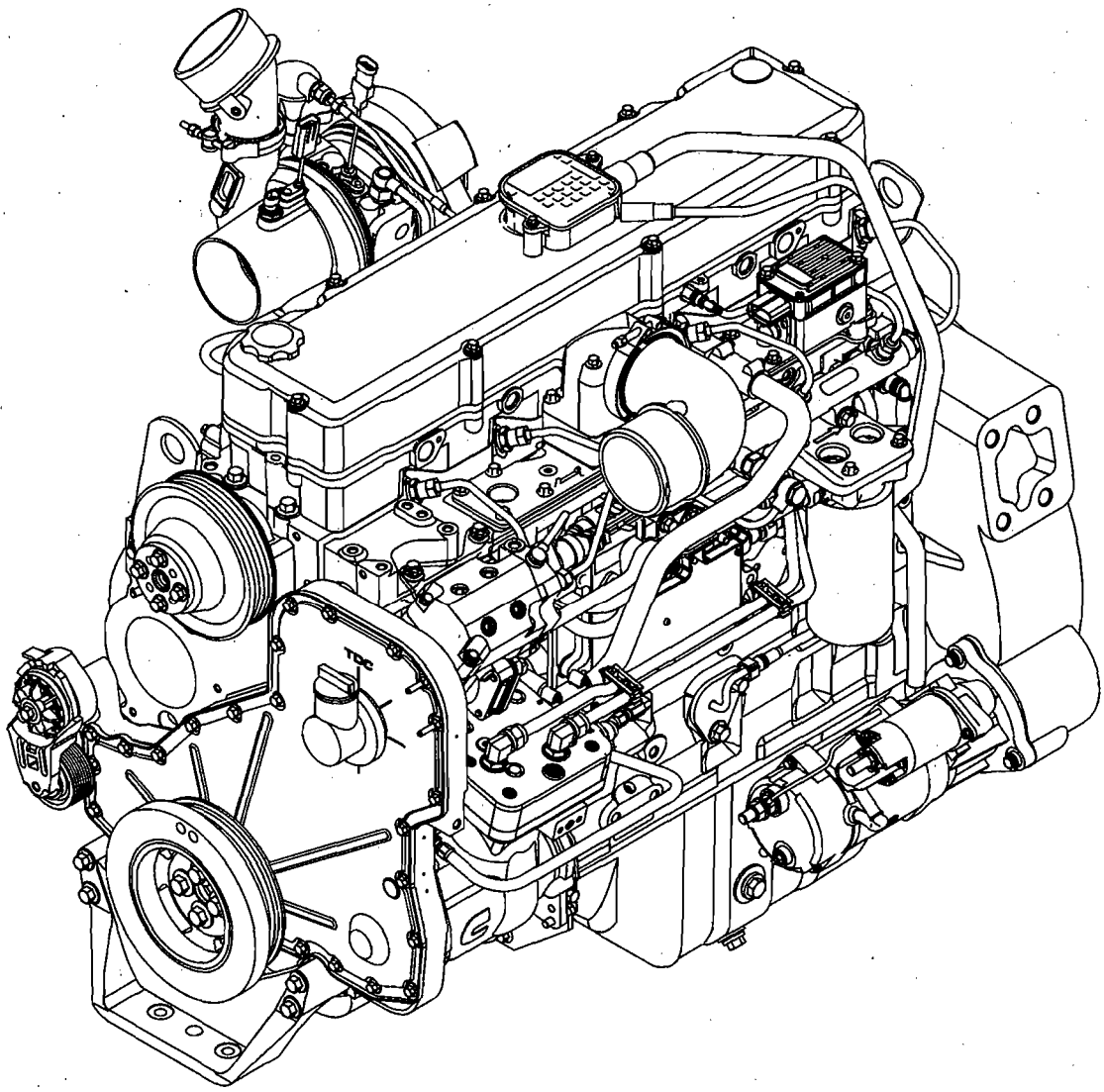
Troubleshooting and Repair Manual ISC, ISCe, QSC8.3, ISL and QSL9 Engines

Open front screen



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Foreword

This manual provides instructions for troubleshooting and repairing this engine in the chassis. Component and assembly rebuild procedures are provided in the engine shop manual. Refer to Section i - Introduction for instructions on how to use this manual.

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

The manual is organized to guide a service technician through the logical steps of identifying and correcting problems related to the engine. This manual does not cover vehicle or equipment problems. Consult the vehicle or equipment manufacturer for repair procedures.

A series of specific service manuals (for example: Shop, Specifications, and Alternative Repair) are available and can be ordered by Contacting your local area Cummins Regional office. A Cummins Regional office listing is located in Service Literature (Section L).

The repair procedures used in this manual are recommended by Cummins Inc. Some service procedures require the use of special service tools. Use the correct tools as described.

Cummins Inc. encourages the user of this manual to report errors, omissions, and recommendations for improvement. Please use the postage paid, pre-addressed Literature Survey Form in the back of this manual for communicating your comments.

The specifications and rebuild information in this manual are based on the information in effect at the time of printing. Cummins Inc. reserves the right to make any changes at any time without obligation. If differences are found between your engine and the information in this manual, contact a Cummins Authorized Repair Location or call 1-800-DIESELS (1-800-343-7357) toll free in the U.S. and Canada.

The latest technology and the highest quality components are used to manufacture Cummins engines. When replacement parts are needed, we recommend using only genuine Cummins or ReCon® exchange parts. These parts can be identified by the following trademarks:

(tr-frwd)

Table of Contents

Section i - Introduction

Section Contents

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About the Manual

General Information

This Troubleshooting and Repair Manual is intended to aid in determining the cause of engine related problems and to provide recommended repair procedures.

The manual is divided into sections. Each section is equivalent to a group used in Cummins' filmcard system. Some sections contain **reference** numbers and **procedure** numbers. **Reference** numbers provide general information, specifications, diagrams, and service tools where applicable. **Procedure** numbers are used to identify and reference specific repair procedures for correcting the problem.

This manual **does not** contain fuel systems electronic troubleshooting. Use the troubleshooting trees in this manual, if there are no electrronic fault codes.

This manual is designed so the troubleshooting trees are used to locate the cause of an engine problem. The troubleshooting trees then direct the user to the correct repair procedure. The repair procedures within a section are in numerical order. However, the repair steps within a given procedure are organized in the order the repair **must** be performed regardless of the numerical order of the steps. The user **must** use the contents pages or the index at the back of the manual to locate specific topics when not using the troubleshooting trees.

How to Use the Manual

General Information

This manual is organized to provide an easy flow from problem identification to problem correction. A list of troubleshooting symptoms containing the most common engine problems is in the Troubleshooting Symptoms, Section (TS). The manual is designed to use the Troubleshooting Symptoms as a guide to locating the problem and directing the end user to the correct procedure for making the repair. Complete the following steps to locate and correct the problem.

(Step 1) Locate the symptom on the Section Contents pages of Section TS.

