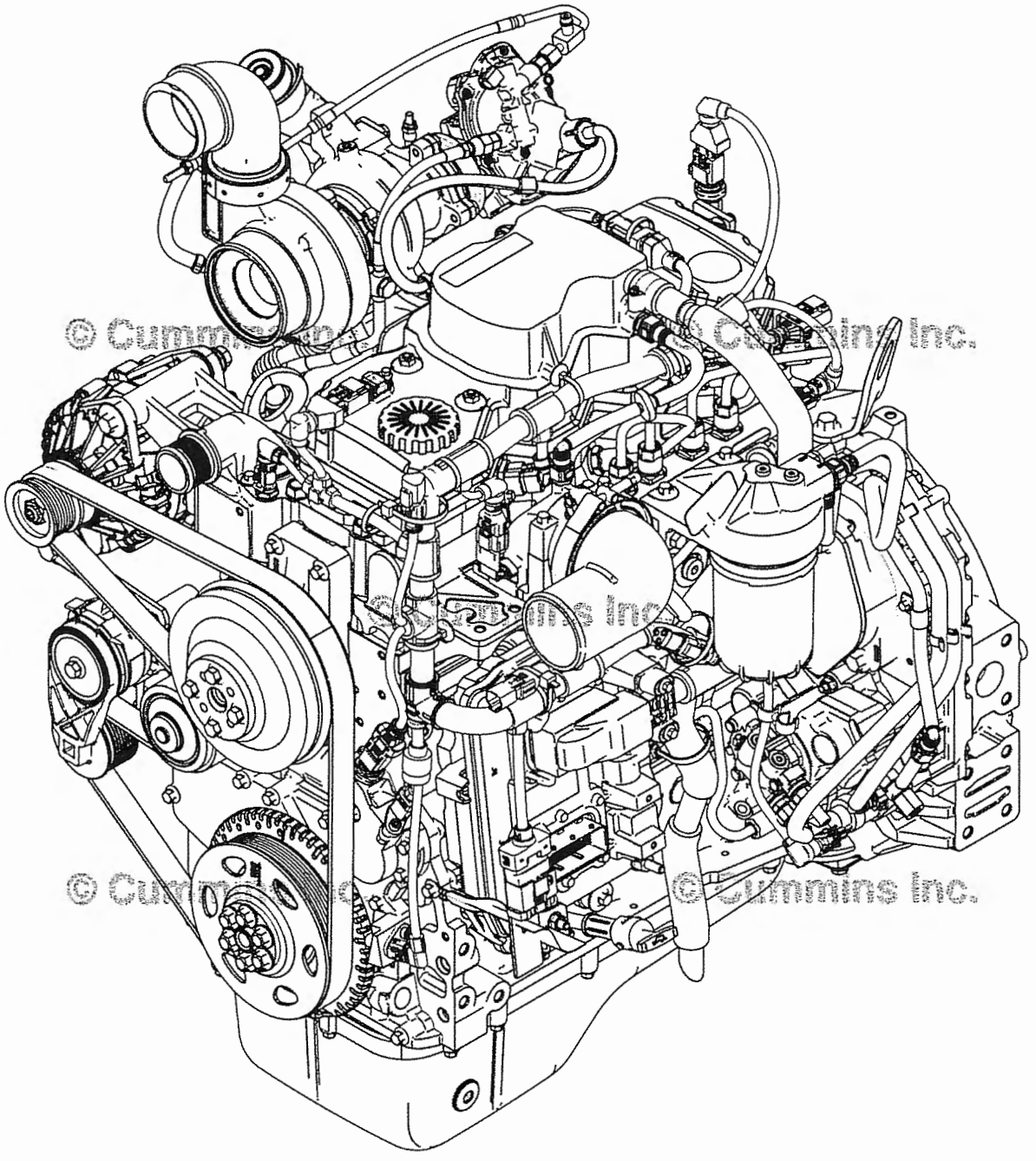
Operation and Maintenance Manual
B4.5 CM2350 B146C



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Foreword

Thank you for depending on Cummins® products. If you have any questions about this product, please contact your Cummins® Authorized Repair Location. You can also visit cumminsengines.com or quickserve.cummins.com for more information, or go to locator.cummins.com for Cummins® distributor and dealer locations and contact information.

Read and follow all safety instructions. See the General Safety instructions in Section i - Introduction.

Table of Contents

Important Reference Numbers

Fill in the blank spaces provided below. This will provide a reference whenever service or maintenance is required.

Description	Number	Comments/Additional Information
Engine		
Engine Model		
Engine Serial Number (ESN)		
Control Parts List (CPL)		
Electronic Control Module (ECM) Part Number(s)		
Electronic Control Module (ECM) Serial Number(s)		
Governor Control Module (GCM) (if applicable)		
Belt Part Number(s)		
Filter Part Numbers:		
Air		
Lubricating Oil		
Fuel*		
Fuel (Water Separator)		
Coolant (if equipped)		
Crankcase/Breather (if equipped)		
Eliminator™ Filter Centrifuge (if equipped)		
*The number of fuel filters may vary by application. Record all fuel filters.		
Aftertreatment (if applicable):		
Aftertreatment Diesel Particulate Filter (if equipped)		
Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter (if equipped)		
Aftertreatment Diesel Exhaust Fluid Dosing Air Oil Separator (if equipped)		
Clutch or Marine Gear (if applicable):		
Model		
Serial Number		
Part Number		
Oil Type		
Sea Water Pump:		
Model		
Part Number		

Section i - Introduction

Section Contents

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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.

About the Manual

General Information

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

The content of this manual is based on the information in effect at the time of publish. Cummins Inc. reserves the right to make any changes at any time without obligation. If differences are found between your engine and the information in this manual, contact a Cummins® Authorized Repair Location.

About

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

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

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

How to Use the Manual

General Information

This manual is 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).

Symbols

General Information

The symbols are used **only** in printed manuals to help communicate the intent of the instructions. Symbols will **not** appear in the online version of this procedure. When one of the symbols appears in the printed manual, it conveys the meaning defined below.

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

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

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

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

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

INSPECTION is required.

CLEAN the part or assembly.

PERFORM a mechanical or time **MEASUREMENT**.

LUBRICATE the part or assembly.

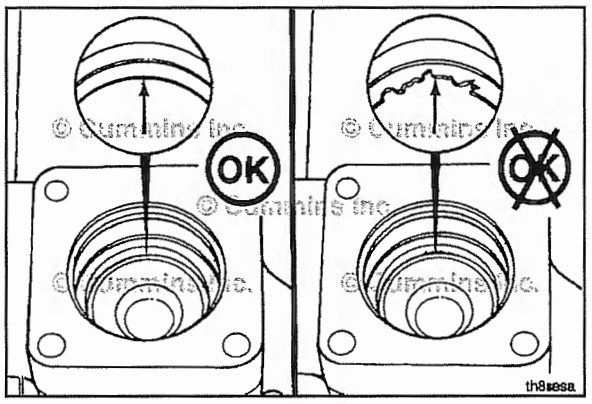
Indicates that a **WRENCH** or **TOOL SIZE** will be given.

TIGHTEN to a specific torque.

PERFORM an electrical **MEASUREMENT**.

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

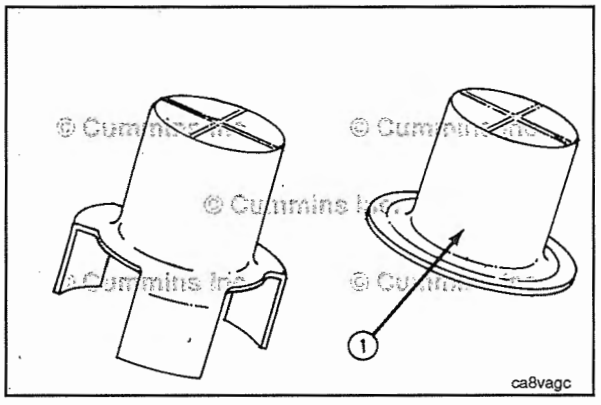
The component weighs 23kg [50 lbs] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.



Illustrations

General Information

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



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

General Safety Instructions

Important Safety Notice

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

Work Environment

Follow these recommended practices when servicing products.

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

Best Practices

Follow these recommended practices when servicing or operating equipment.

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

Perform the following prior to beginning work on any products.

- Shutdown the equipment unless otherwise directed by troubleshooting procedures.
- **Always** allow the product to cool.
- **Always** ensure the product is properly supported by blocks or stands. Do **not** work on a product supported **only** by lifting jacks or hoists.
- Disconnect the battery unless otherwise directed by troubleshooting procedures.
- Disconnect the starting motor, if equipped, unless otherwise directed by troubleshooting procedures.

- Place a "Do NOT Operate" tag in the operator area or near the product controls.
- Become familiar with the tools required for performing the task at hand and how to use those tools correctly.
- Use only genuine Cummins or Cummins Recon replacement parts as instructed.

Personal Protective Equipment (PPE)

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

Eye Protection

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

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

Foot Protection

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

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

Head and Face Protection

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

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

Hand Protection

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

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

Hearing Protection

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

- Single use ear plugs.
- Pre-formed ear plugs.
- Ear muffs.

Protective Clothing

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

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

Respiratory Protection

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

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

Fall Protection

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

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

Fuels

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

Diesel Fuel

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

Gasoline

- Protect eyes.
- Protect skin.
- **Always** be alert for the smell of gas.

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

Biodiesel

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

Compressed Natural Gas

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

- Natural gas accumulates near the ceiling. Check the ceiling of the work area for ignition sources before servicing equipment.
- **Only** disconnect gas lines in a well-ventilated area.
- Do **not** troubleshoot or repair gas leaks while the engine is running.
- Natural gas ignition systems produce high voltage during operation. Do **not** touch ignition wiring or components while the engine is operating. If necessary, use **only** insulated tools.
- Natural gas exhaust systems operate at higher temperatures than similar diesel exhaust systems. Do **not** touch exhaust components. Do **not** route lines or hoses which deteriorate from heat exposure near exhaust components or in the flow path of the exhaust.
- **Always** torque fittings and connections to the required specifications. over or under tightening can damage threads and create leaks.

Liquefied Natural Gas

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

Liquefied Petroleum Gas

- Protect eyes.
- Protect skin.
- **Always** be alert for the smell of gas. Liquefied petroleum gas is typically treated with an odor producing chemical for leak detection.
- **Always** test for fuel leaks as instructed. Odorant can fade.
- Upon entering a room or approaching a vehicle where the smell of gas is present, immediately shutoff all engines and ignition sources.

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

Power Generation Applications

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

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

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

Aftertreatment

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

Diesel Exhaust Fluid

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

Diesel Particulate Filter

- Protect eyes.
- Protect skin.

- Avoid stirring up exhaust particulate dust.
- Avoid inhalation of exhaust particulate dust. Wear a dust mask. If respiratory irritation or discomfort occurs, leave the dusty area. Utilize breathing assistance or oxygen if necessary.
- Elevated concentrations of metals in the form of dust, soot, and contaminants are contained in these filters. Health regulations may exist for the materials found in these filters such as Zinc, Molybdenum, polynuclear aromatic hydrocarbons. Potentially toxic materials found in these filters are oxides of calcium, zinc, phosphorous, silicon, sulfur, and iron.
- Proper disposal of the exhaust dust and filter are required. Dispose of in accordance with local and environmental regulations.
- Diesel particulate filter maintenance **must** be completed by appropriately trained personnel.

Selective Catalytic Reduction (SCR) Catalyst

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

Oxidation Catalysts

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

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

When working with oxidation catalysts, perform the following.

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

Common Substances

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

Coolant

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

Liquid Nitrogen

- Work in a well-ventilated area.
- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes. Receive medical attention immediately.
- Protect skin. In case of contact with skin, receive medical attention immediately.
- Wear protective clothing and gloves that insulate.
- Handle items with tongs or wire hooks.
- Avoid prolonged breathing of liquid nitrogen vapors. Utilize breathing assistance or oxygen if necessary.

Lubricating Oil

See Lubricating Oil in the "Hazardous Substances" step.

Refrigerant

- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes. In case of frostbite, use lukewarm water, not hot. Seek medical attention if irritation continues.
- Protect skin. Wear leather or insulated gloves. In case of contact with skin, wash with soap and water. Seek medical attention if irritation continues.
- Proper disposal is required. Dispose of in accordance with local and environmental regulations.
- **Only** disconnect liquid refrigerant lines in a well-ventilated area. liquid refrigerant systems **must** be properly emptied and filled using equipment that prevents the release of refrigerant gas into the atmosphere. Federal law requires capturing and recycling refrigerant in the United States of America.

Solvents

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

Starting Aids (Starting Fluid)

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

Hazardous Substances

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

Diesel Engine Exhaust

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

Lubricating Oil

- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes.
- Protect skin. In case of contact with skin, wash with soap and water.
- Do **not** ingest. If ingested, contact a physician immediately..
- Proper disposal is required. Dispose of in accordance with local and environmental regulations.

- Do **not** allow water droplets to enter a container of hot oil. A violent reaction can result.

Mercury

- Protect eyes. In case of contact with eyes, flush with water for a minimum of 15 minutes.
- Protect skin. In case of contact with skin, wash with soap and water.
- Do **not** ingest. If ingested, contact a physician immediately.
- Proper disposal is required. Dispose of in accordance with local and environmental regulations.

Vanadium Pentoxide

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

Electrical Components

Follow these recommended practices when interacting with electrical components.

Batteries

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

Common Hazards

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

High Temperature Area

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

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

Recommended Practices:

- Allow components to cool before servicing. Verify the temperature of the component. Utilize an infrared gun, temperature sensor, temperature gauge, or other reliable method to determine component temperature. Take appropriate precautions before starting work.

- Protect eyes.
- Protect skin. Wear insulated gloves.
- Ensure surrounding items do not come in contact with hot components or exhaust. Contact may ignite or melt those materials.

Heavy Objects

Be alert when working with heavy objects.

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

Pressurized Areas

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

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

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

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

Recommended Practices:

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

Job Safety Assessment

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

- Site supervisor
- Customer
- Work supervisor

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

Work Practices

Job Safety Analysis.

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

Ascending or Descending

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

Communication

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

Eyes On Hands and Work.

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

Eyes On Path

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

Line Of Fire

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

Pinch Point

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

Rushing

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

Follow Procedures

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

Ergonomics

Back-Bending and Twisting

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

Knee

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

Lifting and Lowering

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

Pulling or Pushing

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

Tools and Equipment

Selection

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

Condition

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

Use

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

Personal Protective Equipment (PPE)

Eye, Face, and Head Protection

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

Foot Protection

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

Fall Protection

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

Hand Protection

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

Hearing Protection

- Hearing protection should be worn when required or recommended.

Body Protection

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

Work Procedures

Training

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

Working Alone

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

Lockout and Tagout

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

Barricades and Warnings

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

Confined Space

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

Hot Work

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

Place Wheel Chocks

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

Spotter

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

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

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

General Repair Instructions

General Information

This 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.

- 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

General Cleaning Instructions

Definition of Clean

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

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

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

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

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

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

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

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

Abrasive Pads and Abrasive Paper

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

⚠WARNING⚠

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

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

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

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

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

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

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

⚠WARNING⚠

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

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

Gasket Surfaces

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

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

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

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

Solvent and Acid Cleaning

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

⚠WARNING⚠

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

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

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

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

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

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

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

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

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

Steam Cleaning

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

⚠WARNING⚠

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

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

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

Plastic Bead Cleaning

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

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

△CAUTION△

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

△CAUTION△

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

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

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

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

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

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

⚠CAUTION⚠

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

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

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

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

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

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

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

Fuel System

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

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

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

Choose lint free towels for fuel system work.

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

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

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

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

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

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

Acronyms and Abbreviations

General Information

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

ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society of Testing and Materials
ATDC	After Top Dead Center
bhp	Brake Horsepower
BTU	British Thermal Unit
BTDC	Before Top Dead Center
°C	Celsius
CAN	Controller Area Network
CARB	California Air Resources Board
CCA	Cold Cranking Amperes
CCV	Closed Crankcase Ventilation
CES	Cummins Engineering Standard
CIB	Customer Interface Box
C.I.D.	Cubic Inch Displacement
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CPL	Control Parts List
cSt	Centistokes
DEF	Diesel Exhaust Fluid
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
ECM	Engine Control Module
EFC	Electronic Fuel Control
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
ESN	Engine Serial Number
°F	Fahrenheit
ft-lb	Foot-Pound Force
FMI	Failure Mode Indentifier
GVW	Gross Vehicle Weight
Hg	Mercury
hp	Horsepower
H_2O	Water
inHg	Inches of Mercury
in H_2 0	Inches of Water
ICM	Ignition Control Module
IEC	International Electrotechnical Commission
JSA	Job Safety Assessment
km/l	Kilometers per Liter
kPa	Kilopascal
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LTA	Low Temperature Aftercooler
MCRS	Modular Common Rail System

MIL	Malfunction Indicator Lamp
MPa	Megapascal
mph	Miles Per Hour
mpq	Miles Per Quart
N•m	Newton-meter
NOx	Nitrogen Oxides
NG	Natural Gas
O2	Oxygen
OAT	Organic Acid Technology
OBD	On-Board Diagnostics
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Administration
PCCNet	Power Command Control Network
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

Notes

Section E - Engine and System Identification

Section Contents

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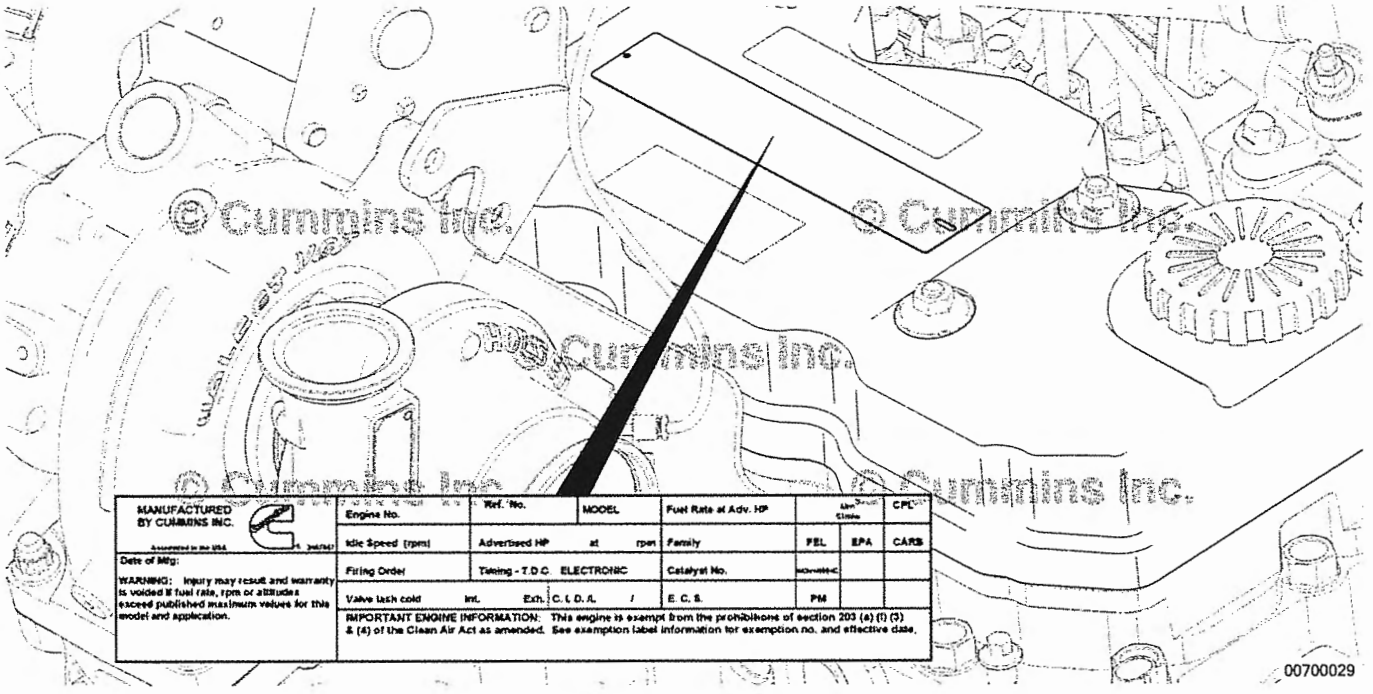
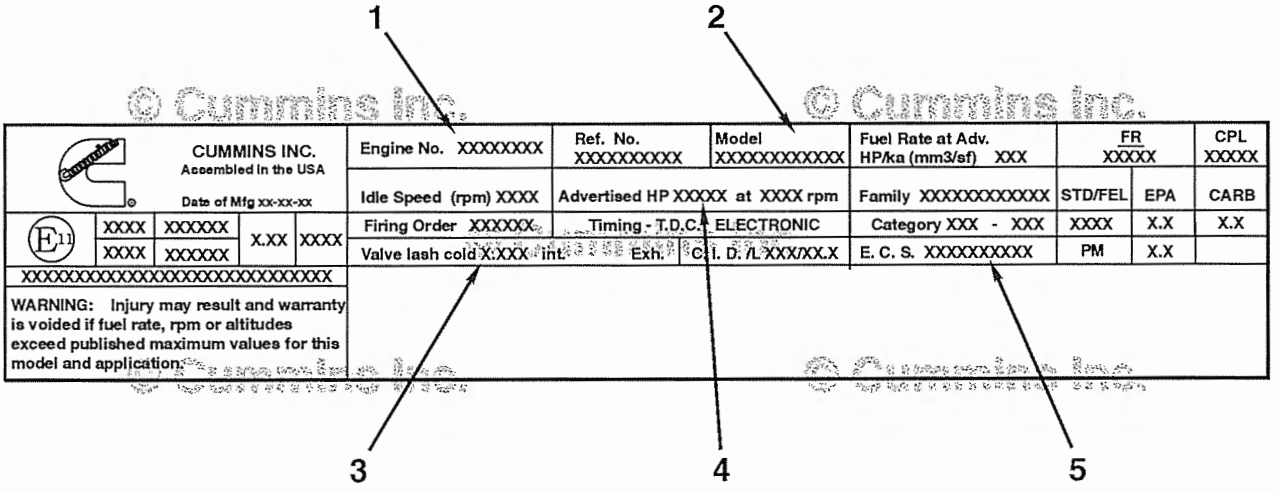
Engine Identification

Engine Dataplate



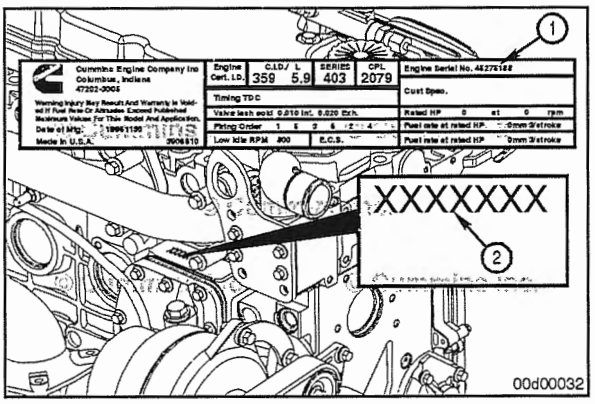
The engine dataplate provides important information about the engine. The engine serial number (ESN) and control parts list (CPL) provide information for service and for ordering parts. The engine dataplate **must not** be changed unless approved by Cummins Inc.

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

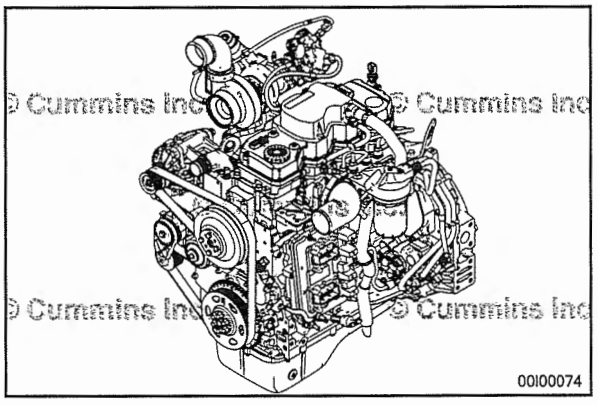


1 Engine serial number
2 Engine model information
3 Valve lash (overhead) setting
4 Horsepower and rpm rating
5 Emission control system.

NOTE: Engine dataplates vary by manufacturing plant. The dataplate may **not** contain all of the emission control systems for the engine.



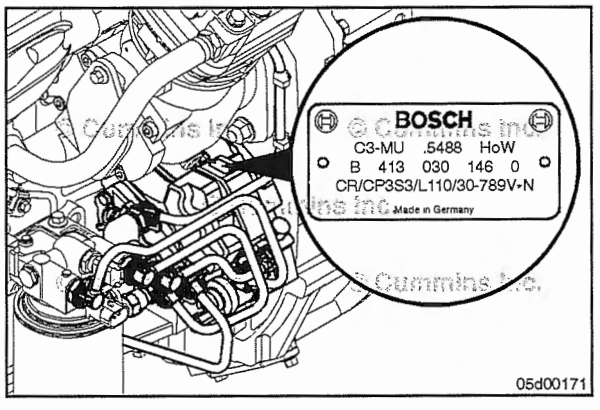
NOTE: If the engine dataplate (1) is **not** legible, the engine serial number (2) can be found on the engine block, on top of the lubricating oil cooler housing. Additional engine information is available by reading the engine control module (ECM) dataplate.



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 100-008 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.



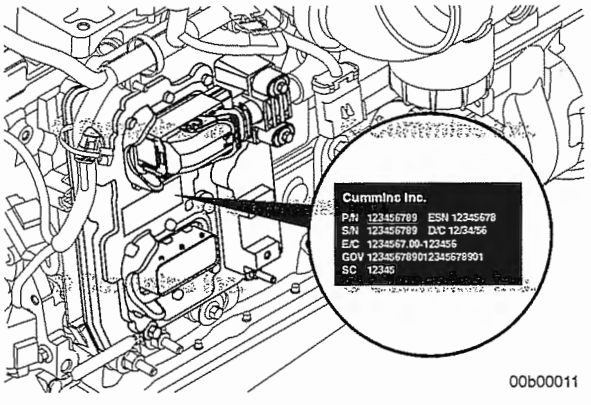
Fuel Injection Pump Dataplate

The Bosch™ fuel injection pump dataplate is located on the fuel pump.

The dataplate contains the following information to assist in servicing or replacement:

- Pump serial number
- Cummins® part number
- Factory code
- Bosch™ part number
- Date code

Engine Control Module Dataplate



NOTE: Not all engines will have ECM dataplates.

Engines covered by this manual are equipped with a CM2350 ECM. A CM2350 ECM has two 96 pin connectors. One of the 96 pin connectors is for inputs and outputs **only**. The second 96 pin connector and the 24 pin connector are for aftertreatment and vehicle inputs and outputs.

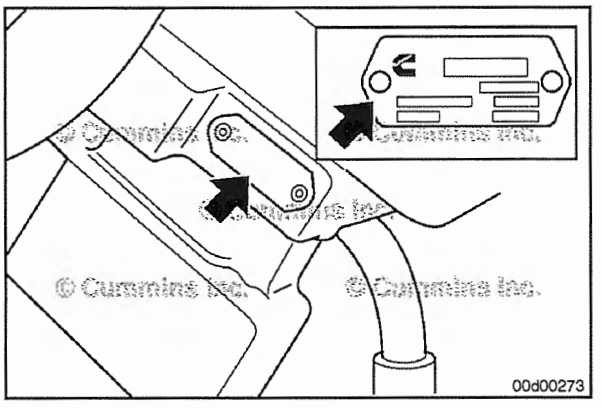
NOTE: The presence of an ECM dataplate depends on the manufacturing plant and the date the engine was manufactured. If an ECM dataplate was not installed by the manufacturing plant, calibration data can be found on the engine dataplate.

Air Compressor

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

The Cummins® branded air compressor dataplate, identified by the Cummins Inc. logo, is typically located on the side of the air compressor. The dataplate contains the following information to assist in servicing or replacement:

- Cummins® part number
- Serial number
- Date code.

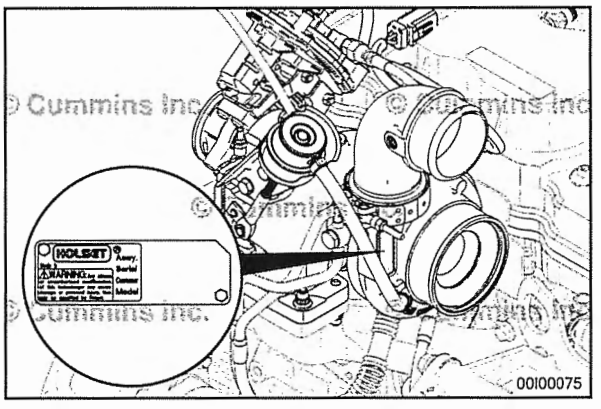


Turbocharger Dataplate

The Holset® turbocharger dataplate is located on the turbocharger inlet compressor housing.

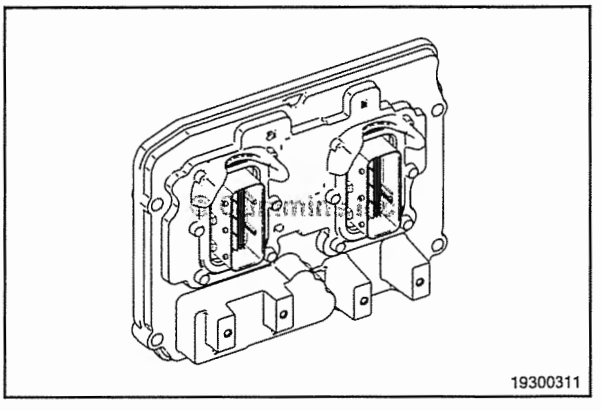
The dataplate contains the following information to assist in servicing or replacement:

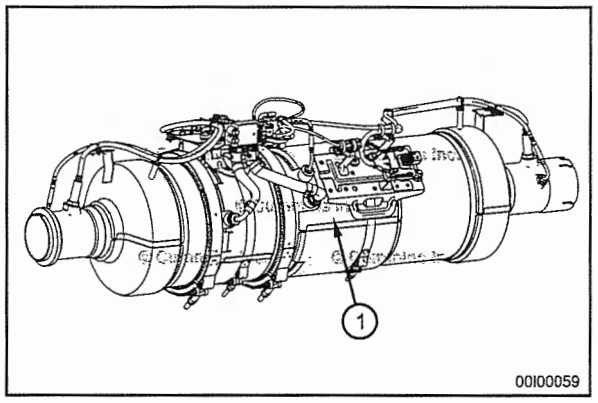
- Cummins® assembly part number
- Serial number
- Customer number
- Model number.



Exhaust System

INSITE™ electronic service tool can read the aftertreatment assembly part and serial numbers. This information can be found in the Aftertreatment section of the Features and Parameters menu.





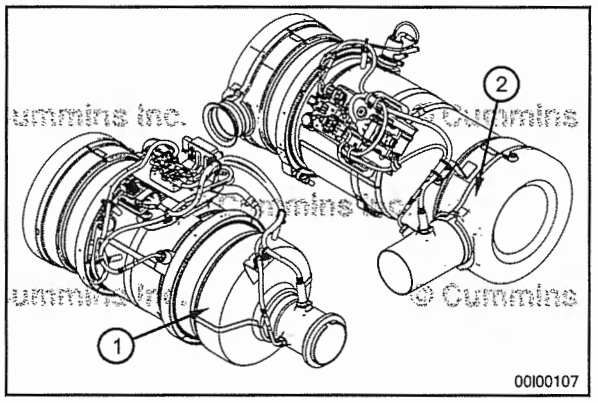
The aftertreatment system can be configured in two styles: Single Module or Flex Module.

The aftertreatment assembly has information laser-etched into the canister. There are several important identification locations on the aftertreatment systems.

Single Module systems have one assembly part number.

Single Module locations:

1 Aftertreatment assembly part identification.

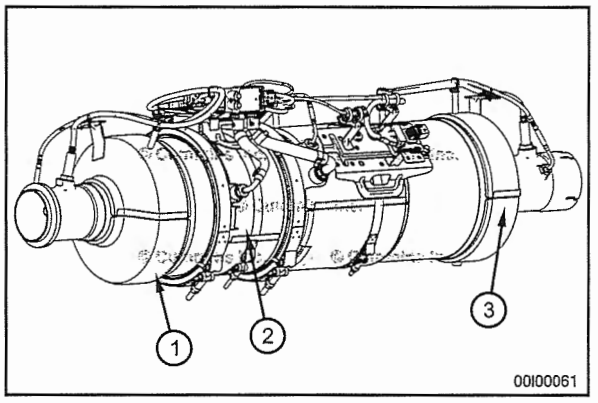


Flex Module systems have two assembly part numbers.

Flex Module locations:

1 Diesel particulate filter (DPF) assembly part identification.

2 Selective catalytic reduction (SCR) assembly part identification.



The aftertreatment system also has several component part numbers laser-etched into the canister.

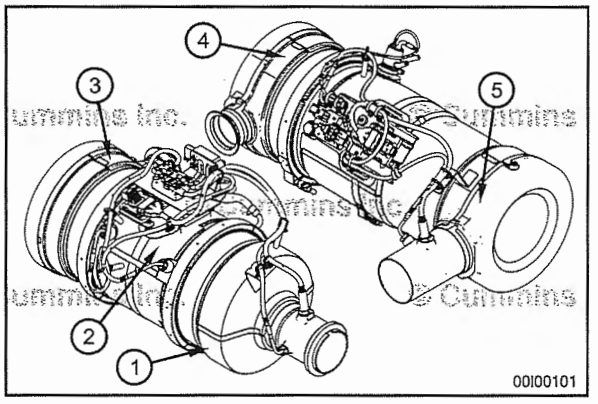
Single Module systems have three component part numbers .

Single Module locations:

1 Diesel oxidation catalyst (DOC) part identification

2 DPF part identification

3 Decomposition reactor tube and SCR part identification.



Flex Module systems have five component part numbers.

Flex Module locations:

1 DOC part identification

2 DPF part identification

3 DPF system outlet part identification

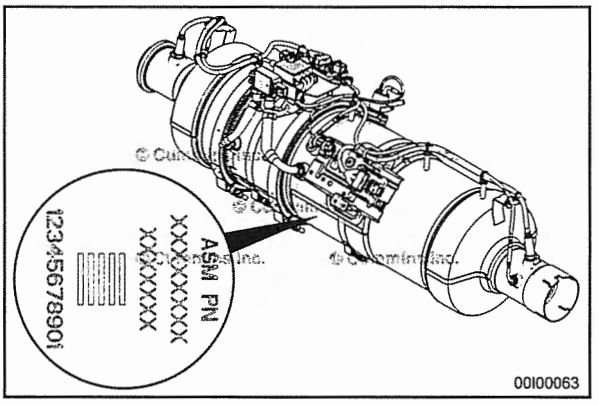
4 SCR system inlet part identification

5 Decomposition reactor tube and SCR part identification.

Aftertreatment Assembly Part Identification

The aftertreatment assembly part identification numbers are located on the side of the module. There are three different numbers on the decomposition reactor tube and SCR.

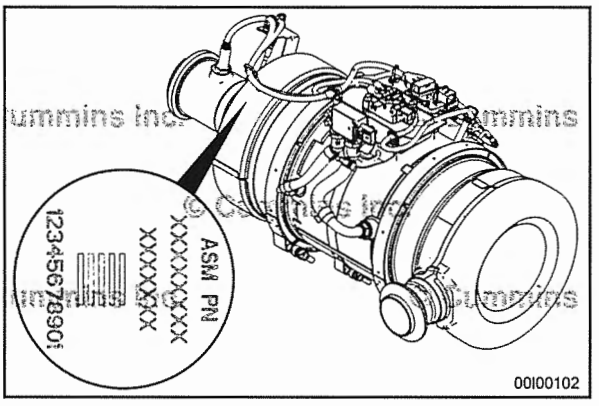
- The Cummins Emission Solutions™ part number (A###A###) (E PN)
- The Cummins part number (########) (C PN)
- The aftertreatment assembly serial number (############).



DPF Assembly Part Identification

The DPF assembly part identification numbers are located on the side of the DOC module. There are three different numbers on the DOC.

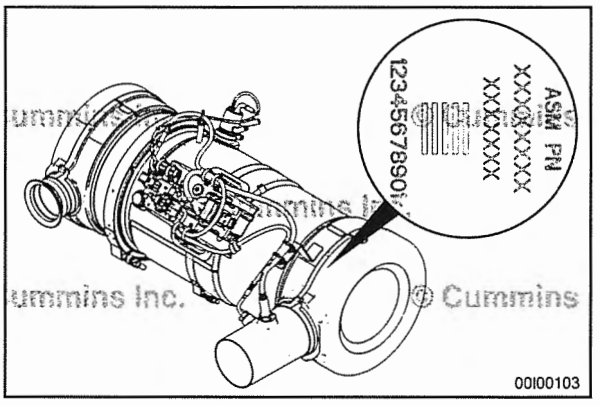
- The Cummins Emission Solutions™ part number (A###A###) (E PN)
- The Cummins part number (########) (C PN)
- The DPF assembly serial number (############).



SCR Assembly Part Identification

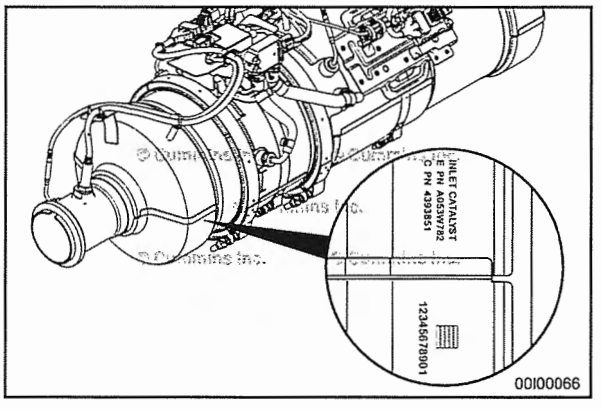
The SCR assembly part identification numbers are located on the side of the module. There are three different numbers on the decomposition reactor tube and SCR.

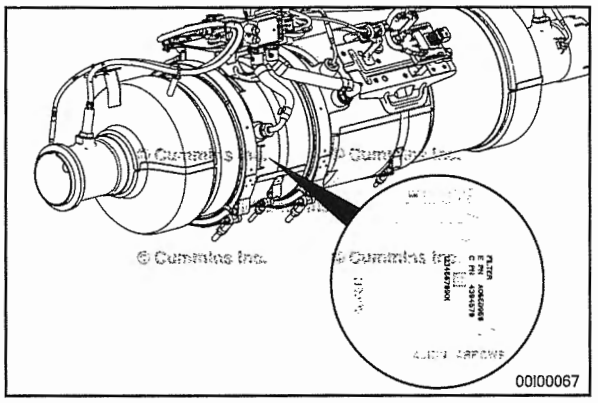
- The Cummins Emission Solutions™ part number (A###A###) (E PN)
- The Cummins part number (########) (C PN)
- The SCR assembly serial number (############).



The DOC part identification numbers are located on the side of the module. There are three different numbers on the DOC.

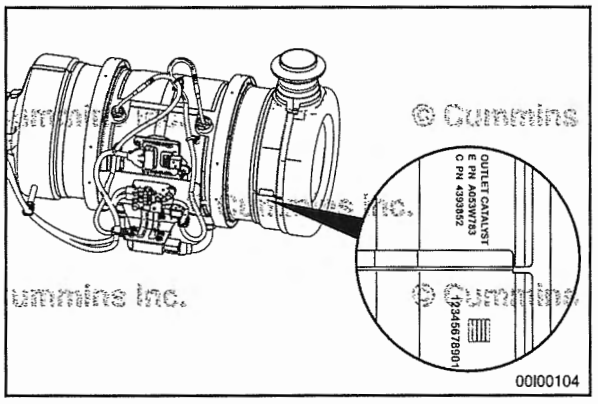
- Cummins Emission Solutions™ number (A###A###) (E PN)
- Cummins® part number (########) (C PN)
- DOC serial number (############).





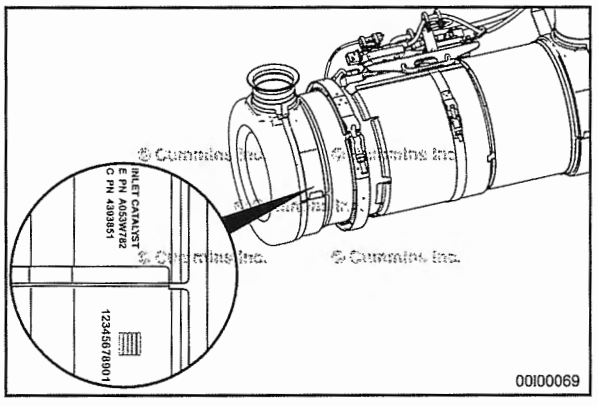
The DPF part identification numbers are located on the side of the module. There are three different numbers on the DPF.

- Cummins Emission Solutions™ part number (A###A###) (E PN)
- Cummins part number (########) (C PN)
- DPF serial number (###########).



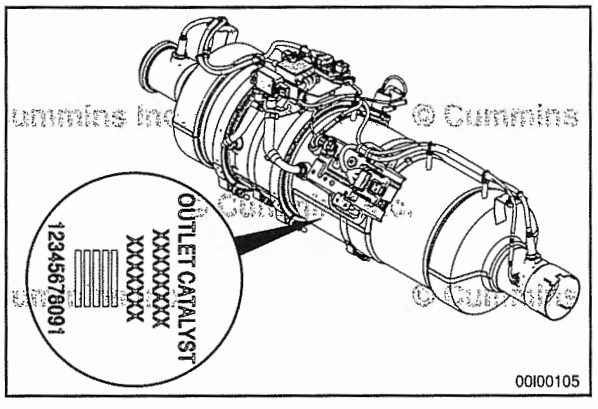
The DPF System outlet part identification numbers are located on the side of the module. There are three different numbers on the outlet module.

- Cummins Emission Solutions™ part number (A###A###) (E PN)
- Cummins part number (########) (C PN)
- DPF serial number (###########).



The SCR system inlet part identification numbers are located on the side of the module. There are three different numbers on the SCR system inlet module.

- Cummins Emission Solutions™ part number (A###A###) (E PN)
- Cummins part number (########) (C PN)
- SCR serial number (###########).

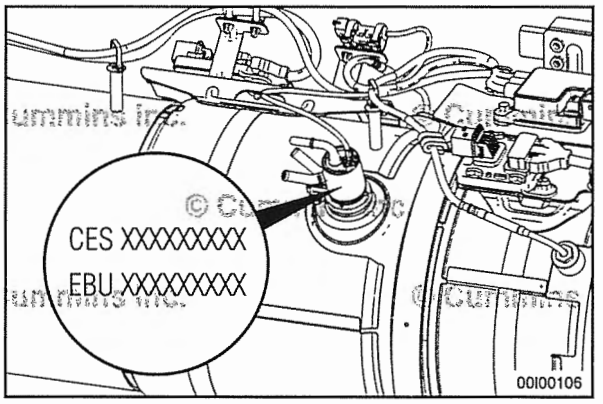


The decomposition reactor tube and SCR part identification numbers are located on the side of the module. There are three different numbers on the decomposition reactor tube and SCR.

- Cummins Emission Solutions™ part number (A###A###) (E PN)
- Cummins part number (########) (C PN)
- SCR serial number (###########).

The diesel exhaust fluid (DEF) dosing valve identification is located on the side.

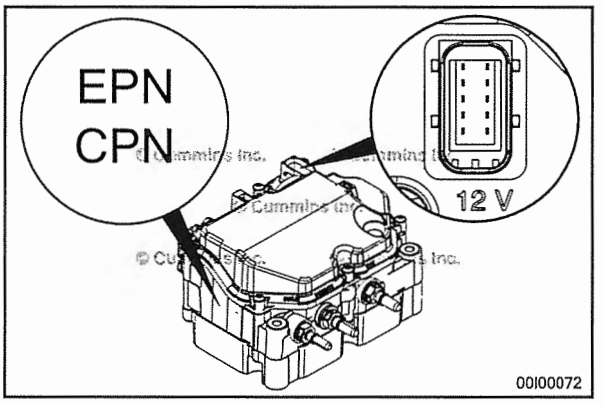
- Cummins Emission Solutions™ part number
- Cummins part number.

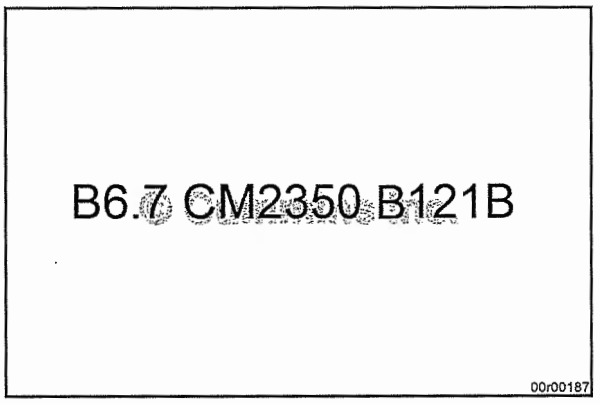


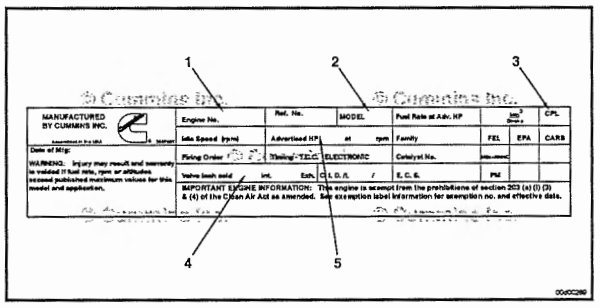
The aftertreatment DEF dosing unit identification is located on the side.

- Cummins Emission Solutions™ part number
- Cummins® part number.

The DEF dosing unit voltage (12V or 24V) identification is located near the electrical connector.







Cummins® Service Engine Model Identification (2017)

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.

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
B6.7	B6.7 CM2350 B121B

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

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

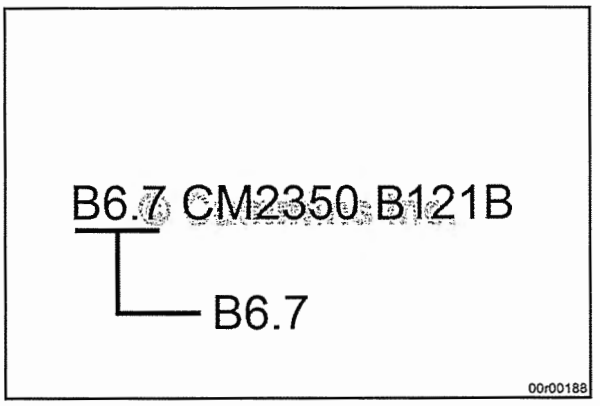
- QuickServe™ Online
- INSITE™ electronic service tool
- Owner's Manual
- Operation and Maintenance Manual
- Master Repair Manual
- Service Manual
- Wiring Diagram
- Fault Code Troubleshooting Manual
- Standard Repair Times
- Technical Service Bulletins
- Service Bulletins

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

The first two letters of the marketing model may still contain an “IS” or “QS” if the engine is an electronic engine.

“IS” prefix designates an on-highway engine.

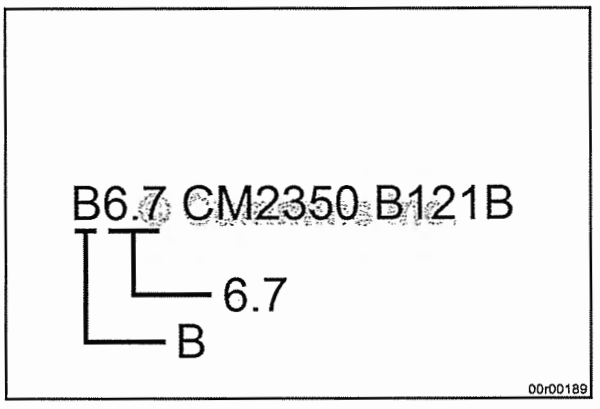
“QS” prefix designates an off-highway engine.



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

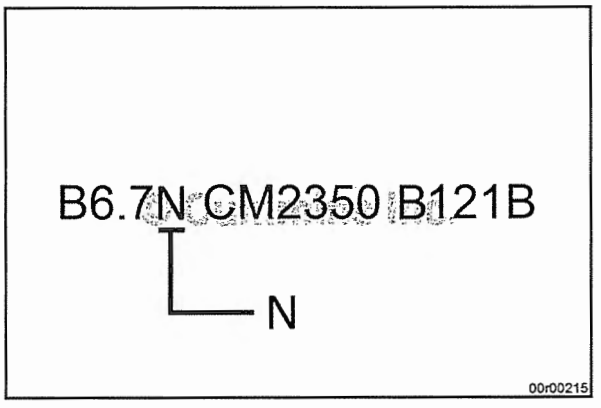
B Series engine.

6.7 Liters in Displacement.

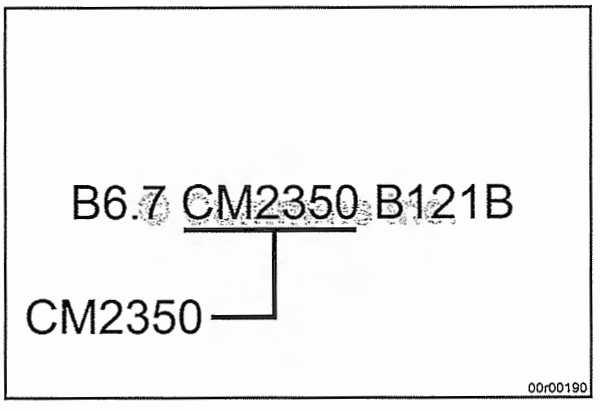


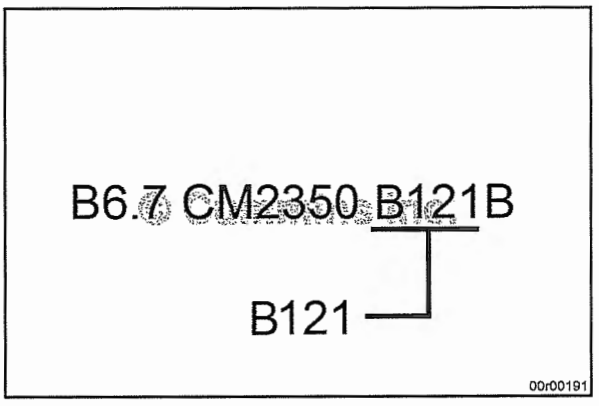
If no letter is located after the engine liter displacement information, the engine is fueled by diesel.

If the letter “N” is located after the engine liter displacement information, the engine is fueled by natural gas.



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

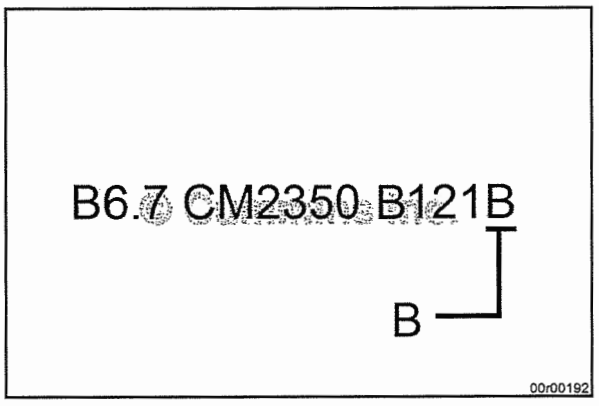




The identifier after the control system is a letter and number combination to identify variations between products.

The letter is the engine platform designation.

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



The letter at the end of the suffix identifies the general application for which the product is intended to be used.

- B – Automotive
- C – Industrial
- G – Power Generation/Generator Drive
- M – Marine

Cummins® Product Technology

General Information

The service model name for this product is **B4.5 CM2350 B146C.**

This engine is being released to meet the following emission regulations:

United States and Canada

- Environmental Protection Agency (EPA)
  - Tier 4 (Final)

European Union

- Stage V (Euro)

Korea (South)

- Tier 4 (Final)

The Control Parts List(s) (CPL) associated with this product are:

- 4936
- 4937
- 4938

EPA Products:

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

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

This engine uses the following product technology:

Engine

- Number of Cylinders: 4
- Engine Configuration
  - Inline
- Engine Orientation
  - Vertical
- Cylinder Block Material
  - Cast Iron
- Cylinder Head Material
  - Cast Iron
- Valves Per Cylinder
  - Exhaust Quantity: 2
  - Intake Quantity: 2
- Camshaft Location
  - Cylinder Block

- Camshaft Followers/Tappets
  - Sliding Followers/Tappets
- Primary Gear Train Location
  - Rear of the Engine
- Engine Balancer Option
  - Internal
- Engine Braking
  - Exhaust Brake Option
- REPTO Option
- Accessory Drive Option
- Crankcase Ventilation System
  - Open

Fuel System

- Diesel
- Common Rail Fuel System
  - Bosch® Common Rail Fuel System

Air Handling

- Turbocharger (Single)
  - Wastegate
- Intake Air Heater
- Charge Air Cooler

Exhaust System

- Aftertreatment Fuel Injection
  - Internal
- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
  - Full Flow
- Selective Catalytic Reduction (SCR) Catalyst
- Bosch® Aftertreatment Diesel Exhaust Fluid (DEF) Dosing System
  - Airless Diesel Exhaust Fluid Dosing Unit
- Exhaust Pressure Regulator

Electrical Equipment

- Starting System
  - Electric Starting Motor Option
    - 12 VDC
    - 24 VDC
- Charging System (Voltage Options)
  - 12 VDC
  - 24 VDC

Electronic Control System

- Engine Control Module (Single)
  - Control Module: CM2350
- ECM Supply Voltage:
  - 12 VDC

  - 24 VDC
- Engine Coolant Level Sensor
- Engine Coolant Temperature Sensor
- Engine Oil Pressure Switch
- Camshaft Position Sensor
- Crankshaft Position Sensor
- Fuel Rail Pressure Sensor
- Water in Fuel Sensor
- Exhaust Gas Pressure Sensor
- Intake Manifold Pressure/Temperature Sensor
- Turbocharger Compressor Intake Pressure/Temperature Sensor
- Aftertreatment Diesel Particulate Filter Differential Pressure Sensor
- Aftertreatment Exhaust Gas Temperature Sensor
- Aftertreatment Diesel Exhaust Fluid Tank Level/Temperature/Quality Sensor
- Aftertreatment Intake NOx Sensor
- Aftertreatment Outlet NOx Sensor

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

Industrial

- Agriculture
- Construction
- Power Unit
- Welding
- Air Compressor

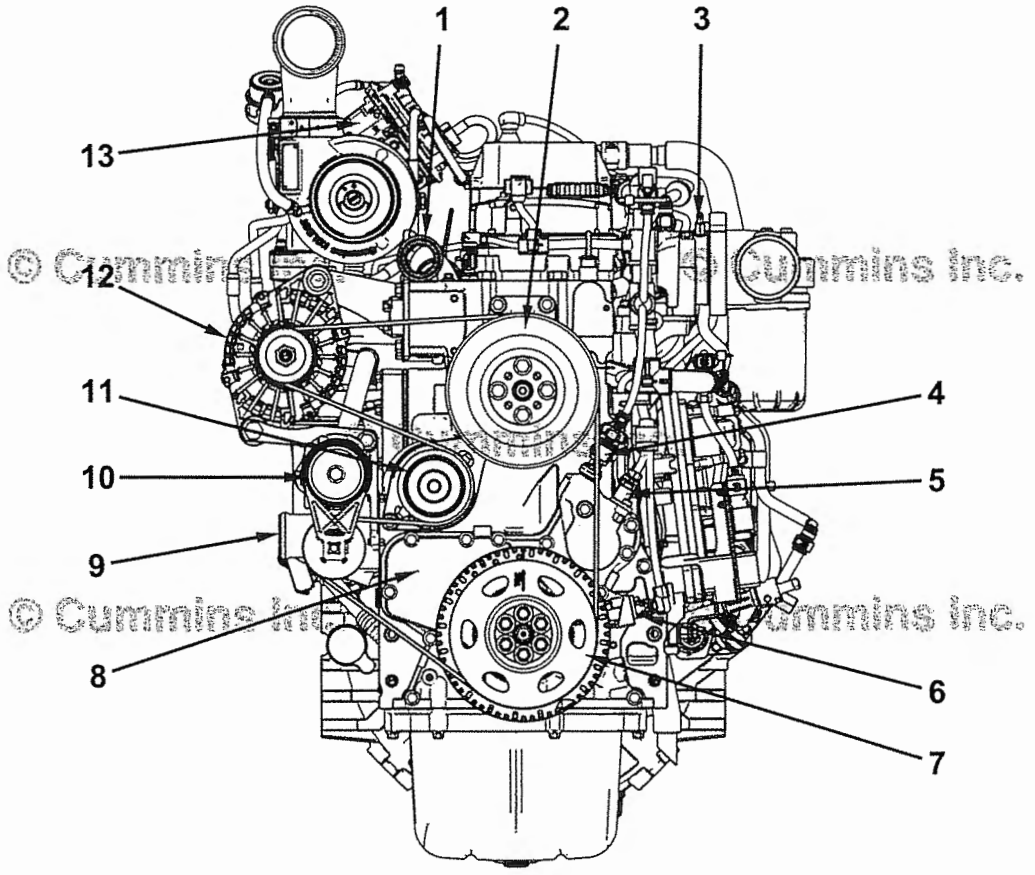
Engine Diagrams

Engine Views

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

Engine Diagrams

Engine Views

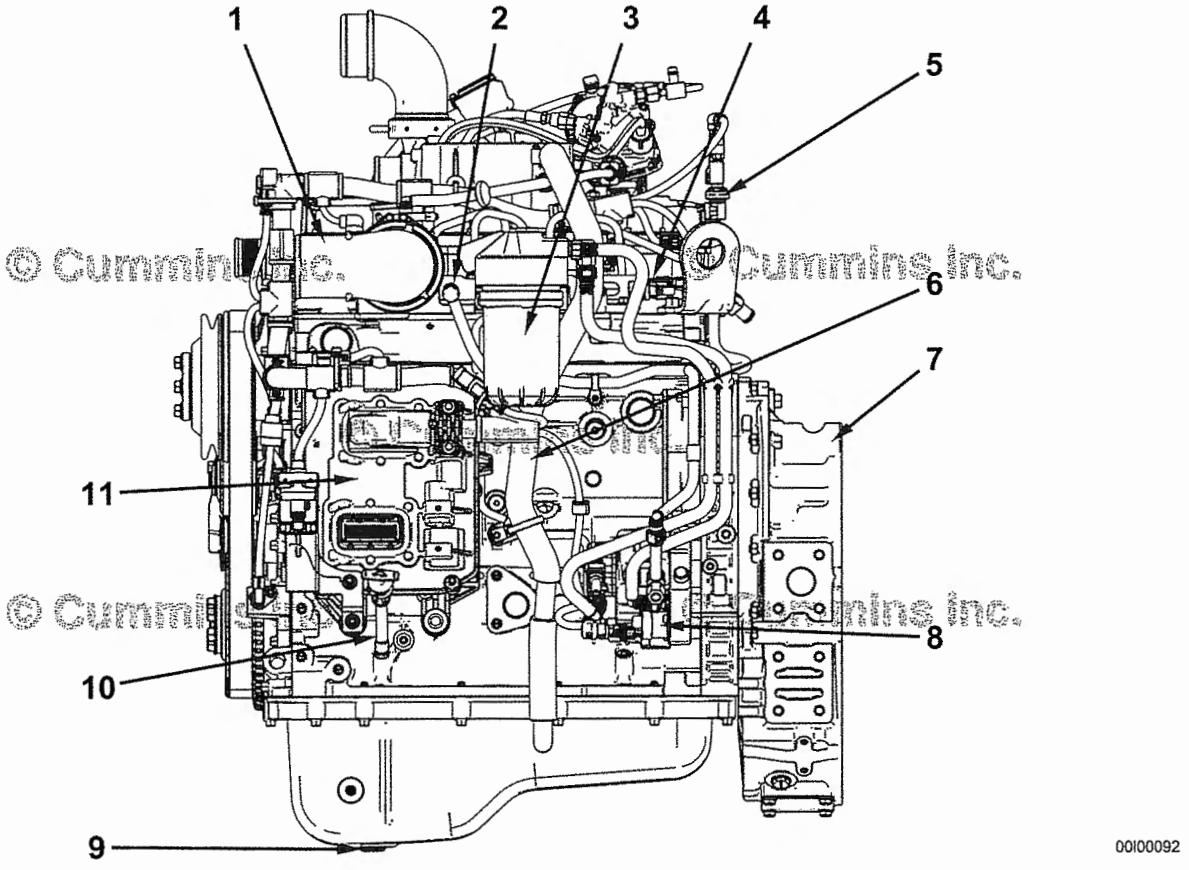


Front View

1 Coolant outlet connection/thermostat housing
2 Fan hub
3 Intake manifold grid heater
4 Oil pressure switch
5 Engine speed/position sensor (camshaft)
6 Engine speed/position sensor (crankshaft)
7 Crankshaft pulley
8 Front gear cover
9 Coolant inlet connection
10 Automatic belt tensioner
11 Water pump
12 Alternator
13 Exhaust pressure regulator.

