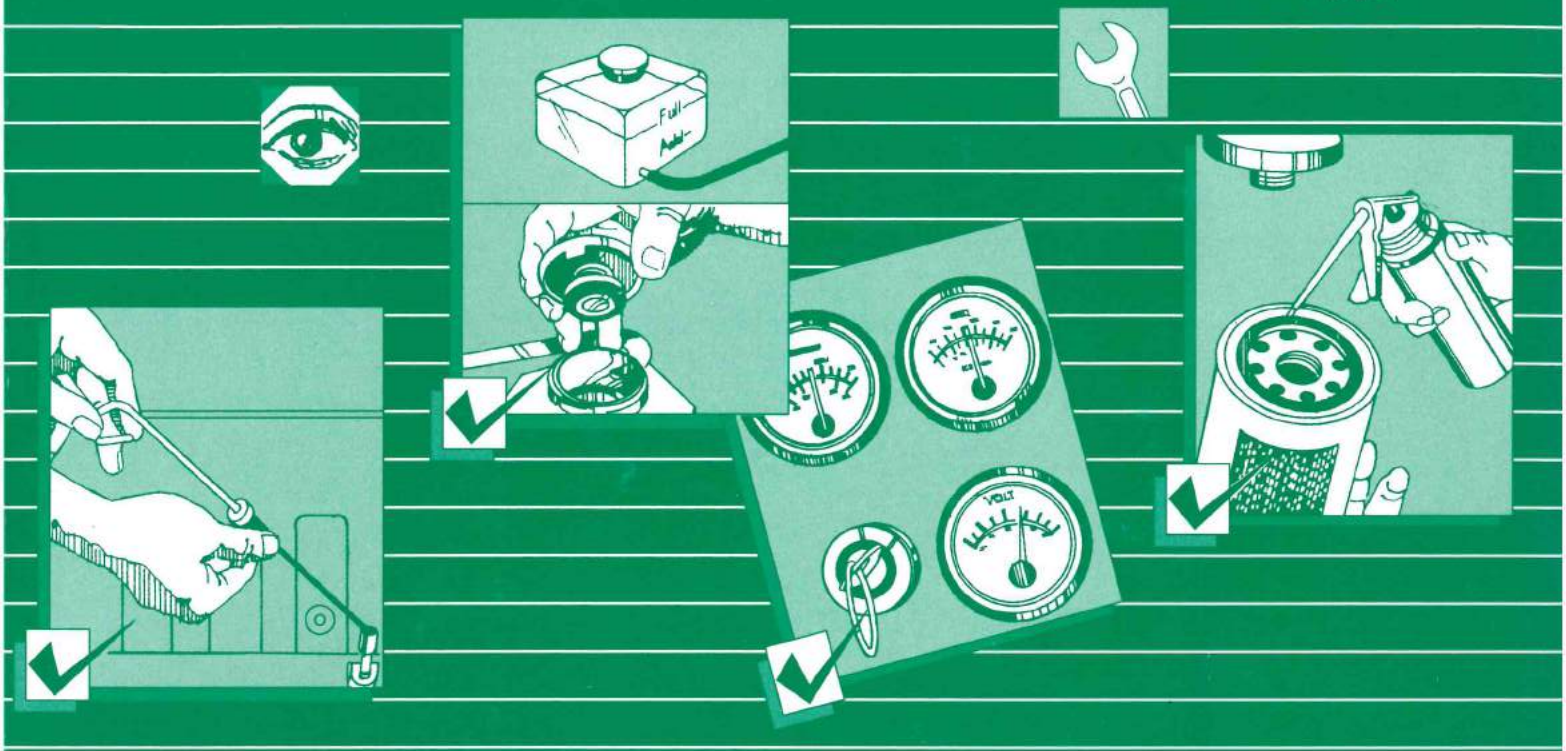
# Operation and Maintenance Manual
# QSF3.8 CM2350 F107

THIS PRINTED CUMMINS MANUAL INCLUDES A COMPANION DVD-ROM VERSION



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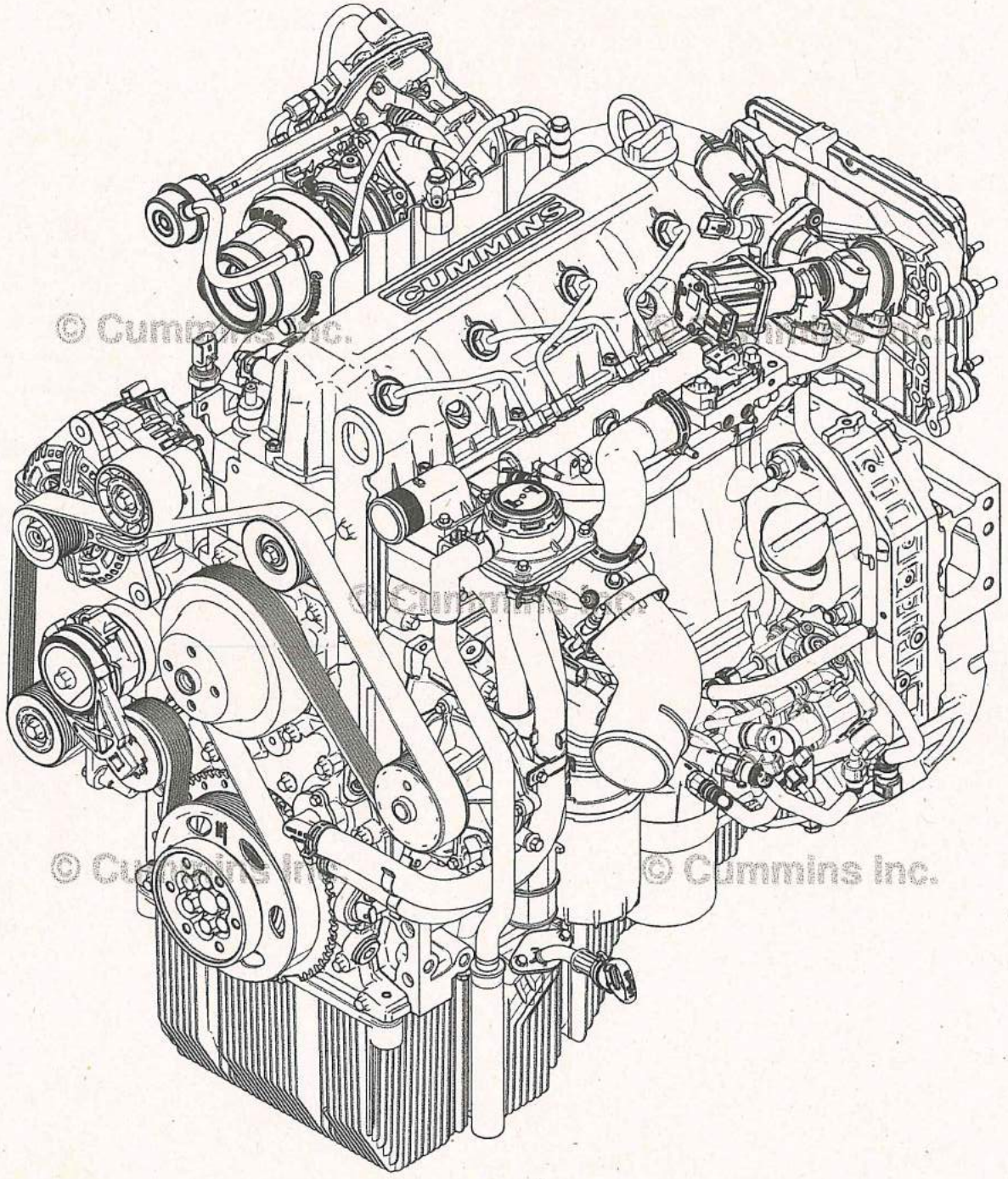




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# Foreword

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**.

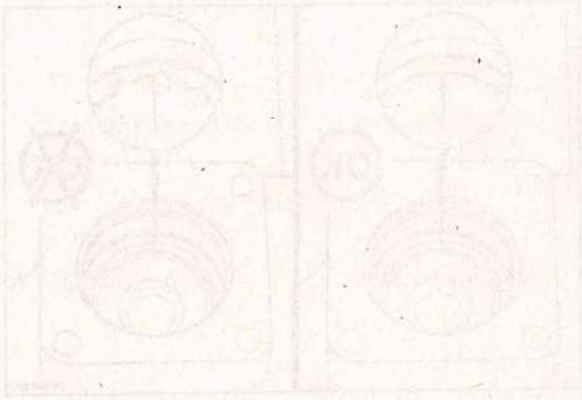
**LUBRICATE** the part or assembly.

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

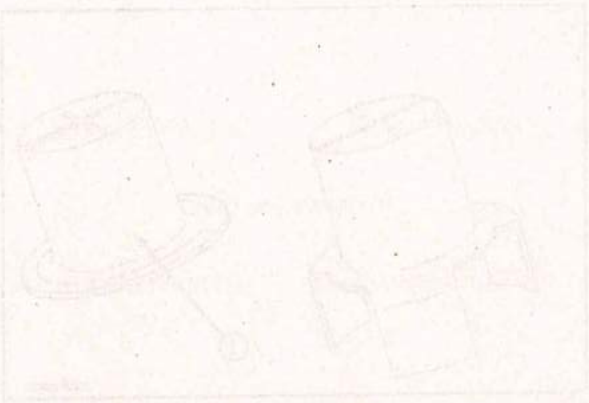
**TIGHTEN** to a specific torque.

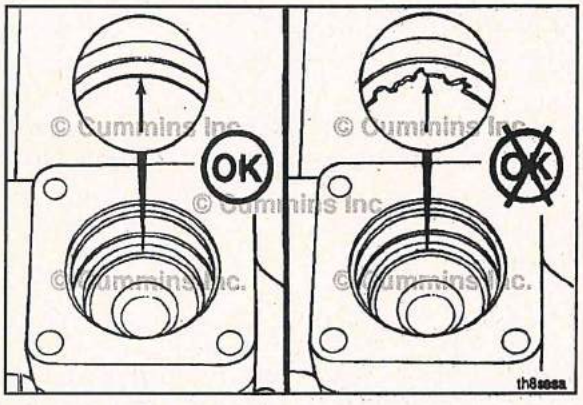
**PERFORM** an electrical **MEASUREMENT**.

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.

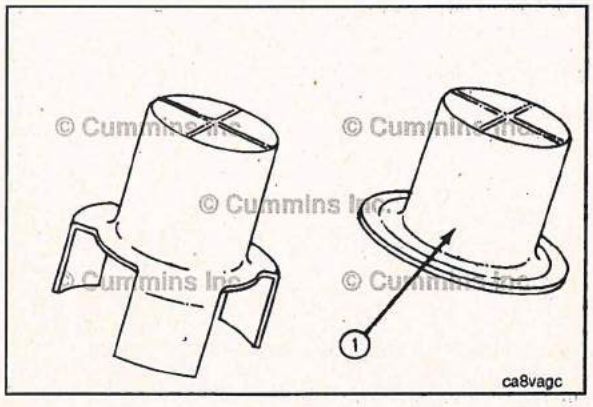





# Illustrations

## 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 $H_20$** | Inches of Water |
| **ICM** | Ignition Control Module |
| **IEC** | International Electrotechnical Commission |
| **JSA** | Job Safety Assessment |
| **km/l** | Kilometers per Liter |
| **kPa** | Kilopascal |
| **LNG** | Liquefied Natural Gas |
| **LPG** | Liquefied Petroleum Gas |
| **LTA** | Low Temperature Aftercooler |
| **MCRS** | Modular Common Rail System |

| | |
|---|---|
| **MIL** | Malfunction Indicator Lamp |
| **MPa** | Megapascal |
| **mph** | Miles Per Hour |
| **mpq** | Miles Per Quart |
| **N•m** | Newton-meter |
| **NOx** | Nitrogen Oxides |
| **NG** | Natural Gas |
| **O2** | Oxygen |
| **OAT** | Organic Acid Technology |
| **OBD** | On-Board Diagnostics |
| **OEM** | Original Equipment Manufacturer |
| **OSHA** | Occupational Safety and Health Administration |
| **PID** | Parameter Identification Descriptions |
| **PPE** | Personal Protective Equipment |
| **ppm** | Parts Per Million |
| **psi** | Pounds Per Square Inch |
| **PTO** | Power Takeoff |
| **QSOL** | QuickServe® Online |
| **REPTO** | Rear Engine Power Takeoff |
| **RGT** | Rear Gear Train |
| **rpm** | Revolutions Per Minute |
| **SAE** | Society of Automotive Engineers |
| **SCA** | Supplemental Coolant Additive |
| **SCR** | Selective Catalytic Reduction |
| **STC** | Step Timing Control |
| **SID** | Subsystem Identification Descriptions |
| **TDC** | Top Dead Center |
| **TSB** | Technical Service Bulletin |
| **ULSD** | Ultra Low Sulfur Diesel |
| **VDC** | Volts of Direct Current |
| **VGT** | Variable Geometry Turbocharger |
| **VS** | Variable Speed |
| **VSS** | Vehicle Speed Sensor |

Notes

# Section E - Engine and System Identification

## Section Contents

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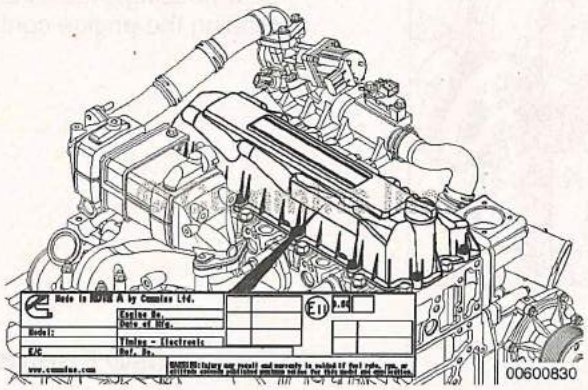
# Engine Identification

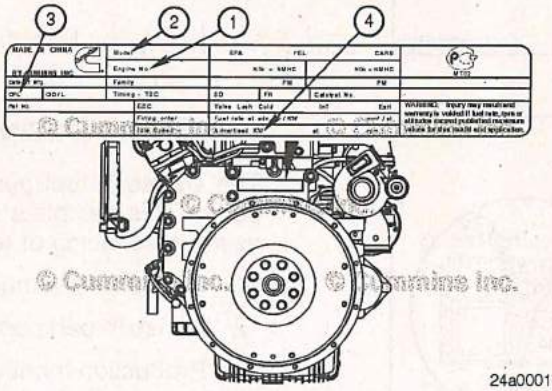
## General Information




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.

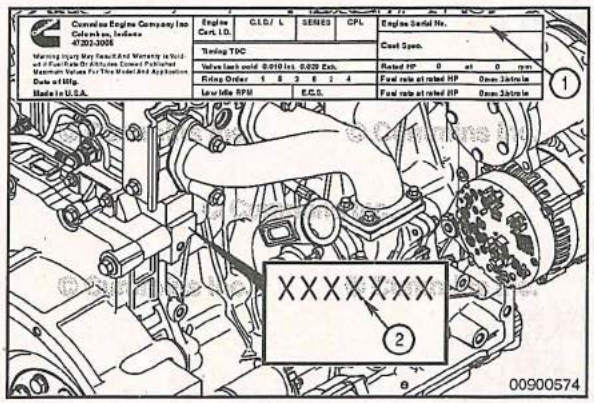
**NOTE:** The dataplates used on engines can differ in appearance and location of information. The following illustrations show examples of common dataplates used and the information contained on these dataplates.

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

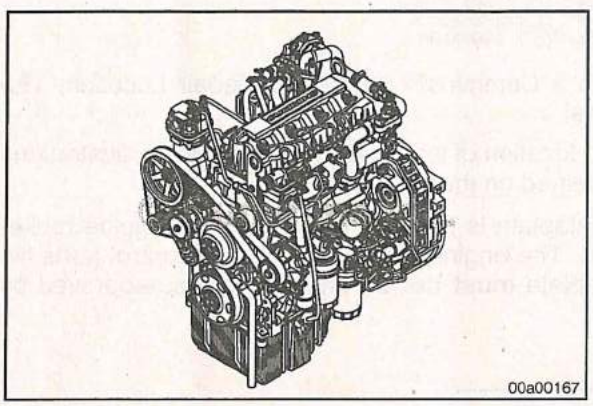



There are four possible dataplates that can be found on the engine rocker lever cover, but can also be located on the side of the gear housing. They contain the following information:

1 Engine serial number
2 Engine model information
3 Control parts list
4 Horsepower and rpm rating.



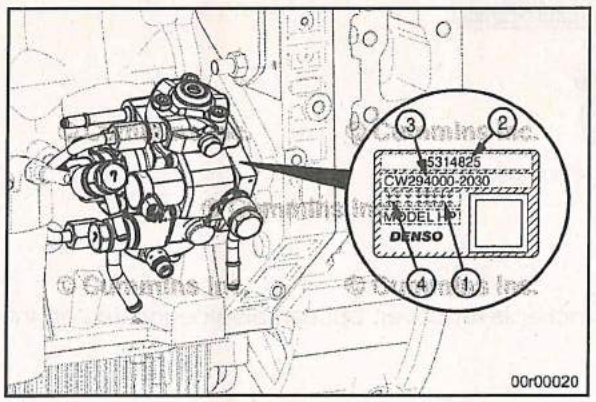

**NOTE:** If the engine dataplate (1) is **not** legible, the engine serial number (2) can be identified on the engine block. It is located on the exhaust side, next to the rear gear housing. Additional engine information is available by reading the engine control module (ECM) dataplate.




## 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 100-005 in Section E.

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

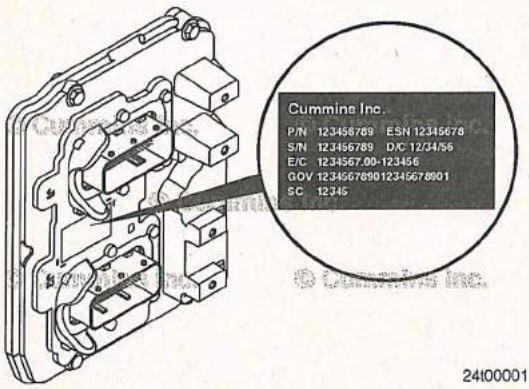


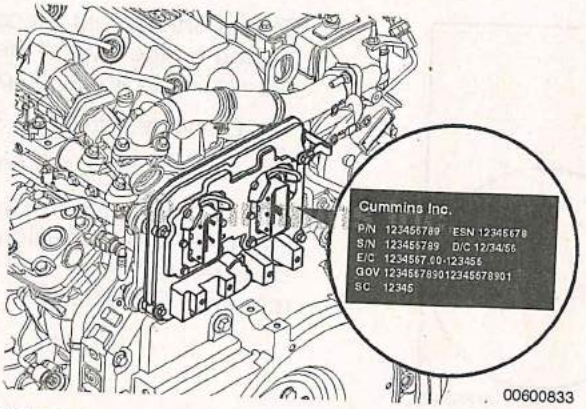

## Fuel Pump Dataplate

The Denso™ fuel pump dataplate is located on the fuel pump. This dataplate contains the following information to assist in servicing or replacement:

1 Customer part number
2 Denso™ part number
3 Production month serial number
4 Customer's certification number
5 QR code.

## Engine Control Module Dataplate






**NOTE:** Not all engines have ECM dataplates.

Engines covered by this manual are equipped with a CM2350 ECM. A CM2350 ECM has two 96-pin connectors. ( of the 96-pin connectors is for engine inputs and outputs **only**. The second 96-pin connector and 14-pin connector for aftertreatment and vehicle inputs and outputs

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

## Turbocharger Dataplate

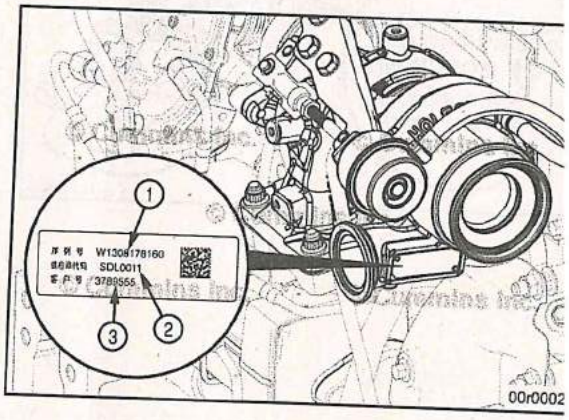
The Holset® turbocharger dataplate is located on the turbocharger inlet compressor housing.

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

1 Serial number

2 Supplier code

3 Customer number.




## Exhaust System

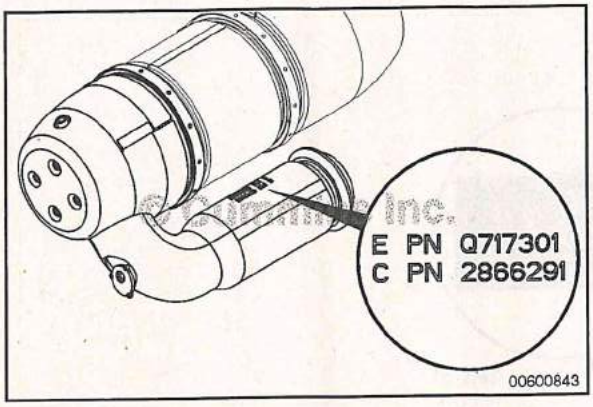
The aftertreatment selective catalytic reduction (SCR) catalyst identification is located on the side of the assembly and contains the following information to assist in servicing or replacement.

1 Assembly part number

2 Cummins Emission Solutions™ part number

3 Cummins® part number.

**NOTE:** Some aftertreatment components.may **only** have the Cummins Emission Solutions™ part number. For cross referencing and part number identification, reference QuickServe™ Online.

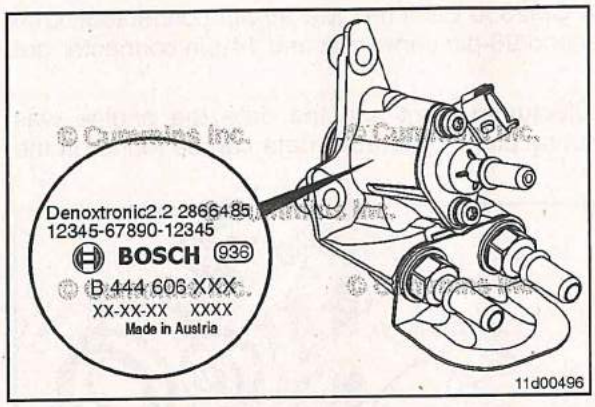



The aftertreatment decompostion tube identification is located on the side of the tube and contains the following information to assist in servicing or replacement.

1 Cummins Emission Solutions™ partnumber

2 Cummins® part number.

**NOTE:** Some aftertreatment components.may only have the Cummins Emission Solutions™ part number. For cross.referencing and part number identification, reference QuickServe™ Online.




The aftertreatment diesel exhaust fluid dosing (DEF) valve identification is located on the side of the valve and contains the following information to assist in servicing or replacement.

1 Cummins® part number

2 Cummins Emission Solutions™ partnumber

3 Bosch™ part number

4 Bosch™ production data (data code,serial number).

Example:

- 2866485 is the Cummins® part number
- 12345-67890-12345 is the location for the Cummins Emission Solutions™ part number
- B 444 606 XXX is the Bosch™ part number
- XX-XX-XX is the date code
- XXXX is the serial number.

**NOTE:** Some aftertreatment components can have **only** the Cummins Emission Solutions™ part number. For cross referencing and part number identification, reference QuickServe™ Online.

The aftertreatment DEF dosing unit identification is located on the side of the unit and contains the following information to assist in servicing or replacement.

1 Cummins Emission Solutions™ partnumber

2 Cummins® part number

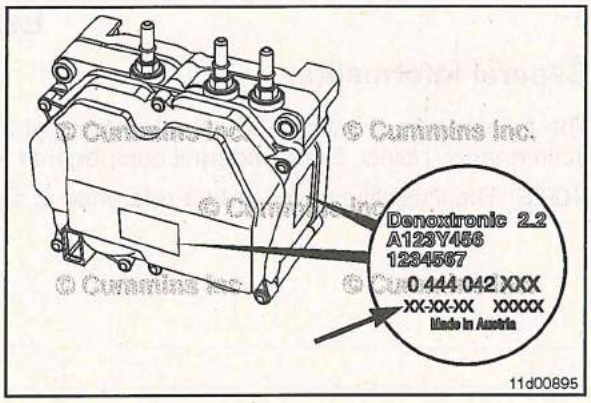
3 Bosch™ part number

4 Bosch™ production data (data code, serial number).

Example:

- A123Y456 is the Cummins EmissionSolutions™ part number
- 1234567 is the Cummins® part number
- 0 444 042 XXX is the Bosch™ partnumber
- XX-XX-XX is the date code
- XXXX is the serial number

**NOTE:** Some aftertreatment components.may have **only** the Cummins Emission Solutions™ part number. For cross referencing and part number identification, reference QuickServe™ Online.



# Engine Diagrams

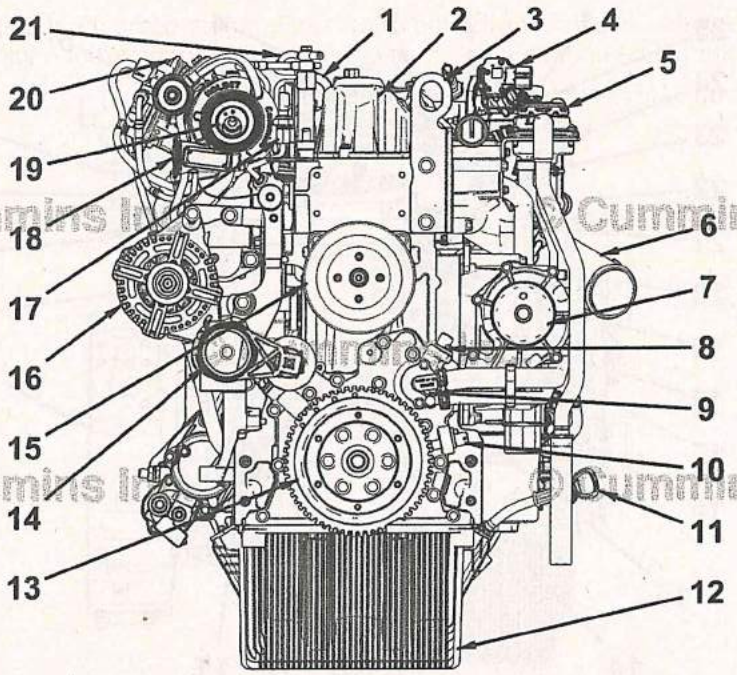
## General Information

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

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

# Engine Diagrams

## General Information

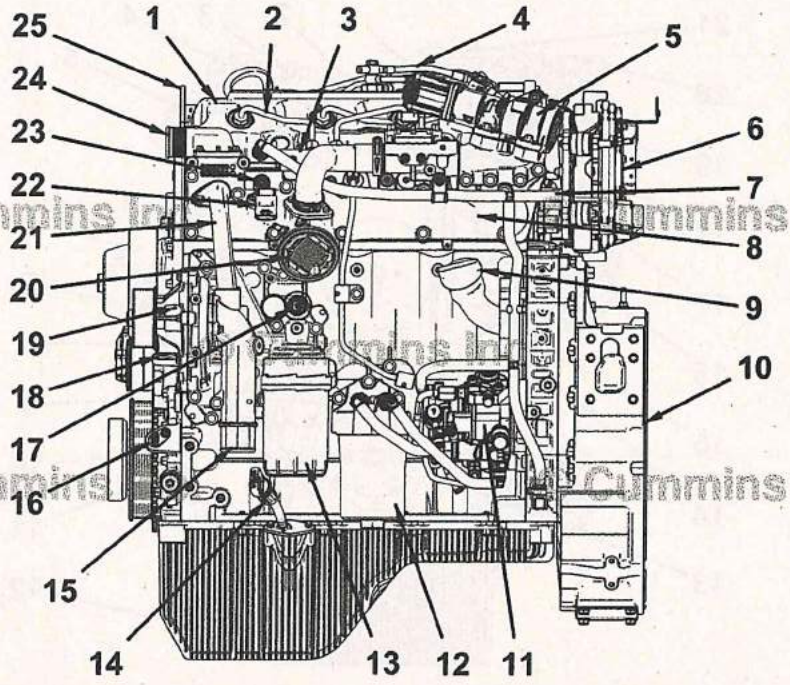



Front View

1 Rear engine lifting bracket
2 Rocker lever cover
3 Front engine lifting bracket
4 Exhaust gas recirculation (EGR) valve
5 Open crankcase ventilation valve
6 Air intake connection
7 Water pump pulley
8 Camshaft speed/position sensor
9 Crankcase breather adapter
10 Crankshaft speed/position sensor
11 Lubricating oil dipstick tube
12 Lubricating oil pan
13 Crankshaft pulley
14 Automatic belt tensioner
15 Fan drive pulley
16 Alternator
17 Exhaust pressure sensor
18 Wastegate turbocharger compressor outlet
19 Wastegate turbocharger compressor inlet
20 Exhaust pressure regulator
21 EGR coolant vent tube.

# Engine Diagrams

## General Information





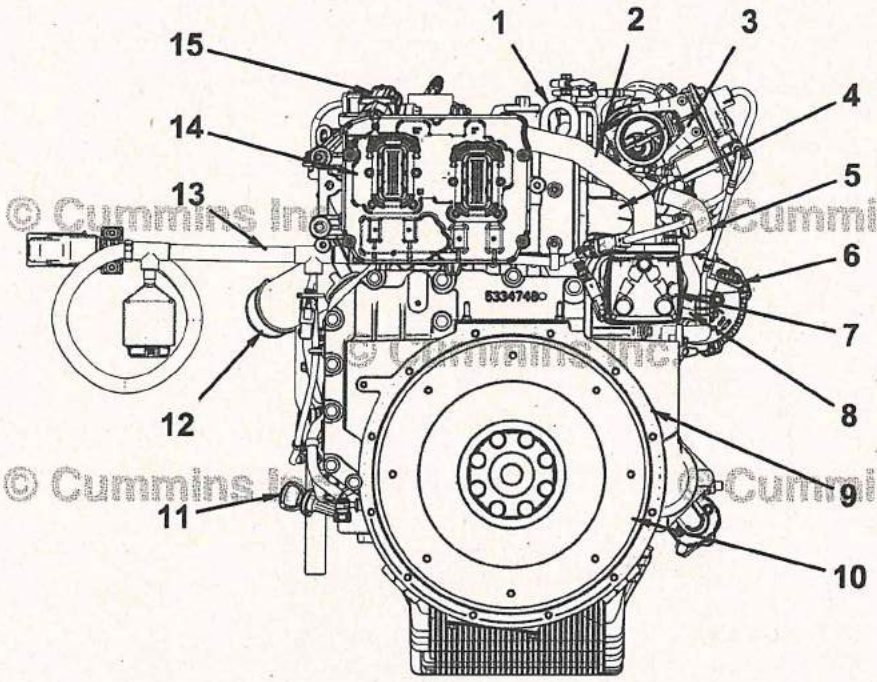

Left View

1 Rocker lever cover
2 Injector fuel supply line
3 Common rail fuel manifold
4 EGR coolant vent tube
5 EGR valve
6 Engine control module (ECM)
7 Fuel return line
8 Intake manifold
9 Lubricating oil fill cap
10 Flywheel housing
11 Fuel pump
12 Fuel filter
13 Lubricating oil filter
14 Lubricating oil dipstick
15 Water inlet connection
16 Crankshaft speed/position sensor
17 Oil pressure sensor
18 Camshaft speed/position sensor
19 Water pump
20 Intake air heater
21 Water bypass tube
22 Intake manifold pressure/temperature sensor
23 Engine coolant temperature sensor
24 Water outlet connection

25 Front engine lifting bracket.

# Engine Diagrams

## General Information

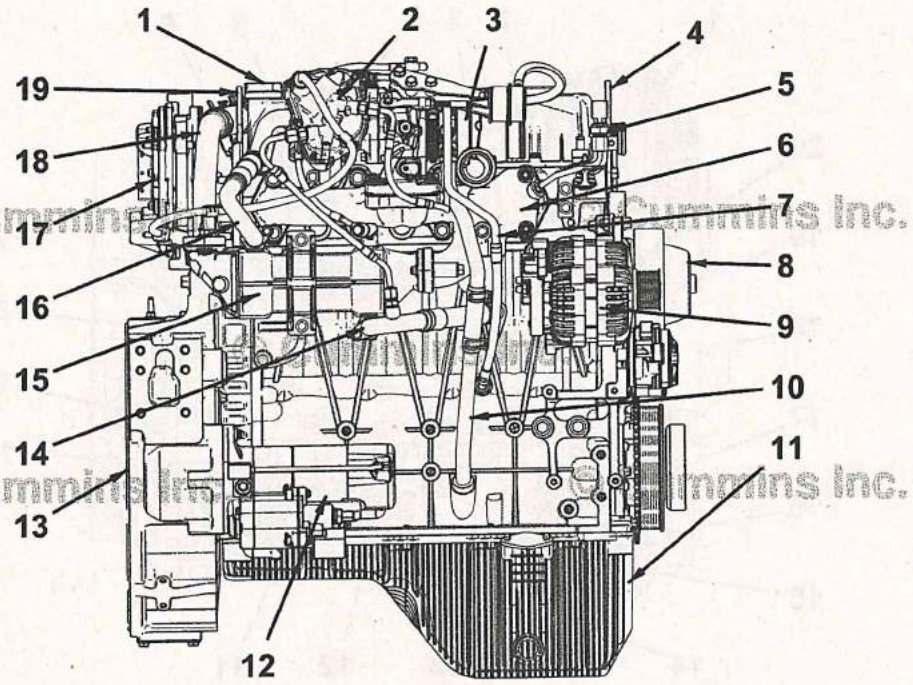



Rear View

1 Rear engine lifting bracket
2 EGR crossover tube
3 Exhaust pressure regulator
4 Exhaust manifold
5 EGR coolant outlet tube
6 Alternator
7 EGR cooler
8 EGR coolant inlet tube
9 Flywheel housing
10 Flywheel
11 Lubricating oil dipstick
12 Intake air connection
13 Wiring harness
14 ECM
15 EGR valve.

# Engine Diagrams

## General Information

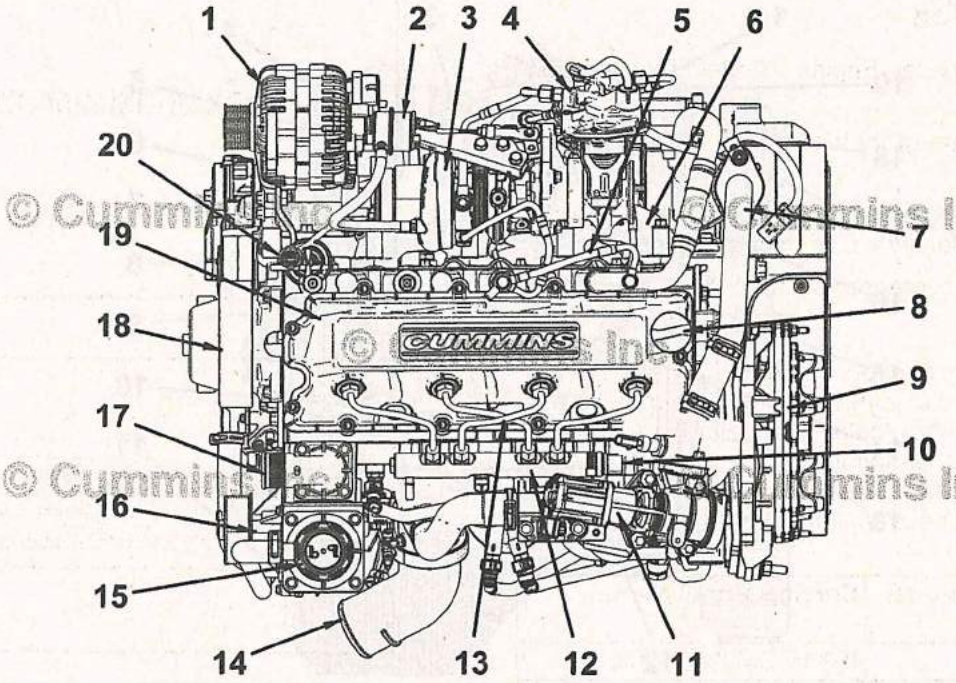



Right View

1 Lubricating oil fill cap
2 Exhaust pressure regulator
3 Wastegate turbocharger
4 Front engine lifting bracket
5 Exhaust pressure sensor
6 Exhaust manifold
7 Turbocharger lubricating oil supply tube
8 Fan hub
9 Alternator
10 Turbocharger lubricating oil drain tube
11 Lubricating oil pan
12 Starting motor
13 Flywheel housing
14 EGR cooler coolant inlet tube
15 EGR cooler
16 EGR cooler coolant outlet tube
17 ECM
18 EGR crossover tube
19 Rear engine lifting bracket.

# Engine Diagrams

## General Information




Top View

1 Alternator
2 Turbocharger wastegate actuator
3 Wastegate turbocharger
4 Exhaust pressure regulator
5 EGR coolant vent tube
6 Exhaust manifold
7 EGR crossover tube
8 Lubricating oil fill cap
9 ECM
10 Fuel rail pressure sensor
11 EGR valve
12 Common rail fuel manifold
13 Injector supply lines
14 Intake air connection
15 Open crankcase ventilation valve
16 Water pump
17 Water outlet connection (thermostat is underneath)
18 Fan hub
19 Rocker lever cover
20 Exhaust temperature sensor.

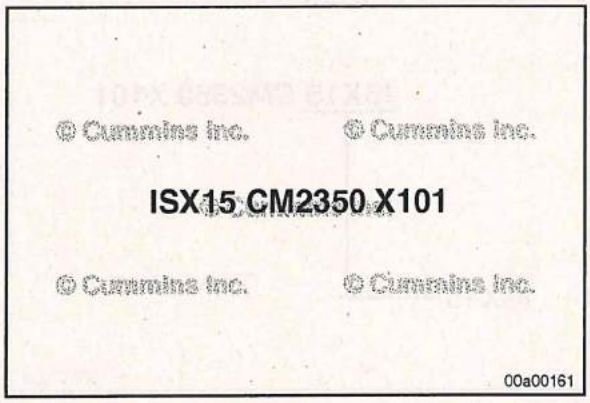
# Cummins® Service Engine Model Identification

## General Information

The Cummins® Service Engine Model Identification procedure describes:

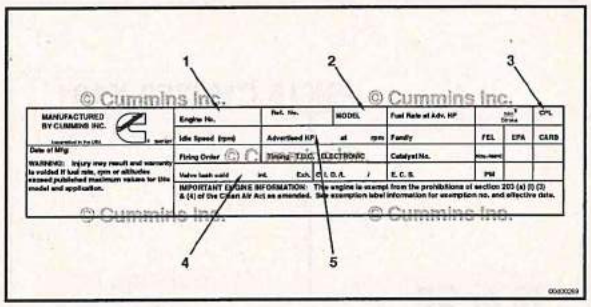
- The purpose of the Cummins® Service Model Name.
- How to interpret a Cummins® Service Model Name to identify a Cummins® Engine.

This includes 2013 and later products.




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

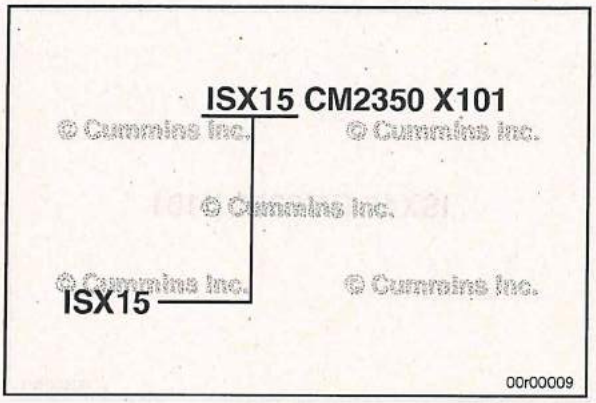
| Marketing Engine Model Name | Service Model Name |
|---|---|
| ISX15 | ISX15 CM2350 X101 |




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

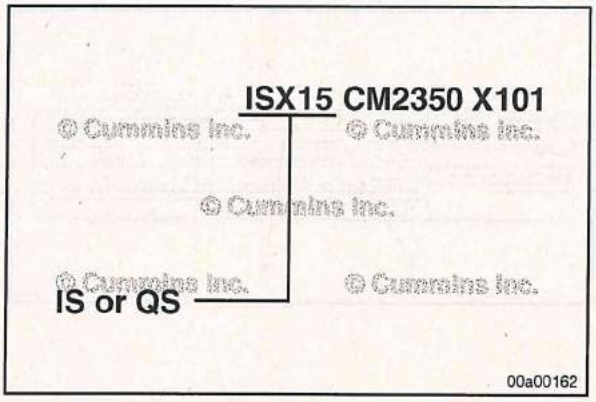
Examples of Cummins® service information and products that use service model names:

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




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

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



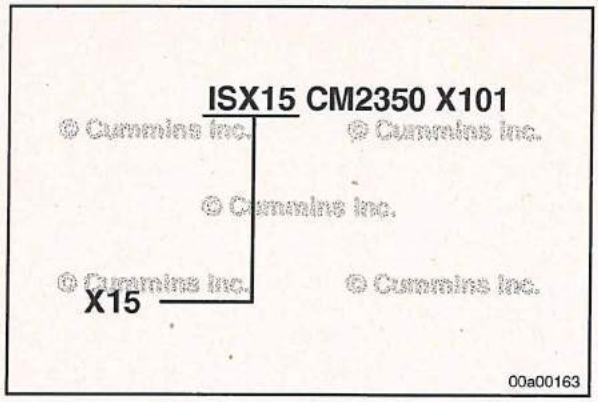

Typically, the first two letters of the marketing model name contain an "IS" or "QS" if the engine is an electronic engine.

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

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

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

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

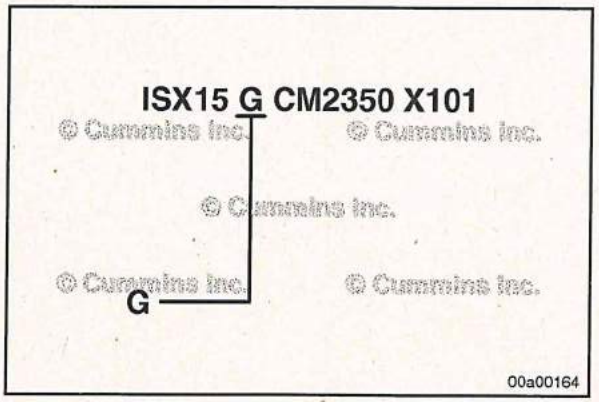



Typically, the third letter is the engine platform/series designation followed by the engine liter displacement. For the example shown in the graphic, the engine is a:

X Series engine

15 Liters in Displacement

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




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

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

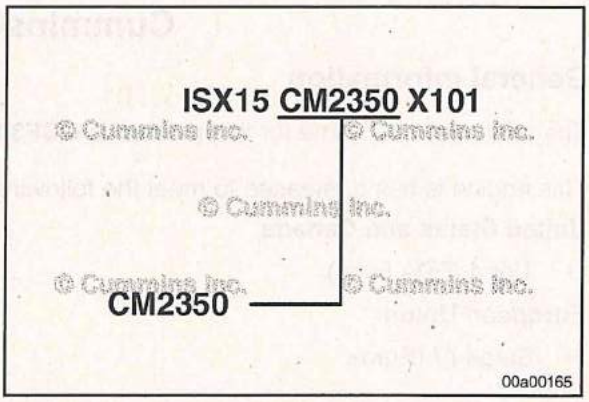
If a "M" is located after the liter displacement, the engine is in a marine application.

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

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

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

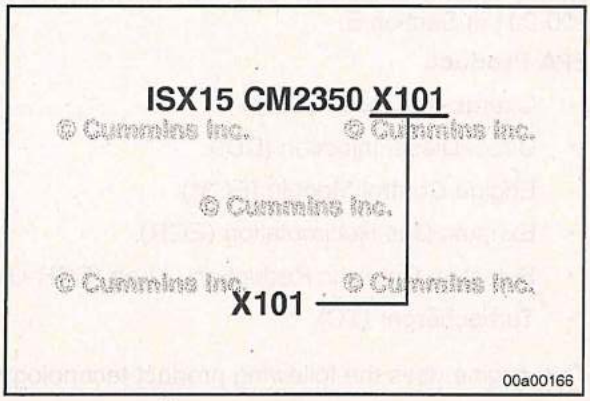
**NOTE:** Use of a parenthesis ( ) indicates that either engine control module (ECM) has been used on the product. Use of a slash "/" indicates that the product has multiple ECMs.




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

The letter is the engine platform designation.

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



# Cummins® Product Technology

## General Information

The service model name for this product is **QSF3.8 CM2350 F107**.

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

**United States and Canada**

- Tier 4 (EPA Final).

**European Union**

- Stage IV (Euro).

This engine uses the following product 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.

**EPA Product**

- Charge-Air Cooler (CAC).
- Direct Diesel Injection (DDI).
- Engine Control Module (ECM).
- Exhaust Gas Recirculation (EGR).
- Selective Catalytic Reduction - Urea (SCR-U).
- Turbocharger (TC).

This engine uses the following product technology:

**Engine**

- Number of Cylinders - 4.
- Engine Configuration - Inline.
- Cylinder Block Material - Cast Iron.
- Cylinder Head Material - Cast Iron.
- Camshaft Location - Cylinder Block.
- Accessory Drive Option.
- Crankcase Ventilation System - Open.

**Air Handling**

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

**Electronic Control System**

- Engine Control Module (Single): CM2350.
- Electrical System Voltage.
- 12-VDC.
- 24-VDC.
- Engine Coolant Level Sensor.
- Engine Coolant Temperature Sensor.
- Engine Oil Pressure Switch.
- Fuel Rail Pressure Sensor.
- Fuel Pump Actuator.
- Water in Fuel Sensor.
- Camshaft Position Sensor.

- Crankshaft Position Sensor.
- EGR Differential Pressure Sensor.
- Exhaust Gas Pressure Sensor.
- Exhaust Temperature Sensor.
- EGR Temperature Sensor.
- Intake Manifold Pressure/Temperature Sensor.
- Aftertreatment Exhaust Gas Temperature Sensor.
- Diesel Exhaust Fluid Quality Sensor.
- Aftertreatment Intake NOx Sensor.
- Aftertreatment Outlet NOx Sensor.

**Exhaust System**

- Turbocharger Wastegate Assembly.
- Exhaust Pressure Regulator.
- Exhaust Gas Recirculation (EGR).
- Selective Catalytic Reduction (SCR) Catalyst.
- Aftertreatment Diesel Exhaust Fluid Dosing System.
- Integrated Diesel Exhaust Fluid Controller (controlled by the engine's ECM).

**Fuel System**

- Diesel.
- Common Rail Fuel System.
- Denso™ Common Rail Fuel System.

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

**Industrial**

- Construction.

# Notes

# Section 1 - Operating Instructions

## Section Contents

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# Operating Instructions - Overview

## General Information

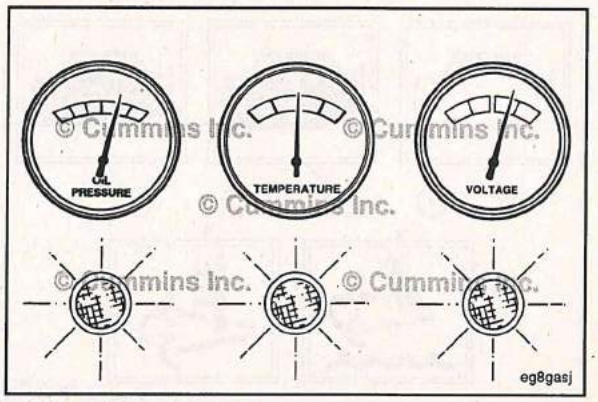
Correct care of your engine will result in longer life, better performance, and more economical operation.

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.

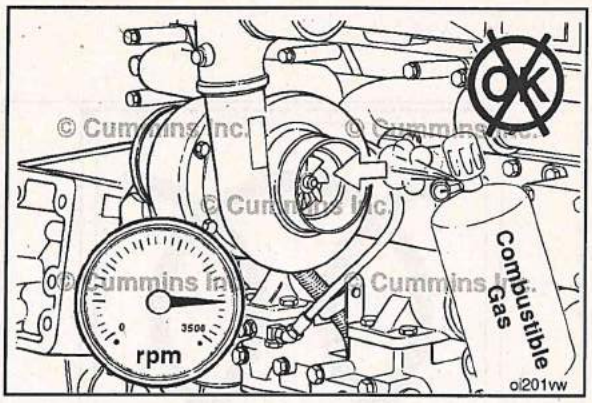
Check the oil pressure indicators, temperature indicators, warning lights, and other gauges daily to make sure they are operational.

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⚠**

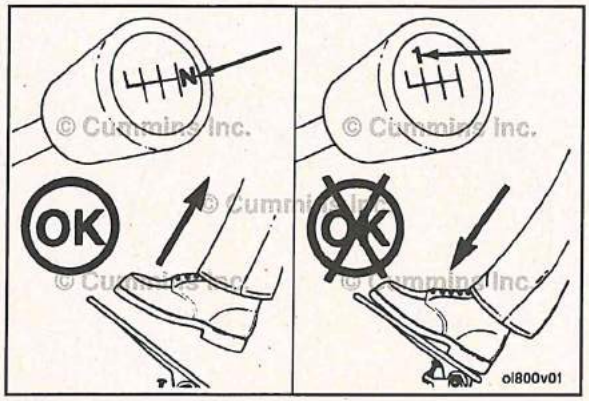
**Do not operate a diesel engine where there are or can BE COMBUSTIBLE vapors. These vapors can be sucked through the air intake system and cause engine acceleration and over speeding that can result in a fire, an explosion, and extensive property damage. Numerous safety devices are available, such as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

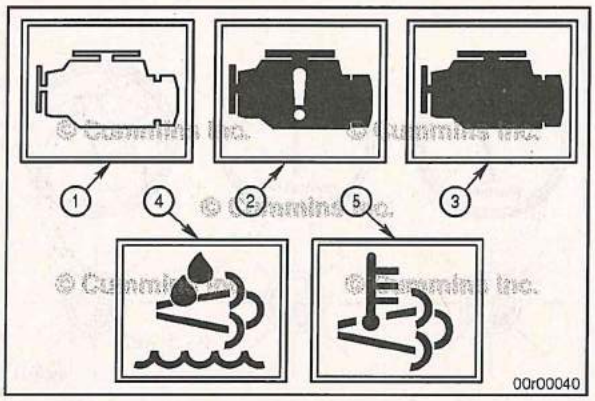



# Normal Starting Procedure

## Starting

Disengage the driving 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 keyswitch 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

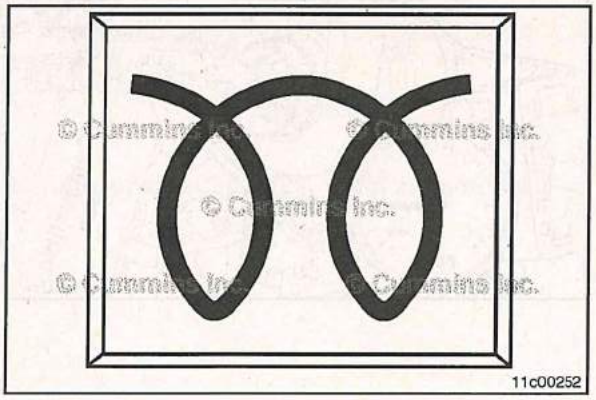
2 STOP (or STOP ENGINE) lamp, red in color

3 MALFUNCTION INDICATOR lamp, amber in color

4 AFTERTREATMENT DIESEL EXHAUST FLUID lamp, amber in color

5 HIGH EXHAUST SYSTEM TEMPERATURE lamp, amber in color.

Use the following procedure if any of the lamps remain on or begin to flash. 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 illuminate at keyswitch ON, and will stay on for a period of up to 30 seconds.

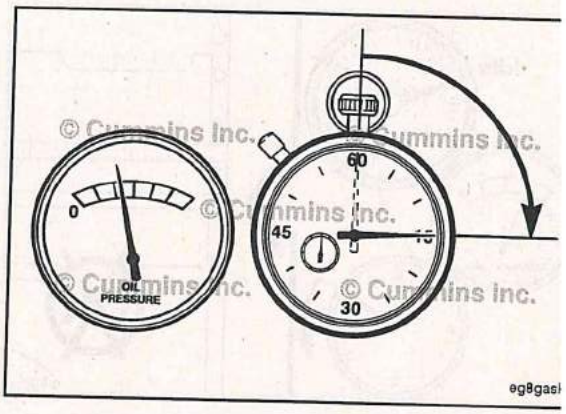
**NOTE:** The length of time the Wait-to-Start lamp remains illuminated depends on the ambient temperature. The lower the ambient temperature, the longer the lamp will be illuminated.

When the Wait-to-Start lamp turns off, turn the key to the starting position to start the engine.

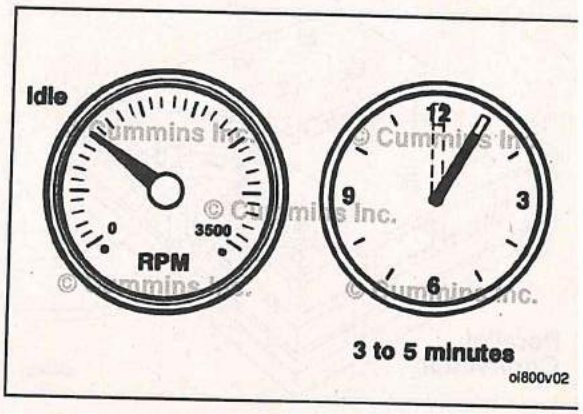
**NOTE:** Some vehicles are equipped with an engine starting motor protection feature. If the starting motor is engaged for 30 seconds or more, without the engine starting, the starting motor will stop operating, allowing for proper cooling of the starting motor. During this time, the Wait-to-Start lamp, if equipped, will flash for 2 minutes. Once the lamp stops flashing, the starting motor will be allowed to function.

