3.2L POWER STROKE DIESEL ENGINE

Direct Injection Turbocharged Diesel Engine

Engine Description • **Systems Overview** • **Component Locations**

REPAIR TECHNIQUES

Appropriate service methods and procedures are essential for the safe, reliable operation of all motor vehicles as well as the personal safety of the individual doing the work. This manual provides general directions for performing service with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedure, techniques, tools and parts for servicing vehicles, as well as in 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 compromise neither their personal safety nor the vehicle integrity by their choice of methods, tools or parts.

NOTE, NOTICE, CAUTION AND WARNING

As you read through this manual, you may come across a **NOTE**, **NOTICE**, **CAUTION** or **WARNING**. Each one is there for a specific purpose. A **NOTE** calls attention to unique, additional or essential information related to the subject procedure. A **NOTICE** identifies a hazard that could damage the vehicle or property. A **CAUTION** identifies a hazard that could result in minor personal injury to yourself or others. A **WARNING** identifies a hazard that could result in severe personal injury or death to yourself or others. Some general **WARNINGS** that you should follow when you work on a vehicle are listed below.

- **ALWAYS WEAR SAFETY GLASSES FOR EYE PROTECTION.**
- **KEEP SOLVENTS AWAY FROM IGNITION SOURCES. SOLVENTS MAY BE FLAMMABLE AND COULD IGNITE OR EXPLODE IF NOT HANDLED CORRECTLY.**
- **USE SAFETY STANDS WHENEVER A PROCEDURE REQUIRES YOU TO BE UNDER THE VEHICLE.**
- **MAKE SURE THAT THE IGNITION SWITCH IS ALWAYS IN THE OFF POSITION, UNLESS OTHERWISE REQUIRED BY THE PROCEDURE.**
- **SET THE PARKING BRAKE WHEN WORKING ON THE VEHICLE. IF YOU HAVE AN AUTOMATIC TRANSMISSION, SET IN PARK UNLESS INSTRUCTED OTHERWISE FOR A SPECIFIC OPERATION. IF YOU HAVE A MANUAL TRANSMISSION, IT SHOULD BE IN REVERSE (ENGINE OFF) OR NEUTRAL (ENGINE ON) UNLESS INSTRUCTED OTHERWISE FOR A SPECIFIC OPERATION. PLACE WOOD BLOCKS (4” X 4” OR LARGER) OR WHEEL CHOCKS AGAINST THE FRONT AND REAR SURFACES OF THE TIRES TO HELP PREVENT THE VEHICLE FROM MOVING.**
- **OPERATE THE ENGINE ONLY IN A WELL-VENTILATED AREA TO AVOID THE DANGER OF CARBON MONOXIDE POISONING.**
- **KEEP YOURSELF AND YOUR CLOTHING AWAY FROM MOVING PARTS WHEN THE ENGINE IS RUNNING, ESPECIALLY THE DRIVE BELTS.**
- **TO PREVENT SERIOUS BURNS, AVOID CONTACT WITH HOT METAL PARTS SUCH AS THE RADIATOR, EXHAUST MANIFOLD, TAIL PIPE, THREE-WAY CATALYTIC CONVERTER AND MUFFLER.**
- **DO NOT SMOKE WHILE WORKING ON A VEHICLE.**
- **TO AVOID INJURY, ALWAYS REMOVE RINGS, WATCHES, LOOSE HANGING JEWELRY AND LOOSE CLOTHING BEFORE BEGINNING TO WORK ON A VEHICLE.**
- **WHEN IT IS NECESSARY TO WORK UNDER THE HOOD, KEEP HANDS AND OTHER OBJECTS CLEAR OF THE COOLING FAN BLADES!**

TOOLS

Commercially available hand tools and equipment are used along with Essential Special Service Tools (ESST) and Rotunda equipment. Power tools have become the acceptable industry standard and are used for disassembly only where applicable, unless specified otherwise in the Workshop Manual. The only exception to this policy is installing wheels in conjunction with the use of torque sticks, when possible.

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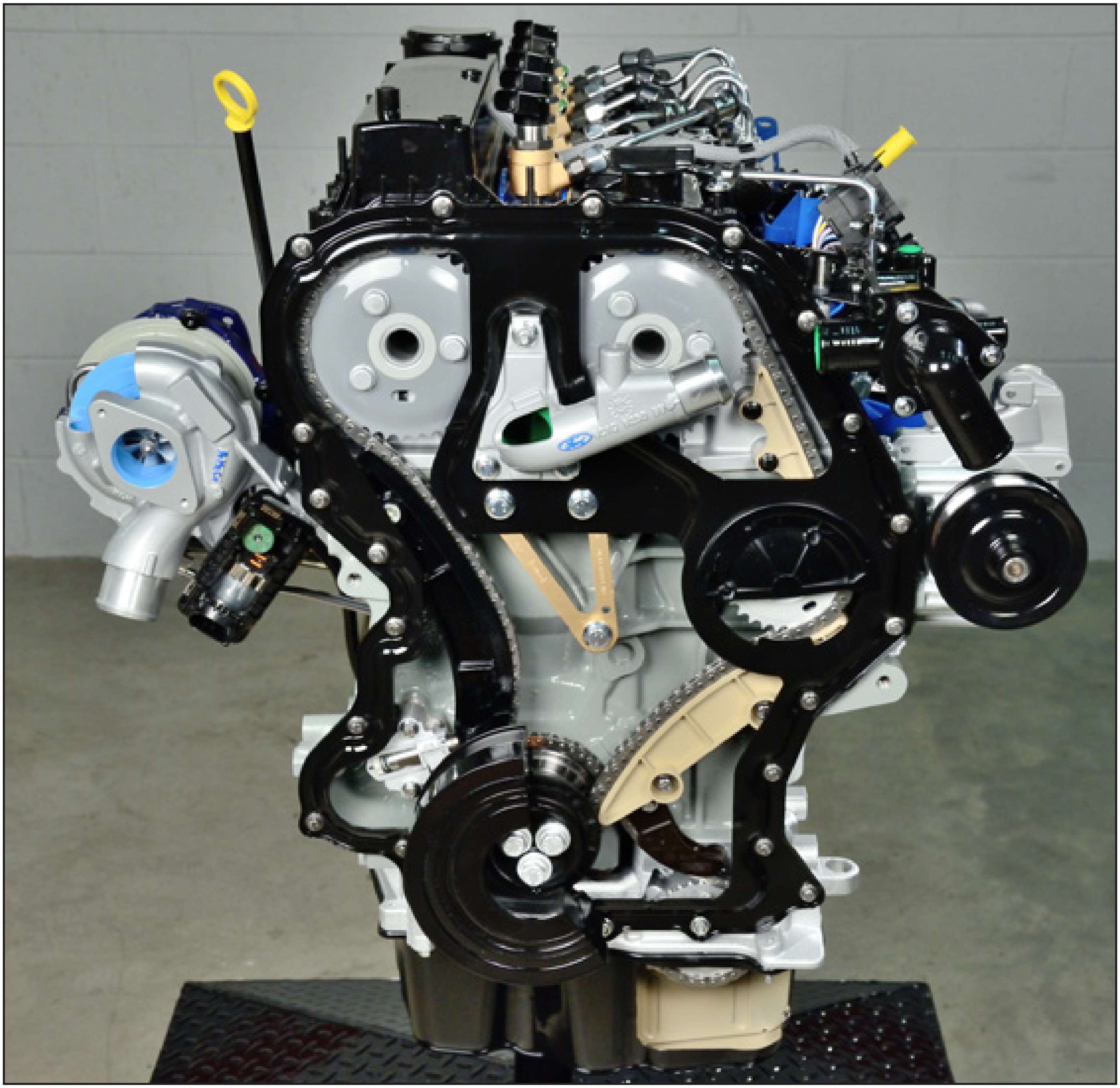
3.2L Power Stroke® Diesel



Direct Injection Turbocharged Diesel Engine

3.2L POWER STROKE® DIESEL OVERVIEW

Engine Features

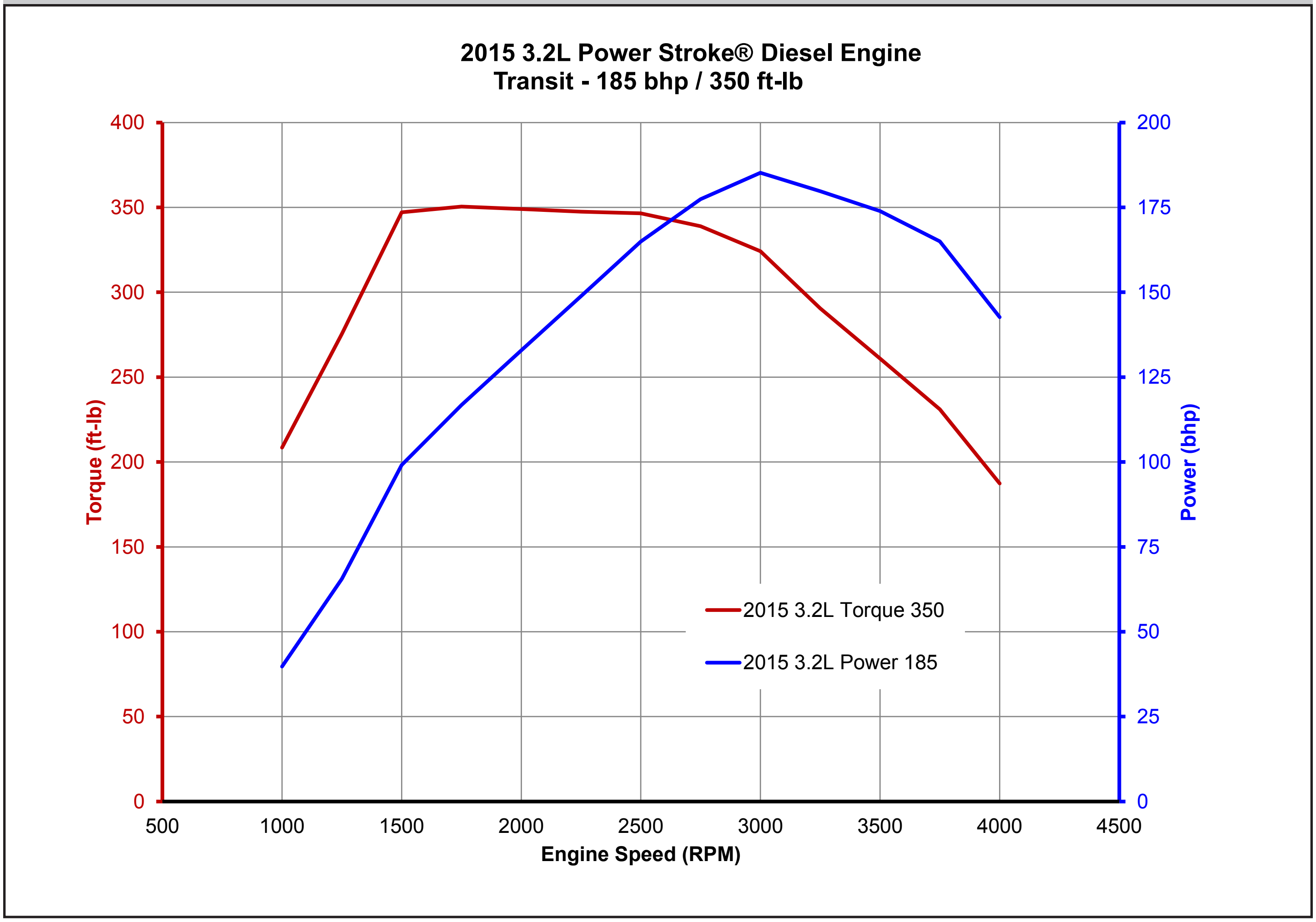
The 3.2L Power Stroke® I-5 diesel engine is an in-line 5 cylinder common rail, turbocharged diesel engine. It is a member of the global puma engine family.

The 3.2L engine has some unique fuel and aftertreatment features. However, aside from the in-line 5 cylinder design, much of the 3.2L engine is similar to other Ford diesel engines.

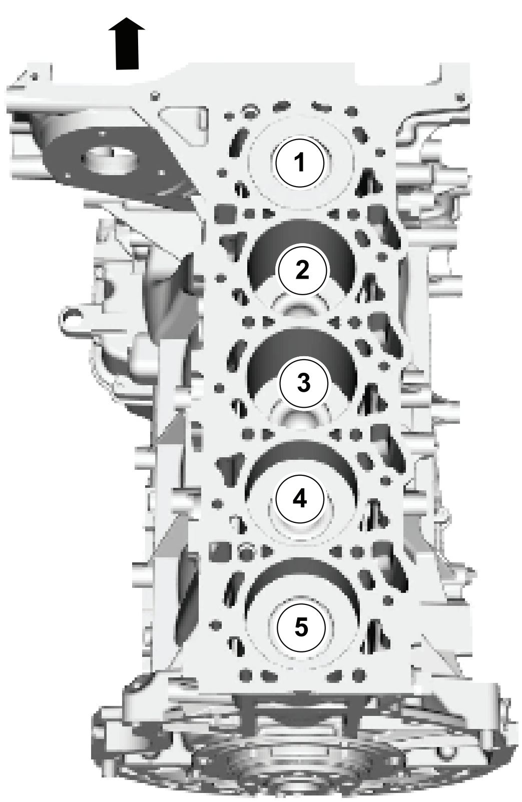
The 3.2L engine performance features include:

- Common rail fuel injection system
- Glow plugs, controlled by the Glow Plug Control Module (GPCM)
- Variable Geometry Turbocharger (VGT)
- A three piston high pressure fuel pump with an Internal Transfer Pump (ITP), similar to the 6.4L diesel
- Aftertreament components including: Single Brick System (SBS), and Selective Catalyst Reduction (SCR) system
- B20 biodiesel capable
- Dual Overhead Camshafts (DOHC), with four valves per cylinder
- Composite intake manifold
- Aluminum cylinder head
- Cast iron in-line 5 cylinder block
- 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, 4 valves per cylinder, and a SCR system.

