


Light Vehicle Diesel Engines
First Edition

Light Vehicle Diesel Engines



Chapter 24
CUMMINS Diesel Engines

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ALWAYS LEARNING

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JAMES D. HALDERMAN
CURT WARD

LEARNING OBJECTIVES (1 of 1)

24.1 Prepare for the Light Vehicle Diesel Engine (A9) ASE certification test content area “A” (General Diagnosis).

24.2 Explain the unique features of each generation of 5.9-liter Cummins engines used in the Ram truck.

24.3 List the specific characteristics of the Cummins 6.7-liter engine.

24.4 Discuss the Cummins 5.0-liter engine used in the Nissan Titan.

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BACKGROUND CUMMINS 5.9/6.7-LITER ENGINE

- **1ST Generation 5.9L**
 - Ram pickup truck from 1989 to 1993
 - 5.9-liter (360.0 cu in) (6BT), “B” series
 - Produced more torque & better fuel economy
- **2nd Generation 5.9L 1994–2002 ISB (INTERACT)**
 - Major changes 998.5 model year
 - Cylinder head configuration went
 - From 2 valves per cylinder to 4 valves
- **3rd Generation Cummins 5.9L/6.7L 2002–2009**
 - ISB CR
- **4th Generation Cummins 6.7L 2010 & Later**
 - See Chart 24-4

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CHART 24-1 First generation Cummins diesel engine used in a pickup truck.

Configuration	Inline 6-cylinder direct injected diesel engine
Displacement	5.9 liters (359 cu. in.)
Bore	102 mm (4.02 inches)
Stroke	120 mm (4.72 inches)
Cylinder block	Cast iron (bores machined in the block rather than using wet cylinder liners as used in most diesel engines previously)
Cylinder head	Cast iron (Two valves per cylinder)
Valve train	Cam-in-block (assembled camshaft)
Compression ratio	17.2:1
Firing order	1-5-3-6-2-4
Horsepower	160 HP
Torque	400 lb.-ft
High-pressure fuel pump	Bosch VE44-rotary
Intake air heater	Intake manifold electric grid heater
Turbocharger	Holset turbocharger (intercooler 1991+)

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CHART 24-2 second generation Cummins diesel engine used in Ram pickup.

Configuration	Inline 6-cylinder direct injected diesel engine
Bore	102 mm (4.02 inches)
Stroke	120 mm (4.72 inches)
Block	Cast iron
Cylinder head	Cast iron 1994-1998 models – two valves per cylinder 1998.5-2002 models – four valves per cylinder
Compression ratio	17.2:1
Horsepower	175-240 depending on model year (Manual transmission-equipped trucks had a higher rating than trucks equipped with an automatic transmission)
Torque	420-505 depending on model year (Manual transmission-equipped trucks had a higher rating than trucks equipped with an automatic transmission)
High-pressure fuel pump	1994-1998 models: P7100 1998.5-2002 models: VP44
Intake air heater	Intake manifold electric grid

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CHART 24-3 Third generation Cummins engine used in Ram trucks.

Configuration	Inline 6-cylinder
Aspiration	Turbocharged Inner-cooled MY91.5+
Displacement	5.9-liter – 359 cu in. 6.7-liter – 408 cu in.
Block	Cast iron
Cylinder head	Cast iron
Horsepower	305-350 depending on model year
Torque	555-650 lb-ft depending on model year
High-pressure fuel system	HPCR

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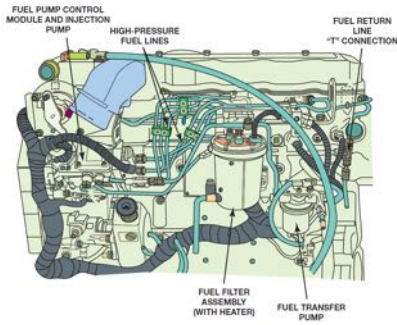
CHART 24-4 6.7-liter Cummins engine used in a pickup or chassis cab model.