Engine Diagrams

Engine Views

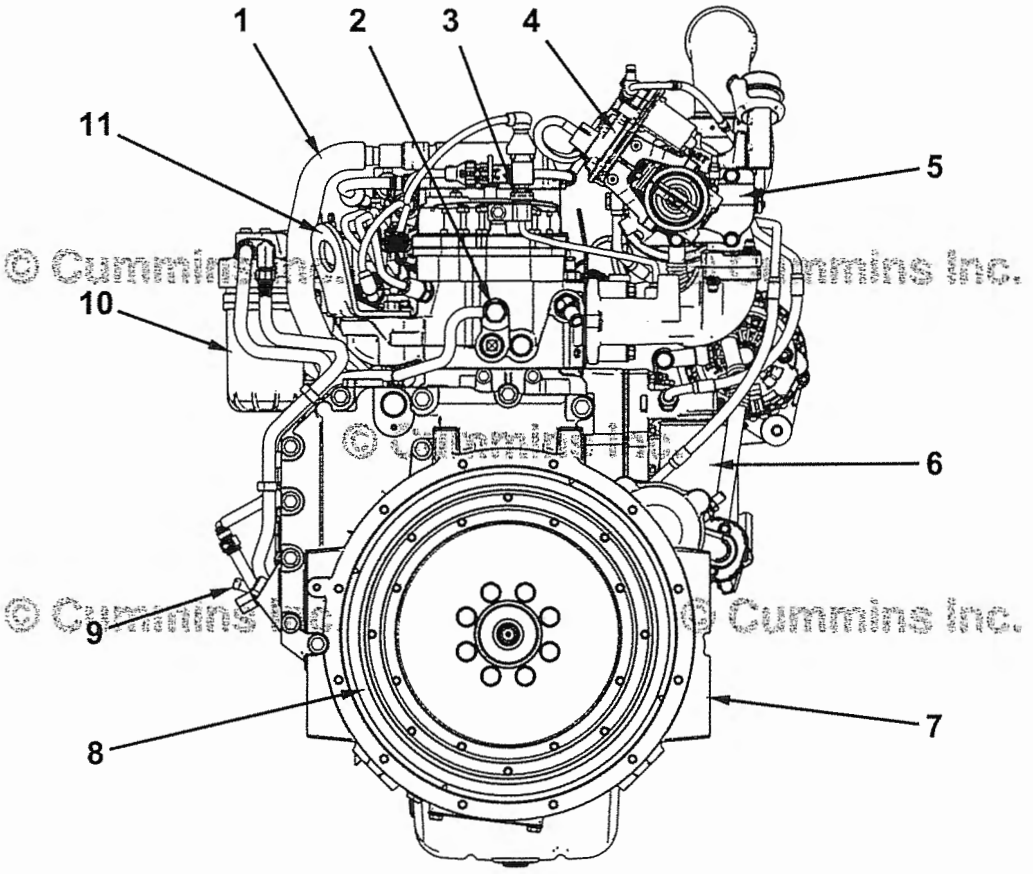


Left Side View

1 Intake air inlet
2 Fuel rail pressure relief valve
3 Fuel filter
4 Fuel pressure sensor
5 Exhaust manifold pressure sensor
6 Breather drain tube
7 Flywheel housing
8 Bosch™ fuel pump
9 Lubricating oil drain plug
10 Lubricating oil dipstick
11 Electronic control module (ECM).

Engine Diagrams

Engine Views

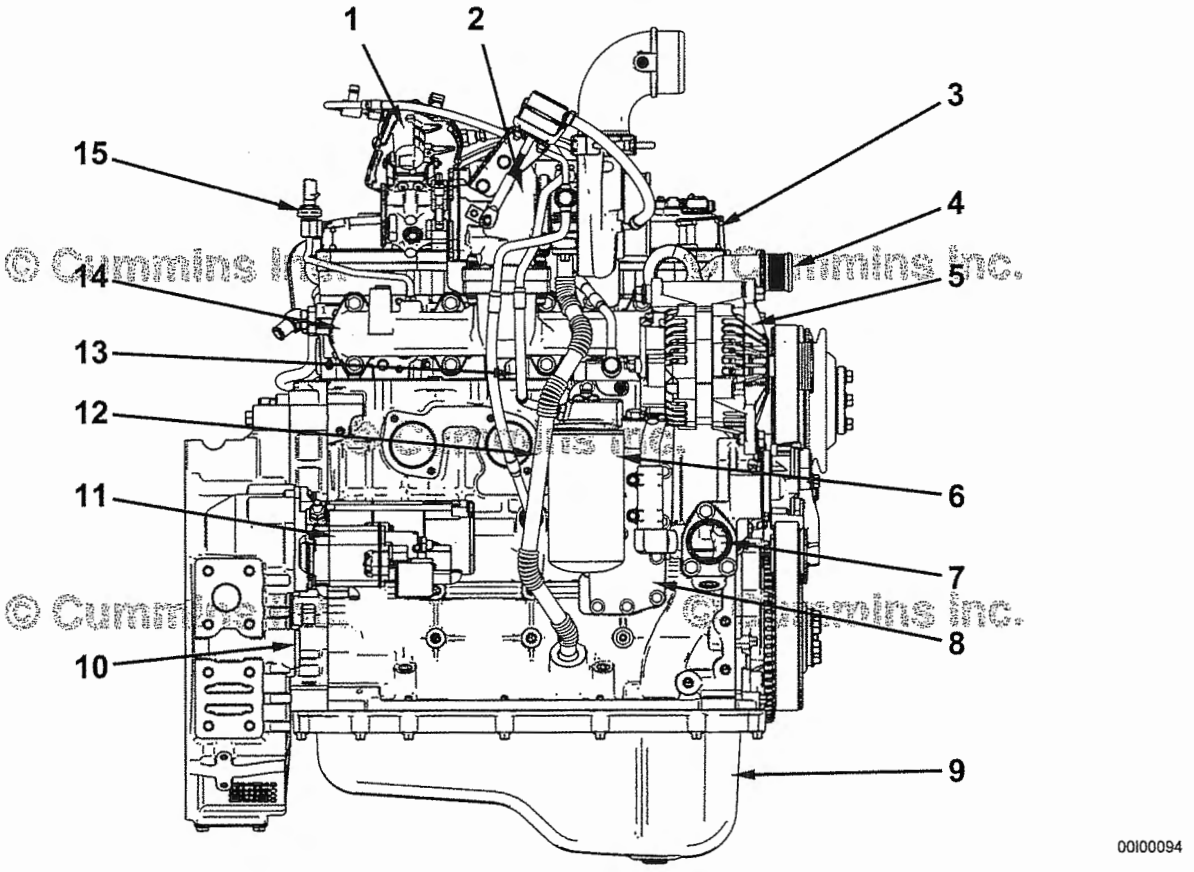


Rear View

1 Breather drain tube
2 Fuel drain tube
3 Exhaust manifold pressure sensor
4 Exhaust pressure regulator
5 wastegate turbocharger
6 Lubricating oil filter
7 Flywheel housing
8 Flywheel
9 Lubricating oil dipstick
10 Fuel filter
11 Rear engine lifting bracket.

Engine Diagrams

Engine Views

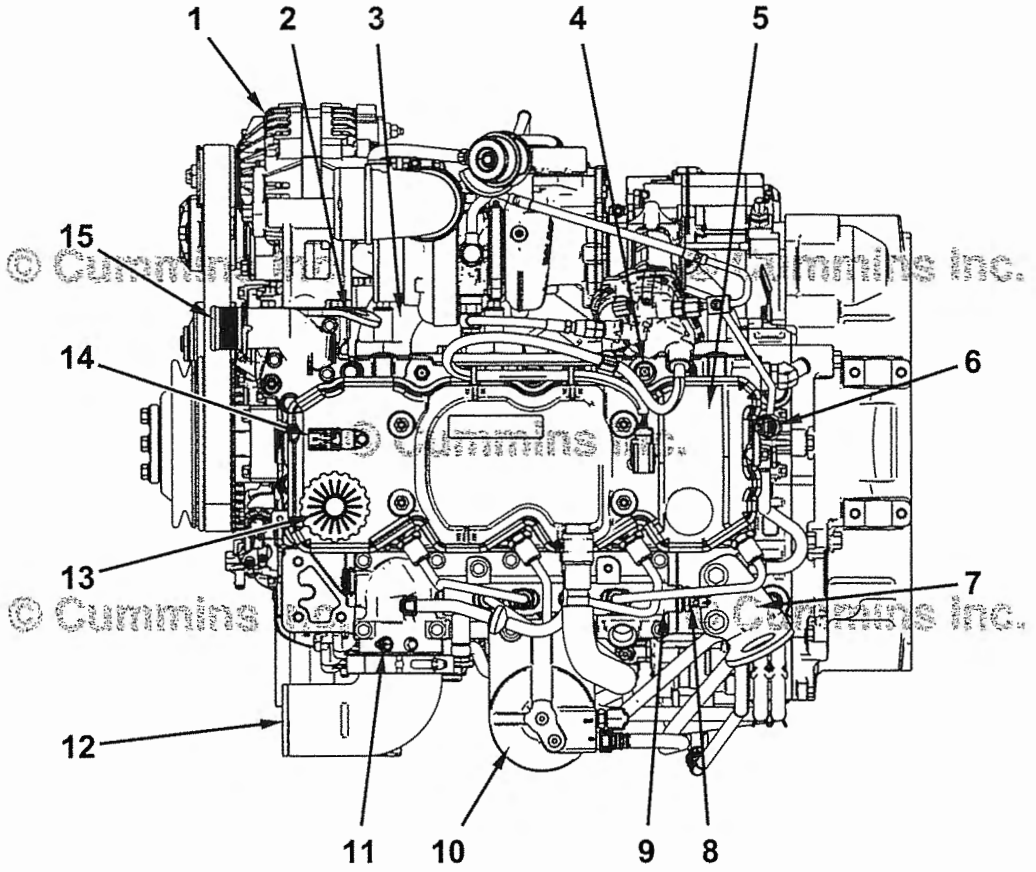


Right Side View

1 Exhaust pressure regulator
2 Wastegate turbocharger
3 Valve cover
4 Coolant outlet
5 Alternator
6 Lubricating oil filter
7 Coolant inlet
8 Lubricating oil cooler
9 Lubricating oil pan
10 Service access barring point
11 Starter
12 Turbocharger lubricating oil drain
13 Turbocharger lubricating oil supply
14 Exhaust manifold
15 Exhaust manifold pressure sensor.

Engine Diagrams

Engine Views

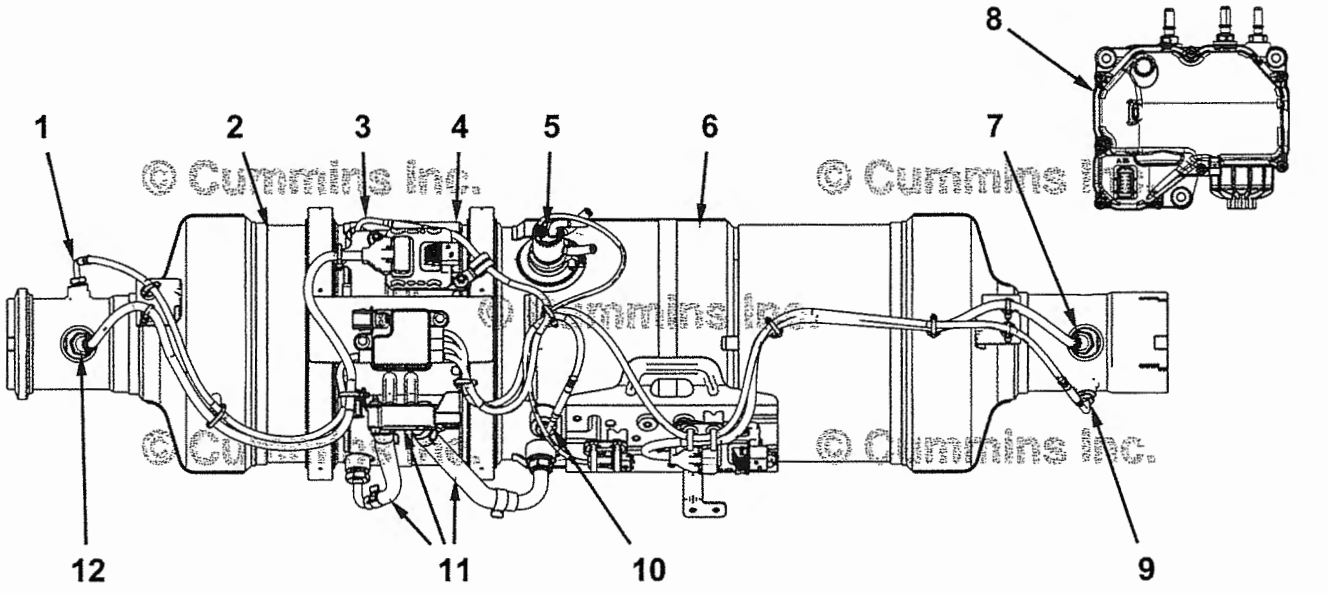


Top View

1 Alternator
2 Front engine lifting bracket
3 Exhaust manifold
4 Coolant dearation port
5 Valve cover
6 Exhaust manifold pressure sensor
7 Rear engine lifting bracket
8 Fuel rail pressure sensor
9 Fuel manifold
10 Fuel filter head
11 Intake air heater
12 Intake manifold inlet connection
13 Oil fill cap
14 Crankcase pressure sensor
15 Coolant outlet.

Aftertreatment System Diagrams

Aftertreatment System Views



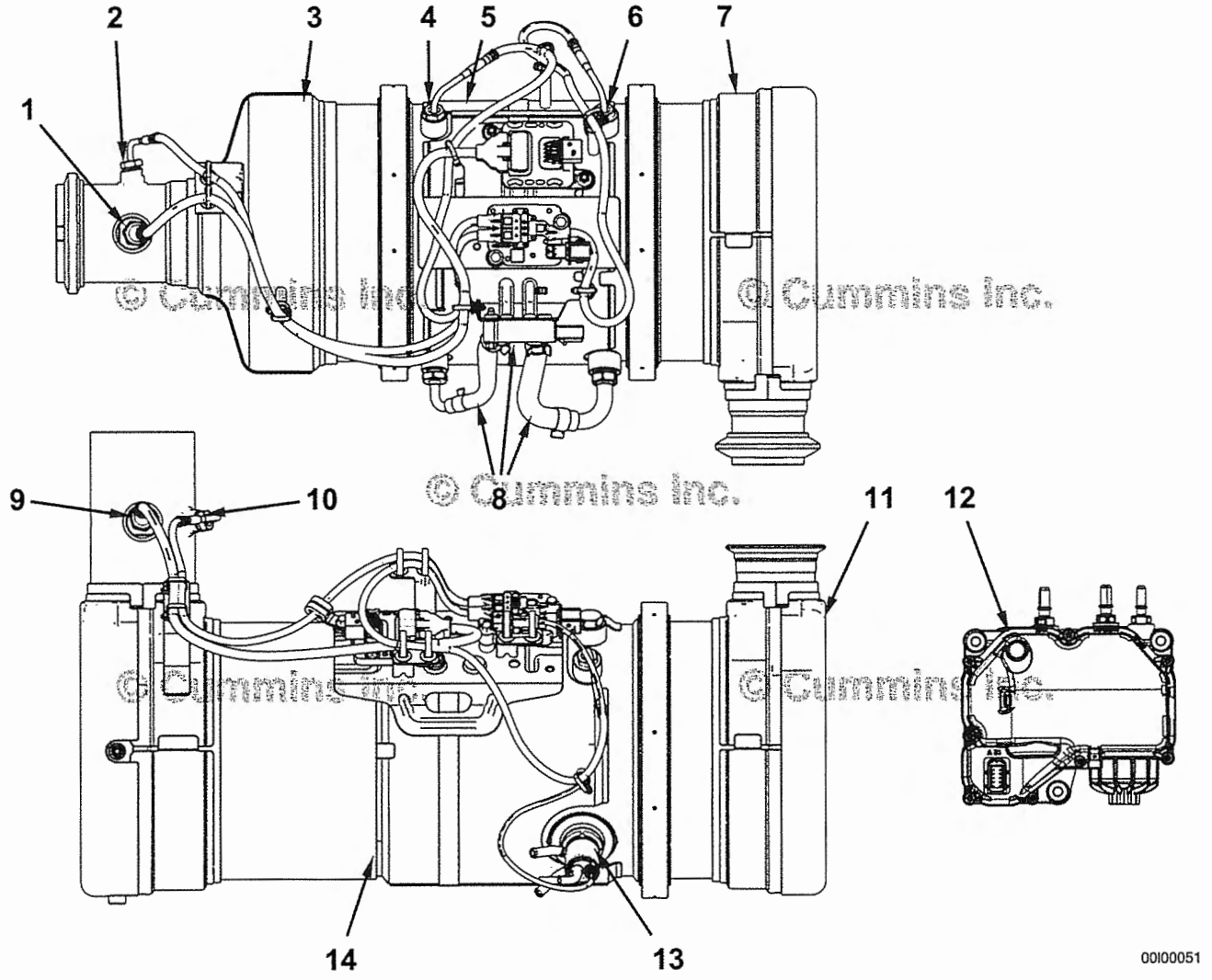
00I00050

Single Module

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

Aftertreatment System Diagrams

Aftertreatment System Views



Single Module Flex Module

1 Aftertreatment intake NOx sensor
2 Aftertreatment DOC intake temperature sensor
3 Aftertreatment DOC
4 Aftertreatment DPF intake temperature sensor
5 Aftertreatment DPF
6 Aftertreatment DPF outlet temperature sensor
7 Aftertreatment DPF system outlet
8 Aftertreatment DPF differential pressure sensor and tubes
9 Aftertreatment outlet NOx sensor
10 Aftertreatment SCR outlet temperature sensor
11 Aftertreatment SCR system inlet
12 Aftertreatment DEF dosing unit
13 Aftertreatment DEF dosing valve
14 Aftertreatment decomposition tube and SCR catalyst assembly.

Notes

Section 1 - Operating Instructions

Section Contents

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Operating Instructions - Overview

General Information

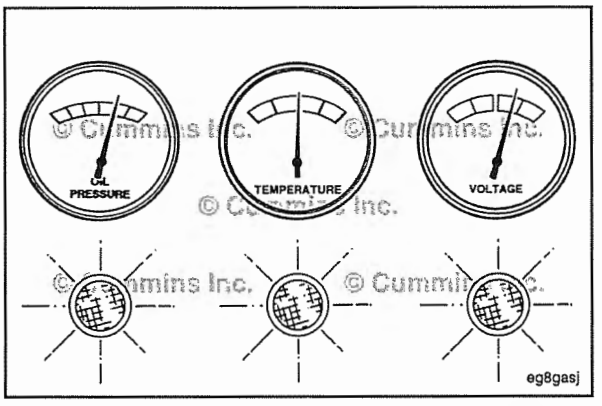
Correct care of your engine will result in longer life, better performance, and more economical operation.

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

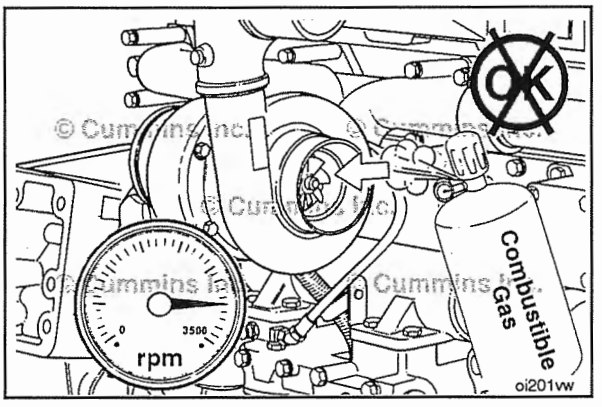
The new Cummins® engine associated with this manual does **not** require a "break-in" procedure. This section of the manual provides all of the necessary information required for proper engine operation.

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

Check the oil pressure, coolant temperature, 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.

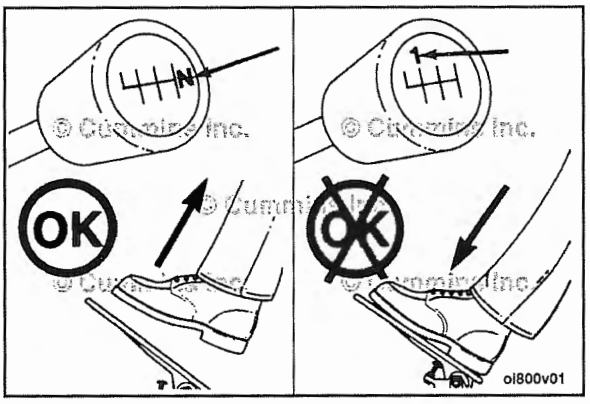


⚠WARNING⚠
Do not operate a diesel engine where there are or can BE COMBUSTIBLE vapors. These vapors can be sucked through the air intake system and cause engine acceleration and over speeding that can result in a fire, an explosion, and extensive property damage. Numerous safety devices are available, 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.

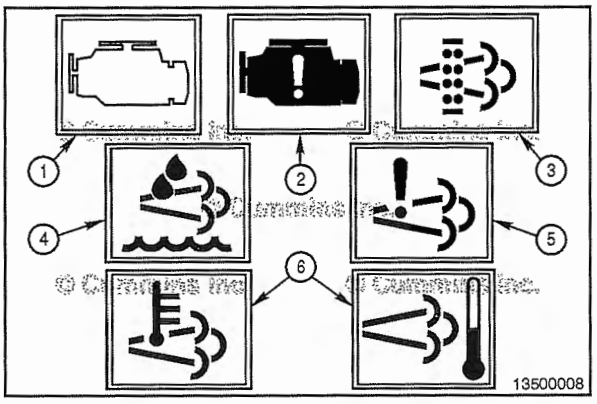


Normal Starting Procedure

Starting

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.



With the key in the ON position, the engine indicator lamps will come on momentarily and then go out. The engine indicator lamps include:

1 WARNING (or CHECK ENGINE) lamp, amber in color

2 STOP (or STOP ENGINE) lamp, red in color

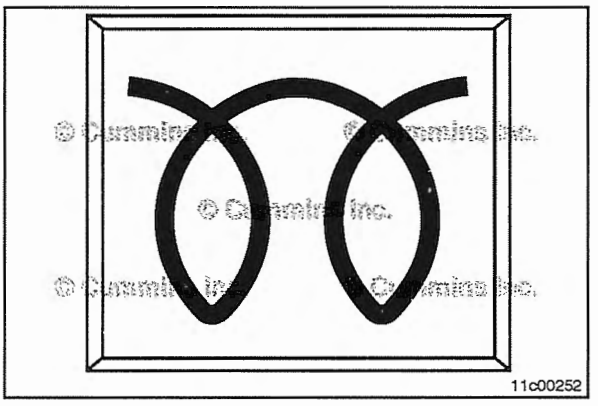
3 SELECTIVE CATALYTIC REDUCTION (SCR) SYSTEM CLEANING lamp, amber in color

4 DIESEL EXHAUST FLUID lamp, amber in color

5 SCR SYSTEM CLEANING INHIBIT lamp, amber in color.

Additionally, some engines have an additional lamp, (6) HIGH EXHAUST SYSTEM TEMPERATURE, which is amber in color. If any of the lamps remain on or begin to flash, see the following procedure. Refer to Procedure 101-048 in Section 1.

⚠CAUTION⚠
Do not engage the starting motor for more than 30 seconds or damage to the starting motor can result. Wait 2 minutes between each attempt to start (electrical starting motors only).



Under cold conditions, the WAIT TO START lamp (generally a yellow lamp using a symbol similar to the graphic, or the words WAIT TO START) will also illuminate at key ON, and will stay on for a period of up to 30 seconds.

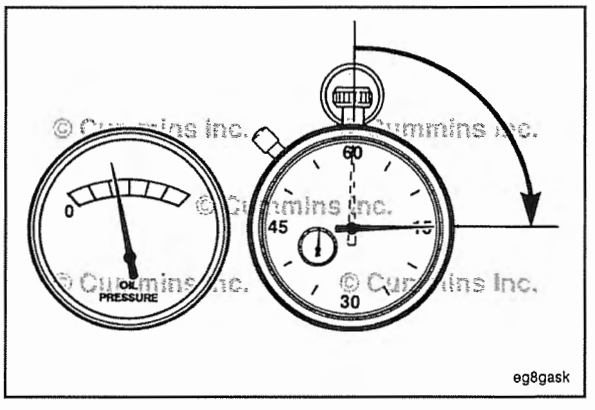
NOTE: The length of time the WAIT TO START lamp remains illuminated depends on the ambient temperature. The lower the ambient temperature, the longer the lamp will be illuminated.

Once the WAIT TO START lamp turns off, turn the key to the start position to start the engine. If the engine will not start, see the appropriate troubleshooting symptoms tree in Section TS in the operation and maintenance manual.

NOTE: Some engines are equipped with an engine starting motor protection feature. If the starting motor is engaged for 30 or more seconds without the engine starting, the starter will be locked out from operating, allowing for proper cooling of the starting motor. During this time, the WAIT TO START lamp will flash for 2 minutes. Once the lamp discontinues flashing, the starting motor will be allowed to function.

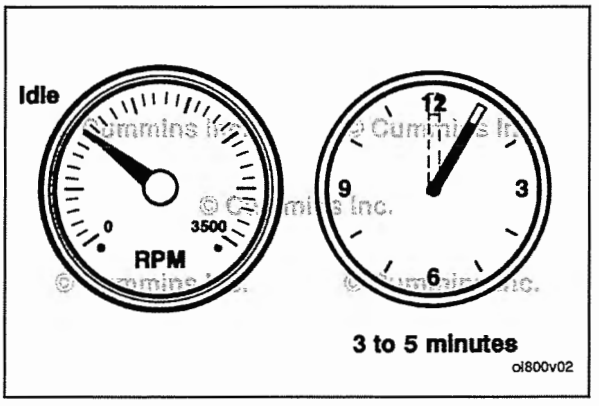
NOTE: Engines equipped with air starting motors require a minimum of 480 kPa [70 psi].

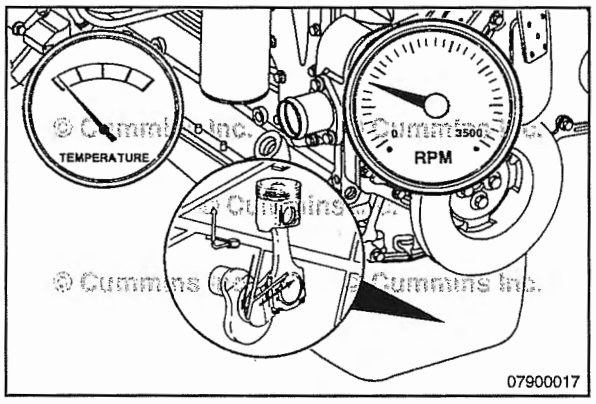
⚠CAUTION⚠
The engine must have adequate oil pressure within 15 seconds after starting. If the WARNING lamp indicating low oil pressure has not gone out or there is no oil pressure indicated on a gauge within 15 seconds, shut the engine OFF immediately to reduce the possibility of engine damage.



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

NOTE: After the engine is started, the voltmeter, if equipped, may show a gauge fluctuation under certain engine temperature conditions (both warm and cold). This cycling operation is caused by the post-heat cycle of the intake manifold heater system. The number of cycles and the length of the cycling operation is controlled by the engine control module. The cycling action will cause temporary dimming of the headlamps, interior lamps, and other vehicle electrical accessories.





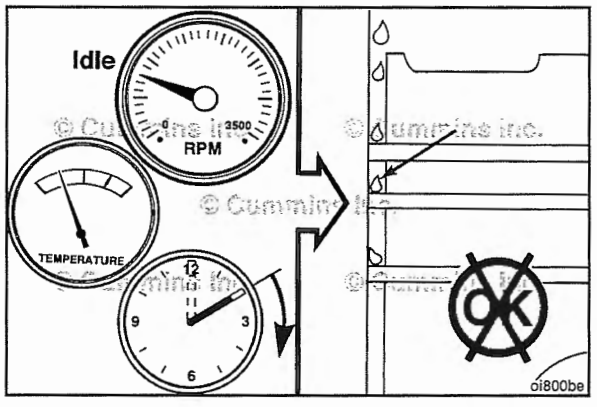
After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

NOTE: For engines equipped with the Engine Warm-Up Protection feature; this feature limits engine speed and torque following engine start-up until sufficient oil pressure is available to the engine components. This feature reduces the risk of engine part damage due to operating at engine speeds too high or excessive loads before adequate oil pressure is achieved.

Some engines are equipped with a Fast Idle Warm Up feature. When enabled, this feature elevates the idle speed of the engine in cold ambient conditions in order to shorten the time necessary to warm up the engine. When the idle speed is elevated, the engine noise can change. This is normal. To bring the engine back to low idle speed:

- For vehicles equipped with a manual transmission and clutch switch: Depress the clutch pedal.
- For vehicles equipped with a brake switch: Depress the service brake pedal.
- Depress the accelerator pedal.

For more information on the Fast Idle Warm Up feature, contact a Cummins® Authorized Repair Location.



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

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

Jump Starting

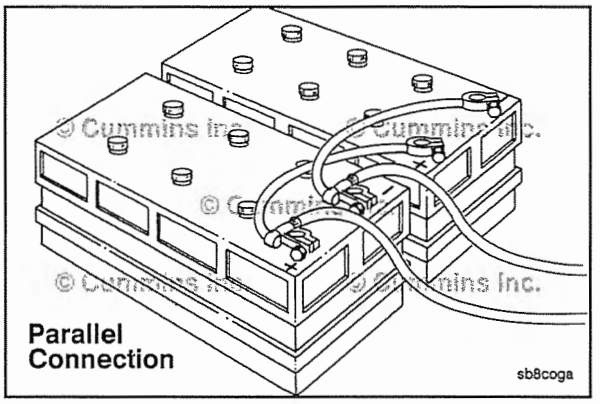
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

△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 the jumper starting or battery charging cable to any fuel system or electronic component.

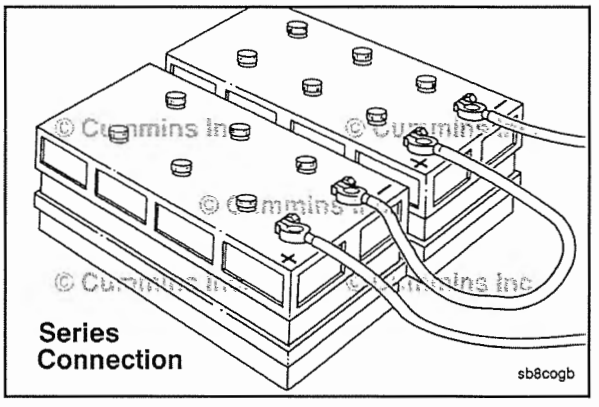
This illustration shows a typical parallel battery connection. This arrangement doubles the cranking amperage.

NOTE: Always use the relevant original equipment manufacturer (OEM) literature for jump starting procedures. Failure to follow correct procedures can result in damage to the engine control module and other electrical equipment.



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

NOTE: Always use the relevant OEM literature for jump starting procedures. Failure to follow correct procedures can result in damage to the engine control module and other electrical equipment.



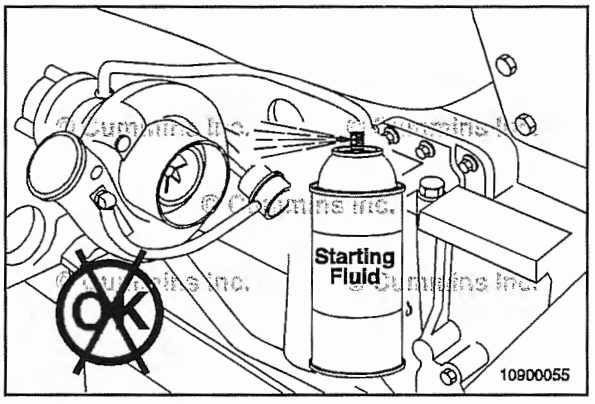
Cold Weather Starting

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.



Using Starting Aids

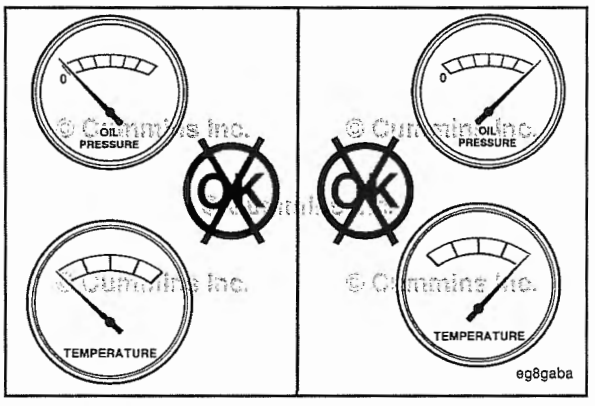
⚠WARNING⚠
Do not use starting fluids with this engine. This engine is equipped with an intake air heater: use of starting fluid can cause an explosion, fire, personal injury, severe damage to the engine, and property damage.

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 **not** start until the minimum cranking oil pressure is detected by the ECM. It can take more cranking time to start the engine after an extended shut down or oil change.

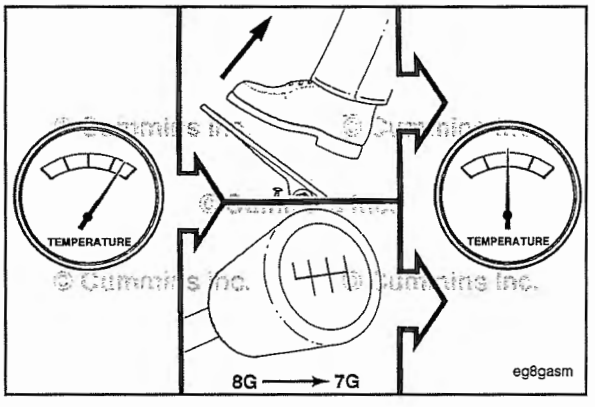


Operating the Engine

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.

△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).

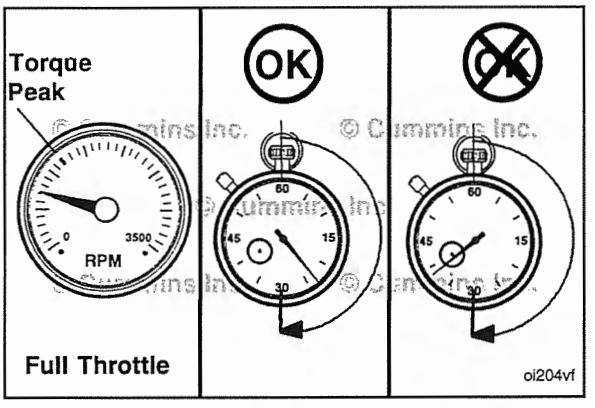
Engine Operating Range

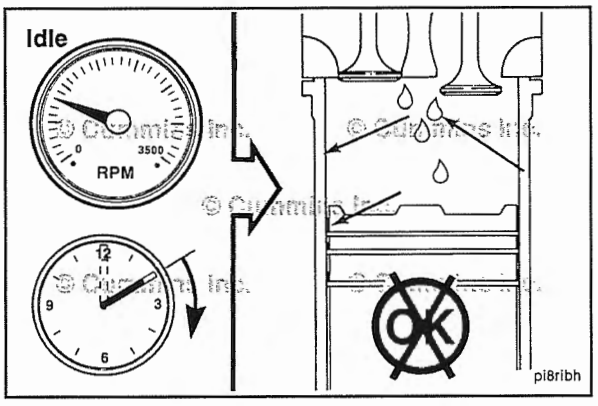
General Information

⚠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.

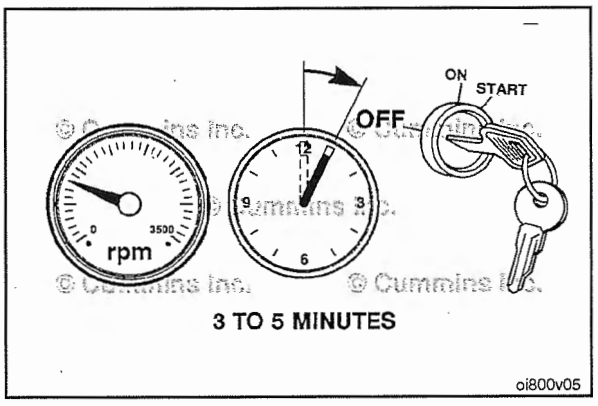
⚠CAUTION⚠
Do not operate the engine beyond the maximum engine speed. Operating the engine beyond the maximum engine speed can cause severe engine damage. Use proper operating techniques for the vehicle, vessel, or equipment to prevent engine overspeed. The maximum engine speed specification is listed 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.





⚠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, if equipped, and shorten the turbocharger life.

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

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, contact a Cummins® authorized repair location.

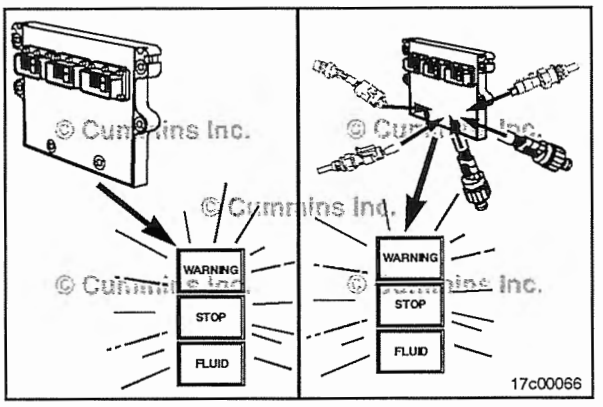
Electronic Controlled Fuel System

General Information

The base functions of the control system include fueling and timing control, limiting the engine speed operating range between the low- and the high-idle set points, and optimizing engine performance while maintaining emissions compliance. The system also controls the engine brakes.

The control system uses inputs from the operator and its sensors to determine the fueling and timing required to operate at the desired engine speed and at the required emissions level.

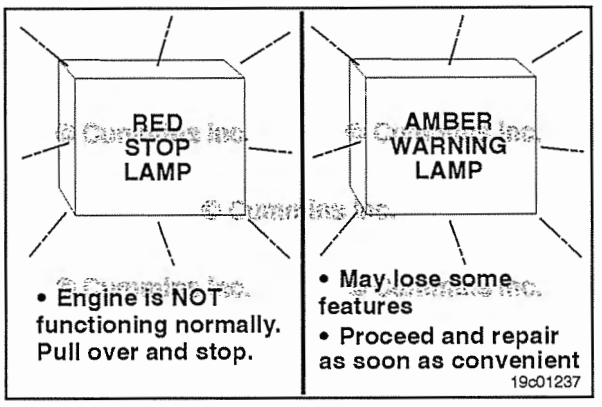
Diagnostic Fault Codes



The electronic engine control system can display and record certain detectable fault conditions. These failures are displayed as fault codes, which make troubleshooting easier. The fault codes are retained in the ECM.

There are two types of diagnostic codes:

- Engine electronic control system fault codes are to inform the operator that there is a problem with the control system that will require troubleshooting.
- Information and engine protection fault codes are to inform the operator that the control system has detected an engine condition outside the normal operating range.



All fault codes recorded will either be active (fault code is presently active on the engine) or inactive (fault code was active at some time, but is **not** presently active).

The "STOP" light is red and indicates the need to stop the engine as soon as it can be safely done. The engine **must** remain shut down until the fault can be repaired.

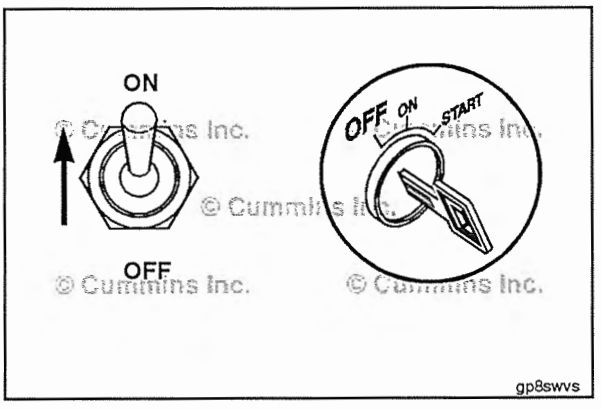
The "WARNING" light is amber and indicates the need to repair the fault at the first available opportunity.

Maintenance type fault codes will flash the amber WARNING light for 30 seconds after the keyswitch is turned to the ON position when one of the following occurs: maintenance is required (if Maintenance Monitor is turned on) or if water in fuel is detected.

If the WARNING light flashes for 30 seconds at key-on and water is drained from the primary, water-separating filter, the secondary filter **must** be replaced.

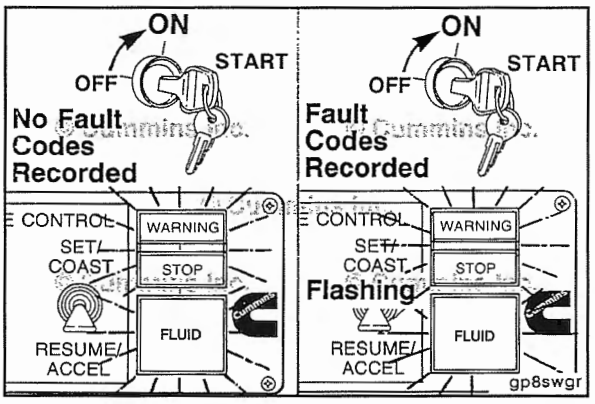
If the Water-In-Fuel lamp illuminates and water is drained from the primary, water-separating filter, the secondary filter **must** be replaced.

NOTE: The names and colors of these lamps can vary with equipment manufacturer.



Fault codes can be accessed in at least two different ways; with the electronic service tool or the fault code flash out.

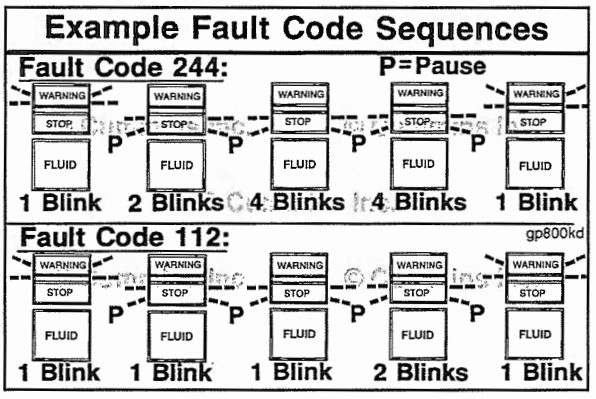
To check for active engine electronic fuel system and engine protection system fault codes, turn the keyswitch OFF and move the diagnostic switch to the ON position.



Turn the vehicle keyswitch to the ON position.

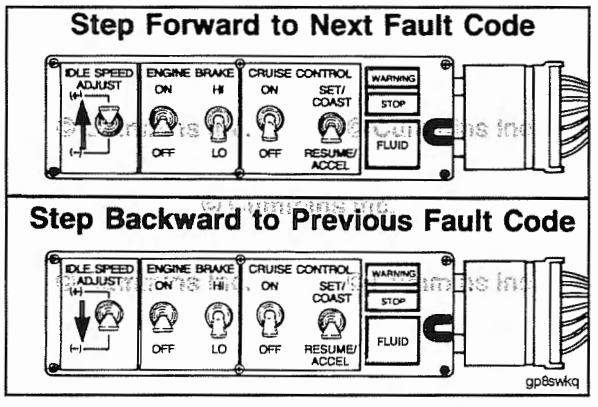
If no active fault codes are recorded, both lights will come on and stay on.

If active fault codes are recorded, both lights will come on momentarily, then begin to flash the code of the recorded faults.

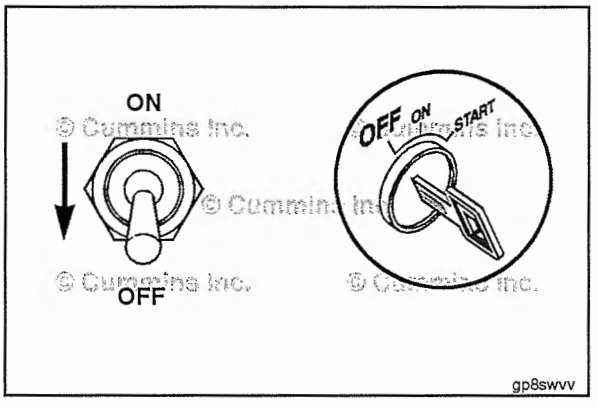


The fault code will flash in the following sequence:

- First, a WARNING (amber) light will flash.
- Then there will be a short one or two second pause after which the number of the recorded fault code will flash in STOP (red).
- There will be a one or two second pause between each number.
- When the number has finished flashing in red, an amber light will appear again.



The lights flash each fault code out three times before advancing to the next code. To skip to the next fault code, move the Increment/Decrement switch, if equipped, momentarily to the increment (+) position. You can go back to the previous fault code by momentarily moving the Increment/Decrement switch, if equipped, to the decrement (-) position. If only one active fault is recorded, the same fault code will continuously be displayed when either (+) or (-) switch is depressed.

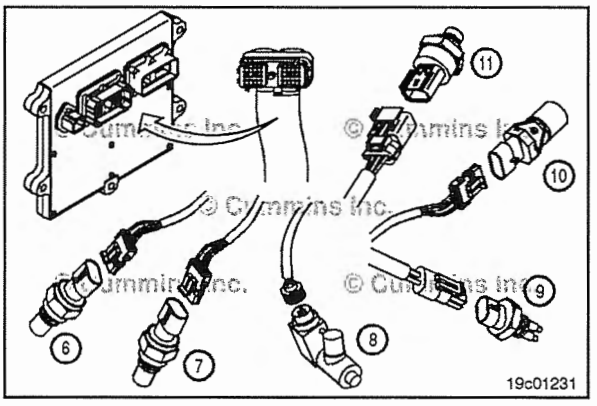


When **not** using the diagnostic system, turn off the diagnostic switch.

Engine Protection System

⚠CAUTION⚠
When the red STOP lamp is illuminated, the driver/ operator must pull to the side of the road when it is safe to do so, to reduce the possibility of engine damage.

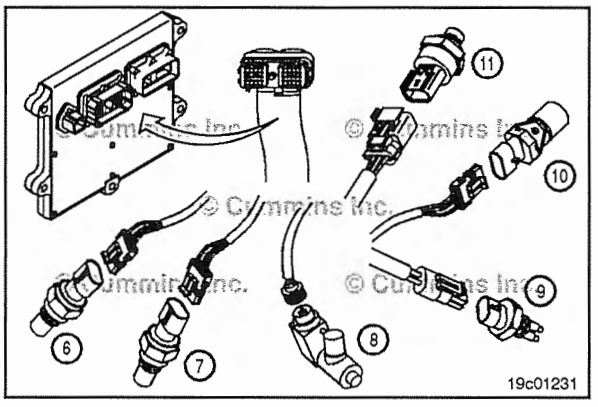
NOTE: Engine power and speed will gradually be reduced, depending on the level of severity of the observed condition. The engine protection system will **not** shut down the engine unless the engine protection shutdown feature has been enabled.



Fault Code Snapshot Data

When a diagnostic fault code is recorded in the ECM, the ECM input and output data is recorded from all sensors and switches. Snapshot data allows the relationships between ECM inputs and outputs to be viewed and used during troubleshooting.

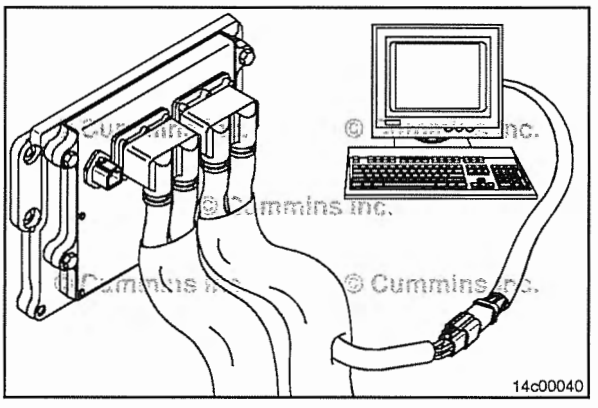
Fault code snapshot data can **only** be viewed using INSITE™ electronic service tool.



INSITE™ Electronic Service Tool Description

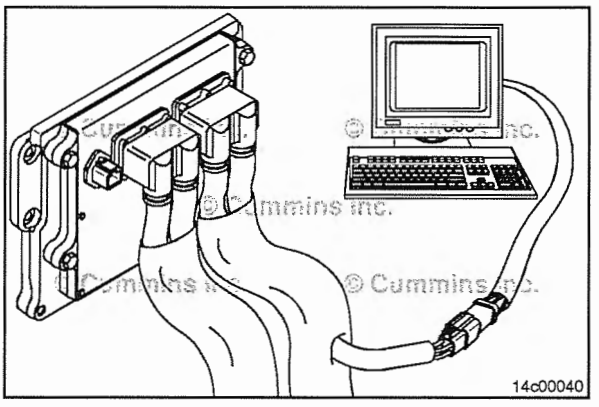
INSITE™ electronic service tool is a service tool for the electronic engine control system. Use INSITE™ electronic service tool to:

- 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 electronic engine control system (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 abnormally fluctuating 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.

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.

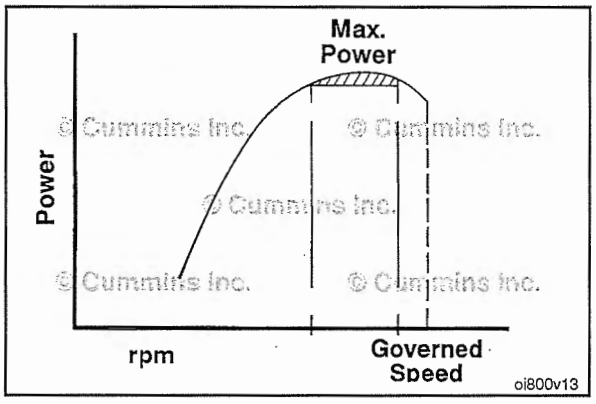
If an interference condition is observed, follow the suggestions below to reduce the amount of interference:

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.



Driving Techniques

General Information

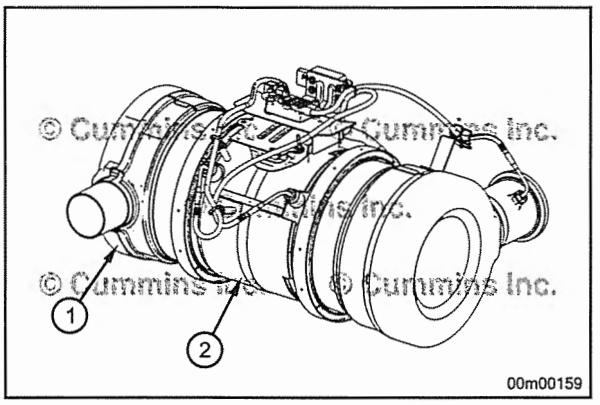
The engine produces maximum power at an rpm less than governed engine speed.

To obtain optimum engine performance on a grade, allow the engine speed to load down to near peak torque before shifting. This will result in an engine operating speed in the maximum power zone after the shift is completed.

Refer to the engine dataplate for peak torque rpm and governed speed rpm.

Unique Operating Characteristics of an Engine with Aftertreatment Diesel Particulate Filter

General Information



The particulate filter system of the aftertreatment system is composed of two main sections. These sections are:

1 The aftertreatment diesel oxidation catalyst (DOC). The aftertreatment DOC is used to oxidize fuel in the exhaust in order to create heat for the regeneration process.

2 The aftertreatment diesel particulate filter (DPF). The aftertreatment DPF captures the soot and ash from the engine exhaust.

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.

DPFs that are filled with ash will be indicated by the maintenance lamp and should be returned to a Cummins Inc. authorized repair location for exchange.

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.

Ultra low sulfur diesel fuel is required for an engine equipped with an aftertreatment DPF. If ultra low sulfur diesel fuel is **not** used, the aftertreatment system 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.

Some engines contain an engine control module (ECM) calibration feature, Aftertreatment Warm-Up, which activates automatically during periods of extended idle to remove water and hydrocarbon accumulations from the aftertreatment system.

The Aftertreatment Warm-Up feature is different from Active or Manual (Non-Mission) Regeneration, as it operates at a lower engine speed (revolutions per minute (rpm)) and does **not** require aftertreatment fuel injection, because of lower aftertreatment system temperature requirements.

The ECM will automatically increase the engine speed to 760 rpm for approximately 15 to 20 minutes, if the ECM detects all of the conditions below have been met:

- More than 4 continuous idle hours with exhaust temperature <110 °C [230 °F] or
- More than 8 continuous idle hours with exhaust temperature <250 °C [482 °F]
- The clutch pedal is released
- The brake pedal is released
- The transmission is in neutral or park
- PTO or Remote PTO is turned OFF
- The vehicle speed is 0 mph
- The accelerator pedal is released.

The Aftertreatment Warm-Up feature can **not** be disabled by activating the active regeneration permit switch, if equipped, because the feature does **not** use aftertreatment fuel injection.

Increasing the temperature of the exhaust gas that enters the aftertreatment system to above 250°C [482°F] for approximately 15 to 20 minutes allows the Aftertreatment Warm-Up feature to deactivate. This can be done by allowing the engine to operate in this condition for approximately 15 to 20 minutes, or by driving the vehicle.

NOTE: The engine speed will **not** be changed during power take-off (PTO) or remote PTO operation.

NOTE: The Aftertreatment Warm-Up feature can **not** be disabled or adjusted with INSITE™ electronic service tool or other electronic tools.

Regeneration

Overview

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 being collected.

Passive regeneration typically occurs when the vehicle is driven at high speeds (ie, highway speeds) and/or 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 being 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. This 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.

Active regeneration **only** occurs if the engine control module 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 engine control module will activate and de-activate active regeneration as needed.

The speed threshold for active regeneration to occur is dictated by the vehicle manufacturer, and can be set at vehicle speeds from 8 to 40 km/hr [5 to 25 mph].

Active regeneration can occur any time the vehicle speed is above the speed threshold.

Use the vehicle owner's manual for information about the speed threshold for active regeneration used for a specific vehicle.

Active regeneration is largely transparent to the vehicle operator. The vehicle 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 original equipment manufacturer (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.

⚠WARNING⚠

If the vehicle is not equipped with a High Exhaust System Temperature Lamp, follow these precautions for active regeneration whenever the vehicle is running and the vehicle slows or comes to a stop. Active regeneration can occur any time the vehicle is moving, and the exhaust temperature can remain hot after the vehicle has stopped moving. The exhaust temperature could reach 816°C [1500°F], which is hot enough to ignite or melt common materials, or to burn people.

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 vehicle operation. When this occurs, the engine will illuminate the aftertreatment DPF lamp to inform the vehicle 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 vehicle operator when the vehicle is **not** moving.

Manual (non-mission) regeneration requires an elevated engine speed of approximately 1000 to 1400 rpm. 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. A vehicle mounted manual (non-mission) regeneration switch. Use the vehicle owners manual for the location and operation of this switch, if so equipped (this switch may also be called a "parked regeneration" switch or "start" switch). The vehicle mounted manual (non-mission) regeneration switch will only initiate a manual (non-mission) regeneration when the aftertreatment DPF lamp is illuminated.
2. The 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 1000 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 vehicle.