**⚠CAUTION⚠**

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

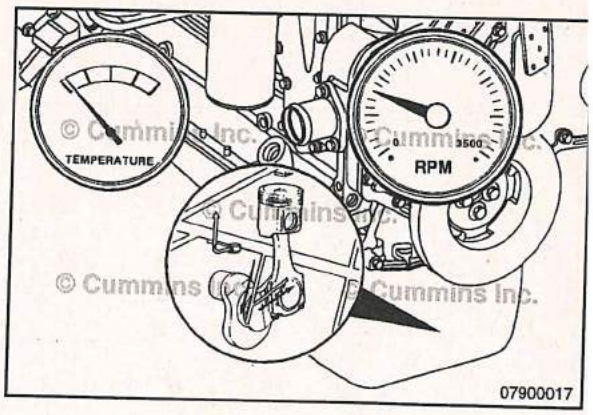



Idle the engine 3 to 5 minutes before operating with a load.




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

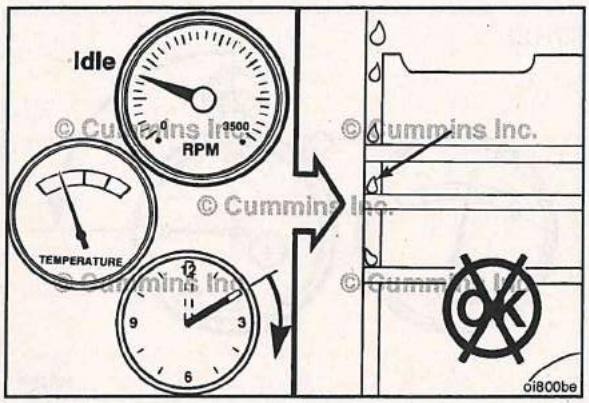
**NOTE:** For engines equipped with the engine warm-up protection feature; this feature limits engine speed and torque following engine start-up until sufficient oil pressure is available to the engine components. This feature reduces the risk of engine part damage due to operating at engine speeds too high or 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 may 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.



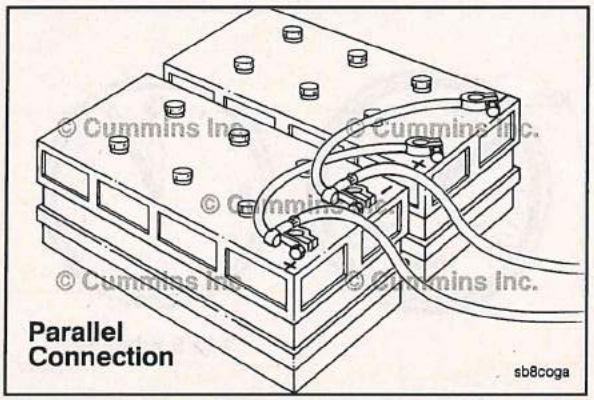

**⚠CAUTION⚠**
**Do not operate the engine at low idle for long periods with engine coolant temperature below the minimum specification in Maintenance Specifications in Section V.**

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.**

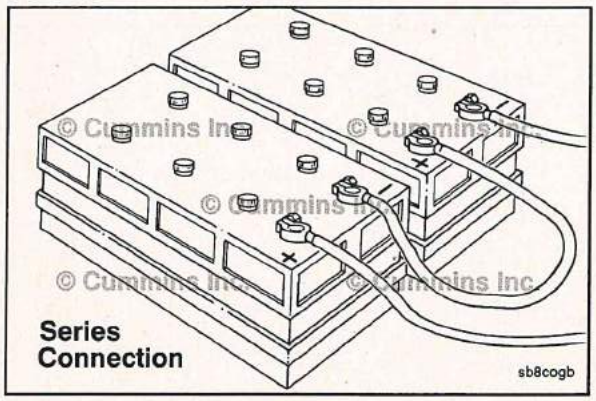



**⚠CAUTION⚠**
**When using jumper cables to start the engine, make sure to connect the cables in parallel: positive (+) to positive (+) and negative (-) to negative (-). When using an external electrical source to start the engine, turn the disconnect switch to the OFF position. Remove the key before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

**⚠CAUTION⚠**
**To reduce the possibility of damage to engine parts, do not connect 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:** See equipment manufacturer service information 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:** See equipment manufacturer service information 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.

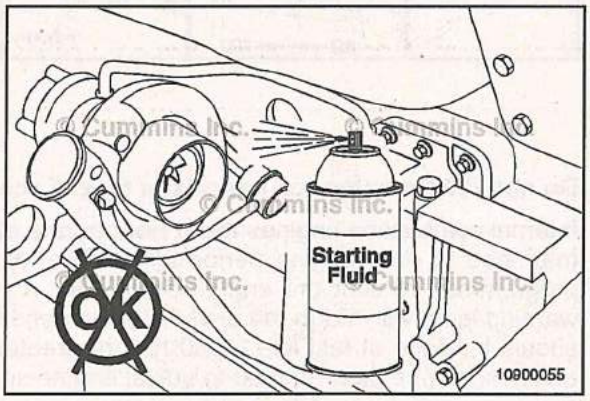
See the equipment manufacturer service information for any additional cold weather starting procedures.

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

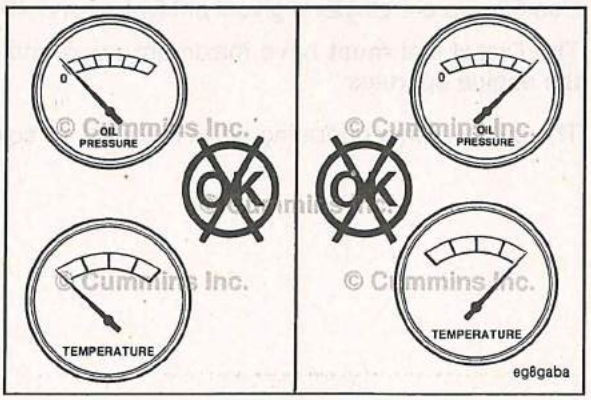
Follow the Normal Starting Procedure in this section. The engine will **not** start until the minimum cranking oil pressure is detected by the ECM. It can take more cranking time to start the engine after an extended shut down or oil change.

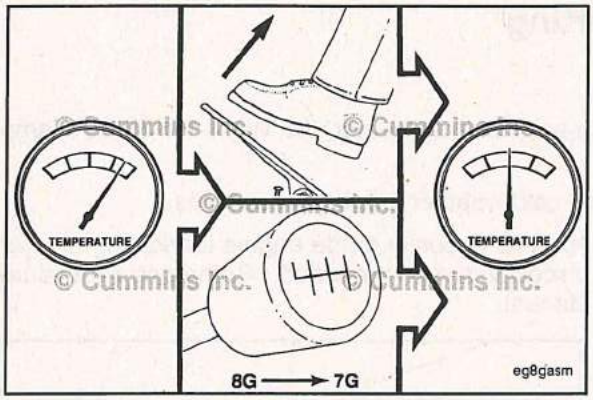
# Operating the Engine

## 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).

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

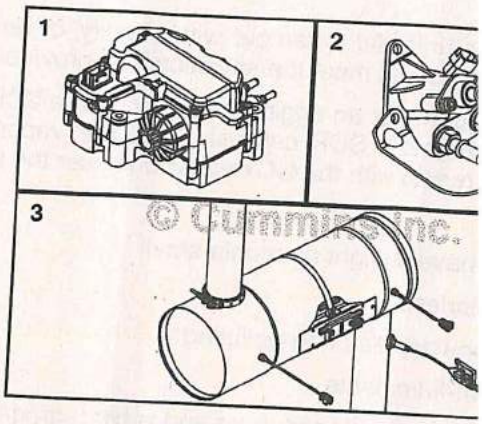
## General Information

The selective catalytic reduction (SCR) system is used to decrease the nitrogen oxides (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 SCR catalyst.



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

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

**DEF:**

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

See the following procedure for DEF specifications. Refer to Procedure 018-026 in Section V.

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

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

See the following procedure for the aftertreatment DEF dosing unit filter maintenance interval. Refer to Procedure 102-002 in Section 2.

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

The aftertreatment SCR catalyst uses DEF to reduce the nitrogen oxide emissions from the engine out of the exhaust into 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].

See the following procedure for additional information on the aftertreatment diesel fluid lamp and associated engine derates. Refer to Procedure 101-048 in Section 1.

DEF is sprayed into the exhaust when the temperature in the aftertreatment SCR catalyst reaches approximately 250°C [482°F]. The amount of DEF consumed 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.

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.

# Engine Indicator Lamps

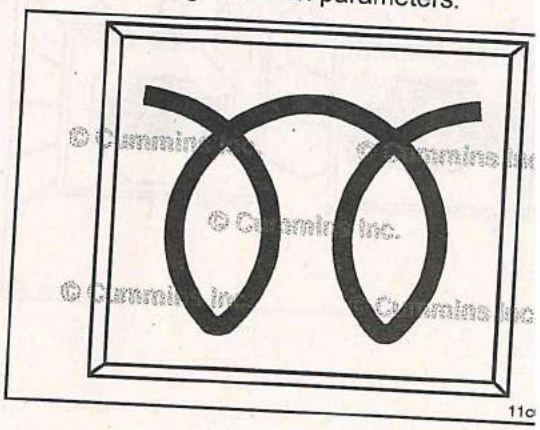
## General Information

The following engine indicator lamps cover **only** the lamps controlled by the engine control module (ECM). The equipment manufacturer can provide additional indicator lamps. Please refer to the equipment owners manual 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 SCR/exhaust system cleaning lamp, are common with Cummins® systems utilizing a diesel particulate filter (DPF). Some OEMs, documentation, and tools may refe 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.

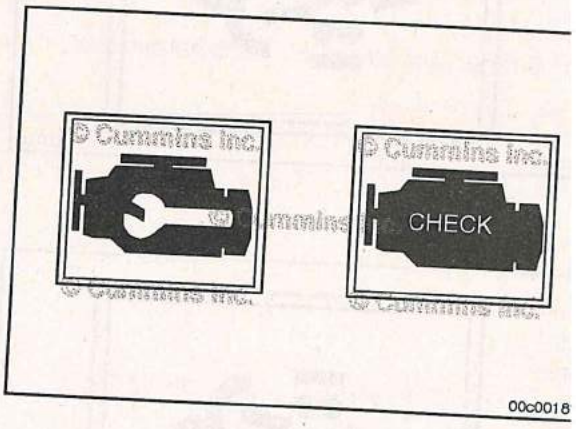
The time for the WAIT TO START lamp to be on will vary, depending on the ambient air temperature. See Normal Starting Procedure in Section 1. Refer to Procedure 101-014 in Section 1.

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 30seconds or more.

The WAIT TO START lamp can look like:

- The words WAIT TO START spelled out
- A symbol similar to the graphic illustrated
- 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



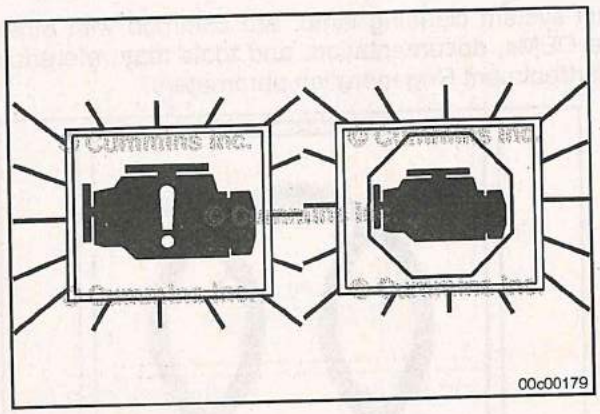

The CHECK ENGINE lamp illuminates when the engine needs to be serviced at the first available opportunity.

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 illustrated.

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
- Low engine lubricating oil level, if equipped with an engine lubricating oil level sensor
- Coolant level is low.



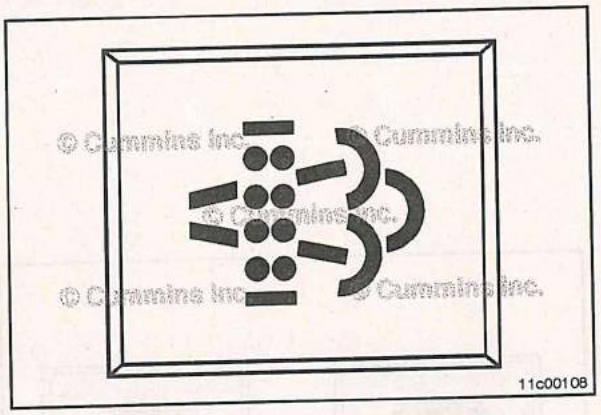

### Stop Engine Lamp

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 illustrated.



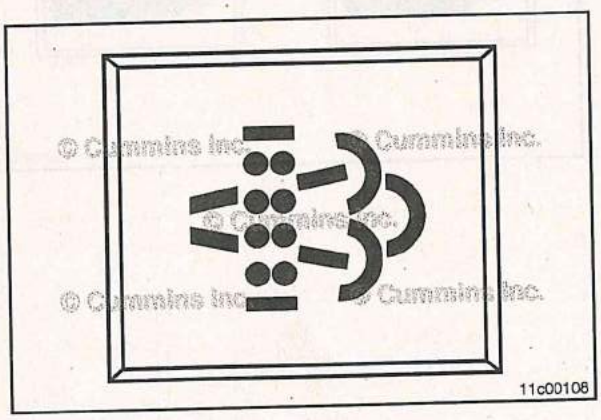

### SCR System Cleaning Lamp

The 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:

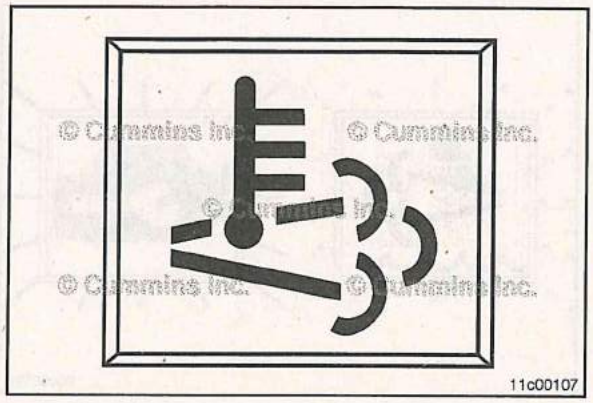
1 Keep the exhaust outlet away from people and anything that can burn, melt, or explode.

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.

### 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, that exhaust temperatures are high due to regeneration of the aftertreatment diesel particulate filter. The lamp could illuminate during normal engine operation or during regeneration.

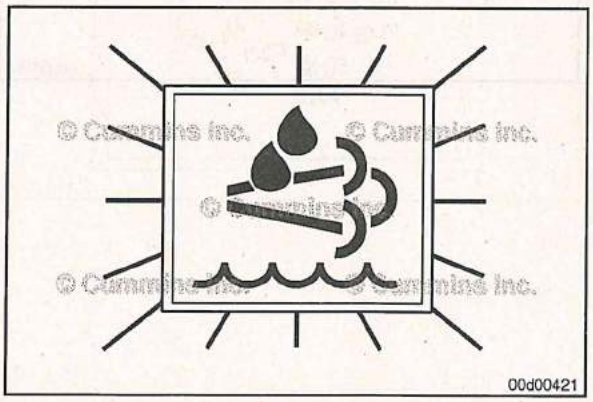
**NOTE:** The OEM determines whether or **not** the HIGH EXHAUST SYSTEM TEMPERATURE lamp is installed on the vehicle. The OEM also specifies the temperatures, vehicle speeds, and other conditions at which the lamp illuminates. See equipment manufacturer service information for additional information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

### Aftertreatment Diesel Exhaust Fluid Lamp

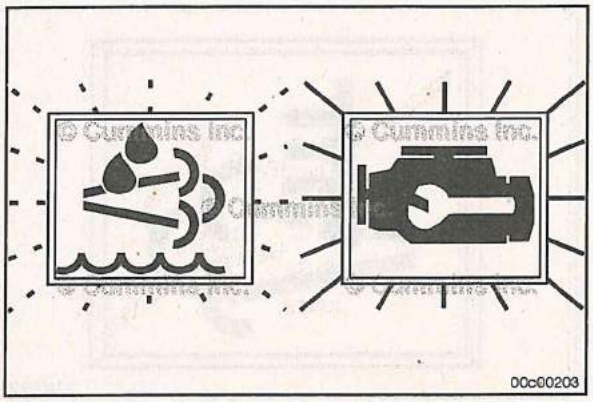



The AFTERTREATMENT DIESEL EXHAUST FLUID lamp indicates, when illuminated or flashing, that the DEF level is low.

**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 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 that the DEF tank be filled completely full of DEF in order to correct any fault conditions.

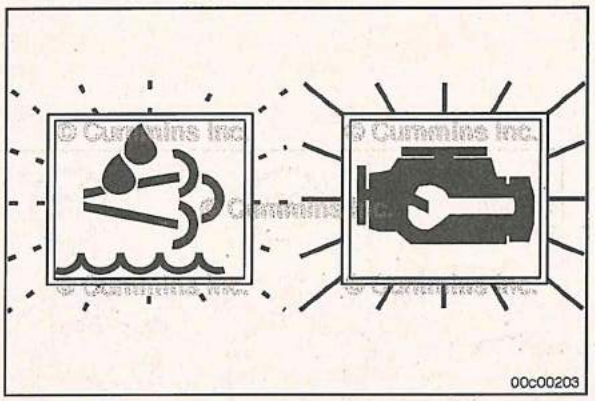



A flashing AFTERTREATMENT DIESEL EXHAUST FLUID lamp indicates that the DEF level has fallen below the critical warning level. This can be corrected by filling the DEF tank with DEF.

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

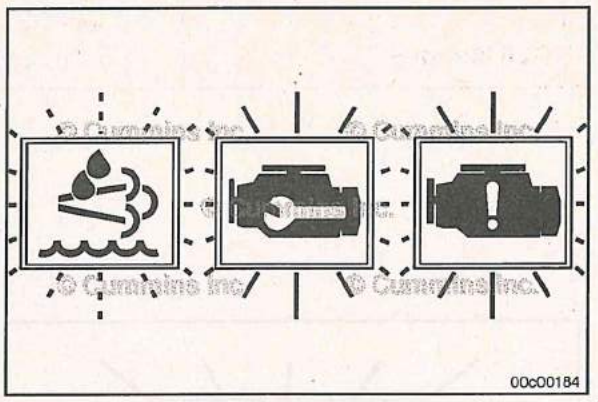
**NOTE:** In order to remove the final derate, the DEF tank must be filled to above 10 percent gauge reading.

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




Allowing the DEF tank to become empty willcause the aftertreatment DEF dosing systemto lose prime. A loss of prime condition maycause fault codes to become active.If corrective action is **not** taken within 30minutes of the CHECK ENGINE lampillumination, the engine will enter the finalderate level, which may include throttle lock orengine shutdown with possible restartlimitations

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




If the engine has been 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 may include low idle lock or engine shutdown with restart limitations.

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

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

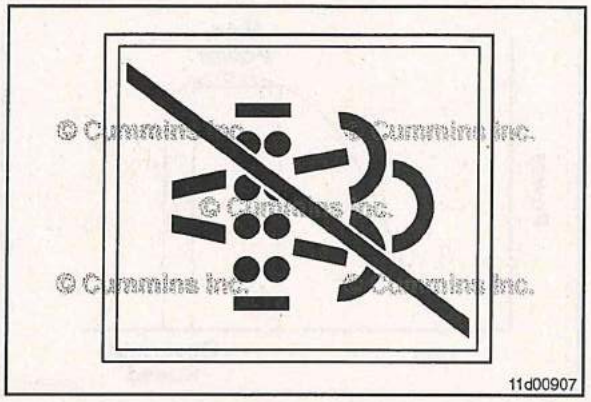
**NOTE:** It is recommended that the DEF tank be filled completely full of DEF in order to correct any fault conditions

### SCR System Cleaning Inhibited Lamp

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

An illuminated SCR SYSTEM CLEANINGDISABLED (INHIBIT) lamp indicates that theinhibit switch is active and automatic ormanual (non-mission) SCR/exhaust systemcleaning will **not** occur. This can be correctedby switching the inhibit switch to permit mode. Refer to Procedure 101-050 in Section 1.

**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 information for additional information regarding this lamp.



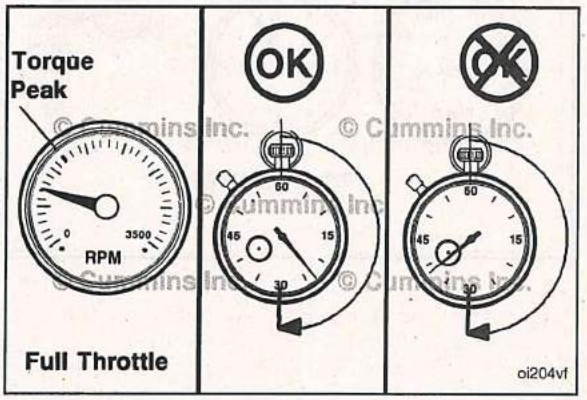

## Engine Operating Range

### General Information

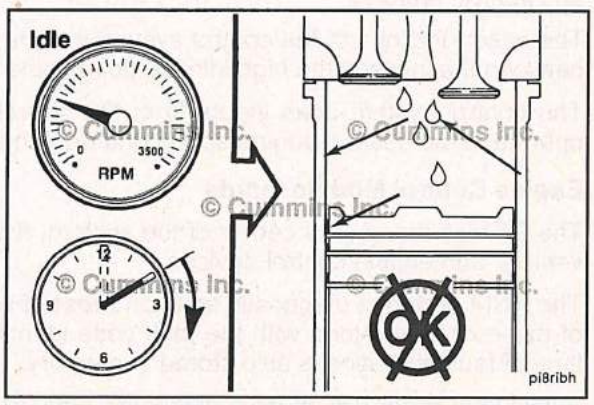
**⚠CAUTION⚠**
**Do not operate the engine at full throttle below peak torque rpm (refer to engine dataplate for peak torque rpm) for more than 30 seconds. Operating the engine at full throttle below peak torque will shorten engine life to overhaul, can cause serious engine damage, and is considered engine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

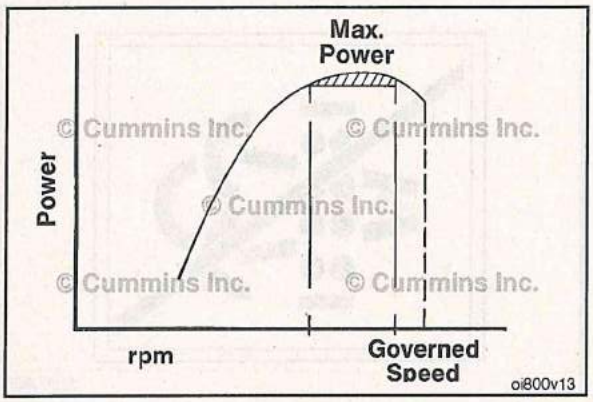
**⚠CAUTION⚠**
**Do not operate the engine beyond the maximum engine speed. Operating the engine beyond the maximum engine speed can cause severe engine damage. Use proper operating techniques for the vehicle, vessel, or equipment to prevent engine overspeed. The maximum engine speed specification is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

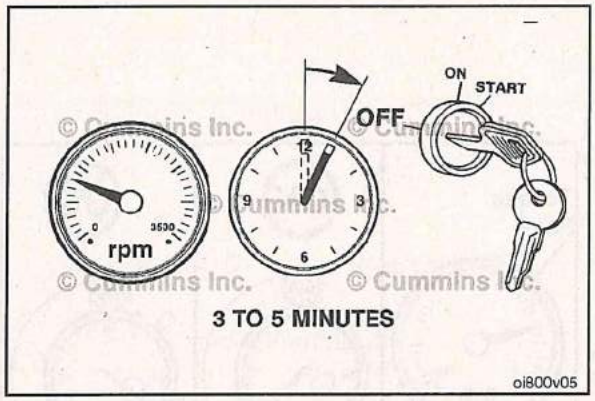
Cummins® engines are designed to operate successfully at full throttle under transient conditions down to peak torque engine speed. This is consistent with recommended operating practices.




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






## 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.

## 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 engine control module (ECM) is an electronically operated fuel control system that also provides many operator and vehicle features.

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 reducing exhaust emissions while optimizing engine performance.

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 the required emissions level.

### Engine Control Module Inputs

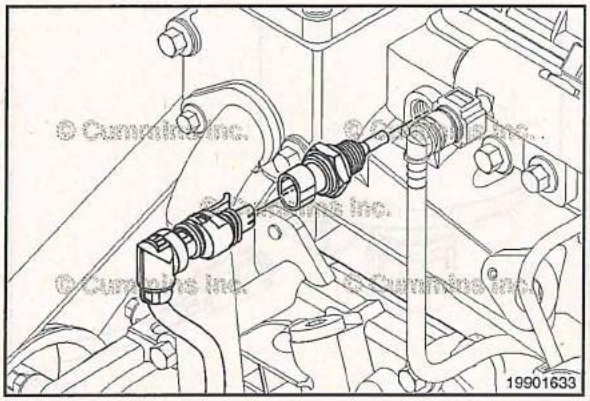
The ECM is the control center of the system. It processes all of the inputs and sends commands to the fuel system, vehicle, and engine control devices.

The ECM performs diagnostic tests on **most** of its circuits and will activate a fault code if a problem is detected in one of these circuits. Along with the fault code identifying the problem, a snapshot of engine operating parameters at the time of fault activation is also stored in memory.

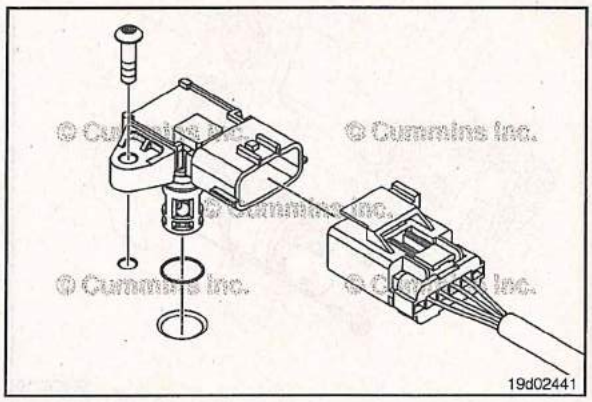
Active fault codes will cause a diagnostic lamp to activate as a signal to the operator.

The control system uses a number of sensors to provide information on engine operating parameters. These sensors include:

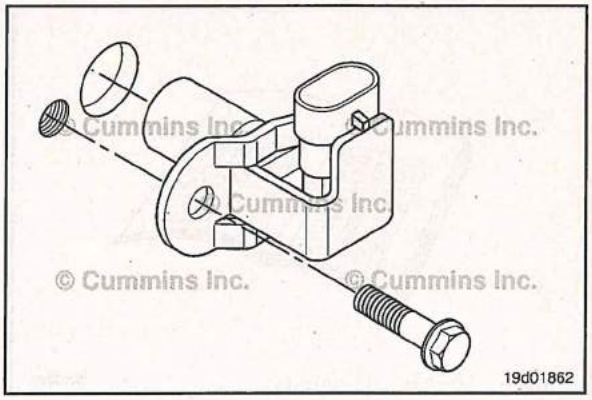
- Engine coolant temperature sensor.



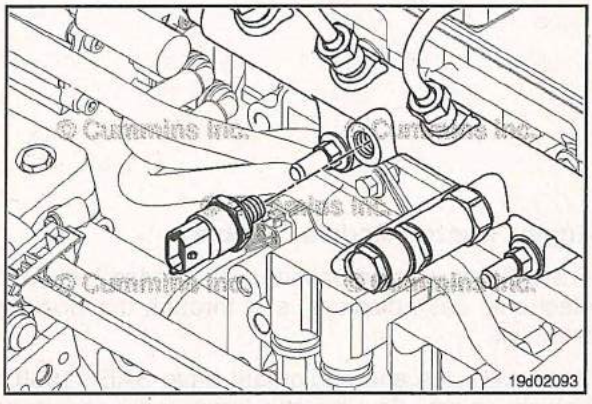

- Ambient air and turbocharger compressor inlet temperature sensor.

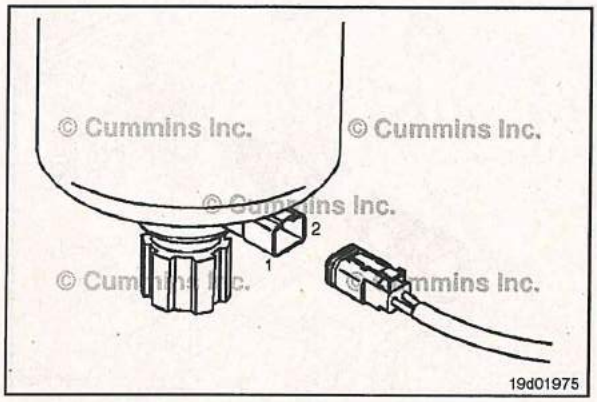



- Engine speed (crankshaft position) sensor
- Camshaft position sensor.

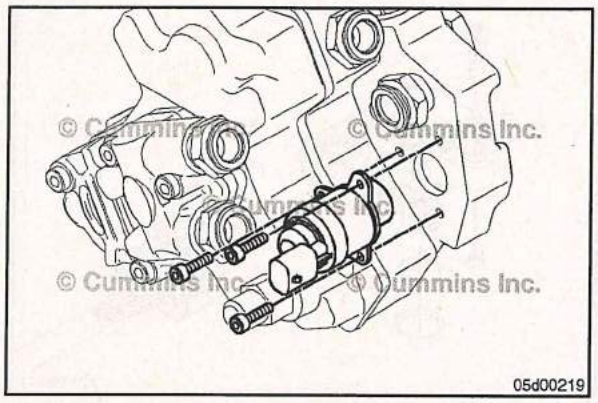



- Fuel rail pressure sensor.

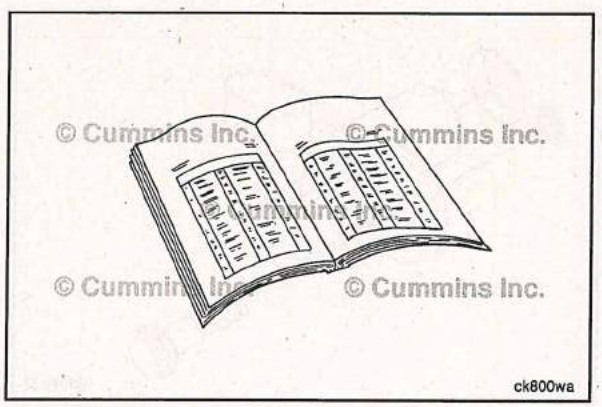





- Water in fuel sensor.




- Electronic fuel control actuator.




- Exhaust gas recirculation (EGR) valve
- Exhaust manifold pressure sensor
- Exhaust return temperature sensor
- EGR differential pressure sensor
- Accelerator pedal/lever position sensor
- Idle validation switch
- Engine coolant level sensor
- Vehicle speed sensors
- Feature control switches (i.e. cruise control switches)
- Fan control switch
- Air conditioner pressure switch
- Remote accelerator
- Remote power takeoff (PTO).

**NOTE:** These inputs are application dependent. Some applications do **not** use all of these inputs.

### Engine Control Module Outputs

The ECM can communicate with service tools and some other vehicle controllers (such as transmissions, ABS, ASR, electronic dash displays, etc) through the Society of Automotive Engineers (SAE) J1939 data link or the SAE J1708 data link.

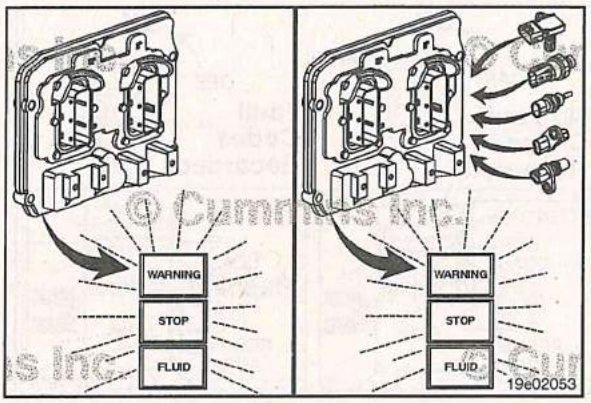
Some vehicles and equipment have SAE J1939 networks on them that link many of the "smart" controllers together. Vehicle control devices can temporarily command engine speed or torque to perform one of their functions (that is, transmission shifting, anti-lock braking, etc).

## Diagnostic Fault Codes

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

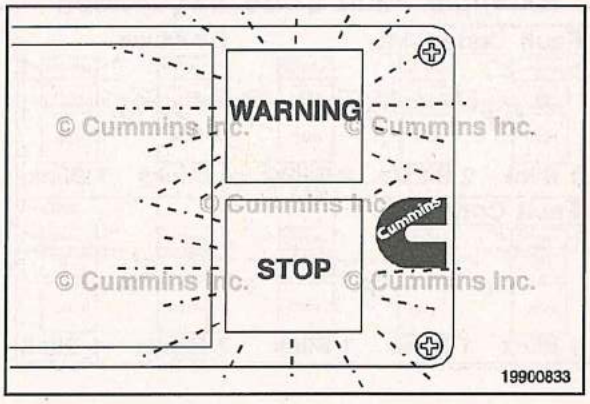
There are two types of diagnostic codes:

- Engine electronic control system fault codes inform the operator that there is a problem with the control system that requires troubleshooting.
- Information and engine protection fault codes 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" or "STOP ENGINE" lamp is red and indicates the need to stop the engine as soon as it can be safely done. The engine **must** remain shut down until the engine can be repaired.

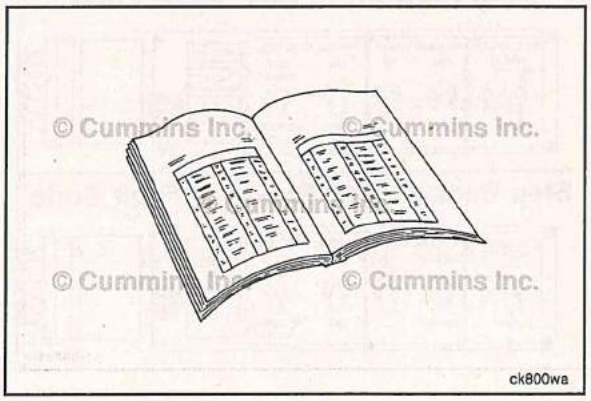



When illuminated, the yellow "WARNING" or "CHECK ENGINE" lamp indicates that the engine is in need of repair at the first available opportunity.

Another function of the WARNING or CHECK ENGINE lamp (yellow lamp) is to flash for 30 seconds at key ON when one of the following occurs:

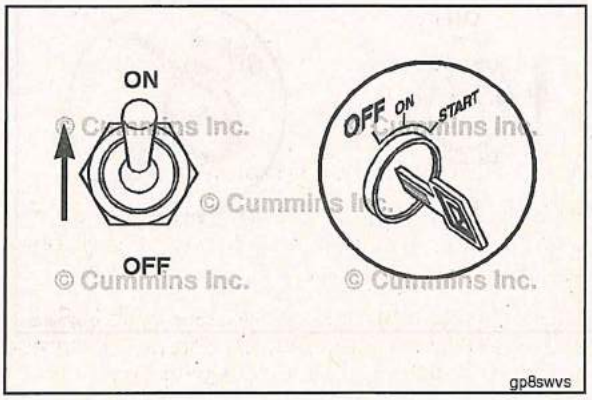
- Maintenance is required (if the Maintenance Monitor feature is enabled)
- Water in fuel is detected.

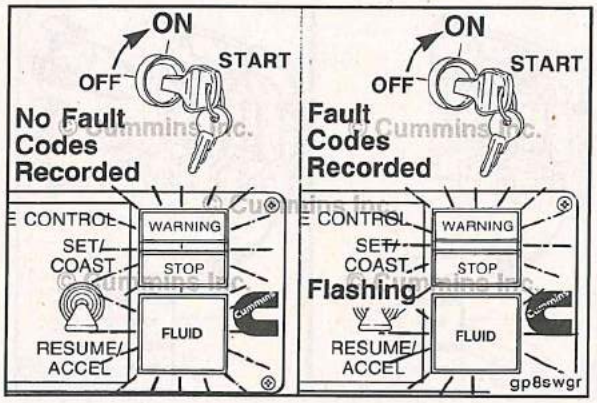
If the warning light flashes for 30 seconds at keyswitch ON and water is drained from the primary water-separating fuel filter, the secondary fuel filter **must** be replaced.




Fault codes can be accessed using the electronic service tool or by 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.

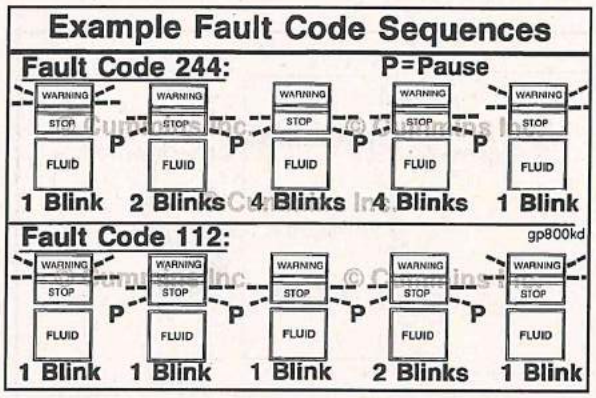





Turn the vehicle keyswitch to the ON position.

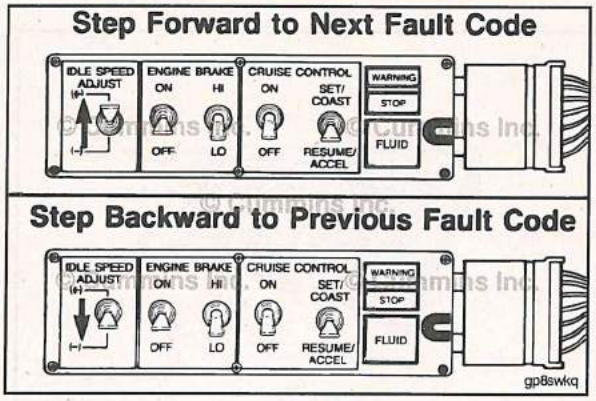
If no active fault codes are recorded, both lights will come on and stay on.

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

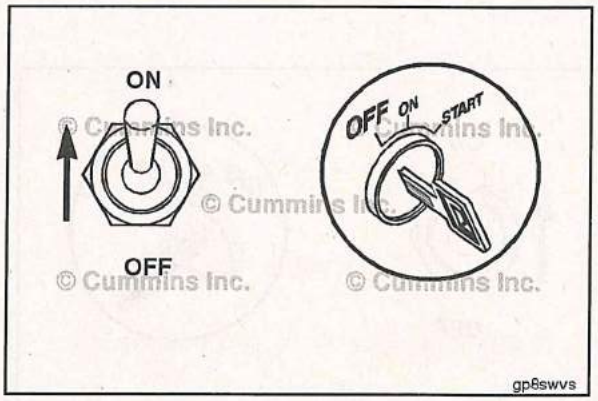



The fault code flashes in the following sequence:

- A WARNING (amber) light flashes.
- Following a short one or two second pause, the number of the recorded fault code flashes in the STOP (red) lamp.
- There is a one or two second pause between each number.
- After the number finishes flashing in red, an amber light appears 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 code is recorded, the same fault code will continuously be displayed when either (+) or (-) switch is depressed.



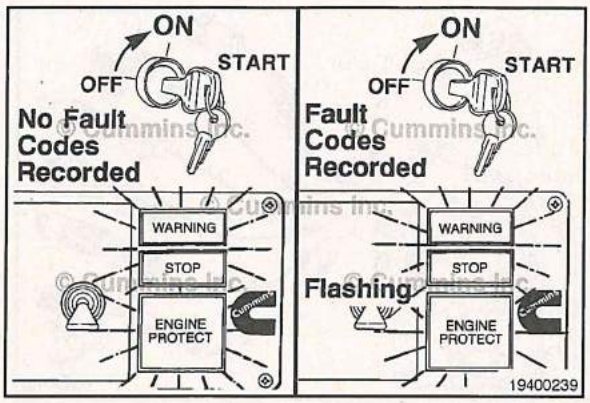

The diagnostic switch **must** remain in the OFF position (shorting plug removed) while the engine is being operated for all fault codes to be logged.

The diagnostic on/off switch circuit signals the system that the operator is requesting to read any active fault code recorded in the ECM.

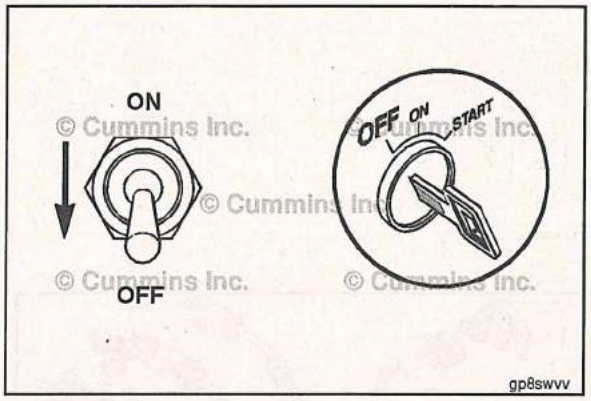
**NOTE:** Some original equipment manufacturers (OEMs) use a shorting plug rather than a switch.

When the ECM receives the signal from the diagnostic ON/OFF switch, the yellow and red warning lights come on and start flashing if any active fault code is recorded in the ECM. If both warning lights remain on and do **not** flash, there are no active fault codes present.

**NOTE:** The equipment **must** be stationary. If road speed is detected, the flashing sequence will **not** occur.

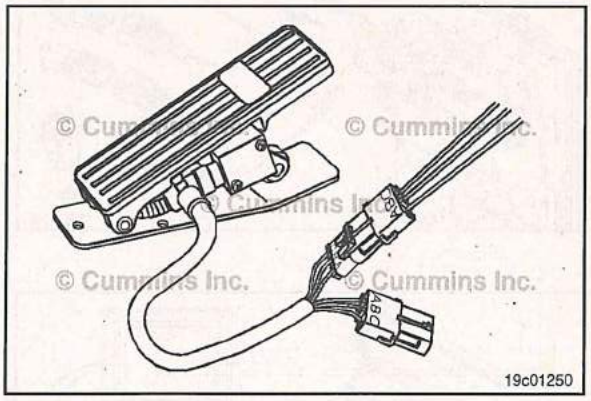



Turn the diagnostic switch OFF when the diagnostic system is **not** in use.



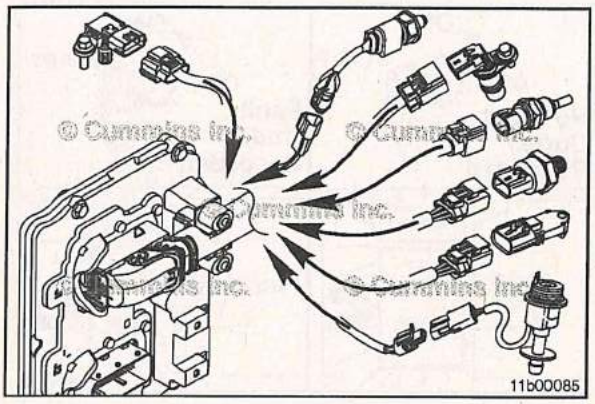

### Throttle Activated Diagnostic Switch

The throttle activated diagnostic switch feature is intended to eliminate the need for a dash-mounted diagnostic switch, which is used to activate the fault code flash out on the lamps. The fault code flash out is activated through a simple sequence of throttle movements. When this feature is enabled, the engine is in stop state and the keyswitch is turned ON. Every successive cycle of the throttle leads to the next fault code to be flashed on the lamps, in the same manner as if the increment switch were depressed.




To activate this feature, the engine **must** be stopped and the keyswitch turned to the ON position. Depress the accelerator pedal completely three times. The feature should then be enabled. Transitioning to the next fault code occurs automatically after the first fault code is flashed out twice or if the throttle pedal is cycled.

**NOTE:** There is an optional, error-sensitive mode for this feature. If any of the throttle-related errors occur, this feature turns on the diagnostic switch automatically when the engine is stopped and the keyswitch is ON. During this mode, **only** the increment switch can be used to flash out the next fault code.

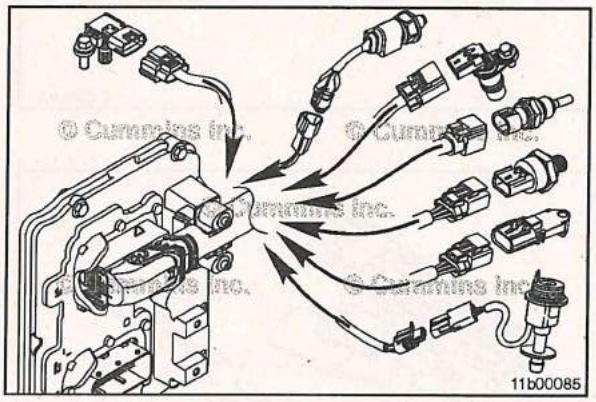



## Engine Protection System

**⚠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.**

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

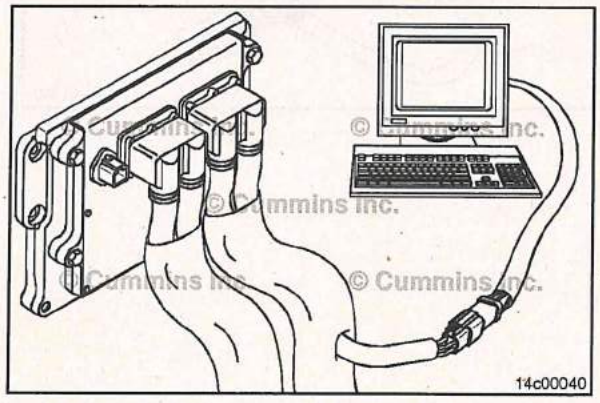
**NOTE:** Engine power and speed will gradually be reduced, depending on the level of severity of the observed condition. The engine protection system will **not** shut down the engine unless the engine protection shutdown feature has been enabled.




## 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.



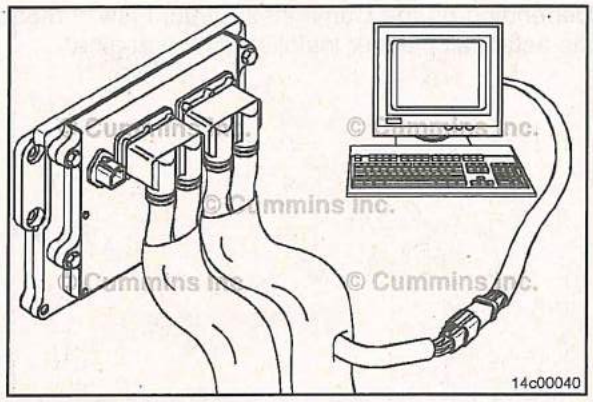

## INSITE™ Electronic Service Tool Description

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 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 is 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.

# 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 may be some variation between the illustration and the actual air cleaner installed on the engine.

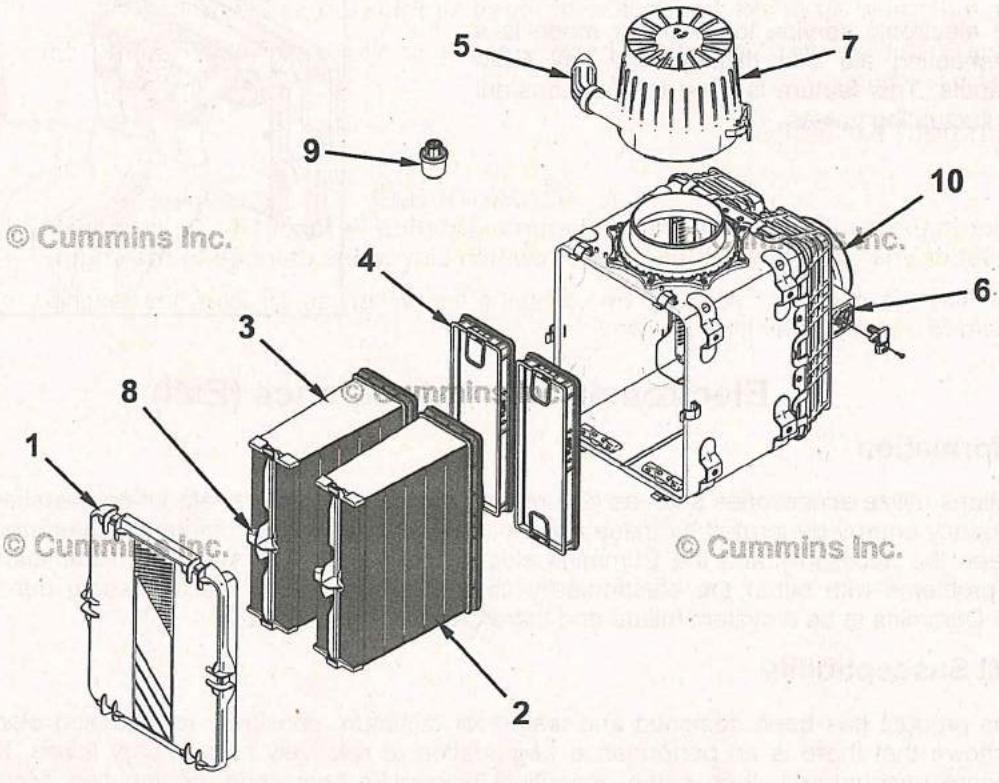



Figure 1, Typical Direct Flow™ Exploded View

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 illuminates 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.

**⚠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.**

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

Cleaning of air filters is **not** recommended by Cummins Inc. When an air filter has reached terminal restriction, it should be discarded and a new air filter installed.

# Notes

# Section 2 - Maintenance Guidelines

## Section Contents

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# Maintenance Guidelines - Overview

## General Information

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

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

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

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

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

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

# Tool Requirements

## General Information

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

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

| Tool Part Number | Description | Used for |
|---|---|---|
| ST-1273 | Pressure gauge | Measure Intake Manifold Pressure |
| 3400158 | Filter Wrench | Oil and Fuel Filters |
| 3824591 | Barring tool | Rotate the engine |
| CC-2800 | Refractometer | Check antifreeze concentration and battery specific gravity |
| 3164488 | Digital Multimeter | Measure voltage on electrical equipment |
| 3822525 | Belt Tensioner Gauge (click type) | Check belt tension (6 to 12 v-ribbed belts) |
| 3164795 | Torque Wrench | Dial type 3/8 drive 0-250 in-lb |
| 3164794 | Torque Wrench | Micro-adjust 3/8 drive 10-100 ft-lb |
| 3164797 | Torque Wrench | Micro-adjust 1/2 drive 50-250 ft-lb |

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

# Maintenance Schedule

## General Information

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

If the engine is operating in ambient temperatures consistently below -18°C [0°F] or above 38°C [100°F], perform maintenance at shorter intervals. Shorter maintenance intervals are also required if the engine is operated in a dusty environment or if frequent stops are made. Contact a Cummins® Authorized Repair Location for recommended intervals.

Use the chart provided to record maintenance. Refer to Procedure 102-001 in Section 2.

If the engine is equipped with a component or an accessory not manufactured by Cummins Inc., see equipment manufacturer service information for maintenance recommendations.

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

For your convenience, listed below are the section numbers that contain specific instructions for performing the maintenance checks.

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

- Crankcase Breather Tube - Check
- Fuel-Water Separator - Check
- Lubricating Oil Level - Check
- Coolant Level - Check
- Fan, Cooling - Check
- Drive Belts - Check
- Air Cleaner Restriction - Check[3]
- Dust Ejection Valve - Check
- Air Intake Piping - Check
- Diesel Exhaust Fluid Level - Check

**Maintenance Procedures at 250 Hour or 3 Months ..... Section 4**

- Charge Air Cooler - Check
- Charge Air Piping - Check

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

- Lubricating Oil and Filters - Change[1]
- Cooling System Antifreeze - Check[2]
- Cooling Fan Belt Tensioner - Check
- Batteries - Check
- Battery Cables and Connectors - Check

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

- Fuel Filter (Canister Type) - Change
- Fuel Filter (Spin-On Type) - Change
- Lubricating Oil and Filters - Change[1]
- Radiator Pressure Cap - Check
- Fan Hub, Belt-Driven - Check

**Maintenance Procedures at 2000 Hours or 2 Years ..... Section 7**

- Cooling System - Drain and Flush
- Radiator Hoses - Check

**Maintenance Procedures at 4000 Hours or 3 Years ..... Section 8**

- Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter - Change

**Maintenance Procedures at 5000 Hours or 4 Years .....Section 9**

- Overhead Set - Adjust

**Notes:**

1 The lubricating oil and lubricating oil filter intervals are based on Cummins Engineering Standard (CES) 20081 and a normal duty cycle. Oil change intervals can be adjusted based on oil type, oil pan size, duty cycle, and fuel consumption. See the Oil Drain Intervals table below.

2 Coolant testing for additive and glycol levels must be performed at least twice a year. The coolant must be tested for replacement limits every 4000 hours or once a year, whichever occurs first.

