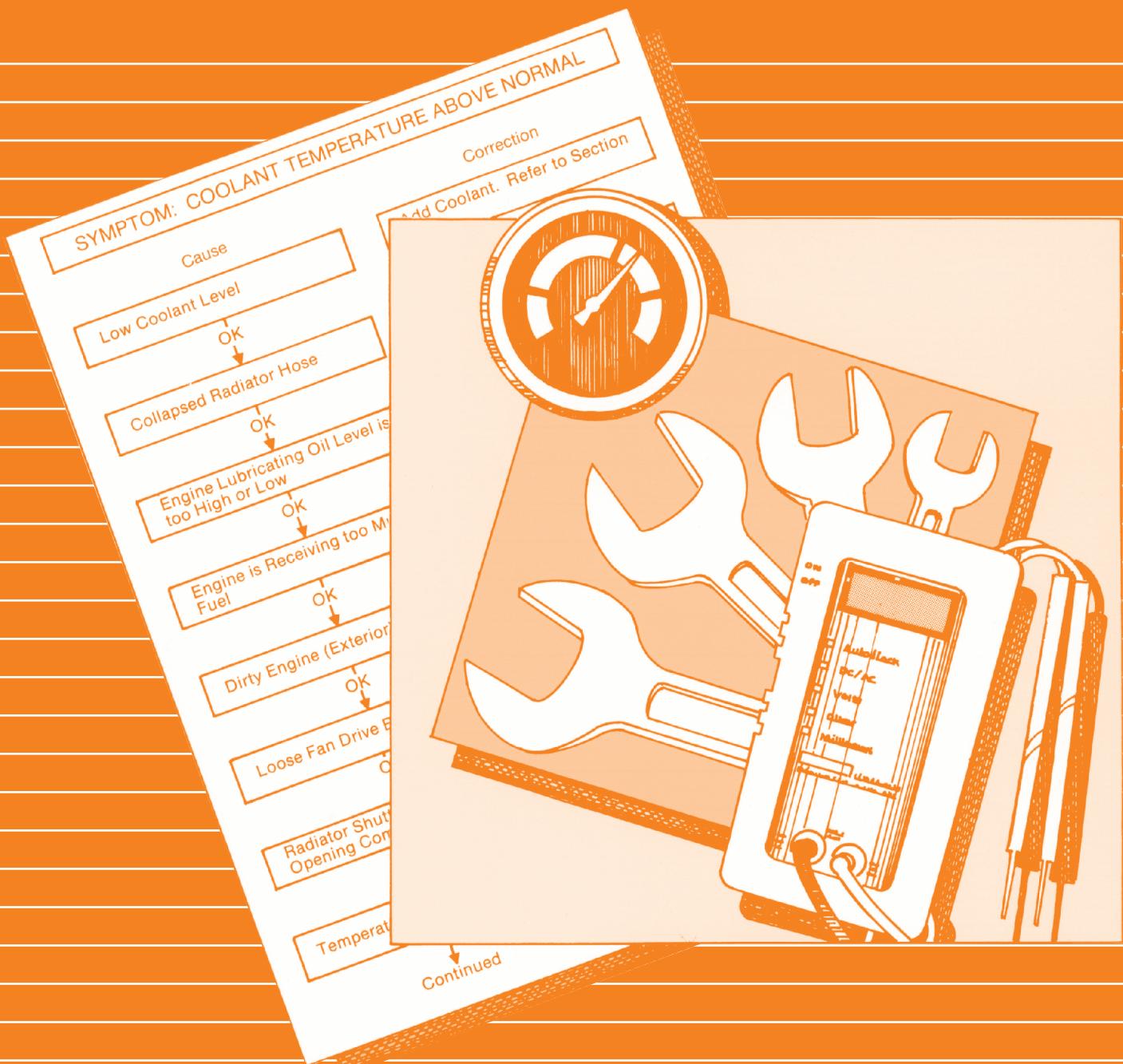




Installation Guide

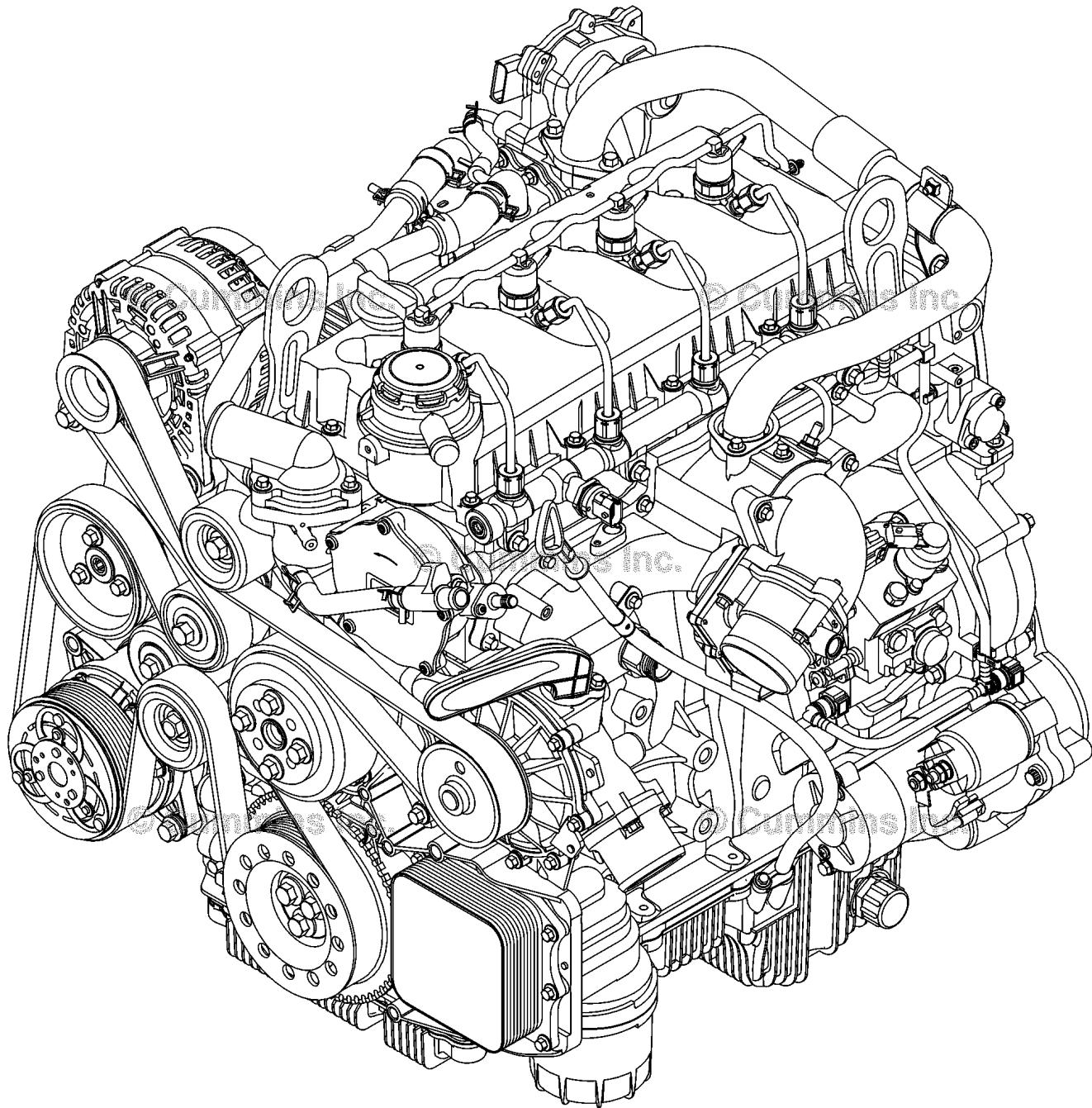
R2.8 CM2220 R101B





Installation Guide

R2.8 CM2220 R101B



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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.

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About the Installation Guide

General Information

Thank you for choosing the Cummins® R2.8 CM2220 R101B engine for your repower.

The recommendations contained in this installation guide are intended to assist you in a safe and successful installation.

Additional information, including a gearing calculator, can be found at:

NOTE: <https://cumminsengines.com/repower.aspx>

Thoroughly read this installation guide before installing the engine in the vehicle. Should you feel uncomfortable completing any of the necessary tasks, it is highly recommended you confer with a capable individual or a Cummins® Authorized Repair Location.

To view an electronic copy of the R2.8 CM2220 R101B Installation Guide or the R2.8 CM2220 R101B Owners Manual, Bulletin 5467558, register with QuickServe® Online (QSOL), for free. Once registered, type your Engine Serial Number (ESN) to find Service and Parts information for your engine.

To register for QSOL:

- 1 Enter <https://quickserve.cummins.com> into a web browser.
- 2 Select 'Create an Account' on left hand side.
- 3 Select Subscription Plan from drop down list. Select Register button.
- 4 Fill in requested information. Select Next button.
- 5 Enter ESN and other requested information. Select 'Add ESN Details'. ESN can be found on the engine dataplate.
- 6 Once finished adding all ESNs, select Next button at bottom.
- 7 Verify all information entered is correct. Select Register.
- 8 An e-mail will be sent to e-mail address provided during registration with a temporary password. Use password to log-in for the first time.
- 9 Once logged in with temporary password, enter permanent password and select Submit button. Account is now officially active and ready to use.



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Figure 1 - Register for QSOL Here (Scan with Phone App) or Type Website Address Above

How to Use the Installation Guide

General Information

This Installation Guide is utilized to provide information on preparing and installing the R2.8 CM2220 R101B engine. Thoroughly read this installation guide before installing the engine in the vehicle. Should you feel uncomfortable completing any of the necessary tasks, it is highly recommended you confer with a capable individual, or contact a Cummins® Authorized Repair Location.

The following information is contained in this guide:

- Section i contains general safety and cleaning instructions that should be followed.
- Section E contains an overview of the engine, kit or crate contents, and diagrams of the engine and other components.
- Section 1 provides a guide to prepare and install the engine and integrate it into the vehicle chassis, by subsystem.
- Section 2 provides guidelines for the initial startup of the engine after installation.
- Section V contains Maintenance specifications.

Safety Precautions

Working on and around vehicles and engines can be hazardous. These hazards, such as pinch points, hot surfaces, high electrical currents, sharp edges, and heavy components will be encountered, along with others **not** specified.

Personal protective equipment **must** be considered when performing many tasks on the engine or vehicle. Personal protective equipment such as, but **not** limited to, eye protection, steel toe shoes, and mechanic gloves, **must** be worn. Securing the vehicle that is to be worked on is critical. Do **not** work under an engine or vehicle that is **not** properly supported.

Refer to Procedure 204-006 in Section i, General Safety Instructions, before beginning the installation.

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.

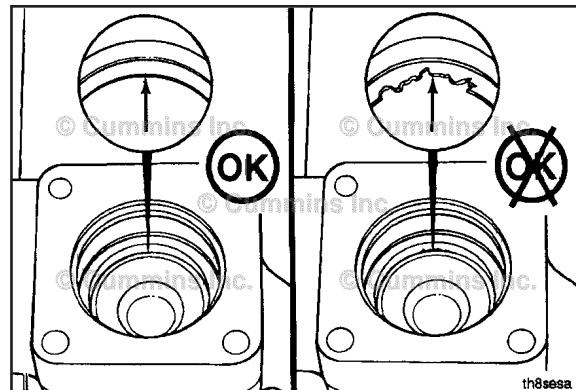


The component weighs 23kg [50 lbs] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

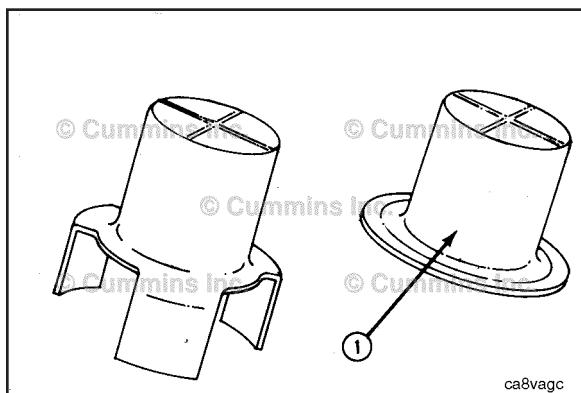
Illustrations

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 petroleum 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 determined 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 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.

Section E - Engine and System Identification

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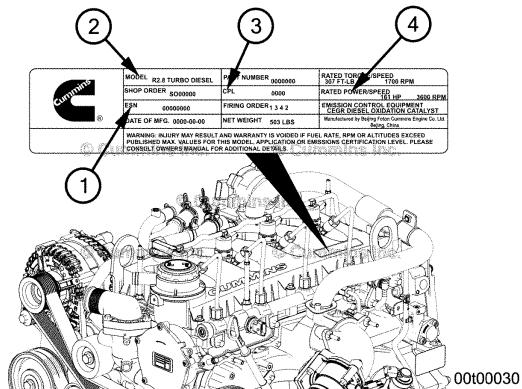
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Engine Identification

Engine Dataplate

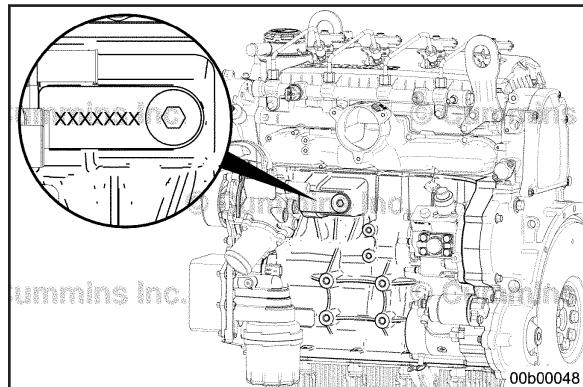
Have the following engine data available when communicating with a Cummins® Authorized Repair Location. The information on the dataplate is mandatory when sourcing service parts.

The engine dataplate shows specific facts about an engine. The dataplate is typically located on the engine rocker lever cover. The engine serial number and CPL provide data for ordering parts and performing service. The engine dataplate **must not** be changed unless approved by Cummins Inc.



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

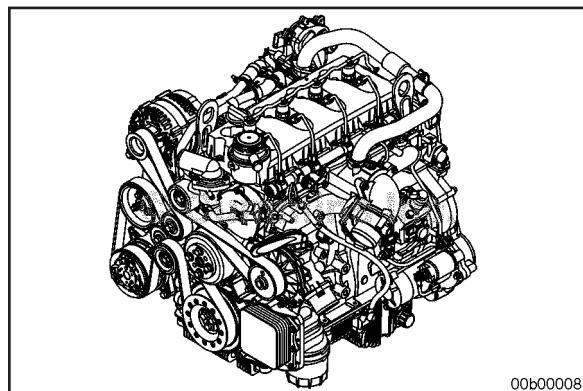
NOTE: If the engine dataplate is **not** readable, the engine serial number can be found on the engine block. This is located on the intake side near the water pump. Additional engine information is available by reading the engine control module (ECM) dataplate.

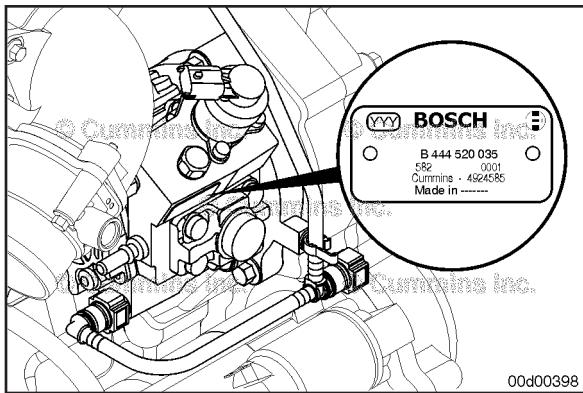


Cummins® Engine Nomenclature

The Cummins® Service Engine Model Identification procedure describes how to use the Cummins® Service Model Name to identify an engine. Refer to Procedure 100-008 in Section E.

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

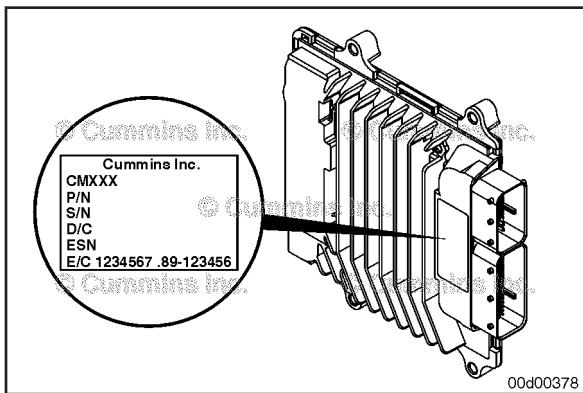




Fuel Injection Pump Dataplate

The Bosch™ fuel injection pump dataplate is located on the fuel pump. The dataplate contains the following information that will assist in servicing or replacement:

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



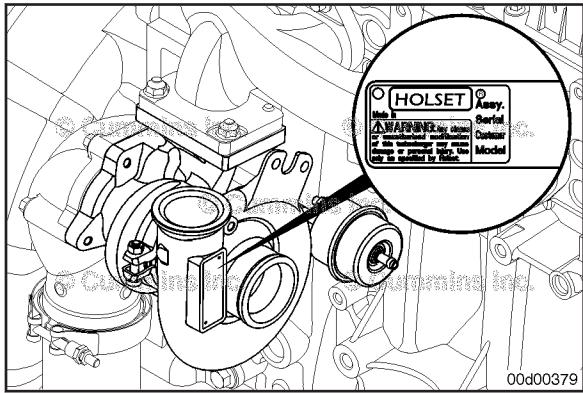
Engine Control Module Dataplate

The ECM dataplate shows information about the ECM and how the ECM was programmed. This dataplate is located on the ECM.

The following information is available on the ECM dataplate:

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

NOTE: Have the ECM code for the engine available when communicating with a Cummins® Authorized Repair Location.



Turbocharger Dataplate

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

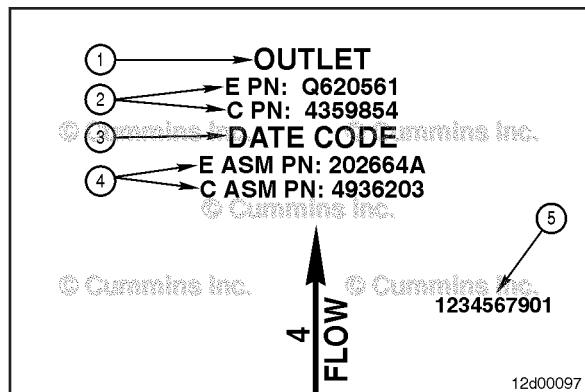
The dataplate contains the following information that will assist in servicing or replacement:

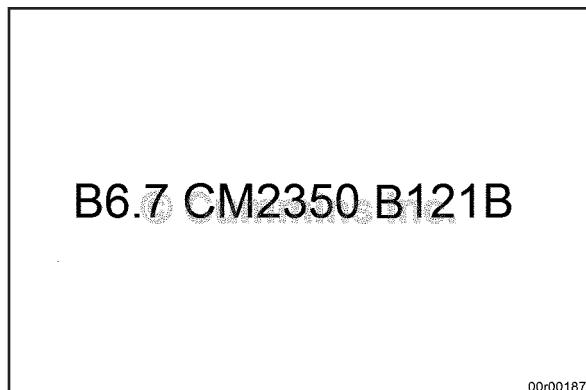
- Cummins® assembly part number
- Serial number
- Customer number
- Model number.

Exhaust System

A typical exhaust aftertreatment system information stamping can provide the following:

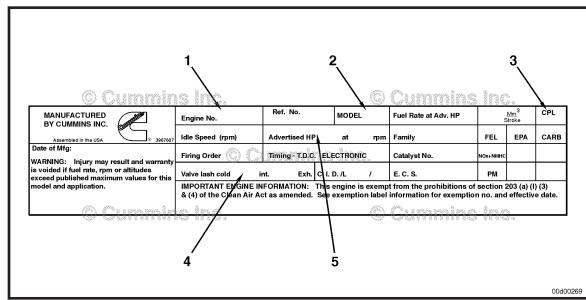
- 1 Section name
- 2 Part number
- 3 Date code
- 4 Assembly number (**only** located on the outlet section)
- 5 Serial number.





B6.7 CM2350 B121B

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MANUFACTURED BY CUMMINS INC.	© Cummins Inc.	© Cummins Inc.	CPL	
Idle Speed (rpm)	Ref. No.	MODEL	Fuel Rate at Adv. HP	Net Gross
Advertised HP	at	rpm	Family	FEL EPA CARB
Firing Order	Timing "T.D.C."	ELECTRONIC	Catalyst No.	NON-HEC
Valve lash cold int.	Esh.	C.L.D.A.	/	E.C. S. PM
IMPORTANT ENGINE INFORMATION: This engine is exempt from the prohibitions of section 203 (a) (1) (3) & (4) of the Clean Air Act as amended. See exemption label information for exemption no. and effective date.				

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Cummins® Service Engine Model Identification (2017)

General Information

The Cummins® Service Engine Model Identification procedure describes:

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

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

Marketing Engine Model Name	Service Model Name
B6.7	B6.7 CM2350 B121B

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

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

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

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

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

"IS" prefix designates an on-highway engine.

"QS" prefix designates an off-highway engine.

B6.7 CM2350 B121B

B6.7

00r00188

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

B Series engine.

6.7 Liters in Displacement.

B6.7 CM2350 B121B

6.7

B

00r00189

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

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

B6.7N CM2350 B121B

N

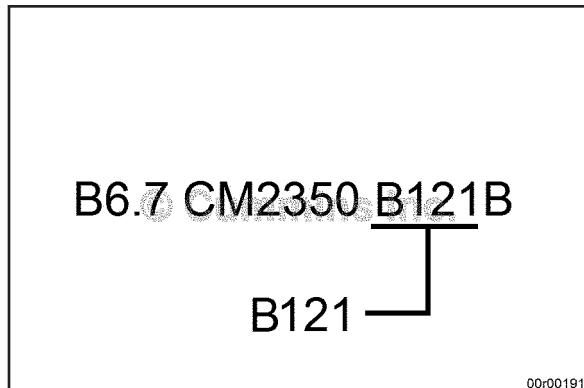
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The engine control system is identified with the letters "CM" followed by the control system model number.

B6.7 CM2350 B121B

CM2350

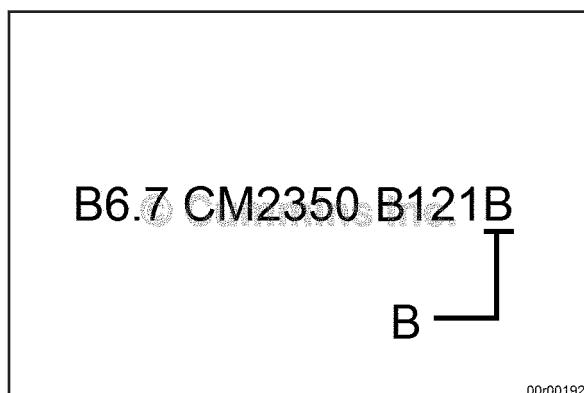
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The identifier after the control system is a letter and number combination to identify variations between products.

The letter is the engine platform designation.

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



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

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

Cummins® Product Technology

General Information

The service model name for this product is **R2.8 CM2220 R101B**.

Additional Product Description: Crate Engine

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

- Engine has demonstrated through the testing procedures prescribed in 40 CFR Part 86 to meet EPA's Tier 0 (LDT 1 and 2) and Tier 1 (LDT 2 weighing less than 4000 lb complete weight) emissions standards. This means that the engine generally is suitable for model year 1999 or earlier light duty trucks. However, the suitability of the engine to any vehicle is the responsibility of the installer and may depend on state or area laws. Installation of this engine in a vehicle for which it is **not** intended may violate U.S. and Canadian laws and regulations related to motor vehicle emissions and will void the applicable engine warranty. Check your state and local emissions requirements before purchasing.

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

- 5290

EPA Product:

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

- Charge-Air Cooler (CAC)
- Direct Diesel Injection (DDI)
- Engine Control Module (ECM)
- Exhaust Gas Recirculation (EGR)
- Turbocharger (TC)
- Oxidation Catalyst (OC)

This engine uses the following product technology:

Engine

- Number of Cylinders: 4
- Engine Configuration
 - Inline
- Engine Orientation
 - Vertical
- Cylinder Block Material
 - Cast Iron
- Cylinder Head Material
 - Cast Iron
- Valves Per Cylinder
 - Exhaust Quantity: 2
 - Intake Quantity: 2
- Camshaft Location
 - Cylinder Head
- Camshaft Followers/Tappets
 - Roller Followers/Tappets
- Primary Gear Train Location
 - Rear of the Engine
- Crankcase Ventilation System

- Closed

Fuel System

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

Air Handling

- Turbocharger (Single)
 - Wastegate
- Charge Air Cooler
- Intake Air Heater
- Engine Intake Throttle Actuator

Exhaust System

- Exhaust Gas Recirculation (EGR)
- Diesel Oxidation Catalyst (DOC)

Electrical Equipment

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

Electronic Control System

- Engine Control Module (Single)
 - Control Module: CM2220
- ECM Supply Voltage:
 - 12 VDC
- Real-Time Clock Battery
- Engine Coolant Temperature Sensor
- Engine Oil Pressure Switch
- Camshaft Position Sensor
- Crankshaft Position Sensor
- Fuel Rail Pressure Sensor
- Fuel Pump Actuator
- Water in Fuel Sensor
- Mass Air Flow Sensor
- Intake Manifold Pressure/Temperature Sensor
- Ambient Air Pressure Sensor.

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

Automotive

- Passenger Vehicle
 - Sport Utility Vehicle
 - Truck

Kit Components

Installation Kit

Below are lists of the engine-mounted and vehicle-mounted components that are shipped in the kit, followed by a table of the complete kit contents.

R2.8 CM2220 R101B Engine Kit			
Part Number	Part Name	Quantity	Status
5467036	Engine, Pre-Configured	1	Crate
5317657	Kit, Filter Fuel	1	Loose in crate
4984760	Sensor, Mass Air Flow (MAF)	1	Loose in crate
5467020	Accelerator Pedal Assembly	1	Loose in crate
5467044	Tube, Air Inlet	1	Loose in crate
135144	T-Bolt Clamp	2	Loose in crate
5467025	Kit, Harness Installation	1	Loose in crate
5467024	Relay, Grid Heater	1	Loose in crate
5467023	Display, User Interface	1	Loose in crate
5504137	R2.8 CM2220 R101B Installation Guide	1	Loose in crate
5467558	R2.8 CM2220 R101B Owners Manual	1	Loose in crate
5467245	Literature, Service Product Registration Flier	1	Loose in crate
4918432	Connector, Quick Disconnect	1	Loose in crate
4918987	Connector, Quick Disconnect	1	Loose in crate
5299831	Connector, Quick Disconnect	2	Loose in crate

Engine Mounted Components

Below is the list of components mounted on the engine prior to shipment.

- Alternator
- Power Steering Pump
- Engine Interface Electrical Harness
- Lubricating Oil Filter, Remote Mounted
- Starting Motor
- Vacuum Pump
- Crankcase Breather Tube
- Drive Belt.

Vehicle Mounted Components

Below is the list of vehicle-mounted components shipped loose in the crate.

- Accelerator Pedal
- Instrument Gauge / Cab Display
- Vehicle / Chassis Interface Electrical Harness
- MAF Sensor Assembly
- Chassis-Mounted Fuel Filter
- Chassis-Mounted Engine Control Module (ECM)

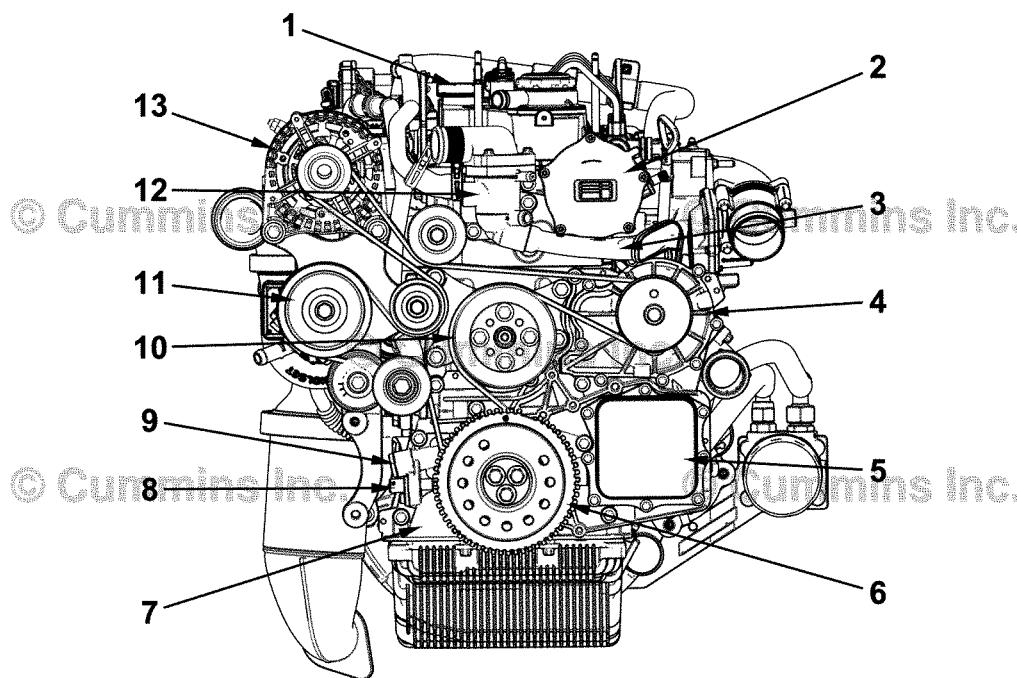
Engine Diagrams

Engine Views

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

Engine Diagrams

Engine Views



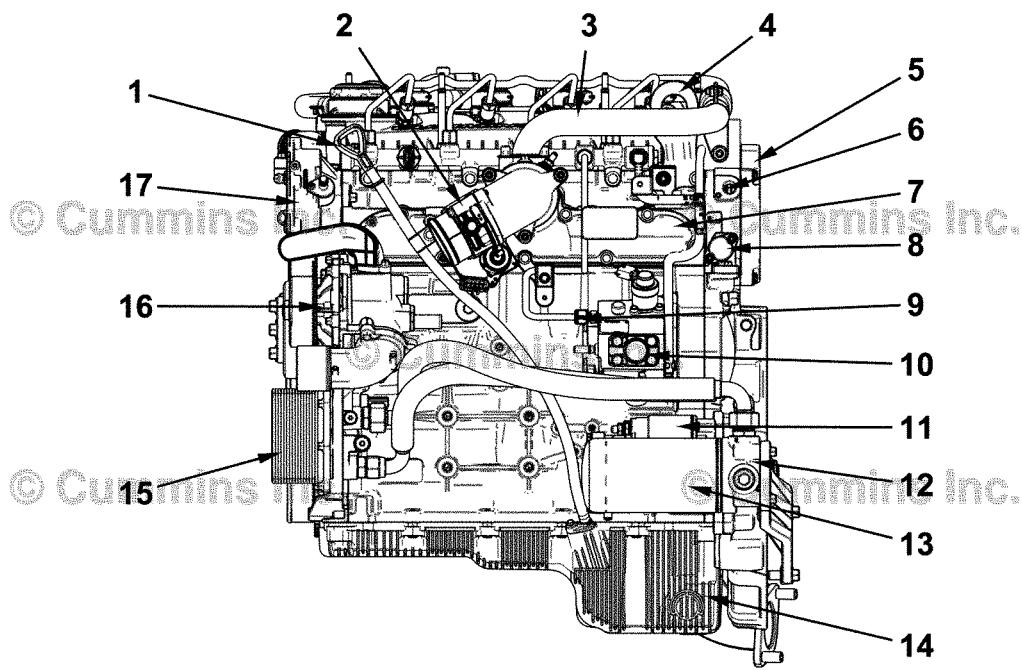
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Front View

- 1 Engine lubricating oil fill location
- 2 Vacuum pump
- 3 Thermostat bypass tube
- 4 Water pump
- 5 Lubricating oil cooler
- 6 Crankshaft pulley
- 7 Front gear cover
- 8 Crankshaft position sensor
- 9 Lubricating oil pressure regulator
- 10 Cooling fan pulley
- 11 Power steering pump
- 12 Thermostat housing
- 13 Alternator.

Engine Diagrams

Engine Views



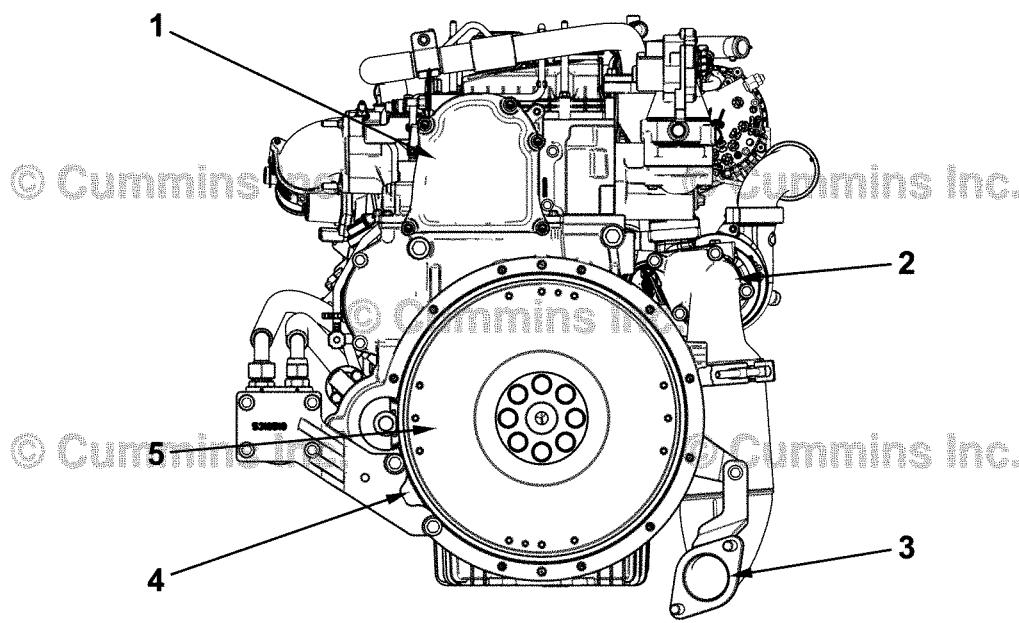
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Left Side View

- 1 Dipstick
- 2 Engine throttle actuator
- 3 Exhaust gas recirculation (EGR) tube
- 4 Rear engine lifting bracket
- 5 Overhead camshaft sprocket housing
- 6 Camshaft position sensor
- 7 Intake manifold
- 8 Camshaft drive chain tensioner
- 9 High-pressure fuel line
- 10 High-pressure fuel pump
- 11 Starting motor
- 12 Lubricating oil filter head
- 13 Lubricating oil filter
- 14 Lubricating oil pan
- 15 Lubricating oil cooler
- 16 Water pump
- 17 Vacuum pump.

Engine Diagrams

Engine Views



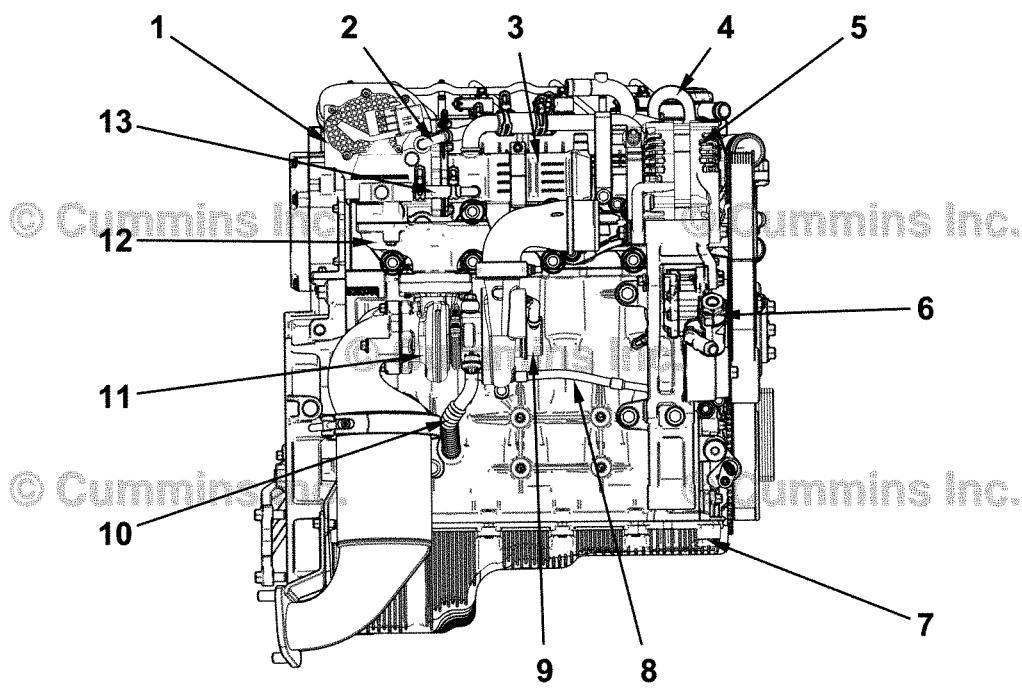
00b00076

Rear View

- 1 Overhead camshaft sprocket housing cover
- 2 Turbocharger exhaust outlet
- 3 Aftertreatment diesel oxidation catalyst outlet
- 4 Flywheel housing
- 5 Flywheel.