2014 3.2L Power Stroke® Diesel Horsepower and Torque Ratings



3.2L Power Stroke® Diesel Specifications	
Engine Type	DOHC Common Rail Diesel I-5
Configuration	4 OHV/DOHC In-line 5 Cylinder Diesel
Displacement	3.2L (195 cu. in.)
Bore and Stroke	89.9x100.7 mm (3.54 x 3.96 in)
Compression Ratio	15.8:1
Induction	Variable Geometry Turbocharger
Rated Power @ RPM	185 hp @ 3000 rpm
Peak Torque @ RPM	350ft.-lb. @ 1,500 - 2500 rpm
Engine Rotation, Facing Flywheel	Counterclockwise
Combustion System	High Pressure Common Rail Direct Injection
Total Engine Weight (auto with oil)	233kg (514 lbs)
Cooling System Capacity without Auxiliary Heater	11L (11.6 qts.)
Cooling System Capacity with Auxiliary Heater	12.1L (12.7 qts.)
Lube System Capacity (including filter)	11.4L (12 qts.)
Firing Order	1-2-4-5-3

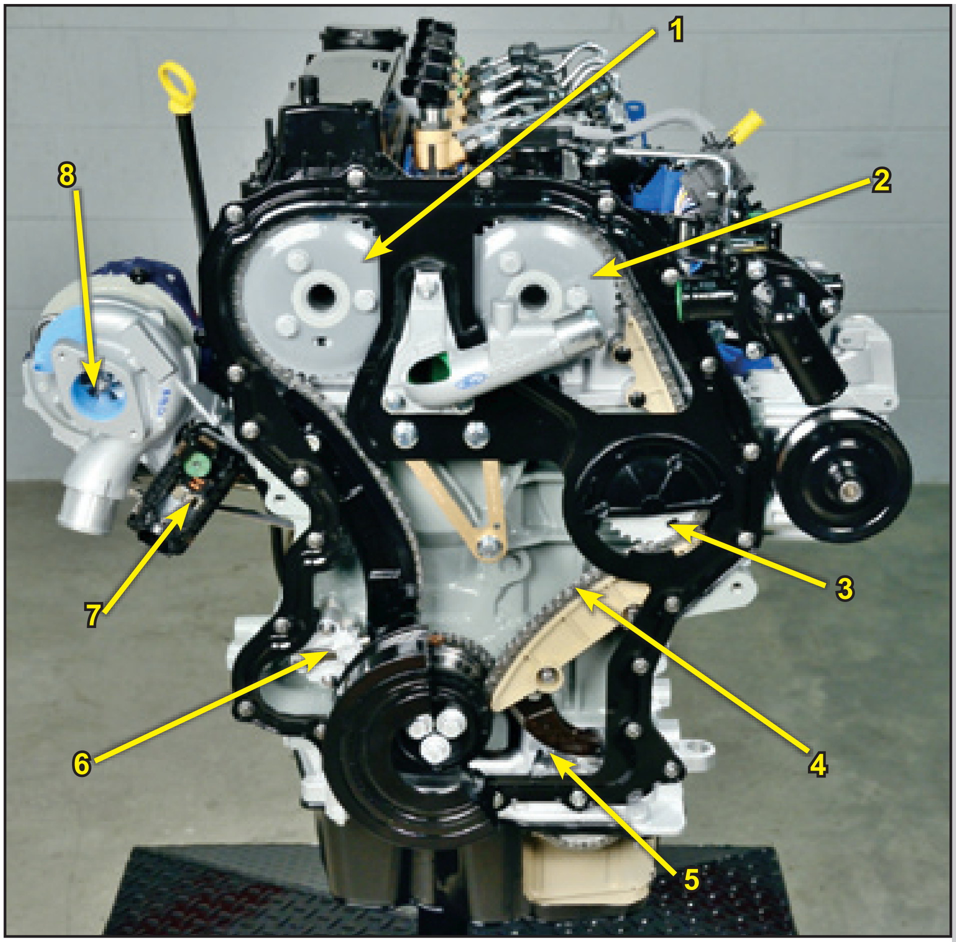


Specifications

The 3.2L Power Stroke® diesel cylinders are numbered from the front, 1, 2, 3, 4, and 5.

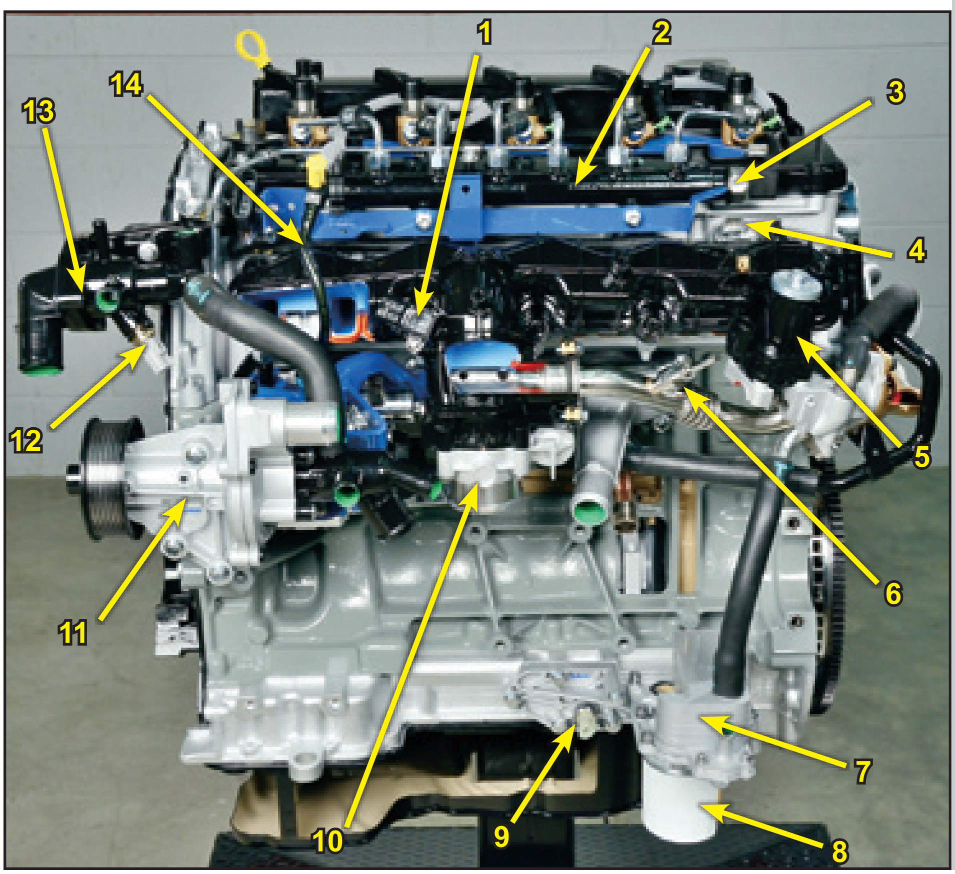
NOTES

COMPONENT LOCATION



Front of Engine

1. Exhaust camshaft
2. Intake camshaft
3. High pressure fuel pump cover
4. Timing chain
5. Oil pump drive chain
6. Timing chain tensioner
7. Variable Geometry Turbocharger (VGT) actuator motor
8. Turbocharger air inlet (from filter)



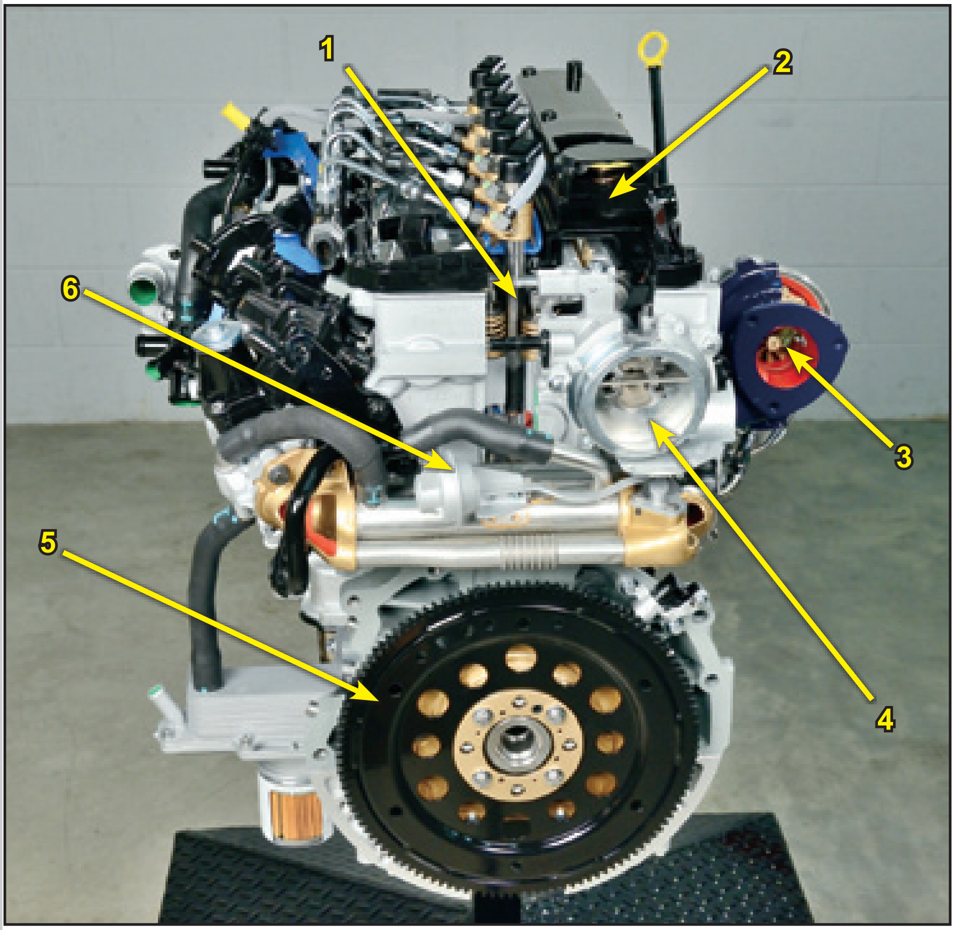
Left of Engine

1. Manifold Absolute Pressure (MAP) sensor
2. Fuel rail
3. Fuel Rail Pressure (FRP) sensor
4. Camshaft Position (CMP) sensor
5. Exhaust Gas Recirculation (EGR) valve
6. Exhaust Gas Recirculation Temperature (EGRT) Bank 1 Sensor 2
7. Oil cooler
8. Oil filter
9. Oil pressure sensor
10. Intake throttle body
11. Coolant pump
12. Engine Coolant Temperature (ECT) sensor
13. Thermostat housing
14. Fuel return line

COMPONENT LOCATIONS

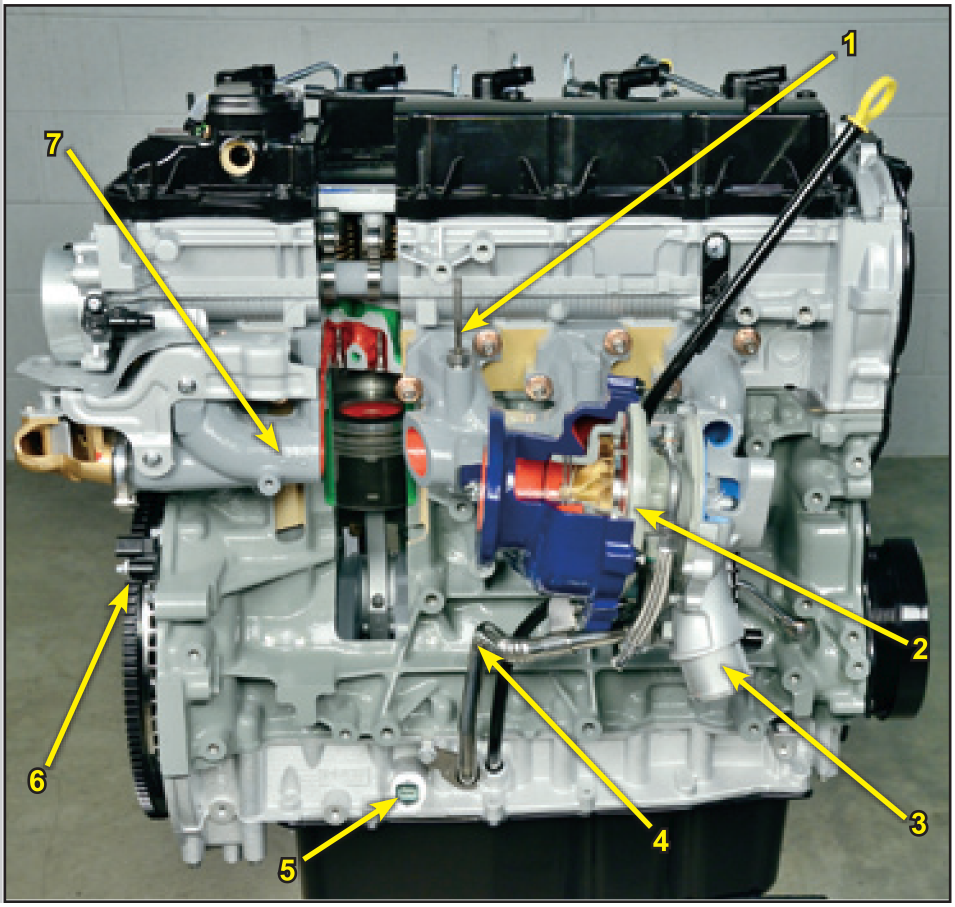
Rear of Engine

1. Fuel injector
2. Crankcase vent oil separator
3. Turbocharger turbine outlet
4. Vacuum pump
5. Flywheel
6. EGR cooler bypass vacuum motor

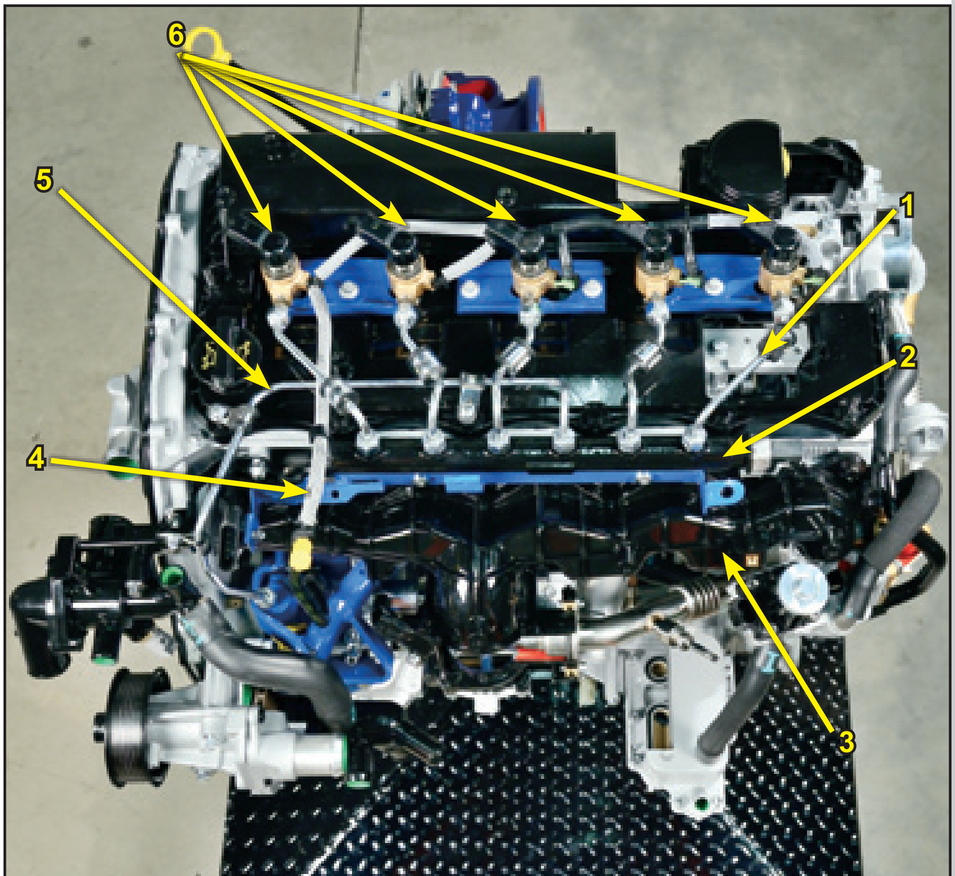


Right of Engine

1. Exhaust Gas Recirculation Temperature (EGRT) Bank 1 Sensor 1
2. Turbocharger
3. Turbocharger air outlet (to Charge Air Cooler [CAC])
4. Turbocharger oil drain line
5. Engine oil level and temperature sensor
6. Crankshaft Position (CKP) sensor
7. Exhaust manifold