Configuration	Inline 6 cylinder
Aspiration	Turbocharged, air cooled
Bore and stroke	107mm (4.21 in.) × 124mm (4.88 in.)
Displacement	6.7-liters (408 cu. in.)
Injection order	1-5-3-6-2-4
Compression ratio	17.3:1
Cooling system capacity	Refer to Service Information
Oil capacity with filter	11.4-liters (12 quarts)
Oil filter	Spin on cartridge type
Engine rotation	Clockwise, viewed from front of engine
Maximum power	350-385 HP @ 2900 RPM based on model year
Peak torque	650-865 lb.-ft. based on model year
Weight (wet, with oil)	507 kg (1,117 lbs.)

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FIGURE 24-1 Cummins inline 6-cylinder diesel engine



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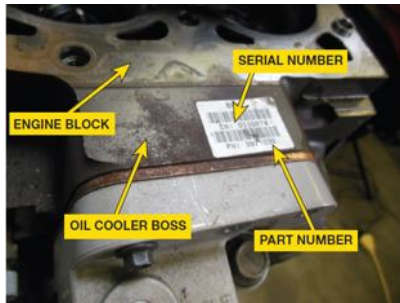
ISB 6.7 ENGINE DETAILS

- **Engine Identification**
 - Data plate on valve cover
 - Engine serial number on top of engine oil cooler boss.
 - Low ash 15W-40 diesel oil CJ-4 for aftertreatment system
- **Coolant**
 - HOAT MS-9769. Do not mix
- **Lower Engine: See Page 292 of text**
- **Upper Engine: See Page 292 of text**
- **Timing System: See Page 294 of text**
- **Air Induction System: See Page 294 of text**

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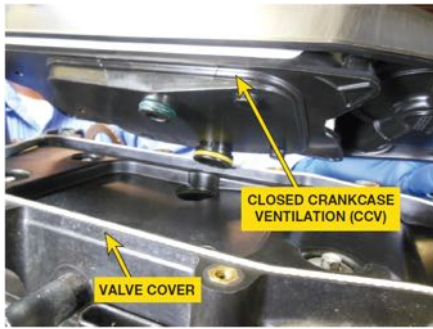
FIGURE 24–2 label on oil cooler boss identifies engine serial number and part number.



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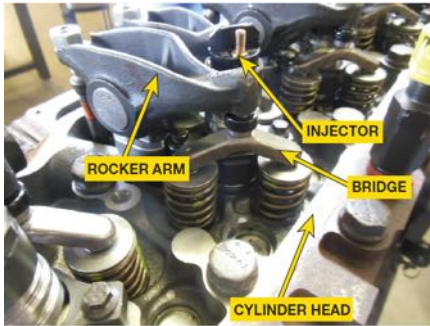
FIGURE 24–3 breather cover must be removed to service CCV filter.



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FIGURE 24–4 push rod and rocker arm bridge assembly must be carefully installed to ensure proper valve operation.



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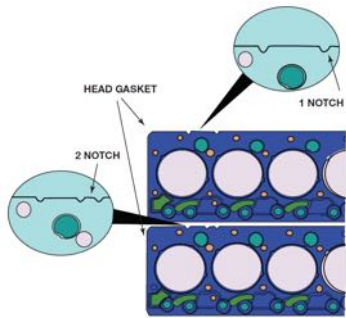
What Do the Markings on the Head Gasket Mean?