Engine Diagrams

Engine Views



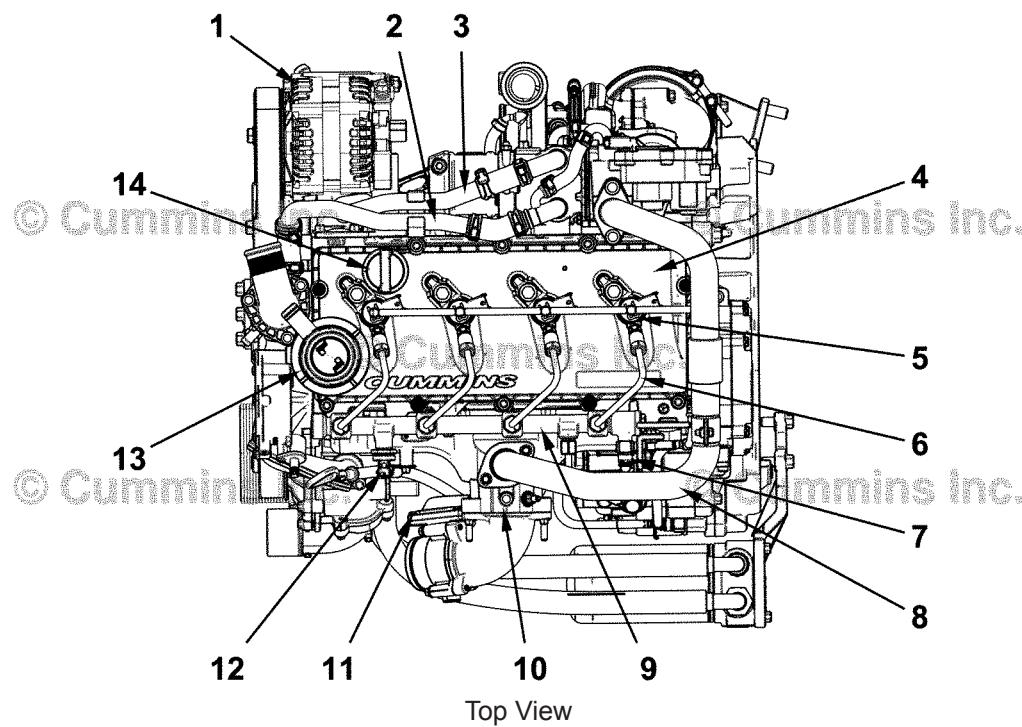
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Right Side View

- 1 EGR valve
- 2 EGR valve coolant return line
- 3 EGR cooler
- 4 Front engine lifting bracket
- 5 Alternator
- 6 Power steering pump
- 7 Lubricating oil pan
- 8 Turbocharger oil supply line
- 9 Turbocharger wastegate
- 10 Turbocharger oil return line
- 11 Turbocharger
- 12 Exhaust manifold
- 13 EGR valve coolant supply line.

Engine Diagrams

Engine Views



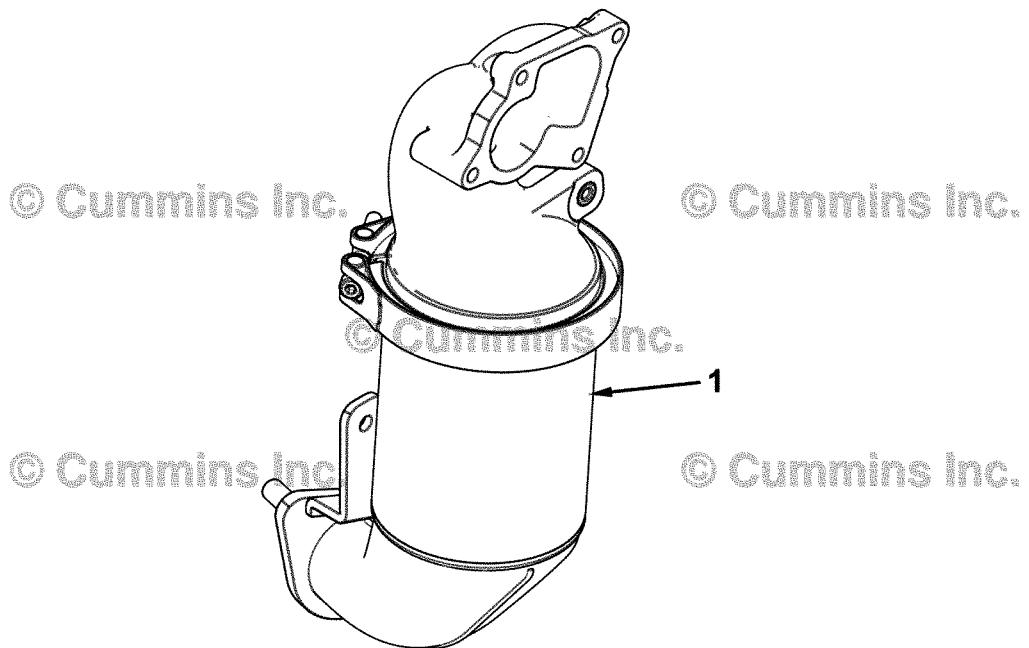
00b00062

Top View

- 1 Alternator
- 2 EGR cooler coolant return line
- 3 EGR cooler coolant supply line
- 4 Valve cover
- 5 Fuel injector
- 6 High-pressure fuel injector supply line
- 7 Fuel pressure relief valve
- 8 EGR tube
- 9 Fuel rail
- 10 Grid heater
- 11 Engine throttle actuator
- 12 Fuel rail pressure sensor
- 13 Breather
- 14 Engine lubricating oil fill location.

Aftertreatment System Diagrams

Aftertreatment System Views



00b00064

- 1 Aftertreatment diesel oxidation catalyst (DOC).

Section 1 - Installation by Subsystem

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Installation Overview (388-001)

General Information

The Cummins® R2.8 CM2220 R101B engine is a repower engine designed to be installed in a multiple of vehicles. Each vehicle is different and a different approach may be required for a successful installation.

The R2.8 CM2220 R101B engine horsepower and torque may exceed the capability of the existing drivetrain components, and thus **must** be addressed during planning for your repower. The original towing capability of the vehicle will **not** be increased by the increase in engine power.

The Cummins® R2.8 Turbo Diesel Crate Engine has demonstrated, in a representative vehicle with a manual transmission, through the testing procedures prescribed in 40 Federal Regulations (CFR) Part 86, to meet Environmental Protection Agency (EPA's) Tier 1 Light Duty Truck LDT2, LDT3, and LDT4 end of useful life emissions standards. The same vehicle also demonstrates Tier 0 LDT1/LDV end of useful life emissions standards. This means that the R2.8 generally is suitable for Model Year 1999 or earlier light duty trucks and Model Year 1993 or earlier passenger cars. However, the suitability of the R2.8 Turbo Diesel Crate Engine to any vehicle is the responsibility of the installer and may depend on state or area laws. Installation of this part in a vehicle or application for which it is **not** intended may violate U.S. and Canadian laws and regulations related to motor vehicle emissions and will void the applicable engine warranty. Check applicable state and local emissions requirements before purchasing this part.

The recommendations contained in this publication are intended to assist you in a safe and successful installation. Should you feel uncomfortable completing any of the necessary tasks, it is highly recommended you confer with a capable individual, or contact a Cummins® Authorized Repair Location.

The engine is shipped in a wooden box or crate. It is the responsibility of the technician to properly secure the engine assembly at all times during the installation process.

At no time can the engine be set on the oil pan. The structure of the oil pan is incapable of supporting the weight of the engine and/or engine transmission system.

Before installing the engine, multiple preparations **must** be made to make the installation successful. Some dimensions are critical. If the correct specifications are **not** adhered to, damage to the engine or vehicle can result.

Items that **must** be considered are:

- Engine and vehicle dimensions
- Chassis interference
- Engine and transmission mountings
- Driveline alignment
- Fuel system preparation
- Cooling system capacity
- Charge air cooler mounting and connection
- Exhaust system
- Electrical system
- Steering system
- Braking system.

NOTE: Additional installation information, including a gearing calculator, can be found at <http://www.cumminsrepower.com>.

Engine Warranty:

Products must be fully registered to qualify for engine warranty.

Installation of this engine in a vehicle for which it is **not** intended may violate U.S. and Canadian laws and regulations related to motor vehicle emissions, and will void the applicable engine warranty.

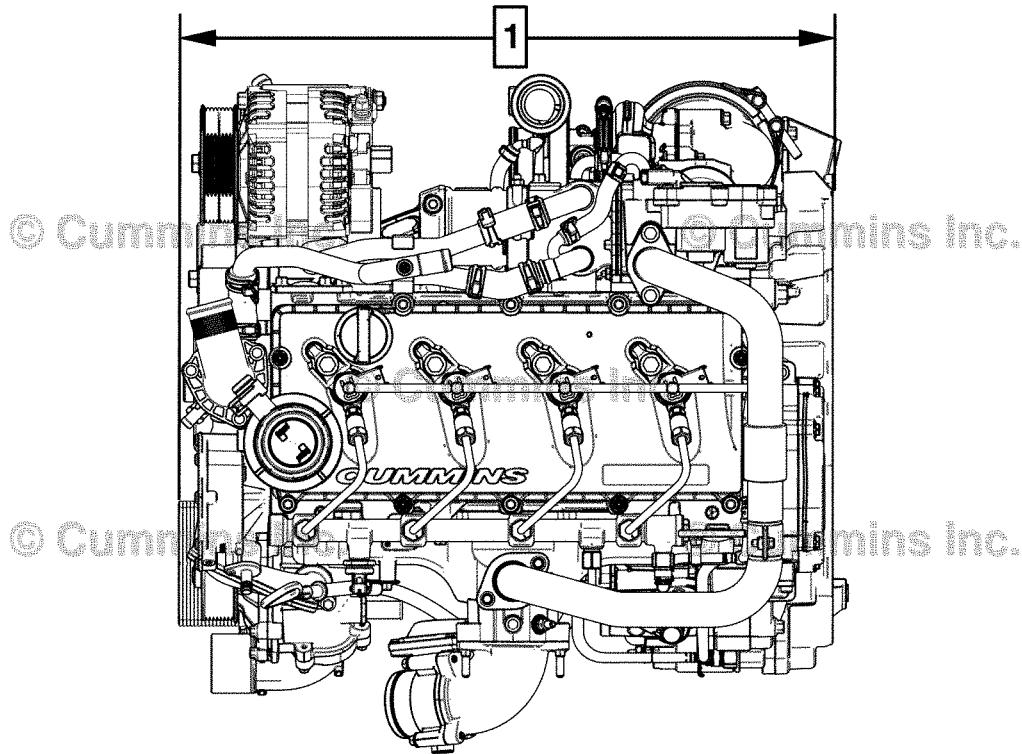
NOTE: Complete the product registration at <http://prodreg.cummins.com> including:

- Engine Serial Number (ESN)
- Vehicle Identification Number (VIN)
- Personal Contact Information.

Engine Mounting (391-001)

General Information

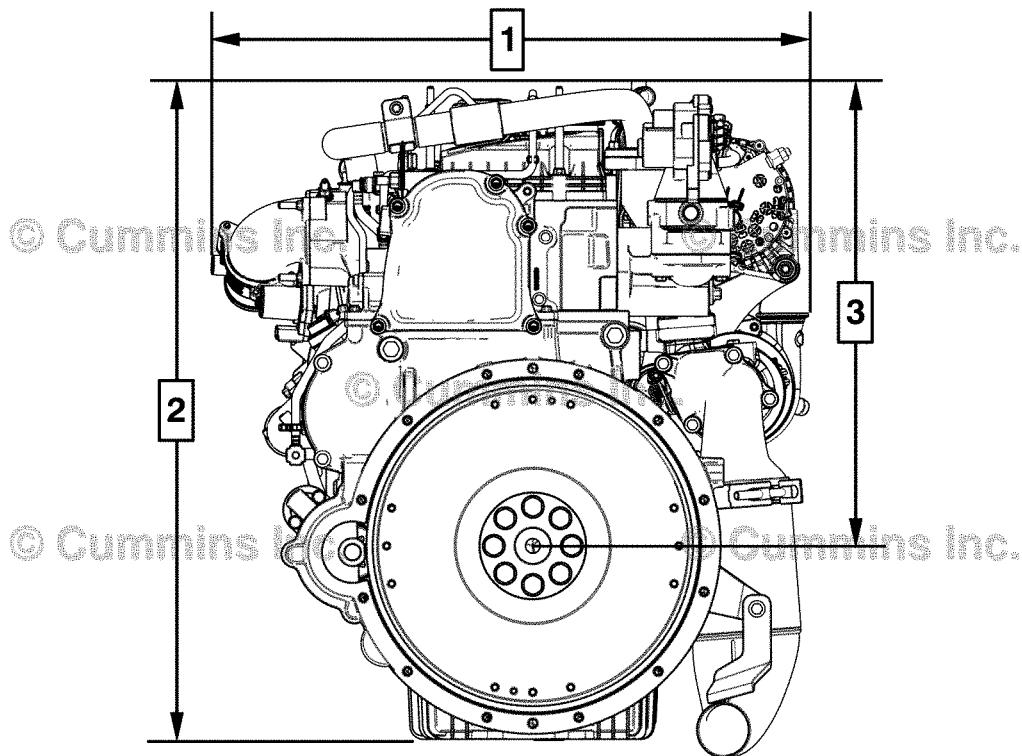
Below are different engine dimensions to better determine the space and alignment points for the overall engine. These dimensions are for the crated engine without additional components, such as clutch, transmission, fan, intake, and exhaust connections.



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Figure 1 - Overall Engine Length

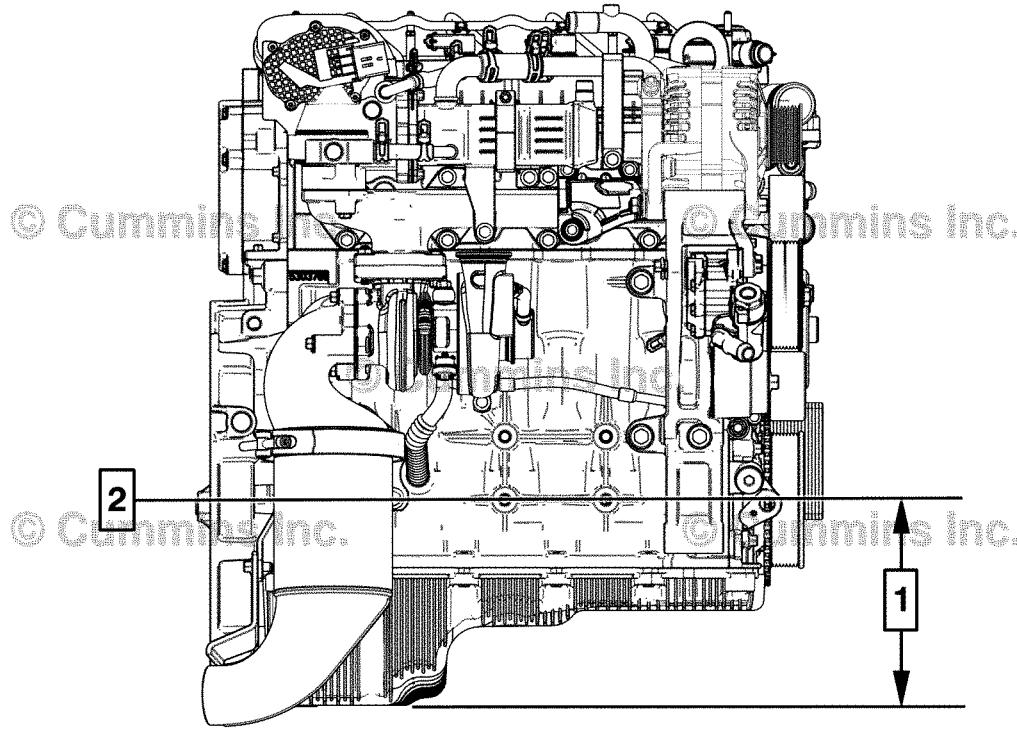
- 1 Approximate overall engine length (engine only) - 639 mm [25.1 in]



00b00074

Figure 2 - Overall Engine Width and Height

- 1 Approximate overall engine width - 656 mm [25.8 in]
- 2 Approximate overall engine height at bottom of lubricating oil pan sump - 718 mm [28.3 in]
- 3 Approximate engine height from crankshaft centerline - 506 mm [19.9 in]



00b00075

Figure 3 - Crankcase/Driveline to Engine Mounts Alignment

- 1 Approximate height from crankshaft centerline to bottom of lubricating oil pan - 212 mm [8.3 in]
- 2 Crankshaft centerline to lower motor mount bolt centerline - 0 mm [0 in]

The dry engine weight is approximately 229 kg [505 lbs].

It is recommended to use a three-point engine-to-vehicle frame mounting system on the R2.8 CM2220 R101B engine and mating transmission, utilizing two engine mount/isolators on either side of the engine block and one at the driveshaft end of the transmission. See Figure 4.

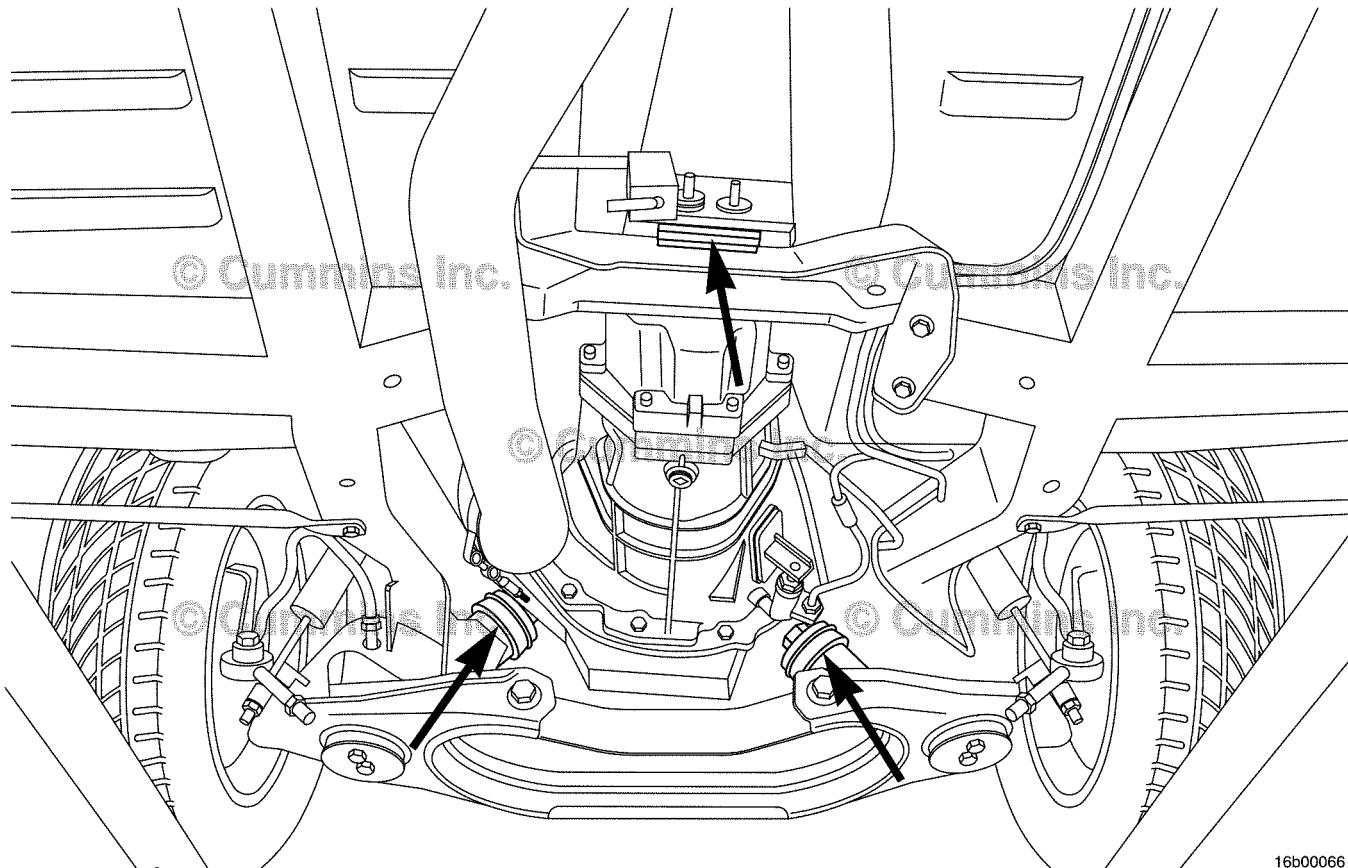


Figure 4 - Three-Point Mounting

The proper selection of engine mounting isolators is critical to minimize the vibration of the engine to the cab, especially at an idling condition. The position of the engine side isolators should be as close as possible to the engine block to limit the amount of engine vibration transmitted to the chassis.

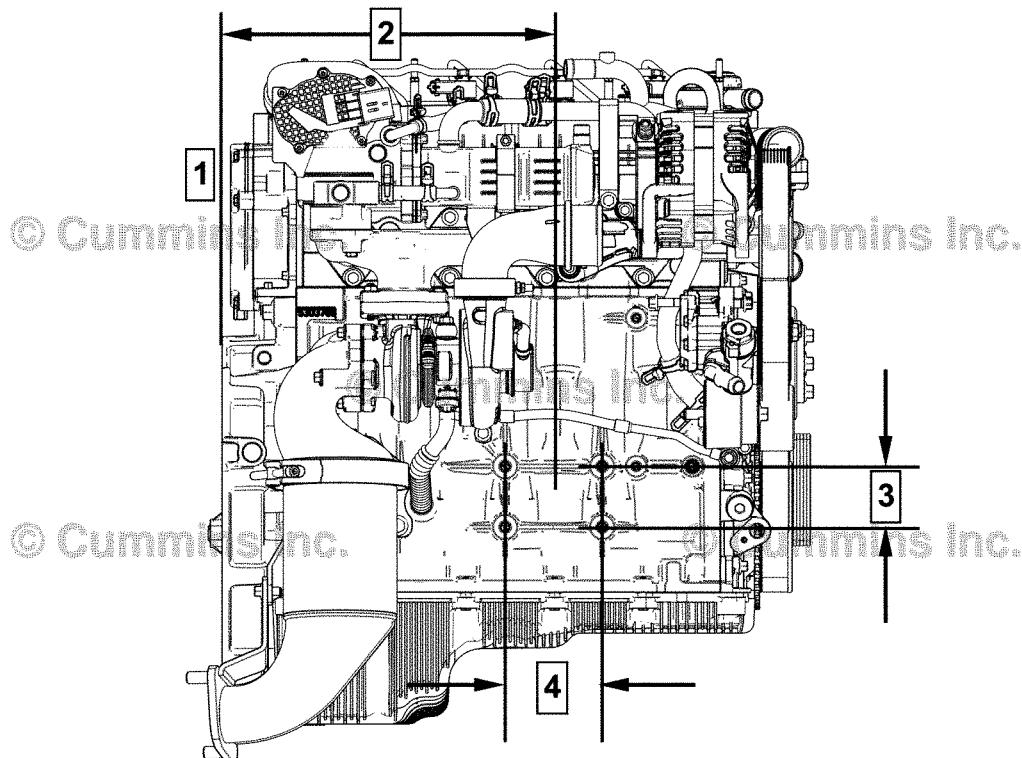
Aftermarket suppliers can be of assistance in providing pre-engineered components to properly support and isolate the natural engine vibration. It is recommended to utilize Specialty Equipment Market Association (SEMA) members, as the R2.8 CM2220 R101B computer aided design (CAD) is available to reputable suppliers through their tech transfer program.

The four engine-side M12 mounting bosses **must** be used for the engine mounting brackets. It is recommended to use a quantity of four Class 10.8 M12x1.75 bolts with a minimum thread engagement into the block of 12 mm [0.472 in] but **not** to exceed 20 mm [0.787 in] when tightened, to install the engine mounts to the cylinder block.

Torque Value:

Engine Mounting Bracket 115 N·m [85 ft-lb]

The mounting bosses are symmetrical on both sides. Figure 5 shows the dimensions of the engine mounting bosses found on each side of the engine. It is recommended that the engine mounting be designed such that the isolator is positioned in the middle of the bolt pattern.



16b00070

Figure 5 - Engine Mount Location

- 1 Rear face of flywheel housing
- 2 Rear face of flywheel housing to center of bolt pattern – 355 mm [13.97 in]
- 3 Center of top-to-bottom bolt pattern – 65 mm [2.56 in]
- 4 Center of front-to-rear bolt pattern – 104 mm [4.09 in].

Engine Lifting (388-002)

General Information

⚠ WARNING ⚠

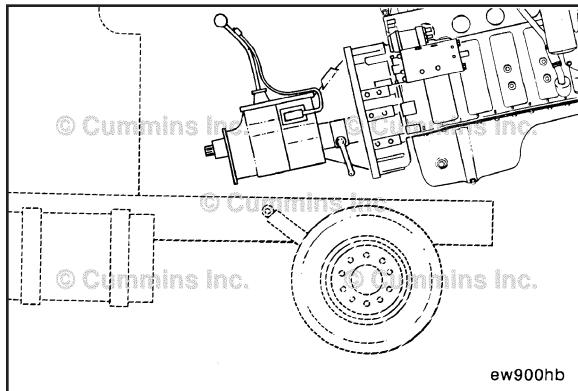
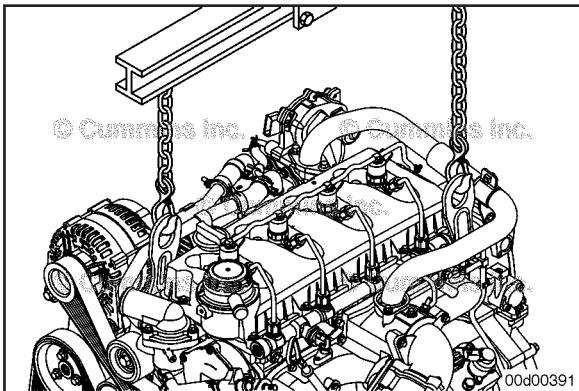
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

⚠ WARNING ⚠

The engine oil sump or cover plate will not support the weight of the engine and/or the engine transmission assembly. Do not set the engine on the oil pan. Doing so can result in equipment damage, severe personal injury, or death.

⚠ CAUTION ⚠

Personal protective equipment must be considered when performing many tasks on the engine or vehicle. Personal protective equipment such as but not limited to: eye protection, steel toe shoes, and mechanic gloves should be worn. Securing the vehicle that is to be worked on is critical. Do not work under an engine or vehicle that is not properly supported.



The R2.8 CM2220 R101B engine has two brackets designed to enable the lifting of the engine and transmission system. These brackets are located on the front and on the rear of the engine, and **must not** be modified in any way. Use a properly rated hoist and engine lifting fixture, Part Number 3162871, attached to the engine-mounted lifting brackets, to install the engine.

Transmission Interface and Mounting (391-002)

General Information

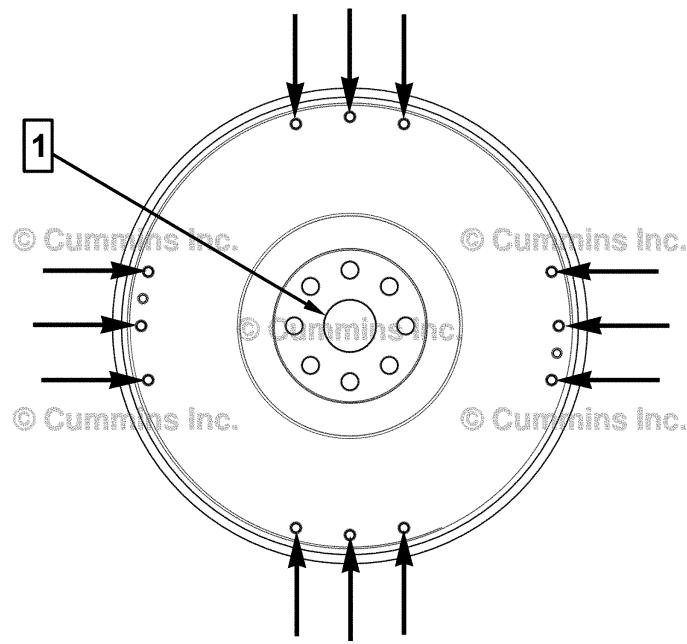


Figure 1 - Clutch to Flywheel Mounting

1 The flywheel pilot bore is designed to accept a 40 mm [1.57 in] outside diameter (O.D.) bearing.

The flywheel is shown in Figure 1. A quantity of 12 threaded holes are available for attachments of the clutch pressure plate cover. It is recommended to use a quantity of 12 Class 10.8 M8 x 1.25 bolts with a thread engagement such that **only** one thread protrudes out the back side of the flywheel when the cover is tightened.

Torque Value: 33 N·m [24 ft-lb]

See Figure 2 for additional dimensions.

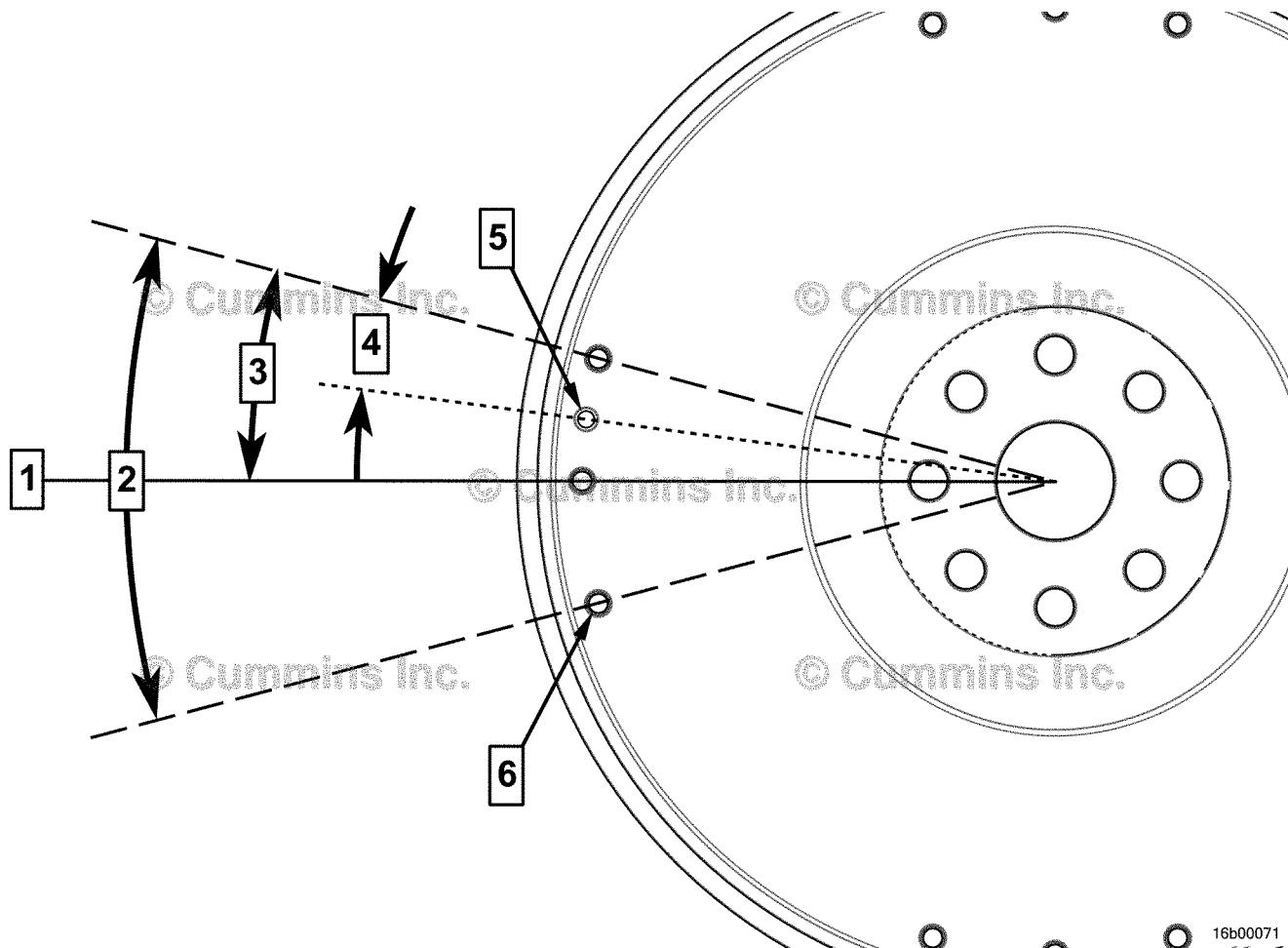
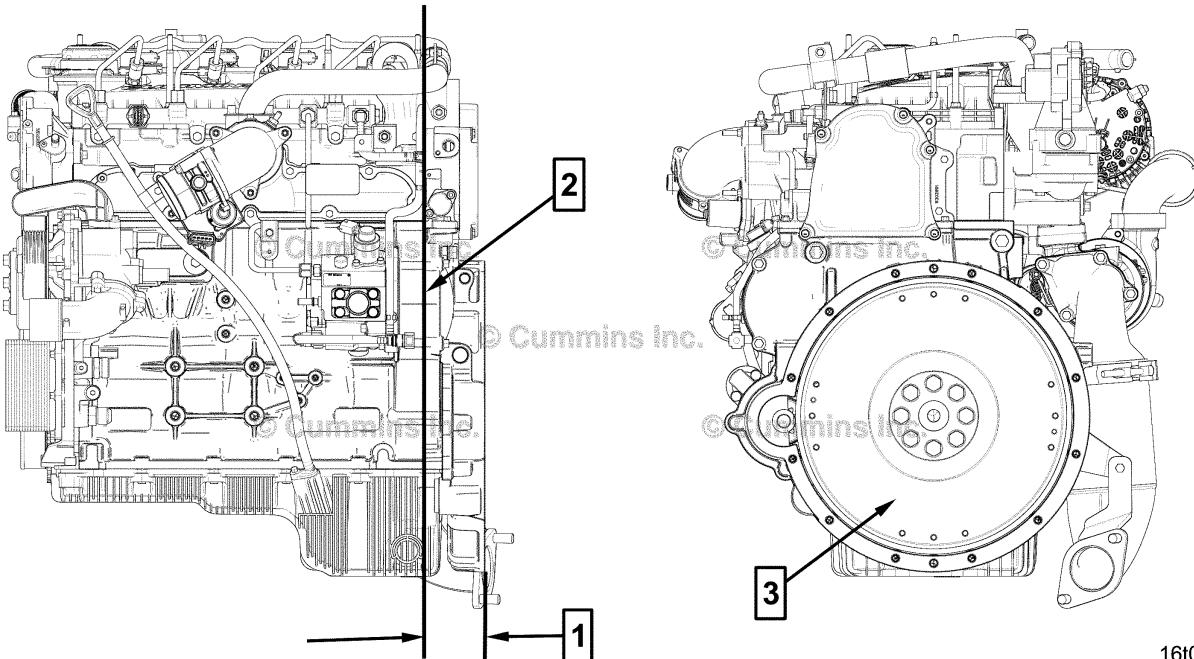


Figure 2 - Flywheel Specifications

- 1 Crankshaft centerline
- 2 Mounting hole spacing - 30 degrees, 4 places
- 3 Mounting hole spacing - 15 degrees, 8 places
- 4 Pilot hole to mounting hole spacing - 7.5 degrees, 2 places
- 5 Pilot holes - 2 equally spaced, on 320 mm [12.6 in] diameter
- 6 Clutch pressure plate mounting holes, 12 - M8 x 1.25, on 320 mm [12.6 in] diameter.

16b00071



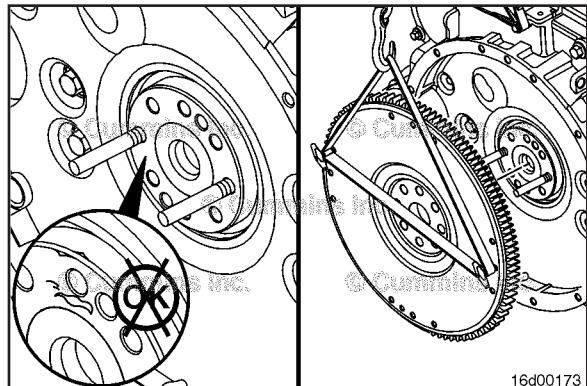
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Figure 3 - Depth Measurement of Flywheel

The face of the flywheel housing (1) is 80 mm [[3.15 in]] from the rear face of the block (2). The face of the flywheel (3) is 71 mm [2.8 in] back from the rear face of the block (2), and/or 9 mm [0.3 in] in from the mounting surface of the flywheel housing (1).

Flywheel/housing adapters as well as flexplate adaptations for automatic transmissions may be available from aftermarket suppliers. It is recommended to utilize Specialty Equipment Market Association (SEMA) members, as the R2.8 CM2220 R101B computer aided design (CAD) is available to reputable suppliers through their tech transfer program.

In the event that the flywheel has been removed from the crankshaft, the procedure below **must** be followed to reinstall the flywheel to the engine crankshaft.



