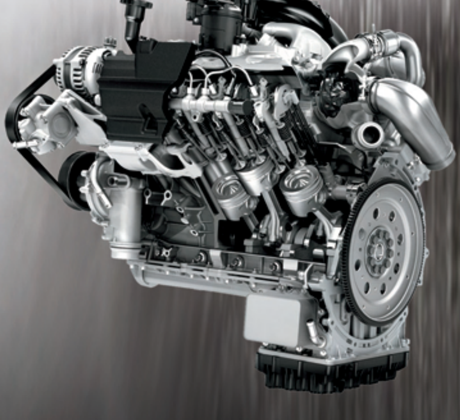
6.7L POWER STROKE® DIESEL ENGINE



2011 "F" SERIES SUPER DUTY

• Engine Description • Systems Overview • Component Location •

This publication is intended to provide technicians and service personnel with an overview of technical advancements in the 6.7L POWER STROKE® DIESEL Engine. The information contained in this publication will supplement information contained in available service information.

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as, the personal safety of the individual performing the work. This manual provides general directions for accomplishing service repair work with tested, effective techniques. Following the directions will assure reliability. There are numerous variations in the procedures; techniques, tools, parts for servicing vehicles and the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from the instructions provided in this manual must first establish that they do not compromise their personal safety or the vehicle integrity by their choice of methods, tools or parts.

The following list contains some general WARNINGS that you should follow when you work on a vehicle.

Always wear safety glasses for eye protection.

Always perform work in a well ventilated area.

Use safety stands whenever a procedure requires you to be under the vehicle.

Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.

Never perform any service to the engine with the air cleaner removed and the engine running unless a turbocharger compressor inlet shield is installed.

Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific service operation. If you have a manual transmission, it should be in REVERSE (engine OFF) or NEUTRAL (engine ON) unless instructed otherwise for a specific service operation.

Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.

Keep yourself and your clothing away from moving parts when the engine is running, especially the fan, belts, and the turbocharger compressor.

To prevent serious burns, avoid contact with hot metal parts such as the radiator, turbocharger pipes, exhaust manifold, tail pipe, catalytic converter and muffler.

Do not smoke while working on the vehicle.

To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind the head.

Keep hands and other objects clear of the radiator fan blades.

TABLE OF CONTENTS

6.7L POWER STROKE® DIESEL OVERVIEW 6
Engine Features 6
2011 6.7L Power Stroke® Diesel Horsepower and Torque Ratings 6
6.7L Power Stroke® Diesel Specifications 7

COMPONENT LOCATION 9

UPPER ENGINE COMPONENTS 15

LOWER ENGINE COMPONENTS 17

COOLING SYSTEM 23
Primary Cooling System 24
Powertrain Secondary Cooling System 27

LUBRICATION SYSTEM 33
Lubrication System Oil Flow 33

AIR MANAGEMENT SYSTEM 37
Air Inlet Components 38
Glow Plug System 42
DualBoost Variable Geometry Turbocharger (VGT) 43
Exhaust Gas Recirculation (EGR) 46

FUEL SYSTEM 51
Fuel Supply System 52
Fuel Management System 56

ELECTRICAL COMPONENTS 63
Pressure Sensors 64
Position Sensors 70
Miscellaneous Sensors 71
Outputs 72

EXHAUST SYSTEM 77
Regeneration Process 81
Selective Catalyst Reduction (SCR) System Operation 86

SPECIAL SERVICE TOOLS 87

6.7L POWER STROKE
B20 TURBO DIESEL

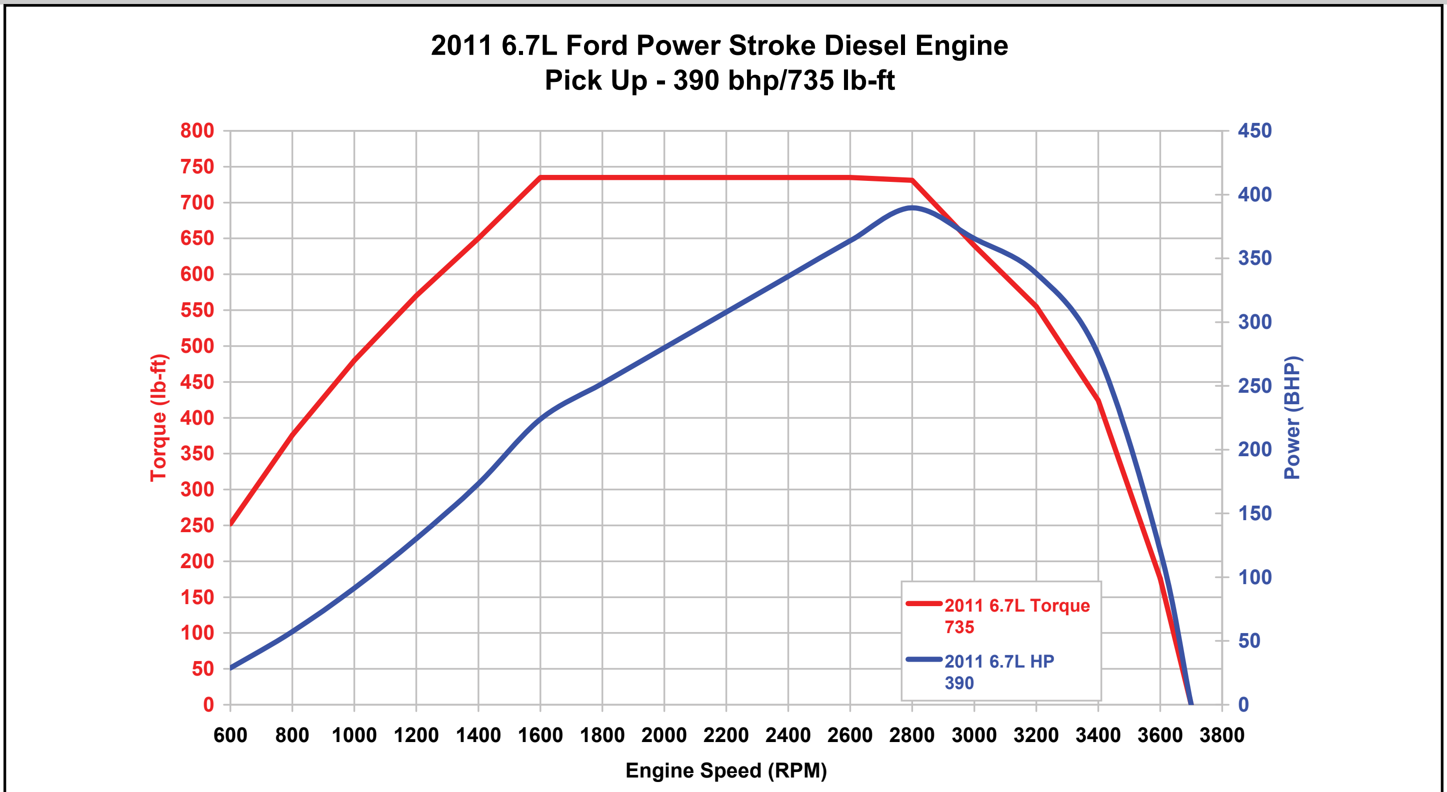
Direct Injection Turbocharged Diesel Engine

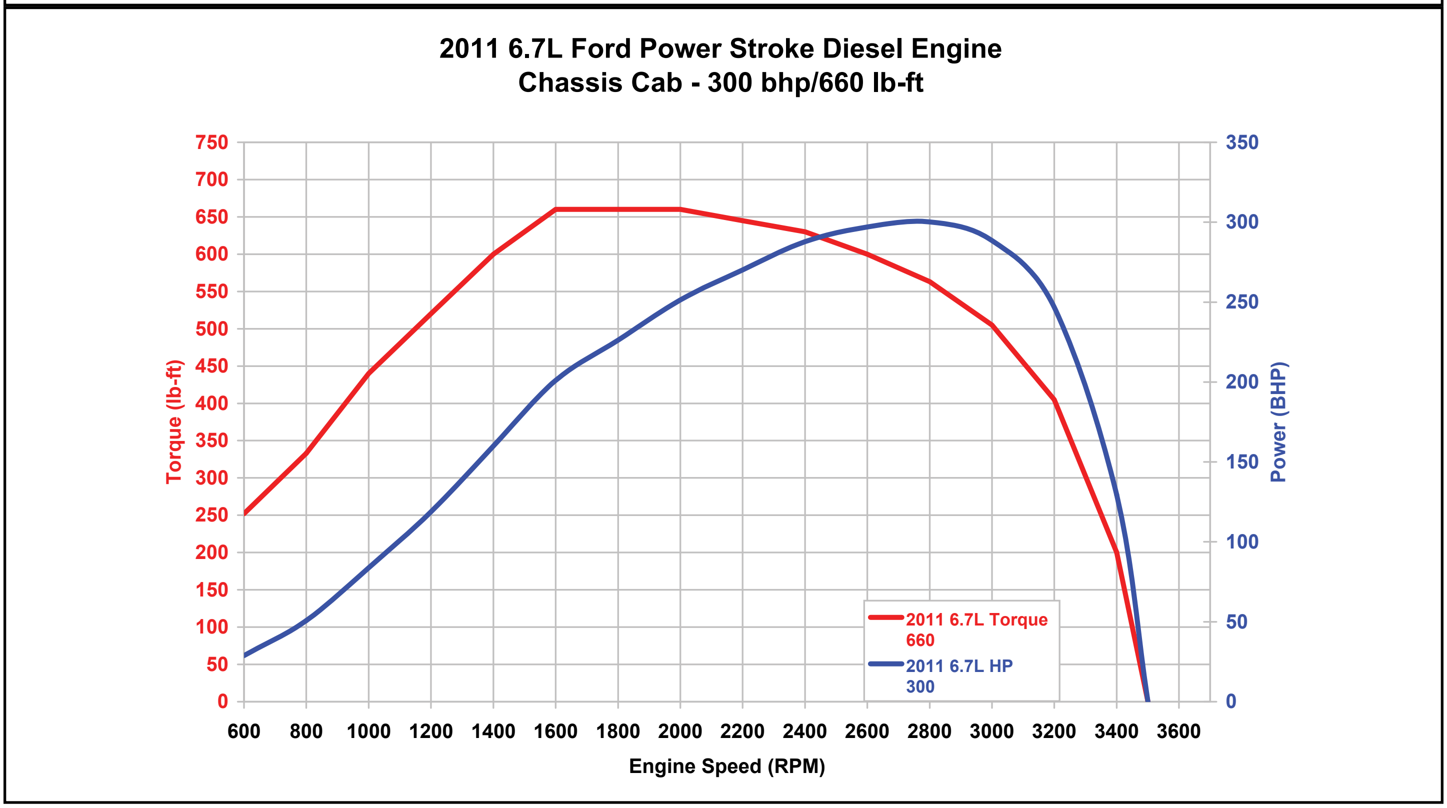
6.7L POWER STROKE® DIESEL OVERVIEW

Engine Features

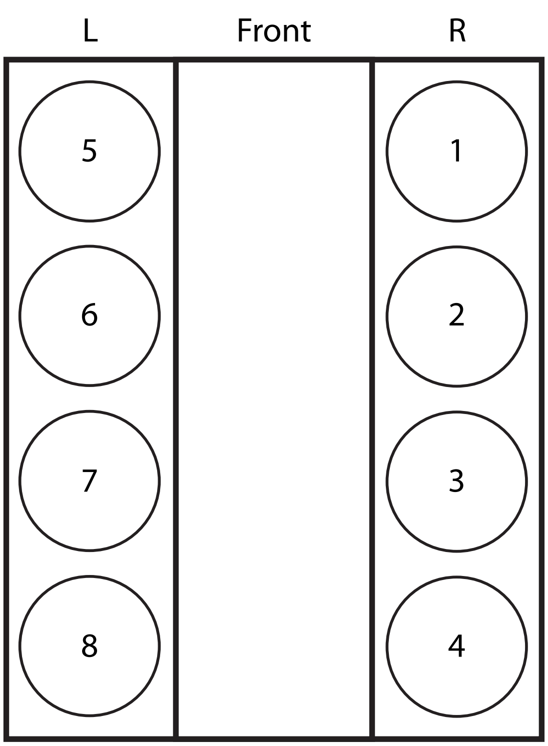
- The 6.7L Power Stroke® diesel has been designed to meet the tougher emissions standards set by the government.
- The 6.7L Power Stroke® diesel has been designed to meet the customer's expectations of high horsepower and torque over a wide RPM range.
- Meeting the more stringent customer and regulatory demands are accomplished in part by a high pressure common rail fuel system, DualBoost turbocharger system, 4 valves per cylinder, and a Selective Catalyst Reduction (SCR) system.

2011 6.7L Power Stroke® Diesel Horsepower and Torque Ratings





6.7L Power Stroke® Diesel Specifications		
Engine Type	Diesel, 4-Cycle	
Configuration	4 OHV/1 Cam-in-Crankcase-V8	
Displacement	6.7L (409 cu. in.)	
Bore and Stroke	99x108 mm (3.90 x 4.25 in)	
Compression Ratio	16.1:1	
Induction	DualBoost Variable Geometry Turbocharger	
	Chassis Cab	Pick Up
Rated Power @ RPM	300 hp @ 2800 rpm	390 hp @ 2,800 rpm
Peak Torque @ RPM	660 ft.-lb. @ 1600 rpm	735 ft.-lb. @ 1,600 rpm
Engine Rotation, Facing Flywheel	Counterclockwise	
Combustion System	High Pressure Common Rail Direct Injection	
Total Engine Weight (auto with oil)	499kg (1100 lbs)	
Primary Cooling System Capacity	27.8L (29.4 qts.)	
Powertrain Secondary Cooling System Capacity	11.1L (11.7 qts.)	
Lube System Capacity (including filter)	12.3L (13 qts.)	
Firing Order	1-3-7-2-6-5-4-8	

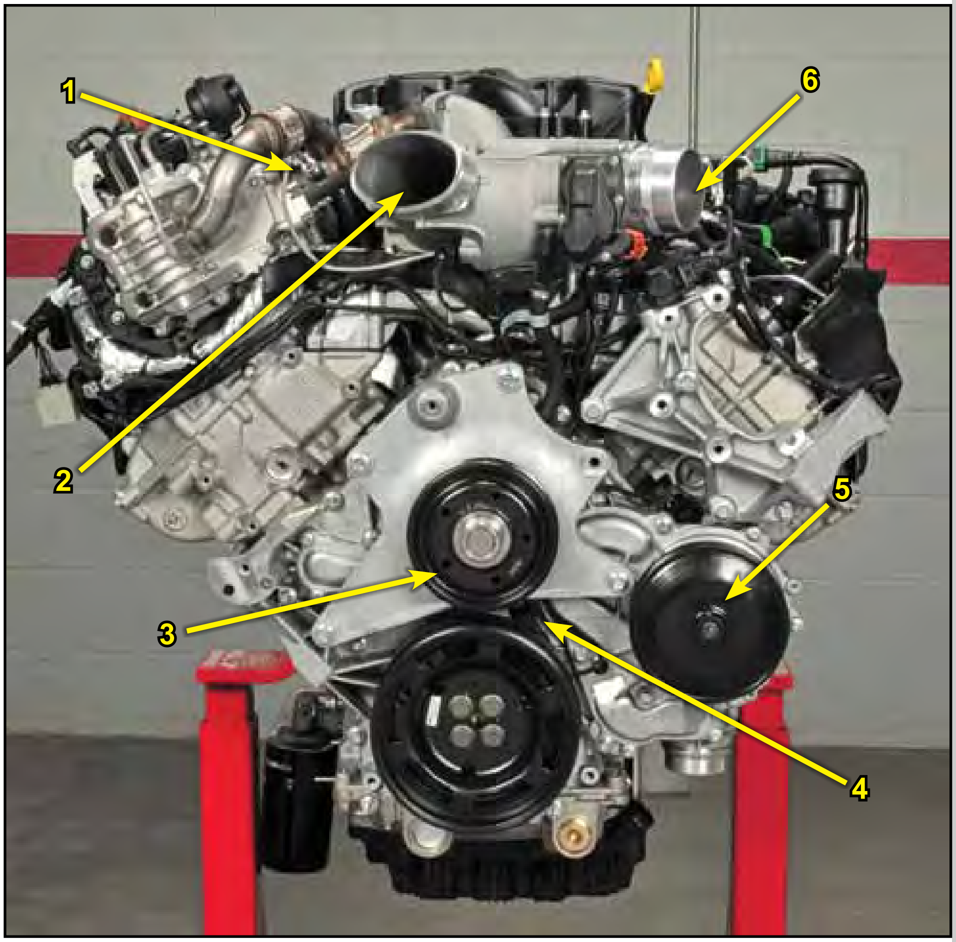


Specifications

The cylinders of the 6.7L Power Stroke® diesel are numbered from the front. The right side are cylinders 1, 2, 3, and 4 and the left side are cylinders 5, 6, 7, and 8.

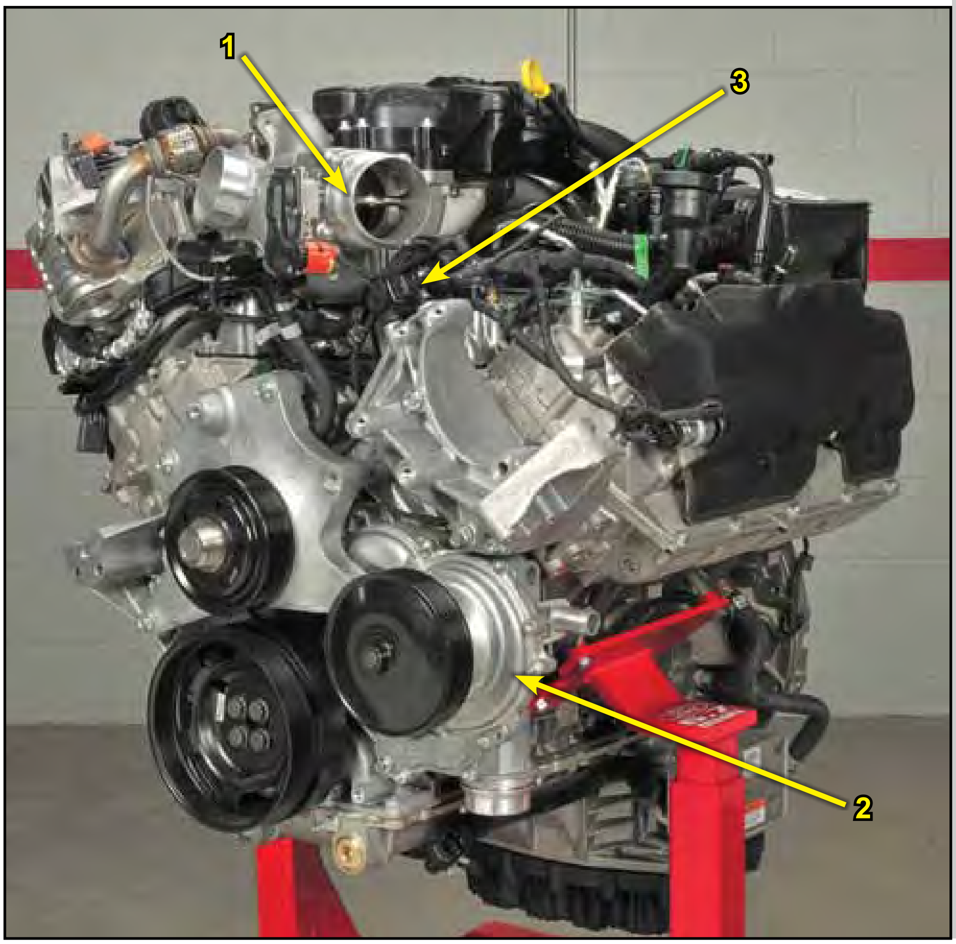
NOTES

COMPONENT LOCATION



Front of Engine

1. Air Inlet from air filter
2. Exhaust Gas Recirculation (EGR) cooler outlet temperature sensor
3. Front Engine Accessory Drive (FEAD) idler pulley
4. Camshaft Position (CMP) sensor
5. Primary coolant pump
6. Air inlet from Charge Air Cooler (CAC)

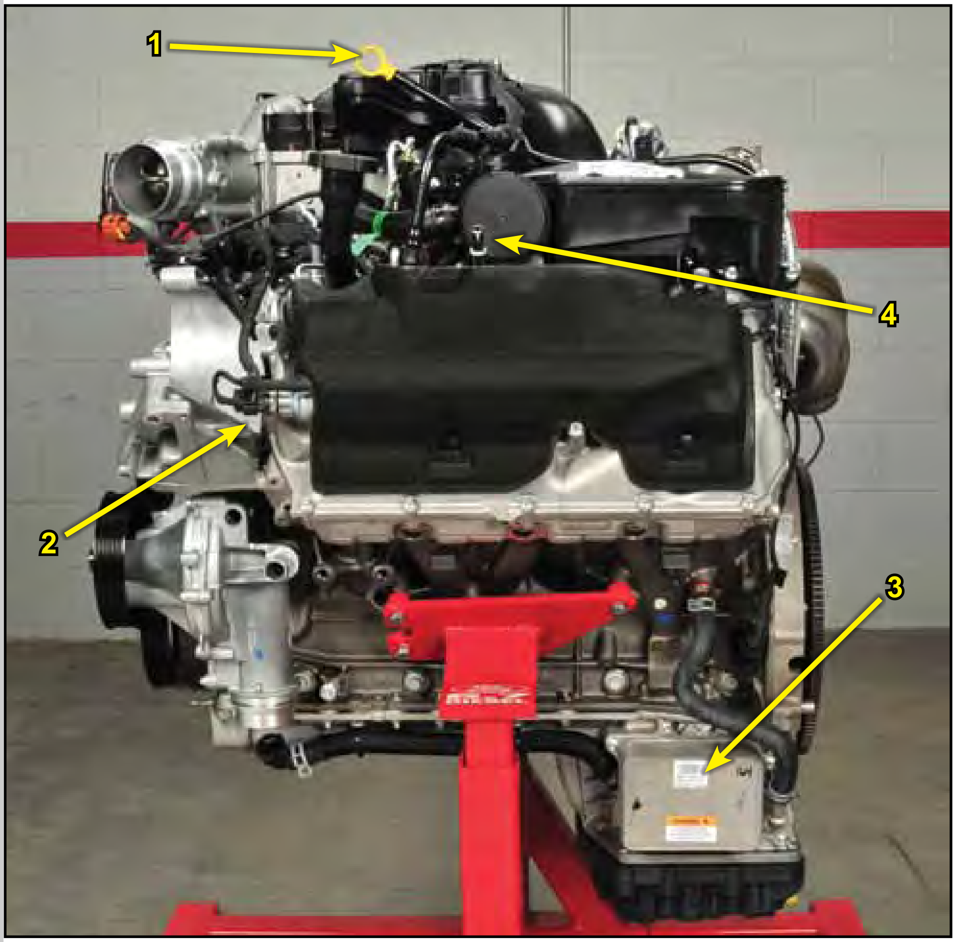


Left Front of Engine

1. Intake throttle body
2. Primary water pump
3. Wastegate control solenoid

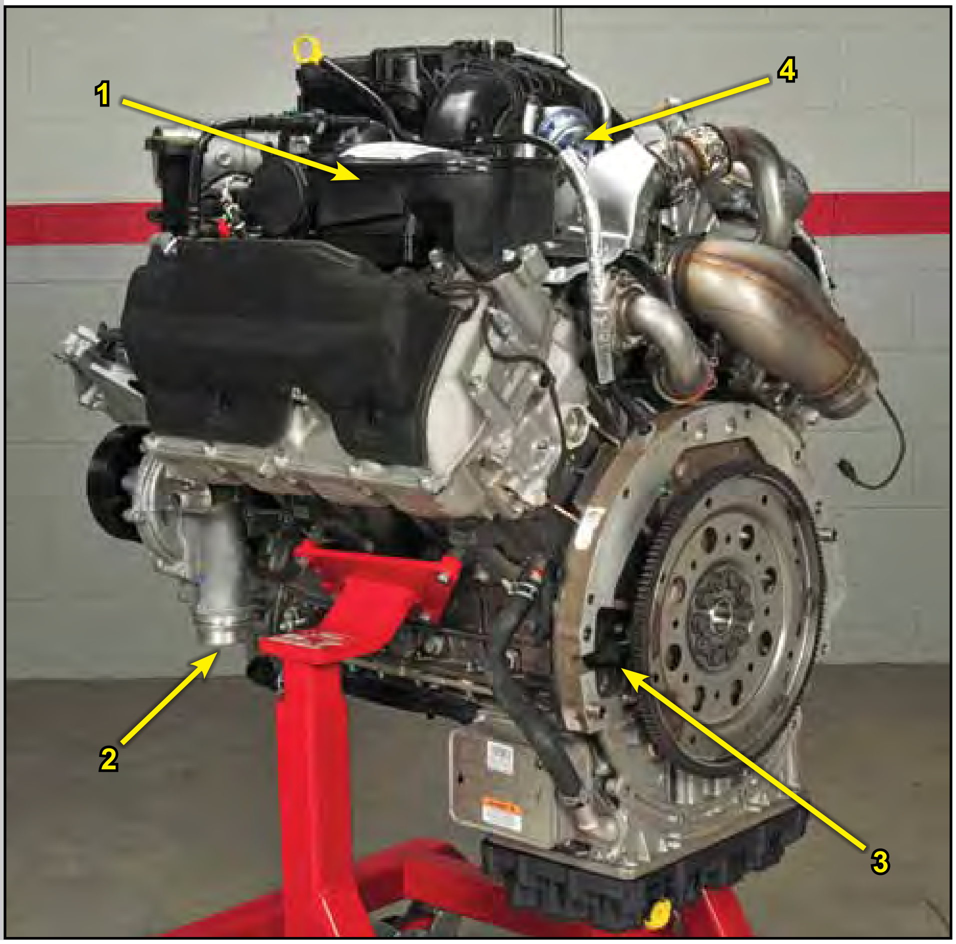
Left of Engine

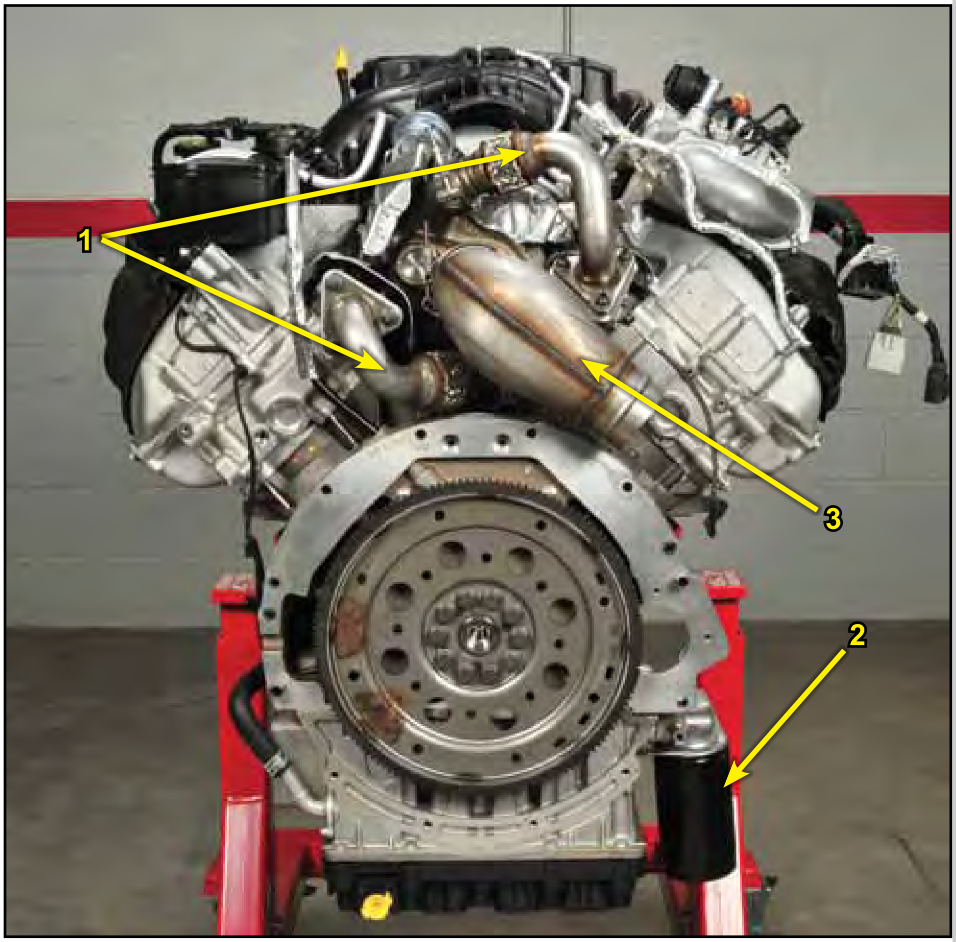
1. Oil level indicator
2. Fuel Rail Pressure (FRP) sensor
3. Engine oil cooler
4. Fuel return line



Left Rear of Engine

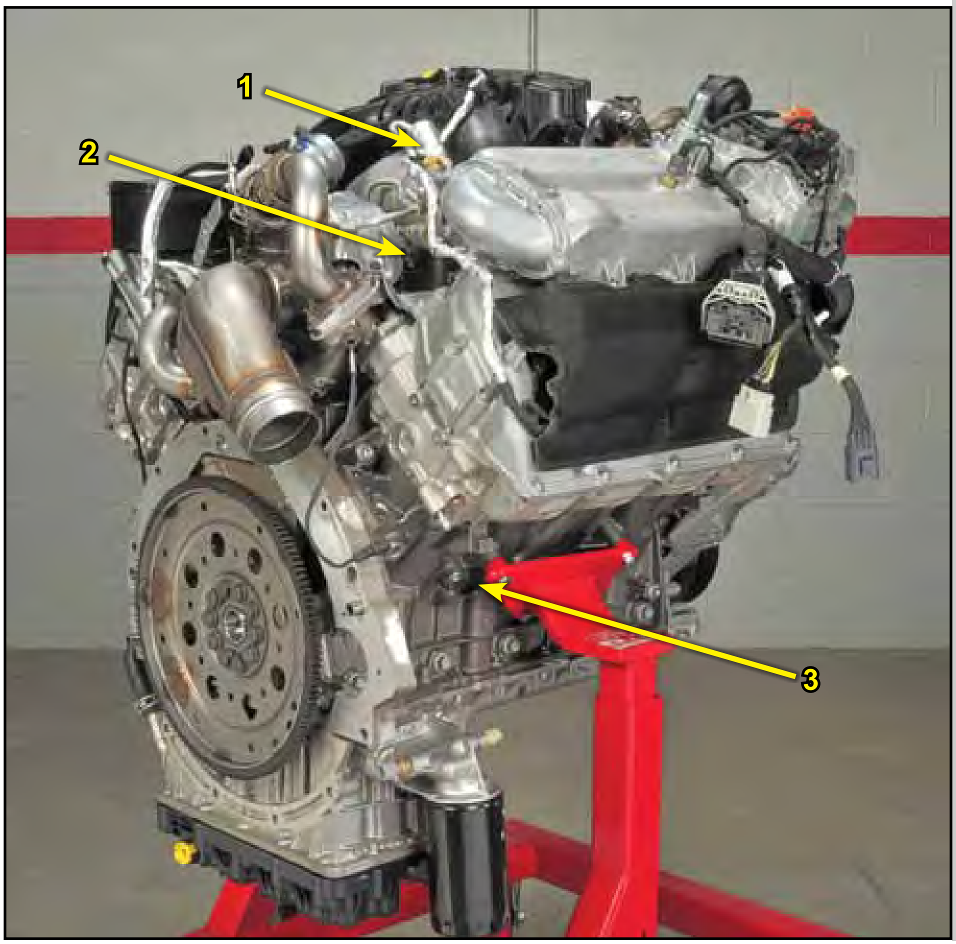
1. Crankcase vent oil separator
2. Water pump inlet
3. Crankshaft Position (CKP) sensor
4. Wastegate actuator





Rear of Engine

1. Turbocharger Exhaust Supply
2. Spin-on oil filter
3. Turbo Outlet Pipe (Cobra Head)



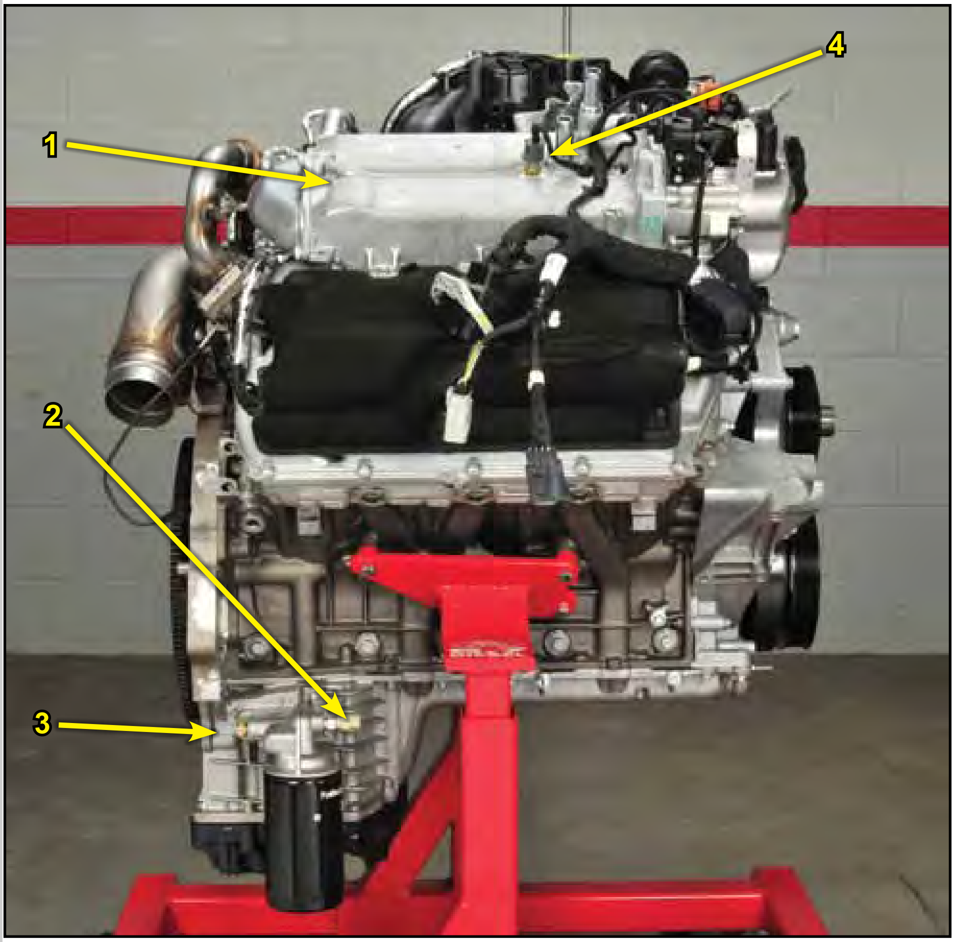
Right Rear of Engine

1. Exhaust Pressure (EP) sensor
2. Variable Geometry Turbocharger (VGT) actuator
3. Block heater

COMPONENT LOCATIONS

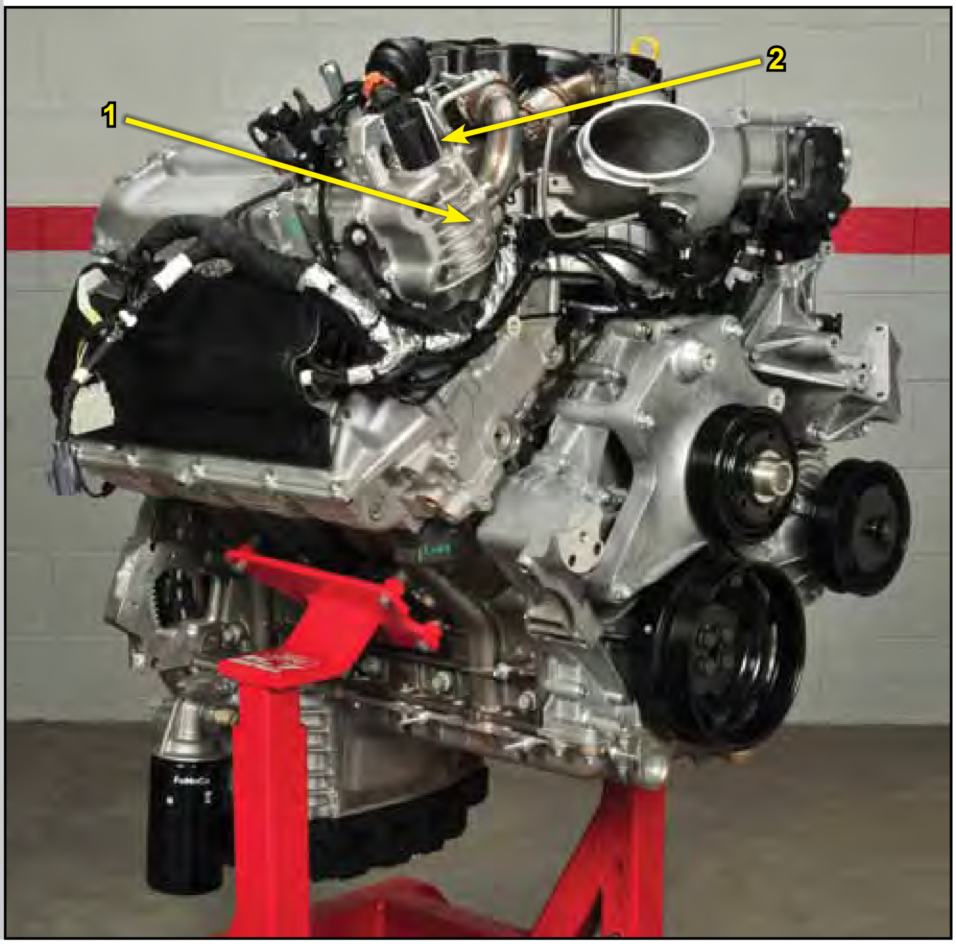
Right Side of Engine

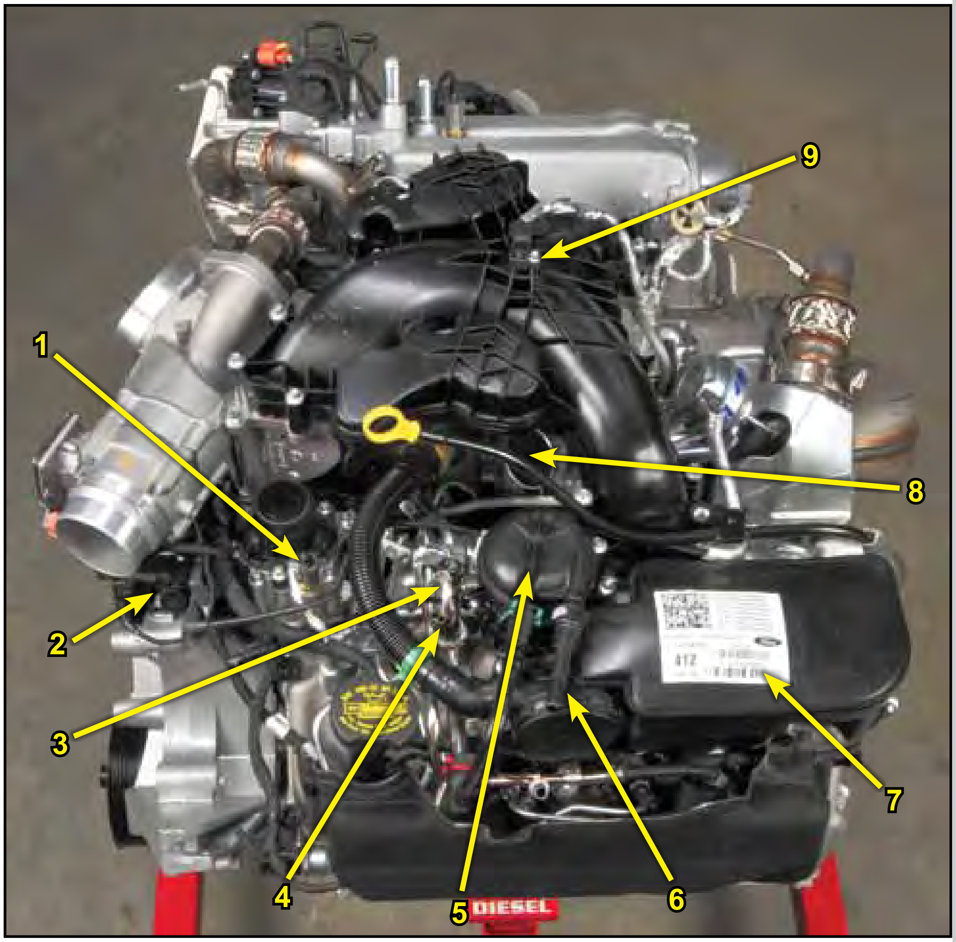
1. EGR cooler
2. Oil pressure switch
3. Engine Oil Temperature (EOT) sensor
4. Engine Coolant Temperature 2 (ECT2) sensor



Right Front of Engine

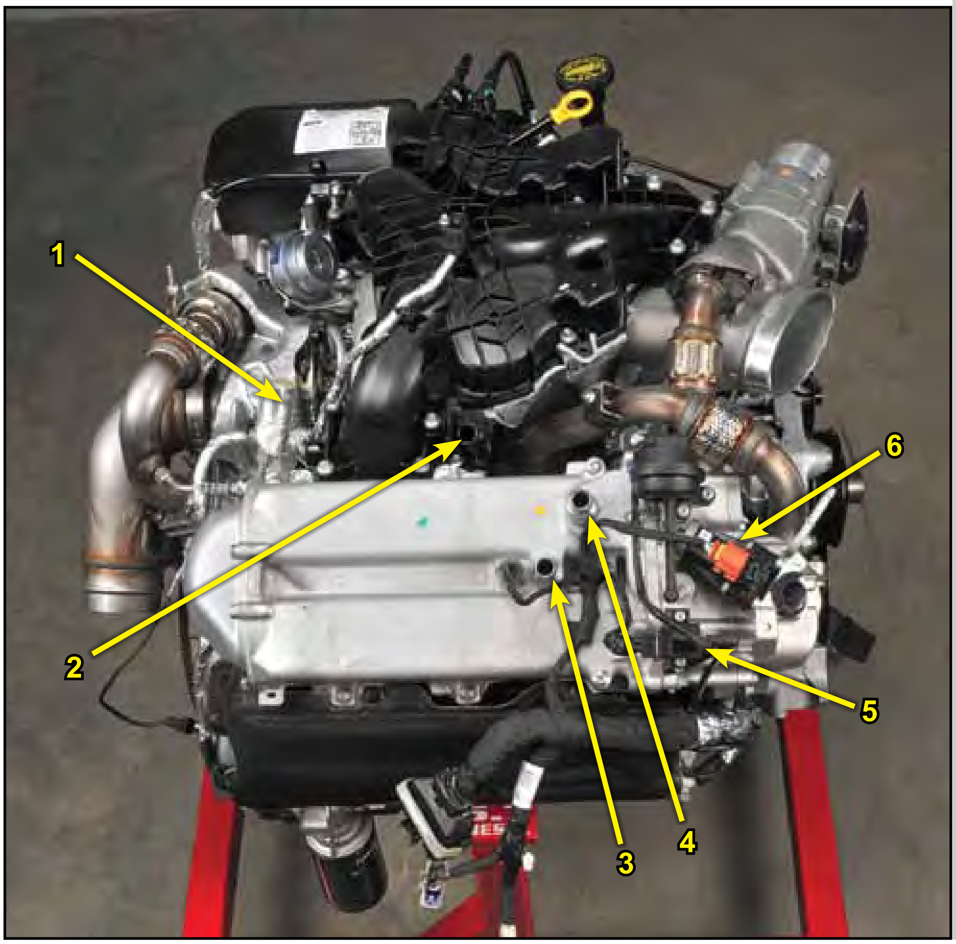
1. EGR valve
2. EGR valve motor with position sensor





Left Top of Engine

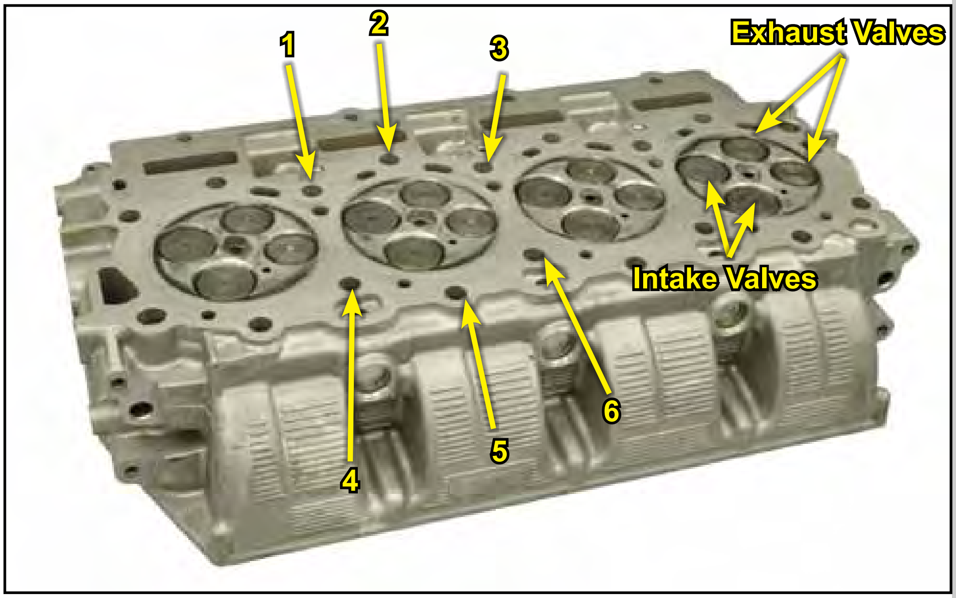
1. Engine Coolant Temperature (ECT) sensor
2. Wastegate control vacuum solenoid
3. Fuel Rail Temperature (FRT)
4. Fuel Pressure Switch (FPS)
5. Engine mounted fuel filter
6. Fuel supply line
7. Injector Quantity Adjustment (IQA) sticker
8. Turbocharger compressor outlet
9. Manifold Absolute Pressure (MAP) sensor



Right Top of Engine

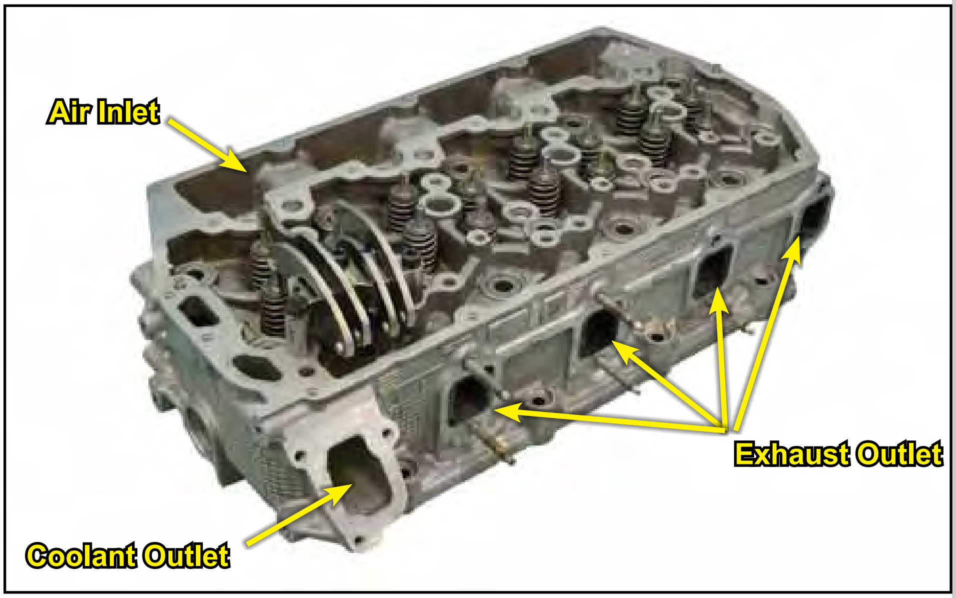
1. Exhaust Pressure (EP) sensor
2. Heater core supply
3. EGR cooler secondary coolant inlet
4. EGR cooler secondary coolant outlet
5. EGR cooler bypass solenoid
6. EGR valve motor and position sensor

NOTES



Bottom Cylinder Heads

Six bolts per cylinder seal the aluminum cylinder heads to the block. Each cylinder has two exhaust valves and two intake valves.