? FREQUENTLY ASKED QUESTION

Head gaskets are multilayer steel (MLS) gaskets and marked to indicate thickness. One notch on edge of gasket means that it is designed to be used when the cylinder head has been machined 0.001 inch (0.25 mm). If cylinder head has been machined 0.002 inch (0.50 mm), then head gasket with a 2ND notch needed. • SEE FIGURE 24-5

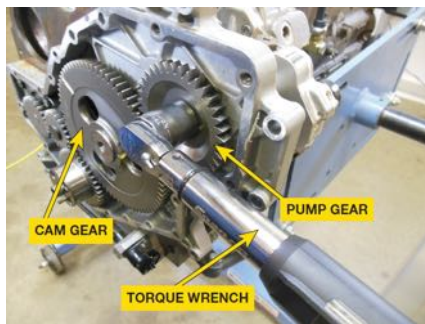
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FIGURE 24-5 markings on head gasket indicates thickness and unless engine has been machined, same thickness head gasket should be installed when reassembling engine.



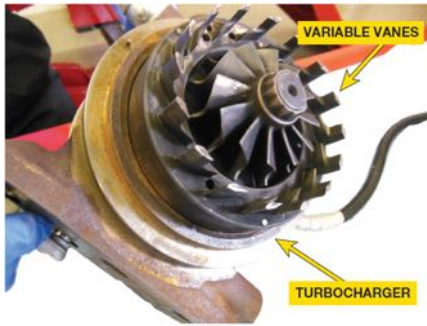
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FIGURE 24-6 gears are properly timed and torqued.



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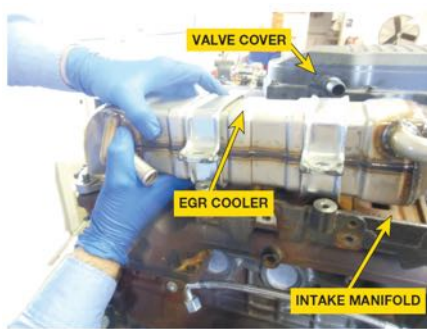
FIGURE 24-7 angle of vanes is varied to regulate boost pressure



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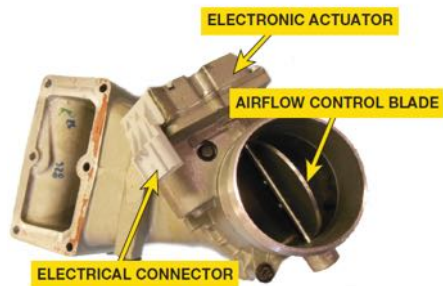
FIGURE 24-8 EGR cooler lowers exhaust gas temperatures. Cooled EGR gases allow for a greater reduction of NOx emissions.



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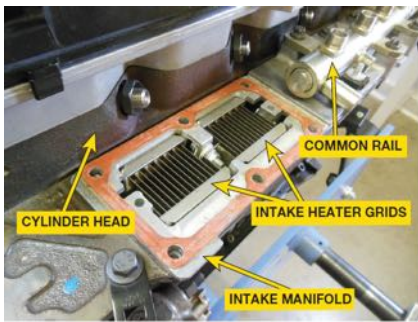
FIGURE 24-9 default position of airflow control blade is wide open.



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FIGURE 24–10 intake heater grids are serviced together after airflow control valve assembly is removed from intake manifold.



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ISB 6.7 ENGINE LOW-PRESSURE FUEL SYSTEM

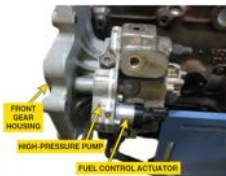
- **Fuel Tank**
 - Single tank with 52-gallons
 - Dual tank fuel 74 gallons
- **Fuel Pump Module: Inside Fuel Tank**
 - Internal fuel filter, pressure regulator
 - Electric fuel pump, sending unit
- **Fuel Filter Assembly**
 - Engine-mounted filter assembly
 - Dual element filter and fuel heater

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ISB 6.7 ENGINE HIGH PRESSURE FUEL SYSTEM (1 of 3)

- **High-Pressure Pump**
 - Bosch CP-3 high-pressure pump
 - 3 piston pump attached to timing gear housing
 - Driven by camshaft
 - Delivers 4,351–26,107 PSI to fuel rail as needed
 - Equipped with **Fuel Control Actuator (FCA)**
 - Limit amount of fuel that flows into high-pressure pump