COMPONENT LOCATIONS



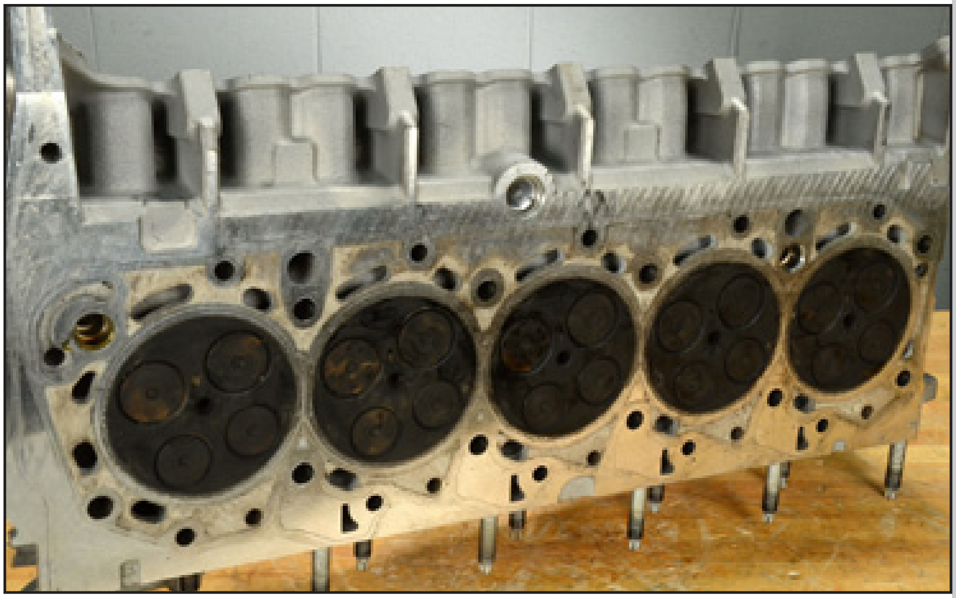
Left Top of Engine

1. High pressure fuel line
2. High pressure fuel rail
3. Intake manifold
4. Fuel Injector return line
5. High pressure fuel supply line to the fuel rail
6. Fuel Injectors

NOTES

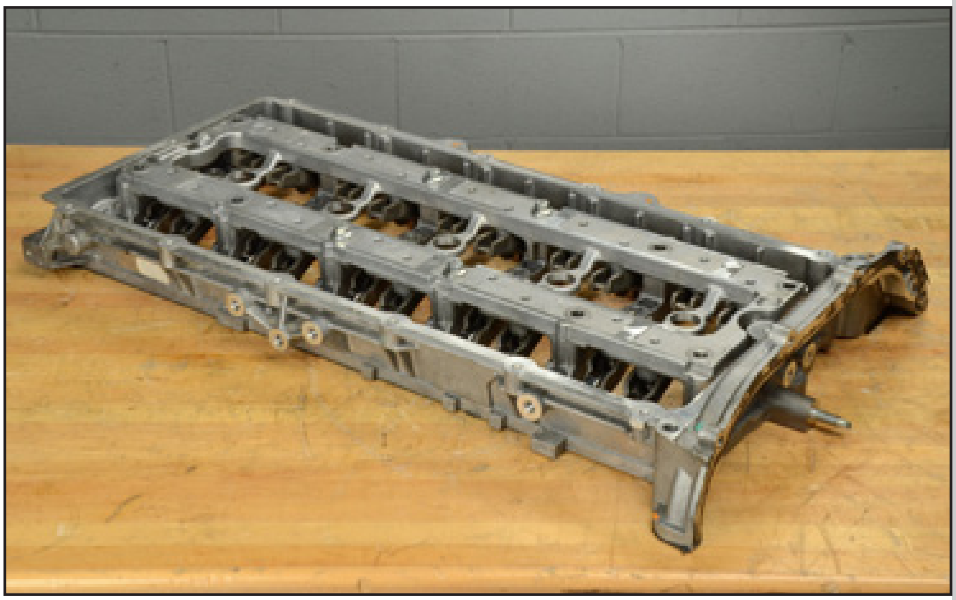
NOTES

UPPER ENGINE COMPONENTS



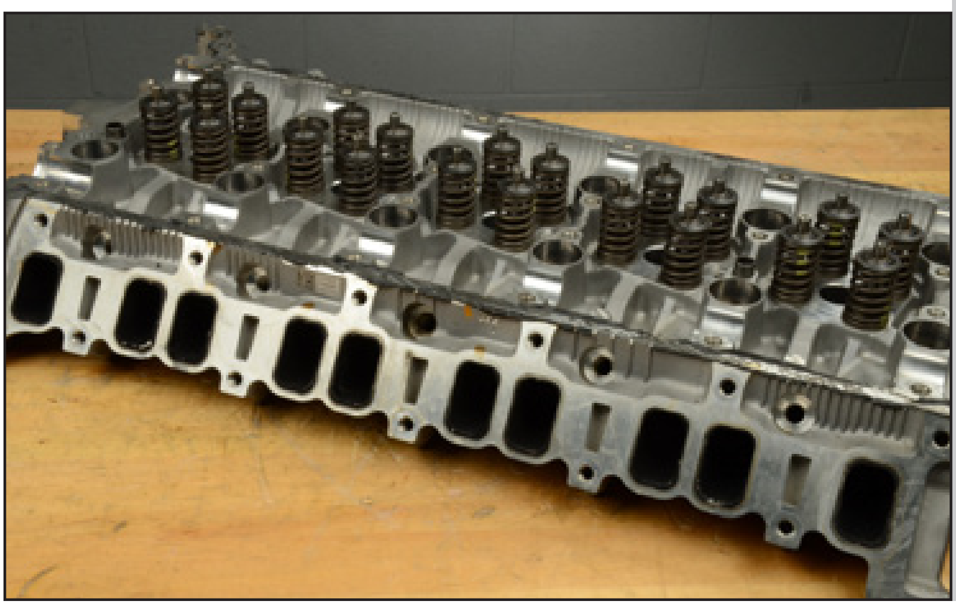
Cylinder Head

- Consists of two parts bolted to each other, the upper and lower cylinder head.
- Both parts are made of aluminum.
- The lower part contains four valves for each combustion chamber and the two camshafts.
- The upper part or cam carrier houses the rocker arm frame with the roller rocker arms.
- The hydraulic valve clearance adjustment is integrated in the roller rocker arms.



Upper Cylinder Head

The upper cylinder head secures the camshafts.



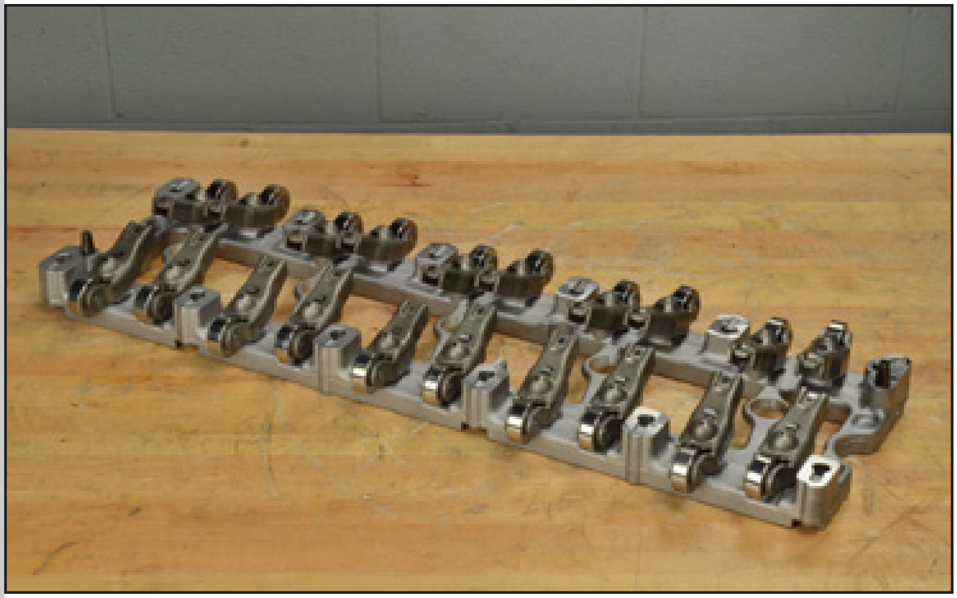
Lower Cylinder Head

The lower cylinder head houses all the valves for each of the 5 cylinders.

UPPER ENGINE COMPONENTS

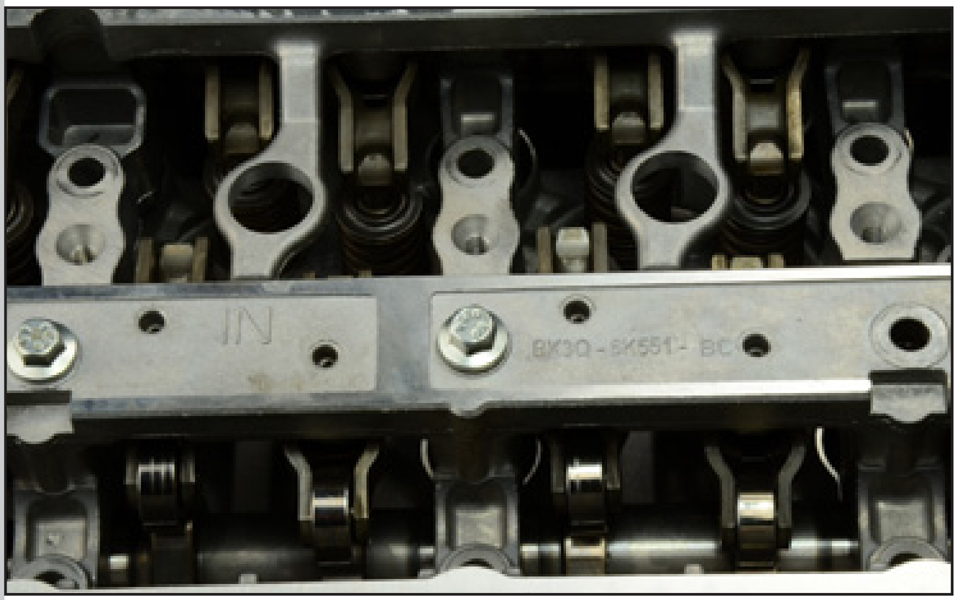
Valve Rocker Arm Housing

All the rocker arms are attached to the valve rocker arm housing.



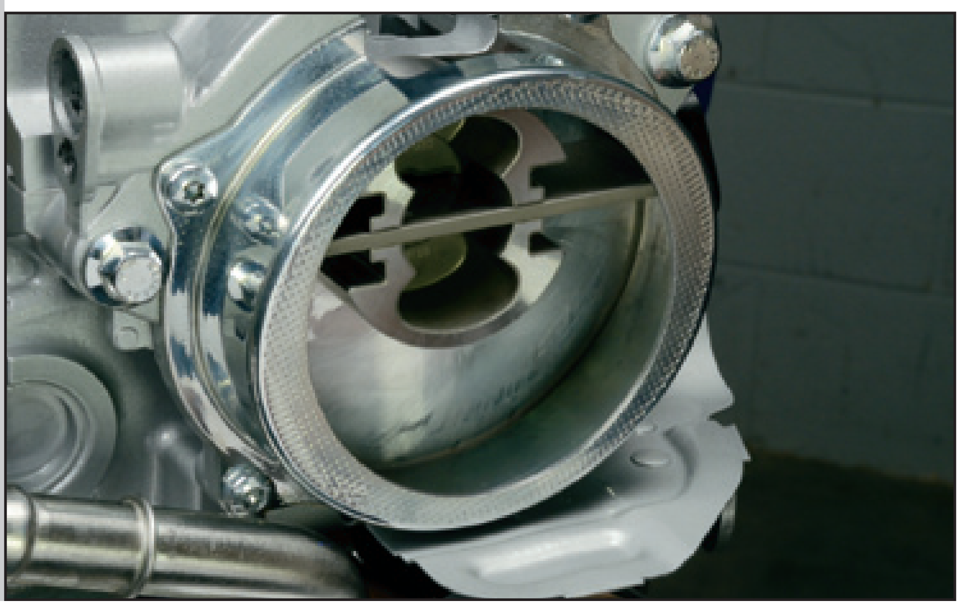
Rocker Arms

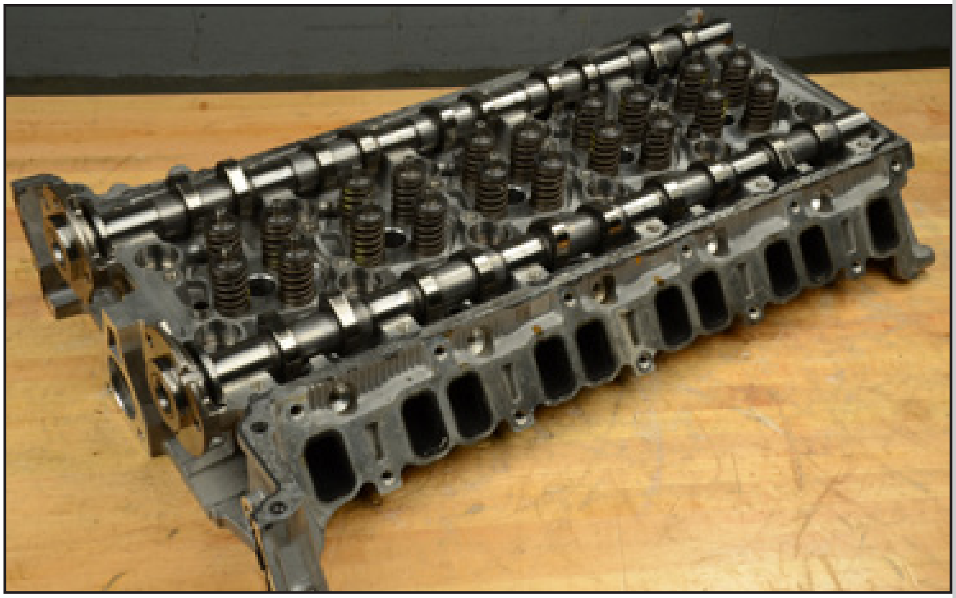
Use the lift of the camshaft lobes to open the intake and exhaust valves.



Vacuum Pump

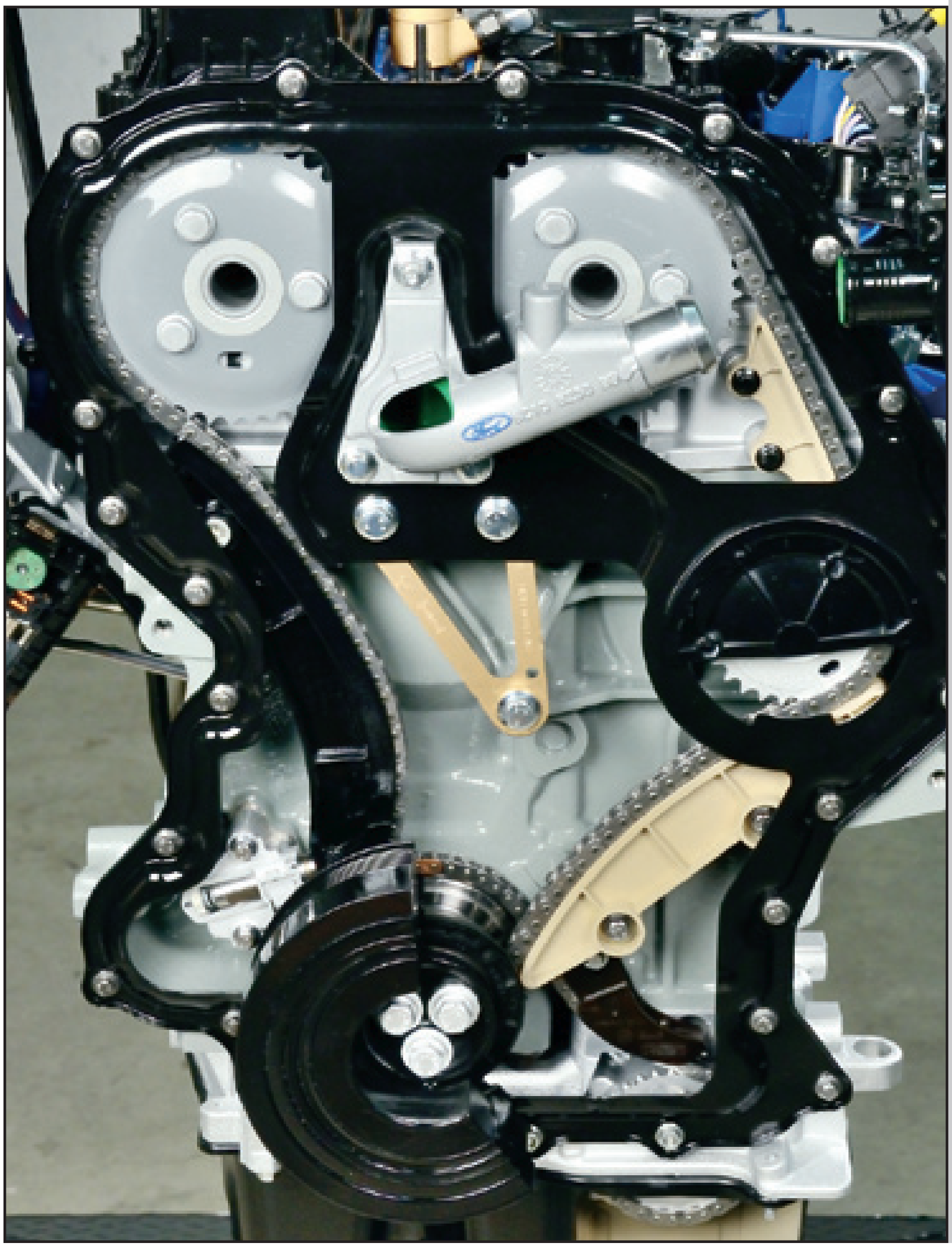
The vacuum pump is located on the rear of the cylinder head and is driven by the exhaust camshaft. Vacuum is used for the EGR cooler bypass and the braking system.





