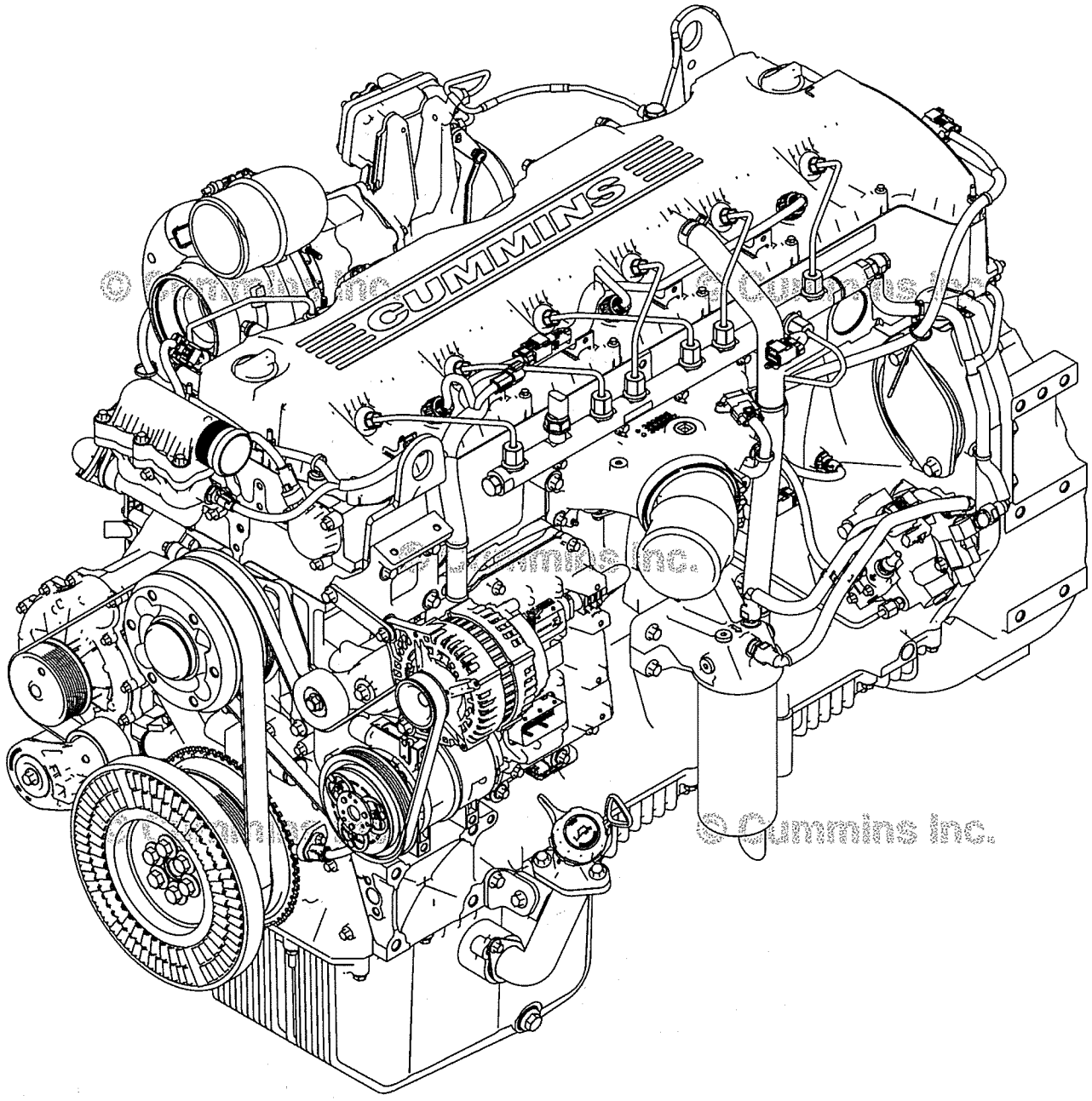
Operation and Maintenance Manual
QSG12 CM2350 G110



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Bulletin 4367322
Printed 06-FEBRUARY-2016

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Foreword

This manual contains information for the correct operation and maintenance of your Cummins® product. It also includes important safety information, product and systems specifications, troubleshooting guidelines, and listings of Cummins® Authorized Repair Locations.

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

Keep this manual with the equipment. If the equipment is traded or sold, give the manual to the new owner.

The information, specifications, and recommended maintenance guidelines in this manual are based on information in effect at the time of printing. Cummins Inc. reserves the right to make changes at any time without obligation. If you find differences between your product and the information in this manual, contact your local 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 were used to produce this product. When replacement parts are needed, we recommend using only genuine Cummins® or ReCon® exchange parts.

NOTE: Warranty information is located in Section W. Make sure you are familiar with the warranty or warranties applicable to your product.

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Important Reference Numbers

Fill in the part name and number in the blank spaces provided below. This will give you a reference whenever service or maintenance is required.

Name	Number	Number
Engine Model		
Engine Serial Number (ESN)		
Control Parts List (CPL)		
Fuel Pump Part Number		
Electronic Control Module (ECM)		
Electronic Control Module Serial Numbers (ECM)		
Filter Part Numbers:		
• Air Cleaner Element		
• Lubricating Oil		
• Fuel		
• Fuel-Water Separator		
• Coolant		
• Crankcase Ventilation		
• Cummins Particulate Filter		
Governor Control Module (GCM) (if applicable)		
Belt Part Numbers:		
•		
•		
•		
Clutch or Marine Gear (if applicable):		
• Model		
• Serial Number		
• Part Number		
• Oil Type		
• Sea Water Pump		
- Model		
- Part Number		

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Section i - Introduction

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To the Owner and Operator

General Information

This guide contains information for the correct operation and maintenance of your Cummins® product. This manual also includes important safety information which can be found in Section i - Introduction.

Thank you for depending on Cummins® products. If you have any questions about this product, please contact your local Cummins® Authorized Repair Location. To locate a Cummins® Authorized Repair Location, refer to Section S - Service Assistance in this manual.

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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.

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How to Use the Manual

General Information

This manual is organized according to intervals at which maintenance on your engine is to be performed. A maintenance schedule, that states the required intervals and maintenance checks, is located in Maintenance Guidelines (Section 2). Locate the interval at which you are performing maintenance; then follow the steps given in that section for all the procedures to be performed.

Keep a record of all the checks and inspections made. A maintenance record form is located in Maintenance Guidelines (Section 2).

Engine troubleshooting procedures for your engine are located in Troubleshooting Symptoms (Section TS).

Specifications for your engine are located in Maintenance Specifications (Section V).

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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.

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



INSPECTION is required.



CLEAN the part or assembly.



PERFORM a mechanical or time **MEASUREMENT**.



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LUBRICATE the part or assembly.



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



TIGHTEN to a specific torque.



PERFORM an electrical **MEASUREMENT**.

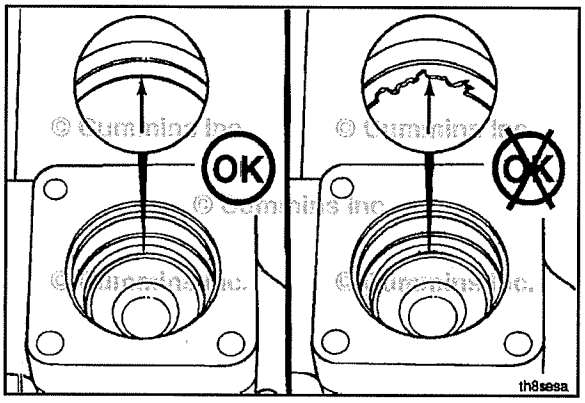
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Refer to another location in this manual or another publication for additional information.



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.

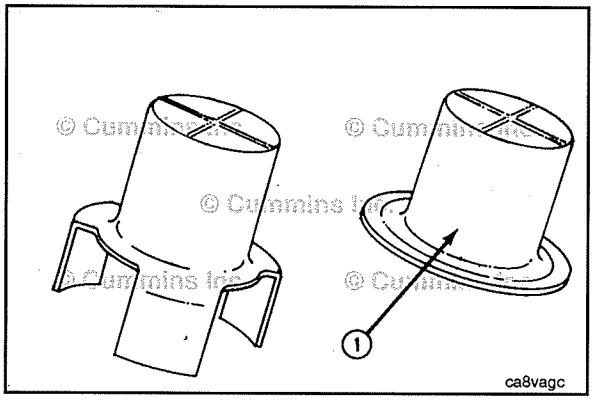




Illustrations

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.

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- 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.

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- 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.

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- 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.

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- 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.

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- 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

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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.

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- 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.

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- 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

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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.

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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

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- 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.

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General Repair Instructions

General Information

This engine or 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
- The engine or system and its components **must** be kept clean during any repair. Contamination of the engine, system or components will cause premature wear.
- All components **must** be kept clean during any repair. Contamination of the components will cause premature wear.

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- 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

Complete rebuild instructions are available in the service manual which can be ordered or purchased from a Cummins Authorized Repair Location. Refer to Section L — Service Literature for ordering instructions.

Welding on a Vehicle with an Electronic Controlled Fuel System

⚠CAUTION⚠

Disconnect both the positive (+) and negative (-) battery cables from the low voltage 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

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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

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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

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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

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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

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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.

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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
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

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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

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Notes

Section E - Engine and System Identification

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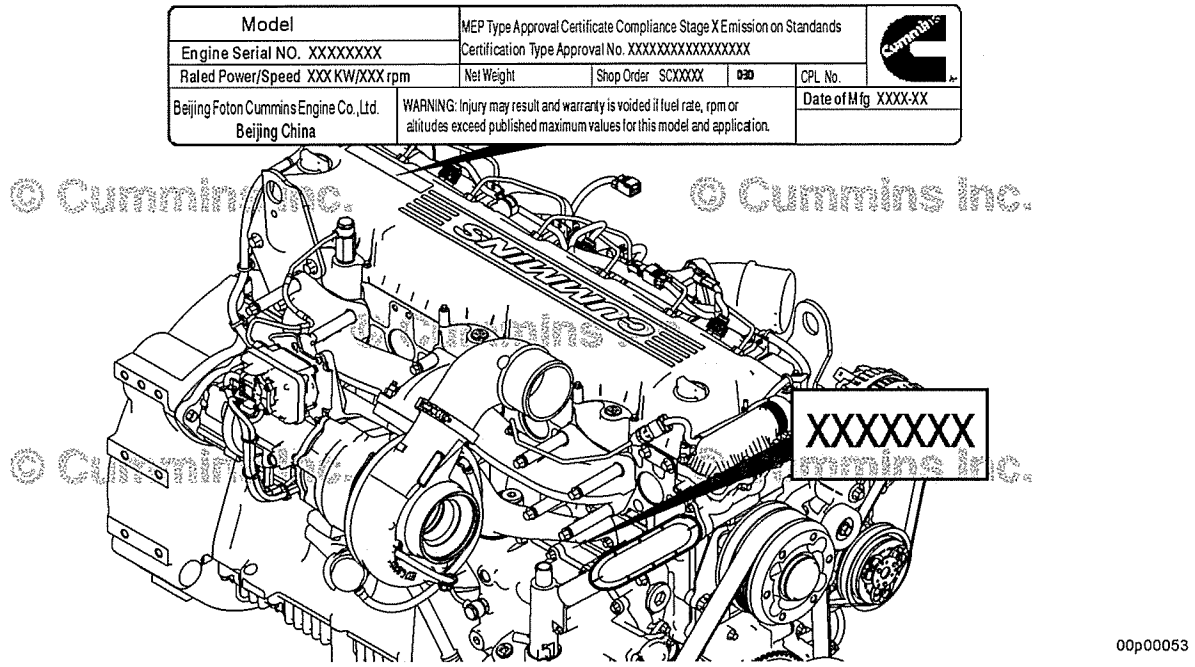
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Engine Identification

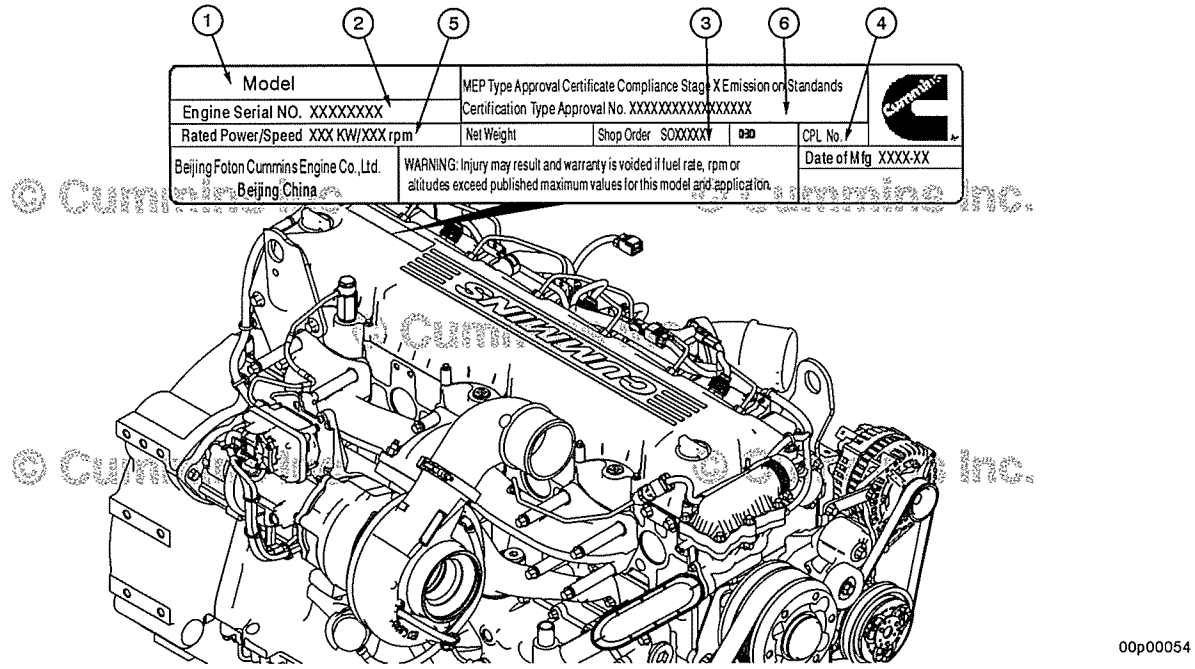
Engine Dataplate



00p00053

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.

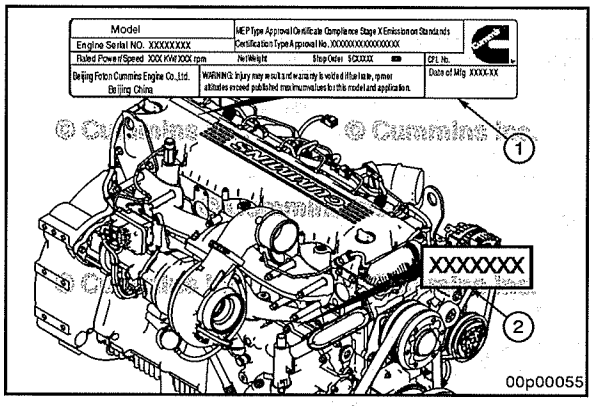


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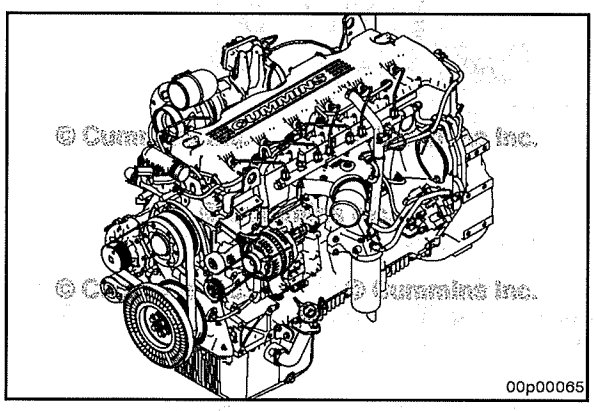
1 Engine model information
2 Engine serial number (ESN)
3 Shop Order (SO)
4 Control parts list (CPL)

5 Horsepower and rpm rating

6 Emissions certification level.



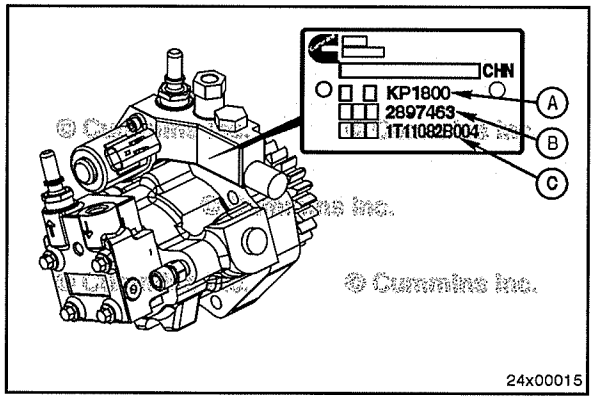
If the engine dataplate (1) is **not** legible, the ESN (2) can be found on the engine block next to the lubricating oil cooler housing. Additional engine information is on the engine control module (ECM) dataplate.



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.



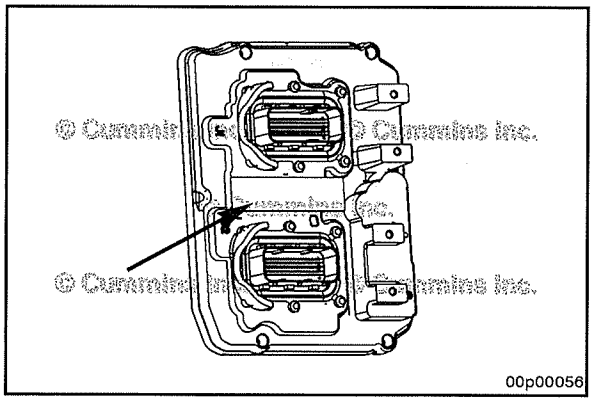
Fuel Injection Pump Dataplate

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

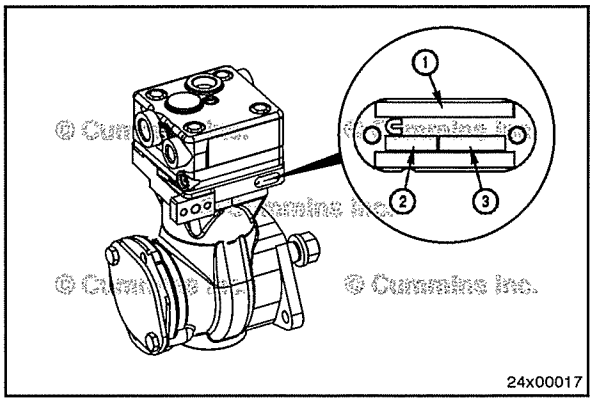
The ECM dataplate is located on the front of the ECM.

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).

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Air Compressor



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

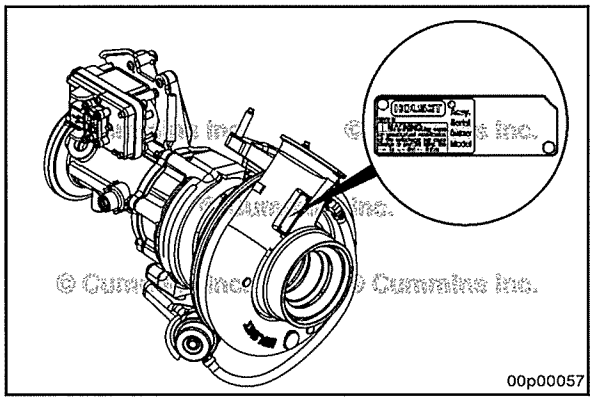
The Cummins® branded air compressor dataplate, identified by the Cummins Inc. logo on the dataplate, is typically located on the rear side of the air compressor. The dataplate contains the following information that assists in service or replacement.

1 Cummins® part number

2 Date code

3 Serial number.

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.

Engine Diagrams

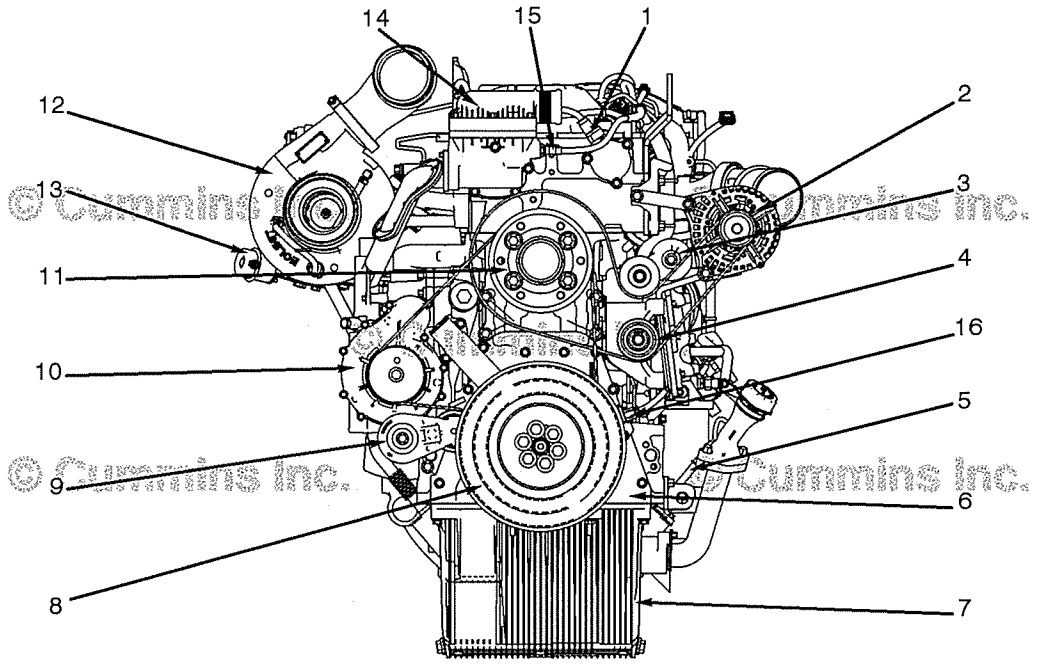
Engine Views

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.

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Engine Diagrams

Engine Views



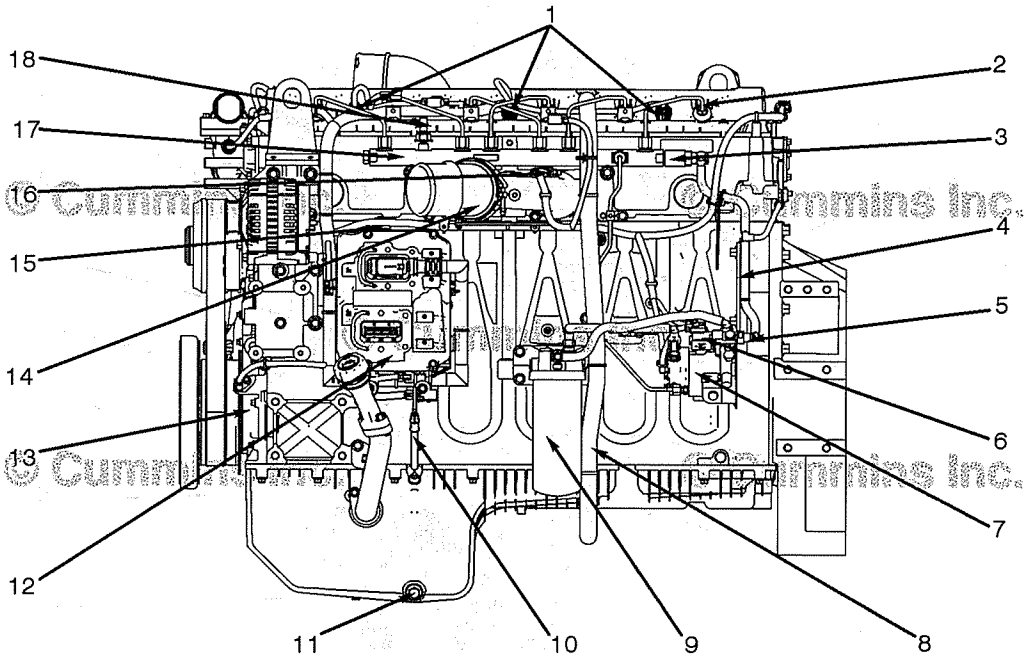
Front

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.

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Engine Diagrams

Engine Views



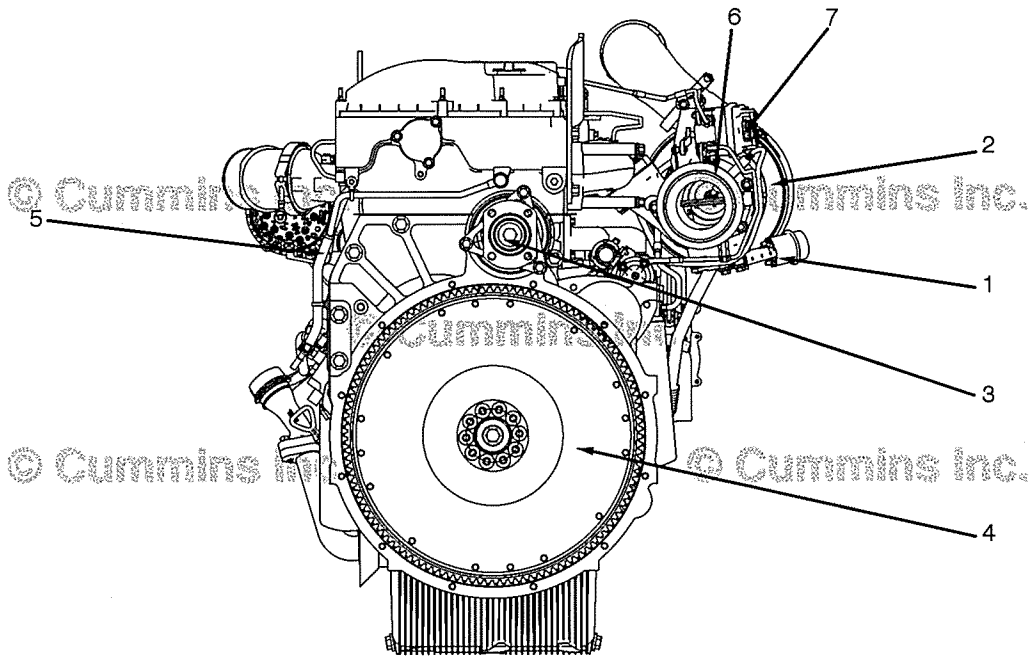
Left

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.

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Engine Diagrams

Engine Views



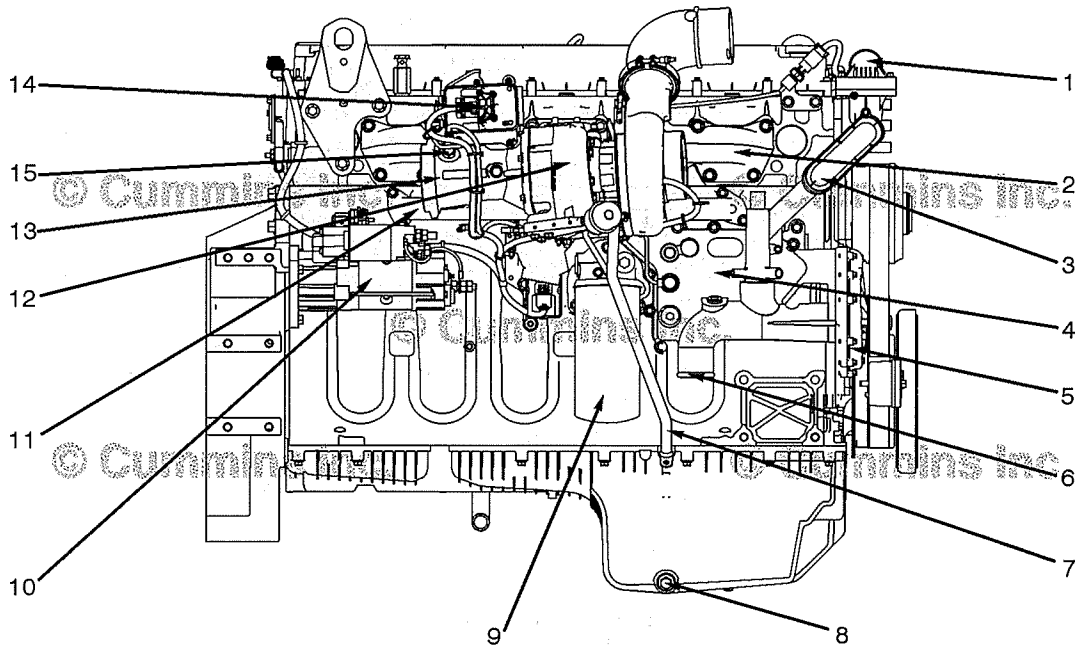
Rear

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

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Engine Diagrams

Engine Views



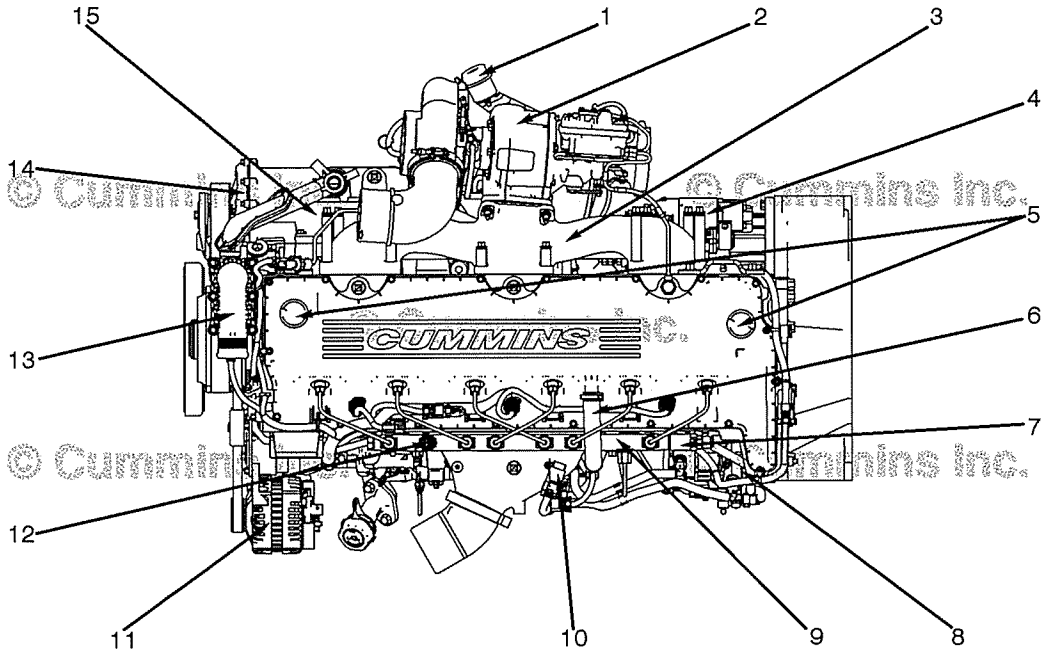
Right

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

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Engine Diagrams

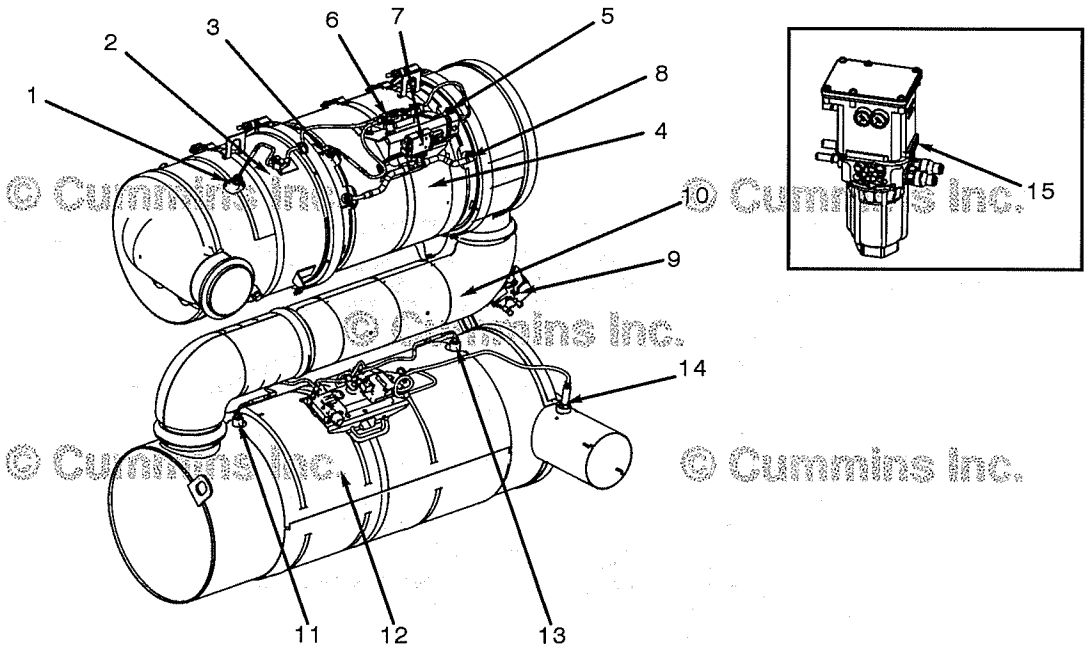
Engine Views



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.

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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.

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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.

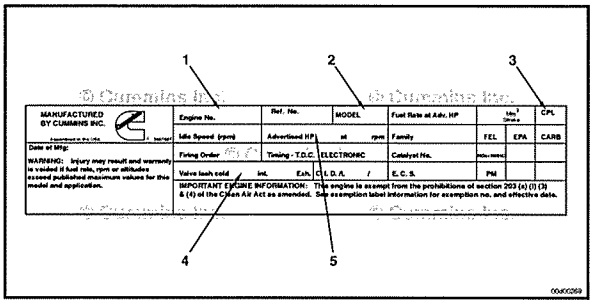
This includes 2013 and later products.



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

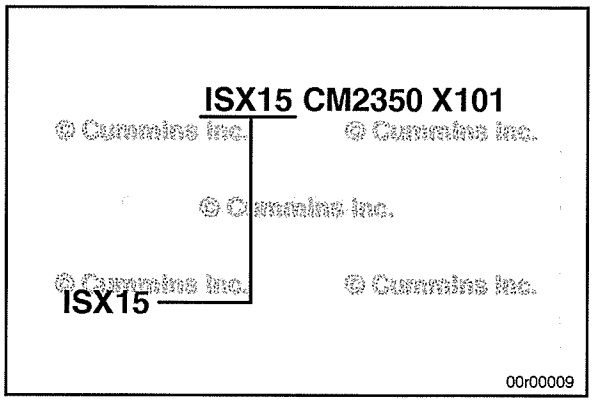
Marketing engine model names (2) can be found on the engine dataplate, Cummins® brochures, and Cummins® promotional literature.



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

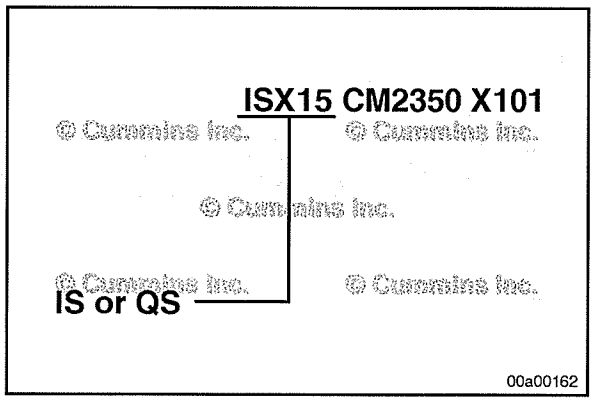
- QuickServe™ Online
- INSITE™ electronic service tool
- Owner's Manual
- Operation and Maintenance Manual
- Master Repair Manual
- Service Manual
- Wiring Diagram
- Fault Code Troubleshooting Manual
- Standard Repair Times
- Technical Service Bulletins
- Service Bulletins

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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".



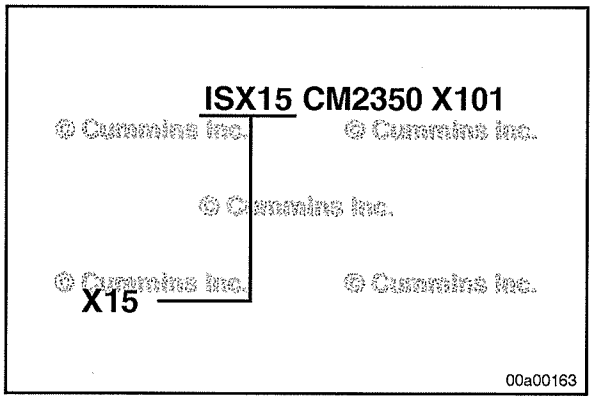
Typically, the first two letters of the marketing model name contain an "IS" or "QS" if the engine is an electronic engine.

"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.

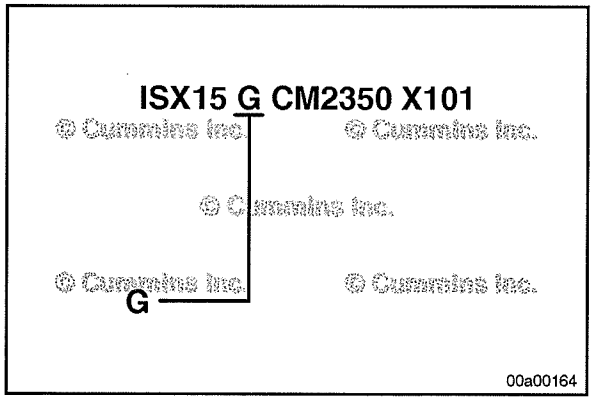


Typically, the third letter is the engine platform/series designation followed by the engine liter displacement. For the example shown in the graphic, the engine is a:

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.

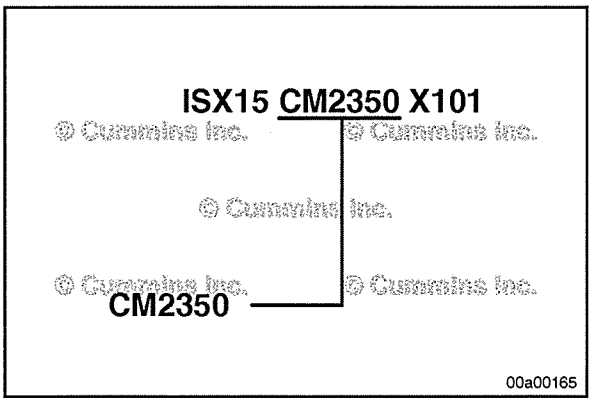
NOTE: Not all engines used in a marine application will have "M" located after the displacement.

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

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

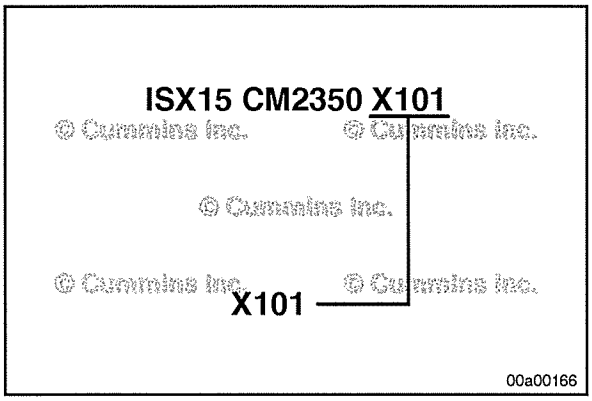
NOTE: Use of a parenthesis ( ) indicates that either engine control module (ECM) has been used on the product. Use of a slash "/" indicates that the product has multiple ECMs.



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

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- 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.

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Operating Instructions - Overview

General Information

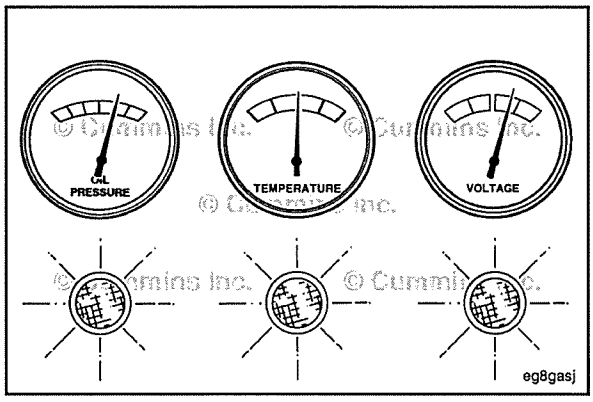
Correct care of your engine will result in longer life, better performance, and more economical operation.

Follow the daily maintenance checks listed in Maintenance Guidelines (Section 2).

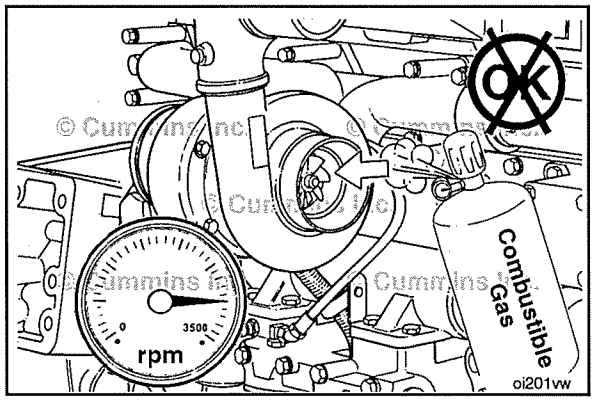
The new Cummins® engine associated with this manual does **not** require a "break-in" procedure. This section of the manual provides all of the necessary information required for proper engine operation.

Check the oil pressure indicators, temperature indicators, warning lights, and other gauges daily to make sure they are operational.

Check the oil pressure, coolant temperatures DEF level, and other engine parameters daily via the OEM front panel to make sure they are operational. Check the panel regularly for any alarm messages. Take appropriate action to rectify the alarm condition or contact your nearest Authorized Cummins® Distributor.

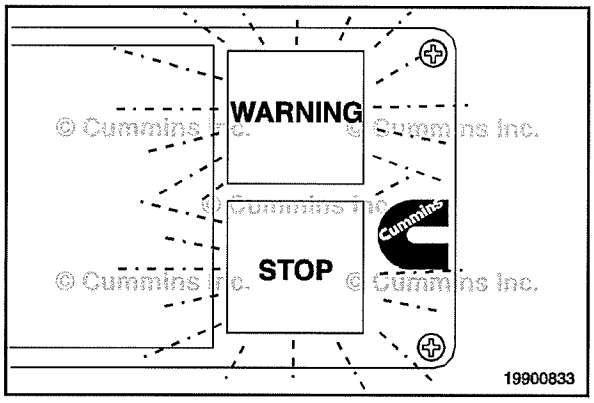


⚠WARNING⚠
Do not operate a diesel engine where there are or can BE COMBUSTIBLE vapors. These vapors can be sucked through the air intake system and cause engine acceleration and over speeding that can result in a fire, an explosion, and extensive property damage. Numerous safety devices are available, such as air intake shutoff devices, to minimize the risk of over speeding where an engine, due to its application, is operating in a combustible environment, such as due to a fuel spill or gas leak. Remember, Cummins Inc. has no way of knowing the use you have for your engine. The equipment owner and operator ARE responsible for safe operation in a hostile environment. Consult A Cummins® Authorized Repair Location for further information.



△CAUTION△
Do not expose the engine to corrosive chemicals. Corrosive chemicals can damage the engine.

Cummins recommends the installation of an air intake shutoff device or a similar safety device to minimize the risk of overspeeding when an engine is operating in a combustible environment, such as due to a fuel spill or gas leak.



Normal Starting Procedure

General Information

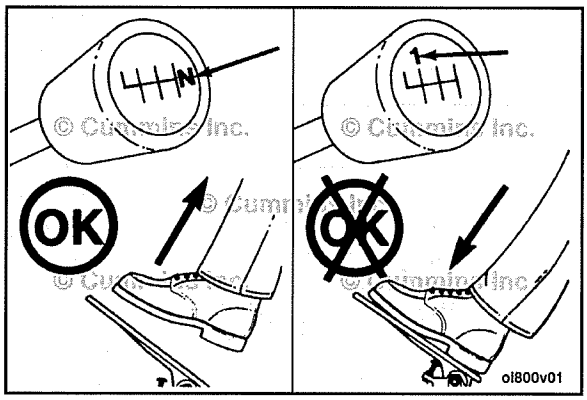
The STOP or STOP ENGINE lamp is red and indicates the need to stop the engine as soon as it can be safely done. The engine **must** then remain shut down until it can be repaired.

The WARNING or CHECK ENGINE lamp is yellow. When it illuminates, the engine is in need of repair at the first available opportunity.

The yellow lamp will flash for 30 seconds at keyswitch ON when one of the following occurs:

- Maintenance required (if Maintenance Monitor is enabled)
- Water-in-fuel is detected
- Low coolant level.

If the warning light flashes for 30 seconds at keyswitch ON and water is drained from the suction side water-separating fuel filter, the pressure side fuel filter **must** be replaced.



△CAUTION△
Do not depress the accelerator pedal or move the accelerator lever from the idle position while cranking the engine. This can result in engine overspeed and severe damage to the engine.

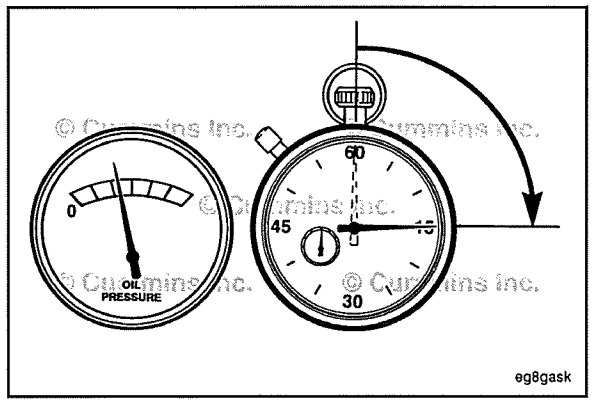
△CAUTION△
To prevent damage to the starting motor, do not engage the starting motor for more than 30 seconds. Wait 2 minutes between each attempt to start (electrical starting motors only).

NOTE: Engines equipped with air starting motors require a minimum of 480 kPa [70 PSI] air pressure.

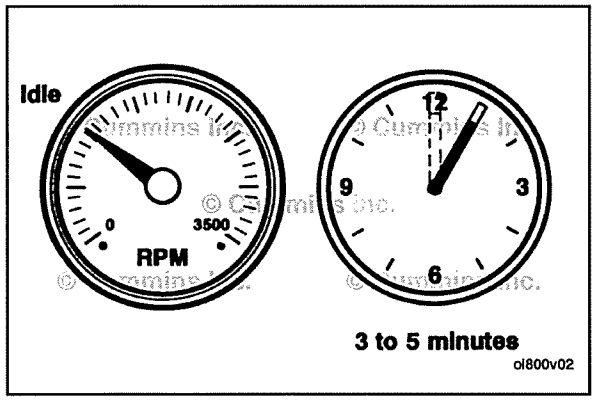
- Disengage the driven unit, or if equipped, put the transmission in neutral.
- With the accelerator pedal or lever in the idle position, turn the keyswitch to the ON position, then turn the keyswitch to the START position.
- If the engine does **not** start after three attempts, check the fuel supply system. Absence of blue or white exhaust smoke during cranking indicates no fuel is being delivered.

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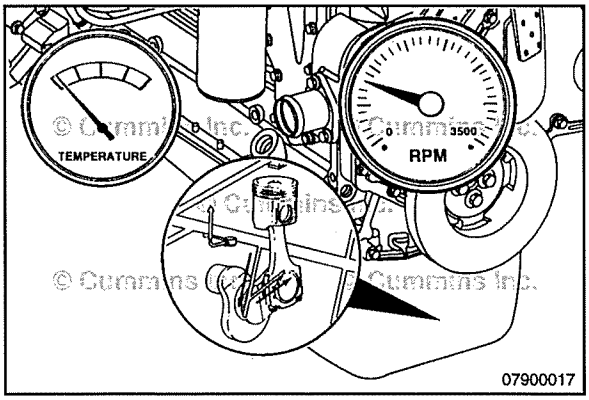
⚠CAUTION⚠
The engine must have adequate oil pressure within 15 seconds after starting. If the warning lamp indicating low oil pressure has not gone out or there is no oil pressure indicated on a gauge within 15 seconds, shut OFF the engine immediately to reduce the possibility of engine damage. The low oil pressure troubleshooting procedure is located in Troubleshooting Symptoms (Section TS).



Idle the engine 3 to 5 minutes before operating with a load.

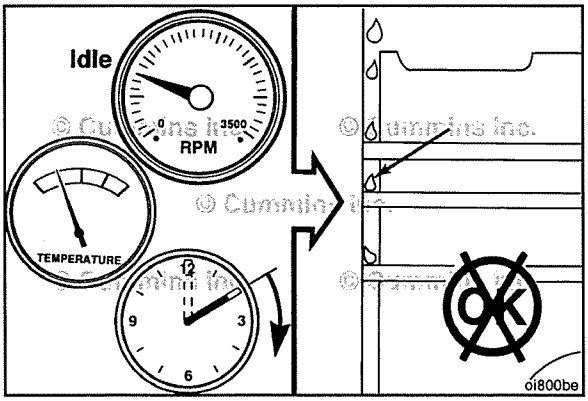


After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

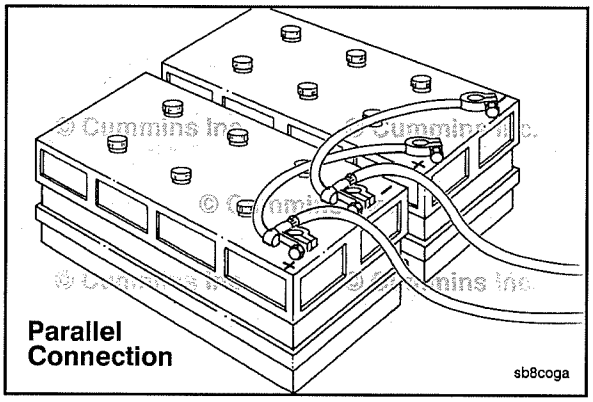


⚠CAUTION⚠
Do not operate engine at low idle for long periods with engine coolant temperature below the minimum specification in Coolant Recommendations and Specifications (Section V). Low coolant temperature can result in:

- Fuel dilution of the lubricating oil
- Carbon buildup in the cylinder
- Cylinder head valve sticking
- Reduced performance.



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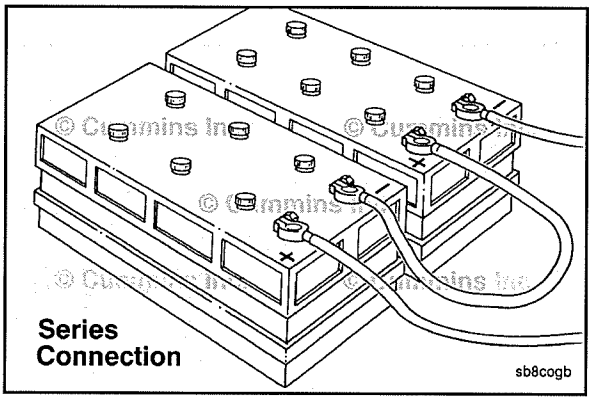
Jump Starting

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

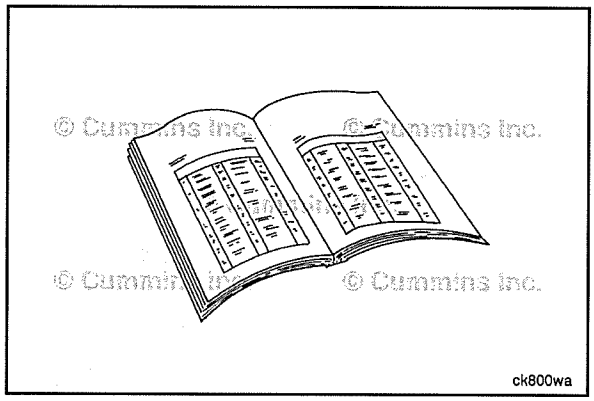
△CAUTION△
When using jumper cables to start the engine, make sure to connect the cables in parallel: Positive (+) to positive (+) and negative (-) to negative (-). When using an external electrical source to start the engine, turn the disconnect switch to the OFF position. Remove the key before attaching the jumper cables.

△CAUTION△
To reduce the possibility of damage to engine parts, do not connect jumper starting or battery charging cable to any fuel system or electronic component.

The accompanying illustration shows a typical parallel battery connection. This arrangement doubles the cranking amperage.



This illustration shows a typical series battery connection. This arrangement, positive (+) to negative (-), doubles the voltage.



Cold Weather Starting

General Information

Follow the normal starting procedure in this section. If equipped with an intake air heater, the WAIT-TO-START lamp will stay on longer.

See the equipment manufacturer service information for any additional cold weather starting procedures.

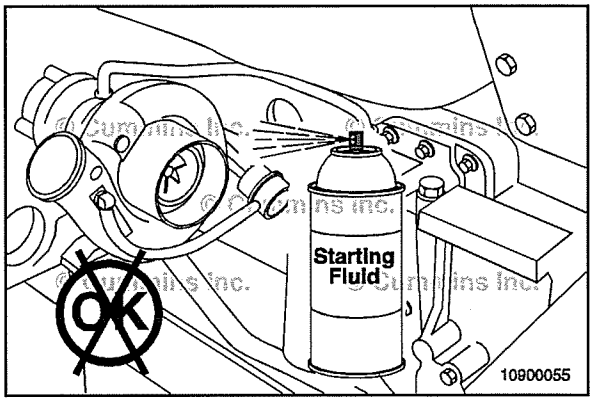
Extreme cold conditions can cause oil pressure delays when using 15W-40 viscosity grade engine lubricating oil. For extreme cold conditions, the use of a different engine lubricating oil viscosity is recommended. Reference Procedure 018-003 in Section V in the appropriate Operation and Maintenance Manual.

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Using Starting Aids

⚠WARNING⚠
Do not use starting fluids with this engine. This engine is equipped with an intake air heater: use of starting fluid can cause an explosion, fire, personal injury, severe damage to the engine, and property damage.

Cold weather starting aids are available for this engine. Contact a Cummins® Authorized Repair Location for more information.



Starting Procedure After Extended Shutdown or Oil Change

General Information

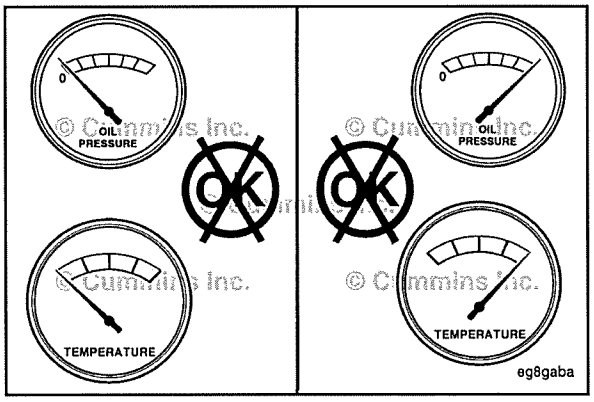
Follow the Normal Starting Procedure in this section. The engine will run at idle **only** until the minimum specified oil pressure is detected by the engine control module (ECM).

Operating the Engine

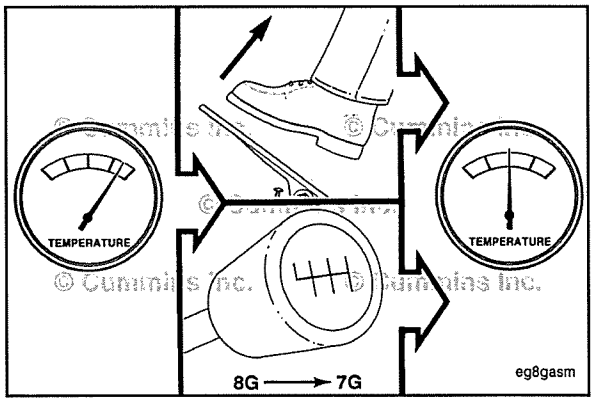
Normal

If equipped, monitor the oil pressure and coolant temperature gauges frequently. Refer to Lubricating Oil System specifications and Cooling System specifications, in Maintenance Specifications (Section V) for recommended operating pressures and temperatures. Shut off the engine if any pressure or temperature does **not** meet the specifications.

Continuous operation with engine coolant temperature above or below the engine coolant temperature specifications listed in Maintenance Specifications (Section V) can damage the engine.



If an overheating condition starts to occur, reduce the power output of the engine by releasing the accelerator pedal or lever or shifting the transmission to a lower gear, or both, until the temperature returns to the normal operating range. If the engine temperature does **not** return to normal, shut off the engine, and refer to Troubleshooting Symptoms (Section TS), or contact a Cummins® Authorized Repair Location.



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⚠CAUTION⚠

Do not idle for extended periods of time. Excessive idle time can cause poor engine performance.

Internal combustion engines **must not** operate at low idle speed for extended periods of time. This operating condition may lead to poor engine performance. The idle shutdown feature, available on most Cummins® engines, can be programmed to shut the engine down after a period of low idle speed operation with no driver activity. A flashing warning lamp will inform the driver of an impending shutdown. If an engine **must** idle for an extended period of time, it should be done at fast idle (1000 rpm or greater). The Power Take-Off (PTO) feature, available on most Cummins® engines, can be programmed to adjust engine speed with the use of OEM switches to pre-programmed set points.

Ambient Temperature

0 to -32°C [32 to -25°F]

Use 50-percent ethylene glycol antifreeze and 50-percent water for the engine coolant mixture.

The Diesel fuel **must** have maximum cloud and pour points 6°C [10°F] lower than the ambient temperature in which the engine operates.

-32 to -54°C [-25 to -65°F]

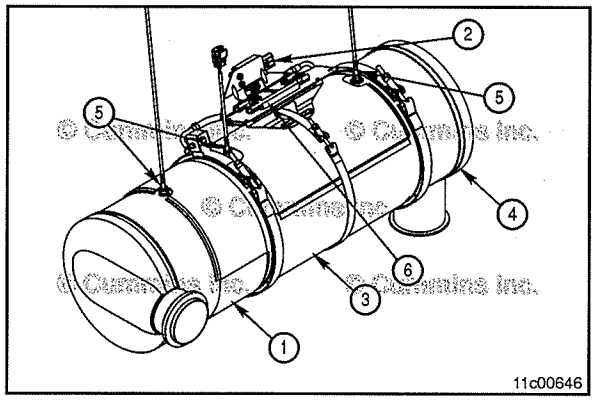
Use 60-percent ethylene glycol antifreeze and 40-percent water for the engine coolant mixture.

The Diesel fuel **must** have maximum cloud and pour points 6°C [10°F] lower than the ambient temperature in which the engine operates.

The cold weather operating aid is required for cold weather situations.

Winterfronts and Shutters

Winterfronts and shutters can be used on a vehicle or equipment to reduce air flow through the radiator core into the engine compartment. This can reduce the time required to warm the engine and help maintain the engine coolant temperature. The engine coolant temperature specifications are in the Maintenance Specification (Section V).



Unique Operating Characteristics of an Engine with Aftertreatment Diesel Particulate Filter

General Information

The aftertreatment 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 diesel particulate filter (DPF) differential/outlet pressure sensor

3 Aftertreatment DPF

4 Aftertreatment outlet

5 Aftertreatment exhaust gas temperature sensors

6 Aftertreatment DPF temperature sensor interface module.

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The components of the aftertreatment system perform the following functions:

The aftertreatment inlet and outlet adapt the equipment exhaust piping to the aftertreatment system.

The aftertreatment DPF differential/outlet pressure sensor measures:

1 The restriction across the aftertreatment DPF.

2 The pressure on the outlet of the aftertreatment DPF.

The aftertreatment DPF captures the soot and ash from the engine exhaust.

The aftertreatment DOC is used to oxidize fuel in the exhaust in order to create heat for the regeneration process.

The aftertreatment exhaust gas temperature sensors are used to measure the exhaust gas temperatures at various points in the aftertreatment system.

Soot is composed of the partially burned particles of fuel that occur during normal engine operation (black smoke).

Ash is composed of the partially burned particles of engine oil that occur during normal engine operation.

Over time, both soot and ash accumulate in the aftertreatment DPF and **must** be removed. Soot is removed by a process called regeneration. Ash is removed by removing the aftertreatment DPF and cleaning it at specified intervals.

Equipment with an aftertreatment system has three additional indicator lamps on the dashboard. Two of the additional lamps, along with the CHECK ENGINE lamp, alert the operator of the status of the aftertreatment DPF. The third additional indicator lamp indicates the position of the Regeneration Permit switch.

Equipment with an aftertreatment system has three additional indicator lamps. Two of the additional lamps, along with the CHECK ENGINE lamp, alert the operator of the status of the aftertreatment DPF. The third additional indicator lamp indicates the position of the Regeneration Permit switch.

NOTE: Use the following procedure for additional information about the engine indicator lamps. Refer to Procedure 101-048 in Section 1.

Ultra low sulfur diesel fuel is required for an engine equipped with an aftertreatment DPF. If ultra low sulfur diesel is **not** used, the aftertreatment DPF or aftertreatment DOC can be damaged.

NOTE: The blending of fuel with new or used engine lubricating oil or other oils is **not** permitted on equipment using an aftertreatment DPF.

NOTE: Use the following procedure for additional information about the fuel recommendations and specifications required for use in the engine being serviced. Refer to Procedure 018-002 in Section V.

To maximize the maintenance intervals of the aftertreatment DPF, Cummins Inc. requires the use of a lubricating engine oil meeting Cummins® Engineering Standard 20081. The use of oil meeting CES 20081 also requires the use of ultra low sulfur diesel fuel to maintain the specified oil drain interval without risk of engine damage.

NOTE: Use the following procedure for additional information about the lubricating oil recommendations and specifications recommended for use in the engine being serviced. Refer to Procedure 018-003 in Section V.

NOTE: Use the following procedure for information on the Maintenance Schedule, which provides the aftertreatment DPF cleaning intervals for the engine being serviced. Refer to Procedure 102-002 in Section 2.

Regeneration

Regeneration is the process of converting the soot collected in the aftertreatment DPF into carbon dioxide.

The regeneration process requires heat to occur, and can be classified into two different types: passive regeneration and active regeneration.

Passive Regeneration

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

Passive regeneration typically occurs when the equipment is operated under heavy loads.

Active 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 accomplished by the engine injecting a small amount of diesel fuel into the exhaust stream, which is then oxidized by the aftertreatment DOC, which creates the heat needed to regenerate the aftertreatment DPF.

Active regeneration will occur more frequently in vehicles with low speed, low load, or stop and go duty cycles.

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Active regeneration **only** occurs if the ECM has detected that the aftertreatment DPF restriction has reached a specified limit, and may **only** occur if the vehicle is moving above a speed threshold. The ECM will activate and de-activate active regeneration as needed.

Active regeneration is largely transparent to the equipment operator. The equipment operator may notice an increase in turbocharger noise during an active regeneration event, and may notice that the high exhaust temperature lamp is illuminated, if the exhaust temperature is greater than the high exhaust system temperature threshold set by the OEM.

During active regeneration, the exhaust temperature can be higher than when the engine is operating at full load. The exhaust temperature during a normal active regeneration event could reach 593°C [1100°F], and possibly 816°C [1500°F] under certain conditions.

NOTE: Use the following procedure for additional information on the engine indicator lamps for the engine being serviced. Refer to Procedure 101-048 in Section 1.

⚠ WARNING ⚠

During regeneration, exhaust gas temperature can reach 800 °C [1500°F], and exhaust system surface temperature can exceed 700 °C [1300°F], which is hot enough to ignite or melt common materials, and to burn people. The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To avoid the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

Manual (Non-Mission) Regeneration

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 operation. When this occurs, the engine will illuminate the aftertreatment DPF lamp to inform the operator that assistance is required, typically in the form of a manual (non-mission) regeneration.

Manual (non-mission) regeneration is a form of active regeneration that is initiated by the equipment operator when **not** in operation.

Manual (non-mission) regeneration requires an engine speed of approximately 900 to 1200 rpm, depending on the application. The length of a manual (non-mission) regeneration will vary, depending on how full the aftertreatment DPF is, but will typically take anywhere from 45 minutes to 1.5 hours to complete.

A manual (non-mission) regeneration can be initiated in one of two ways:

1 An equipment-mounted manual (non-mission) regeneration switch. Use the owners manual for the location and operation of this switch (this switch may also be called a "parked regeneration" switch or "start" switch). The mounted manual (non-mission) regeneration switch will **only** initiate a manual (non-mission) regeneration when the aftertreatment DPF lamp is illuminated.

2 INSITE™ electronic service tool can initiate a manual (non-mission) regeneration by starting the Aftertreatment Diesel Particulate Filter Regeneration Test.

⚠ WARNING ⚠

During regeneration, exhaust gas temperature could reach 816°C [1500°F], and exhaust system surface temperature could exceed 740°C [1300°F], which is hot enough to ignite or melt common materials, and to burn people. Engine speed will increase and could possibly reach between 100 to 1500 rpm. Follow these instructions to avoid the risk of fire, property damage, burns, or other serious personal injury.

To perform a manual (non-mission) regeneration, follow the steps listed:

- Select an appropriate location to park the equipment, preferably on a surface that will **not** burn or melt under high exhaust temperatures (such as clean concrete or gravel, **not** grass or asphalt).
- Make sure there are no items within 0.6 m [2 ft] of the exhaust outlet.
- Items that can burn, melt, or explode **must** be kept at least 1.5 m [5 ft] from the exhaust outlet (such as gasoline, paper, plastics, fabrics, compressed gas containers, and hydraulic lines).
- Make sure there are no gases or vapors nearby that can burn, explode, or contribute to a fire (such as liquid propane (LP) gas, gasoline vapors, oxygen, and nitrous oxide).
- Park the vehicle securely. Place the transmission in Park, if provided, otherwise in Neutral. Set wheel chocks at the front and the rear of at least one tire.
- Set up a safe exhaust area. If bystanders might enter the area, set up barriers to keep people at least 1.5 m [5 ft] from the exhaust outlet during the manual (non-mission) regeneration. When indoors, attach an exhaust discharge pipe rated for at least 816°C [1500°F].

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- Keep a fire extinguisher nearby.
- Check the exhaust system surfaces. Confirm that nothing is on or near the exhaust system surfaces (such as tools, rags, grease, or debris).
- The clutch pedal is released.
- The brake pedal is released.
- The transmission is in neutral or park.
- PTO or Remote PTO is OFF.
- The vehicle speed is 0 kph [0 mph].
- The throttle pedal is released.
- Initiate the manual (non-mission) regeneration by toggling the equipment-mounted manual (non-mission) regeneration switch or by using INSITE™ electronic service tool.
- Once the manual (non-mission) regeneration is initiated, the engine speed may increase, the turbocharger noise will increase, the High Exhaust System Temperature lamp will illuminat, and the aftertreatment DPF lamp will flash.
- When the ECM detects that the aftertreatment DPF has been regenerated, the engine will automatically return to normal idle speed, if increased.
- Monitor the equipment and surrounding area during the manual (non-mission) regeneration. If any unsafe condition occurs, shut the engine OFF immediately.

To stop a manual (non-mission) regeneration before it has completed, depress the clutch, brake, or throttle pedal. Set the regeneration permit switch to the inhibit position, or turn off the engine.

After the manual (non-mission) regeneration is complete, exhaust gas and surface temperatures will remain elevated for 3 to 5 minutes.

NOTE: Applications that use PTO as the **only** method of throttle control can activate a manual (non-mission) regeneration in PTO mode.

NOTE: If a manual (non-mission) regeneration is attempted, and the High Exhaust System Temperature lamp does **not** illuminate, contact a Cummins® Authorized Repair Location for assistance.

NOTE: If the low idle engine speed is 900 rpm or greater, the engine speed will **not** increase when a manual (non-mission) regeneration is initiated. 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. See equipment manufacturer service information.

NOTE: If the Idle Ramp Down feature is in use and a manual regeneration is initiated, the engine speed will increase to low idle, then proceed to the regeneration speed. Depending on the idle ramp down settings, there can be a delay between the time the engine reaches low idle and when the engine speed begins to increase toward the regeneration speed.

Aftertreatment Switches

The equipment manufacturer may choose to equip the equipment with up to two switches that interact with the aftertreatment system:

- A manual (non-mission) regeneration switch (can also be called a START switch or PARKED REGENERATION switch).
- An active regeneration permit switch (can also be called an INHIBIT switch, DISABLE switch, or STOP switch)

Both of these switches are optional. Please see the equipment owners manual for the location and presence of these switches.

The manual (non-mission) regeneration switch is used to initiate a manual (non-mission) regeneration. See the Manual (Non-Mission) Regeneration section of this procedure for further instructions.

The active regeneration permit switch is used to disable active regeneration of the aftertreatment.

The permit switch **must only** be used for special circumstances where it is desirable to **not** allow an active regeneration event. Prolonged engine operation with this switch engaged may result in illumination of the aftertreatment diesel particulate lamp, as the aftertreatment DPF will continue to accumulate soot as the engine operates.

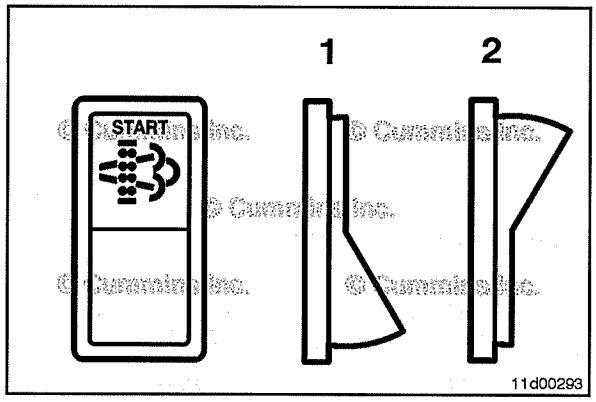
The aftertreatment switches are typically used in two configurations:

- A two-position switch that is used to activate manual (non-mission) regeneration.

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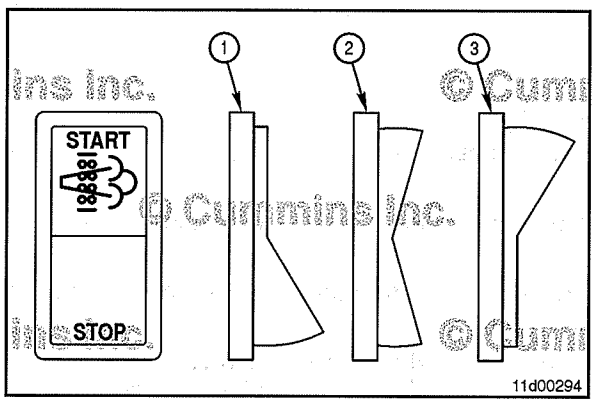
- A three-position switch that is used to activate manual (non-mission) regeneration and also disable active regeneration.

The examples below are generic and show two typical switch configurations. Use the vehicle owner's manual for the location and presence of these switches.



A two-position switch (ON and OFF positions) will, when in the ON position (1), activate a manual (non-mission) regeneration.

The switch should be left in the OFF position (2) when the switch is **not** being used.

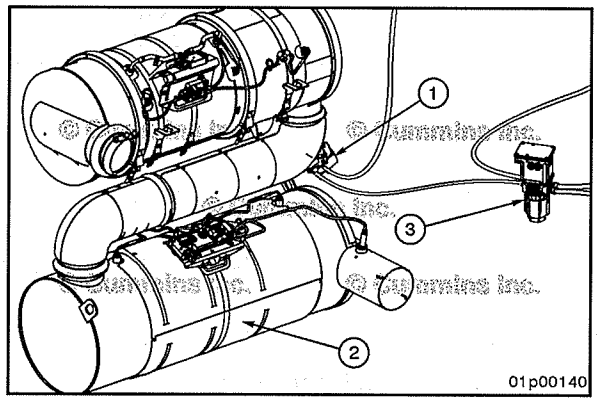


A three-position switch (ON, NEUTRAL, and OFF positions) will typically have both START and PERMIT functions.

In the ON position (1), the START switch is depressed, which will activate a manual (non-mission) regeneration.

In NEUTRAL position (2), neither the START switch or PERMIT switch is depressed as the switch is in the NEUTRAL position. This position is recommended for normal engine operation.

In OFF position (3), the PERMIT switch is depressed. When the switch is in this position, active regeneration of the aftertreatment system will **not** be allowed.



Unique Operating Characteristics of an Engine with Airless Selective Catalytic Reduction (SCR)

General Information

The selective catalytic reduction (SCR) system is used to decrease the NOx emissions from the vehicle tailpipe. The system is composed of several main components:

1 Aftertreatment diesel exhaust fluid (DEF) dosing valve

2 Aftertreatment SCR catalyst

3 Aftertreatment DEF dosing unit.

NOTE: It is unlawful to tamper with, modify, or remove any component of the SCR system. It is also unlawful to use DEF that does **not** meet the specifications provided, or to operate the vehicle/equipment with no DEF.

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DEF is required for an engine equipped with a selective catalytic reduction system. DEF is a fluid that is sprayed into the exhaust gas prior to the aftertreatment SCR catalyst. The DEF vaporizes and decomposes to form carbon dioxide and ammonia. The ammonia reacts with the NOx emissions over the aftertreatment SCR catalyst to form nitrogen and water.

DEF:

- may have a slight ammonia smell
- is colorless
- is non-toxic and non-polluting
- is non-flammable
- urea is naturally occurring and is biodegradable.

See DEF Recommendations and Specifications in Section V for DEF specifications. Refer to Procedure 018-026 in Section V.

NOTE: Cummins Inc. supplies the aftertreatment DEF dosing unit, aftertreatment DEF dosing valve, and the aftertreatment SCR catalyst. The vehicle manufacturer supplies the DEF tank, DEF lines, DEF tank temperature and level sensor, coolant control valves, and all wiring between the components.

The aftertreatment DEF dosing unit pumps DEF from the DEF tank to the aftertreatment DEF dosing valve. The aftertreatment DEF dosing unit is heated using engine coolant, and contains a filter that is a maintenance item.

NOTE: See the Maintenance Schedule in Section 2 for the aftertreatment DEF dosing unit filter maintenance interval. Refer to Procedure 102-002 in Section 2.

The aftertreatment DEF dosing valve is DEF cooled and sprays DEF into the exhaust.

The engine control module (ECM) controls the amount of DEF sprayed into the exhaust. It also controls the DEF line heaters and coolant valves, which control coolant to the aftertreatment system.

The aftertreatment SCR catalyst uses DEF to reduce the NOx emissions by converting the engine-out NOx into nitrogen and water. The aftertreatment SCR catalyst itself requires no maintenance.

A vehicle with SCR will be equipped with an additional lamp on the dashboard, the aftertreatment DEF lamp. This lamp, along with the check engine lamp and stop engine lamp, alert the operator to the level of DEF in the tank. As the DEF tank level approaches empty, the aftertreatment DEF lamp will illuminate and engine power will be reduced. Attempting to operate the vehicle with no DEF in the tank will result in the engine speed or torque being limited.

NOTE: See Section 1 for additional information on the aftertreatment diesel fluid lamp.

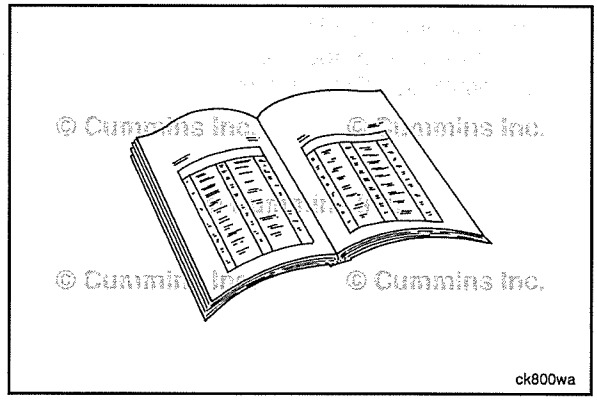
NOTE: See Section 1 for additional information on the aftertreatment diesel fluid lamp. Refer to Procedure 101-048 in Section 1.

DEF is sprayed into the exhaust when the temperature in the aftertreatment SCR catalyst reaches approximately 250°C [482°F]. The amount of DEF consumed will differ from vehicle to vehicle, as DEF consumption depends on engine speed and load.

Even though DEF freezes at approximately -12°C [11°F], the SCR system is designed to be frozen and thawed. The DEF tank and DEF dosing unit is heated by engine coolant, and the DEF lines are electrically heated. No operator interaction is needed when operating in cold temperatures; heating and thawing are controlled automatically by the ECM.

Under certain conditions, cold or very dry, water condensation, in the form of water vapor, can be seen coming from the exhaust pipe. This is normal operation and will clear within a few minutes of normal vehicle operation.

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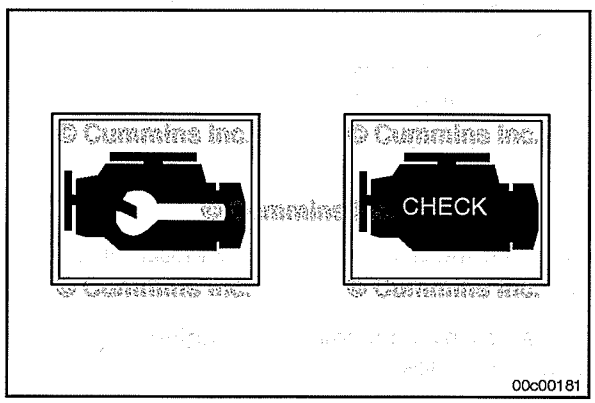


Engine Indicator Lamps

General Information

The following engine indicator lamps cover **only** the lamps controlled by the engine control module (ECM). The vehicle manufacturer can provide additional indicator lamps. Reference the vehicle owners manual for additional lamp information.

- Check engine
- Aftertreatment diesel particulate filter (DPF)
- Stop engine
- Aftertreatment diesel exhaust fluid (DEF)
- Exhaust high temperature.



Check Engine Lamp

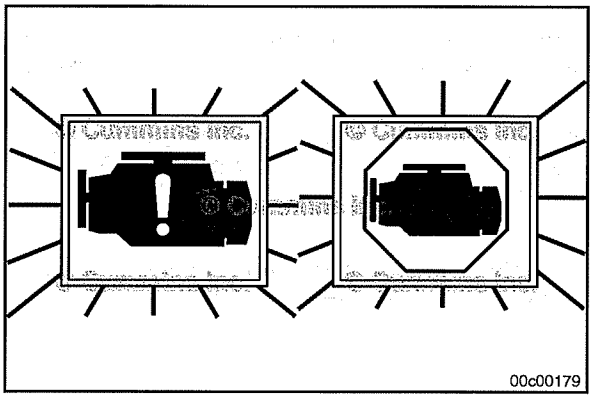
The CHECK ENGINE lamp illuminates when the engine needs to be serviced at the first available opportunity.

The CHECK ENGINE lamp is amber, and can look like:

- The words WARNING or CHECK ENGINE spelled out
- A symbol of an engine, similar to the illustration.

Another function of the CHECK ENGINE lamp is to flash for 30 seconds at key ON to indicate a maintenance condition. This flashing function is referred to as the MAINTENANCE lamp. The MAINTENANCE lamp could flash for the following reasons:

- Maintenance required, if the Maintenance Monitor feature is enabled.
- Water-in-fuel is detected.
- Coolant level is low.



Stop Engine Lamp

The STOP ENGINE lamp indicates, when illuminated, the need to stop the engine as soon as it can be safely done. The engine **must** remain shut down until the engine can be repaired.

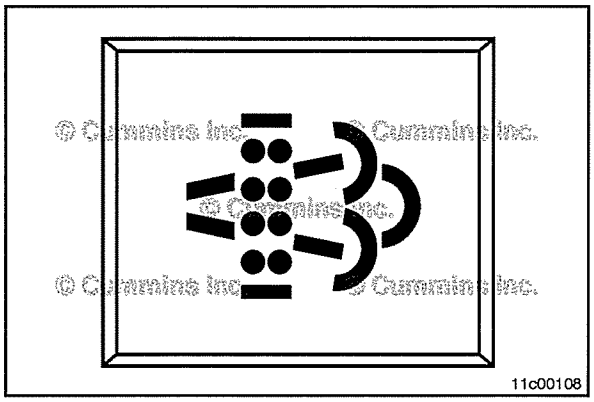
For engines with the Engine Protection Shutdown feature enabled, if the STOP ENGINE lamp begins to flash, the engine will automatically shut down after 30 seconds. The flashing STOP engine lamp alerts the operator to the impending shutdown.

The STOP ENGINE lamp is red in color, and can look like:

- The words STOP or STOP ENGINE spelled out
- A symbol of an engine with an exclamation point in the center, similar to the illustration
- A symbol of a stop sign with an engine outline in the center, similar to the illustration.

