensor.





Engine Control Module (019-031)

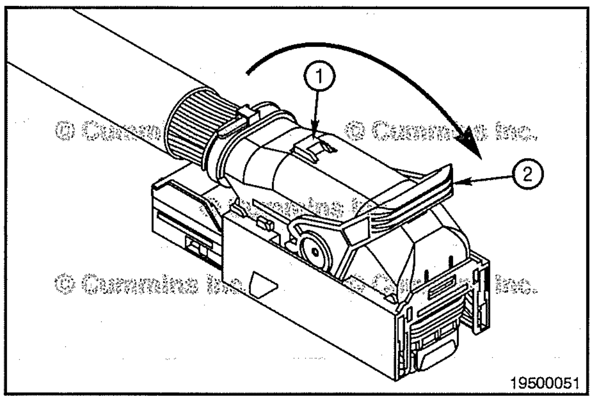
Remove

NOTE: Do **not** remove the ECM harness clamps from the wiring harnesses.

NOTE: Do **not** close the lever after the connector has been removed from the ECM. Attempting to do so may cause damage to the connector.

NOTE: Do **not** remove the wire tie from the ECM connector backshell.

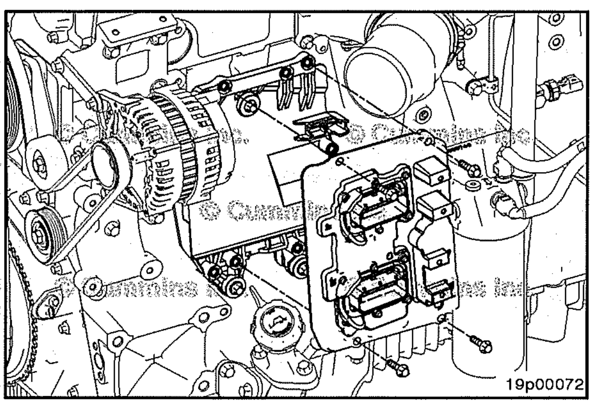
Loosen the ECM harness clamp capscrews on the engine wiring harness connector and the OEM wiring harness connector.



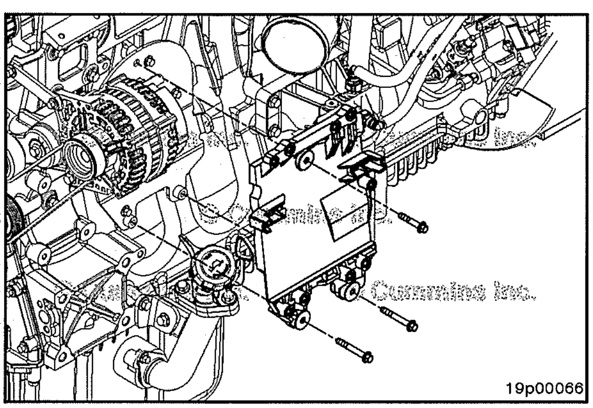
⚠CAUTION⚠

To prevent damage to the ECM connector backshell depress the locking tab prior to lifting the lever. Failure to do so will result in damage to the ECM connector backshell.

Disconnect the OEM harness connector and engine harness connector from the ECM by pressing down on the locking tab (1) and pulling up on the lever (2).



Remove the capscrews that secure the ECM to the ECM mounting plate.



Engine Control Module Mounting Bracket (019-421)

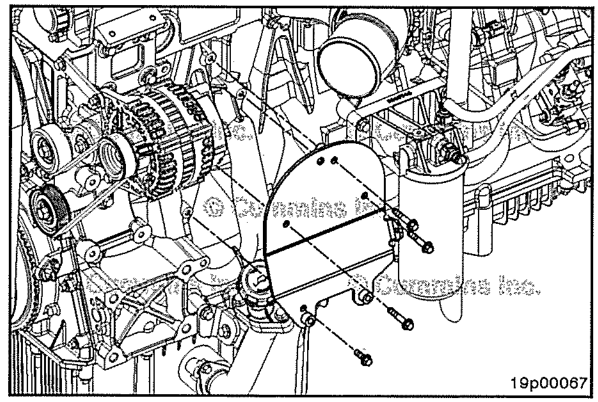
Remove

Remove capscrews.

Remove plastic ECM mounting bracket.

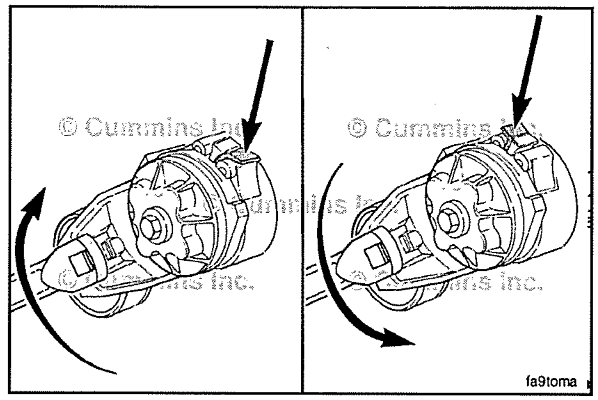
Remove capscrews.

Remove metal ECM mounting bracket.



Drive Belt, Cooling Fan (008-002)

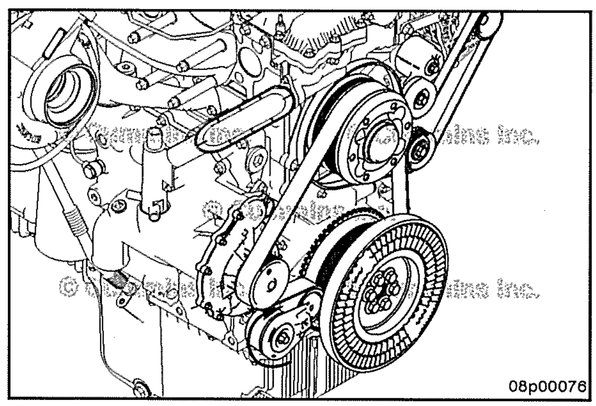
Remove



CAUTION

The belt tensioner is spring loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner or cause personal injury.

The belt tensioner winds in the direction that the spring tang is bent over the tensioner body. To loosen the tension on the belt, rotate the tensioner to wind the spring tighter.



CAUTION

Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to crack or break.

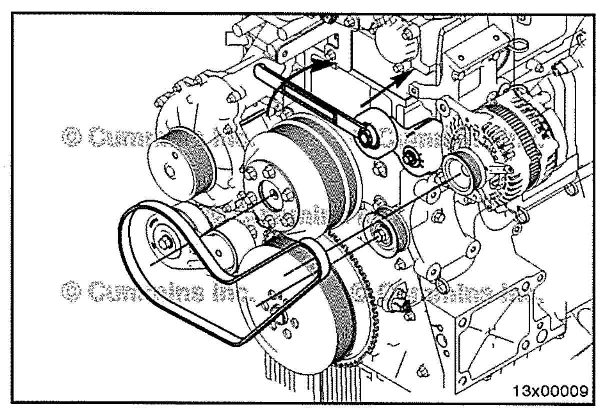
Make a diagram of the belt arrangement prior to removing the drive belt to aid in installation and provide proper routing of the cooling fan drive belt.

Pivot the tensioner in the direction of the spring tang to remove the drive belt.

Remove the drive belt.

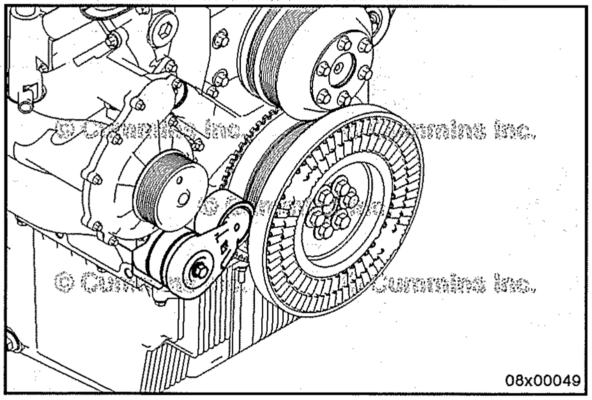
Charging System Alternator Drive Belt (013-005)

Remove



Use a socket and ratchet to rotate the tensioner pulley away from the belt until belt is loose enough to remove.

Remove the alternator belt while holding the tensioner and ratchet.



Cooling Fan Belt Tensioner (008-087)

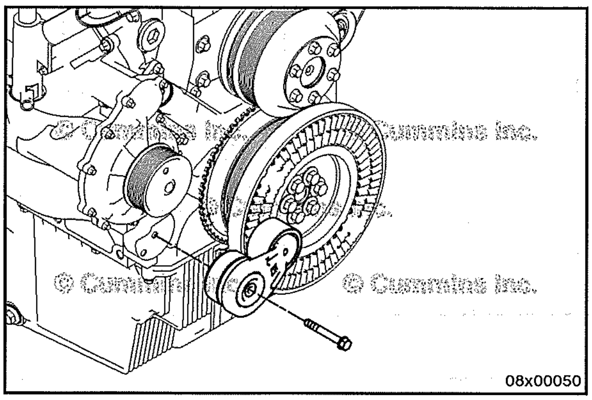
Remove

Remove the drive belt. Refer to Procedure 008-002 in Section 8.

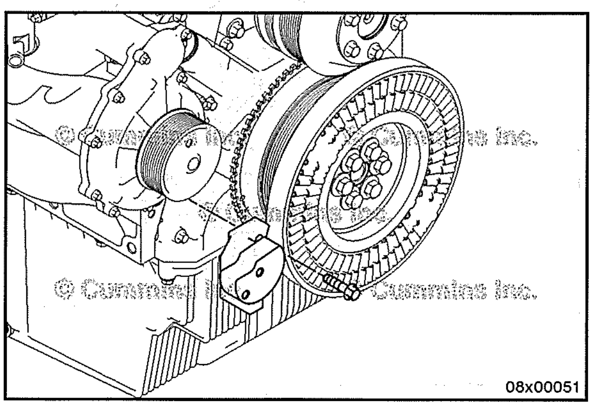
If the belt can be removed without pivoting the tensioner, then the spring in the tensioner has failed. Replace tensioner.

If the tensioner touches its internal stops while unloading the belt, the tensioner has failed. Replace the tensioner.

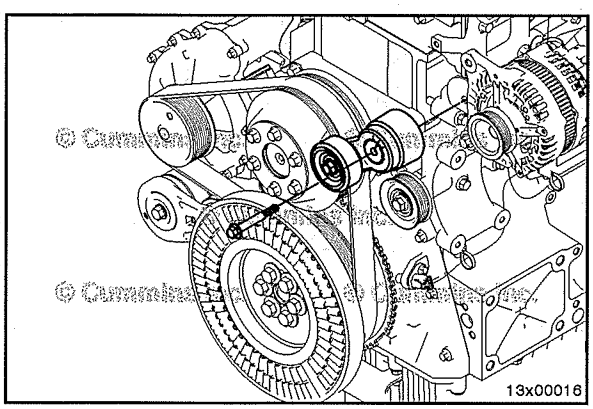
While tensioner is still on the engine, pivot the tensioner through the full range of motion. Tensioner **must** move with resistance from internal spring, if **not** replace tensioner.



Remove the capscrew and belt tensioner from the bracket.



Remove the capscrews and bracket from engine.



Charging System Alternator Automatic Belt Tensioner (013-021)

Remove

While tensioner is still on the engine, pivot the tensioner through the full range of motion. Tensioner **must** move with resistance from internal spring, if **not** replace tensioner.

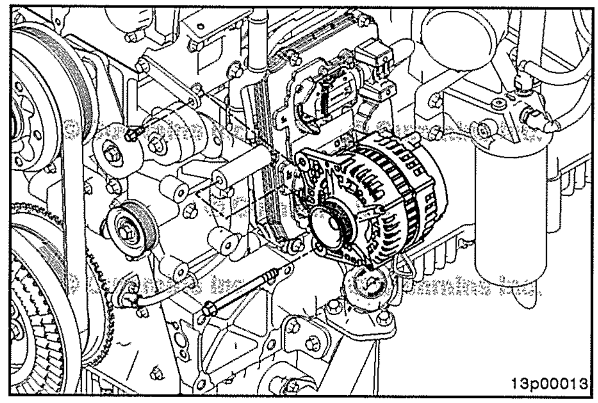
Remove the mounting capscrew and the belt tensioner from the bracket.

Charging System Alternator (013-001)

Remove

Remove the alternator top ear mounting capscrew (1).

Remove the alternator lower ear mounting capscrew (2) and alternator.

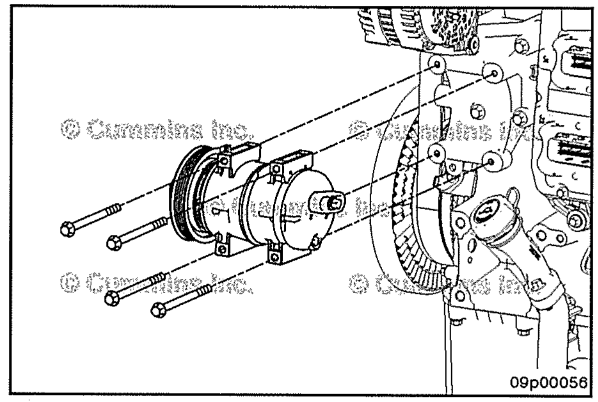


Refrigerant Compressor (009-051)

Remove

Remove the four refrigerant compressor mounting capscrews.

Remove the refrigerant compressor. See equipment manufacturer service information.

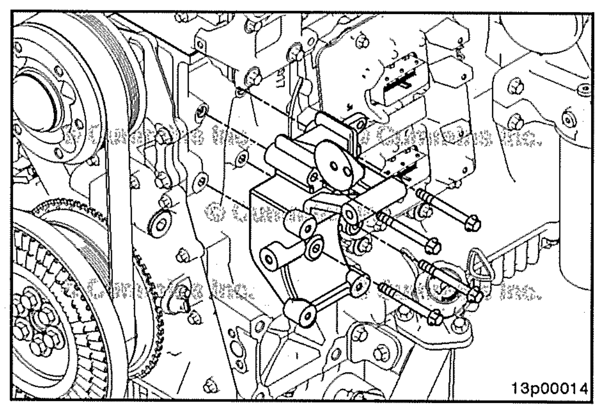


Charging System Alternator Bracket (013-003)

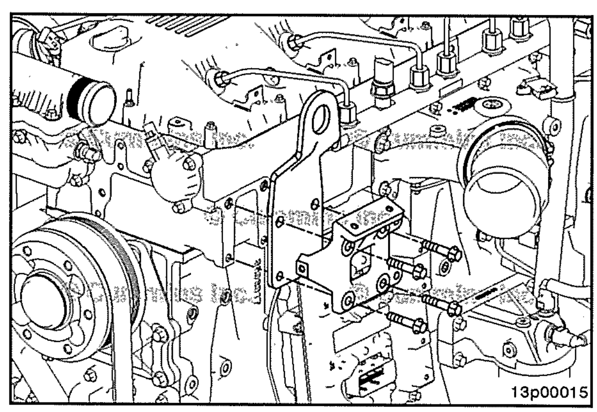
Remove

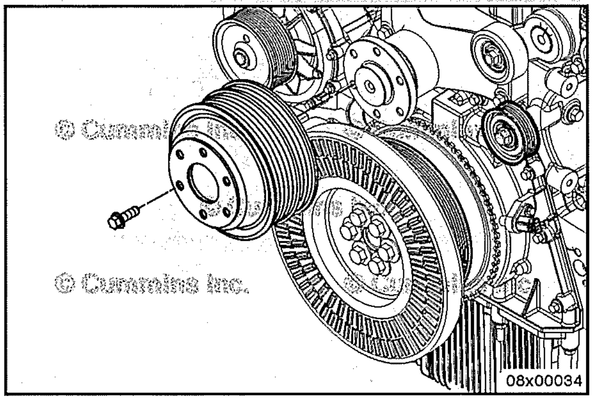
Remove the four alternator bracket mounting capscrews and remove the alternator mounting bracket.

NOTE: There are two dowel pins which are press fitted into the backside of the bracket at the top two mounting capscrews. Make sure these dowel pins stay in the bracket.



Remove the four accessory bracket mounting capscrews, accessory bracket and front lifting bracket.

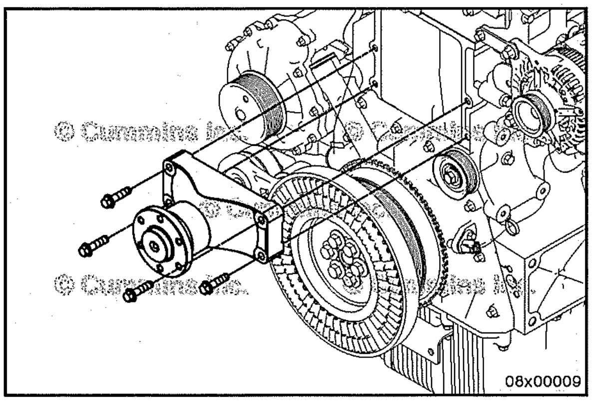




Fan Pulley (008-089)

Remove

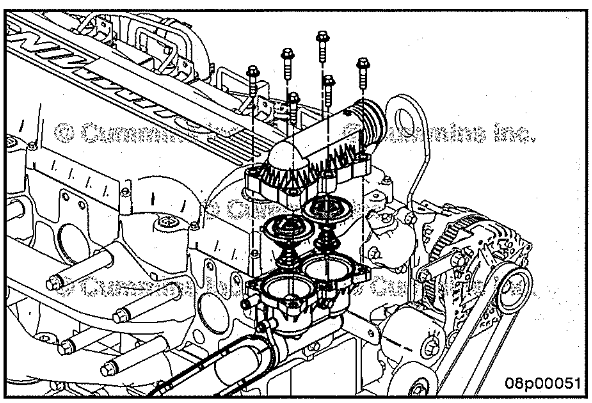
Remove the cooling fan and fan pulley by loosening the six fan pulley mounting capscrews.



Fan Hub, Belt Driven (008-036)

Remove

Remove the four capscrews and the fan support.



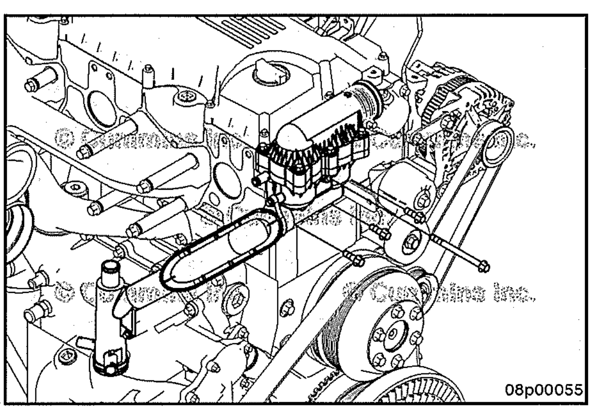
Coolant Thermostat (008-013)

Remove

Remove the water outlet connection capscrews.

Remove the water outlet connection.

Remove the thermostats.

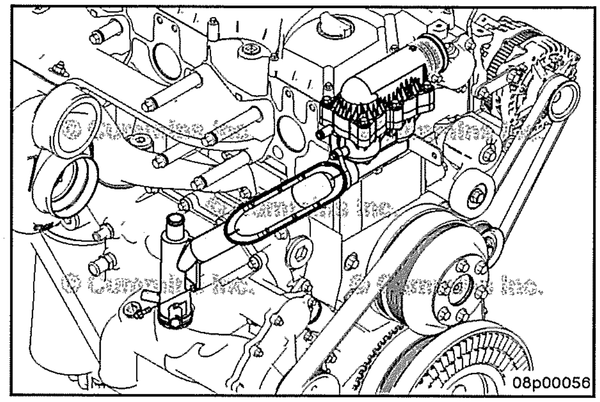


Coolant Thermostat Housing (008-014)

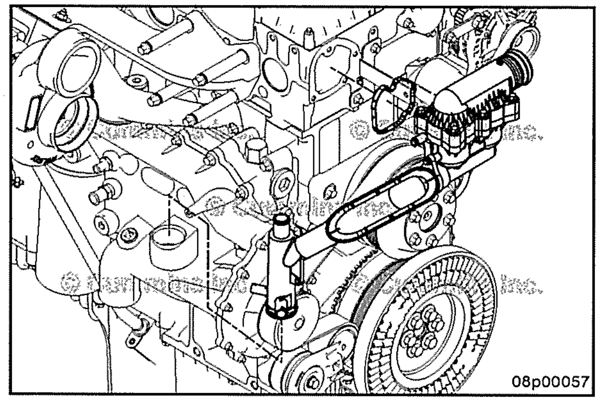
Remove

Remove the capscrews securing the thermostat housing to the cylinder head.

Remove the capscrew securing the coolant bypass tube to the lube oil cooler.



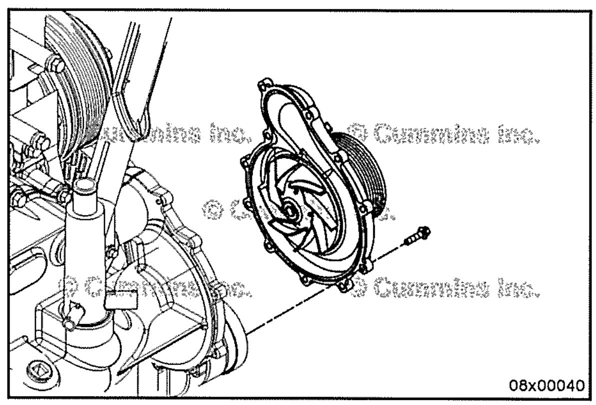
Lift and remove thermostat housing, coolant bypass tube, and coolant outlet connection assembly off of lube oil cooler.



Water Pump Cartridge (008-102)

Remove

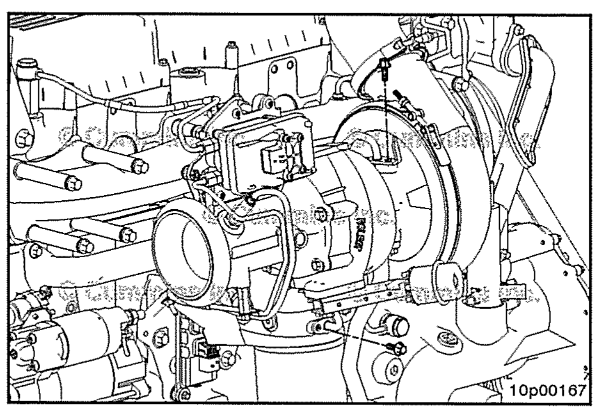
Remove the eleven mounting capscrews and the water pump cartridge from the front of the engine.

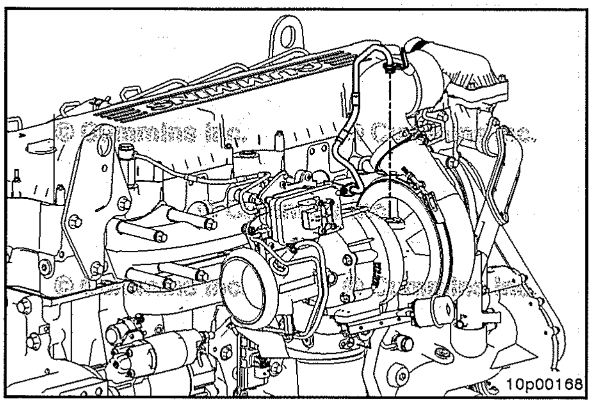


Turbocharger Oil Supply Line (010-046)

Remove

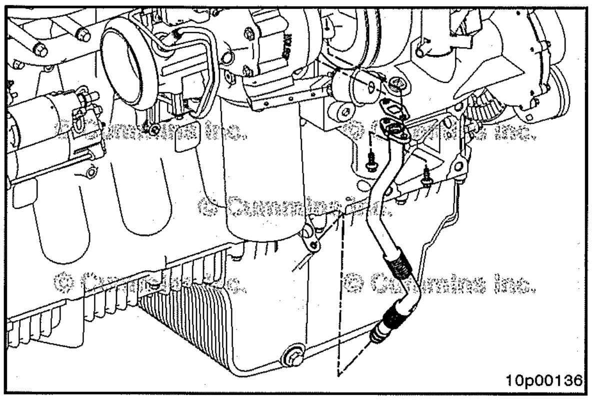
Remove the capcrews from the lubricating oil filter head and the turbocharger bearing housing.





Remove the turbocharger oil supply line from the lubricating oil filter head then the turbocharger bearing housing.

To prevent debris from entering the engine, install plugs into the open ports in the turbocharger and lubricating oil filter head from the clean care kit, Part Number 4919073.



Turbocharger Oil Drain Line (010-045)

Remove

⚠CAUTION⚠

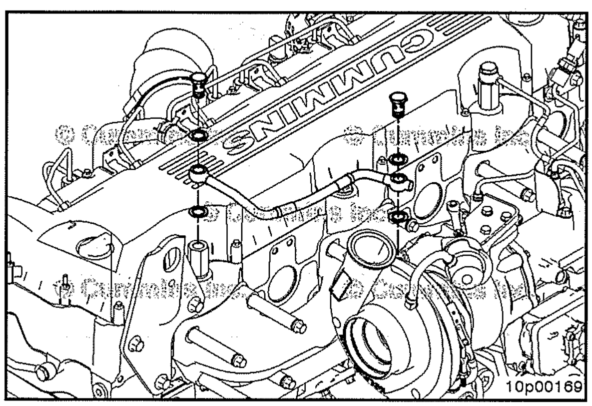
Be careful not to bend or kink the turbocharger oil drain line when removing the line. Doing so can damage the line. If the line is damaged upon removal it must be replaced.

Remove the turbocharger oil drain line from the turbocharger.

Remove and discard the gasket.

Grasp the turbocharger oil drain line at its base and pull oil drain line from the oil pan by hand.

NOTE: The turbocharger oil drain line can be rotated and pulled to assist in removal of the drain line.



Turbocharger Coolant Hoses (010-041)

Remove

Coolant Cooled Turbocharger

NOTE: Use a second wrench to hold the coolant line fitting while loosening the line.

Remove the turbocharger coolant return line retaining clips and mounting capscrews.

Remove the turbocharger coolant return line from the turbocharger and cylinder head.

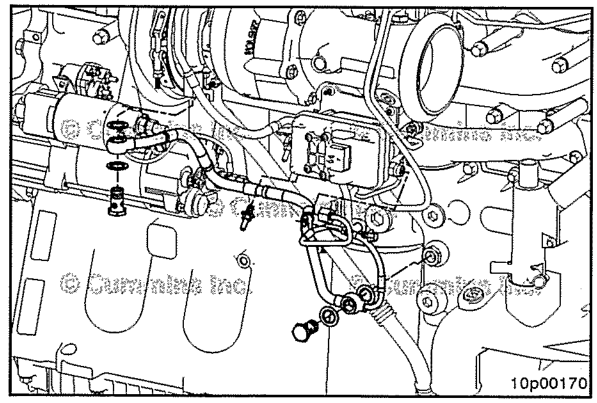
Discard the sealing washers.

NOTE: Use a second wrench to hold the coolant line fitting while loosening the line.

Remove turbocharger coolant supply line retaining clips and mounting capscrews.

Remove the turbocharger coolant supply line from the turbocharger, lubricating oil cooler module and the exhaust pressure regulator.

Discard the sealing washers.

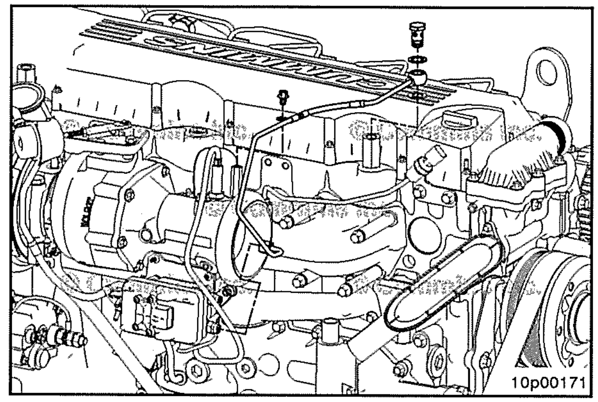


NOTE: Use a second wrench to hold the coolant line fitting while loosening the line.

Remove the exhaust pressure regulator coolant return line retaining clips and mounting capscrews.

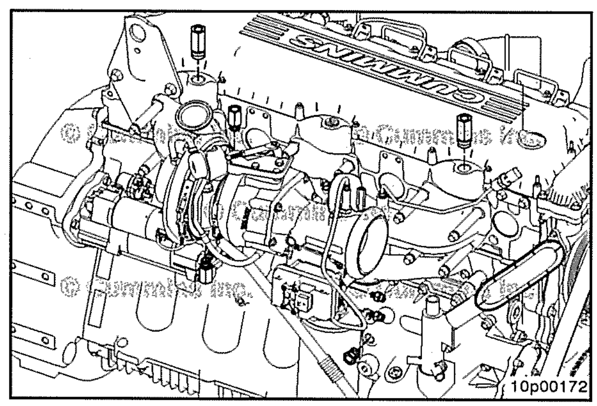
Remove the exhaust pressure regulator coolant return line from the cylinder head and exhaust pressure regulator.

Discard the sealing washers.



NOTE: Remove the coolant line fittings **only** if damaged or required by another part replacement.

If necessary, remove the coolant line fittings from the cylinder head, turbocharger, lubricating oil cooler module and exhaust pressure regulator.



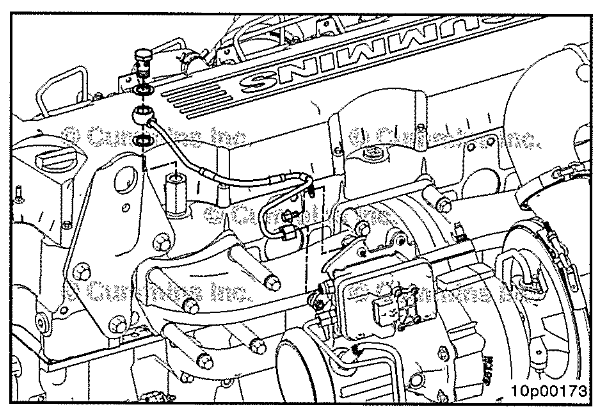
Non-coolant Cooled Turbocharger

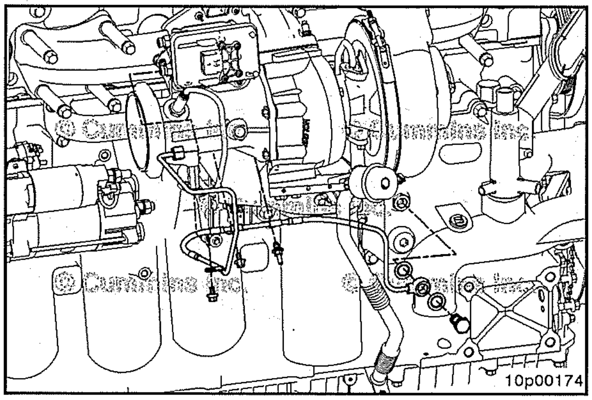
NOTE: Use a second wrench to hold the coolant line fitting while loosening the line.

Remove turbocharger coolant return line retaining clips and mounting capscrews.

Remove the turbocharger coolant return line from the turbocharger and cylinder head.

Discard the sealing washers.



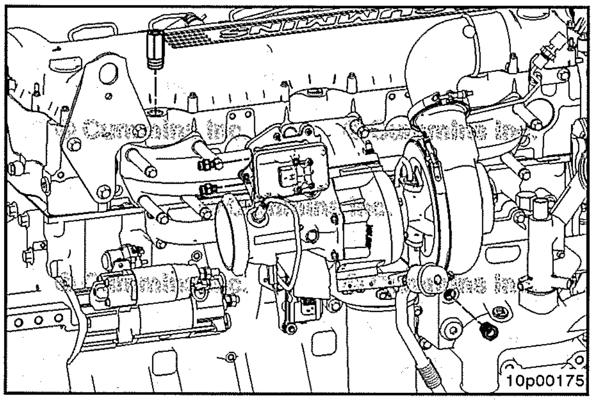


NOTE: Use a second wrench to hold the coolant line fitting while loosening the line.

Remove turbocharger coolant supply line retaining clips and mounting capscrews.

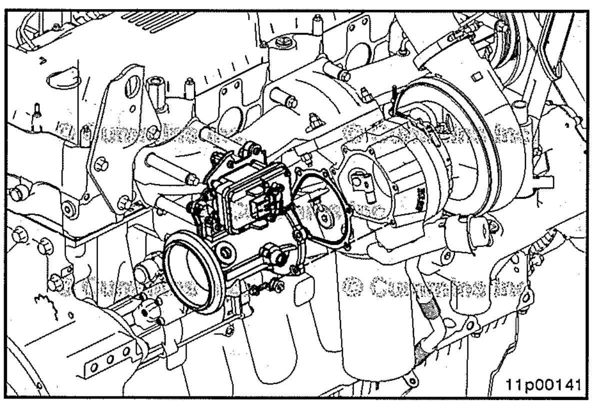
Remove the turbocharger coolant supply line from the turbocharger and the lubricating oil cooler housing.

Discard the sealing washers.



NOTE: Remove the coolant line fittings **only** if damaged or required by another part replacement.

If necessary, remove the coolant line fittings from the cylinder head, lubricating oil cooler module and exhaust pressure regulator.



Exhaust Pressure Regulator (011-105)

Remove

Remove the exhaust pressure regulator and gasket from the turbocharger.

Discard the gasket.

Turbocharger (010-033)

Remove

⚠WARNING⚠

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

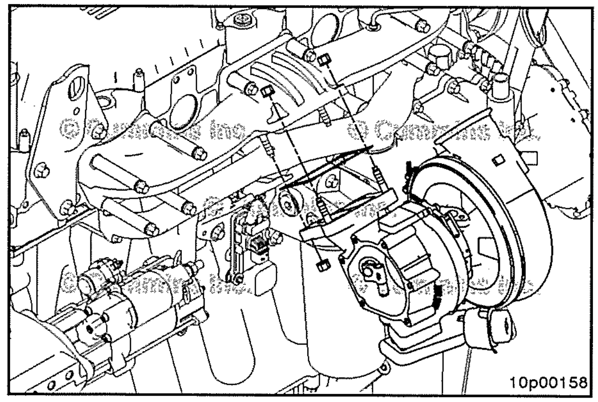
Spray penetrating oil Part Number 2892116, or equivalent on the four turbocharger mounting nuts and let soak for five minutes before trying to remove the nuts.

NOTE: If the turbocharger mounting nuts do **not** loosen freely, split the nuts to avoid breaking a mounting stud.

Remove the four turbocharger mounting nuts.

Remove the turbocharger and discard the gasket.

Cover the opening on the exhaust manifold with heavy tape from Air Handling Clean Care Kit, Part Number 4919588.



Exhaust Manifold, Dry (011-007)

Remove

NOTE: The four center capscrews and spacers are a different length than the eight outer capscrews. Take note of this difference.

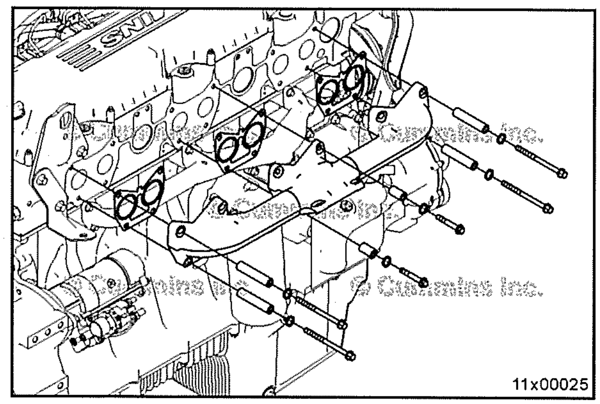
Remove the two upper capscrews, lock washers, and spacers from the end sections of the exhaust manifold and install two guide pins, Part Number 3376488.

NOTE: To make guide pins remove the hexagon head from exhaust manifold mounting capscrews.

Remove the remaining capscrews, lock washers, spacers, exhaust manifold, and gaskets.

Discard the gaskets.

NOTE: Apply a thin coating of nickel-based high-temperature compound grease, Part Number 3824879 or equivalent, to the coarse threads of the manifold capscrews, after removal.



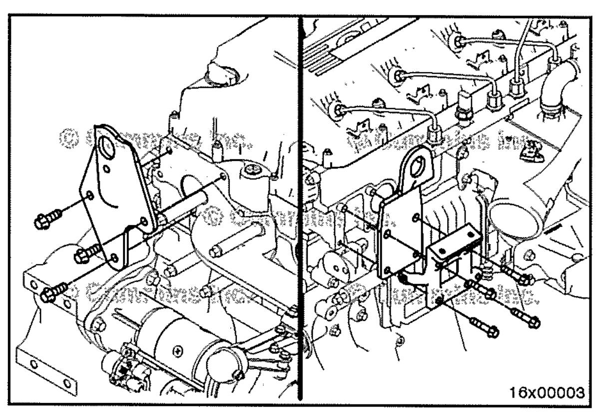
Engine Lifting Brackets (016-001)

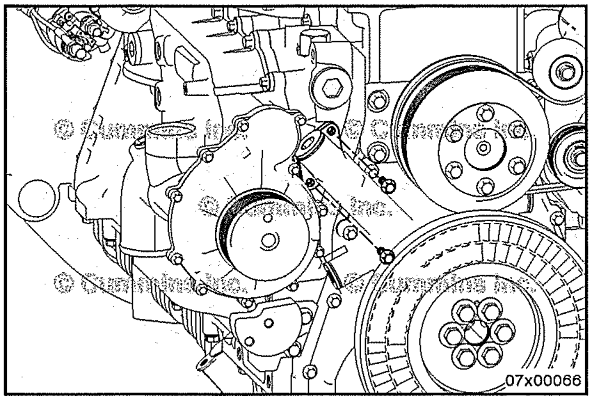
Remove

Remove the capscrews, spacer, and the rear lifting bracket.

Remove the accessory support bracket. Refer to Procedure 013-003 in Section 13.

Remove the front lifting bracket.

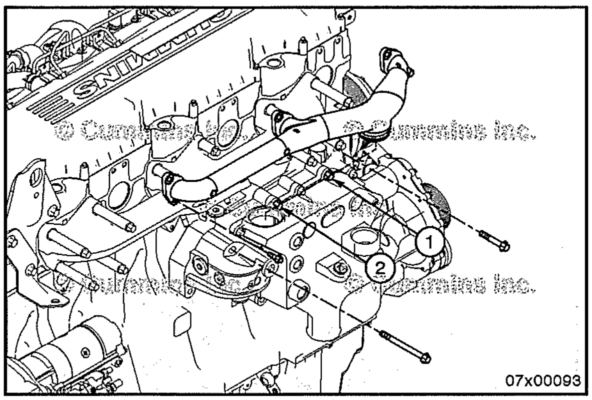




Lubricating Oil Cooler Housing (007-046)

Remove

Remove two capscrews securing lube oil transfer tube to lubricating oil cooler module. Slide lube oil transfer tube towards front of engine, into lube oil pump.



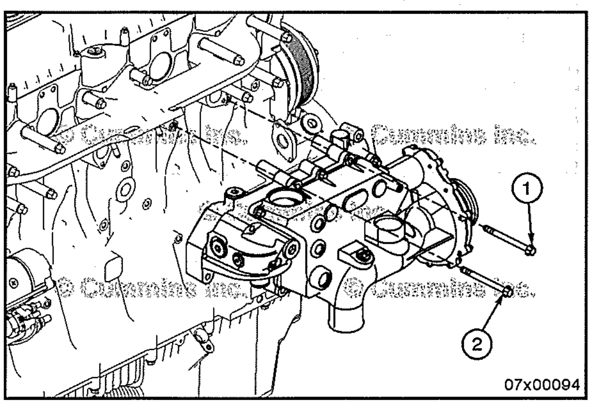
Loosen capscrews 1 and 2 first.

Remove remaining 13 capscrews holding lubricating oil cooler module and coolant manifold to block.

Rock lubricating oil cooler module and coolant manifold assembly away from block.

Remove coolant manifold.

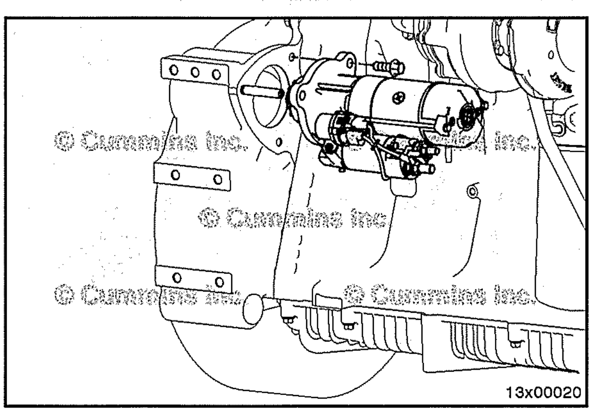
NOTE: The lubricating oil cooler module **must** be removed as an assembly. Take precaution to prevent it from falling.



Remove last two capscrews holding lubricating oil cooler module to block.

Remove lubricating oil cooler module.

NOTE: Take care that no debris enters the lubricating oil or coolant passages in the block.



Starting Motor (013-020)

Remove

Remove the ground strap (if used).

Remove one capscrew and install guide pin 3163934.

Remove remaining two capscrews and starting motor.

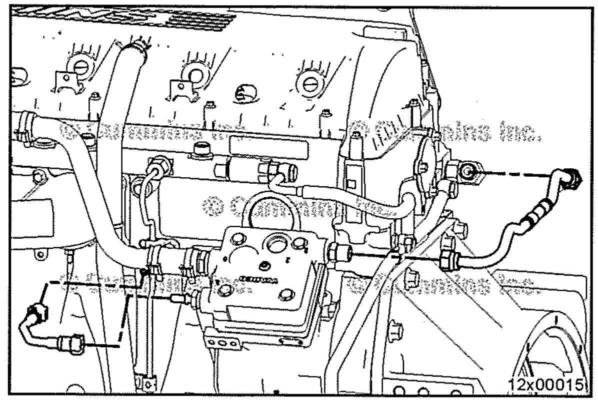
Air Compressor Coolant Lines (012-004)

Remove

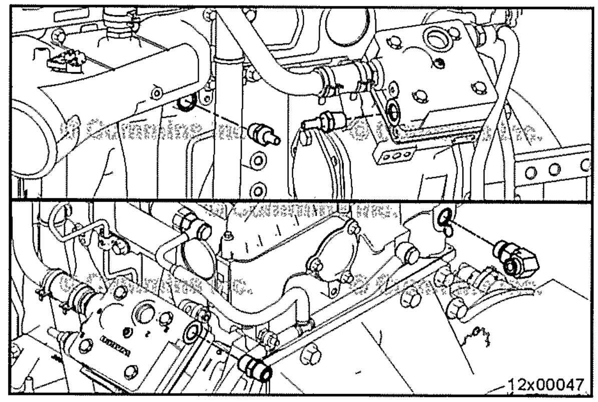
Remove the coolant lines from the fittings.

Use a second wrench to hold the face-seal fitting when loosening the coolant return line connections.

The coolant supply line connections are quick release fittings. To release, press both sides of the connectors.



Remove the quick disconnect fittings and face-seal fittings, if necessary.

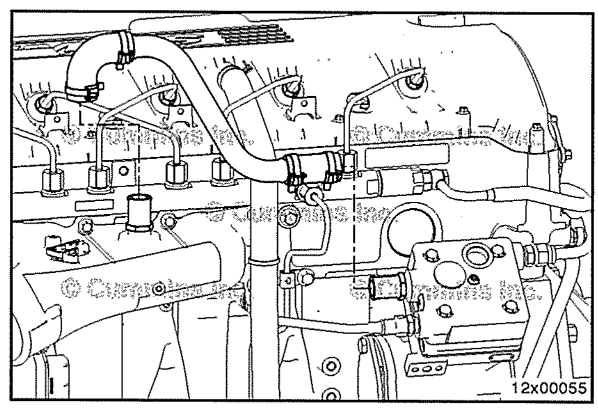


Air Compressor Inlet Tube (012-109)

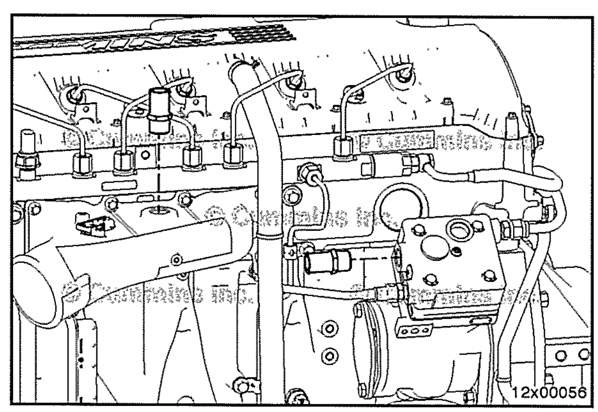
Remove

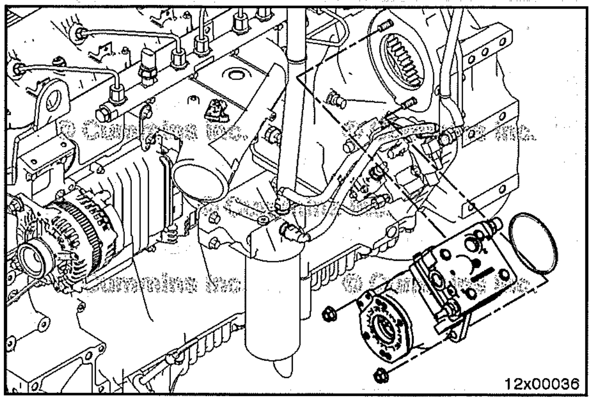
Remove the hoses and hose clamps from the air intake manifold and air compressor.

Remove the air compressor inlet tube from the engine.



If necessary, remove the fitting from the air compressor head and from the air intake manifold.





Air Compressor (012-014)

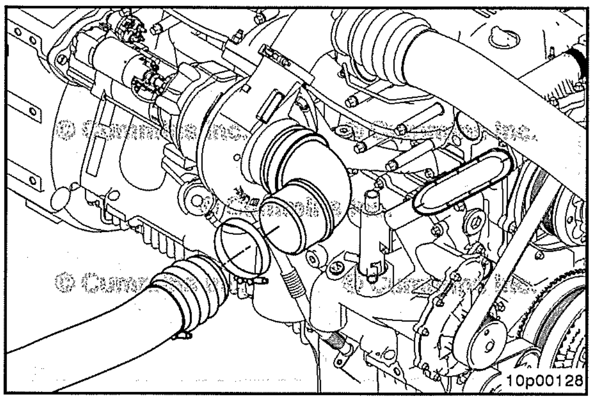
Remove

NOTE: When removing the nuts, the studs may also come loose from the housing. Ensure that neither the nuts nor the studs fall down into the hole in the flywheel housing.

Remove the two mounting nuts, starting with the upper nut, and the air compressor.

Discard the gasket.

If necessary, remove the mounting studs. Otherwise, do **not** remove from housing.



Air Inlet Connection (010-022)

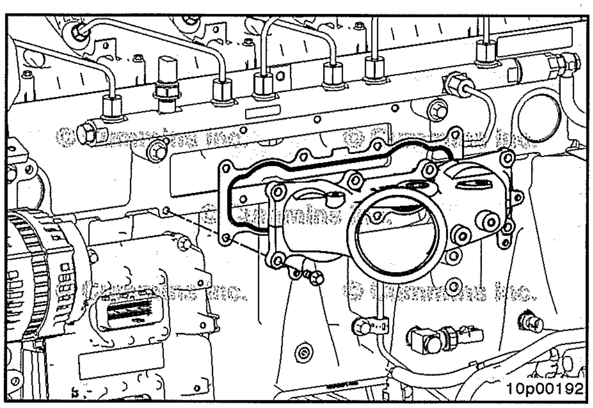
Remove

NOTE: Brush away all loose dirt from around the area of the air handling connections to avoid contamination of the interior of the engine.

Loosen the clamps which hold the air inlet connection to the turbocharger air inlet and the OEM air inlet piping.

Remove the air inlet connection.

Use protective caps from the Air Handling Clean Care Kit, Part Number 4919588, to cover open points on the plumbing and engine.



Air Intake Connection (010-080)

Remove

Remove the fir tree that holds the crankcase breather to the air intake connection.

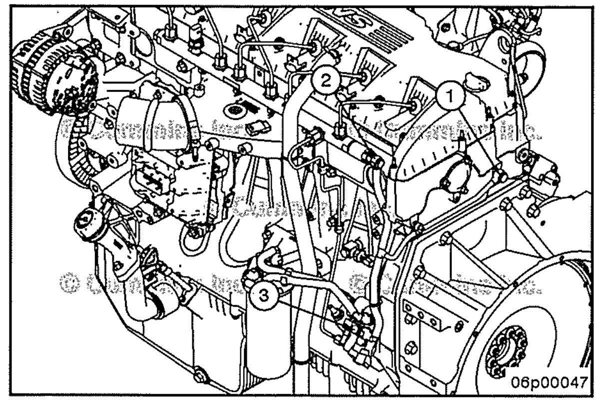
Remove the eight capscrews holding the air intake connection to the cylinder head.

Remove and discard the air intake connection gasket.

Use protective caps and heavy tape from the Air Handling Clean Care Kit, Part Number 4919588, to cover open points on the plumbing and engine.

Fuel Drain Lines (006-013)

Remove



WARNING

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

WARNING

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

The injector drain connects at the back of the cylinder head (1) with an M12 banjo bolt style check valve.

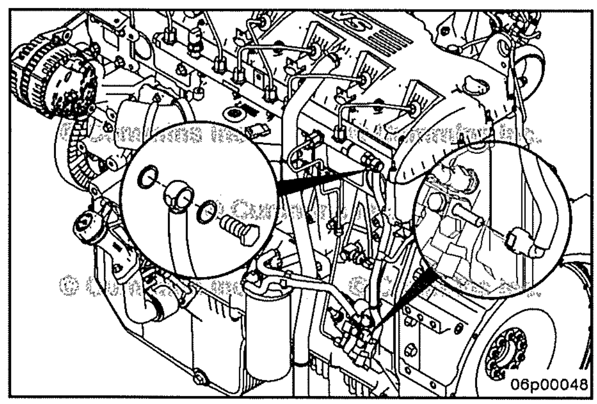
The fuel rail pressure relief valve (2) connects to the fuel rail with an M14 banjo bolt.

The fuel pump drain (3) connects to the fuel pump head with an M12 banjo bolt.

Remove p-clip capscrews, stud, banjo bolts, check valve, and sealing washers.

Discard sealing washers.

Remove fuel drain lines.



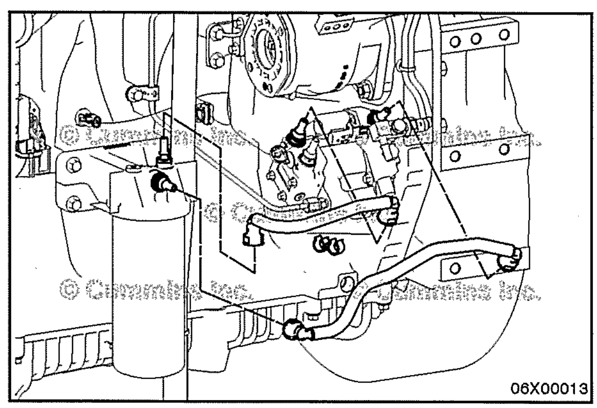
Fuel Supply Lines (006-024)

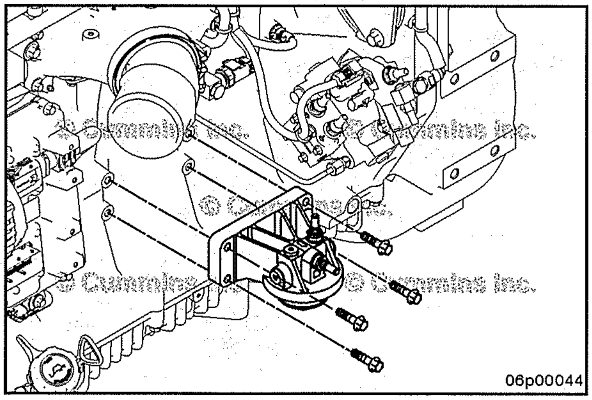
Remove

Mark the location of all p-clips and routing of fuel supply lines to make sure that they are replaced in the correct location during assembly.

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

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



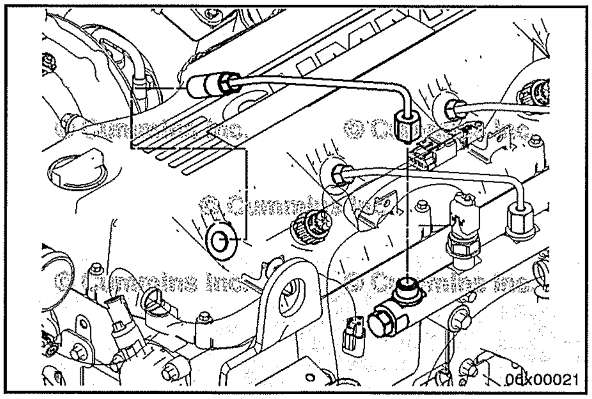


Fuel Filter Head (006-017)

Remove

Remove fuel filter head mounting capscrews.

Remove fuel filter head.



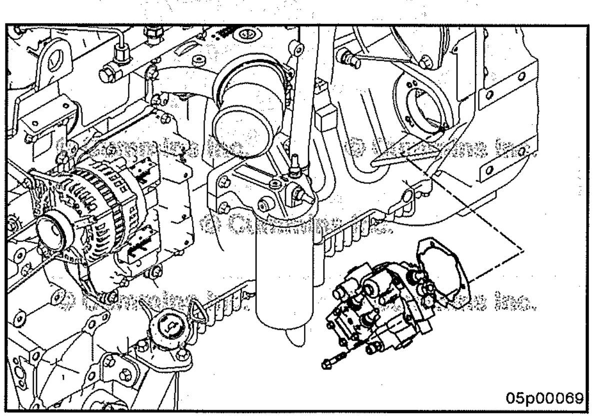
Injector Supply Lines (High Pressure) (006-051)

Remove

Disconnect the high-pressure fuel line from the rail end of injector Number 1. Cover the end of the line and the rail connection immediately.

Disconnect the line from the number 1 injector. Cover the end of the line and the injector connection immediately.

Repeat the steps for all six injectors, removing and capping the connections one at a time.

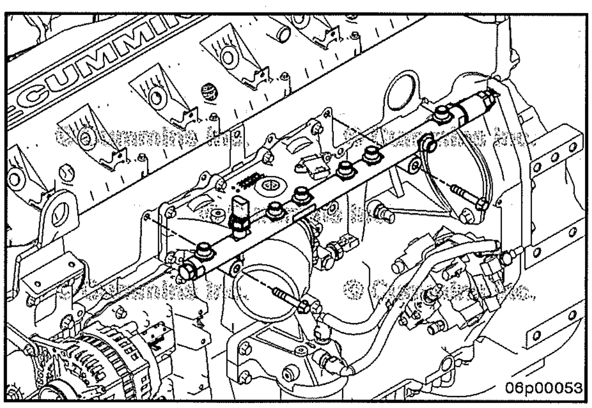


Fuel Pump (005-016)

Remove

Remove the three mounting studs that hold the fuel pump to the gear housing.

Remove the fuel pump and gasket.



Fuel Rail (006-060)

Remove

Remove the two capscrews that secure the fuel rail to the cylinder head.

Remove the fuel rail.

To prevent damage from debris and contamination, cover, cap, or plug any openings as soon as possible when servicing the fuel system. Caps and plugs can be found in Clean Care Kit, Part Number 4919073.

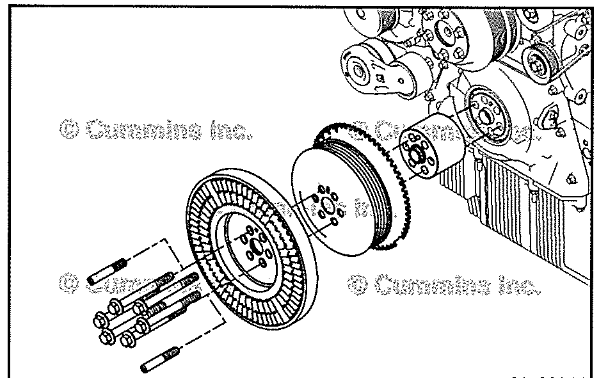
Vibration Damper, Viscous (001-052)

Remove

Remove two capscrews and insert guide pins, Part Number 3376696, to support the damper.

Remove the other four capscrews.

Remove the vibration damper.



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Crankshaft Pulley (001-022)

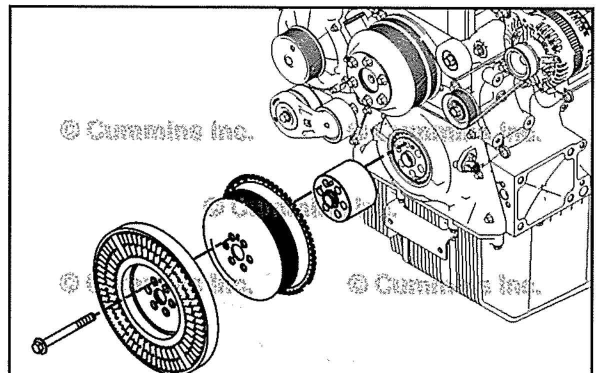
Remove

Remove two capscrews and insert guide pins, Part Number 3376696, to support the damper.

Remove the other four capscrews.

Remove the vibration damper, crankshaft pulley, and crankshaft spacer.

NOTE: The crankshaft speed indicator ring is an integral part of the crankshaft pulley that can **not** be separated.



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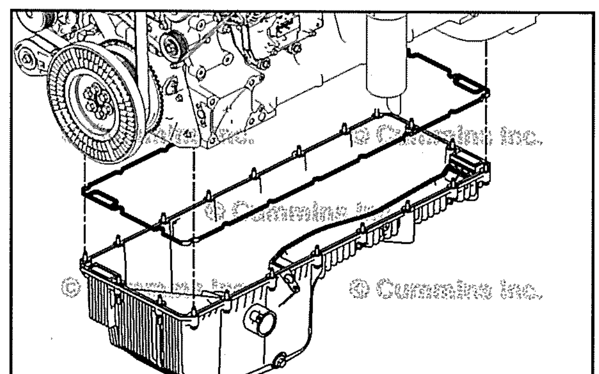
Lubricating Oil Pan (007-025)

Remove

Remove the lubricating oil pan and pan seal.



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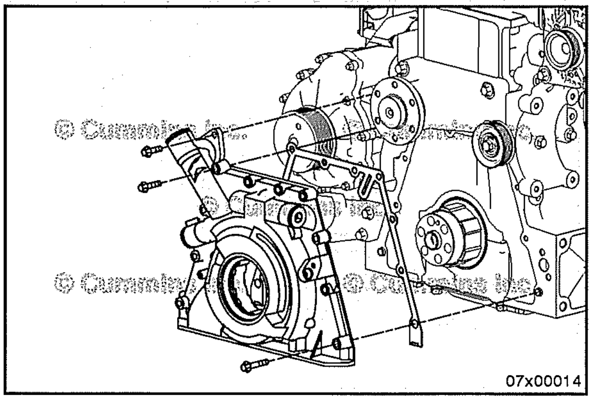


Lubricating Oil Pump (007-031)

Remove

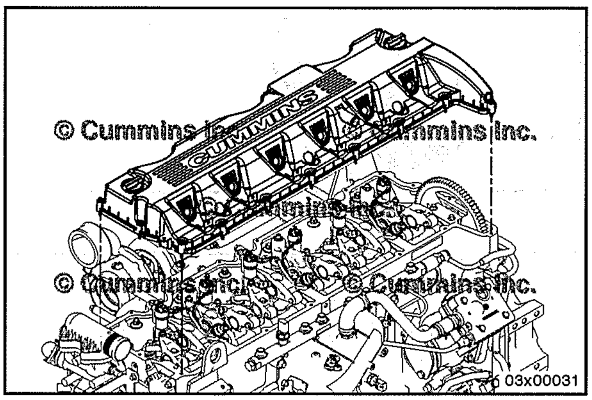
CAUTION

To break the seal, pry the lubricating pump assembly away from the cylinder block. Be careful not to damage the lubricating pump assembly when breaking the seal to the cylinder block.

NOTE: Document the location of the mounting capscrews, the lubricating oil transfer tube capscrews and the lubricating oil pump housing capscrews upon removal.

Remove the 10 lubricating oil pump housing mounting capscrews and 2 lubricating oil transfer tube capscrews. The two capscrews in the bottom corners of the lubricating oil pump housing are longer than the other capscrews.

Remove the lubricating oil pump assembly and lubricating oil transfer tube.



Rocker Lever Cover (003-011)

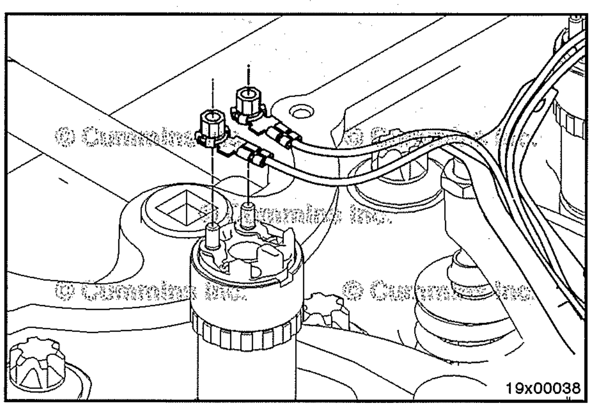
Remove

The mounting capscrews and compression limiters are part of the rocker lever cover. The capscrews are the captive design and will be held in place in the rocker lever cover.

Remove the injector passthrough connector lock rings.

Loosen the rocker lever cover capscrews.

Remove the rocker lever cover gently. The injector passthrough connectors will remain on the engine.

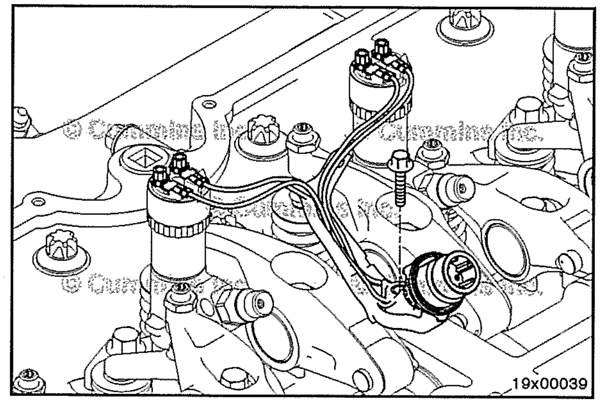


Internal Actuator Wiring Harness (019-063)

Remove

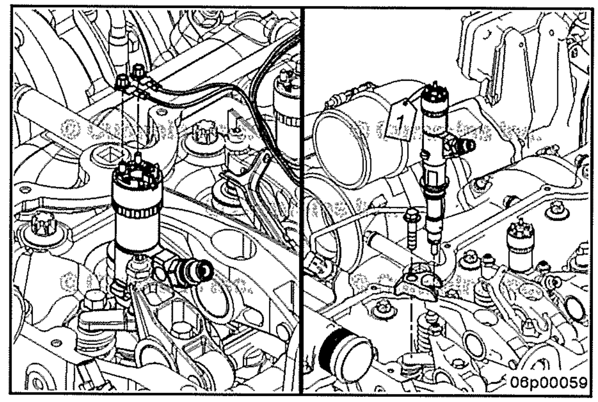
Disconnect the actuator harness from each of the two injector solenoids.

Remove the capscrews securing the actuator harness to the cylinder head.



Injector (006-026)

Remove



⚠CAUTION⚠

When removing the injector, care must be taken not to damage the injector tip.

NOTE: If possible, provide a work area that will **not** have flying debris or dust. Gently place the removed injector(s) on a clean work table or container that has been cleaned of debris and oils. Immediately cover each injector to prevent contamination. Cover the engine if it will be left unattended to prevent contamination.

NOTE: Neighboring work areas may inadvertently contaminate the work area with debris from compressed air, air tools, or cleaning.

Remove the injector actuator wire nuts and wires from the injector.

Loosen and remove the injector hold-down capscrew.

A small heel pry bar can also be used to pry up the injector. Pry up the injector hold-down flange (part of the injector body just above the cylinder head casting).

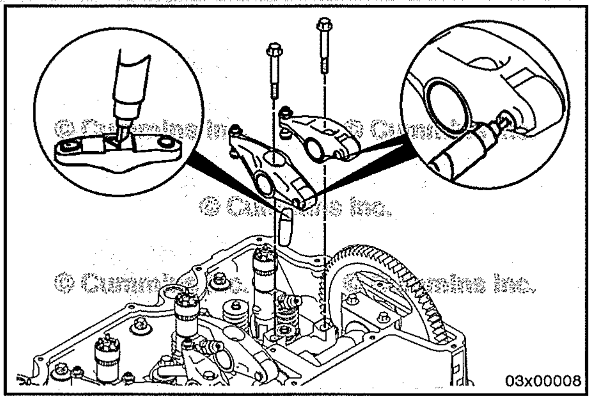
Remove the injector hold-down clamp from the injector.

Remove the injector from the cylinder head.

Apply a protective cap to the injector nozzle.

Insert a blind plug to prevent dust or debris from entering the engine through the cylinder head.

Reused injectors **must** be installed with the same cylinder each time the injector is removed. Mark or tag the fuel injector with the cylinder number to keep track of the correct position of each fuel injector.



Rocker Lever Assembly (003-009)

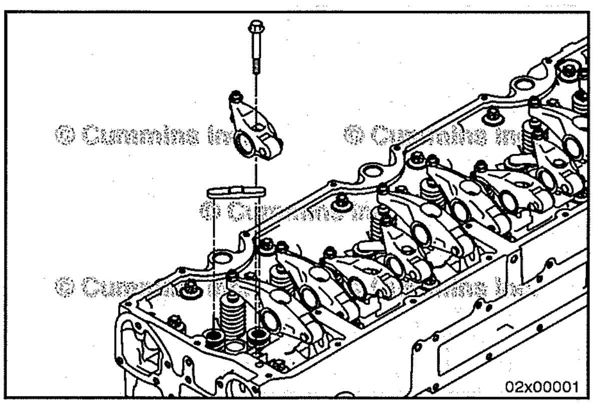
Remove

NOTE: All rocker lever components **must** be installed in their original location and position.

Remove and mark the location of each capscrew.

Remove and mark the location of each rocker and pedestal.

Remove and mark the location of each crosshead .



Crosshead (002-001)

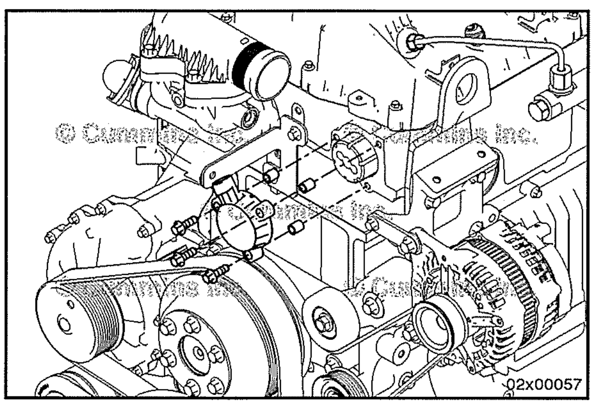
Remove

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

Remove the rocker lever capscrew.

Remove the rocker lever.

Remove the crossheads.

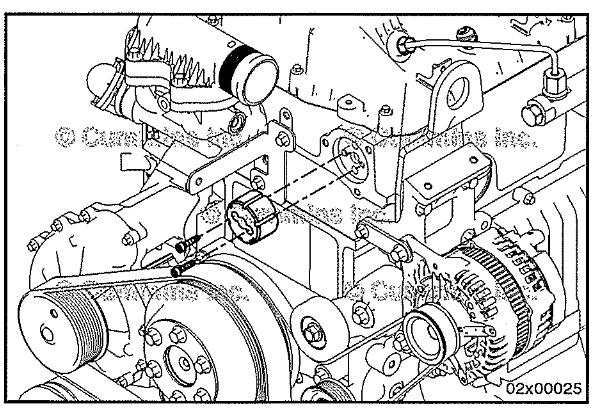


Overhead Camshaft Timing Speed Ring (002-034)

Remove

Remove the three bolts from the cam cover.

Remove the cam cover and spacers from the front of the cylinder head.



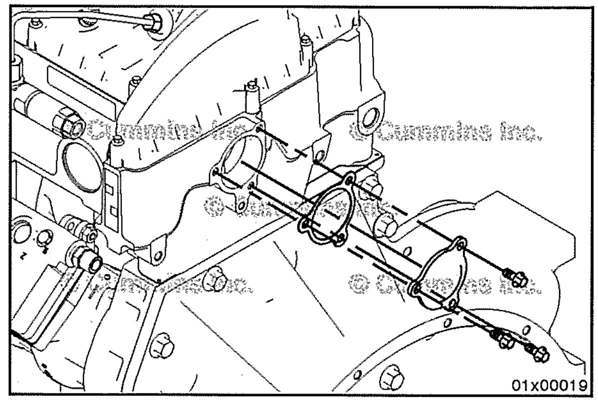
Remove the camshaft capscrews and remove the overhead camshaft timing speed ring.

Camshaft Cover Plate (001-011)

Remove

Remove the rear camshaft cover plate mounting capscrews.

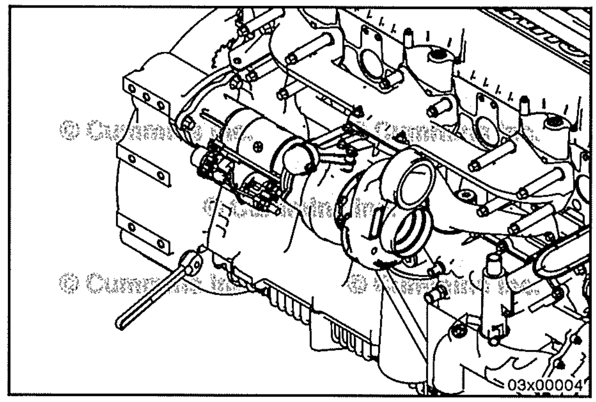
Remove the camshaft cover plate and gasket.



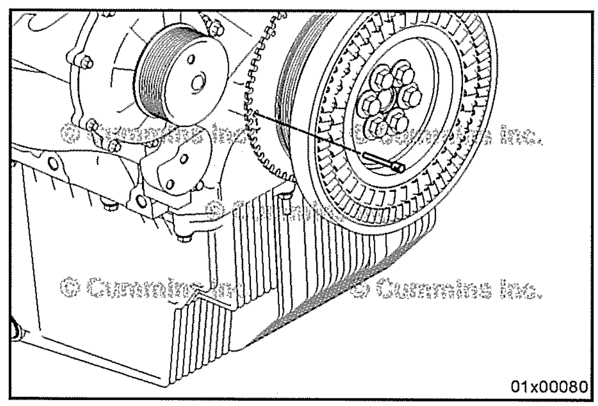
Overhead Camshaft Gear, Valve (002-030)

Remove

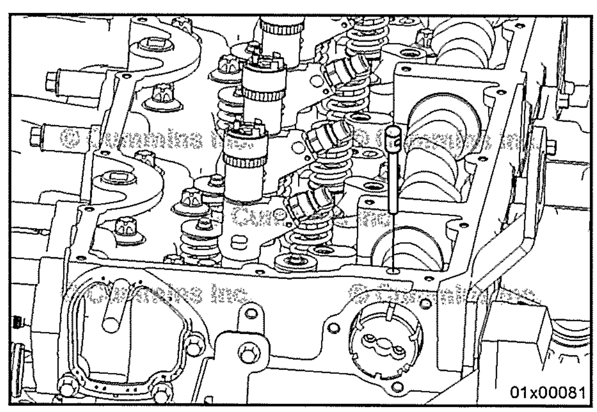
Use the engine barring tool, Part Number 4919092, to rotate the engine **clockwise** when viewed from the crankshaft pulley to top dead center (TDC).

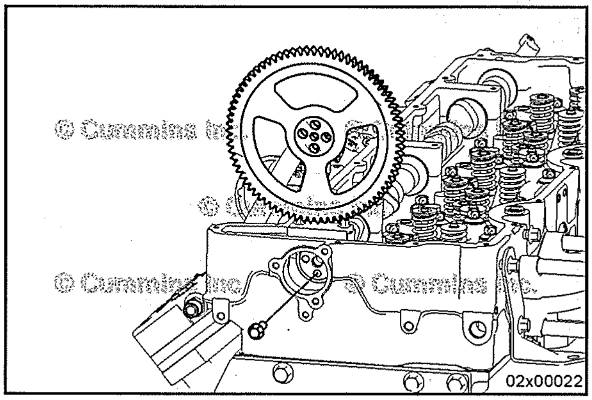


Use the timing pin, Part Number 5298581, to lock the engine by pushing it through the designated holes on the vibration damper and the lubricating pump housing.



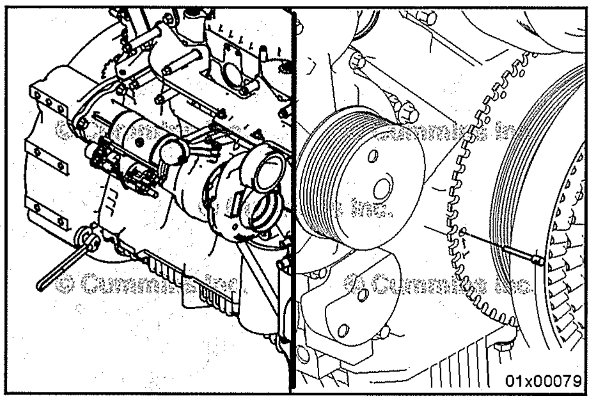
Insert the camshaft timing pin, Part Number 4919342, into the hole found on the front of the camshaft.





Remove the four bolts from the camshaft gear.

Remove the camshaft gear.



Overhead Camshaft, Valve (002-024)

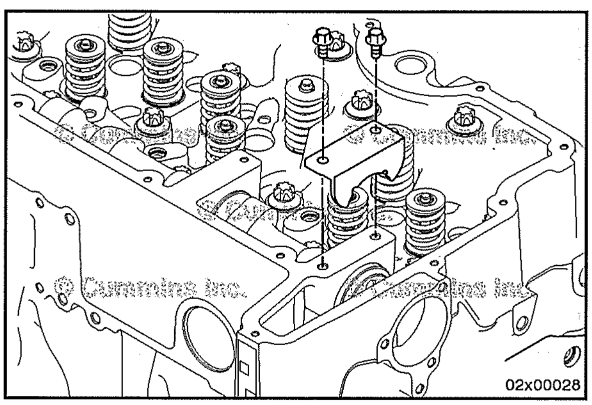
Remove

Rotate the engine to align the timing hole in the crankshaft damper with the corresponding hole in the lubricating pump housing.

When the two holes are aligned, Cylinder 1 is at Top Dead Center (TDC).

Use a suitable pin to lock the crankshaft in position, Part Number 5298582.

The engine can be rotated by installing the engine turning tool, Part Number 4919092, in the allocated slot on the flywheel housing.



Remove the thrust plate capscrews and the thrust plate.

⚠CAUTION⚠

The camshaft will drop once the camshaft clears the last bore if not supported. This can cause damage to the camshaft journal.

⚠CAUTION⚠

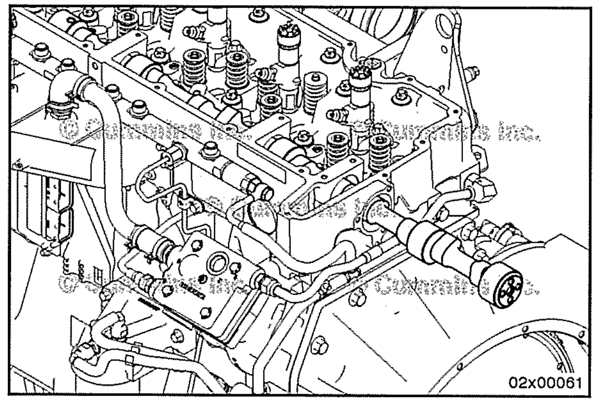
Forcing the camshaft during removal may cause damage to the camshaft and the cylinder head bores.

Remove the camshaft.

While pushing out slightly, rotate the camshaft and carefully work the camshaft through the camshaft bores.

As each camshaft journal passes through a bore, the camshaft will drop slightly and the camshaft lobes will catch on the bores.

Rotating the camshaft frees the lobe from the bore and allows the camshaft removal to continue.

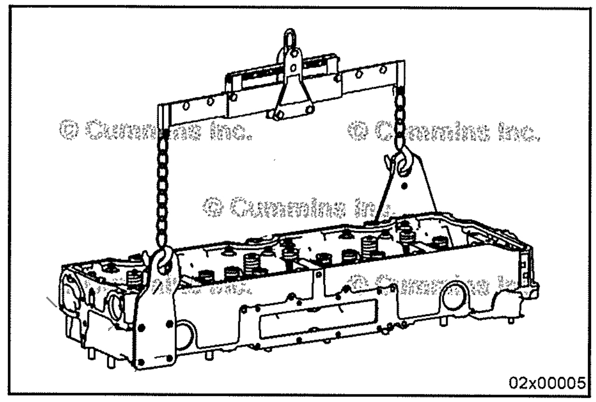


Cylinder Head (002-004)

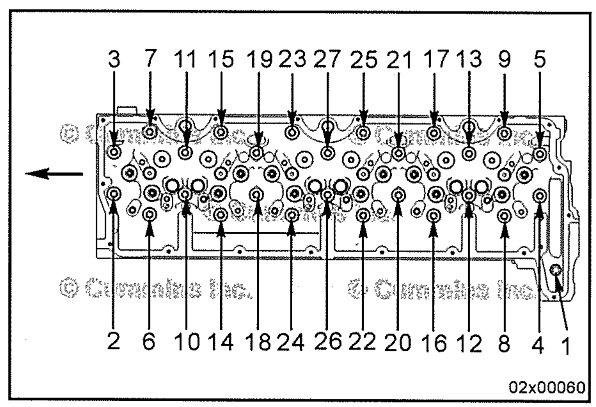
Remove

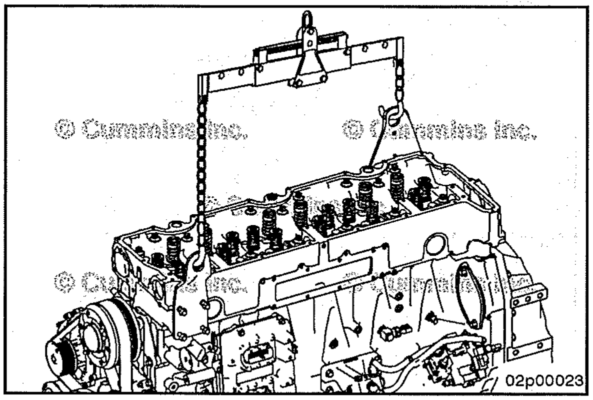
⚠WARNING⚠

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

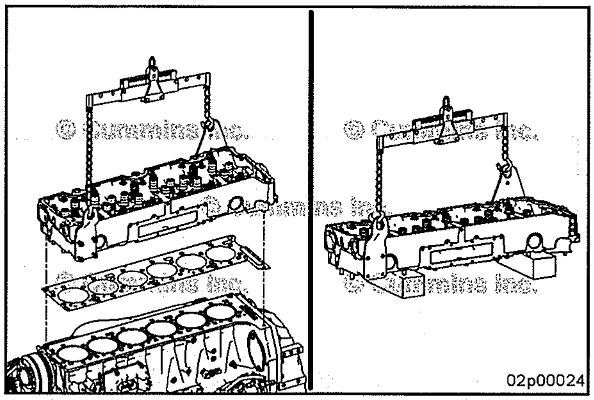


Remove the cylinder head capscrews in the sequence shown.





Attach the engine lifting fixture, Part Number 3162871, to the lifting eyes that are bolted to the head.



CAUTION

Immediately upon removal of the cylinder head, plugs must be installed into all of the oil passage drillings in both the cylinder head and the cylinder block. The plugs are necessary to prevent debris from entering the lubricating system during the repair. Failure to insert oil passage plugs can result in crankshaft failure.

Use a hoist or hydraulic arm to remove the cylinder head.

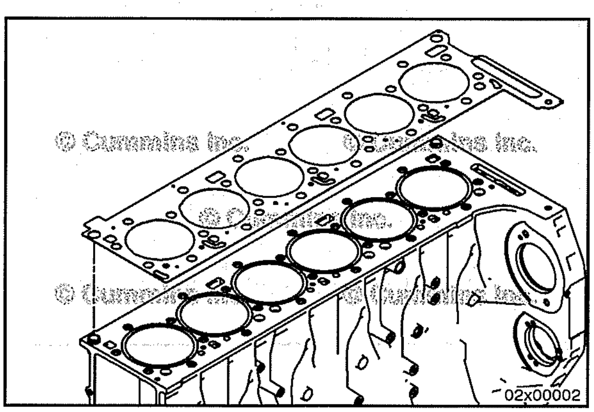
Remove the cylinder head gasket.

Discard the head gasket.

Reusable plugs are included in the oil passage protective plug kit, Part Number 4919403.

Install the plugs in the cylinder block and cylinder head oil drillings.

Place cylinder head onto stand, Part Number ST-583 or equivalent.



Cylinder Head Gasket (002-021)

Remove

Remove the cylinder head gasket.

Discard the gasket.

Flywheel (016-005)

Remove

NOTE: Use the barring tool, Part Number 4919092, to hold the flywheel to prevent rotation.

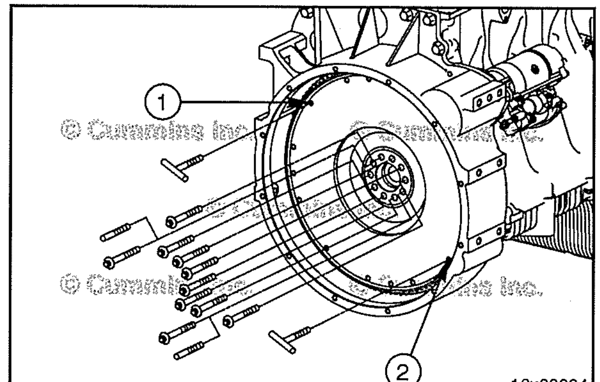
Remove two capscrews 180 degrees apart.

Install two M12x1.25, 150-mm guide pins, Part Number 3376638.

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

Remove the remaining eight flywheel mounting capscrews.

Remove and discard the friction shim.

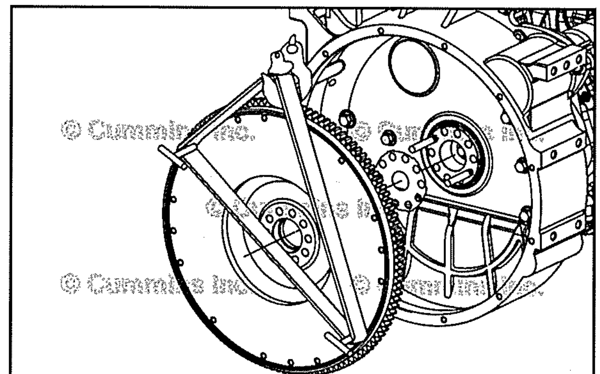


16x00034

WARNING

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

Remove the flywheel from the guide pins.



16x00035

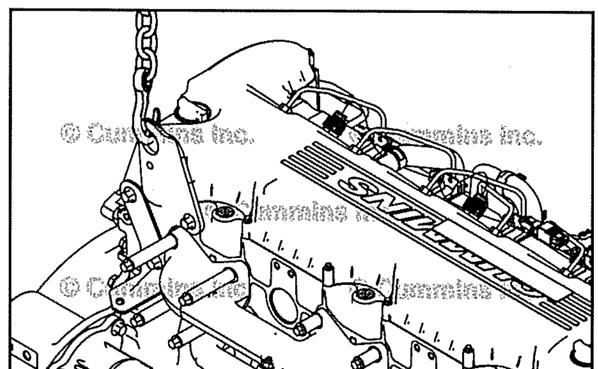
Flywheel Housing (016-006)

Remove

WARNING

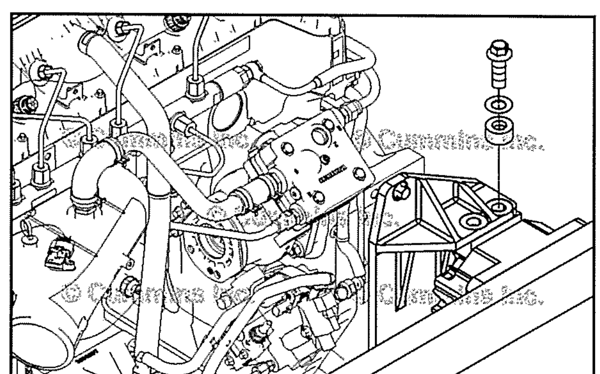
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

Use a hoist or lifting fixture to support the rear of the engine.

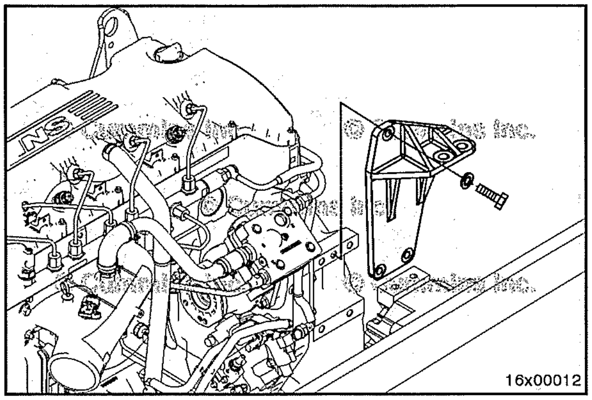


16x00010

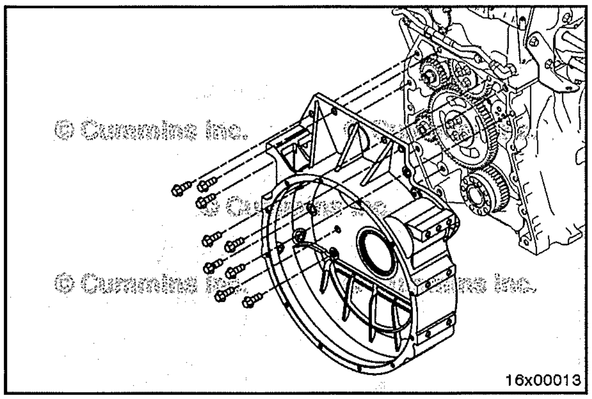
Remove the rear engine supports. Refer to Procedure 016-003 in Section 16.



16x00011



Remove the rear engine brackets. Refer to Procedure 016-003 in Section 16.



WARNING

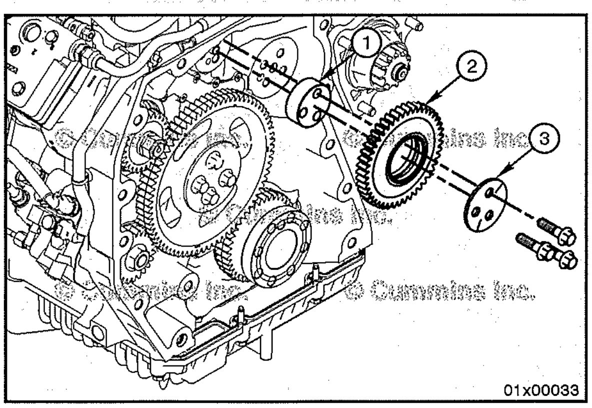
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Loosen the flywheel housing capscrews, but do **not** remove.

Use a rubber hammer to 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: Make sure to note the position of any locating dowel rings.



Idler Gear, Camshaft Rear (001-115)

Remove

NOTE: It is necessary to remove the flywheel housing before the camshaft idler gear can be removed.

Remove the three capscrews.

Remove the idler gear assembly.

Disassemble the idler gear assembly. The components are listed below.

1 Idler gear shaft

2 Idler gear and bushing assembly

3 Idler gear retaining plate.

Mark or tag the individual pieces of the idler gear assembly and attach them together.

Section AS - Engine Assembly - Group 00

Section Contents

Page
Air Compressor AS-38
Install AS-38
Air Compressor Coolant Lines AS-39
Install AS-39
Air Compressor Inlet Tube AS-39
Install AS-39
Air Inlet Connection AS-38
Install AS-38
Air Intake Connection AS-37
Install AS-37
Bearings, Connecting Rod AS-9
Install AS-9
Bearings, Main AS-3
Install AS-3
Bearings, Thrust AS-6
Install AS-6
Block Stiffener Plate AS-15
Install AS-15
Camshaft Cover Plate AS-24
Install AS-24
Charging System Alternator AS-52
Install AS-52
Charging System Alternator Automatic Belt Tensioner AS-52
Install AS-52
Charging System Alternator Bracket AS-51
Install AS-51
Charging System Alternator Drive Belt AS-53
Install AS-53
Coolant Thermostat AS-50
Install AS-50
Coolant Thermostat Housing AS-50
Install AS-50
Cooling Fan Belt Tensioner AS-53
Install AS-53
Crankshaft AS-7
Install AS-7
Crankshaft Pulley AS-33
Install AS-33
Crankshaft Seal, Front AS-31
Install AS-31
Crankshaft Seal, Rear AS-18
Install AS-18
Crosshead AS-25
Install AS-25
Cylinder Head AS-20
Install AS-20
Cylinder Head Gasket AS-20
Install AS-20
Cylinder Liner AS-1
Install AS-1
Drive Belt, Cooling Fan AS-54
Install AS-54
Engine Control Module AS-55
Install AS-55
Engine Control Module Mounting Bracket AS-54
Install AS-54
Engine Lifting Brackets AS-42

Install....AS-42
Exhaust Gas Pressure Sensor AS-57
Install....AS-57
Exhaust Gas Pressure Sensor Tube AS-56
Install....AS-56
Exhaust Manifold, Dry AS-42
Install....AS-42
Exhaust Pressure Regulator AS-44
Install....AS-44
Fan Hub, Belt Driven AS-51
Install....AS-51
Fan Pulley AS-51
Install....AS-51
Flywheel AS-19
Install....AS-19
Flywheel Housing AS-17
Install....AS-17
Fuel Drain Lines AS-37
Install....AS-37
Fuel Filter Head AS-36
Install....AS-36
Fuel Pump AS-35
Install....AS-35
Fuel Rail AS-34
Install....AS-34
Fuel Rail Supply Line (High Pressure) AS-36
Install....AS-36
Fuel Supply Lines AS-37
Install....AS-37
Idler Gear, Camshaft Rear AS-16
Install....AS-16
Idler Gear, Crankshaft Rear AS-16
Install....AS-16
Injector AS-27
Install....AS-27
Injector Supply Lines (High Pressure) AS-35
Install....AS-35
Internal Actuator Wiring Harness AS-29
Install....AS-29
Lubricating Oil Cooler Housing AS-41
Install....AS-41
Lubricating Oil Pan AS-32
Install....AS-32
Lubricating Oil Pump AS-30
Install....AS-30
Overhead Camshaft Gear, Valve AS-23
Install....AS-23
Overhead Camshaft Timing Speed Ring AS-24
Install....AS-24
Overhead Camshaft, Valve AS-22
Install....AS-22
Overhead Set AS-26
Adjust....AS-26
Piston and Connecting Rod Assembly AS-11
Install....AS-11
Piston Cooling Nozzle AS-14
Install....AS-14
Piston Rings AS-7
Install....AS-7
Rear PTO Idler Gear AS-15
Install....AS-15
Refrigerant Compressor AS-52
Install....AS-52
Rocker Lever Assembly AS-25

Install....AS-25
Rocker Lever Cover AS-30
Install....AS-30
Starting Motor AS-41
Install....AS-41
Turbocharger AS-43
Install....AS-43
Turbocharger Compressor Intake Pressure/Temperature Sensor AS-56
Install....AS-56
Turbocharger Coolant Hoses AS-45
Install....AS-45
Turbocharger Oil Drain Line AS-48
Install....AS-48
Turbocharger Oil Supply Line AS-49
Install....AS-49
Vibration Damper, Viscous AS-33
Install....AS-33
Water Pump Cartridge AS-49
Install....AS-49

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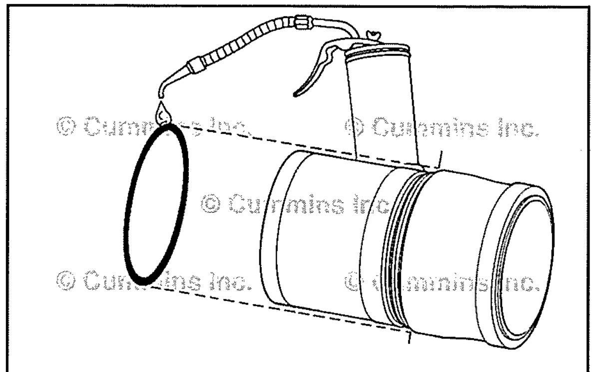
Cylinder Liner (001-028)

Install

Make sure the cylinder block and all parts are clean before assembly.

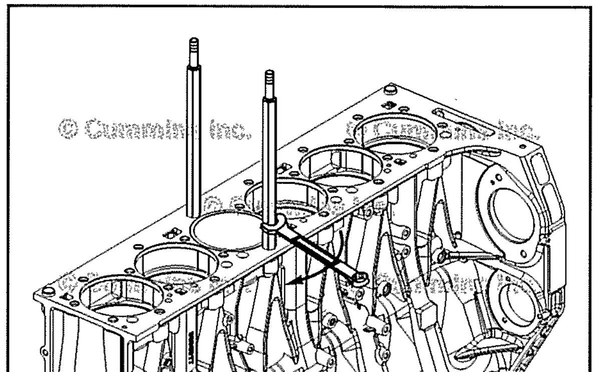
Use clean oil to coat the liner o-ring seals.

Install the o-ring seal on the liner. Make sure the o-ring seal does **not** roll during installation.



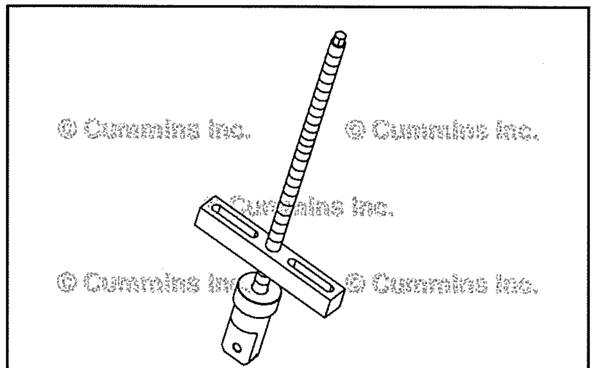
ck2slwc

Install legs (5298762) into cylinder head bolt holes on engine block using a 22mm wrench.



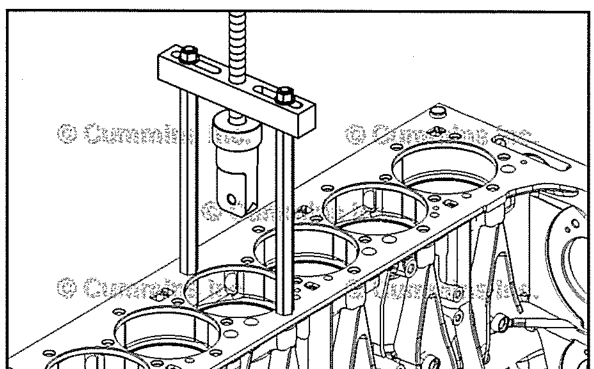
01p00115

Install threaded rod assembly (5298890) into bridge (5298764) (orientation of bridge does **not** matter). Puller plate adapter should be at the bridge, leaving most of the threaded rod length hanging out one side of the bridge.



01p00124

Install bridge and threaded rod assembly onto legs, securing with nuts (5298760). **Only** secure the nuts loosely at this point.



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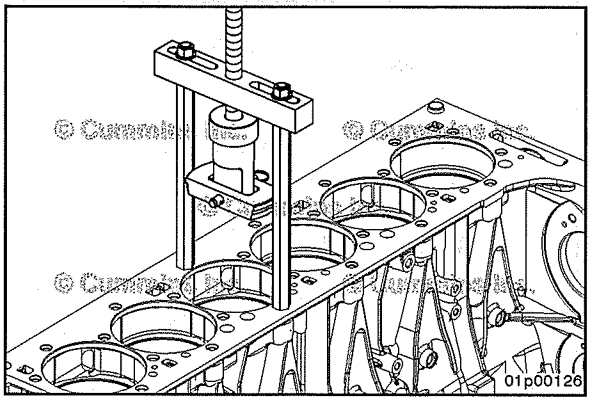
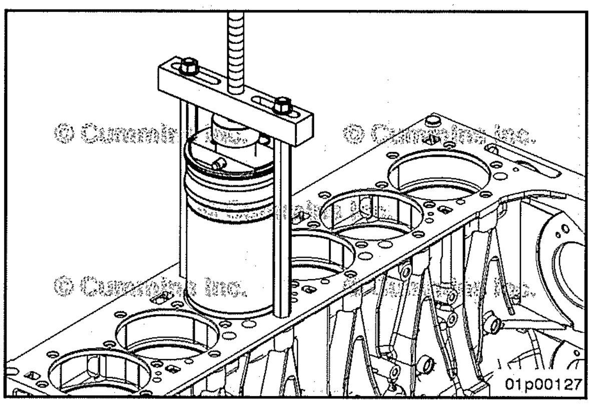


Attach puller plate (5298673) to threaded rod assembly using quick pin (3162878).



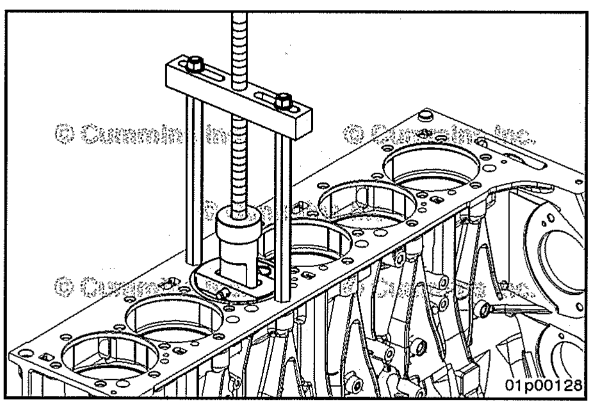
Place the cylinder liner in the engine block. Ensure that it remains vertical during the installation procedure.

When acceptable used liners are installed, rotate the liners 90 degrees from their original position in the engine. Original thrust and anti-thrust surfaces **must** face the front and back of the cylinder block.

Using a 16mm wrench, turn the hex of the threaded rod **clockwise** until the puller plate makes contact with the top of the cylinder liner. At this point, ensure that the puller plate is centered on the cylinder liner, the threaded rod is vertical and the bridge is centered over the cylinder liner. Tighten leg nuts.

If the liner does **not** seat properly, remove the liner. Inspect the counterbore seat and liner for nicks, burrs, and dirt.

Install the liner again.



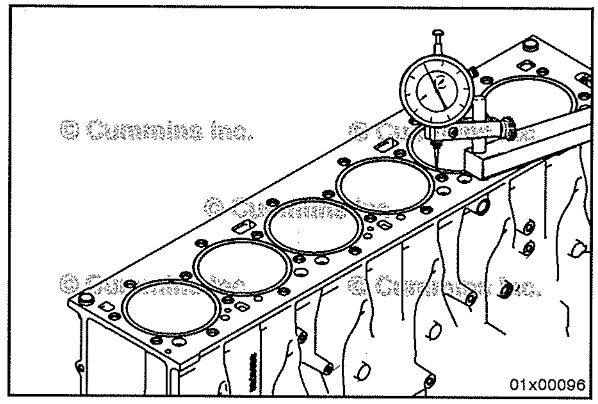
Carefully turn the hex of the threaded rod **clockwise** 1-2 full turns. Ensure that the cylinder liner is entering the cylinder block bore properly and is remaining vertical. If the cylinder liner is **not** remaining vertical, or if excessive force is required on the wrench, remove liner and inspect for debris that might be preventing proper installation.

Continue to turn the hex of the threaded rod **clockwise** to press the cylinder liner in. Keep the threaded rod lubricated during installation.

NOTE: The cylinder liner has a full length light press fit with the cylinder block. Moderate force will need to be applied to the wrench to remove the cylinder liner. If it feels like excessive force is being required, stop and ensure that the puller plate & bridge are still centered over the cylinder liner.

The cylinder liner protrusion **must** be checked before installing the pistons and connecting rods.

Use a depth gauge, Part Number 3164438, to measure the liner protrusion at four points that are 90 degrees apart.



Cylinder Liner Protrusion

mm		in
0.06	MIN	0.002
0.12	MAX	0.005

- The difference between the lowest cylinder liner and the highest cylinder liner can **not** be greater than 0.102 mm [0.004 in].
- The maximum allowable difference between adjacent cylinders is 0.051 mm [0.002 in].
- The protrusion **must** be within 0.0381 mm [0.0015 in] around any cylinder.

Bearings, Main (001-006)

Install

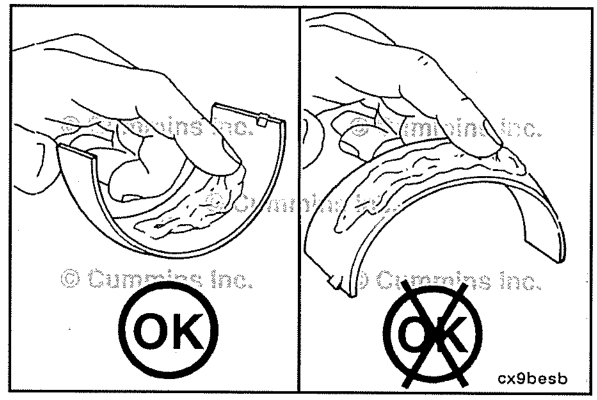
CAUTION

Do not lubricate the side that is against the cylinder block.

Upper 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.

Apply assembly lubricant, Part Number 3163087, to the upper main bearings.



Upper Main Bearing

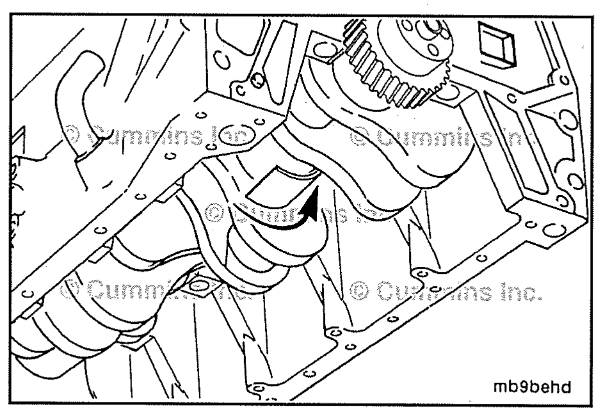
NOTE: The crankshaft thrust bearing **must** be installed in the Number 6 main bearing position.

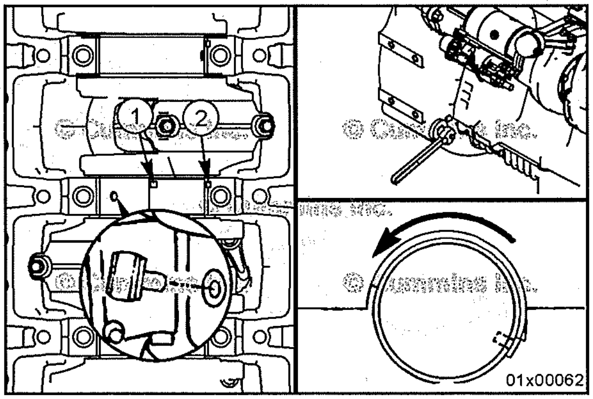
NOTE: The upper and lower main bearing shells are **not** interchangeable. The backs of the main bearings are marked with the proper orientation.

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, do **not** push the crankshaft to the front or rear of the cylinder block as this can damage the piston cooling nozzles.





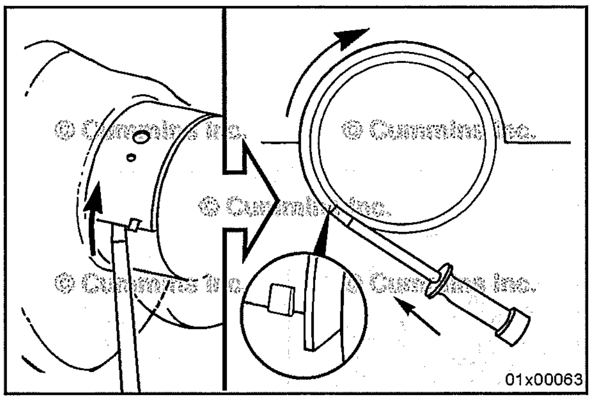
⚠CAUTION⚠

Make sure the pin does not slide under the bearing.

Follow this step to finish installing the upper main bearings, except for Number 7 rear main bearing.

Use the main bearing replacer, Part Number 3823818, to finish installing the main bearing. Rotate the crankshaft with the barring tool, Part Number 4919092.

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 not to damage the crankshaft or cylinder block.

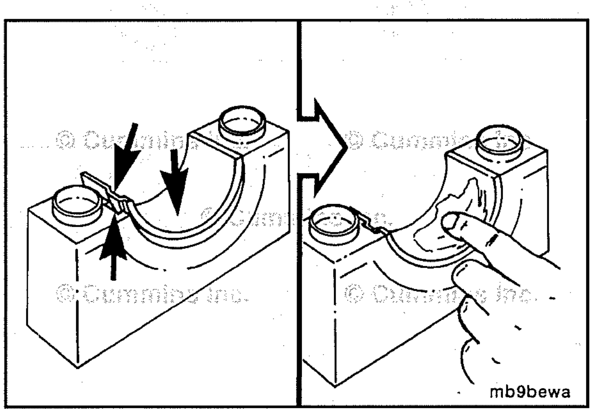
NOTE: The rear main, Number 7, does **not** have a hole in the journal so the pin can **not** be used to replace the bearing.

Install the Number 7 main bearing.

Insert the side of the main bearing opposite the tang first and install as far as possible by hand.

Use a blunt tool to gently 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.



⚠CAUTION⚠

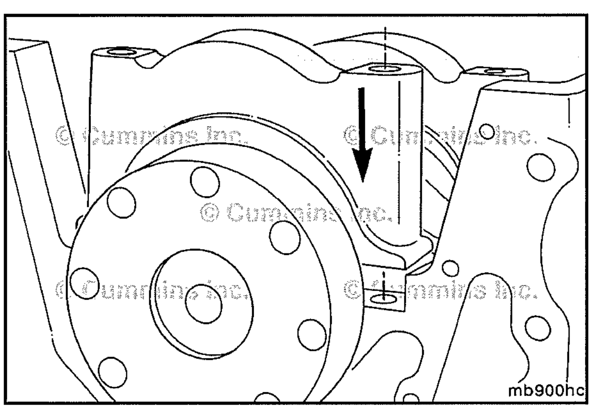
Do not lubricate the back side of the bearing that contacts the main bearing cap.

Lower Main Bearings

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 the tangs on the main bearing caps.

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.

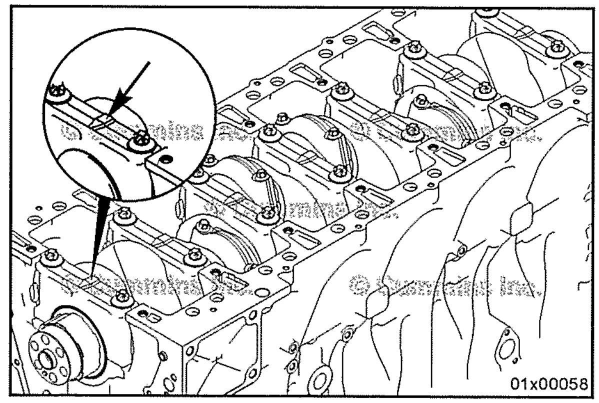
Make sure the surfaces between the main bearing cap and block are clean and free of debris.

Install the main bearing cap into position, aligning the main bearing cap dowel rings with the cylinder block.

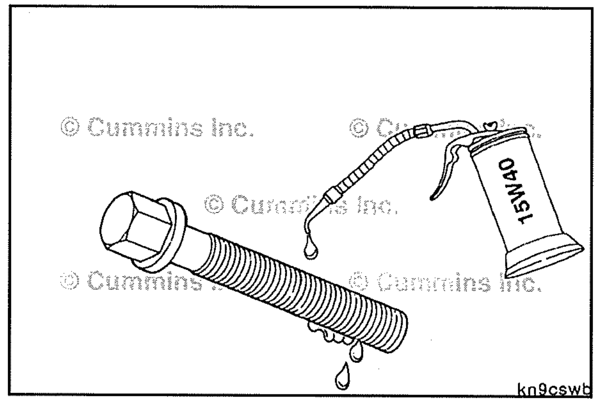
The main bearing caps were numbered before or during the removal process for their location. Number 1 starts with the front of the block.

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.

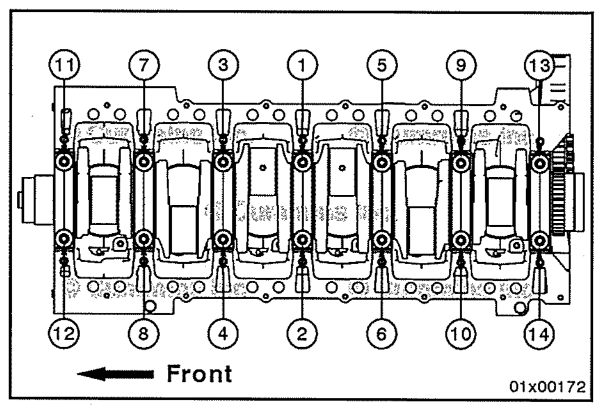
When seated, install the main bearing capscrews and tighten.

Torque Value: 120 N•m [89 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.

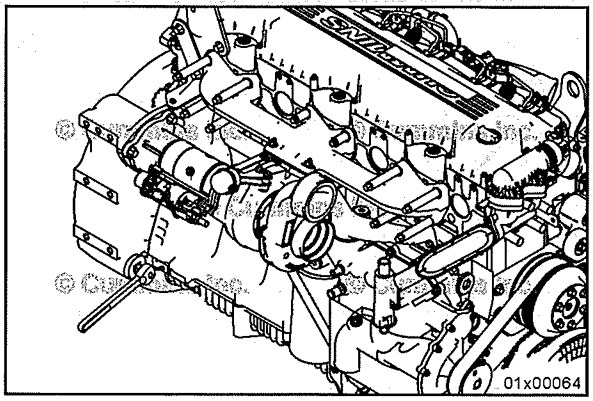
Use the barring tool, Part Number 4919092. The crankshaft **must** rotate freely after installing the main bearing caps.

While applying final torque to the main bearing capscrews, frequently check that the crankshaft rotates freely.



Torque Value:

Step 1	250 N•m	[184 ft-lb]
Step 2	Angle 120 degrees.	



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

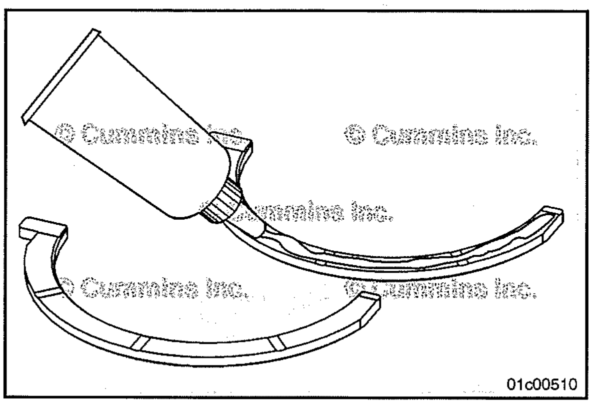
1 Check if the crankshaft is contacting one of the connecting rods.

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.

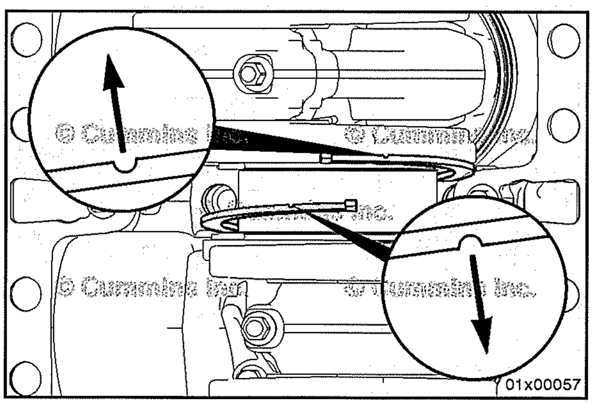
Use the following procedure for the crankshaft end play. Refer to Procedure 001-016 in Section 1.



Bearings, Thrust (001-007)

Install

Use Lubriplate™ 105, Part Number 3163087, or equivalent, to coat the upper thrust bearings.



⚠CAUTION⚠

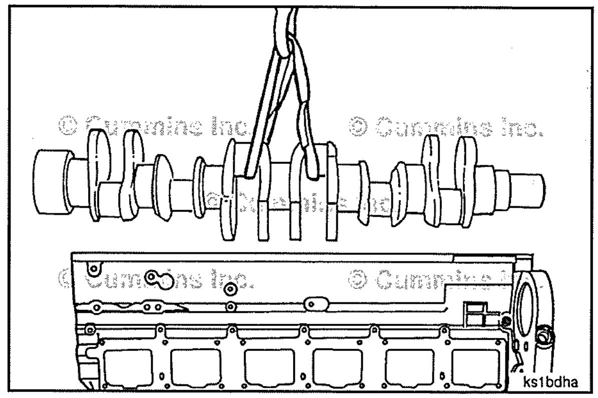
Do not push the crankshaft toward the front or rear of the engine to install the rear thrust bearing. This may damage the piston cooling nozzles.

Install the upper thrust bearings in the number six main bearing saddle.

The grooved side of the thrust bearing **must** be toward the crankshaft.

Crankshaft (001-016)

Install



⚠CAUTION⚠

Use a lifting strap that will not damage the crankshaft. Do not drop the crankshaft on the bearings.

⚠CAUTION⚠

Do not install the thrust bearings before the crankshaft is laid into the block.

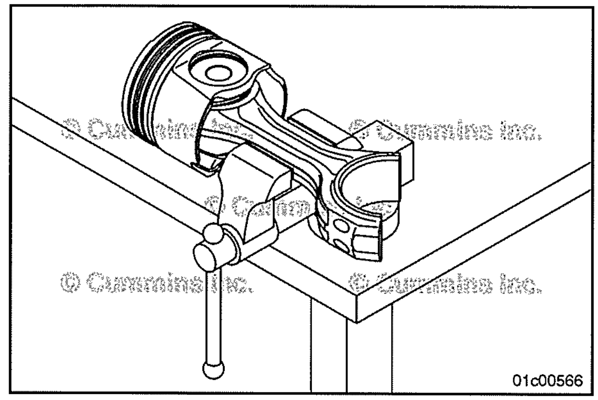
Install the main bearings. Refer to Procedure 001-006 in Section 1.

The end of the crankshaft with the smallest diameter **must** point toward the front of the cylinder block.

Install the crankshaft.

Piston Rings (001-047)

Install



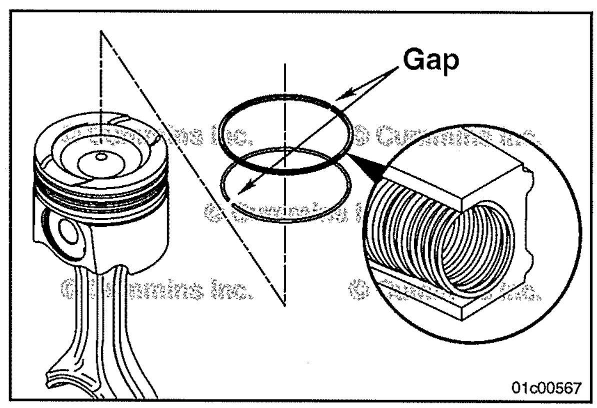
⚠CAUTION⚠

Use a copper or aluminum vise protector when installing the connecting rod in a vise to protect the connecting rod from damage.

When reusing piston rings, be sure the rings are installed on the same piston from which they were removed.

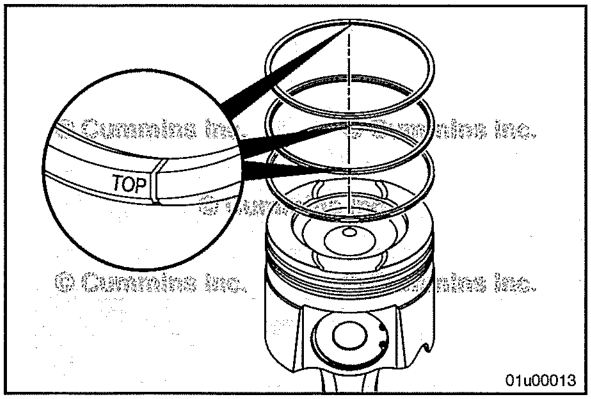
The ring gap of each ring **must not** be aligned with the piston pin or with any other ring. If the ring gaps are **not** positioned correctly, the rings will **not** seal properly.

Install the connecting rod in a vise to hold the assembly in a horizontal position while installing the rings.



A cross-sectioned view of an oil control ring is shown.

The two-piece oil control ring **must** be installed with the expander ring gap 180 degrees from the gap of the oil ring. Do **not** overlap the ends of the expander ring.



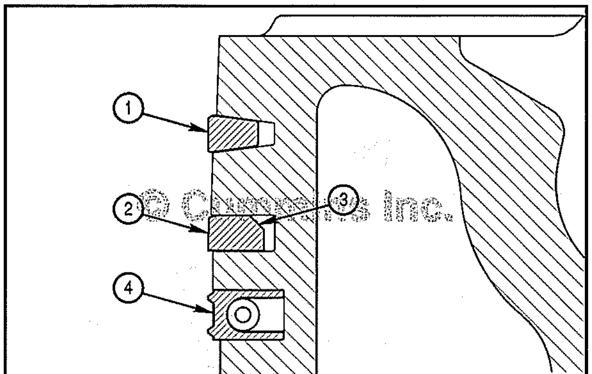
01u00013

Each ring has the top marked for correct installation.

Install the piston rings with TOP toward the top pf the piston.

NOTE: The oil control ring is symmetrical for this engine.

Use a universal piston ring expander to install the second ring into the piston.



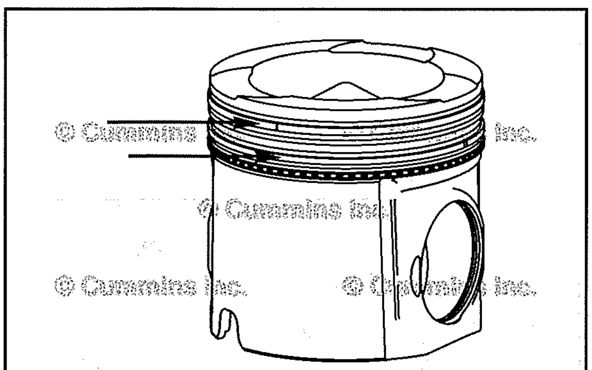
01q00223

The piston **must** be held in a horizontal position to install the rings in order to keep the rings in the groove while installing the ring compressor.

The top piston ring (1) is a keystone ring with no twist or cutback notch.

The second ring has a rectangular cross-section (2) with an angled cut (3) on the upper side of the inner diameter to induce a positive twist. This design improves the slobber-resistance of the ring pack.

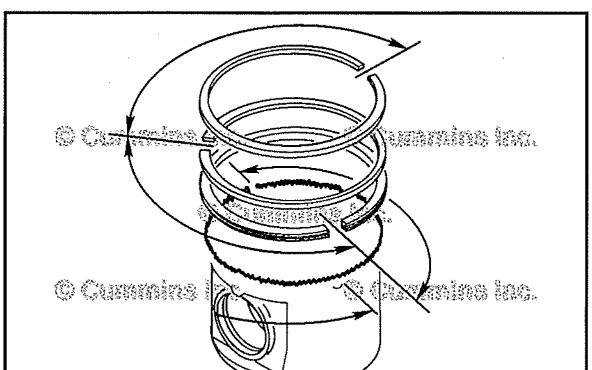
The oil control ring (4) is the bottom piston ring.



01x00041

When installing new piston rings:

- The top ring will show an orange paint stripe to the left of the gap.
- The middle ring will show a yellow paint stripe to the left of the gap.

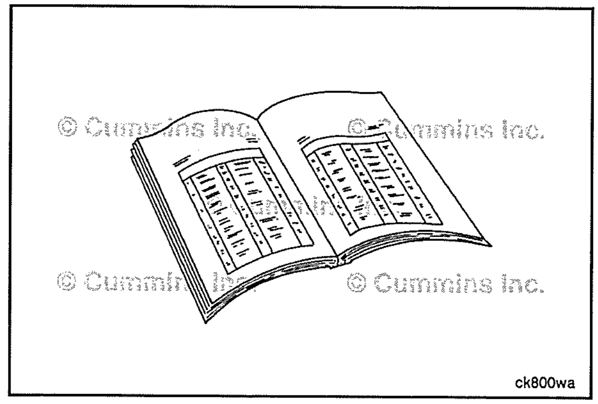


01c00569

Rotate the rings to position the ring gaps 120° apart as shown.

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

If a malfunction resulted in coolant, oil, excessive fuel, or excessive black smoke entering the exhaust system, the aftertreatment system **must** be inspected.



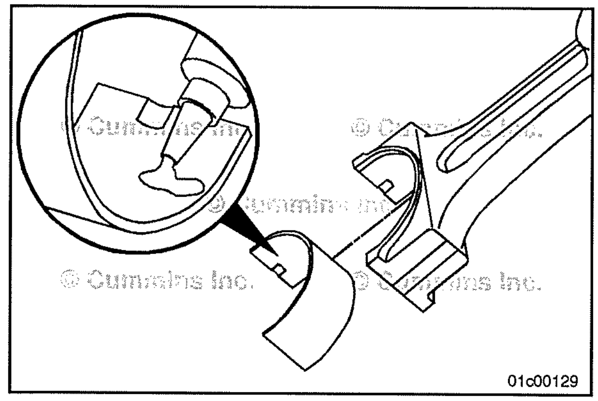
NOTE: When installing new piston rings with used liners, higher than average blowby can be experienced for the first several hours of operation. If excessive blowby is still seen after several hours of engine operation, consult the troubleshooting symptom tree Crankcase Gases (Blowby) Excessive in Section TS.

NOTE: All engines **must** be run-in after a rebuild or a repair involving the replacement of one or more piston ring sets, cylinder liners, or pistons. See the appropriate procedure in Section 14 for the correct run-in procedure.

Use the following procedure for a general run-in test overview. Refer to Procedure 014-004 in Section 14.

Bearings, Connecting Rod (001-005)

Install

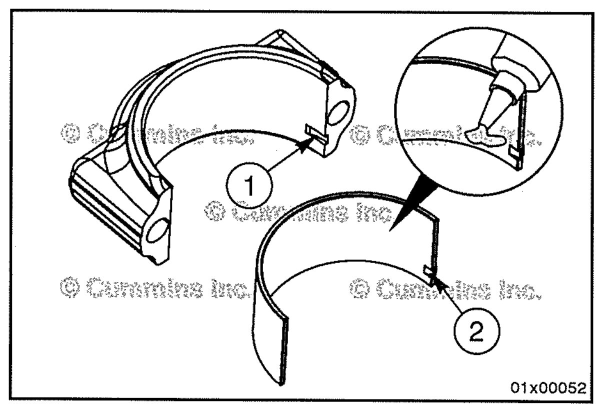


⚠CAUTION⚠

The connecting rod and bearing shell mating surfaces must be clean and dry when the bearing shells are installed. Used bearings must be installed in their original location or engine damage can occur.

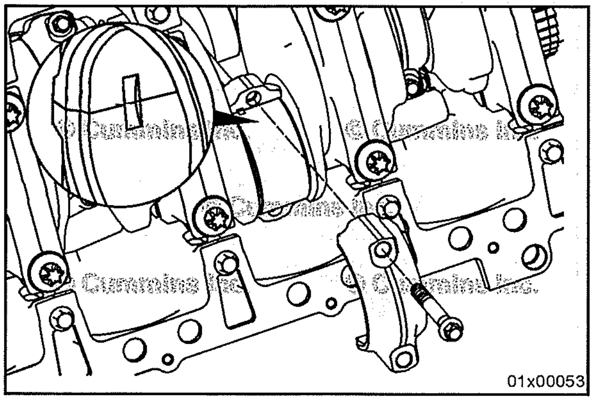
Use clean Lubriplate™ 105 multi-purpose lubricant, Part Number 3163087, or its equivalent, to lubricate the crankshaft journal mating surface of the upper bearing shell.

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



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

Use clean Lubriplate™ 105 multi-purpose lubricant, Part Number 3163087, or its equivalent, to lubricate the bearing shell to the crankshaft journal mating surface.



⚠CAUTION⚠

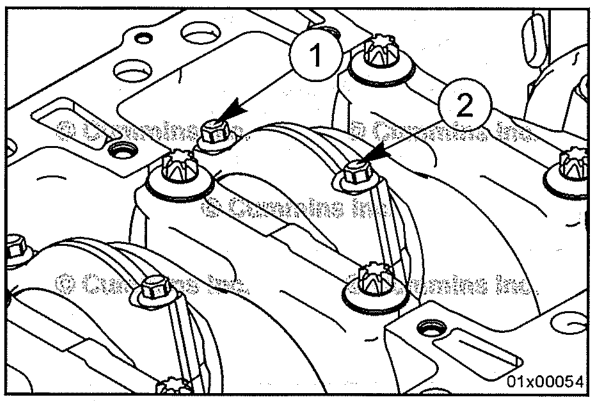
Do not damage the fracture split surface on the connecting rod or connecting rod cap while the connecting rod caps are removed. If the fracture split surface is damaged, the connecting rod and connecting rod cap must be replaced to reduce the possibility of engine damage. Incorrect assembly can damage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

NOTE: Make sure that the rod cap is installed **only** on the connecting rod from which it was removed and that the rod cap is properly oriented during installation.

NOTE: Both the rod cap and the connecting rod are serialized on one face to make sure of proper orientation.

Install the cap onto the connecting rod.

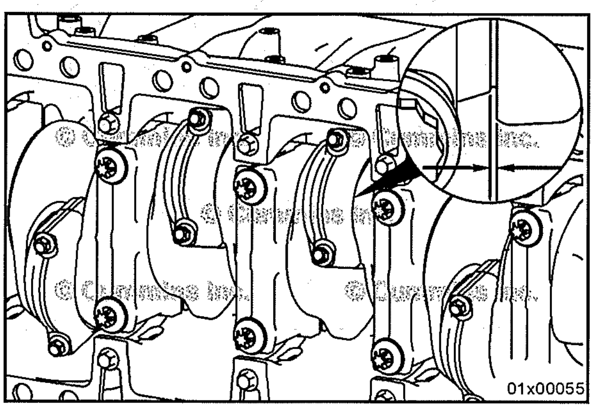
NOTE: Minimize the number of joint interactions between the connecting rod and rod cap. If the fracture split mating surface becomes damaged or worn, the rod cap will **not** fit as designed to the connecting rod. Engine damage can occur.



Lubricate the threads and the underside of the heads of the connecting rod capscrews with clean engine oil.

Thread the capscrews into the connecting rod and hand tighten.

Tighten the capscrews and torque to 85 N·m [63 ft-lb] and angle 60 degrees. Refer to Procedure 001-054 in Section 1.



Measure the connecting rod side clearance.

Connecting Rod Side Clearance		
mm		**in**
0.10	MIN	0.004
0.35	MAX	0.014

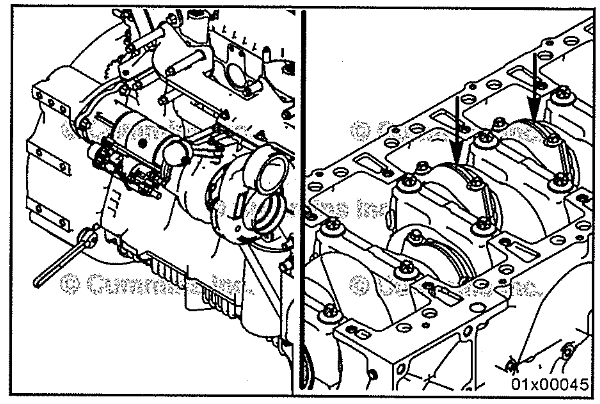
The connecting rod **must** move freely from side to side on the crankshaft journal. If the rod does **not** move freely, remove the rod cap and make sure the bearing shells are the correct size. Check for dirt or damage on the crankshaft and the bearing shells.

Repeat the above steps to install the remaining bearing shells and connecting rod caps.

Piston and Connecting Rod Assembly (001-054)

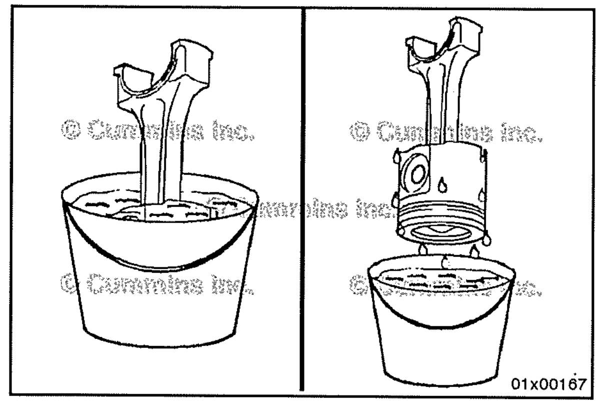
Install

Rotate the crankshaft so the connecting rod journal of the connecting rod being installed is at bottom dead center. Refer to Procedure 000-017 in Section 0.



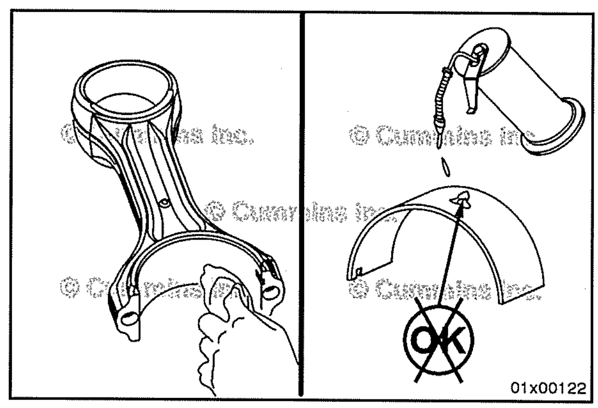
Immerse the piston in a container of clean engine oil.

Remove the piston from the container. Let the excess oil drain from the piston.



Use a clean, lint-free cloth to clean the connecting rods and bearing shells.

Do **not** lubricate the back side of the bearing shells. The operating clearance of the bearing will be reduced and the bearing can be damaged during engine operation.