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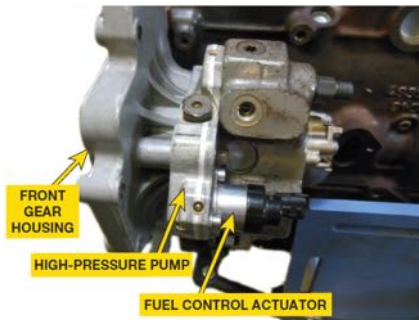
WARNING

High-pressure fuel lines deliver fuel under extreme pressures. Use extreme caution when looking for leaks as fuel under pressure may penetrate the skin, causing injury or death.

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FIGURE 24–11 high-pressure fuel pump is timed to camshaft and provides the needed pressure to common rail.

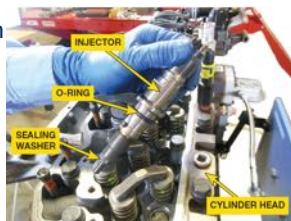


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ISB 6.7 ENGINE HIGH PRESSURE FUEL SYSTEM (2 of 3)

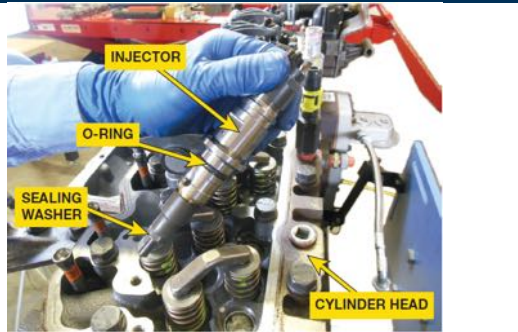
- **Injectors on 6.7-liter**
 - Solenoid controlled high-pressure common rail injectors
 - **Injector Operation:**
 - **Page 296**



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FIGURE 24–12 injector is sealed to cylinder head with an O-ring and a sealing washer.

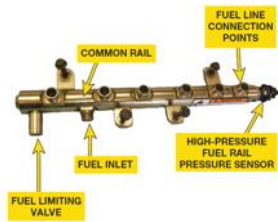


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ISB 6.7 ENGINE HIGH PRESSURE FUEL SYSTEM (3 of 3)

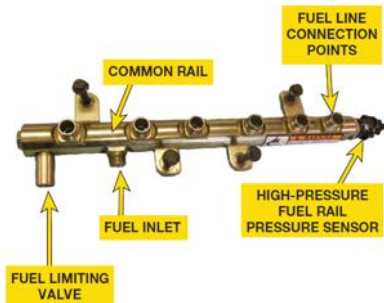
• Fuel Rail

- Mounting point for fuel pressure limiting valve
 - Fuel pressure sensor & feed to each injector
- Fuel pressure limiting valve regulates pressure in rail
- Fuel pressure sensor provides PCM with feedback
- Control high-pressure fuel system pressure



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FIGURE 24–13 common rail stores high-pressure fuel and serves as mounting point for fuel pressure sensor.



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Case of the P0251 DTC (1 of 3)



REAL WORLD FIX

2010 Cummins 6.7-liter diesel complained that truck would lose power when hauling a heavy load and MIL on. Stored P0252 DTC (injection pump metering control A). A previous shop replaced fuel control actuator (FCA), and on a second repair, replaced electrical plug connector to the FCA . Different shop had previously replaced high-pressure pump (CP3). Code sets when output pressure from high-pressure pump does not match commanded pressure. E.G. normal operation includes following pressures: At idle speed, the fuel pressure will be about 5,000 PSI. During normal cruise conditions, the pressure will increase to about 10,000 PSI. If the truck is subjected to high loads, such as accelerating with a heavy load or driving up a steep grade, the pressure can be 23,000 PSI or higher.