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Aftertreatment Diesel Particulate Filter Lamp

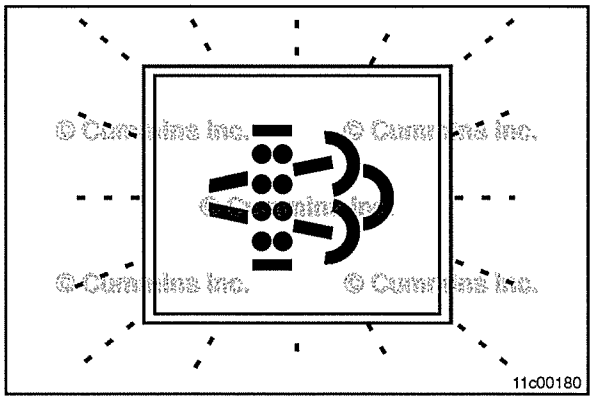


The AFTERTREATMENT DIESEL PARTICULATE FILTER lamp indicates, when illuminated or flashing, the status of the aftertreatment regeneration cleaing events.

An illuminated AFTERTREATMENT DIESEL PARTICULATE FILTER lamp indicates that the aftertreatment DPF needs to be regenerated at the next possible opportunity. This can be accomplished by:

- Changing to a more challenging duty cycle, for at least 20 minutes
- Performing a stationary regeneration. Follow the instructions in Unique Operating Characteristics of an Engine with Aftertreatment, in Section 1.

NOTE: Stationary regeneration is considered a normal maintenance practice and is **not** covered by Cummins Inc. warranty.



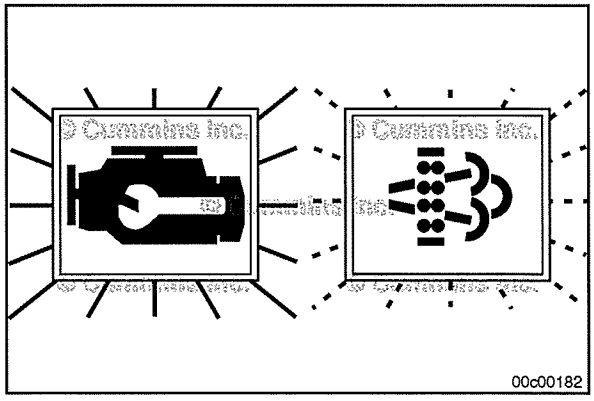
A flashing AFTERTREATMENT DIESEL PARTICULATE FILTER lamp indicates the status of a non-mission (stationary) regeneration when the manual (non-mission) regeneration switch has been activated. See the following procedure for more information on the manual (non-mission) regeneration switch. Refer to Procedure 101-050 in Section 1. When this lamp is flashing, the operator should:

1 Keep the exhaust outlet away from people and anything that can burn, melt, or explode.

2 Nothing within 0.6 m [2 ft] of the exhaust outlet.

3 Nothing that can burn, melt, or explode within 1.5 m [5 ft] (such as gasoline, wood, paper, plastics, fabric, compressed gas containers, or hydraulic lines).

4 In an emergency, turn the engine off to stop the flow of exhaust.



A solid AFTERTREATMENT DIESEL PARTICULATE FILTER lamp combined with an illuminated WARNING or CHECK ENGINE lamp indicates that the aftertreatment DPF needs be regenerated immediately. Engine power will be reduced automatically.

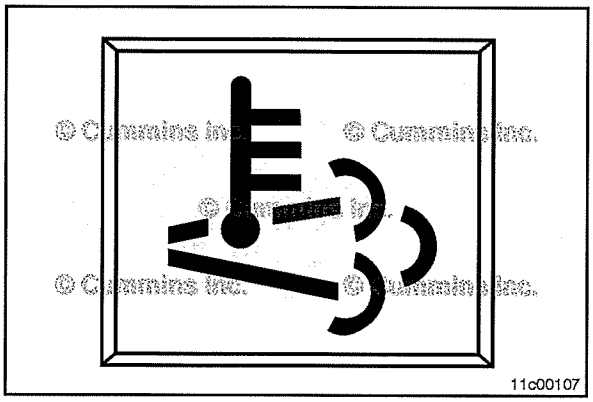
When these lamps are illuminated, a stationary regeneration is required.

- Follow the instructions in Unique Operating Characteristics of an Engine with Aftertreatment, in Section 1.

NOTE: If a stationary regeneration is **not** performed, the STOP ENGINE lamp will illuminate and the vehicle will need to be taken to a Cummins® Authorized Repair Location.

NOTE: Stationary regeneration is considered a normal maintenance practice and is **not** covered by Cummins Inc. warranty.

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High Exhaust System Temperature Lamp

⚠WARNING⚠

During regeneration, exhaust gas temperature can reach 800 °C [1500°F], and exhaust system surface temperature can exceed 700 °C [1300°F], which is hot enough to ignite or melt common materials, and to burn people. The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To avoid the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

The HIGH EXHAUST SYSTEM TEMPERATURE lamp indicates, when illuminated, that exhaust temperatures are high due to regeneration of the aftertreatment DPF. This lamp can illuminate during normal engine operation or during stationary regeneration.

NOTE: The original equipment manufacturer (OEM) determines whether or **not** the HIGH EXHAUST SYSTEM TEMPERATURE lamp is installed on the vehicle. The OEM also specifies the temperatures, vehicle speeds, and other conditions at which the lamp illuminates. See equipment manufacturer serviceinformation for additional information regarding this lamp.

When this lamp is illuminated, make sure that the exhaust pipe outlet is **not** directed at any surface or material that can melt, burn, or explode.

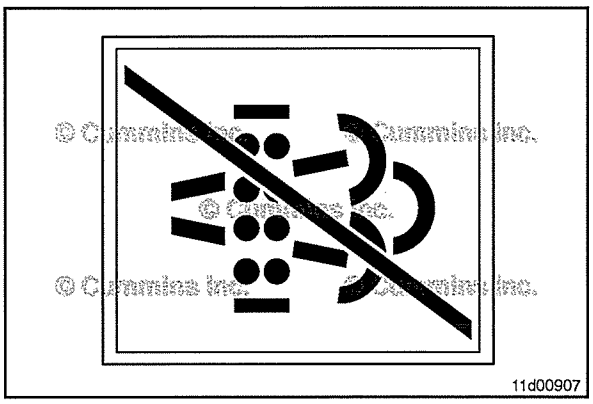
- Keep the exhaust outlet away from people and anything that can melt, burn, or explode
- Nothing within 0.6 m [2 ft] of the exhaust outlet
- Nothing that can melt, burn, or explode within 1.5 m [5 ft], such as gasoline, wood, paper, plastics, fabric, compressed gas containers, and hydraulic lines
- In an emergency, turn the engine OFF to stop the flow of exhaust.

NOTE: The HIGH EXHAUST SYSTEM TEMPERATURE lamp does **not** signify the need for any kind of vehicle or engine service; it merely alerts the vehicle operator to high exhaust temperatures. It will be common for the HIGH EXHAUST SYSTEM TEMPERATURE lamp to illuminate on and off during normal vehicle operation as the engine completes regeneration.

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Regeneration Disabled Lamp

The REGENERATION DISABLED lamp indicates, when illuminated, the Regeneration Disabled (Inhibit) Switch is active; therefore, automatic and manual (non-mission) regeneration can **not** occur.

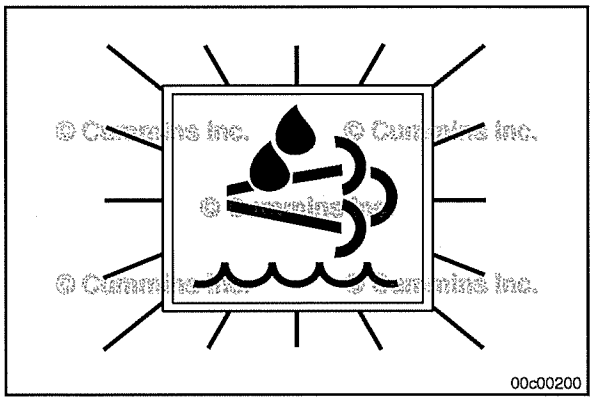


Aftertreatment Diesel Exhaust Fluid Lamp

The DIESEL EXHAUST FLUID lamp indicates, when illuminated or flashing, that the DEF level is low.

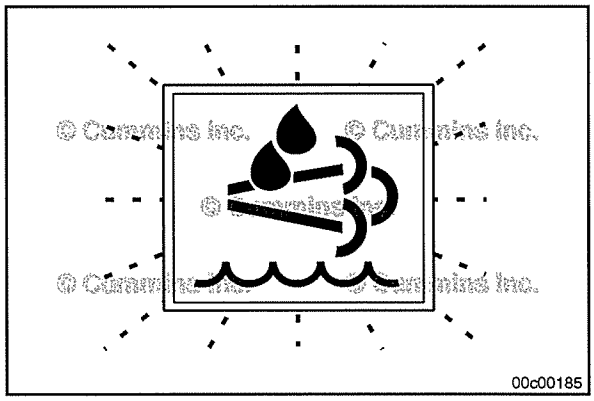
An illuminated DIESEL EXHAUST FLUID lamp indicates that the DEF level has fallen below the initial warning level. This can be corrected by filling the DEF tank with DEF.

NOTE: It is recommended that the DEF tank be filled completely full of DEF in order to correct any fault conditions.



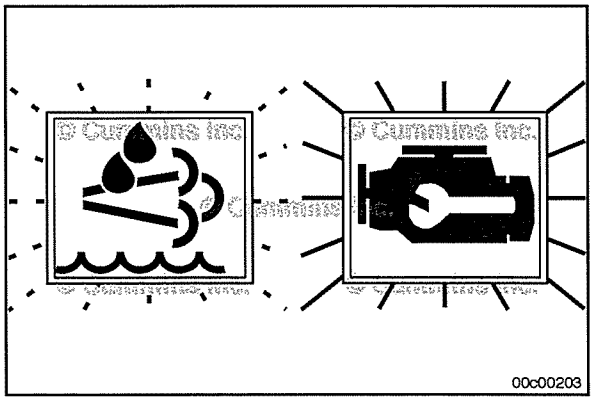
A flashing DIESEL EXHAUST FLUID lamp indicates that the DEF level has fallen below the critical warning level. This can be corrected by filling the DEF tank with DEF.

NOTE: It is recommended that the DEF tank be filled completely full of DEF in order to correct any fault conditions.

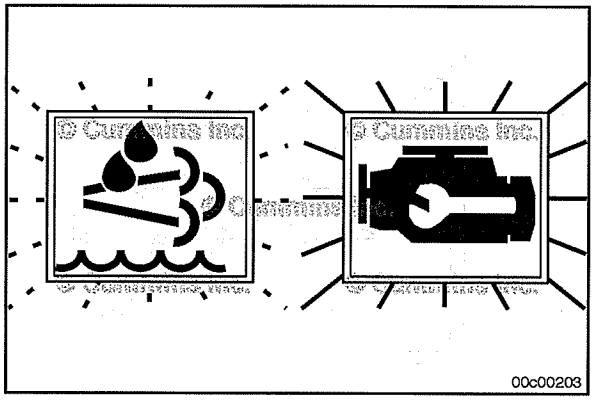


A flashing DIESEL EXHAUST FLUID lamp combined with an illuminated WARNING or CHECK ENGINE lamp indicates that the DEF level has fallen below the initial derate level. The engine power will be limited automatically. This can be corrected by filling the DEF tank with DEF.

NOTE: It is recommended that the DEF tank be filled completely full of DEF in order to correct any fault conditions.

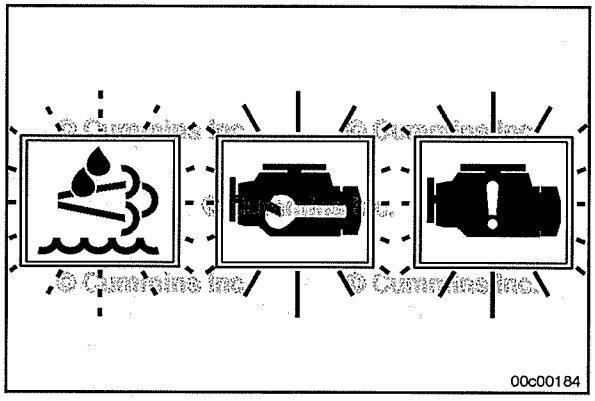


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Allowing the DEF tank to become empty will cause the aftertreatment DEF dosing system to lose prime. A loss of prime condition may cause fault codes to become active.

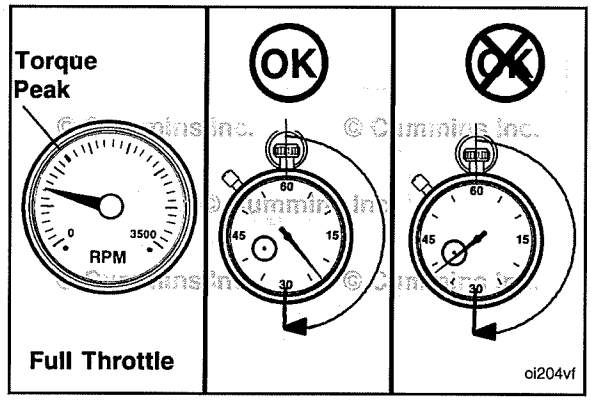
NOTE: It is recommended that the DEF tank be filled completely full of DEF in order to correct any fault conditions.



If the engine has been operated for 30 minutes after the tank has been emptied, the STOP ENGINE lamp will also be illuminated along with the flashing DIESEL EXHAUST FLUID lamp and illuminated CHECK ENGINE lamp. The engine will also either be limited to idle speed or shut down depending on OEM configuration.

NOTE: In order to remove the idle limitation or engine shutdown, the DEF tank **must** be filled to at least 10 percent volume of the tank.

NOTE: It is recommended that the DEF tank be filled completely full of DEF in order to correct any fault conditions.



Engine Operating Range

General Information

⚠CAUTION⚠

Do not operate the engine at full throttle below peak torque rpm (refer to engine dataplate for peak torque rpm) for more than 30 seconds. Operating the engine at full throttle below peak torque will shorten engine life to overhaul, can cause serious engine damage, and is considered engine abuse.

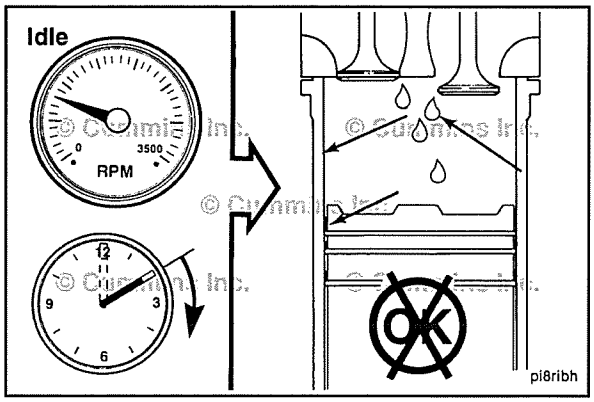
⚠CAUTION⚠

Do not operate the engine beyond the maximum engine speed. Operating the engine beyond the maximum engine speed can cause severe engine damage. Use proper operating techniques for the vehicle, vessel, or equipment to prevent engine overspeed. The maximum engine speed specification is listed in Maintenance Specifications (Section V).

Cummins® engines are designed to operate successfully at full throttle under transient conditions down to peak torque engine speed. This is consistent with recommended operating practices.

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⚠CAUTION⚠
Do not idle the engine for excessively long periods. Long periods of idling, more than 10 minutes, can cause poor engine performance.



Engine Shutdown

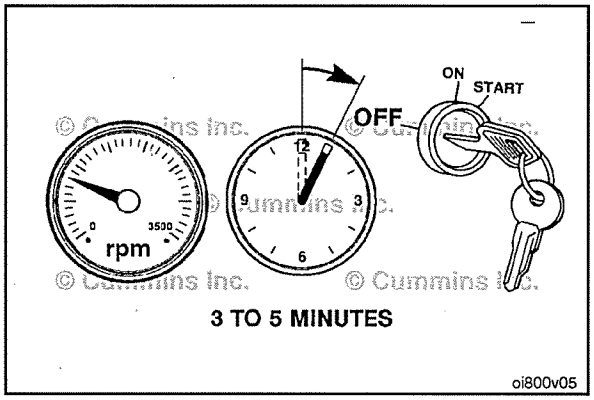
General Information

⚠CAUTION⚠
Failure to follow the correct shutdown procedure may result in damage to the turbocharger and shorten the turbocharger life.

Allow the engine to idle 3 to 5 minutes before shutting it off after a full-load operation. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.

NOTE: For engines equipped with an electronic control module (ECM) ensure the keyswitch is turned off for a minimum of 100 seconds prior to disconnecting the continuous (unswitched) battery power supply. If the unswitched battery power supply is disconnected in less than 100 seconds after the keyswitch is turned off active fault codes and incorrect ECM information can occur.

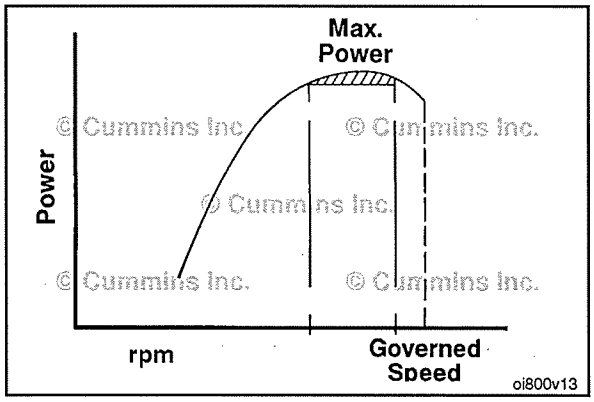
Turn the ignition switch to the OFF position. If the engine does **not** shut down, refer to Troubleshooting Symptom (Section TS) in appropriate Operation and Maintenance manual.



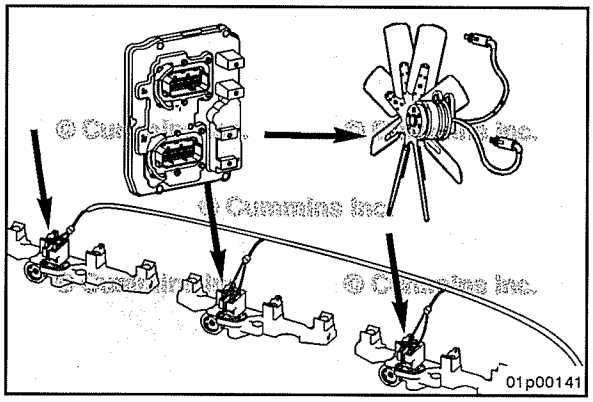
Electronic Controlled Fuel System

General Information

The QSG12 CM2350 G110 fuel system is an electronically controlled fuel injection system that optimizes fuel economy. It does this by controlling the torque and horsepower curve, engine high speed, low idle, and road speed.



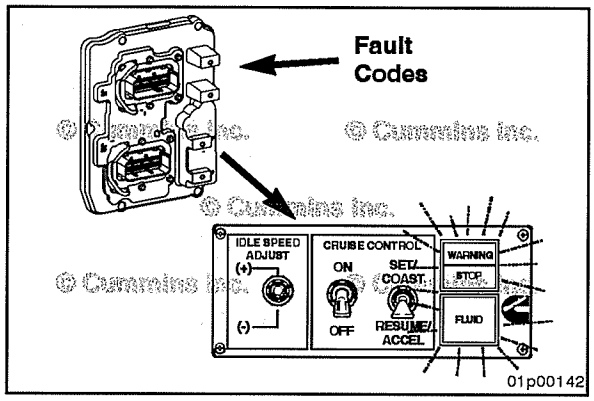
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QSG12 CM2350 G110 has the capability of controlling the fan clutch actuator if an electronically controlled fan clutch is used.

QSG12 CM2350 G110 also allows the engine brakes to be activated by controlling the engine brake solenoids.

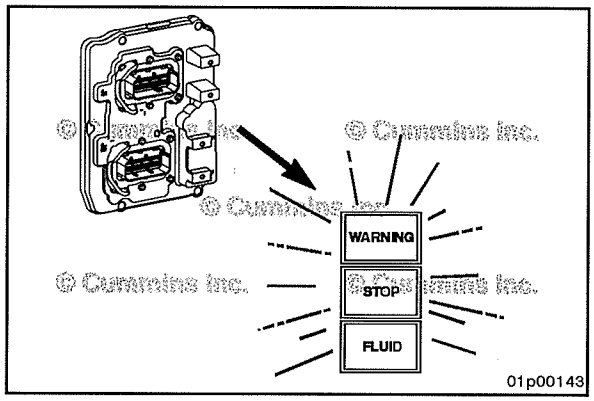
The electronic feature Fan Control Engine Braking can be enabled to activate the fan clutch during engine braking. This increases the load on the engine during engine braking.



Diagnostic Fault Codes

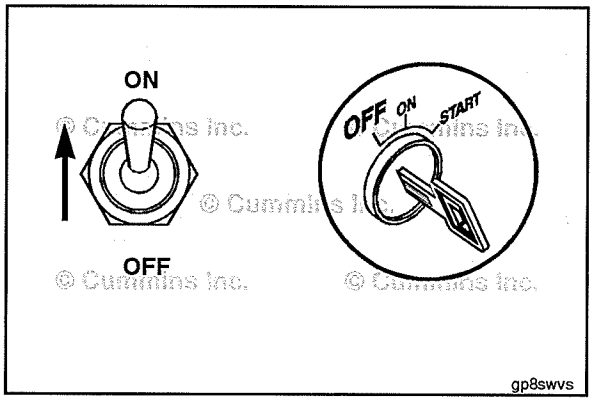
The electronically controlled fuel system can show and record certain engine faults. The faults are shown as fault codes. These fault codes will make troubleshooting easier. The fault codes are recorded in the engine control module (ECM).

NOTE: Not all engine irregularities are shown as fault codes.



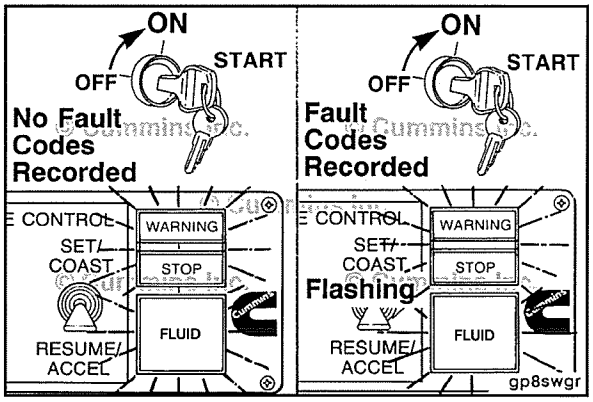
The engine electronic fuel system fault codes can be seen on the WARNING and STOP lights in the cab panel.

NOTE: Inactive fault codes can **not** be flashed out. An electronic service tool **must** be used to read inactive fault codes in the ECM. Contact a Cummins® Authorized Repair Location.



If the equipment is equipped with a diagnostic switch, turn the switch OFF. Turn the equipment OFF. To check for engine electronic fuel system and engine protection system fault codes, move the diagnostic switch to the ON position, or connect the shorting plug into the diagnostic connector.

Turn the equipment keyswitch ON. If any fault codes were active during system power down, the lights will begin to flash the code of the recorded faults. If no fault codes are recorded, the lamps will **not** flash, but will be illuminated.



The fault code will flash in the following sequence:

1 A WARNING (amber) light will flash.

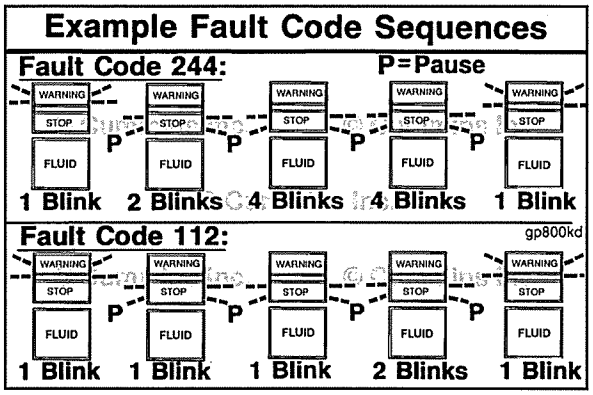
2 There will be a short 1 or 2 second pause.

3 The recorded fault code number will flash STOP (red) light.

4 There will be a 1 or 2 second pause between each number.

5 When the number has finished flashing in red, a yellow light will appear again.

The code will repeat in the same sequence.

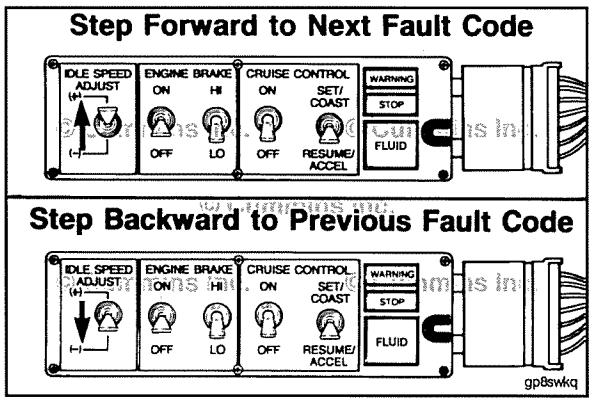


The lights will continue to flash the same code until the system is told to do something else.

To go to the next fault code, move the CRUISE CONTROL/PTO switch momentarily to the RESUME/ ACCEL position.

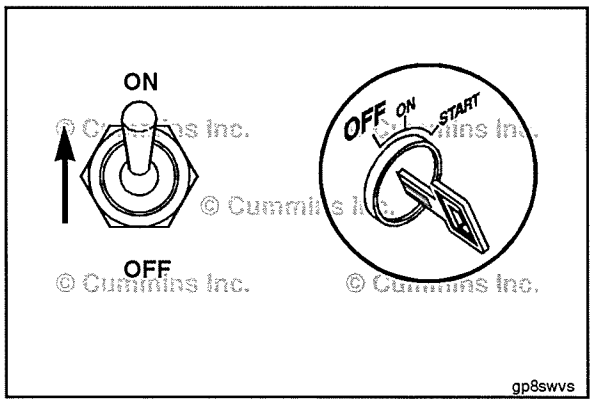
To go back to the previous fault code momentarily, move the CRUISE CONTROL/PTO switch to the SET/COAST position.

If **only** one active fault is recorded, the system will continuously display the same fault code when either RESUME/ACCEL or SET/COAST switch is depressed.

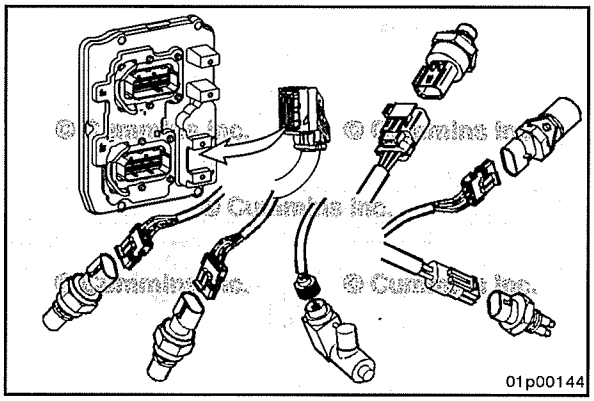


When **not** using the diagnostic system, turn the diagnostic switch OFF, or remove the shorting plug. If the diagnostic switch is left ON or the shorting plug left in, the ECM will **not** log some faults and the maintenance monitor will **not** function correctly.

To stop the diagnostic system, move the diagnostic switch to the OFF position, or remove the shorting plug. Turn the equipment switch OFF.



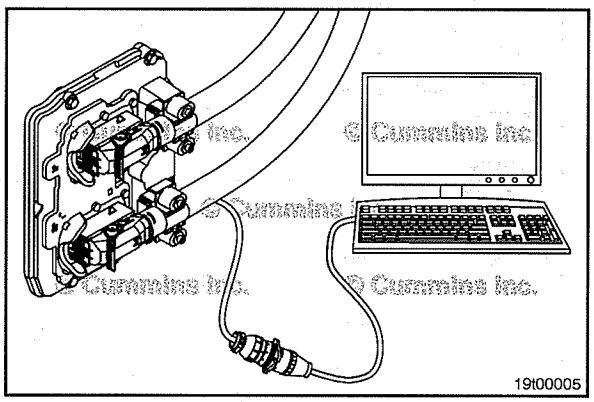
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Engine Protection System

The QSG12 CM2350 G110 engines are equipped with an engine protection system. The system monitors critical engine temperatures and pressures, and logs diagnostic faults when an over or under normal condition occurs. If an out-of-range condition exists and engine derate action is to be initiated, the operator is alerted by an in-cab WARNING lamp. The STOP lamp blinks or flashes when out-of-range conditions continue to worsen. The operator **must** stop when it is safe to do so, to reduce the possibility of engine damage.

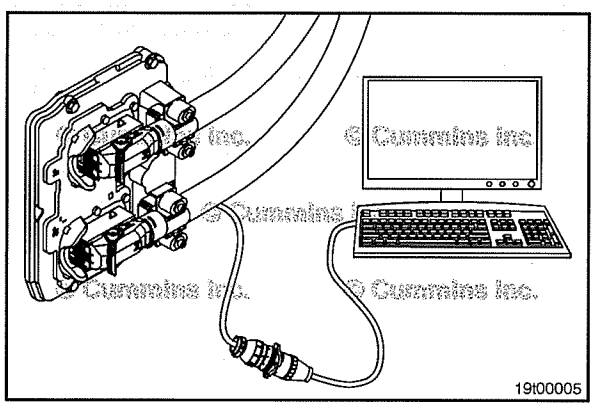
NOTE: Engine power and speed will gradually be reduced, depending on the level of severity of the observed condition. The engine protection system will **not** shut down the engine unless the Engine Protection Shutdown feature has been selected. If the feature has been selected and the engine does shut down, the engine can be started again by turning the keyswitch OFF and then turning it back ON.



INSITE™ Electronic Service Tool Description

INSITE™ electronic service tool is a service tool for the electronic engine control system. Use INSITE™ electronic service tool to:

- Program customer specified information into the ECM (parameter and features)
- Aid in troubleshooting the engine
- Change the engine power or rated speed calibration
- Transfer new or update calibration files to the ECM
- Create and view trip reports, etc.



INSITE™ Electronic Service Tool Monitor Mode

The INSITE™ electronic service tool monitor mode is a useful troubleshooting aid that displays the key ECM inputs and outputs. This feature can be used to spot constant or intermittent out-of-range values.

Electromagnetic Interference (EMI)

General Information

Some applications utilize accessories such as (CB radios, mobile transmitters, etc.) if not installed and used correctly the radio frequency energy generated by these accessories can cause electromagnetic interference (EMI) conditions to exist between the accessory and the Cummins electronically controlled systems. Cummins is **not** liable for any performance problems with either the electronically controlled systems or the accessory due to EMI. EMI is **not** considered by Cummins to be a system failure and therefore is **not** warrantable.

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System EMI Susceptibility

Your Cummins product has been designed and tested for minimum sensitivity to incoming electromagnetic energy. Testing has shown that there is no performance degradation at relatively high energy levels; however, if very high energy levels are encountered, then some noncritical diagnostic fault code logging can occur. The electronically controlled systems EMI susceptibility level will protect your systems from most, if **not** all, electromagnetic energy-emitting devices that meet the legal requirements.

System EMI Radiation Levels

Your Cummins product has been designed to emit minimum electromagnetic energy. Electronic components are required to pass various Cummins and industry EMI specifications. Testing has shown that when the systems are properly installed, they will not interfere with onboard communication equipment or with the vehicle's, equipment's, or vessel's ability to meet any applicable EMI standards and regulated specifications.

If an interference condition is observed, follow the suggestions below to reduce the amount of interference:

1 Locate the transmitting antenna as far away from the electronically controlled systems and as high as possible.

2 Locate the transmitting antenna as far away as possible from all metal obstructions (e.g., exhaust stacks)

3 Consult a representative of the accessory supplier in your area to:

- Accurately calibrate the device for proper frequency, power output, and sensitivity (both base and remote site devices **must** be properly calibrated)
- Obtain antenna reflective energy data measurements to determine the optimum antenna location
- Obtain optimum antenna type and mounting arrangement for your application
- Make sure your accessory equipment model is built for maximum filtering to reject incoming electromagnetic noise.

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Notes

Section 2 - Maintenance Guidelines

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Maintenance Guidelines - Overview

General Information

Cummins Inc. recommends that the system be maintained according to the Maintenance Schedule in this section.

If the system is operating in ambient temperatures below -18°C [0°F] or above 38°C [100°F], perform maintenance at shorter intervals. Shorter maintenance intervals are also required if the system is operated in a dusty environment or if frequent stops are made. For gas fueled generator sets, shorter maintenance intervals are also required, if operating at loads below 70% for prolonged periods. Contact your local Cummins® Authorized Repair Location for recommended maintenance intervals.

Some of these maintenance procedures require special tools or must be completed by qualified personnel. Contact your local Cummins® Authorized Repair Location for detailed information.

If your system is equipped with a component or accessory not manufactured or supplied by Cummins Inc., refer to the component manufacturer's maintenance recommendations.

OEM supplied equipment and components can impact on the performance and reliability of the engine if they are not correctly maintained.

Use the chart provided in this section as a convenient way to record maintenance performed.

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Tool Requirements

General Information

Most of the maintenance operations described in this manual can be performed with common hand tools (metric and SAE wrenches, sockets, and screwdrivers).

The following is a list of special service tools required for some maintenance operations:

Number	Tool Name
CC 2602	Fleetguard® Coolant Test Kit
2892459	Coolant Replacer Kit
3400157	Oil and Fuel Filter Wrench
4919092	Engine Barring Tool
4919363	Overhead Setting Kit
5298582	Timing Pin Kit

See the appropriate sections for a description of the tools and how to use them.

Contact a Cummins® Authorized Repair Location for the required service tools.

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Maintenance Schedule

General Information

Listed below are the section numbers that contain specific instructions for performing the maintenance checks listed in the maintenance schedule.

Perform maintenance at whichever interval occurs first. At each scheduled maintenance interval, perform all previous maintenance checks that are due for scheduled maintenance.

Maintenance Procedures at Daily Interval .....Section 3

- Crankcase Breather Tube - Check
- Fuel-Water Separator - Drain
- Lubricating Oil Level - Check
- Fan, Cooling - Inspect for Reuse
- Coolant Level - Check
- Charge-Air Piping - Check
- Air Intake Piping - Check
- Air Cleaner Restriction - Check
- Dust Ejection Valve - Inspect for Reuse
- Aftertreatment Exhaust Piping - Check
- Air Tanks and Reservoirs - Drain
- Drive Belts - Check
- Diesel Exhaust Fluid (DEF) Level - Check

Maintenance Procedures at 250 Hours or 6 Months .....Section 4

- Pressure Fuel Filter - Change(7)
- Fuel Filter Suction - Change(5)

Maintenance Procedures at 500 Hours or 6 Months .....Section 5

- Lubricating Oil and Filters - Change(1)
- Radiator Pressure Cap - Test
- Supplemental Coolant Additive (SCA) and Antifreeze Concentration - Check(3)
- Charge-Air Cooler - Check(2)

Maintenance Procedures at 1000 Hours or 1 Year .....Section 6

- Aftertreatment Diesel Exhaust Fluid Tank Filter - Inspect for Reuse(8)

Maintenance Procedures at 1500 Hours or 1 Year .....Section 7

- Cooling Fan Belt Tensioner - Check
- Charging System Alternator Automatic Belt Tensioner - Check
- Air Cleaner Element - Change(6)
- Air Leaks, Air Intake and Exhaust Systems - Check
- Air Compressor Discharge Lines - Inspect for Reuse
- Crankshaft Pulley - Check
- Overhead Set - Adjust

Maintenance Procedures at 4500 Hours .....Section 8

- Aftertreatment Diesel Particulate Filter - Check(4)

Maintenance Procedures at 4500 Hours or 3 Years .....Section 9

- Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter - Change

Maintenance Procedures at 6000 Hours or 3 Years .....Section 10

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- Engine Mounting Bolts - Check
- Engine Steam Cleaning - Clean
- Vibration Damper, Viscous - Check
- Cooling System - Flush
- Radiator Hoses - Check
- Radiator Shutter Assembly - Check
- Cold Starting Aid - Inspect for Reuse
- Engine Mounts - Inspect for Reuse
- Fan Hub, Belt Driven - Inspect for Reuse

1 The lubricating oil and lubricating oil filter intervals are based on Cummins® Engineering Standard 20081 and a normal duty cycle. Oil change intervals can be adjusted based on fuel consumption. See the Oil Drain Intervals Table for Severe Duty and Light Duty drain intervals in this section.

2 Follow the manufacturer's recommended maintenance procedures for the starter, alternator, generator, batteries, electrical components, engine brakes, exhaust brake, charge-air cooler, air compressor, air conditioner compressor, and fan clutch.

3 Test the SCA concentration level every 6 months unless the concentration is over three units; then check at every oil drain interval until the concentration is below three units. Use the following procedure for coolant condemnation limits. Refer to Procedure 018-004 in Section V.

4 While air cleaning is allowed, the Cummins Inc. preferred method would be to exchange the DPF at the recommended maintenance interval.

5 Suction fuel filters are original engine manufacturer (OEM) installed. It is important to always use clean, high quality fuel. Failure to use clean, high quality fuel will negatively affect engine life and maintenance intervals. Use the following procedure for fuel requirements. Refer to Procedure 018-002 in Section V.

6 The air cleaner (filter) element change interval is based on restriction, but the elements should be changed at least every 1500 hours or 1 year. It is important to check the restriction daily and change the air cleaners (filters) once they become restricted (635 mm H2O [25 in H2O]). The secondary air cleaner (filter) elements should be changed every other time the primary elements are changed. Proper inspection of the secondary air filter elements should be performed and the secondary elements changed, if necessary.

NOTE: Refer to Procedure 010-014 in Section 6.

7 The fuel filter change intervals can be increased and the engine fuel system can be better protected depending on the suction-side fuel filters used. If a suction side fuel filter is used that has NanoNet™ media with Beta Ratio (filtration efficiency) rating of ß5(C)=75 is used (such as Short Industrial Pro® FH2390000 Series and filter part number FS53015), recommended service interval can be increased to 500 hours or 6 months for the pressure fuel filter. This will also provide additional protection to the engine fuel system from debris in fuel.

8 See equipment manufacturer service information for DEF tank filter service interval. For Cummins® provided DEF tanks, filter replacement is recommended every 2000 hours or one year, whichever occurs first. For dusty environments inspect the filter every 1000 hours and replace if dirty. For low dust environments (such as paved road or indoor equipment), the recommended interval is 4500 or three years, whichever occurs first.

All EPA 07, EPA 10, EPA Tier 4 Interim/European Union Stage IIIB 2011(174 -751 hp), EPA Tier 4 Final/European Union Stage IV (174-751 hp) engine systems equipped with exhaust aftertreatment **must** operate on ultra-low sulfur diesel (ULSD) with a maximum sulfur content of 15 ppm in the United States and 10 ppm in the European Union. Failure to do so can permanently damage engine and aftertreatment systems within a short period of time. This damage could cause the engine to become inoperable and affect the warranty coverage on the engine system.

Aftertreatment Cleaning Intervals	
Oil Classification	**Interval (Hours)**
CES20081	4500

Oil Drain Intervals

NOTE: Extending the oil and filter change interval beyond the recommendation will decrease engine life due to factors such as corrosion, deposits, and wear.

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QSG12 CM2350 G110 Industrial Engines - Oil Drain Intervals by Duty Cycle (Hours)[2]				
	Severe	**Heavy**	**Medium**	**Light**
Oil Classification	**>49.2 liters/hour [13 gallon/hour]**	**37.9 to 49.2 liters/ hour [10 to 13 gallons/hour]**	**32.2 to 37.9 liters/ hour [8.5 to 10 gallons/hour]**	**> 32.2 liters/hour] [8.5 gallons/hour]**
CES 20081/CJ-4/ ACEA E9/JAMA DH-2[1][2]	400	500	625	750
1 The use of Centinel™ or any type of oil blending is prohibited. The use of a high quality filter is mandatory.				
• Engines **must** be operated on ultra-low sulfur diesel (15 ppm sulfur) fuel.				

1 The oil classifications CD, CE, CF, and CG have been obsoleted by American Petroleum Institute (API) and **must not** be used, as their specifications are no longer controlled.

2 Use the following procedure for the lubricating oil filter specification table. Refer to Procedure 018-003 in Section V.

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Maintenance Record Form

Maintenance Data

Maintenance Record	
Product Serial No.:	Product Model:
Owner's Name:	Equipment Model/Number:

Key to table headings:
A = Date
B = Schedule km [Miles], Hours or Time Interval
C = Actual km [Miles] Hour or Time
D = Maintenance Check Performed
E = Check Performed By
F = Comments

A	B	C	D	E	F

Section 3 - Maintenance Procedures at Daily Interval

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Daily Maintenance Procedures - Overview

General Information

Preventative maintenance begins with day-to-day awareness of the system. Before starting the system, check the appropriate fluid levels. Look for:

- Leaks
- Loose or damaged parts
- Worn or damaged belts
- Worn or damage low and high voltage harnesses
- Any change in system appearance.
- Odor of fuel
- Odor of electronic devices

System Operation Report

The system **must** be maintained in top mechanical and electronic condition if the operator is to get optimum satisfaction from its use. The maintenance department needs daily running reports from the operator to make necessary adjustments in the time allocated. The daily running report also helps to make provisions for more extensive maintenance work as the reports indicate the necessity.

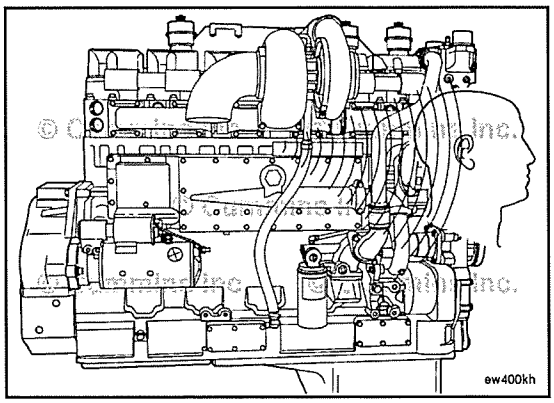
Comparison and intelligent interpretation of the daily report, along with a practical follow-up action, will eliminate most failures and emergency repairs.

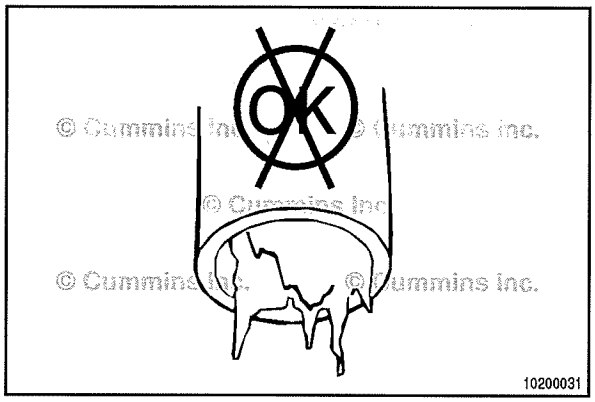
Report to the maintenance department any of the following conditions that may apply:

- Low lubricating oil pressure
- Low power
- Power increases or engine surge
- Erratic or no accelerator control or response
- Any warning lights flashing or staying on
- Abnormal water or oil temperature
- Unusual system noise
- Excessive smoke
- Excessive use of coolant, fuel, or lubricating oil
- Any fuel, coolant, or lubricating oil leaks
- Loose or damaged parts
- Worn or damaged belts
- Worn or damaged low or high voltage harnesses

Unusual System Noise

During daily maintenance checks, listen for any unusual system noise(s) that can indicate that service is required.





Crankcase Breather Tube

Maintenance Check

Inspect the crankcase breather tube outlet for the following conditions that may be blocking or restricting the crankcase breather tube.

NOTE: Some engines may be equipped with a catch bottle at the end of the crankcase breather tube. Removal of the catch bottle may be required to inspect the crankcase breather tube outlet.

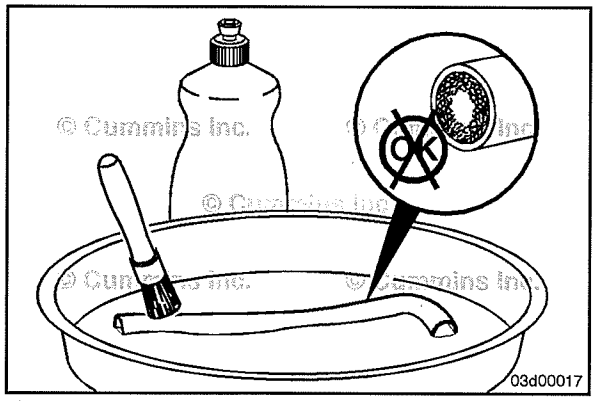
- Sludge
- Debris
- Ice.

If any of the above conditions exist, the crankcase breather tube outlet **must** be cleaned.

Inspect the crankcase breather tube outlet more frequently when ambient temperatures are below freezing. Frequent ice build up in the crankcase breather tube may require one of the following actions.

- A crankcase breather tube heater option be installed.
- If a crankcase breather tube heater is already installed, troubleshoot the crankcase breather tube heater for not operating.

Contact a Cummins® Authorized Repair Location.



⚠CAUTION⚠
If a crankcase breather tube heater option is installed, the crankcase breather heater must be removed prior to submerging the crankcase breather tube in water and/or cleaning solution. Damage to the crankcase breather tube heater will result.

Clean the crankcase breather tube outlet with detergent and warm water.

If equipped, clean the crankcase breather catch bottle. Use detergent and warm water.

If more than the crankcase breather tube outlet requires cleaning, removal of the crankcase breather tube may be required. If removal is required, contact a Cummins® Authorized Repair Location.

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Visually inspect the crankcase breather tube for the following conditions.

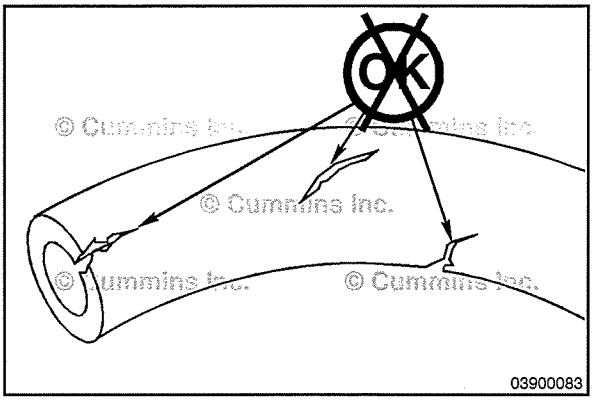
- Cracks
- Material deterioration
- General damage.

If any of the above conditions are exist, replace the crankcase breather tube. Contact a Cummins® Authorized Repair Location.

If equipped, inspect the crankcase breather catch bottle for the following conditions.

- Cracks
- Holes
- General damage.

If and of the above conditions are found, replace the crankcase breather tube catch bottle. Contact a Cummins® Authorized Repair Location.



Fuel-Water Separator

Drain

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

Cummins Inc. requires a fuel-water separator or fuel filter be installed in the fuel supply system.

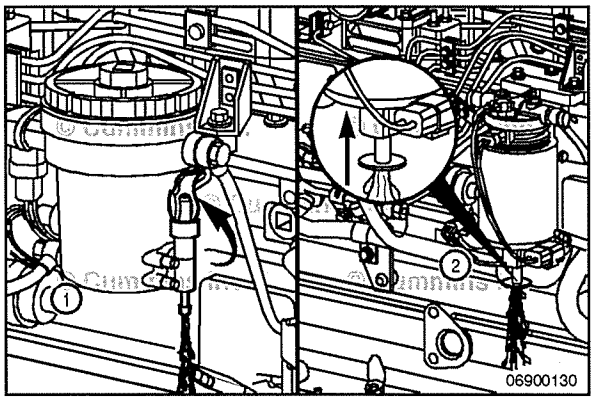
Drain the water and sediment from the separator daily.

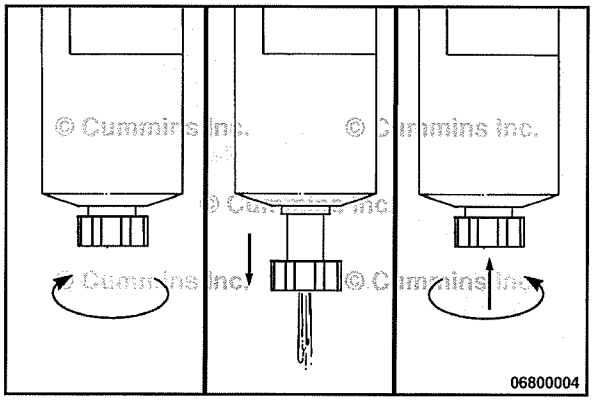
Canister Type

Shut off the engine.

Pull up on the drain valve lever until fluid drains out of the drain tube. Drain the filter sump until clear fuel is visible.

Push up on the drain valve until fluid drains out of the drain tube.





Spin-on Type

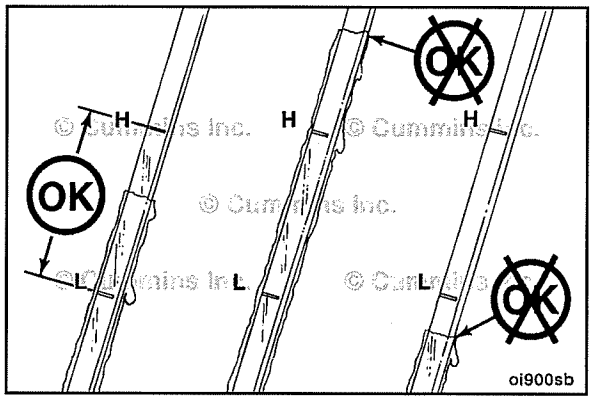
Shut off the engine.

Use your hand to open the drain valve. Turn the valve **counterclockwise** approximately 3½ turns until the valve drops down 25.4mm [1 in] and draining occurs.

Drain the filter sump until clear fuel is visible.

⚠CAUTION⚠
When closing the drain valve, do not overtighten the valve. Overtightening can damage the threads.

To close the valve, lift the valve and turn **clockwise** until it is hand-tight.



Lubricating Oil Level

Maintenance Check

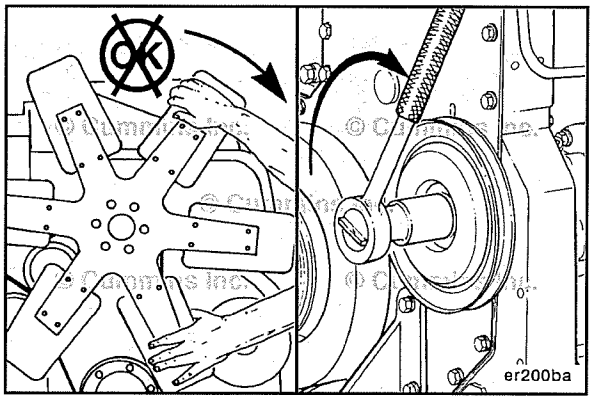
⚠CAUTION⚠
Never operate the engine with oil level below the L (low) mark or above the H (high) mark. Poor engine performance or engine damage can occur.

The engine **must** be level when checking the oil level to make sure the measurement is correct.

Shut off the engine for an accurate reading.

Wait at least 15 minutes after shutting off the engine to check the oil level. This allows time for the oil to drain into the oil pan.

For additional lubricating oil recommendations and oil pan capacity information, refer to Maintenance Specifications (Section V).



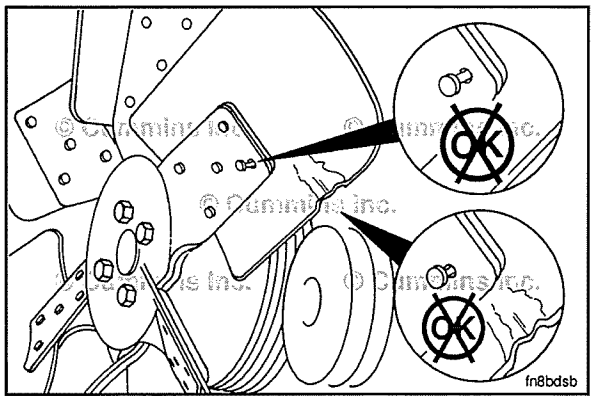
Fan, Cooling

Inspect for Reuse

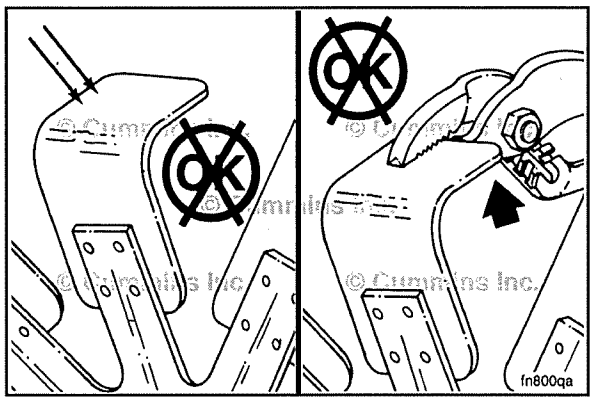
⚠WARNING⚠
Do not rotate the engine by pulling or prying on the fan. The fan blade(s) can be damaged and cause the fan to fail and cause personal injury or property damage. Use the accessory drive shaft or the crankshaft barring tool to rotate the crankshaft.

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A visual inspection of the cooling fan is required daily. Check for cracks, loose rivets, and bent or loose blades. Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.

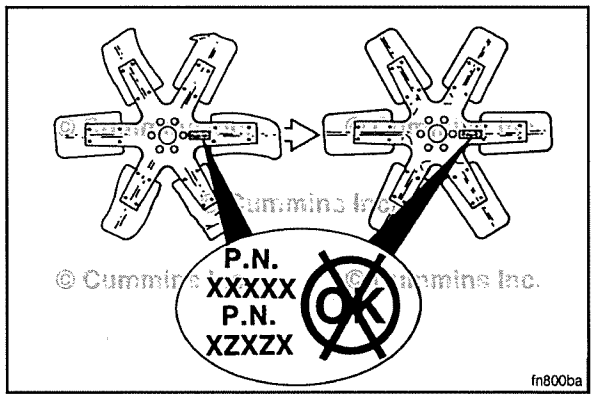


⚠WARNING⚠
Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause personal injury or property damage.



Replace original equipment fan that is damaged with a fan of the identical part number. Cummins Inc. **must** approve any other fan changes to be covered under warranty.

Refer to the vehicle or equipment manufacturer's specifications for capscrew torque.



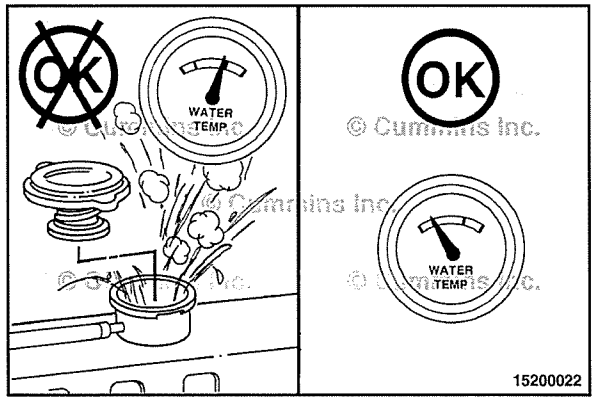
Coolant Level

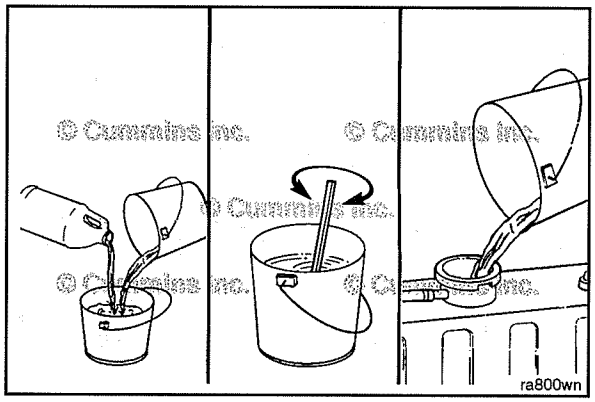
Maintenance Check

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

⚠CAUTION⚠
Never use a sealing additive to stop leaks in the cooling system. This can result in cooling system plugging and inadequate coolant flow, causing the engine to overheat.

The coolant level **must** be checked daily.



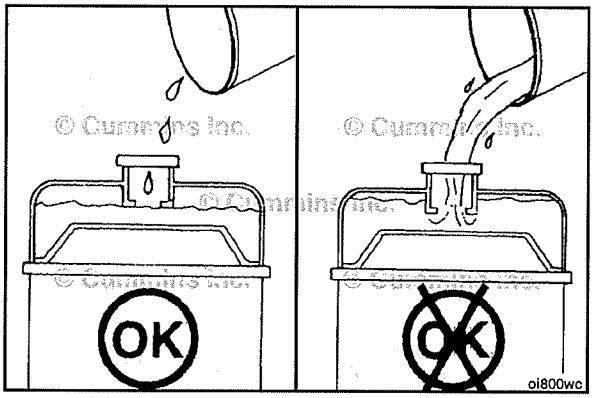


⚠CAUTION⚠

Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool to below 50°C [120°F] before adding coolant.

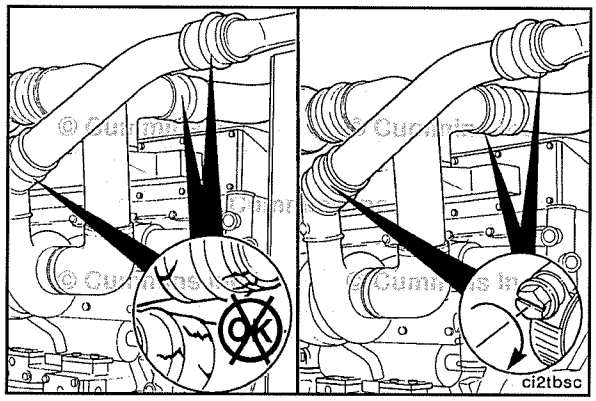
Coolant added to the engine **must** be mixed with the correct proportions of antifreeze, supplemental coolant additive, and water to avoid engine damage.

Coolant recommendations and specification details on correct mixing of coolant can be found in Maintenance Specifications (Section V).



Fill the cooling system with coolant. Refer to the markings on the radiator or expansion tank for coolant levels or refer to the OEM manual.

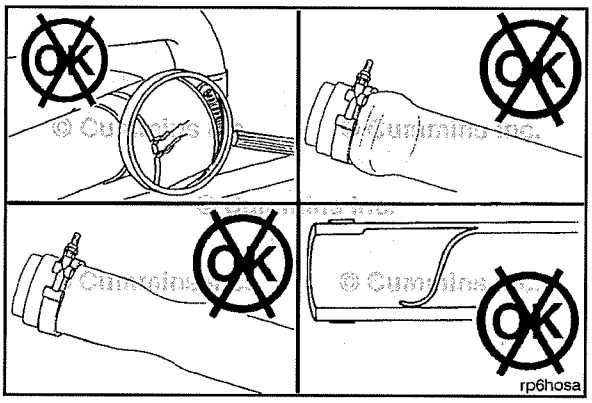
NOTE: Some radiators have two fill necks, both of which **must** be filled when the cooling system is drained.



Charge-Air Piping

Maintenance Check

Inspect the charge-air piping and hoses for leaks, holes, cracks, or loose connections. Tighten the hose clamps if necessary. Refer to the vehicle or equipment manufacturer's specifications for the correct torque value.



Air Intake Piping

Maintenance Check

Inspect the intake piping daily for wear points and damage to piping, loose clamps, and punctures that can damage the engine.

Replace damaged pipes and tighten loose clamps, as necessary, to prevent the air system from leaking.

Torque Value: 8 N•m [71 in-lb]

Check for corrosion under the clamps and hoses of the intake system piping. Corrosion can allow corrosive products and dirt to enter the intake system. Disassemble and clean, as required.

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Air Cleaner Restriction

Maintenance Check

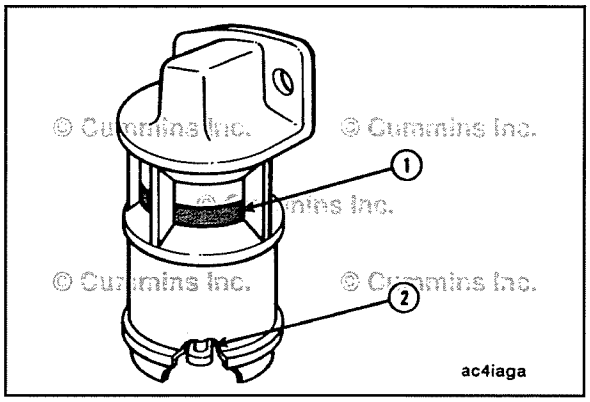
Mechanical Indicator

⚠CAUTION⚠
Never operate the engine without an air cleaner. Intake air must be filtered to prevent dirt and debris from entering the engine and causing premature wear.

NOTE: Do **not** remove the felt washer from the indicator. The felt washer absorbs moisture.

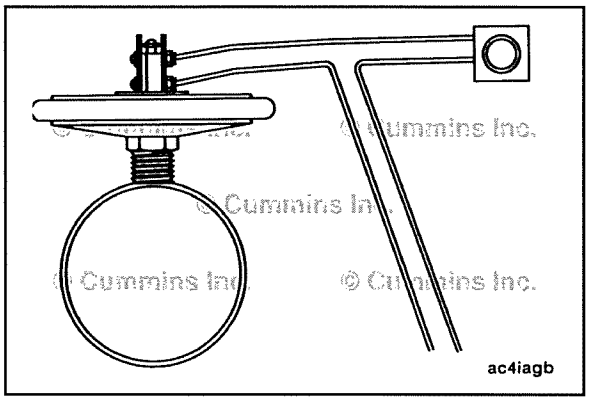
A mechanical restriction indicator is available to indicate excessive air restriction through a dry-type air cleaner. This instrument can be mounted in the air cleaner outlet or on the instrument panel. The red flag (1) in the window gradually rises as the cartridge loads with dirt. After changing or replacing the cartridge, reset the indicator by pushing the reset button (2).

Restriction or vacuum indicators need to be installed as close as possible to the turbocharger air inlet in order to obtain a true indication of restrictions.



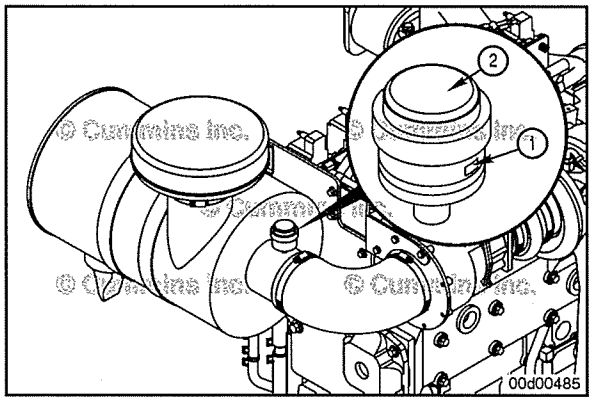
Vacuum Indicator

Vacuum switches actuate a warning light on the instrument panel when the air restriction becomes excessive.



Industrial Gas Mechanical Indicator

A mechanical restriction indicator is available to indicate excessive air restriction through a dry-type air cleaner. This instrument is mounted in the air cleaner outlet. The red flag (1) in the window gradually rises as the cartridge loads with dirt. When air restriction is indicated the air filter **must** be replaced. After changing or replacing the cartridge, reset the indicator by pushing the reset button (2)



Dust Ejection Valve

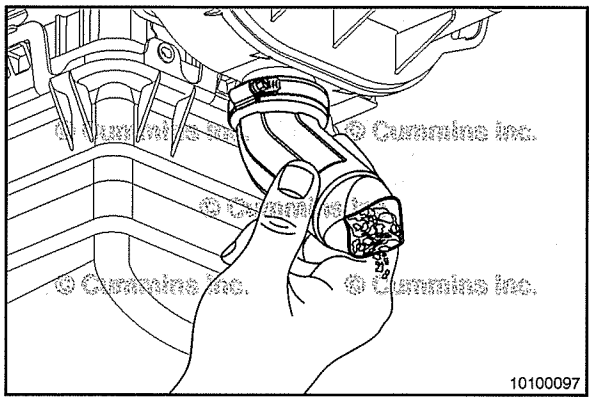
General Information

The dust ejection valve is a thin flexible rubber boot located at the bottom of the pre-cleaner on the air cleaner assembly. It is used to accumulate and remove dust ejected from the pre-cleaner.

If an application is equipped with a pre-cleaner exhaust aspirator, a dust ejection valve will **not** be present, as the aspirator takes place of the dust ejection valve.

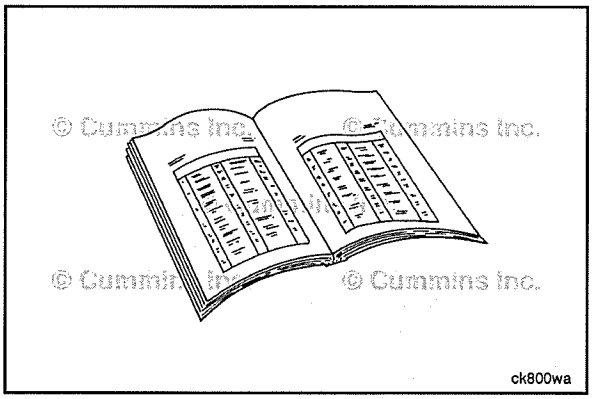
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Do **not** operate the engine without a dust ejection valve or exhaust aspirator. The pre-cleaner efficiency will be greatly reduced and may result in shortened filter element life.



Clean

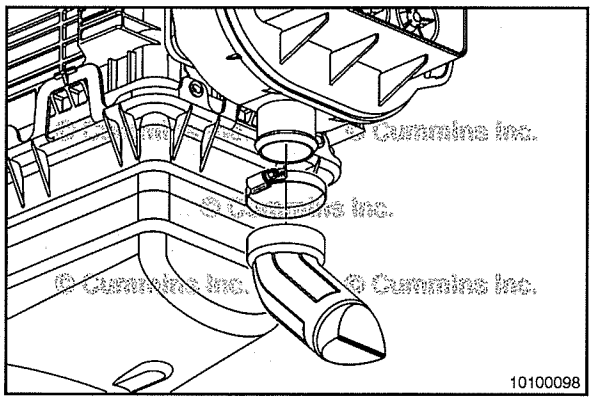
Purge the dust ejection valve of dust by squeezing the valve until it opens. This may have to be performed multiple times depending on the severity of dust or debris found in the valve. If debris is **not** able to be purged from the valve, remove the valve and clean out by hand. See the Remove section.



Preparatory Steps

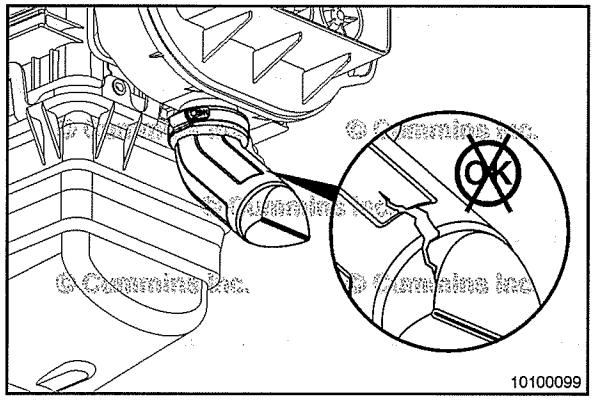
NOTE: Before servicing any intake air system component, (such as the air cleaner, pre-cleaner, hoses, ducting, etc.), clean the fittings, mounting hardware, and the area around the component to be removed.

- Shut the engine OFF.



Remove

Remove the dust ejection valve from the pre-cleaner by loosening the hose clamp, if present, then rotating and pulling downward on the dust ejection tube.



Inspect for Reuse

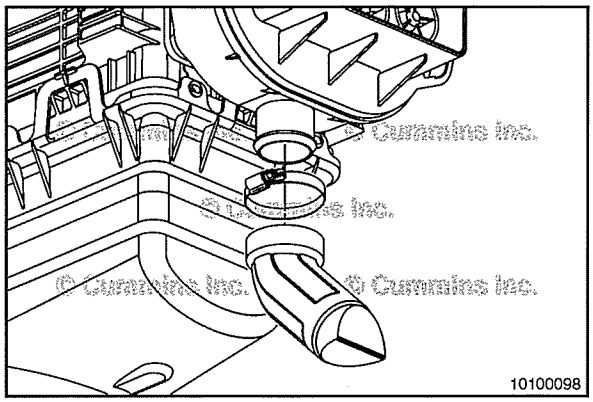
Inspect the dust ejection valve for cuts and tears. Replace the valve if damage is found.

Install



Install the dust ejection valve on the pre-cleaner by attaching the hose clamp, if present. Tighten the hose clamp.

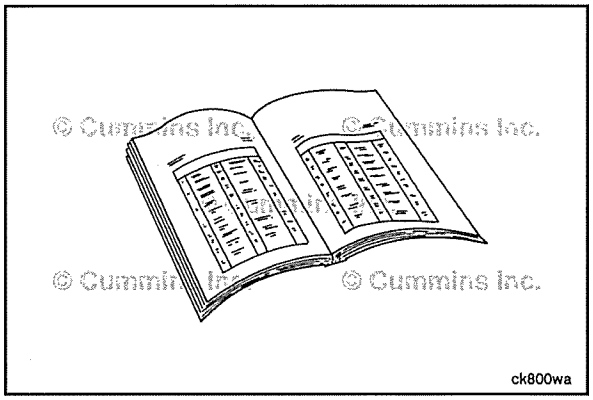
Torque Value: 5 N•m [44 in-lb]



Finishing Steps



- Start the engine.
- Check for leaks.



Aftertreatment Exhaust Piping

Maintenance Check



Inspect the exhaust piping for leaks, cracks, and loose connections.

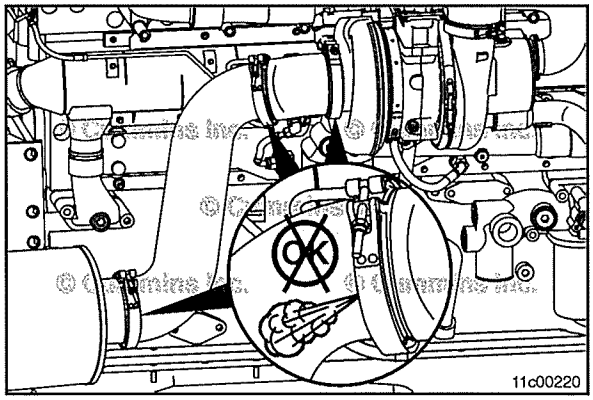


Inspect for leaks at all clamped locations.



Tighten the pipe clamps, if necessary.

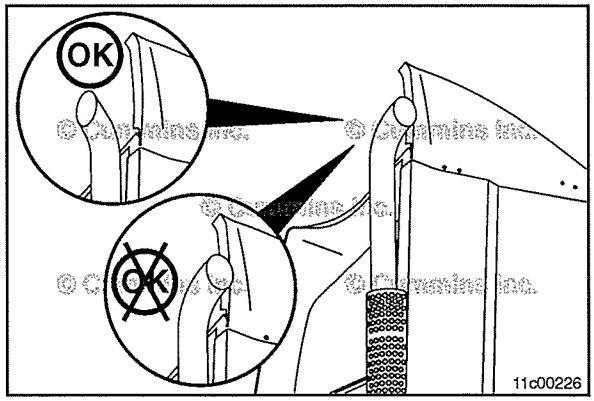
See equipment manufacturer service information for the correct torque value.

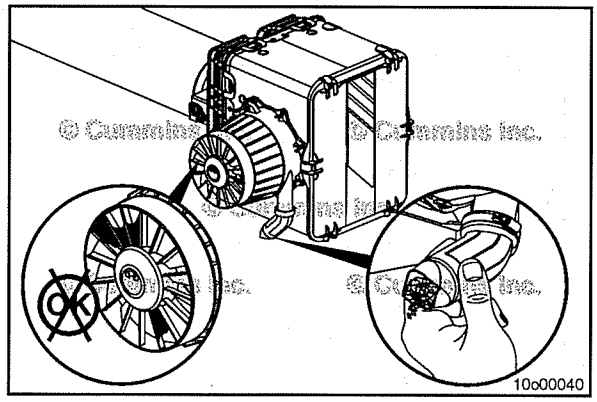




Inspect the exhaust stack piping on trucks for proper orientation.

Correct, if **not** oriented correctly.

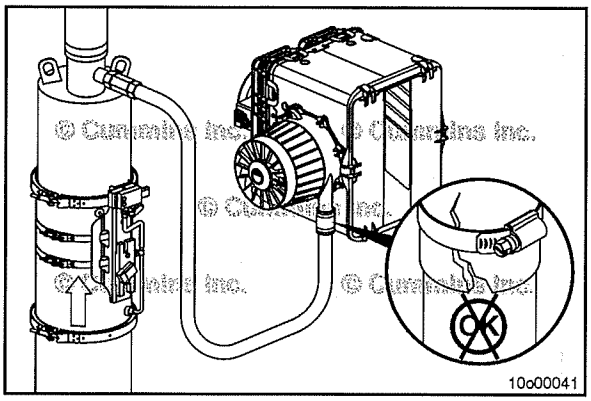




Inspect the exhaust aspirator, if equipped, for debris. Clean the aspirator, if necessary.

Inspect the exhaust diffuser, if equipped, for debris. Clean the diffuser, if necessary.

Inspect the aftertreatment system for debris. Clean the system, if necessary.

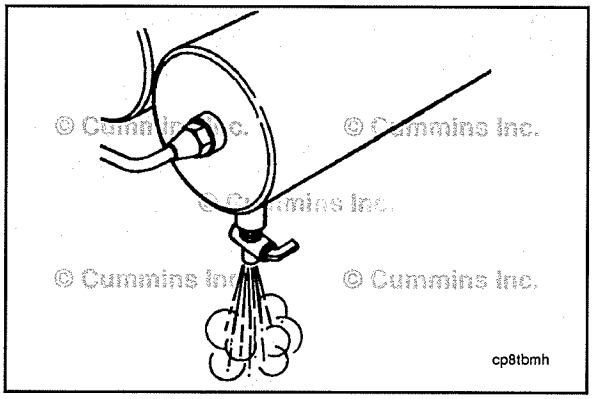


If equipped, inspect the exhaust aspirator piping for leaks, cracks, or loose connections.

Tighten the clamps, if necessary.

See equipment manufacturer service information for the correct torque value.

NOTE: Vacuum leaks in the exhaust aspirator piping can reduce the ability of the air cleaner precleaner to remove debris from the intake air, which can lead to early or frequent air filter plugging.



Air Tanks and Reservoirs

Drain

If automatic purging or spitter valves are used, confirm the valves are operating correctly. If a manual drain valve is used on the wet tank, open the draincock on the wet tank to drain any moisture accumulated in the air system. If oil is present, the air compressor system **must** be checked. Contact your Cummins Authorized Repair Location.

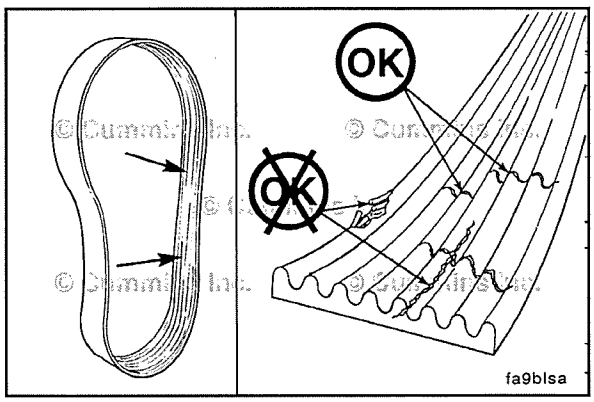
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Drive Belts

Maintenance Check

Poly-Vee Belt





⚠CAUTION⚠
Make sure that the engine is switched off and any starting mechanisms are isolated before any inspections are made. Daily belt inspections can be carried out through an appropriate aperture. Do not remove any guards.

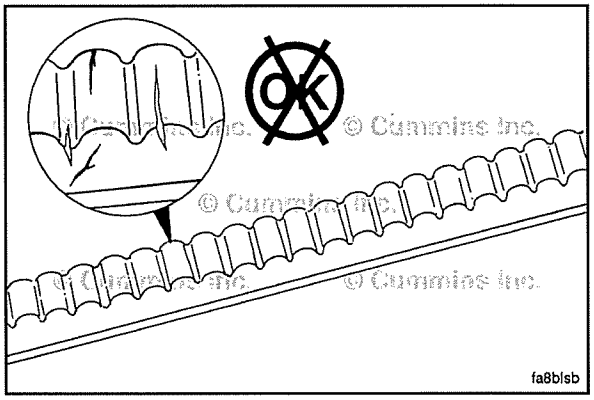
Inspect the belts daily. Check the belt for intersecting cracks. Traverse (across the belt width) cracks are acceptable. Longitudinal (direction of belt length) cracks that intersect with transverse cracks are **not** acceptable. Replace the belt if it is frayed or has pieces of material missing. Refer to Section A for belt adjustment and replacement procedures.

Belt damage can be caused by:

- Incorrect tension
- Incorrect size or length
- Pulley misalignment
- Incorrect installation
- Severe operating environment
- Oil or grease on the side of belts.

Cogged Belt





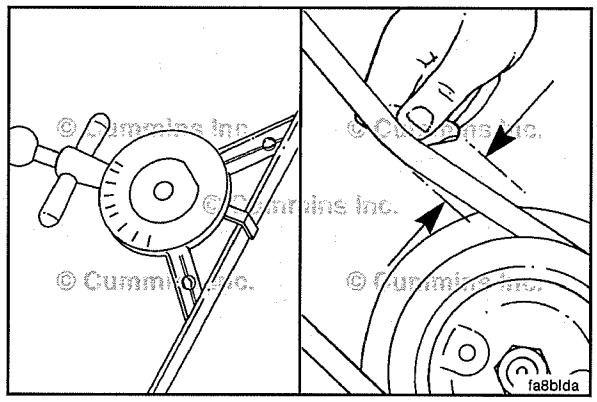
Inspect the belts daily. Replace the belts if they are cracked, frayed, or have chunks of material missing. Small cracks are acceptable.

Adjust the belts that have a glazed or shiny surface, which indicates belt slippage. Correctly installed and tensioned belts will show even pulley and belt wear. Refer to Section A for belt adjustment and replacement procedures.

Belt damage can be caused by:

- Incorrect tension
- Incorrect size or length
- Pulley misalignment
- Incorrect installation
- Severe operating environment
- Oil or grease on the belts

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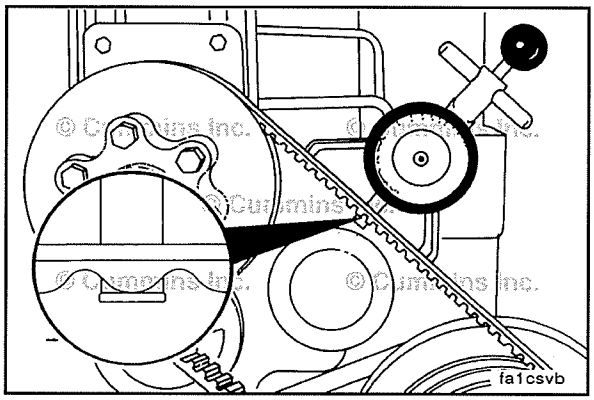


Measure the belt tension in the center span of the pulleys.

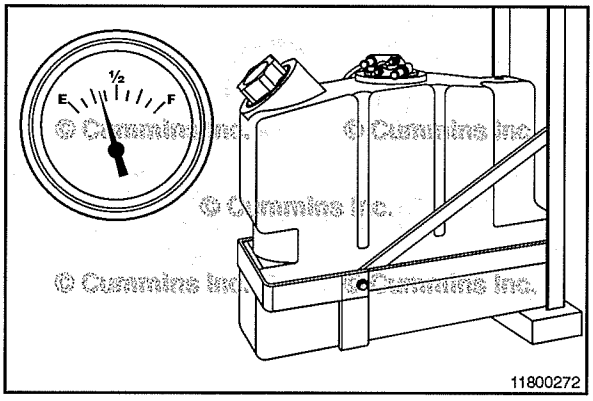
Refer to the Belt Tension Chart in Section V for the correct gauge and tension value for the belt width used.

An alternate method (deflection method) can be used to check belt tension by applying 110 N [25 lbf] force between the pulleys on v-belts. If the deflection is more than one belt thickness per foot of pulley center distance, the belt tension **must** be adjusted.

Refer to Section A for adjustment procedures.



For cogged belts, **make sure** that the belt tension gauge is positioned so that the center tensioning leg is placed directly over the high point (hump) of a cog. Other positioning will result in incorrect measurement.



Diesel Exhaust Fluid (DEF) Level

Maintenance Check

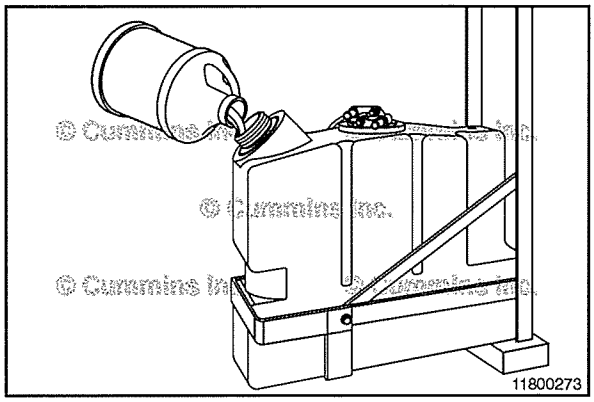
The Diesel Exhaust Fluid level **must** be checked daily.