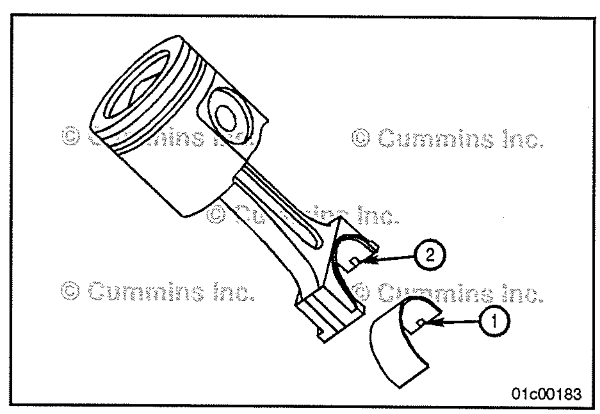


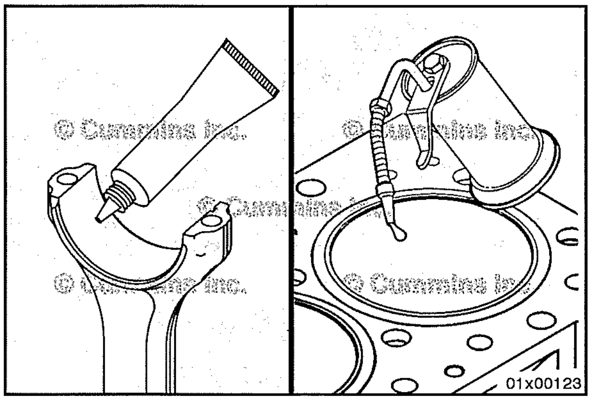
If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod from which they were removed.

Install the upper bearing shell into the connecting rod.

The tang of the bearing shell (1) **must** be in the slot of the connecting rod (2). The end of the bearing shell **must** be even with the cap mounting surface.

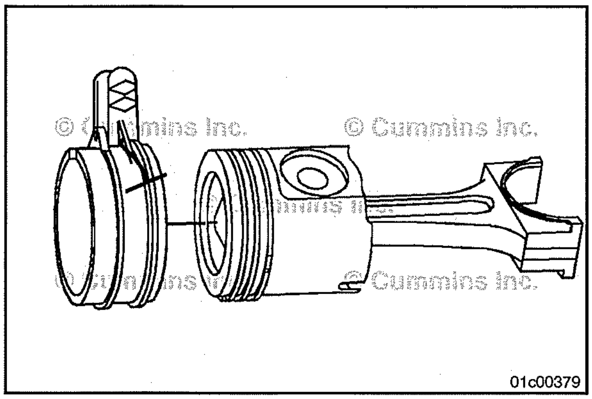
Use Lubriplate™ 105, Part Number 3163087 or equivalent, to coat the entire inside circumference of the bearing shell.



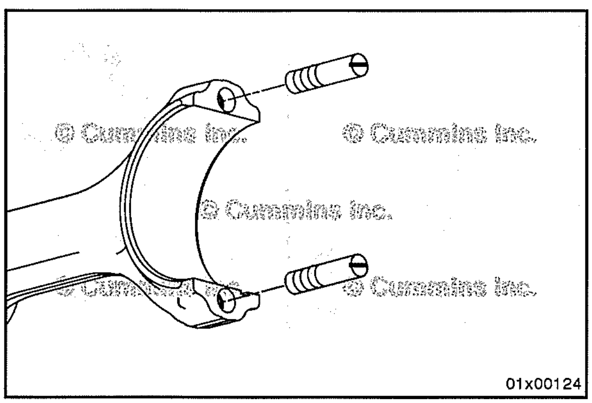


Inspect the cylinder liners for reuse. Refer to Procedure 001-028 in Section 1.

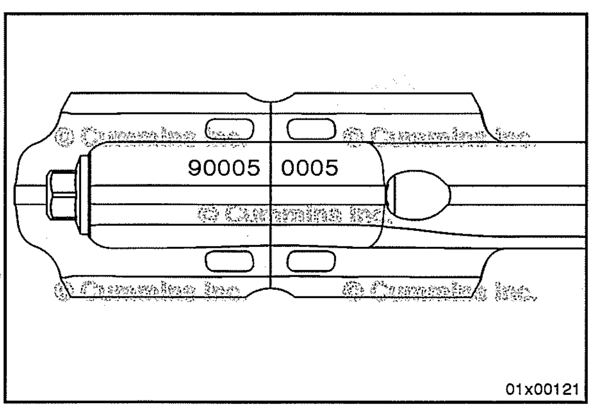
Apply a film of clean engine oil to the cylinder liner.



Use piston ring compressor, Part Number 5298583, to compress the rings. The cylinder block and all parts **must** be clean before assembly.



Install two guide pins, Part Number 5298634, hand-tight in the connecting rod to minimize the risk of damaging the fracture-split surface.



NOTE: Both the rod cap and the connecting rod are serialized on one face to make sure of proper orientation. Make sure that the rod cap is installed **only** on the connecting rod from which it was removed, and that the rod cap is properly oriented when installing.

Fracture-split connecting rods have a unique number, **not** cylinder number, stamped on the connecting rod and matching connecting rod cap. When the connecting rods and connecting rod caps are installed in the engine, the numbers on the connecting rod and cap **must** match and be installed on the same side, the exhaust side, of the engine. Arrows point toward the front of the engine.

⚠WARNING⚠

To reduce the possibility of personal injury or equipment damage, care must be taken during the installation of the connecting rod and piston assembly into the cylinder liner. The assembly can fall into the cylinder liner abruptly, once the piston rings clear the piston ring compressor as it enters the cylinder liner.

⚠CAUTION⚠

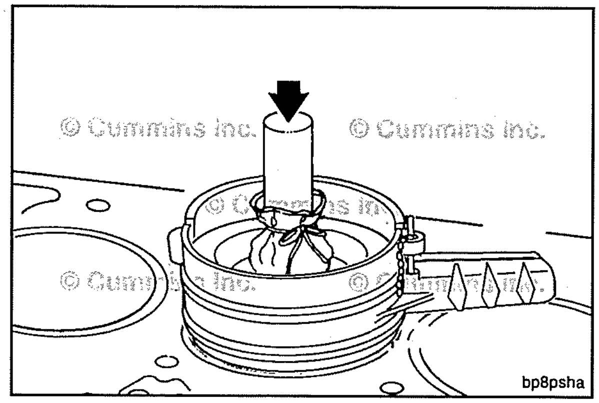
Do not use a metal drift to push the piston into the cylinder liner. The piston rings or cylinder liner can be damaged.

⚠CAUTION⚠

The connecting rod and piston assembly will fall into the cylinder once the rings have cleared the bottom of the ring compressor. The fracture-split surface and crankshaft journal bearing surface can be damaged if it is allowed to contact the crankshaft.

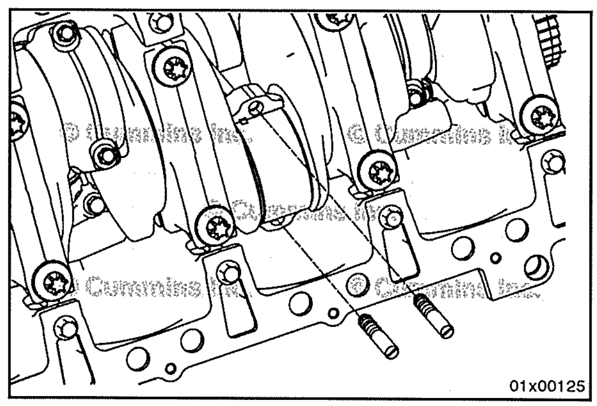
Hold the ring compressor against the cylinder liner. Push the piston through the ring compressor and into the cylinder liner. Push the piston until the top ring is completely in the cylinder liner.

If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.



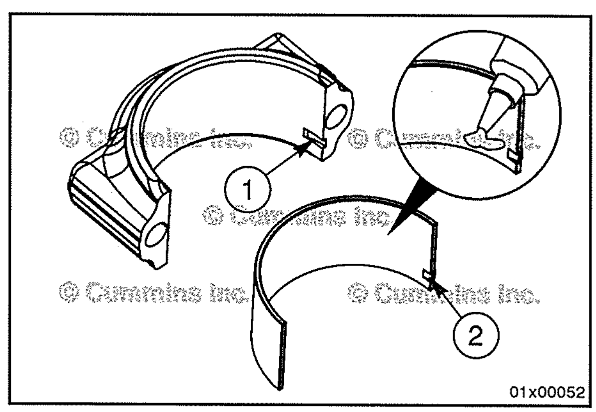
Align the connecting rod with the crankshaft while pushing the piston and connecting rod assembly into place.

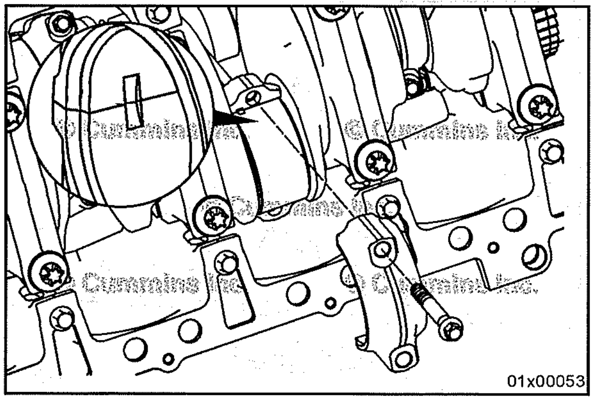
Once the rod is seated in place, remove the guide pins.



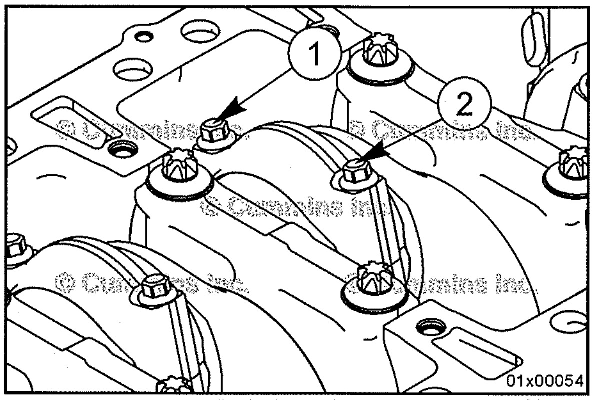
Install the lower bearing shell into the connecting rod cap with the tang (2) of the bearing in the slot (1) of the cap.

Use clean Lubriplate™ 105 multi-purpose lubricant, or its equivalent, to lubricate the bearing shell to crankshaft journal mating surface and the connecting rod capscrews.





Install the cap onto the connecting rod.

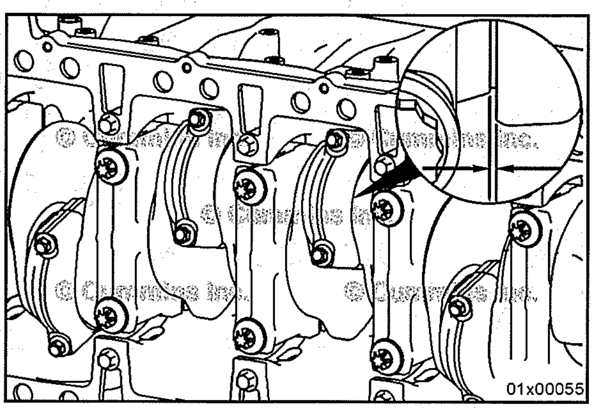


Lubricate the threads and underside of the heads of the connecting rod capscrews with clean engine oil.

Thread the capscrews into the connecting rod and hand-tighten.

Torque Value:

Step 1	85 N•m	[63 ft-lb]
Step 2	Angle 60 degrees.	

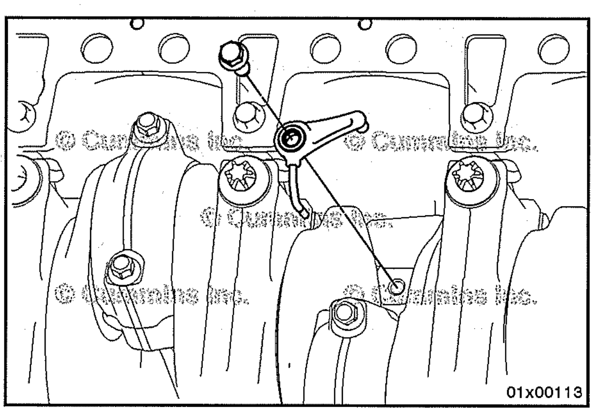


Measure the connecting rod side clearance.

Connecting Rod Side Clearance		
mm		**in**
0.10	MIN	0.004
0.35	MAX	0.014

The connecting rod **must** move freely from side to side on the crankshaft journal. If the connecting rod does **not** move freely, remove the connecting rod cap and make sure the bearing shells are the correct size. Check for dirt or damage on the crankshaft and the bearing shells.

Repeat the above steps to install the remaining bearing shells and connecting rod caps.



Piston Cooling Nozzle (001-046)

Install

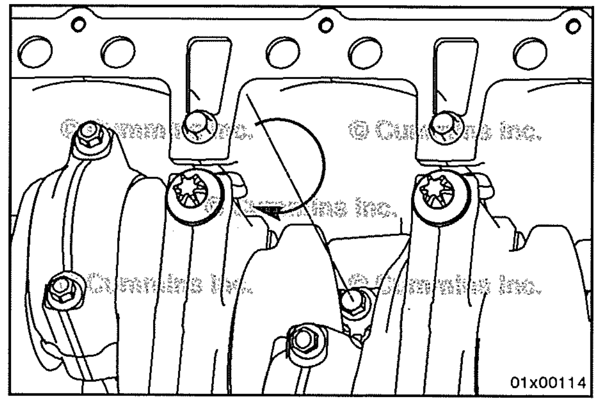
The crankshaft **must** be rotated to allow access to install all of the cooling nozzles. Refer to Procedure 000-017 in Section 0.

Align and install the piston cooling nozzle and capscrew.

Ensure that the locating pin is inserted into block.

Tighten the capscrews.

Torque Value: 28 N•m [248 in-lb]



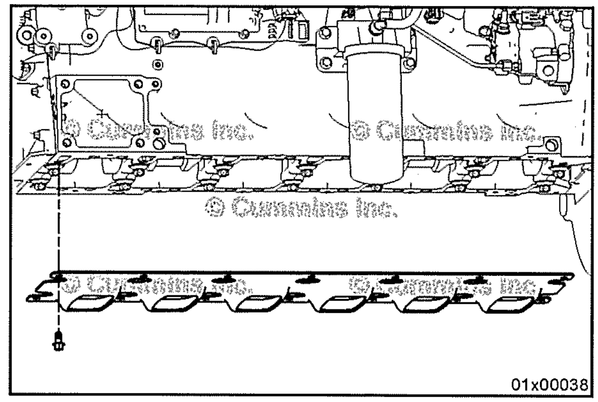
Block Stiffener Plate (001-089)

Install

Install the block stiffener plate and the capscrews.

Tighten the capscrews from the center out.

Torque Value: 46 N•m [34 ft-lb]



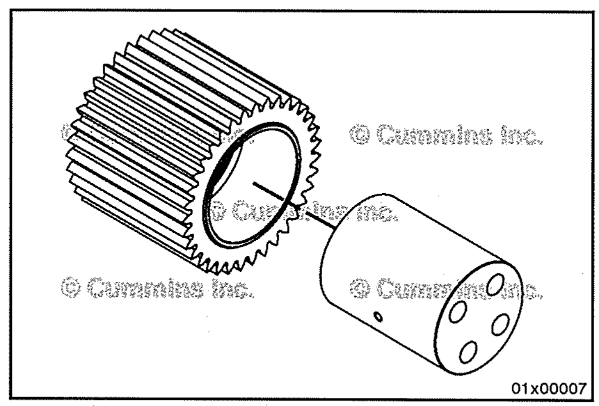
Rear PTO Idler Gear (001-093)

Install

Lubricate the inner diameter of the idler gear with Lubriplate™ 105, Part Number 3163087 or equivalent.

Install the idler gear and bushing assembly over the shaft.

Slide the assembly completely onto the shaft until it is flush against the edge of the idler gear shaft.



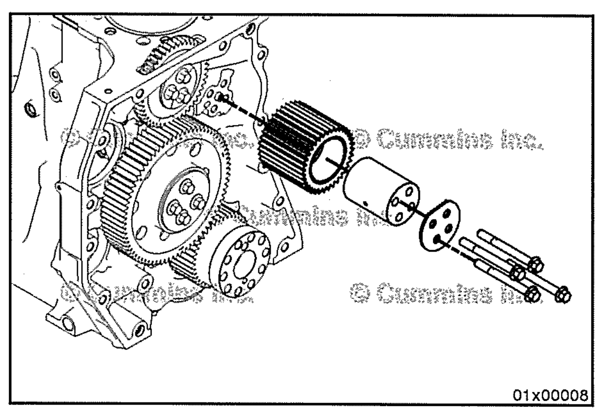
Install the idler gear and shaft assembly on to the engine block.

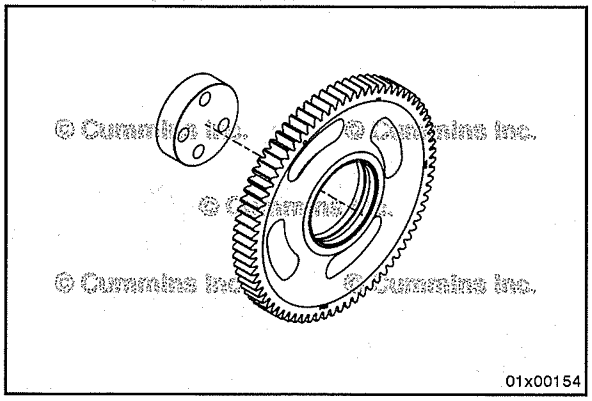
Align the idler shaft ring dowel with the hole in the engine block.

Install the capscrews through the retaining plate, the shaft, and into the gear housing.

Tighten the capscrews and torque.

Torque Value: 113 N•m [83 ft-lb]





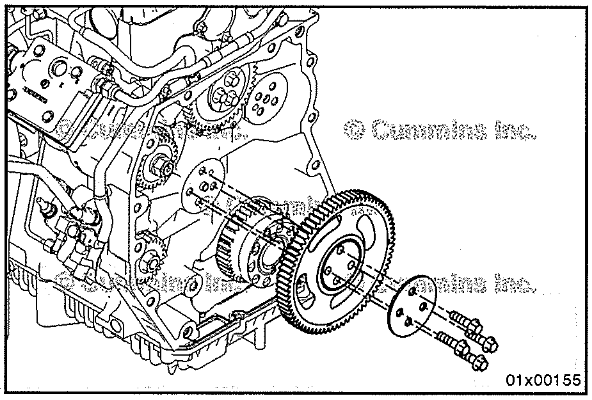
Idler Gear, Crankshaft Rear (001-118)

Install

Lubricate the inner diameter of the idler gear with Lubriplate™ 105, Part Number 3163087 or equivalent.

Install the idler gear and bushing assembly over the shaft.

Slide the assembly completely onto the shaft until it is flush against the edge of the idler gear shaft.



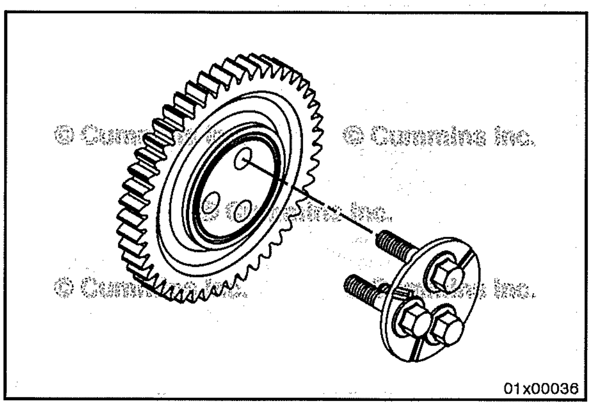
Install the idler gear and shaft assembly on to the gear housing.

Align the idler shaft ring dowel with the hole in the block.

Install the capscrews through the shaft and into the gear housing.

Tighten the capscrews and torque.

Torque Value: 113 N•m [83 ft-lb]



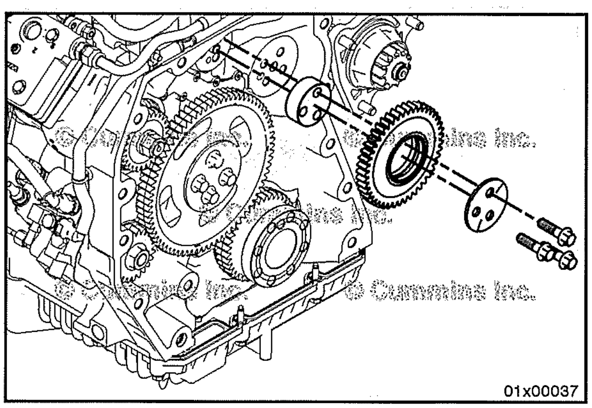
Idler Gear, Camshaft Rear (001-115)

Install

Lubricate the inner diameter of the idler gear with Lubriplate™ 105, Part Number 3163087 or equivalent.

Install the idler gear and bushing assembly over the shaft.

Slide the assembly completely onto the shaft until it is flush against the edge of the idler gear shaft.



Install the idler gear and shaft assembly on to the gear housing.

Align the idler shaft ring dowel with the hole in the engine block.

Install the capscrews through the retaining plate, the shaft, and into the gear housing.

Tighten the capscrews and torque.

Torque Value: 113 N•m [83 ft-lb]

Flywheel Housing (016-006)

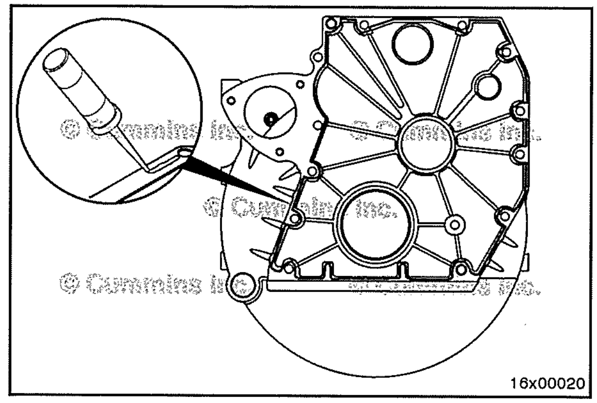
Install

NOTE: If the flywheel housing (or rear gear housing for rear gear train engines) is being replaced or if troubleshooting a vibration/alignment issue, reference the Measure section of this procedure below. Alternative steps **must** be performed before installing a new flywheel housing or if the dowel rings were removed during a previous repair.

Ensure all mating surfaces are cleaned and free from debris, lubrication and preservative.

Apply a 1- to 2-mm silicon bead of Loctite™ 509, Part Number 5298588, or equivalent, to the rear flywheel mounting surface, as shown.

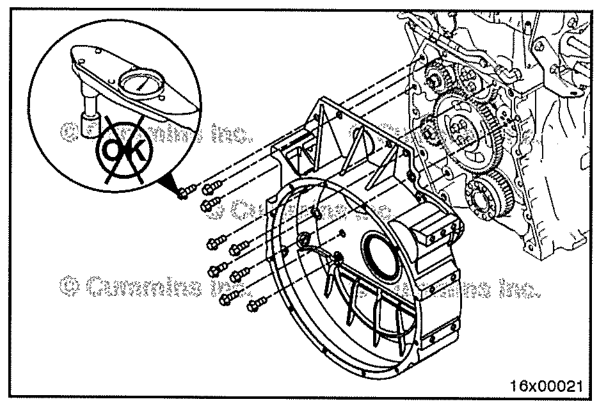
NOTE: Make sure silcon bead path is close to the lower edge as indicated in image


16x00020

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 the locating dowel rings are found to be damaged after a visual inspection, replace the dowel rings.

Install the flywheel housing and capscrews.

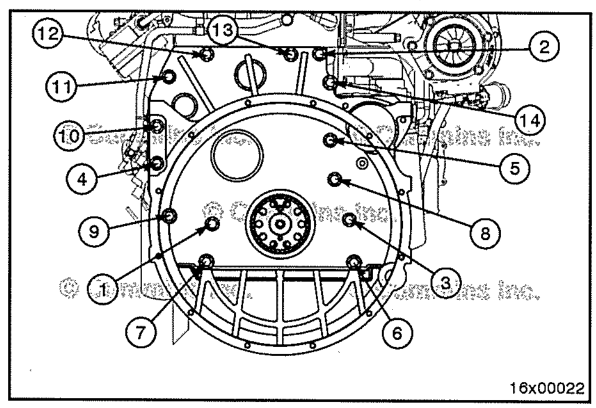
Tighten the flywheel housing capscrews finger tight.



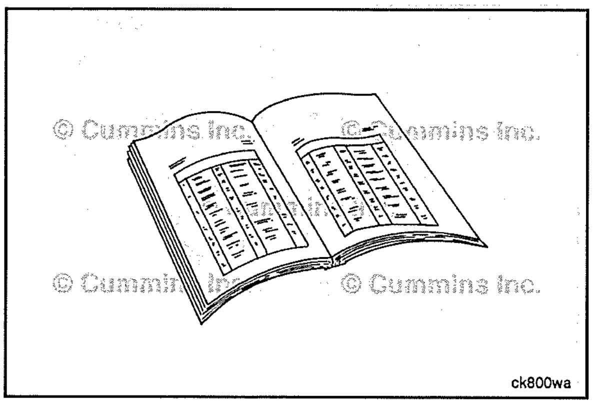
16x00021

See the illustration for the flywheel housing capscrew torque sequence.

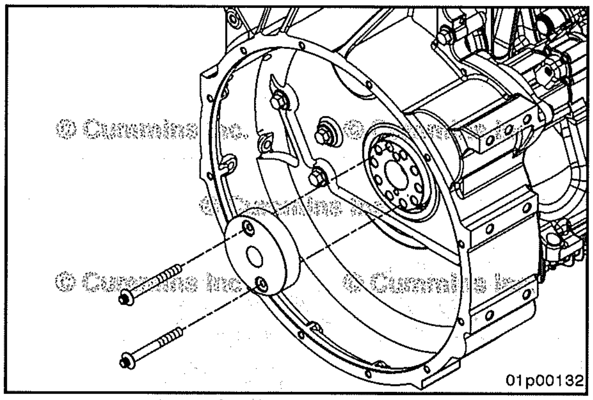
Torque Value:
M14 127 N•m [94 ft-lb]



16x00022



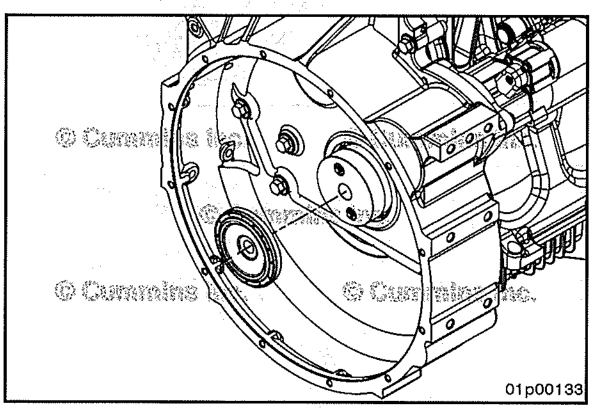
Install a new rear crankshaft seal. Refer to Procedure 001-024 in Section 1.



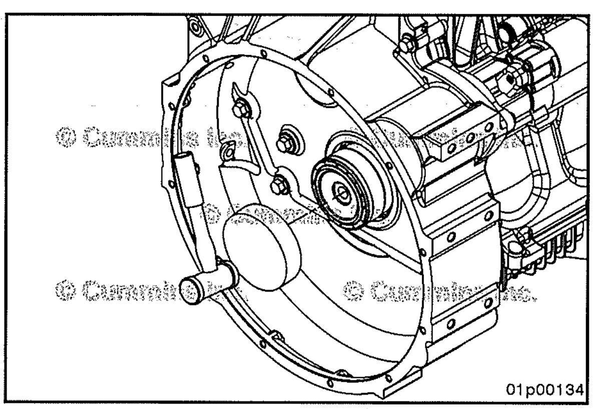
Crankshaft Seal, Rear (001-024)

Install

Install 5299478 onto the crankshaft using two capscrews, p/n 5299479, from kit 5299476.



The new rear crankshaft seal comes with a plastic guide installed in its center. Align the plastic guide with part number 5299478, from kit 5299476, and slide the seal onto part number 5299478.



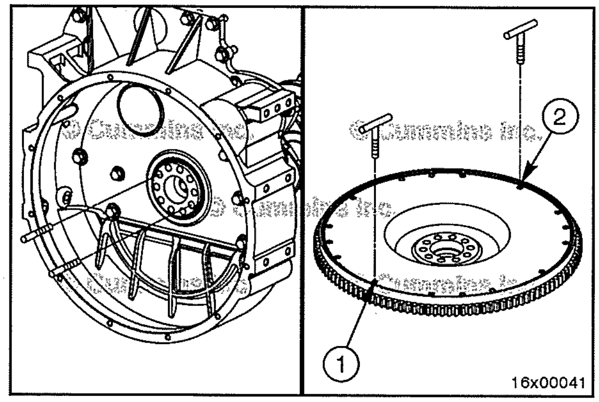
Use driver p/n 5299477 from kit 5299476 to install the seal by using a hammer to tap the tool equally at 90 degree intervals until the tool bottoms out.

Flywheel (016-005)

Install

Install two M12x1.25, 150-mm, Part Number 3376638, guide pins into the crankshaft flange 180 degrees apart.

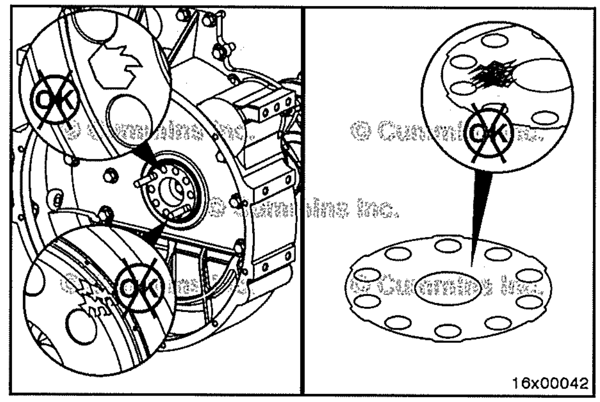
Determine the capscrew thread design and size, and install two T-handles into the flywheel (at points 1 and 2).



16x00041

⚠CAUTION⚠
Friction shim, flywheel, and crank gear interconnecting surfaces must be free of grease upon installation or engine damage may occur.

Inspect the rear face of crankshaft gear, friction shim, and flywheel mounting flange for cleanliness and raised nicks or burrs.



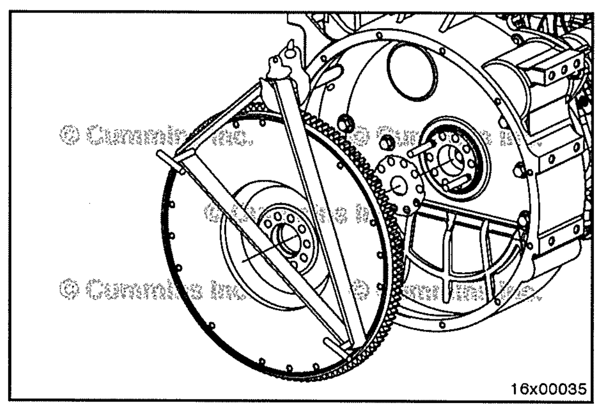
16x00042

⚠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.

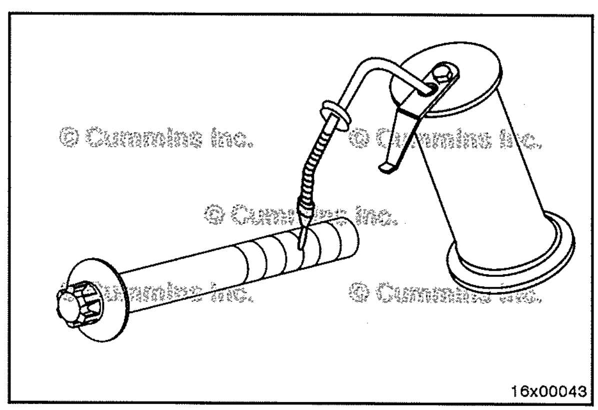
⚠CAUTION⚠
Friction shim must be properly installed or engine damage may occur.

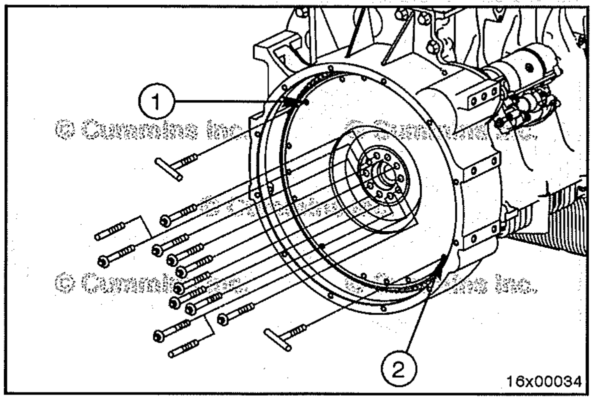
Install new friction shim onto the guide pins between the flywheel and crankshaft gear.

Install flywheel onto the guide pins and slide into place.


16x00035

Lubricate the threads of the capscrews and the surface of the built-in washers with clean lubricating engine oil. Wipe off excess oil with a clean cloth.

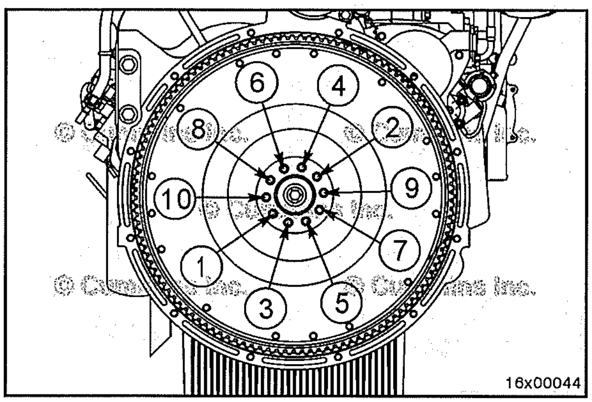

16x00043



Install the eight capscrews.

Remove the T-handles and guide pins.

Install the remaining capscrews into the holes from which the guide pins were removed.

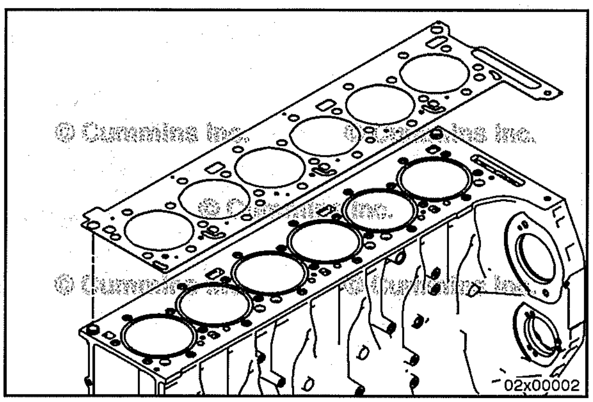


NOTE: Use the barring tool, Part Number 4919092, to hold the flywheel to prevent rotation.

Tighten the capscrews in a star pattern.

Torque Value:

Step 1	85 N•m	[63 ft-lb]
Step 2	Plus 90-degree turn.	

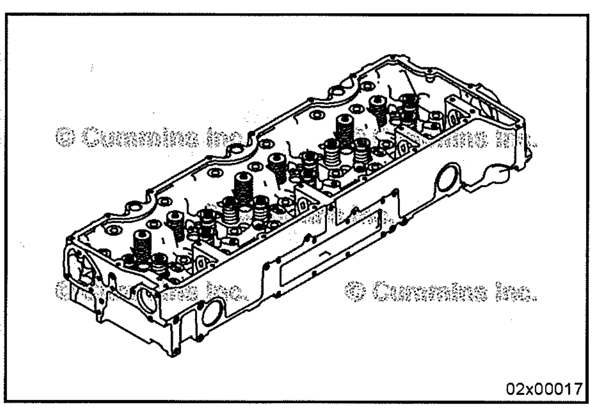


Cylinder Head Gasket (002-021)

Install

A new gasket **must** be installed. Do **not** reuse an old gasket.

Install the cylinder head gasket.

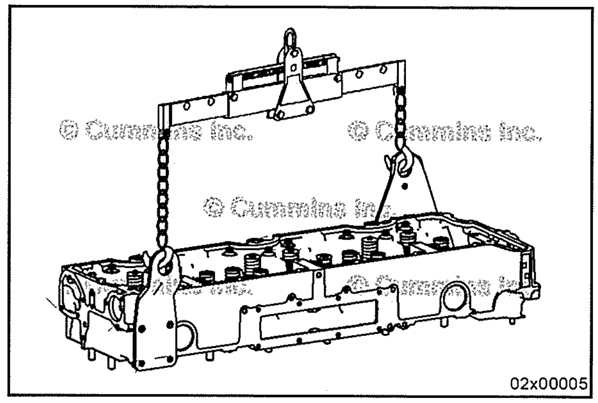


Cylinder Head (002-004)

Install

Remove all cylinder head packaging if present.

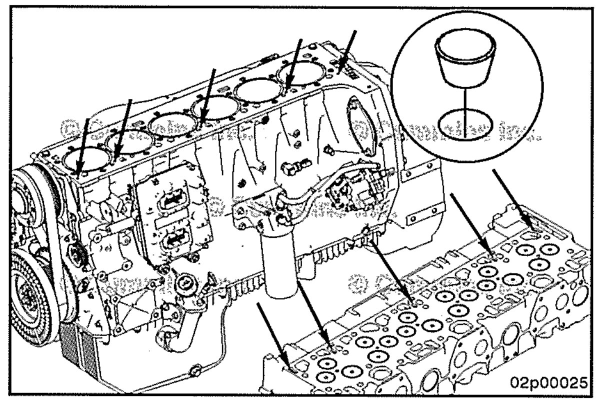
Attach the engine lifting fixture, Part Number 3162871, to the lifting eyes that are bolted to the head.



02x00005

⚠CAUTION⚠
Before the cylinder head is assembled onto the block, all oil passage plugs must be removed. Failure to remove the oil plugs will result in extensive engine damage.

Remove the oil plugs and/or tape from the cylinder head and the cylinder block.



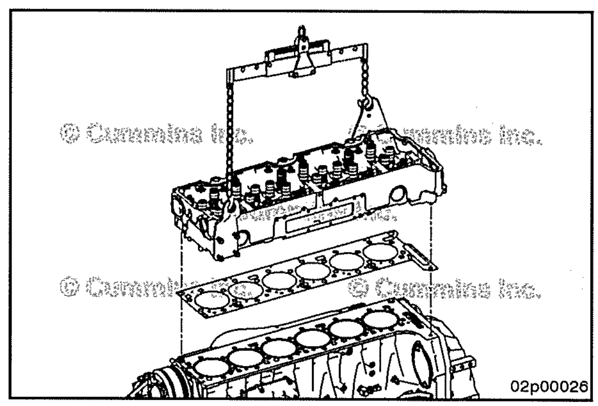
02p00025

⚠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⚠
Do not drop the cylinder head on the cylinder head gasket. The gasket material can be damaged.

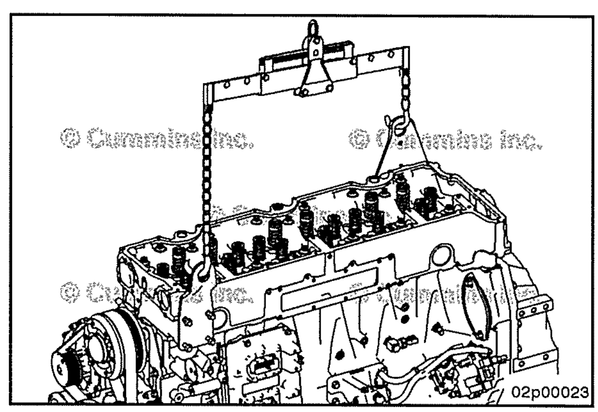
Install a new cylinder head gasket.

Use a hoist or hydraulic arm and install the cylinder head.

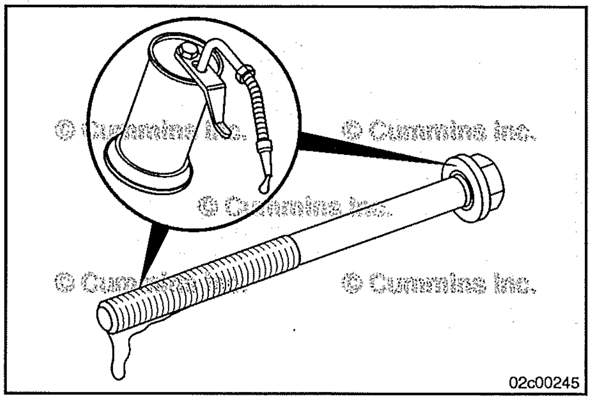


02p00026

Remove the engine lifting fixture, Part Number 3162871, from the lifting eyes that are bolted to the head.



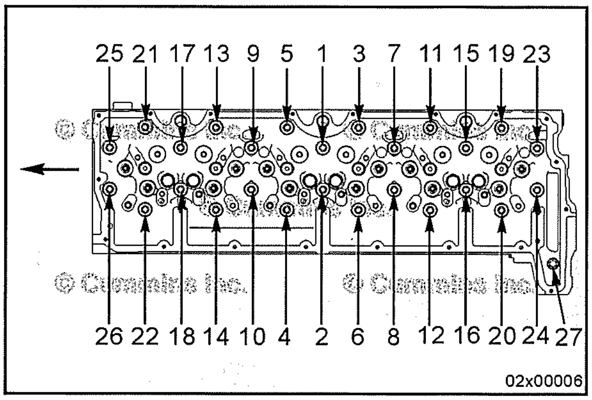
02p00023



Use clean lubricating engine oil to lightly coat the cylinder head capscrew threads and bottom of the flange.

Allow the excess oil to drain from the capscrew threads.

Install the cylinder head capscrews.



Tighten all the capscrews in the sequence shown to the specified values:

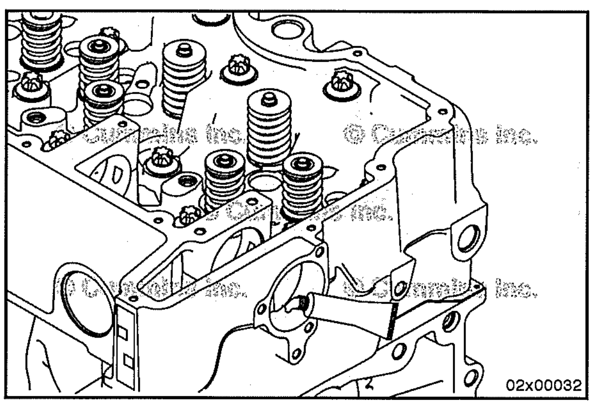
For capscrews 1 to 26

Torque Value:

Step 1	90 N•m	[66 ft-lb]
Step 2	150 N•m	[118 ft-lb]
Step 3	Rotate 120 degrees.	

For capscrew 27

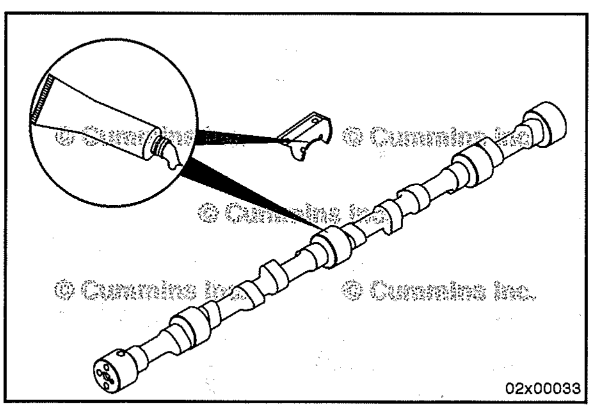
Torque Value: 46 N•m [34 ft-lb]



Overhead Camshaft, Valve (002-024)

Install

Apply assembly lubricant, Part Number 3163087, to the rear camshaft bore.



Lubricate the camshaft lobes, journals, and thrust plate with assembly lubricant, Part Number 3163087.

CAUTION

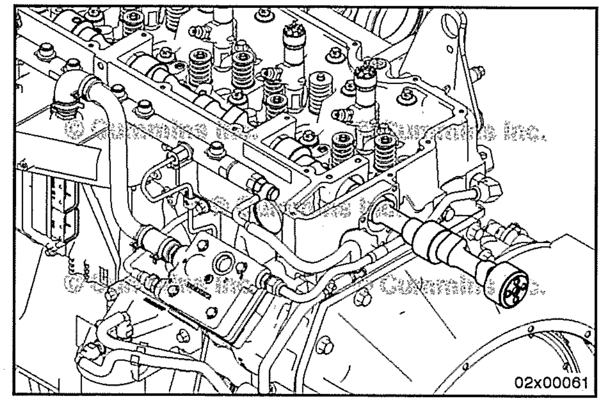
Forcing the camshaft into the cylinder head may cause damage to the camshaft bores.

Install the camshaft.

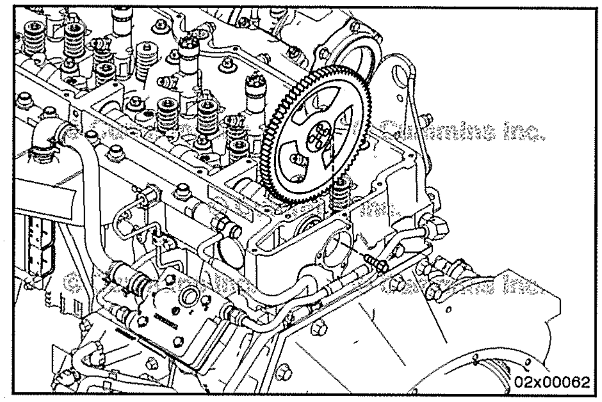
While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bores.

As each camshaft journal passes through a bore, the camshaft will drop slightly and the camshaft lobes will catch on the bores.

Rotating the camshaft frees the lobe from the bore and allows the camshaft installation to continue.

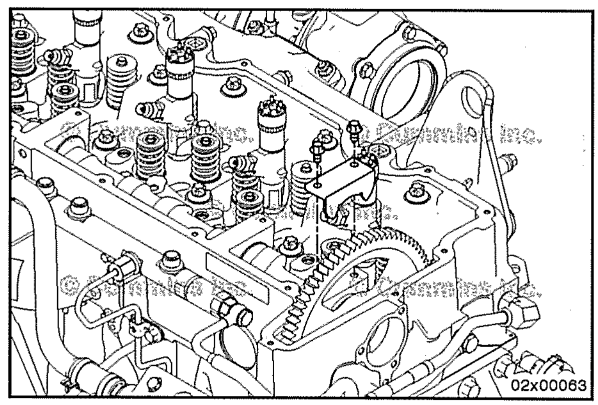


Install the Camshaft Gear. Refer to Procedure 002-030 in Section 2.



Install the thrust plate.

Torque Value: 23 N•m [204 in-lb]

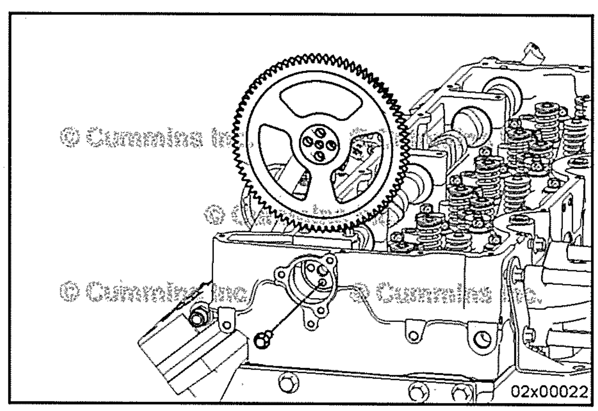


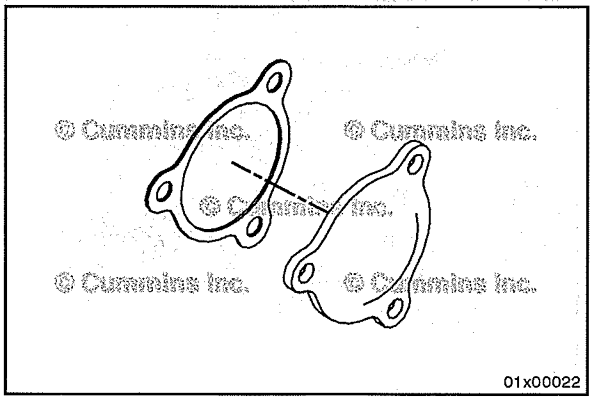
Overhead Camshaft Gear, Valve (002-030)

Install

Install the overhead camshaft gear and tighten the four bolts.

Torque Value: 65 N•m [48 ft-lb]

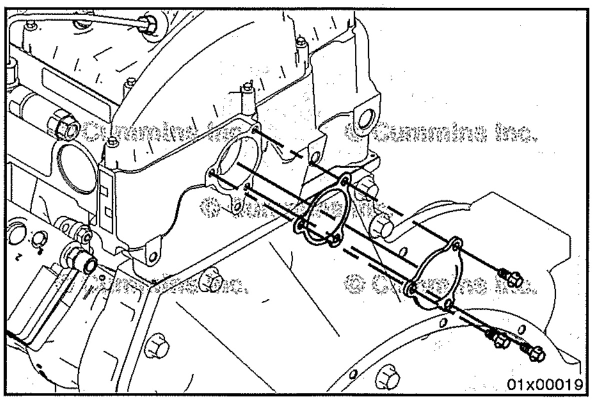



01x00022

Camshaft Cover Plate (001-011)

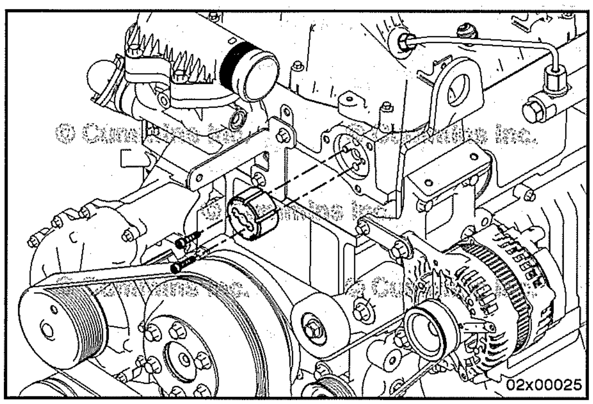
Install

Install a new gasket for the camshaft cover plate.


01x00019

Install the rear camshaft cover plate and mounting capscrews.

Torque Value: 23 N•m [204 in-lb]


02x00025

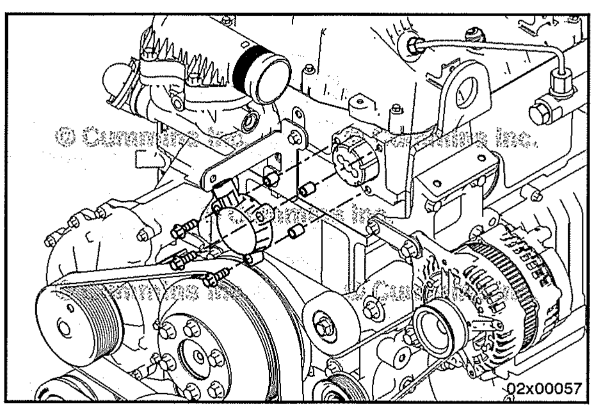
Overhead Camshaft Timing Speed Ring (002-034)

Install

Install the timing speed ring.

Install the two capscrews into the timing speed ring.

Torque Value: 9.5 N•m [84 in-lb]


02x00057

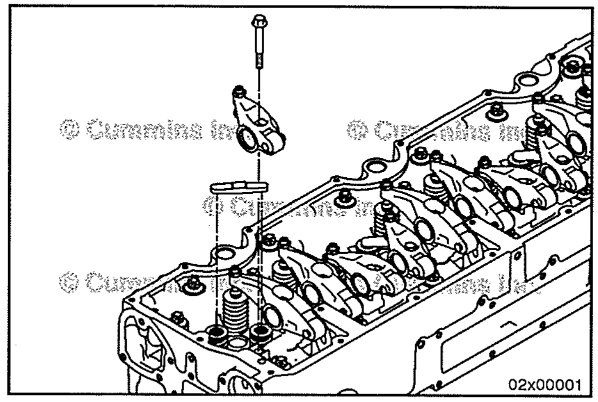
Install the overhead camshaft timing speed ring cover.

Install the three bolts in the overhead camshaft timing speed ring cover.

Torque Value: 23 N•m [204 in-lb]

Crosshead (002-001)

Install



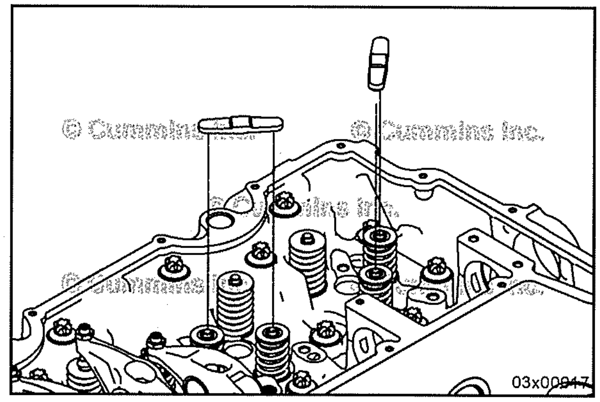
NOTE: The crosshead has a round and oval hole. If installing new crossheads, it is **not** required to place the holes in a particular position. If crossheads are being reused, make sure to install them in their original locations and orientations.

Install the crossheads on the valve stems.

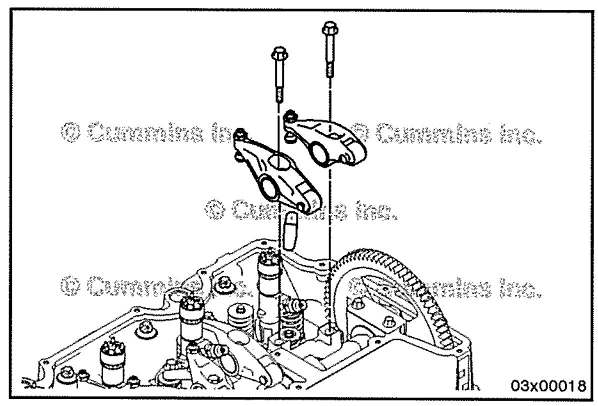
Install the rocker levers to the pedestals. Refer to Procedure 003-009 in Section 3.

Rocker Lever Assembly (003-009)

Install



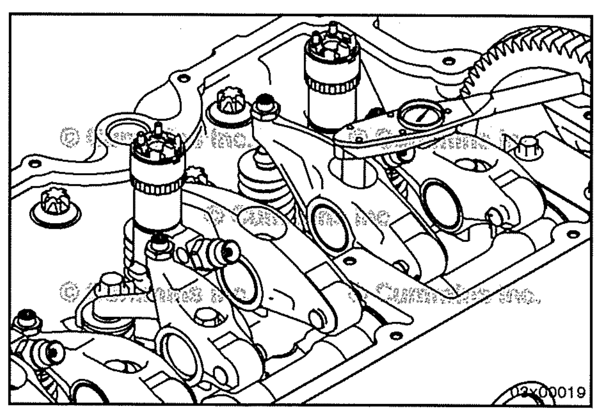
Install the crossheads in their original location and position.



Install the rocker lever assemblies and pedestals in their original position.

Lubricate the mounting capscrews with clean engine oil.

Install the pedestal mounting capscrews.

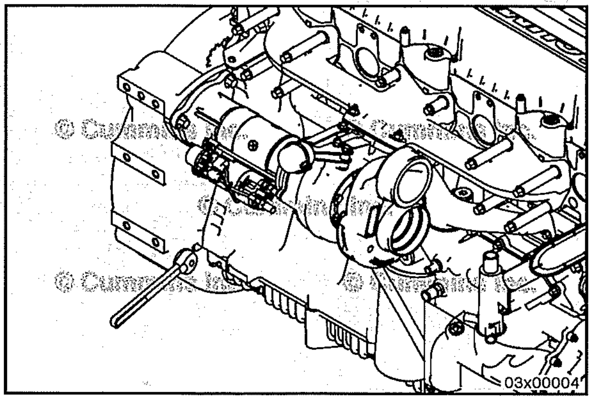


Tighten the intake and exhaust rocker lever mounting capscrews.

Torque Value: 65 N•m [48 ft-lb]

Overhead Set (003-004)

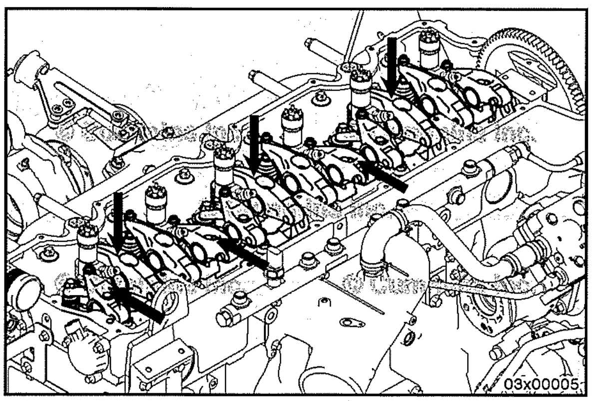
Adjust



NOTE: For ambient air temperatures of 30°C [86°F] and below, allow the engine to cool for 1.5 hours prior to checking or setting the valve lash. For ambient air temperatures above 30°C [86°F], allow the engine to cool for 2.5 hours prior to checking or setting the valve lash.

Use the barring tool, Part Number 4919092, to rotate the crankshaft until the number 1 cylinder is at top dead center (TDC). The barring port can be found on the bottom of the flywheel housing.

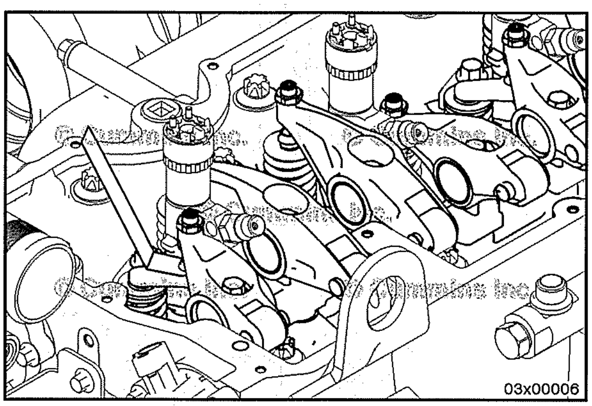
Top dead center (TDC) for the number 1 cylinder can be found by lining up the hole in the vibrations damper and the lubricating pump housing. The rockers for the number 1 cylinder **must** be free to move. If the rockers for the number 6 cylinder are free to move, the crankshaft **must** be rotated 360 degrees.



With the engine in this position, lash can be measured on the following rocker levers:

Exhaust Valve of Cylinder 1, 3 and 5.

Intake Valve Cylinder 1, 2 and 4.



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 specifications.

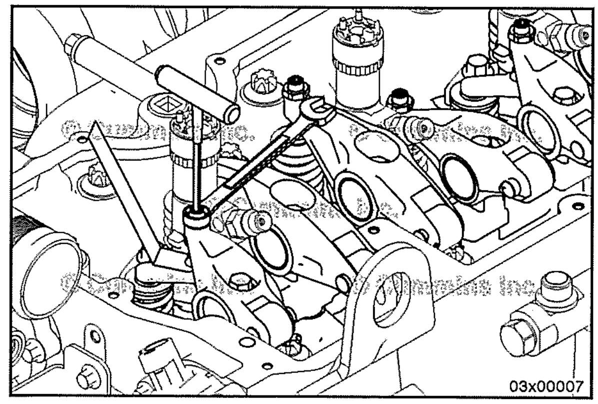
NOTE: The clearance is correct when some resistance is "felt" when the feeler gauge is slipped between the crosshead and the rocker lever socket.

Measure lash by inserting a feeler gauge between the valve and the rocker lever socket. If the lash measurement is out of specification, loosen the locknut, and adjust the lash to nominal specifications. Use Part Number 3163172 and 3163171 to measure the lash.

Intake Valve Lash (Nominal) 0.36 ± 0.08 mm [0.014 ± 0.003 in]

Exhaust Valve Lash (Nominal) 0.69 ± 0.08 mm [0.027 ± 0.003 in]

Tighten the locknut and measure the lash again.



⚠CAUTION⚠

Engine damage can occur if the running clearance is not within specifications.

Torque Value: 28 N•m [248 in-lb]

Use barring tool, Part Number 4919092, to rotate the crankshaft 360 degrees.

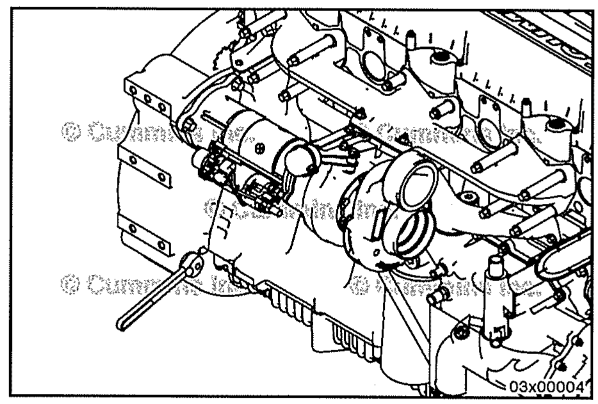
Following the same steps and specifications as previously stated, measure lash for the following rocker levers:

(E = exhaust, I = Intake)

Exhaust Valve of cylinders 2, 4, and 6.

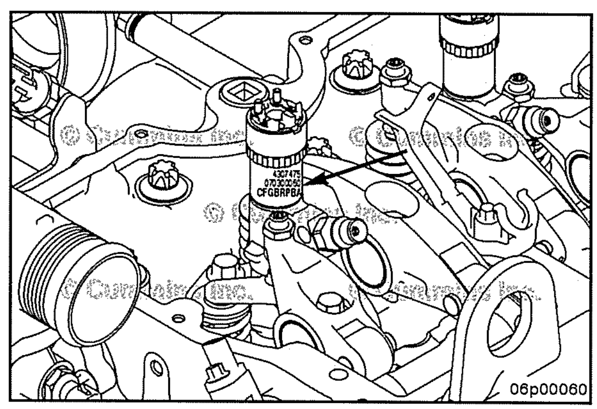
Intake Valve of cylinders 3, 5, and 6.

Reset if out of specification.



Injector (006-026)

Install



⚠CAUTION⚠

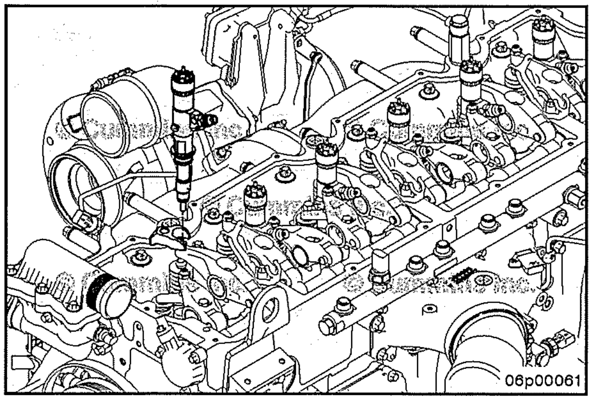
When installing the injector, care must be taken not to damage the injector tip.

NOTE: If the injector solenoid shipping cap is **not** used to install the injector, be careful that pressure is **not** placed on the wire terminals. Wire terminals can break off if they are used to push on the injector.

Record the injector trim codes that are listed on each injector.

Record the cylinder location where each injector will be installed.

NOTE: The injector trim codes are nine-character alphanumeric codes, located on the solenoid at the top of the injector.



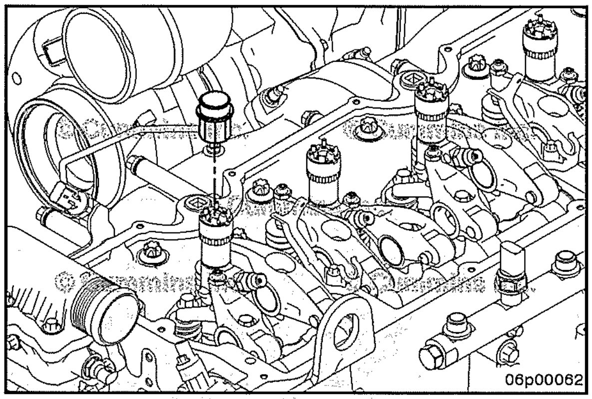
Remove the blind plug installed to prevent dust or debris from entering the engine.

Make sure the injector bore is clean.

Ensure o-ring and injector seal are properly installed.

Lubricate injector o-ring with clean engine oil.

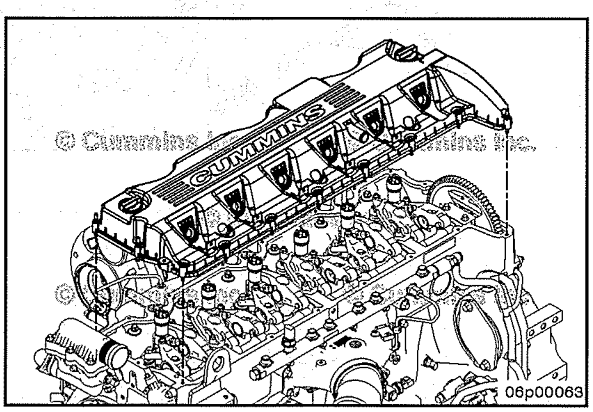
Install injector hold-down clamp on injector before installing injector into the bore.



Use injector solenoid shipping cap to ensure injector is seated in the injector bore.

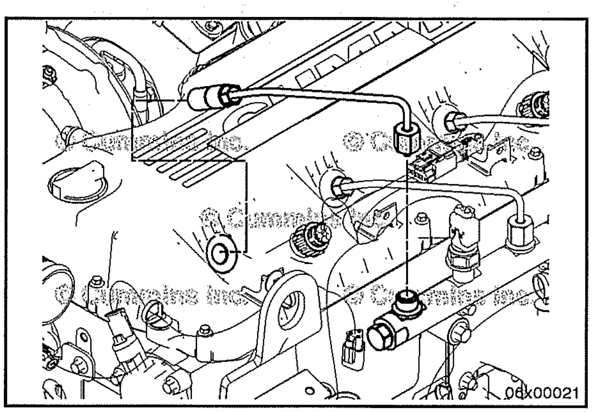
Install injector hold-down capscrew. Do **not** tighten beyond hand-tight at this time.

Repeat process to loosely install the other five injectors.



Install rocker lever cover without the oil seal. Tighten one mounting capscrew on each side of the cover. Refer to Procedure 003-011 in Section 3.

NOTE: The rocker lever cover **must** be installed without the oil seal. If this procedure is performed with the oil seal installed on the rocker lever cover the injectors may **not** align properly, causing oil and/or fuel leaks.



Connect injector end of one of the high-pressure fuel lines to injector. Use injector end nut as a guide and center injector in the grommet.

Remove high-pressure fuel line from injector and repeat process for all six injectors.

Remove rocker lever cover and install the oil seal. Refer to Procedure 003-011 in Section 3.

Tighten the injector hold-down clamp capscrew.

Torque Value:
Injector Hold-down Clamp Capscrews 65 N•m [48 ft-lb]

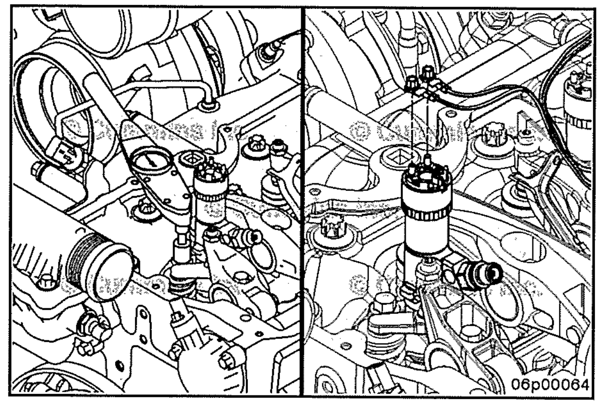
Install the injector actuator wires and nuts onto the injector.

NOTE: Align the injector wires so they will **not** interfere with each other or the rocker levers. If a rocker lever is able to come into contact with the injector harness, it will rub through the wire insulation and cause injector circuit fault codes.

Tighten the nuts.

Torque Value:
Injector Actuator Wire Nuts 2 N•m [18 in-lb]

Repeat the process to install the other five injectors.



Internal Actuator Wiring Harness (019-063)

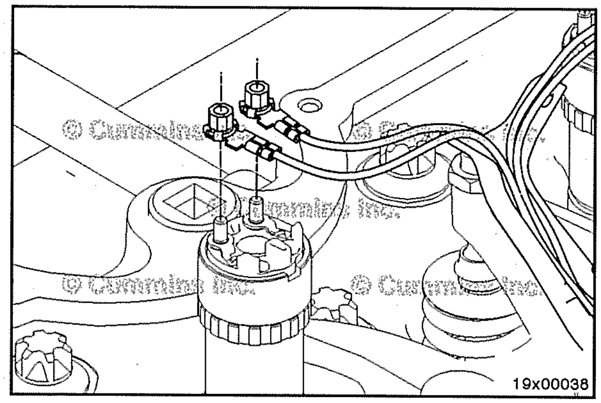
Install

Connect the actuator harness to each of the injector solenoids.

Torque Value: 2 N•m [18 in-lb]

NOTE: Install the injector wires so they will **not** interfere with a rocker lever. If the rocker lever is able to come into contact with the injector harness, it will rub through the wire insulation and cause injector circuit fault codes.

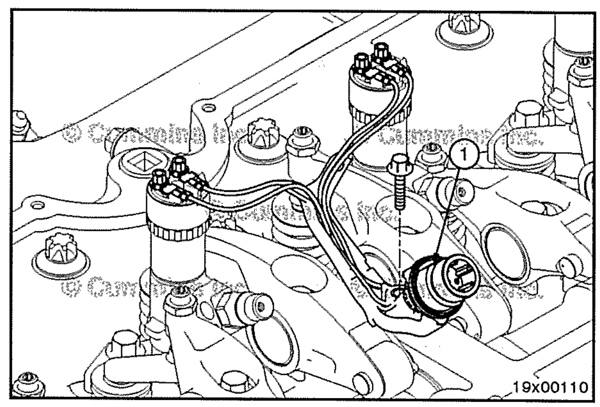
Torque Value: 2 N•m [18 in-lb]



Install the capscrew securing the internal actuator harness to the rocker lever housing.

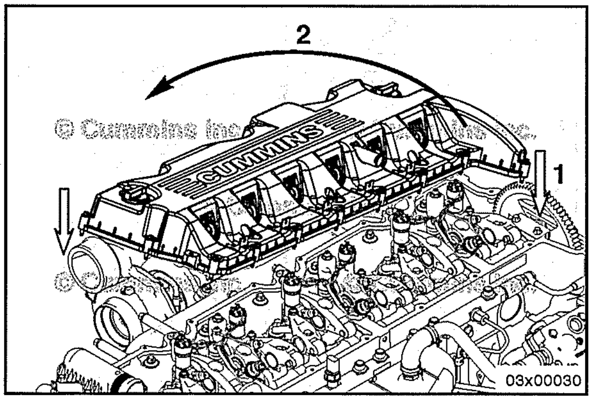
Torque Value: 9.5 N•m [84 in-lb]

NOTE: Verify the passthrough connector is positioned with the locating flat (1) facing up.



Rocker Lever Cover (003-011)

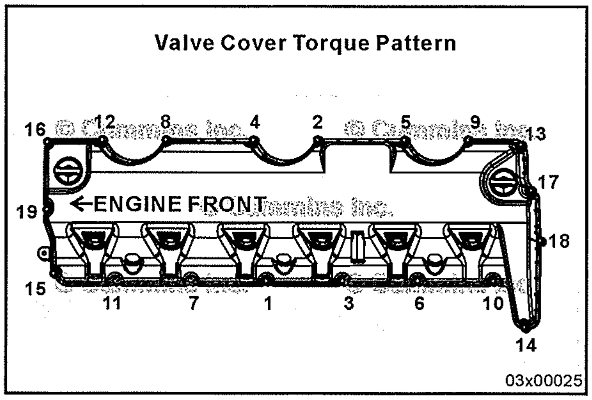
Install



Verify the injector passthrough connector locating flats are positioned on the top of the connector.

Install the rocker lever cover.

To aid installation tilt the cover to the left side of the engine. Lower the left side of the cover onto the head first, then lower the right side. Be sure the pass through connectors have seated properly with the locating flat on the top of the connector.



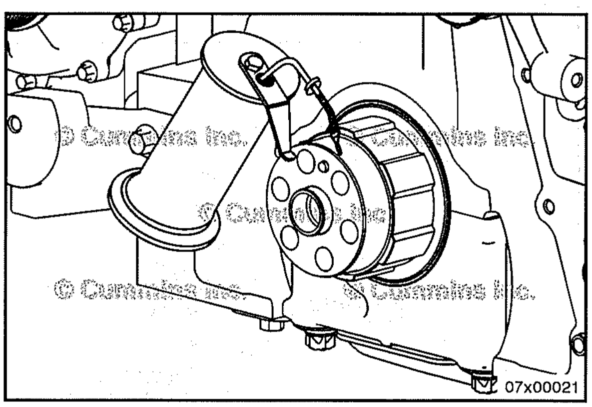
Tighten the mounting capscrews in the sequence shown.

Torque Value: 9.5 N•m [84 in-lb]

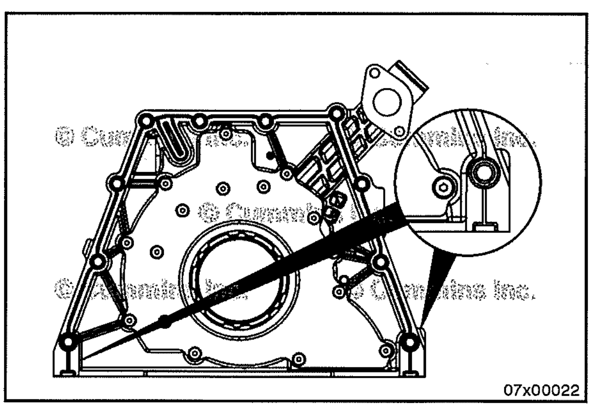
Install the injector passthrough connector lock rings.

Lubricating Oil Pump (007-031)

Install



Lubricate the outside surface of crankshaft with clean engine oil.



When installing the lubricating pump housing gasket, take care **not** to damage the rubber seal on the bottom edges of the gasket.

NOTE: This gasket features pre-installed sealant to seal the joint between the lubricating oil pump housing, engine block and lubricating oil pan. If this sealant is damaged, the gasket **must** be replaced.

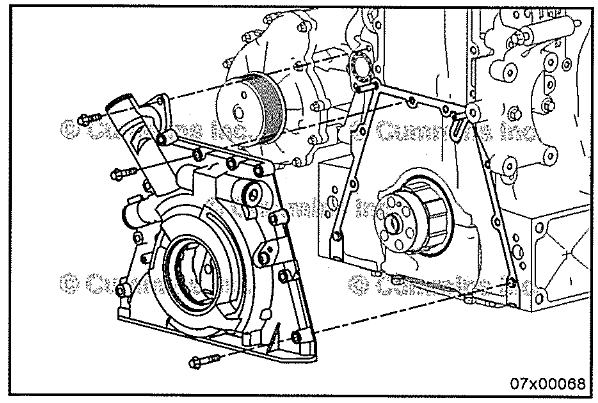
Install guide pins, Part Number 3164977, in the top corner capscrew locations as indicated.

Install the lubricating oil pump gasket. Use the guide pins and dowel rings in the cylinder block to locate and temporarily hold the lubricating oil pump gasket in place.

NOTE: If needed, rotate the lubricating oil pump in the lubricating pump housing to align with the lubricating oil pump drive gear on the crankshaft.

Install the lubricating oil pump.

NOTE: As documented during removal, make sure to install the mounting capscrews in the correct locations.

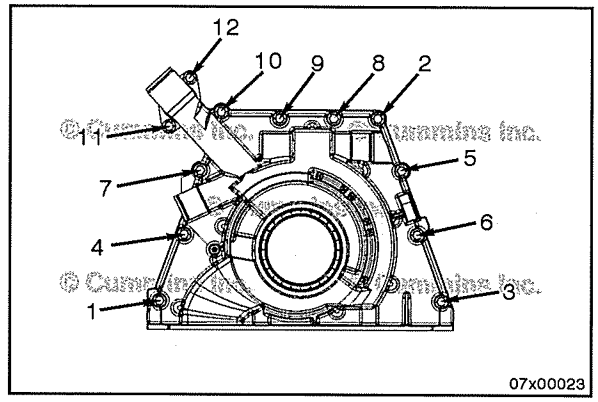


Install the eight lubricating oil pump capscrews and two lubricating oil transfer tube capscrews. Ensure correct length fasteners are used in the correct location. Tighten the capscrews finger tight.

Remove the guide pins and install the two remaining capscrews.

Tighten the capscrews in the sequence shown.

Torque Value: 23 N•m [204 in-lb]



Crankshaft Seal, Front (001-023)

Install

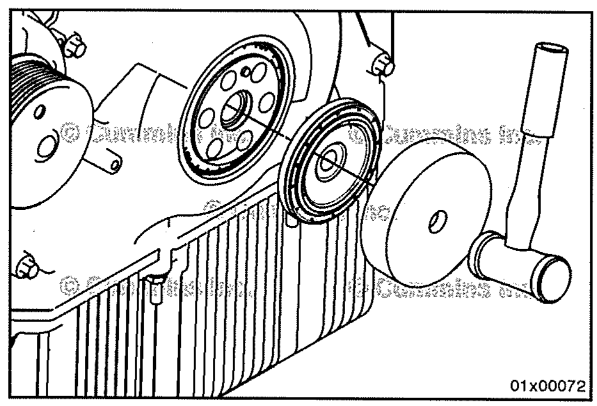
The new front crankshaft seal comes with a plastic guide installed in its center. Do **not** remove this guide before the installation. It should be used to locate the seal on the crankshaft nose.

Lubricate the outside diameter of the seal to prevent tearing upon installation.

Use tool, Part Number 5299870, to install the oil seal into the front gear housing.

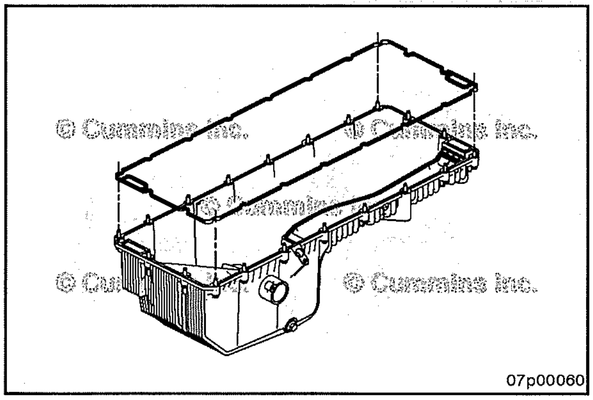
The tool fits over the oil seal and installs the seal to the proper depth when it is flush with the front gear housing face.

Use a plastic hammer to tap the tool equally at 90 degree intervals until the seal is all the way in.



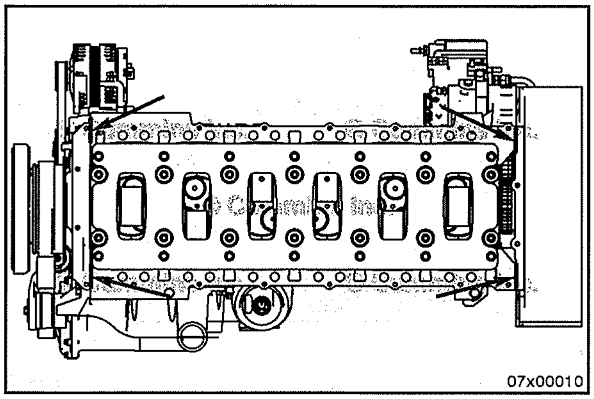
Lubricating Oil Pan (007-025)

Install



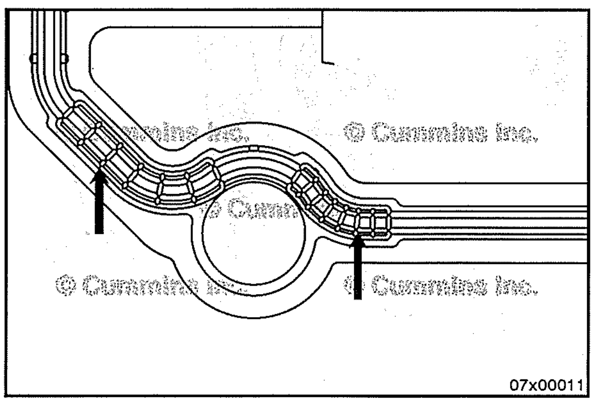
Assemble the gasket fully into the oil pan gasket groove.

NOTE: Gasket **must** be fully seated into the groove in order to avoid gasket damage. Damage to the gasket can result in oil leaks.

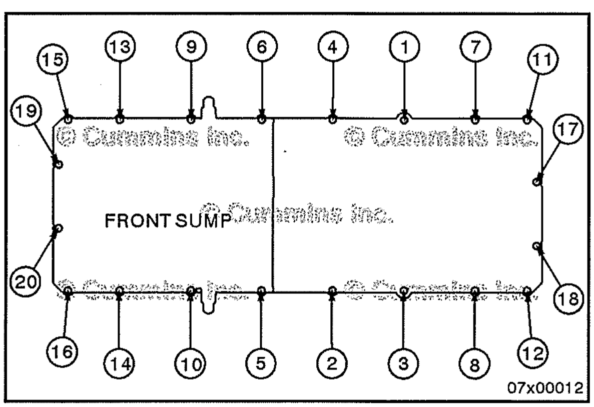


Apply a thin bead of sealant, Part Number 3164070, to the t-joints shown in the illustration.

NOTE: if a new lubricating oil pump housing gasket was installed, do **not** use sealant at the two t-joints on the oil pan rail where the front gear cover meets the engine block.



When applying sealant, apply it to the waffle patterned areas of the gasket.



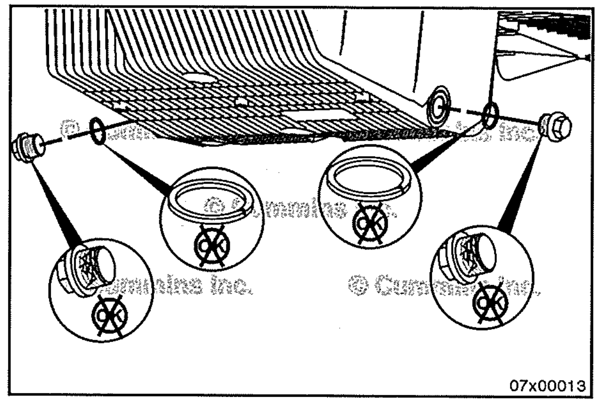
Tighten all capscrews in the sequence shown in the illustration.

Torque Value: 23 N•m [204 in-lb]

Clean and check the oil drain plug threads and sealing surface.

Inspect the oil drain plug o-ring, replace if damaged.

Torque Value: 55 N•m [41 ft-lb]



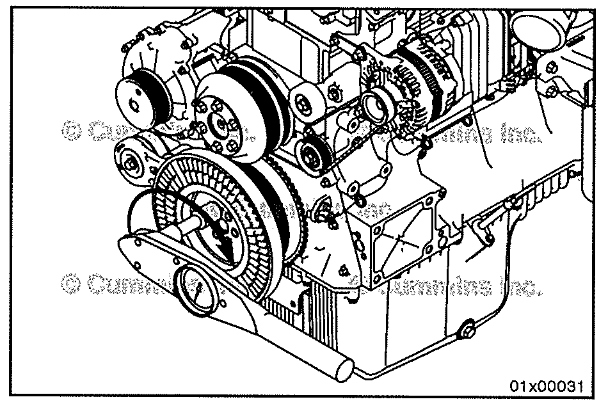
Crankshaft Pulley (001-022)

Install

Install two guide pins, Part Number 3376696.

Assemble the crankshaft pulley, vibration damper, and crankshaft spacer to the crankshaft over the guide pins.

Make sure the dowel pin is aligned correctly.



Lubricate the capscrews with clean engine oil.

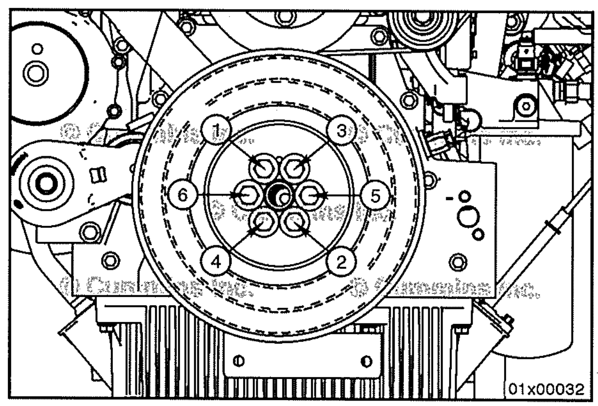
Install four capscrews into the empty holes hand tight.

Remove the two guide pins and install the last two capscrews.

Tighten the six crankshaft pulley capscrews in the proper torque pattern as shown in graphic.

Torque Value:

Step 1	175 N•m	[129 ft-lb]
Step 2	Rotate 60 degrees	



Vibration Damper, Viscous (001-052)

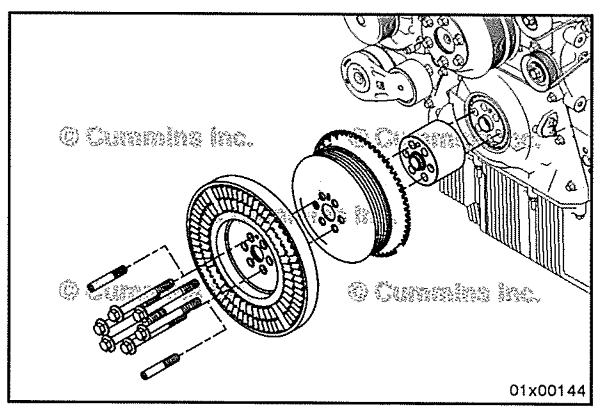
Install

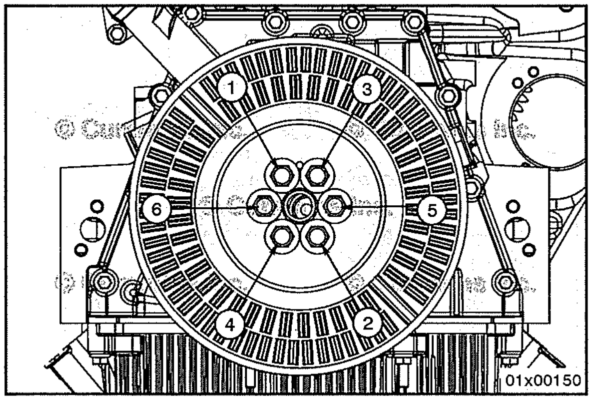
Install two guide pins, Part Number 3376696, to support the crankshaft spacer, pulley, and damper.

Install the crankshaft spacer, pulley, and damper over the guide pins in the same order in which they were removed.

Install four capscrews finger tight and then remove the two guide pins.

Install the last two capscrews.

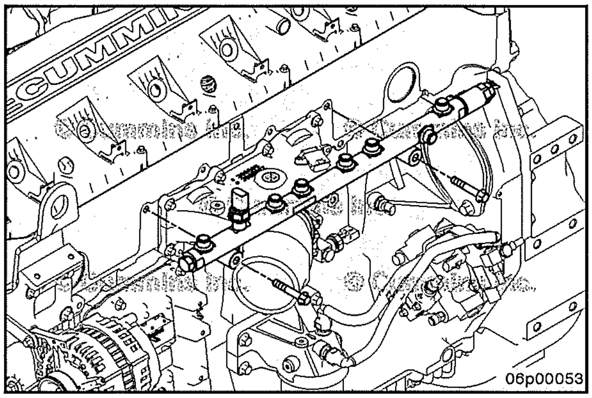




Tighten the six vibration damper capscrews in the proper sequence shown in graphic.

Torque Value:

Step 1	175 N•m	[129 ft-lb]
Step 2	Angle 60 degrees	

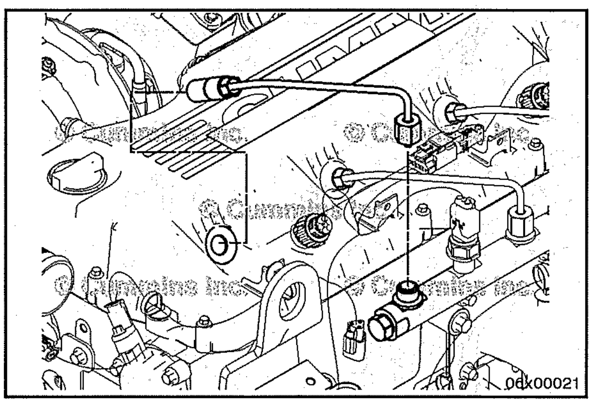


Fuel Rail (006-060)

Install

Install the fuel rail assembly.

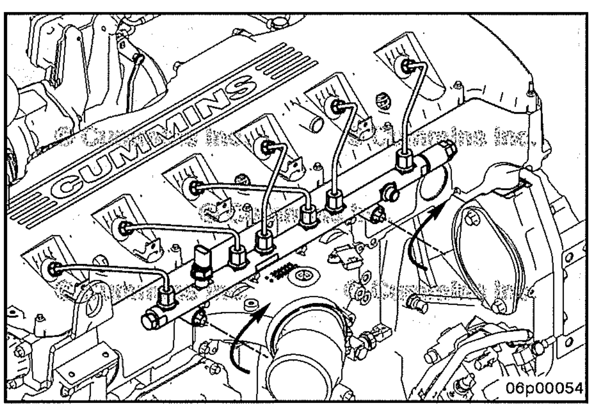
Hand-tighten the fuel rail capscrews.



⚠CAUTION⚠

Injector supply lines and the high-pressure supply line must be torqued prior to tightening the fuel rail cap screws.

Install the injector supply line(s) that connect the fuel rail to the fuel injectors. Refer to Procedure 006-051 in Section 6.



Tighten the fuel rail capscrews.

Torque Value: 46 N•m [36 ft-lb]

Fuel Pump (005-016)

Install

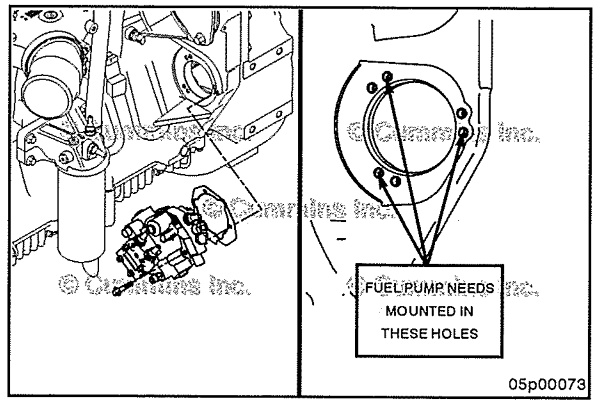
NOTE: Timing of the high-pressure pump with the crankshaft is **not** required.

Install the fuel pump and gasket on the gear housing.

Install the fuel pump mounting capscrews and tighten.

NOTE: Fuel pump needs to be mounted in the correct holes. See illustration.

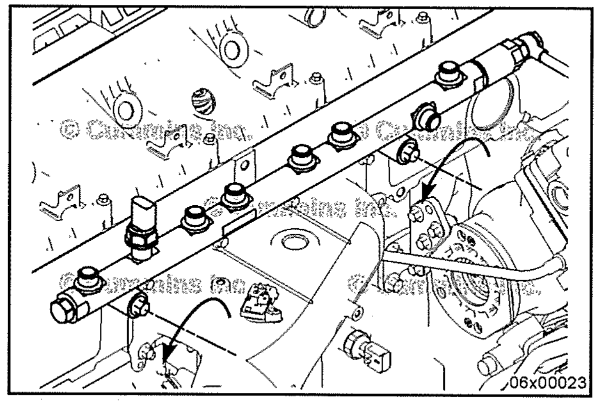
Torque Value: 23 N•m [204 in-lb]



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

Install

Loosen the capscrews for the fuel rail. Do **not** remove the fuel rail. The capscrews are loosened to allow proper alignment of the fuel rail after installing the new fuel line.



Using clean 15W-40 engine oil, lubricate the six injector fuel line seals in the rocker cover before fitting the injector fuel lines.

The fuel lines **must** be aligned correctly. The process below should be followed to avoid any problems.

Hand-tighten the injector fuel line union at the injector. Make sure the line is central within the union.

Hand-tighten fuel line union at the rail. Make sure the line is central within the union.

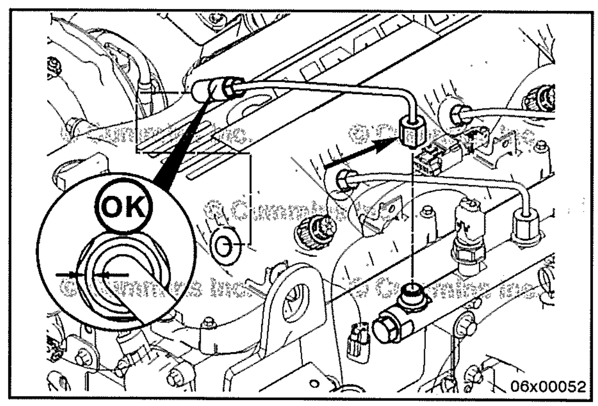
Tighten the injector end, making sure there is no contact between the line and the union at either end.

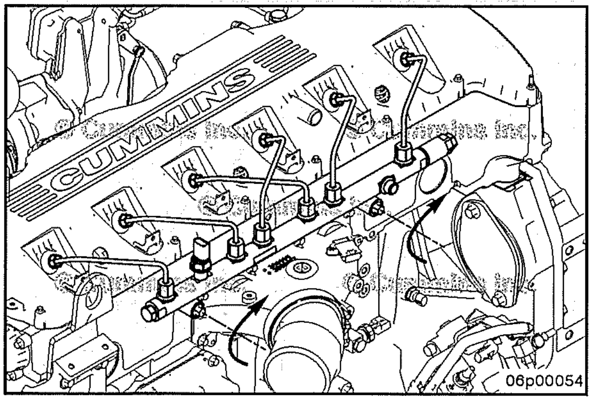
Torque Value: 25 N•m [221 in-lb]

Tighten the injector fuel line union.

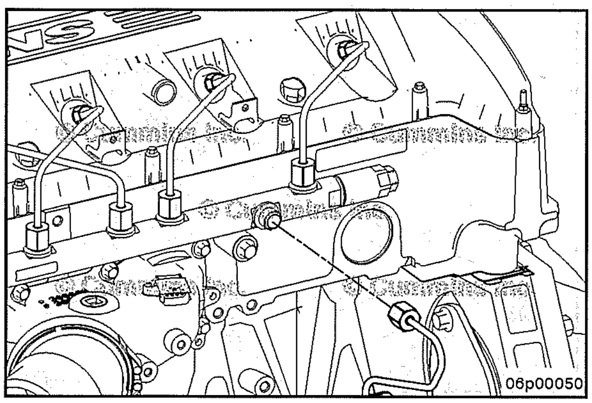
Torque Value: 25 N•m [221 in-lb]

Repeat this process for the other five lines.





Tighten the capscrews for the fuel rail. Refer to Procedure 006-060 in Section 6.



Fuel Rail Supply Line (High Pressure) (006-071)

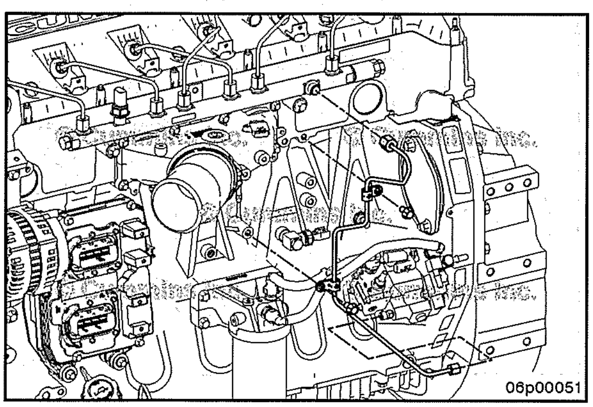
Install

CAUTION

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

Install and tighten the fuel rail supply line.

Torque Value: 25 N•m [221 in-lb]

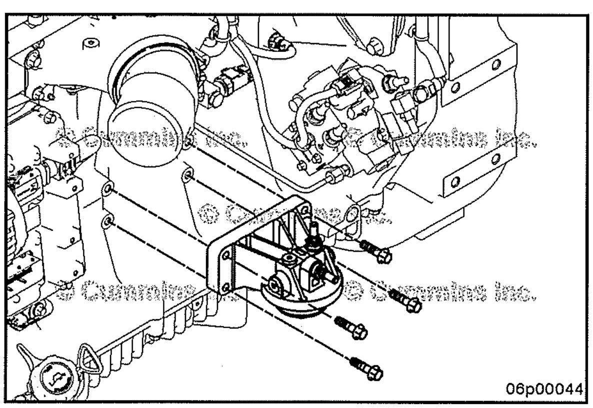


Install the fuel rail supply line clamps.

Tighten the clamps.

Torque Value: 46 N•m [34 ft-lb]

NOTE: Make sure that the fuel line is **not** rubbing on any other components.



Fuel Filter Head (006-017)

Install

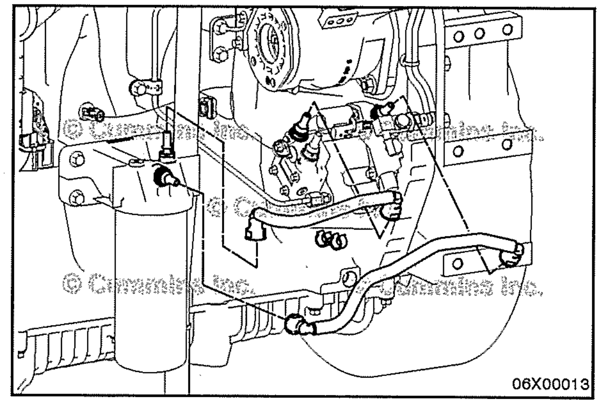
Install fuel filter head.

Tighten capscrews in a crisscross pattern.

Torque Value: 46 N•m [34 ft-lb]

Fuel Supply Lines (006-024)

Install



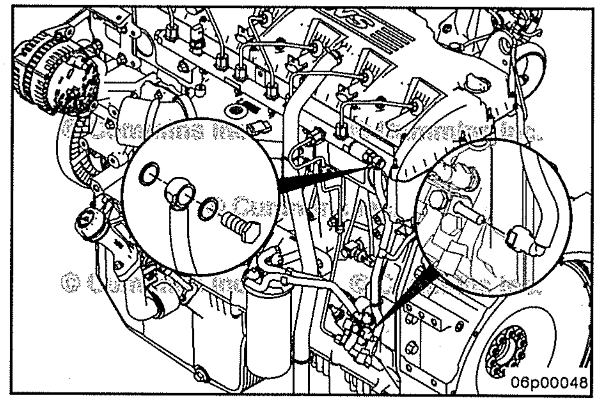
Install the fuel supply line connecting the gear pump to the fuel filter head.

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

Install the p-clips and p-clip mounting capscrews in locations noted during removal.

Fuel Drain Lines (006-013)

Install



Install the drain lines.

Loosely install the p-clip capscrews, stud, banjo fittings, banjo style check valve, and new sealing washers for each drain line.

Tighten the p-clip capscrews, banjo bolts, and banjo style check valve.

Torque Value:
M12 Banjo Bolts and Check Valve 24 N•m [212 in-lb]

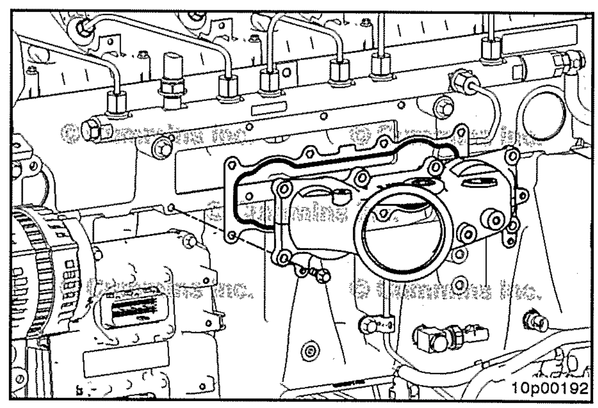
Torque Value:
M14 Banjo Bolts 34 N•m [25 ft-lb]

Torque Value:
P-Clip Capscrew 20 N•m [177 in-lb]

Torque Value:
P-Clip Stud 46 N•m [34 ft-lb]

Air Intake Connection (010-080)

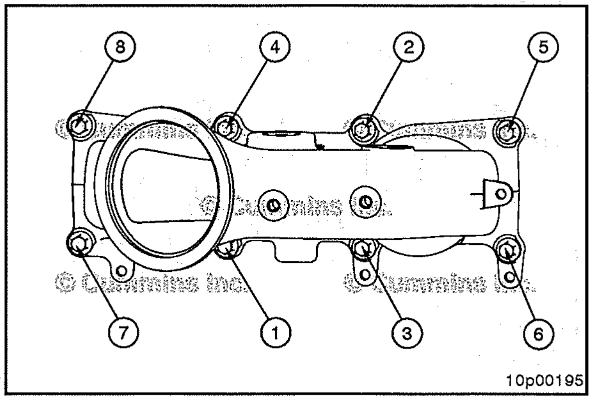
Install



If applicable, install the cold starting aids. Refer to Procedure 010-029 in Section 10.

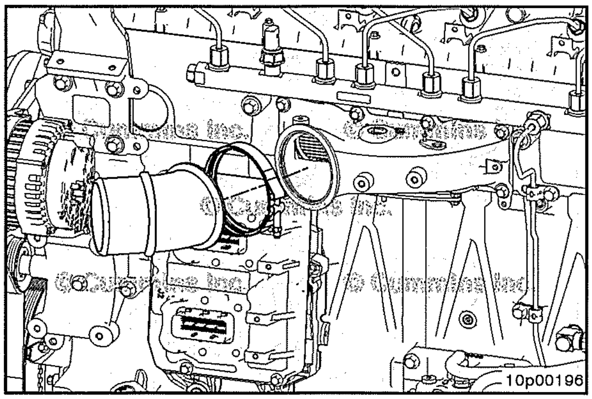
Install a new gasket between the cylinder head and the air intake connection.

Install the eight capscrews hand-tight.



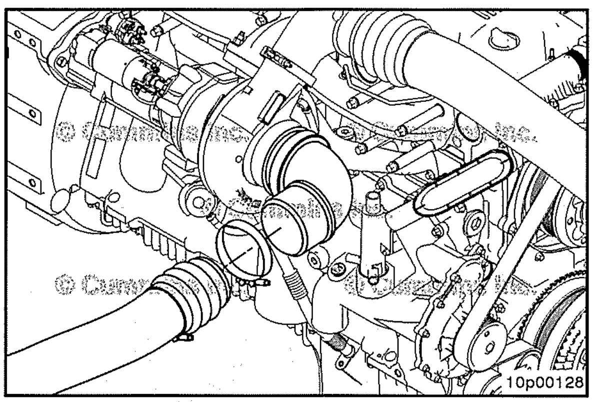
Tighten the capscrews according in the sequence shown.

Torque Value: 23 N•m [204 in-lb]



Install the air intake connection adapter.

Torque Value: 8 N•m [71 in-lb]



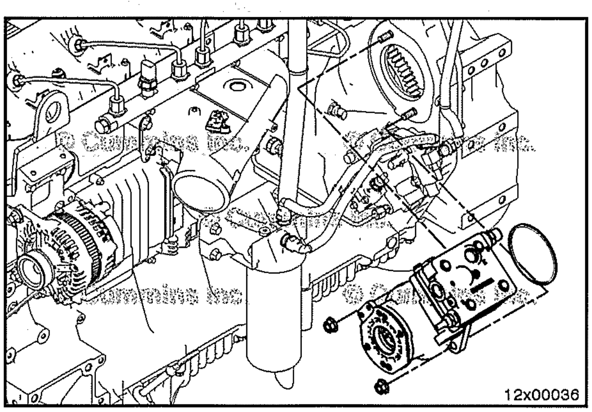
Air Inlet Connection (010-022)

Install

Install the air inlet piping and connections.

Tighten the attaching clamps.

Torque Value: 8 N•m [71 in-lb]



Air Compressor (012-014)

Install

If removed, install and tighten the mounting studs.

Torque Value: 12 N•m [106 in-lb]

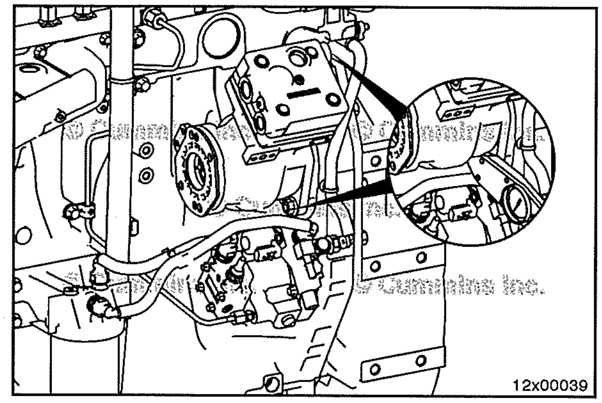
Install the air compressor and the two nuts onto the flywheel housing.

Tighten the nuts.

Torque Value: 80 N•m [59 ft-lb]

Tighten the nuts again.

Torque Value: 80 N•m [59 ft-lb]

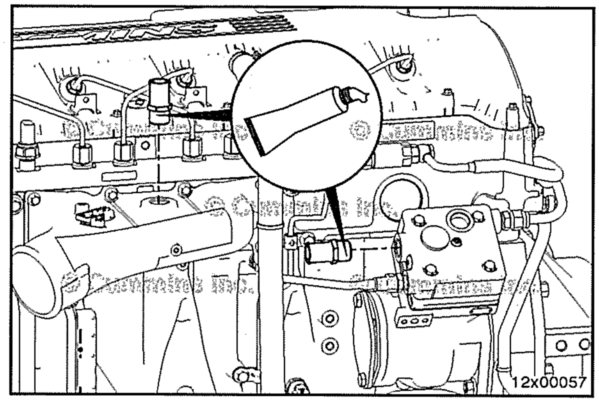


Air Compressor Inlet Tube (012-109)

Install

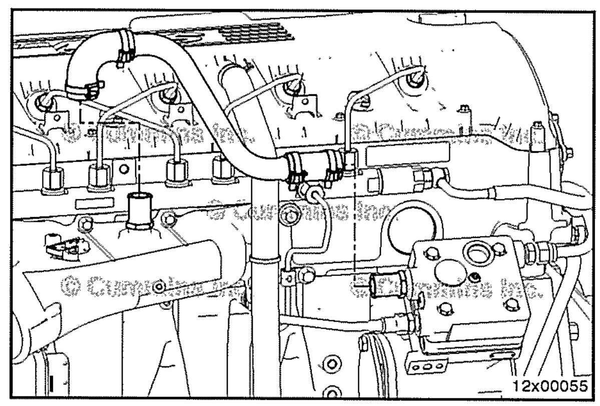
If removed, apply Loctite 592, Part Number 3375066, to the threads before installation. Install and tighten the fittings into the air compressor head and the air intake manifold.

Torque Value: 45 N•m [33 ft-lb]



Install the air compressor inlet tube to the engine.

Install the hoses and hose clamps to the air intake manifold and air compressor.



Air Compressor Coolant Lines (012-004)

Install

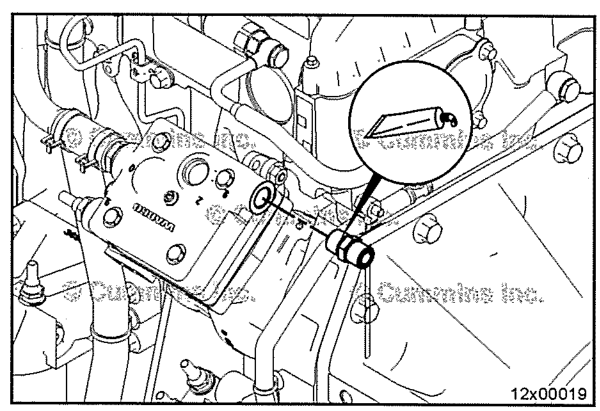
If the o-rings were removed, install new o-rings.

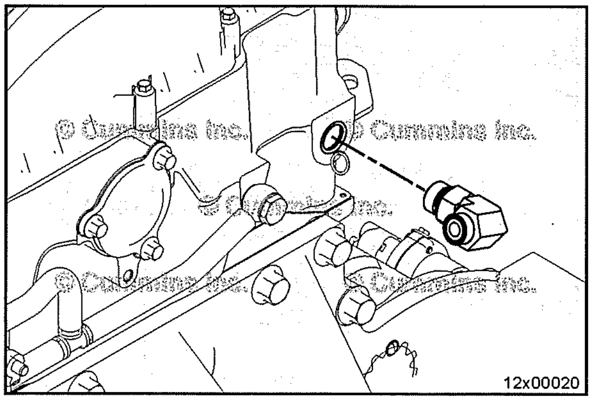
Apply sealant, Part Number 3375066 or equivalent, to the threads of the air compressor head face seal fitting before installation. Do **not** put sealant on the threads of the rocker lever housing face seal fitting.

If removed, install the face seal fittings.

Tighten the fitting into the air compressor head.

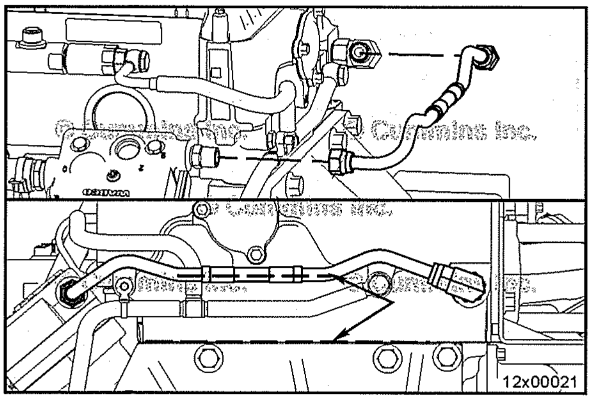
Torque Value: 35 N•m [26 ft-lb]





NOTE: The elbow face seal fitting at the rocker lever housing **must** be installed in the proper orientation to allow for installation of the coolant return line.

Finger tighten the face seal fitting into the rocker lever housing.



NOTE: The elbow face seal fitting at the rocker lever housing **must** be installed in the proper orientation to allow for installation of the coolant return line.

Install the coolant return line to aid in properly orienting the face seal elbow fitting. The coolant return line will mount parallel to the top of the flywheel housing.

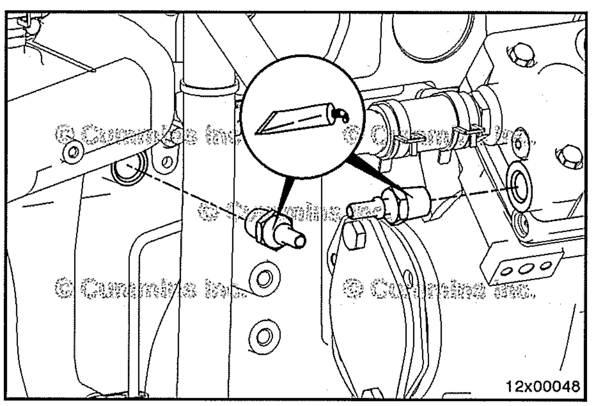
Finger tighten the face seal fittings at the air compressor head and the rocker lever housing.

Holding the coolant return line to prevent kinking, tighten the face seal fittings.

Torque Value: 35 N•m [26 ft-lb]

Tighten the lock nut on the elbow face seal fitting at the rocker lever housing.

Torque Value: 55 N•m [41 ft-lb]



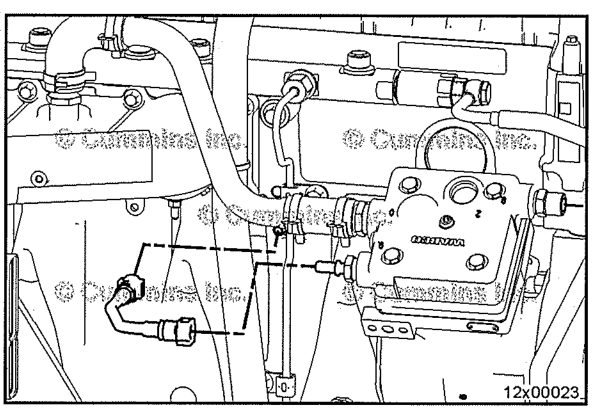
Apply sealant, Part Number 3375066 or equivalent, to the threads of both quick disconnect fittings before installation.

Install and tighten the quick disconnect fitting into the cylinder block.

Torque Value: 35 N•m [26 ft-lb]

Install and tighten the quick disconnect fitting into the air compressor cylinder head.

Torque Value: 35 N•m [26 ft-lb]



Install the air compressor coolant supply line.

Connect the coolant supply line quick disconnect connections.

Starting Motor (013-020)

Install

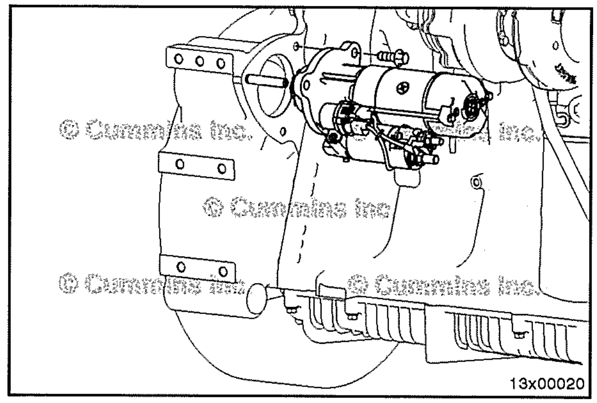
⚠CAUTION⚠

Make sure to use the same thickness of starting motor spacer (if used) as the one removed to install the starting motor, to reduce the possibility of engine or starting motor damage.

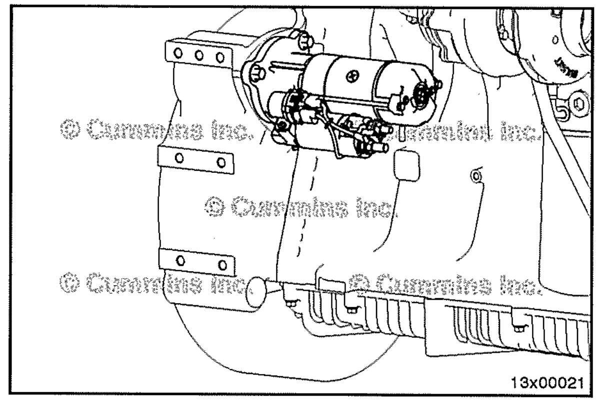
Using guide pin Part Number 3163934, install the starting motor and the three M12 grade 9.8 mounting capscrews.

Tighten the capscrews.

Torque Value: 80 N•m [59 ft-lb]

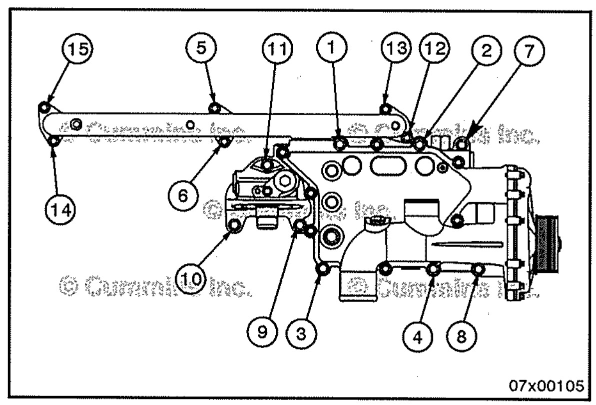


Install and tighten the electrical connections to the starting motor, including the ground strap (if used).



Lubricating Oil Cooler Housing (007-046)

Install



NOTE: Ensure 5 diamond ring seals are present and undamaged prior to installation. 3 in coolant manifold and 2 in lubricating oil cooler module back plate.

Install lubricating oil cooler module to block with 2 capscrews loosely threaded into block.

Lubricate o-ring with non-petroleum based lubricant, P80 or similar, and slide the coolant manifold into lubricating oil cooler housing.

NOTE: Ensure o-ring stays seated in groove while inserting water manifold into lubricating oil cooler housing.

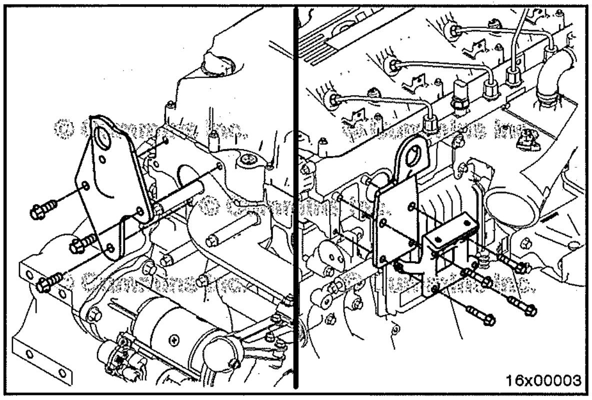
Install capscrews securing the coolant manifold to the block and capscrews securing the lubricating oil cooler module to the block.

NOTE: Ensure diamond seals stay in place when securing water manifold to block.

Tighten according to torque procedure.

Torque Value:
Water manifold 23 N•m [204 in-lb]

Torque Value:
Lubricating oil cooler module 46 N•m [34 ft-lb]



16x00003

Engine Lifting Brackets (016-001)

Install

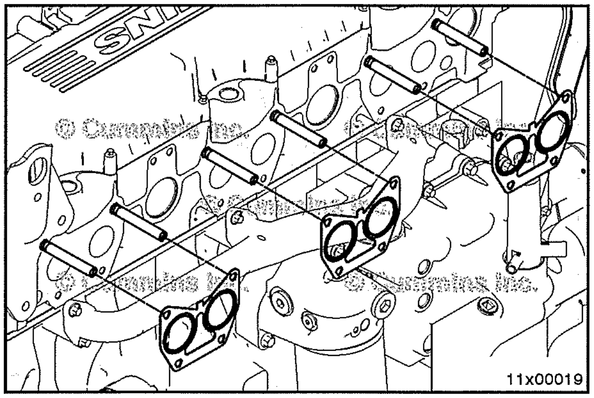
Install the rear lifting bracket, spacer, and capscrews.

Orientate the spacer to align with the mounting holes.

Tighten the capscrews.

Torque Value: 80 N•m [59 ft-lb]

Install the front lifting bracket and the accessory support bracket. Refer to Procedure 013-003 in Section 13.



11x00019

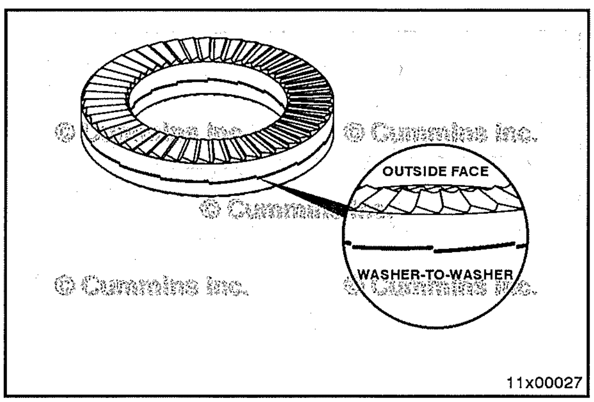
Exhaust Manifold, Dry (011-007)

Install

Install a guide pin, Part Number 3376488, in the top holes of each cylinder head exhaust port.

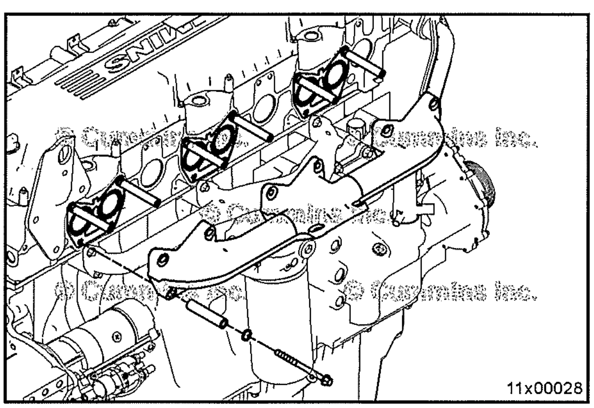
Install a new gasket over each guide pin.

Do **not** use any kind of adhesive to hold the gaskets.



11x00027

NOTE: New lock washers are glued together in the proper orientation. If old lock washers are used, they **must** be installed with the correct faces mated. The washer-to-washer mating surface has gentle slopes but the outside surface has sharper, steeper slopes.



11x00028

NOTE: If using new capscrews, do **not** apply any compounds to the capscrew threads. New capscrews have an anti-seize film already applied.

If a capscrew is reused, to aid in future removal, apply a coating of high temperature anti-seize compound, Part Number 3824879 or equivalent, to the capscrew threads.

NOTE: The four center capscrews and spacers are a different length than the eight outer capscrews. Reinstall per the note in the 'Remove' step.

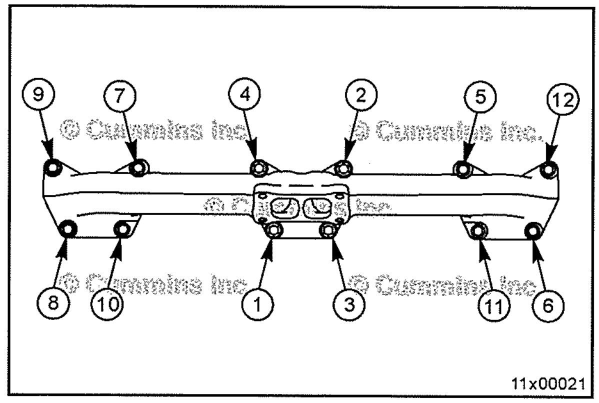
Install the exhaust manifold, tubular spacers, lock washers, and capscrews. Install the bottom capscrews, tubular spacers, and lock washers first. Then remove the guide pins and install the top capscrews, tubular spacers, and lock washers.

Tighten the capscrews in the sequence shown.

The torque values given have been established using anti-seize compound as a lubricant.

Torque Value: 50 N•m [37 ft-lb]

NOTE: Do **not** overtighten the capscrews.

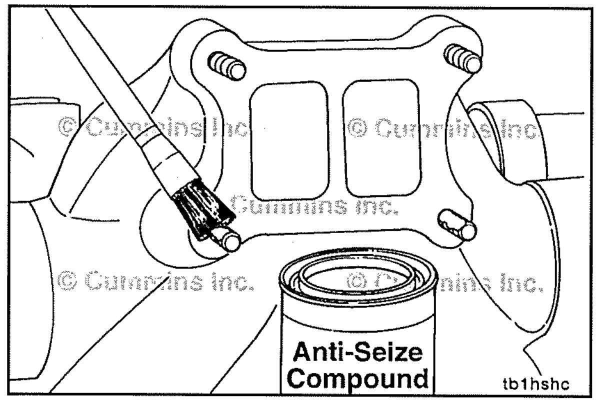


Turbocharger (010-033)

Install

Apply a film of high-temperature anti-seize compound, Part Number 3824879, to the turbocharger mounting studs.

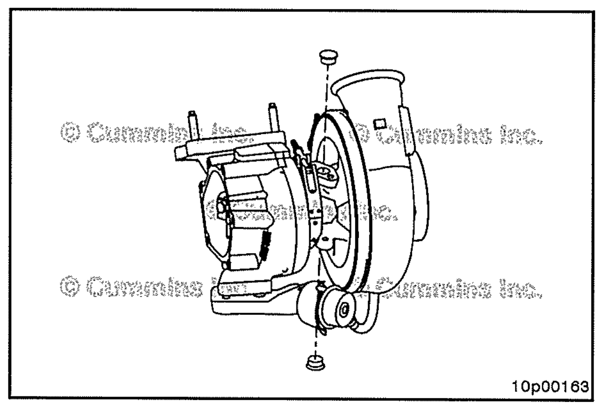
NOTE: Use the following procedure if a turbocharger mounting stud needs to be replaced. Refer to Procedure 011-073 in Section 11.



If installing a new turbocharger:

Remove the plastic shipping plugs from the oil drain and oil supply holes located in the turbocharger bearing housing.

If equipped, remove the plastic shipping plugs from the coolant drain and coolant supply holes located in the turbocharger bearing housing.



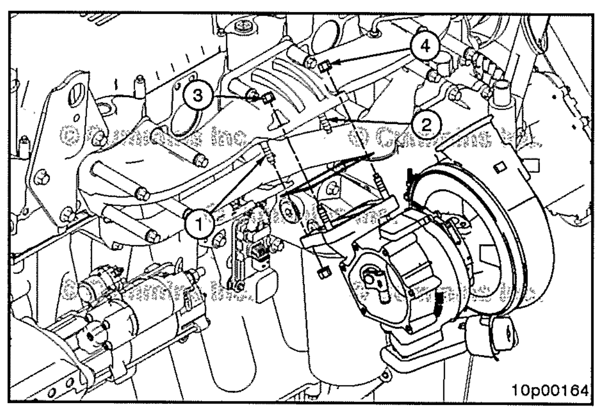
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

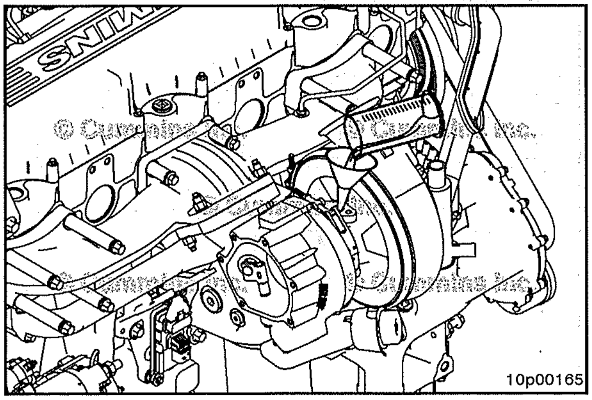
Install a new mounting gasket, the turbocharger and the four mounting nuts.

Tighten the mounting nuts in a criss-cross pattern.

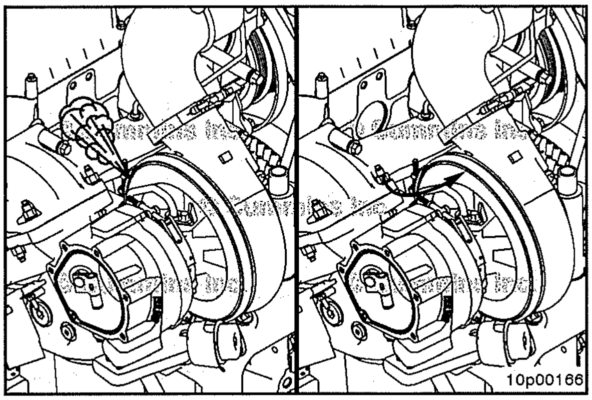
Torque Value: 81 N•m [60 ft-lb]

After all four nuts are tightened, retighten all four nuts in a criss-cross pattern.





Pour approximately 50 to 60 cc [1.7 to 2 oz] of clean engine oil into the turbocharger oil supply opening.



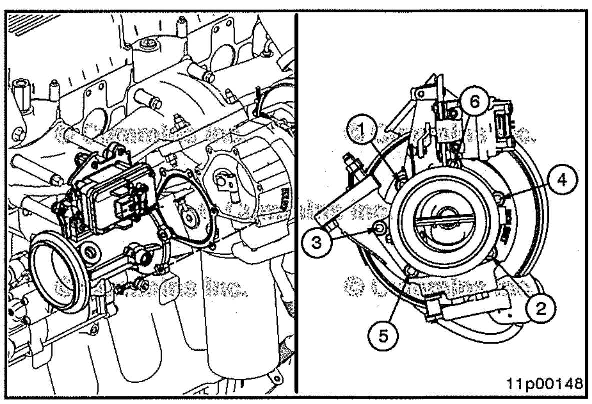
If installing a new turbocharger, it may be necessary to rotate the turbocharger compressor housing to properly align with the charge-air cooler piping.

Rotate the turbocharger compressor housing by loosening the V-band between the turbocharger bearing housing and the turbocharger compressor housing.

Rotate the turbocharger compressor housing to properly align with the charge-air cooler piping.

Tighten the V-band clamp.

Torque Value: 8 N•m [71 ft-lb]



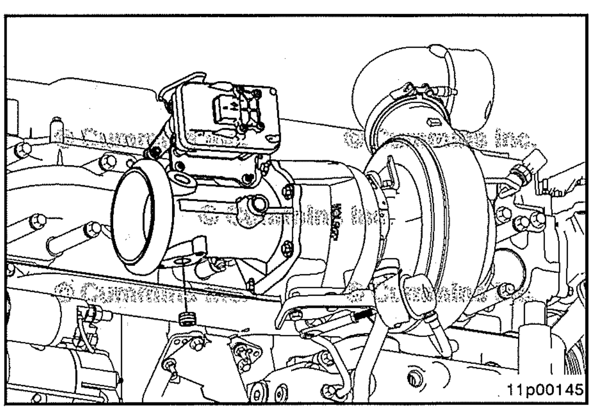
Exhaust Pressure Regulator (011-105)

Install

Install the exhaust pressure regulator and new gasket. Install the six capscrews hand tight.

Tighten the capscrews in the sequence shown.

Torque Value: 25 N•m [18 ft-lb]



NOTE: Depending on the turbocharger configuration the exhaust pressure regulator has two possible NOx sensor mounting locations. The NOx sensor **must** be installed in the top of the exhaust pressure regulator housing. A plug is provided with new exhaust pressure regulators. This plug **must** be installed in the bottom NOx sensor location.

If the exhaust pressure regulator is being replaced install the NOx sensor plug at the **bottom** of the housing.

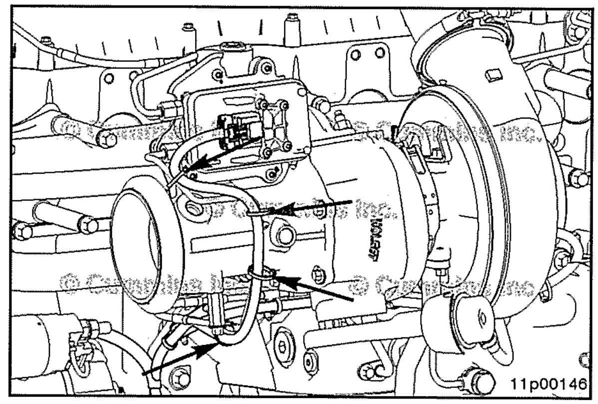
Install the NOx sensor plug.

Torque Value: 50 N•m [37 ft-lb]

NOTE: This stepblock applies to a rear out turbocharger mounting.

Connect the exhaust pressure regulator electrical connection.