Reference to the page number where the Troubleshooting Symptom Tree is found is made to the right of the symptom tree title.

(Step 2) The left column of boxes in the Troubleshooting Symptom Charts indicates a probable cause of the problem, starting at the top with the simplest and easiest to repair, and continuing downward to the most difficult.

The right column of boxes provides a brief description of the corrective action with a reference number to the correct procedure used to make the repair.

(Step 3) Locate the probable cause in the left column then turn to the procedure referenced in the right column.

(Step 4) The Troubleshooting Symptom Charts are based on the following assumptions:

1. The engine has been installed according to the manufacturer's specifications.
2. The easiest repairs are done first.
3. "Generic" solutions to cover problems with the most common applications and Original Equipment Manufacturer (OEM).

Symbols

General Information

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

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, an assembly, or the engine can be damaged if the caution instructions are not followed.

Indicates a **REMOVAL** or **DISASSEMBLY** 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**.

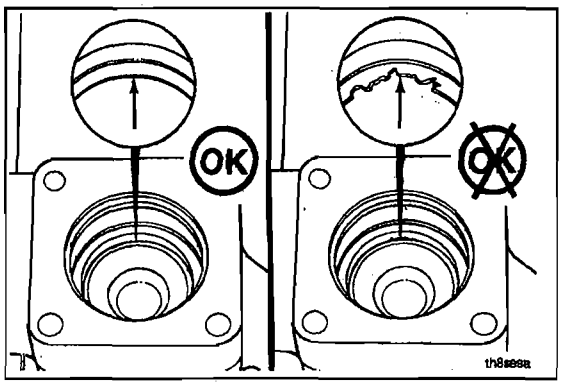
Refer to another location in this manual or another publication for additional information.

The component weighs 23 kg [50 lbs] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component. 17800009

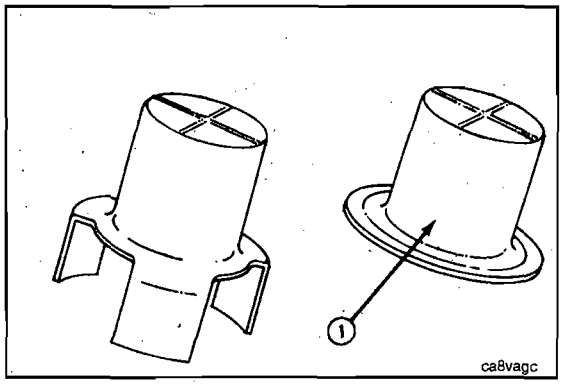
Illustrations

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

⚠ WARNING ⚠

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

Read and understand all of the safety precautions and warnings before performing any repair. This list contains the general safety precautions that **must** be followed to provide personal safety. Special safety precautions are included in the procedures when they apply.

- Work in an area surrounding the product that is dry, well lit, ventilated, free from clutter, loose tools, parts, ignition sources and hazardous substances. Be aware of hazardous conditions that can exist.
- **Always** wear protective glasses and protective shoes when working.
- Rotating parts can cause cuts, mutilation or strangulation.
- Do **not** wear loose-fitting or torn clothing. Remove all jewelry when working.
- Disconnect the battery (negative [-] cable first) and discharge any capacitors before beginning any repair work. Disconnect the air starting motor if equipped to prevent accidental engine starting. Put a "Do **Not** Operate" tag in the operator's compartment or on the controls.
- Use ONLY the proper engine barring techniques for manually rotating the engine. Do **not** attempt to rotate the crankshaft by pulling or prying on the fan. This practice can cause serious personal injury, property damage, or damage to the fan blade(s) causing premature fan failure.
- If an engine has been operating and the coolant is hot, allow the engine to cool before slowly loosening the filler cap to relieve the pressure from the cooling system.
- **Always** use blocks or proper stands to support the product before performing any service work. Do **not** work on anything that is supported ONLY by lifting jacks or a hoist.
- Relieve all pressure in the air, oil, fuel, and cooling systems before any lines, fittings, or related items are removed or disconnected. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do **not** check for pressure leaks with your hand. High pressure oil or fuel can cause personal injury.
- To reduce the possibility of suffocation and frostbite, wear protective clothing and ONLY disconnect liquid refrigerant (Freon) lines in a well ventilated area. To protect the environment, liquid refrigerant systems **must** be properly emptied and filled using equipment that prevents the release of refrigerant gas (fluorocarbons) into the atmosphere. Federal law requires capturing and recycling refrigerant.
- To reduce the possibility of personal injury, use a hoist or get assistance when lifting components that weigh 23 kg [50 lb] or more. Make sure all lifting devices such as chains, hooks, or slings are in good condition and are of the correct capacity. Make sure hooks are positioned correctly. **Always** use a spreader bar when necessary. The lifting hooks **must not** be side-loaded.
- Corrosion inhibitor, a component of SCA and lubricating oil, contains alkali. Do **not** get the substance in eyes. Avoid prolonged or repeated contact with skin. Do **not** swallow internally. In case of contact, immediately wash skin with soap and water. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. IMMEDIATELY CALL A PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.
- Naptha and Methyl Ethyl Ketone (MEK) are flammable materials and **must** be used with caution. Follow the manufacturer's instructions to provide complete safety when using these materials. KEEP OUT OF REACH OF CHILDREN.
- To reduce the possibility of burns, be alert for hot parts on products that have just been turned off, and hot fluids in lines, tubes, and compartments.
- **Always** use tools that are in good condition. Make sure you understand how to use the tools before performing any service work. Use ONLY genuine Cummins or Cummins ReCon® replacement parts.
- **Always** use the same fastener part number (or equivalent) when replacing fasteners. Do **not** use a fastener of lesser quality if replacements are necessary.
- Do **not** perform any repair when fatigued or after consuming alcohol or drugs that can impair your functioning.
- Some state and federal agencies in the United States of America have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.
- Liquified petroleum gas is heavier than air and can accumulate near the floor, in sumps, and low-lying areas.
- Natural gas is lighter than air and can accumulate under hood and awnings.
- To reduce the possibility of suffocation and frostbite, wear protective clothing and ONLY disconnect natural gas and liquified petroleum gas lines in a well ventilated area.
- Coolant is toxic. If **not** reused, dispose of in accordance with local environmental regulations.

General Repair Instructions

General Information

This engine incorporates the latest technology at the time it was manufactured; yet, it is designed to be repaired using normal repair practices performed to quality standards.