  - Preferably on a surface that will **not** burn or melt under high exhaust temperatures (such as clean concrete or gravel, **not** grass or asphalt).
- Park the vehicle away from anything that can burn, melt, or explode.
  - Be sure there are no items within 61 cm [2 ft] of the exhaust outlet.
  - Items that can burn, melt, or explode **must** be kept at least 152 cm [5 ft] from the exhaust outlet (such as gasoline, paper, plastics, fabrics, compressed gas containers, or hydraulic lines).
  - Be sure that there are no gases or vapors nearby that could burn, explode, or contribute to a fire (such as LP gas, gasoline vapors, oxygen, or nitrous oxide).
- Park the vehicle securely. Place the transmission in park, if provided, otherwise in neutral. Set wheel chocks at the front and 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 152 cm [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].
- 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).
- Verify the following conditions are met in the vehicle:
  - The clutch pedal is released.
  - The brake pedal is released.
  - The transmission is in neutral or park.
  - Power Take-Off (PTO) or Remote PTO is off.
  - The vehicle speed is 0 MPH.
  - The throttle pedal is released.
- Initiate the manual (non-mission) regeneration by toggling the vehicle mounted manual (non-mission) regeneration switch or by using INSITE™ electronic service tool.
  - Once the manual (non-mission) regeneration is initiated, the engine speed will increase, and turbocharger noise will increase.
  - The High Exhaust System Temperature Lamp, if equipped, may illuminate during the manual (non-mission) regeneration as the exhaust temperatures increase.
  - When the engine control module detects that the aftertreatment DPF has been regenerated, the engine will automatically return to normal idle speed.
- Monitor the vehicle and surrounding area during the manual (non-mission) regeneration. If any unsafe condition occurs, shut off the engine immediately.

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

Some engines contain an ECM calibration feature, Aftertreatment Idle-Up, that activates automatically and is used to control the aftertreatment system temperature. This feature will maintain an elevated low idle speed, approximately 760 rpm, when an aftertreatment regeneration, active or manual, completes or is cancelled by:

1 Depressing the accelerator, clutch, or service brake pedal

2 Activating the aftertreatment regeneration inhibit switch or

3 Activating another engine feature that may interact with the regeneration, such as remote throttle or PTO.

NOTE: The Aftertreatment Idle-Up feature can **not** be disabled or adjusted with INSITE™ electronic service tool or other electronic tools.

Aftertreatment Switches

The vehicle manufacturer may choose to equip the vehicle 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 reference the vehicle 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. Please reference the "Stationary (Parked) 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:

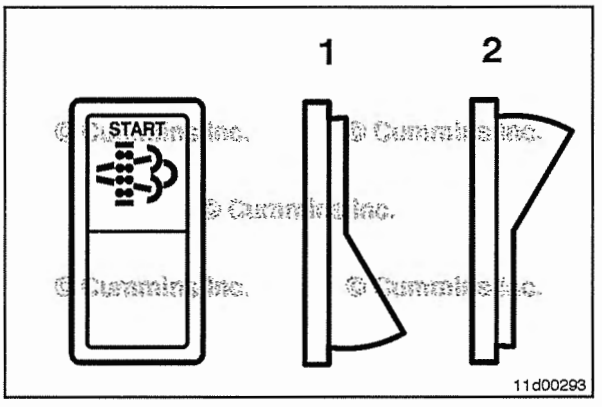
1 A two-position switch that is used to activate manual (non-mission) regeneration.

2 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.

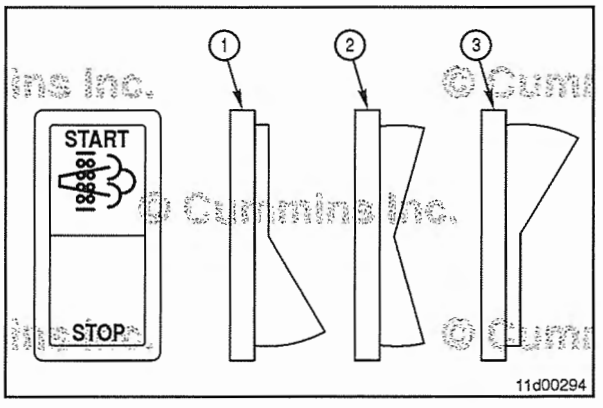


A three-position switch (ON, NEUTRAL, and OFF positions) will typically have both "START" and "PERMIT" functions.

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.



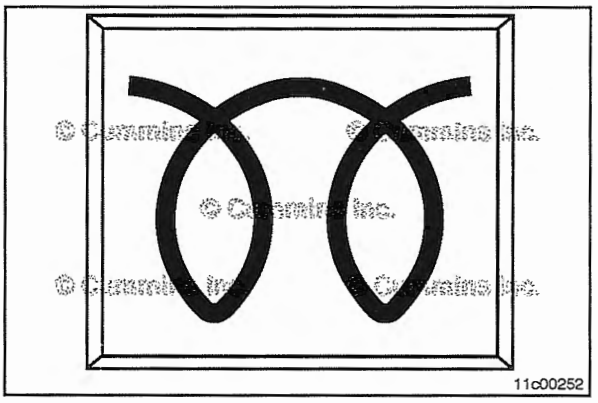
Engine Indicator Lamps

General Information

The following engine indicator lamps cover **only** the lamps controlled by the engine control module (ECM). The equipment manufacturer can provide additional indicator lamps. See equipment manufacturer service information for additional lamp information.

The regulated engine derate conditions vary depending on the original equipment manufacturer (OEM) and local regulations. See equipment manufacturer service information for additional derate information.

NOTE: The start and permit switches, as well as the exhaust system cleaning lamp, are common with other Cummins® systems utilizing a diesel particulate filter (DPF). Some OEMs, documentation, and tools can reference these as Aftertreatment Diesel Particulate Filter Regeneration or Aftertreatment Regeneration parameters.



Wait to Start Lamp

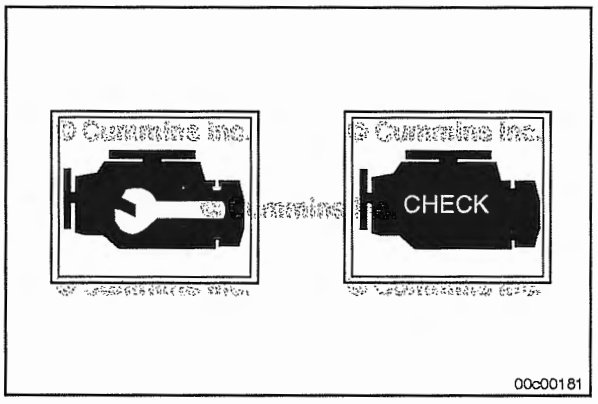
The WAIT TO START lamp illuminates when the intake air heater needs to warm the intake air prior to starting the engine.

The time for the WAIT TO START lamp to be on will vary, depending on the ambient air temperature. Refer to Procedure 101-014 in Section 1.

For vehicles equipped with an engine starting motor protection feature, another function of the WAIT TO START lamp is to flash for two minutes if the starting motor is engaged for 30 seconds or more.

The WAIT TO START lamp can look like:

- The words WAIT TO START spelled out
- A symbol similar to the graphic
- The color of the symbol or words can vary, based on the manufacturer of the vehicle, but will typically be red or amber.



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 graphic.

Another function of the CHECK ENGINE lamp is to flash for 30 seconds at key ON when one of the following occurs. This flashing function is referred to as the MAINTENANCE lamp. The MAINTENANCE lamp could flash for any of the following reasons:

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

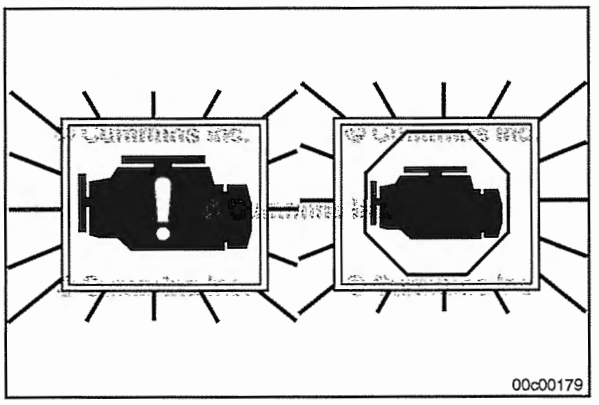
Stop Engine Lamp

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 graphic.



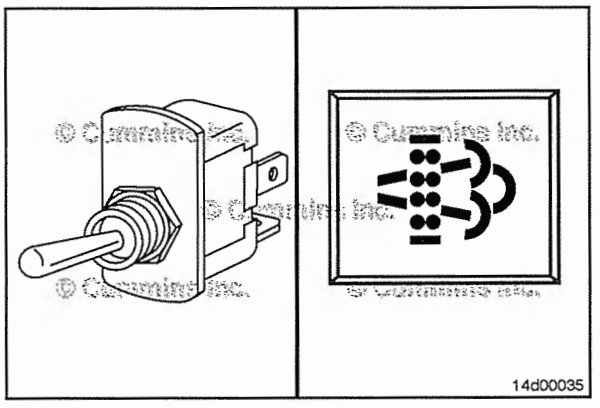
Aftertreatment Diesel Particulate Filter Regeneration

NOTE: Some vehicles can be equipped with and OEM-provided stationary regeneration method. The most common type is a stationary regeneration switch in the cab. The stationary regeneration switch can be a stand-alone switch, or it can be combined with the diagnostic switch, at the discretion of the vehicle manufacturer.

OEM stationary regenerations vary. See equipment manufacturer service information.

In order for the stationary regeneration switch to function, the switch parameter **must** be enabled in the ECM.

This switch will **only** start a stationary regeneration if the soot load of the filter is high enough. This is indicated by an illuminated or flashing aftertreatment lamp.



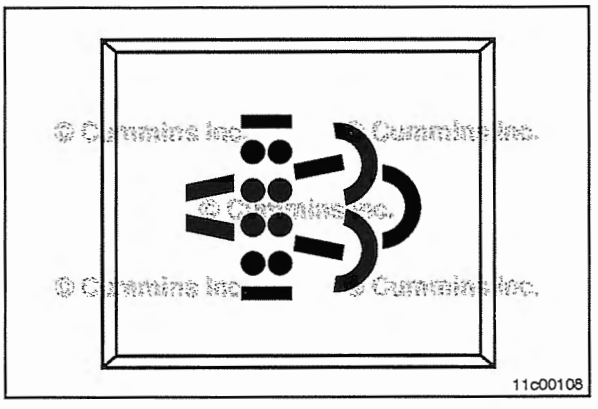
SCR System Cleaning Lamp

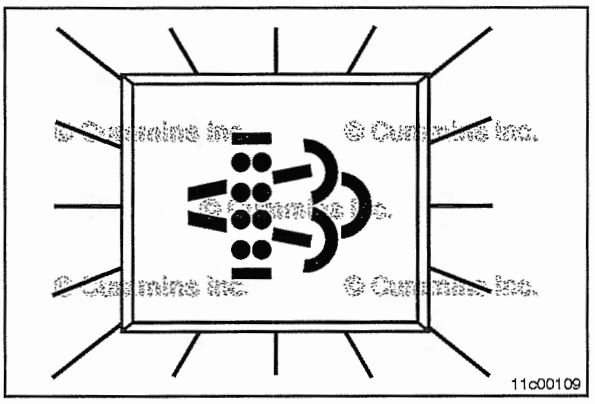
The SELECTIVE CATALYTIC REDUCTION (SCR) SYSTEM CLEANING lamp indicates the status of the aftertreatment SCR system cleaning events.

An illuminated SCR SYSTEM CLEANING lamp indicates that the aftertreatment SCR system needs to be cleaned at the next opportunity. This can be accomplished by:

1. Changing to a more challenging duty cycle, such as highway driving, for at least 20 minutes
2. Performing a stationary SCR/exhaust system cleaning. Refer to Procedure 101-050 in Section 1.

NOTE: Stationary SCR/exhaust system cleaning is considered a normal practice and is **not** covered by Cummins Inc. warranty.





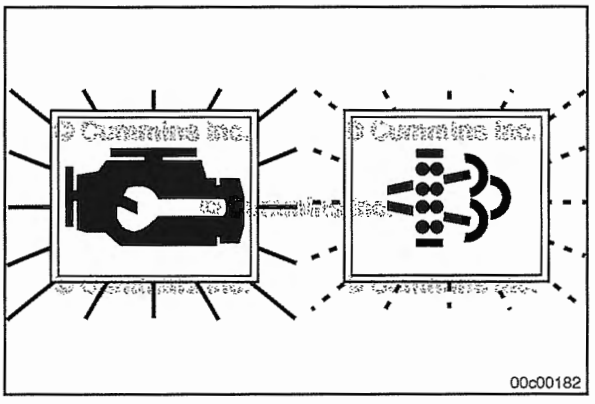
A flashing SCR SYSTEM CLEANING lamp indicates the status of a non-mission (stationary) SCR/ exhaust system cleaning when the SCR System Cleaning Start switch has been activated. See the following procedure for more information on the Start Conditioning switch. Refer to Procedure 101-050 in Section 1. 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.

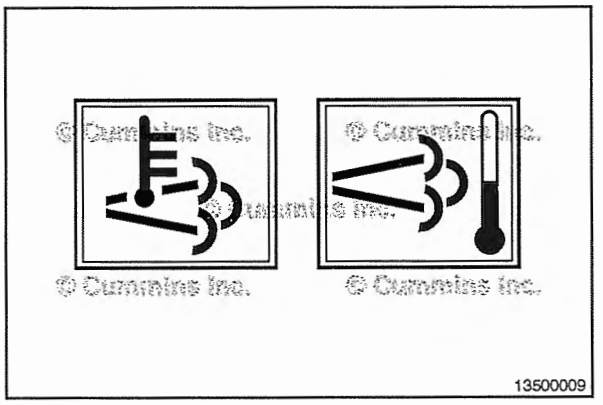


A solid SCR SYSTEM CLEANING lamp combined with an illuminated WARNING or CHECK ENGINE lamp indicates the aftertreatment SCR needs to be cleaned immediately. Engine power will be reduced automatically if action is **not** taken.

When these lamps are illuminated, a stationary SCR/ exhaust system cleaning is required. Refer to Procedure 101-050 in Section 1.

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

High Exhaust System Temperature Lamp



⚠WARNING⚠
When this lamp is illuminated, the exhaust gas temperature could reach 800°C [1500°F], which is hot enough to ignite or melt common materials, and to burn people.

The HIGH EXHAUST SYSTEM TEMPERATURE lamp indicates, when illuminated, exhaust temperatures are high. The lamp could illuminate during normal engine operation or during SCR/exhaust system cleaning.

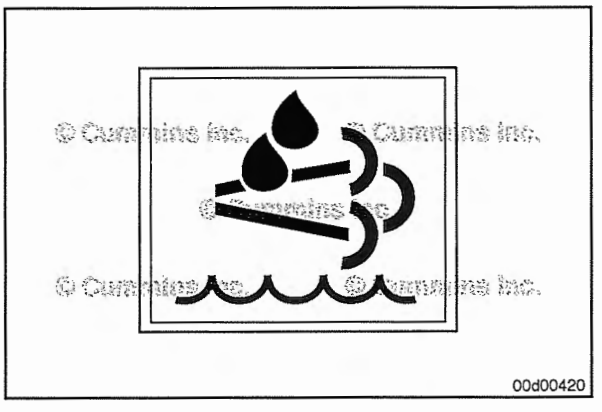
NOTE: The OEM determines whether or **not** the HIGH EXHAUST SYSTEM TEMPERATURE lamp is installed on the vehicle. The OEM also specifies the temperatures, vehicle speeds, and other conditions at which the lamp illuminates. See equipment manufacturer service information for additional information regarding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

When this lamp is illuminated, be sure 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 burn, melt, or explode.
- Nothing within 0.6 m [2 ft] of the exhaust outlet.
- 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).
- 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 SCR/exhaust system cleaning.

Aftertreatment Diesel Exhaust Fluid Lamp

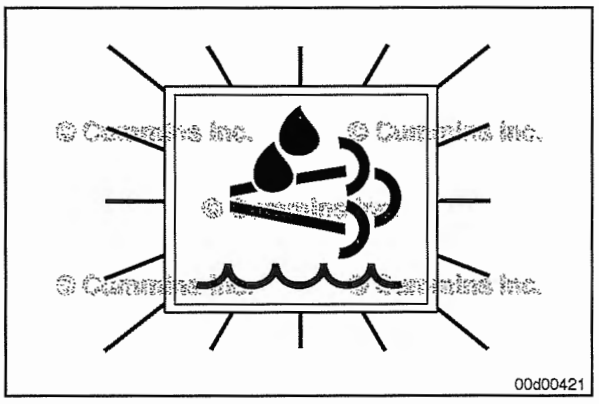


The AFTERTREATMENT DIESEL EXHAUST FLUID lamp indicates, when illuminated or flashing, that the diesel exhaust fluid (DEF) level is low.

NOTE: The OEM determines whether or not the AFTERTREATMENT DIESEL EXHAUST FLUID lamp is installed on the vehicle. The OEM also specifies the level at which the lamp will illuminate or blink. See equipment manufacturer service information for additional information regarding this lamp.

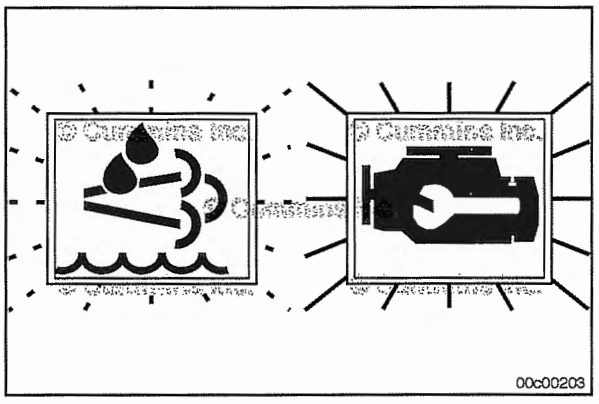
An illuminated AFTERTREATMENT DIESEL EXHAUST FLUID lamp indicates that the DEF level has fallen below the initial warning level. This can be corrected by filling the DEF tank with DEF.

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



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

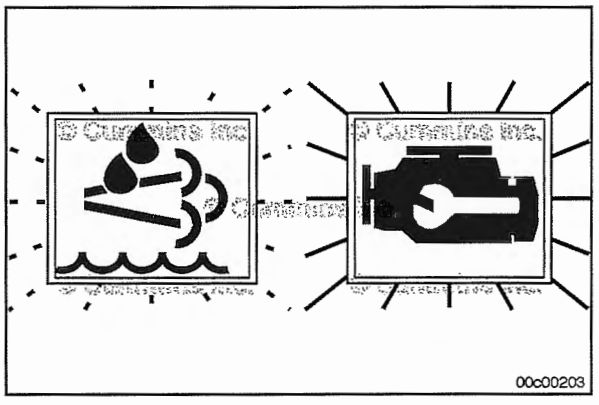
NOTE: It is recommended the DEF tank be filled completely full of DEF in order to correct any fault conditions.



A flashing AFTERTREATMENT DIESEL EXHAUST FLUID lamp combined with an illuminated WARNING or CHECK ENGINE lamp indicates 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.

If corrective action is **not** taken, engine power will be further limited to the secondary derate level.

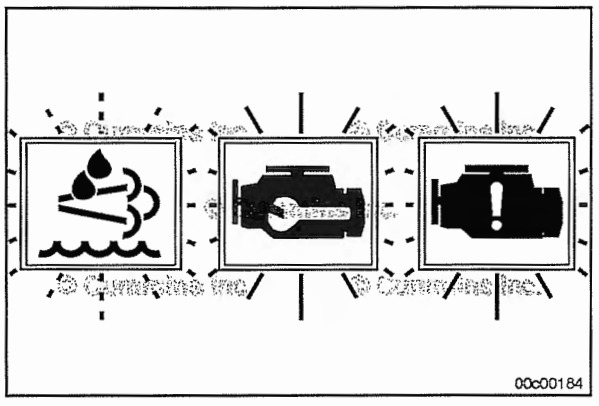
NOTE: It is recommended the DEF tank be filled completely full of DEF in order to correct any fault conditions.



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

If corrective action is **not** taken within 30 minutes of the CHECK ENGINE lamp illumination, the engine will enter the final derate level, which can include throttle lock or engine shutdown with possible restart limitations.

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



If the engine has been shut down or has idled for an extended period of time after the DEF gauge indicates empty, the STOP ENGINE lamp will also be illuminated along with the flashing AFTERTREATMENT DIESEL EXHAUST FLUID lamp and illuminated CHECK ENGINE lamp. The engine will enter the final derate level which can include low idle lock or engine shutdown with restart limitations.

NOTE: Some emergency vehicles can perform differently from the description above.

NOTE: In order to remove the final derate, the DEF tank must be filled to above 10 percent gauge reading.

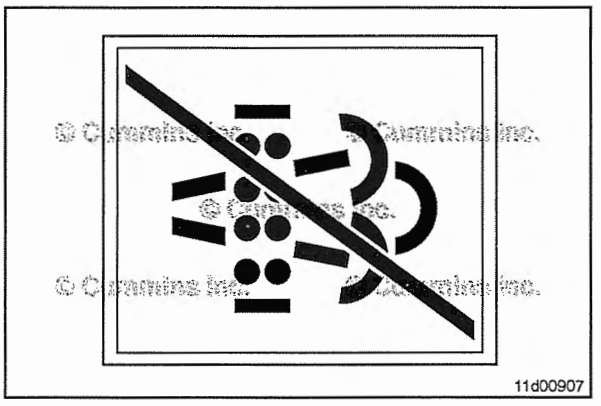
NOTE: It is recommended the DEF tank be filled completely full of DEF in order to correct any fault conditions.

SCR System Cleaning Inhibited Lamp

The SCR SYSTEM CLEANING DISABLED (INHIBIT) LAMP indicates the inhibit switch is active, therefore automatic and manual (non-mission) SCR/exhaust system cleaning can **not** occur.

An illuminated SCR SYSTEM CLEANING DISABLED (INHIBIT) lamp indicates the inhibit switch is active and automatic or manual (non-mission) SCR/exhaust system cleaning will **not** occur. This can be corrected by switching the inhibit switch to permit mode. Refer to Procedure 101-050 in Section 1.

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



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

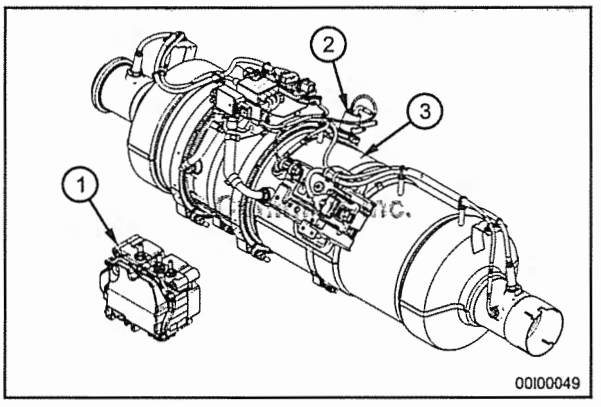
General Information

The 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 unit

2 Aftertreatment DEF dosing valve

3 Aftertreatment decomposition tube and SCR catalyst assembly.



⚠CAUTION⚠

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.

DEF is required for an engine equipped with a SCR system. DEF is a fluid 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:

- can have a slight ammonia smell
- is colorless
- is non-toxic and non-polluting
- is non-flammable.

Urea is naturally occurring and is biodegradable.

NOTE: Cummins Inc. supplies the aftertreatment DEF controller, aftertreatment dosing unit and aftertreatment DEF dosing valve, and the aftertreatment SCR catalyst. The vehicle manufacturer supplies the DEF tank, DEF lines, DEF tank temperature, DEF level, and quality sensors.

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

The aftertreatment DEF dosing valve is coolant 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 tank heater and DEF line heaters.

The aftertreatment SCR catalyst uses DEF to reduce the NOx emissions in engine exhaust to nitrogen and water. The aftertreatment SCR catalyst itself requires no maintenance.

A vehicle with SCR is equipped with an additional lamp on the dashboard. This is 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 illuminates and engine power is reduced. Attempting to operate the vehicle with no DEF in the tank will result in the vehicle speed being limited to 8 kmh [5 mph].

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 differs 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 is heated by engine coolant and the DEF lines and aftertreatment DEF dosing unit are electrically heated. No operator interaction is needed when operating in cold temperatures; heating and thawing are controlled automatically by the ECM.

After turning the keyswitch OFF on a vehicle with SCR, a pumping sound will possibly be heard from beneath the vehicle. This sound is the aftertreatment DEF dosing unit purging any unused DEF from the system and returning it to the tank. This is normal system operation. The purge process takes approximately 60 seconds to complete. Do **not** disconnect the vehicle batteries during this process to reduce the possibility of system damage.

NOTE: When the dosing valve is dosing DEF into the exhaust, there is a noticeable clicking sound. This is normal and does **not** indicate the valve has malfunctioned.

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

Unique Operating Characteristics of an Engine with a Direct Flow™ Air Cleaner

General Information

Cummins® industrial engines certified T4i and later, and less than 18L in displacement, use a Cummins® Direct Flow™ air cleaner. Figure 1 shows a typical arrangement of the Direct Flow™ air cleaner, and identifies the major components. See a Cummins® Authorized Repair Location for additional product information and various filter configurations.

Depending on the Cummins® Direct Flow™ model number, there can be some variation between the illustration and the actual air cleaner installed on the engine.

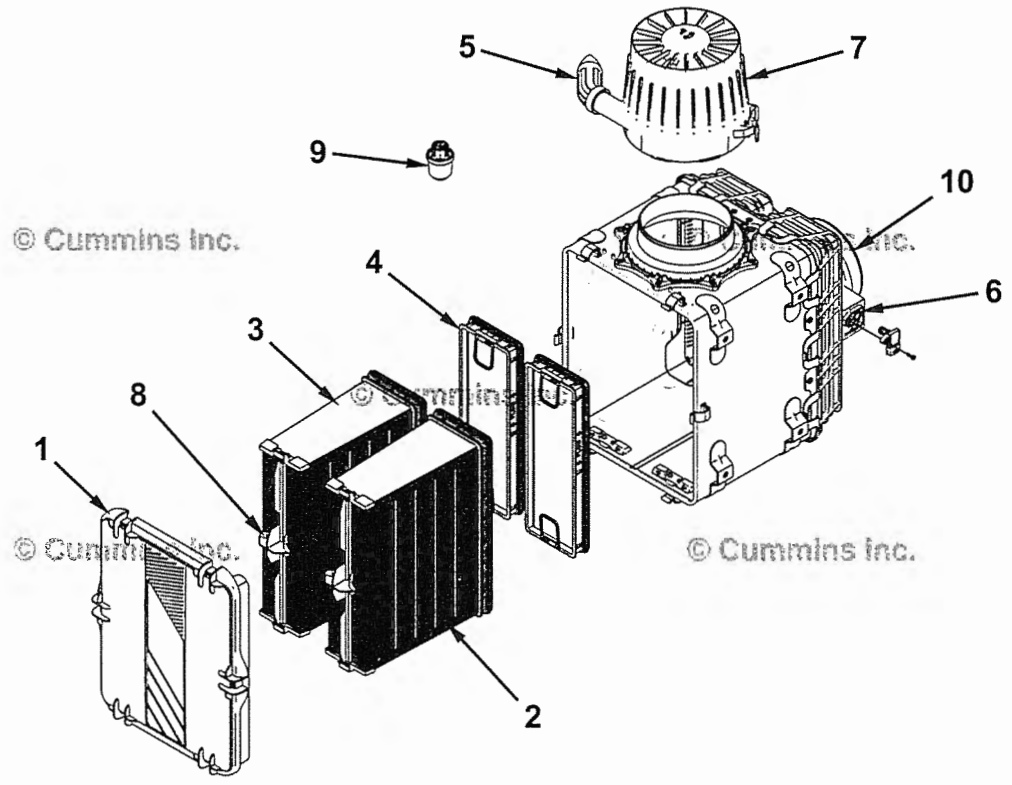


Figure 1, Typical Direct Flow™ Exploded View

1 Service cover
2 Primary element
3 Quick reference label
4 Secondary filter(s)
5 Integrated dust ejector valve
6 Sensor location
7 Inlet with optional pre-cleaner (aspiration optional)
8 Integrated handle to improve serviceability
9 Restriction indicator
10 Outlet.

Maintenance Service

As contaminant is trapped by the air filter, the restriction, or pressure drop across the air filter increases. The pressure drop will continue to increase until maximum restriction, also known as terminal restriction, is reached. The maximum restriction can be found in the appropriate Operation and Maintenance manual, Section V - Maintenance Specifications.

Restriction across the air filter may be measured in the following ways:

- Mechanical restriction indicator on the air cleaner housing
- Electrical sensor on the air cleaner housing which illuminates a dash lamp when the air filter reaches maximum restriction
- Engine control module (ECM) estimates restriction using the turbocharger compressor intake pressure/ temperature sensor and will illuminate a dash lamp when the air filter reaches maximum restriction.

When any of the methods above indicate that the air filter has reached maximum restriction, the air filter **must** be replaced. There is a maximum recommended change interval regardless of restriction values, which can be found in the maintenance schedule. Reference the appropriate Operation and Maintenance manual, Section 2 - Maintenance Schedule.

Do **not** operate beyond recommended maximum air intake restriction levels. The secondary air cleaner (filter) elements **must** be changed every other time the primary elements are changed. Proper inspection of the secondary air filter elements **must** be performed and the secondary elements changed.

⚠CAUTION⚠

Do not continue to operate an engine with a terminally restricted air filter. The result can be physical damage to the air filter, collapsed air intake hoses, and/or loose air intake hose clamps.

Inspection is **not** an effective method for determining air filter restriction. Do **not** remove an air filter just to perform an inspection.

Clean and Inspect for Reuse

⚠CAUTION⚠

Do not clean or inspect air filters before maximum restriction is reached. Daily inspection of air filters risks introducing dust/debris into the air intake system which can cause damage to the engine.

Do **not** clean or reuse a Cummins Direct Flow™ filter. When an air filter has reached terminal restriction, it **must** be discarded and a new air filter installed.

Best Practices

- Always clean the filter housing, specifically the seal zones, before installing the element(s).
- Verify that air cleaner covers, pre-cleaners, and dust ejection valves are in place and properly secured.
- Verify that the dust ejection valve is clear of debris.

Unique Operating Characteristics of an Engine with Stop-Start Technology

Feature Description

General Information

Engines equipped with Cummins® Stop-Start technology improve fuel economy by reducing idle time during normal operation.

The Stop-Start feature interacts with the original equipment manufacturer (OEM) drive system and application to decide when to auto-stop as well as when to auto-start. Various operating conditions and information shared from the OEM via data link will drive the correct functionality of the system.

Stop-Start option is limited to engines used in series hybrid bus applications. In series hybrid bus applications, the engine acts like a generator, which charges the vehicle batteries. Vehicle propulsion is **only** through electric motors.

Operation

The driver will require no special input or action in operating the vehicle that is equipped with this feature.

- The Stop-Start feature can vary between OEM. A recommendation for operators to become familiar with the OEM literature on proper operation of this feature.
- If the engine does **not** automatically start after an Auto-Stop:
- Keep foot on brake.
- Place transmission in neutral.
- Cycle the key and manually start the engine.
- If the engine does **not** automatically stop as indicated by the vehicle OEM's literature:
- Auto-Stop can be disabled. See Conditions That May Prevent Automatic Shutdowns section of this procedure.
- Prior to exiting the drivers seat, make sure the vehicle is in neutral/park and the parking brake is engaged.

Conditions That May Prevent Automatic Shutdowns

Under certain operating conditions, the engine control module (ECM) or an OEM control module can temporarily inhibit operation of the Stop-Start system.

- Inhibit parameters can vary by Stop-Start system operation and specifications:
- Low battery voltage
- Engine protection
- Engine cold

- Service inhibit
- High engine load
- Automatic-Stop frequency high
- Engine oil distribution incomplete
- Coolant temperature (too high or too low)
- Diesel Particulate Filter (DPF) Regeneration is active
- Minimum engine on time and minimum time between stops
- Low diesel exhaust fluid (DEF) tank temperature
- Low intake air temperature
- Engine fan request active
- Fuel system in limp home mode.
- Vehicle conditions can include, but are **not** limited to:
- Hood or service panel is open
- Door is open, if equipped
- Driver **not** in the seat, if equipped
- Hybrid Health/State of charge
- Duty cycle
- Heater/air conditioning requests
- Parasitic loads.

See equipment manufacturer service information. The OEM Stop-Start operating conditions can vary by OEM.

Conditions That Can Initiate Automatic Restarts

- The engine can automatically restart when any one of the following conditions occur:
- OEM requested restart.

Conditions That Can Prevent Automatic Restarts

- The engine can prevent the automatic restart when any one of the following conditions occur:
- Hood or service access open
- Door open (driver/passenger or lift gate, if equipped
- Driver **not** in seat, if equipped
- OEM system **not** ready
- Engine faults.

Notes

Section 2 - Daily Maintenance

Section Contents

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Daily Maintenance Guidelines

General Information

This section contains procedures that support daily maintenance tasks. Cummins Inc. recommends that the product be maintained according to the Daily Maintenance Schedule in this section.

Equipment and components supplied by manufacturers other than Cummins Inc. can impact the performance and reliability of the product if **not** correctly maintained.

If your product is equipped with a component or accessory **not** manufactured or supplied by Cummins Inc., see the maintenance recommendations provided by the component manufacturer.

Use the "Maintenance Record Form" provided in this section to record completed maintenance tasks.

For detailed information or assistance, contact your local Cummins® Authorized Repair Location.

Daily Maintenance Schedule

General Information

Preventative maintenance begins with day-to-day awareness of the system. Prior to engine operation, check for the following:

- Excessive oil, coolant, or fuel consumption
- Leaks
- Loose or damaged parts
- Worn or damaged belts
- Worn or damaged wiring harnesses
- Any change in system appearance
- Odor of fuel
- Odor of electronic devices.

When operating the engine, listen for any unusual system noises which can indicate service is required.

Take appropriate action to rectify any abnormalities or contact a Cummins® Authorized Repair Location.

Schedule

The following daily maintenance schedule lists inspections and procedures which **must** be performed on a daily basis to properly maintain the engine.

Daily Maintenance

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

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

Fuel-Water Separator

Drain

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

NOTE: Not draining fuel water separator for extended periods of time will trigger an engine protection derate. Derate will be removed after fuel water separator is drained and water in fuel faults are inactive.

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

Shut off the engine.

Drain the water and sediment from the separator daily.

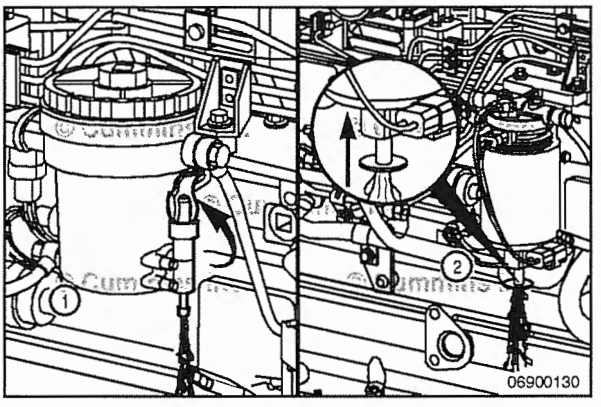
Drain valve opening and closing will vary by design.

Canister Type

Use your hand to open the drain valve.

Drain the filter sump until clear fuel is visible.

Use your hand to close the drain valve.



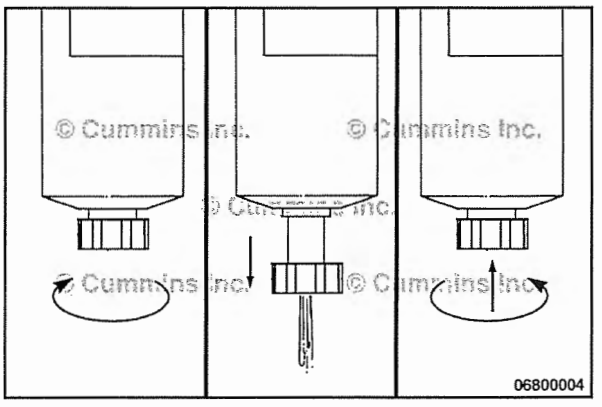
Spin-on Type

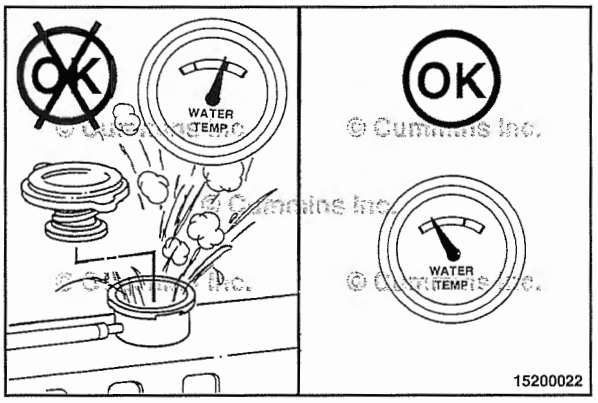
Use your hand to open the drain valve. Turn the valve **counterclockwise** approximately 3½ turns until the valve drops down 25.4mm [1 in] and draining occurs.

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.





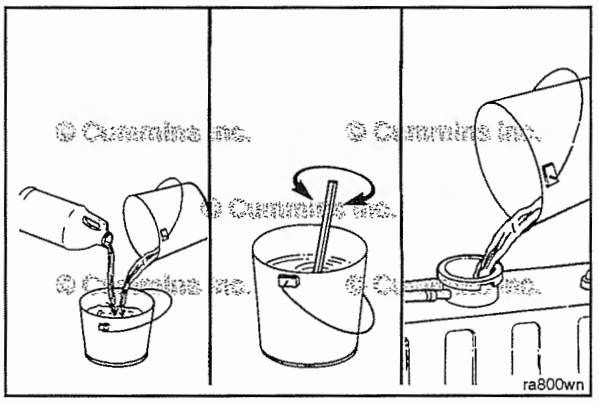
Coolant Level

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.

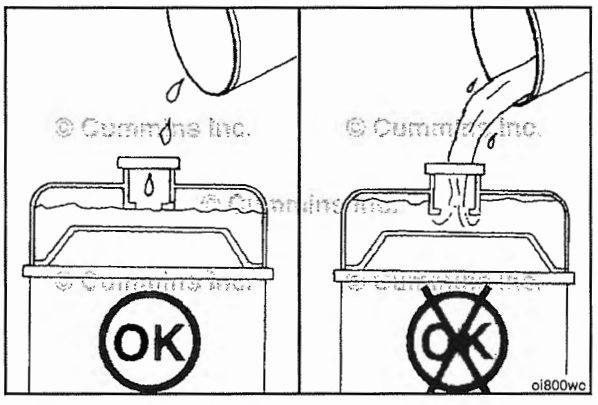
The coolant level **must** be checked daily.



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

Lubricating Oil Level

General Information

The lubricating oil dipstick is located on the left bank side of the engine.

One side of the lubricating oil dipstick is labelled static and is calibrated for measuring the static lubricating oil level.

On specific engines, the other side of the lubricating oil dipstick is labelled run and is calibrated for measuring the running 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.

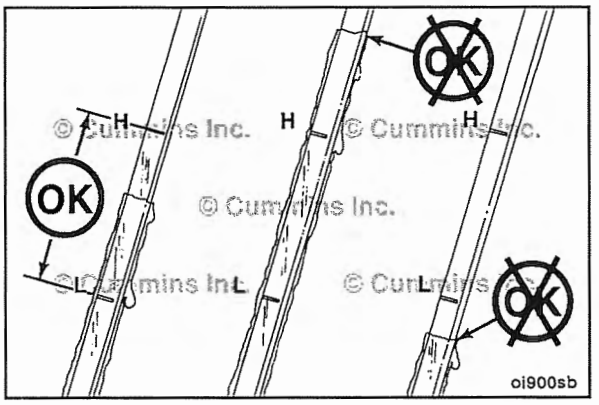
⚠CAUTION⚠
The engine must be level when checking the lubricating oil level to make sure the measurement is correct.

For a static oil level check, shut the engine OFF for an accurate reading.

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

Remove the lubricating oil dipstick and assess the lubricating oil level.

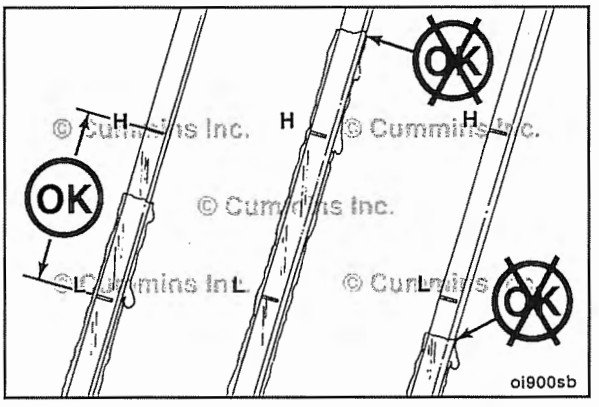
For additional lubricating oil recommendations and lubricating oil pan capacity information, see Section V.



For a run oil level check, run the engine at idle and ensure coolant temperatures have stabilized at 160°F [71°C] before performing the lubricating oil level check.

Remove the lubricating oil dipstick and assess the lubricating oil level.

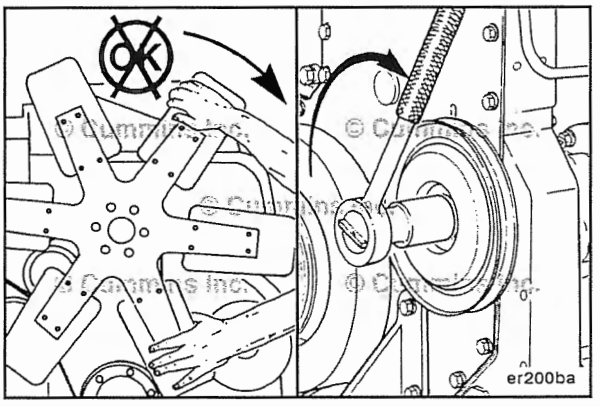
For additional lubricating oil recommendations and lubricating oil pan capacity information, see Section V.

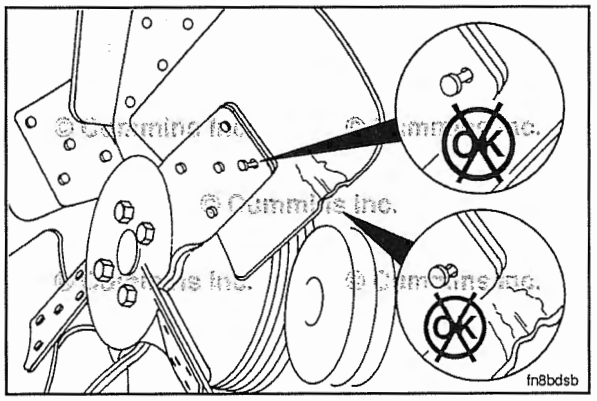


Fan, Cooling

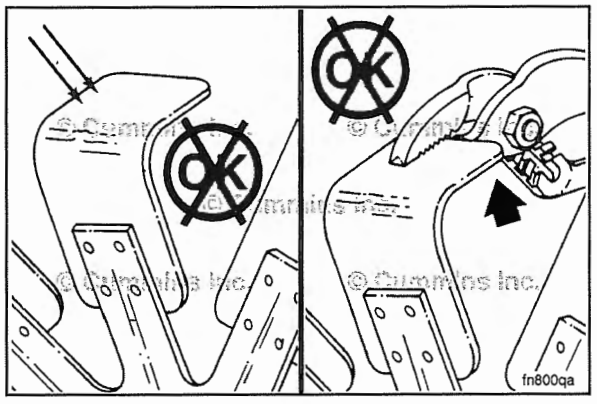
Inspect for Reuse

⚠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.

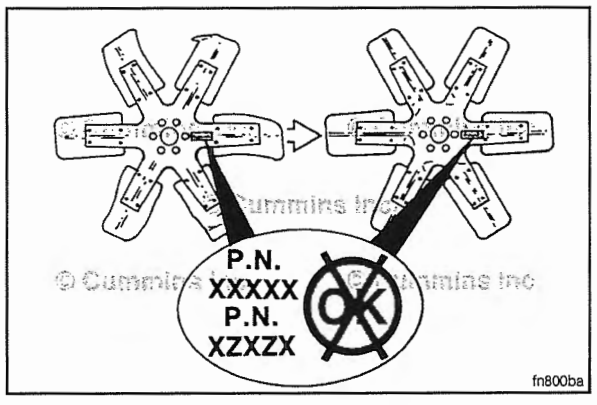




A visual inspection of the cooling fan is required daily. Check for cracks, loose rivets, and bent or loose blades. Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.



⚠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.

Air Intake Piping

Select Service Tools

Recommended Cummins® Service Tools

- No Cummins® service tools required.

Additional Service Items

- No additional service items required.

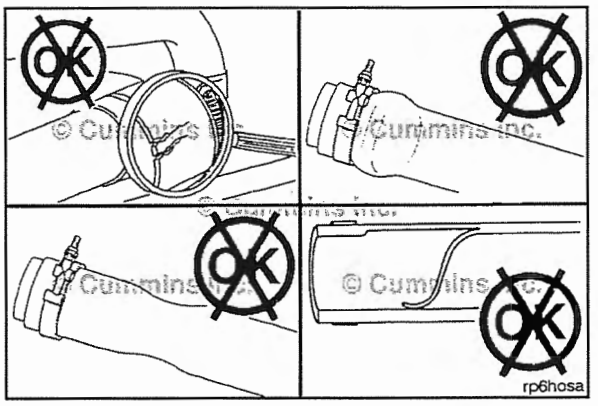
Maintenance Check

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]

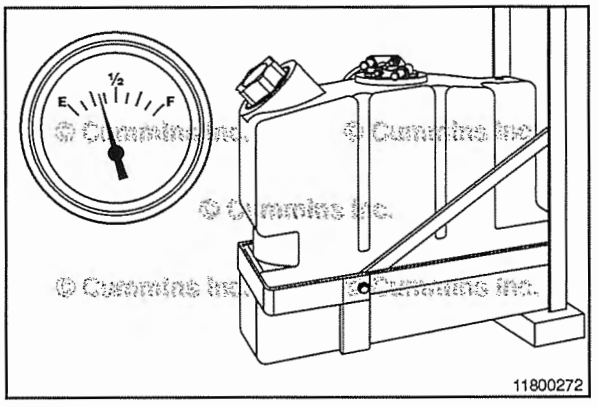
Check for corrosion under the clamps and hoses of the intake system piping. Corrosion can allow corrosive products and dirt to enter the intake system. Disassemble and clean, as required.



Diesel Exhaust Fluid (DEF) Level

Maintenance Check

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

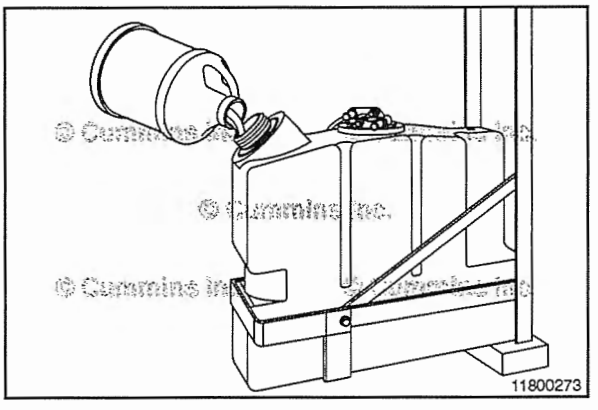


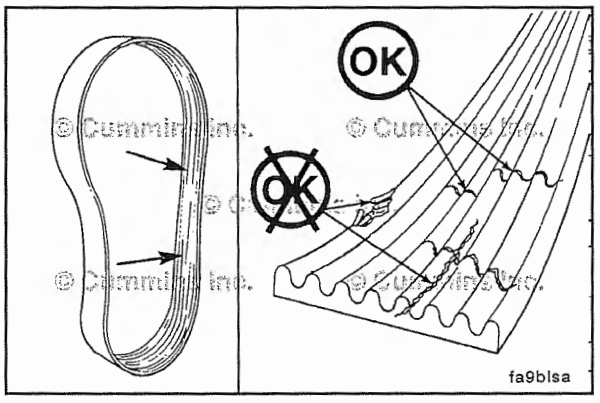
⚠WARNING⚠
Do not allow Diesel Exhaust Fluid to contact the eyes. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. Avoid prolonged contact with skin. In case of contact, immediately wash skin with soap and water. Do not swallow internally. In the event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





Drive Belts

Maintenance Check

Poly-Vee Belt

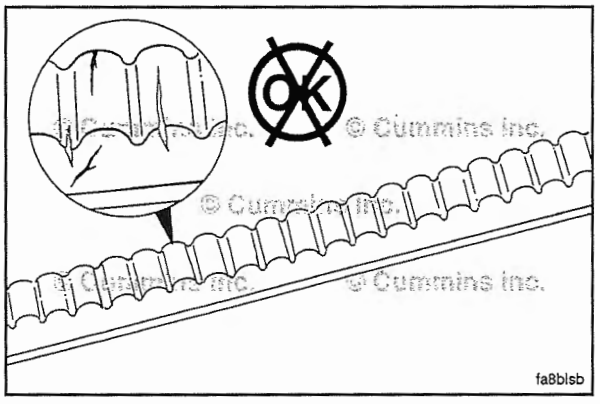
⚠CAUTION⚠

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:

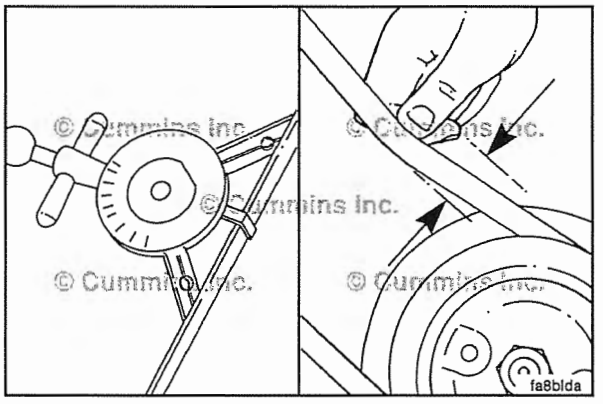
- Incorrect tension
- Incorrect size or length
- Pulley misalignment
- Incorrect installation
- Severe operating environment
- Oil or grease on the belts

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

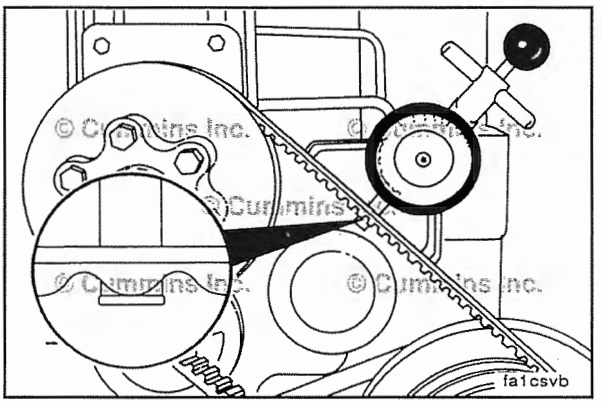
Refer to the Belt Tension Chart in Section V for the correct gauge and tension value for the belt width used.

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.



Air Cleaner Restriction

Maintenance Check

Mechanical Indicator

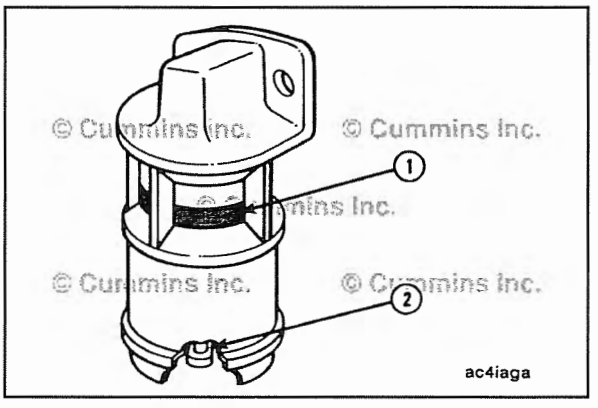
⚠CAUTION⚠

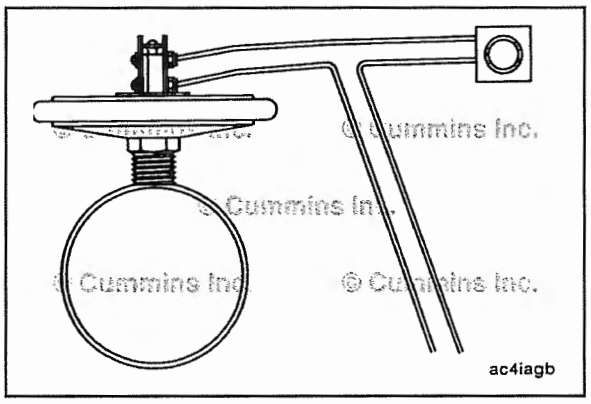
Never operate the engine without an air cleaner. Intake air must be filtered to prevent dirt and debris from entering the engine and causing premature wear.

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).

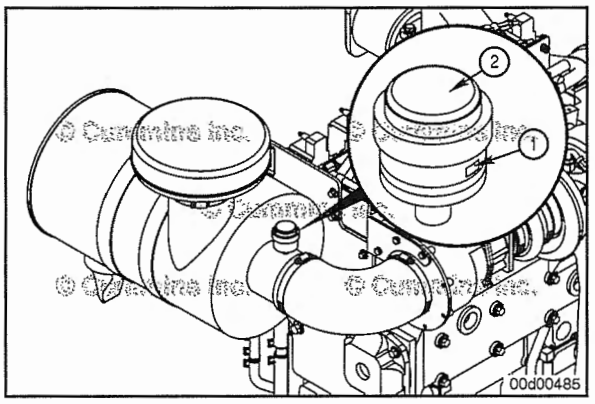
Restriction or vacuum indicators need to be installed as close as possible to the turbocharger air inlet in order to obtain a true indication of restrictions.





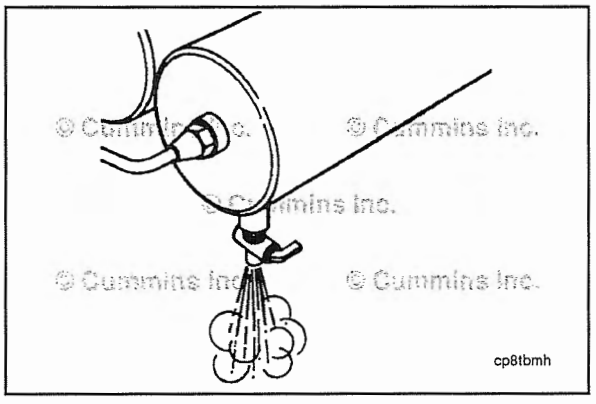
Vacuum Indicator

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)



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.

Dust Ejection Valve

Select Service Tools

Recommended Cummins® Service Tools

- No Cummins® service tools required.

Additional Service Items

- No additional service items required.

General Information

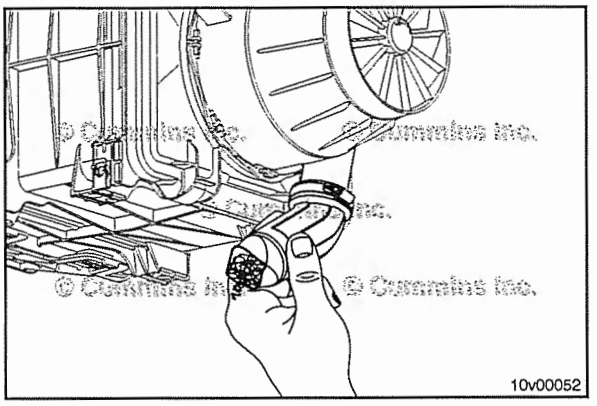
The dust ejection valve is a thin, flexible rubber boot located at the bottom of the precleaner on the air cleaner assembly. It is used to accumulate and remove dust ejected from the precleaner.

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

Do **not** operate the engine without a dust ejection valve or exhaust aspirator. The precleaner efficiency will be greatly reduced and can 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.



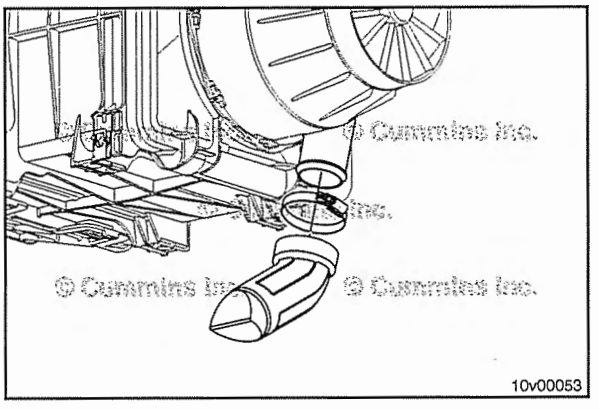
Preparatory Steps

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

- Shut the engine OFF.

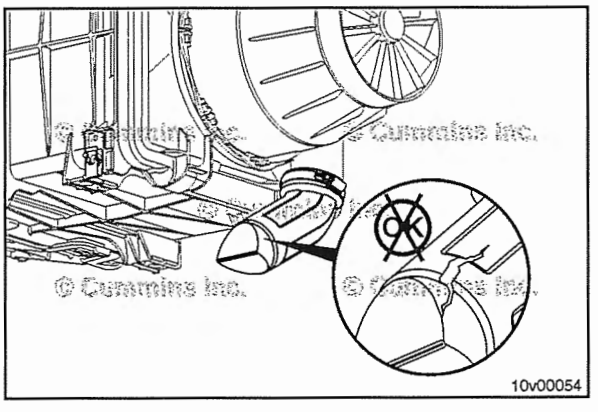
Remove

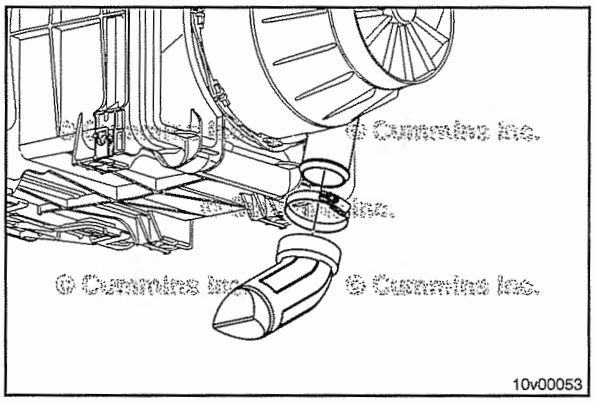
Remove the dust ejection valve from the precleaner by loosening the hose clamp, if present, then rotating and pulling downward on the dust ejection tube.