Top of Cylinder Head

The air inlet is located on the out-board side of the cylinder heads. The exhaust outlet is located on the in-board side of the cylinder head to reduce the loss of radiant heat.

The weight of the engine is reduced due to the configuration of the intake and exhaust ports.

Rocker Arms

Each valve has its own rocker arm and push rod.

Note: The rocker arms are not attached by head bolts.

Rocker Arms continued

The rocker arms for each cylinder ride on their own common fulcrum. They are attached to the cylinder heads by two bolts.

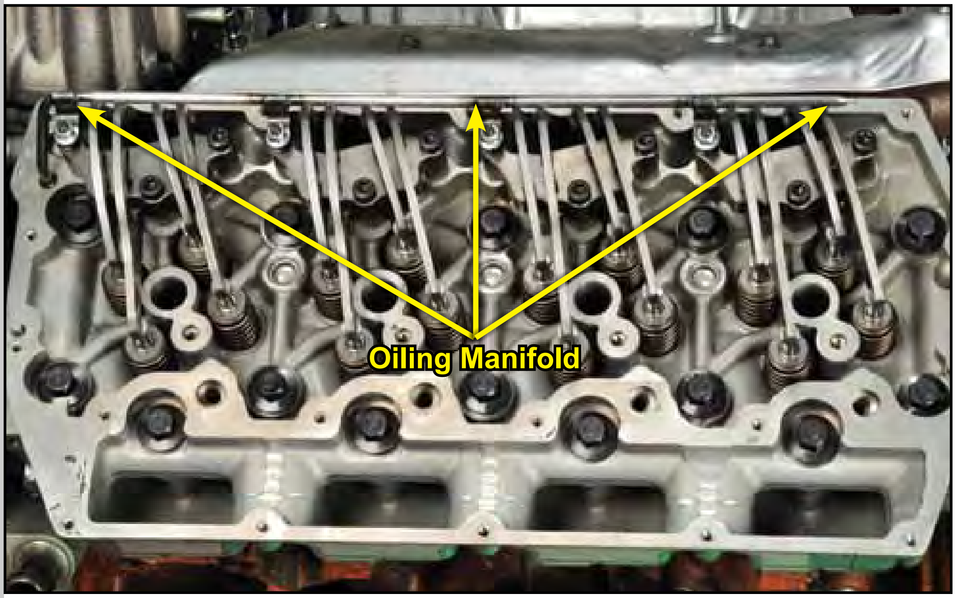
Note: individual rocker arms reduce side loading of the valves.

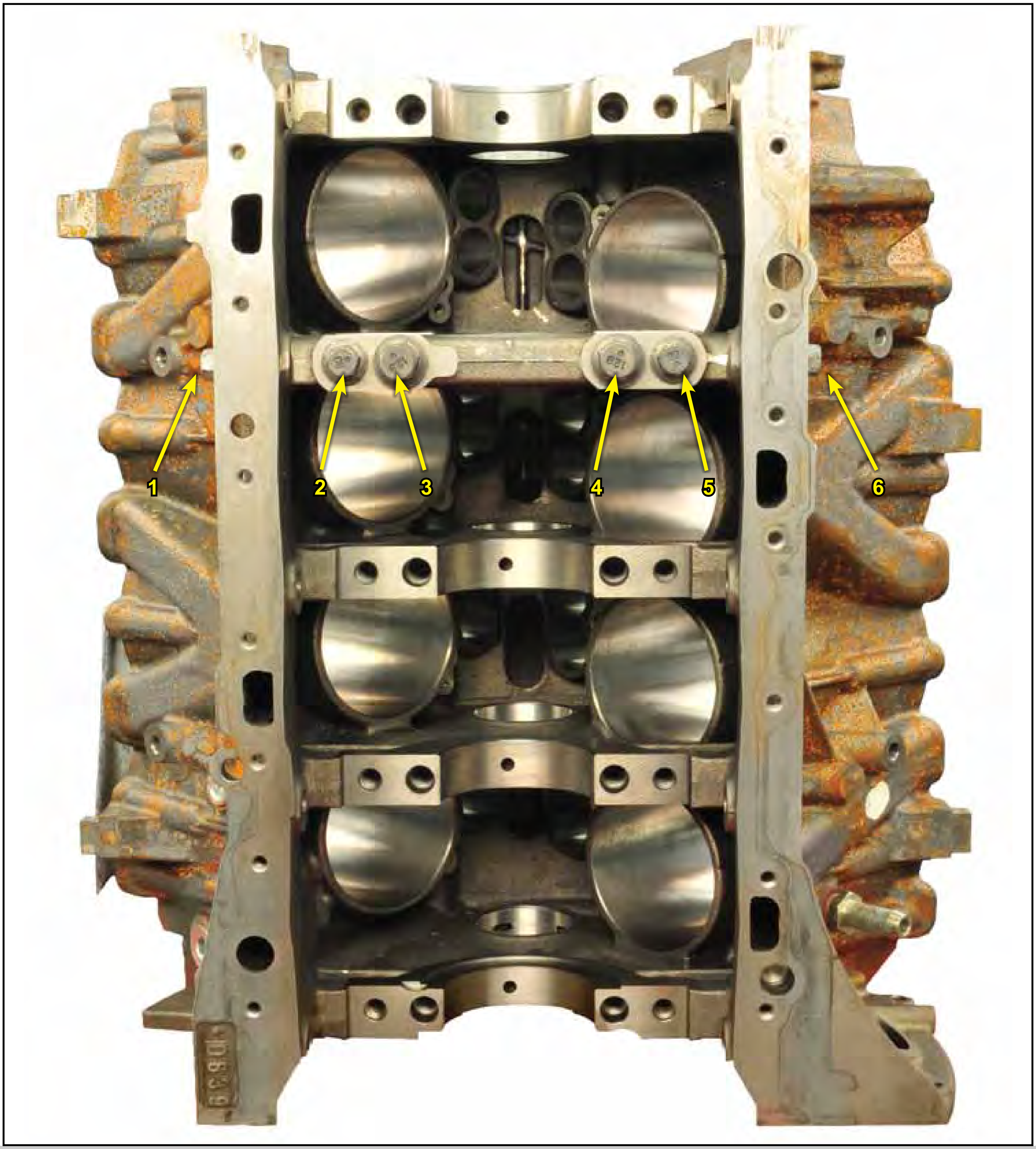
Cam Followers

- Patented design (Ford).
- Each roller lifter contains two hydraulic lash adjusters and each valve is individually actuated through its own pushrod & rocker arm
- Simple stamped rocker arms allow efficient package, robust quality, & reliable motion
- Eliminates the floating bridge used to open a pair of valves with a single rocker arm, improving wear performance and NVH.

Rocker Arm Oiling Manifold

Both cylinder heads have a rocker arm oiling manifold that cools and lubricates the valves and rocker arms.





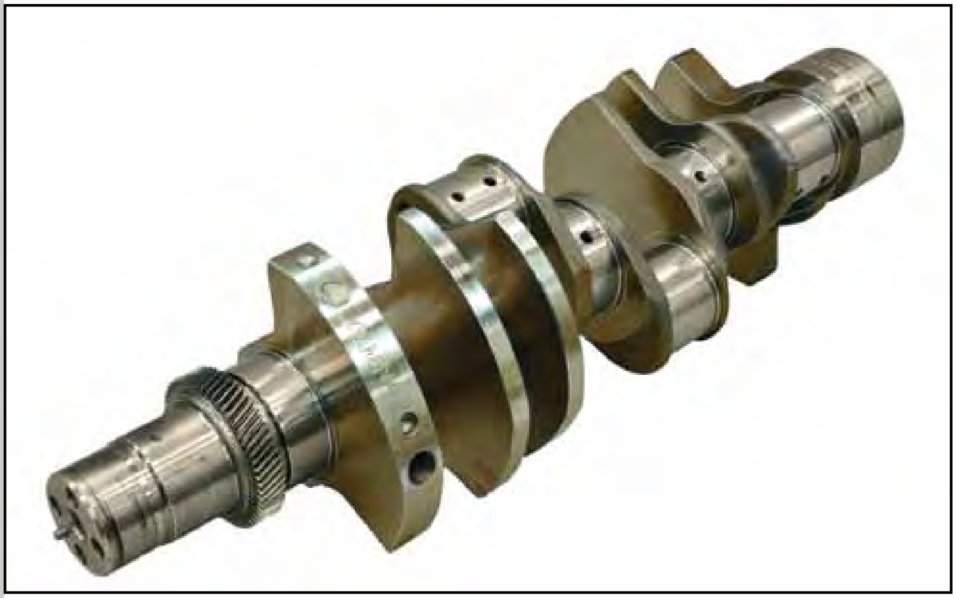
Engine Block

- The engine block is made from a compacted graphite iron (CGI) enables best-in-class weight and improved Noise, Vibration, and Harshness (NVH).
- Cam-in-block design with dry valley
- Integrated Direct Mount for High Pressure Fuel Pump.
- Six head bolts are used per cylinder and six bolts per main bearing cap.

Crankshaft

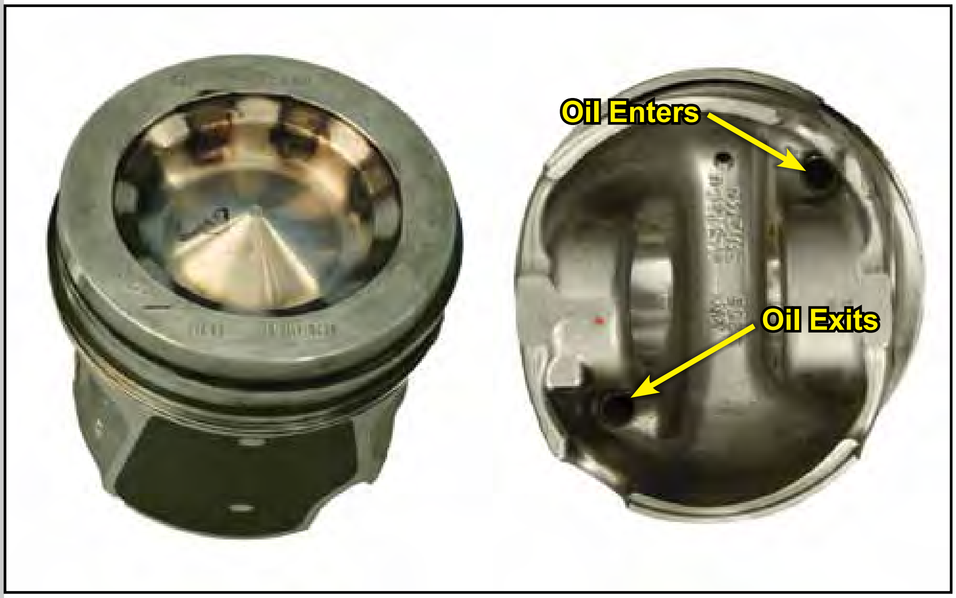
The following improvements have been made to the crankshaft.

- Improved crank quality.
- Fillet radius on each journal
- Forged Modular Steel
- Undercut rolled fillet radius
- Fully lightened crankshaft pins
- Two radiused counterweights
- One piece rear flange:
  - increase torque capabilities.
  - improved sealing and balance.
- Shrink fit assembled front drive gear
- Single mode torsional damper
- Direct accessory drive for improved NVH



Pistons

The pistons are oil cooled. A oil jet that bolts into the block sprays oil into a hole in the bottom of the piston. The oil flows through the top of the piston and exits from a hole in the other side of the piston.



Connecting Rods

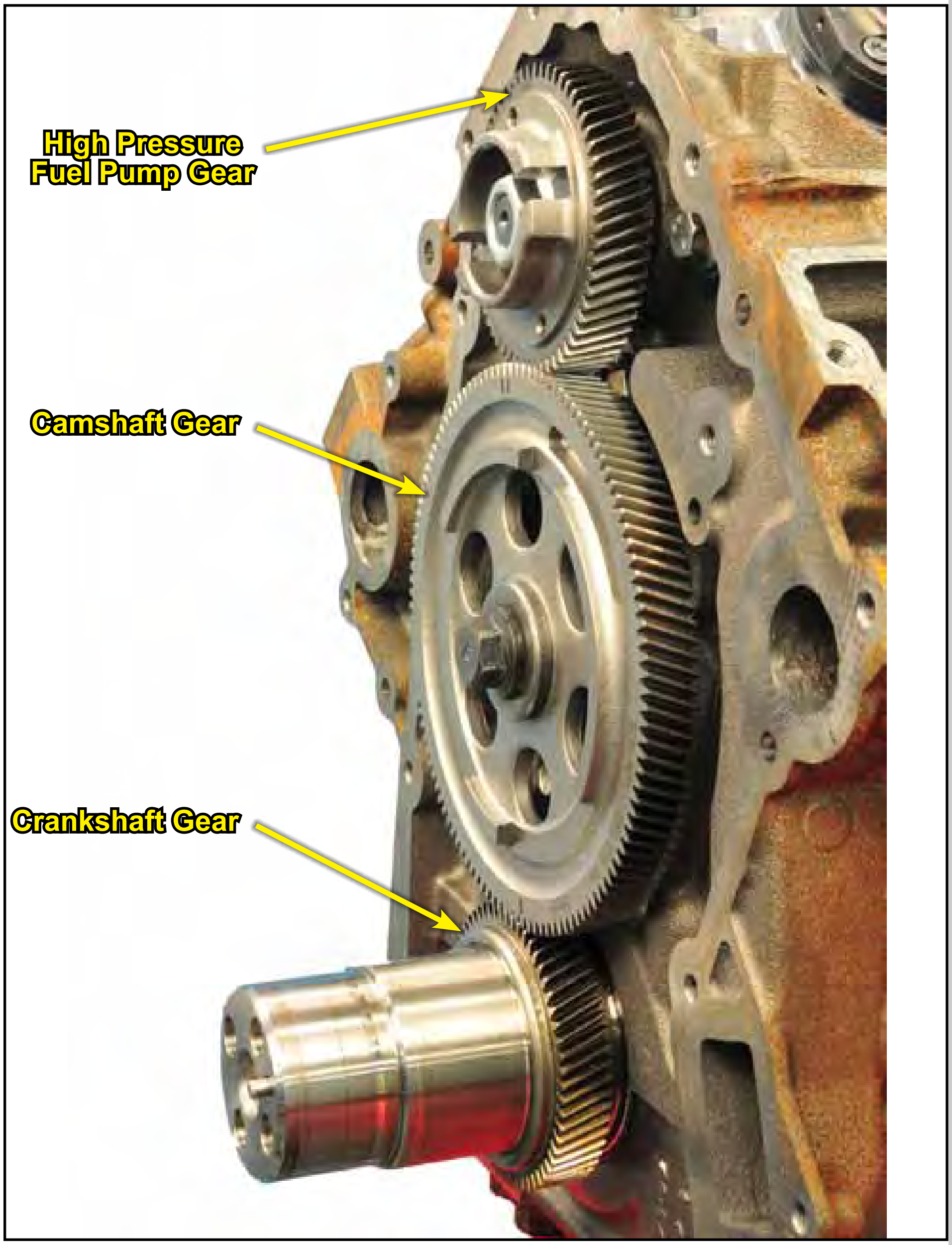
The connecting rod is a fractured cap design.

Camshaft

The camshaft is driven by the crankshaft. The camshaft has one exhaust and one intake lobe per cylinder.

The two exhaust valves are actuated by a single exhaust lobe and the two intake valves are actuated by a single intake lobe.

The camshaft bearings are lubricated by the rear cam groove. This groove receives oil from the block gallery and oil flows through the center of the camshaft to each cam bearing journal.



Gear Timing

The camshaft and high pressure fuel pump are driven off the crankshaft. The timing gears are accessible by removing the front cover. The camshaft, crankshaft and high pressure fuel pump all need to be timed together.

Note: The fuel pump is timed so that the fuel pump stroke happens at the same time as the injection stroke. This provides a more consistent fuel delivery.

See the Workshop Manual for the specific procedure for timing the crankshaft, camshaft and fuel pump.

Crankshaft Main and Connecting Rod Bearings

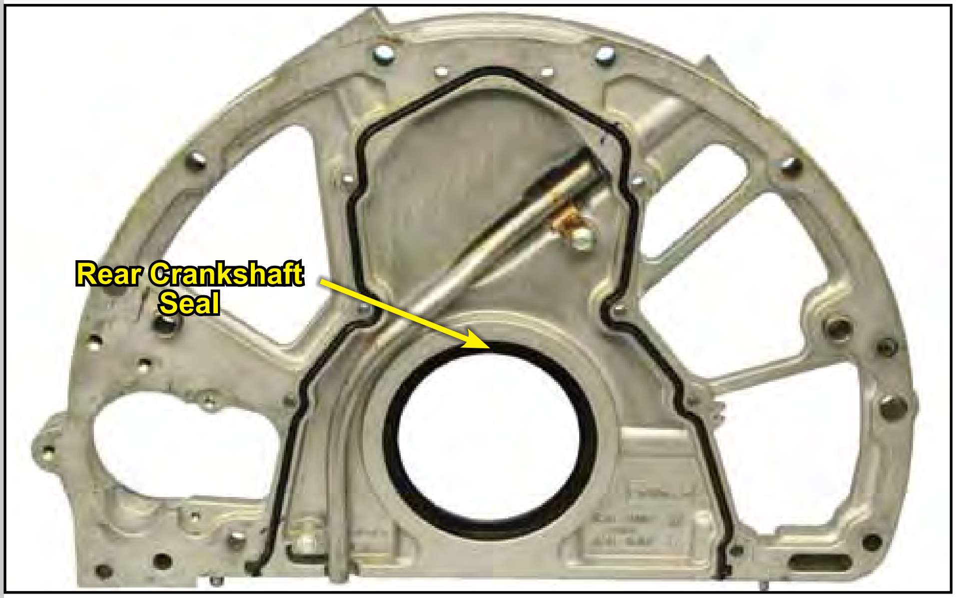
Both the crankshaft main and connecting rod bearings are color coded and a tangless design.

The lower half of the crankshaft main bearings are a dark gray color while the upper half is a bright metal with a lubrication groove and a slot for the oil to flow through.

The upper half of the connecting rod bearings are dark gray while the lower half is a bright metal with no grooves.

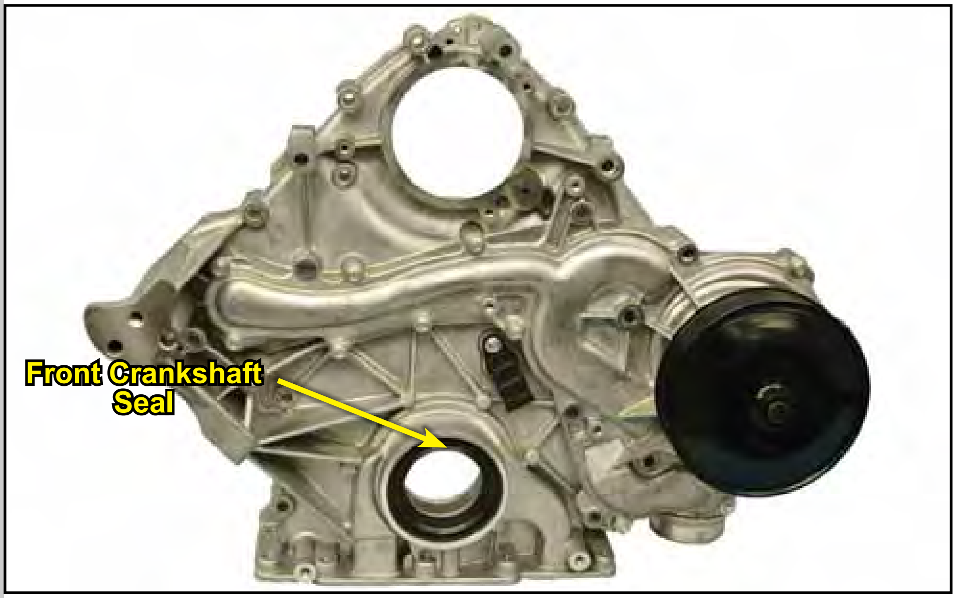
Rear Crankshaft Seal

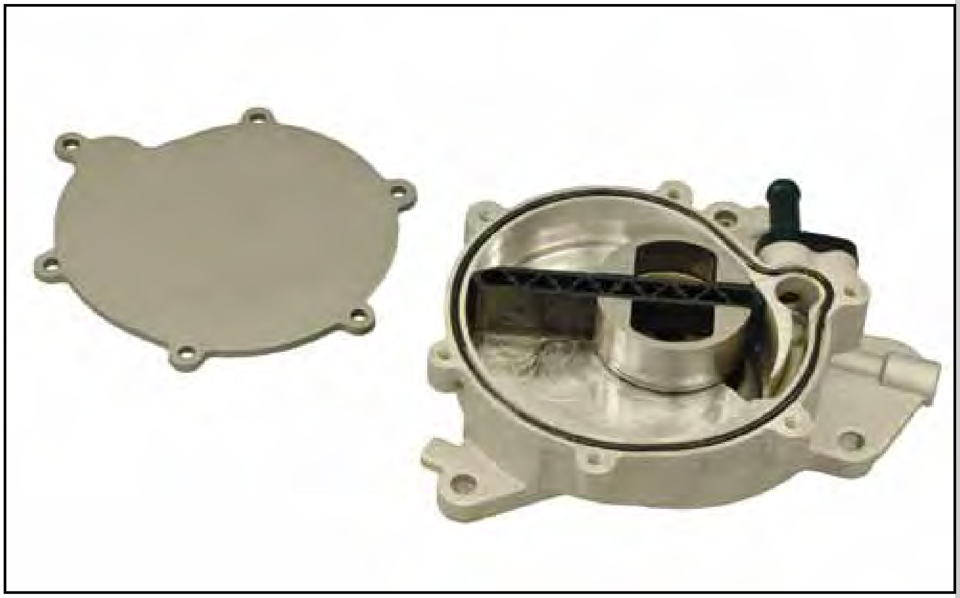
The rear crankshaft seals have no sealing sleeves.



Front Crankshaft Seal

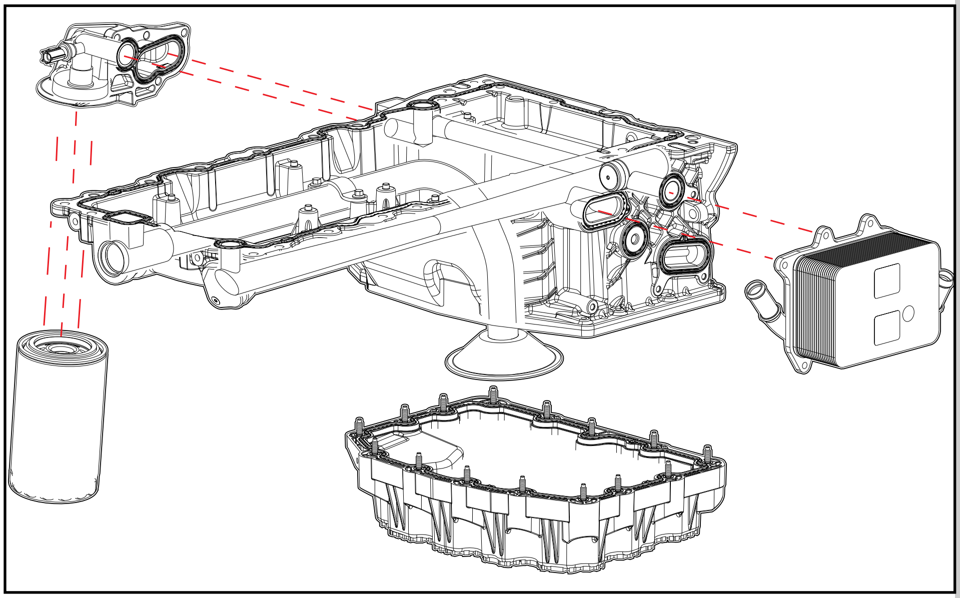
The front crankshaft seal and oil slinger are pressed on together.





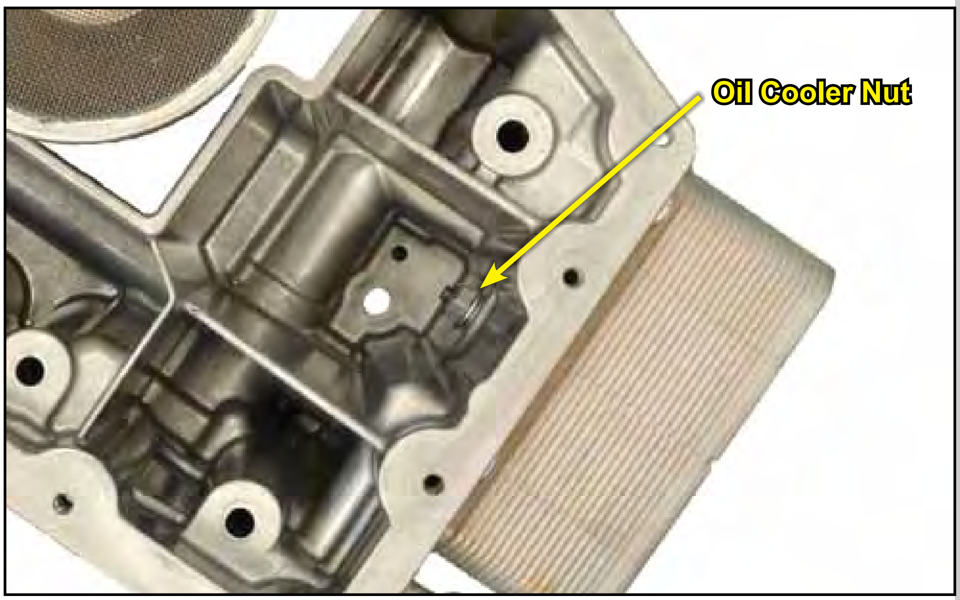
Vacuum Pump

The vacuum pump is located on the upper portion of the front cover and is driven by the high pressure fuel pump. Vacuum is used for the EGR cooler bypass system and the wastegate control system.



Oil Pan

The oil pan provides the mounting locations for the oil cooler and the oil filter adapter. The oil filter adapter is mounted to the right rear of the oil pan and contains the oil pressure switch and the Engine Oil Temperature (EOT) sensor. The oil cooler is mounted to the left rear of the oil pan. The oil cooler is a coolant-to-oil cooler.



Oil Cooler

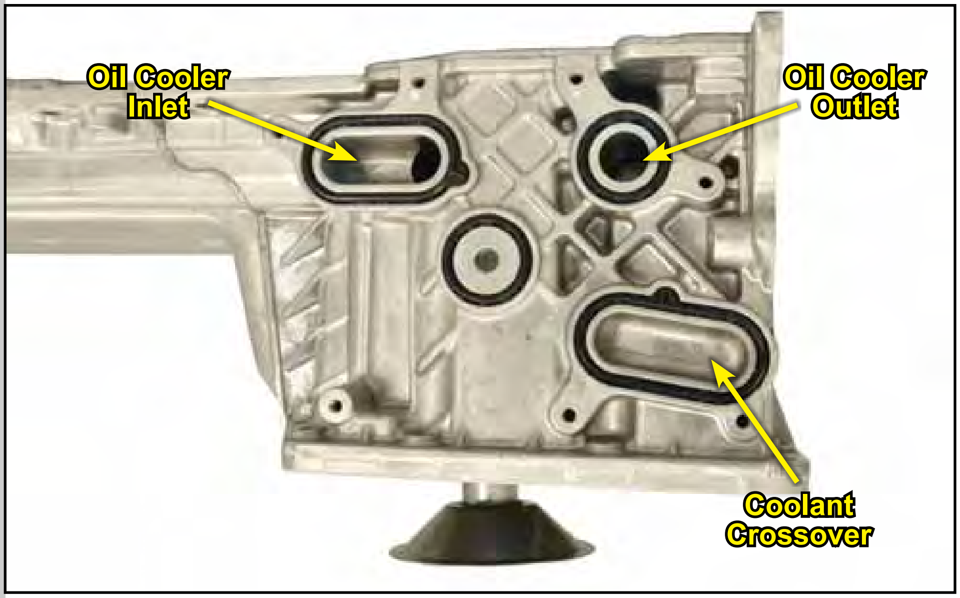
The oil cooler is mounted to the outside of the left side of the oil pan.

It is held onto the oil pan by bolts on the outside of the pan and a nut on the inside of the pan seals the center ports of the cooler.

Note: The lower oil pan must be removed to gain access to the oil cooler nut.

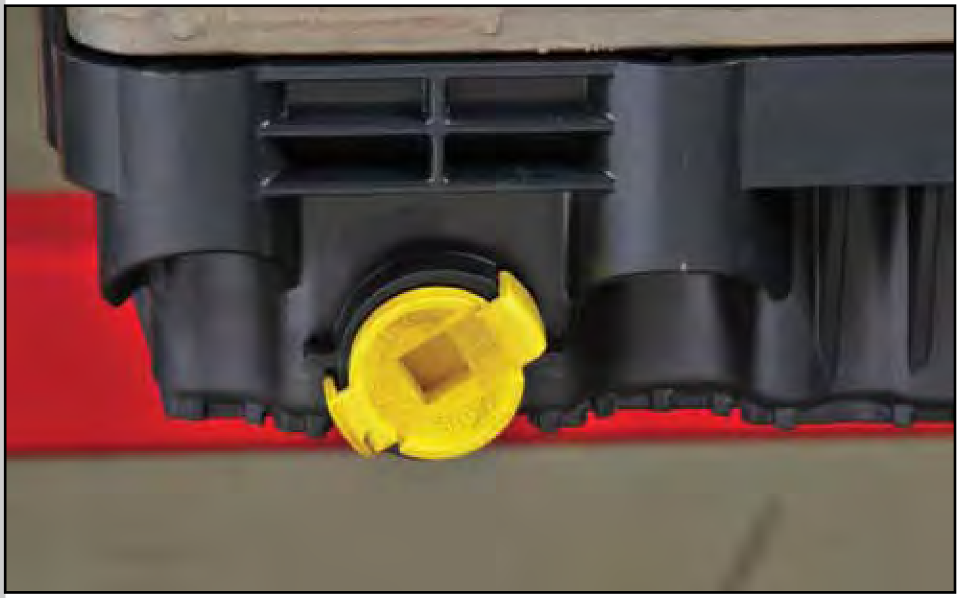
Oil Cooler Passages

The oil travels through the oil pan from the oil pump to the cooler, back into the pan to the oil filter, then back to the pan and feeds the engine.



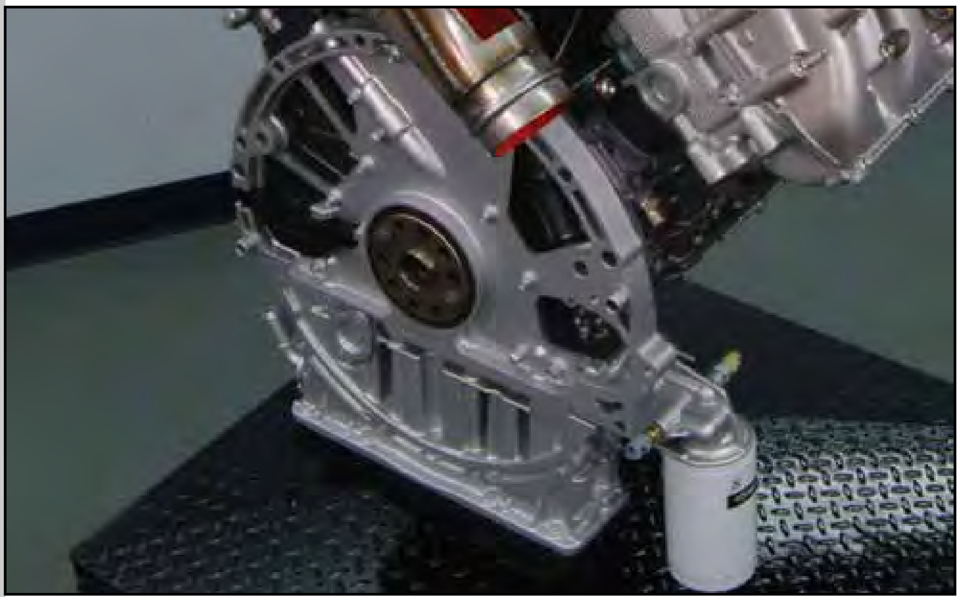
Quarter Turn Drain Plug

The oil drain plug is a quarter turn drain plug located in the left rear of the lower composite pan.



Oil Pan Structural Support

The oil pan is a structural member of the powertrain assembly and contains the lower part of the 6R140 transmission bolt circle to support the transmission.



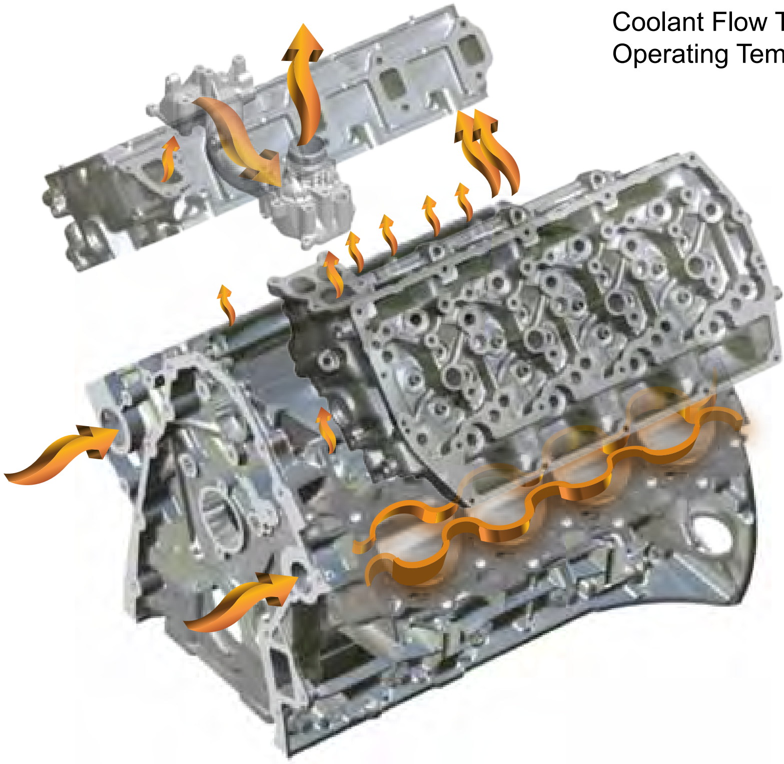
COOLING SYSTEM

The 6.7L Power Stroke® diesel engine has two separate cooling systems:

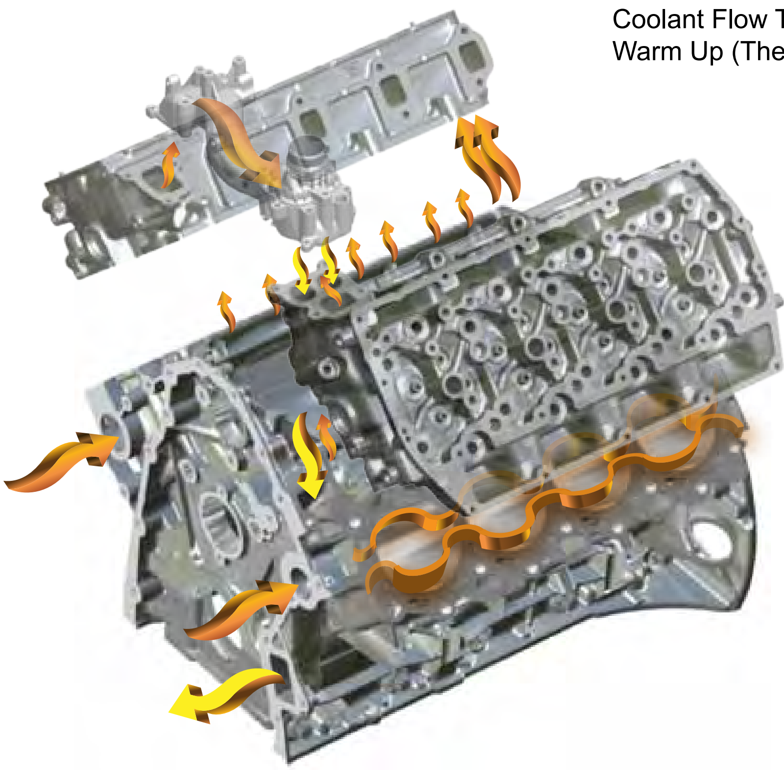
- The engine cooling system, called the primary or high temperature cooling system,
- The powertrain secondary cooling system, a low temperature system which cools the Charge Air Cooler (CAC), fuel cooler, EGR cooler and transmission oil cooler.

Both cooling systems have their own radiator, belt-driven coolant pump, thermostats and degas bottle.

Motorcraft® Specialty Orange coolant mixed with distilled water is the only coolant to use in the 6.7L Power Stroke® diesel engine. Corrosion resistance needs to be checked at specific intervals using Motorcraft® test strip kit. Consult the workshop manual for details.

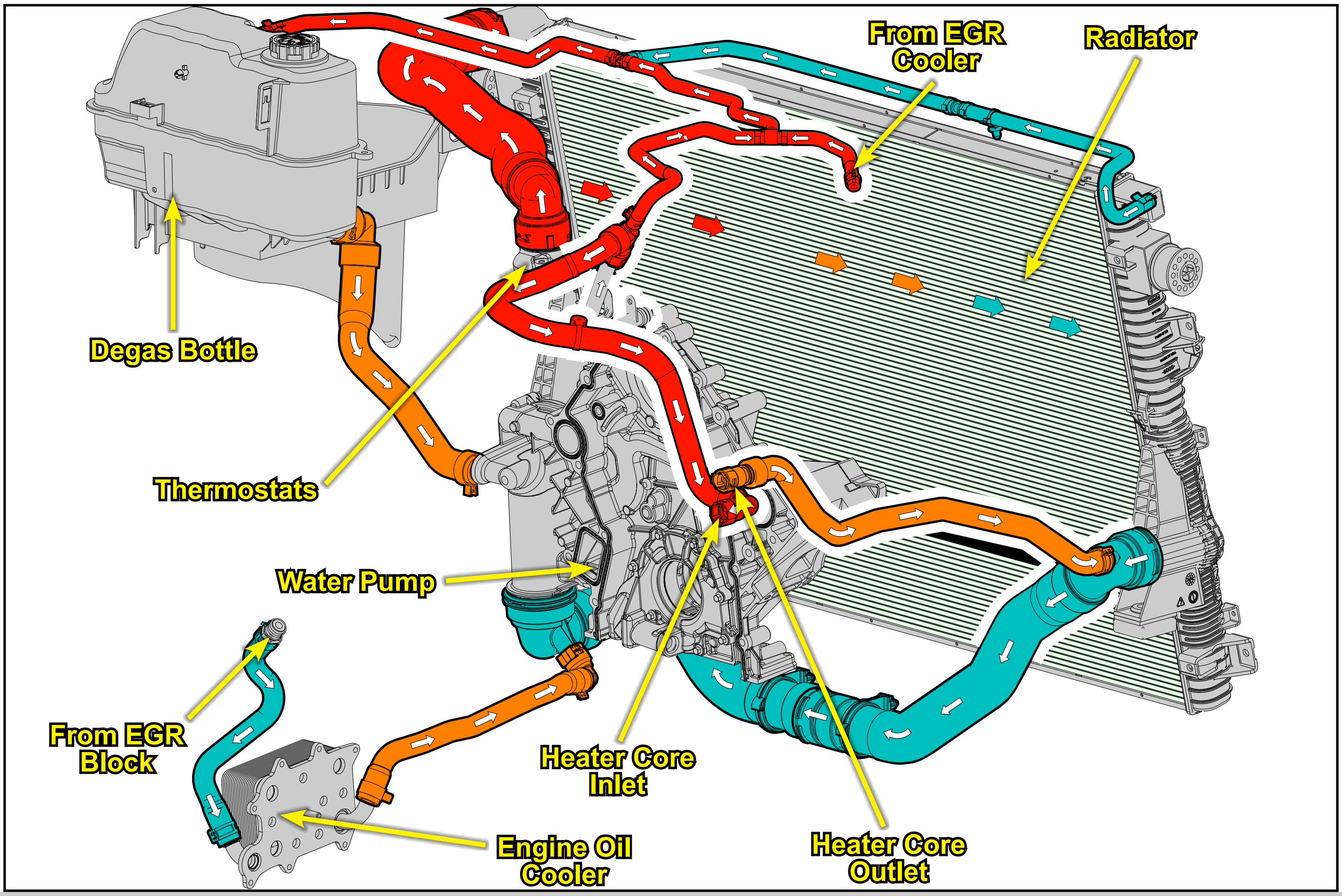


Coolant Flow Through the Block at Operating Temperature (Thermostat Open)



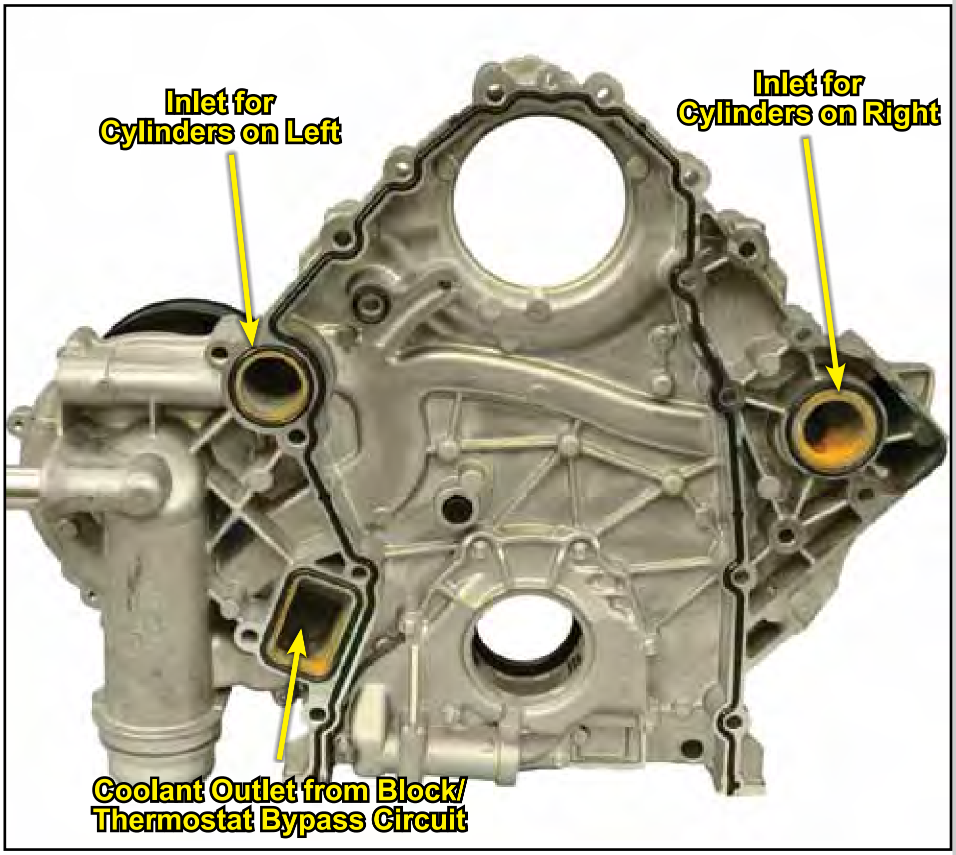
Coolant Flow Through the Block During Warm Up (Thermostat Closed)

Primary Cooling System



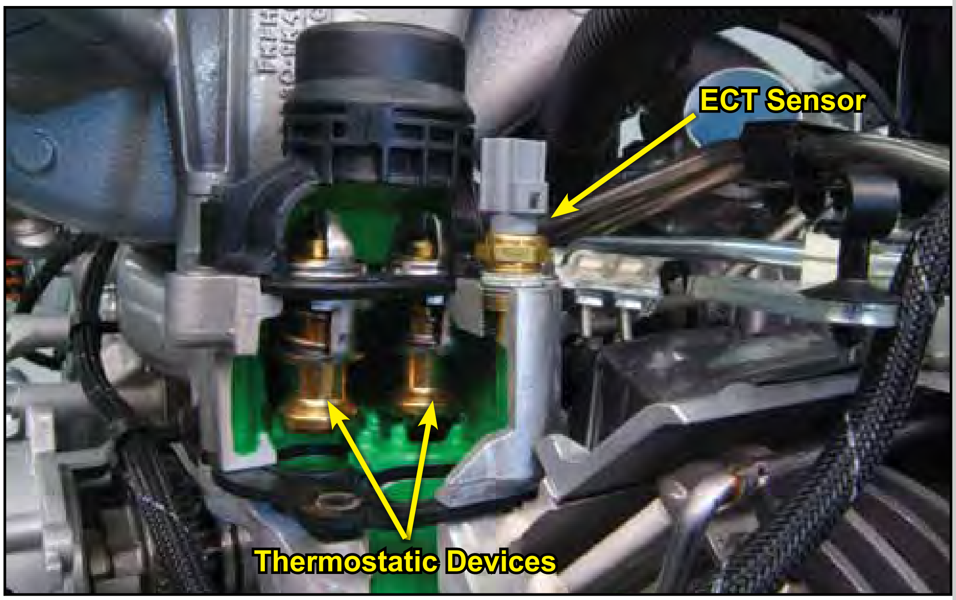
Primary Cooling System Flow

- The primary cooling system cools the following components:
  - engine block
  - cylinder heads
  - engine oil cooler
  - turbocharger
  - EGR cooler
- Coolant is drawn into the pump inlet located in the front cover from the bottom radiator port and flows from the coolant pump through the front cover to the crankcase.
- From the crankcase the coolant is routed to the cylinder heads, turbocharger, engine oil cooler and the heater core.
- The coolant enters the turbocharger from a passageway in the engine block. The coolant exits by a tube mounted on the left side of the turbocharger and goes into the water crossover at the front of the engine.
- Coolant is routed through the right valve cover to the EGR cooler and the EGR valve. Most of the coolant returns to the right valve cover, but there is a small outlet that goes to the degas bottle.
- The inlet for the heater core comes off the front water crossover. The outlet goes into the bottom radiator hose where it attaches to the radiator.
- The inlet for the engine oil cooler comes out of the left side of the engine block. The outlet goes into the bottom radiator hose where it attaches to the front cover.
- A dual thermostat system controls the flow of return coolant to the radiator. If the thermostats are open, coolant flows to the radiator to be cooled. If they are closed the coolant circulates through a bypass passage in the left cylinder head and engine block and return to the pump inlet.