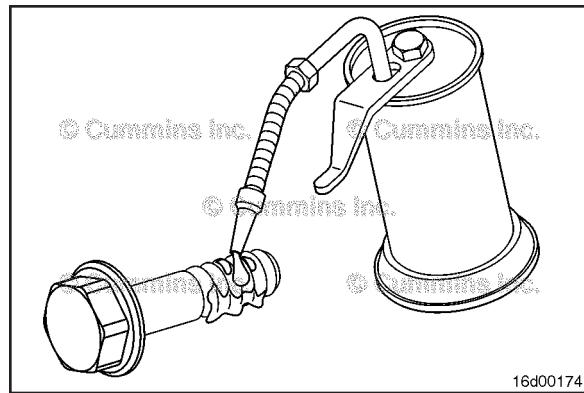
WARNING

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

Inspect the rear face of the crankshaft and flywheel mounting flange for cleanliness and raised nicks or burrs.

Install the flywheel on two M12 x 1.25 guide pins (customer-supplied).

Lubricate the threads of the capscrews and the surface of the washers with clean engine lubricating oil.

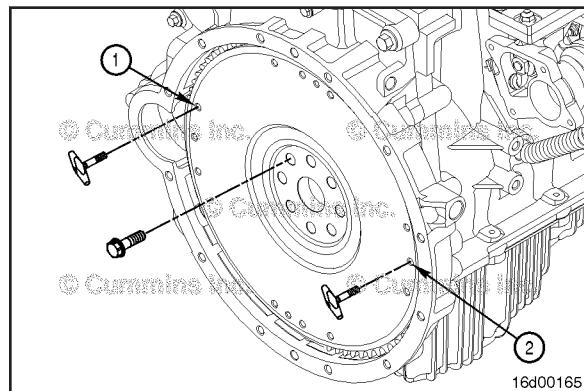


Install the six capscrews.



Remove the T-handles and guide pins (1 and 2).

Install the remaining capscrews into the holes from which the guide pins were removed.



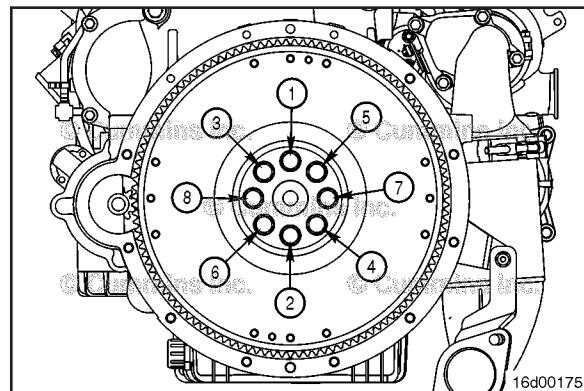
Tighten the capscrews in a star pattern.

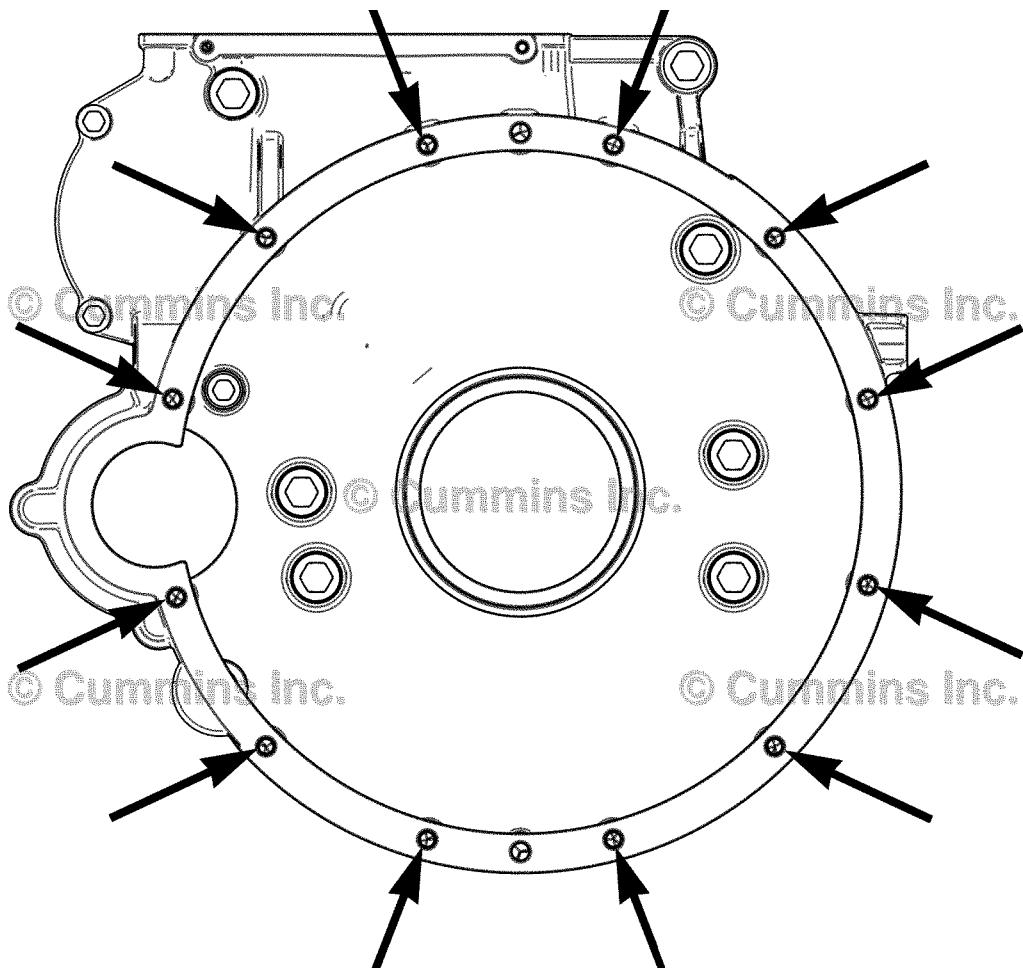


Torque Value:

Step 1	30 N·m	[22 ft-lb]
Step 2	Backoff 180 degrees	
Step 3	30 N·m	[22 ft-lb]
Step 4	Tighten 90-degree turn	

The flywheel face and bore runout will also need to be checked. Refer to Procedure 016-005 in Section 16 of the R2.8 CM2220 R101B Service Manual, Bulletin 5467556.





16b00068

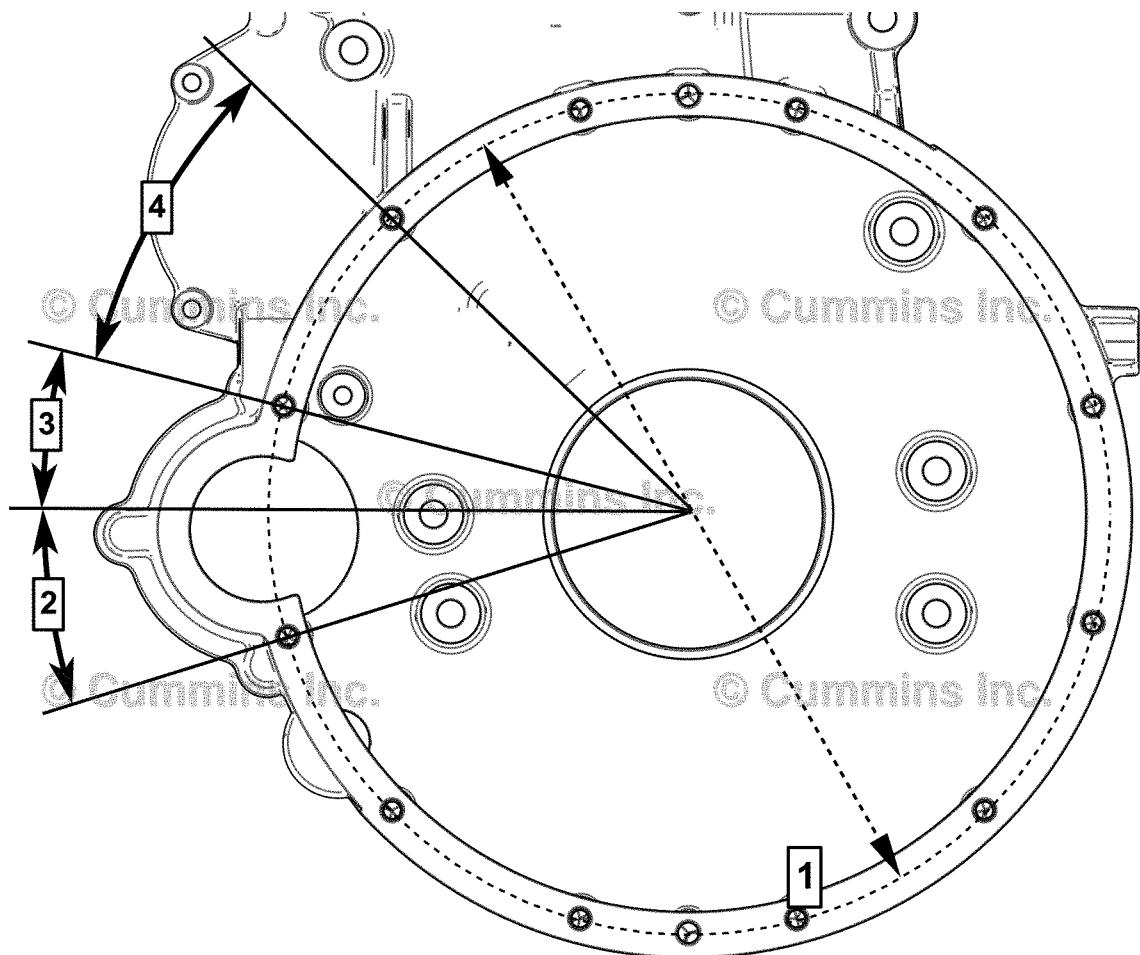
Figure 4 - Transmission to Flywheel Housing Mounting

The transmission to flywheel housing interface is shown in Figure 4.

There are 12 available M10 x 1.5 threaded holes to attach the transmission to the engine flywheel housing. It is recommended to use a quantity of 12 Class 10.8 M10x1.5 bolts with a minimum thread engagement into the flywheel housing of 18 mm [0.71 in], but not to exceed 25 mm [0.98 in] when tightened.

Torque Value: 30 N•m [22 ft-lb]

See Figure 5 for additional dimensions.



16t00011

Figure 5 - Flywheel Housing, Transmission Side

- 1 Flywheel housing diameter at transmission mounting hole circumference - 388 mm [15.3 in]
- 2 Crankshaft centerline to transmission mounting bolt location radius below starting motor bore - 17 degrees
- 3 Crankshaft centerline to transmission mounting bolt location radius above starting motor bore - 15 degrees
- 4 Flywheel housing transmission mounting bolt radius - 30 degrees x 10.

Fuel System (387-007)

Specifications

Rail Pressure Operating Range.....	250 to 1600 bar [3626 to 23,206 psi]
Maximum Pressure Drop across the Fuel Filter.....	27.5 kPa [4 psi]
Maximum Fuel Drain Line Restriction.....	20 kpa [2.9 psi]
Maximum Fuel Inlet Temperature.....	70°C [158°F]
Filter Efficiency.....	5 micron at 95 percent efficiency

General Information

⚠ WARNING ⚠

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

⚠ WARNING ⚠

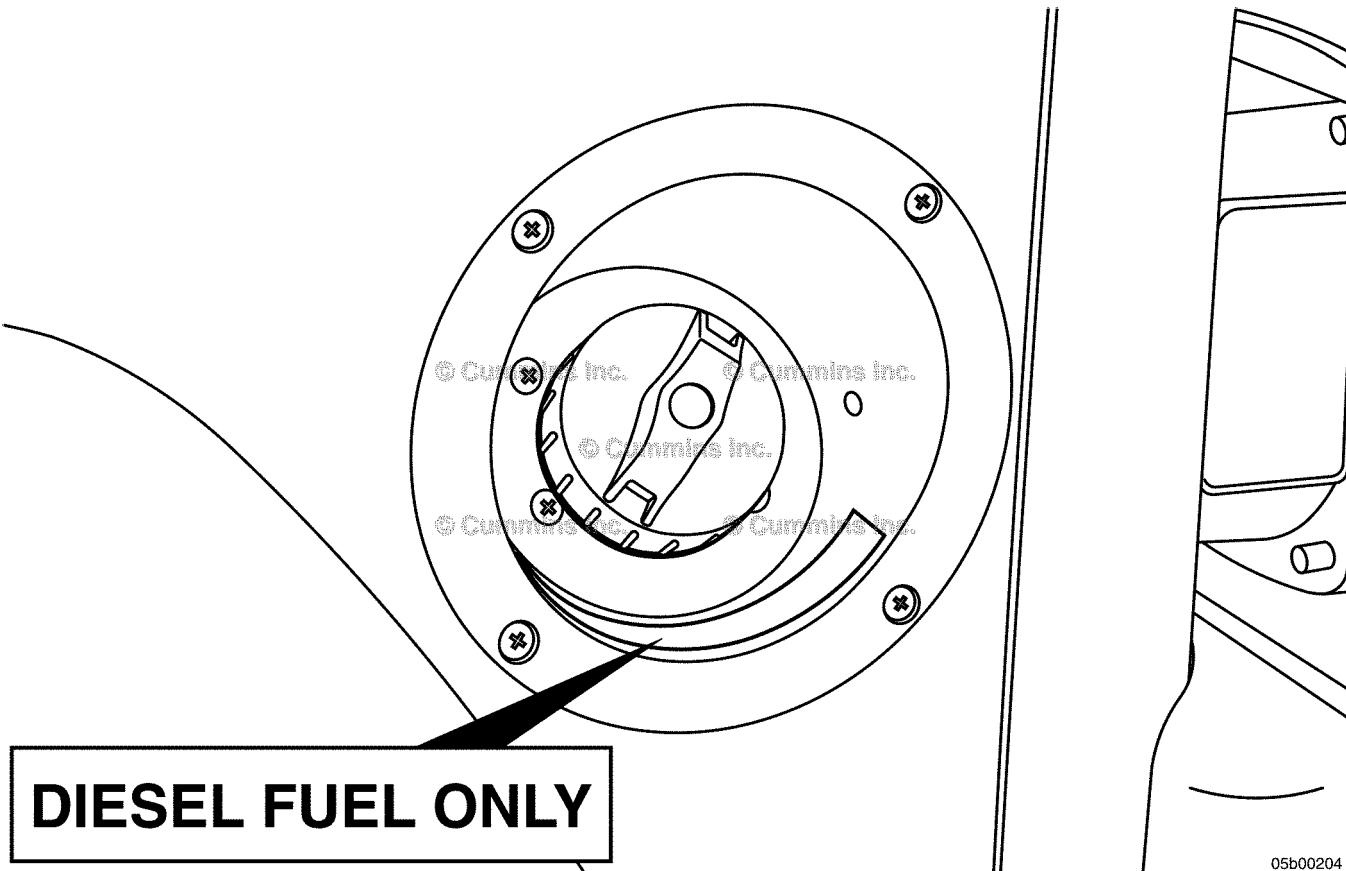
Do not mix gasoline, alcohol, or gasohol with diesel fuel. This mixture can result in a fire or explosion.

⚠ WARNING ⚠

The engine HPCR fuel system, lines, injectors and fitting must not be modified or changed in any manner. High-pressure fuel spray can cause serious injury or death.

The R2.8 CM2220 R101B engine utilizes a high-pressure common rail (HPCR) fuel system.

Certain modifications to the fuel supply, return lines and the fuel tank can possibly be required.



Be sure the fuel tank is clean and empty until all fuel connections are completed. Place a Diesel Fuel Only sticker on or near the fuel fill cap compartment of the vehicle.

The fuel supply connection is typically located on the side of the tank near the bottom, or on the top of the tank with a drop tube used to pick up fuel near the bottom of the tank. Good design practice is to pick up fuel near the center of the tank to minimize sloshing effects, and locate the pickup a short distance, about 25 mm [1 in], above the bottom of the tank to allow for space for condensate and dirt to collect. If a drop tube is used, it **must** be well supported to prevent cracking due to vibration in service. The drop tube assembly **must** be completely airtight to prevent aeration of the fuel supply. The fuel return flow from the engine **must** enter the tank below the fuel level in the tank, and be separated from the supply connection in the tank by a minimum of 305 mm [12 in].

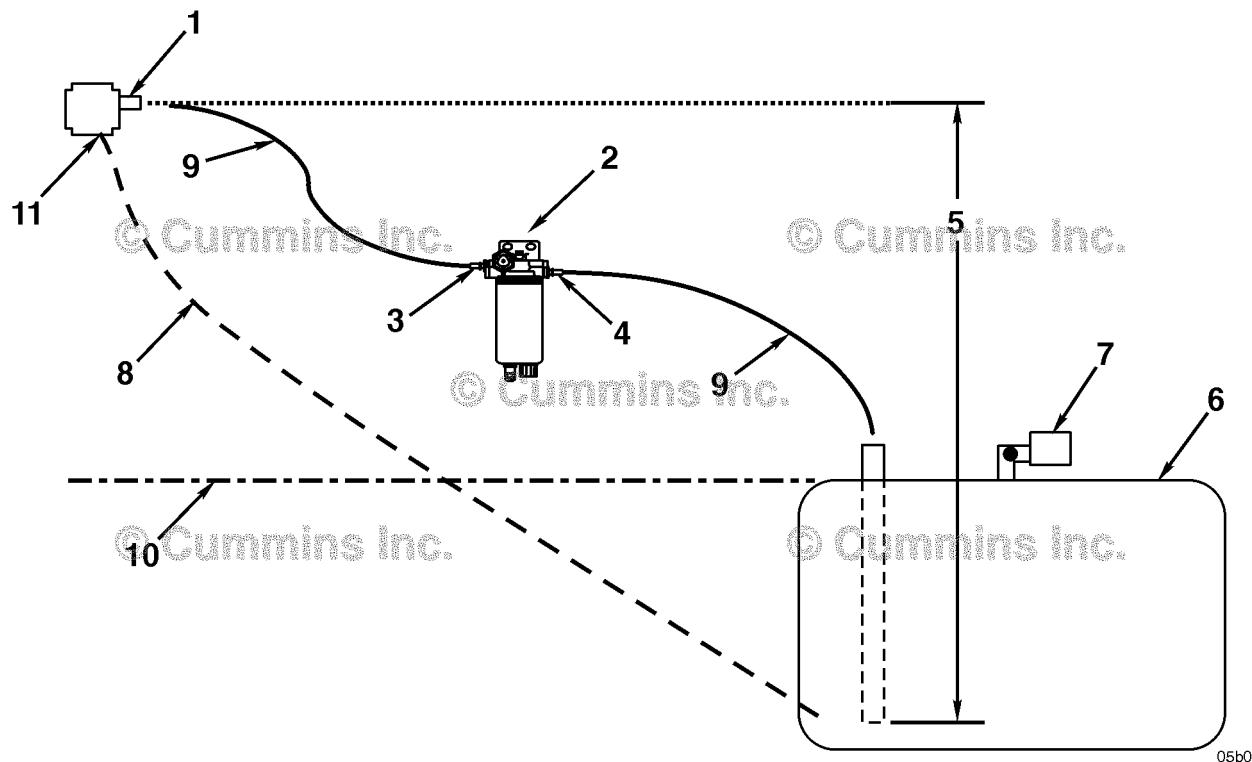


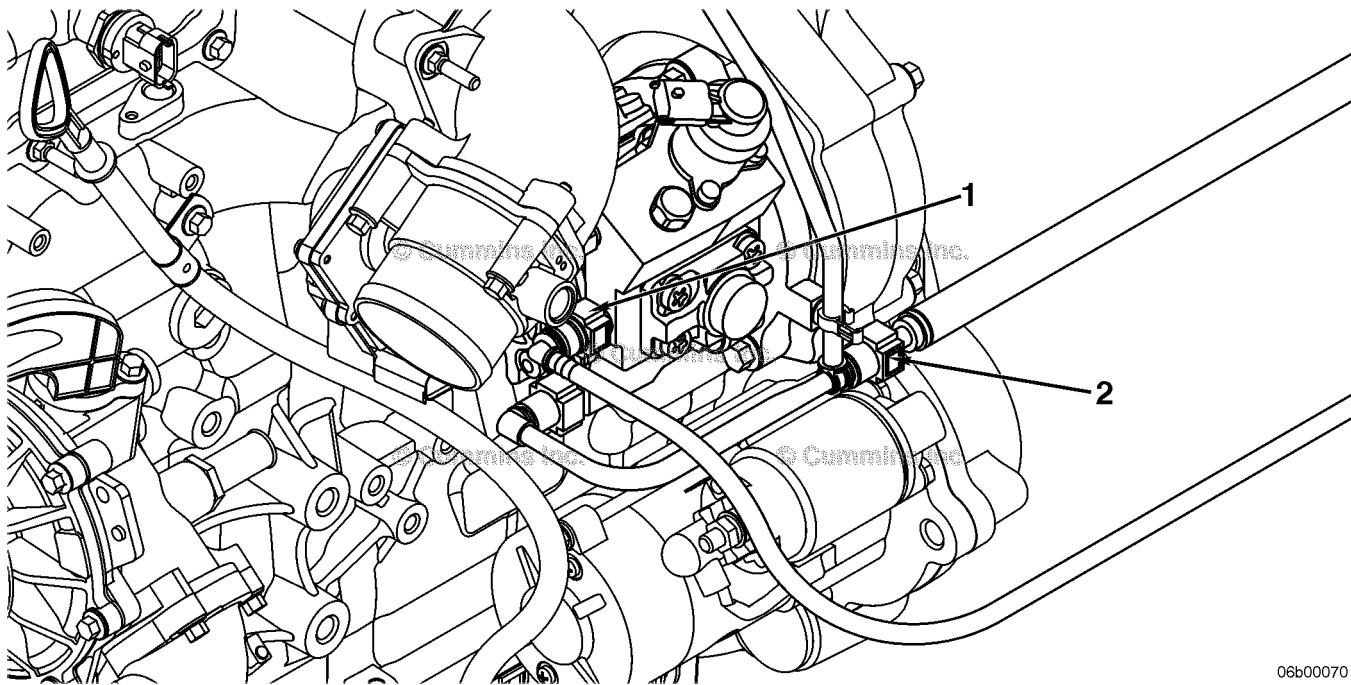
Figure 1 - Typical Fuel System Plumbing

- 1 Fuel supply pump connection
- 2 Fuel filter with water in fuel (WIF) separator
- 3 Fuel filter outlet to fuel pump
- 4 Fuel filter inlet from fuel tank
- 5 Maximum height from bottom of pickup tube in fuel tank to fuel pump inlet, 1 m [3 ft]
- 6 Fuel tank
- 7 Fuel tank vent with recommended check valve and filter; be sure the vent is unobstructed and mounted where it is free from dirt and debris
- 8 Fuel return to fuel tank drain line
- 9 Preferred fuel flow routing
- 10 Recommended minimum filter elevation
- 11 Fuel return connection on fuel pump.

Fuel Supply (9) and Return (8) lines should be routed away from sources of heat and as directly as possible from the tank (6) to the engine, avoiding both upward and downward loops. Upward loops can act as air traps, which can cause erratic engine operation, and downward loops can act as water traps, which can freeze and block fuel flow. The fuel supply and return lines are to enter the fuel tank at the minimum fuel level.

The inside diameter size of both supply and return fuel lines is dependent on the distance from the fuel pump to the tank. The quantity of fuel flowing to the engine would indicate that a 9.5 mm [0.375 in] inside diameter fuel line size would be adequate for most installations. A 8 mm [0.3125] return line is recommended from the pump back to the fuel tank. The installation of electric priming pumps or lift pumps in the fuel supply line is **not** recommended. These pumps can add restriction to the system or over-pressurize the engine's high-pressure common rail (HPCR) fuel pump, resulting in instability and fault codes.

Fuel pump fittings and line routing are shown in Figure 2.

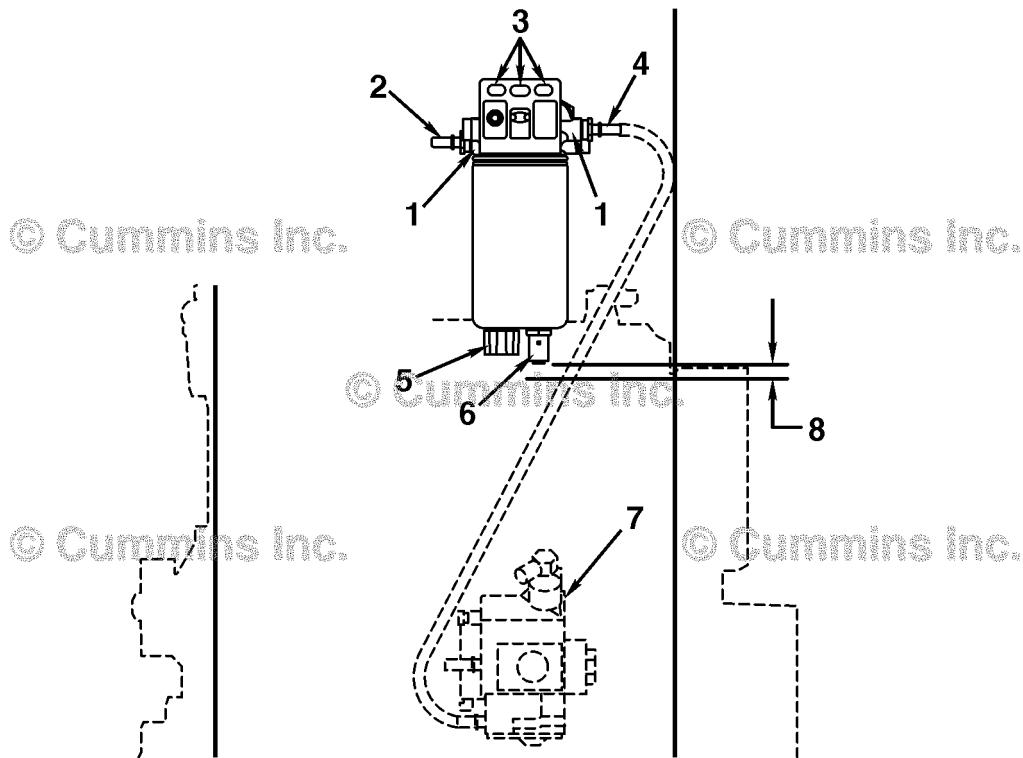


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Figure 2 - Fuel Pump Fittings

- 1 Fuel supply connection from chassis mounted fuel filter – 8 mm male Society of Automotive Engineers (SAE) J2044 quick disconnect fitting (an adaption fitting for the 8 mm male SAE J2044 quick disconnect to a 3/8 inch hose barb is provided in the filter kit, Part Number 4918987)
- 2 Fuel return connection to fuel tank – 8 mm female SAE J2044 quick disconnect fitting (an adaption fitting for the 8 mm female SAE J2044 quick disconnect to a 5/16 inch hose barb is provided in the filter kit, Part Number 4918432).

The mounting dimensions for the filter head and vertical orientation are shown in Figure 3. The filter should be mounted in a spot to allow easy removal and installation, as well as access to the water drain valve.



05b00206

Figure 3 - Fuel Filter Mounting

- 1 M14 x 1.5 – 6H thread in filter head

- 2 Fuel supply from fuel tank (filter inlet), 9.5 mm male Society of Automotive Engineers (SAE) J2044 quick disconnect fitting (an adaption fitting for the 9.5 mm male SAE J2044 quick disconnect to a 3/8 inch hose barb is provided in the Filter Kit, PN 5299831)
- 3 Slots, two places – 17 x 11 mm [0.7 x 0.4 in], 46.5 mm [1.83 in] center-to-center
- 4 Fuel supply to fuel pump (filter outlet), 9.5 mm male SAE J2044 quick connect fitting (an adaption fitting for the 9.5 mm male SAE J2044 quick disconnect to a 3/8 inch hose barb is provided in the Filter Kit, Part Number 5299831)
- 5 Water drain valve
- 6 WIF sensor
- 7 Fuel pump
- 8 Required distance for filter removal 12 mm [0.5 in], filter height 205 mm [8.1 in].

NOTE: The fuel hose to the filter from the fuel tank and the fuel hose from the filter to the fuel pump are supplied by the customer.

The R2.8 CM2220 R101B engine kit provides a fuel filter with provision for vertical chassis mounting. The filter assembly contains a WIF sensor and water drain valve. The WIF will detect the presence of water in the fuel. The filter assembly also contains an integrated fuel priming pump.

⚠ WARNING ⚠

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

⚠ CAUTION ⚠

Do not pre-fill the pressure-side fuel filter with fuel. 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.

The filter assembly should **not** be mounted in very dirty areas such as wheel wells, to reduce the potential for contamination of the system during filter change. Adequate clearance for scheduled maintenance and proximity to sources of heat **must** also be considered when selecting the mounting location of the filter assembly.

The optimum vertical location for the fuel filter is between the top of the fuel tank and the top of the engine valve cover. See Figure 1 and Figure 3 for mounting dimensions for the filter head assembly.

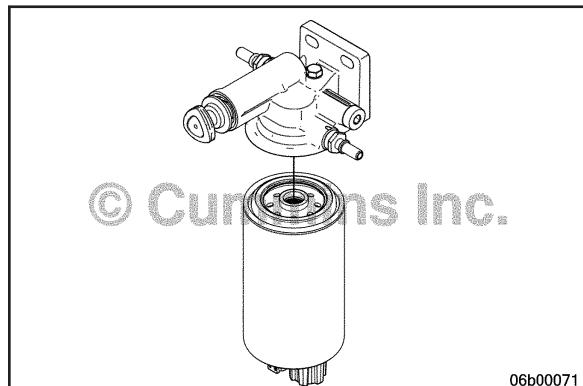
⚠ CAUTION ⚠

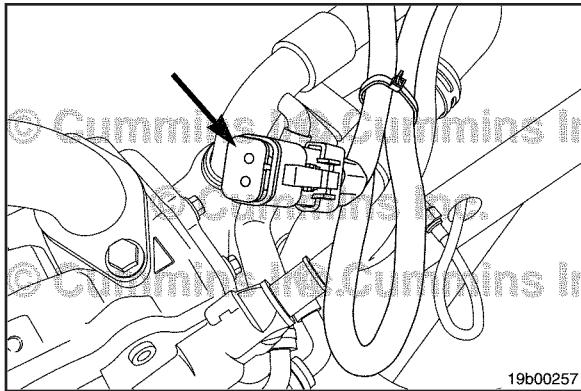
Mechanical over-tightening can distort the threads as well as damage the filter element seal or filter can.

NOTE: Do **not** pre-fill the fuel filter.

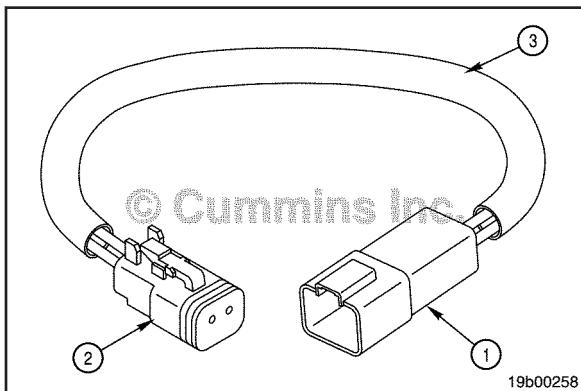
Install the fuel filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten the fuel filter an additional 3/4 of a turn after contact.





Once the fuel filter location on the chassis has been determined and installed, a harness to connect the WIF sensor to the mating engine harness connector will need to be made. The engine harness mating connector is located on the right rear of the engine, near the exhaust gas recirculation (EGR) cooler and valve as shown above. The engine connector harness is 660 mm [26 in] long.



The jumper harness **must** be 18 AWG wire. The engine harness mating connector (1) is a Deutsch DT06-2S-assembly. The WIF sensor connector (2) is a Deutsch DT06-2P-assembly. Pin 1 is water sense, pin 2 is ground.

The length of the harness (3) will be determined by the location of the filter in relation to the engine.

A fault code and warning message will be generated if the engine control system does **not** detect a connected WIF sensor.

Cooling System (387-008)

Specifications

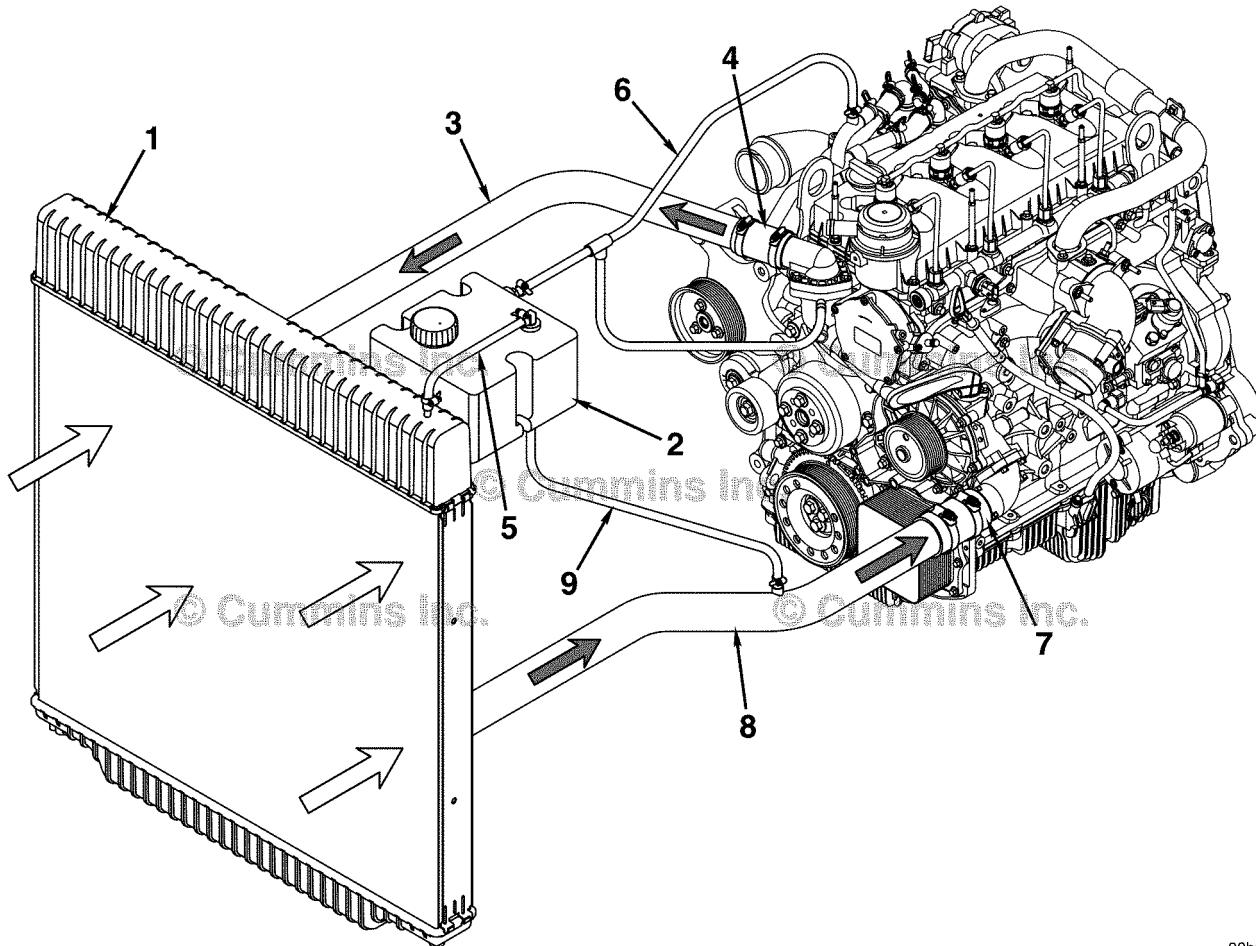
Coolant capacity.....	6 liters [1.6 gal]
Heat rejection.....	60 Kw [3400 BTU/min]
Standard modulating thermostat - range.....	82°C to 95°C [180°F to 203°F]
Maximum allowed water operating temperature.....	107°C [225°F]
Minimum recommended water operating temperature.....	71°C [160°F]
Minimum recommended pressure cap rating.....	100 kPa [15 psi]
Maximum pressure cap rating.....	138 kPa [20 psi]
Recommended radiator coolant flow	
Governed power.....	2.8 L/s [44.4 gpm]
Peak torque.....	2 L/s [32.5 gpm]

General Information

The R2.8 CM2220 R101B engine is designed for use with a positive fully deaerating cooling system. A fully deaerating cooling system enables trapped air in the cooling system to be properly purged. The cooling system is comprised of a radiator, deaeration tank, fill line, and vent lines. The pressure cap on the deaeration tank should always be the highest point of the system. All vent lines **must** continuously run uphill until they connect into the deaeration tank.

The deaeration tank **must** be able to withstand a system pressure of 103 kPa [15 psi]. The minimum recommended pressure cap **must** be 103 kPa [15 psi]. The system pressure **must** stay below 138 kPa [20 psi] to maintain integrity of the water pump seal. Therefore, the maximum recommended pressure cap **must** be 138 kPa [20 psi].

Figure 1 below shows the components of the fully deaerating cooling system.



08b00187

Figure 1 - Engine Cooling System

- 1 Radiator
- 2 Deaeration tank
- 3 Upper radiator hose
- 4 Water outlet, 42 mm [1.65 in]
- 5 Radiator vent line
- 6 Engine vent line, 1/8 in NPT
- 7 Water pump inlet, 50 mm [1.96 in]
- 8 Lower radiator hose
- 9 Fill line to lower radiator hose.

The engine at full power will generate 60 Kw [3400 BTU/min] of heat. The radiator can dissipate the heat generated by the engine via ambient air flowing through the radiator during vehicle motion, or by pulling the air through radiator cooling fans.

The radiator/fan system **must** be designed to enable the vehicle to be used at the ambient temperatures desired and **not** exceed the 107° C [225° F] maximum engine temperature.