3 The air cleaner (filter) element change interval is based upon restriction. It is important to check the restriction daily and change the primary air cleaner filter(s) once they become restricted (635 mm-$H_2O$ [25 in-$H_2O$]). The secondary air cleaner filters should be changed every third time the primary filters are changed. If the primary filter has been breached during vehicle operation, the secondary filter should be changed, if necessary. Refer to Procedure 010-014 in Section A.

Use the following procedure for fuel recommendations and specifications. Refer to Procedure 018-002 in Section V.

## Oil Drain Intervals

The oil drain intervals are based on oil type, oil pan size, duty cycle, and fuel consumption. The table below specifies the maximum oil drain interval for the listed oil types, based on oil pan size.

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

| Oil Classification | Oil Type | Oil Pan Size | Oil Drain and Filter Change Interval (hours) | Oil Drain and Filter Change Interval for Constant Speed[4] or Severe Duty[5] applications (hours) |
|---|---|---|---|---|
| CES 20081/API CJ-4/ ACEA E9 | Conventional | 8 liters [2.1 gal] | 250 | 250 |
| | | 12 liters [3.2 gal] | 500 | 500 |
| | Fully Synthetic | 8 liters [2.1 gal] | 250 | 250 |
| | | 12 liters [3.2 gal] | 1000[3] | 500 |

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

2 Extended oil drain intervals apply only when using ultra low sulfur diesel (ULSD) fuel. Adjustments are required for biodiesel or other alternative fuels. Oil drain intervals for biodiesel blends greater than B5 should **not** exceed 500 hours (with 12 liter oil pan) or 250 hours (with 8 liter oil pan). Use the following procedure for additional fuel considerations. Refer to Procedure 018-002 in Section V.

3 The initial oil change interval should be 500 hours or 1 year, whichever occurs first. Then 1000 hours for every oil and filter change thereafter.

4 Examples of constant speed applications: air compressors, irrigation pumps, water pumps, generators.

5 Severe duty applications: fuel consumption 11.4 liters/hour [3.0 gal/hour] or greater.

# 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 |
|---|---|---|---|---|---|
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# Notes

# Section 3 - Maintenance Procedures at Daily Interval

## Section Contents

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# Daily Maintenance Procedures - Overview

## General Information

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

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

## System Operation Report

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

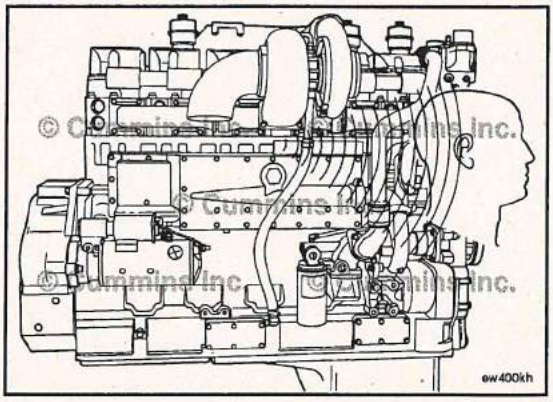
Comparison and intelligent interpretation of the daily report, along with a practical follow-up action, will eliminate most failures and emergency repairs.

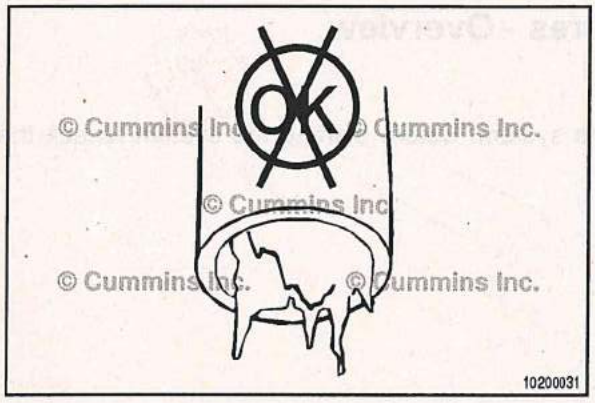
Report to the maintenance department any of the following conditions that may apply:

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

## Unusual System Noise

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






# Crankcase Breather Tube

## Maintenance Check

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.

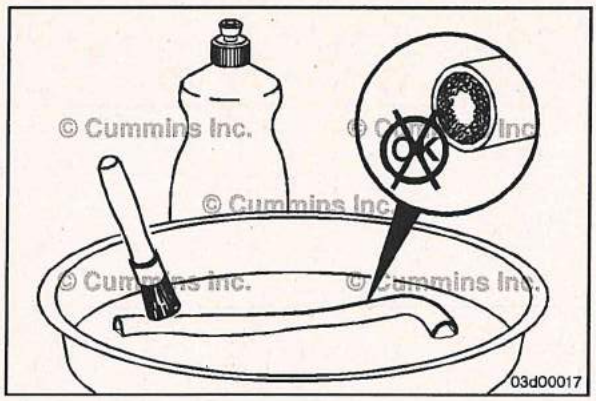
- Sludge
- Debris
- Ice.

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.

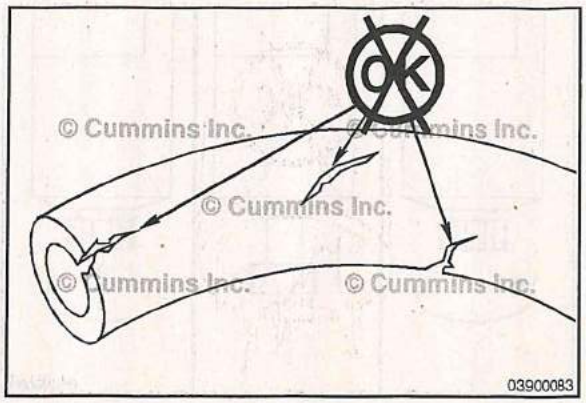
- Cracks
- Material deterioration
- General damage.

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.




# Fuel-Water Separator

## General Information

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

This Fuel-Water Separator is mounted on the vehicle chassis. The location is determined by the original equipment manufacturer (OEM).

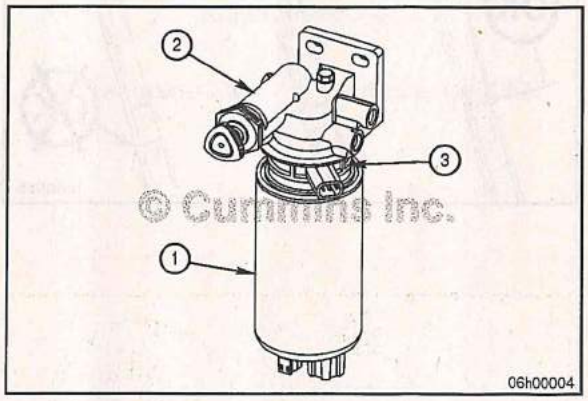
The Fuel-Water Separator is integrated into three components:

1 Fuel Filter

2 Fuel Filter Head (with priming pump)

3 Fuel Heater.

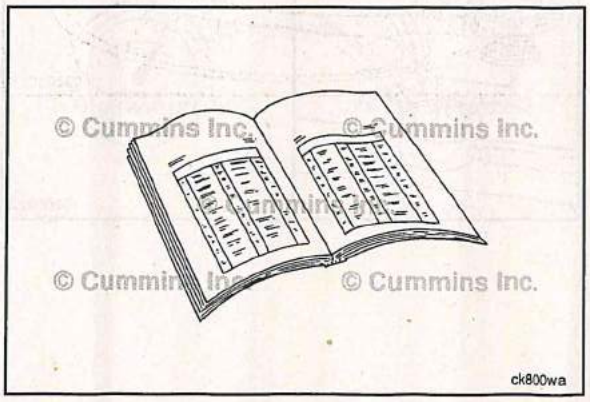
Use the priming pump on the filter head to prime the fuel system, if necessary.

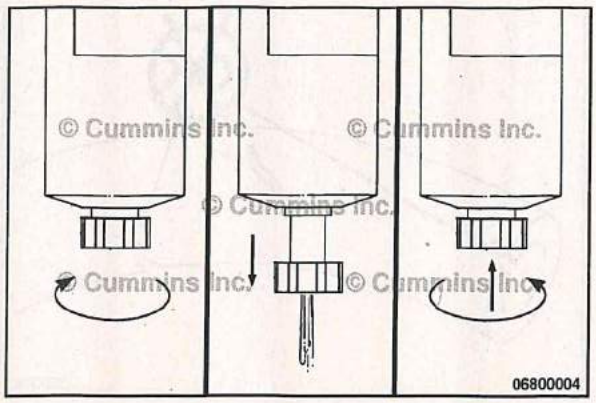



## Drain

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

Drain the water and sediment from the separator daily.





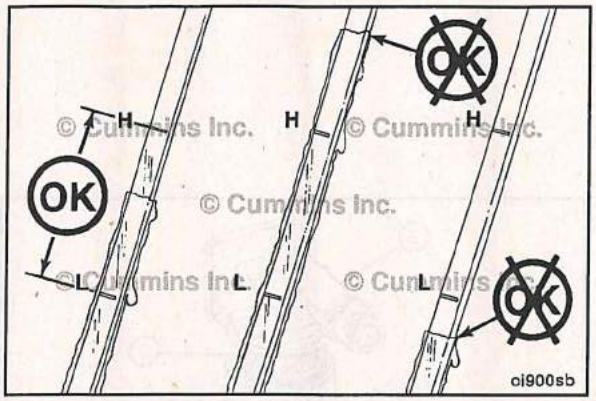

**⚠CAUTION⚠**
**When closing the drain valve, do not overtighten the valve. Overtightening can damage the threads.**

Shut off the engine.

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

Drain the filter sump until clear fuel is visible.

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




## Lubricating Oil Level

### Maintenance Check

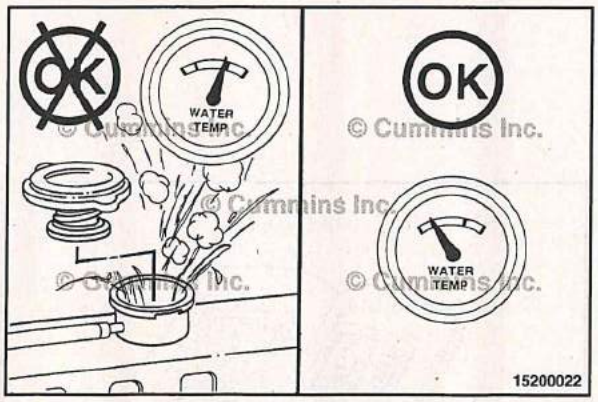
**⚠CAUTION⚠**
**Never operate the engine with oil level below the L (low) mark or above the H (high) mark. Poor engine performance or engine damage can occur.**

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

Shut off the engine for an accurate reading.

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

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




## Coolant Level

### Maintenance Check

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

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

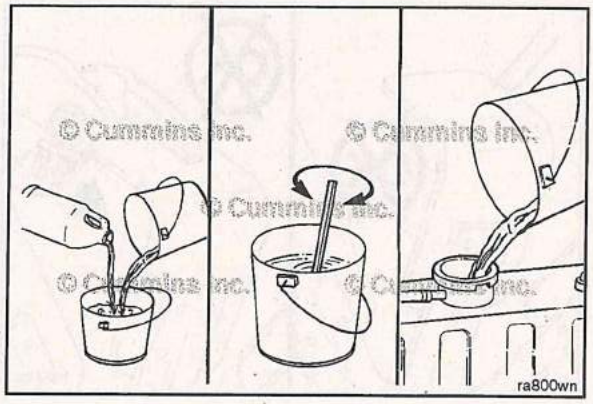
The coolant level **must** be checked daily.

**⚠CAUTION⚠**

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

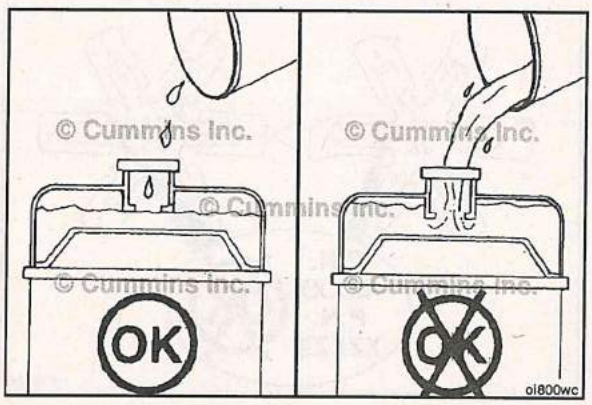
Coolant added to the engine **must** be mixed with the correct proportions of antifreeze, supplemental coolant additive, and water to avoid engine damage.

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




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

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

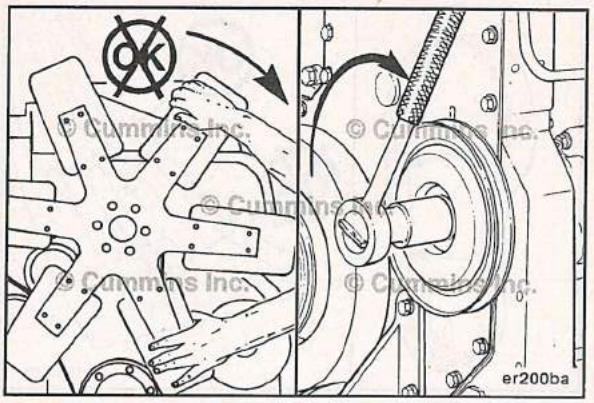



## Fan, Cooling

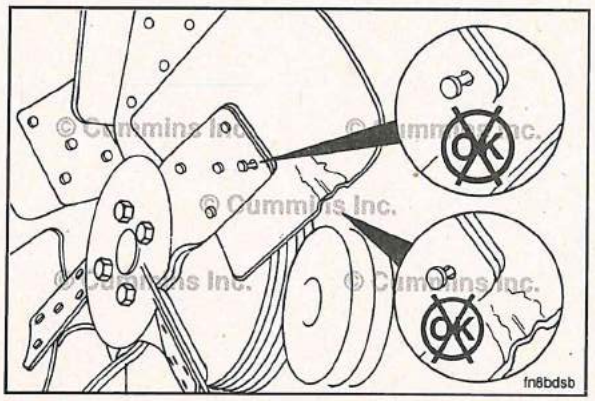
### Inspect for Reuse

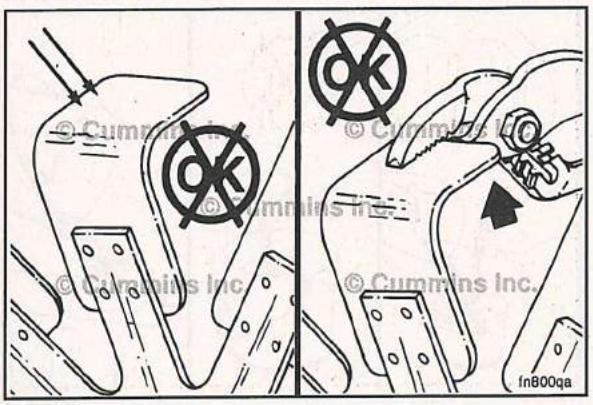
**⚠WARNING⚠**

**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.**

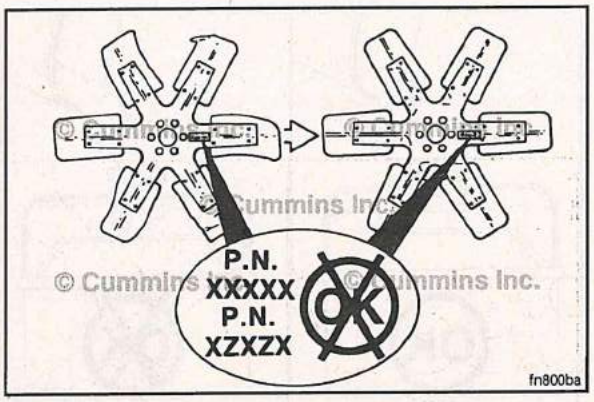



A visual inspection of the cooling fan is required daily. Check for cracks, loose rivets, and bent or loose blades. Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.



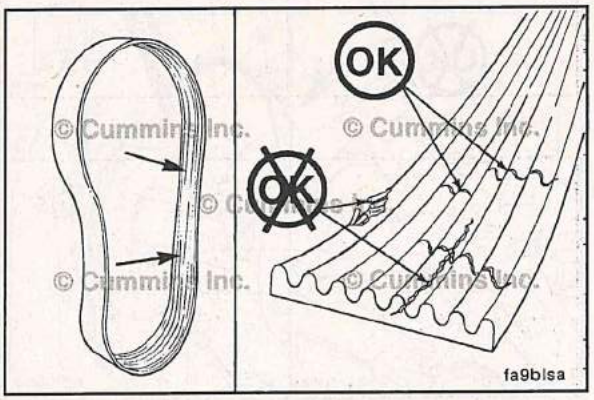



**⚠WARNING⚠**
**Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause personal injury or property damage.**




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.




# 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.**

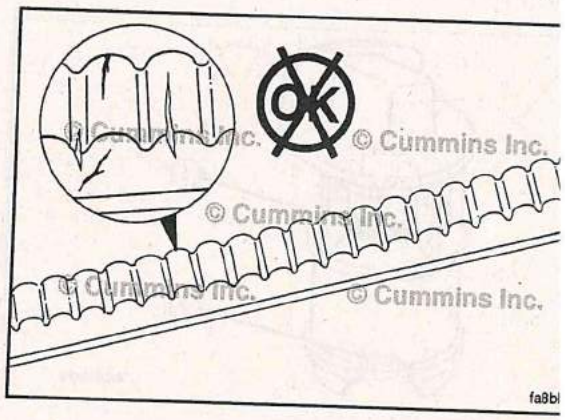
Inspect the belts daily. Check the belt for intersecting cracks. Traverse (across the belt width) cracks are acceptable. Longitudinal (direction of belt length) cracks that intersect with transverse cracks are **not** acceptable. Replace the belt if it is frayed or has pieces of material missing. Refer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

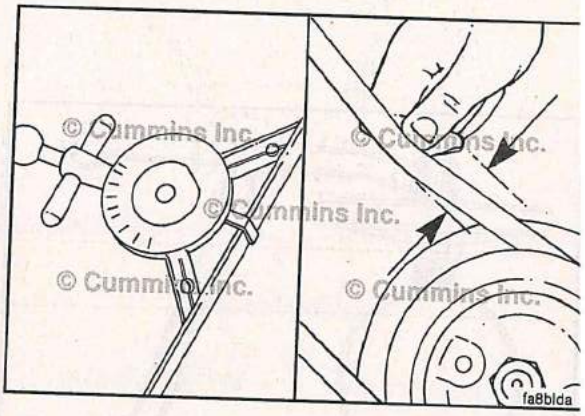
- Incorrect tension
- Incorrect size or length
- Pulley misalignment
- Incorrect installation
- Severe operating environment
- Oil or grease on the belts

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

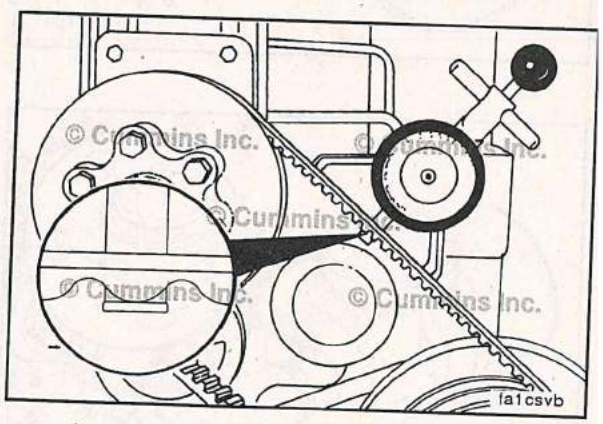
Refer to the Belt Tension Chart in Section V for the correct gauge and tension value for the belt width used.

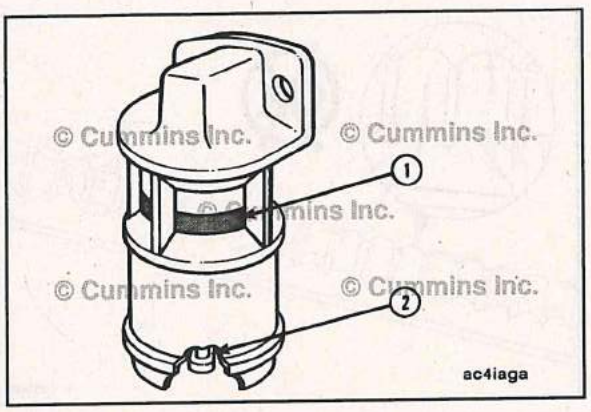
An alternate method (deflection method) can be used to check belt tension by applying 110 N [25 lbf] force between the pulleys on v-belts. If the deflection is more than one belt thickness per foot of pulley center distance, the belt tension **must** be adjusted.

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

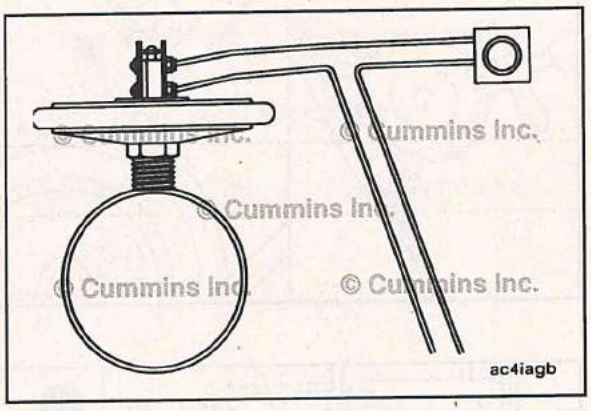
### Mechanical Indicator

**⚠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.

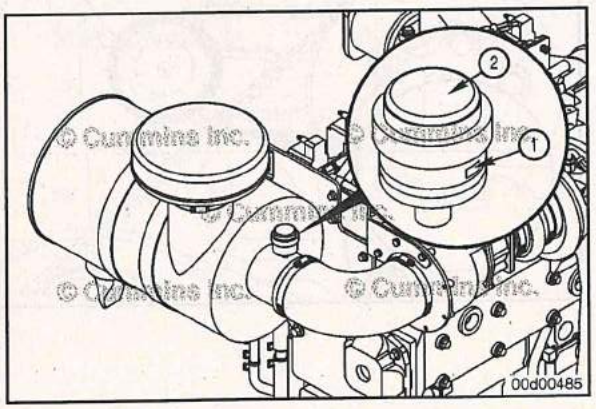
A mechanical restriction indicator is available to indicate excessive air restriction through a dry-type air cleaner. This instrument can be mounted in the air cleaner outlet or on the instrument panel. The red flag (1) in the window gradually rises as the cartridge loads with dirt. After changing or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



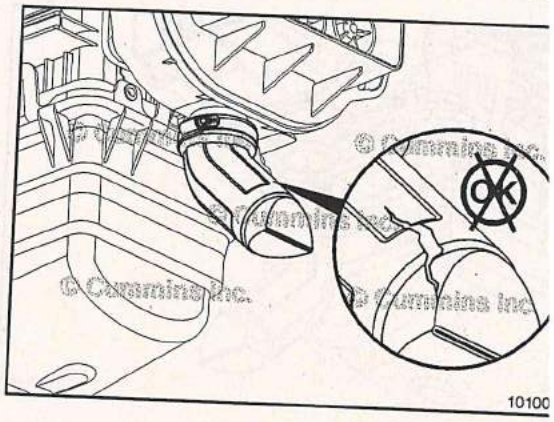

### Industrial Gas Mechanical Indicator

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)

# Dust Ejection Valve

## Maintenance Check

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

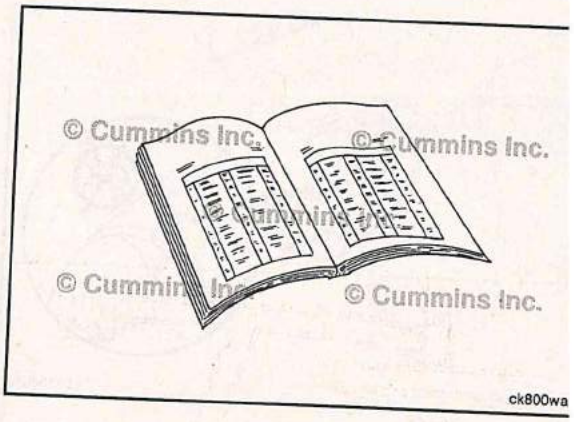



## General Information

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

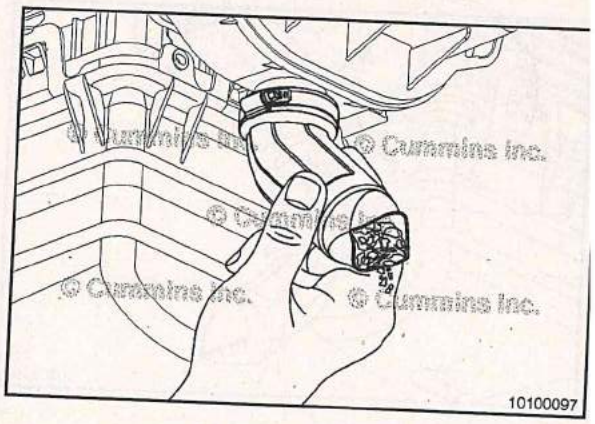
If an application is equipped with a pre-cleaner exhaust aspirator, a dust ejection valve will **not** be present, as the aspirator takes place of the dust ejection valve.

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




## Clean

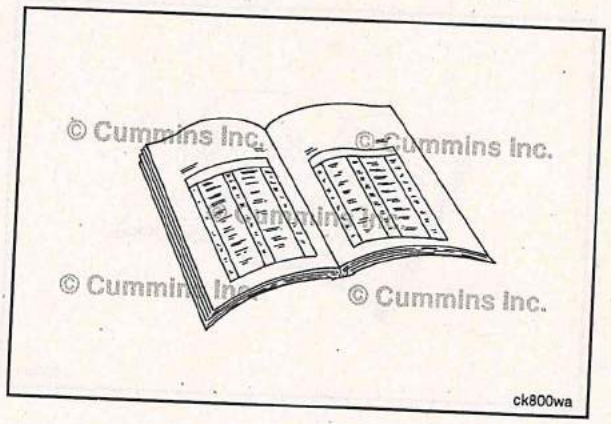
Purge the dust ejection valve of dust by squeezing the valve until it opens. This may have to be performed multiple times depending on the severity of dust or debris found in the valve. If debris is **not** able to be purged from the valve, remove the valve and clean out by hand. Reference the Remove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

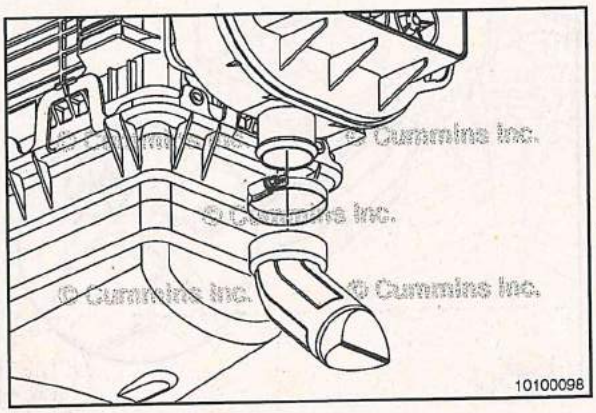



## Preparatory Steps

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

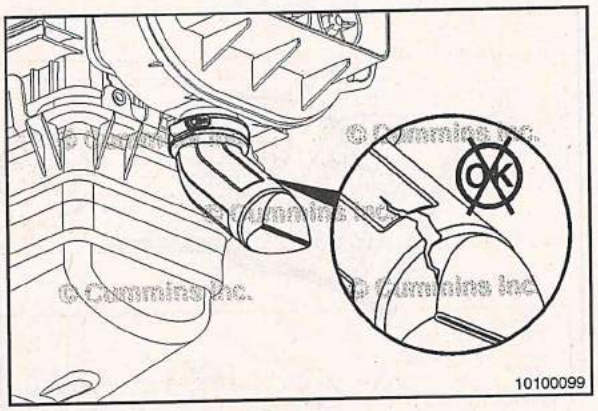
- Shut the engine OFF.





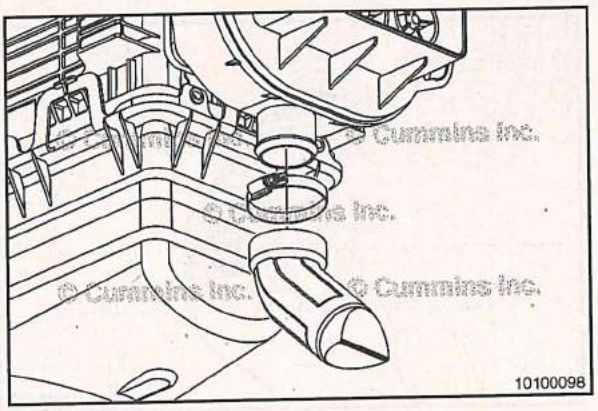

## Remove

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




## Inspect for Reuse

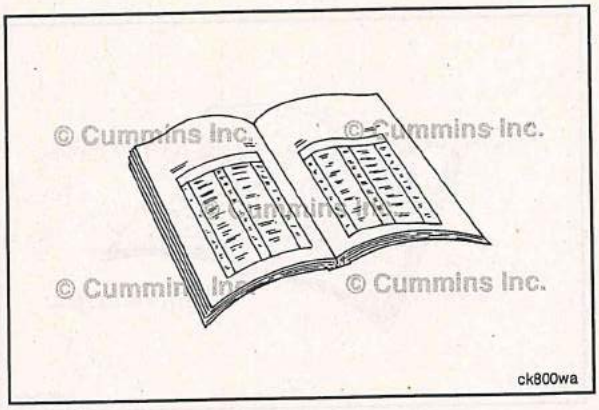
Inspect the dust ejection valve for cuts and tears. Replace the valve if damage is found.




## Install

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

**Torque Value:** 5 N•m [ 44 in-lb ]




## Finishing Steps

- Start the engine.
- Check for leaks.

# Air Intake Piping

## Select Service Tools

### Recommended Cummins® Service Tools

- No Cummins® service tools required.

### Additional Service Items

- No additional service items required.

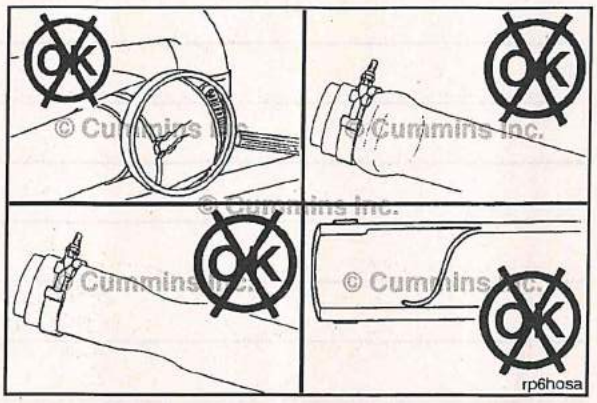
## Maintenance Check

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 ]

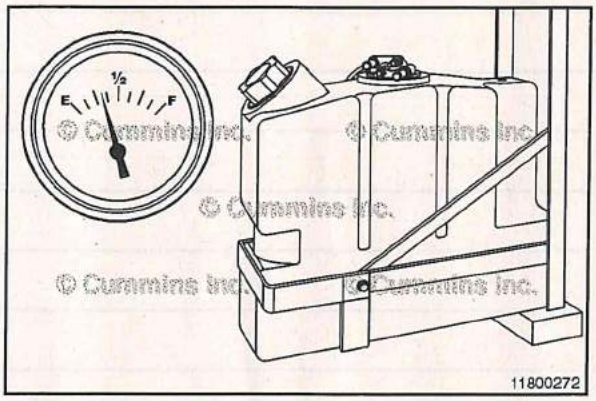
Check for corrosion under the clamps and hoses of the intake system piping. Corrosion can allow corrosive products and dirt to enter the intake system. Disassemble and clean, as required.




# Diesel Exhaust Fluid (DEF) Level

## Maintenance Check

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

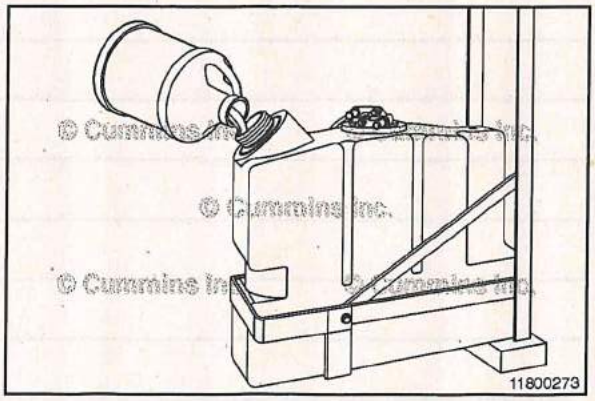



**⚠WARNING⚠**
**Do not allow Diesel Exhaust Fluid to contact the eyes. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. Avoid prolonged contact with skin. In case of contact, immediately wash skin with soap and water. Do not swallow internally. In the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



# Notes

# Section 4 - Maintenance Procedures at 250 Hours or 3 Months

## Section Contents

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# Maintenance Procedures - Overview

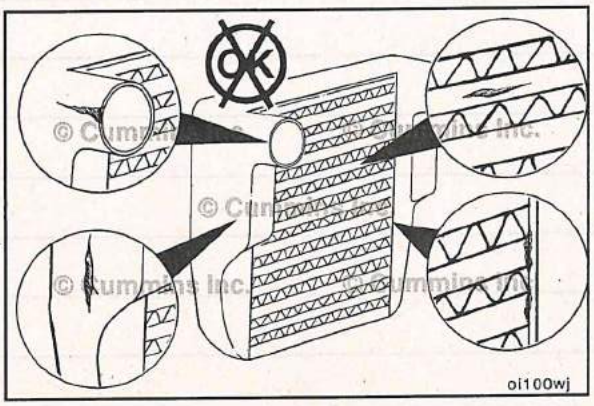
## General Information

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

## Charge-Air Cooler

### Maintenance Check

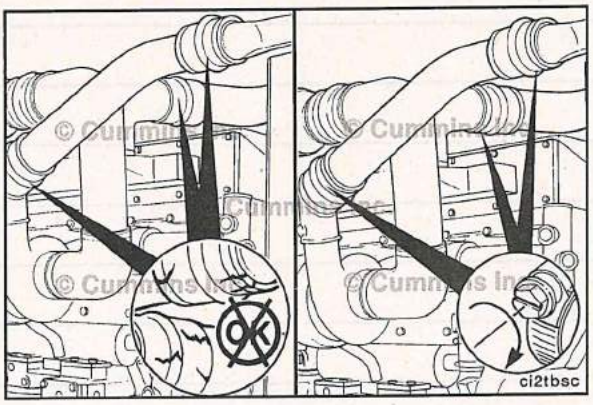
Inspect the charge-air cooler (CAC) for dirt and debris blocking the fins. Check for cracks, holes, or other damage. If damage is found, refer to the vehicle, vessel, or equipment manufacturer.




## 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.



# Notes

# Section 5 - Maintenance Procedures at 500 Hours or 6 Months

## Section Contents

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# Maintenance Procedures - Overview

## General Information

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

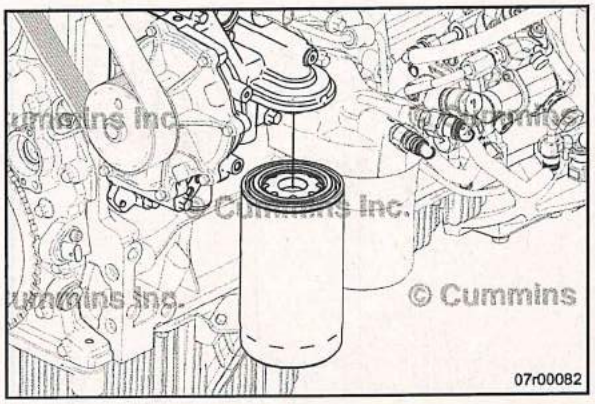
# Lubricating Oil and Filters

## Drain

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

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

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

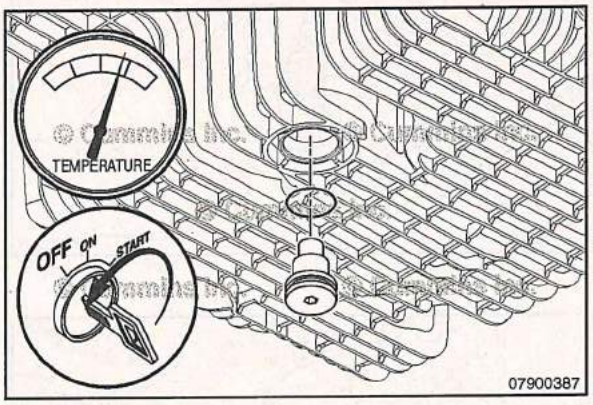


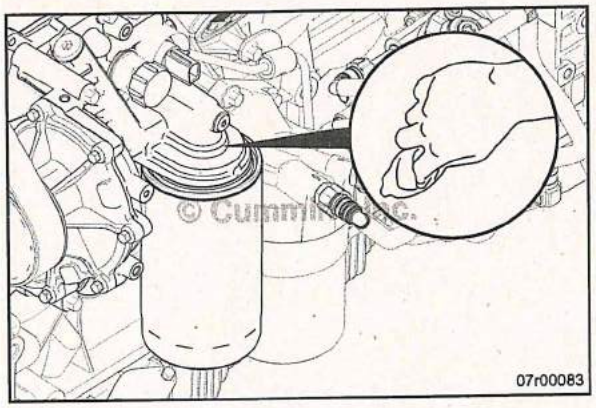

**NOTE:** For most engines, use a container that can hold at least 20 liters [21 qt] of lubricating oil. Some engines may be equipped with an increased capacity oil pan requiring a container that will hold 28 liters [30 qt] of lubricating oil.

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

Shut off the engine.

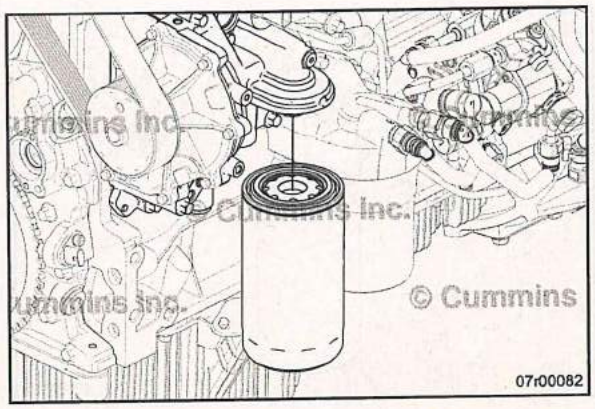
Remove the oil drain plug. Drain the oil immediately to be sure all the oil and suspended contaminants are removed from the engine.



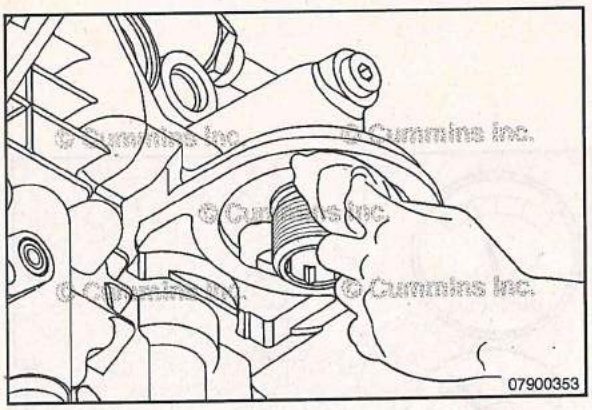



## Remove

Clean the area around the lubricating oil filter head.

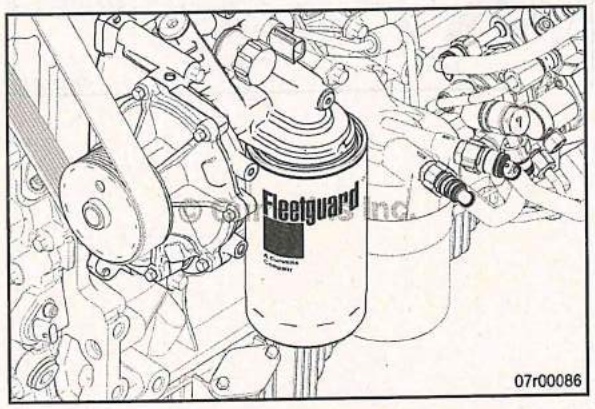



If necessary, use oil filter wrench, Part Number 3400158, to remove filter.




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 Cummins®/Fleetguard® Filter Specifications for the correct oil filter part number. Refer to Procedure 018-024 in Section V.

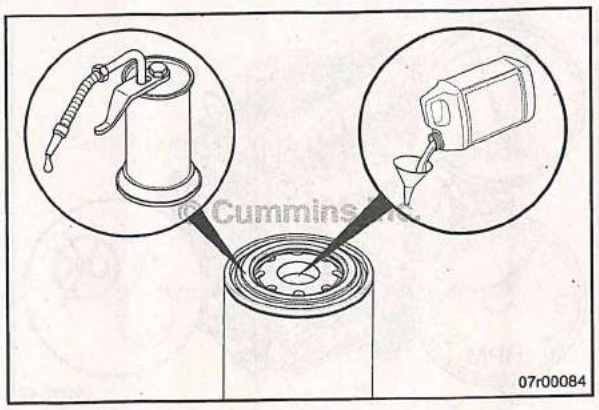
**⚠CAUTION⚠**
**The lack of lubrication during the delay until the filter is pumped full of oil at start-up can damage the engine.**

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

Fill the filter with new 5W-40 engine oil.

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

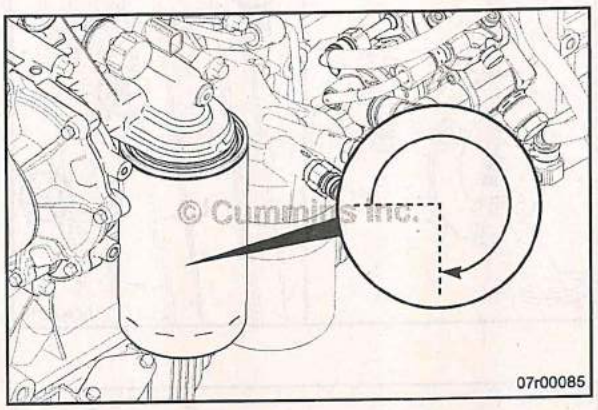
**NOTE:** Be careful that **no** debris is poured into the filter. If using an oil supply with a metallic or plastic seal under the cap, be careful to peel the seal back. Puncturing the seal with a knife or sharp object can create debris in the oil container.




**⚠CAUTION⚠**
**Mechanical overtightening of 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.

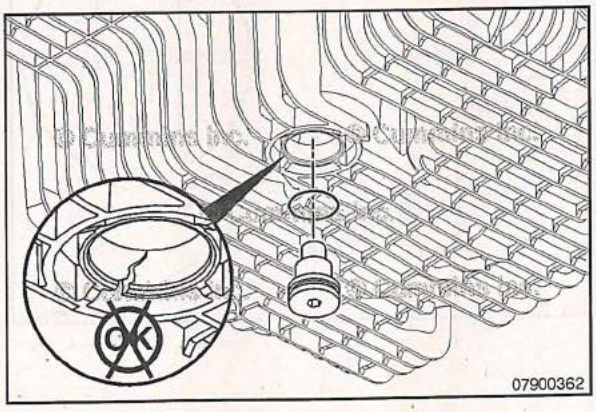



## Fill

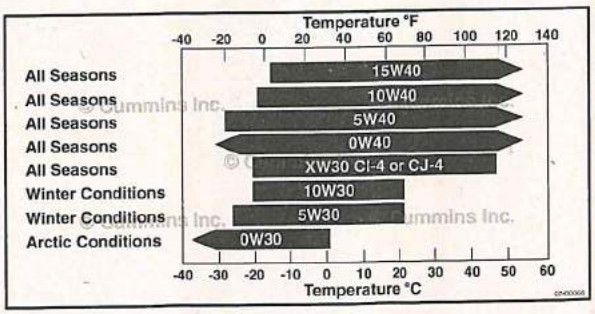
Clean and check the lubricating oil drain plug threads and sealing surface. Use new sealing washer, if damaged.

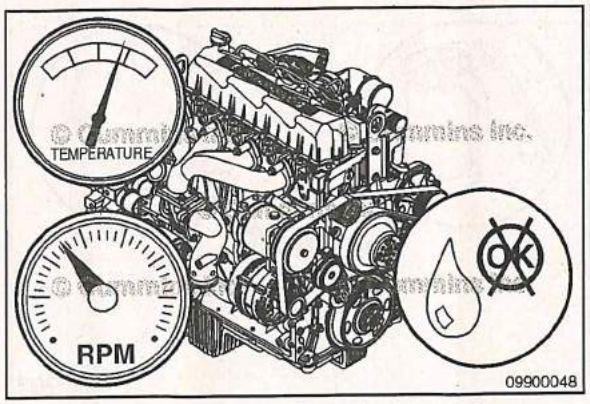
Install the lubricating oil pan drain plug.

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



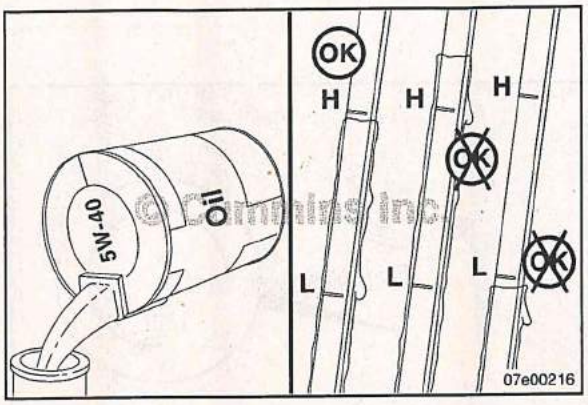

**NOTE:** Use a high-quality 5W-40 multiviscosity lubricating oil, such as Valvoline Premium Blue Extreme®, or its equivalent in this particular Cummins® engine. Choose the correct lubricating oil for your operating climate as outlined in Section V.





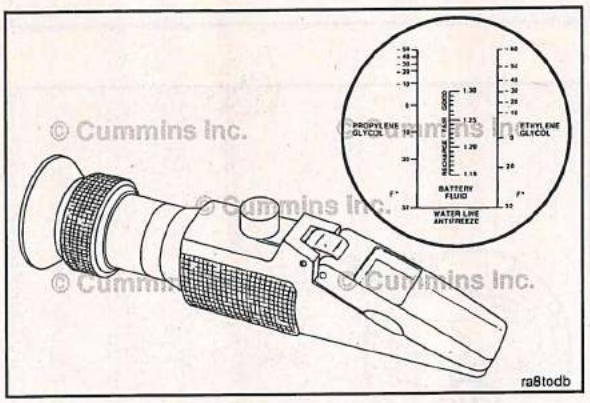

Idle the engine to inspect for leaks at the drain plug and, if replaced, the oil filter seal.

**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 that the correct oil level is in the oil pan.




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

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




## Engine Coolant Antifreeze

### Maintenance Check

**ΔCAUTIONΔ**

**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 CC-2806 or CC-2800, provides a reliable, easy to read, and accurate measurement of freezing point protection and glycol (antifreeze) concentration.

To check the antifreeze concentration:

1. Place a drop of coolant on the refractometer window and shut the lid.
2. Look through the eyepiece and focus.
3. Record the freeze point protection for either ethylene glycol or propylene glycol coolants.

**Antifreeze is essential in every climate.**

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

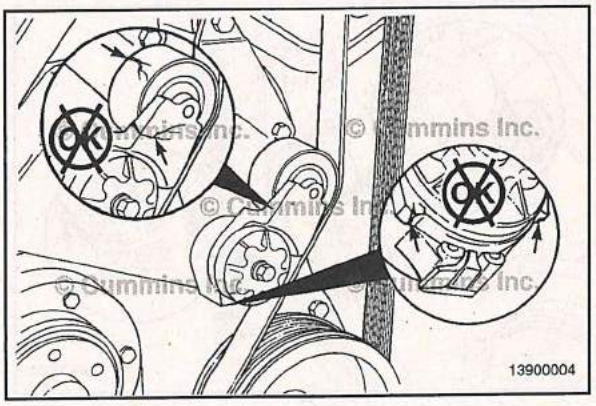
The corrosion inhibitors also protect the cooling system components from corrosion and provide longer component life.

# Cooling Fan Belt Tensioner

## Maintenance Check

**NOTE:** This maintenance check is performed at the Maintenance Procedures at 500 Hours or 6 Months.

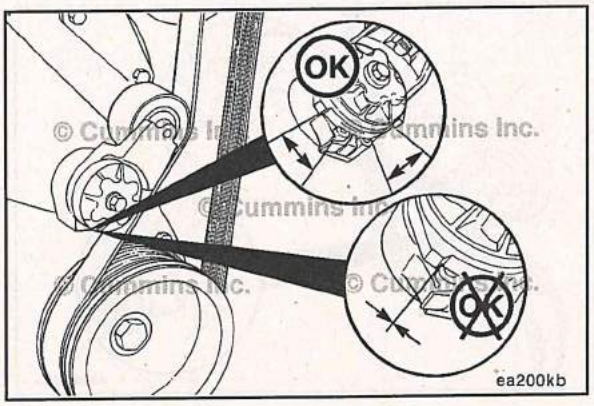
With the engine stopped, check the tensioner arm, pulley, and stops for cracks. If any cracks are noticed, the tensioner **must** be replaced.



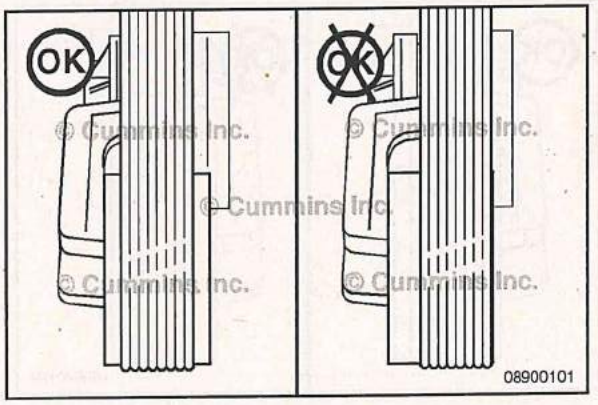

With the belt installed, verify that neither tensioner arm stop is in contact with the spring casing stop. If either of the stops is touching:

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

After replacing the belt, if the tensioner arm stops are still in contact with the spring case stop, replace the tensioner.

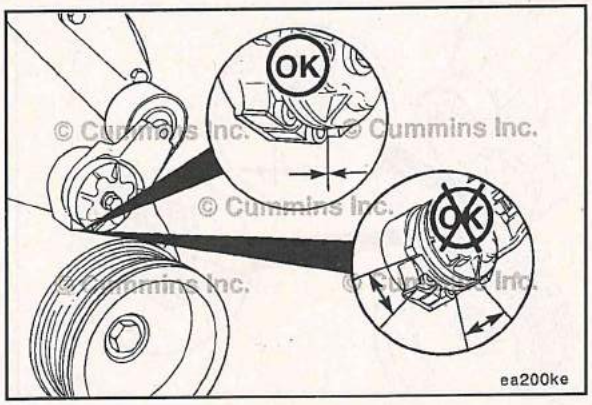


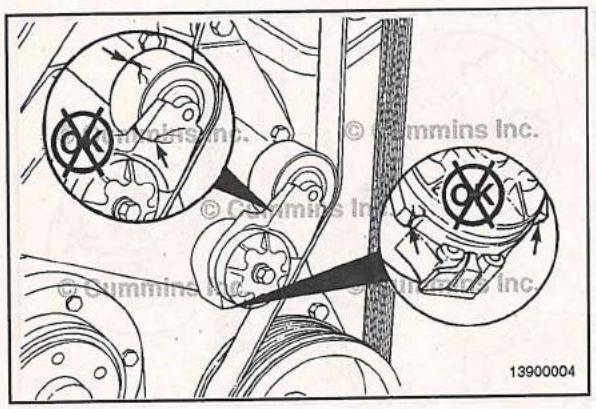

Check the location of the drive belt on the belt tensioner pulley. The belt should be centered on, or close to the middle of, the pulley. Misaligned belts, either too far forward or backward, can cause belt wear, belt roll-off malfunctions, or increase uneven tensioner bushing wear.




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

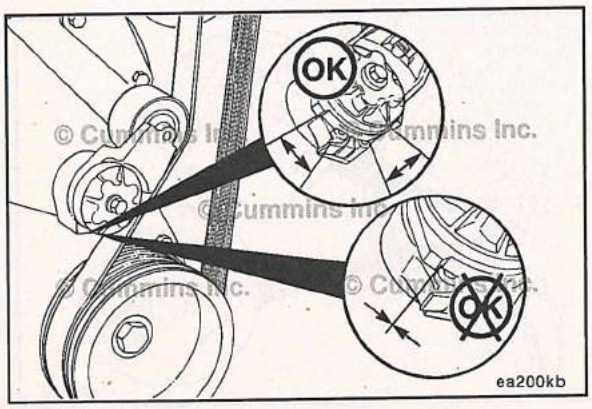
With the belt removed, verify the tensioner arm stop is in contact with the spring case stop. If they are **not** touching, the tensioner **must** be replaced.