Camshafts

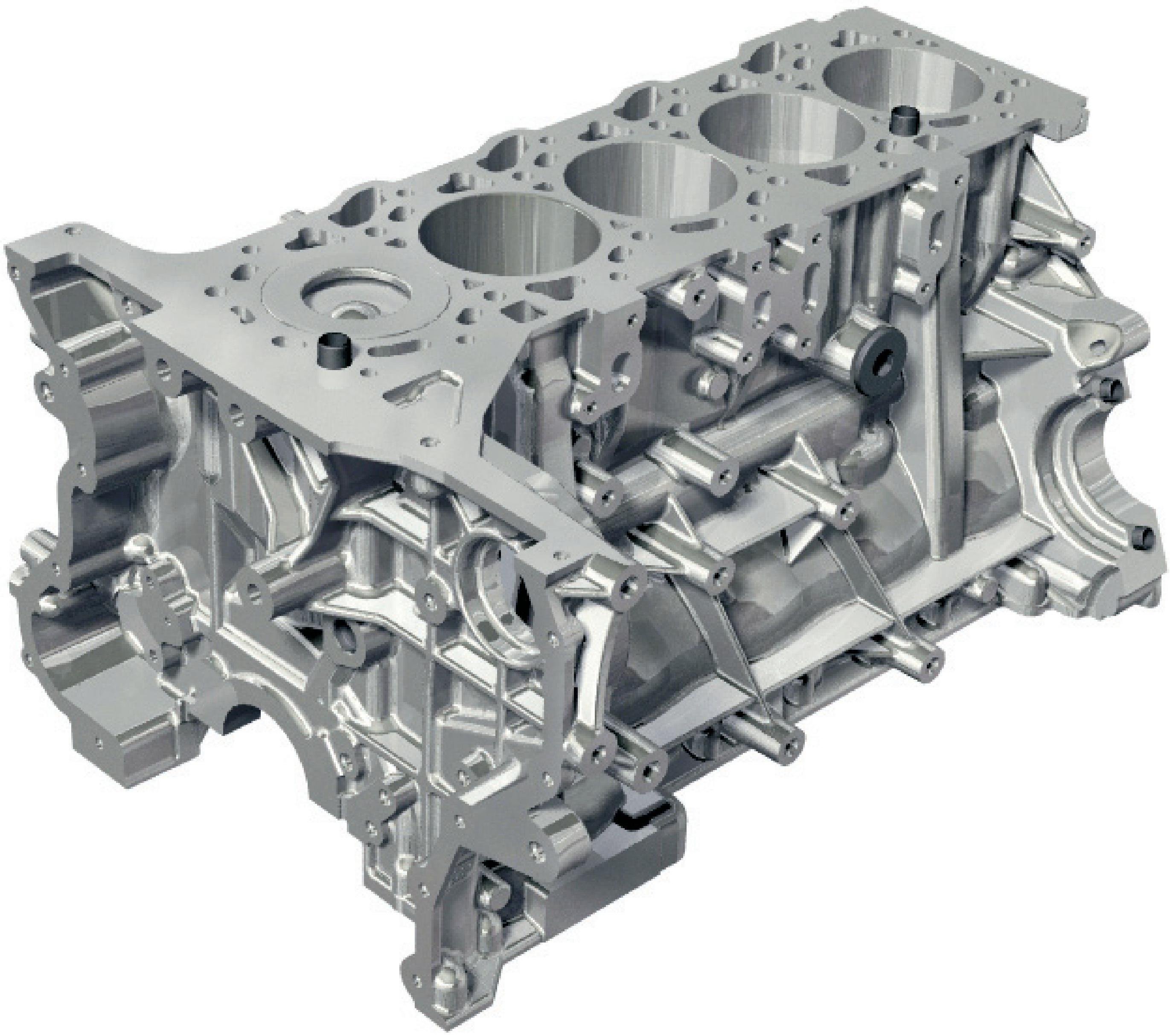
There are two camshafts, one for the intake valves and another for the exhaust valves.



Timing Chain

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

See the Workshop Manual for the specific procedure for timing the crankshaft to the camshafts.



Engine Block

The 3.2L engine uses an iron in-line 5 cylinder block. Some features include:

- 2 bolt main bearing caps
- Ladder frame to increase rigidity and reduce vibration
- Piston cooling jets

Crankshaft

- The 3.2L engine uses a cast crankshaft. The crankshaft is held in place by 2 bolt main bearing caps. To add strength, the main bearing caps have a ladderframe bolted to the bottom of the block.
- The crankshaft sprocket is bolted to the front of the crankshaft. Between the crankshaft and sprocket is a washer coated with diamond dust. The diamond washer acts as a key way and locks the sprocket into the front of the crankshaft.

Pistons

The 3.2L pistons are cooled using a jet bolted into the block to spray oil onto the bottom of the piston.

Connecting Rods

The connecting rod is a fractured cap design.

The 3.2L uses three different length connecting rods and three different head gasket thicknesses. When assembling the engine there is a procedure for calculating the correct rod length and head gasket thickness.

Rear Crankshaft Seal

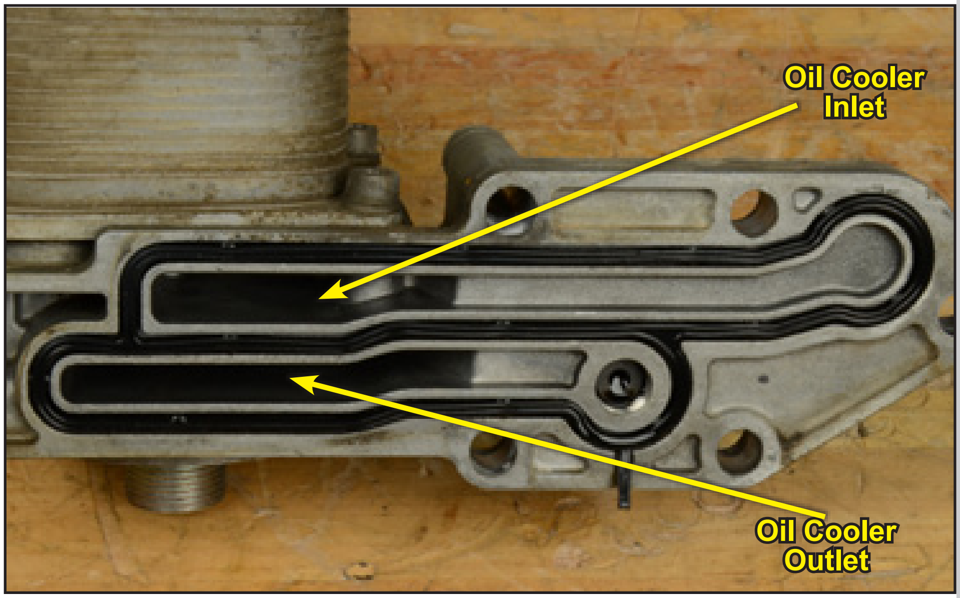
The rear crankshaft seal bolts to the engine block and the ladderframe.

Front Crankshaft Seal

The front crankshaft seal is installed using special service tool 303-679A.

Oil Cooler

The oil cooler is mounted to the ladderframe.



Oil Cooler Passages

The oil cooler receives the oil from the ladderframe. The oil enters the oil cooler and filter adapter from the top opening and exits from the bottom opening.

Ladderframe

The ladderframe is a structural member of the powertrain assembly and contains the lower part of the 6R80 transmission bolt circle. The ladderframe requires an alignment procedure.

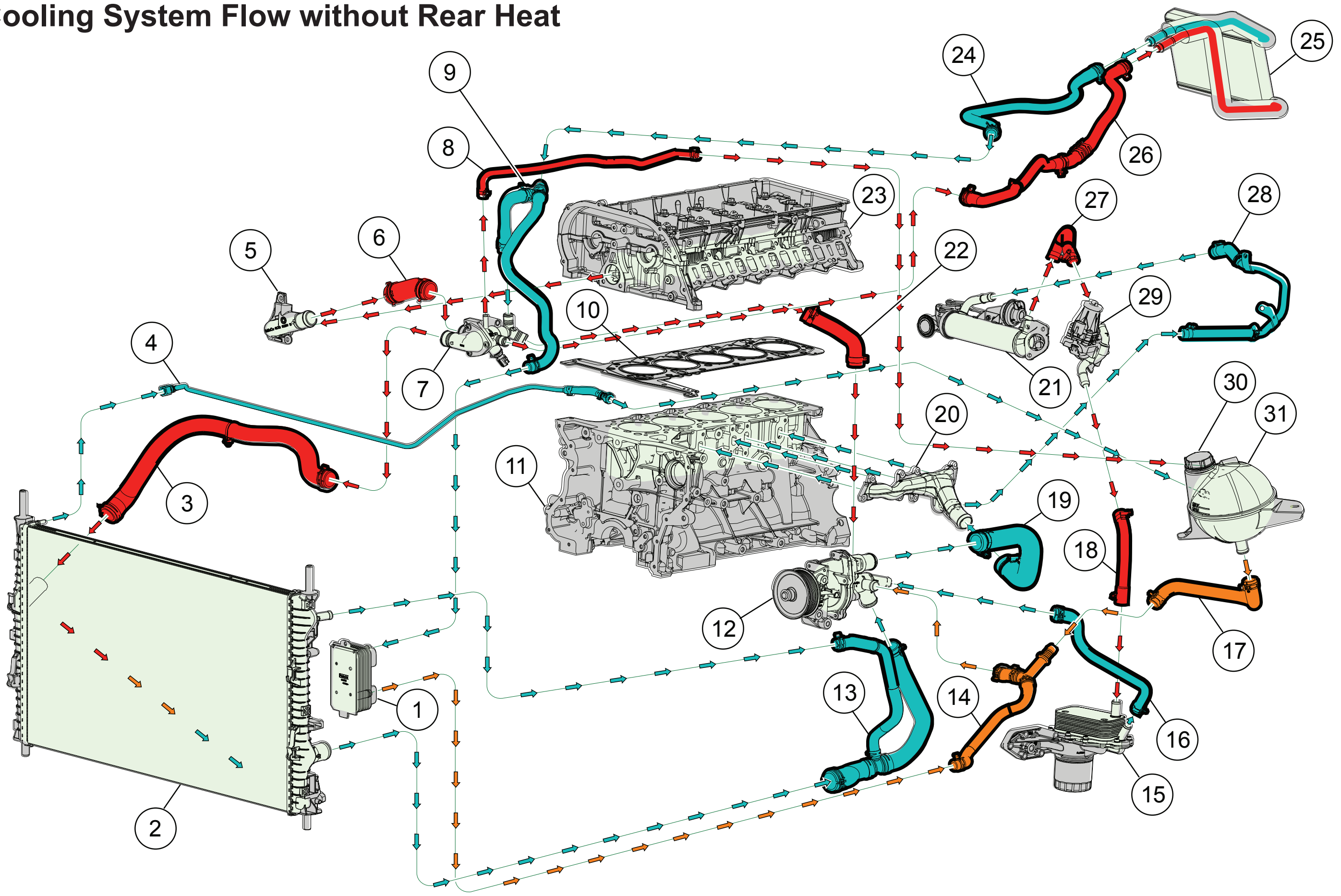
NOTES

COOLING SYSTEM

The cooling system includes the following:

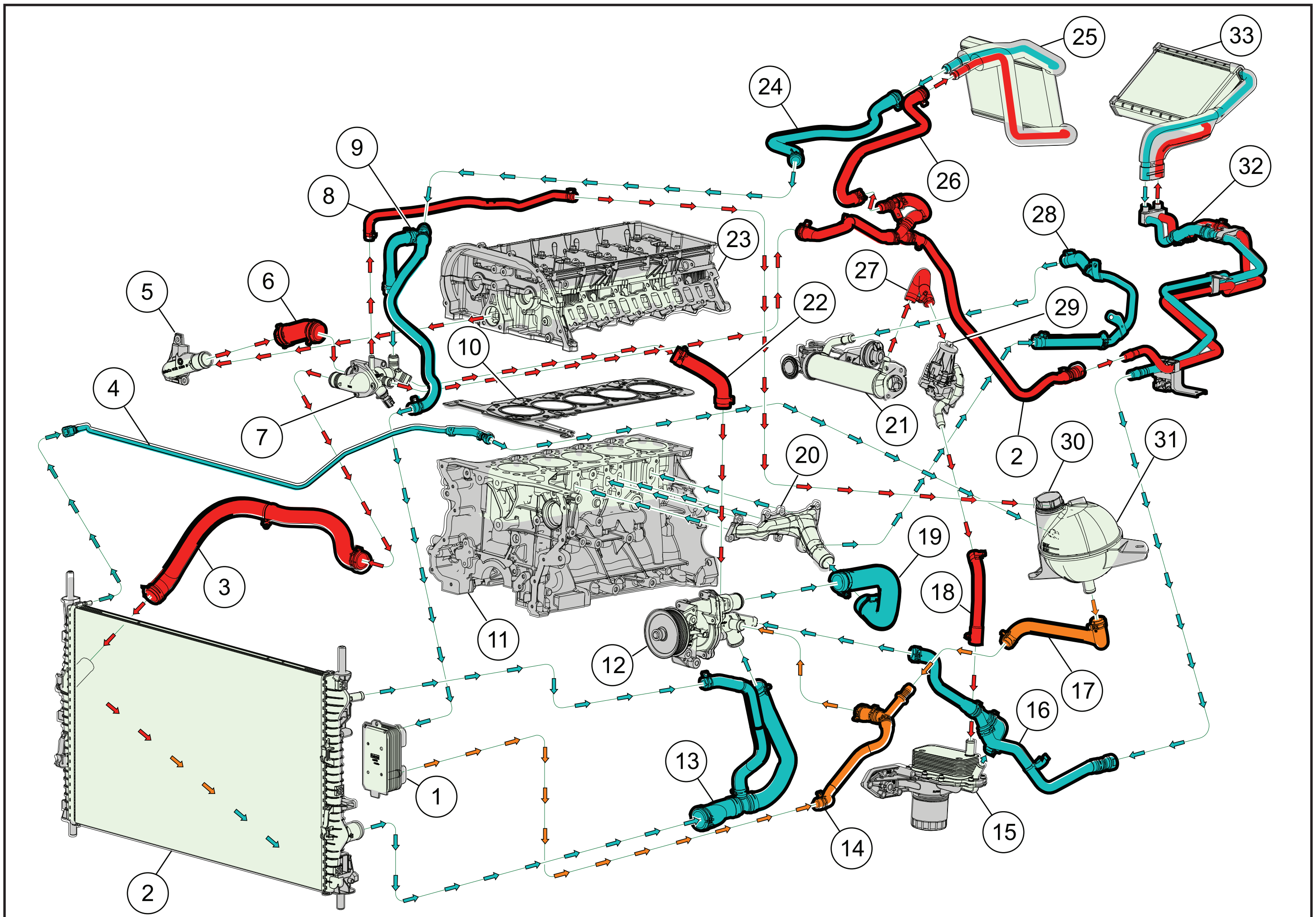
- Radiator
- Coolant pump
- Engine driven fan assembly
- Degas bottle
- Coolant thermostat
- Coolant hoses
- Engine oil cooler
- Exhaust Gas Recirculation (EGR) cooler