Inspect for Reuse

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





Install

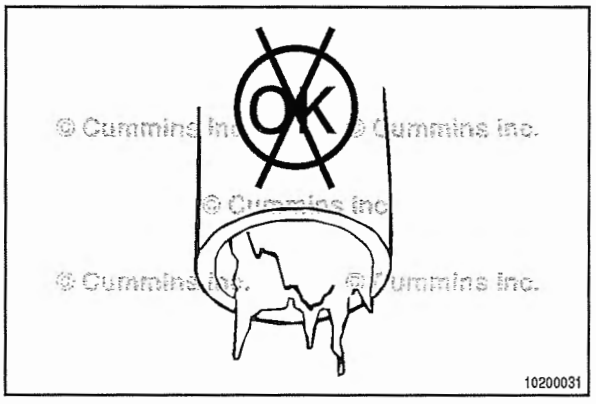
Install the dust ejection valve on the precleaner by attaching the hose clamp, if present. Tighten the hose clamp.

Torque Value: 5 N•m [44 in-lb]

The tip of the dust ejection valve should be pointed downward.

Finishing Steps

- Start the engine.
- Check for leaks.



Crankcase Breather Tube

Maintenance Check

If equipped, drain the catch bottle and properly dispose of contents

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

NOTE: If 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.

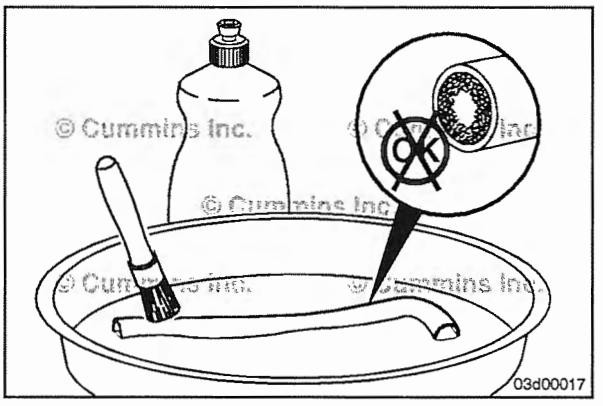
Contact a Cummins® Authorized Repair Location.

⚠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.



Visually inspect the crankcase breather tube for the following conditions.

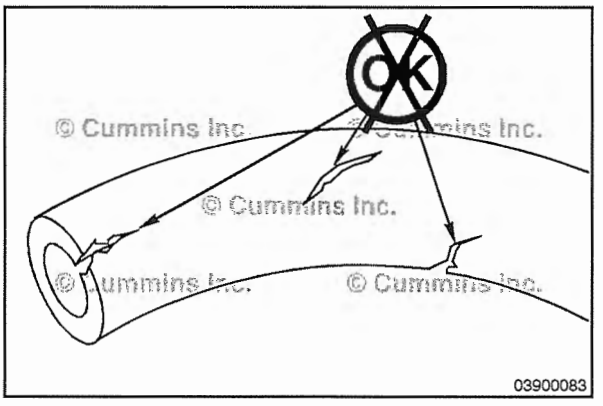
- Cracks
- Material deterioration
- General damage.

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



Notes

Section 3 - Routine Maintenance

Section Contents

Routine Maintenance Guidelines

General Information

This section contains procedures that support routine maintenance tasks. Cummins Inc. recommends that the product be maintained according to the Routine Maintenance Schedule in this section.

Some maintenance procedures require special tools. The Tool Requirements procedure lists the special tools required to perform maintenance procedures listed in this section.

Use the "Routine Maintenance Record Form" provided in this section to record completed maintenance tasks.

For detailed information or assistance, contact your local Cummins® Authorized Repair Location.

Schedule

The routine maintenance schedule provides maintenance intervals and the corresponding procedures that should be performed in order to properly maintain this product.

Intervals marked in the schedule **only** apply to Cummins Inc. components.

Equipment and components supplied by manufacturers other than Cummins Inc. can impact the performance and reliability of the product if **not** correctly maintained. If your product is equipped with a component or accessory **not** manufactured or supplied by Cummins Inc., see the maintenance recommendations provided by the component manufacturer.

Cummins Inc. products are customized for end users. Customer selectable options listed in the routine maintenance schedule may not be on your product. Verification of the components installed on your product may be necessary prior to performing maintenance. For detailed information or assistance, contact your local Cummins® Authorized Repair Location.

The maintenance schedule provides guidance on servicing items supplied by component manufacturers through the use of the following statements

- The statement "See equipment manufacturer service information" indicates the equipment manufacturer service information should be referenced for maintenance information.
- The statement "If equipped" indicates if the item is on your product it should be serviced at the marked interval.
- The statement "See component manufacturer service information" indicates the component manufacturer service information should be referenced for maintenance information.

Multiple intervals may be marked for one maintenance item. The first marked interval indicates a first service event or break-in requirement for that item. The second marked interval indicates the routine service interval which should be followed for that item.

The end of the maintenance schedule does not indicate the end of required maintenance. Continue performing maintenance events at the indicated routine intervals throughout the life of the product.

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

Routine Maintenance Tool Requirements

General Information

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

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

Tool Part Number	Description
3164488	Digital multimeter
3164794	Torque wrench
3164795	Torque wrench
3164797	Torque wrench
3400158	Filter wrench
3822525	Belt tension gauge (click type)
5299073	Barring tool

Tool Part Number	Description
CC-2800	Refractometer
ST-1273	Pressure gauge

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

Routine Maintenance Schedule

Hours		250	500	1000	2000	4000	5000	6500				
Months		3	6									
Years				1	2	3	4					
Procedure	**Step**											
Air Cleaner Restriction	Check	X										
Charge Air Piping	Check	X										
Charge Air Cooler	Check	X										
Batteries	Check		X									
Lubricating Oil and Filters	Change	See Lubricating Oil and Filter Intervals procedure. Refer to Procedure 359-009 in Section 3.										
Battery Cables and Connections	Check		X									
Cooling Fan Belt Tensioner	Check		X									
Drive Belt, Cooling Fan	Check		X									
Engine Coolant Antifreeze	Check		X									
Fuel Filter (Spin-On Type)	Change			X								
Fuel Filter (Canister Type)	Change			X								
Radiator Pressure Cap	Check			X								
Lubricating Oil and Filters	Change			X								
Fan Hub, Belt Driven	Check			X								
Cooling System	Flush				X							
Engine Cleaning	Clean				X							
Drive Belt, Cooling Fan	Change				X							
Radiator Hoses	Check				X							
Air Compressor Discharge Lines	Check				X							
Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter	Change	See Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter Intervals procedure. Refer to Procedure 359-017 in Section 3.										
Overhead Set	Adjust						X					

Routine 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], Hours or Time
D = Maintenance Check Performed

Key to table headings:
E = Check Performed By
F = Comments

A	B	C	D	E	F

Lubricating Oil and Filter Intervals

General Information

- The lubricating oil and lubricating oil filter intervals are based on Cummins Engineering Standard (CES) 20081 or CES 20086 and a standard duty cycle.
- Lubricating oil change intervals can be adjusted based on lubricating oil type, lubricating oil pan size, duty cycle, and fuel consumption. See Table 1 below.
- Table 1 below specifies the maximum lubricating oil drain interval for the listed lubricating oil types, based on lubricating oil pan size.
- Cummins Inc. requires the use of a high-quality, heavy-duty engine lubricating oil. Use the following procedure for lubricating oil recommendations and specifications. Refer to Procedure 018-003 in Section V.
- If the engine is equipped with a component or accessory that is **not** manufactured by Cummins Inc., see equipment manufacturer service information.

Oil Drain Intervals

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

Table 1: Lubricating Oil and Lubricating Oil Filter Change Interval				
Oil Classification[1]	**Lubricating Oil Type**	**Lubricating Oil Pan Size**	**Oil Drain and Filter Change Interval for Standard Duty Cycle[4] [hours]**	**Oil Drain and Filter Change Interval for Severe Duty Cycle[5] or Fuel Type[3] [hours]**
CES 20081/API CJ-4/ ACEA E9	Conventional	Less than 14.2 liters [15 qt]	500	500
		Greater than or equal 14.2 liters [15 qt]	500	500
	Fully Synthetic	Less than 14.2 liters [15 qt]	500	500
		Greater than or equal 14.2 liters [15 qt]	500	500
CES 20086/API CK-4	Conventional	Less than 14.2 liters [15 qt]	500	500
		Greater than or equal 14.2 liters [15 qt]	1000[2]	500
	Fully Synthetic	Less than 14.2 liters [15 qt]	500	500
		Greater than or equal 14.2 [15 qt]	1000[2]	500

1 Cummins Inc. recommends the use of a high quality, Society of Automotive Engineers (SAE), 15W-40 or 5W-40 heavy duty engine lubricating oil, such as Valvoline Premium Blue Extreme™, which meets or exceeds CES 20081 or CES 20086, the American Petroleum Institute (API) performance classification CJ-4 or CK-4, and the European Automotive Manufacturer Association (ACEA) performance classification E9.

2 Extended lubricating oil drain intervals (1000 hours) apply when ultra-low sulfur diesel (ULSD) fuel is used.

- The initial lubricating oil change interval should be 500 hours or 6 months, whichever occurs first, then 1000 hours for every lubricating oil and filter change thereafter.

3 Fuel Type: Oil drain intervals for biodiesel blends greater than B8 should **not** exceed 500 hours. Use the following procedure for additional fuel considerations. Refer to Procedure 018-002 in Section V.

4 Standard Duty Cycle:

- Fuel consumption less than 13.4 liters/hour [3.5 gal/hour], and
- Engine idle time less than 30 percent.

5 Severe Duty Cycle:

- Fuel consumption greater than 13.4 liters/hour [3.5 gal/hour], and/or
- Engine idle time greater than 30 percent.

Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter Intervals

General Information

Aftertreatment Diesel Exhaust Fluid (DEF) Dosing Unit Filter Intervals are based on the following:

- Operating condition.

See Table 1 for Aftertreatment DEF Dosing Unit Filter Intervals.

Table 1: Aftertreatment DEF Dosing Unit Filter Intervals		
Operating Condition	**Step**	**Hours**
Normal	Change	4000
High Dust	Change	2000

Debris can damage the aftertreatment DEF dosing unit or the aftertreatment DEF dosing valve. See equipment manufacturer service information for additional information.

Air Cleaner Restriction

Maintenance Check

Mechanical Indicator

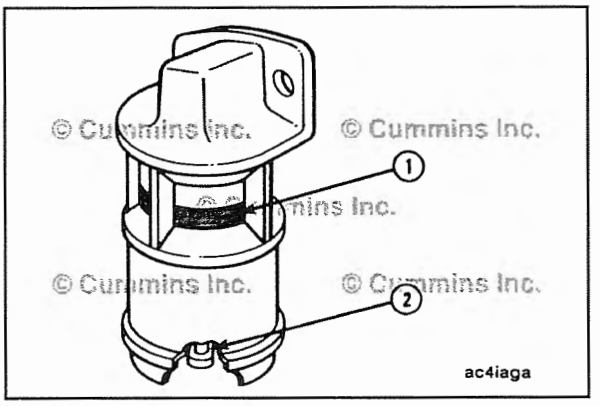
⚠CAUTION⚠

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.

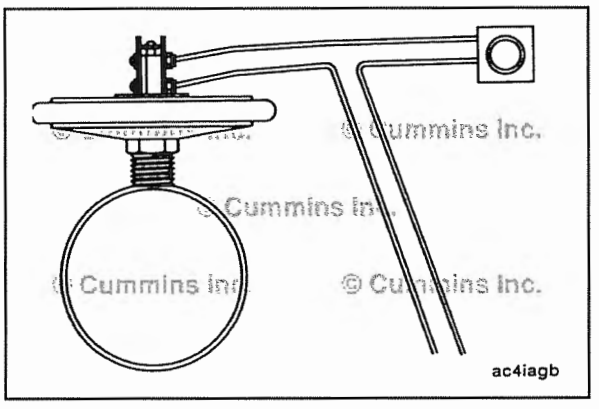
A mechanical restriction indicator is available to indicate excessive air restriction through a dry-type air cleaner. This instrument can be mounted in the air cleaner outlet or on the instrument panel. The red flag (1) in the window gradually rises as the cartridge loads with dirt. After changing or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



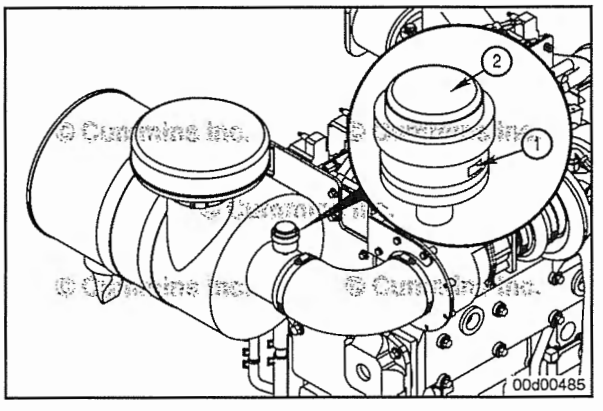
Vacuum Indicator

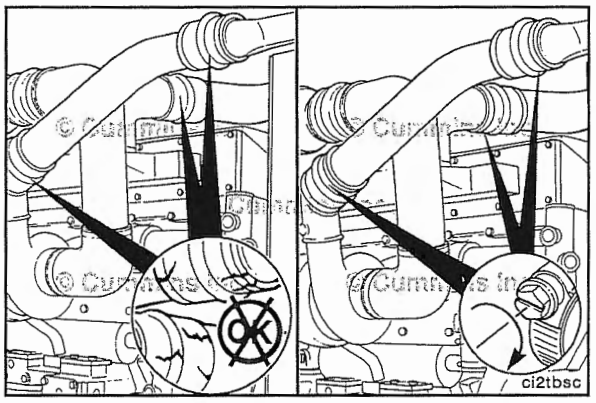
Vacuum switches actuate a warning light on the instrument panel when the air restriction becomes excessive.



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)

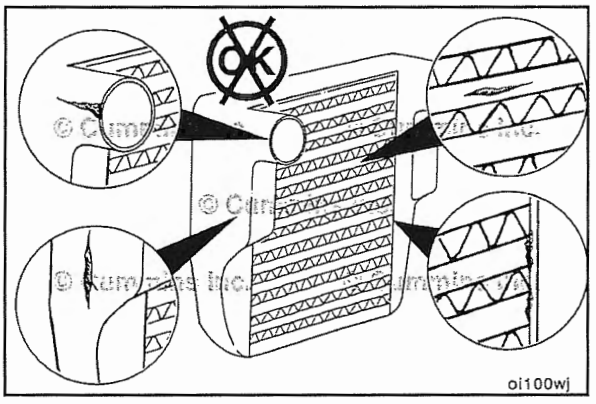




Charge-Air Piping

Maintenance Check

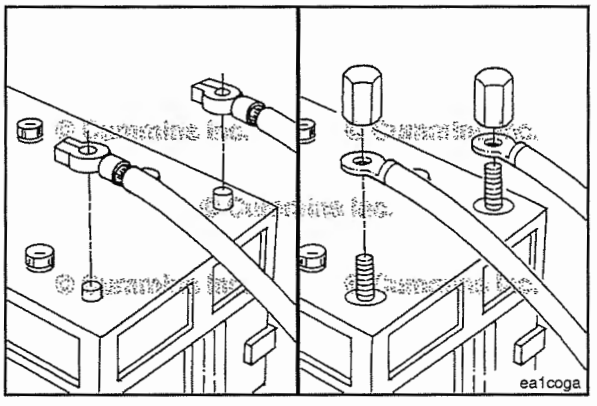
Inspect the charge-air piping and hoses for leaks, holes, cracks, or loose connections. Tighten the hose clamps if necessary. Refer to the vehicle or equipment manufacturer's specifications for the correct torque value.



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.



Batteries

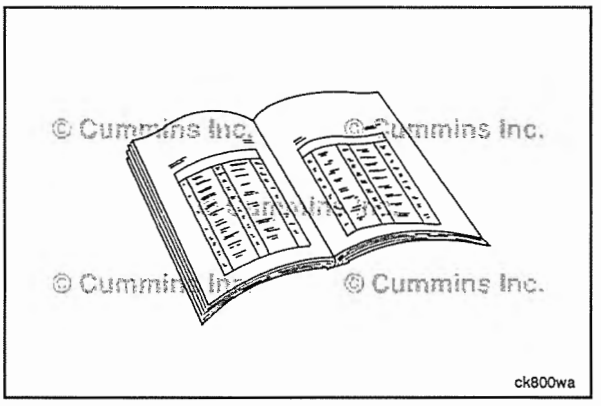
General Information

⚠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.

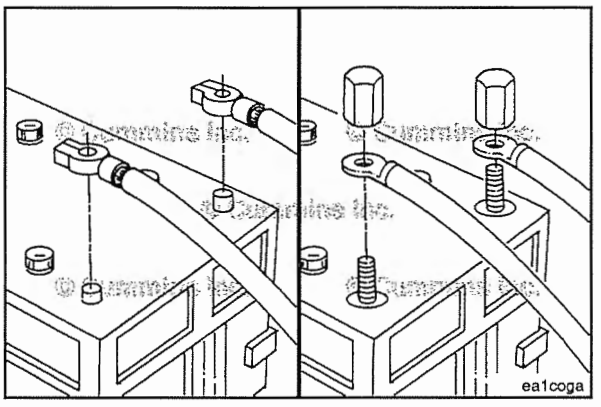


Battery Cables and Connections

Initial Check

There are two possible heavy-duty battery connections:

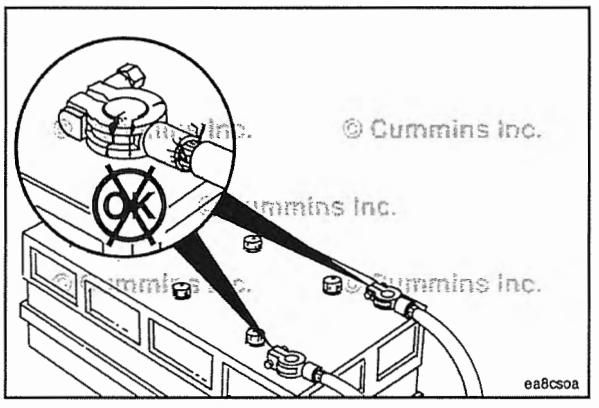
- Battery terminal and clamp (1)
- Threaded battery terminal and nut (2).



⚠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.

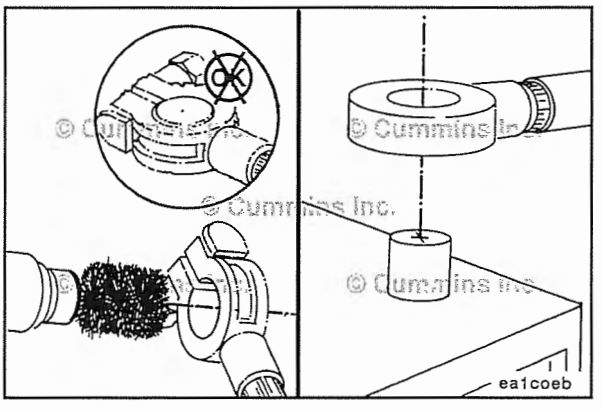
Remove and inspect the battery cables and connections for cracks or corrosion.

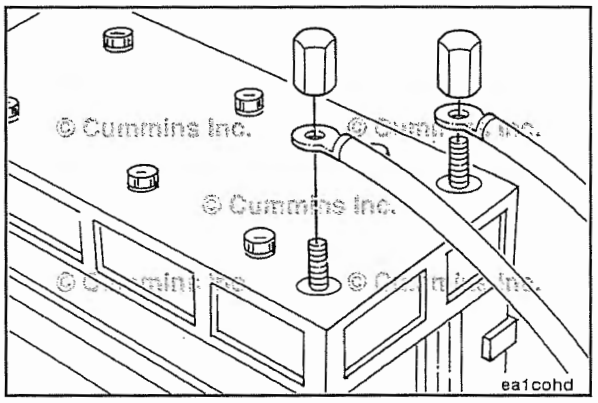
Replace broken terminals, connectors, or cables.



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.

Cooling Fan Belt Tensioner

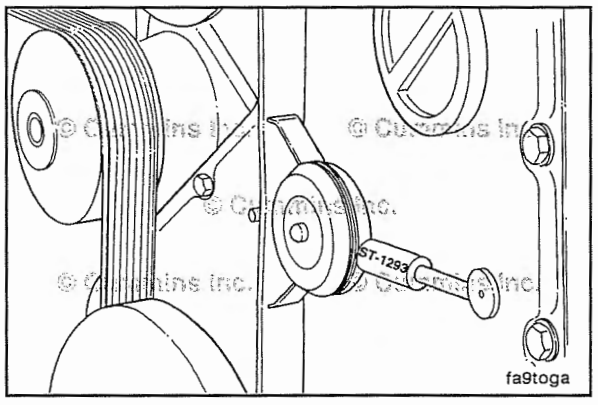
Select Service Tools

Recommended Cummins® Service Tools

- Belt tensioner gauge, Part Number ST-1293

Additional Service Items

- No additional service items required.



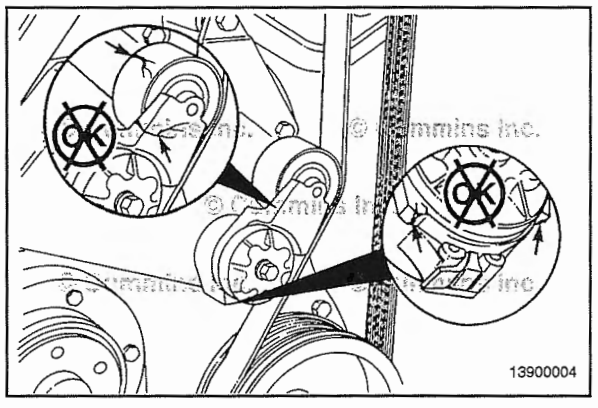
Initial Check

With the engine stopped and the belt installed, record the belt tension generated by the existing belt tensioner.

Use belt tensioner gauge, Part Number ST-1293, to measure the tension in the drive belt.

Belt Tension		
N		lbf
356	MIN	80
534	MAX	120

If the measurement is out of the specified range, replace **only** the belt. Perform the tension test again. If a new belt has been installed and the measurement is still outside of the specified range, replace the belt tensioner.

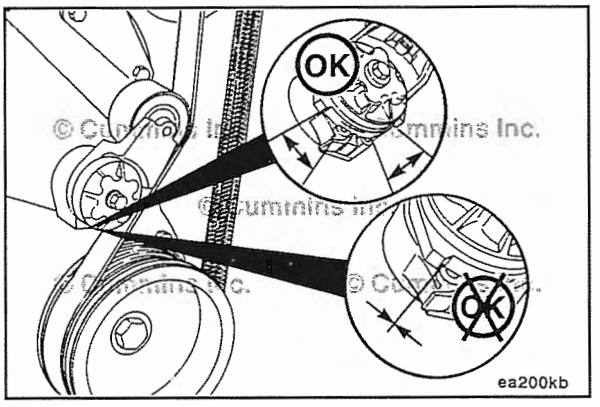


With the engine stopped, check the tensioner arm, pulley, and stops for cracks. If any cracks are found, the tensioner **must** be replaced.

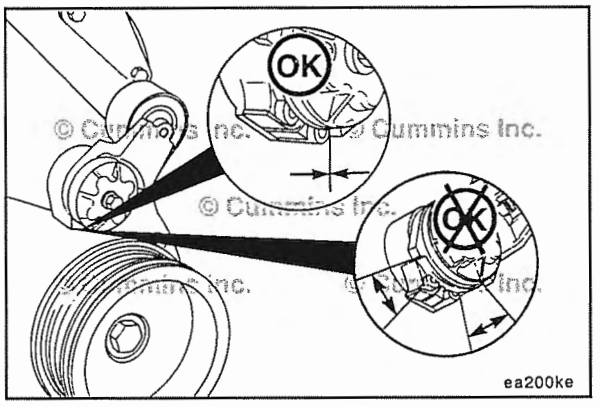
With the belt installed, verify neither tensioner arm stop is in contact with the spring case stop. If either of the stops is touching:

- Verify the correct belt part number is installed.
- If the correct belt is installed, replace the belt. Refer to Procedure 008-002 in Section 3.

After replacing the belt, if the tensioner arm stops are still in contact with the spring case stop, the tensioner **must** be replaced.

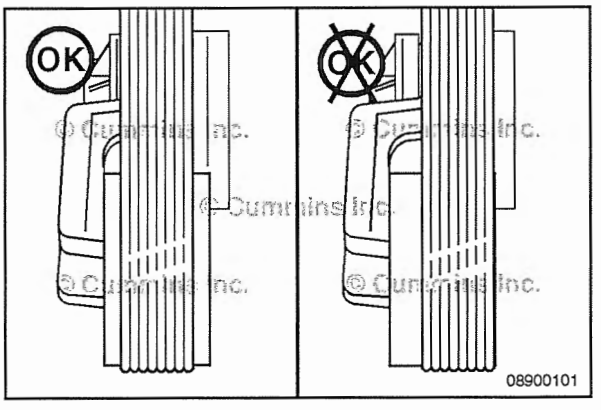


With the belt removed, verify the tensioner arm stop is in contact with the spring case stop. If these two are **not** touching, the tensioner **must** be replaced.



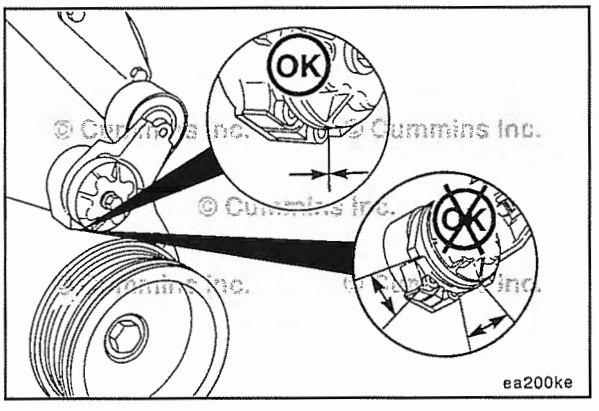
Check the location of the drive belt on the belt tensioner pulley. The belt should be centered on, or close to the middle of, the pulley. Misaligned belts, either too far forward or backward, can cause belt wear, belt roll-offs, or increase uneven tensioner bushing wear.

NOTE: Belt mis-alignment is **not always** a result of a malfunctioning or faulty belt tensioner. Make sure the adjacent pulleys and mounting brackets are aligned and mounted correctly. Refer to Procedure 008-002 in Section 3.



Remove the drive belt. Refer to Procedure 008-002 in Section 3.

With the belt removed, verify the tensioner arm stop is in contact with the spring case stop. If they are **not** in contact, the tensioner **must** be replaced.

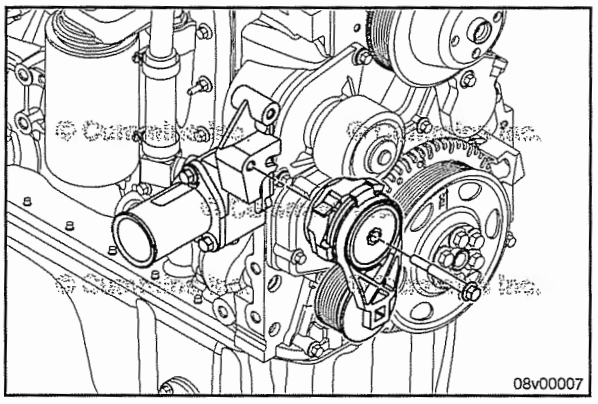


Preparatory Steps

⚠ WARNING ⚠

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

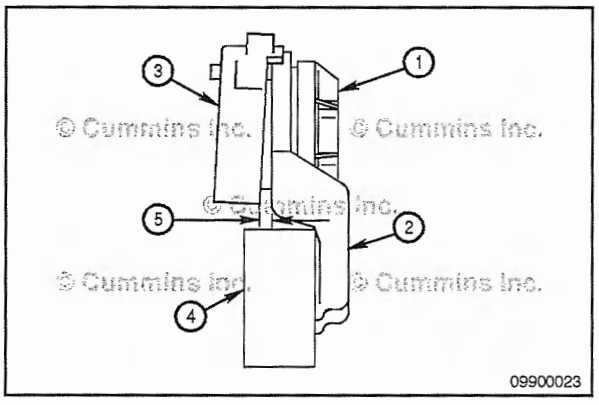
- Disconnect the batteries. See equipment manufacturer service information.
- Remove the drive belt. Refer to Procedure 008-002 in Section 3.



Remove

Remove the capscrew and belt tensioner from the bracket.

NOTE: Most belt tensioners are mounted to the water inlet connection. Some belt tensioners are mounted to a separate mounting bracket and use internal fasteners for clearance.



Clean and Inspect for Reuse

Inspect the cooling fan drive belt for reuse. Refer to Procedure 008-002 in Section 3.

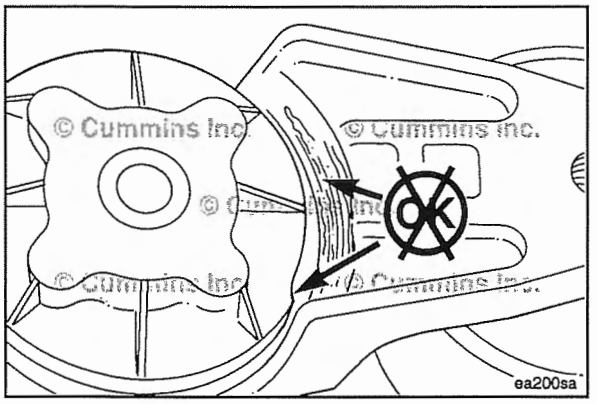
Measure the clearance between the tensioner spring case and the tensioner arm to verify tensioner wear-out and uneven bearing wear. If the clearance at measurement point 5 exceeds 3 mm [0.12 in] at any point, the tensioner is damaged and **must** be replaced as a complete assembly.

Tensioners generally show a larger clearance gap near the lower portion of the spring case, resulting in the upper portion rubbing against the tensioner arm.

1 Tensioner cap
2 Tensioner arm
3 Spring case
4 Tensioner pulley
5 Clearance gap.

NOTE: Always replace the belt when a tensioner is replaced. However, it is **not** always necessary to replace a tensioner when a belt is replaced.

Inspect the tensioner for evidence of the tensioner arm contacting the tensioner cap. If there is evidence of the two areas making contact, the pivot tube bushing has failed and the tensioner **must** be replaced.



Install

If removed, install the belt tensioner mounting bracket and mounting bracket capscrews.

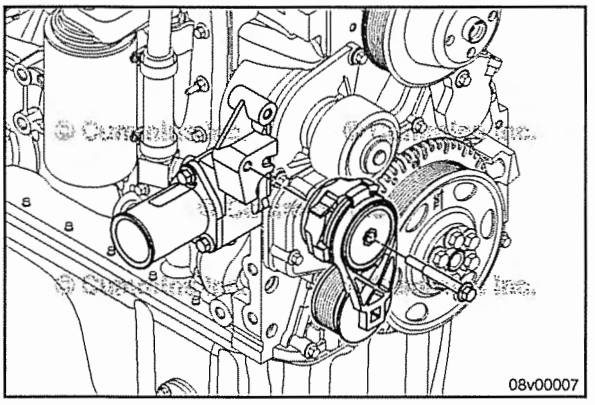
NOTE: Some belt tensioner mounting brackets use internal fasteners for clearance.

Torque Value: 24 N•m [212 in-lb]

Install the belt tensioner and capscrew.

Tighten the capscrew.

Torque Value: 43 N•m [32 ft-lb]



Finishing Steps

⚠WARNING⚠

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

- Install the drive belt. Refer to Procedure 008-002 in Section 3.
- Connect the batteries. See equipment manufacturer service information.

Drive Belt, Cooling Fan

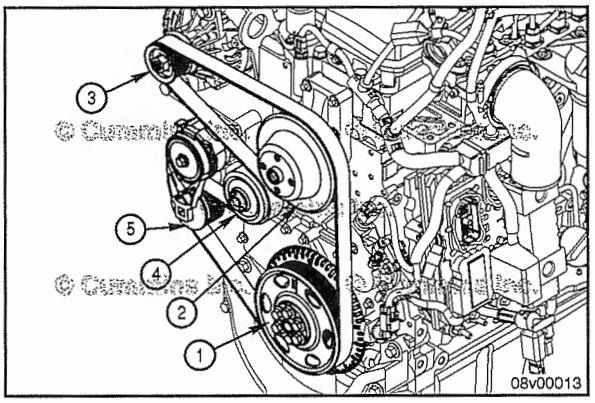
Select Service Tools

Recommended Cummins® Service Tools

- Pulley alignment fixture, Part Number 3163524, or equivalent

Additional Service Items

- Electronic stethoscope, or equivalent



General Information

Due to the number of drive belt arrangements, this procedure does **not** cover all available cooling fan drive belt routing.

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

The cooling fan belt routing typically consists of the following components, but may **not** include all of them:

1 Crankshaft pulley

2 Fan pulley

3 Water pump pulley

4 Alternator pulley

5 Tensioner idler pulley.

NOTE: Some engine driven belts are installed/supplied by the vehicle's original equipment manufacturer (OEM). See equipment manufacturer service information and installation instructions.

Troubleshooting

NOTE: This content in this section is generic and may **not** apply to all available cooling fan drive belt systems.

The following section contains diagnostic information and procedures to aid in identifying drive belt and accessory drive issues. These issues can include:

- Belt noise (squeal and chirp)
- Belt tracking (jumping)
- Belt fraying
- Snub breaks and punctures.

Common causes of drive belt noise, fraying, and breaks are:

- Drive pulley misalignment
- Embedded debris in drive pulley grooves
- Incorrect belt material and/or belt length
- Damaged or incorrect automatic belt tensioner
- Improper drive belt routing
- Improper fan size and/or fan clutch.

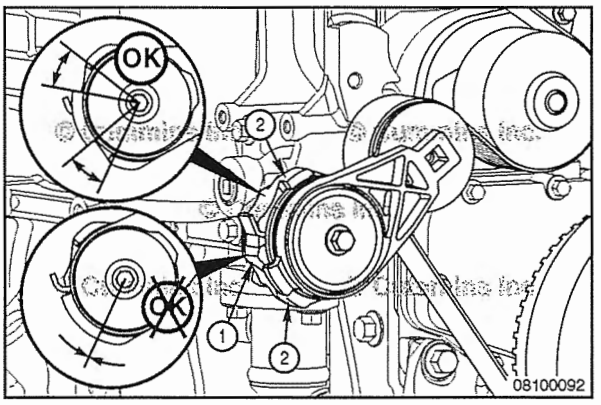
The original drive belt and tensioner should be used if possible while troubleshooting drive belt issues. Replacement of a belt and/or tensioner prior to troubleshooting can mask the root cause of the issue due to the break-in time required for a belt and tensioner.

NOTE: A newly installed belt and/or tensioner will **not** come to rest properly until the engine is operated. Always operate the engine for a brief period of time prior to verifying the tensioner resting location.

Inspect the automatic belt tensioner. Refer to Procedure 008-087 in Section 3. If the belt tensioner does **not** meet the reuse criteria, the belt tensioner **must** be replaced.

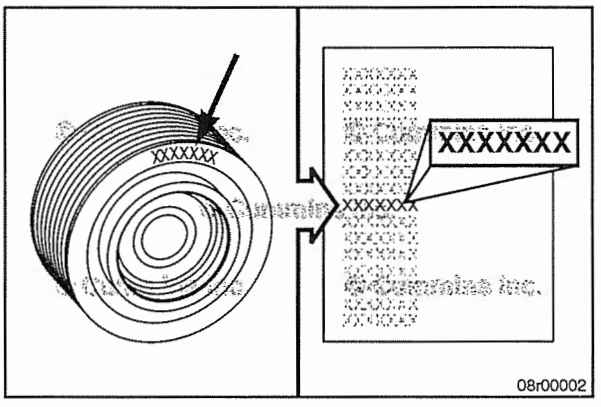
With the belt installed, check the automatic belt tensioner resting position. If the belt tensioner arm stop is contacting either of the spring case stops:

- Verify the correct belt part number is installed.
- If the correct belt is installed, replace the belt.

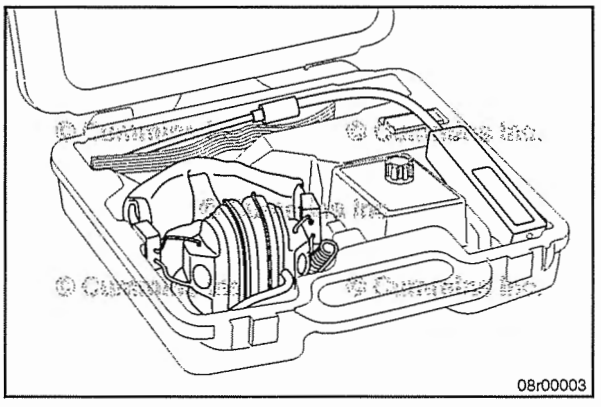


Verify all accessory drive components and pulleys are correct. Components yielding incorrect part numbers, or installed without the appropriate spacers and/or brackets can contribute to gross drive belt misalignment.

Verify proper drive belt routing, if available. See equipment manufacturer service information.



Isolating the source of drive belt noise can be done by use of an electronic stethoscope, or an equivalent device designed to block audible noise other than that desired by use of a microphone.

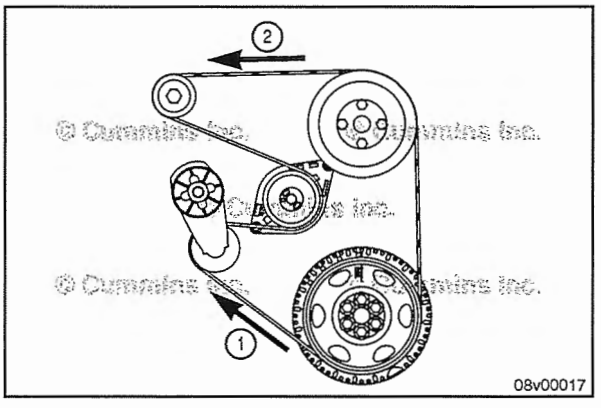


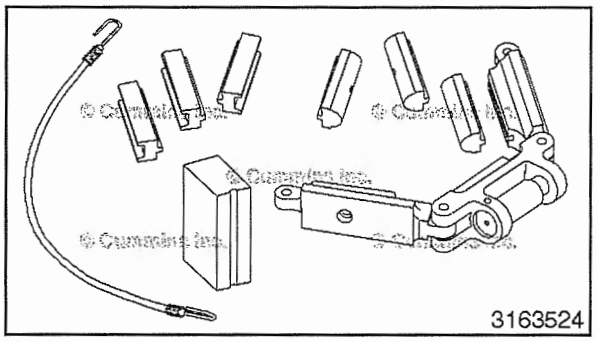
Drive belt noise can be difficult to isolate and troubleshoot. The origin of drive belt noise may **not** be located at the pulley out of alignment, rather 'upstream' from the noise origin.

Troubleshooting should always be completed in a direction opposite belt travel (i.e. counter clockwise) beginning at the pulley where the noise originates.

Arrow number (1) indicates belt travel direction, whereas arrow number (2) represents the direction in which troubleshooting should be conducted.

- Flat pulleys should be inspected for uneven wear patterns.
- Grooved pulleys should be inspected for embedded debris, belt dust buildup, and pulley alignment.



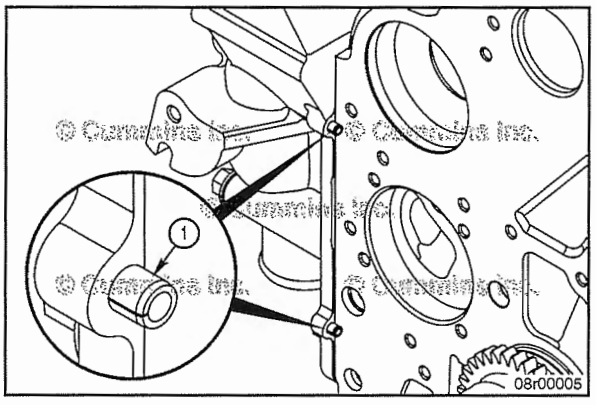


NOTE: The belt alignment laser tool can identify misalignment of pulleys down to ½ of a belt rib. The capability of the alignment fixture is contingent upon proper calibration. Make sure all set-upand calibration procedures are followed before verifying pulley alignment.

Verify all pulleys are aligned correctly using one of the following pulley alignment fixture tools or equivalent:

- Part Number 3163524
- Part Number 93874 (Dayco)

Pulley alignment should always be checked from the fan pulley and crankshaft pulley to other front end mounted grooved pulleys. Contact a Cummins® Authorized Repair Location for drive belt alignment.

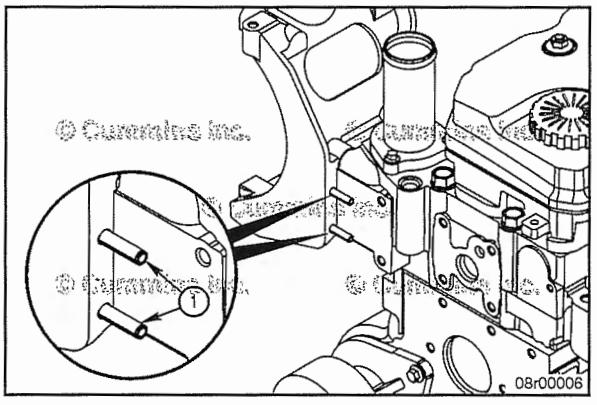


If a pulley is identified as out of alignment, verify the component mounting bracket installation.

Certain engines feature an automatic belt tensioner mounted to the water inlet connection. Verify the locating roll pins (1) are:

- Installed into the connection
- In contact with the cylinder block
- Do **not** appear to be bent or out of place.

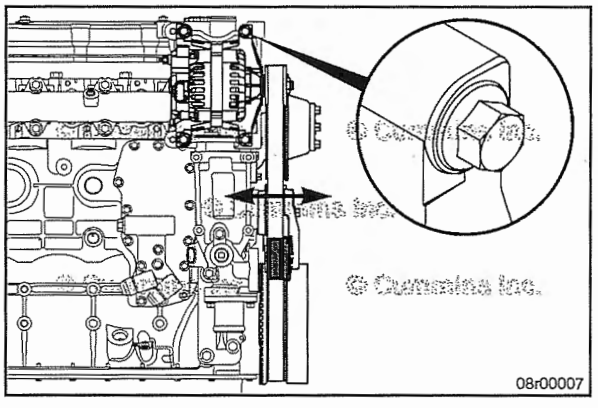
If the water inlet connection and/or roll pins are **not** installed correctly, remount the water inlet connection.



Certain alternator mounting brackets are aligned to the cylinder head by roll pins. Verify the locating roll pins (1) are:

- Installed into the alternator bracket
- In contact with the cylinder head
- Do **not** appear to be bent or out of place.

If the alternator bracket and/or roll pins are not installed correctly, remount the alternator bracket.



Check drive pulley alignment with pulley alignment fixture, Part Number 3163524, or equivalent, after any bracket adjustments are made.

Certain 'pad mounted' components which do **not** contain locating features can be positioned on the mounting brackets for fine adjustments.

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.

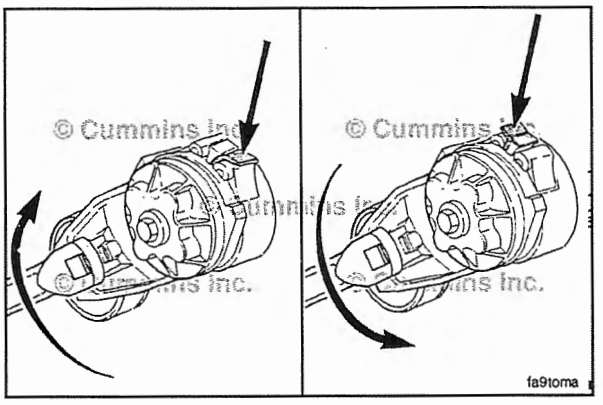
- Disconnect the batteries. See equipment manufacturer service information.

Remove

⚠CAUTION⚠

The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

The belt tensioner winds in the direction the spring tang is bent over the tensioner body. To loosen the tension on the belt, rotate the tensioner to wind the spring tighter.



⚠CAUTION⚠

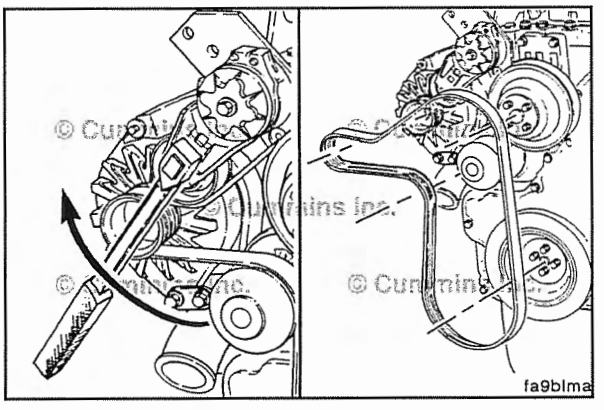
Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to break.

NOTE: Make a diagram of the belt arrangement prior to removing the drive belt. This aids in installation and proper routing of the cooling fan drive belt.

NOTE: The location of the belt tensioner can vary, depending on the front engine accessory arrangement.

Pivot the tensioner in the direction of the spring tang to remove the belt.

Remove the belt.



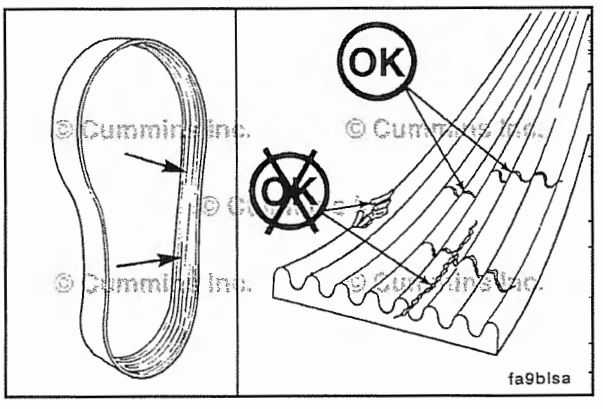
Clean and Inspect for Reuse

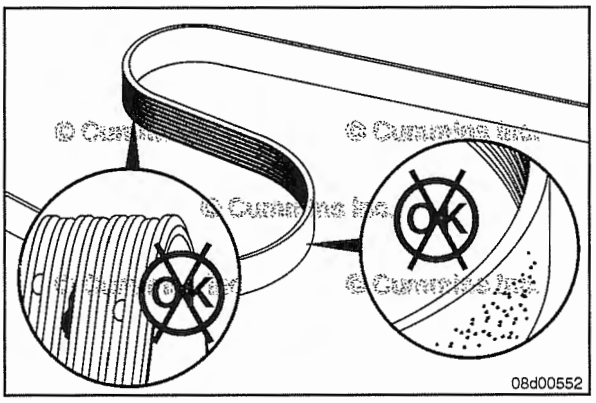
Inspect the drive belt for damage.

Transverse (across the belt) cracks are acceptable.

Longitudinal (direction of belt ribs) cracks that intersect with transverse cracks are **not** acceptable.

If the belt is frayed, punctured, or material is missing, the belt is unacceptable for reuse and **must** be replaced.





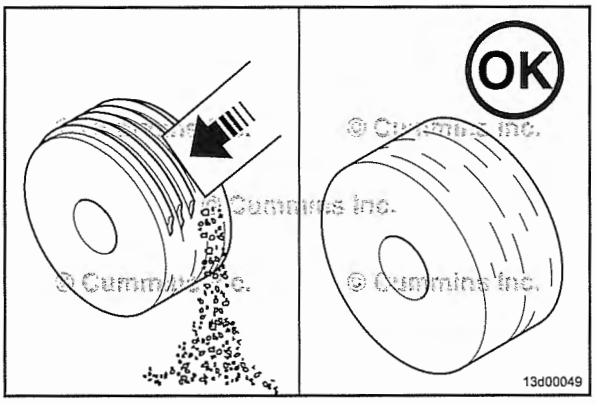
Inspect the belt grooves for:

- Embedded debris
- Uneven/excessive rib wear
- Exposed belt cords.

Inspect the backside of the belt for:

- Glazing (high heat)
- Embedded debris
- Exposed belt cords.

If **any** of the above conditions are present, the belt is unacceptable for reuse and **must** be replaced.



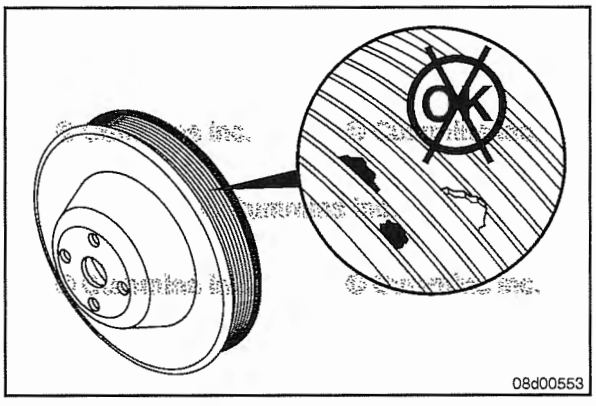
Inspect the idler and drive pulleys for wear or cracks.

Plastic pulleys often have a build-up of road dirt and belt material that is **not** to be confused with wear.

The dirt can be removed with a suitable tool to check for wear.

Clean, check, and reuse all pulleys in the front end accessory drive if **not** damaged, rather than replacing. Pulleys damaged from embedded debris **must** be replaced.

Inspect the tensioner. Refer to Procedure 008-087 in Section 3.

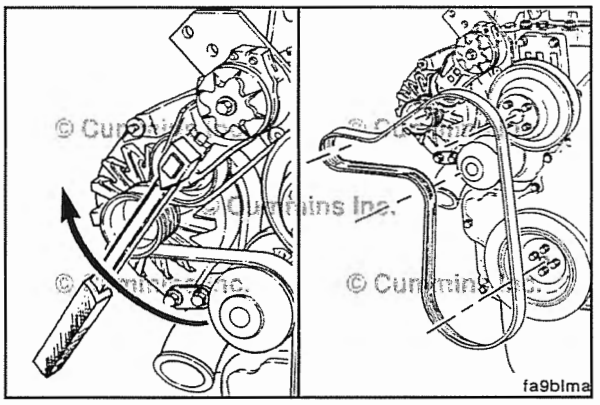


Inspect all system pulleys for embedded debris:

- Rocks, stones
- Metal
- Belt material.

Remove the debris from the grooves of the pulley. If the pulley has been deformed as a result of foreign material embedment, the pulley **must** be replaced.

Install



⚠CAUTION⚠
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

Route the drive belt on the engine using the belt diagram created in the Remove section. Do **not** install the belt over the water pump pulley at this time.

Pivot the tensioner in the direction of the spring tang and install the drive belt, slipping the belt over the water pump pulley last.

Slowly 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 accessory drive.

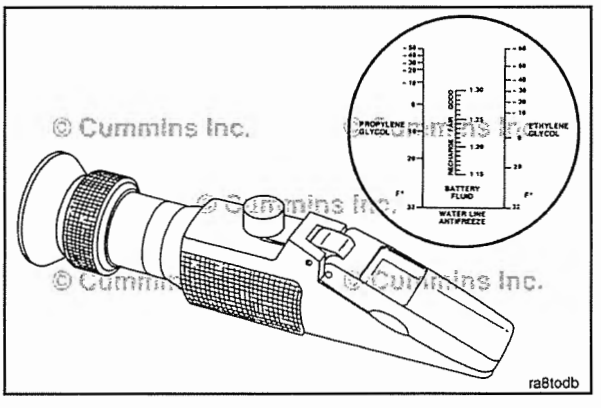
Finishing Steps

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

- Connect the batteries. See equipment manufacturer service information.
- Operate the engine. Check for belt squeal. Excessive belt squeal indicates belt slippage.
- If belt squeal is present, check the routing of the belt to make sure the belt is installed correctly on each pulley.

Engine Coolant Antifreeze

Maintenance Check



⚠CAUTION⚠
Overconcentration 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.

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.

Fuel Filter (Spin-On Type)

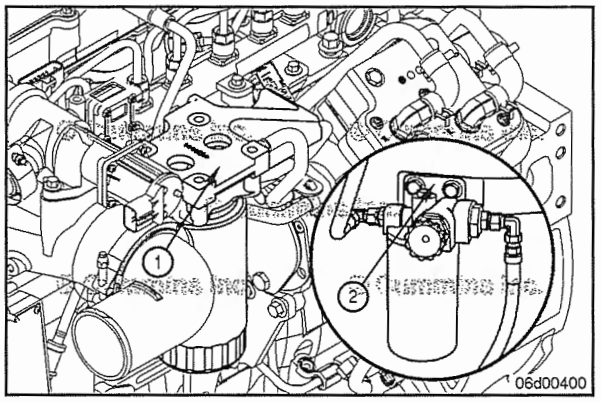
Select Service Tools

Recommended Cummins® Service Tools

- QD™ contact cleaner, Part Number 3824510, or equivalent

Additional Service Items

- 1 inch wrench



General Information

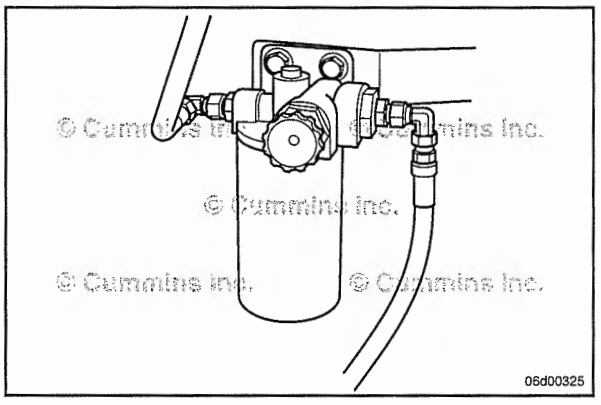
The engine uses a dual fuel filter system.

1 The pressure-side fuel filter is used for filtration **only** and is pressurized by the gear pump mounted on the engine fuel pump.

NOTE: Some applications utilize a chassis-mounted pressure-side filter.

2 The suction-side fuel filter is a fuel/water separator and is located between the gear pump, mounted on the engine fuel pump, and the original equipment manufacturer (OEM) fuel supply tank. This filter is **not** pressurized, but operates under a vacuum.

NOTE: The priming pump can be an OEM-supplied component and can be designed or installed differently. If a priming pump is **not** installed or is a different design, see equipment manufacturer service information for fuel system priming information.



Fuel System Priming

NOTE: The priming pump can be an OEM-supplied component and can be designed or installed differently. If a priming pump is **not** installed or is a different design, see equipment manufacturer service information for fuel system priming information.

A certain amount of air becomes trapped in the fuel system when fuel system components on the supply and/or high-pressure side are serviced or replaced. Fuel system priming is accomplished using a manual priming pump. For priming procedures, see the Prime step of this procedure.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will help prime the fuel system.

Preparatory Steps

⚠WARNING⚠

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

⚠WARNING⚠

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

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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⚠

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

⚠CAUTION⚠

Clean all around the filter area before disassembly. Dirt or contaminants can damage the fuel system.

- Disconnect the batteries. See equipment manufacturer service information.
- Clean the area around the fuel filter.
- If required, disconnect the wiring harness from the water in fuel sensor.

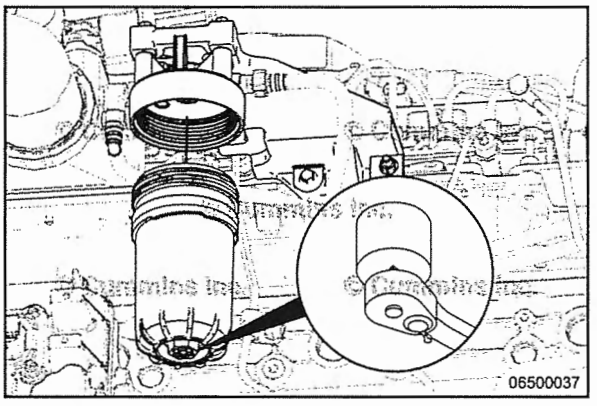
Remove

NOTE: The following steps can be used for replacing the pressure-side and suction-side fuel filter.

Use a 1 inch wrench on the drive feature located on the bottom of the fuel filter.

Loosen and remove the fuel filter.

Make sure the o-ring does **not** stick to the fuel filter head. Remove the o-ring with an o-ring pick, if necessary.



Install

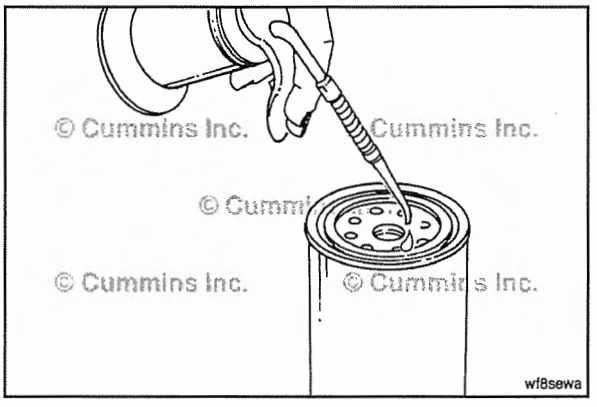
⚠CAUTION⚠

Do not pre-fill the pressure-side fuel filter with fuel unless a clean side block-off plug is used. The system must be primed after the fuel filter is installed. Pre-filling the pressure-side fuel filter can result in debris entering the fuel system and damaging fuel system components.

NOTE: If available, pre-fill new filters, both pressure-side and suction-side, with clean fuel prior to assembly using the clean side block-off plug packed with the filter. Do **not** pour fuel directly in the center of the filter, since this will allow unfiltered fuel to enter the system and can cause damage to fuel system components.

Use the correct fuel filter. Refer to Procedure 018-024 in Section V.

Lubricate the fuel filter o-ring. Use clean lubricating oil.