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Case of the P0251 DTC (2 of 3)



REAL WORLD FIX

If fuel pressure does not reach commanded valve, then P0251 sets. In this case, a scan tool was used to monitor duty cycle of regulator and found that duty cycle was increasing when pressure was dropping. This indicated that regulator was trying to correct pressure, but was not able to. In this case, the most likely parts had already been replaced. A search for why pressure was dropping resulted in loose transfer tubes. These tubes carry high-pressure fuel from rail to injectors. If leaking, it would be at connection in injector end of tube. This leak would not be seen externally, but would instead show up as an increased fuel flow on return side of system. Replacing transfer tubes solved loss of pressure, and code was cleared and did not return.

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Case of the P0251 DTC (3 of 3)



REAL WORLD FIX

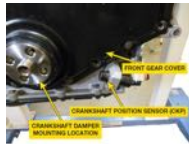
- **Summary:**
- **Concern**—owner of a Ram truck stated that it would lose power when hauling a heavy load and the MIL was on.
- **Cause**—Loose transfer tubes between the fuel rail and the injectors caused a P0251 DTC to be set.
- **Correction**—Replacement of the transfer tubes corrected the loss of pressure.

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CONTROL SYSTEM INPUTS

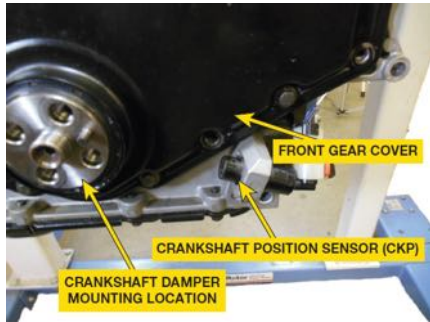
- **Page 298 of text**
 - Crankshaft Position Sensor
 - Camshaft Position Sensor
 - Boost Pressure Sensor
 - Engine Coolant Temperature Sensor
 - Mass Air Flow Sensor
 - Used for EGR not fuel control



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FIGURE 24–14 crankshaft position sensor is mounted on front of engine near crankshaft damper.

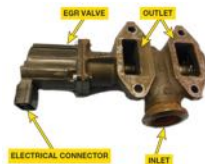


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ENGINE OUTPUTS

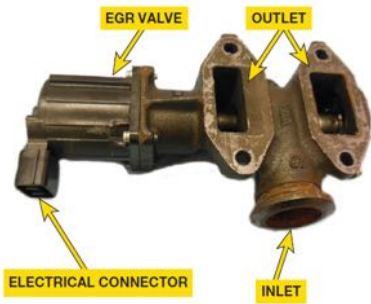
- **Page 299 of text**
 - Exhaust Gas Recirculation Valve (EGR)
 - Intake Air Flow Control Valve
 - EGR Cooler Bypass Valve
 - Turbocharger Actuator
 - Injectors



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FIGURE 24–15 EGR valve meters exhaust gasses into intake manifold to lower combustion temperatures and pressures.



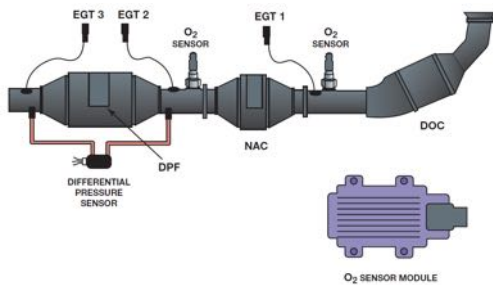
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CUMMINS 6.7-LITER DIESEL AFTERTREATMENT SYSTEM (1 of 2)

- **Aftertreatment System Controls:**
 - Non-methane hydrocarbons (NMHC)
 - Carbon monoxide (CO)
 - Oxides of nitrogen (NOx)
 - Particulate matter (PM)
- **Pages 299-300 of text**
 - Diesel Oxidation Catalyst
 - Diesel Particulate Filter
 - Selective Catalytic Reduction System (SCR)
 - Diesel Exhaust Fluid (DEF) Tank & Injector

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FIGURE 24–16 aftertreatment system reduces the levels of hydrocarbons, carbon monoxide, oxides of nitrogen, and particulate matter to meet emission regulations.