## Initial Check

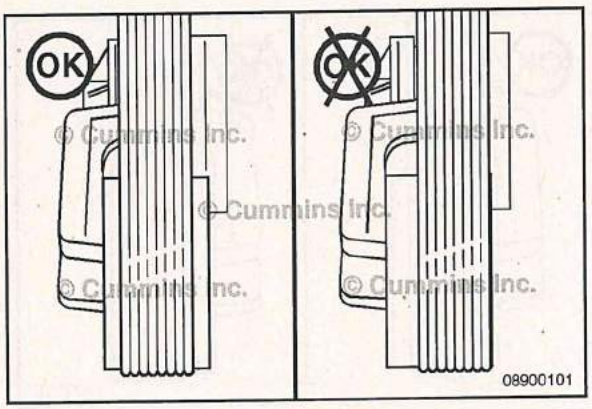
With the engine stopped, check the tensioner arm, pulley, and stops for cracks. If any cracks are noticed, the tensioner **must** be replaced.



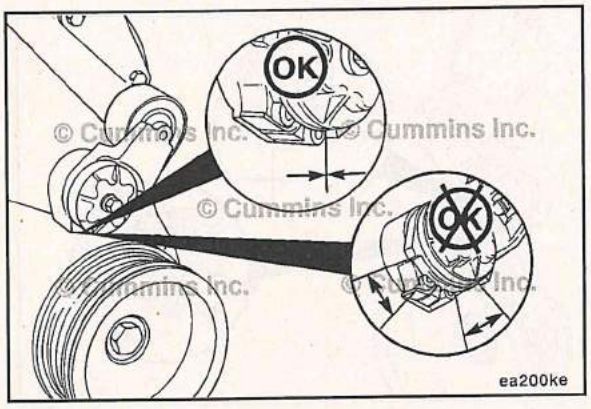

With the belt installed, verify that neither tensioner arm stop is in contact with the spring casing stop. If either of the stops is touching:

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

After replacing the belt, if the tensioner arm stops are still in contact with the spring case stop, replace the tensioner.




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




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

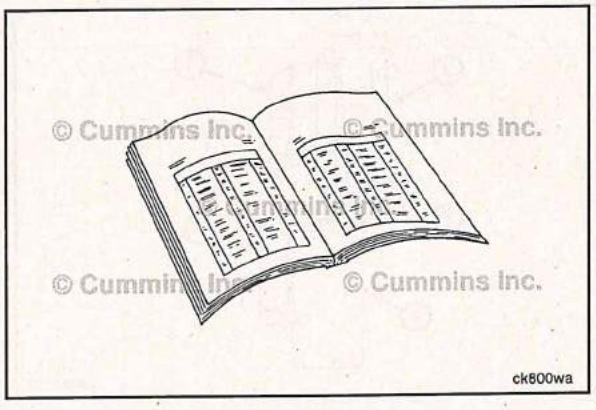
With the belt removed, verify the tensioner arm stop is in contact with the spring case stop. If they are **not** touching, the tensioner **must** be replaced.

## Preparatory Steps

**⚠ WARNING ⚠**

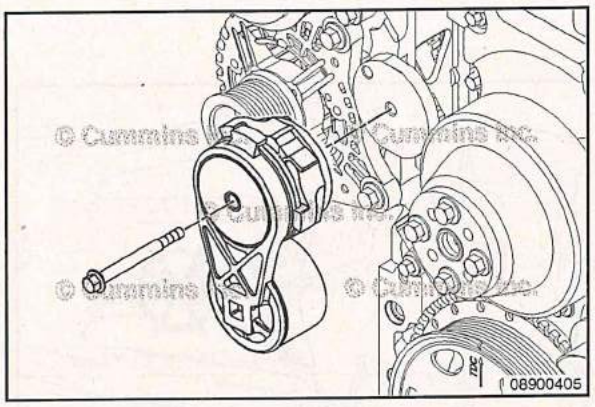
**Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**

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




## Remove

Remove the capscrew and belt tensioner from the bracket.



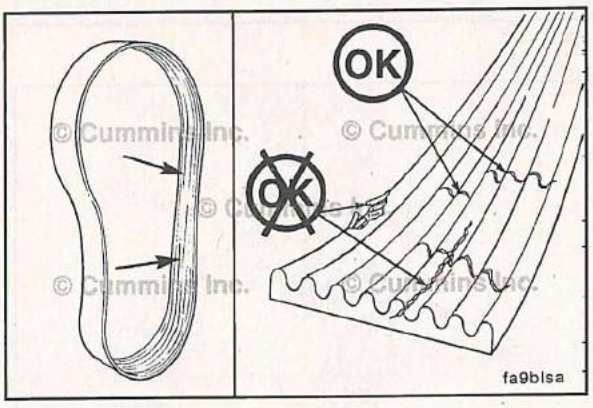

## Clean and Inspect for Reuse

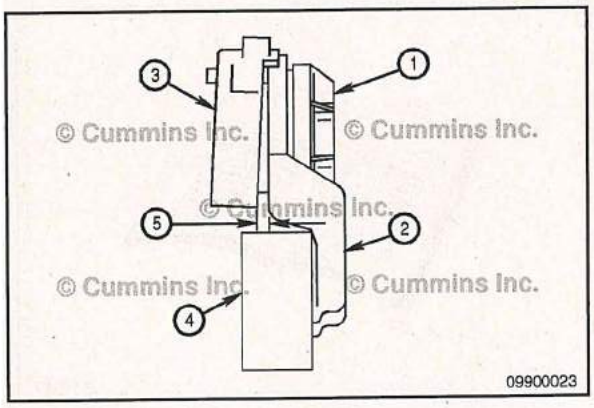
Check the belt for damage.

Transverse (across the belt) cracks are acceptable.

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

If the belt is frayed or has any piece of material missing, the belt is unacceptable and needs to be replaced.

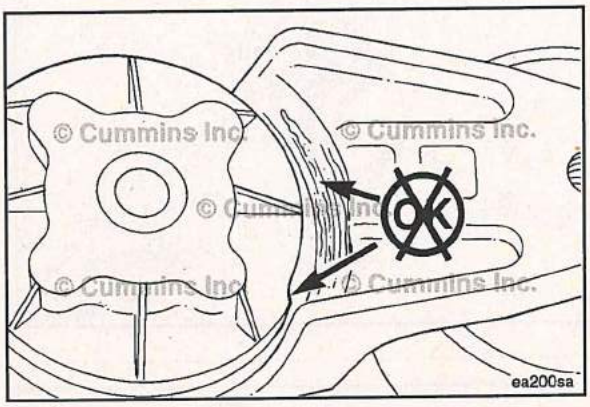




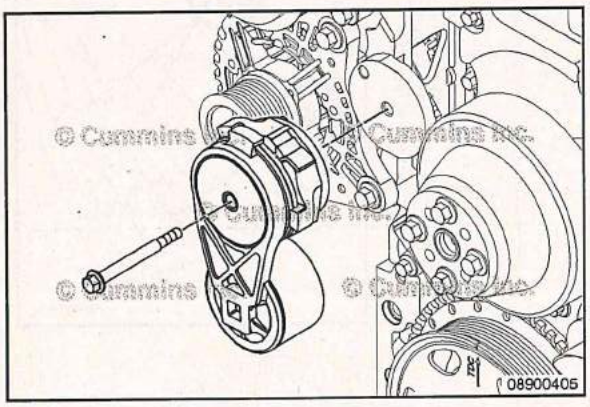

Measure the clearance between the tensioner spring and the tensioner arm to verify tensioner wear-out and uneven bearing wear. If the clearance exceeds 3 mm [0.12 in] at any point, the tensioner has failed and **must** be replaced as a complete assembly.

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. **Always** replace the belt when a tensioner is replaced.

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




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




## Install

Install the belt tensioner and capscrew.

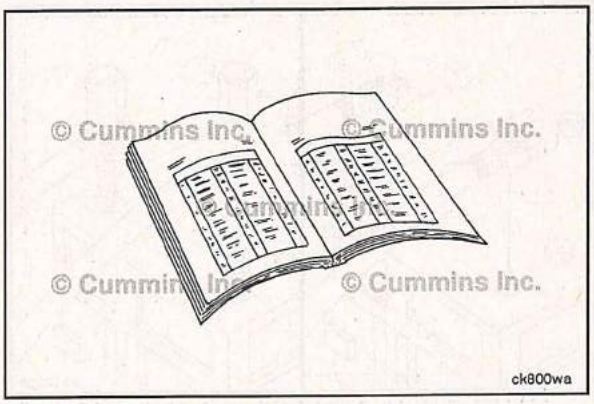
Tighten the capscrew.

**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 A.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to check for proper operation.



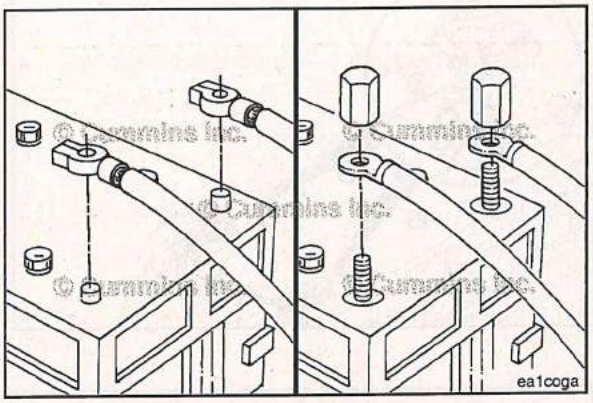

# Batteries

## General Information

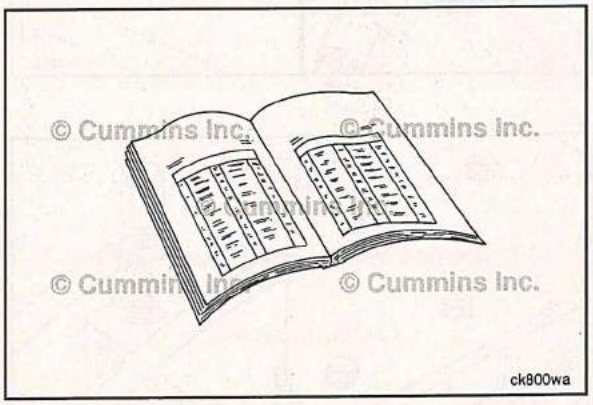
**⚠WARNING⚠**
**Batteries can emit explosive gas. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the battery (-) negative cable first and attach the battery negative cable last.**

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

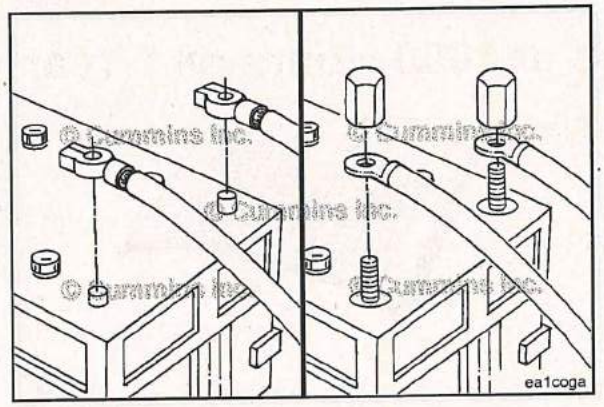



Check Original Equipment Manufacturer (OEM) or battery supplier service literature for battery removal and installation, maintenance, inspection, and testing requirements.



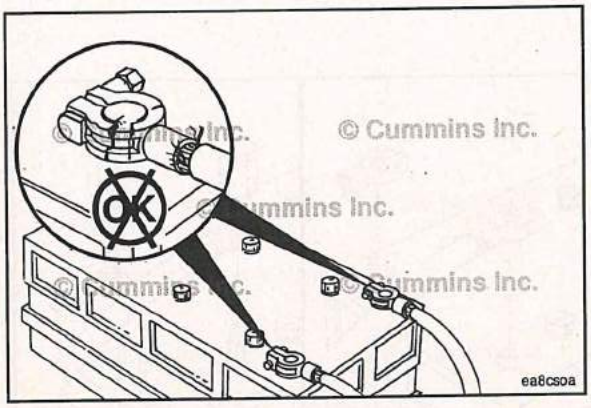
# Battery Cables and Connections

## Initial Check




There are two possible heavy-duty battery connections:

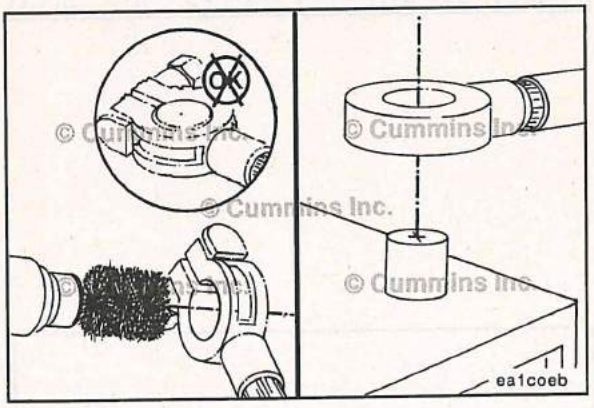
- Battery terminal and clamp (1)
- Threaded battery terminal and nut (2).




**⚠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.**

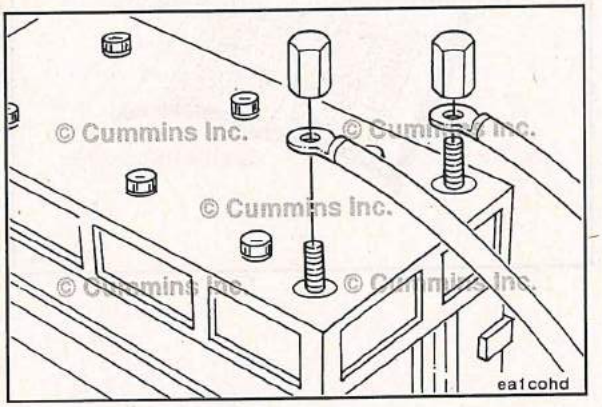
Remove and inspect the battery cables and connections for cracks or corrosion.

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.

# Section 6 - Maintenance Procedures at 1000 Hours or 1 Year

## Section Contents

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# Maintenance Procedures - Overview

## General Information

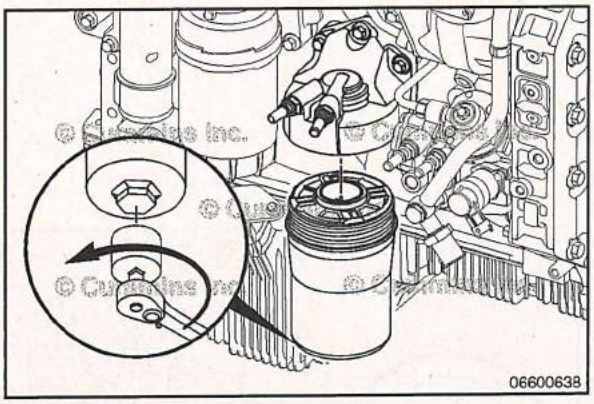
All maintenance checks and inspections listed in previous maintenance intervals **must** also be performed at this time, in addition to those listed under this maintenance interval.

# Fuel Filter (Canister Type)

## Remove

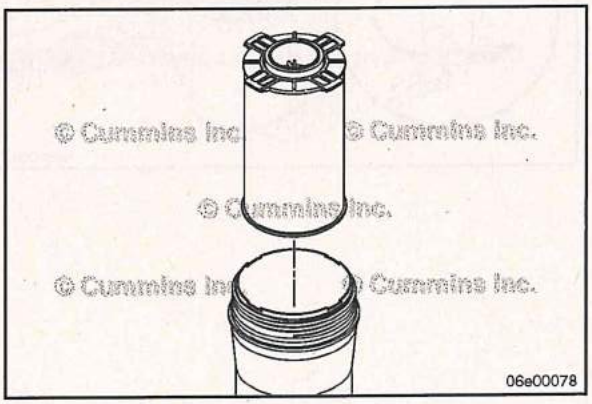
Remove the filter carefully.

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



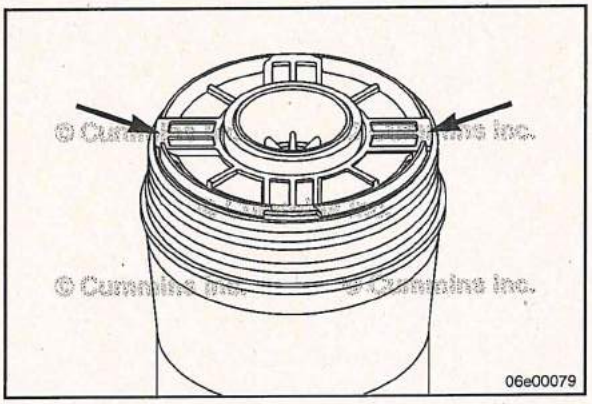

Remove and discard the filter element.

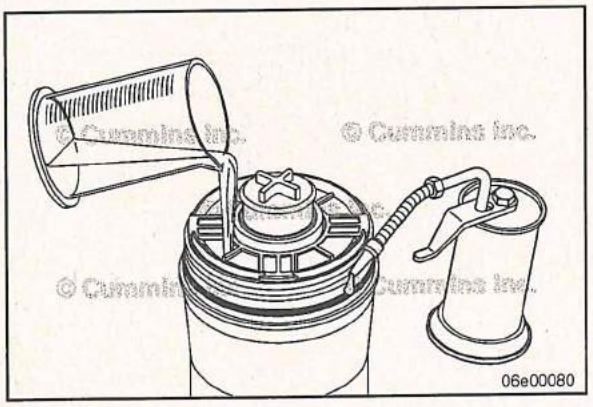
Remove and discard the o-ring seal on the filter canister.




Install a new filter element.

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






## Install

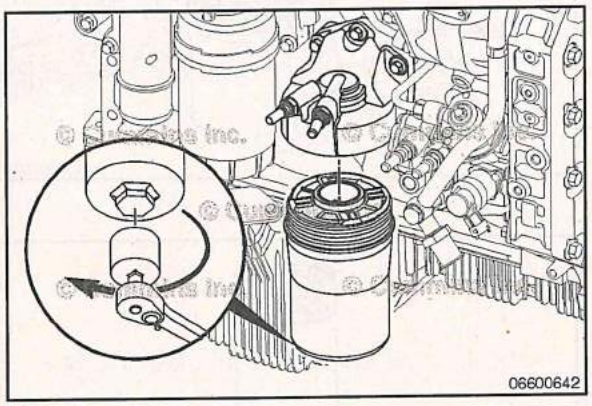
**⚠CAUTION⚠**
**Do not pre-fill the pressure-side fuel filter with fuel unless a clean side block-off plug is used. The system must be primed after the fuel filter is installed. Pre-filling the pressure-side fuel filter can result in debris entering the fuel system and damaging fuel system components.**

**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.**

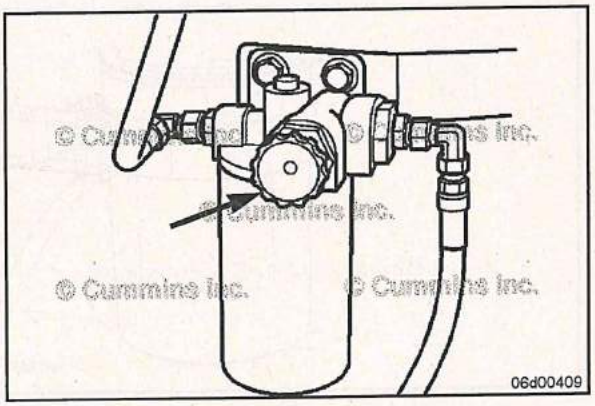
Install the filter on the filter head:

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 ]

## 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.**

**⚠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, Cummins® 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.

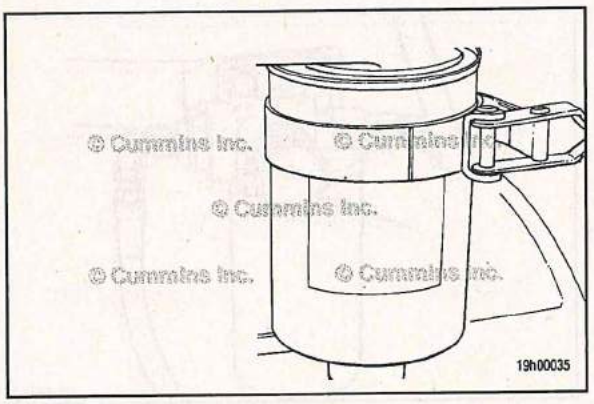
Crank the engine. If the engine does **not** start after 30 seconds, turn the key to the OFF position.

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 that 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, and use INSITE™ electronic service tool to clear the fault code before releasing the vehicle.

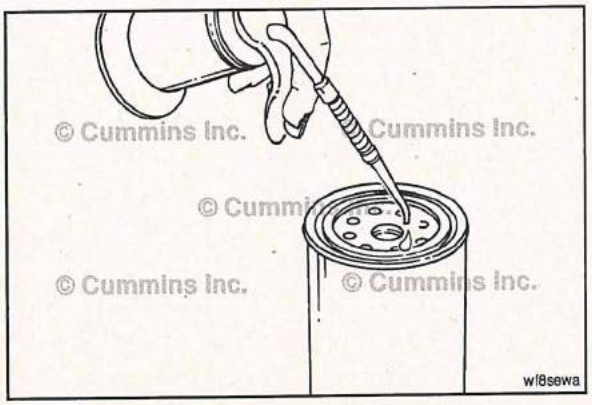
Operate the engine and check for leaks.




# Fuel Filter (Spin-On Type)

## Remove

Remove the fuel filter from the filter head with filter wrench, Cummins® Part Number 3398231, or equivalent.




## Install

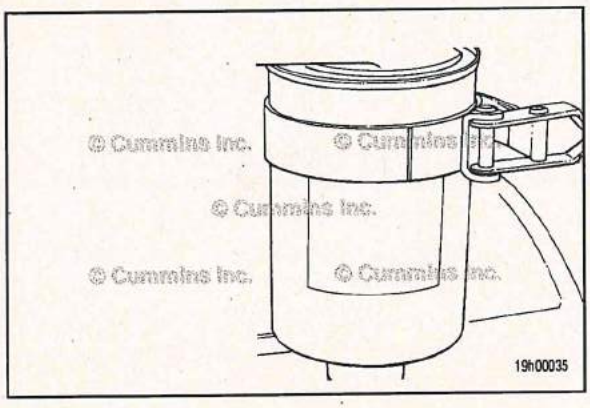
**⚠CAUTION⚠**
**Do not pre-fill the suction side fuel filter with fuel unless a clean side block off plug is used. The system must be primed after the fuel filter is installed. Pre-filling the pressure side fuel filter can result in debris entering the fuel system and damaging fuel system components.**

**NOTE:** If available, pre-fill new filters, 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 as 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 seal with clean lubricating oil.




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

Install the filter on the filter head. Use filter wrench, Cummins® Part Number 3398231, or equivalent. Tighten the filter until the gasket contacts the filter head surface.

Tighten the fuel filter an additional 3/4 turn after contact or see equipment manufacturer service information.

**Torque Value:** 24 N•m [ 204 in-lb ]

### Prime

**⚠WARNING⚠**
**The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. To reduce the possibility of personal injury, never loosen any fittings while the engine is running.**

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

After a fuel filter change or running the vehicle 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 **counterclockwise**. Pump the primer handle until resistance is felt and the handle can **not** be pumped any longer (approximately 140 to 150 strokes for dry filters, or 20 to 60 strokes for pre-filled filters).

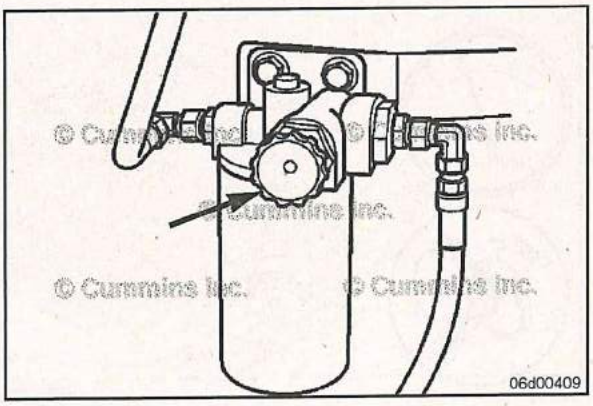
Lock the manual priming pump handle.

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

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

When the engine does start, it may run erratically and with increased noise levels for a few minutes. This is a normal condition.

Operate the engine and check for leaks.



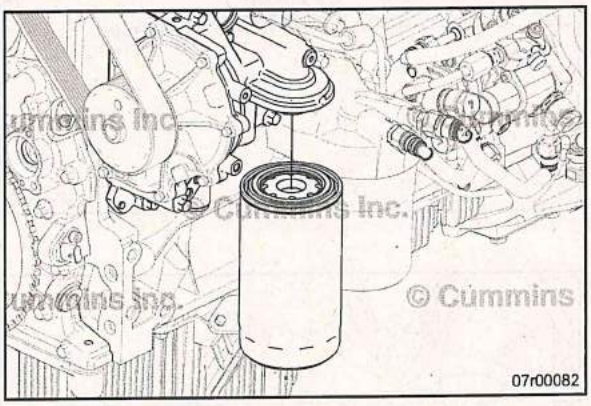

## Lubricating Oil and Filters

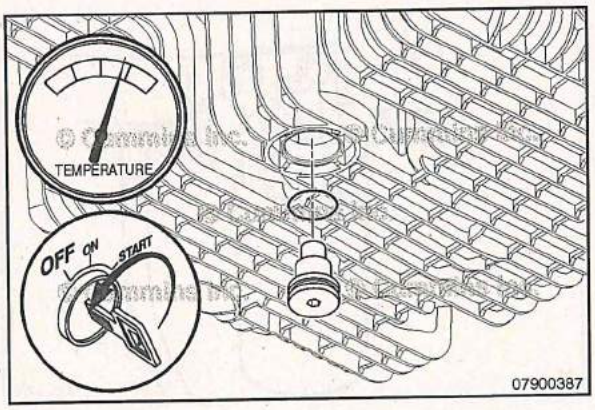
### Drain

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

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

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



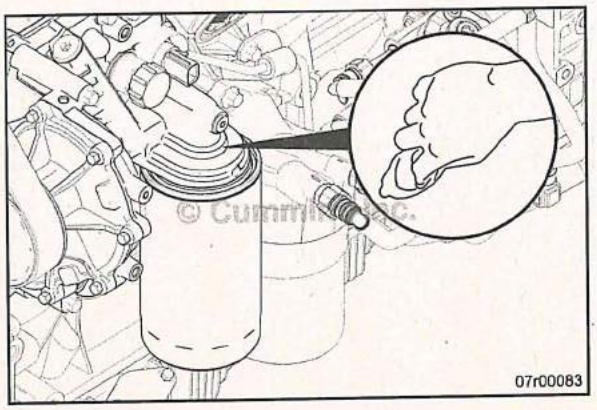



**NOTE:** For most engines, use a container that can hold at least 20 liters [21 qt] of lubricating oil. Some engines may be equipped with an increased capacity oil pan requiring a container that will hold 28 liters [30 qt] of lubricating oil.

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

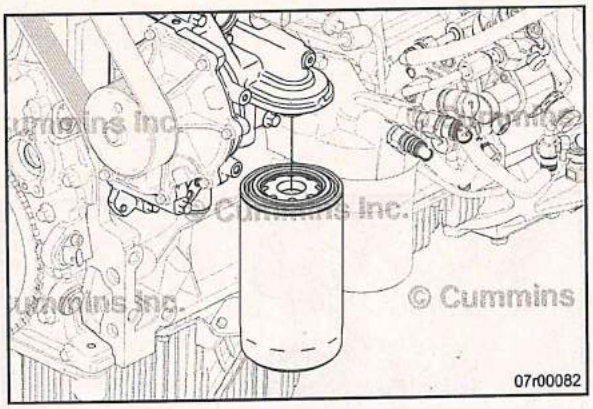
Shut off the engine.

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

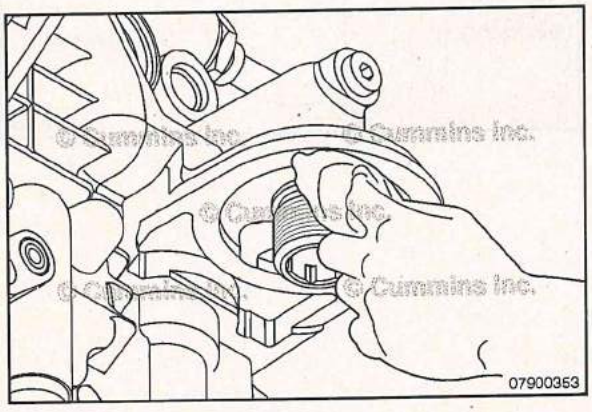



## Remove

Clean the area around the lubricating oil filter head.




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



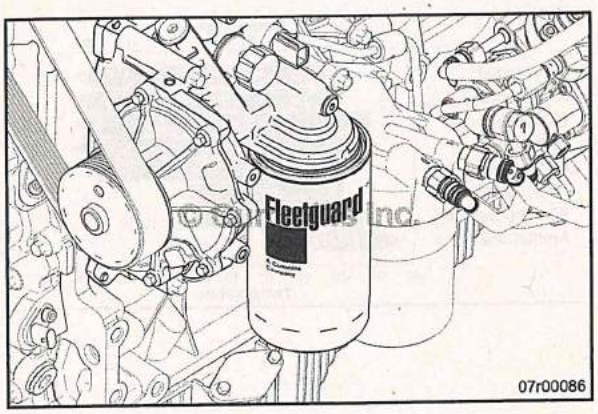

Clean the gasket surface of the filter head.

**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 Cummins®/Fleetguard® Filter Specifications for the correct oil filter part number. Refer to Procedure 018-024 in Section V.



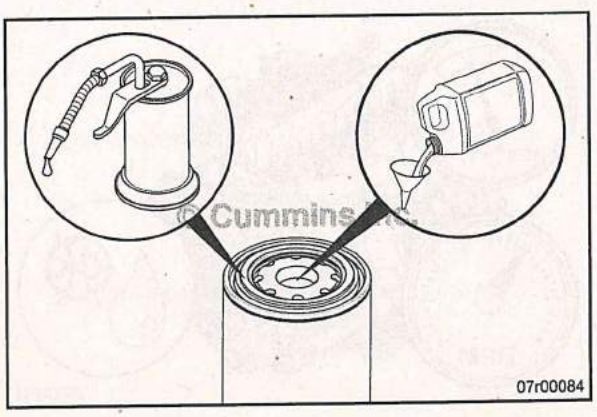

**⚠CAUTION⚠**
**The lack of lubrication during the delay until the filter is pumped full of oil at start-up can damage the engine.**

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

Fill the filter with new 5W-40 engine oil.

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

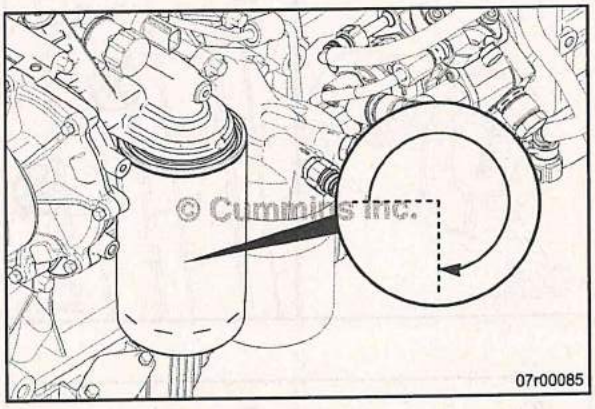
**NOTE:** Be careful that **no** debris is poured into the filter. If using an oil supply with a metallic or plastic seal under the cap, be careful to peel the seal back. Puncturing the seal with a knife or sharp object can create debris in the oil container.




**⚠CAUTION⚠**
**Mechanical overtightening of 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.

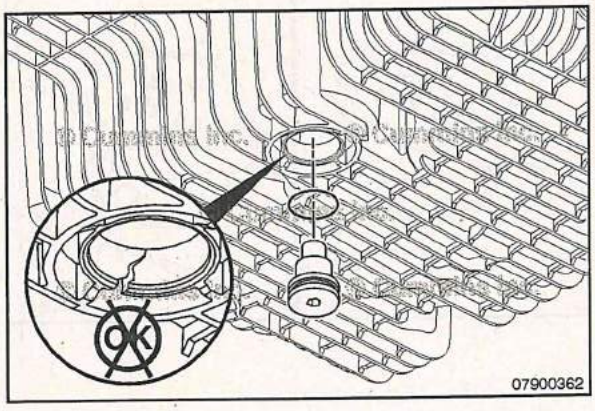


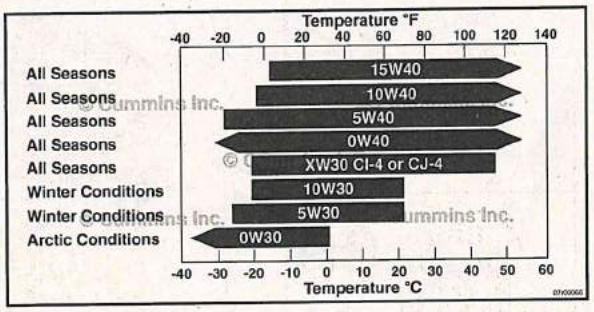

## Fill

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

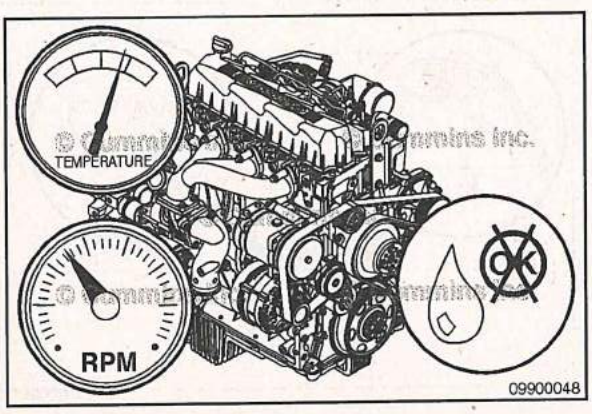
Install the lubricating oil pan drain plug.

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



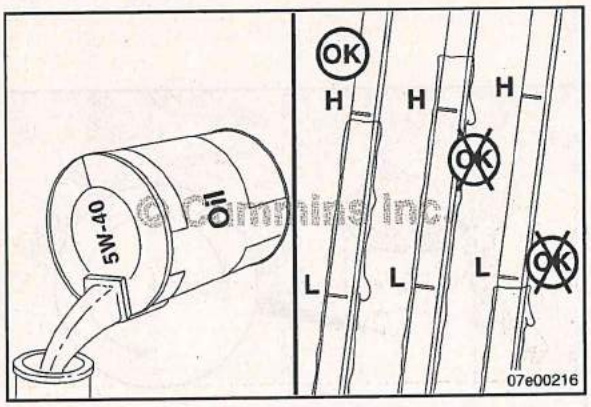



**NOTE:** Use a high-quality 5W-40 multiviscosity lubricating oil, such as Valvoline Premium Blue Extreme®, or its equivalent in this particular Cummins® engine. Choose the correct lubricating oil for your operating climate as outlined in Section V.



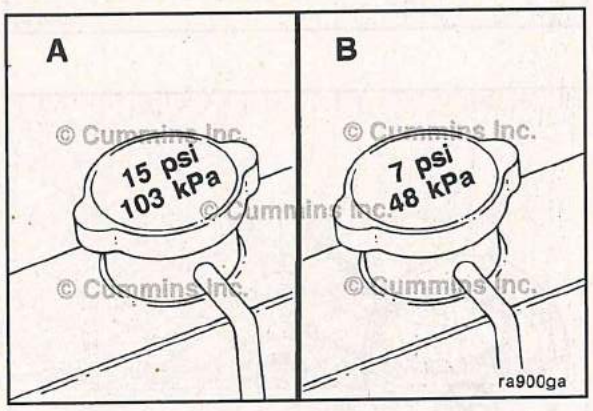

Idle the engine to inspect for leaks at the drain plug and, if replaced, the oil filter seal.

**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 that the correct oil level is in the oil pan.




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

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




## Radiator Pressure Cap

### General Information

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

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

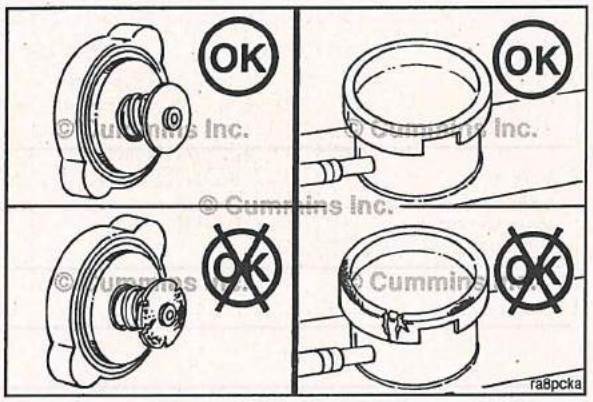
## Inspect for Reuse

Make sure the correct radiator pressure cap is being used.

Inspect the rubber seal of the pressure cap for damage.

Inspect the radiator fill neck for cracks or other damage.

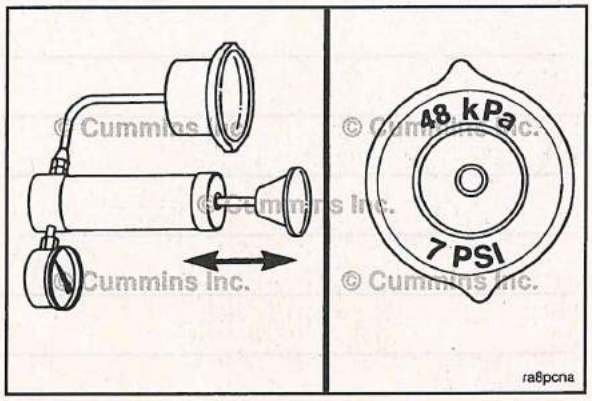
See equipment manufacturer service information for instructions if the fill neck is damaged.




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

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

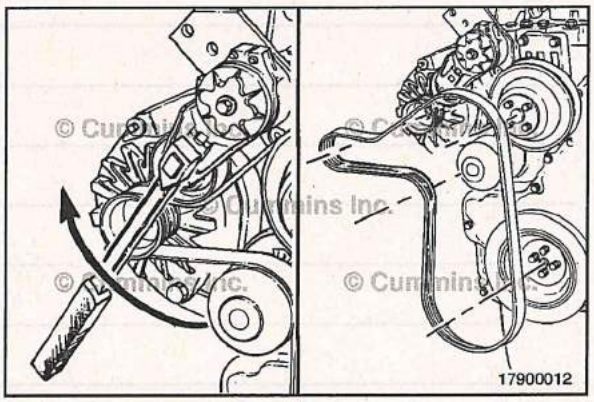
An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.




## Fan Hub, Belt Driven

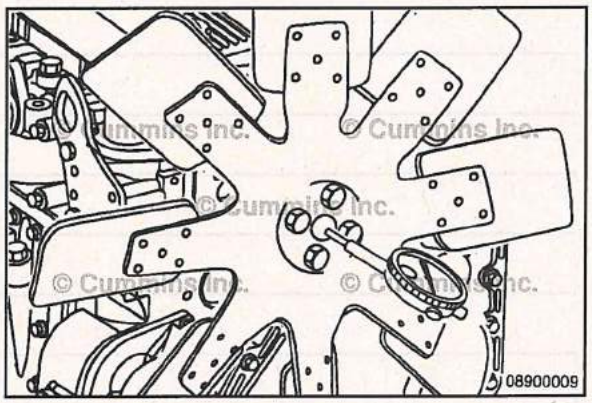
### Maintenance Check

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




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

| Fan Hub End Clearance | | |
|---|---|---|
| mm | | in |
| 0.15 | MAX | 0.006 |



# Notes

# Section 7 - Maintenance Procedures at 2000 Hours or 2 Years

## Section Contents

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# Maintenance Procedures - Overview

## General Information

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

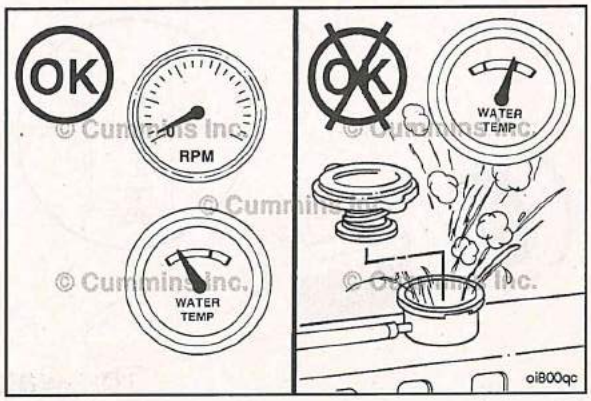
# Cooling System

## General Information

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

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

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



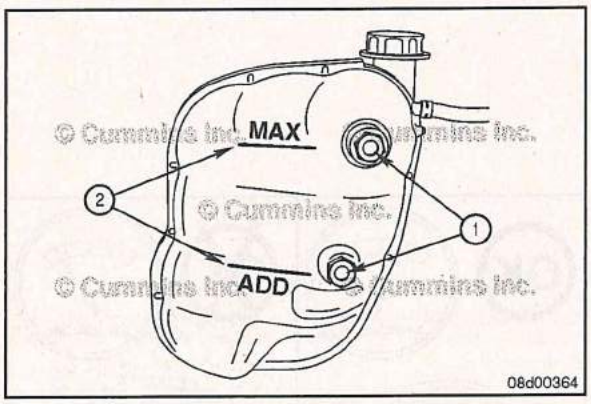

**△CAUTION△**
**Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool below 50°C [122°F] before adding coolant.**

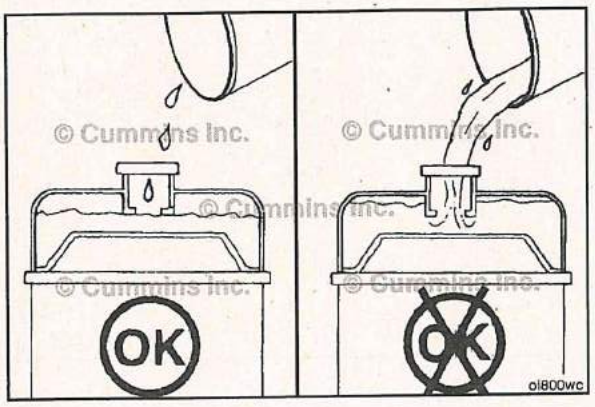
**NOTE:** In the event of a water pump or exhaust gas recirculation (EGR) cooler malfunction, check the coolant level switch or sensor for proper operation. See equipment manufacturer service information for operational checks and repairs.

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

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

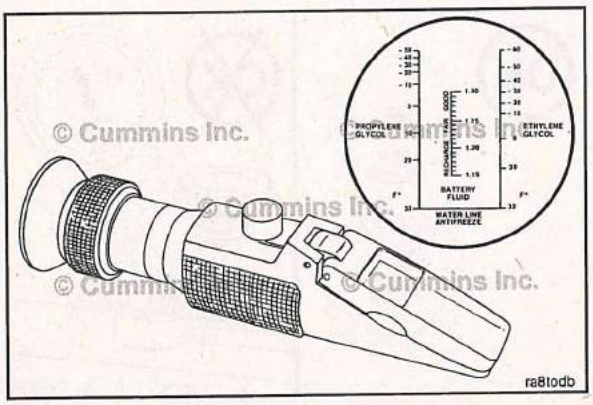
It is important to understand the impact of temperature on the expansion of the coolant. Most "top tanks" do **not** have a provision for a "FULL HOT" coolant level. Filling the top tank while hot will result in a low operating level once the system has cooled.






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 filled.




## Maintenance Check

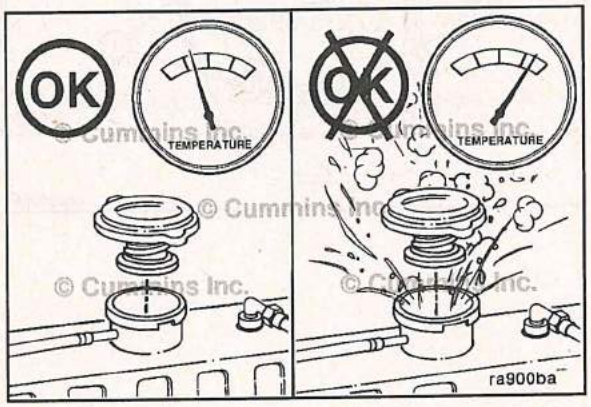
**△CAUTION△**
**Over-concentration of antifreeze or use of high silicate antifreeze can cause damage to the engine.**

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

The Fleetguard™ refractometer, Part Number CC-2806, provides a reliable, easy to read, and accurate measurement of freeze point protection and glycol (antifreeze) concentration.

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

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




## Drain

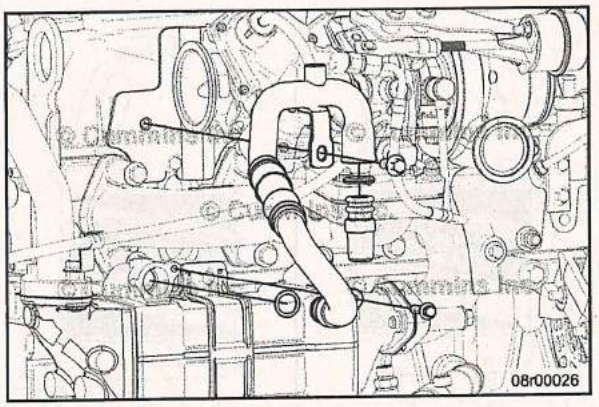
**⚠WARNING⚠**
**Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.**

Remove the radiator/expansion tank cap.

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

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

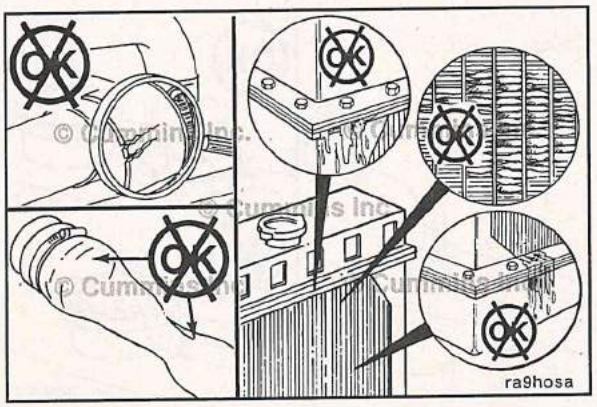
**NOTE:** On applications with an EGR system, disconnect the EGR cooler coolant return line to make sure the coolant is drained from the EGR cooler.




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

Check the radiator for leaks, damage, and buildup of dirt. Clean and replace, as required.

**NOTE:** If coolant has been contaminated, the cooling system should be flushed.



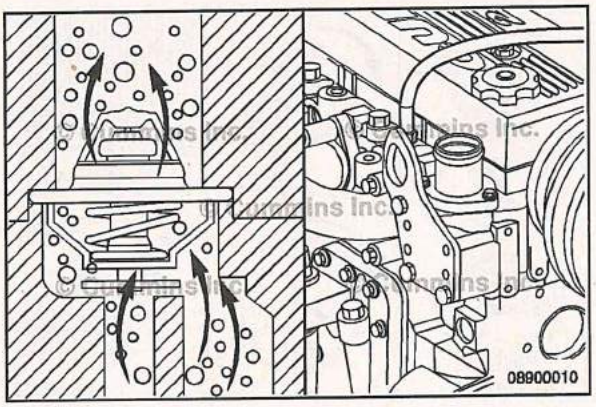

## Flush

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

To make sure air is vented during the fill process:

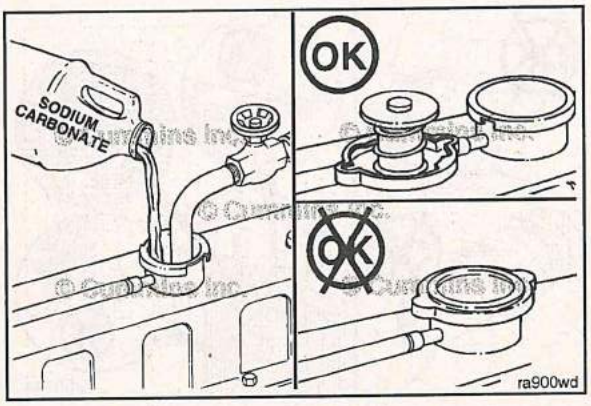
- The thermostat has check balls that allow air to vent through the thermostat when the thermostat is closed.
- A deaeration port is located next to the water outlet connection, which connects to the top tank/coolant recovery tank of the cooling system.

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




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

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




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

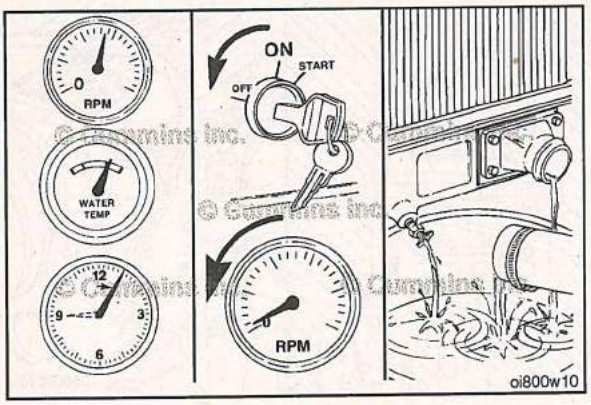
Close the radiator drain valve.

Install the plug in the water inlet connection.

Install the EGR coolant return connection.

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

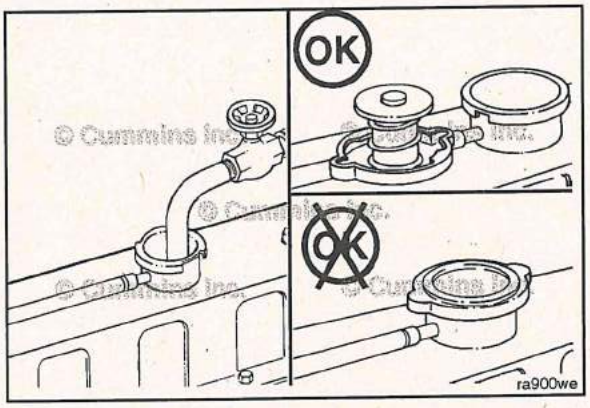
**NOTE:** Adequate venting is provided for a fill rate of 11 liters [3 gal] per minute.




**⚠WARNING⚠**
**Coolant is toxic. Keep away from children and pets. Dispose of in accordance with local environmental regulations.**

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

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



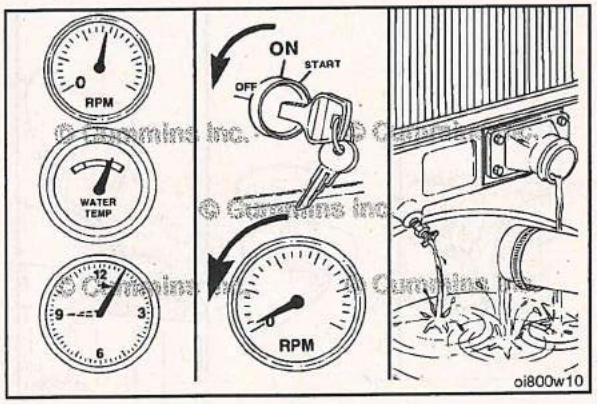

Fill the cooling system with clean water.

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

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

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

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



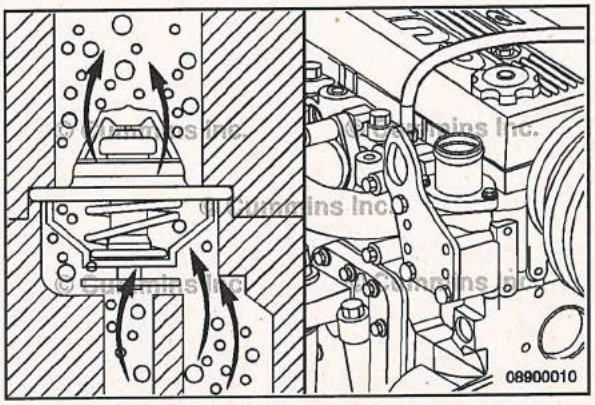

## Fill

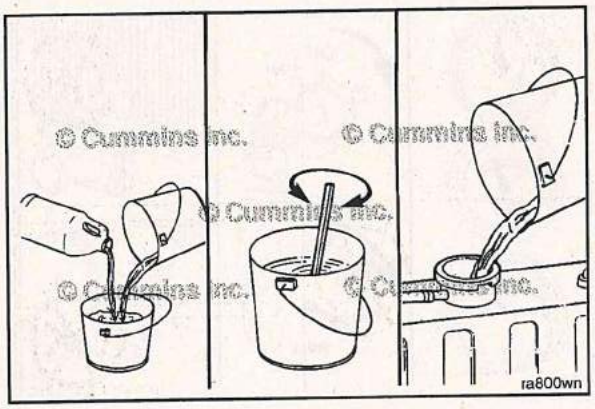
**⚠CAUTION⚠**
**The cooling system must be filled properly to prevent air locks. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.**

To make sure air is vented during the fill process:

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

The system has a design fill rate of 19 liters [5 gal] per minute.






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

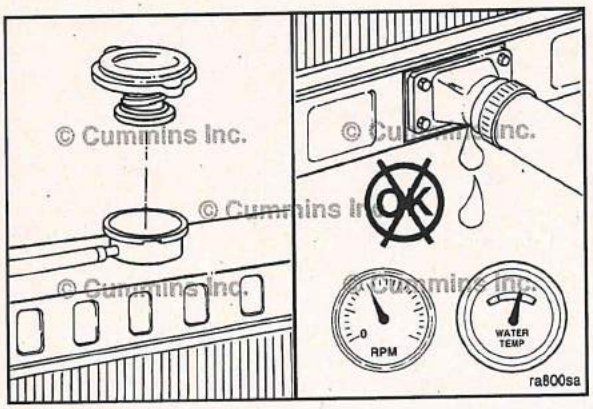
**⚠CAUTION⚠**
**Engine and component damage may result if adequate cool down time is not given after the cooling system pressure has been relieved in order to top off with coolant. System pressure is only generated with the temperature rise of the coolant. Closing the cooling system while hot will not allow for 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 or propylene glycol antifreeze to fill the cooling system.