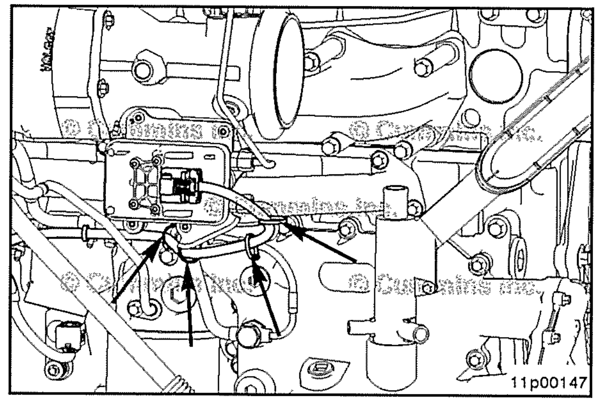
Secure the electrical connection wire harness to the coolant return line as shown.



NOTE: This stepblock applies to a front out turbocharger mounting.

Connect the exhaust pressure regulator electrical connection.

Secure the electrical connection wire harness to the coolant supply line as shown.



Turbocharger Coolant Hoses (010-041)

Install

Coolant Cooled Turbocharger

If removed, install the coolant line fittings.

Tighten the fittings in the cylinder head (1).

Torque Value: 45 N•m [34 ft-lb]

Tighten the fittings in the turbocharger (2).

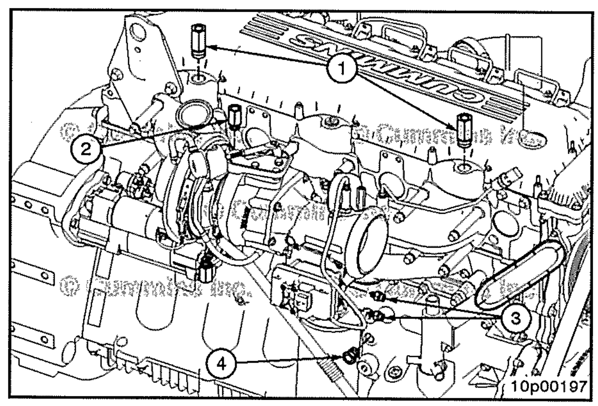
Torque Value: 41 N•m [30 ft-lb]

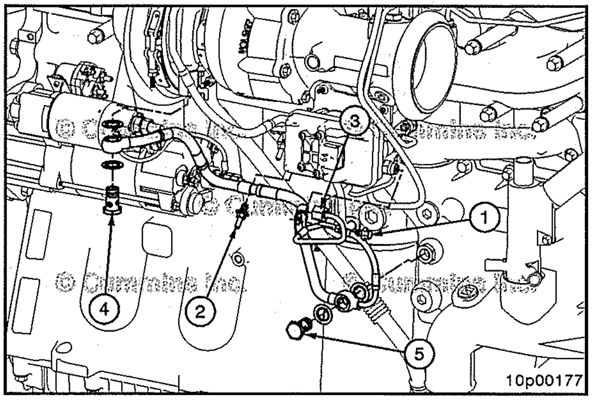
Tighten the fittings in the exhaust pressure regulator (3).

Torque Value: 8 N•m [71 in-lb]

Tighten the fitting in the lubricating oil cooler module (4).

Torque Value: 35 N•m [26 ft-lb]





NOTE: Use a second wrench to hold the coolant line fitting while tightening the line.

Install and hand tighten the turbocharger coolant supply line and new sealing washers at the exhaust pressure regulator, lubricating oil cooler module and turbocharger.

Install and hand tighten the exhaust pressure regulator coolant supply line retaining clips and mounting capscrews.

Tighten the retaining clip on the exhaust pressure regulator housing (1).

Torque Value: 18 N•m [159 in-lb]

Tighten the retaining clip on the NOx sensor mounting bracket (2).

Torque Value: 18 N•m [159 in-lb]

Tighten the coolant line at the exhaust pressure regulator fitting (3).

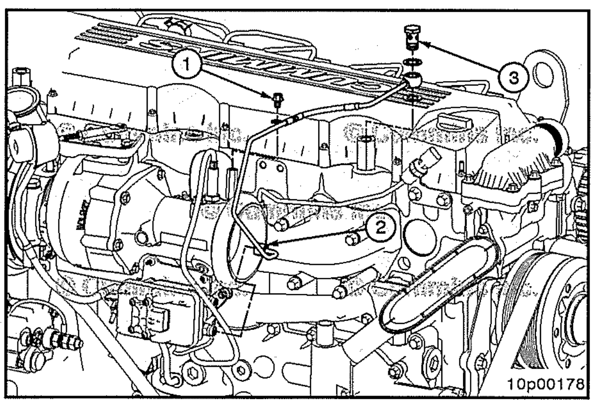
Torque Value: 16 N•m [142 in-lb]

Tighten the coolant line banjo at the turbocharger fitting (4).

Torque Value: 35 N•m [26 ft-lb]

Tighten the coolant line banjo at the lubricating oil cooler module (5).

Torque Value: 35 N•m [26 ft-lb]



NOTE: Use a second wrench to hold the coolant line fitting while tightening the line.

Install and hand tighten the exhaust pressure regulator coolant return line and new sealing washers at the cylinder head and exhaust pressure regulator.

Install and hand tighten the exhaust pressure regulator coolant return line retaining clips and mounting capscrews.

Tighten the retaining clip on the exhaust pressure regulator housing (1).

Torque Value: 18 N•m [159 in-lb]

Tighten the coolant line at the exhaust pressure regulator fitting (2).

Torque Value: 16 N•m [142 in-lb]

Tighten the coolant line banjo at the cylinder head fitting (3).

Torque Value: 35 N•m [26 ft-lb]

NOTE: Use a second wrench to hold the coolant line fitting while tightening the line.

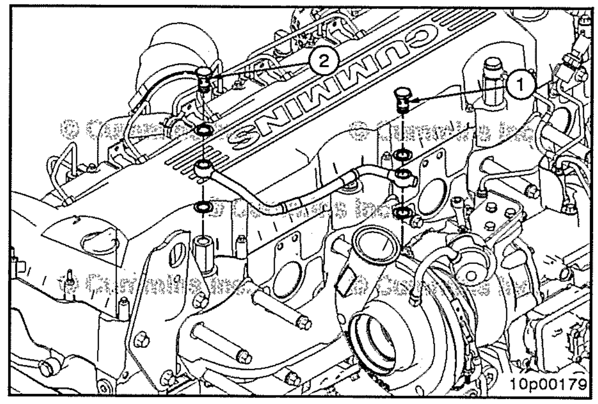
Install and hand tighten the turbocharger coolant return line and new sealing washers from the turbocharger and cylinder head.

Install and hand tighten the turbocharger coolant return line retaining clips and mounting capscrews.

Tighten the coolant lint at the turbocharger fitting (1).

Tighten the coolant line banjo at the cylinder head fitting (2).

Torque Value: 35 N•m [26 ft-lb]



Non-coolant Cooled Turbocharger

If removed, install the coolant line fittings.

Tighten the fittings in the cylinder head (1).

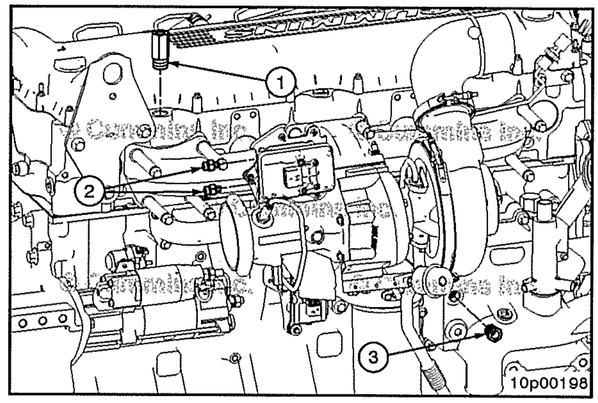
Torque Value: 45 N•m [34 ft-lb]

Tighten the fittings in the exhaust pressure regulator (2).

Torque Value: 8 N•m [71 in-lb]

Tighten the fitting in the lubricating oil cooler module (3).

Torque Value: 35 N•m [26 ft-lb]



NOTE: Use a second wrench to hold the coolant line fitting while tightening the line.

Install and hand tighten the turbocharger coolant supply line and new sealing washers at the exhaust pressure regulator, lubricating oil cooler module and turbocharger.

Install and hand tighten the exhaust pressure regulator coolant supply line retaining clips and mounting capscrews.

Tighten the retaining clip on the exhaust pressure regulator housing (1).

Torque Value: 18 N•m [159 in-lb]

Tighten the retaining clip on the NOx sensor mounting bracket (2).

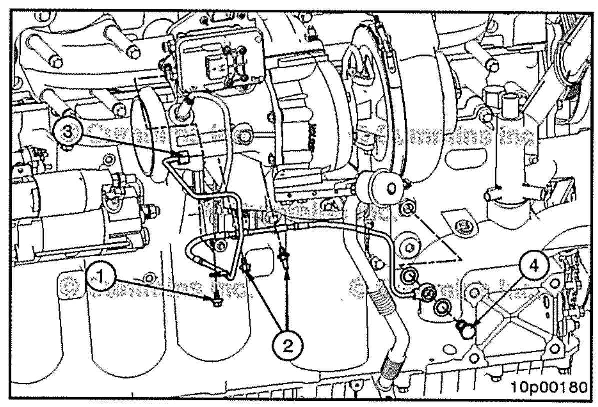
Torque Value: 18 N•m [159 in-lb]

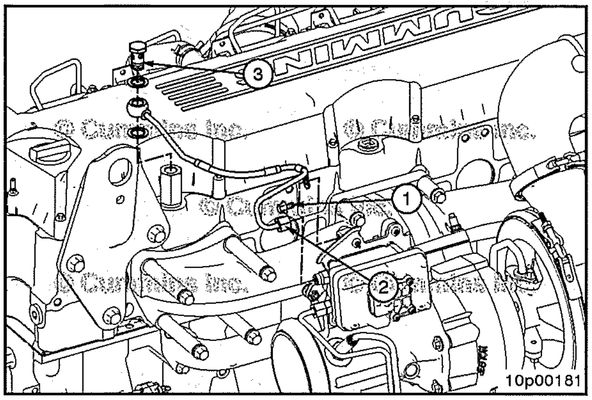
Tighten the coolant line at the exhaust pressure regulator fitting (3).

Torque Value: 16 N•m [142 in-lb]

Tighten the coolant line banjo at the lubricating oil cooler module (4).

Torque Value: 35 N•m [26 ft-lb]





NOTE: Use a second wrench to hold the coolant line fitting while tightening the line.

Install and hand tighten the exhaust pressure regulator coolant return line and new sealing washers at the cylinder head and exhaust pressure regulator.

Install and hand tighten the exhaust pressure regulator coolant return line retaining clips and mounting capscrews.

Tighten the retaining clip on the exhaust pressure regulator housing (1).

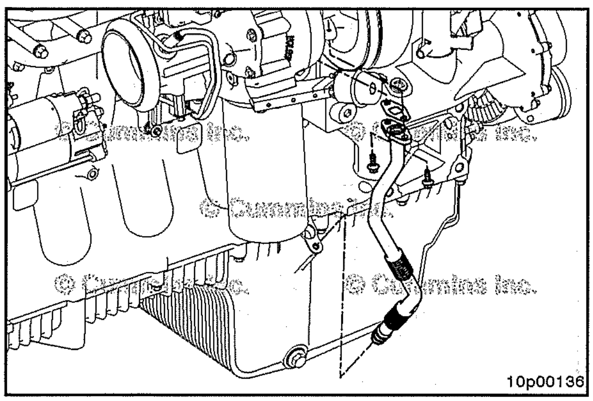
Torque Value: 18 N•m [159 in-lb]

Tighten the coolant line at the exhaust pressure regulator fitting (2).

Torque Value: 16 N•m [142 in-lb]

Tighten the coolant line banjo at the cylinder head fitting (3).

Torque Value: 35 N•m [26 ft-lb]



Turbocharger Oil Drain Line (010-045)

Install

⚠CAUTION⚠

Do not bend or kink the drain line while installing the line. Doing so can possibly damage line. If the line is damaged upon removal it must be replaced.

NOTE: Be sure the o-rings are installed into the turbocharger oil drain line.

NOTE: Clean engine oil can be applied to the turbocharger oil drain line o-rings to ease the installation of the line.

Insert the bottom of the drain line into oil pan.

NOTE: The turbocharger oil drain line can be rotated into place to ease in the installation of the line.

Install the drain line with a new gasket to the bottom of the turbocharger.

Torque Value: 23 N•m [204 in-lb]

Turbocharger Oil Supply Line (010-046)

Install

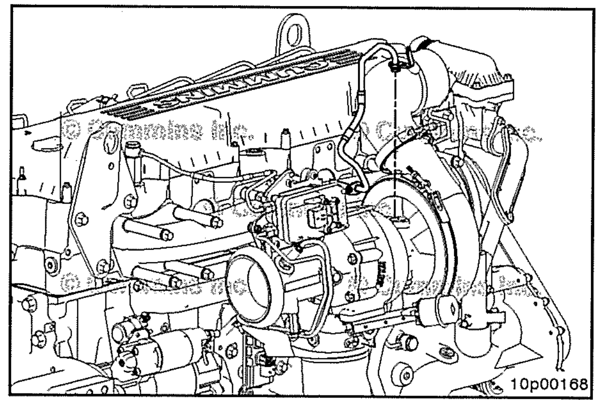
⚠CAUTION⚠

Proper routing of the turbocharger oil supply line is critical to prevent a malfunction. Avoid any line-to-metal contact.

Pour 60 to 90 cc [2 to 3 oz] of clean engine oil into the turbocharger oil supply opening.

Install the supply line at the turbocharger bearing housing then at the lubricating oil filter head.

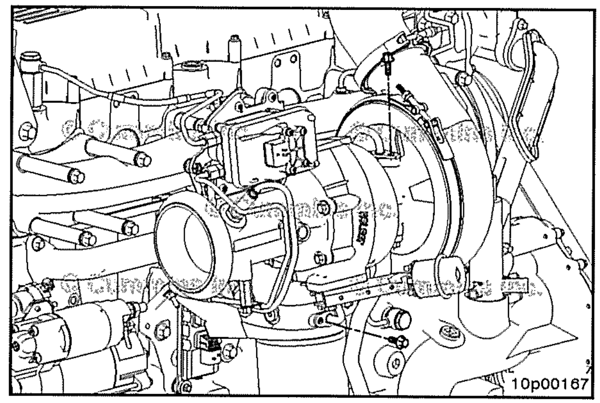
NOTE: Clean engine oil can be applied to the turbocharger oil supply line o-rings to ease the installation of the line.



NOTE: Ensure the capscrews are free of any oil before installing them on the engine.

Install the capcrews onto the lubricating oil filter head and the turbocharger bearing housing.

Torque Value: 18 N•m [159 in-lb]



Water Pump Cartridge (008-102)

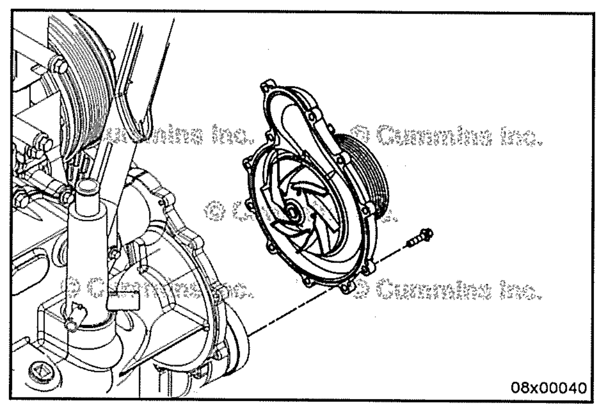
Install

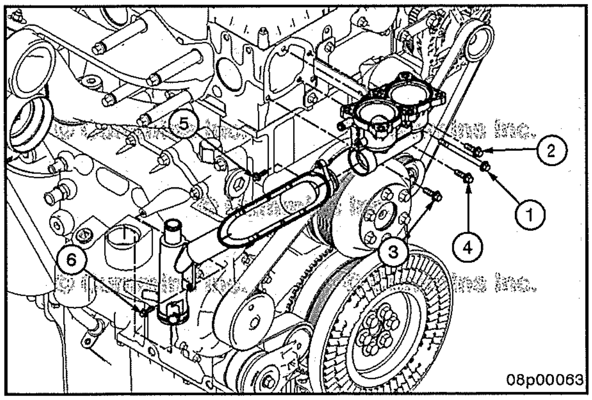
Make sure the water pump mounting surfaces are clean.

Install the water pump cartridge and the mounting capscrews.

Tighten the capscrews evenly.

Torque Value: 7.4 N•m [65 in-lb]





08p00063

Coolant Thermostat Housing (008-014)

Install

Lubricate the o-ring seals with a water-silicon based lubricant.

Slide thermostat housing onto coolant bypass tube.

NOTE: Ensure o-ring remains in o-ring groove during installation.

Loosely install capscrew securing thermostat housing to coolant bypass tube.

Slide coolant bypass tube into lube oil cooler.

NOTE: Ensure o-ring remains in o-ring groove during installation.

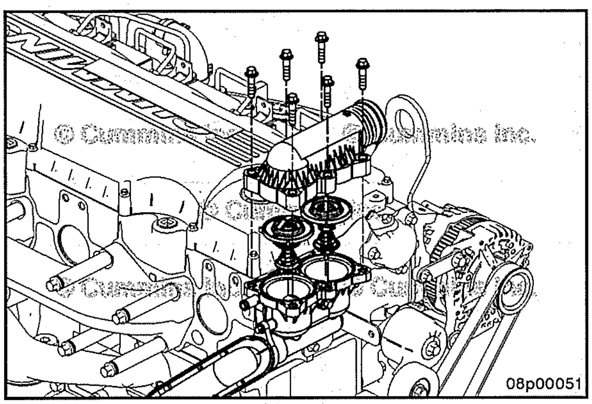
Install the thermostat housing to the cylinder head.

Tighten thermostat housing to cylinder head capscrews according to torque sequence.

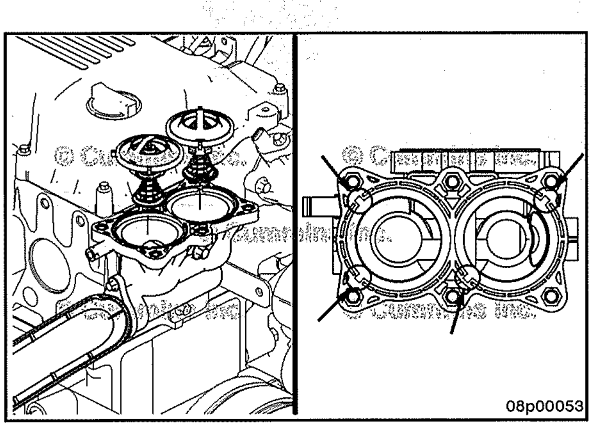
Torque Value: 23 N•m [204 in-lb]

Tighten capscrews securing coolant bypass tube to thermostat housing and lube oil cooler.

Torque Value: 7.4 N•m [65 in-lb]


08p00051

Install thermostats and coolant outlet connection. Refer to Procedure 008-013 in Section 8.


08p00053

Coolant Thermostat (008-013)

Install

⚠CAUTION⚠

Always use correct thermostats or the engine may overheat or run too cold. Never operate engine without thermostats installed or the engine may overheat.

NOTE: If the previously installed thermostats are being used, install new thermostat seals.

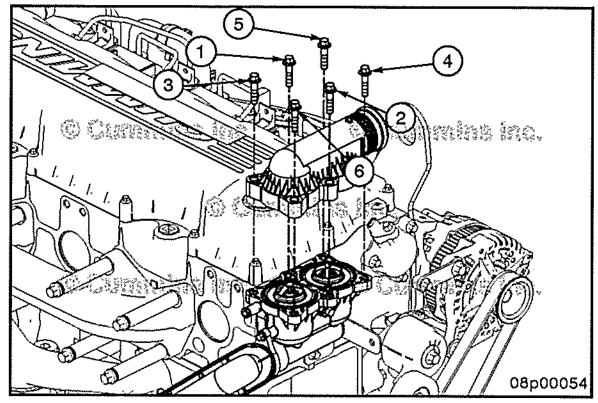
Install the thermostats into the thermostat housing.

Use unique locators on each thermostat to determine the correct location.

Install the water outlet connection and mounting capscrews.

Tighten the capscrews in the sequence shown.

Torque Value: 18 N•m [159 in-lb]

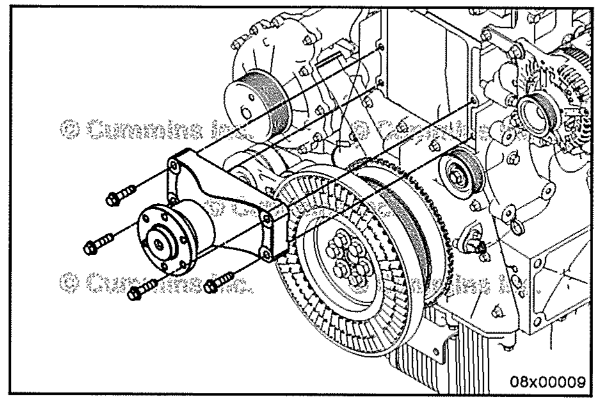


Fan Hub, Belt Driven (008-036)

Install

Install the fan hub and four capscrews.

Torque Value: 46 N•m [34 ft-lb]



Fan Pulley (008-089)

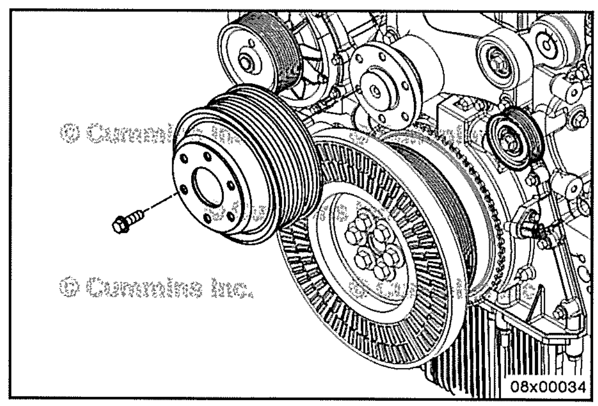
Install

Install the fan pulley on the fan hub.

Install the cooling fan and six mounting capscrews.

Tighten the capscrews in a star pattern.

Torque Value: 46 N•m [34 ft-lb]

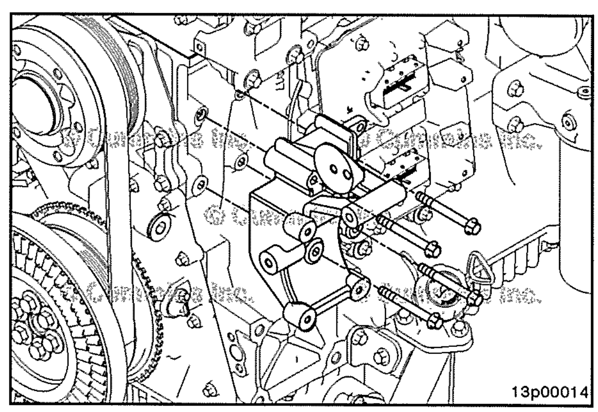


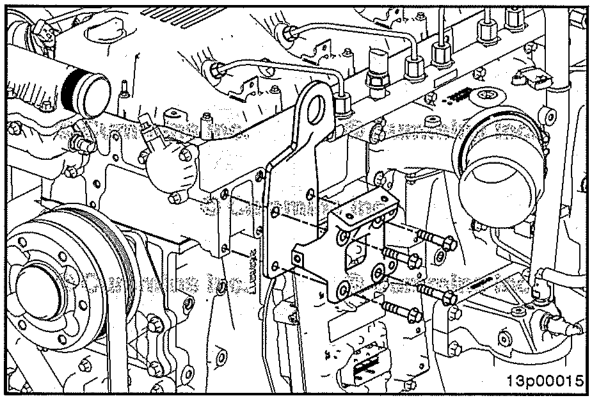
Charging System Alternator Bracket (013-003)

Install

Install the alternator bracket and tighten the four mounting capscrews.

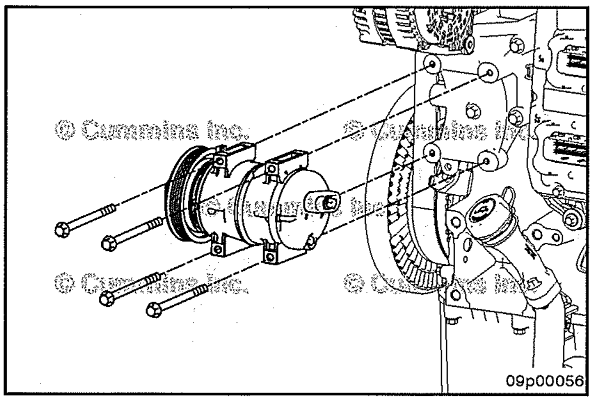
Torque Value: 65 N•m [48 ft-lb]





Install the front lifting bracket and accessory bracket and tighten the four mounting capscrews.

Torque Value: 46 N•m [34 ft-lb]



Refrigerant Compressor (009-051)

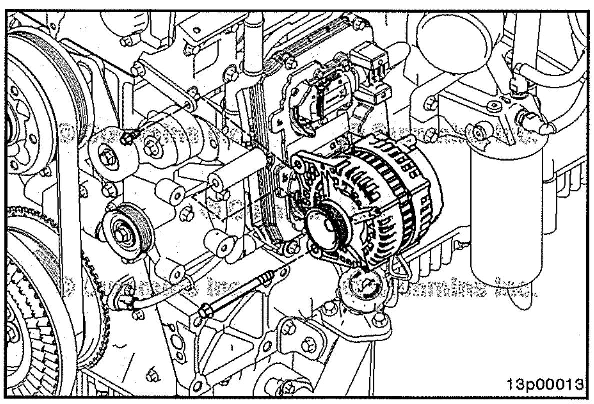
Install

Install the refrigerant compressor. See equipment manufacturer service information.

Install the four mounting capscrews through the refrigerant compressor and refrigerant compressor bracket.

Tighten the capscrews in a crisscross pattern.

Torque Value: 23 N•m [204 in-lb]



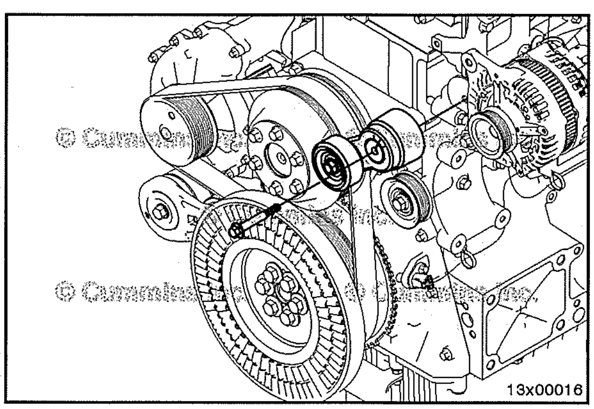
Charging System Alternator (013-001)

Install

Install the alternator, alternator top ear mounting capscrew (1), alternator lower ear mounting capscrew to the mounting bracket (2).

Tighten the mounting capscrews.

Torque Value: 46 N•m [34 ft-lb]



Charging System Alternator Automatic Belt Tensioner (013-021)

Install

Install the belt tensioner. The tensioner has a pin for alignment with the alternator bracket.

Install and tighten capscrew.

Torque Value: 46 N•m [34 ft-lb]

Cooling Fan Belt Tensioner (008-087)

Install

Install the fan shroud bracket and mounting bracket capscrews.

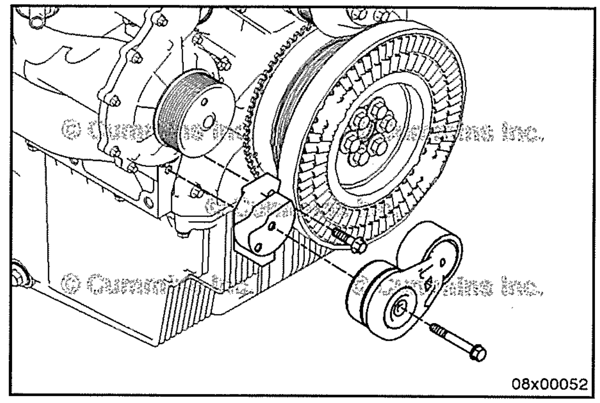
Tighten the capscrew.

Torque Value: 55 N•m [41 ft-lb]

Install the belt tensioner and capscrew.

Tighten the capscrew.

Torque Value: 55 N•m [41 ft-lb]



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Charging System Alternator Drive Belt (013-005)

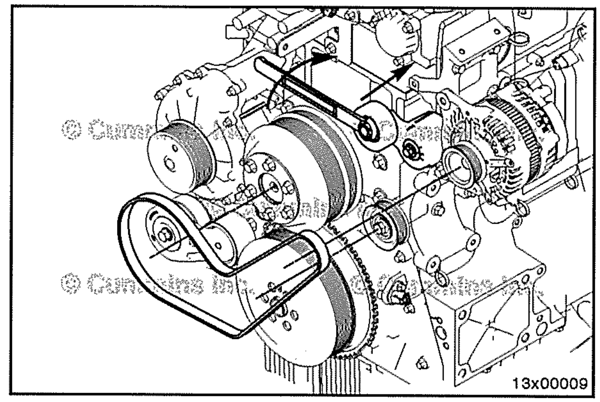
Install

Install a new belt over the pulleys while holding the tensioner back. Be careful **not** to damage the belt while working it over the flanged pulleys.

Do **not** roll a belt over the pulley or pry on it with a tool.

Release the tensioner slowly, and remove the socket and ratchet.

Belt drive systems equipped with an automatic belt tensioner can **not** be adjusted. A belt tension gauge will **not** give an accurate measure of the belt tension. The automatic belt tensioner is designed to maintain the proper belt tension over the life of the belt. **Only** an inspection of the tensioner is required. Refer to Procedure 013-021 in Section 13.



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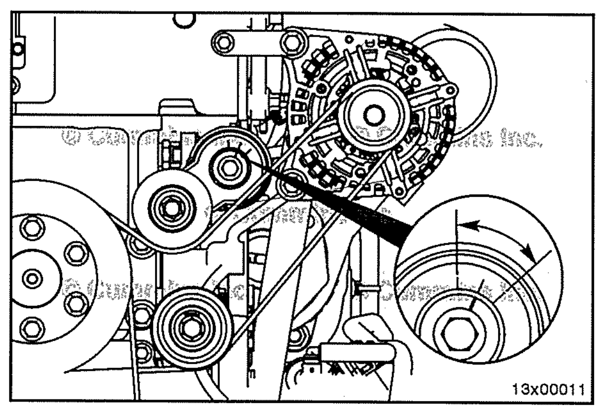
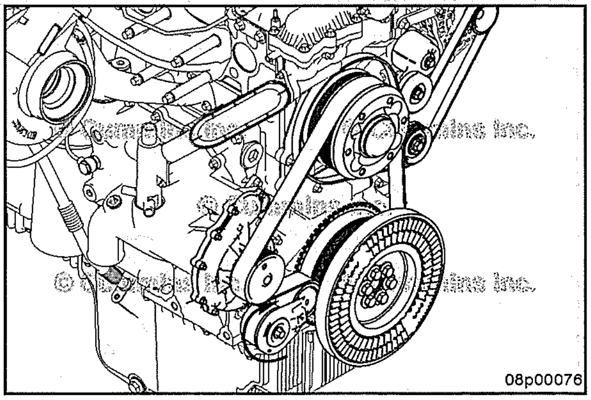
The belt tensioner is designed to operate within the limit of arm movement provided by the internal cast stops when the belt length and geometry are correct. The tensioner contains three external marks to indicate if the tensioner is hitting either of the limits. The middle mark indicates proper tension.

If the tensioner is hitting either of the limits during operation, check the mounting brackets and belt length. Loose brackets, bracket failure, alternator movement, incorrect belt length, or belt failure can cause the tensioner to hit the limits.



13x00011



Drive Belt, Cooling Fan (008-002)

Install

⚠CAUTION⚠
The belt tensioner is spring loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner or cause personal injury.

⚠CAUTION⚠
To reduce the possibility of damage to the pulley and new belt, do not roll the belt over the pulley or pry it on with a tool.

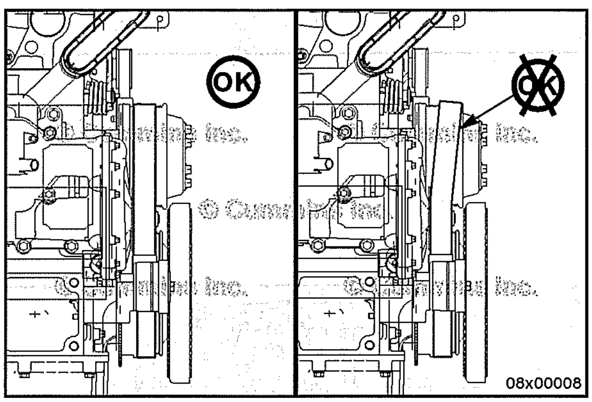
Use the belt diagram created in the remove section to route the drive belt on the engine.

Install a new fan belt on the pulleys.

Pivot the tensioner in the direction of the spring tang and install the drive belt, slipping the belt over the water pump pulley last.

Release the tensioner to apply tension to the drive belt.

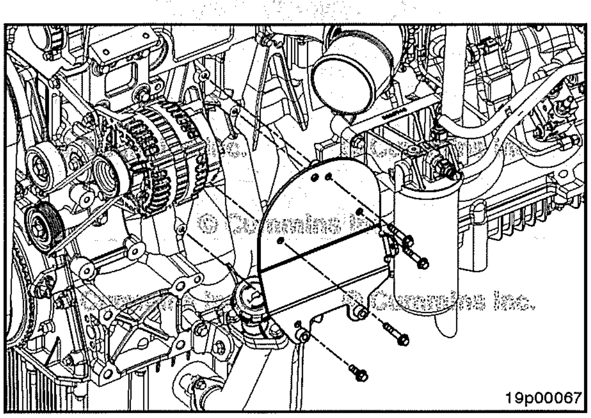
Check the alignment of the belt with the tensioner and the rest of the front end auxiliary drive.



Inspect the pulley alignment.

Pulley misalignment **must not** exceed 6 mm for each meter [1/16 inch for each 12 inches] of distance between the pulley centers.

The pulley alignment fixture, service tool Part Number 3163524, should be used to check alignment.



Engine Control Module Mounting Bracket (019-421)

Install

Install metal ECM mounting bracket.

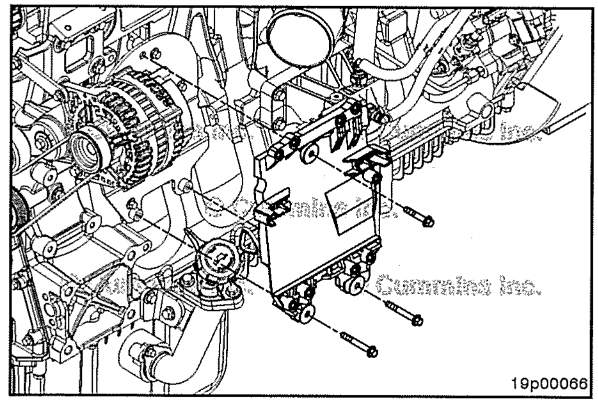
Install and tighten capscrews.

Torque Value: 23 N•m [204 in-lb]

Install plastic ECM mounting bracket.

Install and tighten capscrews.

Torque Value: 23 N•m [204 in-lb]



Engine Control Module (019-031)

Install

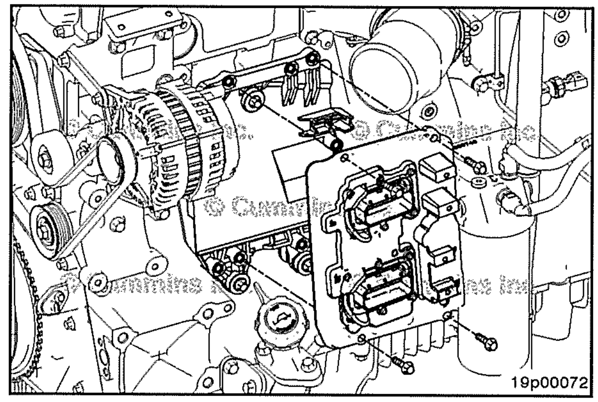
⚠CAUTION⚠

Do not paint the backside of the ECM. Make sure there is no grease or dirt between the ECM and the engine block.

Install the new ECM to the ECM mounting bracket.

Tighten the capscrews.

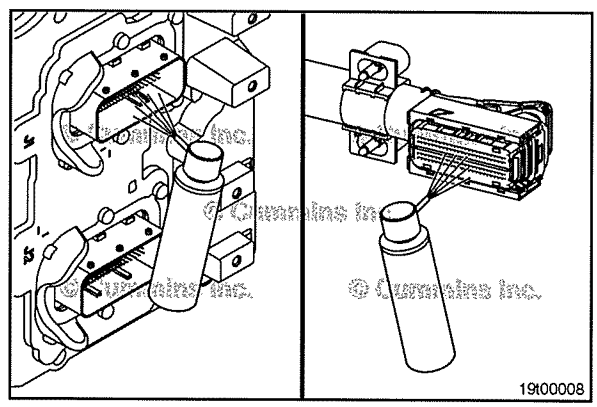
Torque Value: 7.4 N•m [65 in-lb]



⚠CAUTION⚠

Do not blow compressed air into the ECM ports or connectors. Compressed air can contain moisture due to condensation.

Use Cummins® electrical contact cleaner, Part Number 3824510, to remove all dirt and moisture from the ECM connector ports and the harness connectors.



Connect the OEM harness connector (1) and engine harness connector (2) to the ECM by placing the connector into the ECM receptacle. Pull back on the locking lever until the connector is fully seated and the lever locking tab is engaged.

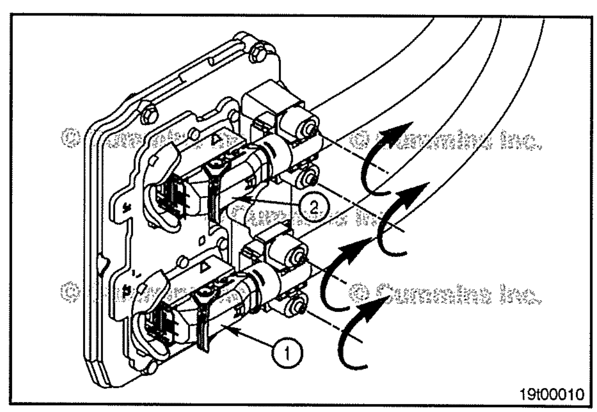
If the wire tie securing the wiring harness to the ECM connector backshell was removed, install a new wire tie.

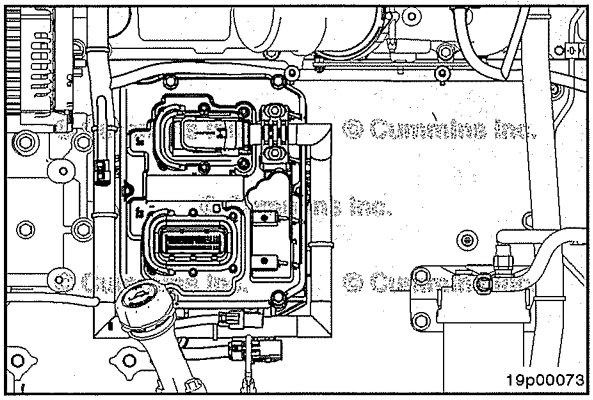
If the ECM harness clamp was removed, use the following procedure for installation instructions. Refer to Procedure 019-043 in Section 19.

NOTE: Do **not** overtighten the ECM harness clamp capscrews.

Tighten the ECM harness clamp capscrews.

Torque Value: 8 to 10 N•m [71 to 89 in-lb]

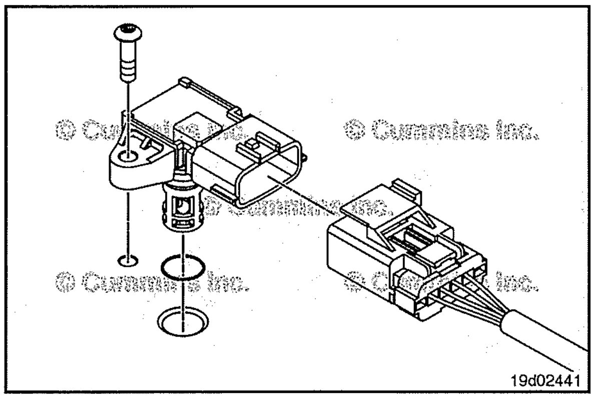




NOTE: When an ECM is replaced, the new ECM **must** be calibrated. Refer to Procedure 019-032 in Section 19.

Use INSITE™ electronic service tool to adjust the following values in the Trip Information section of Features and Parameters after calibrating the ECM.

- ECM Distance Offset
- ECM Time Offset
- Engine Distance Offset
- Engine Time Offset



Turbocharger Compressor Intake Pressure/Temperature Sensor (019-466)

Install

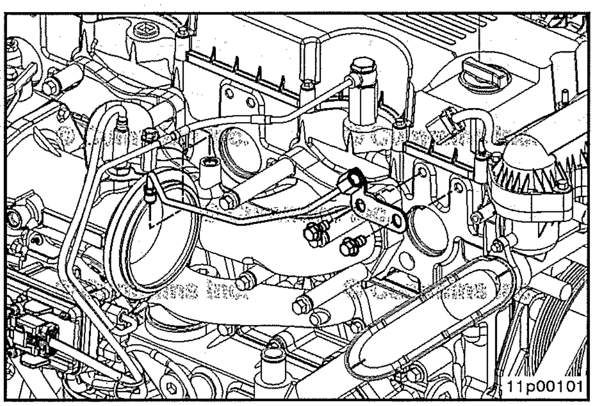
Lubricate the o-ring with clean engine oil before installation.

Install the turbocharger compressor intake pressure/ temperature sensor by pressing firmly on the top of the sensor until the o-ring is fully seated.

Install and tighten the mounting capscrew.

Torque Value: 7 N•m [62 in-lb]

Connect the engine harness to the turbocharger compressor intake pressure/temperature sensor.



Exhaust Gas Pressure Sensor Tube (011-027)

Install

Apply a film of high temperature anti-seize compound to the threads of the tube nuts.

Install the tube.

Install capscrews at cylinder head.

Torque Value: 46 N•m [34 ft-lb]

Tighten the tube nuts.

Torque Value: 16 N•m [142 in-lb]

Exhaust Gas Pressure Sensor (019-376)

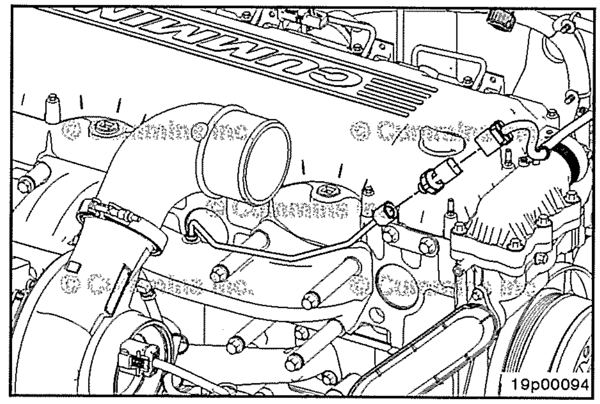
Install

NOTE: Make sure the sealing washer is captured on the threaded portion of the sensor.

Install the sensor and tighten.

Torque Value: 14 N•m [124 in-lb]

Connect the wiring harness to the sensor. An audible click will be heard as the connector locks in place.



Notes

Section 0 - Product - Group 00

Section Contents

Page
Engine Barring 0-15
Finishing Steps 0-16
General Information 0-15
Preparatory Steps 0-15
Rotate 0-16
Engine Installation 0-5
Finishing Steps 0-6
Install 0-5
Engine Painting 0-13
Preparatory Steps 0-13
Engine Removal 0-2
Preparatory Steps 0-2
Remove 0-3
Engine Steam Cleaning 0-15
Clean 0-15
Engine Storage - Long Term 0-8
General Information 0-8
Engine Storage - Short Term 0-11
General Information 0-11
Service Tools 0-1
Engine Removal and Installation 0-1

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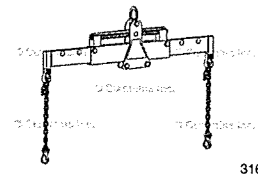
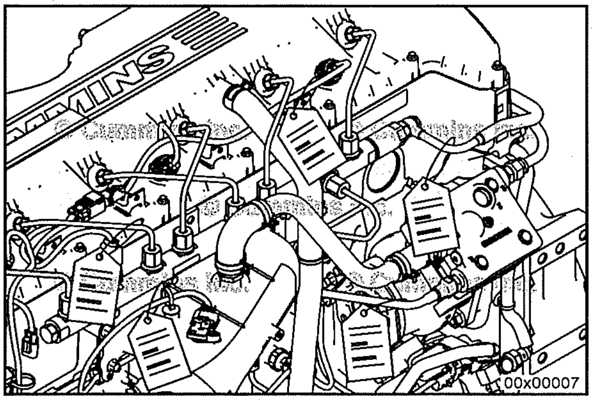
Service Tools

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.

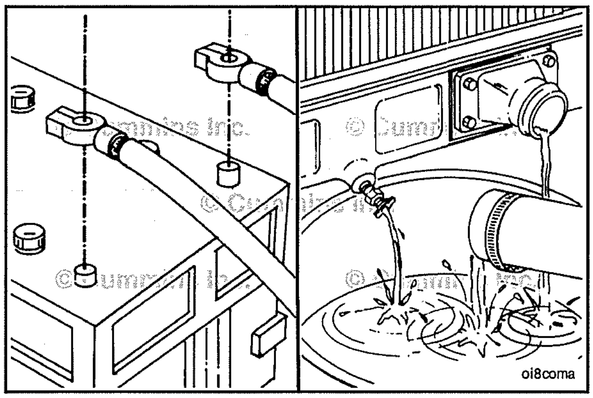
Tool No.	Tool Description	Tool Illustration
3162871	**Engine Lifting Fixture** Used to remove and install the engine.	



Engine Removal (000-001)

Preparatory Steps

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



⚠WARNING⚠

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

⚠WARNING⚠

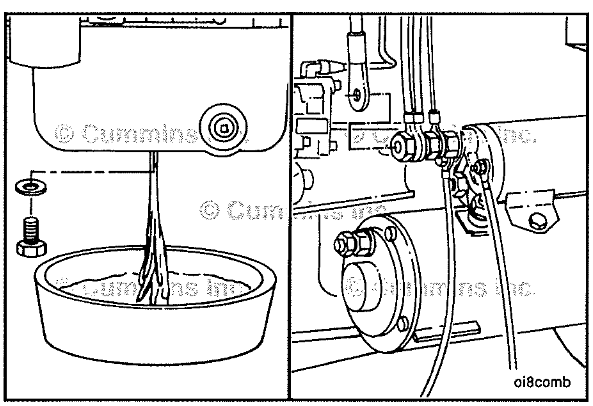
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠

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

Disconnect the battery cables. See equipment manufacturer service information.

Drain the engine coolant. Refer to Procedure 008-018 in Section 8.



⚠WARNING⚠

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

⚠WARNING⚠

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

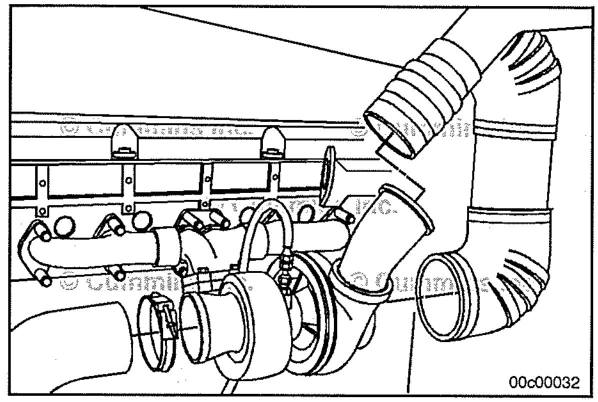
Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.

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

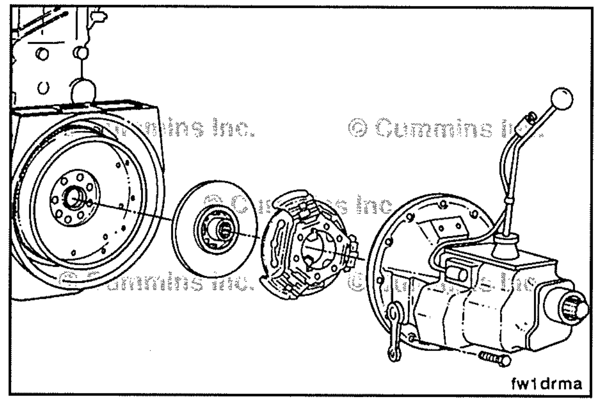
Remove

Disconnect the intake and the exhaust air pipes.

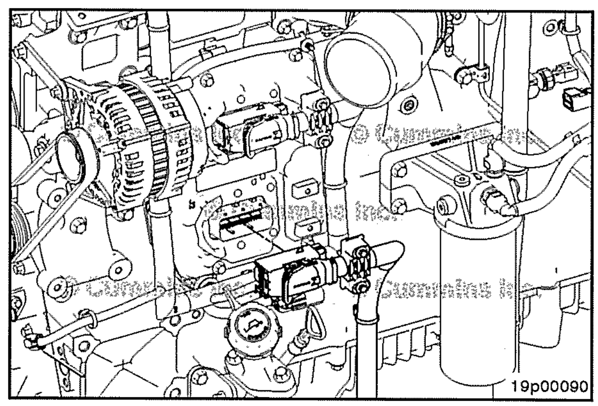
Disconnect all chassis-mounted, engine-driven accessories.



Disconnect the drive units from the flywheel.

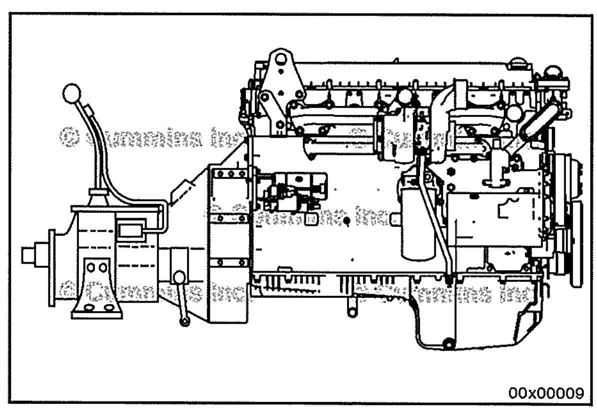


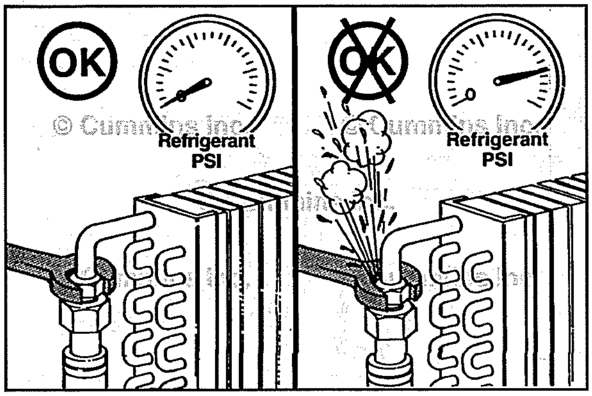
Disconnect the OEM wiring harness from the engine control module (ECM). Refer to Procedure 019-071 in Section 19.



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

Most cab-over configuration vehicles will have the Cummins Inc. factory-installed rear engine lifting bracket still installed.



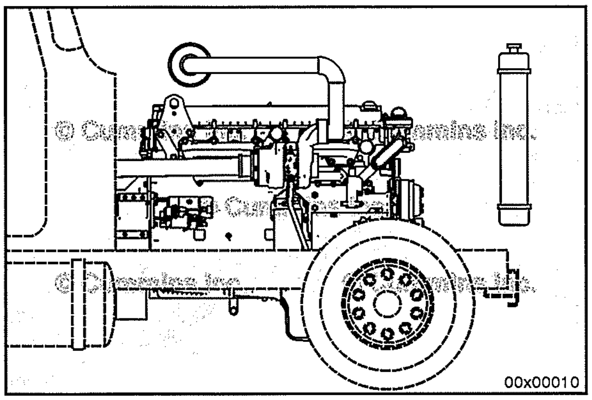


⚠WARNING⚠

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

⚠WARNING⚠

To protect the environment, liquid refrigerant systems must be properly emptied and filled using equipment that prevents the release of refrigerant gas into the atmosphere. Federal law requires capturing and recycling the refrigerant.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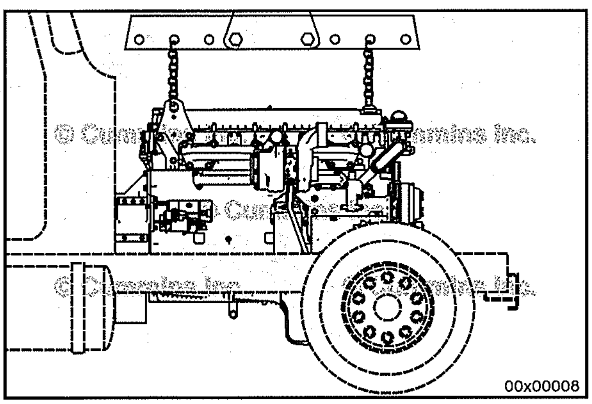
Remove all chassis components necessary to remove the engine.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⚠WARNING⚠

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 [51 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

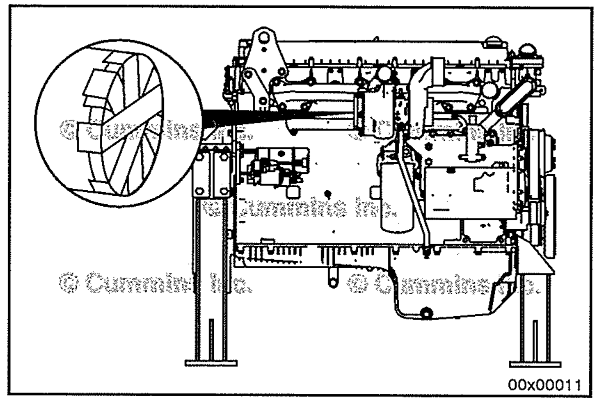
Use a correctly rated hoist, and attach the engine lifting fixture, Part Number 3162871, to the engine-mounted lifting brackets to remove the engine.

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

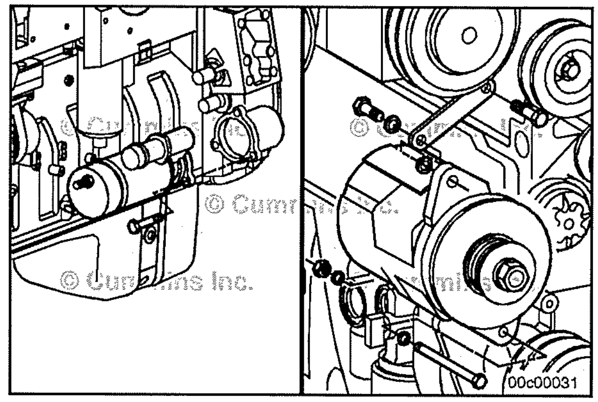
Remove the engine.

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

Place the engine on suitable engine support stands.



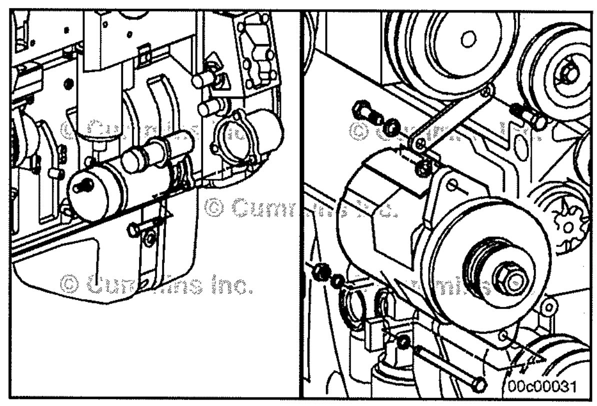
Remove and use all remaining accessories and brackets with the replacement engine.



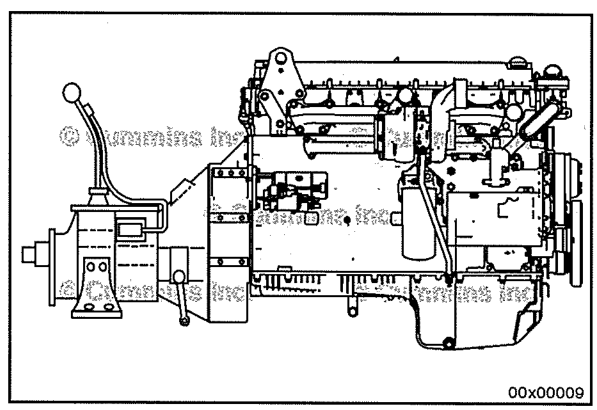
Engine Installation (000-002)

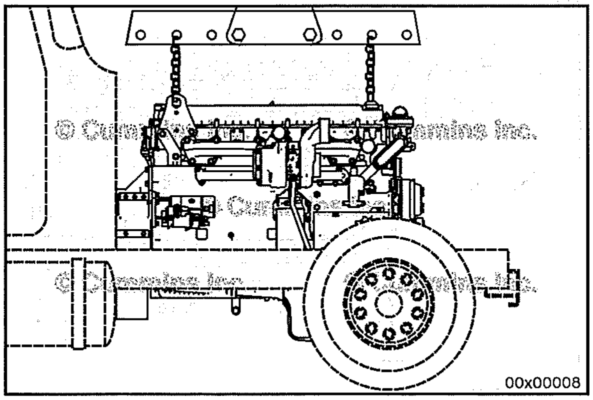
Install

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



If the rear engine mounts are attached to the transmission, it will possibly be necessary to install the engine and the transmission as assembly.





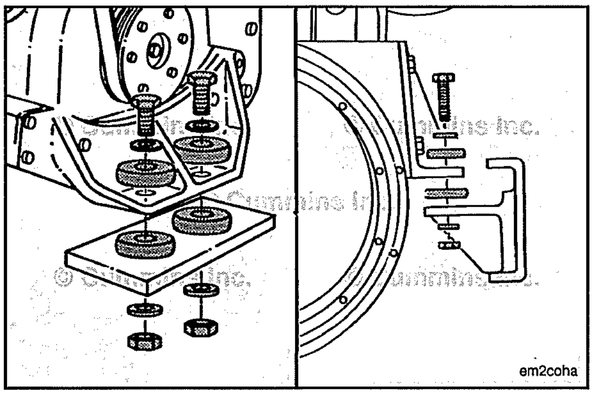
WARNING

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

WARNING

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

Use a correctly rated hoist, and attach engine lifting fixture, Part Number 3162871, to the engine-mounted lifting brackets to install the engine.

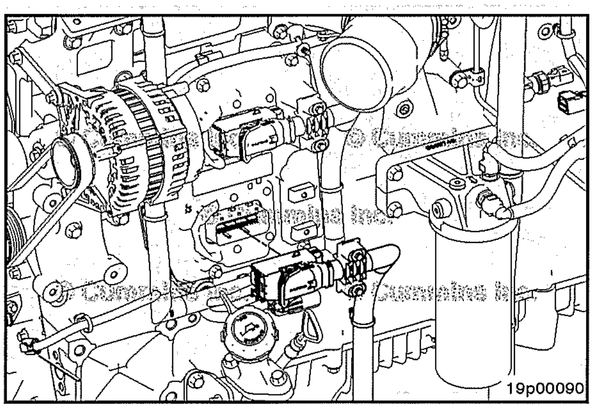


CAUTION

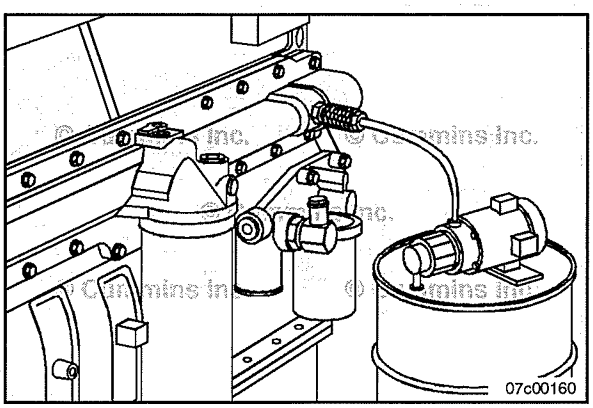
Make sure all lines, hoses, and tubes are correctly routed and fastened to prevent damage.

Align the engine in the chassis, and tighten the engine mounting capscrews. See equipment manufacturer service information for torque specifications.

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



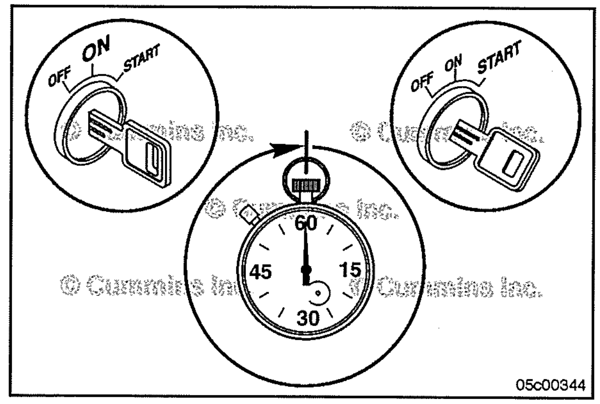
Connect the OEM wiring harness to the ECM. Refer to Procedure 019-071 in Section 19.



Finishing Steps

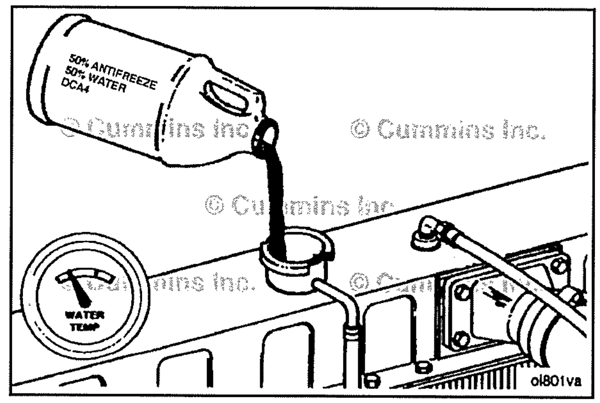
Fill and prime the engine with clean Cummins recommended lubricating oil. Refer to Procedure 007-037 in Section 7.

Fill and prime the fuel system. Refer to Procedure 005-234 in Section 5.

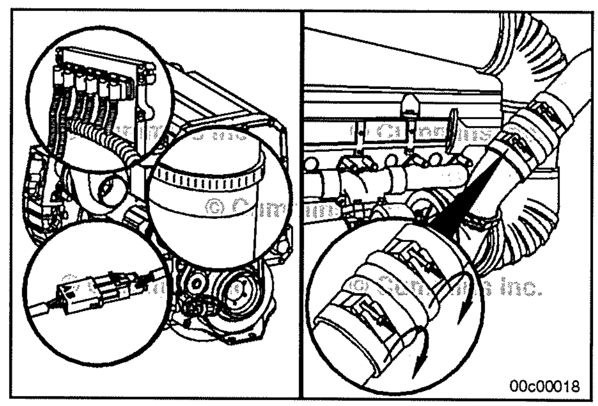


See equipment manufacturer service information for radiator and system capacity.

Fill the cooling system. Refer to Procedure 008-018 in Section 8.



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



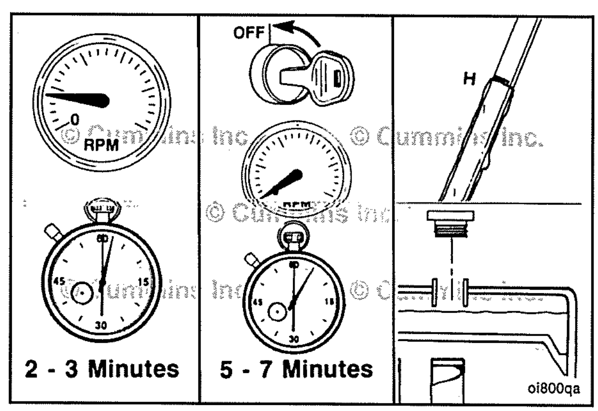
⚠WARNING⚠

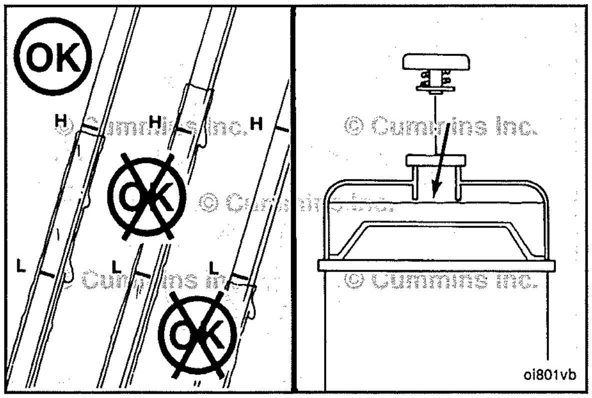
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

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

Stop the engine and wait 15 minutes for the oil to drain to the oil pan.

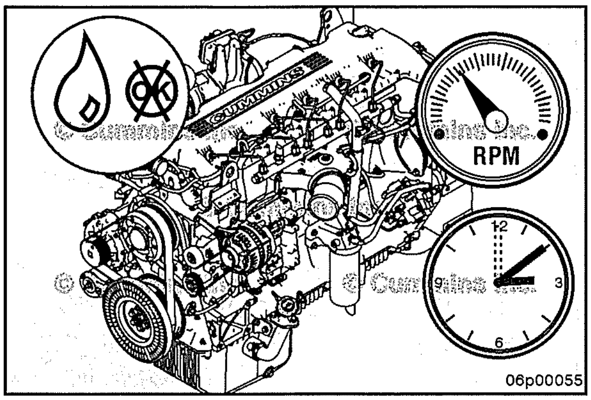
Check the oil and the coolant levels again.





Fill the engine to the correct coolant level, if necessary. Refer to Procedure 008-018 in Section 8.

Fill the engine to the correct oil level, if necessary. Refer to Procedure 007-037 in Section 7.



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

Repair all leaks and component problems. Consult the appropriate 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 external 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. See the Coolant Recommendations and Specifications procedure in Section V of the corresponding owners and/or operation and maintenance manual 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. See the Coolant Recommendations and Specifications procedure in Section V of the corresponding owners and/or operation and maintenance manual 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. See the Coolant Recommendations and Specifications procedure in Section V of the corresponding owners and/or operation and maintenance manual 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 external 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).

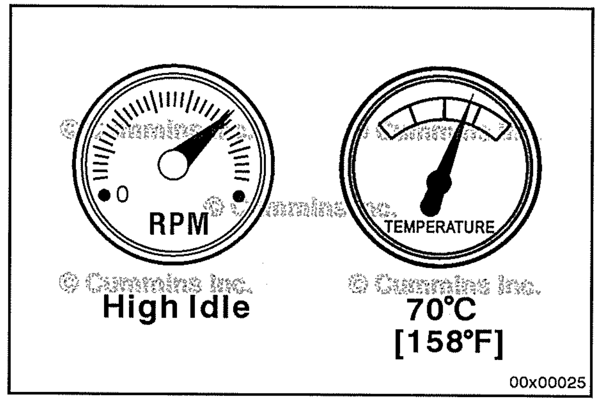
Engine Storage - Short Term (000-006)

General Information

This procedure describes the proper method to prepare an engine for short term storage (1 to 6 months).

Operate the engine at high idle speed until the coolant temperature indicator reaches 70°C [158°F].

Shut off the engine.

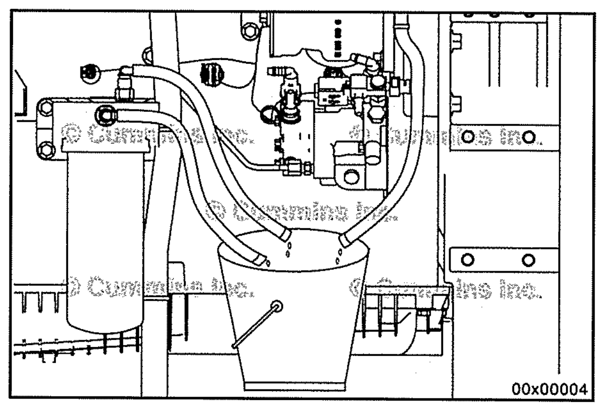


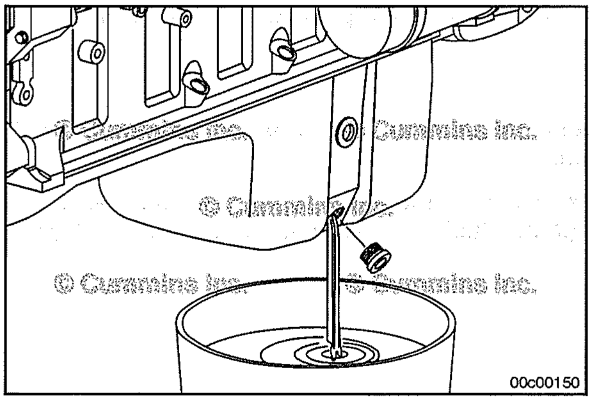
Remove the fuel lines to the fuel pump and the injector return line. Place the ends into a container.

Install a new fuel filter. Refer to Procedure 006-065 in Section 6.

Fill the container with straight Number 1 or Number 2 diesel fuel (no biodiesel content).

Run the engine for 10 minutes to make sure the straight diesel fuel has filled all of the fuel system components.





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⚠WARNING⚠

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

⚠WARNING⚠

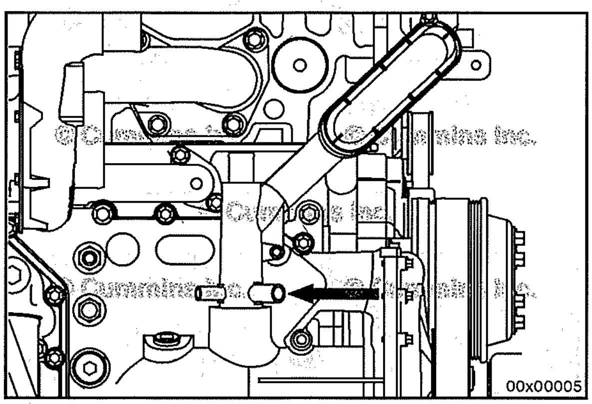
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

Drain the lubricating oil pan, the lubricating oil filter(s), and the fuel filter.

Install the lubricating oil pan drain plug in the oil pan.

Torque Value: 55 N•m [41 ft-lb]

NOTE: The oil pan can remain empty until the engine is ready to use.



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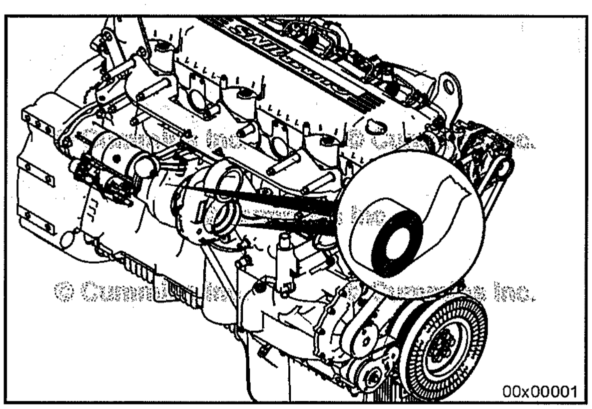
Drain the cooling system. Refer to Procedure 008-018 in Section 8.

NOTE: It is **not** necessary to drain the coolant if it is a permanent type antifreeze with a rust inhibitor. Do **not** drain the coolant if the engine is installed in a vehicle.



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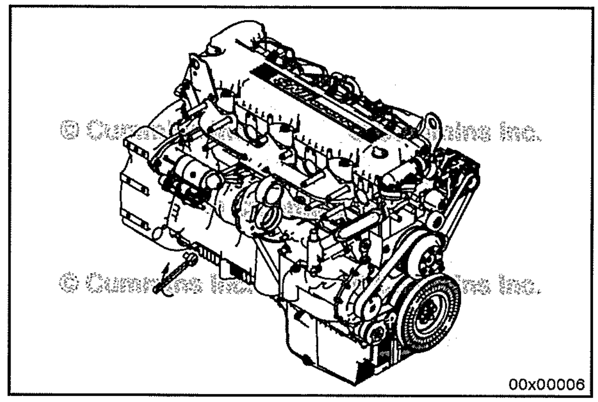
Cover all openings with tape to prevent dirt and moisture from entering the engine.

Install a warning tag on the engine. The tag **must** indicate that the engine does **not** contain oil and **must not** be operated.

⚠WARNING⚠

Do not pull or pry on the fan to manually rotate the engine. To do so can damage the fan blades. Damaged fan blades can cause premature fan failures which can result in serious personal injury or property damage.

Rotate the crankshaft two or three revolutions every 3 to 4 weeks. Refer to Procedure 000-017 in Section 0.



Remove the engine from short term storage.

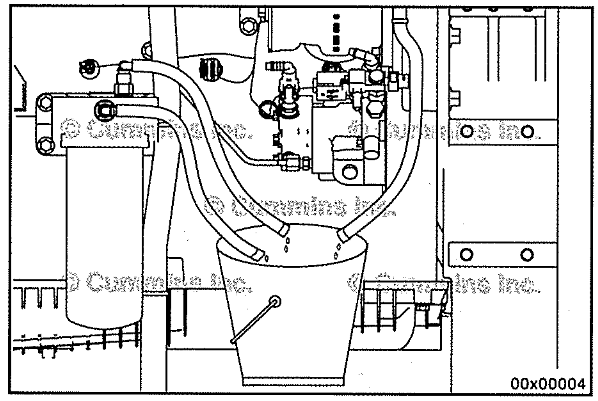
Remove the tape from the openings.

Remove the warning tag.

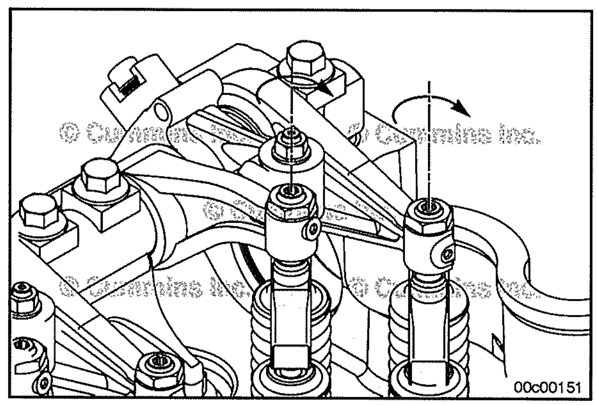
- Replace the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Replace the fuel filter. Refer to Procedure 006-065 in Section 6.

Prime the lubricating oil system. Refer to Procedure 007-037 in Section 7.

Use clean diesel fuel to flush the diesel fuel that was stored in the engine.



- Fill the cooling system (if necessary). Refer to Procedure 008-018 in Section 8.
- Adjust the valve clearance. Refer to Procedure 003-004 in Section 3.



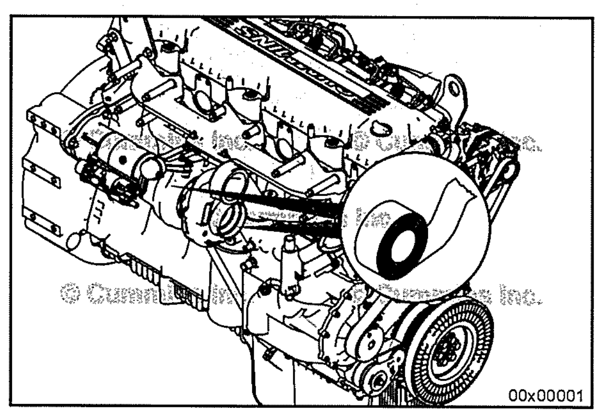
Engine Painting (000-007)

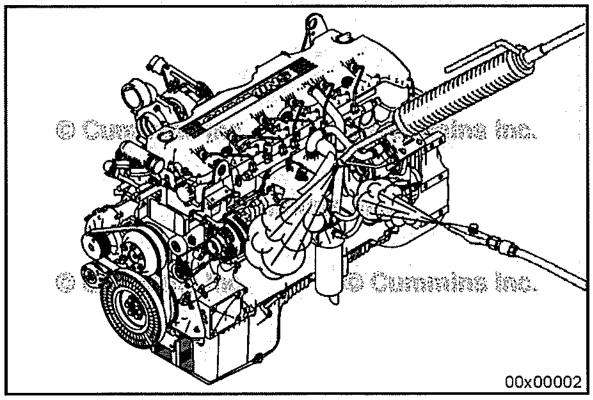
Preparatory Steps

Remove all belts from the engine.

Cover the following parts of the engine:

- 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 personal injury.

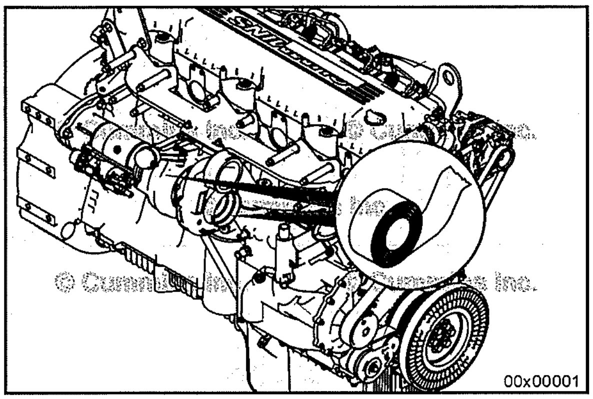
WARNING
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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

Use steam to clean the engine.

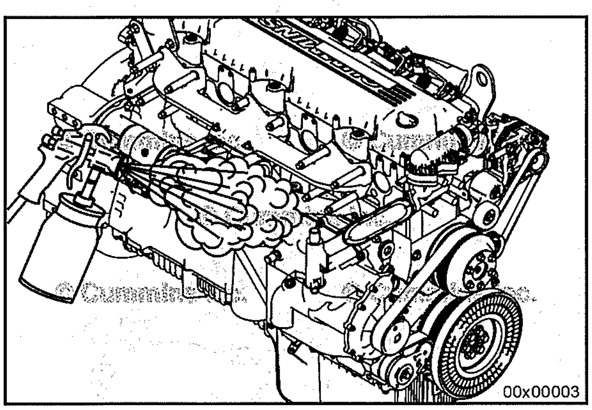
Dry with compressed air.

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



After cleaning the engine, cover the following components to protect them from the paint:

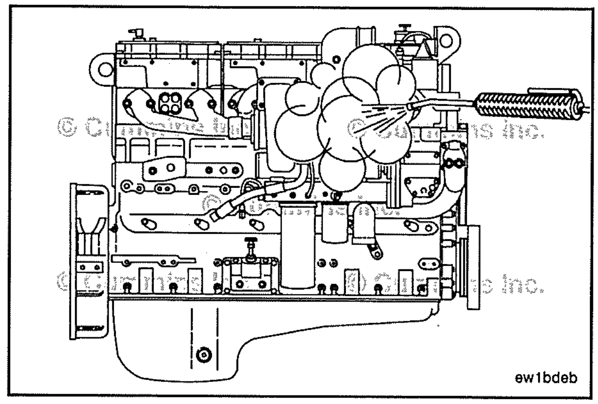
- All dataplates
- Valve and injector set marks
- Exhaust manifold
- Turbocharger turbine housing
- Flywheel
- Flywheel housing transmission mounting surface
- Electrical connections
- All decals
- All pulley belt surfaces
- Any exposed fittings, threads, and electrical wire terminals.



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.

Engine Barring (000-017)

General Information

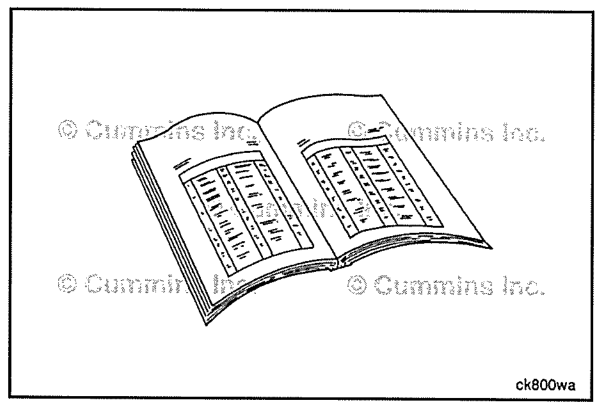
WARNING

Do not pull or pry on the fan to manually rotate the engine. To do so can damage the fan blades. Damaged fan blades can cause premature fan failures which can result in serious personal injury or property damage.

This procedure instructs how to rotate the engine for service events.

NOTE: The illustrations in this procedure are generic and may **not** represent the hardware on all engines.

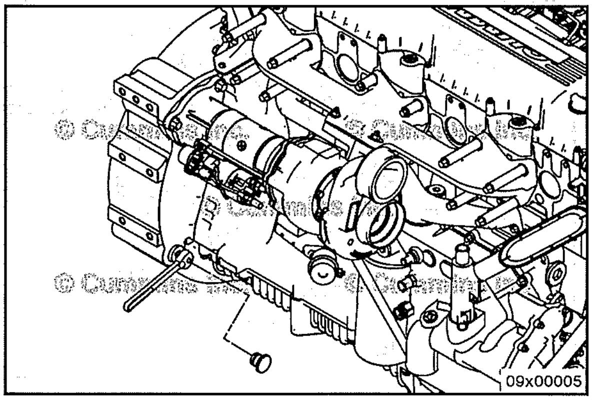
Preparatory Steps



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. See equipment manufacturer service information.

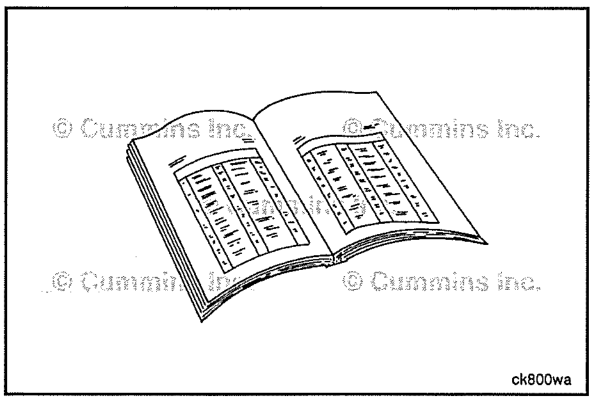


Rotate

⚠ WARNING ⚠

When servicing the engine, do not use a remote starter switch or other means that would engage the starting motor to rotate the engine on a high-pressure common rail engine. Using the starter motor can create highly pressurized fuel in the fuel system. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death. Use a hand barring tool to rotate the engine for servicing the engine. Always loosen the pump-to-rail fuel line at the rail to vent the pressure after rotating the engine. Keep hands clear of the line when loosening and wear appropriate eye protection.

- Remove the plastic cover in the flywheel housing. Insert service tool, Part Number 4919092, into the flywheel housing. Use a 3/4-inch breaker bar and rotate it **counterclockwise** when viewed from the front of the engine.



Finishing Steps

⚠ WARNING ⚠

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

- Remove all tools.
- Connect the batteries. See equipment manufacturer service information.

Section 1 - Cylinder Block - Group 01

Section Contents

	Page
Bearings, Connecting Rod	1-5
Clean and Inspect for Reuse	1-7
Finishing Steps	1-10
General Information	1-5
Install	1-9
Preparatory Steps	1-5
Remove	1-5
Bearings, Main	1-11
Clean and Inspect for Reuse	1-13
Finishing Steps	1-19
Install	1-15
Measure	1-14
Measure	1-18
Preparatory Steps	1-11
Remove	1-11
Bearings, Thrust	1-20
Finishing Steps	1-22
Inspect for Reuse	1-21
Install	1-21
Preparatory Steps	1-20
Remove	1-20
Block Stiffener Plate	1-112
Finishing Steps	1-113
Inspect for Reuse	1-112
Install	1-113
Preparatory Steps	1-112
Remove	1-112
Camshaft Cover Plate	1-22
Clean and Inspect for Reuse	1-23
Install	1-23
Remove	1-22
Connecting Rod	1-24
Clean and Inspect for Reuse	1-25
Finishing Steps	1-31
General Information	1-24
Magnetic Crack Inspect	1-28
Preparatory Steps	1-24
Crankshaft	1-31
Bend and Twist Inspect	1-37
Clean and Inspect for Reuse	1-33
Finishing Steps	1-46
Install	1-46
Magnetic Crack Inspect	1-42
Preparatory Steps	1-32
Remove	1-33
Rotation Check	1-31
Crankshaft Gear, Rear (Crankshaft Installed)	1-47
Clean and Inspect for Reuse	1-49
Finishing Steps	1-50
General Information	1-47
Install	1-49
Preparatory Steps	1-48
Remove	1-48
Crankshaft Pulley	1-50
Clean and Inspect for Reuse	1-51
Finishing Steps	1-53
Install	1-52

Preparatory Steps....1-50
Remove....1-51
Crankshaft Seal, Front 1-53
Clean and Inspect for Reuse....1-55
Finishing Steps....1-56
General Information....1-53
Install....1-55
Preparatory Steps....1-53
Remove....1-54
Crankshaft Seal, Rear 1-56
Clean and Inspect for Reuse....1-58
Finishing Steps....1-59
General Information....1-56
Install....1-58
Preparatory Steps....1-56
Remove....1-57
Crankshaft Speed Indicator Ring 1-109
General Information....1-109
Measure....1-109
Cylinder Block 1-60
Clean and Inspect for Reuse....1-60
Finishing Steps....1-67
Preparatory Steps....1-60
Cylinder Block and Liner Seats 1-67
Finishing Steps....1-69
Leak Test....1-68
Preparatory Steps....1-67
Cylinder Liner 1-70
Clean and Inspect for Reuse....1-74
Finishing Steps....1-81
Initial Check....1-71
Install....1-78
Measure....1-77
Preparatory Steps....1-70
Remove....1-71
Engine Base Timing 1-109
Finishing Steps....1-111
Test....1-109
Engine Dataplate 1-108
Clean and Inspect for Reuse....1-108
General Information....1-108
Install....1-109
Remove....1-108
Gear Cover, Front 1-82
General Information....1-82
Gear Train Backlash, Rear 1-129
Measure....1-129
Idler Gear, Camshaft Rear 1-118
Clean and Inspect for Reuse....1-120
Finishing Steps....1-123
General Information....1-118
Install....1-122
Preparatory Steps....1-119
Remove....1-120
Idler Gear, Crankshaft Rear 1-123
Clean and Inspect for Reuse....1-125
Finishing Steps....1-128
General Information....1-123
Install....1-127
Preparatory Steps....1-124
Remove....1-125
Piston 1-82
Clean and Inspect for Reuse....1-84
Finishing Steps....1-87

General Information....1-82
Preparatory Steps....1-83
Piston and Connecting Rod Assembly 1-95
Assemble....1-101
Clean and Inspect for Reuse....1-101
Disassemble....1-100
Finishing Steps....1-107
General Information....1-95
Install....1-103
Preparatory Steps....1-97
Remove....1-98
Piston Cooling Nozzle 1-87
Clean and Inspect for Reuse....1-88
Finishing Steps....1-89
Install....1-88
Preparatory Steps....1-87
Remove....1-88
Piston Rings 1-89
Clean and Inspect for Reuse....1-90
Install....1-91
Measure....1-91
Preparatory Steps....1-89
Remove....1-90
Rear PTO Idler Gear 1-113
Clean and Inspect for Reuse....1-115
Finishing Steps....1-117
General Information....1-113
Install....1-116
Preparatory Steps....1-114
Remove....1-115
Service Tools 1-1
Cylinder Block....1-1
Vibration Damper, Viscous 1-93
Finishing Steps....1-95
Inspect for Reuse....1-93
Install....1-94
Preparatory Steps....1-93
Remove....1-93

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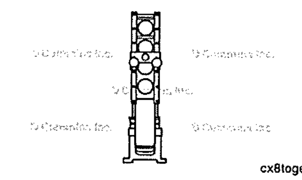
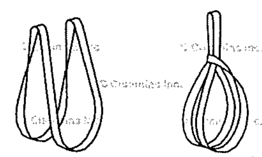
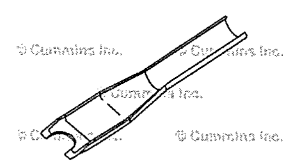
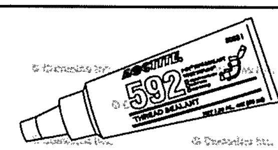
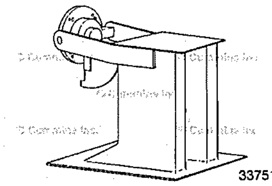
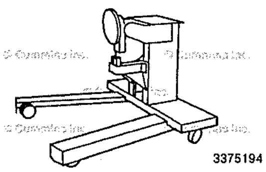
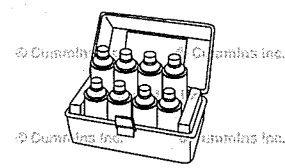
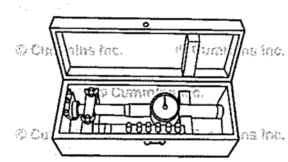
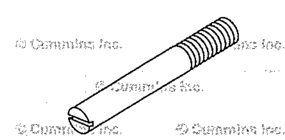
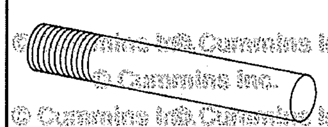
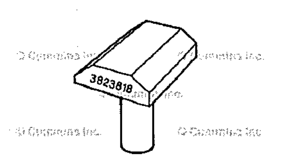
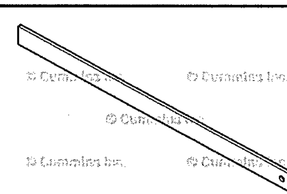
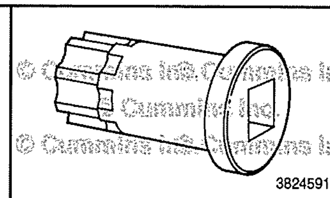
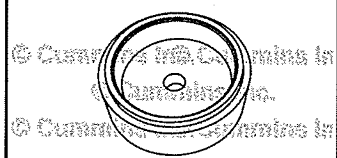
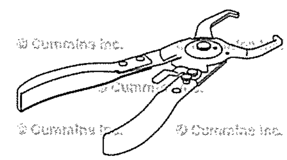
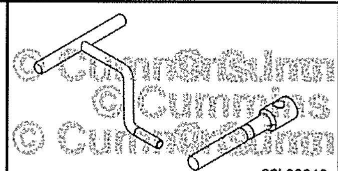
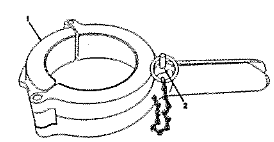
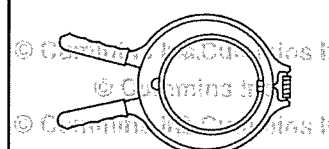
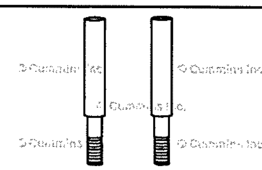
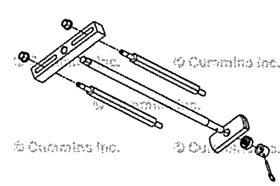
Service Tools

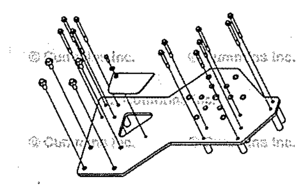
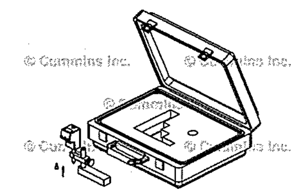
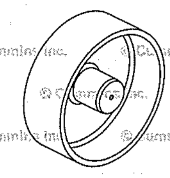
Cylinder Block

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

Tool No.	Tool Description	Tool Illustration
ST-561	**Connecting Rod Checking Fixture** Used to measure connecting rod bend and twist.	
2892501	**2200 lb/1000 kg Nylon Lifting Sling** 30 mm × 2 m EWL polyester duplex webbing sling to EN1492-1 with becket eyes each end and 1 meter long webbing wear sleeve. Safe working load 1000 kg straight lift.	
3163087	**Lubriplate** Lubriplate 105 Assembly Lube 10 oz. tube.	
3165175	**Barring Plug Remover** This tool was designed to aid technicians in removing the plug from the flywheel housing.	
3375066	**Teflon pipe sealant** Loctite® 592, 1.69 oz. tube, used for pipe fittings.	
3375068	**High strength thread locking compound** Loctite® 271, high strength, permanent red liquid thread locking compound good for use on bolts up to 1 inch. 50-ml bottle.	

Tool No.	Tool Description	Tool Illustration
3375193	**Stationary Engine Rebuild Stand** 5000-lb capacity stationary engine rebuild stand. Works with multiple engines with use of appropriate adapter plate.	 3375193
3375194	**Rolling Engine Rebuild Stand** 5000-lb capacity wheeled engine rebuild stand. Works with multiple engines with use of appropriate adapter plate.	 3375194
3375432	**Non-Magnetic Crack Detection Kit** Includes: Part Number 3375433, Crack Detection Cleaner; Part Number 3375434, Crack Detection Developer; Part Number 3375435, Crack Detection Penetrant. This is a non-magnetic crack detection test kit to detect cracks in engine components as required. This product is a long proven product for detecting cracks that can **not** be detected by the naked eye. It also projects the severity of a crack if one is suspected.	 22x00015
3376619	**Dial Bore Gauge Kit** Used to measure bore diameters 3 to 8 inches. Dial face is dimensioned in inches and millimeters.	 22x00014
3376638	**Guide Pins** This guide pin (M12x1.25, 150-mm long) is used during assembly and/or disassembly to align parts and aid in the control of parts.	 22x00023
3376696	**Guide Pins** Used to aid the installation of the vibration damper. Requires two guide pins.	 3822784
3823818	**Main Bearing Rollout Tool** Used to remove and install main bearings with crankshaft installed.	 3823818
4918219	**Precision Straightedge** Used to check cylinder blocks and cylinder heads for flatness.	 22d00222

Tool No.	Tool Description	Tool Illustration
4919092	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591
4919375	**Oil Seal Installer (rear)** Used to install the rear crankshaft seal.	 22d00416
5298504	**Piston Ring Compressor Band** Used with piston ring compressor, Part Number 5298583.	 01p00130
5298582	**Timing Pin Kit** Used for static timing of the engine. Contains camshaft timing pin, Part Number 4919342, and crankshaft timing pin, Part Number 5298581.	 22k00013
5298583	**Piston Ring Compressor** Used to compress piston rings on pistons during installation of pistons in the cylinder block.	
5298585	**Piston Ring Expander** Used to remove and install piston rings on pistons.	 pi8togd
5298634	**Connecting Rod Guide Pins (Two)** Used to guide the connecting rod into the engine during piston installation and removal.	 cx8togg
5298758	**Liner Installation/Removal Tool** Used to seat and hold the liner while liner protrusion is measured.	 22x00013

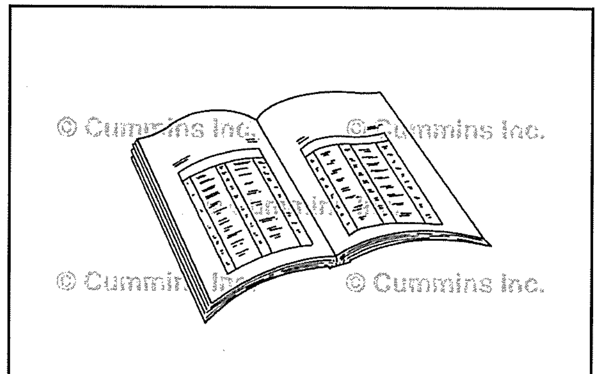
Tool No.	Tool Description	Tool Illustration
5299152	**ISG Series Engine Rollover Stand Adapter Plate Kit** Used to mount the ISG family of engines onto the mobile and stationary engine rollover stands for out-of-chassis maintenance work.	 22x00019
5299194	**Gauge Block** Used to measure cylinder protrusion on the cylinder block and gear housing protrusion below the cylinder block.	 01p00129
5299870	**Oil Seal Installer (front)** Used to install the front crankshaft seal.	 01p00131

Bearings, Connecting Rod (001-005)

General Information

The connecting rod for this engine uses a fracture split connection between the rod cap and the rod. Connecting rods with a fracture split surface **must** be treated with caution. The two pieces of the connecting rod can **not** be rubbed together. This will damage the mating surfaces. Use care to **not** drop either piece of the connecting rod. Fracture split connecting rods **must only** be handled if the two pieces of the connecting rod are tightened to the correct specification, or completely separated.

Preparatory Steps



ck800wa

WARNING

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

WARNING

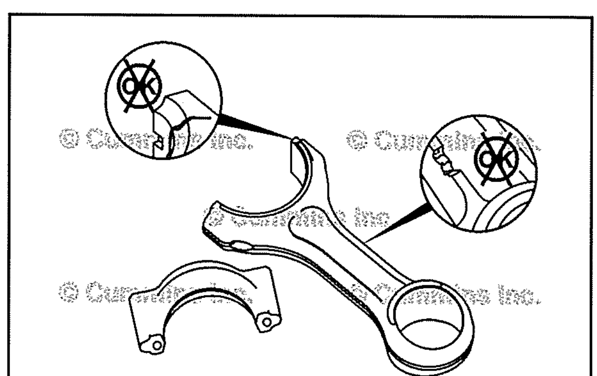
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

CAUTION

Rotating the engine with the connecting rod caps loose or removed can cause damage to the piston cooling nozzles. Always remove the piston cooling nozzles prior to removing the connecting rod and piston assembly.

- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Remove the piston cooling nozzles. Refer to Procedure 001-046 in Section 1.

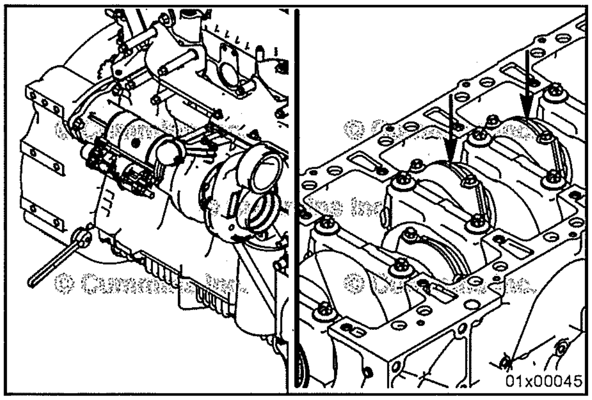
Remove



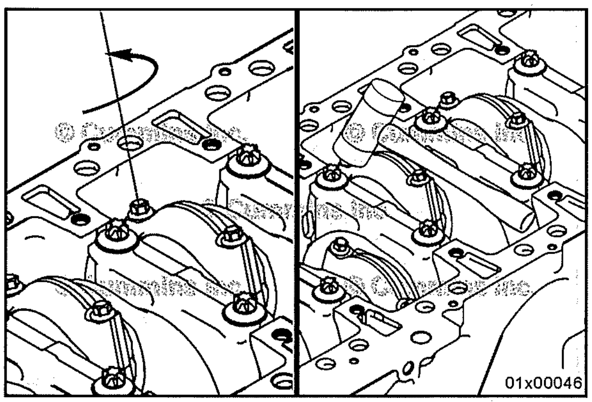
01x00009

CAUTION

To prevent damage to the fracture split connecting rod, do not set the connecting rod or rod cap on the fracture split connection. This can cause polishing and damage to the mating surface.



Rotate the crankshaft, using Part Number 4919092, so that two of the connecting rods are at bottom dead center.



CAUTION

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

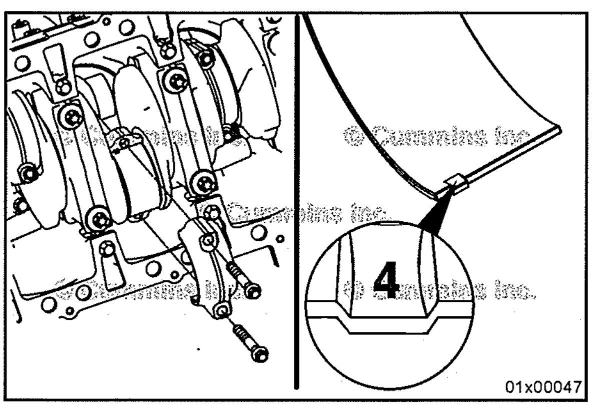
CAUTION

Make sure the piston cooling nozzles have been removed before removing the connecting rod cap. Damage to the nozzles can occur if they are not removed.

Do **not** remove the capscrews at this time.

Loosen the connecting rod capscrews.

Hit the connecting rod capscrews with a rubber hammer to loosen the rod caps.



Remove the capscrews and the rod cap. Note the corresponding rod and rod cap as well as the orientation of the rod cap.

Be careful **not** to damage the fracture split connection.

Do **not** set the rod cap down on its fracture split face.

NOTE: Both the rod cap and the connecting rod are serialized on one face to make sure of proper orientation.

NOTE: Minimize the number of joint interactions between the connecting rod and rod cap. If the fracture split mating surface becomes damaged or worn, the rod cap will **not** fit as designed to the connecting rod. Engine damage can occur.

Lower connecting rod shell bearing location is denoted by LOWER or LWR, for the connecting rod cap, stamped into the back of the bearing shells.

Remove the bearing shell from the rod cap and use and awl to mark the cylinder number on the flat surface of the bearing tangs.

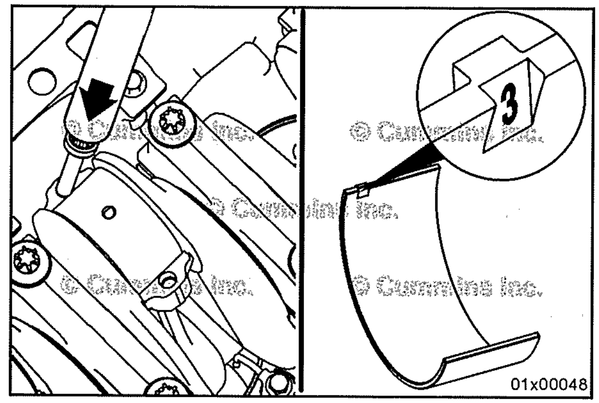
Use a connecting rod guide pin, Part Number 5298634, to push the rod up far enough to allow the upper bearing shell to be removed.

Do **not** push against the fracture split face of the rod.

Use caution to avoid scratching or other damage to the journal with the rod, capscrew or piston pusher.

Upper connecting rod shell bearing location is denoted by UPPER or UPR, for the connecting rod, stamped into the back of the bearing shells. The upper connecting rod shell bearing can also be identified by the oil port in the bearing.

Remove the bearing shell and mark the cylinder number on the flat surface of the bearing tang.

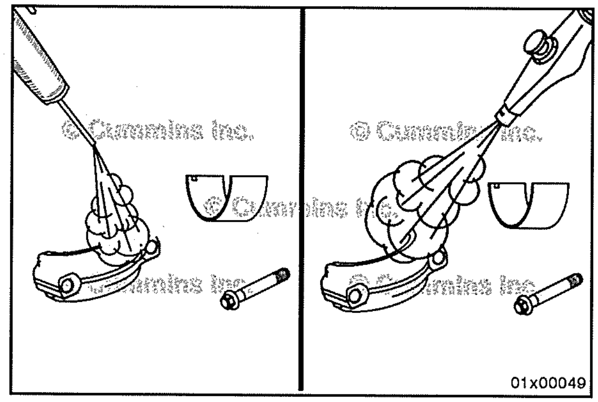


Clean and Inspect for Reuse

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

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

Steam clean the parts and dry with compressed air.



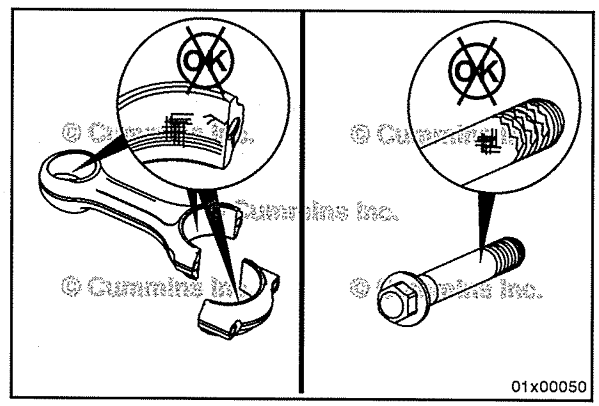
Inspect the rod caps, connecting rod bearing saddles, and capscrews for nicks, cracks, burrs, scratches, and fretting.

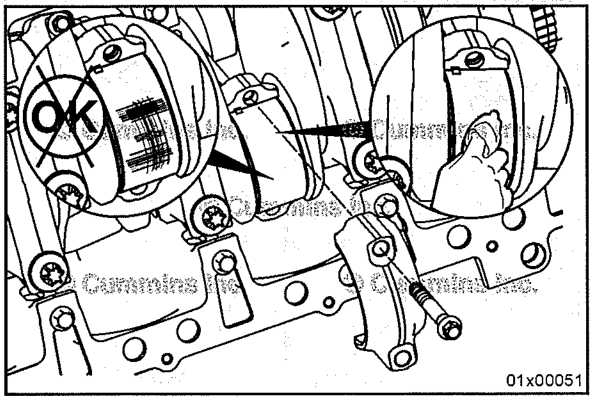
Inspect the fracture surface for damage and signs of polishing.

Polished spots on either the connecting rod or connecting rod cap mating surfaces indicate fretting and indicate that the rod **must** be replaced.

Dark areas on the face indicate carbonized oil deposits. Connecting rods with dark areas are reusable, if fretting is **not** present.

Polishing may be observed on the thrust face of the connecting rod or rod cap, which is normal. Use the following procedure for inspection criteria. Refer to Procedure 001-007 in Section 1.

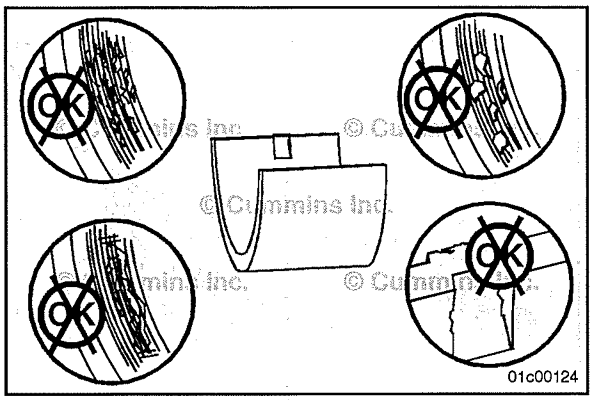




Inspect the connecting rod journal of the crankshaft for scratches or nicks.

Use a fine grit crocus cloth to remove the nicks and scratches.

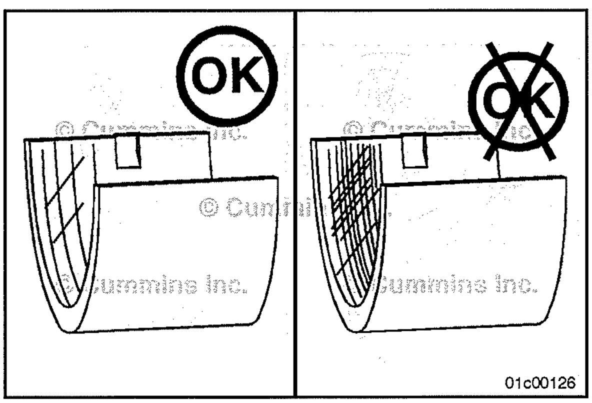
Clean off any dust or debris released while using the crocus cloth.



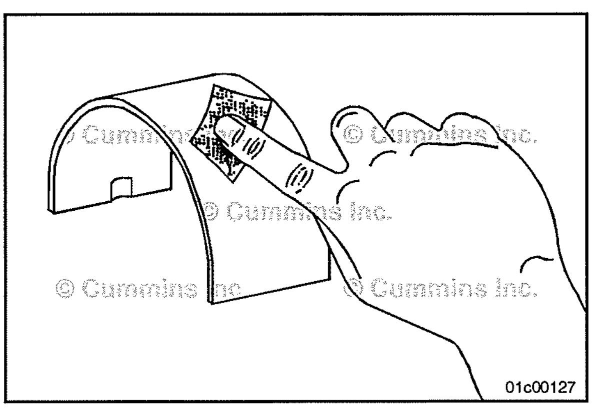
Inspect the bearings for damage.

Replace any bearings with the following damage:

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



Normal bearing wear produces a smooth finish that will wear into the lining. Refer to the Parts Reuse Guidelines, Bulletin 3810303.



Refer to the Analysis and Prevention of Bearing Failures, Bulletin 3810387, for more detailed information of bearing damage.

Inspect the bearing seating surface for nicks or burrs.

If nicks or burrs can **not** be removed with a fine crocus cloth, the bearings **must** be replaced.

Clean off any dust or debris released while using the crocus cloth.

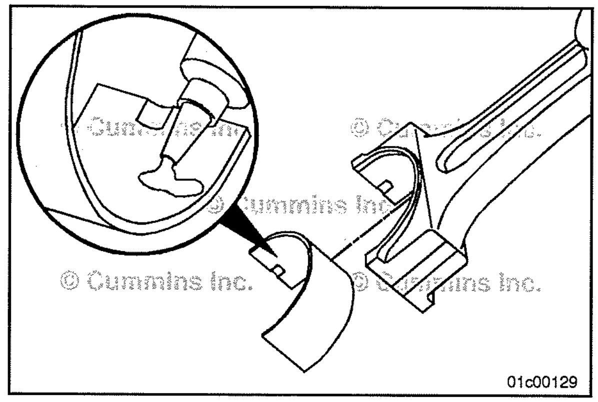
Install

⚠CAUTION⚠

The connecting rod and bearing shell mating surfaces must be clean and dry when the bearing shells are installed. Used bearings must be installed in their original location or engine damage can occur.

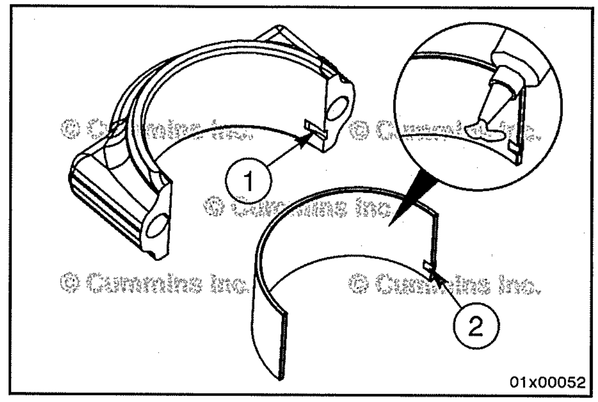
Use clean Lubriplate™ 105 multi-purpose lubricant, Part Number 3163087, or its equivalent, to lubricate the crankshaft journal mating surface of the upper bearing shell.

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



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

Use clean Lubriplate™ 105 multi-purpose lubricant, Part Number 3163087, or its equivalent, to lubricate the bearing shell to the crankshaft journal mating surface.



⚠CAUTION⚠

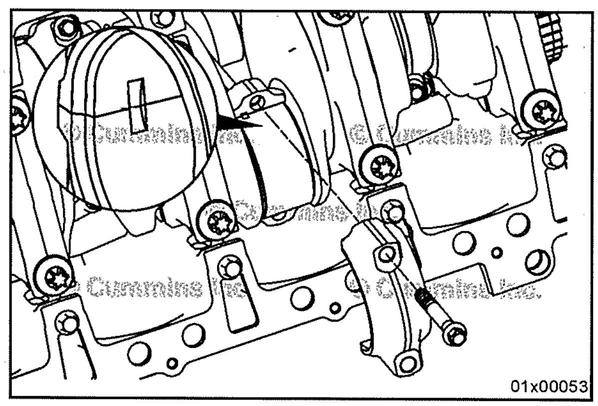
Do not damage the fracture split surface on the connecting rod or connecting rod cap while the connecting rod caps are removed. If the fracture split surface is damaged, the connecting rod and connecting rod cap must be replaced to reduce the possibility of engine damage. Incorrect assembly can damage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

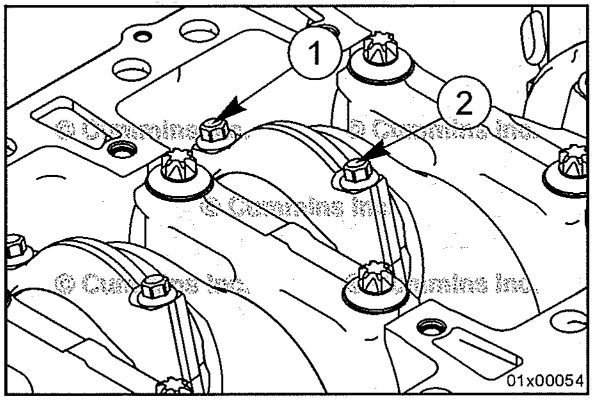
NOTE: Make sure that the rod cap is installed **only** on the connecting rod from which it was removed and that the rod cap is properly oriented during installation.

NOTE: Both the rod cap and the connecting rod are serialized on one face to make sure of proper orientation.

Install the cap onto the connecting rod.

NOTE: Minimize the number of joint interactions between the connecting rod and rod cap. If the fracture split mating surface becomes damaged or worn, the rod cap will **not** fit as designed to the connecting rod. Engine damage can occur.

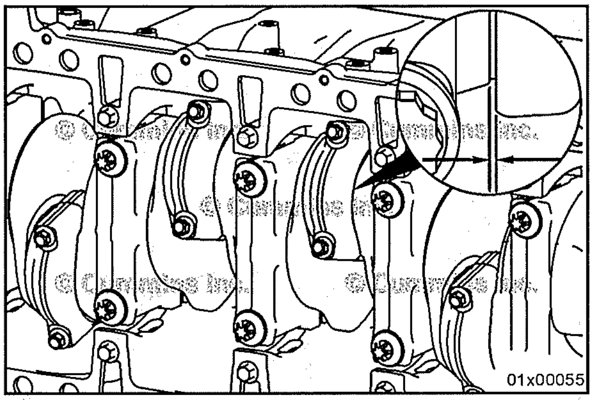




Lubricate the threads and the underside of the heads of the connecting rod capscrews with clean engine oil.

Thread the capscrews into the connecting rod and hand tighten.

Tighten the capscrews and torque to 85 N·m [63 ft-lb] and angle 60 degrees. Refer to Procedure 001-054 in Section 1.

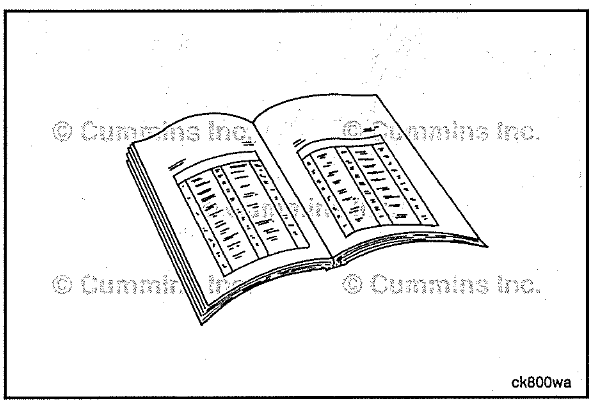


Measure the connecting rod side clearance.

Connecting Rod Side Clearance		
mm		in
0.10	MIN	0.004
0.35	MAX	0.014

The connecting rod **must** move freely from side to side on the crankshaft journal. If the rod does **not** move freely, remove the rod cap and make sure the bearing shells are the correct size. Check for dirt or damage on the crankshaft and the bearing shells.

Repeat the above steps to install the remaining bearing shells and connecting rod caps.



Finishing Steps

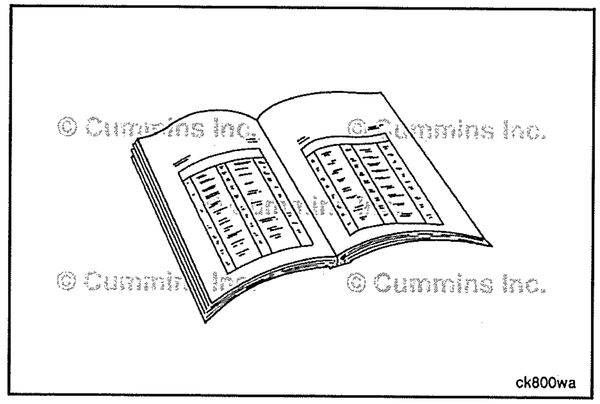
⚠CAUTION⚠

The lubricating oil system must be primed before operating the engine after any internal engine repairs to reduce the possibility of internal component damage.

- Install the piston cooling nozzles. Refer to Procedure 001-046 in Section 1.
- Install the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Prime the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Operate the engine to normal operating temperature and check for leaks.

Bearings, Main (001-006)

Preparatory Steps



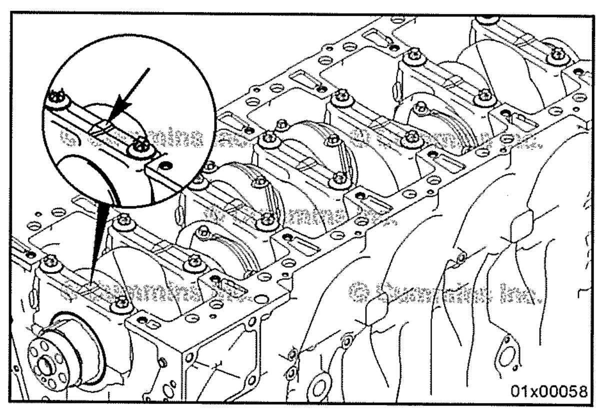
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠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.

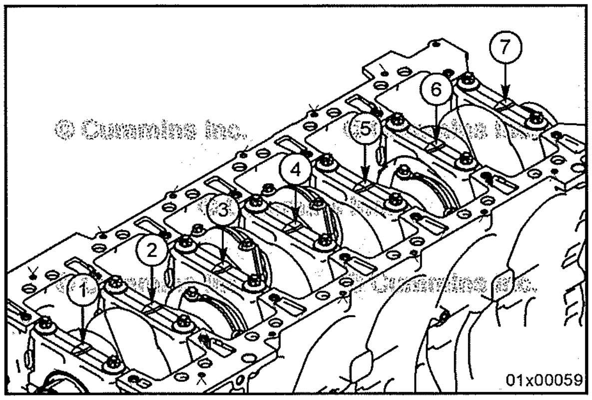
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil dipstick. Refer to Procedure 007-009 in Section 7.
- Remove the lubricating oil dipstick tube. Refer to Procedure 007-011 in Section 7.
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Check crankshaft end play.

Remove

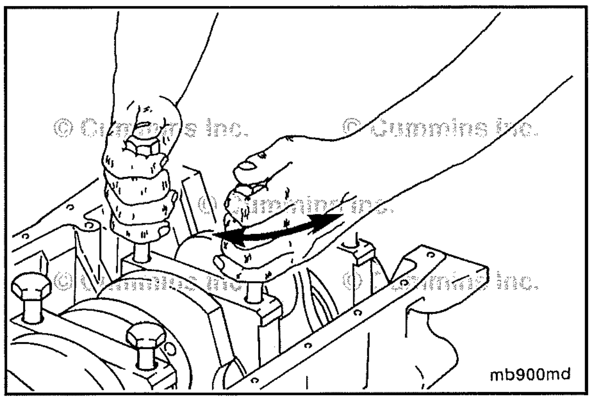


Before removing the main bearing caps, make certain the caps are clearly marked for their location on the main bearing cap and the cylinder block. The caps have an arrow on them that point towards the front of the engine.

The Number 1 cap is at the front of the engine.



NOTE: When replacing bearings in chassis: 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.



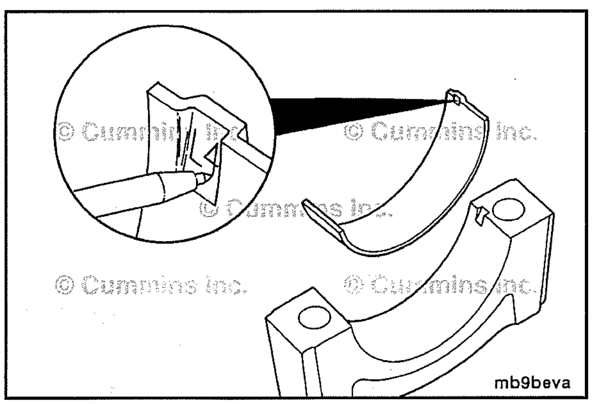
CAUTION

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.

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

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

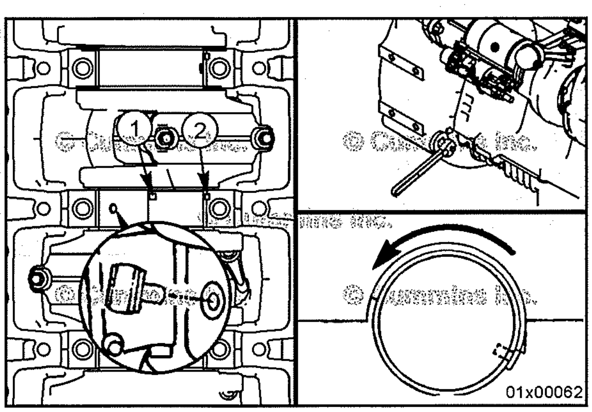
Remove the main bearing cap.



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 7 rear main bearing.

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

Use a barring tool, Part Number 4919092, to 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.

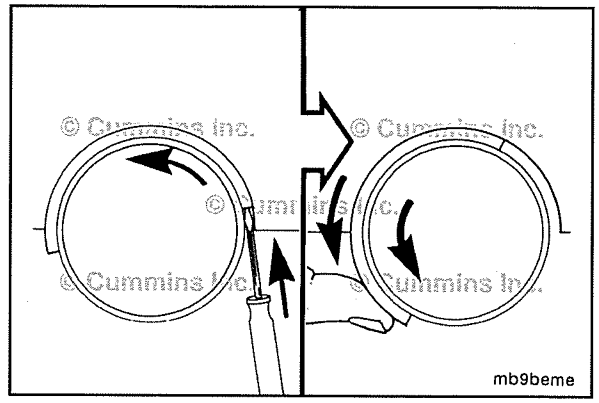
Remove the bearing.

CAUTION

Use care not to damage the crankshaft or cylinder block.

NOTE: The rear main bearing, Number 7, does **not** have a hole in the journal, so the tool can **not** be used to replace the bearing.

Use a blunt tool to 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

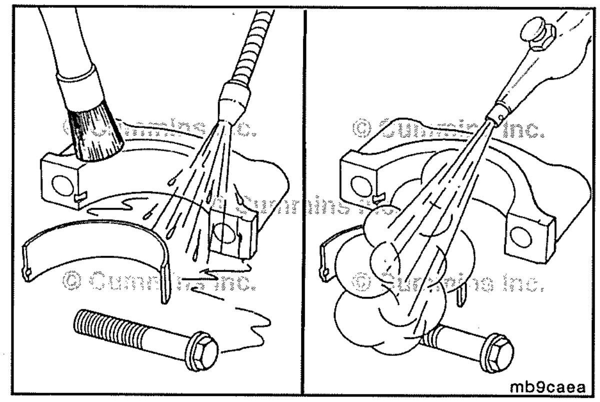
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

WARNING

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

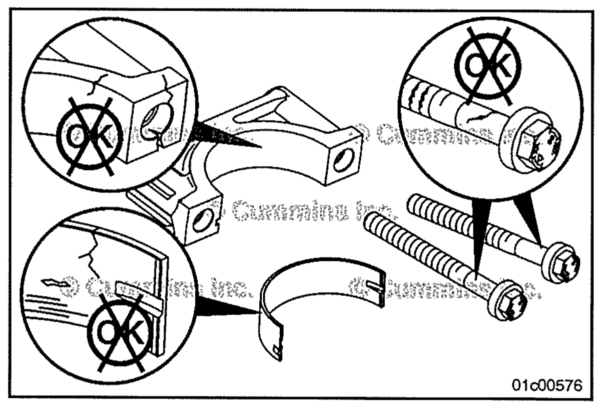
Steam clean or use hot, soapy water to clean the main bearing caps.

Dry with compressed air.

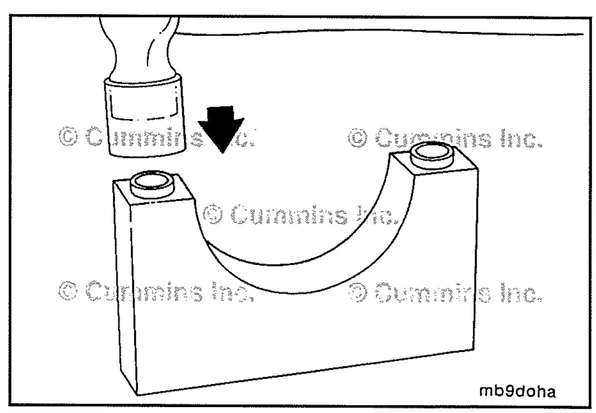


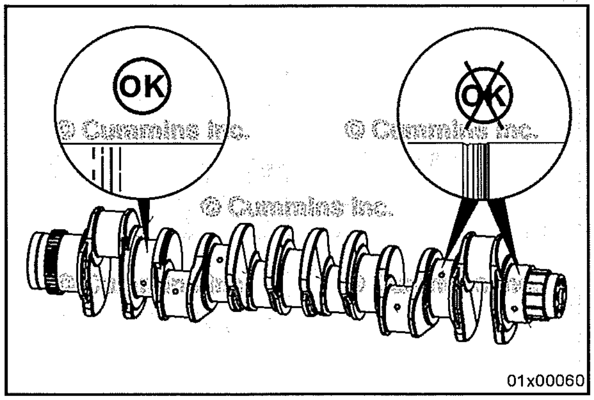
Inspect all main bearing caps, capscrews and thrust bearings for deep scoring, overheating, etc.

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.





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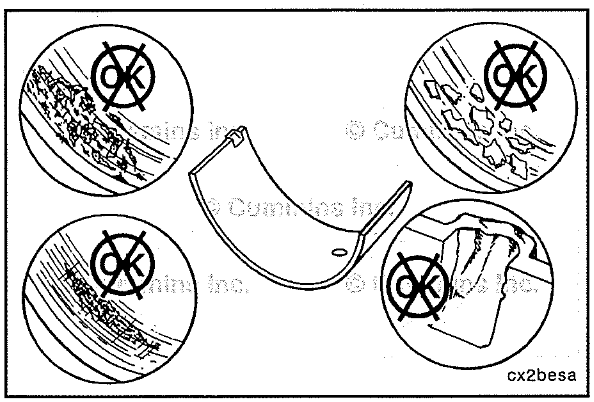
Check the crankshaft main bearing journals for damage or excessive wear. Minor scratches are acceptable.

If crankshaft end play measured during the initial check was found to be out of specification, make sure to check the crankshaft thrust surface for excessive wear or damage. Refer to Procedure 001-016 in Section 1. Minor scratches are acceptable.

Thrust bearing location: the Number 6 main bearing journal.

If damage is found, the crankshaft will need to be removed. Refer to Procedure 001-016 in Section 1.

Also check the thrust bearing surfaces for excessive wear. Replace the thrust bearing if excessive wear is found.



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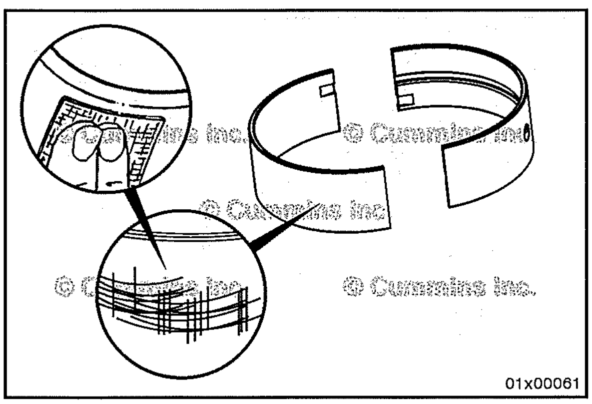
Inspect the bearings for damage.

Replace any bearings with the following damage:

- Pitting
- Flaking
- Corrosion
- Lock tang damage
- Scratches.

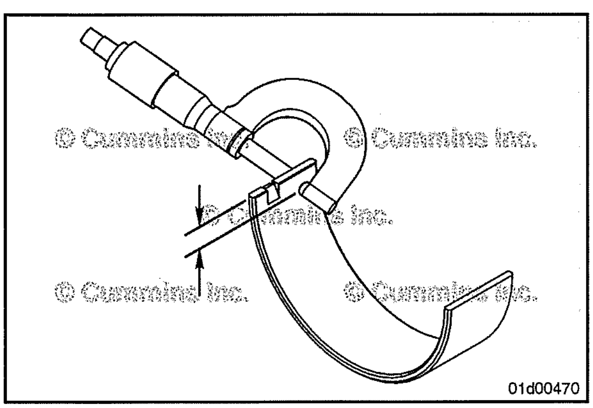


01x00061

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: Refer to the Analysis and Prevention of Bearing Failures, Bulletin 3810387, for more detailed information on bearing damage.



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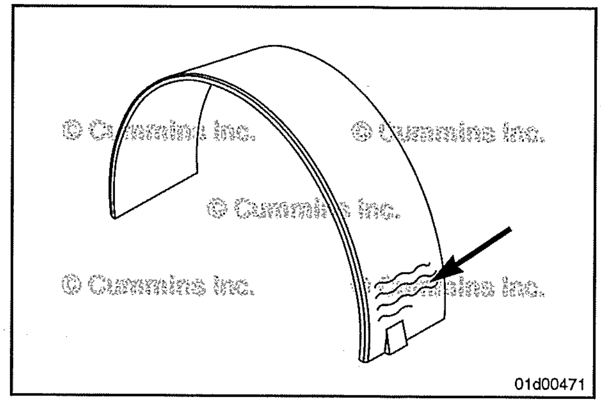
Measure

Measure the main bearing shell thickness with an outside micrometer that has a ball tip. This measurement should be taken at least 5 mm [0.2 in] from the face of the bearing, **not** at the very edge.

Main Bearing Dimensions Standard		
mm		in
2.950	MIN	0.116
2.966	MAX	0.117

If the bearing shell is **not** within specifications, it **must** be replaced.

NOTE: Main bearings are identified with a part number stamped on the back side. They are also identified as lower or upper.



Install

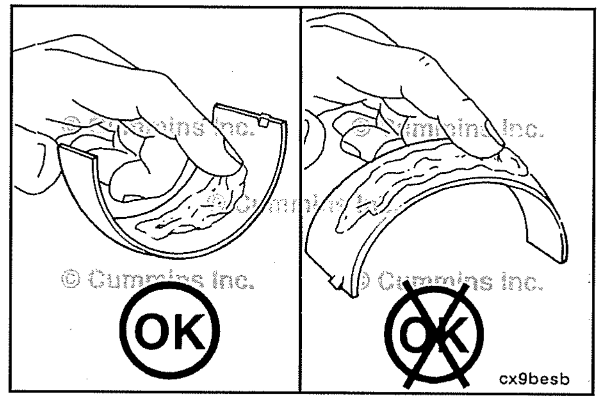
CAUTION

Do not lubricate the side that is against the cylinder block.

Upper 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.

Apply assembly lubricant, Part Number 3163087, to the upper main bearings.