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CUMMINS 6.7-LITER DIESEL AFTERTREATMENT SYSTEM (2 of 2)

• DEF Warning System

- Messages displayed on instrument cluster
- 3 levels of warning when fluid is low or incorrect
 - **First warning will occur at 3 gallons left**
 - Message will read **LOW DEF REFILL SOON**
 - **Second warning at 2 gallons left**
 - REFILL DEF ENGINE NOT START IN XXX MILES.
 - **Third warning at 0.7 gallons of fluid left**
 - REFILL DEF ENGINE WILL NOT START
 - Driver must add at least 2.5 gallons of DEF before vehicle will restart

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CUMMINS 5.0-LITER V-8 ENGINE (1 of 2)

• 2016 Model Year 5.0-liter Cummins Engine

- Option in Nissan Titan "XD"
- V8 common rail
- 0° overhead valve design
- compacted graphic iron block
- Aluminum cylinder heads
- 4 valves per cylinder,
- Dual overhead camshafts
- Hydraulic valve lash adjusters
- Dual-stage turbocharger
- Charge air cooler



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FIGURE 24-17 Cummins 5.0-liter V-8 diesel engine.



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CHART 24-5 Cummins 5.0-liter engine used in the Nissan Titan.

Cylinder configuration	90° V-block
Number of cylinders	8
Displacement	5.0 liters (305 CID)
Bore	3.701 in. (94mm)
Stroke	3.622 in. (92mm)
Compression ratio	16.3:1
Valves per cylinder	4
Dry weight	362 kg (800 lbs.)
Maximum power	210 hp. (156 kW) @1200 RPM
Maximum torque	555 lbs./ft. (745 Nm) @1600 RPM
Block configuration	Compacted graphite iron
Cylinder head	Aluminum DOHC
Valve train	DOHC with chain drive
Fuel system	High-pressure common rail with a CP 4.2 pump
Air charge system	Dual Stage M-2 turbocharging with charge air cooler
Engine preheat	Ceramic glow plug
Engine rotation	Clockwise, viewed from front cover
Target idle	700 RPM
Turbocharger	Single variable geometry turbocharger
Aftertreatment	DOC + DPF + SCR
Emissions	TIER 2 BIN 3 (FEI) LEV3-LEV (CA)

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CUMMINS 5.0-LITER V-8 ENGINE (2 of 2)

- **Pages 300-301 of text**
 - **Engine Oil**
 - **Lower Engine**
 - **Upper Engine**
 - Aluminum alloy DOHC cylinder head with 4 valves per cylinder
 - **Timing System**
 - Two timing chains, a high-pressure fuel pump chain, and an
 - Engine oil lubricating pump chain

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5.0 LITER V-8 ENGINE LOW-PRESSURE FUEL SYSTEM

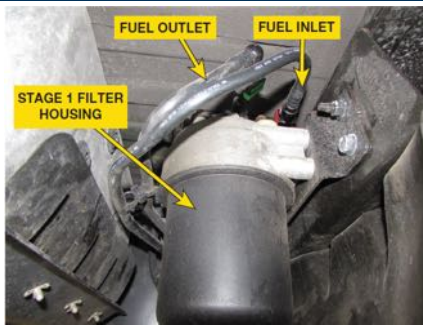
- **Low-Pressure System:**
 - Pages 301-302**
 - Stage 1 fuel filter housing
 - Stage 2 fuel filter housing
 - Injector drains, high-pressure pump returns
 - **Fuel Tank** does not contain LIFT pump.
 - **Stage 1 Fuel Filter Housing:**
 - **Figure 24-18**
 - **Stage 2 Fuel Filter Housing:**
 - **Figure 24-19**
 - **Injector Drain Lines & High-pressure Pump Return**