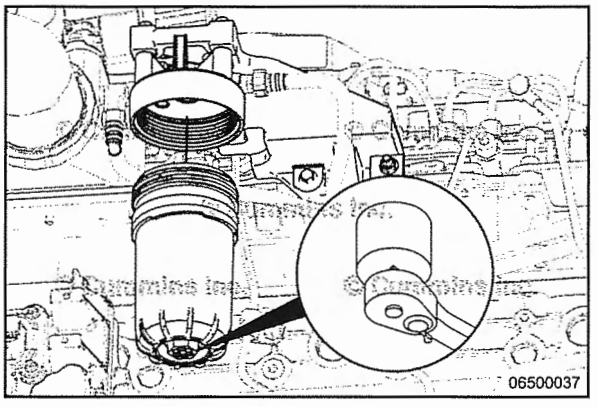


⚠CAUTION⚠

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

Install and tighten the fuel filter onto the filter head, or follow manufacturer instructions.

Torque Value: 8 N•m [71 in-lb]



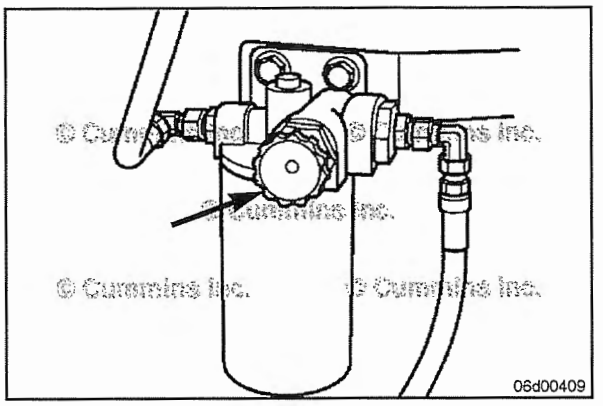
Finishing Steps

⚠WARNING⚠

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

- If required, connect the wiring harness to the water in fuel sensor.
- Connect the batteries. See equipment manufacturer service information.

Prime



⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

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

△CAUTION△
Do not engage the starter motor for more than 30 seconds at a time. Allow two minutes between cranking intervals.

NOTE: Some vehicles are equipped with an engine starting motor protection feature. If the starting motor is engaged for 30 or more seconds, without the engine starting, the starting motor will be locked out from operating, allowing for proper cooling of the starting motor. During this time, the WAIT TO START lamp, if equipped, will flash for 2 minutes. Once the lamp discontinues flashing, the starting motor will be allowed to function.

NOTE: The priming pump can be an OEM-supplied component and can be designed or installed differently. If a priming pump is **not** installed or is a different design, see equipment manufacturer service information for fuel system priming information.

NOTE: To reduce the possibility of damage to the hand pump priming seals, clean the fuel pump head and priming pump with QD™ contact cleaner, Part Number 3824510, or equivalent, and compressed air prior to priming the fuel system.

After filter change or running the fuel tank dry: Make sure there is fuel in the vehicle fuel tank.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Unlock the manual priming pump handle by turning it **counterclockwise**. Pump the primer handle until resistance is felt and the handle can **not** be pumped anymore (approximately 140 to 150 strokes for dry filters, or 20 to 60 strokes for pre-filled filters).

Lock the manual priming pump handle.

Crank the engine. If the engine does **not** start after 30 seconds, turn the key to the OFF position.

Pump the priming pump again, repeating the previous steps until the engine starts.

When the engine does start, it can operate erratically and with increased noise levels for a few minutes. This is a normal condition as air is being removed from the system.

NOTE: It is possible for Fault Code 559 to become active after fuel filter replacement due to air introduced in the system. Be sure to run the engine until air is purged. Use INSITE™ electronic service tool to clear the fault code before releasing the vehicle.

Operate the engine. Check for leaks.

Fuel Filter (Canister Type)

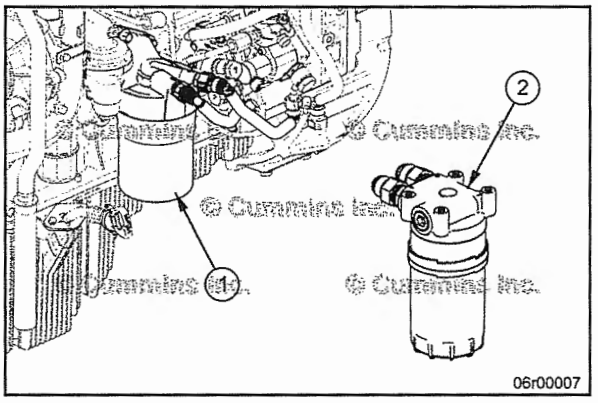
Select Service Tools

Recommended Cummins® Service Tools

- INSITE™ electronic service tool
- QD™ contact cleaner, Part Number 3824510, or equivalent

Additional Service Items

- No additional service items required.



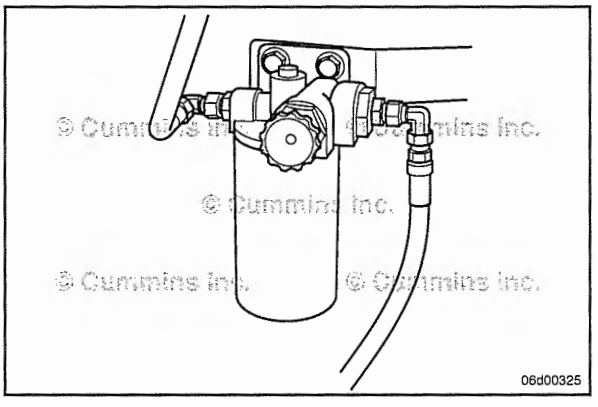
General Information

The engine uses a dual fuel filter system.

1 The pressure-side fuel filter is used for filtration **only** and is pressurized by the gear pump mounted on the engine's fuel pump. See equipment manufacturer service information for testing the pressure-side fuel filter.

2 The suction-side fuel filter is a fuel/water separator and is located between the gear pump, mounted on the engine's fuel pump, and the original equipment manufacturer (OEM) fuel supply tank. This filter is **not** pressurized, but operates under a vacuum. Use the following procedure for maximum inlet restriction at the inlet and to test the suction-side fuel filter condition.

NOTE: The priming pump can be an OEM-supplied component and can be designed or installed differently. If a priming pump is **not** installed or is a different design, see equipment manufacturer service information for fuel system priming information.



Fuel System Priming

A certain amount of air becomes trapped in the fuel system when fuel system components on the supply and/or high-pressure-side are serviced or replaced. Fuel system priming is accomplished using a manual priming pump. For priming procedures, see the Prime section of this procedure.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will help prime the fuel system.

NOTE: It is possible Fault Code 559 can become active after fuel filter replacement, due to air introduced into the system. Be sure to operate the engine until the air is purged. Use INSITE™ electronic service tool to clear the fault code before releasing the vehicle.

Preparatory Steps

⚠WARNING⚠

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

⚠WARNING⚠

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

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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⚠

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

△CAUTION△

Clean all around the filter area before disassembly. Dirt or contaminants can damage the fuel system.

- Disconnect the batteries. See the equipment manufacturer service information.
- Clean the area around the fuel filter.
- If required, disconnect the wiring harness from the water in fuel sensor.

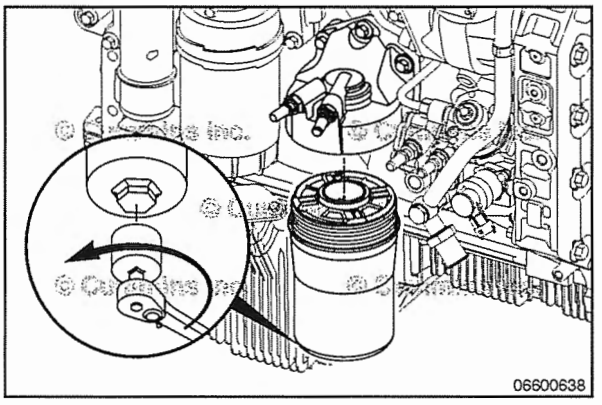
Remove

⚠WARNING⚠

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

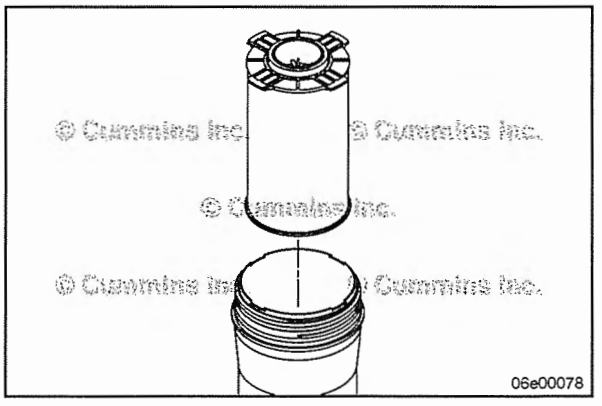
Remove the filter carefully.

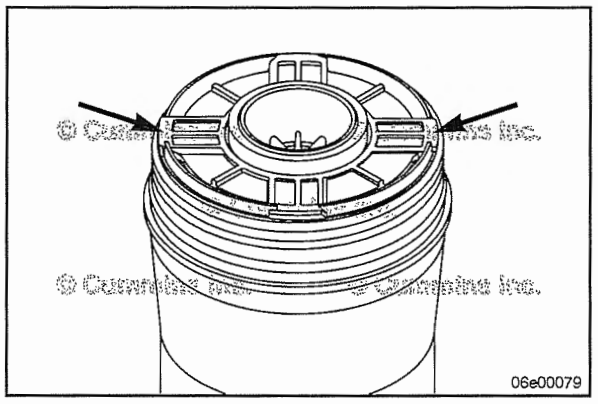
Use a 32 mm hex drive on the bottom of the filter canister to remove the canister.



Remove and discard the filter element.

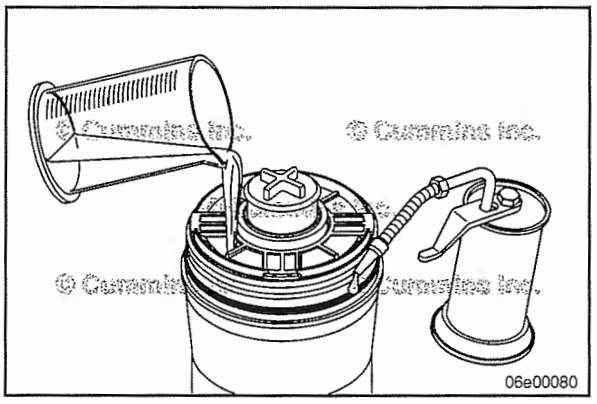
Remove and discard the o-ring seal on the filter canister.





Install a new filter element.

Make sure the tabs of the filter element are properly seated in the canister.



Install

⚠CAUTION⚠

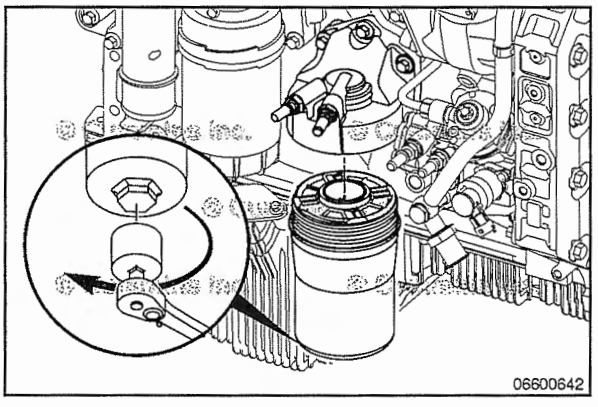
Do not pre-fill the pressure-side fuel filter with fuel unless a clean side block-off plug is used. The system must be primed after the fuel filter is installed. Pre-filling the pressure-side fuel filter can result in debris entering the fuel system and damaging fuel system components.

NOTE: If available, pre-fill new filters, both pressure-side and suction-side, with clean fuel prior to assembly using the clean side block-off plug packed with the filter. Do **not** pour fuel directly into the center of the filter, since this will allow unfiltered fuel to enter the system. Unfiltered fuel can cause damage to fuel system components.

Use the correct fuel filter. Refer to Procedure 018-024 in Section V.

Install the new fuel filter canister o-ring seal.

Lubricate the fuel filter o-ring with clean lubricating oil.



⚠CAUTION⚠

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

Install the filter on the filter head.

Install to the point of first contact for the filter and head.

Use a 32 mm hex drive to tighten the canister.

Torque Value: 32 N•m [24 ft-lb]

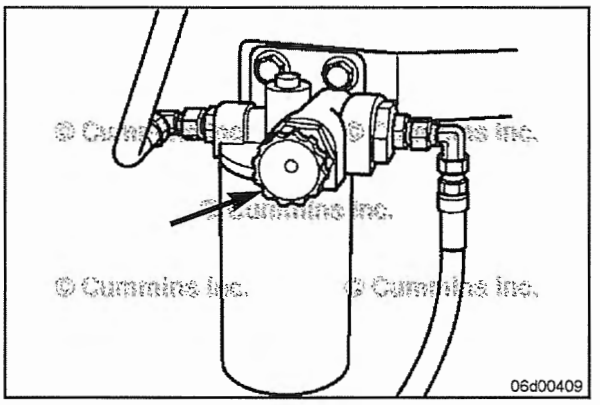
Finishing Steps

⚠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.

- If required, connect the wiring harness to the water in fuel sensor.
- Connect the batteries. See the equipment manufacturer service information.

Prime



⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

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

△CAUTION△
Do not engage the starter motor for more than 30 seconds at a time. Allow two minutes between cranking intervals.

NOTE: If the starting motor is engaged for 30 or more seconds, without the engine starting, the starting motor will be locked out from operating, allowing for proper cooling of the starting motor. During this time, the WAIT TO START lamp, if equipped, will flash for 2 minutes. Once the lamp discontinues flashing, the starting motor will be allowed to function.

NOTE: The priming pump can be an OEM-supplied component and can be designed or installed differently. If a priming pump is **not** installed or is a different design, see equipment manufacturer service information for fuel system priming information.

NOTE: To prevent damage to the hand pump priming seals, clean the fuel pump head and priming pump with electrical contact cleaner, Part Number 3824510, or equivalent, and compressed air prior to priming the fuel system.

After a filter change or running the fuel tank dry, make sure there is fuel in the vehicle fuel tank.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Unlock the manual priming pump handle by turning it **counterclockwise**. Pump the primer handle until resistance is felt and the handle can **not** be pumped anymore (approximately 140 to 150 strokes for dry filters, or 20 to 60 strokes for pre-filled filters).

Lock the manual priming pump handle.

Crank the engine. If the engine does **not** start after 30 seconds, turn the key to the OFF position.

Pump the priming pump again, repeating the previous steps until the engine starts.

When the engine does start, it can operate erratically and with increased noise levels for a few minutes. This is a normal condition as air is being removed from the system.

NOTE: It is possible Fault Code 559 can become active after fuel filter replacement, due to the air introduced in the system. Be sure to run the engine until the air is purged. Use INSITE™ electronic service tool to clear the fault code before releasing the vehicle.

Operate the engine. Check for leaks.

Radiator Pressure Cap

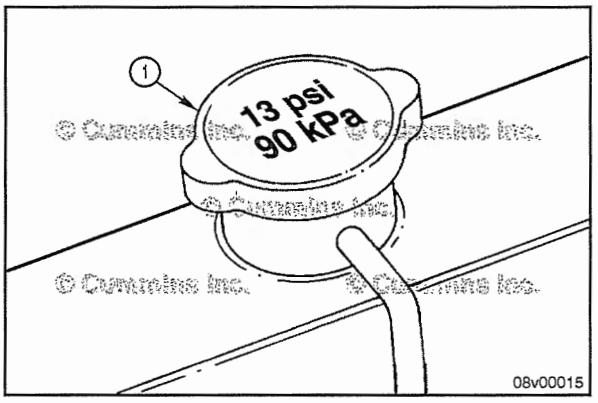
Select Service Tools

Recommended Cummins® Service Tools

- No Cummins® service tools required.

Additional Service Items

- No additional service items required.

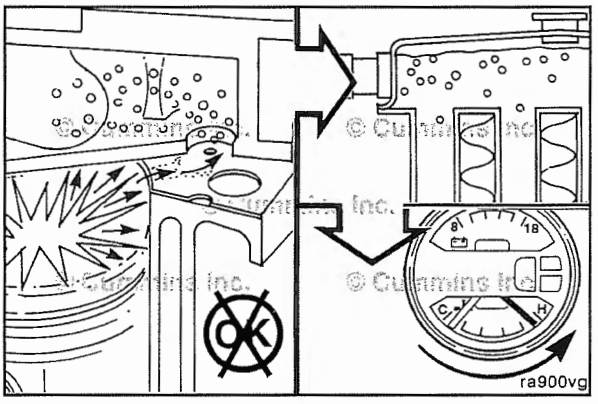


General Information

The system is designed to use a pressure cap to prevent boiling of the coolant.

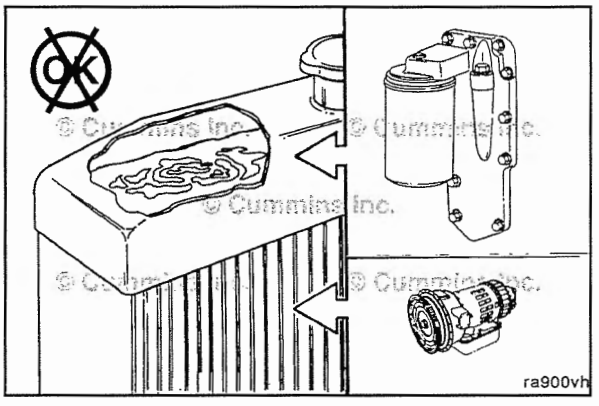
Different caps are specified for different pressure systems. Refer to Procedure 018-018 in Section V.

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



Installed radiator caps should have a minimum value of 90 kpa [13 psi] to a maximum of 276 kpa [40 psi] from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gases to the coolant system.



The operating pressure of the coolant system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems, such as the head gasket or oil cooler.

Transmission fluid can also leak into the coolant through radiator bottom tank transmission oil coolers. See equipment manufacturer service information.

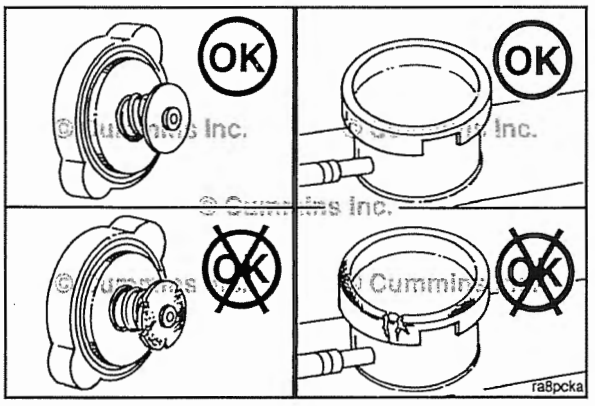
Inspect for Reuse

Make sure the correct radiator cap is being used. Use the following procedure for correct pressure cap specification. Refer to Procedure 018-018 in Section V.

Inspect the rubber seal of the pressure cap for damage.

Inspect the radiator fill neck for cracks or other damage.

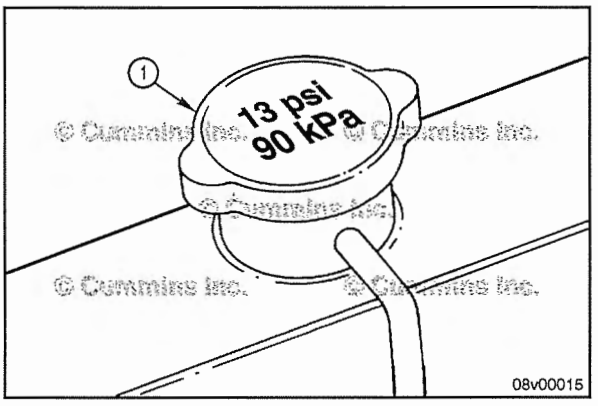
See the radiator manufacturer for instructions, if the fill neck is damaged.



Pressure Test

The system is designed to use the pressure cap (1) to prevent boiling of the coolant.

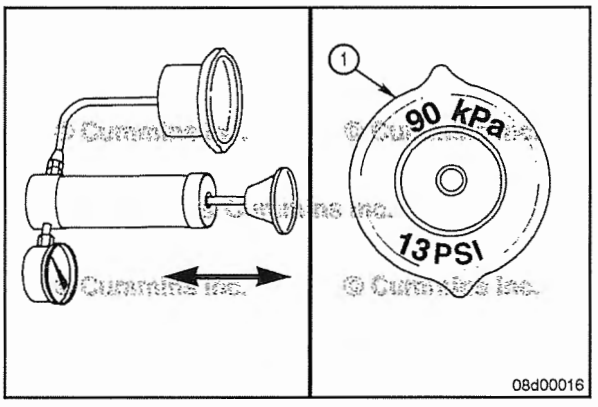
Different caps are specified for different pressure systems. Refer to Procedure 018-018 in Section V.



NOTE: An incorrect or malfunctioning cap (1) can result in loss of coolant and the engine running hot.

Pressure-test the radiator cap.

The pressure cap **must** seal within the value stated on the cap, or it **must** be replaced.



Lubricating Oil and Filters

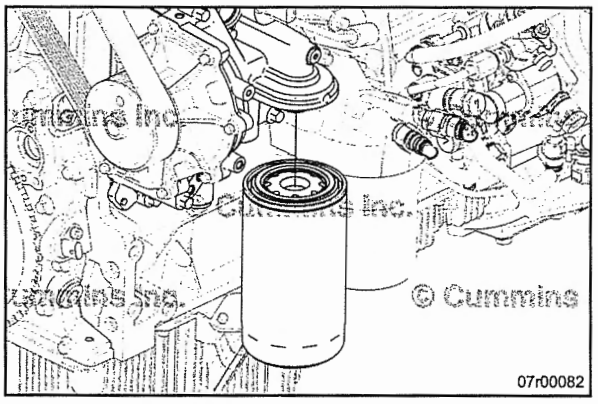
Select Service Tools

Recommended Cummins® Service Tools

- Oil filter wrench, Part Number 3400158, or equivalent

Additional Service Items

- Container suitable for lubricating oil

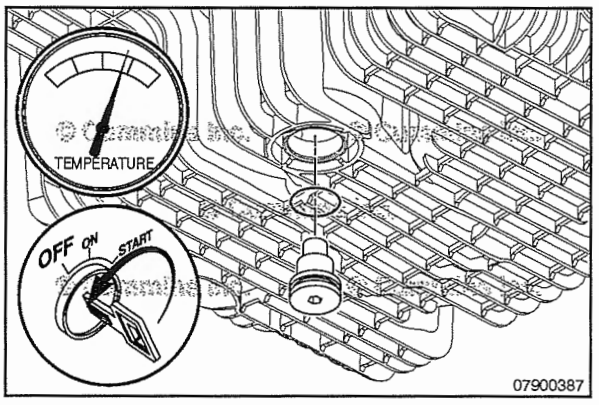


Drain

⚠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.

Change the lubricating oil and filter(s) at the specified oil change interval. See the Maintenance Schedule to find the correct change interval for the application.

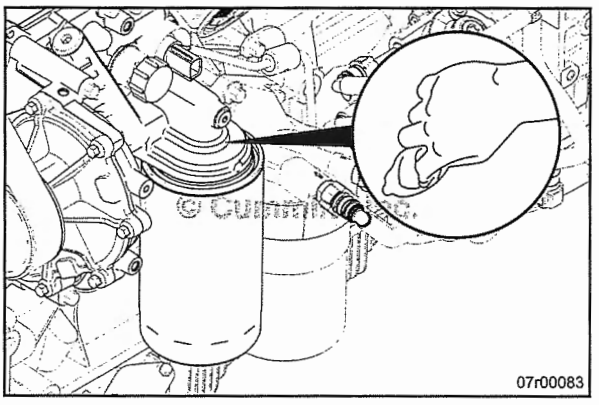


NOTE: For most engines, use a container that can hold at least 20 liters [21 qt] of lubricating oil. Some engines can be equipped with an increased capacity oil pan requiring a container that will hold 28 liters [30 qt] of lubricating oil.

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

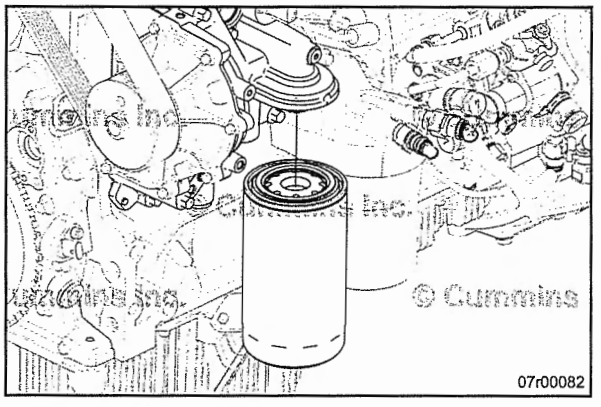
Shut off the engine.

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



Remove

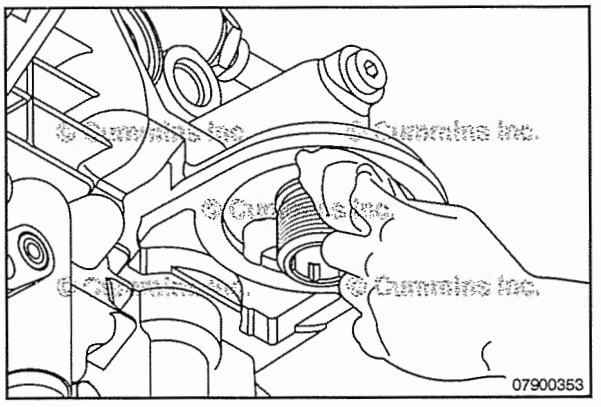
Clean the area around the lubricating oil filter head.



If necessary, use oil filter wrench, Part Number 3400158, to remove filter.

Clean the gasket surface of the filter head.

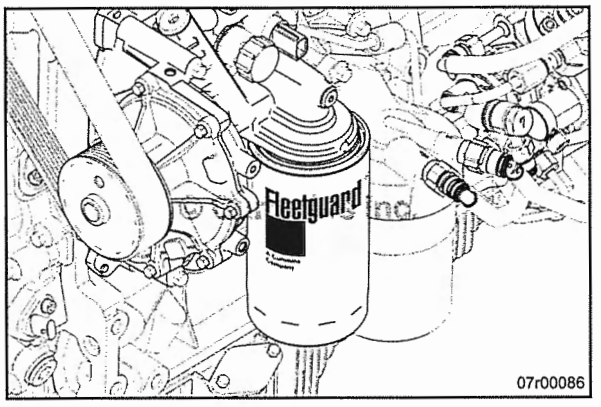
NOTE: The o-ring can stick on the filter head. Make sure it is removed before installing the new filter.



Install

Use the correct oil filter.

See Filter Specifications for the correct oil filter part number. Refer to Procedure 018-024 in Section V.



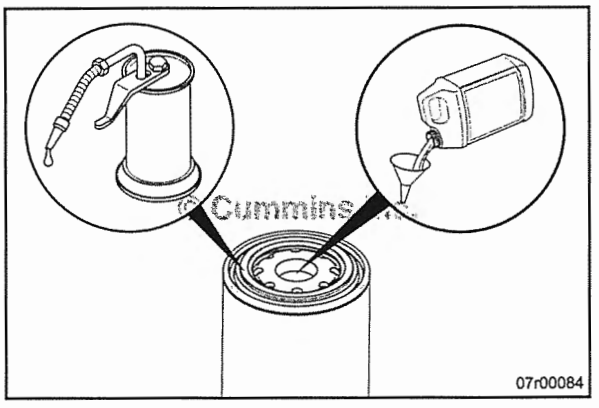
⚠CAUTION⚠
The lack of lubrication during the delay until the filter is pumped full of oil at start-up can damage the engine.

Use clean engine oil to coat the gasket surface of the filter.

Fill the filter. Use new 15W-40 or 5W-40 engine oil.

Apply a light film of lubricating oil to the gasket sealing surface before installing the filter.

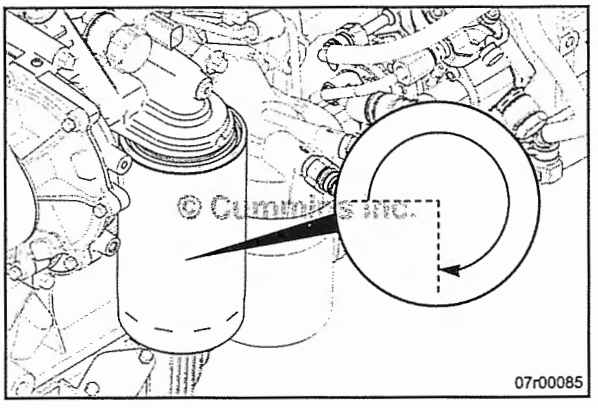
NOTE: Be careful **no** debris is poured into the filter. If using an oil supply with a metallic or plastic seal under the cap, be careful to peel the seal back. Puncturing the seal with a knife or sharp object can create debris in the oil container.

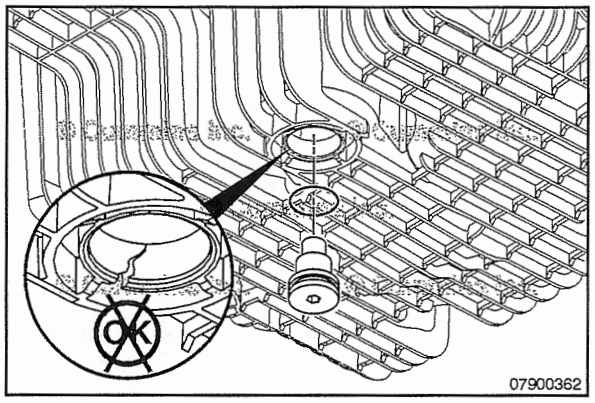


⚠CAUTION⚠
Mechanical overtightening of filter can distort the threads or damage the filter element seal.

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

Tighten 3/4 to 1 turn after gasket makes contact with the filter head.





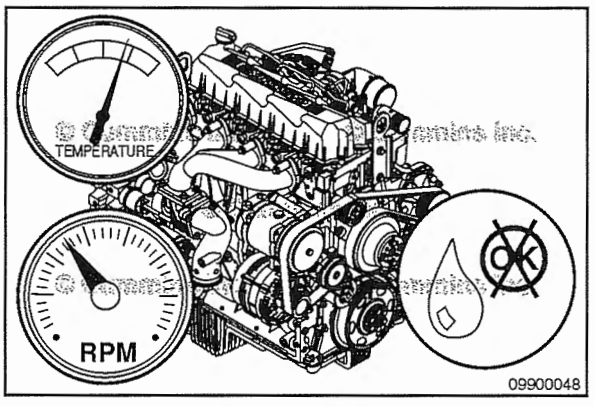
Fill

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

Install the lubricating oil pan drain plug.

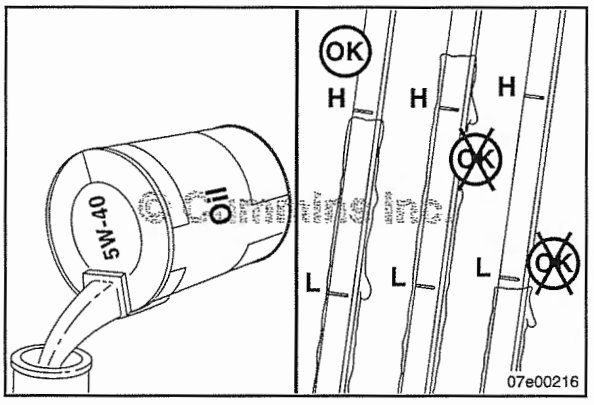
Torque Value:
Plastic Oil Pan Drain Plug Torque 24 N•m [212 in-lb]

NOTE: Use a high-quality 15W-40 or 5W-40 multiviscosity lubricating oil, such as Valvoline Premium Blue Extreme®, or its equivalent. Choose the correct lubricating oil for the operating climate as outlined in Section V.



Idle the engine to inspect for leaks at the drain plug and, if replaced, the oil filter seal.

NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm the correct oil level is in the oil pan.



Shut off the engine. Wait approximately 5 minutes to let the oil drain from the upper parts of the engine. Check the level again.

Add oil as necessary to bring the oil level to the H (high) mark on the dipstick.

Fan Hub, Belt Driven

Select Service Tools

Recommended Cummins® Service Tools

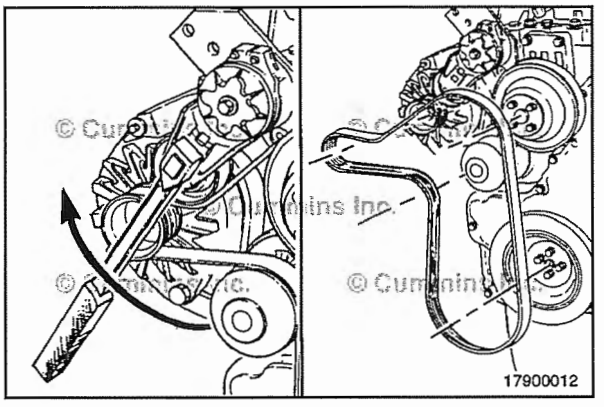
- No Cummins® service tools required.

Additional Service Items

- No additional service items required.

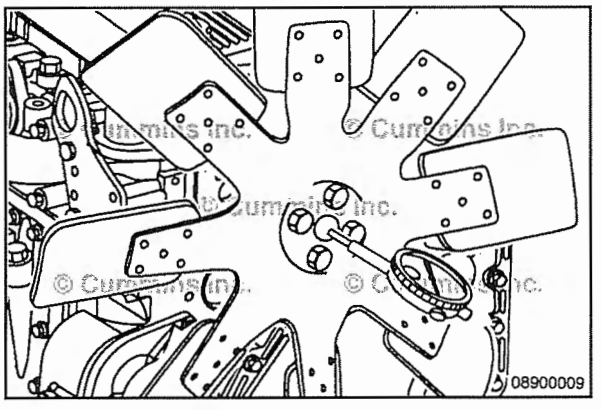
Maintenance Check

Remove the drive belt.



NOTE: The fan hub **must** rotate without **any** wobble or excessive end clearance.

Fan Hub End Clearance		
mm		in
0.15	MAX	0.006



Cooling System

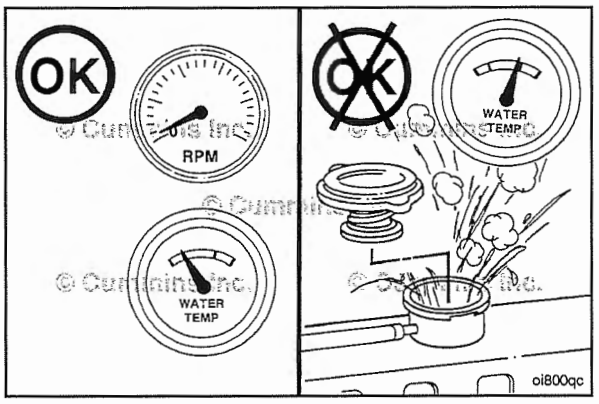
Select Service Tools

Recommended Cummins® Service Tools

- No Cummins® service tools required.

Additional Service Items

- Container suitable for coolant



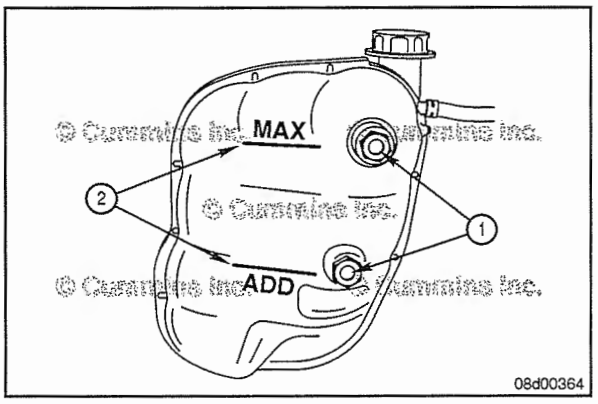
General Information

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

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

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.

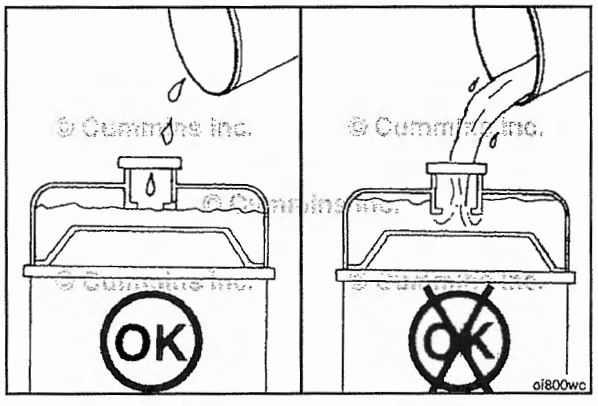


⚠CAUTION⚠
Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool below 50°C [120°F] before adding coolant.

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

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

It is important to understand the impact of temperature on the expansion of the coolant. Most "top tanks" do **not** have a provision for a "FULL HOT" coolant level. Filling the "top tank" while hot will result in a low operating level once the system has cooled.

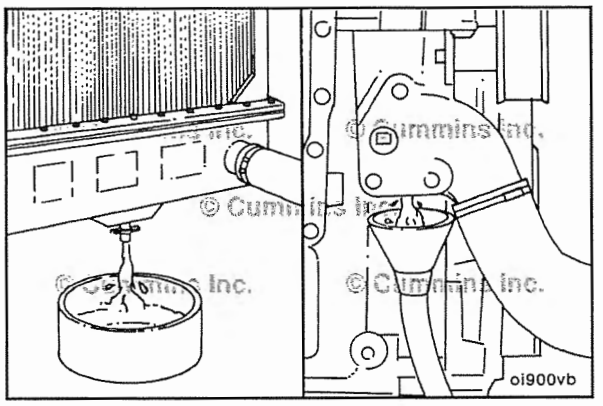


Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill or recovery/expansion tank.

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

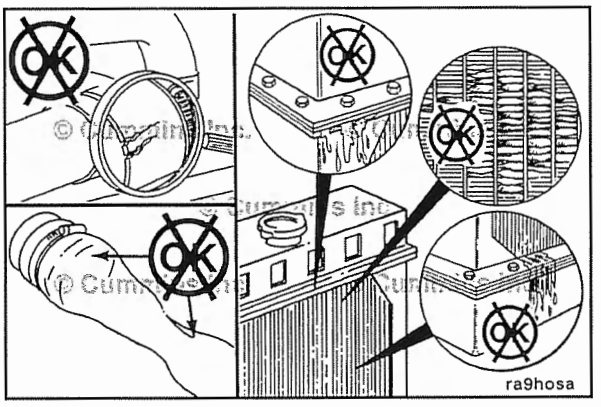
Drain

Drain the cooling system by opening the drain valve on the radiator and removing the plug in the bottom of the water inlet. A drain pan with a capacity of 20 liters [5 gal] will be adequate in most applications.



Check for damaged hoses and loose or damaged hose clamps. Replace as necessary.

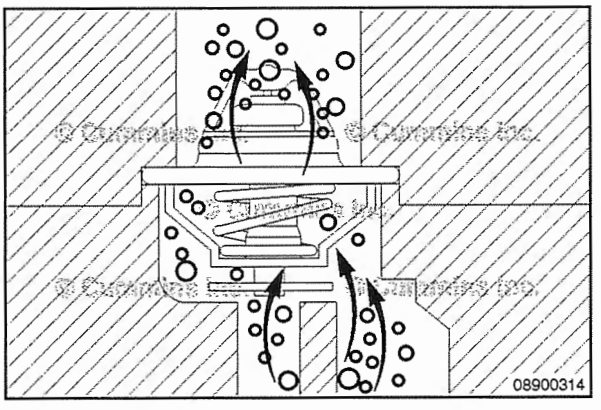
Check the radiator for leaks, damage, and buildup of dirt. Clean and repair, as necessary.



Flush

During fill, air **must** be vented from the engine coolant passages. The air vents through the "jiggle pins" opening to the top radiator hose and out the fill opening. Additional venting is provided for the cylinder head.

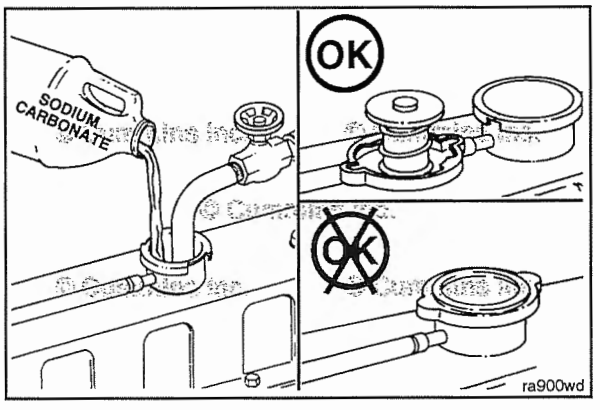
Adequate venting is provided for a fill rate of 11 liters/ minute [3.0 gal/minute].

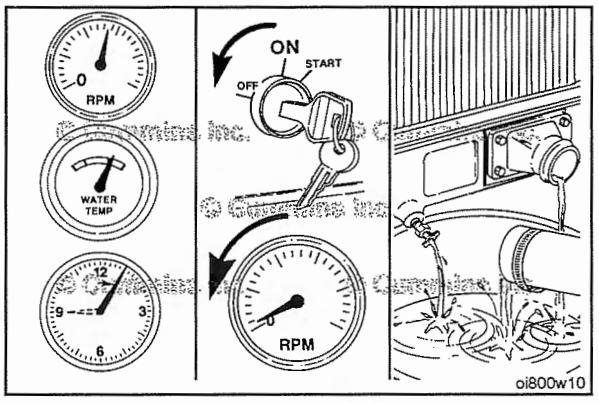


NOTE: Do **not** install the radiator cap. The engine **must** be operated without the cap for this process.

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

Use 0.5 kg [1.0 lb] of sodium carbonate for every 23 liters [6 gal] of water.

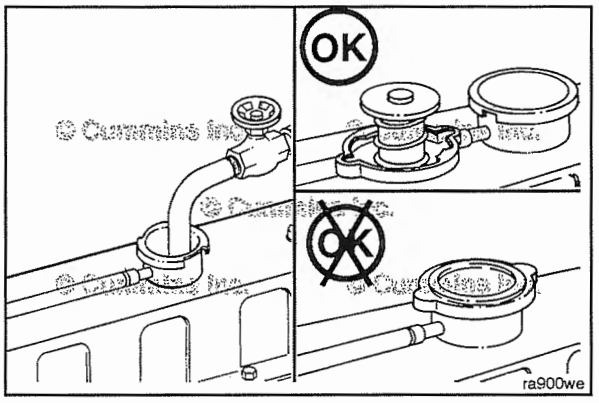




⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Operate the engine for 5 minutes with a coolant temperature above 82°C [180°F].

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

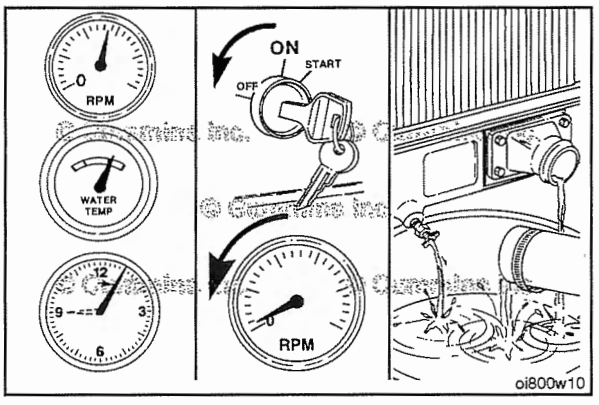


△CAUTION△
The cooling system must be filled properly to prevent air locks in the cooling passages. Failure to vent the cooling system properly can cause damage to the cooling system.

Fill the cooling system with clean water.

Make sure to vent the engine for complete system fill.

Do **not** install the radiator cap.

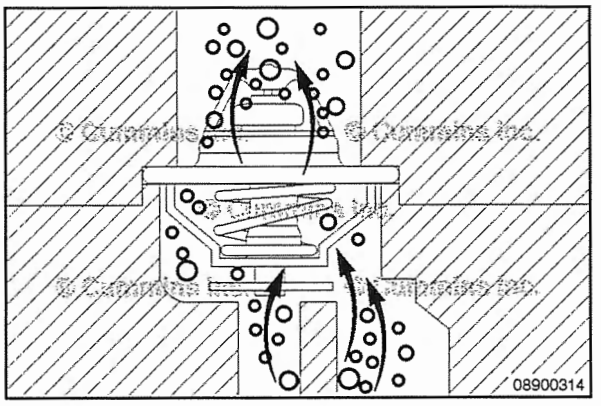


Operate the engine for 5 minutes with the coolant temperature above 82°C [180°F].

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

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

Fill

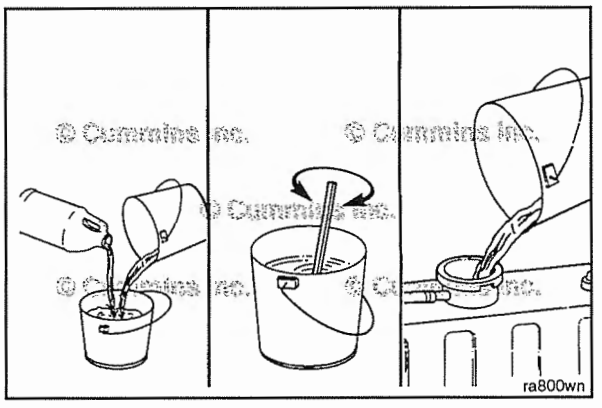


⚠CAUTION⚠
The cooling system must be filled properly to prevent air locks in the cooling passages. Failure to vent the cooling system properly can cause damage to the cooling system.

Make sure air is vented during the fill process.

- Some thermostats have check balls that allow air to vent through the thermostat when the thermostat is closed.
- An air vent port connection, which connects to the top tank/coolant recovery tank of the cooling system, is located next to the water outlet.

Adequate venting is provided for a fill rate of 11 liters/ minute [3.0 gal/minute].



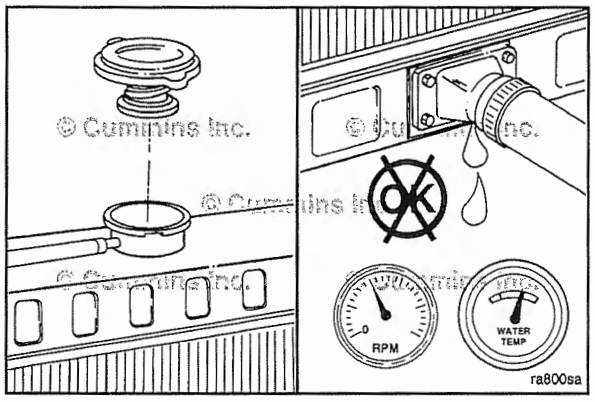
⚠CAUTION⚠
Before topping off coolant, allow the system temperature to cool to ambient. This will ensure that an adequate amount of coolant is available to the water pump during all periods of operation.

⚠CAUTION⚠
Engine and component damage can result if adequate cooldown time is not given after the cooling system pressure has been relieved in order to "top off". System pressure is only generated with the rise of coolant temperature. Closing the cooling system while hot will not allow pressure to build.

⚠CAUTION⚠
Do not use water alone for coolant. Damage from corrosion can severely damage the engine cooling system.

Use a mixture of 50 percent water and 50 percent ethylene glycol antifreeze to fill the cooling system to the capacity or level stated in the equipment manufacturer service information. See the following procedure for the coolant capacity of the engine. Refer to Procedure 018-018 in Section V.

See Service Bulletin, Cummins® Coolant Requirements and Maintenance, Bulletin 3666132, for additional cooling system information.

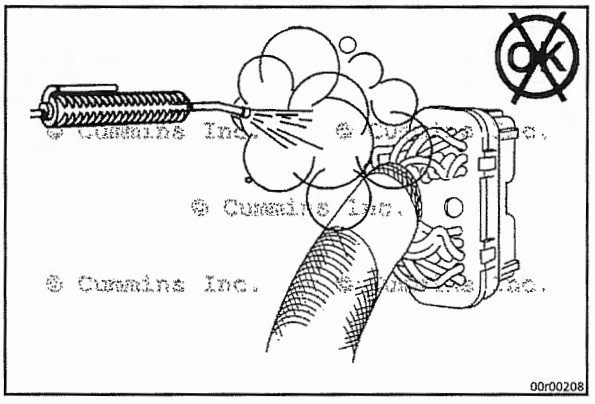


⚠WARNING⚠
Do not stand near the surge tank or radiator while operating the engine with the pressure cap off. If the vehicle is equipped with a fill door on the side of the surge tank, keep it closed due to coolant expansion.

⚠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 82°C [180°F]. Check for coolant leaks.

Check the coolant level again to make sure the system is full of coolant, or the coolant level has risen to the hot level in the recovery container on the system, if equipped.



Engine 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.

△CAUTION△
Steam ingress into electrical components can cause damage.

Steam is the recommended method of cleaning a dirty engine or a piece of equipment.

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

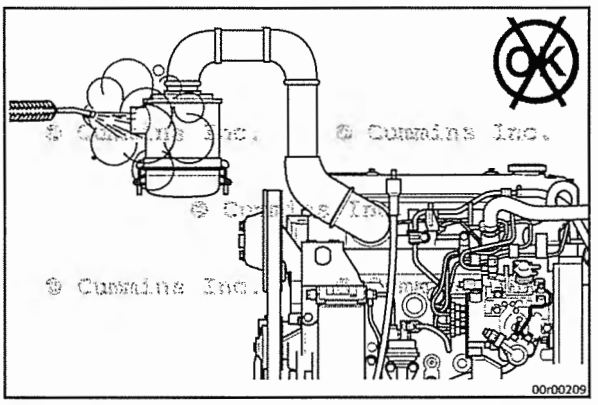
Components to protect include, but are **not** limited to the following:

- Electrical components and connectors
- Wiring harnesses
- Electronic control module (ECM) and connectors, if equipped.
- Belts and hoses
- Bearings (ball or taper roller)

For additional cleaning information. Refer to Procedure 204-008 in Section i.

⚠CAUTION⚠
Soap, solvent, or water ingress into air intake system can cause engine damage.

Do **not** directly spray or allow soap, solvent, or water to enter any passages, ports, or cowlings that lead to the engine air intake system.



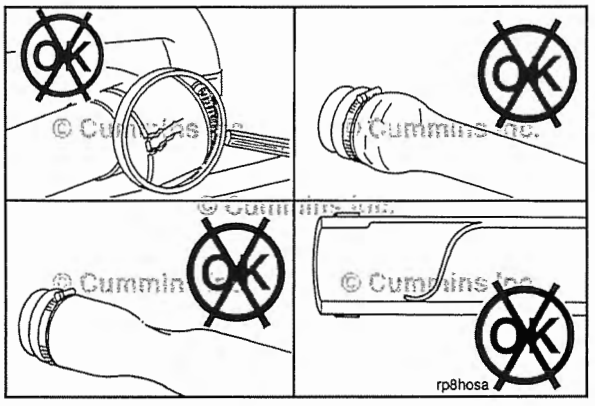
Radiator Hoses

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.



Air Compressor Discharge Lines

General Information

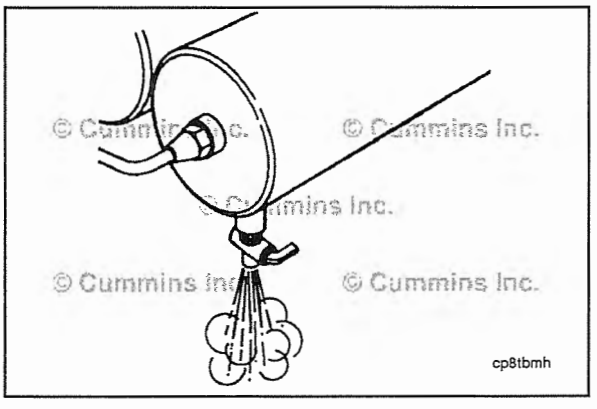
All air compressors have a small amount of lubricating oil carryover that lubricates the piston rings and moving parts. When this lubricating oil is exposed to normal air compressor operating temperatures over time, the lubricating oil will form varnish or carbon deposits. If the following maintenance check are not performed, the air compressor piston rings will wear and not seal correctly.

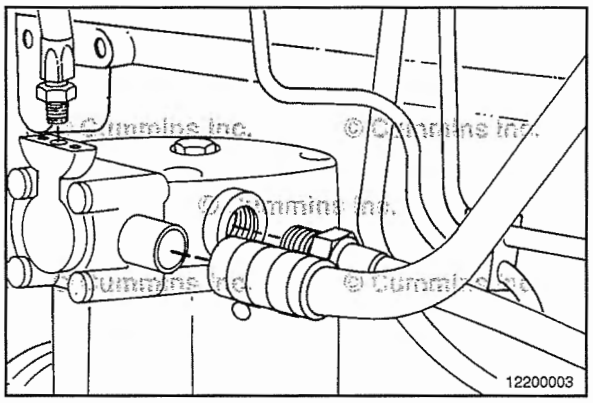
Maintenance Check

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

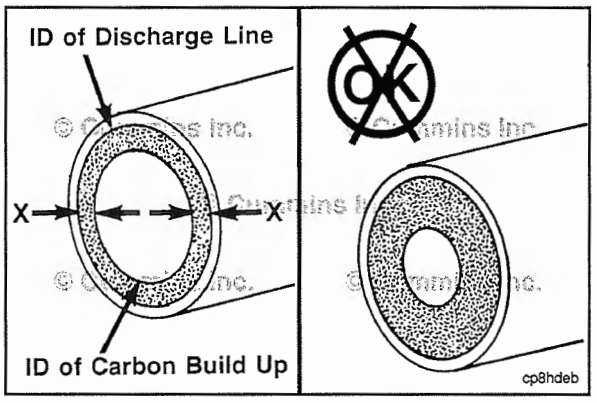
Shut off the engine.

Open the drain valve on the wet tank to release the system air pressure.

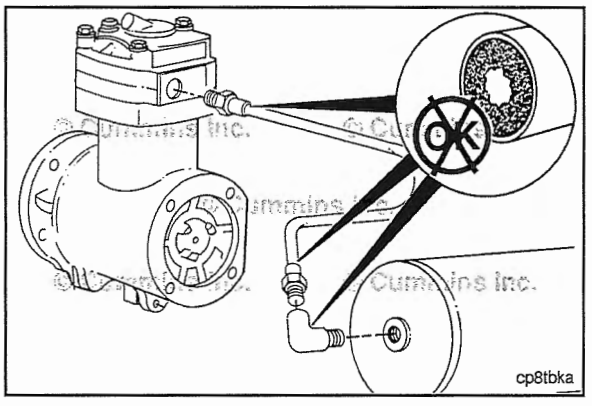




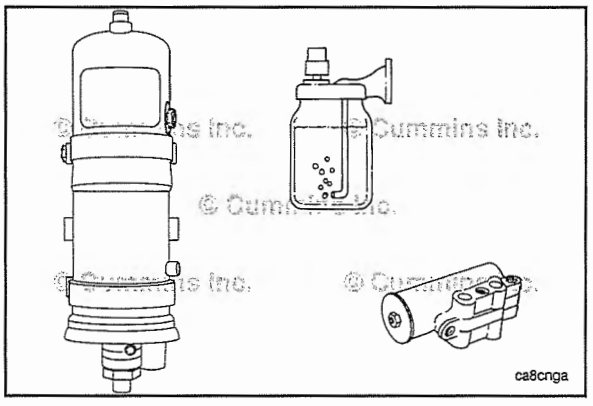
Remove the air compressor discharge line from the air compressor. Location of the air compressor discharge line can be found in Flow Diagram, Compressed Air System in System Diagrams (Section D).



Measure the total carbon deposit thickness inside the air discharge line as shown. If the total carbon deposit (X + X) exceeds 2 mm [1/16 in], clean and inspect the cylinder head, the valve assembly, and the discharge line. Replace if necessary. Contact the Cummins Authorized Repair Location for procedures.



If the total carbon deposit exceeds specifications, continue checking the air discharge line connections up to the first tank until total carbon deposit is less than 2 mm [1/16 in]. Clean or replace any lines or connections that exceed this specification.



Inspect any air driers, splitter valves, pressure relief valves, and alcohol injectors for carbon deposits or malfunctioning parts. Inspect for air leaks. Maintain and repair the parts according to the manufacturer's specifications.

Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter

Select Service Tools

Recommended Cummins® Service Tools

- No Cummins® service tools required.

Additional Service Items

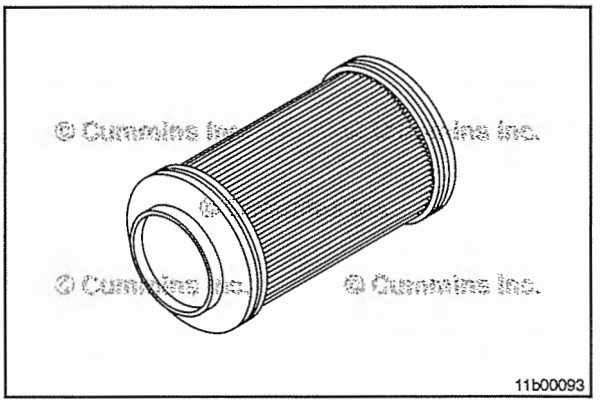
- Container suitable for diesel exhaust fluid (DEF)
- 27 mm wrench

General Information

The DEF dosing unit filter is designed to prevent foreign objects suspended in the DEF from entering the dosing system.

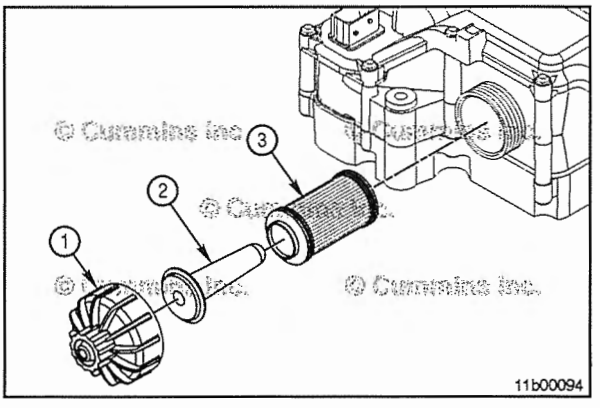
Debris can cause permanent damage and premature failure to either the aftertreatment DEF dosing unit or the aftertreatment DEF dosing valve. The aftertreatment DEF dosing unit filter is a maintenance item.