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

Use the following procedure for cooling system capacity. Refer to Procedure 018-018 in Section V.




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

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

Install the pressure cap.

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

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

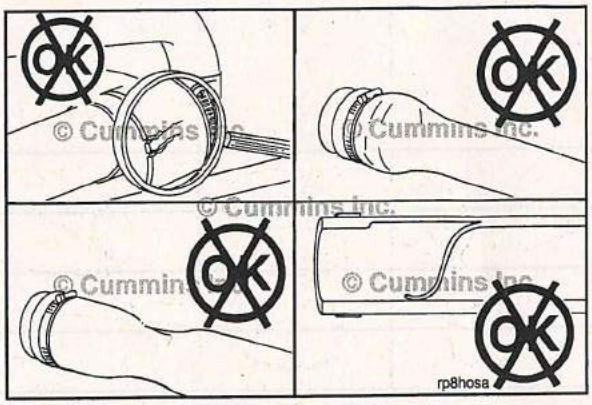
# Radiator Hoses

## Maintenance Check

Check all hoses for cracks, cuts, or collapsing.

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

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



# Notes

# Section 8 - Maintenance Procedures at 4000 Hours or 3 Years

## Section Contents

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# Maintenance Procedures - Overview

## General Information

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

# Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter

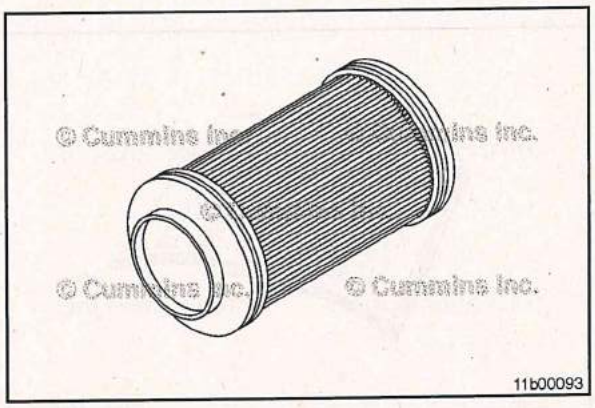
## General Information

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

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

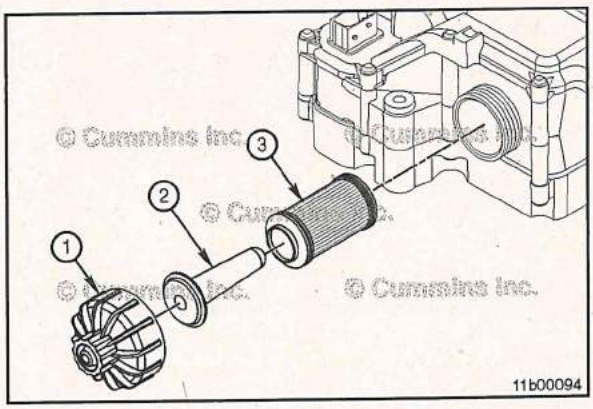
For handling incorrect or contaminated DEF, contact a Cummins® Authorized Repair Location.

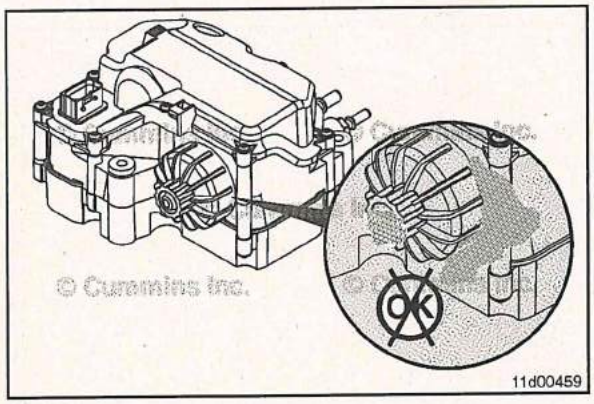
Use the following procedure for handling incorrect or contaminated DEF.




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.





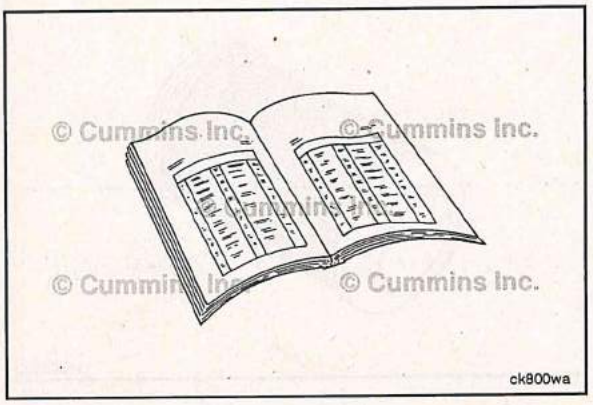

## Initial Check

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

**NOTE:** The location of the aftertreatment DEF dosing unit varies on vehicles. Locate the DEF tank and 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 five 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. Refer to the equipment manufacturer service information.

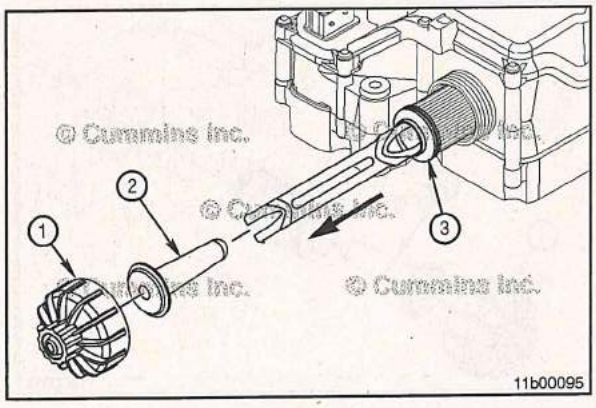
## Remove

**NOTE:** There may 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

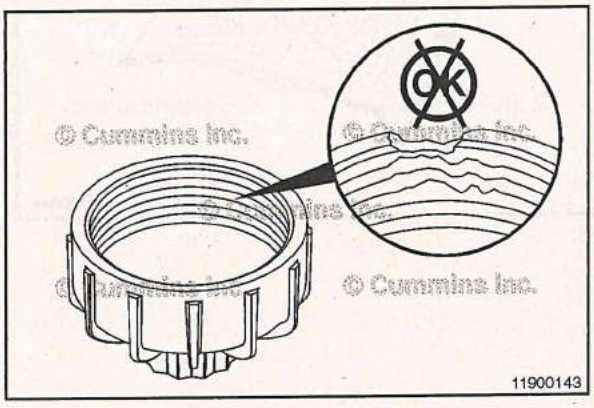
Inspect the aftertreatment DEF dosing unit filter cap for cracks or holes that could create a DEF leak path.

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.

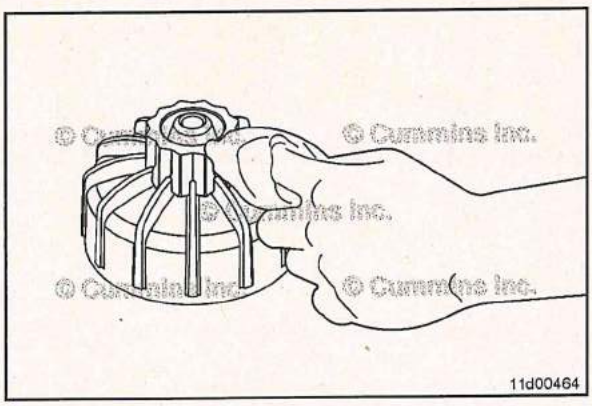
Inspect the aftertreatment DEF dosing unit threads. This is especially important if the aftertreatment DEF dosing unit cap was damaged.

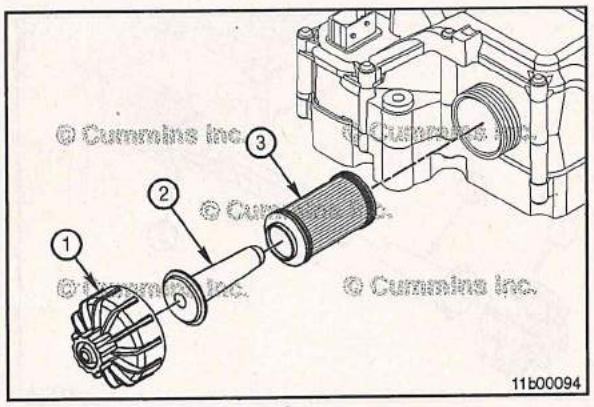
If the aftertreatment DEF dosing unit threads are damaged, replace the entire aftertreatment DEF dosing unit.




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

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






## Install

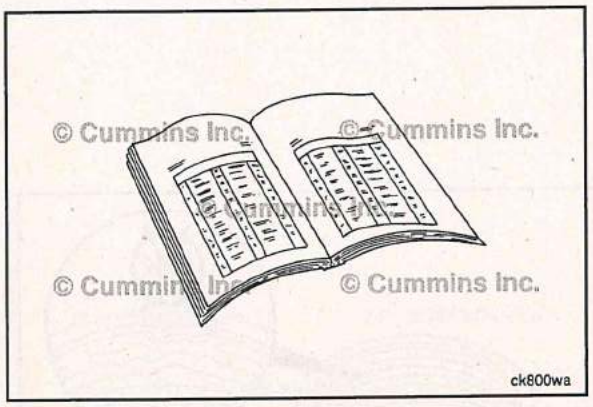
**NOTE:** Lubrication of the DEF filter o-rings is **not** required.

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.**

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

- Connect the batteries. Refer to the equipment manufacturer service information.
- Use INSITE™ electronic service tool to perform the Aftertreatment Diesel Exhaust Fluid Leak Test, under Engine Control Module Diagnostics Tests.
- Operate the engine and check for leaks.

# Section 9 - Maintenance Procedures at 5000 Hours or 4 Years

## Section Contents

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# Maintenance Procedures - Overview

## General Information

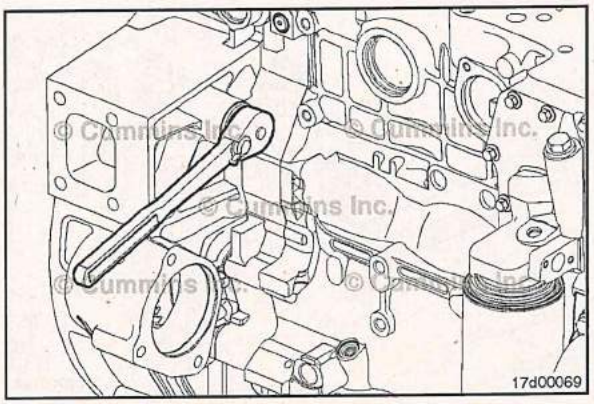
All maintenance checks and inspections listed in previous maintenance intervals **must** also be performed at this time, in addition to those listed under this maintenance interval.

# Overhead Set

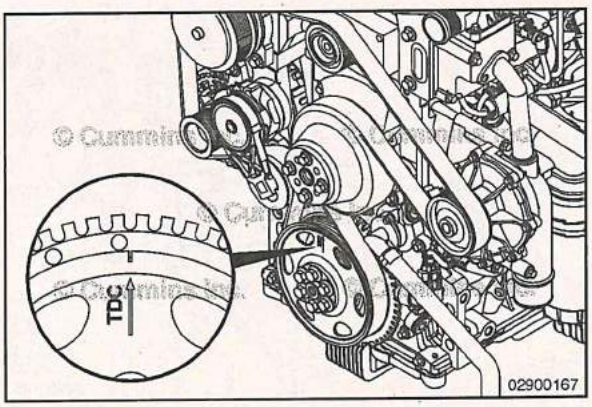
## Adjust

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

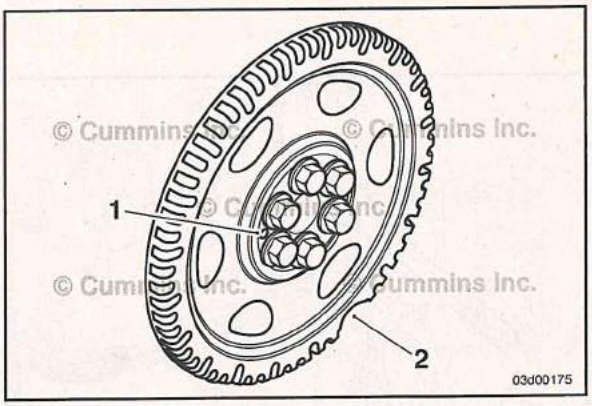
Use the barring tool, Cummins® Part Number 3824591, to rotate the crankshaft until the number 1 cylinder is at top dead center (TDC).

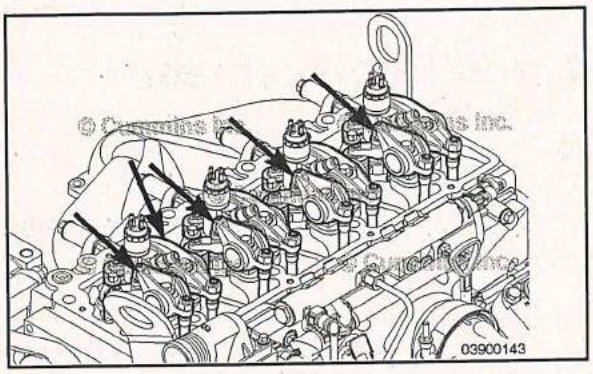



The TDC indicator is on the crankshaft speed indicator ring.




**NOTE:** If no TDC mark is present on either 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 and check the proper levers again.

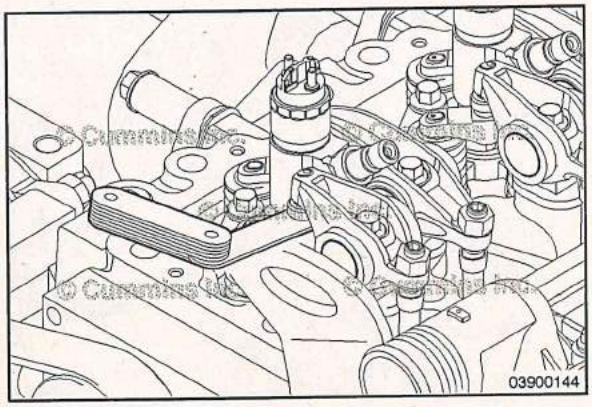





With the engine in this position, lash can be measured on the following rocker levers:

(E = Exhaust, I = Intake)

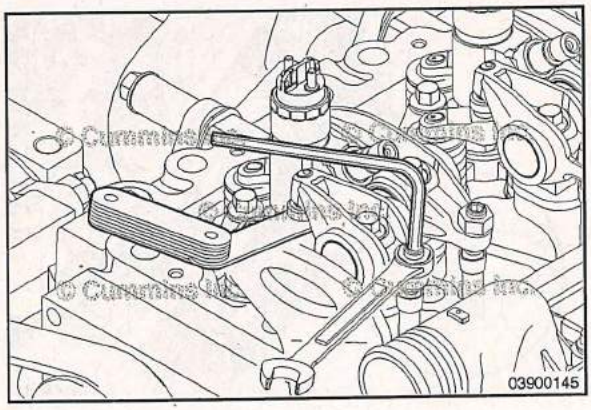
1I, 1E, 2I, and 3E:




**Lash Check Limits**

| | mm | | in |
|---|---|---|---|
| Intake | 0.28 | MIN | 0.011 |
| | 0.381 | MAX | 0.015 |
| Exhaust | 0.53 | MIN | 0.021 |
| | 0.63 | MAX | 0.025 |

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



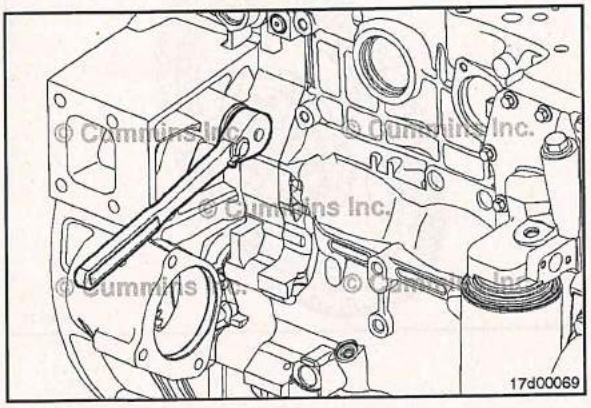

**NOTE:** The clearance is correct when some resistance is "felt" when the feeler gauge is slipped between the crosshead and the rocker lever socket.

Measure lash by inserting a feeler gauge between the crosshead and the rocker lever socket. If the lash measurement is out of specification, loosen the locknut and adjust the lash to nominal specifications.

| Valve Lash Specifications (Nominal) | |
|---|---|
| | mm |
| Intake | 0.33 |
| Exhaust | 0.58 |

Tighten the locknut and measure the lash again.

**Torque Value:** 24 N•m [ 212 in-lb ]




Use barring tool, Cummins® Part Number 3824591, 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)

2E, 3I, 4E, and 4I

Adjust the lash, if out of specification.

# Section A - Adjustment, Repair, and Replacement

## Section Contents

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# Charging System Alternator

## Initial Check

Check the drive belt and alternator pulley to be sure the alternator is rotating properly.

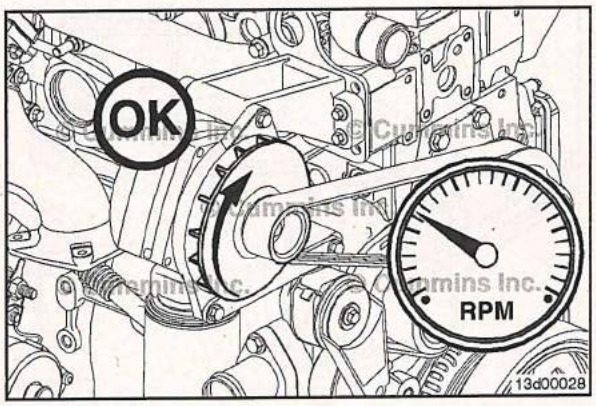
If any problems exist, check the following:

1 Use the following procedure to inspect the drive belt, if the drive belt is slipping on the alternator pulley. Refer to Procedure 008-002 in Section A. Use the following to inspect the belt tensioner. Refer to Procedure 008-087 in Secton A.

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

3 Check if the alternator pulley is loose on the shaft. If loose, remove the pulley and inspect for damage. Refer to the alternator manufacturer's and/or see equipment manufacturer service information.

4 If the alternator will **not** rotate or does **not** rotate freely, the alternator **must** be replaced. See the remove and install section of this procedure.

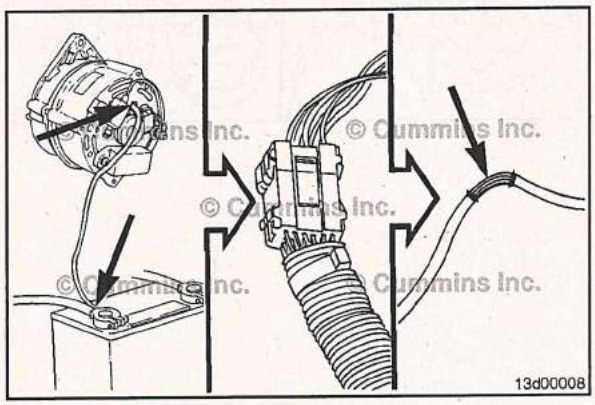



**⚠WARNING⚠**
**Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**

Check the battery and all wiring connections.

Inspect the wiring for defects.

Check all connections for tightness and cleanliness, including the slip connectors at the alternator and engine compartment bulkhead, and the connections at the battery.




## Test

**NOTE:** Any multimeter reading of zero voltage indicates an open circuit.

Check for open circuits.

Turn the keyswitch to the ON position.

Connect a multimeter, Cummins® Part Number 3164488 or 3164489, to the following locations:

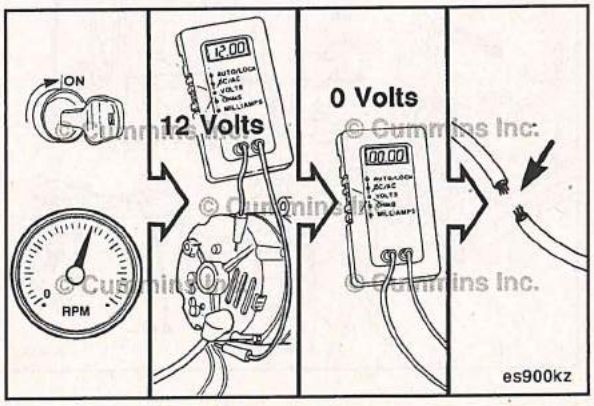
Delco™ Alternators

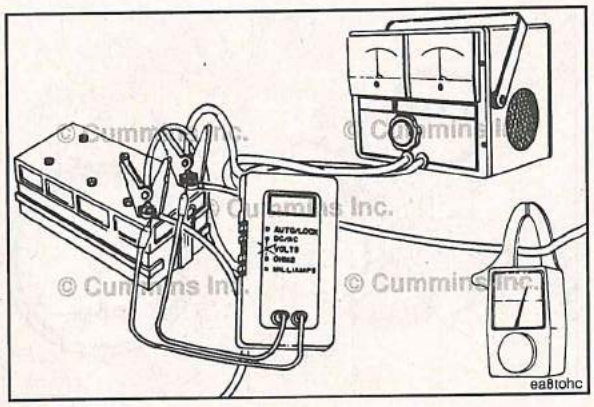
1 Alternator "BAT" terminal to ground

2 Alternator blade terminal "number 1" to ground

3 Alternator blade terminal "number 2" to ground.

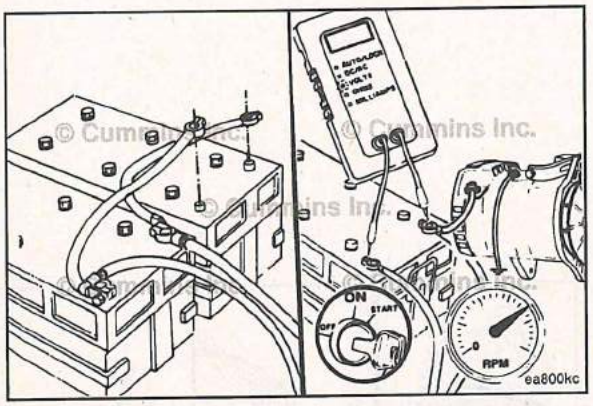
Locate and repair the open circuit.






Connect a carbon-pile load (battery/alternator tester) across the batteries in one of the battery boxes.

Clamp an induction pickup-type ampere-hour meter around the battery cable; or use the digital multimeter, Cummins® Part Number 3164488 or 3164489, with the clamp-on current probe, Part Number 3164490.

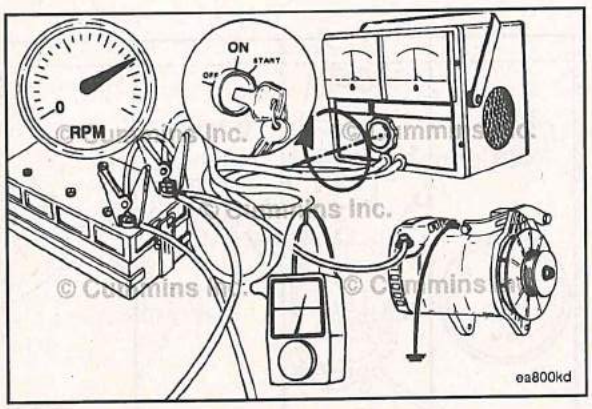



**⚠WARNING⚠**
**Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**

**⚠WARNING⚠**
**Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.**

Disconnect any cables that lead to any other battery boxes in the circuit, negative (-) cables first.

Operate the engine at high idle; and measure the alternator voltage output to the batteries with digital multimeter, Cummins® Part Number 3164488 or 3164489. See equipment manufacturer service information.




Operate the engine at high idle and adjust the carbon-pile load-testing equipment to apply the maximum rated amperage load to the alternator. Refer to the specifications in the OEM service manual.

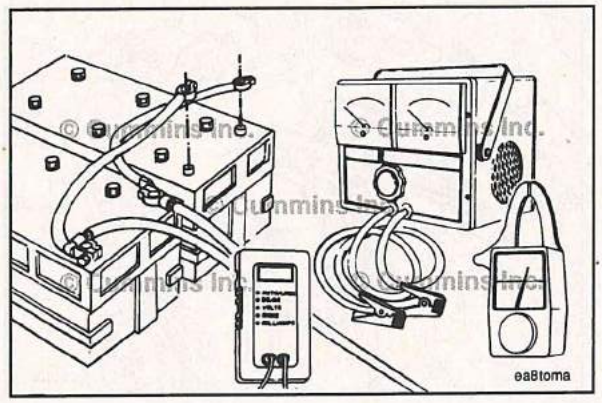
**NOTE:** The alternator maximum rated amperage output is normally stamped or labeled on the alternator.

Measure the alternator amperage output. See equipment manufacturer service information for specifications.

If the alternator output (amps) is **not** within 10 percent of rated output, repair or replace the alternator. See equipment manufacturer service information for repair procedures.

Shut off the engine and remove the test equipment.

Connect all battery cables, negative (-) cable last.

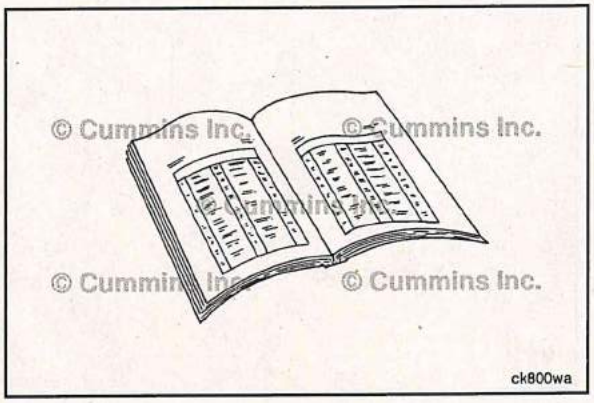



## Preparatory Steps

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

**⚠WARNING⚠**
**Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.**

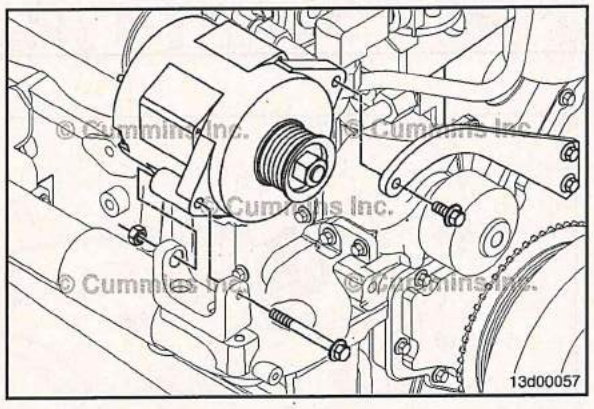
- Disconnect the batteries. See equipment manufacturer service information.
- Remove the drive belt from the alternator pulley. Refer to Procedure 008-002 in Section A.
- Tag and label all wires on the alternator.
- Disconnect the wires.

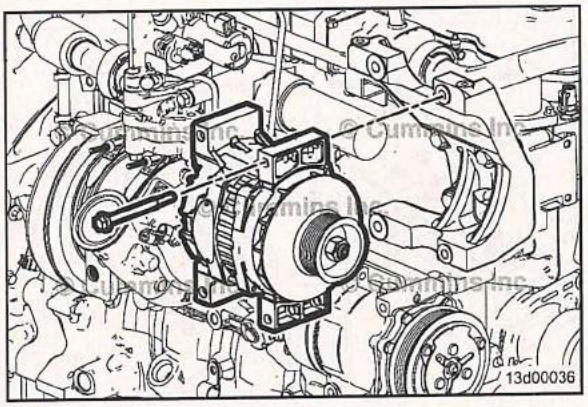



## Remove

### Spool Mount

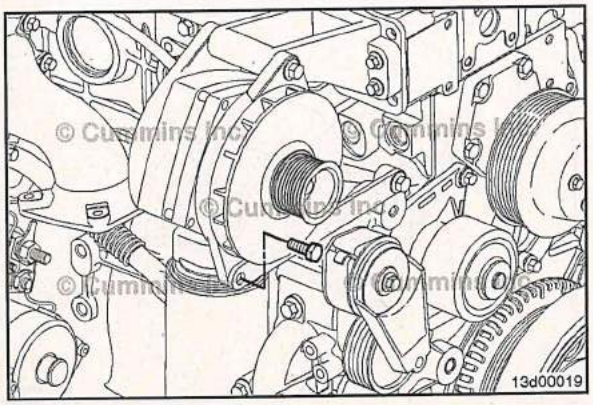
- Remove the upper alternator link capscrew.
- Remove the mounting capscrew and nut at the bottom of the alternator and alternator mounting bracket.
- Remove the alternator.





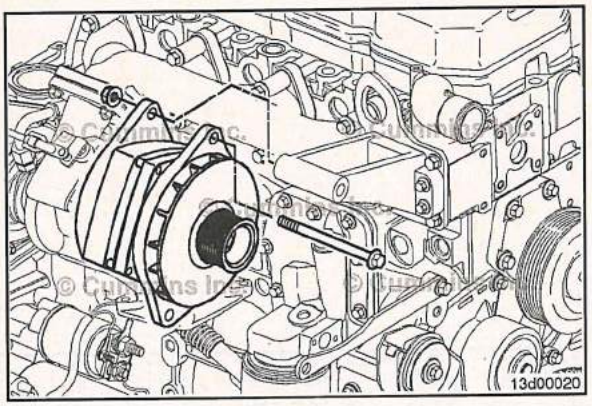

**Pad Mount**

- Remove the alternator mounting capscrews.
- Remove the alternator.

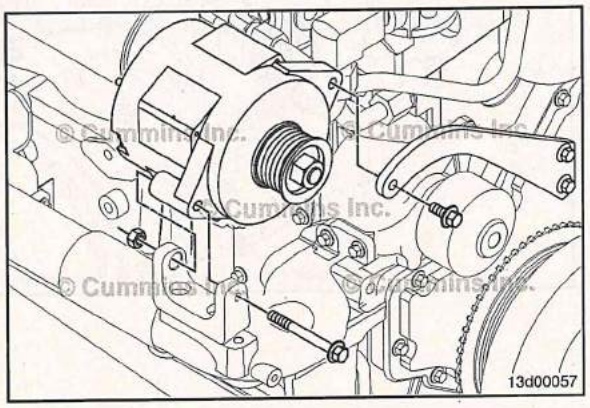



**Hinge Mount**

- Remove the alternator link capscrew.




- Remove the alternator mounting capscrew.
- Remove the alternator.




## Install

**Spool Mount**

- Install the alternator and the bottom alternator mounting capscrew and nut.
- Install the upper alternator link mounting capscrew at the top of the alternator.
- Tighten the capscrews.

**Torque Value:**
Lower Mounting Capscrew 40 N•m [ 30 ft-lb ]

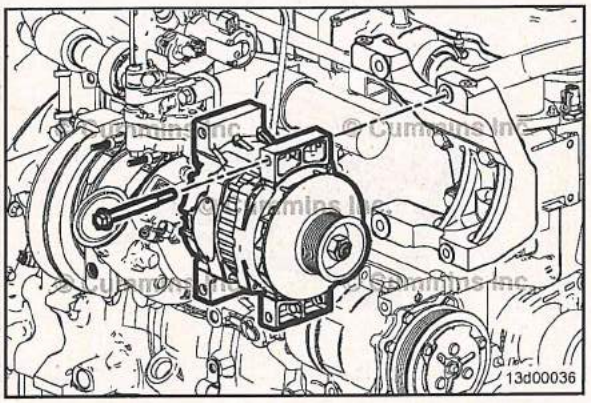
**Torque Value:**
Upper Link Mounting Capscrew 24 N•m [ 212 in-lb ]

### Pad Mount

- Install the alternator.
- Install and tighten the alternator mounting capscrews.

**Torque Value:**
M10 Capscrew 36 N•m [ 27 ft-lb ]

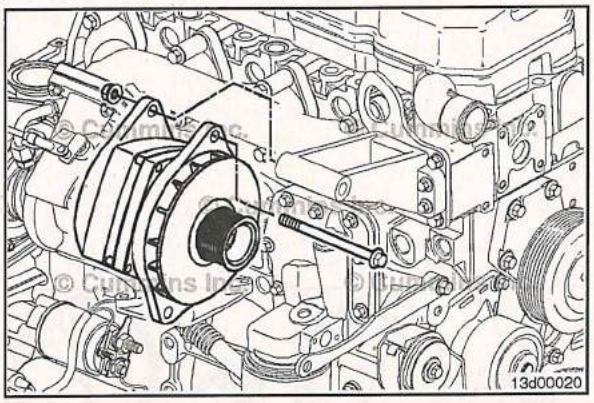
**Torque Value:**
M12 Capscrew 64 N•m [ 47 ft-lb ]




### Hinge Mount

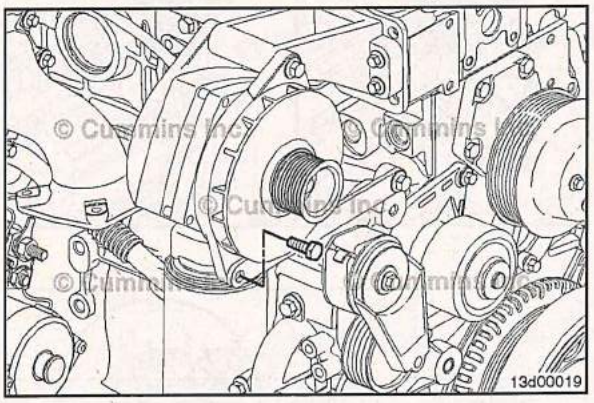
- Install the alternator.
- Install and tighten the alternator mounting capscrew.

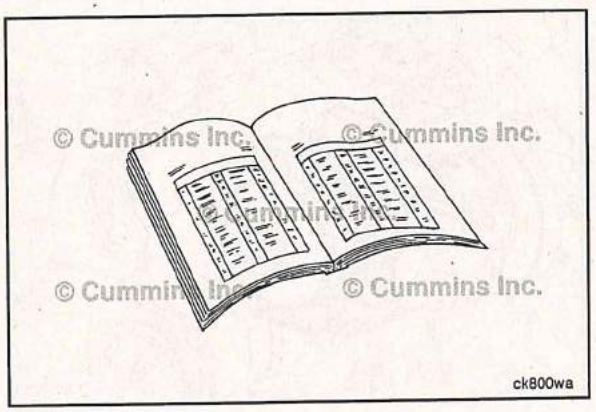
**Torque Value:** 40 N•m [ 30 ft-lb ]




- Install the alternator link capscrew.

**Torque Value:** 24 N•m [ 212 in-lb ]



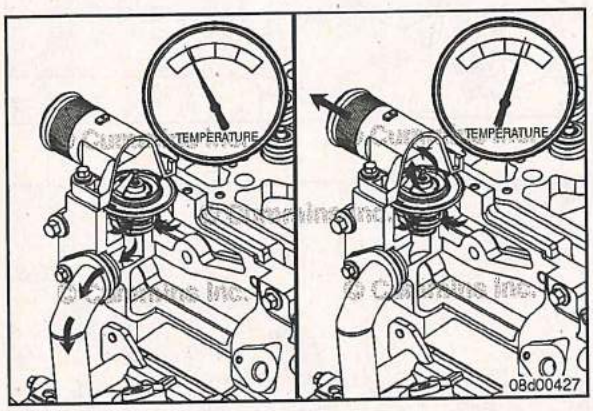



## Finishing Steps

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

**⚠WARNING⚠**
**Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.**

- Connect all wires to the alternator.
- Install the drive belt. Refer to Procedure 008-002 in Section A.
- Connect the batteries. Refer to the OEM instructions.
- Operate the engine and check for proper operation.

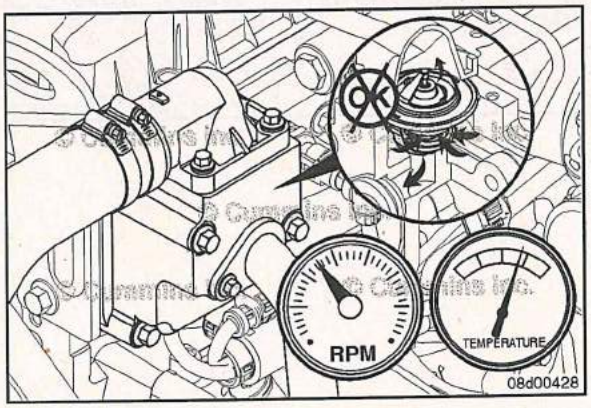



# Coolant Thermostat

## General Information

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

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

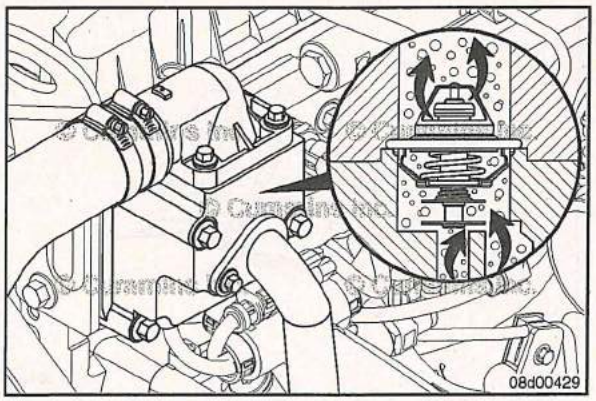



**⚠CAUTION⚠**
**Never operate the engine without a thermostat. Without a thermostat, the path of least resistance for the coolant is through the bypass to the water pump inlet. This can cause the engine to overheat.**

**⚠CAUTION⚠**

**A missing check ball can cause the engine to run cold, resulting in engine damage.**

The thermostat contains two check balls to vent air past the thermostat when it is closed. This helps to vent air during the cooling system fill process.

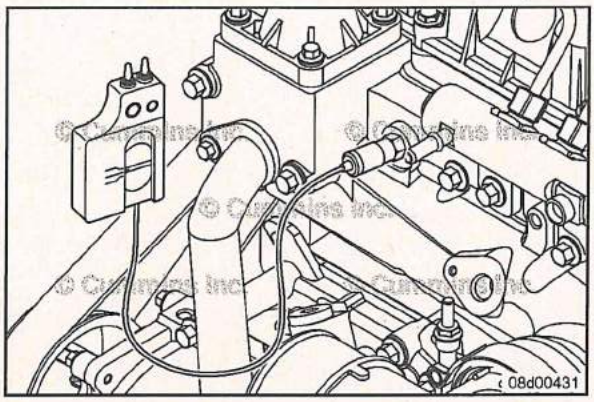



## Leak Test

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

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

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

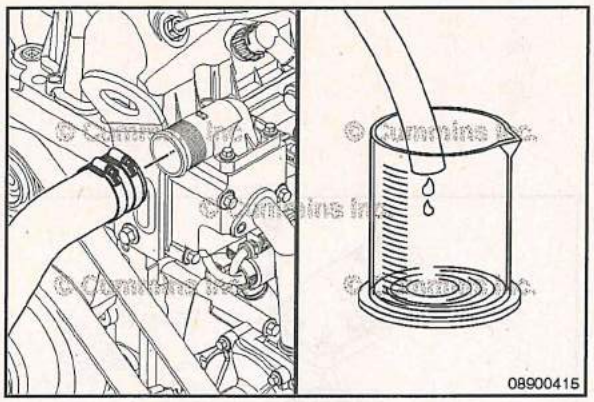



Disconnect the radiator top hose from the water outlet connection.

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

Install and tighten a hose clamp on the outlet connection.

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



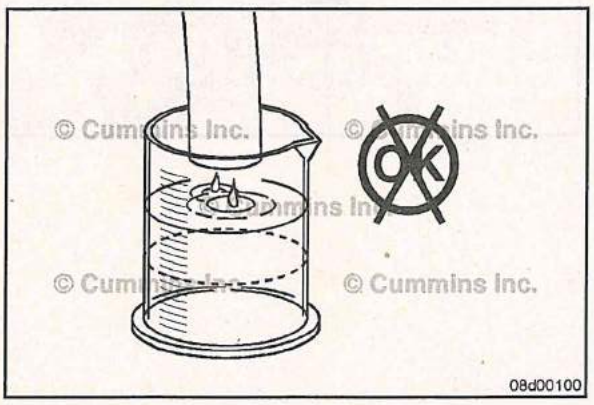

The coolant temperature should be monitored during this test to determine if the coolant temperature reaches the nominal opening temperature of the thermostat. See the Measurement step of this procedure for nominal opening temperature.) If the thermostat opens during this test, the test is invalid and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

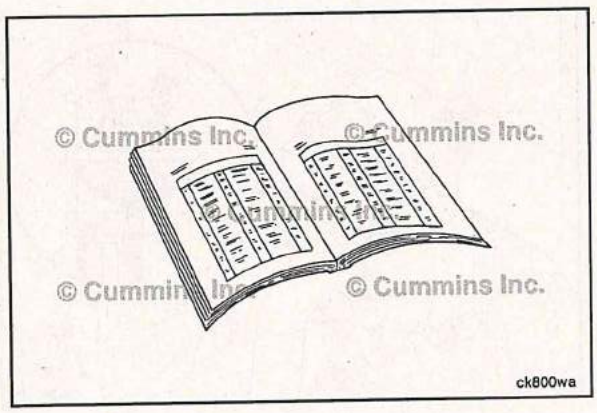
Operate the engine at rated rpm for 1 minute.

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

The amount of coolant **must not** be more than 100 cc [3.3 fl oz].

If more than 100 cc [3.3 fl oz] of coolant is collected, the thermostat is leaking and **must** be replaced.






## Preparatory Steps

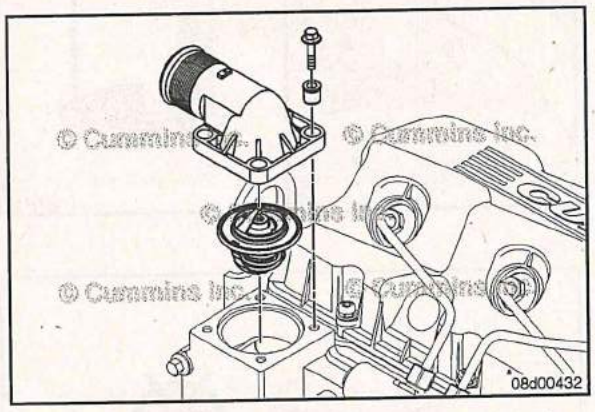
**⚠WARNING⚠**
**Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**

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

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

**△CAUTION△**
**Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.**

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the coolant below the level of the thermostat. Refer to Procedure 008-018 in Section 7.
- Disconnect the upper radiator hose from the water outlet connection. See equipment manufacturer service information.




## Remove

Remove the water outlet connection capscrews.

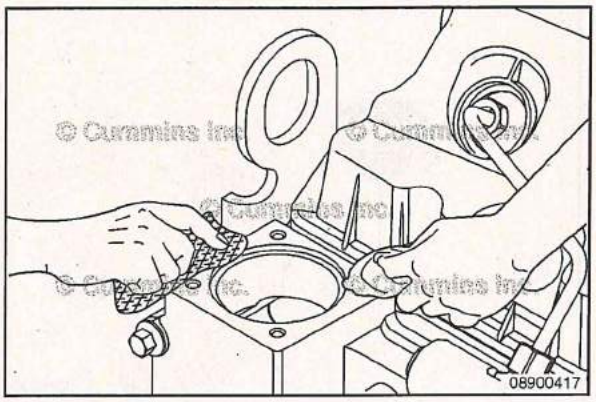
Remove the water outlet connection.

Remove the thermostat.

## Clean and Inspect for Reuse

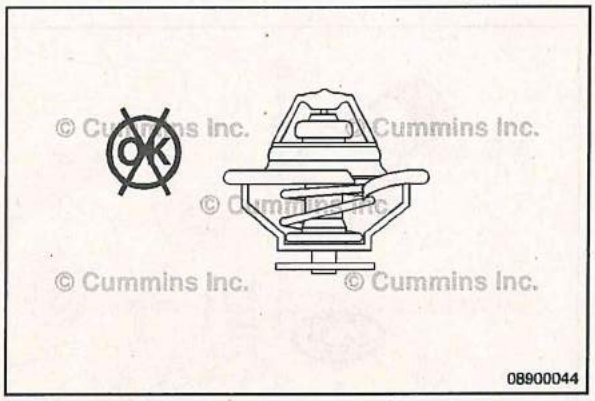
**⚠CAUTION⚠**
**Do not let any debris fall into the thermostat cavity when cleaning the gasket surfaces. Damage to the cooling system and engine can occur.**

Clean the mating surfaces with an abrasive pad, Cummins® Part Number 3823258, or equivalent, and a clean cloth.




Inspect the thermostat for external damage. Inspect for cracks, embedded debris, missing check balls, damaged seat, and other damage.

Replace the thermostat if any damage is found.

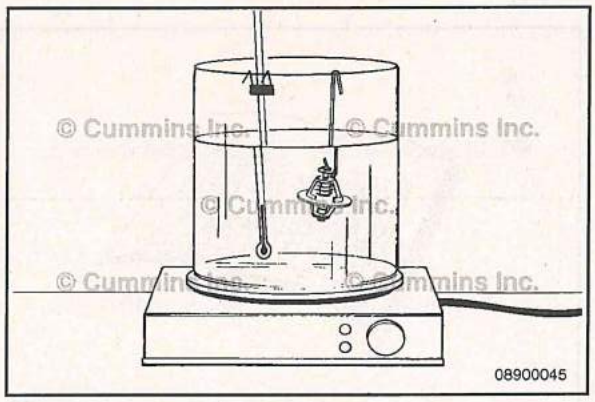



## Measure

If the thermostat is suspected to be malfunctioning, the opening temperature of the thermostat should be measured to determine if the thermostat is functioning correctly.

**NOTE:** Do **not** allow the thermostat or thermometer to touch the container.

Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.

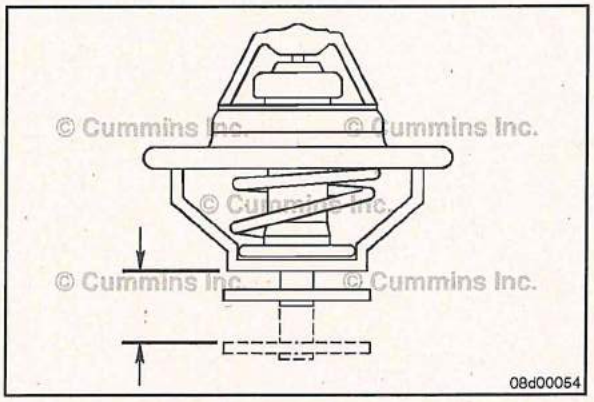



Heat the water and check the thermostat as follows:

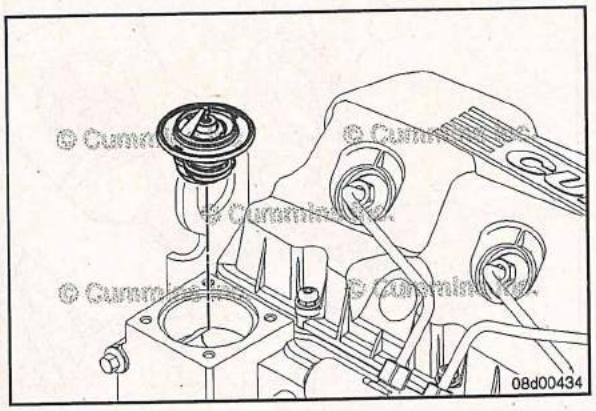
**NOTE:** The nominal operating temperature is stamped on the thermostat. To verify the correct temperature range thermostat is installed, make sure to reference the appropriate Part Information resources.

The thermostat **must** meet the following criteria:

82°C [180°F] Nominal Temperature Thermostat




| Thermostat Opening Temperature | | | |
|---|---|---|---|
| | °C | | °F |
| Initial Opening | 79 | MIN | 175 |
| | 83 | MAX | 182 |
| Fully Opened | 95 | MAX | 203 |

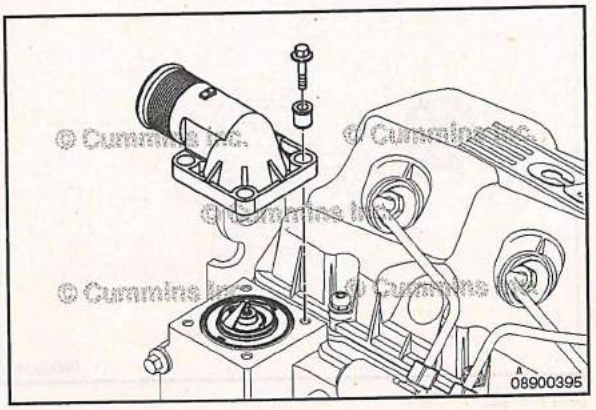



## Install

**⚠CAUTION⚠**
**Always use the correct thermostat and do not operate the engine without a thermostat installed. The engine can overheat if operated without a thermostat because the path of least resistance for the coolant is through the bypass to the pump inlet. An incorrect thermostat can cause the engine to overheat or run too cold.**

**NOTE:** If a previously installed thermostat is being used, make sure a new thermostat seal is used.

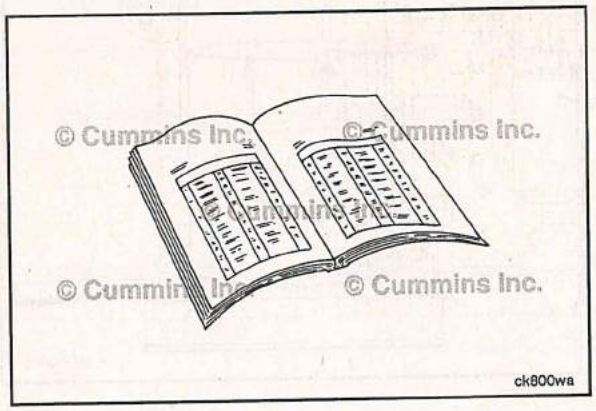
Install the thermostat into the thermostat housing.




Install the water outlet connection and mounting capscrews.

Tighten the capscrews.

**Torque Value:** 7 N•m [ 62 in-lb ]




## Finishing Steps

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

**⚠CAUTION⚠**
**Always vent the engine during filling to remove air from the coolant system, or overheating can result.**

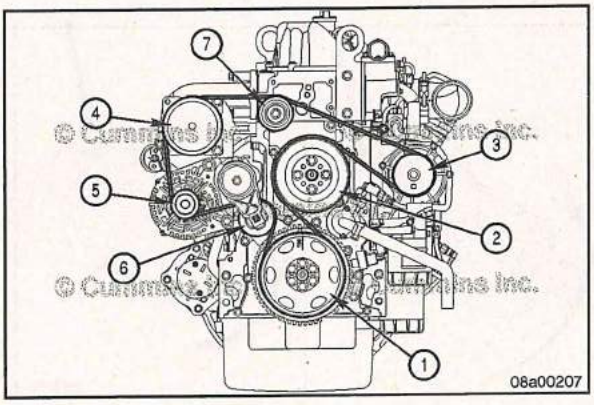
- Connect the upper radiator hose to the water outlet connection. See equipment manufacturer service information.
- Fill the cooling system. Refer to Procedure 008-018 in Section 7.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

# Drive Belt, Cooling Fan

## General Information

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

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:

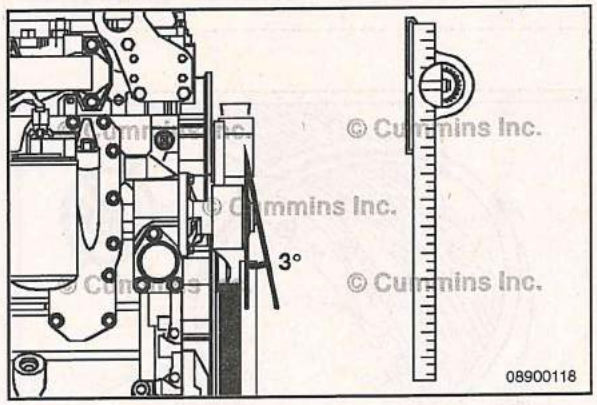
1 Crankshaft pulley/Vibration damper
2 Fan pulley
3 Water pump pulley
4 Refrigerant compressor pulley
5 Alternator pulley
6 Tensioner idler pulley
7 Idler pulley.

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

A worn belt tensioner or misaligned pulley can cause a belt to "walk" off.

To check pulley alignment, use Cummins® Pulley Alignment Fixture, Part Number 3163524. If **not** available, this measurement can be taken with a straight-edge and an inclinometer.

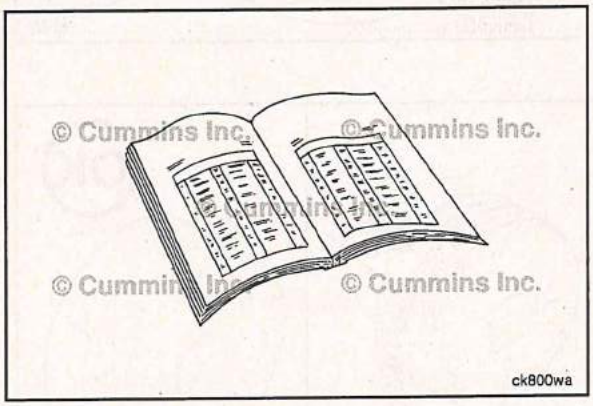
Maximum pulley misalignment is 3 degrees. Repair, adjust, or replace misaligned components as necessary.