- **Cummins Inc. does not recommend or authorize any modifications or repairs to engines or components except for those detailed in Cummins Service Information. In particular, unauthorized repair to safety-related components can cause personal injury or death. Below is a partial listing of components classified as safety-related:**

  Air Compressor
  Air Controls
  Air Shutoff Assemblies
  Balance Weights
  Cooling Fan
  Fan Hub Assembly
  Fan Mounting Bracket(s)
  Fan Mounting Capscrews
  Fan Hub Spindle
  Flywheel
  Flywheel Crankshaft Adapter
  Flywheel Mounting Capscrews
  Fuel Shutoff Assemblies
  Fuel Supply Tubes
  Lifting Brackets
  Throttle Controls
  Turbocharger Compressor Casing
  Turbocharger Oil Drain Line(s)
  Turbocharger Oil Supply Line(s)
  Turbocharger Turbine Casing
  Vibration Damper Mounting Capscrews

- **Follow all safety instructions noted in the procedures**
  - — Follow the manufacturer's recommendations for cleaning solvents and other substances used during the repair of the engine. Some solvents and used engine oil have been identified by government agencies as toxic or carcinogenic. Avoid excessive breathing, ingestion and contact with such substances. **Always** use good safety practices with tools and equipment.
- **Provide a clean environment and follow the cleaning instructions specified in the procedures**
  - — The engine and its components **must** be kept clean during any repair. Contamination of the engine or components will cause premature wear.
- **Perform the inspections specified in the procedures**
- **Replace all components or assemblies which are damaged or worn beyond the specifications**
- **Use genuine Cummins new or ReCon® service parts and assemblies**
  - — The assembly instructions have been written to use again as many components and assemblies as possible. When it is necessary to replace a component or assembly, the procedure is based on the use of new Cummins or Cummins ReCon® components. All of the repair services described in this manual are available from all Cummins Distributors and most Dealer locations.
- **Follow the specified disassembly and assembly procedures to reduce the possibility of damage to the components**

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

Welding on a Vehicle with an Electronic Controlled Fuel System

△ CAUTION △

Disconnect both the positive (+) and negative (-) battery cables from the battery before welding on the vehicle. Attach the welder ground cable no more than 0.61 meters [2 feet] from the part being welded. Do not connect the ground cable of the welder to the ECM cooling plate or ECM. Welding on the engine or engine mounted components is not recommended or damage to the engine or components can result.

General Cleaning Instructions

Solvent and Acid Cleaning

Several solvent and acid-type cleaners can be used to clean the engine parts. Experience has shown that the best results can be obtained using a cleaner that can be heated to 90 to 95 degrees Celsius [180 to 200 degrees Fahrenheit]. 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 ⚠

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

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

If the parts are **not** to be used immediately after cleaning, dip them in a suitable rustproofing compound. The rustproofing compound **must** be removed from the parts before 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 way to clean the oil drillings.

⚠ 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 parts:

1. Electrical Components
2. Wiring
3. Injectors
4. Fuel Pump
5. Belts and Hoses
6. Bearings
7. Electronic Control Module (ECM)
8. ECM Connectors

Glass or Plastic Bead Cleaning

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

△ CAUTION △

Do not use glass or plastic bead cleaning on aluminum piston skirts. Do not use glass bead cleaning on aluminum ring grooves. Small particles of glass or plastic will embed in the aluminum and result in premature wear. Valves, turbocharger shafts, etc., can also be damaged. Follow the cleaning directions listed in the procedures.

NOTE: Plastic bead blasting media, Part No. 3822735, can be used to clean aluminum ring grooves. Do **not** use any bead blasting media on pin bores or aluminum skirts.

Follow the equipment manufacturer's cleaning instructions. The following guidelines can be used to adapt to manufacturer's instructions:

1. Bead size:
   a. Use U.S. size No. 16-20 for piston cleaning with plastic bead media, Part No. 3822735.
   b. Use U.S. size No. 70 for piston domes with glass media.
   c. Use U.S. size No. 60 for general purpose cleaning with glass media.
2. Operating Pressure:
   a. Glass: Use 620 kPa [90 psi] for general purpose cleaning.
   b. Plastic: Use 270 kPa [40 psi] for piston cleaning.
3. Steam clean or wash the parts with solvent to remove all of the foreign material and glass or plastic beads after cleaning. Rinse with hot water. Dry with compressed air.
4. Do **not** contaminate the wash tanks with glass or plastic beads.

Acronyms and Abbreviations

General Information

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

API	American Petroleum Institute
ASTM	American Society of Testing and Materials
°C	Celsius
CARB	California Air Resources Board
C.I.D.	Cubic Inch Displacement
CNG	Compressed Natural Gas
CPL	Control Parts List
cSt	Centistokes
ECM	Electronic Control Module
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
°F	Fahrenheit
FMI	Failure Mode Indentifier
GVW	Gross Vehicle Weight
LPG	Liquified Petroleum Gas
Hg	Mercury
hp	Horsepower
H_2O	Water
ICM	Ignition Control Module
km/l	Kilometers per Liter
kPa	Kilopascal
LNG	Liquid Natural Gas
LTA	Low Temperature Aftercooling
MPa	Megapascal
mph	Miles Per Hour
mpq	Miles Per Quart
N•m	Newton-meter
NG	Natural Gas
OEM	Original Equipment Manufacturer
PID	Parameter Identification Descriptions
ppm	Parts Per Million
psi	Pounds Per Square Inch
PTO	Power Takeoff
rpm	Revolutions Per Minute
SAE	Society of Automotive Engineers
SCA	Supplemental Coolant Additive
STC	Step Timing Control
SID	Subsystem Identification Descriptions
VS	Variable Speed
VSS	Vehicle Speed Sensor

Section E - Engine and System Identification

Section Contents

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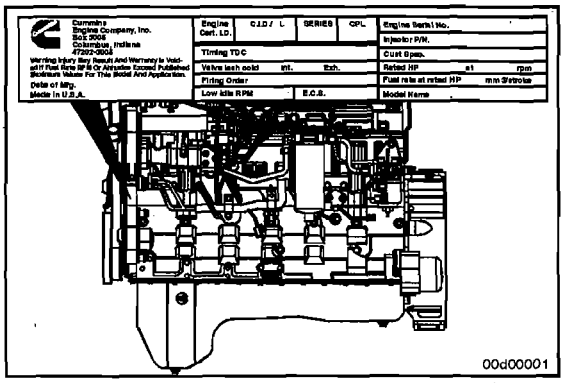
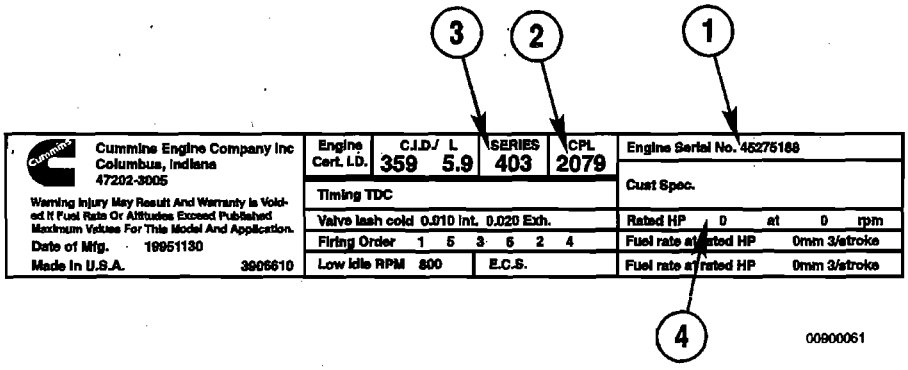
Engine Identification