⚠WARNING⚠
Do not allow Diesel Exhaust Fluid to contact the eyes. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. Avoid prolonged contact with skin. In case of contact, immediately wash skin with soap and water. Do not swallow internally. In the event the Diesel Exhaust Fluid is ingested, contact a physician immediately.

⚠CAUTION⚠
It is unlawful to tamper with or remove any component of the aftertreatment system. It is also unlawful to use a catalyst solution that does not meet the specifications provided or to operate the vehicle/ equipment with no catalytic solution.

If the Diesel Exhaust Fluid level is found to be low, Diesel Exhaust Fluid **must** be added.

Refer to the OEM service manual for Diesel Exhaust Fluid level check and fill instructions.



Notes

Section 4 - Maintenance Procedures at 250 Hours or 6 Months

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Pressure Fuel Filter 4-1
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Install....4-2
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Remove....4-2

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Maintenance Procedures - Overview

General Information

All maintenance checks and inspections listed in previous maintenance intervals **must** also be performed at this time, in addition to those listed under this maintenance interval.

Pressure Fuel Filter

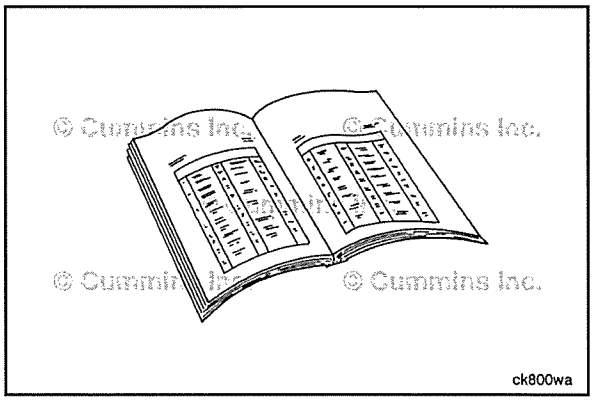
General Information

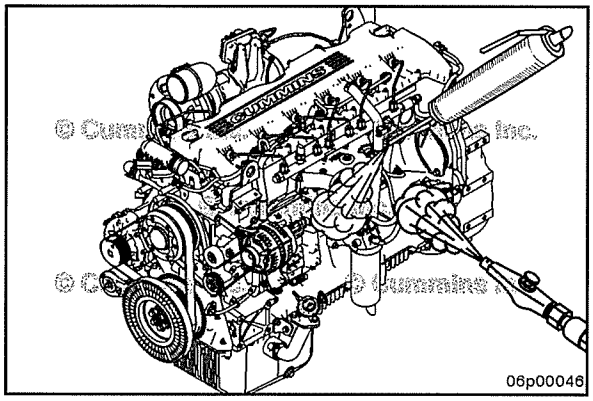
Use **only** the Cummins Inc. recommended fuel filter of the correct part number for this application.

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.



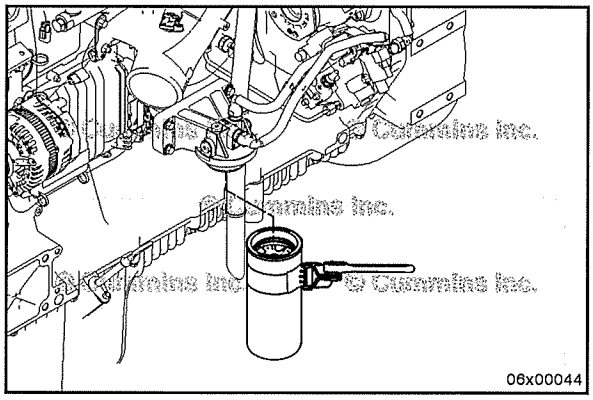


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠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.

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 fuel filter head connections, fittings, and mating components with contact cleaner, Part Number 3824510, or equivalent.



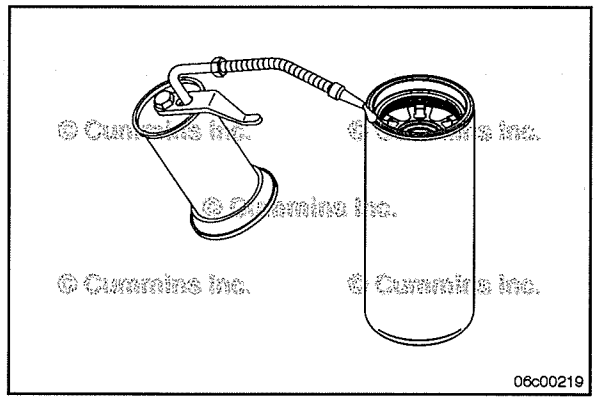
Remove

⚠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.

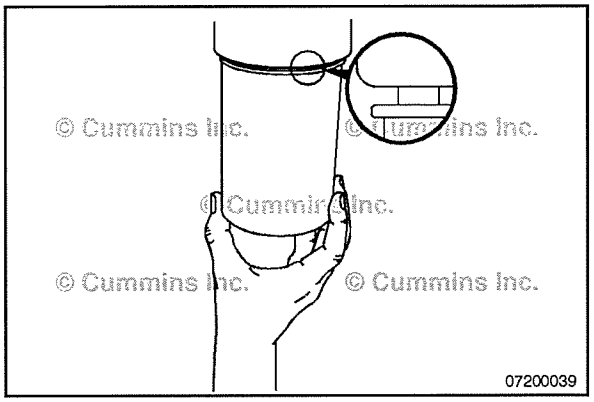


Install

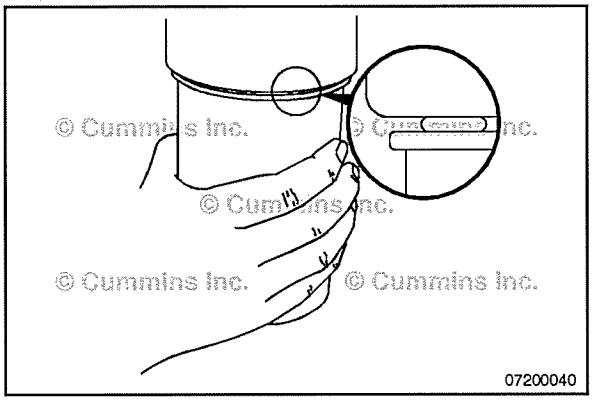
Apply a thin coating of clean engine oil to the filter gasket surface and the center seal.

⚠CAUTION⚠
Mechanical over tightening of the filter can distort the threads and damage the fuel filter seal.

Install filter onto the filter head. Turn the filter until the gasket contacts the filter head surface.



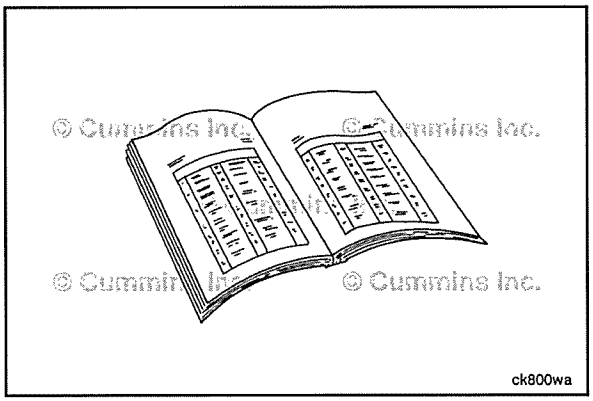
Tighten filter an additional 3/4 of a turn after the gasket contacts the filter head surface, or as specified by the filter manufacturer.

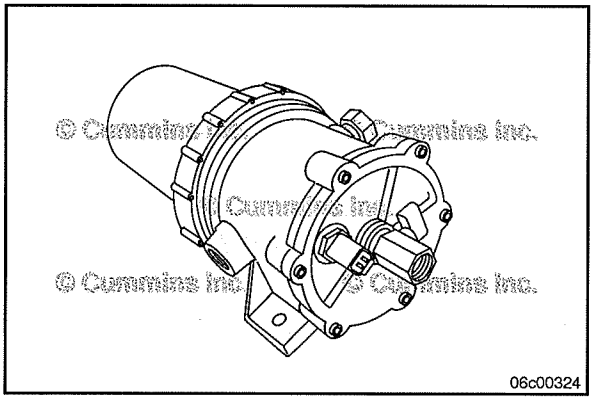


Finishing Steps

⚠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.
- Prime the fuel system. Refer to Procedure 005-234 in Section A.
- Operate the engine and check for leaks.





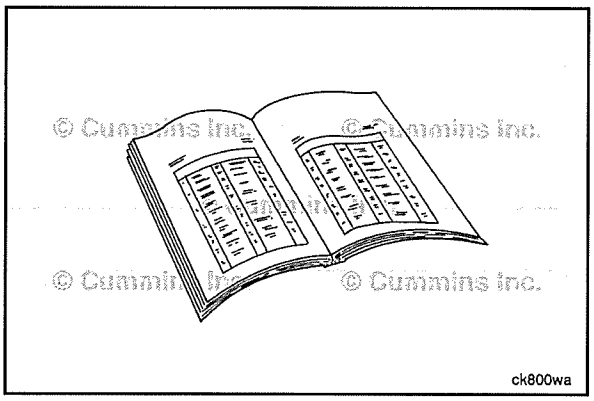
Fuel Filter Suction

General Information

The fuel system requires the use of two fuel filters. An equivalent suction fuel filter can be used, but it **must** meet or exceed the following characteristics:

- Remove a minimum of 95 percent of free and emulsified water
- NanoNet™ media with Beta Ratio (filtration efficiency) rating of ß5(C)=75, or equivalent, is recommended in order to extend fuel filter service intervals, but a minimum of 7-micron rating at 98.7 percent efficiency is required
- Water-in-fuel sensor with shunt resistor
- Water drain valve

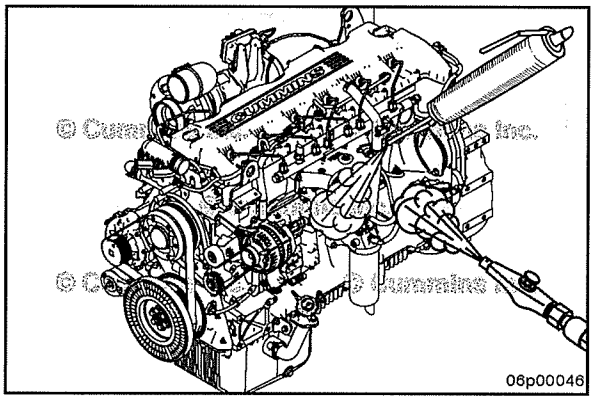
See equipment manufacturer service information for more information on the suction side fuel filter.



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.



⚠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△
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 fuel filter head with Cummins® contact cleaner, Part Number 3824510, or equivalent.

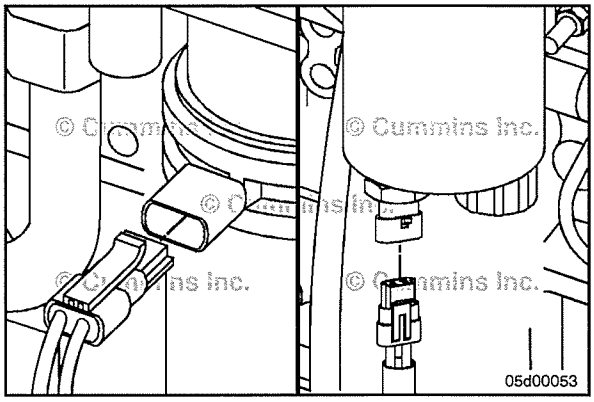
Remove



⚠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.

See equipment manufacturer service information for information regarding the removal of the suction side fuel filter.

NOTE: Suction-side fuel filters are OEM supplied. See equipment manufacturer service information for appropriate service intervals.

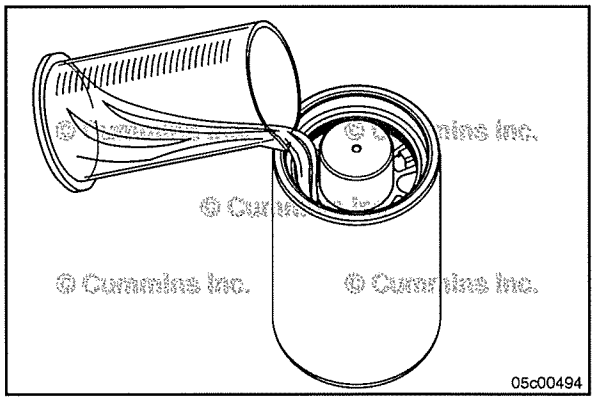


Install



Use the correct filter(s) for your engine. The suction side fuel filter **must** remove a minimum of 95 percent of free and emulsified water. It **must** also have a 5-micron particle removal efficiency.

See equipment manufacturer service information for information regarding proper installation of the suction-side fuel filter.

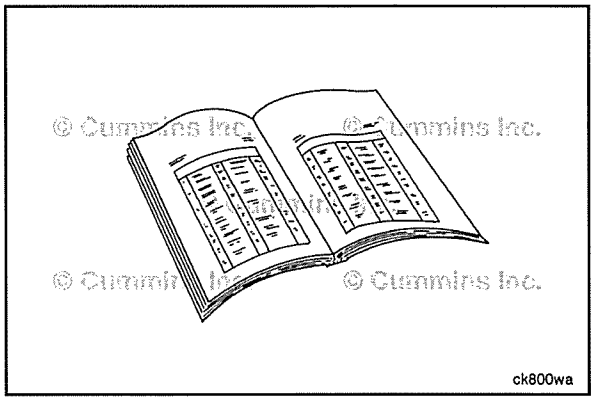


Finishing Steps



⚠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.
- Prime the fuel system. Refer to Procedure 005-234 in Section A.
- Operate the engine and check for leaks.



Notes

Section 5 - Maintenance Procedures at 500 Hours or 6 Months

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Maintenance Procedures - Overview

General Information

All maintenance checks and inspections listed in previous maintenance intervals **must** also be performed at this time, in addition to those listed under this maintenance interval.

Lubricating Oil and Filters

Drain

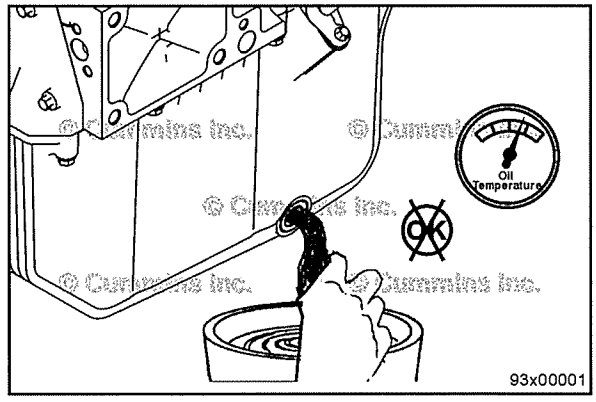
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

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

Operate the engine until the water temperature reaches 60°C [140°F].

Shut the engine OFF.

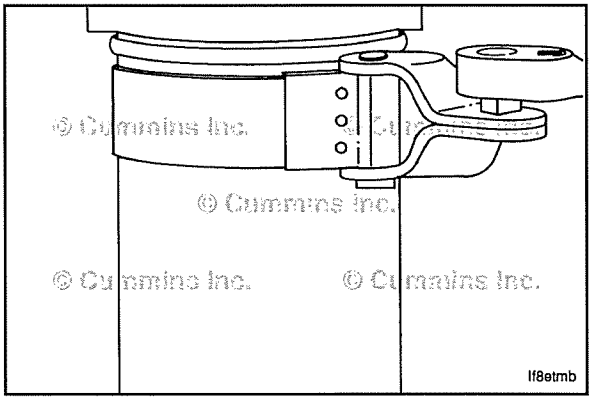
Remove the oil drain plug from the oil pan sump. Drain the oil immediately to make sure all the oil and suspended contaminants are removed from the engine.

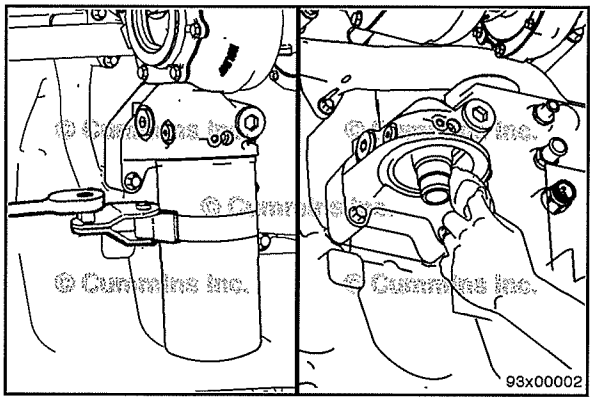


Remove

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

Remove the lubricating oil filter.

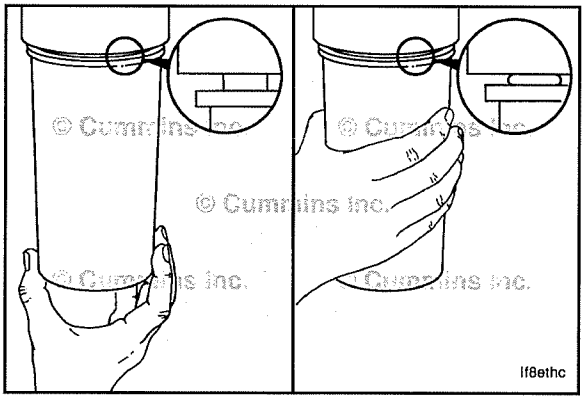




Clean the area around the lubricating oil filter head.

Use oil filter wrench, Part Number 3400157, to remove the oil filter.

Clean the gasket surface of the oil filter head. The o-ring can stick on the filter head. Be sure it is removed.



Install

⚠CAUTION⚠

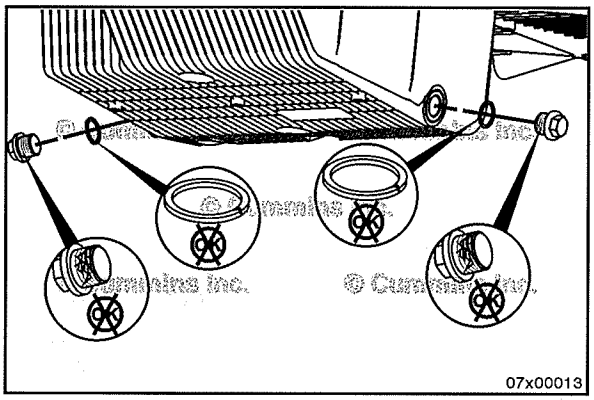
Mechanical overtightening can distort the threads or damage the filter element seal.

NOTE: Lubricate the gasket with clean 15W-40 engine oil before installing.

Fill and install the lubricating oil filter.

Install the oil filter onto the oil filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten the filter an additional 3/4 to 1 turn, or follow the instructions supplied with the filter.



Fill

Clean and check the lubricating oil drain plug threads and sealing surface. Use new sealing washer, if damaged.

Install the lubricating oil pan drain plug.

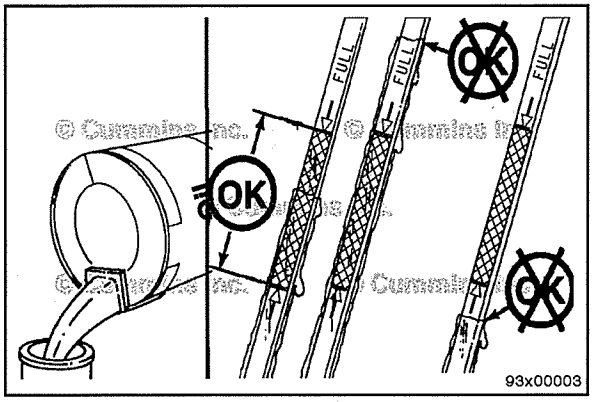
Torque Value:
Plastic Oil Pan Drain Plug 28 N•m [21 ft-lb]



NOTE: Use a high-quality multiviscosity lubricating oil, such as Valvoline Premium Blue™, or its equivalent in Cummins® engines. Choose the correct lubricating oil for your operating climate as outlined in Section V.

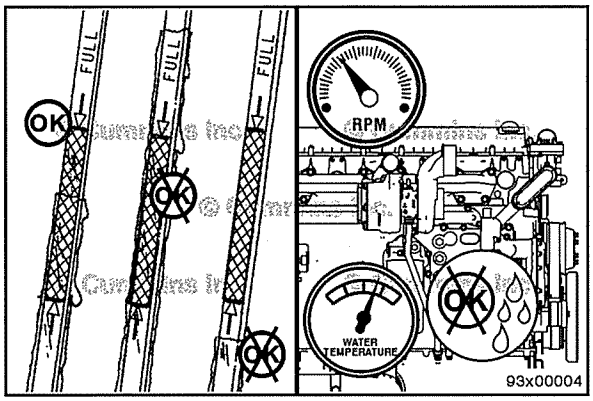
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Add the specified amount of clean oil to fill the oil pan. Refer to Procedure 018-017 in Section V.



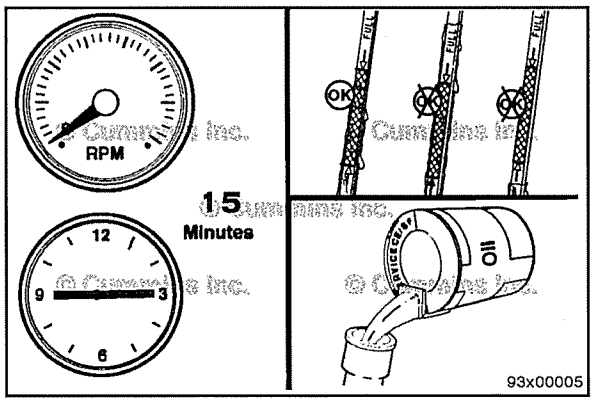
Check the oil level on the dipstick. It **must** be filled to the "Full" mark.

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



Shut the engine OFF. Wait approximately 15 minutes for the oil to drain back to the oil pan.

Check the oil level again. Add oil as necessary to bring the level up to the "Full" mark on the dipstick.

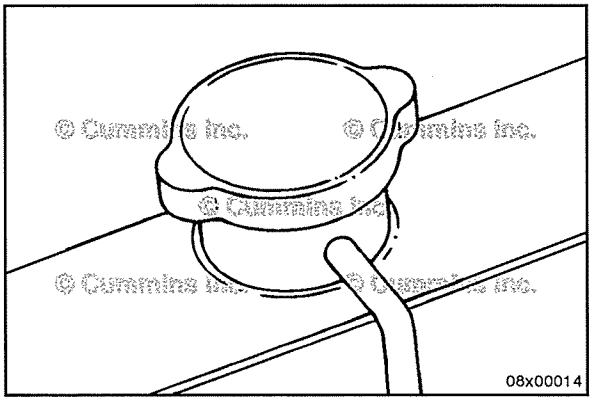


Radiator Pressure Cap

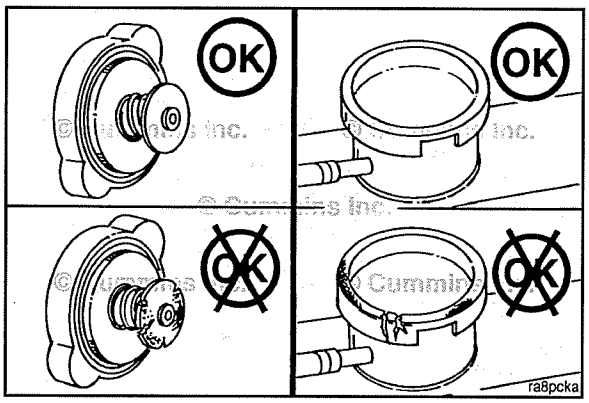
General Information

The cooling system is designed to use a pressure cap to prevent boiling of the coolant. See equipment manufacturer service information's cooling system specifications for the correct radiator pressure cap for a specific engine application.

An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.



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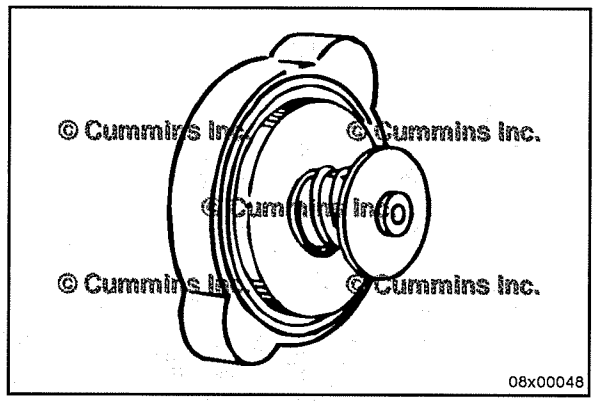
Inspect for Reuse

Make sure the correct radiator pressure cap is being used.

Inspect the rubber seal of the pressure cap for damage.

Inspect the radiator fill neck for cracks or other damage.

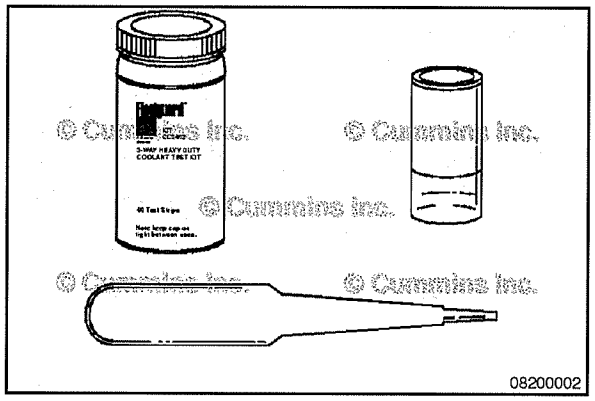
See equipment manufacturer service information for instructions if the fill neck is damaged.



Pressure-test the radiator cap. See equipment manufacturer service information for radiator cap test procedures.

The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.

An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.



Supplemental Coolant Additive (SCA) and Antifreeze Concentration

Maintenance Check

Supplemental Coolant Additive (SCA)

⚠CAUTION⚠

Failing to maintain the required SCA concentration level can cause engine damage.

Check the SCA concentration level

- At least twice a year
- At every subsequent oil drain interval if the concentration is above 3 units
- Whenever coolant is added to the cooling system between filter changes.

Use Fleetguard® coolant test kit, Part No. CC2602, to check the SCA concentration level. Instructions are included with the test kit. Use the Coolant Recommendations and Specifications in Maintenance Specifications (Section V) for the correct SCA and antifreeze level.

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Antifreeze

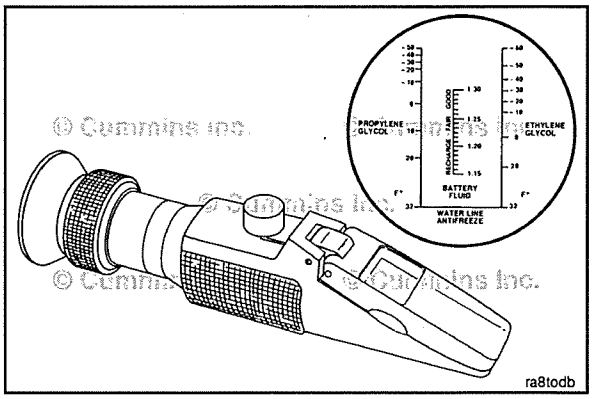


⚠CAUTION⚠

Overconcentration of antifreeze or use of high-silicate antifreeze can damage the engine.

Check the antifreeze concentration. Use a mixture of 50-percent water and 50-percent ethylene glycol or propylene glycol-based antifreeze to protect the engine to -32°C [-26°F] year-around.

The Fleetguard® refractometer, Part Number C2800, provides a reliable, easy-to-read, and accurate measurement of freezing point protection and glycol (antifreeze) concentration.



Antifreeze is essential in every climate.

Antifreeze broadens the operating temperature range by lowering the coolant freezing point and by raising its boiling point.

The corrosion inhibitors also protect the cooling system components from corrosion and prolong component life.

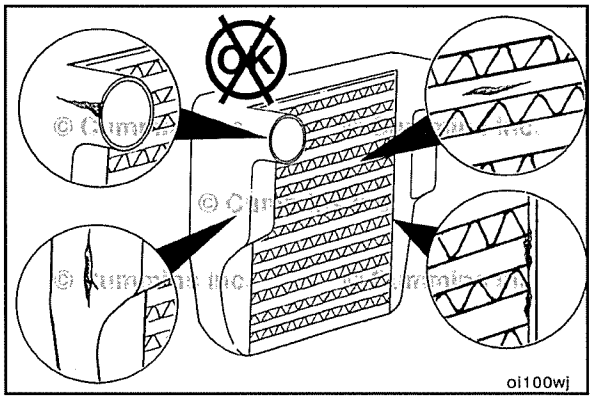
Charge-Air Cooler

Maintenance Check





Inspect the charge-air cooler (CAC) for dirt and debris blocking the fins. Check for cracks, holes, or other damage. If damage is found, refer to the vehicle, vessel, or equipment manufacturer.



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Notes

Section 6 - Maintenance Procedures at 1000 Hours or 1 Year

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Maintenance Procedures - Overview

General Information

All maintenance checks and inspections listed in previous maintenance intervals **must** also be performed at this time, in addition to those listed under this maintenance interval.

Aftertreatment Diesel Exhaust Fluid Tank Filter

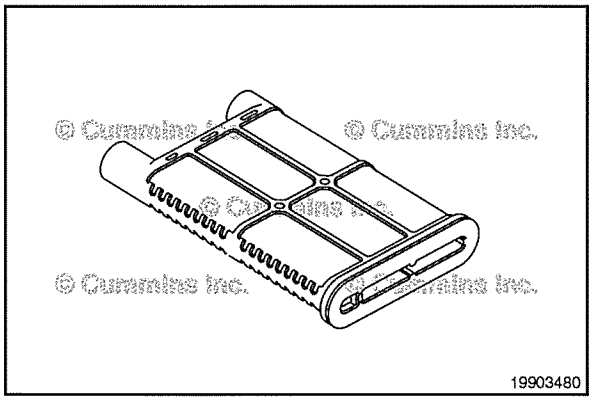
General Information

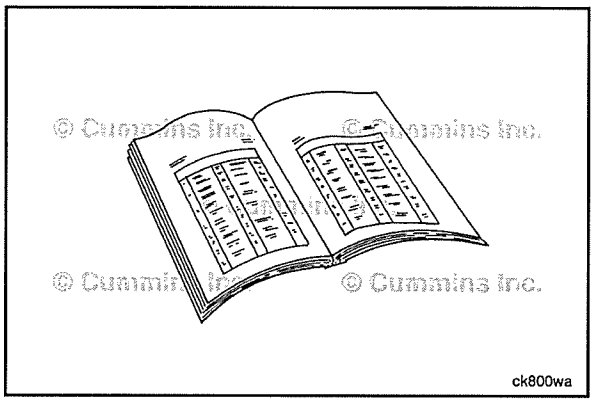
The diesel exhaust fluid (DEF) tank filter is designed to prevent foreign objects that may be suspended in the DEF from entering the dosing system. See equipment manufacturer service information for the maintenance interval for the application.

NOTE: The vehicle may be equipped with a different DEF tank filter. The illustration is for reference only.

NOTE: See equipment manufacturer service information for the DEF tank filter service interval. For Cummins® provided DEF tanks, filter replacement is recommended every 2000 hours or one year, whichever occurs first. For dusty environments, inspect the filter every 1000 hours and replace if dirty. For low dust environments, such as paved road or indoor equipment, the recommended interval is 4500 hours or three years, whichever occurs first.

For handling incorrect or contaminated DEF, contact a Cummins® Authorized Repair Location.





Preparatory Steps

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

⚠WARNING⚠
The coolant line(s) can be hot and under pressure. Do not disconnect the coolant lines while the engine is running or before the system has cooled down after engine shutdown. Heated coolant spray can cause personal injury. To reduce the possibility of personal injury, use eye and face protection, gloves and appropriate personal protective equipment.

⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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△
Do not pressure wash or steam clean this unit. Pressure washing or steam can damage the unit. Use compressed air to remove any loose debris.

△CAUTION△
Make sure the environment is smoke and dust free. Contamination in the DEF tank can cause damage to the aftertreatment DEF dosing unit.

NOTE: Do **not** disconnect the vehicle batteries until the DEF dosing system has completed the purge cycle.

- Disconnect the batteries. See equipment manufacturer service information.
- Remove the DEF tank level and temperature sensor. See equipment manufacturer service information.

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Remove

Use a clean, damp cloth to clean the area.

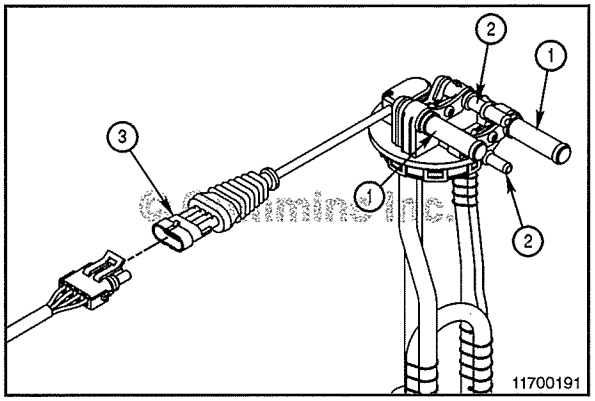
Disconnect the DEF tank assembly.

1 Coolant supply and return

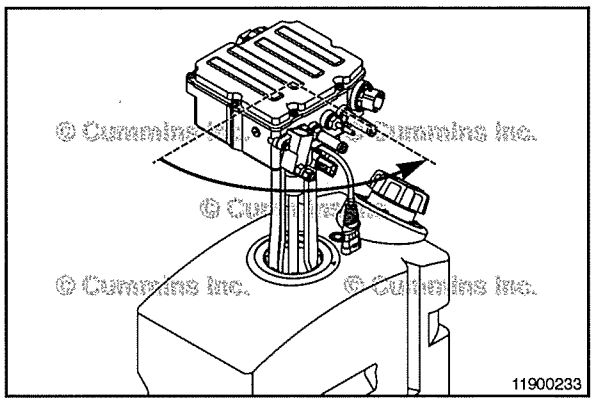
2 DEF supply and return

3 DEF electrical connector last, to prevent accidental contamination.

Cap the open plumbing and electrical connectors to prevent contamination.



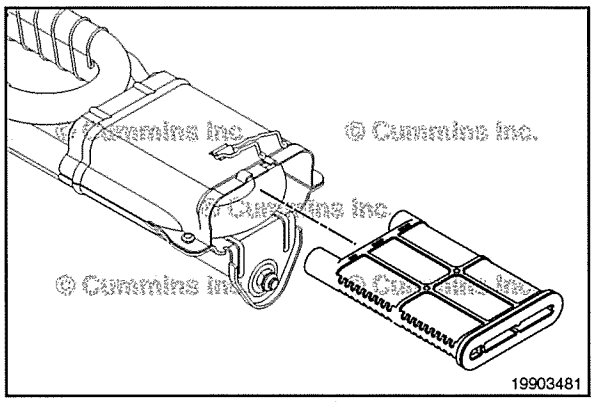
Remove the DEF level and temperature sensor assembly from the DEF tank. Rotate **counterclockwise** a quarter turn.



Disassemble

Unlatch the buckle from the DEF tank filter manifold.

Remove the DEF tank filter.

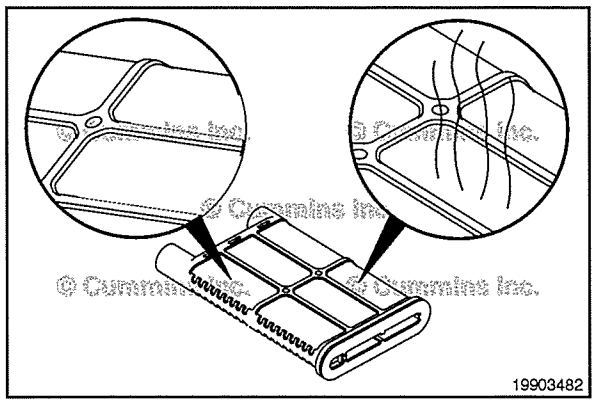


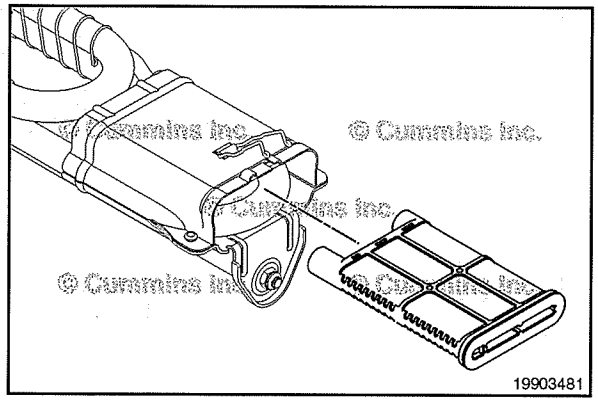
Clean and Inspect for Reuse

Inspect the DEF tank filter for evidence of contaminated DEF. If contamination is evident, contact a Cummins® Authorized Repair Location.

Inspect the DEF tank filter for evidence of debris. If debris is evident, inspect the DEF dosing unit filter. Refer to Procedure 011-060 in Section 8.

Discard the DEF tank filter.

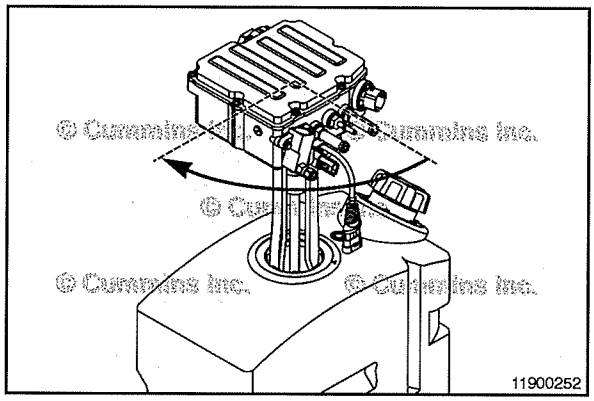




Assemble

Insert the DEF tank filter into the DEF tank filter manifold.

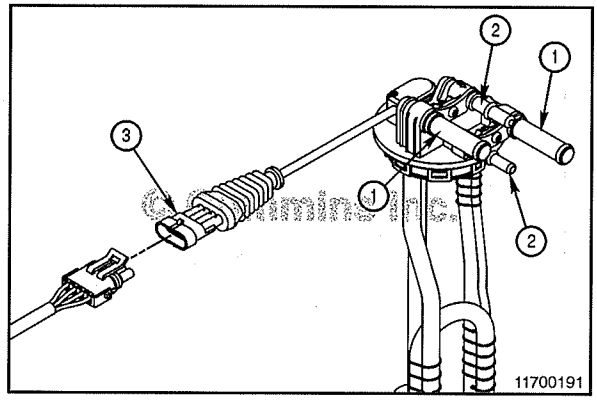
Latch the buckle to secure the filter.



Install

Insert the DEF level and temperature sensor assembly into the DEF tank.

Align the tank mount adapter teeth with the DEF tank opening teeth. Once aligned, rotate the DEF level and temperature sensor assembly **clockwise**.



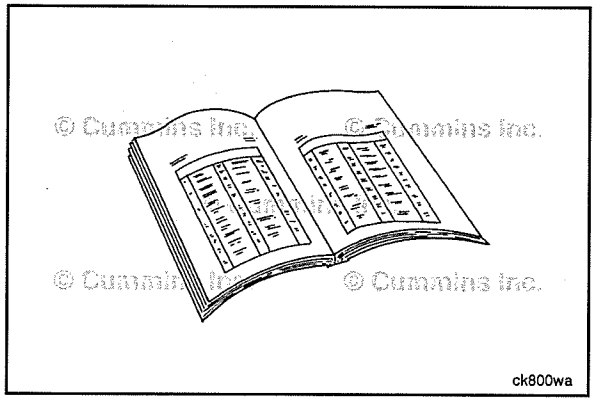
Remove caps from the plumbing and electrical connectors.

Connect the DEF tank assembly in the following order:

1 DEF electrical connector (3) first, to prevent accidental contamination

2 DEF supply and return (2)

3 Coolant supply and return (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 DEF tank level and temperature sensor. See equipment manufacturer service information.
- Check the coolant level sensor. Refer to Procedure 008-066 in Section 3.
- Connect the batteries. See equipment manufacturer service information.

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Section 7 - Maintenance Procedures at 1500 Hours or 1 Year

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Maintenance Procedures - Overview

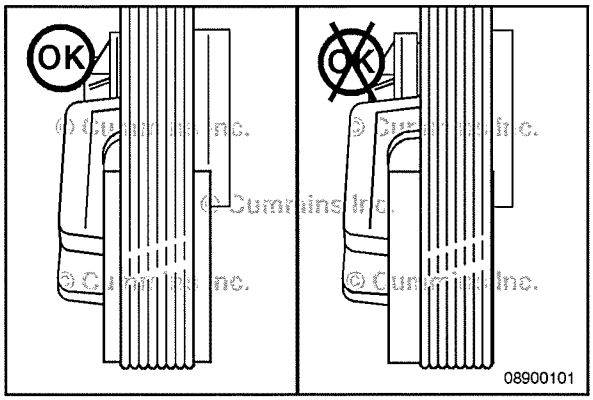
General Information

All maintenance checks and inspections listed in previous maintenance intervals **must** also be performed at this time, in addition to those listed under this maintenance interval.

Cooling Fan Belt Tensioner

Initial Check

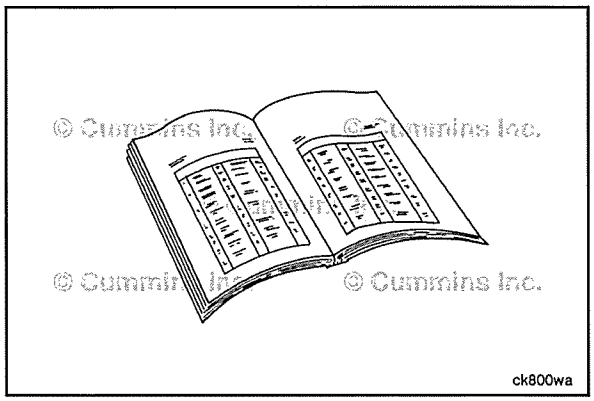
Check the location of the drive belt on each belt tensioner pulley. The belt should be centered on, or close to the middle of, the pulley. Misaligned belts, either too far forward or backward, can cause belt wear, belt roll-off failures, or increase uneven tensioner bushing wear.



Preparatory Steps

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

- Disconnect the batteries. See equipment manufacturer service information.



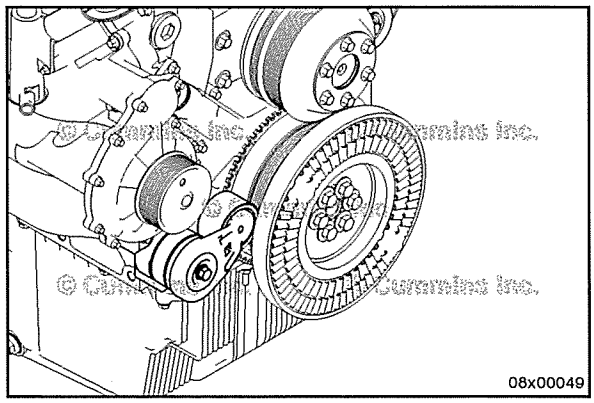
Remove

Remove the drive belt. Refer to Procedure 008-002 in Section A.

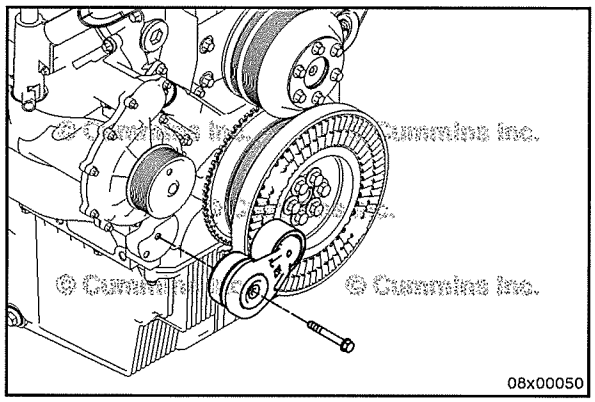
If the belt can be removed without pivoting the tensioner, then the spring in the tensioner has failed. Replace tensioner.

If the tensioner touches its internal stops while unloading the belt, the tensioner has failed. Replace the tensioner.

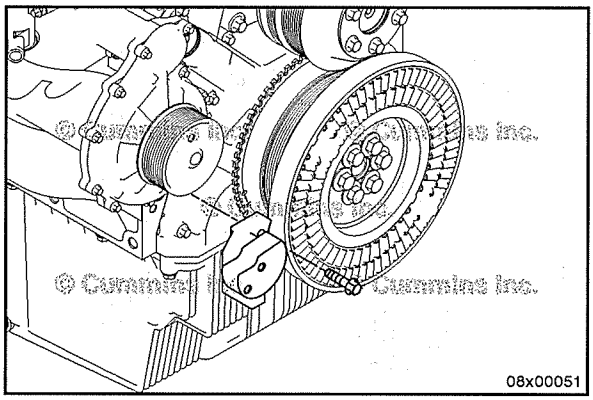
While tensioner is still on the engine, pivot the tensioner through the full range of motion. Tensioner **must** move with resistance from internal spring, if **not** replace tensioner.



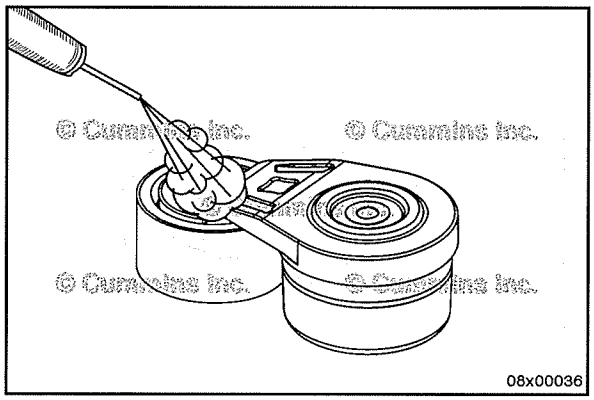
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Remove the capscrew and belt tensioner from the bracket.



Remove the capscrews and bracket from engine.

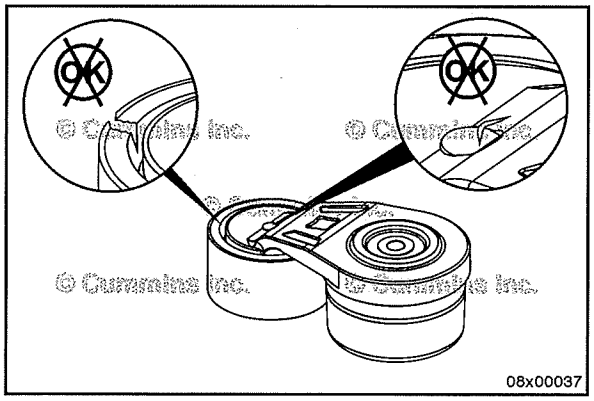


Clean and Inspect for Reuse

⚠WARNING⚠
The belt tensioner is spring loaded. Do not attempt to disassemble the tensioner. Personal injury can result.

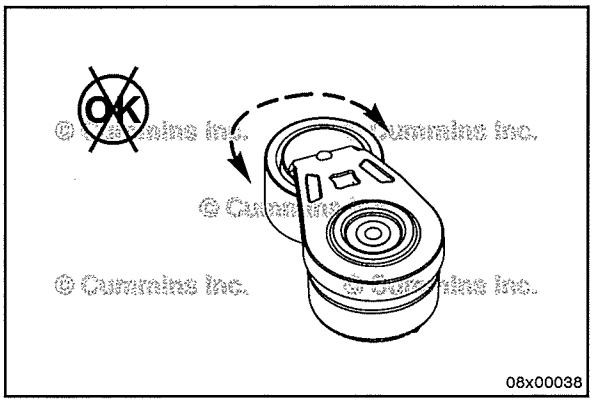
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Check the tensioner for dirt buildup. If tensioner has dirt buildup, remove and use safety solvent to clean belt tensioner.

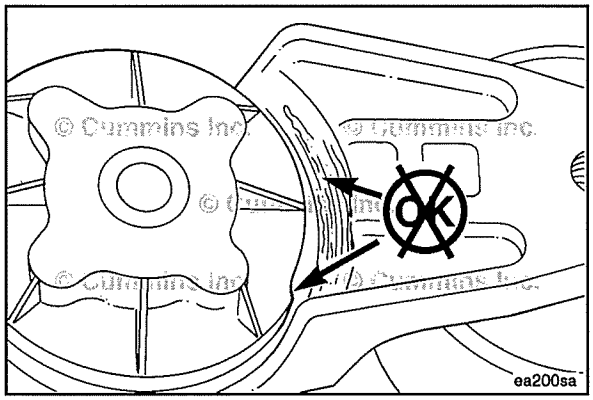


Check the belt tensioner pulley and body for cracks. If cracks are found, replace the tensioner.

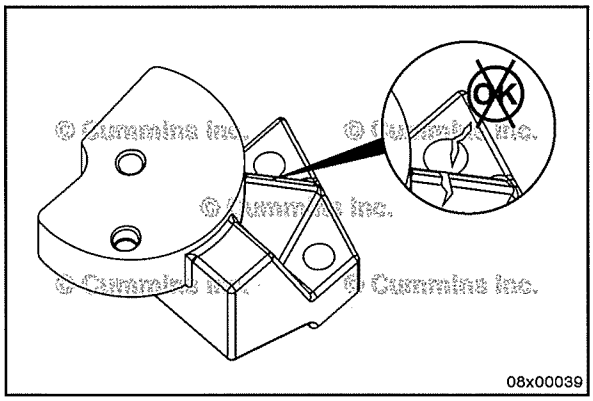
Spin the tensioner pulley. The pulley **must** spin freely. If pulley does **not** spin freely, replace the belt tensioner.



Inspect the belt tensioner for evidence of the tensioner pivoting arm contacting the stationary circular base of the tensioner or the fan shroud bracket. If so, the pivot bushing is excessive worn. Replace the belt tensioner.



Inspect bracket for cracks or damages. Replace if damaged.



Install

Install the fan shroud bracket and mounting bracket capscrews.

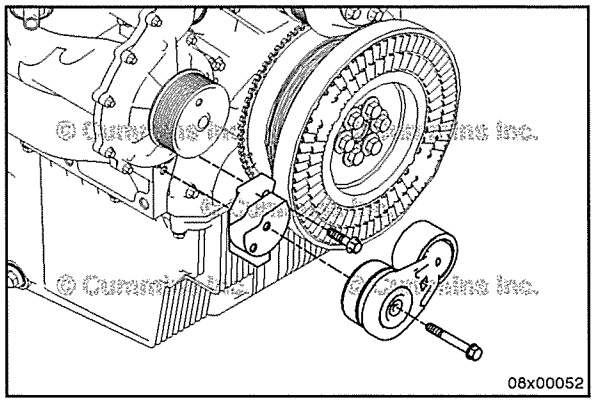
Tighten the capscrew.

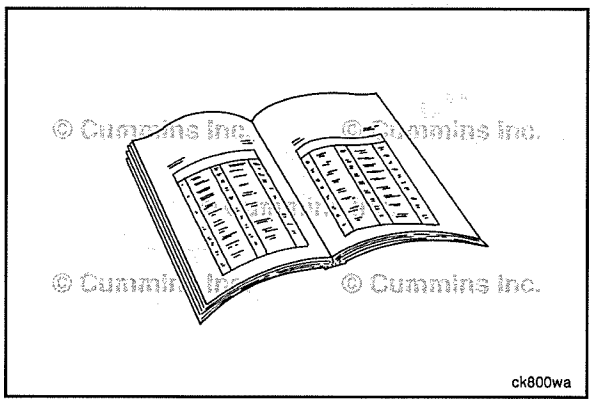
Torque Value: 55 N•m [41 ft-lb]

Install the belt tensioner and capscrew.

Tighten the capscrew.

Torque Value: 55 N•m [41 ft-lb]



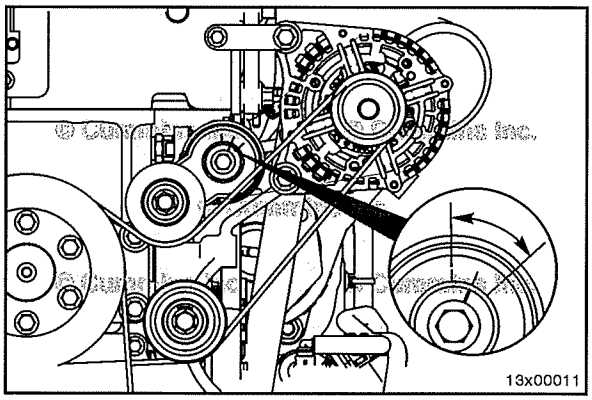


Finishing Steps

⚠WARNING⚠

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

- Install the drive belt. Refer to Procedure 008-002 in Section A.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for proper operation.

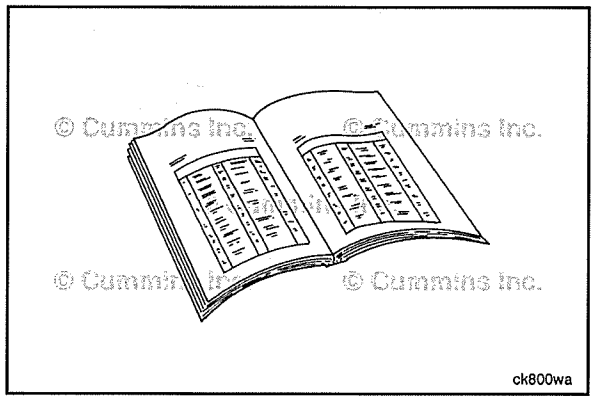


Charging System Alternator Automatic Belt Tensioner

Initial Check

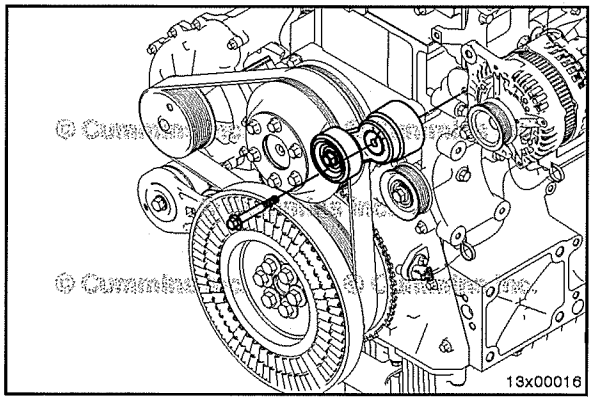
The tensioner has marks on the front to indicate tension. The middle of the three marks indicates proper tension.

If the tensioner marks indicate improper tension, check the mounting brackets and the belt length. Loose brackets, bracket failure, alternator movement, incorrect belt length, or belt failure can cause the tensioner to give improper tension.



Preparatory Steps

- Remove the cooling fan drive belt. Refer to Procedure 008-002 in Section A.
- Remove the alternator drive belt. Refer to Procedure 013-005 in Section A.



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.

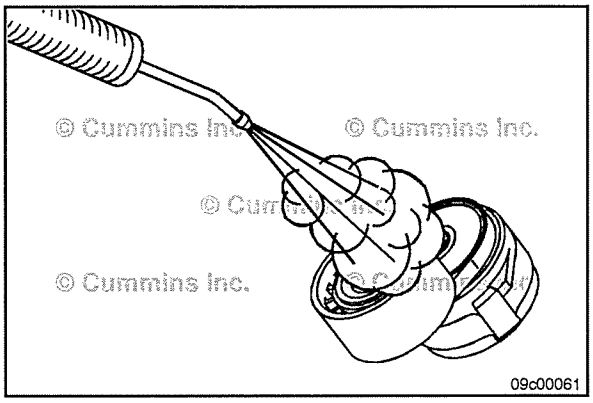
Remove the mounting capscrew and the belt tensioner from the bracket.

Clean and Inspect for Reuse

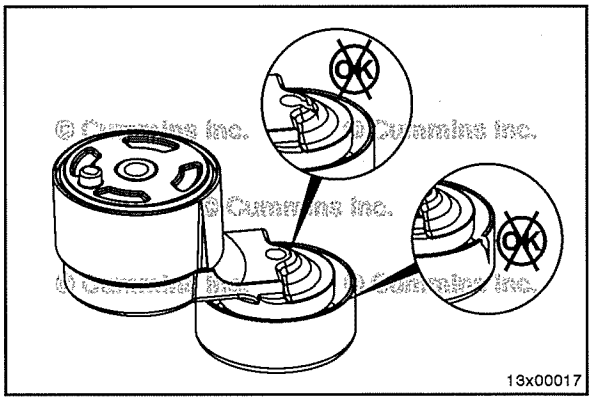
⚠WARNING⚠
The belt tensioner is spring loaded. Do not attempt to disassemble the tensioner. Personal injury can result.

⚠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.

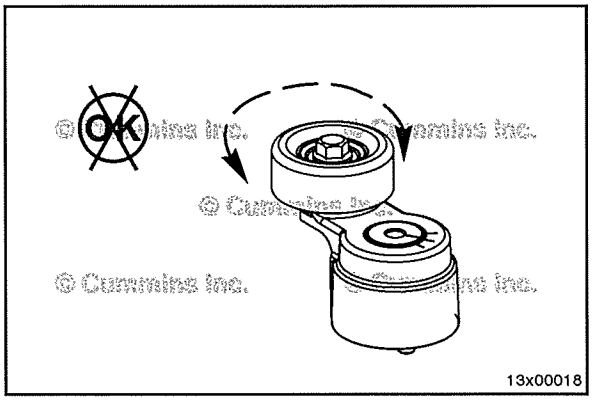
Check the tensioner for dirt buildup. If tensioner has dirt buildup, remove and use safety solvent to clean belt tensioner.



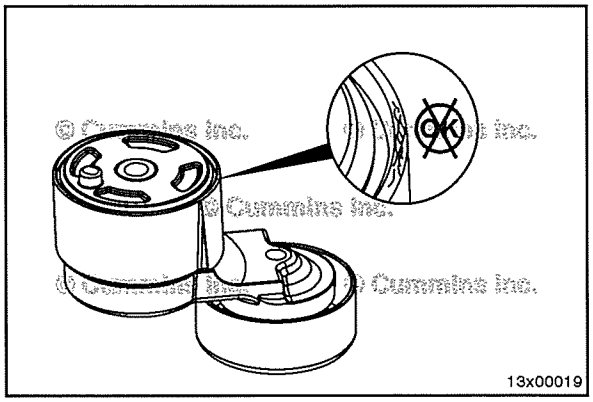
Check the belt tensioner pulley and body for cracks. If cracks are found, replace the tensioner.

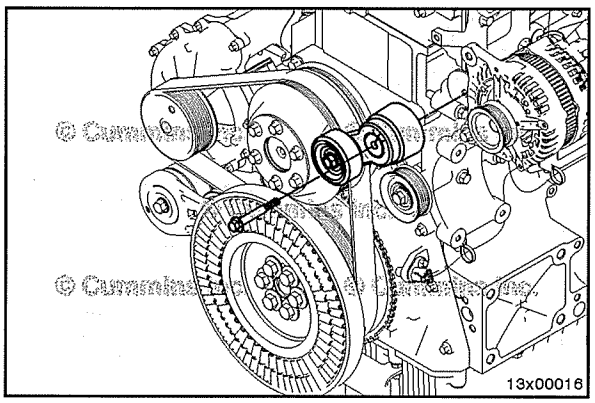


Spin the tensioner pulley. The pulley **must** spin freely. If pulley does **not** spin freely, replace the belt tensioner.



Inspect the belt tensioner for evidence of the tensioner pivoting arm contacting the stationary circular base of the tensioner or the alternator bracket. If so, the pivot bushing is excessive worn. Replace the belt tensioner.



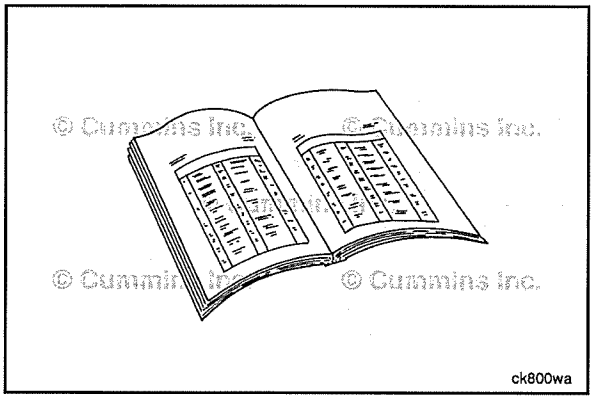


Install

Install the belt tensioner. The tensioner has a pin for alignment with the alternator bracket.

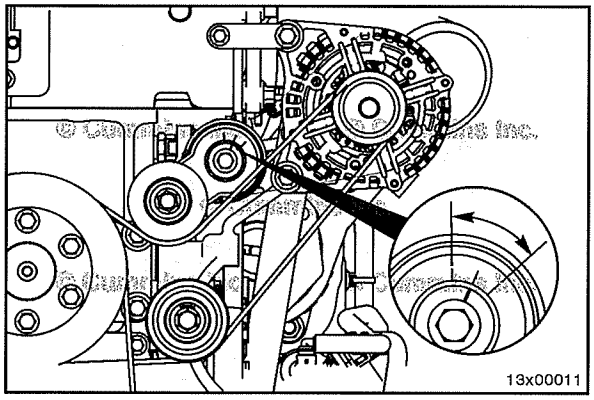
Install and tighten capscrew.

Torque Value: 46 N•m [34 ft-lb]



Finishing Steps

- Install the alternator drive belt. Refer to Procedure 013-005 in Section A.
- Install the cooling fan drive belt. Refer to Procedure 008-002 in Section A.



The tensioner has marks on the front to indicate tension. The middle of the three marks indicates proper tension.

If the tensioner marks indicate improper tension, check the mounting brackets and the belt length. Loose brackets, bracket failure, alternator movement, incorrect belt length, or belt failure can cause the tensioner to give improper tension.

Air Cleaner Element

General Information

△CAUTION△

Only use the approved Cummins Filtration™ direct flow replacement filter elements to service the air cleaner. Use of improper filters can lead to engine damage.

The direct flow air cleaner uses both primary and secondary air filter elements for Industrial applications. The direct flow air cleaner has been designed for a maximum restriction at 635 mm H_20 [25 in H_20], at which point the filter element(s) require changing. The secondary air filter elements **must** be changed every other time the primary air filter elements are changed. Proper inspection of the secondary air filter elements **must** be performed and the secondary elements changed, if necessary.

Measure

NOTE: The maximum restriction is reached when the vehicle is under full load. The restriction indicator will hold the maximum restriction value read during operation, even after the engine is shut down.

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Restriction Indicator Check

- Check the air cleaner restriction by inspecting the restriction indicator located on the outlet end of the air cleaner. A restriction indicator can be purchased separately if one is **not** present on the housing. The restriction indicator is located at the pressure tap on the outlet side of the housing.

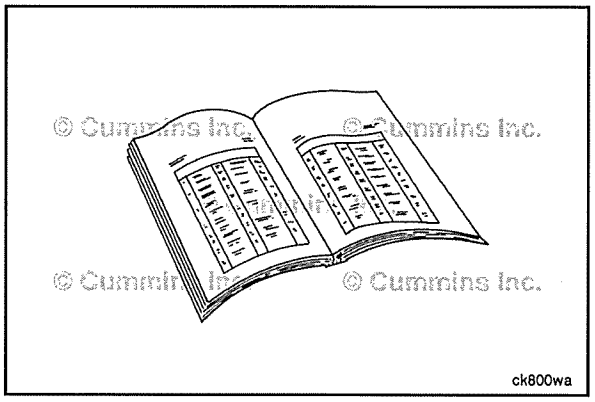
Some restriction indicators are installed with an electronic switch that illuminates a lamp in the cab at full restriction of 635 mm H_20 [25 in H_20].

Pressure/Vacuum Gauge Measure

- If a restriction indicator is **not** present, attach a pressure gauge to the pressure port on the outlet side of the filter housing. Measure the vacuum during operating conditions at full load.

Use the following procedure for additional information on restriction indicators. Refer to Procedure 010-059 in Section 3.

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.

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

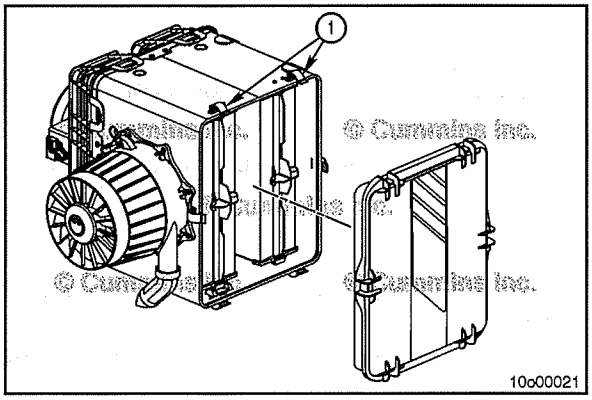
△CAUTION△
Dirt or contaminants can be introduced into the system and engine if the surrounding areas are not cleaned, resulting in damage to the engine.

NOTE: It is **not** recommended to open the housing if a service event is **not** required.

NOTE: Before servicing any intake air system component, (such as the air cleaner, pre-cleaner, hoses, ducting, etc.), clean the fittings, mounting hardware, and the area around the component to be removed.

- Shut the engine OFF.
- Disconnect the batteries. See equipment manufacturer service information.

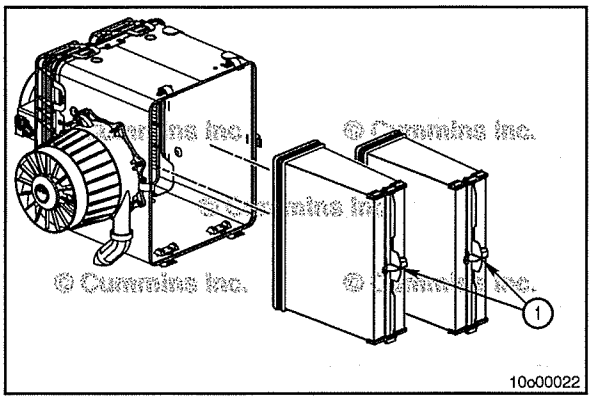
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Remove

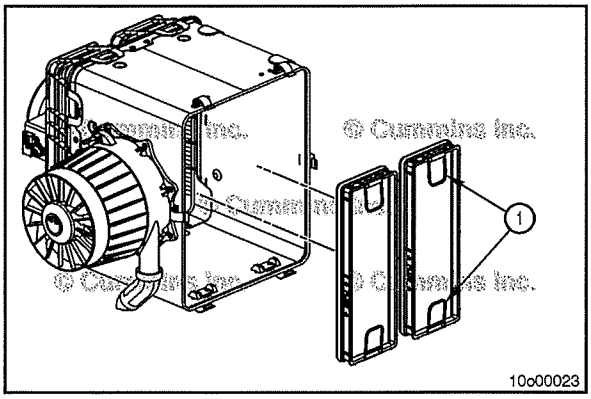
- To access the filter elements, remove the service door by lifting on the metal clips (1) around the perimeter of the service door.

Make sure the gasket around the service door or pre-cleaner remains seated.



The direct flow primary filter elements have a built-in handle (1) for easy removal. Grasp the handle in the center of the element and pull the filter element outward.

Clean the inside of the housing with a damp rag to remove all loose dirt and dust.



△CAUTION△
Take caution when removing the secondary elements. Any loose debris can fall into the air intake plumbing leading directly to the engine. Clean the area around the secondary filter elements and replace the secondary filters promptly to avoid engine contamination ingestion.

△CAUTION△
Do not attempt to clean the filter elements. Cleaning filter elements by impact or compressed air voids the warranty and can degrade or damage the filter media leading to malfunction.

NOTE: The secondary elements **must** be changed every other time the primary elements are changed. Proper inspection of the secondary elements **must** be performed and the elements changed, if necessary.

The secondary elements are removed by pulling on the plastic ring tab (1) on the inside face of the filter element.

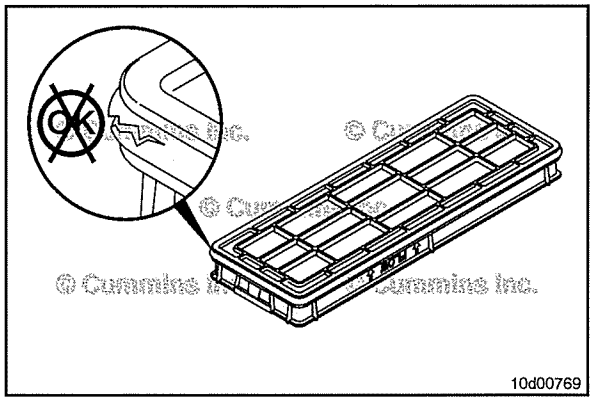
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Inspect for Reuse

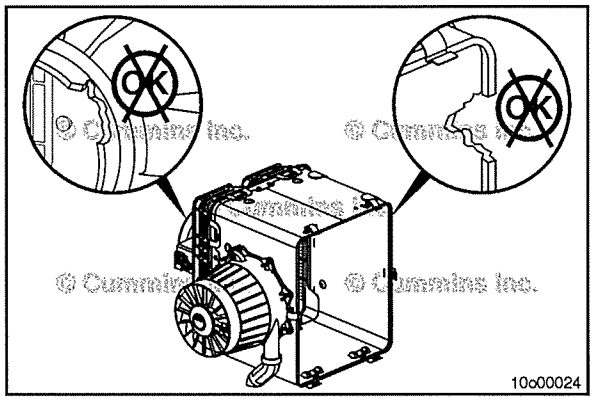
If the used filter element is to be installed into the filter housing, the following precautions **must** be taken:

- Inspect the gasket around the base of the filter element. If the gasket exhibits damage, replace the entire filter element assembly.
- Inspect the filter media for any tears or excessive wear. Replace the entire filter element assembly if the filter media is **not** intact. The filter media rows may **not** appear straight and exhibit some amount of a wave pattern. This appearance is normal due to standard operation and does **not** require a replacement.

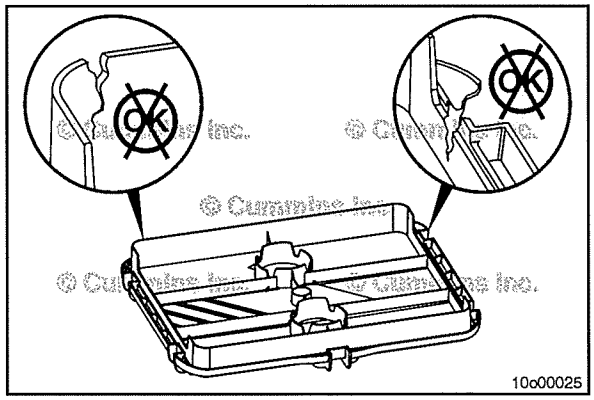
NOTE: The secondary elements **must** be changed every other time the primary elements are changed. Proper inspection of the secondary elements **must** be performed and the elements changed, if necessary.

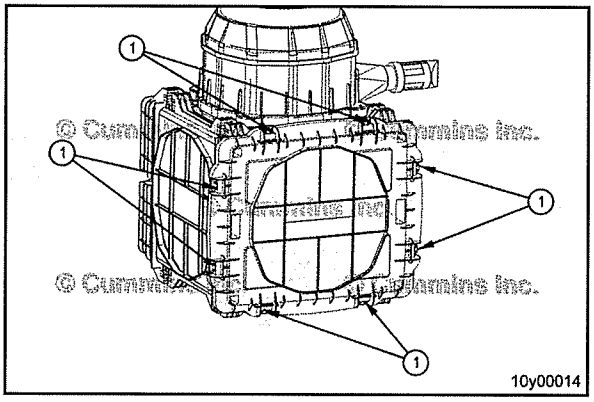


- Inspect the direct flow housing for damage, cracks, or areas where air can bypass the filter elements. Replace the direct flow housing if damage is found.



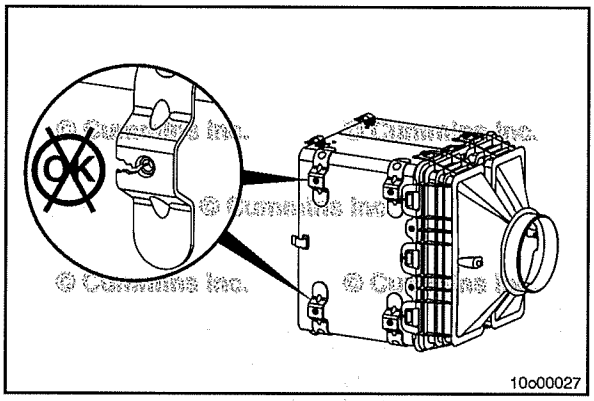
- Inspect the service door and gasket for damage. Replace the service door and gasket if damage is found.



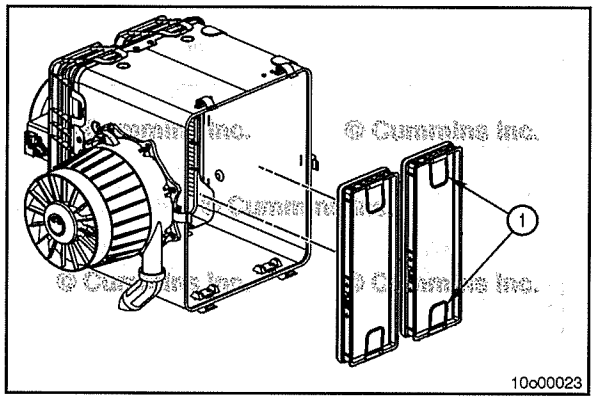


- Inspect the six clips (1) on the housing which are used to hold the service door. If any of the clips are damaged, broken, or missing, the direct flow housing **must** be replaced.

These clips are vital to keeping the service door locked in place during operation. If one of the clips is **not** properly engaged, it can allow the service door and air filters to become unseated during operation and potentially allow debris past the air filter elements.



- Make sure the direct flow air filter housing is properly mounted. Do **not** operate the equipment if the housing is loose or improperly mounted.
- Inspect the mounting tabs on the side of the housing for damage. Replace the housing if damage is found. Replace any missing mounting hardware.



Install

⚠CAUTION⚠
Only use the approved Cummins Filtration™ aftermarket direct flow replacement filter elements to service the air cleaner. Use of improper filters can lead to engine damage.

⚠CAUTION⚠
Make sure any cloth or tools used during the removal process are not left in the filter housing (before installing the filter elements) or engine damage can occur.

NOTE: The secondary elements **must** be installed first if both the secondary and primary elements were removed.

Secondary Elements

- Insert the elements so the orientation of the plastic removal rings (1) are facing the inside of the housing and are accessible for the next service interval.
- Push the secondary elements into the back of the housing so all surfaces are seated inside the housing.
- Apply pressure to all four corners to make sure the elements are secure within the housing.

The secondary filter elements include an o-ring that is glued to the filter elements to provide an airtight seal.

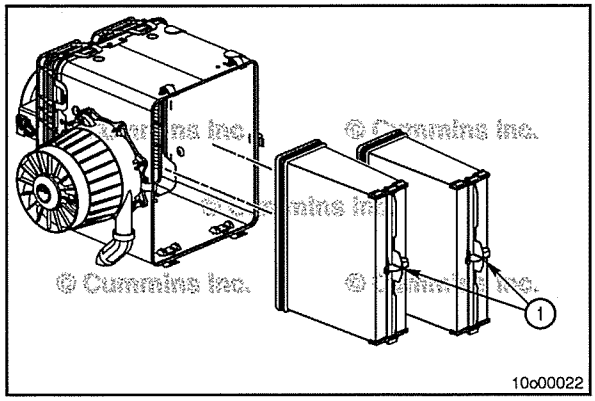
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Service Tip: Before installing a new primary filter element, use a marker to note on the element handle if a new secondary element **must** be installed at the next primary element service event.

Primary Filter Element

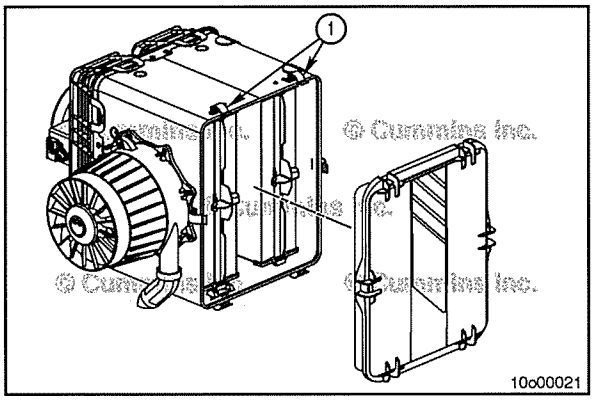
- Place new primary filter elements in the housing so the o-rings are toward the secondary elements.
- Push the primary elements into the housing so all surfaces are seated inside the housing.
- Apply pressure to the two tabs (1) on the side of the primary elements to make sure the elements are secure within the housing. The tabs on the filter **must** seat between the locating tabs inside the housing.

The primary filter element also includes an o-ring that is glued to the filter element to provide an airtight seal.



- Install the service door and fasten the metal clips (1) around the perimeter of the service door.

Make sure the gasket around the service door or pre-cleaner remains seated.



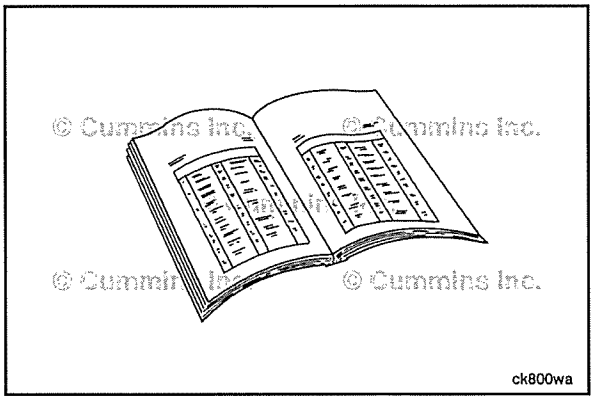
Finishing Steps

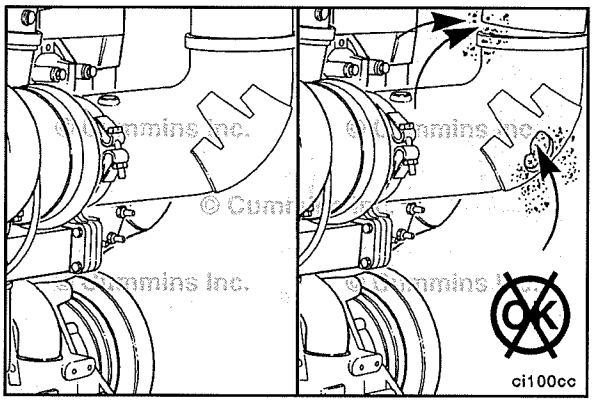
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

NOTE: The service door or pre-cleaner assembly will **not** latch if the primary filter elements are **not** fully seated into the housing.

NOTE: The direct flow filter elements are completely disposable.

- Install the service door by latching to the housing.
- Reset the restriction indicator by pushing the reset button.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and listen for a noise that could indicate an air leak. Use the following procedure to locate any air leaks in the air system. Refer to Procedure 010-024 in Section 6.





Air Leaks, Air Intake and Exhaust Systems

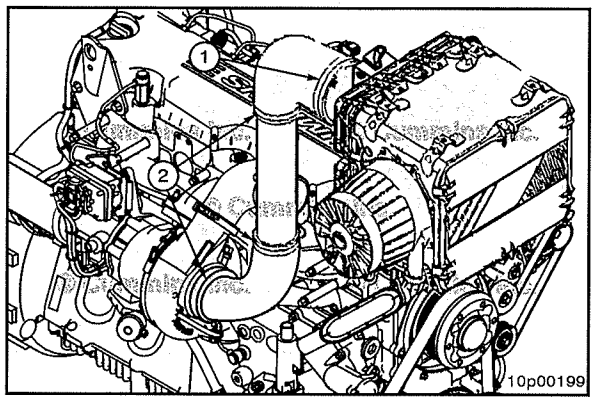
Initial Check

⚠CAUTION⚠
Engine intake air must be filtered to prevent dirt and debris from entering the engine. If intake air piping is damaged or loose, unfiltered air will enter the engine and cause premature wear.

Inspect for loose clamps or damage between the intake air piping, air cleaner, turbocharger, charge-air cooler, and intake manifold.

Check for corrosion of the intake system piping under the clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system. Disassemble and clean as required.

Replace any damaged pipes and tighten any loose clamps.



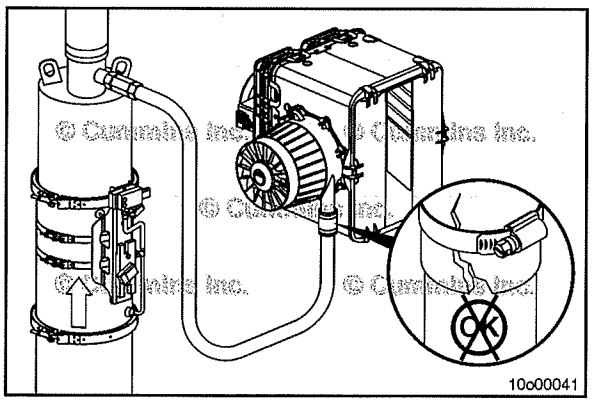
Inspect the intake piping between the direct flow air filter housing and the turbocharger for wear points and damage to piping, loose clamps, or punctures that can allow unfiltered intake air into the engine.