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



The aftertreatment DEF dosing unit filter consists of the following components:

1 Aftertreatment DEF dosing unit filter cap
2 Aftertreatment DEF dosing unit filter equalizing element
3 Aftertreatment DEF dosing unit filter element.



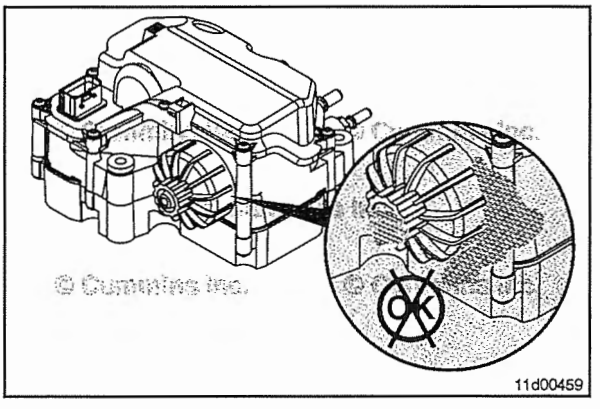
Initial Check

Locate the aftertreatment DEF dosing unit on the vehicle. Notice the dome-shaped filter cap.

NOTE: The location of the aftertreatment DEF dosing unit varies on vehicles. Locate the DEF tank. Follow the DEF lines to the aftertreatment DEF unit.

Inspect the area around the seal and vent of the aftertreatment DEF dosing unit filter cap for signs of leakage.

DEF leaks leave a white deposit. If deposits are found, see the Clean and Inspect for Reuse section in 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 DEF dosing unit to the aftertreatment DEF 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.

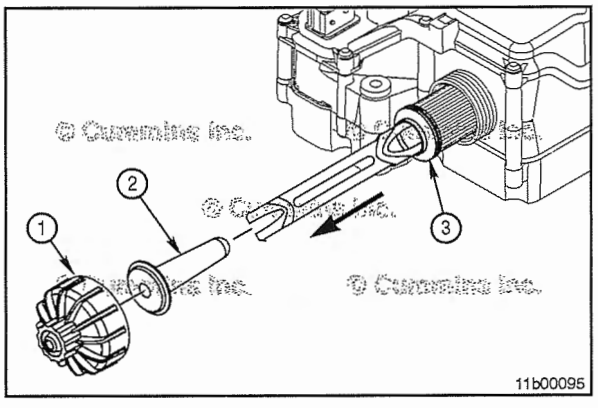
⚠WARNING⚠

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

NOTE: Do **not** disconnect the vehicle batteries until the DEF dosing system has completed the purge cycle. Before beginning to remove and/or disconnect any components, wait at least 5 minutes after the keyswitch is turned OFF for the aftertreatment DEF dosing system to purge the DEF from the system. The purge cycle is an automatic process and does **not** require intervention to occur. The aftertreatment DEF dosing unit will create an audible pumping noise during the purging process.

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



Remove

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

Unscrew the DEF filter cap (1). A 27 mm wrench can be used on the cap to aid in removal.

Remove the aftertreatment DEF filter equalizing element (2).

Remove the old aftertreatment DEF dosing unit filter element (3). A disposable service tool is included with the filter to aid in filter removal. Use the appropriate end of the tool, depending on the color of the plastic on the filter. When inserting the tool, a "click" sound can be heard which indicates proper engagement with the filter.

NOTE: If the filter element and equalizing element are removed from the aftertreatment DEF dosing unit, they **must** be discarded and replaced, regardless of condition.

Clean and Inspect for Reuse

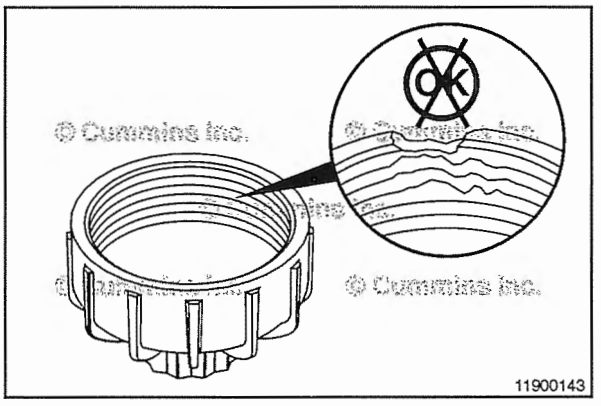
Inspect the aftertreatment DEF dosing unit filter cap for cracks or holes that could create a DEF leak path.

Check the condition of the threads on the aftertreatment DEF dosing unit cap.

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

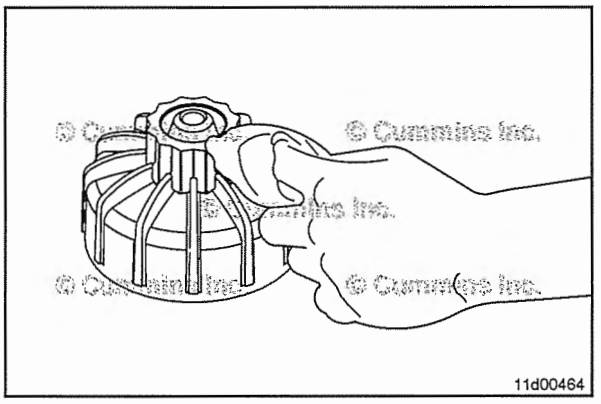
Inspect the aftertreatment DEF dosing unit threads. This is especially important if the aftertreatment DEF dosing unit cap was damaged.

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



NOTE: Never operate the vehicle with the DEF cap removed.

Clean the aftertreatment DEF dosing unit cap and threads on the dosing unit. Use warm water and a clean cloth.



Install

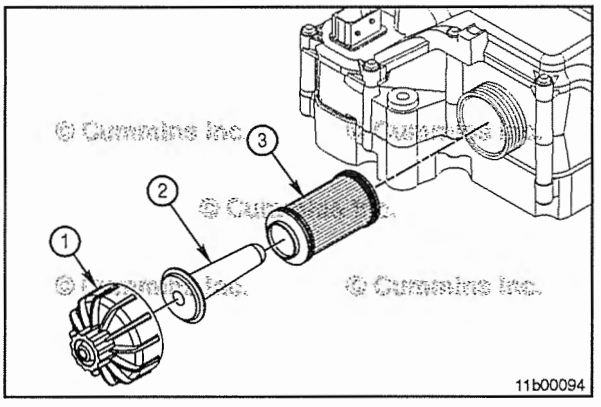
NOTE: Lubrication of the DEF filter o-rings is **not** required.

Slide the DEF filter equalizing element (2) into the DEF filter cartridge (3).

Insert the assembly into the aftertreatment DEF dosing unit.

Install and tighten the cap (1). A 27 mm wrench can be used to install and tighten the filter cap.

Torque Value: 20 N•m [177 in-lb]

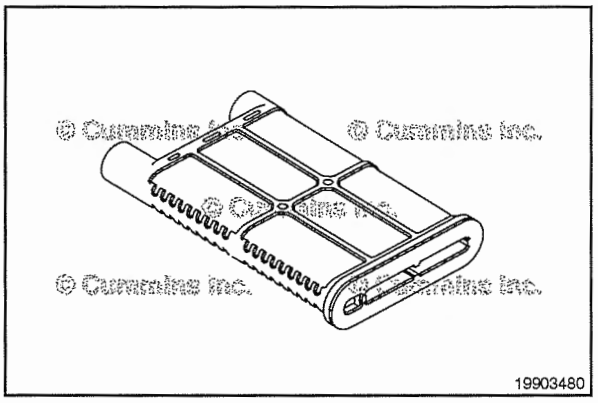


Finishing Steps

⚠WARNING⚠

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

- Connect the batteries. See equipment manufacturer service information.
- Prime the system. Check for leaks.



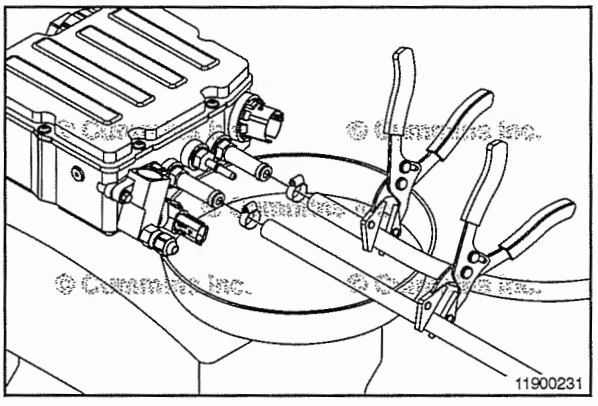
Aftertreatment Diesel Exhaust Fluid Tank Filter

General Information

The diesel exhaust fluid (DEF) filter is designed to prevent foreign objects from entering the dosing system. See equipment manufacturer service information for the correct service interval for the application.

The DEF tank and filter will vary, depending on vehicle type and/or manufacturer. Not all illustrations within this procedure will represent the application being serviced.

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△
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.
- Drain the coolant or, if the coolant hose to DEF tank assembly is flexible material, use pinch-off pliers.

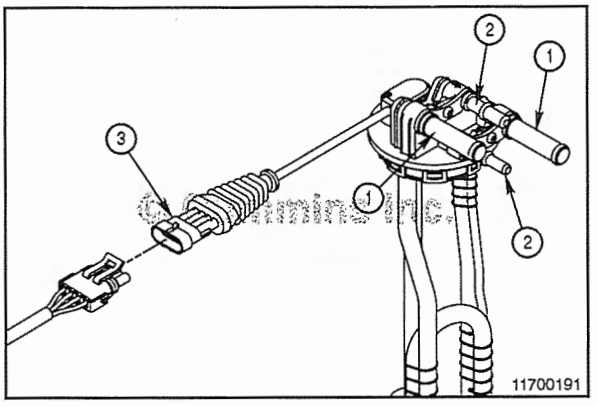
Remove

Use a clean, damp cloth to clean the area to reduce risk of contaminants entering the tank.

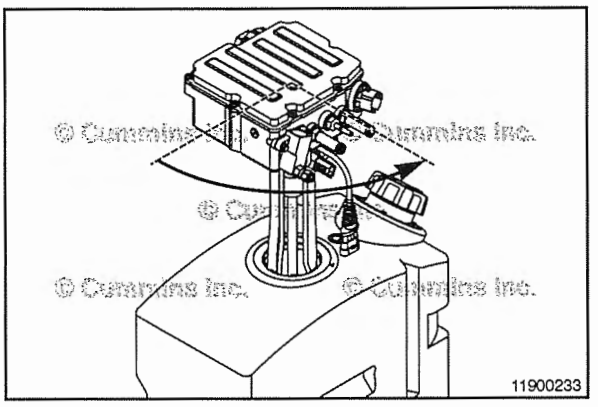
Disconnect the DEF tank assembly in the following order:

- Coolant supply and return (1)
- DEF supply and return (2)
- DEF electrical connector (3) last, to prevent accidental contamination.

Cap the open plumbing and electrical connectors to prevent contamination.



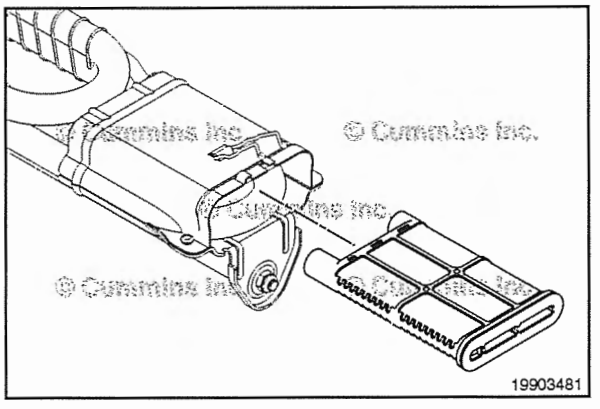
Remove the DEF level and temperature sensor assembly from the DEF tank. Rotate **counterclockwise** a quarter turn.



Disassemble

Unlatch the buckle from the DEF tank filter manifold.

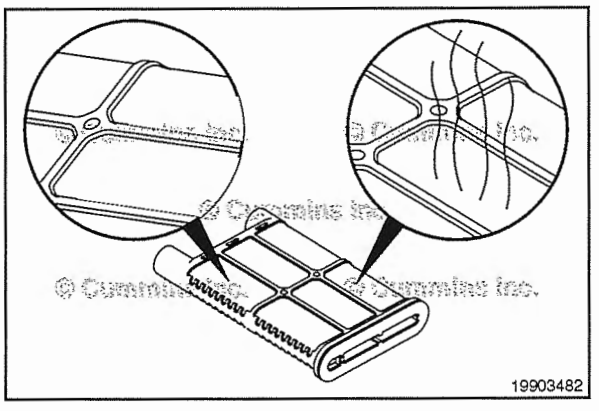
Remove the DEF tank filter.

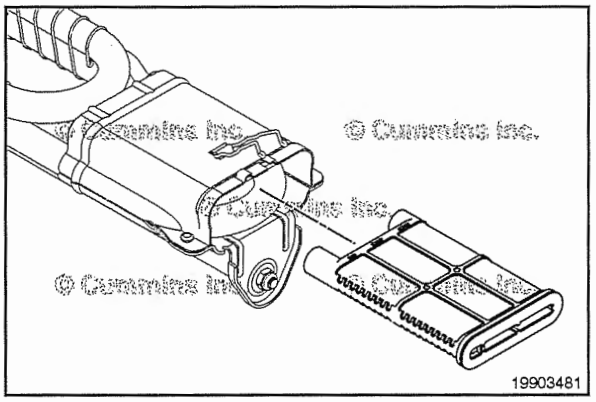


Clean and Inspect for Reuse

If contamination is evident in the DEF tank filter, inspect the DEF dosing unit filter. Refer to Procedure 011-060 in Section 9.

Discard the DEF tank filter.

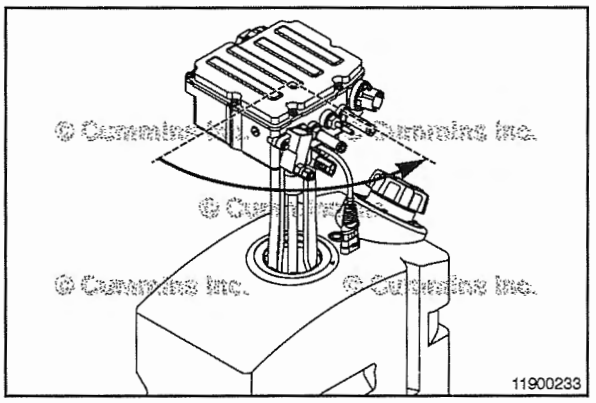




Assemble

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

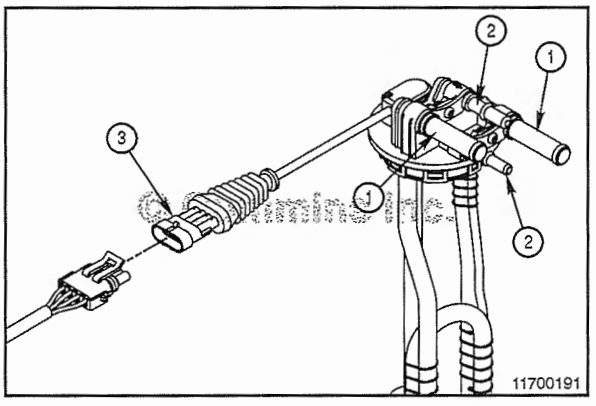
Latch the buckle to secure the filter.



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**.

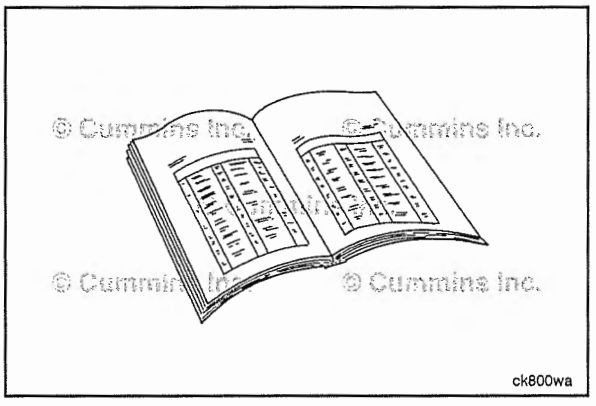


Remove caps from the plumbing and electrical connectors.

Connect the DEF tank assembly in the following order:

- DEF electrical connector (3) first, to prevent accidental contamination
- DEF supply and return (2)
- Coolant supply and return (1).

Cap the open plumbing and electrical connectors to prevent contamination.



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.

- Unblock the coolant hose to DEF tank assembly.
- Check the coolant level. Refer to Procedure 008-066 in Section 3.
- Connect the batteries. See equipment manufacturer service information.

Overhead Set

Select Service Tools

Recommended Cummins® Service Tools

- Barring tool, Part Number 5299073

Additional Service Items

- Feeler gauge

Preparatory Steps

⚠WARNING⚠

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

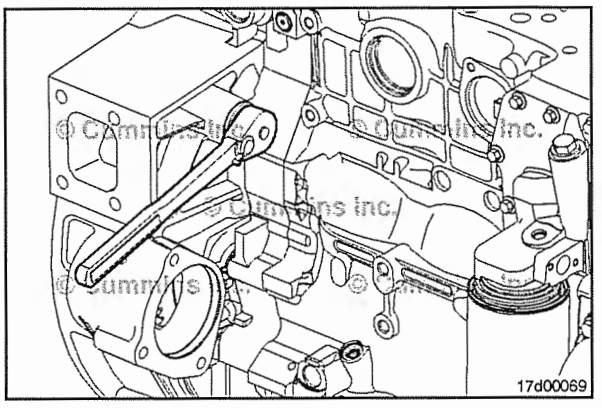
- Disconnect the batteries. See equipment manufacturer service information.
- Remove the rocker lever cover and gasket. See equipment manufacturer service information.

Adjust

NOTE: Engine coolant temperature **must** be less than 60°C [140°F].

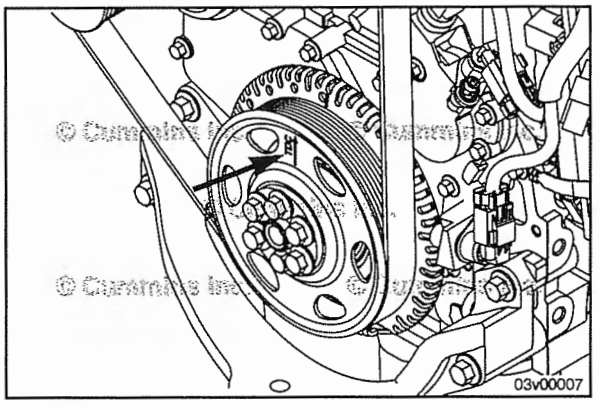
Use barring tool, Part Number 5299073, to rotate the crankshaft until the number 1 cylinder is at top dead center (TDC).

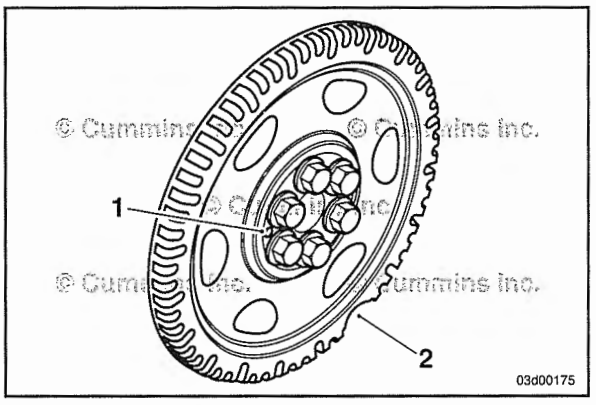
TDC can be determined by the following methods:



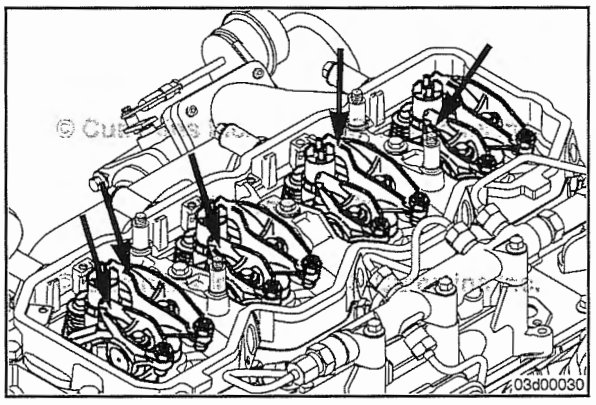
NOTE: The TDC indicator is on the crankshaft speed indicator ring.

For engines with exhaust gas recirculation (EGR), align the crankshaft speed indicator ring so the TDC indicator is at the 12 o'clock position. If both number 1 cylinder rocker levers are loose, move to the following steps. If both number 1 cylinder rocker levers are **not** loose, rotate the crankshaft 360 degrees.





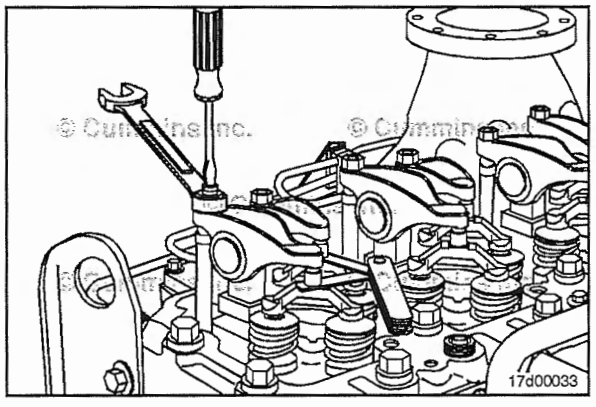
NOTE: If no TDC mark is present on the crankshaft speed indicator ring, align the large gap in the crankshaft speed indicator ring to the 5 o'clock position (2). The dowel pin could also be visible in the 9 o'clock position (1). Check that both number 1 cylinder rocker levers are loose. If they are **not** loose, rotate the crankshaft 360 degrees. Recheck.



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

(E = exhaust, I = Intake)

Four-cylinder 1I, 1E, 2I, and 3E.



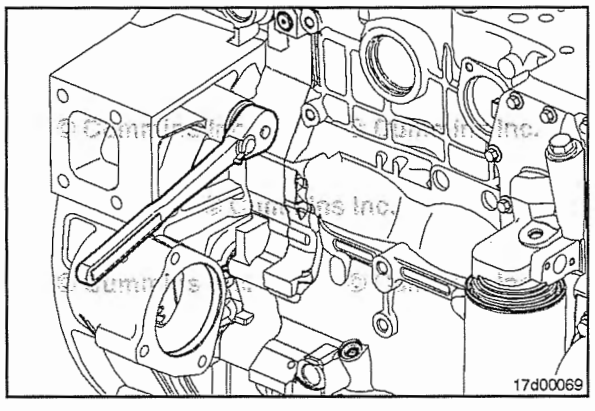
NOTE: The clearance is correct when some resistance is "felt" when the feeler gauge is slipped between the crosshead and the rocker lever socket.

Measure lash by inserting a feeler gauge between the crosshead and the rocker lever socket. If the lash measurement is out of specification, loosen the locknut and adjust the lash to nominal specifications.

Valve Lash Specifications (Nominal)		
	mm	in
Intake	0.254	0.010
Exhaust	0.508	0.020

Tighten the locknut. Measure the lash again.

Torque Value: 24 N•m [212 in-lb]



Use barring tool, Part Number 5299073, 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)

Four-cylinder 2E, 3I, 4E, and 4I.

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

Notes

Section A - Adjustment, Repair, and Replacement

Section Contents

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Adjustment, Repair and Replacement - Overview

General Information

This section contains supplemental procedures to support maintenance and repair practices.

These procedures provide additional instructions necessary to complete select maintenance tasks. Procedures for basic repair practices are also included in this section. If additional instructions are needed, contact your local Cummins® Authorized Repair Location for assistance.

Engine Barring

Select Service Tools

Recommended Cummins® Service Tools

- Barring tool, Part Number 5299073, or equivalent

Additional Service Items

- No additional service items required.

General Information

⚠WARNING⚠

Do not pull or pry on the fan to manually rotate the engine. To do so can damage the fan blades. Damaged fan blades can cause premature fan failures which can result in serious personal injury or property damage.

This procedure instructs how to rotate the engine for service events.

NOTE: The illustrations in this procedure are generic and may **not** represent the hardware on all engines.

Preparatory Steps

⚠WARNING⚠

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

- Disconnect the batteries. See equipment manufacturer service information.

Rotate

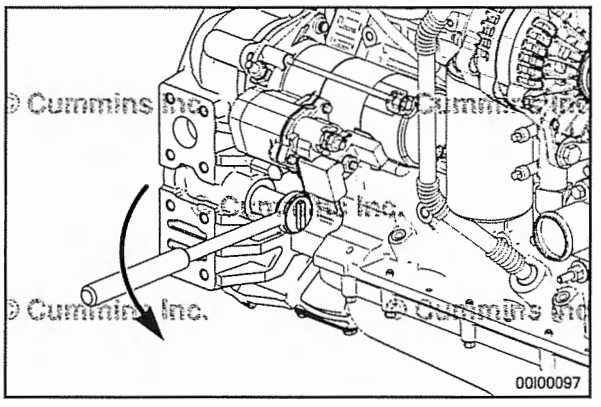
⚠WARNING⚠

When servicing the engine, do not use a remote starter switch or other means that would engage the starting motor to rotate the engine on a high-pressure common rail engine. Using the starter motor can create highly pressurized fuel in the fuel system. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death. Use a hand barring tool to rotate the engine for servicing the engine. Always loosen the pump-to-rail fuel line at the rail to vent the pressure after rotating the engine. Keep hands clear of the line when loosening and wear appropriate eye protection.

Remove the access cover from the flywheel housing.

Rotate the engine by hand. Use barring tool, Part Number 5299073, or equivalent.

Rotate the engine **clockwise** when viewed from the front of the engine.



Finishing Steps

⚠WARNING⚠

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

- Remove the barring tool from the flywheel housing.
- Install the access cover in the flywheel housing.
- Connect the batteries. See equipment manufacturer service information.

Charging System Alternator

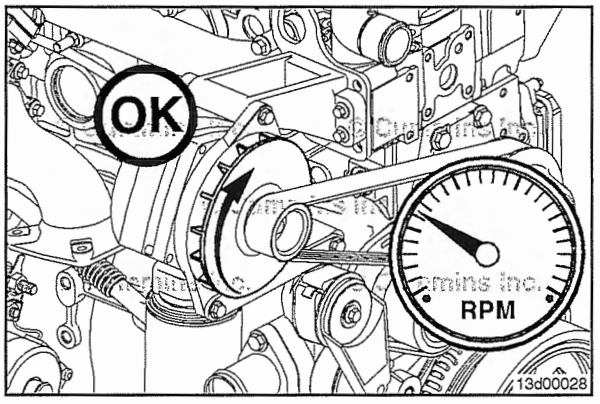
Select Service Tools

Recommended Cummins® Service Tools

- Digital multimeter, Part Number 3164488 or 3164489
- Clamp on current probe, Part Number 3164490

Additional Service Items

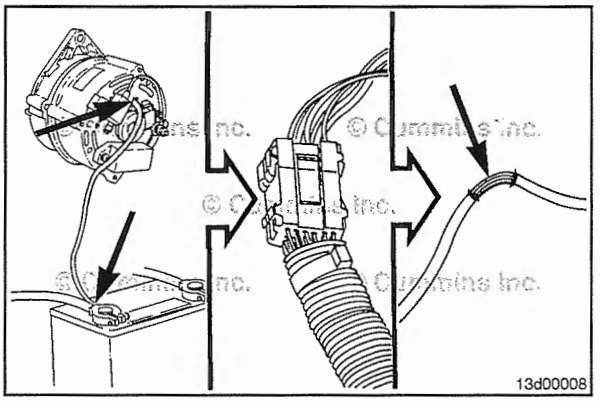
- No additional service items required.

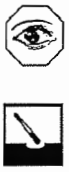


Initial Check

Check the drive belt and alternator pulley, to be sure the alternator is rotating properly.

- Use the following procedure if the drive belt is slipping on the alternator pulley. Refer to Procedure 008-002 in Section 3.
- Use the following procedure to inspect the belt tensioner. Refer to Procedure 008-087 in Section 3.
- Remove the drive belt. Refer to Procedure 008-002 in Section 3. Check if the alternator pulley is loose on the shaft. If loose, remove the pulley and inspect for damage. See alternator manufacturer and/or equipment manufacturer service information.
- If the alternator will **not** rotate or does **not** rotate freely, the alternator **must** be replaced. See the Remove and Install sections of this procedure.





⚠WARNING⚠

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

Check the battery and all wiring connections.

Inspect the wiring for damage.

Check all connections for tightness and cleanliness, including the slip connectors at the alternator and engine compartment bulkhead, and the connections at the battery.

Test

NOTE: Any multimeter reading of zero voltage indicates an open circuit.

Check for open circuits.

Turn the keyswitch to the ON position.

Connect digital multimeter, Part Number 3164488 or 3164489, to the following locations:

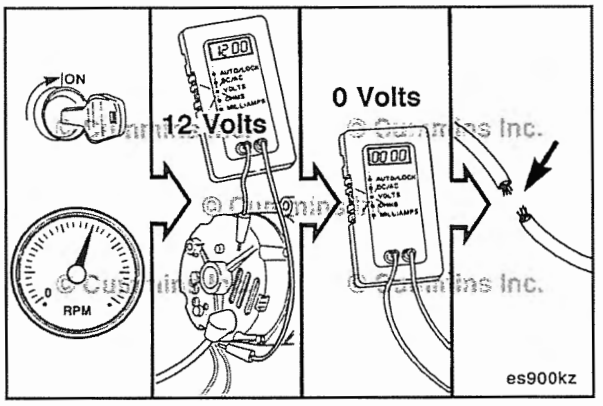
Delco™ Alternators

1 Alternator "BAT" terminal to ground.

2 Alternator blade terminal "number 1" to ground.

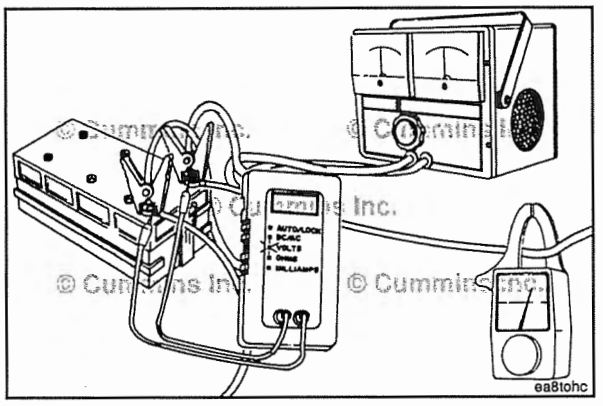
3 Alternator blade terminal "number 2" to ground.

Locate and repair the open circuit.



Connect a carbon-pile load (battery/alternator tester) across the batteries in one of the battery boxes.

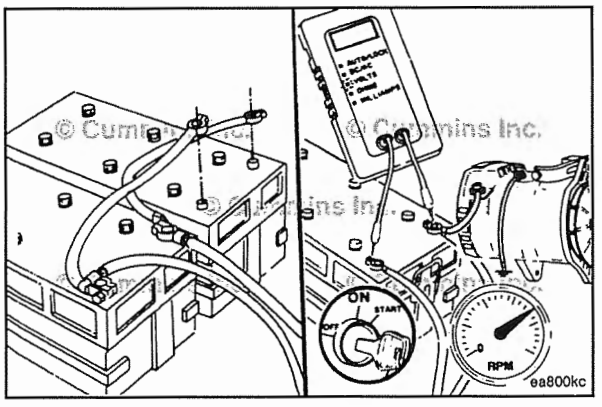
Clamp an induction pickup-type ampere-hour meter around the battery cable; or use digital multimeter, Part Number 3164488 or 3164489, with clamp on current probe, Part Number 3164490.

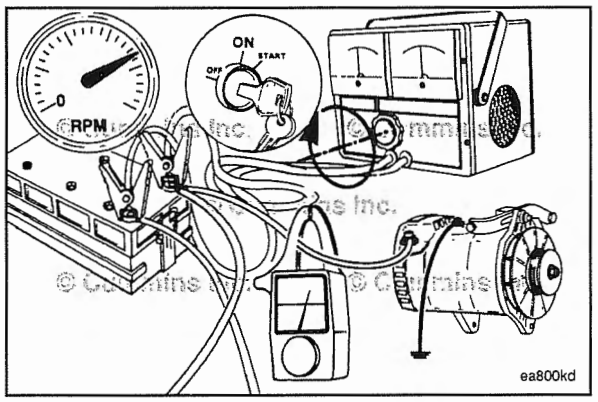


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect any cables that lead to any other battery boxes in the circuit, negative (-) cables first.

Operate the engine at high idle. Measure the alternator voltage output to the batteries with digital multimeter, Part Number 3164488 or 3164489. See equipment manufacturer service information.



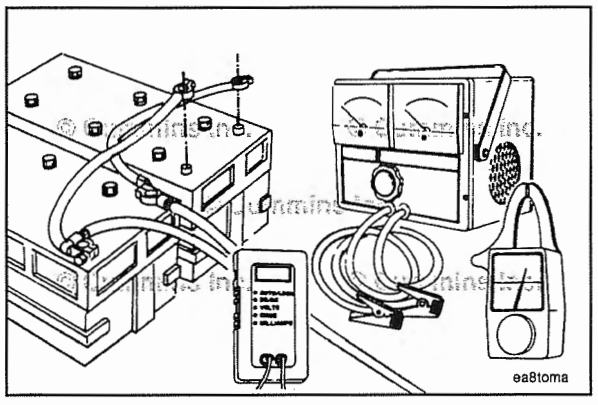


Operate the engine at high idle. Adjust the carbon-pile load-testing equipment to apply the maximum rated amperage load to the alternator. See equipment manufacturer service information.

NOTE: The alternator maximum rated amperage output is normally stamped or labeled on the alternator.

Measure the alternator amperage output. See equipment manufacturer specifications.

If the alternator output (amperes) is **not** within 10 percent of rated output, repair or replace the alternator. See equipment manufacturer service information for repair procedures.



Shut the engine OFF. Remove the test equipment.

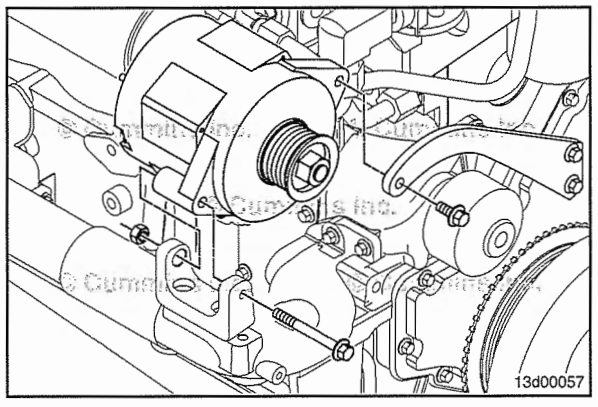
Connect all battery cables, negative (-) cable last.

Preparatory Steps

⚠WARNING⚠

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

- Disconnect the batteries. See equipment manufacturer service information.
- Remove the drive belt from the alternator pulley. Refer to Procedure 008-002 in Section 3.
- Tag and label all wires on the alternator.
- Disconnect the wires.



Remove

Remove the upper alternator link capscrew.

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

Remove the alternator.

Install

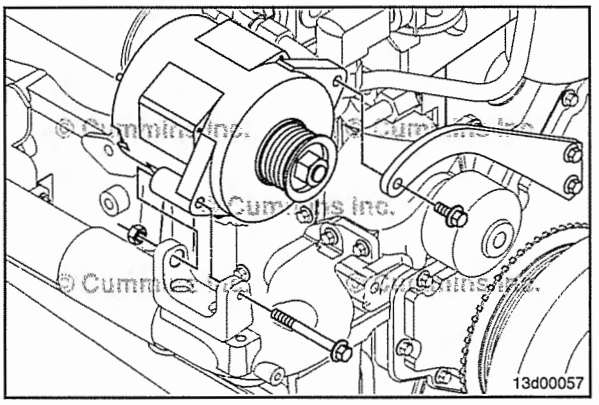
Install the alternator and the bottom alternator mounting capscrew and nut.

Install the upper alternator link mounting capscrew at the top of the alternator.

Tighten the capscrews.

Torque Value:
Lower Mounting Capscrew 66 N•m [49 ft-lb]

Torque Value:
Upper Link Mounting Capscrew 31 N•m [23 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 avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect all wires to the alternator.
- Install the drive belt. Refer to Procedure 008-002 in Section 3.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine. Check for proper operation.

Notes

Section D - System Diagrams

Section Contents

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System Diagrams - Overview

General Information

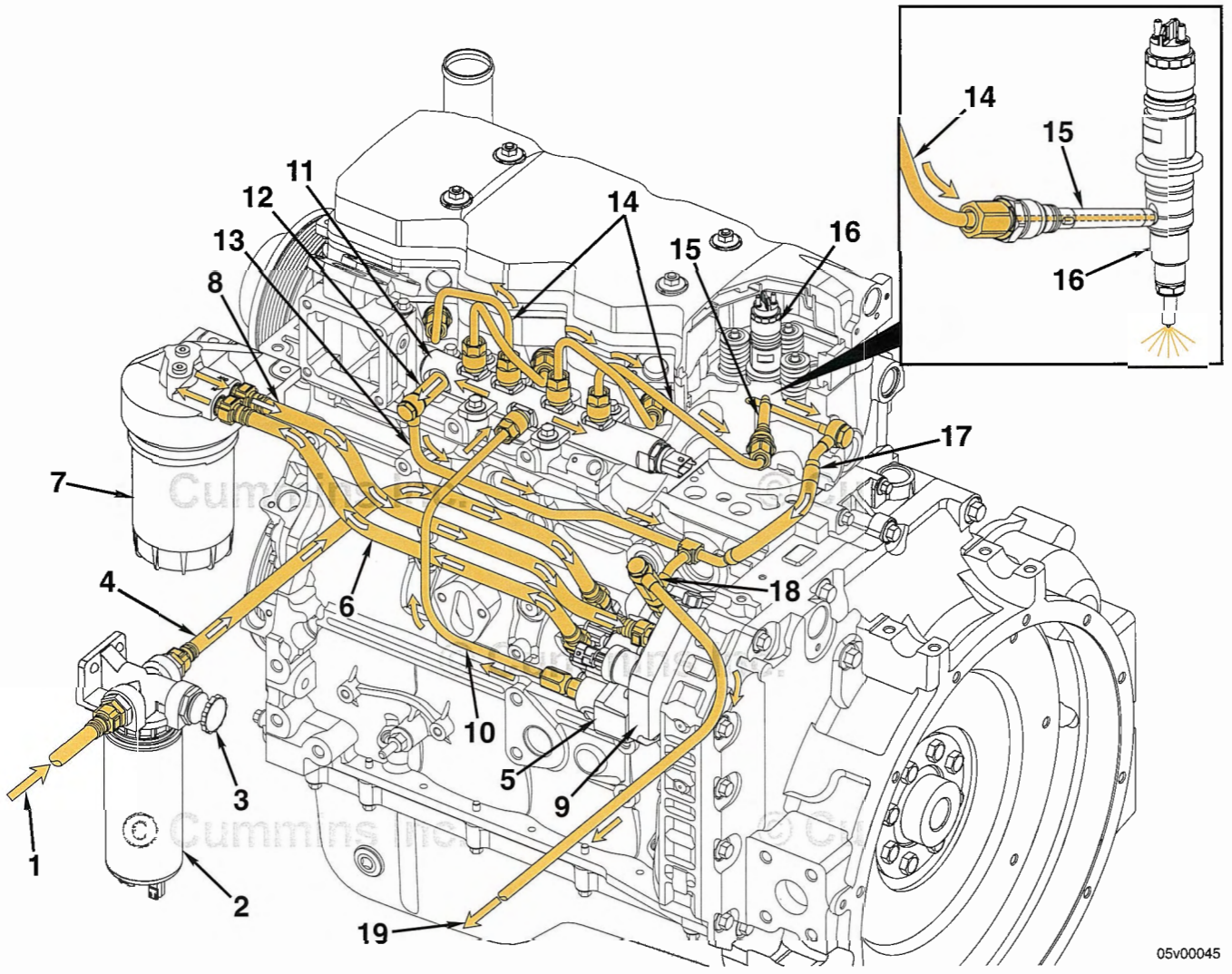
The following drawings show the flow through the engine systems. Although parts can change between different applications and installations, the flow remains the same. The systems shown are:

- 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.

Flow Diagram, Fuel System

General Information



1 From fuel supply tank
2 Water/fuel separator (remote mounted or engine mounted)
3 Priming pump (remote mounted or engine mounted)
4 Fuel supply to fuel gear pump
5 Fuel gear pump
6 To pressure side fuel filter
7 Pressure side fuel filter
8 To high-pressure fuel pump
9 High-pressure fuel pump
10 To fuel rail
11 Fuel rail
12 Fuel rail pressure relief valve
13 Common rail fuel return
14 High-pressure fuel line to injector
15 High-pressure connector
16 Injector

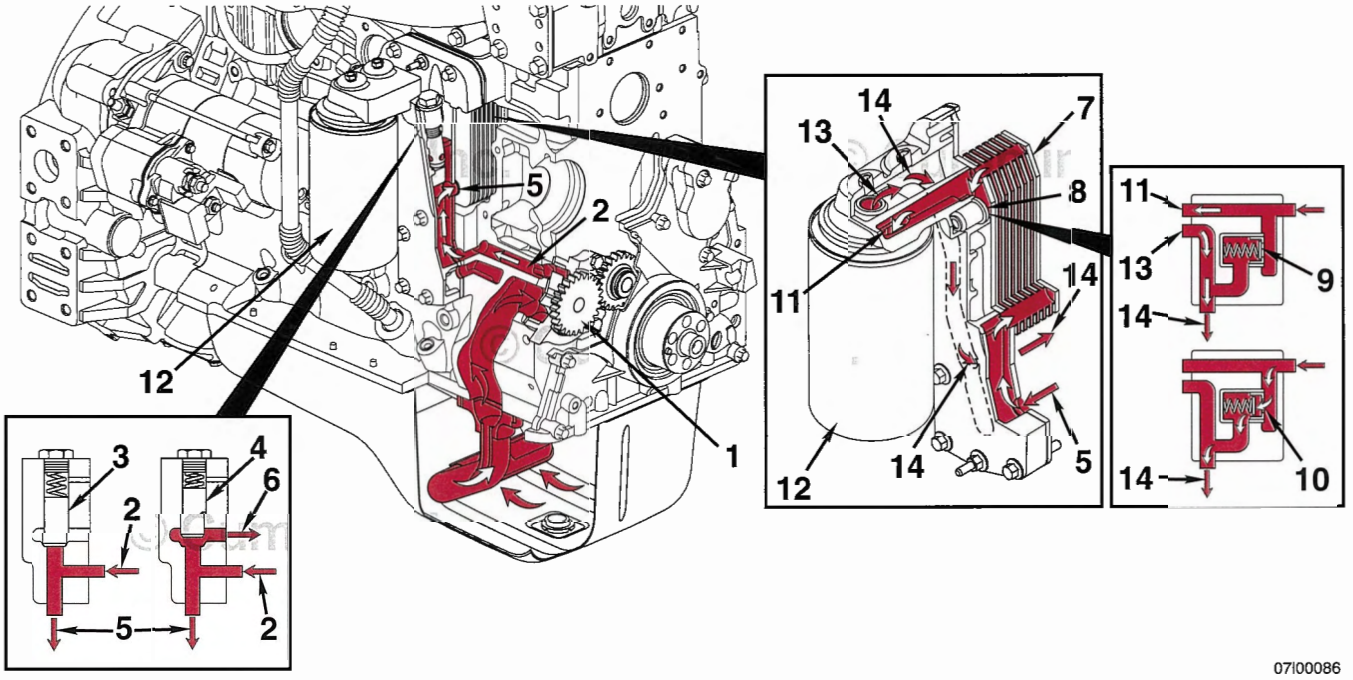
17 Fuel return from injectors

18 Combined fuel return

19 Fuel return to fuel supply tank.

Flow Diagram, Lubricating Oil System

General Information

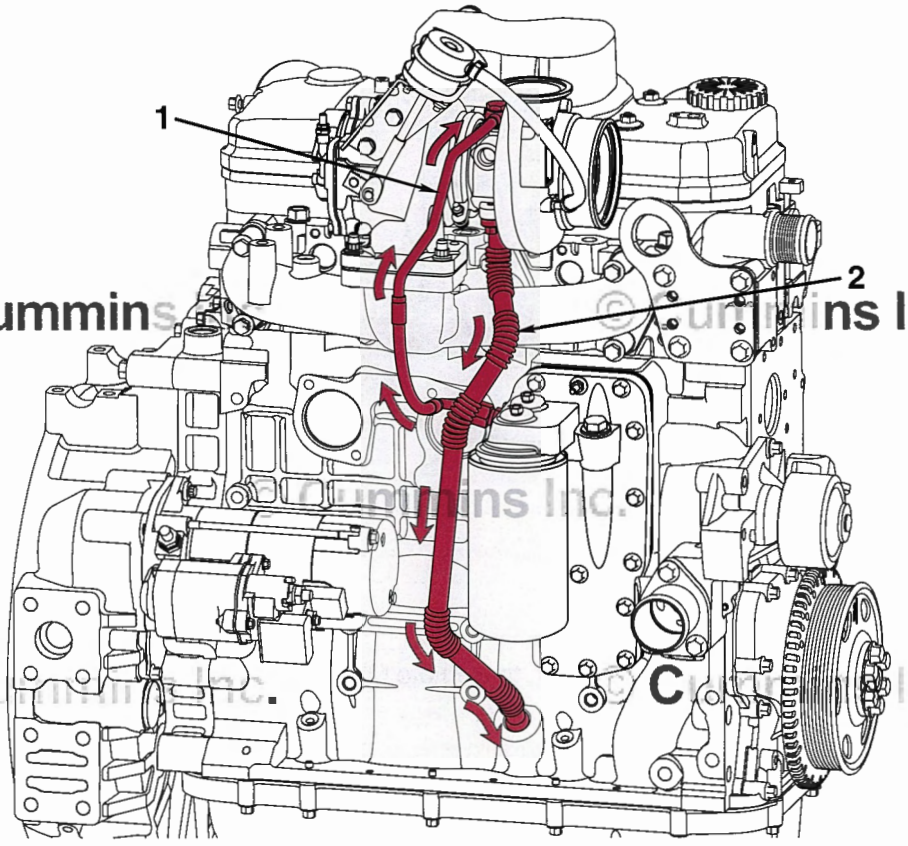


07I00086

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

Flow Diagram, Lubricating Oil System

General Information



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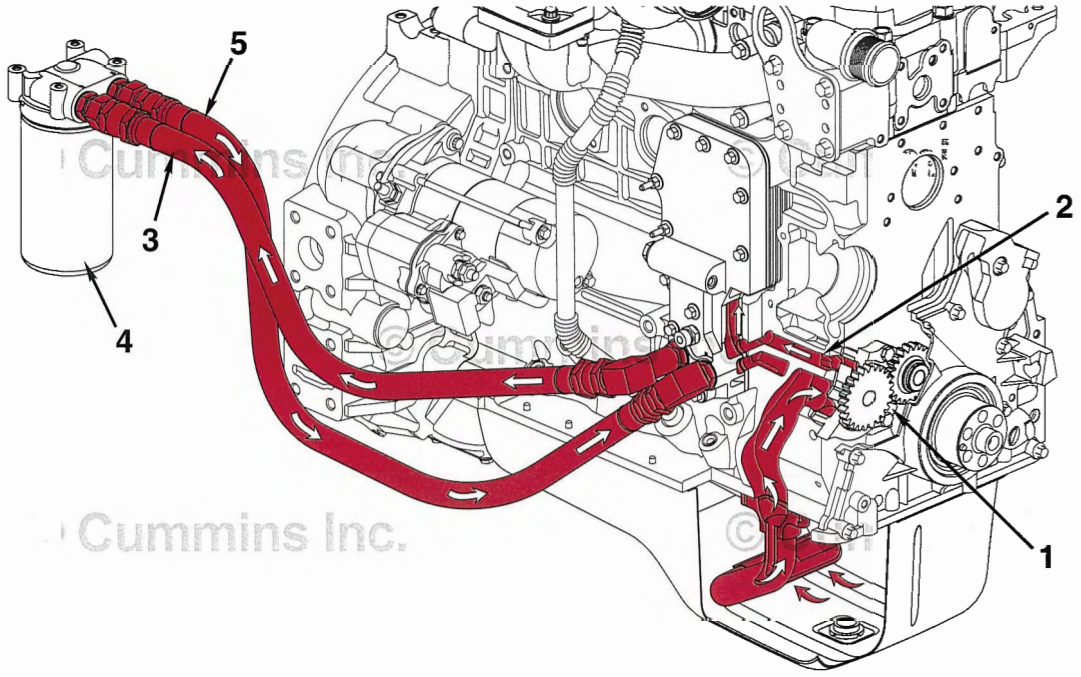
Lubrication for the Turbocharger

1 Turbocharger lubricating oil supply
2 Turbocharger lubricating oil drain.

Flow Diagram, Lubricating Oil System

General Information

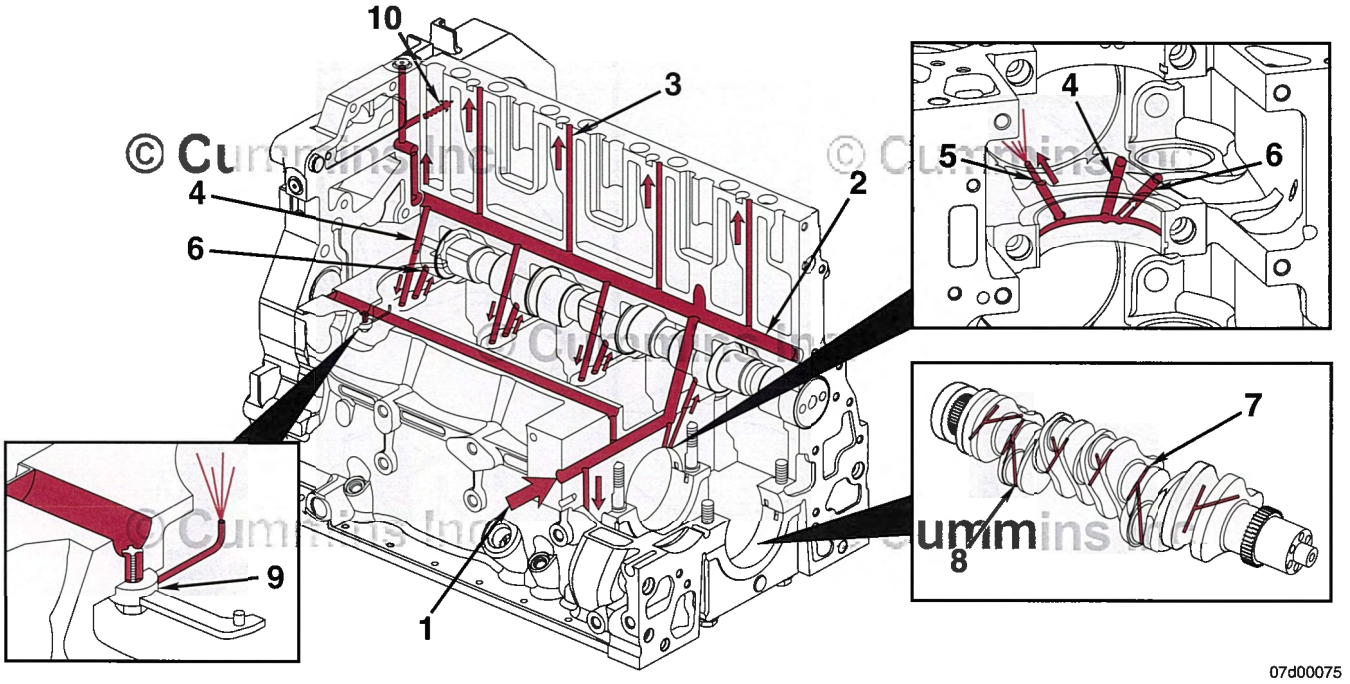


Lubrication to Remote Mount Oil Filter

1 Gerotor lubricating oil pump
2 From lubricating oil pump
3 To lubricating oil filter
4 Full-flow lubricating oil filter
5 From lubricating oil filter.

Flow Diagram, Lubricating Oil System

General Information

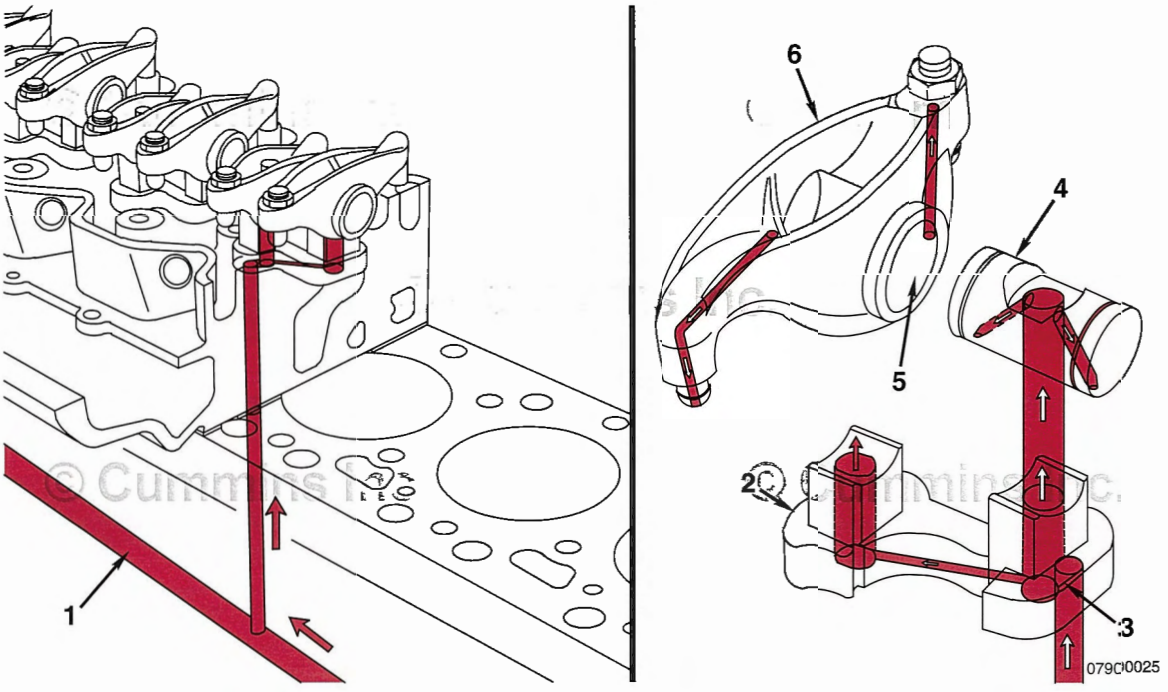


Lubrication for the Power Components

1 From lubricating oil cooler
2 Main lubricating oil rifle
3 To valve train
4 From main lubricating oil rifle
5 To piston-cooling nozzle
6 To camshaft
7 Crankshaft main journal
8 Oil supply to rod bearings
9 Directed piston-cooling nozzle
10 To internal lubrication of air compressor.

Flow Diagram, Lubricating Oil System

General Information

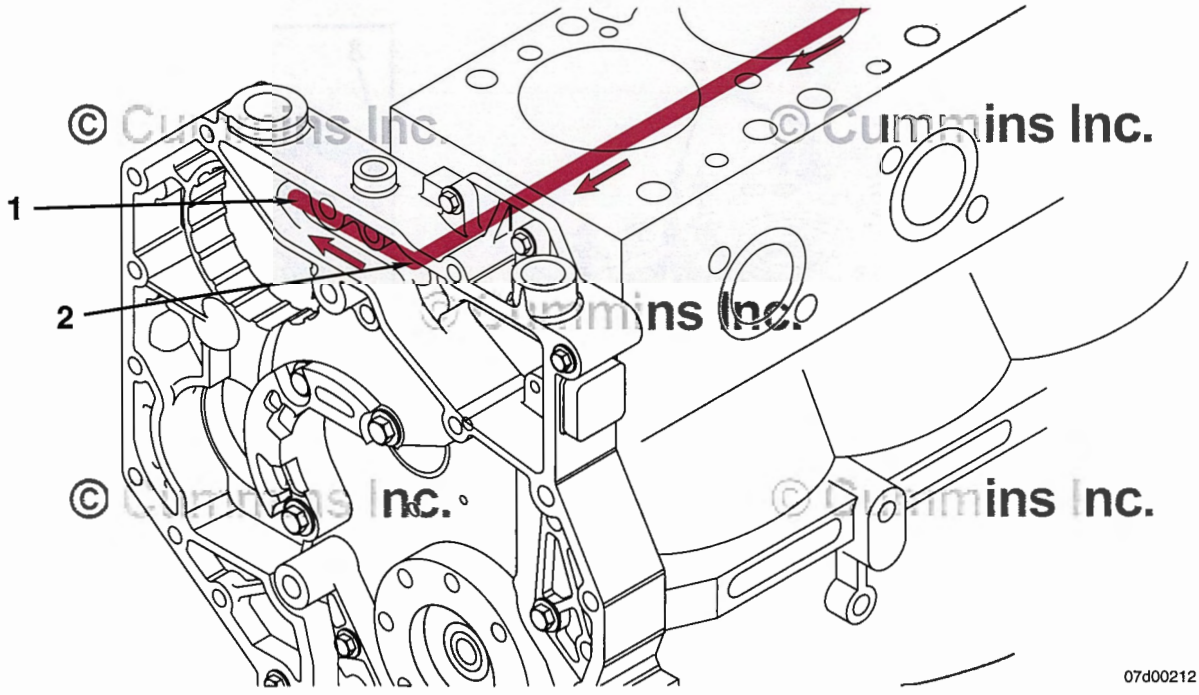


Lubrication for the Overhead Components

1 Main lubricating oil rifle
2 Rocker lever support
3 Transfer slot
4 Rocker lever shaft
5 Rocker lever bore
6 Rocker lever.