Engine Dataplate

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

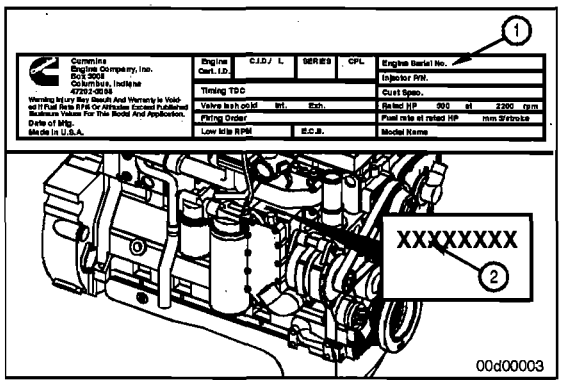




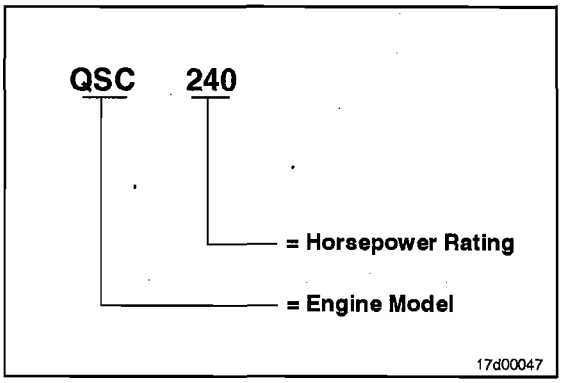
The dataplate is located on the top side of the gear housing.

Have the following engine data available when communicating with a Cummins Authorized Repair Location:

1. Engine serial number (ESN)
2. Control parts list (CPL)
3. Model
4. Horsepower and rpm rating.

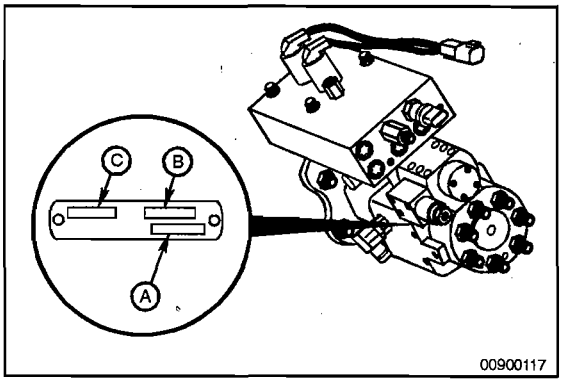


NOTE: If the engine dataplate (1) is **not** readable, the ESN (2) can be found on the engine block on top of the lubricating oil cooler housing. Additional engine information is on the electronic control module (ECM) dataplate.



Cummins Engine Nomenclature

The Cummins engine nomenclature provides the engine model and horsepower rating.



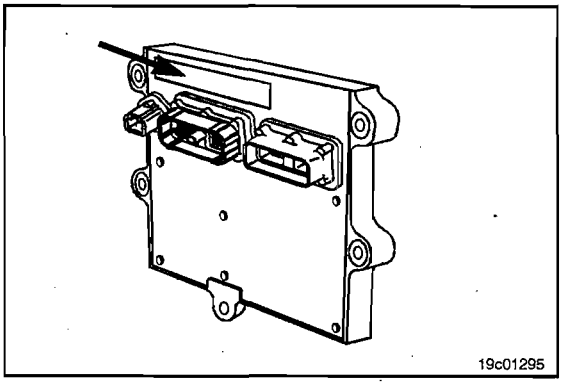
Fuel Injection Pump Dataplate

The Cummins Accumulator Pump System (CAPS) fuel injection pump dataplate is located on the side of the injection pump. The dataplate contains the following information:

A. Cummins part number

B. Pump serial number

C. Factory code.



ECM Dataplate

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

The following information is found on the ECM dataplate:

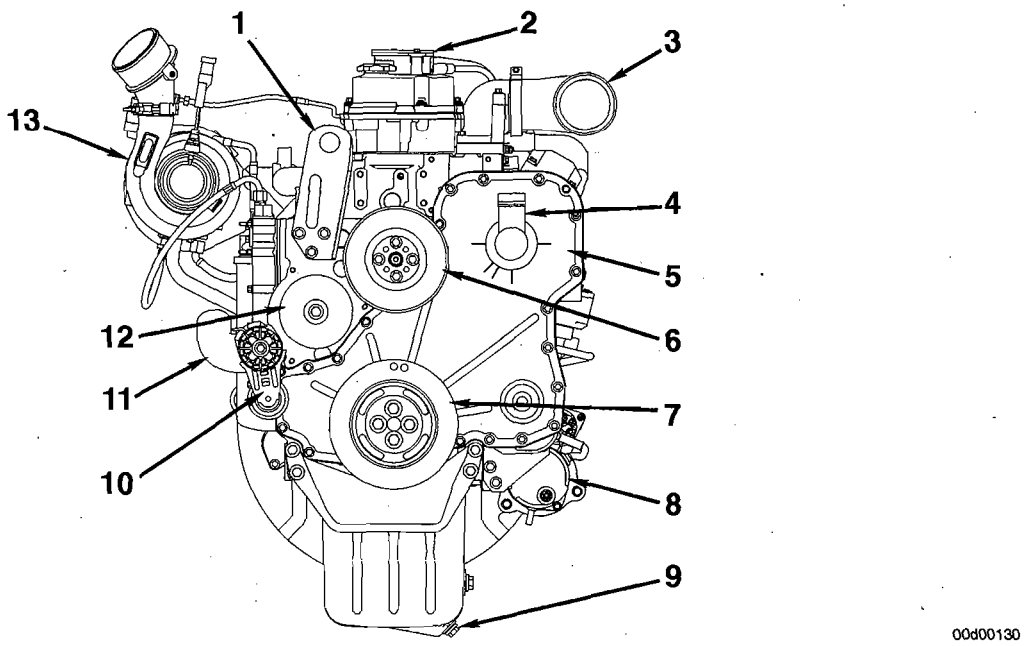
- ECM part number (PN)
- ECM serial number (SN)
- ECM date code (DC)
- Engine serial number (ESN)
- ECM Code (identifies the software in the ECM).