Replace damaged pipes and tighten loose clamps, as necessary, to prevent the air system from leaking.

Torque Value:
Intake Piping at Direct Flow Air Filter Housing (1) 4.5 N•m [40 in-lb]

Torque Value:
All Other Intake Piping (2) 8 N•m [71 in-lb]

Check for corrosion under the clamps and hoses of the intake system piping. Corrosion can allow corrosive products and dirt to enter the intake system. Disassemble and clean, as required.



If equipped, inspect the exhaust aspirator piping for leaks, cracks, or loose connections.

Tighten the clamps, if necessary.

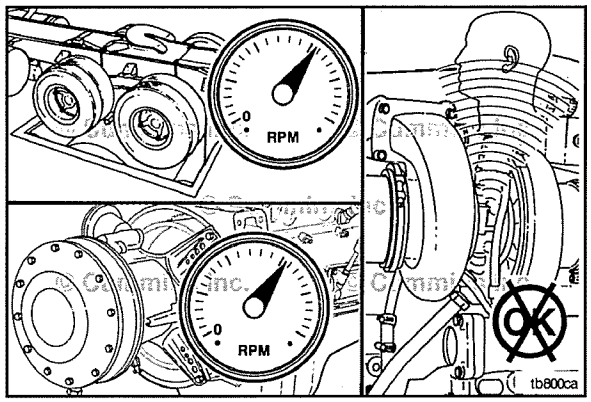
See equipment manufacturer service information for the correct torque value.

NOTE: Vacuum leaks in the exhaust aspirator piping can reduce the ability of the air cleaner precleaner to remove debris from the intake air, which can lead to early or frequent air filter plugging.

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Excessive back pressure can cause exhaust leaks. Verify the exhaust back pressure is within specified limits. Refer to a Cummins® Authorized Repair Location for specifications.

Operate the engine at full throttle and maximum load, and check for air leaks. Listen for a whistling noise caused by high-pressure air leaks.

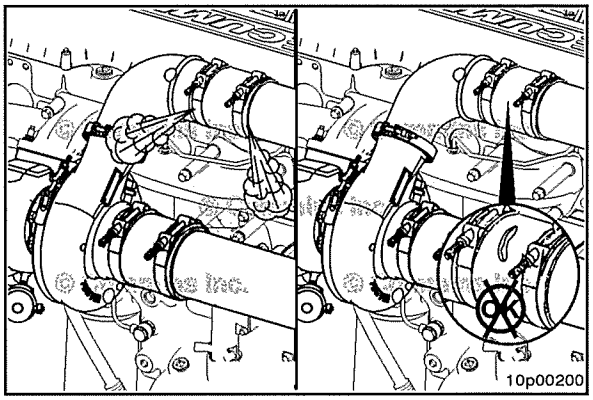


⚠CAUTION⚠
Do not use air tools to remove or install the nut on the V-band clamp. Use of these tools can seriously damage the threads or the bolt and cause the clamp to not be able to be reused.

The noise can be caused by an air leak from the following:

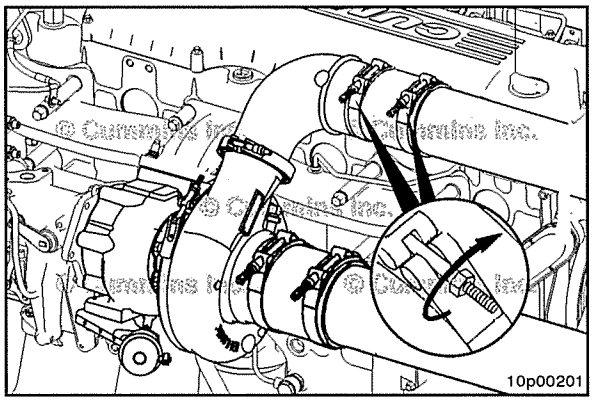
- Turbocharger to charge-air cooler elbow connection
  - Inspect the connection and o-ring for damage.
  - Tighten the band clamps. See equipment manufacturer service information or the following torque value.

Torque Value: 11 N•m [97 in-lb]



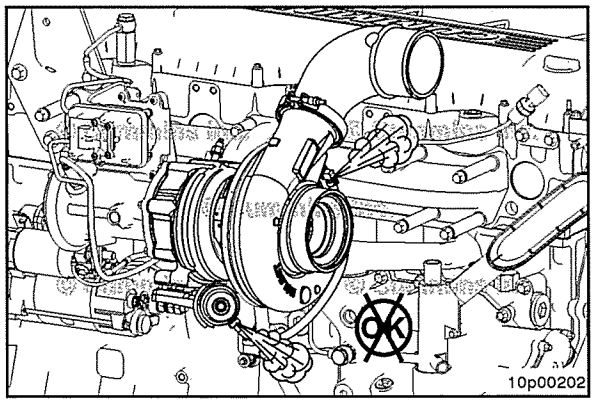
- Any charge-air cooler piping or connecting hose.
  - Inspect the hose and piping for damage.
  - Tighten the band clamps. See equipment manufacturer service information or the following torque value.

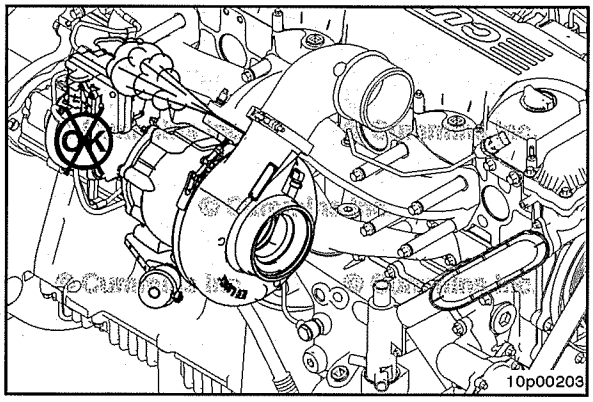
Torque Value: 11 N•m [97 in-lb]



Air leak noise can be caused by a loose connection in the turbocharger wastegate system.

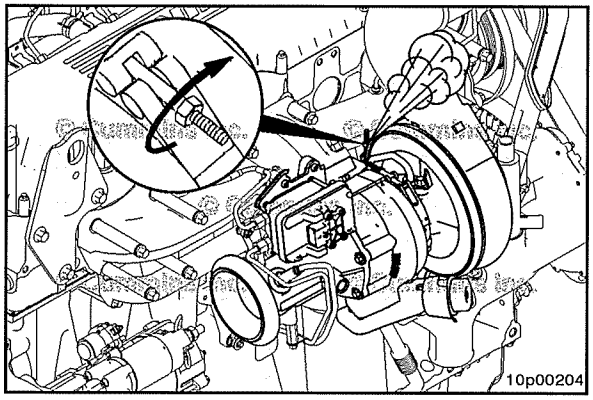
Inspect the turbocharger actuator air line and connections.





Air leak noise can be caused by an air leak from the turbocharger-to-exhaust manifold mounting gasket.

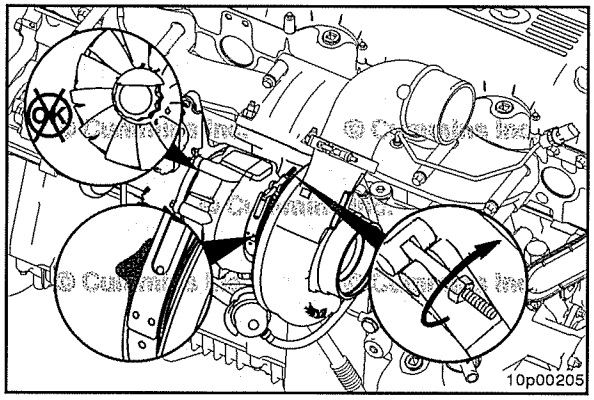
Inspect for signs of leakage, such as soot streaks which may appear yellowish, brown, or black. If signs of leakage are present, replace the turbocharger mounting gasket. Refer to a Cummins® Authorized Repair Location.



Air leak noise can be caused by an air leak from the turbocharger compressor housing. Air leaks from the turbocharger compressor housing are acceptable. It is possible for even a brand new turbocharger to have an air leak at this location.

Be sure the compressor housing clamp is tightened to the following torque.

Torque Value: 8.5 N•m [75 in-lb]



Air leak noise can be caused by an air leak from the turbine housing sealing surface.

It is acceptable to see soot streaks appearing yellowish, brown, or black coming from the turbine housing sealing surface.

If soot streaks are found check the turbocharger turbine wheel for damage. If turbine wheel damage is found the turbocharger **must** be replaced. Refer to a Cummins® Authorized Repair Location.

If no turbine wheel damage is found, make sure the turbine housing clamp is tight.

Torque Value: 11 N•m [97 in-lb]

If no turbine wheel damage is found, the turbocharger can be used.

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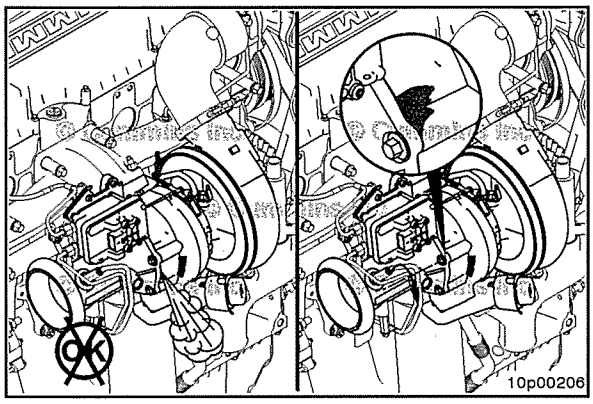
Air leak noise can be caused by an air leak from the turbine outlet sealing surface.

It is acceptable to see soot streaks appearing yellowish, brown, or black coming from the turbine outlet sealing surface.

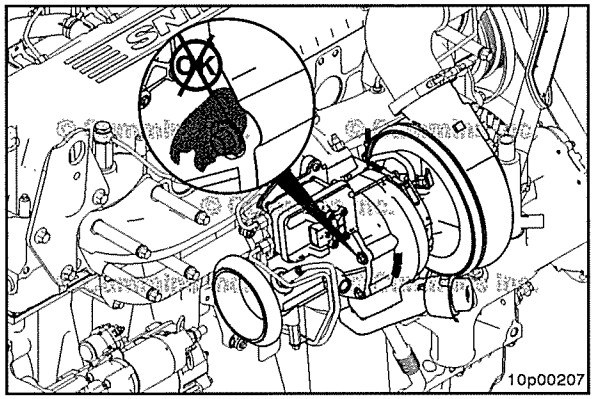
It is **not** acceptable to see exhaust coming from the turbine outlet sealing surface.

If visible exhaust coming from the turbine outlet sealing surface, tighten the turbine outlet cap screws. Refer to a Cummins® Authorized Repair Location.

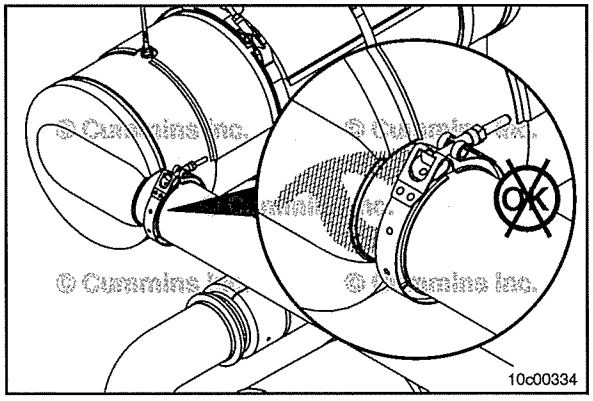
Check again for a visible exhaust leak. If a leak is visible, remove and replace the turbocharger. Refer to a Cummins® Authorized Repair Location.



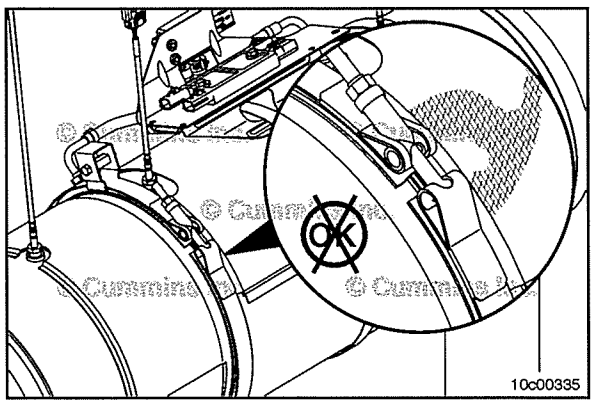
- Check the exhaust pressure regulator.
  - Inspect for visible soot streaks at the V-band joint.
  - If soot streaks are found, tighten the V-band clamp.
  - Operate the engine at full throttle and check for leakage at full throttle condition.
  - If a leak is still present, remove and replace the gasket with a new gasket and a new V-band clamp.

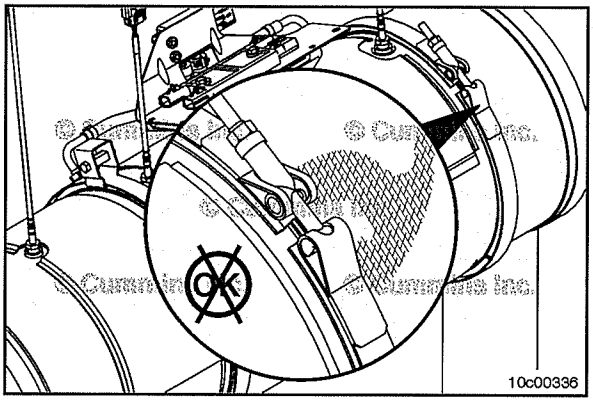


- Check the aftertreatment inlet connection.
  - Inspect for visible soot streaks at the Torca™ clamp or V-band clamp joint. Also inspect for loose or damaged insulation wrapping, if applicable.
  - If soot streaks are found, tighten the V-band or Torca™ clamp.
  - Operate the engine at full throttle and check for leakage at full throttle condition.
  - If a leak is still present, remove and replace the clamp with a new Torca™ clamp or V-band clamp.

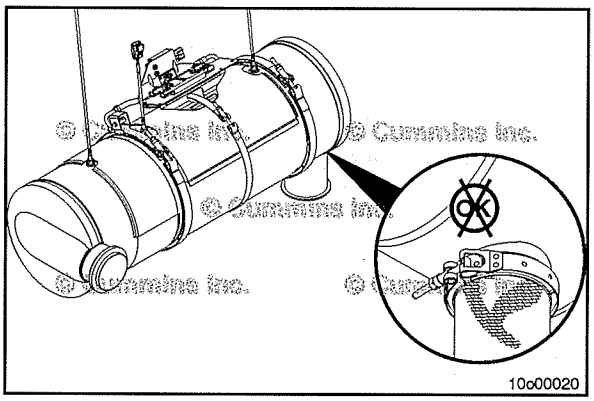


- Check the catalyst to aftertreatment particulate filter connection.
  - Inspect for visible soot streaks at the V-band joint.
  - If soot streaks are found, check for fault codes relating to high differential pressure in the aftertreatment system. If no fault codes are found, tighten the V-band clamp.
  - Operate the engine at full throttle and check for leakage at full throttle condition.
  - If a leak is still present, remove and replace the gasket with a new gasket and V-band clamp.

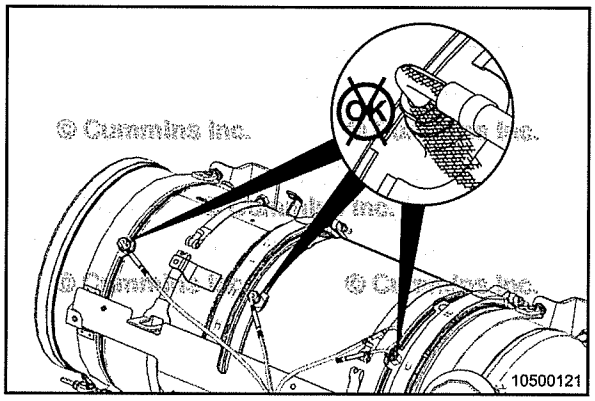




- Check the aftertreatment diesel particulate filter to outlet connection.
  - Inspect for visible soot streaks at the V-band joint.
  - If soot streaks are found, check for fault codes relating to high differential pressure in the aftertreatment system. If no fault codes are found, tighten the V-band clamp.
  - Operate the engine at full throttle and check for leakage at full throttle condition.
  - If a leak is still present, remove and replace with a new gasket and V-band clamp.



- Check the aftertreatment outlet connection.
  - Inspect for visible soot streaks at the V-band joint.
  - If soot streaks are found, check for fault codes relating to high differential pressure in the aftertreatment system. If no fault codes are found, tighten the V-band clamp.
  - Operate the engine at full throttle and check for leakage at full throttle condition.
  - If a leak is still present, remove and replace with a new gasket and V-band clamp.

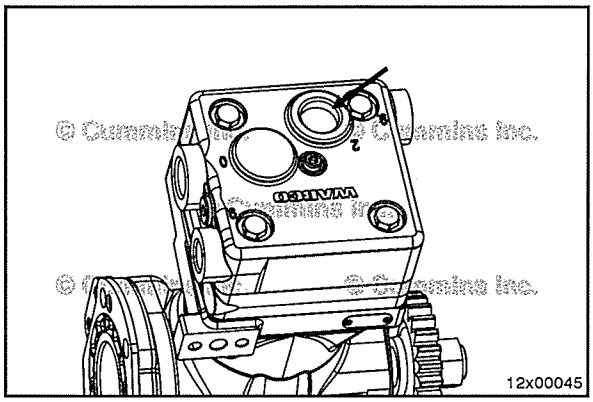


- Check the aftertreatment diesel particulate filter differential pressure sensor tube connections.
  - Inspect for visible soot streaks at the threaded bosses or hose connections.
  - If soot streaks are found at the threaded boss, loosen the differential pressure sensor tube nut, apply a coating of anti-seize compound, and tighten the differential pressure sensor tube nut.
  - If soot streaks are found at the hose connections, remove and connect the hose.
- Operate the engine at full throttle and check for leakage at full throttle condition.
  - If a leak is still present at the threaded boss, remove and replace the differential pressure sensor tube.
  - If a leak is still present at the hose connection, replace the differential pressure sensor tube or differential pressure sensor, depending on which component the hose is permanently attached to.
  - If damage resulted in coolant, oil, excessive fuel or excessive black smoke entering the exhaust system, the aftertreatment system **must** be inspected. Refer to a Cummins® Authorized Repair Location.

Air Compressor Discharge Lines

General Information

The air discharge line is supplied and connected directly to the engine's air compressor by the vehicle OEM.

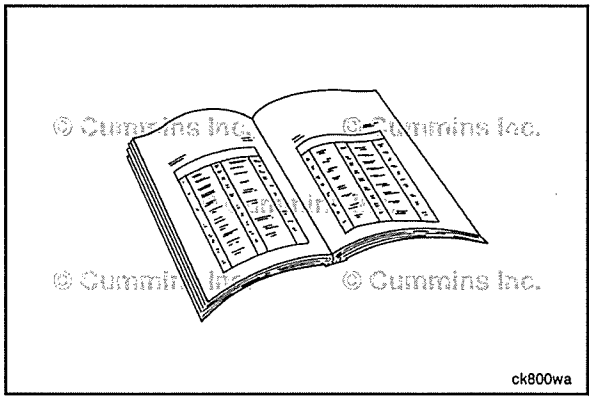


Preparatory Steps

⚠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⚠
Air discharge lines can be very hot. Make sure the lines are cool before touching to reduce the possibility of personal injury.

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the vehicle air system. See equipment manufacturer service information.



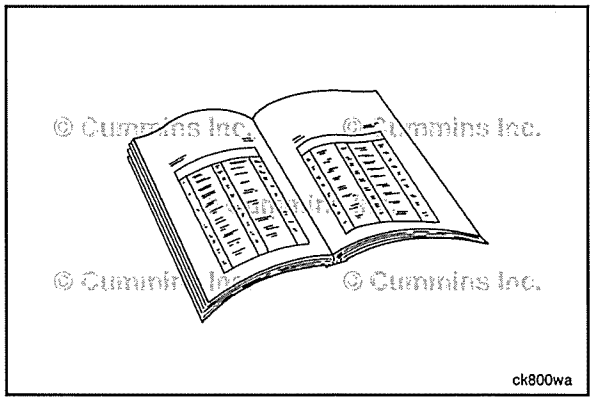
Remove

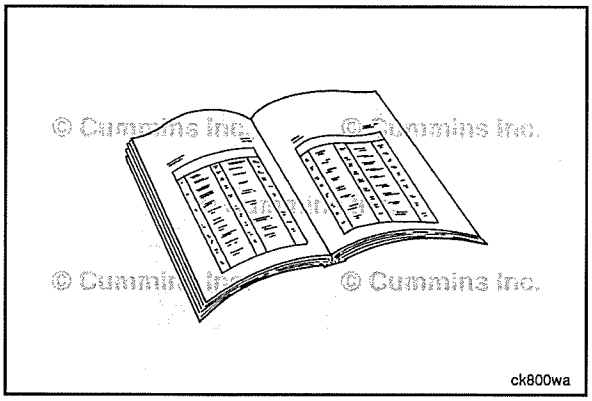
NOTE: Apply a counter-torque to the air compressor discharge fitting when loosening the discharge line.

See equipment manufacturer service information.

Disconnect the air compressor discharge.

Remove the discharge line.





Clean and Inspect for Reuse

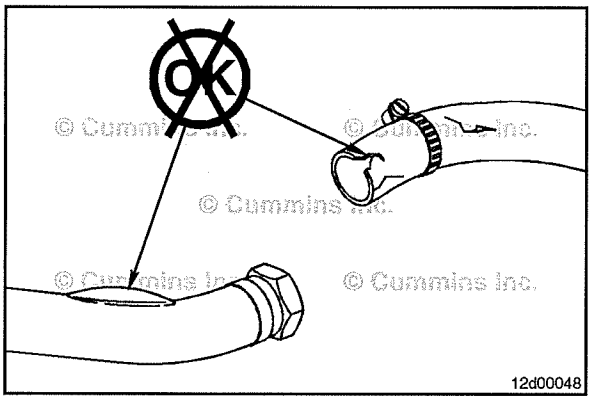
⚠WARNING⚠

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

See equipment manufacturer service information.

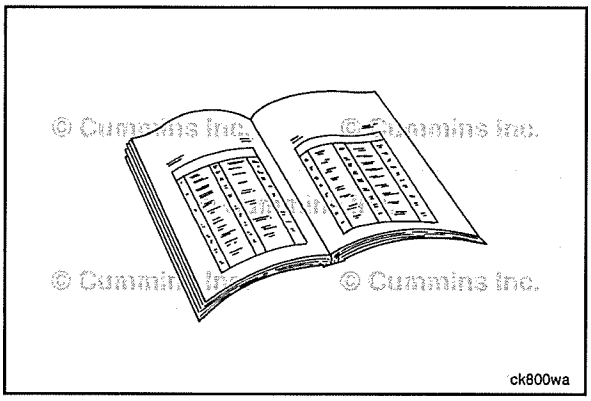
Clean the air compressor discharge line.

Inspect the air compressor discharge line for any internal restrictions. Replace the component if any restrictions are found.



Inspect the air compressor discharge line for splits, cracks, hardening, or other damage.

Replace the component if any damage is found.



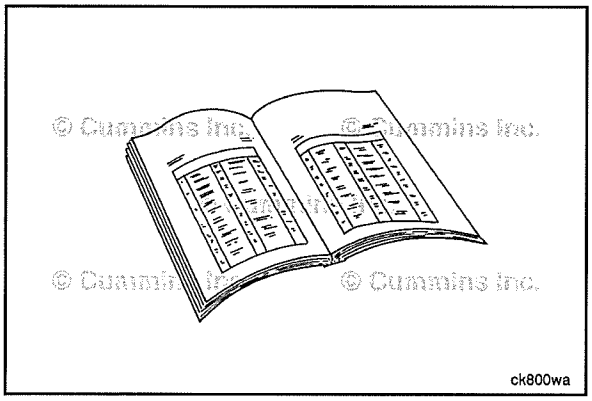
Install

NOTE: Apply a counter-torque to the air compressor discharge fitting when tightening the discharge line.

See equipment manufacturer service information.

Connect the air compressor discharge line.

Tighten the air compressor discharge line fittings.



Finishing Steps

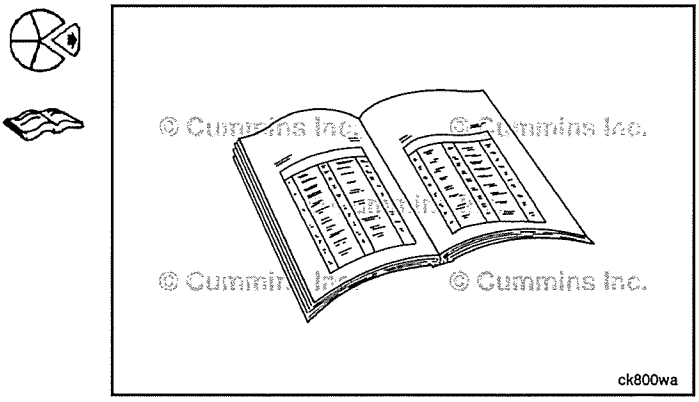
⚠WARNING⚠

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 to normal operating temperature and check for leaks.

Crankshaft Pulley

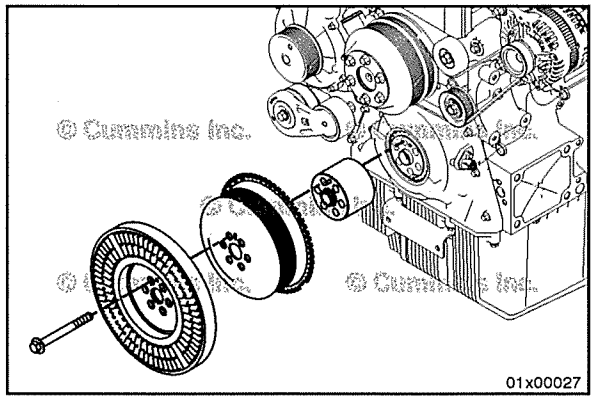
Preparatory Steps



⚠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 A.
- Remove the cooling fan drive belt. Refer to Procedure 008-002 in Section A.

Remove



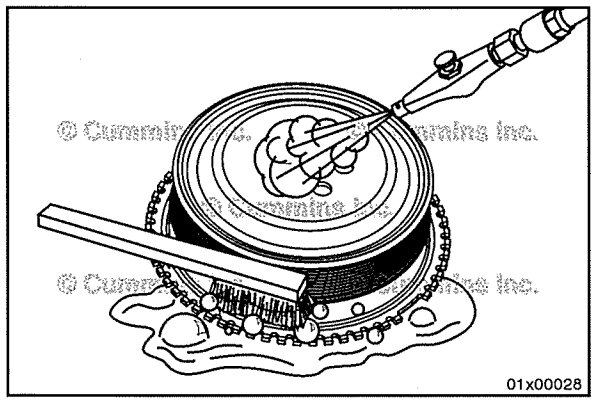
Remove two capscrews and insert guide pins, Part Number 3376696, to support the damper.

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.

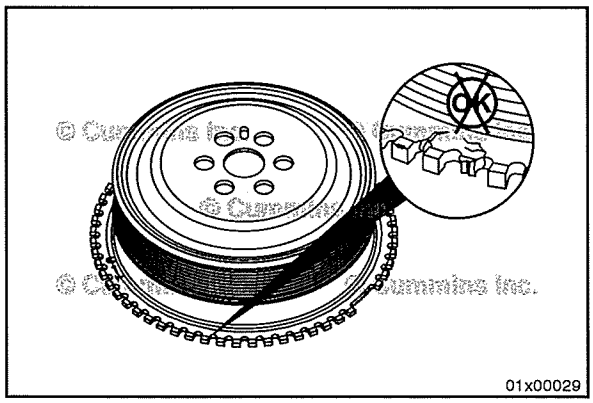
Clean and Inspect for Reuse



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

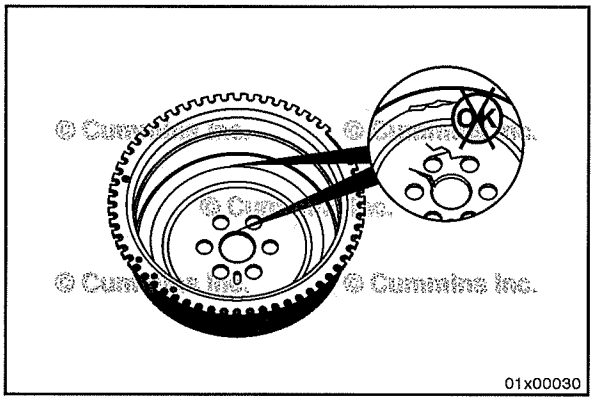
Use soapy water to clean any oil from the crankshaft pulley.

Dry the crankshaft pulley with compressed air.

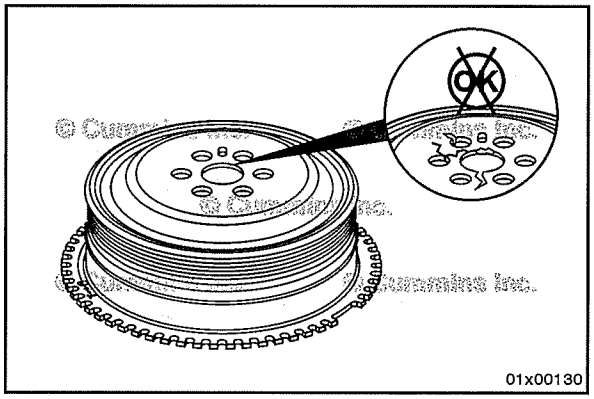


Inspect the crankshaft speed indicator ring for missing teeth, cracks, or damaged surfaces.

If any damage is found, the crankshaft pulley **must** be replaced.

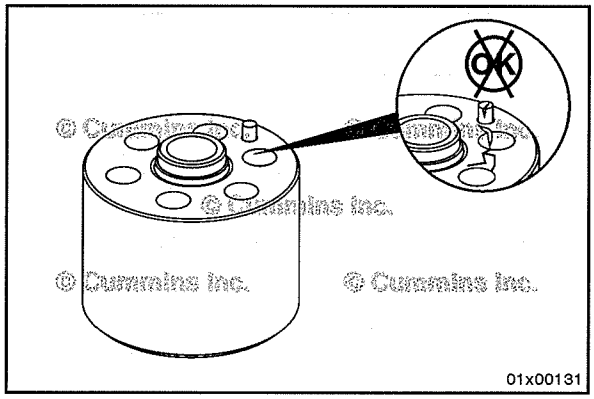


Inspect the mounting web for cracks.



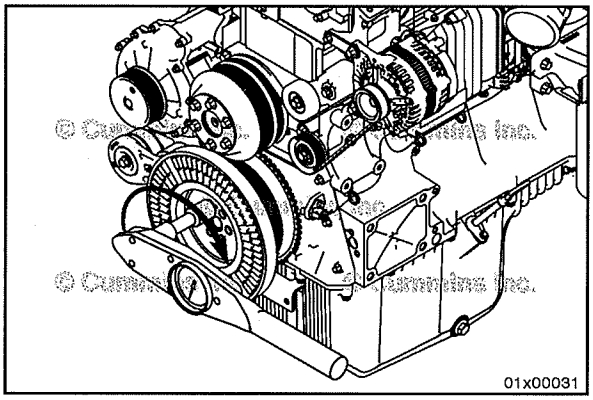
Inspect the crankshaft pulley hub for cracks.

Replace the pulley if the hub is cracked.



Inspect the crankshaft spacer hub for cracks.

Replace the spacer if it is cracked or dowel is broken or cracked.



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.

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Lubricate the capscrews with clean engine oil.

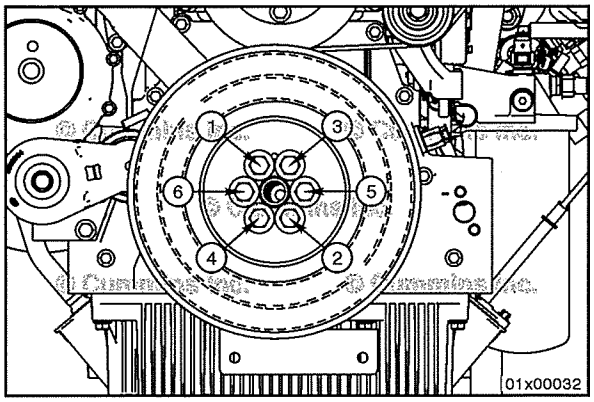
Install four capscrews into the empty holes hand tight.

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:

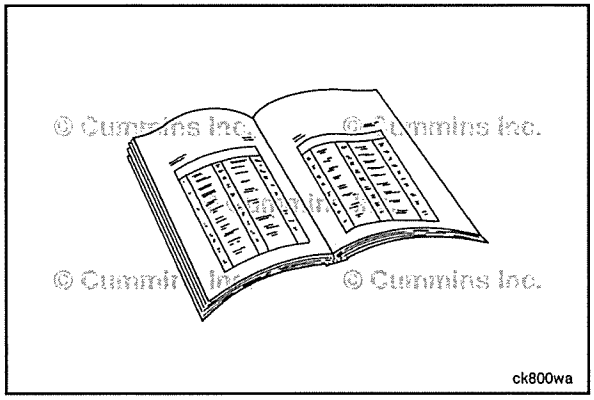
Step 1	175 N•m	[129 ft-lb]
Step 2	Rotate 60 degrees	



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 A.
- Connect the batteries. Refer to Procedure 013-009 in Section A.

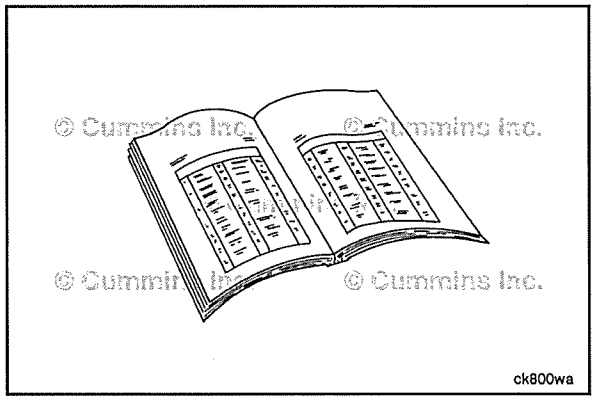


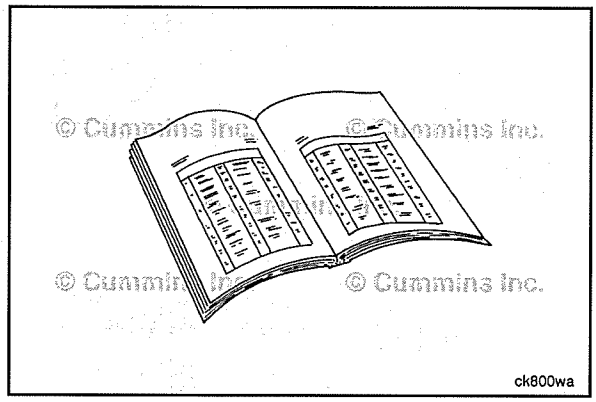
Overhead Set

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.



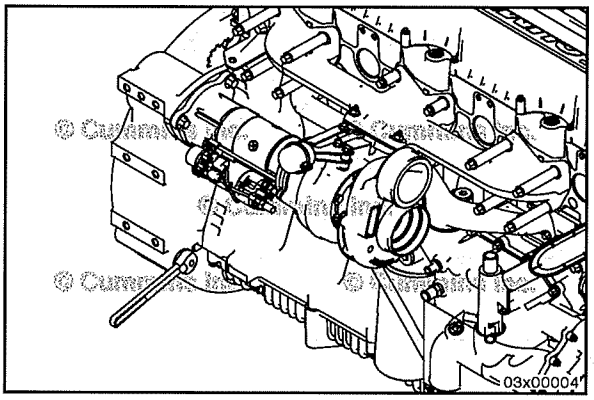


Preparatory Steps

⚠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 A.
- Remove the open crankcase ventilation hose.
- Remove the fuel injector supply lines. Refer to Procedure 003-011 in Section A.
- Remove the rocker lever cover and gasket. Refer to Procedure 003-011 in Section A.

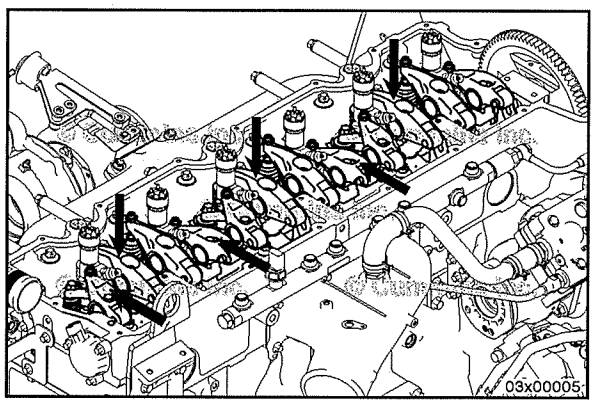


Adjust

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.



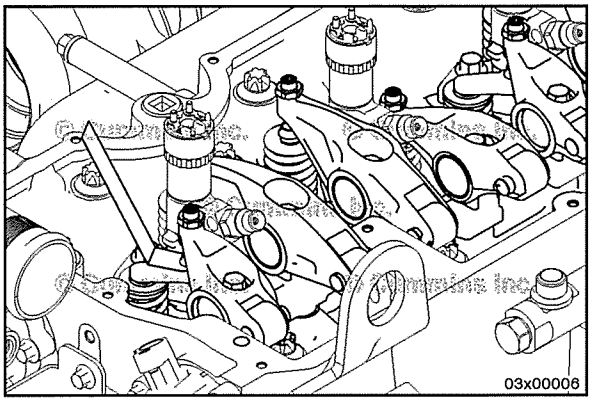
With the engine in this position, lash can be measured on the following rocker levers:

Exhaust Valve of Cylinder 1, 3 and 5.

Intake Valve Cylinder 1, 2 and 4.

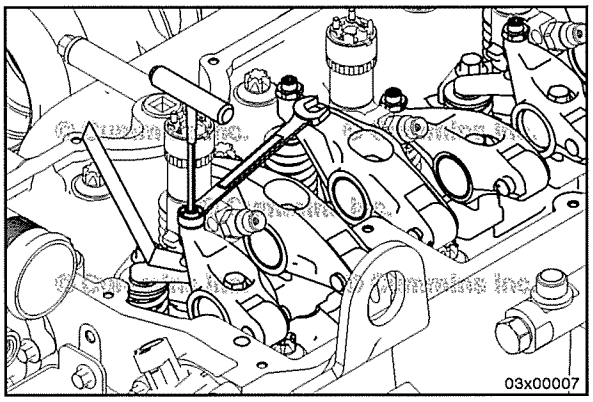
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NOTE: Checking the overhead setting is usually performed as part of a troubleshooting procedure, and resetting is **not** required during checks, as long as the lash measurements are within specifications.



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.

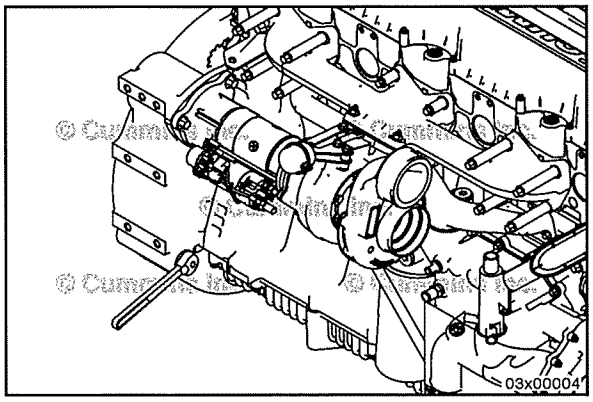
Following the same steps and specifications as previously stated, measure lash for the following rocker levers:

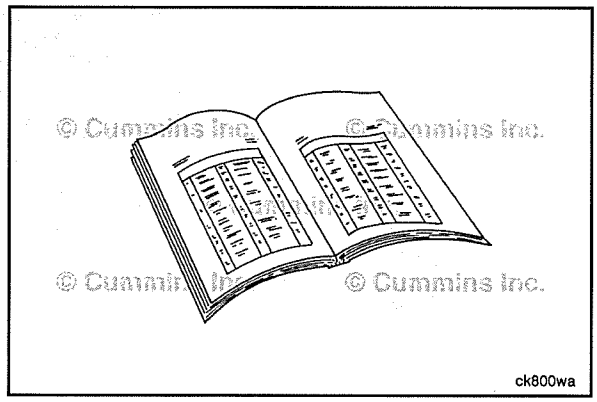
(E = exhaust, I = Intake)

Exhaust Valve of cylinders 2, 4, and 6.

Intake Valve of cylinders 3, 5, and 6.

Reset if out of specification.





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 A.
- Install the fuel injector supply lines. Refer to Procedure 003-011 in Section A.
- Install the crankcase ventilation hose. Refer to Procedure 003-018 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section A.
- Operate the engine and check for leaks.

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Section 8 - Maintenance Procedures at 4500 Hours

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General Information 8-1

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Maintenance Procedures - Overview

General Information

All maintenance checks and inspections listed in previous maintenance intervals **must** also be performed at this time, in addition to those listed under this maintenance interval.

Aftertreatment Diesel Particulate Filter

General Information

⚠WARNING⚠
During regeneration, exhaust gas temperature could reach 800°C [1500°F], and exhaust system surface temperature could exceed 700°C [1300°F], which is hot enough to ignite or melt common materials, and to burn the skin. The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To avoid the risk of fire, property damage, burns, or personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

△CAUTION△
The aftertreatment diesel oxidation catalyst (DOC) elements contained in the aftertreatment system are made of brittle material. Do not drop or strike the side of the aftertreatment system as damage to the aftertreatment DOC element can result.

Due to the number of varying exhaust aftertreatment applications, this procedure contains generic information. **Not** all illustrations within this procedure will represent the applications being serviced.

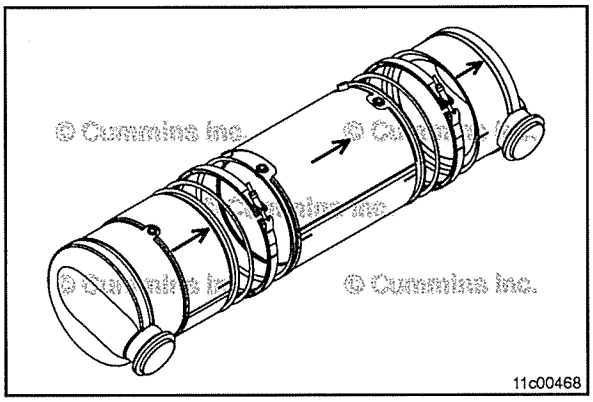
The aftertreatment system is composed of three sections. These sections are:

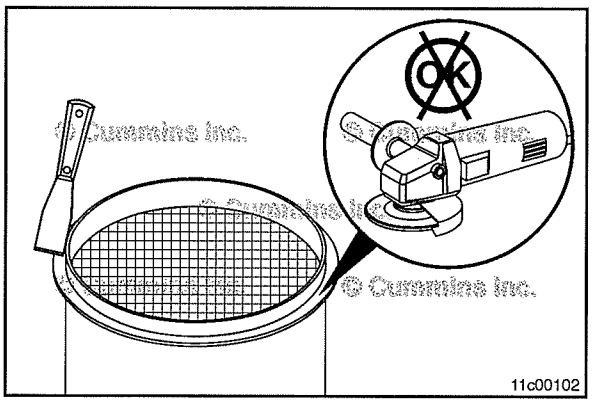
1 Aftertreatment DOC

2 Aftertreatment Diesel Particulate Filter (DPF)

3 Outlet.

NOTE: Damage to the aftertreatment system due to mishandling, vehicle collision, and road debris is **not** covered by Cummins Inc. warranty.





Maintenance Check

If the aftertreatment DPF is being removed for an ash cleaning or soot cleaning maintenance interval, the aftertreatment DPF will need to be removed and cleaned using a cleaning tool approved by Cummins Inc. Refer to a Cummins® Authorized Repair Location for information regarding parts and operation of Cummins Inc. approved cleaning tools. Conventional cleaning can **not** be used to clean aftertreatment DPFs.

If the aftertreatment DPF is being removed for an ash cleaning or soot cleaning maintenance interval, the aftertreatment DPF will need to be removed and cleaned using a cleaning tool approved by Cummins Inc. Consult the Service Tool Instruction, Bulletins 3400284 and 3400253, for information regarding parts and operation of Cummins Inc. approved cleaning tools. Conventional cleaning can **not** be used to clean aftertreatment DPFs.

While air cleaning is allowed, the Cummins Inc. preferred method would be to exchange the DPF at the recommended maintenance interval.

Because it can be difficult to determine if an aftertreatment DPF is plugged with ash or soot, it will be necessary to clean the aftertreatment DPF before performing a stationary regeneration to prevent any system damage from occurring. For information on how to perform a stationary regeneration, refer to a Cummins® Authorized Repair Location.

While air cleaning is allowed, the Cummins Inc. preferred method would be to exchange the DPF at the recommended maintenance interval.

Performing the ash and/or soot cleaning procedure will:

- Remove excess soot to allow a stationary regeneration without damaging the aftertreatment DPF.
- Allow the aftertreatment DPF to be reused after a 1981 and/or 1922 fault code occurs.
- Remove excess ash and improve regeneration frequency.

Performing a stationary regeneration after cleaning the aftertreatment DPF for ash and/or soot will:

- Remove any residual soot from the system that was **not** removed during the cleaning procedure.
- Test the diesel oxidation catalyst efficiency.
- Test the aftertreatment system functionality.

NOTE: Soot will plug the cleaning machine filter quicker than ash. Cleaning soot from a DPF by using Cummins Inc. approved machines can result in the need for increased maintenance intervals of the cleaning machine filter.

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Section 9 - Maintenance Procedures at 4500 Hours or 3 Years

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Maintenance Procedures - Overview

General Information

All maintenance checks and inspections listed in previous maintenance intervals **must** also be performed at this time, in addition to those listed under this maintenance interval.

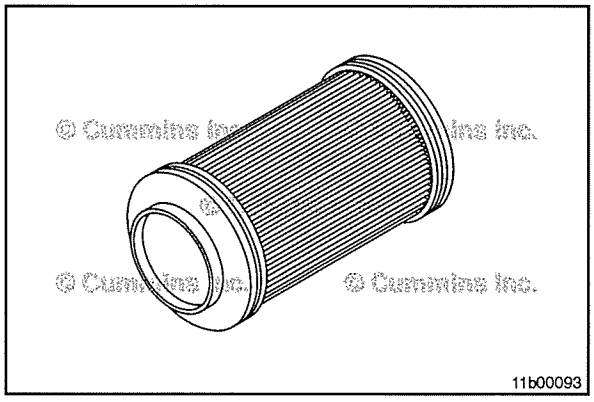
Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter

General Information

The aftertreatment diesel exhaust fluid (DEF) dosing unit filter is designed to prevent foreign objects, that may be suspended in the DEF, from entering the dosing system.

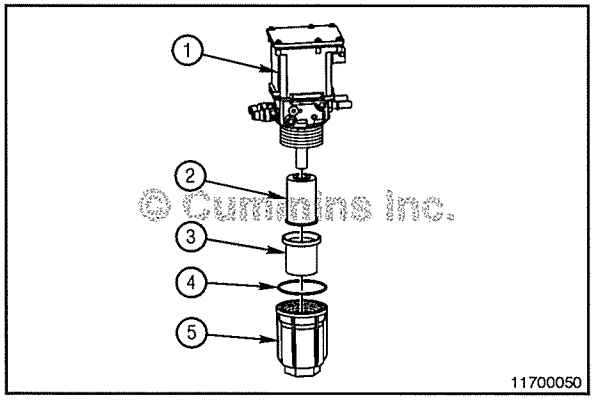
Debris can cause permanent damage and premature malfunction to either the aftertreatment DEF dosing unit or the aftertreatment DEF dosing valve. The aftertreatment DEF dosing unit filter is a maintenance item.

For handling incorrect or contaminated DEF, contact a Cummins® Authorized Repair Location.



The aftertreatment DEF dosing unit consists of the following components:

1 Aftertreatment DEF dosing unit
2 Aftertreatment DEF dosing unit element
3 Aftertreatment DEF dosing unit frost protection membrane
4 Aftertreatment DEF dosing unit filter o-ring
5 Aftertreatment DEF dosing unit filter housing.

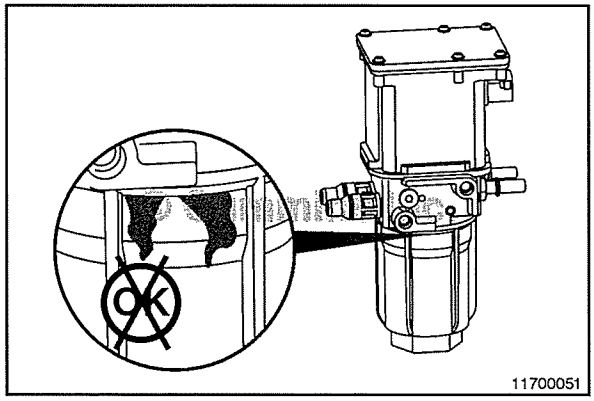


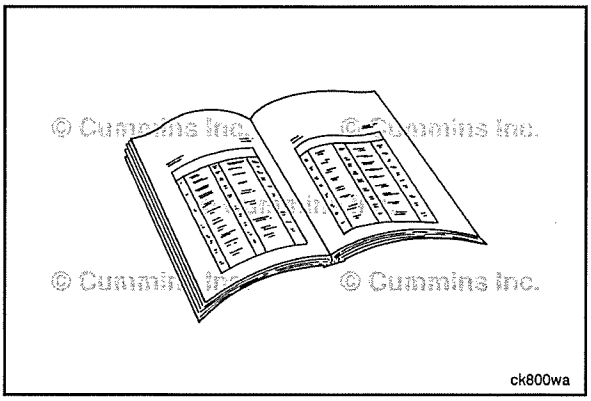
Initial Check

Locate the aftertreatment DEF dosing unit on the vehicle. Inspect the black plastic filter housing.

Inspect the area around the seal and filter housing for signs of leakage.

DEF leaks leave a white deposit. If deposits are found, see the Clean and Inspect for Reuse section of this procedure.





Preparatory Steps

⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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⚠
The diesel exhaust fluid (DEF) line connecting the aftertreatment diesel exhaust fluid dosing unit to the aftertreatment diesel exhaust fluid dosing valve is under low pressure and should not be disconnected while the engine is running or before the system has completed the purge process after engine shutdown. Disconnecting the DEF line while under low pressure could cause DEF to spray.

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

NOTE: Do **not** power wash or steam clean this unit. Use compressed air to remove any loose debris.

- Disconnect the batteries. See equipment manufacturer service information.

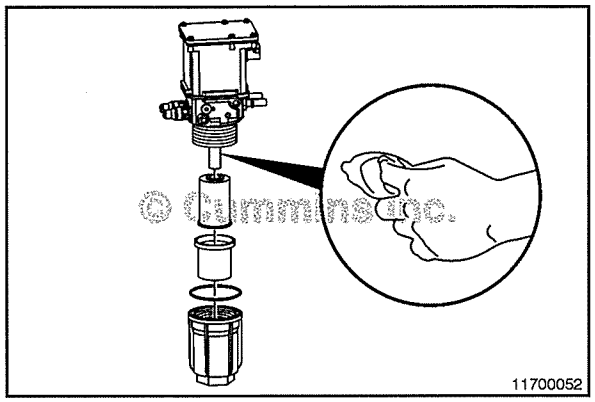
NOTE: The dosing unit around the filter housing **must** be cleaned using a clean damp cloth, warm water, and a mild detergent.

- Use a clean damp cloth to remove any contamination, to reduce the risk of contaminants entering the DEF dosing unit.

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Remove





⚠CAUTION⚠
A small amount of dirt and debris can be very harmful to the DEF dosing system. Dirt or other foreign objects must not get into the DEF dosing unit.

NOTE: There may be residual DEF in the filter housing. A collection container placed below the DEF filter housing is recommended.

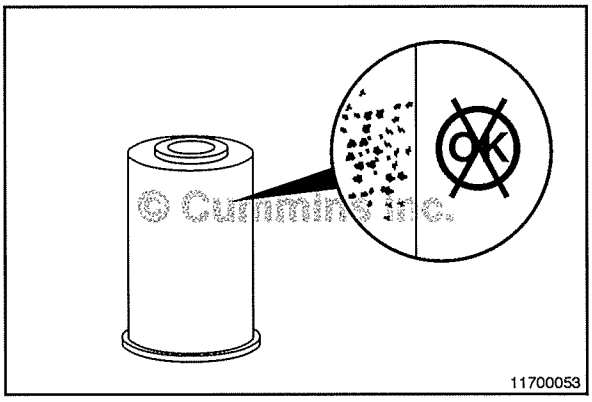
- Use a 46 mm socket to remove the DEF filter housing.
- Remove and discard the o-ring.

NOTE: In the next step, the frost protection membrane will be removed. A small amount of DEF could leak.

- Remove the frost protection membrane and inspect. A small amount of DEF could leak out of it.
- Remove the filter element from the unit by twisting, while pulling. Absorb the dripping DEF with a dry clean lint-free cloth and dry the unit.
- Discard the o-ring, frost protection membrane, and filter element.







If there is the possibility that contaminated DEF has gone through the DEF dosing system, check the DEF filter prior to discarding it.

Check the diesel exhaust filter for evidence of contaminated DEF. Use visual and aroma characteristics of the filter to determine if contaminated fluid has passed through the dosing system.

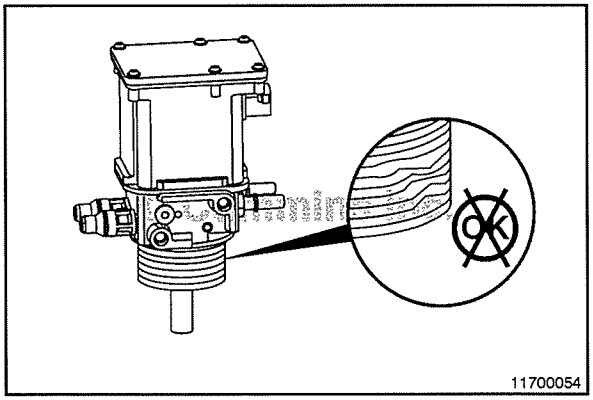
Inspect the DEF filter for debris. If debris is evident, also check:

- DEF tank filter. See equipment manufacturer service information.
- The aftertreatment DEF dosing unit inlet connector. Contact a Cummins® Authorized Repair Location.

Clean and Inspect for Reuse



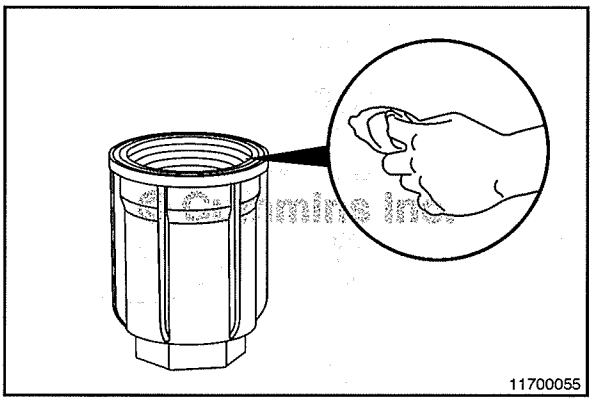




Inspect the aftertreatment DEF dosing unit threads. This is especially important if the aftertreatment DEF dosing unit cap was damaged.

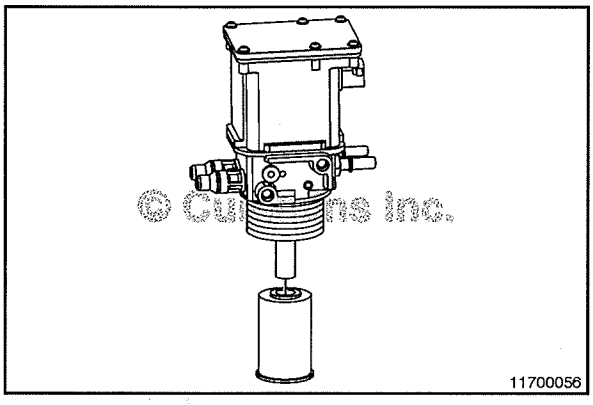
If the aftertreatment DEF dosing unit threads are damaged, replace the entire aftertreatment DEF dosing unit.

Be sure the frost protection membrane groove is clean and free of debris. Clean using a clean damp cloth, warm water, and a mild detergent.



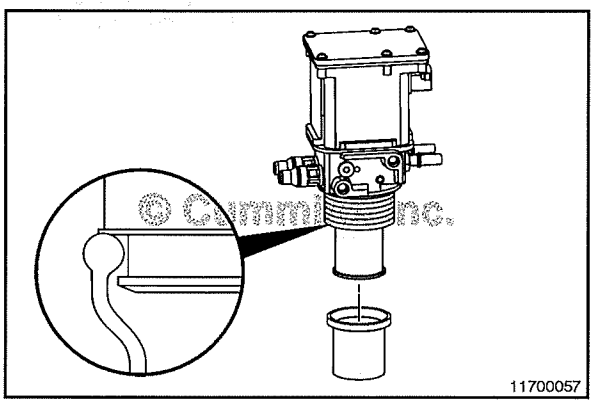
NOTE: Never operate the vehicle with the DEF filter or filter housing removed.

Clean the new aftertreatment DEF dosing unit filter housing and threads on the dosing unit with warm water and a clean cloth.



Install

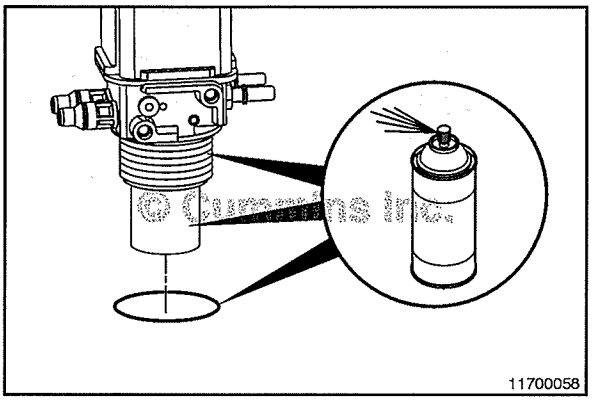
Slide the filter element onto the DEF dosing unit. Push up on the filter to make sure it is fully seated.



Slide the filter element onto the DEF dosing unit and make sure it is seated.

Put the frost membrane over the filter element.

NOTE: The sealing bead of the frost protection membrane **must** sit completely in the groove of the pump housing.



NOTE: The provided lubricant **must** be used when installing the filter housing.

Spray the threads on the pump housing and sealing bead of the frost protection membrane with Bio Lube

Put the o-ring into the groove on the filter housing. The groove **must** be free of dirt and foreign particle.

Install and tighten the filter housing with a socket.

Torque Value: 80 N•m [59 ft-lb]

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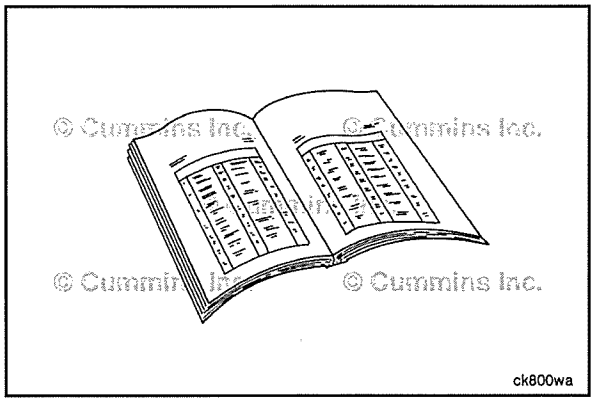
Finishing Steps



⚠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.

⚠CAUTION⚠
Do not use the flow test portion of the INSITE™ electronic service tool Diesel Exhaust Fluid Doser Pump Override Test to check the system for leaks. This will spray diesel exhaust fluid into the exhaust system at to low of temperatures to evaporate, resulting in deposit formations in the exhaust system.

- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



Notes

Section 10 - Maintenance Procedures at 6000 Hours or 3 Years

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Maintenance Procedures - Overview

General Information

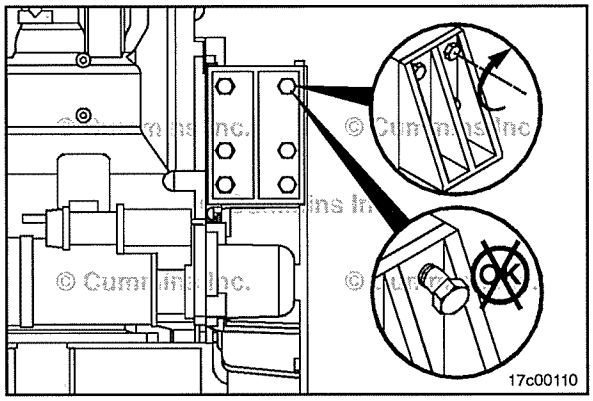
All maintenance checks and inspections listed in previous maintenance intervals **must** also be performed at this time, in addition to those listed under this maintenance interval.

Engine Mounting Bolts

Maintenance Check

Check the torque on the engine mounting nuts and bolts. Tighten any that are loose. See equipment manufacturer service information.

Inspect the rubber for deterioration and age hardening. Replace any broken or lost bolts, capscrews, or damaged rubber.



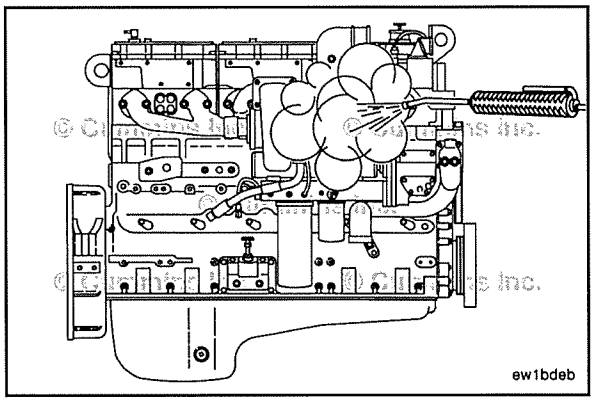
Engine Steam Cleaning

Clean

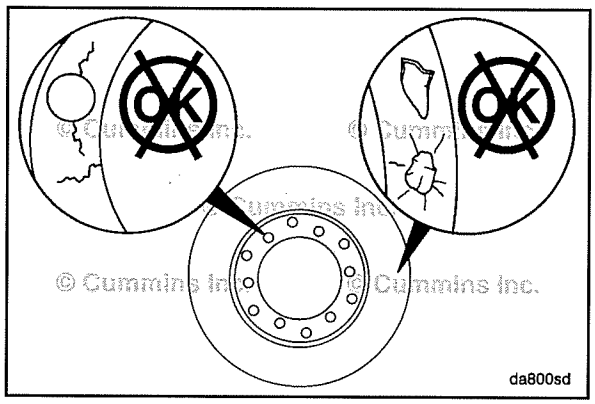
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

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.



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Vibration Damper, Viscous

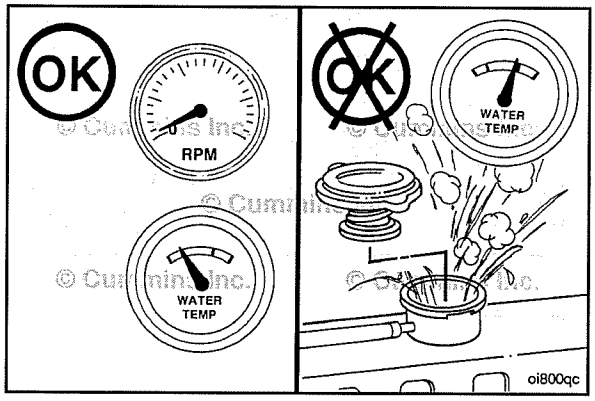
Inspect

⚠CAUTION⚠
The silicone fluid in the vibration damper will become solid after extended service and will make the damper inoperative. An inoperative vibration damper can cause major engine or drivetrain failures.

Check the vibration damper for evidence of fluid loss, dents, and wobble. Inspect the vibration damper thickness for any deformation or raising of the damper cover plate.

If any of these conditions are identified, contact your local Cummins Authorized Repair Location to replace the vibration damper.

For vibration damper location, refer to Engine Diagrams in Engine Identification (Section E).



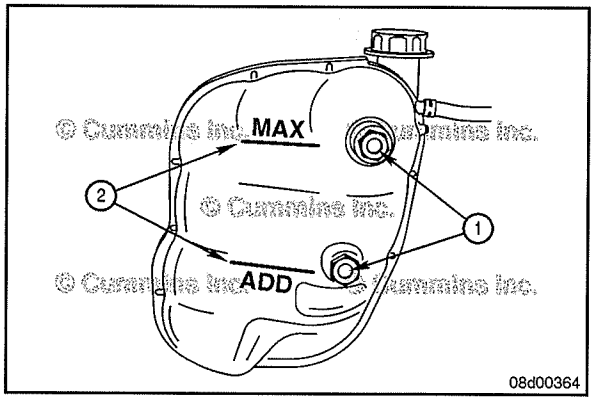
Cooling System

General Information

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

NOTE: Never use a sealing additive to stop leaks in the coolant system. This can result in coolant system plugging and inadequate coolant flow, causing the engine to overheat.

The engine coolant level **must** be checked daily.



⚠CAUTION⚠
Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool below 50°C [122°F] before adding coolant.

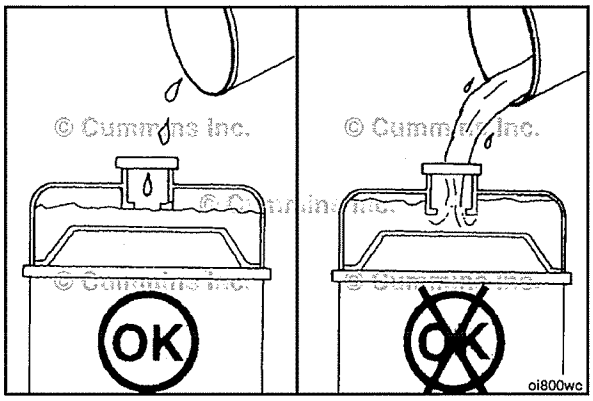
On applications that use a coolant recovery system, check to make sure the coolant is at the appropriate level on the coolant recovery tank, for the engine temperature.

Many coolant recovery/expansion tanks, also called "top tanks", have sight glasses (1) or are made of a clear material (**not** shown) to aid in checking the coolant level (2) without removing the radiator cap.

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Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill or recovery/expansion tank.

NOTE: Some radiators have two fill necks, both of which **must** be filled when the cooling system is filled.



Maintenance Check

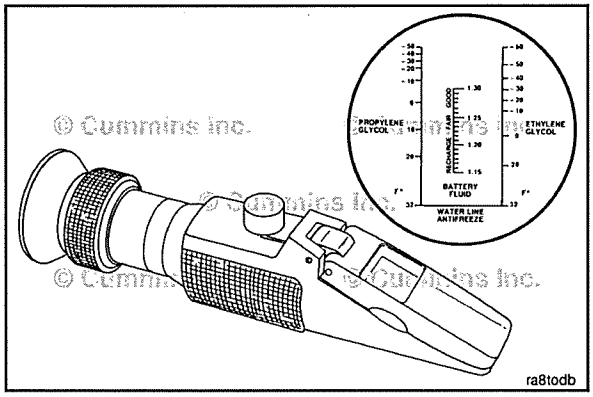
⚠CAUTION⚠
Over-concentration of antifreeze or use of high silicate antifreeze can cause damage to the engine.

Check the antifreeze concentration. Use a mixture of 50-percent water and 50-percent ethylene glycol or propylene glycol-base antifreeze to protect the engine to -32°C [-25°F] year-around.

The Fleetguard® refractometer, Part Number C2800, provides a reliable, easy to read, and accurate measurement of freezing point protection and glycol (antifreeze) concentration.

Antifreeze is essential in every climate as it broadens the operating temperature by lowering the coolant freezing point and by raising its boiling point.

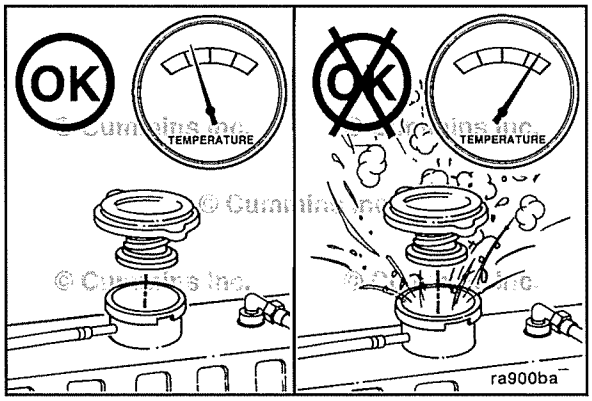
The corrosion inhibitors also protect the cooling system components from corrosion and provides longer component life.

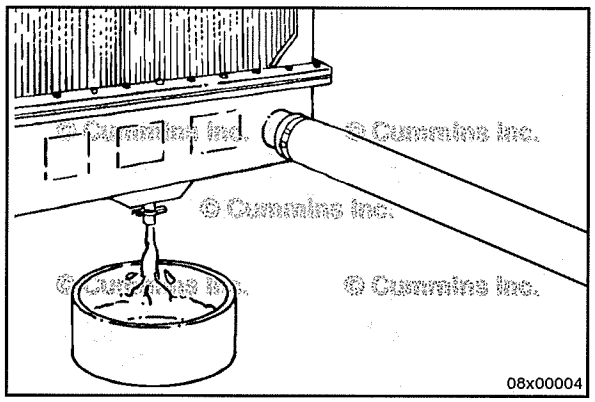


Drain

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

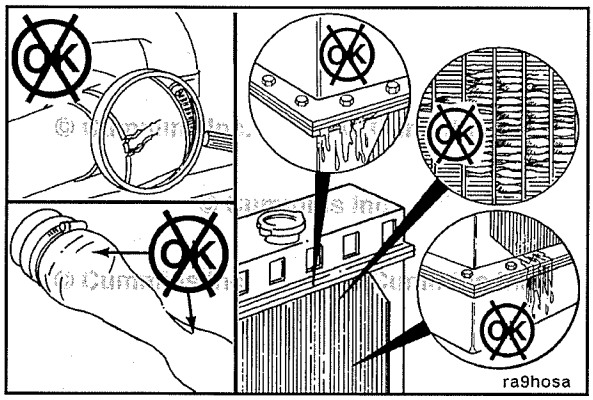
Remove the radiator/expansion tank cap.



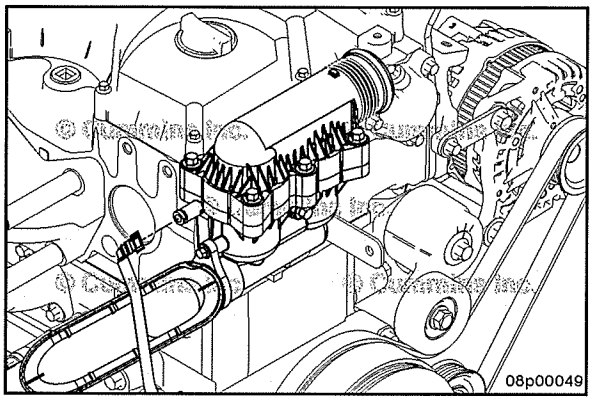


⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain the cooling system by opening the drain valve on the radiator and lower radiator hose. A drain pan with a capacity of 19 liters [5 gal] will be adequate in most applications.



Check for damaged hoses and loose or damaged hose clamps. Replace as required. Check the radiator for leaks, damage, and buildup of dirt. Clean and replace as required.



Flush

△CAUTION△
The system must be filled properly to prevent air locks. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

Be sure air is vented during the fill process. A deaeration port is located on the thermostat housing, which connects to the top tank/coolant recovery tank of the cooling system.

This provides adequate venting for a fill rate of 19 liters [5 gal] per minute.



NOTE: An alternate to using sodium carbonate, as outlined in this procedure, is to use Restore™.

Restore™ is a heavy-duty cooling system cleaner that removes corrosion products, silica gel, and other deposits. The performance of Restore™ is dependent on time, temperature, and concentration levels. An extremely scaled or flow-restricted system, for example, can require higher concentrations of cleaner, higher temperatures, longer cleaning times, or the use of Restore Plus™. Up to twice the recommended concentration levels of Restore™ can be used safely. Restore Plus™ **must** be used **only** at its recommended concentration level. Extremely scaled or fouled systems can require more than one cleaning.

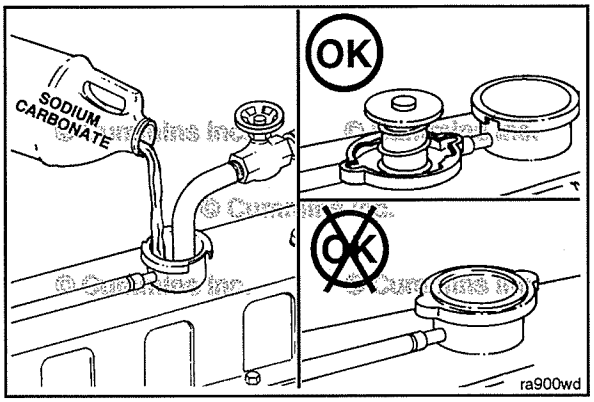
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⚠CAUTION⚠

Do not install the radiator cap. The engine is to be operated without the cap for this process.

Fill the system with a mixture of sodium carbonate and water (or a commercially available equivalent).

NOTE: Adequate venting is provided for a fill rate of 19 liters [5 gal] per minute.

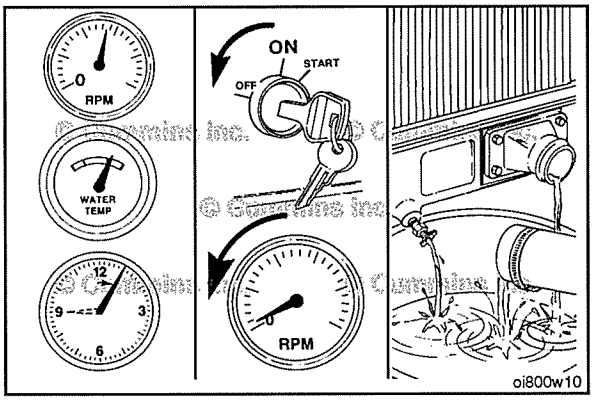


⚠WARNING⚠

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

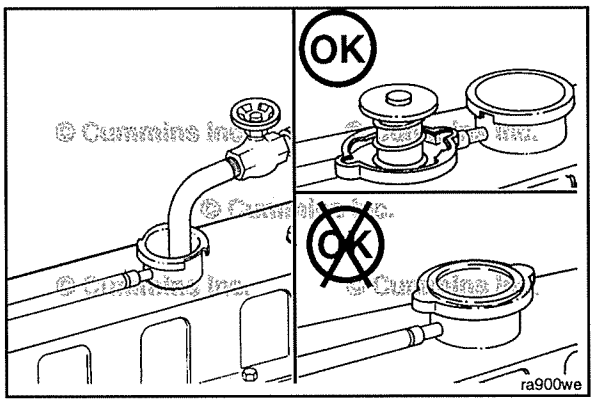
Operate the engine for 5 minutes with the coolant temperature above 80°C [176°F].

Shut the engine OFF, allow to cool to 50° C [120°F], and drain the cooling system.



Fill the cooling system with clean water.

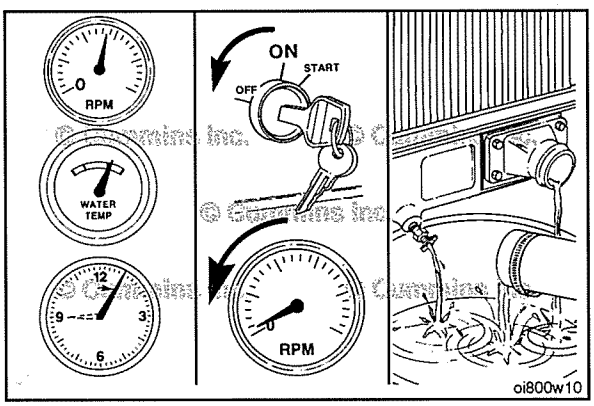
NOTE: Do **not** install the radiator cap.

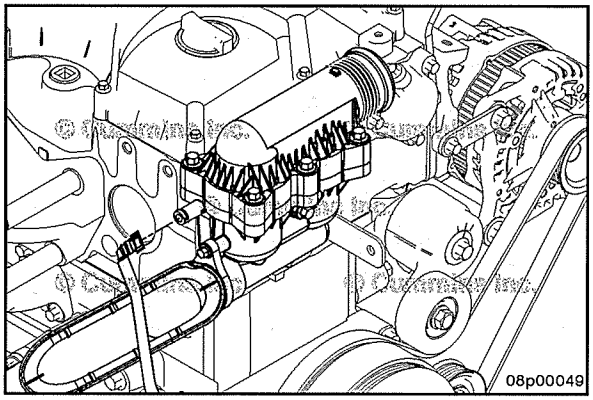


Operate the engine for 5 minutes with the coolant temperature above 80°C [176°F].

Shut the engine OFF, allow to cool to 50° C [120°F], and drain the cooling system.

NOTE: If the water being drained is still dirty, the system **must** be flushed again until the water is clean.



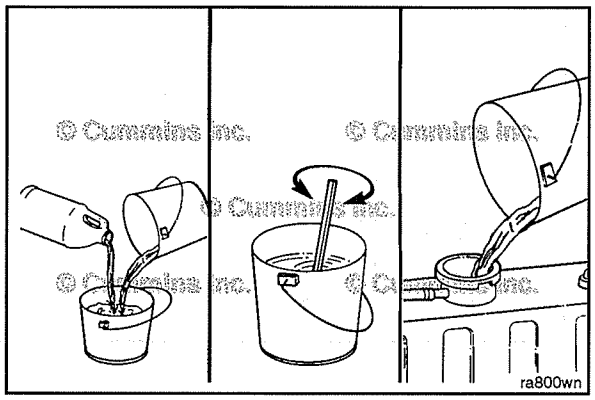


Fill

⚠CAUTION⚠
The system must be filled properly to prevent air locks. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

To be sure air is vented during the fill process. A deaeration port is located next to the water outlet connection, which connects to the top tank/coolant recovery tank of the cooling system.

This provides adequate venting for a fill rate of 19 liters [5 gal] per minute.

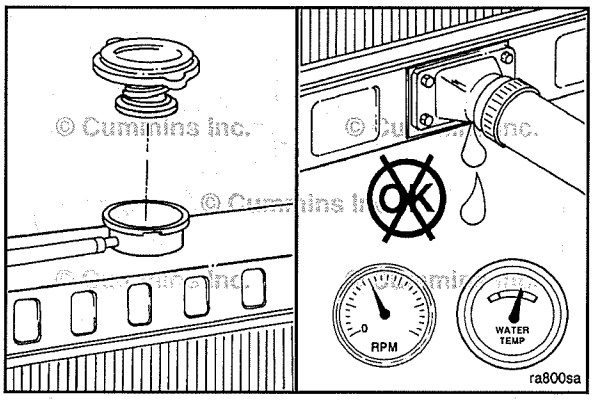


⚠CAUTION⚠
Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant.

Use a mixture of 50-percent water and 50-percent ethylene glycol or propylene glycol antifreeze to fill the cooling system.

Refer to the Cummins® Coolant Requirements and Maintenance, Bulletin 3666132, for engine coolant specifications.

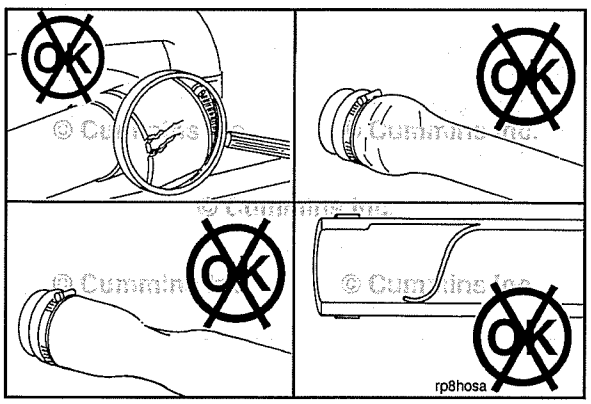
For cooling system capacity. Refer to Procedure 018-018 in Section V.



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

Install the pressure cap. Operate the engine until it reaches a temperature of 80°C [176°F] and check for coolant leaks.

Check the coolant level again to make certain the system is full of coolant or that the coolant level has risen to the hot level in the recovery/expansion tank in the system, if so equipped.



Radiator Hoses

Maintenance Check

Check all hoses for cracks, cuts, or collapsing.

NOTE: The silicone engine coolant hose will exhibit swelling due to the elasticity of the hose.