Coolant System Flow (Back of Front Cover)

- Coolant is sealed via rubber O-ring seals.
- Coolant is directed through two passages in the front cover. One for the right bank of cylinders and one for the left bank of cylinders.
- During warm up the thermostat blocks the coolant flow to the radiator and the coolant is routed back to the pump through the bypass circuit.
- At normal operating temperature the thermostats are completely opened and the coolant is routed to the pump via the radiator.



Primary Thermostat

The primary thermostat has two thermostatic devices in one assembly. It is located in the coolant crossover at the front of the engine. The thermostat regulates the engine coolant temperature by controlling the flow of coolant through the primary radiator.

The two thermostatic devices do not open at the same coolant temperature. The opening temperatures are staggered by design, one opens at 90°C (194°F), other opens at 94°C (201°F).

Engine Coolant Temperature ECT Sensor

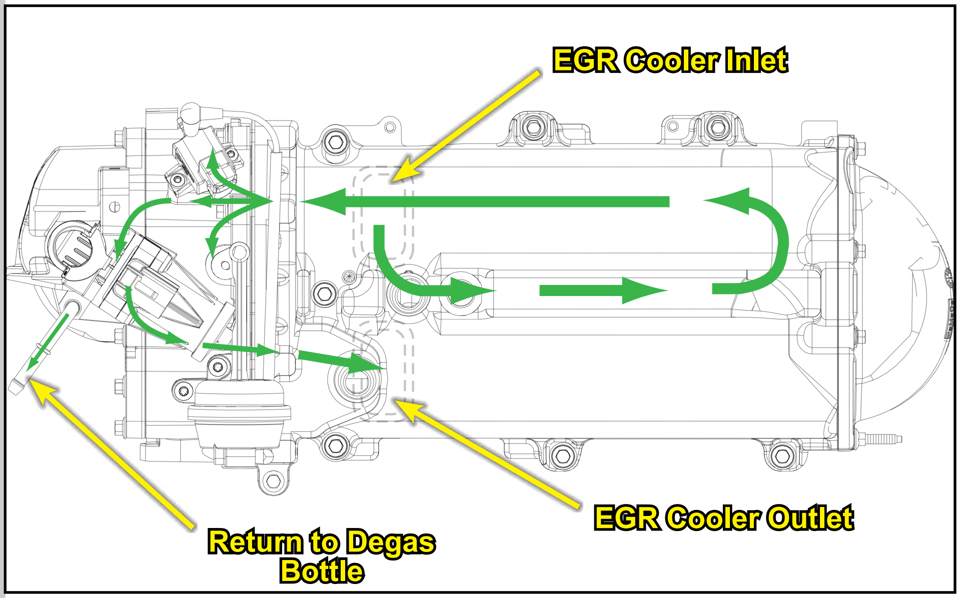
The ECT sensor is located in the coolant crossover, above the coolant pump and next to the thermostat housing.

Engine Oil Cooler

The engine oil cooler is located on the left side of the engine oil pan. Coolant flows from the lower rear of the block through the heat exchanger and back to the coolant pump inlet at the lower hose connection.

EGR Cooler Flow

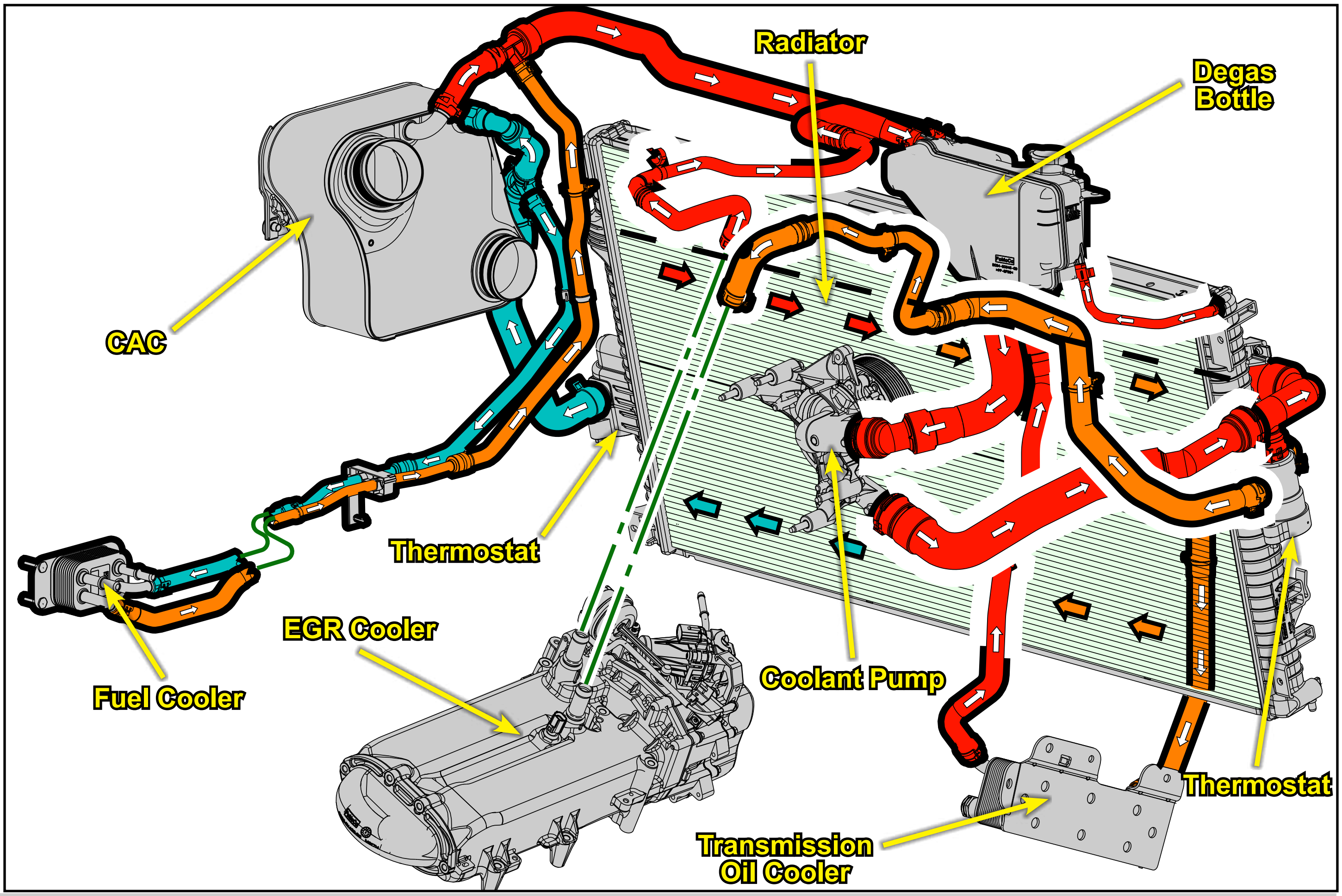
The coolant also passes from the cylinder head into the first half of the EGR cooler and then back into the cylinder head to cool the exhaust gases before they enter the cylinder.



Primary Coolant Pump

The primary coolant pump is located on the left front of the engine.
The heater core transfers heat from the primary cooling system to the passenger compartment. Coolant is routed into the heater core from the coolant crossover pipe at the front of the engine. Coolant passes through the heater core and routed to the lower radiator hose.

Powertrain Secondary Cooling System



Powertrain Secondary Cooling System Flow

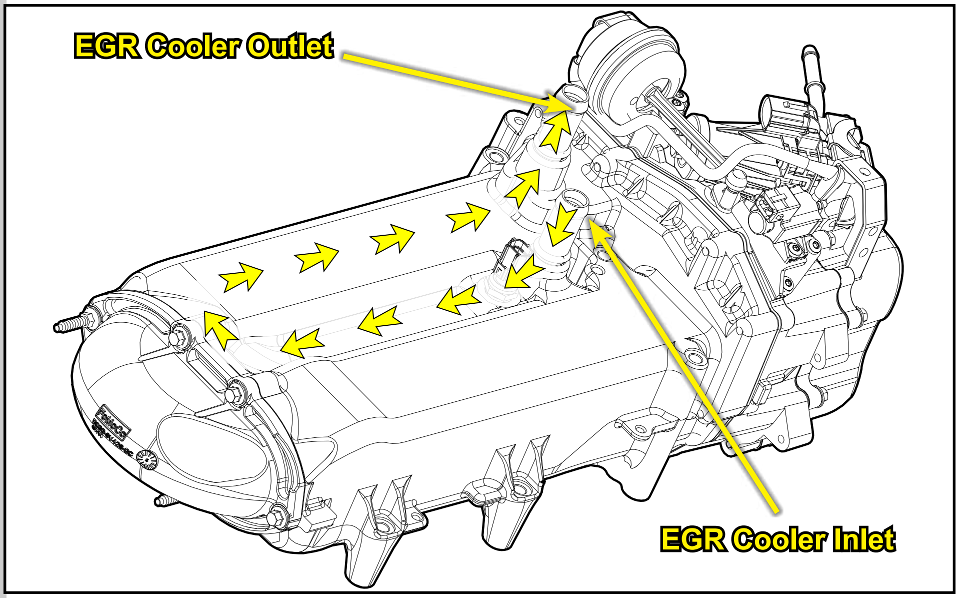
- The powertrain secondary cooling system cools the following components:
  - Charge Air Cooler (CAC)
  - fuel cooler
  - EGR cooler
  - transmission oil cooler
- The coolant is drawn into the inlet of the coolant pump from the degas bottle. The coolant exits the pump and is routed to the radiator.
- The radiator for the powertrain secondary cooling system has two stages.
- The inlet for the transmission oil cooler and the EGR cooler comes from the right side of the radiator after the first stage of cooling.
- The inlet for the CAC and the fuel cooler comes from the left side of the radiator after both stages of cooling.
- The outlet for all heat exchangers returns to the degas bottle.

Charge Air Cooler (CAC)

The 6.7L CAC is an air-to-coolant heat exchanger. This allows for more cooling capacity in a smaller under hood space.

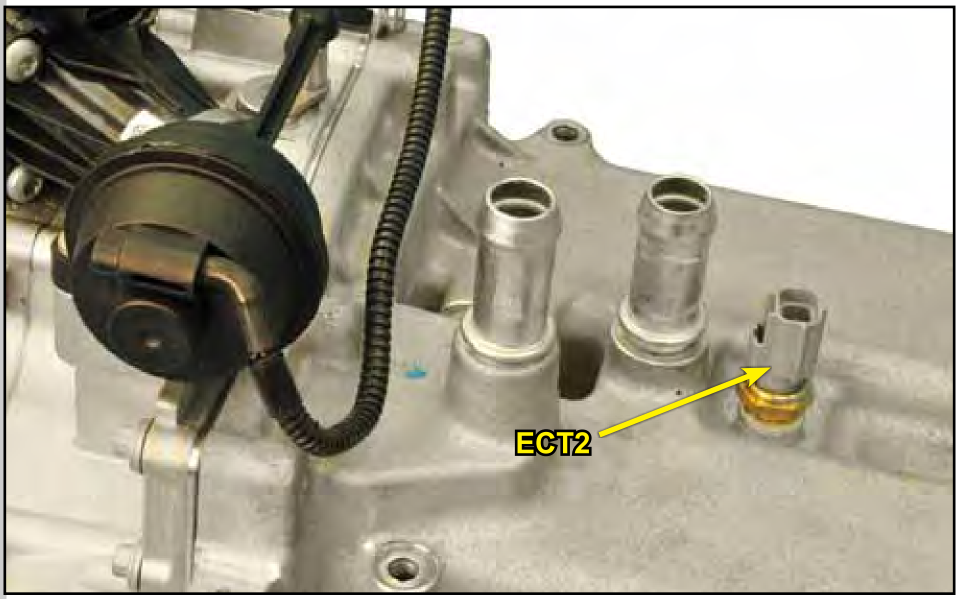
EGR Cooler Flow

The EGR cooler is located on top of the right valve cover and cools the exhaust gas before it enters the engine. This device, like the CAC, is also an air-to-coolant heat exchanger.



Engine Coolant Temperature (ECT2) Sensor

The ECT2 sensor is located in the powertrain secondary cooling system part of the EGR cooler, just after the coolant inlet.

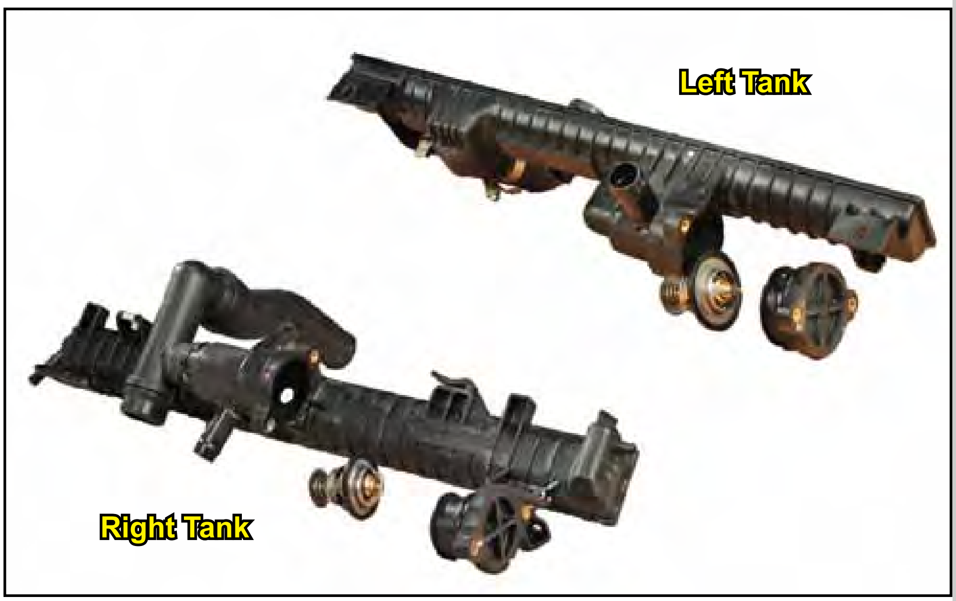


Transmission Cooler

The transmission cooler for the 6R140 transmission is located on the right front inner frame rail.

Fuel Cooler

The fuel cooler is located on the left frame rail between the engine and the Diesel Fuel Conditioning Module (DFCM). It cools the return fuel before it is sent to the DFCM.



Secondary Thermostats

The high temperature thermostat is located on the right side of the secondary radiator and regulates the upper radiator temperature to approximately 60°C (140°F).

The low temperature thermostat is located on the left side of the secondary radiator and regulates the lower radiator temperature to approximately 45°C (113°F).

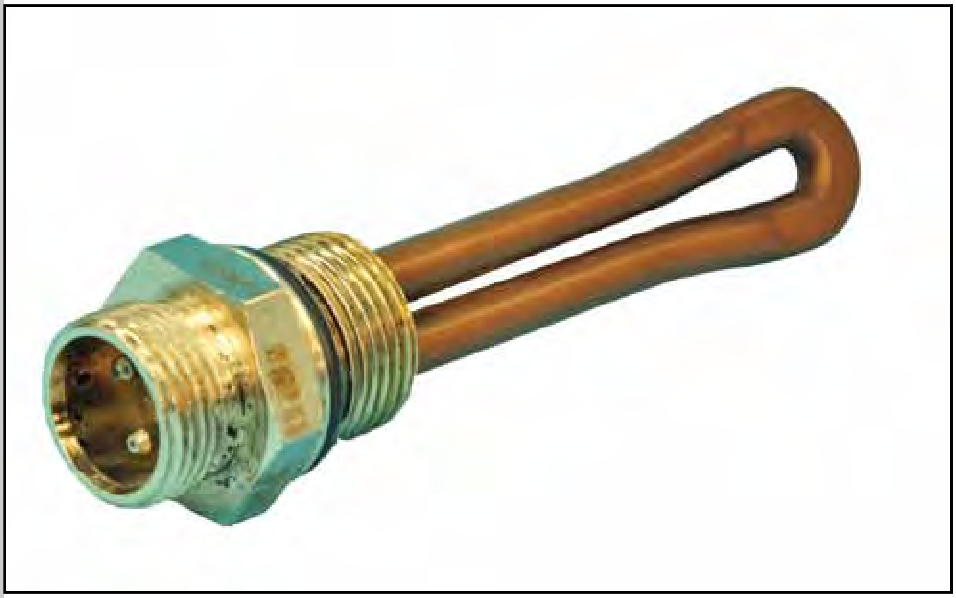
Secondary Coolant Pump

The secondary coolant pump is located on the right front of the engine.

Engine Block Heater

The engine block heater is located on the right side of the engine block. The block heater uses 110V AC to heat the engine coolant in cold weather climates. Use the engine block heater must be used whenever ambient temperatures are at or below -23°C (-9°F).

The engine block heater is standard on every engine. The power cord is an optional accessory.



Engine Cooling Fan

The engine cooling fan is an electro-viscous design. The engine cooling fan clutch is electronically controlled by the PCM, based on input information received from various engine sensors. The PCM provides a Pulse Width Modulated (PWM) signal to the fan clutch and monitors fan speed through the Fan Speed Sensor (FSS).

Radiators

The coolers that are located at the front of the grille opening include:

- primary radiator.
- secondary radiator.
- air conditioning condenser.
- power steering cooler.

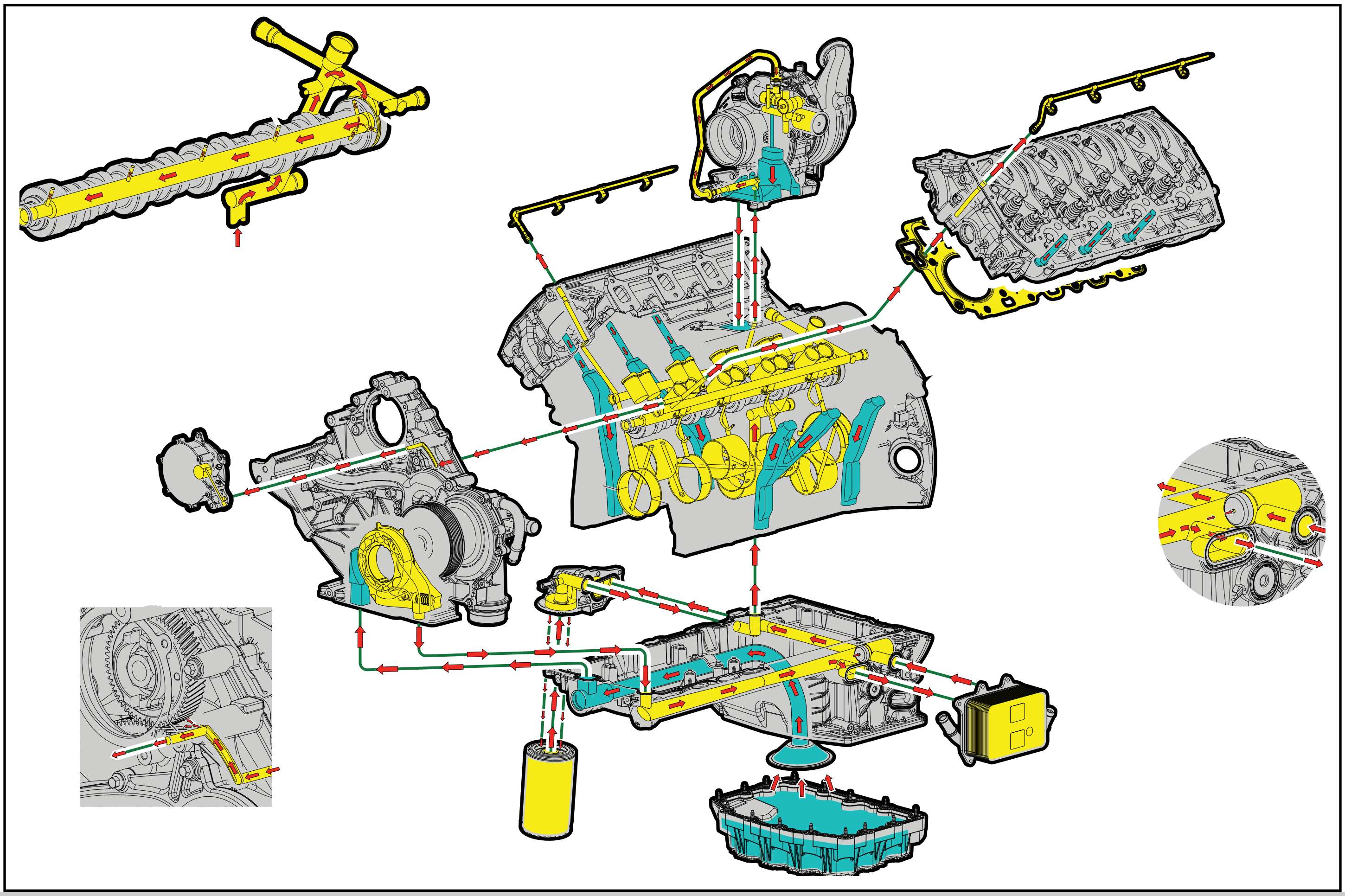
The secondary radiator is located in front of the primary radiator to allow the powertrain secondary cooling system to operate at a lower temperature than the primary cooling system.

Quick-Connect Fittings

Both cooling systems use unique quick-connect fittings on the larger coolant hoses and standard style clamps on the smaller hoses.

NOTES

LUBRICATION SYSTEM



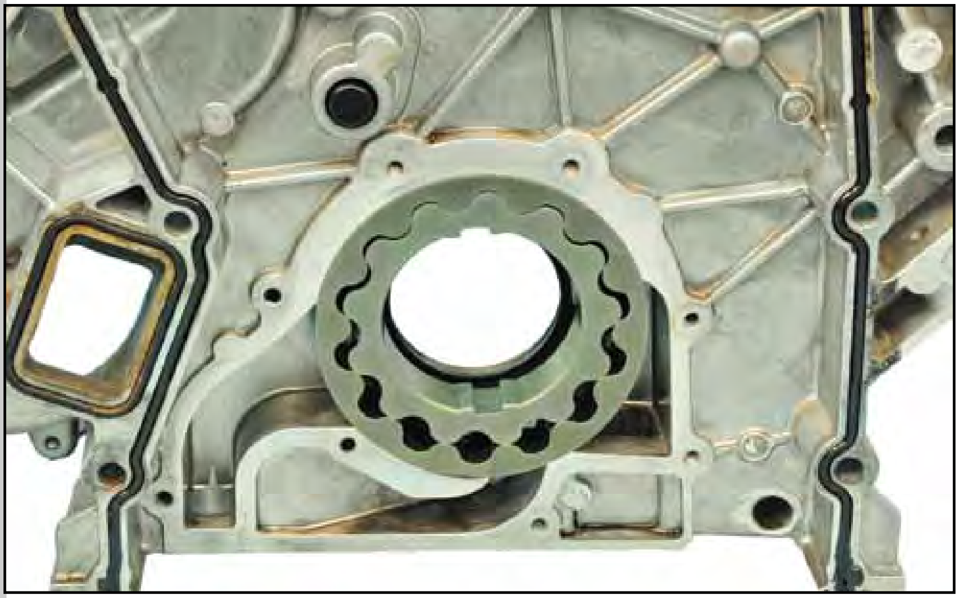
Lubrication System Oil Flow

- Oil is drawn from the oil pan through the pickup tube. The oil is then routed through a passage cast into the upper oil pan then to the oil pump inlet.
- From the oil pump, oil is directed to the oil cooler and then to the oil filter.
- The main oil passage in the rear of the engine block feeds the right, left and the camshaft galleries.
- Right oil gallery feeds the:
  - – rocker arm oiling manifold for the right cylinder head.
  - – cam followers and hydraulic lifters on the right side.
  - – piston cooling jets on the right side.
  - – crankshaft main bearings,
    - a separate oil passage for each main bearing.
    - also used to lubricate the connecting rod bearings.
  - – turbocharger.
- Left oil gallery feeds the:
  - – rocker arm oiling manifold for the left cylinder head.
    - An oil passage connected to the gallery going up to the left cylinder head also provides engine oil to the:
      - – vacuum pump.
      - – meshed gears of the crankshaft, camshaft and high pressure fuel pump.
  - – cam followers and hydraulic lifters on the left side.
  - – piston cooling jets on the left side.
- Camshaft oil gallery feeds the camshaft bearings.

Oil Pump

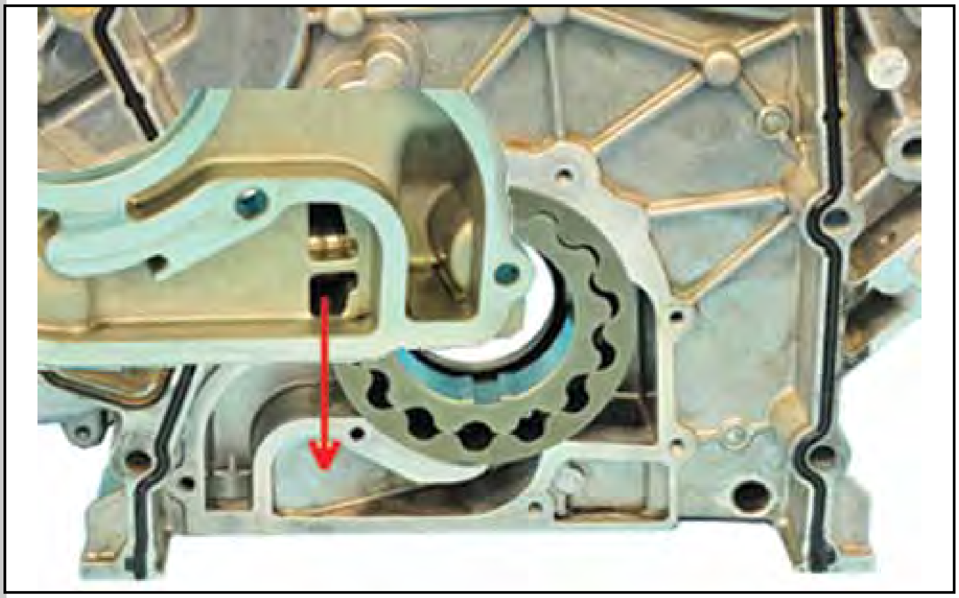
The gerotor style oil pump is mounted to the back side of the front cover.

Note: The front cover must be replaced to service the oil pump.



Oil Pressure Regulator

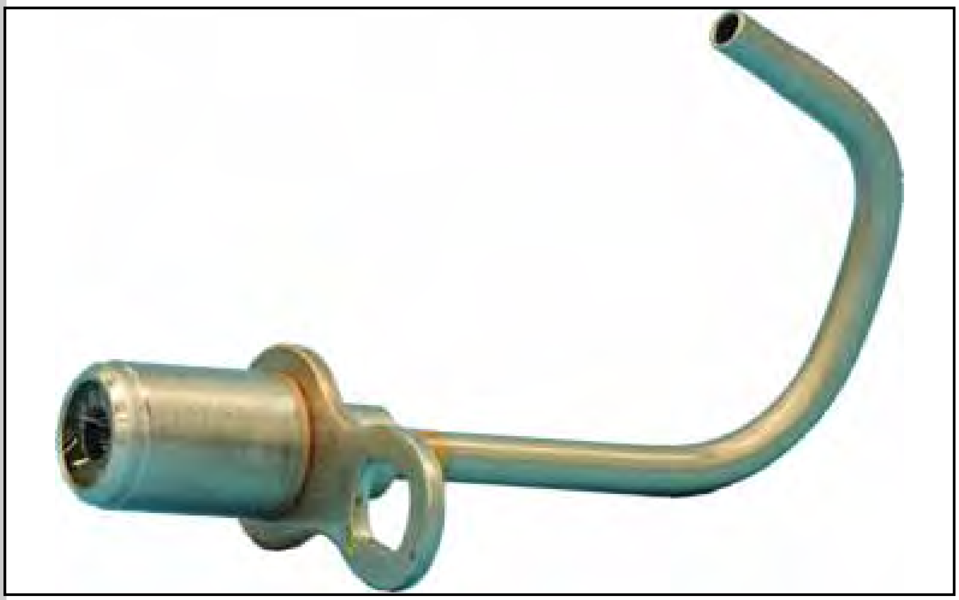
The oil pressure regulator valve is located in the oil pump cover on the back of the front cover.

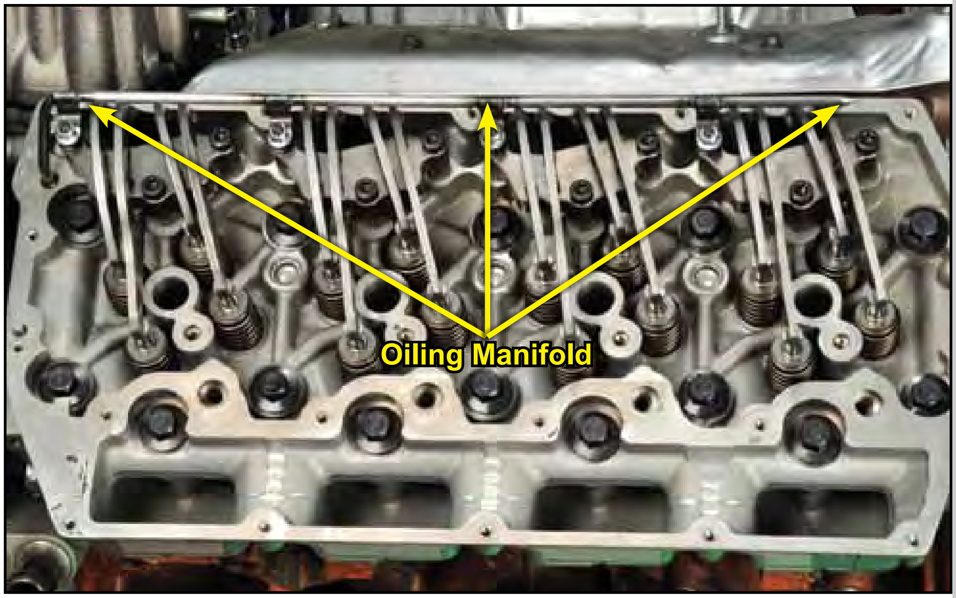


Piston Cooling Jets

The 6.7L engine incorporates piston cooling jets that spray oil into a hole in the bottom of the piston to cool the top of the piston.

The oil jets bolt into the bottom of the block and direct the oil into the piston.





Cylinder Head Lubrication

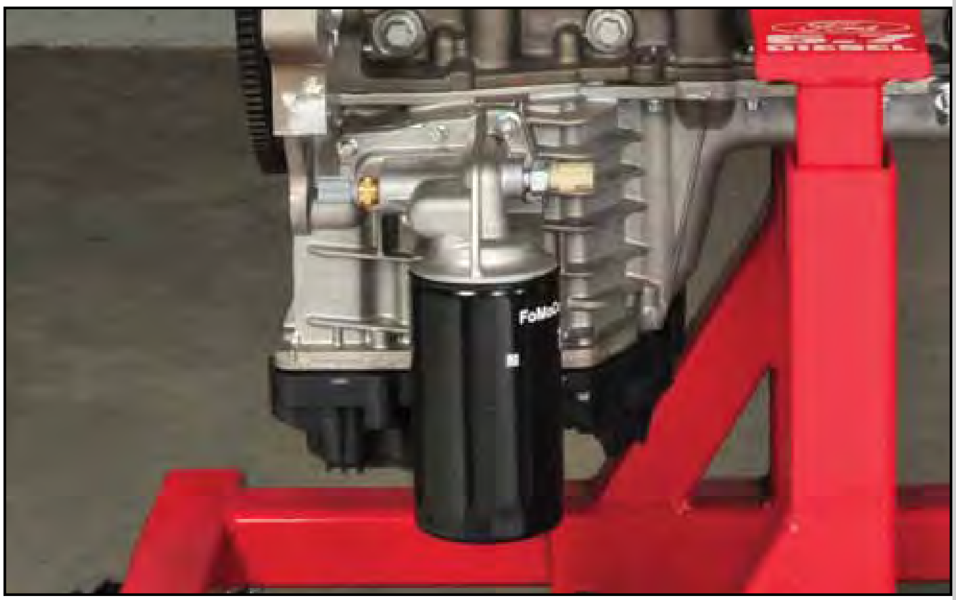
There is an oil manifold in each cylinder head that sprays oil onto the rocker arms and valve springs for cooling and lubrication.

Oil Cooler

The oil cooler is mounted on the oil pan of the engine and uses engine coolant to dissipate heat from the engine oil.

The coolant and oil are separated by multiple plates that create passages in the oil cooler.

After oil has been cooled, it exits the oil cooler and travels through the oil pan to the oil filter.



Oil Filter

The oil filter is a spin-on style mounted on the right side of the oil pan.

NOTES

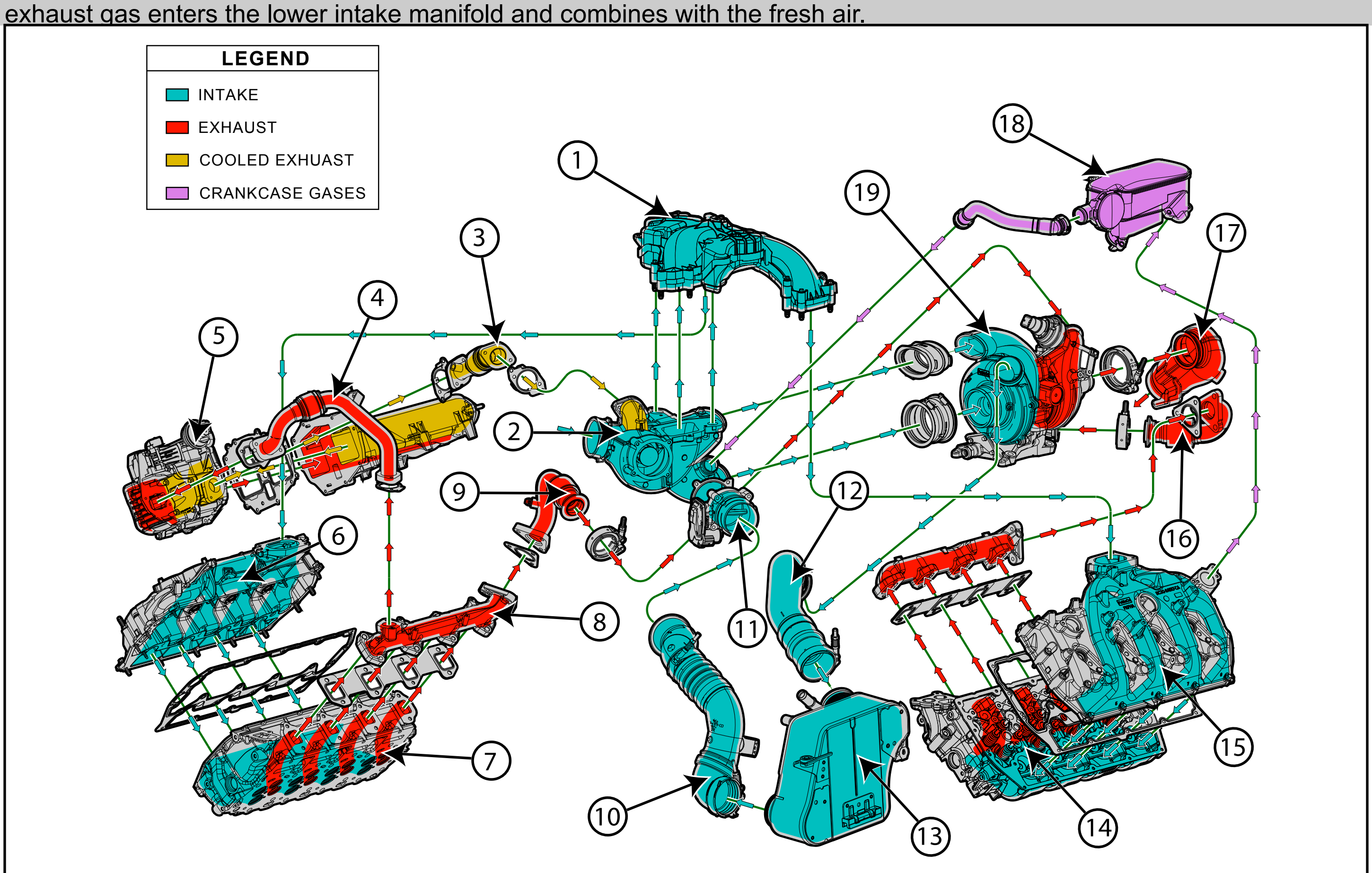
AIR MANAGEMENT SYSTEM

Intake Side

Air is drawn through the air filter then past the Mass Air Flow (MAF) and Intake Air Temperature (IAT) sensors. The MAF sensor measures the mass of the air entering the engine and IAT obtains the temperature. Next, the air enters the compressor side of the turbocharger through the lower intake manifold. The air is compressed above atmospheric pressure. The compressing process causes the air to heat up. Directing the air to an air to coolant Charge Air Cooler (CAC). From the CAC the air passes the CAC temperature sensor and through the intake throttle body and into the other side of the lower intake manifold. Inside the lower intake manifold the air mixes with EGR gases (if EGR valve is open), travels to the upper intake manifold, and through the right and left side rocker covers to the intake ports of the cylinder heads.

Exhaust Side

Exhaust gases exit the exhaust ports into the inboard exhaust manifolds. Exhaust gases are directed to the dual inlet of the turbo via the right and left side up-pipe. The exhaust spins the turbine wheel inside the turbocharger. The turbine wheel spins the compressor wheel(s) via their common shaft. Some of the exhaust from the passenger side manifold is directed to the EGR valve through the EGR inlet pipe. When the EGR valve is being operated, exhaust flow goes through the valve then either through the EGR cooler or bypassing the cooler. This is done by the EGR cooler bypass valve. The exhaust gas enters the lower intake manifold and combines with the fresh air.



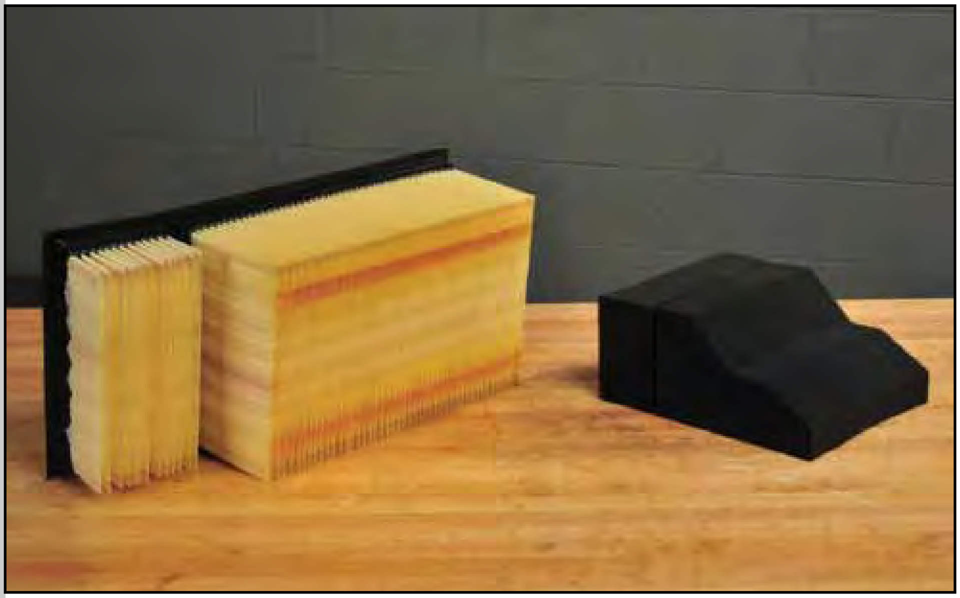
Number	Component	Number	Component
1	Upper intake manifold	11	Intake Throttle Body
2	Lower intake manifold	12	CAC inlet
3	EGR outlet tube	13	CAC
4	Exhaust manifold to EGR tube	14	Left cylinder head
5	EGR valve	15	Left valve cover
6	Right valve cover	16	Left turbo inlet pipe
7	Right cylinder head	17	Turbocharger down pipe
8	Right exhaust manifold	18	Crank Case Vent (CCV)
9	Right turbo inlet pipe	19	Turbocharger
10	CAC outlet		

Air Inlet Components

Air Filter

The air filter is located on the passenger side of the engine compartment in front of the battery.

The air filter housing includes a non-electrical filter minder to measure inlet restriction. When the filter element becomes contaminated beyond useful limits, the filter minder visually indicates the need for replacement.



Mass Air Flow/Intake Air Temperature (MAF/IAT) Sensor

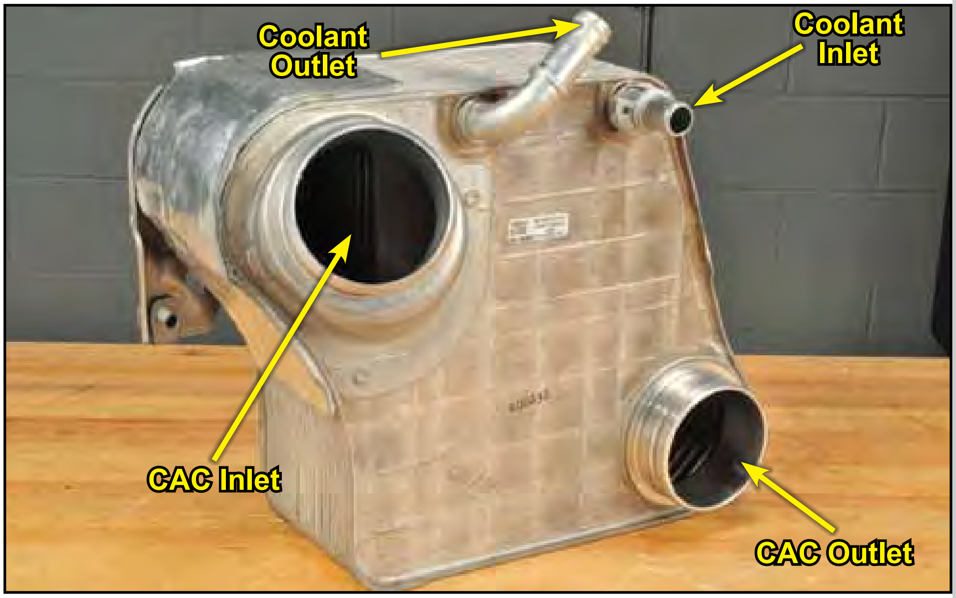
The air intake system includes a MAF and IAT sensors integrated into one unit. The MAF/IAT sensor is located in the air inlet tube after the air filter.

Pickup Turbocharger (Wide Frame)

The turbocharger pickup models use a DualBoost turbocharger. This turbocharger has one exhaust turbine, two intake compressors and incorporates a wastegate. The exhaust turbine has variable vanes that change with engine oil pressure from a PCM-controlled solenoid.

Chassis Cab Turbocharger (Narrow Frame)

The chassis cab use a standard Variable Geometry Turbocharger (VGT) operated with engine oil pressure that is controlled by the PCM. This turbocharger does not incorporate a wastegate.



Charge Air Cooler (CAC)

The CAC is located on the left side of the engine, on top of the fender well.

The CAC is a air-to-coolant heat exchanger used to reduce the temperature of the compressed air from the turbocharger prior to entering the combustion chambers. Cooler air is denser (improving volumetric efficiency), resulting in increased power.