Cooling System Flow without Rear Heat



Number	Component	Number	Component
1	Transmission oil cooler	17	Engine coolant reservoir hose
2	Radiator	18	Engine oil cooler hose
3	Upper radiator hose	19	Coolant pump outlet to coolant manifold hose
4	Radiator air aspirator hose	20	Coolant manifold
5	Cylinder head outlet connection	21	EGR cooler
6	Coolant outlet hose	22	Coolant bypass hose
7	Thermostat housing	23	Cylinder head
8	Air aspirator hose	24	Heater outlet hose
9	Transmission oil cooler inlet hose	25	Heater core
10	Cylinder head gasket	26	Heater inlet hose
11	Cylinder block	27	EGR cooler outlet hose
12	Coolant pump	28	EGR cooler inlet hose
13	Lower radiator hose	29	EGR valve
14	Transmission oil cooler outlet hose	30	Pressure relief cap
15	Oil filter adapter and cooler	31	Degas bottle
16	Coolant outlet hose		

Cooling System Flow with Rear Heat



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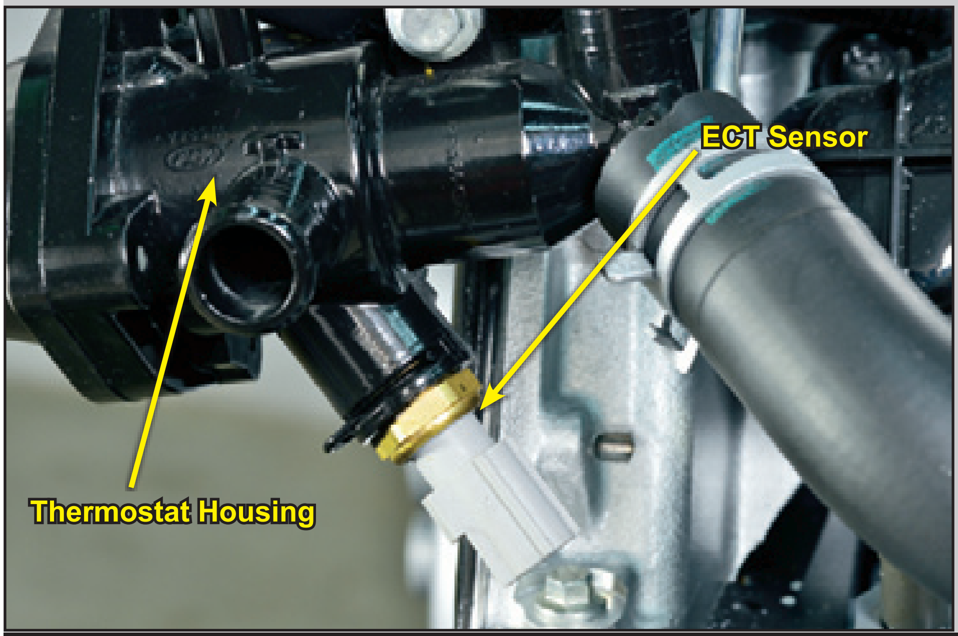
11	Cylinder block	28	EGR cooler inlet hose
12	Coolant pump	29	EGR valve
13	Lower radiator hose	30	Pressure relief cap
14	Transmission oil cooler outlet hose	31	Degas bottle
15	Oil filter adapter and cooler	32	Rear heater tube assembly
16	Coolant outlet hose	33	Rear heater core
17	Engine coolant reservoir hose		

Cooling System Flow

- The cooling system cools the following components:
  - Engine block
  - Cylinder heads
  - Engine oil cooler
  - Transmission cooler
  - EGR cooler
- Engine coolant flows primarily from the engine to the radiator circuit and back to the coolant pump. Coolant is sent from the coolant pump through the engine block and cylinder head. A coolant circuit from the engine feeds the EGR cooler and oil cooler with coolant. Another coolant circuit from the thermostat housing feeds the heater core and transmission oil cooler with coolant. The coolant pump is driven by the Front End Accessory Drive (FEAD) belt, circulating the coolant. The coolant thermostat is a control valve actuated by coolant temperature. When the thermostat is closed, coolant flow bypasses the radiator circuit and returns to the coolant pump. When the thermostat is opened, coolant flows through the radiator circuit to transfer engine-generated heat to the outside air.
- This vehicle is equipped with a mechanical engine driven cooling fan.
- The degas bottle holds surplus coolant and removes air from the cooling system. It also allows for coolant expansion and system pressurization, replenishes coolant to the cooling system and serves as the location for service fill.



Thermostat

The thermostat is located in the thermostat housing above the coolant pump. The thermostat regulates the engine coolant temperature by controlling the flow of coolant through the radiator.

Engine Coolant Temperature (ECT) Sensor

The ECT sensor is located on the bottom of the thermostat housing.

NOTES

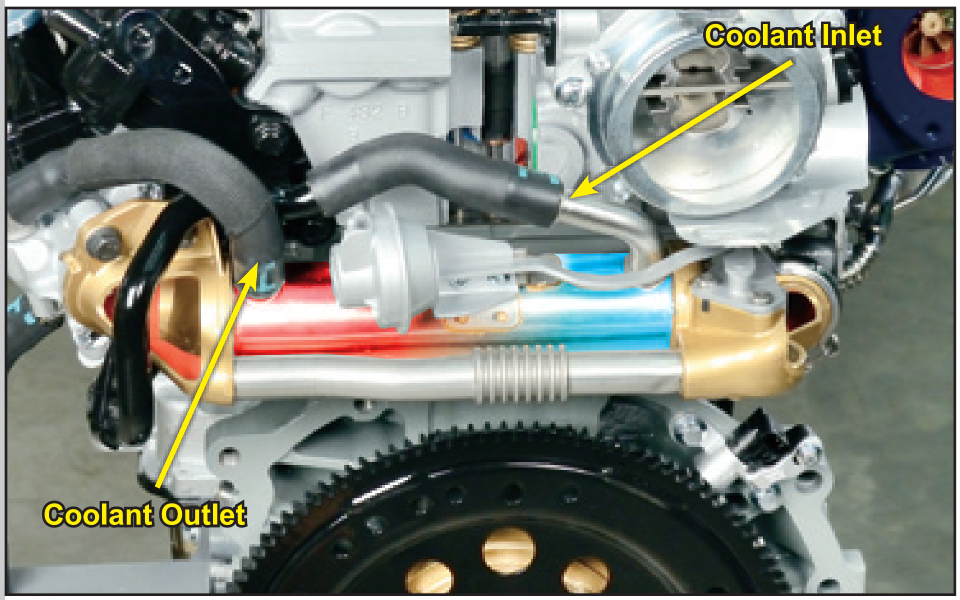
Engine Oil Cooler

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 Coolant Flow

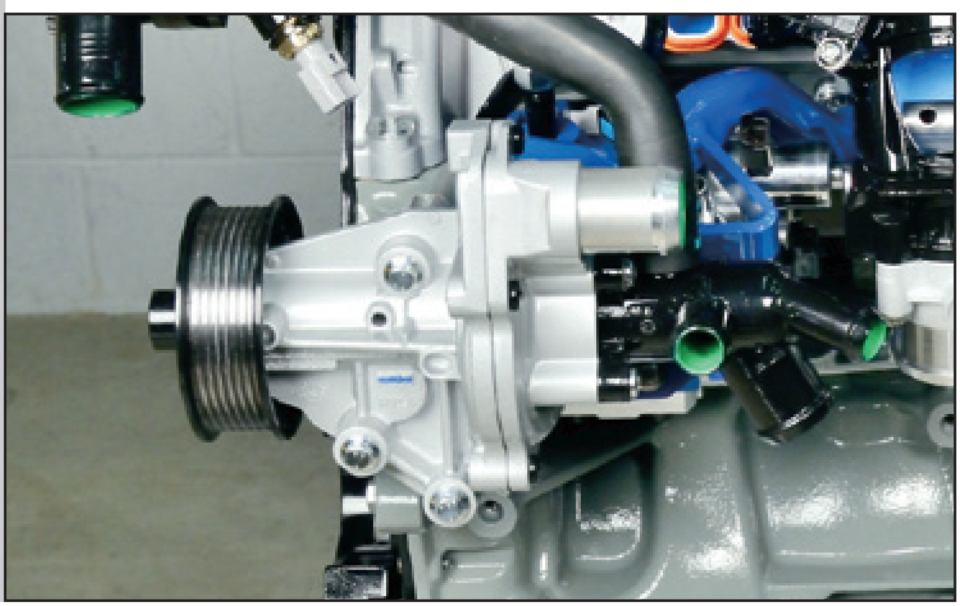
The EGR gases are cooled by engine coolant.

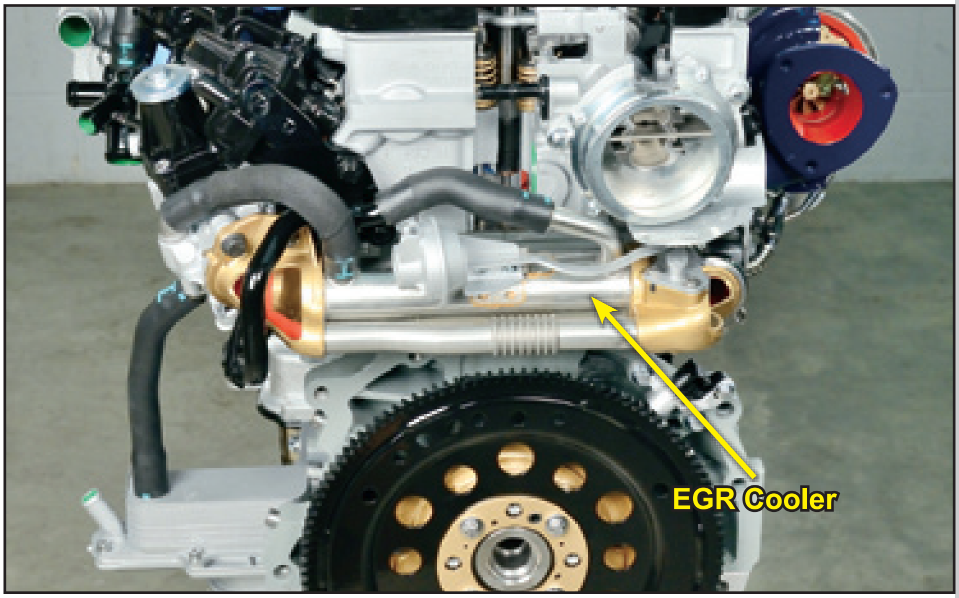
The coolant flows from the passenger side to driver side of the vehicle.



Coolant Pump

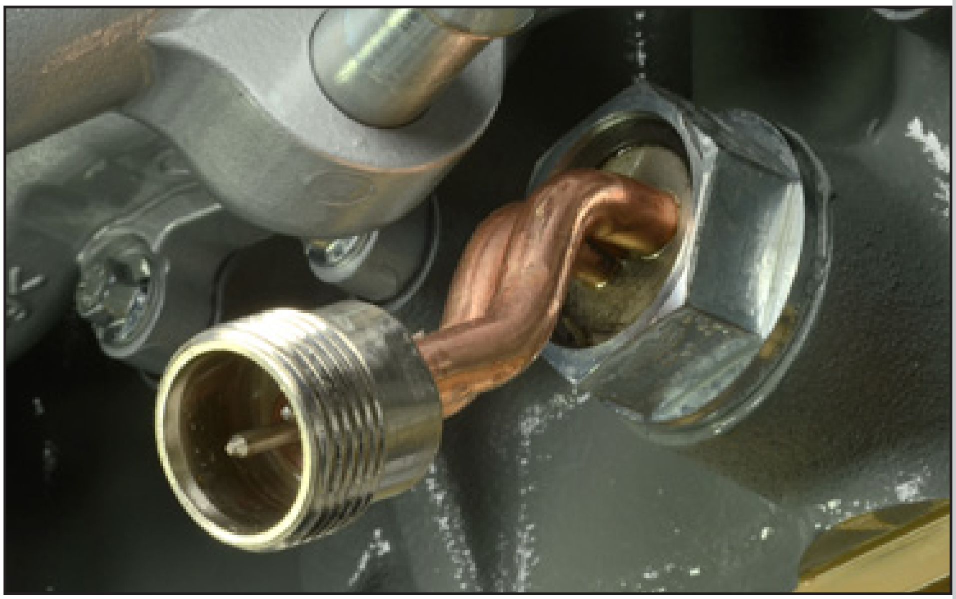
The coolant pump circulates the coolant through the engine.





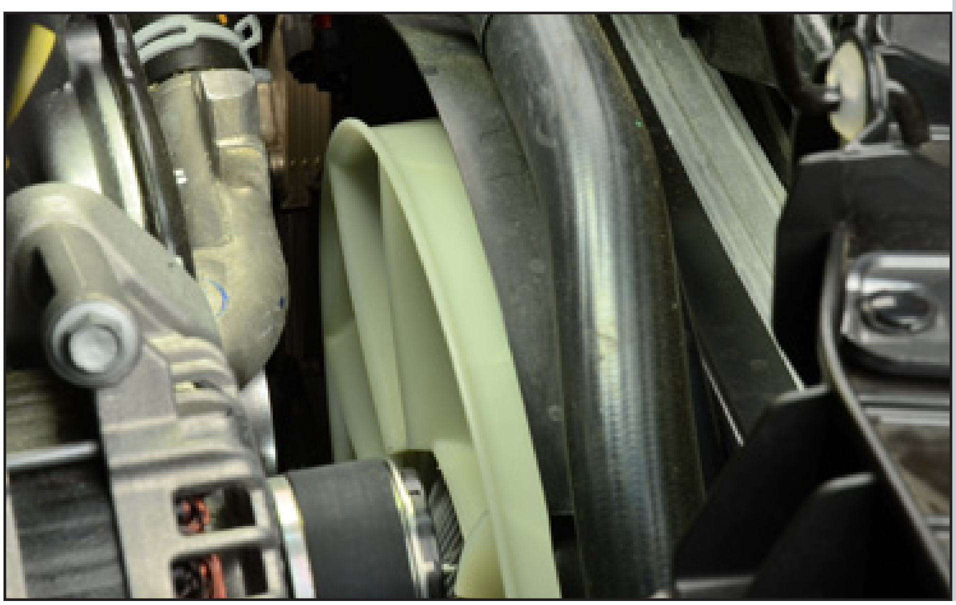
EGR Cooler

The EGR cooler removes heat from the exhaust gases before they enter the intake manifold. The EGR cooler is located at the back of the engine. When the exhaust gases are directed through the EGR cooler, engine coolant reduces the temperature of the gases. The exhaust gases are directed through the EGR cooler by a PCM-controlled EGR cooler bypass valve solenoid that provides or vents vacuum to the EGR cooler bypass valve actuator.