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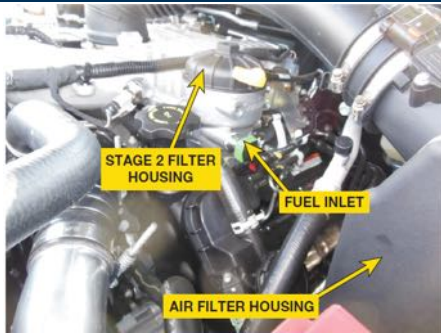
FIGURE 24–18 Stage 1 filter assembly is mounted on left frame rail just forward of fuel tank.



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FIGURE 24–19 stage 2 filter housing contains 3-micron filter and serves as return after high-pressure portion of fuel system.



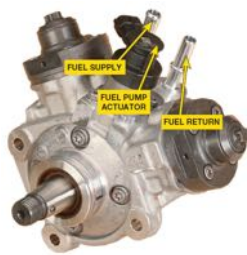
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5.0 LITER V-8 HIGHPRESSURE FUEL SYSTEM (1 of 2)

• **Bosch CP 4.2 2-Cylinder Fuel Pump**

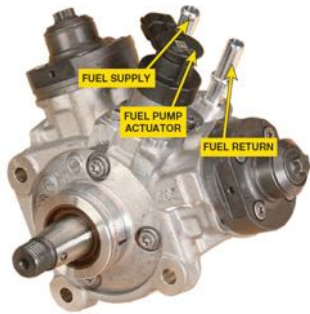
- Valley on front of engine
- Driven by a chain and sprocket at 1:1 ratio to crankshaft
- Pump timed to engine
- 29,000 PSI
- Cascade overflow valve
Regulates fuel to fuel pump actuator



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FIGURE 24–20 Bosch CP 4.2 high-pressure pump is timed to engine for proper fuel delivery and minimal vibrations.



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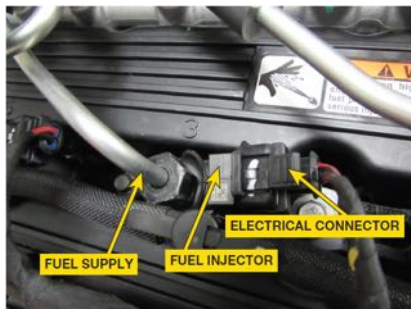
5.0 LITER V-8 HIGH-PRESSURE FUEL SYSTEM (2 of 2)

- Fuel Rail Supply Lines: Page 302
- Fuel Rails: Page 303
- Fuel Injectors Page 303
 - Eight Bosch piezoelectric fuel injectors
- Fuel Injector Replacement Page 303



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FIGURE 24–21 high-voltage piezoelectric injector uses a hold down clamp that secures it in cylinder head.



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AIR INDUCTION SYSTEM

• Air Induction System:

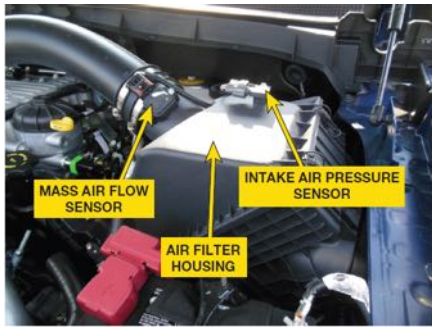
- Air filter box
- Low-pressure turbocharger
 - In valley, larger turbocharger & primary supplier of boost
- Compressor bypass valve
 - Allows air from low-pressure turbocharger to flow directly to CAC
- High-pressure turbocharger
 - smaller unit & spins at higher speed, used to reduce turbo lag
- Charge air cooler



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FIGURE 24-22 electronic pressure sensor used to determine air filter restriction instead of traditional manometer.



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How Will I Know When I Need to Replace Air Filter Element?