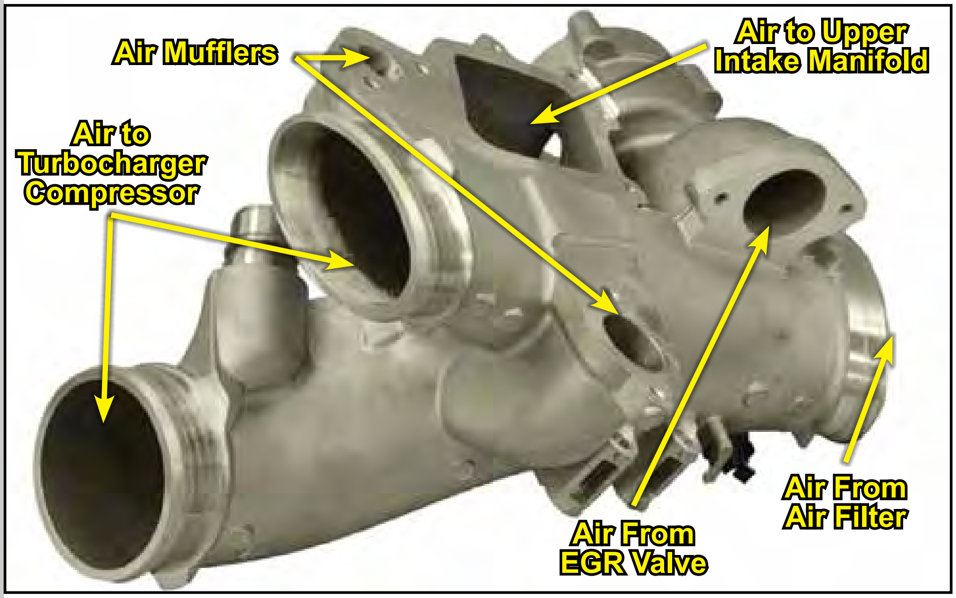
Intake Throttle Body

The intake throttle body is located on the top of the engine, attached to the lower intake manifold.

The intake throttle body controls air flow into the intake air system.

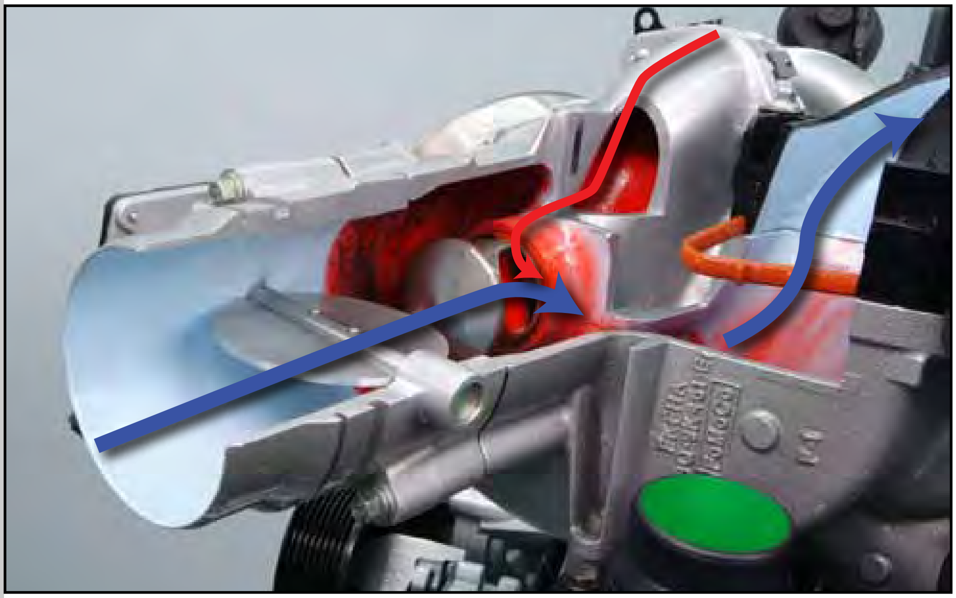
Lower Intake Manifold

The lower intake manifold is on the top of the engine and intake air passes through it twice. The first time it flows through the lower intake manifold before going to the turbocharger inlet. Crankcase vapors are pulled into the lower intake manifold with the air on its way to the turbocharger.



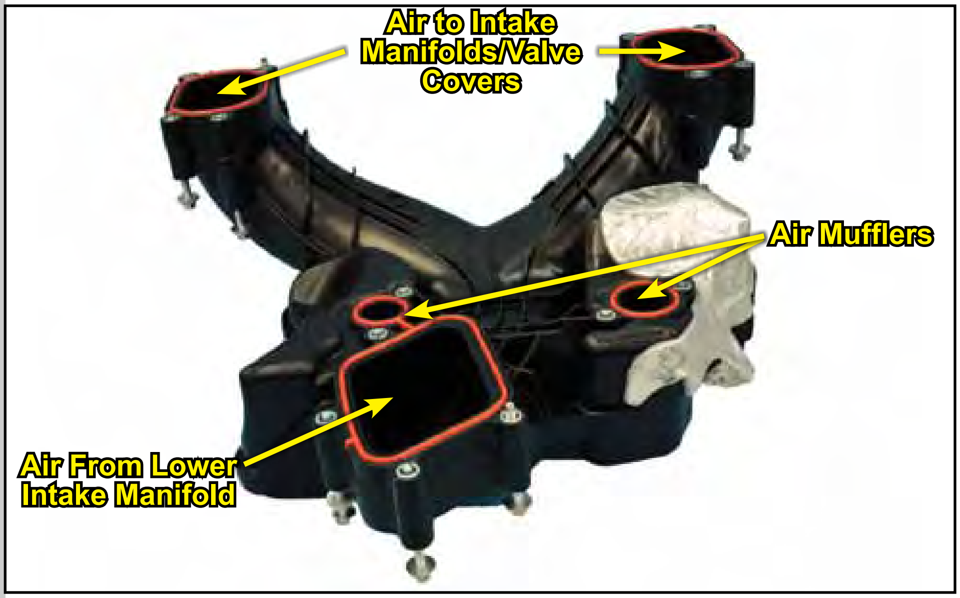
Lower Intake Air Flow after the CAC

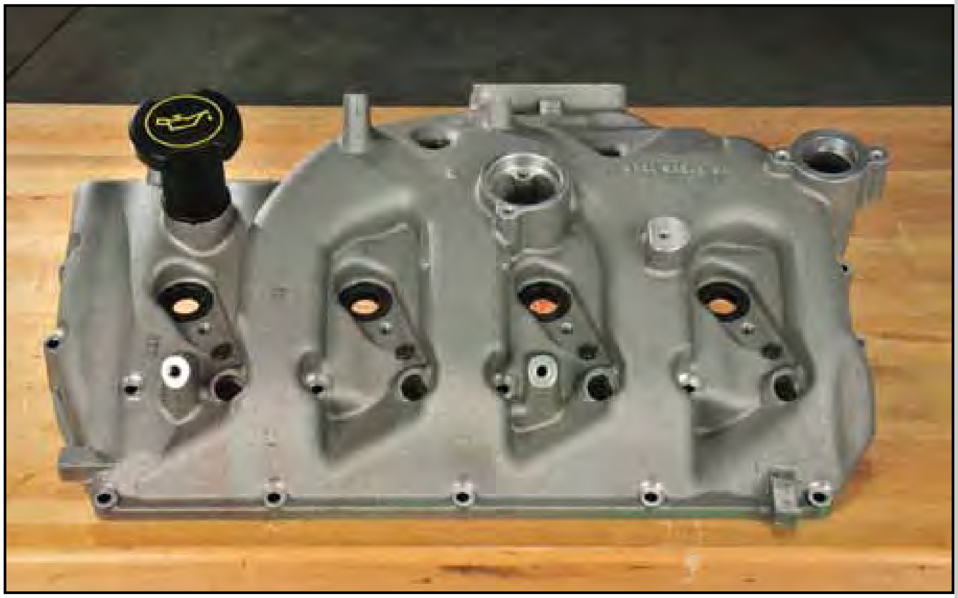
After leaving the turbocharger outlet the air goes through the CAC and then through the intake throttle body before it is mixed with exhaust gases from the EGR valve. The blue line represents the flow of cooled intake air and the red line represents the flow of EGR gases.



Upper Intake Manifold

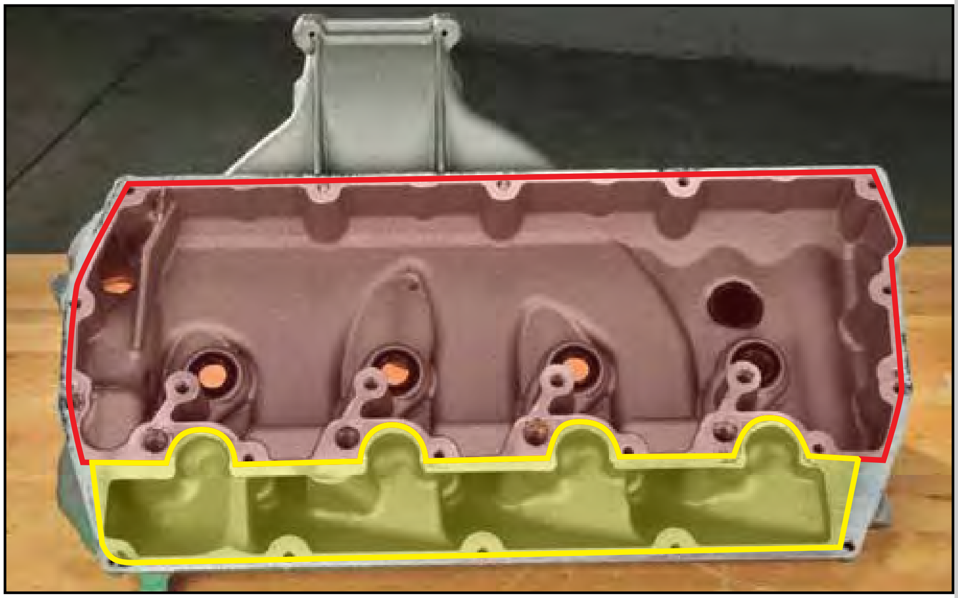
The upper intake manifold directs pressurized air from the lower intake manifold to the intake manifold/valve covers. The upper intake manifold contains two intake noise mufflers to reduce intake noise.





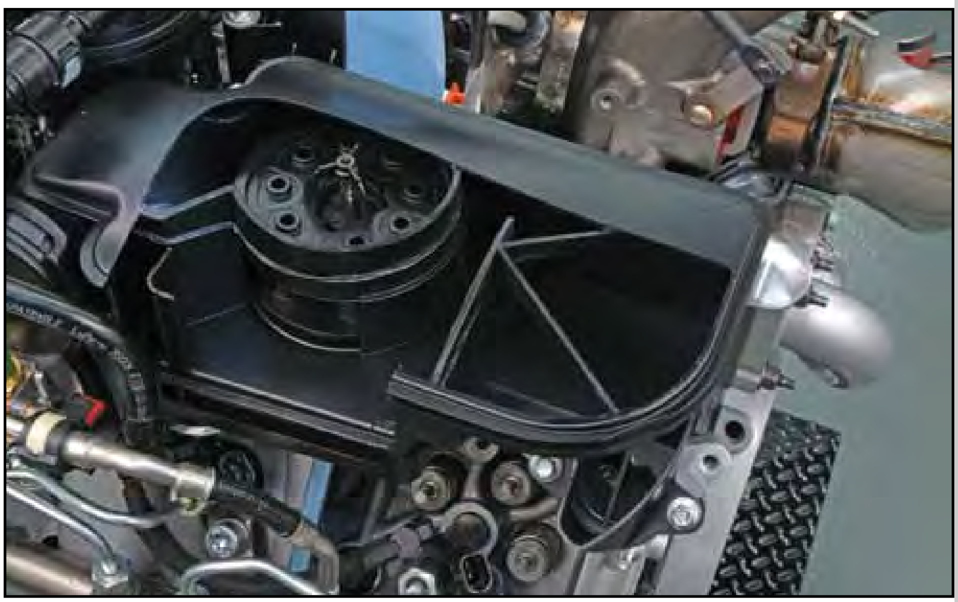
Intake Manifold/Valve Cover

The intake manifold/valve cover for each cylinder head are incorporated into one piece. The air flows from the upper intake manifold into the top of the valve cover and across to the intake ports.



Bottom of Valve Cover

In the picture you can see the intake manifold port on the bottom and the valve cover cavity on the top.



Crankcase Vent Oil Separator

The crankcase vent oil separator is attached to the left valve cover.

The engine crankcase vent oil separator, separates the oil from crankcase vapors and returns it to the crankcase through the valve cover. The vapors are routed into the intake ducting at the lower intake, before the turbo inlet.

Glow Plug System

Glow Plug Control Module (GPCM)

The GPCM is located under the passenger side battery box.

The glow plug system is electronically controlled by the PCM. The PCM monitors the ambient temperature, ECT and BARO sensors to control glow plug operation.

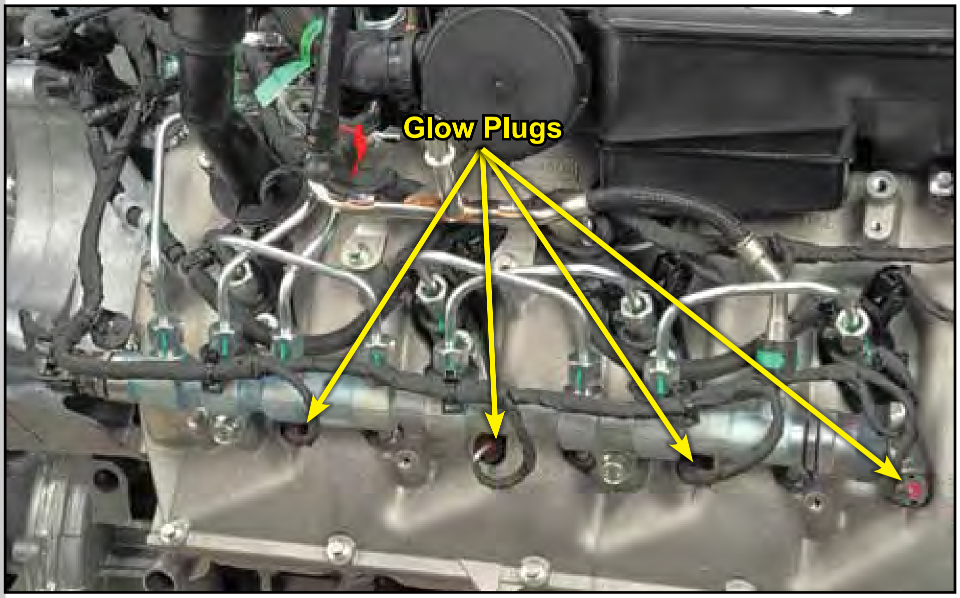
The GPCM controls the glow plugs and the reductant system heating elements.

When required, the PCM supplies a signal to the GPCM which in turn supplies current to the glow plugs.

Glow Plugs

The glow plugs are mounted in the cylinder heads and are accessible through the valve cover.

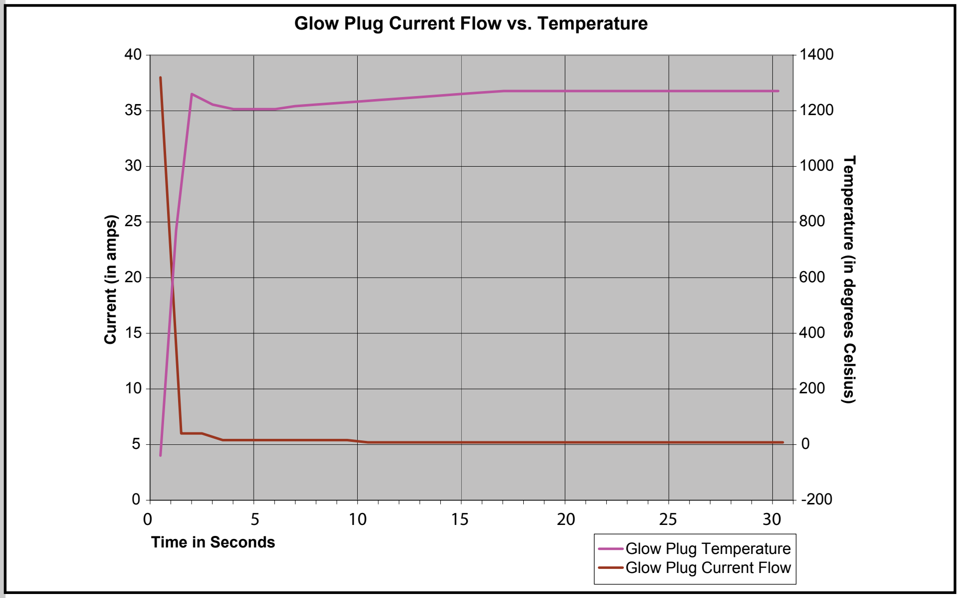
The GPCM supplies the required current to each glow plug, based on commands from the PCM. Ground is provided through the glow plug body to the cylinder head.



Glow Plug Operation

Some of the features of the ceramic glow plugs that are used on the 6.7L Power Stroke® diesel are:

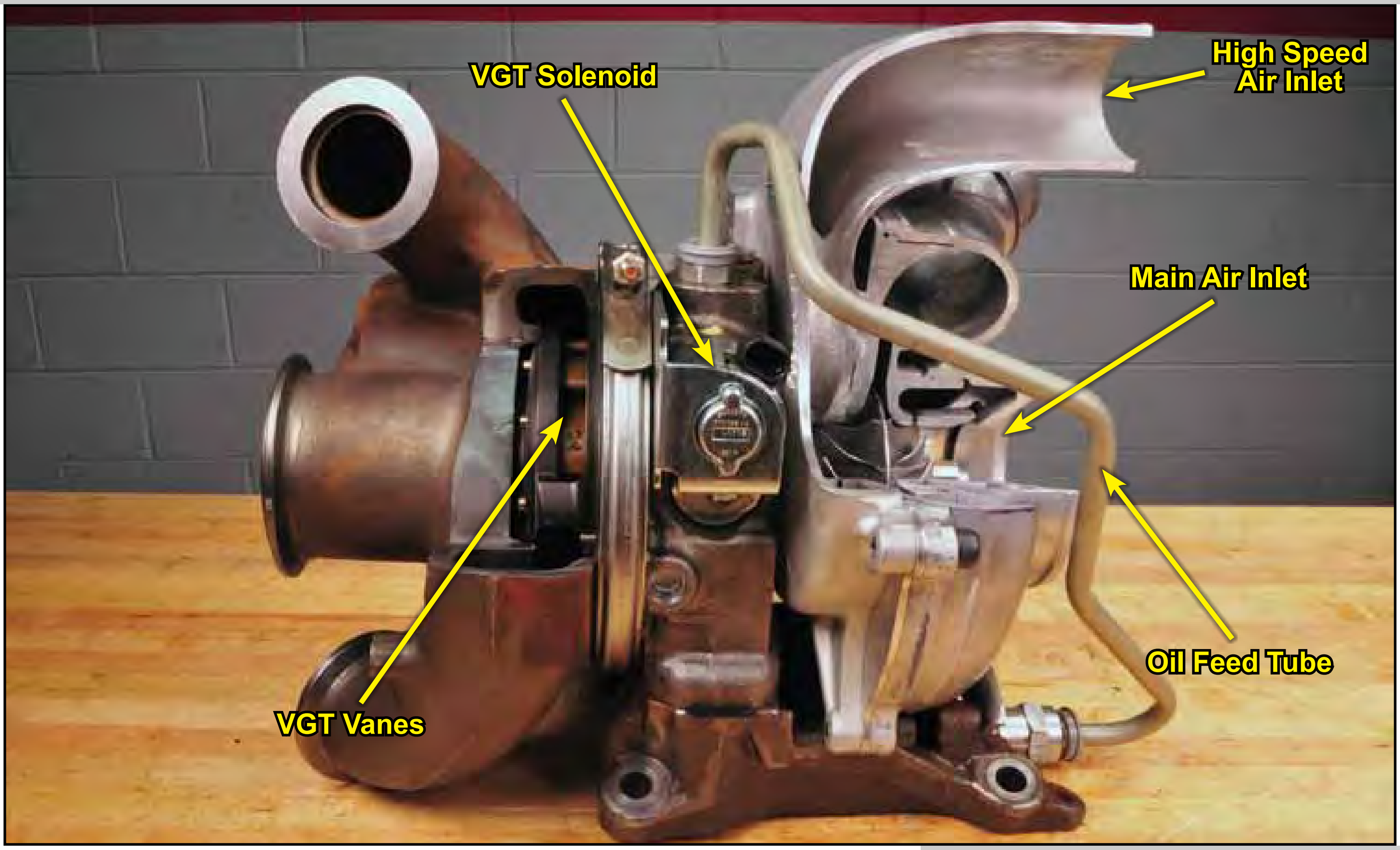
- End of compression temperature is high enough to auto-ignite the fuel.
- The ceramic glow plugs can reach 1250°C (2282°F) in 2 seconds.
- The tip of the glow plug is closer to the rim of the piston than the injector. This causes the heat from the glow plug to contact the rim zone of the fuel spray.

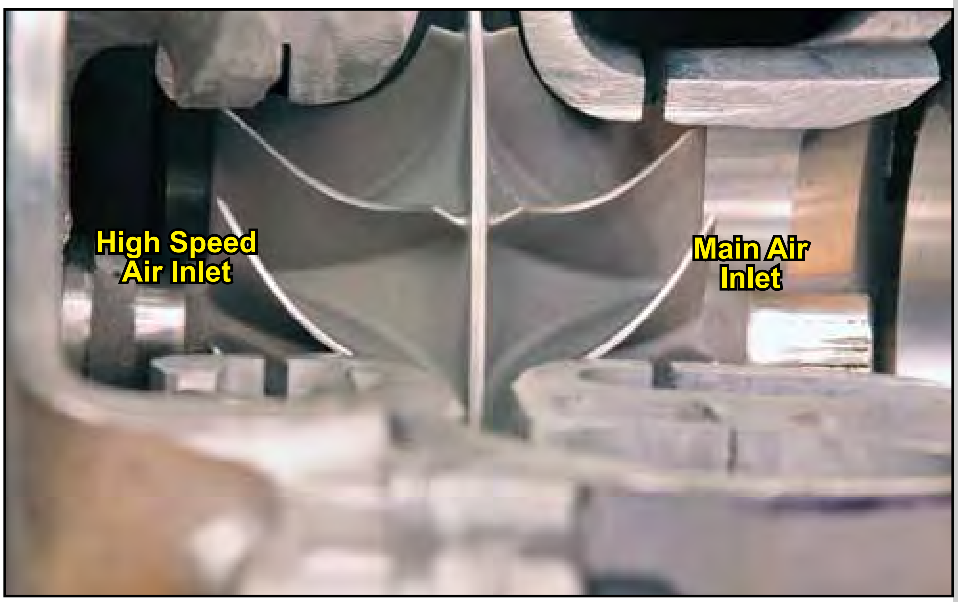


DualBoost Variable Geometry Turbocharger (VGT)

Turbocharger control is based off an air system model that produces a desired intake pressure to meet the power requirements requested by the operator.. The PCM commands the VGT control valve by a feedback loop on the intake pressure to achieve the desired intake pressure to meet the driver's needs (pedal position, engine load). The air system model considers engine temperature, air temperature, EGR operation, RPM, and engine load.

The turbocharger on pickup box models have a wastegate. The PCM controls the wastegate solenoid to supply vacuum to the actuator. When intake pressure is greater than desired and the VGT has commanded the vanes to the full open position the wastegate opens allowing exhaust gases to bypass the turbine fins, reducing exhaust pressure thus reducing intake pressure.



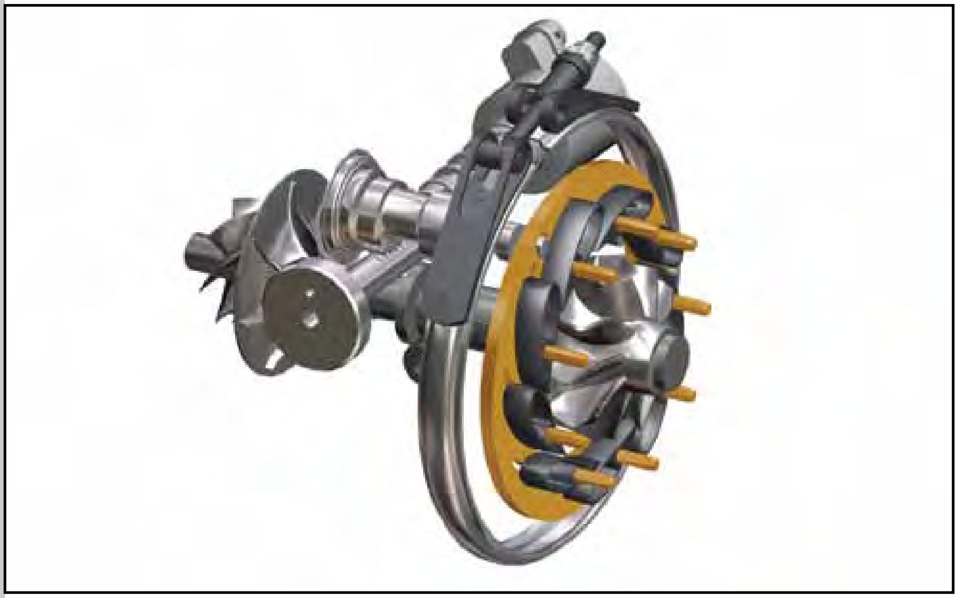


Intake Compressors.

The DualBoost VGT has two intake compressors and one exhaust turbine on a common shaft.

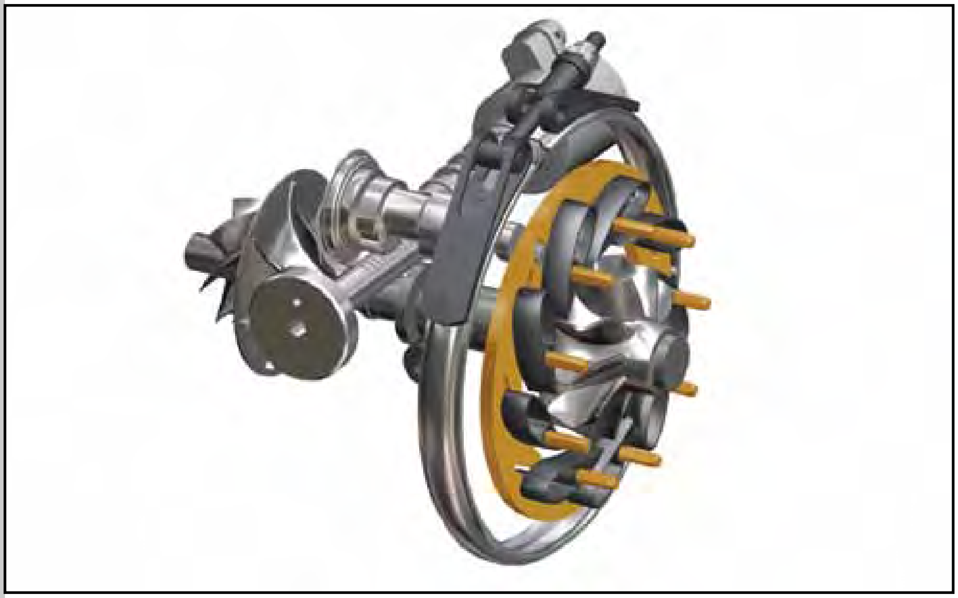
VGT Closed

When the VGT is closed it maximizes the use of the energy that is available at low speeds. Closing the VGT accelerates exhaust gas flow across the vanes of the turbine wheel. This allows the turbocharger to behave as a smaller turbocharger. Closing the vanes also increases the exhaust pressure in the exhaust manifold, which aids in pushing exhaust gas into the intake. This is also the position for cold ambient warm-up.



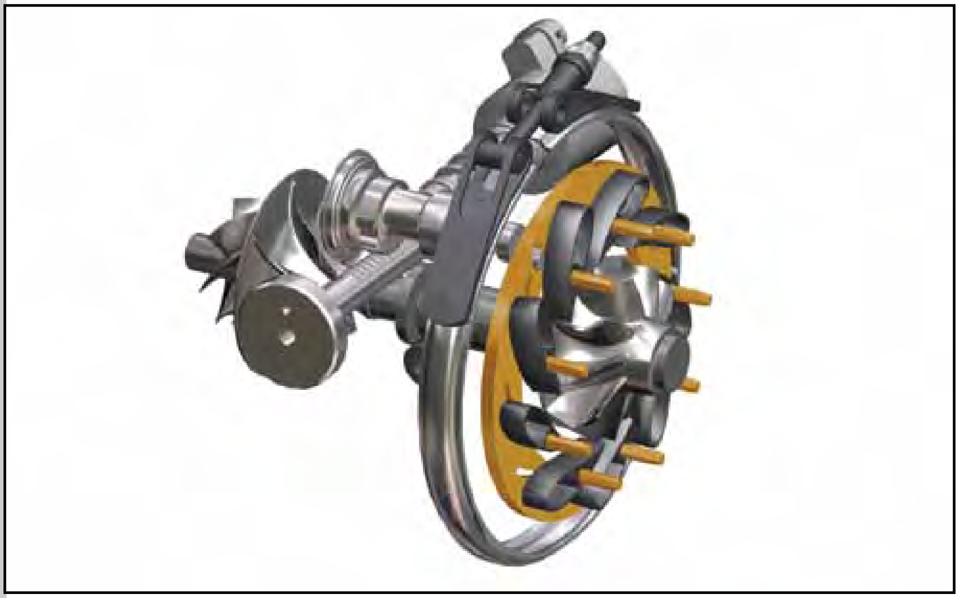
VGT Partially Open

During engine operation at moderate engine speeds and load, the vanes are commanded partially open. The vanes are set to this intermediate position to supply the correct amount of boost to the engine for optimal combustion, as well as providing the necessary exhaust pressure to drive exhaust gas.



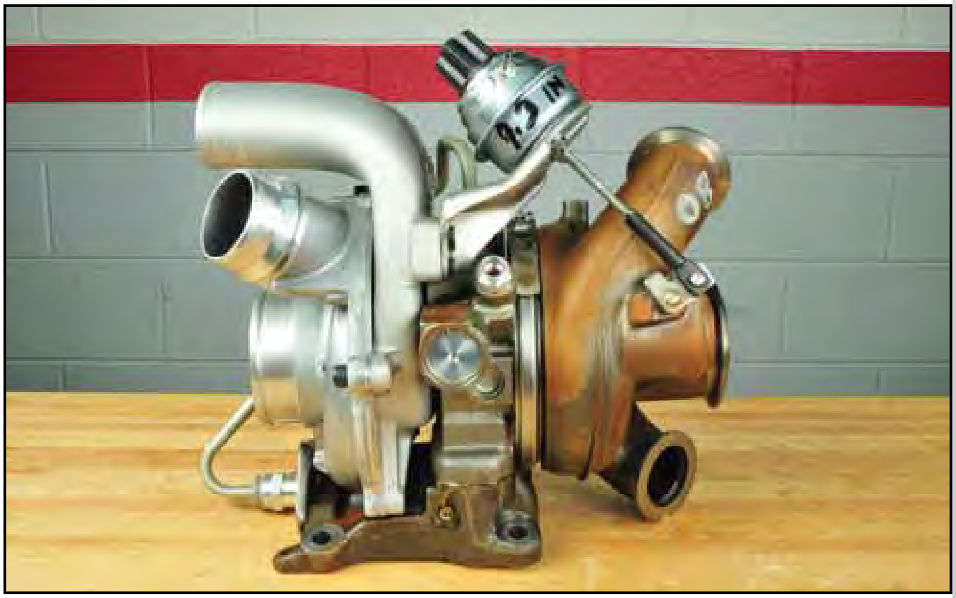
VGT Open

During engine operation at high engine speeds and load, there is a great deal of energy available in the exhaust. Excessive boost under high speed, high load conditions can negatively affect component durability. Therefore, the vanes are commanded open preventing turbocharger overspeed. Essentially, this allows the turbocharger to act as a large turbocharger.



VGT Actuator

The 6.7L VGT actuator uses engine oil pressure on a piston to move the vanes on the exhaust turbine. The VGT actuator is commanded by the PCM, based on a desired MAP pressure. This actuator meters engine oil to either side of the piston. This design feature reacts quickly to changes in demand based on driving conditions. When one side of the piston is pressurized, the opposite side is vented.

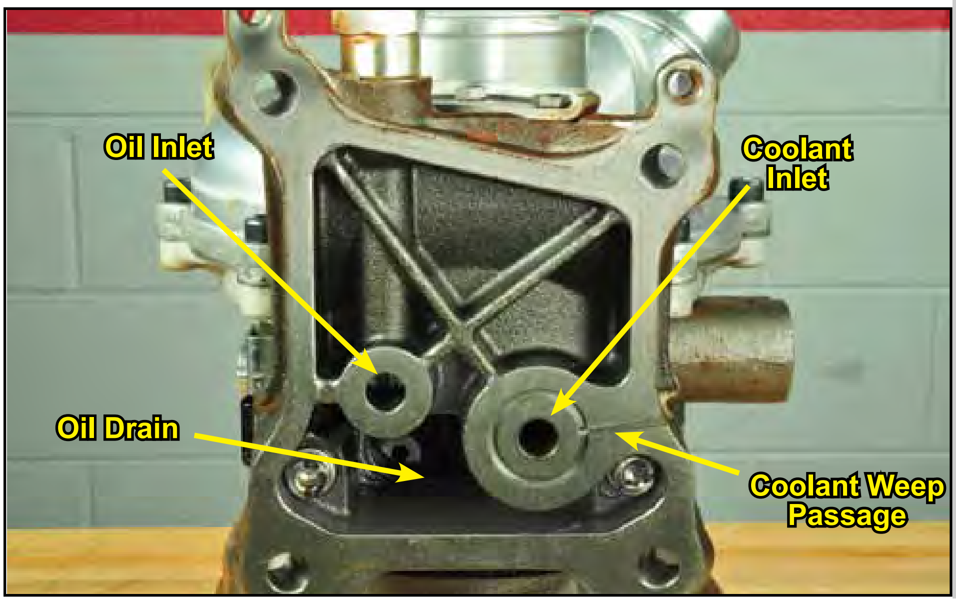


Wastegate Solenoid and Actuator

The wastegate on the DualBoost VGT is vacuum controlled through a solenoid that is controlled by the PCM. The wastegate is only used on the DualBoost turbocharger.

The wastegate opens to relieve excessive exhaust pressure at higher RPMs.

When the VGT cannot react quickly enough to reduce MAP pressure, the wastegate will open to reduce EP to slow down the turbo.



Coolant Passages

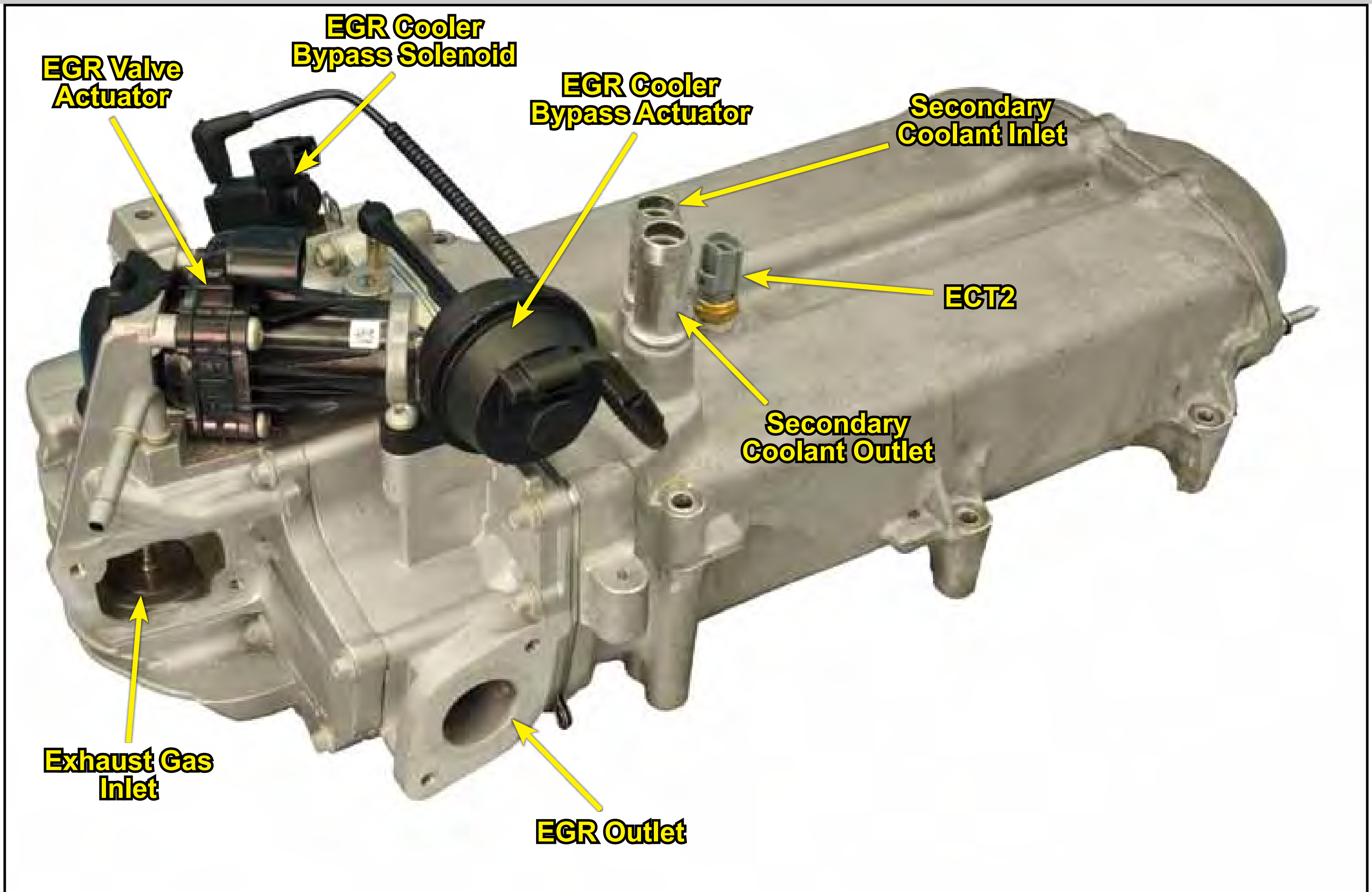
The turbocharger is cooled using coolant from the primary cooling system. Coolant enters the turbocharger from the block on the bottom of the turbocharger and flows through and out the top of the turbocharger through a line back to the coolant crossover tube.

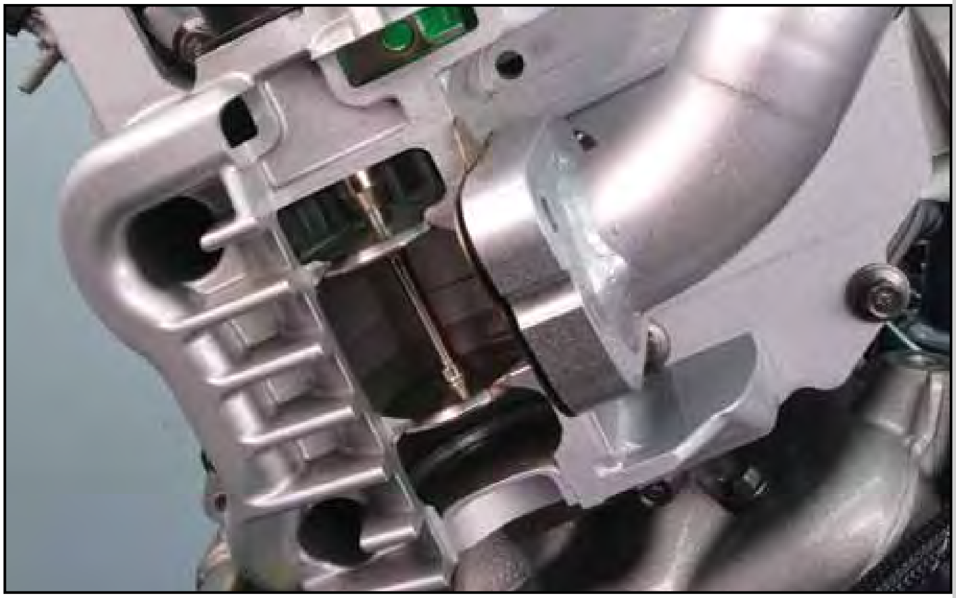
Exhaust Gas Recirculation (EGR)

The EGR system allows cooled (inert) exhaust gases to re-enter the combustion chamber, which lowers combustion temperatures and Oxides of Nitrogen (NO_x) emissions.

EGR system control is based off an air system model to estimate the percentage of exhaust gas in the cylinder. The PCM looks at engine temperature, intake pressure, exhaust pressure (EP), RPM, and engine load to determine the EGR flow rate. The ratio of MAP and EP is used by the PCM to estimate a desired EGR valve position. The desired position is compared to the actual and the duty cycle is adjusted to meet that desired position for the required EGR flow rate. If the rate is not achieved with EGR valve position, the intake throttle body closes to a desired position, reducing intake manifold pressure. Reducing the intake manifold pressure increases the pressure ratio allowing more exhaust to fill the intake manifold at a given EGR valve position. As more exhaust gas is introduced into the intake manifold the amount of air measured by the Mass Air Flow (MAF) sensor is decreased.

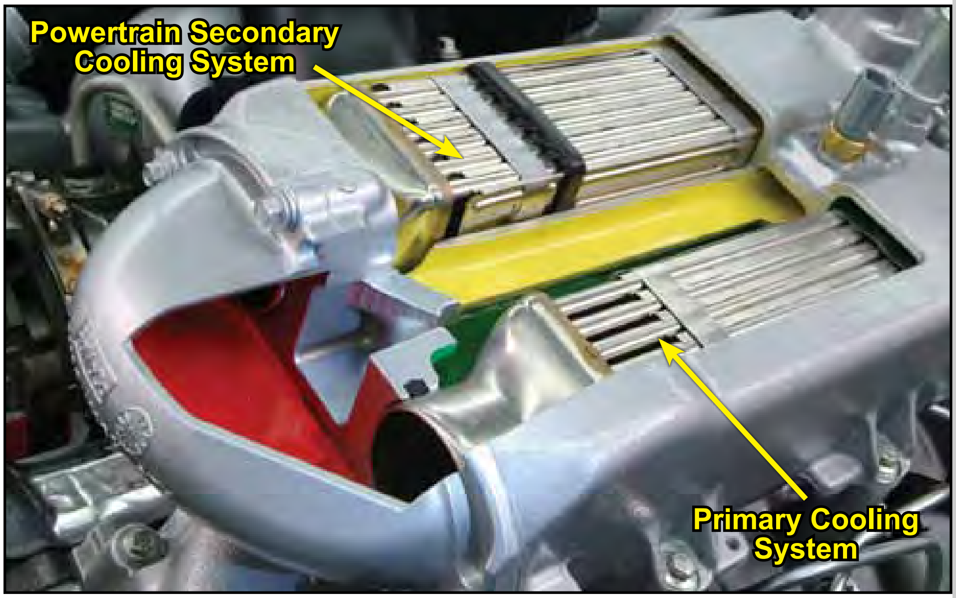
The 6.7L has a hot side EGR valve due to it being before the EGR cooler. Once past the EGR valve, the exhaust gas is either directed through the EGR cooler or bypasses the EGR cooler. This is done by the PCM controlling the EGR cooler bypass solenoid which turns vacuum on or off to the actuator on the bypass door. The EGR outlet temperature (EGRT) sensor measures the temperature of the exhaust gas leaving the system for cooler effectiveness and bypass control.





EGR Valve

The EGR valve receives a duty cycle signal from the PCM and sends a variable voltage signal from the Exhaust Gas Recirculation Valve Position (EGRVP) sensor back to the PCM to indicate actual position. Internally, it has two valves connected by a common shaft. Exhaust gases are routed from the right exhaust manifold to the center of the valve. When the valve is opened, exhaust gases flow out the top and bottom poppet valves either through the EGR Cooler and to the intake manifold or directly to the intake manifold if the EGR cooler bypass valve is in bypass position.

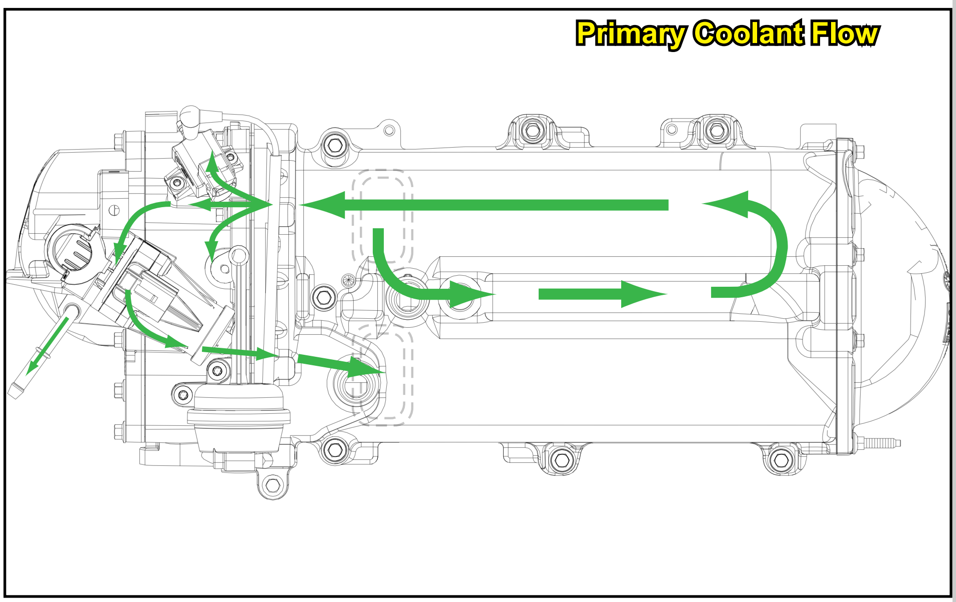


EGR Cooler

The EGR system uses an EGR cooler after the EGR valve. This keeps the EGR valve cleaner than previous engines.