Upper Main Bearing

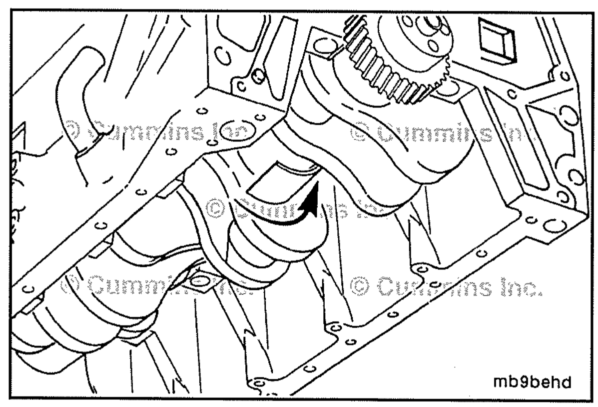
NOTE: The crankshaft thrust bearing **must** be installed in the Number 6 main bearing position.

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, do **not** push the crankshaft to the front or rear of the cylinder block as this can damage the piston cooling nozzles.



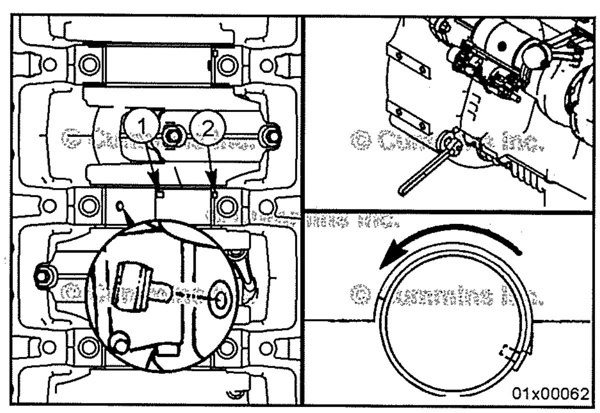
CAUTION

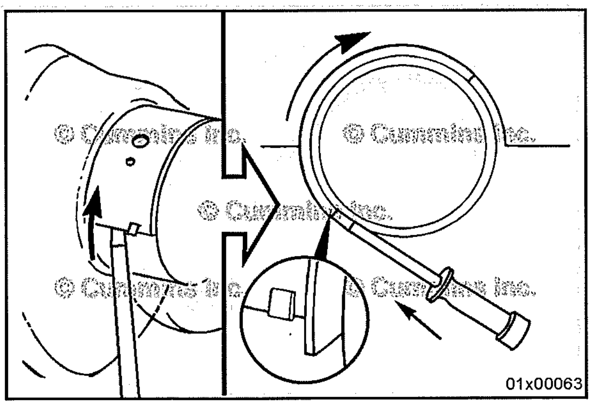
Make sure the pin does not slide under the bearing.

Follow this step to finish installing the upper main bearings, except for Number 7 rear main bearing.

Use the main bearing replacer, Part Number 3823818, to finish installing the main bearing. Rotate the crankshaft with the barring tool, Part Number 4919092.

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 not to damage the crankshaft or cylinder block.

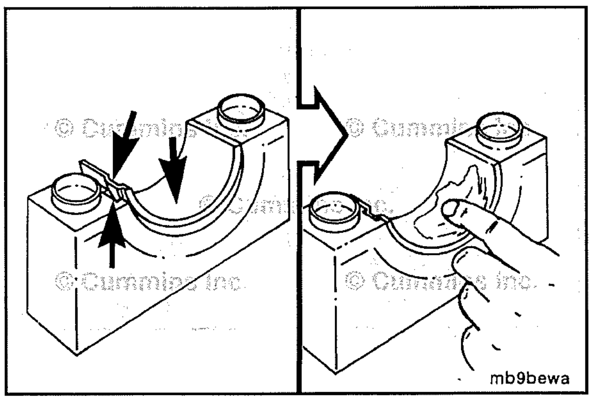
NOTE: The rear main, Number 7, does **not** have a hole in the journal so the pin can **not** be used to replace the bearing.

Install the Number 7 main bearing.

Insert the side of the main bearing opposite the tang first and install as far as possible by hand.

Use a blunt tool to gently 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.



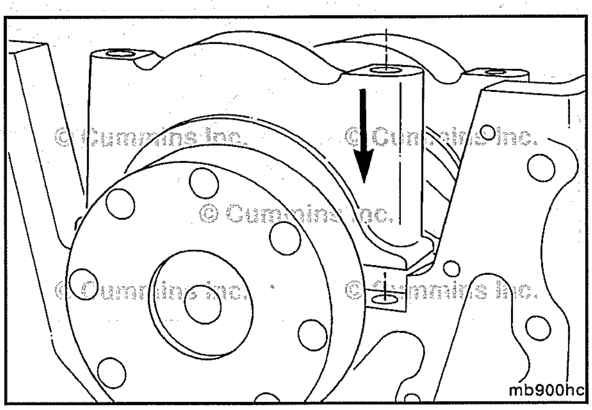
⚠CAUTION⚠
Do not lubricate the back side of the bearing that contacts the main bearing cap.

Lower Main Bearings

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 the tangs on the main bearing caps.

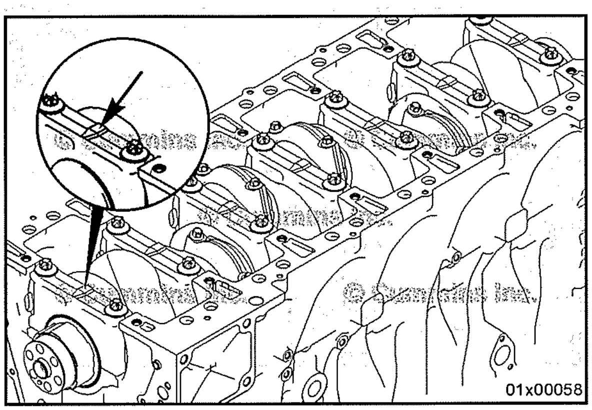
Apply a coat of assembly lube, Part Number 3163087, to the crankshaft side of the main bearings and thrust bearing surfaces.



⚠CAUTION⚠
Make sure the caps are correctly installed in the same position as removed.

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

Install the main bearing cap into position, aligning the main bearing cap dowel rings with the cylinder block.

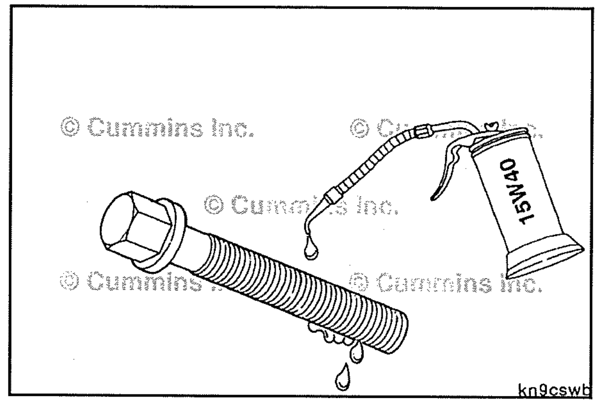


The main bearing caps were numbered before or during the removal process for their location. Number 1 starts with the front of the block.

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: 120 N•m [89 ft-lb]

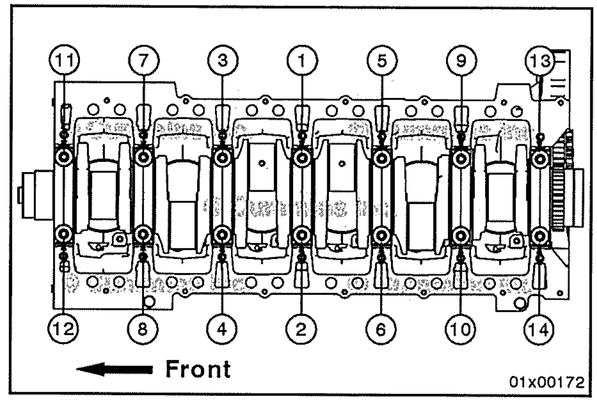
Do **not** tighten to the final torque value at this time. Final torque should be applied after all main bearing caps are installed.

Use the barring tool, Part Number 4919092. 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.

Torque Value:

Step 1	250 N•m	[184 ft-lb]
Step 2	Angle 120 degrees.	



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

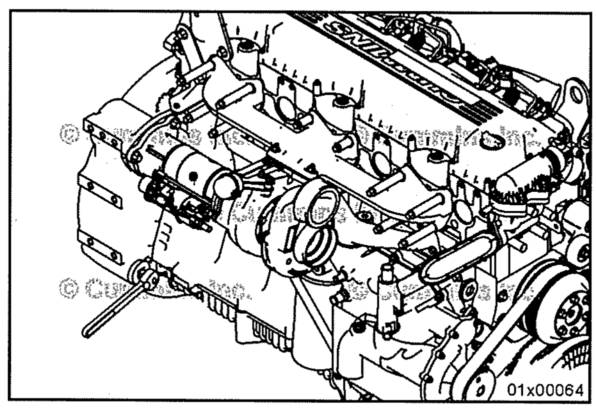
1 Check if the crankshaft is contacting one of the connecting rods.

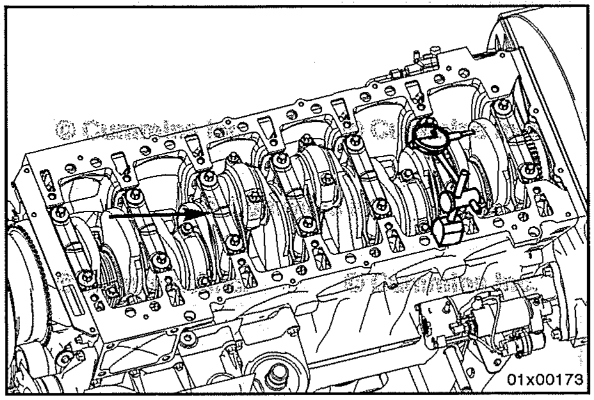
2 Check if the correct main bearing caps were installed correctly.

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.

Use the following procedure for the crankshaft end play. Refer to Procedure 001-016 in Section 1.



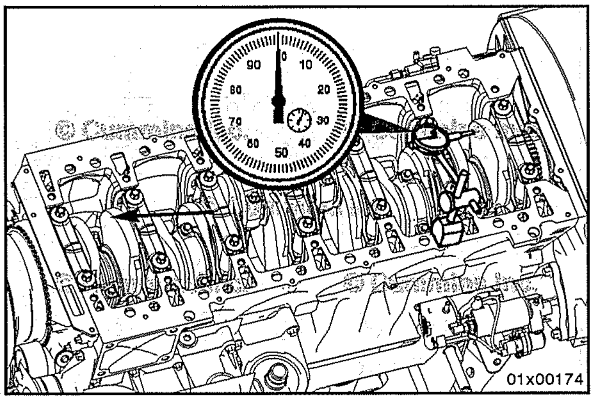


Measure

To measure the end clearance of the crankshaft, install a dial indicator onto the oil pan flange.

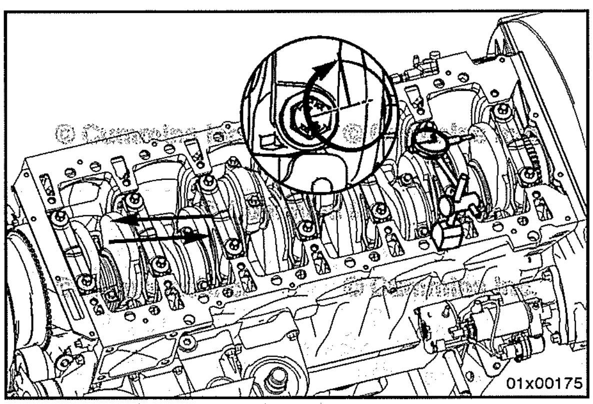
Place the tip of the gauge against the crankshaft counterweight.

Push the crankshaft toward the rear of the cylinder block.



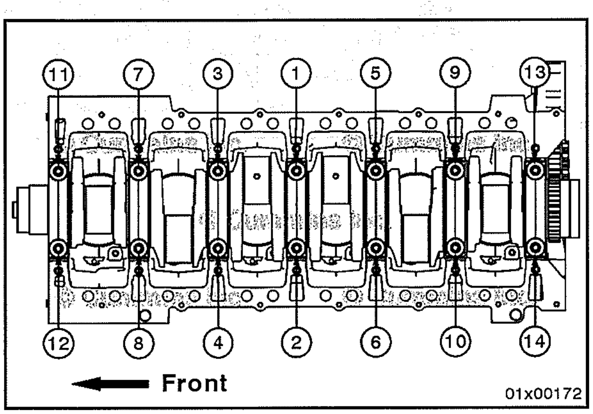
Set the dial indicator at "0" (zero).

Push the crankshaft toward the front of the cylinder block.



If the end clearance is less than 0.175 mm [0.007 in], loosen all main bearing capscrews one turn.

Push the crankshaft toward the front and then toward the rear of the cylinder block.



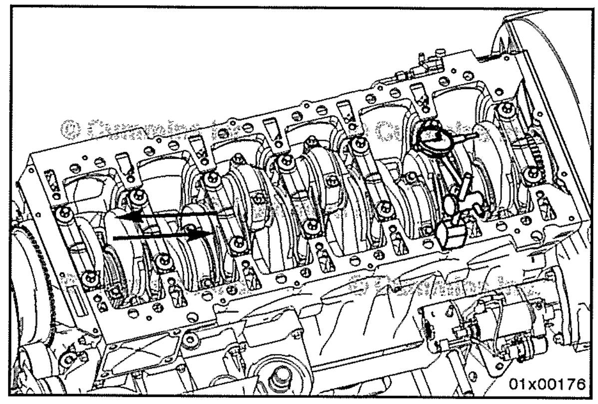
Tighten the main bearing capscrews in sequence.

Torque Value:

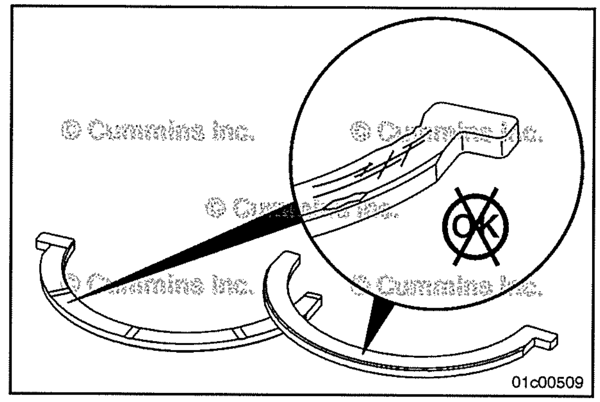
Step 1	120 N•m	[89 ft-lb]
Step 2	250 N•m	[184 ft-lb]
Step 3	Rotate 120 degrees.	

Measure the crankshaft end clearance.

Crankshaft End Clearance - New or Reground		
mm		**in**
0.175	MIN	0.007
0.425	MAX	0.017



If the crankshaft end play is excessive, remove the thrust bearings and inspect the thrust bearing. Worn bearings can cause excess end play. Refer to Procedure 001-007 in Section 1.

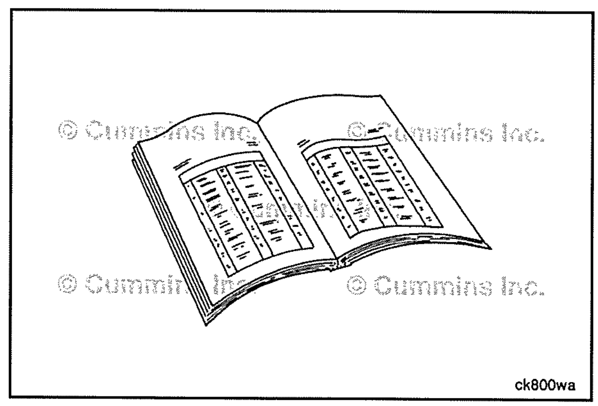


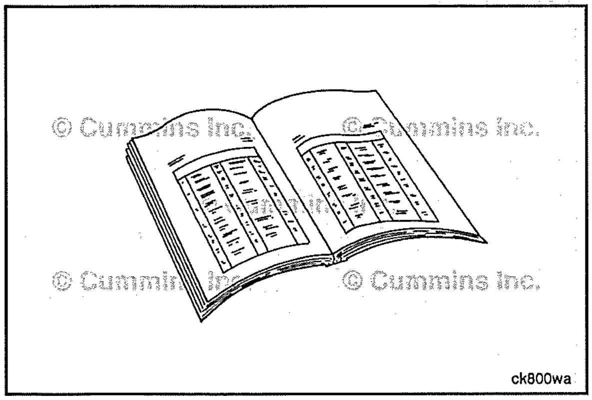
Finishing Steps

WARNING

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

- Install the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Install the lubricating oil dipstick tube. Refer to Procedure 007-011 in Section 7.
- Install the lubricating oil dipstick. Refer to Procedure 007-009 in Section 7.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine at idle for 5 to 10 minutes. Check for loose parts, leaks and proper oil pressure.





Bearings, Thrust (001-007)

Preparatory Steps

WARNING

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

WARNING

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

WARNING

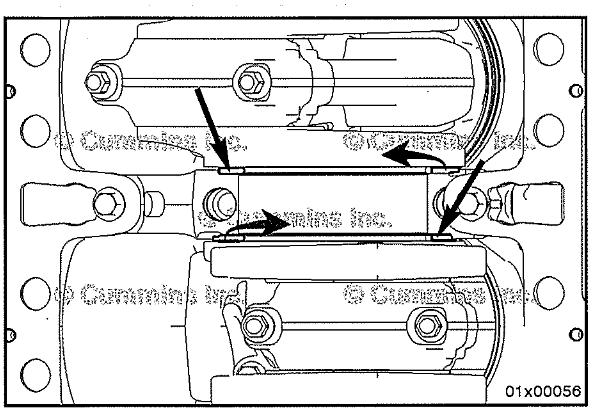
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

CAUTION

If the crankshaft is removed from the engine do not install the thrust bearings before the crankshaft is laid into the block.

Cummins Inc. recommends replacing the thrust bearings when the main bearings are replaced.

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Remove the Number 6 main bearing cap. Refer to Procedure 001-006 in Section 1.



Remove

CAUTION

To reduce the possibility of damage to the crankshaft, use care when removing the upper thrust bearings.

Use a blunt tool to remove the upper thrust bearings.

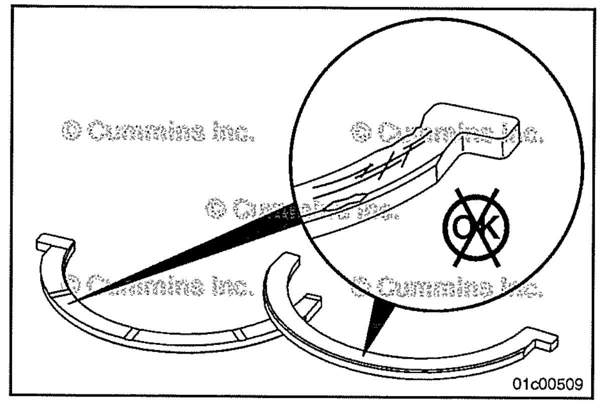
Mark these bearings as being upper and front or rear bearings.

Inspect for Reuse

Inspect the thrust bearings for scratches, galling, uneven wear, or other damage.

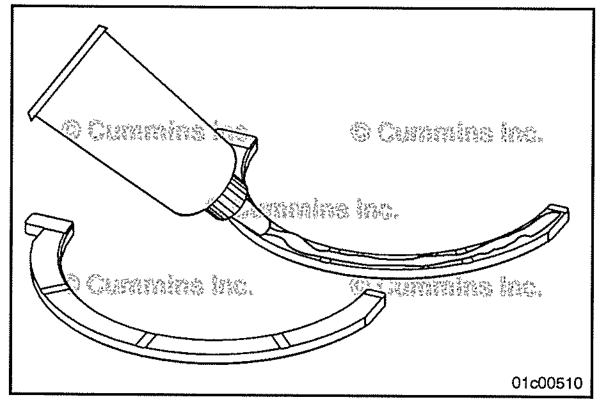
Replace the thrust bearings if damage is found.

If damage is found on any of the thrust bearings, be sure to inspect the crankshaft, block, and main bearing cap for damage.



Install

Use Lubriplate™ 105, Part Number 3163087, or equivalent, to coat the upper thrust bearings.

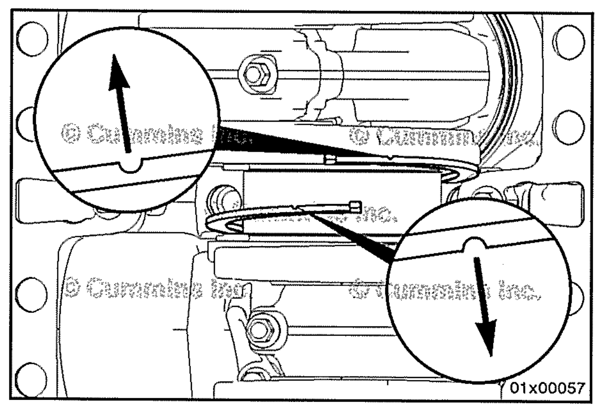


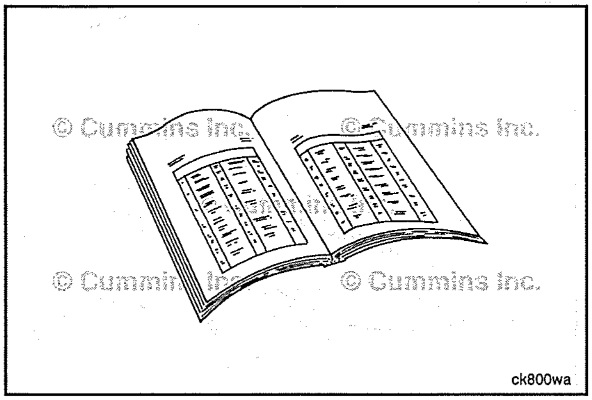
CAUTION

Do not push the crankshaft toward the front or rear of the engine to install the rear thrust bearing. This may damage the piston cooling nozzles.

Install the upper thrust bearings in the number six main bearing saddle.

The grooved side of the thrust bearing **must** be toward the crankshaft.





Finishing Steps

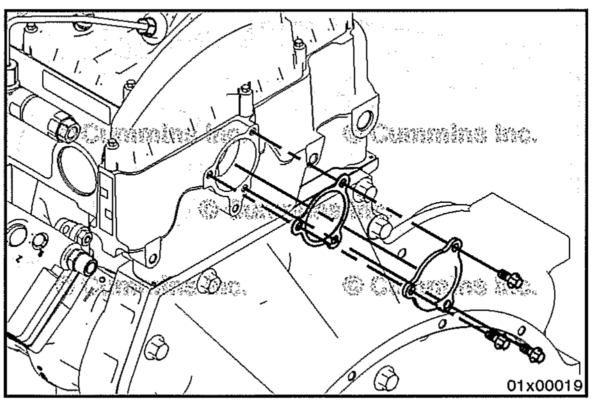
⚠WARNING⚠

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

⚠CAUTION⚠

The engine must have adequate oil pressure within 15 seconds after starting. If the warning light indicating low oil pressure has not gone out or there is no oil pressure indicated on a gauge within 15 seconds, shut off the engine immediately to reduce the possibility of engine damage. Confirm that the correct oil level is in the oil pan.

- Install the main bearing cap. Refer to Procedure 001-006 in Section 1.
- Install the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Fill the engine with lubricating oil. Refer to Procedure 007-025 in Section 7.
- Fill the engine with clean lubricating oil. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to normal operating temperature and check for leaks.



Camshaft Cover Plate (001-011)

Remove

Remove the rear camshaft cover plate mounting capscrews.

Remove the camshaft cover plate 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

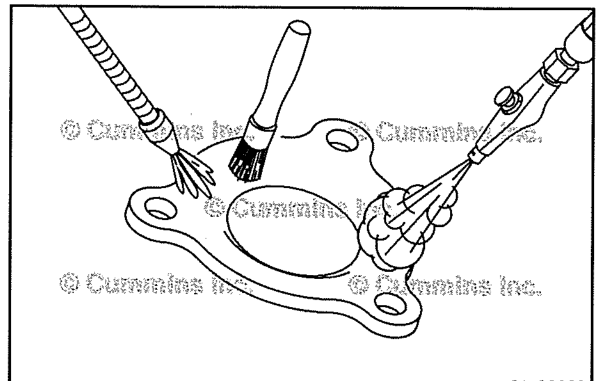
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

WARNING

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

Use steam or solvent to clean the camshaft cover plate.

Dry with compressed air.



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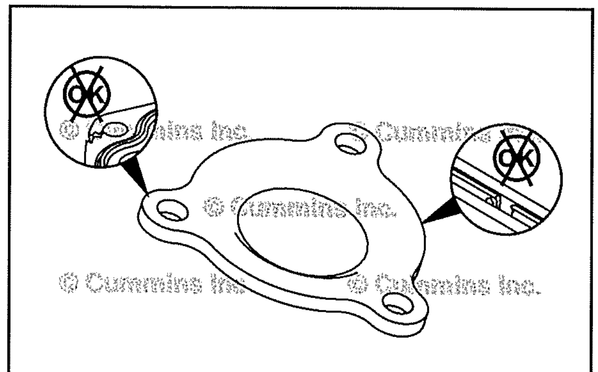
Inspect the camshaft cover plate for cracks, dents, or other damage.

Replace the camshaft cover plate if the sealing surface is damaged or bent, creating a leak path.



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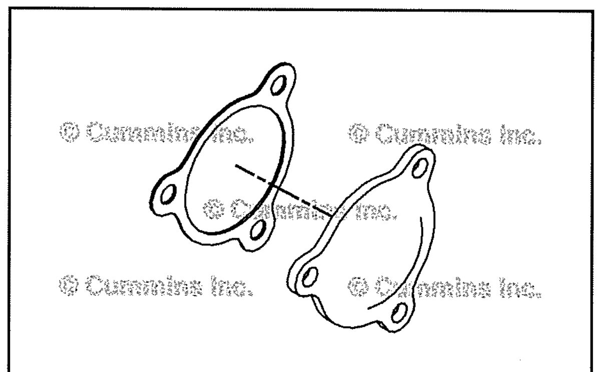
Install

Install a new gasket for the camshaft cover plate.



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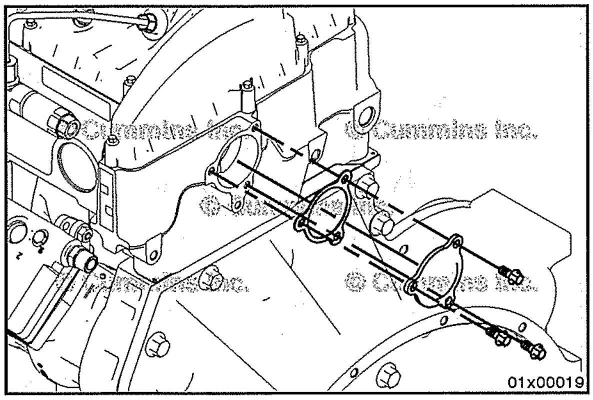


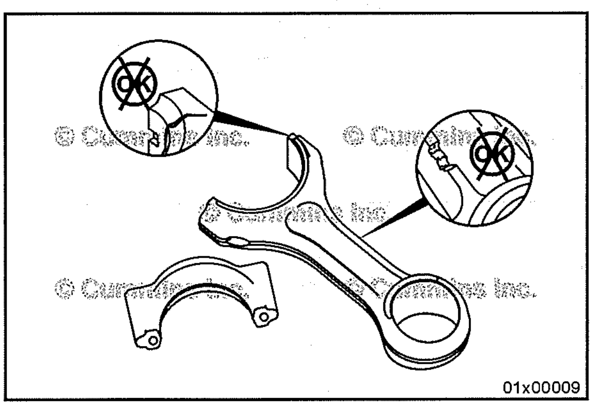
Install the rear camshaft cover plate and mounting capscrews.

Torque Value: 23 N•m [204 in-lb]

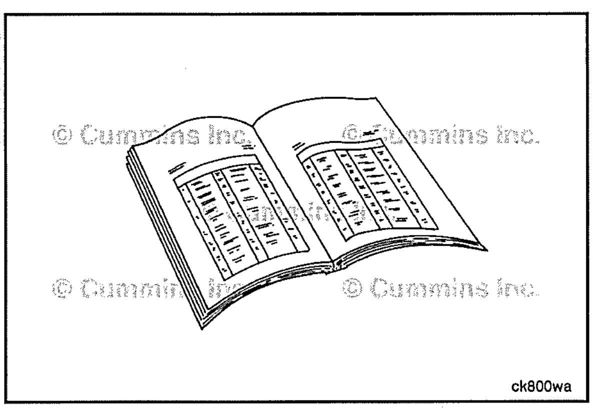
Connecting Rod (001-014)

General Information

The connecting rod uses a fracture split connection between the rod cap and the rod. Connecting rods with a fracture split surface **must** be treated with caution. The two pieces of the connecting rod can **not** be rubbed together. This will damage the mating surfaces. Use care to **not** drop either piece of the connecting rod. Fracture split connecting rods **must only** be handled if the two pieces of the connecting rod are tightened to the correct specification, or completely separated.



⚠CAUTION⚠
To prevent damage to the fracture split connecting rod, do not set the connecting rod or rod cap on the fracture split connection. This can cause polishing and damage to the mating surface.

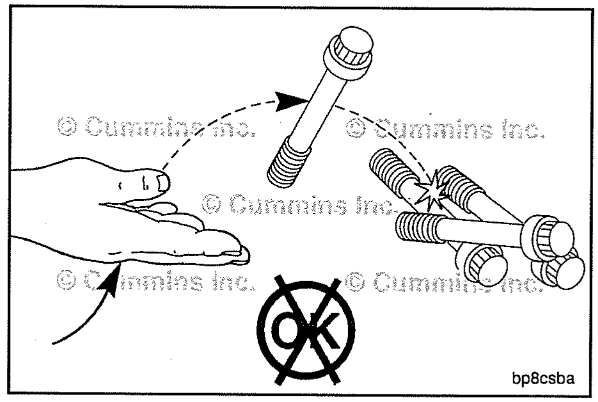


Preparatory Steps

NOTE: The piston and connecting rod **must** be removed as an assembly.

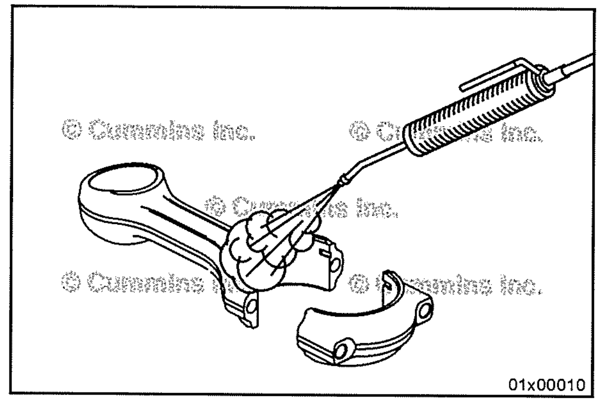
- Remove and disassemble the piston and connecting rod assembly. Refer to Procedure 001-054 in Section 1.

Clean and Inspect for Reuse



⚠CAUTION⚠

Prevent damage to the capscrews. Nicks in the body of the capscrew can cause an area of stress that can fail during engine operation. Damage to the threads will cause torque values to be incorrect and will damage the mating parts.



⚠WARNING⚠

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

⚠WARNING⚠

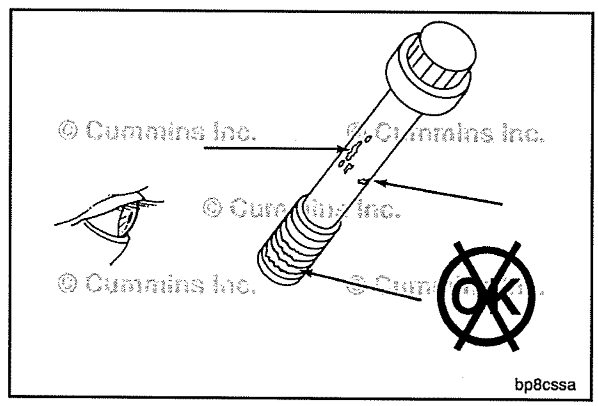
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠

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

Use solvent or steam to clean the capscrews, connecting rod, and connecting rod cap.

Dry with compressed air.



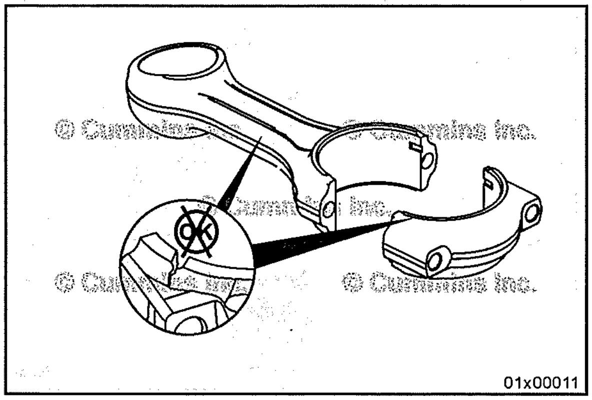
⚠CAUTION⚠

Repair of rolled threads by use of a thread die is not recommended. The die can create a sharp corner on the minor diameter (root) of the threads. This sharp corner can cause an area of increased stress.

Inspect the capscrews for the following:

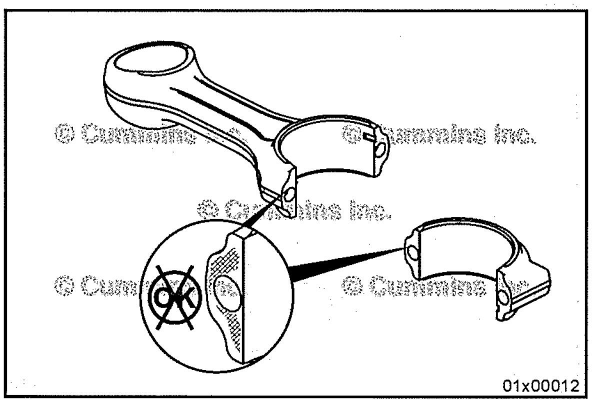
- Damaged threads
- Rust or corrosion-caused pitting
- Nicked, bent, stretched, or galled.

The capscrew **must** be replaced if it has any of the listed damage.



Inspect the connecting rod and connecting rod cap for damage.

Replace the connecting rod if the I-beam or connecting rod cap is damaged.



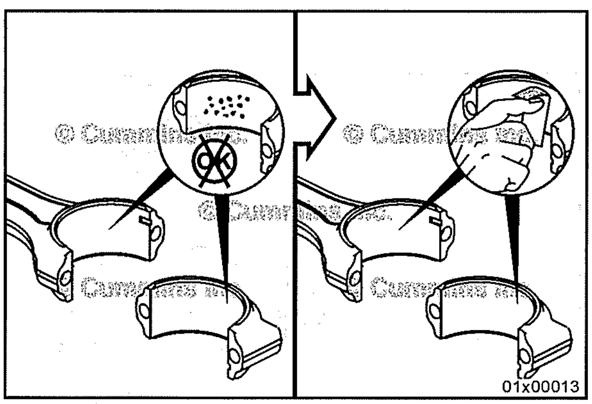
Inspect the connecting rod and connecting rod cap for fretting damage on the mating surfaces.

Polished spots on either the connecting rod or connecting rod cap mating surfaces indicate fretting and the rod **must** be replaced.

Dark areas on the face indicate carbonized oil deposits. Connecting rods with dark areas are reusable if there is no fretting present.

The connecting rod and connecting rod cap **must** be replaced as an assembly if fretting damage is visible on either piece.

Polishing may be observed on the thrust face of the connecting rod or rod cap which is normal. Use the following procedure for inspection criteria. Refer to Procedure 001-007 in Section 1.



Check the bearing surface for nicks or burrs.

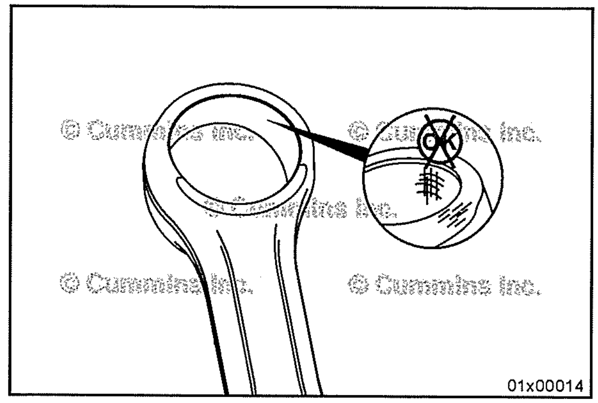
If it is **not** possible to remove any nicks or burrs with a fine emery cloth, the connecting rod **must** be replaced.

Inspect the rod pin bushing for damage.

Replace any piston pin bushing that has evidence of scoring, galling, or scuffing.

Replace any bushing that has turned in the bore.

Special tools and precision machining are required to replace bushings. If Cummins Inc. approved tools and procedures are **not** available, the connecting rod **must** be replaced.



⚠CAUTION⚠

The connecting rod and connecting rod cap have a machined face on one side of the connecting rod. The connecting rod must be installed with the machined surfaces aligned to reduce the possibility of damage to the connecting rods and crankshaft.

⚠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.

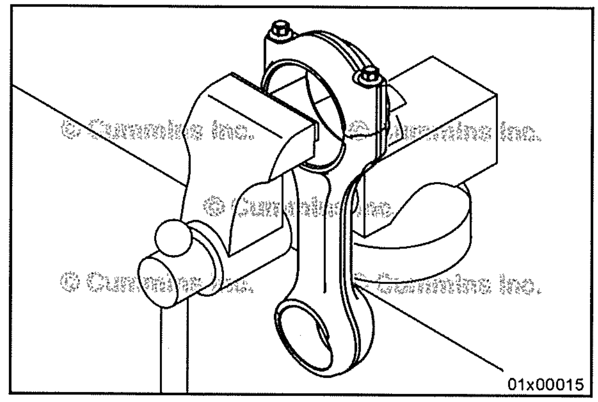
Place the connecting rod into a vise with brass jaws. Support the connecting rod at the large bearing end to avoid I-beam damage.

Install the connecting rod cap onto the connecting rod.

Lubricate the threads of the capscrews with clean engine oil.

Thread the capscrews into the connecting rod and hand tighten.

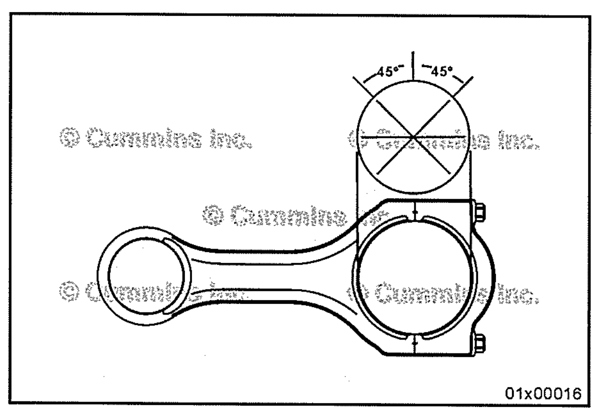
Tighten the capscrews.



Torque Value:

Step 1	85 N•m	[63 ft-lb]
Step 2	Check torque 85 N•m [63 ft-lb]	
Step 3	Rotate capscrews in numerical sequence 60 degrees.	

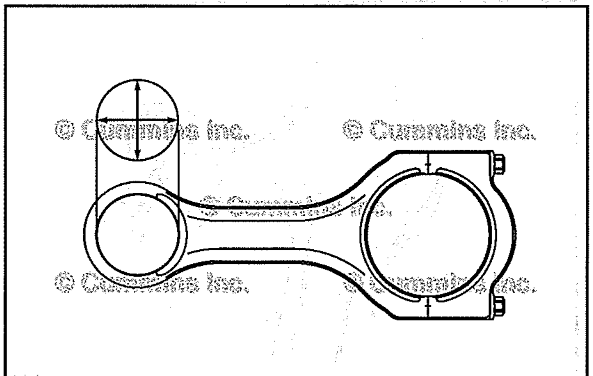
Measure the connecting rod crankshaft bore inside diameter with a bore dial guage, Part Number 3376619.



Connecting Rod Crankshaft Bore Inside Diameter

mm		in
94.980	MIN	3.739
95.006	MAX	3.740

If the connecting rod crankshaft bore inside diameter is **not** within specifications, the connecting rod **must** be replaced.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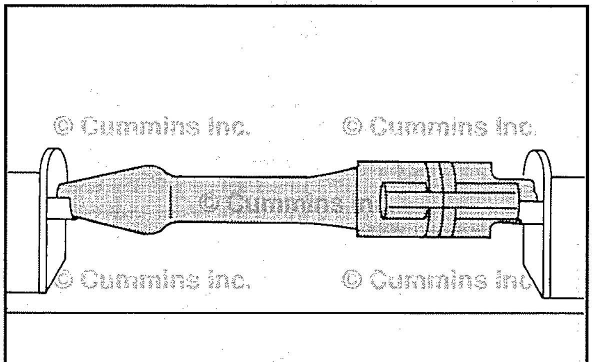
Measure the connecting rod piston pin bushing inside diameter with a bore dial gauge, Part Number 3376619.

Connecting Rod Piston Pin Bushing Inside Diameter		
mm		in
58.047	MIN	2.285
58.023	MAX	2.284

If the connecting rod piston pin bushing inside diameter is **not** within specifications, the connecting rod **must** be replaced.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Magnetic Crack Inspect

This procedure describes the magnetic particle inspection for the connecting rod and connecting rod cap.

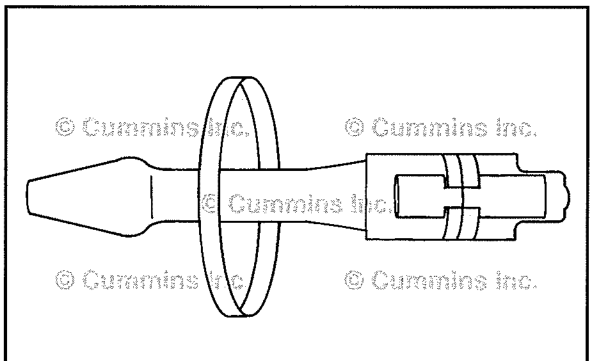
Use a magnetic particle testing machine.

The connecting rod and connecting rod cap **must** be assembled during this process.

Use the residual method. Apply head shot amperage. Adjust the amperage to 1500 ampere direct current or rectified alternating current.

Check for cracks.

The connecting rod **must** be replaced if any cracks are visible.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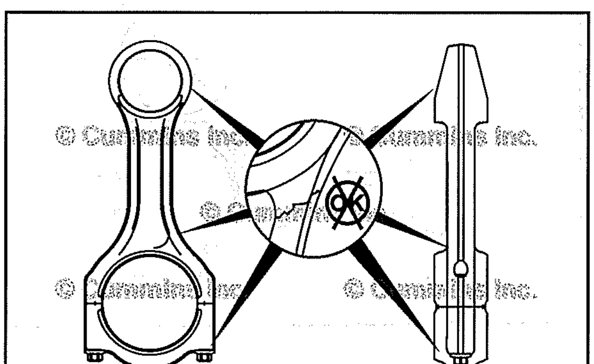
Use the residual method. Apply coil shot amperage.

Amperage (Ampere Turns)	
Minimum	Maximum
2600 amps direct current	2800 amps direct current

Ampere turn is an electrical current of one ampere flowing through the coil, multiplied by the number of turns in the coil.



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Check for cracks.

The connecting rod **must** be replaced if any indications of cracks are visible in the critical (shaded) areas.

⚠WARNING⚠

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

⚠WARNING⚠

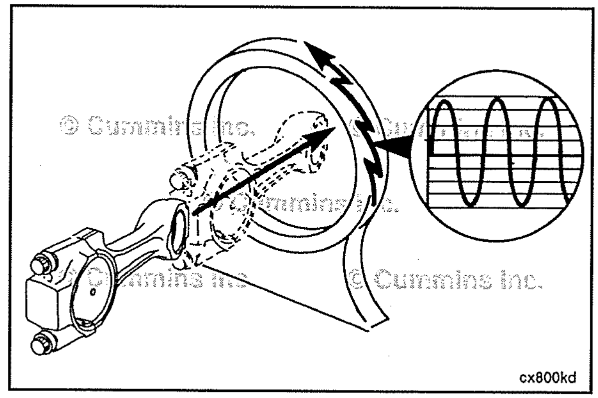
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠CAUTION⚠

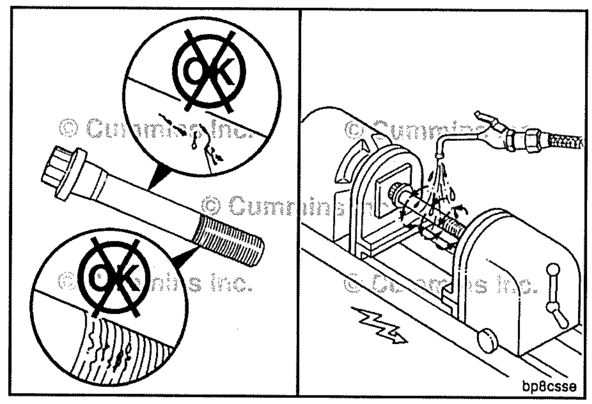
The connecting rod must be demagnetized completely and cleaned thoroughly. Any small metal particles will cause engine damage.

Demagnetize the connecting rod.

Use solvent or steam to clean the connecting rod.

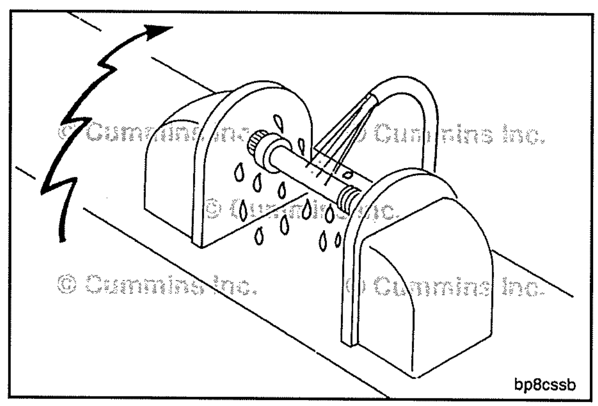


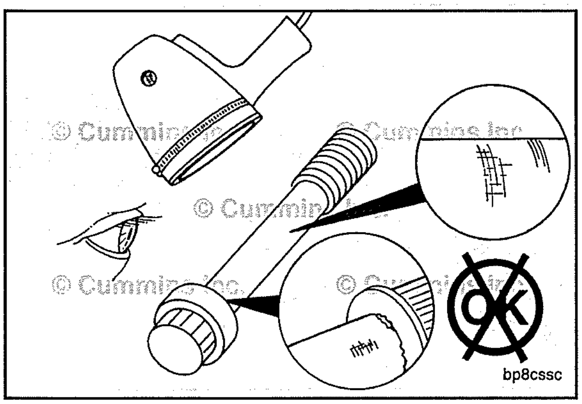
This procedure describes the magnetic particle inspection for the connecting rod capscrew.



Use a Magnaflux™ or similar magnetic particle testing machine.

Use the continuous method. Apply a head shot of 300 to 400 amperes direct current or rectified alternating current.

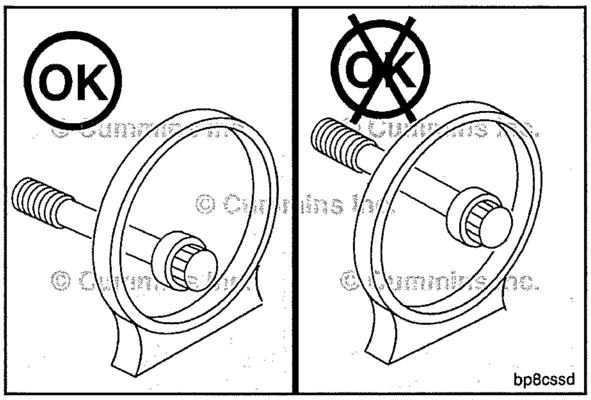




Use an ultraviolet light. Check for indications of cracks.

The magnetic particles tend to form on sharp corners and edges. Do **not** mistake these for cracks.

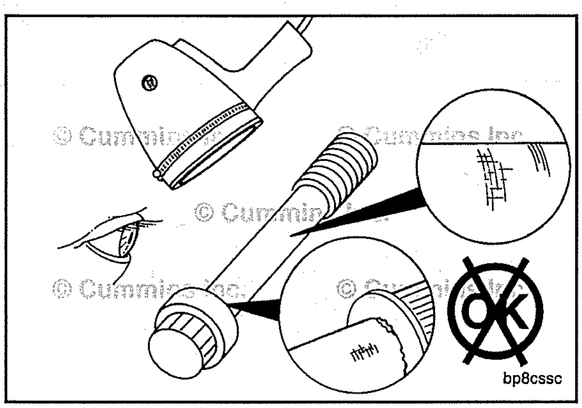
Any indications of cracks are **not** acceptable.



Prepare the machine for a coil shot.

Make sure the capscrew is near one side of the coil and **not** in the center.

Apply 1000 to 1350 ampere-turns.



Use an ultraviolet light. Check for indications of cracks.

Any indications of cracks are **not** acceptable.

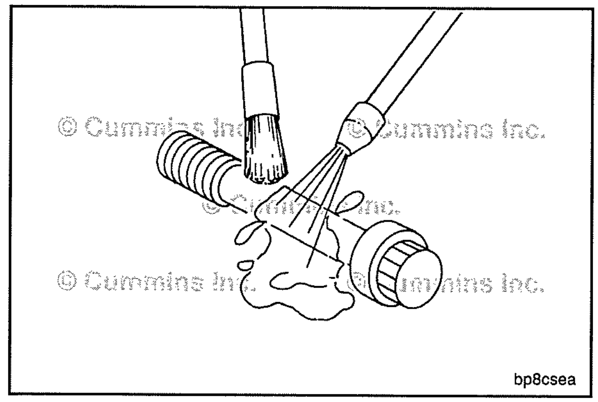
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

⚠CAUTION⚠
The connecting rod must be demagnetized completely and cleaned thoroughly. Any small metal particles will cause engine damage.

Demagnetize the capscrew thoroughly.

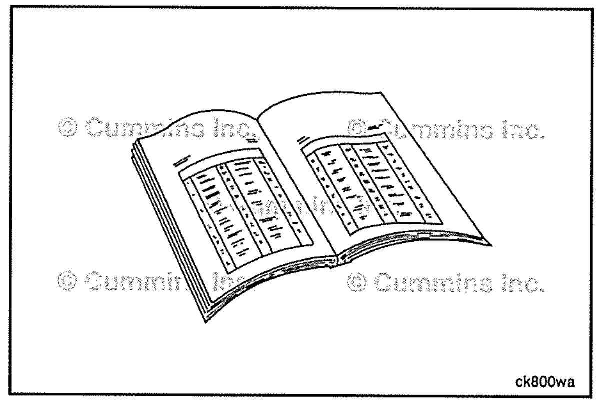
Use solvent to clean the capscrew and dry with compressed air.



Finishing Steps

NOTE: The piston and connecting rod **must** be installed as an assembly.

- Assemble and install the piston and connecting rod. Refer to Procedure 001-054 in Section 1.
- Operate the engine to normal operating temperature and check for leaks.



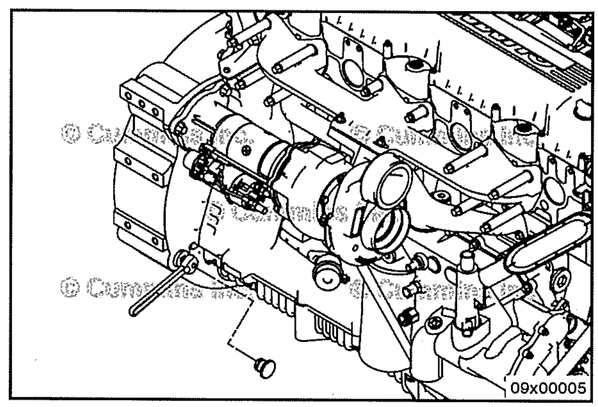
Crankshaft (001-016)

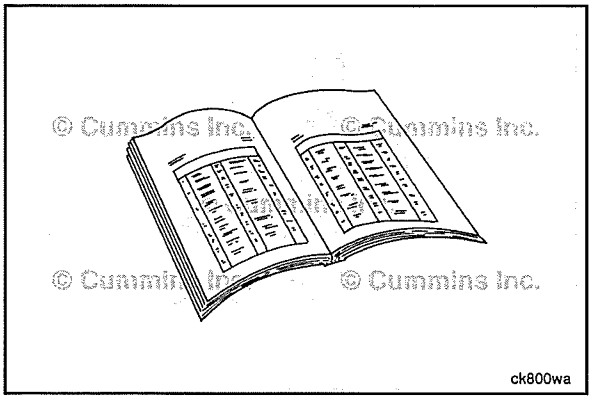
Rotation Check

Use **only** a barring device on the rear of the flywheel housing to rotate the crankshaft.

Rotate the crankshaft **clockwise** through two complete revolutions. Refer to Procedure 000-017 in Section 0.

If the engine does **not** turn freely, the equipment can have a malfunction or was assembled incorrectly. See equipment manufacturer service information.





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Preparatory Steps

⚠WARNING⚠

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

⚠WARNING⚠

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

⚠WARNING⚠

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

⚠WARNING⚠

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

⚠WARNING⚠

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

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the engine and install on a rollover stand. Refer to Procedure 000-001 in Section 0.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.
- Remove the flywheel. Refer to Procedure 016-005 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil pump. Refer to Procedure 007-031 in Section 7.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Remove the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.
- Remove the main bearing caps. Refer to Procedure 001-006 in Section 1.
- Remove the thrust bearing. Refer to Procedure 001-007 in Section 1.

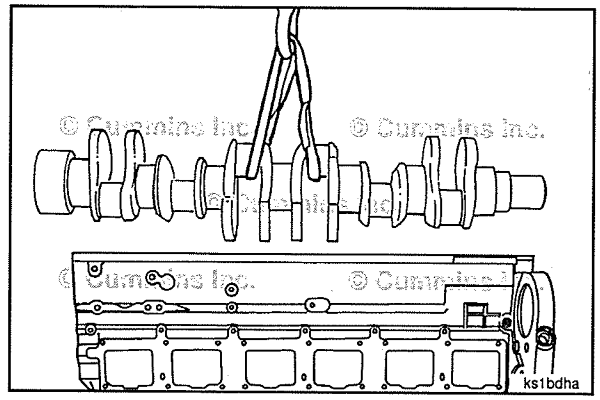
Remove

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

NOTE: Lift the crankshaft straight up to avoid damage to the crankshaft and cylinder block.

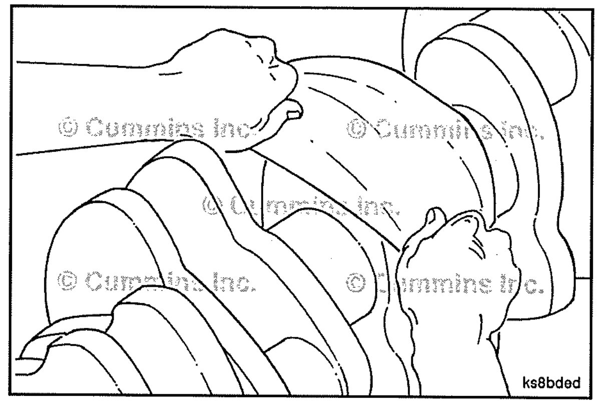
Attach a lift sling, Part Number 2892501 , around the number 3 and number 4 rod bearing journals.

Attach the sling to a hoist and remove the crankshaft.



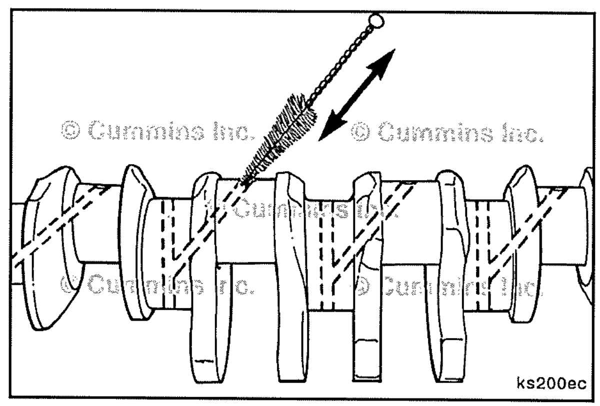
Clean and Inspect for Reuse

Use crocus cloth to remove discoloration or light scratches from the machined surfaces of the crankshaft.



⚠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 a bristle brush and solvent to clean all of the crankshaft oil drillings.

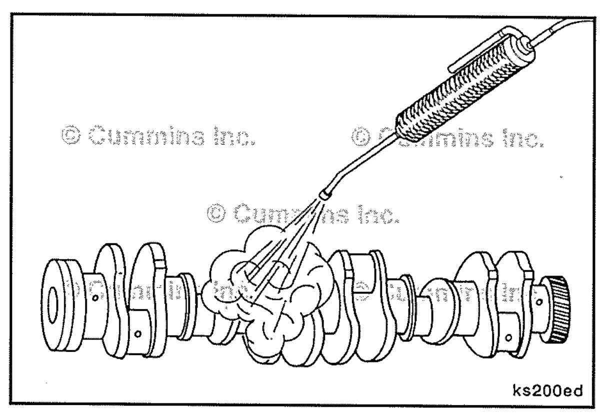


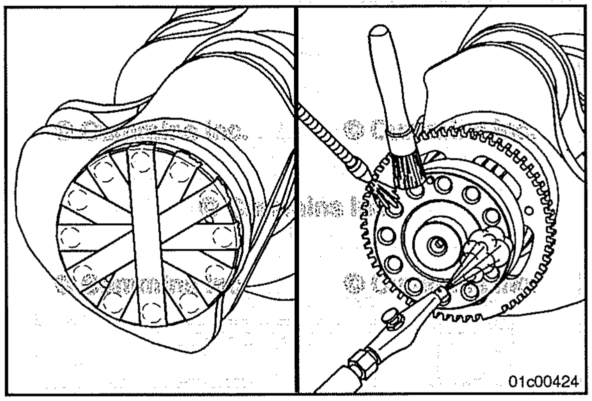
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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

Clean the crankshaft with solvent.

Dry with compressed air.





CAUTION

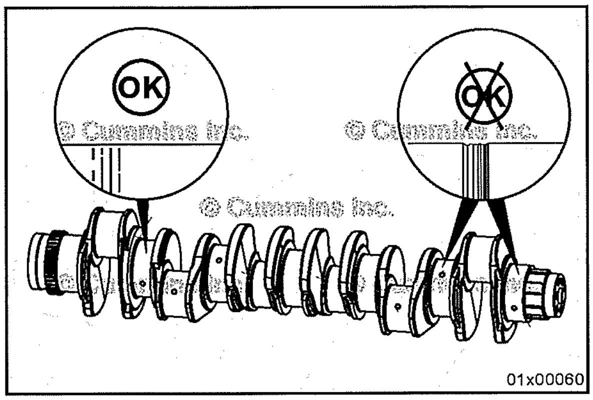
Do not use a thread chaser to clean the capscrew threads in the crankshaft, severe engine damage can result.

This engine uses rolled capscrew threads in the capscrew holes of the crankshaft.

To clean the rolled threads, flush with solvent, and dry with compressed air.

If additional cleaning is required, brush with a nylon bristle brush.

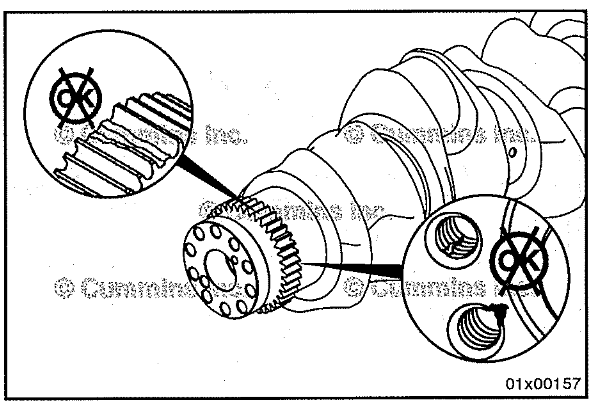
Place tape over the threaded capscrew holes.



Inspect the machined surfaces for scratches or nicks.

Use a crocus cloth to remove any nicks and scratches.

If scratches or nicks can be felt with a fingernail after the crankshaft has been polished with crocus cloth, the crankshaft **must** be replaced.



CAUTION

This engine uses friction enhancing shims between the crank and gear and between the gear and flywheel. These shims should not be re-used in service and must be replaced anytime either of these joints is split. This design is unique in that the rear crank gear is a separate piece bolted on to the last main journal of the crank, rather than being a press fit gear in more conventional designs. It is not desirable to separate the crank and the gear pieces.

Inspect the threaded capscrew holes for damage.

If the threaded capscrew holes are damaged, the crankshaft **must** be replaced.

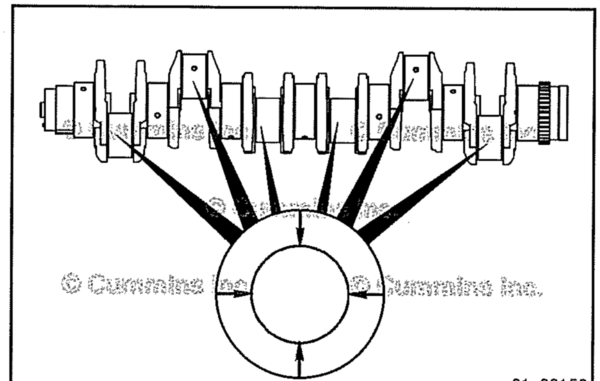
Inspect the crankshaft gear for excessive wear or damage.

If any teeth on the crankshaft gear are missing, chipped, or pitted, the crankshaft gear **must** be replaced.

Measure the crankshaft connecting rod journal outside diameter.

Crankshaft Connecting Rod Journal Outside Diameter		
mm		**in**
89.987	MIN	3.543
90.013	MAX	3.544

If the crankshaft connecting rod journal outside diameter is **not** within specifications, the crankshaft **must** be replaced.

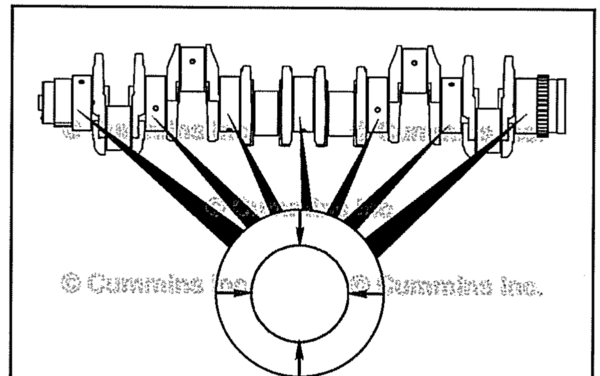


01x00158

Measure the crankshaft main bearing journal outside diameter.

Crankshaft Main Bearing Journal Outside Diameter		
mm		**in**
111.987	MIN	4.409
112.013	MAX	4.410

If the crankshaft main bearing journal outside diameter is **not** within specifications, the crankshaft **must** be replaced.

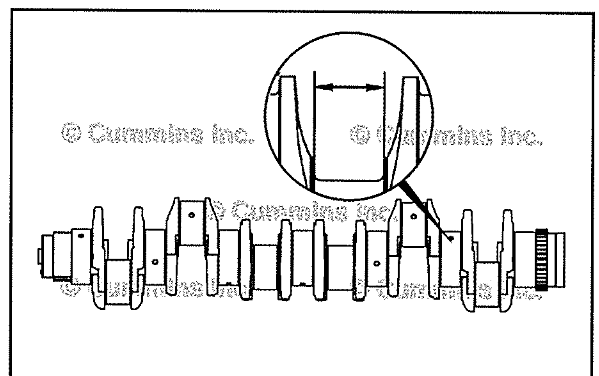


01x00159

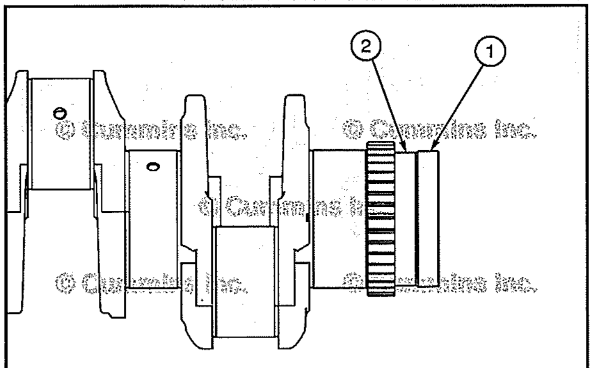
Measure the crankshaft thrust face width.

Crankshaft Thrust Face Width		
mm		**in**
45.975	MIN	1.810
46.050	MAX	1.813

If the crankshaft thrust face width is **not** within specifications, the crankshaft **must** be replaced.



01x00160



01x00161

Measure the crankshaft rear oil seal flange outside diameter.

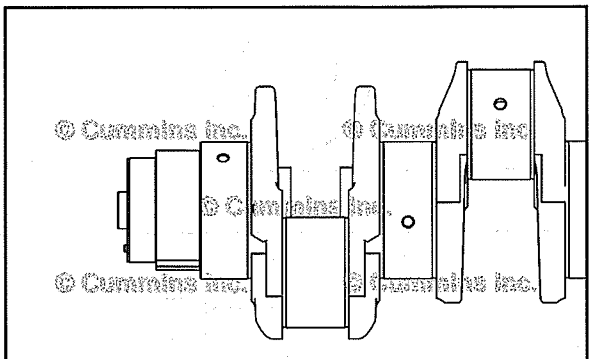
Crankshaft Rear Oil Seal Flange Outside Diameter

	mm		in
Flange Diameter Location (1)	109.920	MIN	4.328
	109.970	MAX	4.330
Flange Diameter Location (2)	107.750	MIN	4.242
	108.250	MAX	4.262

If the crankshaft rear oil seal flange outside diameter is **not** within specifications, the crankshaft **must** be replaced.

Check the crankshaft rear oil seal flange for nicks, burrs, and grooves.

If a fingernail catches in a nick, burr, or groove, the crankshaft **must** be replaced. Damage to the sealing surface can result in a seal leak.



01x00162

Measure the crankshaft front oil seal flange outside diameter.

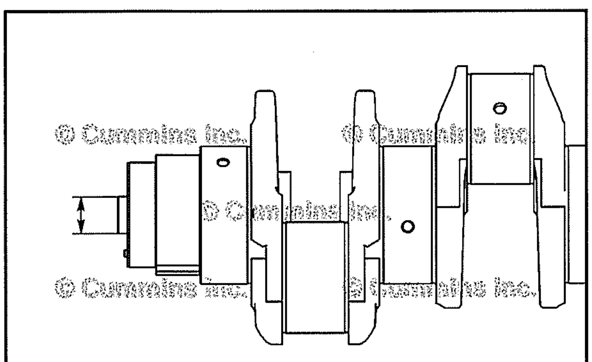
Crankshaft Front Oil Seal Flange Outside Diameter

	mm		in
Flange Diameter Location	84.99	MIN	3.346
	85.01	MAX	3.347

If the crankshaft front oil seal flange outside diameter is **not** within specifications, the crankshaft **must** be replaced.

Check the crankshaft front oil seal flange for nicks, burrs, and grooves.

If a fingernail catches in a nick, burr, or groove, the crankshaft **must** be replaced. Damage to the sealing surface can result in a seal leak.



01x00163

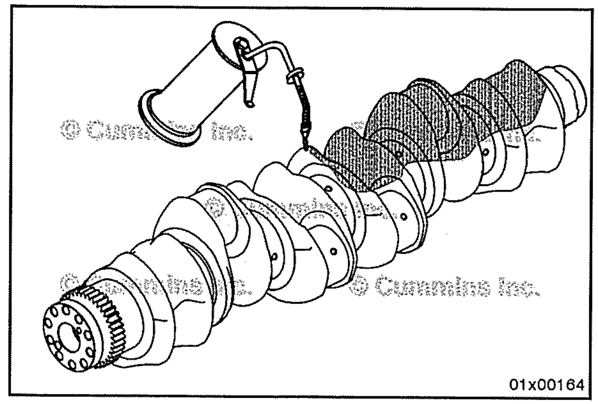
Measure the crankshaft damper pilot outside diameter.

Crankshaft Pilot Outside Diameter

mm		in
29.987	MIN	1.181
30.013	MAX	1.182

If the crankshaft pilot outside diameter is **not** within specifications, the crankshaft **must** be replaced.

Lubricate the entire crankshaft with clean Cummins recommended oil to prevent rust.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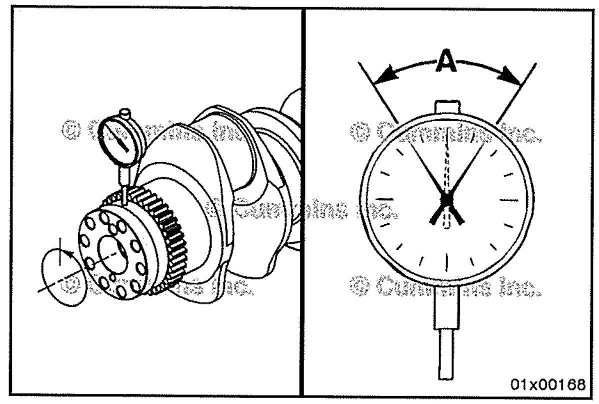
Bend and Twist Inspect

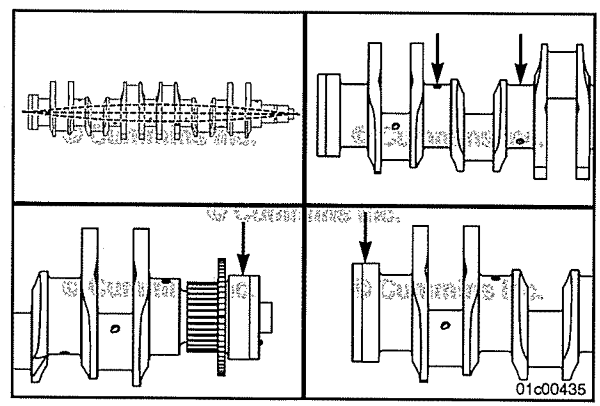
The crankshaft alignment limits are based on total indicator runout. The runout is measured as the crankshaft is turned one revolution, while recording the total movement of the dial indicator.



01x00168

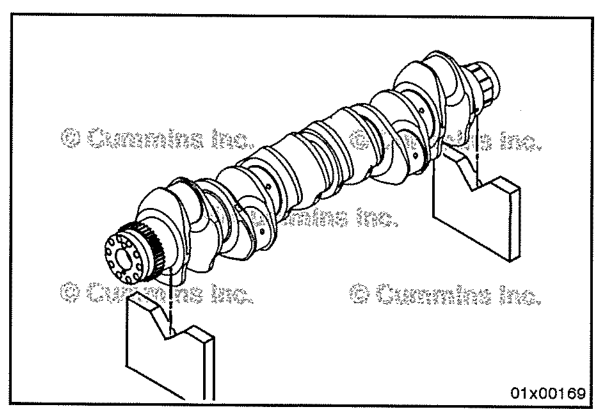
When measuring the crankshaft alignment, four measurements **must** be taken:

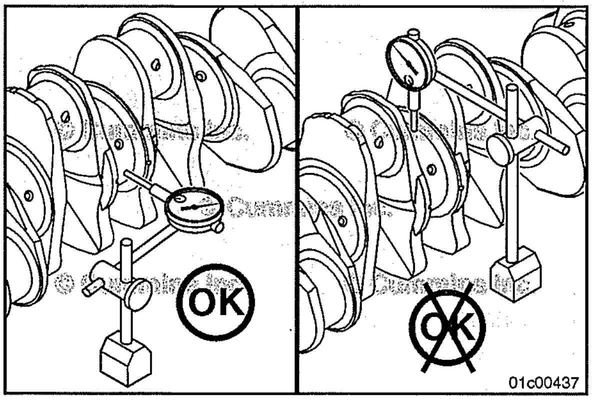
- Full length alignment
- Bearing to bearing runout
- Rear oil seal flange diameter runout
- Front oil seal crankshaft adapter diameter runout.


01c00435

⚠CAUTION⚠
Measuring from the top of the main bearing journal will cause inaccurate alignment measurements because of crankshaft sag.

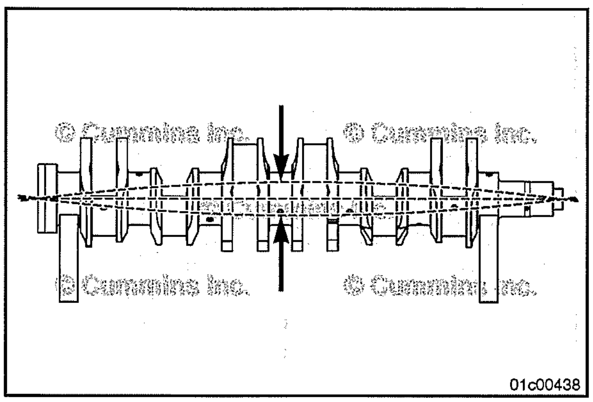
To check the crankshaft full length alignment, support the crankshaft on the Number 1 and Number 7 main bearing journals.


01x00169



The dial indicator **must** be set up so the indicator is located on the side of the Number 4 main bearing journal.

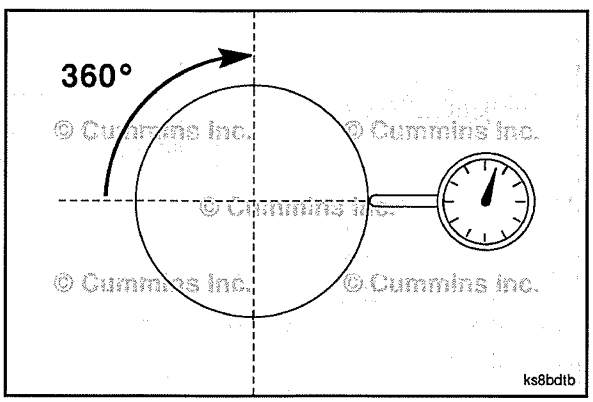
Set up the dial indicator.



Rotate the crankshaft one complete revolution and record the total indicator runout.

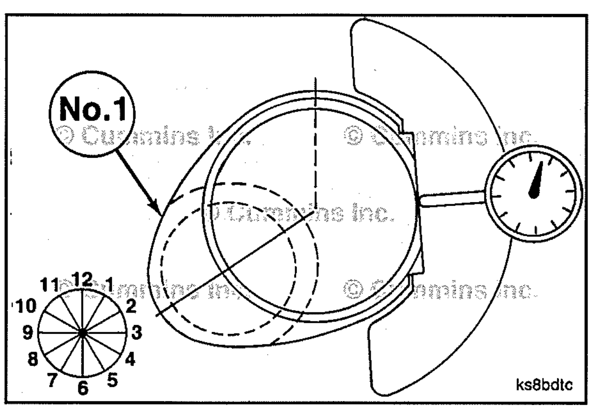
Total Indicator Runout		
mm		**in**
0.23	MAX	0.009

If the crankshaft total indicator runout is **not** within specifications, the crankshaft **must** be replaced.



Bearing to bearing runout is defined as the relationship of the total indicator runout of a main bearing journal, as it is rotated on a common axis, to the total indicator runout of an adjacent journal.

Bearing to bearing runout is often referred to as step runout, adjacent runout, or journal-to-journal runout.



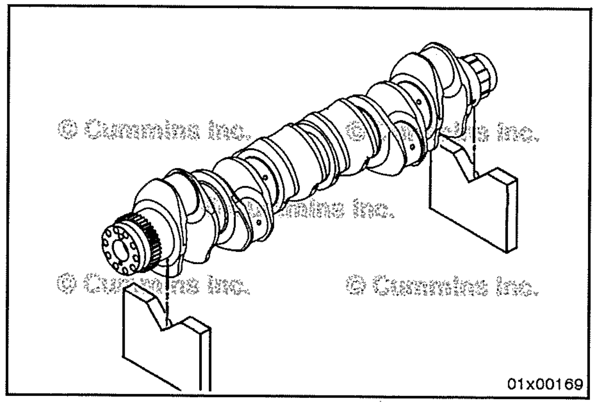
The clock position is defined as the location of the journal at the highest total indicator runout point. Compare its angular relationship with the Number 1 crankshaft pin, as viewed from the front of the crankshaft.

In the illustration, the crankshaft pin is at the 8 o'clock position. This is the clock position of the journal being measured.

⚠CAUTION⚠

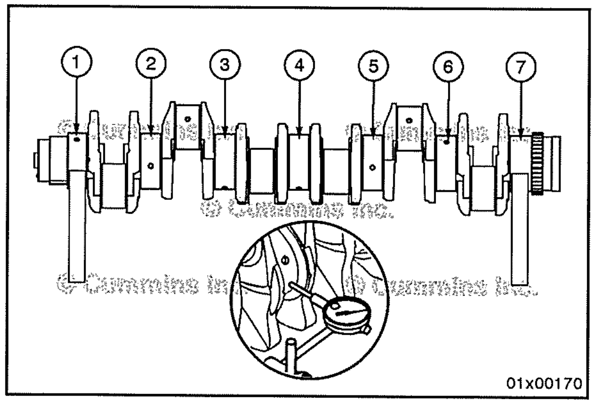
Measuring from the top of the main bearing journal will cause inaccurate alignment measurements because of crankshaft sag.

To check the crankshaft full length alignment, support the crankshaft on the Number 1 and Number 7 main bearing journals.



01x00169

Set the dial indicator up on the side of the main bearing journal.



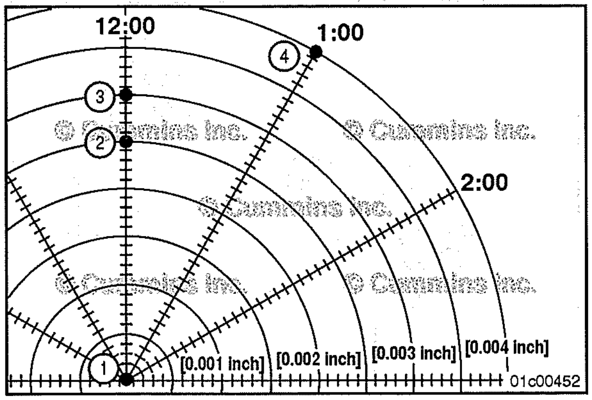
01x00170

Rotate the crankshaft and measure the total indicator runout at each bearing journal.

Record the value and clock position for each location.

ITEM	RUNOUT TIR [INCH]	CLOCK POSITION
JOURNAL STEP		
1	[0]	0
2	[0.0021]	12
3	[0.0030]	12
4	[0.0039]	1
5	[0.0025]	1
6	[0.0016]	2
7	[0]	0

ks8bdtf



For each journal, plot the total indicator runout value at each clock position on a polar chart.

The end journals, supported by vee blocks, **must** be plotted at the center of the chart.

The illustration illustrates the plot points.

Journal	**Total Indicator Runout**	**Clock Position**
(1)	0	0
(2)	0.002	12
(3)	0.003	12
(4)	0.004	1

Draw a straight line between the plotted points. From journal Number 1, to journal Number 2, to journal Number 3, until all journals are plotted on the chart.

To determine the adjacent journal runout, measure the length of the line from each journal to its corresponding journal point.

In the above table journal Number 3 and Number 4 are 51 mm [2 in]. This represents a runout of 0.051 mm [0.002 in].

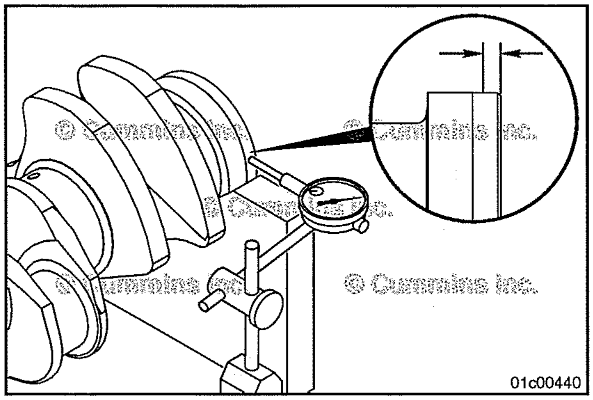
Record the adjacent runout for each main bearing journal.

Adjacent Journal Runout		
mm		**in**
0.08	MAX	0.003

Scale 1 in = 0.001 in
1 mm = 0.001 mm
The small graduations are 0.1 of an inch = 0.0001 in.

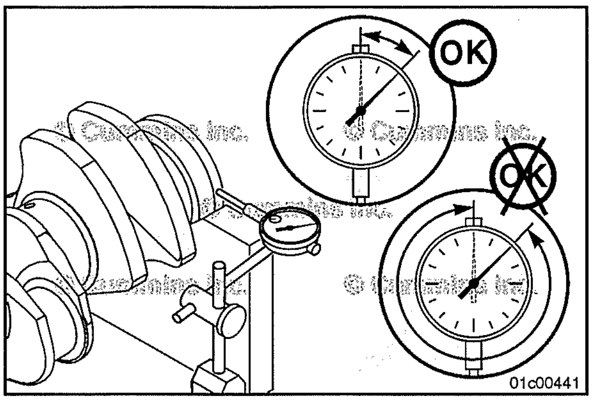
01400348

If the alignment between adjacent journals is **not** within specifications, it can **not** be repaired by grinding. The crankshaft **must** be replaced. This engine crankshaft is deep rolled and can **not** be straightened.



The rear oil seal flange diameter runout measurement is accomplished by:

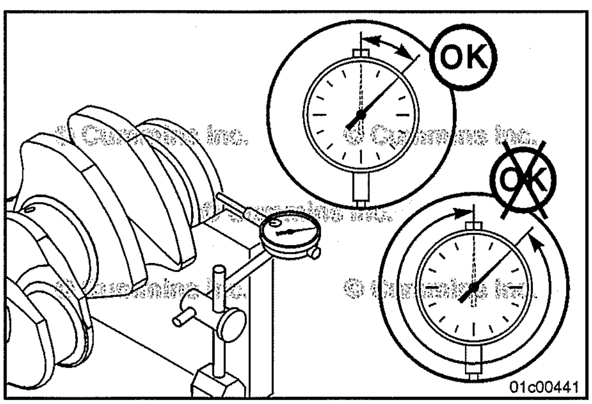
With the crankshaft supported on the Number 1 and Number 7 main bearing journals, position a dial indicator 25.4 mm [1.0 in] from the flywheel mounting face of the crankshaft.



Rotate the crankshaft one complete revolution and record the total indicator runout.

Rear Oil Seal Flange Total Indicator Runout		
mm		**in**
0.13	MAX	0.005

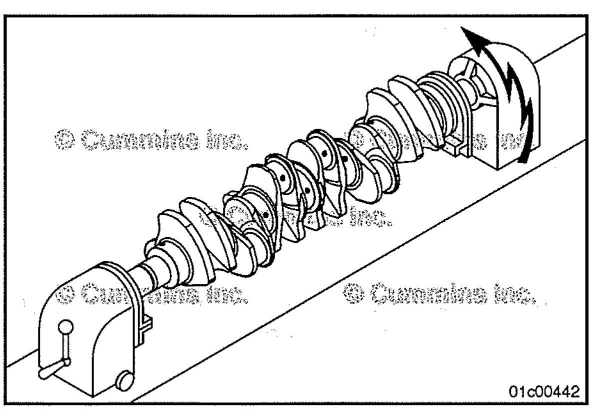
If the rear oil seal flange total indicator runout is **not** within specifications, the crankshaft **must** be replaced.



Rotate the crankshaft one complete revolution and record the total indicator runout.

Front Oil Seal Flange Diameter Runout		
mm		**in**
0.025	MAX	0.001

If the front oil seal flange diameter runout is **not** within specifications, the crankshaft **must** be replaced.



Magnetic Crack Inspect

The crankshaft **must** be tested by the "continuous method". The entire surface **must** be wetted with the magnetic bath solution before and during the flow of magnetic current through the crankshaft.

For the head shot (longitudinal magnetization) method, apply the magnetic bath solution to the crankshaft and use 3800 amperes with VDC or rectified VAC to magnetize the crankshaft.

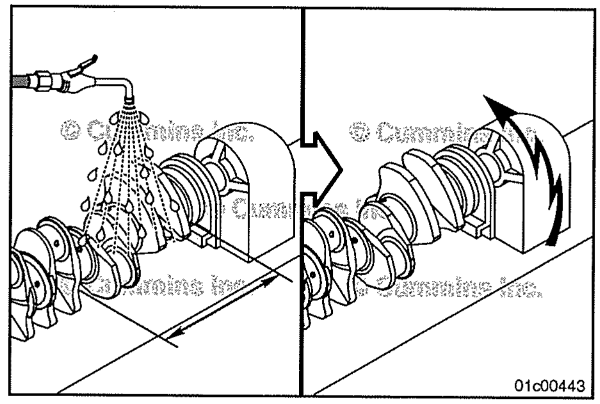
A minimum of three successive head shots are required for each section of the crankshaft.

Flow the magnetic solution over the first 1/3-length of the crankshaft and apply two head shots of magnetizing current.

To prevent washing the metal particles off the crankshaft, turn the magnetic solution flow off.

Apply a third head shot of magnetizing current.

Inspect the crankshaft for open indications.

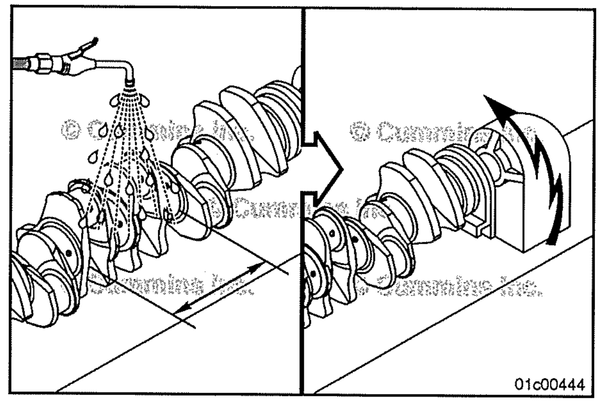


Flow the magnetic solution over the second 1/3-length of the crankshaft and apply two head shots of magnetizing current.

To prevent washing the metal particles off the crankshaft, turn the magnetic solution flow off.

Apply a third head shot of magnetizing current.

Inspect the crankshaft for open indications.

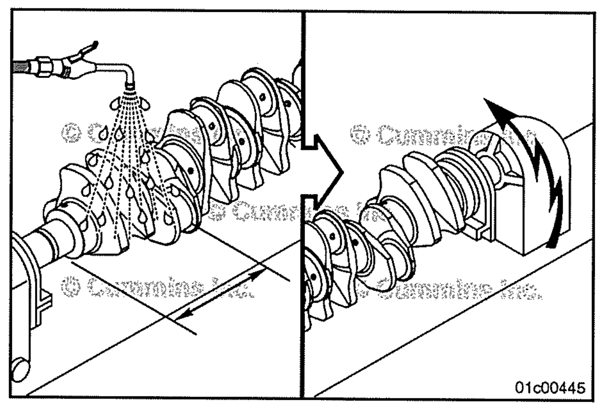


Flow the magnetic solution over the last 1/3-length of the crankshaft and apply two head shots of magnetizing current.

To prevent washing the metal particles off the crankshaft, turn the magnetic solution flow off.

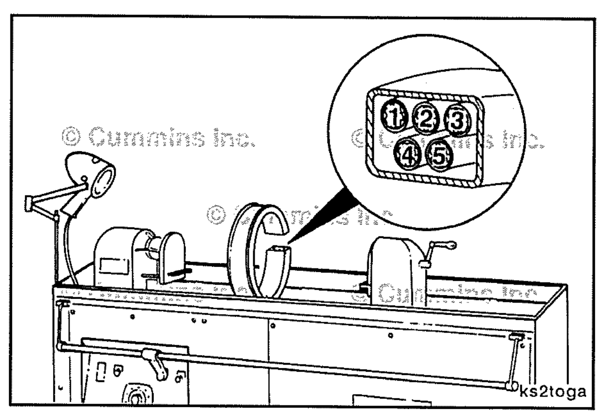
Apply a third shot of magnetizing current.

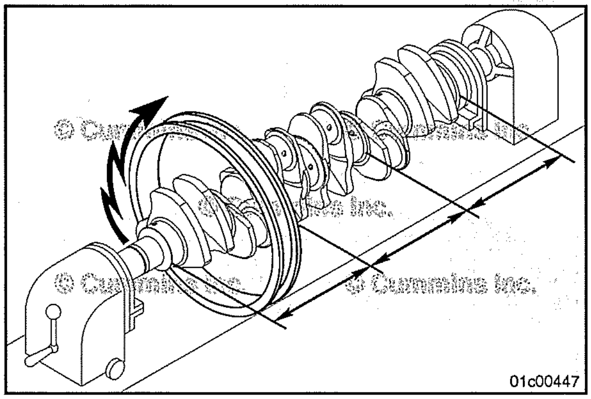
Inspect the crankshaft for open indications.



For the coil shot (circumferential magnetization) method, apply the magnetic solution and magnetize the crankshaft in a 51.35-mm [2.02-in] inside coil or equivalent. Use 3600 to 4000 ampere-turns with VDC or rectified VAC.

Ampere-turn is the amperage flowing through the coil, multiplied by the number of turns in the coil.





A minimum of three coil shots are required for each 457-mm [18-in] length to correctly magnetize the crankshaft.

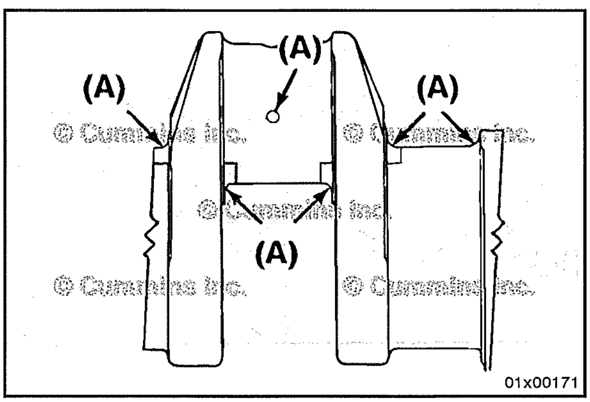
Flow the magnetic solution over the crankshaft in 1/3 sections.

Apply two coil shots, after wetting with the magnetic solution, with the coil placed at ¼-length points along the crankshaft.

To prevent washing the metal particles off the crankshaft, turn the magnetic solution flow off.

Apply the third coil shot with the coil placed at 1/4-length points along the crankshaft.

Inspect each 457-mm [18-in] section after the third coil shot is completed.



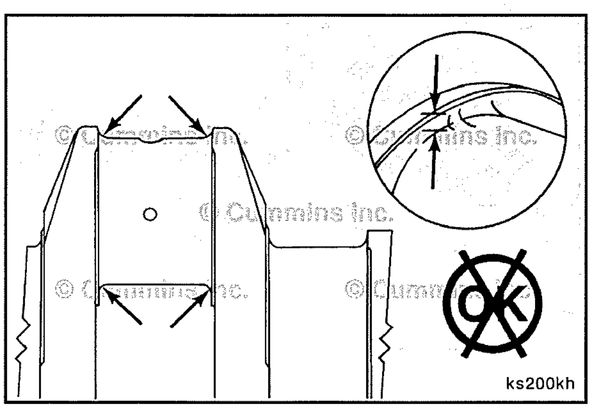
An open indication is a crack open to the surface that can be observed without using optical enhancement.

An open indication can sometimes be felt with a fingernail.

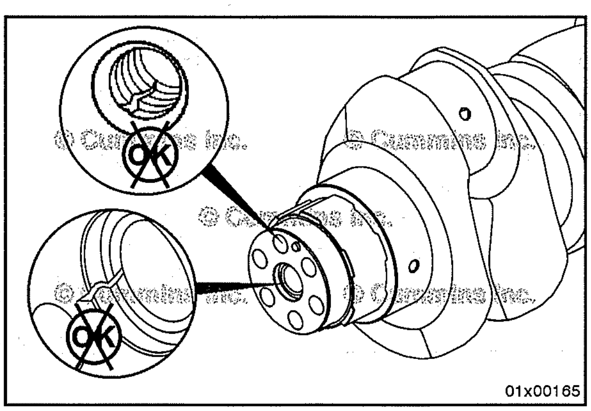
Do **not** mistake casting trim lines for crack indications.

If open indications are observed in the fillet area or the critical areas shown (A), the crankshaft **must** be replaced. (cast crank fillets are **not** hardened).

Need to check oil drilling also.



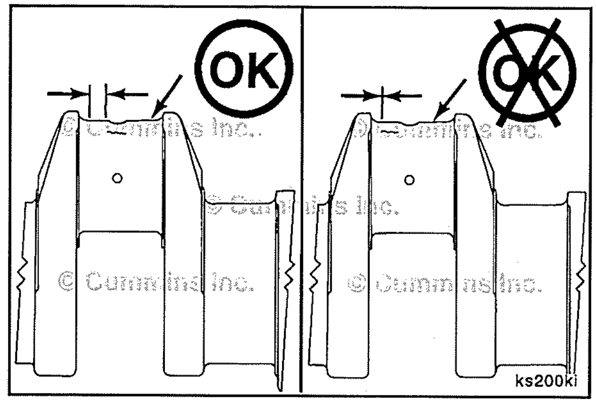
Open indications in any fillets or the noted critical areas are **not** acceptable.



Open indications that extend over the face of the crankshaft or extend into the damper mounting capscrew holes are **not** acceptable.

Subsurface indications can **not** be seen with the eye after magnetic particles have been removed. These are indications of open areas or foreign objects below the surface.

Inspect for subsurface indications.



ks200ki

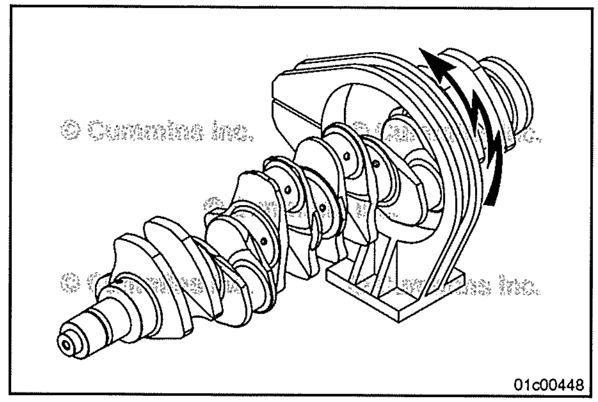
CAUTION

All magnetism must be removed from the crankshaft completely and the crankshaft cleaned thoroughly. Small metal particles will cause engine damage.

Demagnetize the crankshaft.

The maximum residual magnetic field on any pin or main bearing journal is 8 gauss.

It will possibly be necessary to use reverse D.C.-30 point step down equipment, or equivalent, to remove the magnetism.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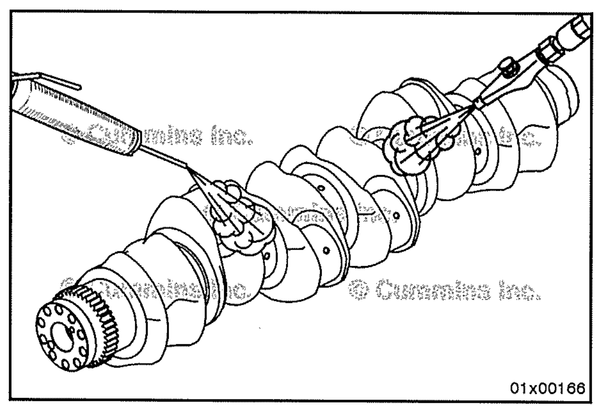
WARNING

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

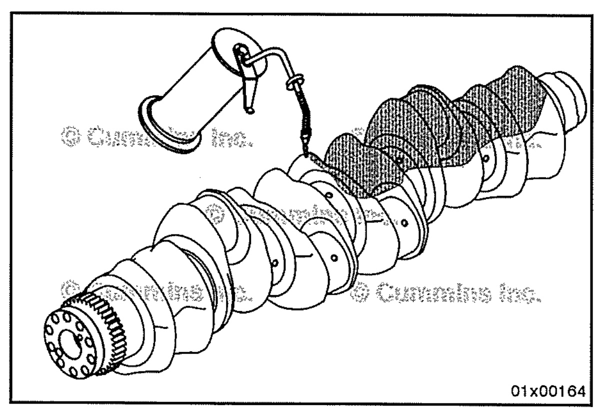
Steam clean the crankshaft.

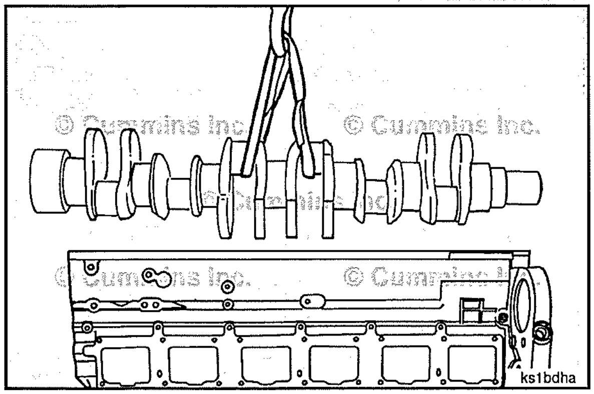
Dry the crankshaft with compressed air.


01x00166

Use a light preservative oil to lubricate the crankshaft to prevent rust.

If the crankshaft is **not** going to be used immediately, protect it with a plastic cover to prevent dirt from sticking to the oil.


01x00164



Install

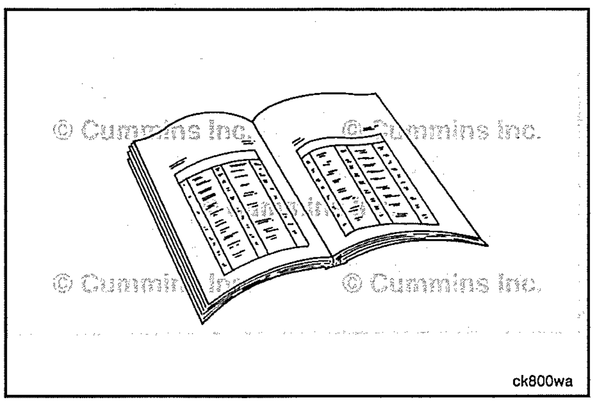
⚠CAUTION⚠
Use a lifting strap that will not damage the crankshaft. Do not drop the crankshaft on the bearings.

⚠CAUTION⚠
Do not install the thrust bearings before the crankshaft is laid into the block.

Install the main bearings. Refer to Procedure 001-006 in Section 1.

The end of the crankshaft with the smallest diameter **must** point toward the front of the cylinder block.

Install the crankshaft.



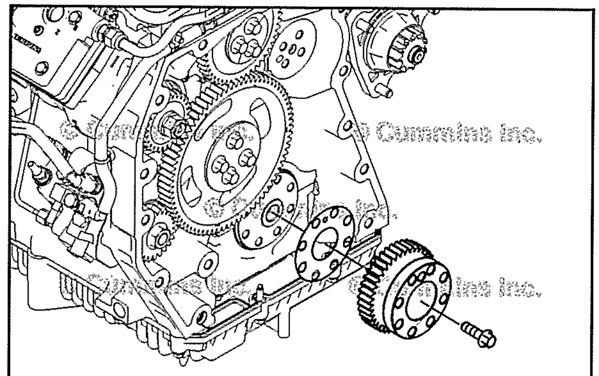
Finishing Steps

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

- Install the main bearing caps. Refer to Procedure 001-006 in Section 1.
- Install the thrust bearings. Refer to Procedure 001-007 in Section 1.
- Install the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.
- Install the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install the lubricating oil pump. Refer to Procedure 007-031 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- 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 cylinder head. Refer to Procedure 002-004 in Section 2.
- Remove the engine from the rollover stand and install the engine. Refer to Procedure 000-002 in Section 0.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to normal operating temperature and check for leaks and proper operation.

Crankshaft Gear, Rear (Crankshaft Installed) (001-020)

General Information


01x00073

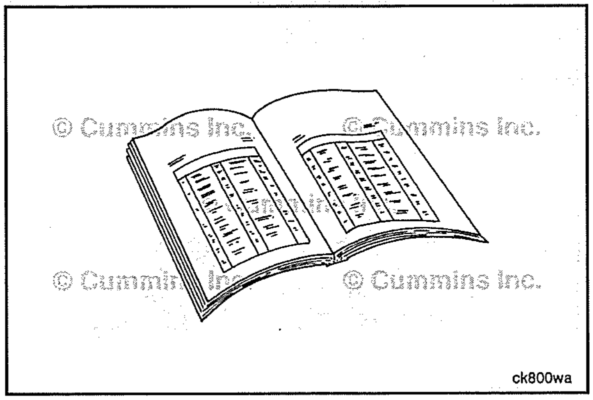
The rear crankshaft gear is bolted on to the last main journal of the crank. The crankshaft gear should **not** be removed unless it is being replaced.

This engine uses friction enhancing shims between the crank and gear and between the gear and flywheel. This design is unique in that the rear crank gear is a separate piece bolted on to the last main journal of the crank, rather than being a press fit gear in more conventional designs.

The crankshaft and crankshaft gear should **not** be separated unless the crankshaft gear is being replaced. If they are separated insure that a new shim is replaced in the joint.

△CAUTION△
Do not reuse or stack frictions shims or engine damage may occur.

△CAUTION△
Friction shim, flywheel, and crank gear interconnecting surfaces must be free of grease upon installation or engine damage may occur.



ck800wa

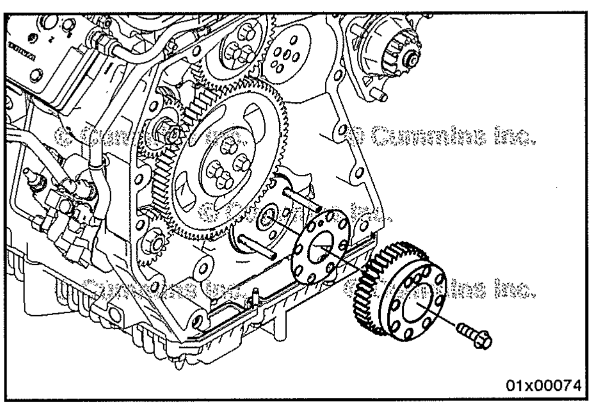
Preparatory Steps

WARNING

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

NOTE: This procedure is intended to be performed in-chassis with the transmission removed. However, some applications can require the engine to be removed if space is limited or the engine can **not** be adequately supported.

- Disconnect the batteries. See equipment manufacturer service information.
- Rotate the engine to insert the crankshaft and camshaft timing pins. Refer to Procedure 001-088 in Section 1.
- Disconnect the transmission. See equipment manufacturer service information.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the flywheel. Refer to Procedure 016-005 in Section 16.
- Remove the rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Use a jackstand or a suitable lifting fixture to support the rear of the engine.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.



01x00074

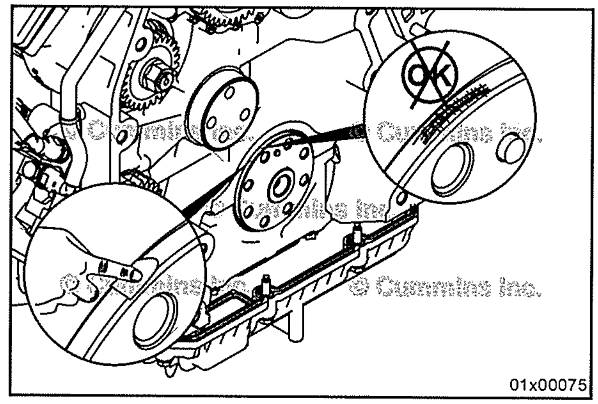
Remove

Install guide pins, Part Number 3376638, in two of the flywheel mounting locations to support the crankshaft gear.

Remove the crankshaft gear retaining capscrew.

Remove the crankshaft gear and discard friction shim.

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.

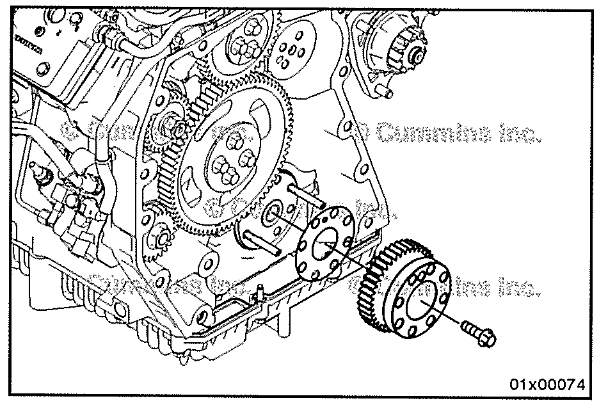
Clean the crankshaft nose with cleaning pad, Part Number 3823258 or equivalent. Debris remaining on the crankshaft can prevent the correct installation of the gear.

Inspect the machined surface for scratches or nicks.

Use a crocus cloth to remove any scratches or nicks.

If scratches or nicks can be felt with a fingernail after the crankshaft has been polished with the crocus cloth, the crankshaft **must** be replaced.

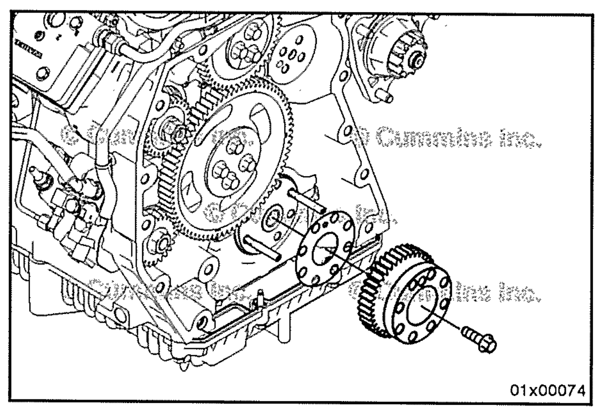
Install



Slide the new friction shim and the crankshaft gear over the guide pins, Part Number 3376638.

⚠CAUTION⚠
Do not reuse or stack frictions shims or engine damage may occur.

⚠CAUTION⚠
Friction shim, flywheel, and crank gear interconnecting surfaces must be free of grease upon installation or engine damage may occur.

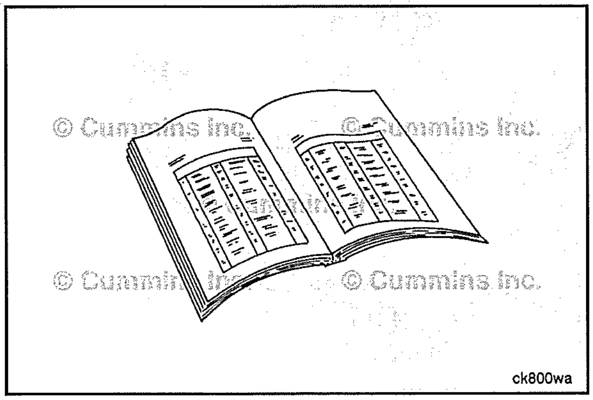


Align dowel pin.

Install the crankshaft gear retaining capscrew through the gear and the shim and into the crankshaft.

Tighten the capscrew.

Torque Value: 281 N•m [207 ft-lb]



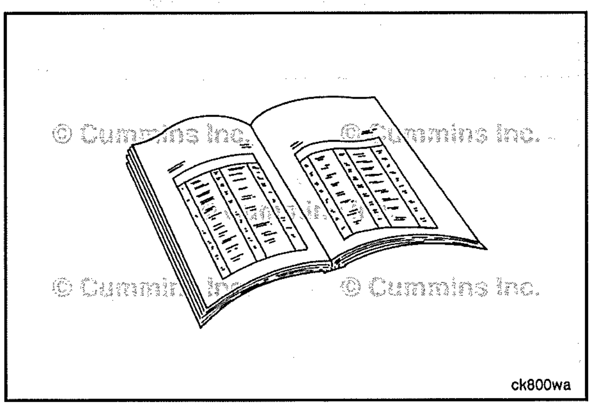
ck800wa

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.

- Set the base engine timing. Refer to Procedure 001-088 in Section 1.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Install the flywheel. Refer to Procedure 016-005 in Section 16.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the transmission. See equipment manufacturer service information.
- Remove the crankshaft and camshaft timing pins. Refer to Procedure 001-088 in Section 1.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for proper operation.



ck800wa

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. Refer to Procedure 013-009 in Section 13.
- Remove the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.

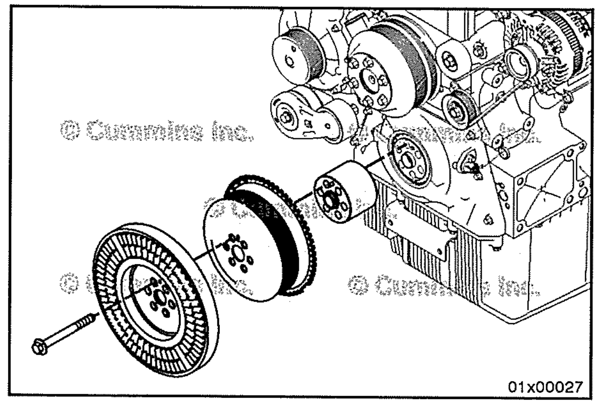
Remove

Remove two capscrews and insert guide pins, Part Number 3376696, to support the damper.

Remove the other four capscrews.

Remove the vibration damper, crankshaft pulley, and crankshaft spacer.

NOTE: The crankshaft speed indicator ring is an integral part of the crankshaft pulley that can **not** be separated.



01x00027

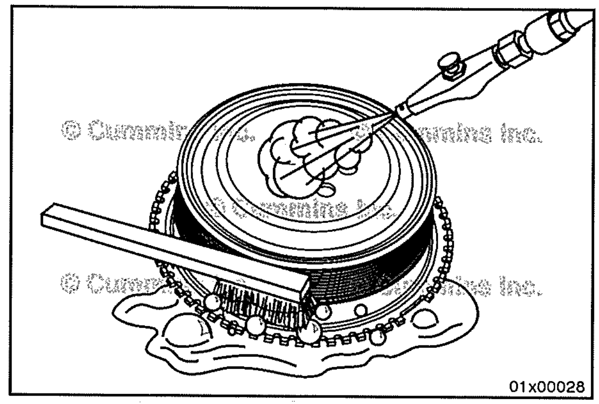
Clean and Inspect for Reuse

WARNING

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

Use soapy water to clean any oil from the crankshaft pulley.

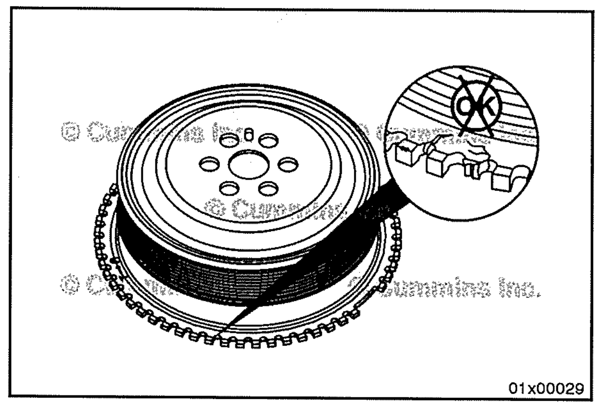
Dry the crankshaft pulley with compressed air.



01x00028

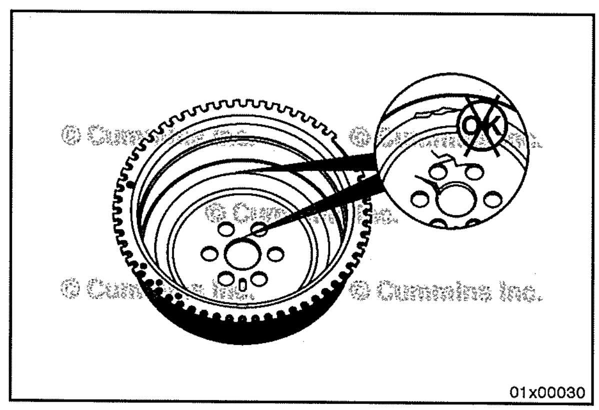
Inspect the crankshaft speed indicator ring for missing teeth, cracks, or damaged surfaces.

If any damage is found, the crankshaft pulley **must** be replaced.

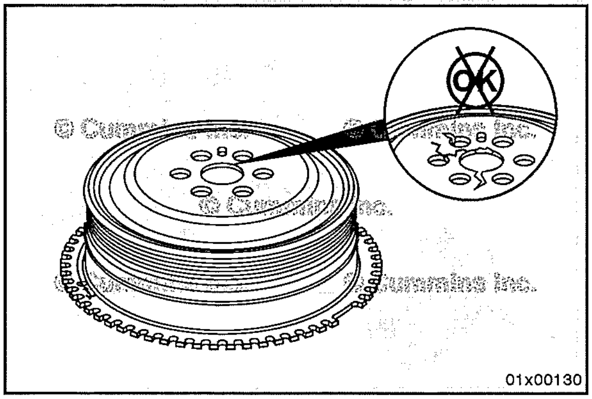


01x00029

Inspect the mounting web for cracks.



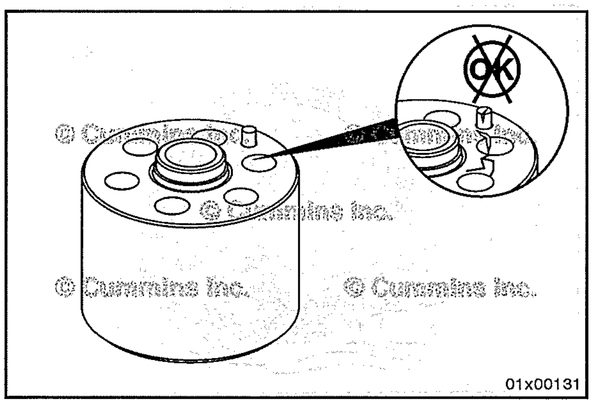
01x00030



01x00130

Inspect the crankshaft pulley hub for cracks.

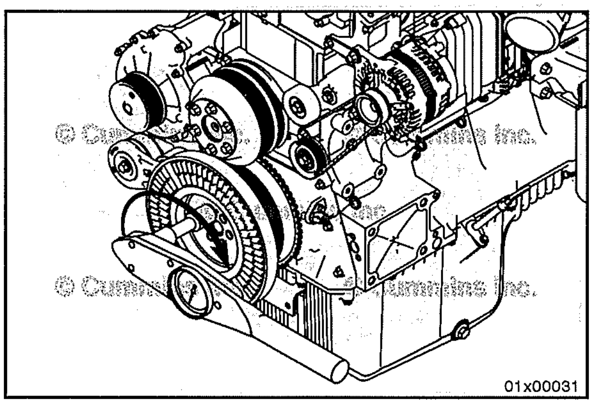
Replace the pulley if the hub is cracked.



01x00131

Inspect the crankshaft spacer hub for cracks.

Replace the spacer if it is cracked or dowel is broken or cracked.

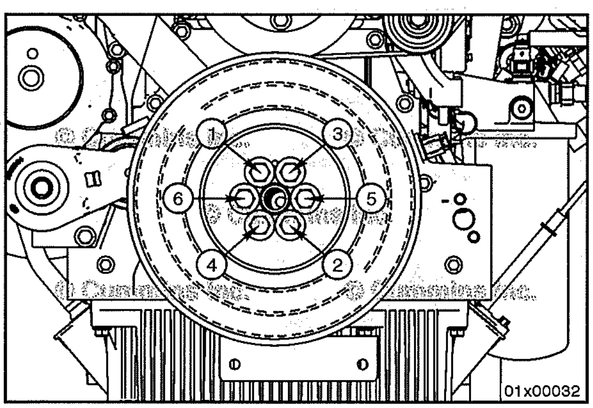

01x00031

Install

Install two guide pins, Part Number 3376696.

Assemble the crankshaft pulley, vibration damper, and crankshaft spacer to the crankshaft over the guide pins.

Make sure the dowel pin is aligned correctly.



01x00032

Lubricate the capscrews with clean engine oil.

Install four capscrews into the empty holes hand tight.

Remove the two guide pins and install the last two capscrews.

Tighten the six crankshaft pulley capscrews in the proper torque pattern as shown in graphic.

Torque Value:

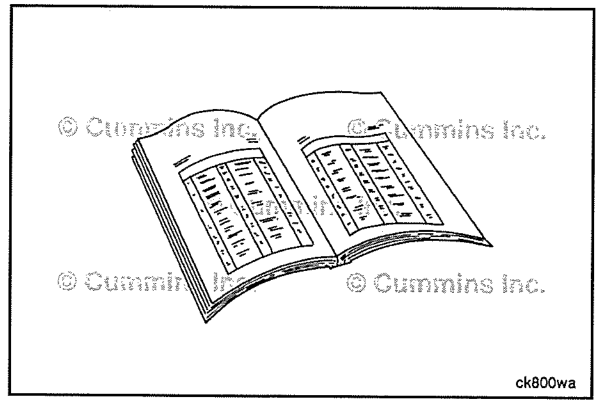
Step 1	175 N•m	[129 ft-lb]
Step 2	Rotate 60 degrees	

Finishing Steps

WARNING

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

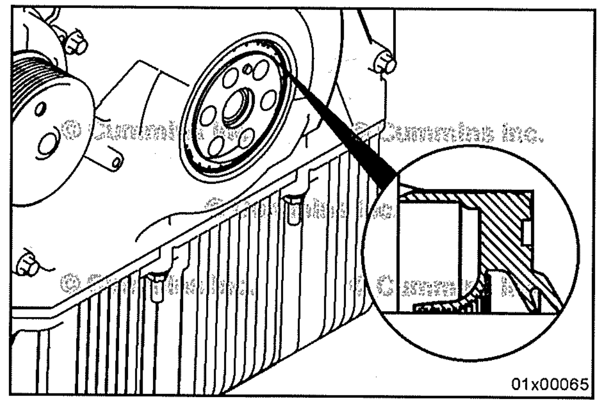
- Install the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.



Crankshaft Seal, Front (001-023)

General Information

This engine uses 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.

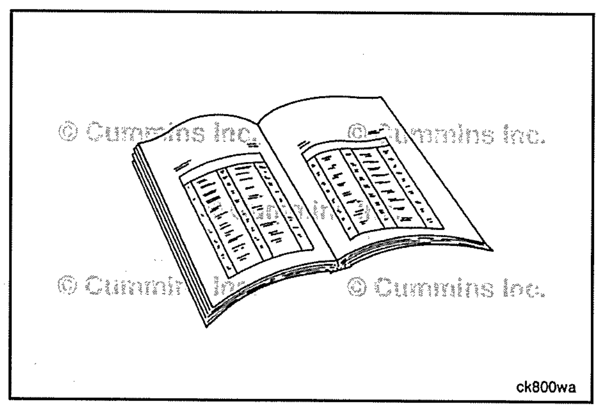


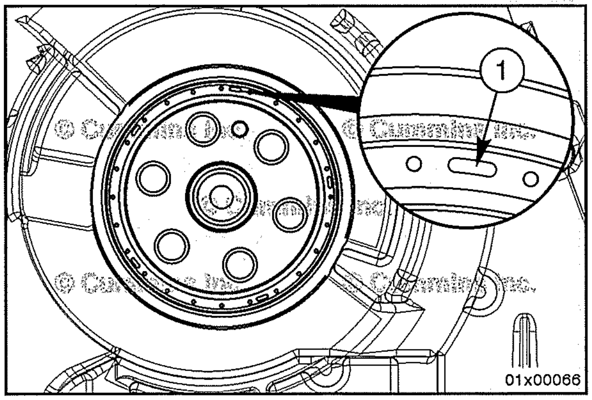
Preparatory Steps

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.

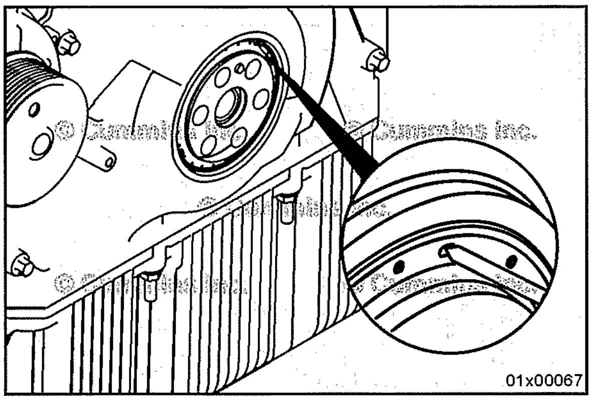
- Disconnect the batteries. See equipment manufacturer service information.
- Remove the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the crankshaft pulley. Refer to Procedure 001-022 in Section 1.





Remove

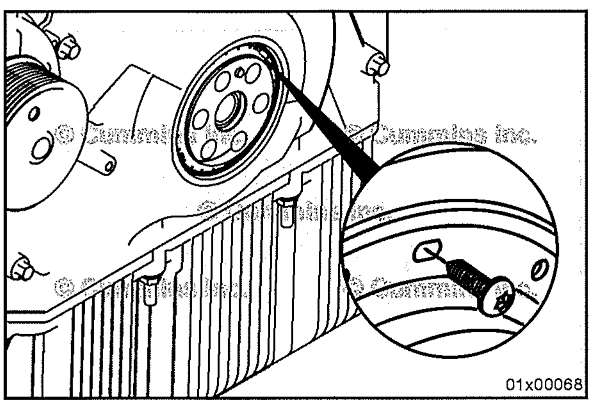
This engine has a front crankshaft seal with five pre-drilled slots in the casing (1), covered with rubber molding. These slots are designed into the seal to aid with removal, so drilling of the seal is **not** necessary.



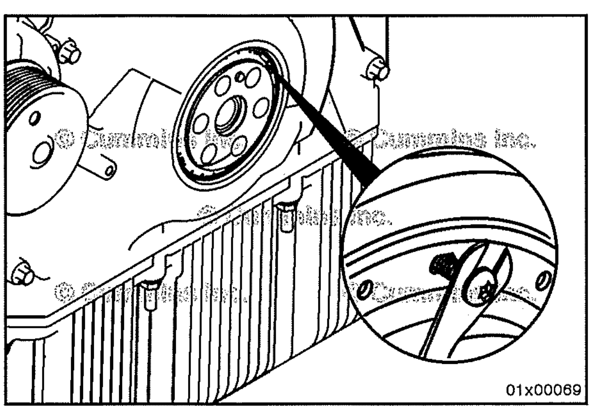
Clean the surface of the front crankshaft seal.

The rubber molding over the pre-drilled slots in the seal casing are recessed. These "dimples" are visible on the front crankshaft seal surface.

Push a suitable pin through the dimples to further identify the locations of the pre-drilled slots.



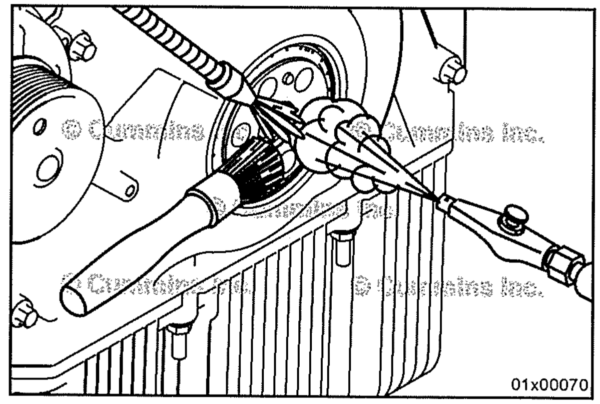
Install 3.5 x 20 mm self-tapping screws into the pre-drilled slots in the seal casing.



Use a standard prying tool with a forked end to grip the screws and pull the front crankshaft seal out.

Discard the seal.

Clean and Inspect for Reuse


01x00070

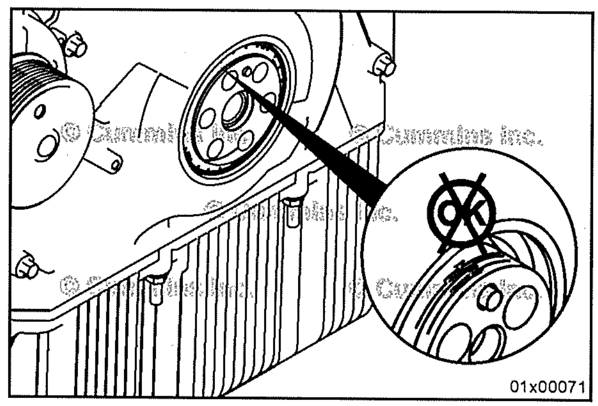
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

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

Use solvent to clean the oil and seal residue from the crankshaft surface.

Dry with compressed air.

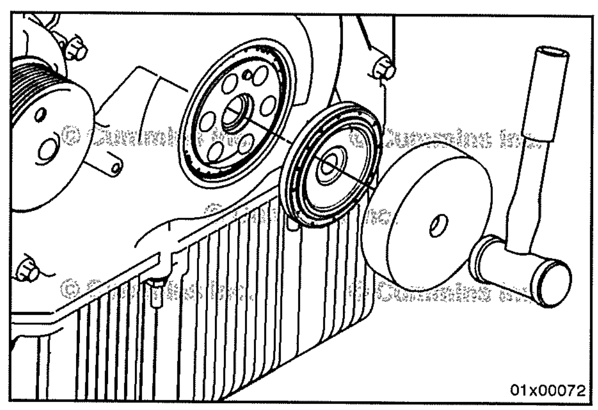

01x00071

⚠CAUTION⚠
The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Inspect the nose of the crankshaft for excessive wear.

Use a fine crocus cloth to remove any nicks or burrs. No wear sleeve is available if the crankshaft nose sealing surface is damaged.

Install


01x00072

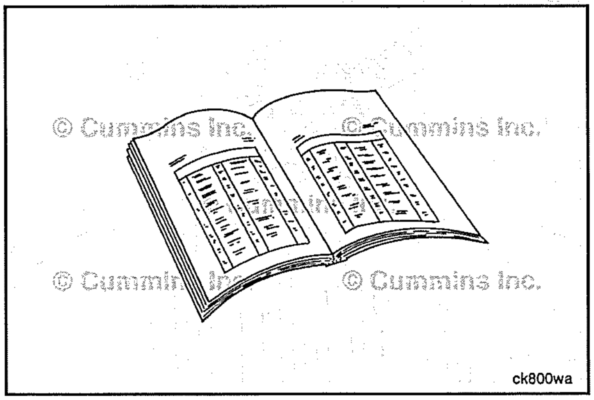
The new front crankshaft seal comes with a plastic guide installed in its center. Do **not** remove this guide before the installation. It should be used to locate the seal on the crankshaft nose.

Lubricate the outside diameter of the seal to prevent tearing upon installation.

Use tool, Part Number 5299870, to install the oil seal into the front gear housing.

The tool fits over the oil seal and installs the seal to the proper depth when it is flush with the front gear housing face.

Use a plastic hammer to tap the tool equally at 90 degree intervals until the seal is all the way in.

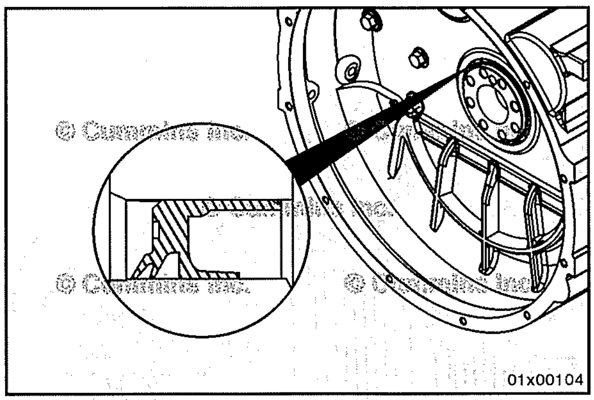

ck800wa

Finishing Steps

⚠WARNING⚠

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

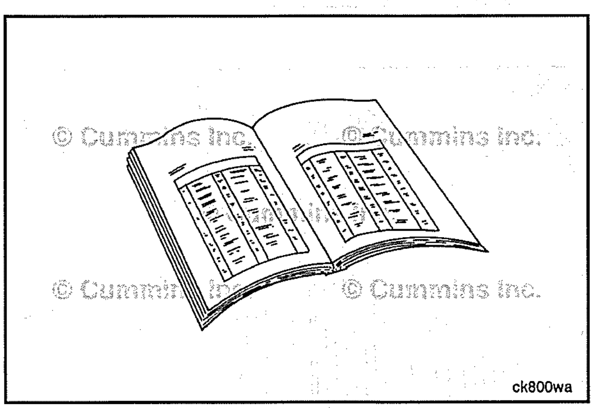
- Install the crankshaft pulley. Refer to Procedure 001-022 in Section 1.
- Install the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.


01x00104

Crankshaft Seal, Rear (001-024)

General Information

This engine uses 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 rear crankshaft seal and the crankshaft.


ck800wa

Preparatory Steps

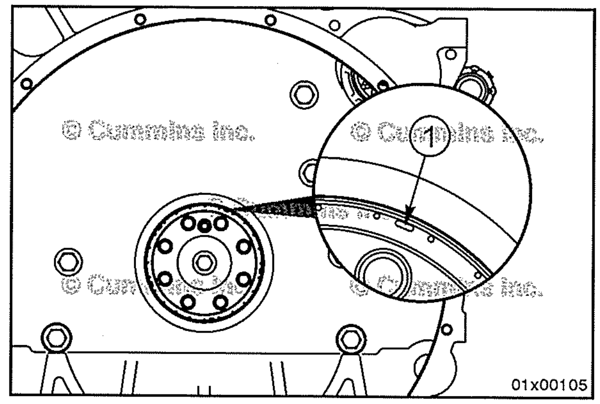
⚠WARNING⚠

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

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the transmission and all related components, if equipped. See equipment manufacturer service information.
- Remove the flywheel. Refer to Procedure 016-005 in Section 16.

Remove

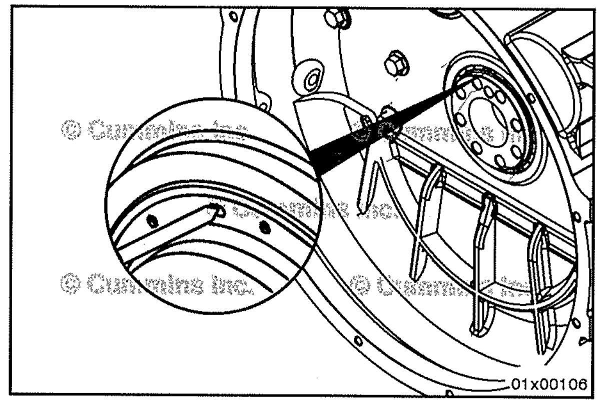
This engine has a rear crankshaft seal with five pre-drilled slots (1) in the casing, covered with rubber molding. These slots are designed into the seals to aid with removal, so drilling of the seals is **not** necessary.



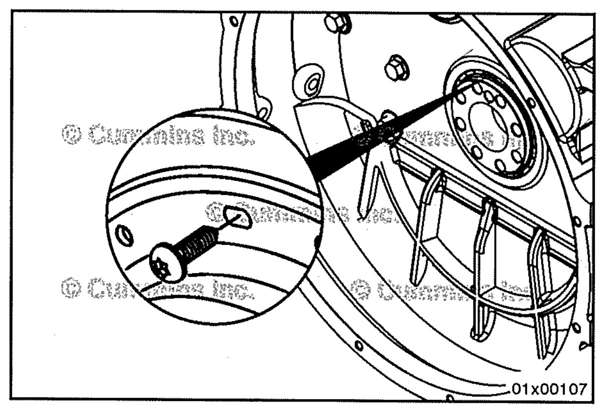
Clean the surface of the rear crankshaft seal.