Engine Diagrams

Engine Views

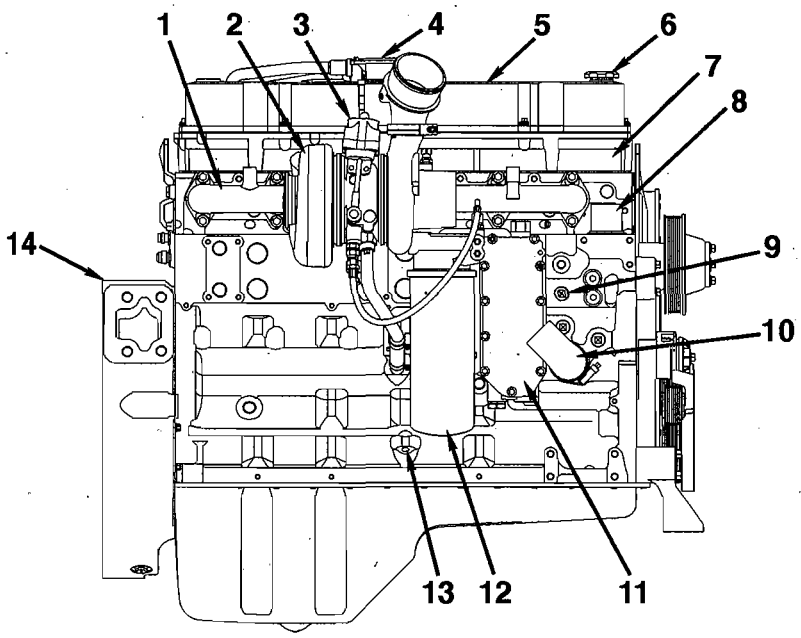
The following illustrations provide the locations of the major external engine components, filters, and other service and maintenance points. Some external components will be at different locations for different engine models.

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



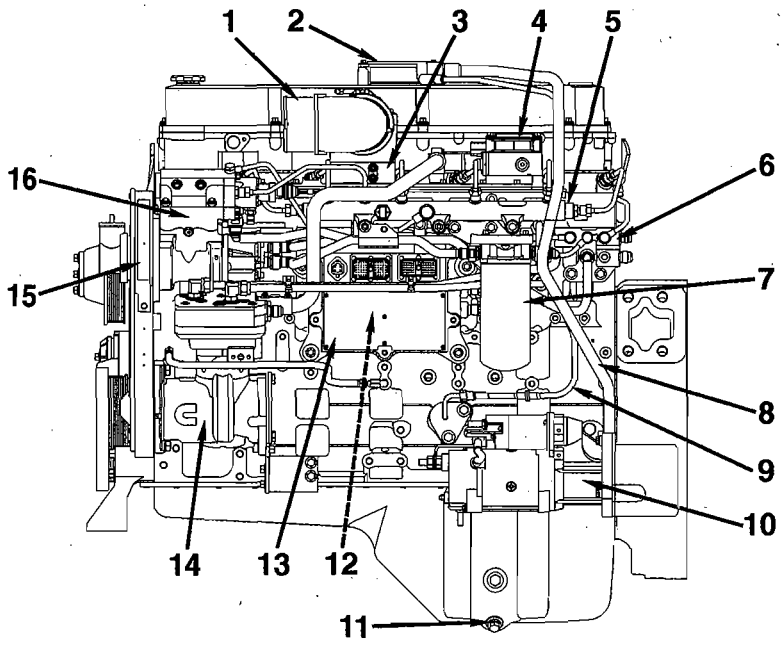
Front Engine View (CM850 Electronic Control Module)

1. Engine lifting bracket
2. Crankcase breather
3. Air intake connection
4. Engine oil fill
5. Front gear cover
6. Fan pulley
7. Vibration Damper
8. Starter
9. Engine oil pan drain plug
10. Automatic belt tensioner
11. Coolant inlet connection
12. Water pump
13. Turbocharger (VGT shown)



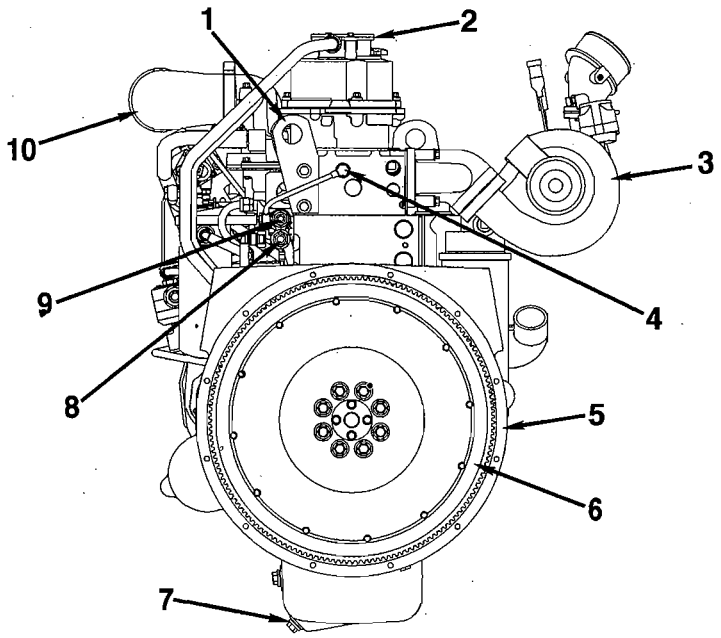
Exhaust Side Engine View (CM850 Electronic Control Module)

1. Exhaust manifold
2. Turbocharger (VGT shown)
3. Variable geometry turbocharger actuator
4. Crankcase breather
5. Rocker lever cover
6. Engine oil fill
7. Rocker lever housing
8. Coolant outlet connection
9. Coolant heater port
10. Coolant inlet connection
11. Lubricating oil cooler
12. Lubricating oil filter
13. Dipstick location
14. Flywheel housing



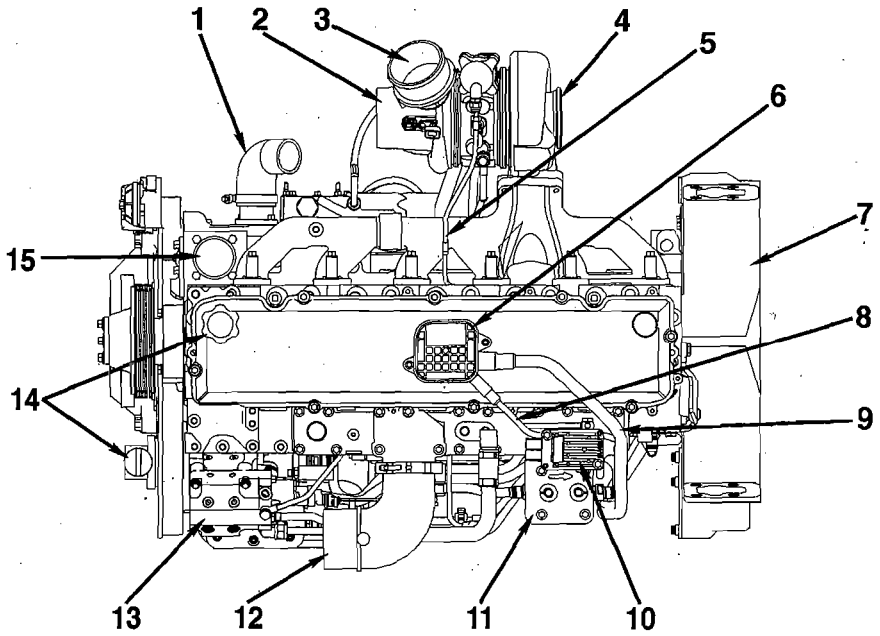
Intake Side Engine View (CM850 Electronic Control Module)