The EGR cooler is located on the right valve cover, for easier service.

The cooler EGR temperature reduces NO_x emissions.



EGR Primary Coolant Flow:

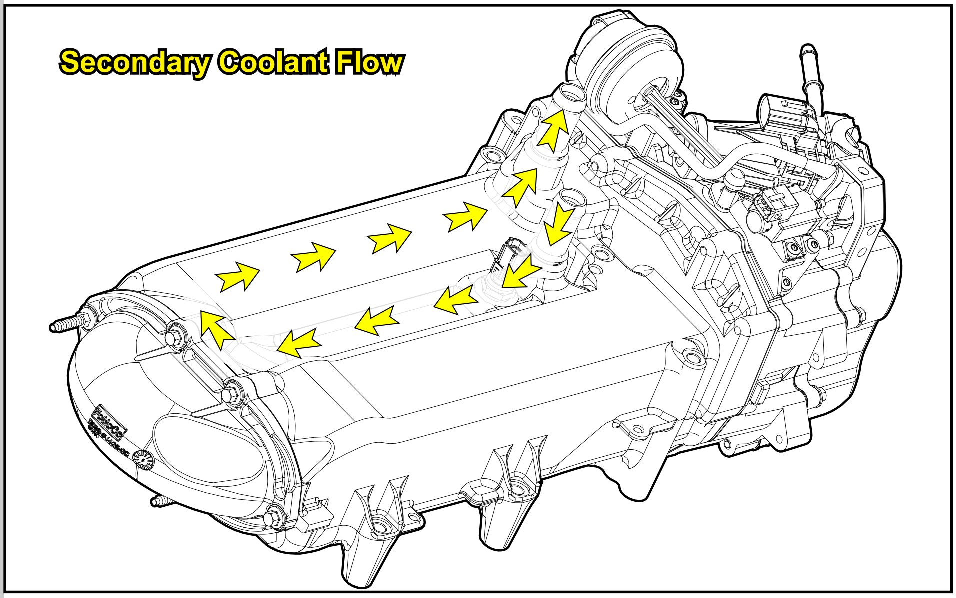
The first part of the EGR cooler is cooled by the primary cooling system.

An internal air-to-coolant heat exchanger absorbs heat from the exhaust gases and dissipates heat to the atmosphere through the primary radiators.

EGR Powertrain Secondary Coolant Flow

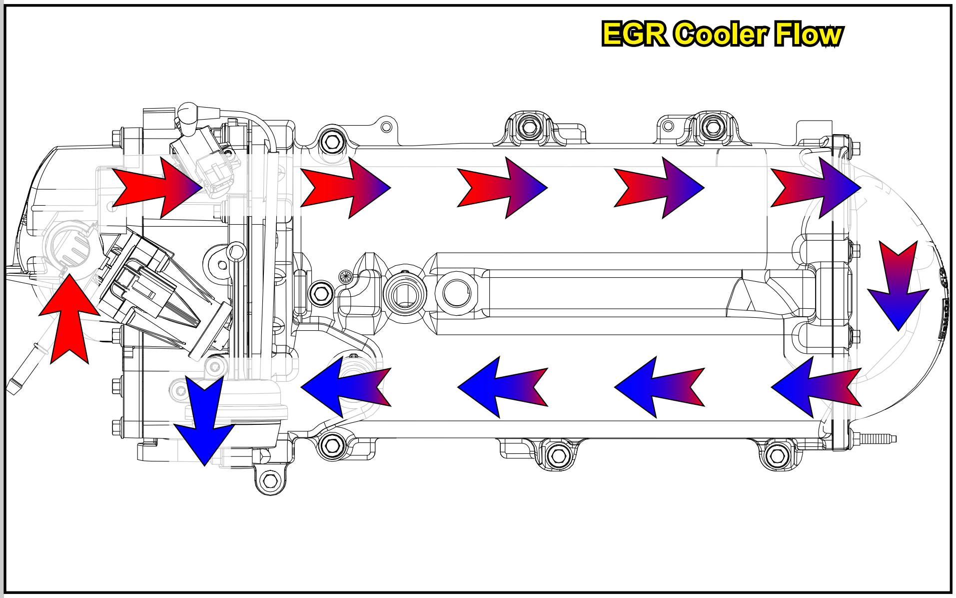
The second part of the EGR cooler is cooled by the powertrain secondary cooling system.

An internal air-to-coolant heat exchanger absorbs heat from the exhaust gases and dissipates heat to the atmosphere through the powertrain secondary radiators.



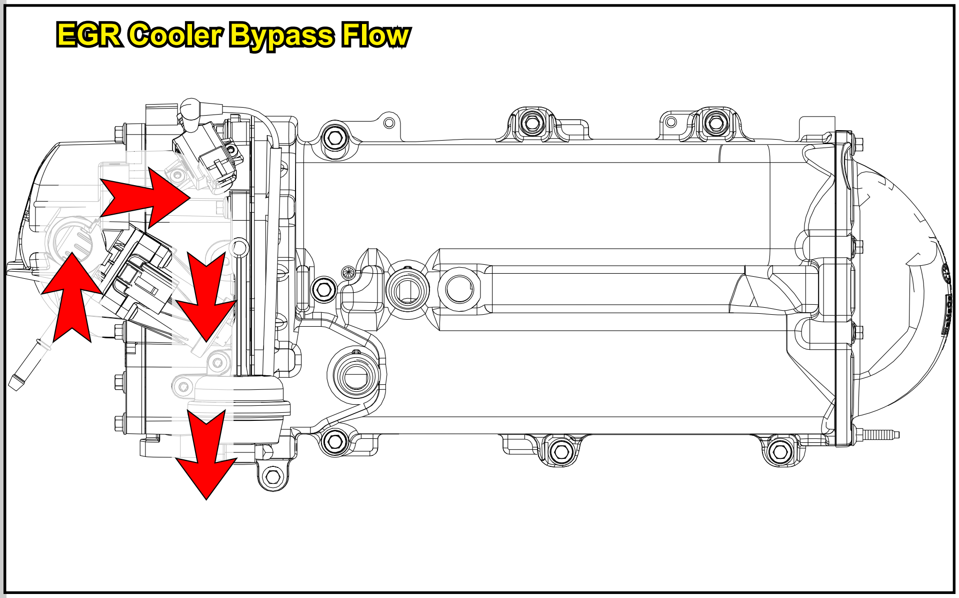
EGR Flow

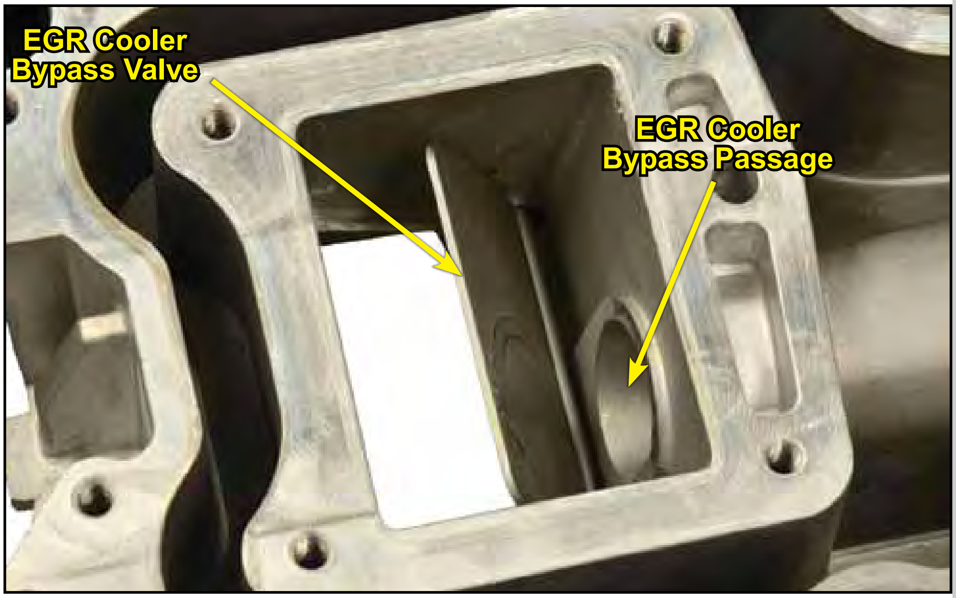
The exhaust gas enters through the EGR valve and then goes through the EGR bypass valve. As the exhaust gas enters the EGR cooler, it is first cooled by the primary cooling system. It flows through the secondary EGR cooler where it is cooled further before exiting the EGR cooler and entering the intake air system.



EGR Cooler Bypass Flow

During some operating conditions the EGR cooler is bypassed.

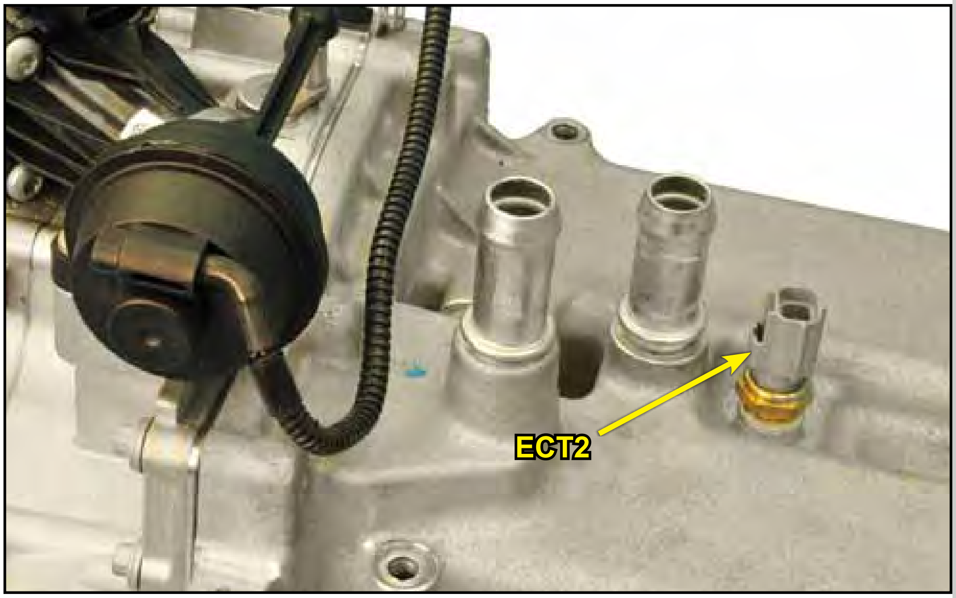




EGR Cooler Bypass Valve

The EGR cooler bypass valve alters the flow of EGR gases to increase the temperature of the gas at low engine speeds. The vacuum controlled valve is solenoid controlled by the PCM.

If the PCM determines that it does not need to cool the exhaust gas,it commands the EGR solenoid to close the bypass valve and route the exhaust gas directly to the intake air system.



Engine Coolant Temperature Sensor 2 (ECT2)

ECT2 monitors secondary cooling system temperature, which affects EGR cooler temperature and performance.

Intake Throttle Body

The intake throttle body is mounted on the lower intake manifold.

The intake throttle body promotes flow of EGR gases to the intake manifold by creating a differential between exhaust pressure and intake pressure.

NOTES

FUEL SYSTEM

At key on, the fuel pump within the Diesel Fuel Conditioning Module (DFCM) is turned on and the low pressure fuel system is pressurized. If the engine is not started, the pump runs for up to 30 seconds. The PCM obtains information from the Ambient Air Temperature (AAT), Engine Coolant Temperature (ETC) , Engine Oil Temperature (EOT) , and Fuel Rail Temperature (FRT) sensors for fuel delivery calculations. The Volume Control Valve (VCV) and Pressure Control Valve (PCV) are open.

During engine cranking the PCM identifies Top Dead Center (TDC) within approximately 120 degrees of crankshaft rotation and PCV is closing, allowing fuel pressure in the rail to achieve the calibrated value. This allows the engine to start very quickly.

Once the Fuel Rail Pressure (FRP) sensor detects the required fuel pressure, the PCM begins fuel injection operation to meet the desired idle RPM based upon the temperature sensors and engine load. During this initial start up mode, the high pressure fuel system is run in PCV mode for a calibrated amount of time. The VCV is set to a specified point while PCV is duty cycled to meet the desired fuel rail pressure.

The high pressure fuel system operates in PCV mode until a calibrated fuel temperature and time is achieved.

In VCV mode the fuel volume entering the high pressure fuel pump is adjusted by the VCV to meet the required fuel rail pressure while still being trimmed by the PCV. VCV mode is a more efficient operating mode because only the amount of fuel required for combustion is being compressed by the pump and sent to the fuel rails.

During acceleration, the VCV and PCV are commanded to meet the driver’s demand (accelerator pedal input/engine load). The PCM’s commands to the VCV and PCV are based upon: FRT, ECT, EOT, ATT, engine load, and regeneration state.

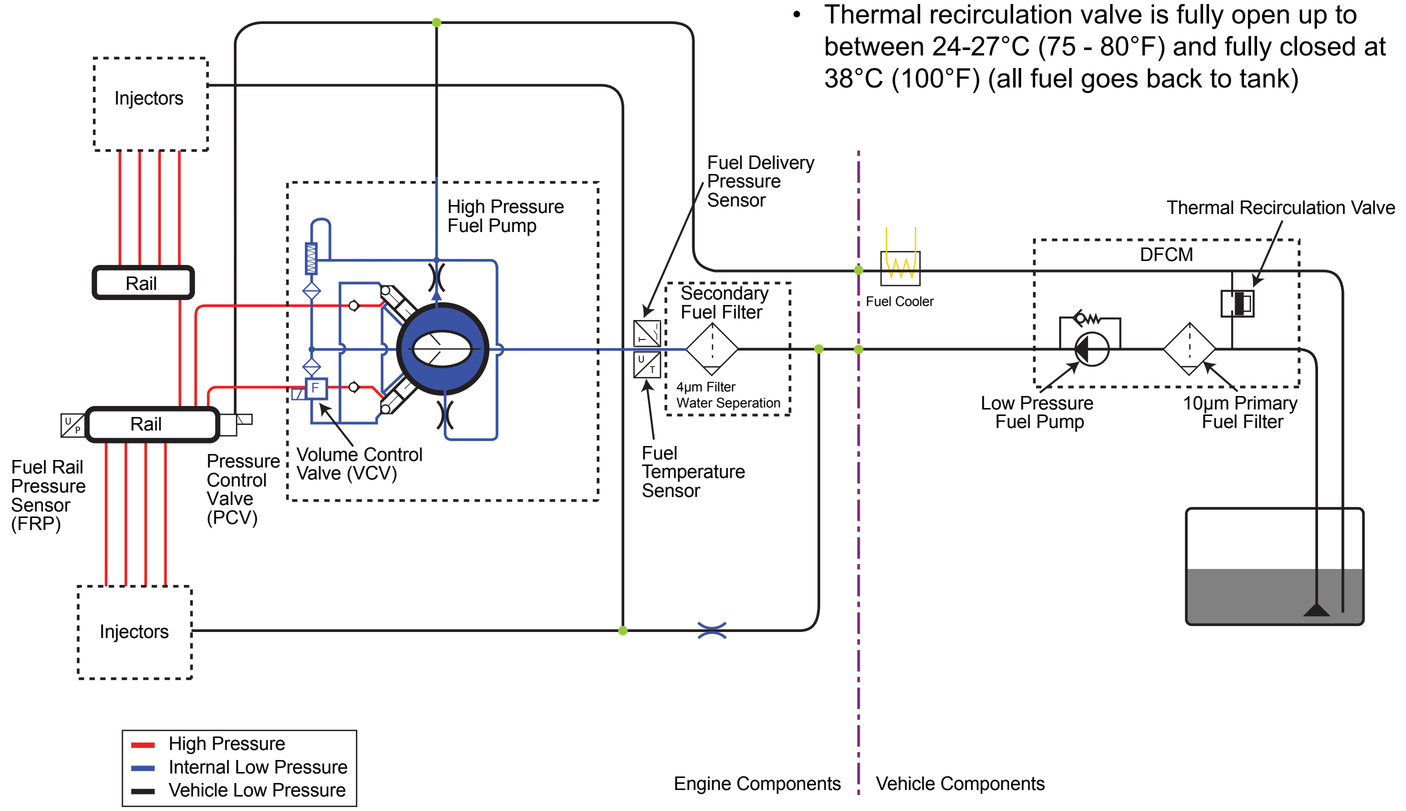
On deceleration, the VCV is closed and the PCV is opening to max position to reduce fuel pressure. When RPM is approaching the desired idle speed, the VCV begins to open to prepare for injector usage.

During regeneration, the left side injectors perform post injection. The right side injectors do not provide fuel for regeneration because right side cylinders supply exhaust gas to the EGR valve and EGR cooler.

Under certain conditions, like battery disconnect and fuel system reset, the fuel system operates in Adaptive PCV (APCV) mode on the first start. In the APVC mode, the PCM is learning the duty cycle needed for the PCV to achieve the desired fuel pressure.

High pressure fuel system operating mode:

- High pressure fuel system runs in PCV mode at start up until a calibrated time and temperature have been met.
- Thermal recirculation valve is fully open up to between 24-27°C (75 - 80°F) and fully closed at 38°C (100°F) (all fuel goes back to tank)



Fuel Supply System

- The DFCM includes the following components:
  - low pressure fuel pump
  - 10 micron primary fuel filter
  - thermal recirculation valve
  - water fuel separator (~200ml)
  - Water in Fuel (WIF) sensor
  - water drain (manual operation)
- After the fuel is conditioned by the DFCM, the clean pressurized fuel is sent to the engine mounted fuel filter assembly where particles larger than 4 micron are filtered out of the fuel. After the fuel is filtered, it is routed to the high pressure fuel pump.

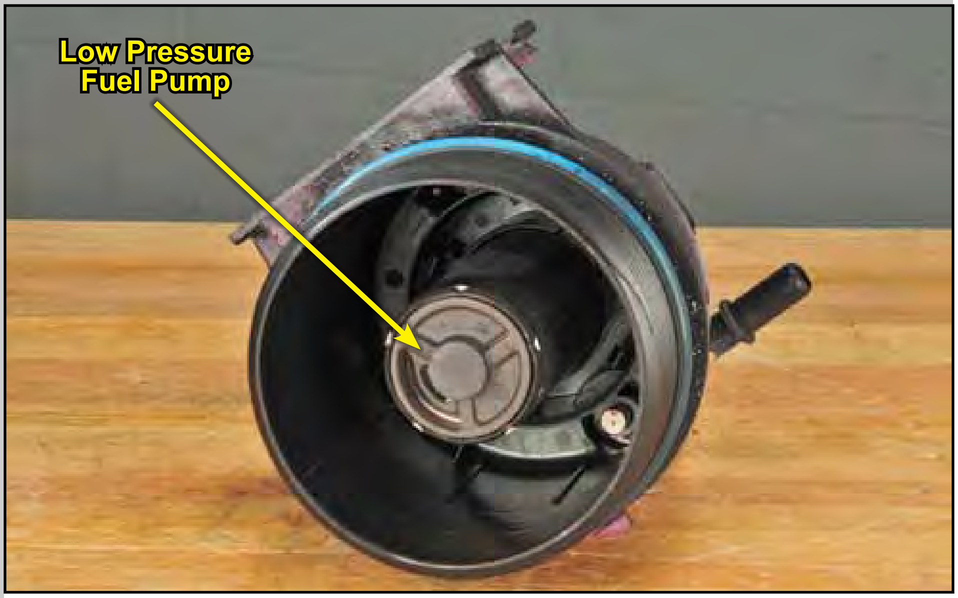
Low Pressure Fuel Pump

The low pressure fuel pump is located inside the DFCM assembly.

The low pressure fuel pump draws fuel from the fuel tank through the 10 micron primary fuel filter and pushes it to the engine mounted fuel filter. The fuel pump pressure relief valve is integral to the fuel pump and is not serviceable separately. The fuel pump pressure regulator limits fuel pressure to 827 kPa (120 psi).

The low pressure fuel pump supplies approximately 3 times the maximum amount of fuel required for combustion. The excess fuel is used for lubrication and cooling of the high pressure fuel pump.

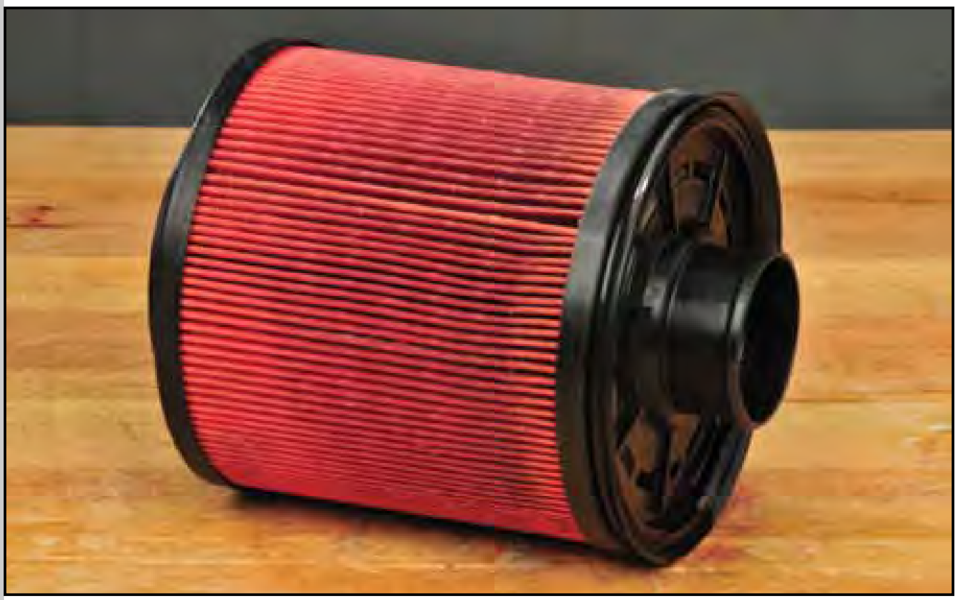
The IDS has a PID "FPL_CMD#" to command the low pressure fuel pump on and off.

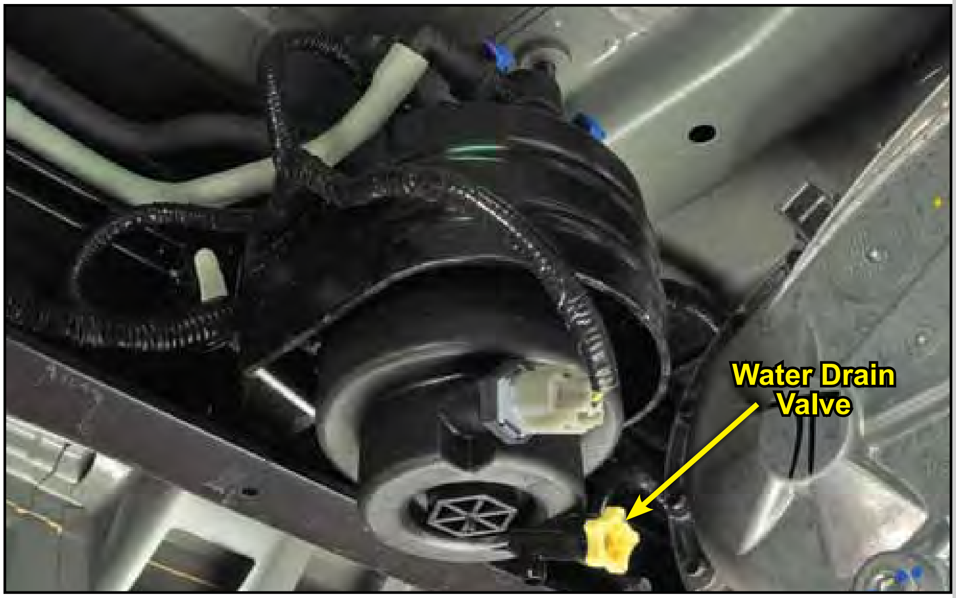


Primary Fuel Filter

The primary fuel filter is located in the DFCM.

The primary fuel filter removes particulates larger than 10 microns from the fuel. The DFCM has a recessed nut on the bottom to remove the fuel filter. The service interval of the fuel filter varies with usage; always consult the Owners Guide or Workshop Manual for service intervals.

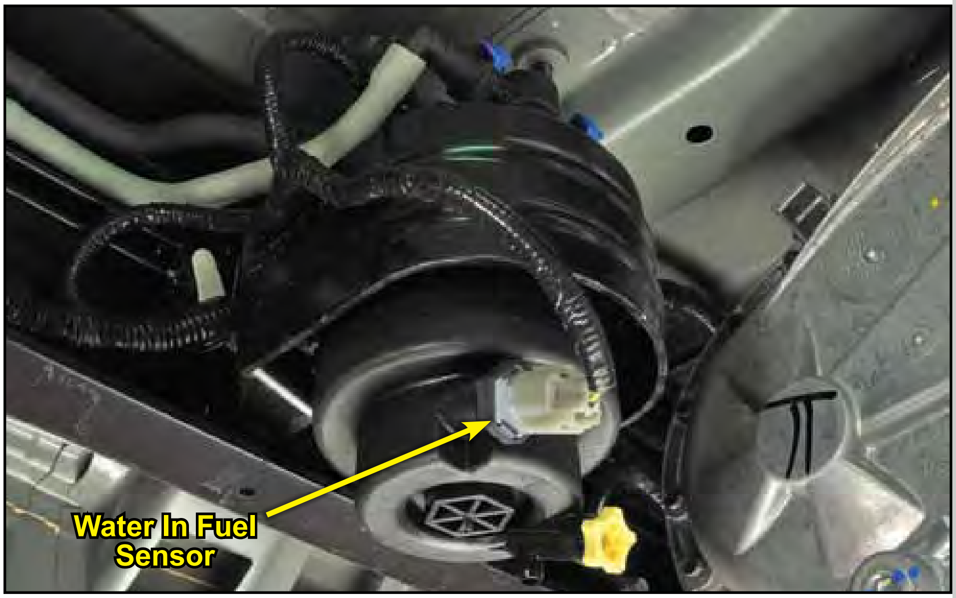




Water Drain Valve

The water drain valve is located on the bottom of the DFCM.

To drain water that has accumulated in the DFCM, turn the drain valve to the open position.



Water In Fuel (WIF) Sensor

The DFCM also includes a WIF sensor that indicates when the reservoir in the water separator is full and needs to be drained. When this occurs, an indicator lamp illuminates and a message appears in the message center.

Secondary Fuel Filter Assembly

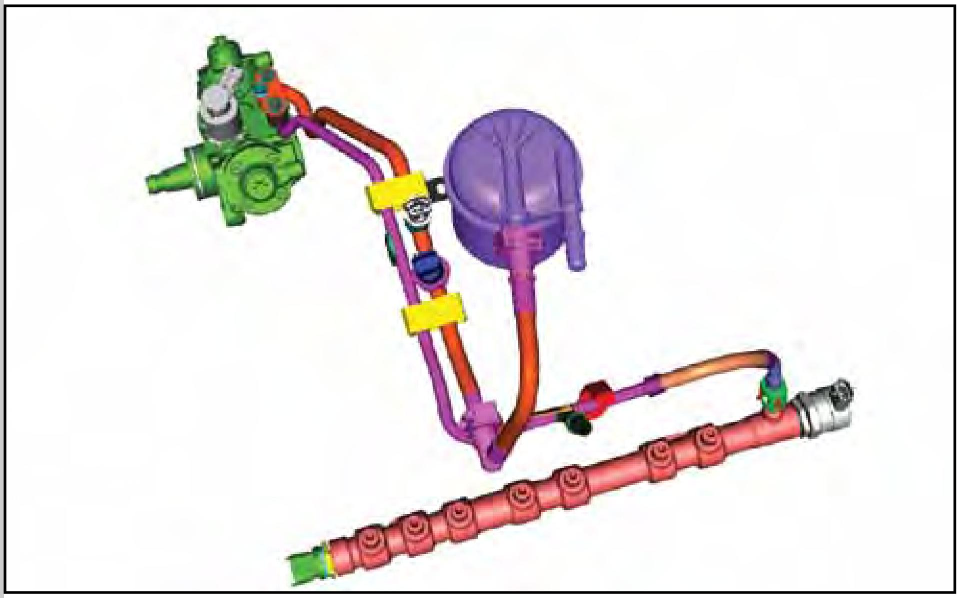
To provide additional fuel filtering, an engine mounted secondary fuel filter is located on the top of the left valve cover. The secondary fuel filter is a 4 micron cartridge style filter and is replaced as a complete unit.

Secondary Fuel Filter Assembly from the Factory

The secondary fuel filter that is equipped on the vehicle from the factory has three ports. The third port is used during the assembly process. The service part only has two ports: the inlet from the DFCM and the outlet to the VCV inlet which is mounted on the high pressure fuel pump.

Low Pressure Fuel Supply to High Pressure Fuel Pump

The fuel supply system uses a Fuel Rail Temperature (FRT) to calculate fuel delivery and fuel pressure switch to help protect the high pressure fuel system.



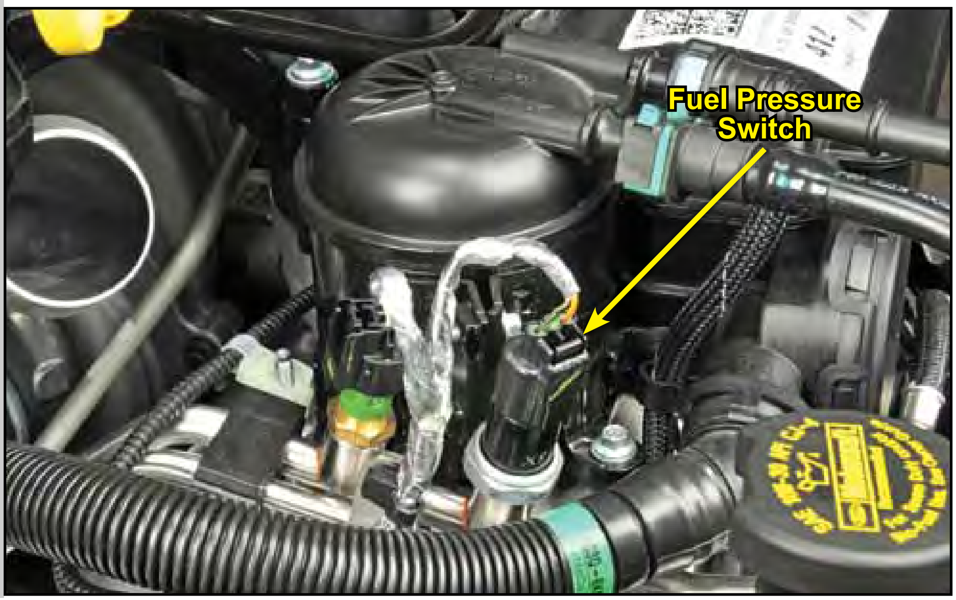
Fuel Pressure Switch (FPS)

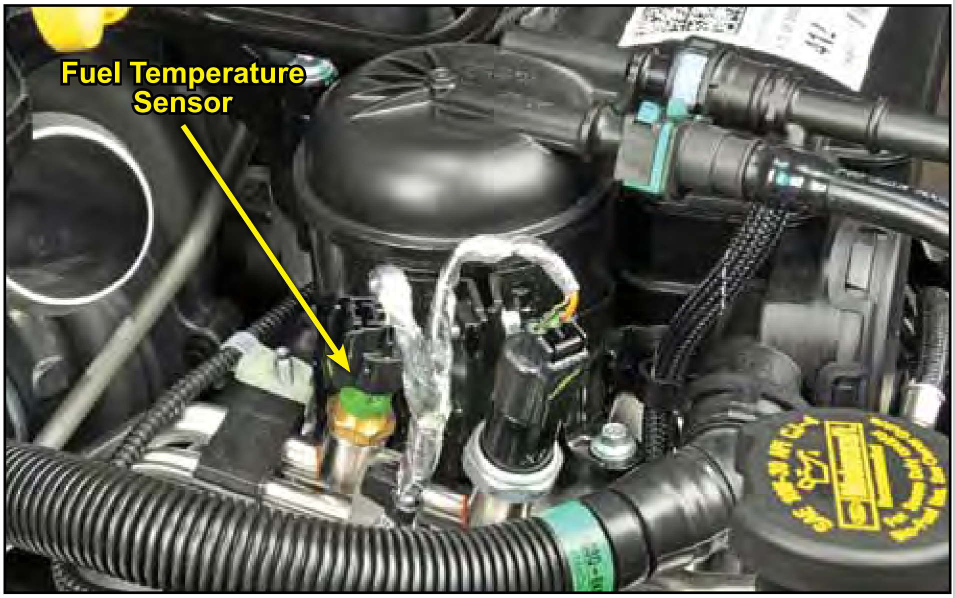
The fuel pressure switch is mounted in the fuel line that runs between the secondary fuel filter and the high pressure fuel pump.

The FPS has a 48-58 psi-gauge set-point for detection of a low pressure fuel supply. The PCM de-rated the engine's power by 30% if the switch is triggered.

The FPS protects the high pressure fuel system from damage due to low fuel pressure supply.

LOW FUEL PRESSURE is displayed in the message center to advise the customer of a low fuel pressure concern.





Fuel Rail Temperature (FRT)

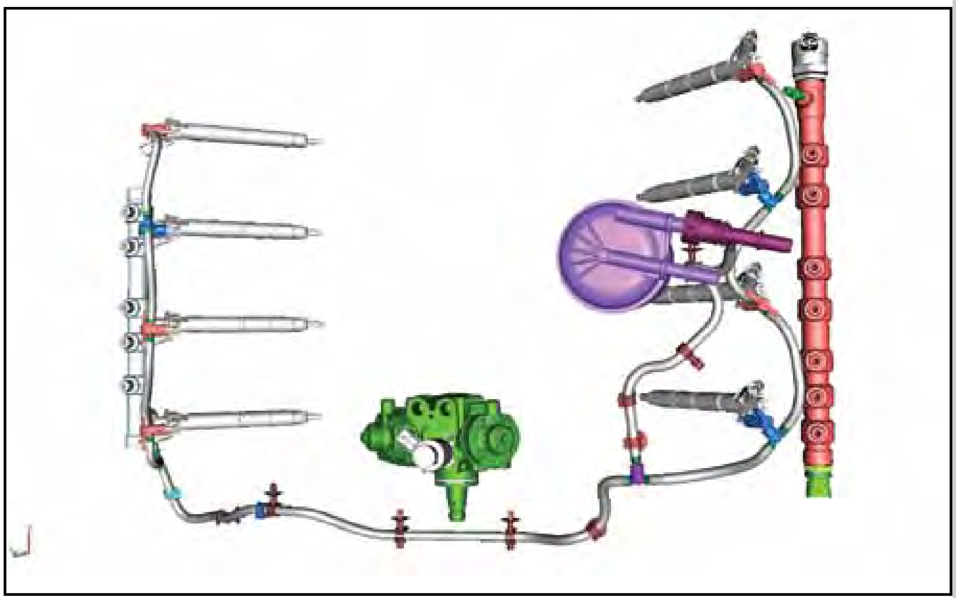
The FRT is mounted in the fuel line that runs between the secondary fuel filter and the high pressure fuel pump. It is green in color.

The PCM monitors the temperature of the fuel using the FRT before the fuel enters the high pressure fuel pump.

Fuel temperature effects fuel viscosity. The PCM uses this information for more precise fueling no matter what the fuel temperature.

Fuel Cooler

A fuel cooler is located on the left frame rail forward of the DFCM. The black fuel line is used for fuel return from the engine to the cooler. The gray fuel line returns fuel from the cooler to the DFCM. Depending on the temperature of the fuel from the injectors, the fuel cooler can be used to cool or heat the fuel going back to the DFCM. The powertrain secondary cooling system provides the coolant for the fuel cooler.



Injector Low Pressure Connectors

The injector low pressure connectors have a dual purpose. First, it is not really a return but a low pressure feed to keep fuel pressure inside the hydraulic coupler. Without fuel pressure in the hydraulic coupler, the injector will not deliver fuel. Second, the fuel that passes through the injector during the injection process exits the injector through the low pressure connectors.

Biodiesel

The 6.7L Power Stroke® diesel engine may be operated on diesel fuels containing up to 20% biodiesel, also known as B20.

To help achieve acceptable engine performance and durability when using biodiesel in your vehicle:

- be alert to fuel gelling/waxing.
- the fuel system must be flushed out with regular diesel fuel if the vehicle is going to be in storage for more than a month
- only use biodiesel fuel of good quality that complies with industry standards.
- do not use raw oils, fats or waste cooking greases.

Use of fuels containing more than 20% biodiesel can damage engine and fuel system components, resulting in a non-warranty condition.

Fuel Management System

The Volume Control Valve (VCV) controls how much fuel enters the two high pressure pump pistons. The high pressure fuel pump is restricted as required by the PCM. Under varying conditions the fuel system is in PCV or VCV mode.

Two high pressure fuel lines from the high pressure fuel pump transport the fuel to the diverter volume area of the left (driver's side) fuel rail. From the diverter volume area, fuel goes through an orifice to supply the left fuel rail and through a high pressure fuel line over to the right fuel rail.

Excess fuel from the high pressure fuel pump is routed back to the DFCM/fuel tank. The left fuel rail supplies fuel to the 4 injectors in the left cylinder head via high pressure fuel lines and it supplies fuel to the right side fuel rail via another high pressure fuel line.

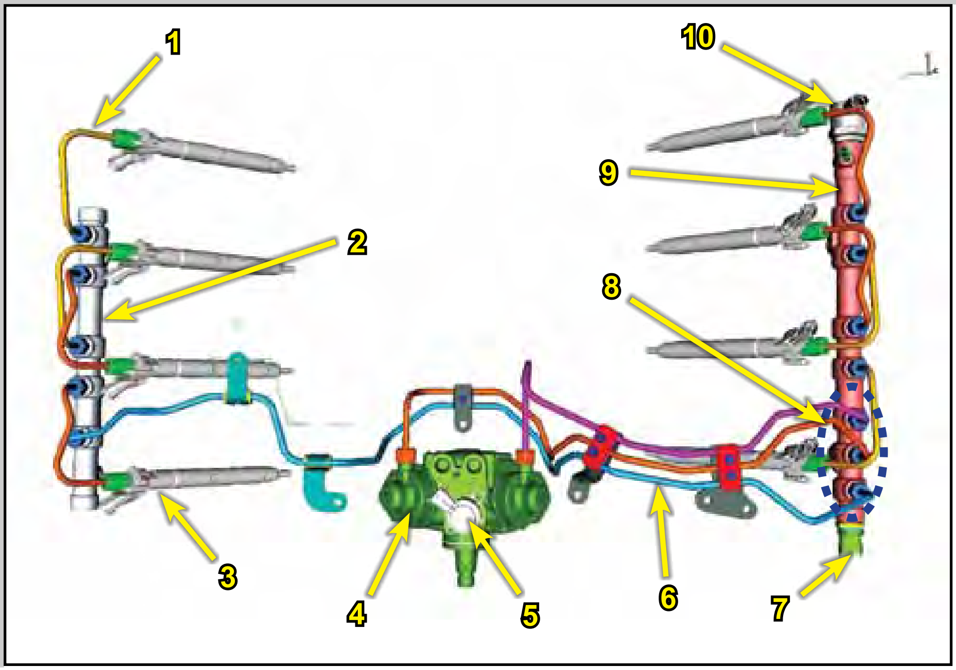
The left side fuel rail contains the Pressure Control Valve (PCV) mounted in the rear of the fuel rail and the Fuel Rail Pressure (FRP) sensor in the front of the fuel rail The PCV regulates the pressure in the fuel rails under specific operating conditions. When operating in PCV mode, fuel released by the PCV is returned to the DFCM/fuel tank.

The high pressure fuel pump is capable of producing up to 199,948 kPa (29,000 psi) to the fuel injectors.

Each fuel rail has 4 individual high pressure fuel lines to supply fuel to the injectors. Injector return fuel is directed back to the low pressure line supplying the secondary fuel filter. The injector return line assembly contains a single throttle (orifice) to generate back flow for proper injector operation. Fuel being directed back to the DFCM/fuel tank goes through the fuel cooler first then to the DFCM.

Fuel Management Components

1. High pressure fuel line
2. Right high pressure fuel rail
3. Fuel injector
4. High pressure fuel pump
5. Volume Control Valve (VCV)
6. High pressure fuel transfer Line from the left fuel rail to the right fuel rail
7. Fuel Pressure Sensor (FPS)
8. Diverter volume area
9. Left high pressure fuel rail
10. Pressure Control Valve (PCV)



High Pressure Fuel Pump

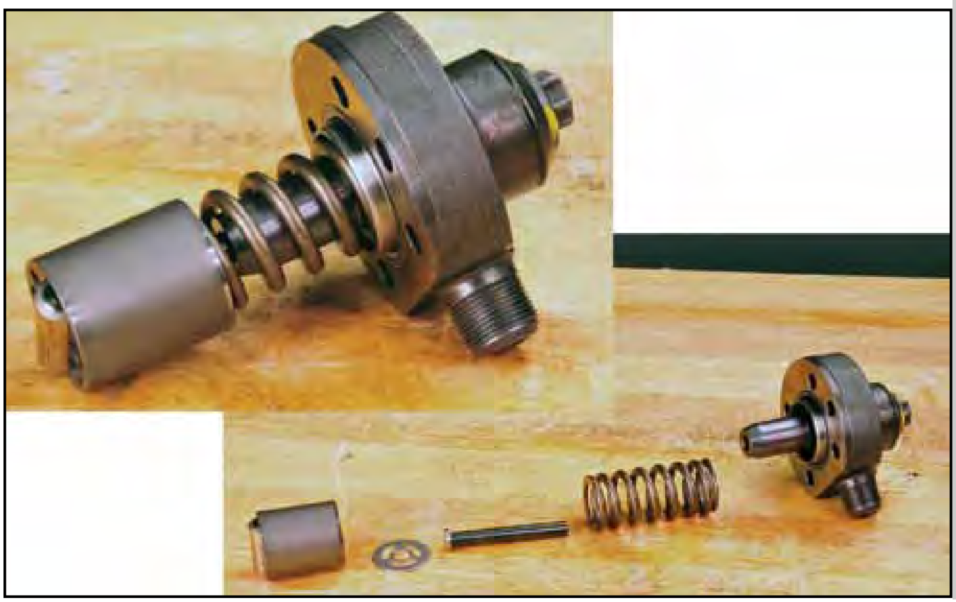
The high pressure fuel pump is mounted in the front valley of the engine and is gear driven by the camshaft.

The high pressure fuel pump is timed to the crankshaft and camshaft to optimize the effects of the high pressure fuel pulses.

The high pressure fuel pump is lubricated by diesel fuel.

High Pressure Fuel Pump Operation

The high pressure fuel pump is a 2-cylinder design. The main shaft has two actuating lobes. The actuating lobes are offset 180 degrees from each other. Each pump piston is actuated twice per crankshaft revolution.

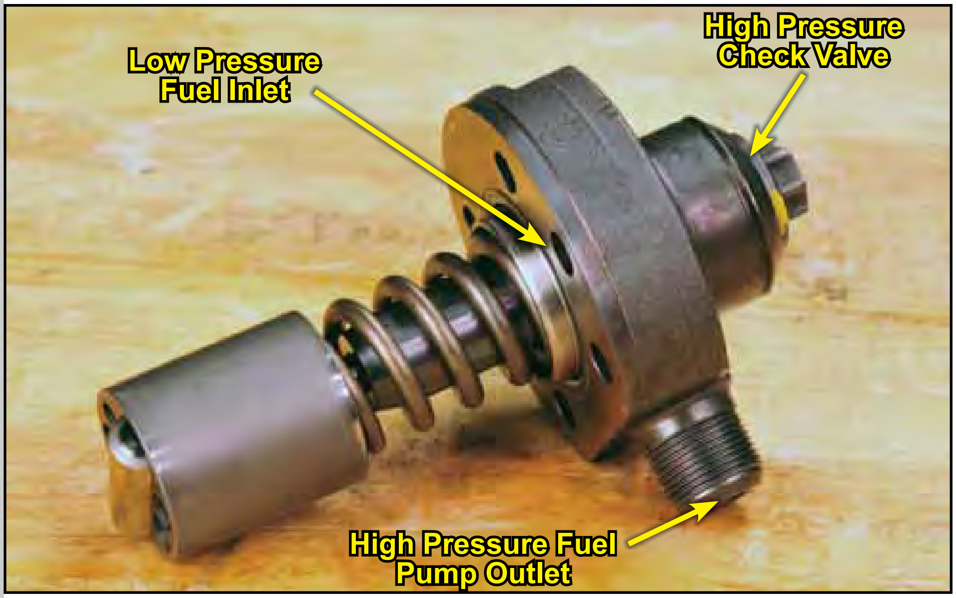


Piston Assemblies

The pistons are actuated via the actuating lobes and are returned to rest via spring pressure. The pistons receive fuel from the through a one-way check valve. Fuel is drawn into the cylinder while the piston is returning to rest. The fuel flow to the cylinders of the pump are metered by the Volume Control Valve (VCV).