If damage is found, replace damaged hoses. Contact your local Cummins Authorized Repair Location.

Radiator Shutter Assembly

Maintenance Check

NOTE: The shutters and the fan clutch **must** be set to operate in the same temperature range as the thermostat with which they are used.

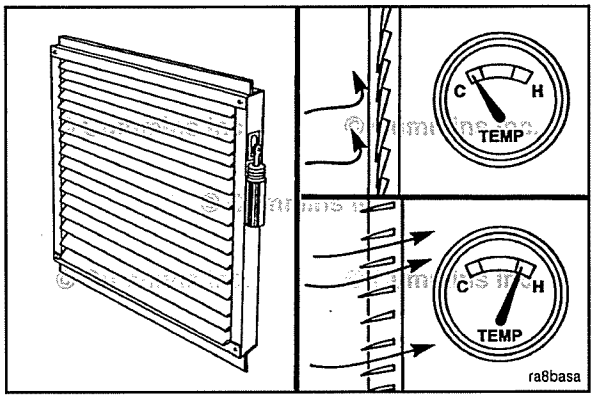
Check the shutters and the fan clutch according to the appropriate maintenance schedule.

Check the shutters in the closed position to be sure they are completely closed.

NOTE: If the shutters are **not** closed, see equipment manufacturer service information.

Make sure the shutters open completely at the desired temperature setting.

NOTE: If the shutters remain closed, see equipment manufacturer service information.

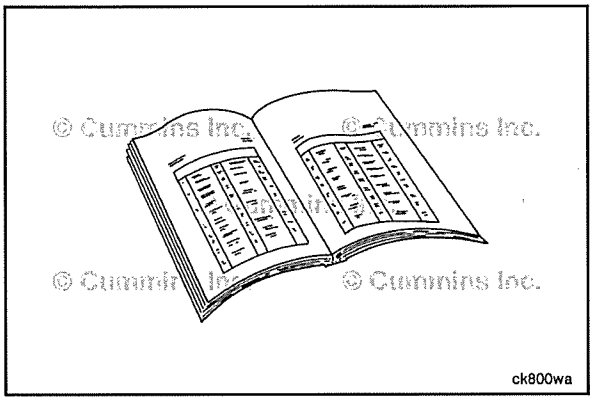


Cold Starting Aid

Preparatory Steps

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

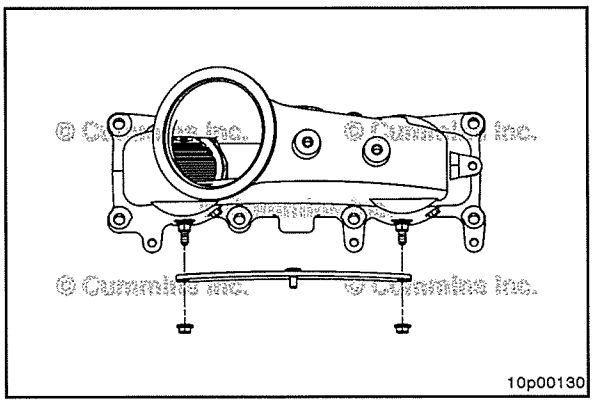
- Disconnect the batteries. Refer to Procedure 013-009 in Section A.
- Remove the charge air piping. See equipment manufacturer service information.
- Disconnect the cold starting aid wiring. See equipment manufacturer service information.
- Remove the air intake connection.

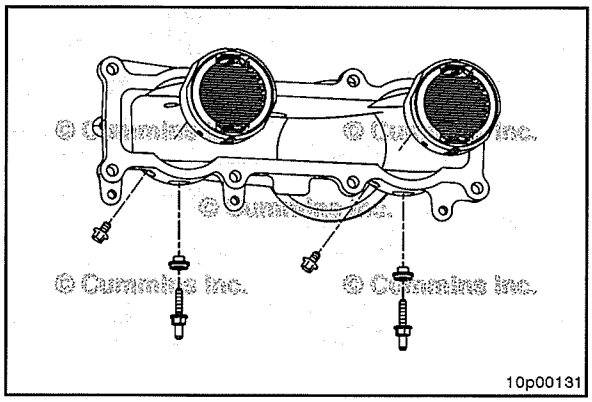


Remove

Remove the two electrical connection nuts.

Remove the electrical connection.

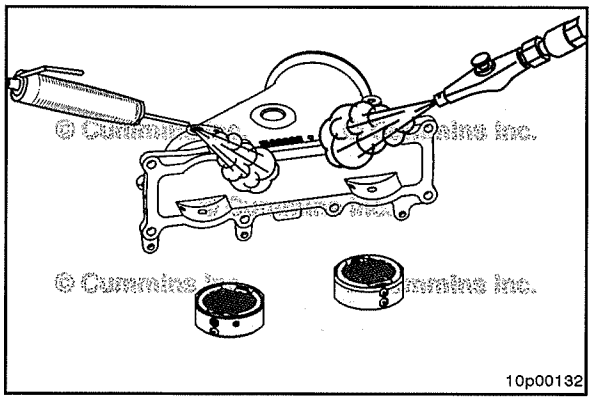




Remove electrical supply studs and spacers.

Remove ground capscrews.

Remove the cylindrical cold starting aid assemblies from the air intake connection.



Clean and Inspect for Reuse

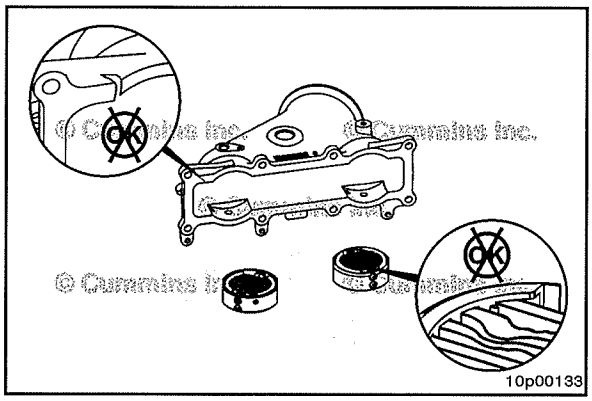
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

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

Use heavy tape from the Air Handling Clean Care Kit, Part Number 4919588, to cover open points on the plumbing and engine.

Steam clean the air intake connection.

Steam clean the cold starting aids, and electrical connection. Dry with compressed air.



Inspect the cold starting aid and air intake connection sealing surfaces for cracks or other damage.

Replace any damaged components.

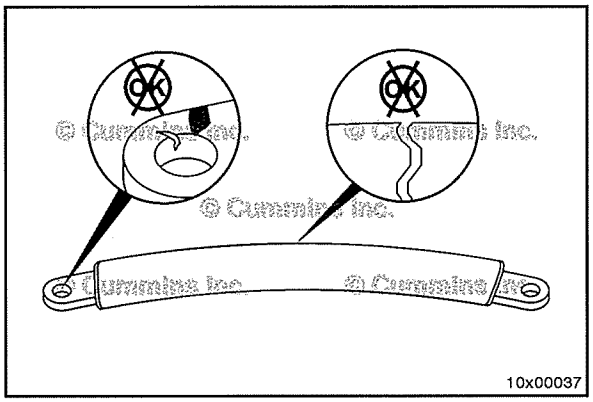
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Inspect the electrical connection insulation and connector for damage.

Replace the electrical connection if damage is found.

Inspect the electrical connection of signs of corrosion, If corrosion is found remove all traces of corrosion.

If the corrosion can **not** be removed, or resulted in damage to the connection the electrical connection **must** be replaced.

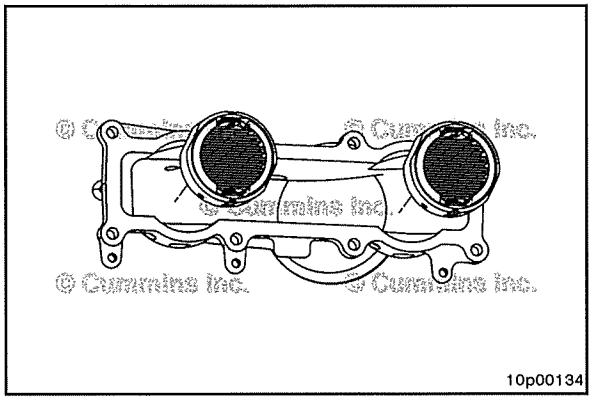


10x00037

Install

Fit the two cold starting aids into the air intake connection.

Rotate the cold starting aids to align the cold starting aid holes with the machined holes in the bottom of the air intake connection.


10p00134

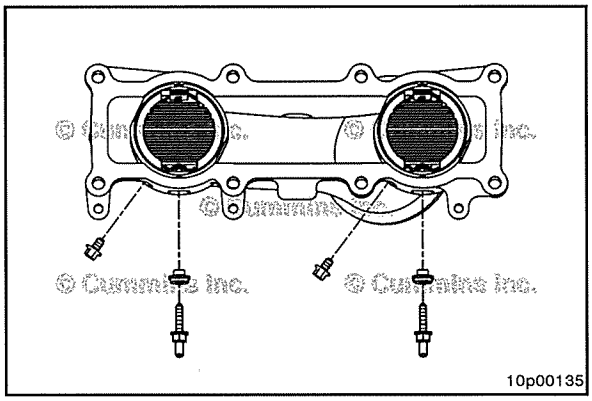
Install the two ground capscrews hand tight.

Install the two electrical studs and spacers hand tight.

NOTE: Be sure to install the larger end of the spacer against the air intake connection.

Tighten the ground capscrews and electrical studs to the following specification.

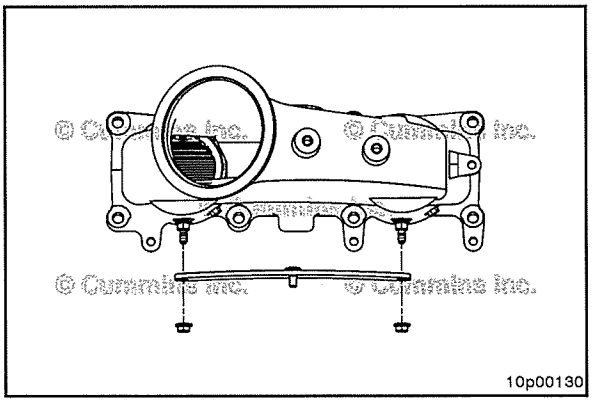
Torque Value: 5.6 N•m [50 in-lb]

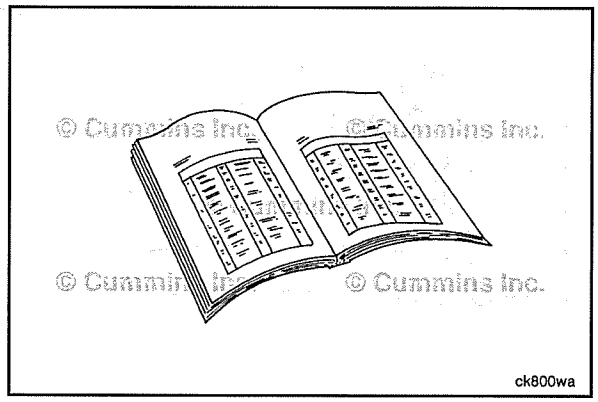

10p00135

Install the electrical connection.

Install the two electrical connection nuts.

Torque Value: 5.6 N•m [50 in-lb]


10p00130

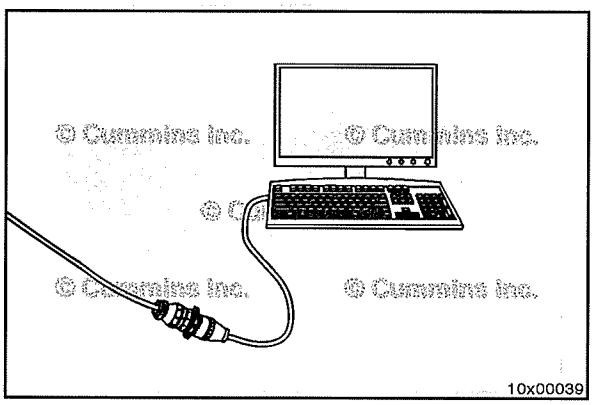


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Install the Air Intake Connection.

Connect the cold starting aid wiring. See equipment manufacturer service information.

Connect the batteries. Refer to Procedure 013-009 in Section A.



Test

⚠WARNING⚠
To reduce the possibility of personal injury, wear protective gloves when handling parts that have been heated.

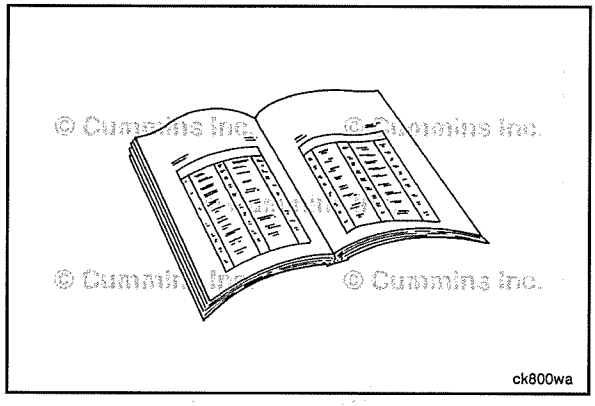
Connect INSITE™ electronic service tool.

From the list of ECM diagnostic tests, select "Intake Air Heater Override".

Follow the on-screen instructions to determine if the cold starting aid is functioning properly.

Measure the current draw at the OEM wiring of the cold starting aid by using a clamp on current probe Part Number 3164490, or equivalent.

Cold Starting Aid Current Draw		
MIN		MAX
112.5	Amps	137.5



Finishing Steps

- Install the charge air piping. See equipment manufacturer service information.
- Operate engine and check for leaks.

Engine Mounts

General Information

Some vibration exists in all piston type engines, due to the pulsating power inputs and reciprocating components. Some of these vibrations are internal to the engine and are compensated, or balanced, by opposing forces within the engine structure. These are generally **not** of interest to vibration isolation designs. The vibrations that are offset or balanced internally will cause shaking moments and forces that **must** be reacted to by the engine mounts. If these moments and forces are **not** adequately reduced by the engine mounting and isolation systems, they can cause customer dissatisfaction and/or damage, due to component fatigue.

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The effectiveness of an engine mounting system in isolating the vehicle structure from engine vibration depends on the relationship between the frequency of the vibration coming from the engine and the natural frequency of the engine mounting system. The mounting system effectiveness is commonly measured with the term “transmissibility”. Transmissibility is the amount of engine vibration which is transmitted through the mounting system to the vehicle structure.

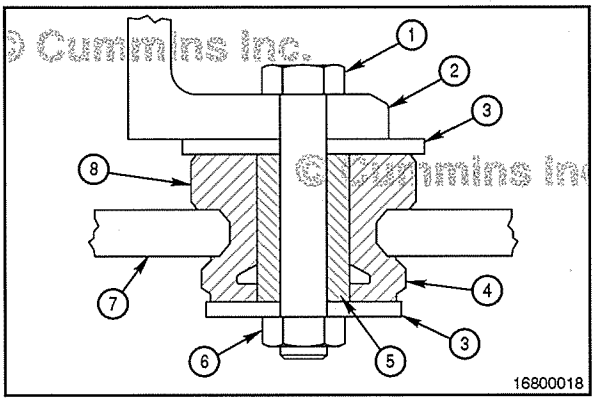
Transmissibility values greater than one indicate the engine mounting system is actually transmitting more vibration into the vehicle structure than is coming from the engine. This is possible if the natural frequency of the mounting system is close to the frequency of the engine vibration. This can result in the mounting system operating at or near resonance, with a resulting magnification of the input vibration. This is obviously an undesirable situation.

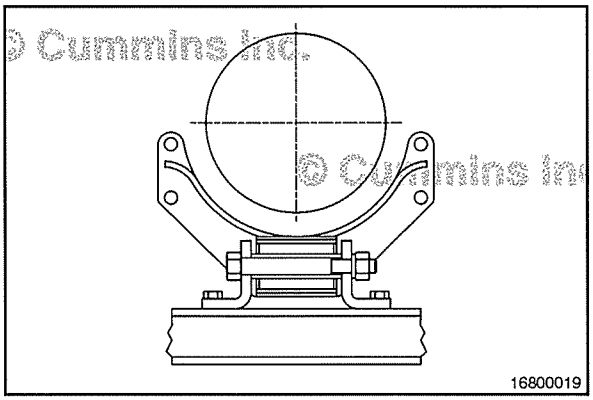
Transmissibility values of less than one indicate the mounting system is transmitting **only** a fraction of the vibration input from the engine, thus isolating the vehicle from engine vibration. Good engine mounts will reduce the amount of engine vibration transmitted to the chassis frame by at least 50 percent at idle.

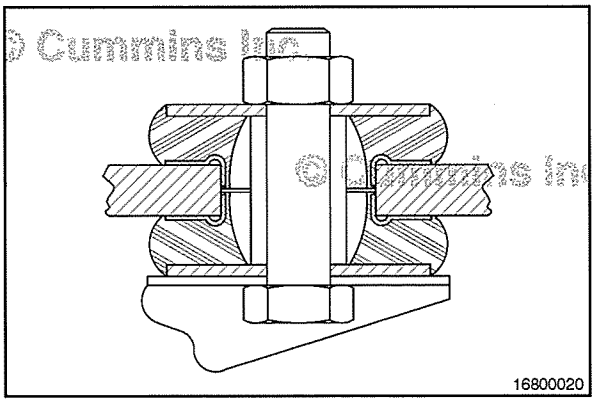
Stiffness (durometer) and size of the isolator, along with the weight of the engine or component applied, are the determining factors when designing a mounting system. An isolator that is correct for one engine may **not** be right for another. Likewise, because of weight differential, a particular isolator designed for the rear of an engine probably will **not** be ideal for the front. Hard engine mounts will give little or no isolation, and can actually magnify the vibration transmitted to the chassis.

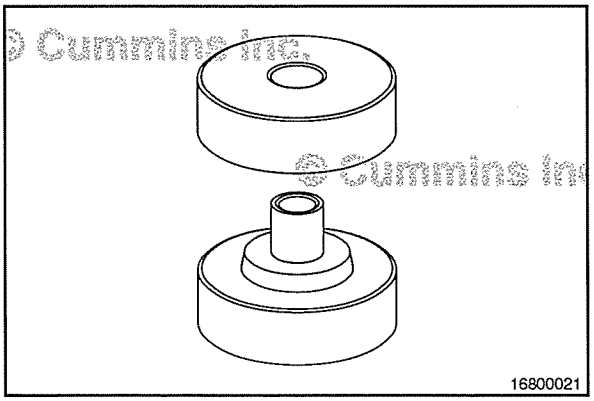
The following are illustrations of typical FRONT engine mounts.

1 Bolt
2 Supported member
3 Snubbing washer (or flat bracket surface of equal diameter
4 Rebound tail
5 Bonded metal center
6 Locknut
7 Supporting member
8 Rubber mount.

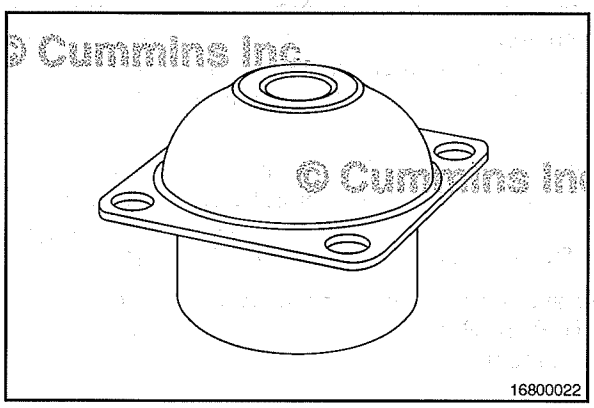


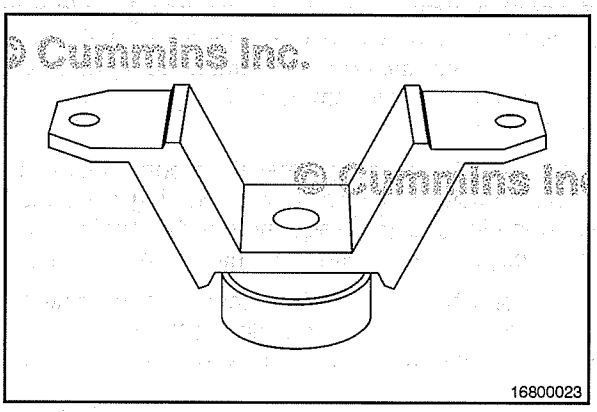


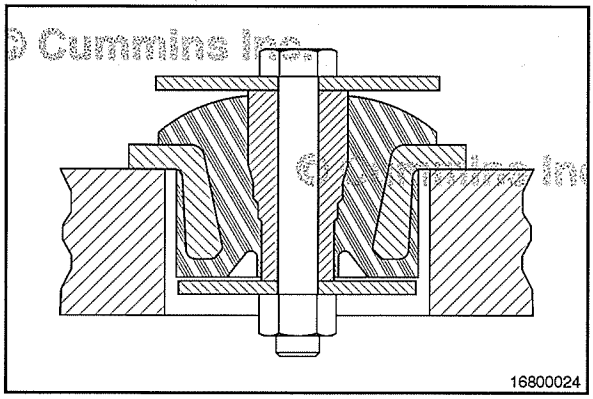


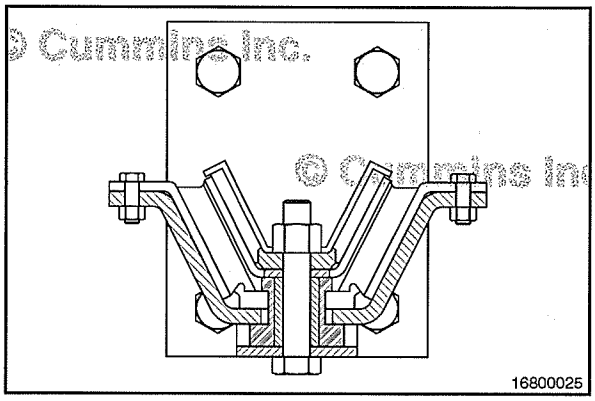


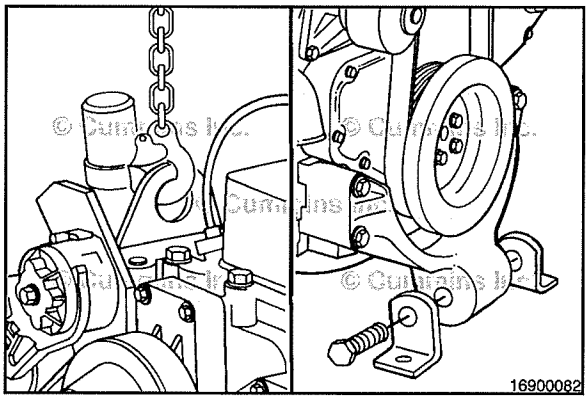
The following are illustrations of typical REAR engine mounts.











Remove

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

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

Use a hoist or lifting fixture to support the engine.

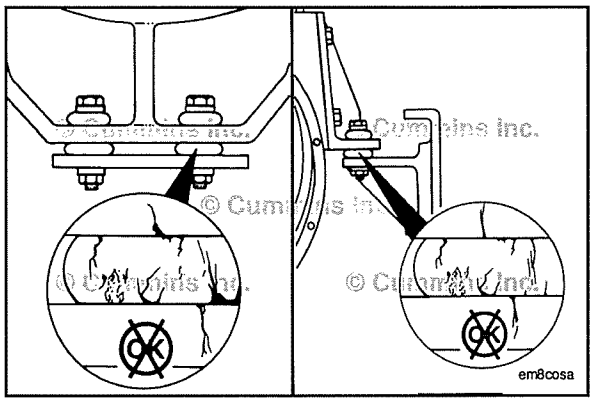
NOTE: When removing the engine mount fasteners, note the location of any shims or spacers used.

Remove the capscrews from the engine mounts.

NOTE: Certain applications will require loosening of the rear engine mount fasteners to allow removal of the front engine support bracket.

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Inspect for Reuse



⚠CAUTION⚠
Damaged engine mounts and brackets can cause engine misalignment. Drivetrain component damage can result in excessive vibration complaints.

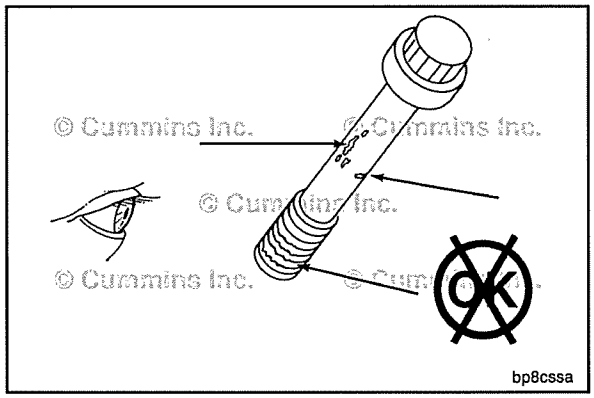
Inspect all rubber-cushioned mounts for cracks and other damage. Look for interference or contact between metal components.

Inspect all mounting brackets for cracks and damaged bolt holes.

Inspect the mounting capscrew to make sure it is **not** too long, which will **not** provide enough preload on the mount.

Replace any damaged parts as necessary.

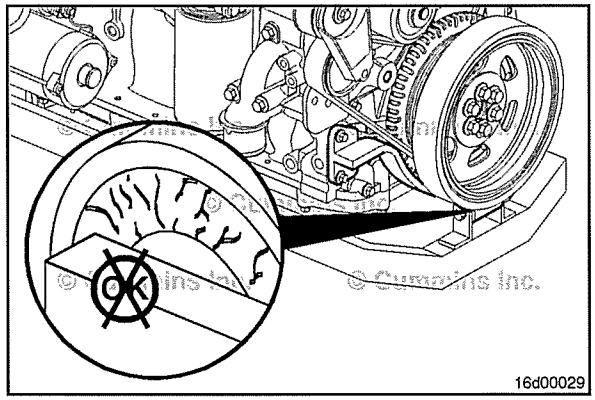
NOTE: Damaged engine mounts, brackets, and mounting hardware can cause the engine to move out of alignment and damage the driveline components in the equipment. This can result in vibration complaints.



Inspect the capscrew for the following:

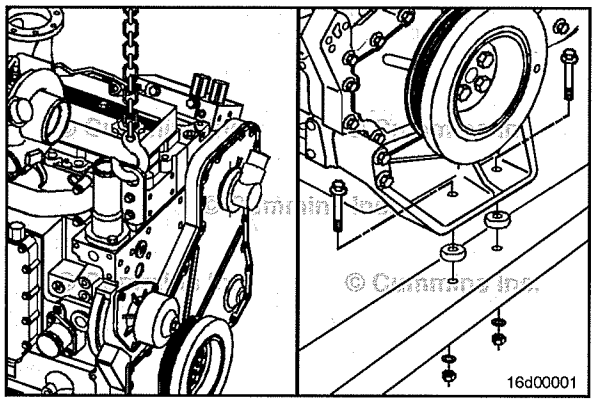
- Damaged threads
- Rust or corrosion-caused pitting
- Nicked, bent, stretched, or galled.

The capscrew **must** be replaced if it has any of the listed damages.



For barrel mounts, inspect for signs of contact between the side brackets and the front engine support bracket.

Contact between the engine mount and side brackets can cause vibration complaints. If contact is found, replace the front engine support bracket.



Install

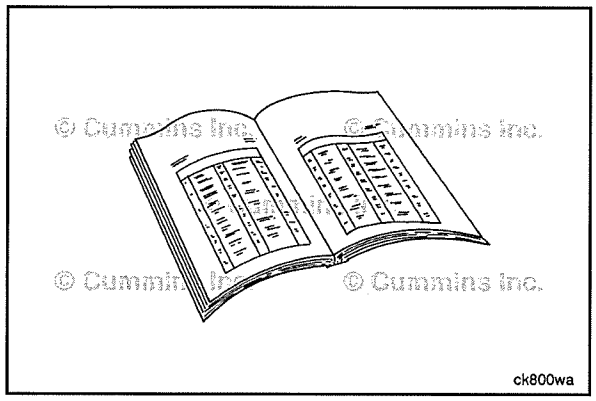
NOTE: Make sure to install any shims or spacers in the same location as removed.

Align the engine in the chassis.

Install the engine mount fasteners and tighten. Refer to the OEM service manual for torque specifications.

Remove the lifting fixture or hoist from the engine lifting brackets.

Connect all engine and chassis mounted accessories that were removed.

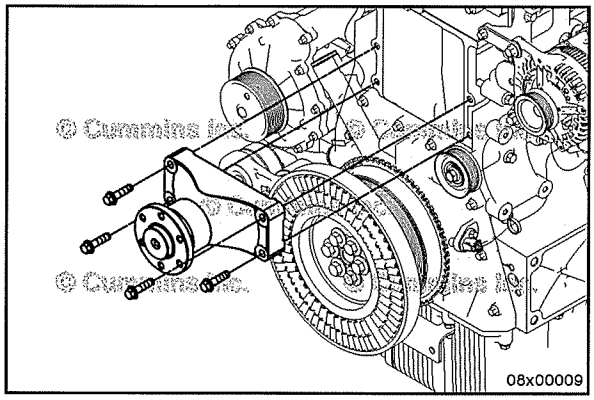


Fan Hub, Belt Driven

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.

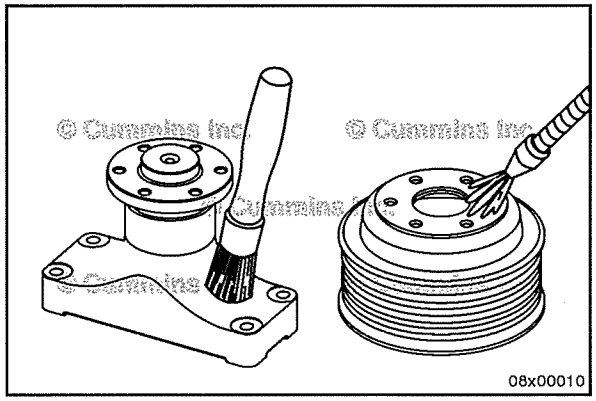
- Disconnect the batteries. See equipment manufacturer service information.
- Remove the drive belt. Refer to Procedure 008-002 in Section A.
- Remove the cooling fan. See equipment manufacturer service information for instructions.
- Remove the fan pulley and spacer. Refer to Procedure 008-089 in Section A.



Remove

Remove the four capscrews and the fan support.

Clean and Inspect for Reuse



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

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

⚠CAUTION⚠
Do not expose the cooling fan drive belt to solvents, acids, or alkaline materials for cleaning. Belt damage can result.

Clean the fan hub and fan pulley with solvent.

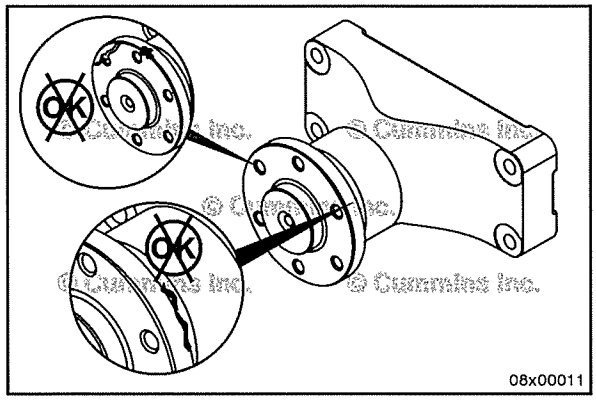
Dry with compressed air.

Inspect the fan hub for indications of oil seal leakage.

Inspect the fan hub for cracks or other damage.

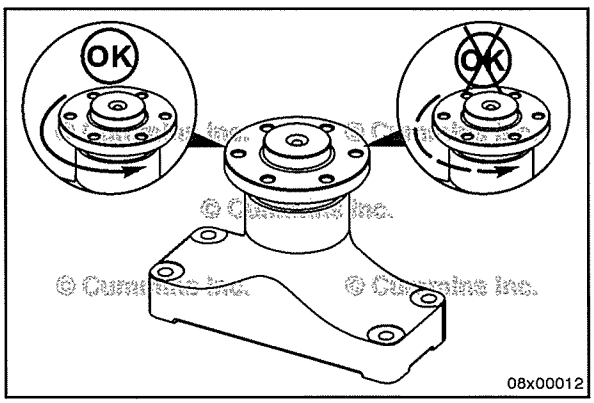
Inspect the fan hub chamfer and pulley mating surface for damage.

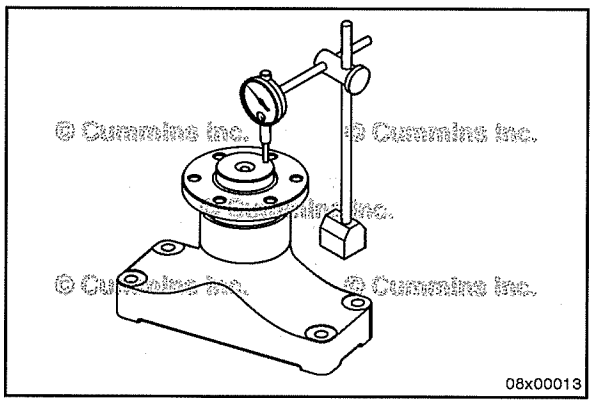
Replace the fan hub if damage is found.



Turn the fan hub by hand to check for freedom of rotation.

The fan hub **must** spin freely without any wobble or excessive end clearance.



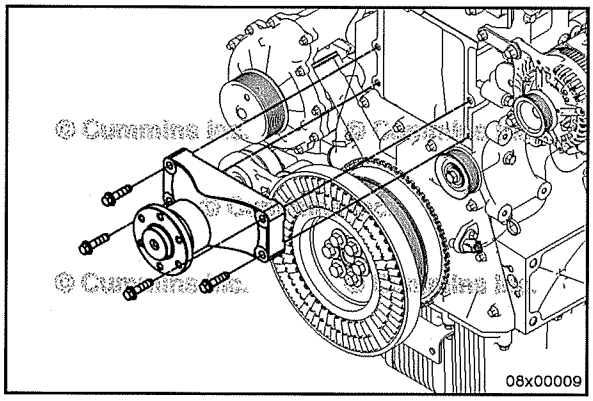


Inspect the fan hub bearing for wear.

The bearing **must** have a minimal amount of side-to-side or end-play movement.

Replace the fan hub if there is more than 0.15 mm [0.006 in] of end play in the fan hub. Measure end play with a dial indicator, service tool Part Number 3376050.

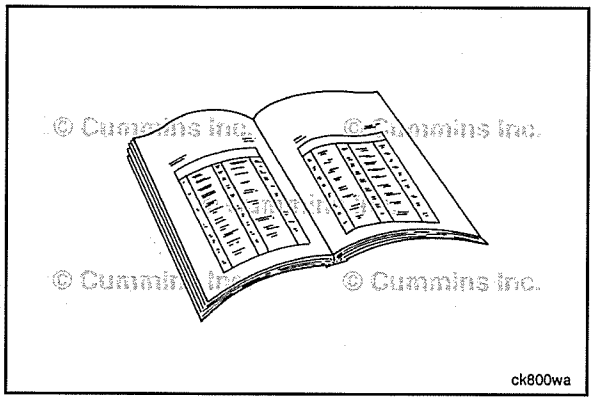
Fan Hub End Play		
mm		in
0.15	MAX	0.006



Install

Install the fan hub and four capscrews.

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.

NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

- Install the fan pulley and spacer. Refer to Procedure 008-089 in Section A.
- Install the cooling fan. See equipment manufacturer service information.
- Install the drive belt. Refer to Procedure 008-002 in Section A.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for proper operation.

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Section A - Adjustment, Repair, and Replacement

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Rocker Lever Cover

Preparatory Steps



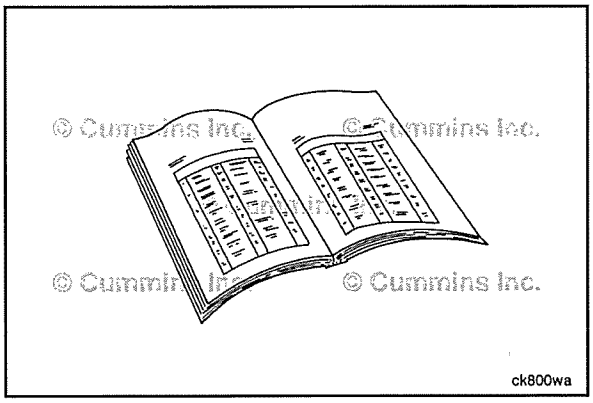




⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠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 A.
- Disconnect the injector passthrough connectors.



Remove



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]

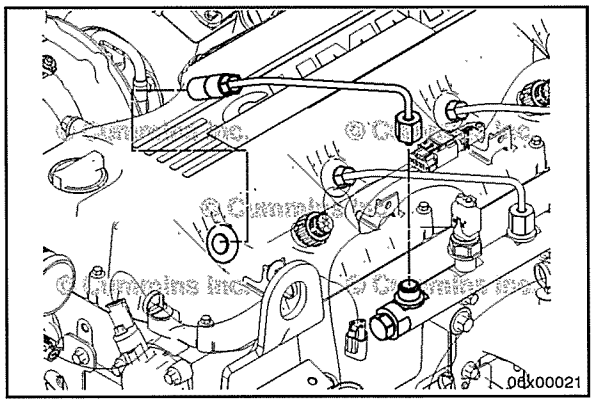
NOTE: A machined slot in this fittig directs the fuel spray towards the engine block.

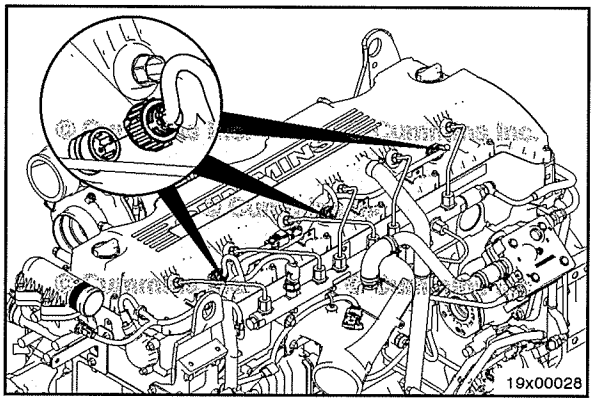


Disconnect the high-pressure fuel line from the rail end of number 1 injector. Cover the end of the line immediately.

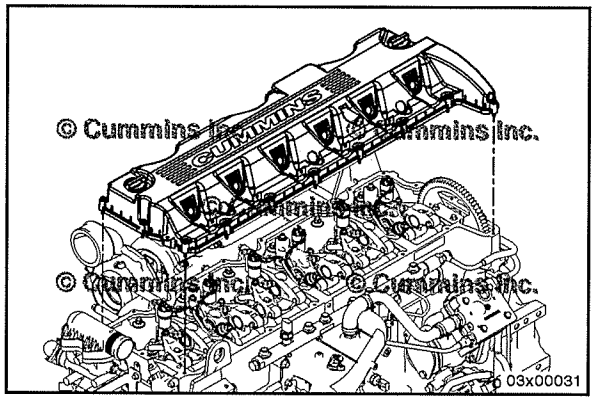
Disconnect the line from the number 1 injector. Cover the end of the line and the injector connection immediately.

Repeat the steps for all six injectors, removing and capping the connections on at a time.





Disconnect the three injector passthrough electrical connectors.

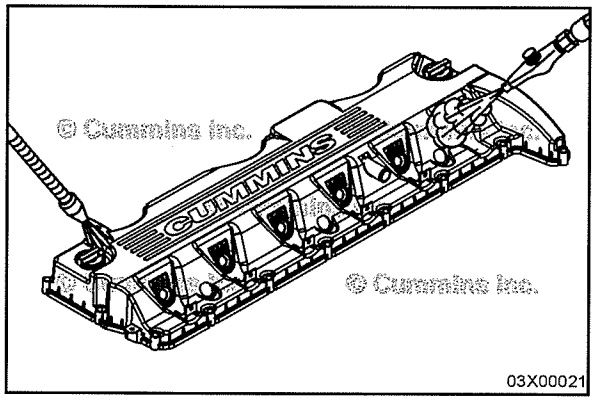


The mounting capscrews and compression limiters are part of the rocker lever cover. The capscrews are the captive design and will be held in place in the rocker lever cover.

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.

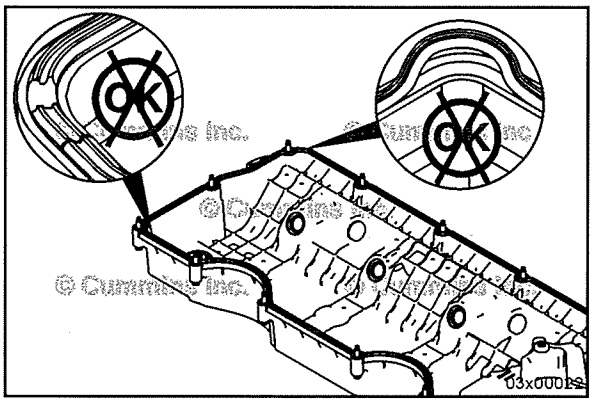
Dry with compressed air.

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NOTE: Check the gasket while it is installed in the valve cover.

Check the gasket for cracks on the sealing surface.

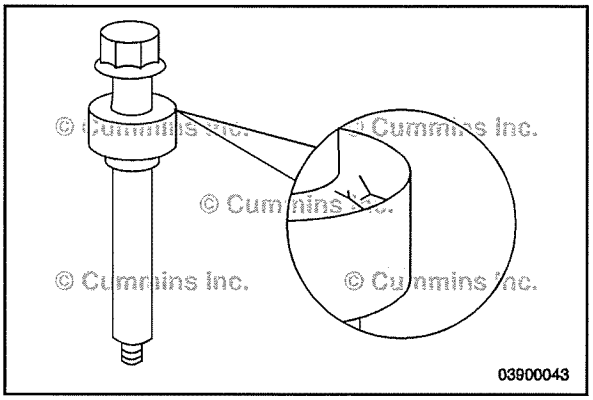
Replace the gasket if damage is present.



NOTE: It may be necessary to replace the capscrew/ compression limiter as an assembly.

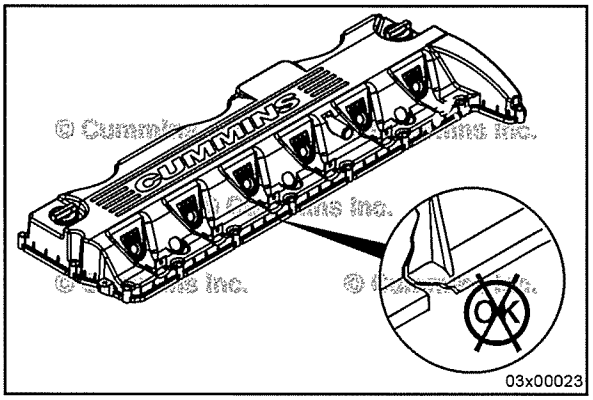
Inspect the compression limiters and rocker lever cover edge for cracks or other damage.

Replace the compressions limiters and/or capscrew assembly if damage is found.



Inspect the rocker lever cover for cracks or other damage.

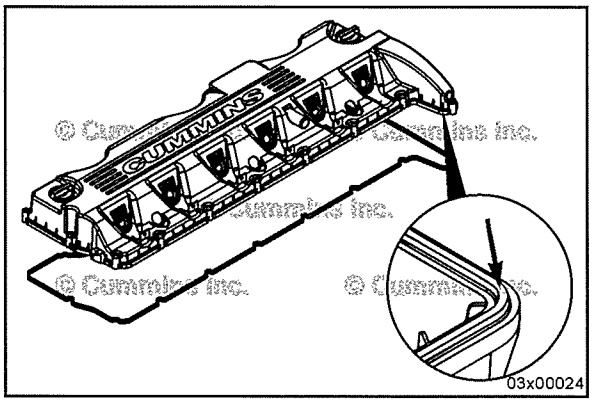
Replace the rocker lever cover if any damage is found.

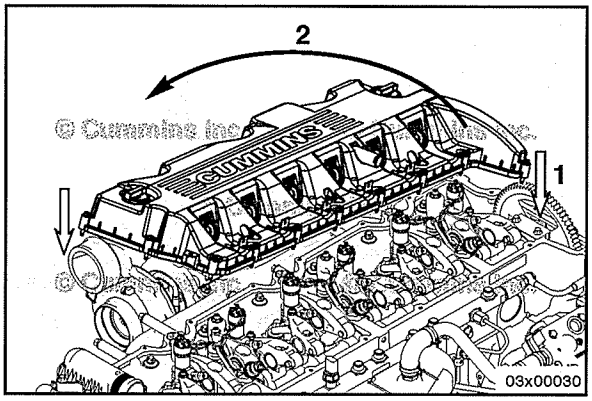


If replacing the rocker lever gasket, the following installation procedure **must** be used when installing the press-in gasket.

1 Press the molded gasket into the corners of the rocker lever cover.

2 Press the remaining gasket into the rocker lever cover.



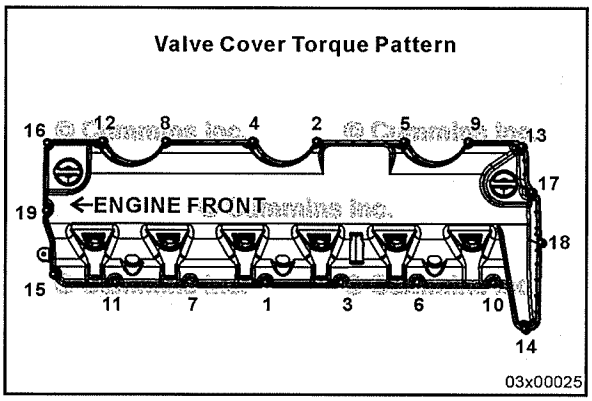


Install

Verify the injector passthrough connector locating flats are positioned on the top of the connector.

Install the rocker lever cover.

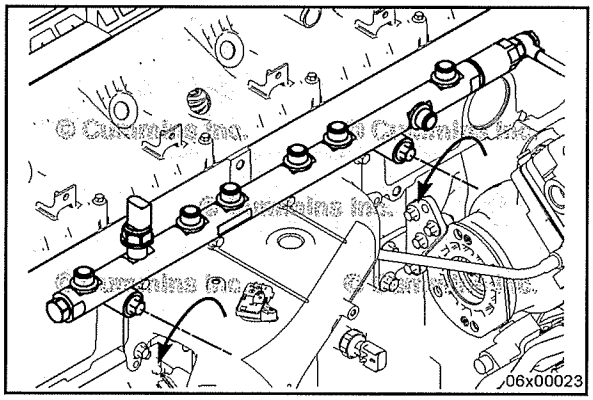
To aid installation tilt the cover to the left side of the engine. Lower the left side of the cover onto the head first, then lower the right side. Be sure the pass through connectors have seated properly with the locating flat on the top of the connector.



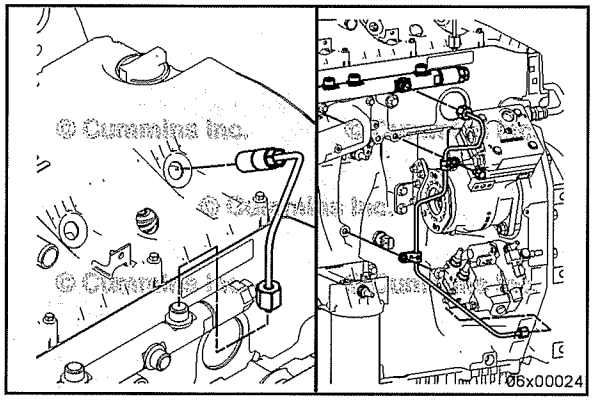
Tighten the mounting capscrews in the sequence shown.

Torque Value: 9.5 N•m [84 in-lb]

Install the injector passthrough connector lock rings.



Loosen the capscrews for the fuel rail. Do **not** remove the fuel rail. The capscrews are loosened to allow proper alignment of the fuel rail after installing the new fuel line.



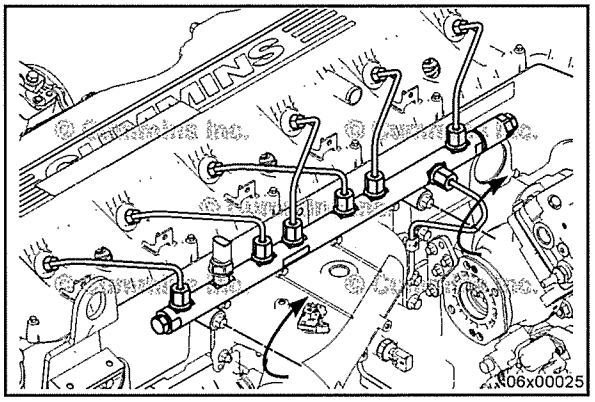
Install and hand-tighten all of the fuel lines.

Tighten the injector high pressure supply lines:

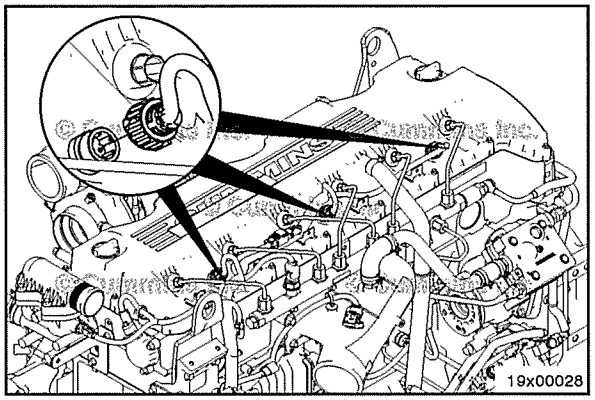
Torque Value: 25 N•m [221 in-lb]

Tighten the capscrews for the fuel rail.

Torque Value: 46 N•m [34 ft-lb]



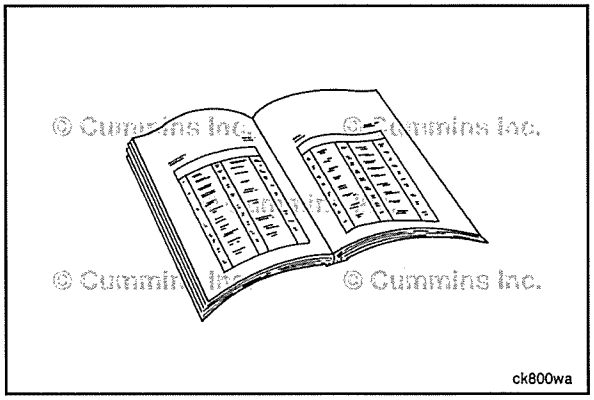
Connect the three injector passthrough electrical connectors.



Finishing Steps

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

- Connect the batteries. Refer to Procedure 013-009 in Section A.
- Operate the engine and check for leaks.



Fuel System Priming

Prime

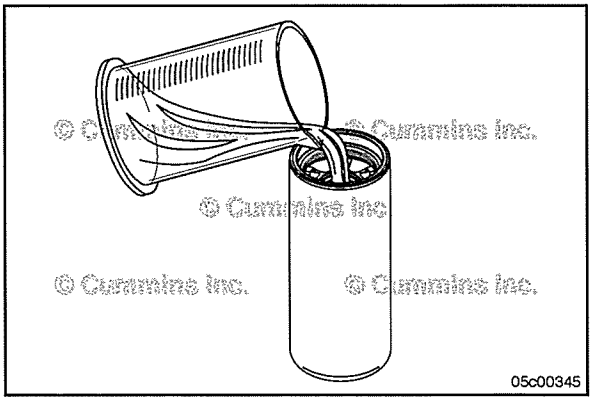
The fuel system should be primed after replacing the fuel filter or running the engine out of fuel.

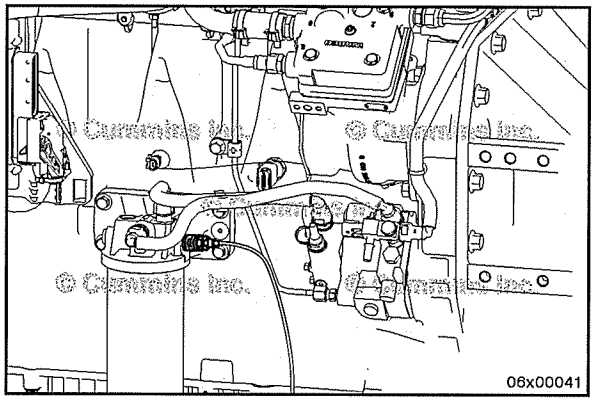
To prime the fuel system, fill the suction-side and pressure-side fuel filters with clean diesel fuel.

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 4.

Install the pressure-side fuel filter. Refer to Procedure 006-065 in Section 4.





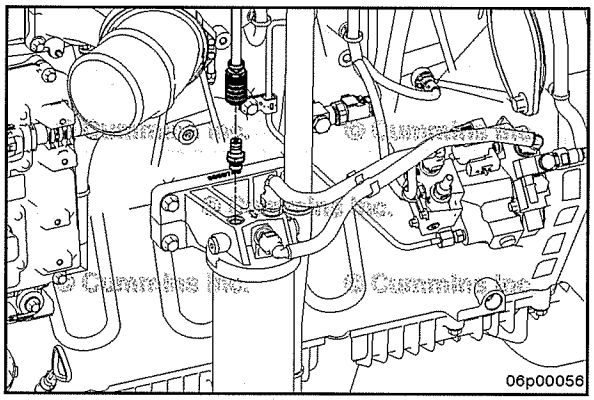
To assist in fuel system priming and removing air from the fuel system, an orificed diagnostic fuel line, Part Number 3164621, may be used to bleed air from the low-pressure fuel system.

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 A.



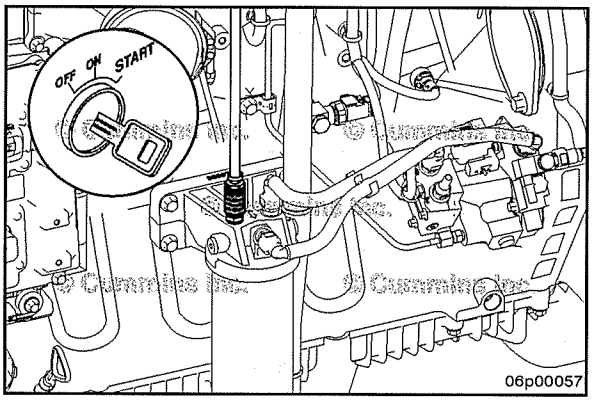
Air in Fuel

Setup

Install a Compuchek™ fitting, Part Number 3824844, at the outlet to the fuel filter head.

Install orificed diagnostic fuel line, Part Number 3164621, onto the Compuchek™ fitting at the inlet to the pressure side fuel filter.

The orificed diagnostic fitting is used in procedures to create rated flow through the low pressure fuel system without the need to operate the engine under load.



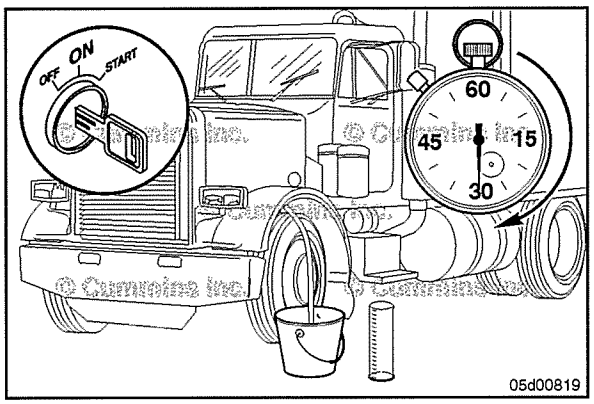
Measure

NOTE: A symptom of air-in-fuel for the engines equipped with a common rail fuel system is an audible surge associated with fuel system pressure fluctuations, due to air in the fuel supply.

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Use a quick-connect to route the fuel that exits the orificed diagnostic fitting into a container suitable for collection of fuel, such as a 19 liter [5 gal] bucket.

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

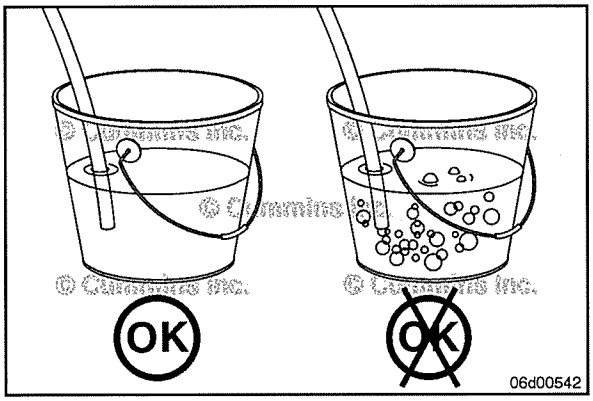


Observe the fuel flow exiting the diagnostic fuel line while the engine runs at idle speed. No air should be present in the fuel.

Air in the fuel is an indication of a leak that allows air to enter, a severe inlet restriction that causes cavitation, or a system that is **not** yet primed. Use the following procedure to check inlet restriction. Refer to Procedure 006-020 in Section A.

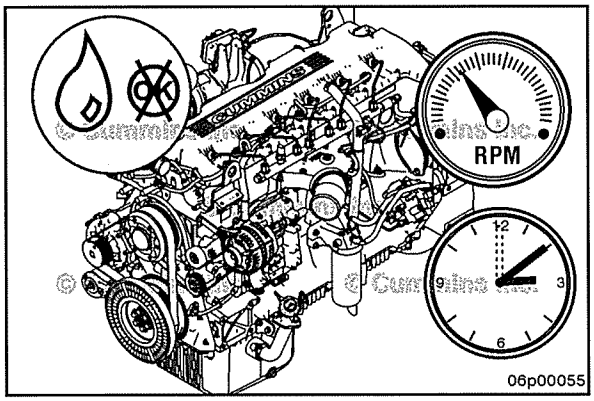
If fuel inlet restriction is **not** excessive, the source of air entry should be isolated to one of the following:

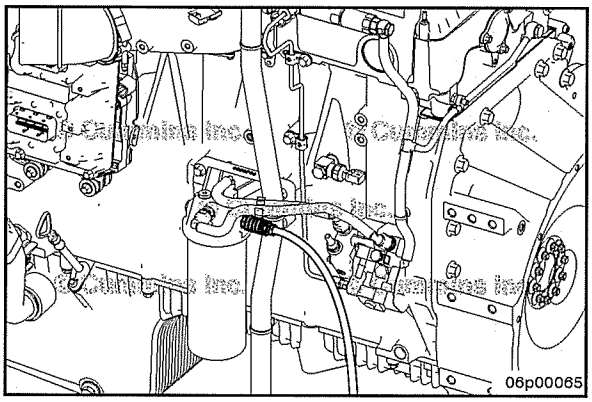
- Suction fuel lines
- OEM fuel lines
- Suction-side fuel filter assemblies
- Stand-pipe(s) in the fuel tank(s).



Finishing Steps

- Remove all test fuel lines.
- Operate the engine and check for leaks.





Fuel Inlet Restriction

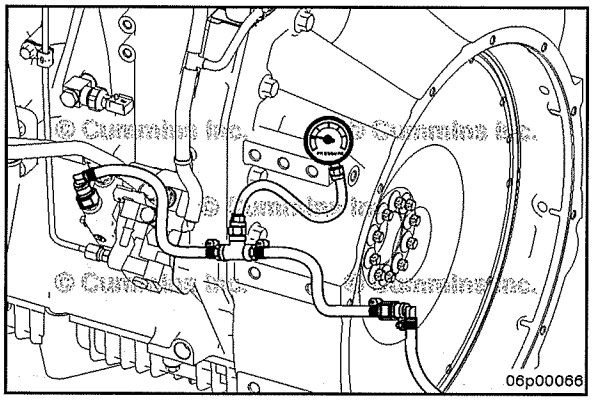
Setup

Install Compuchek™ fitting, Part Number 3824844, at the inlet to the pressure side fuel filter.

Install orificed diagnostic fuel line, Part Number 3164621, onto the Compuchek™ fitting at the inlet to the pressure side fuel filter.

A 1.09-mm [0.043-in] orificed diagnostic fuel line is used to create rated flow through the low pressure fuel system without the need to operate the engine under load.

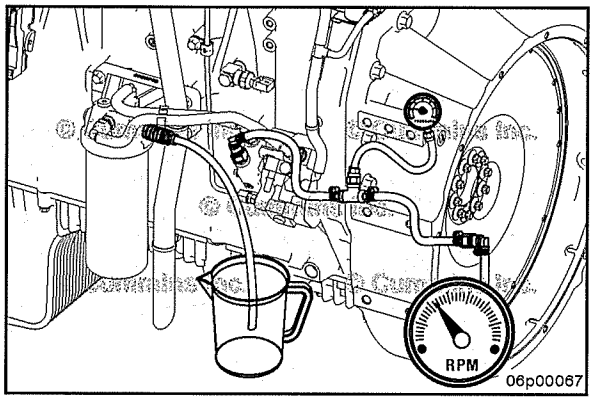
Route the hose from this adapter to a suitable container.



If equipped with a quick disconnect inlet, install Part Number 4918696 in line with fuel gear pump inlet and OEM fuel supply line.

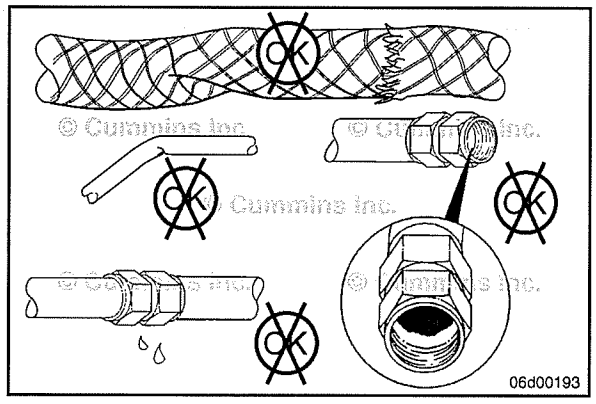
If equipped with a threaded inlet, install Part Number ST-434-2 in line with fuel gear pump inlet and OEM fuel supply line.

Attach a 0 to 762 mm-Hg [0 to 30 in-Hg] vacuum gauge, found in kit part number 3400162, to the Compuchek™ test fitting Part Number 3376920 at the gear pump inlet.



Measure

Operate the engine at high idle and measure the inlet restriction.

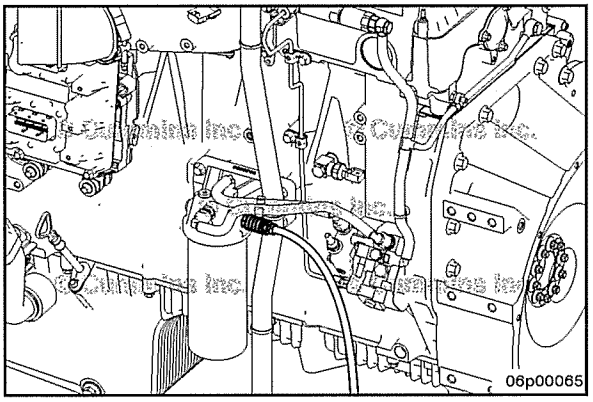


If the inlet restriction is excessive, look for the root cause:

- Suction side fuel filter plugged
- Fuel heater valves are restricted
- OEM fuel lines pinched or restricted
- Fuel tank stand pipes restricted.

Finishing Steps

Disconnect all diagnostic test fittings and install all components removed during testing.

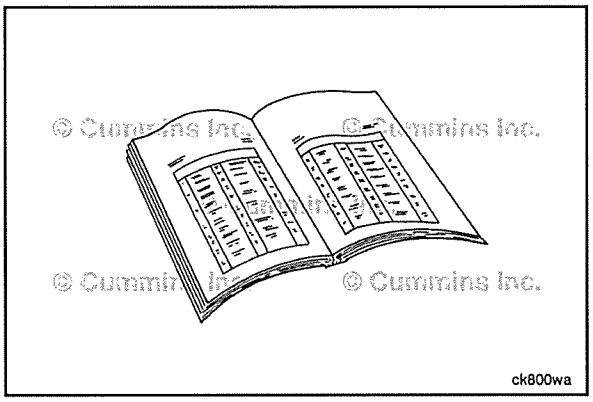


Drive Belt, Cooling Fan

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.

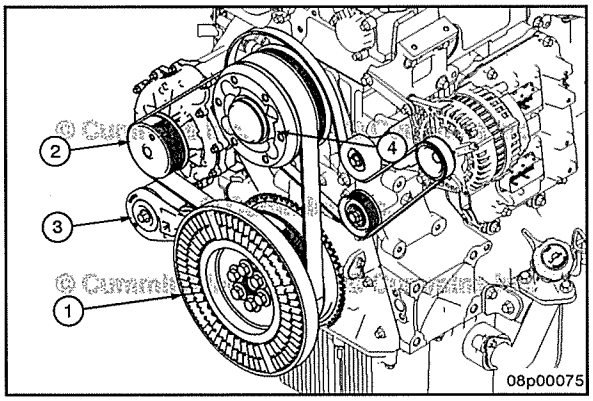
- Disconnect the batteries. See equipment manufacturer service information.



To be sure the cooling fan drive belt is routed correctly upon installation, make a diagram of the cooling fan belt routing, as shown in the illustration, prior to removing the belt.

The cooling fan belt routing consists of the following components.

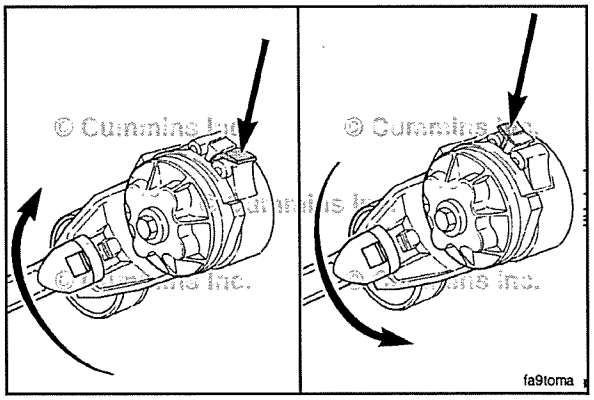
1 Crankshaft pulley/vibration damper
2 Water pump pulley
3 Tensioner(s)
4 Fan pulley.

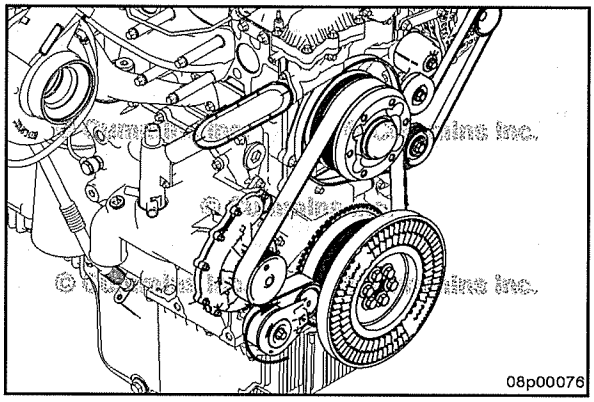


Remove

⚠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.





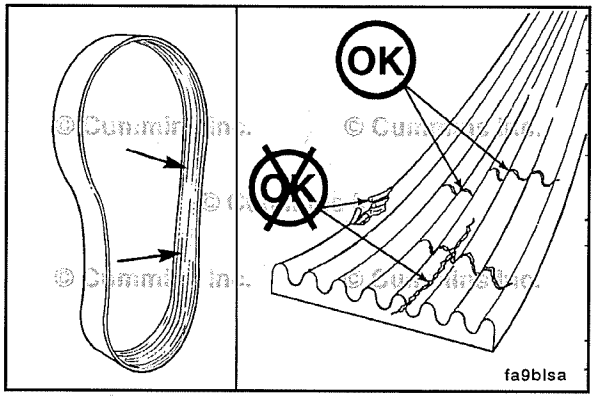
⚠CAUTION⚠

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.



Clean and Inspect for Reuse

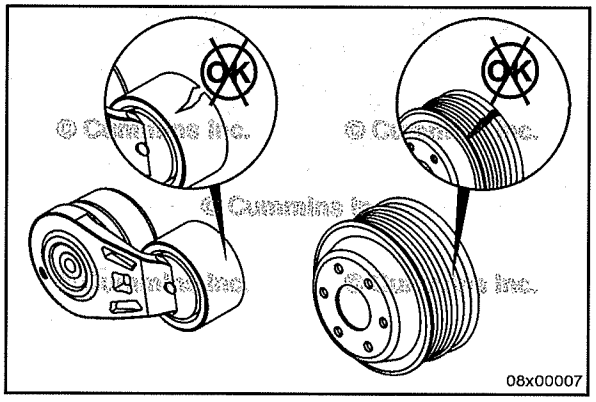
Check the belt for damage. Transverse (across the belt width) cracks are acceptable. Longitudinal (direction of the belt length) cracks that intersect with transverse cracks are **not** acceptable. If the belt is frayed or has any piece of material missing, the belt is unacceptable and needs to be replaced.

Inspect the belt for:

- Cracks
- Glazing
- Tears or cuts
- Excessive wear.

Replace the belt if any damage is found.

NOTE: If a damaged belt has spun on a pulley, inspect the pulley and assembly for damage. Refer to Procedure 008-089 in Section A.



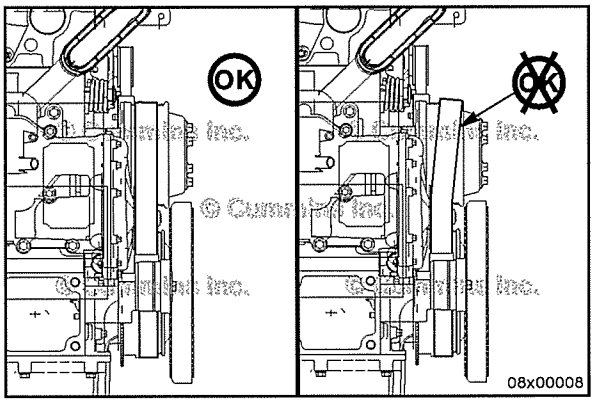
Inspect the pulleys for wear or cracks.

Inspect the belt tensioner. Refer to Procedure 008-087 in Section 6.

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.



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.

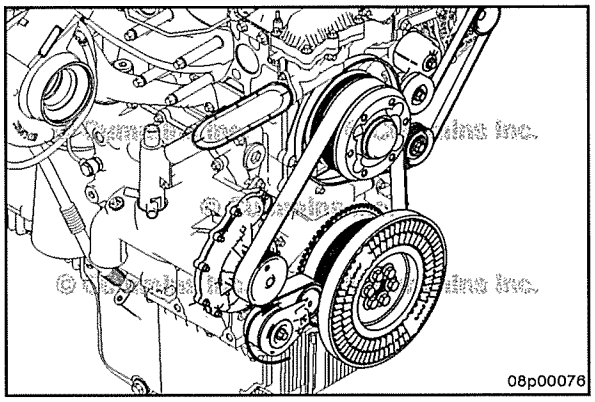
Use the belt diagram created in the remove section to route the drive belt on the engine.

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.

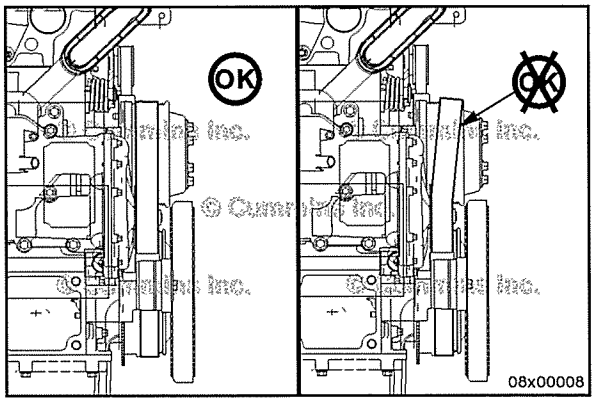
Check the alignment of the belt with the tensioner and the rest of the front end auxiliary drive.

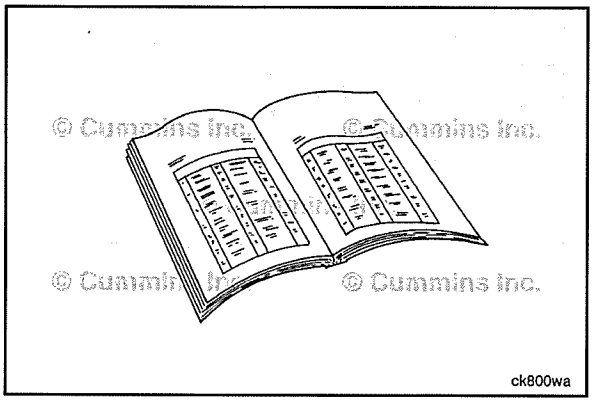


Inspect the pulley alignment.

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.



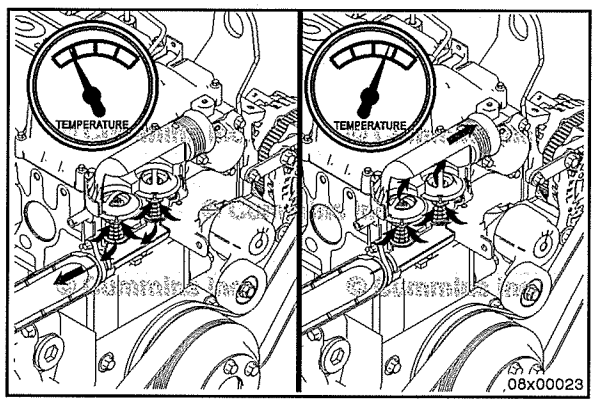


Finishing Steps

⚠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 belt squeal. Excessive belt squeal indicates belt slippage.
- If belt squeal is present, check the routing of the belt and make sure that the belt is installed correctly on each pulley.



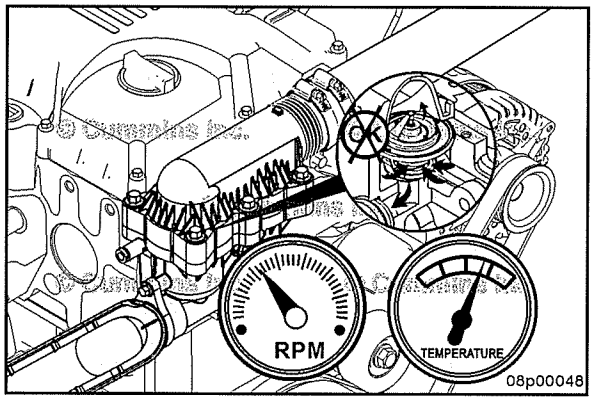
Coolant Thermostat

General Information

The thermostats control the engine coolant temperature. When the coolant temperature is below the operating range, engine coolant is bypassed back to the inlet of the water pump. When the engine coolant temperature reaches the operating range, the thermostat opens, sealing off the bypass, forcing engine coolant to flow to the radiator or heat exchanger.

This engine is equipped with two modulating thermostats. The dual thermostat design increases the coolant flow area. This increased flow area reduces the pressure necessary to circulate coolant.

An incorrect or malfunctioning thermostat can cause the engine to run too hot or too cold.



△CAUTION△

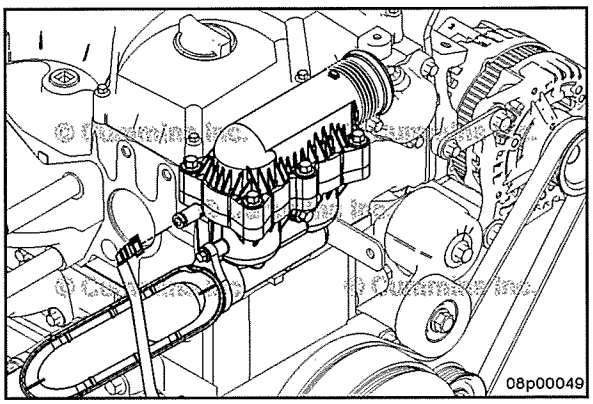
Always use correct thermostats or the engine may overheat or run too cold. Never operate engine without thermostats installed or the engine may overheat.

This engine is equipped with two thermostats. The low range thermostat opens from 82 to 95°C [180 to 203°F] The high range thermostat opens from 88 to 97°C [190 to 207°F].

Always run this engine with both of the correct thermostats.

Be sure air is vented during the fill process. A deaeration port is located next to the water outlet connection, which connects to the top tank/coolant recovery tank of the cooling system.

This provides adequate venting for a fill rate of 19 liters [5 gal] per minute.

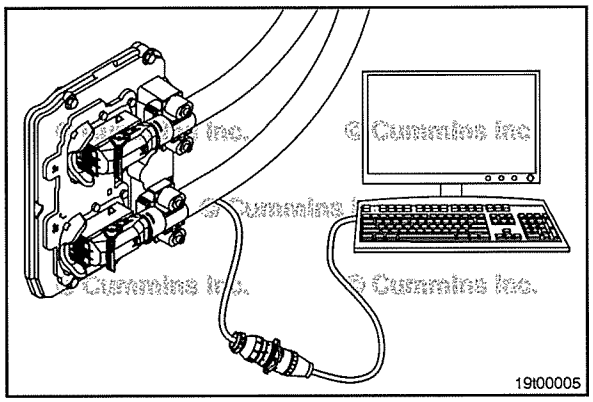


Leak Test

If the thermostat is suspected to be leaking, the following steps can be performed to check for leakage.

The following check **must** be performed with the thermostat closed for 1 minute of engine operation.

Use an INSITE™ electronic service tool to monitor the coolant temperature. The coolant temperature should be less than 38°C [100°F] to ensure the thermostat does **not** open during the test.

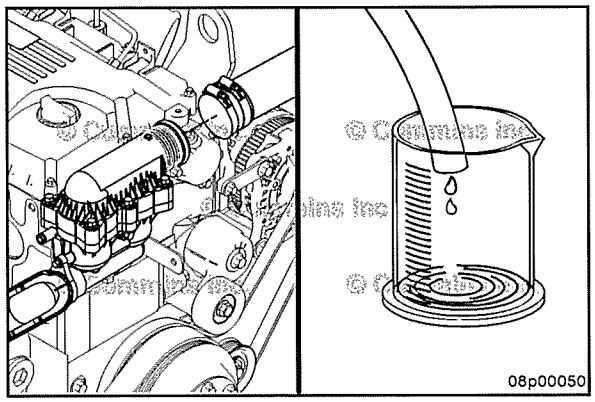


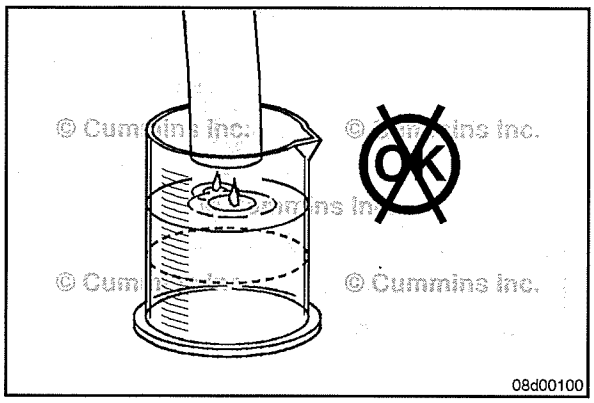
Disconnect the radiator top hose from the water outlet connection.

Install a hose of the same size on the water outlet connection long enough to reach a remote, dry container that will be used to collect coolant.

Install and tighten a hose clamp on the outlet connection.

Place the other end of the hose in a dry container.





The coolant temperature should be monitored during this test to determine if the coolant temperature reaches the nominal opening temperature of the thermostats. See the Measurement step of this procedure for nominal opening temperature.) If a thermostat opens during this test, the test is invalid and **must** be repeated.

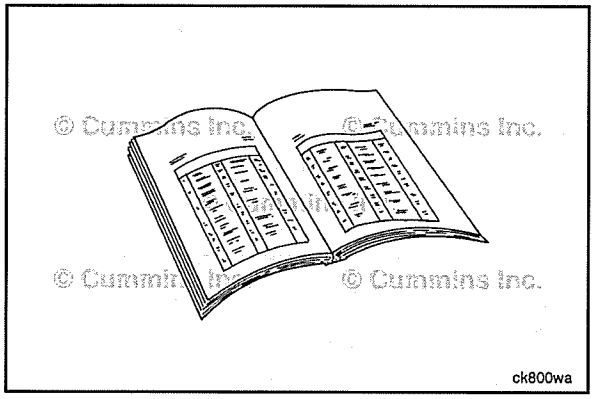
Operate the engine at rated rpm for 1 minute.

Stop the engine and measure the amount of coolant collected in the container.

The amount of coolant **must not** be more than 100 cc [3.4 fl oz].

If more than 100 cc [3.4 fl oz] of coolant is collected, one or both of the thermostats is leaking. Measure each thermostats opening temperature to diagnose the leaking thermostat. This thermostat **must** be replaced.

Procedures for measuring the thermostat opening temperature are included in the "Measure" step of this document.