1. Air intake connection
2. Crankcase breather
3. Intake air heater
4. Turbocharger control valve
5. Fuel rail
6. Fuel drain manifold
7. Fuel filter
8. Crankcase breather draft tube
9. Crankcase breather oil drain tube
10. Starter
11. Engine oil drain plug
12. Fuel lift pump
13. Electronic control module (ECM)
14. Air compressor
15. Engine data plate
16. High-pressure pump



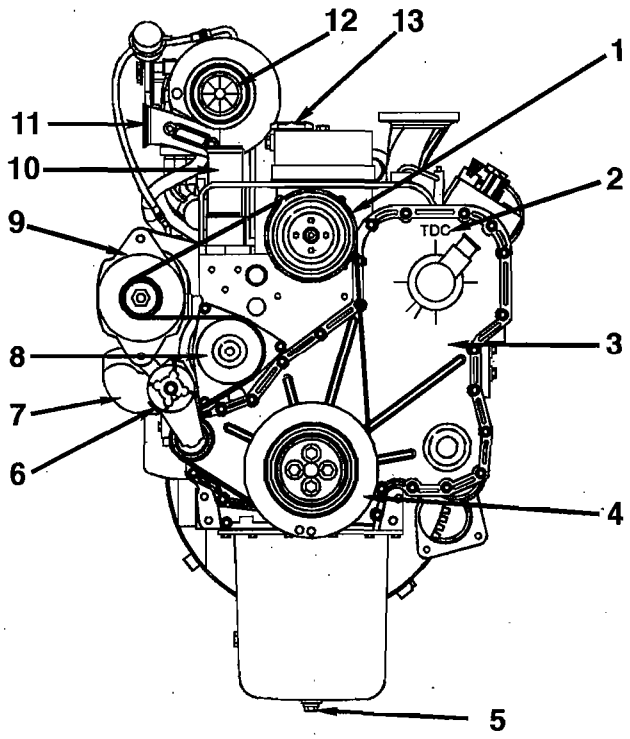
Rear Engine View (CM850 Electronic Control Module)

1. Engine lifting bracket
2. Crankcase breather
3. Turbocharger (VGT shown)
4. Injector drain line connection
5. Flywheel housing
6. Flywheel
7. Engine oil drain plug
8. OEM fuel supply line connection
9. OEM fuel drain line connection
10. Air intake connection



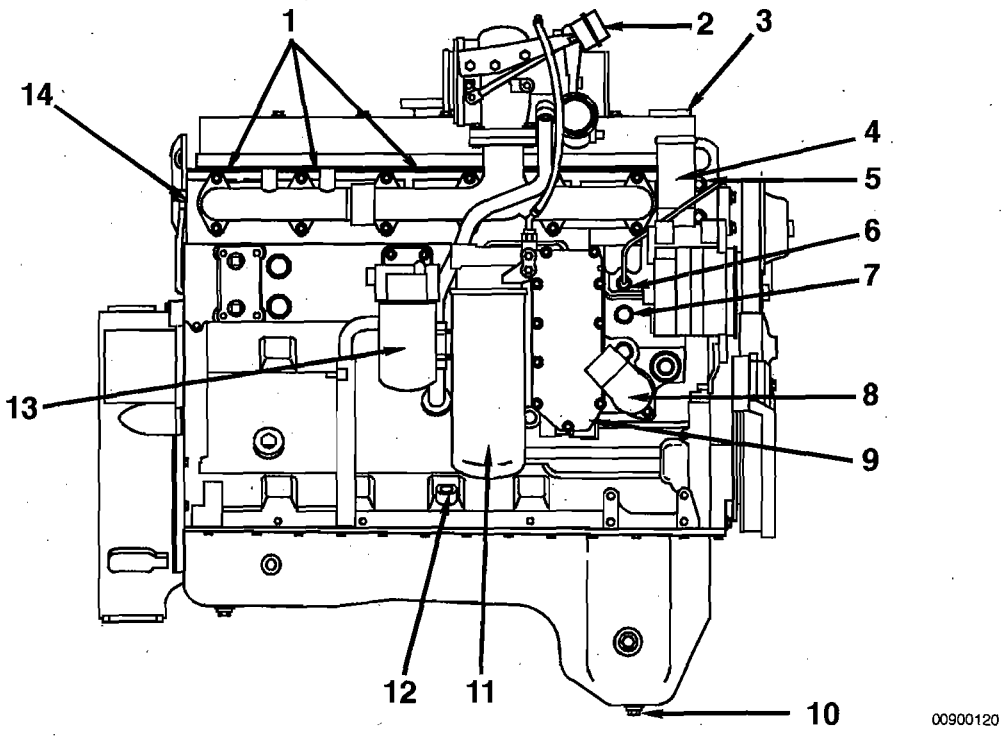
Top Engine View (CM850 Electronic Control Module)

1. Coolant inlet connection
2. Turbocharger air inlet
3. Turbocharger air outlet
4. Turbocharger exhaust outlet
5. Turbocharger actuator air line
6. Crankcase breather
7. Flywheel housing
8. Crankcase breather oil drain tube
9. Crankcase breather draft tube
10. Turbocharger control valve
11. Fuel filter bracket
12. Air inlet connection
13. High-pressure pump
14. Engine oil fill
15. Coolant outlet connection



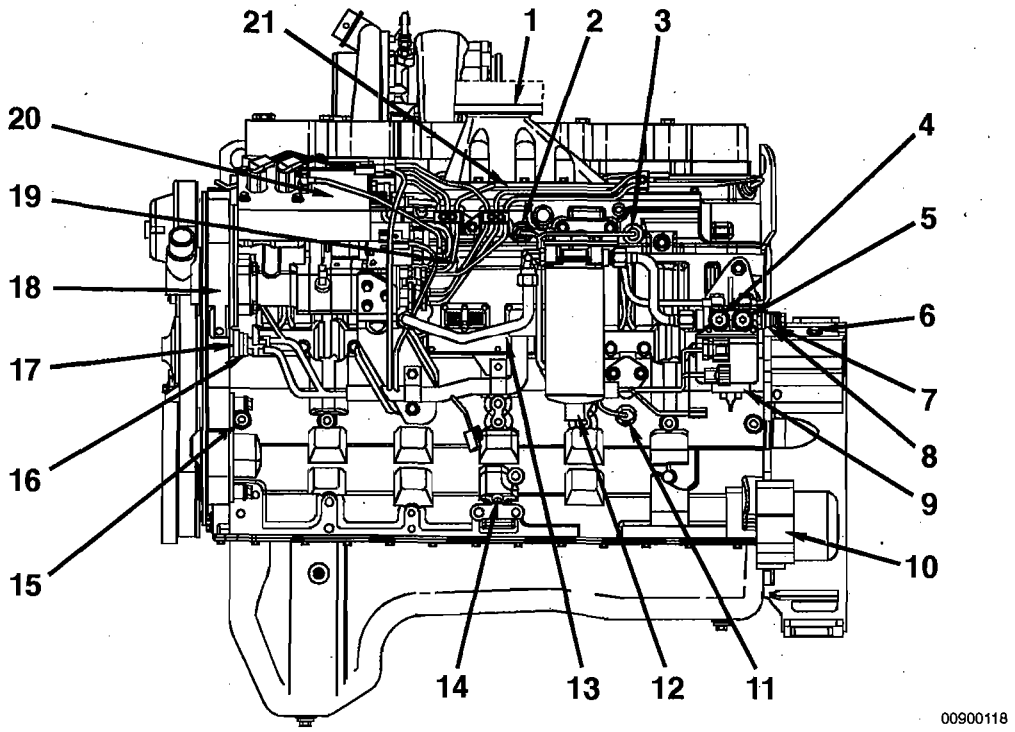
Front View (Without CM850 Electronic Control Module)