The rubber molding over the pre-drilled slots in the seal casing is recessed. These "dimples" are visible on the rear crankshaft seal surface.

Push a suitable pin through the dimples to further identify the locations of the pre-drilled slots.

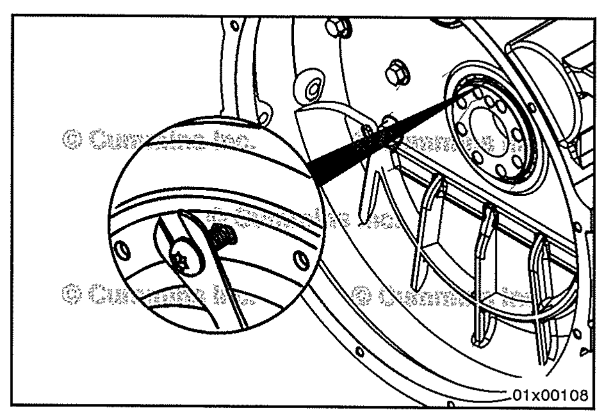


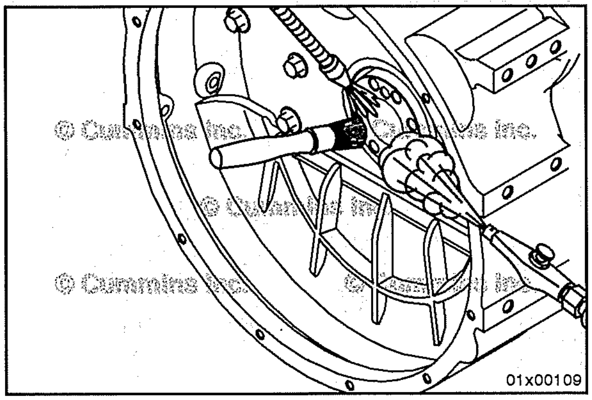
Install 3.5 x 20 mm self-tapping screws into the pre-drilled slots in the seal casing.



Use a standard prying tool with a forked end to grip the screws and pull the rear crankshaft seal out.

Discard the seal.





Clean and Inspect for Reuse

WARNING

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

WARNING

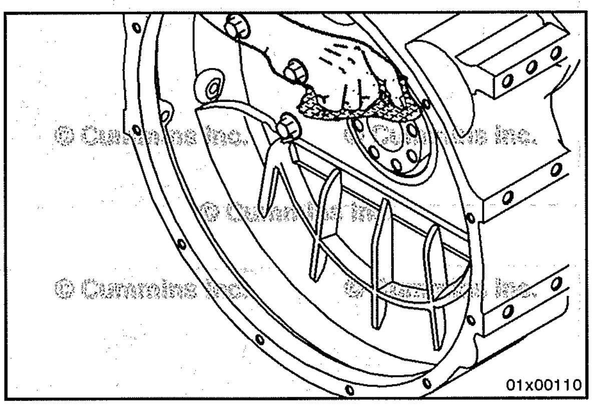
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

CAUTION

The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

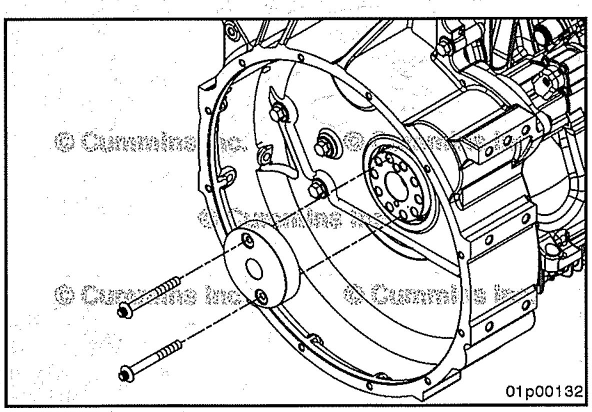
Clean the rear crankshaft sealing surface and bore with solvent.

Dry the surface with compressed air.



Inspect the nose of the crankshaft for damage or excessive wear.

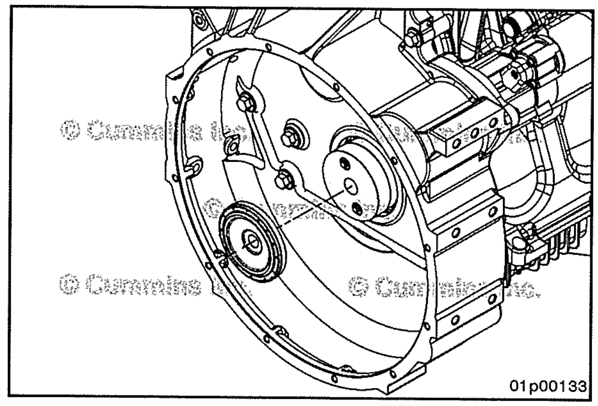
Use a fine crocus cloth to remove any nicks or burrs. No wear sleeve is available if the crankshaft nose sealing surface is damaged.



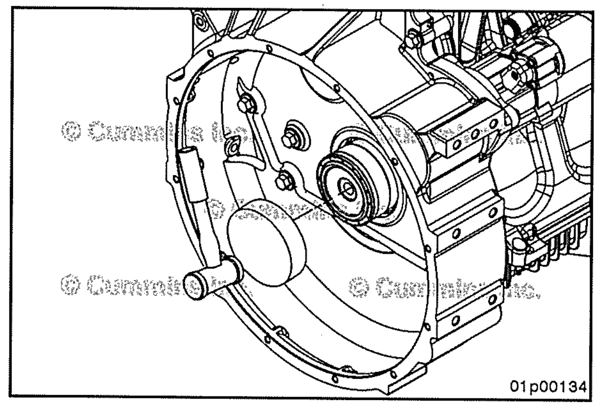
Install

Install 5299478 onto the crankshaft using two capscrews, p/n 5299479, from kit 5299476.

The new rear crankshaft seal comes with a plastic guide installed in its center. Align the plastic guide with part number 5299478, from kit 5299476, and slide the seal onto part number 5299478.



Use driver p/n 5299477 from kit 5299476 to install the seal by using a hammer to tap the tool equally at 90 degree intervals until the tool bottoms out.

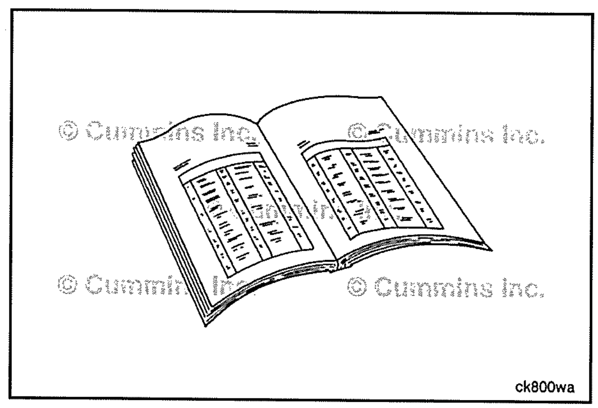


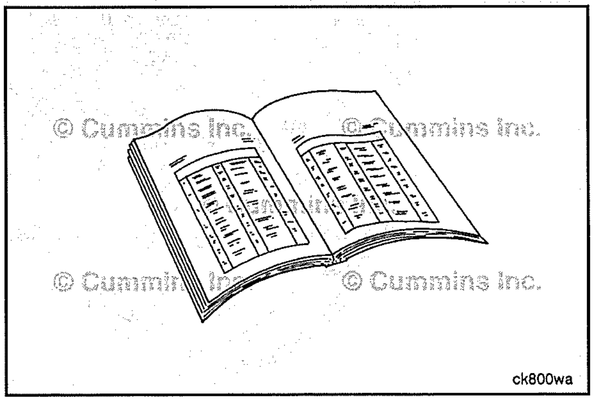
Finishing Steps

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. Refer to Procedure 016-005 in Section 16.
- Install the transmission and all related components, if equipped. See equipment manufacturer service information.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

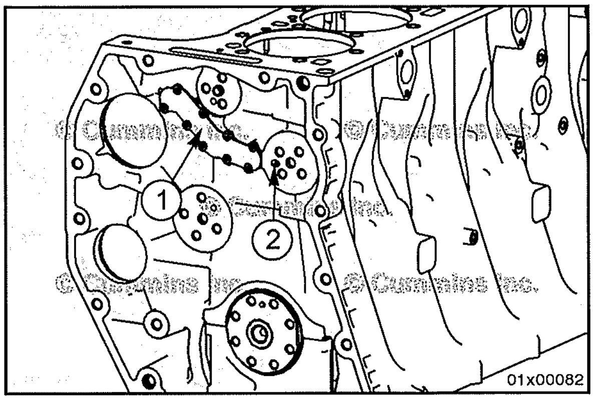




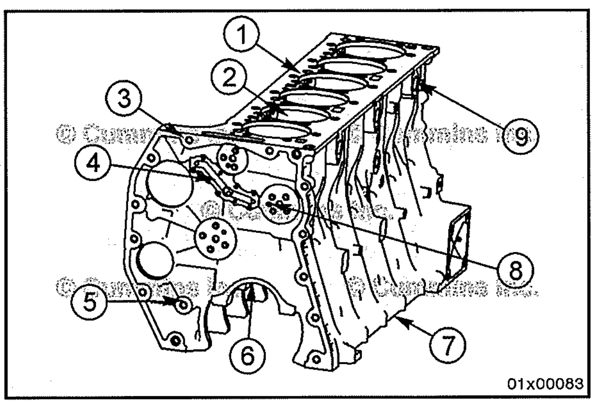
Cylinder Block (001-026)

Preparatory Steps

- Disassemble the engine to cylinder block component level. Use the procedures in Section DS (Engine Disassembly).
- Remove the straight thread plugs. Refer to Procedure 017-011 in Section 17.



1 Remove cover to oil passage.
2 If applicable remove cup plug. Applications using the REPTO, do **not** have cup plug. Refer to Procedure 017-002 in Section 17.



Clean and Inspect for Reuse

Before cleaning or further disassembly of the block, perform an inspection to see if there is any damage (cracks, fretting, etc.) that would prohibit reuse. If any cracks are found, the cylinder block **must** be replaced.

Pay close attention to areas of the block that include:

1 Cylinder block combustion deck
2 Cylinder bores
3 Front and rear of block sealing surfaces
4 Oil passage
5 Threaded bosses
6 Main bearing caps and bores
7 Oil pan mounting surface
8 Cup plug bore
9 Coolant inlet mounting surface.

⚠WARNING⚠
Use caution while handling and cleaning the cylinder block. The cylinder block may contain sharp edges that can cause personal injury.

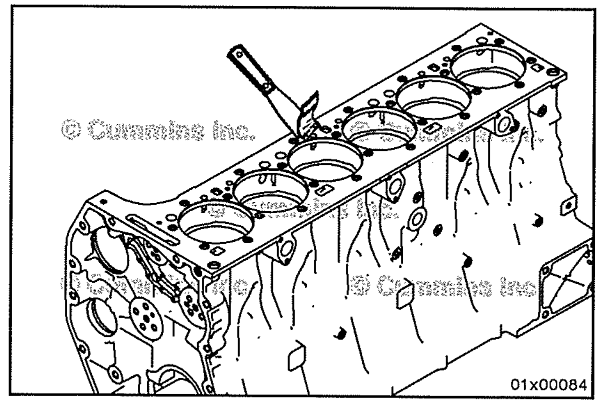
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠CAUTION⚠
Use care not to damage the machined gasket surfaces.

Use a gasket scraper to clean the cylinder block deck surface.

Use Scotch-Brite™ 7747 abrasive pad, Part Number 3823258, or equivalent, and solvent to remove any residual gasket material from the cylinder block deck surface.

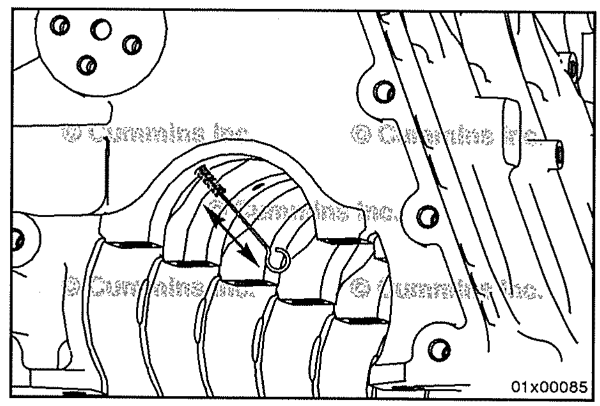
Remove any remaining adhesive sealant from other cylinder block sealing surfaces.


01x00084

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

Use clean solvent and a non-metallic brush to clean the block oil drillings.

Dry with compressed air.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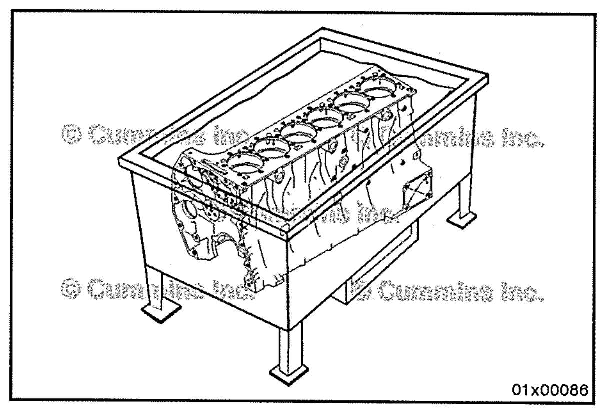
NOTE: Cummins Inc. does **not** recommend any specific cleaning solution.

Remove the block from the engine stand and place the block in a cleaning tank.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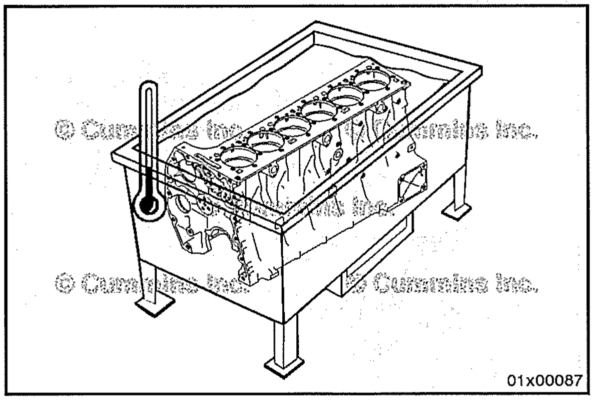
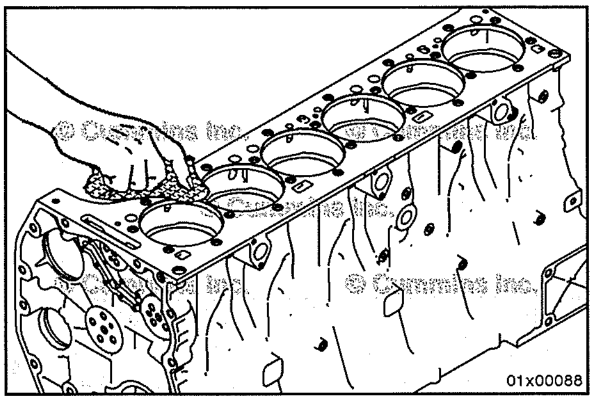


Follow the instructions of the manufacturer of the cleaning tank and the manufacturer of the cleaning solution.

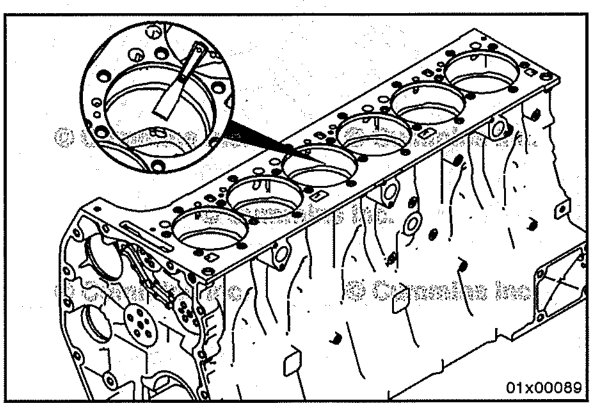
The best results can be obtained by using a cleaning solution that can be heated to 80°C to 95°C [176°F to 203°F].

Use a cleaning tank that will mix and filter the cleaning solution to get the best results.

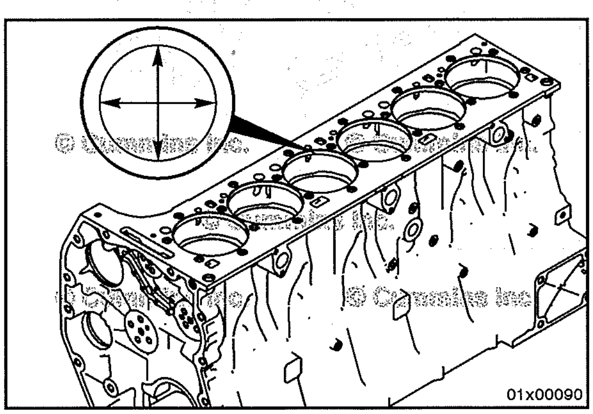


Remove the cylinder block from the cleaning tank.

Clean the cylinder head deck surface with safety solvent to remove any residual cleaning solution from the steps above.



Clean the cylinder liner midstop area and remove any corrosion, buildup, or residual o-ring material.



⚠CAUTION⚠

All measurements of the cylinder block must be made when the block is positioned on a flat surface. If the block is mounted on the engine stand, the measurements can be wrong because of distortion.

Measure the cylinder block liner ledge at four points.

Cylinder Block Liner Ledge Inside Diameter

mm		in
138.525	MAX	5.454

If the ledge measurement is greater than 138.525 mm [5.454 in], replace the cylinder block.

Inspect the liner ledge for pitting and fretting.

If liner ledge pitting is discovered during block inspection, the block can be reused if no leak is evident in the liner-to-liner ledge (block) interface.

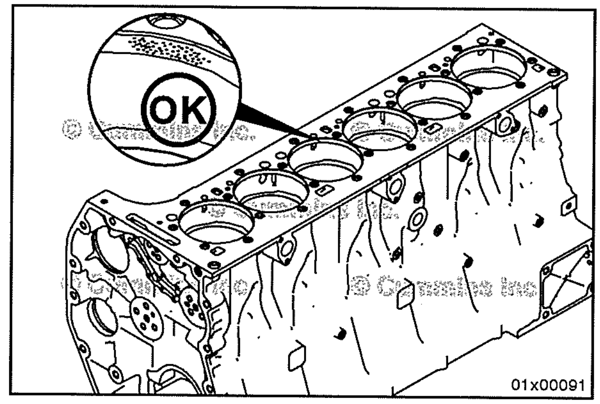
In most cases pitting in this area would **not** be a block malfunction.

Liner ledge pitting has an appearance very similar to liner pitting.

If there is pitting it can indicate a malfunction in these areas.

Contributing factors to its formation are:

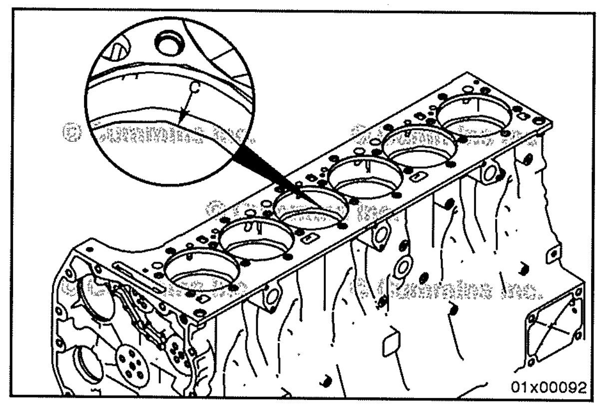
- Combustion gases in the cooling system
- Poorly maintained coolant chemistry
- Excessive load reversal at the liner to block contact area.



Inspect the cylinder liner seat "C" for extreme wear, cracks, or fretting.

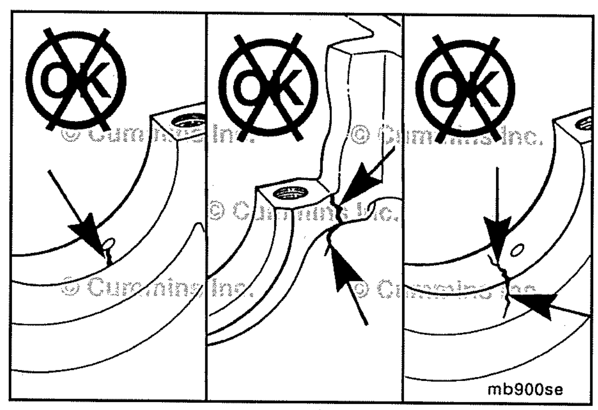
If surface "C" has signs of extreme wear, the cylinder liner seat will require machining and the installation of shims for the correct liner protrusion.

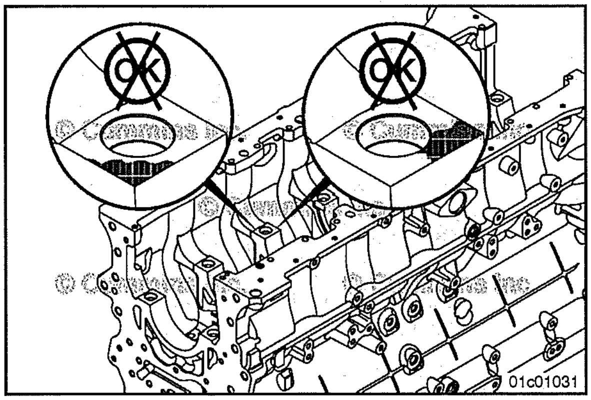
There **must not** be any coolant leaks past the lower O-ring. Refer to Procedure 001-027 in Section 1.



Clean the main bearing saddles and caps. Make sure to inspect the main bearing caps and main bearing saddle areas for cracks, fretting, and signs of discoloration.

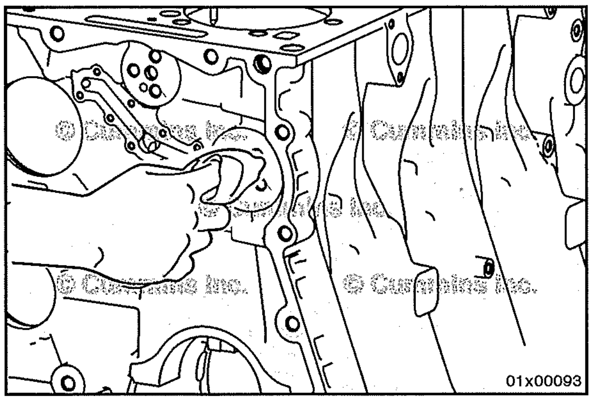
If any cracks are found, the cylinder block **must** be replaced.



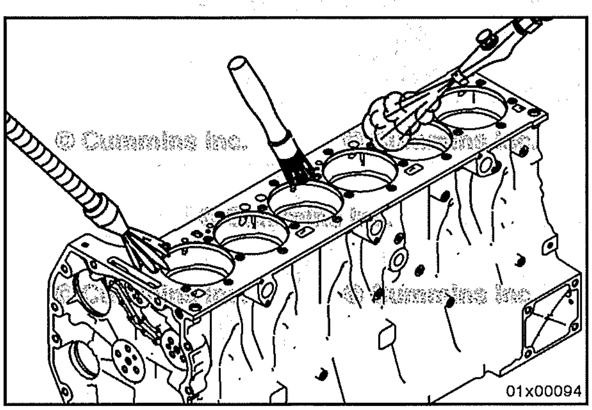


Inspect the main saddles and caps mating surface for fretting.

Fretting appears as a frosted surface or orange peel texture.



Clean the cup plug sealing area.



Thoroughly clean all gasket sealing surfaces of any remaining gasket residue.

⚠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.

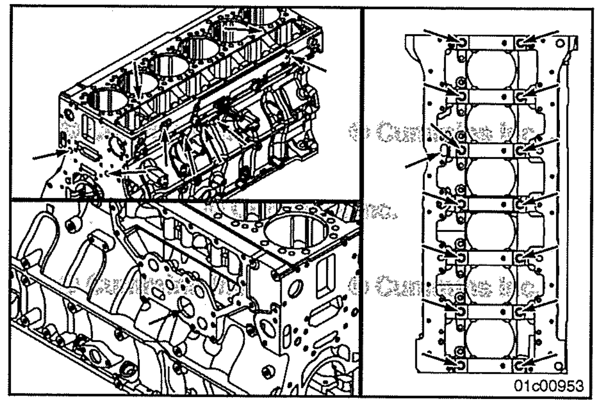
⚠WARNING⚠
Use caution while handling and cleaning the cylinder block. The cylinder block may contain sharp edges that can cause personal injury.

⚠CAUTION⚠
Make sure all the water is removed from the capscrew holes and the oil passages to prevent rust formation in the cylinder block.

Use a soft bristle brush with a long handle to clean all the oil passages. Pay specific attention to the oil passages indicated in the illustration.

Use a steam cleaner to clean the oil passages.

Dry with compressed air.



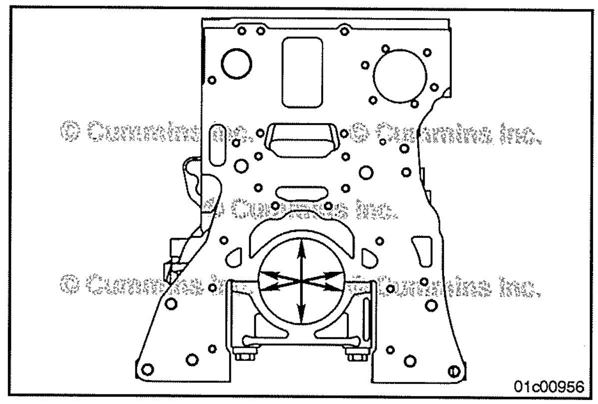
Install main bearing caps in the same location in which they were removed.

Measure the inside diameter, of all the main bearing bores using the Dial Bore Gauge Kit, Part Number 3376619, or equivalent. Measure the bore at six points.

If the measurements are out of specifications, replace the block.

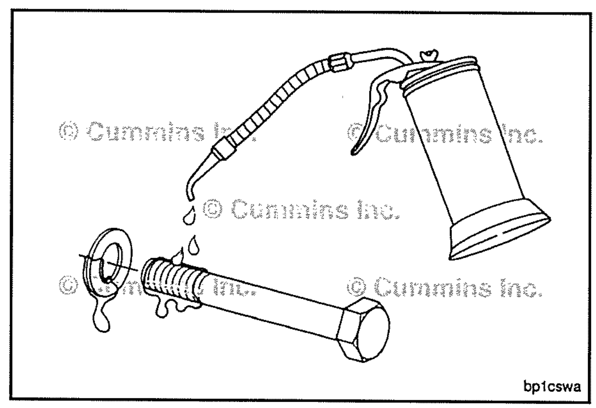
Main Bearing Bore Inside Diameter (Capscrews Tightened to Specification)

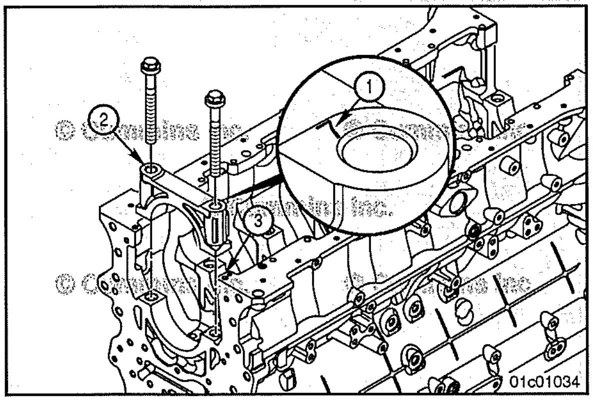
mm		in
117.99	MIN	4.645
118.015	MAX	4.646



Use clean engine oil to lubricate the main bearing capscrew threads and the flat washers.

Use a lint free cloth to wipe the excess oil from the capscrews before installation.

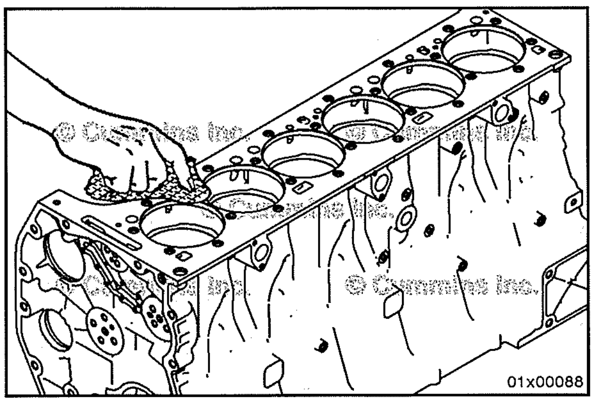




⚠CAUTION⚠

If main caps are reused the location number should be stamped on the arrow pad during disassembly. New caps must be stamped with the location during assembly. The main caps are marked with a direction arrow pointing to the front of the engine. Install the caps in the correct location and direction to prevent engine damage.

Align the capscrew holes in the cap with the holes in the cylinder block.



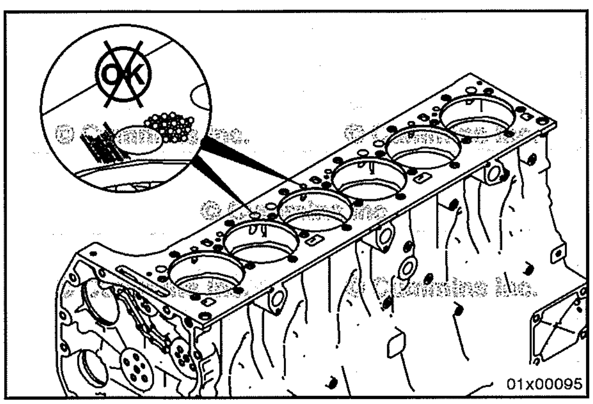
⚠CAUTION⚠

All measurements of the cylinder block must be made when the block is positioned on a flat surface. If the block is mounted on the engine stand, the measurements can be wrong because of distortion.

Inspect the gasket surfaces.

Inspect for burrs or damage.

Use a burr knife or a crocus cloth to remove the burrs.

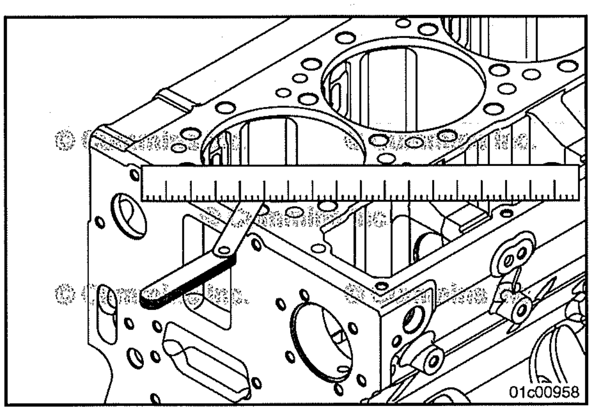


Check the top surface of the block for wear.

Fretting or pitting of the cylinder block head deck is **not** uncommon. It is **only** detrimental to the head gasket joint if the fretting or pitting is close to the coolant or oil passages. These areas, if damaged, prevent the head gasket from sealing.

If fretting damage, scratches, cracks, or corrosion deeper than 0.08 mm [0.003 in] are present in an area where a cylinder, coolant or oil passage makes contact, the surface **must** be repaired. There **must not** be any defect which extends more than 2.41 mm [0.095 in] from the edge of the cylinder, coolant or oil passages.

Fretting wear in any other area is acceptable if it does **not** change the protrusion measurement of the cylinder liner.

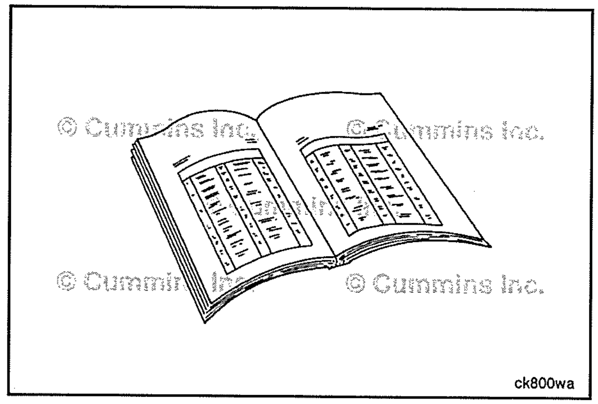


Use a precision straight edge, Part Number 4918219 or equivalent, to check the head deck of the cylinder block for flatness.

The total head deck surface **must** be flat within 0.15 mm [0.006 in] and can **not** vary more than 0.025 mm [0.001 in] within a diameter of 50 mm [1.968 in].

If total head deck surface flatness does **not** meet specifications, the block **must** be replaced.

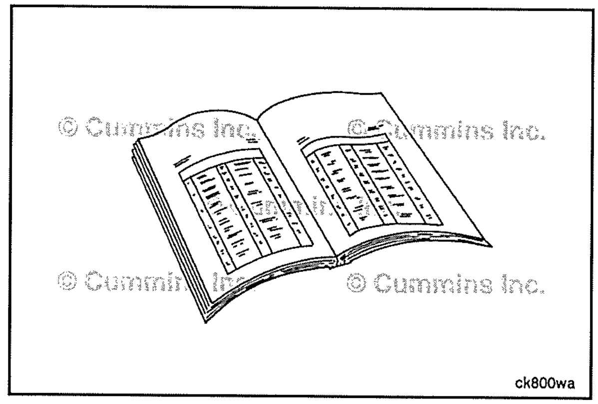
Finishing Steps



- Install the straight thread plugs. Refer to Procedure 017-011 in Section 17.
- If applicable, install the REPTO cup plug. Refer to Procedure 017-002 in Section 17.
- Assemble the engine. Use the procedures in Section AS (Engine Assembly).
- Operate the engine and check for proper operation.

Cylinder Block and Liner Seats (001-027)

Preparatory Steps



WARNING

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

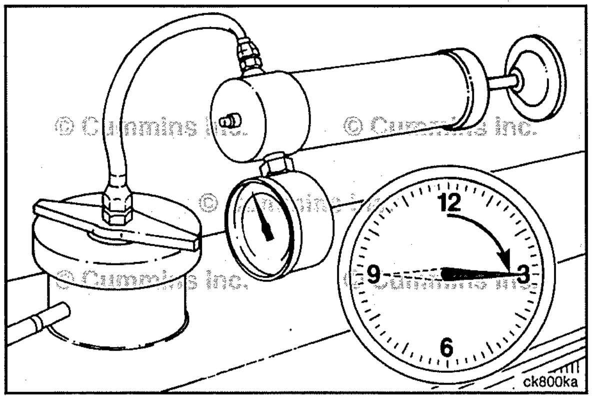
WARNING

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

WARNING

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

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the engine lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.

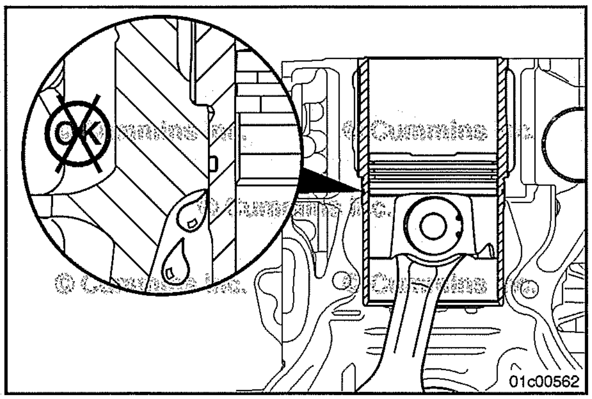


Leak Test

Pressurize the engine cooling system. Refer to Procedure 008-020 in Section 8.

Apply air pressure 15 minutes before inspecting the cylinder liner seats. Be sure the system is holding air pressure before beginning the inspection.

Air Pressure 138 kPa [20 psi]



Inspect the outside circumference of the cylinder liners and the area below the cylinder liner seats in the cylinder block for coolant leaks.

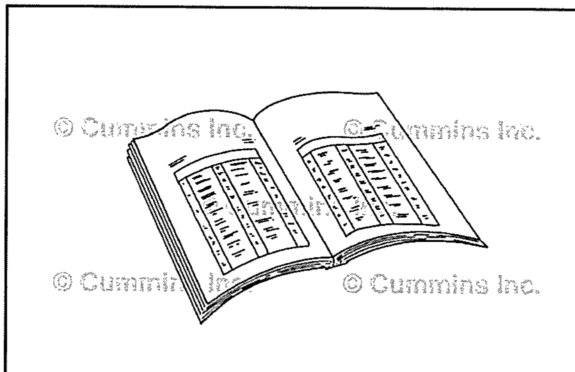
Liner ledge pitting has an appearance very similar to liner pitting. Contributing factors to its formation are combustion gases in the cooling system, poorly maintained coolant chemistry, and excessive load reversal at the liner to cylinder block contact area. Liner ledge pitting starts at the radius and progresses towards the center of the bore. In most circumstances this would **not** be a block malfunction.

To determine if cylinder block meets the reuse guidelines, the following conditions **must** be met. First, the correct liner protrusion **must** be obtainable. Refer to Procedure 001-028 in Section 1. Next, there can be no coolant leaks past the liner seat and the lower o-ring.

If a leak is found:

- Remove and inspect the cylinder liners. Refer to Procedure 001-028 in Section 1.
- Inspect the cylinder block liner bore area. If fretting or wear is found, the cylinder block **must** be replaced.

Finishing Steps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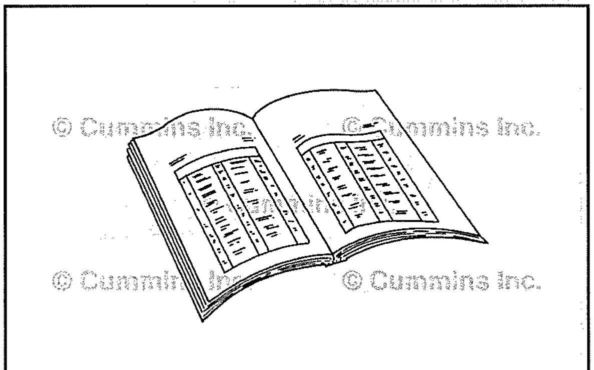
WARNING

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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 block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Prime the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information.
- Operate engine to normal operating temperature and check for leaks.

NOTE: If a malfunction resulted in coolant, oil, excessive fuel or excessive black smoke entering the exhaust system, the aftertreatment system **must** be inspected.

- Use the following procedure to check the aftertreatment selective catalytic reduction (SCR) catalyst. Refer to Procedure 011-036 in Section 11.
- Use the following procedure to check the aftertreatment diesel particulate filter (DPF). Refer to Procedure 011-041 in Section 11.
- Use the following procedure to check the aftertreatment diesel oxidation catalyst (DOC). Refer to Procedure 011-049 in Section 11.



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Cylinder Liner (001-028)

Preparatory Steps

WARNING

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

WARNING

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

WARNING

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

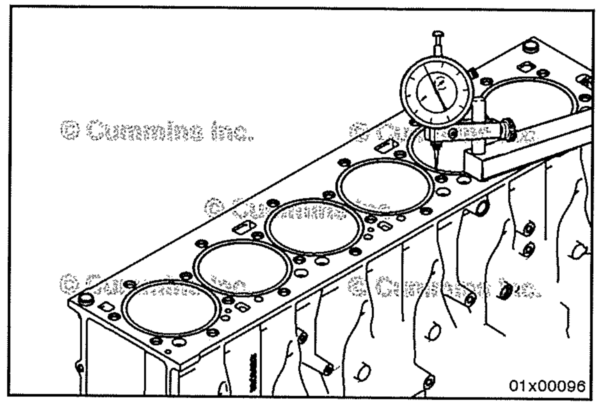
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

NOTE: Cummins Inc. does **not** recommend removing the cylinder liners to reduce oil consumption unless the cylinder liners are damaged and **must** be replaced.

- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the piston cooling nozzles. Refer to Procedure 001-046 in Section 1.
- Remove the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.

Initial Check

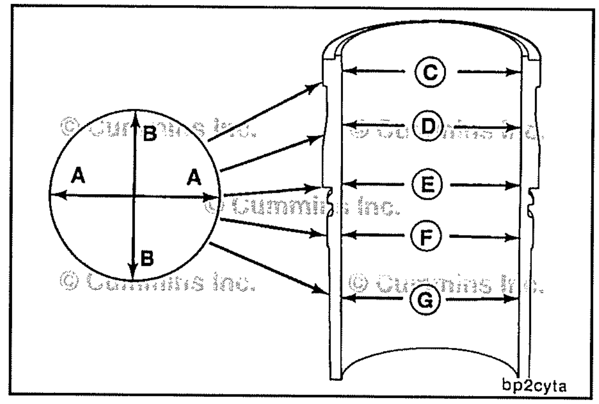
Use a depth gauge, Part Number 3164438, to measure the liner protrusion at four points that are 90 degrees apart.



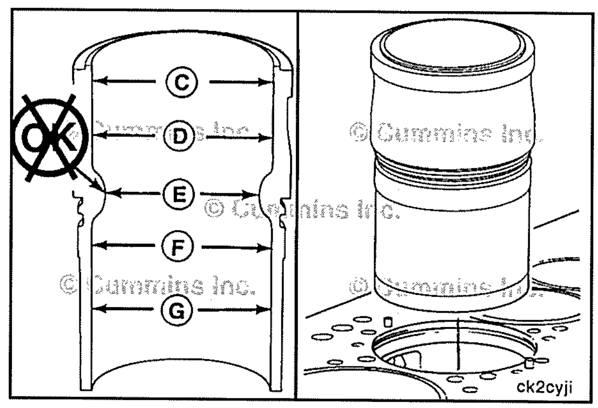
Cylinder Liner Protrusion

mm		in
0.06	MIN	0.002
0.12	MAX	0.005

Measure the liner bore for out-of-roundness at points "C," "D," "E," "F," and "G." Measure each point in the direction "AA" and "BB". The bore **must not** be more than 0.03 mm [0.001 in] out-of-round.

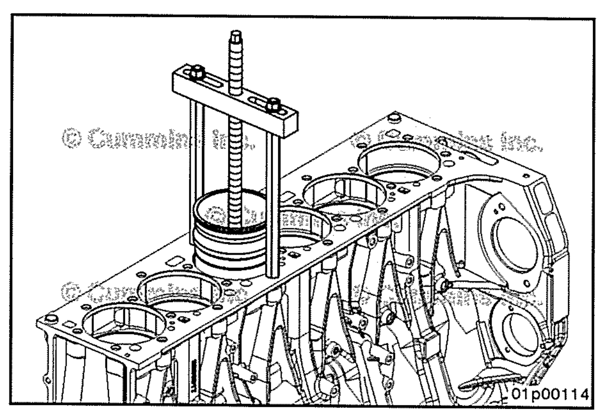


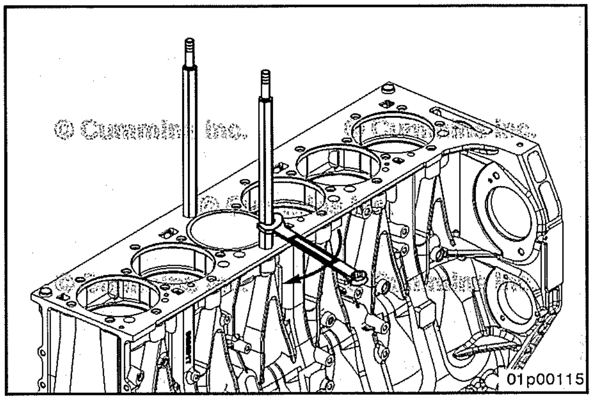
If the liner bore is more than 0.03 mm [0.001 in] out-of-round, remove the liner so the cylinder block liner bore can be measured.



Remove

The cylinder liners can be removed using cylinder liner puller kit, Part Number 5298758.

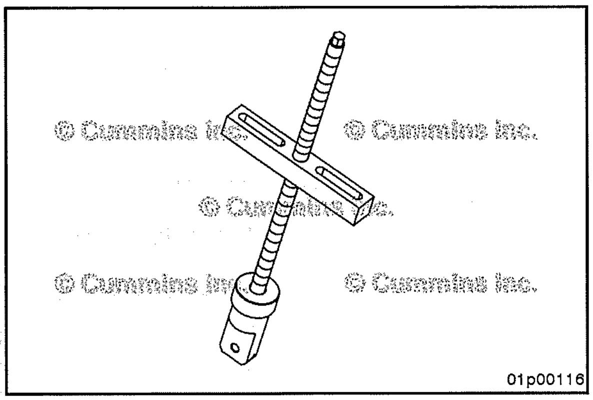




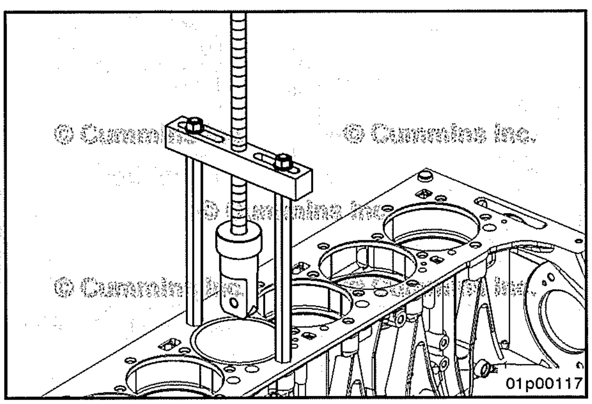
⚠CAUTION⚠

The cylinder liner puller must be installed and used as described to reduce the possibility of damage to the cylinder block. The puller plate must be parallel to the main bearing saddles and must not extend past the cylinder liner outside diameter.

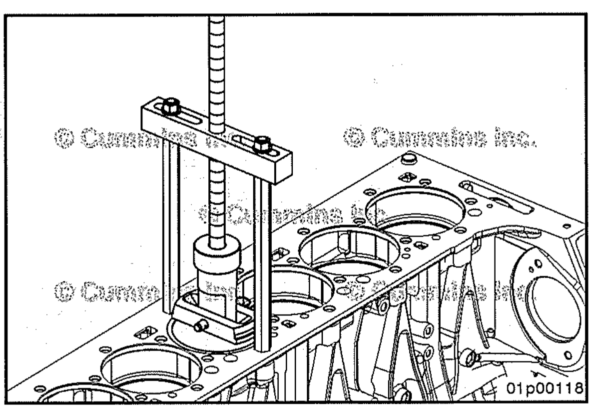
Install legs (5298762) into cylinder head bolt holes on engine block using a 22mm wrench.



Install threaded rod assembly (5298890) into bridge (5298764) (orientation of bridge does **not** matter). Leave 1/4 of threaded rod length hanging below bridge. Puller plate adapter should be below the bridge.



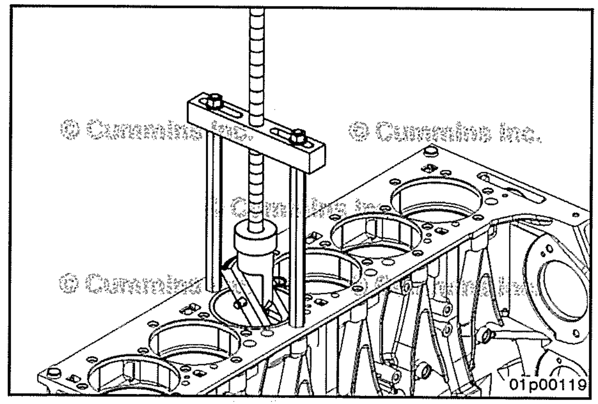
Install bridge and threaded rod assembly onto legs, securing with nuts (5298760). **Only** secure the nuts loosely at this point.



Attach puller plate (5298673) to threaded rod assembly using quick pin (3162878).

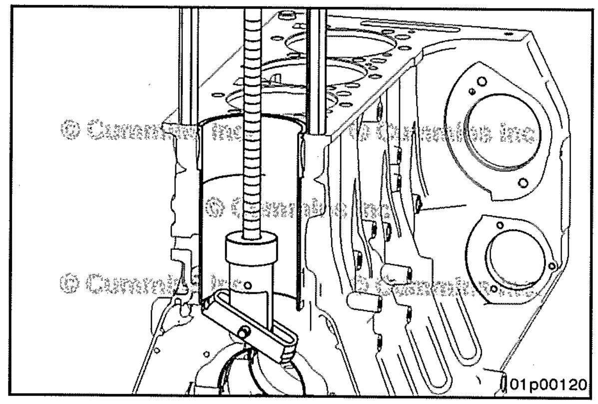
Carefully lower the puller plate by using a 16mm wrench to turn the hex of the threaded rod **clockwise**. Guide the puller plate so that it does **not** scratch the cylinder liner.

NOTE: The puller plate should travel down the cylinder liner in an L-shaped configuration

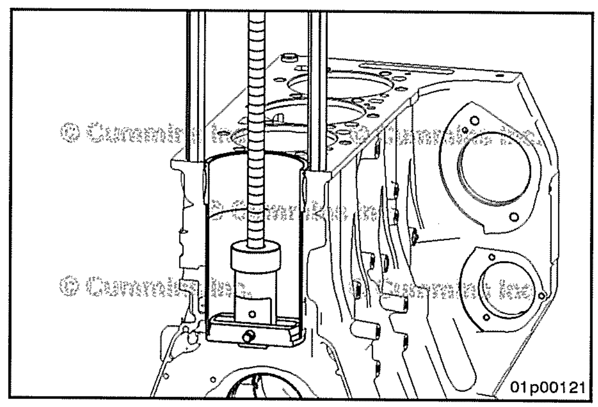


As the threaded rod reaches the end of its travel, allow the puller plate to rotate 90 degrees.

NOTE: It may be necessary to allow the bridge to slide to one side to allow the puller plate to rotate 90 degrees without hitting the crankshaft.

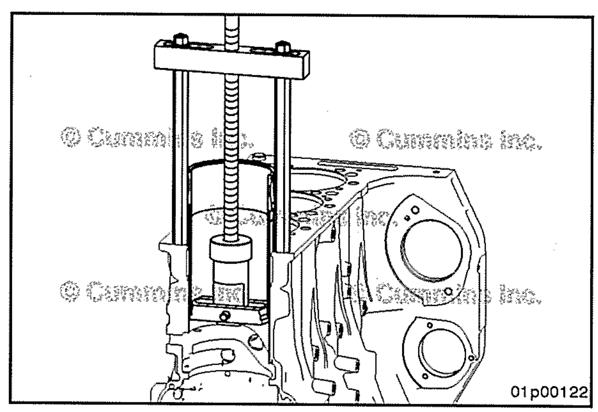


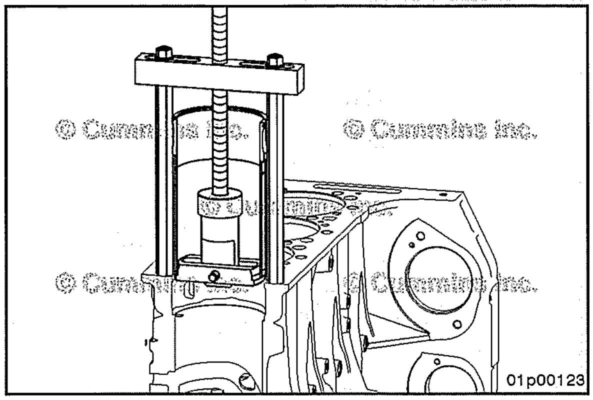
Carefully use a 16mm wrench to turn the hex of the threaded rod **counter clockwise** until the puller plate makes contact with the bottom of the cylinder liner. At this point, ensure that the the puller plate is centered on the cylinder liner, the threaded rod is vertical and the bridge is centered over the cylinder liner. Tighten leg nuts using a 22mm wrench.



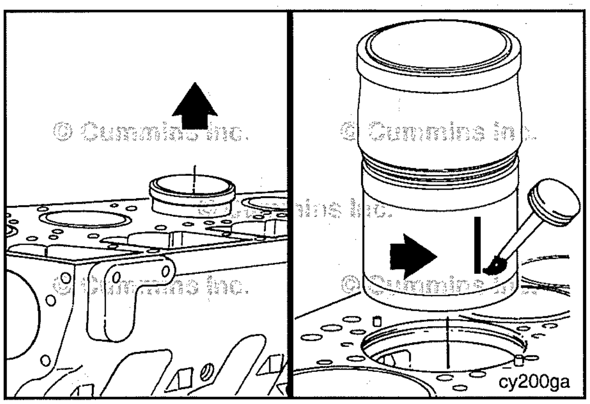
Turn the hex of the threaded rod **counter clockwise** to pull the cylinder liner out. Keep the threaded rod lubricated during removal.

NOTE: The cylinder liner has a full length light press fit with the cylinder block. Moderate force will need to be applied to the wrench to remove the cylinder liner. If it feels like excessive force is being required, stop and ensure that the puller plate & bridge are still centered over the cylinder liner.

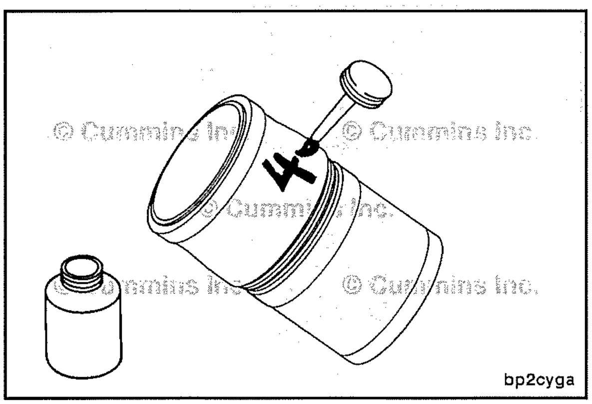




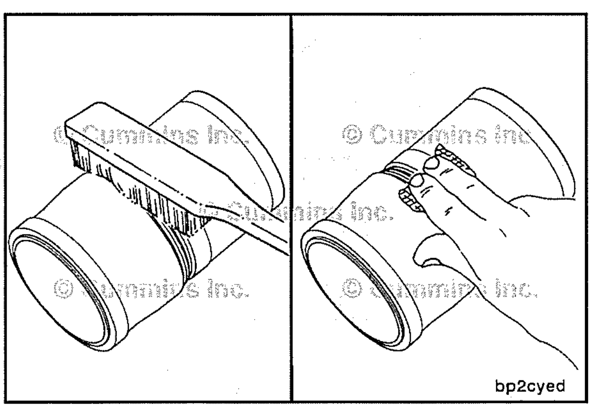
Once the cylinder liner is free of the block, disassemble tool as required to free the cylinder liner.



When the liner is removed from the cylinder block, use Dykem™, or equivalent, to place a mark on the camshaft side of the liner to show liner orientation.



Use Dykem™, or equivalent, to mark the cylinder number on each liner.



Clean and Inspect for Reuse

⚠CAUTION⚠

Do not use emery cloth or sandpaper to remove carbon from the cylinder liners. Aluminum oxide or silicon particles from emery cloth or sand paper can cause serious engine damage. Do not use any abrasives in the ring travel area. The cylinder liner can be damaged.

Use a soft wire brush to clean the flange seating area.

Use a fine, fibrous, abrasive pad such as Scotch-Brite™ 7448, or equivalent, to remove the remaining scale and rust.

⚠WARNING⚠

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

⚠WARNING⚠

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

⚠WARNING⚠

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

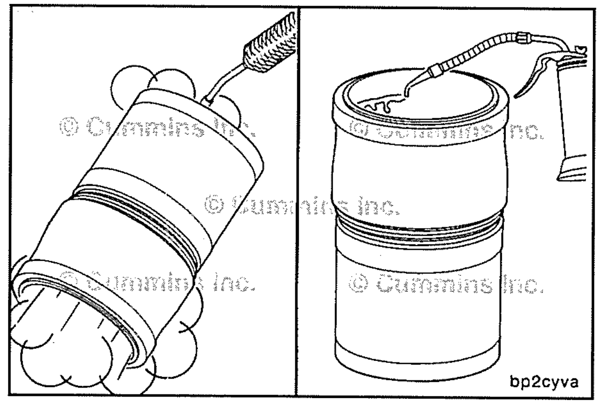
⚠WARNING⚠

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

Use solvent or steam to clean the liners, and dry with compressed air.

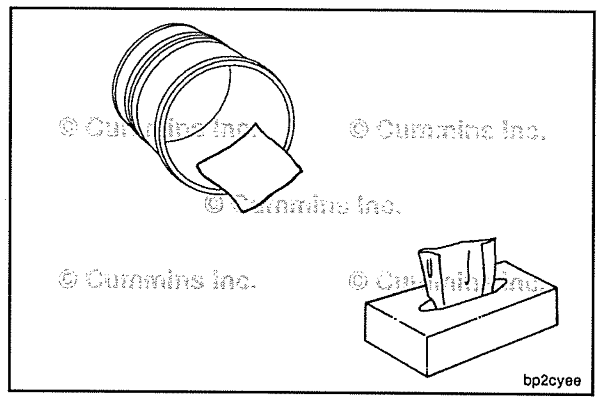
Use clean engine oil to lubricate the inside diameter of the liners.

Allow the oil to soak into the liners for 5 to 10 minutes.

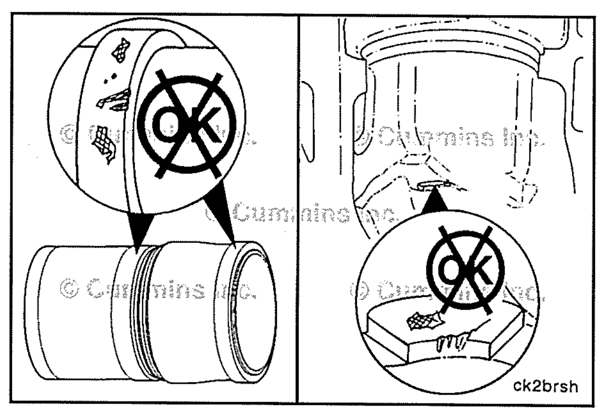


Use lint-free paper towels to wipe the excess oil from the inside of the cylinder liners.

Continue to lubricate the inside of the cylinder liners and wipe them clean until the paper towel shows no gray or black residue.

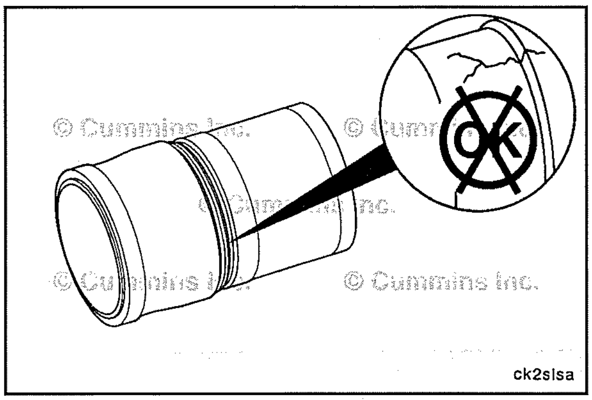


Inspect the liners and cylinder block for dirt or damage.



Inspect the liners for cracks on the inside and outside diameters.

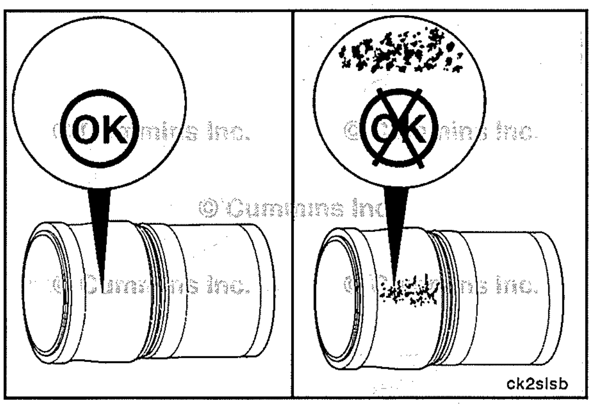
If cracks are found, the liner **must** be replaced.



Inspect for cracks under the cylinder liner flange.

Cracks can also be detected using either magnetic inspection or the dye penetrant method.

If cracks are found, the liner **must** be replaced.

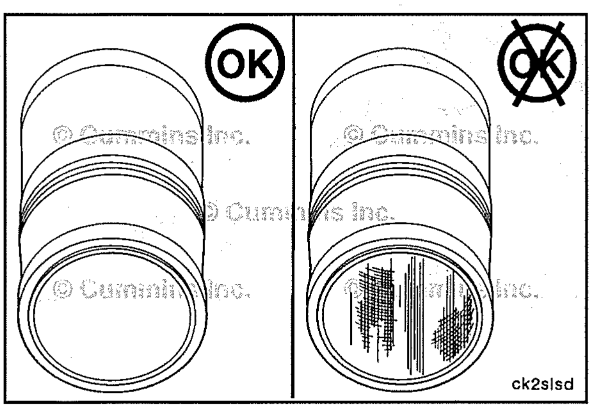


Inspect the outside circumference for excessive corrosion or pitting.

Cylinder liners with pitting generally can **not** be used.

However, if the pitting is light and can be removed with fine emery cloth, the cylinder liner can be used.

Max Cylinder Liner Pitting Depth		
mm		**in**
1.40	MAX	0.055



Inspect the inside surface for vertical scratches deep enough to be felt with a fingernail.

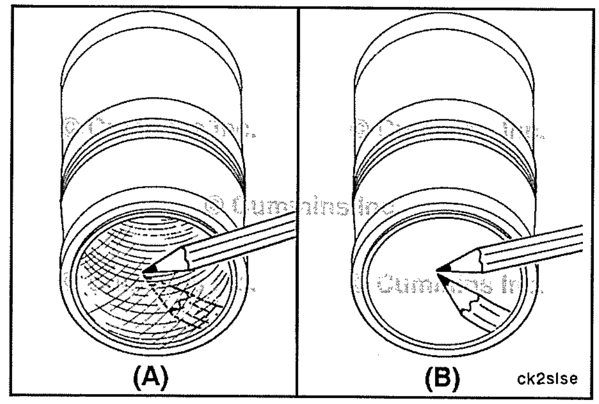
If a fingernail catches in the scratch, the cylinder liner **must** be replaced.

Inspect the inside surface for scuffing or scoring.

Inspect the inside surface for cylinder liner bore polishing.

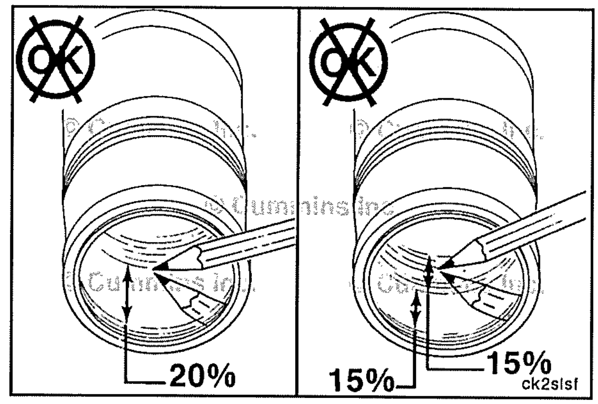
A moderate polish (A) produces a mirror finish in the worn area with traces of the original hone marks or an indication of an etch pattern.

A heavy polish (B) produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.



Replace the cylinder liner if:

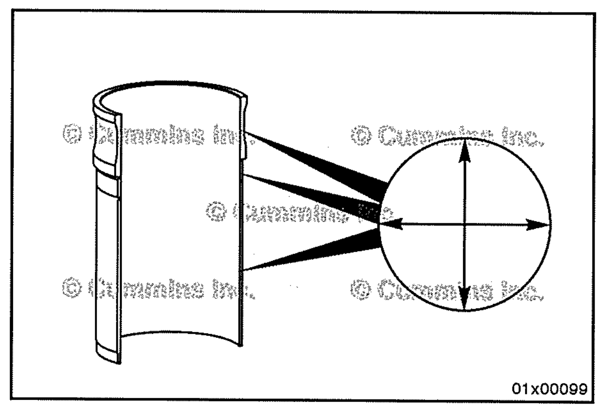
- A heavy polish is present over 20 percent of the piston ring travel area.
- 30 percent of the piston ring travel has both moderate and heavy polish and one half (15 percent) is heavy polish.



Measure

Use a dial bore gauge to measure the liner inside diameter in four places, 90-degrees apart, at the top and bottom of the piston travel area.

Cylinder Liner Inside Diameter		
mm		in
132.00	MIN	5.1966
132.04	MAX	5.1984

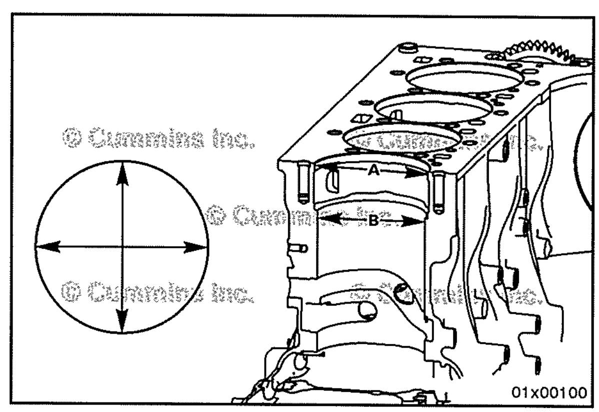


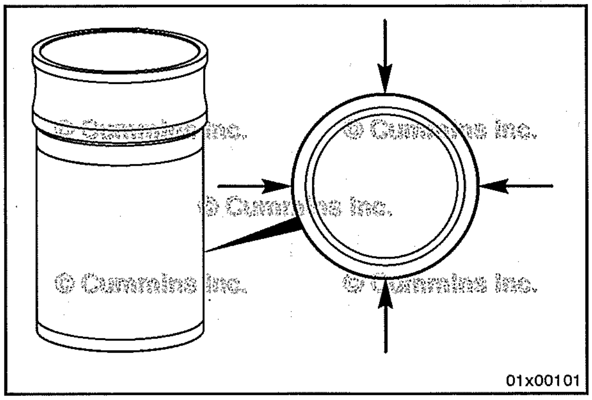
Measure the cylinder block upper liner bore (A).

Cylinder Block Upper Liner Bore Inside Diameter (A)		
mm		in
145.475	MIN	5.727
145.525	MAX	5.729

Measure the cylinder block liner seal seat bore (B) 8 to 13.5 mm [0.31 to 0.53 in] below the counterbore.

Cylinder Block Liner Seal Seat Bore Inside Diameter (B)		
mm		in
138.475	MIN	5.452
138.525	MAX	5.454



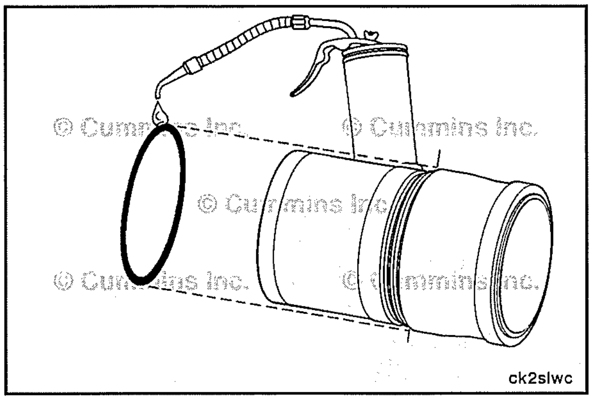


Measure the liner outside diameter (A).

Cylinder Liner Press Fit Outside Diameter (A)

mm		in
137.95	MIN	5.43
138.45	MAX	5.45

The cylinder block liner counterbore flange diameter is **not** a critical dimension and does **not** need to be measured.

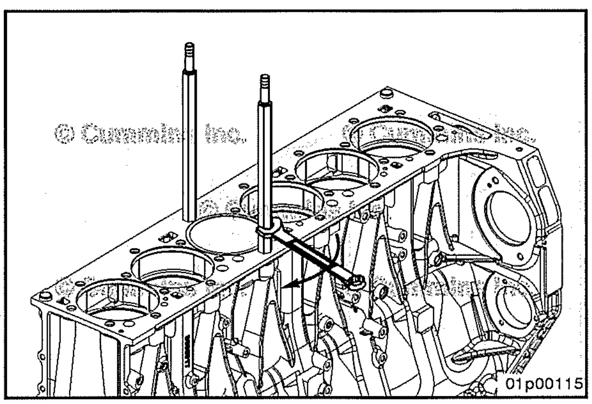


Install

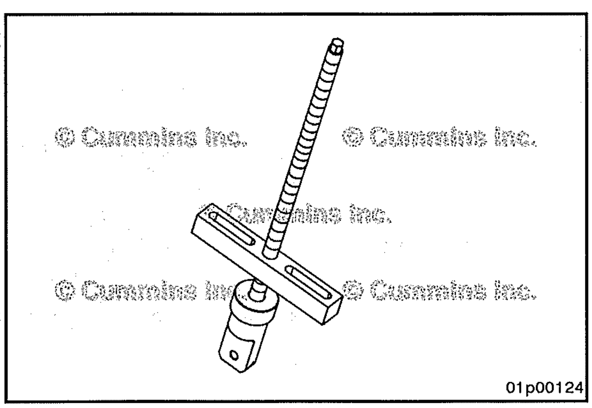
Make sure the cylinder block and all parts are clean before assembly.

Use clean oil to coat the liner o-ring seals.

Install the o-ring seal on the liner. Make sure the o-ring seal does **not** roll during installation.

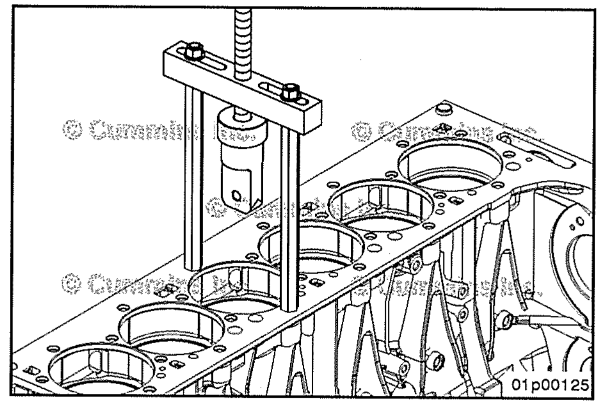


Install legs (5298762) into cylinder head bolt holes on engine block using a 22mm wrench.

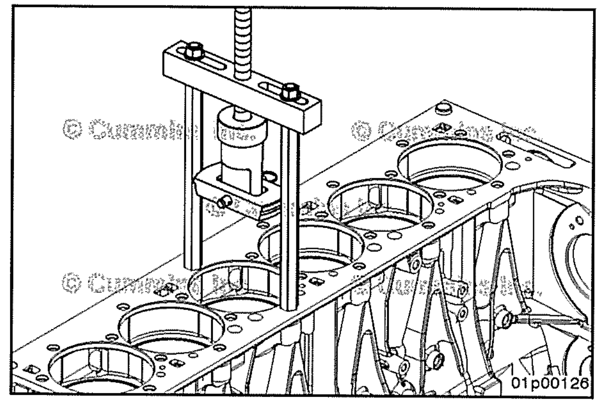


Install threaded rod assembly (5298890) into bridge (5298764) (orientation of bridge does **not** matter). Puller plate adapter should be at the bridge, leaving most of the threaded rod length hanging out one side of the bridge.

Install bridge and threaded rod assembly onto legs, securing with nuts (5298760). **Only** secure the nuts loosely at this point.



Attach puller plate (5298673) to threaded rod assembly using quick pin (3162878).



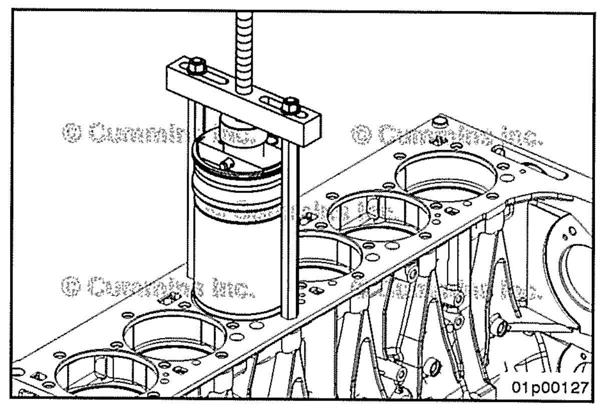
Place the cylinder liner in the engine block. Ensure that it remains vertical during the installation procedure.

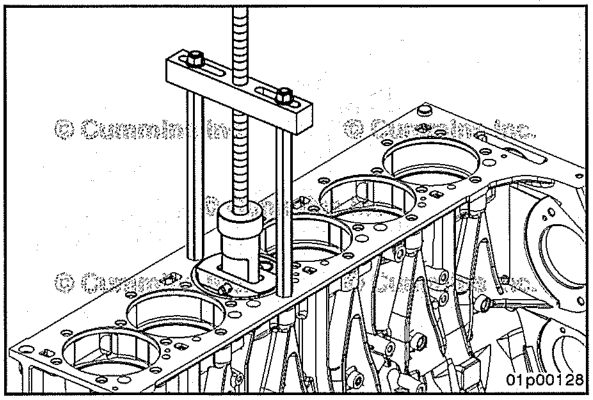
When acceptable used liners are installed, rotate the liners 90 degrees from their original position in the engine. Original thrust and anti-thrust surfaces **must** face the front and back of the cylinder block.

Using a 16mm wrench, turn the hex of the threaded rod **clockwise** until the puller plate makes contact with the top of the cylinder liner. At this point, ensure that the puller plate is centered on the cylinder liner, the threaded rod is vertical and the bridge is centered over the cylinder liner. Tighten leg nuts.

If the liner does **not** seat properly, remove the liner. Inspect the counterbore seat and liner for nicks, burrs, and dirt.

Install the liner again.

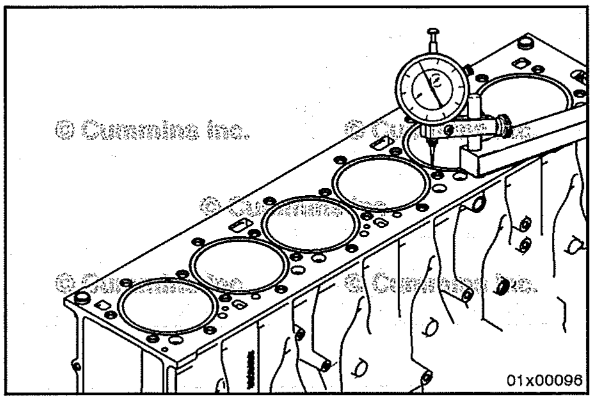




Carefully turn the hex of the threaded rod **clockwise** 1-2 full turns. Ensure that the cylinder liner is entering the cylinder block bore properly and is remaining vertical. If the cylinder liner is **not** remaining vertical, or if excessive force is required on the wrench, remove liner and inspect for debris that might be preventing proper installation.

Continue to turn the hex of the threaded rod **clockwise** to press the cylinder liner in. Keep the threaded rod lubricated during installation.

NOTE: The cylinder liner has a full length light press fit with the cylinder block. Moderate force will need to be applied to the wrench to remove the cylinder liner. If it feels like excessive force is being required, stop and ensure that the puller plate & bridge are still centered over the cylinder liner.



The cylinder liner protrusion **must** be checked before installing the pistons and connecting rods.

Use a depth gauge, Part Number 3164438, to measure the liner protrusion at four points that are 90 degrees apart.

Cylinder Liner Protrusion		
mm		**in**
0.06	MIN	0.002
0.12	MAX	0.005

- The difference between the lowest cylinder liner and the highest cylinder liner can **not** be greater than 0.102 mm [0.004 in].
- The maximum allowable difference between adjacent cylinders is 0.051 mm [0.002 in].
- The protrusion **must** be within 0.0381 mm [0.0015 in] around any cylinder.

Finishing Steps

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

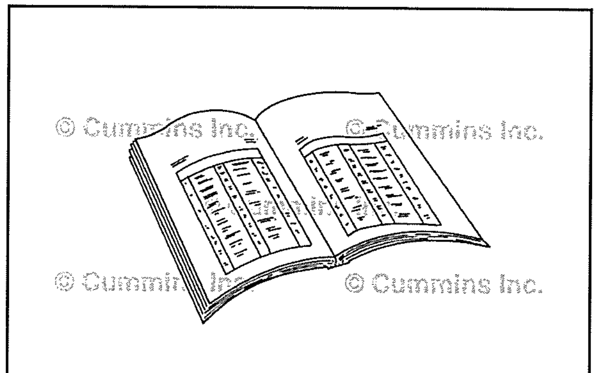
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

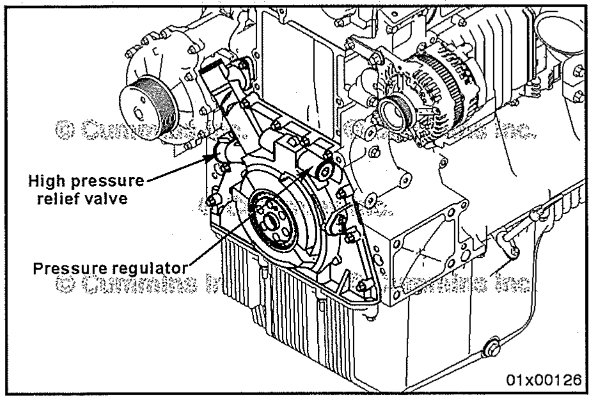
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

- Install the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.
- Install the piston cooling nozzles. Refer to Procedure 001-046 in Section 1.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Operate the engine to normal operating temperature and check for proper operation and leaks.

NOTE: All engines **must** be run-in after a rebuild or a repair involving the replacement of one or more piston ring sets, cylinder liners, or pistons. Use one of the following two procedures to complete the run-in procedure. Refer to Procedure 014-004 in Section 14.

- Use the following procedure for general run-in test overview. Refer to Procedure 014-004 in Section F.


ck800wa



01x00126

Gear Cover, Front (001-031)

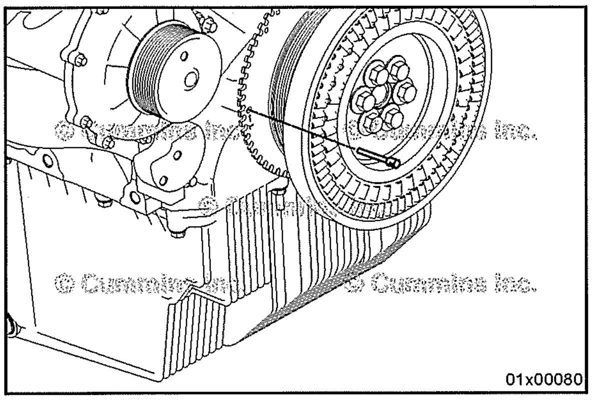
General Information

This engine features a rear gear train design and a rotor style lubricating oil pump mounted the front of the engine. The lubricating oil pressure regulator and lubricating oil high pressure relief valves are located in the lubricating oil pump housing.

Refer to Procedure 007-031 in Section 7 for more information on the lubricating oil pump.

Refer to Procedure 007-029 in Section 7 for more information on the lubricating oil pressure regulator.

Refer to Procedure 007-021 in Section 7 for more information on the lubricating oil high pressure relief valve.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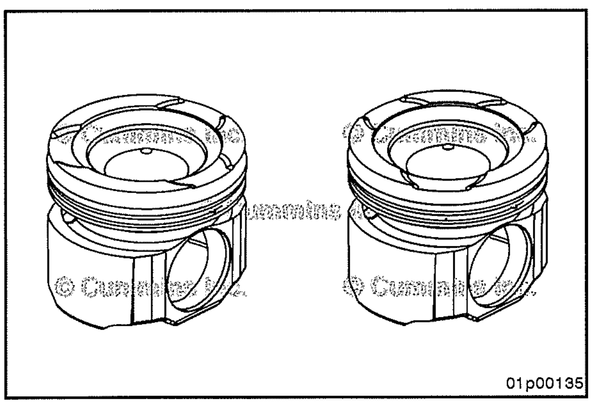
The crankshaft pin boss hole is located in the lubricating oil pump housing. The crankshaft locking pin is inserted through the crankshaft pulley into the crankshaft pin boss hole to hold the crankshaft in place for service.

Refer to Procedure 001-088 in Section 1 for more information on the crankshaft pin boss hole.


01p00135

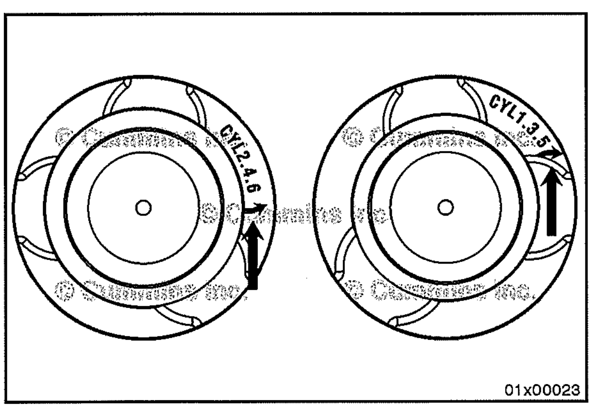
Piston (001-043)

General Information

This engine configuration has a one-piece piston, which does **not** have a bushing. The piston is forged from a high-strength alloy steel.

A cover plate, which is **not** removable, is located on the underside of the piston to capture oil and cool the piston.

Do **not** remove this cover plate under any circumstances.



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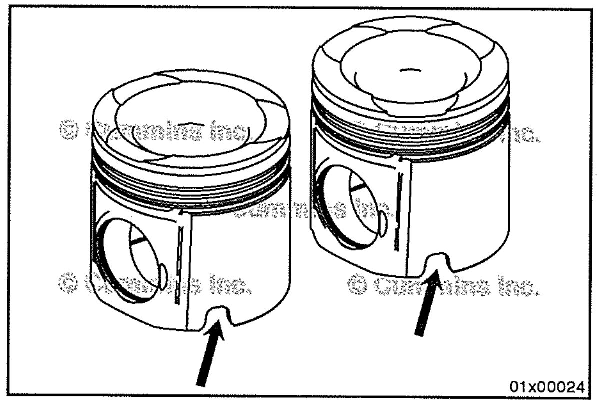
There are two different pistons on this engine. One piston is used in cylinders 1, 3, 5. The other piston is used in cylinders 2, 4, 6.

Each piston is stamped with 1, 3, 5 or 2, 4, 6 on top to show which cylinders it should be used in.

Each piston has an arrow on the top that points towards the front of the engine.

Each piston has a notch in it that faces the rear of the engine.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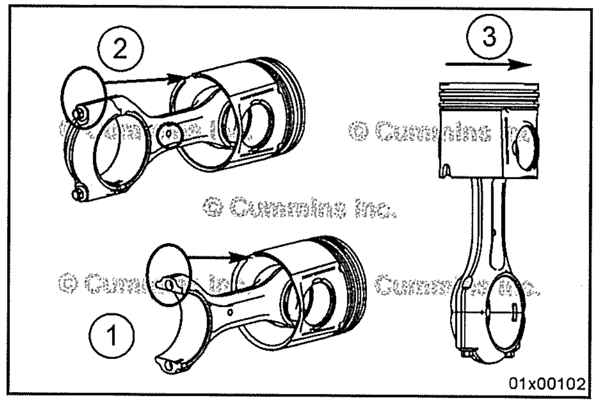
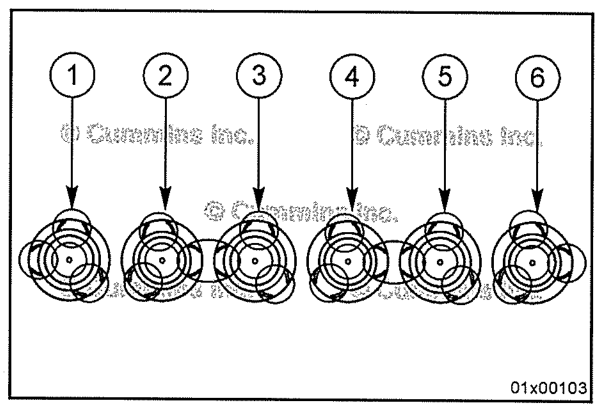
Piston and connecting rod orientation.

1 Tang is under skirt notch.
2 Dimples are under notch.
3 Arrow points to front of engine.



01x00102

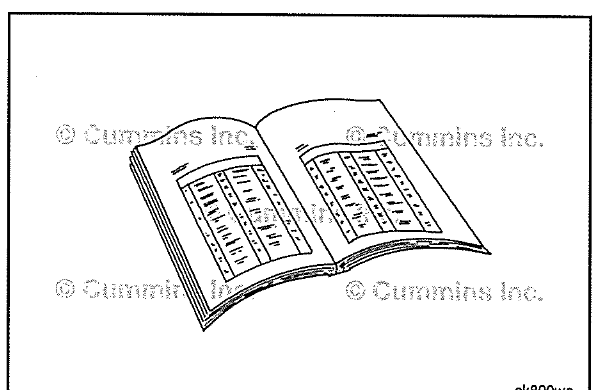
Pay close attention to the valve configuration if 1, 3, 5 or 2, 4, 6 is **not** legible on the top of the piston. See graphic for valve configuration.



01x00103

Preparatory Steps

- Remove and disassemble the piston and connecting rod assemblies from the engine. Refer to Procedure 001-054 in Section 1.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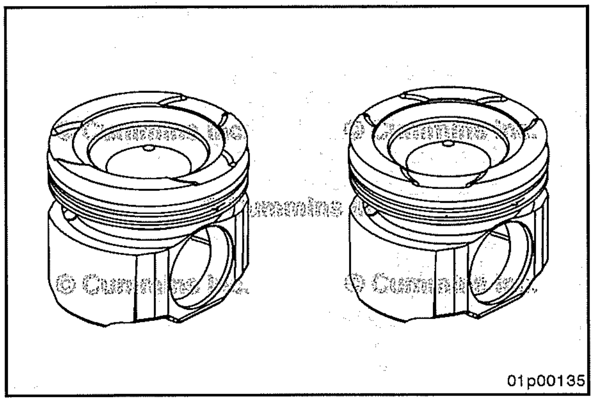
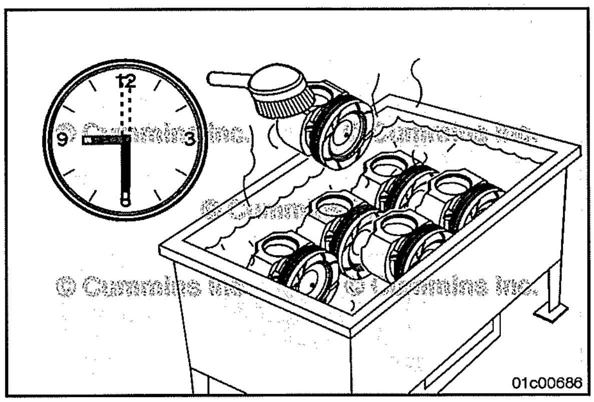


Clean and Inspect for Reuse

CAUTION

Never, under any circumstances, remove the flat, oil cover plate located on the underside of the single-piece pistons.



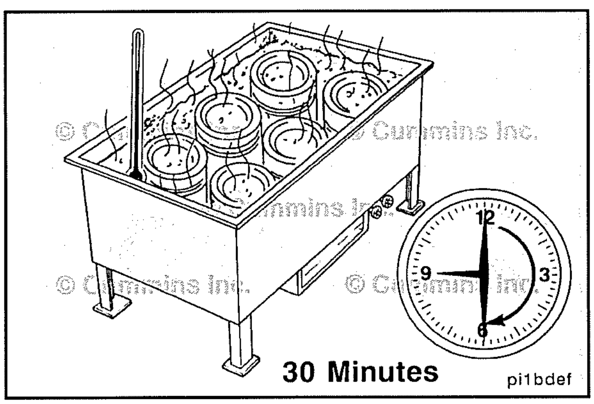
WARNING

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

If necessary, brush the pistons with a soft non-metallic brush. A metallic brush can damage the piston ring grooves.

It is **only** necessary to remove the carbon buildup. It is **not** necessary to make the crown appear to be new.



CAUTION

When using walnut shell blast to clean steel pistons, use the minimum recommended pressure and do not concentrate the blast in any one area for extended lengths of time. To prevent damage of the surface finish, make sure the pin bore area is protected from the blast.

Do **not** use glass or plastic bead media to clean the piston crowns.

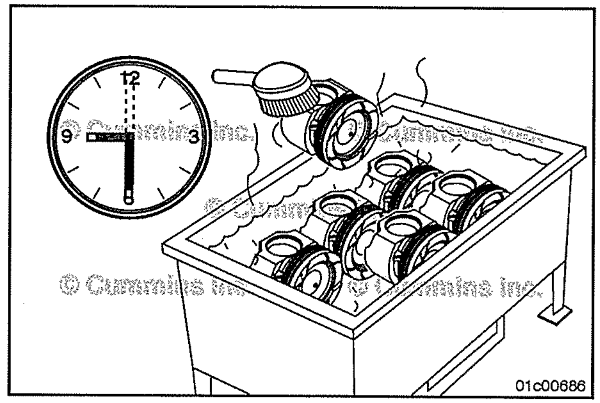
Carbon deposits can be cleaned from the pistons by soaking in an approved solution and/or by blasting with walnut shell media.

Soak steel pistons for at least 30 minutes in an approved cleaning solvent for steel. Use a non-metallic brush to remove carbon deposits.

For best results, soak the pistons for several hours or overnight.

CAUTION

If necessary, brush the pistons with a soft non-metallic brush. A metallic brush can damage the surface finish.



01c00686

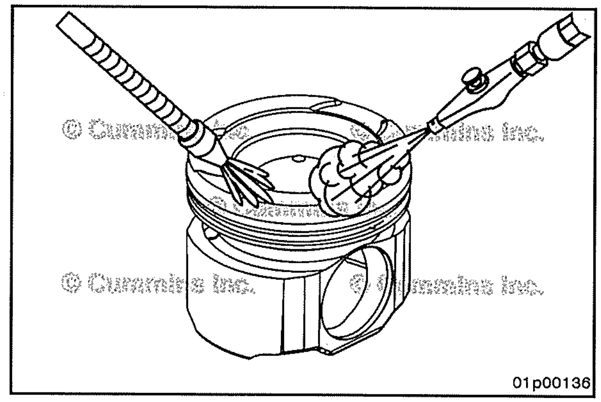
WARNING

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

Use solvent to clean the pistons.

Dry with compressed air.

Make certain there is **not** walnut shell blast media remaining between the oil cover plate and the piston.



01p00136

CAUTION

Do not use pistons with cracks. If the crown is cracked, the piston must be replaced. Failure to replace the damaged piston can cause serious engine damage.

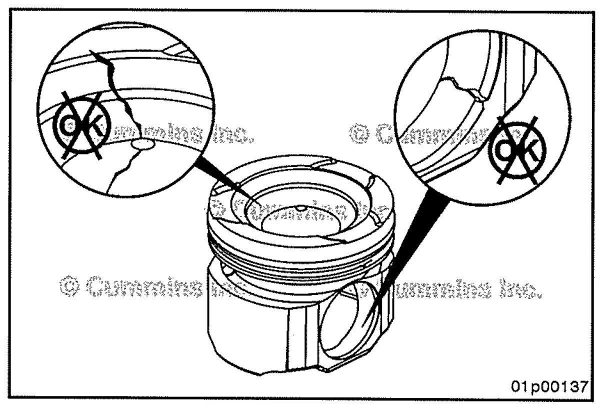
Inspect the piston bowl for cracks and other damage.

Inspect the piston pin bore for cracks, scratches, galling, dents, and other damage.

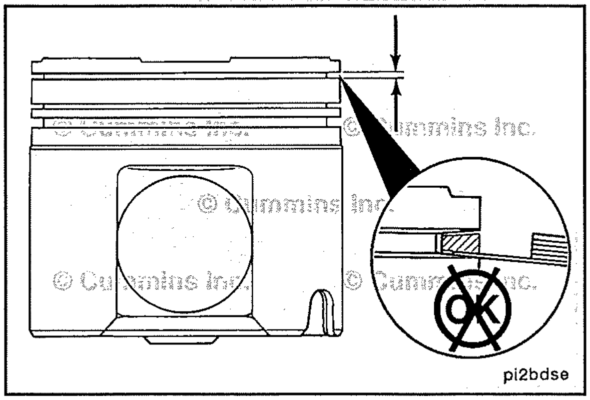
If significant damage is found, the piston **must** be replaced.

Inspect the piston second land for scuffing. See the Single Piece, Open Skirt Piston Reuse Guidelines, Bulletin 4021925.

Inspect the skirt for scratches. In general, if the scratches can be felt with a fingernail, do **not** reuse the piston.

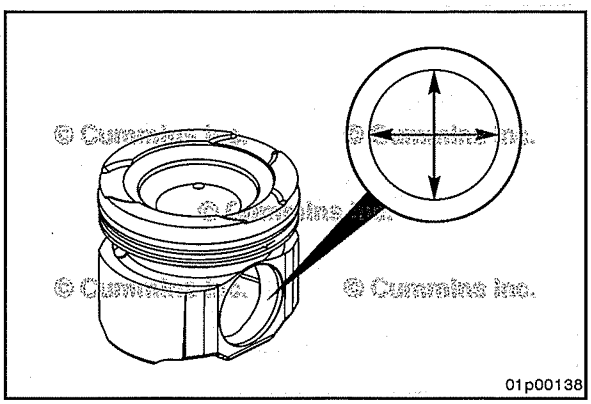


01p00137



The ring groove can be inspected with a new ring and a feeler gauge.

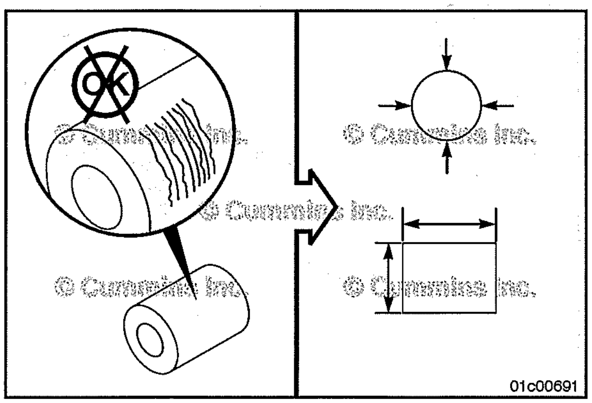
Hold a new ring in the groove even with the outside diameter of the piston. Install a 0.15-mm [0.006-in] feeler gauge. If the feeler gauge enters the groove without resistance, replace the piston.



Measure the piston pin bore inside diameter.

Pin Bore Inside Diameter

mm		in
58.1240	MIN	2.2883
58.1090	MAX	2.2877



Inspect the piston pin for scratches, grooves, and other damage. Do **not** reuse the pin if it is visually unacceptable.

Measure the piston pin outside diameter.

Piston Pin Outside Diameter

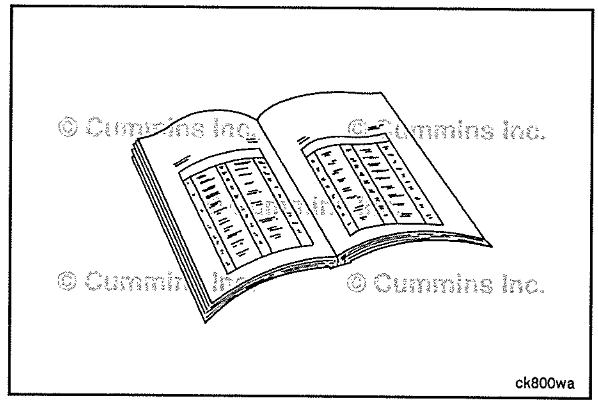
mm		in
58.0035	MIN	2.2836
57.9965	MAX	2.2833

Measure the piston pin length.

Piston Pin Length

mm		in
90.38	MIN	3.56
89.62	MAX	3.53

Finishing Steps



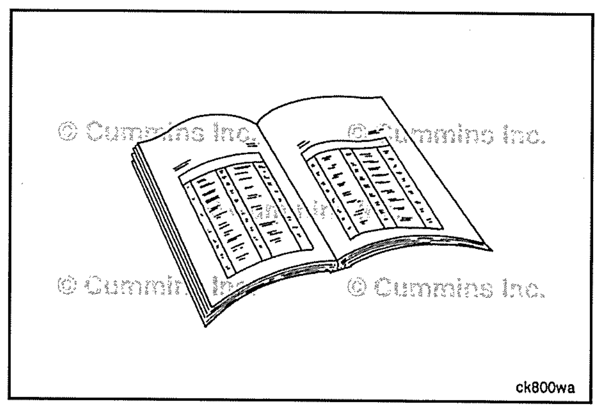
- Assemble the piston and connecting rod. Refer to Procedure 001-054 in Section 1.
- Install the piston and connecting rod assembly.Refer to Procedure 001-054 in Section 1.
- If failure resulted in coolant, oil, excessive fuel, or excessive black smoke entering the exhaust system, the aftertreatment system **must** be inspected.
  - Use the following procedure to check the aftertreatment selective catalytic reduction (SCR) catalyst. Refer to Procedure 014-015 in Section 14.
  - Use the following procedure to check the aftertreatment diesel particulate filter (DPF).Refer to Procedure 014-016 in Section 14.
- Operate the engine to normal operating temperature and check for leaks and proper operation.

NOTE: All engines **must** be run-in after a rebuild or a repair involving the replacement of one or more piston ring sets, cylinder liners, or pistons. See Section 14 (Engine Testing) for the appropriate run-in procedure.

- Use the following procedure for a general run-in test overview. Refer to Procedure 014-999 in Section F.

Piston Cooling Nozzle (001-046)

Preparatory Steps



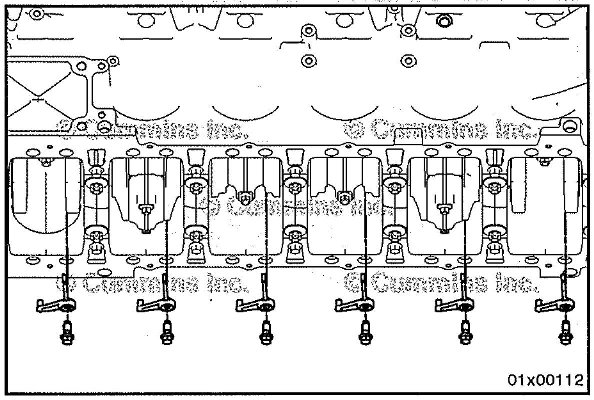
⚠WARNING⚠

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

⚠WARNING⚠

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

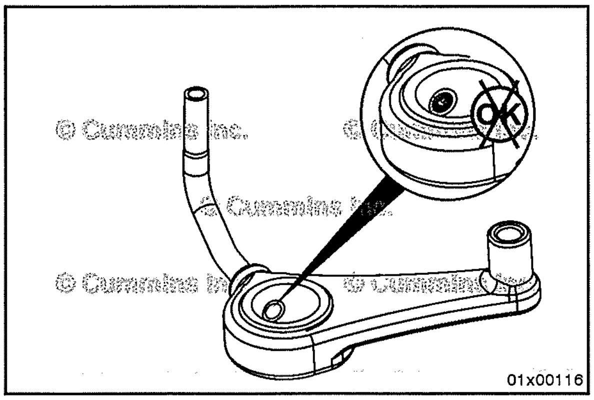
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.



Remove

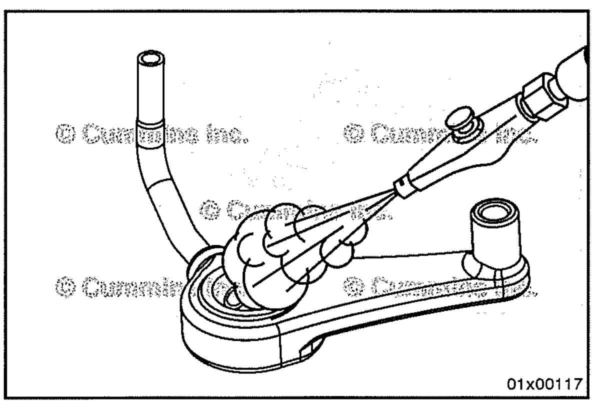
The crankshaft **must** be rotated to allow access to remove all of the nozzles. Refer to Procedure 000-017 in Section 0.

Remove the piston cooling nozzle capscrews and nozzles.

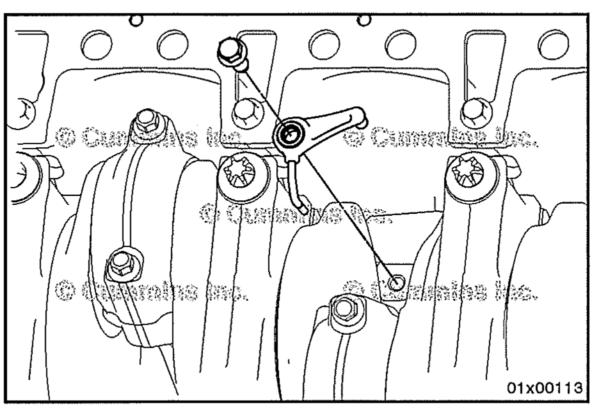


Clean and Inspect for Reuse

Inspect the piston cooling nozzles for damage. If any damage is found, replace the piston cooling nozzle.



Clean with compressed air. Run air through the nozzle and the banjo fitting.



Install

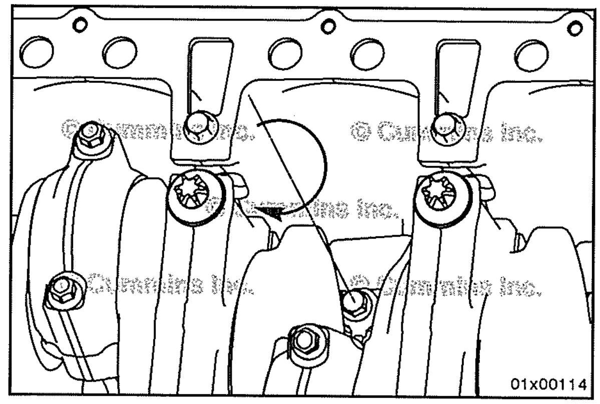
The crankshaft **must** be rotated to allow access to install all of the cooling nozzles. Refer to Procedure 000-017 in Section 0.

Align and install the piston cooling nozzle and capscrew.

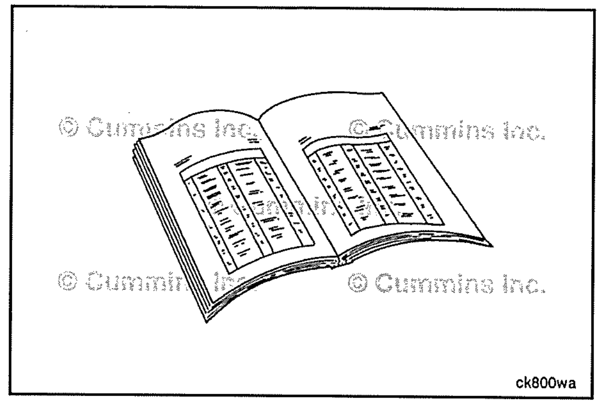
Ensure that the locating pin is inserted into block.

Tighten the capscrews.

Torque Value: 28 N•m [248 in-lb]



Finishing Steps



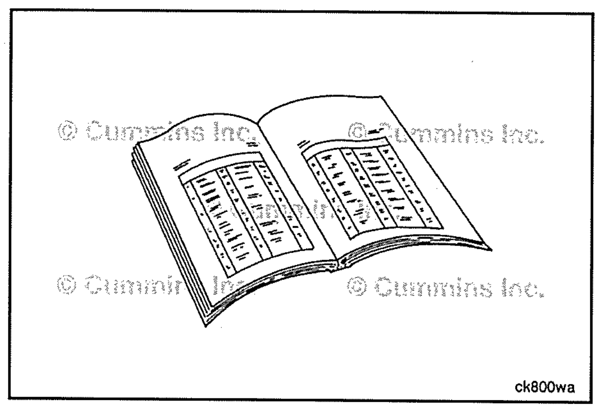
⚠WARNING⚠

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

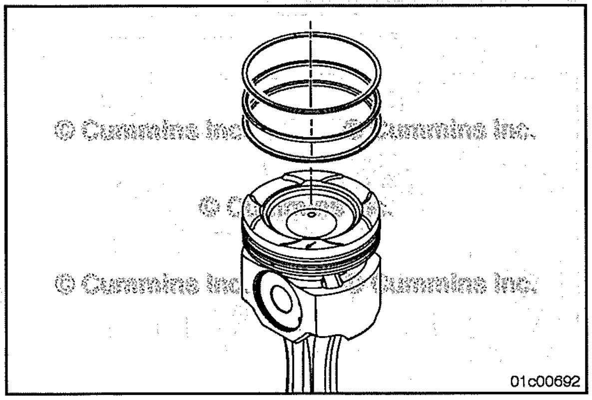
- Install the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill and prime the engine with clean lubricating oil. Refer to Procedure 007-037 in Section 7.
- Operate the engine to normal operating temperature and check for oil leaks.

Piston Rings (001-047)

Preparatory Steps



- Remove and disassemble the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.

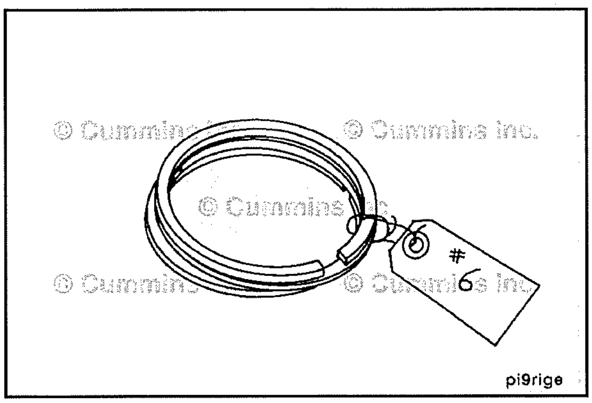


Remove

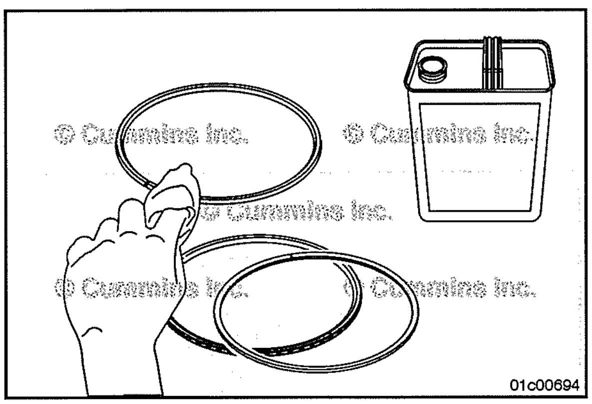
⚠CAUTION⚠

Do not over-expand second piston ring.

Remove the piston rings.



Place a tag on the rings, and record the cylinder number of the piston on the tag for future use, if required.

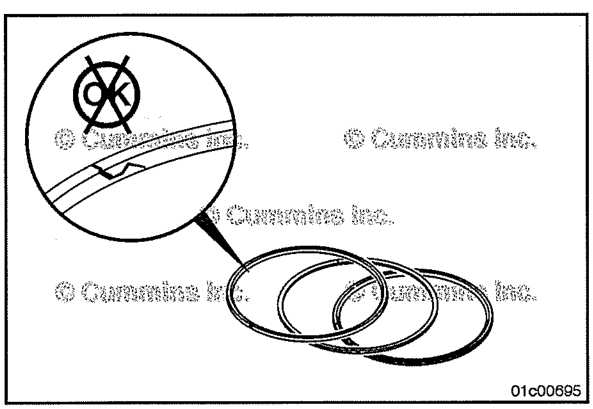


Clean and Inspect for Reuse

⚠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 rings with mineral spirits.



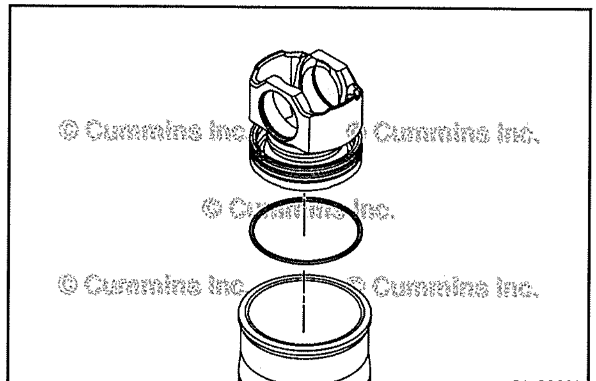
Inspect all rings for any cracks or chips on the ring face that mates with the liner.

Discard and replace any rings that are damaged.

Measure

To check the ring cap, install the piston rings into the cylinder liner in which they were used, below the ring reversal area.

Use the top part of the piston to correctly position the ring in the liner.

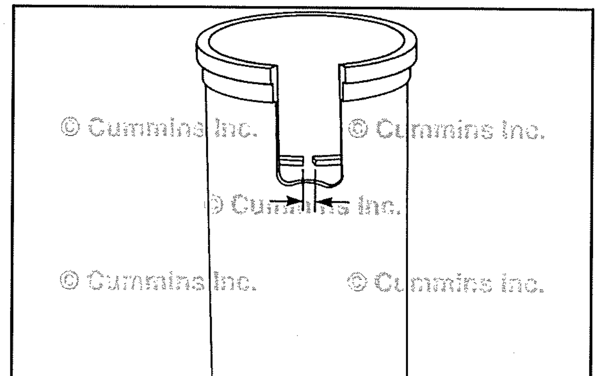


01c00696

Use a feeler gauge to inspect the ring end cap.

Piston Ring Gap

	mm		in
Top	0.27	MIN	0.011
	0.37	MAX	0.015
Second	0.45	MIN	0.018
	0.59	MAX	0.023
Oil	0.25	MIN	0.010
	0.50	MAX	0.020



pi1ritb

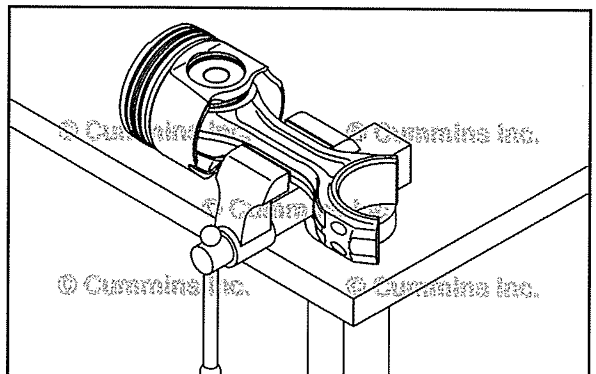
Install

⚠CAUTION⚠
Use a copper or aluminum vise protector when installing the connecting rod in a vise to protect the connecting rod from damage.

When reusing piston rings, be sure the rings are installed on the same piston from which they were removed.

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

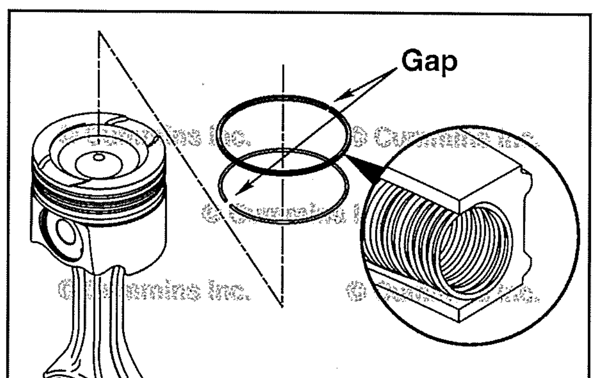
Install the connecting rod in a vise to hold the assembly in a horizontal position while installing the rings.



01c00566

A cross-sectioned view of an oil control ring is shown.

The two-piece oil control ring **must** be installed with the expander ring gap 180 degrees from the gap of the oil ring. Do **not** overlap the ends of the expander ring.



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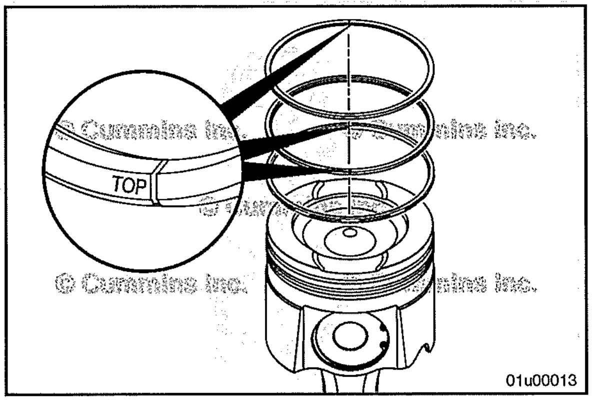
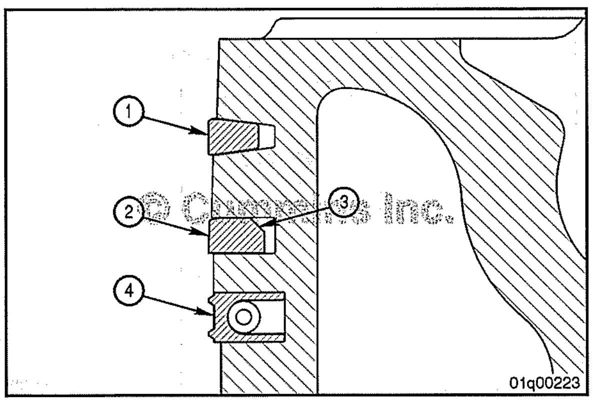


Each ring has the top marked for correct installation.

Install the piston rings with TOP toward the top pf the piston.

NOTE: The oil control ring is symmetrical for this engine.

Use a universal piston ring expander to install the second ring into the piston.

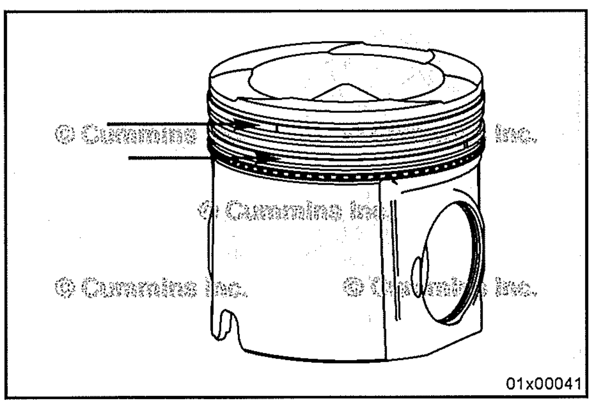


The piston **must** be held in a horizontal position to install the rings in order to keep the rings in the groove while installing the ring compressor.

The top piston ring (1) is a keystone ring with no twist or cutback notch.

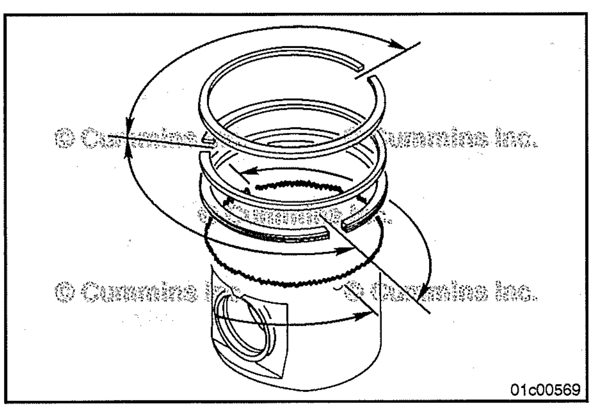
The second ring has a rectangular cross-section (2) with an angled cut (3) on the upper side of the inner diameter to induce a positive twist. This design improves the slobber-resistance of the ring pack.

The oil control ring (4) is the bottom piston ring.



When installing new piston rings:

- The top ring will show an orange paint stripe to the left of the gap.
- The middle ring will show a yellow paint stripe to the left of the gap.



Rotate the rings to position the ring gaps 120° apart as shown.

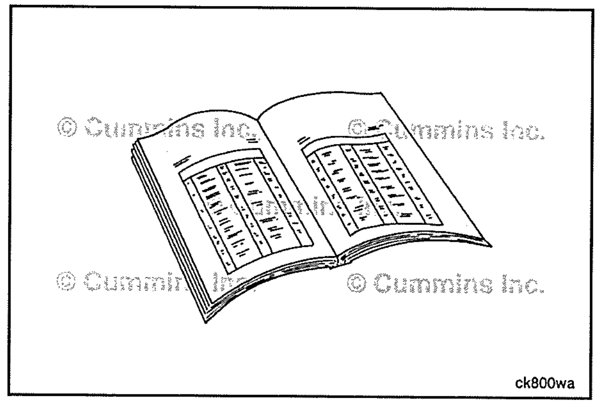
The ring gap of each ring **must not** be aligned with the piston pin, or with any other ring gap. If the ring gaps are **not** positioned correctly, the rings will **not** seal properly.

If a malfunction resulted in coolant, oil, excessive fuel, or excessive black smoke entering the exhaust system, the aftertreatment system **must** be inspected.

NOTE: When installing new piston rings with used liners, higher than average blowby can be experienced for the first several hours of operation. If excessive blowby is still seen after several hours of engine operation, consult the troubleshooting symptom tree Crankcase Gases (Blowby) Excessive in Section TS.

NOTE: All engines **must** be run-in after a rebuild or a repair involving the replacement of one or more piston ring sets, cylinder liners, or pistons. See the appropriate procedure in Section 14 for the correct run-in procedure.

Use the following procedure for a general run-in test overview. Refer to Procedure 014-004 in Section 14.

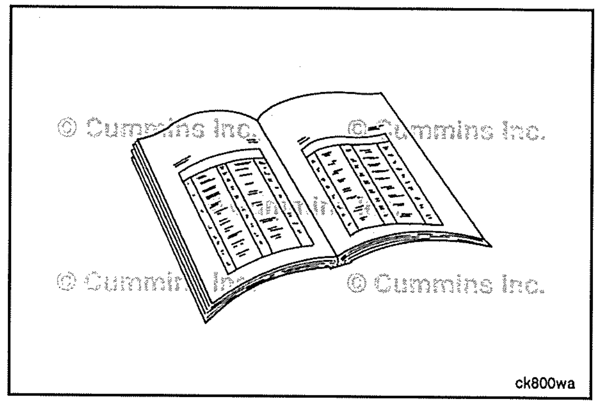


Vibration Damper, Viscous (001-052)

Preparatory Steps

Remove the drive belt. Refer to Procedure 008-002 in Section 8.

Remove the fan. Refer to Procedure 008-036 in Section 8.

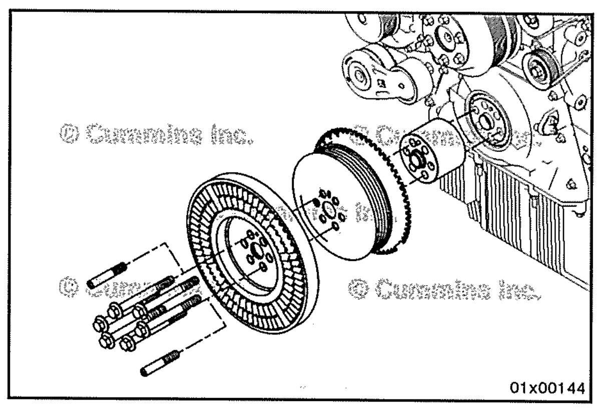


Remove

Remove two capscrews and insert guide pins, Part Number 3376696, to support the damper.

Remove the other four capscrews.

Remove the vibration damper.

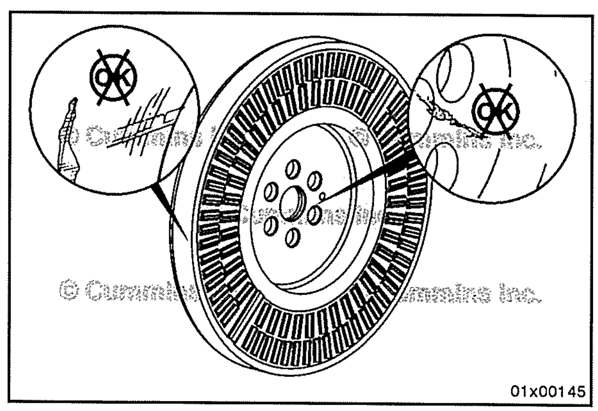


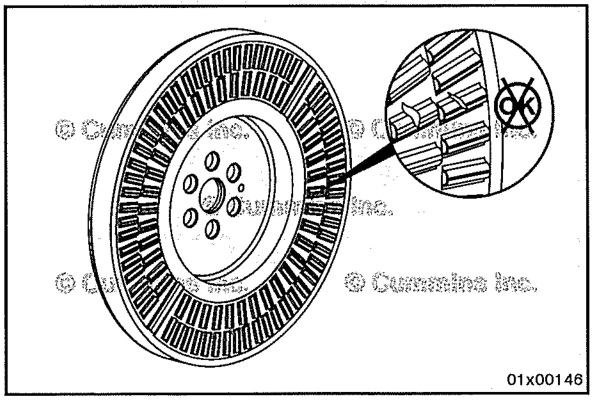
Inspect for Reuse

Check the mounting web for cracks.

Check the housing for dents or raised surfaces.

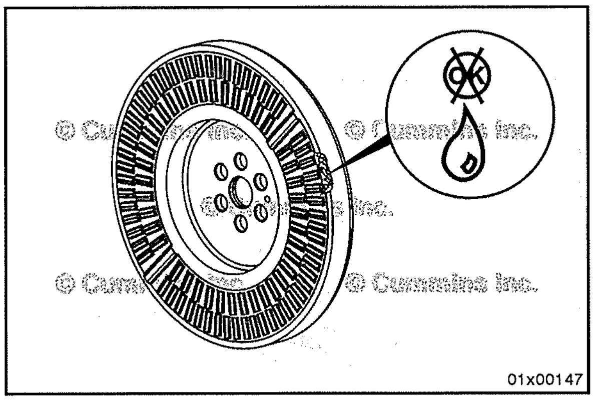
Replace the damper if any of these defects are identified.



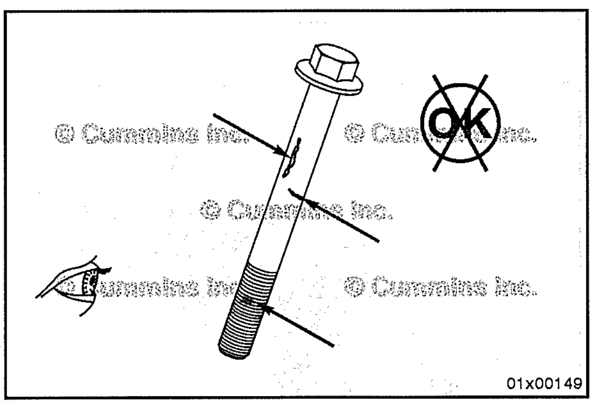


Check the damper cooling fins for damage.

If more than 33 percent of fins are completely crushed, the damper should be replaced.



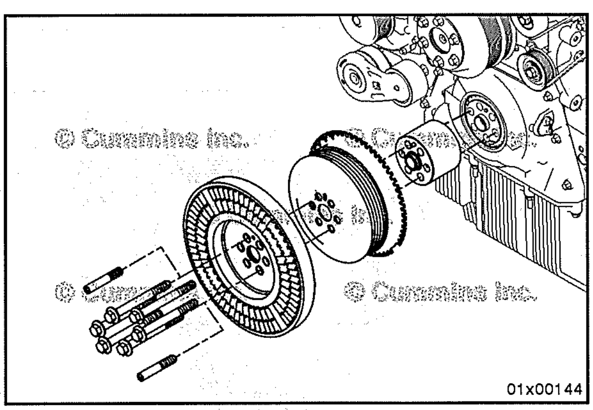
Inspect the damper for silicone leaks. If any leaks are found, even minor leaks, the damper **must** be replaced.



Inspect the capscrews for the following:

- Damaged threads
- Rust or corrosion-caused pitting
- Nicked, bent, stretched, or galled.

The capscrew **must** be replaced if it has any of the listed damage.



Install

Install two guide pins, Part Number 3376696, to support the crankshaft spacer, pulley, and damper.

Install the crankshaft spacer, pulley, and damper over the guide pins in the same order in which they were removed.

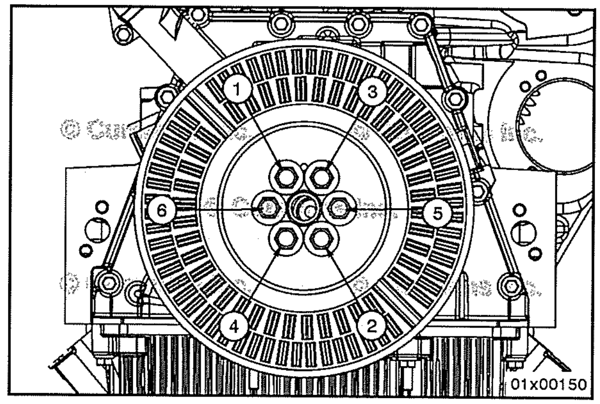
Install four capscrews finger tight and then remove the two guide pins.

Install the last two capscrews.

Tighten the six vibration damper capscrews in the proper sequence shown in graphic.

Torque Value:

Step 1	175 N•m	[129 ft-lb]
Step 2	Angle 60 degrees	

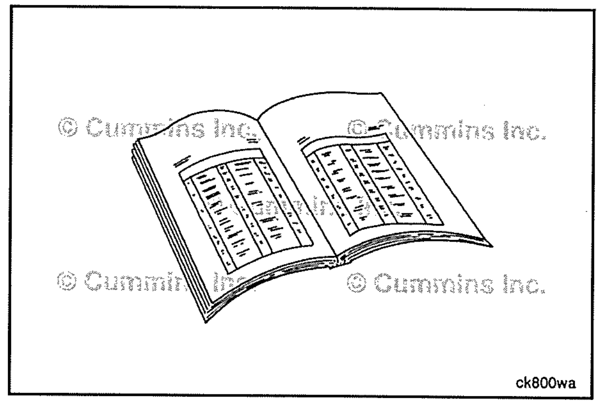


01x00150

Finishing Steps

Install the drive belt. Refer to Procedure 008-002 in Section 8.

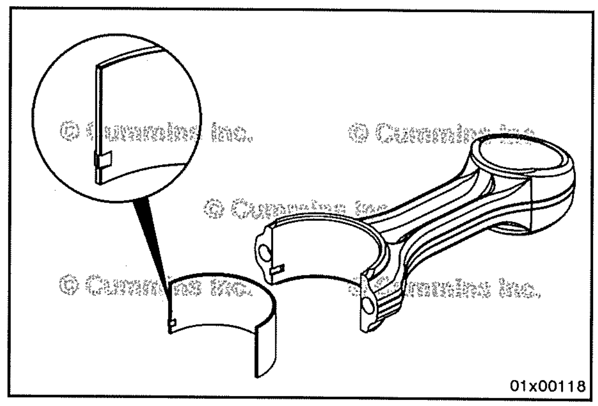
Operate the engine to check the vibration damper and drive belt operation.


ck800wa

Piston and Connecting Rod Assembly (001-054)

General Information

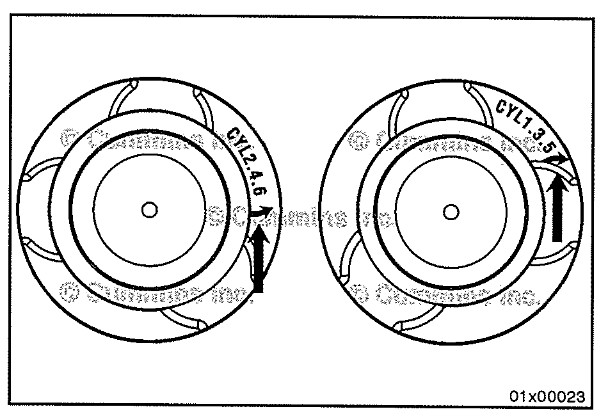
The connecting rod uses a fracture-split connection between the rod cap and the rod. Connecting rods with a fracture-split surface **must** be treated with caution. The two pieces of the connecting rod **must not** be rubbed together. This will damage the mating surfaces. Use care to **not** drop either piece of the connecting rod. Fracture-split connecting rods **must only** be handled if the two pieces of the connecting rod are tightened to the correct specification, or completely separated.


01x00118

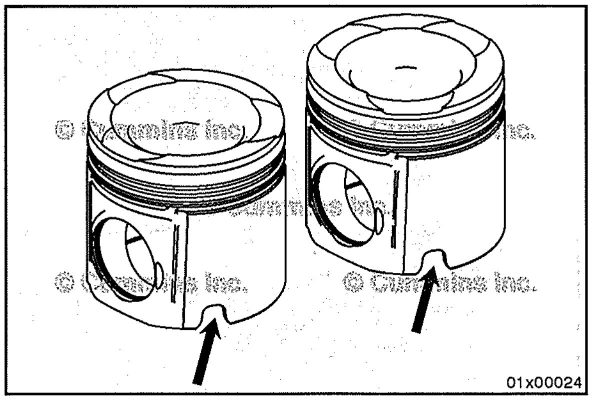
There are two different pistons on this engine. One piston is used in cylinders 1, 3, 5. The other piston is used in cylinders 2, 4, 6.

Each piston is stamped with 1, 3, 5 or 2, 4, 6 on top to show which cylinders it should be used in.

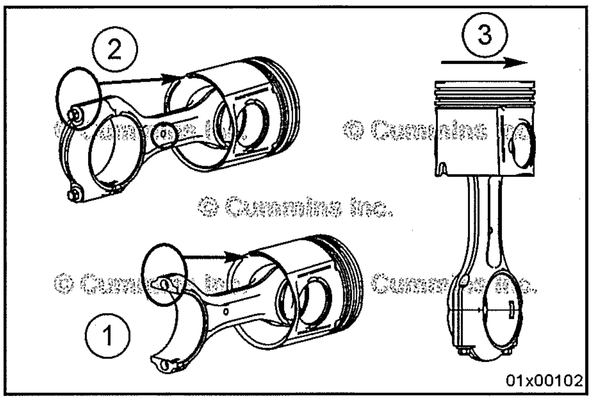
Each piston has an arrow on the top that points towards the front of the engine.



01x00023

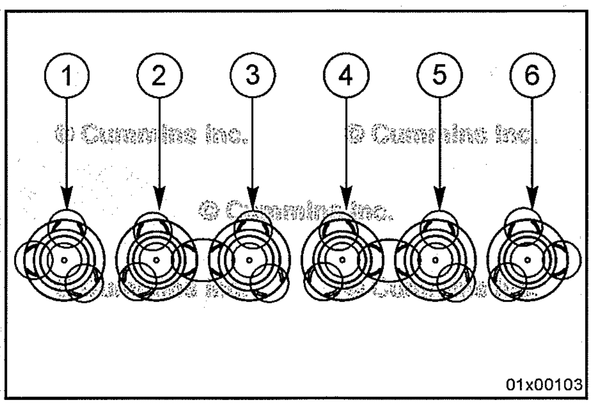


Each piston has a notch in it that faces the rear of the engine.



Piston and connecting rod orientation.

1 Tang is under skirt notch.
2 Dimples are under notch.
3 Arrow points to front of engine.



Pay close attention to the valve configuration if 1, 3, 5 or 2, 4, 6 is **not** legible on the top of the piston. See graphic for valve configuration.