Electric fan control wiring is provided in the engine side harness. Although three wires are in the fan control wiring harness, only the high speed signal yellow wire, pin 33, and the ground white wire, pin 34, are active. The third wire, low speed signal green wire, pin 35, is **not** used on the R2.8 CM2220 R101B. Two speed electric, 3 wire, fan drives are **not** supported.

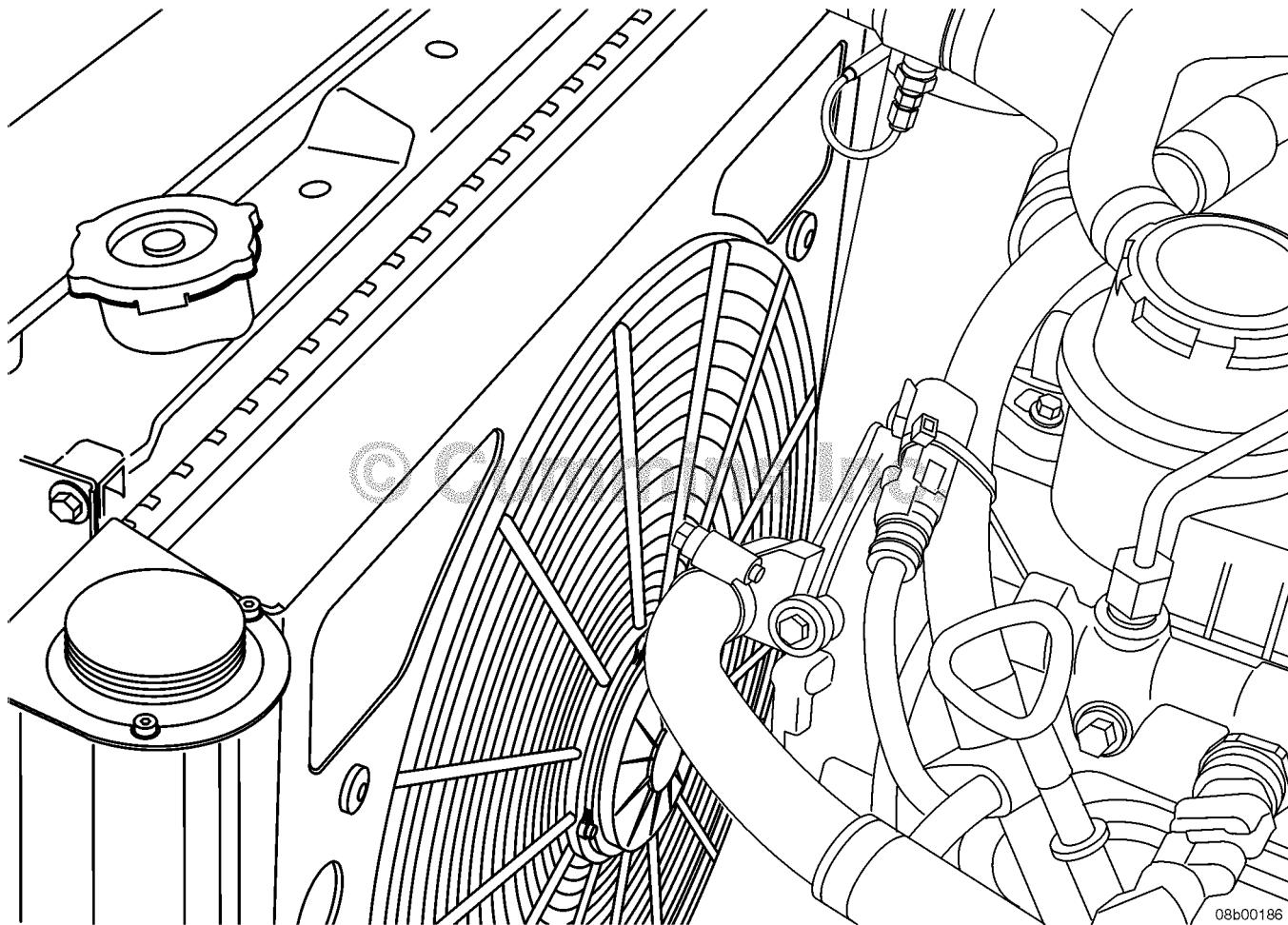
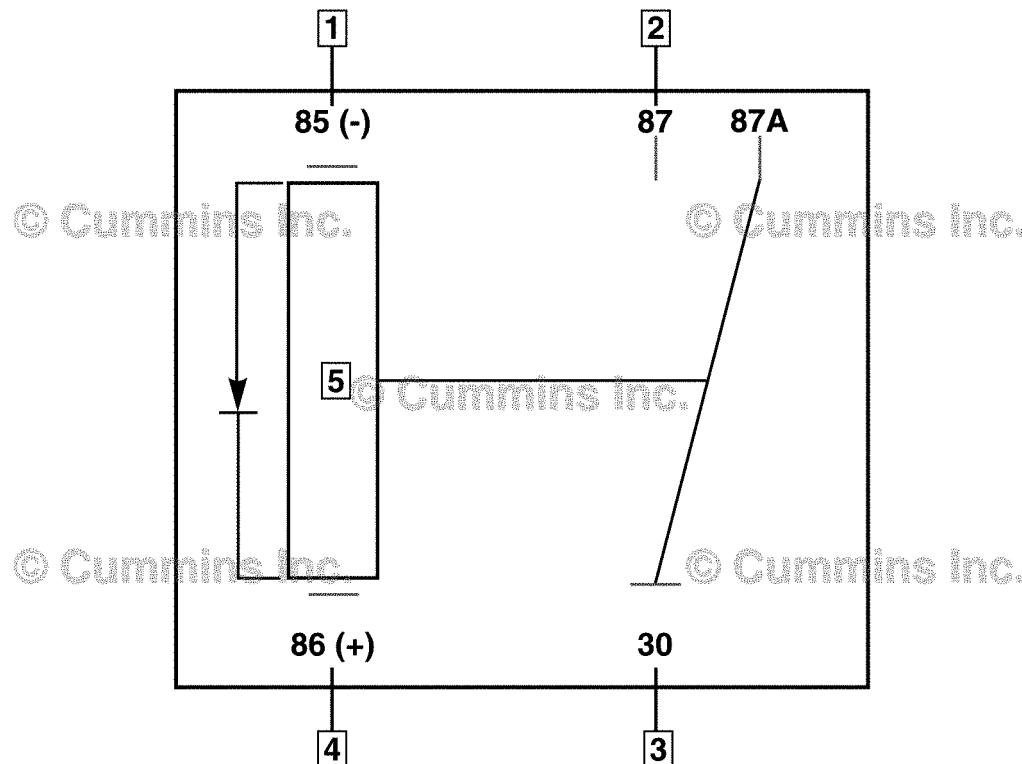


Figure 2 - Electric Cooling Fan

NOTE: The fan signal and return wires are meant to power a relay, and **not** the fan directly. Follow the manufacturer recommendation for the electric fan installation wiring and the size of the control relay. Figure 3 is a typical fan relay with **no** current flowing to pin 33, fan OFF. See the R2.8 CM2220 R101B Wiring Diagram, Bulletin 5467560, on QuickServe™ Online.



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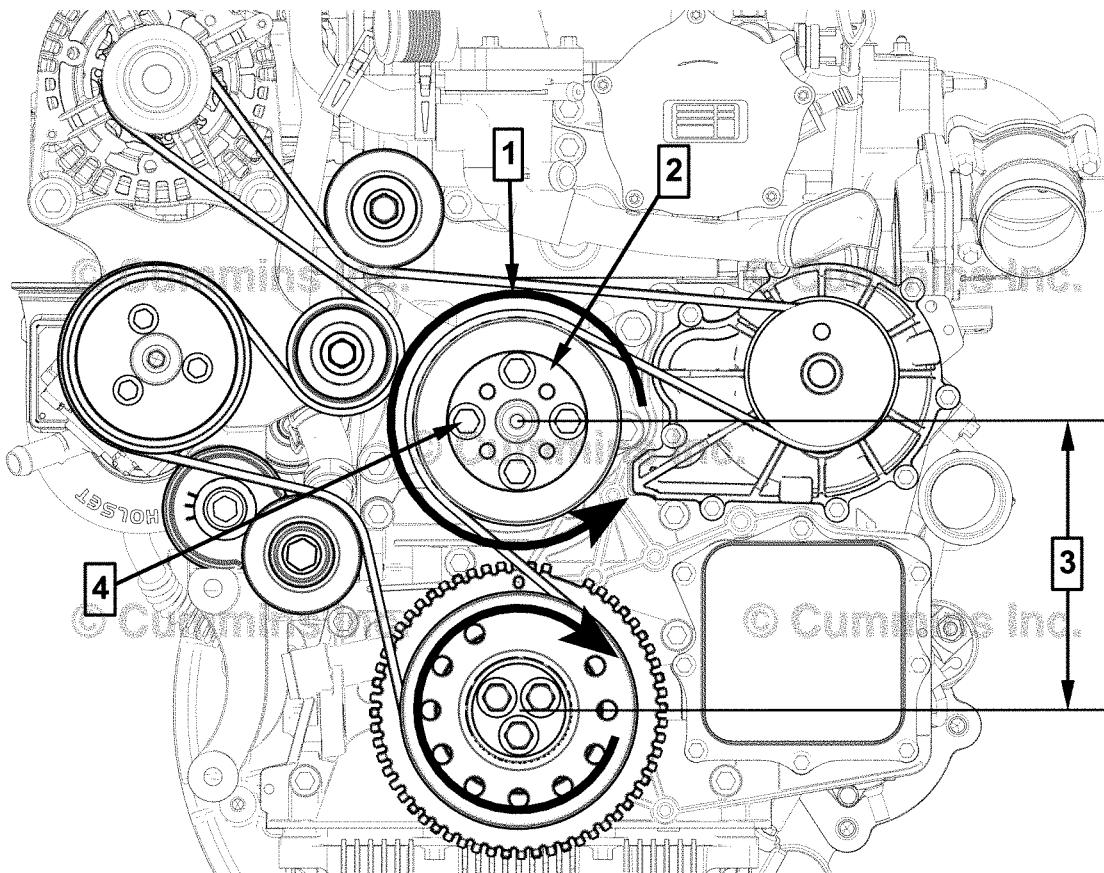
Figure 3 - Electric Fan Relay

- 1 Fan Ground White wire, pin 34
- 2 To fan
- 3 Battery, 12 volt power
- 4 High Speed Signal Brown wire, pin 33
- 5 Coil.

Adaptations to use a mechanical fan may be available from aftermarket suppliers. It is recommended to utilize Specialty Equipment Market Association (SEMA) members, as the R2.8 CM2220 R101B computer-aided design (CAD) is available to reputable suppliers through their tech transfer program.

Should a mechanical fan drive be required, the information in Figure 4 can be used to direct mount a cooling fan or a clutching mechanism for the cooling fan.

The engine fan hub pulley rotates **counterclockwise**. The belt driven front engine accessory drive (FEAD) system is capable of driving up to a 15 HP cooling fan. The fan drive hub will contain a bearing spacer that **must** be discarded, enabling the 25.4 mm [1 in] pilot to be used for the cooling fan or fan clutch. The pilot length is 10 mm [0 .4 in] thick. The bending moment imposed on the fan hub by the weight of the fan and the length of the spacers **must not** exceed 2.5 N·m (1.8 ft-lb) and spacer length **must not** exceed 76.2 mm [3 in].



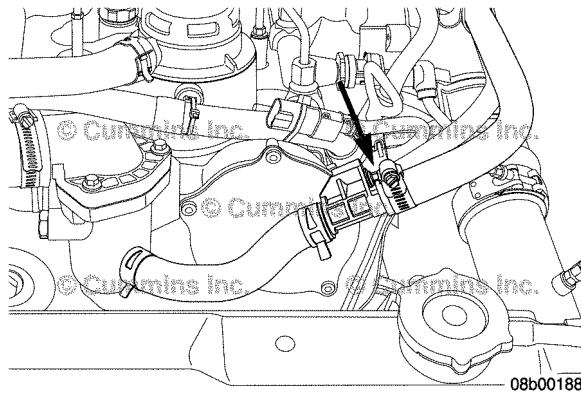
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Figure 4 - Mechanical Fan Drive

- 1 Fan hub: **counterclockwise** rotation at 1.1 times engine speed
- 2 Bearing plate - 8.4 mm [0.33 in]
- 3 Distance between crankshaft centerline and fan hub centerline - 175 mm [6.9 in]
- 4 Four M10 x 1.5 threaded holes on 60 mm [2.36 in] bolt circle. Torque to 43 N·m [32 ft-lb] in a crisscross pattern.

Cab Heater Supply and Return Coolant Connections

The engine has two provisions for supplying engine coolant to the cab heater core.



08b00188

Figure 5 - Coolant Supply for Heater Core

An engine coolant outlet connection is located below the thermostat housing. This connection is for coolant supply to the heater core. See Figure 5 above.

Cab Heater Supply Connection

- **Outside Diameter:** 17 mm [0.7 in]
- **Clamping Distance:** 14 mm [0.6 in] from the end

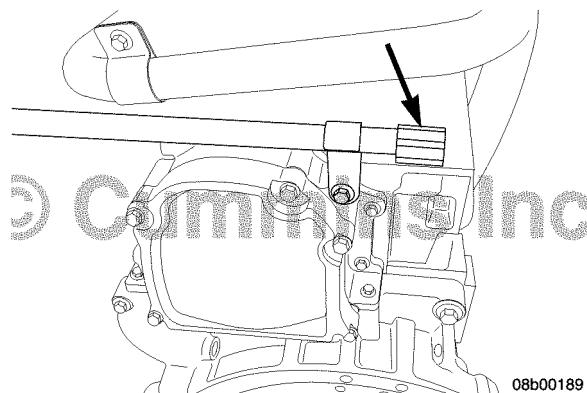


Figure 6 - Coolant Return from Heater Core

A connection is located at the back of the engine for reduced pressure coolant returning from the heater core. See Figure 6 above.

Cab Heater Return Connection

- **Outside Diameter:** 16 mm [0.6 in]
- **Clamping Distance:** 32 mm [1.3 in] from the end

Auxiliary Coolant Sensor Location

Should an auxiliary coolant temperature sensor be required for an accessory device or dash gage, there is a port on the engine that can be used. This sensor is customer-supplied. An M12 port (1) is shown below in Figure 7, located between the coolant outlet and the FEAD idler pulley.

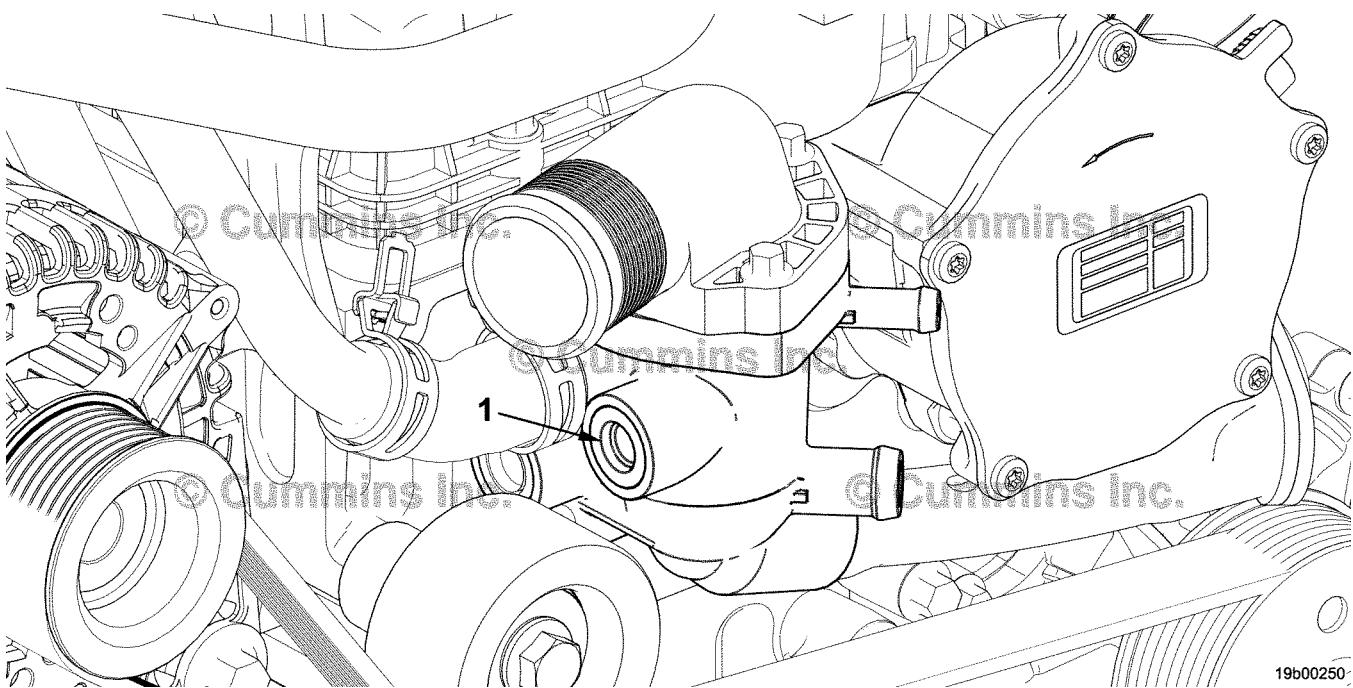


Figure 7 - Auxiliary Coolant Sensor Location

NOTE: The housing is non-conductive, thus a single pole sensor switch will require an additional ground wire to be installed.

Lubricating Oil System (391-003)

Specifications

Oil Pressure:

Low idle (minimum allowed).....	69 kPa [10 psi]
At rated (minimum allowed).....	321 kPa [47 psi]
Oil-regulating valve-opening pressure range.....	350 to 360 kPa [51 to 52 psi]

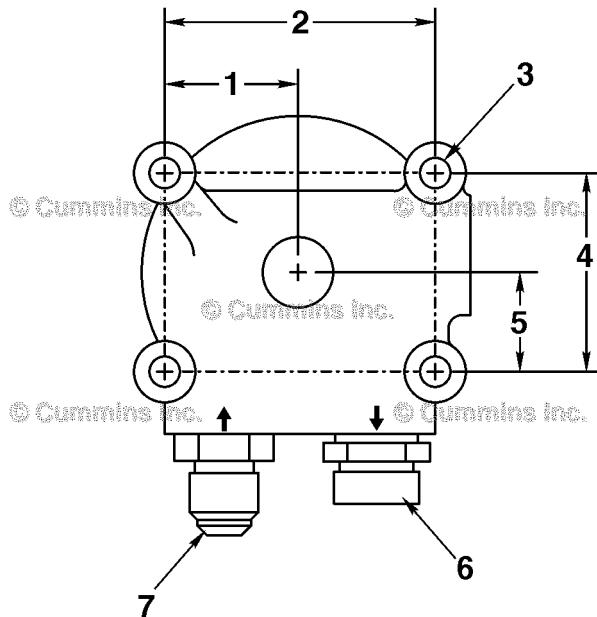
Oil filter differential pressure to open bypass.....	310 to 379 kPa [45 to 55 psi]
Lubricating Oil Filter Capacity.....	0.436 liters [0.461 qt]
Oil Capacity:	
Oil change with filter change.....	5.4 liters [5.74 qt]
Oil change without filter change.....	5.0 liters [5.28 qt]
High to Low (on dipstick).....	1 liter [1.06 qt]
Maximum Oil Temperature:.....	136°C [275°F]

General Information

A remote, off-engine, full flow lubricating oil filter is used on this engine.

The lubricating oil filter is temporarily mounted on the engine flywheel housing with the bracket for shipping purposes **only**. The lubricating oil filter should be mounted on the chassis vertically for the proper operation and ease of service.

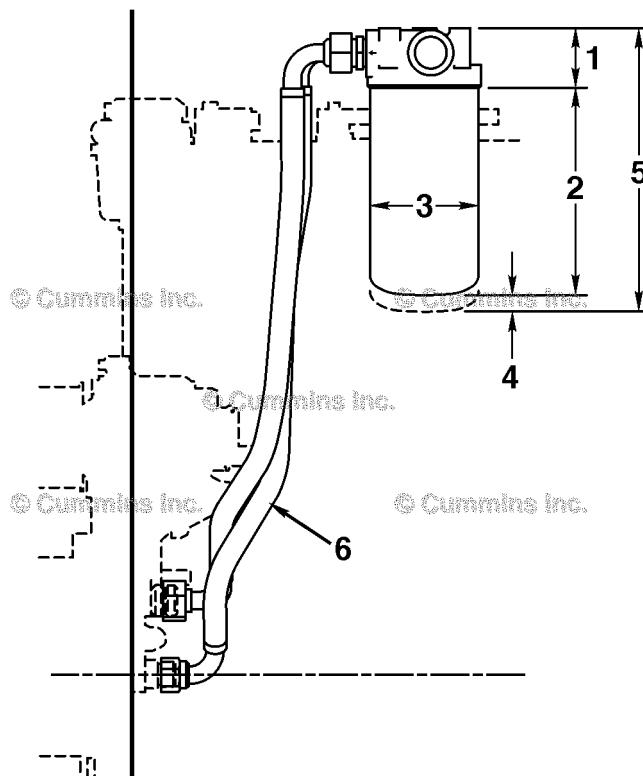
Refer to Procedure 018-024 in Section V for lubricating oil filter part numbers. Figures 1 and 2 provide the dimensions to design and build a suitable chassis-mounted, vertical lubricating oil filter mounting bracket. The hoses provided with the remote lubricating oil filter system should be used to maintain cleanliness of the system.



07b00309

Figure 1 - Lubricating Oil Filter Head Top View

- 1 Mounting holes, front-to-rear centerline to rear mounting holes 42 mm [1.6 in]
- 2 Mounting hole width, front-to-rear - 83 mm [3.27 in]
- 3 Mounting hole size - M8 x 1.25-6H, 17 mm [0.7 in] deep, four places
- 4 Mounting hole width, side-to-side - 60 mm [2.36 in]
- 5 Mounting hole width, side-to-side centerline to front mounting holes - 30 mm [1.2 in]
- 6 Front lubricating oil hose fitting, M26 x 1.5-6g, 12 degrees inverted flare, both ends
- 7 Rear lubricating oil hose fitting, 7/8-14 UNF - 2A, 37 degrees flare, both ends.



07b00310

Figure 2 - Lubricating Oil Filter Head Side View

- 1 Lubricating oil filter head height, 49 mm [1.9 in]
- 2 Lubricating oil filter height, 178 mm [7.0 in]
- 3 Lubricating oil filter diameter, 93 mm [3.7 in]
- 4 Required distance for filter replacement, 14 mm [0.6 in]
- 5 Total required height for mounting and replacement, 241 mm [9.4 in]
- 6 Lubricating oil hose length, 490 mm [19.3 in].

The length of the lubricating oil hoses can **not** exceed 490 mm [19.3 in]. The lubricating oil hose inside diameter **must** remain the same as the hoses included in the kit.

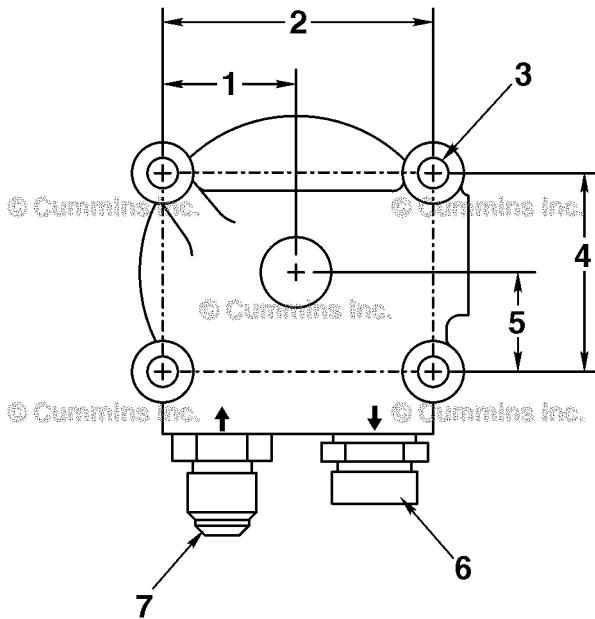
For engines manufactured after August 2021, follow instructions below:

If use of on-engine mounted oil filter is desired, no further installation is required. Engine comes as-delivered from the factory with oil filter, Part Number 5399594, installed on the engine utilizing filter head adapter, Part Number 5337936.

If use of optional remote, off-engine, full flow lubricating oil filter is desired, reference installation instructions as follows:

Remove engine mounted oil filter, Part Number 5399594, and install adapter, Part Number 5308353, and cover, Part Number 5309233 as supplied with the engine.

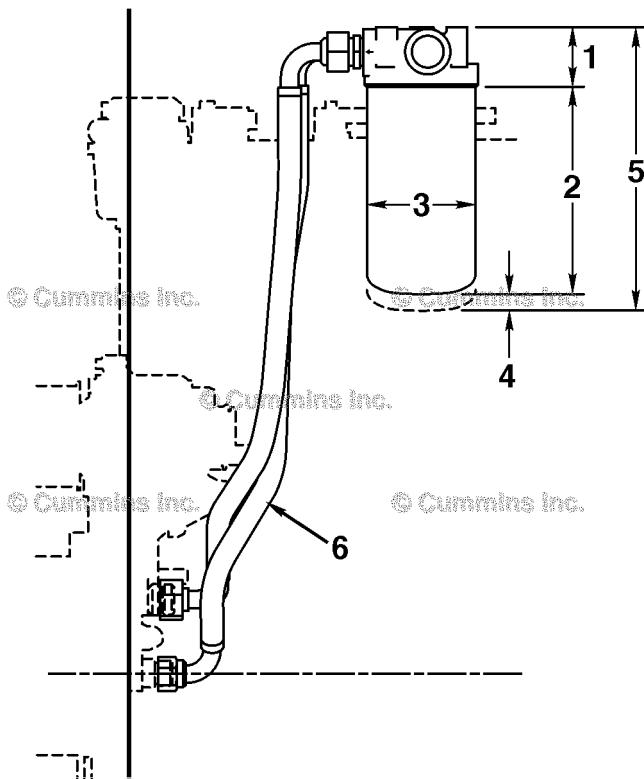
Figures 3 and 4 provide the dimensions to design and build a suitable chassis-mounted, vertical lubricating oil filter mounting bracket. The hoses provided with the remote lubricating oil filter system **must** be used to maintain cleanliness of the system.



07b00309

Figure 3 - Lubricating Oil Filter Head Top View

- 1 Mounting holes, front-to-rear centerline to rear mounting holes 41.5 mm [1.6 in]
- 2 Mounting hole width, front-to-rear 83 mm [3.27 in]
- 3 Mounting hole size - M8 x 1.25-6H, 17 mm [0.7 in] deep, four places
- 4 Mounting hole width, side-to-side 60 mm [2.36 in]
- 5 Mounting hole width, side-to-side centerline to front mounting holes 30 mm [1.2 in]
- 6 Front lubricating oil hose fitting, M30 x 1.5-6g, 36.75 degrees flare both ends
- 7 Rear lubricating oil hose fitting, 1 1/16-12 UN-2A, 29.75 degrees flare, both ends.



07b00310

Figure 4 - Lubricating Oil Filter Head Side View

- 1 Lubricating oil filter head height, 49 mm [1.9 in]
- 2 Lubricating oil filter height, 176.7 mm [6.95 in]
- 3 Lubricating oil filter diameter, 94.8 mm [3.73 in]
- 4 Required distance for filter replacement, 14 mm [0.6 in]
- 5 Total required height for mounting and replacement, 239.7 mm [9.44 in]
- 6 Lubricating oil hose length, 790 mm [31.1 in].

The lubricating oil hose inside diameter **must** remain the same as the hoses included in the kit, and the length of the lubricating hoses is **not** to exceed 790 mm [31.1 in].

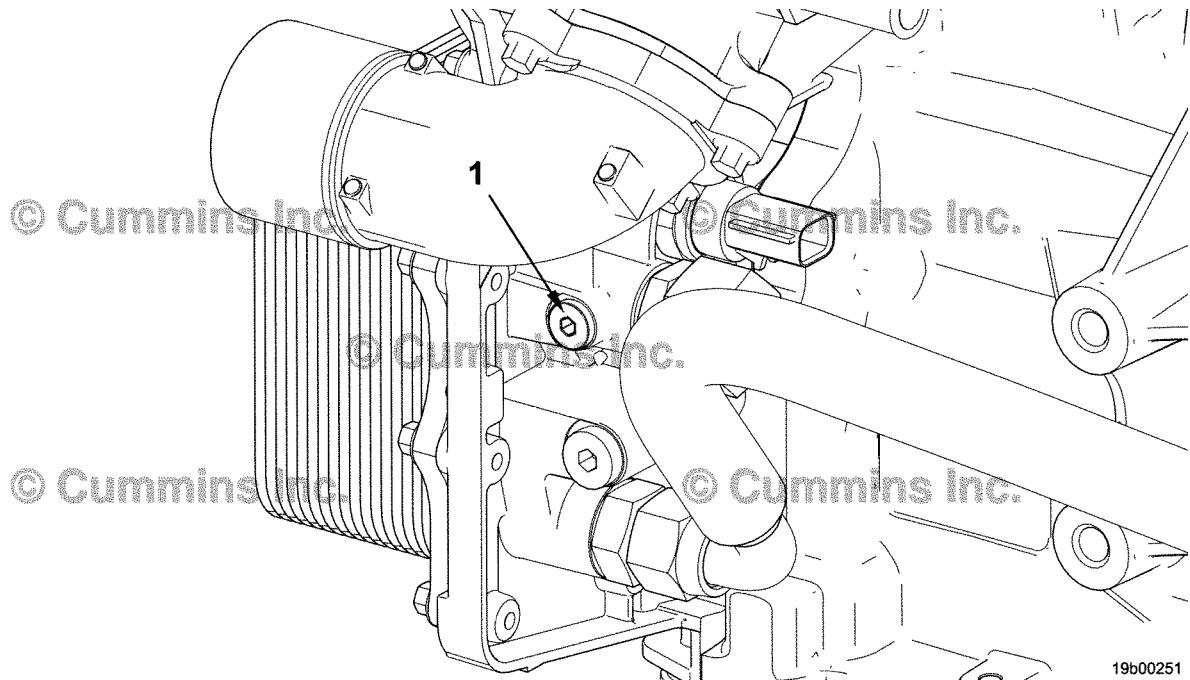


Figure 5 - Accessory Oil Pressure Port

There is an oil pressure switch included in the engine controls. Therefore, there is **not** a live oil pressure reading available on the CAN network. For the installation of an auxiliary oil pressure gauge or switch, the upper M10 x 1.0 thread port illustrated in Figure 5 above can be used.

Air Intake System (388-017)

Specifications

Rise Over Ambient (at compressor inlet).....	15°C delta [27°F delta]
Maximum Air Flow.....	300 CFM
Required Filter Efficiency. 99.9 percent (International Organization for Standardization (ISO) 5011 full life efficiency test with fine dust)	
Minimum Required Filter Capacity.....	900 grams
Maximum Intake Restriction (clean air filter element).....	3.7 kPa [15 in H ₂ O]
Maximum Intake Restriction (dirty air filter element).....	6.2 kPa [25 in H ₂ O]

Charge Air Cooler

Minimum Outlet Differential to Ambient.....	30°C delta [54°F delta]
Maximum Pressure Differential.....	13 kPa [4 in-Hg]

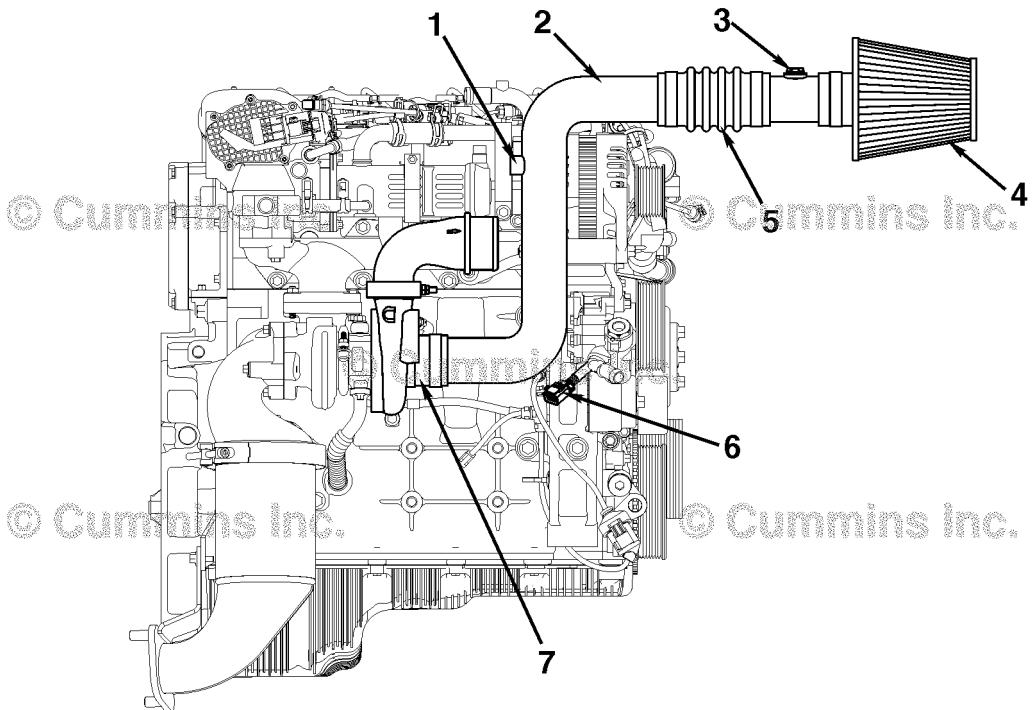
General Information

The air entering the engine at the turbocharger compressor inlet **must** be clean, dry, and as close to ambient temperature as possible. The type of air filter and the filter mounting location in the vehicle will have the greatest impact in providing the engine with clean, dry, ambient air. The air temperature as measured at the turbocharger compressor inlet **must not** be greater than 15°C [27°F] above ambient.

The air filter size should be such that the filter can hold 900 grams of contaminants and dirt, given the maximum air flow through the filter is 300 cubic feet per minute. The larger the dirt holding capacity, the longer the service interval

will be before the filter **must** be changed. Minimum full life efficiency at removing airborne dirt when tested, according to ISO 5011 full-life efficiency test with fine dust, **must** be 99.9 percent.

The entire intake system restriction, including a new, clean air filter, as measured at the turbocharger compressor inlet, **must not** be greater than 3.7 kPa [15 in H₂O]. The filter **must** be replaced when the restriction is greater than 6.2 kPa [25 in H₂O]. The use of filter elements impregnated with oil or other fluids **must** be avoided, as they can poison the mass air flow (MAF) sensor and affect the performance and emissions of the engine. Cylindrical or conical air filters will provide uniform air distribution at the air filter outlet, which is critical to the function of the MAF sensor.



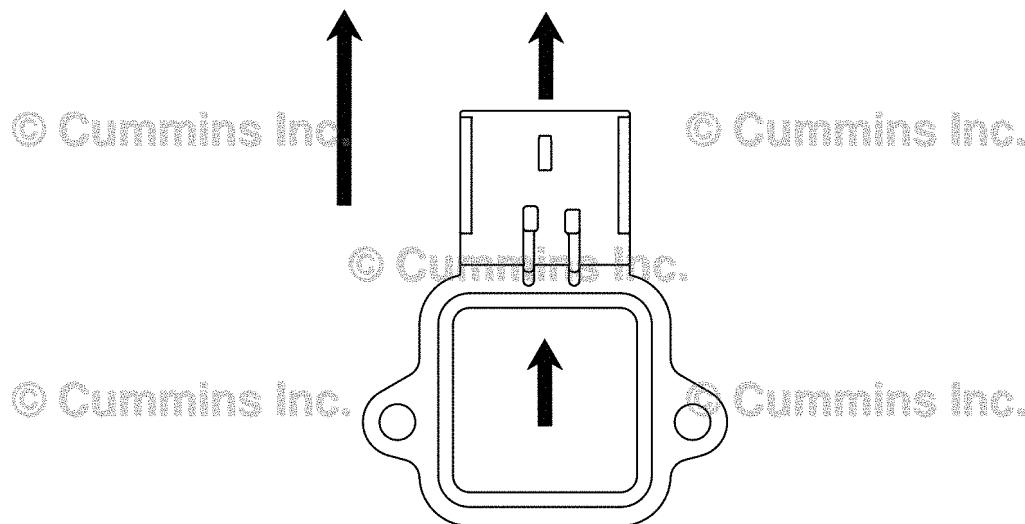
10b50166

Figure 1 - Air Intake System

- 1 Breather connection
- 2 Intake pipe minimum diameter - 76.2 mm [3 in]
- 3 MAF sensor
- 4 Air filter
- 5 Flexible hose
- 6 Approximate location of MAF sensor engine harness connector
- 7 Air intake connection at turbocharger compressor - 54 mm [2.1 in].

The R2.8 CM2220 R101B Engine Kit will include an air intake tube to house the MAF sensor. The air intake tube is specifically designed for steady, laminar airflow across the MAF sensor to optimize engine emissions and performance. Therefore, the tube should be used in the installation of the air intake system. The MAF sensor kit contains one sensor and two M4 x 0.7 x 16 mm Torx 15 screws. The MAF sensor is to be installed in the provided tube. See Figure 2. Tighten the Torx screws.