Piston Assembly Check Valves

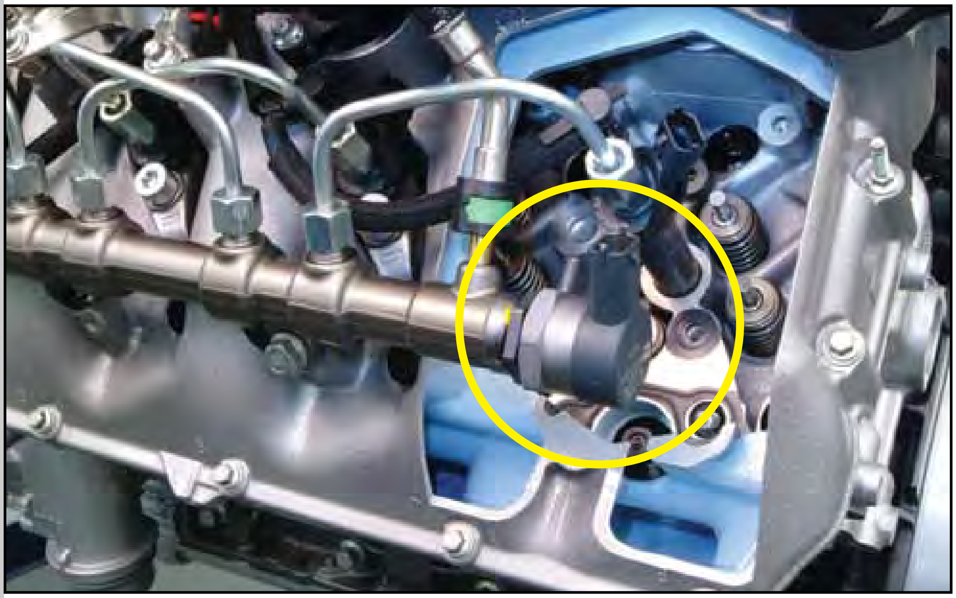
The outlet check valve closes while fuel is being drawn in due to a pressure difference on the two sides of the check valve. Once the piston starts its compression stroke, the inlet check valve closes via the spring and fuel pressure and the outlet check valve opens due to increasing fuel pressure, forcing the check valve off its seat.



Pressure Control Valve (PCV)

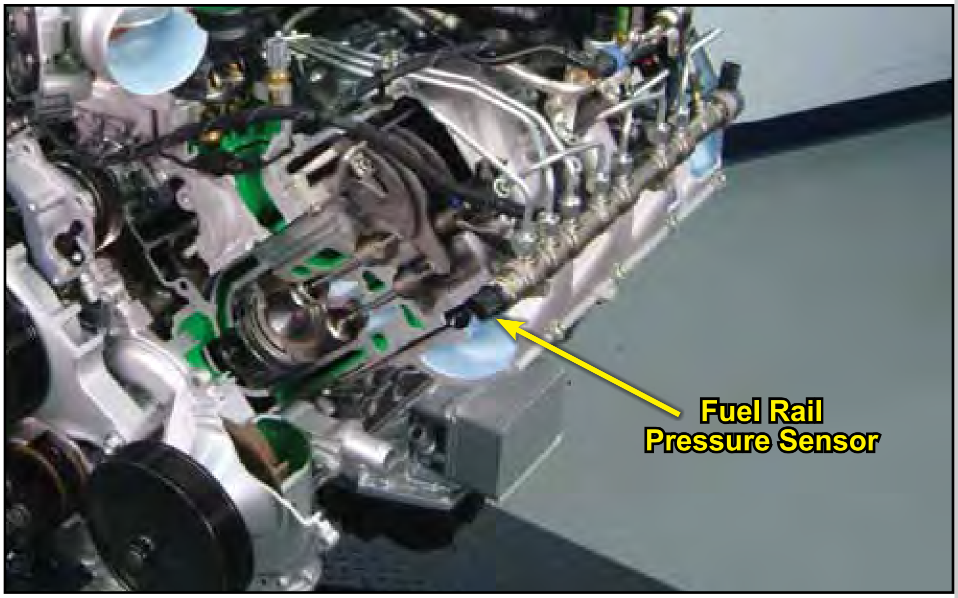
The PCV is threaded into the rear of the left fuel rail. The PCV is a two wire normally open Pulse Width Modulated (PWM) solenoid. The PCM relay supplies system voltage to one wire of the solenoid. The PCM uses a pulse width modulates ground to control the PCV until the desired fuel pressure is reached.

The PCV regulates the pressure in the fuel rails under specific operating conditions. The PCV controls the fuel pressure using information from the Fuel Rail Pressure (FRP) sensor.



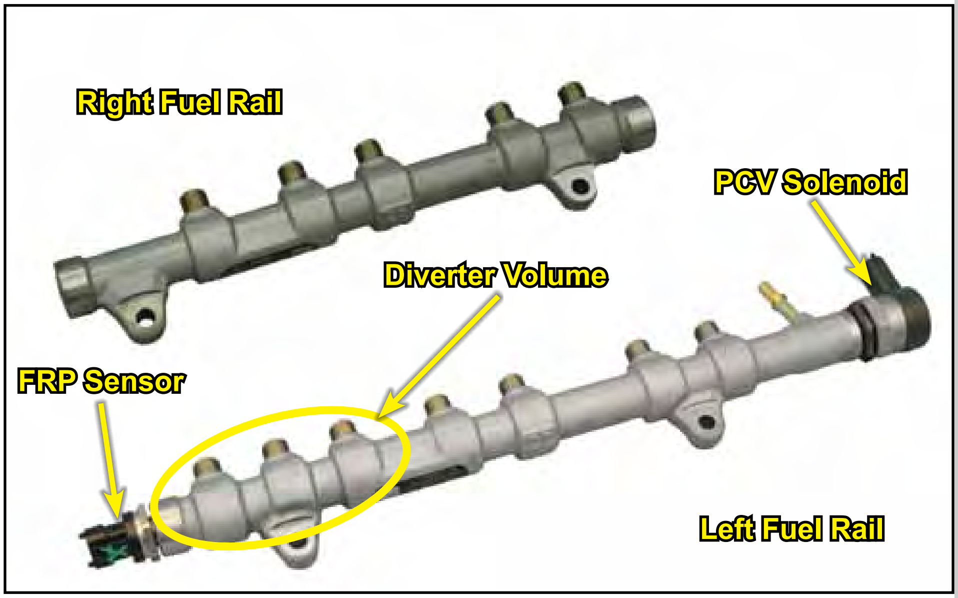
Volume Control Valve (VCV)

The fuel VCV is mounted on the top of the high pressure fuel pump. The VCV is pulse width modulated by the PCM to control the amount of fuel that enters the high pressure fuel pump. Together with the Pressure Control Valve (PCV), the VCV regulates the fuel rail pressure. The VCV also interrupts the fuel supply to the high pressure fuel pump elements when the engine is switched off and during engine deceleration.



Fuel Rail Pressure (FRP) Sensor

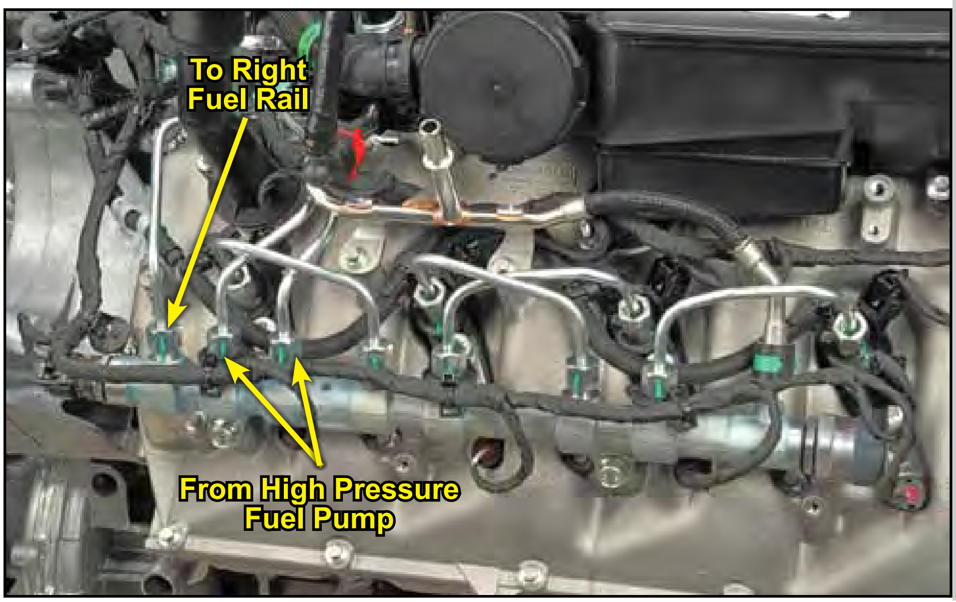
The FRP is threaded into the front of the left fuel rail. The FRP sensor is a three-wire variable capacitance sensor. The PCM supplies a 5 volt reference signal which the FRP sensor uses to produce a linear analog voltage that indicates pressure. The FRP sensor actively monitors fuel rail pressure to provide a feedback signal to the PCM.



Fuel Rails

The fuel rails on the 6.7L Power Stroke® diesel engine are on the outside of the valve covers. The left fuel rail has the FRP sensor and the PCV solenoid. The right fuel rail does not have any sensors or solenoids.

The left fuel rail is longer due to a diverter volume.



High Pressure Fuel Lines

The high pressure fuel lines run between the:

- high pressure fuel pump and left fuel rail.
- right and left fuel rails.
- fuel rails and the fuel injectors on the outside of the valve covers.

Piezo Fuel Injectors

There are eight fuel injectors; four mounted on each cylinder head. They are serviced without removing the valve covers. The Injector Quantity Adjustment (IQA) must be programmed into the PCM when a new injector is installed.

The injector is a 19 mm piezo-actuated injector with an 8 hole nozzle.

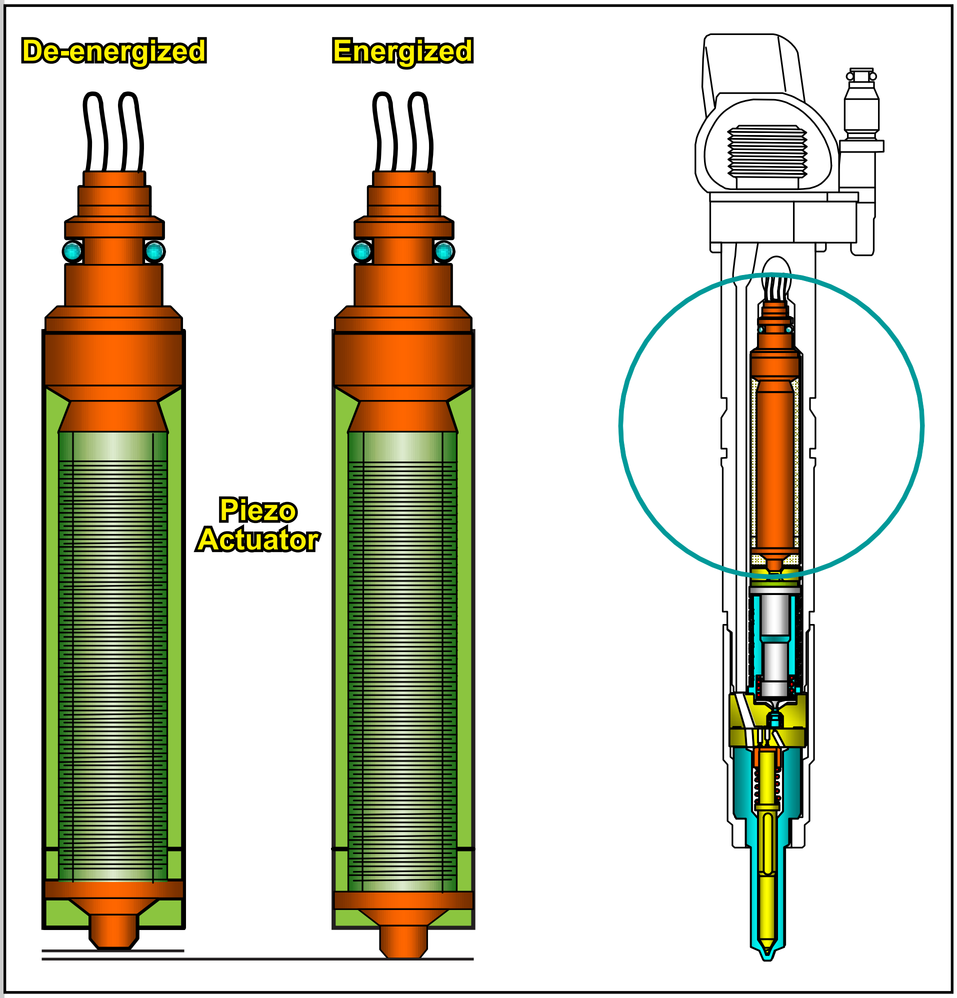
Each fuel injector is retained with a single clamp and bolt through the rocker cover to the cylinder head.

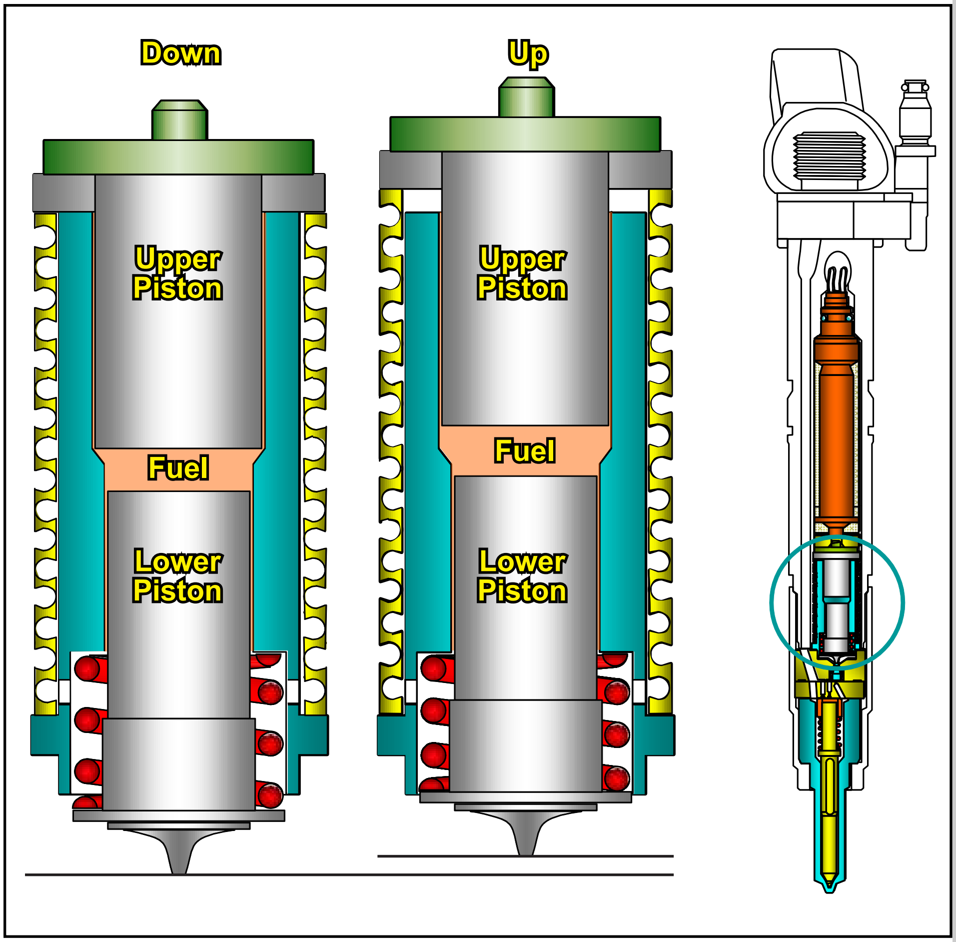
A stepped copper gasket is used to better distribute the sealing load between the cylinder head and injector. This allows heat to transfer from the injector nozzle to the cylinder head. The step is installed towards the cylinder head.

Fuel Injector Piezo Actuator

The piezo actuator is a stack of piezo crystals. When current is applied to the crystals, the crystals expand. When the PCM supplied current is removed from the piezo crystals, they contract. When the crystals contract, they create voltage (current flow reverses).

PCM supplies current to the piezo stack and when the injector is de-energized the current is removed from the piezo stack and stored by the PCM to actuate the injector on a companion cylinder

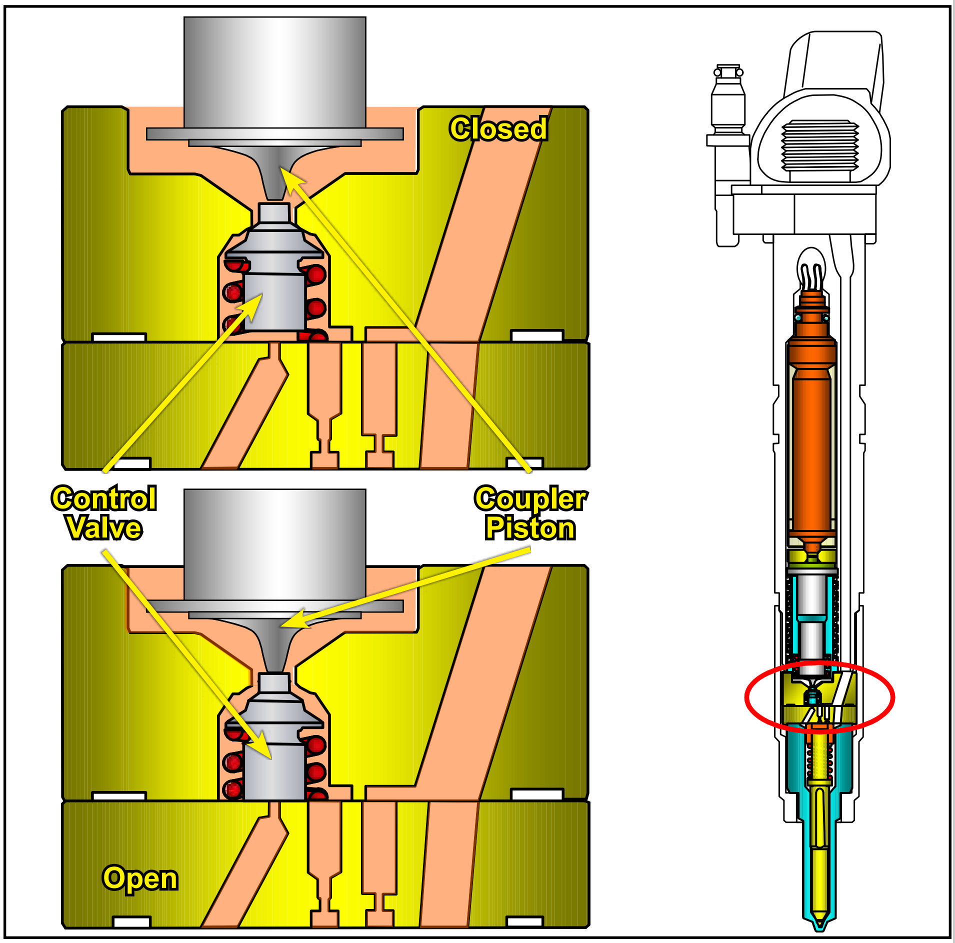




Hydraulic Coupler

The piezo stack is linked to the control valve of the fuel injector via a fuel-filled hydraulic coupler. The upper piston of the coupler is a larger diameter than the lower piston. This difference in diameter causes an increase in the linear movement of the lower piston (more travel).

Note: If the hydraulic coupler is not full of fuel, the lower piston will **not** move and fuel will **not** be injected into the combustion chamber. The hydraulic coupler is supplied with fuel by the low pressure fuel pump when the key is turned on and from return fuel when the engine is running.



Control Valve

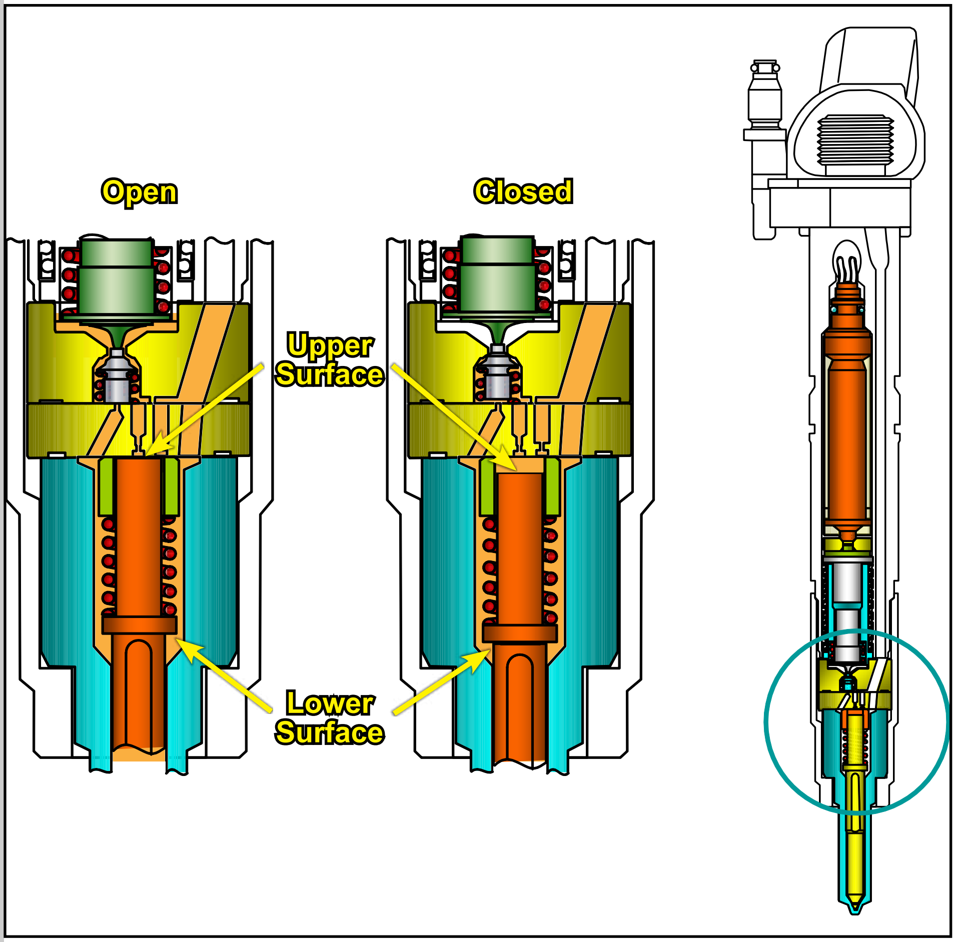
The lower hydraulic coupler piston moves the control valve down to relieve high pressure from the top of the nozzle needle (the control chamber).

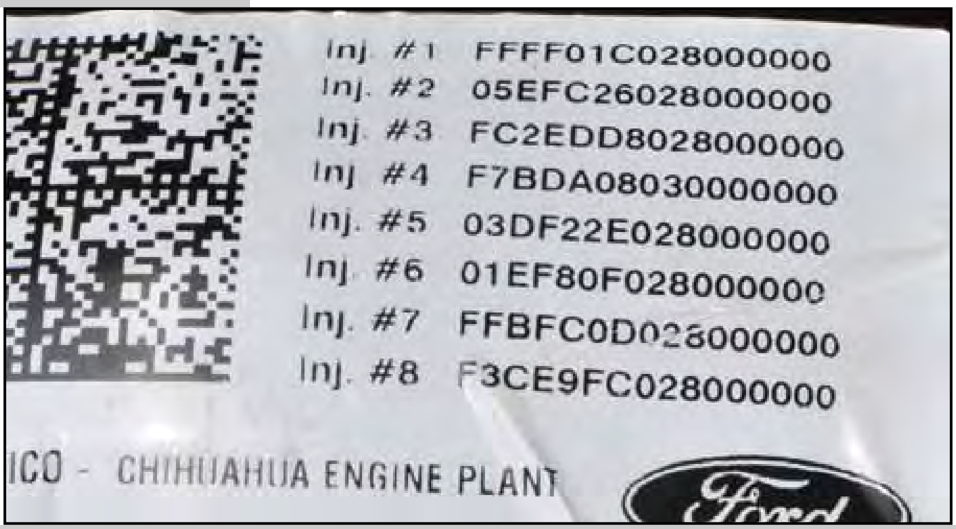
When the control valve is pushed fully down, it seals off an orifice in the intermediate plate, stopping that fuel flow path of high pressure fuel to the top of the nozzle needle. Fuel is allowed to flow past the control valve, also removing pressure from the top of the nozzle needle.

Injector Nozzle Needle

When the high pressure is relieved from the top of the nozzle needle, high pressure on the lower surfaces force the needle up and allows fuel to be sprayed into the combustion chamber.

When the control valve is released, spring pressure and high pressure fuel moves the needle back up against the seat in the control valve housing, sealing the nozzle control chamber. High pressure fuel is again applied to the top of the nozzle needle, pushing the needle down to stop fuel flow into the combustion chamber.



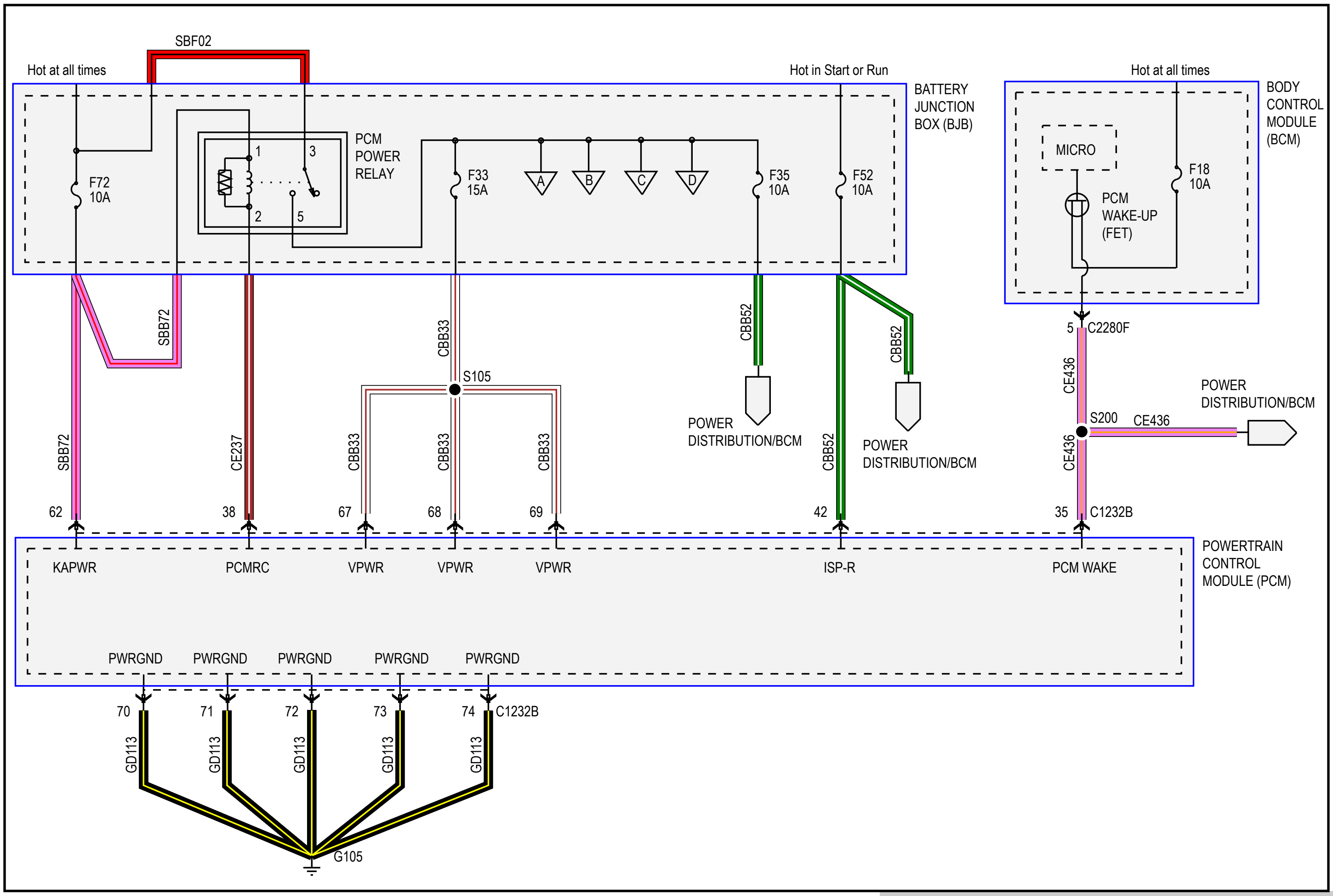


Injector Quantity Adjustment (IQA) Code

Each injector has a unique 10 digit code representing the flow characteristic of that injector. The IQA code is located on each injector head and is also printed on a factory label located on the engine. The factory installed label indicates the IQA data for all the original injectors installed at the factory. In addition, there are individual injector IQA labels provided with each service replacement injector. Refer to both the factory label and the individual service labels to obtain the latest IQA data. If the labels are missing or damaged retrieve the IQA data from each injector head.

When an injector is replaced, program the IQA code for the injector using the IDS. The IDS will automatically clear the keep alive memory values associated with the old injector when the new injector IQA code is entered. The new injector IQA sticker must be affixed next to the old sticker.

Note: If an injector is being swapped to a different cylinder the IQA number must be programmed.



Powertrain Control Module (PCM)

The PCM is located on the top right side of the bulkhead.

The PCM receives battery power from the PCM power relay through the chassis connector. Ground is provided through the chassis connector and also includes a case ground.

Pressure Sensors

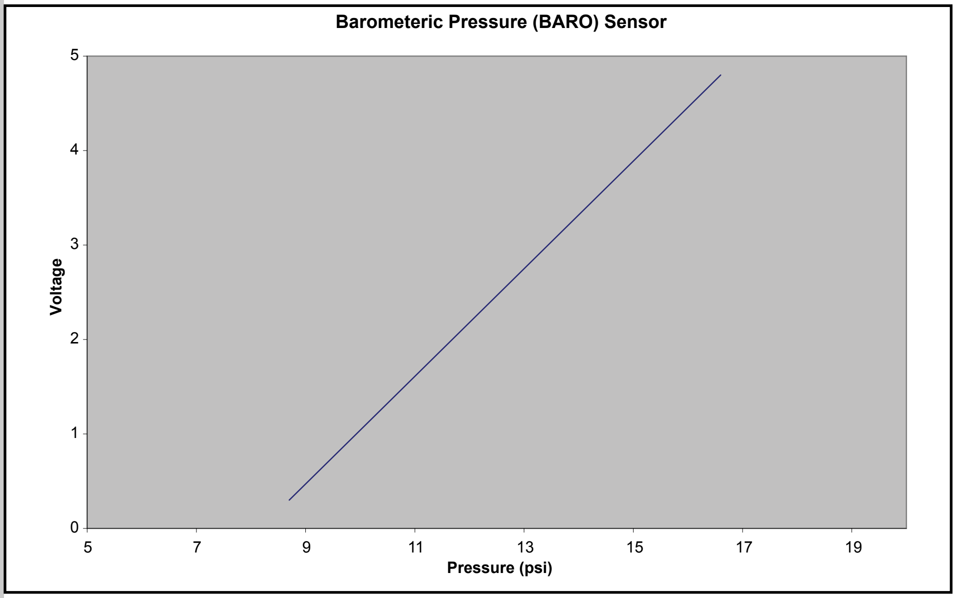
Barometric Pressure (BARO)

The BARO sensor is internal to the PCM.

The PCM supplies a 5 volt reference signal (VREF) which the BARO sensor uses to produce a linear analog voltage that indicates pressure.

The PCM uses the BARO sensor to determine atmospheric pressure for fuel control, timing, and turbocharger control.

IDS: BARO (volts) and BARO (pressure)

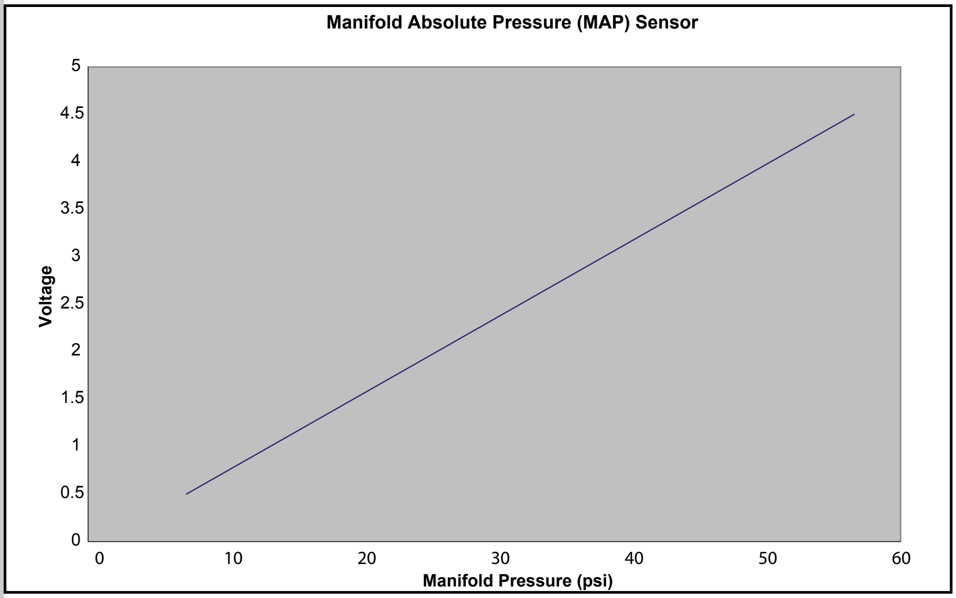


Manifold Absolute Pressure (MAP)

The MAP sensor is a 3-wire variable capacitance sensor. The PCM supplies a 5 volt reference (VREF) signal which the MAP uses to produce a linear analog voltage that indicates pressure.

The MAP sensor is used for turbocharger, EGR, and regeneration control.

IDS: MAP (volts) and MAP_A (pressure)

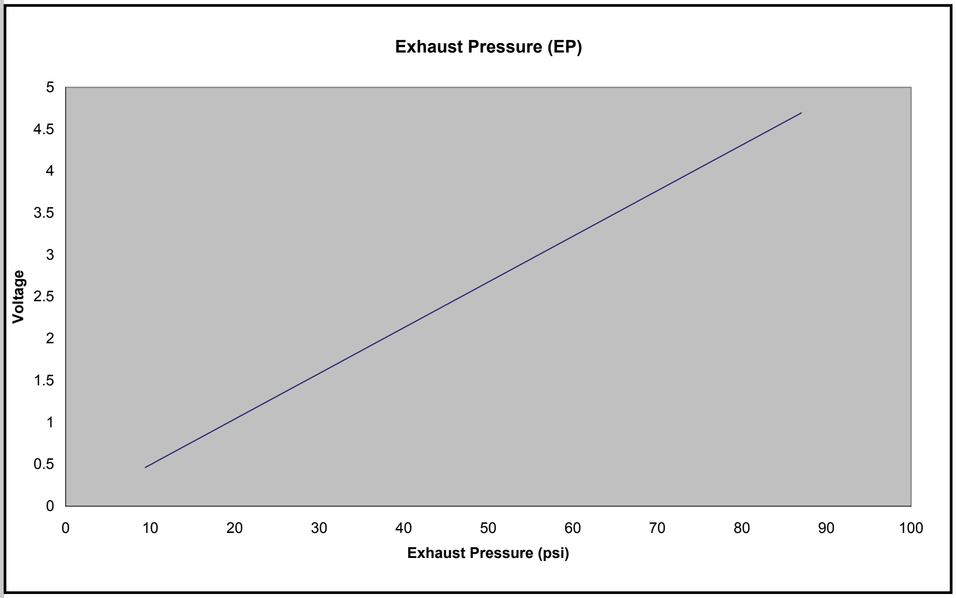


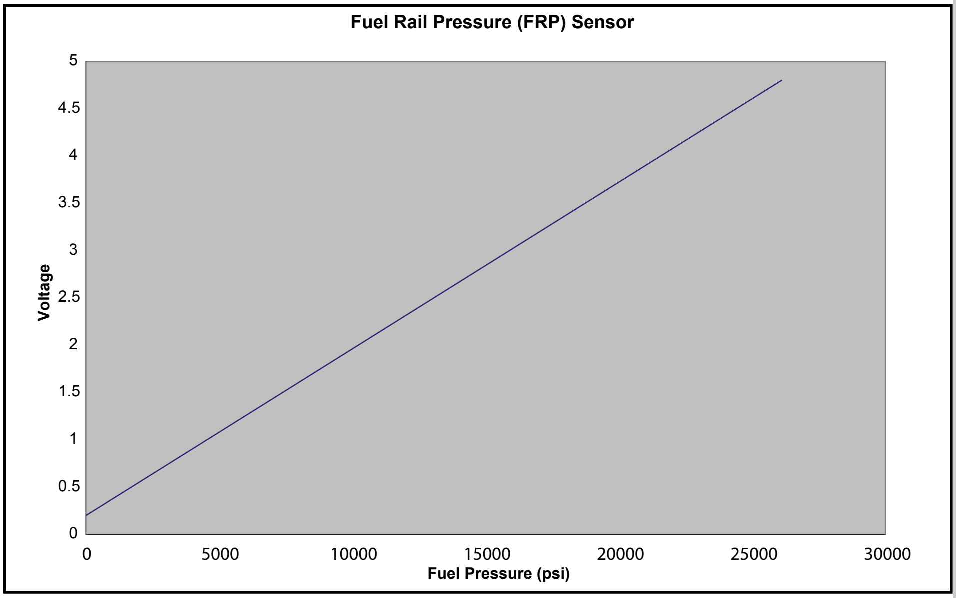
Exhaust Pressure (EP)

The EP sensor is a 3-wire variable capacitance sensor. The PCM supplies a 5 volt reference (VREF) signal which the EP uses to produce a linear analog voltage that indicates pressure.

The PCM monitors the EP sensor as an input into EGR operation for the delta pressure calculation.

IDS: EP (pressure) and EP_V (volts)



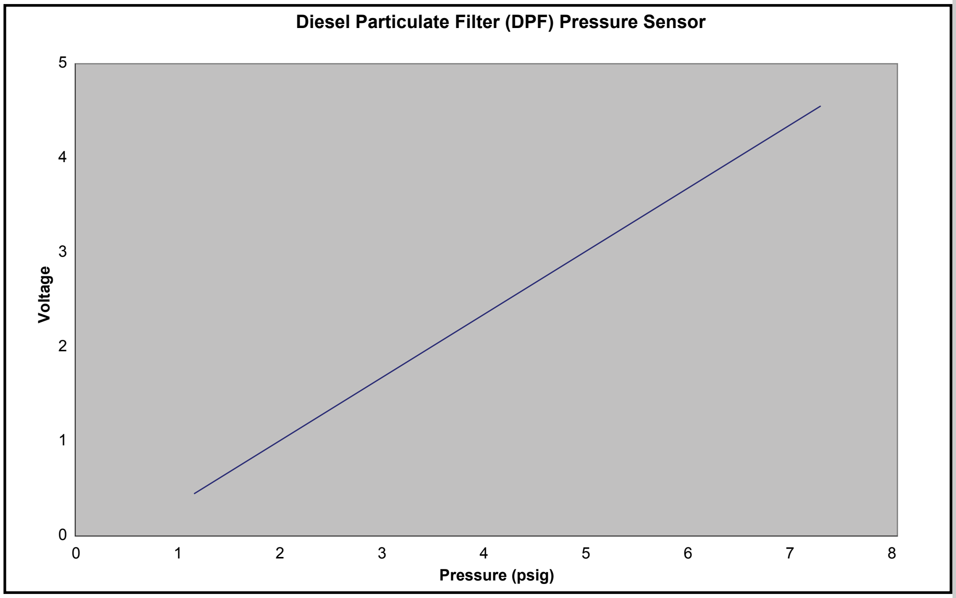


Fuel Rail Pressure (FRP)

The FRP is a 3-wire variable capacitance sensor. The FRP produces a linear analog voltage that indicates pressure of the high pressure fuel system.

The PCM monitors fuel rail pressure as the engine is operating to control fuel pressure. This is a closed loop function which means the PCM continuously monitors and adjusts for ideal fuel rail pressure determined by conditions such as load, speed and temperature.

IDS: FRP (volts) and FRP_A (pressure)



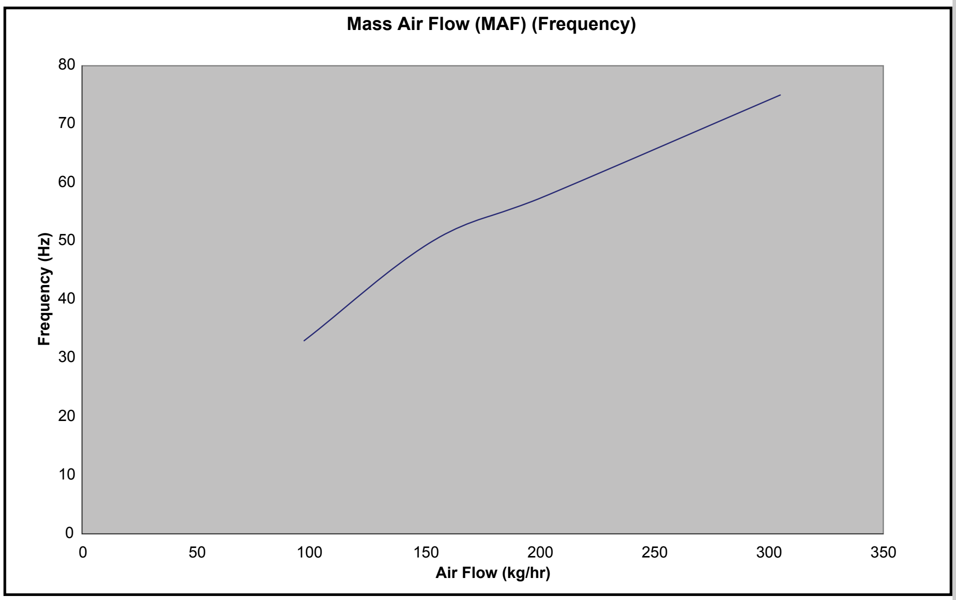
Diesel Particulate Filter (DPF) Pressure

The DPF sensor is a 3-wire variable capacitance sensor. The PCM supplies a 5 volt reference (VREF) signal which the DPF pressure sensor uses to produce a linear analog voltage that indicates pressure.

The DPF pressure sensor measures the exhaust pressure upstream of the diesel particulate filter.

Used as part of the diesel particulate filter load calculation for active regeneration.

IDS: DPF (pressure) and DPF_V (volts)



Mass Air Flow (MAF)

The MAF sensor uses a hot wire sensing element to measure the air flow rate entering the engine. The hot wire is maintained at a constant temperature. The temperature of the hot wire changes with varying air flow. The current required to keep the constant temperature is measured and converted to a voltage which is converted by the PCM to an air flow value.

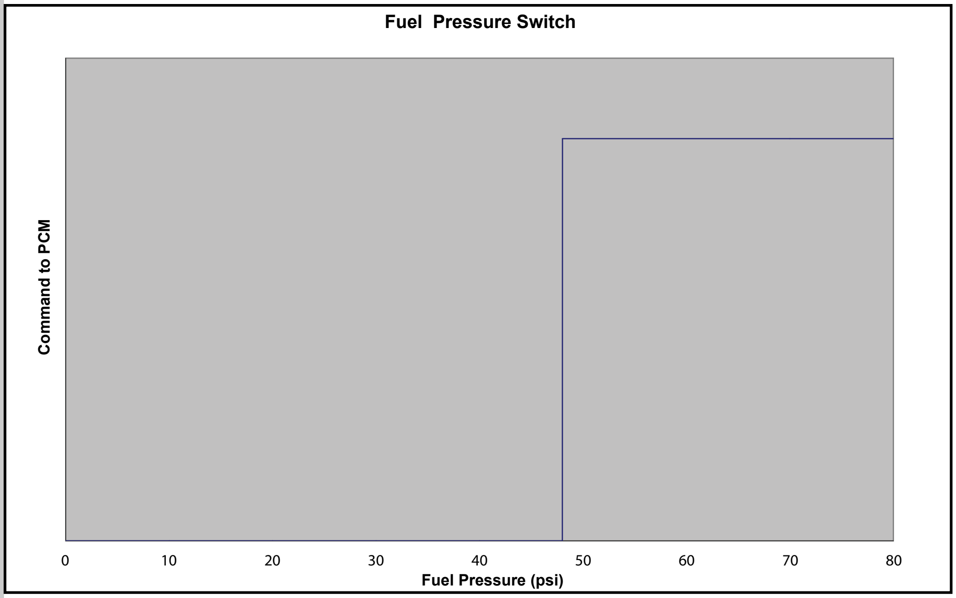
PCM uses the MAF sensor to measure the air flow into the engine. MAF sensor used for EGR, fuel system, and regeneration.

IDS: MAF_A (flow) and MAF_HZ (frequency)

Fuel Pressure Switch

The fuel pressure switch provides input to the PCM when a low fuel pressure condition exists. The PCM notifies the customer via an instrument panel cluster warning and an engine derate occurs.

IDS: LP_FUEL_SW (low/not low)

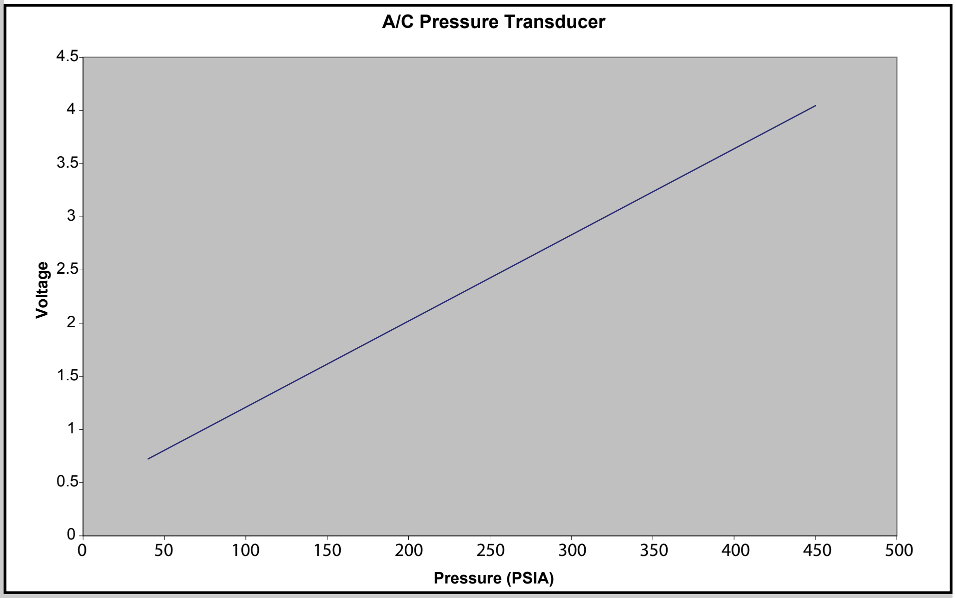


A/C Pressure Transducer

The A/C pressure transducer is a 3 wire sensor. The PCM applies 5 volts to the A/C pressure transducer. The ground for the A/C pressure transducer is provided by the PCM. The output signal from the A/C pressure transducer changes depending on the pressure of the refrigerant.