Preparatory Steps

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

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

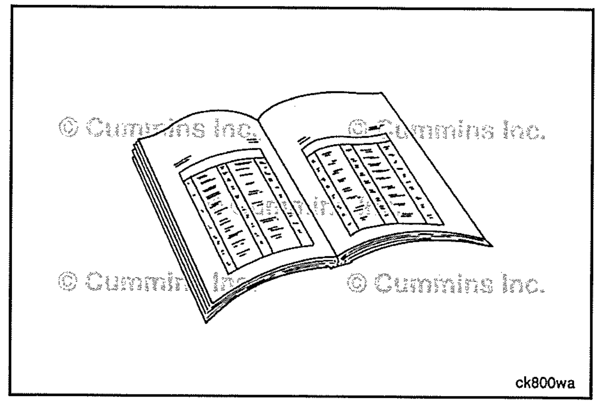
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

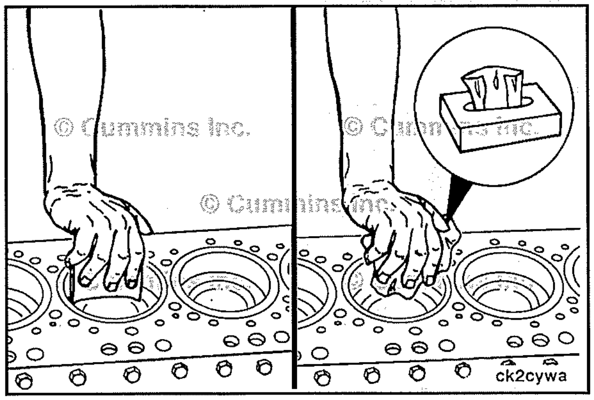
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

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

⚠CAUTION⚠
Do not rotate the crankshaft with loose or missing connecting rod caps. Damage to the piston cooling nozzles can occur.

- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Remove the piston cooling nozzles. Refer to Procedure 001-046 in Section 1.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.





Remove

WARNING

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

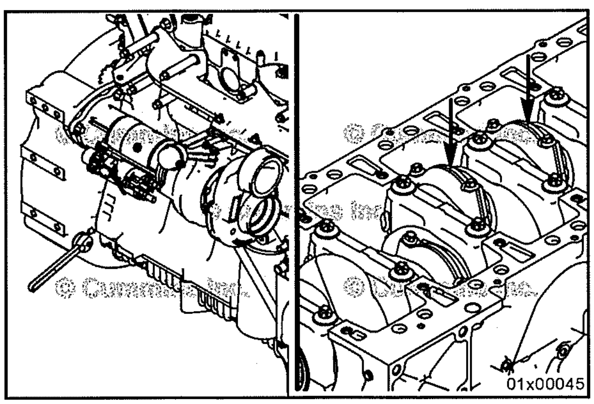
WARNING

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

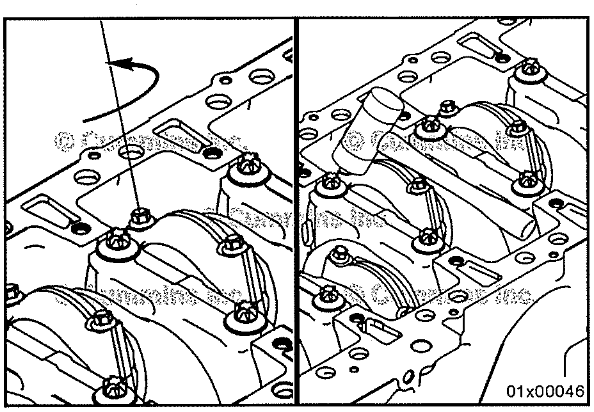
CAUTION

Do not use emery cloth or sandpaper to remove carbon from the cylinder liners. Aluminum oxide or silicon particles from emery cloth or sandpaper can cause serious engine damage. Do not use any abrasives in the ring travel area. The cylinder liner can be damaged.

Use a fine, fibrous, abrasive pad such as Scotch-Brite™ 7448, Part Number 3823258, or equivalent, and solvent to remove the carbon.



Rotate the crankshaft so that two of the connecting rods are at bottom dead center. Refer to Procedure 000-017 in Section 0.



CAUTION

Use care not to damage the fracture-split mating face(s) on the connecting rod and connecting rod cap while the connecting rod caps are removed. If the fracture-split surface is damaged, the connecting rod and connecting rod cap must be replaced to reduce the possibility of engine damage. Incorrect assembly can also damage the connecting rod and connecting rod cap.

Do **not** remove the capscrews at this time.

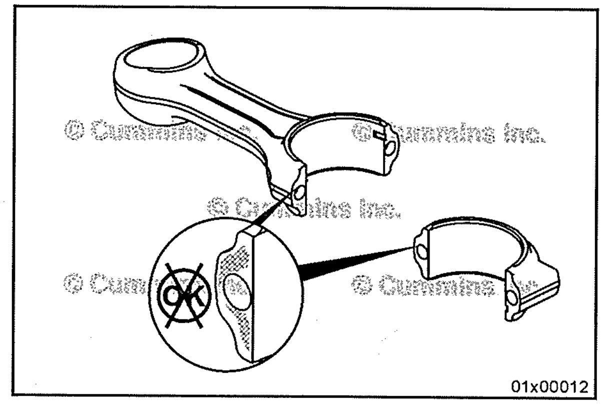
Loosen the connecting rod capscrews.

Hit the connecting rod capscrews with a rubber hammer to loosen the connecting rod caps from the dowels.

⚠CAUTION⚠

To prevent damage to the fractured-split connecting rod and connecting rod cap, do not set the connecting rod or connecting rod cap on the fracture-split mating face(s). This can cause polishing and damage to the mating surface(s).

NOTE: Minimize the number of joint interactions between the connecting rod and rod cap. If the facture-split mating surface becomes damaged or worn, the rod cap will **not** fit as designed to the connecting rod and engine damage can occur.



01x00012

Remove the capscrews and the rod cap. Note the corresponding rod and rod cap as well as the orientation of the rod cap.

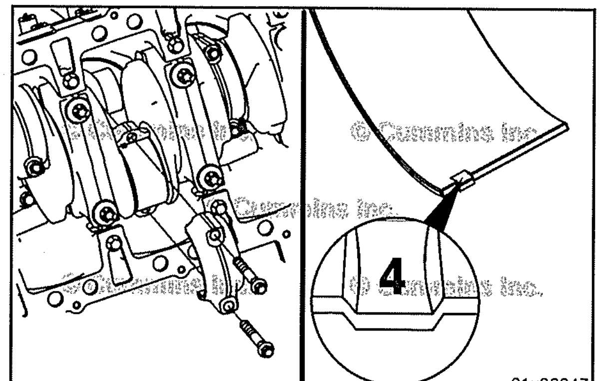
Use care **not** to damage the fracture-split connection.

Do **not** set the rod cap down on the fracture-split face.

NOTE: Both the connecting rod cap and the connecting rod are serialized on one face to make sure of proper orientation.

Connecting rod shell bearing upper or lower location is denoted by UPPER or UPR (for connecting rod) and LOWER or LWR (for connecting rod cap) stamped into the back of the bearing shells. The upper connecting rod shell bearing can also be identified by the oil port in the bearing.

Remove the bearing shell from the rod cap and mark the cylinder number on the flat surface of the bearing tangs.



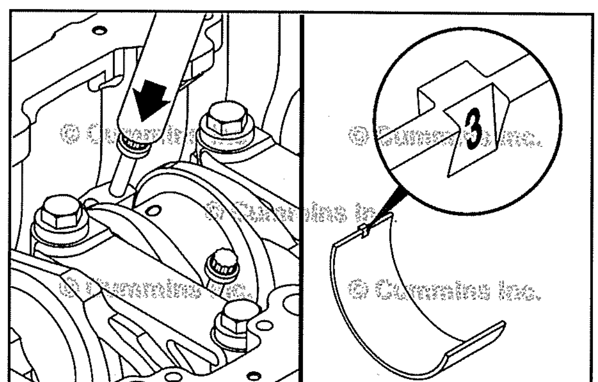
01x00047

Use a connecting rod guide pin, Part Number 5298634, to push the rod up far enough to allow the upper bearing shell to be removed.

Do **not** push against the fracture-split face of the rod.

Use caution **not** to scratch or damage the journal with the rod, capscrew, or piston pusher.

Remove the bearing shell and mark the cylinder number on the flat surface of the bearing tangs.



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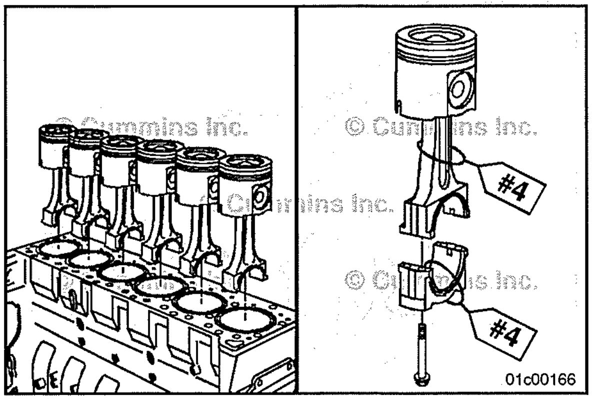


Remove the piston and connecting rod assembly.

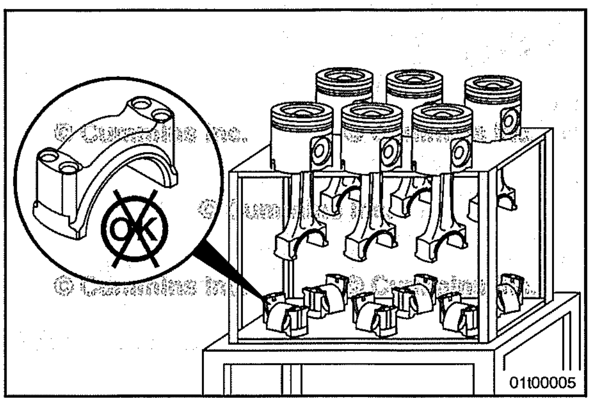
CAUTION

Avoid contact between rod and liner upon removal of connecting rod assembly to avoid damaging the liner surface.

The piston and connecting rod assemblies **must** be installed in the same cylinder from which they were removed.

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

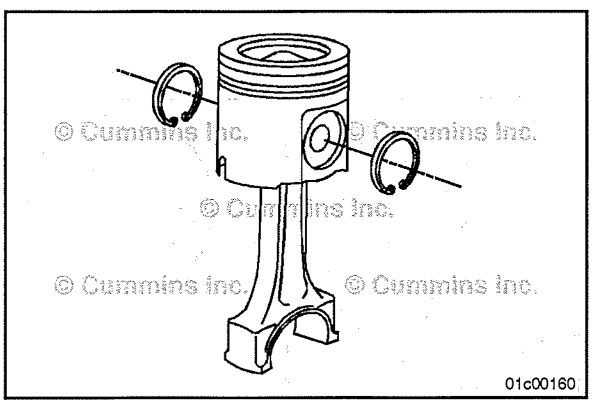
NOTE: Pistons that are reused **must** be installed in the same orientation as when removed from the engine. Mark the front side of the piston and piston pin with Dykem.



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

The two mating faces of the fracture-split connecting rod can **not** be rubbed together. This will damage the mating surfaces.

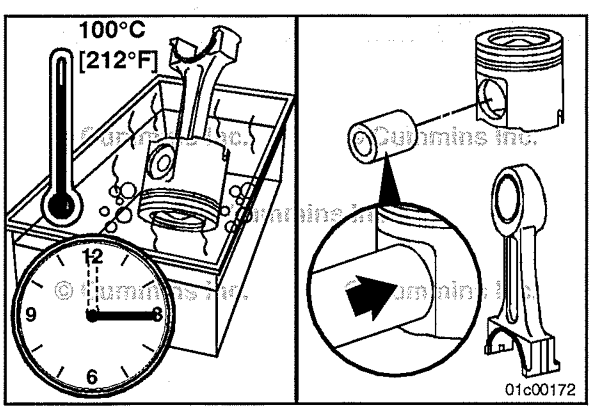
Use care to **not** drop either piece of the connecting rod. Fracture-split connecting rods **must only** be handled if the two pieces of the connecting rod are tightened to the correct specification or completely separated.



Disassemble

Use internal snap ring pliers to remove the snap rings from both sides of the piston.

NOTE: If the piston is being replaced, the piston pin **must** also be replaced.



CAUTION

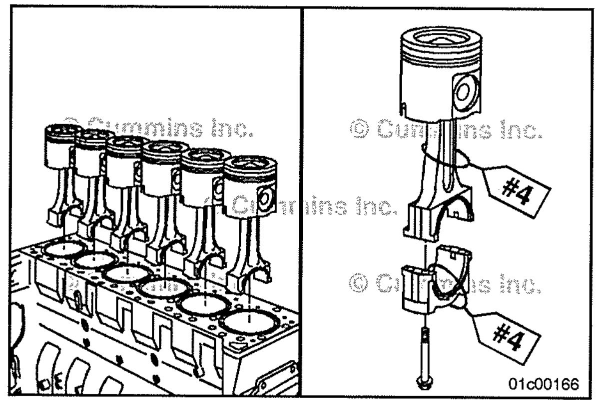
Do not use a hammer to remove the piston pins. The piston can distort, causing it to seize in the liner.

If the piston pin can **not** be easily removed by hand, place the piston and the connecting rod assembly in a container of water. Heat the piston in boiling water for 15 minutes.

Use a blunt tool to push the piston pin from the piston and connecting rod assembly.

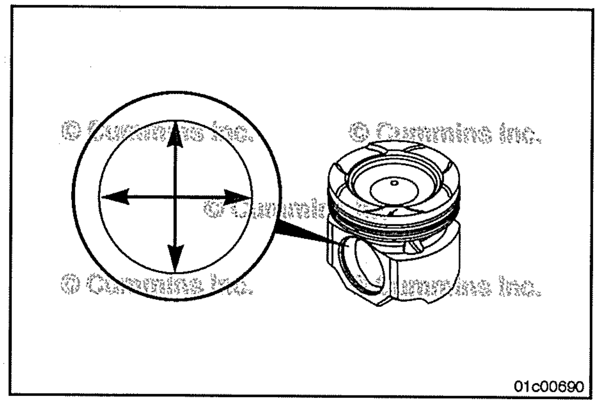
The piston and connecting rod assemblies **must** be installed in the same cylinder from which they were removed to provide for proper fit of worn mating surfaces if parts are reused.

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

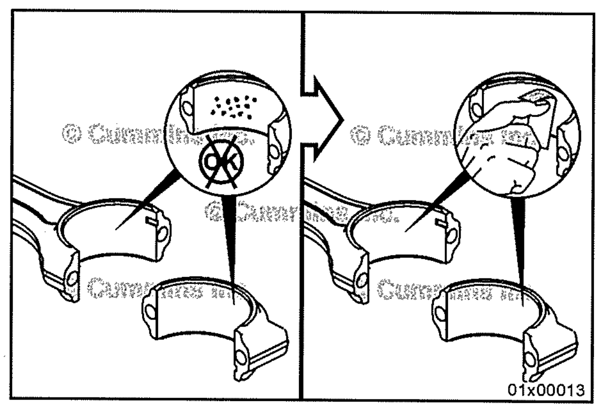


Clean and Inspect for Reuse

Clean and inspect the pistons and piston pins. Refer to Procedure 001-043 in Section 1.



Clean and inspect the connecting rods.Refer to Procedure 001-014 in Section 1.



Assemble

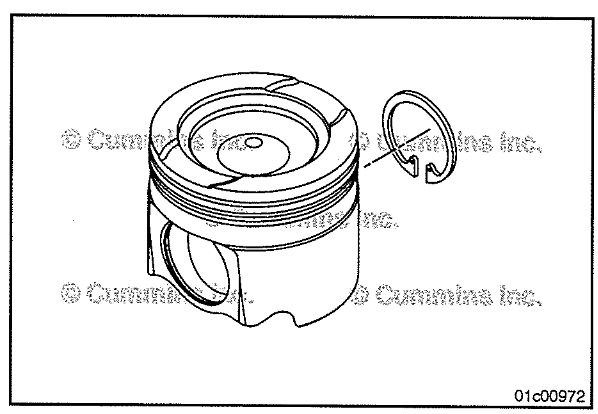
⚠CAUTION⚠

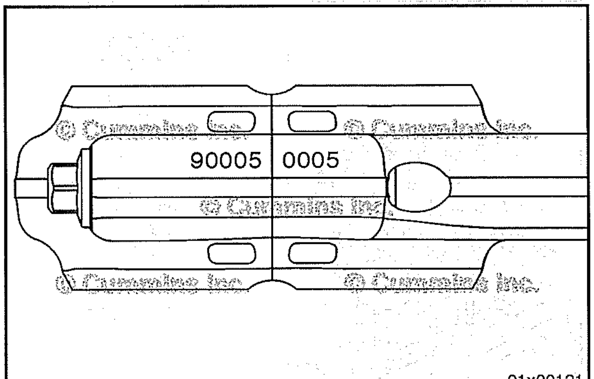
The retainer snap ring must be seated completely in the piston pin groove to prevent engine damage.

NOTE: Do **not** reuse piston pin snap rings.

Install a new snap ring into one piston pin bore of each piston with the gap of the snap ring at the top or bottom of the piston pin bores.

If the pistons are being reused, the piston and pin **must** be matched as they were when they were removed.





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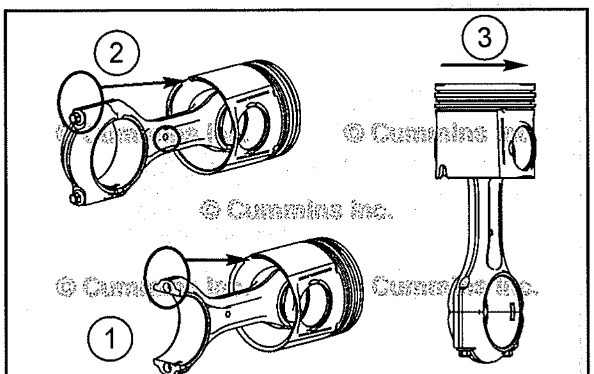
The pistons have a directional arrow etched into the top of the piston crown. Fracture split connecting rods have a unique serialization number, **not** cylinder number, stamped on the connecting rod and cap. Orient the piston and connecting rod so the piston arrows point to the front of the engine when the piston connecting rod assembly is installed properly.

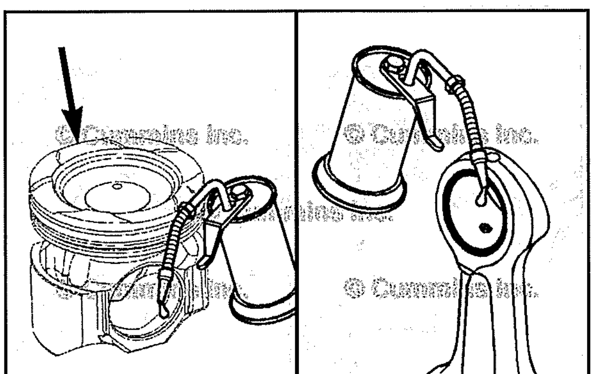
If the piston directional arrow is **not** present, align the piston with the fracture-split connecting rod, so both piston deep valve pocket and connecting rod serialization numbers face the exhaust side of the engine.



01x00102

Piston and connecting rod orientation.

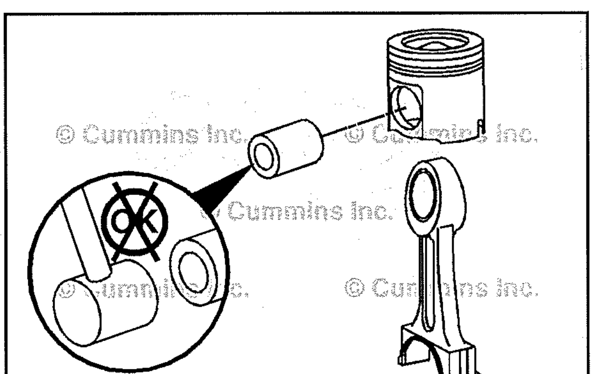
1 Tang is under skirt notch.
2 Dimples are under notch.
3 Arrow points to front of engine.


01c00396

⚠CAUTION⚠

Generously coat both piston pin bores with a heavy weight gear oil, such as 85W-140 EP, when assembling the pistons. Also lubricate the connecting rod bushing. If gear oil is not available, Lubriplate™, Part Number 3163086, is permissible. Failure to adequately lubricate the pin joint can result in extensive engine damage.

Use clean 85W-140 oil to coat the piston pin.



01c00181

⚠CAUTION⚠

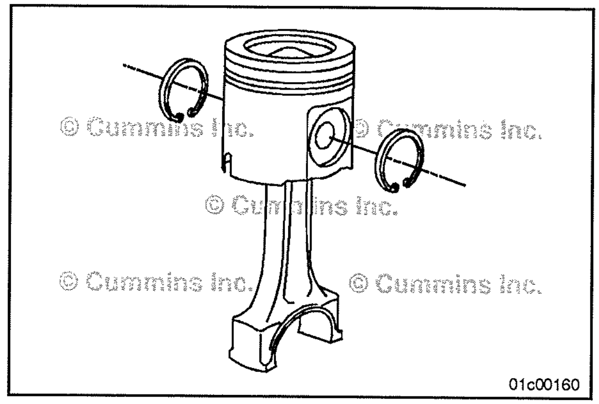
Do not use a hammer to install the piston pin. The piston can distort, causing it to seize in the liner.

For pistons that are being reused, the piston, piston pin and connecting rod **must** be installed in the same orientation as when they were removed from the engine.

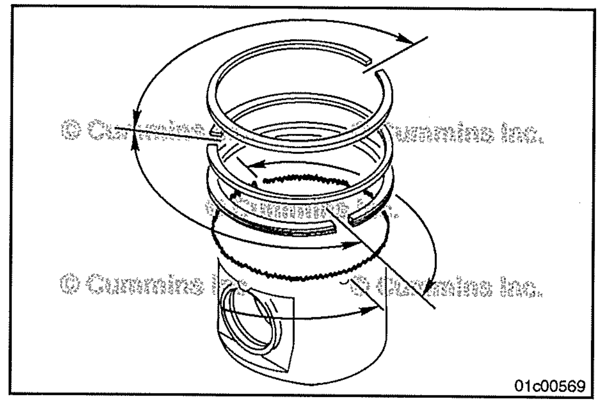
NOTE: Pistons do **not** require heating to install the pin, however, the pistons do need to be at room temperature or above.

Install the pin through the piston and connecting rod.

Install a new snap ring into the piston pin bore with the snap ring gap at the top or bottom of the piston pin bore.

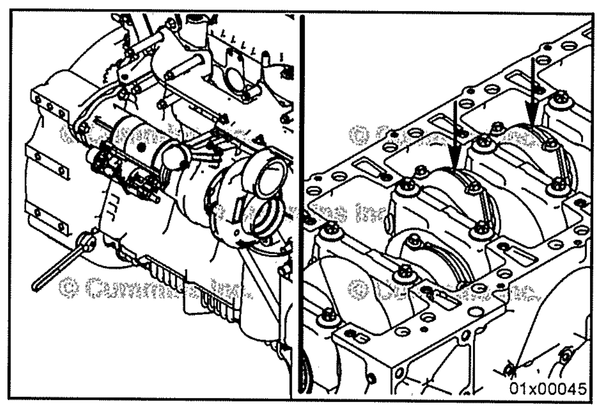


Install the piston rings. Refer to Procedure 001-047 in Section 1.



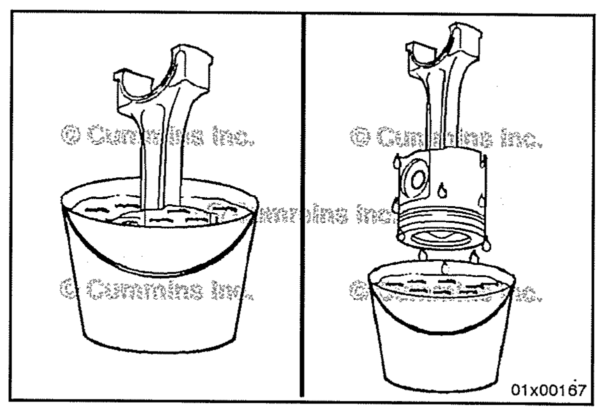
Install

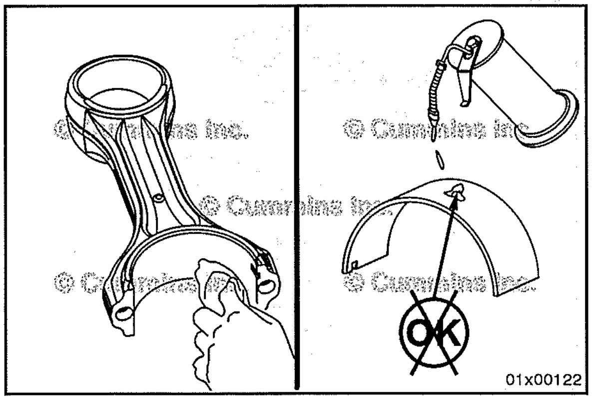
Rotate the crankshaft so the connecting rod journal of the connecting rod being installed is at bottom dead center. Refer to Procedure 000-017 in Section 0.



Immerse the piston in a container of clean engine oil.

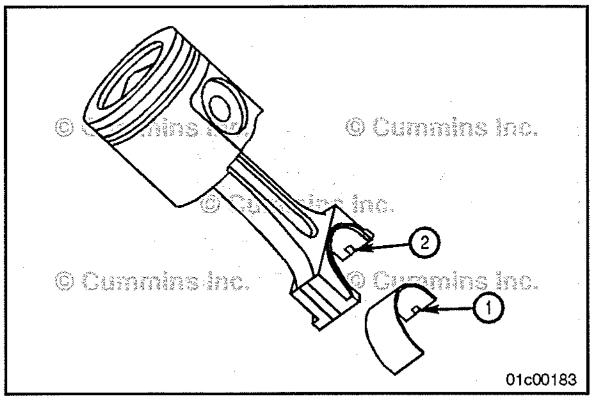
Remove the piston from the container. Let the excess oil drain from the piston.





Use a clean, lint-free cloth to clean the connecting rods and bearing shells.

Do **not** lubricate the back side of the bearing shells. The operating clearance of the bearing will be reduced and the bearing can be damaged during engine operation.

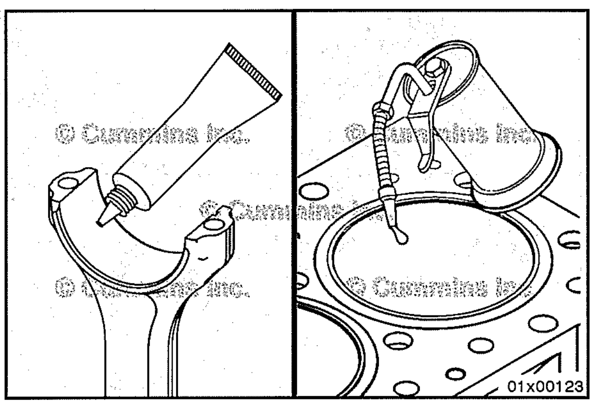


If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod from which they were removed.

Install the upper bearing shell into the connecting rod.

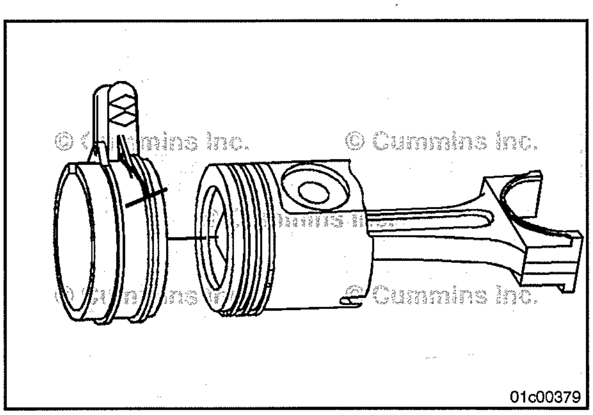
The tang of the bearing shell (1) **must** be in the slot of the connecting rod (2). The end of the bearing shell **must** be even with the cap mounting surface.

Use Lubriplate™ 105, Part Number 3163087 or equivalent, to coat the entire inside circumference of the bearing shell.



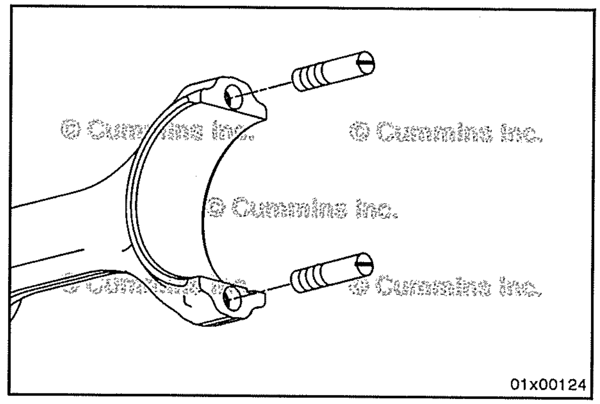
Inspect the cylinder liners for reuse. Refer to Procedure 001-028 in Section 1.

Apply a film of clean engine oil to the cylinder liner.



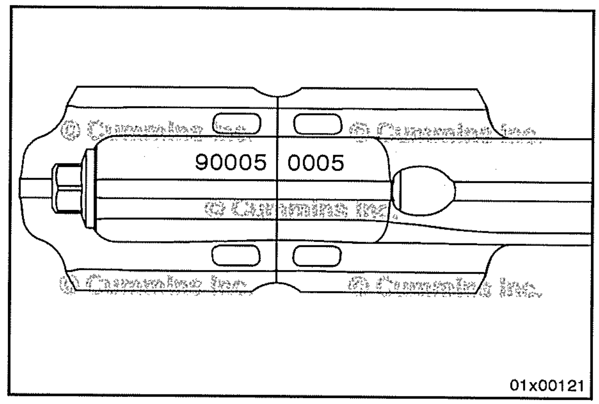
Use piston ring compressor, Part Number 5298583, to compress the rings. The cylinder block and all parts **must** be clean before assembly.

Install two guide pins, Part Number 5298634, hand-tight in the connecting rod to minimize the risk of damaging the fracture-split surface.



NOTE: Both the rod cap and the connecting rod are serialized on one face to make sure of proper orientation. Make sure that the rod cap is installed **only** on the connecting rod from which it was removed, and that the rod cap is properly oriented when installing.

Fracture-split connecting rods have a unique number, **not** cylinder number, stamped on the connecting rod and matching connecting rod cap. When the connecting rods and connecting rod caps are installed in the engine, the numbers on the connecting rod and cap **must** match and be installed on the same side, the exhaust side, of the engine. Arrows point toward the front of the engine.



WARNING

To reduce the possibility of personal injury or equipment damage, care must be taken during the installation of the connecting rod and piston assembly into the cylinder liner. The assembly can fall into the cylinder liner abruptly, once the piston rings clear the piston ring compressor as it enters the cylinder liner.

CAUTION

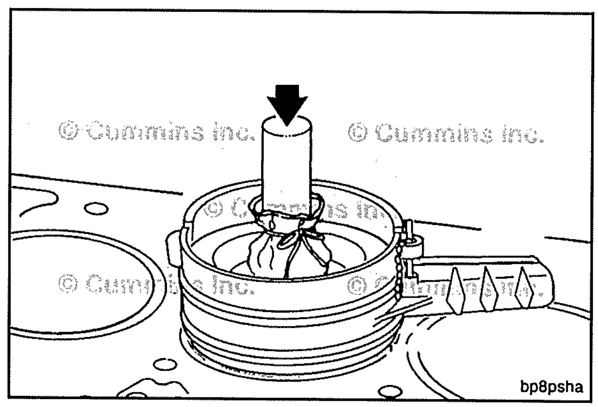
Do not use a metal drift to push the piston into the cylinder liner. The piston rings or cylinder liner can be damaged.

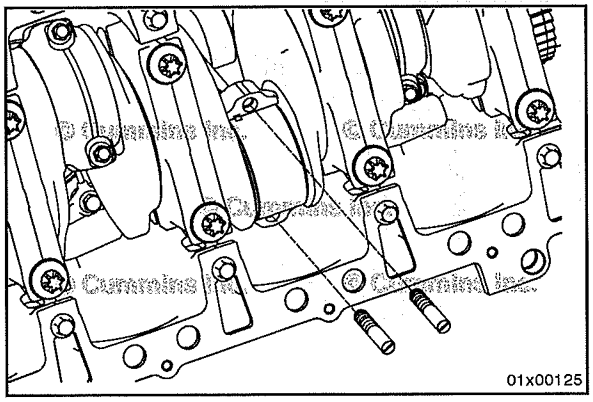
CAUTION

The connecting rod and piston assembly will fall into the cylinder once the rings have cleared the bottom of the ring compressor. The fracture-split surface and crankshaft journal bearing surface can be damaged if it is allowed to contact the crankshaft.

Hold the ring compressor against the cylinder liner. Push the piston through the ring compressor and into the cylinder liner. Push the piston until the top ring is completely in the cylinder liner.

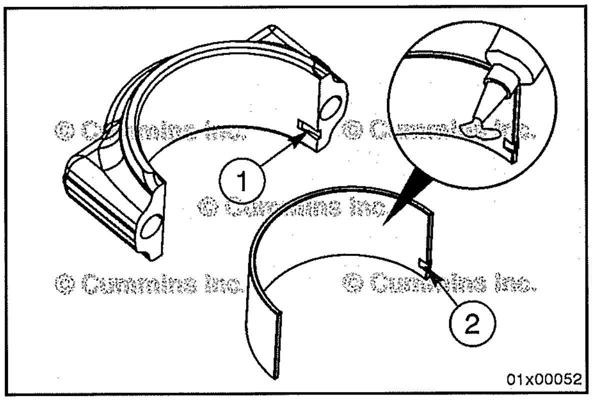
If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.





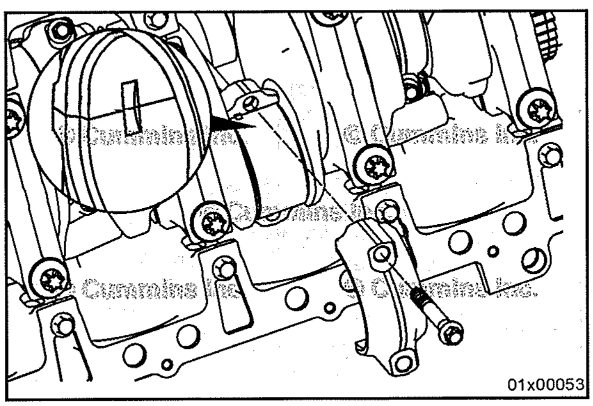
Align the connecting rod with the crankshaft while pushing the piston and connecting rod assembly into place.

Once the rod is seated in place, remove the guide pins.

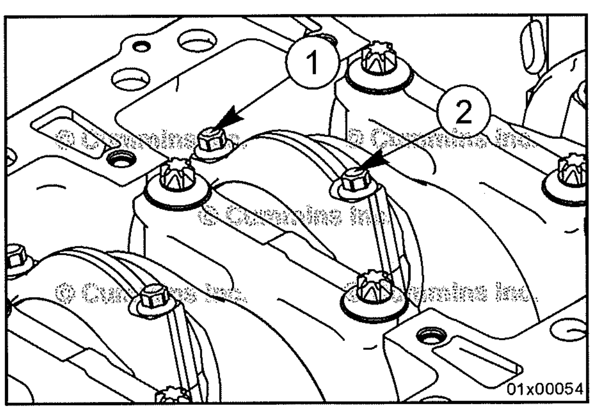


Install the lower bearing shell into the connecting rod cap with the tang (2) of the bearing in the slot (1) of the cap.

Use clean Lubriplate™ 105 multi-purpose lubricant, or its equivalent, to lubricate the bearing shell to crankshaft journal mating surface and the connecting rod capscrews.



Install the cap onto the connecting rod.



Lubricate the threads and underside of the heads of the connecting rod capscrews with clean engine oil.

Thread the capscrews into the connecting rod and hand-tighten.

Torque Value:

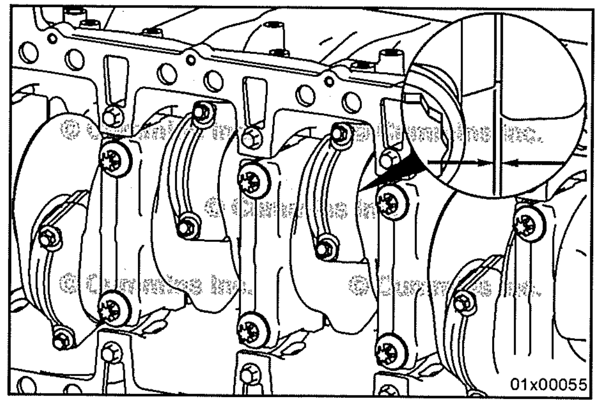
Step 1	85 N•m	[63 ft-lb]
Step 2	Angle 60 degrees.	

Measure the connecting rod side clearance.

Connecting Rod Side Clearance		
mm		in
0.10	MIN	0.004
0.35	MAX	0.014

The connecting rod **must** move freely from side to side on the crankshaft journal. If the connecting rod does **not** move freely, remove the connecting rod cap and make sure the bearing shells are the correct size. Check for dirt or damage on the crankshaft and the bearing shells.

Repeat the above steps to install the remaining bearing shells and connecting rod caps.



Finishing Steps

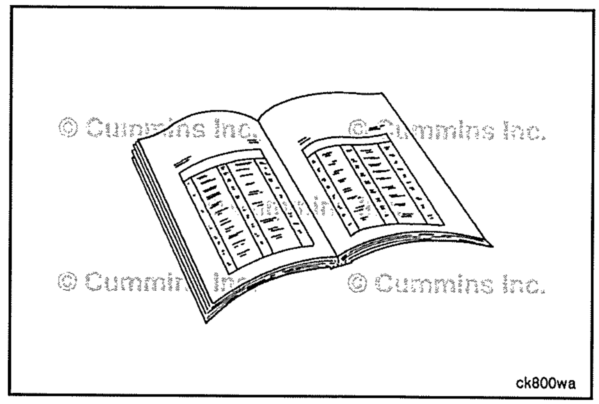
- Install the piston cooling nozzles. Refer to Procedure 001-046 in Section 1.
- Install the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Prime and fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Fill the cooling system with coolant. Refer to Procedure 008-018 in Section 8.
- Operate the engine to normal operating temperature and check for leaks and proper operation.

NOTE: All engines **must** be run-in after a rebuild or a repair involving the replacement of one or more piston ring sets, cylinder liners, or pistons. See Section 14 - Engine Testing for the appropriate run-in procedure.

Use the following procedure for a general run-in test overview. Refer to Procedure 014-999 in Section F.

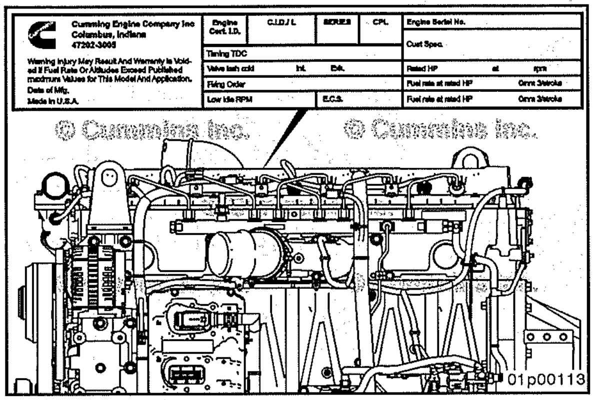
If a malfunction resulted in coolant, oil, excessive fuel, or excessive black smoke entering the exhaust system, the aftertreatment system **must** be inspected.

- Use the following procedure to check the aftertreatment selective catalytic reduction (SCR). Refer to Procedure 011-036 in Section 11.



Engine Dataplate (001-057)

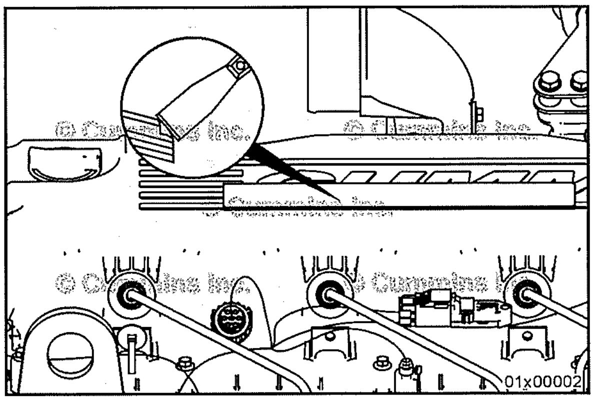
General Information



The engine dataplate is located on the rocker lever cover. The dataplate for this engine is a printed plastic dataplate label adhered in place.

If the dataplate is damaged, missing, or incorrect, contact a Cummins® Authorized Repair Location to obtain a new dataplate.

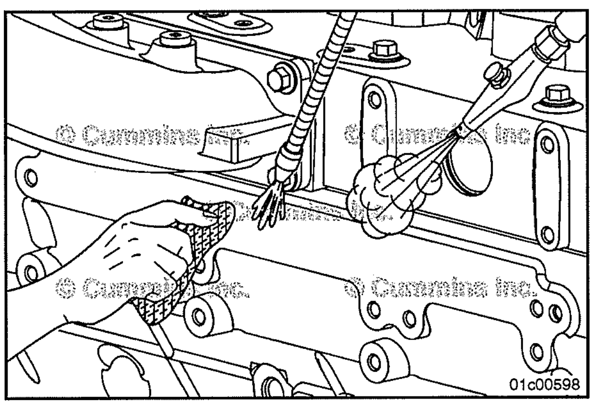
Remove



Printed plastic dataplates require use the sharp edge of a gasket scraper to peel up a corner of the dataplate. Then pull on the corner to remove the dataplate.

NOTE: In most instances the dataplate will be damaged during removal. Contact a Cummins® Authorized Repair Location to obtain a new dataplate.

Clean and Inspect for Reuse



⚠WARNING⚠

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

⚠WARNING⚠

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

Use solvent to clean the area where the dataplate will be mounted.

Remove any excess adhesive from the printed plastic dataplate. Use solvent with an abrasive pad, Part Number 3823258 or equivalent.

Dry with compressed air.

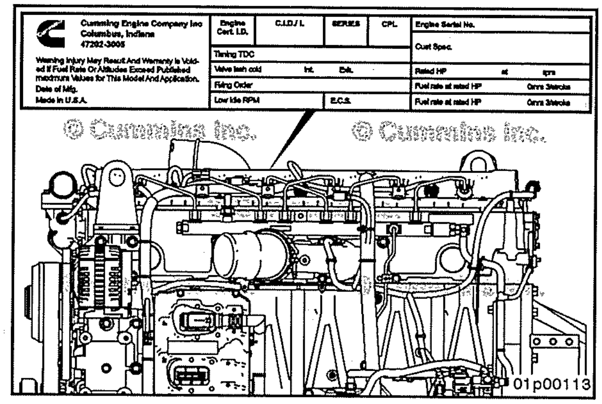
Install

For printed plastic dataplates, peel the backing off the new dataplate.

Apply the new dataplate to the appropriate mounting surface.

Rub the dataplate with a clean rag to work out any air bubbles and to adhere the dataplate to the mounting surface.

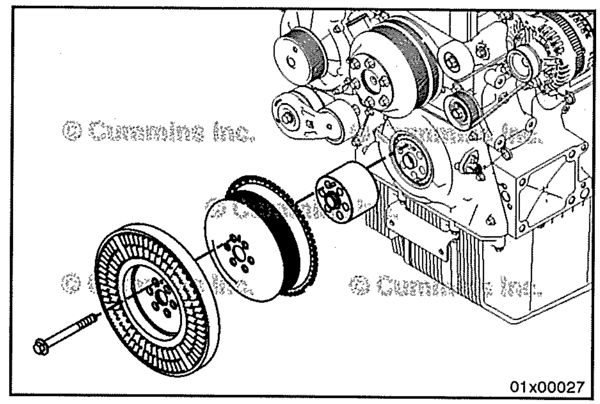
NOTE: The dataplate should be located in the same area as it was previously installed.



Crankshaft Speed Indicator Ring (001-071)

General Information

The crankshaft speed indicator ring is permanently attached to the crankshaft pulley. If the crankshaft speed indicator ring is damaged and/or requires replacement, the crankshaft pulley/crankshaft speed indicator ring **must** be replaced as an assembly. Refer to Procedure 001-022 in Section 1.



Measure

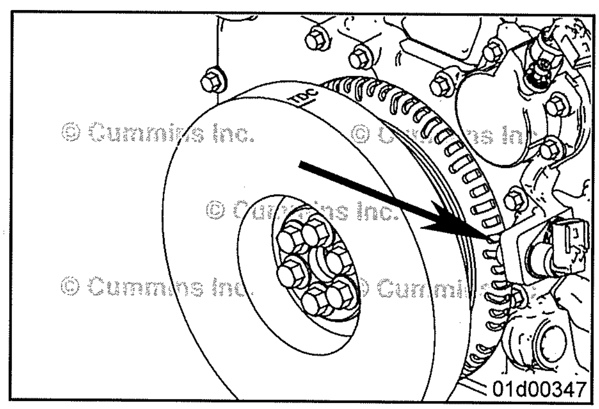
Crankshaft Speed/Position Sensor Air Gap Check

With the vibration damper and crankshaft speed indicator ring installed, use a feeler gauge to measure the air gap between the crankshaft speed/position sensor and crankshaft speed indicator ring.

Crankshaft Speed/Position Sensor Air Gap

mm		in
0.25	MIN	0.01
1.50	MAX	0.06

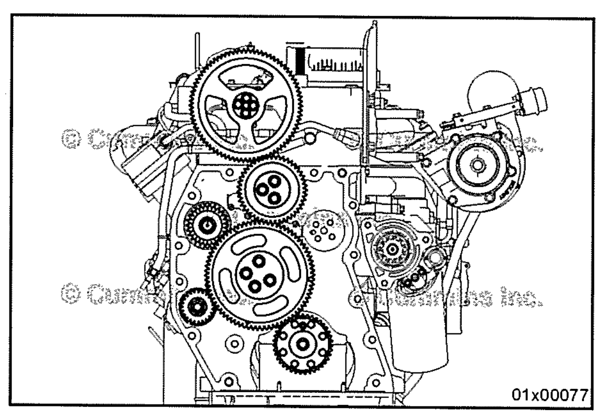
If the air gap is **not** within specification, remove and inspect the crankshaft speed/position sensor for damage.

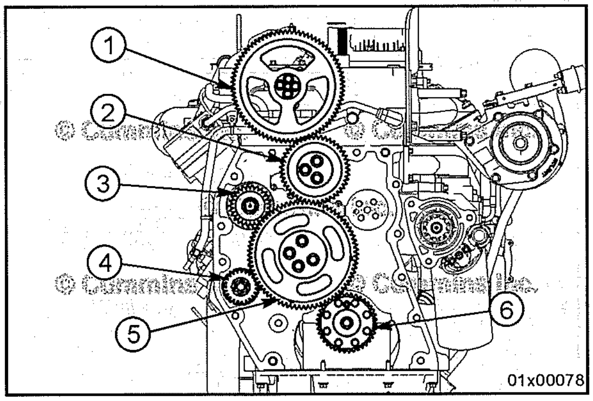


Engine Base Timing (001-088)

Test

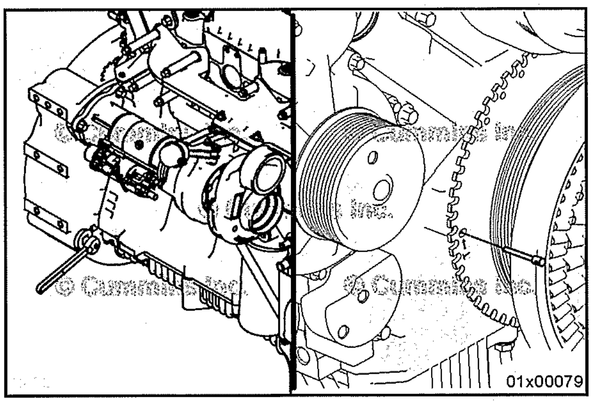
This procedure describes the basic orientation of the rear gear train and engine timing.





The illustration shows the assembly.

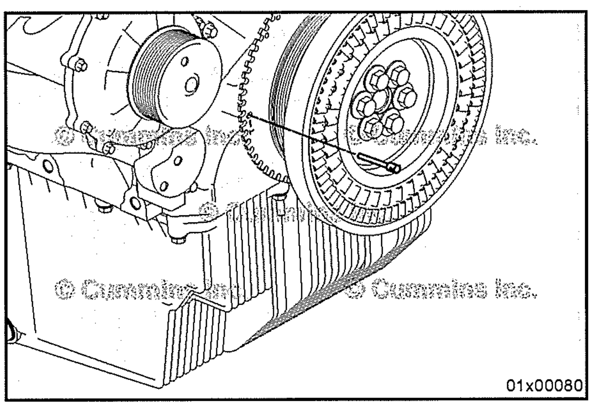
1 Camshaft gear
2 Camshaft idler gear
3 Air compressor gear
4 Fuel pump gear
5 Crankshaft idler gear
6 Crankshaft gear.



⚠CAUTION⚠

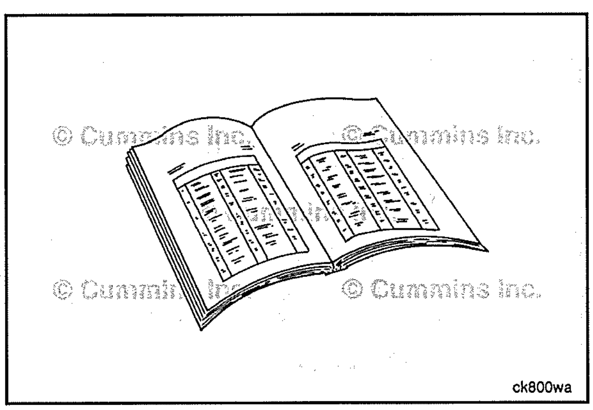
The crankshaft timing pin and the camshaft timing pin must be installed before any gears are removed and must remain in place until all gears are fully installed and tightened. Failure to install the timing pins can lead to improper timing of the engine, resulting in severe engine damage or engine failure.

Rotate the crankshaft **clockwise** until the hole in the crankshaft pulley is aligned with the crankshaft pin boss hole in the lubricating oil pump.



Insert the crankshaft locking pin, Part Number 5298581, included in kit number 5298582, into the timing pin boss hole.

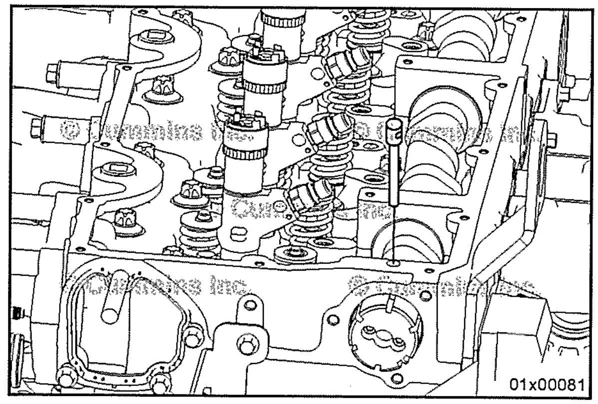
The crankshaft will be locked in place when the pin is properly seated.



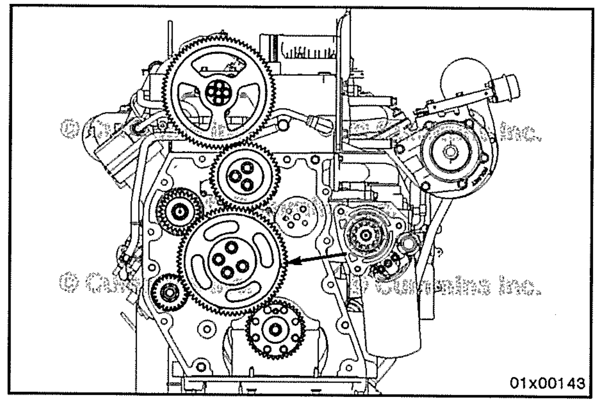
- Remove the rocker lever cover and gasket. Refer to Procedure 003-011 in Section 3.
- Remove the rocker lever assemblies. Refer to Procedure 003-009 in Section 3.

Insert timing pin, Part Number 4919342, to lock the camshaft. The camshaft will be locked in place when the pin is properly in place.

NOTE: When the crankshaft and the camshaft are both pinned, the engine is timed. If the engine is **not** timed properly, the camshaft **must** be turned to the proper position so it can be pinned.

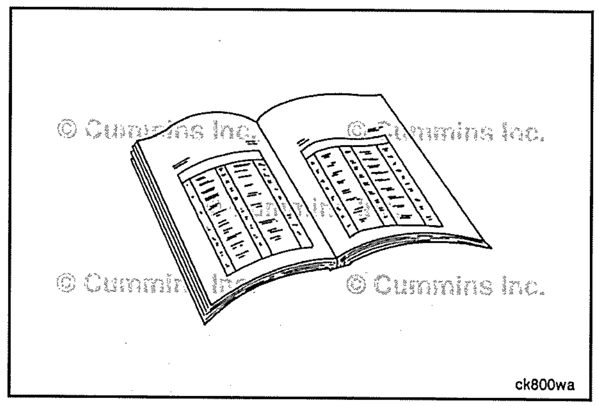


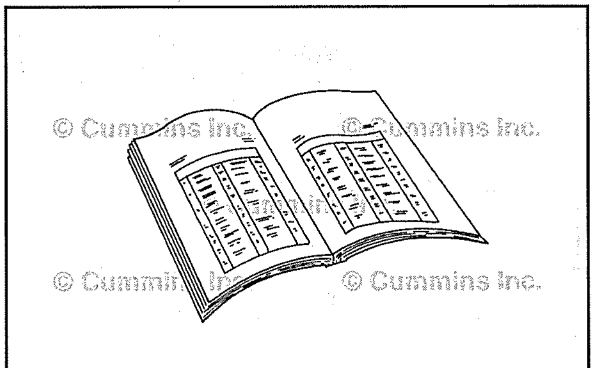
NOTE: To turn the camshaft, the crankshaft idler gear **must** be removed. Refer to Procedure 001-118 in Section 1.



Finishing Steps

- Remove crankshaft and camshaft pins.
- Install the rocker lever cover and gasket. Refer to Procedure 003-011 in Section 3.
- Operate the engine to normal operating temperature and check for leaks and proper operation.





ck800wa

Block Stiffener Plate (001-089)

Preparatory Steps

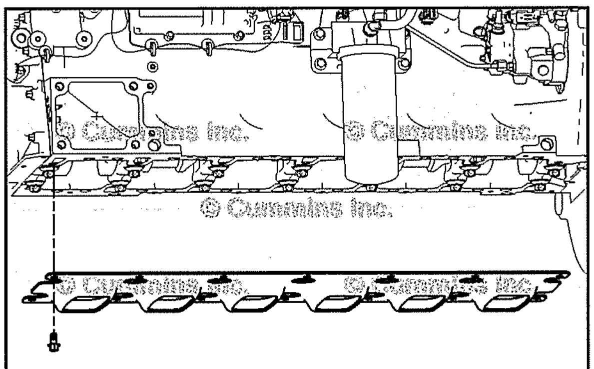
WARNING

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

WARNING

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

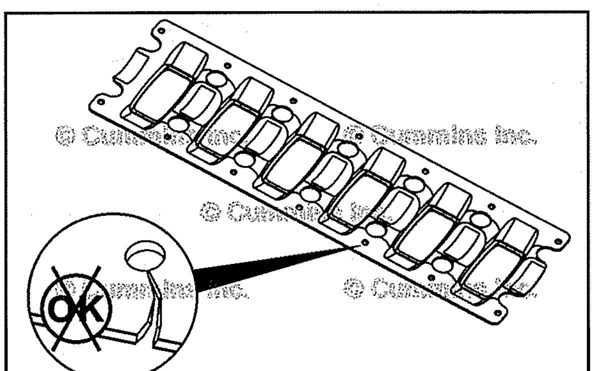
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.



01x00038

Remove

Remove the capscrews and the block stiffener plate.



01x00039

Inspect for Reuse

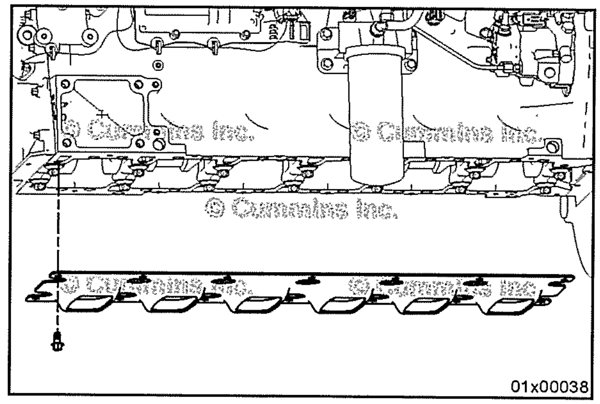
Inspect the block stiffener plate for cracks or other damage.

Install

Install the block stiffener plate and the capscrews.

Tighten the capscrews from the center out.

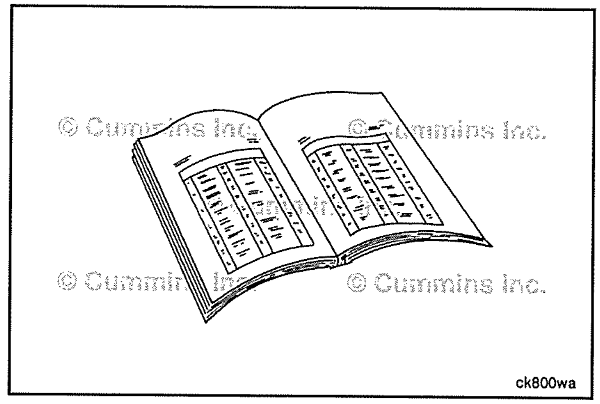
Torque Value: 46 N•m [34 ft-lb]



01x00038

Finishing Steps

- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Operate the engine to normal operating temperature and check for leaks.



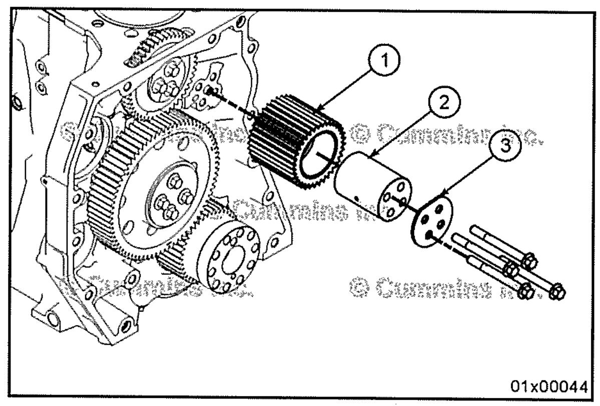
ck800wa

Rear PTO Idler Gear (001-093)

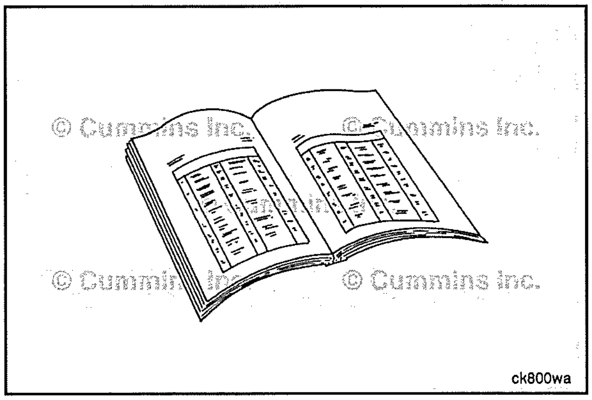
General Information

The rear engine power take-off (REPTO) idler gear uses a straight shaft and bushing assembly.

1 Idler gear and bushing assembly
2 Idler gear shaft
3 Idler gear retaining plate.



01x00044



Preparatory Steps

WARNING

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

WARNING

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

WARNING

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

WARNING

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

WARNING

Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause personal injury.

CAUTION

Failure to check the engine timing can cause severe engine damage.

- Disconnect the batteries. See equipment manufacturer service information.
- Pin the crankshaft and camshaft to ensure proper timing. Refer to Procedure 001-088 in Section 1.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the rear power take-off drive assembly. See equipment manufacturer service information.
- Remove the REPTO. Refer to Procedure 009-022 in Section 9.
- Support the rear of the engine and remove the transmission. See equipment manufacturer service information.
- Remove the flywheel. Refer to Procedure 016-005 in Section 16.
- Remove rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.

Remove

NOTE: It is necessary to remove the flywheel housing before the REPTO idler gear can be removed.

Remove the four capscrews on the idler gear.

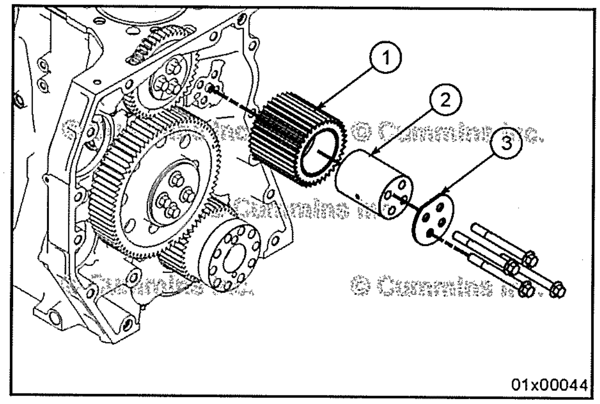
Remove the idler gear assembly.

Disassemble the idler gear assembly. The components are listed below.

1 Idler gear and bushing assembly

2 Idler gear shaft

3 Idler gear retaining plate.



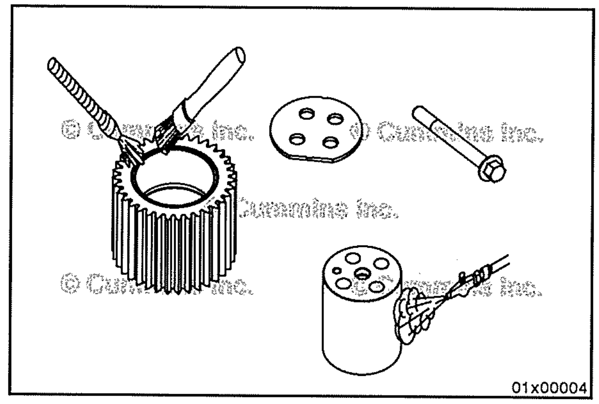
Clean and Inspect for Reuse

⚠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.

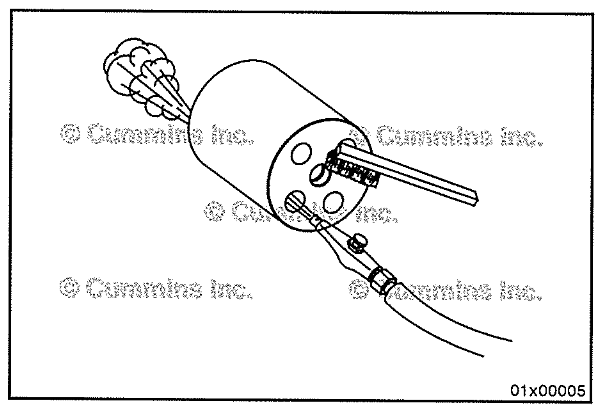
Clean the parts with solvent.

Dry with compressed air.



Use a bristle brush to clean the idler gear shaft.

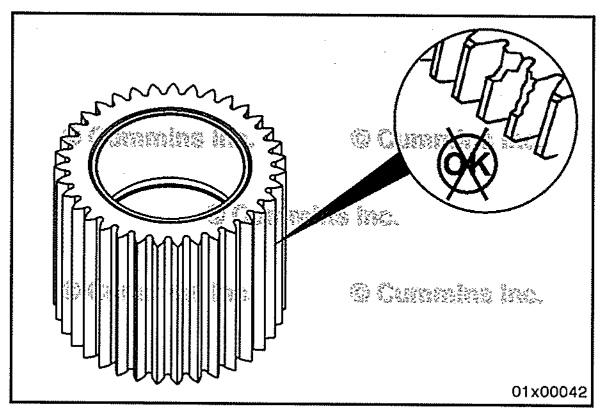
Blow out the capscrew holes with compressed air.

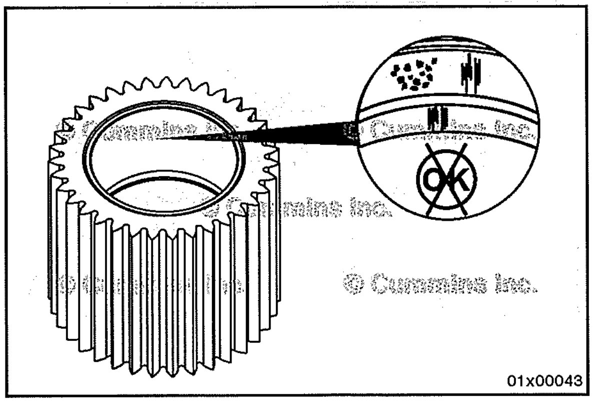


NOTE: If any parts of the PTO idler gear teeth are damaged, the idler gear **must** be replaced.

Inspect the idler gear and bushing assembly for chipped, broken, or cracked teeth.

Replace the idler gear and bushing assembly if damage is found.





NOTE: If any part of the PTO idler gear and bushing assembly is damaged, the entire assembly **must** be replaced.

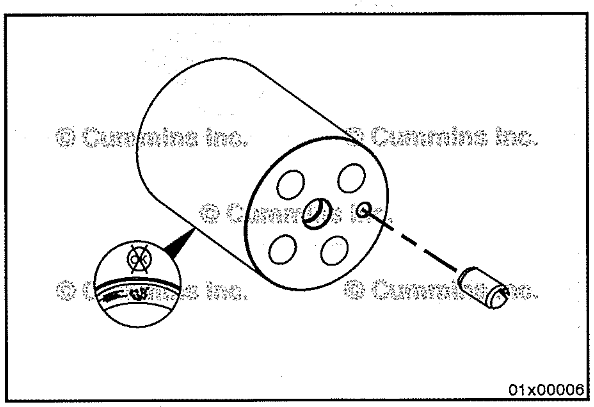
Inspect the entire inside diameter of the idler gear and bushing assembly, both visually and by feel.

Replace the assembly if any of the following damage is found:

- Debris
- Pitting
- Flaking
- Corrosion
- Heavy wear
- Scratches.

If evidence of the bushing inside the PTO idler gear is loose then the crankshaft idler gear and bushing assembly **must** be replaced.

NOTE: Scratches that can **not** be felt with your fingernail are acceptable.



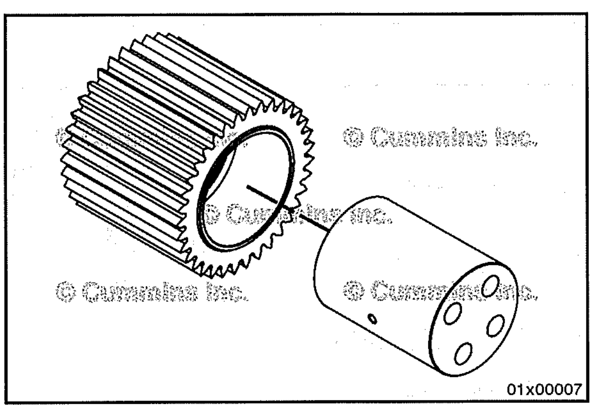
NOTE: If any part of the idler gear shaft is damaged, the shaft **must** be replaced.

Replace the idler gear shaft if any of the following damage is found:

- Debris
- Pitting
- Flaking
- Corrosion
- Heavy wear
- Scratches.

The idler shaft has a dowel that is press fit into the shaft. If the dowel is loose then the idler gear and bushing assembly **must** be replaced.

NOTE: Scratches that can **not** be felt with your fingernail are acceptable.



Install

Lubricate the inner diameter of the idler gear with Lubriplate™ 105, Part Number 3163087 or equivalent.

Install the idler gear and bushing assembly over the shaft.

Slide the assembly completely onto the shaft until it is flush against the edge of the idler gear shaft.

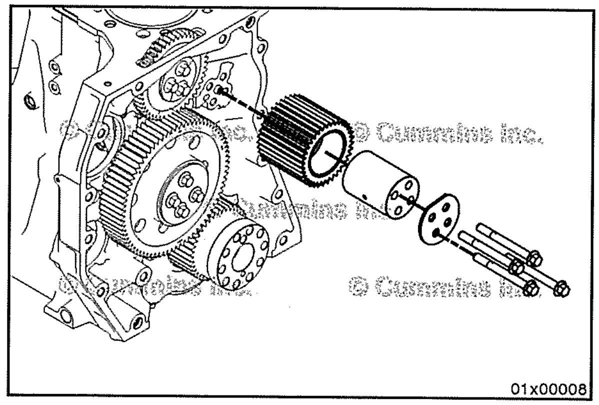
Install the idler gear and shaft assembly on to the engine block.

Align the idler shaft ring dowel with the hole in the engine block.

Install the capscrews through the retaining plate, the shaft, and into the gear housing.

Tighten the capscrews and torque.

Torque Value: 113 N•m [83 ft-lb]

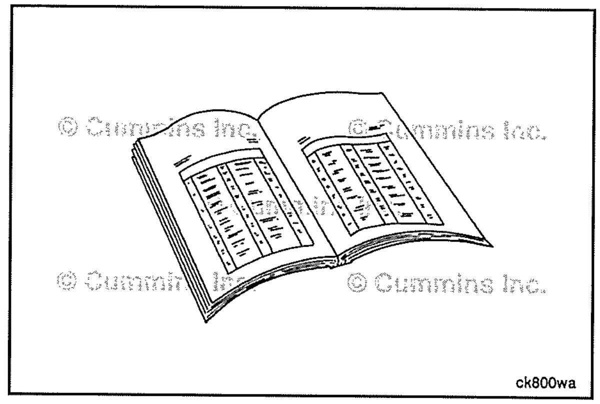


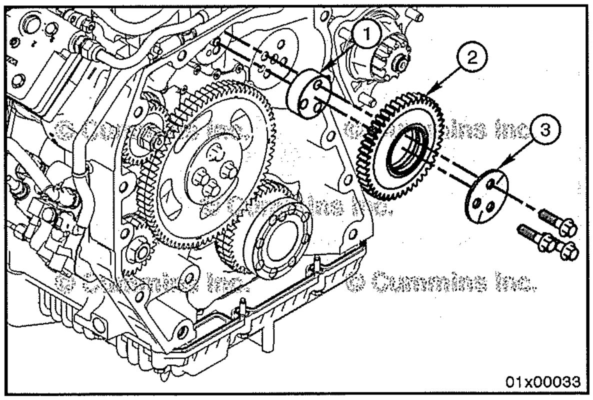
Finishing Steps

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

WARNING
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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 housing. Refer to Procedure 016-006 in Section 16.
- Install rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Install the flywheel. Refer to Procedure 016-005 in Section 16.
- Install the rear support brackets. Refer to Procedure 016-003 in Section 16.
- Install the transmission. See equipment manufacturer service information.
- Remove the rear engine support.
- Install the rear power take-off. See equipment manufacturer service information.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to normal operating temperature and check for leaks and proper operation.





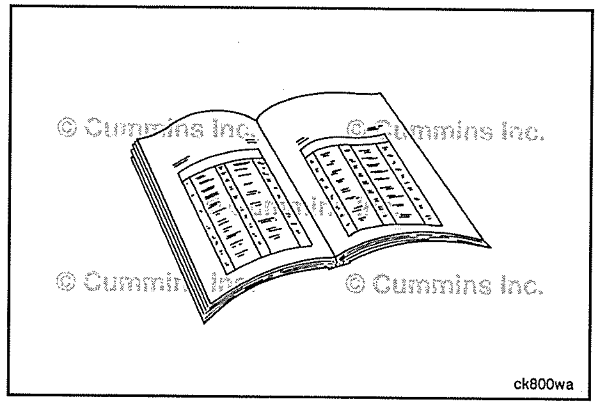
Idler Gear, Camshaft Rear (001-115)

General Information

The camshaft idler gear is located on the rear of the engine.

1 Idler gear shaft
2 Idler gear and bushing assembly
3 Gear retaining plate.

Preparatory Steps



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

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

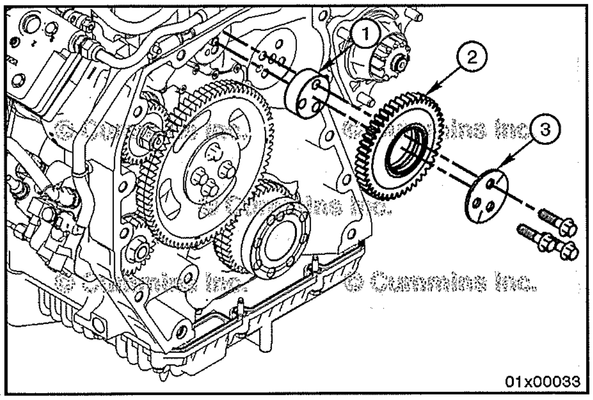
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

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

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause personal injury.

⚠CAUTION⚠
Failure to check the engine timing can cause severe engine damage.

- Disconnect the batteries. See equipment manufacturer service information.
- Pin the crankshaft and camshaft to ensure timing is kept. Refer to Procedure 001-088 in Section 1.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- If equipped, remove the rear power take-off. See equipment manufacturer service information.
- Support the rear of the engine and remove the transmission. See equipment manufacturer service information.
- Remove the flywheel. Refer to Procedure 016-005 in Section 16.
- Remove rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Remove the crankshaft idler gear. Refer to Procedure 016-006 in Section 16.



Remove

NOTE: It is necessary to remove the flywheel housing before the camshaft idler gear can be removed.

Remove the three capscrews.

Remove the idler gear assembly.

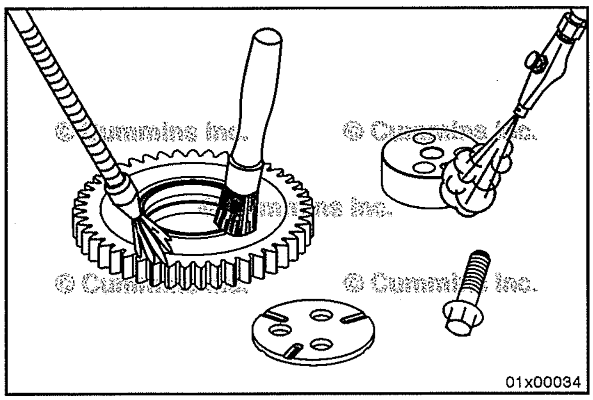
Disassemble the idler gear assembly. The components are listed below.

1 Idler gear shaft

2 Idler gear and bushing assembly

3 Idler gear retaining plate.

Mark or tag the individual pieces of the idler gear assembly and attach them together.



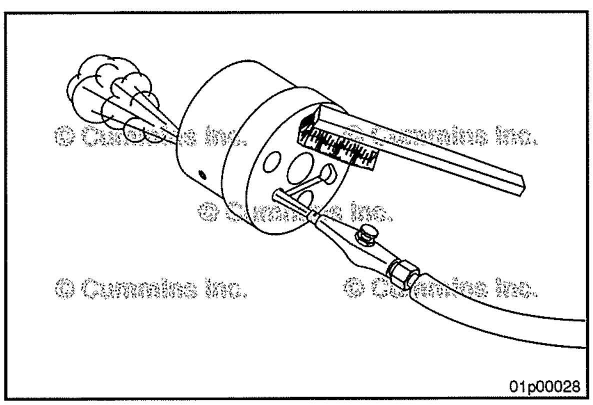
Clean and Inspect for Reuse

⚠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 parts with solvent.

Dry with compressed air.

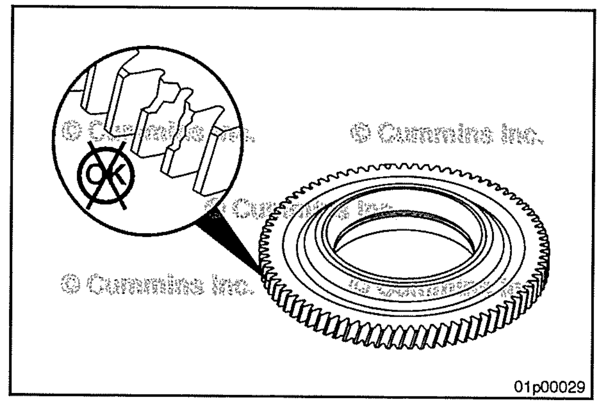


Use a bristle brush to clean the idler gear shaft.

Blow out the capscrew holes with compressed air.

Inspect the idler gear and bushing assembly for chipped, broken, or cracked teeth.

Replace the idler gear and bushing assembly if damage is found.

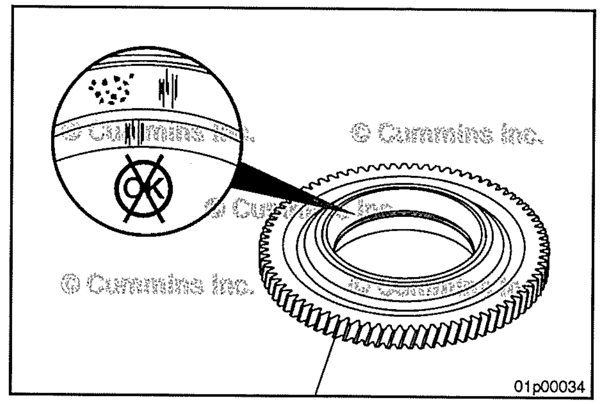


NOTE: If any part of the camshaft gear and bushing assembly damaged, the entire assembly **must** be replaced.

Inspect the entire inside diameter of the camshaft idler gear and bushing assembly, both visually and by feel.

Replace the assembly if any of the following damage is found:

- Debris
- Pitting
- Flaking
- Corrosion
- Heavy wear
- Scratches.



If evidence of the bushing inside the camshaft gear is loose then the camshaft idler gear and bushing assembly **must** be replaced.

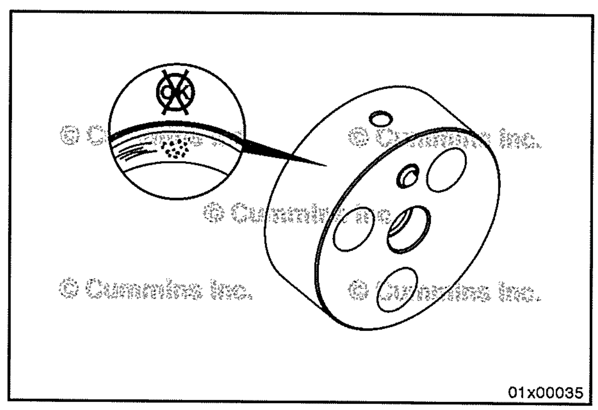
NOTE: Scratches that can **not** be felt with your fingernail are acceptable.

NOTE: If any part of the idler shaft is damaged, the idler shaft **must** be replaced.

Inspect the idler shaft for damage, both visually and by feel.

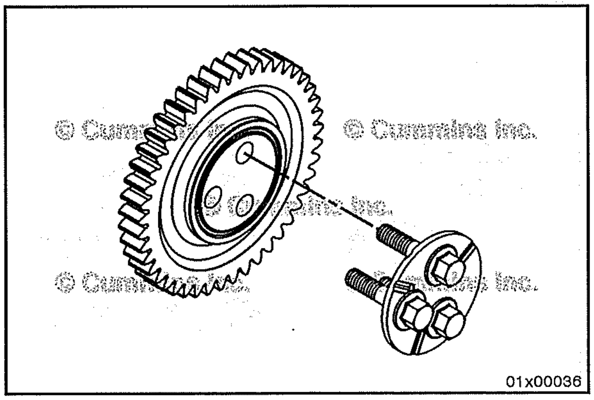
Replace the idler shaft if any of the following damage is found:

- Debris
- Pitting
- Flaking
- Corrosion
- Heavy wear
- Scratches.



The idler shaft has a dowel that is press fit into the shaft. If the dowel is loose then the idler gear and bushing assembly **must** be replaced.

NOTE: Scratches that can **not** be felt with your fingernail are acceptable.

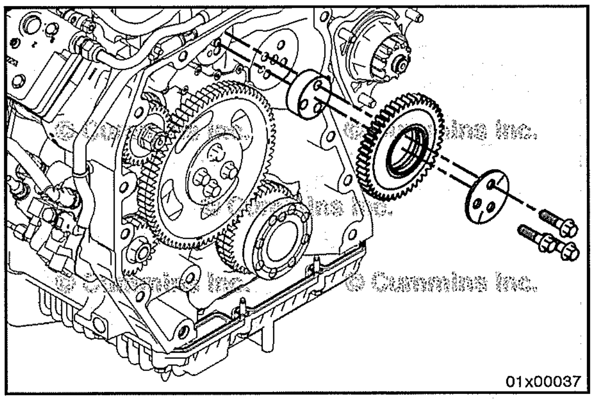


Install

Lubricate the inner diameter of the idler gear with Lubriplate™ 105, Part Number 3163087 or equivalent.

Install the idler gear and bushing assembly over the shaft.

Slide the assembly completely onto the shaft until it is flush against the edge of the idler gear shaft.



Install the idler gear and shaft assembly on to the gear housing.

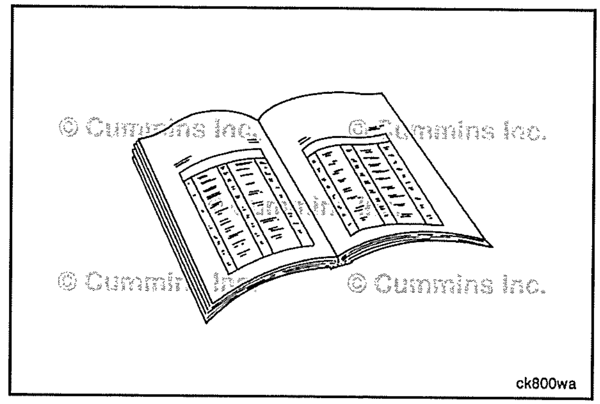
Align the idler shaft ring dowel with the hole in the engine block.

Install the capscrews through the retaining plate, the shaft, and into the gear housing.

Tighten the capscrews and torque.

Torque Value: 113 N•m [83 ft-lb]

Finishing Steps



⚠WARNING⚠

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

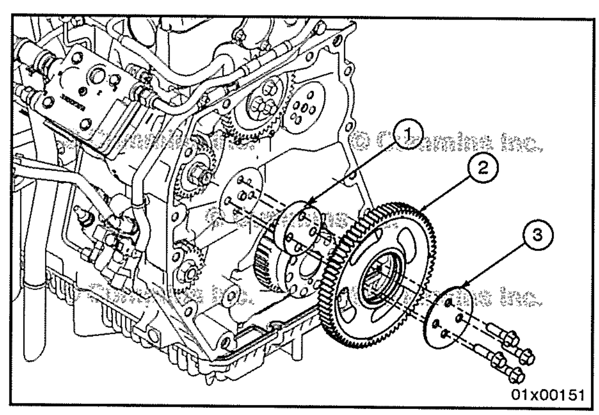
⚠WARNING⚠

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

- Install the crankshaft idler gear. Refer to Procedure 016-006 in Section 16.
- Check engine timing. Refer to Procedure 001-088 in Section 1.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Install the flywheel. Refer to Procedure 016-005 in Section 16.
- Install the rear support brackets. Refer to Procedure 016-003 in Section 16.
- Install the transmission. See equipment manufacturer service information.
- Remove the rear engine support.
- If equipped, install the rear power take-off. See equipment manufacturer service information.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to normal operating temperature and check for leaks and proper operation.

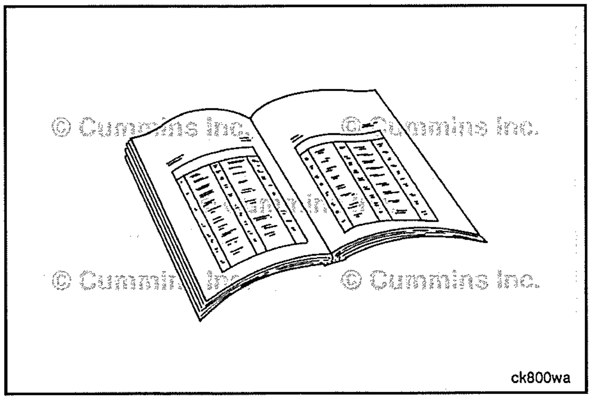
Idler Gear, Crankshaft Rear (001-118)

General Information



The crankshaft idler gear is located on the rear of the engine.

1 Idler gear shaft
2 Idler gear and bushing assembly
3 Gear retaining plate.



Preparatory Steps

⚠WARNING⚠

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

⚠WARNING⚠

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

⚠WARNING⚠

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

⚠WARNING⚠

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

⚠WARNING⚠

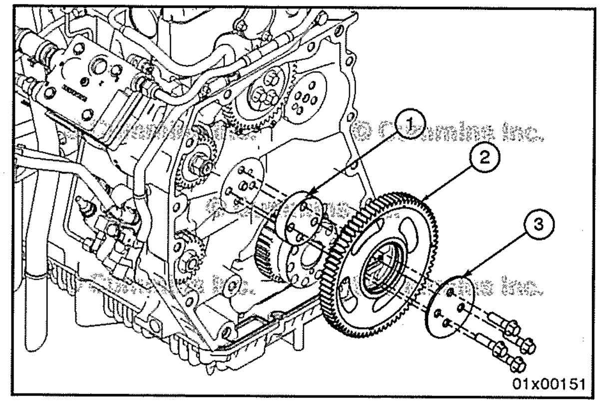
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause personal injury.

⚠CAUTION⚠

Failure to check the engine timing can cause severe engine damage.

- Disconnect the batteries. See equipment manufacturer service information.
- Pin the crankshaft and camshaft to ensure timing is kept. Refer to Procedure 001-088 in Section 1.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- If equipped, remove the rear power take-off. See equipment manufacturer service information.
- Support the rear of the engine and remove the transmission. See equipment manufacturer service information.
- Remove the flywheel. Refer to Procedure 016-005 in Section 16.
- Remove rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.

Remove



NOTE: It is necessary to remove the flywheel housing before the crankshaft idler gear can be removed.

Remove the four capscrews.

Remove the idler gear assembly.

Disassemble the idler gear assembly. The components are listed below.

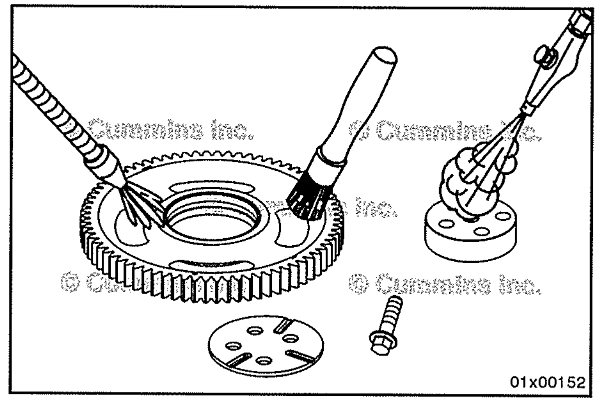
1 Idler gear shaft

2 Idler gear and bushing assembly

3 Gear retaining plate.

Mark or tag the individual pieces of the idler gear assembly and attach them together.

Clean and Inspect for Reuse



⚠WARNING⚠

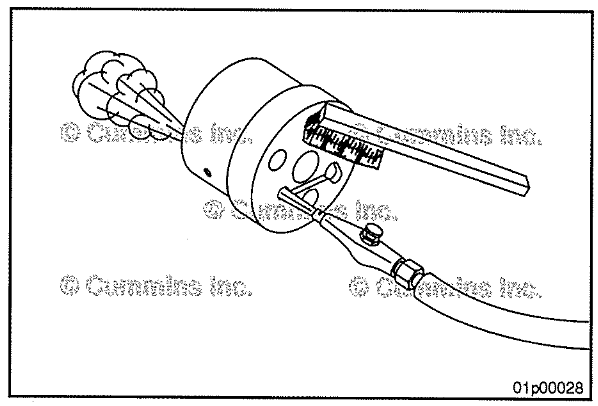
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠

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

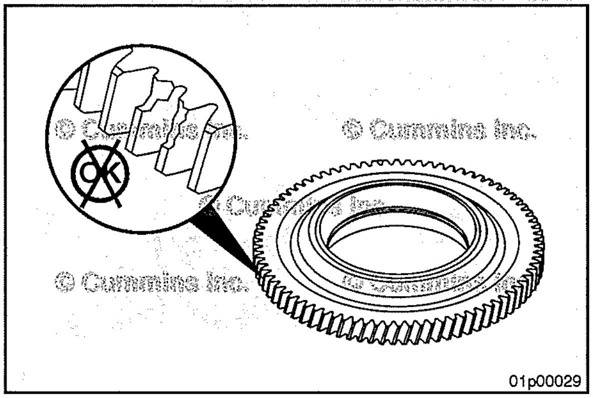
Clean the parts with solvent.

Dry with compressed air.



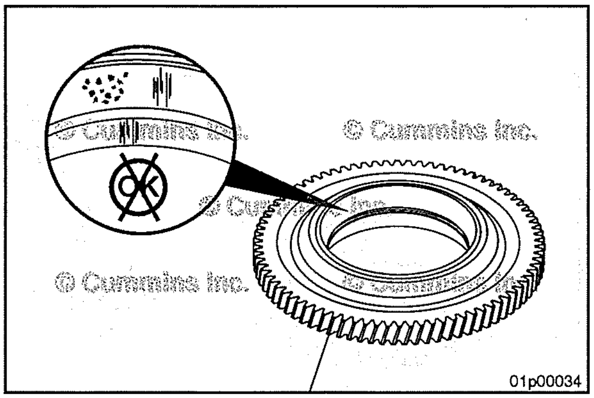
Use a bristle brush to clean the idler gear shaft.

Blow out the capscrew holes with compressed air.



Inspect the idler gear for chipped, broken, or cracked teeth.

Replace the idler gear if damage is found.



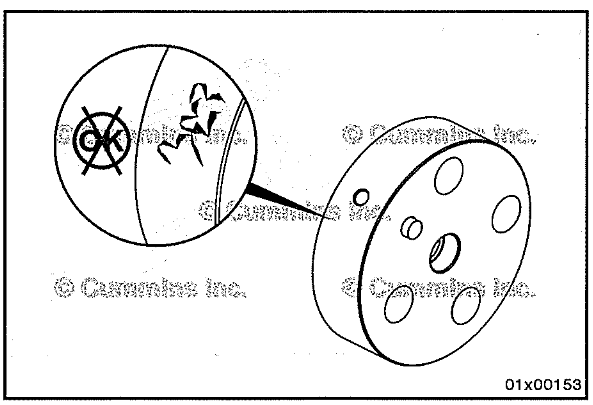
Inspect the entire inside diameter crankshaft idler gear and bushing assembly, both visually and by feel.

Replace the bearing assembly if any of the following damage is found.

- Debris
- Pitting
- Flaking
- Corrosion
- Heavy wear
- Scratches.

If evidence of the bushing inside the crankshaft gear is loose then the crankshaft idler gear and bushing assembly **must** be replaced.

NOTE: Scratches that can **not** be felt with your fingernail are acceptable.



NOTE: If any part of the idler shaft is damaged, the idler shaft **must** be replaced.

Inspect the idler shaft for damage, both visually and by feel.

Replace the idler shaft if any of the following damage is found:

- Debris
- Pitting
- Flaking
- Corrosion
- Heavy wear
- Scratches.

The idler shaft has a dowel that is press fit into the shaft. If the dowel is loose then the idler gear and bushing assembly **must** be replaced.

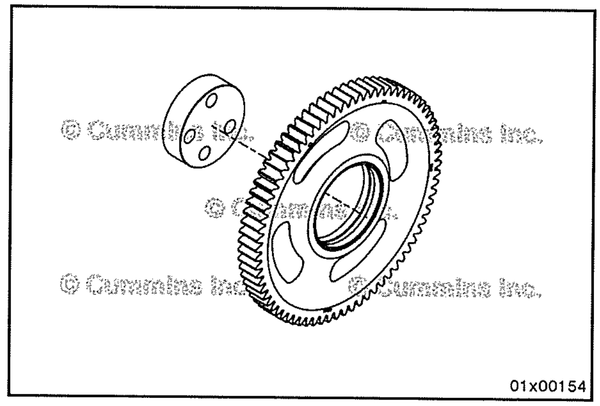
NOTE: Scratches that can **not** be felt with your fingernail are acceptable.

Install

Lubricate the inner diameter of the idler gear with Lubriplate™ 105, Part Number 3163087 or equivalent.

Install the idler gear and bushing assembly over the shaft.

Slide the assembly completely onto the shaft until it is flush against the edge of the idler gear shaft.



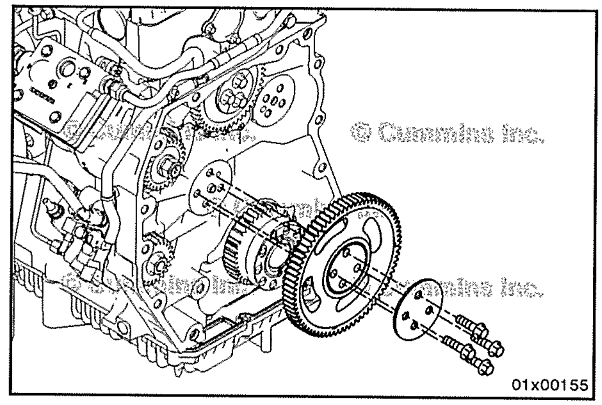
Install the idler gear and shaft assembly on to the gear housing.

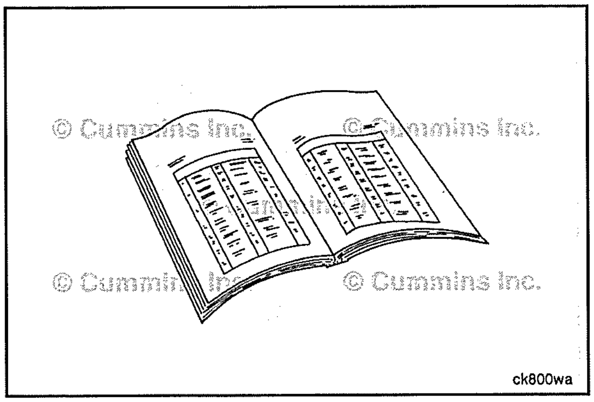
Align the idler shaft ring dowel with the hole in the block.

Install the capscrews through the shaft and into the gear housing.

Tighten the capscrews and torque.

Torque Value: 113 N•m [83 ft-lb]





Finishing Steps

⚠WARNING⚠

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

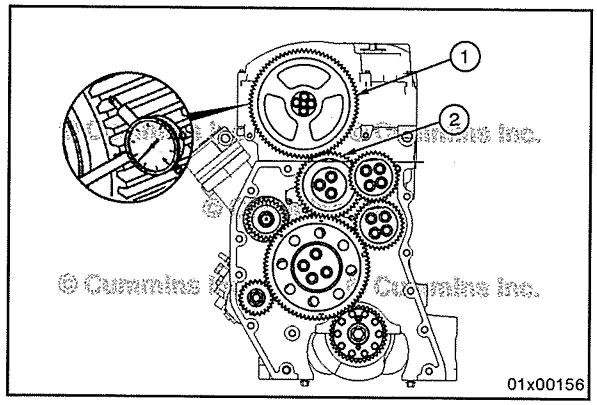
⚠WARNING⚠

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

- Check engine timing. Refer to Procedure 001-088 in Section 1.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Install the flywheel. Refer to Procedure 016-005 in Section 16.
- Install the rear support brackets. Refer to Procedure 016-003 in Section 16.
- Install the transmission. See equipment manufacturer service information.
- Remove the rear engine support.
- If equipped, install the rear power take-off. See equipment manufacturer service information.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to normal operating temperature and check for leaks and proper operation.

Gear Train Backlash, Rear (001-119)

Measure



NOTE: It is important that the adjacent mating gear does **not** turn during the measurement.

NOTE: This procedure is to measure gear backlash.

Rotate the gear being measured (1) **clockwise** to remove any backlash with the mating gear (2).

Position a dial indicator so the tip is contacting the surface of the gear tooth, as shown in the illustration. Do **not** allow the mating gear (2) to turn.

Position the indicator to "0".

Rotate the gear (1) **counterclockwise** and read the indicator.

Measure the backlash at the following locations:

- Rear camshaft gear to rear camshaft idler gear
- Crankshaft gear (rear) to rear crankshaft idler gear
- Fuel pump gear to crankshaft idler gear
- Crankshaft idler gear to camshaft idler gear
- Air compressor gear to crankshaft idler gear
- REPTO idler gear to crankshaft idler gear.

NOTE: If gear backlash is **not** within specifications, the gear out of specification **must** be changed.

- Camshaft gear to camshaft idler gear backlash

Camshaft gear to camshaft idler gear backlash		
mm		in
0.24	MIN	0.009
0.30	MAX	0.012

- Crankshaft gear (rear) to rear crankshaft idler gear backlash
- Fuel pump gear to crankshaft idler gear
- Crankshaft idler gear to camshaft idler gear backlash
- Air compressor gear to crankshaft idler gear backlash
- REPTO idler gear to crankshaft idler gear backlash.

REPTO idler gear to crankshaft idler gear backlash		
mm		in
0.12	MIN	0.005
0.215	MAX	0.008

Notes

Section 2 - Cylinder Head - Group 02

Section Contents

	Page
Crosshead	2-3
Clean and Inspect for Reuse	2-3
Finishing Steps	2-4
Install	2-4
Preparatory Steps	2-3
Remove	2-3
Cylinder Head	2-5
Assemble	2-17
Clean and Inspect for Reuse	2-14
Disassemble	2-10
Finishing Steps	2-23
Install	2-20
Leak Test	2-7
Preparatory Steps	2-5
Remove	2-6
Vacuum Test	2-8
Cylinder Head Gasket	2-24
Clean and Inspect for Reuse	2-24
Finishing Steps	2-25
General Information	2-24
Install	2-25
Preparatory Steps	2-24
Remove	2-24
Overhead Camshaft End Clearance, Valve	2-32
Finishing Steps	2-33
Measure	2-33
Preparatory Steps	2-32
Overhead Camshaft Gear, Valve	2-33
Clean and Inspect for Reuse	2-35
Finishing Steps	2-36
Install	2-35
Preparatory Steps	2-33
Remove	2-34
Overhead Camshaft Timing Speed Ring	2-36
Clean and Inspect for Reuse	2-37
Finishing Steps	2-39
Install	2-38
Preparatory Steps	2-36
Remove	2-36
Overhead Camshaft, Valve	2-25
Assemble	2-29
Clean and Inspect for Reuse	2-28
Disassemble	2-27
Finishing Steps	2-32
Initial Check	2-25
Install	2-30
Measure	2-29
Preparatory Steps	2-26
Remove	2-26
Service Tools	2-1
Cylinder Head	2-1

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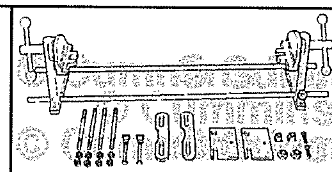
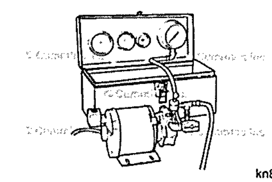
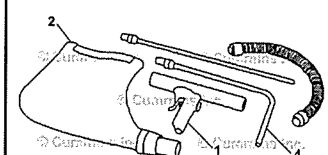
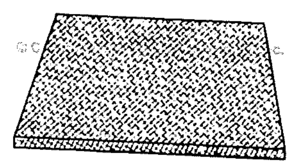
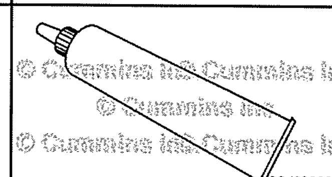
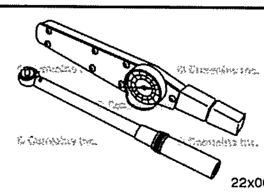
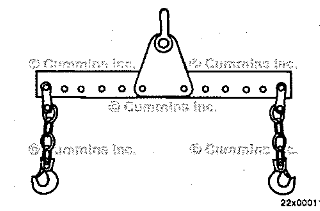
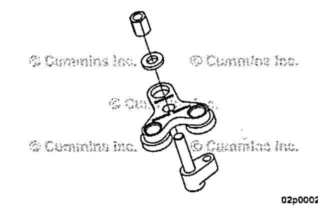
Service Tools

Cylinder Head

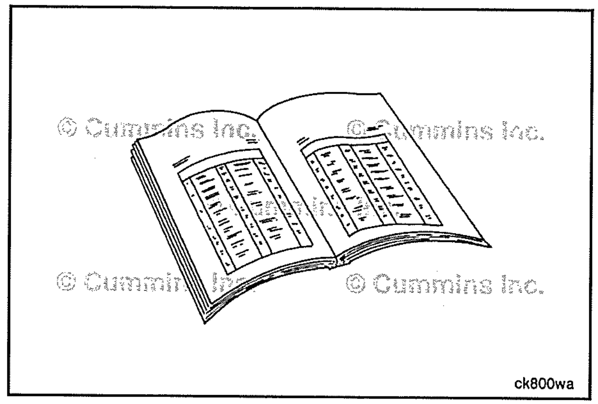
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-583	**Head Holding Fixture** This fixture is designed to hold and rotate the cylinder head to various positions during the inspection process, as required. The fixture can be adjusted to the desired length by moving the end brackets.	 22d00320
3824278	**Valve Vacuum Tester** Used to determine if the valves are correctly seated in the cylinder head. This kit is set up for 220VAC, 50/60 Hz electrical.	 kn8togr
3823461	**Super Chip Vacuum Kit** Used to make sure the cylinder head capscrew holes are clean and free of debris, oil, and coolant.	 22x00009
3823258	**Abrasive Hand Pad** Used to remove residual gasket material from the cylinder block deck surface.	 22x00010
3163087	**Lubriplate 105** A 10-ounce tube of multi-purpose lubricant.	 22d00293
2892439	**Torque Wrench - 12.5 to 250 ft-lb - 1/2 drive** This digital torque plus angle wrench is used for general purpose when a specified torque is required.	 22x00004

Tool No.	Tool Description	Tool Illustration
3162871	**Cylinder Head Lifting Fixture** Used to lift the cylinder head during removal from and installation onto the engine.	
5298594	**Valve Spring Compressor** This kit is used to compress the valve springs 3 at a time.	

Crosshead (002-001)

Preparatory Steps

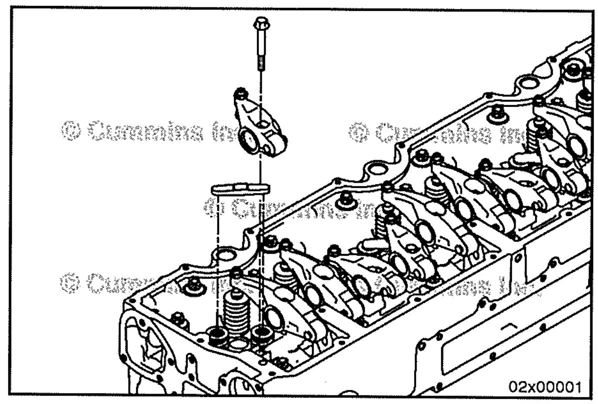


WARNING

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

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Disconnect the injector passthrough connectors and internal actuator wiring harness lock rings. Refer to Procedure 019-043 in Section 19.
- Remove the fuel injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the crankcase ventilation hose. Refer to Procedure 003-018 in Section 3.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.

Remove



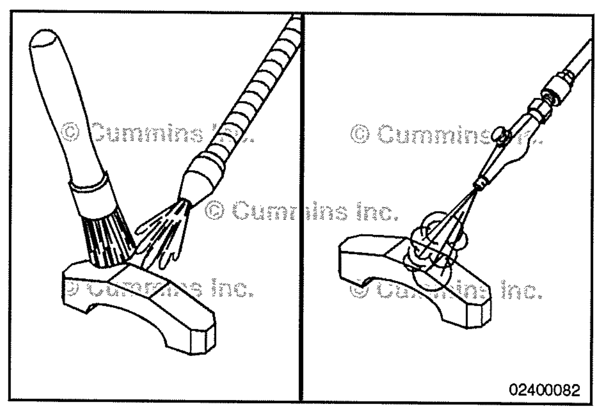
NOTE: Make note of the crosshead location and orientation. If the crossheads are to be reused, they **must** be installed in their original locations and orientations.

Remove the rocker lever capscrew.

Remove the rocker lever.

Remove the crossheads.

Clean and Inspect for Reuse



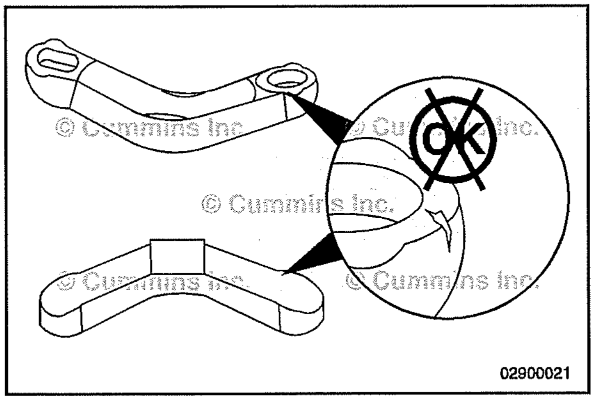
WARNING

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.

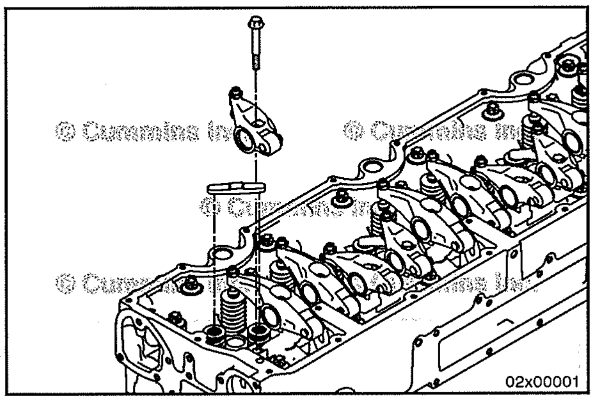
Clean the crossheads with solvent. Dry with compressed air.



Inspect the crossheads for cracks and/or excessive wear on the rocker lever and valve tip mating surfaces.

Inspect the contact pads for cracks and other damage.

Replace the crossheads if any damage is found.

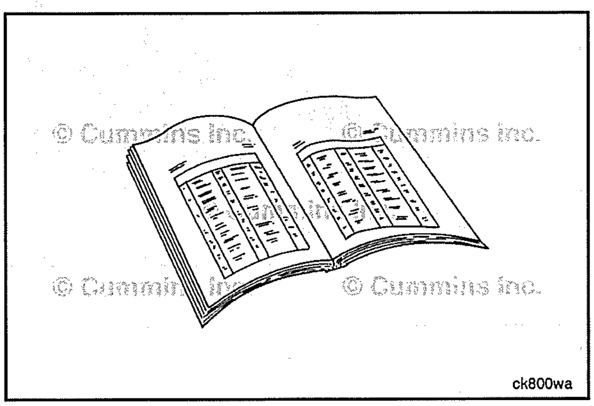


Install

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 locations and orientations.

Install the crossheads on the valve stems.

Install the rocker levers to the pedestals. Refer to Procedure 003-009 in Section 3.



Finishing Steps

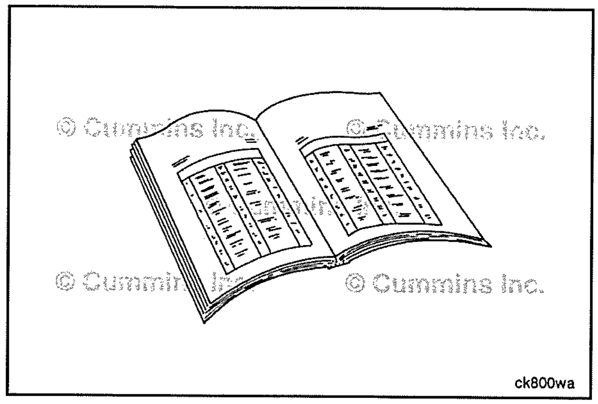
WARNING

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.

- Set valve lash for intake and exhaust valves. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover and gasket. Refer to Procedure 003-011 in Section 3.
- Install the crankcase ventilation hose. Refer to Procedure 003-018 in Section 3.
- Install the fuel injector supply lines. Refer to Procedure 006-051 in Section 6.
- Install the internal actuator wiring harness lock rings and connect the injector passthrough connectors. Refer to Procedure 019-043 in Section 19.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

Cylinder Head (002-004)

Preparatory Steps



WARNING

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

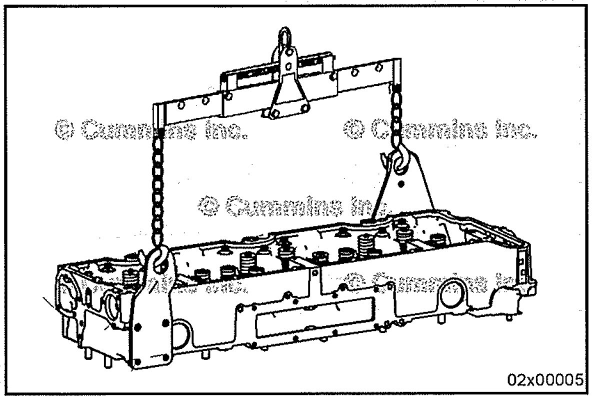
WARNING

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

WARNING

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

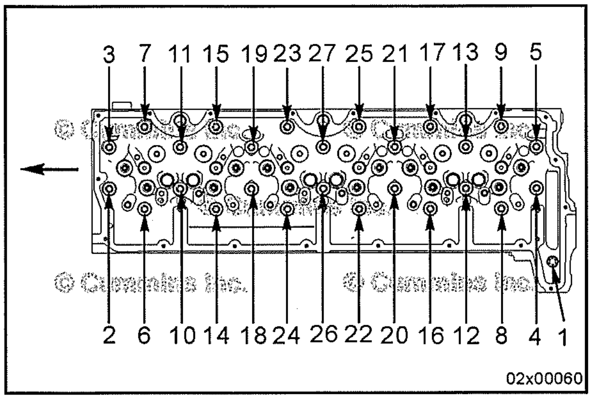
- Disconnect the batteries. See equipment manufacturer service information.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove the air piping from the intake manifold and turbocharger. See equipment manufacturer service information.
- Remove the crankcase breather hose. Refer to Procedure 003-002 in Section 3.
- Remove the high-pressure injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Pin the crankshaft. Refer to Procedure 001-088 in Section 1.
- Remove the camshaft cover plate. Refer to Procedure 001-011 in Section 1.
- Remove the overhead camshaft gear. Refer to Procedure 002-030 in Section 2.
- Remove the camshaft thrust plate. Refer to Procedure 002-024 in Section 2.
- Remove the camshaft. Refer to Procedure 002-024 in Section 2.
- Remove the internal actuator harness. Refer to Procedure 019-063 in Section 19.
- Remove the rocker lever assemblies. Refer to Procedure 003-009 in Section 3.
- Remove the crossheads. Refer to Procedure 002-001 in Section 2.
- Remove the fuel rail. Refer to Procedure 006-060 in Section 6.
- Remove the injectors. Refer to Procedure 006-026 in Section 6.
- Remove the coolant thermostat housing. Refer to Procedure 008-014 in Section 8.
- Remove the air compressor coolant return line. Refer to Procedure 012-004 in Section 12.
- 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 fuel drain line. Refer to Procedure 006-013 in Section 6.
- Remove the air intake connection. Refer to Procedure 010-080 in Section 10.
- Remove all the necessary brackets and clamps.



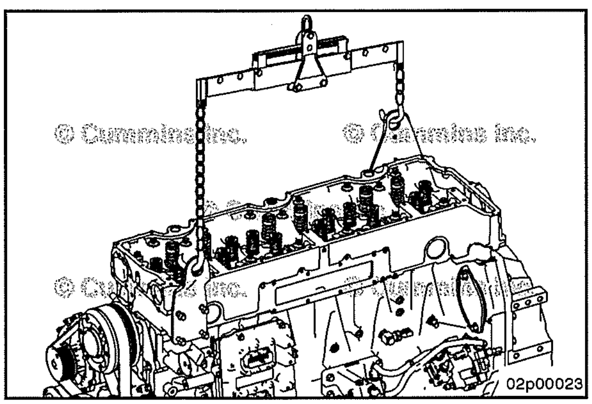
Remove

⚠WARNING⚠

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



Remove the cylinder head capscrews in the sequence shown.



Attach the engine lifting fixture, Part Number 3162871, to the lifting eyes that are bolted to the head.

⚠CAUTION⚠
Immediately upon removal of the cylinder head, plugs must be installed into all of the oil passage drillings in both the cylinder head and the cylinder block. The plugs are necessary to prevent debris from entering the lubricating system during the repair. Failure to insert oil passage plugs can result in crankshaft failure.

Use a hoist or hydraulic arm to remove the cylinder head.

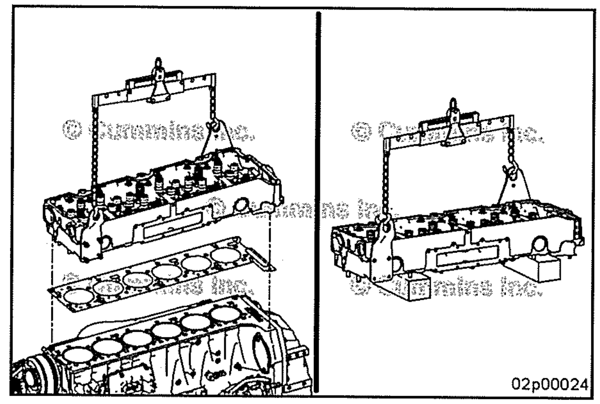
Remove the cylinder head gasket.

Discard the head gasket.

Reusable plugs are included in the oil passage protective plug kit, Part Number 4919403.

Install the plugs in the cylinder block and cylinder head oil drillings.

Place cylinder head onto stand, Part Number ST-583 or equivalent.



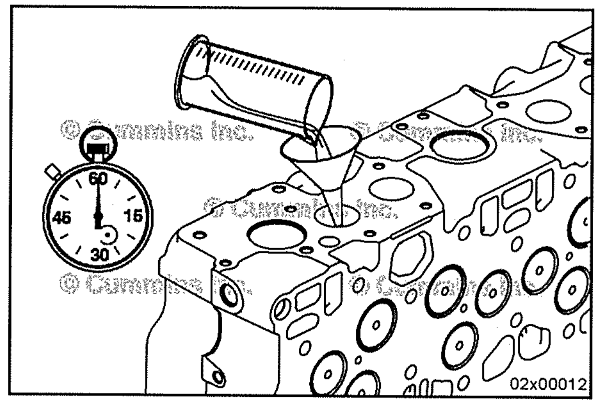
02p00024

Leak Test

Inspect the valves for indications of leaking or burning. If indications of leaking or burning are found, the cylinder head **must** be replaced.

Set the cylinder head down with the exhaust ports facing up. Secure the cylinder head, as it may be unbalanced.

Pour fuel into one of the exhaust ports until it is full. Set the container of fuel down, and start a timer.



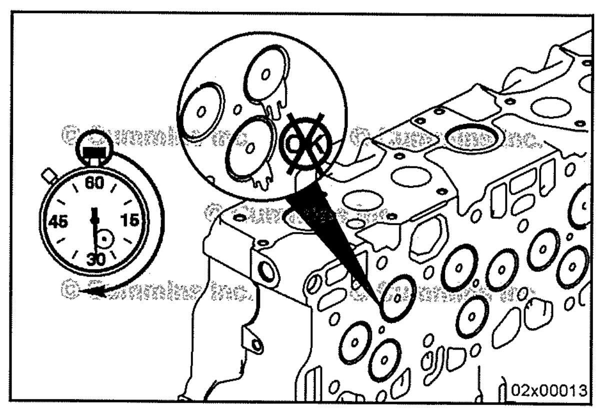
02x00012

If a drop of fuel drips or runs down the face of the cylinder head within 30 seconds, the exhaust valves and the seats are **not** sealing properly. The cylinder head **must** be replaced.

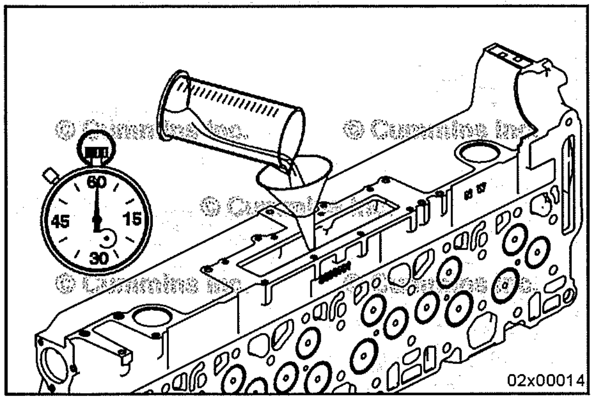
If a drop of fuel has **not** run down the face of the cylinder head in 30 seconds, the exhaust valves are acceptable.

Repeat the process for all six cylinders.

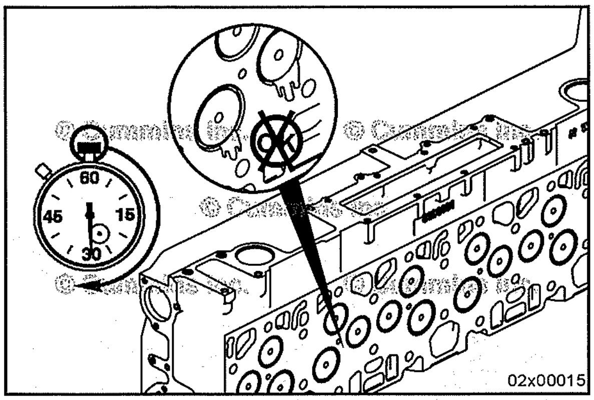
Flip the cylinder head over and set it down with the intake ports facing up. Secure the cylinder head to prevent it from tipping over, as it may be unbalanced.



02x00013



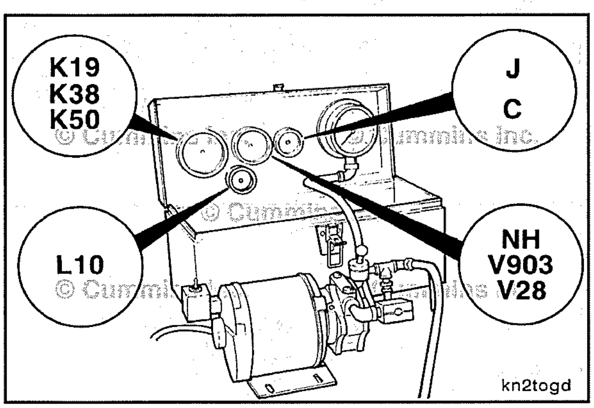
Pour fuel into one of the intake ports until it is full. Set the container of fuel down, and start the timer.



If a drop of fuel drips or runs down the face of the cylinder head within 30 seconds, the intake valves and the seats are **not** sealing properly. The cylinder head **must** be replaced.

If a drop of fuel has **not** run down the face of the cylinder head in 30 seconds, the intake valves are acceptable.

If any of the intake or exhaust valves do **not** pass the test, the cylinder head **must** be replaced.

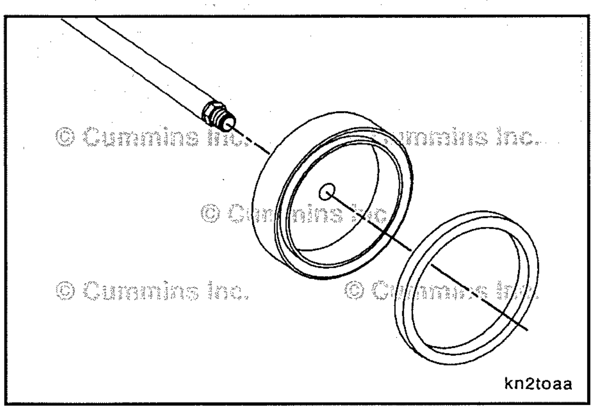


Vacuum Test

Use the vacuum tester, Part Number 3824278, to inspect the seal between the valve and the valve seat.

See the Leak Test section of this procedure for the recommended procedure to check used cylinder heads.

The valve vacuum tester can be used to test all Cummins® engine models.

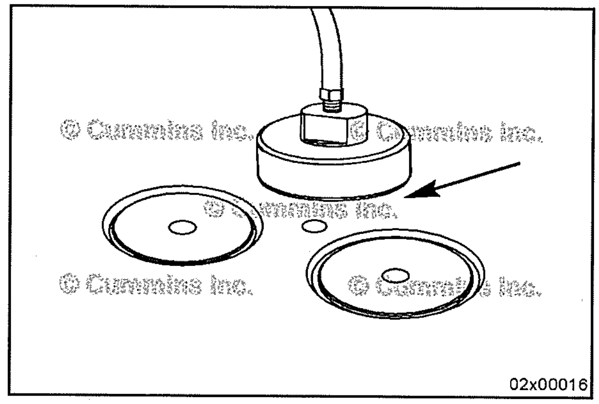


Install the seal ring and vacuum cup to the vacuum line hose.

The valves and valve seats **must** be clean and dry when vacuum testing.

Cover the valve with the cup and seal.

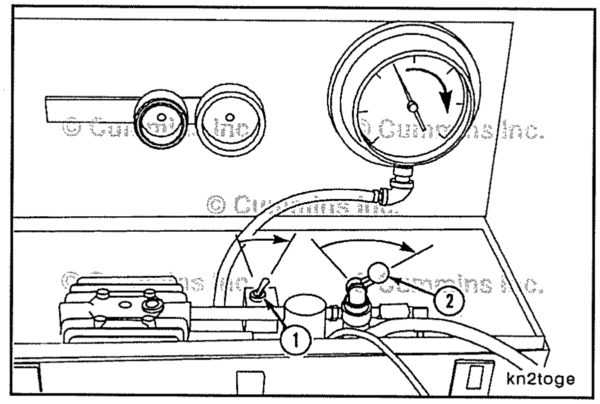
The seal **must** make a tight contact on the cylinder head around the valve.



Move the toggle switch (1) to the ON position.

Turn the vacuum control valve (2) to the OPEN position.

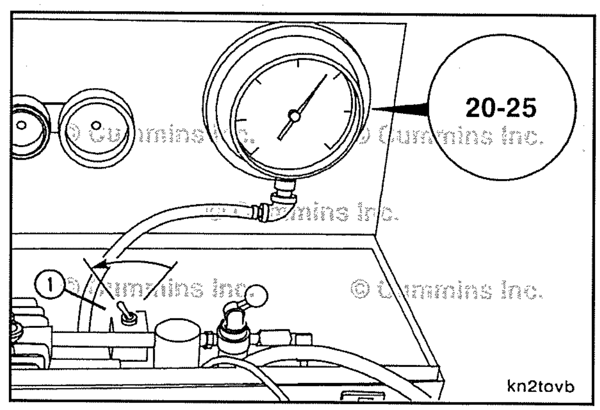
The vacuum control valve is in the OPEN position if the vacuum gauge needle moves **clockwise**.



Operate the vacuum pump until the gauge indicates the specified vacuum.

Valve to Valve Seat Vacuum		
mm Hg		in Hg
508	MIN	20
685	MAX	27

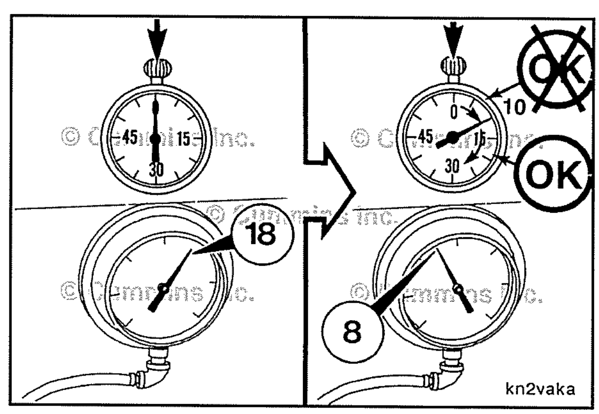
Turn the toggle switch to the OFF position.

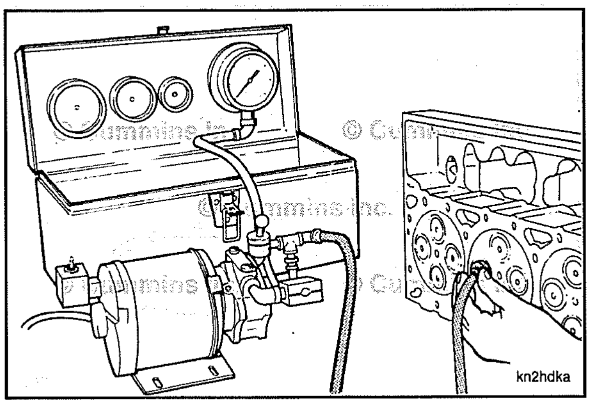


Use a stopwatch and start timing when the needle on the gauge indicates 457 mm Hg [18 in Hg].

Stop timing when the needle on the gauge indicates 203 mm Hg [8 in Hg].

The elapsed time for the needle to move between the specified gauge readings **must** be 10 seconds or more.



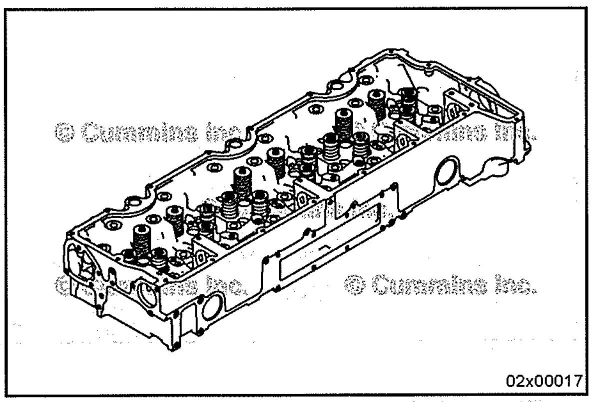


If the elapsed time is less than 10 seconds, perform the following checks:

- Repeat the test to be sure the equipment is operating properly.
- Use a soft faced mallet to lightly tap the valve head to make sure the valve is seated. Repeat the test.
- Apply a thin layer of grease on the outside diameters of the insert and the valve head. Repeat the test. The grease pattern will show the point of leakage.

A break in the grease seal pattern will indicate leakage between the valves and valve seat or the valve seat insert and the cylinder head.

If a leak is found, replace the cylinder head.

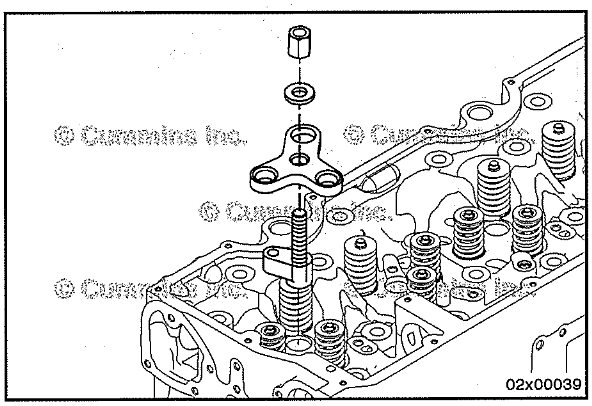


Disassemble

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.

Place the cylinder head combustion face down on a clean, smooth and level work surface that is sturdy enough to support the weight of the cylinder head.

NOTE: This section should **only** be used when necessary and is **not** needed in every situation.



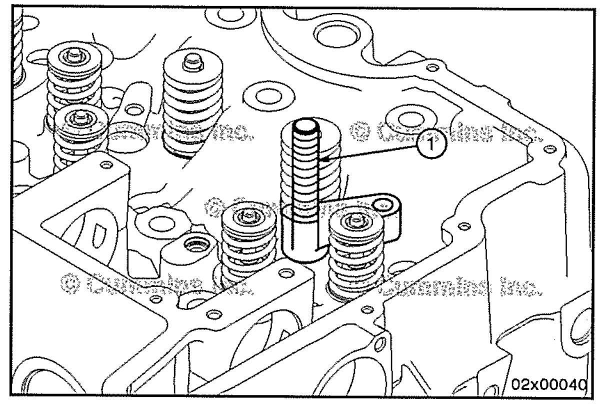
WARNING
Wear appropriate eye and face protection when performing this procedure. Springs are under tension and can act as a projectile if released, causing personal injury.

CAUTION
Do not use an impact tool for any part of this procedure. Doing so can damage the tool and/or the engine.

Use the three valve spring compressor, Part Number 5298594, to compress the valve springs.

The replacer screw pilots in the injector bore and is secured using the injector hold-down clamp.

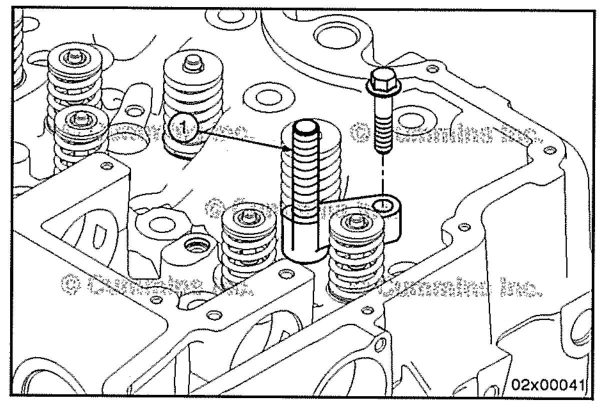
Position the replacer screw (1) in the injector hole with the threaded end pointing up.



Secure the replacer screw (1) in the injector hole with the injector clamp and capscrew.

Tighten the capscrew.

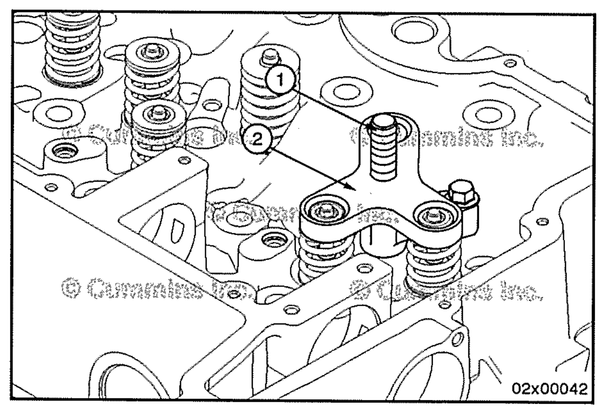
Torque Value: 46 N•m [34 ft-lb]



⚠CAUTION⚠

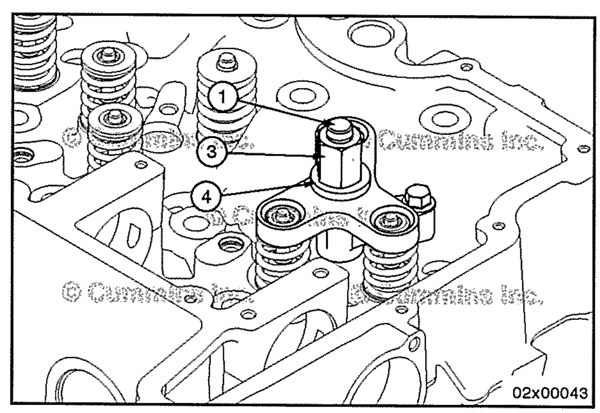
The side of the retainer plate with the larger diameter chamfers faces down to accommodate the valve springs. Failure to position the retainer plate properly can result in damage to the engine and/or tool.