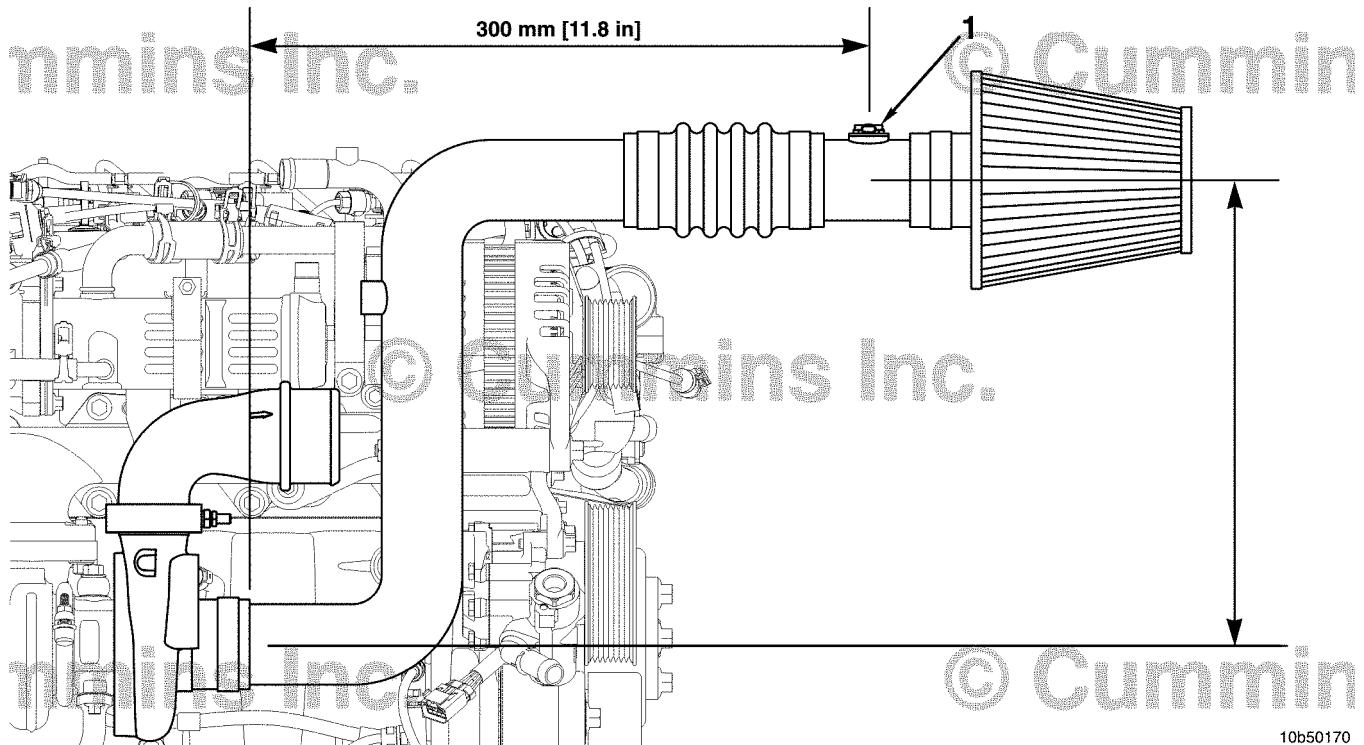
Torque Value: 3.4 N·m [30 in-lb]



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Figure 2 - MAF Sensor Airflow

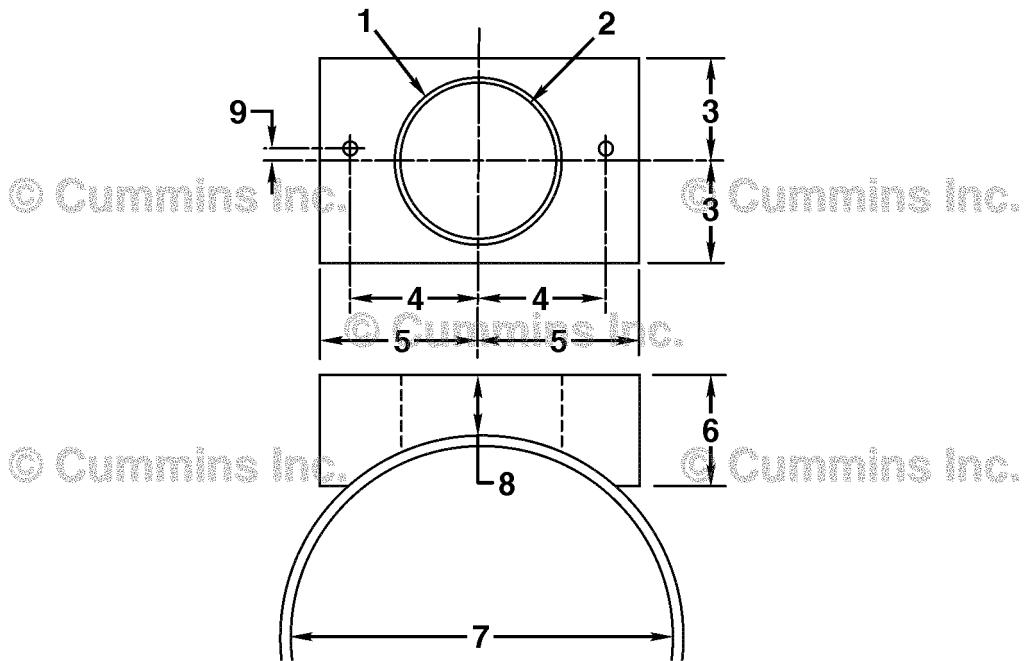
The tube ends are designed such that the non-beaded end will connect directly to a 76.2 mm [3 in] diameter air filter outlet, shown in Figure 3. The MAF sensor (1) should be mounted no less than 300 mm [11.8 in] from the turbocharger compressor inlet, and **not** in direct line of sight of the compressor wheel.



10b50170

Figure 3 - Kit Supplied MAF Tube

Should the installer choose to fabricate a custom intake tube, the critical dimensions are shown in Figure 4. The custom tube **must** meet all the requirements of the provided tube. The MAF sensor **must** be mounted in a 76.2 mm [3 in] diameter tube so that there is 101.6 mm [4 in] of straight section between the air filter and the sensor, and a minimum of 76 mm [3 in] of straight section post sensor before the first bend. Make sure the MAF sensor will be oriented correctly in the air intake system. An arrow is located on the sensor indicating the correct airflow direction. This direction **must** be verified prior to welding the boss onto the tube, as the sensor will **only** mount in the boss one way.



10b50176

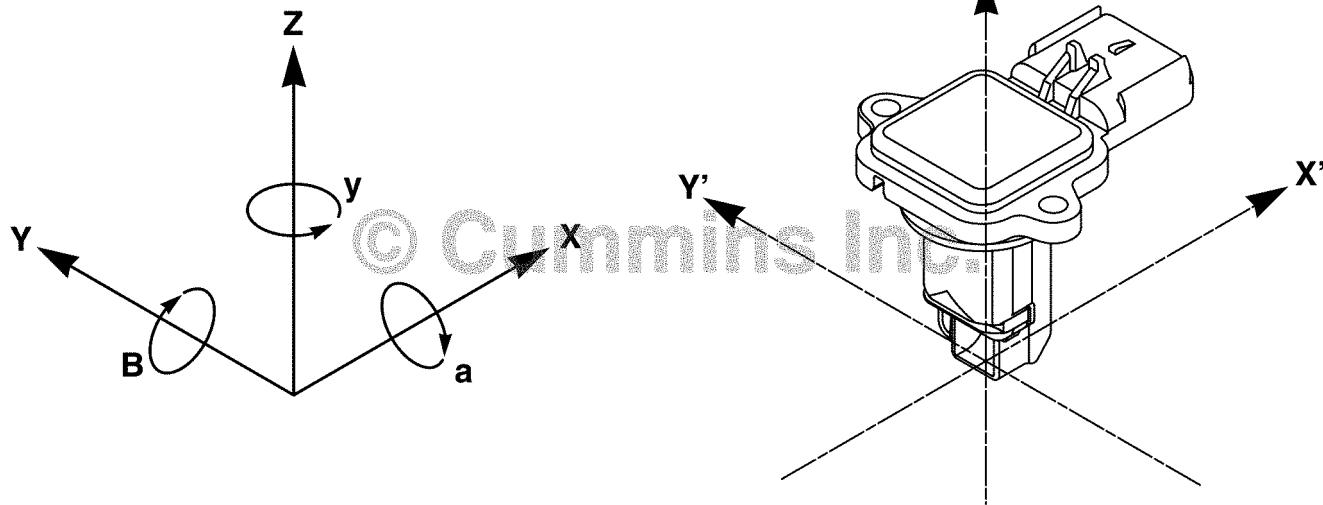
Figure 4 - Customer Fabricated Intake Tube and MAF Sensor Mounting Location

- 1 Break top edge for o-ring
- 2 Bore diameter - 33 mm [1.3 in]
- 3 Bore centerline to edge of MAF sensor mounting boss- 22 mm [0.87 in]
- 4 Mounting capscrew center-to-center - 23.5 mm [0.92 in], M4 x 0.7, 10 mm [0.4 in] deep
- 5 Boss width - 32 mm [1.25 in]
- 6 Boss height - 24 mm [0.95 in]
- 7 Intake tube diameter - 76.2 mm [3.0 in]
- 8 Top of intake tube to top of boss - 10 mm [0.4 in]
- 9 Boss centerline to screw centerline - 3.5 mm [0.13 in].

The acceptable orientation of the MAF sensor is shown in Figure 5. The mating engine harness connector (6 in Figure 1) is located just behind the power steering pump for shipping purposes. The engine harness lead is 670 mm [26.4 in] long enabling connection to the MAF sensor as installed in the intake pipe.

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Figure 5 - MAF Sensor Orientation

Consider the initial orientation with the axes X, Y, Z and X', Y', Z' aligned. The rotations of the sensor axes X', Y', Z' about the vehicle axes X, Y, Z are represented by the rotation angles a, B, and Y respectively.

- a: $< \pm 90$ degrees
- B: $< \pm 45$ degrees
- Y: open

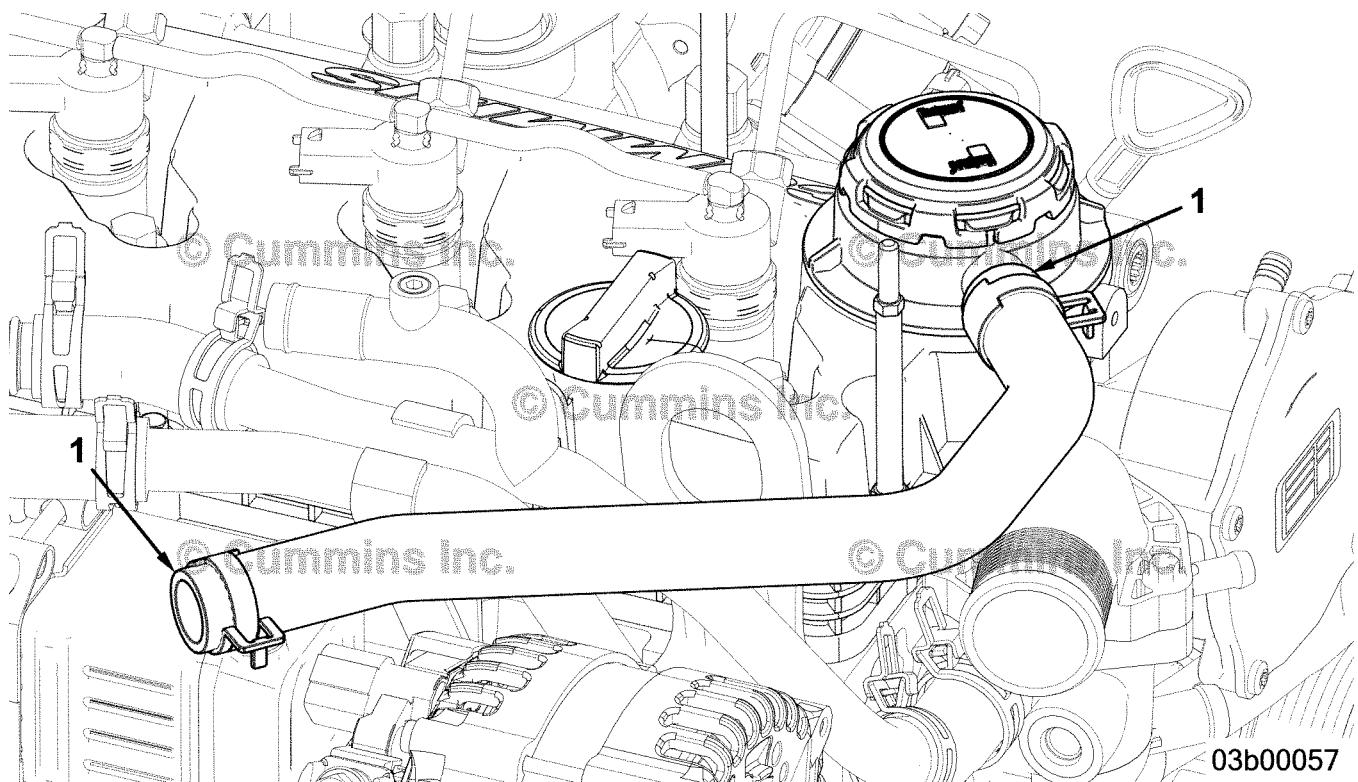


Figure 6 - Crankcase Breather Connection

Shown in Figure 6, a hose (1) is to be fitted between the crankcase breather connection and the engine intake system to reduce the release of crankcase vapors to the atmosphere. To be emission compliant, the breather tube **must** be plumbed back into the intake system. It should be installed a minimum of 3 duct diameters between the MAF sensor

and the turbocharger compressor inlet to reduce oil fouling of the MAF sensor and excessive oil pulled through the turbocharger. The breather hose inside diameter **must** be 20 mm [0.79 in].

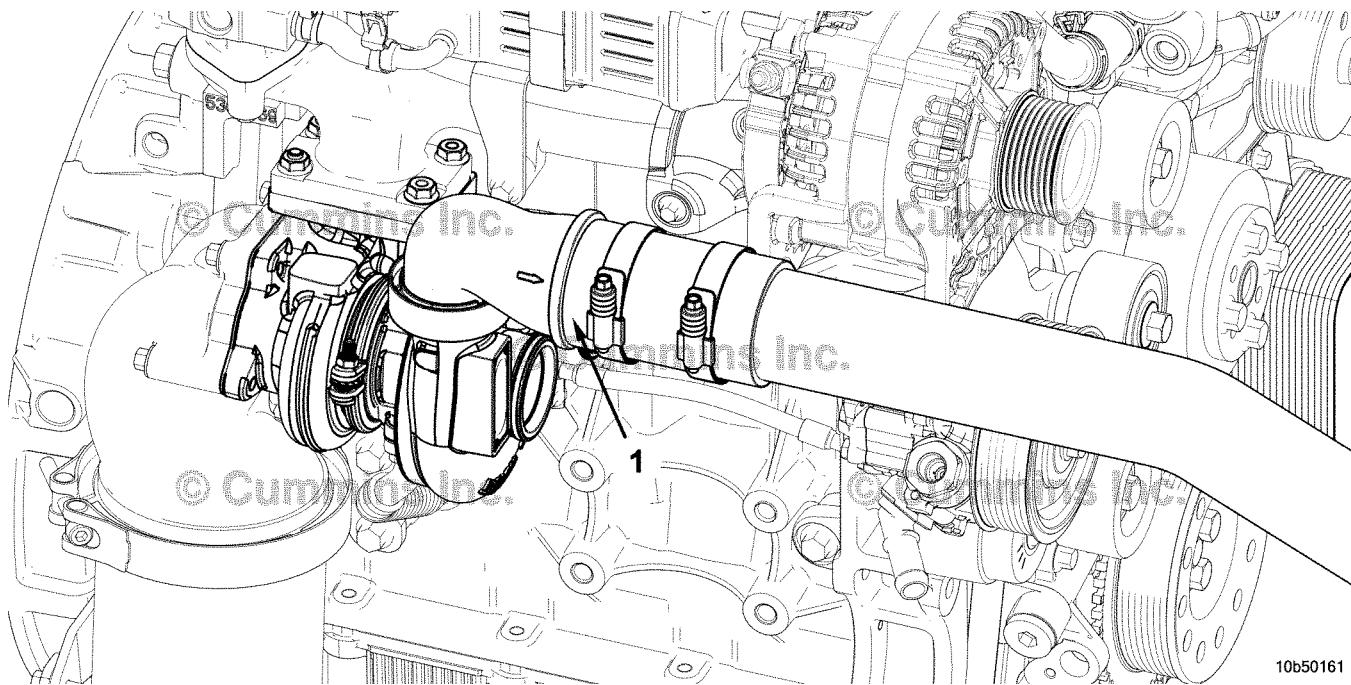
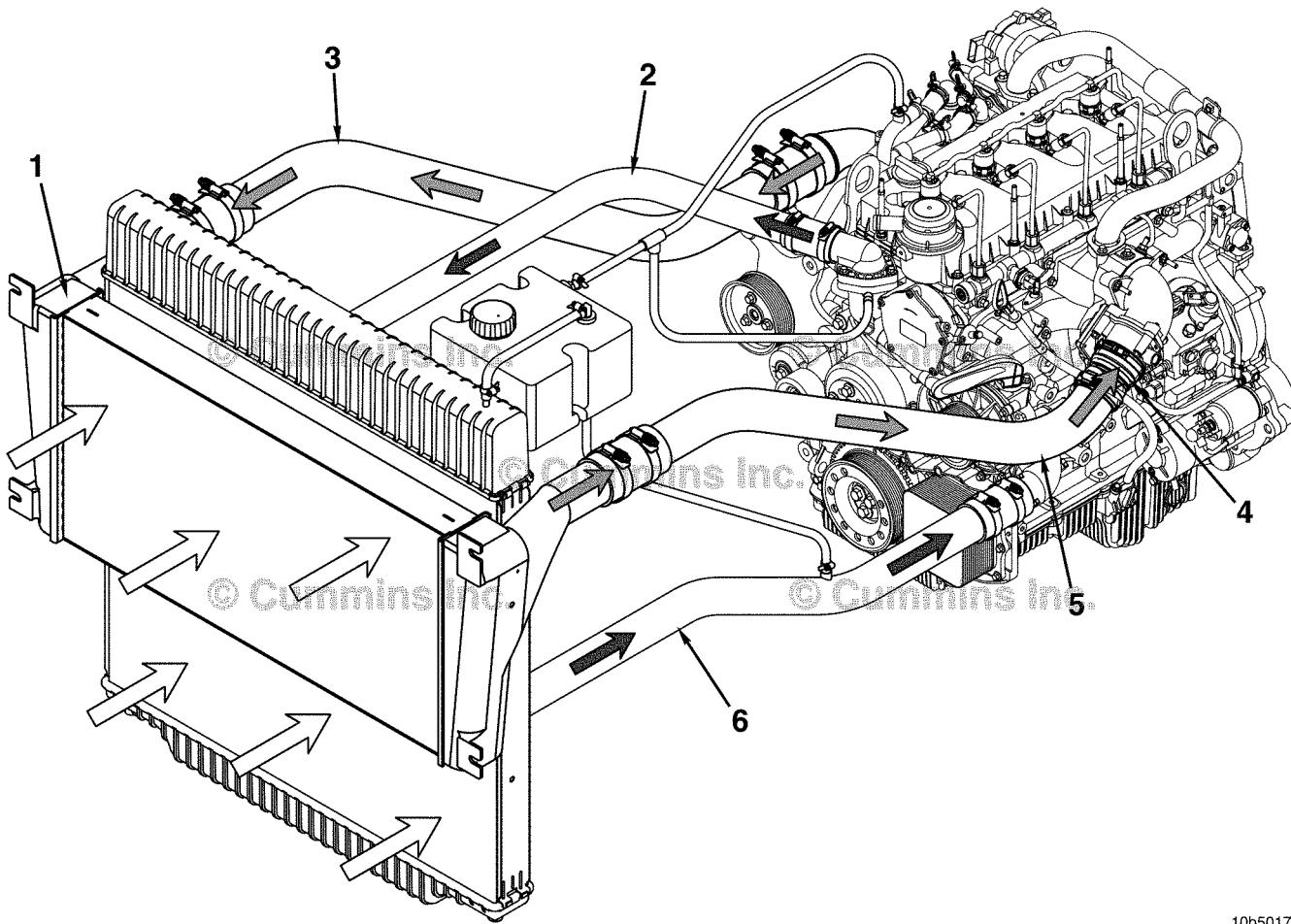


Figure 7 - Turbocharger Compressor Outlet Connection

1 Turbocharger compressor outlet, 66 mm [2.5 in], 24 mm [0.9 in] clamping distance.

To enhance the engine performance and reduce emissions, the hot compressed ambient air **must** be cooled before entering the engine. It is the purpose of the charge air cooler (CAC) to reduce the temperature of the compressed ambient air before entering the engine intake manifold.



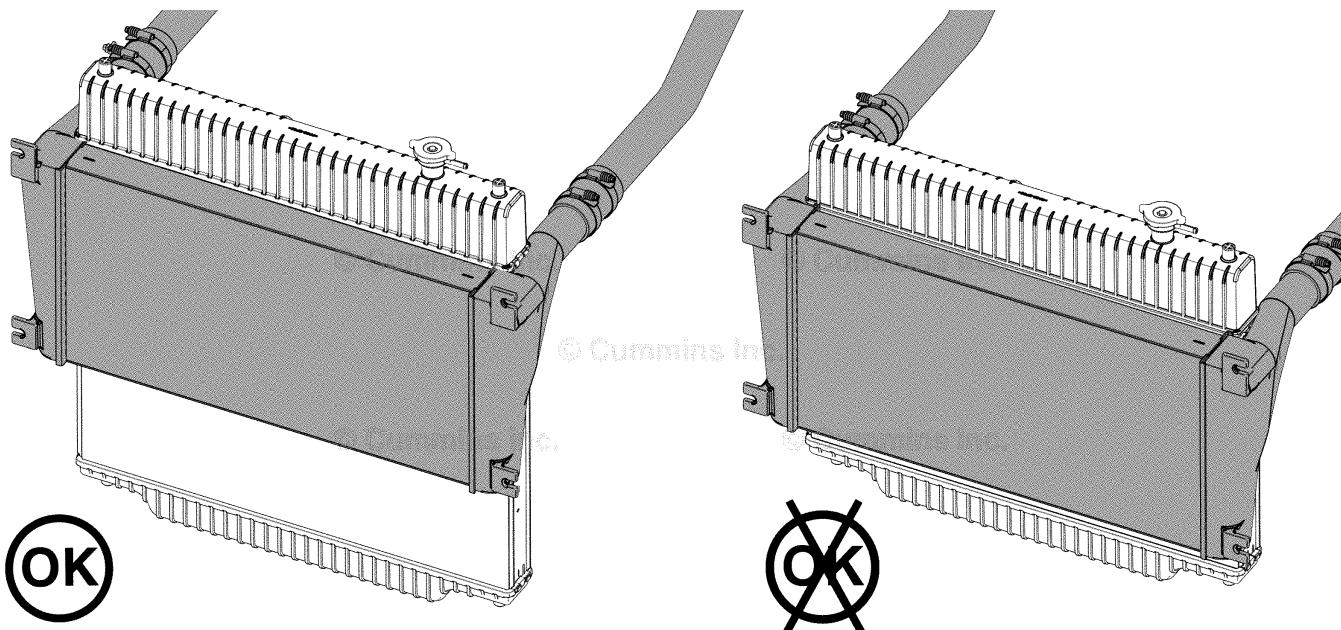
10b50178

Figure 8 - CAC Configuration

- 1 Charge air cooler
- 2 Upper radiator hose
- 3 Hot side CAC pipe
- 4 Beaded CAC hose connection, 63 mm [2.5 in], 29 mm [1.1 in] clamping distance
- 5 Cold side CAC pipe
- 6 Lower radiator hose.

Charge Air Cooling and Radiator System Design

The goal of the radiator and CAC system design **must** be to enable the cooling ambient air get to the radiator core. The blockage of the radiator core by the CAC **must** be avoided. In a good design, part of the radiator core receives cooling ambient air **not** previously travelling through the CAC. In a poor design, there is little un-blocked area and much of the radiator core receives heated ambient air from the CAC. See Figure 9.



10t00118

Figure 9 - Good and Bad Radiator and CAC Design

Recommended Air Flow Improvements

- 1 Reduce obstructions in the path of ambient air flow through the CAC and radiator
- 2 Make sure airflow is being funneled through the heat exchangers and **not** allowed to mix with hot engine compartment air
- 3 Allow for a path for air to exit the engine compartment to reduce restriction through the heat exchangers
- 4 Utilize fan shrouding covering the entire radiator core area. The fan should be located about 3 inches behind the radiator to promote uniform air flow distribution.

Exhaust System (387-010)

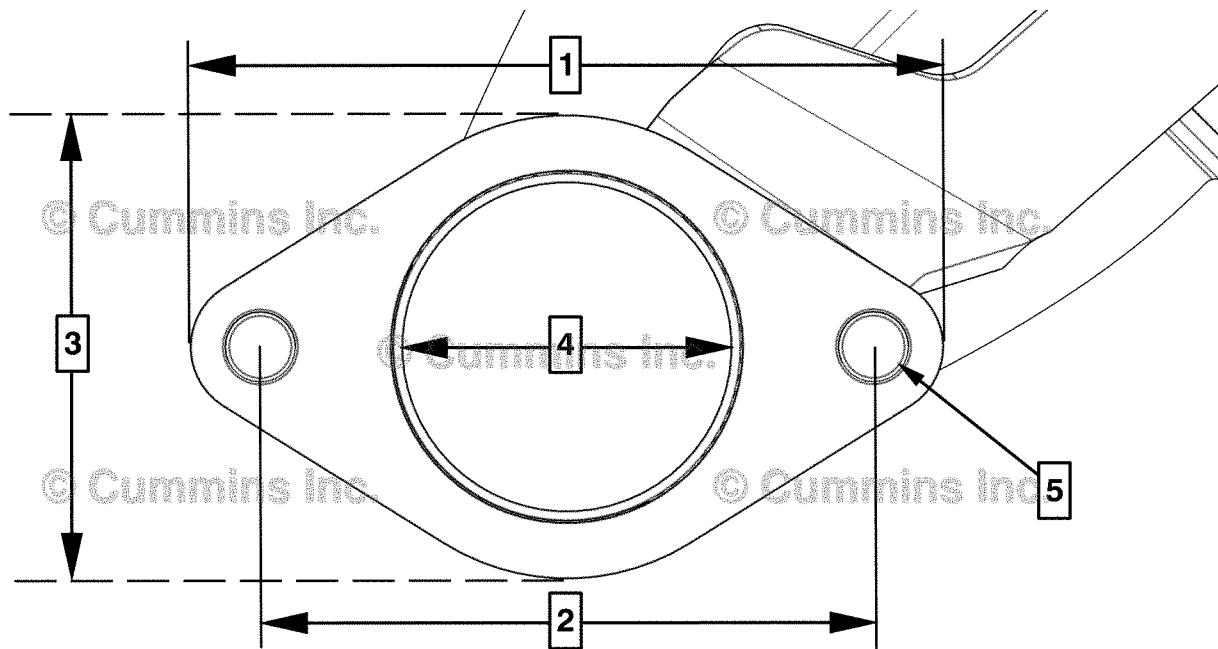
Specifications

Maximum back pressure imposed by complete exhaust system..... 20 kpa [3 psi]
Exhaust pipe size (normally acceptable inside diameter)..... 76 mm [3 in]

General Information

The R2.8 CM2220 R101B engine is supplied with a diesel oxidation catalyst (DOC). The DOC is part of the engine emission control system and **must not** be removed from the engine assembly.

Typical automotive exhaust systems can be successfully used with this engine. The exhaust flange, see Figure 1, is designed to accept a 50.8 - 57.15 mm [2.0 to 2.25 in] exhaust pipe.

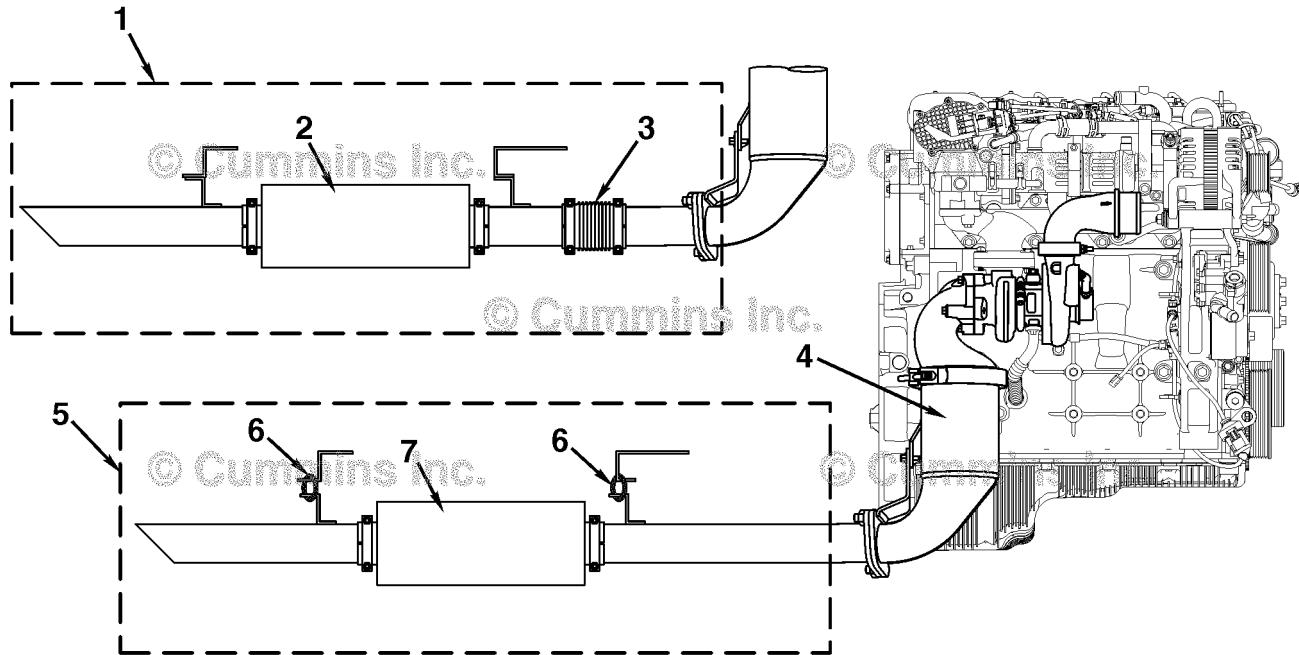


11b00141

Figure 1 - Engine Exhaust System Flange

- 1 Overall width - 130 mm [5.11 in]
- 2 Stud centerline - 106 mm [4.17 in]
- 3 Overall height - 80 mm [3.14 in]
- 4 Inside diameter - 56 mm [2.20 in]
- 5 Stud size - M10 x 1.25, 32 mm long with 24 mm thread.

Figure 2 shows the use of a flex section (3) with a solid-mounted exhaust system (1). A flex section is **not** necessary if isolating the exhaust system with rubber hangers (6).



11b00140

Figure 2 - Exhaust System

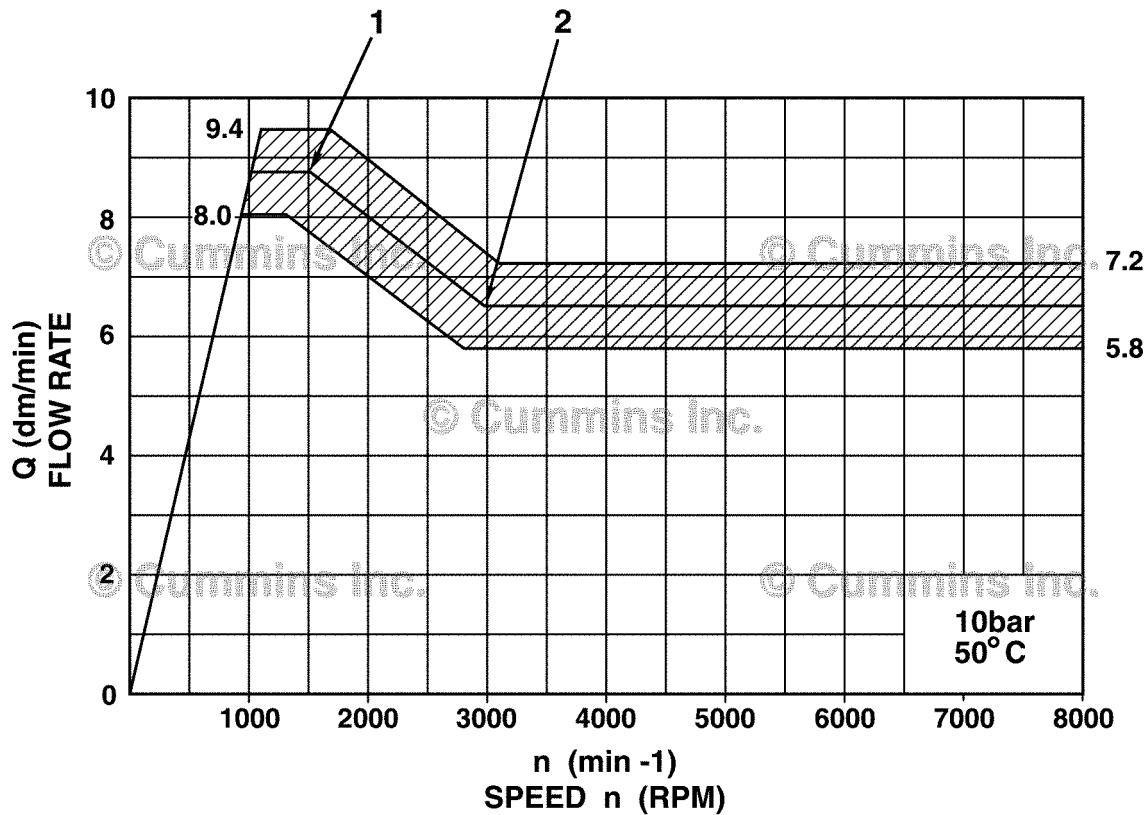
- 1 Solid-mounted exhaust system
- 2 Muffler
- 3 Flex section
- 4 DOC
- 5 Hanging exhaust system
- 6 Rubber donut hangers
- 7 Muffler.

The exhaust system back pressure, as measured at the DOC outlet flange, can **not** exceed 20 kPa [3 psi]. The larger the exhaust pipe diameter with the fewest number of bends will better the performance of the engine.

Steering and Braking (391-004)

General Information

The belt-driven pump for power steering is provided with the engine assembly. Its performance data is shown in Figure 1.



09b00034

Figure 1 - Powe Steering Performance Data

- 1 Vertical axis - flow rate, decimeters per minute (dm/m)
- 2 Horizontal axis - speed in rpm
- 3 8.7 liters/min at 1500 rpm
- 4 6.5 liters/min at 3000 rpm.

The low-pressure and high-pressure connections are shown in Figure 2. Power steering hoses are provided by the customer.