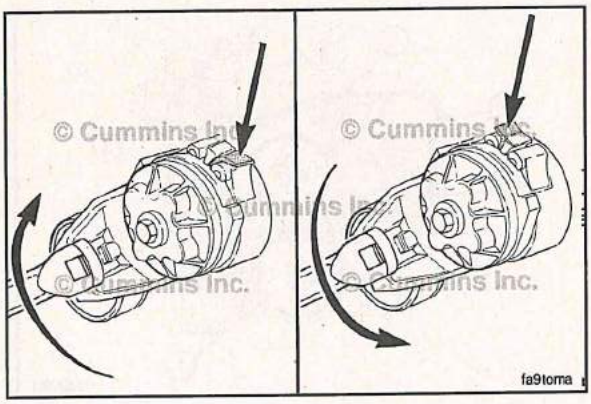



## Preparatory Steps

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

- Disconnect the batteries. See equipment manufacturer service information.

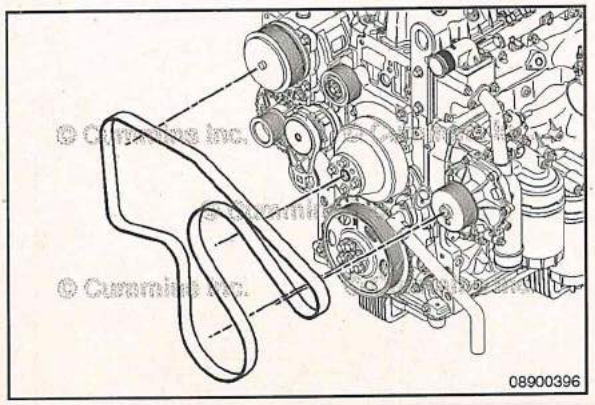





## Remove

**⚠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 that the spring tang is bent over the tensioner body. To loosen the tension on the belt, rotate the tensioner to wind the spring tighter.



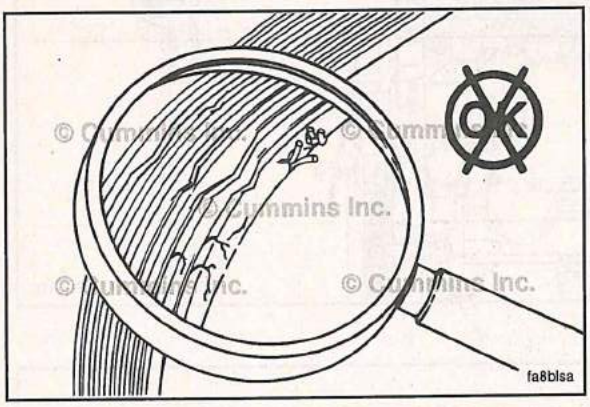

**⚠CAUTION⚠**
**Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to break.**

**NOTE:** Make a diagram of the belt arrangement prior to removing the drive belt. This aids in installation for 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.

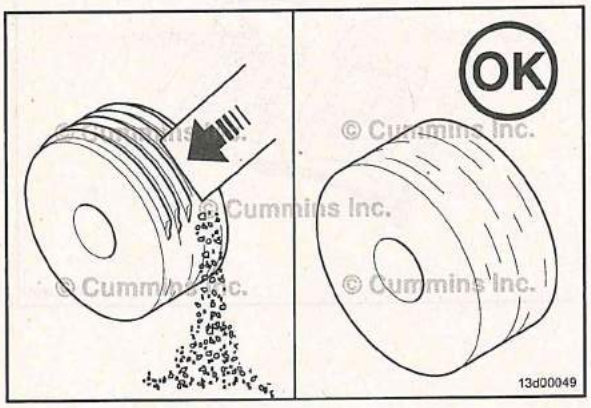



## Clean and Inspect for Reuse

Inspect the drive belt for:

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

Replace the belt if any damage is found.




Inspect the idler and drive pulleys for wear or cracks.

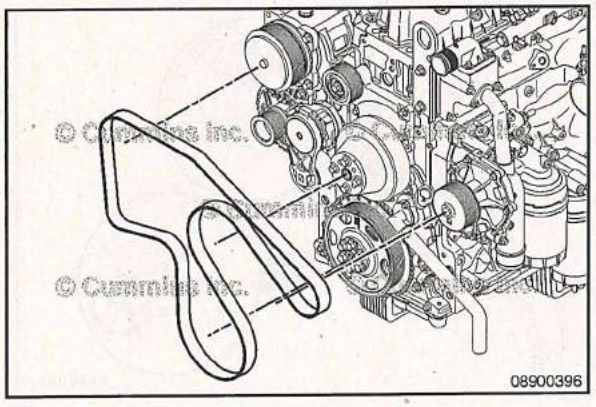
Plastic pulleys often have a buildup of road dirt and belt material that is not to be confused with wear.

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

Clean, check, and reuse idlers with a buildup of dirt, rather than replacing.

Inspect the tensioner. Refer to Procedure 008-087 in Section 8.

## 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.**

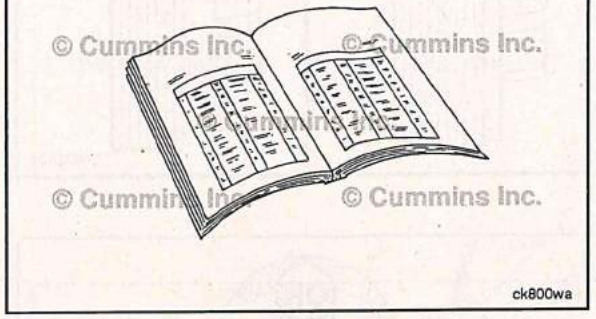
Route the drive belt on the engine. Use the belt diagram created in the Remove section. Do **not** install the belt over the water pump pulley at this time.

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

Release the tensioner to apply tension to the drive belt.

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

## Finishing Steps

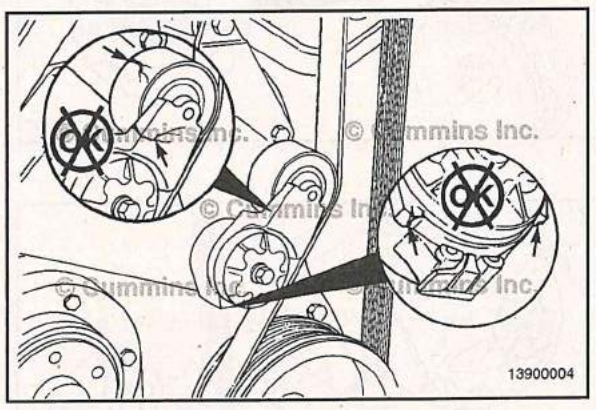



**⚠WARNING⚠**
**Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**

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

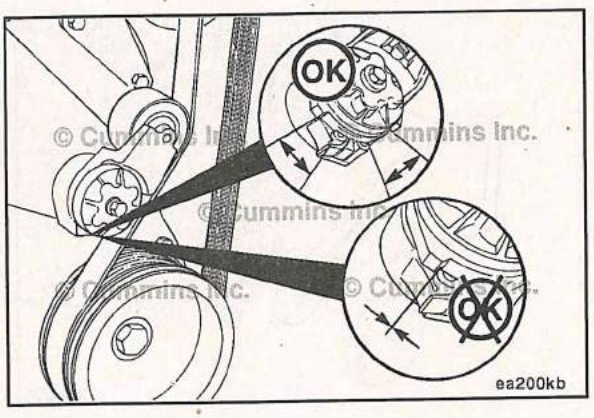
# Cooling Fan Belt Tensioner

## Maintenance Check




**NOTE:** This maintenance check is performed at the Maintenance Procedures at 500 Hours or 6 Months.

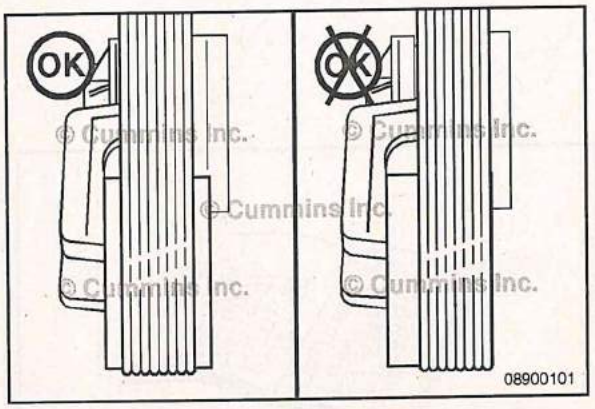
With the engine stopped, check the tensioner arm, pulley, and stops for cracks. If any cracks are noticed, the tensioner **must** be replaced.



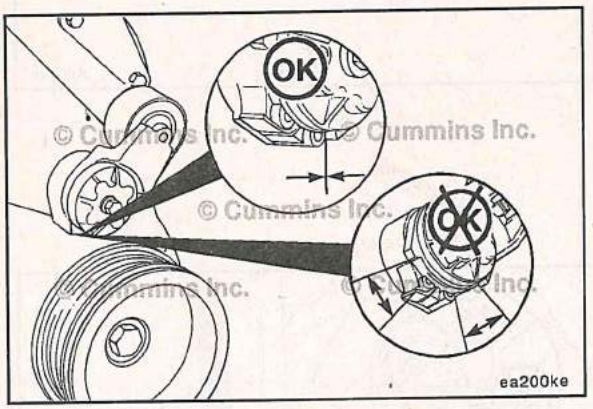

With the belt installed, verify that neither tensioner arm stop is in contact with the spring casing stop. If either of the stops is touching:

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

After replacing the belt, if the tensioner arm stops are still in contact with the spring case stop, replace the tensioner.

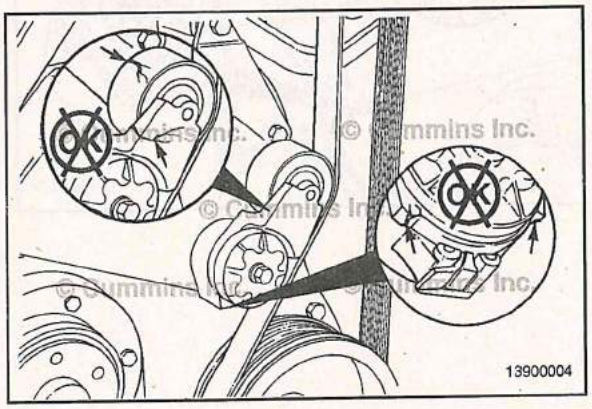



Check the location of the drive belt on the belt tensioner pulley. The belt should be centered on, or close to the middle of, the pulley. Misaligned belts, either too far forward or backward, can cause belt wear, belt roll-off malfunctions, or increase uneven tensioner bushing wear.




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

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



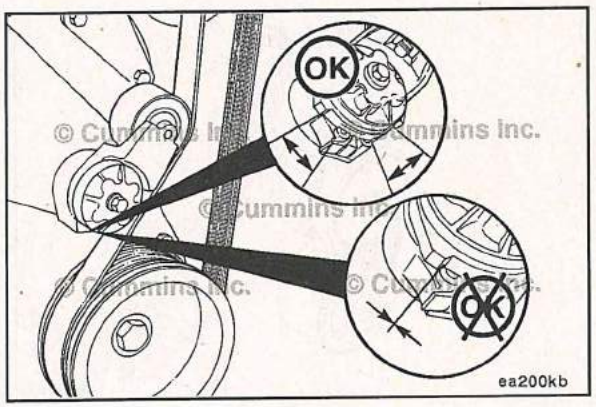

## Initial Check

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

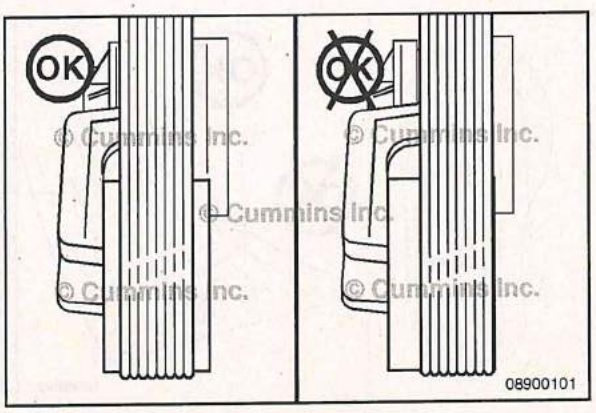
With the belt installed, verify that neither tensioner arm stop is in contact with the spring casing stop. If either of the stops is touching:

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

After replacing the belt, if the tensioner arm stops are still in contact with the spring case stop, replace the tensioner.

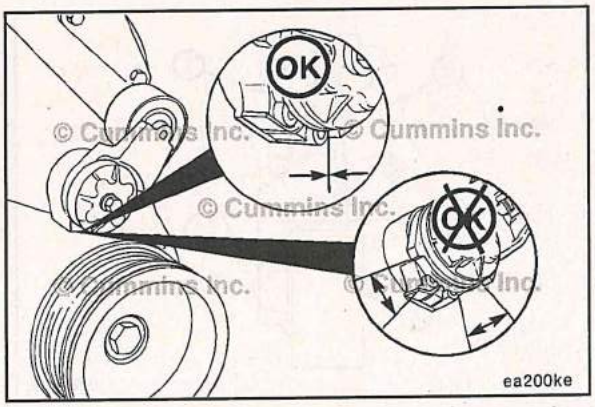



Check the location of the drive belt on the belt tensioner pulley. The belt should be centered on, or close to the middle of, the pulley. Misaligned belts, either too far forward or backward, can cause belt wear, belt roll-off malfunctions, or increase uneven tensioner bushing wear.




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

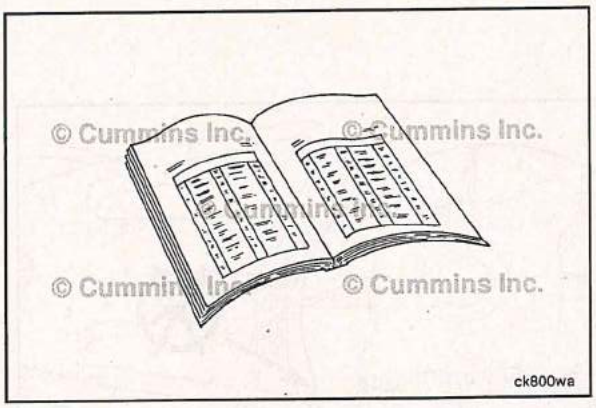
With the belt removed, verify the tensioner arm stop is in contact with the spring case stop. If they are **not** touching, the tensioner **must** be replaced.

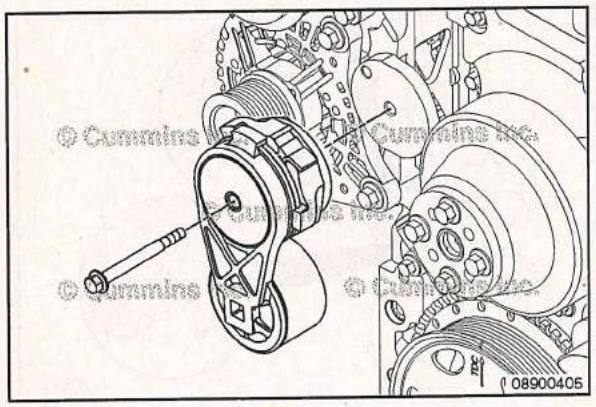



## Preparatory Steps

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

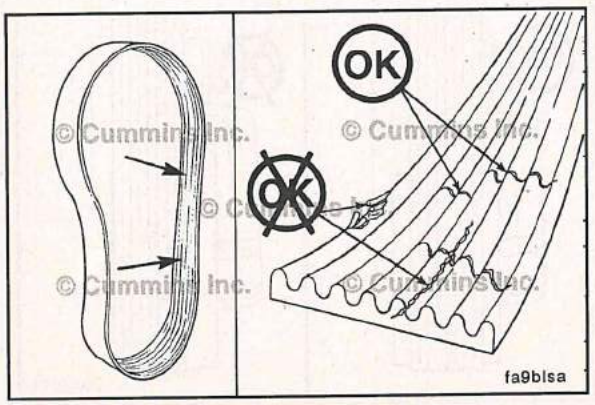
- Disconnect the batteries. See equipment manufacturer service information.
- Remove the drive belt. Refer to Procedure 008-002 in Section A.






## Remove

Remove the capscrew and belt tensioner from the bracket.



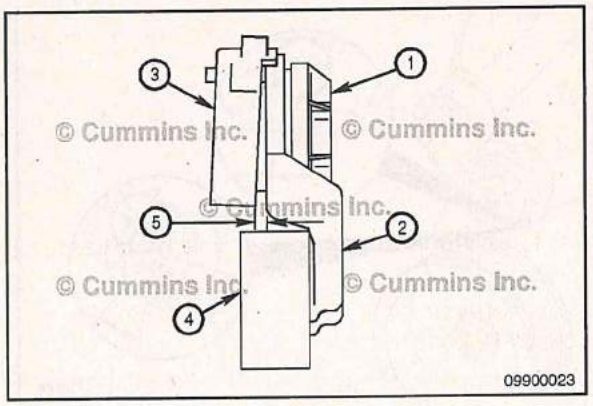

## Clean and Inspect for Reuse

Check the belt for damage.

Transverse (across the belt) cracks are acceptable.

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

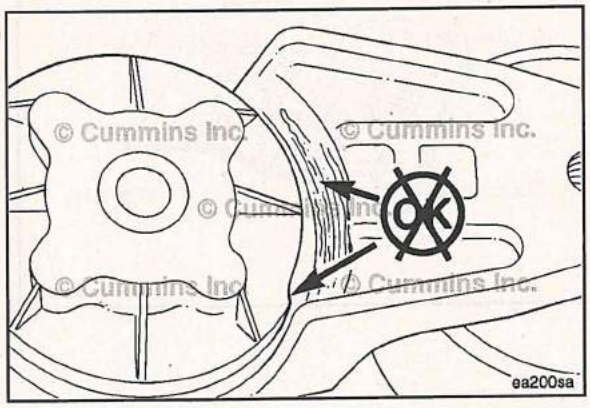
If the belt is frayed or has any piece of material missing, the belt is unacceptable and needs to be replaced.




Measure the clearance between the tensioner spring and the tensioner arm to verify tensioner wear-out and uneven bearing wear. If the clearance exceeds 3 mm [0.12 in] at any point, the tensioner has failed 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. **Always** replace the belt when a tensioner is replaced.

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



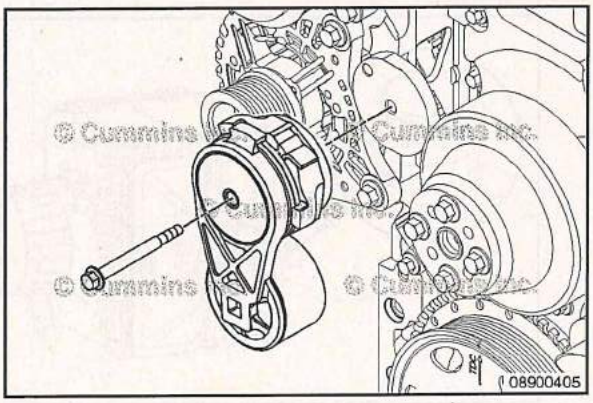

Inspect the tensioner for evidence of the tensioner arm contacting the tensioner cap. If there is evidence of the two areas making contact, the pivot tube bushing has failed and the tensioner **must** be replaced.

## Install

Install the belt tensioner and capscrew.

Tighten the capscrew.

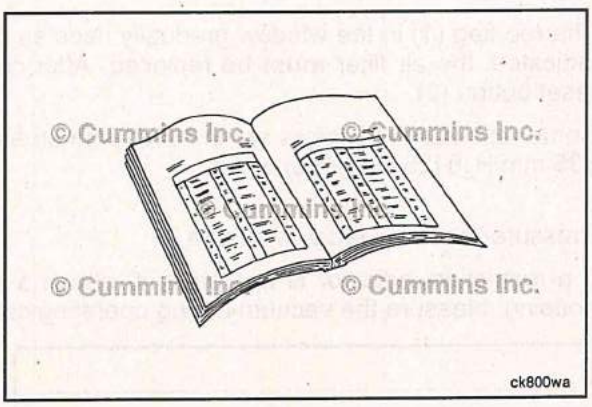
**Torque Value:** 43 N•m [ 32 ft-lb ]




## 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 A.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to check for proper operation.




# Air Cleaner Element

## General Information

**△CAUTION△**
**Only use the approved Cummins Filtration™ Direct Flow replacement filter elements to service the air cleaner. Use of improper filters can lead to engine damage.**

**NOTE:** There are two different configurations in which the direct flow air cleaners can be serviced: a front service or a side service direction. Verify the configuration by reviewing the appropriate illustrations in this manual.

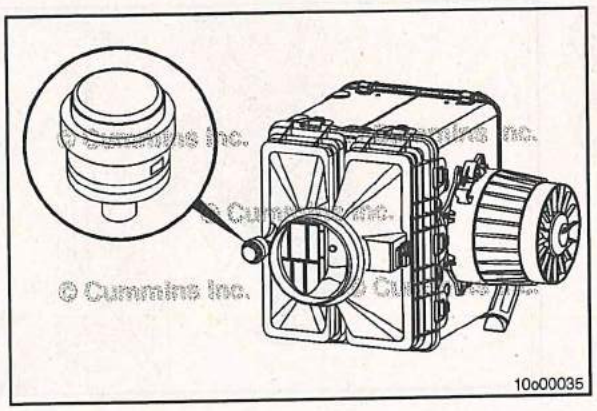
The direct flow air cleaner uses both a primary and secondary filter element for industrial applications. The direct flow air cleaner has been designed for a maximum restriction at 635 mm $H_20$ [25 in $H_20$] of water, at which point the filter element(s) should be changed.

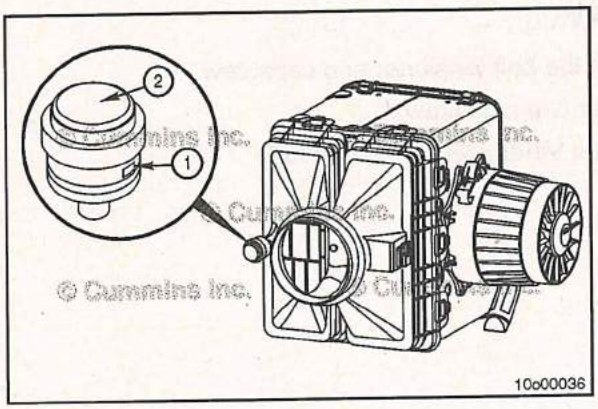
## Measure

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

Restriction Indicator Check

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



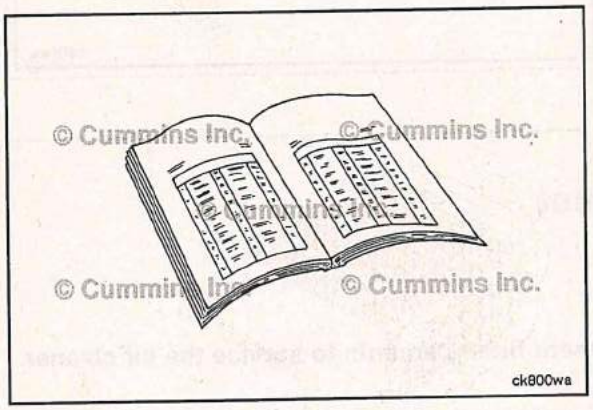




The red flag (1) in the window gradually rises as the air filter loads with dirt. When the maximum air filter restriction is indicated, the air filter **must** be replaced. After changing or replacing the air filter, reset the indicator by pushing the reset button (2).

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

Pressure/Vacuum Gauge Measure

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




## Preparatory Steps

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

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

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

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

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

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

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

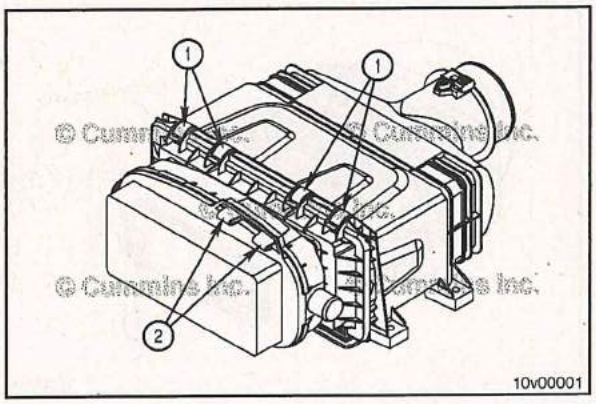
## Remove

Front Service Filter Housing

Release the J-clamps to remove the pre-cleaner from the main filter housing. If present, the inlet ducting to the pre-cleaner could possibly need to be loosened or removed to remove the pre-cleaner from the housing. The pre-cleaner can be separated from the housing by sliding the mounting tabs out of the slots on the main housing.

1 Clip locations.

2 Tab locations.

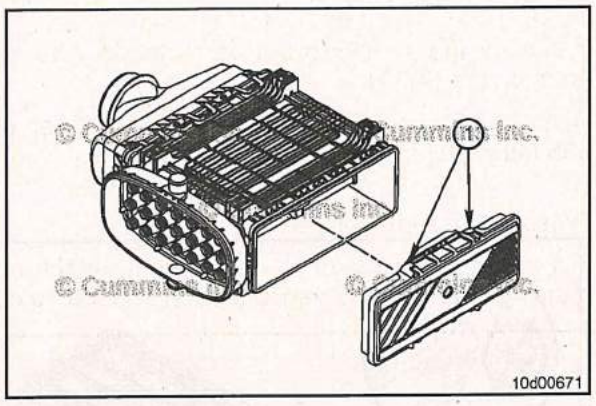



Side Service Filter Housing

The inlet ducting does **not** need to be removed to service the filter elements. To access the filter elements, remove the service door by lifting on the plastic clips on both the top and bottom sides of the housing. The service door will be completely removed from the main housing.

1 Service door clip (both sides).

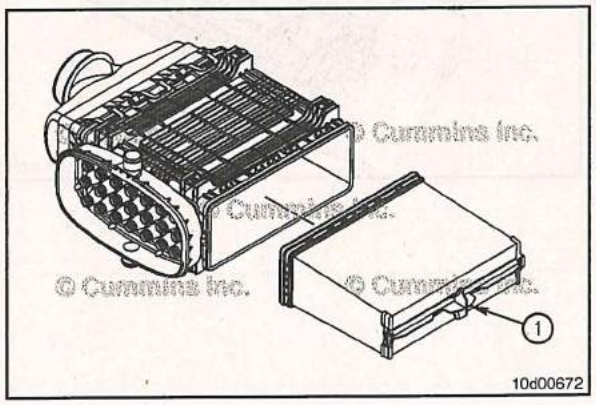
Make sure the gasket around the service door or pre-cleaner remains seated.

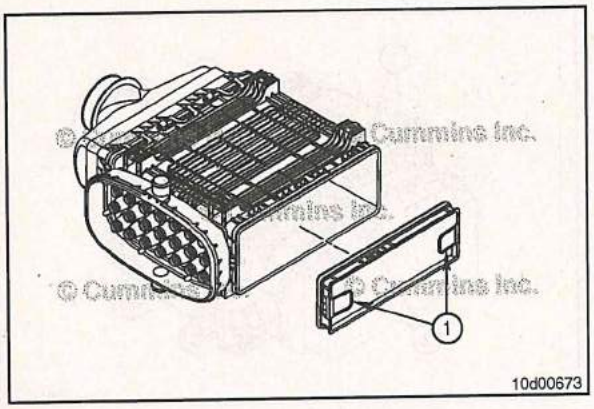



The Direct Flow primary filter element has a built-in handle for easy removal. Grasp the handle in the center of the element and pull the filter element outward.

1 Primary element removal handle.

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





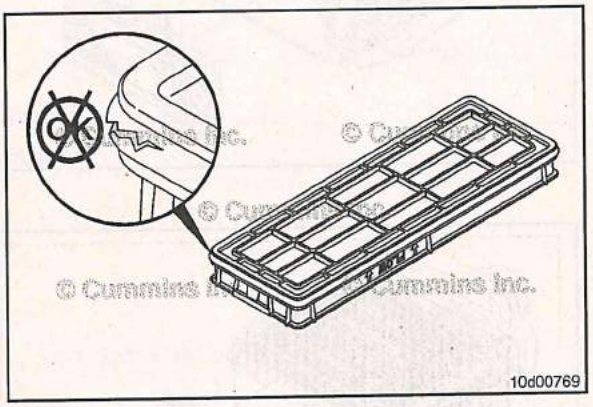

**⚠CAUTION⚠**
**Use caution when removing the secondary element. Any loose debris can fall into the air intake plumbing leading directly to the engine. Clean the area around the secondary filter element and replace the secondary promptly to avoid engine contamination ingestion.**

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

**NOTE:** The secondary element should be changed every-other time the primary element is changed. Proper inspection of the secondary element is to be performed and the element is to be changed, if necessary.

The secondary element is removed by pulling on the plastic ring tab on the inside face of the filter element.

1 Secondary element removal ring tab.

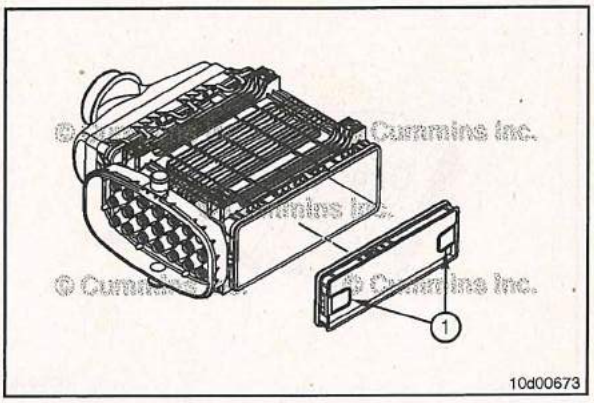



## Inspect for Reuse

If the used filter element is to be used again, the following precautions must be taken:

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

## Install




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

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

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

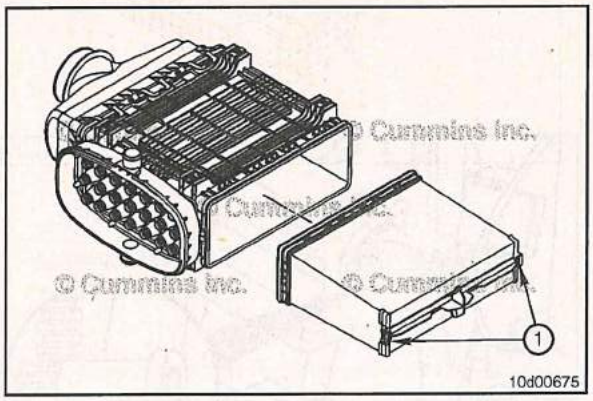
Secondary Element

Insert the element so the orientation of the plastic removal ring is facing the inside of the housing and is accessible for the next service interval.

1 Secondary element removal ring tab should be visible.

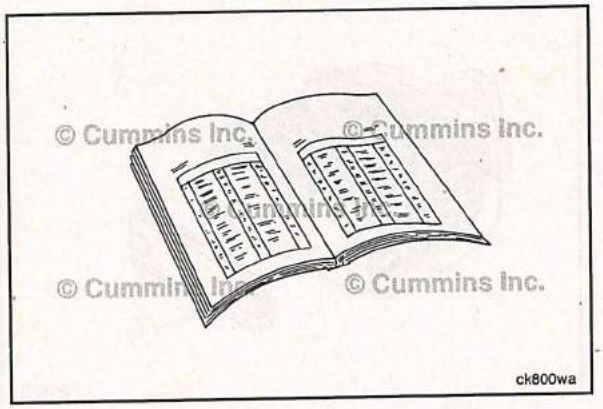
Push the secondary element into the back of the housing so all surfaces are seated inside the housing. Apply pressure to all four corners to make sure the element is secure within the housing. The secondary filter element includes an o-ring that is glued to the filter element to provide an airtight seal.

Primary Filter Element




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

Place a new primary filter element in the housing so the o-ring is toward the secondary element. Push the primary element into the housing so all surfaces are seated inside the housing. Apply pressure to the two tabs on the side of the primary element to make sure the element is secure within the housing. The tabs should seat against the center of the housing. The primary filter element also includes an o-ring that is glued to the filter element to provide an airtight seal.




## Finishing Steps

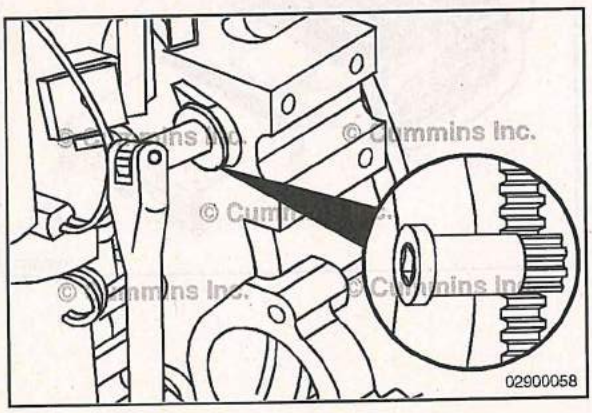
**⚠WARNING⚠**
**Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.**

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

**NOTE:** For the 127 mm x 381 mm x 204 mm [5 in x 15 in x 8 in] version, the pre-cleaner assembly has tabs on the opposite side that will interface with slots on the housing.

**NOTE:** The Direct Flow filter elements are completely disposable.

- Install the service door or pre-cleaner assembly by latching to the housing.
- Reset the restriction indicator by pushing the reset button.
- Connect the battery cables. See equipment manufacturer service information.
- Operate the engine and listen for a noise that could indicate an air leak. Use the following procedure to locate any air leaks in the air system. Refer to Procedure 010-024 in Section 10 in the QSF308 CM2350 F107 Service Manual, Bulletin 4367316.
- Operate the engine and listen for a noise that could indicate an air leak.




# Starting Motor

## Rotation Check

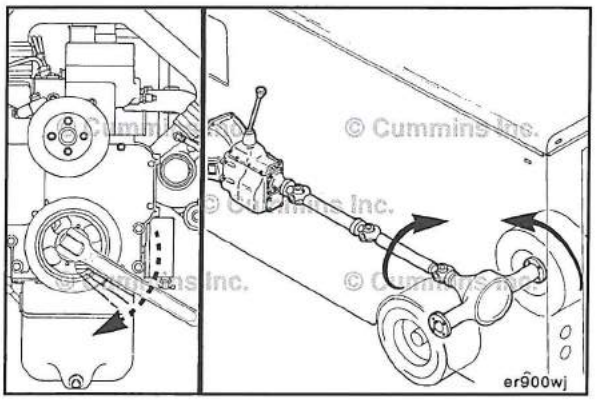
If the starter solenoid is making a sound, but the engine is **not** rotating, turn the keyswitch to the OFF position, and attempt to bar the crankshaft in both directions.

Bar the engine with barring tool, Cummins® Part Number 3824591.

If the crankshaft will bar over, attempt to start the engine. If the starter motor cranks the engine, check the starter motor pinion gear and flywheel ring gear for damage.

If damage to the starter motor pinion gear and/or flywheel ring gear is found when replacing the components, make sure to measure the distance from the starting motor mounting flange to the forward face of the front side of the flywheel ring gear. Follow the measure step of this procedure.

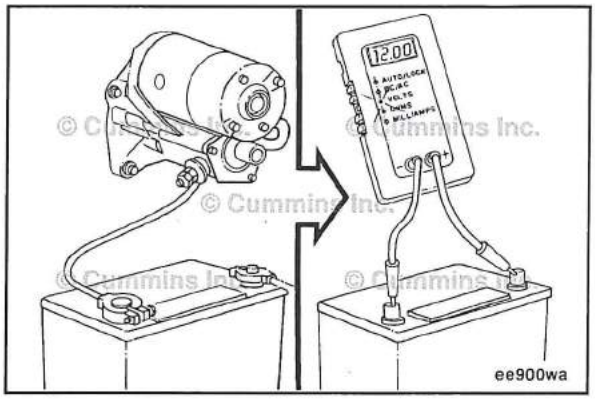
If the crankshaft does **not** rotate or requires more than the normal effort to bar, check for an internal malfunction or a problem with the drive unit and/or accessories.




If the engine cranking speed is too slow or will **not** crank at all, and the engine rotates freely:

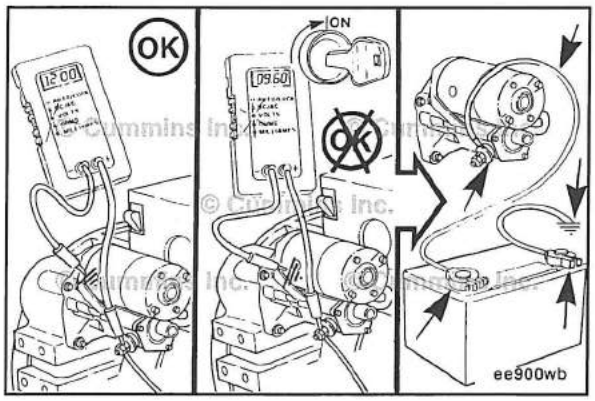
Make sure the wiring connections are clean, tight, and **not** damaged.

Check the battery voltage. See equipment manufacturer service information and/or manufacturer for specifications.




Check the voltage at the starting motor during cranking. If the voltage drops more than 2.4-VDC on a 12-VDC system and 4.8-VDC on a 24-VDC system, check that all connections are clean and tight.

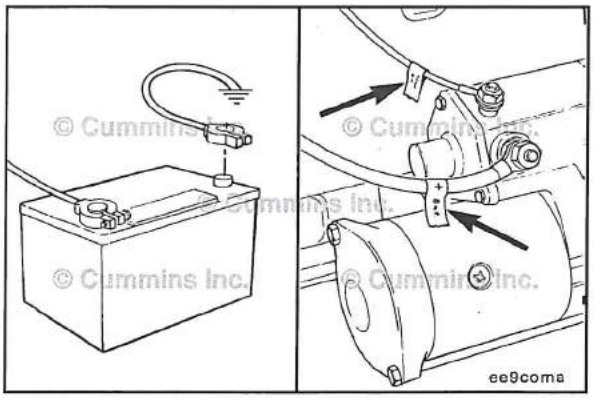
If the cables are correct and the voltage drop exceeds the limit, replace the starting motor.

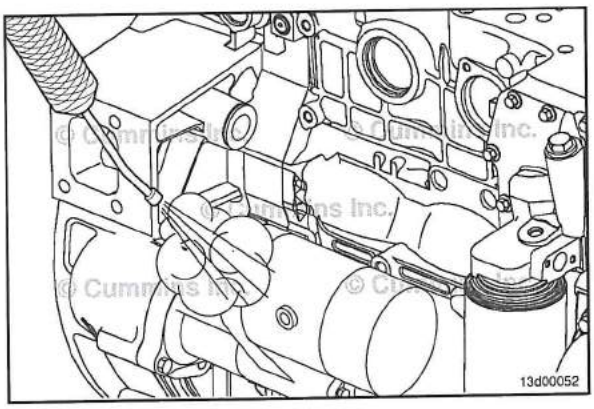



## Preparatory Steps

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

- Disconnect the batteries. See equipment manufacturer service information.
- Identify each wire with a tag indicating location on the starting motor.
- Remove the electrical connections from the starting motor.



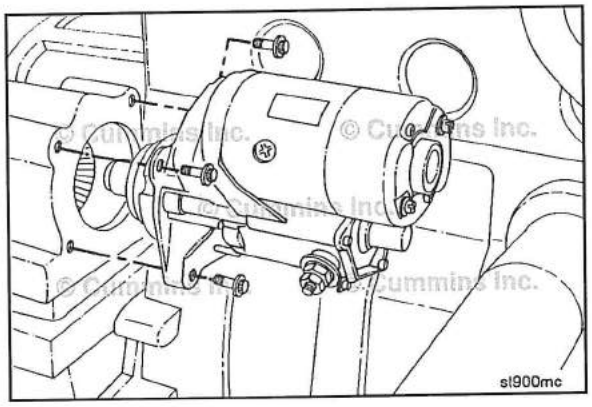



**⚠WARNING⚠**
**When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.**

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

Prior to removing the starter, use steam to clean the area around the starting motor to prevent debris from entering the flywheel housing.

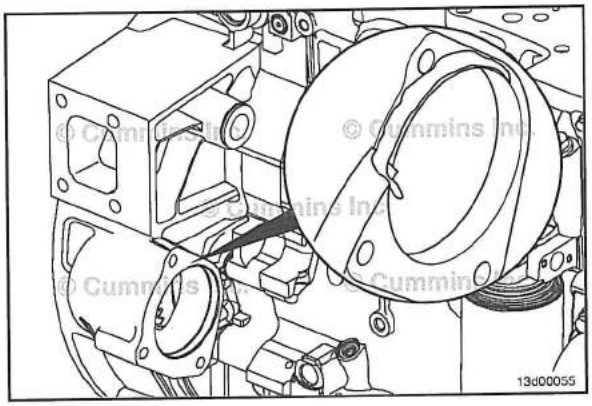
Dry with compressed air.




## Remove

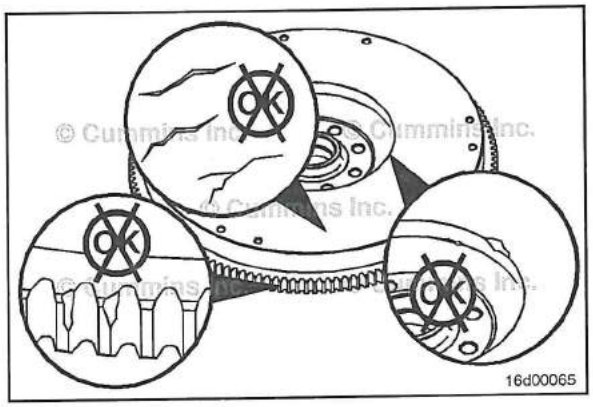
Remove the three capscrews and the starting motor.

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




## Clean and Inspect for Reuse

For engines that use wet flywheel housings, clean any leftover sealant from the starting motor mounting flange on both the flywheel housing and starting motor. Make sure these surfaces are clean of oil and debris.




Inspect the starter motor pinion gear and/or flywheel ring gear for chipping or uneven wear.

**NOTE:** If the starter motor pinion gear and/or flywheel ring gear teeth are damaged, they **must** be replaced.

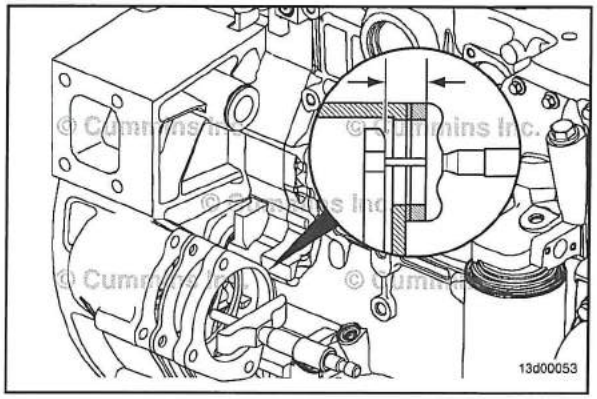
## Measure

Use an inside micrometer or a vernier caliper to measure the distance from the starting motor mounting flange to the forward face of the front side of the flywheel ring gear.

**NOTE:** Include any spacers previously removed when completing the measurement.

| Starting Motor Spacing | | |
|---|---|---|
| **mm** | | **in** |
| 49.28 | MIN | 1.94 |
| 52.32 | MAX | 2.06 |

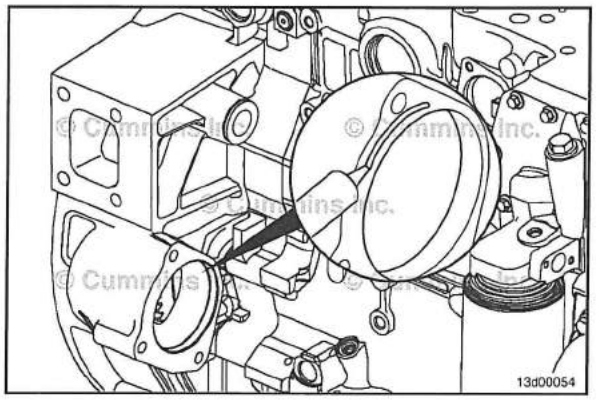
Add or remove spacers as necessary to achieve the correct starting motor spacing.




## Install

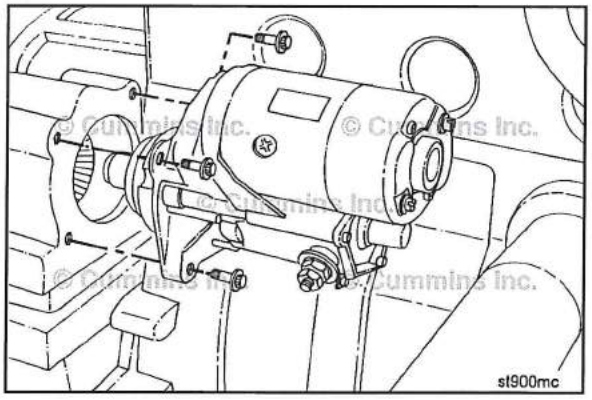
For engines with wet flywheel housings, apply a 1.5 to 2.0 mm [0.06 to 0.09 in] wide bead of sealant, Cummins® Part Number 3164067, to the flywheel housing starting motor mounting flange.

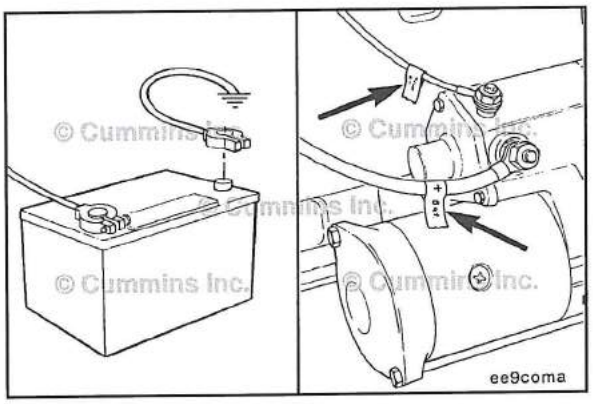
**NOTE:** If a starting motor spacer is required, make sure to apply sealant to the side of the spacer that contacts the starting motor.




Install the three capscrews, the starting motor, and starting motor spacer, if required.

**Torque Value:** 43 N•m [ 32 ft-lb ]






### Cummins® Branded Starters

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

**△CAUTION△**
**Do not overtighten the electrical connections. Starter damage can result.**

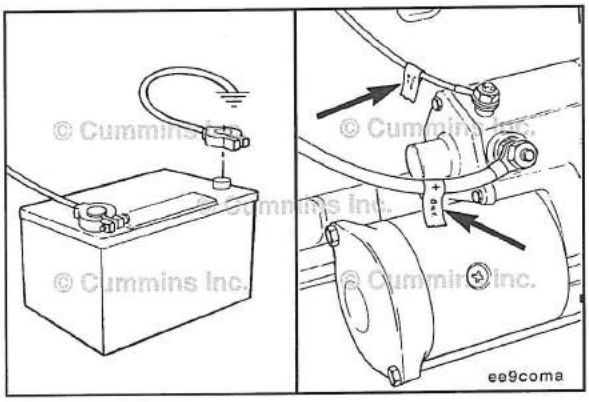
**NOTE:** Use the location tags to help identify where each wire connection goes.

Connect the electrical connections to the starter motor.

**Torque Value:**
M5 4 N•m [ 35 in-lb ]

**Torque Value:**
M10 21 N•m [ 186 in-lb ]

Connect the ground cable to the battery terminal.



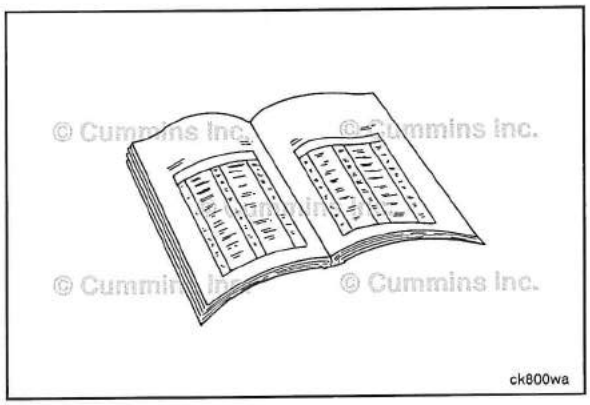

### Non-Cummins® Branded Starters

**△CAUTION△**
**Do not overtighten the electrical connections. Starter damage can result.**

**NOTE:** Use the location tags to help identify where each wire connection goes.

Install the starter motor electrical connections.

For Non-Cummins® branded starters, see equipment manufacturer service information for torque specifications.




## Finishing Steps

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

- Connect the batteries. See equipment manufacturer service information.
- Operate the starter to check for proper function.

# Section D - System Diagrams

## Section Contents

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# System Diagrams - Overview

## General Information

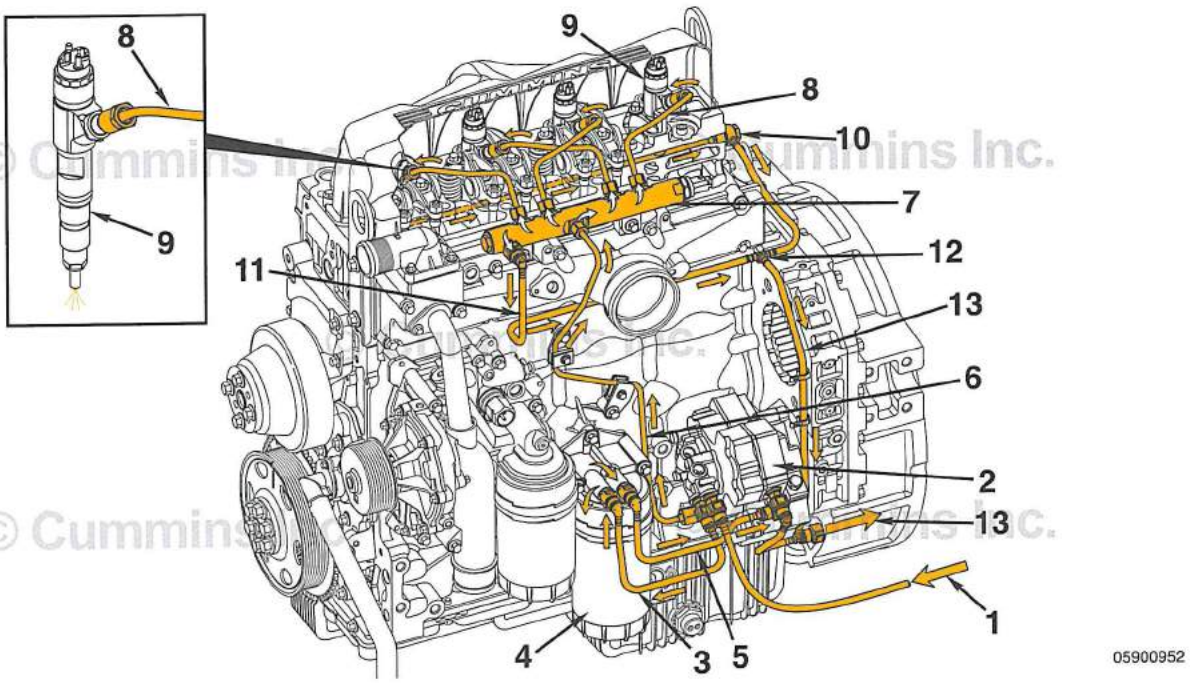
The following drawings show the flow through the engine systems. Although parts can change between different applications and installations, the flow remains the same. The systems shown are:

- 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

## Flow Diagram

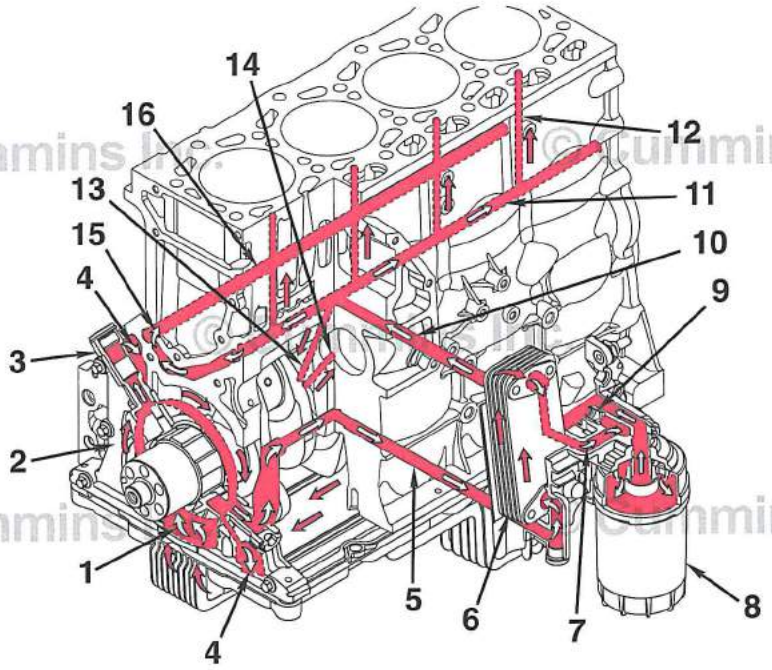





1 Fuel supply from tank
2 Fuel pump
3 Fuel supply to filter
4 Fuel filter (spin-on)
5 Fuel flow out of fuel pump
6 Fuel supply to common fuel rail
7 Common fuel rail
8 High pressure fuel to injector
9 Injector
10 Fuel return from cylinder head
11 Fuel return from common rail
12 Fuel return junction
13 Fuel return to tank.