1. Fan pulley
2. Top dead center (TDC) mark
3. Front gear cover
4. Vibration damper
5. Engine oil pan drain plug
6. Automatic belt tensioner
7. Water inlet
8. Water pump
9. Alternator
10. Water outlet
11. Turbocharger air outlet
12. Turbocharger air inlet
13. Engine oil fill



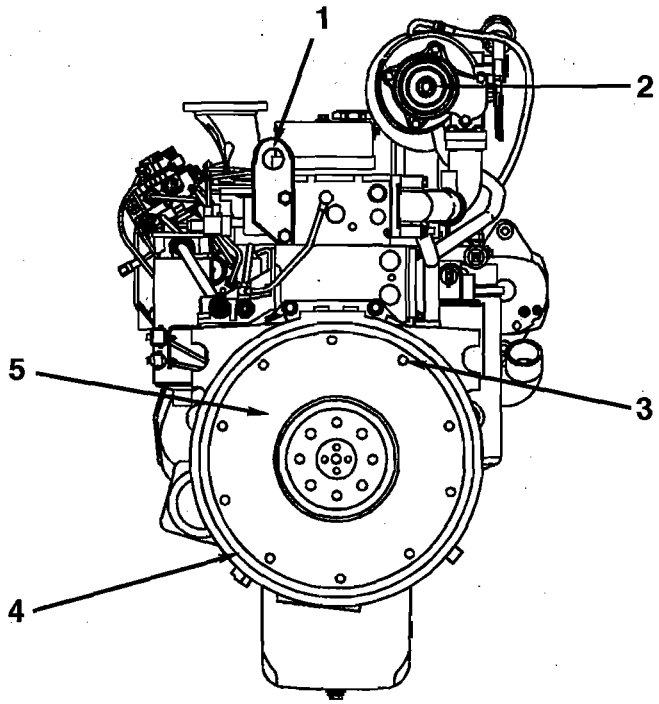
Exhaust Side View (Without CM850 Electronic Control Module)

1. 1/2-inch (NPTF) coolant taps
2. Turbocharger wastegate actuator
3. Engine oil fill
4. Coolant outlet
5. Front engine lifting bracket
6. Coolant temperature sensor
7. Coolant heater port
8. Coolant inlet
9. Lubricating oil cooler
10. Engine oil pan drain plug
11. Lubricating oil filter
12. Dipstick location
13. Coolant filter
14. Injector drain fuel outlet connection



Fuel Pump Side View (Without CM850 Electronic Control Module)

1. Engine air inlet
2. Intake manifold pressure sensor
3. Intake manifold temperature sensor
4. M10 (STOR) fuel pressure after-lift pump
5. M10 (STOR) fuel pressure before-lift pump
6. Magnetic pickup location 3/4-16 UNF
7. Fuel return connection
8. Fuel inlet connection
9. Fuel lift pump
10. Starter mounting flange
11. Oil pressure sensor
12. Fuel filter/water separator
13. Electronic control module (ECM)
14. Dipstick location
15. M10 (STOR) oil pressure port
16. Engine position sensor (EPS) - (inboard)
17. Engine speed sensor (ESS) - (outboard)
18. Engine dataplate
19. High-pressure fuel lines
20. Cummins Acumulator Pump System (CAPS) injection pump
21. Intake air heater



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Rear View (Without CM850 Electronic Control Module)

1. Rear engine lifting bracket
2. Turbocharger exhaust outlet
3. Clutch mounting holes
4. Flywheel housing
5. Flywheel

Section F - Familiarization

Section Contents

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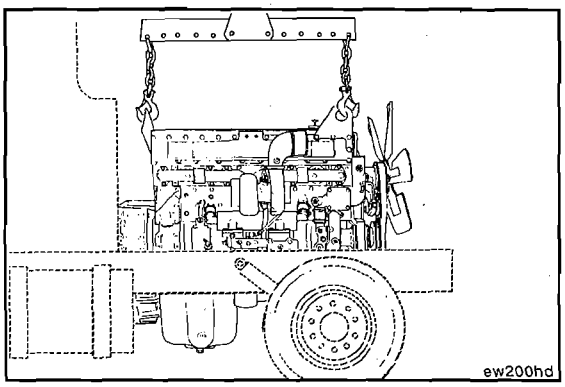
Complete Engine - Overview

General Information

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

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

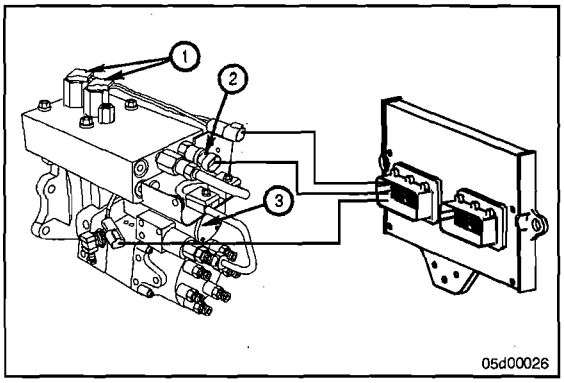


Fuel System - Overview

General Information

CAPS Fuel System

The CAPS fuel system is a distributor-type injection system. CAPS stands for Cummins Accumulator Pump System. An accumulator is used to store pressurized fuel for the injection event. There are four components that provide or receive input to the electronic control module (ECM). There are two pumping control valves (1) that are controlled by the ECM. These valves control the pressure in the accumulator. The accumulator fuel pressure/temperature (2) sensor is located on the accumulator and provides the ECM with pressure and temperature information. The injection control valve (3) is also controlled by the ECM and regulates fuel injected into the cylinder.