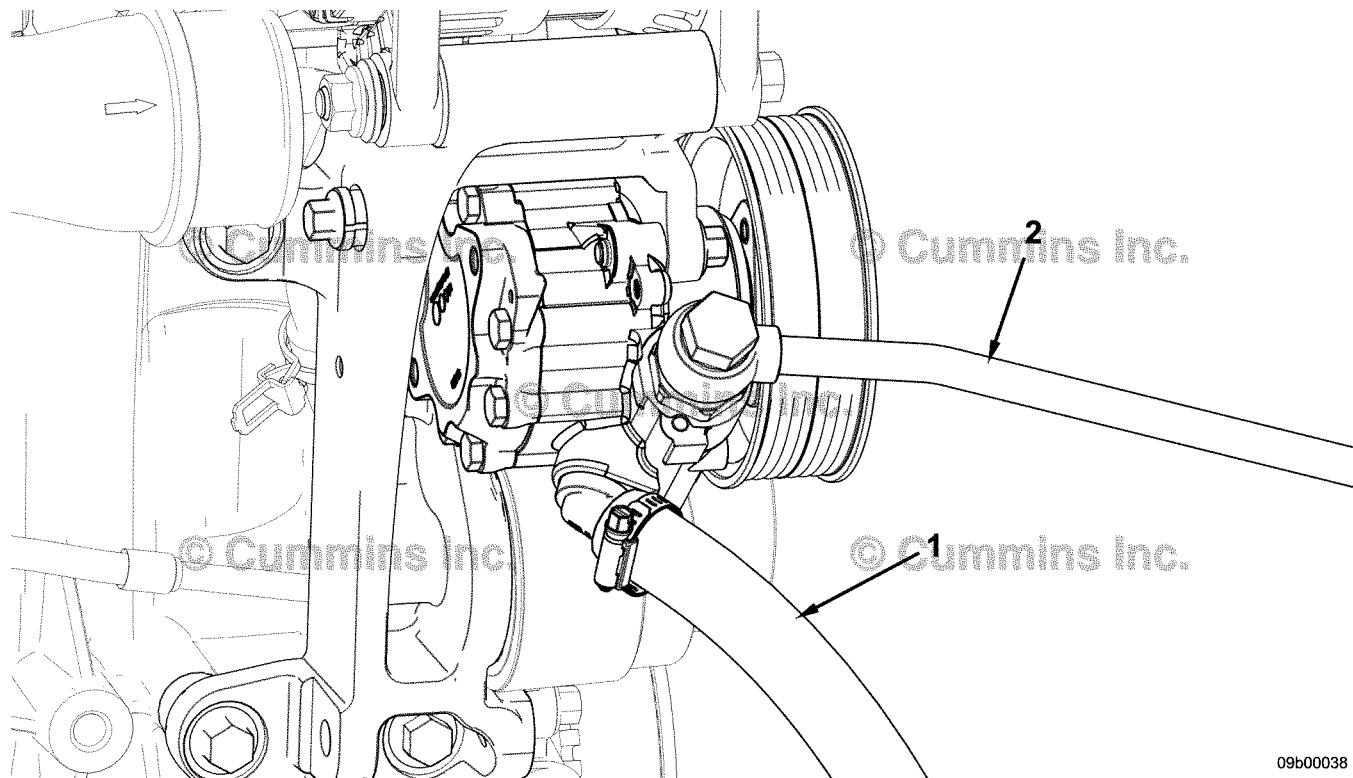


Figure 2 - Power Steering Pump Connections

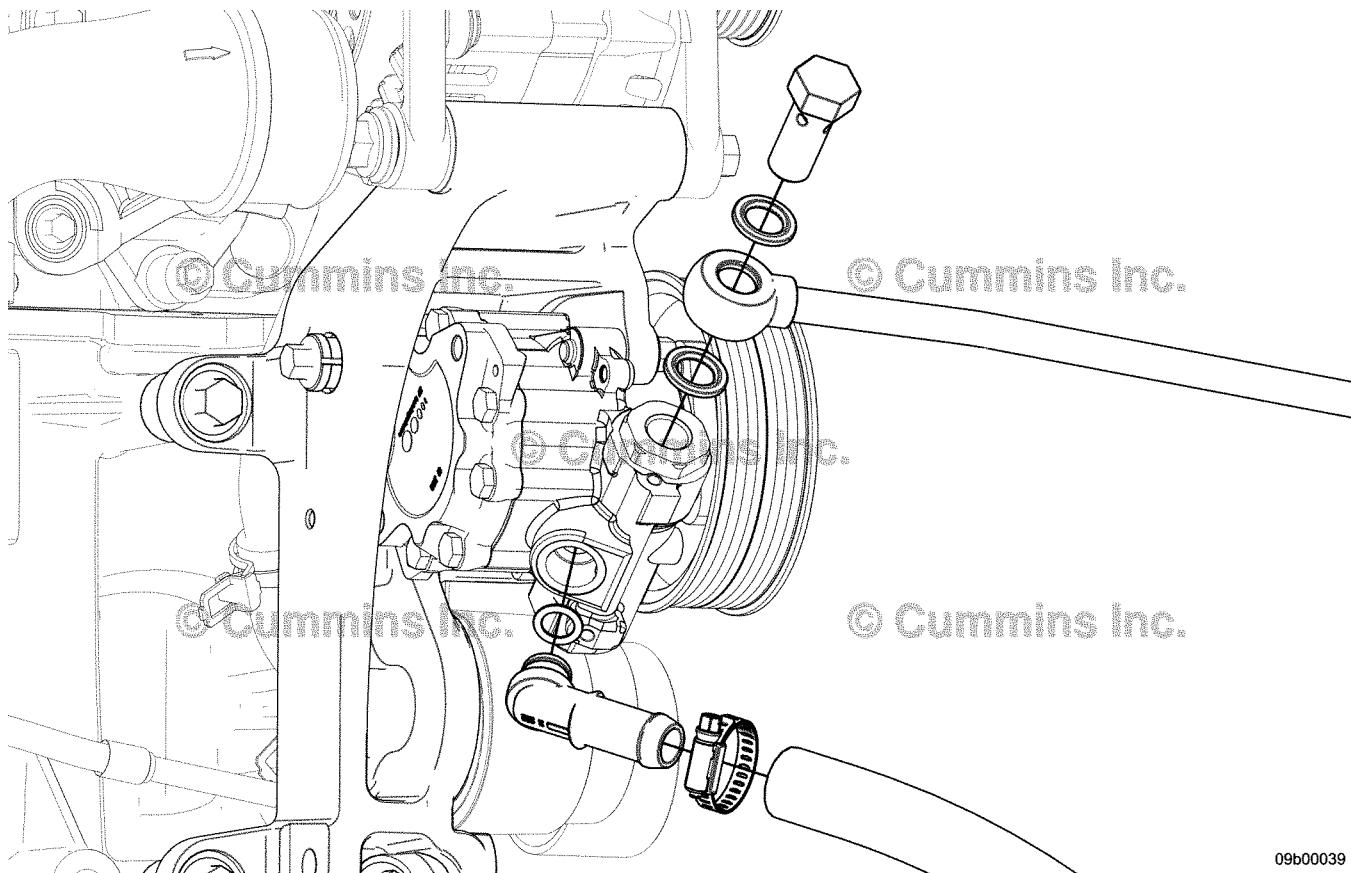
- 1 Low-pressure - 16 mm [0.63 in] OD beaded hose, 22 mm [0.86 in] clamping distance
- 2 High-pressure - M16 - 1.5 6H banjo fitting.

Connect all power steering lines to the pump.

The outlet of the power steering pump uses a banjo connection, shown in Figure 3. Install new washers on both sides of the banjo connection and then tighten to specification.

While applying the final torque, make sure to counter the torque with the fitting on the power steering pump to reduce the possibility of damage to the power steering pump threads.

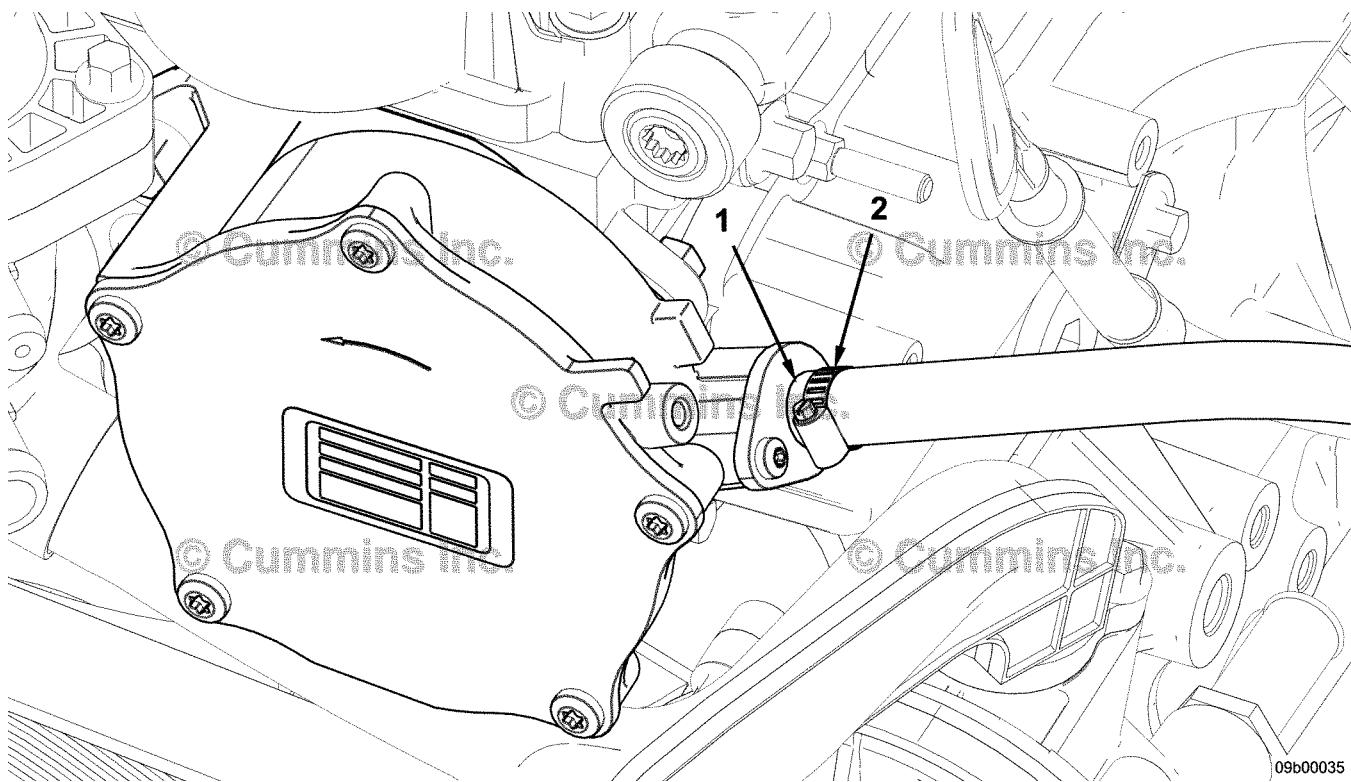
Torque Value: 40 N·m [30 ft-lb]



09b00039

Figure 3 - Power Steering Pump Banjo Connection

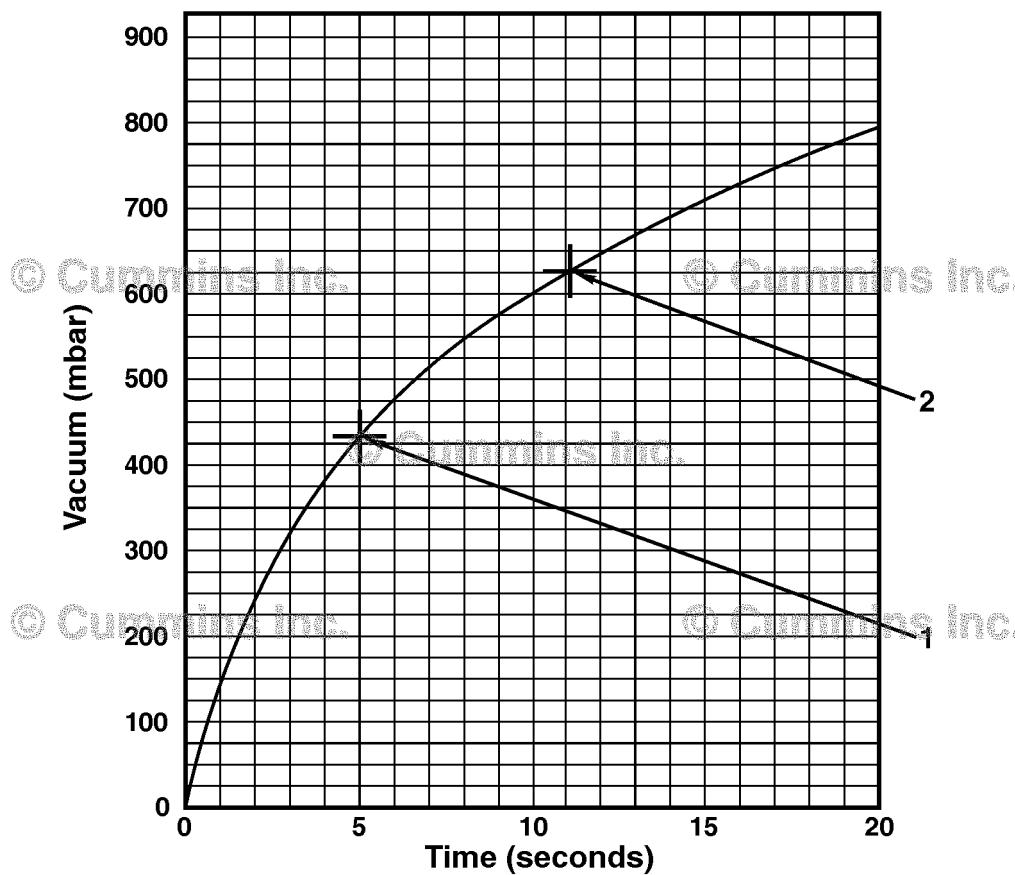
A single vane, vehicle-brake vacuum pump is located at the front of the cylinder head, driven from the camshaft. Connect a valve to the vacuum line connection between the pump and vehicle air reservoir to prevent engine oil from entering the reservoir. The valve **must** also be located above the vacuum reservoir. The vacuum hose connection on the pump is 9 mm [0.35 in] with a clamping distance of 23 mm [0.90 in].



09b00035

Figure 4 - Vacuum Pump Connection

- 1 Vacuum hose connection - 9 mm [0.35 in]
- 2 Clamping distance - 23 mm [0.90 in].



09b00036

Figure 5 - Vacuum Pump Performance Curve

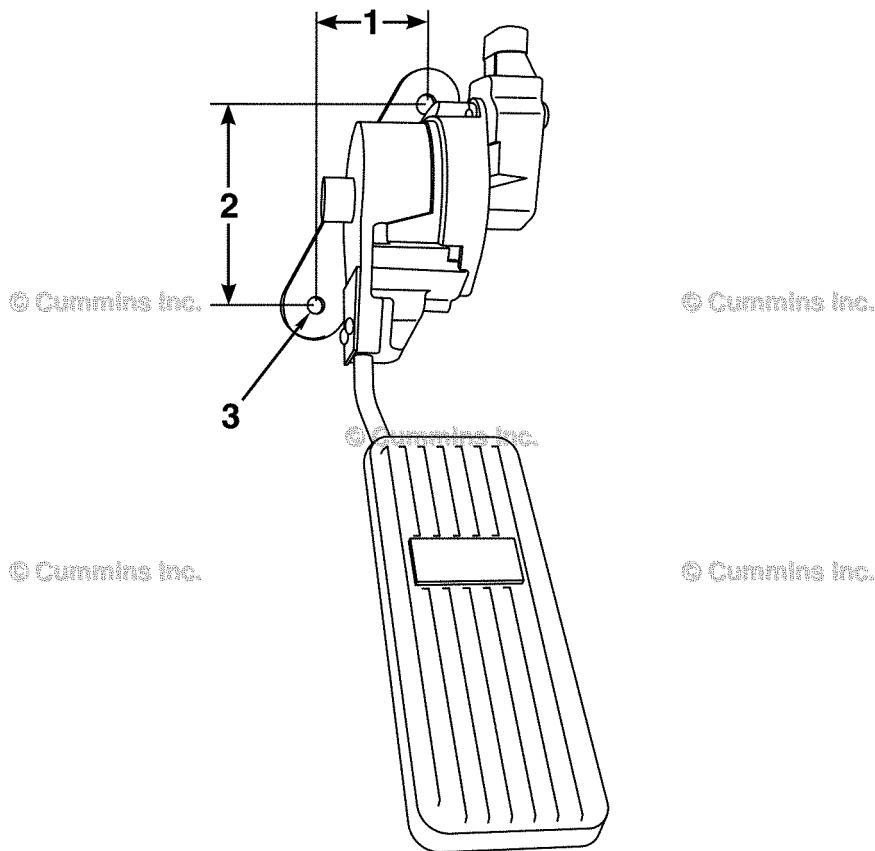
- 1 5 seconds = 425 mbar
- 2 11 seconds = 620 mbar.

The list below is the conversion of mbar to pounds per square inch (psi).

- 100 mbar = 1.45 psi
- 425 mbar = 6.16 psi
- 620 mbar = 8.99 psi

Accelerator Pedal Assembly (388-016)

General Information

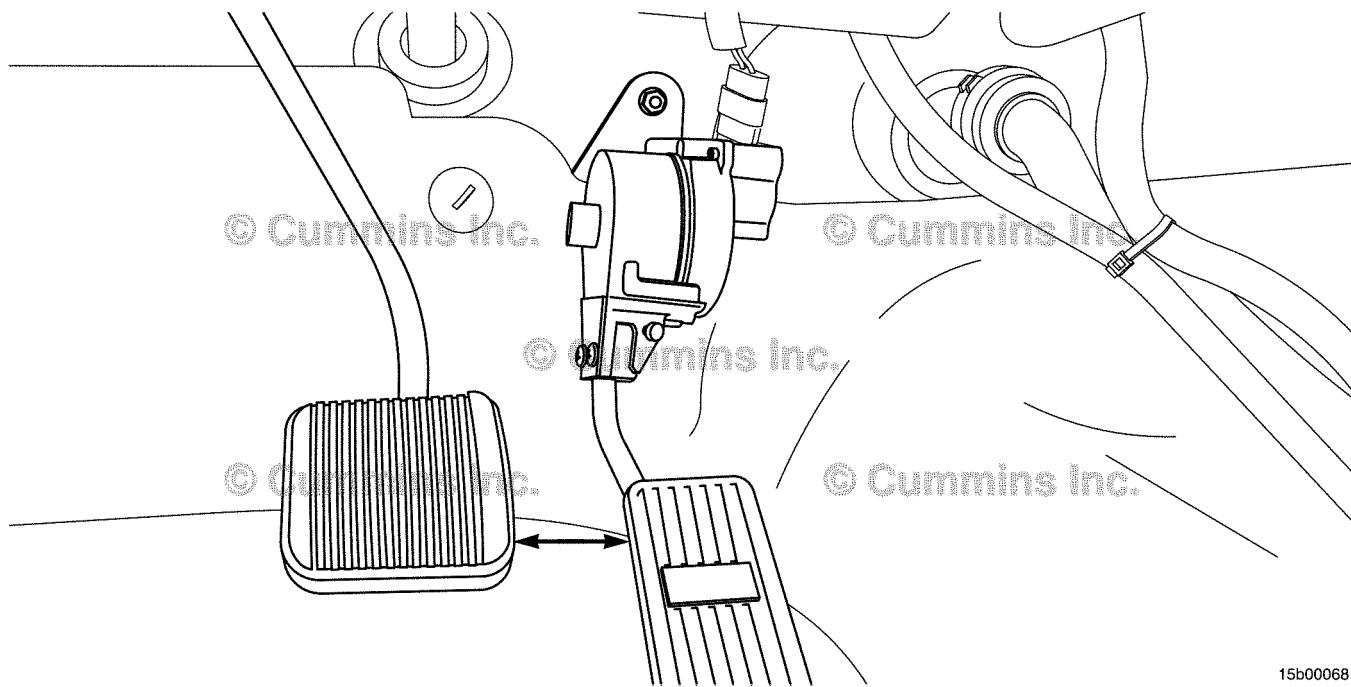


15b00067

Figure 1 - Accelerator Pedal Mounting

The mounting dimensions for the electronic accelerator pedal are shown in Figure 1.

- 1 Mounting hole, left to right - 97 mm [3.81 in]
- 2 Mounting hole, top to bottom - 97 mm [3.81 in]
- 3 Mounting hole diameter - 8 mm [3.14 in] x 2 holes.



15b00068

Figure 2 - Accelerator Pedal Spacing

It is recommended the spacing between the brake pedal and electronic accelerator pedal be no less than the spacing of the mechanical pedal that was removed.

Additional mounting information can be found by following the link below. The accelerator pedal that is included in the kit is WM 540 - Suspended Electronic Accelerator Pedal.

NOTE: http://www.tectran.com/images/pdf/CAT_williams_catalog_download.pdf

Electrical System (387-011)

Battery

The R2.8 CM2220 R101B engine is a 12 volt, negative ground system **only**.

Recommended Battery Capacity			
Ambient Temperature			
System Voltage	0°C [32°F] Cranking Amperes	-18°C [0°F] Cold Cranking Amperes (CCA)	Reserve Capacity (minutes) ^{1, 2}
12 VDC	950	800	180

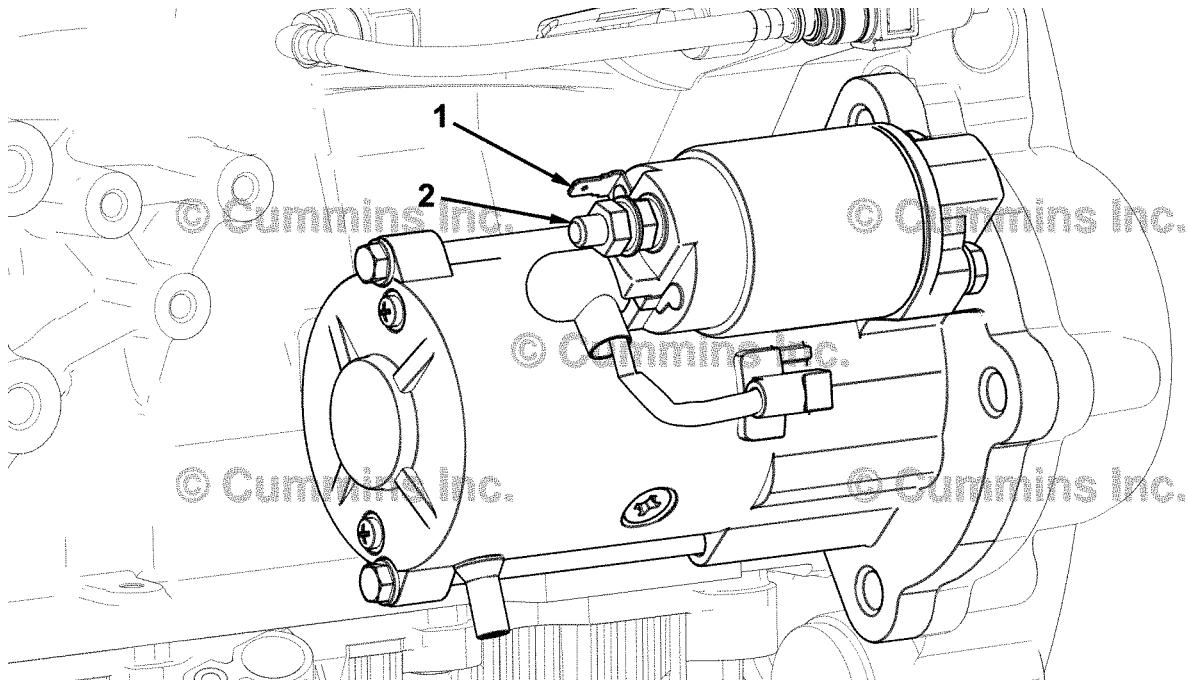
1 The number of plates within a given battery size determines reserve capacity.
2 Reserve capacity is the length of time for which a battery at 27°C [81°F] can supply 25 amperes at 10.5 VDC or greater.

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

Starter

The engine kit includes an engine-mounted 12 volt starting motor. Make sure the batteries are disconnected prior to installing the starting motor cables.

The starting motor connections are an M8 x 1.25 for the high amperage cable (2) and a 6.3 mm flat, male, push-on terminal (1) for the switch circuit, see Figure 1. The switch circuit should maintain the original vehicle interlock devices, such as brake and clutch switches, along with any transmission gear position switch. To adequately enable the starting motor to rotate the engine for starting, it is recommended that a 12 volt, 800 CCA, or greater, battery be used along with suitable starting motor cables sized to minimize electrical resistance in the circuit.



13b00027

Figure 1 - Starting Motor Electrical Connections

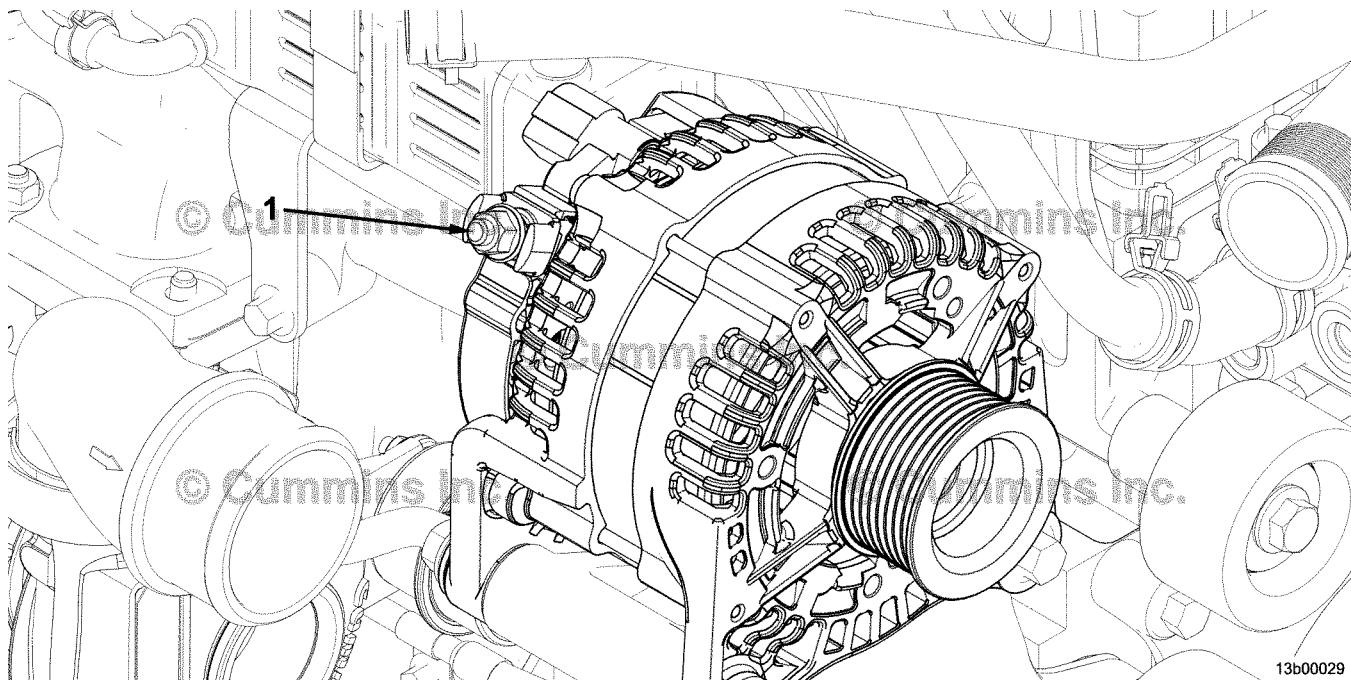
- 1 Switch - male flat 6.3 mm [0.25 in] terminal connection, 50 amp pull-in and 20 amp hold-in current
- 2 M8 x 1.25 stud, to battery positive post.

Torque Value: 23 N·m [204 in-lb]

Alternator

The R2.8 CM2220 R101B Engine Kit includes an engine-mounted alternator, rated at 12 volt /120 amps.

The connection on the alternator is a M8 stud for the high current cable, as shown in Figure 2.



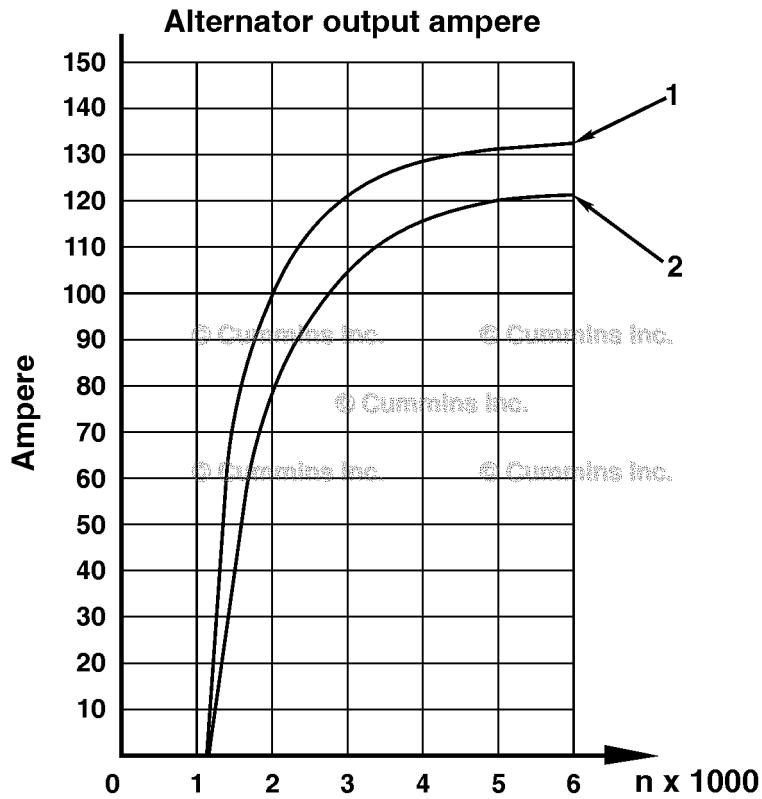
13b00029

Figure 2 - Alternator

1 Alternator to battery positive cable stud, 8 mm.

Torque Value: 23 N·m [204 in-lb]

The engine-mounted alternator is rated at 12 volt /120 amps as shown in the performance graph, Figure 3.



13b00028

Figure 3 - Alternator Output Ampere

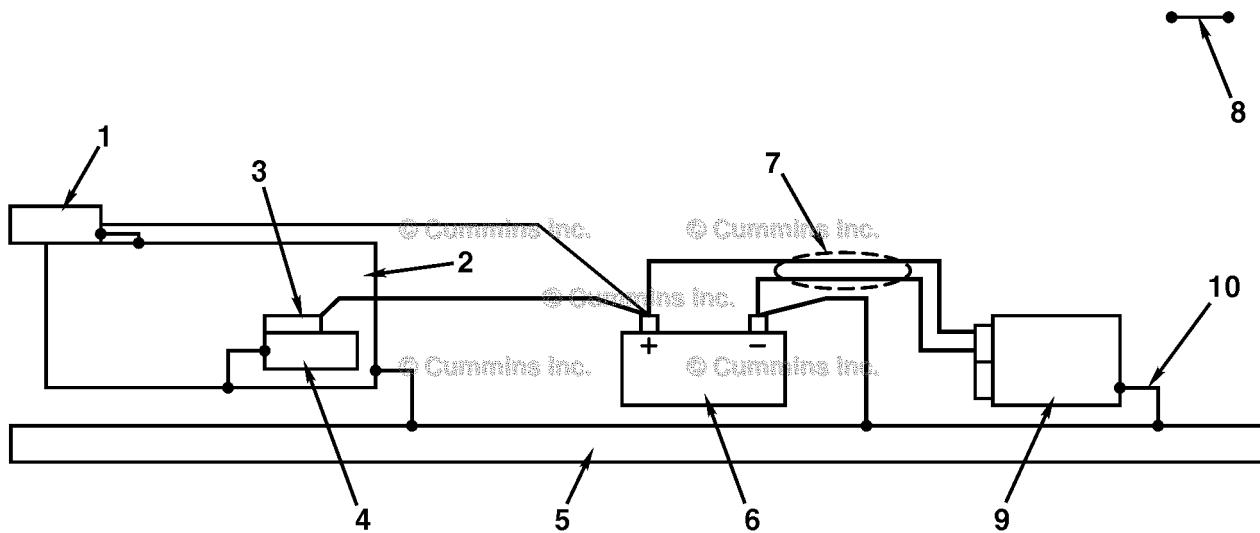
1 Cold

2 Hot - Alternator speed (rpm x 1000), drive ratio = 2.3 x rpm.

Grounding

The high amperage starting motor and alternator cannot share the same ground path to the battery negative post with the engine control module (ECM). If done improperly, the voltage spikes from the high amperage starter and alternator will have an undesirable effect on the ECM, and thus the performance of the engine.

It is very important the starting motor, alternator, ECM, and battery negative circuit be configured as shown in Figure 4.



13b00030

Figure 4 - Electrical System Grounding

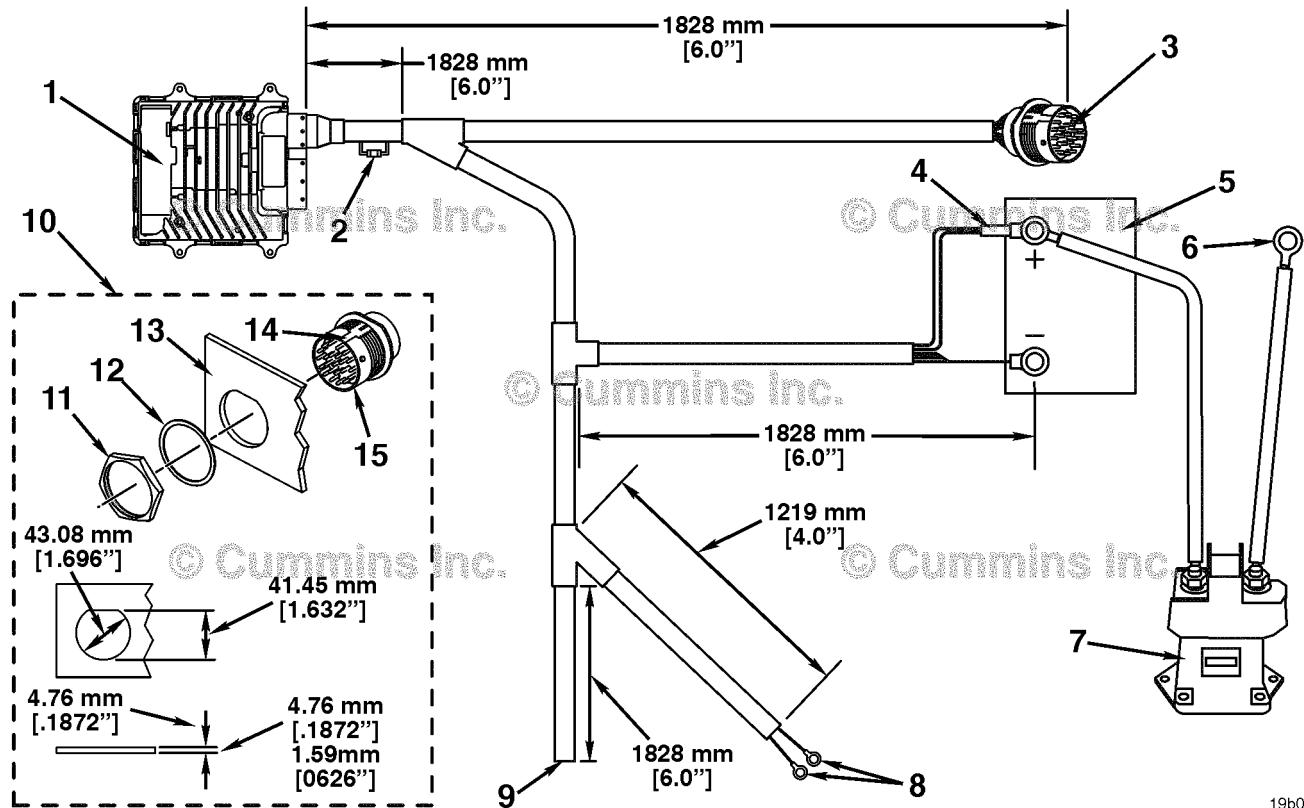
- 1 Alternator
- 2 Engine block
- 3 Starter motor solenoid/relay
- 4 Starter motor
- 5 Vehicle frame
- 6 Battery
- 7 ECM power and ground wires as part of supplied harness
- 8 Designates structural ground connection
- 9 CM2220 ECM
- 10 12 AWG ground cable.

Wiring Harness

There are two main components in the wiring harness – the engine compartment harness and the cab harness. A schematic of both components is available on QuickServe® Online (QSOL). Reference the R2.8 CM2220 R101B Wiring Diagram, Bulletin 5467560.

The engine-side wiring harness includes the connection to the ECM, power connection to the battery, grid heater, fan control wiring, and the interface connection to the cab-side harness.

Figure 5 below identifies the component on the engine-side harness and the length of each lead, along with details of the 23 pin Deutsch™ pass-through connector. The Deutsch™ pass-through connector incorporates a gasket that is to be inserted on the engine bay-side of the connector to prevent dust from entering the cab area.

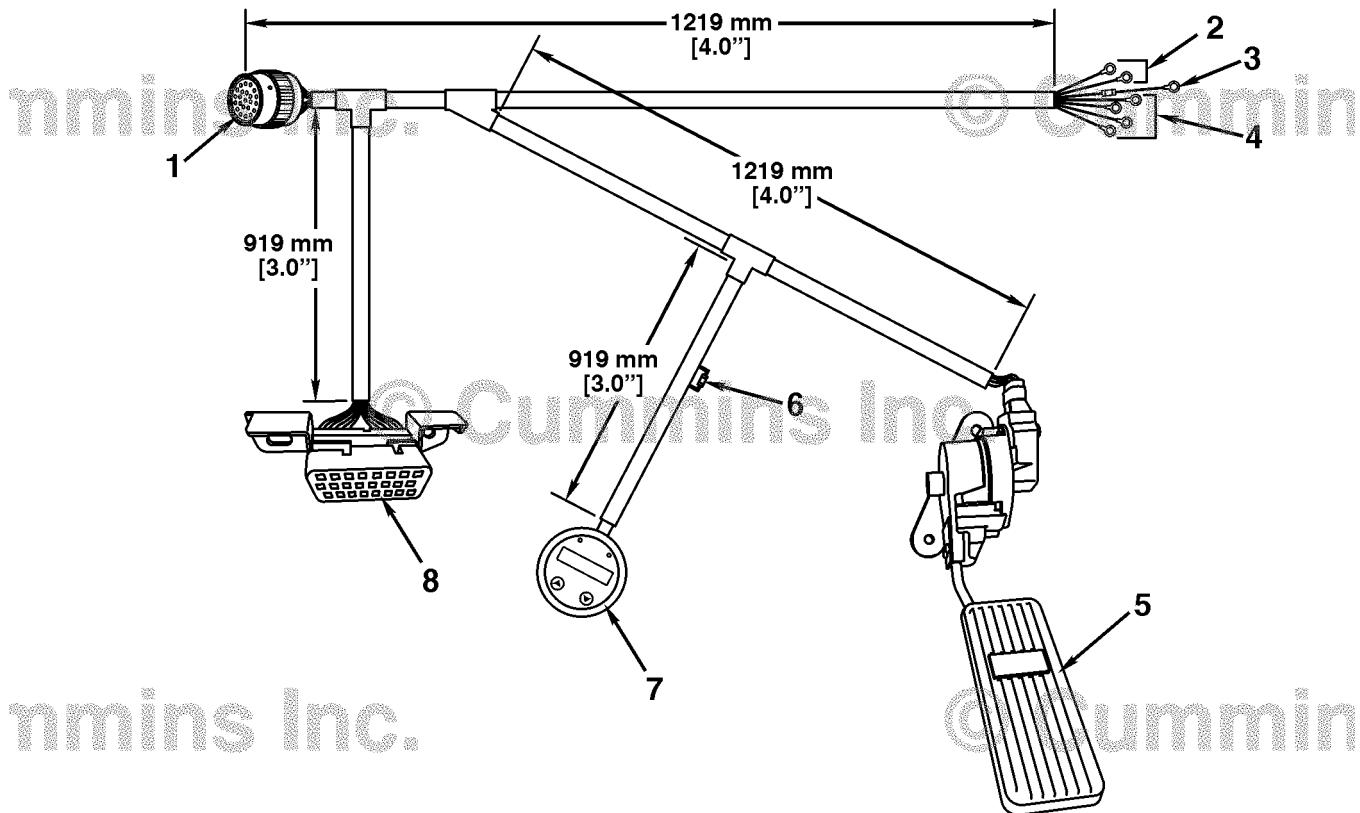


19b00256

Figure 5 - Engine-Side Harness

- 1 ECM
- 2 120 ohm termination resistor
- 3 23 pin bulkhead Deutsch™ pass-through connector
- 4 30 amp fuse
- 5 Battery
- 6 Terminal connector to grid heater post on engine
- 7 Grid heater relay
- 8 [3/16 in] Stud grid heater relay ring terminals
- 9 Fan Hi signal - brown; Fan ground - white
- 10 23 pin Deutsch™ connector detail
- 11 Panel nut
- 12 Lockwasher
- 13 Panel
- 14 Locating flat
- 15 Connector receptacle

The cab-side harness includes a 23 pin Deutsch™ mating interface connector, an output data cab display, an accelerator pedal assembly, data link connector, provisions for fan controls, and dash lights. Figure 6 identifies these components on the cab-side harness and the length of each lead.