Preparatory Steps

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

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

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

△CAUTION△
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

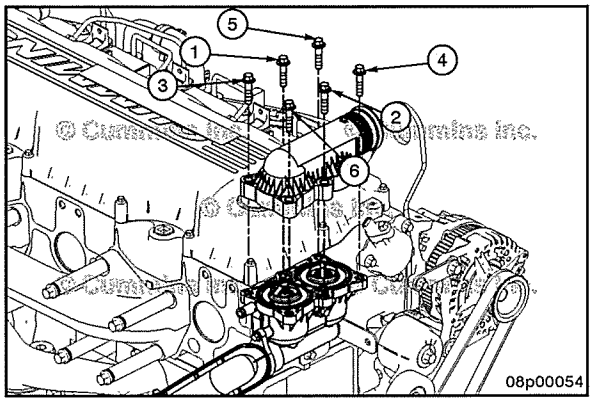
- Disconnect the batteries. See equipment manufacturer service information..
- Drain the coolant below the level of the thermostat. Refer to Procedure 008-018 in Section 9.
- Disconnect the upper radiator hose from the water outlet connection. See equipment manufacturer service information.

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Install the water outlet connection and mounting capscrews.

Tighten the capscrews in the sequence shown.

Torque Value: 18 N•m [159 in-lb]

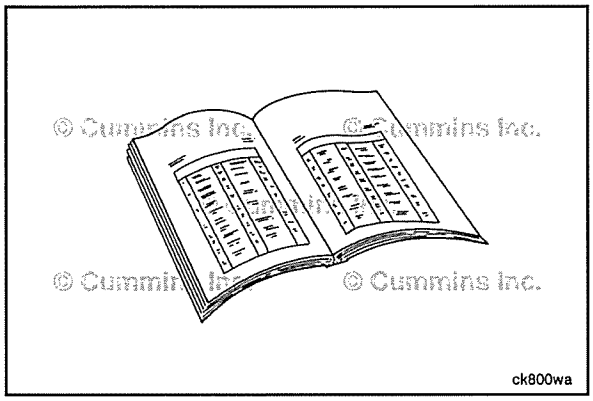


Finishing Steps

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

△CAUTION△
Always vent the engine during filling to remove air from the coolant system, or overheating can result.

- Connect the upper radiator hose to the water outlet connection. See equipment manufacturer service information.
- Fill the cooling system. Refer to Procedure 008-018 in Section 9.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

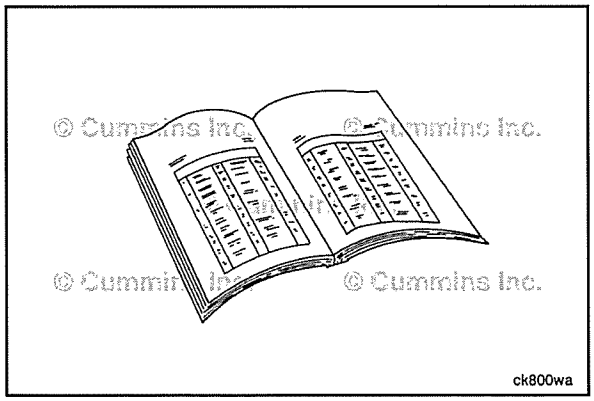


Fan Pulley

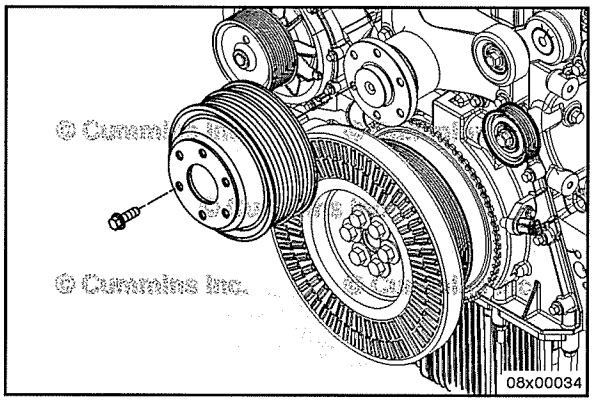
Preparatory Steps

⚠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 A.
- Remove the alternator drive belt. Refer to Procedure 013-005 in Section A.

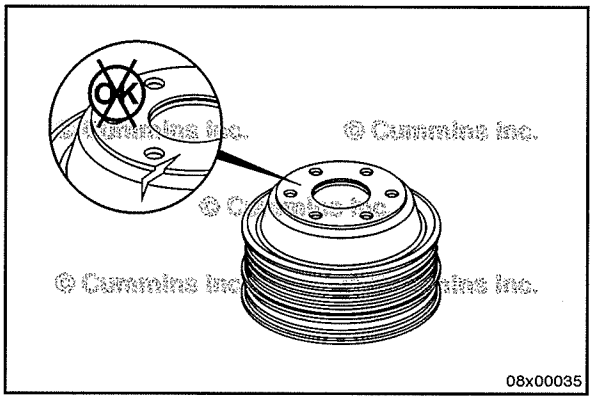


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Remove

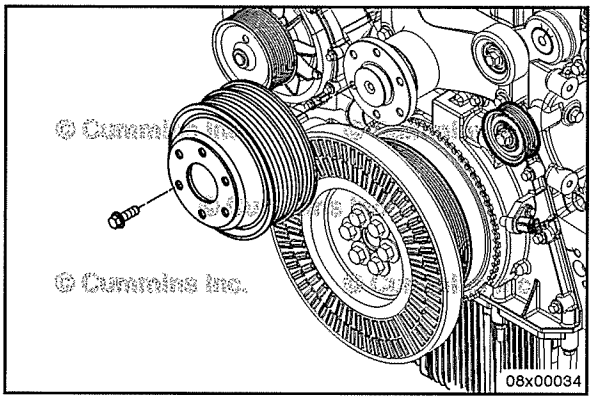
Remove the cooling fan and fan pulley by loosening the six fan pulley mounting capscrews.



Clean and Inspect for Reuse

Inspect the fan pulley for cracks, excessive wear in the belt grooves, and other damage.

Replace the pulley if damage is found.



Install

Install the fan pulley on the fan hub.

Install the cooling fan and six mounting capscrews.

Tighten the capscrews in a star pattern.

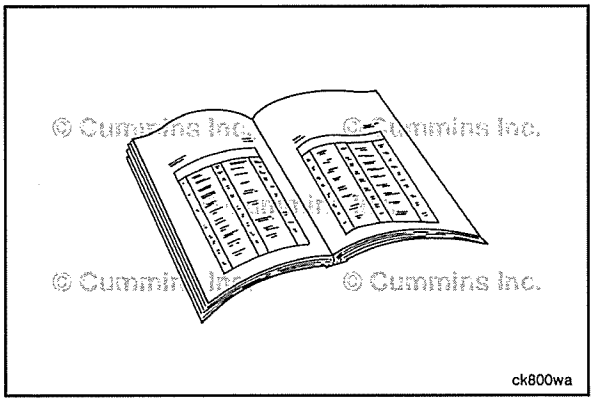
Torque Value: 46 N•m [34 ft-lb]

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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.

- Connect the batteries. See equipment manufacturer service information.
- Install the alternator drive belt. Refer to Procedure 013-005 in Section A.
- Install the cooling fan drive belt. Refer to Procedure 008-002 in Section A.
- Operate the engine and check for proper operation.

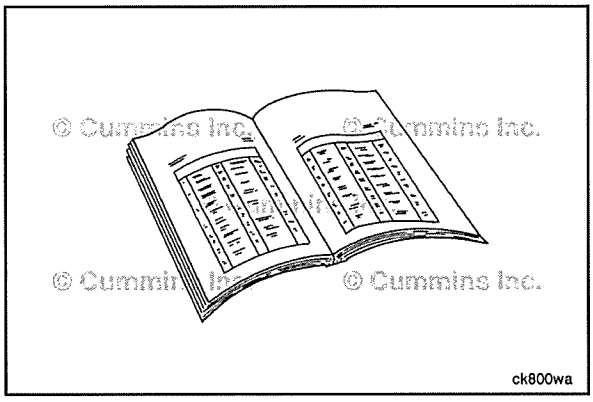


Charging System Alternator Drive Belt

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.

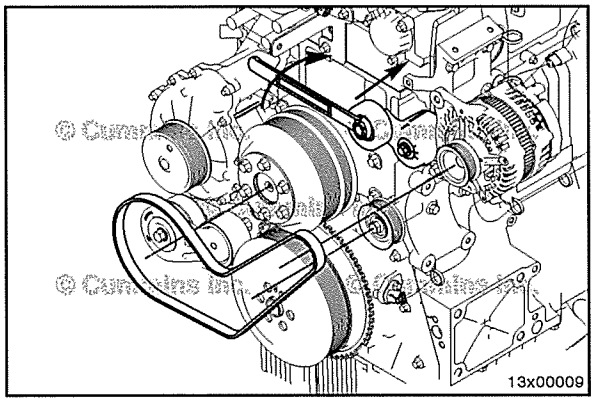
- Disconnect the batteries. See equipment manufacturer service information.
- Make a diagram of the cooling fan belt routing and remove the cooling fan drive belt. Refer to Procedure 008-002 in Section A.

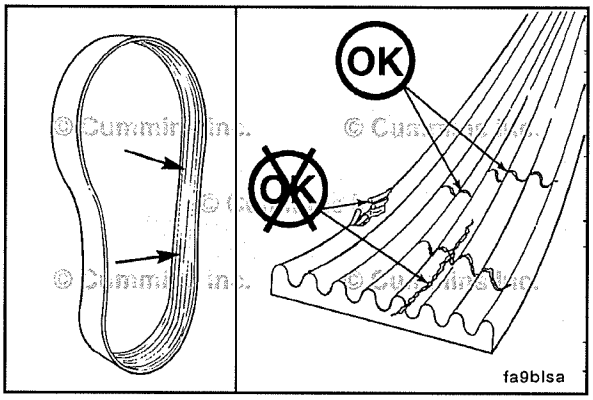


Remove

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.





Clean and Inspect for Reuse

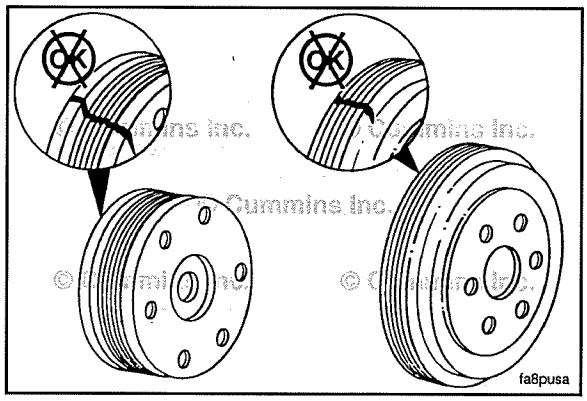
Check the belt for damage. Transverse (across the belt width) cracks are acceptable. Longitudinal (direction of the belt length) cracks that intersect with transverse cracks are **not** acceptable. If the belt is frayed or has any piece of material missing, the belt is unacceptable and needs to be replaced.

Inspect the belt for:

- Cracks
- Glazing
- Tears or cuts
- Excessive wear.

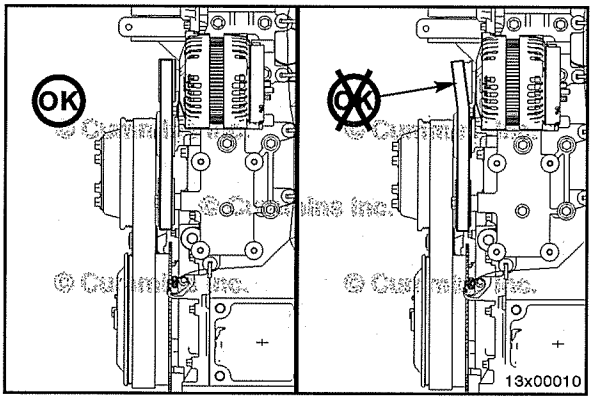
Replace the belt if any damage is found.

NOTE: If a damaged belt spun on a pulley, inspect the pulley for damage. Use the following procedure for pulley inspection. Refer to an Cummins Authorized repair location.



Inspect the idler and drive pulleys for wear or cracks.

Inspect the alternator drive belt tensioner. Refer to Procedure 013-021 in Section 6.



Inspect the pulley alignment.

Pulley misalignment **must not** exceed 4.5 mm for each meter of distance between the pulley centers.

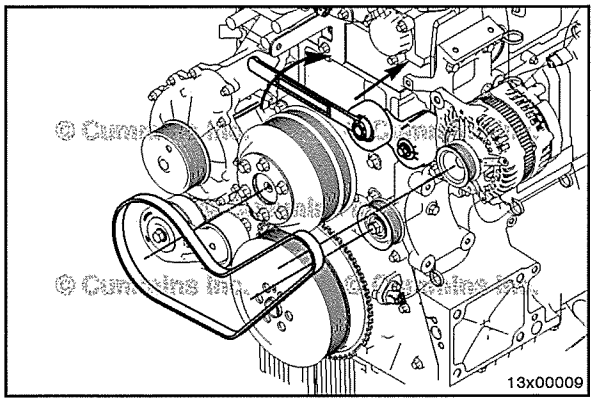
Install

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.

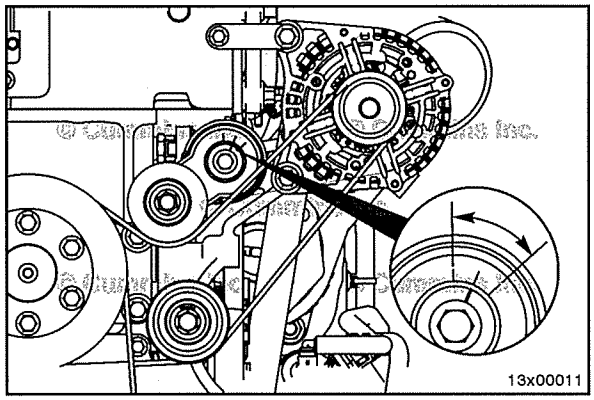
Release the tensioner slowly, and remove the socket and ratchet.

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 6.



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.

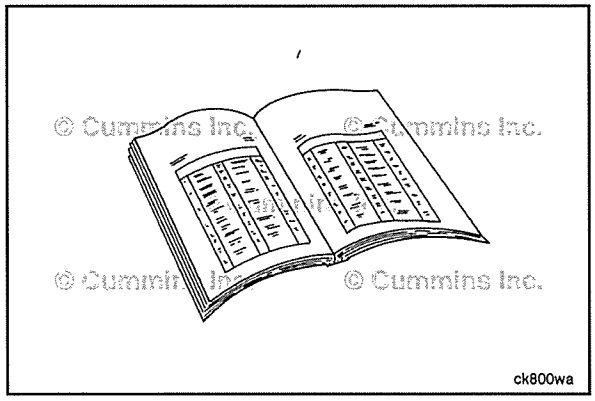
If the tensioner is hitting either of the limits during operation, check the mounting brackets and belt length. Loose brackets, bracket failure, alternator movement, incorrect belt length, or belt failure can cause the tensioner to hit the limits.

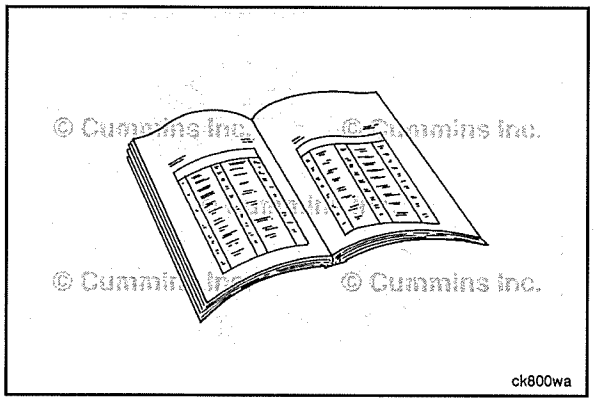


Finishing Steps

⚠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 A.
- Connect the batteries. See equipment manufacturer service information.
- Run engine and check operation.





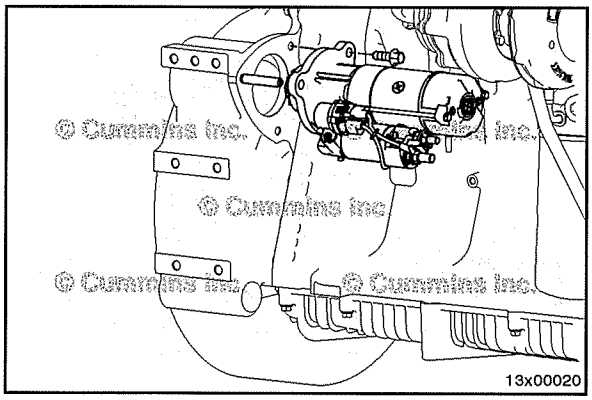
Starting Motor

Preparatory Steps

⚠WARNING⚠

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

- Disconnect the batteries. See equipment manufacturer service information.
- Tag and remove the electrical connections from the starting motor.

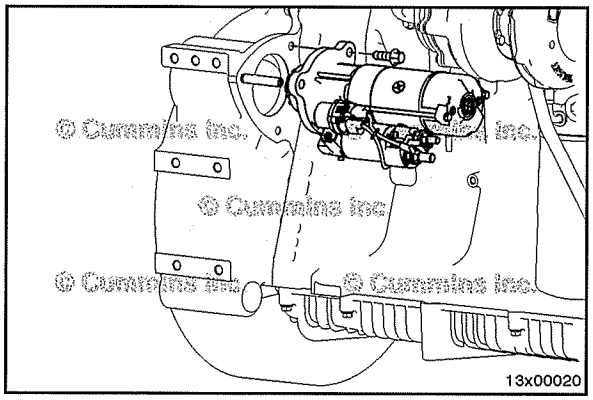


Remove

Remove the ground strap (if used).

Remove one capscrew and install guide pin 3163934.

Remove remaining two capscrews and starting motor.



Install

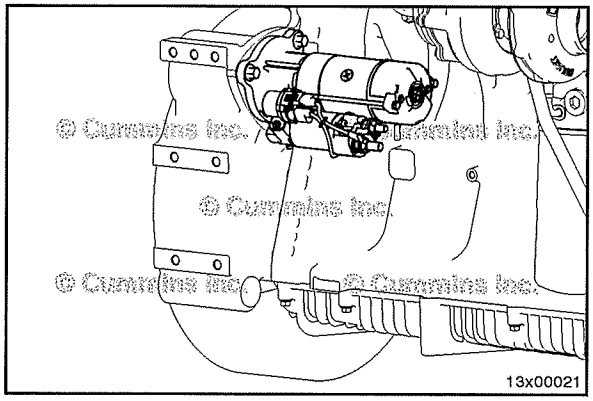
△CAUTION△

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]

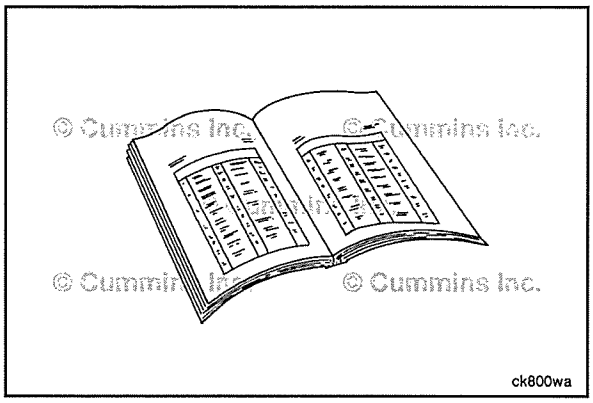


Install and tighten the electrical connections to the starting motor, including the ground strap (if used).

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 and tighten the battery electrical connections. See equipment manufacturer service information.
- Operate the engine and check for proper operation.

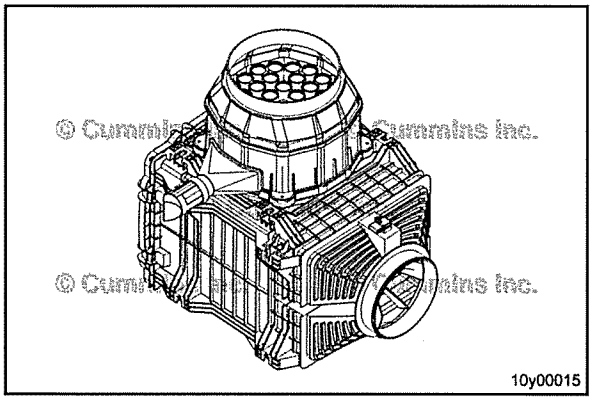


Air Cleaner Precleaner

General Information

Air filtration precleaners are used to remove debris from the air stream in order to extend the life of the air filter elements. There are several types of precleaners that can be used, including, but **not** limited to:

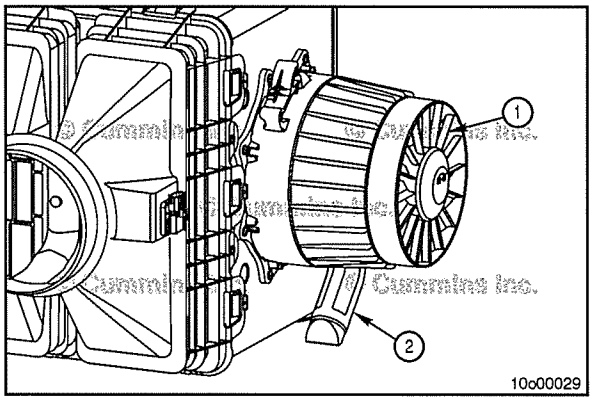
- Vortex style precleaner with dust ejection valve
- Vortex style with aspiration
- Radial fin precleaner with dust ejection valve
- Non-captive style precleaner
- Radial fin precleaner with aspiration.



A vortex style precleaner with dust ejection valve removes debris from the intake air by using fins (1) to create centrifugal motion in the intake air stream.

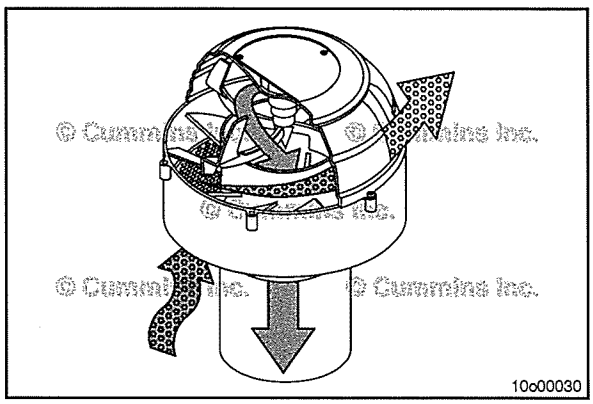
The centrifugal motion causes debris to be forced to the outside of the precleaner, where it is then collected in the dust ejection valve (2).

NOTE: If the dust ejection valve becomes full of debris, the precleaner will **not** function and the debris will remain in the air stream, which can lead to frequent air filter plugging or low air filter service life. Refer to Procedure 010-146 in Section 3.

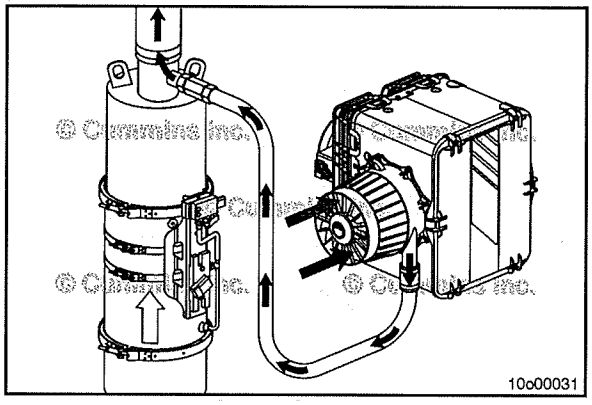


Non-captive style precleaners work similarly to radial fin precleaners by using centrifugal motion to force debris to the outside of the precleaner. However, instead of being collected in the dust ejection valve, the debris is immediately expelled back into the outside air.

NOTE: These precleaners are typically more costly than the radial fin precleaner with dust ejection valve and can create higher intake restriction.



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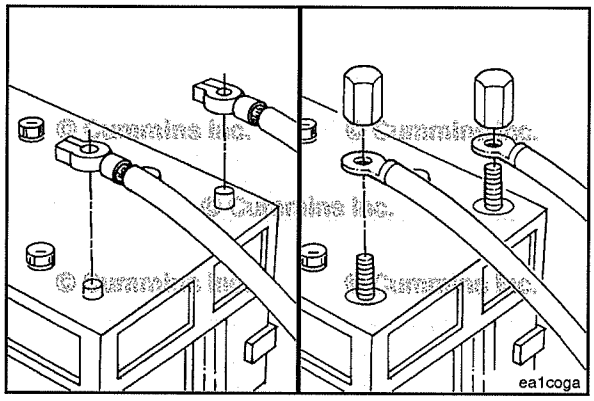
Vortex style precleaning with exhaust aspiration is used for applications that are exposed to extremely dirty and dusty environments, such as agricultural equipment.

An exhaust aspirator uses exhaust flow to create suction. The suction tube from the aspirator is plumbed to the radial fin precleaner and helps to separate debris out of the intake air. The debris is sucked from the precleaner through the suction tube and travels out through the exhaust

A check valve **must** be used with an exhaust aspirator to prevent exhaust gases from traveling through the air cleaner in instances when the exhaust suction force is low.

NOTE: Vacuum leaks in the exhaust aspirator piping can reduce the ability of the air cleaner precleaner to remove debris from the intake air, which can lead to frequent air filter plugging or low air filter service life.

NOTE: Other aspiration options are available.



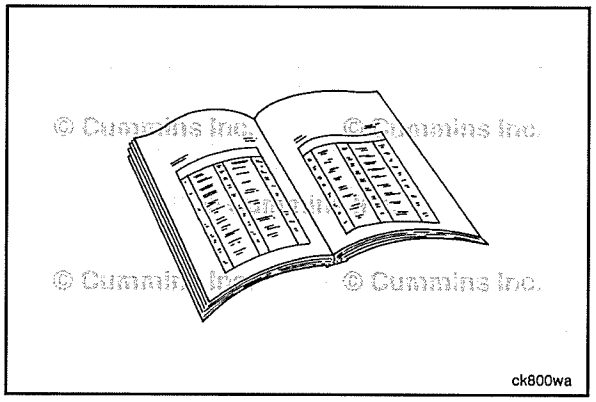
Batteries

General Information

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

There are many types of batteries with varying technology. Common battery types include:

- Standard lead acid (also called flooded or wet cell)
- Starting
- Deep cycle
- Serviceable or maintenance free
- Maintenance free absorbent glass mat (AGM)
- Maintenance free gel cell



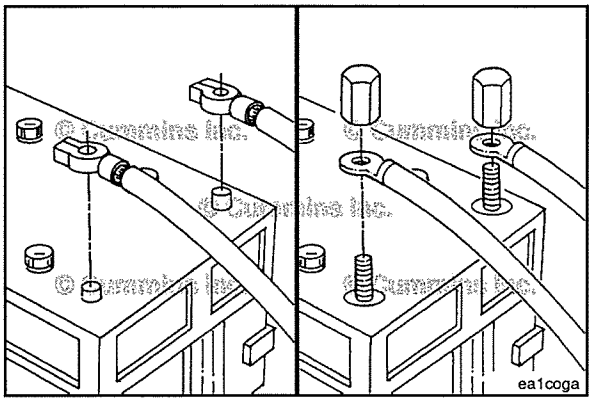
Check Original Equipment Manufacturer (OEM) or battery supplier service literature for battery removal and installation, maintenance, inspection, and testing requirements.

Battery Cables and Connections

Initial Check

There are two possible heavy-duty battery connections:

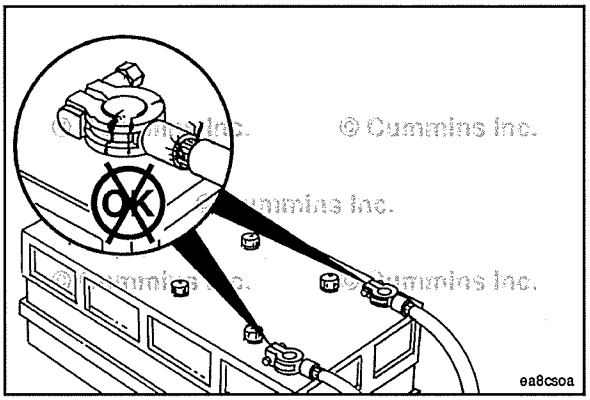
- Battery terminal and clamp (1)
- Threaded battery terminal and nut (2).



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

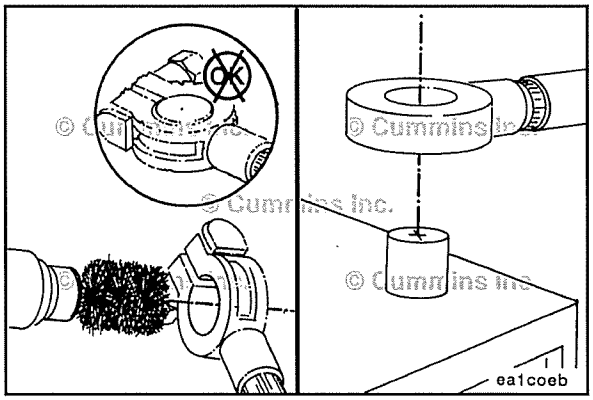
Remove and inspect the battery cables and connections for cracks or corrosion.

Replace broken terminals, connectors, or cables.



If the connections are corroded, use a battery brush or wire brush to clean the connections until shiny.

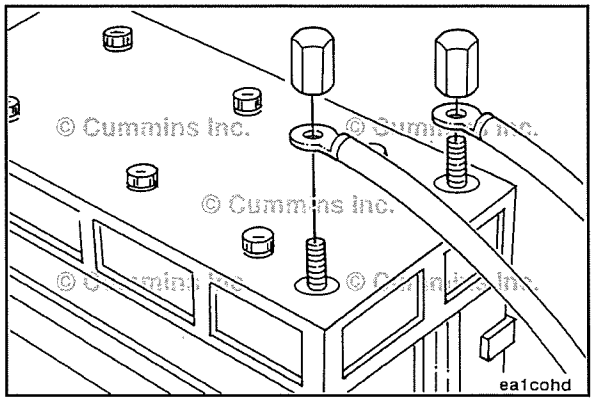
Make sure all debris is removed from the connecting surfaces.

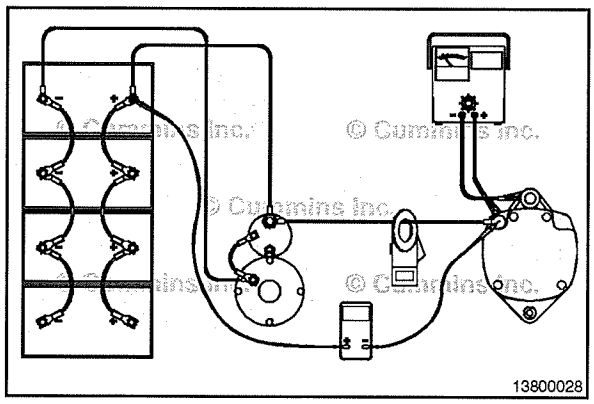


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Install the cables and tighten the battery connections.

Coat the terminals with grease to prevent corrosion.





Charging System Alternator

Initial Check

Alternator Wiring Test

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

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

Systems that are 24-VDC **must** be connected into a temporary 12-VDC configuration.

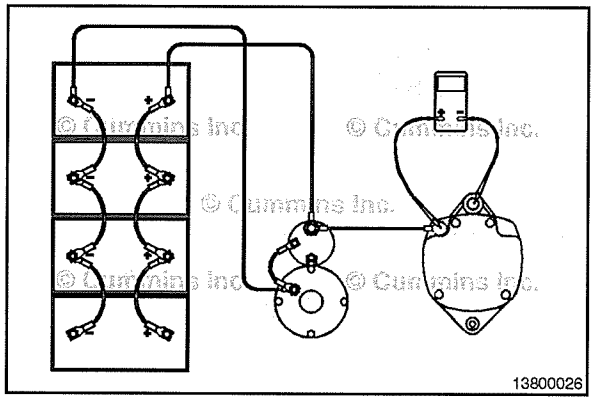
Attach the carbon-pile and clip-on ammeter, Part Number 3164490, as shown.

Adjust the load from the carbon-pile tester to the rated performance of the alternator.

Measure the voltage drop in both the positive and negative circuits.

Add these together and compare the sum to the table below.

System Voltage	Maximum Voltage Drop
12	0.5
24	1.0



Alternator Voltage Output Check

Attach the multimeter, from kit Part Number 3400162, to the alternator as shown in the illustration.

With the batteries in a fully charged condition and all the accessories off, start the engine and run it at high idle.

Allow time for the voltage to stabilize before taking any readings.

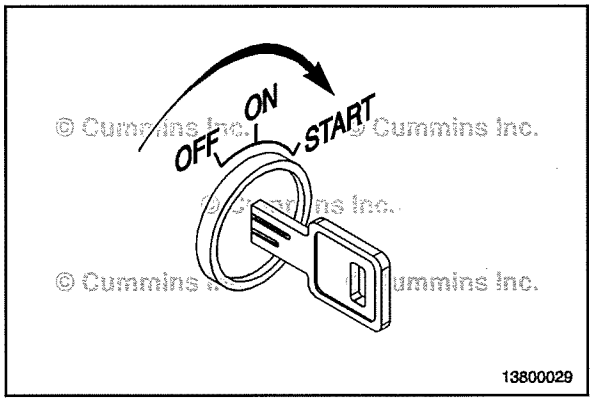
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Measure the alternator output voltage.

System Voltage	Maximum Output Voltage Limit
12	15.5
24	31.0

Repair or replace the alternator or regulator if the voltage limit exceeds the value in the table.

Refer to the manufacturer's specifications for minimum voltage output.

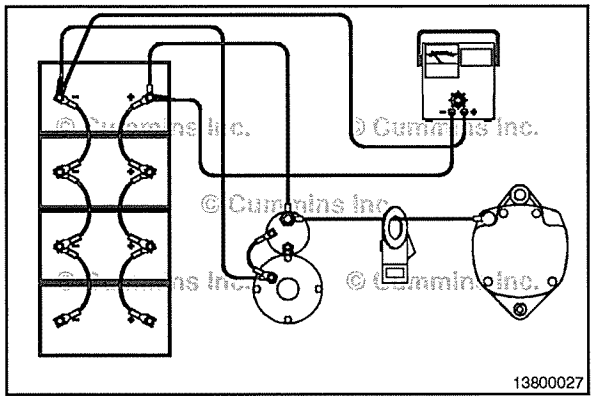


Alternator Current Output Test

Connect the carbon-pile tester to the batteries in parallel.

If more than one wire is connected to the alternator output terminal, clamp the ammeter around all wires.

Clamp the induction ammeter, Part Number 3164490, around the alternator output wire.



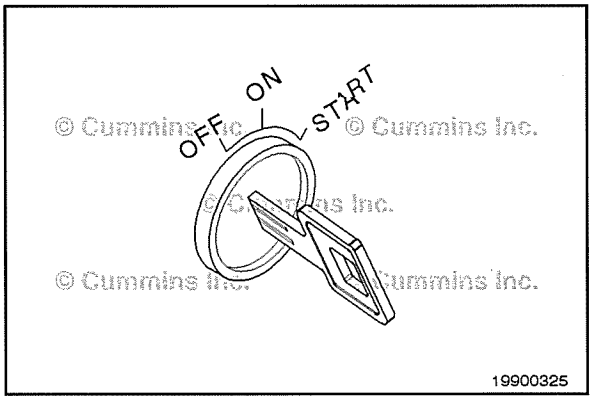
The alternator **must** be turning at approximate rated speed.

Most heavy-duty alternators are rated at 5000 rpm. Check the manufacturer's specifications for the specific alternator being tested.

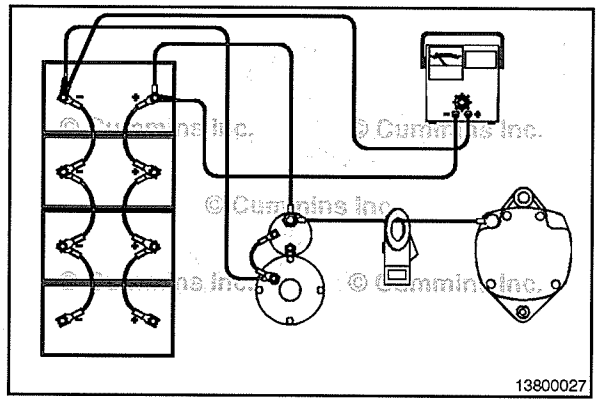
Make sure that all vehicle electrical loads are turned off.

Start the engine and operate at high idle.

Check the speed of the alternator using a digital optical tachometer. A slipping alternator drive belt can result in a low output reading. The alternator output is directly related to alternator speed.



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Turn the carbon-pile tester on and adjust until the ammeter reaches its highest reading. Record this value.

Turn the carbon-pile tester off and shut the engine OFF.

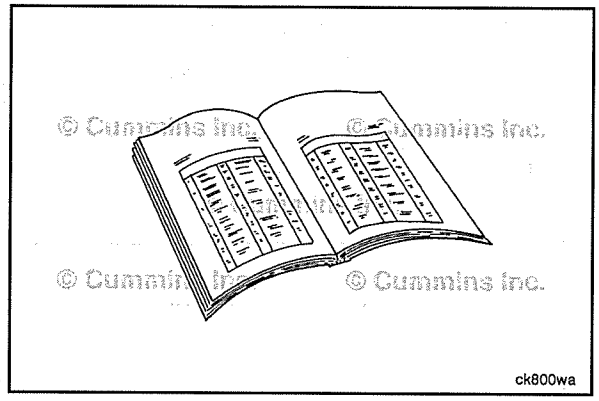
If the reading on the ammeter is 0 (no output), magnetize the rotor with the alternator hooked up normally.

Momentarily connect a jumper lead from the battery positive (+) to the alternator relay (R) or indicator (I) terminal.

This procedure applies to both negative (-) and positive (+) ground systems, and will restore the normal residual magnetism.

Repeat the test. If the output is still 0, replace the alternator.

If the alternator output is **not** within 10 percent of the rated output (stamped on the alternator case), replace the alternator.

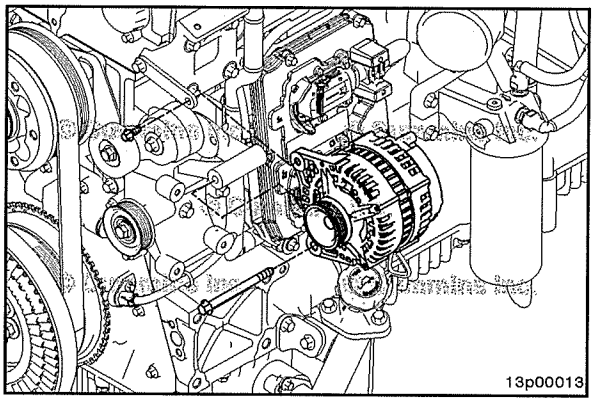


Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gasses. To reduce the possibility of personal injury, always ventilate the 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 electrical connection from the alternator. Label the connections as they are removed.
- Remove the alternator drive belt. Refer to Procedure 013-005 in Section A.



Remove

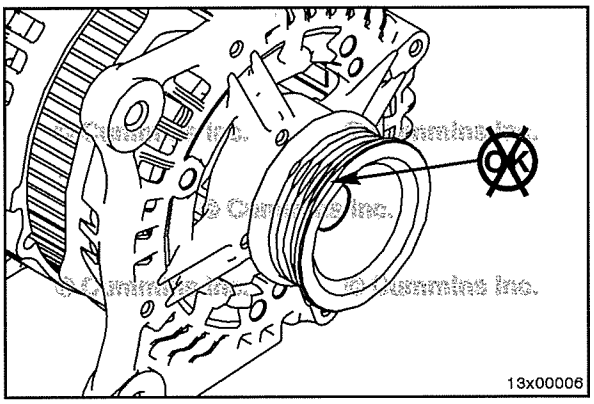
Remove the alternator top ear mounting capscrew (1).

Remove the alternator lower ear mounting capscrew (2) and alternator.

Clean and Inspect for Reuse

Inspect the alternator pulley for cracks or broken grooves.

If damage is found, replace the alternator.

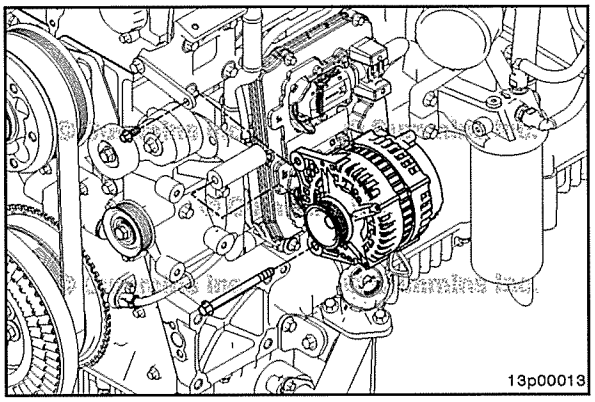


Install

Install the alternator, alternator top ear mounting capscrew (1), alternator lower ear mounting capscrew to the mounting bracket (2).

Tighten the mounting capscrews.

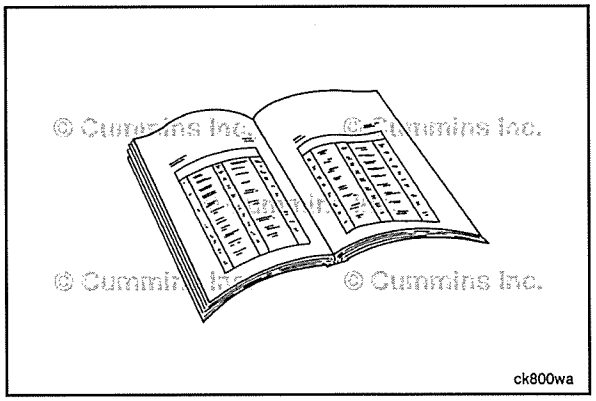
Torque Value: 46 N•m [34 ft-lb]



Finishing Steps

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

- Install the alternator drive belt. Refer to Procedure 013-005 in Section A.
- Connect the alternator electrical connections.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for proper operation.



Notes

Section D - System Diagrams

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System Diagrams - Overview

General Information

The following drawings show the flow through the engine systems. Although parts can change between different applications and installations, the flow remains the same. The systems shown are:

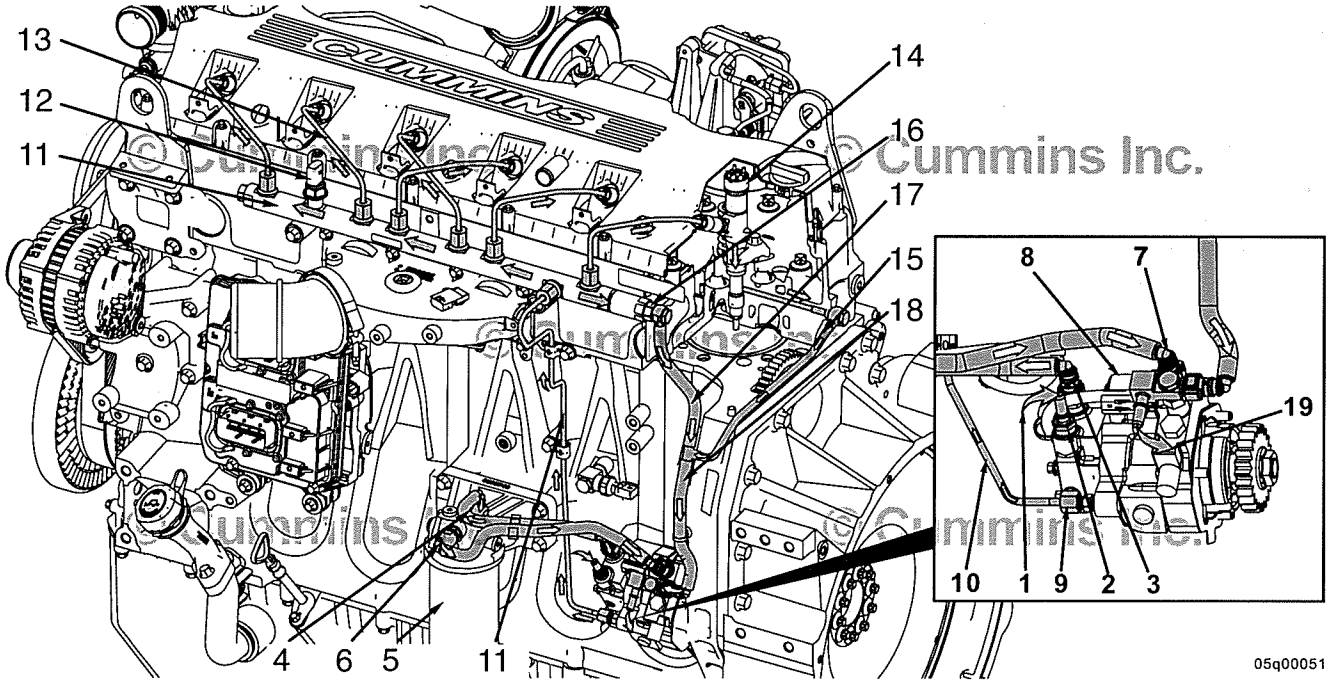
- Fuel System
- Lubricating Oil System
- Coolant System
- Intake Air System
- Exhaust System
- Compressed Air System.

Knowledge of the engine systems can help you in troubleshooting, service, and general maintenance of your engine.

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Flow Diagram, Fuel System

Flow Diagram



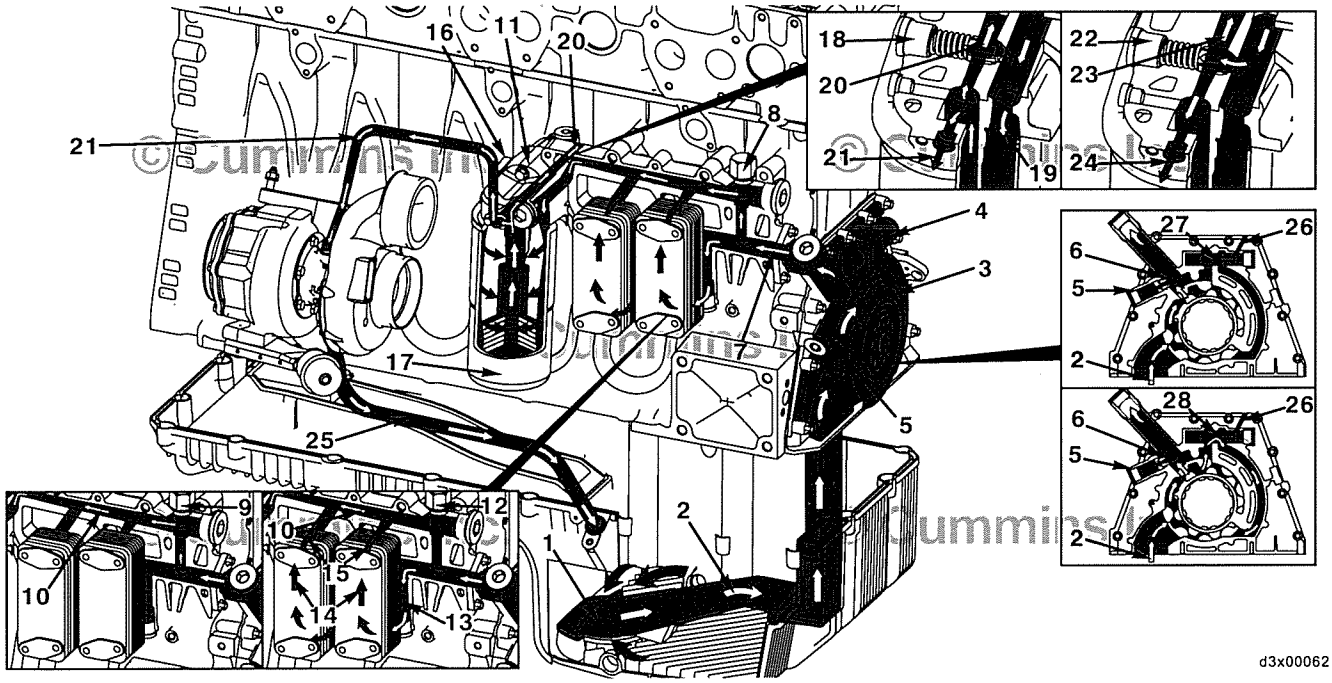
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1 Fuel supply - from suction side filter
2 Fuel pump gear pump inlet
3 Fuel pump gear pump outlet
4 Pressure side fuel filter inlet
5 Pressure side fuel filter
6 Pressure side fuel filter outlet
7 High pressure fuel pump inlet
8 Fuel pump actuator
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.

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Flow Diagram, Lubricating Oil System

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

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26 Block oil riffle pressure sensing channel

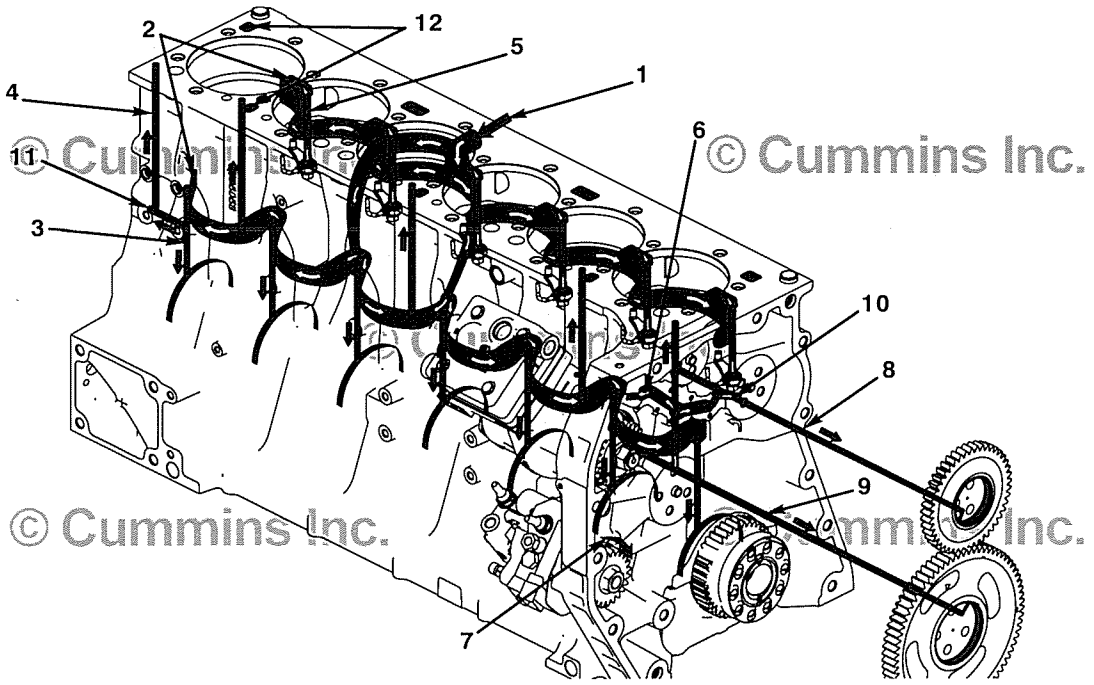
27 Flow with pressure regulator valve closed

28 Flow with pressure regulator valve open.

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Flow Diagram, Lubricating Oil System

Flow Diagram



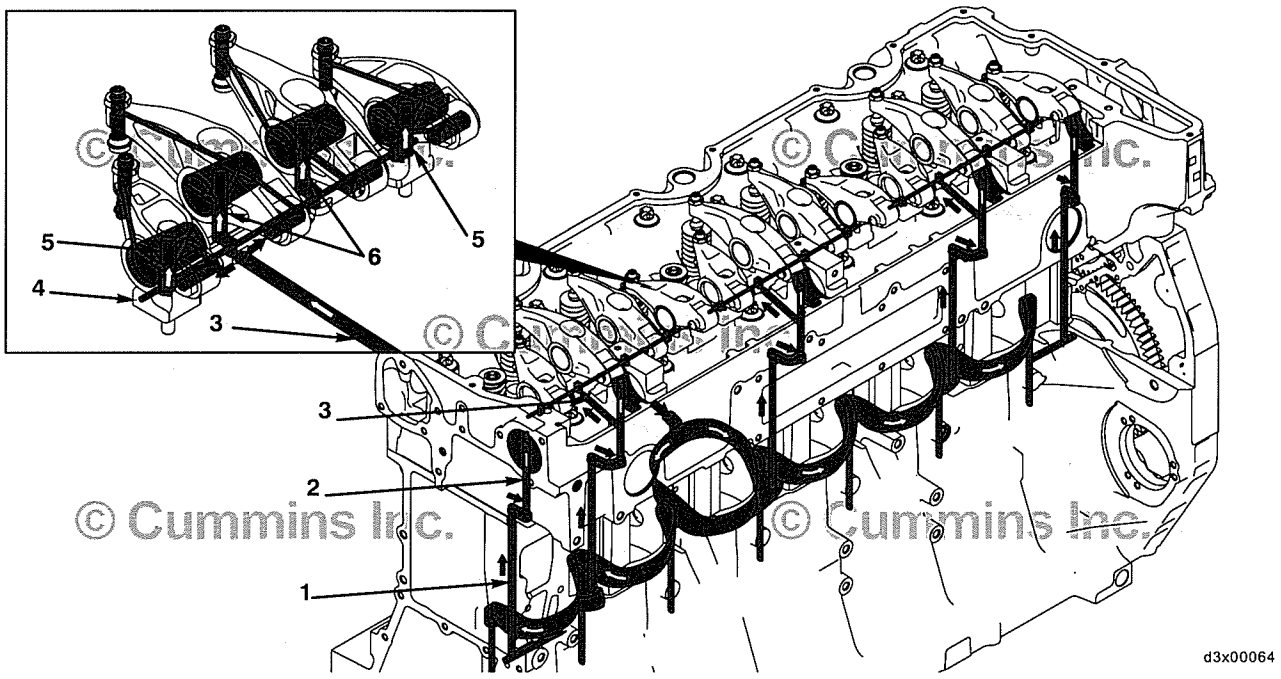
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1 Lubricating oil flow from lubricating oil filter head to engine block main oil rifle
2 Main oil rifle
3 Flow to main bearings
4 Flow to cylinder head
5 Flow to piston cooling nozzle
6 Flow to air compressor
7 Flow to fuel pump
8 Flow to camshaft 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.

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Flow Diagram, Lubricating Oil System

Flow Diagram

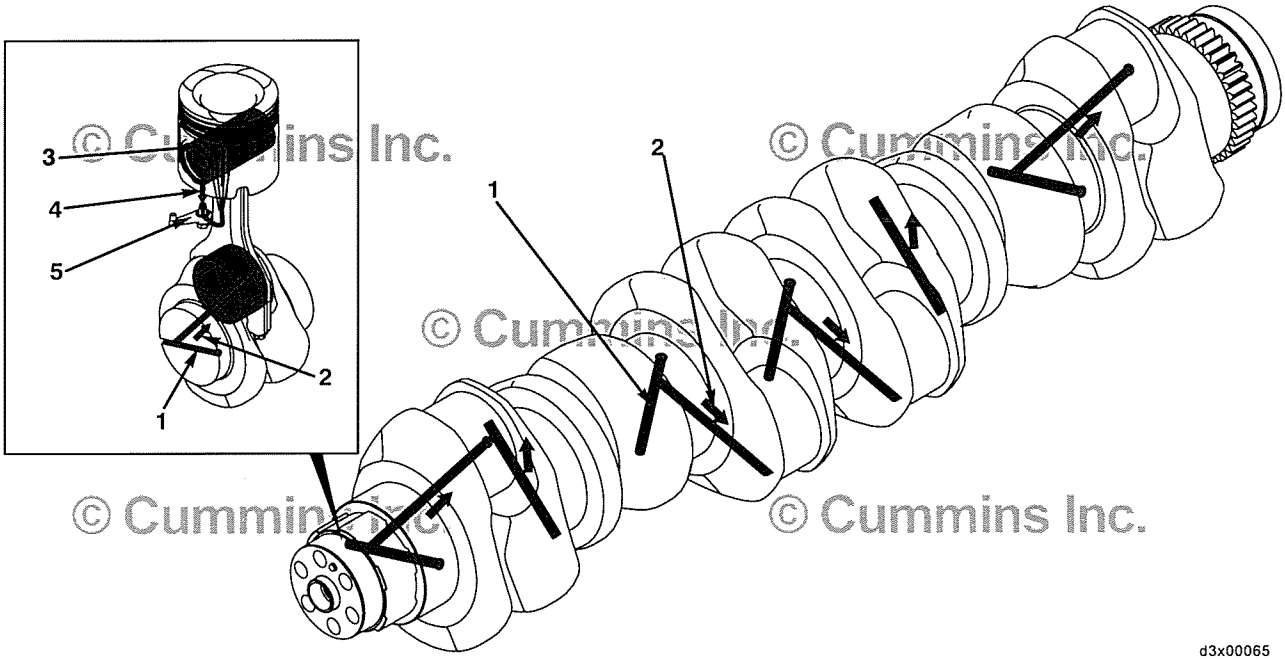


1 Flow from cylinder block to cylinder head
2 Flow to camshaft bushings
3 Flow to rocker lever shafts
4 Rocker lever shaft
5 Flow from rocker lever shaft to intake rocker levers
6 Flow from rocker lever shaft to exhaust rocker levers.

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Flow Diagram, Lubricating Oil System

Flow Diagram



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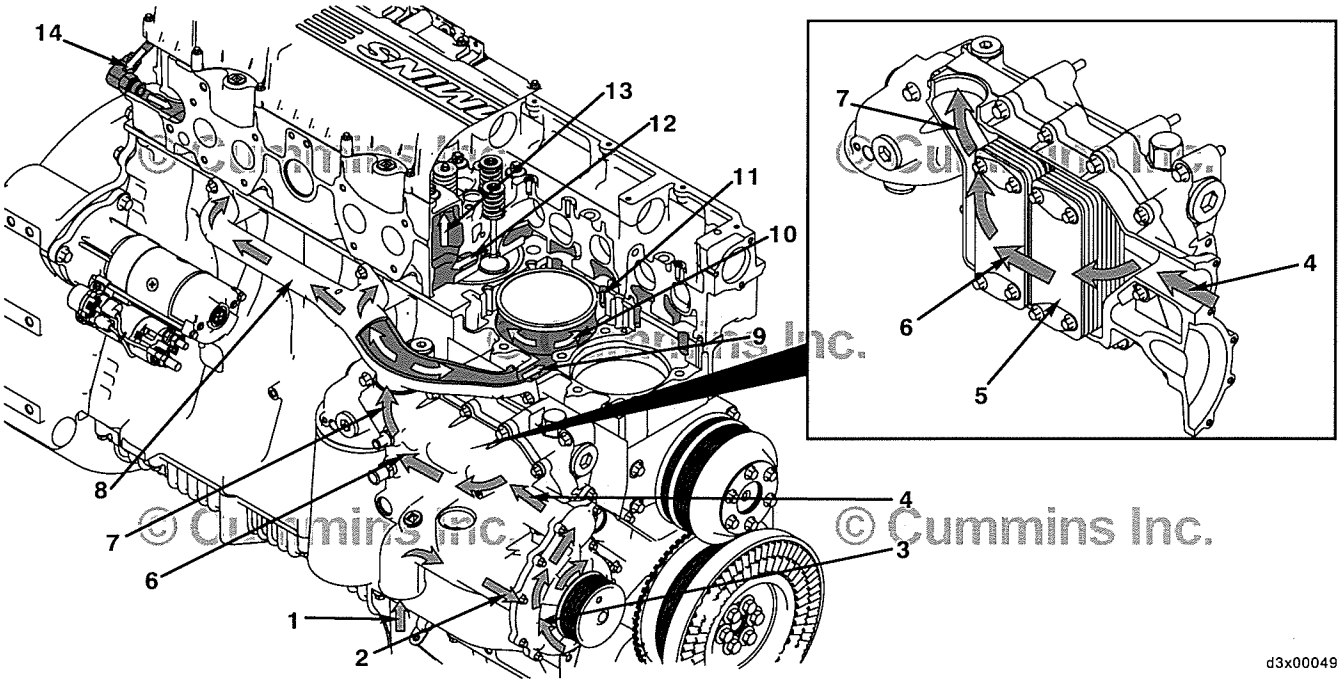
d3x00065

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.

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Flow Diagram, Cooling System

Flow Diagram



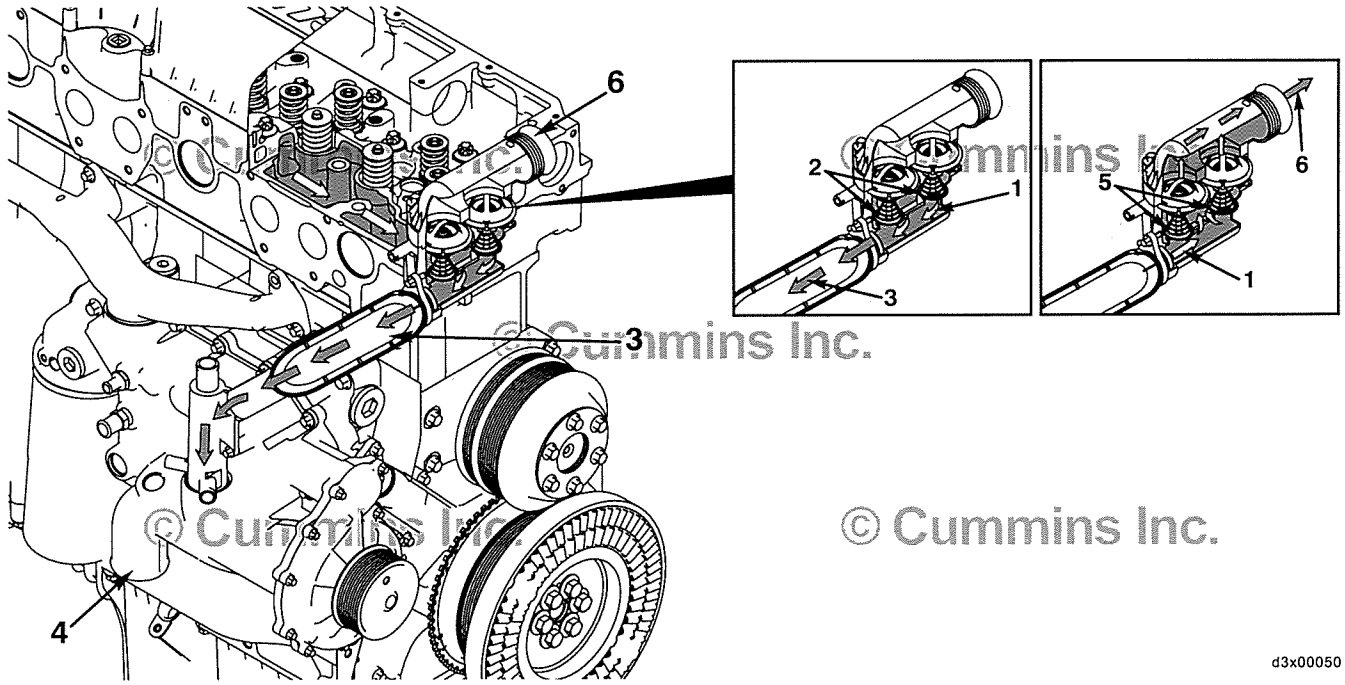
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1 Coolant from radiator
2 Coolant flow to water pump
3 Water pump
4 Coolant flow from water pump to oil cooler module
5 Oil cooler element
6 Coolant flow around oil cooler element
7 Coolant flow from oil cooler module to coolant manifold
8 Coolant 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.

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Flow Diagram, Cooling System

Flow Diagram



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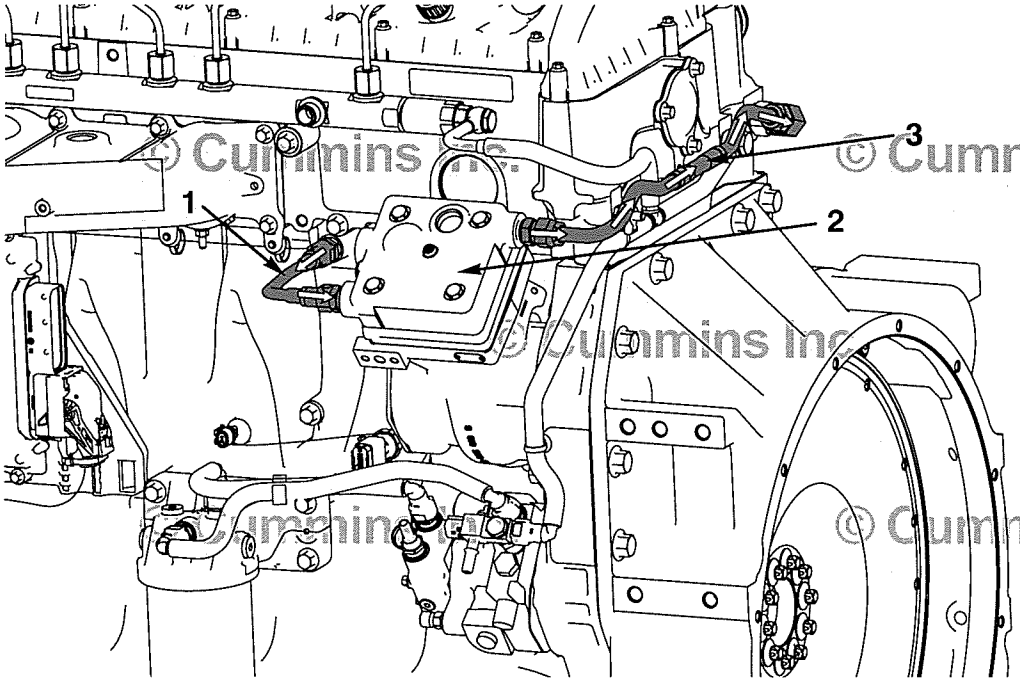
d3x00050

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.

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Flow Diagram, Cooling System

Flow Diagram



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1 Coolant flow from cylinder block to air compressor

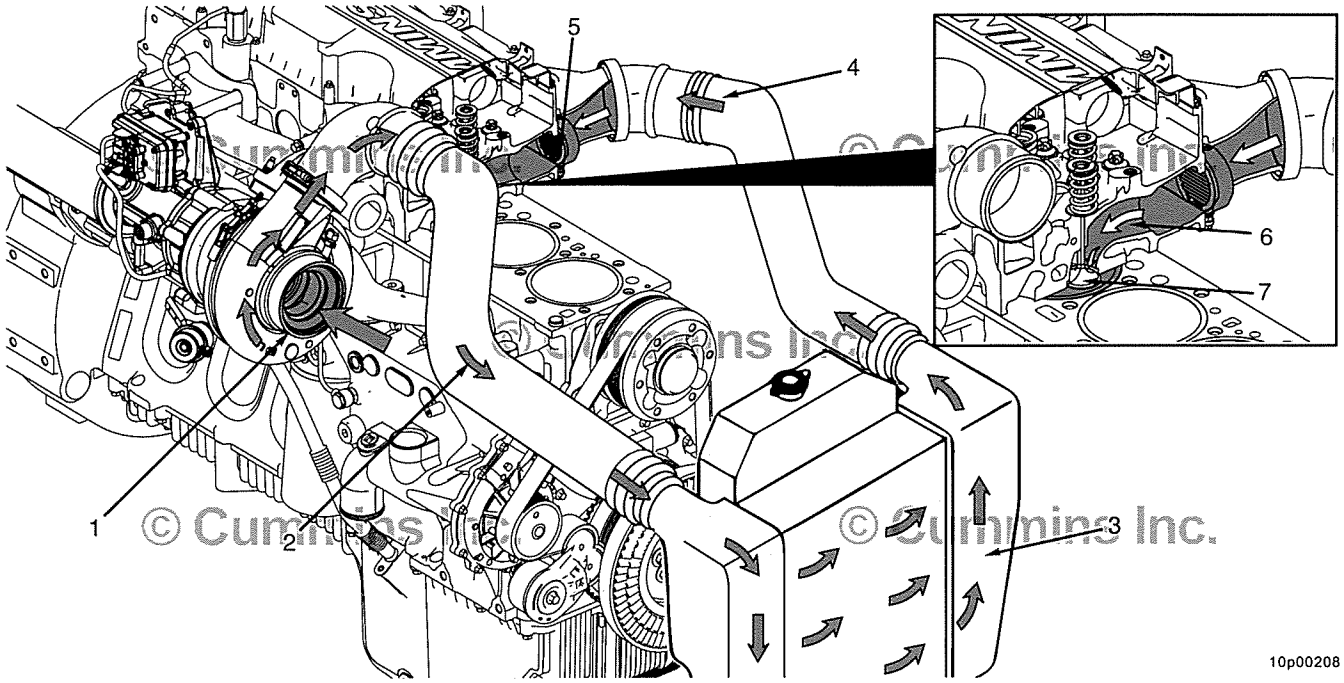
2 Air compressor

3 Coolant flow from air compressor to cylinder head.

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Flow Diagram, Air Intake System

Flow Diagram



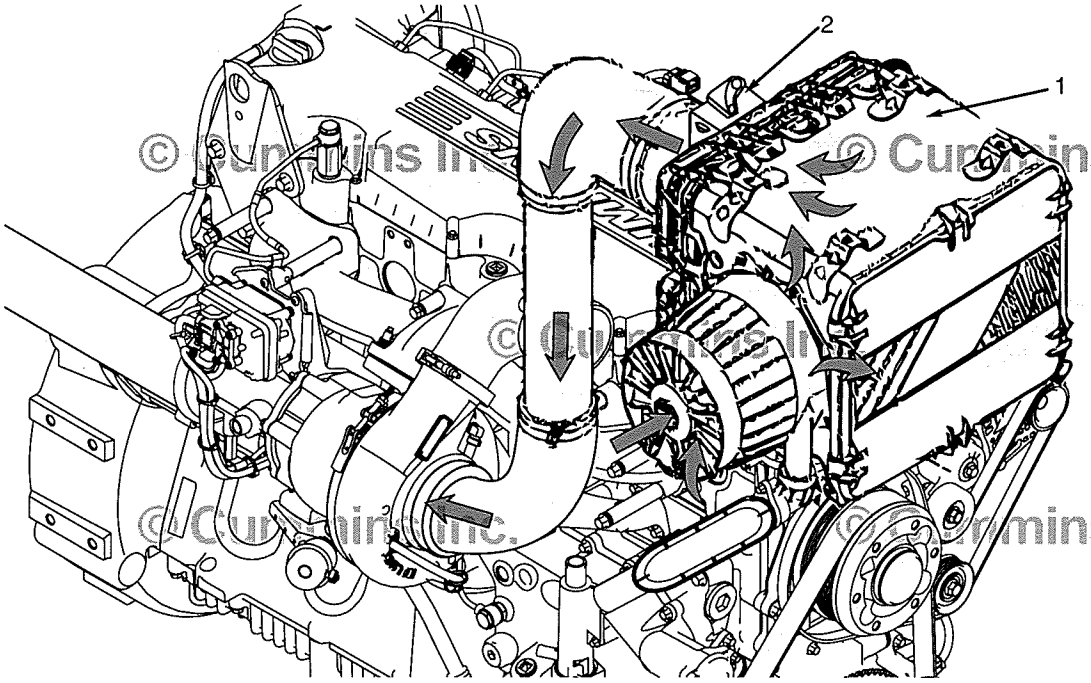
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1 Intake air inlet to turbocharger.
2 Turbocharger air to charge-air cooler.
3 Charge-air cooler.
4 From charge-air cooler to intake air connection.
5 Cold starting aid.
6 Intake port.
7 Intake valve.

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Flow Diagram, Air Intake System

Flow Diagram



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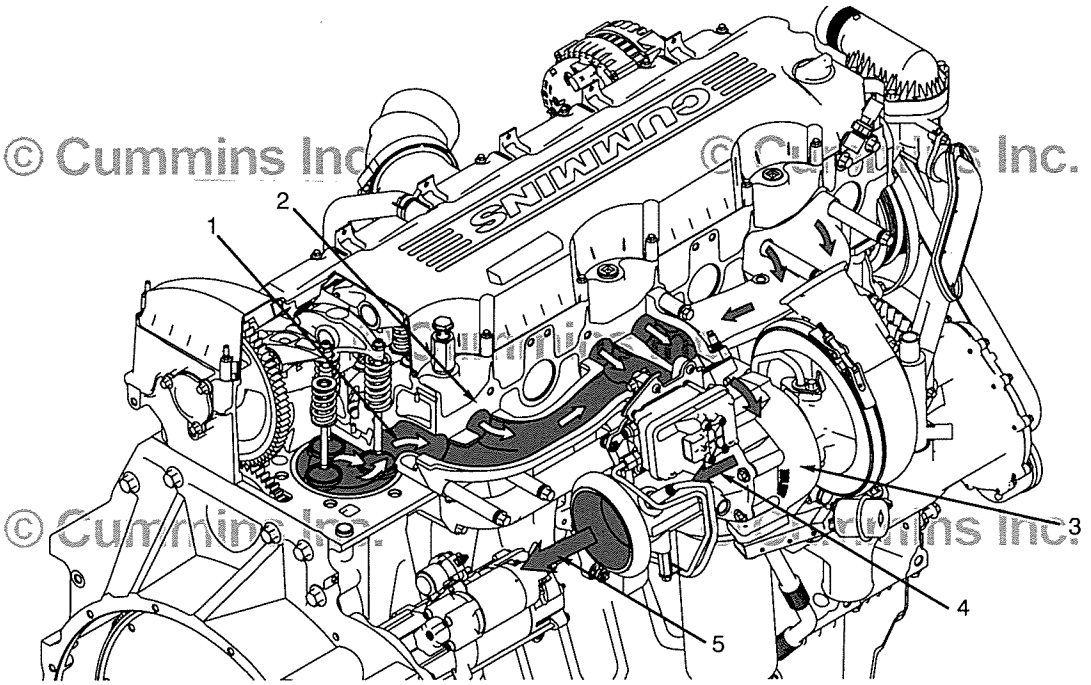
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1 Direct Flow ™ air filter housing.

2 Engine turbocharger compressor intake temperature sensor.

Flow Diagram, Exhaust System

General Information



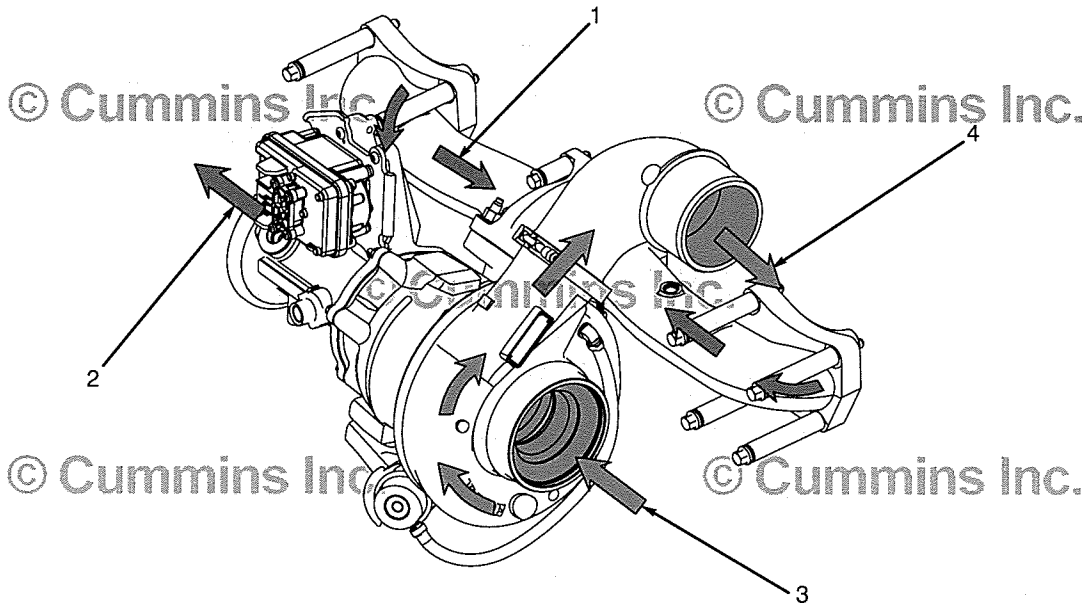
Exhaust Flow Through Engine

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

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Flow Diagram, Exhaust System

General Information



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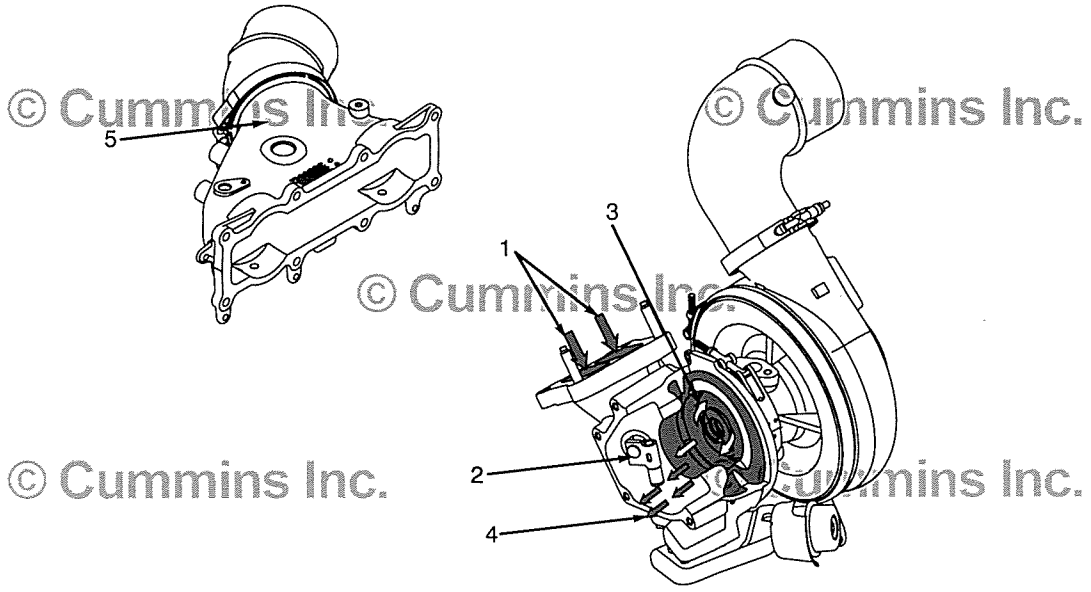
Flow Through Turbocharger

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.

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Flow Diagram, Exhaust System

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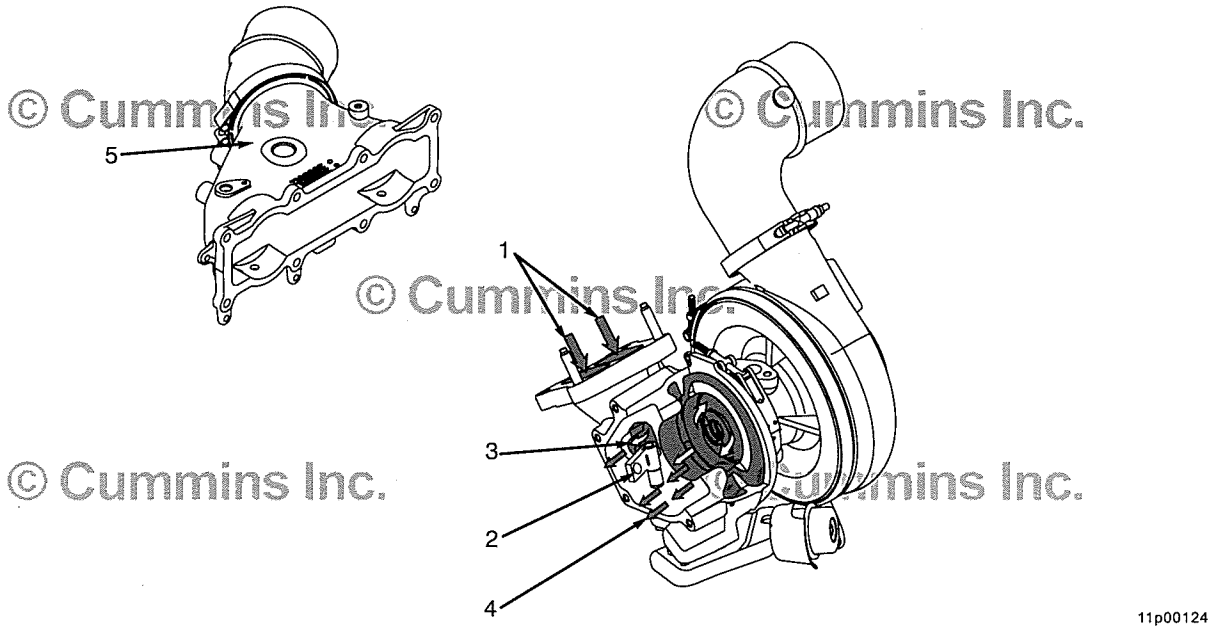
Wastegate Closed (Low Intake Manifold Pressure)

1 Exhaust flow from exhaust manifold
2 Wastegate closed
3 All exhaust flow through turbine
4 Turbocharger exhaust outlet
5 Intake manifold.