# Flow Diagram, Lubricating Oil System

## Flow Diagram



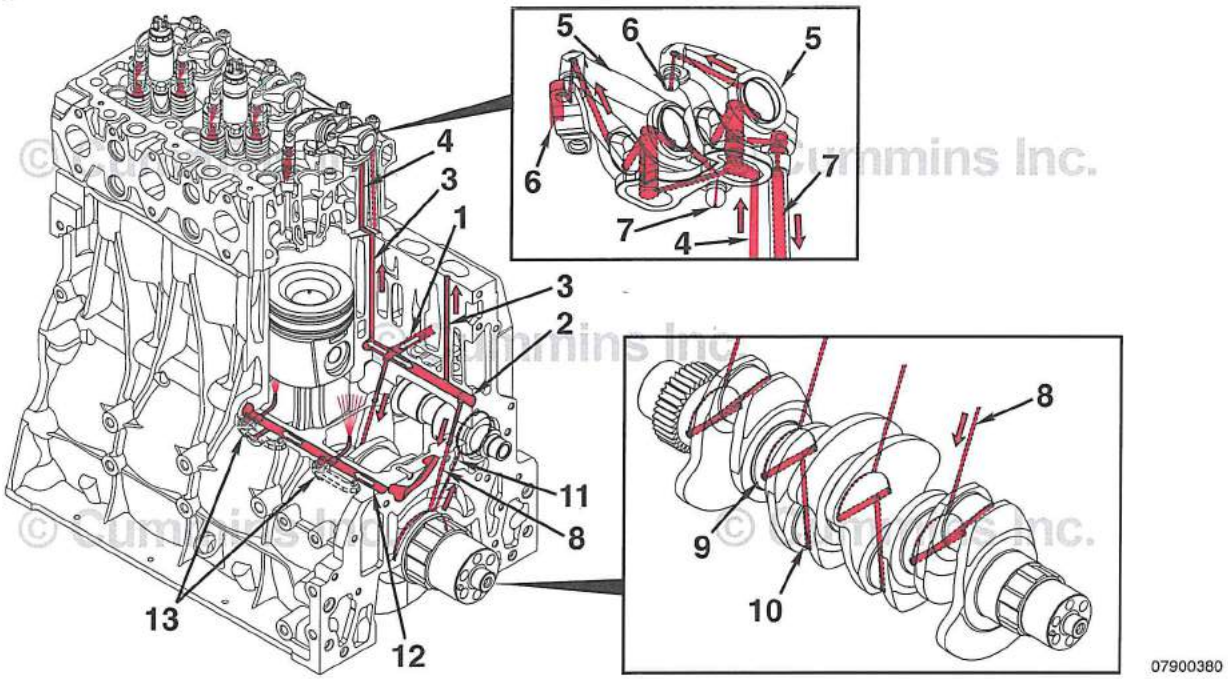



00d00405

1 Lubricating oil pump inlet from oil pan
2 Lubricating oil pump
3 Lubricating oil pressure regulator
4 Lubricating oil return to oil pan
5 Lubricating oil flow to oil filter
6 Lubricating oil cooler
7 Lubricating oil flow from cooler to filter
8 Lubricating oil filter
9 Lubricating oil filter bypass valve
10 Flow to main oil rifle
11 Main oil rifle
12 Lubricating oil flow to overhead
13 Lubricating oil supply to main bearing feed
14 Lubricating oil supply to camshaft
15 Lubricating oil flow to piston cooling rifle
16 Piston cooling rifle.

# Flow Diagram, Lubricating Oil System

## Flow Diagram

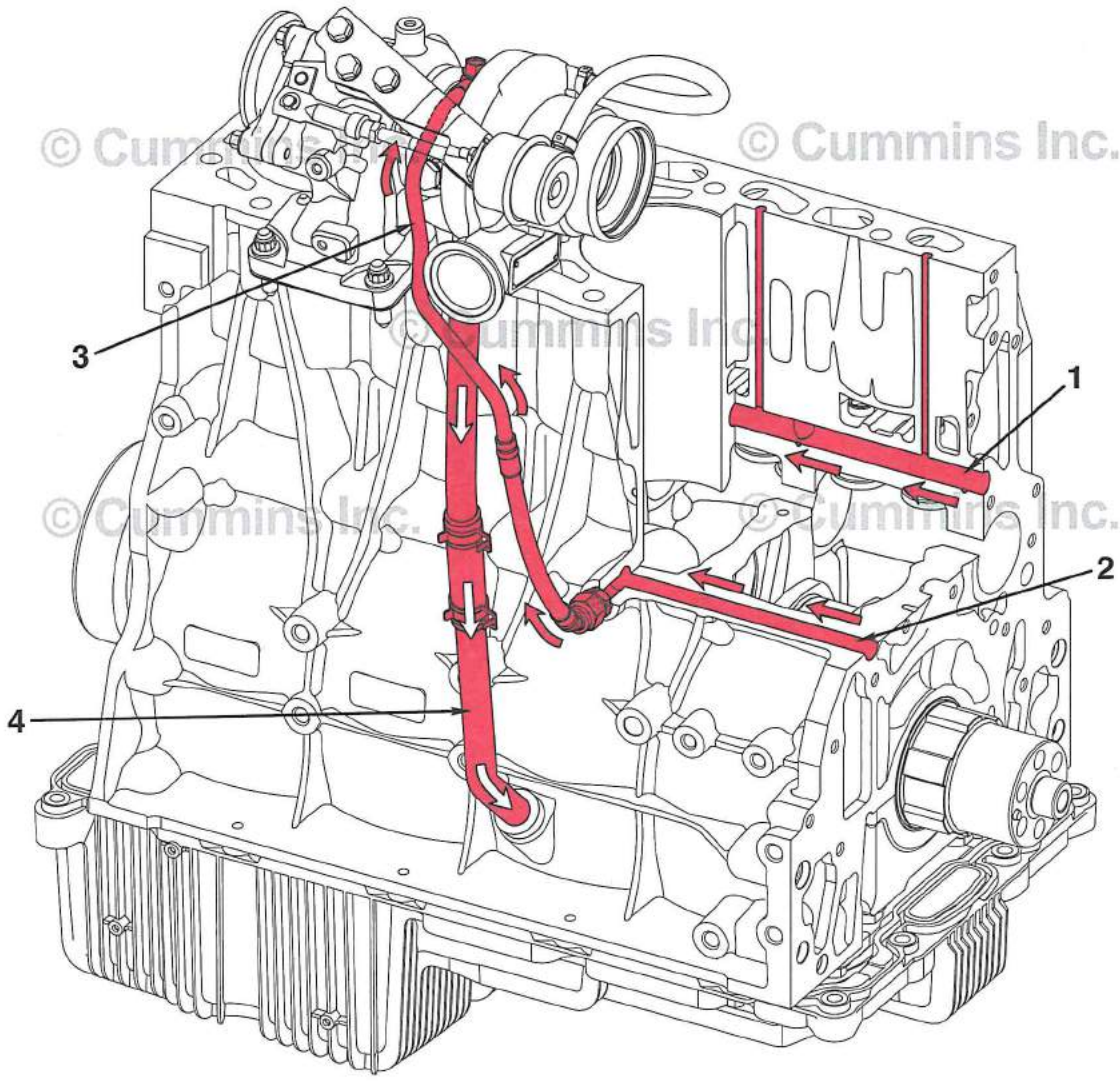





1 Lubricating oil flow from oil cooler
2 Main oil rifle
3 Lubricating oil flow to overhead
4 Lubricating oil flow to rocker levers
5 Rocker lever
6 Lubricating oil return to oil pan
7 Lubricating oil flow through push tube
8 Lubricating oil flow to crankshaft main journal
9 Crankshaft main journal
10 Crankshaft connecting rod journal
11 Lubricating oil flow to camshaft
12 Piston cooling rifle
13 Piston cooling nozzle.

# Flow Diagram, Lubricating Oil System

## Flow Diagram

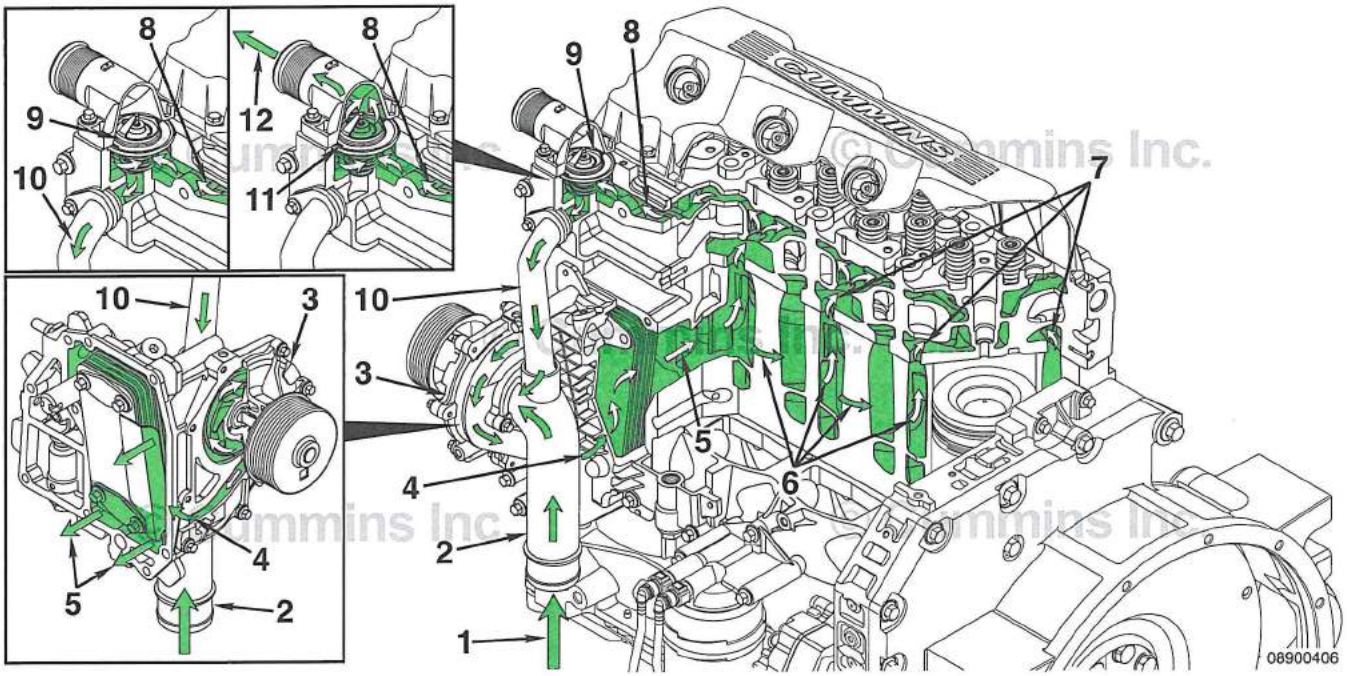



Turbocharger Oil Lubrication

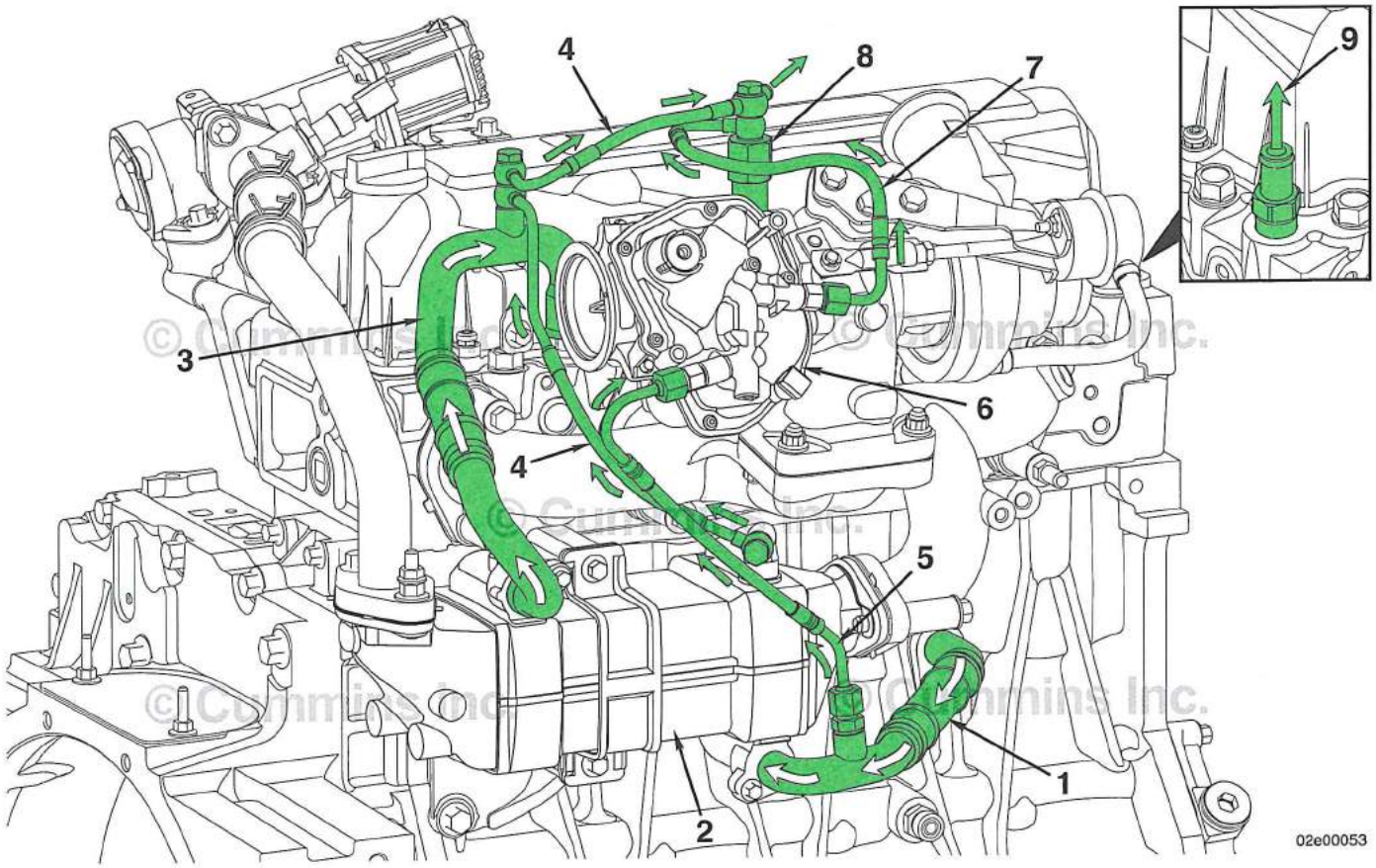
1 Main oil rifle
2 Piston cooling rifle
3 Turbocharger oil supply
4 Turbocharger oil drain.

# Flow Diagram, Cooling System

## Flow Diagram




1 Coolant flow from radiator
2 Water pump inlet
3 Water pump
4 Coolant flow from water pump to lubricating oil cooler
5 Coolant flow from lubricating oil cooler to cylinder block
6 Coolant flow around cylinders
7 Coolant flow from cylinder block to cylinder head
8 Coolant flow from cylinder head to thermostat housing
9 Thermostat closed
10 Coolant bypass to water pump
11 Thermostat open
12 Coolant return to radiator.

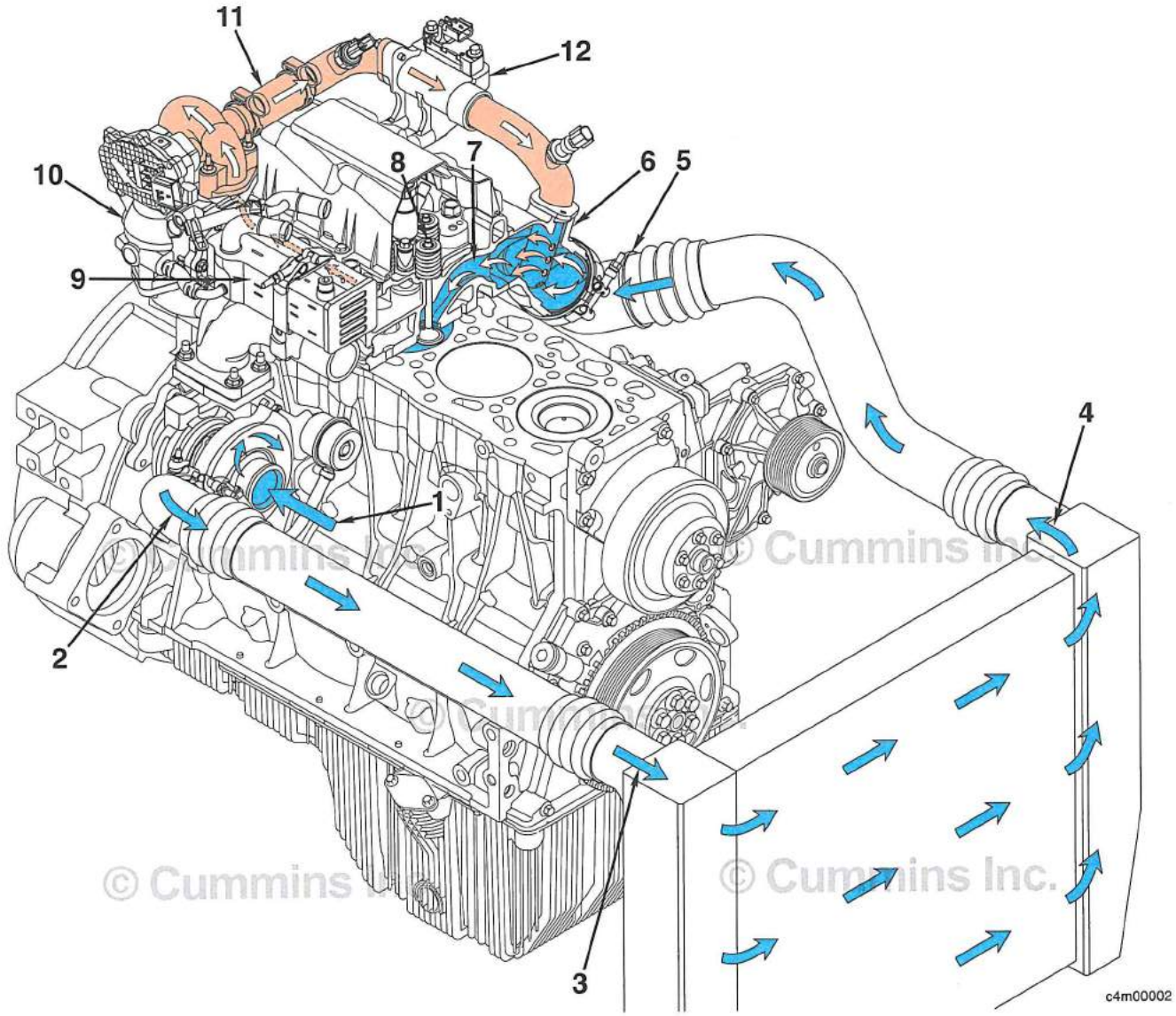





1 EGR cooler coolant supply
2 EGR cooler
3 EGR cooler coolant return
4 EGR cooler coolant vent line
5 Exhaust pressure regulator coolant supply
6 Exhaust pressure regulator
7 Exhaust pressure regulator coolant return
8 Cooling system vent
9 Cylinder head vent line.

# Flow Diagram, Air Intake System

## Flow Diagram

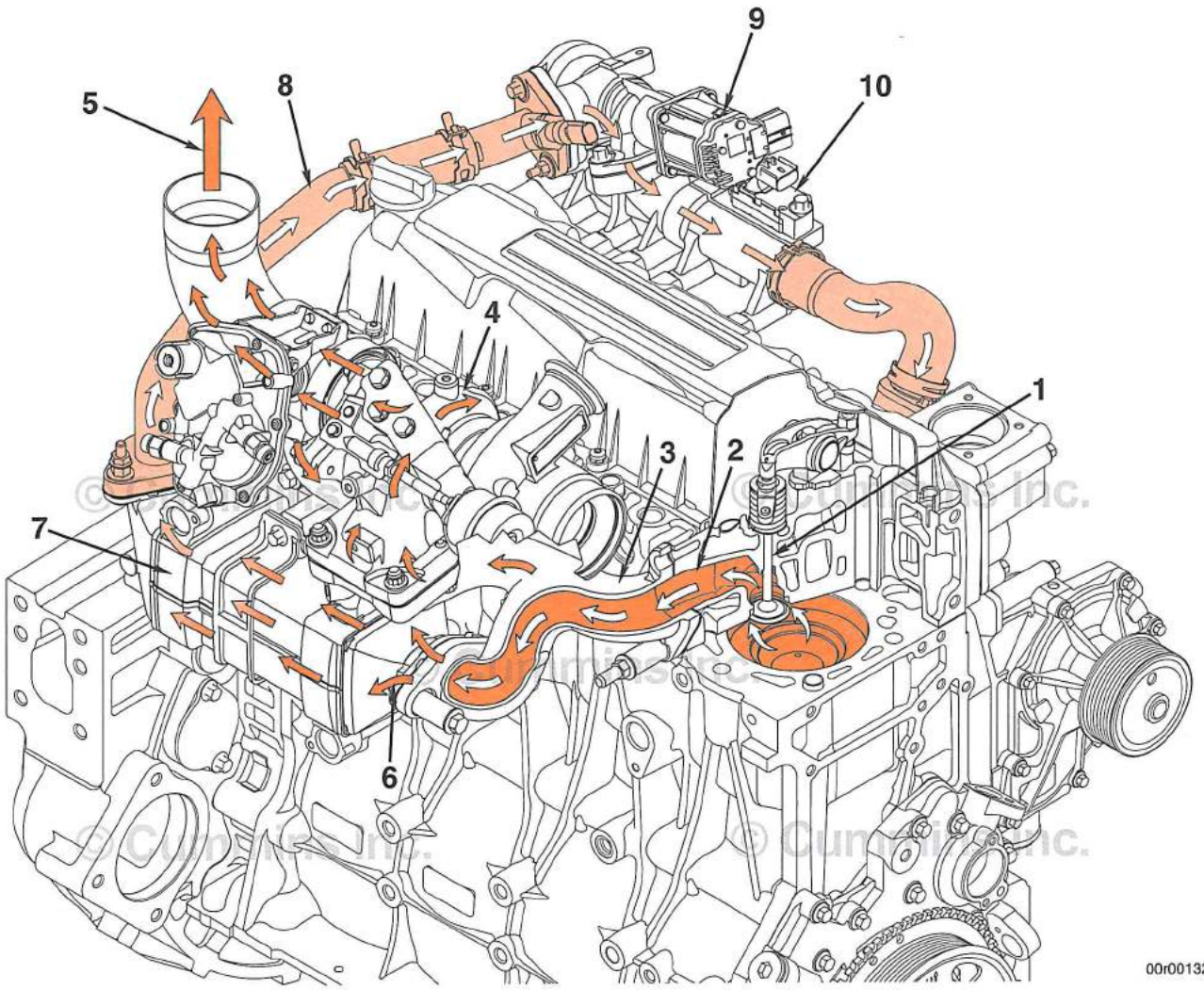





1 Filtered air supply to turbocharger compressor inlet
2 Turbocharger compressor outlet
3 Charge-air cooler inlet
4 Charge-air cooler outlet
5 Air intake connection
6 Air intake manifold
7 Intake port
8 Intake valve
9 Exhaust gas recirculation (EGR) cooler
10 EGR valve
11 EGR crossover tube
12 EGR mass measurement flow assembly.

# Flow Diagram, Exhaust System

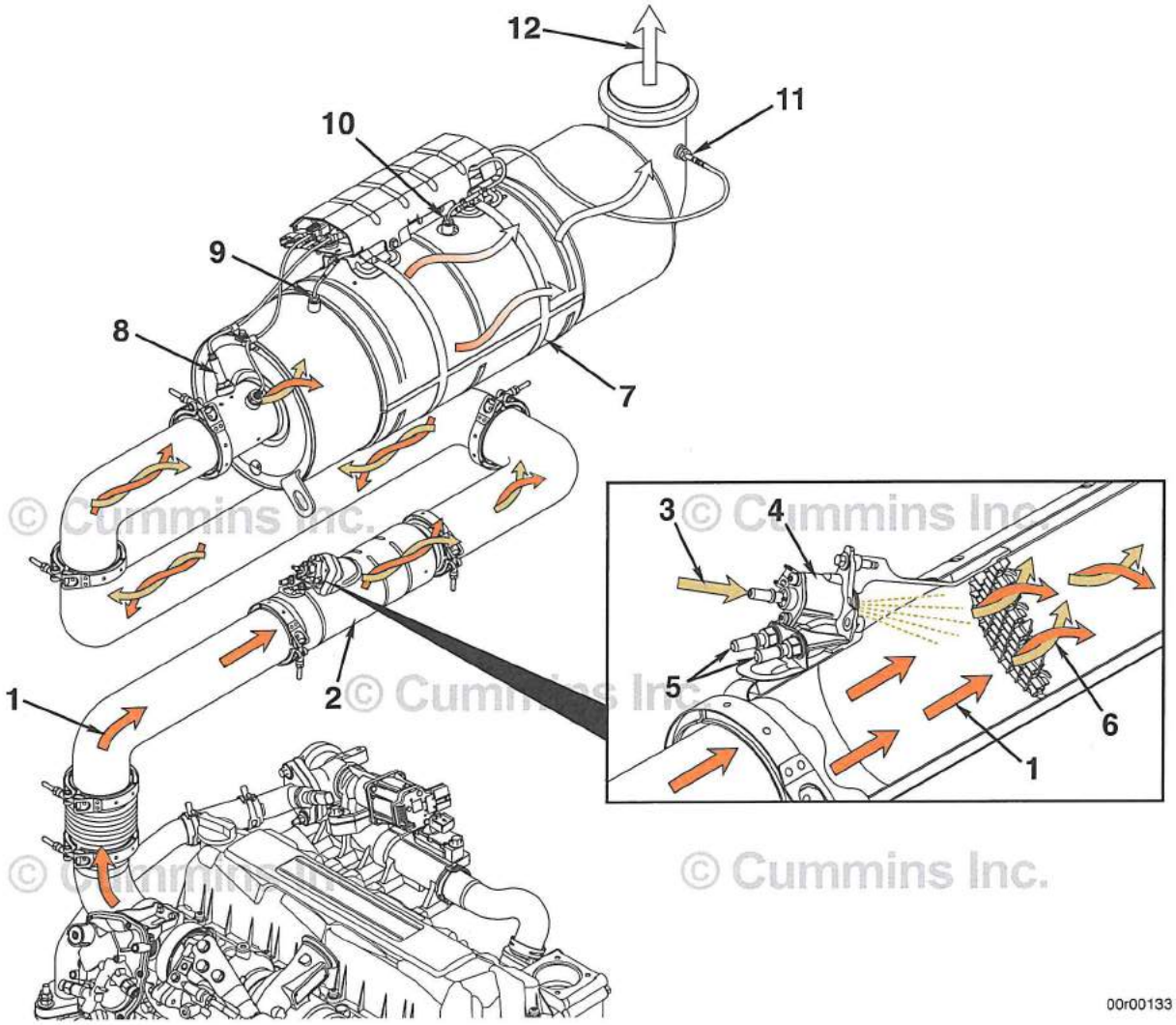
## Flow Diagram



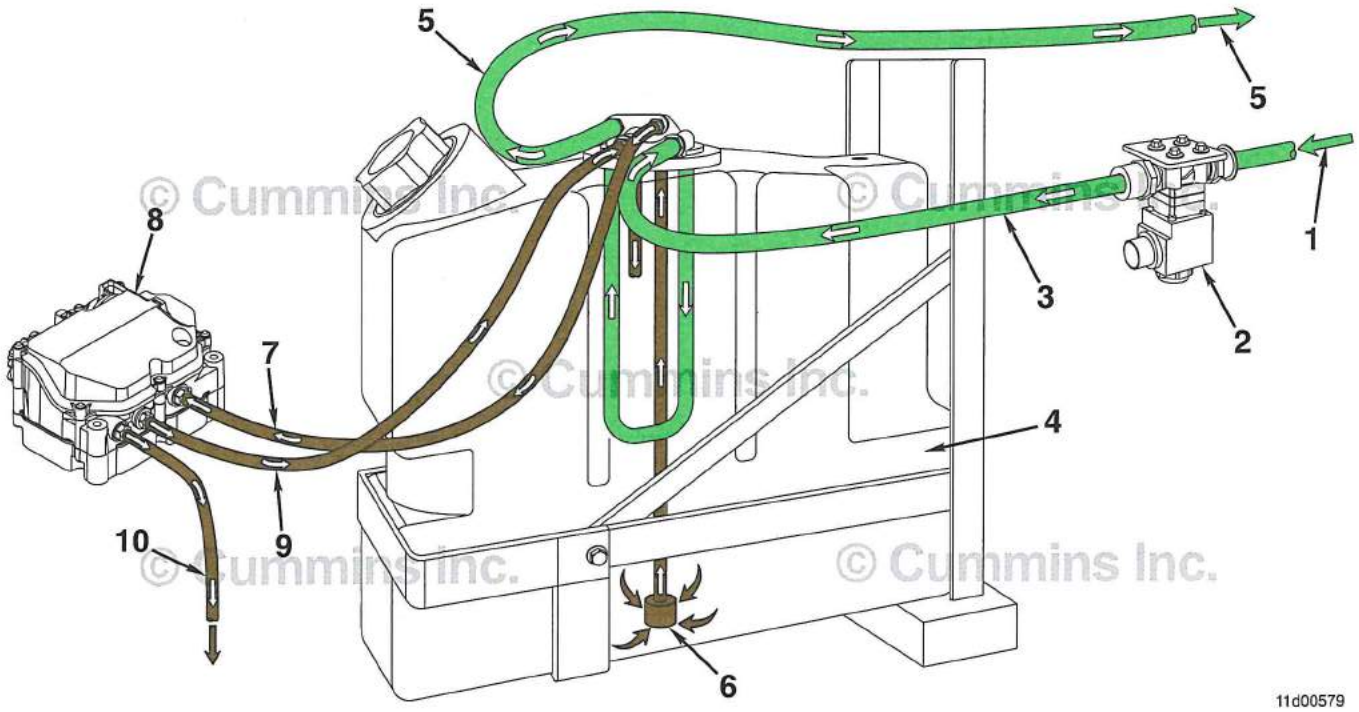

1 Exhaust valve
2 Exhaust port
3 Exhaust manifold
4 Turbocharger
5 Turbocharger exhaust outlet to aftertreatment
6 Exhaust inlet to EGR cooler
7 EGR cooler
8 Cooled exhaust outlet to EGR valve
9 EGR valve
10 Exhaust valve differential pressure sensor.

# Flow Diagram, Exhaust System

## Flow Diagram




1 Exhaust from turbocharger
2 Decomposition reactor
3 DEF supply to aftertreatment DEF dosing valve
4 Aftertreatment DEF dosing valve
5 Aftertreatment DEF dosing valve coolant fittings
6 Exhaust and DEF mixture
7 Aftertreatment SCR catalyst
8 Aftertreatment SCR inlet NOx sensor
9 Aftertreatment SCR intake temperature sensor
10 Aftertreatment SCR outlet temperature sensor
11 Aftertreatment SCR outlet NOx sensor
12 Exhaust flow exiting aftertreatment system.






1 Coolant flow from engine
2 Aftertreatment DEF tank coolant valve
3 Coolant flow to aftertreatment DEF tank (only when aftertreatment DEF tank coolant valve is open)
4 Aftertreatment DEF tank
5 Coolant flow to engine
6 Aftertreatment DEF supply from aftertreatment DEF tank
7 Aftertreatment DEF flow to aftertreatment DEF dosing control valve
8 Aftertreatment DEF control valve
9 Aftertreatment DEF flow to aftertreatment DEF tank
10 Aftertreatment DEF flow to aftertreatment DEF dosing valve.

# Notes

# Section L - Service Literature

## Section Contents

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# Additional Service Literature

## General Information

The following publications can be purchased:

| Bulletin | Title of Publication |
|---|---|
| 4367316 | QSF3.8 CM2350 F107 Service Manual |
| 4367319 | QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual |
| 4367320 | QSF3.8 CM2350 F107 Wiring Diagram |
| 4367317 | QSF3.8 CM2350 F107 Operation and Maintenance Manual |
| 4367318 | QSF3.8 CM2350 F107 Owners Manual |
| 3379000 | Air for Your Engine |
| 3379001 | Fuel for Cummins® Engines |
| 3379009 | Operation - Cold Weather |
| 3666132 | Cummins® Coolant Requirements and Maintenance |
| 3810340 | Cummins® Engine Oil and Oil Analysis Recommendations |
| 4021566 | Diesel Exhaust Fluid Specifications for Cummins® Selective Catalytic Reduction Systems |

# 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/store

# Cummins Customized Parts Catalog

## General Information

Cummins is pleased to announce the availability of a parts catalog compiled specifically for you. Unlike the generic versions of parts catalogs that support general high volume parts content; Cummins Customized catalogs contain only the new factory parts that were used to build your engine.

The catalog cover, as well as the content, is customized with you in mind. You can use it in your shop, at your worksite, or as a coffee table book in your RV or boat. The cover contains your name, company name, address, and telephone number.

This new catalog was designed to provide you with the exact information you need to order parts for your engine. This will be valuable for customers that do not have easy access to Cummins QuickServe Online.

Additional Features of the Customized Catalog include:

- Engine Configuration Data
- Table of Contents
- Separate Option and Parts Indexes
- Service Kits (when applicable)
- ReCon Part Numbers (when applicable)

## Ordering the Customized Parts Catalog

### Ordering by Telephone

- North American Distributors, Original Equipment Manufacturers and Cummins Factory personnel order by calling Iron Mountain Fulfillment Services (IMFS) at 1-800-646-5609.
- International Distributors and Original Equipment Manufacturers order the CPC from their regional Cummins Parts Distribution Centers (PDC).
- International PDC orders are called into Iron Mountain at (++) 630-283-2420.
- Retail Credit Card Orders require a 2 step ordering process.

### Ordering On-Line

Access the Cummins QSOL store at https://store.cummins.com

- Find the Customized Parts Catalog button located on the left of the homepage
- Select format. Your Price is also shown here
- Finalize Shopping Cart and Check Process as described on the website

North America call Iron Mountain Fulfillment Services (IMFS) at 800-646-5609, International customers call (++) 630-283-2420. Provide IMFS the catalog detail as described on the website. This step is required until we have our On Line form available.

Required information needed for your Customized Parts Catalog Order.

- Customer Name
- Street Address
- Company Name (optional)
- Telephone no.
- Credit Card No.
- Cummins Engine Serial Number (located on the engine data plate)

Unfortunately not all Cummins Engines can be supported by Customized Parts Catalogs. Engines older than 1984 or newer than 3 months may not have the necessary parts information to compile a catalog. We will contact you if this occurs and explain why we are unable to fill your order.

Customized Parts Catalogs are produced specifically for a single customer. This means they are not returnable for a refund. If we make an error and your catalog is not useable, we will correct that error by sending you a new catalog.

# Notes

# Section S - Service Assistance

## Section Contents

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# Service Assistance

## General Information

To contact the nearest Cummins® Authorized Repair Location, utilize the Service Locator at www.cummins.com.

Cummins Inc. provides a 24-hour, toll free telephone number to aid in technical and emergency service when a Cummins® Authorized Repair Location can **not** be reached or is unable to resolve an issue with a Cummins® product.

**U.S. and Canada**

- 1-800-CUMMINS™ (1-800-286-6467)

**Mexico**

- 01-800-CUMMINS (2866467)
- Email: contacto.mexico@cummins.com

**Australia/New Zealand**

- For Australia: 1-800-CUMMINS (1800 286 646)
- For New Zealand: 0-800-CUMMINS (0800 286 646)
- Email: marketingsouthpac@cummins.com

**Brazil**

- 0800 CUMMINS (0800 286 6467)
- Email: falecom@cummins.com

**Europe**

- From the UK, Ireland, Germany, France, and the Netherlands - Freephone: 00 8000 2866467
- Email: emea.customerassistance@cummins.com

**China**

- 400 810 5252 or (+86) 400 810 5252
- Email: customersupport@cummins.com

**India**

- 800 210 2525
- Email: powermaster-India@cummins.com

**Russia**

- Primary: +7 495 926 8624
- Alternate: +7 962 943 1211

**For All Other Areas:**

- +44 (0) 1327 886464

# Routine Service and Parts

## General Information

Personnel at Cummins Authorized Repair Locations can assist you with the correct operation and service of your system. Cummins has a worldwide service network of more than 5,000 Distributors and Dealers who have been trained to provide sound advice, expert service, and complete parts support. Check the telephone directory, refer to the directory in this section, or the Service Locator at www.cummins.com for the nearest Cummins Authorized Repair Location.

# 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**<br>Alternator pulley is loose on the shaft | Tighten the pulley. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Batteries have malfunctioned | Check the condition of the batteries. Replace the batteries, if necessary. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Battery cables or connections are loose, broken, or corroded (excessive resistance) | Check the battery cables and connections. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Alternator is overloaded, or alternator capacity is below specification | Install an alternator with a higher capacity. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>Alternator or voltage regulator is malfunctioning | Test the alternator output. Replace the alternator or voltage regulator, if necessary. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>Battery temperature is above specification | Position the batteries away from heat sources. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Electrical system is "open" (blown fuses, broken wires, or loose connections) | Check the fuses, wires, and connections. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>Vehicle gauge is malfunctioning | Check the vehicle gauge. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 9**<br>Contact a Cummins® Authorized Repair Facility | |

## Charging System Alternator Overcharging

| Cause | Correction |
| --- | --- |
| **STEP 1**<br>Batteries have failed | Check the condition of the batteries. Replace the batteries, if necessary. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Voltage regulator is malfunctioning | Check the voltage regulator. Replace the voltage regulator, if necessary. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Contact a Cummins® Authorized Repair Facility | |

## Coolant Contamination

| Cause | Correction |
|---|---|
| **STEP 1**<br>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 7. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>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<br>Go To Next Step | |
| **STEP 3**<br>Lubricating oil cooler is leaking | Check the lubricating oil cooler for coolant leaks and cracks. Refer to a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Cylinder head gasket is leaking | Check the cylinder head gasket. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>Contact a Cummins® Authorized Repair Facility | |

# Coolant Loss - External

| Cause | Correction |
|---|---|
| **STEP 1**<br>Coolant level is below specification | Check the coolant level. Check for an external leak. Refer to equipment manufacturer service information. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak). |

OK
Go To Next Step

| | |
|---|---|
| **STEP 2**<br>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, exhaust gas recirculation cooler 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 original equipment manufacturer mounted components that have coolant flow. If necessary, pressure test the cooling system. Refer to Procedure 008-018 in Section 7. |

OK
Go To Next Step

| | |
|---|---|
| **STEP 3**<br>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**<br>Cooling system hose is collapsed, restricted, or leaking | Inspect the hoses. Refer to Procedure 008-045 in Section 7. |

OK
Go To Next Step

| | |
|---|---|
| **STEP 5**<br>Coolant fill line is restricted or obstructed | Check the coolant fill line for restrictions or obstructions. Refer to Procedure 008-018 in Section 7. |

OK
Go To Next Step

| | |
|---|---|
| **STEP 6**<br>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 7. |

OK
Go To Next Step

| | |
|---|---|
| **STEP 7**<br>Engine is overheating | Refer to the Coolant Temperature is Above Normal - Sudden Overheat or the Coolant Temperature is Above Normal - Gradual Overheat troubleshooting symptom tree in Section TS. |

OK
Go To Next Step

## Coolant Loss - External

| Cause | Correction |
| --- | --- |
| **STEP 8**<br>Contact a Cummins® Authorized Repair Facility | |

# Coolant Temperature Above Normal - Gradual Overheat

| Cause | Correction |
|---|---|
| **STEP 1**<br>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 4 and see equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>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<br>Go To Next Step | |
| **STEP 3**<br>Coolant level is below specification | Check the coolant level. Check for an external leak. Refer to Procedure 008-066 in Section 3. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak). |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>Fan shroud is damaged or missing or the air recirculation baffles are damaged or missing | Inspect the shroud and the recirculation baffles. Repair, replace, or install, as necessary. Refer to Procedure 101-007 in Section 1. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>Lubricating oil is contaminated with coolant or fuel | Refer to the Lubricating Oil Contaminated symptom tree in Section TS. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Cooling system hose is collapsed, restricted, or leaking | Inspect the hoses. Refer to Procedure 008-045 in Section 7. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>Coolant mixture of antifreeze and water is **not** correct | Verify the concentration of antifreeze in the coolant. Add antifreeze or water to correct the concentration. Refer to Procedure 008-018 in Section 7 and Procedure 018-004 in Section V. |
| OK<br>Go To Next Step | |

## Coolant Temperature Above Normal - Gradual Overheat

| Cause | Correction |
|---|---|
| **STEP 9**<br>Lubricating oil level is above or below specification | Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-043 in Section 3 and Procedure 018-003 in Section V. |

OK
Go To Next Step

| | |
|---|---|
| **STEP 10**<br>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 11**<br>Fan drive belt is loose, tight, or **not** in alignment | Check the fan drive belt. Refer to Procedure 008-087 in Section 7. |

OK
Go To Next Step

| | |
|---|---|
| **STEP 12**<br>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**<br>Coolant level is below specification | Check the coolant level. Check for an external leak. Refer to Procedure 008-066 in Section 3. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak). |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Air in the cooling system | Inspect and vent the cooling system. Refer to Procedure 008-018 in Section 7. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Fan drive belt is broken | Check the fan drive belt. Replace the belt, if necessary. Refer to Procedure 008-002 in Section A. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating | Check the radiator pressure cap. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>Cooling system hose is collapsed, restricted, or leaking | Inspect the hoses. Refer to Procedure 008-045 in Section 7. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Coolant temperature gauge is malfunctioning | Test the temperature gauge. Repair or replace the gauge, if necessary. Contact a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>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 4 and equipment manufacturer service information. |
| OK<br>Go To Next Step | |

## Coolant Temperature Above Normal - Sudden Overheat

| Cause | Correction |
| --- | --- |
| **STEP 9**<br>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 10**
Contact a Cummins® Authorized Repair Facility

# Coolant Temperature Below Normal

| Cause | Correction |
|---|---|
| **STEP 1**<br>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<br>Go To Next Step | |
| **STEP 2**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>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 the following bulletin, Cold Weather Operation, Bulletin 3387266. Refer to Procedure 101-015 in Section 1. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Fan drive or fan controls are malfunctioning | Check the fan drive and controls. Contact a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>Coolant temperature gauge is malfunctioning | Test the temperature gauge. Repair or replace the gauge, if necessary. Contact a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>Thermostat is **not** correct or is malfunctioning | Check the thermostat for the correct part number and for correct operation. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Contact a Cummins® Authorized Repair Facility | |

## Engine Acceleration or Response Poor

| Cause | Correction |
|---|---|
| **STEP 1**<br>Operator technique is **not** correct | Refer to Procedure 101-014 in Section 1. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Fuel level is low in the tank | Fill the supply tank. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>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<br>Go To Next Step | |
| **STEP 4**<br>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<br>Go To Next Step | |
| **STEP 5**<br>Drivetrain is **not** correctly matched to the engine | Check for correct gearing and drivetrain components. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>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<br>Go To Next Step | |
| **STEP 8**<br>Intake manifold air temperature is above specification | Refer to the Intake Manifold Air Temperature Above Specification symptom tree in Section TS. |
| OK<br>Go To Next Step | |
| **STEP 9**<br>Charge-air cooler is restricted or leaking | Inspect the charge-air cooler for air restrictions or leaks. Refer to Procedure 010-027 in Section 4. |
| OK<br>Go To Next Step | |

## Engine Acceleration or Response Poor

| Cause | Correction |
|---|---|
| **STEP 10**<br>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<br>Go To Next Step | |
| **STEP 11**<br>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 3. |
| OK<br>Go To Next Step | |
| **STEP 12**<br>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 3. |
| OK<br>Go To Next Step | |
| **STEP 13**<br>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<br>Go To Next Step | |
| **STEP 14**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 15**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 16**<br>Contact a Cummins® Authorized Repair Facility | |

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

| Cause | Correction |
|---|---|
| **STEP 1**<br>Starting procedure is **not** correct | Verify the correct starting procedure. Refer to Procedure 101-014 in Section 1. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Fuel level is low in the tank | Fill the supply tank. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Starting aid, if necessary for cold weather, is malfunctioning | Check for correct operation of the cold weather starting aid. Refer to Procedure 101-004 in Section 1 or the manufacturer's instructions. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>Engine block heater is malfunctioning, if equipped | Check the electrical sources and wiring to the cylinder block heater. Replace the block heater, if necessary. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>Fuel heater is malfunctioning, if equipped | Check the fuel heater and replace, if necessary. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Battery voltage is low | Check the batteries and the unswitched battery supply circuit. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>Keyswitch circuit is malfunctioning | Check the vehicle keyswitch circuit. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 9**<br>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 symptom tree. |
| OK<br>Go To Next Step | |

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

| Cause | Correction |
|---|---|
| **STEP 10**<br>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<br>Go To Next Step | |
| **STEP 11**<br>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<br>Go To Next Step | |
| **STEP 12**<br>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<br>Go To Next Step | |
| **STEP 13**<br>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 3. |
| OK<br>Go To Next Step | |
| **STEP 14**<br>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<br>Go To Next Step | |
| **STEP 15**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 16**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 17**<br>Contact a Cummins® Authorized Repair Facility | |

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

| Cause | Correction |
|---|---|
| **STEP 1**<br>Starting procedure is **not** correct | Verify the correct starting procedure. Refer to Procedure 101-014 in Section 1. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Fuel level is low in the tank | Fill the supply tank. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>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<br>Go To Next Step | |
| **STEP 4**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>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<br>Go To Next Step | |
| **STEP 6**<br>Battery voltage is low | Check the batteries and the unswitched battery supply circuit. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Keyswitch circuit is malfunctioning | Check the vehicle, equipment, or vessel keyswitch circuit. Refer to a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>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<br>Go To Next Step | |
| **STEP 9**<br>Moisture in the wiring harness connectors | Dry the connector with Cummins® electrical contact cleaner, Part Number 3824510. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |

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

| Cause | Correction |
|---|---|
| **STEP 10**<br>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**<br>Engine control module (ECM) is locked up | Disconnect the battery cables for 30 seconds. Connect the battery cables and start the engine. |

OK
Go To Next Step

| | |
|---|---|
| **STEP 12**<br>Fuel filter or fuel suction line is restricted | Replace the fuel filter. Check the fuel suction line for restriction. Refer to Procedure 006-015 Section 5. |

OK
Go To Next Step

| | |
|---|---|
| **STEP 13**<br>Fuel supply is **not** adequate | Check the flow through the filter to locate the source of the restriction. Refer to Procedure 006-015 Section 5. |

OK
Go To Next Step

| | |
|---|---|
| **STEP 14**<br>Fuel drain backup | Verify the fuel return line is plumbed to the bottom of the fuel tank. |

OK
Go To Next Step

**STEP 15**
Contact a Cummins® Authorized Repair Facility

# Engine Noise Excessive

| Cause | Correction |
|---|---|
| **STEP 1**<br>Fan drive belt is loose, tight, or **not** in alignment | Check the fan drive belt. Refer to Procedure 008-087 in Section 5. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>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<br>Go To Next Step | |
| **STEP 3**<br>Crankshaft pulley is damaged | Inspect the crankshaft pulley. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>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 3. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>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<br>Go To Next Step | |
| **STEP 6**<br>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 3. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Coolant temperature is above specification | Refer to the Coolant Temperature is Above Normal - Sudden Overheat or the Coolant Temperature is Above Normal - Gradual Overheat symptom tree in Section TS. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>Engine mounts are worn, damaged, or **not** correct | Check the engine mounts. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 9**<br>Fan clutch, hydraulic pump, or refrigerant compressor noise is excessive | Isolate each component and check for noise. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |

## Engine Noise Excessive

| Cause | Correction |
| --- | --- |
| **STEP 10**<br>Fan is loose, damaged, or has excessive hub bearing end clearance | Check the fan. Refer to Procedure 008-087 in Section 5. |

OK
Go To Next Step

**STEP 11**
Contact a Cummins® Authorized Repair Facility

# Engine Noise Excessive - Combustion Knocks

| Cause | Correction |
|---|---|
| **STEP 1**<br>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<br>Go To Next Step | |
| **STEP 2**<br>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<br>Go To Next Step | |
| **STEP 3**<br>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<br>Go To Next Step | |
| **STEP 4**<br>Coolant temperature is below specification | Refer to the Coolant Temperature Below Normal troubleshooting symptom tree in Section TS. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>Contact a Cummins® Authorized Repair Facility | |

# Engine Power Output Low

| Cause | Correction |
|---|---|
| **STEP 1**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>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<br>Go To Next Step | |
| **STEP 3**<br>Engine is operating above recommended altitude | Engine power decreases above recommended altitude. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>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<br>Go To Next Step | |
| **STEP 5**<br>Intake and exhaust system restricted | Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to Procedure 010-059 in Section 3. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>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 3. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>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 3. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>Air leak between the turbocharger and the intake manifold | Check for leaks in the air crossover tube, charge-air cooler connections, hoses, or through holes in the manifold cover and repair or replace if necessary. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |

## Engine Power Output Low

| Cause | Correction |
|---|---|
| **STEP 9**<br>Charge-air cooler is restricted or leaking | Inspect the charge-air cooler for air restrictions or leaks. Refer to Procedure 010-027 in Section 4. |
| OK<br>Go To Next Step | |
| **STEP 10**<br>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<br>Go To Next Step | |
| **STEP 11**<br>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<br>Go To Next Step | |
| **STEP 12**<br>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<br>Go To Next Step | |
| **STEP 13**<br>Fuel return restriction excessive | Inspect the fuel return lines for restrictions. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 14**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 15**<br>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<br>Go To Next Step | |
| **STEP 16**<br>Lubricating oil level above specification | Check the oil level. Verify the oil pan capacity. Fill the system to the specified level. Refer to Procedure 018-017 in Section V. |
| OK<br>Go To Next Step | |
| **STEP 17**<br>Contact a Cummins® Authorized Repair Facility | |

# Engine Runs Rough at Idle

| Cause | Correction |
|---|---|
| **STEP 1**<br>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<br>Go To Next Step | |
| **STEP 2**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Idle speed is set too low for accessories | Check and adjust the low-idle screw. Refer to a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>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<br>Go To Next Step | |
| **STEP 5**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Engine mounts are worn, damaged, or **not** correct | Check the engine mounts. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>Moisture in the wiring harness connectors | Dry the connector with Cummins® electrical contact cleaner, Part Number 3824510. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 9**<br>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<br>Go To Next Step | |

## Engine Runs Rough at Idle

| Cause | Correction |
| --- | --- |
| **STEP 10**<br>Contact a Cummins® Authorized Repair Facility | |

# Engine Runs Rough or Misfires

| Cause | Correction |
|---|---|
| **STEP 1**<br>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<br>Go To Next Step | |
| **STEP 2**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>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. Vent air from the system. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>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<br>Go To Next Step | |
| **STEP 5**<br>Fuel leak | Check the fuel lines, fuel connections, and fuel filters for leaks. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>Fuel filter is plugged | Measure the fuel pressure before and after the fuel filter. Refer to Procedure 006-015 in Section 5. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>Engine mounts are worn, damaged, or **not** correct | Check the engine mounts. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |

## Engine Runs Rough or Misfires

| Cause | Correction |
| --- | --- |
| **STEP 9**<br>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 10**
Contact a Cummins® Authorized Repair Facility

# Engine Shuts Off Unexpectedly or Dies During Deceleration

| Cause | Correction |
|---|---|
| **STEP 1**<br>Engine will **not** restart | Refer to the Engine Difficult to Start or Will **Not** Start troubleshooting symptom tree in Section TS. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Fuel level is low in the tank | Fill the supply tank. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Idle Shutdown or power takeoff (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<br>Go To Next Step | |
| **STEP 5**<br>Moisture in the wiring harness connectors | Dry the connectors with electrical contact cleaner, Part Number 3824510. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>OEM engine protection system is malfunctioning | Isolate the OEM engine protection system. Follow the OEM service manual instructions to check for a malfunction. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Battery voltage supply to the engine control module (ECM) is low, interrupted, or open | Check the battery connections, the fuses, and the unswitched battery supply circuit. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>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<br>Go To Next Step | |
| **STEP 9**<br>Contact a Cummins® Authorized Repair Facility | |

## Engine Speed Surges at Low or High Idle

| Cause | Correction |
|---|---|
| **STEP 1**<br>Fuel level is low in the tank | Fill the supply tank. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Engine idle speed is set too low | Adjust the idle speed. Refer to a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Moisture in the wiring harness connectors | Dry the connector with Cummins® electrical contact cleaner, Part Number 3824510. Refer to Procedure 101-007 in Section 1. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>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<br>Go To Next Step | |
| **STEP 6**<br>Fuel filter is plugged | Measure the fuel pressure before and after the fuel filter. Refer to Procedure 006-015 in Section 5. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>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<br>Go To Next Step | |
| **STEP 9**<br>Contact a Cummins® Authorized Repair Facility | |

## Engine Speed Surges Under Load or in Operating Range

| Cause | Correction |
|---|---|
| **STEP 1**<br>Fuel level is low in the tank | Fill the supply tank. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Moisture in the wiring harness connectors | Dry the connector with Cummins® electrical contact cleaner, Part Number 3824510. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>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<br>Go To Next Step | |
| **STEP 5**<br>Fuel filter is plugged | Measure the fuel pressure before and after the fuel filter. Refer to Procedure 006-015 in Section 5. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>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<br>Go To Next Step | |
| **STEP 8**<br>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<br>Go To Next Step | |
| **STEP 9**<br>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<br>Go To Next Step | |

## Engine Speed Surges Under Load or in Operating Range

| Cause | Correction |
| --- | --- |
| STEP 10<br>Contact a Cummins® Authorized Repair Facility | |

# Engine Speed Surges in PTO or Cruise Control

| Cause | Correction |
|---|---|
| **STEP 1**<br>Engine speed also surges at idle | Refer to the Engine Speed Surges at Low or High Idle troubleshooting symptom tree in Section TS. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Engine speed surges while in the normal operating range and **not** in PTO or cruise control | Refer to the Engine Speed Surges Under Load or in Operating Range troubleshooting symptom tree in Section TS. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Moisture in the wiring harness connectors | Dry the connector with Cummins® electrical contact cleaner, Part Number 3824510. Refer to the Engine Speed Surges Under Load or in Operating Range troubleshooting symptom tree in Section TS. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>Fuel filter is plugged | Measure the fuel pressure before and after the fuel filter. Refer to Procedure 006-015 in Section 5. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Contact a Cummins® Authorized Repair Facility | |

## Engine Starts But Will Not Keep Running

| Cause | Correction |
|---|---|
| **STEP 1**<br>Fuel level is low in the tank | Fill the supply tank. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>Battery voltage supply to the control module (ECM) is low, interrupted, or open | Check the battery connections. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Idle speed is set too low for accessories | Check and adjust the low-idle screw. Refer to a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>Engine-driven units are engaged | Disengage engine-driven units. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>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<br>Go To Next Step | |
| **STEP 7**<br>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 5. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>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<br>Go To Next Step | |
| **STEP 9**<br>Contact a Cummins® Authorized Repair Facility | |

# Engine Vibration Excessive

| Cause | Correction |
|---|---|
| **STEP 1**<br>Belt-driven accessories are malfunctioning | Check the fan hub, alternator, refrigerant compressor, and hydraulic pump for interference. Isolate belt-driven accessories and check for vibration. Refer to Procedure 008-036 in Section 6 and Procedure 013-001 in Section A. |
| OK<br>Go To Next Step | |
| **STEP 2**<br>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<br>Go To Next Step | |
| **STEP 3**<br>Engine mounts are worn, damaged, or **not** correct | Check the engine mounts. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>Fan is loose, damaged, or has excessive hub bearing end clearance | Check the fan. Refer to equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 5**<br>Engine is misfiring | Refer to the Engine Runs Rough or Misfires troubleshooting symptom tree in Section TS. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>Crankshaft pulley is damaged or loose | Inspect the crankshaft pulley. Refer to a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |
| **STEP 8**<br>Alternator bearing worn or damaged | Replace the alternator, if damaged. See equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 9**<br>Contact a Cummins® Authorized Repair Facility | |

## Engine Will Not Reach Rated Speed (RPM)

| Cause | Correction |
|---|---|
| **STEP 1**<br>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<br>Go To Next Step | |
| **STEP 2**<br>Electronic fault codes are active or high counts of inactive fault codes | Review instructions for reading active fault codes. |
| OK<br>Go To Next Step | |
| **STEP 3**<br>Vehicle speed is too low for adequate cooling with high engine load | Reduce the engine load. Increase the engine (fan) rpm by downshifting. |
| OK<br>Go To Next Step | |
| **STEP 4**<br>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<br>Go To Next Step | |
| **STEP 5**<br>Air-fuel tube leaking, wastegate diaphragm ruptured, or wastegate plumbing damaged | Tighten the fittings, repair the plumbing, and/or replace the wastegate diaphragm. Refer to equipment manufacturer service information or contact a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |
| **STEP 6**<br>Charge-air cooler restricted, if equipped | Inspect the charge-air cooler for internal and external restrictions. Replace the restricted cooler if necessary. See equipment manufacturer service information. |
| OK<br>Go To Next Step | |
| **STEP 7**<br>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<br>Go To Next Step | |
| **STEP 8**<br>Exhaust back pressure too high | Measure and correct if above specification. Refer to equipment manufacturer service information or contact a Cummins® Authorized Repair Location. |
| OK<br>Go To Next Step | |

## Engine Will Not Reach Rated Speed (RPM)

| Cause | Correction |
| --- | --- |
| **STEP 9**<br>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 this engine.

| | |
|---|---|
| Horsepower | Refer to engine dataplate |
| Bore and Stroke | 102 mm [4.02 in] x 115 mm [4.53 in] |
| Firing Order | 1-3-4-2 |
| **Engine Weight (with standard accessories):** | |
| Dry Weight for 3.8 liter engine [231 C.I.D.] | 348 kg [767 lb] |
| Crankshaft Rotation (viewed from the front of the engine) | **Clockwise** |
| **Valve Clearance:** | |
| Intake | 0.330 mm [0.013 in] |
| Exhaust | 0.584 mm [0.023 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 | 700 rpm |
| **Altitude Maximum Before Derate Occurs** | |
| 3.8 liter engine | 1676 m [5500 ft] |
| **Oil Carryover:** | |
| Open crankcase ventilation system | Less than 2 grams/hour [0.07 oz/hr] |
| **Engine Blowby (with orifice size 5.61 mm [0.221 in]):** | |
| New | 101.6 mm $H_2O$ [ 4.0 in $H_2O$] |
| Used | 431.8 mm $H_2O$ [ 17.0 in $H_2O$] |

**NOTE:** The engine features a no-adjust overhead. 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 0.229 to 0.457 mm [0.009 to 0.018 in] intake valve lash and 0.457 to 0.838 mm [0.018 to 0.033 in] exhaust valve lash. It is recommended that the valve lash be checked at 5000 hours and every 2000 hours thereafter.