Engine Block Heater (if equipped

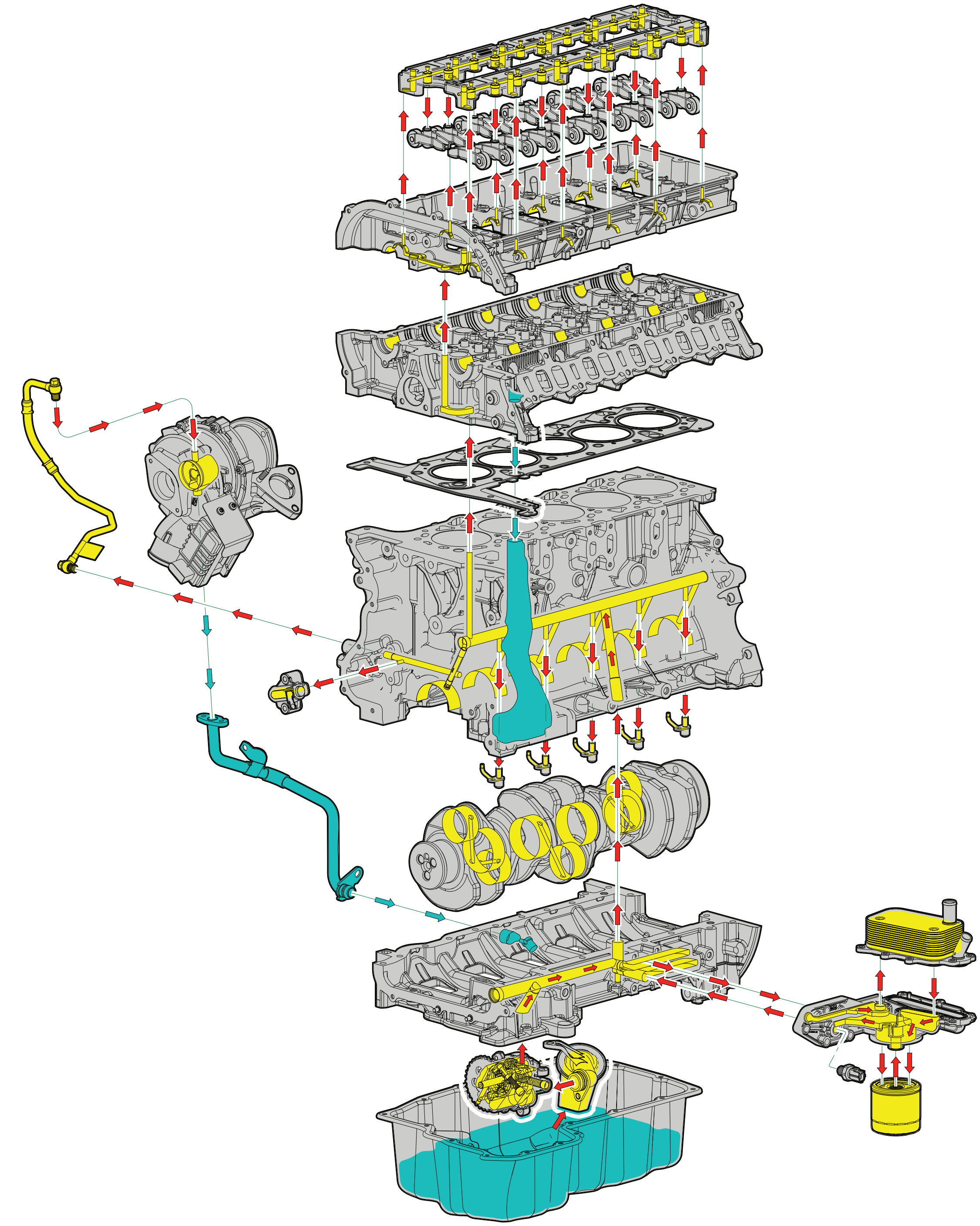
The engine block heater uses 110V AC to heat the engine coolant in cold weather climates. Use the engine block heater whenever ambient temperatures are at or below -23°C (-9°F).



Engine Cooling Fan

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).

NOTES



Lubrication System Oil Flow

- Oil is drawn from the oil pan through the pickup tube. It is then routed through a passage cast into the ladderframe and then to the oil pump inlet.
- From the oil pump, oil is directed to the ladderframe. The ladderframe oil galley feeds oil to the cooler and oil filter housing, the main oil galley in the engine block and the oil pump.
- The main oil galley in the engine block feeds:
  - Main bearings/rod bearings
  - Turbocharger
  - Piston cooling jets
  - Timing chain tensioner
  - Cylinder head
- The oil gallery in the lower cylinder head is a pass-through passage. The oil passes through to the upper cylinder head.
- The upper cylinder head provides oil to the camshaft bearing surfaces and the valve rocker arm housing.
- The valve train carrier provides oil to the rocker assemblies and hydraulic lifters.

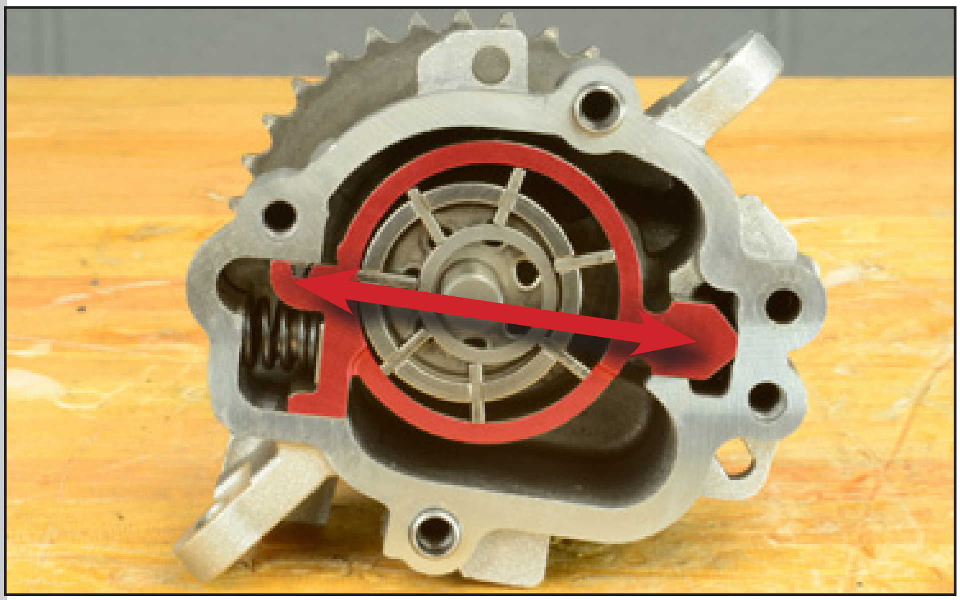
Lubrication System Components

Oil Pump

The 3.2L engine uses a variable displacement oil pump. A conventional oil pump has a linear output of pressure based on engine RPM. The oil pump in the 3.2L has a feedback line that takes oil pressure from the ladderframe and feeds it back to the variable displacement portion of the pump. At idle the oil pressure is about 15 psi, as the RPM increases to 2000 the oil pressure will also linearly increase to 44 psi. The oil pressure stays at 44 psi for any additional RPM increase above 2000 RPM.

Oil Pressure Regulator

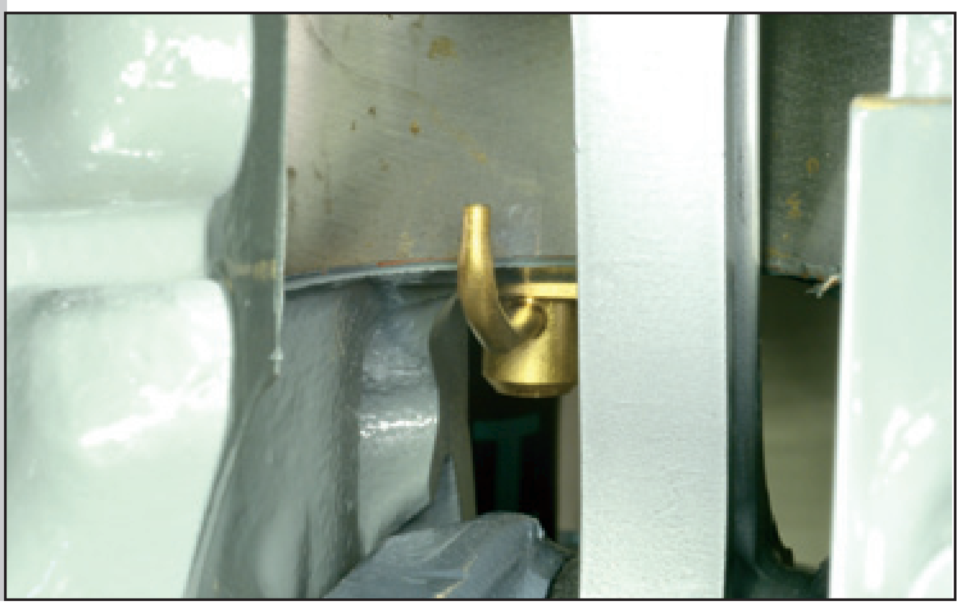
Depending on the oil pressure from the ladderframe and the oil pump RPM. The red highlighted part of the oil pump moves back and forth to change the oil pump displacement.



Piston Cooling Jets

To cool the top of the piston, the 3.2L engine uses piston cooling jets to spray oil into a hole in the bottom of the piston.

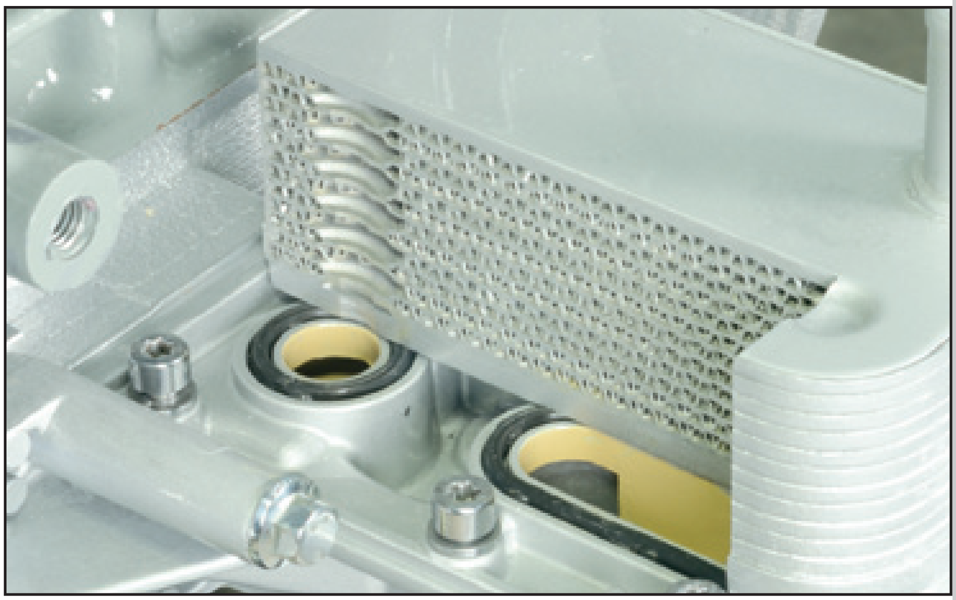
The oil jets bolt into the bottom of the engine block and direct the oil into the piston.



Engine Oil Level and Temperature Sensor

The 3.2L engine is equipped with a engine oil level and temperature sensor.

The sensor has 2 parts, a wire used by the PCM to cycle current through to determine oil level and a temperature sensor. Currently only the temperature sensor is being used for vehicles sold in North America.



Oil Cooler

The oil cooler is mounted on the left side of the ladderframe 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 the oil has been cooled, it exits the oil cooler and travels through the adapter to the oil filter.

Oil Filter Adapter

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

NOTES

AIR MANAGEMENT SYSTEM

Intake Side

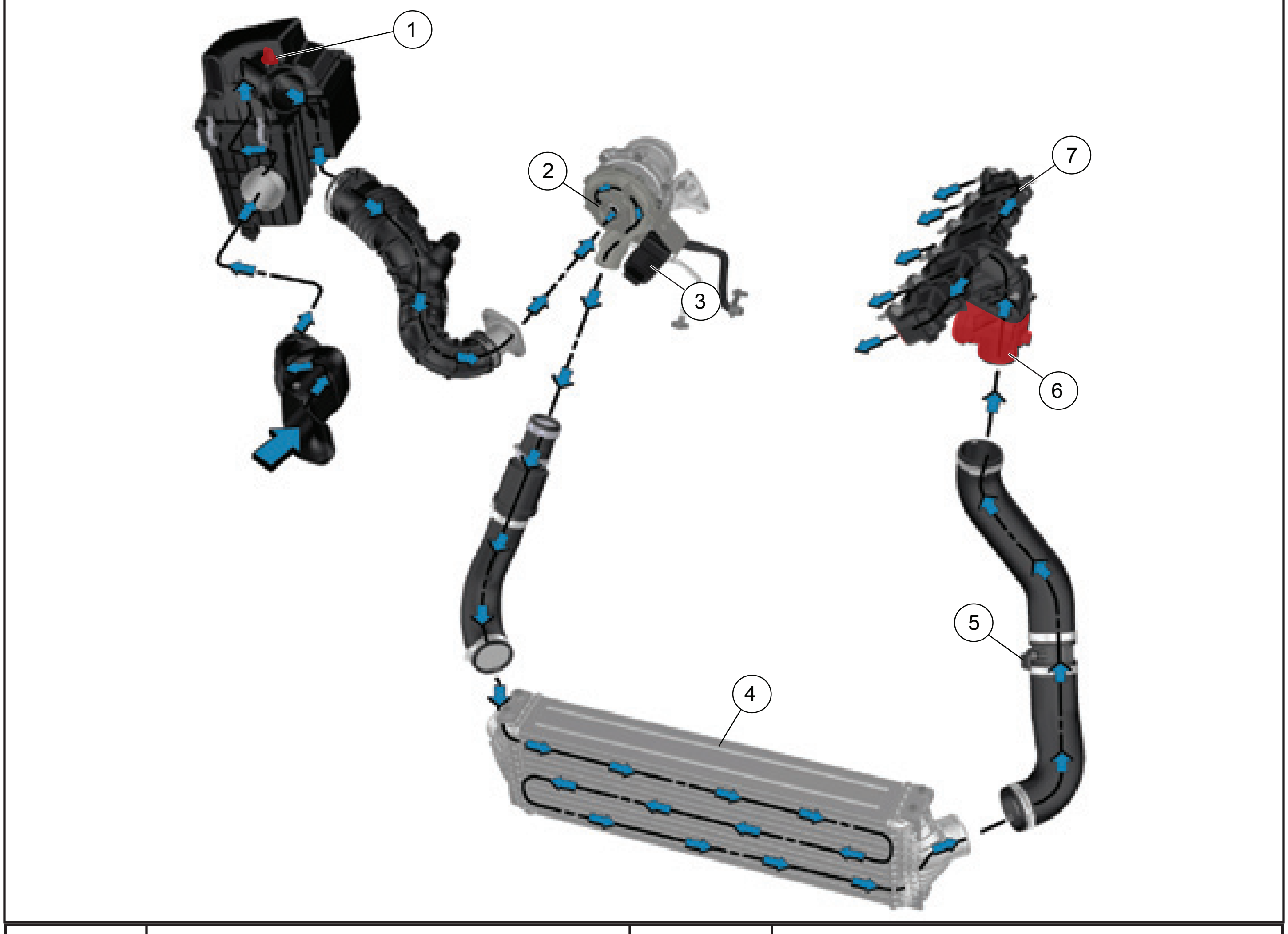
Air is drawn through the air filter, past the Mass Air Flow and Temperature (MAFT) sensor. The MAFT sensor measures the mass and temperature of the air entering the engine. Next, the air enters the compressor side of the turbocharger. The air is compressed above atmospheric pressure, causing the air to heat up. The hot, pressurized air is routed through an air-to-air Charge Air Cooler (CAC) which cools the air charge, increasing power capability of the engine. From the CAC the air passes the Charge Air Cooler Temperature (CACT) sensor, through the intake throttle body and into the intake manifold. Inside the intake manifold the air mixes with Exhaust Gas Recirculation (EGR) gases (if the EGR valve is open), and travels to the cylinder head.