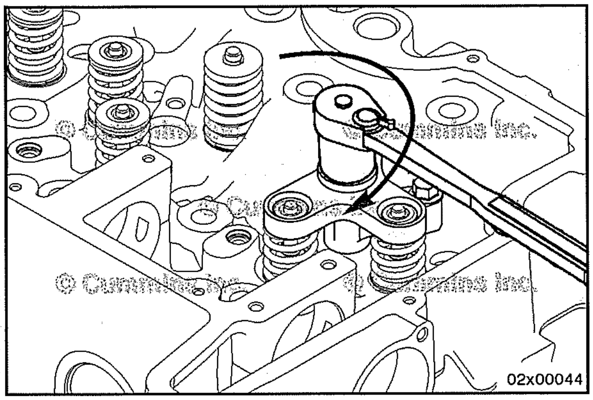
Position the compressor plate (2) over the replacer screw (1) and onto the valve springs.



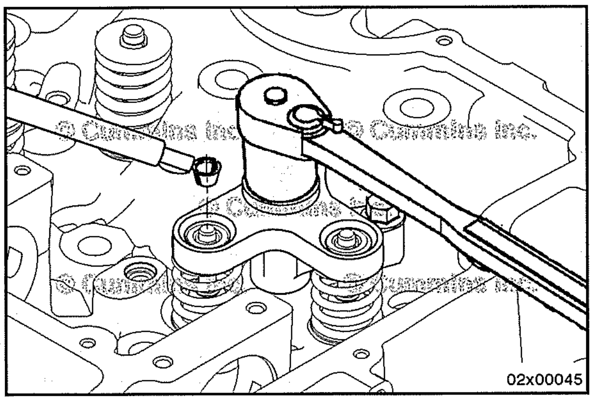
Install the washer (4) and forcing nut (3) on the replacer screw (1).

Tighten hand-tight.





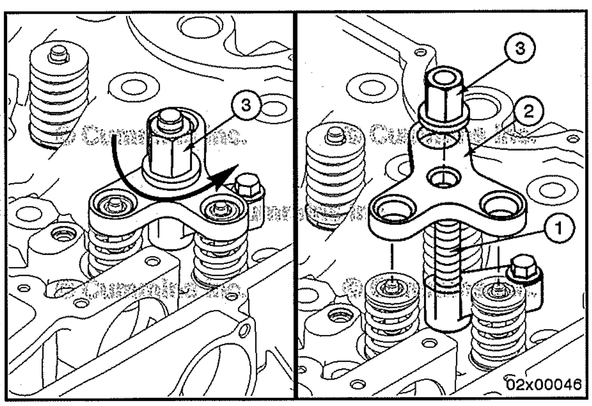
Turn the forcing nut (3) **clockwise** until the valve springs start to compress.



⚠CAUTION⚠
Do not overtighten the forcing nut. Doing so can damage the tool and/or springs.

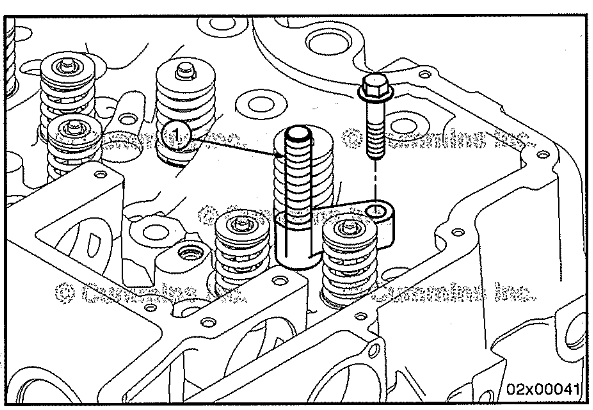
Continue turning the forcing nut (3) **clockwise** until the valve collets can be removed with a magnetic tool.

Remove and discard the valve collets.



Carefully turn the forcing nut (3) **counterclockwise** until the tension is released from the valve springs.

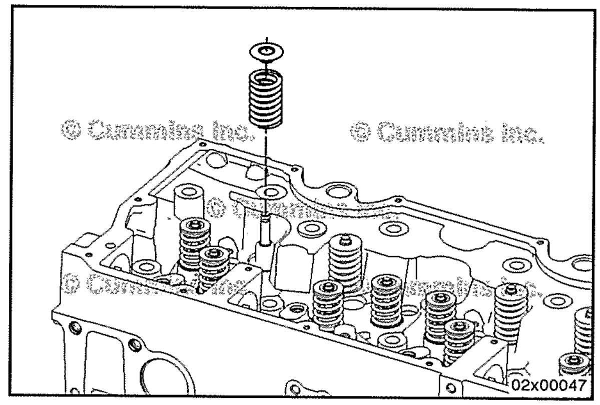
Remove the forcing nut (3) and compressor plate (2) from the replacer screw (1).



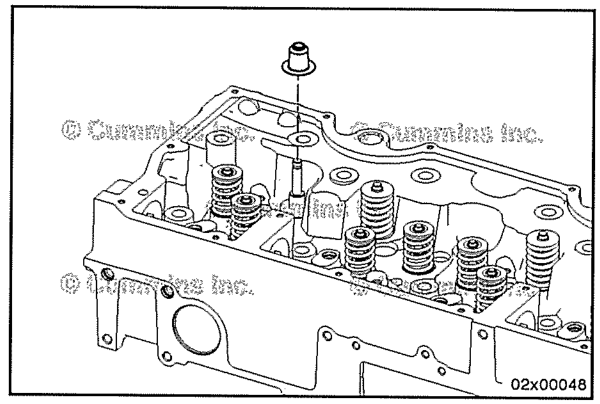
Remove the replacer screw (1) by removing the injector hold-down bolt and injector hold-down clamp.

Remove the valve spring retainer.

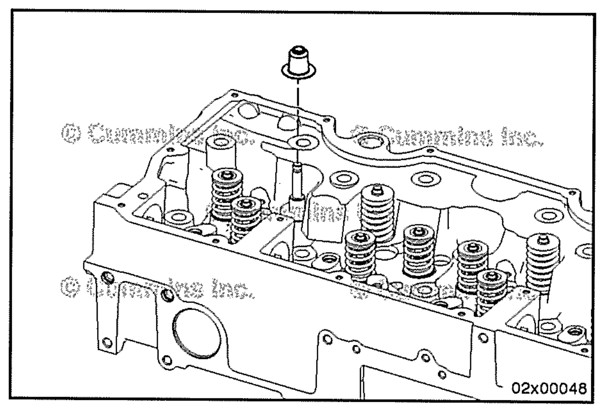
Remove the valve spring.



Remove the valve spring guide.



Remove the valve seal jacket.

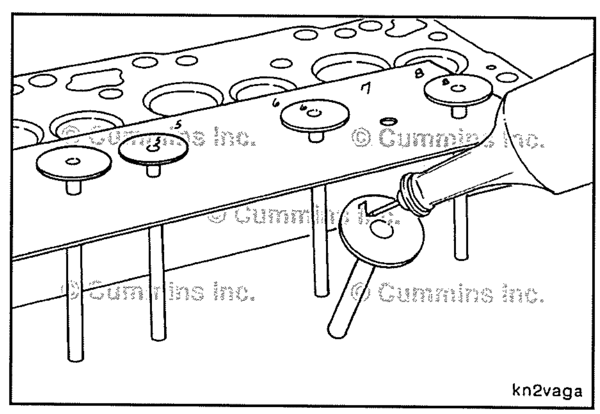


With the use of a lifting device, roll the head up on its side to gain access to the valves.

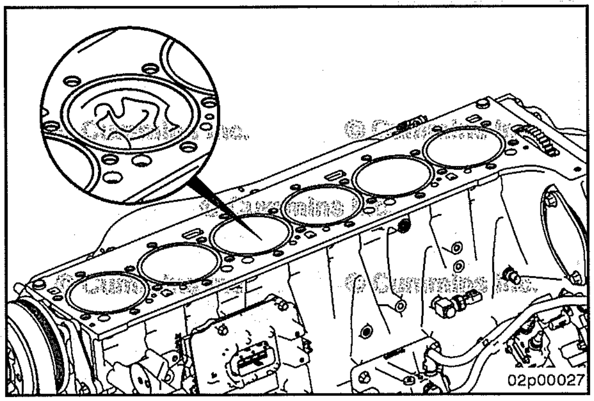
Remove the valves.

Mark the valves with an electric pencil (engraving tool) for location as they are removed.

The intake and exhaust valves are **not** interchangeable due to being differing sizes.

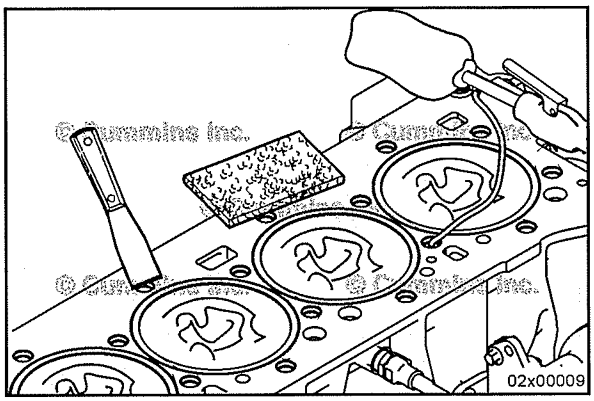


Clean and Inspect for Reuse



Place clean, lint-free rags above the pistons to prevent debris from falling into the engine.

Plug or cover the coolant and oil passages in the cylinder block deck.



⚠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.

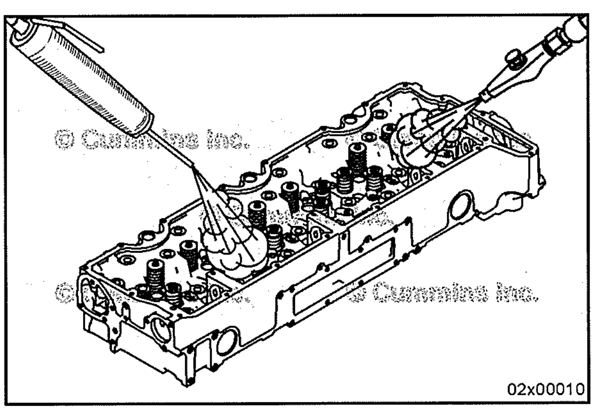
Use a gasket scraper to clean the cylinder block deck surface.

Use Scotch-Brite™ 7448 abrasive pad, Part Number 3823258 or equivalent, and solvent to remove any residual gasket material from the cylinder block deck surface.

Use a chip vacuum, Part Number 3823461 or equivalent, to make sure the cylinder head capscrew holes are clean and free of debris, oil, and coolant.

Do **not** use power tools to clean the cylinder block head deck.

Use the following procedure to inspect the cylinder block head deck. Refer to Procedure 001-026 in Section 1.



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

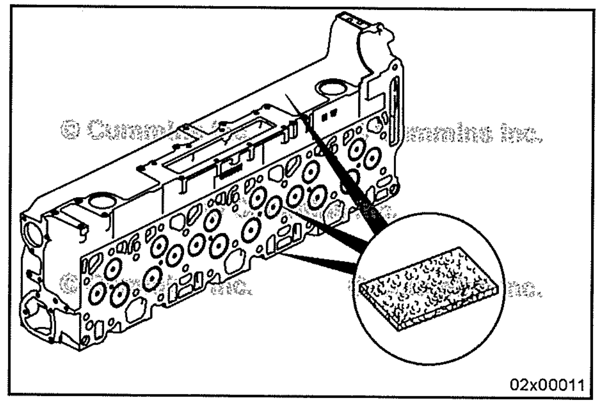
Steam clean the cylinder head.

Dry with compressed air.

Use compressed air to blow out all capscrew holes.

Use Scotch-Brite™ 7448 abrasive pad, Part Number 3823258 or equivalent, and solvent to clean the cylinder head combustion face.

Clean the exhaust manifold and intake manifold gasket surfaces.



⚠CAUTION⚠

Do not use caustic or acid solutions to clean the cylinder head capscrews to avoid damage to cylinder head capscrews.

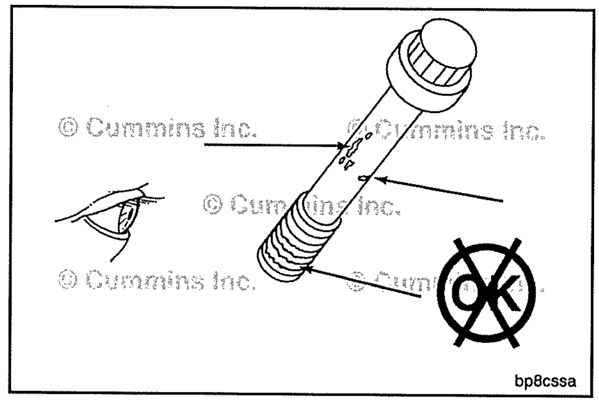
Clean the cylinder head capscrews.

Clean the capscrews thoroughly with a wire brush, a wire wheel (soft), or a nonabrasive bead blast to remove deposits from the shank and threads.

Inspect the capscrews for the following:

- Damaged threads
- Rust or corrosion caused by pitting
- Nicks, bent, or galled.

The capscrew **must** be replaced if it has any of the listed damages.



Measure the flatness of the cylinder head combustion face surface as follows:

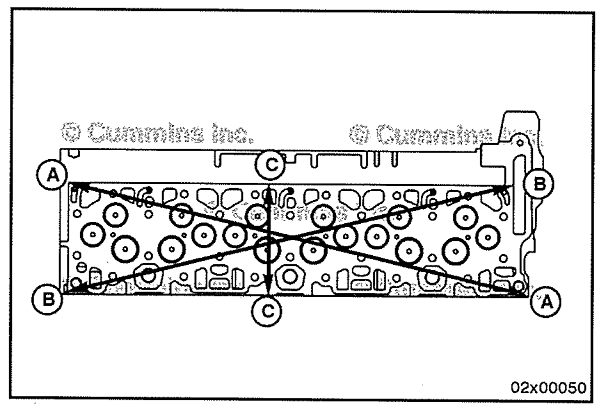
- A to A and B to B (corner to corner)
- C to C (across combustion face).

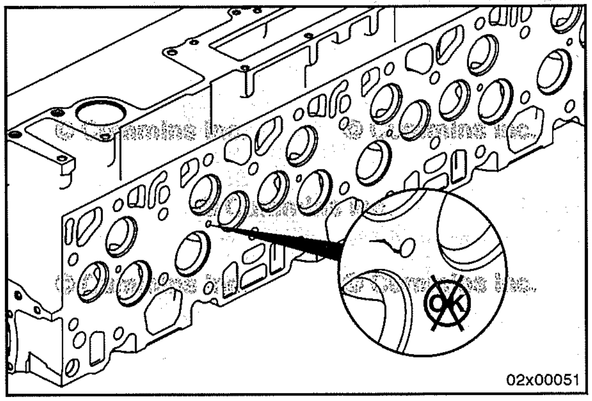
Dimensions for C to C **must** be checked at multiple locations from front to rear of the cylinder head.

Cylinder Head Flatness

	mm		in
A to A	0.15	MAX	0.006
B to B	0.15	MAX	0.006
C to C	0.15	MAX	0.006

If the cylinder head is pitted, grooved, or is **not** within specifications, the cylinder head **must** be replaced.





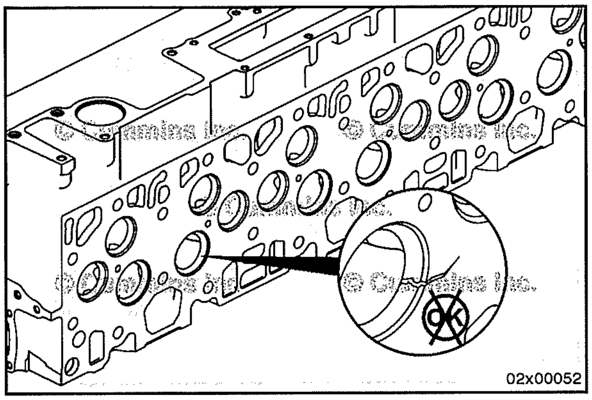
Cylinder Head Cracks - Reuse Guidelines.

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 head, use the crack detection kit, Part Number 3375432.

Pay close attention to areas of the cylinder head that include:

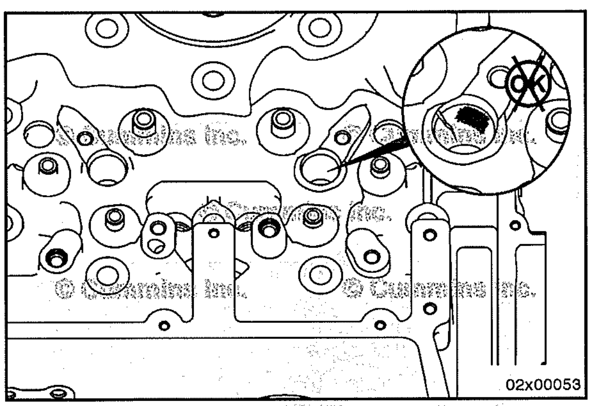
- Injector bore
- Combustion face
- Valve seals.



CAUTION

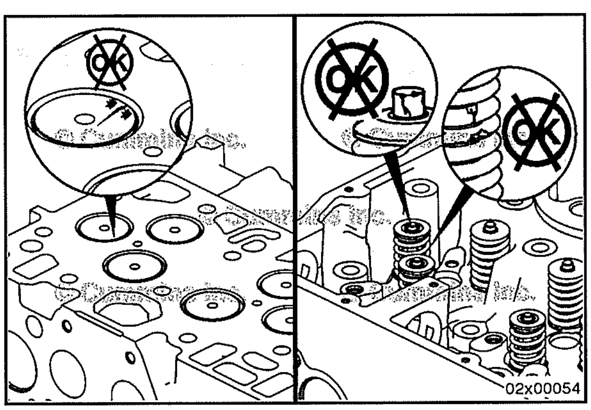
Failure to replace the cylinder head for a crack that extends into or through the valve seat bore will result in a valve seat insert falling out. Engine damage will result.

- If any cracks are found, the cylinder head **must** be replaced.



Inspect the injector bores for wear, cracks, other damage, or mis-drilled passages.

The cylinder head can **not** be used if wear, cracks, other damage, or mis-drilled passages are detected in the injector bores.



Inspect the valves and valve springs for cracks, bent or broken valve stems, or other damage.

Inspect the valves for indications of leakage or burning.

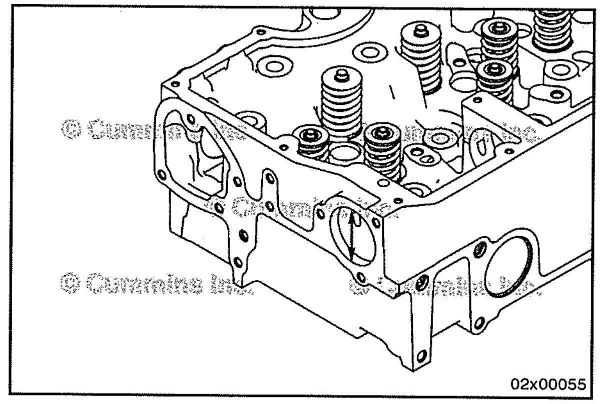
If any of the following damage is found, the cylinder head **must** be rebuilt or replaced.

- Cracks
- Leaks
- Burnt valves
- Other damage.

Inspect the camshaft bores.

Camshaft Bore Diameter without Camshaft Installed		
mm		in
55.720	MAX	2.194

If a camshaft bore is out of specification, the head **must** be replaced. No camshaft bushings are available for the journals.

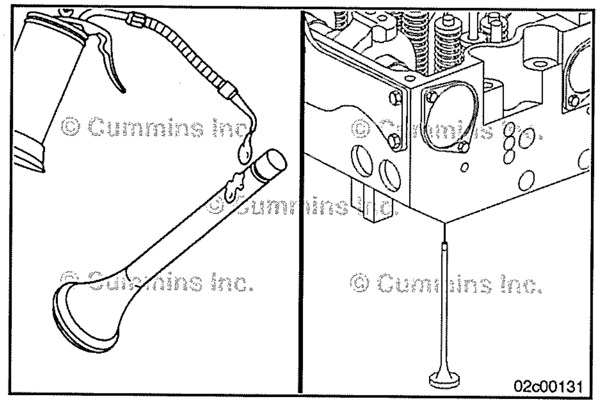


Assemble

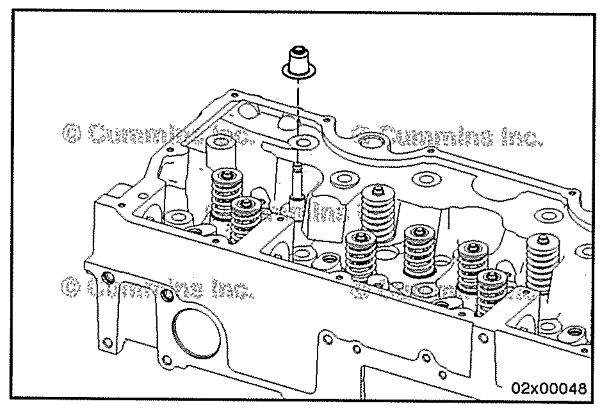
Use clean engine oil to lubricate the valve stems.

Install the valves.

After the valves are installed, place the cylinder head on a flat surface that will **not** damage the cylinder head surface.

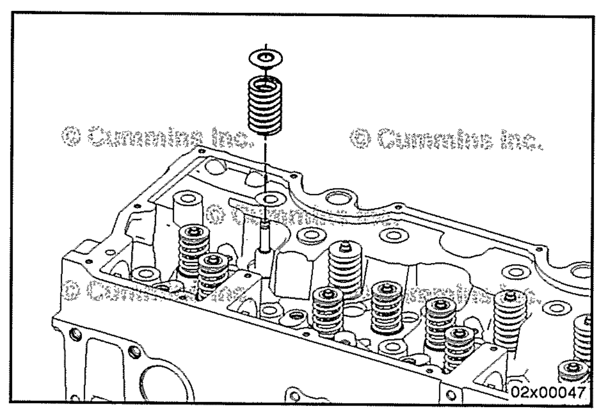


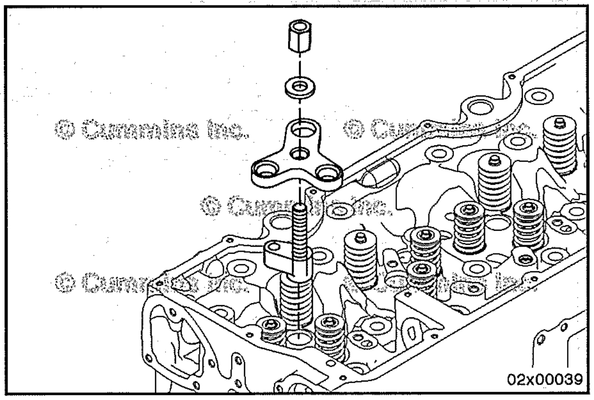
Install the valve spring guides.



Install the valve springs.

Install the valve spring retainers.



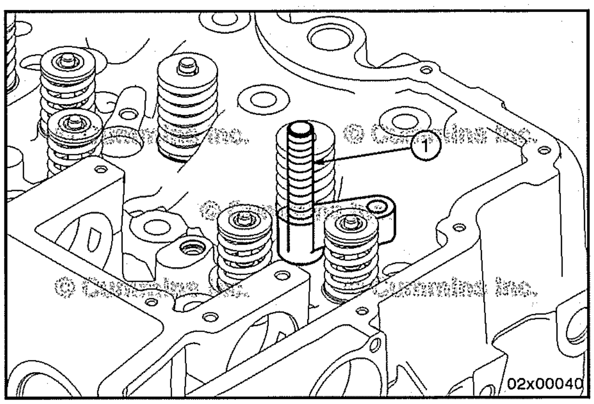


⚠CAUTION⚠

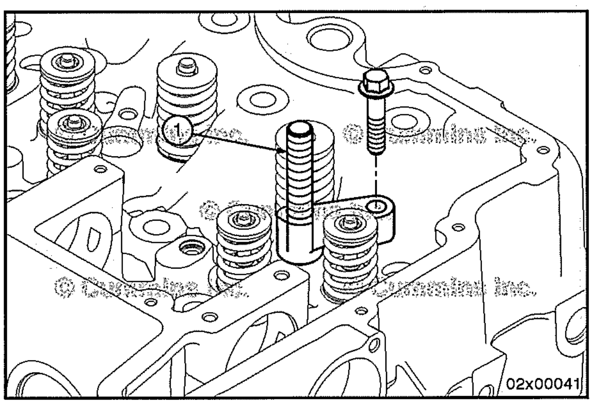
Do not use an impact tool for any part of this procedure. Doing so can damage the service tool and/ or the engine.

Use the three valve spring compressor, Part Number 5298594, to compress the valve springs.

The replacer screw pilots into the injector bore and is secured with the injector hold-down clamp.



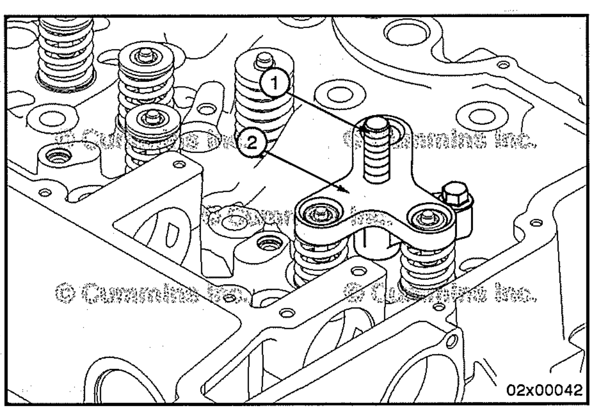
Position the replacer screw (1) in the injector hole with the threaded end pointing up.



Secure the replacer screw (1) in the injector hole with the injector clamp and capscrew.

Tighten the capscrew.

Torque Value: 54 N•m [40 ft-lb]



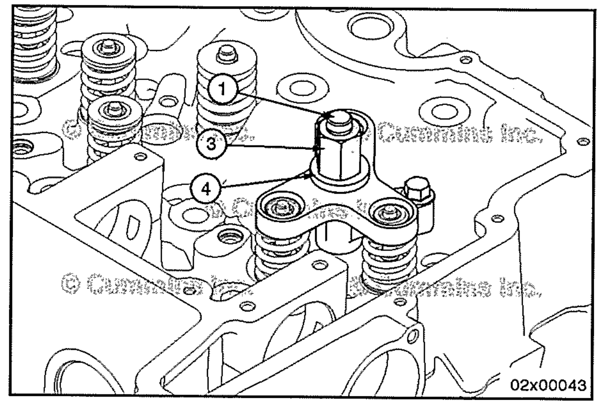
⚠CAUTION⚠

The side of the retainer plate with the larger diameter chamfers faces down to accommodate the valve springs. Failure to position the retainer plate properly can result in damage to the engine and/or tool.

Position the compressor plate (2) over the replacer screw (1) and onto the valve springs.

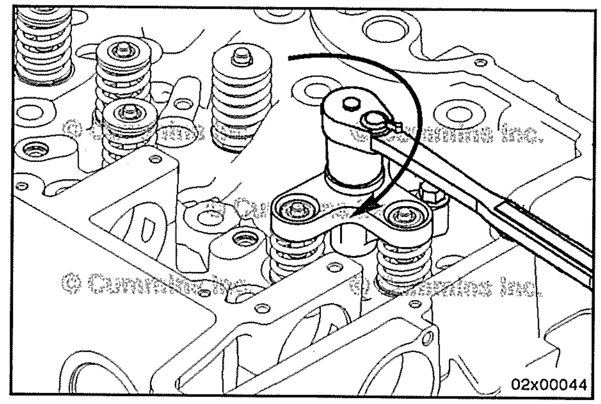
Install the washer (4) and forcing nut (3) on the replacer screw (1).

Tighten the nut hand-tight.



⚠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.

Turn the forcing nut (3) **clockwise** until the valve springs start to compress.



⚠CAUTION⚠
Do not overtighten the forcing nut. Doing so can damage the tool and/or springs.

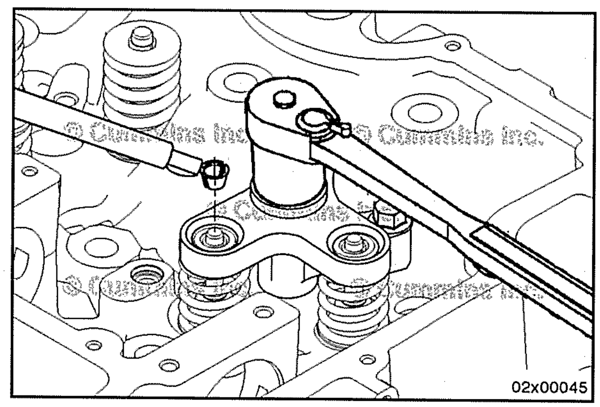
Always use new collets when rebuilding the cylinder head.

Install the new valve spring retainer collets.

Inspect the collets for proper seating and installation.

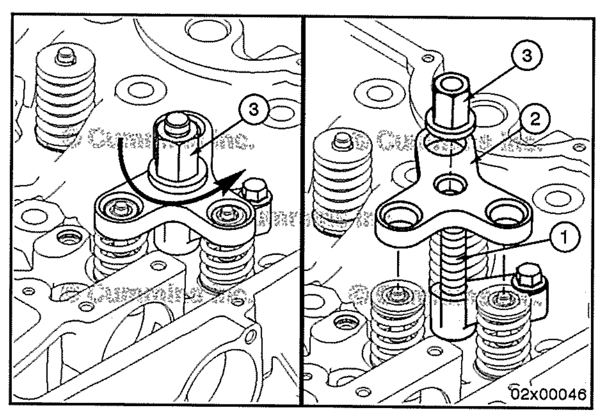
Once the cylinder head is assembled, it will be necessary to run the vacuum test to assure good valve to seat sealing.

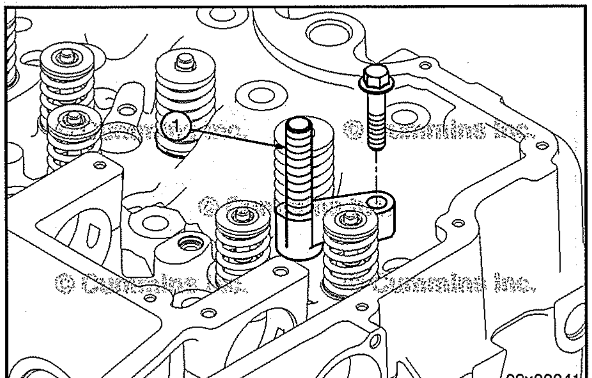
See the Vacuum Test section in this procedure.



Carefully turn the forcing nut (3) **counterclockwise** until the tension is released from the valve springs.

Remove the forcing nut (3) and compressor plate (2) from the replacer screw (1).

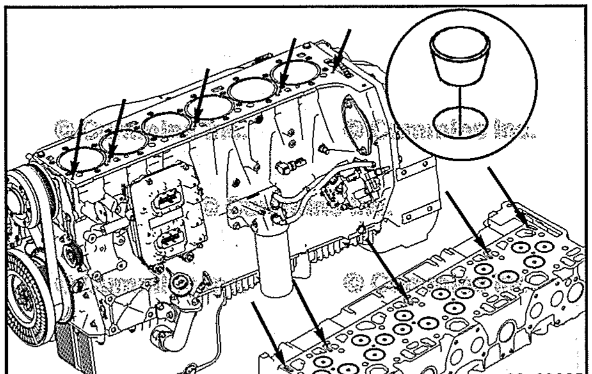




02x00041

Remove the replacer screw (1) by removing the injector hold down bolt and injector hold down clamp.

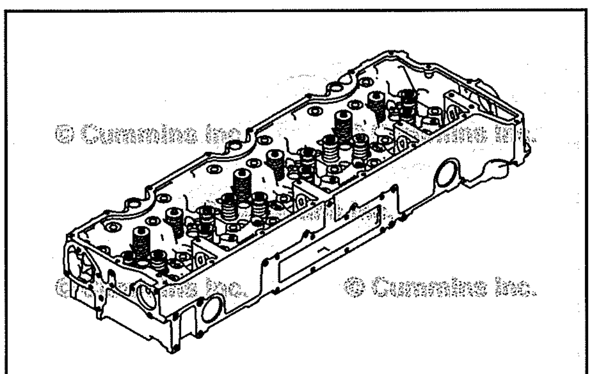
Repeat the above steps for each cylinder as needed.


02p00025

⚠CAUTION⚠

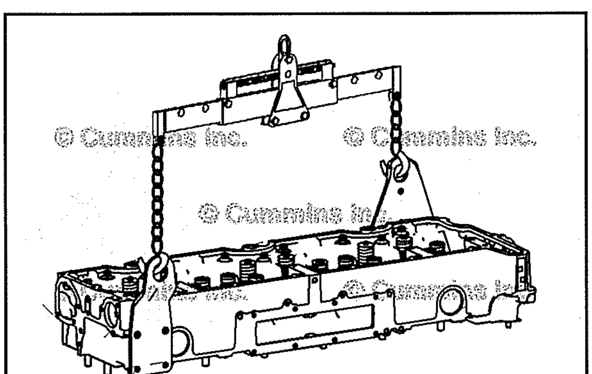
Before the cylinder head is assembled onto the block, all oil passage plugs must be removed. Failure to remove the oil plugs will result in extensive engine damage.

Remove the oil plugs from the cylinder head and the cylinder block.


02x00017

Install

Remove all cylinder head packaging if present.

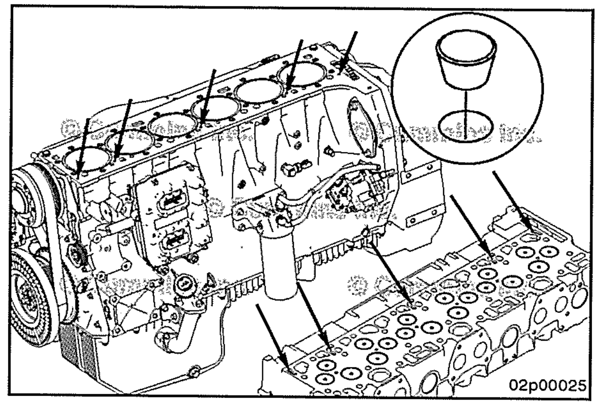

02x00005

Attach the engine lifting fixture, Part Number 3162871, to the lifting eyes that are bolted to the head.

⚠CAUTION⚠

Before the cylinder head is assembled onto the block, all oil passage plugs must be removed. Failure to remove the oil plugs will result in extensive engine damage.

Remove the oil plugs and/or tape from the cylinder head and the cylinder block.



⚠WARNING⚠

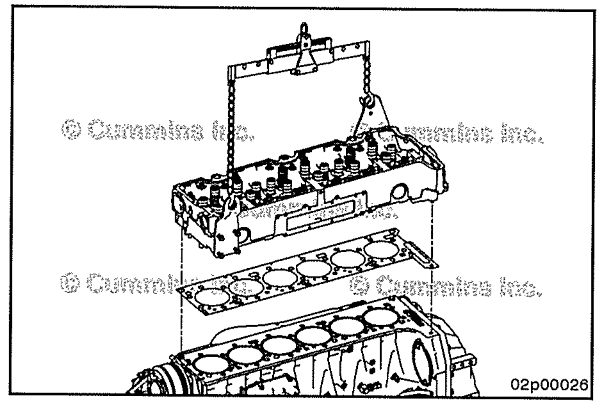
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

⚠CAUTION⚠

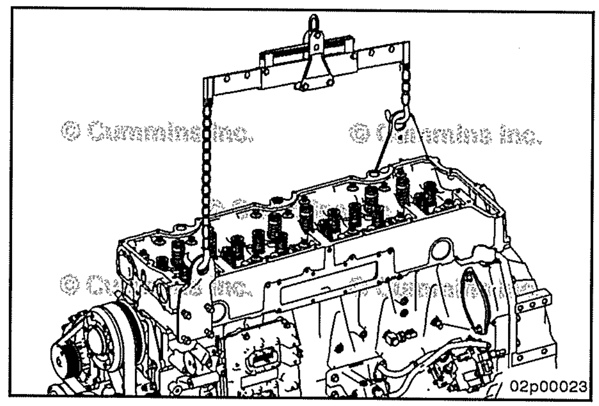
Do not drop the cylinder head on the cylinder head gasket. The gasket material can be damaged.

Install a new cylinder head gasket.

Use a hoist or hydraulic arm and install the cylinder head.



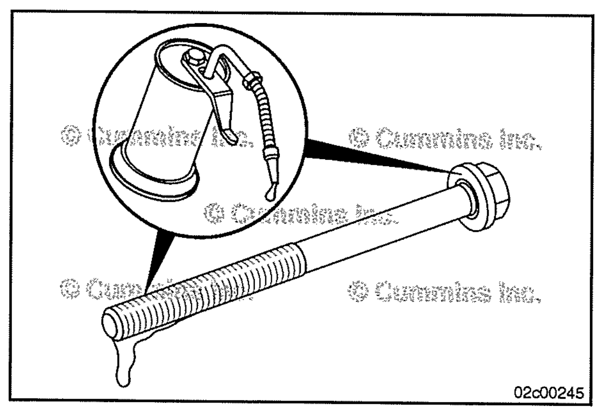
Remove the engine lifting fixture, Part Number 3162871, from the lifting eyes that are bolted to the head.

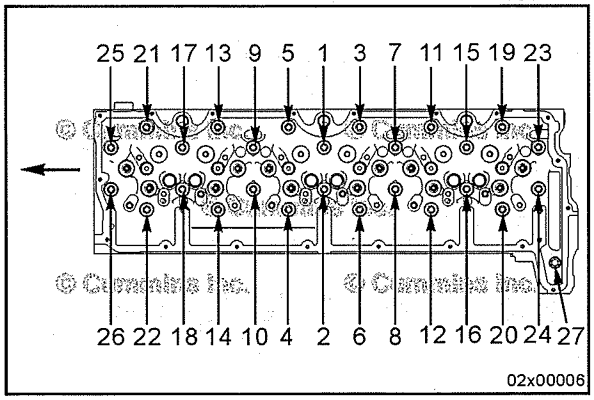


Use clean lubricating engine oil to lightly coat the cylinder head capscrew threads and bottom of the flange.

Allow the excess oil to drain from the capscrew threads.

Install the cylinder head capscrews.





Tighten all the capscrews in the sequence shown to the specified values:

For capscrews 1 to 26

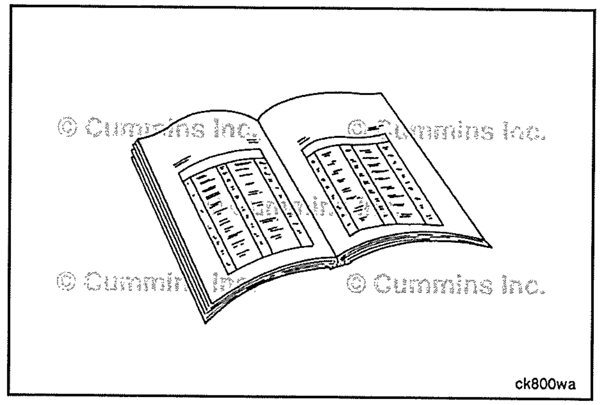
Torque Value:

Step 1	90 N•m	[66 ft-lb]
Step 2	150 N•m	[118 ft-lb]
Step 3	Rotate 120 degrees.	

For capscrew 27

Torque Value: 46 N•m [34 ft-lb]

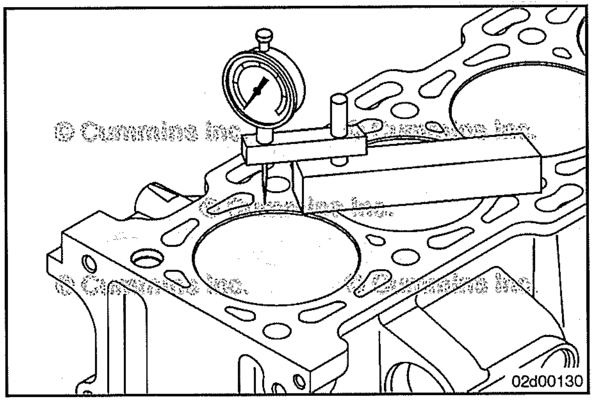
Finishing Steps



WARNING

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

- Install all the necessary brackets and clamps.
- Install the camshaft. Refer to Procedure 002-024 in Section 2.
- Install the air intake connection. Refer to Procedure 010-080 in Section 10.
- Install the fuel drain line. Refer to Procedure 006-013 in Section 6.
- Install the exhaust manifold. Refer to Procedure 011-007 in Section 11.
- Install the turbocharger. Refer to Procedure 010-033 in Section 10.
- Install the air compressor coolant return line. Refer to Procedure 012-004 in Section 12.
- Install the coolant thermostat housing. Refer to Procedure 008-013 in Section 8.
- Install the injectors. Refer to Procedure 006-026 in Section 6.
- Install the fuel rail. Refer to Procedure 006-060 in Section 6.
- Install the crossheads. Refer to Procedure 002-001 in Section 2.
- Install the rocker lever assemblies. Refer to Procedure 003-009 in Section 3.
- Set the valve lash. Refer to Procedure 003-004 in Section 3.
- Install the camshaft thrust plate. Refer to Procedure 002-024 in Section 2.
- Install the overhead camshaft gear. Refer to Procedure 002-030 in Section 2.
- Install the camshaft cover plate. Refer to Procedure 001-011 in Section 1.
- Time the camshaft to the crankshaft. Refer to Procedure 001-088 in Section 1.
- Install the internal actuator harness. Refer to Procedure 019-063 in Section 19.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the high-pressure injector supply lines. Refer to Procedure 006-051 in Section 6.
- Install the crankcase breather hose. Refer to Procedure 003-002 in Section 3.
- Connect the air piping to the intake manifold and turbocharger. See equipment manufacturer service information.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to normal operating temperature and check for leaks.



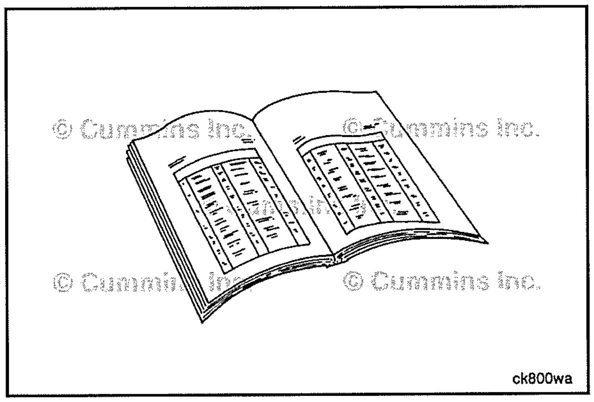
Cylinder Head Gasket (002-021)

General Information

A specific cylinder head gasket with an increased thickness is **not** available for combustion deck resurfacing of the cylinder block or cylinder head. If the combustion deck needs be resurfaced such that the correct specifications can **not** be maintained, the block and/or cylinder head **must** be replaced.

Remove and install instructions and specifications can be found in the following procedures:

- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.

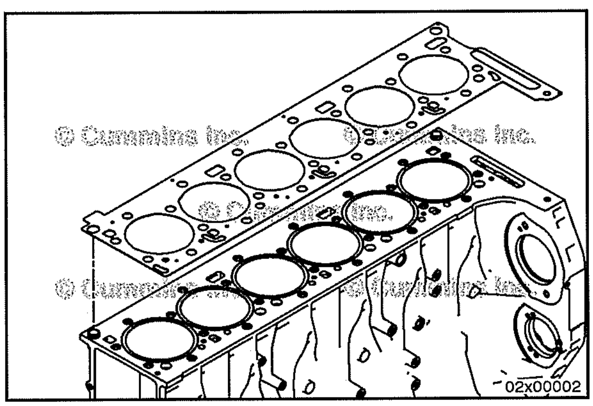


Preparatory Steps

WARNING

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

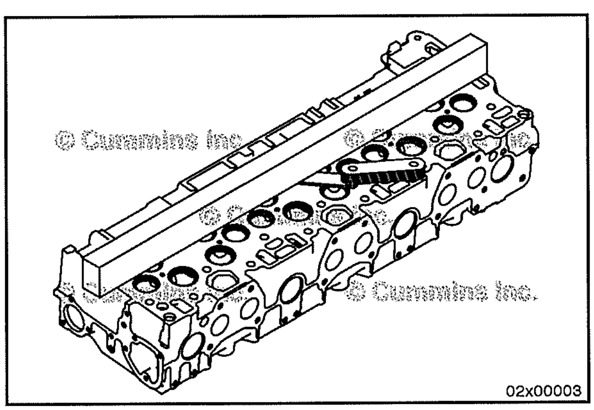
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.



Remove

Remove the cylinder head gasket.

Discard the gasket.

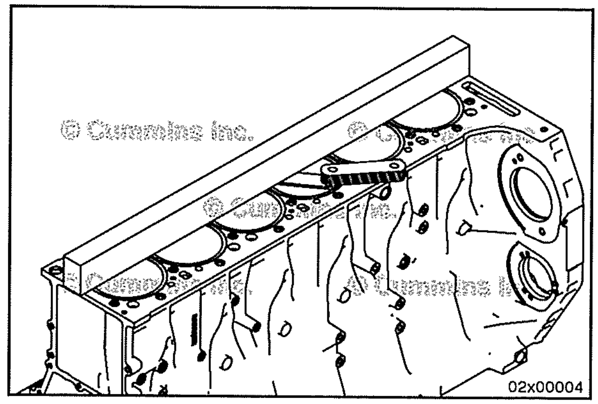


Clean and Inspect for Reuse

NOTE: Cylinder head gaskets can **not** be reused. A new cylinder head gasket **must** be used.

Clean the cylinder head combustion deck. Inspect and measure the cylinder head combustion deck flatness. Refer to Procedure 002-004 in Section 2.

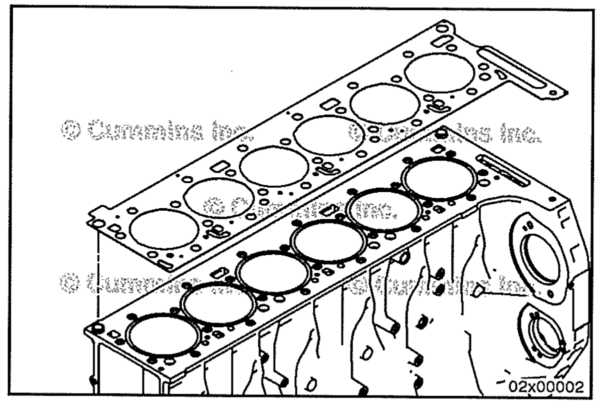
Clean the cylinder block combustion deck. Inspect and measure the cylinder block combustion deck flatness. Refer to Procedure 001-026 in Section 1.



Install

A new gasket **must** be installed. Do **not** reuse an old gasket.

Install the cylinder head gasket.

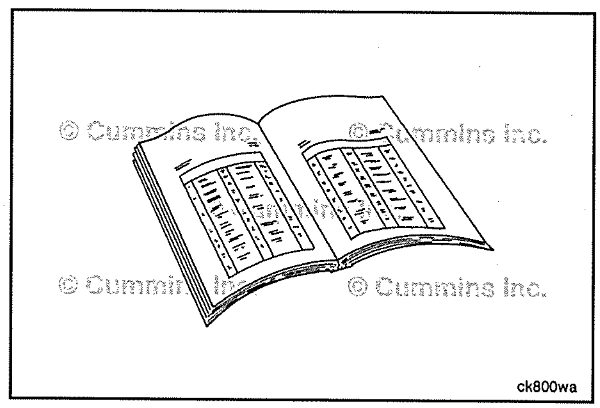


Finishing Steps

WARNING

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

- Install the cylinder head. Refer to Procedure 002-004 in Section 2.



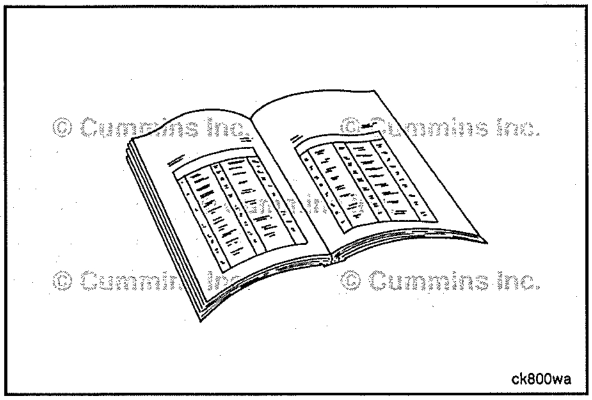
Overhead Camshaft, Valve (002-024)

Initial Check

Prior to starting this procedure, make sure there is adequate clearance in rear of the engine to remove the camshaft.

NOTE: It may be necessary to remove OEM components (radiator, charge-air cooler assembly, etc.) for access. See equipment manufacturer service information.

If adequate clearance can **not** be obtained, the cylinder head **must** be removed.

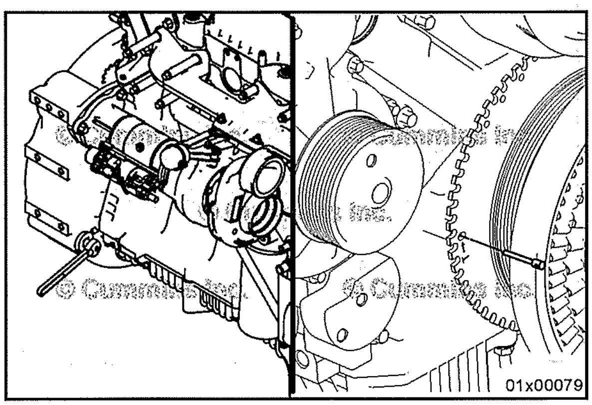


Preparatory Steps

WARNING

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

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the OEM accessories attached to the cylinder head. See equipment manufacturer service information.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the crankcase breather hose. Refer to Procedure 003-018 in Section 3.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker lever assemblies. Refer to Procedure 003-009 in Section 3.
- Remove the camshaft cover plate. Refer to Procedure 001-011 in Section 1.
- Remove the overhead camshaft gear. Refer to Procedure 002-030 in Section 2.



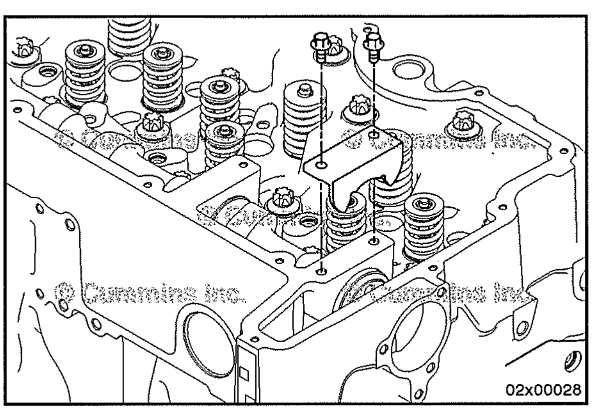
Remove

Rotate the engine to align the timing hole in the crankshaft damper with the corresponding hole in the lubricating pump housing.

When the two holes are aligned, Cylinder 1 is at Top Dead Center (TDC).

Use a suitable pin to lock the crankshaft in position, Part Number 5298582.

The engine can be rotated by installing the engine turning tool, Part Number 4919092, in the allocated slot on the flywheel housing.



Remove the thrust plate capscrews and the thrust plate.

⚠CAUTION⚠
The camshaft will drop once the camshaft clears the last bore if not supported. This can cause damage to the camshaft journal.

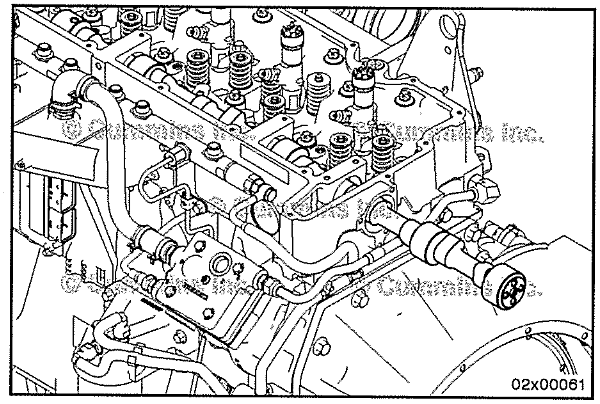
⚠CAUTION⚠
Forcing the camshaft during removal may cause damage to the camshaft and the cylinder head bores.

Remove the camshaft.

While pushing out slightly, rotate the camshaft and carefully work the camshaft through the camshaft bores.

As each camshaft journal passes through a bore, the camshaft will drop slightly and the camshaft lobes will catch on the bores.

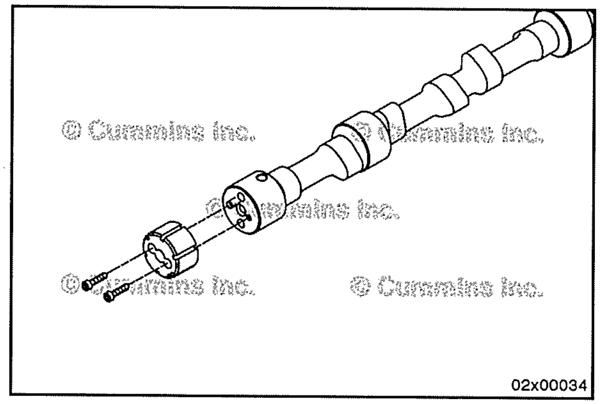
Rotating the camshaft frees the lobe from the bore and allows the camshaft removal to continue.



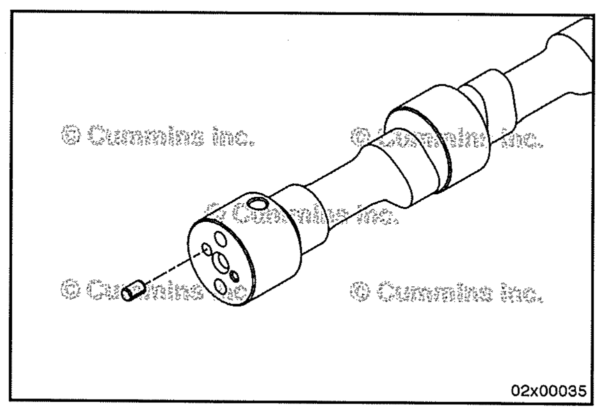
Disassemble

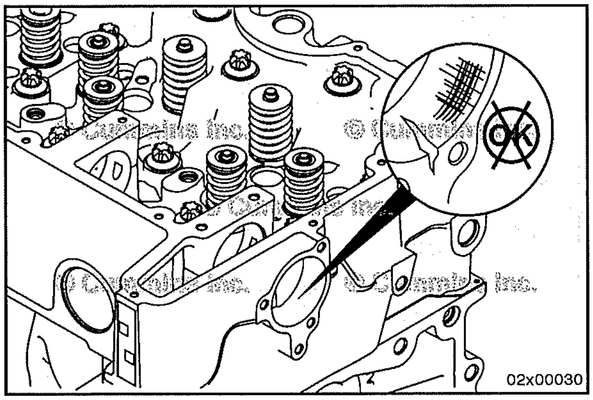
Remove the two capscrews from the timing speed ring located on the front of the camshaft.

Remove the timing speed ring.



Remove the roller pin from the front of the camshaft.

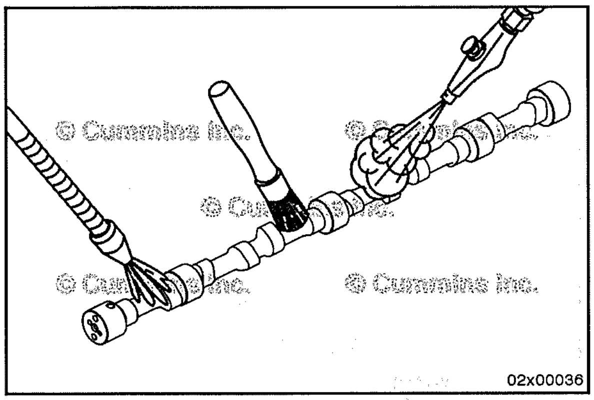




02x00030

Clean and Inspect for Reuse

Inspect the bores. If there is damage or the sizes of the bores are outside the specifications, replace the cylinder head. Refer to Procedure 002-004 in Section 2.



02x00036

WARNING

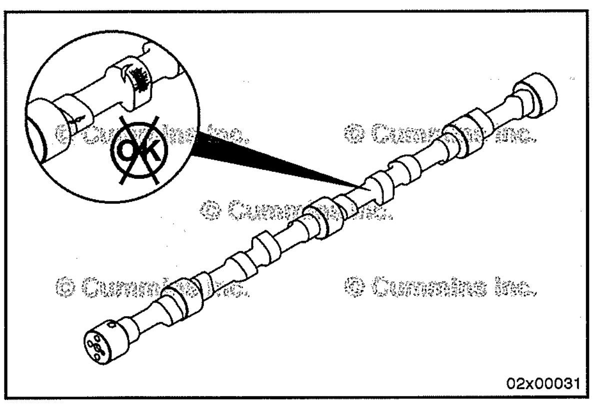
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

WARNING

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

Clean the camshaft with solvent.

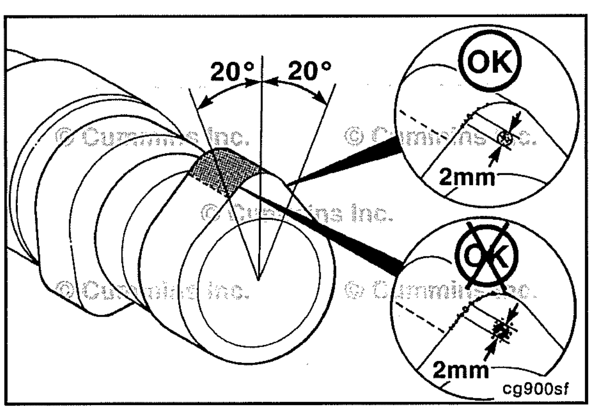
Dry with compressed air.



02x00031

Inspect the valve lobes and journals for cracking, pitting, or scoring.

Inspect the camshaft gear mounting surface on the camshaft.

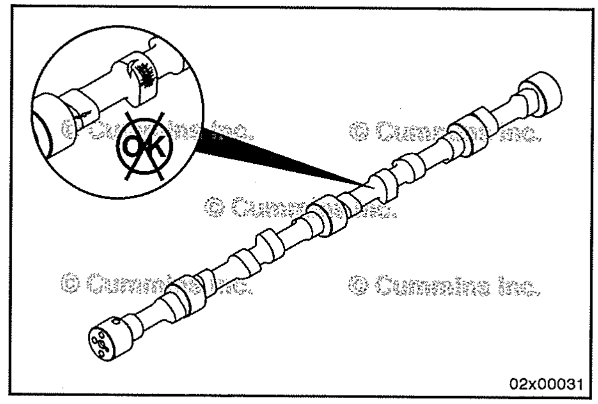


cg900sf

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

Outside of the ± 20 degrees of 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, replace the camshaft.

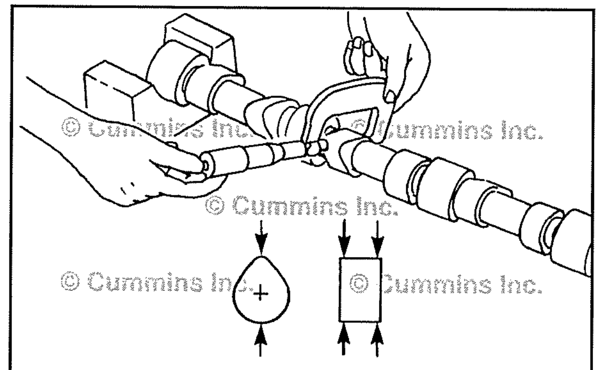


02x00031

Measure

Measure the peak of the camshaft valve lobes.

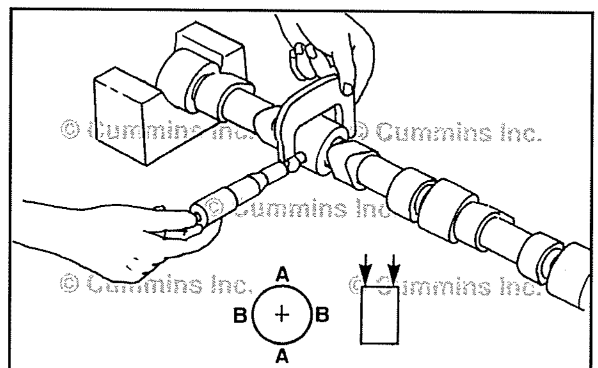
Diameter of Peak of Lobe	mm		in
Intake	46.820	MIN	1.843
	46.895	MAX	1.846
Exhaust	45.194	MIN	1.780
	45.269	MAX	1.782



cg900tb

Measure the camshaft journals.

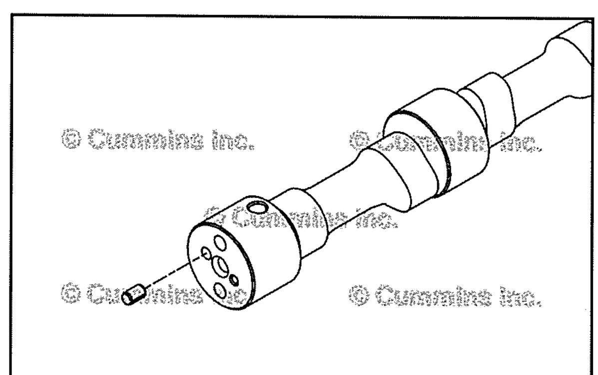
Journal Diameter Numbers 1 to 5 mm		in
55.56	MIN	2.187
55.60	MAX	2.189



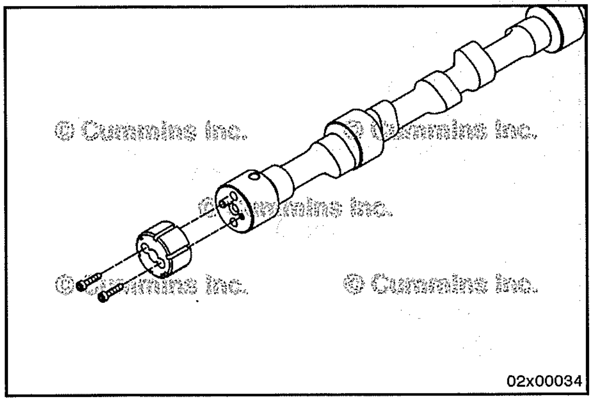
cg900tc

Assemble

Install the roller pin into the camshaft.



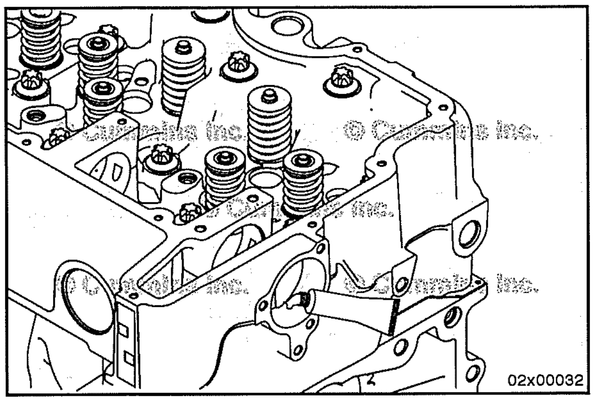
02x00035


02x00034

Install the timing speed ring.

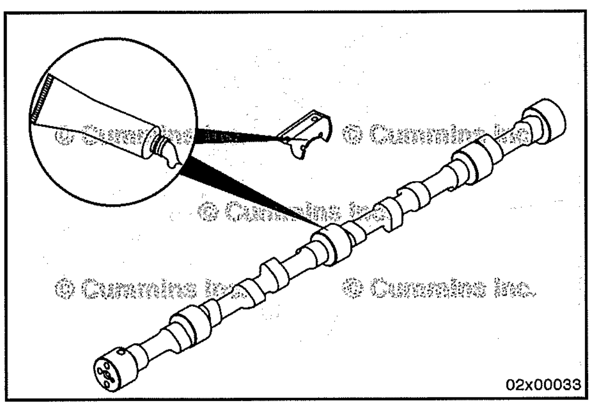
Install the two capscrews into the timing speed ring located on the front of the camshaft.

Torque Value: 9.5 N•m [84 in-lb]

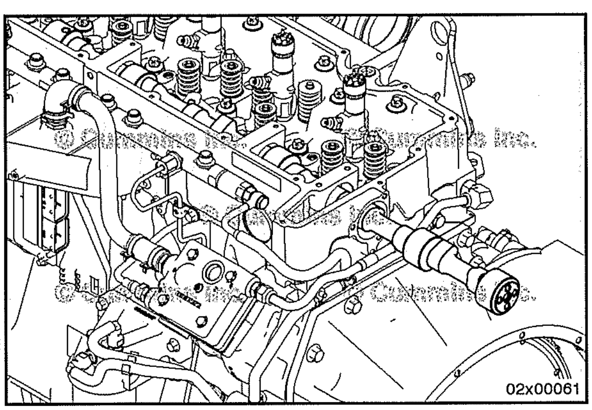

02x00032

Install

Apply assembly lubricant, Part Number 3163087, to the rear camshaft bore.


02x00033

Lubricate the camshaft lobes, journals, and thrust plate with assembly lubricant, Part Number 3163087.


02x00061

CAUTION

Forcing the camshaft into the cylinder head may cause damage to the camshaft bores.

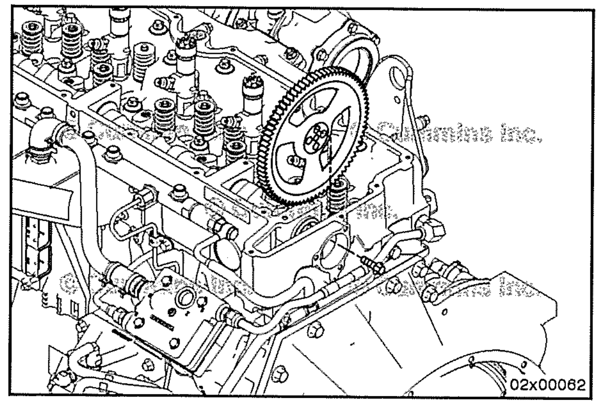
Install the camshaft.

While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bores.

As each camshaft journal passes through a bore, the camshaft will drop slightly and the camshaft lobes will catch on the bores.

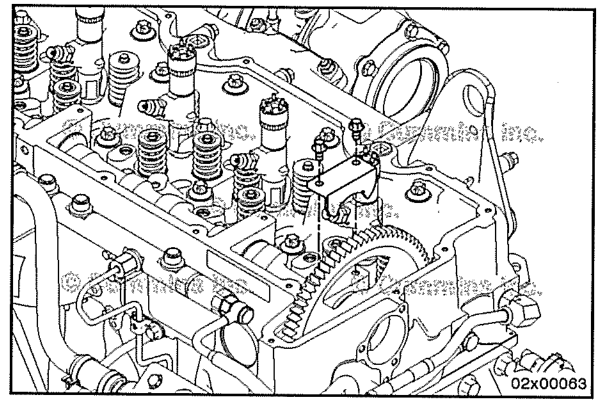
Rotating the camshaft frees the lobe from the bore and allows the camshaft installation to continue.

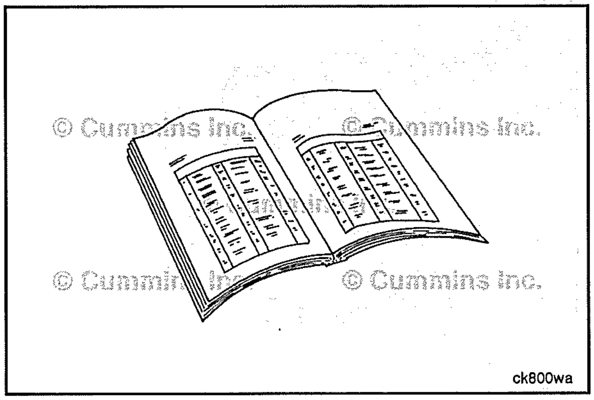
Install the Camshaft Gear. Refer to Procedure 002-030 in Section 2.



Install the thrust plate.

Torque Value: 23 N•m [204 in-lb]





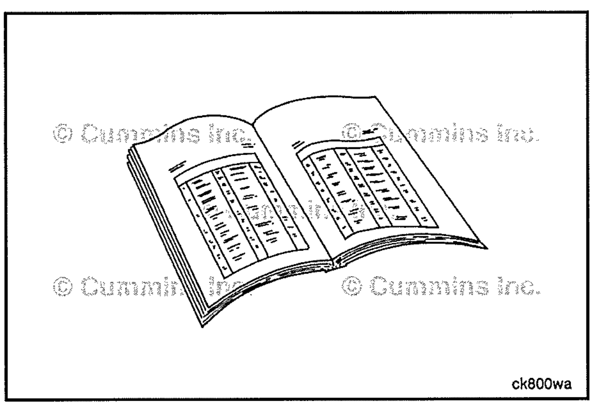
ck800wa

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.

- Time the camshaft to the crank. Refer to Procedure 001-088 in Section 1.
- Install the camshaft cover plate. Refer to Procedure 001-011 in Section 1.
- Measure the camshaft end clearance. Refer to Procedure 002-028 in Section 2.
- Install the rocker lever assemblies. Refer to Procedure 003-009 in Section 3.
- Set the valve lash for the intake and exhaust valves. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the crankcase breather hose. Refer to Procedure 003-018 in Section 3.
- Install the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Install the OEM accessories attached to the cylinder head. See equipment manufacturer service information.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine at idle for 5 to 10 minutes and check for leaks and loose parts.



ck800wa

Overhead Camshaft End Clearance, Valve (002-028)

Preparatory Steps

- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker lever assembly. Refer to Procedure 003-009 in Section 3.
- Loosen the adjustable camshaft idler gear. Refer to Procedure 001-115 in Section 1.

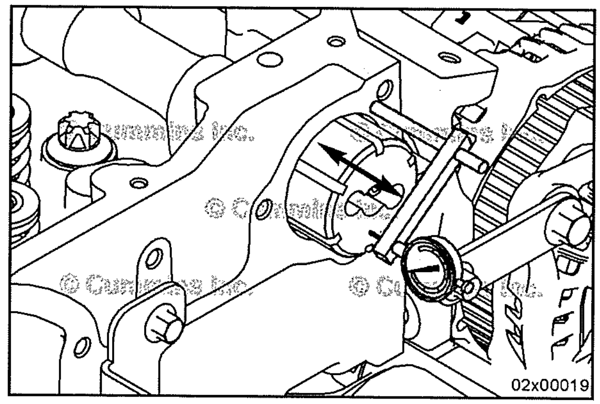
Measure

⚠CAUTION⚠
The rear camshaft cover plate must be installed.

Use a dial indicator, Part Number 3376050, to check the end clearance of the camshaft.

Push the camshaft to the rear and set the dial indicator at "0".

Pull the gear forward and measure the end clearance off the front of the camshaft.

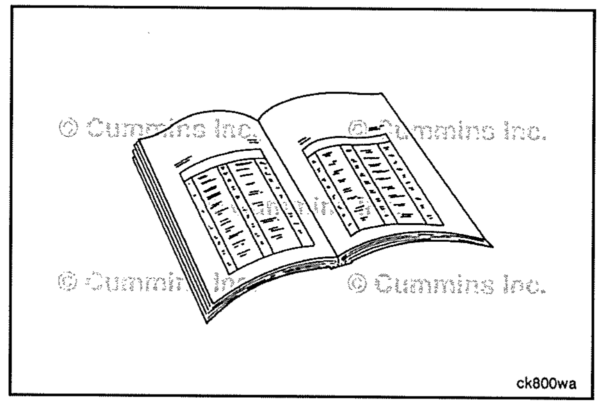


Valve Camshaft End Clearance

mm		in
0.50	MAX	0.020

If the measurement exceeds the specifications, replace the overhead valve camshaft. Refer to Procedure 002-024 in Section 2.

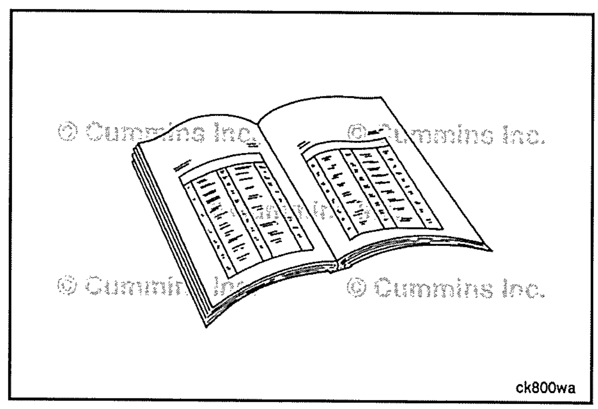
Finishing Steps



- Install the adjustable camshaft idler gear. Refer to Procedure 001-115 in Section 1.
- Install the rocker lever assembly. Refer to Procedure 003-009 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Operate the engine and check for leaks.

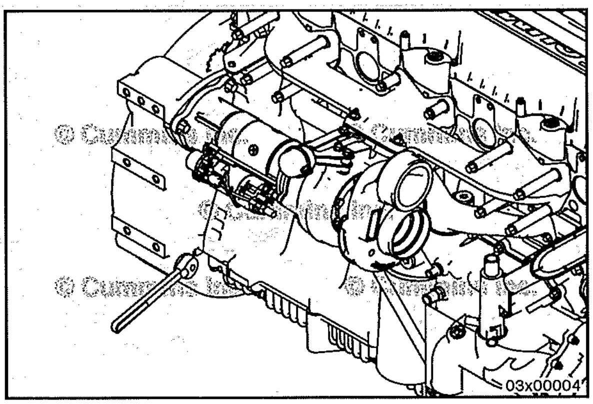
Overhead Camshaft Gear, Valve (002-030)

Preparatory Steps



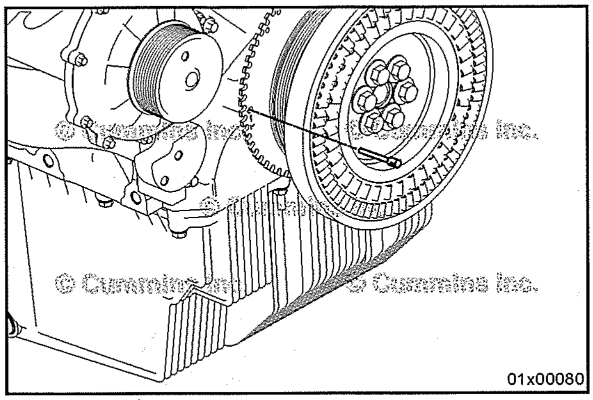
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. See equipment manufacturer service information.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the camshaft cover plate. Refer to Procedure 001-011 in Section 1.

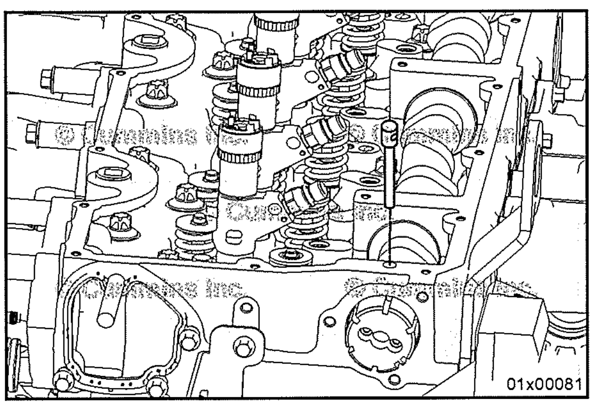


Remove

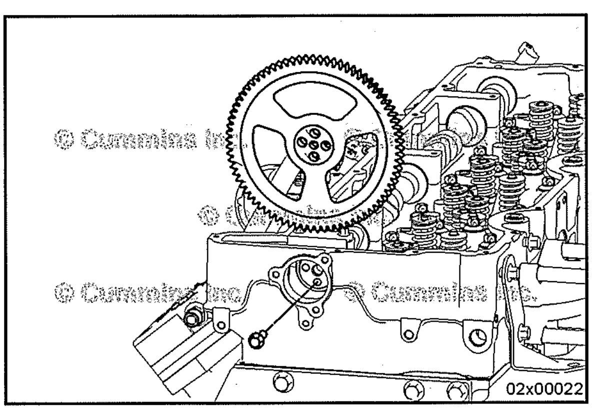
Use the engine barring tool, Part Number 4919092, to rotate the engine **clockwise** when viewed from the crankshaft pulley to top dead center (TDC).



Use the timing pin, Part Number 5298581, to lock the engine by pushing it through the designated holes on the vibration damper and the lubricating pump housing.



Insert the camshaft timing pin, Part Number 4919342, into the hole found on the front of the camshaft.



Remove the four bolts from the camshaft gear.

Remove the camshaft gear.

Clean and Inspect for Reuse

WARNING

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

WARNING

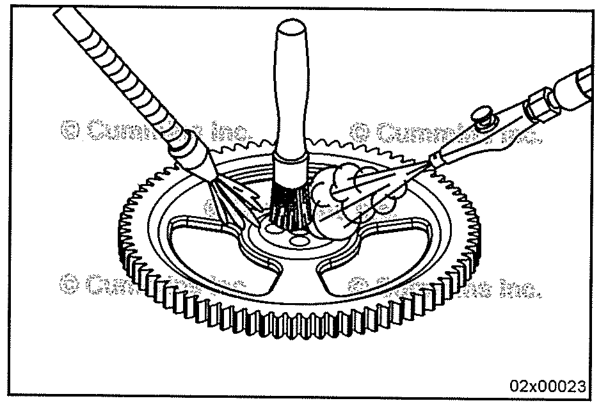
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

WARNING

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

Clean the overhead camshaft gear with solvent.

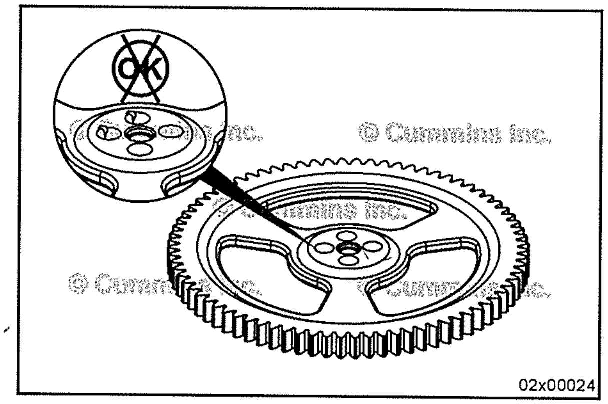
Dry with compressed air.



Inspect the gear for cracks or excessive wear.

Check for missing or bent teeth.

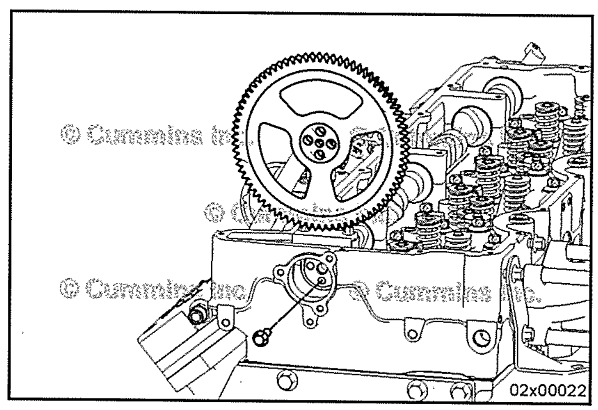
Replace if any damage is found.

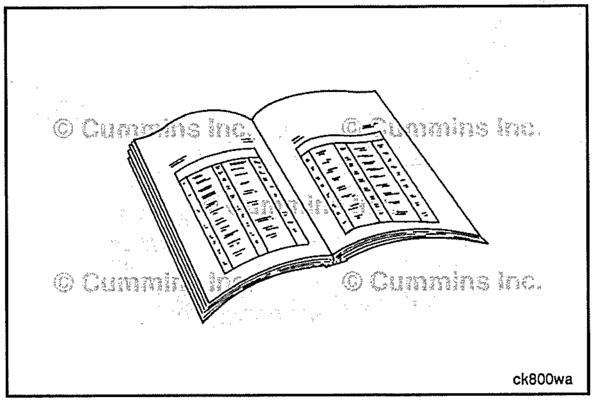


Install

Install the overhead camshaft gear and tighten the four bolts.

Torque Value: 65 N•m [48 ft-lb]



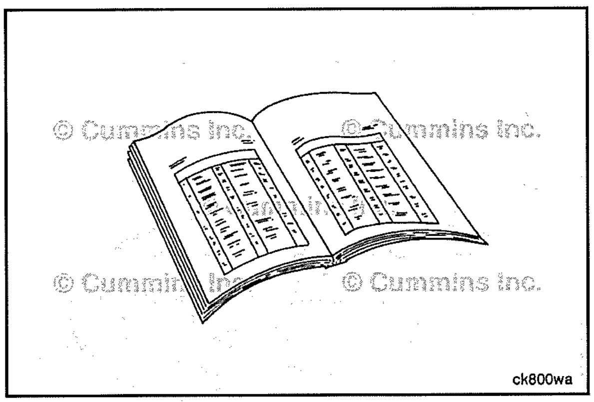


Finishing Steps

WARNING

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

- Install the camshaft cover plate. Refer to Procedure 001-011 in Section 1.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



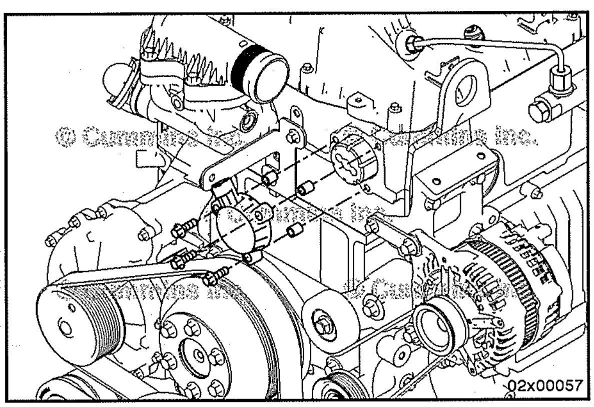
Overhead Camshaft Timing Speed Ring (002-034)

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. See equipment manufacturer service information.
- Remove the camshaft position sensor. Refer to Procedure 019-363 in Section 19.

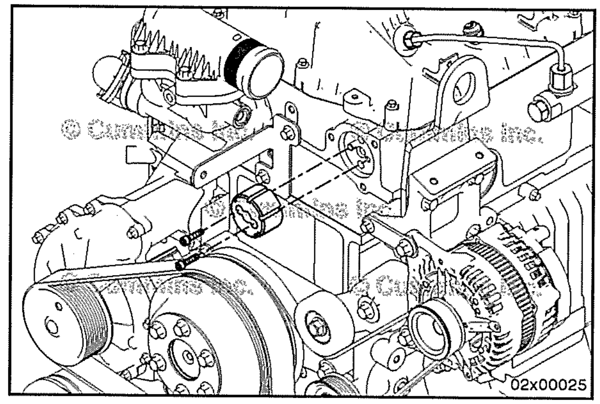


Remove

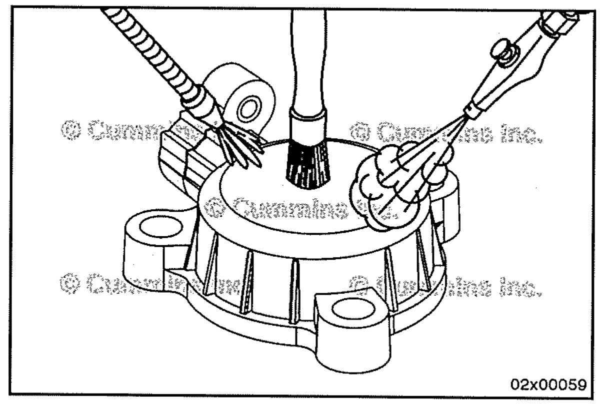
Remove the three bolts from the cam cover.

Remove the cam cover and spacers from the front of the cylinder head.

Remove the camshaft capscrews and remove the overhead camshaft timing speed ring.



Clean and Inspect for Reuse



WARNING

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

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

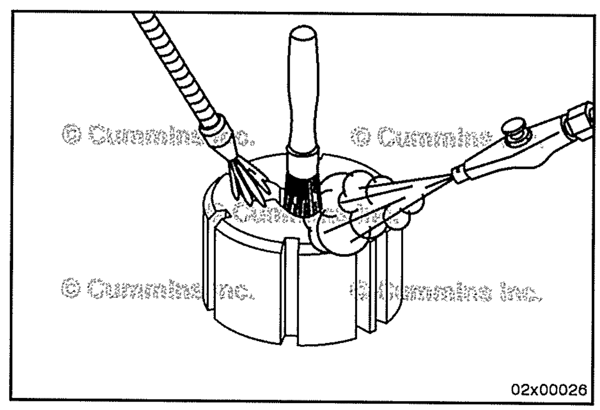
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

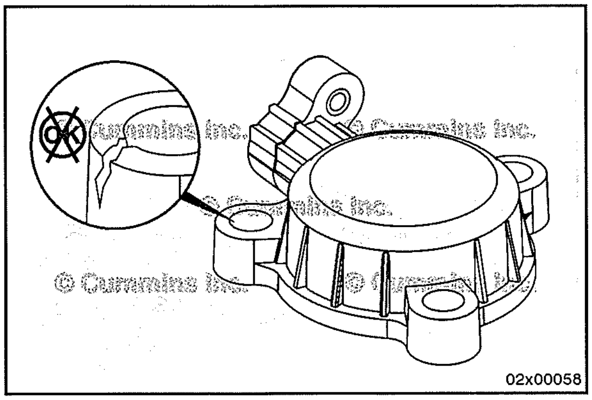
Clean the overhead camshaft timing speed ring cover with suitable solvent.

Dry with compressed air.

Clean the overhead camshaft timing speed ring with solvent.

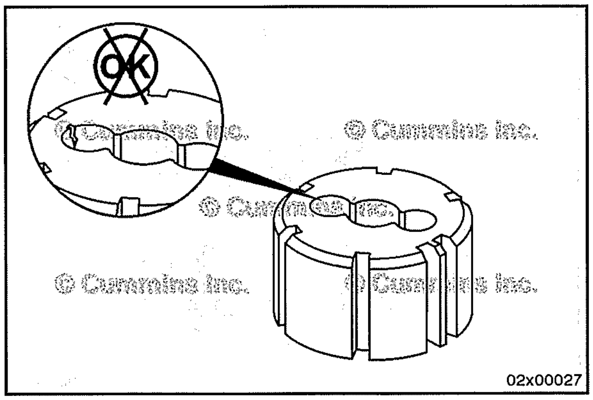
Dry with compressed air.





Inspect the speed ring cover for cracks.

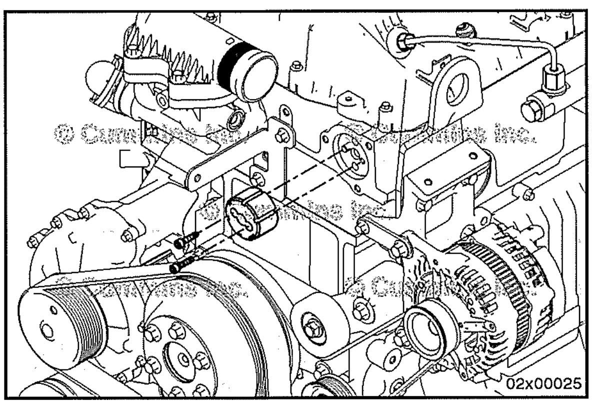
Replace if any damage is found.



Inspect the speed ring for cracks.

Check for missing or bent teeth.

Replace if any damage is found.

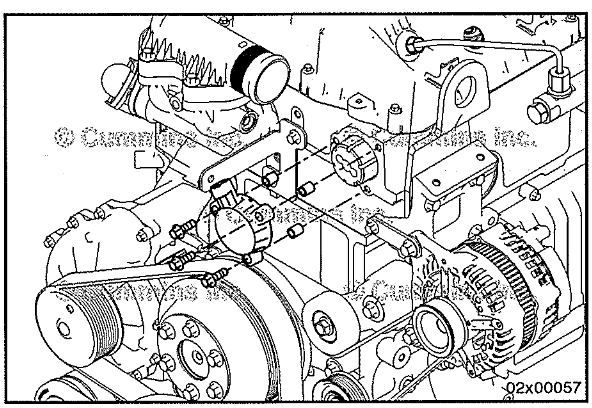


Install

Install the timing speed ring.

Install the two capscrews into the timing speed ring.

Torque Value: 9.5 N•m [84 in-lb]



Install the overhead camshaft timing speed ring cover.

Install the three bolts in the overhead camshaft timing speed ring cover.

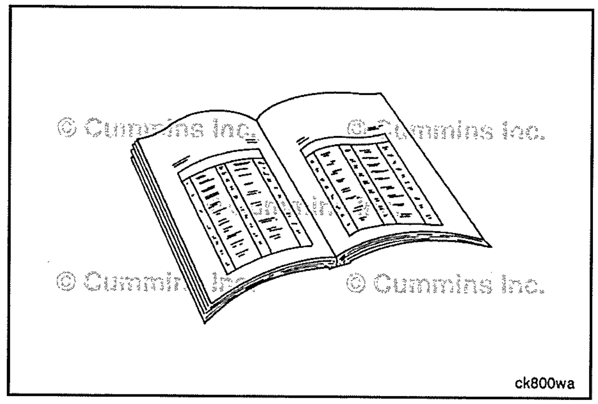
Torque Value: 23 N•m [204 in-lb]

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 camshaft position sensor. Refer to Procedure 019-363 in Section 19.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



Notes

Section 3 - Rocker Levers - Group 03

Section Contents

	Page
Crankcase Breather (Internal)	3-2
Clean and Inspect for Reuse	3-2
Install	3-3
Remove	3-2
Crankcase Breather Tube	3-15
Clean and Inspect for Reuse	3-16
Finishing Steps	3-17
Install	3-16
Preparatory Steps	3-15
Remove	3-15
Overhead Set	3-3
Adjust	3-4
Finishing Steps	3-6
General Information	3-3
Preparatory Steps	3-4
Rocker Lever Assembly	3-6
Assemble	3-9
Clean and Inspect for Reuse	3-7
Disassemble	3-7
Finishing Steps	3-11
Install	3-10
Preparatory Steps	3-6
Remove	3-6
Rocker Lever Cover	3-12
Clean and Inspect for Reuse	3-13
Finishing Steps	3-15
Install	3-14
Preparatory Steps	3-12
Remove	3-12
Service Tools	3-1
Rocker Levers	3-1

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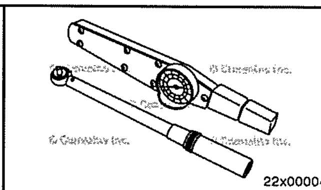
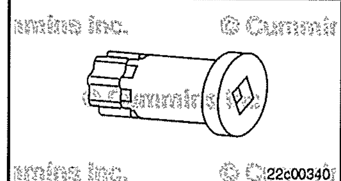
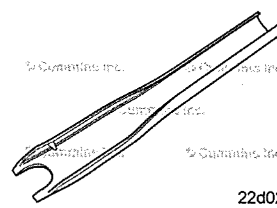
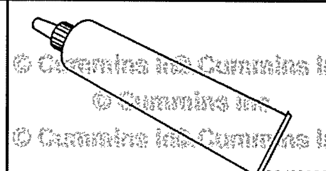
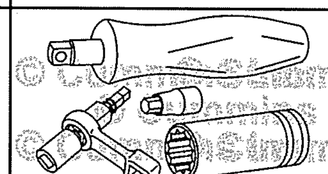
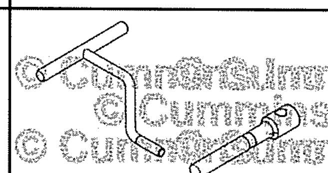
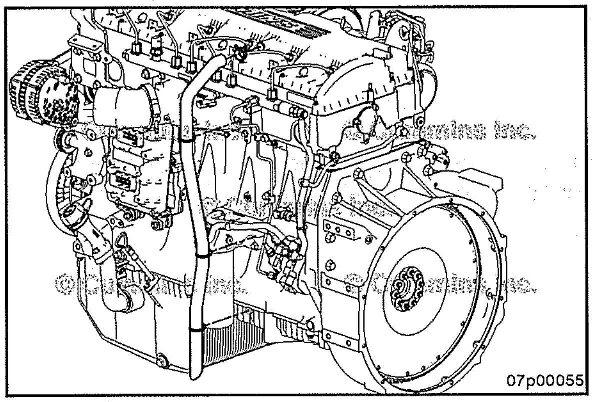
Service Tools

Rocker Levers

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

Tool No.	Tool Description	Tool Illustration
2892438	**Torque Wrench - 10 to 100 ft.lb. Micro-Adjust - 3/8 drive** These torque wrenches are used for general purpose when a specified torque is required.	 22x00004
4919092	**Barring Tool** Used to bar the engine by hand.	 22c00340
3165175	**Barring Plug Remover** Quickly removes stubborn barring plugs from flywheel housing.	 22d0223
3163087	**Lubriplate™ 105** A 10-ounce tube of multi-purpose lubricant.	 22d00293
5298979	**Overhead Setting Kit** This kit includes all of the tools needed to set the overhead.	 22200228
5298582	**Timing Pins** Timing pins are used to lock the camshaft and the flywheel when timing the engine.	 22k00013



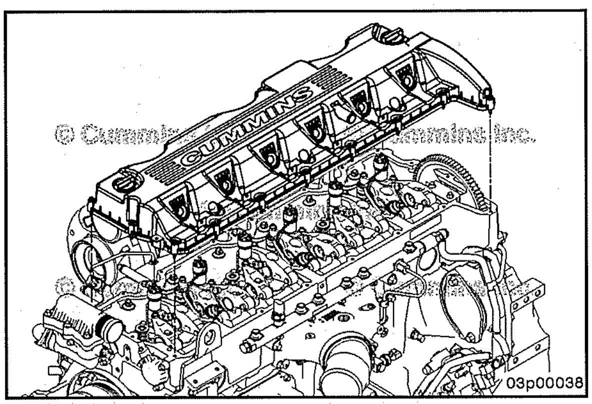
Crankcase Breather (Internal) (003-002)

Remove

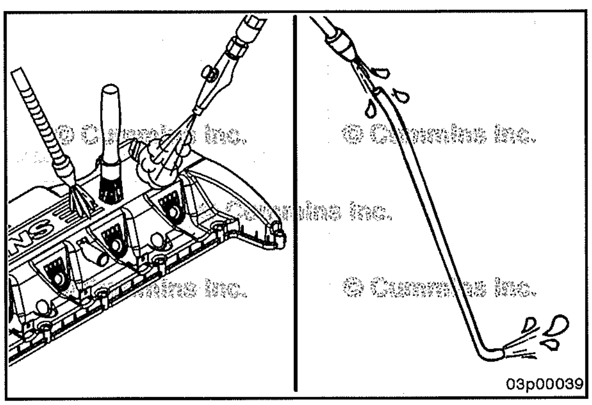
Remove the crankcase breather tube from the rocker lever cover.

Remove the three fir tree clips securing the crankcase breather tube to the engine. Refer to Procedure 003-018 in Section 3.

Remove the crankcase breather tube from the engine.



Remove the rocker lever housing cover. Refer to Procedure 003-011 in Section 3.



Clean and Inspect for Reuse

WARNING

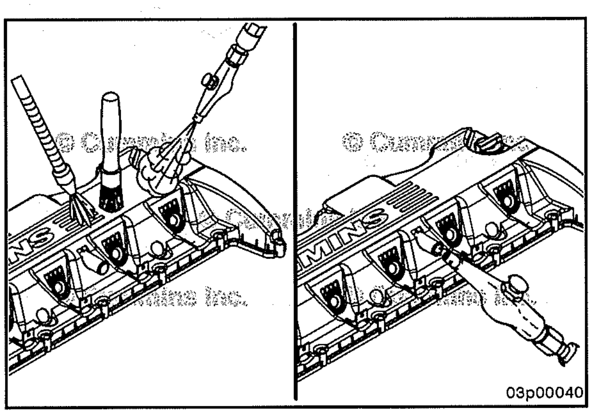
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

WARNING

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

Use solvent to clean the cover, breather cavity, and breather tube.

Dry with compressed air.



WARNING

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

Use compressed air to blow through the breather cavity.

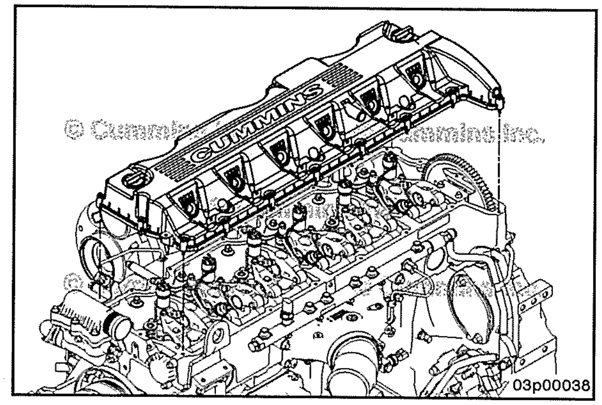
If the breather cavity is clogged and the restriction can **not** be removed by cleaning, the cover **must** be replaced.

Use air pressure to blow through the tube.

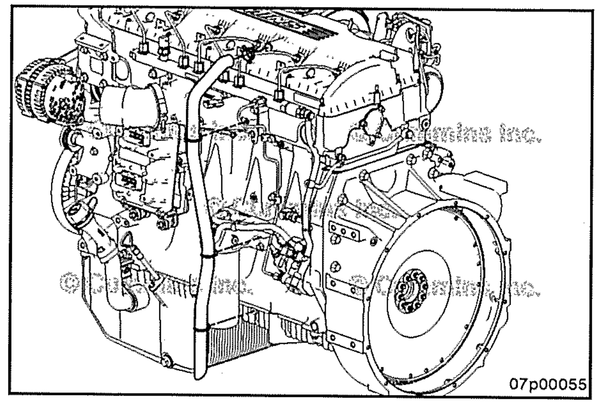
Replace the tube if it is clogged.

Install

Install the rocker lever housing cover. Refer to Procedure 003-011 in Section 3.



Install the crankcase breather tube on the engine with the three fir tree clips and attach to the rocker lever cover.



Overhead Set (003-004)

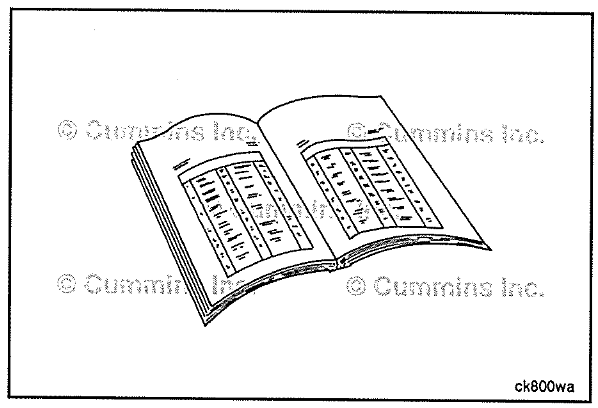
General Information

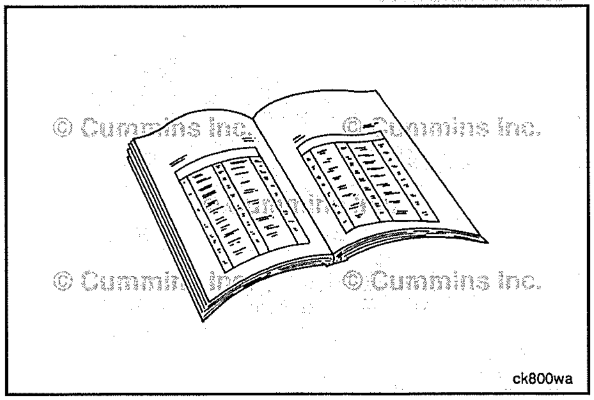
Overhead setting is **only** required at the interval specified in the appropriate Operation and Maintenance Manual/ Owners Manual or when engine repairs cause removal of the rocker levers and/or loosening of the adjusting screws.

Excessive valve lash prior to this can indicate an overhead set incorrectly from a previous repair, worn valve stems, crossheads, camshaft, or rocker levers.

Refer to Procedure 002-004 in Section 2 for inspection of the cylinder head.

Refer to Procedure 003-009 in Section 3 for inspection of the rocker levers.



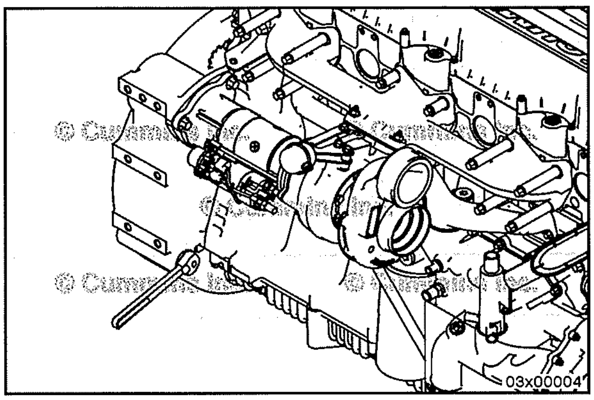


Preparatory Steps

WARNING

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

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the open crankcase ventilation hose.
- Remove the fuel injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the rocker lever cover and gasket. Refer to Procedure 003-011 in Section 3.

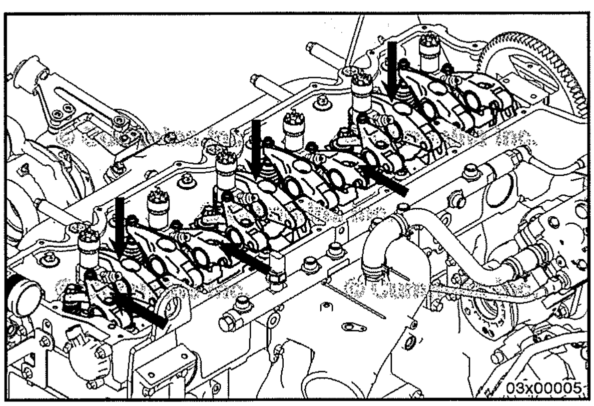


Adjust

NOTE: For ambient air temperatures of 30°C [86°F] and below, allow the engine to cool for 1.5 hours prior to checking or setting the valve lash. For ambient air temperatures above 30°C [86°F], allow the engine to cool for 2.5 hours prior to checking or setting the valve lash.

Use the barring tool, Part Number 4919092, to rotate the crankshaft until the number 1 cylinder is at top dead center (TDC). The barring port can be found on the bottom of the flywheel housing.

Top dead center (TDC) for the number 1 cylinder can be found by lining up the hole in the vibrations damper and the lubricating pump housing. The rockers for the number 1 cylinder **must** be free to move. If the rockers for the number 6 cylinder are free to move, the crankshaft **must** be rotated 360 degrees.

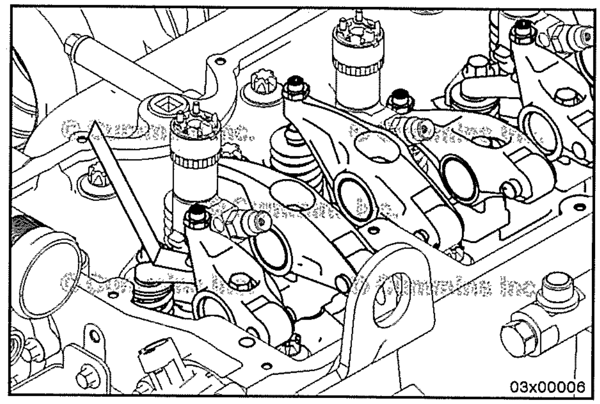


With the engine in this position, lash can be measured on the following rocker levers:

Exhaust Valve of Cylinder 1, 3 and 5.

Intake Valve Cylinder 1, 2 and 4.

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 specifications.



03x00006

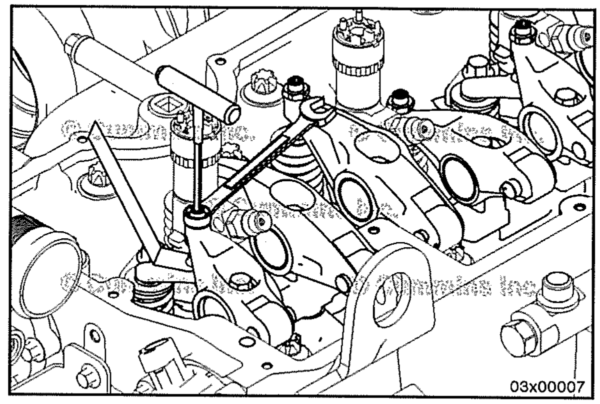
NOTE: The clearance is correct when some resistance is "felt" when the feeler gauge is slipped between the crosshead and the rocker lever socket.

Measure lash by inserting a feeler gauge between the valve and the rocker lever socket. If the lash measurement is out of specification, loosen the locknut, and adjust the lash to nominal specifications. Use Part Number 3163172 and 3163171 to measure the lash.

Intake Valve Lash (Nominal) 0.36 ± 0.08 mm [0.014 ± 0.003 in]

Exhaust Valve Lash (Nominal) 0.69 ± 0.08 mm [0.027 ± 0.003 in]

Tighten the locknut and measure the lash again.



03x00007

⚠CAUTION⚠

Engine damage can occur if the running clearance is not within specifications.

Torque Value: 28 N•m [248 in-lb]

Use barring tool, Part Number 4919092, to rotate the crankshaft 360 degrees.

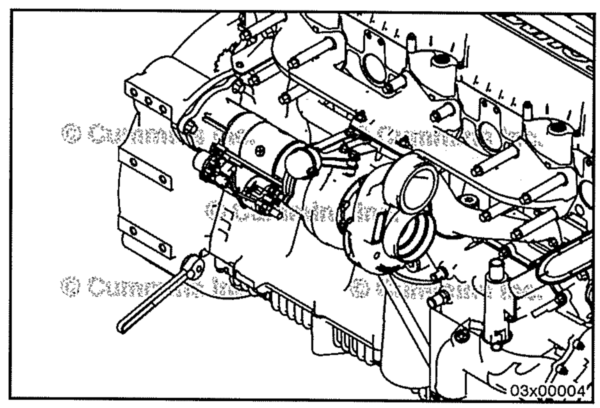
Following the same steps and specifications as previously stated, measure lash for the following rocker levers:

(E = exhaust, I = Intake)

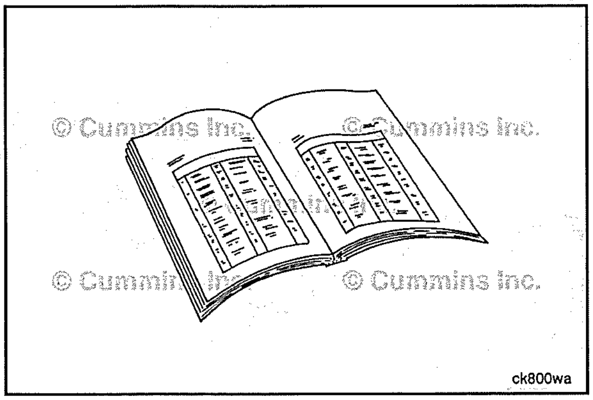
Exhaust Valve of cylinders 2, 4, and 6.

Intake Valve of cylinders 3, 5, and 6.

Reset if out of specification.



03x00004

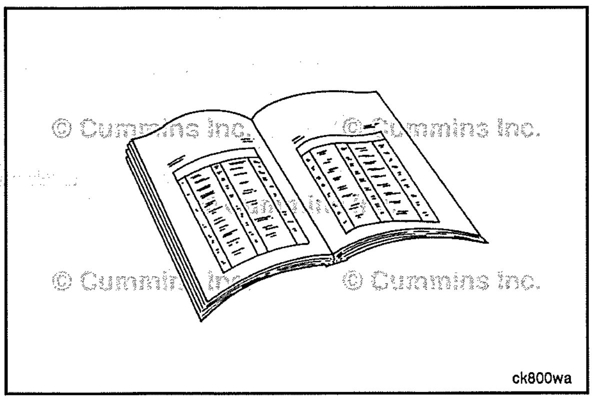


Finishing Steps

⚠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 gasket and rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the fuel injector supply lines. Refer to Procedure 006-051 in Section 6.
- Install the crankcase ventilation hose. Refer to Procedure 003-018 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



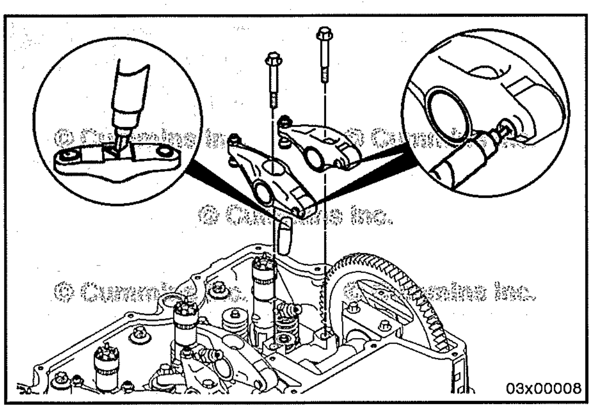
Rocker Lever Assembly (003-009)

Preparatory Steps

⚠WARNING⚠

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

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.



Remove

NOTE: All rocker lever components **must** be installed in their original location and position.

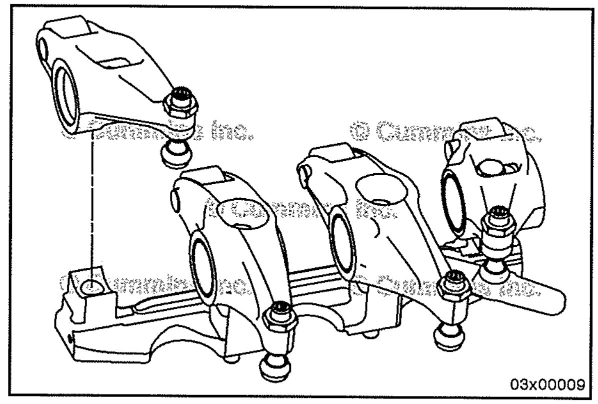
Remove and mark the location of each capscrew.

Remove and mark the location of each rocker and pedestal.

Remove and mark the location of each crosshead .

Disassemble

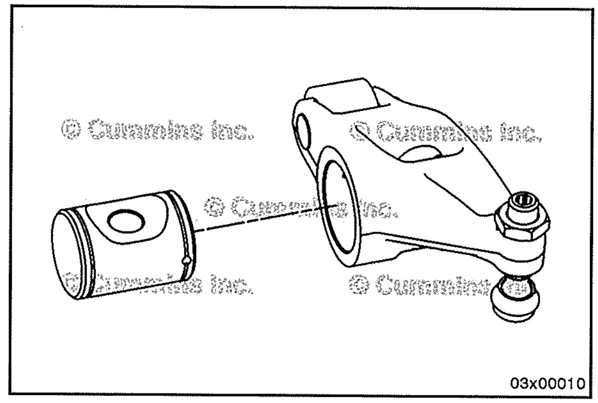
Remove the rocker lever from the pedestal.



03x00009

Remove the rocker lever shafts from the rocker levers.

Mark the location and orientation of each shaft.



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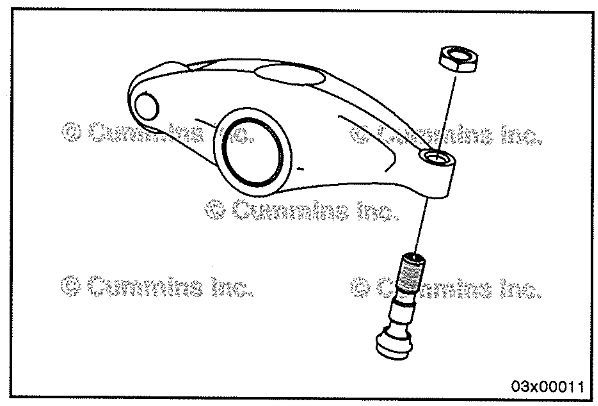
Remove the locknut and adjusting screw.

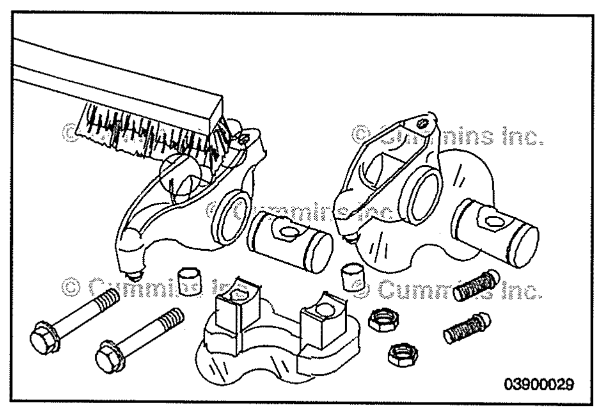
NOTE: The socket at the tip of the adjusting screw is **not** serviceable and should **not** be separated from the adjusting screw.



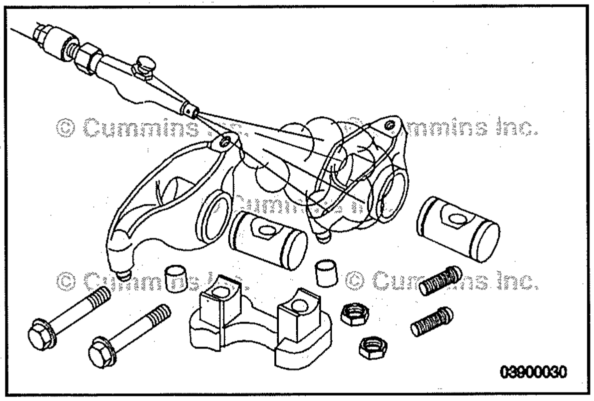
03x00011

Clean and Inspect for Reuse

Clean all parts in solvent and hot water.



03900029

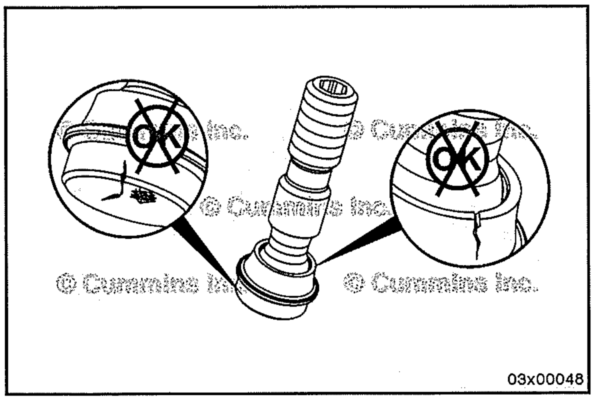


WARNING

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.

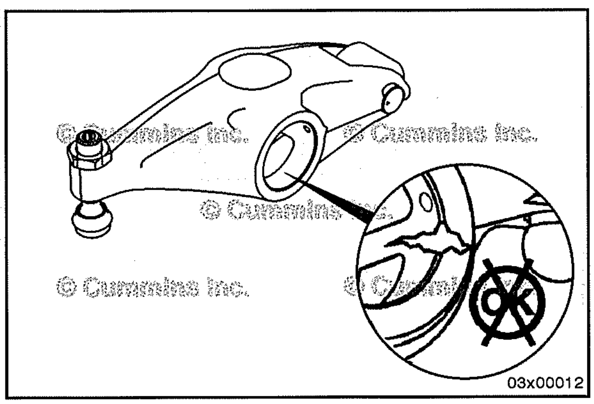
NOTE: The pedestals are made from powdered metal and will appear wet even after they have been cleaned and dried.



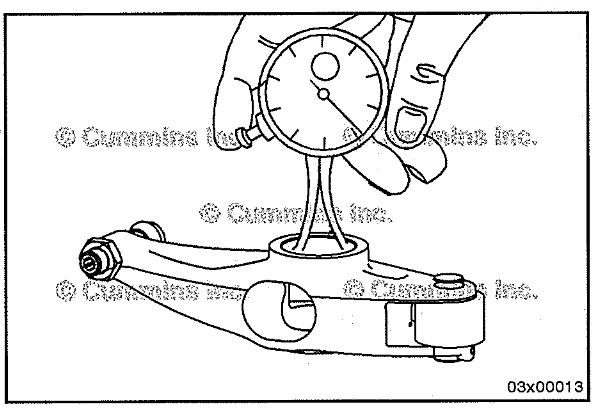
Inspect the adjusting screw socket for excessive wear and cracks. The socket should move freely on the rocker lever.

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.



Inspect for cracks and excessive wear in the bore.



Measure the rocker lever bore.

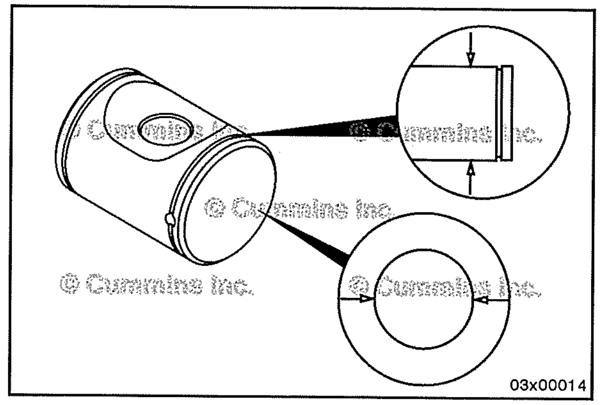
Rocker Lever Bore		
mm		in
30.01	MAX	1.181

Inspect the rocker lever pedestal and rocker lever shaft.

It is common 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
29.95	MIN	1.179

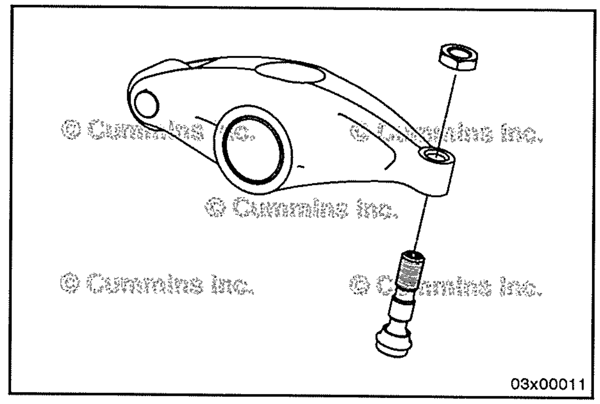


Assemble

NOTE: All rocker lever components **must** be installed in their original location and position.

Install the adjusting screw until it stops.

Install the locknut.

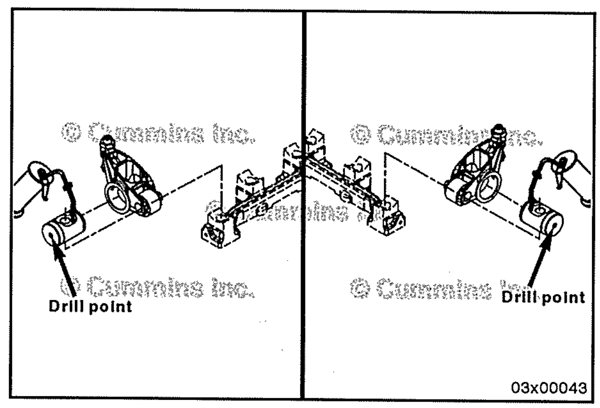


Lubricate the rocker lever shafts with clean engine oil.

Install the intake rocker lever shafts into their original rocker levers so that the drill point is visible on each end of the assembly. Incorrect orientation may result in engine damage.

Rotate the rocker levers 180 degrees about the rocker lever shafts. The rocker lever should rotate freely without any binding.

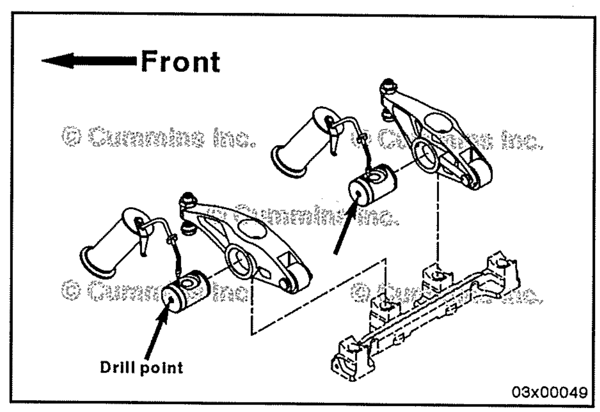
If the rocker lever does **not** rotate freely, replace the rocker lever shaft and rocker lever.

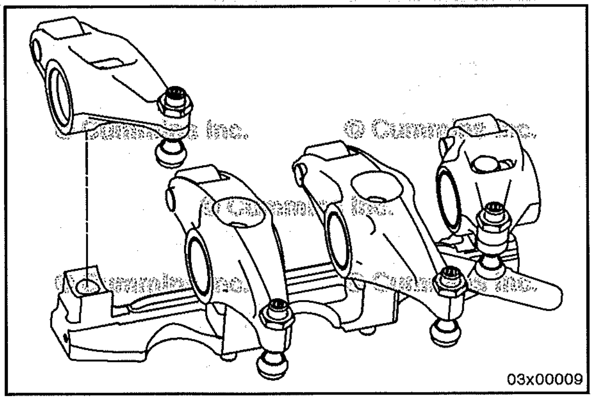


Install the exhaust rocker lever shafts onto the rocker lever so that the drill point is visible from the front of the engine.

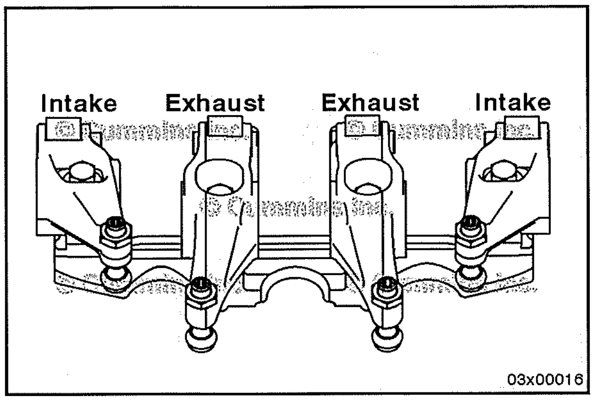
Rotate the rocker levers 180 degrees about the rocker lever shafts. The rocker lever should rotate freely without any binding.

If the rocker lever does **not** rotate freely, replace the rocker lever shaft and rocker lever.



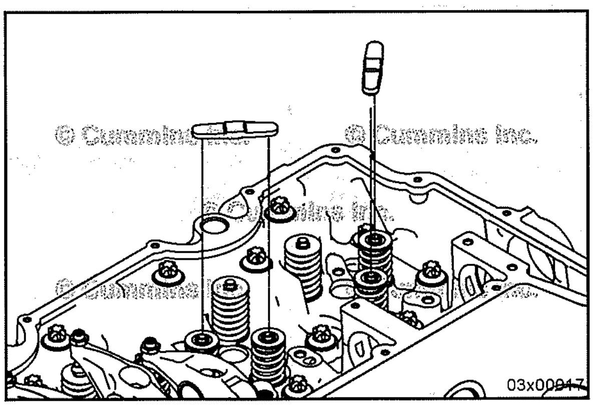


Position the rocker levers on the rocker pedestal.



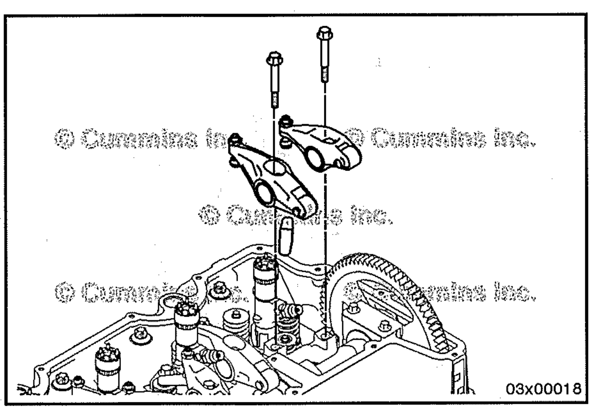
⚠CAUTION⚠

Make sure to assemble the intake and exhaust rocker levers in the correct location. Failure to do so may result in engine damage.



Install

Install the crossheads in their original location and position.



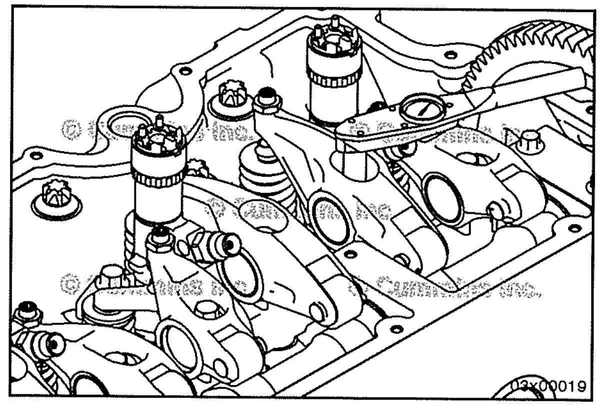
Install the rocker lever assemblies and pedestals in their original position.

Lubricate the mounting capscrews with clean engine oil.

Install the pedestal mounting capscrews.

Tighten the intake and exhaust rocker lever mounting capscrews.

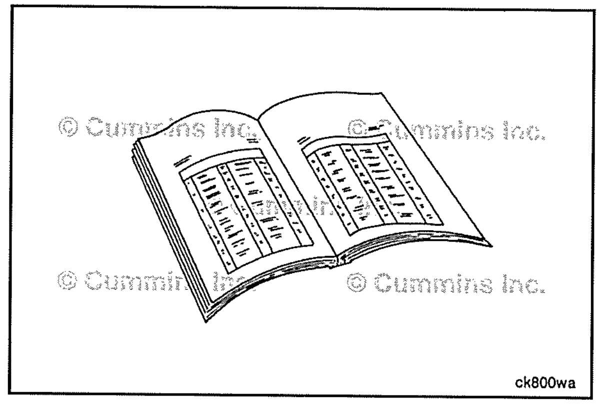
Torque Value: 65 N•m [48 ft-lb]



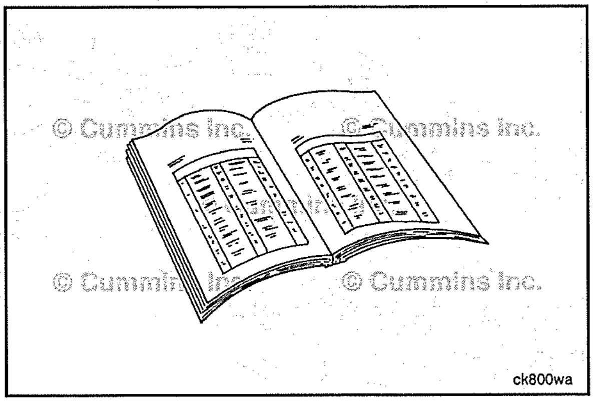
Finishing Steps

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.



- Set valve lash for intake and exhaust valves. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate engine and check for leaks.



Rocker Lever Cover (003-011)

Preparatory Steps

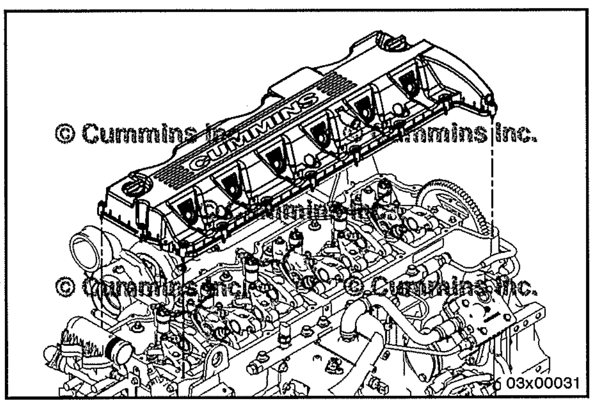
WARNING

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.

WARNING

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

- Clean the valve cover surface and injector supply lines before beginning this procedure. Prior to removing any components, clean around the mounting fasteners and sealing joints with compressed air to remove any loose debris.
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Disconnect the injector passthrough connectors. Refer to Procedure 019-043 in Section 19.



Remove

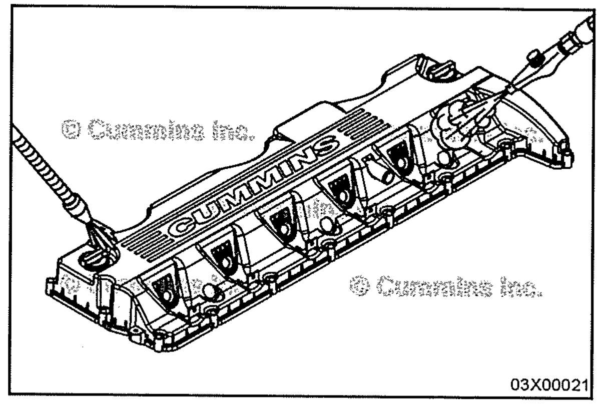
The mounting capscrews and compression limiters are part of the rocker lever cover. The capscrews are the captive design and will be held in place in the rocker lever cover.

Remove the injector passthrough connector lock rings.

Loosen the rocker lever cover capscrews.

Remove the rocker lever cover gently. The injector passthrough connectors will remain on the engine.

Clean and Inspect for Reuse



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

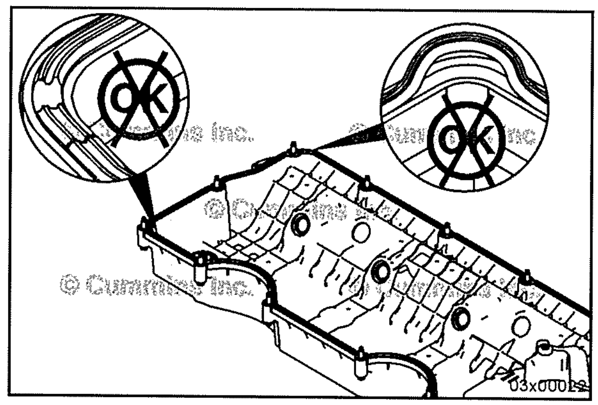
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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

NOTE: 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.

Clean the rocker lever cover with solvent.

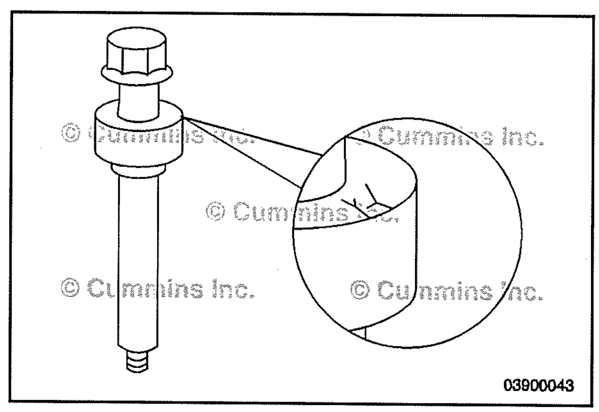
Dry with compressed air.