# Fuel System

## Specifications

For performance and fuel rate values, see the Engine Data Sheet.

Maximum Fuel Inlet Restriction - With gear pump **only** (at gear pump inlet)..... 41 kPa [12 in-Hg]
Rail Pressure.....250 to 2,000 bar [3,626 to 29,008 psi]
Maximum Fuel Pressure Range at Fuel Filter Outlet (engine cranking) - With gear pump **only** ....207 to 750 kPa [30 to 109 psi] Maximum
Fuel Pressure Range at Fuel Filter Inlet (engine running) - With gear pump **only** ..... 450 to 750 kPa [65 to 109 psi]
Maximum Fuel Drain Line Restriction..... 20 kPa [5.9 in-Hg]
Maximum Fuel Inlet Temperature.....70°C [158°F]

# Lubricating Oil System

## Specifications

**Oil Pressure**
- Low idle (minimum allowed) ..... 69 kPa [10 psi]
- At rated speed (minimum allowed) ..... 275 kPa [40 psi]

Oil-regulating valve-opening pressure range ..... 525 kPa to 600 kPa [76 psi to 87 psi]
Oil filter differential pressure to open bypass ..... 345 kPa [50 psi]
Lubricating oil filter capacity ..... 0.85 liters [0.9 qt]

**Oil Temperature**
- Maximum oil temperature ..... 135°C [275°F]

**Oil Capacity of Standard Engine**

**Option 1 - Low Capacity Rear Sump Oil Pan**
- Pan **only** ..... 8 liters [8.4 qt]
- Total system ..... 10.6 liters [11.2 qt]
- High to low (on dipstick) ..... 1.5 liters [1.6 qt]

**Option 2 - High Capacity Rear Sump Oil Pan**
- Pan **only** ..... 12 liters [12.8 qt]
- Total system ..... 14.6 liters [15.4 qt]
- High to low (on dipstick) ..... 2 liters [2.1 qt]

**NOTE:** If the type/oil capacity of the oil pan is **not** known:

1. Contact a Cummins® Authorized Repair Location.
2. Determine the capacity of the oil pan option for the engine being serviced. Use QuickServe™ Online and the engine serial number.
3. Fill the lubricating oil pan to the smallest oil pan capacity listed for the engine being serviced. Then add 0.95 liters [1 qt] of oil at a time until it reaches the high mark on the dipstick. Record the number of quarts added, so that the capacity is known the next time the oil is drained.

# Cooling System

## Specifications

| | |
|---|---|
| Engine Coolant Capacity | 7.3 liters [7.7 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 | 70°C [158°F] |
| Minimum Recommended Pressure Cap at Sea Level | 90 kPa [13 psi] |

# Air Intake System

## Specifications

**Maximum Intake Restriction:**
- Clean Air Filter Element ..... 3.71 kPa / 378 mm $H_2O$ [15 in $H_2O$]
- Dirty Air Filter Element ..... 6.2 kPa / 632 mm $H_2O$ [25 in $H_2O$]

**Charge-Air Cooler Temperature Differential:**
- Maximum Differential ..... 30°C [86°F]

**Charge-Air Cooler Pressure Differential:**
- Maximum Charge-Air Cooler Pressure Drop ..... 13.5 kPa [1.96 psi]
- Recommended Intake Piping Size ..... 76 mm [3 in]

# Exhaust System

## Specifications

Maximum Back Pressure (imposed by complete exhaust system)..... 18 kPa [5.3 Hg]
Exhaust Pipe Size (normally acceptable inside diameter)..... 75 mm [3 in]

# Electrical System

## Specifications

Recommended Battery Capacity

| System Voltage | Ambient Temperature | | | |
|---|---|---|---|---|
| | -18°C [0°F] | | -29°C [-20°F] | |
| | Cold Cranking Amperes | Reserve Capacity (minutes)[1] | Cold Cranking Amperes | Reserve Capacity (minutes)[1] |
| 12-VDC | 950 | 180 | 1200 | 180 |
| 24-VDC[2] | 550 | 130 | 700 | 130 |
| [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 amperes are based on two 12-VDC batteries in series. | | | | |

## Batteries (Specific Gravity)

| Specific Gravity at 27°C [81°F] | State of Charge |
|---|---|
| 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 | 5399594 |
| Fleetguard® Part Number | LF17535 |

| **Fuel Filter Cartridge (Primary)** | |
|---|---|
| Cummins® Part Number | 5335504 |
| Fleetguard® Part Number | FF266 |

| **Fuel Filter (Prefilter with water in fuel sensor) *** | |
|---|---|
| Cummins® Part Number | 5319680 |
| Fleetguard® Part Number | FS1098 |

* The fuel filter (prefilter with water in fuel sensor) could be supplied by the original equipment manufacturer (OEM).

| **Aftertreatment DEF Dosing Unit Filter** | |
|---|---|
| Cummins® Part Number | 2888182 |

Air Cleaner Element:

There are several air cleaner elements available. **Always** replace the element with the same part number as the element removed.

# 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.**

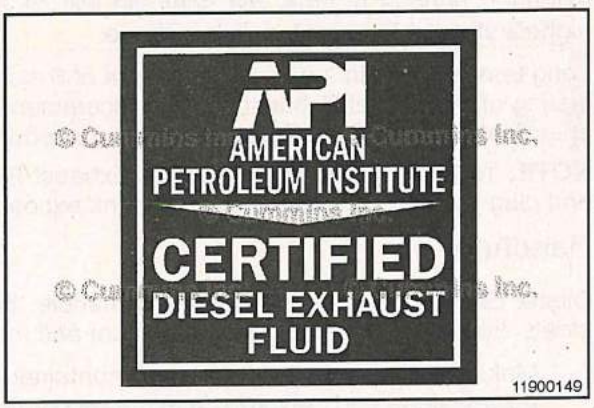
Cummins Inc. requires the use of Diesel Exhaust Fluid meeting ISO 22241-1. There is NO acceptable substitute.

**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.

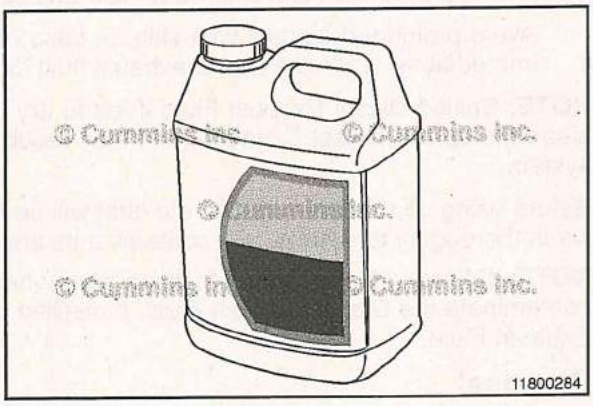
For engines using SCR operating in the United States and Canada, it is also strongly recommended that the Diesel Exhaust Fluid (DEF) used be certified by the American Petroleum Institute (API). This would be indicated by a symbol on the container/dispensing system as shown.




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.

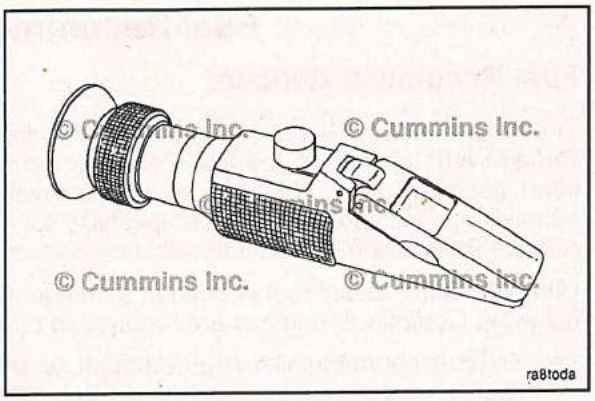
Before using containers, funnels, etc. that will be used to dispense, handle or store Diesel Exhaust Fluid, make sure to wash thoroughly to remove any contaminants and then rinse with distilled water.

**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.

# Fuel Recommendations and Specifications

## Fuel Recommendations

The engine **must** operate on ultra-low sulfur diesel with a maximum sulfur content of 15 ppm in the united States and Canada and 10 ppm in the EU. Failure to do so can permanently damage engine and aftertreatment systems in a short period of time. Ultra-low sulfur biodiesel brands up to B20 (20% biodiesel) supplied by a BQ9000 certified supplier are acceptable. Fuel compatibility for Cummins® engines is documented in Fuels for Cummins® Engines, Service Bulletin 3379001 at https://quickserve.cummins.com.

Ultra-low sulfur diesel fuel is defined as diesel fuel **not** exceeding 0.0010 (10 ppm) mass percent sulfur content. The following Cummins® engines are required to operate on ULSD.

- Engines operating with aftertreatment systems including: diesel particulate filters (DPF) ,diesel oxidation catalysts (DOC), and selective catalytic reduction (SCR).
- Engines operating where regional, national, or international regulations require the use of ultra-low sulfur diesel in diesel engines.

In general, ultra-low sulfur diesel regulations make the fuel compatible with diesel engines with higher tolerance for sulfur content. The low sulfur content does slightly change some of the fuel properties. When transitioning from low sulfur diesel which can contain up to 500ppm sulfur, to ultra-low sulfur diesel, the following precautions are beneficial

- Properly label all fuel tanks and delivery pumps.
- Be sure that the fuel lubricity meets the specifications outlined in Table 1: Cummins Inc. Required Diesel Fuel Specifications in this bulletin.
- Ultra-low sulfur diesel has lower lubricity than low sulfur diesel, so lubricity additives need to be added by the fuel supplier to prevent fuel system damage.
- Be sure that fuel tanks are completely empty before transitioning from low sulfur diesel to ultra-low sulfur diesel, and consider tank cleaning.
- It takes **only** a small amount of low sulfur diesel blended with ultra-low sulfur diesel to bring the fuel sulfur content above 15 ppm.
- Consider using a stability additive for fuel in bulk storage.
- Ultra-low sulfur diesel is more prone to oxidation than low sulfur diesel.
- Consult your fuel supplier to determine if an additive is needed to maintain fuel quality in storage tanks.
- Closely monitor the fuel system for leaks, especially when first transitioning to ultra-low sulfur diesel, and correct them immediately.
- Ultra-low sulfur diesel reacts differently than low sulfur diesel with certain seal and gasket compounds commonly found in fuel systems, which means that leaks are more likely to occur, especially in older engines which were designed to run on low sulfur diesel.

Fuels meeting national and international specifications can be used if they observe the specifications listed in Table 1: Cummins Inc. Required Diesel Fuel Specifications. Cummins® engines will operate satisfactorily on fuels meeting all the properties listed in Table 1; however, fuels meeting **only** the required specifications will **not** give the same level of performance, efficiency, reliability, or maintenance costs as premium fuels.

**Table 1: Cummins Inc. Required Diesel Fuel Specifications[1]**

| | |
|---|---|
| Viscosity | 1.3 to 4.1 centistokes at 40°C [104°] |
| Cetane Number | 42 minimum above 0°C [32°F]; 45 minimum below 0°C [32°F][2] |
| Sulfur Content | Maximum sulfur content of 15 ppm in the United States and Canada and 10 ppm in the EU |
| Active Sulfur | Copper strip corrosion **not** to exceed number 3 rating after 3 hours at 50°C [122°F]. |
| Water Sediment | **Not** to exceed 0.05 volume-percent |
| Carbon Residue | **Not** to exceed 0.35 mass-percent on 10 volume-percent residuum |
| Density | 0.816 to 0.876 grams per cubic centimeter (g/cc) at 15°C [59°F] |
| Cloud Point | 6°C or 11°F below lowest ambient temperature at which the fuel is expected to operate |

| Table 1: Cummins Inc. Required Diesel Fuel Specifications[1] | |
|---|---|
| Ash | Not to exceed 0.02 mass-percent. For vehicles equipped with exhaust aftertreatment, there shall be no detectable ash in the fuel |
| Distillation | 10 volume-percent at 282°C [540°F] maximum, 90 volume-percent at 360°C [680°F] maximum, 100 volume-percent at 385°C [725°F]maximum. The distillation curve **must** be smooth and continuous |
| Lubricity (HFRR)or (SLBOCLE) | High Frequency Reciprocating Rig (HFRR): Maximum of 0.52 mm[0.020 in] Wear Scar Diameter (WSD) at 60°C [140°F].Scuffing Load Ball-on-Cylinder Lubricity Evaluator (SLBOCLE):Minimum of 3100 grams |

1. In addition to the requirement in Table 1, Cummins Inc. strongly recommends the use of fuel with particle counts less than the ISO 4406 code of 18/16/13.

2. Fuel **must** observe proper flashpoint requirements to satisfy local safety regulations.

Regional, national, or international regulations can require a lower sulfur content than what is listed in Table 1.

# Lubricating Oil Recommendations and Specifications

## General Information

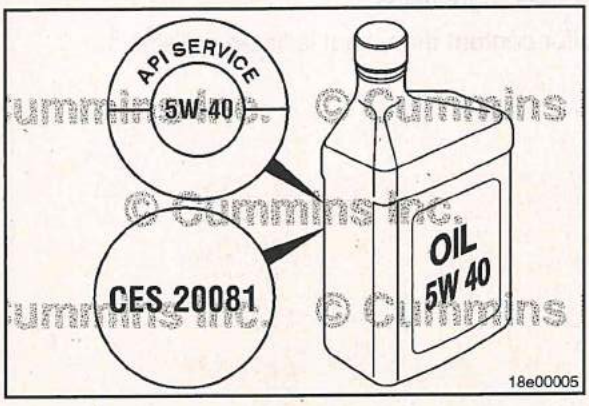
**⚠CAUTION⚠**

**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 engine requires low ash oil that meets Cummins® Engineering Standard CES 20081 as referenced in Cummins® Engine Oil and Oil Analysis Recommendations, Service Bulletin, 3810340 located at www.quickserve.com. This oil is commonly referred to as CJ-4 or ACEA E9.

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 102-002 in Section 2.

**NOTE:** The responsibility is with the owner. If recommendations are ignored, warranty could be affected.




| | |
|---|---|
| CES | Cummins® Engineering Standard |
| API | American Petroleum Institute |
| ACEA | Association des Constructeurs Européen d'Automobiles |

To determine if the oil meets CES, API, or ACEA standard, review the label on the back of the lubricating oil bottle for a label containing the specification information. If acquiring the lubricating oil in bulk, contact the supplier to confirm the oil recommendation is met.

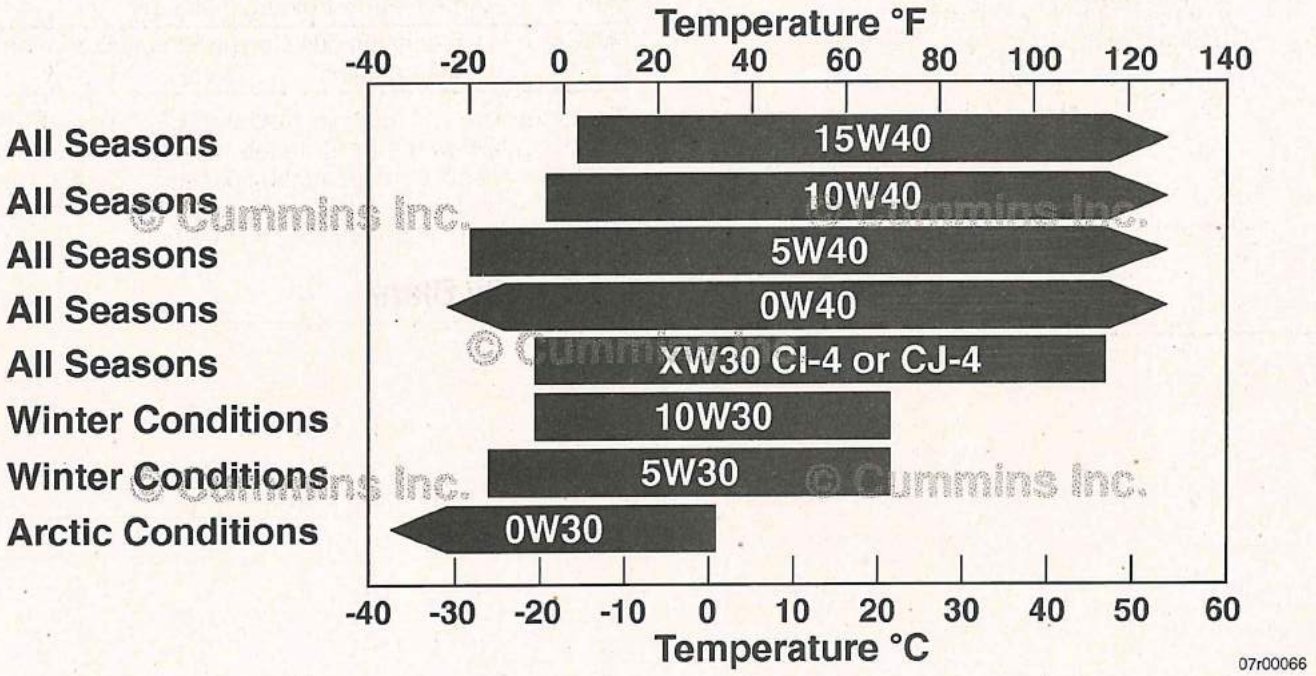
Cummins Inc. recommends the use of a high-quality Society of Automotive Engineers (SAE) 5W-40 heavy-duty engine oil, such as Valvoline Premium Blue Extreme™, which meets or exceeds CES 20081, the API performance classification CJ-4, and the ACEA performance classification E9.

| Cummins® Engineering Standard (CES) Classifications | American Petroleum Institute (API) Classification | Association des Constructeurs Européen d'Automobiles (ACEA) Classification |
|---|---|---|
| CES-20081 | API CJ-4 | ACEA E-9 |

Special break-in oils are **not** recommended for use in new or rebuilt Cummins® engines. Use the same lubricating oil that will be used in normal engine operations.

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, see the following service bulletin; Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.




While the preferred viscosity grade is 5W-40, lower viscosity multigrade oils can be used in colder climates. See the accompanying chart. Any viscosity grade lower than 5W-40 **must** still meet CES 20081.

Synthetic engine oils, API Group III and Group IV basestocks, are recommended for use in Cummins® engines operating in ambient temperature conditions consistently below -25°C [-13°F]. Synthetic 0W-30 oils that meet the requirements of API Group III or Group IV basestocks, can be used in operations where the ambient temperature **never** exceeds 0°C [32°F]. Multiviscosity oils rated 0W-30 do **not** offer the same level of protection against fuel dilution as do higher multigrade oils. Higher cylinder wear can be experienced when using 0W-30 oils in high-load situations.

As these oils have directionally thinner oil films than 15W-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.

## AfterMarket Oil Additive Usage

Cummins Inc. does **not** recommend the use of aftermarket oil additives. Present high-quality fully additive engine lubricating oils are very sophisticated, with precise amounts of additives blended into the lubricating oil to meet stringent requirements. 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.

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# Coolant Recommendations and Specifications

## Fully Formulated Coolant/Antifreeze

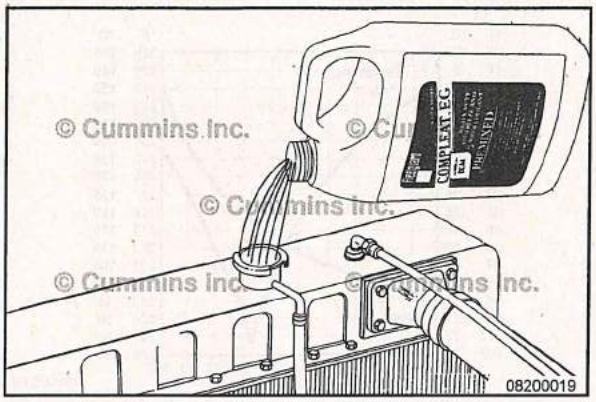
Cummins Inc. recommends the use of fully formulated antifreeze/coolant meeting Cummins® Engineering Standards (C.E.S.) 14603. For further details and discussion of coolant for Cummins® engines, refer to Cummins® Coolant Requirements and Maintenance, Bulletin 3666132.

Typically, antifreeze/coolants meeting ASTM D3306 or ASTM D6210 criteria are acceptable antifreeze/coolants.

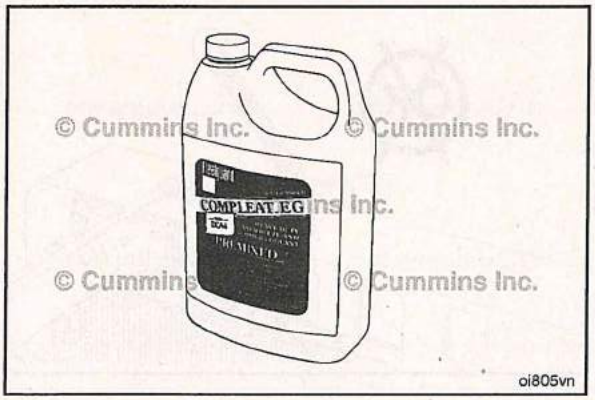
Cummins Inc. recommends using either a 50/50 mixture of water (See water quality table.) and fully formulated antifreeze, or fully formulated coolant when filling the cooling system.

Water quality 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 ($CaCO_3$ + $MgCO_3$) |
| Chlorides | Maximum 40 ppm as (Cl) |
| Sulfur | Maximum 100 ppm as ($SO_4$) |




Cummins Inc. recommends using Fleetguard® COMPLEAT™. It is available in both glycol forms (ethylene and propylene).

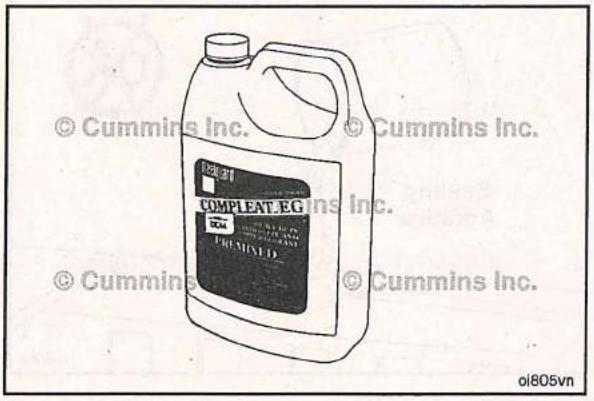


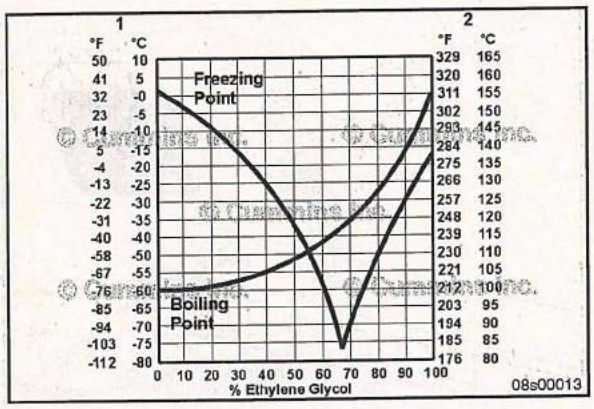

Coolant Testing

Reasons for testing the coolant:

1. To determine the additive concentration and glycol level of the coolant.
2. To make sure there is adequate freeze point protection.

Coolant testing for additive and glycol levels **must** be performed at least twice a year. The coolant **must** be tested for replacement limits every 4000 hours, or once a year, whichever occurs first.



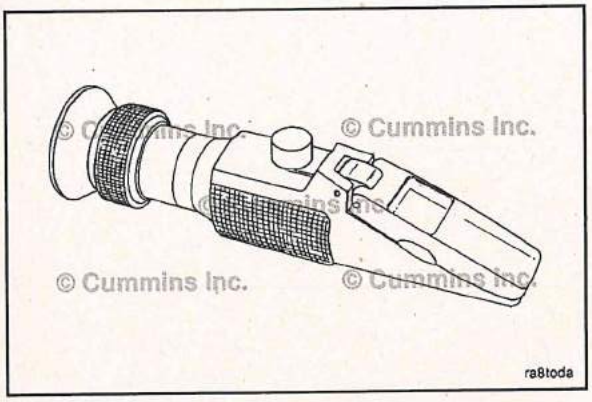



Fully formulated antifreeze **must** be mixed with water (See water quality table.) at a 50/50 ratio (40- to 60-percent working range). A 50/50 mixture of antifreeze and water gives a -36°C [-33°F] freezing point and a 108°C [226°F] boiling point, which is adequate for locations in North America. The actual lowest freezing point of ethylene glycol antifreeze is at 68 percent. Use of higher concentrations of antifreeze will raise the freezing point of the solution and increase the possibility of a silica gel problem.

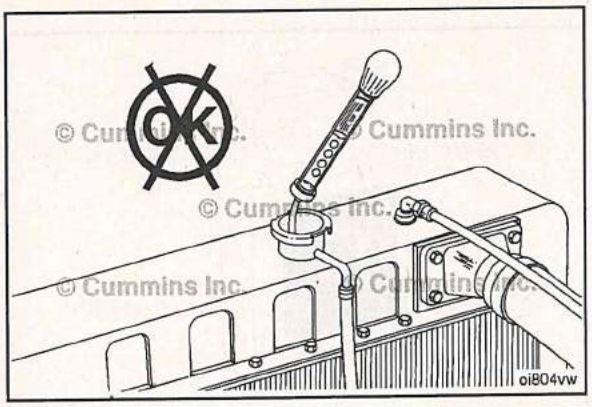
**Legend**

1 Freezing Point Temperature Scale

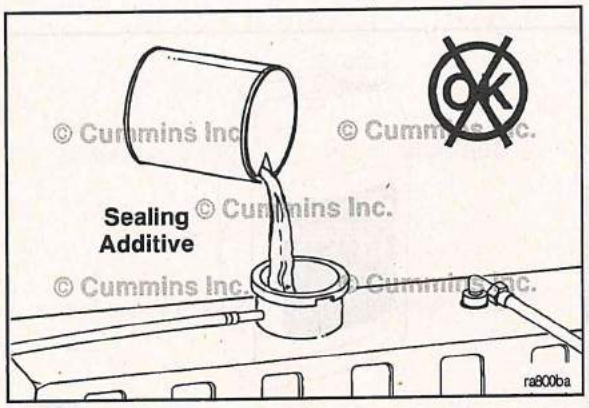
2 Boiling Point Temperature Scale.




A refractometer **must** be used to measure the freezing point of the coolant **accurately**. Use Fleetguard® refractometer, Part Number CC-2806.




Do **not** use a floating ball hydrometer. The use of a floating ball hydrometer can give an incorrect reading.

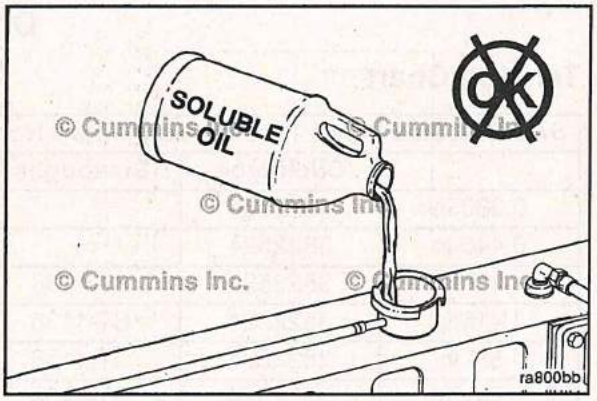



## Cooling System Sealing Additives

Do **not** use sealing additives in the cooling system. The use of sealing additives will:

- Cause 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.

# 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 Lube |
| 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 |

# Capscrew Markings and Torque Values

## General Information

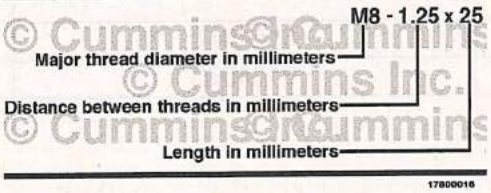
**⚠CAUTION⚠**

**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.

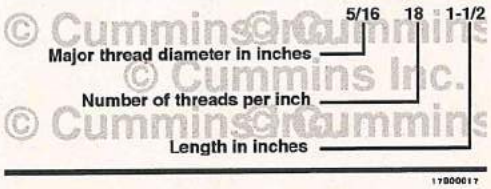
The following examples indicate how capscrews are identified:

**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]**

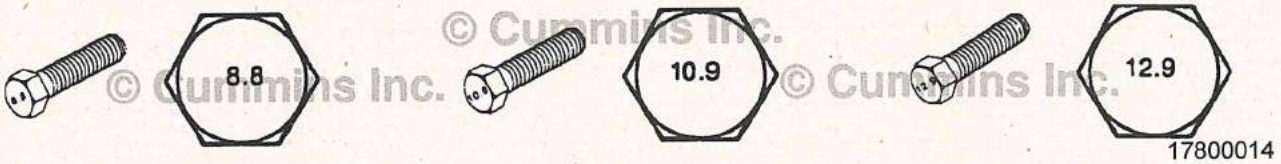



- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.

## 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

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 |

# Fraction, Decimal, Millimeter Conversions

## Conversion Chart

| Fraction | inch | mm | Fraction | inch | mm |
|---|---|---|---|---|---|
| 1/64 | 0.0156 | 0.397 | 33/64 | 0.5156 | 13.097 |
| 1/32 | 0.0313 | 0.794 | 17/32 | 0.5313 | 13.494 |
| 3/64 | 0.0469 | 1.191 | 35/64 | 0.5469 | 13.891 |
| 1/16 | 0.0625 | 1.588 | 9/16 | 0.5625 | 14.288 |
| 5/64 | 0.0781 | 1.984 | 37/64 | 0.5781 | 14.684 |
| 3/32 | 0.0938 | 2.381 | 19/32 | 0.5938 | 15.081 |
| 7/64 | 0.1094 | 2.778 | 39/64 | 0.6094 | 15.478 |
| 1/8 | 0.1250 | 3.175 | 5/8 | 0.6250 | 15.875 |
| 9/64 | 0.1406 | 3.572 | 41/64 | 0.6406 | 16.272 |
| 5/32 | 0.1563 | 3.969 | 21/32 | 0.6563 | 16.669 |
| 11/64 | 0.1719 | 4.366 | 43/64 | 0.6719 | 17.066 |
| 3/16 | 0.1875 | 4.763 | 11/16 | 0.6875 | 17.463 |
| 13/64 | 0.2031 | 5.159 | 45/64 | 0.7031 | 17.859 |
| 7/32 | 0.2188 | 5.556 | 23/32 | 0.7188 | 18.256 |
| 15/64 | 0.2344 | 5.953 | 47/64 | 0.7344 | 18.653 |
| 1/4 | 0.2500 | 6.350 | 3/4 | 0.7500 | 19.050 |
| 17/64 | 0.2656 | 6.747 | 49/64 | 0.7656 | 19.447 |
| 9/32 | 0.2813 | 7.144 | 25/32 | 0.7813 | 19.844 |
| 19/64 | 0.2969 | 7.541 | 51/64 | 0.7969 | 20.241 |
| 5/16 | 0.3125 | 7.938 | 13/16 | 0.8125 | 20.638 |
| 21/64 | 0.3281 | 8.334 | 53/64 | 0.8281 | 21.034 |
| 11/32 | 0.3438 | 8.731 | 27/32 | 0.8438 | 21.431 |
| 23/64 | 0.3594 | 9.128 | 55/64 | 0.8594 | 21.828 |
| 3/8 | 0.3750 | 9.525 | 7/8 | 0.8750 | 22.225 |
| 25/64 | 0.3906 | 9.922 | 57/64 | 0.8906 | 22.622 |
| 13/32 | 0.4063 | 10.319 | 29/32 | 0.9063 | 23.019 |
| 27/64 | 0.4219 | 10.716 | 59/64 | 0.9219 | 23.416 |
| 7/16 | 0.4375 | 11.113 | 15/16 | 0.9375 | 23.813 |
| 29/64 | 0.4531 | 11.509 | 61/64 | 0.9531 | 24.209 |
| 15/32 | 0.4688 | 11.906 | 31/32 | 0.9688 | 24.606 |
| 31/64 | 0.4844 | 12.303 | 63/64 | 0.9844 | 25.003 |
| 1/2 | 0.5000 | 12.700 | 1 | 1.0000 | 25.400 |

**Conversion Factor: 1 inch = 25.4 mm**

# Newton-Meter to Foot-Pound Conversions

## Conversion Chart

| N•m | ft-lb | N•m | ft-lb | N•m | ft-lb |
|---|---|---|---|---|---|
| 1 | 9 in-lb | 55 | 41 | 155 | 114 |
| 5 | 44 in-lb | 60 | 44 | 160 | 118 |
| 6 | 53 in-lb | 65 | 48 | 165 | 122 |
| 7 | 62 in-lb | 70 | 52 | 170 | 125 |
| 8 | 71 in-lb | 75 | 55 | 175 | 129 |
| 9 | 80 in-lb | 80 | 59 | 180 | 133 |
| 10 | 89 in-lb | 85 | 63 | 185 | 136 |
| 11 | 97 in-lb | 90 | 66 | 190 | 140 |
| 12 | 106 in-lb | 95 | 70 | 195 | 144 |
| 14 | 124 in-lb | 100 | 74 | 200 | 148 |
| 15 | 133 in-lb | 105 | 77 | 205 | 151 |
| 16 | 142 in-lb | 110 | 81 | 210 | 155 |
| 18 | 159 in-lb | 115 | 85 | 215 | 159 |
| 20 | 15 ft-lb | 120 | 89 | 220 | 162 |
| 25 | 18 | 125 | 92 | 225 | 165 |
| 30 | 22 | 130 | 96 | 230 | 170 |
| 35 | 26 | 135 | 100 | 235 | 173 |
| 40 | 30 | 140 | 103 | 240 | 177 |
| 45 | 33 | 145 | 107 | 245 | 180 |
| 50 | 37 | 150 | 111 | 250 | 184 |
| **NOTE: To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.** | | | | | |

# Pipe Plug Torque Values

## Torque Table

| Size | | Torque | | Torque | |
|---|---|---|---|---|---|
| Thread | Actual Thread O.D. | In Aluminum Components | | In Cast Iron or Steel Components | |
| **in** | **in** | **N•m** | **ft-lb** | **N•m** | **ft-lb** |
| 1/16 | 0.32 | 5 | 45 in-lb | 15 | 10 |
| 1/8 | 0.41 | 15 | 10 | 20 | 15 |
| 1/4 | 0.54 | 20 | 15 | 25 | 20 |
| 3/8 | 0.68 | 25 | 20 | 35 | 25 |
| 1/2 | 0.85 | 35 | 25 | 55 | 40 |
| 3/4 | 1.05 | 45 | 35 | 75 | 55 |
| 1 | 1.32 | 60 | 45 | 95 | 70 |
| 1-1/4 | 1.66 | 75 | 55 | 115 | 85 |
| 1-1/2 | 1.90 | 85 | 65 | 135 | 100 |

# Tap-Drill Chart - U.S. Customary and Metric

## General Information

NOTE ON SELECTING TAP-DRILL SIZES: The tap drill sizes shown on this card give the theoretical tap drill size for approximately 60% and 75% of full thread depth. Generally, it is recommended that drill sizes be selected in the 60% range as these sizes will provide about 90% of the potential holding power. Drill sizes in the 75% range are recommended for shallow hole tapping (less than 1 1/2 times the hole diameter) in soft metals and mild steel.

| Tap Size | | Drill |
|---|---|---|
| 60% | 75% | Size |
| | | 48 |
| | | 1.95mm |
| | | 5/64 |
| | 3-48 | 47 |
| | | 2.00mm |
| | M2.5x.45 | 2.05mm |
| | | 46 |
| 3-48 | 3056 | 45 |
| | | 2.10mm |
| M2.5x.45 | M2.6x.45 | 2.15mm |
| 3-56 | 4-36 | 44 |
| | | 2.20mm |
| M2.6x.45 | | 2.25mm |
| 4-36 | 4-40 | 43 |
| | | 2.30mm |
| | | 2.35mm |
| 4-40 | 4-48 | 42 |
| | | 3/32 |
| | M3x.6 | 2.40mm |
| 4-48 | | 41 |
| | | 2.45mm |
| | | 40 |
| M3x.6 | M3x.5 | 2.50mm |
| | | 39 |
| | 5-40 | 38 |
| M3x.5 | | 2.60mm |
| 5-40 | 5-44 | 37 |
| | | 2.70mm |
| 5-44 | 6-32 | 36 |
| | | 2.75mm |
| | | 7/64 |
| | | 35 |
| | | 2.80mm |
| | | 34 |
| 6-32 | 6-40 | 33 |
| | M3.5x6 | 2.90mm |
| | | 32 |
| M3.5x6 | | 3.00mm |
| 6-40 | | 31 |
| | | 3.10mm |
| | | 1/8 |
| | | 3.20mm |
| | M4x.75 | 3.25mm |
| | | 30 |
| | M4x.7 | 3.30mm |
| M4x.75 | | 3.40mm |
| M4x.7 | 8-32 | 29 |
| | | 3.50mm |
| | 8-36 | 28 |
| 8-32 | | 9/64 |
| | | 3.60mm |
| 8-36 | | 27 |
| | | 3.70mm |
| | | 26 |
| | M4.5x.75 | 3.75mm |
| | 10-24 | 25 |
| | | 3.80mm |
| | | 24 |
| M4.5x.75 | | 3.90mm |
| | | 23 |
| | | 5/32 |
| 10-24 | | 22 |
| | M5x1 | 4.00mm |
| | 10-32 | 21 |
| | | 20 |
| | M5x.9 | 4.10mm |
| M5x1 | M5x.8 | 4.20mm |
| 10-32 | | 19 |
| M5x.9 | | 4.25mm |
| M5x.8 | | 4.30mm |
| | | 18 |
| | | 11/64 |
| | | 17 |

| Tap Size | | Drill |
|---|---|---|
| 60% | 75% | Size |
| | | 4.40mm |
| | 12-24 | 16 |
| | | 4.50mm |
| | | 15 |
| | M5.5x.9 | 4.60mm |
| 12-24 | 12-28 | 14 |
| | | 13 |
| | | 4.70mm |
| M5.5x.9 | | 4.75mm |
| 12-28 | | 3/16 |
| | | 12 |
| | | 4.80mm |
| | | 11 |
| | | 4.90mm |
| | | 10 |
| | | 9 |
| | M6x1 | 5.00mm |
| | | 8 |
| | | 5.10mm |
| | 1/4-20 | 7 |
| | | 13/64 |
| | | 6 |
| M6x1 | | 5.20mm |
| | | 5 |
| | M6x.75 | 5.25mm |
| | | 5.30mm |
| 1/4-20 | | 4 |
| M6x.75 | | 5.40mm |
| | 1/4-28 | 3 |
| | | 5.50mm |
| | | 7/32 |
| | | 5.60mm |
| 1/4-28 | | 2 |
| | | 5.70mm |
| | | 5.75mm |
| | | 1 |
| | | 5.80mm |
| | | 5.90mm |
| | | A |
| | | 15/64 |
| | M7x1 | 6.00mm |
| | | B |
| | | 6.10mm |
| | | C |
| M7x1 | | 6.20mm |
| | | D |
| | M7x.75 | 6.25mm |
| | | 6.30mm |
| | | E |
| | | 1/4 |
| M7x.75 | | 6.40mm |
| | | 6.50mm |
| | 5/16-18 | F |
| | | 6.60mm |
| | | G |
| | | 6.70mm |
| | | 17/64 |
| | M8x1.25 | 6.75mm |
| 5/16-18 | | H |
| | | 6.80mm |
| | | 6.90mm |
| | 5.16-24 | I |
| M8x1.25 | M8x1 | 7.00mm |
| | | J |
| | | 7.10mm |
| 5/16-24 | | K |
| | | 9/32 |
| M8x1 | | 7.20mm |
| | | 7.25mm |
| | | 7.30mm |
| | | L |
| | | 7.40mm |
| | | M |

| Tap Size | | Drill |
|---|---|---|
| 60% | 75% | Size |
| | | 7.50mm |
| | | 19/64 |
| | | 7.60mm |
| | | N |
| | | 7.70mm |
| | M9x1.25 | 7.75mm |
| | | 7.80mm |
| | | 7.90mm |
| | 3/8-16 | 5/16 |
| M9x1.25 | M9x1 | 8.00mm |
| | | O |
| | | 8.10mm |
| M9x1 | | 8.20mm |
| | | P |
| | | 8.25mm |
| | | 8.30mm |
| 3/8-16 | 1/8-27NPT | 21/64 |
| | | 8.40mm |
| | 3/8-24 | Q |
| | M10x1.5 | 8.50mm |
| | | 8.60mm |
| 3/8-24 | | R |
| 1/8-27NPT | | 8.70mm |
| | M10x1.25 | 11/32 |
| M10x1.5 | | 8.75mm |
| | | 8.80mm |
| | | S |
| | | 8.90mm |
| M10x1.25 | M10x1 | 9.00mm |
| | | T |
| | | 9.10mm |
| | | 23/64 |
| M10x1 | | 9.20mm |
| | | 9.30mm |
| | 7/16-14 | U |
| | | 9.40mm |
| | M11x1.5 | 9.50mm |
| | | 3/8 |
| | | V |
| | | 9.60mm |
| | | 9.70mm |
| | | 9.75mm |
| M11x1.5 | | 9.80mm |
| 7/16-14 | | W |
| | | 9.90mm |
| | 7/16-20 | 25/64 |
| | | 10.00mm |
| 7/16-20 | | X |
| | M12x1.75 | 10.20mm |
| | | Y |
| | | 13/32 |
| | | Z |
| M12x1.75 | M12x1.5 | 10.50mm |
| | 1/2-13 | 27/64 |
| M12x1.5 | M12x1.25 | 10.75mm |
| M12x1.25 | | 11.00mm |
| 1/2-13 | | 7/16 |
| 1/4-18NPT | | |
| | | 11.25mm |
| | | 11.50mm |
| | | 29/64 |
| | | 11.75mm |
| | | 11.50mm |
| | 1/2-20 | 29/64 |
| | 9/16-12 | 15/32 |
| | M14x2 | 12.00m |
| | | 12.25mm |
| 9/16-12 | | 31/64 |
| M14x2 | M14x1.5 | 12.50mm |
| | 9/16-18 | 1/2 |
| M14x1.5 | M14x1.25 | 12.75mm |
| M14x1.25 | | 13.00mm |
| 9/16-18 | | 33/64 |

| Tap Size | | Drill |
|---|---|---|
| 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 |

17800013

# 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 |

# Notes

# 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 | max. 15 parts per million |
| EPA Tier 4 Interim / Final | max. 15 parts per million |
| EU Stage IV 2011 | max. 15 parts per million |
| Euro 4/5 | max. 50 parts per million |
| Euro 6 | max. 10 parts per million |

Cummins is not responsible for failures or damage resulting from what Cummins determines to be abuse or neglect, including, but not limited to: operation without adequate coolants or lubricants; overfueling; overspeeding; lack of maintenance of lubricating, cooling or intake systems; improper storage, starting, warm-up, run-in or shutdown practices; unauthorized modifications of the Engine. Cummins is also not responsible for failures caused by incorrect oil, fuel or diesel exhaust fluid or by water, dirt or other contaminants in the fuel, oil or diesel exhaust fluid.

For power units and fire pumps (package units), this Warranty applies to accessories, except for clutches and filters, supplied by Cummins which bear the name of another company.

Cummins Compusave units are covered by a separate Warranty.

Before a claim for excessive oil consumption will be considered, Owner must submit adequate documentation to show that consumption exceeds Cummins published standards.

Failures of belts and hoses supplied by Cummins are not covered beyond the first 500 hours or one year of operation, whichever occurs first.

Parts used to repair a Warrantable Failure may be new Cummins parts, Cummins approved rebuilt parts or repaired parts. Cummins is not responsible for failures resulting from the use of parts not approved by Cummins.

A new Cummins or Cummins approved rebuilt part used to repair a Warrantable Failure assumes the identity of the part it replaced and is entitled to the remaining Coverage hereunder.

For all A Series Applications, including Industrial, travel reimbursement for non-transportable equipment will be limited to 4.0 hours, $0.25/mile and 250 miles maximum. Any costs beyond this limit are the customer's responsibility.

**CUMMINS DOES NOT COVER WEAR OR WEAROUT OF COVERED PARTS.**

**CUMMINS IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.**

**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 | max. 15 parts per million |
| EPA Tier 4 Interim / Final | max. 15 parts per million |
| EU Stage IV 2011 | max. 15 parts per million |
| Euro 4/5 | max. 50 parts per million |
| Euro 6 | max. 10 parts per million |

Failures, other than those resulting from defects in materials or workmanship, are not covered by this Warranty.

Cummins is not responsible for failures or damage resulting from what Cummins determines to be abuse or neglect, including, but not limited to: operation without adequate coolant or lubricants; overfueling; overspeeding; lack of maintenance of lubricating, cooling or intake systems; improper storage, starting, warm-up, run-in or shutdown practices; unauthorized modifications of the Engine. Cummins is also not responsible for failures caused by incorrect oil, fuel or diesel exhaust fluid or by water, dirt or other contaminants in the fuel, oil or diesel exhaust fluid.

Cummins is not responsible for non-Engine repairs, "downtime" expenses, cargo damage, fines, all business costs or other losses resulting from a Warrantable Failure.

**CUMMINS IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.**

* United States includes American Samoa, the Commonwealth of Northern Mariana Islands, Guam, Puerto Rico and the U.S. Virgin Islands.

** Emissions Warranty for BLPG Industrial Off-Highway Engines is 5 years / 3,500 hours.

# 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 | max. 15 parts per million |
| EPA Tier 4 Interim / Final | max. 15 parts per million |
| EU Stage IIIB 2011 | max. 15 parts per million |
| Euro 4/5 | max. 50 parts per million |
| Euro 6 | max. 10 parts per million |

Cummins is not responsible for failures or damage resulting from what Cummins determines to be abuse or neglect, including, but not limited to: operation without adequate coolants or lubricants; overfueling; overspeeding; lack of maintenance of lubricating, cooling or intake systems; improper storage, starting, warm-up, run-in or shutdown practices; unauthorized modifications of the Engine. Cummins is also not responsible for failures caused by incorrect oil, fuel or diesel exhaust fluid or by water, dirt or other contaminants in the fuel, oil or diesel exhaust fluid.

For power units and fire pumps (package units) the Warranty applies to accessories, except for clutches and filters supplied by Cummins which bear the name of another company.

Cummins Compusave units are covered by a separate Warranty.

Before a claim for excessive oil consumption will be considered, Owner must submit adequate documentation to show that consumption exceeds Cummins published standards.

Failures of belts and hoses supplied by Cummins are not covered beyond the first 500 hours or one year of operation, whichever occurs first.

Parts used to repair a Warrantable Failure may be new Cummins parts, Cummins approved rebuilt parts or repaired parts. Cummins is not responsible for failures resulting from the use of parts not approved by Cummins.

A new Cummins or Cummins approved rebuilt part used to repair a Warrantable Failure assumes the identity of the part it replaced and is entitled to the remaining Coverage hereunder.

For all A Series Applications, including Industrial, travel reimbursement for non-transportable equipment will be limited to 4.0 hours, $0.25/mile and 250 miles maximum. Any costs beyond this limit are the customer's responsibility.

**CUMMINS DOES NOT COVER WEAR OR WEAROUT OF COVERED PARTS.**

**CUMMINS IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.**

**THESE WARRANTIES SET FORTH HEREIN ARE THE SOLE WARRANTIES MADE BY CUMMINS IN REGARD TO THESE ENGINES. CUMMINS MAKES NO OTHER WARRANTIES, EXPRESS OR IMPLIED, OR OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.**

In the case of consumer sales, in some countries, the Owner has statutory rights which cannot be affected or limited by the terms of this Warranty.

Nothing in this Warranty excludes or restricts any contractual rights the Owner may have against third parties.

# 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 2017 and 2018 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 2016 and 2017 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.

**THIS WARRANTY, TOGETHER WITH THE EXPRESS COMMERCIAL WARRANTIES ARE THE SOLE WARRANTIES MADE BY CUMMINS INC. THERE ARE NO OTHER WARRANTIES, EXPRESS OR IMPLIED, OR OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.**

# Notes

## NOTES