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Flow Diagram, Exhaust System

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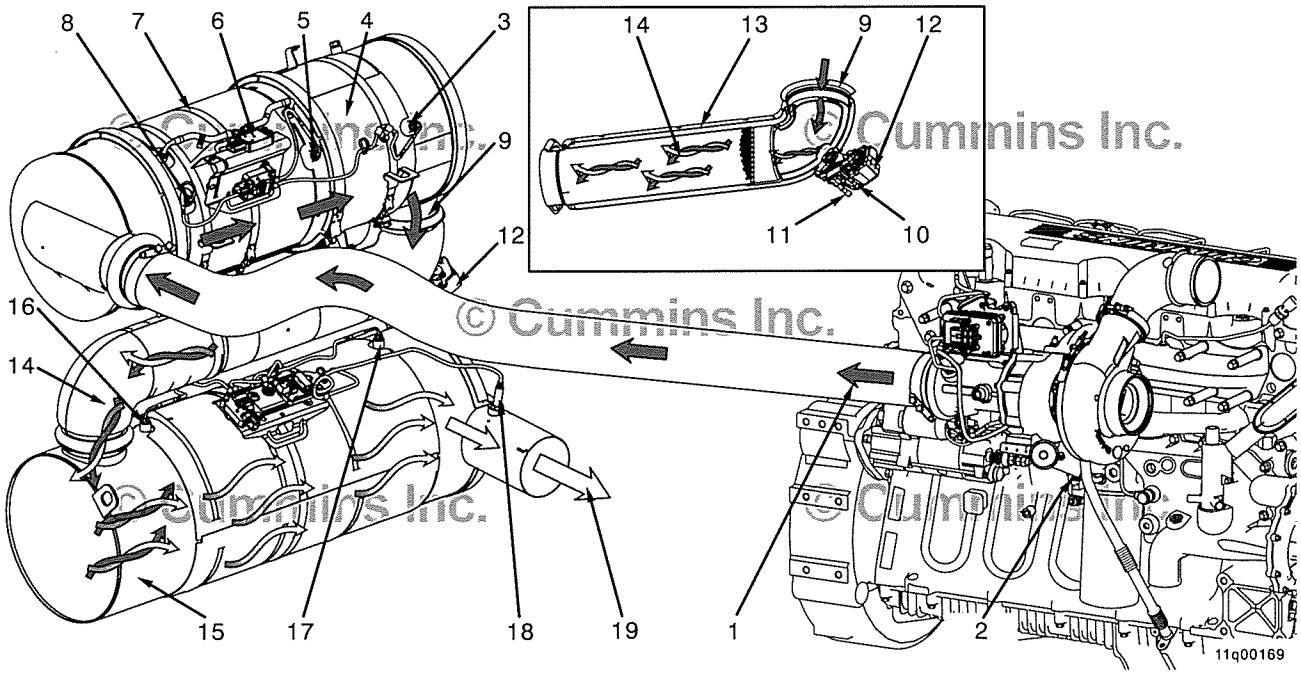
Wastegate Open (High Intake Manifold Pressure)

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

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Flow Diagram, Exhaust System

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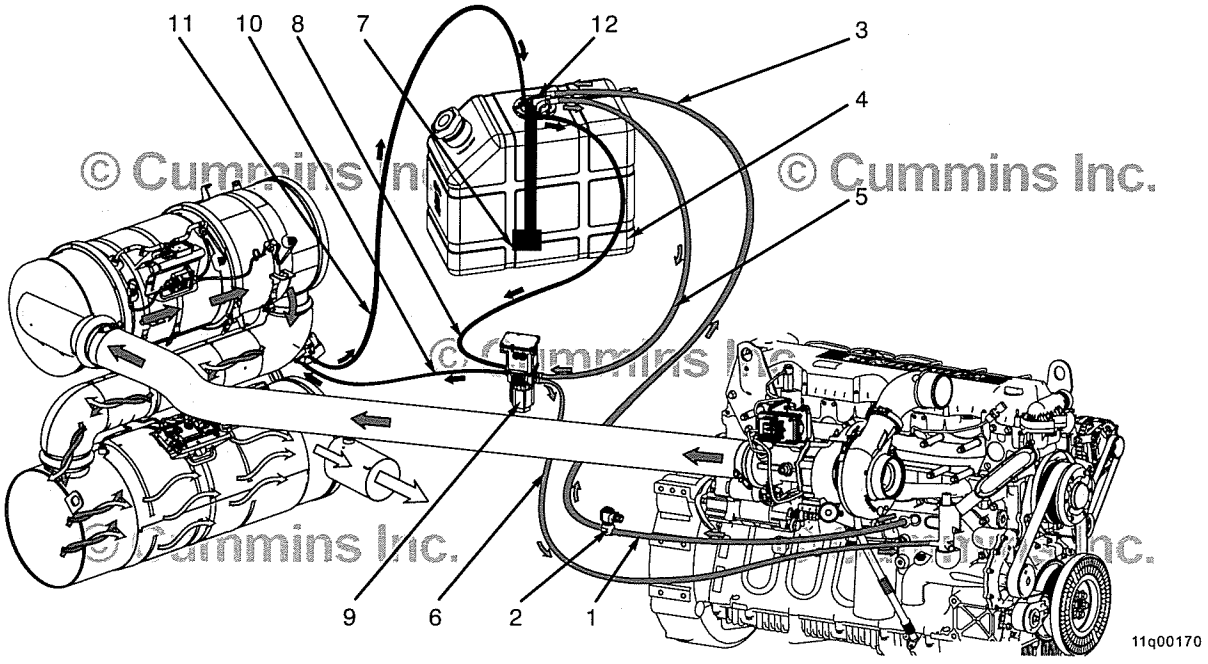
Aftertreatment System, Exhaust Flow – QSG12 CM2350 G110

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.

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Flow Diagram, Exhaust System

General Information



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Aftertreatment System, Coolant and DEF Flow - QSG12 CM2350 G110

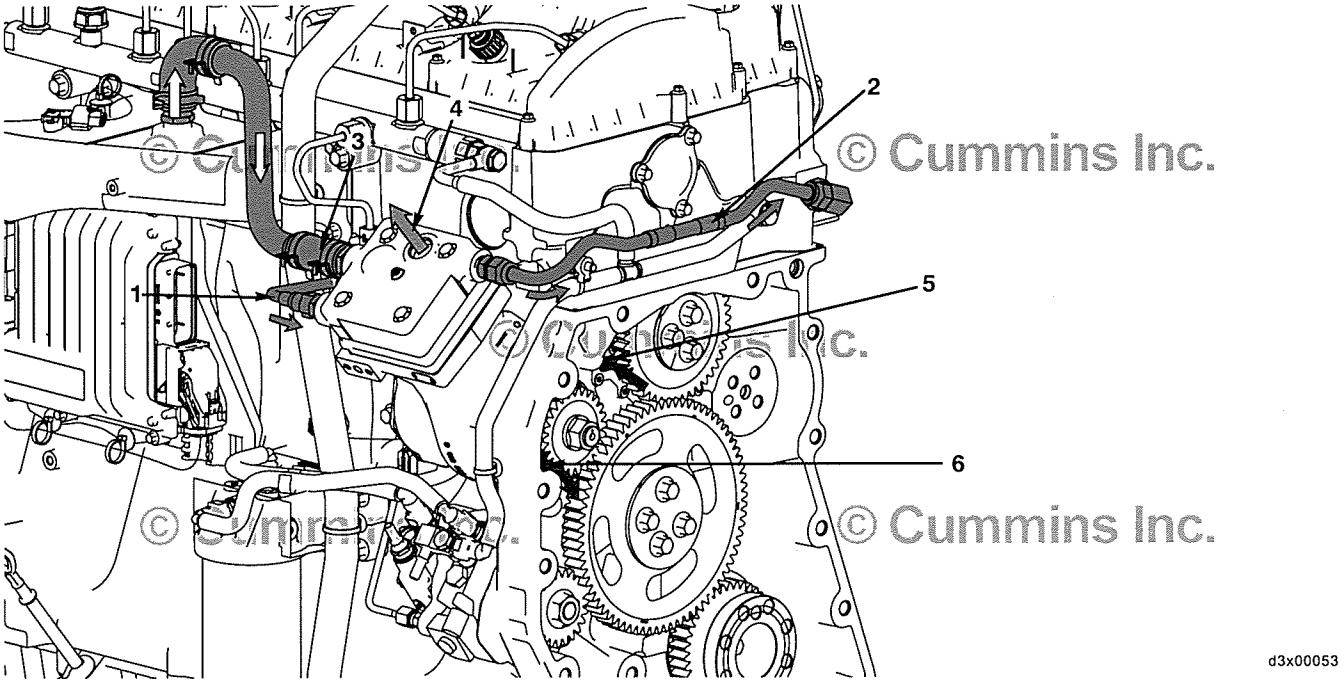
1 Coolant flow from engine to aftertreatment DEF tank heater control valve
2 Aftertreatment DEF tank heater control valve
3 Coolant flow to aftertreatment DEF tank (**only** when aftertreatment DEF tank heater control valve is open)
4 Aftertreatment DEF tank
5 Coolant flow to aftertreatment DEF dosing 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.

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Flow Diagram, Compressed Air System

Flow Diagram



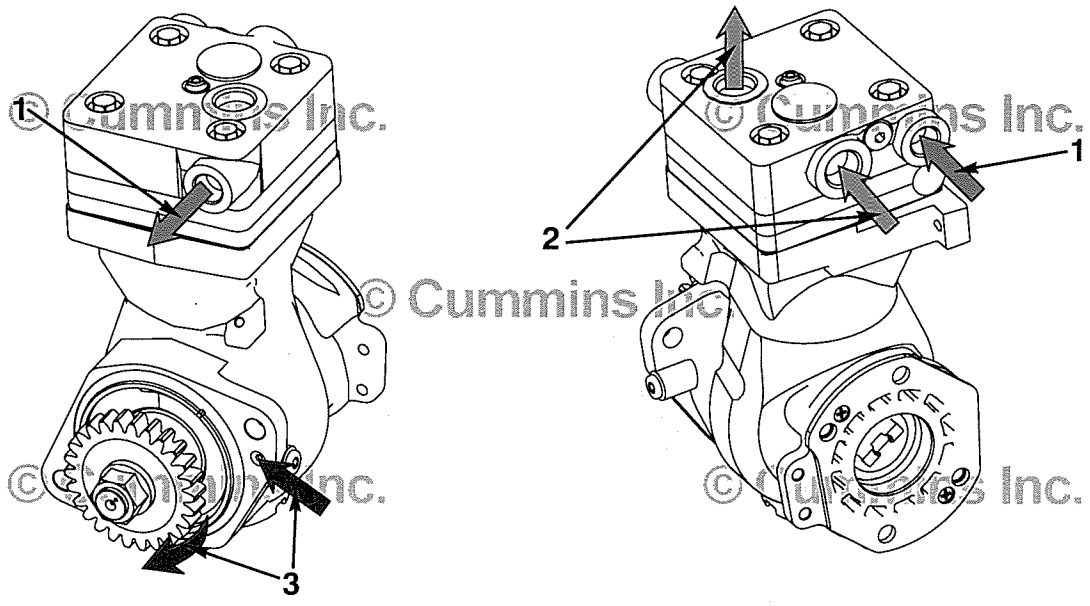
WABCO 318

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.

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Flow Diagram, Compressed Air System

Flow Diagram



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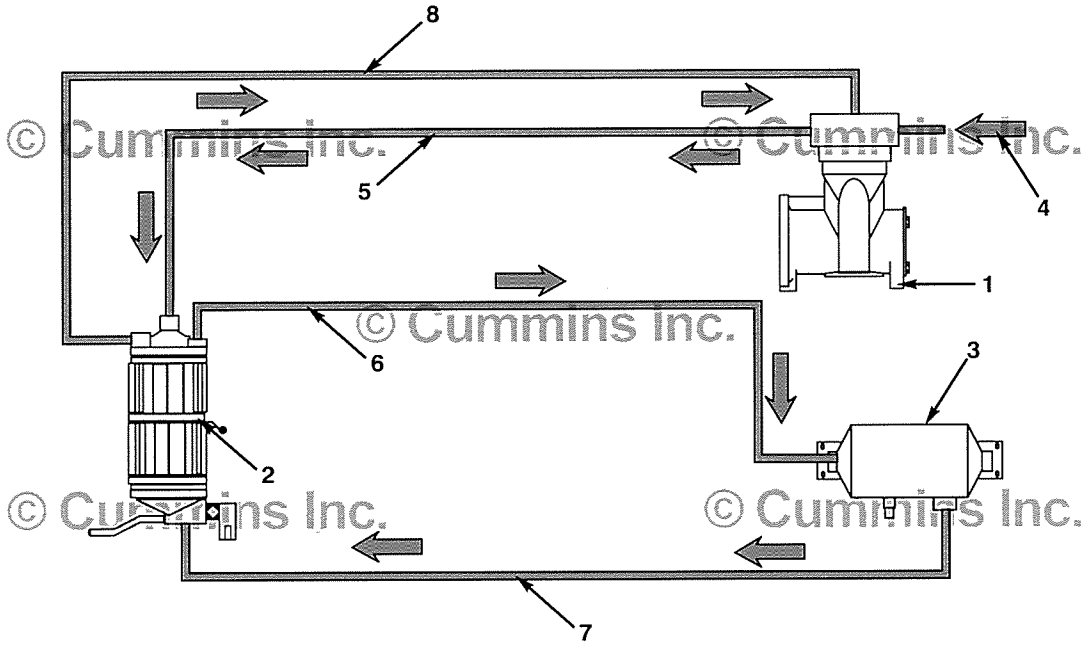
d3x00054

WABCO 318

1 Coolant flow
2 Air flow
3 Lubricating oil flow.

Flow Diagram, Compressed Air System

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.

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Flow Diagram, Compressed Air System

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.

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Section ES - Engine Storage

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Engine Storage - Long Term

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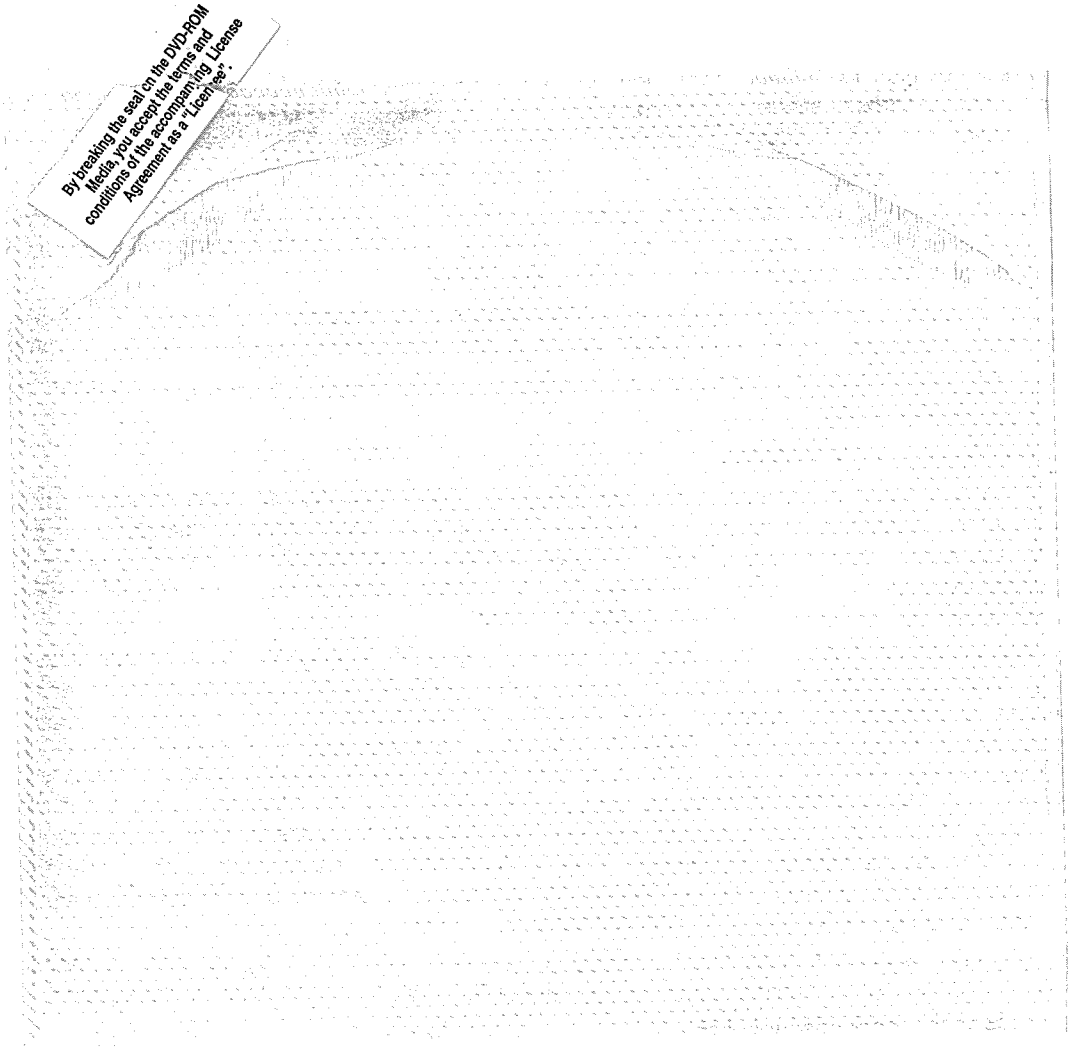
If the engine will be out of service longer than 6 months, special precautions **must** be taken. Follow the long term storage procedure in the base engine troubleshooting and repair manual or service manual or contact the nearest Cummins® Authorized Repair Location for additional information.

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Additional Service Literature

General Information

The following publications can be purchased by contacting your Cummins® distributor:

Bulletin Number	Title of Publication
4367323	QSG12 CM2350 G110 Service Manual
4367324	QSG12 CM2350 G110 Fault Code Troubleshooting Manual
4367325	QSG12 CM2350 G110 Wiring Diagram
4367322	QSG12 CM2350 G110 Operation and Maintenance Manual
4367321	QSG12 CM2350 G110 Owners Manual
3379000	Air for Your Engine
3379001	Fuel for Cummins® Engines
3666132	Cummins® Coolant Requirements and Maintenance
3810340	Cummins® Engine Oil and Oil Analysis Recommendations

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Service Literature Ordering Location
Contact Information

Region	Ordering Location
United States and Canada	Cummins Distributors or Credit Cards at https://store.cummins.com
All Other Countries	Cummins Distributors or Dealers

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Cummins Customized Parts Catalog

General Information

Cummins is pleased to announce the availability of a parts catalog compiled specifically for you. Unlike the generic versions of parts catalogs that support general high volume parts content; Cummins Customized catalogs contain only the new factory parts that were used to build your engine.

The catalog cover, as well as the content, is customized with you in mind. You can use it in your shop, at your worksite, or as a coffee table book in your RV or boat. The cover contains your name, company name, address, and telephone number.

This new catalog was designed to provide you with the exact information you need to order parts for your engine. This will be valuable for customers that do not have easy access to Cummins QuickServe Online.

Additional Features of the Customized Catalog include:

- Engine Configuration Data
- Table of Contents
- Separate Option and Parts Indexes
- Service Kits (when applicable)
- ReCon Part Numbers (when applicable)

Ordering the Customized Parts Catalog

Ordering by Telephone

- North American Distributors, Original Equipment Manufacturers and Cummins Factory personnel order by calling Iron Mountain Fulfillment Services (IMFS) at 1-800-646-5609.
- International Distributors and Original Equipment Manufacturers order the CPC from their regional Cummins Parts Distribution Centers (PDC).
- International PDC orders are called into Iron Mountain at (++) 630-283-2420.
- Retail Credit Card Orders require a 2 step ordering process.

Ordering On-Line

Access the Cummins QSOL store at https://store.cummins.com

- Find the Customized Parts Catalog button located on the left of the homepage
- Select format. Your Price is also shown here
- Finalize Shopping Cart and Check Process as described on the website

North America call Iron Mountain Fulfillment Services (IMFS) at 800-646-5609, International customers call (++) 630-283-2420. Provide IMFS the catalog detail as described on the website. This step is required until we have our On Line form available.

Required information needed for your Customized Parts Catalog Order.

- Customer Name
- Street Address
- Company Name (optional)
- Telephone no.
- Credit Card No.
- Cummins Engine Serial Number (located on the engine data plate)

Unfortunately not all Cummins Engines can be supported by Customized Parts Catalogs. Engines older than 1984 or newer than 3 months may not have the necessary parts information to compile a catalog. We will contact you if this occurs and explain why we are unable to fill your order.

Customized Parts Catalogs are produced specifically for a single customer. This means they are not returnable for a refund. If we make an error and your catalog is not useable, we will correct that error by sending you a new catalog.

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Service Assistance

General Information

To contact the nearest Cummins® Authorized Repair Location, utilize the Service Locator at www.cummins.com.

Cummins Inc. provides a 24-hour, toll free telephone number to aid in technical and emergency service when a Cummins® Authorized Repair Location can **not** be reached or is unable to resolve an issue with a Cummins® product.

U.S. and Canada

- 1-800-DIESELS (1-800-343-7357)

Mexico

- 01-800-CUMMINS (2866467)
- Email: contacto.mexico@cummins.com

Australia/New Zealand

- For Australia: 1-800-CUMMINS (1800 286 646)
- For New Zealand: 0-800-CUMMINS (0800 286 646)
- Email: marketingsouthpac@cummins.com

Brazil

- 0800 CUMMINS (0800 286 6467)
- Email: falecom@cummins.com

Europe

- From the UK, Ireland, Germany, France, and the Netherlands - Freephone: 00 8000 2866467
- Email: emea.customerassistance@cummins.com

China

- 400 810 5252 or (+86) 400 810 5252
- Email: customersupport@cummins.com

India

- 800 210 2525
- Email: powermaster-India@cummins.com

For All Other Areas:

- +44 (0) 1327 886464

Routine Service and Parts

General Information

Personnel at Cummins Authorized Repair Locations can assist you with the correct operation and service of your system. Cummins has a worldwide service network of more than 5,000 Distributors and Dealers who have been trained to provide sound advice, expert service, and complete parts support. Check the telephone directory, refer to the directory in this section, or the Service Locator at www.cummins.com for the nearest Cummins Authorized Repair Location.

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Troubleshooting Procedures and Techniques

General Information

This guide describes some typical operating problems, their causes, and some acceptable corrections to those problems. Unless noted otherwise, the problems listed are those which an operator can diagnose and repair.

⚠WARNING⚠

Performing troubleshooting procedures NOT outlined in this section can result in equipment damage or personal injury or death. Troubleshooting must be performed by trained, experienced technicians. Consult a Cummins Authorized Repair Location for diagnosis and repair beyond that which is outlined, and for symptoms not listed in this section. Before beginning any troubleshooting, refer to General Safety Instructions in Section i of this manual.

Follow the suggestions below for troubleshooting:

- Study the complaint thoroughly before acting
- Refer to the engine system diagrams
- Do the easiest and most logical things first
- Find and correct the cause of the complaint

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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.

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Air Compressor Air Pressure Rises Slowly

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 010-059 in Section 3.

OK
Go To Next Step

STEP 2 Air system leaks	Block the vehicle wheels and check the air system for leaks with the spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to the OEM service manual. For applications fitted with selective catalytic reduction exhaust systems, check the air supply line to the dosing control unit.

OK
Go To Next Step

STEP 3 Carbon buildup is excessive in the air discharge line, downstream air valves	Check for carbon buildup. Replace the air compressor discharge line, or air compressor. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedure 012-015 in Section 6.

OK
Go To Next Step

STEP 4
Contact a Cummins® Authorized Repair Facility

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Air Compressor Cycles Frequently

Cause	Correction
STEP 1 Air system leaks	Block the vehicle wheels and check the air system for leaks with the spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to the OEM service manual. For applications fitted with selective catalytic reduction exhaust systems, check the air supply line to the dosing control unit.
OK Go To Next Step	
STEP 2 Carbon buildup is excessive in the air discharge line, check valve	Check for carbon buildup. Replace the air compressor discharge line, if necessary. Refer to Procedure 012-015 in Section 6.
OK Go To Next Step	
STEP 3 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 OEM service manual.
OK Go To Next Step	
STEP 4 Contact a Cummins® Authorized Repair Facility	

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Air Compressor Noise is Excessive

Cause	Correction
STEP 1 Carbon buildup is excessive in the air discharge line, downstream air valves	Check for carbon buildup. Replace the air compressor discharge line, or air compressor. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedure 012-015 in Section 6.
OK Go To Next Step	
STEP 2 Air compressor is sending air pulses into the air tanks	Install a ping tank between the air dryer and the wet tank. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Ice buildup in the air system components	For all models, check for ice in low spots of the air discharge line, dryer inlet, and elbow fittings. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Contact a Cummins® Authorized Repair Facility	

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Air Compressor Pumping Excess Lubricating Oil into the Air System

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.
OK Go To Next Step	
STEP 2 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 010-059 in Section 3.
OK Go To Next Step	
STEP 3 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 OEM service manual.
OK Go To Next Step	
STEP 4 Carbon buildup is excessive in the air discharge line, check valve	Check for carbon buildup. Replace the air compressor discharge line, if necessary. Refer to Procedure 012-015 in Section 6.
OK Go To Next Step	
STEP 5 Contact a Cummins® Authorized Repair Facility	

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

Cause	Correction
STEP 1 Air system leaks	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to the OEM service manual. For applications fitted with selective catalytic reduction exhaust systems, check the air supply line to the dosing control unit.

OK
Go To Next Step

STEP 2
Contact a Cummins® Authorized Repair Facility

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Air Compressor Will Not Stop Pumping

Cause

STEP 1
Air system leaks

OK
Go To Next Step

STEP 2
Contact a Cummins® Authorized Repair Facility

Correction

Block the vehicle wheels and check the air system for leaks with the spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to the OEM service manual. For applications fitted with selective catalytic reduction exhaust systems, check the air supply line to the dosing control unit.

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Charging System Alternator Not Charging or Insufficient Charging

Cause	Correction
STEP 1 Alternator belt is loose	Check the alternator belt tension. Refer to Procedure 018-005 in Section V.
OK Go To Next Step	
STEP 2 Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections.
OK Go To Next Step	
STEP 3 Batteries have malfunctioned	Check the condition of the batteries. Replace the batteries, if necessary. 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.
OK Go To Next Step	
STEP 5 Alternator pulley is loose on the shaft	Replace the alternator. Refer to Procedure 013-001 in Section A.
OK Go To Next Step	
STEP 6 Contact a Cummins® Authorized Repair Facility	

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Coolant Loss - External

Cause	Correction
STEP 1 Coolant level is above specification	Check the coolant level. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 External coolant leak	Inspect the engine for coolant leaking from hoses, draincocks, water manifold, jumper tubes, expansion and pipe plugs, fittings, radiator core, air compressor and cylinder head gaskets, lubricating oil cooler, water pump seal, cylinder block, and OEM-mounted components that have coolant flow. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047 in Section 5.
OK Go To Next Step	
STEP 4 Fill line or vent lines are restricted, obstructed, or **not** routed correctly	Check the vent lines and the fill line for correct routing and for restriction. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Coolant fill line is restricted or obstructed	Check the coolant fill line for restrictions or obstructions. Refer to Procedure 008-066 in Section 3.
OK Go To Next Step	
STEP 6 Engine is overheating	Refer to the Coolant Temperature Above Normal - Gradual Overheat or the Coolant Temperature Above Normal - Sudden Overheat symptom tree in Section TS.
OK Go To Next Step	
STEP 7 Contact a Cummins® Authorized Repair Facility	

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Coolant Loss - Internal

Cause	Correction
STEP 1 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047 in Section 5.
OK Go To Next Step	
STEP 2 Misdiagnosed coolant leak (external)	Pressure test the cooling system. Refer to a Cummins® Authorized Repair Location. Inspect for coolant leaking externally from items such as coolant hoses, drain valves, coolant manifolds, expansion and pipe plugs, fittings, air compressor coolant lines, turbocharger coolant lines (if equipped), transmission oil cooler or torque converter oil cooler, water pump seal, radiator core, heat exchanger, lubricating oil cooler housing, and OEM mounted components that have coolant flow. If necessary, pressure test the OEM mounted components.
OK Go To Next Step	
STEP 3 Fuel heater is leaking coolant	If applicable, check the fuel heater for coolant leaks. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Transmission oil cooler or torque converter cooler is leaking	If applicable, check the transmission oil cooler and torque converter cooler for coolant leaks. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Aftertreatment diesel exhaust fluid tank heater is leaking coolant	Inspect the aftertreatment diesel exhaust fluid tank for internal coolant leaks. Refer to the OEM service manual. Check the concentration of the diesel exhaust fluid. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 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 the OEM service manual.
OK Go To Next Step	
STEP 7 Turbocharger bearing housing leaking coolant	Check the turbocharger bearing housing. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	

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Coolant Loss - Internal

Cause	Correction
STEP 8 Cylinder head injector sleeve(s) are leaking coolant to the fuel return, or fuel to the cooling system	Check for fuel in the cooling system or coolant in the fuel tank(s). Refer to the OEM service manual. If coolant is found in the fuel tank(s), or fuel is found in the cooling system, pressure test the cylinder head. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
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 a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 10 Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks. Contact a Cummins® Authorized Repair Location
OK Go To Next Step	
STEP 11 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 12 Cylinder head is cracked or porous	Pressure test the cylinder head. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 13 Cylinder block is cracked or porous	Inspect the cylinder block. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 14 Contact a Cummins® Authorized Repair Facility	

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Coolant Temperature Above Normal - Gradual Overheat

Cause	Correction
STEP 1 Coolant level is below specification	Check the coolant level. Check for an external leak. Refer to Procedure 008-066 in Section 3. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak).
OK Go To Next Step	
STEP 2 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 010-028 in Section 3 and the OEM service manual.
OK Go To Next Step	
STEP 3 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 784 cm^2 [122 in^2] or approximately 28 x 28 cm [11 x 11 in] of opening at all times. Refer to Procedure 101-004 in Section 1.
OK Go To Next Step	
STEP 4 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-045 in Section 9.
OK Go To Next Step	
STEP 5 Fan drive belt or water pump belt is loose	Check the belt tension and tighten if necessary. Refer to Procedure 018-005 in Section V.
OK Go To Next Step	
STEP 6 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-043 in Section 3.
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.
OK Go To Next Step	
STEP 8 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to the OEM service manual.
OK Go To Next Step	

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Coolant Temperature Above Normal - Gradual Overheat

Cause

STEP 9

Supplemental coolant additive (SCA) level is above specification or the coolant is over-concentrated with antifreeze

Correction

Check the SCA level. Verify the antifreeze concentration. Refer to Procedure 008-046 in Section 5 and Procedure 018-004 in Section V.

OK

Go To Next Step

STEP 10

Contact a Cummins® Authorized Repair Facility

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Coolant Temperature Above Normal - Sudden Overheat

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Coolant level is below specification	Check the coolant level. Check for an external leak. Refer to Procedure 008-066 in Section 3. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak).
OK Go To Next Step	
STEP 3 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 the OEM service manual.
OK Go To Next Step	
STEP 4 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-045 in Section 9.
OK Go To Next Step	
STEP 5 Fan drive belt is broken	Check the fan drive belt. Replace the belt, if necessary. Refer to Procedure 008-002 in Section A.
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 4.
OK Go To Next Step	
STEP 7 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.
OK Go To Next Step	
STEP 8 Fill line or vent lines are restricted, obstructed, or **not** routed correctly	Check the vent lines and the fill line for correct routing and for restriction. Refer to the OEM service manual.
OK Go To Next Step	
STEP 9 Contact a Cummins® Authorized Repair Facility	

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Coolant Temperature Below Normal

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.

OK
Go To Next Step

STEP 2 Engine is operating at low ambient temperature	Check the winterfront, shutters, and under-the-hood air. Use under-the-hood intake air in cold weather. Refer to Procedure 101-004 in Section 1.

OK
Go To Next Step

STEP 3 Radiator shutters are stuck open or opening early	Check the shutter operation. Repair or replace the shutters, if necessary. Refer to the OEM service manual.

OK
Go To Next Step

STEP 4 Coolant temperature gauge or sensor is malfunctioning	Test the gauge and the sensor. Repair or replace, if necessary. Refer to the OEM service manual.

OK
Go To Next Step

STEP 5
Contact a Cummins® Authorized Repair Facility

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Crankcase Gases (Blowby) Excessive

Cause

STEP 1
Crankcase ventilation system is plugged

Correction

Check and clean the crankcase breather and vent tube. Refer to Procedure 003-018 in Section 3.

OK
Go To Next Step

STEP 2
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Engine Acceleration or Response Poor

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Engine is operating at low ambient temperature	Check the winterfront, shutters, and under-the-hood air. Use under-the-hood intake air in cold weather. Refer to Procedure 101-004 in Section 1.
OK Go To Next Step	
STEP 3 Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024 in Section 6.
OK Go To Next Step	
STEP 4 Fuel temperature is above specification	Fill the fuel tanks. Turn off or bypass the fuel heater, if equipped. Refer to the OEM service manual.
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.
OK Go To Next Step	
STEP 6 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 7 Engine is operating at high ambient temperature	Use outside air to the turbocharger in hot weather.
OK Go To Next Step	
STEP 8 Contact a Cummins® Authorized Repair Facility	

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Engine Decelerates Slowly

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Accelerator pedal or lever is sticking	Check for a sticking accelerator pedal. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Contact a Cummins® Authorized Repair Facility	

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

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Engine-driven units are engaged	Disengage any engine-driven units.
OK Go To Next Step	
STEP 4 Engine cranking speed is too slow	Check the engine cranking speed with a handheld tachometer or electronic service tool. Determine if the cranking speed is slower than 150 rpm. Refer to the Engine Will **Not** Crank or Cranks Slowly symptom tree.
OK Go To Next Step	
STEP 5 Fuel shutoff valve(s) closed (electronically controlled injection)	Check the fuel shutoff valve and circuit.
OK Go To Next Step	
STEP 6 Fuse(s) malfunctioning	Replace the fuse(s) in the OEM interface harness. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Exhaust system restriction	Check the exhaust system for restrictions. Contact a Cummins® Authorized Repair Location
OK Go To Next Step	
STEP 8 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.
OK Go To Next Step	
STEP 9 Starting aid is necessary for cold weather or starting aid is malfunctioning	Check for the correct operation of the starting aid. Refer to the OEM service manual. Refer to Procedure 010-029 in Section 9.
OK Go To Next Step	

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

Cause	Correction
STEP 10 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Check the fuel suction line for restriction. Refer to Procedure 006-065 or Procedure 006-066 in Scetion 4.

OK
Go To Next Step

STEP 11 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 010-059 in Section 3.

OK
Go To Next Step

STEP 12
Contact a Cummins® Authorized Repair Facility

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

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.

OK
Go To Next Step

STEP 2 Fuel level is low in the tank	Fill the supply tank. Refer to the OEM service manual.

OK
Go To Next Step

STEP 3 Starting motor rotation is not correct	Check the direction of crankshaft rotation. Replace the starting motor if necessary. Refer to the OEM service manual.

OK
Go To Next Step

STEP 4 Engine cranking speed is too slow	Check the engine cranking speed with a handheld tachometer or electronic service tool. Determine if the cranking speed is slower than 150 rpm. Refer to the Engine Will **Not** Crank or Cranks slowly symptom tree in Section TS.

OK
Go To Next Step

STEP 5 Exhaust system leaking hot air into engine compartment	Check the exhaust plumbing for leaks or broken components. Refer to the OEM service manual.

OK
Go To Next Step

STEP 6 Fuel shutoff valve is closed	Check for loose wires. Check for power to the fuel shutoff valve solenoid.

OK
Go To Next Step

STEP 7 Battery supply to the engine control module (ECM) is low, interrupted, or open	Check the battery connections, fuses, and unswitched battery supply circuit. Refer to the OEM service manual.

OK
Go To Next Step

STEP 8 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Check the fuel suction line for restriction. Refer to Procedure 006-065 or Procedure 006-066 in Section 4.

OK
Go To Next Step

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

Cause	Correction
STEP 9 Fuel connections on the low-pressure side of the pump are loose	Tighten all fuel fittings and connections between the fuel tanks and the fuel pump. Refer to the OEM serivce manual.

OK
Go To Next Step

STEP 10 Fuel drain line restriction	Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary.

OK
Go To Next Step

STEP 11 Fuel suction standpipe in the fuel tank is broken	Check and repair the standpipe, if necessary. Refer to the OEM service manual.

OK
Go To Next Step

STEP 12
Contact a Cummins® Authorized Repair Facility

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Engine Noise Excessive

Cause	Correction
STEP 1 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Lubricating oil is thin or diluted	Refer to Procedure 018-003 in Section V. Refer to the Lubricating Oil Contaminated symptom tree. If the oil pressure is low, refer to the Lubricating Oil Pressure Low troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 3 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Sudden Overheat or the Coolant Temperature Above Normal - Gradual Overheat symptom tree in Section TS.
OK Go To Next Step	
STEP 4 Fan drive belt is loose, tight, or **not** in alignment	Check the fan drive belt. Refer to Procedure 008-002 in Section A.
OK Go To Next Step	
STEP 5 Vibration damper is damaged or loose	Inspect the vibration damper. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 6 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Contact a Cummins® Authorized Repair Facility	

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Engine Noise Excessive - Combustion Knocks

Cause	Correction
STEP 1 Engine is operating at low ambient temperature	Check the winterfront, shutters, and under-the-hood air. Use under-the-hood intake air in cold weather. Refer to Procedure 101-004 in Section 1.
OK Go To Next Step	
STEP 2 Starting aid is necessary for cold weather or starting aid is malfunctioning	Check for the correct operation of the starting aid. Refer to the OEM service manual. Refer to Procedure 010-029 in Section 9.
OK Go To Next Step	
STEP 3 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.
OK Go To Next Step	
STEP 4 Contact a Cummins® Authorized Repair Facility	

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Engine Power Output Low

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 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 3 Engine is operating above recommended altitude	Engine power decreases above recommended altitude. Refer to the Engine Data Sheet for specifications.
OK Go To Next Step	
STEP 4 Turbocharger is not correct	Check the turbocharger part number and compare it to the Control Parts List (CPL). Replace the turbocharger, if necessary.
OK Go To Next Step	
STEP 5 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Check the fuel suction line for restriction. Refer to Procedure 006-066 in Section 5.
OK Go To Next Step	
STEP 6 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. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 7 Air intake system restriction is above specification	Replace the air filter and inlet piping as necessary. Refer to Procedure 010-059 in Section 3.
OK Go To Next Step	
STEP 8 Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024 in Section 6.
OK Go To Next Step	
STEP 9 Air in the fuel system	Check for air in the fuel system. Tighten or replace the fuel connections, fuel lines, fuel tank standpipe, and fuel filters as necessary.
OK Go To Next Step	

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Engine Power Output Low

Cause	Correction
STEP 10 Fuel drain line restriction	Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary.
OK Go To Next Step	
STEP 11 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.
OK Go To Next Step	
STEP 12 Intake manifold air temperature is above specification	Refer to the Intake Manifold Air Temperature Above Specification symptom tree in Section TS.
OK Go To Next Step	
STEP 13 Fuel inlet temperature to pump is above specification	Fill the fuel tank, turn off or bypass the fuel heaters, and check the fuel cooler. Refer to the OEM service manual.
OK Go To Next Step	
STEP 14 Contact a Cummins® Authorized Repair Facility	

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Engine Runs Rough at Idle

Cause	Correction
STEP 1 Engine is operating at low ambient temperature	Check the winterfront, shutters, and under-the-hood air. Use under-the-hood intake air in cold weather. Refer to Procedure 101-004 in Section 1.
OK Go To Next Step	
STEP 2 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 3 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Engine idle speed is set too low (electronically controlled fuel systems)	Check the engine data plate to verify the correct idle speed setting. Refer to the OEM service manual. Increase the idle speed with the idle increment switch or an electronic service tool. Refer to the appropriate electronic service tool manual.
OK Go To Next Step	
STEP 5 Air in the fuel system	Check for air in the fuel system. Tighten or replace the fuel connections, fuel lines, fuel tank standpipe, and fuel filters as necessary.
OK Go To Next Step	
STEP 6 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-002 in Section V.
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 6.
OK Go To Next Step	
STEP 8 Contact a Cummins® Authorized Repair Facility	

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Engine Runs Rough or Misfires

Cause	Correction
STEP 1 Condition occurs **only** at idle	Refer to the Engine Runs Rough at Idle symptom tree in Section TS.
OK Go To Next Step	
STEP 2 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 Procedure 101-004 in Section 1.
OK Go To Next Step	
STEP 3 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 4 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 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.
OK Go To Next Step	
STEP 6 Air in the fuel system	Check for air in the fuel system. Tighten or replace the fuel connections, fuel lines, fuel tank standpipe, and fuel filters as necessary.
OK Go To Next Step	
STEP 7 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Refer to Procedure 006-066 in Section 4.
OK Go To Next Step	
STEP 8 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to the OEM service manual.
OK Go To Next Step	
STEP 9 Valve lash adjustments are **not** correct	Measure and adjust the valve lash setting. Refer to Procedure 003-004 in Section 6.
OK Go To Next Step	
STEP 10 Contact a Cummins® Authorized Repair Facility	

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Engine Shuts Off Unexpectedly or Dies During Deceleration

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Battery supply to the engine control module (ECM) is low, interrupted, or open	Check the battery connections, fuses, and unswitched battery supply circuit. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 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 OEM service manual.
OK Go To Next Step	
STEP 4 Engine will **not** restart	Refer to the Engine Difficult to Start or Will **Not** Start symptom tree.
OK Go To Next Step	
STEP 5 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Check the fuel suction line for restriction. Refer to Procedure 006-066 in Section 4.
OK Go To Next Step	
STEP 6 Air in the fuel system	Check for air in the fuel system. Tighten or replace the fuel connections, fuel lines, fuel tank standpipe, and fuel filters as necessary.
OK Go To Next Step	
STEP 7 Original equipment manufacturer (OEM) engine protection system is malfunctioning	Isolate the OEM engine protection system. Follow the OEM service manual instructions to check for a malfunction
OK Go To Next Step	
STEP 8 Fuel shutoff valve is closed	Check for loose wires. Check for power to the fuel shutoff valve solenoid.
OK Go To Next Step	
STEP 9 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.
OK Go To Next Step	

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Engine Shuts Off Unexpectedly or Dies During Deceleration

Cause	Correction
STEP 10	
Contact a Cummins® Authorized Repair Facility	

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Engine Speed Surges at Low or High Idle

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Fuel level is low in the tank	Fill the supply tank. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Check the fuel suction line for restriction. Refer to Procedure 006-066 in Section 4.
OK Go To Next Step	
STEP 4 Air in the fuel system	Check for air in the fuel system. Tighten or replace the fuel connections, fuel lines, fuel tank standpipe, and fuel filters as necessary.
OK Go To Next Step	
STEP 5 Contact a Cummins® Authorized Repair Facility	

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Engine Speed Surges Under Load or in Operating Range

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location..
OK Go To Next Step	
STEP 2 Fuel level is low in the tank	Fill the supply tank. Refer to the OEM service manual..
OK Go To Next Step	
STEP 3 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Check the fuel suction line for restriction. Refer to Procedure 006-066 in Section 4.
OK Go To Next Step	
STEP 4 Air in the fuel system	Check for air in the fuel system. Tighten or replace the fuel connections, fuel lines, fuel tank standpipe, and fuel filters as necessary.
OK Go To Next Step	
STEP 5 Contact a Cummins® Authorized Repair Facility	

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Engine Starts But Will Not Keep Running

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Idle Shutdown or Power Take-Off (PTO) Shutdown features are activated	Use INSITE™ electronic service tool to check the Idle Shutdown and PTO parameters.
OK Go To Next Step	
STEP 3 Fuel level is low in the tank	Fill the supply tank. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Air in the fuel system	Check for air in the fuel system. Tighten or replace the fuel connections, fuel lines, fuel tank standpipe, and fuel filters as necessary.
OK Go To Next Step	
STEP 5 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Check the fuel suction line for restriction. Refer to Procedure 006-066 in Section 4.
OK Go To Next Step	
STEP 6 Engine-driven units are engaged	Disengage any engine-driven units.
OK Go To Next Step	
STEP 7 Fuel is waxing due to cold weather	Check the fuel heater, if installed. Weather conditions sometimes require a fuel heater.
OK Go To Next Step	
STEP 8 Fuel shutoff valve is closed	Check for loose wires. Check for power to the fuel shutoff valve solenoid.
OK Go To Next Step	
STEP 9 Exhaust system restriction	Check the exhaust system for restrictions. Contact a Cummins® Authorized Repair Location
OK Go To Next Step	

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Engine Starts But Will Not Keep Running

Cause	Correction
STEP 10 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.

OK
Go To Next Step

STEP 11 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 010-059 in Section 3.

OK
Go To Next Step

STEP 12
Contact a Cummins® Authorized Repair Facility

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Engine Vibration Excessive

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Engine is misfiring	Refer to the Engine Runs Rough or Misfires symptom tree in Section TS.
OK Go To Next Step	
STEP 3 Engine idle speed is set too low (electronically controlled fuel systems)	Check the engine data plate to verify the correct idle speed setting. Refer to the OEM service manual. Increase the idle speed with the idle increment switch or an electronic service tool. Refer to the appropriate electronic service tool manual.
OK Go To Next Step	
STEP 4 Fan is loose, damaged, or **not** balanced	Check the fan. Refer to Procedure 008-040 in Section 3.
OK Go To Next Step	
STEP 5 Belt-driven accessories are malfunctioning	Check the fan hub, alternator, refrigerant compressor, and hydraulic pump for interference. Isolate belt-driven accessories and check for vibration. Refer to Procedure 008-036 in Section 9.
OK Go To Next Step	
STEP 6 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Vibration damper is damaged or loose	Inspect the vibration damper. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 8 Contact a Cummins® Authorized Repair Facility	

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Engine Will Not Crank or Cranks Slowly (Electric Starter)

Cause		Correction
STEP 1 Battery cables or connections are loose, broken, or corroded (excessive resistance)	.....	Check the battery cables and connections.
OK Go To Next Step		
STEP 2 Engine-driven units are engaged	.....	Disengage any engine-driven units.
OK Go To Next Step		
STEP 3 Lubricating oil temperature is below specification	.....	Install an oil pan heater, or drain the oil and fill the system with warm oil.
OK Go To Next Step		
STEP 4 Lubricating oil does **not** meet specifications for operating conditions	.....	Change the oil and filters. Refer to Procedure 007-002 in Section 5. Use the oil recommended in Section V.
OK Go To Next Step		
STEP 5 Contact a Cummins® Authorized Repair Facility		

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Engine Will Not Reach Rated Speed (RPM)

Cause	Correction
STEP 1 Keyswitch circuit is malfunctioning	Check the vehicle, equipment, or vessel keyswitch circuit. Refer to the OEM service manual or contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Tachometer is **not** calibrated or is malfunctioning	Compare the tachometer reading with a handheld tachometer or an electronic service tool reading. Calibrate or replace the tachometer as necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
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 Engine power output is low	Refer to the Engine Power Output Low symptom tree in Section TS.
OK Go To Next Step	
STEP 6 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-002 in Section V.
OK Go To Next Step	
STEP 7 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Check the fuel suction line for restriction. Refer to Procedure 006-066 in Section 4.
OK Go To Next Step	
STEP 8 Valve lash adjustments are **not** correct	Measure and adjust the valve lash setting. Refer to Procedure 003-004 in Section 6.
OK Go To Next Step	

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Engine Will Not Reach Rated Speed (RPM)

Cause	Correction
STEP 9 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 the OEM service manual or contact a Cummins® Authorized Repair Location.

OK
Go To Next Step

STEP 10
Contact a Cummins® Authorized Repair Facility

Engine Will Not Shut Off

Cause	Correction
STEP 1 Keyswitch circuit is malfunctioning	Check the vehicle, equipment, or vessel keyswitch circuit. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 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 3 Contact a Cummins® Authorized Repair Facility	

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Fuel Consumption Excessive

Cause	Correction
STEP 1 Verify the complaint	If low power is relevant, refer to the Engine Power Output Low symptom tree. If acceleration is poor, refer to the Engine Acceleration or Response Poor symptom tree. If fuel consumption is relevant, continue with this tree.
OK Go To Next Step	
STEP 2 Lubricating oil level is above specification	Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 3 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 010-059 in Section 3.
OK Go To Next Step	
STEP 4 Fuel leak	Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines from the supply tank(s). Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Operator technique is **not** correct	Refer to Procedure 101-014 in Section 1.
OK Go To Next Step	
STEP 6 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 7 Speedometer is malfunctioning or the road speed is excessive	Calibrate the speedometer. Refer to the OEM service manual.
OK Go To Next Step	
STEP 8 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 9 Contact a Cummins® Authorized Repair Facility	

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Fuel in Coolant

Cause	Correction
STEP 1 Bulk coolant supply is contaminated	Check the bulk coolant supply. Drain the coolant and replace with non-contaminated coolant.
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 Contact a Cummins® Authorized Repair Facility	

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Fuel in the Lubricating Oil

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 007-002 in Section 5.
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 the OEM service manual or contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 3 Contact a Cummins® Authorized Repair Facility	

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Intake Manifold Air Temperature Above Specification

Cause	Correction
STEP 1 Vehicle speed is too low for adequate cooling with high engine load	Reduce the engine load. Increase the engine (fan) rpm by downshifting.
OK Go To Next Step	
STEP 2 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.
OK Go To Next Step	
STEP 3 Fan drive belt is broken or loose	Check the fan drive belt. Replace the belt, if necessary. Refer to Procedure 008-002 in Section A.
OK Go To Next Step	
STEP 4 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.
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 010-028 in Section 3 and the OEM service manual.
OK Go To Next Step	
STEP 6 Contact a Cummins® Authorized Repair Facility	

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Intake Manifold Pressure (Boost) is Below Normal

Cause	Correction
STEP 1 Turbocharger is not correct	Check the turbocharger part number and compare it to the Control Parts List (CPL). Replace the turbocharger, if necessary.
OK Go To Next Step	
STEP 2 Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024 in Section 6.
OK Go To Next Step	
STEP 3 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 4 Contact a Cummins® Authorized Repair Facility	

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Lubricating Oil Consumption Excessive

Cause	Correction
STEP 1 Verify the oil consumption rate	Check the amount of oil added versus the mileage/ hours.
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. Contact a Cummins® Authorized Repair Location.
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.
OK Go To Next Step	
STEP 4 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Use the oil type recommended in Section V of the engine operation and maintenance manual Procedure 007-002 in Section 5 and Procedure 018-003 in Section V. Use the oil type recommended in Section V of the engine operation and maintenance manual.
OK Go To Next Step	
STEP 5 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-018 in Section 3.
OK Go To Next Step	
STEP 6 Contact a Cummins® Authorized Repair Facility	

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Lubricating Oil Contaminated

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).
OK Go To Next Step	
STEP 3 Lubricating oil sludge is excessive	Change the oil and filters. Refer to the Lubricating Oil Sludge in the Crankcase Excessive symptom tree in Section TS.
OK Go To Next Step	
STEP 4 Fuel in the lubricating oil	Refer to the Fuel in the Lubricating Oil symptom tree in Section TS.
OK Go To Next Step	
STEP 5 Contact a Cummins® Authorized Repair Facility	

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Lubricating Oil Pressure High

Cause	Correction
STEP 1 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. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Coolant temperature is below specification	Refer to the Coolant Temperature Below Normal symptom tree.
OK Go To Next Step	
STEP 3 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filter(s). Refer to Procedure 007-002 in Section 5 and Procedure 018-003 in Section V. Use the oil type recommended in Section V of the engine operation and maintenance manual.
OK Go To Next Step	
STEP 4 Contact a Cummins® Authorized Repair Facility	

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Lubricating Oil Pressure Low

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-043 in Section 3.
OK Go To Next Step	
STEP 3 Lubricating oil leak (external)	Inspect the engine for external oil leaks. Tighten the capscrews, pipe plugs, and fittings. Replace gaskets, if necessary.
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. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 5 Engine angularity during operation exceeds specification	Refer to the Engine Specification data sheet.
OK Go To Next Step	
STEP 6 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filter(s). Refer to Procedure 007-002 in Section 5. Use the oil type recommended in Section V of the engine operation and maintenance manual.
OK Go To Next Step	
STEP 7 Lubricating oil is contaminated with coolant or fuel	Refer to Lubricating Oil Contaminated symptom tree in Section TS.
OK Go To Next Step	
STEP 8 Lubricating oil filter is plugged	Change the oil and filter(s). Refer to Procedure 007-002 in Section 5. Review the oil change interval.
OK Go To Next Step	
STEP 9 Contact a Cummins® Authorized Repair Facility	

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Lubricating Oil Sludge in the Crankcase Excessive

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 007-002 in Section 5.
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 007-002 in Section 5. Use the oil type recommended in Section V of the engine 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.
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.
OK Go To Next Step	
STEP 5 Lubricating oil is contaminated with coolant	Check the lubricating oil for coolant. Refer to the Coolant Loss - Internal symptom tree in Section TS.
OK Go To Next Step	
STEP 6 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-018 in Section 3.
OK Go To Next Step	
STEP 7 Contact a Cummins® Authorized Repair Facility	

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Lubricating Oil Temperature Above Specification

Cause	Correction
STEP 1 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-043 in Section 3.

OK
Go To Next Step

STEP 2 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Sudden Overheat or the Coolant Temperature Above Normal - Gradual Overheat symptom tree in Section TS.

OK
Go To Next Step

STEP 3 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 the OEM service manual.

OK
Go To Next Step

STEP 4
Contact a Cummins® Authorized Repair Facility

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Lubricating or Transmission Oil in the Coolant

Cause

STEP 1
Bulk coolant supply is contaminated

Correction

Check the bulk coolant supply. Drain the coolant and replace with non-contaminated coolant. Refer to Procedure 008-018 in Section 9.

OK
Go To Next Step

STEP 2
Contact a Cummins® Authorized Repair Facility

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Operating Fuel Pressure is Low

Cause	Correction
STEP 1 Air in the fuel system	Prime the fuel pump. Refer to Procedure 005-234 in Section A.
OK Go To Next Step	
STEP 2 Fuel inlet restriction	Check the fuel filter. Refer to Procedure 006-065 in Section 4 or a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 3 Contact a Cummins® Authorized Repair Facility	

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PTO or Cruise Control Does Not Operate

Cause	Correction
STEP 1 Cruise control/PTO on/off switch is off	Turn on the switch.
OK Go To Next Step	
STEP 2 Cruise control/PTO switch wires or connectors are loose	Check the cruise control/PTO on/off switch, selector switch, clutch switch, and brake switch for loose wires and connections.
OK Go To Next Step	
STEP 3 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 4 Contact a Cummins® Authorized Repair Facility	

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Smoke, Black - Excessive

Cause	Correction
STEP 1 Turbocharger wheel clearance is out of specification	Check the radial bearing and axial clearances. Inspect the turbocharger. Repair or replace the turbocharger, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 2 Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024 in Section 6.
OK Go To Next Step	
STEP 3 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.
OK Go To Next Step	
STEP 4 Fuel drain line restriction	Check the fuel drain lines for restriction. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Contact a Cummins® Authorized Repair Facility	

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Smoke, White - Excessive

Cause	Correction
STEP 1 Electronic fault codes are active	Review instructions for reading active fault codes. Refer to Procedure 101-007 in Section 1. If fault codes are active, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Engine block heater is malfunctioning, if equipped	Check the electrical sources and wiring to the cylinder block heater. Replace the block heater, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Coolant temperature is below specification	Refer to the Coolant Temperature Below Normal symptom tree in Section TS.
OK Go To Next Step	
STEP 4 Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal symptom tree in Section TS.
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.
OK Go To Next Step	
STEP 6 Valve lash adjustments are **not** correct	Measure and adjust the valve lash setting. Refer to Procedure 003-004 in Section 6.
OK Go To Next Step	
STEP 7 Contact a Cummins® Authorized Repair Facility	

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Turbocharger Boost Pressure Low

Cause	Correction
STEP 1 Intake and exhaust system restricted	Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to original equipment manufacturer (OEM) service manual and Procedure 010-059 in Section 3.
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 6.
OK Go To Next Step	
STEP 3 Contact a Cummins® Authorized Repair Facility	

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Turbocharger Leaks Engine Oil or Fuel

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 101-014 in Section 1.
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 the OEM service manual or contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 4 Contact a Cummins® Authorized Repair Facility	

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Stationary Regeneration - Will Not Activate

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Refer to Procedure 101-007 in Section 1 .
OK Go To Next Step	
STEP 2 The correct stationary regeneration procedure is **not** being followed	Refer to the original equipment manufacturer (OEM) service manual. 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.
OK Go To Next Step	
STEP 3 OEM or customer-selected inhibit feature is preventing a stationary regeneration	Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 4 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 5 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 6 Engine control module system calibration is not correct	Compare the calibration in the engine control module with the engine rating and the Control Parts List (CPL). If necessary, calibrate the system.
OK Go To Next Step	
STEP 7 Contact a Cummins® Authorized Repair Facility	

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

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Refer to Procedure 101-007 in Section 1.
OK Go To Next Step	
STEP 2 Engine control module system calibration is not correct	Compare the calibration in the engine control module with the engine rating and the Control Parts List (CPL). If necessary, calibrate the system.
OK Go To Next Step	
STEP 3 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 a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 4 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 011-053 in Section 3 and the OEM service manual. 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 5 Aftertreatment Diesel Particulate Filter is full of ash	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.
OK Go To Next Step	
STEP 6 Engine produces excessive black smoke	Refer to the Smoke, Black - Excessive troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 7 Contact a Cummins® Authorized Repair Facility	

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Air Filter Plugging Frequent

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.
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 3.
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 a Cummins Authorized Repair Location.
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 the 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 010-059 in Section 3.
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 A.
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 A.
OK Go To Next Step	

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Air Filter Plugging Frequent

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 6.

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 6.

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 6.

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 6.

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.

OK
Go To Next Step

STEP 14
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Aspirator Not Functioning

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 A.
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 A.
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 A.
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 A.
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 A.
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.
OK Go To Next Step	
STEP 8 Contact a Cummins® Authorized Repair Facility	

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General Engine

Specifications

Horsepower.....Reference engine dataplate
Engine Speed @ Maximum Output.....Reference engine dataplate
Bore and Stroke.....132 mm [5.197 in] x 144 mm [5.669 in]
Displacement.....11.8 liters [720 C.I.D.]
Firing Order.....1-5-3-6-2-4
Engine Weight (dry weight with standard accessories).....795 kg [1753 lb]
Engine Weight (wet weight with standard accessories).....831 kg [1832 lb]
Crankshaft Rotation (viewed from the front of the engine)..... **Clockwise**

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Fuel System

Specifications

Maximum Fuel Drain Line Pressure
- Rated Power....525 mm-Hg [21 in-Hg]

Maximum Fuel Inlet Restriction
- At Gear Pump Inlet (Dirty Filter, Loaded Condition)....254 mm-Hg [10 in-Hg]
- At OEM Connection (Dirty Filter, Loaded Condition)....203 mm-Hg [8 in-Hg]

Minimum Gear Pump Pressure
- During Cranking Condition....375 mm-Hg [14.7 in-Hg]
- During Rated Condition....483 kPa [70 psi]
- Maximum Filter Pressure-Drop....138 kPa [20 psi]
- Minimum Engine Cranking Speed....100 rpm

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Lubricating Oil System

Specifications

Oil Pressure:

Low idle (minimum allowed).....124 kPa [18 psi]
At rated (minimum allowed).....207 kPa [30 psi]
High Pressure dump valve opening pressure range.....1034 kPa [150 psi]
Main rifle regulating valve opening pressure range.....241 kPa [35 psi]
Oil filter differential pressure to open bypass.....758 kPa [110 psi]

Oil Capacity of Standard Engine:

Pan **only** .....9 gal to high
High to Low (on dipstick).....34 liters [9 gal]
Maximum Oil Temperature:.....136°C [277°F]

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Cooling System

Specifications

Coolant capacity(engine only).....14.4 liters [15.2 quarts]
Standard modulating low thermostat .....82°C [180°F]
Standard modulating high thermostat (fully open).....94°C [202°F]
Maximum allowed water outlet temperature.....97°C [207°F]
Minimum recommended operating temperature.....70°C [158°F]
Minimum recommended pressure cap.....50 kPa [7 psi]

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Air Intake System

Specifications

Maximum Intake Restriction

Maximum Intake Restriction (Clean Air Filter Element).....381 mm H_2O [15.0 in H_2O]

Maximum Intake Restriction (Dirty Air Filter Element).....635 mm H_2O [25.0 in H_2O]

Maximum Temperature Rise (At Ambient Temperature above 0°C [32°F])

Between Ambient Air and Engine Inlet Air.....11°C [20°F]

Maximum Allowable Pressure Drop

Across Charge Air Cooler.....102 mm Hg [4.0 in Hg]

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Exhaust System

Specifications

Maximum Back Pressure at Turbocharger:.....40 kPa 300 mm Hg [5.8 psi 11.8 in Hg]
Exhaust Pipe Normally Acceptable Inside Diameter.....127 mm [5.0 in]

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Electrical System

Specifications

Minimum Recommended Battery Capacity			
System Voltage	Application	Ambient Temperatures (-18°C [0°F])	
		Cold Cranking Amperes	Reserve Capacity[1] Amperes
12 VDC	Industrial	1875	580
24 VDC[2]	Industrial	1250	360

1 The number of plates within a given battery size determines reserve capacity. Reserve capacity is the number of minutes a battery at 26.7°C [80°F] can be discharged at 25 amperes and maintain a voltage of 10.5 VDC for a 12 VDC battery. Reserve capacity is aimed at a vehicle whose charging system is **not** functional and all electrical loads are running off of battery without aid of the alternator. Cold cranking amperes determines the length of time sustained cranking can occur.

2 CCA ratings are based on two 12 VDC batteries in series.

A minimum of 9 VDC continuous, 6 VDC at engine cranking at the OEM connector is required to power up the engine control module.

Maximum Starting Circuit Resistance
Battery Cable Size.....According to the starter manufacturer recommendations for maximum starting resistance.
Minimum Ambient Air Temperature
Without Starting Aid.....-17.8°C [0°F]
Minimum Cranking Speed
Without Starting Aid.....110 rpm

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Compressed Air System

Specifications

This section is for the Wabco™ 318 Single Boost Air Compressor.

Cylinders....1
Compressor Swept Volume @ 2100 ERPM/1MPa....14.0 liters per sec [29.7 cfm]
Piston Displacement....318 cc [19.4 C.I.D.]
Bore....85 mm [3.35 in]
Stroke....56 mm [2.2 in]
Speed....1.5 x Engine Speed
Cooling....Engine Coolant
Lubrication....Engine Lubricating Oil
Plumbing Line Sizes:
- Coolant Inlet and Outlet (pipe fitting)....½-14 NPTF
- Air Inlet (inside diameter)....¾ -14 NPTF
- Air Outlet (minimum inside diameter)....M26 x 1.5

Unloader Port....M10 x 1
Governor Mounting (direct)....M8 x 1.25
Height, Overall (approximate)....284mm [11.2 in]
Width, Overall (approximate)....154 mm [6.1 in]
Length, Overall (approximate)....164 mm [6.5 in]
Weight (approximate)....13.613 Kg [30.0 lb]

NOTE: In applications where duty cycles average 10 percent or more or air pressures are above 862 kPa [125 psi], use a discharge line with a minimum inside diameter of 15.9 mm [0.625 in] for single-cylinder compressors and 25.4 mm [1.00 in] for twin-cylinder compressors to prevent carbon buildup. Examples of these applications are as follows: refuse trucks, pickup and delivery trucks, transit buses, and equipment with high accessory air usage.

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Cummins®/Fleetguard® Filter Specifications

Specifications

Fleetguard® filters are manufactured by Cummins Filtration Inc., which is a subsidiary of Cummins Inc. Fleetguard® filters are developed through joint testing at Cummins Inc. and at Cummins Filtration Inc. Fleetguard® filters are standard on new Cummins® engines. Cummins Inc. recommends their use.

Fleetguard® products meet all Cummins Inc. Source Approval Test standards to provide the quality filtration necessary to achieve the engine's design life. If other brands are substituted, the purchaser **must** insist on products that the supplier has tested to meet Cummins Inc. high-quality standards.

Cummins Inc. can **not** be responsible for problems caused by non-genuine filters that do **not** meet Cummins Inc. performance or durability requirements.

Filter Type	
QSG12 CM2350 G110	
Lubricating Oil Filter	
Cummins® Part Number	3889310
Fleetguard® Part Number	LF670
Suction Fuel Filter	
Fleetguard® Part Number	FS19763(1) (Industrial Pro, StratoPore™ media) FS53015(1) (Short Industrial Pro, NanoNet™ media)
Spin-On Pressure Fuel Filter (on-engine fuel filter option)	
Cummins® Part Number	3697844(2)
Fleetguard® Part Number	FF63028(2)
Spin-On Pressure Fuel Filter (with remote fuel filter option)	
Cummins® Part Number	3689131(2)
Fleetguard® Part Number	FF63010(2)
Air Filter (Primary) - DF1800 Series Air Filter Housing	
Cummins® Part Number	5261249
Fleetguard® Part Number	AF55014
Air Filter (Secondary) - DF1800 Series Air Filter Housing	
Cummins® Part Number	5261251
Fleetguard® Part Number	AF55308
Air Filter (Primary) - DF2100 Series Air Filter Housing	
Cummins® Part Number	3688918
Fleetguard® Part Number	AF55024
Air Filter (Secondary) - DF2100 Series Air Filter Housing	
Cummins® Part Number	3688919
Fleetguard® Part Number	AF55318
Diesel Exhaust Fluid Filter	
Cummins® Part Number	5312352

1 An equivalent suction fuel filter can be used, but it **must** meet or exceed the following characteristics:

- Remove a minimum of 95 percent of free and emulsified water
- NanoNet™ media or equivalent with Beta Ratio (filtration efficiency) rating of ß4(C)=75, or equivalent, is recommended in order to extend fuel filter service intervals, but a minimum of 7-micron rating at 98.7 percent efficiency is required
- Water-in-fuel sensor with shunt resistor
- Water-in-fuel drain valve
- See equipment manufacturer service infomation for more information on the suction side fuel filter.

2 An equivalent pressure fuel filter can be used, but it **must** meet or exceed the following characteristics:

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- Beta Ratio (filtration efficiency) rating of $ß_{4(C)}$=200

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Diesel Exhaust Fluid Recommendations and Specifications

General Information

⚠WARNING⚠

It is unlawful to tamper with or remove any component of the aftertreatment system. It is also unlawful to use a Diesel Exhaust Fluid (DEF) that does not meet the specifications provided or to operate the vehicle/ equipment with no Diesel Exhaust Fluid (DEF).

⚠WARNING⚠

Diesel Exhaust Fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow internally. In the event the diesel exhaust fluid is ingested, contact a physician immediately. Reference the Materials Safety Data Sheet (MSDS) for additional information.

⚠CAUTION⚠

Never attempt to create Diesel Exhaust Fluid by mixing agricultural grade urea with water. Agricultural grade urea does not meet the necessary specifications required and the aftertreatment system may be damaged.

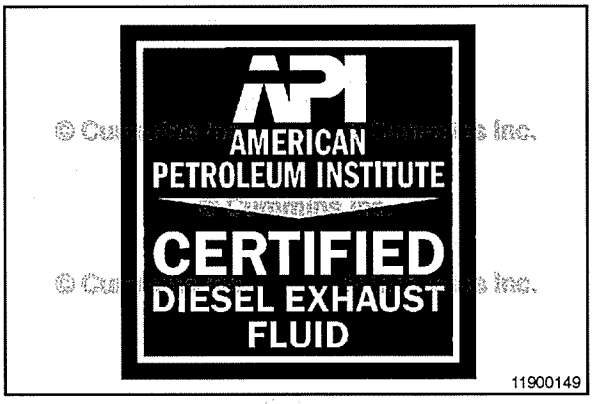
Cummins Inc. requires the use of Diesel Exhaust Fluid meeting ISO 22241-1. There is NO acceptable substitute.

NOTE: Some locations may reference the DIN 70070 standard. Diesel Exhaust Fluid specification limits of this standard are identical to ISO 22241-1.

Cummins Inc. is not responsible for failures or damage resulting from what Cummins Inc. determines to be abuse or neglect, including but not limited to: operation without correctly specified Diesel Exhaust Fluid; lack of maintenance of aftertreatment; improper storage, or shutdown practices; unauthorized modifications of the engine and aftertreatment. Cummins is also not responsible for failures caused by incorrect Diesel Exhaust Fluid or by water, dirt or other contaminants in the Diesel Exhaust Fluid

For further details and discussion of Diesel Exhaust Fluid (DEF) for Cummins® engines. Refer to the Diesel Exhaust Fluid Specifications for Cummins® Selective Catalytic Reduction Systems, Service Bulletin Number 4021566.

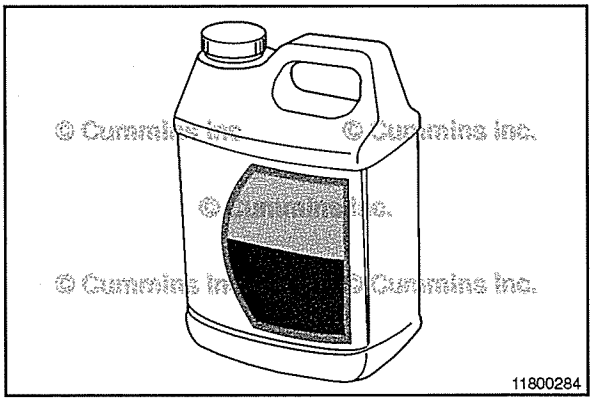
For engines using SCR operating in the United States and Canada, it is also strongly recommended that the Diesel Exhaust Fluid (DEF) used be certified by the American Petroleum Institute (API). This would be indicated by a symbol on the container/dispensing system as shown.



To ensure the correct Diesel Exhaust Fluid (DEF) is used, Cummins Inc. recommends the use of Fleetguard® Diesel Exhaust Fluid. Fleetguard® carries different quantity options from small to bulk containers.

For customers located in the United States and Canada, for assistance locating Diesel Exhaust Fluid (DEF), contact the Cummins Customer Assistance Center: 1-800 DIESELS (1-800-343-7357).

For customers outside of the United States and Canada, contact you local Cummins authorized repair location for assistance in locating Diesel Exhaust Fluid (DEF).



The following are other common names used for Diesel Exhaust Fluid (DEF):

- Urea
- AUS 32 (Aqueous Urea Solution 32)
- AdBlue
- NOx Reduction Agent
- Catalyst Solution
- DEF

Regardless of what the Diesel Exhaust Fluid is called, the Diesel Exhaust Fluid must meet the specifications as outlined in the General Information section of this procedure.

Storage

NOTE: The following information is for reference and is to be used as a guideline only. There are many factors that determine Diesel Exhaust Fluid (DEF) shelf life, with temperature and duration being two of the major determining contributors. If in doubt, check the concentration of the Diesel Exhaust Fluid (DEF), refer to the Test step of this procedure, or replace the fluid with known quality Diesel Exhaust Fluid.

Diesel Exhaust Fluid has a limited shelf life, both in the vehicle's diesel exhaust fluid tank and in storage/bulk/ transportation containers.

The following conditions are ideal for maintaining DEF quality and shelf life during prolonged transportation and storage:

- Storage temperature between 23°F and 77°F (-5°C and 25°C)
- Store in sealed containers to avoid contamination
- Avoid direct sunlight

In these conditions, DEF has a minimum expected shelf life of 18 months. If stored at higher temperatures for extended periods of time, the shelf life will be reduced by approximately 6 months for every 5°C [9°F] above the highest storage temperature listed above.

Long term storage in a vehicle (in excess of 6 months) is not recommended. If long term storage is necessary, periodic testing of the Diesel Exhaust Fluid is recommended to be performed to ensure the concentration does not fall out of specification. Follow the Test step of this procedure.

NOTE: To assist in preventing Diesel Exhaust Fluid from deteriorating when stored in the vehicles DEF tank, locate and plug the tanks venting to seal the tank exposure to the atmosphere.

Handling

Diesel Exhaust Fluid is not harmful to handle, but can be corrosive to certain materials over time. Such as carbon steels, iron, zinc, nickel, copper, aluminum and magnesium.

- Make sure to only use approved containers to transport and store Diesel Exhaust Fluid. Containers made of polyethylene and polypropylene are recommended.
- If Diesel Exhaust Fluid is spilled, rinse and clean immediately with water.
- Avoid prolonged contact with skin. In case of contact, wash with immediately with soap and water. If not washed immediately, when the diesel exhaust fluid dries, a white film will be left that can be more difficult to wash off.

NOTE: Spilled Diesel Exhaust Fluid if left to dry or wiped away with a cloth only will leave a white residue. Failure to clean the spilled Diesel Exhaust Fluid may result in an incorrectly diagnosed leak of the Diesel Exhaust Fluid Dosing system.

Before using containers, funnels, etc. that will be used to dispense, handle or store Diesel Exhaust Fluid, make sure to wash thoroughly to remove any contaminants and then rinse with distilled water.

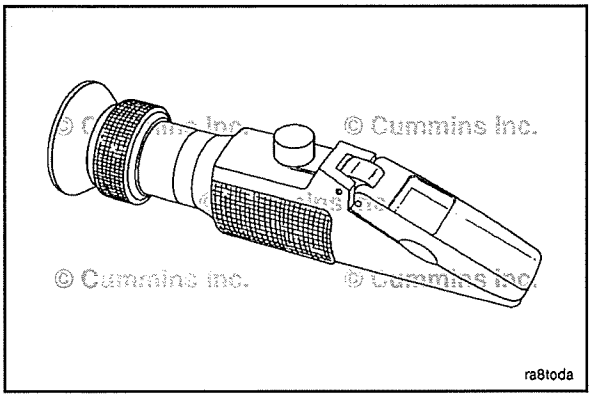
NOTE: Do not use tap water to rinse components that will be used to deliver diesel exhaust fluid. Tap water will contaminate the Diesel Exhaust Fluid. If distilled water is not available, rinse with tap water and then rinse with Diesel Exhaust Fluid.

Disposal

If disposing of Diesel Exhaust Fluid (DEF), always check with the local authority regulations on proper disposing process and requirements.

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Test



Having the correct concentration of Diesel Exhaust Fluid is critical to the engine and aftertreatment system performing correctly.

To test the concentration of the Diesel Exhaust Fluid, use the Cummins Diesel Exhaust Fluid Refractometer, service tool part number 4919554. Follow the instructions provided with the service tool.

Percent Urea Concentration: 32.5 +/- 1.5%

The specification listed above takes into consideration the refractometer tool tolerances, varibility, and calibration when measuring Diesel Exhaust Fluid concentration.

If the Diesel Exhaust Fluid concentration is found to be outside of this specification, drain the Diesel Exhaust Fluid tank, flush with distilled water and fill with new and/or known good Diesel Exhaust Fluid. Recheck the Diesel Exhaust Fluid concentration.

Concentration of the Diesel Exhaust Fluid should be checked when:

- The vehicle has been stored for an extended period of time.
- It is suspected that water has been added to the Diesel Exhaust Fluid tank

Contamination/Incorrect Fluid

⚠CAUTION⚠

Never add water or any other fluid besides what is specified to the Diesel Exhaust Fluid (DEF) tank. The aftertreatment system may be damaged.

In the event that the incorrect fluid is added to the Diesel Exhaust Fluid tank, such as, but not limited to:

- Water
- Diesel Fuel
- Hydraulic Fluid
- Coolant
- Windshield Washer Fluid

Contact a local Cummins Authorized Repair location to determine the appropriate repair direction.

If only water has been added to the Diesel Exhaust Fluid (DEF) tank, drain the Diesel Exhaust Fluid (DEF) tank, flush with distilled water and refill with new and/or known good Diesel Exhaust Fluid (DEF). Check the Diesel Exhaust Fluid (DEF) concentration after completing the refill, follow to the Test step of this procedure.

Freezing

⚠CAUTION⚠

Do NOT add any chemicals/additives to the Diesel Exhaust Fluid in an effort to prevent freezing. If chemicals/ additives are added to the Diesel Exhaust Fluid, the aftertreatment system may be damaged.

Diesel Exhaust Fluid will freeze around -11°C [12°F]. The diesel exhaust fluid system on the vehicle is designed to accommodate this and does not require any intervention by the vehicle operator.

The Operating the Engine (101-015) procedure in Section 1 of the Owners and Operation and Maintenance Manual will provide information on proper cold weather set up for your engine/vehicle.

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Fuel Recommendations and Specifications

Fuel Recommendations

⚠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.

⚠WARNING⚠

Do not mix gasoline, alcohol, or gasohol with diesel fuel. This mixture can result in an explosion.

△CAUTION△

Due to the precise tolerances of diesel injection systems, it is extremely important that the fuel be kept clean and free of dirt or water. Dirt or water in the system can cause severe damage to both the fuel pump and the fuel injectors.

△CAUTION△

Do not use diesel fuel blended with lubricating oil in engines equipped with an aftertreatment device. Service intervals for aftertreatment devices will be reduced.

△CAUTION△

Lighter fuels can reduce fuel economy or possibly damage fuel system components.

△CAUTION△

Ultra-low sulfur diesel fuel is required for correct operation of the aftertreatment system.

Cummins Inc. recommends the use of American Society of Testing and Materials (ASTM) number 2D fuel. The use of number 2D diesel fuel will result in optimum engine performance.

The engine has been optimized for use with an exhaust aftertreatment to meet the Tier 4 Final/Stage IV off-highway emissions regulations. It **must** operate on ultra-low sulfur diesel (ULSD) with a maximum sulfur content of 15 ppm in the United States and 10 ppm in the European Union. Failure to do so can permanently damage engine and aftertreatment systems within a short period of time. This damage could cause the engine to become inoperable and affect the warranty coverage on the engine.

Ultra-low sulfur diesel fuel, also defined by ASTM S-15, is defined as diesel fuel **not** exceeding 0.0015 (15 ppm) mass percent sulfur content. There is no acceptable substitute.

At operating temperatures below 0°C [32°F], acceptable performance can be obtained by using blends of number 2D and number 1D.

The following chart lists acceptable types of fuels for this engine.

Acceptable Types of Fuels									
Number 1D Diesel(1) (2)	Number 2D Diesel(2)	Number 1K Kerosene	Jet-A	Jet-A1	JP-5	JP-8	Jet-B	JP-4	CITE
OK	OK	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
48-34(3)	40-24(3)	50-35(3)	51-37(3)	51-37(3)	48-36(3)	51-37(3)	57-45(3)	57-45(3)	57-45(3)

1 Any adjustment to compensate for reduced performance with a fuel system using alternate fuel is **not** warrantable.

2 Winter blend fuels, such as found at commercial fuel dispensing outlets, are combinations of number 1D and number 2D diesel fuel and are acceptable.

3 BTU Content/Degree API Gravity - Low American Petroleum Institute (API) gravity fuels have a higher thermal energy content (BTU). As a general rule, there is a 3 to 5 percent decrease in BTU content for every 10 degree increase in API gravity, there is also a 0.7 degree API gravity increase with an increase in fuel temperature. This decrease in energy content equates roughly to the same percentage of power loss. Use of fuels with higher API gravity will cause higher than normal fuel consumption.

NOTE: Cummins Inc. recommends that the cetane number of diesel fuel be a minimum of 45 for engines that are expected to operate at temperatures below 0°C [32°F] and a minimum of 42 for engines that are operated at temperatures above 0°C [32°F].

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NOTE: Using diesel fuel with a lower than recommended cetane number can cause hard starting, instability, and excessive white smoke. To maintain satisfactory operation at low ambient temperatures, it is important to specify diesel fuel of the correct cetane number.

NOTE: Cummins Inc. requires all permissible fuels to have adequate fuel lubricity. Lubricity can be measured by ASTM, specification D6079, ISO 12156, High Frequency Reciprocating Rig (HFRR) in which the fuel **must** have a wear scar diameter of 0.52 mm [0.02 in] or less.

The equipment original equipment manufacturer (OEM) is required to display readily visible labels on the dashboard (or instrument panel) and near all fuel fill inlets that state "Use Ultra Low-Sulfur Diesel Fuel **Only**" or "Ultra Low-Sulfur Diesel Fuel **Only**".

ULSD/Biodiesel blends up to B20 (20 percent biodiesel) supplied by a BQ9000 certified supplier are acceptable.

For information on alternative fuels, such as biodiesel, and additional information for fuel recommendations and specifications, see the latest revision of Fuels for Cummins® Engines Service Bulletin, Bulletin 3379001. See ordering information in Section L.

Fuel Recommended Properties	
Cummins Inc. recommends the use of fuels that meet the following specifications:	
Property	Recommended Specifications
Viscosity (ASTM D445)	1.3 to 4.1 centistokes [1.3 to 4.1 mm per second] at 40°C [104°F].
Cetane Number (ASTM D613)	40 minimum above 0°C [32°F]. 45 minimum below 0°C [32°F].
Sulfur Content (ASTM D129 or D1552)	**Not** to exceed 0.05 mass percent for engines without aftertreatment devices. For engines with aftertreatment devices, sulfur content can **not** exceed 0.0015 (15 ppm) mass percent.
Active Sulfur (ASTM D130)	Copper strip corrosion **not** to exceed number 3 rating after three hours at 50°C [122°F].
Water and Sediment (ASTM D1796)	**Not** to exceed 0.05 volume percent.
Carbon Residue (Rams bottom, ASTM D524 or Conradson, ASTM D189)	**Not** to exceed 0.35 mass percent on 10 volume percent residuum.
Density (ASTM D287)	42 to 30° API gravity at 0.816 to 0.876 g/cc at 15°C [60°F].
Cloud Point (ASTM D97)	6°C [10°F] below lowest ambient temperature at which the fuel is expected to operate.
Ash (ASTM D482)	**Not** to exceed 0.02 mass percent (0.05 mass percent with lubricating oil blending). Oil blending is prohibited on engines with aftertreatment devices.
Distillation (ASTM D86)	The distillation curve **must** be smooth and continuous.
Acid Number (ASTM D664)	**Not** to exceed 0.1 mg KOA per 100 ml.