19b00244

Figure 6 - Cab-Side Harness

- 1 23 Pin bulkhead Deutsch™ pass-through connector
- 2 Optional output signals:
 - Tachometer - white, pin 9
 - Tachograph - blue, pin 40 (not used)
- 3 Keyswitch - black, 5 amp inline fuse
- 4 Lamp wires:
 - WAIT TO START - yellow, pin 35
 - STOP ENGINE - green, pin 49
 - WARNING - blue, pin 36
 - MALFUNCTION INDICATOR LAMP (MIL) - white, pin 22
- 5 Accelerator pedal
- 6 120 ohm termination resistor 2
- 7 Cab display
- 8 Data link Onboard Diagnostics (OBD) connector.

The circuit wiring table identifies circuits, their descriptions, required or optional, wire colors, and pin numbers on the ECM connector.

Circuit Wiring Table			
Name	Description	Wire Color	Pin Number on ECM Connector
Battery Positive	Power to ECM, multiple wires	Red	1, 3, 5
Battery Negative	Return from ECM, multiple wires	Black	2, 4, 6
J1939 Data Link	CAN_H-Positive	Yellow	14
J1939 Data Link	CAN_L-Return	Green	15

Circuit Wiring Table			
Name	Description	Wire Color	Pin Number on ECM Connector
Keyswitch	12 volt power to ECM from keyswitch in CRANK and RUN position	Black	41
Lamp, STOP ENGINE	Critical Engine Issue, Stop Engine Also Available on provided Murphy Gage	Green	49
Lamp, WARNING	Engine Issue Detected, Service Soon Also Available on provided Murphy Gage	Blue	36
Lamp, WAIT TO START	Do not start the engine until the lamp is not illuminated Also Available on provided Murphy Gage	Yellow	35
Lamp, MIL	An emission related engine issue has been detected Not used on the R2.8 CM2220 R101B product	White	22
Tachometer	Output to drive tachometer	White	9
Fan-Hi Signal	Fan supply +12 volt	Brown	33
Fan Ground	Fan ground	White	34

The power for the ECM, black 5 amp wire from the keyswitch, **must** provide a minimum of 12 volts in the run position and during engine cranking.

The lamp circuits require power from the keyswitch to each lamp, with the ECM providing a path to ground via a sink circuit as engine conditions dictate.

Any unused wire leads should be taped off to prevent water intrusion into the unused circuit and properly secured.

Figure 7 below shows available locations for supporting electrical harness **only**.

The location and size will **not** allow for any brackets over one pound to be attached.

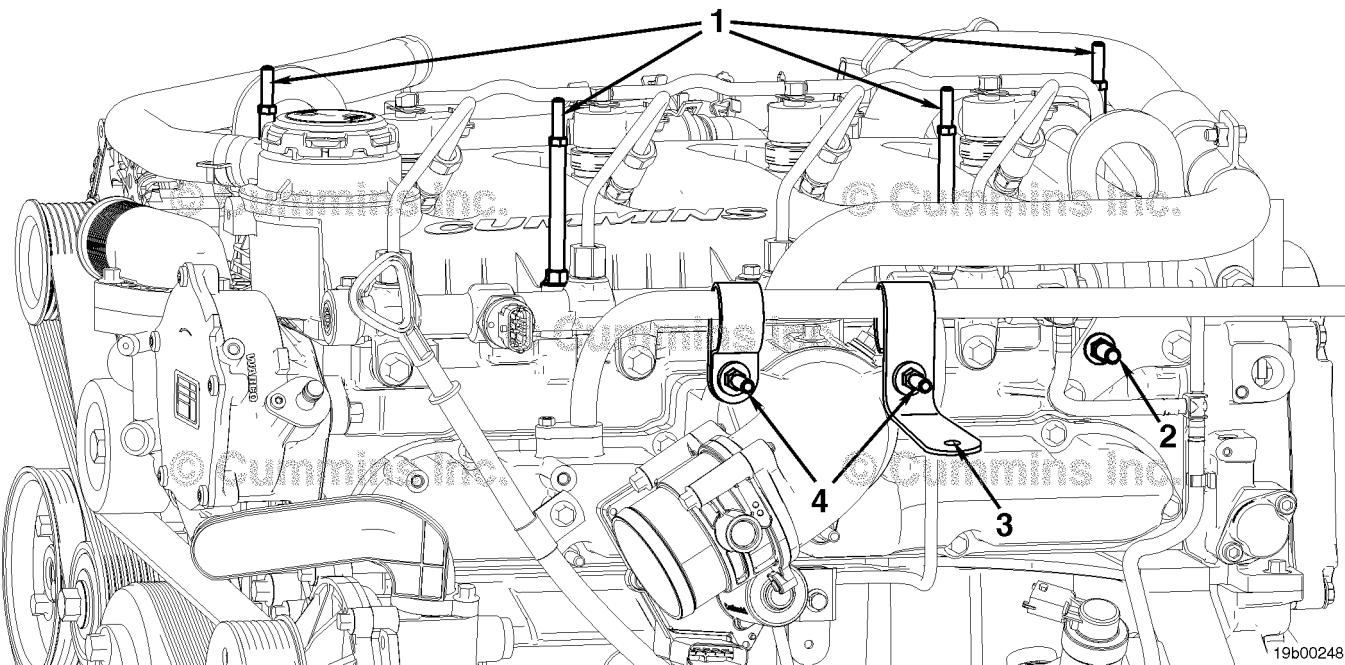


Figure 7 - Supporting Locations

- 1 Valve cover studded capscrews, M6 x 1.0, 20 mm threaded
- 2 Lifting bracket studded capscrews, M8 x 1.25, 20 mm threaded
- 3 6.5 mm [0.26 in] through hole
- 4 Air intake connection studded capscrews, M6 x 1.0, 20 mm threaded.

It is important for all harness leads to be properly routed and supported to eliminate wire chaffing and strain on the mating connectors.

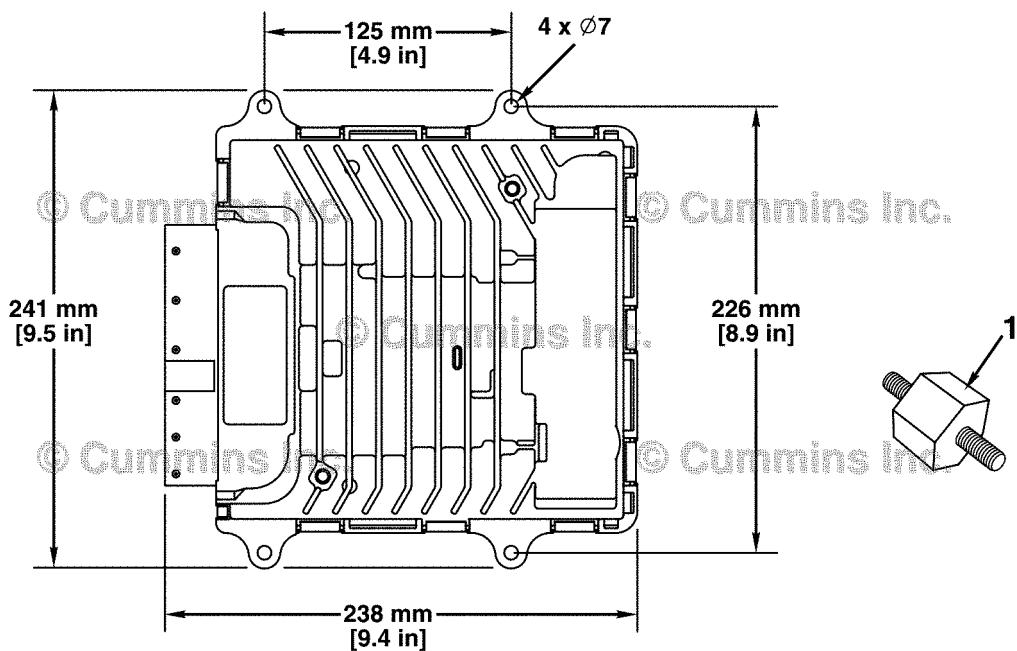
The ECM connector/harness **must** be supported no greater than 100 mm [4 in] away from the connection point.

Engine Control Module

The ECM **must** be mounted in the engine compartment away from high temperatures, road spray, and dirt.

The ECM **must not** be engine-mounted.

Figure 8 shows the dimensions and acceptable attachment locations for the ECM. To reduce vibration to the module, isolators (1) should be used at the mounting locations.

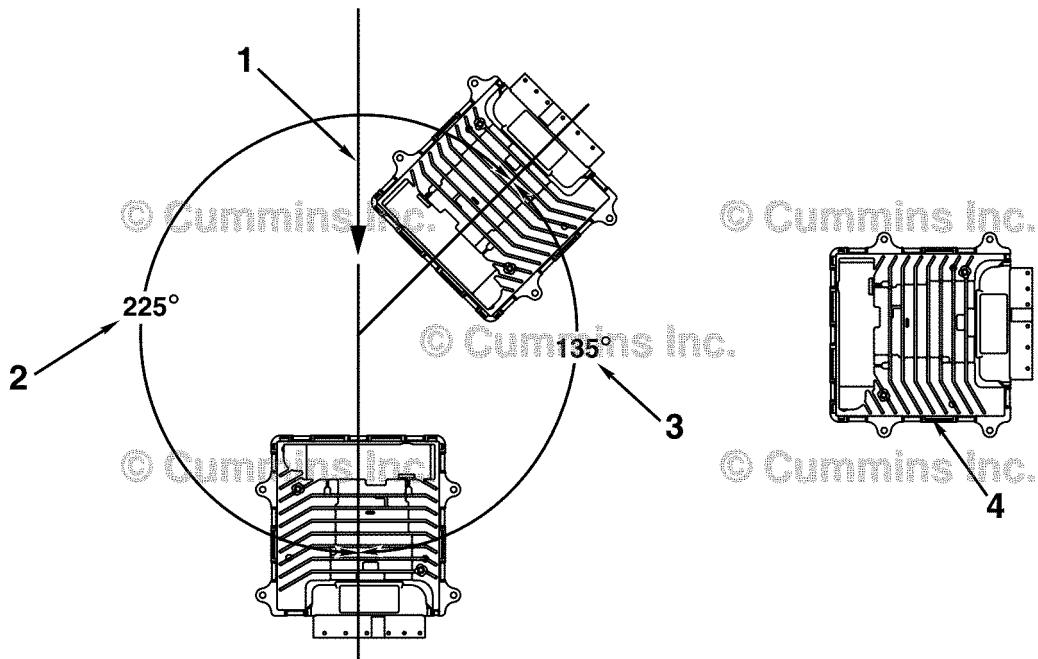


19b00239

Figure 8 - ECM Dimensions and Mounting Locations

1 Representative optional ECM isolator

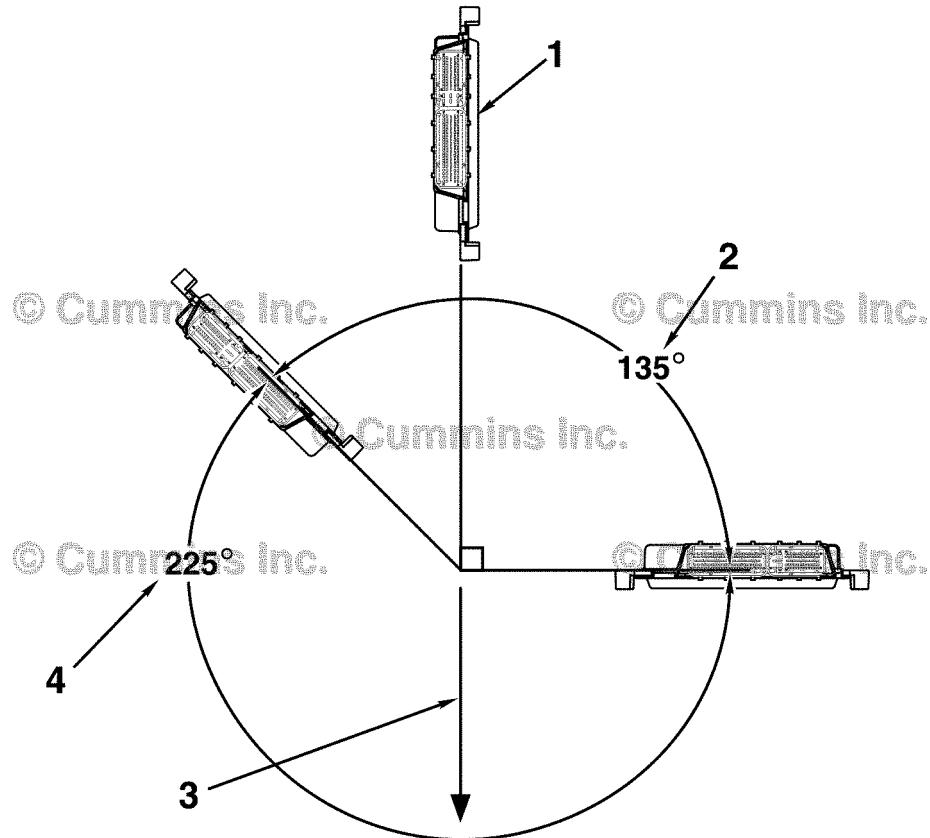
The acceptable ECM mounting orientation is shown in Figures 9 and 10. The preferred ECM mounting orientation has been shown to minimize the accumulation of moisture and dirt on the ECM connectors, and maximize the transfer of heat away from the ECM.



19b00240

Figure 9 - ECM Mounting Orientation

- 1 Gravity
- 2 Prohibited mounting orientation angle range (225 degrees)
- 3 Permissible mounting orientation angle range (135 degrees)
- 4 Preferred mounting orientation (fins vertical, connector to the right).



19b00241

Figure 10 - ECM Mounting Orientation

- 1 Preferred mounting orientation (vertical)

- 2 Permissible mounting orientation angle range (135 degrees)
- 3 Gravity
- 4 Prohibited mounting orientation angle range (225 degrees).

Electric Starting Aid

⚠ WARNING ⚠

To reduce the possibility of personal injury and property damage, never use starting fluid if the grid heater option is used. Starting fluid, which contains ether, can cause an explosion.

The grid heater is also referred to as an electric starting aid as illustrated on the warning label placed on the top of the engine. See Figure 11.

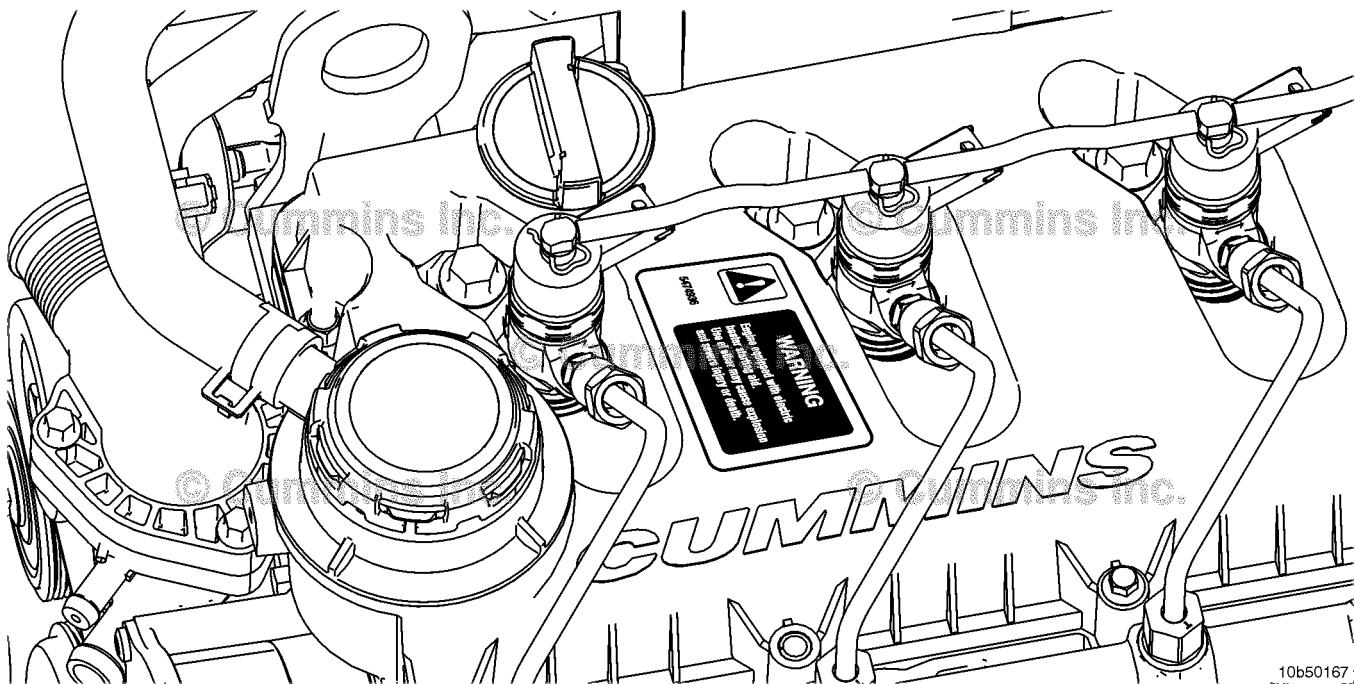
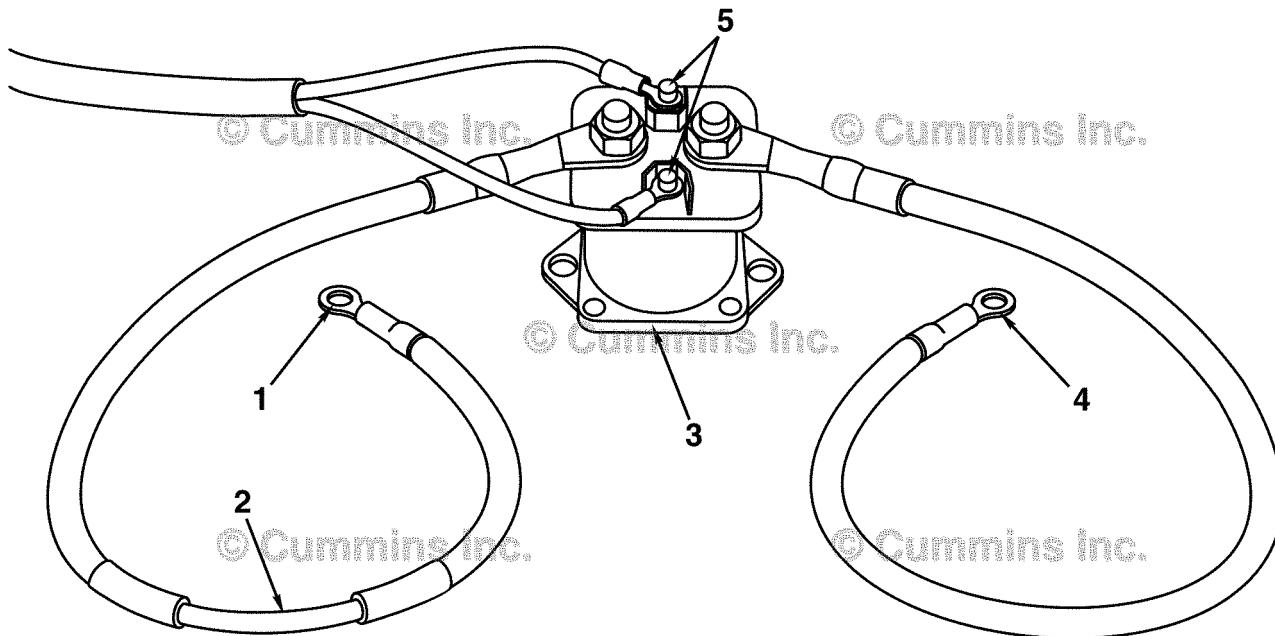


Figure 11 - Grid Heater Warning Label

To enhance the engine starting at cold temperature, an electric grid heater is standard on the engine. The grid heater system **must** be installed and functional on the vehicle. A grid heater high current relay is provided as part of the R 2.8 CM2220 R101B engine kit. The grid heater relay is controlled by the ECM. The high current power cable with the fusible link **must** be used for the connection to battery positive post, Figure 2. The other cable is for connection between the grid heater relay and the grid heater post on the engine. The grid heater relay **must not** be mounted on the engine. The recommended mounting orientation of the grid heater relay is with the posts pointed upward or horizontal.

For proper operation of the grid heater, the control circuit to the ECM **must** be connected to the wiring harness. The o-ring connectors are marked "Grid Heater" on the wiring harness.



10b50174

Figure 12 - Grid Heater Harness and Relay

- 1 To battery positive post
- 2 Fusible link
- 3 Grid heater relay
- 4 To engine grid heater post
- 5 To the ECM via the harness leads.

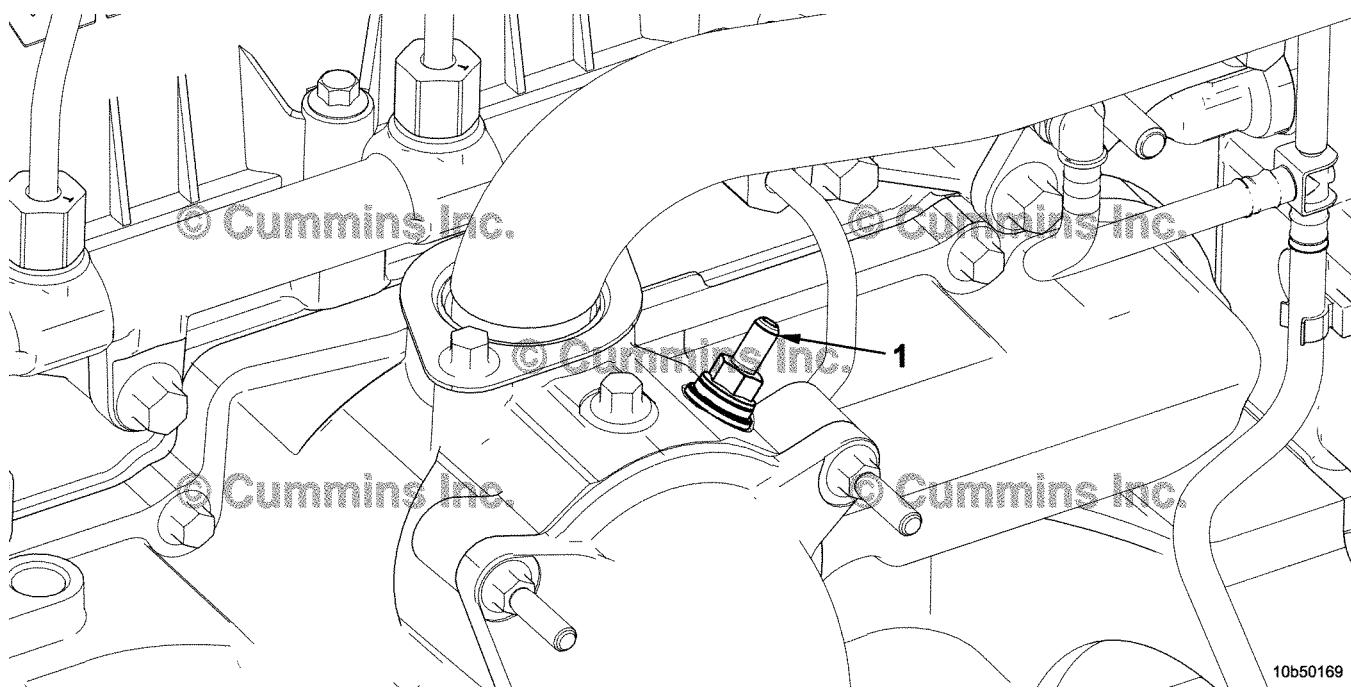
Tighten the grid heater relay posts nuts to the following values.

Torque Value:

Large Post Nut 5.6 N·m [50 in-lb]

Torque Value:

Small Post Nut 1.7 N·m [15 in-lb]



10b50169

Figure 13 - Grid Heater Engine Post Location

The engine grid heater electrical power stud (1) is 6 mm [0.236 in]. Tighten to the following value.

Torque Value: 5 N·m [44 in-lb]

Dash Displays

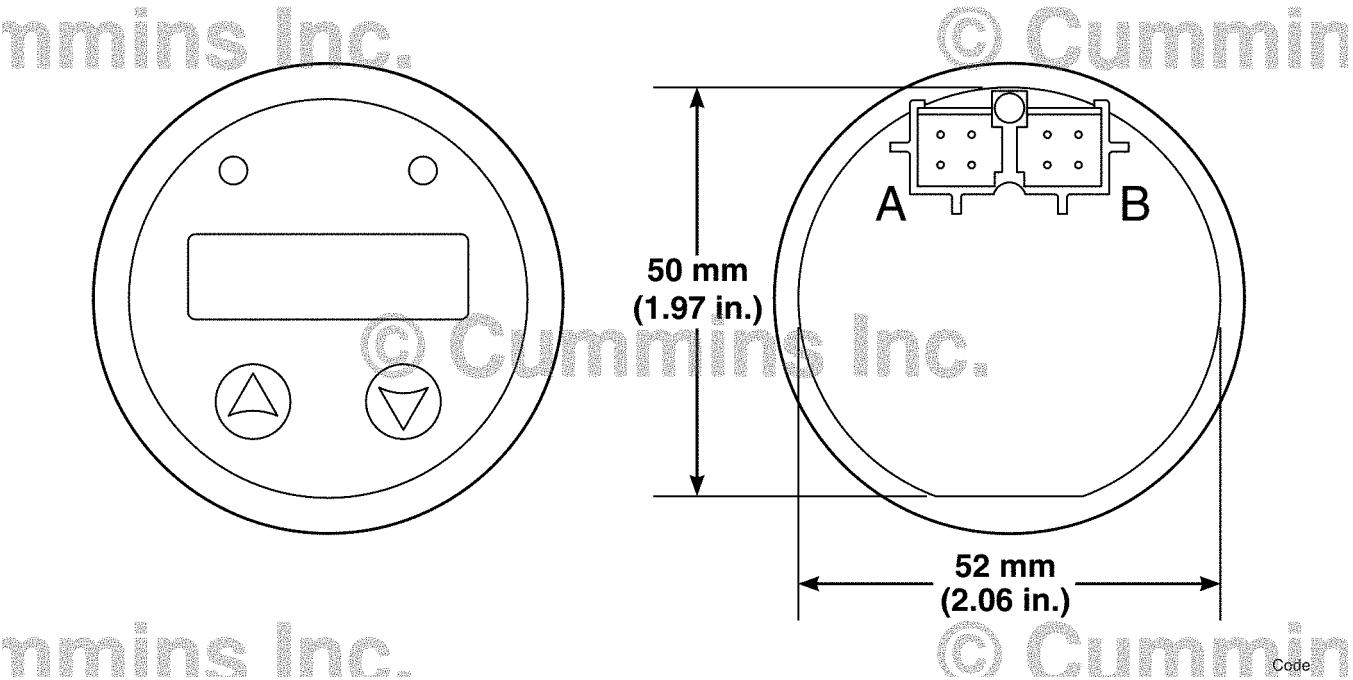


Figure 14 - J1939 Cab Display

The R2.8 CM2220 R101B Engine Kit includes a cab display within a small box within the crate. In the small box is a booklet outlining the functions and installation instructions from the manufacturer. The information in the booklet can also be found at the internet link below.

NOTE: <http://www.murphybyenovationcontrols.com/products/displays/pv25>

The dash display reads engine parameters over the J1939 CAN Network. Also provided on the engine harness is a 16 pin data link OBD connector. An electronic service tool can be connected to read engine parameters over the J1979 CAN network. See Figure 15.

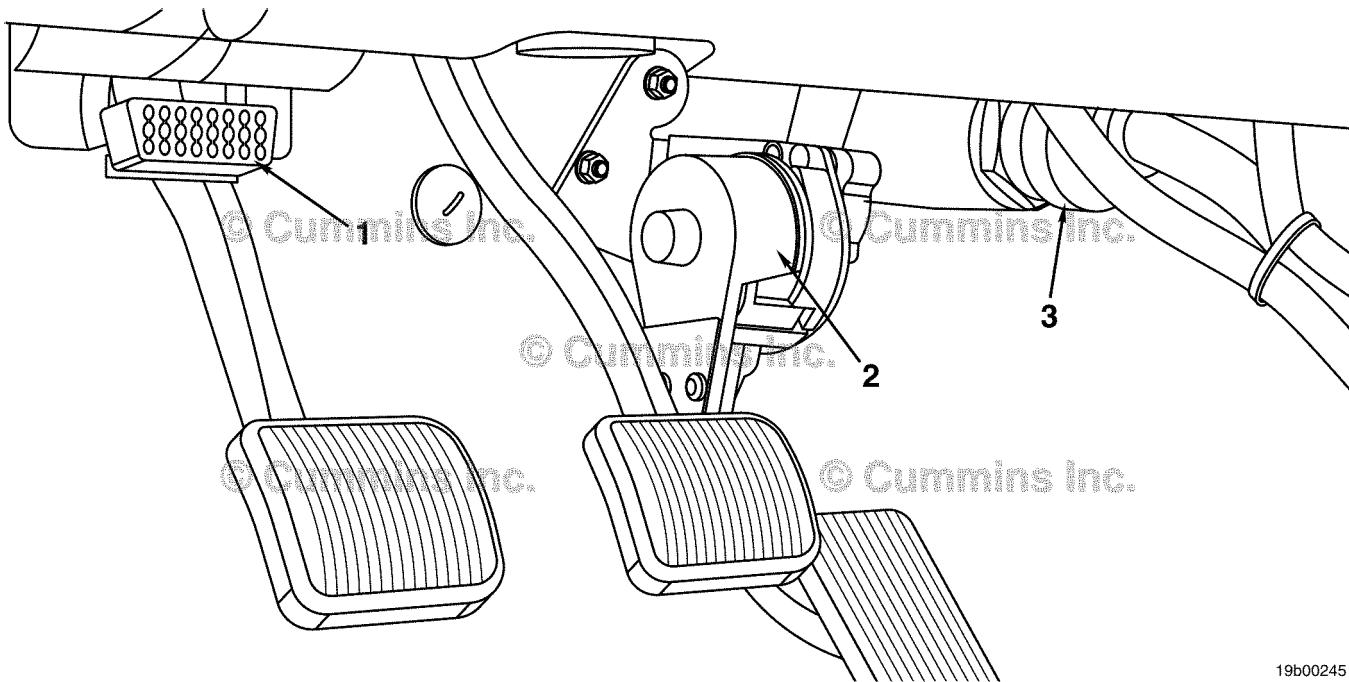


Figure 15 - Cab Components

19b00245

- 1 16 Pin Data Link Onboard Diagnostics Connector
- 2 Accelerator Pedal
- 3 23 Pin Bulkhead (Deutsch™) Connector

Should the user choose **not** to install the J1939 cab display (with integrated warning and stop engine lights) it is **strongly recommended** to install and connect to the ECM three engine indicator lamps to properly communicate the engine state to the driver. The cab-side harness provides four lamps to alert the driver to the condition of the engine.

Red, STOP Lamp

- If the driver receives a STOP lamp indication, the driver should cease operation of the vehicle and engine as quickly as possible to reduce damage to the engine or associated systems. This lamp is required.

Yellow, WARNING Lamp

- If the driver receives a WARNING lamp indication for a maintenance or service condition, the driver should have the condition corrected as soon as convenient. This lamp is required.

White, WAIT TO START Lamp

- The WAIT TO START Lamp indicates the driver has turned the keyswitch to an engine run position, but should wait to start the vehicle. The most common reason for this is to wait for the intake air heaters to complete a preheat cycle during cold ambient conditions. This lamp is required.

MIL Lamp

- The MIL lamp displays messages which require prompt operator attention and diagnostics messages. If the driver receives a MIL lamp indication for an emissions fault, the driver should take the vehicle to a service center as soon as possible. The MIL lamp color can **not** be red, and the lettering is to comply with International Organization for Standardization (ISO) 2575 number F01 or F22. This lamp is **not** used on the R2.8 CM2220 R101B product.

NOTE: For proper operation of the warning lights, the installer needs to provide positive battery connection to the light, and connect another side to the labeled lead of the harness. The ECM will enable a grounding path for the warning light to illuminate.

General Lamp Information	
Item	Requirement
Standard	Society of Automotive Engineers (SAE) Recommended Practice J1211
Type	Incandescent or Light-Emitting Diode (LED)
Typical Voltage	12 VDC
Minimum Luminosity	2 Candle Power
2 Candle Power	500 mA Steady State

NOTE: The ECM supports the use of LED or incandescent indicator lamps. There is a small leakage current through the lamp driver circuit that can cause some LEDs to appear to be ON when they are actually OFF. The LED illumination should be verified. If appropriate, a resistor should be wired in parallel with the LED to prevent the LED appearing ON when actually OFF. A resistor on the order of 4.0-7.0 k ohms should be sufficient. Verify this value for your application.

The J1939 cab display also reads engine speed. If the user chooses to integrate the factory tachometer, the R2.8 CM2220 R101B wiring harness includes a tachometer output signal wire. The signal wire (white wire, labeled Tach, pin 9) exists in one of two states, source or sink.

The ECM toggles the state rapidly to produce a square wave with a variable frequency and a fixed nominal duty cycle of 50 percent. Four pulses are produced for each crankshaft revolution, for an output frequency (Hz), per the following formula:

- Engine rpm x 4 pulses per revolution x 1 minute per 60 seconds

There is a minimum allowable frequency for the square-wave, which corresponds to a lower threshold of the engine speed which can be reported to the tachometer.

The ECM provides a single pin output interface for the tachometer output with the following requirements in the table below.

Item	Requirement
Operational States	Two: SOURCE and SINK
Modes	One: pulse width modulation (PWM)
Minimum Source Voltage (@Maximum Source Current)	6.0 volts

Item	Requirement
Maximum Source Current	5 mA
Minimum Load Resistance	1100 ohms
Maximum Sink Voltage (@Maximum Sink Current)	0.5 volts
Maximum Sink Current	5Ma
Frequency Range	2-8500 Hz

Section 2 - Start-Up and Troubleshooting

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Starting the Engine (389-001)

General Information

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

The cooling fan will engage when the engine is started. To prevent serious personal injury, keep your hands clear of the fan's path when starting the engine and during engine operation.

⚠️ WARNING ⚠️

Do not mix gasoline, alcohol, or gasohol with diesel fuel. This mixture can result in a fire or explosion.

⚠️ WARNING ⚠️

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

Before attempting to start the engine for the first time, review the installation, paying special attention to safety issues that may occur during the initial engine starting. Read this procedure entirely before starting the engine.

Electrical

⚠️ 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.

Install the cables and tighten the battery connections. Coat the terminals with grease to prevent corrosion.

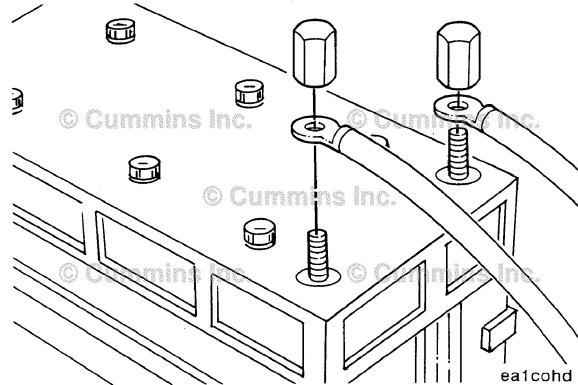


Figure 1 - Install Battery Connection

Fluids

Lubricating Oil

Check the lubricating oil drain plug to make sure it is tight.