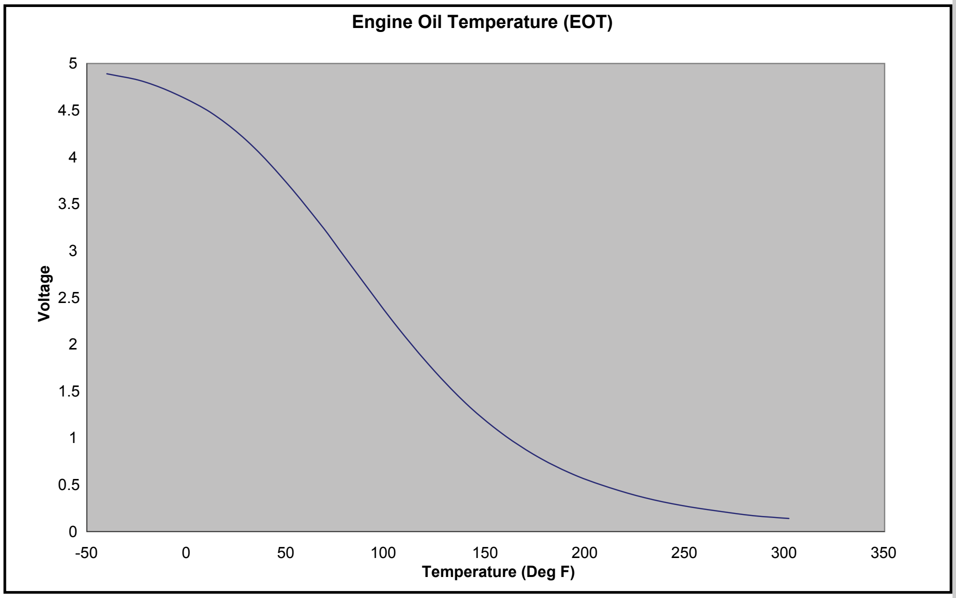
The A/C pressure transducer sends the voltage signal to the PCM to indicate the A/C pressure.

IDS: ACP_V



Temperature Sensors

Temperature sensors are thermistor devices in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature. Unless specified otherwise, all the temperature sensors operate this way.

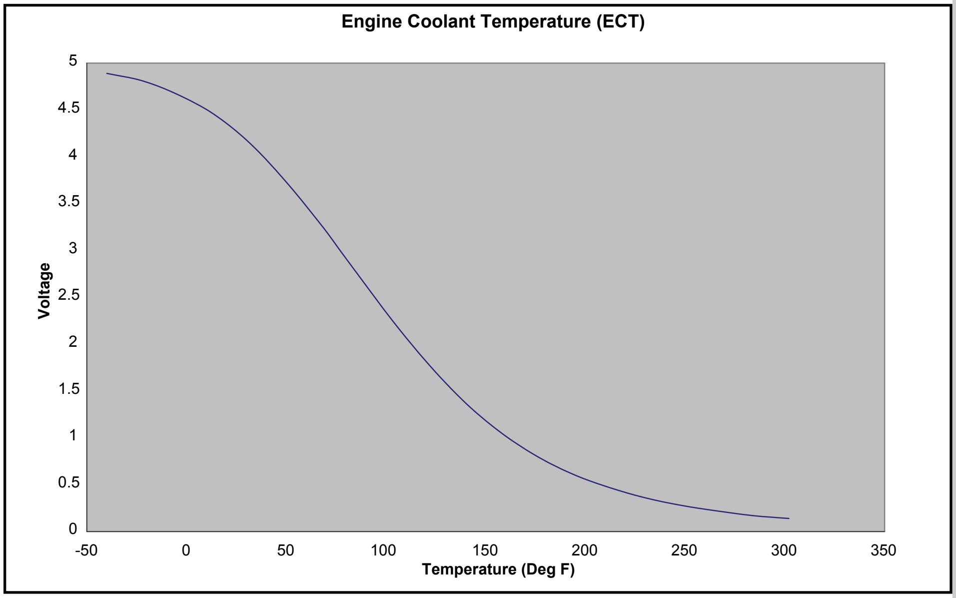


Engine Oil Temperature (EOT)

The EOT sensor is a 2 wire thermistor-type sensor. The PCM applies 5 volts to the EOT sensor circuit. The sensor changes the internal resistance as engine oil temperature changes. The EOT sensor is used in operation of the cooling fan, VGT, and engine control plus diagnostics.

The EOT sensor signal allows the PCM to compensate for oil viscosity variations due to temperature changes in the operating environment.

IDS: EOT (volts) and EOT (temperature)

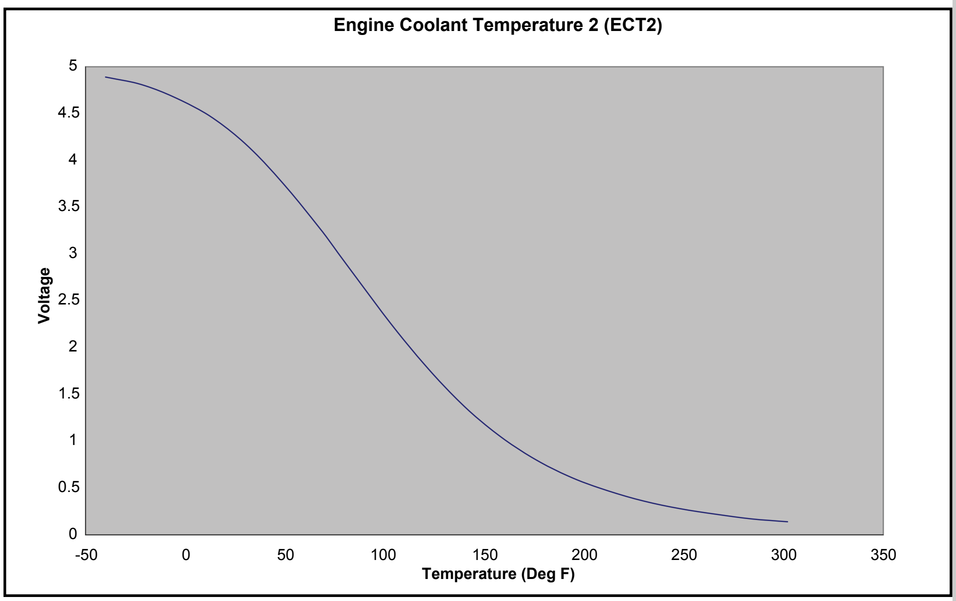


Engine Coolant Temperature (ECT)

The ECT sensor is a 2 wire thermistor-type sensor. The PCM applies 5 volts to the ECT sensor circuit. The sensor changes the internal resistance as the coolant temperature changes. The PCM uses the ECT sensor for engine temperature protection, input for EGR function, fuel control, and engine fan operation.

The ECT sensor measures temperature of the primary cooling system.

IDS: ECT (temperature) and ECT_V (volts)



Engine Coolant Temperature 2 (ECT2)

The ECT2 sensor is a 2 wire thermistor-type sensor. The PCM applies 5 volts to the ECT2 sensor circuit. The sensor changes the internal resistance as the coolant temperature changes.

The PCM uses the ECT2 sensor to monitor EGR cooler effectiveness by measuring the amount of heat being absorbed by the coolant.

The ECT2 sensor Measures coolant temperature in the powertrain secondary cooling system.

IDS: ECT2 (temperature) and ECT2_V (volts)

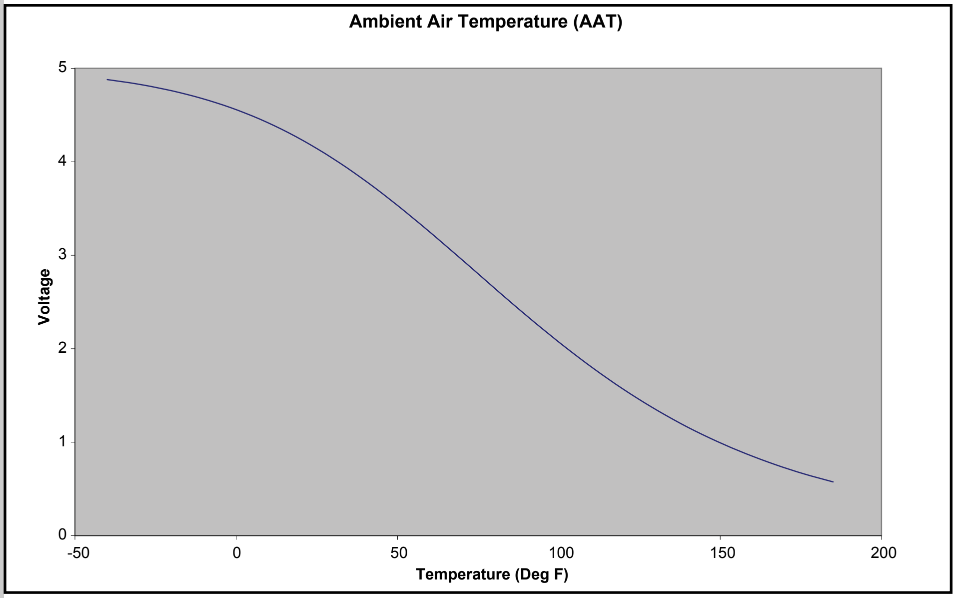
Ambient Air Temperature (AAT) Sensor

The AAT sensor is a 2-wire thermistor-type sensor. The PCM applies 5 volts to the AAT sensor circuit. The sensor changes the internal resistance as the ambient air temperature changes.

The AAT sensor is used as an input into the engine controls, particularly, engine coolant fan operation, glow plug system control and for diagnostics.

The AAT sensor is located in the passengers mirror.

IDS: AAT (temperature) and AAT_V (volts)

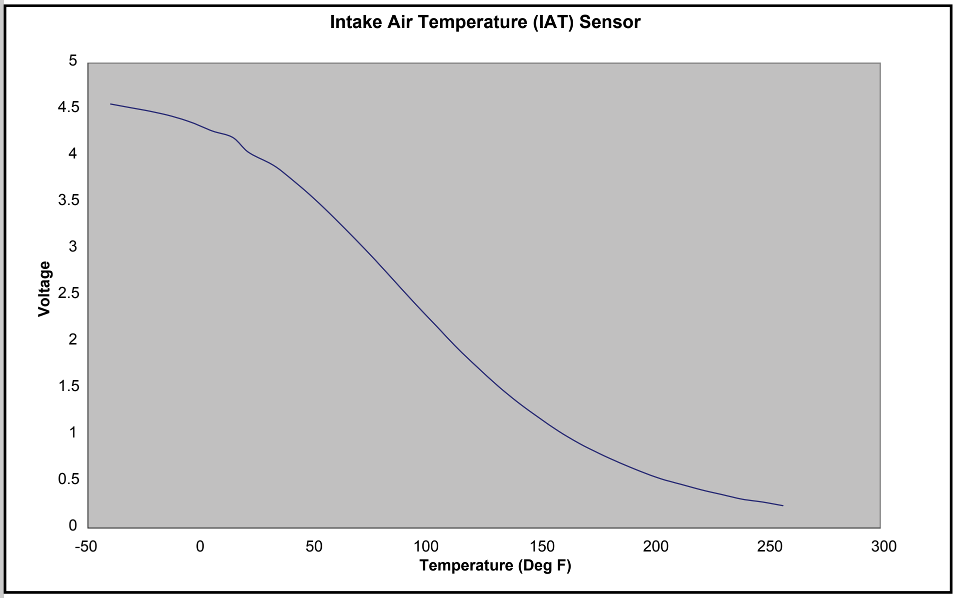


Intake Air Temperature (IAT)

The IAT sensor is a 2-wire thermistor-type sensor. The PCM applies 5 volts to the IAT sensor circuit. The sensor changes the internal resistance as the intake air temperature changes.

The intake air temperature is used for MAF sensor correction and an input into the engine controls, particularly, engine coolant fan operation and for diagnostics.

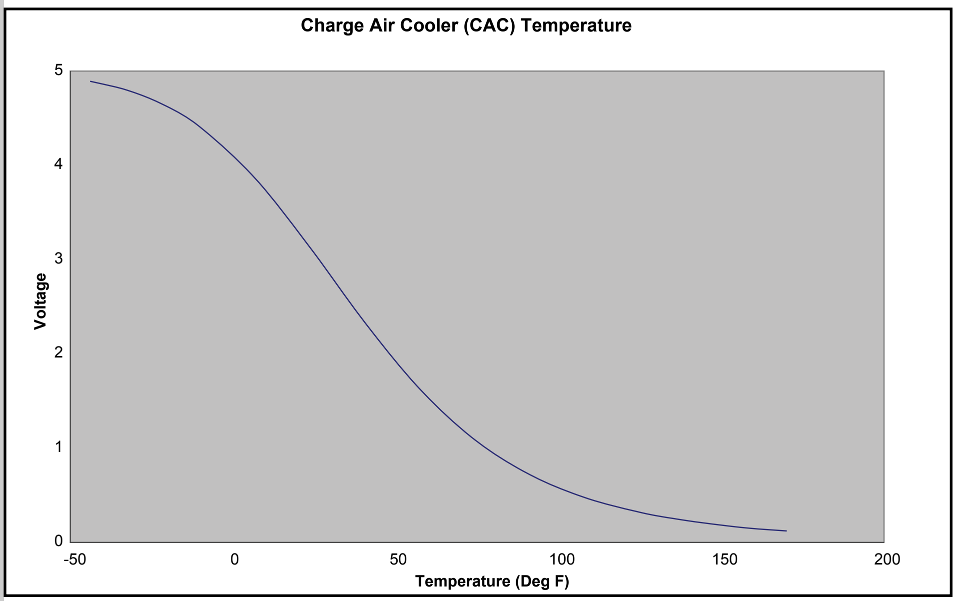
IDS: IAT (temperature) and IAT_V (volts)

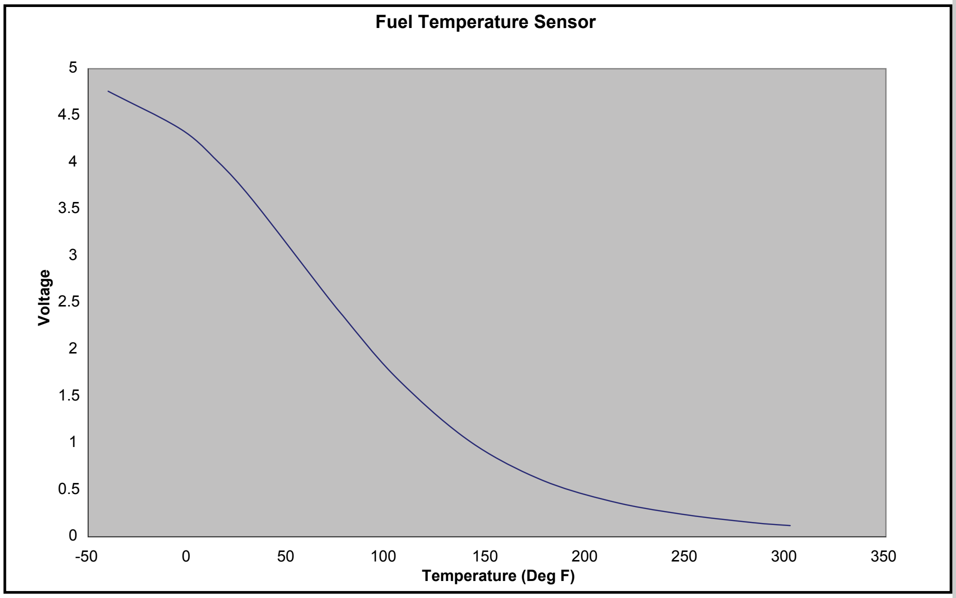


Charge Air Cooler (CAC) Temperature

The CAC temperature sensor is a 2 wire thermistor-type sensor. The PCM applies 5 volts to the CAC temperature sensor circuit. The sensor changes the internal resistance as the air temperature changes. The PCM uses the CAC temperature sensor as an input in determining turbocharger, EGR, fuel control and regeneration.

IDS: CAC_T (temperature) and CAC_V (volts)



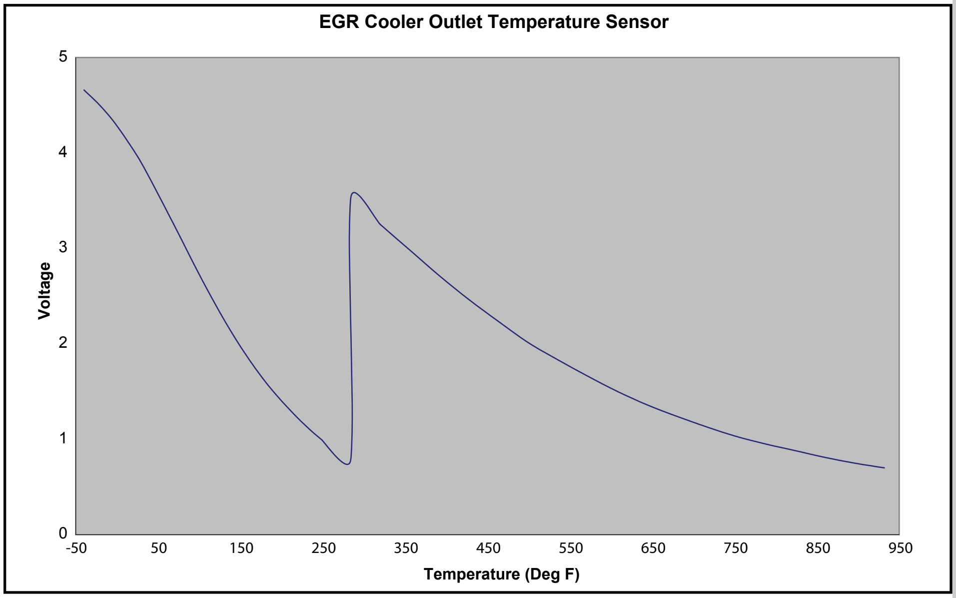


Fuel Rail Temperature (FRT)

The FRT is a 2 wire thermistor-type sensor. The PCM supplies 5 volts to the FRT sensor circuit. The sensor changes the internal resistance as the fuel temperature changes.

The PCM uses the fuel temperature for fuel delivery correction and determine fuel pressure control mode (PCV or VCV mode).

IDS: FRT (volts) and FRT_A (temperature)



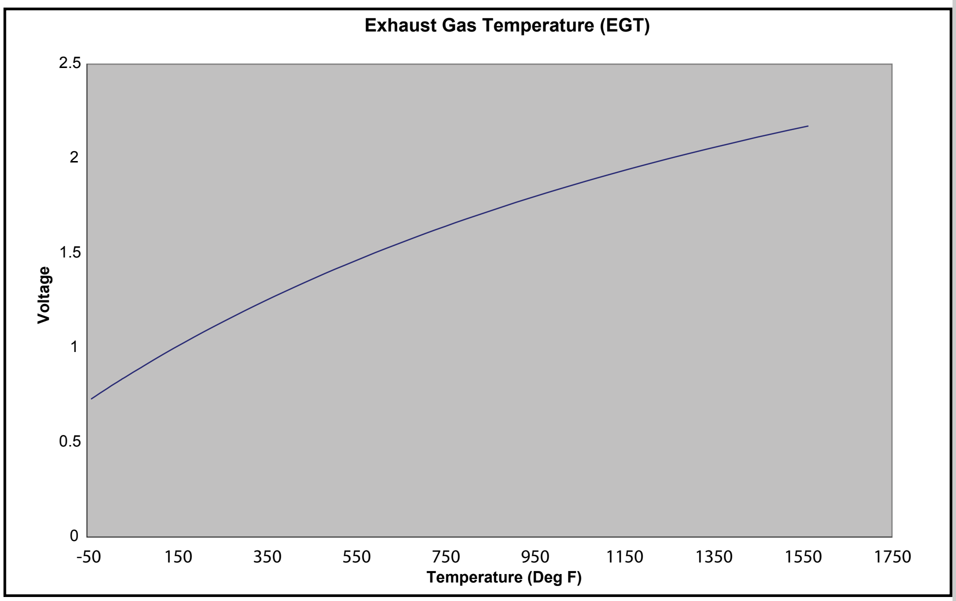
EGR Cooler Outlet Temperature Sensor

The EGR cooler outlet temperature sensor is a 2 wire thermistor-type sensor. The PCM supplies 5 volts to the EGR cooler outlet temperature sensor circuit. The sensor changes the internal resistance as the temperature changes.

This sensor has a two step pull-up resistor. Notice the two temperature curves with voltage.

The PCM uses the EGR cooler outlet temperature sensor as an input in determining EGR cooler bypass actuator function, cooler effectiveness, turbocharger, EGR, fuel control and regeneration.

IDS: EGRT11 (temperature) and EGRT11_V (volts)



Exhaust Gas Temperature (EGT)

The EGT sensors are a Resistance Temperature Detector (RTD) type sensor. The electrical resistance of the sensor increases as the temperature increases, and resistance decreases as the temperature decreases.

There are four EGT sensors used as part of the regeneration operation reductant injection.

IDS: EGT11 (temperature) and EGT11_V (volts), EGT12 (temperature) and EGT12_V (volts), EGT13 (temperature) and EGT13_V (volts), EGT14 (temperature) and EGT14_V (volts)

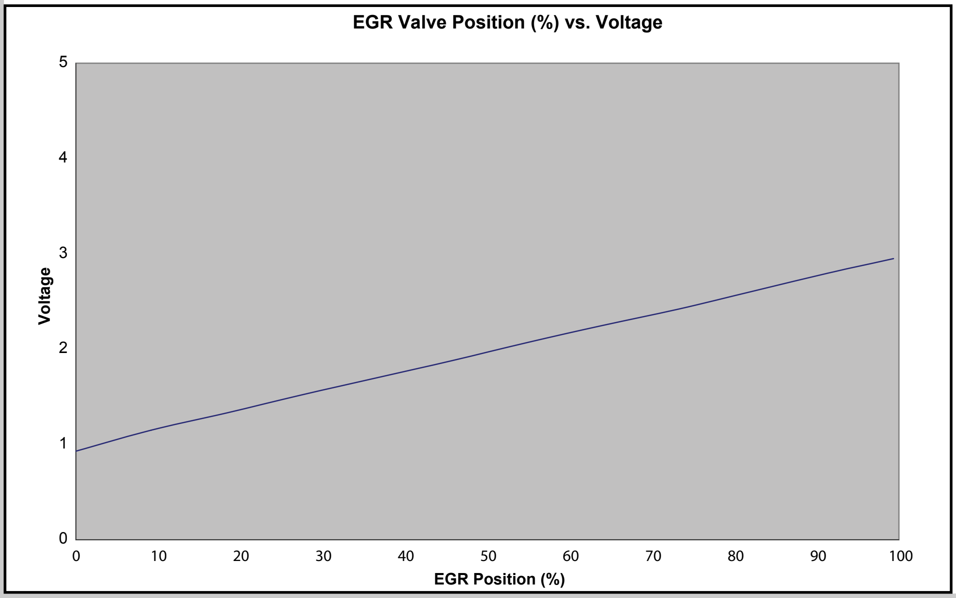
Position Sensors

Exhaust Gas Recirculation Valve Position (EGRVP)

The EGRVP sensor is a 3-wire non-contacting position sensor based upon the magneto-resistive effect (that is, a non-contacting Hall-effect). The PCM supplies a 5 volt reference (VREF) signal which the EGR position sensor uses to produce a linear analog voltage indicating EGRVP.

The PCM uses the EGRVP sensor to determine EGRVP and compares it to the calculated desired position.

IDS: EGRVP (volts) and EGR_A_ACT (%)



Crankshaft Position (CKP)

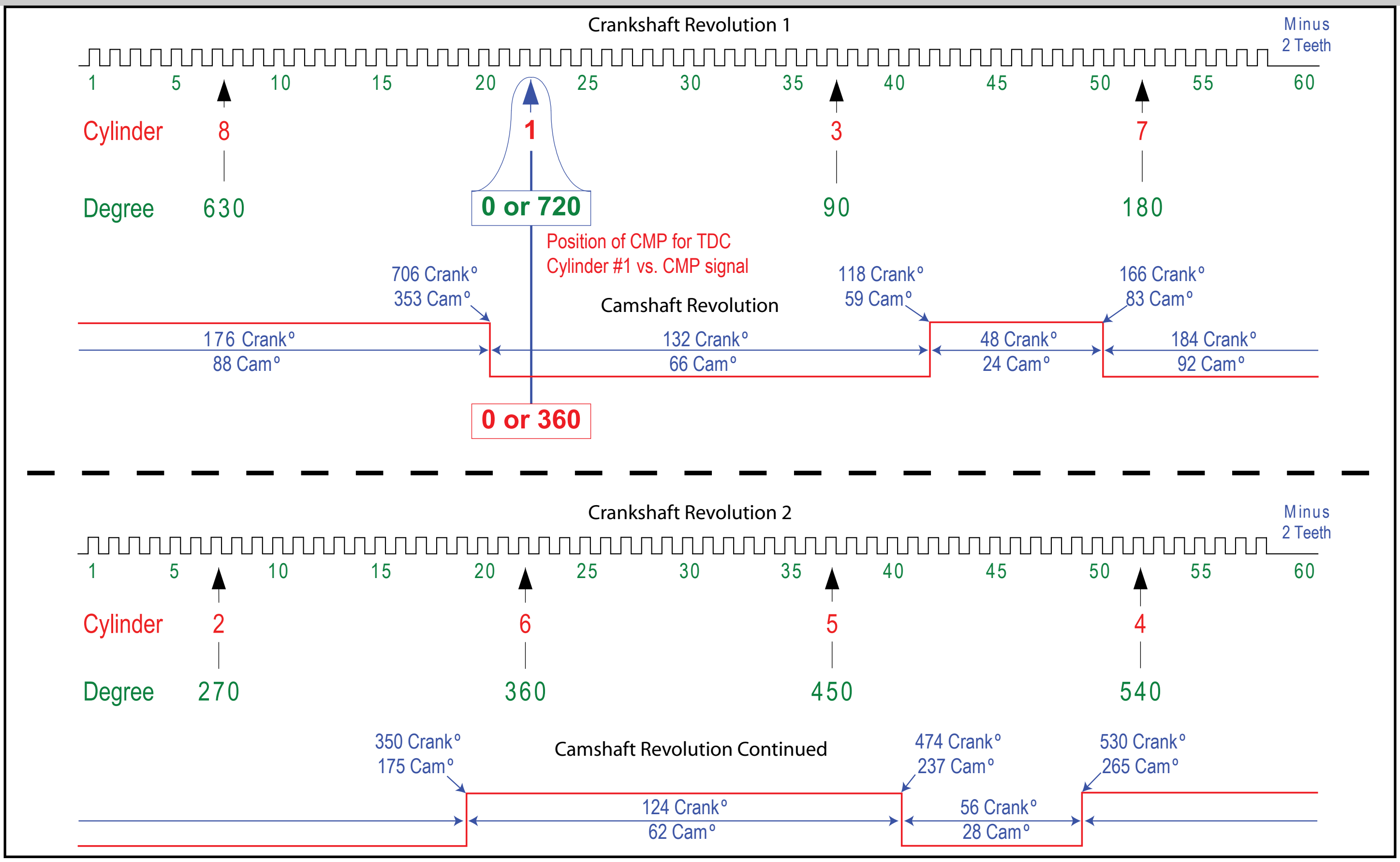
The CKP sensor is a Hall-effect sensor. The PCM converts the information from the sensor into a square wave which indicates the tooth edges of the magnetic trigger wheel. There are 2 teeth removed to help the PCM to find the crankshaft position therefore knowing piston position within each cylinder.

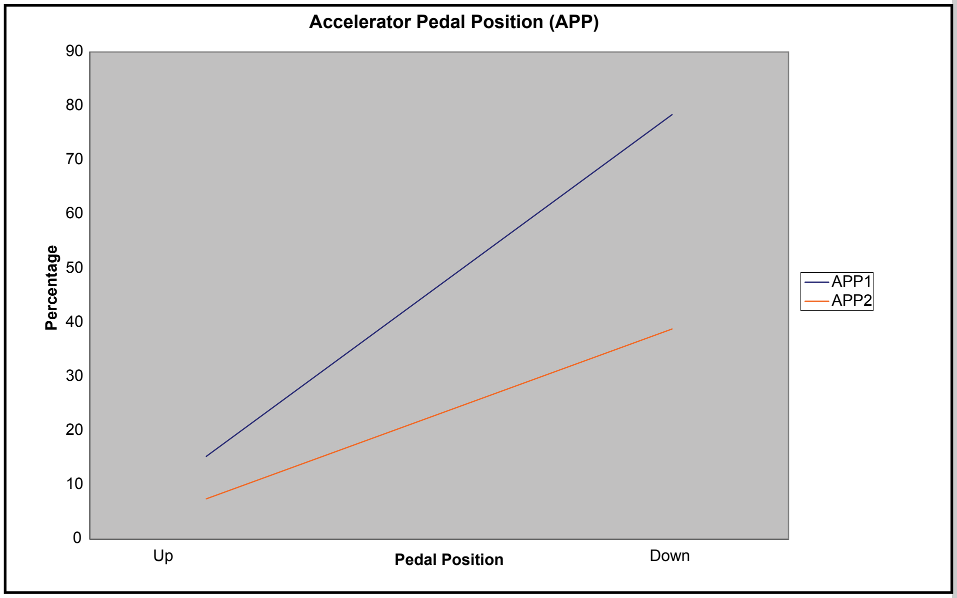
The PCM uses the CKP sensor for engine speed and crankshaft position calculation.

Camshaft Position (CMP)

The CMP sensor is a Hall-effect sensor. The PCM converts the information from the sensor into a square wave which indicates the 6 targets on the target wheel.

The PCM uses CMP sensor for diagnostics and as a backup for the CKP sensor in the event of CMP failure.





Accelerator Pedal Position (APP)

The APP is a 2-track position pedal. The pedal has 2 potentiometers providing pedal position to the PCM. This is a safety feature.

IDS: APP1 (volts) and APP1 [APP_D] (%)

IDS: APP2 (volts) and APP2 [APP_E] (%)

Miscellaneous Sensors

NOx sensor

The NO_x sensor is mounted next to the EGT14 sensor. The NO_x sensor monitors the amount of NO_x out of the tailpipe. The PCM uses the information to adjust how much reductant is being injected into the exhaust as well as an input for fuel trim. The information from the NO_x sensor can also tell the effectiveness of the Selective Catalyst Reduction (SCR) system.

Water In Fuel (WIF)

The WIF sensor monitors the water level within the DFCM to determine if the water reservoir requires draining.

The PCM notifies the customer when the water needs to be drained from the DFCM to protect the high pressure fuel system.

IDS: WIF (yes/no)

Outputs

Intake Throttle Body

The intake throttle body has an electric DC motor to move the throttle plate. The intake throttle body is controlled by the PCM. The valve is powered in both the open and closed positions.

The intake throttle body helps create the delta pressure difference between intake and exhaust for EGR flow, regeneration and shutdown noise.

IDS: EGRTP_CMD (%)

EGR Valve

The EGR valve is an electric DC motor controlled by the PCM. The valve is powered in both the open and closed positions.

The EGR valve is opened to allow exhaust gases to mix with the intake air for NO_x emissions purposes.

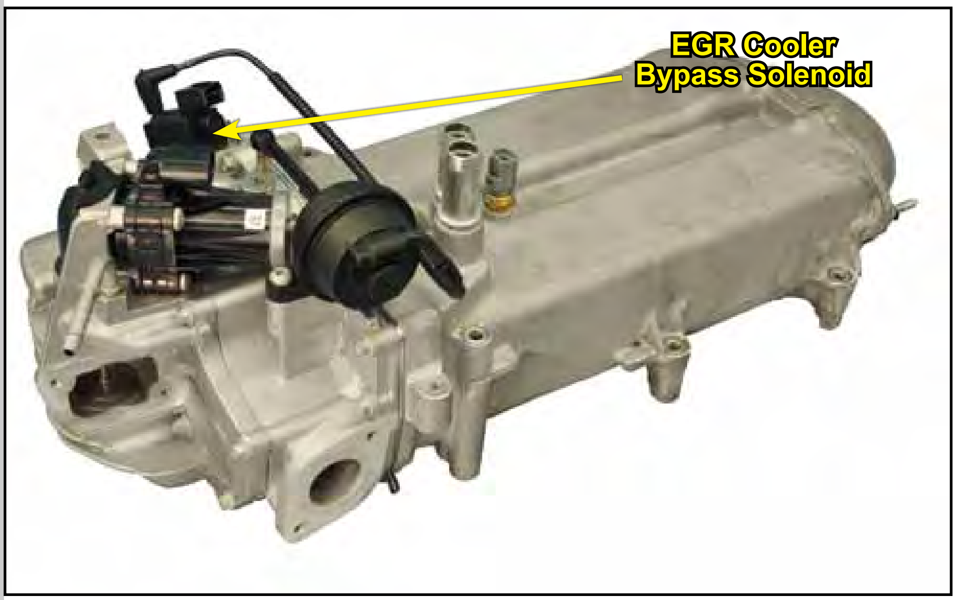
IDS: EGR_A_CMD (%)

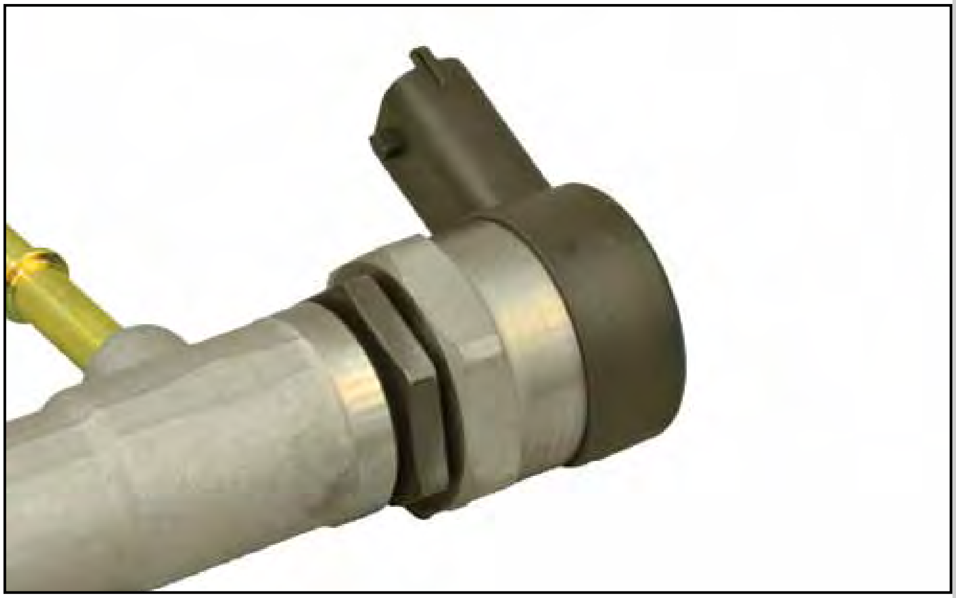
EGR Cooler Bypass Solenoid

A duty cycle is applied to the solenoid from the PCM to turn vacuum to the actuator on or off. This change causes the EGR cooler bypass door to move.

The EGR cooler bypass solenoid changes the state of the EGR cooler bypass door to either allow exhaust gases to bypass the EGR cooler or direct the gases through the cooler.

IDS: EGRCBY (%)

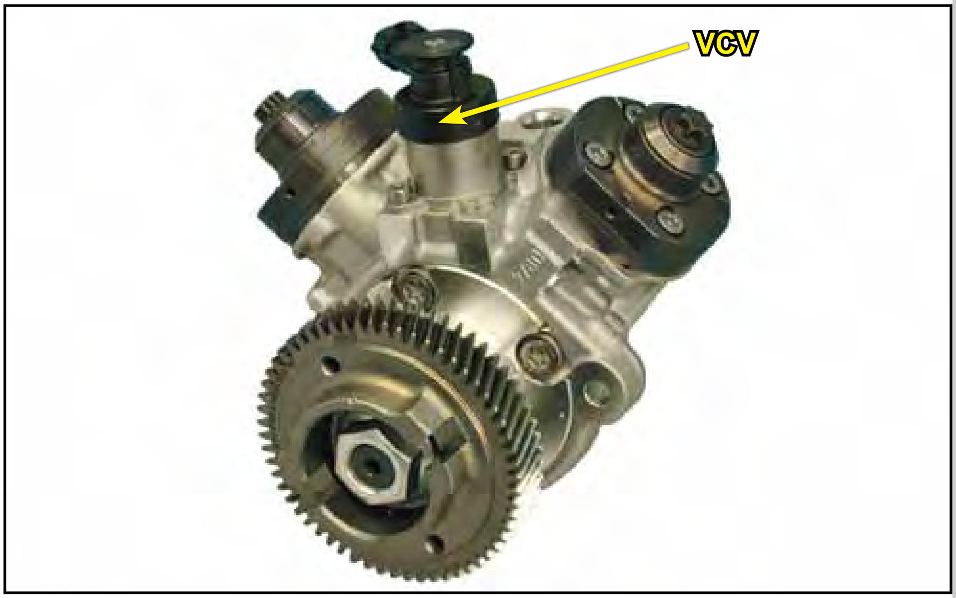




Pressure Control Valve (PCV)

The PCV is threaded into the rear of the left fuel rail. The PCM controls the fuel rail pressure by modulating the PCV which regulates the fuel rail pressure.

The PCM regulates fuel rail pressure by controlling the on/off time of the PCV solenoid. A high duty cycle indicates a high fuel rail pressure is being commanded. A low duty cycle indicates a low fuel rail pressure is being commanded.



Volume Control Valve (VCV)

The fuel VCV is mounted on the high pressure fuel pump. The PCM controls the volume of low pressure fuel that enters the inlet one-way check valve and two main pump pistons by activating the fuel VCV.

The PCM regulates fuel volume by controlling the on/off time of the fuel VCV solenoid. A high duty cycle indicates less volume is being commanded. A low duty cycle indicates a high fuel volume is being commanded.

Fuel Injectors

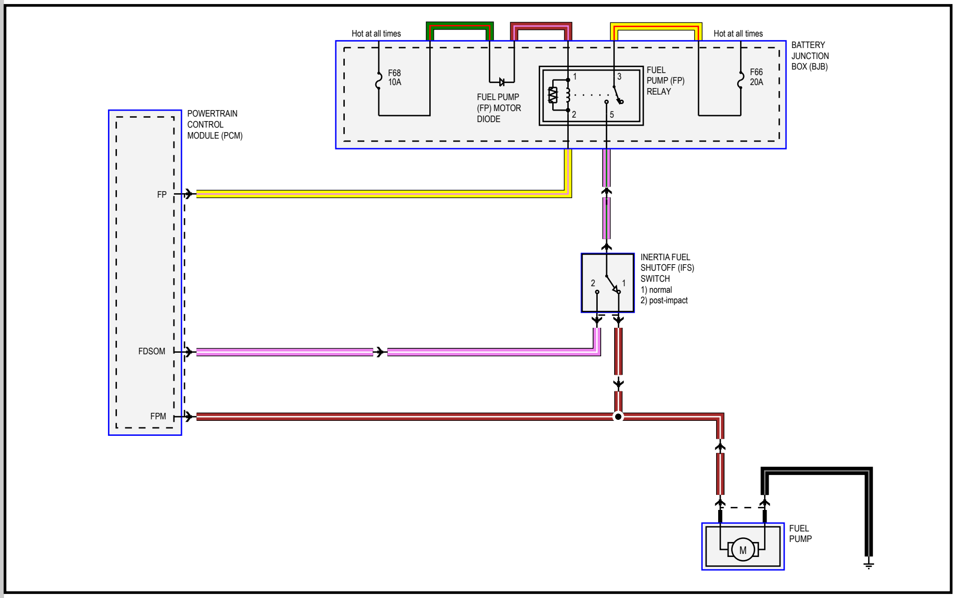
The fuel injectors are connected to the high pressure fuel rail and deliver a calibrated amount of fuel directly into the combustion chamber. The on and off time of the fuel injectors are controlled by the piezo actuator device, which allows extreme precision during the injection cycle. The piezo actuator is commanded on by the PCM during the main injection stage for approximately 0-400 micro seconds.

Variable Geometry Turbocharger (VGT) Actuator

The VGT actuator is mounted on the top of the turbocharger. The VGT actuator is commanded by the PCM, based on engine speed and load. The magnetic field generated by this signal moves a shaft in the control valve. A cam follower at the end of the valve assembly provides feedback to the valve, allowing it to reach a neutral position during times the vanes are not commanded to move.

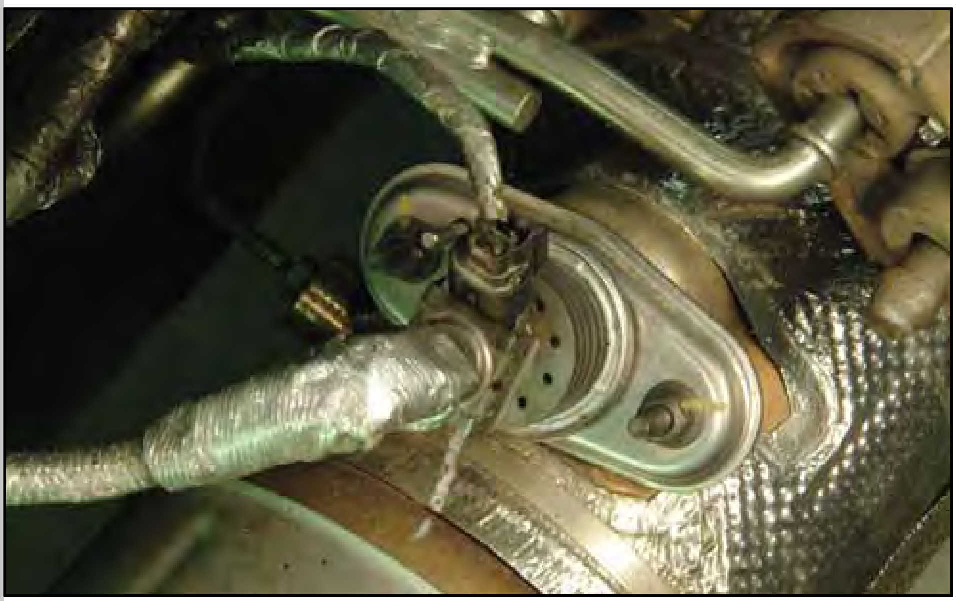
Fuel Pump Relay

The fuel pump relay is located in the Battery Junction Box (BJB). The PCM controls when the relay is on and off.



Reductant Dosing Module

The reductant dosing module is mounted next to EGT12 sensor. The reductant dosing module is the part that injects the Diesel Exhaust Fluid (DEF) into the exhaust system.



Glow Plug Control Module (GPCM)

The GPCM is mounted under the right side battery box. The PCM commands the GPCM to power the individual glow plugs, which the GPCM does by providing battery voltage. The GPCM is also responsible for powering the heaters used in the reductant system.

Transmission Control Module (TCM)

The TCM is mounted under the vehicle, on the driver side outside the frame rail. The TCM controls the operation of the transmission.

Cooling Fan

The cooling fan is mounted on the front of the engine and is controlled by the PCM.

Wastegate Control Solenoid

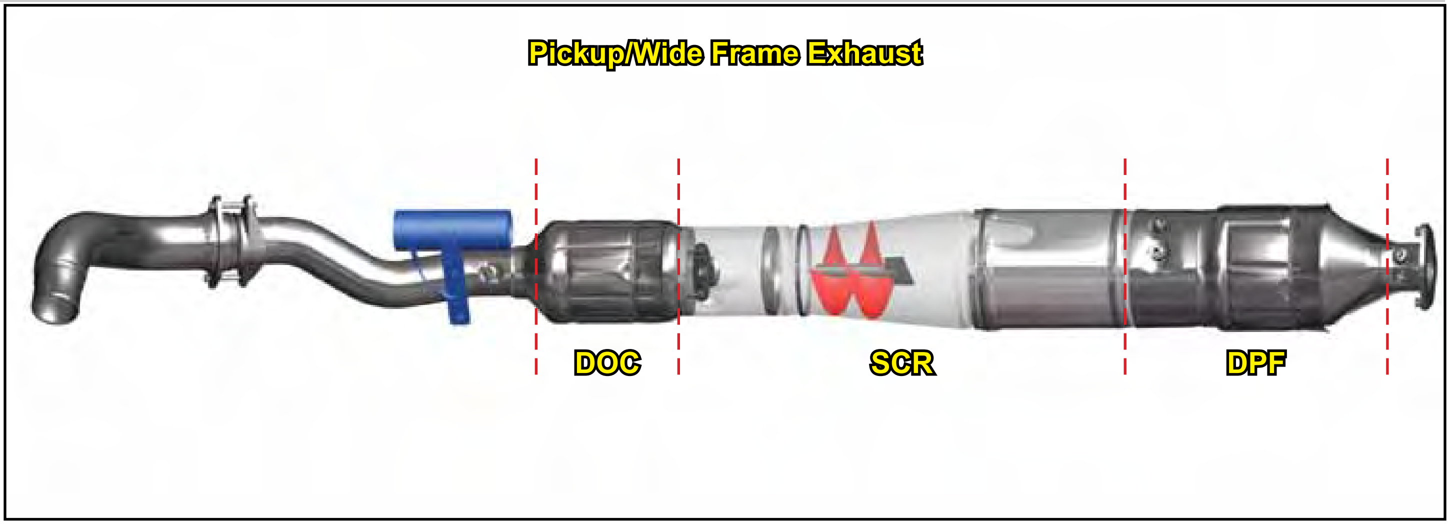
The PCM provides a duty cycle to the solenoid which changes the vacuum flow to the actuator causing the wastegate to open and allow exhaust gases to bypass the turbine.