1 In addition to the requirements in the Fuel Recommended Properties table, Cummins Inc. strongly recommends the use of fuel with particle counts less than the ISO 4406 code of 18/16/13. Refer to the "Fuel Cleanliness" section of the Fuels For Cummins® Engines, Bulletin 3379001 for more details.

2 For additional information on fuel recommendations and specifications, refer to Fuels for Cummins® Engines, Bulletin 3379001,. See ordering information in Section L.

Fuel Cleanliness

This section explains the importance of fuel cleanliness to the successful operation of Cummins® Engines.

Modern fuel systems have been developed to improve combustion performance and fuel consumption, and improve engine performance. These high-pressure fuel systems operate at pressures approaching 2600 bar [37,700 psi], and with component match clearances typically from 2- to 5-microns for injectors. At these pressures, very small, hard particles are potential sources of a fuel system malfunction.

Excessive contamination of diesel fuel can cause premature clogging of diesel fuel filters and/or premature wear of critical fuel injection system parts. Depending on the size and nature of the particles, this can lead to:

- reduced component life
- component malfunction
- fuel system and/or engine malfunction.

Determining fuel cleanliness requires measuring both the size and number of particles per size class in the fuel, i.e. the particle size distribution. The International Standards Organization (ISO) has developed a protocol for expressing

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the level of contamination by coding the size distribution called ISO 4406. ISO 4406 cleanliness codes are expressed as a series of three numbers (x/x/x), which correspond respectively to the number of particles greater than 4-, 6-, and 14-microns. For example, the numbers in the ISO 4406 rating of 18/16/13 translate to:

- 18 - Up to 2500 particles larger than 4µm (per mL of fuel)
- 16 - Up to 640 particles larger than 6µm (per mL of fuel)
- 13 - Up to 80 particles larger than 14µm (per mL of fuel).

ISO 4406		
ISO Code	Number of Particles per mL	
	More Than	Up to and Including
24	80,000	160,000
23	40,000	80,000
22	20,000	40,000
21	10,000	20,000
20	5000	10,000
19	2500	5000
18	1300	2500
17	640	1300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	0.64	1.3
6	0.32	0.64
5	0.16	0.32
4	0.08	0.16
3	0.04	0.08
2	0.02	0.04
1	0.01	0.02
0	0.005	0.01
00	0.0025	0.005

Engine builders and fuel injection equipment manufacturers have found that the particles greater than 4-microns and greater than 6-microns are particularly critical to the durability of the fuel injection system. They also recognize that the fuel systems **must** tolerate hard particles smaller than 4-microns that are difficult to filter out, even with the finest filtration. To maximize the efficiency and effectiveness of filtration, Cummins Inc. has adopted the recommendation of the World Wide Fuel Charter that fuel supplied to engines meet the ISO 4406 code of 18/16/13 maximum for respectively 4-, 6-, and 14-micron particle sizes.

Cummins Inc. recommends that if the fuel does **not** meet the ISO cleanliness code of 18/16/13 when supplied to the engine, additional filtration be applied before the fuel is delivered to the equipment's fuel tank. A Cummins® Distributor or Cummins Filtration™ representative can supply hardware and additional filtration guidance and can recommend countermeasures such as improved fuel quality from the fuel supplier, and/or better fuel handling, storage, dispensing, and fuel tank cleaning techniques.

Tank Vent Filtration

Particles in the 4- to 6-micron size range require laboratory equipment to identify, yet can do significant damage to high-pressure fuel systems when the cleanliness of the fuel in the tank exceeds the ISO 4406 code 18/16/13 maximum. Cummins Inc. requires that fuel tanks for QSG12 CM2350 G110 engines be fitted with a tank vent filter of

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at least 98.7 percent efficiency at 10-micron (3-micron is recommended) to prevent dirt from entering the tank as the fuel level drops.

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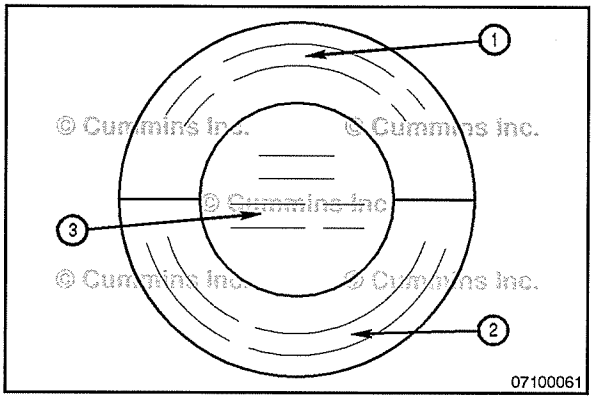
Lubricating Oil Recommendations and Specifications

General Information

- The use of quality engine lubricating oils, combined with appropriate oil drain and lubricating oil filter change intevals, is a critical factor in maintaining engine performance and durability.
- Cummins Inc. recommends the use of a high quality 5W30, 10W30, or 15W40 multiviscosity heavy duty engine lubricating oil that meets the requirements of Cummins® Engineering Specification (CES) 20081 (such as Valvoline™ Premium Blue™ or Valvoline™ Premium Blue Extreme™).
- Shortened drain intervals can be required with monograde oils, as determined by close monitoring of the oil condition with scheduled oil sampling. Use of single grade oils can affect engine oil control.
- Synthetic engine oils, American Petroleum Institute (API) Group III and Group IV basestocks, are recommended for use in Cummins® engines operating in ambient temperature conditions consistently below -25°C [-13°F]. Above this temperature, petroleum-based multigrade lubricants are recommended. Synthetic 0W-30 oils that meet API Group III and Group IV basestocks can be used in operations where the ambient temperature **never** exceeds 0°C [32°F]. 0W-30 oils do **not** offer the same level of protection against fuel dilution as do higher multigrade oils. Higher cylinder wear can be experienced when using 0W-30 oils in high-load situations.

For further details and an explanation of engine lubricating oils for Cummins® engines, see Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.

Additional information regarding lubricating oil availability throughout the world is available in the Engine Manufacturing Association (EMA) Lubricating Oils Data Book for Heavy Duty Automotive and Industrial Engines. This data book can be ordered from: Engine Manufacturers Association, Two North LaSalle Street, Suite 2200, Chicago, IL 60602; Phone: (312) 827-8700, Facsimile: (312) 827-8737 (www.enginemanufacturers.org).

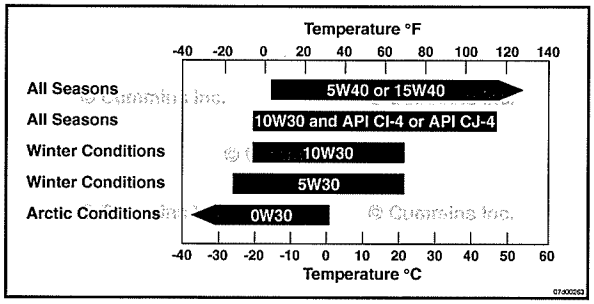


The API service symbols are shown in the accompanying illustration.

1 The upper half of the symbols display the appropriate oil categories.

2 The lower half contains additional oil information.

3 The center section identifies the SAE oil viscosity grade.



Oil viscosity **must** be chosen according to the typical climate conditions experienced by the user. Use of 15W-40 is recommended for the best engine durability at higher ambient temperatures. For cold conditions, 10W-30 or 5W-30 viscosity can be used for easier starting, improved oil flow, and improved fuel economy.

AfterMarket Oil Additive Usage

Cummins Inc. does **not** recommend the use of aftermarket oil additives. Present high-quality fully additive engine lubricating oils are very sophisticated, with precise amounts of additives blended into the lubricating oil to meet stringent requirements defined in CES 20081 that is similar to API CJ-4.

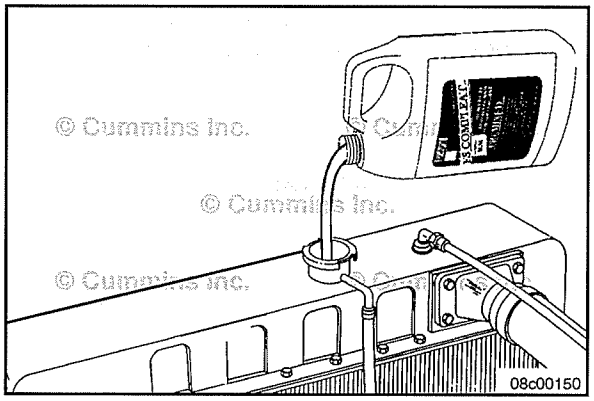
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These furnished oils meet performance characteristics that conform to the lubricant industry standards. Aftermarket lubricating oil additives are **not** necessary to enhance engine oil performance, and in some cases they can reduce the finished oil's ability to protect the engine.

New Engine Break-in Oils

Special "break-in" engine lubricating oils are **not** recommended for new or rebuilt Cummins® engines. Use the same lubricating oil that will be used during normal operation.

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Coolant Recommendations and Specifications

Fully Formulated Coolant/Antifreeze

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

NOTE: Low-silicate antifreeze meeting ASTM D4985 is inadequate for these extended service intervals of 80,467 to 241,402 km [50,000 to 150,000 miles].

Cummins Inc. recommends using either a 50/50 mixture of good-quality water and fully formulated antifreeze, or fully formulated coolant when filling the cooling system. The fully formulated antifreeze or coolant **must** meet CES14603 specifications.

Most coolants which meet ASTM D6210 also meet CES14603. However, some OAT coolants such as Shell Rotella™ ELC, Chevron Texaco Delo™ ELC, and their private label counterparts meet ASTM D6210 but do **not** meet the elastomer compatibility test of CES14603. These coolants are acceptable for use assuming the OEM added silicate at initial fill. Refer to Service Bulletin, Cummins® Coolant Requirements and Maintenance, Bulletin 3666132 for more details.

Most coolants which meet ASTM D6210 also meet CES14603. However, some OAT coolants such as Shell Rotella™ ELC, Chevron Texaco Delo™ ELC, and their private label counterparts meet ASTM D6210 but do **not** meet the elastomer compatibility test of CES14603. These coolants are acceptable for use assuming the OEM added silicate at initial fill. Refer to Service Bulletin, Cummins® Coolant Requirements and Maintenance, Bulletin 3666132 for more details.

Good-quality water is important for cooling system performance. Excessive levels of calcium and magnesium contribute to scaling problems, and excessive levels of chlorides and sulfates cause cooling system corrosion.

Water Quality	
Calcium Magnesium (Hardness)	Maximum 170 ppm as ($CaCO_3$ + $MgCO_3$)
Chloride	40 ppm as (Cl)
Sulfate	100 ppm as (SO_4)

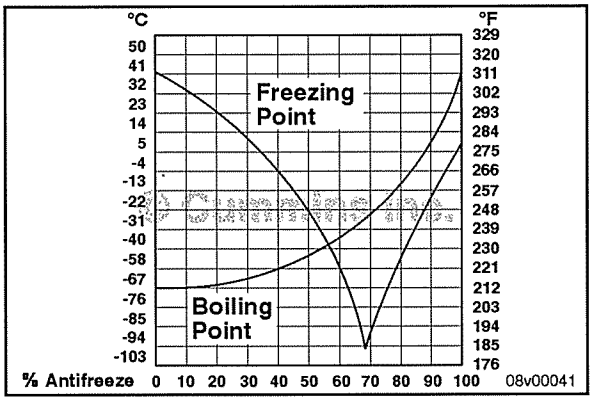
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Cummins Inc. recommends use of Fleetguard® COMPLEAT ES™. It is fully formulated and meets or exceeds the following standards:

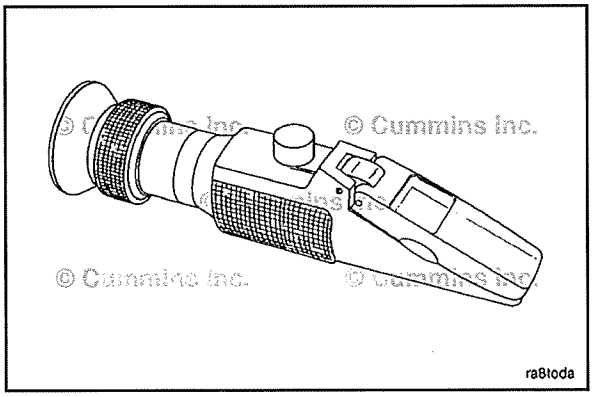
- CES14603
- ASTM D6210
- TMC RP329
- TMC RP330.



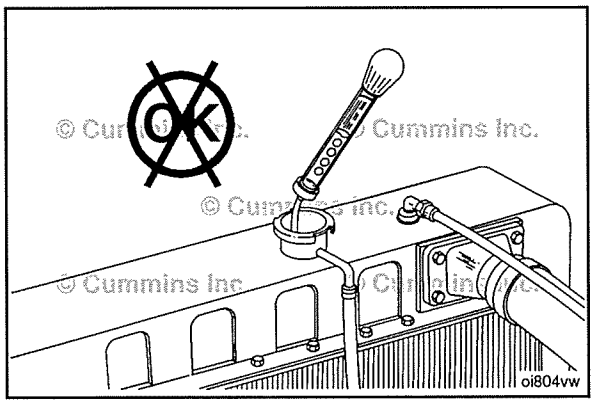
Fully formulated antifreeze **must** be mixed with quality water at a 50/50 ratio (40-percent to 60-percent working range). A 50/50 mixture of antifreeze and water gives a -36°C [-33°F] freezing point and a 110°C [230°F] boiling point, which is adequate for locations in North America. The actual lowest freezing point of ethylene glycol antifreeze is 68 percent. Using higher concentrations of antifreeze will raise the freezing point of the solution and increase the possibility of a silica gel problem.

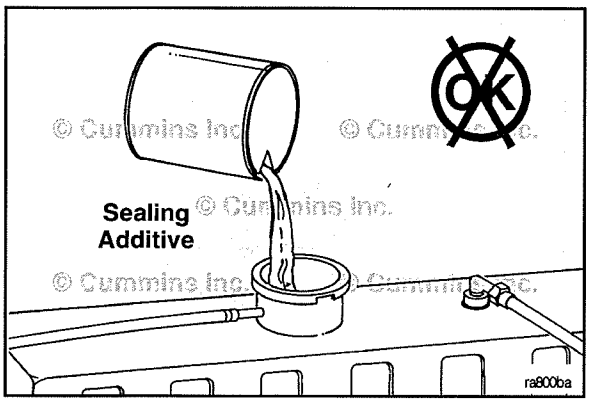


A refractometer **must** be used to measure the freezing point of the coolant **accurately**.



Do **not** use a floating ball hydrometer. Using a floating ball hydrometer can give an incorrect reading.

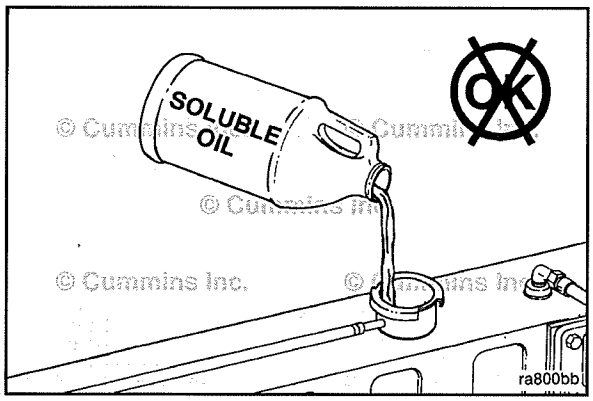




Cooling System Sealing Additives

Do **not** use sealing additives in the cooling systems. The use of sealing additives can:

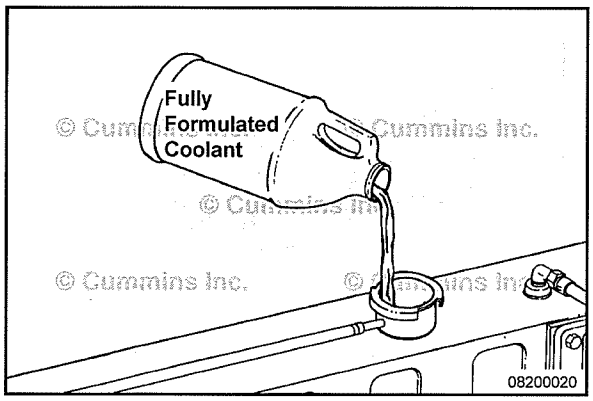
- Build up in coolant low-flow areas
- Clog coolant filters
- Plug radiator and oil cooler.



Cooling System Soluble Oils

Do **not** use soluble oils in the cooling system. The use of soluble oils can:

- Allow cylinder liner pitting
- Corrode brass, aluminum, and copper
- Damage heat transfer surfaces
- Damage seals and hoses.



Supplemental Coolant Additive (SCA)

⚠CAUTION⚠
The engines use aluminum parts that are in contact with the coolant. Improper coolant, coolant filter selection, and maintenance will likely result in perforation of one of these parts. Insufficient concentration of the coolant additives will result in liner pitting and engine failure.

Fully formulated products contain SCAs and are required to protect the cooling system from scale and fouling, solder corrosion, and general corrosion. The coolant filter is required to protect the cooling system from abrasive materials, debris, and precipitated coolant additives.

Fleetguard® DCA4 Service Filters and Liquid Precharge

Coolant Filter Options for Standard Service or Extended Service Intervals:

NOTE: Filters **must** meet Cummins Inc. SAM 10769. Fleetguard® filters meet Cummins Inc. SAM 10769. For systems larger than 416 liters [100 gal], use 1 liter [1 qt] of SCA per 57 liters [15 gal]. Consult the vehicle manufacturer for total cooling system capacity.

WF2121 - This filter is an extended service filter option. This filter designed for use with the Fleetguard® extended service cooling system, which extends cooling system service to 1 year, 401,402 km [150,000 miles], or 4000 hours, whichever comes first. This filter is used for cooling systems up to 76 liters [20 gal]. Fully formulated coolant meeting CES14603 or ASTM D6210 **must** be used for all fill and top-off, which is critical for extended cooling system maintenance intervals.

WF2122 - This filter is for standard service or extended service intervals. This filter has been designed for extended service interval of 80,467 to 241,402 km [50,000 to 150,000 miles]. It has no chemical additives and can be used in the following systems:

- Cooling systems above 76 liters [20 gal] in capacity.

- See maintenance chart in this procedure.

When using WF2122 filter, the following volumes of treatment **must** be added at the designated mileages:

Cooling System Capacity	**50,000-Mile - Standard service interval with fully formulated standard service coolant. Use standard SCA such as Fleetguard® DCA2 or DCA4**	**150,000-Mile - Extended service interval with fully formulated extended service coolant. Use extender SCA such as Fleetguard® ES extender liquid. DCA4 can also be used.**
0 to 76 liters [0 to 20 gal]	1 liter [1 qt] (10 units)	1 liter [1 qt] (15 units)
76 to 151 liters [20 to 40 gal]	1.9 liter [2 qt] (20 units)	1.9 liter [2 qt] (30 units)
151 to 227 liters [40 to 60 gal]	2.8 liters [3 qt] (30 units)	2.8 liters [3 qt] (45 units)
227 to 303 liters [60 to 80 gal]	3.8 liters [4 qt] (40 units)	3.8 liters [4 qt] (60 units)
303 to 379 liters [80 to 100 gal]	4.7 liters [5 qt] (50 units	4.7 liters [5 qt] (75 units)

Testing SCA Concentration Level CC-2602 Test Kit

Precautions and Instructions for Proper Kit Use

Carefully follow the instructions to test the coolant. Take the appropriate action recommended by the kit.

- The coolant sample to be tested **must** be between 10 and 54°C [50 and 130°F]. If the sample is too cold or too hot, you will get incorrect results.
- To get the best color match results, compare test strip pads to the color chart in daylight or under cool white fluorescent lighting. If unsure about a specific color match when a test does fall between two colors on the color chart, choose the lower numbered (or lettered) block. It is safer to underestimate your results than to overestimate.
- The test strips do have a limited shelf life and are sensitive to humidity and extreme heat. Proper handling and storage is necessary to protect the life of the strips.
- Keep the cap tightly sealed on the test strip bottle **except** when removing a strip. Store away from direct sunlight and in an area where the temperature will generally stay below 32°C [90°F].
- Do **not** use the test strips after the expiration date stamped on the bottle.
- Discard the kit if the top pad on the unused strips have turned light brown.
- Use one strip at a time and take care **not** to touch any of the pads on the strip. Doing so will contaminate the pads and skew the test results.
- If the strip container is left uncapped for 24 hours, moisture in the air will render the strips useless, even though no discoloration will be evident.
- **Only** use the color chart supplied with the kit.
- Following the correct test times is very important. Use a clock or stopwatch.
- Do **not** utilize the test kit to maintain minimum SCA concentration levels (i.e., 1.5 units).
- When performing service that requires draining the cooling system, take special precautions to collect coolant in a clean non-galvanized container, seal coolant to prevent contamination, and save for reuse.

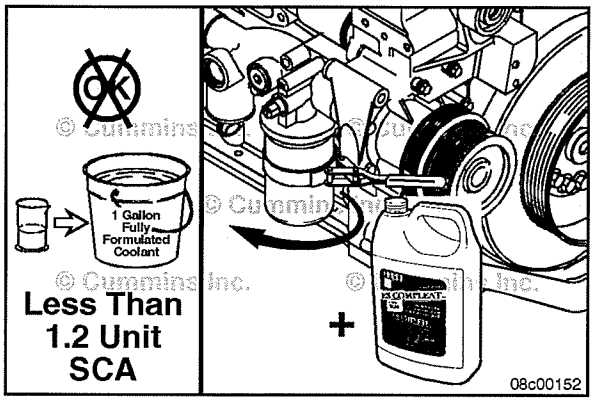
Probablizer:

- 3318169S Plug - Installs on the engine for easy coolant sampling
- 3318168S Cap - Use with Monitor C™ bottle to sample coolant
- CC2700 Monitor C™ - Use lab analysis of coolant samples for more detailed analysis.

CC2602 Coolant Test kit

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- Works with any SCA formulation. Call 1-800-22FILTER (800-223-4583) if you have this test kit and the color chart does **not** show the number of units of SCA gallon of coolant.



Test Intervals

⚠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.

Testing is recommended if the operator is **not** sure of his cooling system condition due to leaks, uncontrolled topping off of the system, or major coolant loss.

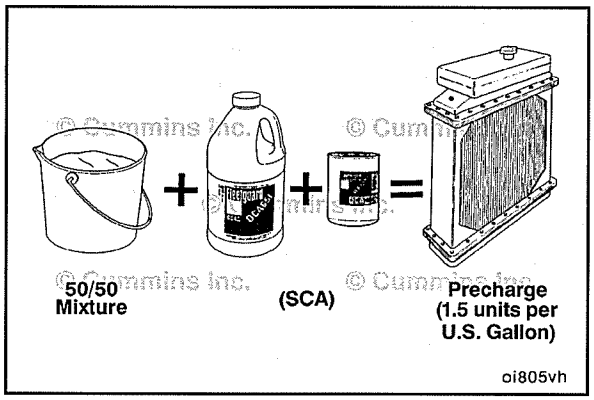
If the concentration is below 1.2 units per 3.8 liters [1gal], replace the filter and precharge with liquid.

Check the SCA concentration level at least every 6 months, and anytime the coolant condition is unknown or corrosion is apparent within the cooling system.

Use Fleetguard® coolant test kit, CC2602, to check the concentration level. Instructions are included with the test kit.

Call the following numbers to get answers to any questions you have about cooling system maintenance:

Cummins Inc.	Fleetguard®
1-800-DIESELS	1-800-22FILTER
1-800-343-7357	1-800-223-4583



Coolant Replacement Requirements

⚠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.

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

Drain and flush the cooling system after 6000 hours or 3 years of service. However, if Fleetguard® ES coolant and ES filters are used, check chloride, sulfate, and pH levels according to Service Bulletin, Coolant Requirements and Maintenance, Bulletin 3666132, to determine whether the coolant **must** be replaced. Refill with either new fully formulated coolant or ES coolant.

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Drive Belt Tension

Tension Chart

SAE Belt Size	Belt Tension Gauge Part No.		Belt Tension New		Belt Tension Range Used*	
	Click-type	Burroughs	N	lbf	N	lbf
0.380 in	3822524		620	140	270 to 490	60 to 110
0.440 in	3822524		620	140	270 to 490	60 to 110
1/2 in	3822524	ST-1138	620	140	270 to 490	60 to 110
11/16 in	3822524	ST-1138	620	140	270 to 490	60 to 110
3/4 in	3822524	ST-1138	620	140	270 to 490	60 to 110
7/8 in	3822524	ST-1138	620	140	270 to 490	60 to 110
4 rib	3822524	ST-1138	620	140	270 to 490	60 to 110
5 rib	3822524	ST-1138	670	150	270 to 530	60 to 120
6 rib	3822525	ST-1293	710	160	290 to 580	65 to 130
8 rib	3822525	ST-1293	890	200	360 to 710	80 to 160
10 rib	3822525	3823138	1110	250	440 to 890	100 to 200
12 rib	3822525	3823138	1330	300	530 to 1070	120 to 240
12 rib K section	3822525	3823138	1330	300	890 to 1070	200 to 240
31 rib	-	3164750	1668	375	1330 to 1560	300 to 350

NOTE: This chart does not apply to automatic belt tensioners.

* A belt is considered used if it has been in service for ten minutes or longer.

* If used belt tension is less than the minimum value, tighten the belt to the maximum used belt value.

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Capscrew Markings and Torque Values

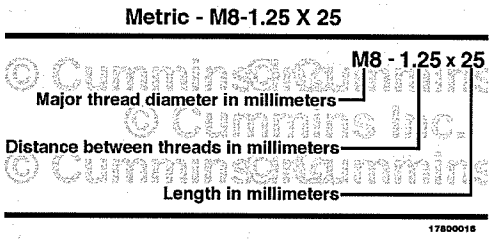
General Information

⚠CAUTION⚠

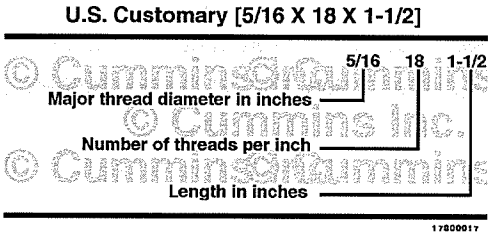
When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using the wrong capscrews can result in engine damage.

Metric capscrews and nuts are identified by the grade number stamped on the head of the capscrew or on the surface of the nuts. U.S. Customary capscrews are identified by radial lines stamped on the head of the capscrew.

The following examples indicate how capscrews are identified:



- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.



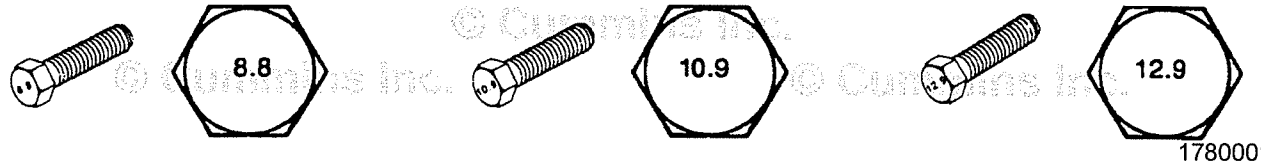
- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.

Capscrew Markings and Torque Values - Metric

Commercial Steel Class

8.8	10.9	12.9

Capscrew Head Markings



17800014

Capscrew Grade	8.8				10.9				12.9			
Material	Cast Iron		Aluminum		Cast Iron		Aluminum		Cast Iron		Aluminum	
Capscrew Body Diameter [mm]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]
6	9	5	7	4	13	10	7	4	14	9	7	4

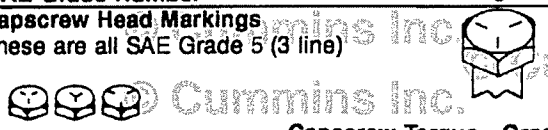
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Capscrew Grade	8.8				10.9				12.9			
Material	Cast Iron		Aluminum		Cast Iron		Aluminum		Cast Iron		Aluminum	
Capscrew Body Diameter [mm]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]
7	14	9	11	7	18	14	11	7	23	18	11	7
8	23	17	18	14	33	25	18	14	40	29	18	14
10	45	33	30	25	65	50	30	25	70	50	30	25
12	80	60	55	40	115	85	55	40	125	95	55	40
14	125	90	90	65	180	133	90	65	195	145	90	65
16	195	140	140	100	280	200	140	100	290	210	140	100
18	280	200	180	135	390	285	180	135	400	290	180	135
20	400	290	—	—	550	400	—	—	—	—	—	—

Capscrew Markings and Torque Values - U.S. Customary

SAE Grade Number 5 8

Capscrew Head Markings
These are all SAE Grade 5 (3 line)



17800015

Capscrew Torque - Grade 5 Capscrew

Capscrew Torque - Grade 8 Capscrew

Capscrew Grade	5				8			
Material	Cast Iron		Aluminum		Cast Iron		Aluminum	
Capscrew Body Diameter [in] and T.P.I.	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]
1/4 - 20	9	7	8	6	15	11	8	6
1/4 - 28	12	9	9	7	18	13	9	7
5/16 - 18	20	15	16	12	30	22	16	12
5/16 - 24	23	17	19	14	33	24	19	14
3/8 - 16	40	30	25	20	55	40	25	20
3/8 - 24	40	30	35	25	60	45	35	25
7/16 - 14	60	45	45	35	90	65	45	35
7/16 - 20	65	50	55	40	95	70	55	40
1/2 - 13	95	70	75	55	130	95	75	55
1/2 - 20	100	75	80	60	150	110	80	60
9/16 - 12	135	100	110	80	190	140	110	80
9/16 - 18	150	110	115	85	210	155	115	85
5/8 - 11	180	135	150	110	255	190	150	110
5/8 - 18	210	155	160	120	290	215	160	120
3/4 - 10	325	240	255	190	460	340	255	190
3/4 - 16	365	270	285	210	515	380	285	210
7/8 - 9	490	360	380	280	745	550	380	280
7/8 - 14	530	390	420	310	825	610	420	310

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Capscrew Grade	5				8			
Material	Cast Iron		Aluminum		Cast Iron		Aluminum	
Capscrew Body Diameter [in] and T.P.I.	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]	Torque [N•m]	Torque [ft-lb]
1 - 8	720	530	570	420	1100	820	570	420
1 - 14	800	590	650	480	1200	890	650	480

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Fraction, Decimal, Millimeter Conversions

Conversion Chart

Fraction	inch	mm	Fraction	inch	mm
1/64	0.0156	0.397	33/64	0.5156	13.097
1/32	0.0313	0.794	17/32	0.5313	13.494
3/64	0.0469	1.191	35/64	0.5469	13.891
1/16	0.0625	1.588	9/16	0.5625	14.288
5/64	0.0781	1.984	37/64	0.5781	14.684
3/32	0.0938	2.381	19/32	0.5938	15.081
7/64	0.1094	2.778	39/64	0.6094	15.478
1/8	0.1250	3.175	5/8	0.6250	15.875
9/64	0.1406	3.572	41/64	0.6406	16.272
5/32	0.1563	3.969	21/32	0.6563	16.669
11/64	0.1719	4.366	43/64	0.6719	17.066
3/16	0.1875	4.763	11/16	0.6875	17.463
13/64	0.2031	5.159	45/64	0.7031	17.859
7/32	0.2188	5.556	23/32	0.7188	18.256
15/64	0.2344	5.953	47/64	0.7344	18.653
1/4	0.2500	6.350	3/4	0.7500	19.050
17/64	0.2656	6.747	49/64	0.7656	19.447
9/32	0.2813	7.144	25/32	0.7813	19.844
19/64	0.2969	7.541	51/64	0.7969	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.3281	8.334	53/64	0.8281	21.034
11/32	0.3438	8.731	27/32	0.8438	21.431
23/64	0.3594	9.128	55/64	0.8594	21.828
3/8	0.3750	9.525	7/8	0.8750	22.225
25/64	0.3906	9.922	57/64	0.8906	22.622
13/32	0.4063	10.319	29/32	0.9063	23.019
27/64	0.4219	10.716	59/64	0.9219	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.4531	11.509	61/64	0.9531	24.209
15/32	0.4688	11.906	31/32	0.9688	24.606
31/64	0.4844	12.303	63/64	0.9844	25.003
1/2	0.5000	12.700	1	1.0000	25.400

Conversion Factor: 1 inch = 25.4 mm

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Newton-Meter to Foot-Pound Conversions

Conversion Chart

N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1	9 in-lb	55	41	155	114
5	44 in-lb	60	44	160	118
6	53 in-lb	65	48	165	122
7	62 in-lb	70	52	170	125
8	71 in-lb	75	55	175	129
9	80 in-lb	80	59	180	133
10	89 in-lb	85	63	185	136
11	97 in-lb	90	66	190	140
12	106 in-lb	95	70	195	144
14	124 in-lb	100	74	200	148
15	133 in-lb	105	77	205	151
16	142 in-lb	110	81	210	155
18	159 in-lb	115	85	215	159
20	15 ft-lb	120	89	220	162
25	18	125	92	225	165
30	22	130	96	230	170
35	26	135	100	235	173
40	30	140	103	240	177
45	33	145	107	245	180
50	37	150	111	250	184
NOTE: To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.					

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Pipe Plug Torque Values

Torque Table

Size		Torque		Torque	
Thread	Actual Thread O.D.	In Aluminum Components		In Cast Iron or Steel Components	
in	**in**	**N•m**	**ft-lb**	**N•m**	**ft-lb**
1/16	0.32	5	45 in-lb	15	10
1/8	0.41	15	10	20	15
1/4	0.54	20	15	25	20
3/8	0.68	25	20	35	25
1/2	0.85	35	25	55	40
3/4	1.05	45	35	75	55
1	1.32	60	45	95	70
1-1/4	1.66	75	55	115	85
1-1/2	1.90	85	65	135	100

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Tap-Drill Chart - U.S. Customary and Metric

General Information

NOTE ON SELECTING TAP-DRILL SIZES: The tap drill sizes shown on this card give the theoretical tap drill size for approximately 60% and 75% of full thread depth. Generally, it is recommended that drill sizes be selected in the 60% range as these sizes will provide about 90% of the potential holding power. Drill sizes in the 75% range are recommended for shallow hole tapping (less than 1 1/2 times the hole diameter) in soft metals and mild steel.

Tap Size		Drill Size
60%	75%	
		48
		1.95mm
		5/64
	3-48	47
		2.00mm
	M2.5x.45	2.05mm
		46
3-48	3056	45
		2.10mm
M2.5x.45	M2.6x.45	2.15mm
3-56	4-36	44
		2.20mm
M2.6x.45		2.25mm
4-36	4-40	43
		2.30mm
		2.35mm
4-40	4-48	42
		3/32
	M3x.6	2.40mm
4-48		41
		2.45mm
		40
M3x.6	M3x.5	2.50mm
		39
	5-40	38
M3x.5		2.60mm
5-40	5-44	37
		2.70mm
5-44	6-32	36
		2.75mm
		7/64
		35
		2.80mm
		34
6-32	6-40	33
	M3.5x6	2.90mm
		32
M3.5x6		3.00mm
6-40		31
		3.10mm
		1/8
		3.20mm
	M4x.75	3.25mm
		30
	M4x.7	3.30mm
M4x.75		3.40mm
M4x.7	8-32	29
		3.50mm
	8-36	28
8-32		9/64
		3.60mm
8-36		27
		3.70mm
		26
	M4.5x.75	3.75mm
	10-24	25
		3.80mm
		24
M4.5x.75		3.90mm
		23
		5/32
10-24		22
	M5x1	4.00mm
	10-32	21
		20
	M5x.9	4.10mm
M5x1	M5x.8	4.20mm
10-32		19
M5x.9		4.25mm
M5x.8		4.30mm
		18
		11/64
		17

Tap Size		Drill Size
60%	75%	
		4.40mm
	12-24	16
		4.50mm
		15
	M5.5x.9	4.60mm
12-24	12-28	14
		13
		4.70mm
M5.5x.9		4.75mm
12-28		3/16
		12
		4.80mm
		11
		4.90mm
		10
		9
	M6x1	5.00mm
		8
		5.10mm
	1/4-20	7
		13/64
		6
M6x1		5.20mm
		5
	M6x.75	5.25mm
		5.30mm
1/4-20		4
M6x.75		5.40mm
	1/4-28	3
		5.50mm
		7/32
		5.60mm
1/4-28		2
		5.70mm
		5.75mm
		1
		5.80mm
		5.90mm
		A
		15/64
	M7x1	6.00mm
		B
		6.10mm
		C
M7x1		6.20mm
		D
	M7x.75	6.25mm
		6.30mm
		E
		1/4
M7x.75		6.40mm
		6.50mm
	5/16-18	F
		6.60mm
		G
		6.70mm
		17/64
	M8x1.25	6.75mm
5/16-18		H
		6.80mm
		6.90mm
	5.16-24	I
M8x1.25	M8x1	7.00mm
		J
		7.10mm
5/16-24		K
		9/32
M8x1		7.20mm
		7.25mm
		7.30mm
		L
		7.40mm
		M

Tap Size		Drill Size
60%	75%	
		7.50mm
		19/64
		7.60mm
		N
		7.70mm
	M9x1.25	7.75mm
		7.80mm
		7.90mm
	3/8-16	5/16
M9x1.25	M9x1	8.00mm
		O
		8.10mm
M9x1		8.20mm
		P
		8.25mm
		8.30mm
3/8-16	1/8-27NPT	21/64
		8.40mm
	3/8-24	Q
	M10x1.5	8.50mm
		8.60mm
		R
3/8-24		8.70mm
1/8-27NPT		11/32
	M10x1.25	8.75mm
M10x1.5		8.80mm
		S
		8.90mm
M10x1.25	M10x1	9.00mm
		T
		9.10mm
		23/64
M10x1		9.20mm
		9.30mm
	7/16-14	U
		9.40mm
	M11x1.5	9.50mm
		3/8
		V
		9.60mm
		9.70mm
		9.75mm
M11x1.5		9.80mm
7/16-14		W
		9.90mm
	7/16-20	25/64
		10.00mm
7/16-20		X
	M12x1.75	10.20mm
		Y
		13/32
		Z
M12x1.75	M12x1.5	10.50mm
	1/2-13	27/64
M12x1.5	M12x1.25	10.75mm
M12x1.25		11.00mm
1/2-13		7/16
1/4-18NPT		
		11.25mm
		11.50mm
		29/64
		11.75mm
		11.50mm
	1/2-20	29/64
	9/16-12	15/32
	M14x2	12.00m
		12.25mm
9/16-12		31/64
M14x2	M14x1.5	12.50mm
	9/16-18	1/2
M14x1.5	M14x1.25	12.75mm
M14x1.25		13.00mm
9/16-18		33/64

Tap Size		Drill Size
60%	75%	
		13.25mm
	5/8-11	17/32
	M15x1.5	13.50mm
M15x1.5		13.75mm
5/8-11		35/64
	M16x2	14.00mm
		14.25mm
	5/8-18	9/16
M16x2	M16x1.5	14.50mm
5/8-18		37/64
		14.75mm
M16x1.5		15.00mm
		19.32
		15.25mm
		39/64
	M17x1.5	15.50mm
M17x1.5	M18x2.5	15.75mm
		5/8
M18x2.5	M18x2	16.00mm
M18x2		16.25mm
	3/4-10	41/64
	M18x1.5	16.50mm
3/4-10	M19x2.5	21/32
M18x1.5		16.75mm
M19x2.5		17.00mm
		43/64
		17.25mm
3/4-16	3/4-16	11/16
	M20x2.5	17.50mm
		17.75mm
		45/64
M20x2.5	M20x2	18.00mm
M20x2		18.25mm
		23/32
	M20x1.5	18.50mm
		47/64
M20x1.5		18.75mm
		19.00mm
		3/4
		19.25mm
	7/8-9	49/64
	M22x2.5	19.50mm
7/8-9		25/32
		19.75mm
M22x2.5	M22x2	20.00mm
	7/8-14	51/64
M22x2		20.25mm
	M22x1.5	20.50mm
7/8-14		13/16
		20.75mm
M22x1.5	M24x3	21.00mm
		53/64
		21/25mm
		27/32
M24x3		21.50mm
		21.75mm
		55/64
	M24x2	22.00mm
	1"-8	7/8
M24x2		22.25mm
	M24x1.5	22.50mm
1"-8		57/64
M24x1.5		22.75mm
	M25x2	23.00mm
	1"-12	29/32
M25x2		23.25mm
1"x12	1"-14	59/64
	M25x1.5	23.50mm
M20x1.5		23.75mm
1"-14		15/16

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Weights and Measures - Conversion Factors

Conversion Chart

Quantity	U.S. Customary		Metric		From U.S. Customary To Metric Multiply By	From Metric To U.S. Customary Multiply By
	Unit Name	Abbreviation	Unit Name	Abbreviation		
Area	sq. inch	in^2	sq. millimeters	mm^2	645.16	0.001550
			sq. centimeters	cm^2	6.452	0.155
	sq. foot	ft^2	sq. meter	m^2	0.0929	10.764
Fuel Consumption	pounds per horsepower hour	lb/hp-hr	grams per kilowatt hour	g/kW-hr	608.277	0.001645
Fuel Performance	miles per gallon	mpg	kilometers per liter	km/l	0.4251	2.352
	gallons per mile	gpm	liters per kilometer	l/km	2.352	0.4251
Force	pounds force	lbf	Newton	N	4.4482	0.224809
Length	inch	in	millimeters	mm	25.40	0.039370
	foot	ft	millimeters	mm	304.801	0.00328
Power	horsepower	hp	kilowatt	kW	0.746	1.341
Pressure	pounds force per sq. inch	psi	kilopascal	kPa	6.8948	0.145037
	inches of mercury	in Hg	kilopascal	kPa	3.3769	0.29613
	inches of water	in H_2O	kilopascal	kPa	0.2488	4.019299
	inches of mercury	in Hg	millimeters of mercury	mm Hg	25.40	0.039370
	inches of water	in H_2O	millimeters of water	mm H_2O	25.40	0.039370
	bars	bars	kilopascals	kPa	100.001	0.00999
	bars	bars	millimeters of mercury	mm Hg	750.06	0.001333
Temperature	fahrenheit	°F	centigrade	°C	(°F-32) ÷1.8	(1.8 x °C) +32
Torque	pound force per foot	ft-lb	Newton-meter	N•m	1.35582	0.737562
	pound force per inch	in-lb	Newton-meter	N•m	0.113	8.850756
Velocity	miles/hour	mph	kilometers/hour	kph	1.6093	0.6214
Volume: liquid displacement	gallon (U.S.)	gal.	liter	l	3.7853	0.264179
	gallon (Imp*)	gal.	liter	l	4.546	0.219976
	cubic inch	in^3	liter	l	0.01639	61.02545
	cubic inch	in^3	cubic centimeter	cm^3	16.387	0.06102
Weight (mass)	pounds (avoir.)	lb	kilograms	kg	0.4536	2.204623
Work	British Thermal Unit	BTU	joules	J	1054.5	0.000948
	British Thermal Unit	BTU	kilowatt-hour	kW-hr	0.000293	3414
	horsepower hours	hp-hr	kilowatt-hour	kW-hr	0.746	1.341

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Barometric Pressure at Altitude

Specifications

Barometric Pressure at Altitude					
Pressure				Altitude	
kPa	PSI	mm Hg	in Hg	m	ft.
103.2	14.96	773.9	30.47	-152	-500
101.3	14.69	760.0	29.92	0	0
99.5	14.43	746.3	29.38	152	500
97.7	14.17	733.0	28.86	305	1000
96.0	13.92	719.8	28.34	458	1500
94.2	13.66	706.6	27.82	610	2000
92.5	13.42	693.9	27.32	762	2500
90.8	13.17	681.2	26.82	914	3000
89.2	12.93	668.8	26.33	1067	3500
87.5	12.69	656.3	25.84	1219	4000
85.9	12.46	644.3	25.37	1372	4500
84.3	12.23	632.2	24.89	1524	5000
82.8	12.01	620.7	24.44	1677	5500
81.2	11.78	609.1	23.98	1829	6000
79.7	11.56	597.8	23.54	1982	6500
78.2	11.34	586.5	23.09	2134	7000
76.7	11.13	575.5	22.66	2286	7500
75.2	10.91	564.4	22.22	2438	8000
73.8	10.71	553.8	21.80	2591	8500
72.4	10.50	543.1	21.38	2743	9000
71.1	10.31	532.8	20.98	2896	9500
69.7	10.11	522.5	20.57	3048	10,000
67.1	9.73	502.8	19.80	3353	11,000
64.4	9.34	483.1	19.02	3658	12,000
62.0	8.99	464.7	18.30	3963	13,000
59.5	8.63	446.3	17.57	4267	14,000
57.2	8.30	429.0	16.89	4572	15,000
54.9	7.96	411.7	16.21	4877	16,000

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Section W - Warranty

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All Engines Worldwide Generator Drive

Engines Warranted

This Warranty applies to new Engines sold by Cummins and delivered to the first user on or after April 1, 1999, that are used in generator drive applications anywhere in the world where Cummins approved service is available. These Engines will have the following rating designations:

Standby Power Rating
Engines of this rating are applicable for supplying emergency power for the duration of the utility power outage. No overload capability is available for this rating. Under no condition is an Engine allowed to operate in parallel with the public utility at the Standby Power rating. This rating should be applied where reliable utility power is available. A Standby rated Engine is to be sized for a maximum of an 80 percent average load factor and 200 hours of operation per year. This includes less than 25 hours per year at the Standby Power rating. Standby rating should never be applied except in true emergency power outages. Negotiated power outages contracted with a utility company are not considered an emergency.

Unlimited Time Running Prime Power Rating
Engines with this rating are available for an unlimited number of hours per year in a variable load application. Variable load is not to exceed a 70 percent average of the Prime Power rating during any operating period of 250 hours. Total operating time at 100 percent Prime Power shall not exceed 500 hours per year.

A 10 percent overload capability is available for a period of one hour within a twelve hour period of operation. Total operating time at the 10 percent overload power shall not exceed 25 hours per year.

Limited Time Running Prime Power Rating
Engines of this rating are available for a limited number of hours in a non-variable load application. It is intended for use in situations where power outages are contracted, such as in utility power curtailment. Engines may be operated in parallel to the public utility up to 750 hours per year at power levels never to exceed the Prime Power rating.

Limited Time Running Prime Power ratings differ from Unlimited Time Running in that even though the maximum power output of the Engines is the same, the Limited Time Running allows the Engine to be parallel to the public utility and run at the full Prime Power rating and must never exceed the Prime Power rating.

Continuous/Base Power Rating
Engines with this rating are available for supplying utility power at a constant 100 percent load for an unlimited number of hours per year. No overload capability is available for this rating.

Continuous/Base Power ratings differ from Unlimited Time Running Prime Power ratings in that the Continuous/Base Load ratings are significantly reduced from the Prime Power ratings. Continuous/Base Load ratings have no load factor or application restrictions.

Coverage

Base Engine Warranty
This Warranty covers any failures of the Engine, under normal use and service, which result from a defect in material or factory workmanship (Warrantable Failure).

Coverage begins with the sale of the Engine by Cummins and continues for the Duration stated below. The Duration commences either on the date of delivery of the Engine to the first user, or on the date the Engine is first leased, rented or loaned, or when the Engine has been operated for 50 hours, whichever occurs first.

Base Engine Warranty

	Duration	
	Whichever Occurs First	
Rating	Months	Hours
Standby Power	24	400
Unlimited Prime Power	12	Unlimited
Limited Prime Power	12	750
Continuous/Base Power	12	Unlimited

Engine aftertreatment components included in the Cummins Critical Parts List (CPL) and marked with a Cummins part number are covered under Base Engine Warranty.

Additional Coverage is outlined in the Emission Warranty section.

Extended Major Components Warranty
The Extended Major Components Warranty covers Warrantable Failures of the Engine cylinder block, camshaft, crankshaft and connecting rods (Covered Parts). Bushing and bearing failures are not covered. This Coverage begins with the expiration of the Base Engine Warranty and continues for the following stated Duration. The Duration

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commences either on the date of delivery of the Engine to the first user, or on the date the Engine is first leased, rented or loaned, or when the Engine has been operated for 50 hours, whichever occurs first.

Extended Major Components Warranty

Rating	Duration Whichever Occurs First Months	Hours
Standby Power	36	600
Unlimited Prime Power	36	10,000
Limited Prime Power	36	2,250
Continuous/Base Power	36	10,000

Consumer Products

This Warranty on Consumer Products in the United States* is a LIMITED Warranty. **CUMMINS IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.** Any implied Warranties applicable to Consumer Products terminate concurrently with the expiration of the express Warranties applicable to the product. In the United States*, some states do not allow the exclusion of incidental or consequential damages, or limitations on how long an implied Warranty lasts, so the limitations or exclusions herein may not apply to you.

These Warranties are made to all Owners in the chain of distribution and Coverage continues to all subsequent Owners until the end of the periods of Coverage.

Cummins Responsibilities

During The Base Engine Warranty

Cummins will pay for all parts and labor needed to repair the damage to the Engine resulting from a Warrantable Failure when performed during normal business hours. All labor costs will be paid in accordance with Cummins published Standard Repair Time guidelines.

Alternators, starters and fans ARE covered for the duration of the Base Engine Warranty on B3.3 Engines.

Cummins will pay for the lubricating oil, antifreeze, filter elements and other maintenance items that are not reusable due to the Warrantable Failure.

Cummins will pay reasonable travel expenses for mechanics to travel to and from the Engine site, including meals, mileage and lodging when the repair is performed at the site of the failure.

Cummins will pay reasonable labor costs for Engine removal and reinstallation when necessary to repair a Warrantable Failure.

During The Extended Major Components Warranty

Cummins will pay for the repair or, at its option, replacement of the defective Covered Part and any Covered Part damaged by a Warrantable Failure of the defective Covered Part.

Owner Responsibilities

During The Base Engine Warranty

Owner is responsible for the cost of lubricating oil, antifreeze, filter elements and other maintenance items replaced during Warranty repairs unless such items are not reusable due to the Warrantable Failure.

During The Extended Major Components Warranty

Owner is responsible for the cost of all labor needed to repair the Engine, including the labor cost for Engine removal and reinstallation. When Cummins elects to repair a part instead of replacing it, the Owner is not responsible for the labor needed to repair the part.

Owner is responsible for the cost of all parts required for the repair except for the defective Covered Part and any Covered Part damaged by a Warrantable Failure of the defective Covered Part.

Owner is responsible for the cost of lubricating oil, antifreeze, filter elements and other maintenance items replaced during repair of a Warrantable Failure.

During The Base Engine And Extended Major Components Warranties

Owner is responsible for the operation and maintenance of the Engine as specified in the applicable Cummins Operation and Maintenance Manual. Owner is also responsible for providing proof that all recommended maintenance has been performed.

Before the expiration of the applicable Warranty, Owner must notify a Cummins distributor, authorized dealer or other repair location approved by Cummins of any Warrantable Failure and make the Engine available for repair by such facility. Service locations are listed on the Cummins Worldwide Service Locator at cummins.com.

Owner is responsible for communication expenses, meals, lodging and similar costs incurred as a result of a Warrantable Failure.

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Owner is responsible for non-Engine repairs, "downtime" expenses, fines, all applicable taxes, all business costs and other losses resulting from a Warrantable Failure.

Owner is responsible for providing sufficient access to and reasonable ability to remove the Engine from the installation in the event of a Warrantable Failure.

Owner is responsible for maintaining an operating Engine hourmeter. If the hourmeter is not operational, Engine usage will be estimated at 400 hours per month.

Emission Warranty

Products Warranted

This Emission Warranty applies to new Engines marketed by Cummins that are used in the United States* or Canada in generator drive applications for Off-Highway use. This Warranty applies to Engines delivered to the ultimate purchaser on or after April 1, 1999 for Engines up to 750 horsepower and on or after January 1, 2000 for Engines 751 and over.

Coverage

Cummins warrants to the ultimate purchaser and each subsequent purchaser that the Engine is designed, built and equipped so as to conform at the time of sale by Cummins with all U.S. Federal emission regulations applicable at the time of manufacture and that it is free from defects in workmanship or material which would cause it not to meet these regulations within the longer of the following periods: (A) Five years or 3,000 hours of operation for industrial applications, five years or 3,500 hours of operation for industrial spark-ignited Engines (GTA855, G855, G5.9C, G8.3C, GTA8.9E, QSK19G, QSK60G) and five years or 2,500 hours of operation for industrial spark-ignited Engines (GKTA19-GC), whichever occurs first, as measured from the date of delivery of the Engine to the ultimate purchaser, or (B) The Base Engine Warranty.

If the vehicle in which the Engine is installed is registered in the state of California, a separate California Emission Warranty also applies.

Limitations

Engines with an emissions certification listed below must be operated using only diesel fuel having no more than the corresponding maximum sulfur content. Failure to use the specified fuel as listed in the Cummins Fuel Bulletin #3379001 Table 1 (Cummins Inc. Required Diesel Fuel Specifications) can damage the Engine and aftertreatment system within a short period of time. This damage could cause the Engine to become inoperable and failures attributable to the use of incorrect fuels will be denied Warranty Coverage. Fuel specifications also need to comply with local fuel regulations (EN590 for Europe and ASTM D975 for North America) for Warranty eligibility.

Maximum sulfur levels by emissions certification level as listed on the Engine's dataplate are:

EPA 2007/2010/2013	max. 15 parts per million
EPA Tier 4 Interim / Final	max. 15 parts per million
EU Stage IIIB 2011	max. 15 parts per million
Euro 4/5	max. 50 parts per million
Euro 6	max. 10 parts per million

Additions to Limitations for HHP LBNG Engines:

Engines with an emissions certification listed below must be operated using only pipeline natural gas or non-commercial natural gas having no more than the corresponding sulfur content. Failure to use the specified fuel as listed in the engines applicable Operation and Maintenance Manual, Procedure 018-002 in Section V – Maintenance Specifications, can damage the Engine and after treatment system within a short period of time. This damage could cause the Engine to become inoperable and failures attributable to the use of incorrect fuels will be denied Warranty Coverage.

Maximum Sulfur Levels by Emissions Certification Level as listed on the Engine's Dataplate are (High Horsepower Lean-Burn Natural Gas Engines):	
EPA Tier 2 Nonroad	Maximum 20 parts per million (ppmv)
EPA NSPS	Maximum 20 parts per million (ppmv)

Before a claim for excessive oil consumption will be considered, Owner must submit adequate documentation to show that consumption exceeds Cummins published standards.

Failure of belts and hoses supplied by Cummins is not covered beyond the first 500 hours or one year of operation, whichever occurs first after the Warranty start date.

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Parts used to repair a Warrantable Failure may be new Cummins parts, Cummins approved rebuilt parts or repaired parts. Cummins is not responsible for failures resulting from the use of parts not approved by Cummins.

A new Cummins or Cummins approved rebuilt part used to repair a Warrantable Failure assumes the identity of the part it replaced and is entitled to the remaining Coverage hereunder.

Cummins is not responsible for Engine performance problems or failures resulting from:

1 Use or application of the Engine inconsistent with its rating designation as set forth above.

2 Inadequate or incorrect installations deviating from Cummins Generator Drive Installation Guidelines.

CUMMINS IS NOT RESPONSIBLE FOR WEAR OR WEAROUT OF COVERED PARTS.

CUMMINS IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.

THE WARRANTIES SET FORTH HEREIN ARE THE SOLE WARRANTIES MADE BY CUMMINS IN REGARD TO THESE ENGINES. CUMMINS MAKES NO OTHER WARRANTIES, EXPRESS OR IMPLIED, OR OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

In the United States* and Canada, this Warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

Outside the United States* and Canada, in the case of consumer sales, in some countries, the Owner has statutory rights which cannot be affected or limited by the terms of this Warranty.

Nothing in this Warranty excludes or restricts any contractual rights the owner may have against third parties.

* United States includes American Samoa, the Commonwealth of Northern Mariana Islands, Guam, Puerto Rico and the U.S. Virgin Islands.

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All Engines United States And Canada Industrial (Off-Highway)

Coverage

Products Warranted

This Warranty applies to new Engines sold by Cummins and delivered to the first user on or after April 1, 1999, that are used in Industrial (Off-Highway) applications in the United States* and Canada, except for Engines used in marine, generator drive, QSK95 T4 locomotive and certain defense applications, for which different Warranty Coverage is provided.

Base Engine Warranty

This Warranty covers any failures of the Engine, under normal use and service, which result from a defect in material or factory workmanship (Warrantable Failures).

Coverage begins with the sale of the Engine by Cummins. Coverage continues for two years or 2,000 hours of operation, whichever occurs first, from the date of delivery of the Engine to the first user, or from the date the unit is first leased, rented or loaned, or when the Engine has been operated for 50 hours, whichever occurs first. If the 2,000 hour limit is exceeded during the first year, Coverage continues until the end of the first year.

Engine aftertreatment components included in the Cummins Critical Parts List (CPL) and marked with a Cummins part number are covered under Base Engine Warranty.

Additional Coverage is outlined in the Emission Warranty section.

Extended Major Components Warranty

The Extended Major Components Warranty covers Warrantable Failures of the Engine cylinder block, camshaft, crankshaft and connecting rods (Covered Parts).

Bushing and bearing failures are not covered.

This Coverage begins with the expiration of the Base Engine Warranty and ends three years or 10,000 (3,000 hours for A Series Engines) hours of operation from the date of delivery of the Engine to the first user, or from the date the unit is first leased, rented or loaned, or from when the Engine has been operated for 50 hours, whichever occurs first.

Consumer Products

The Warranty on Consumer Products in the United States* is a LIMITED Warranty. **CUMMINS IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.** Any implied Warranties applicable to Consumer Products in the United States* terminate concurrently with the expiration of the express Warranties applicable to the product. In the United States*, some states do not allow the exclusion of incidental or consequential damages, or limitations on how long an implied Warranty lasts, so the limitations or exclusions herein may not apply to you.

These Warranties are made to all Owners in the chain of distribution and Coverage continues to all subsequent Owners until the end of the periods of Coverage.

Cummins Responsibilities

During The Base Engine Warranty

Cummins will pay for all parts and labor needed to repair the damage to the Engine resulting from a Warrantable Failure.

Alternators, starters, and fans ARE covered for the duration of the Base Engine Warranty on A Series and B3.3 Engines.

Alternators and starters are covered for the duration of the Base Engine Warranty on QSK23 Engines.

Cummins will pay for the lubricating oil, antifreeze, filter elements and other maintenance items that are not reusable due to the Warrantable Failure.

Cummins will pay reasonable costs for mechanics to travel to and from the equipment site, including meals, mileage and lodging, when the repair is performed at the site of the failure.

Cummins will pay reasonable labor costs for Engine removal and reinstallation when necessary to repair a Warrantable Failure.

During The Extended Major Components Warranty

Cummins will pay for the repair or, at its option, replacement of the defective Covered Part and any Covered Part damaged by a Warrantable Failure of the defective Covered Part.

Owner Responsibilities

During The Base Engine Warranty

Owner is responsible for the cost of lubricating oil, antifreeze, filter elements and other maintenance items provided during Warranty repairs unless such items are not reusable due to the Warrantable Failure.

During The Extended Major Components Warranty

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Owner is responsible for the cost of all labor needed to repair the Engine, including the labor to remove and reinstall the Engine. When Cummins elects to repair a part instead of replacing it, Owner is not responsible for the labor needed to repair the part.

Owner is responsible for the cost of all parts required for the repair except for the defective Covered Part and any Covered Part damaged by a Warrantable Failure of the defective Covered Part.

Owner is responsible for the cost of lubricating oil, antifreeze, filter elements and other maintenance items replaced during repair of a Warrantable Failure.

During The Base Engine And Extended Major Components Warranties

Owner is responsible for the operation and maintenance of the Engine as specified in the applicable Cummins Operation and Maintenance Manual. Owner is also responsible for providing proof that all recommended maintenance has been performed.

Before the expiration of the applicable Warranty, Owner must notify a Cummins distributor, authorized dealer or other repair location approved by Cummins of any Warrantable Failure and make the Engine available for repair by such facility. Service locations are listed on the Cummins Worldwide Service Locator at cummins.com.

Owner is responsible for communication expenses, meals, lodging and similar costs incurred as a result of a Warrantable Failure.

Owner is responsible for non-Engine repairs, "downtime" expenses, cargo damage, fines, all applicable taxes, all business costs and other losses resulting from a Warrantable Failure.

Limitations

Engines with an emissions certification listed below must be operated using only diesel fuel having no more than the corresponding maximum sulfur content. Failure to use the specified fuel as listed in the Cummins Fuel Bulletin #3379001 Table 1 (Cummins Inc. Required Diesel Fuel Specifications) can damage the Engine and aftertreatment system within a short period of time. This damage could cause the Engine to become inoperable and failures attributable to the use of incorrect fuels will be denied Warranty Coverage. Fuel specifications also need to comply with local fuel regulations (EN590 for Europe and ASTM D975 for North America) for Warranty eligibility.

Maximum sulfur levels by emissions certification level as listed on the Engine's dataplate are:	
EPA 2007/2010/2013	max. 15 parts per million
EPA Tier 4 Interim / Final	max. 15 parts per million
EU Stage IIIB 2011	max. 15 parts per million
Euro 4/5	max. 50 parts per million
Euro 6	max. 10 parts per million

Cummins is not responsible for failures or damage resulting from what Cummins determines to be abuse or neglect, including, but not limited to: operation without adequate coolants or lubricants; overfueling; overspeeding; lack of maintenance of lubricating, cooling or intake systems; improper storage, starting, warm-up, run-in or shutdown practices; unauthorized modifications of the Engine. Cummins is also not responsible for failures caused by incorrect oil, fuel or diesel exhaust fluid or by water, dirt or other contaminants in the fuel, oil or diesel exhaust fluid.

For power units and fire pumps (package units), this Warranty applies to accessories, except for clutches and filters, supplied by Cummins which bear the name of another company.

Cummins Compusave units are covered by a separate Warranty.

Before a claim for excessive oil consumption will be considered, Owner must submit adequate documentation to show that consumption exceeds Cummins published standards.

Failures of belts and hoses supplied by Cummins are not covered beyond the first 500 hours or one year of operation, whichever occurs first.

Parts used to repair a Warrantable Failure may be new Cummins parts, Cummins approved rebuilt parts or repaired parts. Cummins is not responsible for failures resulting from the use of parts not approved by Cummins.

A new Cummins or Cummins approved rebuilt part used to repair a Warrantable Failure assumes the identity of the part it replaced and is entitled to the remaining Coverage hereunder.

For all A Series Applications, including Industrial, travel reimbursement for non-transportable equipment will be limited to 4.0 hours, $0.25/mile and 250 miles maximum. Any costs beyond this limit are the customer's responsibility.

CUMMINS DOES NOT COVER WEAR OR WEAROUT OF COVERED PARTS.

CUMMINS IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.

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THESE WARRANTIES SET FORTH HEREIN ARE THE SOLE WARRANTIES MADE BY CUMMINS IN REGARD TO THESE ENGINES. CUMMINS MAKES NO OTHER WARRANTIES, EXPRESS OR IMPLIED, OR OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

This Warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

Emission Warranty

Products Warranted

This Emission Warranty applies to new Engines marketed by Cummins that are used in the United States* and Canada in vehicles designed for Industrial Off-Highway use. This Warranty applies to Engines delivered to the ultimate purchaser on or after April 1, 1999, for Engines up to 750 horsepower and on or after January 1, 2000, for Engines 751 horsepower and over.

Coverage

Cummins warrants to the ultimate purchaser and each subsequent purchaser that the Engine is designed, built and equipped so as to conform at the time of sale by Cummins with all U.S. Federal emission regulations applicable at the time of manufacture and that it is free from defects in workmanship or material which would cause it not to meet these regulations within the longer of the following periods: (A) **Five years or 3,000 hours of operation for industrial applications, five years or 3,500 hours of operation for industrial spark-ignited Engines (GTA855, G855, G5.9C, G8.3-C, GTA8.9E, QSK19G) and five years or 2,500 hours of operation for industrial spark-ignited Engines (GKTA19-GC), whichever occurs first, as measured from the date of delivery of the Engine to the ultimate purchaser, or (B) The Base Engine Warranty.

If the vehicle in which the Engine is installed is registered in the state of California, a separate California Emission Warranty also applies.

Limitations

Engines with an emissions certification listed below must be operated using only diesel fuel having no more than the corresponding maximum sulfur content. Failure to use the specified fuel as listed in the Cummins Fuel Bulletin #3379001 Table 1 (Cummins Inc. Required Diesel Fuel Specifications) can damage the Engine and aftertreatment system within a short period of time. This damage could cause the Engine to become inoperable and failures attributable to the use of incorrect fuels will be denied Warranty Coverage. Fuel specifications also need to comply with local fuel regulations (EN590 for Europe and ASTM D975 for North America) for Warranty eligibility.

Maximum sulfur levels by emissions certification level as listed on the Engine's dataplate are:	
EPA 2007/2010/2013	max. 15 parts per million
EPA Tier 4 Interim / Final	max. 15 parts per million
EU Stage IIIB 2011	max. 15 parts per million
Euro 4/5	max. 50 parts per million
Euro 6	max. 10 parts per million

Failures, other than those resulting from defects in materials or workmanship, are not covered by this Warranty.

Cummins is not responsible for failures or damage resulting from what Cummins determines to be abuse or neglect, including, but not limited to: operation without adequate coolant or lubricants; overfueling; overspeeding; lack of maintenance of lubricating, cooling or intake systems; improper storage, starting, warm-up, run-in or shutdown practices; unauthorized modifications of the Engine. Cummins is also not responsible for failures caused by incorrect oil, fuel or diesel exhaust fluid or by water, dirt or other contaminants in the fuel, oil or diesel exhaust fluid.

Cummins is not responsible for non-Engine repairs, "downtime" expenses, cargo damage, fines, all business costs or other losses resulting from a Warrantable Failure.

CUMMINS IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.

* United States includes American Samoa, the Commonwealth of Northern Mariana Islands, Guam, Puerto Rico and the U.S. Virgin Islands.

** Emissions Warranty for BLPG Industrial Off-Highway Engines is 5 years / 3,500 hours.

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All Engines International Industrial (Off-Highway)

Coverage

Products Warranted

This Warranty applies to new Engines sold by Cummins and delivered to the first user on or after April 1, 1999, that are used in Industrial (Off-Highway) applications anywhere in the world where Cummins approved service is available, except the United States and Canada. Different Warranty Coverage is provided for Engines used in marine, generator drive, QSK95 T4 locomotive and certain defense applications.

Base Engine Warranty

This Warranty covers any failures of the Engine, under normal use and service, which result from a defect in material or factory workmanship (Warrantable Failure).

Coverage begins with the sale of the Engine by Cummins. Coverage continues for two years or 2,000 hours of operation, whichever occurs first, from the date of delivery of the Engine to the first user, or from the date the unit is first leased, rented or loaned, or when the Engine has been operated for 50 hours, whichever occurs first. If the 2,000 hour limit is exceeded during the first year, Coverage continues until the end of the first year.

Engine aftertreatment components included in the Cummins Critical Parts List (CPL) and marked with a Cummins part number are covered under Base Engine Warranty.

Extended Major Components Warranty

The Extended Major Components Warranty covers Warrantable Failures of the Engine cylinder block, camshaft, crankshaft and connecting rods (Covered Parts).

Bushing and bearing failures are not covered.

This Coverage begins with the expiration of the Base Engine Warranty and ends three years or 10,000 hours (3,000 hours for A Series Engines) of operation, from the date of delivery of the Engine to the first user, or from the date the unit is first leased, rented or loaned, or when the Engine has been operated for 50 hours, whichever occurs first.

These Warranties are made to all Owners in the chain of distribution, and Coverage continues to all subsequent Owners until the end of the periods of Coverage.

Cummins Responsibilities

During The Base Engine Warranty

Cummins will pay for all parts and labor needed to repair the damage to the Engine resulting from a Warrantable Failure.

Alternators, starters, and fans ARE covered for the duration of the Base Engine Warranty on A Series and B3.3 Engines.

Alternators and starters are covered for the duration of the Base Engine Warranty on QSK23 Engines.

Cummins will pay for the lubricating oil, antifreeze, filter elements and other maintenance items that are not reusable due to a Warrantable Failure.

Cummins will pay reasonable costs for mechanics to travel to and from the equipment site, including meals, mileage and lodging, when the repair is performed at the site of the failure.

Cummins will pay reasonable labor costs for Engine removal and reinstallation when necessary to repair a Warrantable Failure.

During The Extended Major Components Warranty

Cummins will pay for the repair or, at its option, replacement of the defective Covered Part and any Covered Part damaged by a Warrantable Failure of the defective Covered Part.

Owner Responsibilities

During The Base Engine Warranty

Owner is responsible for the cost of lubricating oil, antifreeze, filter elements and other maintenance items replaced during Warranty repairs unless such items are not reusable due to the Warrantable Failure.

During The Extended Major Components Warranty

Owner is responsible for the cost of all labor needed to repair the Engine, including the labor to remove and reinstall the Engine. When Cummins elects to repair a part instead of replacing it, Owner is not responsible for the labor needed to repair the part.

Owner is responsible for the cost of all parts required for the repair except for the defective Covered Part and any Covered Part damaged by a Warrantable Failure of the defective Covered Part.

Owner is responsible for the cost of lubricating oil, antifreeze, filter elements and other maintenance items replaced during repair of a Warrantable Failure.

During The Base Engine Warranty And Extended Major Components Warranties

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Owner is responsible for the operation and maintenance of the Engine as specified in the applicable Cummins Operation and Maintenance Manual. Owner is also responsible for providing proof that all recommended maintenance has been performed.

Before the expiration of the applicable Warranty, Owner must notify a Cummins distributor, authorized dealer or other repair location approved by Cummins of any Warrantable Failure and make the product available for repair by such facility. Service locations are listed in the Cummins Worldwide Service Locator at cummins.com.

Owner is responsible for communication expenses, meals, lodging and similar costs incurred as a result of a Warrantable Failure.

Owner is responsible for non-Engine repairs, "downtime" expenses, cargo damage, fines, all applicable taxes, all business costs and other losses resulting from a Warrantable Failure.

Limitations

Engines with an emissions certification listed below must be operated using only diesel fuel having no more than the corresponding maximum sulfur content. Failure to use the specified fuel as listed in the Cummins Fuel Bulletin #3379001 Table 1 (Cummins Inc. Required Diesel Fuel Specifications) can damage the Engine and aftertreatment system within a short period of time. This damage could cause the Engine to become inoperable and failures attributable to the use of incorrect fuels will be denied Warranty Coverage. Fuel specifications also need to comply with local fuel regulations (EN590 for Europe and ASTM D975 for North America) for Warranty eligibility.

Maximum sulfur levels by emissions certification level as listed on the Engine's dataplate are:	
EPA 2007/2010/2013	max. 15 parts per million
EPA Tier 4 Interim / Final	max. 15 parts per million
EU Stage IIIB 2011	max. 15 parts per million
Euro 4/5	max. 50 parts per million
Euro 6	max. 10 parts per million

Cummins is not responsible for failures or damage resulting from what Cummins determines to be abuse or neglect, including, but not limited to: operation without adequate coolants or lubricants; overfueling; overspeeding; lack of maintenance of lubricating, cooling or intake systems; improper storage, starting, warm-up, run-in or shutdown practices; unauthorized modifications of the Engine. Cummins is also not responsible for failures caused by incorrect oil, fuel or diesel exhaust fluid or by water, dirt or other contaminants in the fuel, oil or diesel exhaust fluid.

For power units and fire pumps (package units) the Warranty applies to accessories, except for clutches and filters supplied by Cummins which bear the name of another company.

Cummins Compusave units are covered by a separate Warranty.

Before a claim for excessive oil consumption will be considered, Owner must submit adequate documentation to show that consumption exceeds Cummins published standards.

Failures of belts and hoses supplied by Cummins are not covered beyond the first 500 hours or one year of operation, whichever occurs first.

Parts used to repair a Warrantable Failure may be new Cummins parts, Cummins approved rebuilt parts or repaired parts. Cummins is not responsible for failures resulting from the use of parts not approved by Cummins.

A new Cummins or Cummins approved rebuilt part used to repair a Warrantable Failure assumes the identity of the part it replaced and is entitled to the remaining Coverage hereunder.

For all A Series Applications, including Industrial, travel reimbursement for non-transportable equipment will be limited to 4.0 hours, $0.25/mile and 250 miles maximum. Any costs beyond this limit are the customer's responsibility.

CUMMINS DOES NOT COVER WEAR OR WEAROUT OF COVERED PARTS.

CUMMINS IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.

THESE WARRANTIES SET FORTH HEREIN ARE THE SOLE WARRANTIES MADE BY CUMMINS IN REGARD TO THESE ENGINES. CUMMINS MAKES NO OTHER WARRANTIES, EXPRESS OR IMPLIED, OR OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

In the case of consumer sales, in some countries, the Owner has statutory rights which cannot be affected or limited by the terms of this Warranty.

Nothing in this Warranty excludes or restricts any contractual rights the Owner may have against third parties.

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California Emission Control Warranty Statement, Off-Highway Your Warranty Rights and Obligations

The California Air Resources Board and Cummins Inc., are pleased to explain the emission control system warranty on your 2015 and 2016 model year engine. In California, new heavy-duty off-road diesel engines must be designed, built and equipped to meet the State's stringent anti-smog standards. Cummins Inc. must warrant the emission control system on your engine for the periods of time listed below provided there has been no abuse, neglect or improper maintenance of your engine. Your emission control system may include parts such as the fuel injection system and the air induction system. Also included may be hoses, belts, connectors and other emission-related assemblies.

Where a warrantable condition exists, Cummins Inc. will repair your heavy-duty off-road diesel engine at no cost to you including diagnosis, parts and labor.

Manufacturer's Warranty Coverage

This warranty coverage for 2015 and 2016 model year heavy-duty off-road engines is provided for 5 years or 3,000 hours of engine operation, whichever first occurs from the date of delivery of the engine to the first user. If any emission-related part on your engine is defective, the part will be repaired or replaced by Cummins Inc.

Owner's Warranty Responsibilities

As the engine owner, you are responsible for the performance of the required maintenance listed in your Cummins® Owners and/or Operation and Maintenance Manual. Cummins Inc. recommends that you retain all receipts covering maintenance on your engine, but Cummins Inc. cannot deny warranty solely for the lack of receipts or for your failure to substantiate the performance of all scheduled maintenance.

You are responsible for presenting your engine to a Cummins® dealer as soon as a problem exists. The warranty repairs should be completed in a reasonable amount of time, not to exceed 30 days.

As an engine owner, you should also be aware that Cummins Inc. may deny you warranty coverage if your engine or a part has failed due to abuse, neglect, improper maintenance or unapproved modifications.

If you have any questions regarding your warranty rights and responsibilities, you should contact Cummins® Customer Relation Department at 1-800-343-7357 or the California Air Resources Board at 9528 Telstar Avenue, El Monte, CA 91731.

A warranted part which is scheduled for replacement as required maintenance is warranted up to the first schedule replacement point.

Prior to the expiration of the applicable warranty, Owner must give notice of any warranted emission control failure to a Cummins® distributor, authorized dealer or other repair location approved by Cummins Inc. and deliver the engine to such facility for repair. Repair locations are listed in Cummins® United States and Canada Service Directory.

Owner is responsible for incidental costs such as: communication expenses, meals, lodging incurred by Owner or employees of Owner as a result of a Warrantable Condition.

Owner is responsible for "downtime" expenses, cargo damage, fines, all applicable taxes, all business costs, and other losses resulting from a Warrantable Condition.

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California Emission Control System Warranty

Coverage

This list of emission control parts may be covered by the emission control system warranty under certain failure modes:

Aftertreatment System	**Base Engine System**
Component	**Component**
Aftertreatment Electroconnections	Cam Shaft
Aftertreatment Fuel Drain Valve	Cam Shaft Valve Lobe
Aftertreatment Fuel Injector/Regulator	Coolant Temperature Sensor
Aftertreatment Fuel Pressure Sensor	Crankcase Breather
Aftertreatment Fuel Shut-off Valve	Engine Oil Pressure Sensor
Aftertreatment Injector Manifold	Engine Oil Temperature
Aftertreatment Inlet and Outlet Modules	Engine Speed, Position Sensor, Cam Position Sensor
Aftertreatment Temperature Interface Module	Exhaust Valve
Aftertreatment System (cont')	**EGR System**
Component	**Component**
Aftertreatment Temperature Sensors	EGR Cooler
Decomposition Tube	EGR Differential Pressure Sensor
DEF Dosing Unit (Pump)	EGR Mixer/Venturi
DEF Dosing Valve	EGR Temperature Sensor
Diesel Oxidation Catalyst	EGR Mixer/Venturi
Diesel Particulate Filter (except for ash maintenance)	EGR Valve
Diesel Particulate Filter Differential Pressure Sensor	
NOx Sensors	
SCR Catalyst	
Air Handling	**Electronic Control System**
Component	**Component**
Barometric Air Pressure Sensor	Engine Control Module
Exhaust Gas Pressure Sensor	Engine Control Module Calibration
Exhaust Manifold	
Air Handling (cont')	**Fuel System**
Component	**Component**
Charge Air Cooler and Associated Plumbing	Fuel Lines
Intake Manifold	Fuel Pressure Sensor
Intake Manifold Temperature/Pressure Sensor	Fuel Pump
Turbocharger Actuator	Injector
Turbocharger Assembly	Secondary Fuel Pressure/Temperature Sensor
Turbocharger Compressor Inlet Air Temperature Sensor	
Turbocharger Speed Sensor	

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California Emission Control System Warranty

Replacement Parts

Cummins Inc. recommends that any service parts used for maintenance, repair or replacement of emission control systems be new, genuine Cummins® or Cummins® approved rebuilt parts and assemblies, and that the engine be serviced by a Cummins® distributor, authorized dealer or the repair location approved by Cummins Inc. The owner may elect to have maintenance, replacement or repair of the emission control parts performed by a facility other than a Cummins® distributor, an authorized dealer or a repair location approved by Cummins Inc., and may elect to use parts other than new genuine Cummins® or Cummins® approved rebuilt parts and assemblies for such maintenance, replacement or repair; however, the cost of such service or parts and subsequent failures resulting from such service or parts will not be covered under this emission control system warranty, except for Emergency Repairs as described below.

Cummins Responsibilities

The warranty coverage begins when the engine is delivered to the ultimate purchaser.

Repairs and service will be performed by any Cummins® distributor, authorized dealer or other repair locations approved by Cummins Inc. using new, genuine Cummins® or Cummins® approved rebuilt parts and assemblies. Cummins Inc. will repair any of the emission control parts found by Cummins Inc. to be defective without charge for parts or labor (including diagnosis which results in determination that there has been a failure of a warranted emission control part).

Emergency Repairs

In the case of an emergency where a Cummins® distributor, authorized dealer, or other repair location approved by Cummins Inc. is not available, repairs may be performed by any available repair location or by any individual using any replacement parts. A part not being available within 30 days or a repair not being complete within 30 days constitutes an emergency. Cummins Inc. will reimburse the Owner for expenses (including diagnosis), not to exceed the manufacturer's suggested retail price for all warranted parts replaced and labor charges based on the manufacturer's recommended time allowance for the warranty repair and the geographically appropriate hourly labor rate. Replaced parts and paid invoices must be presented at a Cummins® authorized repair facility as a condition of reimbursement for emergency repairs not performed by a Cummins® distributor, authorized dealer, or other repair location approved by Cummins Inc.

Warranty Limitations

Cummins Inc. is not responsible for failures or damage resulting from what Cummins Inc. determines to be abuse or neglect, including, but not limited to: operation without adequate coolants or lubricants; overfueling; overspeeding; lack of maintenance of cooling, lubricating or intake systems; improper storage, starting, warm-up, run-in or shutdown practices; unauthorized modifications to the engine. Cummins Inc. is also not responsible for failures caused by incorrect oil, fuel, or coolant or by water, dirt or other contaminants in the fuel or oil or contaminants in the coolant.

Cummins Inc. is not responsible for failures resulting from improper repair or the use of parts which are not genuine Cummins® or Cummins® approved parts.

Cummins Inc. is not responsible for the material and labor costs of emission control parts and assemblies replaced during Scheduled Maintenance of the engine as specified in Cummins® Owners and/or Operation and Maintenance Manuals.

THIS WARRANTY, TOGETHER WITH THE EXPRESS COMMERCIAL WARRANTIES ARE THE SOLE WARRANTIES MADE BY CUMMINS INC. THERE ARE NO OTHER WARRANTIES, EXPRESS OR IMPLIED, OR OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

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