Flow Diagram, Lubricating Oil System

General Information



Lubrication for the Accessory Drive

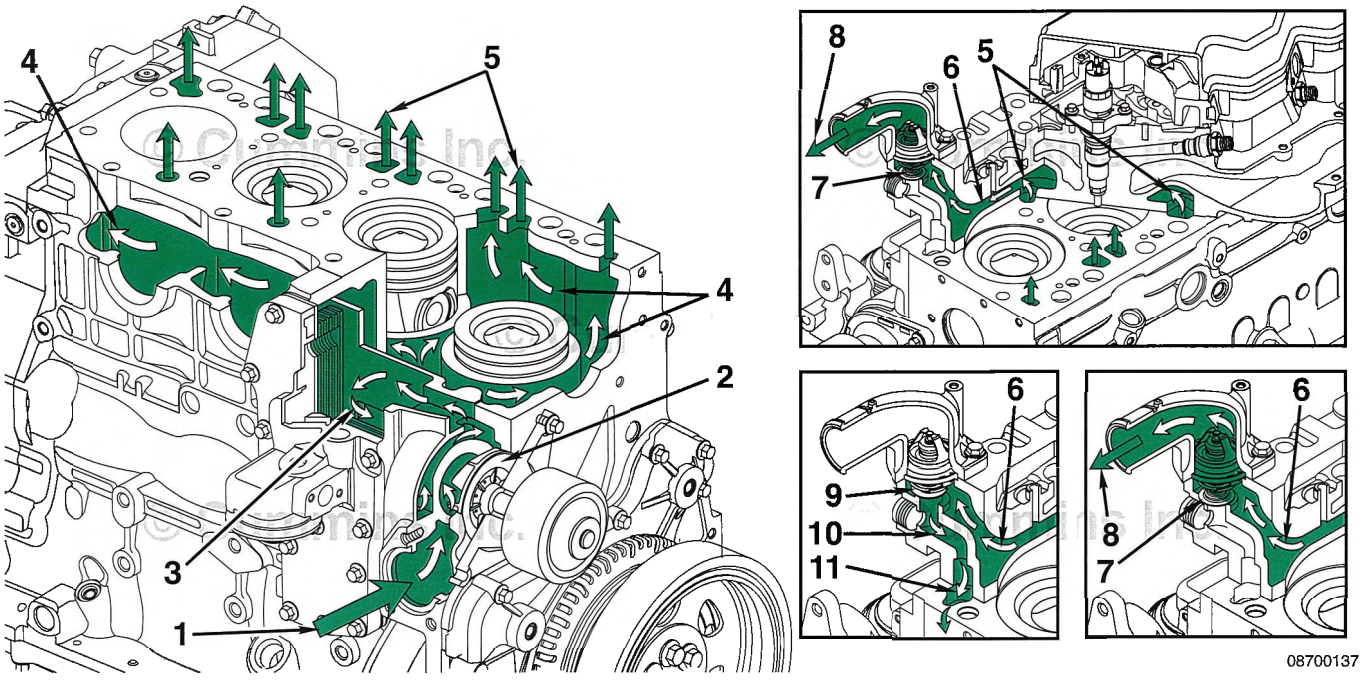
1 Oil feed from block

2 Oil supply to accessory drive.

NOTE: Oil returns to pan through the gear housing.

Flow Diagram, Cooling System

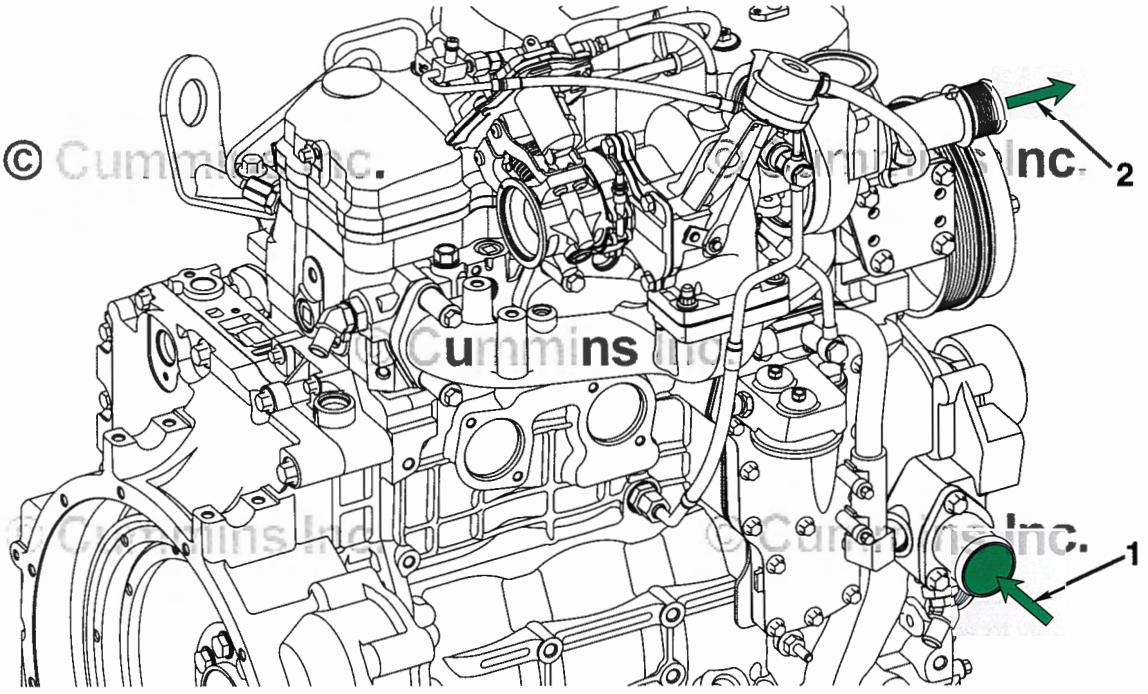
Flow Diagram



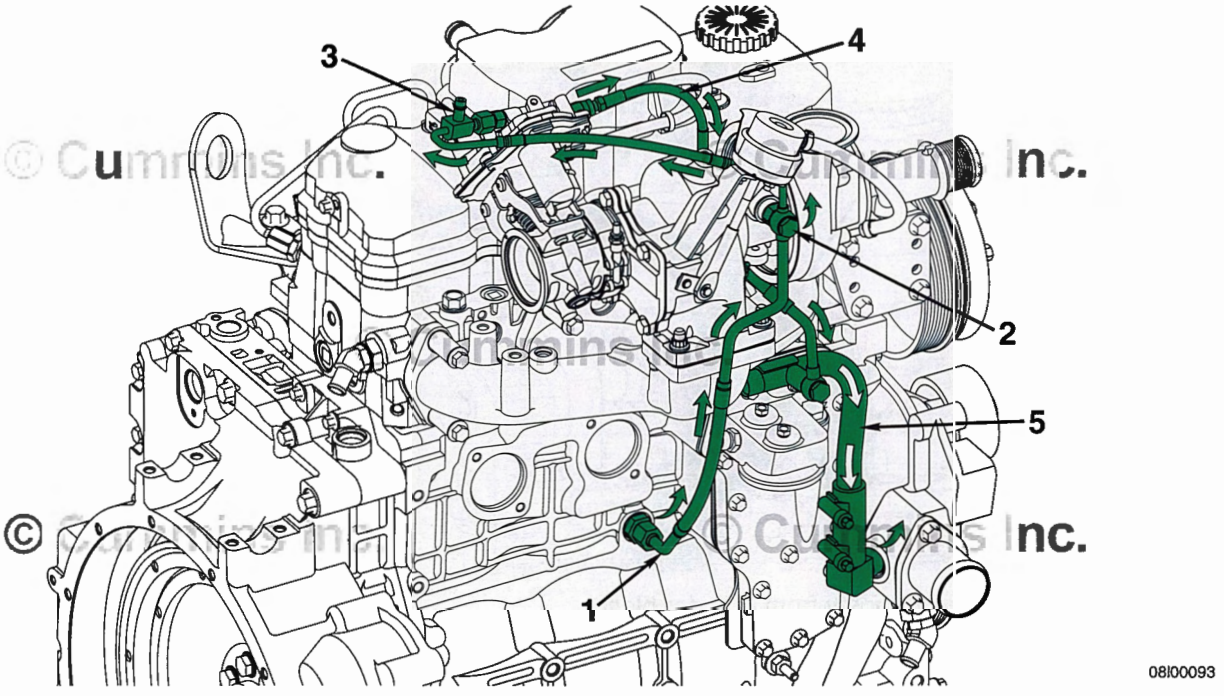
1 Coolant inlet
2 Pump impeller
3 Coolant flow past lubricating oil cooler
4 Coolant flow around cylinders
5 Coolant flow from cylinder block to cylinder head
6 Coolant flow to thermostat housing
7 Thermostat closed
8 Coolant flow back to radiator
9 Thermostat open
10 Coolant bypass passage
11 Coolant flow to water pump inlet.

Flow Diagram, Cooling System

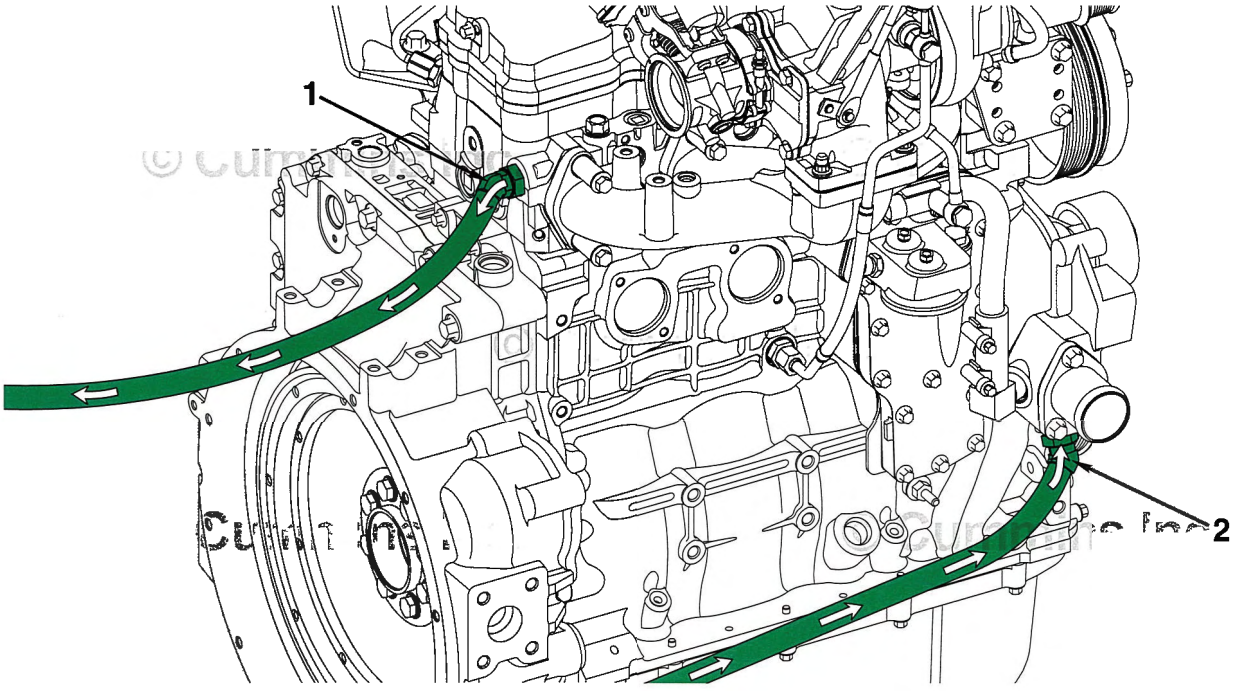
Flow Diagram



1 Coolant flow from radiator to inlet connection
2 Coolant return flow to radiator.

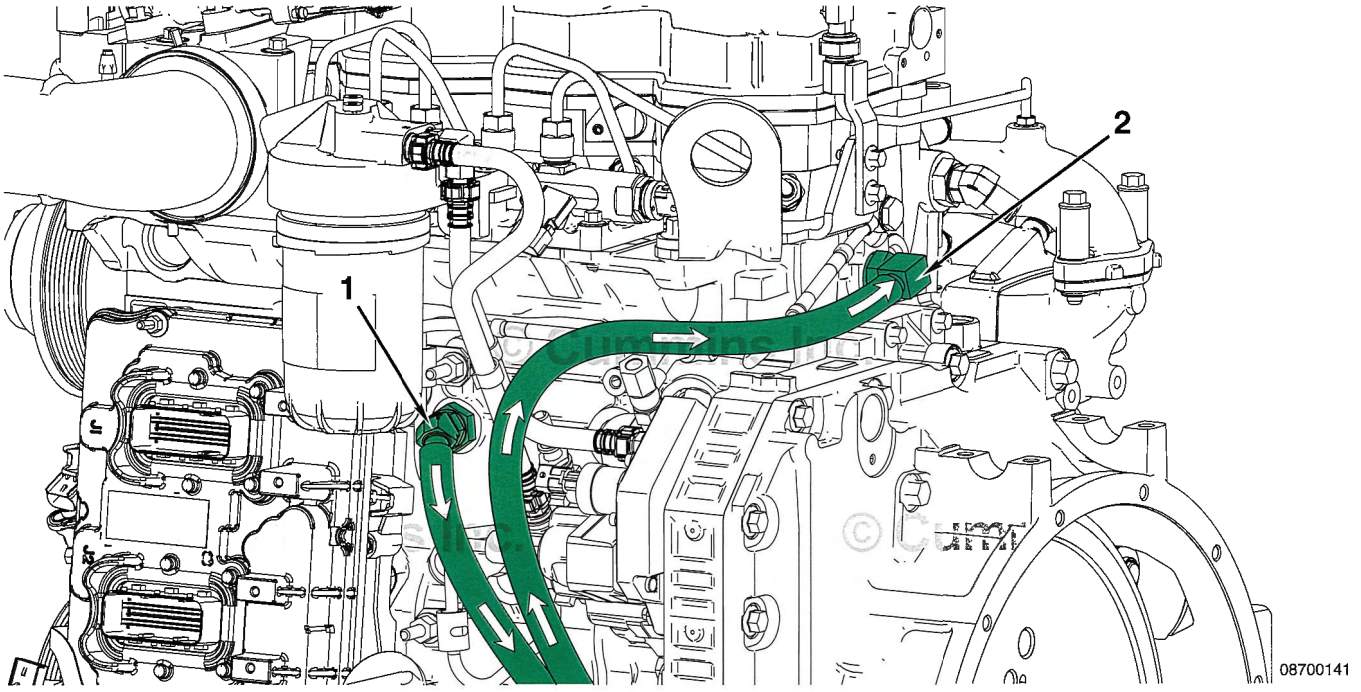


1 Coolant supply from cylinder block
2 Exhaust throttle valve coolant supply
3 De-aeration to radiator top tank
4 Exhaust throttle valve coolant return
5 Coolant flow to coolant inlet connection.



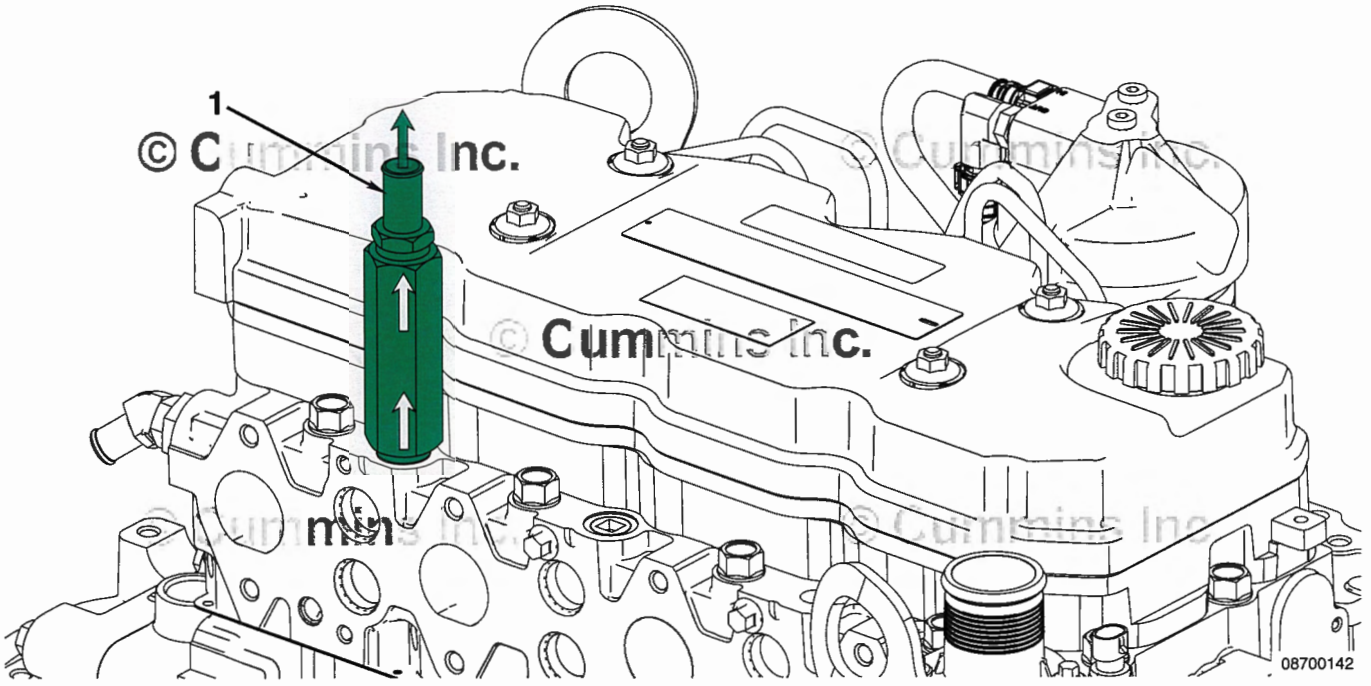
1 Coolant supply to aftertreatment diesel exhaust fluid (DEF) dosing valve and DEF tank

2 Coolant return to engine coolant inlet connection.



1 Air compressor coolant supply from cylinder block

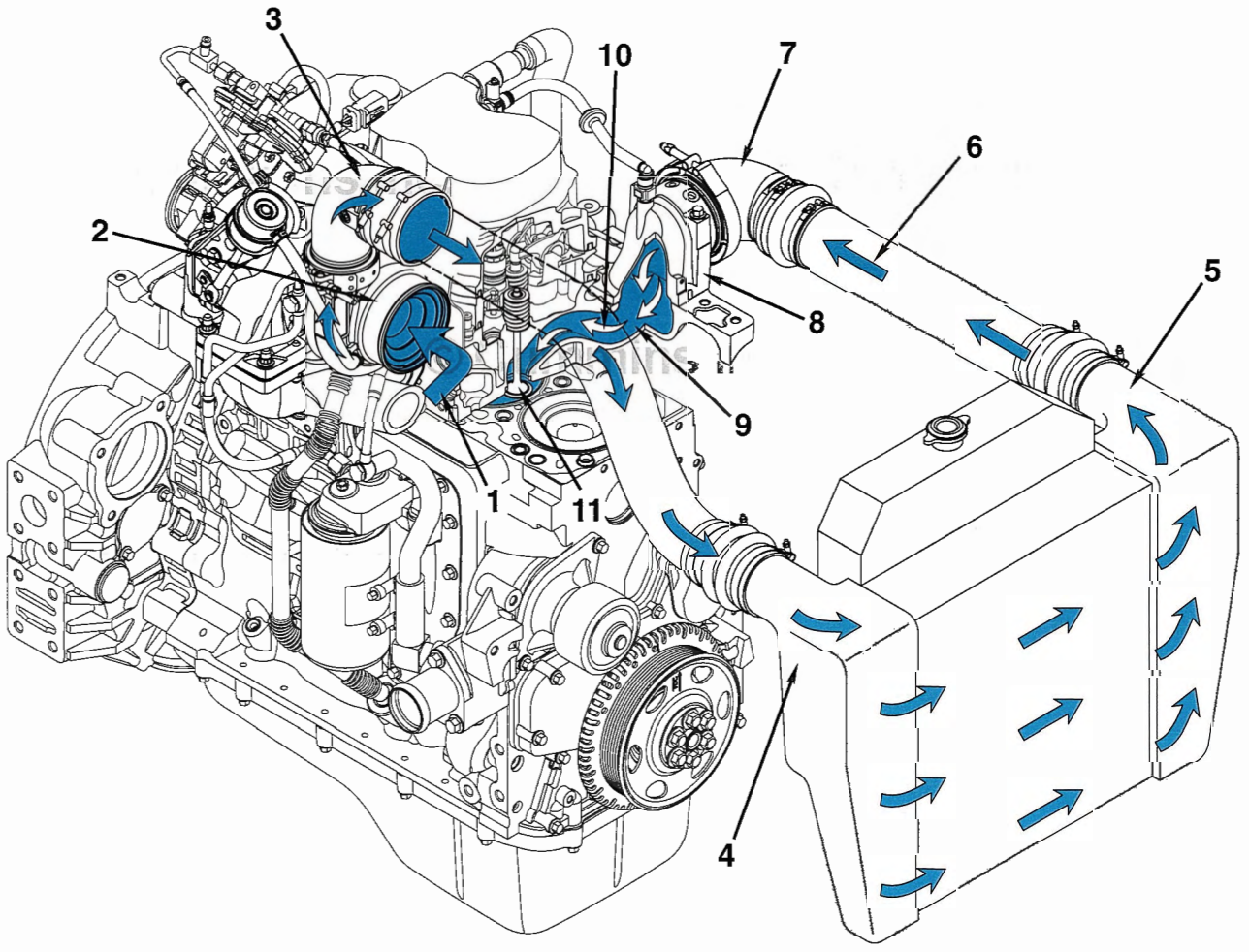
2 Air compressor coolant return to cylinder head.



1 For mid-mount rear outlet turbocharger configuration, the coolant port between cylinders 3 and 4 is recommended for coolant supply to the aftertreatment DEF dosing valve and DEF tank.

Flow Diagram, Air Intake System

General Information

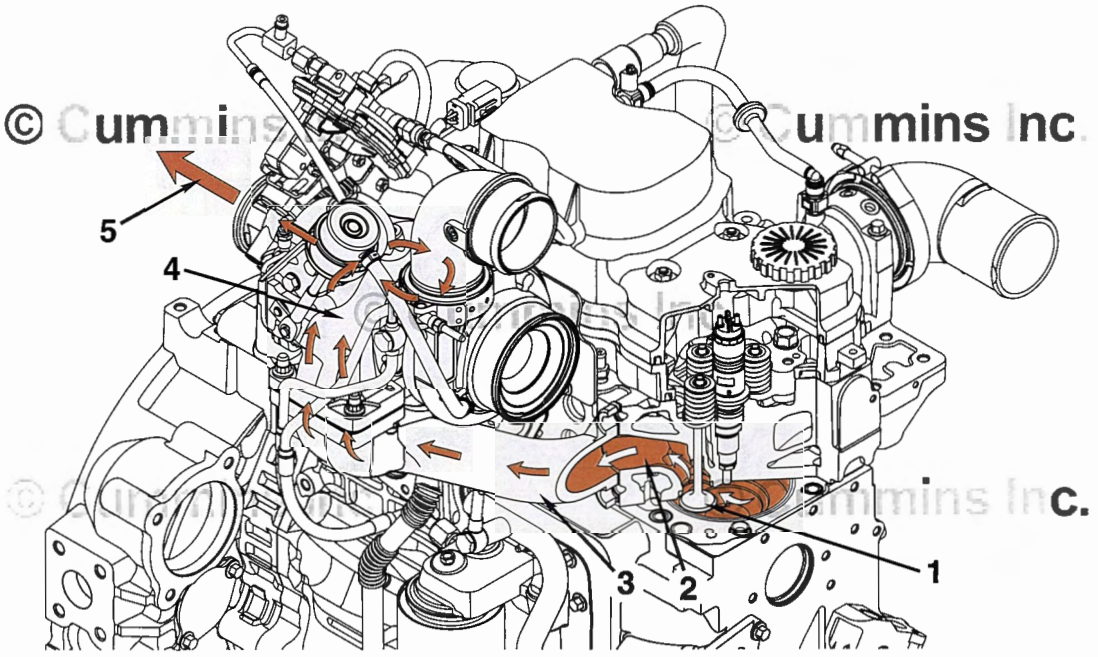


10I00259

1 Air cleaner
2 Turbocharger compressor inlet
3 Turbocharger compressor outlet
4 Charge air cooler inlet
5 Charge air cooler outlet
6 Charge air cooled intake air
7 Air intake connection adapter
8 Air intake manifold cover
9 Intake port
10 Intake valve
11 Air to combustion cylinder.

Flow Diagram, Exhaust System

Flow Diagram

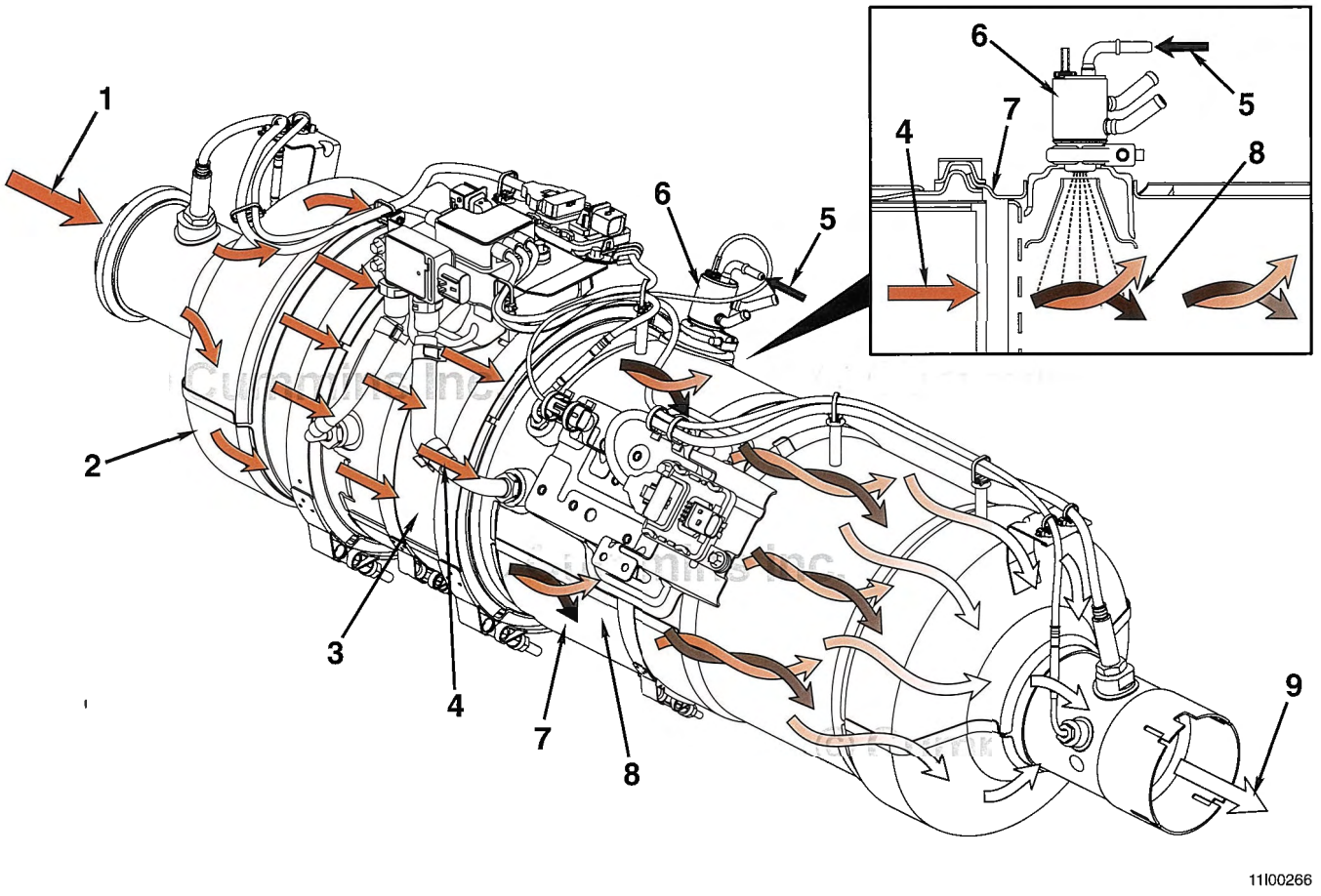


11I00375

1 Exhaust valve
2 Exhaust port
3 Exhaust manifold
4 Turbocharger
5 Turbocharger exhaust outlet to aftertreatment.

Flow Diagram, Exhaust System

Flow Diagram

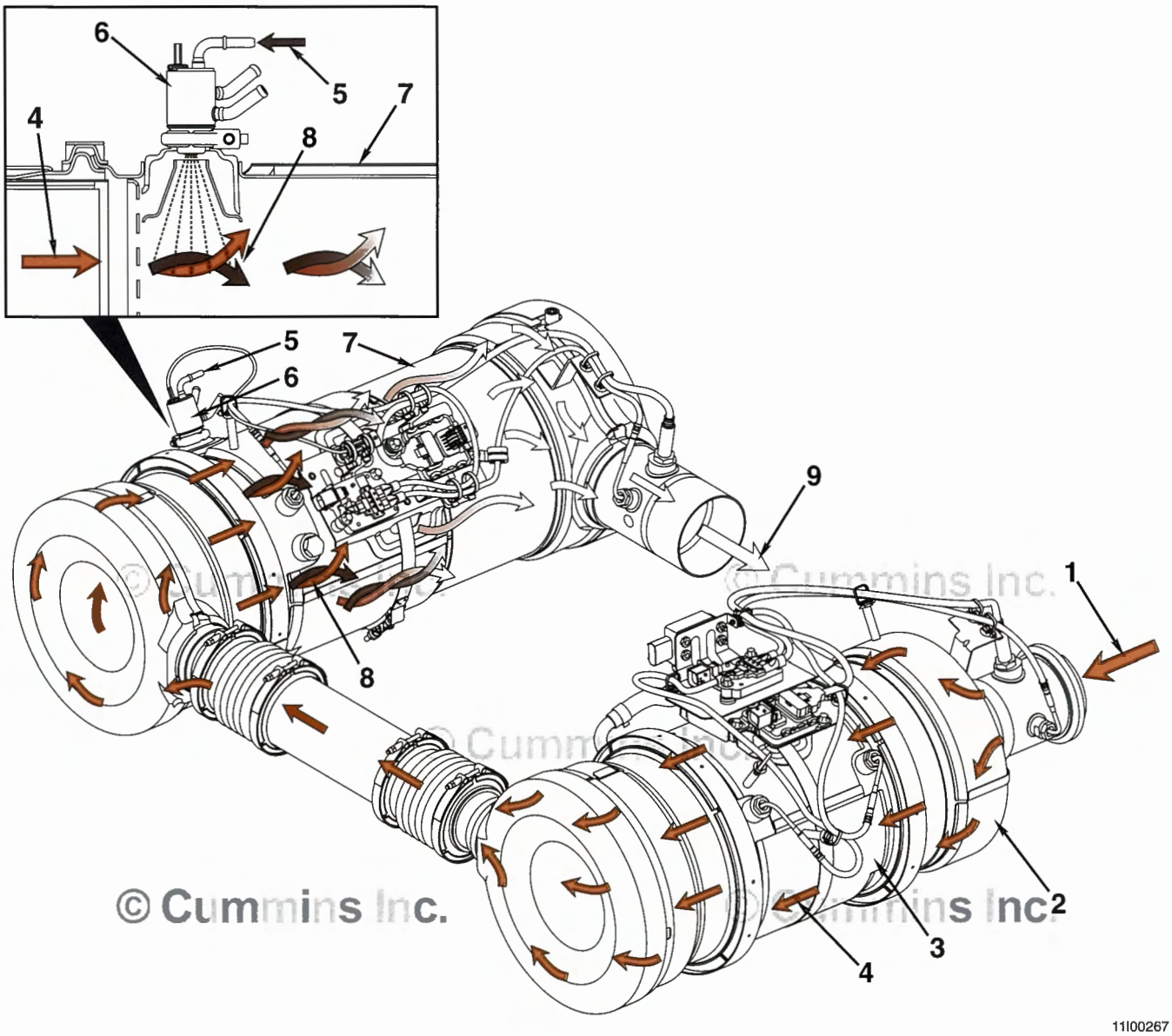


Single Module Aftertreatment System

1 Exhaust flow from turbocharger
2 Aftertreatment diesel oxidation catalyst (DOC)
3 Aftertreatment diesel particulate filter (DPF)
4 Exhaust gas flow from DPF
5 Diesel exhaust fluid (DEF) supply to the aftertreatment DEF dosing valve
6 Aftertreatment DEF dosing valve
7 Decomposition tube and selective catalytic reduction (SCR) catalyst assembly
8 Exhaust and DEF mixture
9 Exhaust flow exiting aftertreatment system.

Flow Diagram, Exhaust System

Flow Diagram

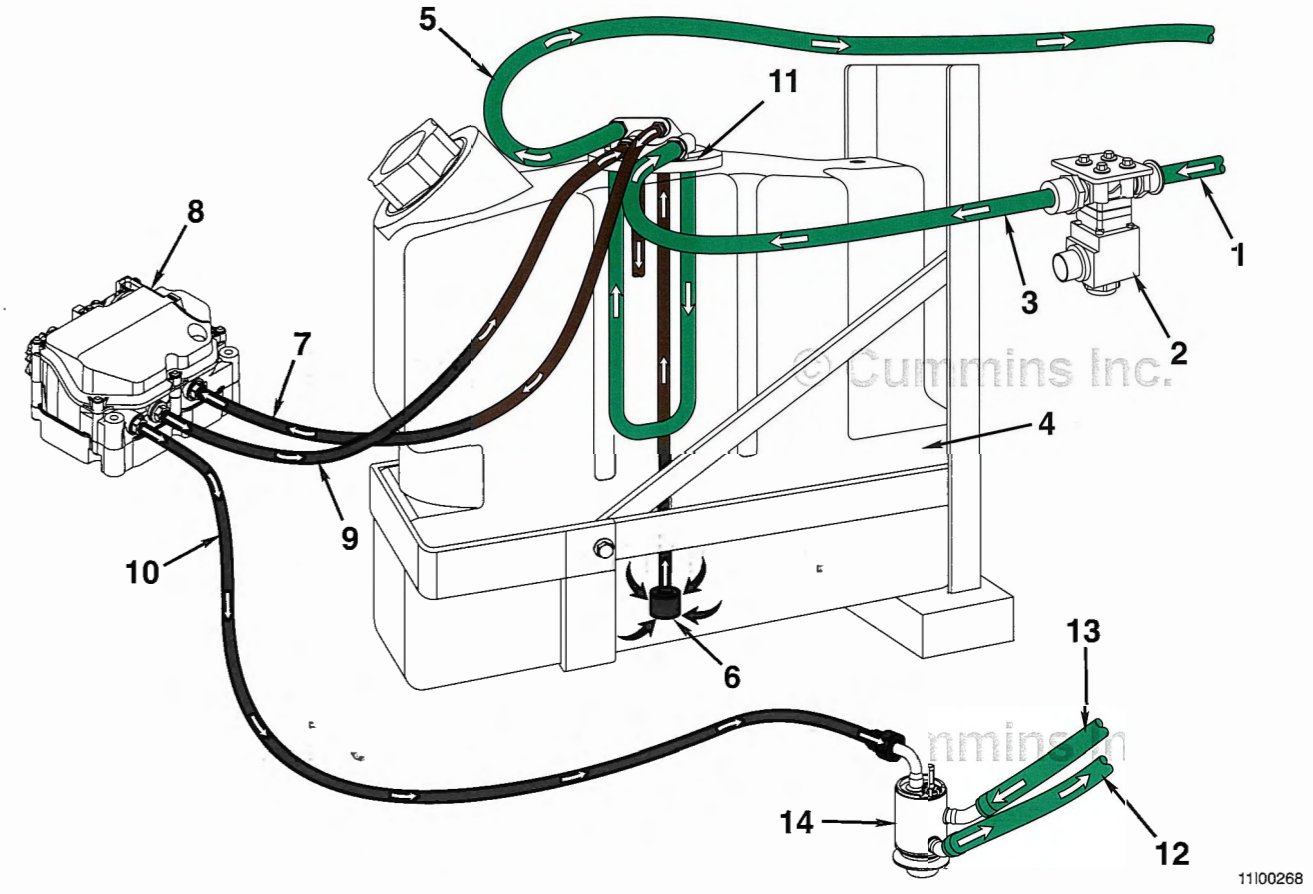


Flex Module Aftertreatment System

1 Exhaust flow from turbocharger
2 Aftertreatment DOC
3 Aftertreatment DPF
4 Exhaust gas flow from DPF
5 DEF supply to the aftertreatment DEF dosing valve
6 Aftertreatment DEF dosing valve
7 Decomposition tube and SCR catalyst assembly
8 Exhaust and DEF mixture
9 Exhaust flow exiting aftertreatment system.

Flow Diagram, Exhaust System

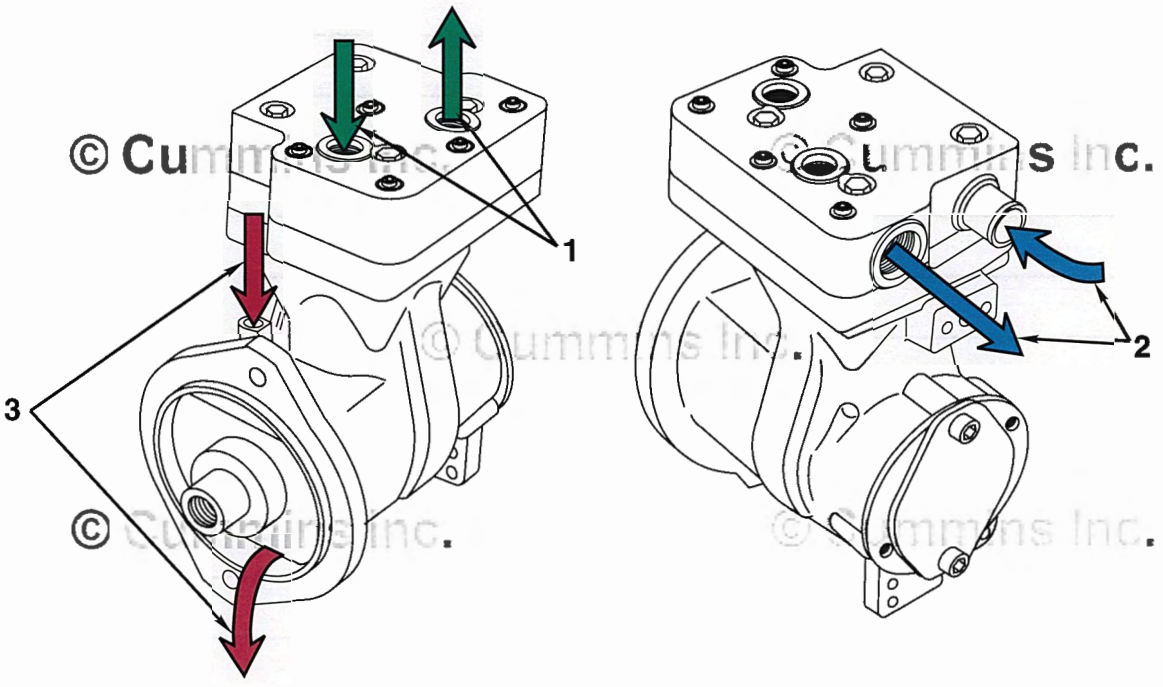
Flow Diagram



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

Flow Diagram, Compressed Air System

Flow Diagram



12d00033

1 Coolant
2 Air
3 Lubricant.

Notes

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- Color Monitor with at least 1024x768 resolution graphics
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Section L - Service Literature

Section Contents

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Additional Service Literature

General Information

The following publications can be purchased:

Bulletin Number	Title of Publication
5504283	B4.5 CM2350 B146C Service Manual
5504284	B4.5 CM2350 B146C Fault Code Troubleshooting Manual
5504285	B4.5 CM2350 B146C Wiring Diagram
5504282	B4.5 CM2350 B146C Operation and Maintenance Manual
5504281	B4.5 CM2350 B146C Owners Manual
3379000	Air for Your Engine
3379001	Fuels for Cummins® Engines
3379009	Operation of Diesel Engines in Cold Climates
3666132	Cummins® Coolant Requirements and Maintenance
3810340	Cummins® Engine Oil and Oil Analysis Recommendations

Service Literature Ordering Location

Contact Information

Service literature can be obtained from the appropriate location listed below:

- Any Cummins® Distributor
- Iron Mountain Fulfillment Services
  - Help Desk (U.S.): 1-800-646-5609
  - Help Desk (Outside U.S.): 1-630-283-2420
  - Email: CECOteam@ironmountain.com
- QuickServe® Online Store
  - https://store.cummins.com

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

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Required information needed for your Customized Parts Catalog Order.

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- Street Address
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- Credit Card No.
- Cummins Engine Serial Number (located on the engine data plate)

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Customized Parts Catalogs are produced specifically for a single customer. This means they are not returnable for a refund. If we make an error and your catalog is not useable, we will correct that error by sending you a new catalog.

Notes

Section S - Service Assistance

Section Contents

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Service Assistance

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- Email: contacto.mexico@cummins.com

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- 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

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- From the UK, Ireland, Germany, France, and the Netherlands - Freephone: 00 8000 2866467
- Email: emea.customerassistance@cummins.com

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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.

Notes

Section ES - Engine Storage

Section Contents

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Engine Storage - Long Term

General Information

If the engine will be out of service longer than 12 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.

Notes

Section TS - Troubleshooting Symptoms

Section Contents

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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

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.

Charging System Alternator Not Charging or Insufficient Charging

Cause	Correction
STEP 1 Vehicle gauge is malfunctioning	Check the vehicle gauge. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 2 Engine speed too low for charging	Move the throttle to raise the engine speed to 1200 rpm to excite the alternator. Refer to Procedure 013-001 in Section A. Verify correct engine idle speed and operation.
OK Go To Next Step	
STEP 3 Alternator belt is loose	Check the alternator belt tension. Adjust as necessary. Refer to Procedure 013-001 in Section A.
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 equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009 in Section 3.
OK Go To Next Step	
STEP 6 Malfunctioning battery sensor, if equipped	Check the battery sensors, if equipped. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 7 Batteries have malfunctioned	Check the condition of the batteries. Replace the batteries, if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 8 Alternator pulley is loose on the shaft	Tighten the pulley. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 9 Battery temperature is above specification	Position the batteries away from heat sources. Refer to equipment manufacturer service information.
OK Go To Next Step	

Charging System Alternator Not Charging or Insufficient Charging

Cause	Correction
STEP 10 Alternator or voltage regulator is malfunctioning	Test the alternator output. Replace the alternator or voltage regulator, if necessary. Refer to Procedure 013-001 in Section A and equipment manufacturer service information.

OK
Go To Next Step

STEP 11 Electronic fault codes active or high counts of inactive fault codes	Refer to equipment manufacturer service information. Read the fault codes with an electronic service tool.

OK
Go To Next Step

STEP 12 Alternator is overloaded, or alternator capacity is below specification	Install an alternator with a higher capacity. Refer to Procedure 013-001 in Section A and equipment manufacturer service information.

OK
Go To Next Step

STEP 13
Contact a Cummins® Authorized Repair Facility

Charging System Alternator Overcharging

Cause		Correction
STEP 1 Battery cables or connections are loose, broken, or corroded (excessive resistance)	.....	Check the battery cables and connections. Refer to Procedure 013-009 in Section 3.
OK Go To Next Step		
STEP 2 Battery cell is damaged (open circuit)	.....	Check the condition of the batteries. Replace the batteries, if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step		
STEP 3 Voltage regulator is malfunctioning	.....	Check the voltage regulator. Replace the voltage regulator, if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step		
STEP 4 Electronic fault codes active or high counts of inactive fault codes	.....	Refer to equipment manufacturer service information. Read the fault codes with an electronic service tool.
OK Go To Next Step		
STEP 5 Contact a Cummins® Authorized Repair Facility		

Coolant Contamination

Cause	Correction
STEP 1 Coolant is rusty and has debris	Drain and flush the cooling system. Fill with the correct mixture of antifreeze and water. Refer to Procedure 008-018 in Section 3.
OK Go To Next Step	
STEP 2 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 equipment manufacturer service information.
OK Go To Next Step	
STEP 3 Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks and cracks. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 4 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 5 Contact a Cummins® Authorized Repair Facility	

Coolant Loss - External

Cause	Correction
STEP 1 Power system coolant level is above specification	Check the power system coolant level. Refer to Procedure 008-066 in Section 2.
OK Go To Next Step	
STEP 2 External coolant leak	Inspect the engine 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, transmission oil cooler or torque converter oil cooler, water pump seal, radiator core, heat exchanger, lubricating oil cooler housing, aftertreatment diesel exhaust fluid tank heater and hoses, aftertreatment diesel exhaust fluid dosing valve coolant lines, and OEM mounted components that have coolant flow. If necessary, pressure test the cooling system. Refer to Procedure 008-018 in Section 3 and equipment manufacturer service information.
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 equipment manufacturer service information.
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 3.
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 008-018 in Section 3.
OK Go To Next Step	
STEP 6 Engine is overheating	Refer to the Coolant Temperature is Above Normal - Sudden Overheat troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 7 Contact a Cummins® Authorized Repair Facility	

Coolant Temperature Above Normal - Gradual Overheat

Cause	Correction
STEP 1 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1. If required, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 387 cm² [60 in²] of opening at all times. Refer to Procedure 101-015 in Section 1.
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 Procedure 010-027 in Section 3.
OK Go To Next Step	
STEP 4 Coolant level is below specification	Check the coolant level. Check for an external leak. Refer to Procedure 008-066 in Section 2. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak).
OK Go To Next Step	
STEP 5 Coolant mixture of antifreeze and water is **not** correct	Verify the concentration of antifreeze in the coolant. Add antifreeze or water to correct the concentration. Refer to Procedure 008-115 in Section 3.
OK Go To Next Step	
STEP 6 Fan shroud is damaged or missing or the air recirculation baffles are damaged or missing	Inspect the shroud and the recirculation baffles. Repair, replace, or install, as necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 7 Fan drive belt is loose, tight, or **not** in alignment	Check the fan drive belt. Refer to Procedure 008-002 in Section 3.
OK Go To Next Step	
STEP 8 Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge, if necessary. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

Cause	Correction
STEP 9 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-045 in Section 3.

OK
Go To Next Step

STEP 10 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 2.

OK
Go To Next Step

STEP 11 Lubricating oil is contaminated with coolant or fuel	Change the oil and filters. Refer to Lubricating Oil Contaminated troubleshooting symptom tree in Section TS.

OK
Go To Next Step

STEP 12 Vehicle cooling system is **not** adequate	Verify that the engine and vehicle cooling systems are using the correct components. Refer to equipment manufacturer service information.

OK
Go To Next Step

STEP 13
Contact a Cummins® Authorized Repair Facility

Coolant Temperature Above Normal - Sudden Overheat

Cause	Correction
STEP 1 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1.
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 2. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak).
OK Go To Next Step	
STEP 3 Fan drive belt is broken	Check the fan drive belt. Replace the belt, if necessary. Refer to Procedure 008-002 in Section 3.
OK Go To Next Step	
STEP 4 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 387 cm^2 [60 in^2] of opening at all times. Refer to Procedure 101-015 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 010-027 in Section 3.
OK Go To Next Step	
STEP 6 Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge, if necessary. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 7 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-045 in Section 3.
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 equipment manufacturer service information.
OK Go To Next Step	
STEP 9 Contact a Cummins® Authorized Repair Facility	

Coolant Temperature Below Normal

Cause	Correction
STEP 1 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1.
OK Go To Next Step	
STEP 2 Coolant temperature gauge or sensor is malfunctioning	Test the gauge or the sensor. Repair or replace, if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 3 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 101-015 in Section 1.
OK Go To Next Step	
STEP 4 Contact a Cummins® Authorized Repair Facility	

Engine Acceleration or Response Poor

Cause	Correction
STEP 1 Operator technique is **not** correct	Refer to Procedure 101-014 in Section 1.
OK Go To Next Step	
STEP 2 Fuel level is low in the tank	Fill the supply tank. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 3 Vehicle parasitics are excessive	Check the vehicle for brakes dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Clutch is malfunctioning or is **not** correct	Compare the drivetrain specifications to Cummins Inc. recommendations. Check the clutch for correct operation. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Drivetrain is **not** correctly matched to the engine	Check for correct gearing and drivetrain components. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 6 Electronic fault codes are active or high counts of inactive fault codes	Review instructions for reading active fault codes.
OK Go To Next Step	
STEP 7 Fuel leak	Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines to the supply tanks. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 8 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 9 Charge air cooler is restricted or leaking	Inspect the charge air cooler for air restrictions or leaks. Refer to Procedure 010-027 in Section 3.
OK Go To Next Step	

Engine Acceleration or Response Poor

Cause	Correction
STEP 10 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 11 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 010-058 in Section 2.
OK Go To Next Step	
STEP 12 Air intake system restriction is above specification	Check the air intake system for restriction. Replace the air filter and inlet piping as necessary. Refer to Procedure 010-059 in Section 2.
OK Go To Next Step	
STEP 13 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-002 in Section V.
OK Go To Next Step	
STEP 14 Fuel filter or fuel suction line is restricted	Replace the fuel filter. Check the fuel suction line for restriction. Refer to Procedure 006-015 in Section 3.
OK Go To Next Step	
STEP 15 Fuel supply is **not** adequate	Check the flow through the filter to locate the source of the restriction. Refer to Procedure 006-015 in Section 3.
OK Go To Next Step	
STEP 16 Contact a Cummins® Authorized Repair Facility	

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

Cause	Correction
STEP 1 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1.
OK Go To Next Step	
STEP 2 Fuel level is low in the tank	Fill the supply tank. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 3 Battery voltage is low	Inspect the batteries and the unswitched battery supply circuit. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Engine cranking speed is too slow	Determine if the cranking speed is slower than 150 rpm. Refer to the Engine Will Not Crank or Cranks Slowly troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 5 Starting aid is necessary for cold weather or starting aid is malfunctioning	Check for the correct operation of the starting aid. Refer to Procedure 101-004 in Section 1.
OK Go To Next Step	
STEP 6 Engine block heater is malfunctioning, if equipped	Check the electrical sources and wiring to the cylinder block heater. Replace the block heater, if necessary. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 7 Fuel heater is malfunctioning, if equipped	Check the fuel heater and replace, if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 8 Fuel leak	Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines to the supply tanks. Refer to equipment manufacturer service information.
OK Go To Next Step	

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

Cause	Correction
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	
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 Vehicle parasitics are excessive	Check the vehicle for brakes dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 13 Contact a Cummins® Authorized Repair Facility	

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

Cause	Correction
STEP 1 Fuel level is low in the tank	Fill the supply tank. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 2 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1.
OK Go To Next Step	
STEP 3 Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to Procedure 013-007 in Section 3.
OK Go To Next Step	
STEP 4 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 equipment manufacturer service information.
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 Moisture in the wiring harness connectors	Dry the connectors with Cummins® electronic cleaner, Part Number 3824510.
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 Engine control module (ECM) is malfunctioning	Replace the ECM. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 9 Contact a Cummins® Authorized Repair Facility	

Engine Noise Excessive

Cause	Correction
STEP 1 Fan drive belt is loose, tight, or **not** in alignment	Check the fan drive belt. Refer to Procedure 008-002 in Section 3.
OK Go To Next Step	
STEP 2 Fan is loose, damaged, or **not** balanced	Check the fan. Refer to Procedure 008-040 in Section 2.
OK Go To Next Step	
STEP 3 Fan clutch, hydraulic pump, or refrigerant compressor noise is excessive	Isolate each component and check for noise. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Alternator noise is excessive	Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 5 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 010-058 in Section 2.
OK Go To Next Step	
STEP 6 Air intake or exhaust piping is contacting the chassis or cab	Inspect the air piping, chassis, and cab for contact points. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 7 Lubricating oil level is below specification	Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-043 in Section 2.
OK Go To Next Step	
STEP 8 Lubricating oil is thin or diluted	Refer to Procedure 018-003 in Section V. 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 9 Vibration damper is damaged or loose	Inspect the vibration damper. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	

Engine Noise Excessive

Cause	Correction
STEP 10 Coolant temperature is above specification	Refer to the Coolant Temperature is Above Normal - Sudden Overheat symptom tree in Section TS.
OK Go To Next Step	
STEP 11 Engine mounts are worn, damaged, or **not** correct	Inspect the engine mounts. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 12 Air compressor noise is excessive	Refer to the Air Compressor Noise Is Excessive symptom tree in Section TS.
OK Go To Next Step	
STEP 13 Contact a Cummins® Authorized Repair Facility	

Engine Noise Excessive - Combustion Knocks

Cause	Correction
STEP 1 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-002 in Section V.
OK Go To Next Step	
STEP 2 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 3 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1.
OK Go To Next Step	
STEP 4 Coolant temperature is below specification	Refer to the Coolant Temperature is Below Normal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 5 Contact a Cummins® Authorized Repair Facility	

Engine Power Output Low

Cause	Correction
STEP 1 Operator technique is **not** correct	Explain the correct engine operation to the operator. Refer to Procedure 101-015 in Section 1.
OK Go To Next Step	
STEP 2 Original equipment manufacturer (OEM) machine constrained operation	OEM machine constrained operation through an OEM controller. Verify that the OEM system is configured to deliver correct power output. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 3 Lubricating oil pressure is above specification	Check the oil pressure. Contact a Cummins® Authorized Repair Location
OK Go To Next Step	
STEP 4 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1.
OK Go To Next Step	
STEP 5 Fuel grade is **not** correct for the application or fuel quality is poor	Operate the engine with a known good fuel supply and determine if the performance symptoms are eliminated. Verify if the customer is using any fuel additives and is using the correct fuel grade. Refer to Procedure 018-002 in Section V.
OK Go To Next Step	
STEP 6 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 equipment manufacturer service information.
OK Go To Next Step	
STEP 7 Fuel level is low in the tank	Fill the fuel supply tank. See equipment manufacturer service information.
OK Go To Next Step	
STEP 8 Fuel filter is plugged	Measure the fuel pressure before and after the fuel filter. Refer to Procedure 006-015 in Section 3 and contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 9 Fuel suction line restricted	Inspect for pinched, crimped, or kinked fuel lines. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	

Engine Power Output Low

Cause	Correction
STEP 10 Fuel leak	Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines from the supply tank(s). Refer to equipment manufacturer service information.
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 2.
OK Go To Next Step	
STEP 12 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 010-058 in Section 2.
OK Go To Next Step	
STEP 13 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 14 Vehicle parasitics are excessive	Check the vehicle for brakes dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 15 Fuel tank vents are plugged or damaged	Remove and clean the tank vents. Replace the vents, if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 16 Charge air cooler is restricted or leaking	Inspect the charge air cooler for air restrictions or leaks. Refer to Procedure 010-027 in Section 3.
OK Go To Next Step	
STEP 17 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 18 Contact a Cummins® Authorized Repair Facility	

Engine Runs Rough at Idle

Cause	Correction
STEP 1 Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 2 Electronic fault codes are active or high counts of inactive fault codes	Review instructions for reading active fault codes.
OK Go To Next Step	
STEP 3 Idle speed is set too low for accessories	Check and adjust the low-idle screw. Refer to a Cummins® Authorized Repair Location.
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 006-015 in Section 3.
OK Go To Next Step	
STEP 6 Fuel supply is **not** adequate	Check the flow through the filter to locate the source of the restriction. Refer to Procedure 006-015 in Section 3.
OK Go To Next Step	
STEP 7 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 8 Moisture in the wiring harness connectors	Dry the connector with Cummins® electrical contact cleaner, Part Number 3824510. Refer to equipment manufacturer service information.
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	

Engine Runs Rough at Idle

Cause	Correction
STEP 10 Contact a Cummins® Authorized Repair Facility	

Engine Runs Rough or Misfires

Cause	Correction
STEP 1 Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature is Below Normal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 2 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1.
OK Go To Next Step	
STEP 3 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 4 Fuel supply line restriction between the fuel pump and the injectors	Check the fuel supply line from the fuel pump to the cylinder head for sharp bends that can cause restrictions. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Moisture in the wiring harness connectors	Dry the connectors with Cummins® electronic cleaner, Part Number 3824510.
OK Go To Next Step	
STEP 6 Fuel quality is poor	Operate the engine from a temporary tank of known high quality number 2 diesel fuel. Clean and flush the vehicle's fuel system. Fill the fuel system with a known high quality number 2 diesel fuel.
OK Go To Next Step	
STEP 7 Vehicle parasitics are excessive	Check the vehicle for brakes dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 8 Contact a Cummins® Authorized Repair Facility	

Engine Shuts Off Unexpectedly or Dies During Deceleration

Cause		Correction
STEP 1 Engine will **not** restart	.....	Refer to the Engine Difficult to Start or Will **Not** Start troubleshooting symptom tree in Section TS.
OK Go To Next Step		
STEP 2 Fuel level is low in the tank	.....	Fill the supply tank. Refer to equipment manufacturer service information.
OK Go To Next Step		
STEP 3 Electronic fault codes are active or high counts of inactive fault codes	.....	Review instructions for reading active fault codes.
OK Go To Next Step		
STEP 4 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 Procedure 101-007 in Section 1.
OK Go To Next Step		
STEP 5 Moisture in the wiring harness connectors	.....	Dry the connectors with Cummins® electronic cleaner, Part Number 3824510.
OK Go To Next Step		
STEP 6 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 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 equipment manufacturer service information.
OK Go To Next Step		
STEP 8 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 9 Contact a Cummins® Authorized Repair Facility		

Engine Speed Surges at Low or High Idle

Cause	Correction
STEP 1 Fuel level is low in the tank	Fill the supply tank. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 2 Engine idle speed is set too low	Adjust the idle speed. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 3 Electronic fault codes are active or high counts of inactive fault codes	Review instructions for reading active fault codes.
OK Go To Next Step	
STEP 4 Moisture in the wiring harness connectors	Dry the connectors with Cummins® electronic cleaner, Part Number 3824510.
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 filter is plugged	Measure the fuel pressure before and after the fuel filter. Refer to Procedure 006-015 in Section 3.
OK Go To Next Step	
STEP 7 Fuel supply is **not** adequate	Check the flow through the filter to locate the source of the restriction. Refer to Procedure 006-015 in Section 3.
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 Contact a Cummins® Authorized Repair Facility	

Engine Speed Surges Under Load or in Operating Range

Cause	Correction
STEP 1 Fuel level is low in the tank	Fill the supply tank. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 2 Electronic fault codes active or high counts of inactive fault codes	Check for active or inactive fault codes. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 3 Fast Idle Warm-up feature is activating	If enabled, monitor Fast Idle Warm-up status with INSITE™ electronic service tool. Refer to 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 equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Fuel inlet restriction	Check for fuel inlet restriction. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 6 Fuel filter or fuel suction inlet restriction	Check the flow through the fuel filter. Replace the fuel filter, if necessary. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 7 Air in the fuel system	Check for air in the fuel system. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 8 Engine control module (ECM) calibration is malfunctioning	Verify the ECM calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. Reference the calibration history spreadsheet on QuickServe™ Online internet website or the INCAL™ calibration DVD-ROM. Make sure the correct calibration is being used. If necessary, calibrate the ECM. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	

Engine Speed Surges Under Load or in Operating Range

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. Contact a Cummins® Authorized Repair Location.