Torque Value: 24 N·m [212 in-lb]

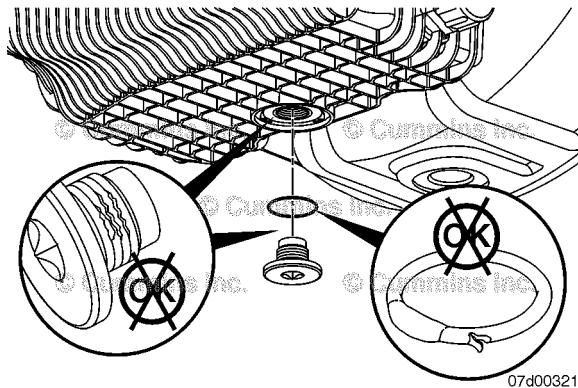


Figure 2 - Lubricating Oil Drain Plug

NOTE: Use a high-quality multiviscosity oil, such as Valvoline™ Premium Blue™, or its equivalent, in Cummins® engines. Choose the correct oil for your operating climate. Refer to Service Bulletin Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.



Figure 3 - Valvoline™ Premium Blue™

⚠ WARNING ⚠

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

⚠ WARNING ⚠

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

Fill the lubricating oil pan with clean lubricating oil. Refer to Procedure 391-003 in Section 1 for lubricating oil system capacities.

NOTE: Wait at least 5 minutes before measuring the oil level with the dipstick to allow the oil to drain to the pan.

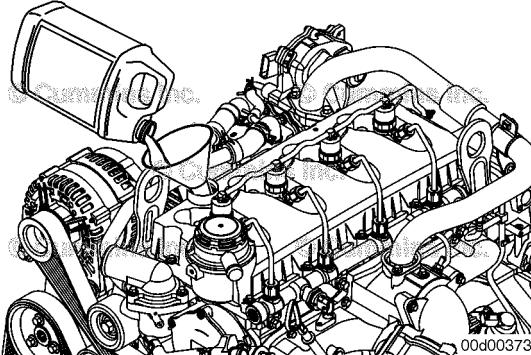


Figure 4 - Fill Engine with Oil

Coolant

△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 from the cooling system during the fill process:

- The thermostat has provisions that allow air to vent through the thermostat when the thermostat is closed.

NOTE: There is a manual bleed vent plug on the exhaust gas recirculation (EGR) cooler coolant return line. To help purge air from the system, open this vent while filling the system. Close the bleed vent plug after filling the system.

The system has a design fill rate of 11 liters [3 gal] per minute.

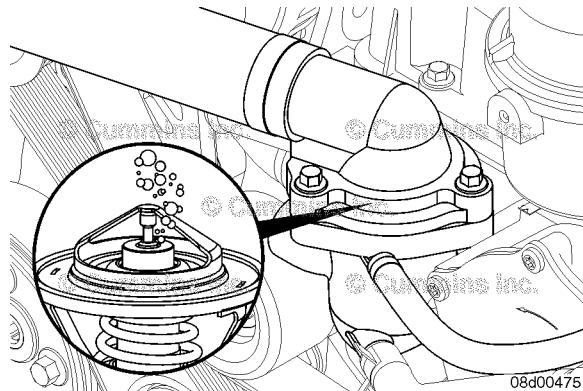


Figure 5 - Thermostat Air Vent

△CAUTION△

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

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

Refer to Procedure 018-004 in Section V for coolant recommendations and specifications. Refer to Procedure 387-008 in Section 1 for cooling system capacities.

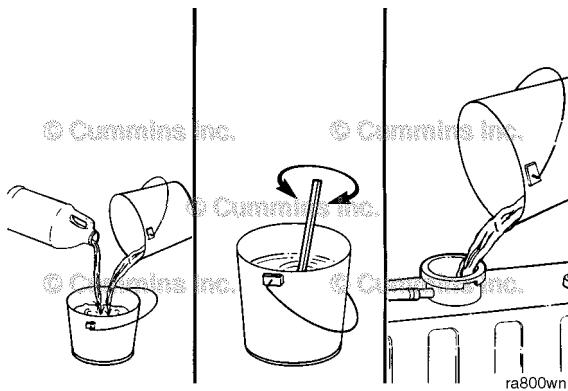


Figure 6 - Mix and Fill Coolant

⚠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.

NOTE: Make sure the manual bleed vent plug on the EGR cooler coolant return line is closed before operating the engine.

Install the pressure cap.

The coolant level will drop once the coolant is circulated in the system during engine running.

Have coolant available to replenish the system of the purged air.

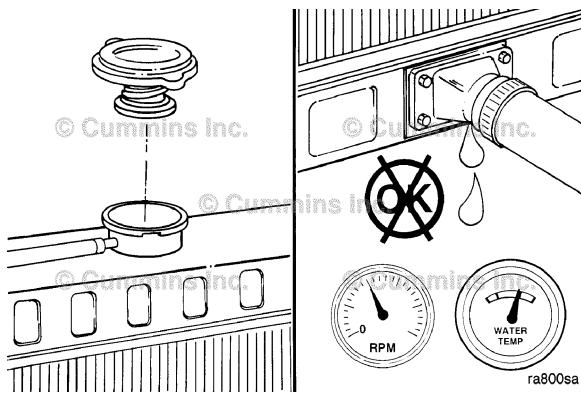


Figure 7 - Install Pressure Cap

Power Steering Pump

Check the volume of fluid in the power steering pump reservoir. Fill the reservoir according to the manufacturer specifications.

Fuel

⚠️ WARNING ⚠️

The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

⚠️ CAUTION ⚠️

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

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

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.

Lock the manual priming pump handle.

If the engine does **not** start after 30 seconds of cranking, 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. Use an electronic service tool to clear the fault code.

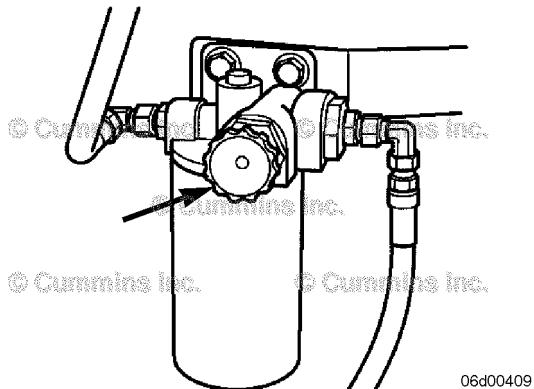


Figure 8 - Prime Fuel System

Starting

⚠️ 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.

Disengage the driven unit, or if equipped, put the transmission in neutral.

With the accelerator pedal or lever in the idle position, turn the keyswitch to the ON position.

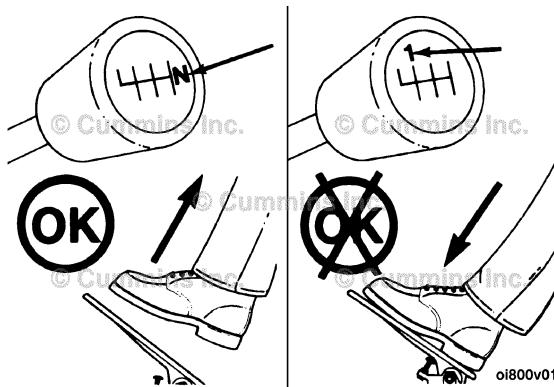


Figure 9 - Starting Pedal and Transmission Position

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

- 1 WARNING (or CHECK ENGINE) lamp, amber in color
- 2 STOP (or STOP ENGINE) lamp, red in color
- 3 ENGINE MALFUNCTION or MALFUNCTION INDICATOR LAMP (MIL)
- 4 WAIT-TO-START lamp.

The WAIT-TO-START lamp will remain on for a minimum of 5 seconds and a maximum of 30 seconds, based on coolant and air temperature while the grid heater cycles.

If any of the lamps remain on or begin to flash, reference the J1939 CAN display for fault code information and visit Cummins® QuickServe® Online (QSOL) for troubleshooting information.

Once the WAIT-TO-START lamp turns OFF, turn the key to the starting position to start the engine.

⚠️ 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).

⚠️ 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.

Once the engine starts, **immediately** check the oil pressure gauge and indicator lights.

If all indicating lights are OFF and adequate oil pressure is present, continue to idle the engine for 3 to 5 minutes, monitoring the condition of the engine and looking for any fluid leaks that may be present.

After the minimum idle time and a thorough review of the installation, load and engine speed can be slowly increased while continuing to monitor the condition of the engine. Continue this process until the thermostat opens, enabling coolant to flow throughout the system while checking for fluid leaks.

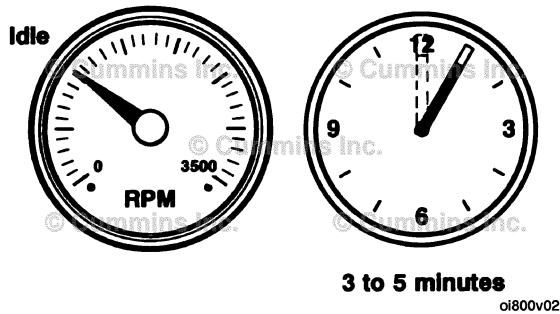


Figure 10 - Idle Engine for 3 to 5 Minutes

⚠ 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.

Bring the engine back to idle for 3 to 5 minutes, allowing the engine to cool down and proceed to shut the engine off.

Check the fluid level as done before start up.

Monitor

Service and Troubleshooting Information

- Cummins® QuickServe® Online (QSOL) web site is available for service and troubleshooting information.

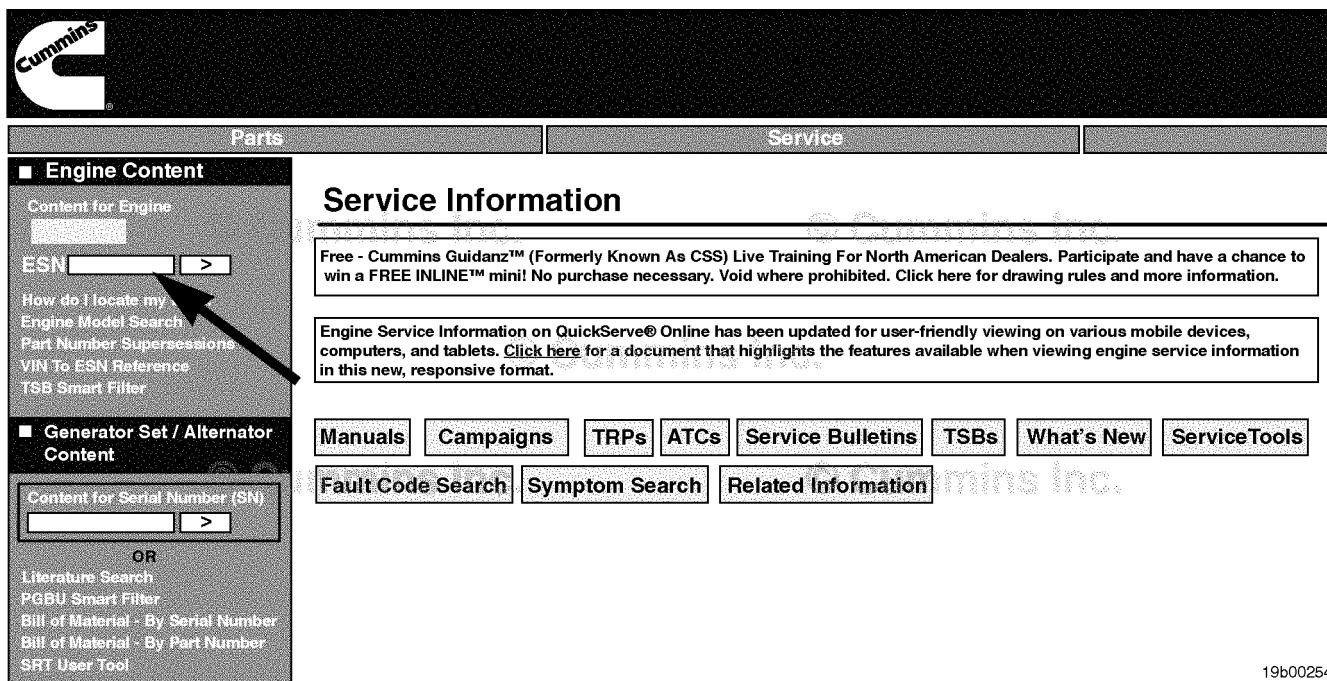
NOTE: The link to QSOL is: <https://quickserv.cummins.com/info/index.html>

The screenshot shows the Cummins QuickServe Online homepage. On the left, there's a sidebar with 'Customer Login' fields for Username and Password, and buttons for 'Login', 'Forgot Password', and 'Trouble logging in?'. Below that is the 'Information' section with links for 'Create an Account', 'Related Links', and 'Service Location'. An arrow points to the 'Create an Account' link. The main content area features a large 'Welcome to Cummins QuickServe Online' header. It includes sections for 'Why Register?' (describing it as the best source of Cummins engine parts and service information), 'Second only to your local Cummins service shop!' (with a Cummins logo), and 'When you register, you may view information specific to your Cummins Engine, including: Your Owners Manual, the Parts Catalog for Your Engine Serial Number, Engine Dataplate Information for Your Engine, 15 Million Engines. 1 Website.' It also mentions 'QuickServe Online contains parts and service information for over 15 million Cummins engine serial numbers.' and 'Discover What Every Cummins Service Shop Already Knows.' At the bottom, it says 'Parts content and service documents available by engine serial number or engine family. QuickServe Online is your complete reference for Cummins parts and service information on the Internet.' and 'Do You Own Multiple Cummins Engines?' followed by a note about fleet/distributor account subscription information.

Figure 11 - Register for Cummins® QuickServe® Online

You will need to create an account to utilize the website as shown above.

Once your account is active and you log in, you will use the engine serial number (ESN) of your R2.8 CM2220 R101B engine to gain access to the available information. The ESN is noted on the engine data tag affixed to the top of the valve cover.

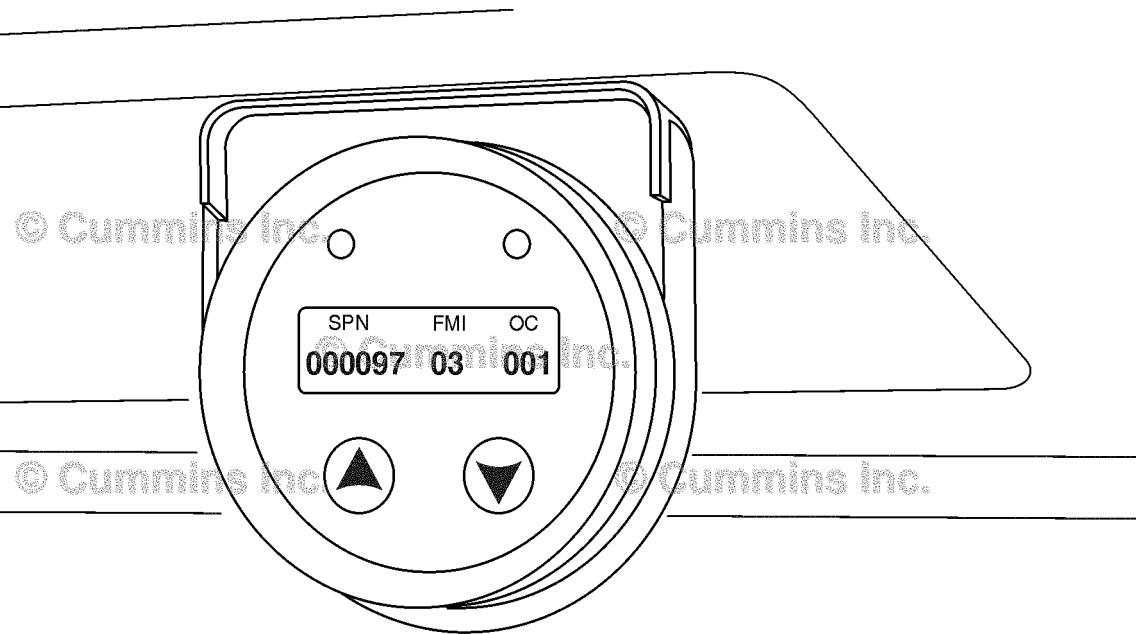


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Figure 12 - Cummins® QuickServe® Online Screen for ESN

Enter the ESN in the screen above to display the information. The information available is shown in the illustration above such as:

- Manuals and wiring diagram for troubleshooting
- Service Bulletins
- Service Tools
- Fault Code Search
- Symptom Search
- Related Information.



19b00253

Figure 13 - J1939 Dash Display Fault Code Read Out

Fault code search tab will provide a conversion from SPN and FMI information provided by the dash display, see illustration above, in the form of Cummins® fault code numbers. The Cummins® fault codes can then be used in the

Fault Code Troubleshooting Manual. See the User Interface Display guide, Part Number 5467023, included in the R2.8 CM2220 R101B Engine Kit for instructions on using the dash display.

Mass Air Flow Offset Correction (392-001)

General Information

The R2.8 CM2220 R101B calibration contains a feature that allows the user to auto-calibrate the mass air flow (MAF) sensor to the specific air intake setup. This allows the sensor to accurately read fresh air flow into the engine and calculate the appropriate ratio of exhaust gas recirculation (EGR). Even when using the intake setup described in Procedure 388-017 in Section 1 (Air Intake System), it is still recommended to complete the MAF-Offset Correction sequence to properly calibrate the MAF sensor.

The calibration sequence is initiated via a pedal dance. Coolant temperature **must** be greater than 70°C [158°F] for the sequence to initiate. This can be monitored via the J1949 Dash Display.

- 1 Turn vehicle off for 10 seconds
- 2 Press accelerator pedal to the floor, key the vehicle on, and continue depressing the pedal for 3 seconds
- 3 Release accelerator pedal for 3 seconds
- 4 Depress the accelerator pedal and hold for 5 seconds. Start the vehicle (pedal remains pressed to the floor)
 - If the engine speed instantly revs up, the process did **not** initiate properly
 - If the engine speed stays at idle, the vehicle is in calibration mode
- 5 Continue holding pedal to floor while engine performs calibration sequence. Engine speed will step up from idle to 3000 rpm in 200 rpm increments, and then reduce back to idle
- 6 Once complete, continue holding pedal at idle for 10 seconds. Release pedal.
 - An engine speed blip will be seen/heard.
 - Key vehicle off for at least 1 minute to save new calibration.

Available INSITE™ Electronic Service Tool Trimmables (392-002)

General Information

Fast Idle Warm Up

Fast Idle Warm Up feature enables the engine to increase idle speed for a pre-determined amount of time, based on coolant temperature. The raised idle speed assists with the rate at which the engine warms up in cold ambient temperatures. The Fast Idle Warm Up feature is available to turn ON via INSITE™ electronic service tool. It is defaulted OFF in the mainline calibration, but is available to be set to ON.

There is a 30 second delay before the feature is enabled, engine speed is ramped from 800 rpm to 1250 rpm at a rate of 50 rpm/s. The feature is enabled at a coolant temperature below 10°C [50°F] and deactivates at or above 20°C [68°F]. It also deactivates upon accelerator pedal application.

Vehicle Speed

Vehicle speed can be calculated by the engine control module (ECM) and broadcast on the J1939 CAN network for use with aftermarket gauges. The Vehicle Speed feature is available to trim via INSITE™ electronic service tool. It is defaulted to None in the mainline calibration, but is available to be set to either Magnetic or Data Link - Tailshaft. Tire size, in rev/km, as well as rear axle ratio (RAR) need to be trimmed with INSITE™ electronic service tool as well. Should a hardwired vehicle speed sensor be necessary, Pin J2-40 in the ECM wiring is required to be moved to pin J2-28.

Idle Adjustment

Low Speed Idle is selectable via INSITE™ electronic service tool, between 700 and 1100 rpm in 25 rpm increments. It is defaulted to 800 rpm for the optimal noise, vibration, and harshness (NVH). The R2.8 CM2220 R101B also offers a temporary idle increment/decrement option, where the user can temporarily raise or lower idle speed to better facilitate the operation of additional accessories. Should this feature be desired, it is required to wire switches to ECM pins J2-24 (Increment) and J2-37 (Decrement).

Section V - Maintenance Specifications

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General Engine

Specifications

Listed below are the general specifications for the engines covered by this manual.

Bore x Stroke.....	94 mm x 100 mm
Horsepower.....	Refer to engine dataplate
Displacement.....	2.8 liters [171 C.I.D]
Firing Order.....	1-3-4-2

Approximate Engine Weight:

Dry Weight, excludes flywheel, alternator, and starter.

Dry Weight, with exhaust gas recirculation (EGR).....	228 kg [503 lb]
Crankshaft Rotation (viewed from the front of the engine).....	Clockwise

Valve Clearance:

Intake.....	0.25 mm [0.010 in]
Exhaust.....	0.51 mm [0.020 in]

Filter Specifications

General Information

Cummins Filtration Inc. is a subsidiary of Cummins Inc. Fleetguard® filters are developed through joint testing at Cummins Inc. and Fleetguard Filtration Inc.. Fleetguard® filters 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 should 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 nongenuine filters that do **not** meet Cummins Inc. performance or durability requirements.

Filter Part Numbers					
Part Description	Original Remote Lubricating Oil Filter	New Remote Lubricating Oil Filter	Medium Length Lubricating Oil Filter (Optional)	Short Length Lubricating Oil Filter (Optional)	Fuel filter
Cummins® Part Number	4989314	5399594*	-	4899247*	5268019
Fleetguard® Part Number	LF16015	LF17535*	LF16229*	LF16121*	FS36209
Height (mm) [in]	177 mm [6.96 in]	177 mm [6.96 in]	141mm [5.55 in]	91 mm [3.58 in]	-

*Used for engines built after August 2021 and engines using lubricating oil filter head, Part Number 5308354.

Fuel Recommendations and Specifications

Fuel Recommendations

⚠️ WARNING ⚠️

Do not mix gasoline, alcohol, or gasohol with diesel fuel. This mixture can cause an explosion.

⚠️ CAUTION ⚠️

Due to the precise tolerances of diesel injection systems, it is extremely important that the fuel be kept clean and free of dirt or water. Dirt or water in the system can cause severe damage to both the fuel pump and the fuel injectors.

⚠️ CAUTION ⚠️

Lighter fuels can reduce fuel economy or possibly damage fuel system components.

For engines optimized for use with an aftertreatment system to meet the Euro IV emission regulations. In order to meet these regulations, with a maximum sulfur content of 50 ppm is required for correct operation of the aftertreatment system. By **not** doing so can permanently damage the engine and aftertreatment systems within a short period of time. This damage could cause the engine to become inoperable and affect the warranty coverage on the engine.

Cummins Inc. engines without exhaust aftertreatment should **only** be operated with diesel fuel containing less than 5,000 ppm sulfur content.

Cummins Inc. recommends the use of American Society of Testing and Materials (ASTM) number 2D fuel. The use of number 2D diesel fuel will result in optimum engine performance.

Cummins Inc. recommends the use of ASTM number 2D fuel. The use of number 2D diesel fuel will result in optimum engine performance.

At operating temperatures below 0°C [32°F], acceptable performance can be obtained by using blends of number 2D and number 1D.

The following chart lists acceptable substitute fuels for this engine.

Acceptable Substitute Fuels - Cummins® Fuel System									
Number 1D Diesel ⁽¹⁾ ⁽²⁾	Number 2D Diesel ⁽²⁾	Number 1K Kerosene	Jet-A	Jet-A1	JP-5	JP-8	Jet-B	JP-4	CITE
OK	OK	Not OK							
48-34 ⁽³⁾	40-24 ⁽³⁾	50-35 ⁽³⁾	51-37 ⁽³⁾	51-37 ⁽³⁾	48-36 ⁽³⁾	51-37 ⁽³⁾	57-45 ⁽³⁾	57-45 ⁽³⁾	57-45 ⁽³⁾

- 1 Any adjustment to compensate for reduced performance with a fuel system using alternate fuel is **not** warrantable.
- 2 Winter blend fuels, such as found at commercial fuel dispensing outlets, are combinations of number 1D and number 2D diesel fuel and are acceptable.
- 3 British Thermal Unit (BTU) Content/Degree American Petroleum Institute (API) Gravity - Low API gravity fuels have a higher thermal energy content (BTU). As a general rule of thumb, there is a 3 to 5 percent decrease in BTU content for every 10 degree increase in API gravity. There is also a 0.7 degree API gravity increase with an increase in fuel temperature. This decrease in energy content equates roughly to the same percentage of power loss. Use of fuels with higher API gravity will cause higher than normal fuel consumption.

NOTE: Cummins Inc. recommends that the cetane number of diesel fuel be a minimum of 45 for engines that are expected to operate at temperatures below 0°C [32°F] and a minimum of 40 for engines that are operated at temperatures above 0°C [32°F].

NOTE: Using a diesel fuel with a lower than recommended cetane number can cause hard starting, instability, and excessive white smoke. To maintain satisfactory operation at low ambient temperatures, it is important to specify diesel fuel of the correct cetane number.

NOTE: Cummins Inc. requires all permissible fuels to have adequate fuel lubricity. This means the Ball On Cylinder Evaluator (BOCLE) number is 3100 or greater as measured by ASTM specification D6078, Scuffing Load Ball On Cylinder Evaluator (SLBOCLE). Lubricity can also be measured by ASTM specification D6079, ISO 12156, High Frequency Reciprocating Rig (HFRR) in which the fuel **must** have a wear scar diameter of 0.45 mm [0.02 in] or less.

Additional information for fuel recommendations and specifications can be found in Fuel for Cummins® Engines, Bulletin 3379001. See ordering information in the back of this manual.

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.

△CAUTION△

A sulfated ash limit of 1.85 percent has been placed on all engine lubricating oils recommended for use in Cummins® engines. Higher ash oils can cause valve and/or piston damage and lead to excessive oil consumption.

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. Reference Procedure 102-002 in Section 2 to determine which oil drain interval to use for the application.

Cummins Inc. recommends the use of high-quality Society of Automotive Engineers (SAE) 15W-40 heavy-duty engine oil, such as Valvoline™ Premium Blue™ (USA) or Valvoline™ Premium Blue™ Extra (International).

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

API: American Petroleum Institute

CES: Cummins® Engineering Standard

ACEA - Association des Constructeurs European d' Association

JAMA - Japanese Automobile Manufacturerrs Association

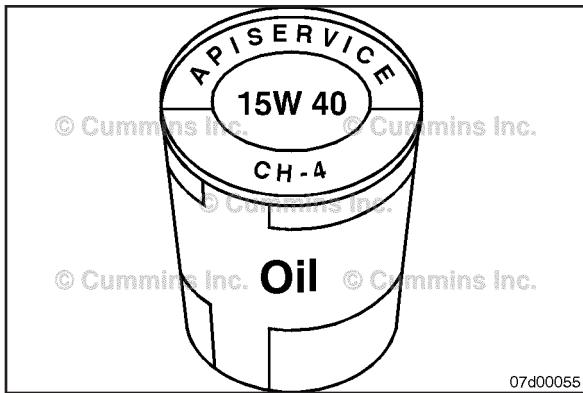
Table 1: CES for Lubricants			
CES	North American Classification	International Classifications	Comments
Obsolete. Do not use.	API CD API CE	ACEA E-1	Obsolete. Do not use.
	API CG-4/SH		
CES-20075 ¹	API CF-4/SG	ACEA E-2	Minimum acceptable oil classification for MidRange engines, but is not recommended.
		ACEA E-3	
		JAMA DH-1	
CES-20071 ²	API CH-4 4/SJ	ACEA E5	Acceptable oil classification for MidRange engines.
CES-20076 ²			
CES-20077 ²			
CES-20078	API CI-4	ACEA E7	Excellent oil for MidRange engines.
CES-20081	API1 CJ-4	ACEA E9	Excellent oil for MidRange engines where ultra-low sulfur diesel fuel is used. ³
		JAMA DH-2	

Table Notes

- For MidRange engines, in areas where CH-4/SJ or CG-4/SH oils are **not** available, refer to the oil drain intervals in Section 2. As an alternative, oils meeting CES-20075 can be used, but the oil drain interval and filter change interval **must** be reduced by half.
- Outside North America, where oil meeting CES-20071, CES-20076, or CES20077 might **not** be available, Cummins Inc. primary recommendation is for an oil meeting Global DHD-1, as jointly developed by EMA, ACEA, and JAMA.
- Ultra-low sulfur diesel fuel is defined as diesel fuel **not** exceeding 0.0015 (15 ppm) mass percent sulfur content (ultra-low diesel fuel is also defined by ASTM S-15).

A sulfated ash limit of 1.0 mass percent is suggested for optimum valve and piston deposit and oil consumption control.

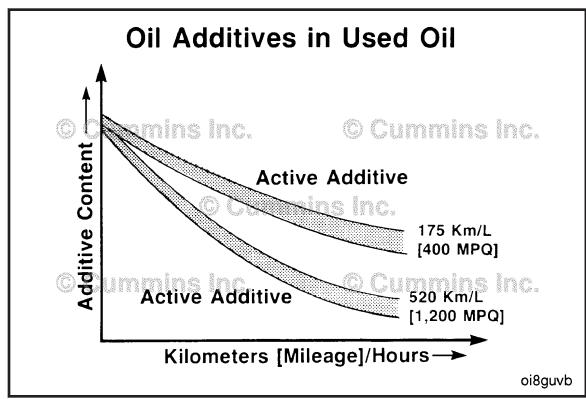
For further details and discussion of engine lubricating oils for Cummins® engines, refer to Fluids for Cummins® Products Service Manual, Bulletin 5411406.



The API service symbols are shown in the accompanying illustration. The upper half of the symbols display the appropriate oil categories.

The lower half can contain words to describe oil energy-conserving features.

The center section identifies the SAE oil viscosity grade.



As the engine oil becomes contaminated, essential oil additives are depleted. Lubricating oils protect the engine as long as these additives are functioning properly. Progressive contamination of the oil between oil and filter change intervals is normal. The amount of contamination will vary, depending on the operation of the engine, kilometers or miles on the oil, fuel consumed, and new oil added.

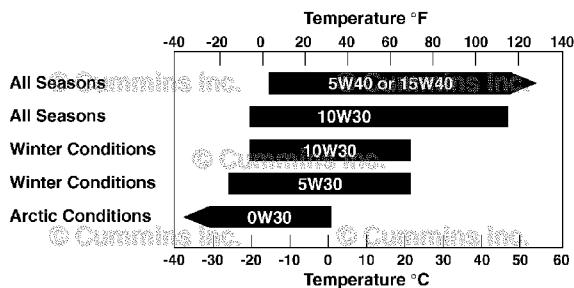
Extending oil and filter change intervals beyond the recommendations will decrease engine life due to factors such as corrosion, deposits, and wear.

Reference the oil drain chart in this section to determine which oil drain interval to use for your application.

The primary Cummins Inc. recommendation is for the use of 15W-40 multigrade lubricating oil for normal operation at ambient temperatures above -15°C [5°F]. The use of multigrade oil reduces deposit formation, improves engine cranking in low temperature conditions, and increases engine durability by maintaining lubrication during high temperature operating conditions. Since multigrade oils have been shown to provide approximately 30 percent lower oil consumption compared with monograde oils, it is important to use multigrade oils to be certain the engine will meet applicable emissions requirements.

Use of "synthetic engine oils" (those made with API group 3 or group 4 base stocks) is permitted, subject to the same performance and viscosity limitations of petroleum (mineral) based engine oils. The same oil change intervals that are applied to petroleum (mineral) based engine oils **must** be applied to synthetic oils.

For further details and discussion of engine lubricating oils for Cummins® engines, refer to Fluids for Cummins® Products Service Manual, Bulletin 5411406



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While the preferred viscosity grade is 15W-40, lower viscosity multigrade oils can be used in colder climates. See the accompanying chart. Any viscosity grade lower than 15W-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.

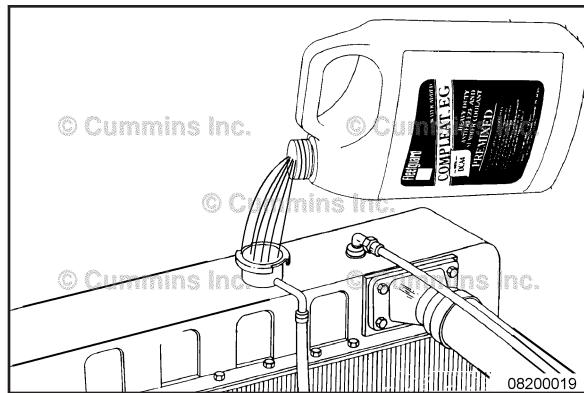
As these oils have directionally thinner oil films than 15W-40 oils, top-quality Fleetguard® filters **must** be used above 20°C [70°F]. Some oil suppliers might claim better fuel economy for these oils. Cummins Inc. can neither approve nor disapprove any product **not** manufactured by Cummins Inc. 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.

New Engine Break-in Oils

Special "break-in" engine lubricating oils are **not** recommended for new or rebuilt Cummins® engines. Use the same type of oil during the break-in as is used in normal operation.

AfterMarket Oil Additive Usage

Cummins Inc. does **not** recommend the use of aftertreatment 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.



Coolant Recommendations and Specifications

Fully Formulated Coolant/Antifreeze

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

Typically, antifreeze/coolants meeting American Society of Testing and Materials (ASTM) D3306 or ASTM D6210 criteria are acceptable antifreeze/coolants for the engines covered by this manual.

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 $(\text{CaCO}_3 + \text{MgCO}_3^3)$
Chloride	Maximum 40 ppm as (Cl)
Sulfur	Maximum 100 ppm as (SO_4)



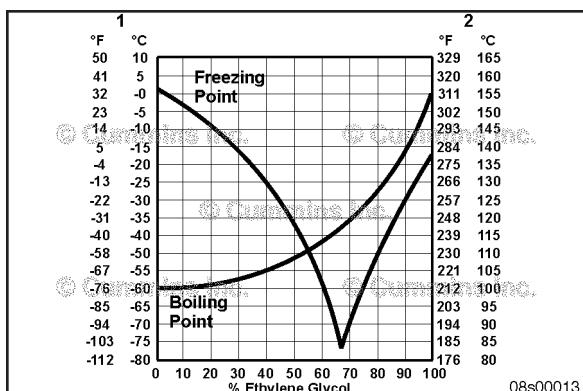
Cummins Inc. recommends using Fleetguard® Compleat™. It is available in both glycol forms (ethylene and propylene).

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. Using higher concentrations of antifreeze will raise the freezing point of the solution and increase the possibility of a silica gel problem.

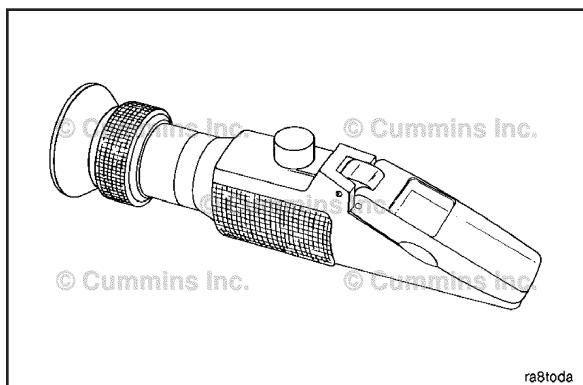
Legend

- 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 C2800.

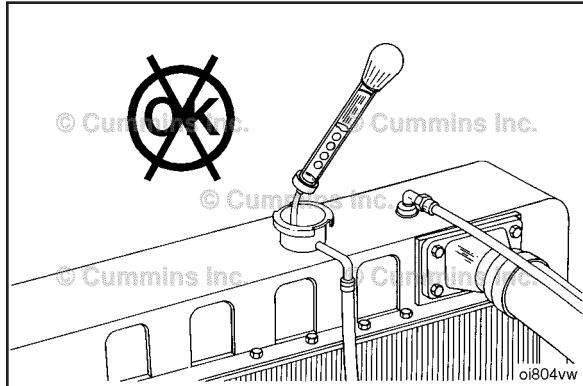


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ra8toda

Do **not** use a floating ball hydrometer. The use of floating ball hydrometers can result in incorrect readings.

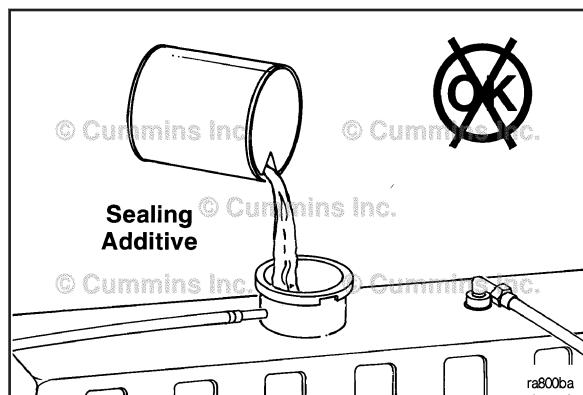


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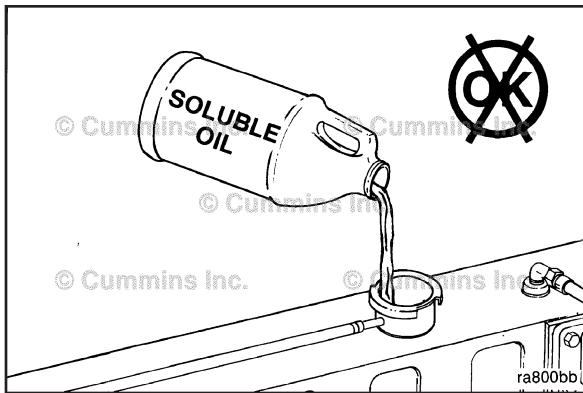
Cooling System Sealing Additives

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.



ra800ba



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.

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