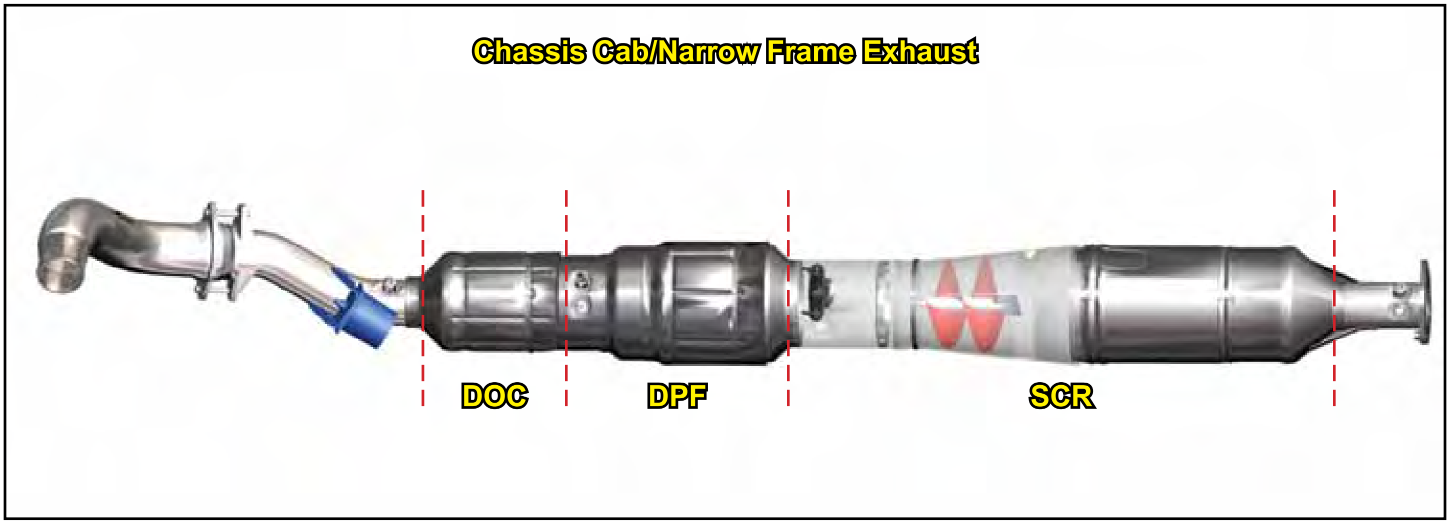
The wastegate helps maintain the required intake manifold pressure. It is used when mostly when intake manifold pressure needs to be decreased quickly. When the wastegate is opened, exhaust back pressure is decreased, reducing the turbocharger turbine speed.

IDS: TURBO_WGATE (%)

EXHAUST SYSTEM

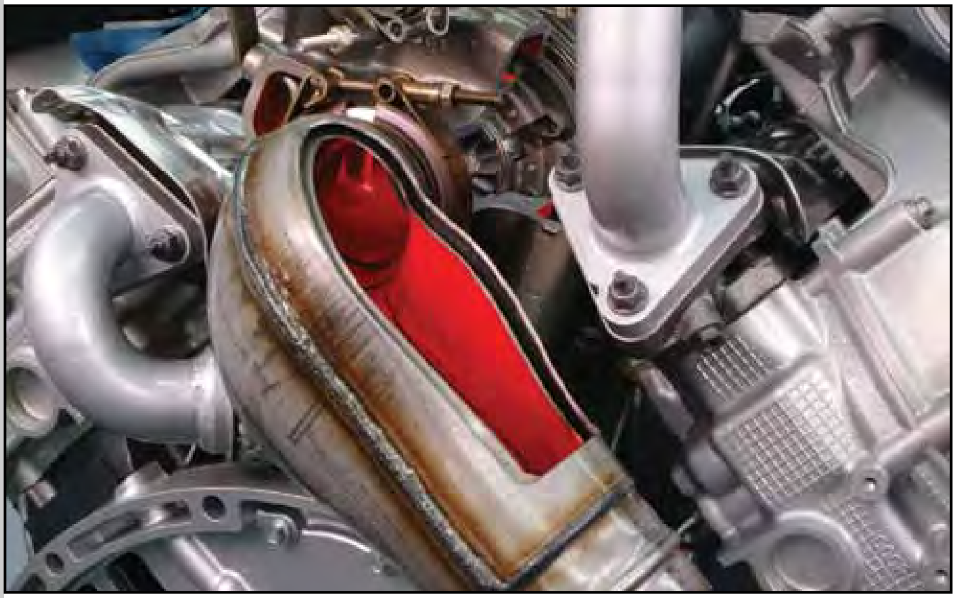
Exhaust gases exit the exhaust ports into the inboard exhaust manifolds and are directed to the dual turbine inlet of the turbo through the right and left side up-pipes. The exhaust gas and heat spins the turbine wheel inside the turbocharger. The turbine wheel spins the compressor wheel(s) via their common shaft. Some of the exhaust from the passenger side manifold is directed to the EGR valve through the EGR inlet pipe. When the EGR valve is being operated, exhaust flow goes through the valve and is routed through either the EGR cooler or bypasses the cooler. This is done by the EGR cooler bypass valve. The exhaust gas enters the lower intake manifold and combines with the fresh air.





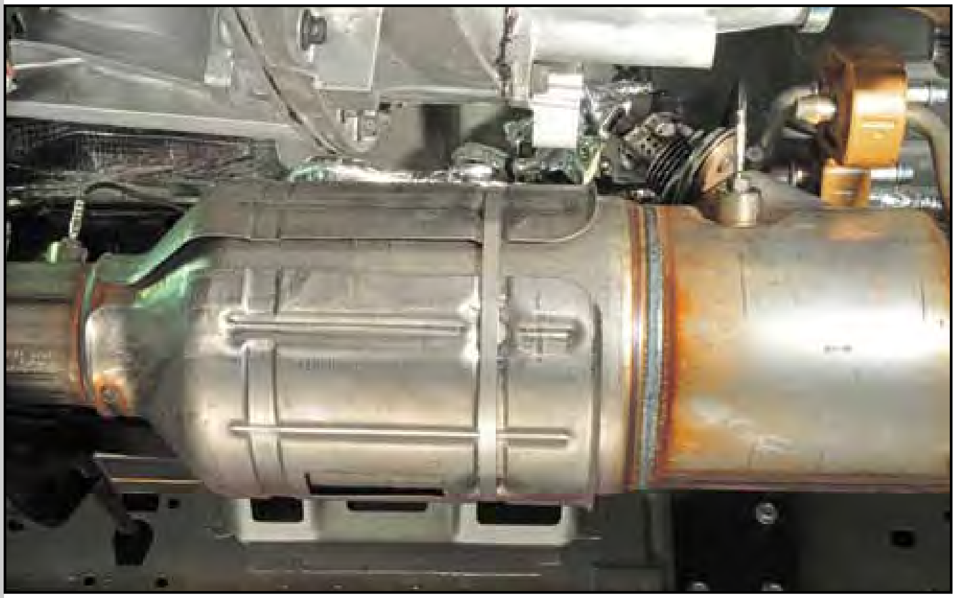
Turbocharger Down Pipe

The turbocharger down pipe is double-walled to help retain heat for the after treatment system. It connects to the turbocharger with a V-band clamp connector.



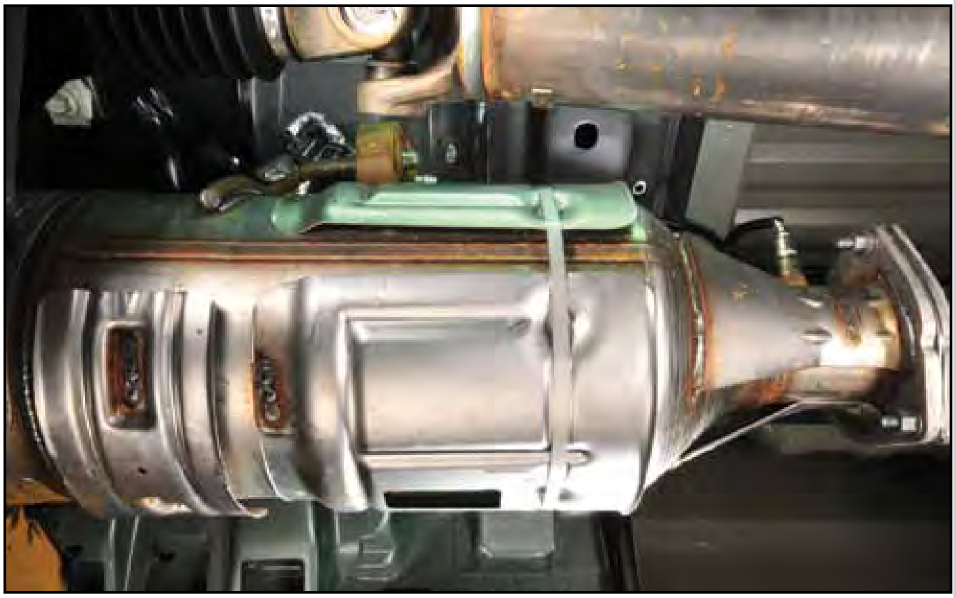
Diesel Oxidation Catalyst (DOC)

The DOC is a ceramic catalytic converter which oxidizes hydrocarbons in the exhaust and generates heat for the SCR and DPF to function properly.



Selective Catalyst Reduction (SCR)

The SCR reduces NO_x in the exhaust. To do this the SCR system uses a ceramic catalyst that has been coated with copper and iron, and injecting DEF into the exhaust stream.

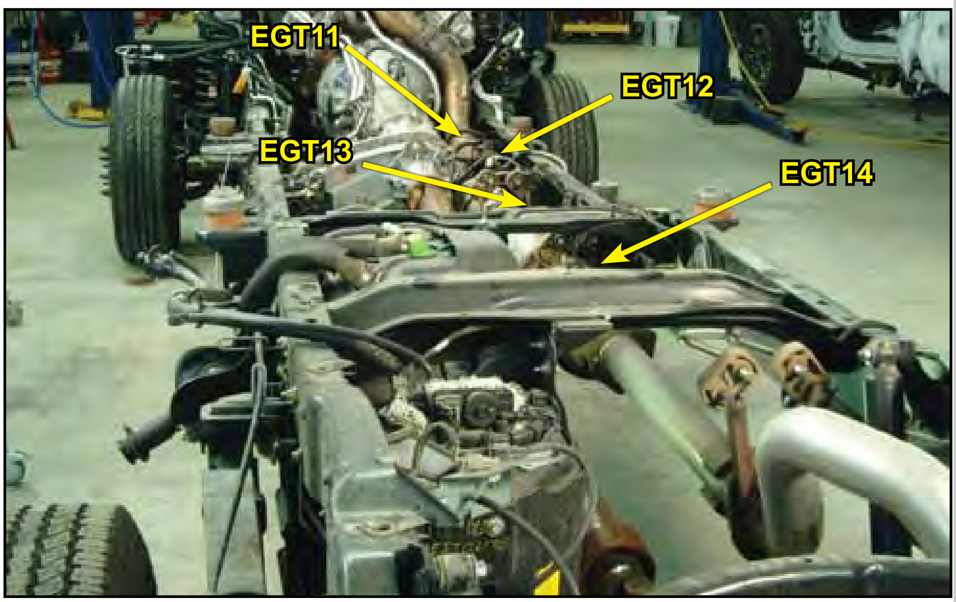


Diesel Particulate Filter (DPF)

The DPF is a highly engineered silicon carbide wall-flow catalyst that traps particulates, reducing the amount of black smoke emitted from the tailpipe. The three modes of DPF regeneration are active, passive and manual.

DPF Pressure Sensor

The DPF pressure sensor is an input to the PCM and measures the pressure before the DPF. The sensor is a differential-type sensor that is referenced to atmospheric pressure. The DPF pressure sensor is used by the PCM to monitor the amount of exhaust pressure produced by the DPF. An active regeneration is performed when the reading reaches a specified point.

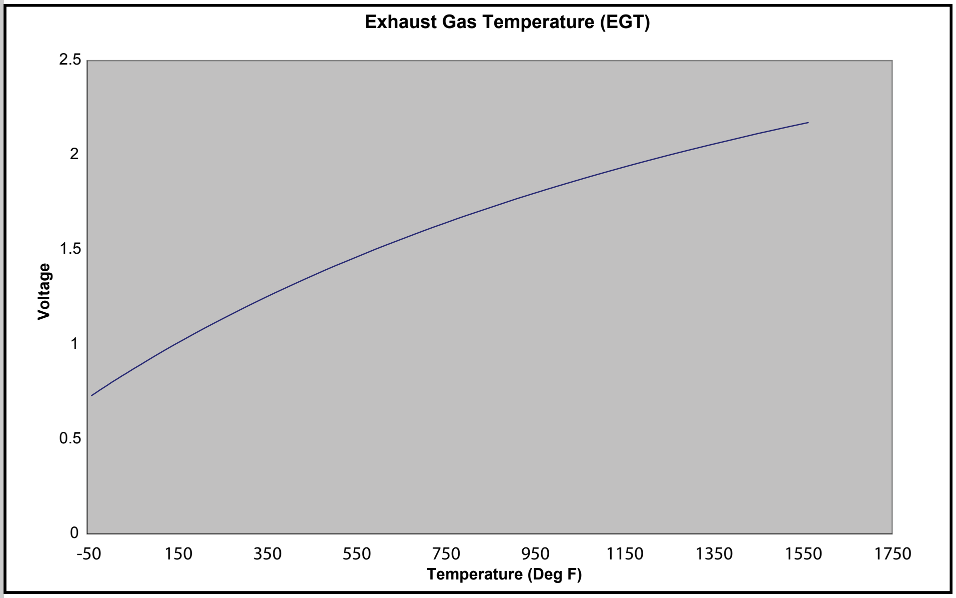


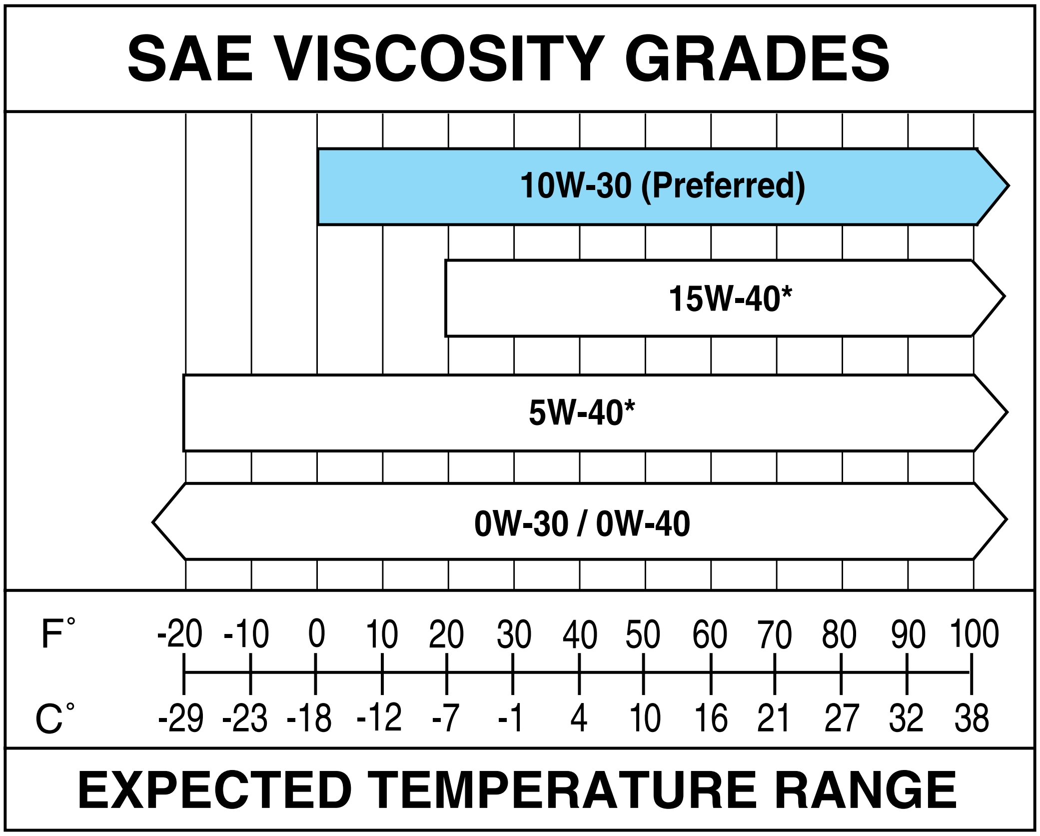
Exhaust Gas Temperature (EGT) Sensors

The EGT sensors are Resistance Temperature Detector (RTD) type sensors. The EGT sensors are inputs to the PCM. They measure the temperature of the exhaust gas passing through the exhaust system at four different points.

EGT Sensor Operation

The electrical resistance of the sensor increases as the temperature increases, and resistance decreases as the temperature decreases. The varying resistance changes the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature. The PCM uses the input from four EGT sensors to monitor the exhaust gas temperature.





Recommended Motor Oil

For normal or severe service, use Motorcraft® oil or equivalent conforming to Ford specifications or American Petroleum Institute (API) service categories CJ-4 or CJ-4/SM. It is important to use these oils because they are compatible with the emission control equipment of your vehicle to meet the more stringent emission standards. CJ-4 oil is low in sulfated ash, and has qualities that maintain the life of the DPF and DOC.

The use of correct oil viscosities for diesel engines is important for satisfactory operation. Determine which oil viscosity best suits the temperature range you expect to encounter for the next service interval from the following SAE viscosity grade chart.

*For severe duty use and/or when using biodiesel (grades B5-B20), SAE 5W-40 or SAE 15W-40 API CJ-4 is recommended.

The service interval for the engine oil depends on the vehicle operating conditions. Always consult the maintenance schedule for the proper maintenance interval for the operating conditions.

The following can be negatively affected by not using the recommended API rated engine oil are:

- increased Particulate Matter (PM) in the aftertreatment system may cause more ash build up in the DPF
- more frequent DPF regenerations
- reduction of DPF service life.
- engine oil system

Regeneration Process

As soot gathers in the aftertreatment system, the exhaust begins to become restricted. Regeneration is the process in which soot is burned off from the inside of the DPF. Regeneration is commanded by the PCM.

The PCM starts regeneration of the DPF if the soot load exceeds a calibrated value. The PCM determines the load condition of the DPF, based on the exhaust gas pressure upstream of the DPF. The DPF pressure sensor provides the pressure input to the PCM.

This soot can be cleaned by passive, active, or manual regeneration. Manual regeneration is performed by using the IDS.

Passive Regeneration

Passive regeneration takes place when exhaust temperatures exceed 300°C (572°F). This process does not affect engine performance and is transparent to the driver.

Active Regeneration

Active regeneration occurs when exhaust temperatures are insufficient to achieve passive regeneration and the DPF pressure sensor is indicating the need for regeneration.

The PCM automatically activates the left bank fuel injectors only during the exhaust stroke to raise exhaust temperature to begin regeneration while the vehicle is in motion.

Engine performance is not affected by active regeneration, however the engine or exhaust tone may change.

Manual Regeneration

The IDS can be used to perform a manual regeneration of the DPF in the shop and set the ash value under stationary conditions to clean and calibrate the system. The Malfunction Indicator Lamp (MIL) may illuminate when service or maintenance of the DPF is necessary.

CAUTION: The manual regeneration of the DPF produces high temperatures in the exhaust system. Due to high exhaust gas temperatures, always follow the Workshop Manual Cautions, Warnings, and procedures when performing a manual DPF regeneration.

Frequency of Regeneration

The mileage between regenerations varies significantly, depending on vehicle usage.

Post Regeneration

After regeneration, the PCM reads the pressure at the DPF pressure sensor and compares it with a calibrated value. From this comparison, the PCM determines the ash quantity inside the DPF.

Non-Burnable Ash

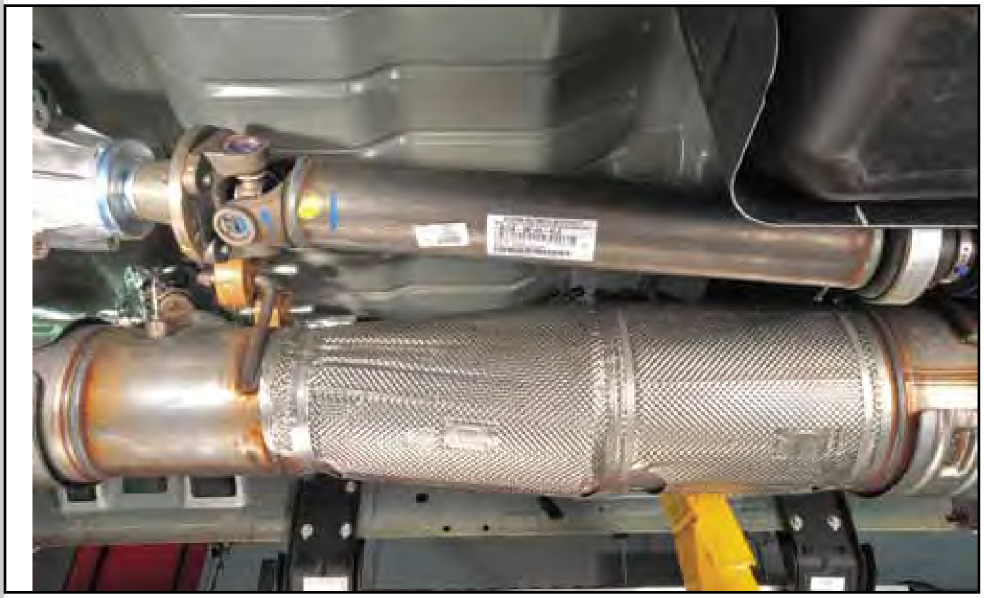
Over time a slight amount of non-burnable ash builds up in the DPF which is not removed during the regeneration process. Ash comes from the fuel, oils and other materials that remain after the DPF regeneration process. The DPF may need to be removed for ash cleaning and replaced with a new or remanufactured part.

Handle the DPF with care. Dropping the DPF may cause internal damage.

Selective Catalyst Reduction (SCR)

The SCR system components include the:

- reductant or Diesel Exhaust Fluid (DEF)
- reductant tank
- reductant dosing module
- reductant pump and heater assembly
- reductant pressure line heater assembly
- reductant tank heater and sensor assembly
- reductant purge valve
- reductant pressure sensor
- NOx sensor and module
- exhaust mixing system.



Reductant or Diesel Exhaust Fluid (DEF)

Reductant, also known as Diesel Exhaust Fluid (DEF) is 32.5% urea/ water solution. When injected into the exhaust, there is a chemical reaction that converts NO_x into N_2 and H_2O. The freezing point of reductant is -11°C (12°F).

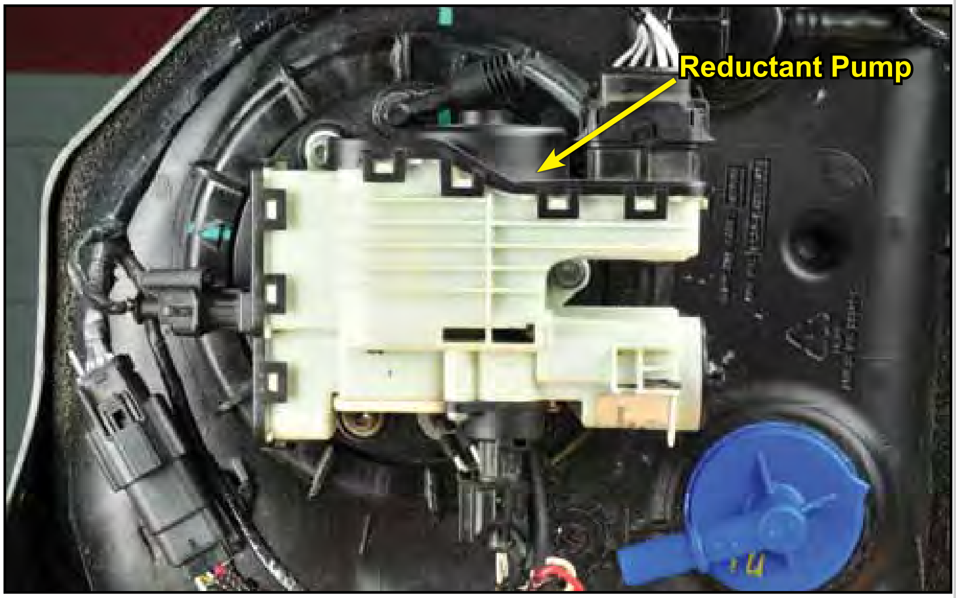
Reductant is very caustic; take care not to spill onto connectors, wiring harnesses or the vehicle's paint.

Reductant Tank

The reductant tank stores the reductant or DEF. Under normal use it needs to be refilled at the same interval as the oil change.

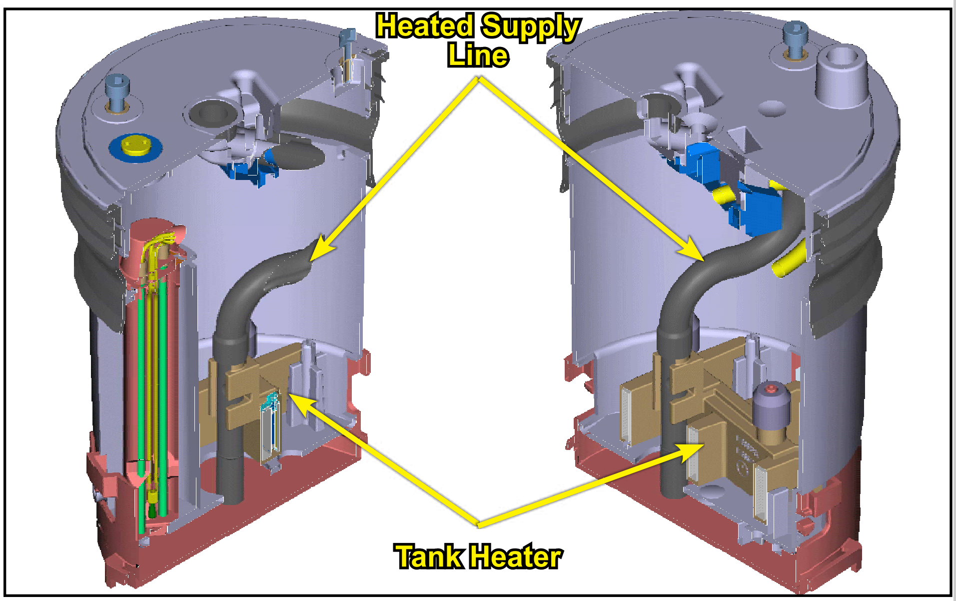
Reductant Dosing Module

The reductant dosing module is controlled by the PCM. The reductant dosing module injects reductant into the exhaust system to reduce NO_x coming out of the tailpipe. The injector is made to resist the corrosive properties of the reductant.



Reductant Pump

The reductant pump supplies urea to the dosing module. One unique function of the pump is that when the ignition is turned off, the pump pulls all of the reductant out of the lines. This prevents damage to the lines if the reductant was to freeze.

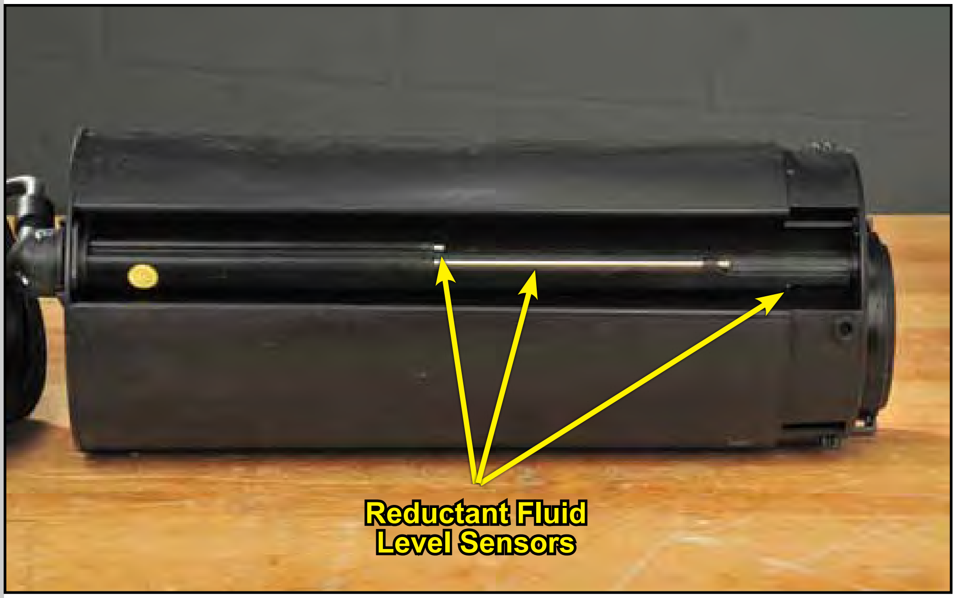


Reductant Heaters

Below a specified temperature the PCM commands the Glow Plug Control Module (GPCM) to activate the heaters in the reductant system. The reductant system has heaters in the tank, pump, and lines. The heaters in the tank thaw the DEF if it is frozen and allow it to flow to the pump without freezing. The heaters in the pump and lines allow the DEF to flow to the injector without freezing.

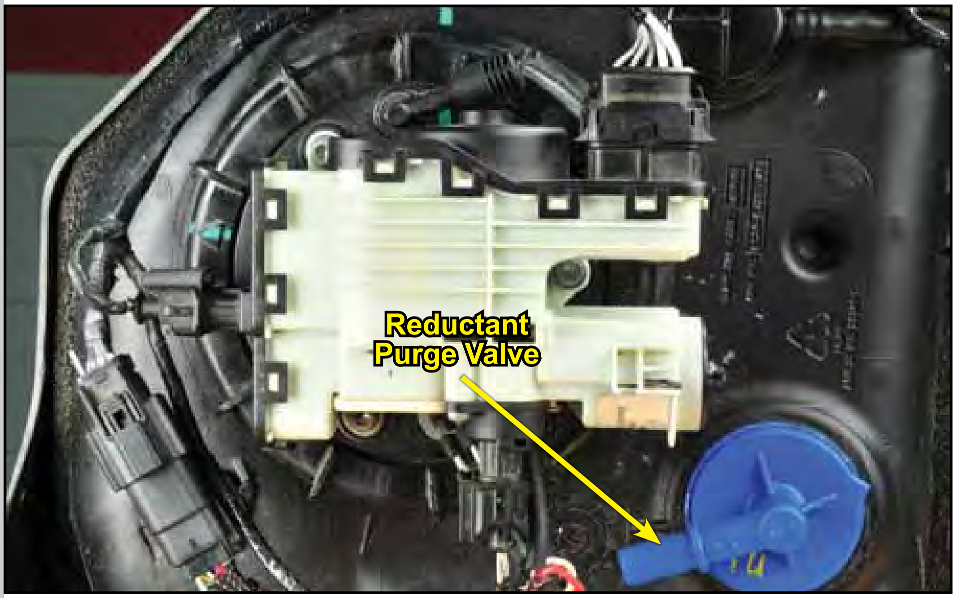
Reductant Fluid Level Sensors

The reductant fluid level sensor operates by using four electrodes (one not visible in the picture) that are mounted on the sensor at different levels. The reductant solution closes the electric circuit between electrodes for each level interface. The signal is then converted before being sent to the PCM.



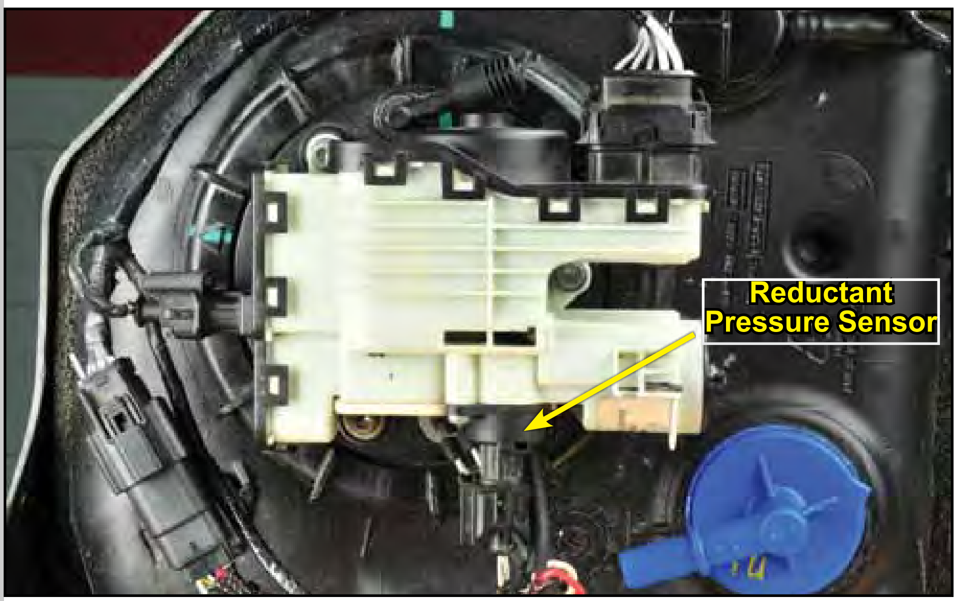
Reductant Purge Valve

The reductant purge valve is opened by the PCM allowing the pressure to equalize in the fluid tank.



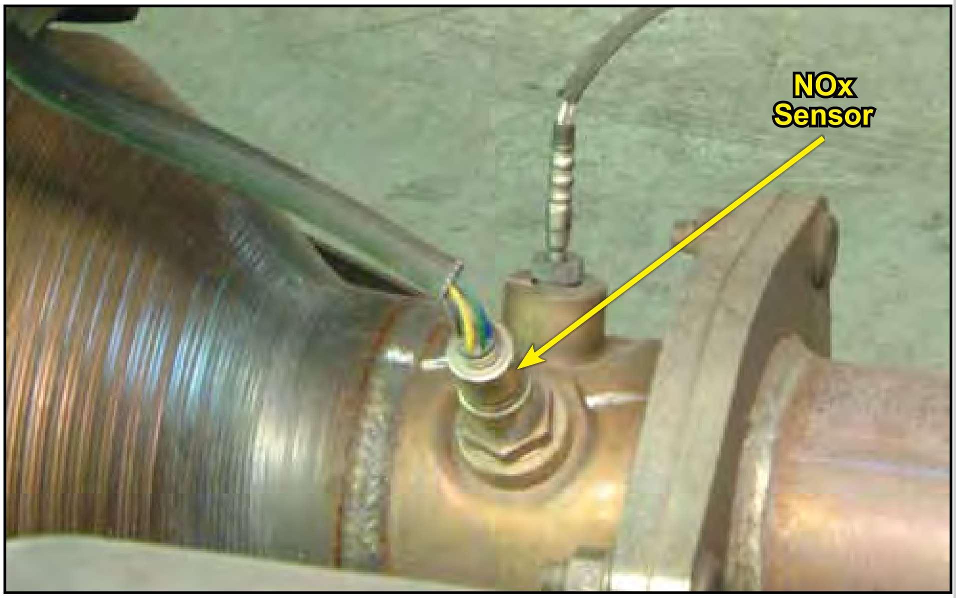
Reductant Pressure Sensor

The PCM monitors the reductant pressure sensor to calculate how much reductant to be injected into the exhaust. The reductant pressure sensor is also be used to shut the pump off when the lines are being drained after the ignition is shut off.



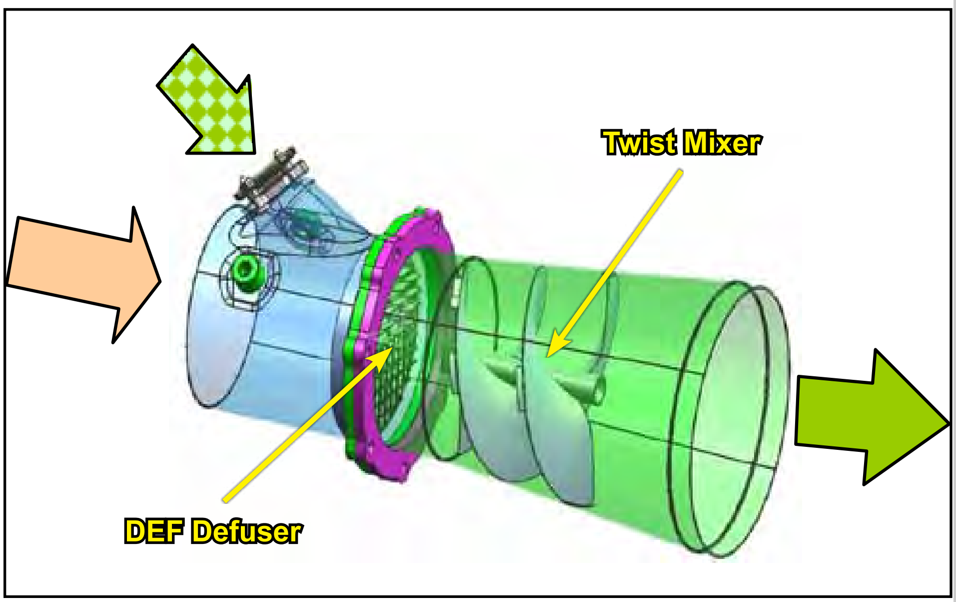
NOx Sensor Module

The NO_x sensor module is mounted to the vehicle frame under the body. It controls the NO_x sensor mounted in the diesel aftertreatment exhaust system downstream of the SCR and DPF. It communicates to the PCM via the CAN2 to report NO_x and O_2 concentrations as well as sensor and controller errors.



NOx Sensor

The NO_x sensor is used primarily to sense O_2 and NO_x concentrations in diesel exhaust gas. The sensor is mounted in a vehicle's exhaust pipe, perpendicular to exhaust gas flow. The sensor is mounted downstream of the SCR and DPF. The sensor interfaces with the NO_x sensor module that controls the sensor and heater circuits.



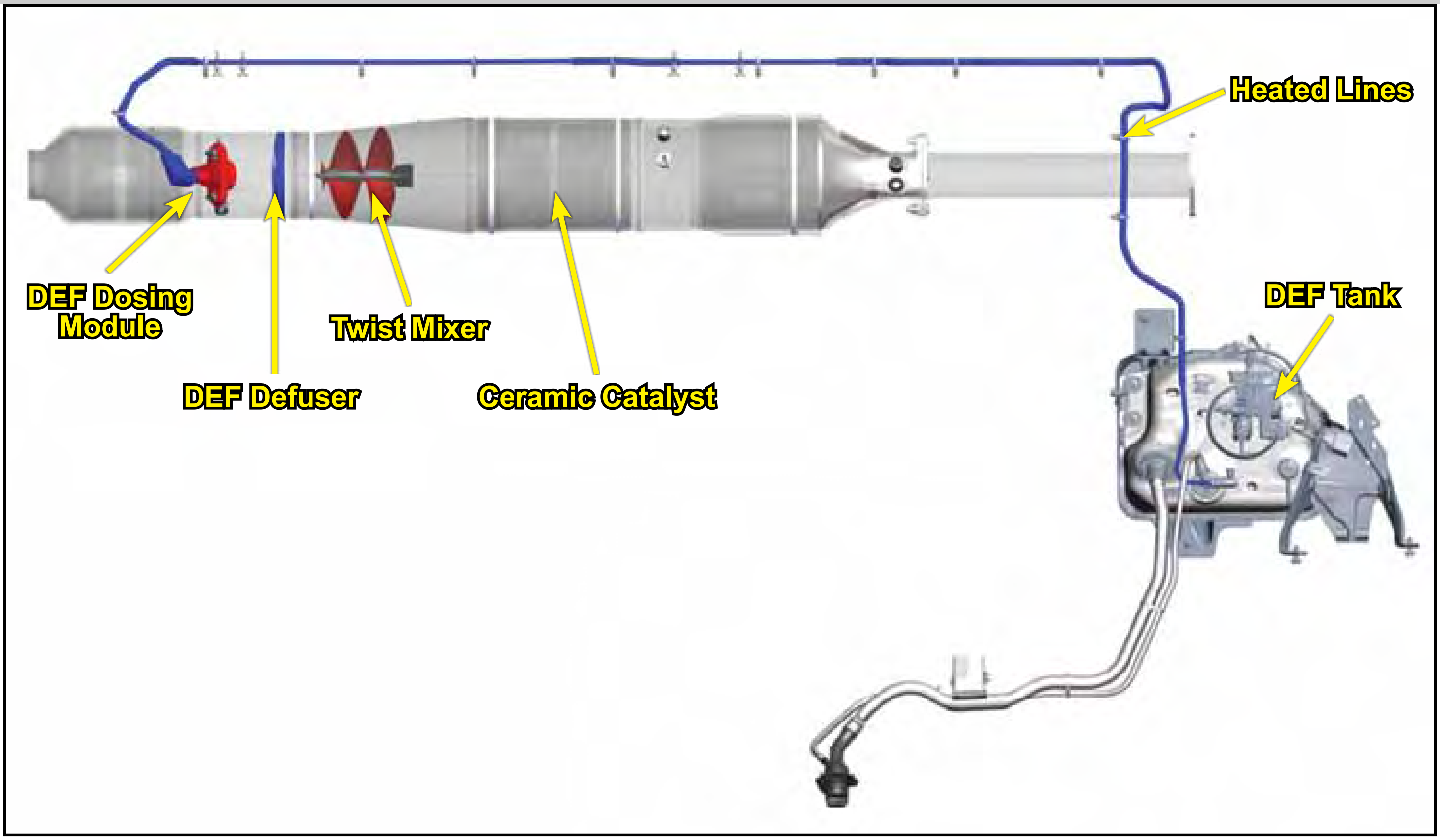
Reductant Exhaust Mixer

There is an exhaust mixing system in the exhaust stream to mix the reductant with the exhaust gas. The mixer is made up of an atomizer and a twist mixer. The atomizer breaks up and vaporizes the reductant droplets. The twist mixer evenly distributes the reductant in the exhaust gases for maximum efficiency.

Selective Catalyst Reduction (SCR) System Operation

The SCR system reduces nitrogen oxides (NO_x) present in the exhaust stream to nitrogen (N_2) and water (H_2O). The SCR contains a ceramic catalyst washcoated with copper and iron on a zeolite substrate. At the inlet of the SCR catalyst is a port for the reductant dosing module, followed by a grate diffuser and a twist mixer. When Diesel Exhaust Fluid (DEF) is introduced into the system, it finely atomizes in the grate diffuser and mixes evenly with exhaust gases in the twist mixer. During this time, the heat of the exhaust gases causes the urea to split into carbon dioxide (CO_2) and ammonia (NH_3). As the ammonia and NO_x pass through the ceramic SCR catalyst, a reduction reaction takes place and the ammonia and NO_x are converted to N_2 and H_2O.

The engine is able to run leaner and therefore more efficiently because of the efficiency of the SCR system eliminating the high NO_x levels that are produced under lean conditions.



Front Crank Seal Remover

The Front Crank Seal Remover, 303-1510 is used to remove the front crankshaft seal.

Front Crank Seal Installer

The Front Crank Seal Installer, 303-1509 is used to install the front crankshaft seal.

Rear Crank Seal Remover

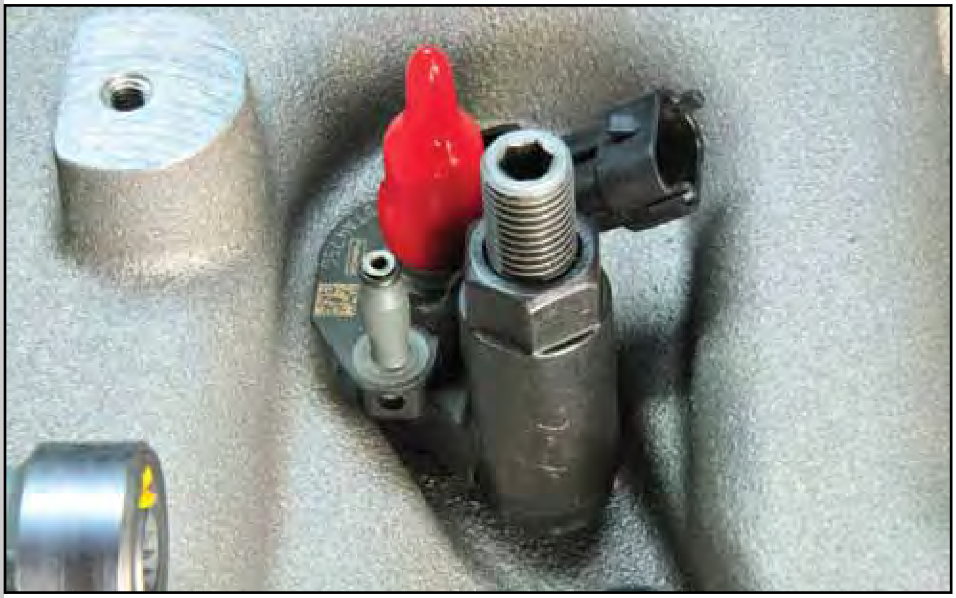
The Rear Crank Seal Remover, 303-1513 is used to remove the rear crankshaft seal.

Rear Crank Seal Installer

The Rear Crank Seal Installer, 303-1514 is used to install the rear crankshaft seal.

Fuel Injector Removal Tool

The Fuel Injector Remover, 310-230 is used to remove the fuel injectors from the 6.7L diesel engine.



Engine Removal Bracket

The Engine Removal Bracket, 303-1518 is used to remove and install the 6.7L diesel engine.

EGR Pressure Tester

The EGR Pressure Tester, 303-1511 is used to check for coolant leaks.

EGR Cooler Primary Coolant Passage Tester

EGR Pressure Tester

The EGR Pressure Tester, 303-1511 is used to check for coolant leaks.

EGR Cooler Secondary Coolant Passage Tester

Valve Spring Compressor

The Valve Spring Compressor, 303-1516 is used to compress the valve springs to remove the valve keepers.

Compression Adapter Tester

The Compression Adapter Tester, 303-1515 is used to adapt the compression tester to the 6.7L diesel engine.

Camshaft Removal and Installation Adapter

The Camshaft Removal and Installation Adapter, 303-1517 is used to remove and install the camshaft.


BUILT
Ford
TOUGH