OK
Go To Next Step

STEP 10 J1939 control devices are interfering with the engine controls	.....	Alternately disconnect all other J1939 control devices from the data link circuit until communication or functionality is restored. Refer to a Cummins® Authorized Repair Location.

OK
Go To Next Step

STEP 11 Gain Adjust setting is incorrect for the application (Power Generation Engines **Only**)	.....	The Gain Adjust can be used to resolve issues with engine surge. Use the Features and Parameters menu in INSITE™ electronic service tool to determine how the Gain Adjust is set. The following options are available; the INSITE™ electronic service tool trimmable calibration, hardwired control knob, or the data link. Verify that the Gain Adjust is set correctly. If applicable, verify that the engine is able to receive messages from the data link or from the potentiometer. Refer to a Cummins® Authorized Repair Location.

OK
Go To Next Step

STEP 12 Accelerator pedal or lever is restricted or malfunctioning	.....	Check the percent accelerator pedal or lever reading on an electronic service tool. Verify that it reads 100 percent with the accelerator pedal depressed and 0 percent when released. Check the remote accelerator pedal. Calibrate the accelerator pedal if possible. Refer to a Cummins® Authorized Repair Location.

OK
Go To Next Step

STEP 13 Moisture in the wiring harness connectors	.....	Dry the connectors with Cummins® electronic cleaner, Part Number 3824510.

OK
Go To Next Step

STEP 14 Equipment and/or engine parastics are excessive	.....	Check the equipment for excessive loads from the engine-driven components. Refer to equipment manufacturer service information.

OK
Go To Next Step

Engine Speed Surges Under Load or in Operating Range

Cause	Correction
STEP 15 Engine speed sensor or circuit is malfunctioning	Check the engine speed sensor for correct adjustment and for debris on the sensor. Check the engine speed sensor circuit. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 16 Engine position sensor (EPS) or circuit is malfunctioning	Check the engine position sensor and circuit. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 17 Vehicle speed sensor (VSS) or circuit is malfunctioning	Refer to the appropriate electronic service tool manual. If the monitor shows speed, check the sensor and circuit. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 18 Fuel heater is malfunctioning (if equipped)	Check the fuel heater and replace if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 19 Fuel connector is leaking fuel	Measure the drain line fuel quantity. Inspect the fuel connector and injector for nicks or damage that can cause fuel leaks. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 20 Injector sealing washer is **not** correct	Remove the injectors and verify the injector sealing washer thickness. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 21 Injector(s) are malfunctioning	Perform diagnostics to find the malfunctioning injector(s). Replace the injector(s) as necessary. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 22 Injectors are **not** correct	Reference QuickServe™ Online to verify the injector part numbers. Replace the injector(s), if necessary. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	

Engine Speed Surges Under Load or in Operating Range

Cause	Correction
STEP 23 Clutch is malfunctioning or is **not** correct	Check the clutch for correct operation. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 24 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 25 Turbocharger is **not** correct	Reference QuickServe™ Online to verify the turbocharger part number. Replace the turbocharger, if necessary. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 26 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 a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 27 Fuel pump is malfunctioning	Check the fuel pump output pressure with INSITE™ electronic service tool. Replace the fuel pump, if necessary. Monitor fuel rail pressure commanded against that measured during engine operation. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 28 Vibration damper is damaged or loose	Inspect the vibration damper. Refer to equipment manufactuer service information.
OK Go To Next Step	
STEP 29 Flywheel housing is **not** aligned correctly	Check the flywheel housing alignment. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 30 Transmission damaged	Problem is related specifically to the transmission. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	

Engine Speed Surges Under Load or in Operating Range

Cause	Correction
STEP 31 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Contact a Cummins® Authorized Repair Location.

OK
Go To Next Step

STEP 32 Contact a Cummins® Authorized Repair Facility

Engine Speed Surges in PTO or Cruise Control

Cause	Correction
STEP 1 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1.
OK Go To Next Step	
STEP 2 Engine speed also surges at idle	Refer to the Engine Speed Surges at Low or High Idle troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 3 Engine speed surges while in the normal operating range and **not** in PTO or cruise control	Refer to the Engine Speed Surges at Low or High Idle troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 4 Contact a Cummins® Authorized Repair Facility	

Engine Starts But Will Not Keep Running

Cause		Correction
STEP 1 Fuel level is low in the tank	.....	Fill the supply tank. Refer to equipment manufacturer service information.
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 equipment manufacturer service information.
OK Go To Next Step		
STEP 3 Engine indicator lamps illuminated	.....	Refer to Procedure 101-048 in Section 1.
OK Go To Next Step		
STEP 4 Fuel supply is **not** adequate	.....	Check the flow through the filter to locate the source of the restriction. Refer to equipment manufacturer service information.
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 Contact a Cummins® Authorized Repair Facility		

Engine Vibration Excessive

Cause	Correction
STEP 1 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1.
OK Go To Next Step	
STEP 2 Engine is misfiring	Refer to the Engine Runs Rough or Misfires troubleshooting 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 Procedure 101-007 in Section 1. 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 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 008-002 in Section 3.
OK Go To Next Step	
STEP 5 Fan is loose, damaged, or **not** balanced	Check the fan. Refer to Procedure 008-040 in Section 2.
OK Go To Next Step	
STEP 6 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to equipment manufacturer service information.
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	

Engine Will Not Reach Rated Speed (RPM)

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 Tachometer is **not** calibrated or is malfunctioning	Compare the tachometer reading with a handheld tachometer. Replace the tachometer as necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 3 Air-fuel tube leaking or damage to the turbocharger system	Tighten the fittings, repair the plumbing, and inspect the turbocharger system for damaged or broken components. Refer to equipment manufacturer service information or a contact Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 4 Charge air cooler restricted, if equipped	Inspect the charge air cooler for internal and external restrictions. Replace the restricted cooler if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Fuel supply is **not** adequate	Check the flow through the filter to locate the source of the restriction. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 6 Exhaust back pressure too high	Measure and correct if above specification. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 7 Vehicle parasitics are excessive	Check the vehicle for brakes dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 8 Engine power output is low	Refer to the Engine Power Outlet Low troubleshooting symptom tree in Section TS. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 9 Contact a Cummins® Authorized Repair Facility	

Fault Code Warning Lamps Stay On (No Apparent Reason)

Cause		Correction
STEP 1 Diagnostic shorting plug is installed	.....	Remove the diagnostic shorting plug.

OK
Go To Next Step

STEP 2 Diagnostic switch is in the ON position	.....	Turn the diagnostic switch OFF.

OK
Go To Next Step

STEP 3 Electronic fault codes are active or high counts of inactive fault codes	.....	Review instructions for reading active fault codes.

OK
Go To Next Step

STEP 4
Contact a Cummins® Authorized Repair Facility

Fuel Consumption Excessive

Cause	Correction
STEP 1 Operator technique is **not** correct	Refer to Procedure 101-015 in Section 1.
OK Go To Next Step	
STEP 2 Fuel leak	Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines to the supply tanks. Refer to equipment manufacturer service informtation.
OK Go To Next Step	
STEP 3 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 4 Hour meter is miscalibrated	Check the hour meter. Calibrate or replace the hour meter, if necessary. Calculate fuel consumption with new figures.
OK Go To Next Step	
STEP 5 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 a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 6 Air intake system restriction is above specification	Check the air intake system for restrictions. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-059 in Section 2.
OK Go To Next Step	
STEP 7 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 8 Lubricating oil level above specification	Check the oil level. Verify the oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-043 in Section 2 and Procedure 018-003 in Section V.
OK Go To Next Step	
STEP 9 Contact a Cummins® Authorized Repair Facility	

Fuel in Coolant

Cause	Correction
STEP 1 Broken valve seat insert	Check the bulk coolant supply. Drain the coolant and replace with non-contaminated coolant. Change the coolant filters. Refer to Procedure 008-018 in Section 3.

OK
Go To Next Step

STEP 2
Contact a Cummins® Authorized Repair Facility

Fuel in the Lubricating Oil

Cause	Correction
STEP 1 Engine idle time is excessive	Low oil and coolant temperatures can be caused by long idle time (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 Procedure 101-015 in Section 1.
OK Go To Next Step	
STEP 2 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with non-contaminated oil. Replace the oil filter(s). Refer to Procedure 008-018 in Section 3.
OK Go To Next Step	
STEP 3 Contact a Cummins® Authorized Repair Facility	

Intake Manifold Air Temperature Above Specification

Cause	Correction
STEP 1 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 equipment manufacturer service information.
OK Go To Next Step	
STEP 2 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 387 cm^2 [60 in^2] of opening at all times. Refer to Procedure 101-004 in Section 1.
OK Go To Next Step	
STEP 3 Fan drive belt or water pump belt is broken	Check the fan drive belt and water pump belt. Replace the belts, if necessary. Refer to Procedure 008-002 in Section 3.
OK Go To Next Step	
STEP 4 Coolant level is below specification	Add coolant. Verify the cooling system capacity.
OK Go To Next Step	
STEP 5 Fan shroud is damaged or missing or the air recirculation baffles are damaged or missing	Inspect the shroud and the recirculation baffles. Repair, replace, or install, as necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 6 Radiator shutters are **not** opening completely or the shutterstat setting is wrong	Inspect the radiator shutters. Repair or replace, if necessary. Refer to the manufacturer's instructions. Check the shutterstat setting. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 7 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 8 Vehicle cooling system is **not** adequate	Verify that the engine and vehicle cooling systems are using the correct components. Refer to equipment manufacturer service information.
OK Go To Next Step	

Intake Manifold Air Temperature Above Specification

Cause	Correction
STEP 9 Intake manifold temperature gauge is malfunctioning, if equipped	Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 10 Fan is **not** an adequate size for the application	Verify that the fan is the correct size. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 11 Contact a Cummins® Authorized Repair Facility	

Intake Manifold Pressure (Boost) is Below Normal

Cause	Correction
STEP 1 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 a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 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 2.
OK Go To Next Step	
STEP 3 Charge air cooler is restricted or leaking	Inspect the charge air cooler for air restrictions or leaks. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 4 Engine power output is low	Refer to the Engine Power Output Low troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 5 Contact a Cummins® Authorized Repair Facility	

Lubricating Oil Consumption Excessive

Cause	Correction
STEP 1 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-018 in Section 2.
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 018-003 in Section V.
OK Go To Next Step	
STEP 3 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to Procedure 358-001 in Section 2.
OK Go To Next Step	
STEP 4 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 5 Verify the oil consumption rate	Check the amount of oil added versus the hours of operation.
OK Go To Next Step	
STEP 6 Air compressor is pumping lubricating oil into the air system and turbocharger leaking oil internally	Check the air lines for carbon buildup and lubricating oil. Remove the turbocharger inlet and exhaust tubing and check for oil deposits. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 7 Contact a Cummins® Authorized Repair Facility	

Lubricating Oil Contaminated

Cause	Correction
STEP 1 Lubricating oil sludge is excessive	Change the oil and filters. Refer to the Lubricating Oil Sludge in the Crankcase Excessive troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 2 Lubricating oil is contaminated with coolant or fuel	Change the oil and filters. Refer to Procedure 018-003 in Section V.
OK Go To Next Step	
STEP 3 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 A.
OK Go To Next Step	
STEP 4 Contact a Cummins® Authorized Repair Facility	

Lubricating Oil Loss

Cause	Correction
STEP 1 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 2 Lubricating oil level below specification	Check the oil level. Verify the oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-043 in Section 2 and Procedure 018-003 in Section V.
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 A.
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.
OK Go To Next Step	
STEP 5 Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks and cracks. Refer to equipment manufacturer service information or contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 6 Air compressor is pumping lubricating oil into the air system	Check the air lines for carbon buildup and lubricating oil. Refer to equipment manufacturer service information or contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 7 Blowby excessive	Check for excessive blowby. Contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 8 Turbocharger oil seal is leaking	Check the turbocharger for oil seals and for leaks. Refer to the Turbocharger Leaks Engine Oil or Fuel troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 9 Contact a Cummins® Authorized Repair Facility	

Lubricating Oil Pressure High

Cause	Correction
STEP 1 Coolant temperature is below specification	Refer to the Coolant Temperature Below Normal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 2 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007-002 in Section A. Use the oil recommended in Section V.
OK Go To Next Step	
STEP 3 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.
OK Go To Next Step	
STEP 4 Contact a Cummins® Authorized Repair Facility	

Lubricating Oil Pressure Low

Cause	Correction
STEP 1 Engine angularity during operation exceeds specification	Refer to equipment manufacturer service information.
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 A. Use the oil recommended in the following procedure. Refer to Procedure 018-003 in Section V.
OK Go To Next Step	
STEP 3 Lubricating oil is diluted with water	Check for a missing dipstick, rain caps, or oil fill caps. Change the oil and filter. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Lubricating oil filter is plugged	Change the oil and filter(s). Refer to Procedure 007-002 in Section A. Use the oil recommended in the following procedure. Refer to Procedure 018-003 in Section V.
OK Go To Next Step	
STEP 5 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 6 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 7 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-002 in Section A. Use the oil recommended in the following procedure. Refer to Procedure 018-003 in Section V.
OK Go To Next Step	
STEP 8 Electronic fault codes are active or high counts of inactive fault codes	Review instructions for reading active fault codes.
OK Go To Next Step	

Lubricating Oil Pressure Low

Cause	Correction
STEP 9 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.

OK
Go To Next Step

STEP 10
Contact a Cummins® Authorized Repair Facility

Smoke, Black - Excessive

Cause	Correction
STEP 1 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1. If required, contact a Cummins® Authorized Repair Location.

OK
Go To Next Step

STEP 2 Contact a Cummins® Authorized Repair Facility

Smoke, White - Excessive

Cause	Correction
STEP 1 Engine indicator lamps illuminated	Refer to Procedure 101-048 in Section 1. If required, contact a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 2 Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to Coolant Temperature is Below Normal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 3 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 101-015 in Section 1.
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 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 2.
OK Go To Next Step	
STEP 6 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 010-058 in Section 2.
OK Go To Next Step	
STEP 7 Charge air cooler is restricted or leaking	Inspect the charge air cooler for air restrictions or leaks. Refer to Procedure 010-027 in Section 3.
OK Go To Next Step	
STEP 8 Engine is operating above recommended altitude	Engine power decreases above recommended altitude. Refer to Engine Power Output Low troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 9 Contact a Cummins® Authorized Repair Facility	

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 101-999 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. Refer to a Cummins® Authorized Repair Location.
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 a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 4 Turbocharger oil supply line loose or leaking	Check and tighten oil supply line fitting(s), if necessary. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 5 Contact a Cummins® Authorized Repair Facility	

Diesel Exhaust Fluid Usage - Abnormal

Cause	Correction
STEP 1 Electronic fault codes are active or high counts of inactive fault codes	Review instructions for reading active fault codes. Refer to a Cummins® Authorized Repair Location, if fault codes are active.
OK Go To Next Step	
STEP 2 Aftertreatment diesel exhaust fluid leak (external)	Inspect for external aftertreatment diesel exhaust fluids leaks near the aftertreatment diesel exhaust fluid tank, aftertreatment diesel exhaust fluid lines, aftertreatment diesel exhaust fluid inline filter, if equipped, and associated connections. Repair or replace parts as necessary.
OK Go To Next Step	
STEP 3 Aftertreatment diesel exhaust fluid low level or warning level not set correctly.	The vehicle manufacturer has the ability to change when the warnings for low diesel exhaust fluid level activate, which may cause the low diesel exhaust fluid level warnings to activate earlier than expected. Verify the warnings are correctly set per the OEM service manual.
OK Go To Next Step	
STEP 4 Engine control module (ECM) calibration is malfunctioning	Verify that the ECM calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. If necessary, calibrate the ECM. Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 5 Aftertreatment diesel exhaust fluid level gauge is inaccurate	Verify that the aftertreatment diesel exhaust fluid level gauge is correctly calibrated and matched to the diesel exhaust fluid tank. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 6 Engine out NOx emissions above normal	Refer to a Cummins® Authorized Repair Location.
OK Go To Next Step	
STEP 7 Contact a Cummins® Authorized Repair Facility	

Section V - Maintenance Specifications

Section Contents

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General Engine

Specifications

Listed below are the general specifications for the engine covered by this manual.

Horsepower ..... See the engine dataplate.
Compression ratio 17.2:1
Crankshaft rotation (viewed from the front of the engine) ..... **Clockwise**
Bore and Stroke
For 4.5 liters [272 C.I.D.] engines ..... 107 mm [4.21 in] X 124 mm [4.88 in]
Displacement (four-cylinder engine) ..... 4.5 liters [272 C.I.D.]
Firing order (four-cylinder engine) 1-3-4-2
Approximate Engine Weight:
Dry weight for 4.5 liters (272 C.I.D.) ..... 447 kg [985 lb]
Crankshaft Rotation (viewed from the front of the engine) ..... **Clockwise**
Valve Clearance:
Intake ..... 0.254 mm [0.010 in]
Exhaust ..... 0.508 mm [0.020 in]
Maximum overspeed capability (15 seconds maximum) ..... 3750 rpm
Minimum ambient air temperature for unaided cold start ..... -12.2°C [10°F]
Minimum engine cranking speed ..... 120 rpm
Engine idle speed ..... Minimum 700 to maximum 1200 rpm
Oil Carryover:
Open-crankcase ventilation system ..... Less than 2 grams/hour [0.07 oz/hour]
Engine Blowby:
New ..... 1 kPa [4 in H_2O]
Used ..... 2.49 kPa [10 in H_2O]

NOTE: The engine features a no-adjust overhead. The valve train is designed such that adjustment of the valve lash is **not** required for normal service during the first 5000 hours. The valve train operates acceptably within the limits of 0.152 to 0.381 mm [0.006 to 0.015 in] intake valve lash and 0.381 to 0.762 mm [0.015 to 0.030 in] exhaust valve lash. It is recommended the valve lash be checked around 5000 hours and every 1500 hours thereafter.

Fuel System

Specifications

For performance and fuel rate values, see the Engine Data Sheet.

Maximum Fuel Inlet Restriction (vacuum)*..... 305 mm-hg [12 in-hg]
Rail Pressure Operating Range..... 250 to 1800 bar [3626 to 26,107 psi]
Fuel Pressure Range at Fuel Filter Inlet and Outlet (Engine Cranking).....207 to 500 kPa [30 to 72.5 psi]
Fuel Pressure Range at Fuel Filter Inlet and Outlet (Engine Running).....207 to 652 kPa [30 to 94.5 psi]
Maximum Pressure Drop across Fuel Filter..... 81 kPa [11.7 psi]
Maximum Fuel Drain Line Restriction..... 19 kPa [2.7 psi]
Maximum Fuel Inlet Temperature.....80°C [176°F]

* Inlet restriction measured at the fuel gear pump inlet using a diagnostic test line. See equipment manufacturer service information.

* Inlet restriction measured at the fuel gear pump inlet.

Lubricating Oil System

Specifications

Oil Pressure:
- Low Idle (minimum allowed)..... 69 kPa [10 psi]
- At Rated (minimum allowed).....207 kPa [30 psi]

Oil-regulating Valve-opening Pressure Range..... 448 kPa [65 psi] to 517 kPa [75 psi]
Oil Filter Differential Pressure to Open Bypass.....345 kPa [50 psi]
Lubricating Oil Filter Capacity..... 0.95 liters [1 qt]

Oil Capacity of Standard Engine (Four-cylinder):
4.5 liters [275 C.I.D.] Engines (Suspended Oil Pan)
- Pan **Only** .....11 liters [11.6 qt]
- Total System..... 13 liters [13.7 qt]
- High to Low (on dipstick)..... 1.9 liters [2.0 qt]

Oil Capacity of Standard Engine (Four-cylinder):
4.5 liters [275 C.I.D.] Engines (Aluminum Oil Pan)
- Pan **Only** ..... 13 liters [13.7 qt]
- Total System..... 15 liters [15.9 qt]
- High to Low (on dipstick)..... 3.0 liters [3.2 qt]

Oil Capacity of Standard Engine (Four-cylinder):
4.5 liters [275 C.I.D.] Engines (High Capacity Oil Pan)
- Pan **Only** ..... 16 liters [16.9 qt]
- Total System..... 18 liters [19.0 qt]
- High to Low (on dipstick)..... 6.0 liters [6.3 qt]

Maximum Oil Temperature:
- For 4.5 Liter [275 C.I.D.] Engines..... 135°C [275°F]

NOTE: If the type or oil capacity of the oil pan is **not** known:

1. Contact a Cummins® Distributor/Dealer.
2. Determine the capacity of the oil pan option for the engine being serviced by using QuickServe™ Online and the engine serial number.
3. Fill the lubricating oil pan to the lowest oil pan capacity listed for the engine being serviced. Add 0.95 liters [1 qt] of oil at a time until it reaches the high mark on the dipstick. Record the number of quarts added so the capacity is known the next time the oil is drained.

Cooling System

Specifications

Coolant Capacity (includes block, cylinder head, and water pump volute)..... 8.86 liters [9.36 qt]
Standard Modulating Thermostat - Range..... 82 to 95°C [180 to 203°F]
Maximum Allowed Operating Temperature..... 107°C [225°F]
Minimum Recommended Operating Temperature..... 71°C [160°F]
Minimum Recommended Pressure Cap..... 90 kPa [13 psi]
Maximum Recommended Pressure Cap..... 172 kPa [25 psi]

Air Intake System

Specifications

Industrial:

Maximum Intake Restriction (clean air filter element)..... 381 mm-H_2O [15 in-H_2O]

Maximum Intake Restriction (dirty air filter element)..... 635 mm-H_2O [25 in-H_2O]

Charge Air Cooler Temperature Differential:

Maximum Differential (Intake manifold - Ambient air temperature)..... 17°C or 30.6°F

Maximum Charge Air Cooler Pressure Differential..... 13.5 kPa [4 in-Hg]

Exhaust System

Specifications

Maximum Exhaust Restriction..... 14 kPa [4 in-hg]

Electrical System

Specifications

Recommended Battery Capacity

System Voltage		Ambient Temperature		
-18°C [0°F]		-31.7°C [-25°F]		
4 Cylinder Engines	Cold Cranking Amperes	Reserve Capacity (minutes)[1]	Cold Cranking Amperes	Reserve Capacity (minutes) [1]
12 VDC	1300	-	-	-
24 VDC [2]	650	260	1300	260

[1] The number of plates within a given battery size determines reserve capacity. Reserve capacity is the length of time for which a battery at 27°C [81°F] can supply 25 amperes at 10.5 VDC or greater.

[2] Cold cranking amp(s) ratings are based on two 12 VDC batteries in series.

Batteries (Specific Gravity)

Specific Gravity at 27°C [81°F]	State of Charge (Percent)
1.260 to 1.280	100
1.230 to 1.250	75
1.200 to 1.220	50
1.170 to 1.190	25
1.110 to 1.130	Discharged

Filter Specifications

General Information

Cummins Filtration™, which produces Fleetguard® products, is a division of Cummins Inc. Fleetguard® filters are developed through joint testing at Cummins Inc. and are standard on new Cummins® engines. Cummins Inc. recommends their use.

Fleetguard® products meet all Cummins® Source Approval Test standards to provide the quality filtration necessary to achieve the engine's design life. If other brands are substituted, the purchaser **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 Part Numbers

Lubricating Oil Filter	
Cummins® Part Number	3937736
Fleetguard® Part Number	LF3970

Fuel Filter (Pressure-Side)	
Cummins® Part Number	5303743
Fleetguard® Part Number	FF63004

Fuel Filter (Suction-Side with Water in Fuel Sensor)[1]	
Cummins® Part Number	5319680
Fleetguard® Part Number	FS19596

1. The fuel filter (Suction-side with Water in Fuel Sensor) could be original equipment manufacturer-supplied.

Air Filter (Primary)	
Direct Flow™ 390 Series 178 x 178 x 203 mm [7 x 7x 8 in]	
Cummins® Part Number	5283826
Fleetguard® Part Number	AF55020
Direct Flow™ 585 Series 178 x 178 x 305 mm [7 x 7 x 12 in]	
Cummins® Part Number	5288553
Fleetguard® Part Number	AF55021
Direct Flow™ 600 Series 127 x 381 x 203 mm [5 x 15 x 8 in]	
Cummins® Part Number	5261248
Fleetguard® Part Number	AF55005

Air Filter (Secondary)	
Direct Flow™ 390 Series 178 x 178 x 203 mm [7 x 7x 8 in]	
Cummins® Part Number	5310325
Fleetguard® Part Number	AF55320
Direct Flow™ 585 Series 178 x 178 x 305 mm [7 x 7 x 12 in]	
Cummins® Part Number	5310325
Fleetguard® Part Number	AF55320
Direct Flow™ 600 Series 127 x 381 x 203 mm [5 x 15 x 8 in]	
Cummins® Part Number	5261251
Fleetguard® Part Number	AF55308

Diesel Exhaust Fluid Filter	
Cummins® Part Number	5303604
Cummins® Engineering Standard (CES) Part Number	A042T663

Fuel Recommendations and Specifications

Fuel Recommendations

⚠WARNING⚠

Do not mix gasoline, alcohol, or gasohol with diesel fuel. This mixture can cause 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 and water. Dirt or water in the system can cause severe damage to both the fuel pump and the fuel injectors.

⚠CAUTION⚠

Lighter fuels can reduce fuel economy or possibly damage the fuel injection pump.

⚠CAUTION⚠

Do not use diesel fuel blended with lubricating oil in engines equipped with an aftertreatment system. Service intervals for aftertreatment systems will be reduced.

⚠CAUTION⚠

Ultra-low sulfur diesel fuel is required for correct operation of the aftertreatment system. If ultra-low sulfur diesel fuel is not used, the engine could possibly not meet emission regulations and the aftertreatment system could possibly be damaged.

Cummins Inc. recommends the use of 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 system to meet the Stage V 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 alternative fuels.

Table 1: Acceptable Substitute Fuels - Cummins® Fuel System

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)

NOTE: Cummins Inc. recommends that the cetane number of diesel fuel be a minimum of 45 for engines expected to operate at temperatures below 0°C [32°F] and a minimum of 40 for engines operated at temperatures above 0°C [32°F].

NOTE: The use of 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 lubinder Lubricity Evaluator (SLBOCLE). Lubricity can also be measured by ASTM specification D6079, ISO 12156, High Freqricity. This means the BOCLE number is 3100 or greater as measured by ASTM specification D6078, Scuffing Load Ball On Cyluency Reciprocating Rig (HFRR), in which the fuel **must** have a wear scar diameter of 0.45 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 states "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.

Reference the following bulletin for information on alternative fuels, such as biodiesel, and additional information for fuel recommendations and specifications. See Service Bulletin, Fuels for Cummins® Engines, Bulletin 3379001.

Paraffinic Fuels

Petroleum diesel contains chemical compounds known as paraffins and aromatics. Paraffinic fuels are predominantly paraffins and are derived from a variety of sources. The most common sources are natural gas, coal, plant oils, and animal fats. Natural gas fuels are often referred to as gas-to-liquid (GTL). Fuels from plant oils and fats are often referred to as renewable diesel (RD) or hydrogenated vegetable oil (HVO). Renewable diesels are **not** the same as biodiesel or fatty acid methyl ester (FAME) which are chemically different and have different properties. Unique characteristics of paraffin-based fuel include reduced density and increased cetane. Paraffinic fuels have a density up to 10 percent lower than petroleum diesels and can result up to 10 percent lower energy content by volume, resulting in reduced fuel economy and possible reduction in engine power.

Cummins Inc. test data on the operating effects of paraffinic fuels indicates typically smoke, power, and fuel economy are all reduced. There is a specification for paraffinic fuels issued in Europe under EN15940. These fuels also meet the US ASTM D975 diesel fuel specification. Cummins Inc. requires paraffinic fuels **always** meet both EN 15940 and ASTM D975. Paraffinic fuel does **not** meet the requirements in Table 1 of this procedure due to the reduced density.

Paraffinic fuel is approved in blends up 20 percent for all Cummins® engines less than 19 liters in displacement, provided the final blend meets properties listed in Table 1 in this procedure. Paraffinic fuel is approved for all blends up to 100 percent **only** in products listed in Table 2 below.

Table 2: Product and Applications Approved for up to 100 Percent Blend of Paraffinic Fuels

Product Series	Applications
B	On and Off Highway
C	
F	
L	

Lubricating Oil Recommendations and Specifications

General Information

⚠CAUTION⚠

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

The use of quality engine lubricating oils, combined with appropriate oil drain and filter change intervals, is a critical factor in maintaining engine performance and durability. Extending the oil and filter change interval beyond the recommendations will decrease engine life due to factors such as corrosion, deposits, and wear. Use the following procedure to determine which oil drain interval to use for an application. Refer to Procedure 359-001 in Section 3.

NOTE: The responsibility is with the owner. If recommendations are ignored, warranty could be affected.

API: American Petroleum Institute

CES: Cummins® Engineering Standard

Cummins Inc. allows, for midrange applications, the use of lubricating oils that meet or exceed CES 20078, CES 20081, or CES 20086 with no change in oil drain interval. But, if a non-low ash lubricating oil meeting the CES classification CEA 20078 is used, the service interval(s) for the aftertreatment system will be reduced. Refer to Procedure 359-001 in Section 3.

Cummins Inc. requires the use of a high quality Society of Automotive Engineers (SAE) 15W-40 or 5W-40 heavy-duty engine oil, such as Valvoline Premium Blue™ (USA) or Valvoline Premium Blue™ Extra (International), which meets or exceeds CES 20081 or CES 20086 and the API performance classification CJ-4 or CK-4.

To determine if the lubricating oil meets CES 20081 or CES 20086, review the label on the back of the lubricating oil bottle for the CES 20081 or CES 20086 reference. If acquiring the lubricating oil in bulk, contact the supplier for the lubricating oil specifications and confirm that the oil meets CES 20081 or CES 20086.

Also located on the lubricating oil bottle is the API service symbol, which is shown in the accompanying illustration. The upper half of the symbol displays the appropriate oil categories. The center section identifies the SAE oil viscosity grade. The table below shows how the CES compares to the API classification.

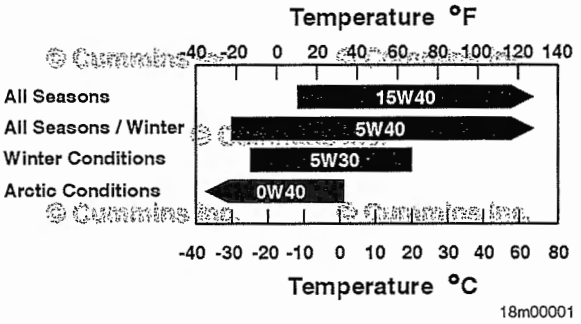
Cummins® Engineering Standard Classifications (CES)	American Petroleum Institute Classification (API)	Comments
CES 20081	CJ-4/SL	Minimum oil classification required.
CES 20086	CK-4	Minimum oil classification required.

NOTE: A lubricating oil that meets the API performance classification CJ-4/SL may **not** meet the CES 20081 requirement. Always make sure that the lubricating oil used meets the CES 20081 requirement, in addition to the API performance classification CJ-4/SL.

The primary Cummins Inc. recommendation is for the use of 15W-40 or 5W-40 multigrade lubricating oil for normal operation at ambient temperatures above -15°C [5°F]. The use of multigrade oil reduces deposit formation, improves engine cranking in low temperature conditions, and increases engine durability by maintaining lubrication during high temperature operating conditions. Since multigrade oils have been shown to provide approximately 30 percent lower oil consumption than monograde oils, it is important to use multigrade oils to be certain the engine will meet applicable emissions requirements.

Use of "synthetic engine oils" (those made with API group 3 or group 4 base stocks) is permitted, subject to the same performance and viscosity limitations of petroleum (mineral) based engine oils. The same oil change intervals that are applied to petroleum (mineral) based engine oils **must** be applied to synthetic oils.

For further details and discussion of engine lubricating oils for Cummins® engines, reference the following bulletin. See Service Bulletin, Cummins® Engine Oil Recommendations, Bulletin 3810340.



While the preferred viscosity grade is 15W-40 or 5W-40, lower viscosity multigrade oils can be used in colder climates. See the accompanying chart. Any viscosity grade lower than 15W-40 or 5W-40 **must** still meet CES 20081 or CES 20086.

As these oils have directionally thinner oil films than 15W-40 or 5W-40 oils, top-quality Fleetguard® filters **must** be used above 20°C [70°F]. Some oil suppliers might claim better fuel economy for these oils. Cummins Inc. can neither approve nor disapprove any product **not** manufactured by Cummins Inc. These claims are between the customer and the oil supplier. Obtain a commitment from the oil supplier that the oil will give satisfactory performance in Cummins® engines, or do **not** use the oil.

New Engine Break-in Oils

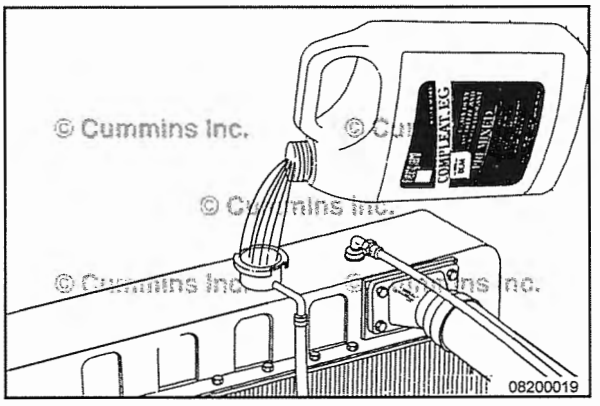
Special break-in engine lubricating oils are **not** recommended for new or rebuilt Cummins® engines. Use the same type of oil during the break-in period as is to be used in normal operation.

AfterMarket Oil Additive Usage

Cummins Inc. does **not** recommend the use of aftermarket oil additives. Present high-quality fully additized engine lubricating oils are very sophisticated, with precise amounts of additives blended into the lubricating oil to meet stringent requirements. These 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, can reduce the finished oil's ability to protect the engine.

Coolant Recommendations and Specifications

Fully Formulated Coolant/Antifreeze



Cummins Inc. recommends the use of fully formulated antifreeze/coolant meeting Cummins® Engineering Standards (CES) 14603. For further details and discussion of coolant for Cummins® engines, see Service Bulletin, Coolant Requirements and Maintenance, Bulletin 3666132.

Typically, antifreeze/coolants meeting ASTM4985 (GM6038M specification) or ASTM D6210 criteria are acceptable antifreeze/coolants for engines covered by the manual.

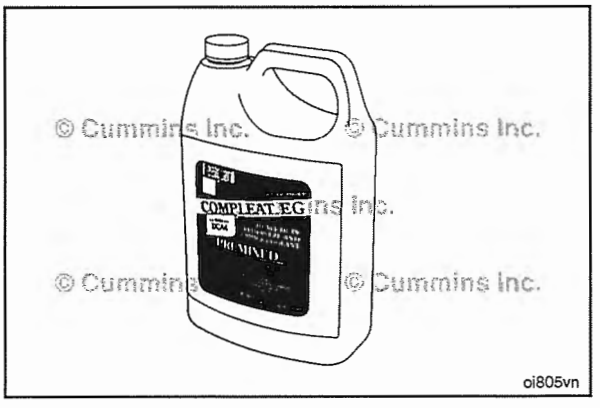
Low-silicate antifreeze/coolants meeting ASTM D4985 (GM6038M specification) are **not** adequate for extended service intervals.

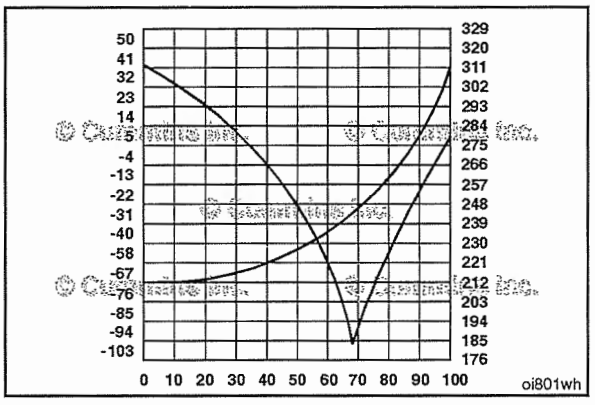
Cummins Inc. recommends using either a 50/50 mixture of good-quality water and fully formulated antifreeze, or fully formulated coolant when filling the cooling system.

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.

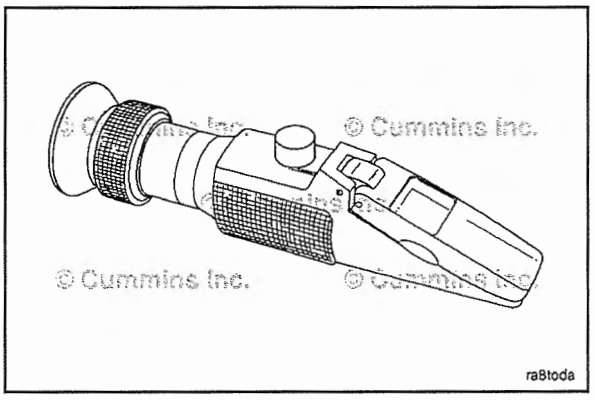
Water Quality	
Calcium Magnesium (hardness)	**Maximum 170 ppm as ($CaCO_3$ + $MgCO_3$)**
Chloride	40 ppm as (Cl)
Sulfur	100 ppm as (SO_4)

Cummins Inc. recommends using Fleetguard® Compleat. It is available in both glycol forms (ethylene and propylene).

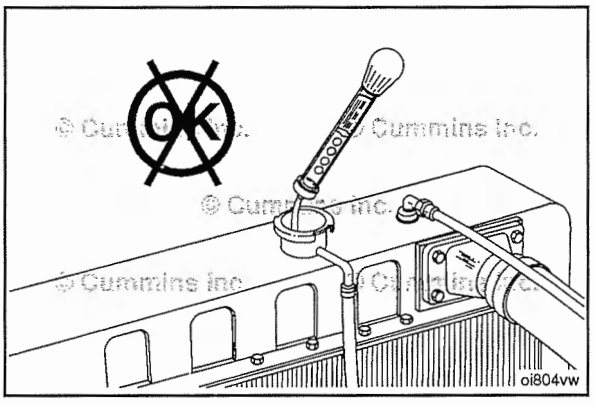




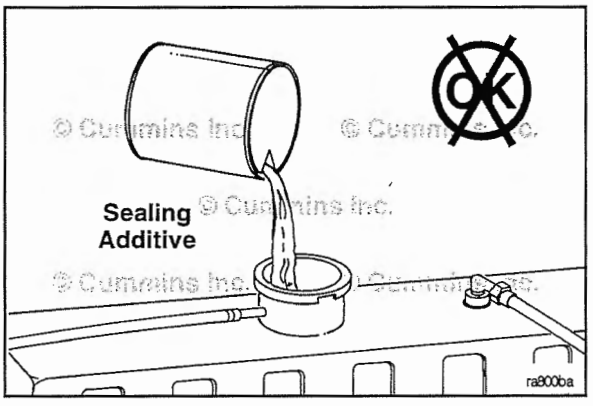
Fully formulated antifreeze **must** be mixed with good-quality water at a 50/50 ratio (40 to 60 percent working range). A 50/50 mixture of antifreeze and water gives a -36°C [-33°F] freezing point and a 108°C [226°F] boiling point, which is adequate for locations in North America. The actual lowest freezing point of ethylene glycol antifreeze is at 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**. Use Fleetguard® refractometer, Part Number CC-2800.



Do **not** use a floating ball hydrometer. The use of floating ball hydrometers can give an incorrect reading.

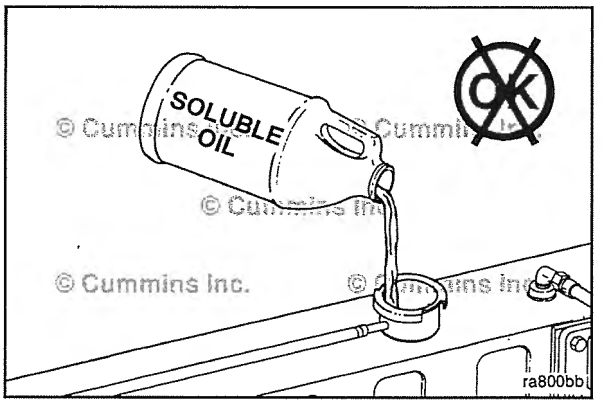


Cooling System Sealing Additives

Do **not** use sealing additives in the cooling system. The use of sealing additives will:

- Buildup in coolant low-flow areas
- Plug the radiator and oil cooler
- Possibly damage the water pump seal.

Cooling System Soluble Oils



Do **not** use soluble oils in the cooling system. The use of soluble oils will:

- Corrode brass and copper
- Damage heat transfer surfaces
- Damage seals and hoses.

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△

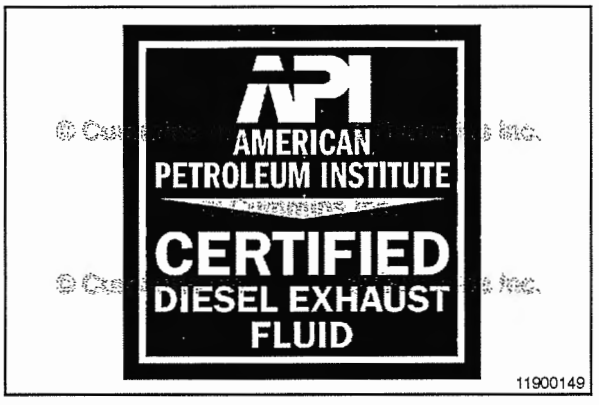
Never attempt to create Diesel Exhaust Fluid by mixing agricultural grade urea with water. Agricultural grade urea does not meet the necessary specifications required and the aftertreatment system may be damaged.

Cummins Inc. requires the use of Diesel Exhaust Fluid meeting ISO 22241-1. There is NO acceptable substitute.

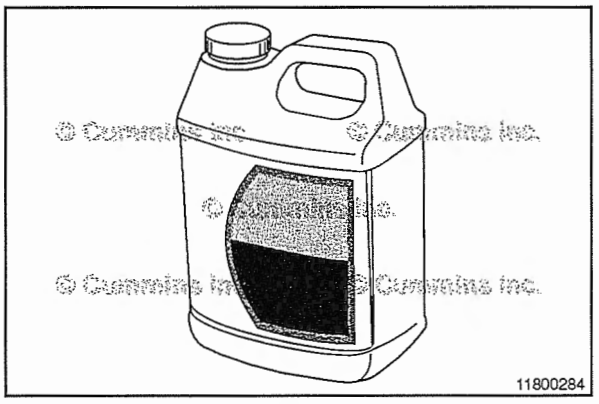
NOTE: Some locations may reference the DIN 70070 standard. Diesel Exhaust Fluid specification limits of this standard are identical to ISO 22241-1.

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.

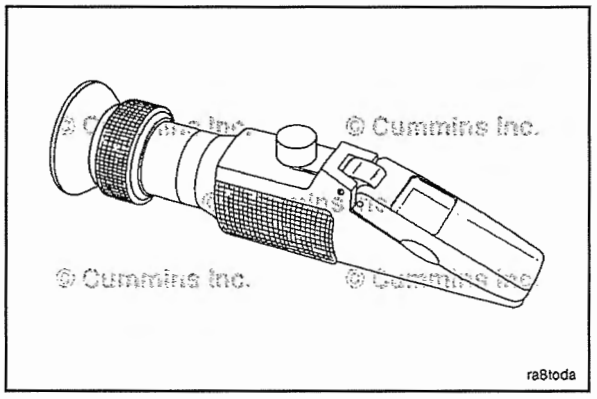
NOTE: Spilled Diesel Exhaust Fluid if left to dry or wiped away with a cloth only will leave a white residue. Failure to clean the spilled Diesel Exhaust Fluid may result in an incorrectly diagnosed leak of the Diesel Exhaust Fluid Dosing system.

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.



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.

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.

Sealants

General Information

Use the sealants listed below or sealants containing equivalent properties.

Item	Cummins® Part Number	Generic Description
Pipe Plugs	3375066	Teflon™ Pipe Sealant
Cup Plugs	3375068	Sealant
O-Rings	3163087	Assembly Lubricant
Oil Pan T-Joint	3164067	RTV Sealant
Flywheel Housing to Rear Gear Housing Joint	3164070	RTV Sealant
Front Gear Cover to Block Joint	3164070	RTV Sealant
Rear Gear Housing to Block Joint	3164070	RTV Sealant
Intake Manifold to Cylinder Head Joint	3164070	RTV Sealant

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

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

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.					

Capscrew Markings and Torque Values

General Information

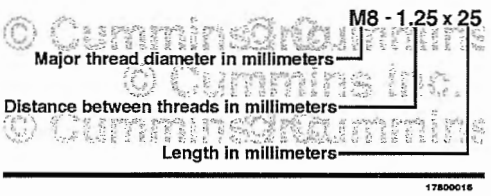
⚠CAUTION⚠

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.

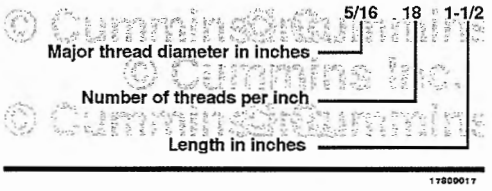
The following examples indicate how capscrews are identified:

Metric - M8-1.25 X 25



- **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.

U.S. Customary [5/16 X 18 X 1-1/2]

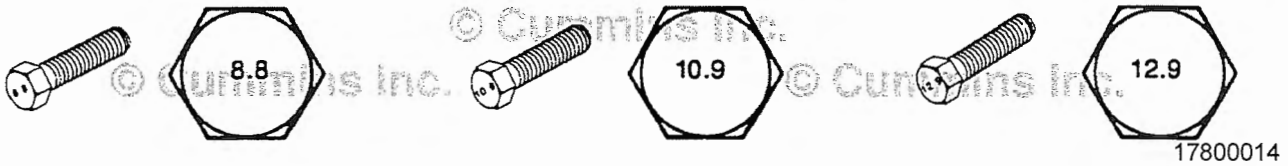


- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.

Capscrew Markings and Torque Values - Metric

Commercial Steel Class 8.8 10.9 12.9

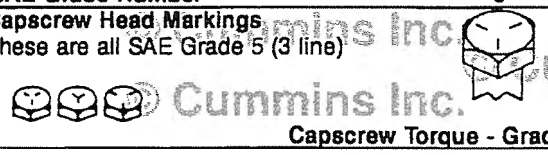
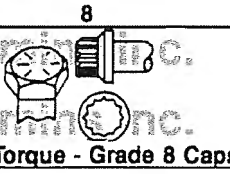
Capscrew Head Markings



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

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)		
	Capscrew Torque - Grade 5 Capscrew	Capscrew Torque - Grade 8 Capscrew

17800015

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

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

Pipe Plug Torque Values

Torque Table

Size		Torque		Torque	
Thread	Actual Thread O.D.	In Aluminum Components		In Cast Iron or Steel Components	
in	**in**	**N•m**	**ft-lb**	**N•m**	**ft-lb**
1/16	0.32	5	45 in-lb	15	10
1/8	0.41	15	10	20	15
1/4	0.54	20	15	25	20
3/8	0.68	25	20	35	25
1/2	0.85	35	25	55	40
3/4	1.05	45	35	75	55
1	1.32	60	45	95	70
1-1/4	1.66	75	55	115	85
1-1/2	1.90	85	65	135	100

Tap-Drill Chart - U.S. Customary and Metric

General Information

NOTE ON SELECTING TAP-DRILL SIZES: The tap drill sizes shown on this card give the theoretical tap drill size for approximately 60% and 75% of full thread depth. Generally, it is recommended that drill sizes be selected in the 60% range as these sizes will provide about 90% of the potential holding power. Drill sizes in the 75% range are recommended for shallow hole tapping (less than 1 1/2 times the hole diameter) in soft metals and mild steel.

Tap Size		Drill
60%	75%	Size
		48
		1.95mm
		5/64
	3-48	47
		2.00mm
	M2.5x.45	2.05mm
		46
3-48	3056	45
		2.10mm
M2.5x.45	M2.6x.45	2.15mm
3-56	4-36	44
		2.20mm
M2.6x.45		2.25mm
4-36	4-40	43
		2.30mm
		2.35mm
4-40	4-48	42
		3/32
	M3x.6	2.40mm
4-48		41
		2.45mm
		40
M3x.6	M3x.5	2.50mm
		39
	5-40	38
M3x.5		2.60mm
5-40	5-44	37
		2.70mm
5-44	6-32	36
		2.75mm
		7/64
		35
		2.80mm
		34
6-32	6-40	33
	M3.5x6	2.90mm
		32
M3.5x6		3.00mm
6-40		31
		3.10mm
		1/8
		3.20mm
	M4x.75	3.25mm
		30
	M4x.7	3.30mm
M4x.75		3.40mm
M4x.7	8-32	29
		3.50mm
	8-36	28
8-32		9/64
		3.60mm
8-36		27
		3.70mm
		26
	M4.5x.75	3.75mm
	10-24	25
		3.80mm
		24
M4.5x.75		3.90mm
		23
		5/32
10-24		22
	M5x1	4.00mm
	10-32	21
		20
	M5x.9	4.10mm
M5x1	M5x.8	4.20mm
10-32		19
M5x.9		4.25mm
M5x.8		4.30mm
		18
		11/64
		17

Tap Size		Drill
60%	75%	Size
		4.40mm
	12-24	16
		4.50mm
		15
	M5.5x.9	4.60mm
12-24	12-28	14
		13
		4.70mm
M5.5x.9		4.75mm
12-28		3/16
		12
		4.80mm
		11
		4.90mm
		10
		9
	M6x1	5.00mm
		8
		5.10mm
	1/4-20	7
		13/64
		6
M6x1		5.20mm
		5
	M6x.75	5.25mm
		5.30mm
1/4-20		4
M6x.75		5.40mm
	1/4-28	3
		5.50mm
		7/32
		5.60mm
1/4-28		2
		5.70mm
		5.75mm
		1
		5.80mm
		5.90mm
		A
		15/64
	M7x1	6.00mm
		B
		6.10mm
		C
M7x1		6.20mm
		D
	M7x.75	6.25mm
		6.30mm
		E
		1/4
M7x.75		6.40mm
		6.50mm
	5/16-18	F
		6.60mm
		G
		6.70mm
		17/64
	M8x1.25	6.75mm
5/16-18		H
		6.80mm
		6.90mm
	5.16-24	I
M8x1.25	M8x1	7.00mm
		J
		7.10mm
5/16-24		K
		9/32
M8x1		7.20mm
		7.25mm
		7.30mm
		L
		7.40mm
		M

Tap Size		Drill
60%	75%	Size
		7.50mm
		19/64
		7.60mm
		N
		7.70mm
	M9x1.25	7.75mm
		7.80mm
		7.90mm
	3/8-16	5/16
M9x1.25	M9x1	8.00mm
		O
		8.10mm
M9x1		8.20mm
		P
		8.25mm
		8.30mm
3/8-16	1/8-27NPT	21/64
		8.40mm
	3/8-24	Q
	M10x1.5	8.50mm
		8.60mm
		R
3/8-24		8.70mm
1/8-27NPT		11/32
	M10x1.25	8.75mm
M10x1.5		8.80mm
		S
		8.90mm
M10x1.25	M10x1	9.00mm
		T
		9.10mm
		23/64
M10x1		9.20mm
		9.30mm
	7/16-14	U
		9.40mm
	M11x1.5	9.50mm
		3/8
		V
		9.60mm
		9.70mm
		9.75mm
M11x1.5		9.80mm
7/16-14		W
		9.90mm
	7/16-20	25/64
		10.00mm
7/16-20		X
	M12x1.75	10.20mm
		Y
		13/32
M12x1.75	M12x1.5	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
60%	75%	Size
		13.25mm
	5/8-11	17/32
	M15x1.5	13.50mm
M15x1.5		13.75mm
5/8-11		35/64
	M16x2	14.00mm
		14.25mm
	5/8-18	9/16
M16x2	M16x1.5	14.50mm
5/8-18		37/64
		14.75mm
M16x1.5		15.00mm
		19.32
		15.25mm
		39/64
	M17x1.5	15.50mm
M17x1.5	M18x2.5	15.75mm
		5/8
M18x2.5	M18x2	16.00mm
M18x2		16.25mm
	3/4-10	41/64
	M18x1.5	16.50mm
3/4-10	M19x2.5	21/32
M18x1.5		16.75mm
M19x2.5		17.00mm
		43/64
		17.25mm
3/4-16	3/4-16	11/16
	M20x2.5	17.50mm
		17.75mm
		45/64
M20x2.5	M20x2	18.00mm
M20x2		18.25mm
		23/32
	M20x1.5	18.50mm
		47/64
M20x1.5		18.75mm
		19.00mm
		3/4
		19.25mm
	7/8-9	49/64
	M22x2.5	19.50mm
7/8-9		25/32
		19.75mm
M22x2.5	M22x2	20.00mm
	7/8-14	51/64
M22x2		20.25mm
	M22x1.5	20.50mm
7/8-14		13/16
		20.75mm
M22x1.5	M24x3	21.00mm
		53/64
		21/25mm
		27/32
M24x3		21.50mm
		21.75mm
		55/64
	M24x2	22.00mm
	1"-8	7/8
M24x2		22.25mm
	M24x1.5	22.50mm
1"-8		57/64
M24x1.5		22.75mm
	M25x2	23.00mm
	1"-12	29/32
M25x2		23.25mm
1"x12	1"-14	59/64
	M25x1.5	23.50mm
M20x1.5		23.75mm
1"-14		15/16

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Section W - Warranty

Section Contents

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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, locomotive/railcar 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

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 2007/2010/2013/2017/2021	max. 15 parts per million
EPA Tier 4 Interim / Final / Stage V in North America	max. 15 parts per million
EU Stage IIIB 2011	max. 15 parts per million
EU Stage IV 2011	max. 15 parts per million
EU Stage V	max. 10 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.

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 2007/2010/2013/2017/2021	max. 15 parts per million
EPA Tier 4 Interim / Final / Stage V in North America	max. 15 parts per million
EU Stage IIIB 2011	max. 15 parts per million
EU Stage IV 2011	max. 15 parts per million
EU Stage V	max. 10 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.

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

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 2007/2010/2013/2017/2021	max. 15 parts per million
EPA Tier 4 Interim / Final / Stage V in North America	max. 15 parts per million
EU Stage IIIB 2011	max. 15 parts per million
EU Stage IV 2011	max. 15 parts per million
EU Stage V	max. 10 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.

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 2020, 2021 and 2022 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 2020, 2021 and 2022 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.

Coverage

This emission control system warranty applies only to the following A series, B3.3, B3.9, B4.5s, B5.9, B6.7s, QSB3.9-30, QSB4.5-30, QSB5.9-30, QSB5.9-44, C8.3, QSC8.3, QSF2.8, QSF3.8, and QSL9 emission control parts:

EPA Diesel

Aftertreatment System
Component
Aftertreatment Electrical Connections
Aftertreatment Fuel Drain Valve
Aftertreatment Fuel Injector/Regulator
Aftertreatment Fuel Pressure Sensor
Aftertreatment Fuel Shut-Off Valve
Aftertreatment Injector Manifold
Aftertreatment Inlet and Outlet Modules
Aftertreatment Temperature Interface Module
Aftertreatment Temperature Sensors

Aftertreatment System (cont')
Component
Decomposition Tube
DEF Dosing Controller (DCU)
DEF Dosing Unit (Pump)
DEF Dosing Valve
Diesel Oxidation Catalyst
Diesel Particulate Filter (except for ash maintenance)
Diesel Particulate Filter Differential Pressure Sensor
NH3 Sensor
NOx Sensors
SCR Catalyst

Air Handling
Component
Barometric Air Pressure Sensor
Exhaust Gas Pressure Sensor
Exhaust Manifold
Grid Heater
Humidity Sensor
Intake Air Throttle Actuator
Intake Manifold
Intake Manifold Air Temperature Sensor

Air Handling (cont')
Component
Intake Manifold Temperature/Pressure Sensor
Turbocharger Actuator
Turbocharger Assembly
Turbocharger Compressor Inlet Air Temperature Sensor
Turbocharger Speed Sensor

Base Engine System
Component
Camshaft
Camshaft Injector Lobe
Camshaft Valve Lobe
Coolant Temperature Sensor
Crankcase Breather
Engine Oil Pressure Sensor
Engine Speed, Position Sensor, Cam Position Sensor
Exhaust Valve
Static Cam Timing

EGR System
Component
EGR Cooler
EGR Differential Pressure Sensor
EGR Mixer/Venturi
EGR Temperature Sensor
EGR Valve

Electronic Control System
Component
Engine Control Module
Wiring Harness Circuits Connected at Both Ends to Emissions Warrantable Components
Engine Control Module Calibration
Engine Control Module Calibration

Fuel System
Component
Fuel Control Valve
Fuel Lines
Fuel Pressure Sensor
Fuel Pump
Fueling/Timing Actuators

EPA Diesel

Ignition System
Component
Ignition Coils
Ignition Control Module

Fuel System (cont')
Component
Injector
Secondary Fuel Pressure/Temperature Sensor

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.

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