NOTE: Check the gasket while it is installed in the valve cover.

Check the gasket for cracks on the sealing surface.

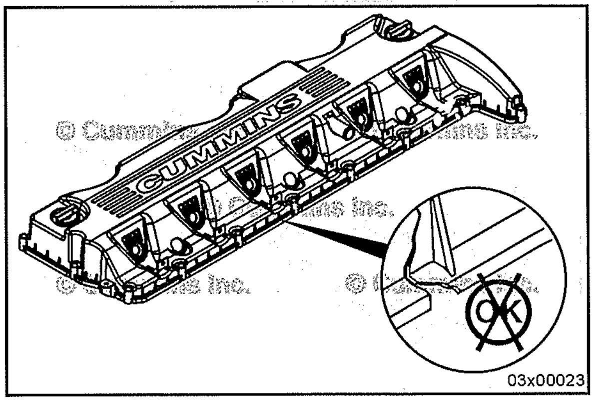
Replace the gasket if damage is present.



NOTE: It may be necessary to replace the capscrew/ compression limiter as an assembly.

Inspect the compression limiters and rocker lever cover edge for cracks or other damage.

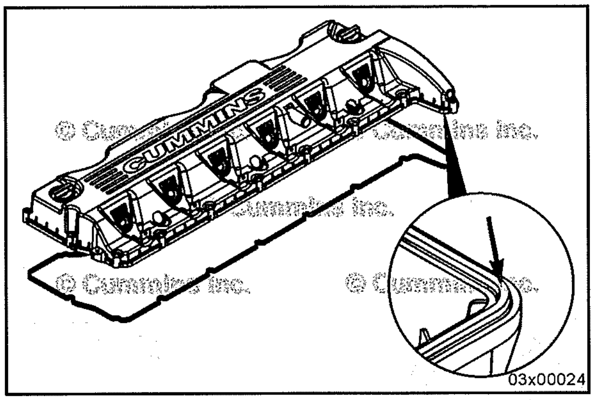
Replace the compressions limiters and/or capscrew assembly if damage is found.



03x00023

Inspect the rocker lever cover for cracks or other damage.

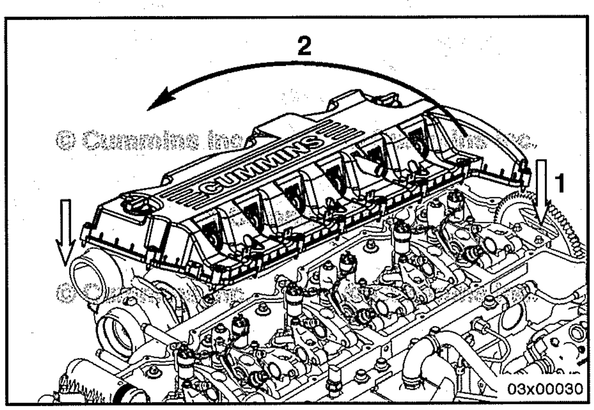
Replace the rocker lever cover if any damage is found.


03x00024

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.



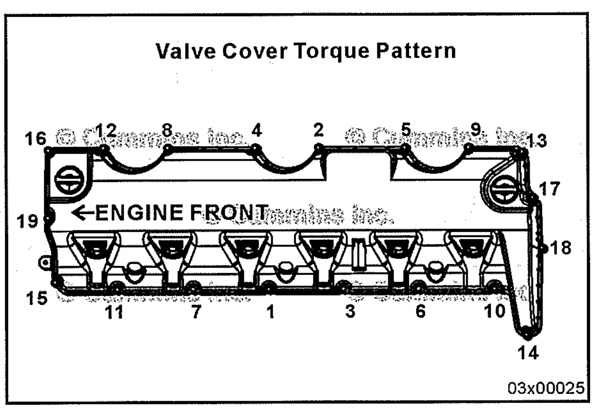
03x00030

Install

Verify the injector passthrough connector locating flats are positioned on the top of the connector.

Install the rocker lever cover.

To aid installation tilt the cover to the left side of the engine. Lower the left side of the cover onto the head first, then lower the right side. Be sure the pass through connectors have seated properly with the locating flat on the top of the connector.



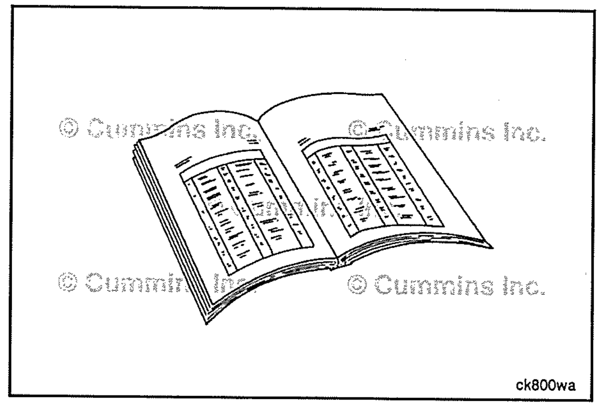
03x00025

Tighten the mounting capscrews in the sequence shown.

Torque Value: 9.5 N•m [84 in-lb]

Install the injector passthrough connector lock rings.

Finishing Steps

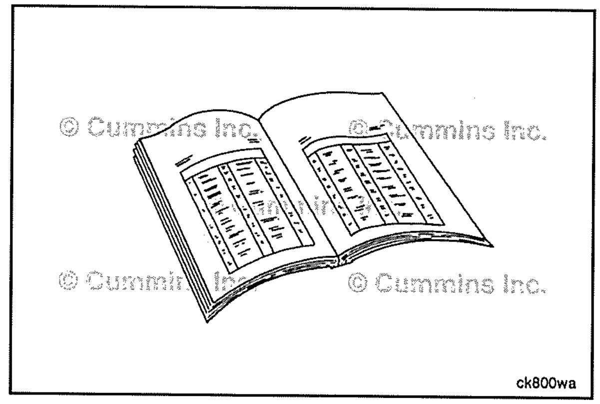


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the injector passthrough connectors. Refer to Procedure 019-043 in Section 19.
- Install the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

Crankcase Breather Tube (003-018)

Preparatory Steps

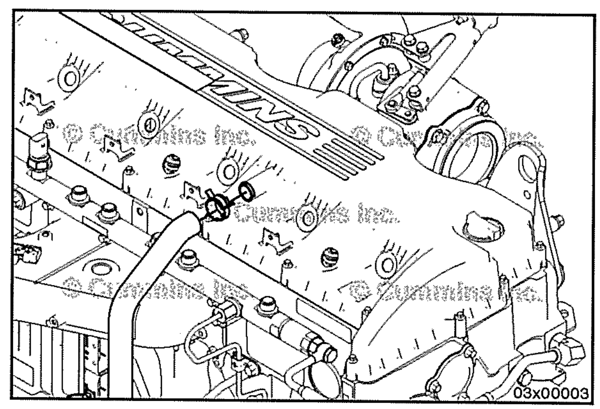


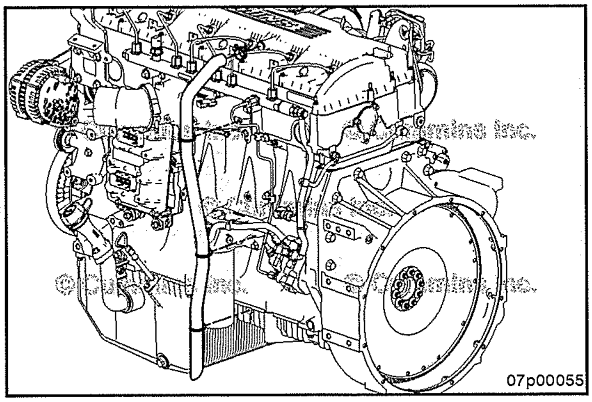
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. See equipment manufacturer service information.

Remove

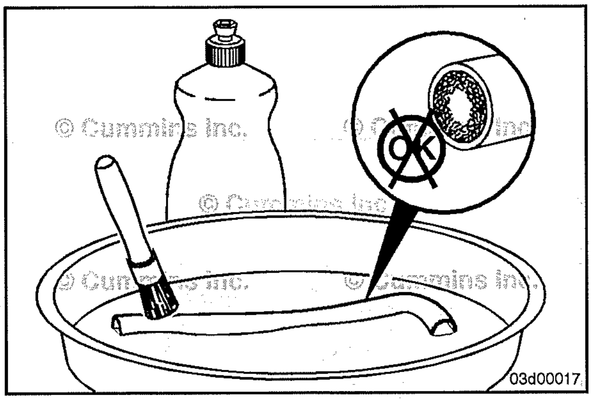
Disconnect the crankcase breather vent tube from the rocker lever cover.





Remove the three fir tree clips securing the crankcase breather tube to the intake connection, cylinder block, and oil pan.

Remove the crankcase breather vent tube.



Clean and Inspect for Reuse

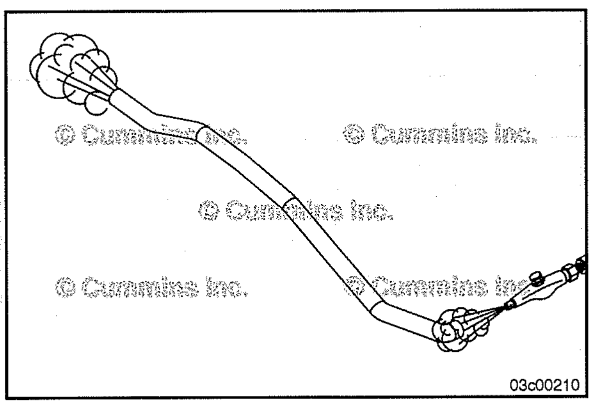
⚠WARNING⚠

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

Check the tube and lines internally for obstructions or sludge buildup.

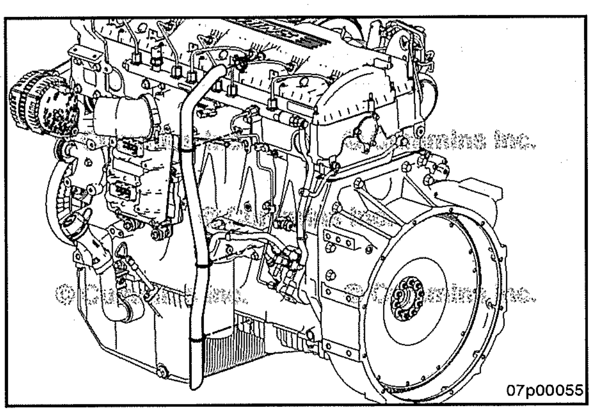
Clean the tube and lines with hot, soapy water and a soft brush.

Use compressed air to dry the tube and lines after rinsing in clean water.



Use air pressure to blow through the vent tube. Replace the crankcase breather tube if it remains clogged.

An obstructed line will lead to excessive crankcase pressure.



Install

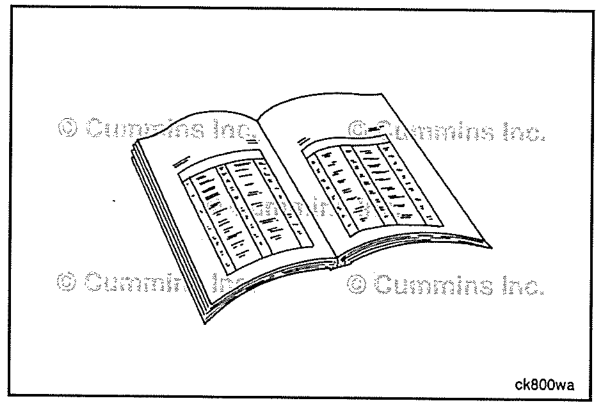
NOTE: Make sure the crankcase breather tube does **not** contact any high pressure fuel lines.

Install the three fir tree clips to the engine. One fir tree clip attaches to the intake connection, one to the cylinder block, and one to the oil pan.

Connect the crankcase breather tube to the rocker lever housing.

Secure the hose clamp around the crankcase breather tube and the rocker lever housing fitting.

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. See equipment manufacturer service information.
- Operate the engine and check for leaks.

Notes

Section 5 - Fuel System - Group 05

Section Contents

	Page
Fuel Consumption	5-3
Measure	5-3
Fuel Pump	5-7
Assemble	5-10
Disassemble	5-8
Finishing Steps	5-12
Inspect for Reuse	5-9
Install	5-11
Preparatory Steps	5-7
Remove	5-8
Fuel Pump Gear Pump	5-13
Clean and Inspect for Reuse	5-14
Finishing Steps	5-15
Install	5-15
Preparatory Steps	5-13
Remove	5-14
Fuel Pump Head Outlet Fitting	5-21
Clean and Inspect for Reuse	5-23
Finishing Steps	5-24
Install	5-23
Preparatory Steps	5-21
Remove	5-22
Fuel System Diagnostics	5-25
Fuel Filter Restriction	5-29
Fuel Pressure Relief Valve Return Flow Test	5-33
Fuel Pump Gear Pump Pressure Test	5-28
General Information	5-25
High-Pressure Injector Return Flow Isolation Test	5-31
High-Pressure Injector Return Flow Test	5-29
High-Pressure System Leak Down Test	5-26
Low-Pressure System Check	5-26
Fuel System Priming	5-24
Prime	5-24
Service Tools	5-1
Fuel System	5-1
Stall Speed Test	5-15
Stall Speed Check	5-15
Stall Speed Check List	5-19
Time Speed Check	5-18

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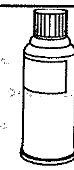
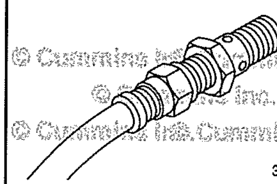
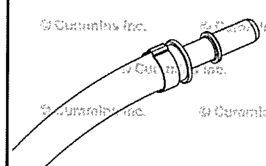
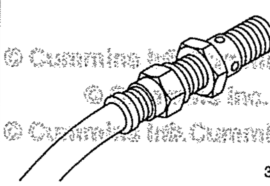
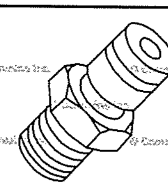
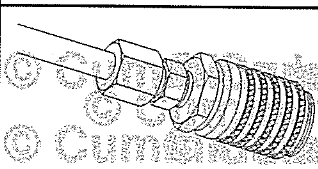
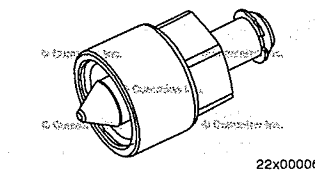
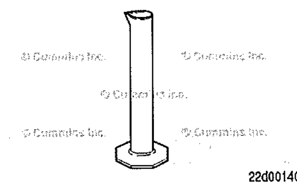
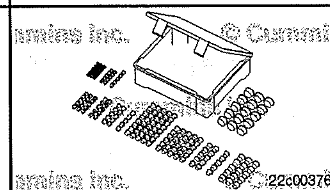
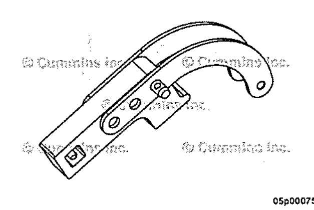
Service Tools

Fuel System

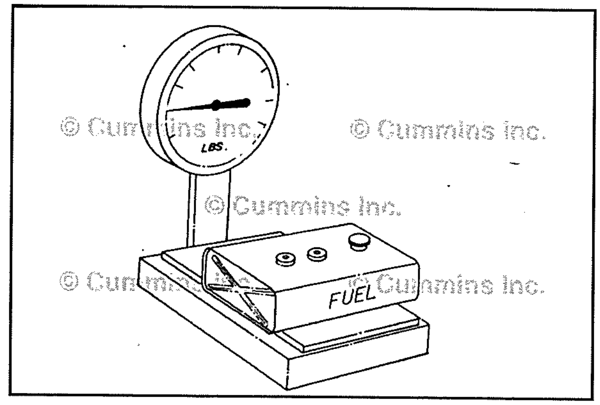
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3824510	**QD™ Contact Cleaner** Use this non-petroleum cleaner to clean electrical connections and fuel pump internal parts.	 oi8togt
3164617	**14 mm Banjo Adapter Fitting (Leakage Flow Adapter)** Used to isolate drain flow from the fuel drain lines where they connect with a 14 mm banjo screw.	 3164614
4918697	**3/8 in Quick Disconnect Adapter Fitting** Used to isolate drain flow from the fuel drain lines where they connect with a 3/8 inch quick disconnect fitting.	 05p00074
4918679	**12 mm Banjo Adapter Fitting (Leakage Flow Adapter)** Used to isolate drain flow from the fuel drain lines where they connect with a 12 mm banjo screw.	 3164614
3824844	**Compuchek™ Fitting** Used to attach quick connect fuel lines at various points in the fuel system.	 22x00005
3164621	**Fuel Line with 1.09 mm [0.043 in] Orifice** Used to create rated fuel flows through the low-pressure fuel system without loading the engine.	 22c00253

Tool No.	Tool Description	Tool Illustration
5299021	**Injector Isolation Tool** Used to isolate single injectors for diagnostic testing.	
4919139	**Graduated Cylinder** Used for measuring fuel during diagnostic tests.	
4919073	**Fuel System Clean Care Kit** Used to cap or plug the fuel system fittings during service to prevent debris from entering the fuel system.	
5298951	**Fuel Pump Gear Replacer** Used to hold the fuel pump and prevent the fuel pump camshaft from rotating while installing or removing the fuel pump gear.	

Fuel Consumption (005-010)

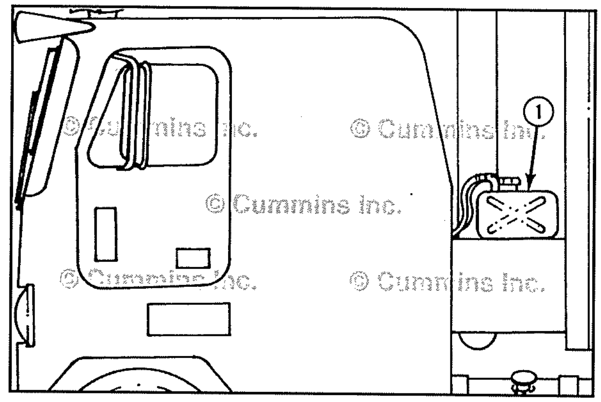
Measure



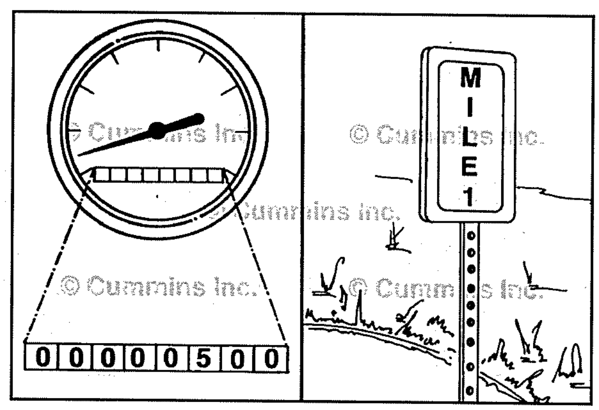
See the fuel consumption check list sheets in the back of Section TS.

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

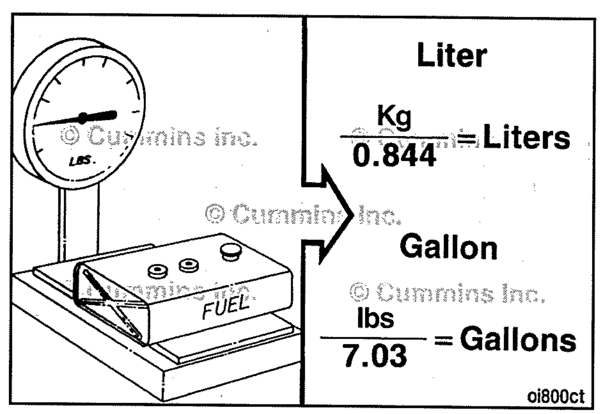
Fill the fuel tank. Weigh the tank with the fuel. The weight on Number 2 diesel fuel is nominally 0.844 kg per liter [7.03 lb per gallon].



Install the remote tank (1).



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



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

$$\frac{\text{Miles}}{\text{Gallons}} = \text{MPG}$$

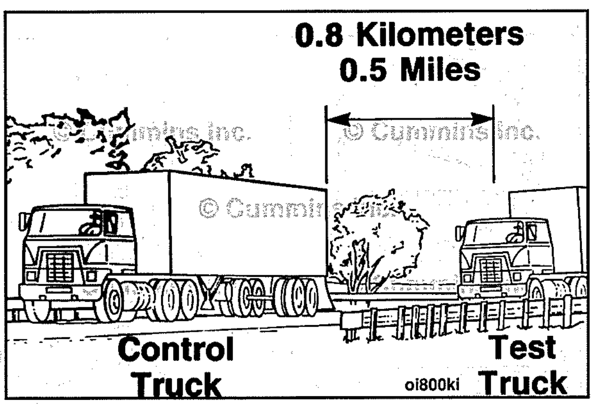
$$\frac{\text{Kilometers}}{\text{Liters}} = \text{KPL}$$

Compute the kilometers per liter or miles per gallon.

Type II
Fuel Test
SAE
RCCC
ATA

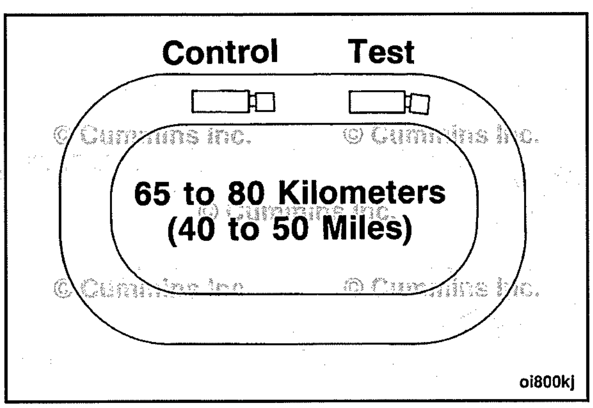
In addition to the measurement of the fuel used, the following factors provide points for running a test similar to the recognized Type II Society of Automotive Engineers Fuel Test.

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



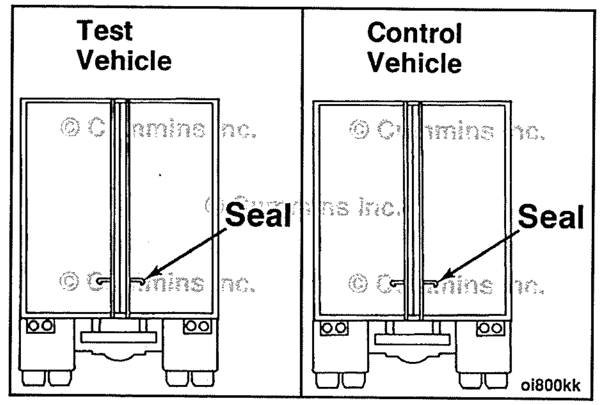
Perform the test with the test vehicle and a control vehicle. The control vehicle compensates for changes in traffic conditions.

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

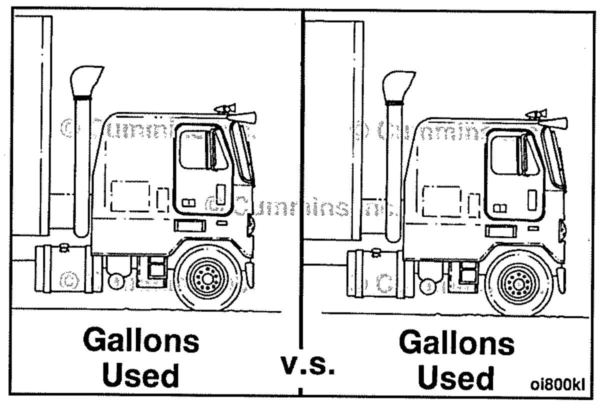


The test course **must** be 65 to 80 km [40 to 50 mi] long.

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

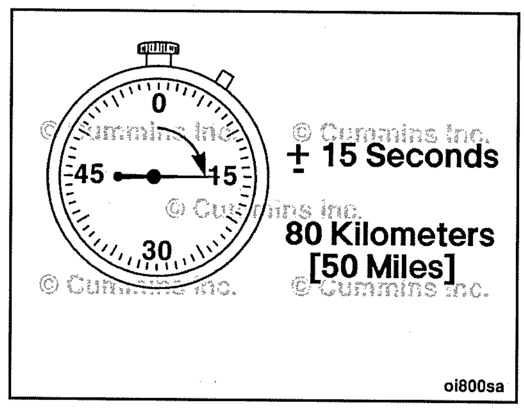


All of the test results are based on comparing the fuel used by the test truck to the fuel used by the control truck.



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

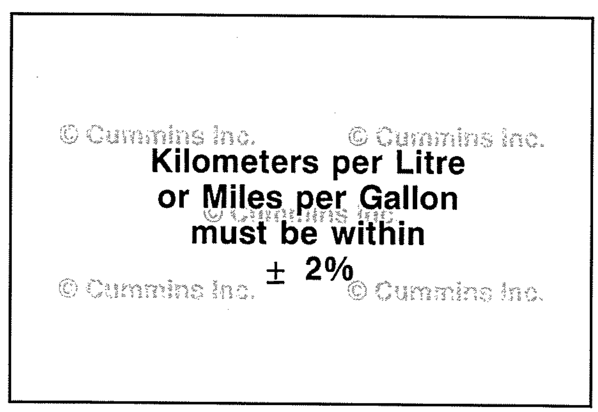
- Difference in elapsed time between each test run can **only** be plus or minus 0.5 percent. This will be ±15 seconds on 80 km [50 mi] at 60 mph.

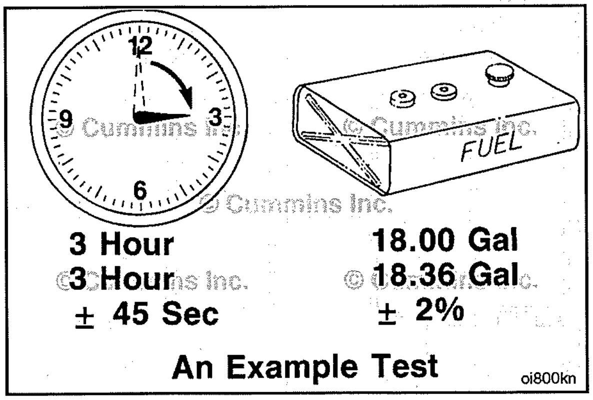


The fuel usage of the test truck between test drives **must** fall within a 2-percent range (6.00 mpg vs. 6.12 mpg).

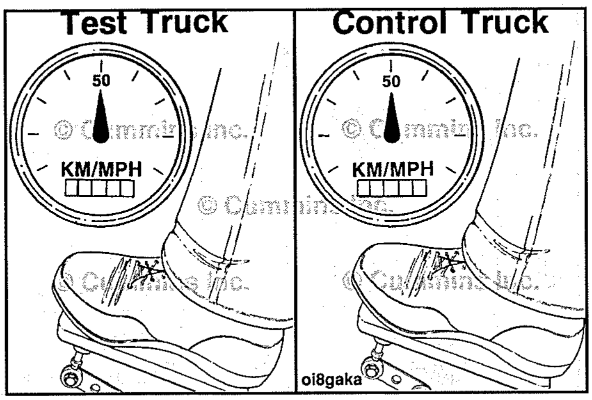
The same range also applies between drives of the control truck.

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



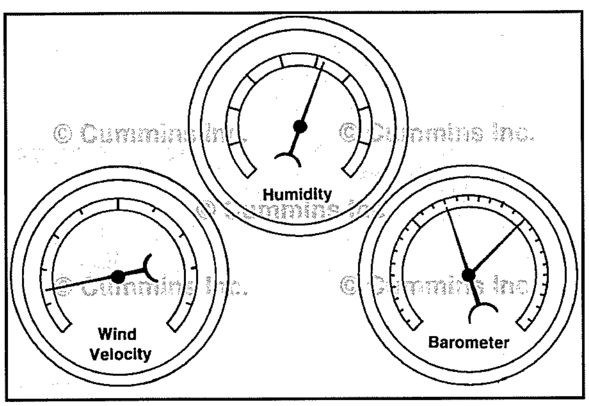


A minimum of three test drives that meet these conditions make a valid test. A single test drive is unreliable.



Use the same experienced drivers for all of the tests.

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



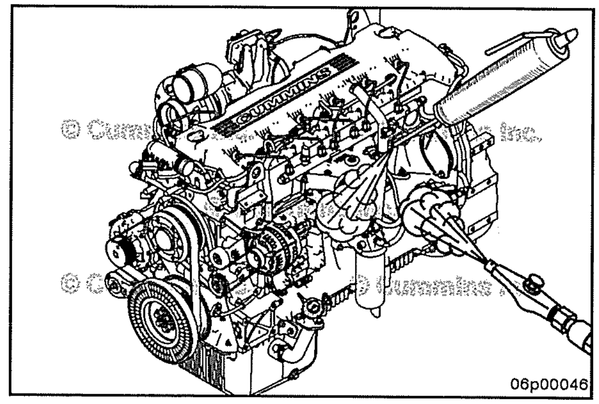
During the test, record the following:

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

NOTE: Avoid testing under any extreme conditions.

Fuel Pump (005-016)

Preparatory Steps



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

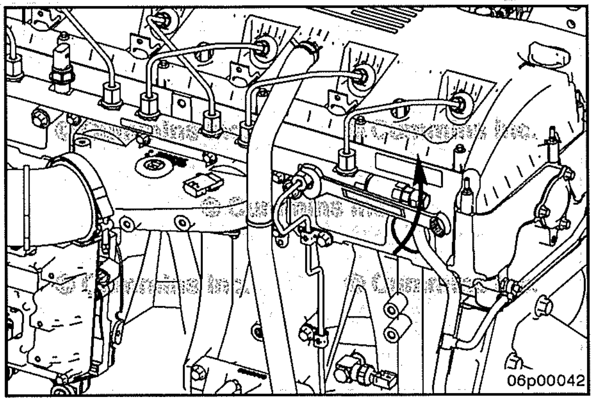
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

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

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

- Clean the engine. Refer to Procedure 000-009 in Section 0.
- Use contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.
- To prevent damage from debris and contamination, cover, cap, or plug any openings as soon as possible when servicing the fuel system. Caps and plugs can be found in Clean Care Kit, Part Number 4919073.



06p00042

WARNING

When servicing the engine do not use the starting motor to rotate the engine with a high-pressure fuel system joint open. Rotating the engine can create highly pressurized fuel in the fuel system. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

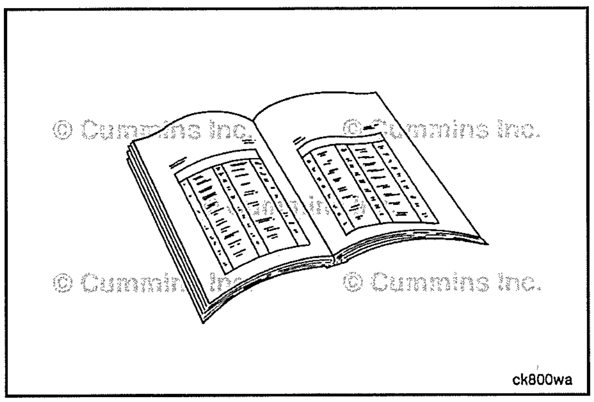
Before servicing the fuel system, loosen the pump to rail line at the rail to vent the pressure.

Keep hands clear of the line when loosening.

Tighten the fuel rail nut.

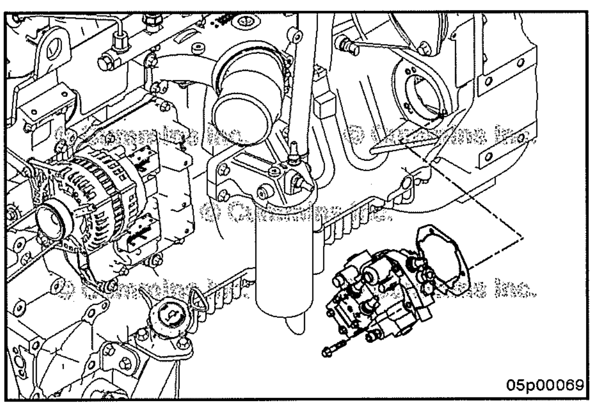
Torque Value: 25 N•m [221 in-lb]

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



ck800wa

- Disconnect the battery. Refer to Procedure 013-009 in Section 13.
- Remove the high-pressure fuel rail supply line from the fuel pump. Refer to Procedure 006-071 in Section 6.
- Remove the fuel supply lines from the fuel pump gear pump. Refer to Procedure 006-024 in Section 6.
- Remove the fuel drain line from the fuel pump. Refer to Procedure 006-013 in Section 6.
- Disconnect the engine harness from the fuel pump actuator. Refer to Procedure 019-117 in Section 19.

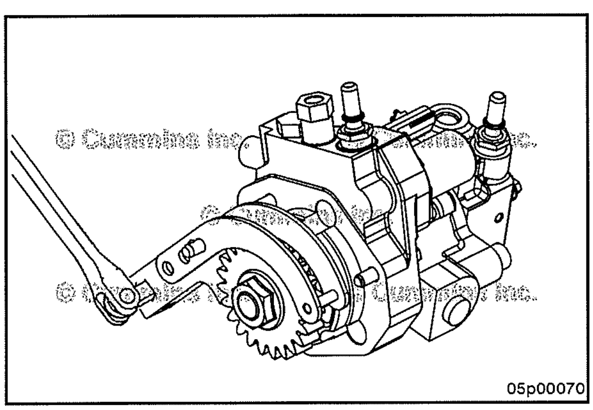


05p00069

Remove

Remove the three mounting studs that hold the fuel pump to the gear housing.

Remove the fuel pump and gasket.



05p00070

Disassemble

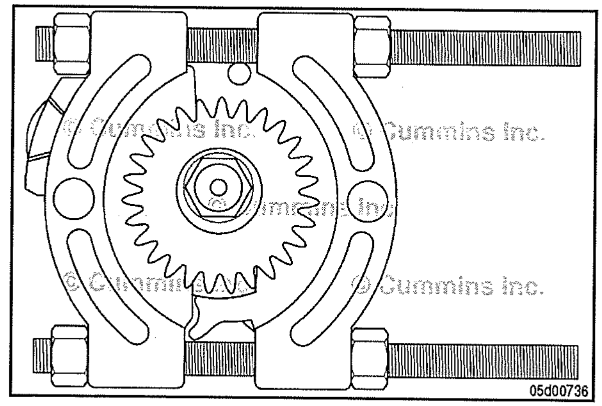
NOTE: The fuel pump drive gear **only** needs to be removed if worn or damaged.

Use a fuel pump retention tool, Part Number 5298951, and a 1/2-inch breaker bar to retain the fuel pump drive gear.

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

Install a bearing separator, Snap-On™ Part Number CJ951, or equivalent, between the fuel pump mounting flange and drive gear.

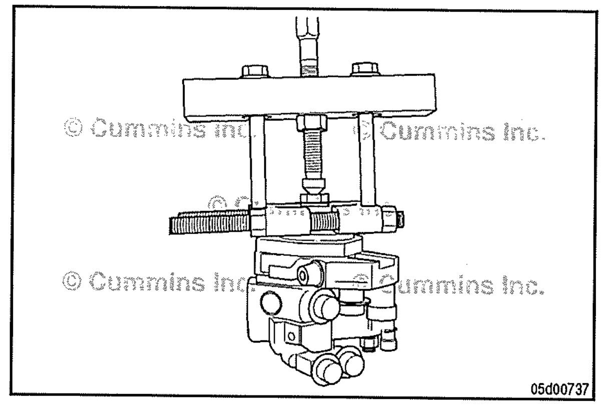
Secure the bearing separator.



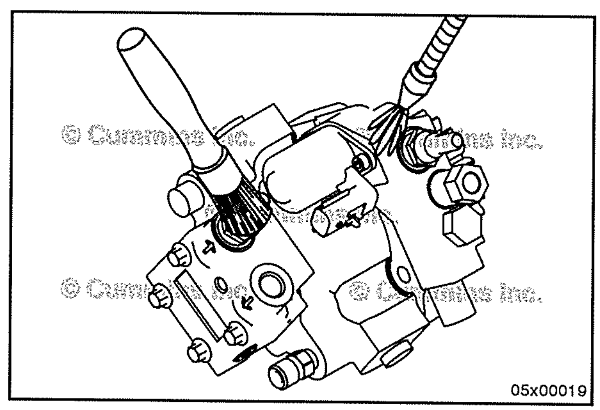
Install a Snap-On™ puller, Part Number CG150, or equivalent, onto the bearing separator, Snap-On™ Part Number CJ951, and the fuel pump driveshaft.

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

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



Inspect for Reuse



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

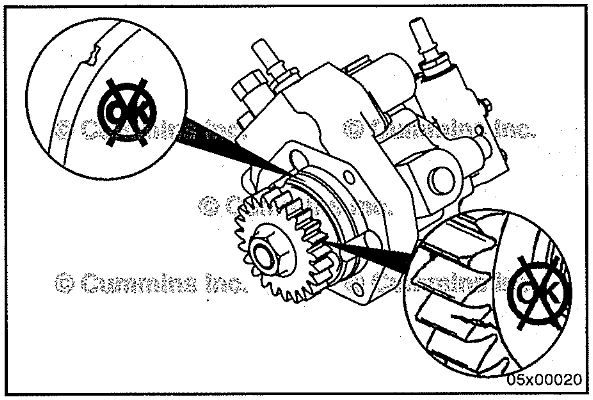
WARNING
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

CAUTION
Use solvent or cleaner that will not harm aluminum.

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

Clean the fuel pump with solvent.

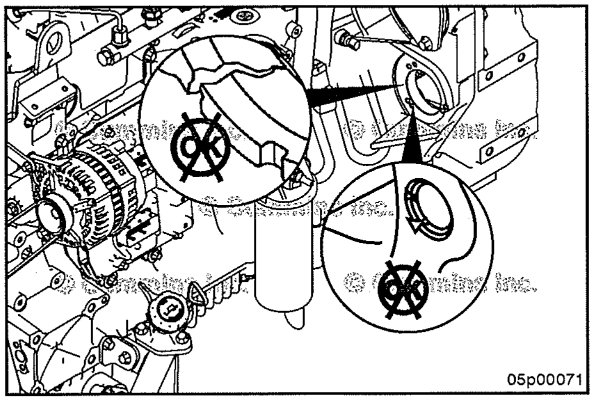
Dry with compressed air.



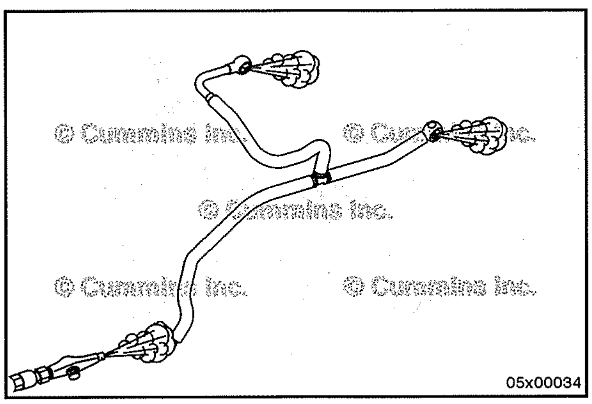
Inspect the driveshaft and gear for damage. Replace if damage is found.

Inspect the gasket for damage. Replace if damage is found.

Inspect the gasket sealing surfaces for damage. Clean and repair any burred surfaces.



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

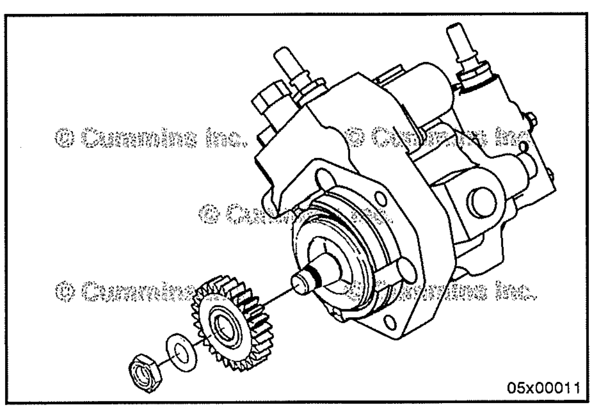


CAUTION

If replacing fuel pump due to failure, debris may enter the fuel pump from the drain line causing damage to fuel pump.

Inspect fuel pump return line for debris.

Remove and clean if debris is found. Refer to Procedure 006-013 in Section 6.



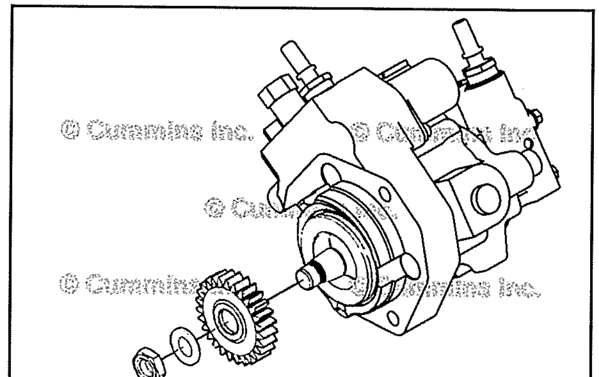
Assemble

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

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

Install the drive gear onto the driveshaft.

Install the driveshaft lock washer and retaining nut and finger tighten.



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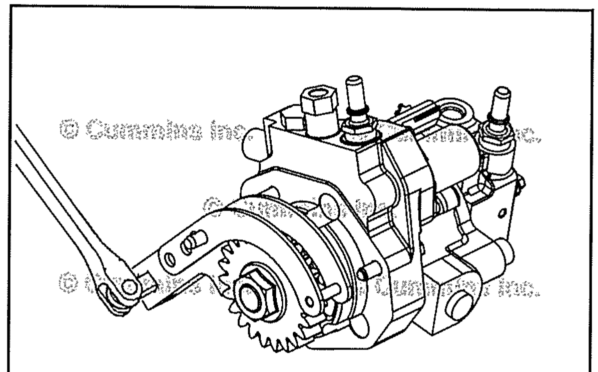
Use the fuel pump gear retention tool, Part Number 5298951, and a 1/2-inch breaker bar to hold the drive gear in place while tightening the drive gear retaining nut.

Torque Value: 100 N•m [74 ft-lb]



05p00070

Install

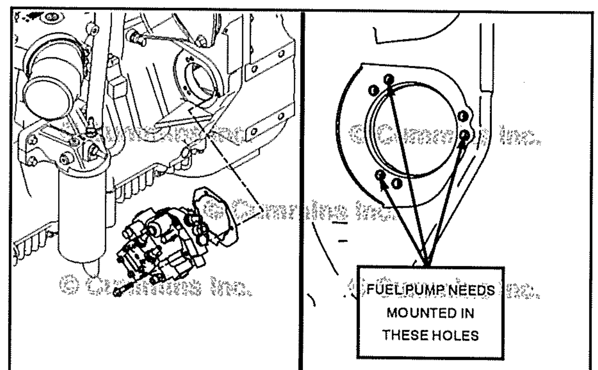
NOTE: Timing of the high-pressure pump with the crankshaft is **not** required.

Install the fuel pump and gasket on the gear housing.

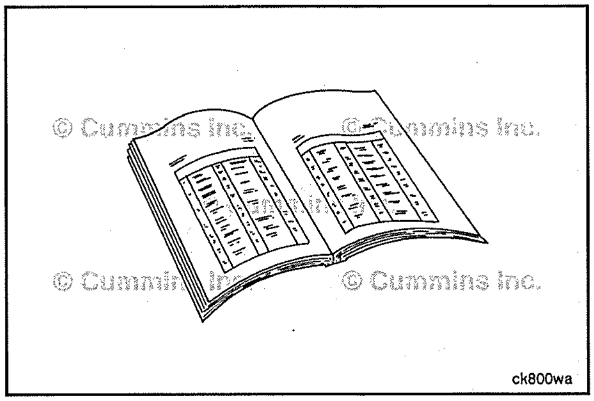
Install the fuel pump mounting capscrews and tighten.

NOTE: Fuel pump needs to be mounted in the correct holes. See illustration.

Torque Value: 23 N•m [204 in-lb]



05p00073



Finishing Steps

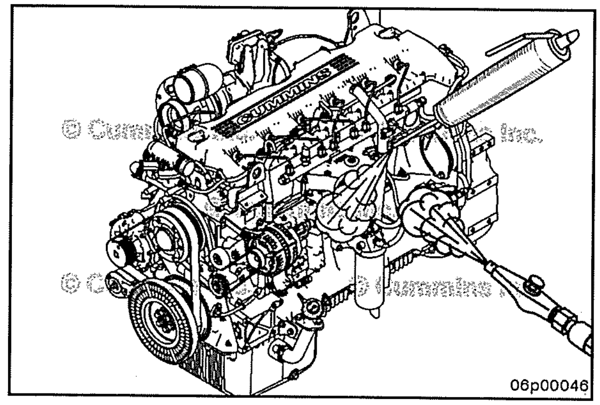
WARNING

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

- Install the fuel drain lines to the fuel pump. Refer to Procedure 006-013 in Section 6.
- Install the fuel supply lines to the fuel pump gear pump. Refer to Procedure 006-024 in Section 6.
- Install the high-pressure fuel rail supply line to the fuel pump. Refer to Procedure 006-071 in Section 6.
- Connect the engine harness to the fuel pump actuator. Refer to Procedure 019-117 in Section 19.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

Fuel Pump Gear Pump (005-025)

Preparatory Steps



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

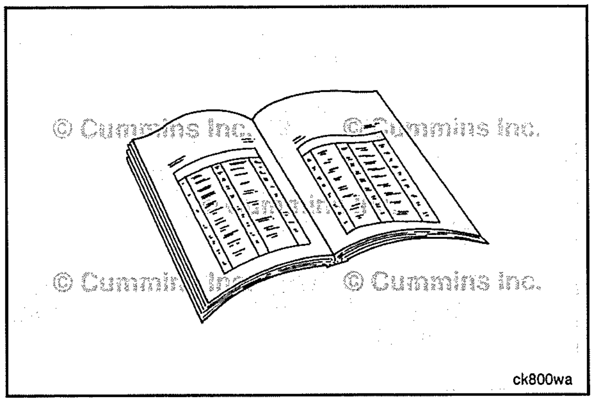
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

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

NOTE: All fuel system diagnostics procedures and component specifications have been moved to procedure 005-236 (Fuel System Diagnostics).

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

- Clean the engine. Refer to Procedure 000-009 in Section 0.
- Use contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.



WARNING

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

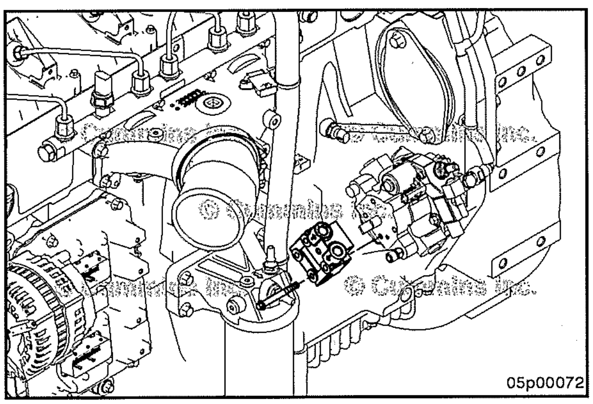
WARNING

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

WARNING

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

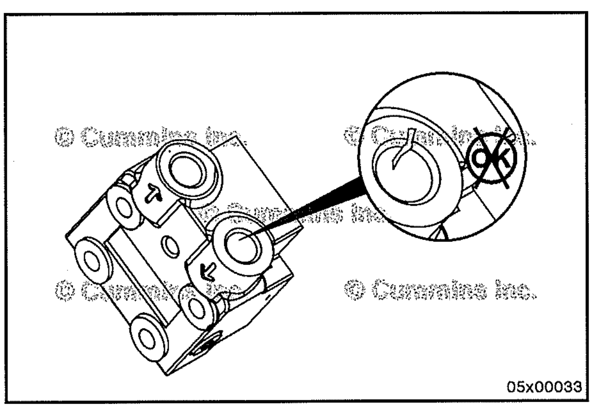
- Disconnect the battery. Refer to Procedure 013-009 in Section 13.
- Clean any fuel, oil, and debris from the gear pump.
- Remove the fuel supply lines from the gear pump. Refer to Procedure 006-024 in Section 6.



Remove

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

Remove and discard the gear pump o-ring.



Clean and Inspect for Reuse

Inspect the gear pump for damage.

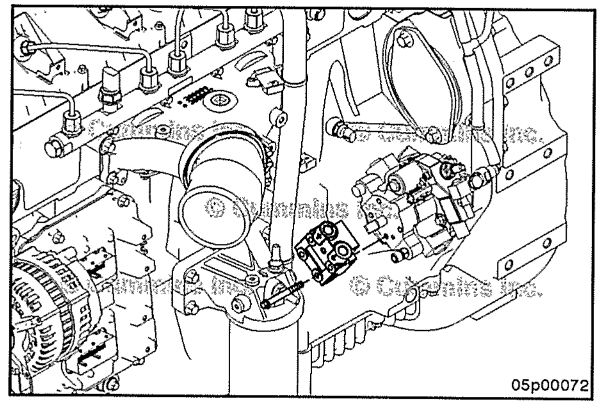
Install

Install a new sealing o-ring onto the gear pump.

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

Install the four gear pump bolts and tighten.

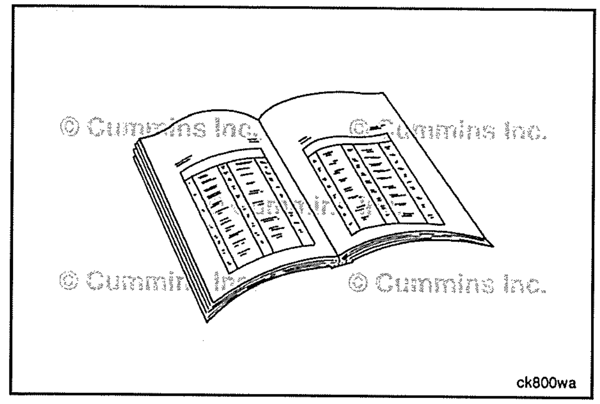
Torque Value: 9.5 N•m [84 in-lb]



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 fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

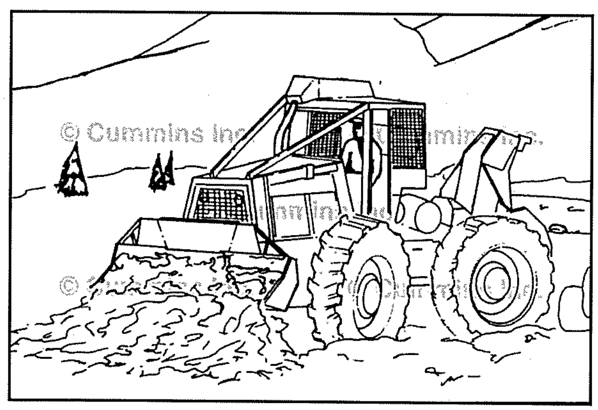


Stall Speed Test (005-054)

Stall Speed Check

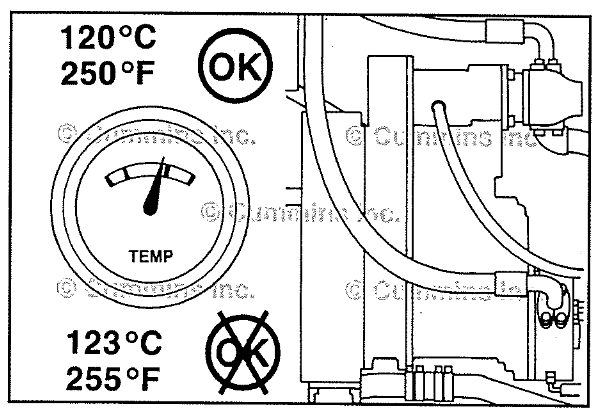
The stall speed is the engine speed (rpm) obtained at full throttle when the converter output shaft is locked.

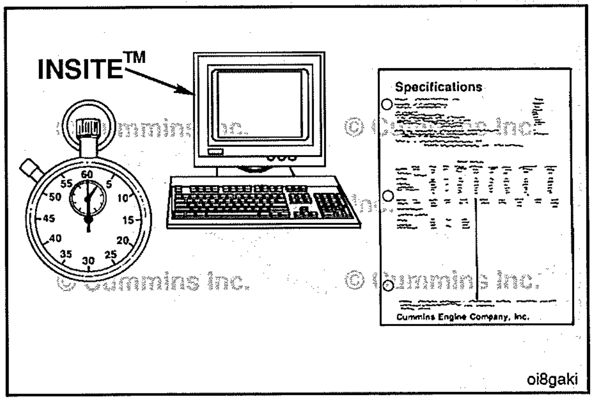
NOTE: It is possible that the vehicle brakes will **not** hold an electronically controlled transmission.



⚠CAUTION⚠
Do not exceed 120°C [250°F] converter oil temperature. Overheating can result and converter damage can occur. If the oil temperature exceeds 120°C [250°F], put the transmission in NEUTRAL, and operate the engine until the oil temperature is below 120°C [250°F].

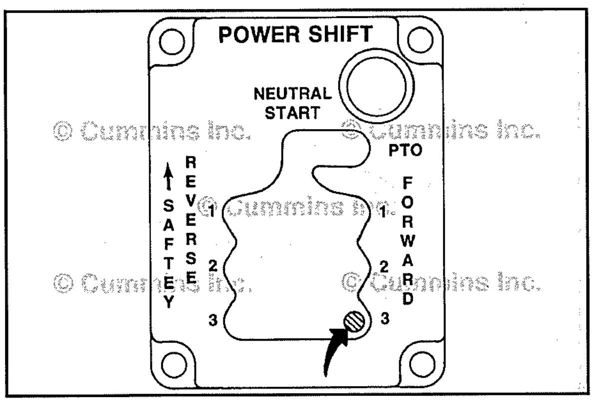
Check the converter oil level.



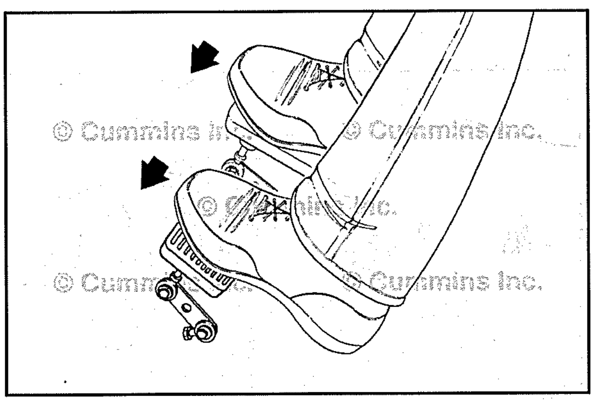


The following equipment is needed for this check:

- Stopwatch
- Optical tachometer, Part Number 3377462 or INSITE™ electronic service tool
- Equipment manufacturer's stall speed and time-to-stall specifications.

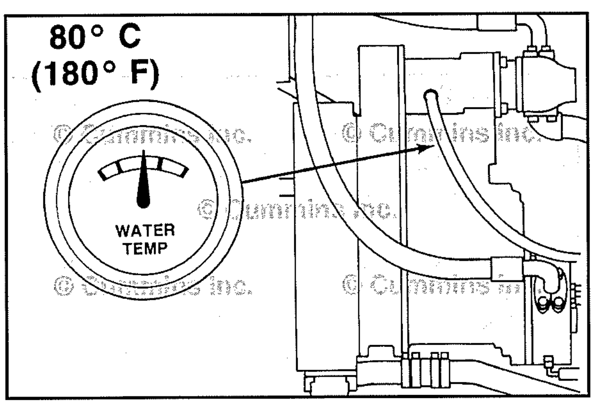


Place the gear selector in the highest gear or full forward.



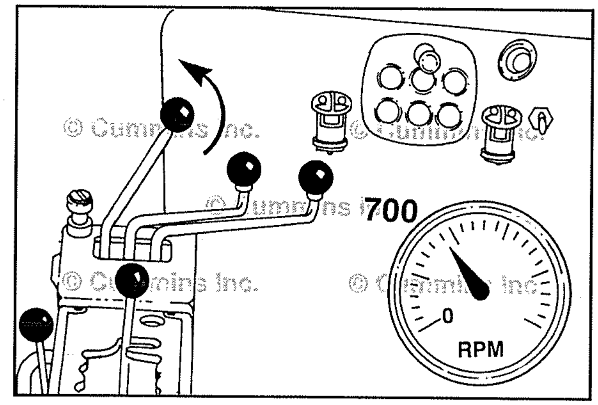
Make certain the vehicle has good brakes and air pressure in the brake system.

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



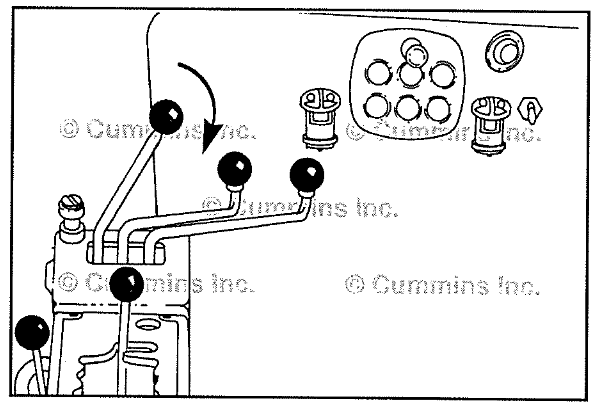
Operate the engine until the converter temperature is 80°C [180°F] or above.

Bring the engine speed back to low idle.



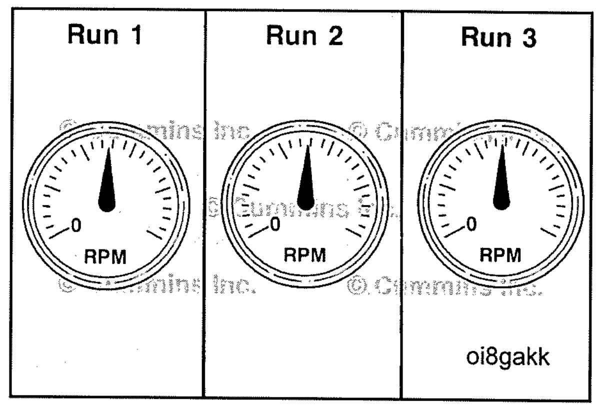
⚠CAUTION⚠
Do not exceed 120°C [250°F] converter oil temperature. Overheating can result and converter damage can occur. If the oil temperature exceeds 120°C [250°F], put the transmission in NEUTRAL and operate the engine until the oil temperature is below 120°C [250°F].

Quickly move the throttle to the full-open position.



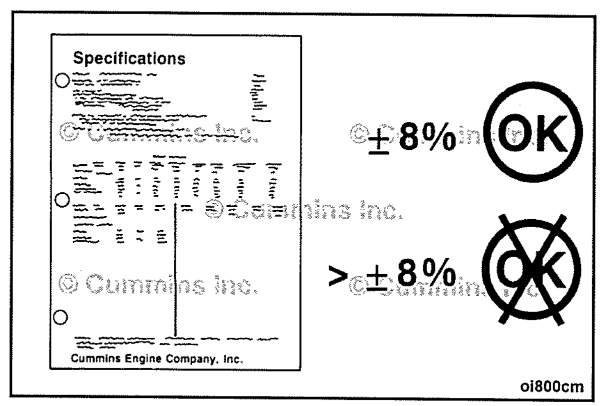
Check the engine speed (rpm) at the point of stall:

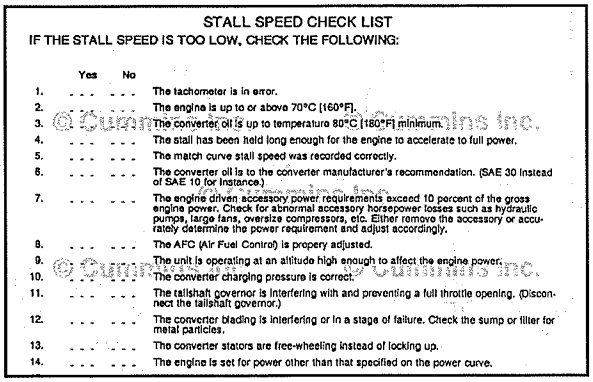
- **Always** hold the speed until it is stable.
- Take several readings.
- Make sure the readings are accurate.



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

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





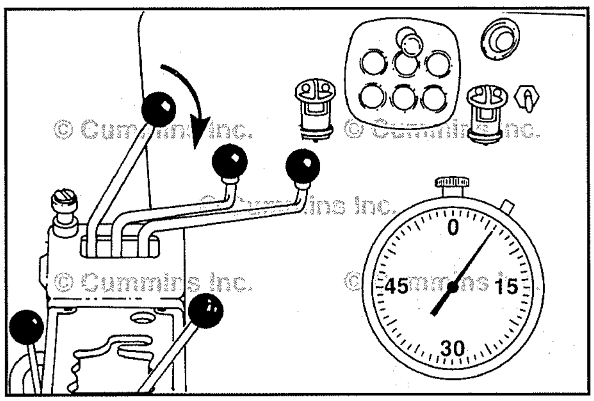
STALL SPEED CHECK LIST

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

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

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

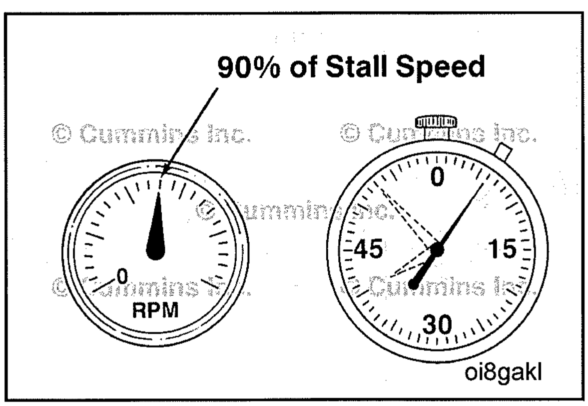
Check the equipment manufacturer's troubleshooting procedures for other reasons for stall speed problems.



Time Speed Check

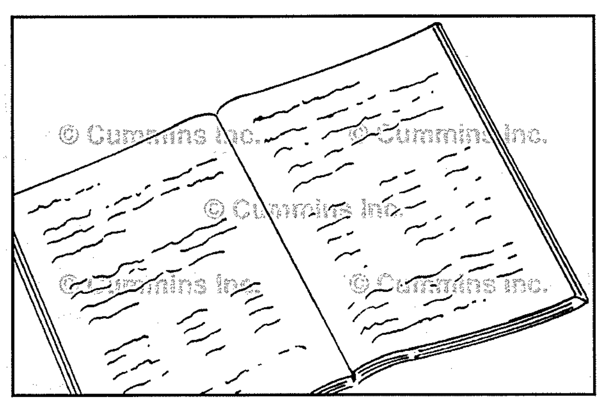
Perform the previous Stall Speed Check procedure through the "check the engine speed (rpm) at the point of stall" step, then:

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



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

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



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

Stall Speed Check List

Stall Speed Too Low

Stall Speed - Too Low		
The tachometer is in error.	Yes	No
Engine temperature is up to or above 70°C [160°F].	Yes	No
The converter oil is up to temperature 80°C [180°F].	Yes	No
The stall has been held long enough for the engine to accelerate to full-power.	Yes	No
The match curve stall speed was recorded correctly.	Yes	No
The converter oil meets the converter manufacturer's recommendation (SAE 30 rather than SAE 10, for instance).	Yes	No
The engine-driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversize compressors, and so on. Either remove the accessory or accurately determine the power requirement and adjust accordingly.	Yes	No
The unit is operating at an altitude high enough to affect the engine power.	Yes	No
The converter charging pressure is correct.	Yes	No
The converter blading is interfering, or in a stage of failure. Check the sump or filter for particles.	Yes	No
The converter stators are freewheeling rather than locking up.	Yes	No
The converter stators are free-wheeling instead of locking up.	Yes	No
The engine is set for power other than that specified on the power curve.	Yes	No
The converter is wrong due to improper build or rebuild of unit.	Yes	No
The converter is performing to the published absorption curve.	Yes	No
The engine and converter match is correct. Check the engine and converter models for the proper match.	Yes	No
The engine is matched to too large of a converter. If this condition is believed to exist, please report the engine-converter accessory information to the factory.	Yes	No

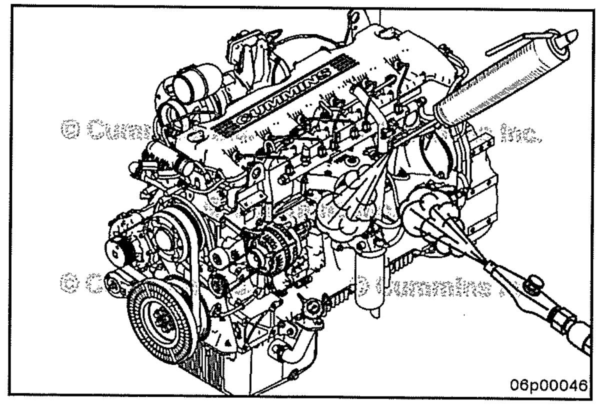
Stall Speed - Too Low		
The engine power is down. Perform a cylinder performance test to find the cylinder with low power.	Yes	No

Stall Speed Too High

Stall Speed - Too High		
The engine is high in power.	Yes	No
The tachometer is in error.	Yes	No
The accessory power requirements are less than 10 percent of the gross engine power.	Yes	No
The converter oil is aerating or foaming. Check for low oil level, air leaks in suction line, lack of foam inhibitor in the oil, or suction screen or filter. Would be accompanied by a noticeable loss of machine performance.	Yes	No
The converter is being held at full stall. Check for slipping front disconnect clutch or a rotating output shaft. On the converter-transmission package, this can be impossible to check.	Yes	No
The converter turbine element is beginning to fail and lose blades, or the converter was originally built with the wrong size element.	Yes	No
The engine and converter match is correct due to a revision in the engine rating or the converter performance.	Yes	No
If the oil level is too high on the transmission-converter units with the oil sump in the transmission, it can cause severe aeration due to parts dipping in the oil.	Yes	No
The converter is performing to the published absorption curve.	Yes	No
The converter charging pressure is correct.	Yes	No

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

Fuel Pump Head Outlet Fitting (005-226)



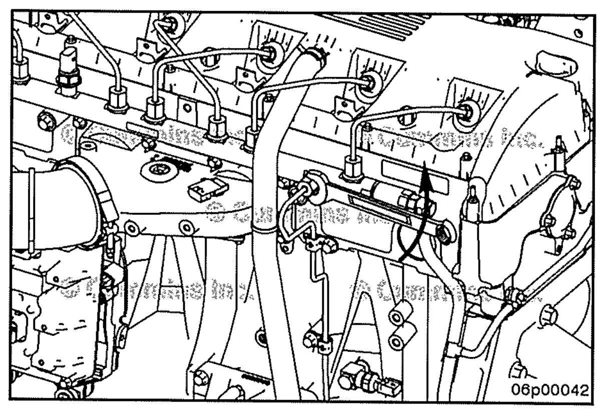
Preparatory Steps

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

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

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

- Clean the engine. Refer to Procedure 000-009 in Section 0.
- Use electrical contact cleaner, Part Number 3824510, or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.



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

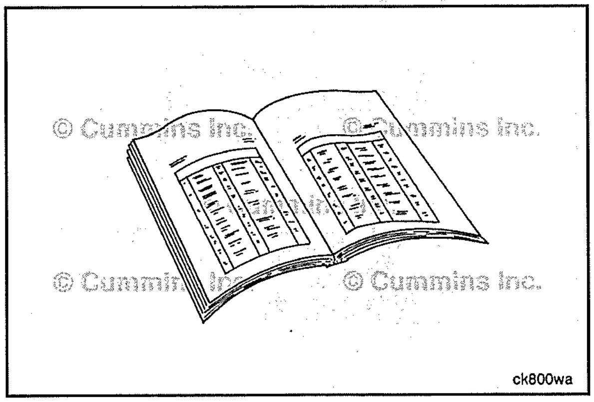
NOTE: A machined slot in this fitting directs the fuel spray towards the engine block.

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

Keep hands clear of the line when loosening.

Tighten the fuel rail nut.

Torque Value: 25 N•m [221 in-lb]



WARNING

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

WARNING

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

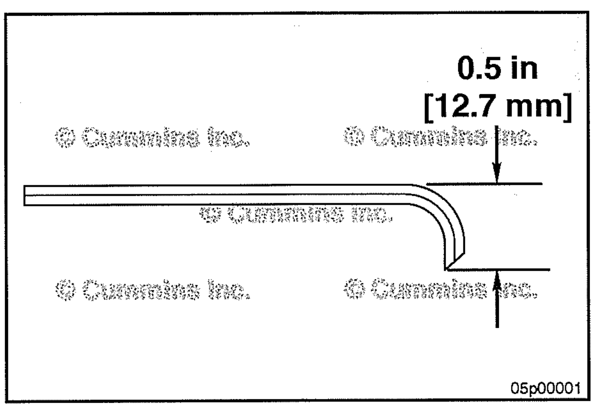
WARNING

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

WARNING

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

- Disconnect the batteries. See equipment manufacturer service information.
- Thoroughly clean the entire fuel pump. Dry the fuel pump with compressed air.
- If equipped close the fuel supply valve. See equipment manufacturer service information.
- Remove the high-pressure fuel rail supply line from the fuel pump. Refer to Procedure 006-051 in Section 6.



Remove

Removal of a "flat washer"

The flat sealing washer is swaged into the inlet fitting bore during installation.

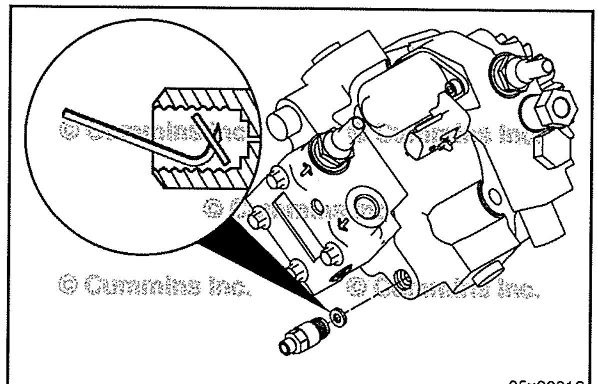
A special tool can be created to aid in its removal by grinding a 45 degree angle on the short leg of a 1/8-inch or 3/16-inch Allen wrench, so that the wrench is no longer than 13-mm [1/2-in] long (measured from the outside of the long leg).

This tool acts as mini heel bar to pry out the sealing washer without damaging the back of the hole.

Remove the fuel pump head outlet fitting.

Pry out the old sealing washer from the threaded hole in the fuel pump using the modified Allen wrench.

NOTE: Considerable force is required to remove the sealing washer.



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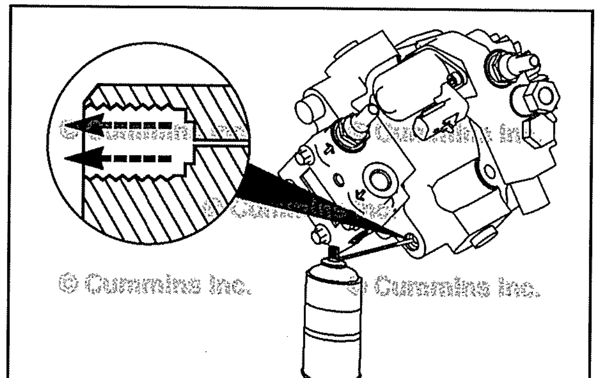
Clean and Inspect for Reuse

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

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

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

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



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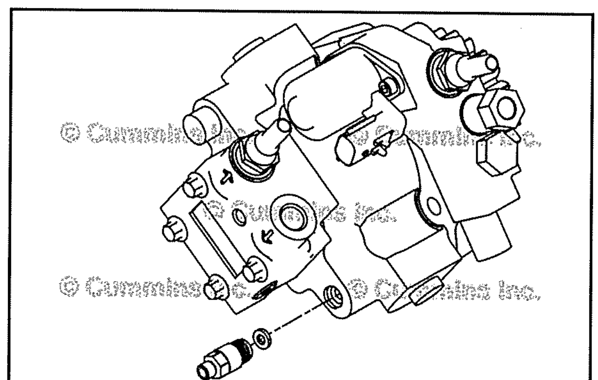
Install

NOTE: This joint is designed to seal in excess of 2000 bar [29,007 psi]. Seal washers **must not** be reused.

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

Torque Value: 81 N•m [60 ft-lb]



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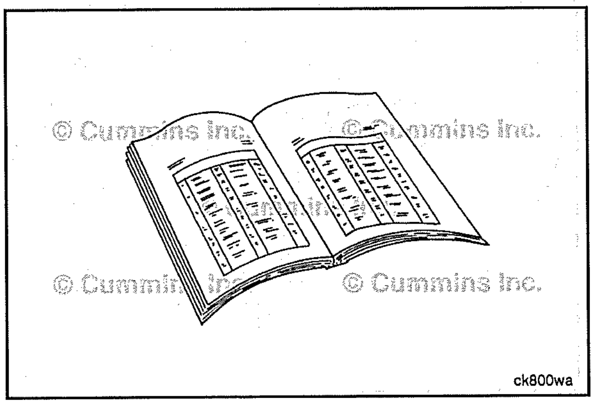
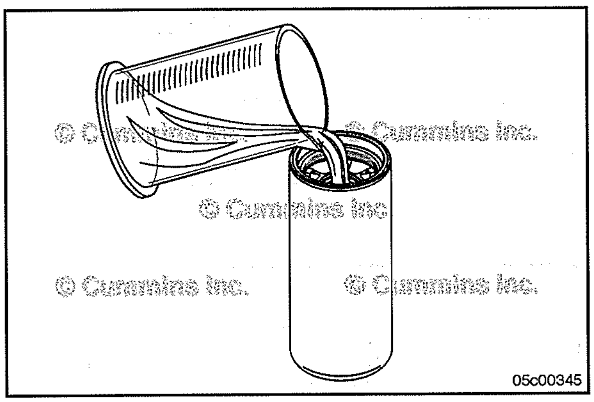


Finishing Steps

⚠WARNING⚠

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

- Install the high-pressure fuel rail supply line to the fuel pump. Refer to Procedure 006-051 in Section 6.
- If equipped, open the fuel supply valve. See equipment manufacturer service information.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.
- Perform several throttle snaps so that increased fuel rail pressure will be developed.



Fuel System Priming (005-234)

Prime

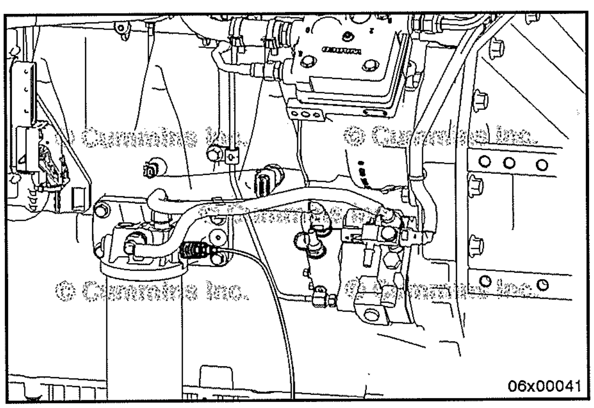
The fuel system should be primed after replacing the fuel filter or running the engine out of fuel.

To prime the fuel system, fill the suction-side and pressure-side fuel filters with clean diesel fuel.

Pour clean diesel 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.

Install the suction-side fuel filter. Refer to Procedure 006-066 in Section 6.

Install the pressure-side fuel filter. Refer to Procedure 006-065 in Section 6.



To assist in fuel system priming and removing air from the fuel system, an orificed diagnostic fuel line, Part Number 3164621, may be used to bleed air from the low-pressure fuel system.

Install a Compuchek™ fitting, Part Number 3824844, at the inlet to the pressure-side fuel filter.

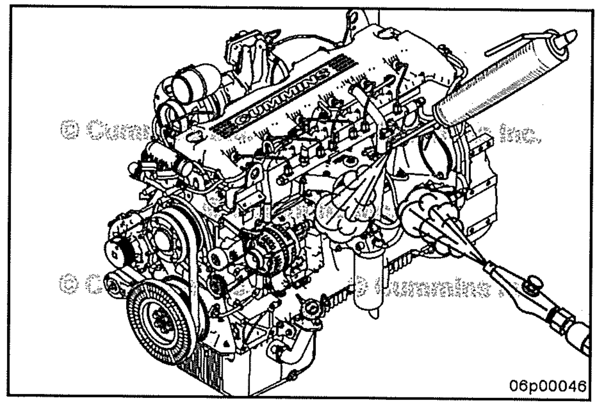
Attach the diagnostic fuel line to the Compuchek™ fitting at the inlet to the pressure-side fuel filter. Crank or start the engine and allow it to run until the air is removed from the fuel system and a solid stream of fuel exits the diagnostic fuel line.

Stop the engine after a solid stream of fuel begins exiting the diagnostic fuel line. Wait 4 to 5 seconds to allow any compressed air trapped in the fuel filter head to exit through the diagnostic fuel line.

Repeat this process until air no longer exits the diagnostic fuel line when cranking or starting the engine. If air continues to exit the diagnostic fuel line after four or more repetitions, check the suction side of the fuel system for leaks. Refer to Procedure 006-003 in Section 6.

Fuel System Diagnostics (005-236)

General Information



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⚠WARNING⚠

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

⚠WARNING⚠

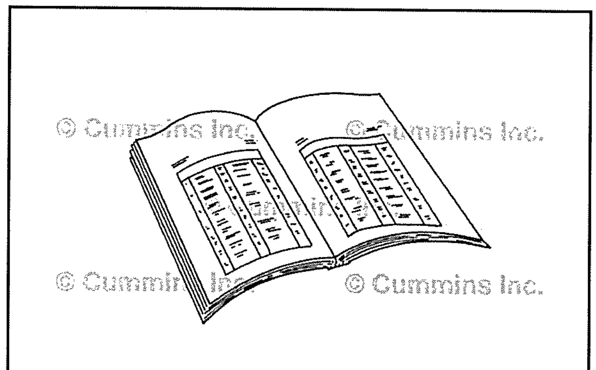
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠CAUTION⚠

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

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

To prevent engine damage from debris or contamination, cover, cap, or plug any openings as soon as possible when servicing the fuel system. Caps and plugs can be found in Clean Care Kit, Part Number 4919073.



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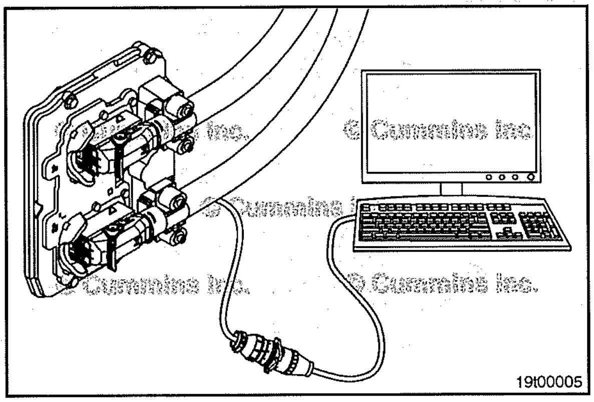
The following procedures are used to diagnose fuel system issues. These checks and measurements are referenced throughout the applicable troubleshooting and fault code trees as needed.

This procedure is **not** intended to take the place of the troubleshooting tree repair direction.

See the appropriate troubleshooting symptom tree for repair direction.



High-Pressure System Leak Down Test

NOTE: This test can **not** be performed if the engine will **not** start.

Connect INSITE™ electronic service tool.

Operate the engine.

Monitor the fuel rail pressure.

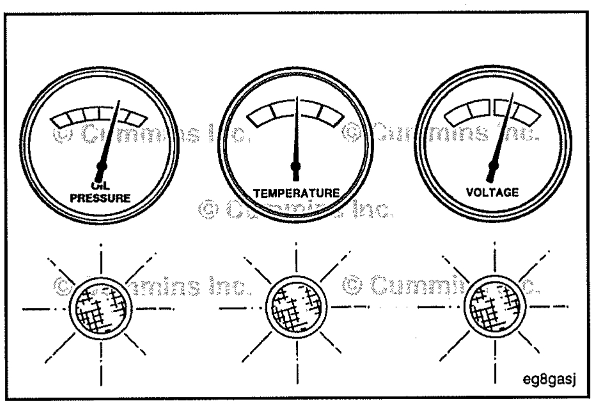
Check the fuel pressure decay.

Shut off the engine and wait for it to completely stop. Turn the key switch ON quickly.

Monitor INSITE™ electronic service tool and record the fuel rail pressure for 1 minute.

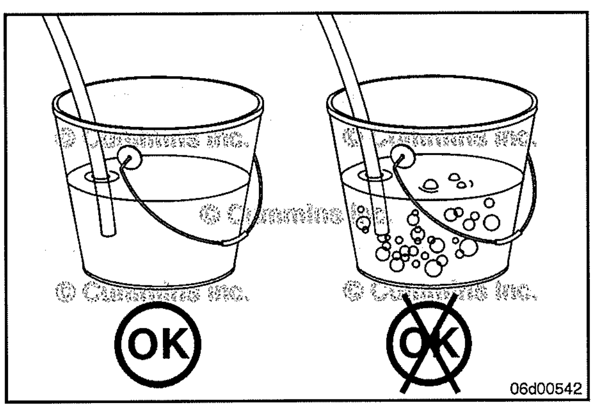
A change in fuel pressure greater than 100 bar [1450 psi] in 1 minute is an indication of a high-pressure fuel system leak.

See the appropriate troubleshooting symptom tree for repair direction.



Low-Pressure System Check

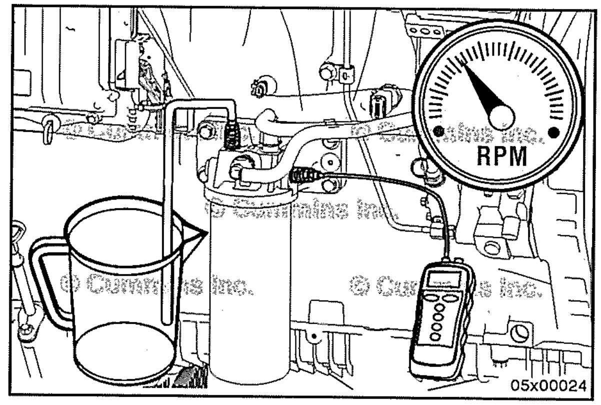
The low-pressure system check consists of a number of measurements and checks to make sure that the low pressure fuel system is functioning properly. These checks will vary, depending on whether or **not** engine will start.



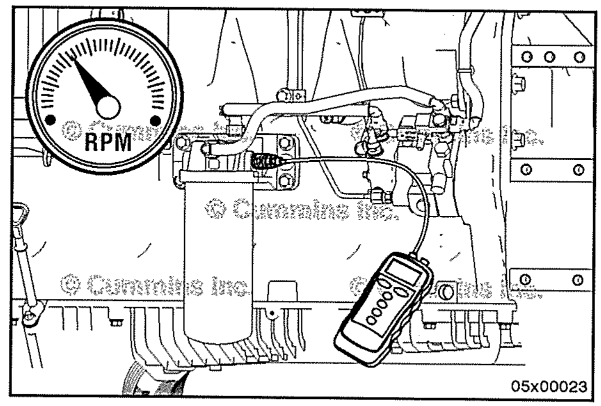
Measurement - Engine Will Start

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

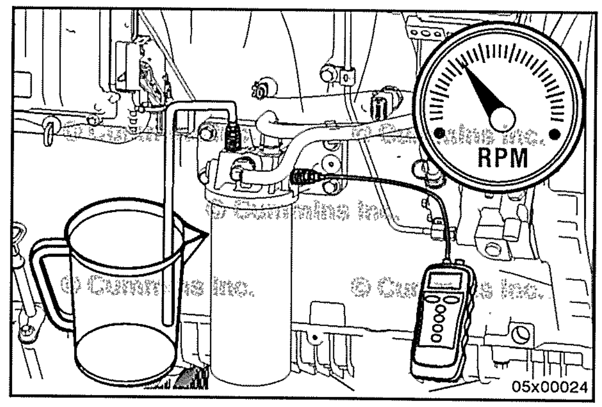
Measure the fuel inlet restriction. Refer to Procedure 006-020 in Section 6.



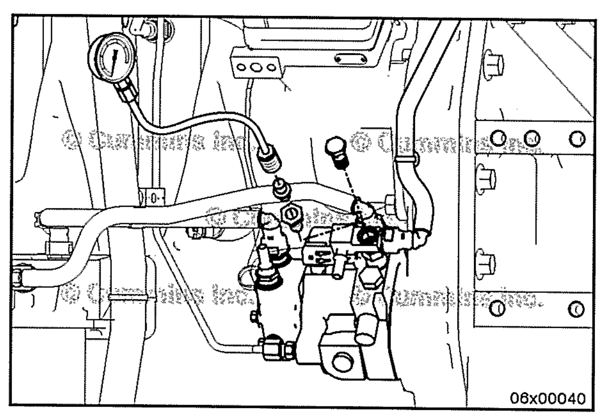
Measure the fuel gear pump output pressure. Use the instructions in the Fuel Pump Gear Pump Pressure Test section of this procedure.

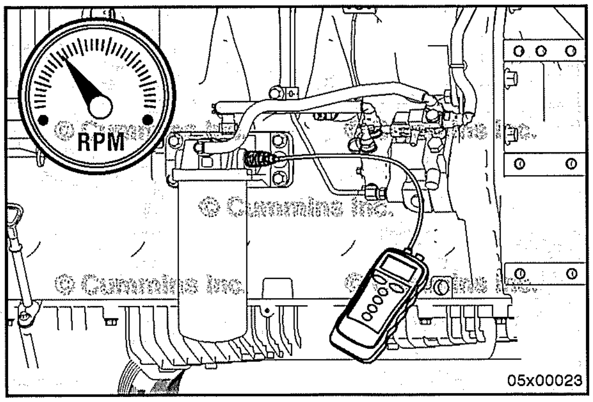


Measure the fuel filter restriction. Use the instructions in the Fuel Filter Restriction section of this procedure.



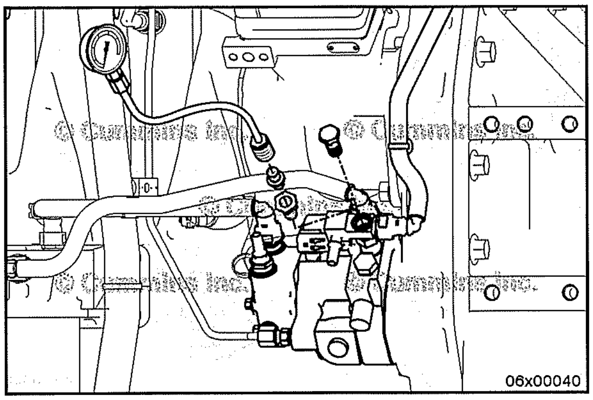
Measure the fuel drain line restriction. Refer to Procedure 006-012 in Section 6.



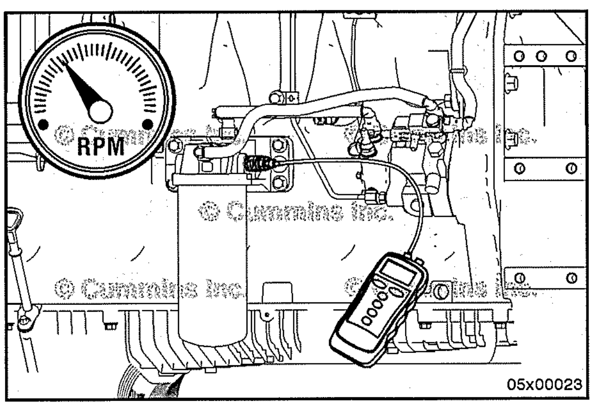


Measurement - Engine Will Not Start

Measure the fuel gear pump output pressure while cranking. Use the instructions in the Fuel Pump Gear Pump Pressure Test section of this procedure.



Measure the fuel drain line restriction. Refer to Procedure 006-012 in Section 6.



Fuel Pump Gear Pump Pressure Test

Measurement - Engine Will Start

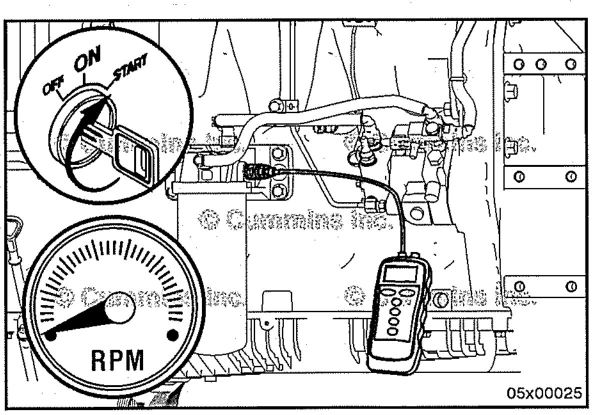
Install a Compuchek™ fitting, Part Number 3824844, at the inlet to the fuel filter head.

Install a 0 to 2068 kPa [0 to 300 psi] pressure gauge at the Compuchek™ fitting at the inlet to the fuel filter head.

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

Gear Pump Pressure at High Idle

kPa		psi
517	MIN	75



Measurement - Engine Will Not Start

Install a Compuchek™ fitting, Part Number 3824844, at the inlet to the fuel filter head.

Install a 0 to 207 kPa [0 to 30 psi] pressure gauge at the Compuchek™ fitting at the inlet to the fuel filter head.

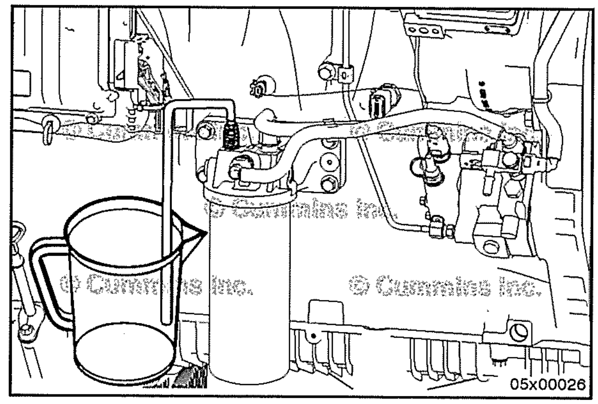
Crank the engine and observe the fuel gear pump pressure.

Gear Pump Pressure at Cranking

kPa		psi
69	MIN	10

Fuel Filter Restriction

Initial Setup

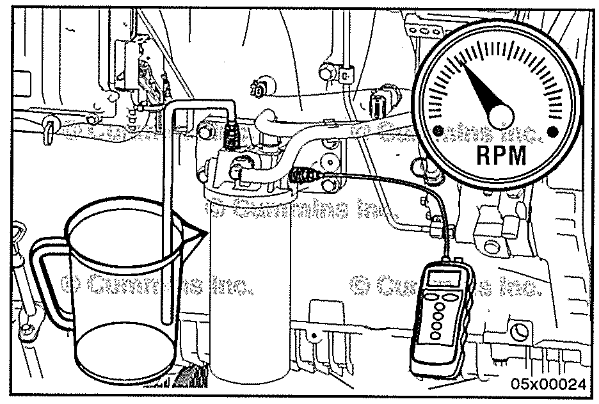


Install a Compuchek™ fitting, Part Number 3824844, at both of the outlets to the fuel filter head.

Connect orificed diagnostic fuel line, Part Number 3164621, to the Compuchek™ fitting at the outlet to the fuel filter head and route to the engine fuel tank or other suitable container.

The orificed diagnostic fuel line is used in procedures to create rated flow through the low pressure fuel system without the need to operate the engine under load.

Measurement



Install a Compuchek™ fitting, Part Number 3824844, at the inlet to the fuel filter head.

Install a 0 to 2068 kPa [0 to 300 psi] pressure gauge at the Compuchek™ fitting at the inlet to the fuel filter head.

Operate the engine at high idle and observe the filter inlet pressure.

Install a 0 to 2068 kPa [0 to 300 psi] pressure gauge at the Compuchek™ fitting at the outlet to the fuel filter head.

Operate the engine at high idle and observe the filter outlet pressure.

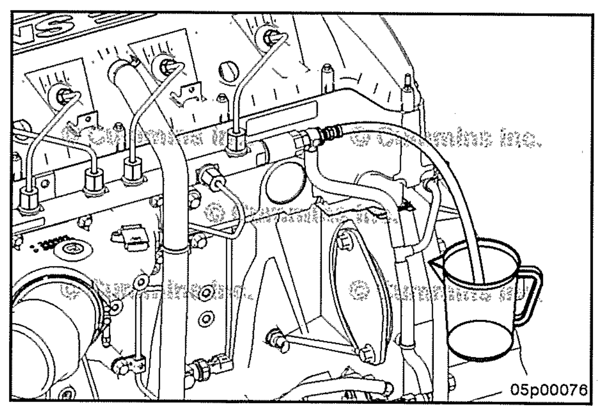
Fuel Filter Restriction

kPa		psi
138	MAX	20

If the difference between the filter inlet pressure and filter outlet pressure is greater than the specification, replace the fuel filter.

High-Pressure Injector Return Flow Test

Initial Setup

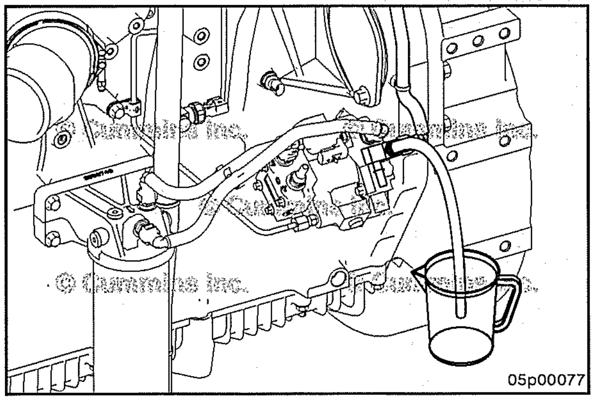


NOTE: Make sure the engine is at operating temperature before beginning this test.

Remove the banjo bolt that connects the fuel pressure relief valve to the fuel drain line.

Install the fuel pump tester, Part Number 3164617, onto the fuel pressure relief valve.

Route the hose from this adapter to a suitable container.



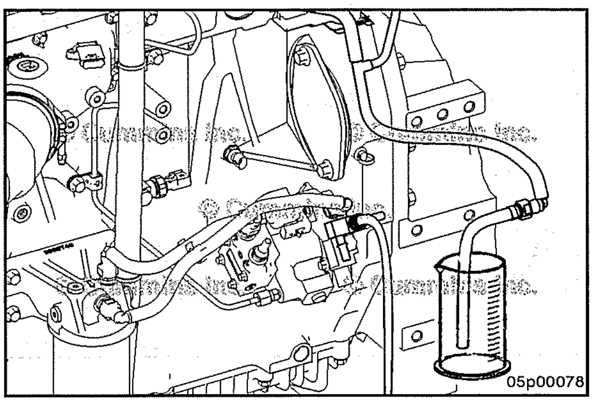
WARNING

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

Remove the banjo bolt that connects the common drain line to the fuel drain connection at the fuel pump.

Install the fuel system leak tester, Part Number 4918679, at the fuel drain connection at the fuel pump.

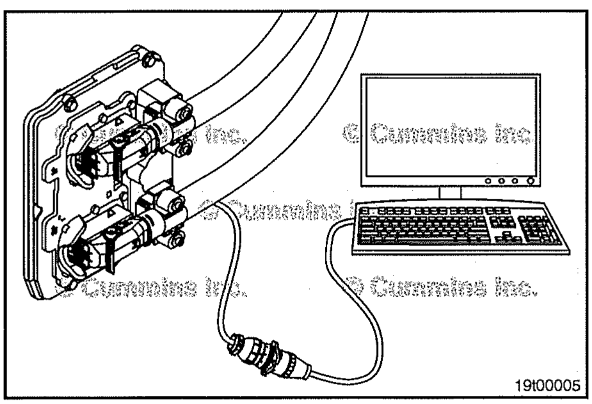
Route the hose from this adapter to a suitable container.



Disconnect the fuel drain line from the fuel drain connection.

Install the fuel system leak tester, Part Number 4918697, at the fuel drain line.

Route the hose from this adapter to a graduated cylinder, Part Number 4919139, or equivalent.



Measurement - Engine Will Start

Connect INSITE™ electronic service tool.

Start the engine and allow the engine to idle with fuel flowing into a collection device.

Perform INSITE™ electronic service tool High-Pressure Leakage Test.

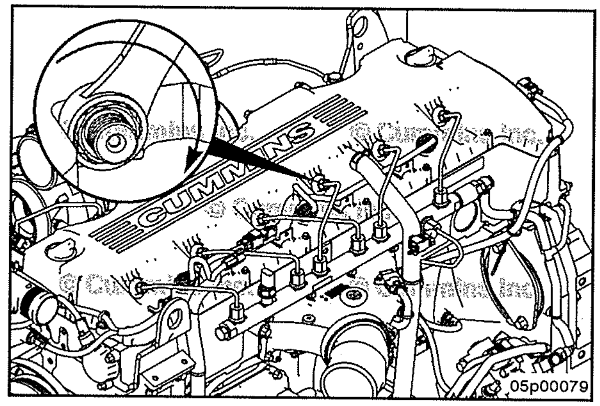
Leakage Specification with Engine Running	
Maximum Leakage in 1 Minute	70 ml (cc)

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

After recording the fuel leakage quantity, stop INSITE™ electronic service tool High-Pressure Leak Test and turn the key switch to OFF.

NOTE: Be sure a steady flow of fuel is present at the drain line before beginning the measurement. Air in the line and movement of the hose during measurement can result in inaccurate measurements.

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



Measurement - Engine Will Not Start

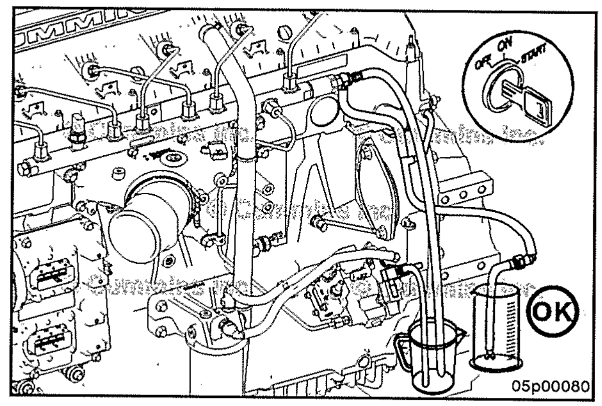
Crank the engine until fuel exits the drain line.

NOTE: Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second pause between intervals. This reduces the possibility of overheating the starting motor.

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

The leakage should **only** be a few drops. Any more than a few drops indicates an injector failure.

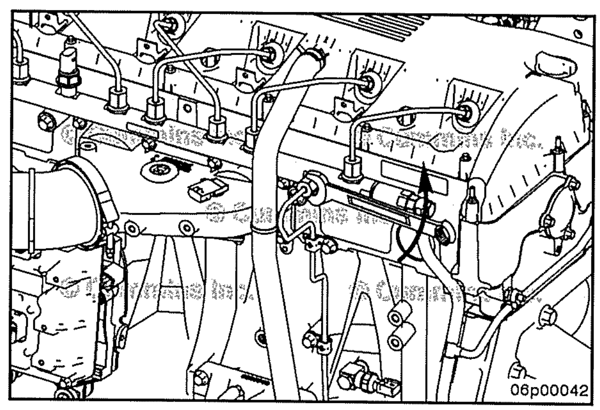
NOTE: Vent the pressure from the fuel system as directed after each cranking event.



High-Pressure Injector Return Flow Isolation Test

WARNING

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



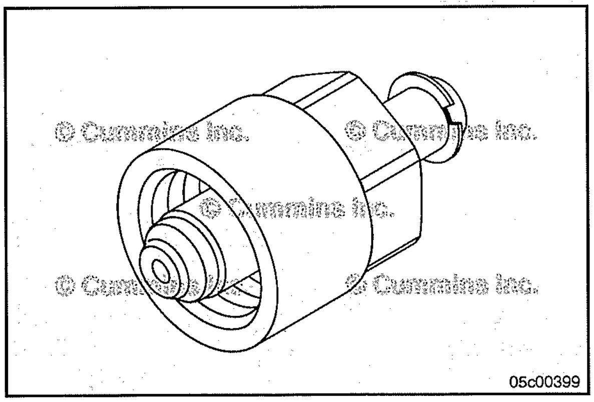
Before servicing the high-pressure fuel system, loosen the pump to rail line at the rail to vent the pressure.

Keep hands clear of the line when loosening.

Tighten the fuel rail nut.

Torque Value: 25 N•m [221 in-lb]

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



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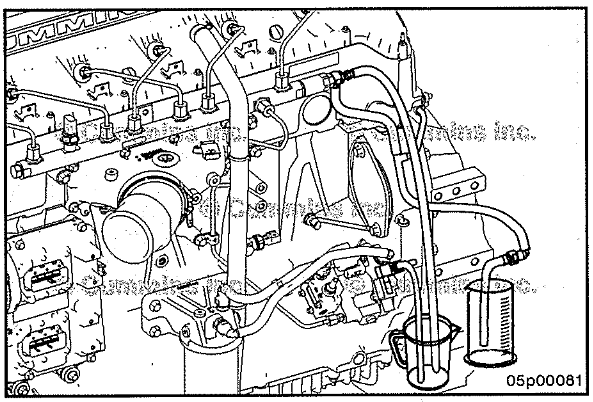
⚠CAUTION⚠
Do not install the isolation tool at the high pressure pump outlet fitting. Severe engine damage will result. This tool must only be installed at the fuel rail for the purpose of isolating the high-pressure fuel supply from individual injectors.

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

Use leak test isolation tool, Part Number 5299021, to isolate excessive fuel drain from injectors.

NOTE: Follow the pressure relief step (shown in the previous step) prior to every installation of the isolation tool.



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Isolate the injector for each cylinder by installing the isolation tool at the fuel rail in place of the high-pressure fuel line that supplies the injector.

Torque Value: 25 N•m [221 in-lb]

Cylinder	Quantity
1	
2	
3	
4	
5	
6	

06d00483

Record the amount of fuel flow from the injector drain line in 1 minute while the engine is running. Use INSITE™ electronic service tool High Pressure Leak Test. Do this up to six (6) times, once while each line is isolated.

If isolating a single injector causes the leakage to decrease significantly compared to the rest of the set, that injector **must** be inspected.

NOTE: Make sure a steady flow of fuel is present at the drain line before beginning the measurement. Air in the line and movement of the hose during measurement can result in inaccurate measurements.

Inspect the suspect injector. Refer to Procedure 006-026 in Section 6. If necessary, replace the injector.

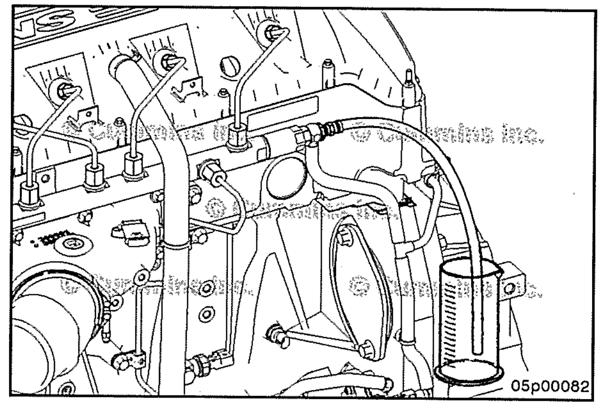
Fuel Pressure Relief Valve Return Flow Test

Initial Setup

Remove the banjo bolt that connects the fuel pressure relief valve to the fuel drain line.

Install the fuel pump tester, Part Number 3164617, onto the fuel pressure relief valve.

Route the hose from this adapter to a graduated cylinder, Part Number 4919139, or equivalent.



Measurement - Engine Will Start

Connect INSITE™ electronic service tool.

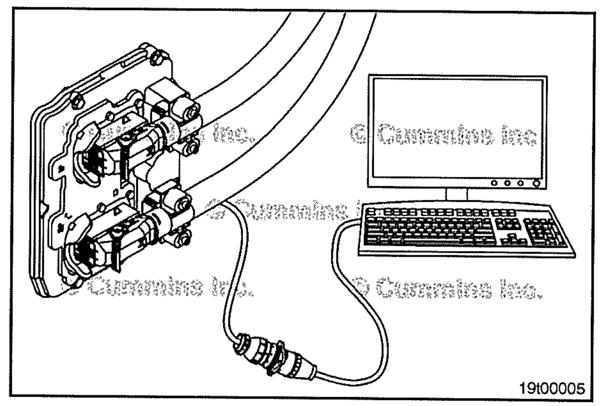
Start the engine and allow the engine to idle with fuel flowing into a collection device.

Perform INSITE™ electronic service tool High-Pressure Leakage Test.

When fuel begins to exit the drain line, route the drain flow into a graduated cylinder.

The leakage **must** be less than 10 drops per minute.

See the appropriate troubleshooting symptom tree for repair directions.



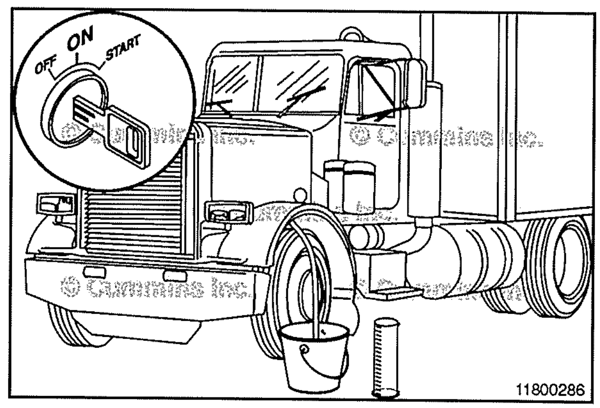
Measurement - Engine Will Not Start

Begin cranking the engine until fuel exits the drain line.

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

NOTE: Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second pause between intervals. This reduces the possibility of overheating the starting motor.

The leakage should be less than 10 drops per minute.



Notes

About the Manual i-1
About....i-1
General Information....i-1
Acronyms and Abbreviations i-27
General Information....i-27
Aftertreatment Diesel Exhaust Fluid Not Pumping....TS-21
Aftertreatment Diesel Particulate Filter - Excessive Automatic and/or Stationary Regeneration....TS-105
Aftertreatment Diesel Particulate Filter - Excessive Soot Loading....TS-20
Air Compressor DS-26
Remove....DS-26
Air Compressor AS-38
Install....AS-38
Air Compressor Air Pressure Rises Slowly TS-12
Air Compressor Coolant Lines DS-25
Remove....DS-25
Air Compressor Coolant Lines AS-39
Install....AS-39
Air Compressor Cycles Frequently....TS-13
Air Compressor Inlet Tube DS-25
Remove....DS-25
Air Compressor Inlet Tube AS-39
Install....AS-39
Air Compressor Noise is Excessive....TS-14
Air Compressor Pumping Excess Lubricating Oil into the Air System TS-15
Air Compressor Will Not Maintain Adequate Air Pressure (Not Pumping Continuously)....TS-17
Air Compressor Will Not Pump Air....TS-18
Air Compressor Will Not Stop Pumping....TS-19
Air Filter Plugging Frequent....TS-112
Air Inlet Connection DS-26
Remove....DS-26
Air Inlet Connection AS-38
Install....AS-38
Air Intake Connection DS-26
Remove....DS-26
Air Intake Connection AS-37
Install....AS-37
Air Intake System - Overview F-28
General Information....F-28
Aspirator Not Functioning....TS-114
Bearings, Connecting Rod AS-9
Install....AS-9
Bearings, Connecting Rod 1-5
Clean and Inspect for Reuse....1-7
Finishing Steps....1-10
General Information....1-5
Install....1-9
Preparatory Steps....1-5
Remove....1-5
Bearings, Main AS-3
Install....AS-3
Bearings, Main 1-11
Clean and Inspect for Reuse....1-13
Finishing Steps....1-19
Install....1-15
Measure....1-14
Measure....1-18
Preparatory Steps....1-11
Remove....1-11
Bearings, Thrust AS-6
Install....AS-6
Bearings, Thrust 1-20
Finishing Steps....1-22
Inspect for Reuse....1-21
Install....1-21
Preparatory Steps....1-20
Remove....1-20
Block Stiffener Plate AS-15
Install....AS-15
Block Stiffener Plate 1-112
Finishing Steps....1-113
Inspect for Reuse....1-112
Install....1-113
Preparatory Steps....1-112
Remove....1-112
Camshaft Cover Plate DS-33
Remove....DS-33
Camshaft Cover Plate AS-24
Install....AS-24
Camshaft Cover Plate 1-22
Clean and Inspect for Reuse....1-23
Install....1-23
Remove....1-22
Camshaft Position Sensor DS-12
Remove....DS-12
Charging System Alternator DS-17
Remove....DS-17
Charging System Alternator AS-52
Install....AS-52
Charging System Alternator Automatic Belt Tensioner DS-16
Remove....DS-16
Charging System Alternator Automatic Belt Tensioner AS-52
Install....AS-52
Charging System Alternator Bracket DS-17
Remove....DS-17
Charging System Alternator Bracket AS-51
Install....AS-51
Charging System Alternator Drive Belt DS-15
Remove....DS-15
Charging System Alternator Drive Belt AS-53
Install....AS-53
Charging System Alternator Not Charging or Insufficient Charging....TS-24
Charging System Alternator Overcharging....TS-26
Complete Engine - Overview F-1
General Information....F-1
Compressed Air System - Overview F-47
General Information....F-47
Connecting Rod 1-24
Clean and Inspect for Reuse....1-25
Finishing Steps....1-31
General Information....1-24
Magnetic Crack Inspect....1-28
Preparatory Steps....1-24
Coolant in the Lubricating Oil....TS-37
Coolant Loss - External....TS-27
Coolant Loss - Internal....TS-29
Coolant Temperature Above Normal - Gradual Overheat....TS-31
Coolant Temperature Above Normal - Sudden Overheat....TS-34
Coolant Temperature Below Normal....TS-36
Coolant Thermostat DS-18
Remove....DS-18
Coolant Thermostat AS-50
Install....AS-50
Coolant Thermostat Housing DS-18
Remove....DS-18
Coolant Thermostat Housing AS-50
Install....AS-50
Cooling Fan Belt Tensioner DS-16
Remove....DS-16
Cooling Fan Belt Tensioner AS-53
Install....AS-53
Cooling System - Overview F-23
General Information....F-23
Crankcase Breather (Internal) 3-2
Clean and Inspect for Reuse....3-2
Install....3-3
Remove....3-2
Crankcase Breather Tube DS-6
Remove....DS-6
Crankcase Breather Tube 3-15
Clean and Inspect for Reuse....3-16
Finishing Steps....3-17
Install....3-16
Preparatory Steps....3-15
Remove....3-15
Crankcase Gases (Blowby) Excessive....TS-38
Crankshaft AS-7
Install....AS-7
Crankshaft 1-31
Bend and Twist Inspect....1-37
Clean and Inspect for Reuse....1-33
Finishing Steps....1-46
Install....1-46
Magnetic Crack Inspect....1-42
Preparatory Steps....1-32
Remove....1-33
Rotation Check....1-31
Crankshaft Gear, Rear (Crankshaft Installed) 1-47
Clean and Inspect for Reuse....1-49
Finishing Steps....1-50
General Information....1-47
Install....1-49
Preparatory Steps....1-48
Remove....1-48
Crankshaft Position Sensor DS-11
Remove....DS-11
Crankshaft Pulley DS-29
Remove....DS-29
Crankshaft Pulley AS-33
Install....AS-33
Crankshaft Pulley 1-50
Clean and Inspect for Reuse....1-51
Finishing Steps....1-53

Install..........1-52
Preparatory Steps..........1-50
Remove..........1-51
Crankshaft Seal, Front..........AS-31
Install..........AS-31
Crankshaft Seal, Front..........1-53
Clean and Inspect for Reuse..........1-55
Finishing Steps..........1-56
General Information..........1-53
Install..........1-55
Preparatory Steps..........1-53
Remove..........1-54
Crankshaft Seal, Rear..........AS-18
Install..........AS-18
Crankshaft Seal, Rear..........1-56
Clean and Inspect for Reuse..........1-58
Finishing Steps..........1-59
General Information..........1-56
Install..........1-58
Preparatory Steps..........1-56
Remove..........1-57
Crankshaft Speed Indicator Ring..........1-109
General Information..........1-109
Measure..........1-109
Crosshead..........DS-32
Remove..........DS-32
Crosshead..........AS-25
Install..........AS-25
Crosshead..........2-3
Clean and Inspect for Reuse..........2-3
Finishing Steps..........2-4
Install..........2-4
Preparatory Steps..........2-3
Remove..........2-3
Crystallization Buildup in the SCR Aftertreatment System..........TS-23
Cummins® Product Technology..........E-14
General Information..........E-14
Cummins® Service Engine Model Identification..........E-11
General Information..........E-11
Cylinder Block..........1-60
Clean and Inspect for Reuse..........1-60
Finishing Steps..........1-67
Preparatory Steps..........1-60
Cylinder Block - Overview..........F-3
General Information..........F-3
Cylinder Block and Liner Seats..........1-67
Finishing Steps..........1-69
Leak Test..........1-68
Preparatory Steps..........1-67
Cylinder Head..........DS-35
Remove..........DS-35
Cylinder Head..........AS-20
Install..........AS-20
Cylinder Head..........2-5
Assemble..........2-17
Clean and Inspect for Reuse..........2-14
Disassemble..........2-10
Finishing Steps..........2-23
Install..........2-20
Leak Test..........2-7
Preparatory Steps..........2-5
Remove..........2-6
Vacuum Test..........2-8
Cylinder Head - Overview..........F-5
General Information..........F-5
Cylinder Head Gasket..........DS-36
Remove..........DS-36
Cylinder Head Gasket..........AS-20
Install..........AS-20
Cylinder Head Gasket..........2-24
Clean and Inspect for Reuse..........2-24
Finishing Steps..........2-25
General Information..........2-24
Install..........2-25
Preparatory Steps..........2-24
Remove..........2-24
Cylinder Liner..........AS-1
Install..........AS-1
Cylinder Liner..........1-70
Clean and Inspect for Reuse..........1-74
Finishing Steps..........1-81
Initial Check..........1-71
Install..........1-78
Measure..........1-77
Preparatory Steps..........1-70
Remove..........1-71
Diesel Exhaust Fluid Contaminated..........TS-109
Diesel Exhaust Fluid Usage - Abnormal..........TS-102
Drive Belt, Cooling Fan..........DS-15
Remove..........DS-15
Drive Belt, Cooling Fan..........AS-54
Install..........AS-54
ECM - No Communication Troubleshooting Tree..........TT-1
Electrical Equipment - Overview..........F-54
General Information..........F-54
Engine Barring..........0-15
Finishing Steps..........0-16
General Information..........0-15
Preparatory Steps..........0-15
Rotate..........0-16
Engine Base Timing..........1-109
Finishing Steps..........1-111
Test..........1-109
Engine Control Module..........DS-14
Remove..........DS-14
Engine Control Module..........AS-55
Install..........AS-55
Engine Control Module Mounting Bracket..........DS-14
Remove..........DS-14
Engine Control Module Mounting Bracket..........AS-54
Install..........AS-54
Engine Coolant Temperature Sensor..........DS-11
Remove..........DS-11
Engine Cranks Slowly - (Electric Starter)..........TS-69
Engine Dataplate..........1-108
Clean and Inspect for Reuse..........1-108
General Information..........1-108
Install..........1-109
Remove..........1-108
Engine Decelerates Slowly..........TS-39
Engine Diagrams..........E-4
Engine Views..........E-4
Engine Difficult to Start or Will Not Start (No Exhaust Smoke)..........TS-40
Engine Fan Does Not Operate, Operates Erratically, or Operates Continuously..........TS-43
Engine Identification..........E-1
Air Compressor..........E-3
Cummins® Engine Nomenclature..........E-2
Engine Control Module Dataplate..........E-2
Engine Dataplate..........E-1
Fuel Injection Pump Dataplate..........E-2
Turbocharger Dataplate..........E-3
Engine Installation..........0-5
Finishing Steps..........0-6
Install..........0-5
Engine Lifting Brackets..........DS-23
Remove..........DS-23
Engine Lifting Brackets..........AS-42
Install..........AS-42
Engine Noise Excessive..........TS-44
Engine Noise Excessive - Combustion Knocks..........TS-47
Engine Noise Excessive - Connecting Rod..........TS-48
Engine Noise Excessive - Drive Belt..........TS-110
Engine Noise Excessive - Main Bearing..........TS-49
Engine Noise Excessive - Piston..........TS-51
Engine Noise Excessive - Turbocharger..........TS-52
Engine Oil Pressure Sensor/Switch..........DS-12
Remove..........DS-12
Engine Oil Temperature Sensor..........DS-12
Remove..........DS-12
Engine Painting..........0-13
Preparatory Steps..........0-13
Engine Power Output Low..........TS-53
Engine Removal..........DS-1
Remove..........DS-1
Engine Removal..........0-2
Preparatory Steps..........0-2
Remove..........0-3
Engine Runs Rough or Misfires..........TS-55
Engine Shuts Off Unexpectedly or Dies During Deceleration..........TS-57
Engine Speed Surges in PTO or Cruise Control..........TS-62
Engine Speed Surges Under Load or in Operating Range..........TS-59
Engine Starts But Will Not Keep Running..........TS-65
Engine Steam Cleaning..........0-15
Clean..........0-15
Engine Storage - Long Term..........0-8
General Information..........0-8
Engine Storage - Short Term..........0-11
General Information..........0-11
Engine Testing - Overview..........F-55
General Information..........F-55
Engine Will Not Crank - (Electric Starter)..........TS-67
Engine Will Not Shut Off..........TS-71
Engine Wiring Harness..........DS-7

Remove....DS-7
Exhaust Gas Pressure Sensor DS-13
Remove....DS-13
Exhaust Gas Pressure Sensor AS-57
Install....AS-57
Exhaust Gas Pressure Sensor Tube DS-13
Remove....DS-13
Exhaust Gas Pressure Sensor Tube AS-56
Install....AS-56
Exhaust Manifold, Dry DS-23
Remove....DS-23
Exhaust Manifold, Dry AS-42
Install....AS-42
Exhaust Pressure Regulator DS-22
Remove....DS-22
Exhaust Pressure Regulator AS-44
Install....AS-44
Exhaust System - Overview F-33
General Information....F-33
Fan Hub, Belt Driven DS-18
Remove....DS-18
Fan Hub, Belt Driven AS-51
Install....AS-51
Fan Pulley DS-18
Remove....DS-18
Fan Pulley AS-51
Install....AS-51
Fault Code Warning Lamps Do Not Illuminate....TS-73
Fault Code Warning Lamps Stay On (No Apparent Reason)....TS-72
Flow Diagram, Air Intake System F-31
Flow Diagram....F-31
Flow Diagram, Compressed Air System F-50
Flow Diagram....F-50
Flow Diagram, Cooling System F-25
Flow Diagram....F-25
Flow Diagram, Exhaust System F-41
General Information....F-41
Flow Diagram, Fuel System F-10
Flow Diagram....F-10
Flow Diagram, Lubricating Oil System F-18
Flow Diagram....F-18
Flywheel DS-37
Remove....DS-37
Flywheel AS-19
Install....AS-19
Flywheel Housing DS-37
Remove....DS-37
Flywheel Housing AS-17
Install....AS-17
Fuel Consumption 5-3
Measure....5-3
Fuel Consumption Excessive....TS-74
Fuel Drain Lines DS-27
Remove....DS-27
Fuel Drain Lines AS-37
Install....AS-37
Fuel Filter Head DS-28
Remove....DS-28
Fuel Filter Head AS-36
Install....AS-36
Fuel in Coolant....TS-77
Fuel in the Lubricating Oil....TS-78
Fuel Pump DS-28
Remove....DS-28
Fuel Pump AS-35
Install....AS-35
Fuel Pump 5-7
Assemble....5-10
Disassemble....5-8
Finishing Steps....5-12
Inspect for Reuse....5-9
Install....5-11
Preparatory Steps....5-7
Remove....5-8
Fuel Pump Gear Pump 5-13
Clean and Inspect for Reuse....5-14
Finishing Steps....5-15
Install....5-15
Preparatory Steps....5-13
Remove....5-14
Fuel Pump Head Outlet Fitting 5-21
Clean and Inspect for Reuse....5-23
Finishing Steps....5-24
Install....5-23
Preparatory Steps....5-21
Remove....5-22
Fuel Rail DS-28
Remove....DS-28
Fuel Rail AS-34
Install....AS-34
Fuel Rail Supply Line (High Pressure) DS-3
Remove....DS-3
Fuel Rail Supply Line (High Pressure) AS-36
Install....AS-36
Fuel Supply Lines DS-27
Remove....DS-27
Fuel Supply Lines AS-37
Install....AS-37
Fuel System - Overview F-8
General Information....F-8
Fuel System Diagnostics 5-25
Fuel Filter Restriction....5-29
Fuel Pressure Relief Valve Return Flow Test....5-33
Fuel Pump Gear Pump Pressure Test....5-28
General Information....5-25
High-Pressure Injector Return Flow Isolation Test....5-31
High-Pressure Injector Return Flow Test....5-29
High-Pressure System Leak Down Test....5-26
Low-Pressure System Check....5-26
Fuel System Priming 5-24
Prime....5-24
Gear Cover, Front 1-82
General Information....1-82
Gear Train Backlash, Rear 1-129
Measure....1-129
General Cleaning Instructions i-22
Abrasive Pads and Abrasive Paper....i-22
Definition of Clean....i-22
Fuel System....i-25
Gasket Surfaces....i-23
Plastic Bead Cleaning....i-24
Solvent and Acid Cleaning....i-23
Steam Cleaning....i-24
General Repair Instructions i-20
General Information....i-20
Welding on a Vehicle with an Electronic Controlled Fuel System....i-21
General Safety Instructions i-8
Aftertreatment....i-13
Best Practices....i-8
Common Hazards....i-16
Common Substances....i-14
Electrical Components....i-16
Fuels....i-10
Hazardous Substances....i-15
Important Safety Notice....i-8
Job Safety Assessment....i-17
Personal Protective Equipment (PPE)....i-9
Power Generation Applications....i-13
Work Environment....i-8
How to Use the Manual i-2
General Information....i-2
Idler Gear, Camshaft Rear DS-38
Remove....DS-38
Idler Gear, Camshaft Rear AS-16
Install....AS-16
Idler Gear, Camshaft Rear 1-118
Clean and Inspect for Reuse....1-120
Finishing Steps....1-123
General Information....1-118
Install....1-122
Preparatory Steps....1-119
Remove....1-120
Idler Gear, Crankshaft Rear AS-16
Install....AS-16
Idler Gear, Crankshaft Rear 1-123
Clean and Inspect for Reuse....1-125
Finishing Steps....1-128
General Information....1-123
Install....1-127
Preparatory Steps....1-124
Remove....1-125
Illustrations i-7
General Information....i-7
Injector DS-31
Remove....DS-31
Injector AS-27
Install....AS-27
Injector Supply Lines (High Pressure) DS-28
Remove....DS-28
Injector Supply Lines (High Pressure) AS-35
Install....AS-35
Injectors and Fuel Lines - Overview F-11
General Information....F-11
Intake Manifold Air Temperature Above Specification....TS-79

Intake Manifold Pressure (Boost) is Below Normal....TS-81
Intake Manifold Pressure/Temperature Sensor DS-11
Remove....DS-11
Internal Actuator Wiring Harness DS-30
Remove....DS-30
Internal Actuator Wiring Harness AS-29
Install....AS-29
Low Idle Adjust Switch Does Not Work....TS-83
Lubricating Oil Consumption Excessive....TS-85
Lubricating Oil Contaminated....TS-87
Lubricating Oil Cooler Housing DS-24
Remove....DS-24
Lubricating Oil Cooler Housing AS-41
Install....AS-41
Lubricating Oil Dipstick Tube DS-5
Remove....DS-5
Lubricating Oil Fill Tube DS-5
Remove....DS-5
Lubricating Oil Filter (Spin-On) DS-4
Remove....DS-4
Lubricating Oil Filter Plugged....TS-88
Lubricating Oil in the Fuel....TS-84
Lubricating Oil Pan DS-29
Remove....DS-29
Lubricating Oil Pan AS-32
Install....AS-32
Lubricating Oil Pressure High....TS-90
Lubricating Oil Pressure Low....TS-91
Lubricating Oil Pump DS-30
Remove....DS-30
Lubricating Oil Pump AS-30
Install....AS-30
Lubricating Oil Sludge in the Crankcase Excessive....TS-93
Lubricating Oil System - Overview F-12
General Information....F-12
Lubricating Oil Temperature Above Specification....TS-95
Lubricating or Transmission Oil in the Coolant....TS-96
Overhead Camshaft End Clearance, Valve 2-32
Finishing Steps....2-33
Measure....2-33
Preparatory Steps....2-32
Overhead Camshaft Gear, Valve DS-33
Remove....DS-33
Overhead Camshaft Gear, Valve AS-23
Install....AS-23
Overhead Camshaft Gear, Valve 2-33
Clean and Inspect for Reuse....2-35
Finishing Steps....2-36
Install....2-35
Preparatory Steps....2-33
Remove....2-34
Overhead Camshaft Timing Speed Ring DS-32
Remove....DS-32
Overhead Camshaft Timing Speed Ring AS-24
Install....AS-24
Overhead Camshaft Timing Speed Ring 2-36
Clean and Inspect for Reuse....2-37
Finishing Steps....2-39
Install....2-38
Preparatory Steps....2-36
Remove....2-36
Overhead Camshaft, Valve DS-34
Remove....DS-34
Overhead Camshaft, Valve AS-22
Install....AS-22
Overhead Camshaft, Valve 2-25
Assemble....2-29
Clean and Inspect for Reuse....2-28
Disassemble....2-27
Finishing Steps....2-32
Initial Check....2-25
Install....2-30
Measure....2-29
Preparatory Steps....2-26
Remove....2-26
Overhead Set AS-26
Adjust....AS-26
Overhead Set 3-3
Adjust....3-4
Finishing Steps....3-6
General Information....3-3
Preparatory Steps....3-4
Piston 1-82
Clean and Inspect for Reuse....1-84
Finishing Steps....1-87
General Information....1-82
Preparatory Steps....1-83
Piston and Connecting Rod Assembly AS-11
Install....AS-11
Piston and Connecting Rod Assembly 1-95
Assemble....1-101
Clean and Inspect for Reuse....1-101
Disassemble....1-100
Finishing Steps....1-107
General Information....1-95
Install....1-103
Preparatory Steps....1-97
Remove....1-98
Piston Cooling Nozzle AS-14
Install....AS-14
Piston Cooling Nozzle 1-87
Clean and Inspect for Reuse....1-88
Finishing Steps....1-89
Install....1-88
Preparatory Steps....1-87
Remove....1-88
Piston Rings AS-7
Install....AS-7
Piston Rings 1-89
Clean and Inspect for Reuse....1-90
Install....1-91
Measure....1-91
Preparatory Steps....1-89
Remove....1-90
Pressure Fuel Filter DS-4
Remove....DS-4
PTO or Cruise Control Does Not Operate....TS-97
Rear PTO Idler Gear AS-15
Install....AS-15
Rear PTO Idler Gear 1-113
Clean and Inspect for Reuse....1-115
Finishing Steps....1-117
General Information....1-113
Install....1-116
Preparatory Steps....1-114
Remove....1-115
Refrigerant Compressor DS-17
Remove....DS-17
Refrigerant Compressor AS-52
Install....AS-52
Rocker Lever Assembly DS-32
Remove....DS-32
Rocker Lever Assembly AS-25
Install....AS-25
Rocker Lever Assembly 3-6
Assemble....3-9
Clean and Inspect for Reuse....3-7
Disassemble....3-7
Finishing Steps....3-11
Install....3-10
Preparatory Steps....3-6
Remove....3-6
Rocker Lever Cover DS-30
Remove....DS-30
Rocker Lever Cover AS-30
Install....AS-30
Rocker Lever Cover 3-12
Clean and Inspect for Reuse....3-13
Finishing Steps....3-15
Install....3-14
Preparatory Steps....3-12
Remove....3-12
Rocker Levers - Overview F-7
General Information....F-7
Service Tools 0-1
Engine Removal and Installation....0-1
Service Tools 1-1
Cylinder Block....1-1
Service Tools 2-1
Cylinder Head....2-1
Service Tools 3-1
Rocker Levers....3-1
Service Tools 5-1
Fuel System....5-1
Service Tools and Hardware - Overview F-56
General Information....F-56
Initial Check....F-56
INSITE™ Electronic Service Tool Description....F-56
Resistance Check....F-63
Setup....F-59
Smoke, Black - Excessive....TS-98
Smoke, White - Excessive....TS-100
Stall Speed Test 5-15
Stall Speed Check....5-15

Stall Speed Check List....5-19
Time Speed Check....5-18
Starting Motor DS-24
Remove....DS-24
Starting Motor AS-41
Install....AS-41
Stationary Regeneration - Will Not Activate....TS-103
Stationary Regeneration - Will Not Complete....TS-107
Symbols i-3
General Information....i-3
Troubleshooting Overview TS-3
Connecting Rod Bearing Noise....TS-3
Coolant Loss Pre-Troubleshooting Guide....TS-9
Driveability - General Information....TS-3
Driveability/Low Power - Customer Complaint Form....TS-5
Driveability/Low Power/Excessive Fuel Consumption - Checklist....TS-6
Engine Noise Diagnostic Procedures - General Information....TS-3
Fuel Consumption - Customer Complaint Form....TS-7
Fuel Consumption - General Information....TS-7
Main Bearing Noise....TS-3
Oil Consumption....TS-9
Piston Noise....TS-3
Troubleshooting Procedures and Techniques TS-1
General Information....TS-1
Troubleshooting Symptoms Overview TS-2
General Information....TS-2
Turbocharger DS-23
Remove....DS-23
Turbocharger AS-43
Install....AS-43
Turbocharger Compressor Intake Pressure/Temperature Sensor DS-13
Remove....DS-13
Turbocharger Compressor Intake Pressure/Temperature Sensor AS-56
Install....AS-56
Turbocharger Coolant Hoses DS-20
Remove....DS-20
Turbocharger Coolant Hoses AS-45
Install....AS-45
Turbocharger Leaks Engine Oil or Fuel....TS-101
Turbocharger Oil Drain Line DS-20
Remove....DS-20
Turbocharger Oil Drain Line AS-48
Install....AS-48
Turbocharger Oil Supply Line DS-19
Remove....DS-19
Turbocharger Oil Supply Line AS-49
Install....AS-49
Vibration Damper, Viscous DS-29
Remove....DS-29
Vibration Damper, Viscous AS-33
Install....AS-33
Vibration Damper, Viscous 1-93
Finishing Steps....1-95
Inspect for Reuse....1-93
Install....1-94
Preparatory Steps....1-93
Remove....1-93
Vibration Excessive TT-20
Water Pump Cartridge DS-19
Remove....DS-19
Water Pump Cartridge AS-49
Install....AS-49