FREQUENTLY ASKED QUESTION

Unlike many diesel engines with a mechanical filter minder, Nissan Titan XD with a 5.0-liter Cummins engine uses electronic pressure sensor. When filter needs to be replaced, a warning message will appear on instrument panel indicating service is needed.

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GLOW PLUG SYSTEM

- **Glow Plugs**
 - Glow plugs threaded into top of cylinder heads
 - Tapered seat to ensure it seals tightly
 - Energized, can reach 1,500° F within two seconds.
- **Glow Plug Control Module**
 - Controls operation of glow plugs based on
 - CAN Bus messages from ECM
 - Uses Wait to start light

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EGR SYSTEM

- **See Page 304 of text**
 - **EGR VALVE**
 - **EGR COOLER**
 - **EGR COOLER BYPASS VALVE**

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EXHAUST AFTERTREATMENT SYSTEM

- **Nissan Titan Cummins 5.0-liter diesel:**
 - Diesel oxidation catalyst (DOC)
 - Diesel particulate filter (DPF)
 - Selective catalyst reduction (SCR)

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QUESTION 1

- What is the combined operation of the low-pressure and high-pressure turbocharger on the Nissan Titan equipped with a Cummins 5.0-liter V-8 engine?

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ANSWER 1

- Low-pressure turbocharger
 - In valley, larger turbocharger & primary supplier of boost
- Compressor bypass valve
 - Allows air from low-pressure turbocharger to flow directly to CAC
- High-pressure turbocharger
 - smaller unit & spins at higher speed, used to reduce turbo lag

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QUESTION 2

- What is the purpose of the diesel exhaust fluid (DEF) in the exhaust aftertreatment system of a Cummins 6.7 liter engine?

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ANSWER 2

- DEF IS A Mixture of 32.5% laboratory grade urea
- 67.5% deionized water
 - Deionized water deeply demineralized
- Urea: synthetic ammonia & CO₂
- Nontoxic & not harmful to handle
- Injected into exhaust stream upstream of SCR
- Once inside catalyst, heat causes DEF to decompose into ammonia and CO₂

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Summary (1 of 3)

- The 5.9/6.7-liter Cummins engine that is used in the Ram truck has evolved over four generations to meet customer demands and tailpipe emission requirements.
- 6.7-liter Cummins engine and aftertreatment was updated in 2010 to meet stricter emission requirements.
- The third generation 5.9/6.7-liter Cummins engine is first of engines to be equipped with the closed crankcase ventilation (CCV) system, replacing the road draft tube.
- High-pressure common rail (HPCR) fuel injection was introduced on the third generation 5.9/6.7-liter engine to increase horsepower, improve fuel economy, and lower tailpipe emissions.

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Summary (2 of 3)

- The exhaust aftertreatment system behind the 2010 and newer 6.7-liter engine uses diesel exhaust fluid (DEF) and a SCR catalyst to meet stricter emission standards.
- The Cummins 5.0-liter engine uses a compacted graphic iron block for strength and weight reduction.
- The cylinder heads on the 5.0-liter Cummins are constructed from an aluminum alloy for reduced weight. There are four valves per cylinder in a DOHC configuration that utilizes hydraulic valve lash adjusters.
- The high-pressure fuel system on the 5.0-liter Cummins engine uses piezoelectric injectors that can deliver fuel up to seven times during a single cycle.

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Summary (3 of 3)

- The air induction system on the 5.0-liter Cummins uses a dual-turbocharger configuration and a charge air cooler to reduce “turbo lag” at low speeds.
- To meet current emission regulations, the 5.0-liter engine is equipped with a cooled EGR system that consists of the EGR valve, EGR cooler, and the EGR cooler bypass valve.
- The exhaust aftertreatment system behind the 5.0-liter Cummins engine contains a diesel oxidation catalyst, a diesel particulate filter, and a selective catalyst reduction system.

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