Exhaust Side

Exhaust gases exit the exhaust ports and go through the exhaust manifold. The gasses enter either the turbine side of the turbo or the EGR cooler.

Gases that go to the turbine side of the turbo spin the turbine wheel inside. The turbine wheel is connected to the compressor wheel through their common shaft. Exhaust exits the turbine housing and enters the Single Brick System (SBS). From the SBS the exhaust flows through the SCR then muffler and out the tail pipe.

Gasses going to the EGR cooler will either be directed around (bypass) or through the EGR cooler then directed to the EGR valve. When the EGR valve is operating gases flow from it to the intake manifold where the exhaust gases are combined with fresh air.



Number	Component	Number	Component
1	Mass Air Flow and Temperature (MAFT) sensor	5	Charge Air Cooler Temperature (CACT) sensor
2	Turbocharger	6	Intake throttle body
3	Variable Geometry Turbocharger (VGT) actuator	7	Intake manifold
4	Charge Air Cooler (CAC)		

Air Inlet Components

Air Filter

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

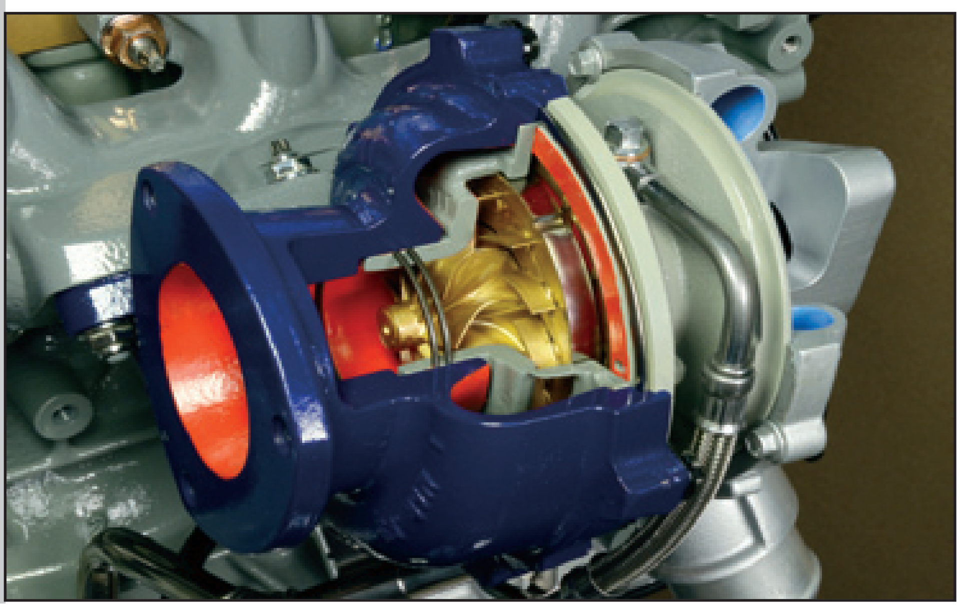
Mass Air Flow and Temperature (MAFT) Sensor

The air intake system includes MAFT sensor. The MAFT sensor is located in the air inlet tube after the air filter.

The MAFT is a mass air flow sensor and air temperature sensor combined.

Turbocharger

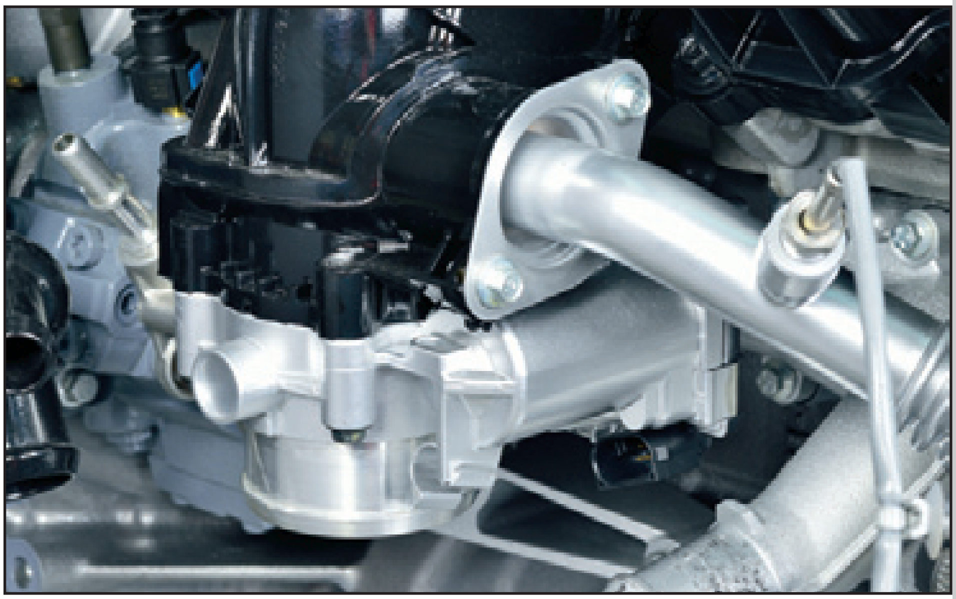
The 3.2L uses a Variable Geometry Turbocharger (VGT) operated with a PCM-controlled electric actuator. The turbocharger does not incorporate a wastegate.



Charge Air Cooler (CAC)

The CAC is located in front of the radiator and below the A/C condenser.

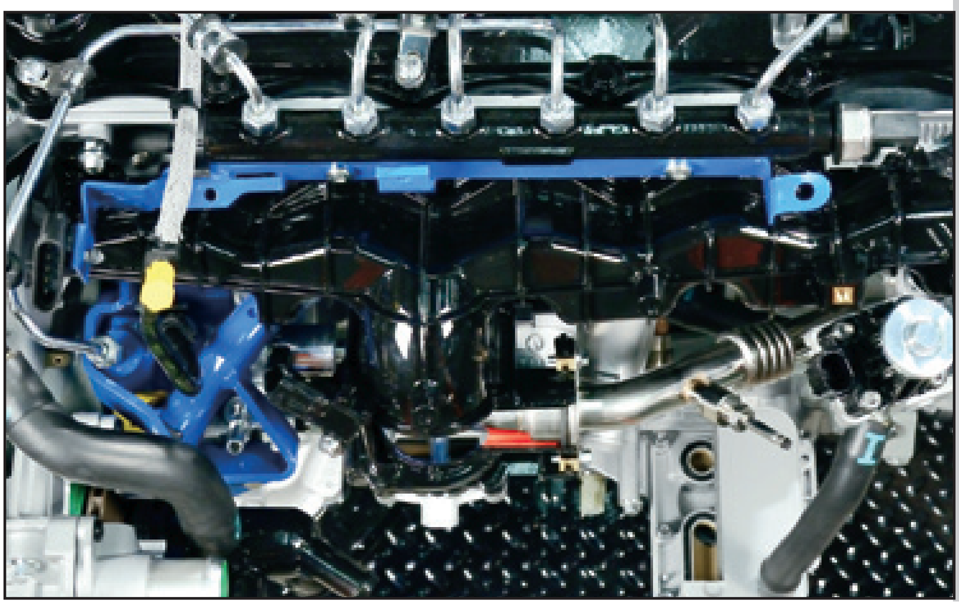
The CAC is an air-to-air heat exchanger used to reduce the temperature of the compressed air from the turbocharger prior to entering the combustion chambers. Cooler air is denser (improving volumetric efficiency), resulting in increased power.



Intake Throttle Body

The intake throttle body is located on the left side of the engine, attached to the intake manifold.

The intake throttle body creates a pressure difference for EGR flow when EGR flow pressure is lower than intake air pressure.



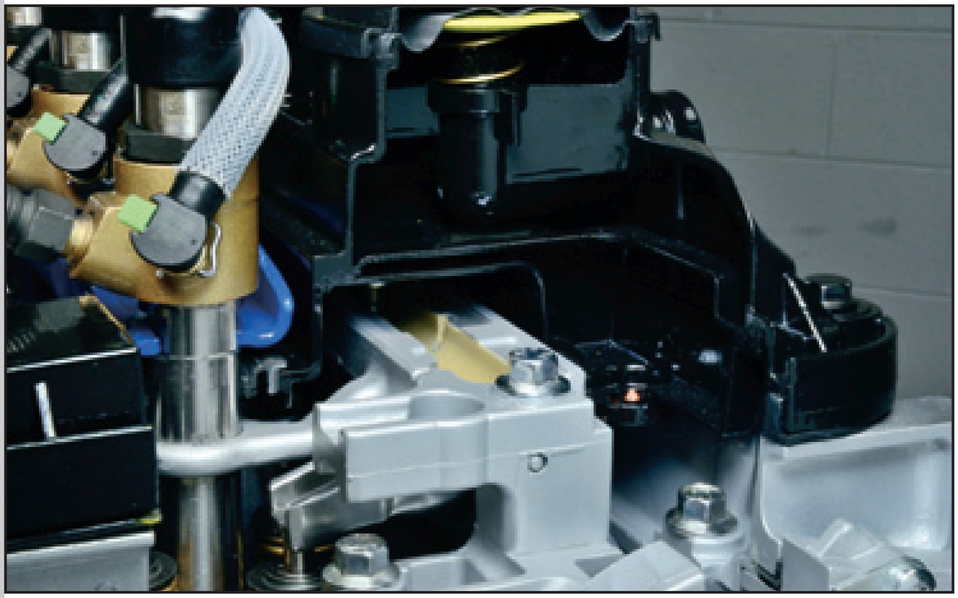
Intake Manifold

The intake manifold directs pressurized air from the CAC and mixes it with exhaust gas from the EGR for distribution to the cylinder head.

Crankcase Vent Oil Separator

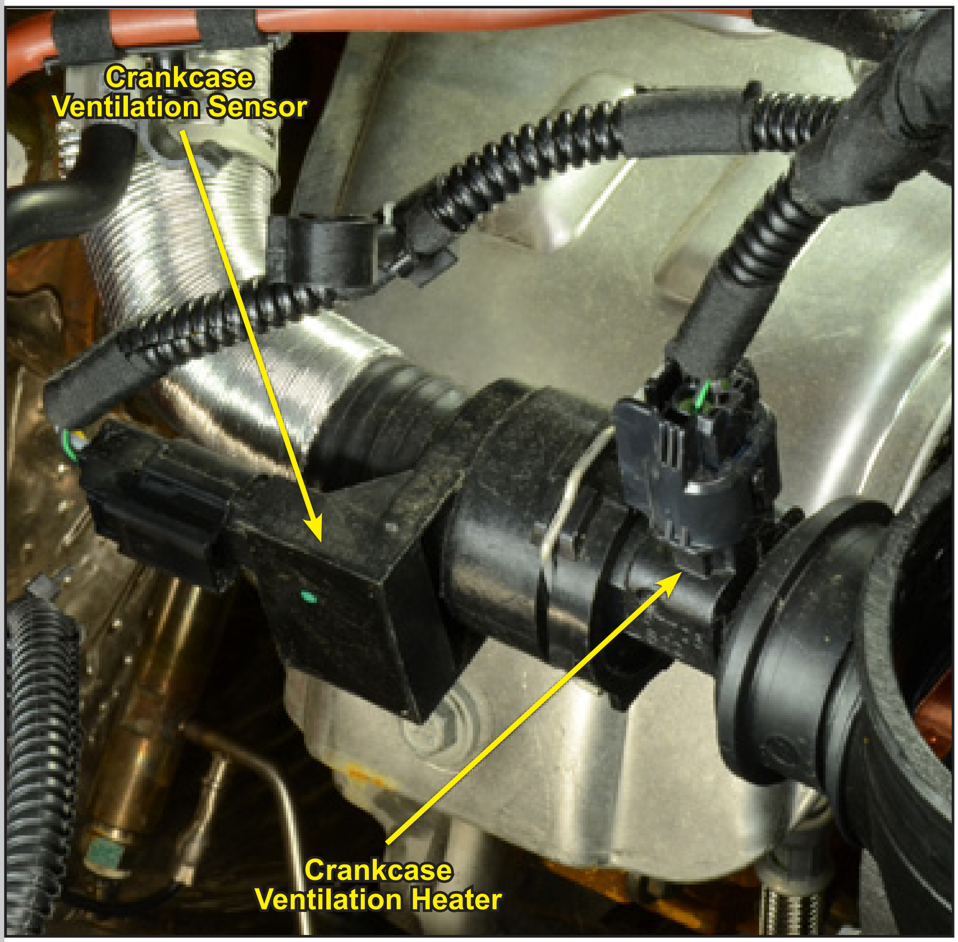
The crankcase vent oil separator is attached to the right rear of the valve cover.

The engine crankcase vent oil separator separates the oil from crankcase vapors and returns the oil to the crankcase through the valve cover. The vapors are routed to the air tube before the turbo inlet.



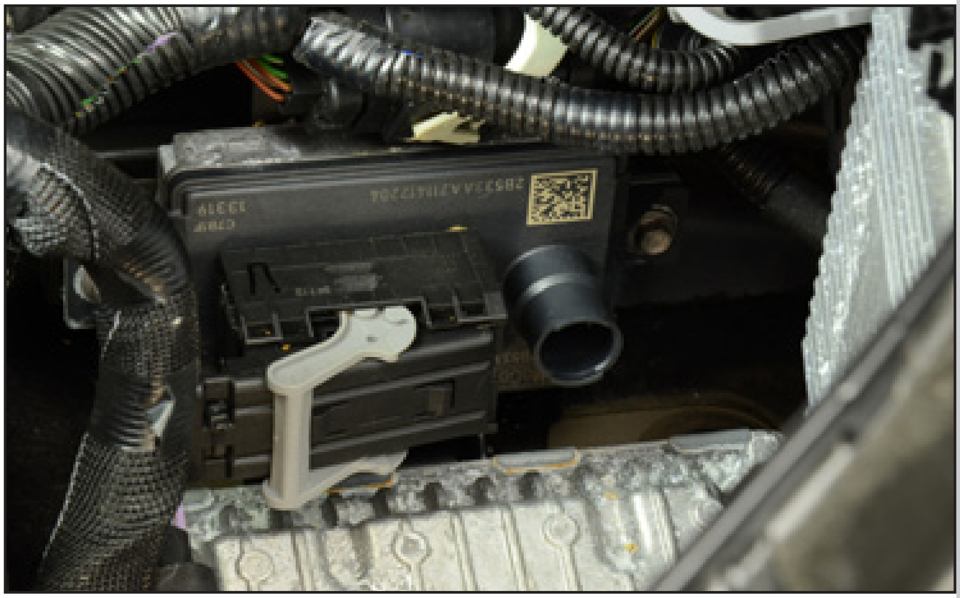
Crankcase Ventilation Sensor

The crankcase ventilation sensor is a Hall-effect sensor mounted on the crankcase ventilation hose at the air inlet connection. The crankcase ventilation separator is integral to the rocker cover. The crankcase ventilation hose on the air inlet side has a tamper-proof connector. The crankcase ventilation sensor monitors the crankcase ventilation hose connection at the fresh air inlet. The crankcase ventilation sensor signal to the PCM indicates if the crankcase ventilation hose is connected or disconnected.