The CAPS injection pump can be divided into six distinct units/modules. They are the gear pump, cam housing, accumulator, rate shape tube, injection control valve (ICV), and distributor. Fuel flows through the modules in the following order:

gear pump - 5

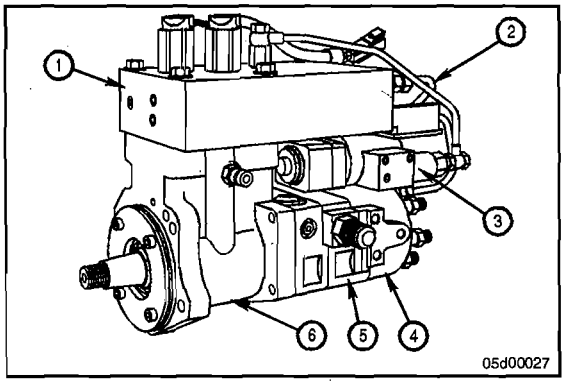
cam housing - 6

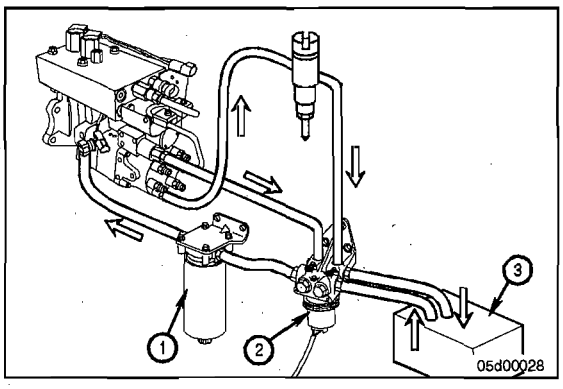
accumulator - 1

rate shape tube - 2

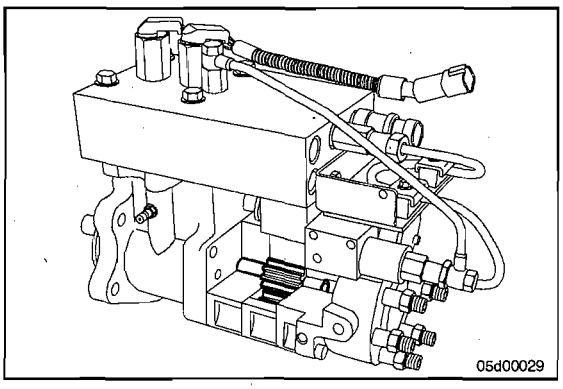
injector control valve (ICV) - 3

distributor - 4.

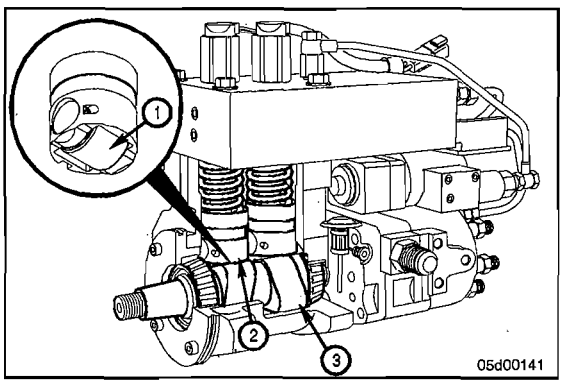




A lift pump is used for priming the pump at start-up. The lift pump runs for approximately 30 seconds after key-on. Once the engine is started, the gear pump is able to maintain prime without any assistance from the lift pump.

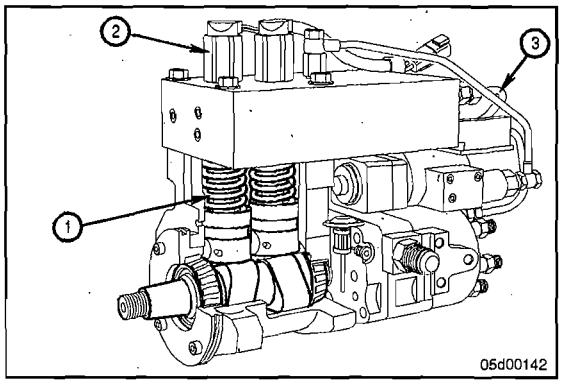


The gear pump supplies fuel to the pumping plungers through internal drillings in the cam housing. The gear pump also supplies fuel to the distributor for lubrication. The fuel pressure is regulated to approximately 160 psi at rated engine rpm. The gear pump has an internal filter to catch any debris generated downstream of the main, external fuel filter. The pump camshaft is driven off the engine camshaft; therefore, pump rpm is one-half engine rpm. The gear pump is driven by the pump camshaft through an internal coupling. The gear pump shaft then turns the distributor rotor through a second internal coupling.

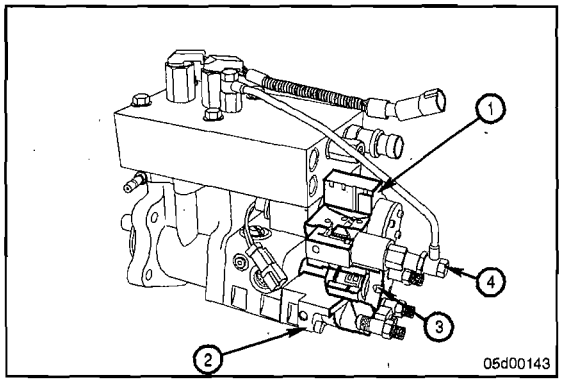


Each of the two pumping plungers is driven by a three lobed camshaft (3). The camshaft is located in the cam housing module by tapered roller bearings. The bearings that support the camshaft, as well as the tappets (2), rollers (1), and camshaft itself are lubricated with engine oil. These are the **only** components in the pump lubricated with engine oil.

A pumping control valve (2) is located above each pumping plunger (1). The supply fuel from the gear pump flows around the plunger of this normally open valve into the chamber above the plunger. The volume above each pumping plunger is filled, by the gear pump, as the plungers travel downward. As the plunger starts to move upward, the fuel is pushed backward into the gear pump. When the pumping control valve closes, the fuel is pushed into the accumulator and then held by check valves. The time when the pumping control valve is energized (closed) is based on engine speed, accumulator pressure, and throttle position. A 0- to 24,000-psi pressure sensor is located in the accumulator. The pressure sensor provides direct feedback to the ECM, so the desired accumulator pressure is maintained. This pressure sensor also has temperature sensing capabilities built into it. Fuel moves from the accumulator to the distributor and through the rate shape tube (3).



Fuel is delivered to the injection control valve (1) by the rate shape tube and through a drilling in the distributor (2). The ICV controls both fueling and timing. The injection control valve contains an inner pin and outer valve. The outer valve is moved by magnetic force generated inside the ICV by a current from the ECM. The inner pin is moved by spring force and fuel pressure. When the two pins are in the closed position, no fuel flows through the control valve. The position of these internal parts controls fuel flow to the distributor rotor (3) and to the drain (4). The injection control valve opens and closes once for each injection event.



The distributor (1) directs the fuel to the correct injector using the rotor. The drain fuel from the ICV is routed through the ICV pressure regulator (4) and is returned to the tank.

The position of the rotor directs the fuel to one of six drillings in the distributor housing. These drillings communicate the fuel to six fuel pump delivery valves (3). There is one injector line per delivery valve. The injection line carries the fuel to the injector.