Crankcase Ventilation Heater

The crankcase ventilation heater heats used to heat the crankcase ventilation system vapor to keep any oil that may be present from sludging in the CAC, turbocharger and intake manifold. The crankcase ventilation heater is located on the crankcase ventilation hose, between the crankcase ventilation sensor and the fresh air inlet. For additional information on the crankcase ventilation system, refer to Crankcase Ventilation System in this section.

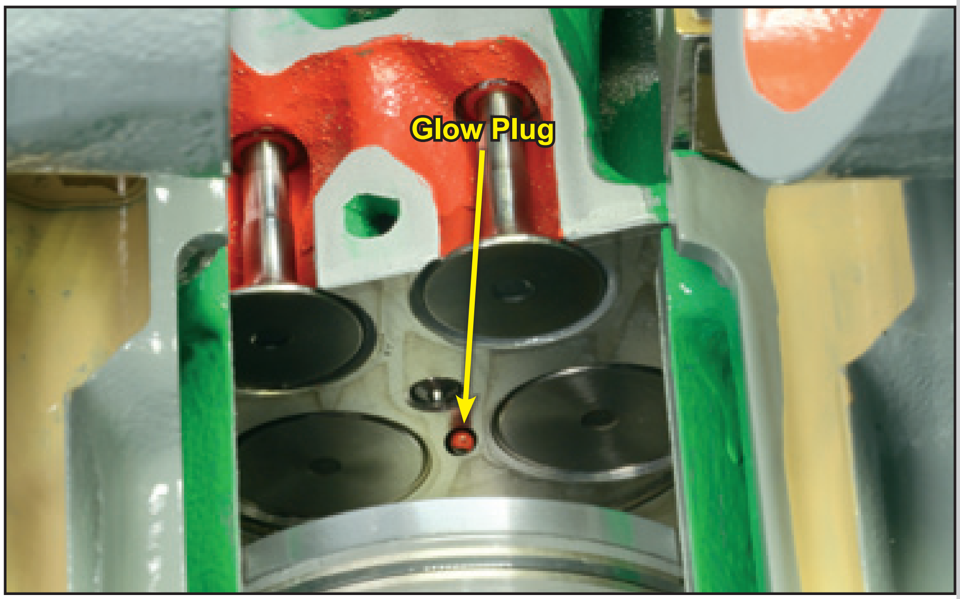


Glow Plug System

Glow Plug Control Module (GPCM)

The Glow Plug Control Module (GPCM) is located on the drivers side under the degas bottle next to the PCM and TCM. The GPCM provides battery voltage for the glow plugs, then modulates the voltage to maintain temperature. The lower the coolant temperature, the longer the preheat time.

Once the engine starts, the glow plugs enter an afterglow phase. The afterglow phase helps to improve idling and reduce hydrocarbon emissions. The afterglow phase only operates at engine speeds below 2500 RPM.



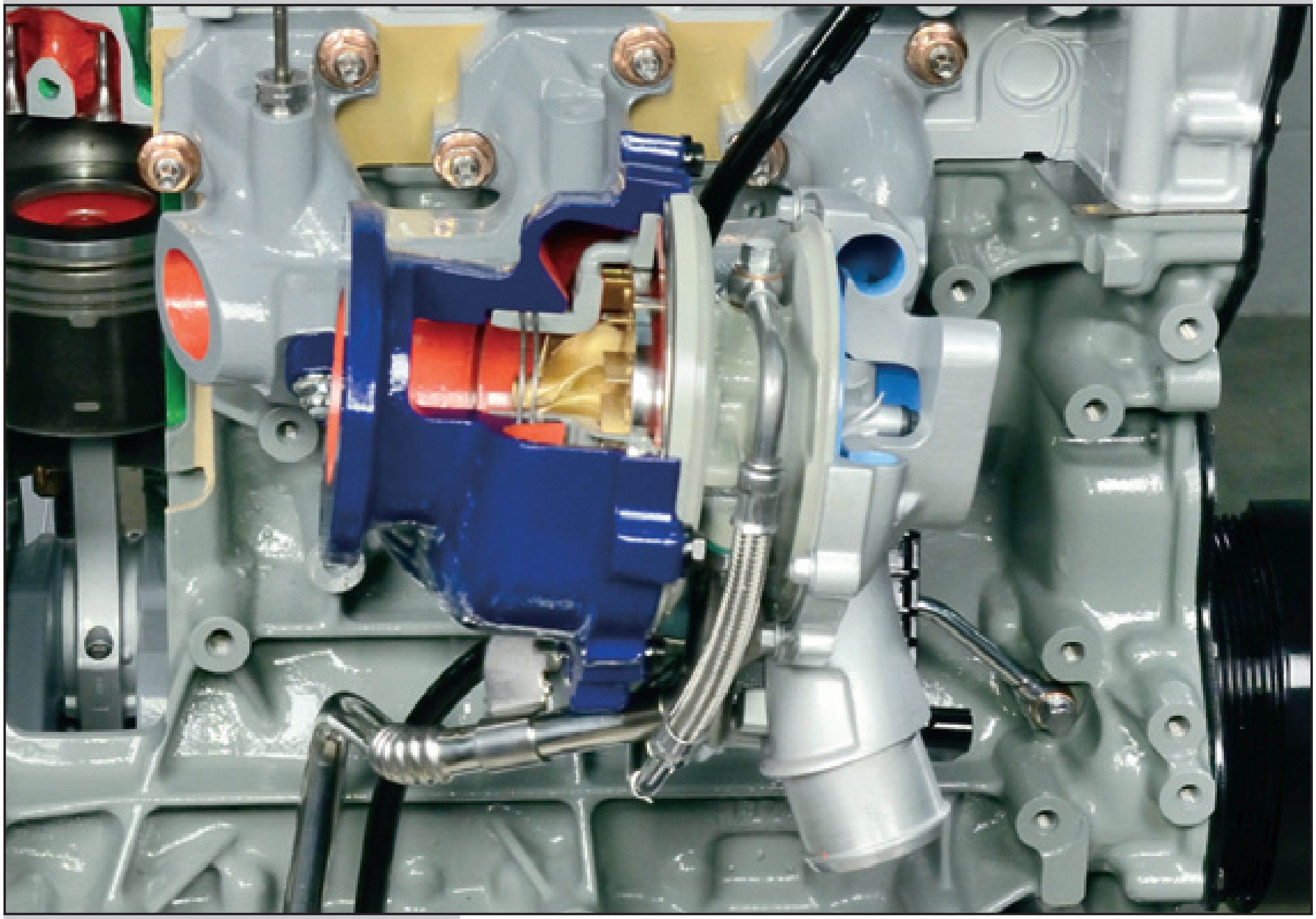
Glow Plugs

The glow plugs are mounted in the cylinder heads and are accessible when the intake manifold is removed.

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.

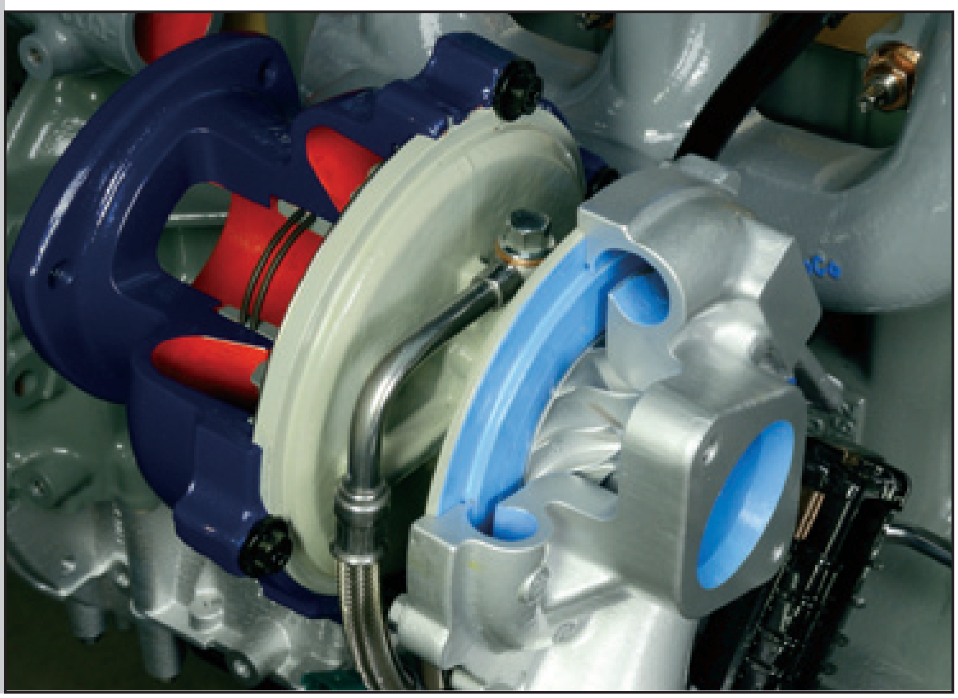
Variable Geometry Turbocharger (VGT)

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 turbocharger actuator to achieve the desired intake pressure to meet the driver's demands (pedal position, engine load). The air system model considers engine temperature, air temperature, EGR operation, RPM, and engine load.



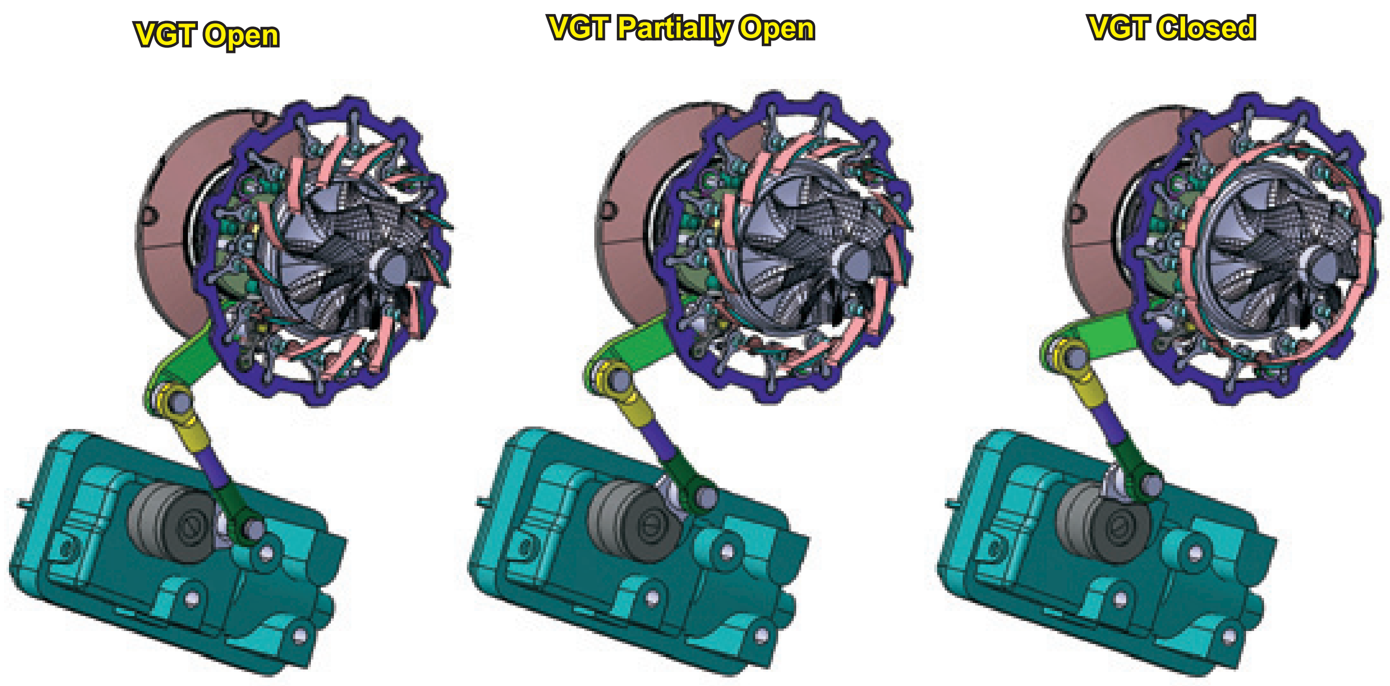
Intake Compressors

The turbocharger has a single compressor wheel and single turbine wheel on a common shaft.



VGT Actuator

The 3.2L VGT actuator uses an electronic motor to move the vanes on the exhaust turbine. The VGT actuator is commanded by the PCM, based on a desired manifold pressure.



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 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 assist in EGR flow.

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 gases 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 gases into the intake. This is also the position for cold ambient warm-up.

NOTES

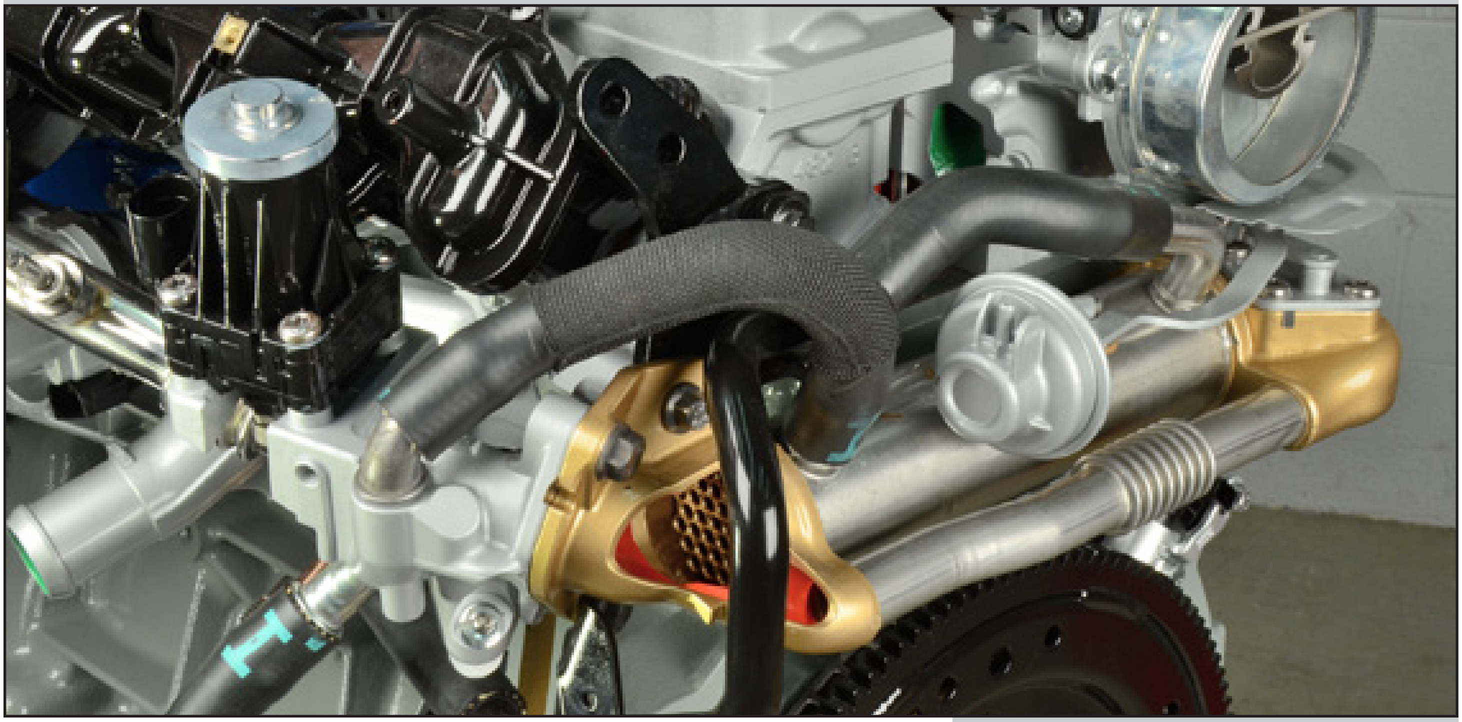
Exhaust Gas Recirculation (EGR)

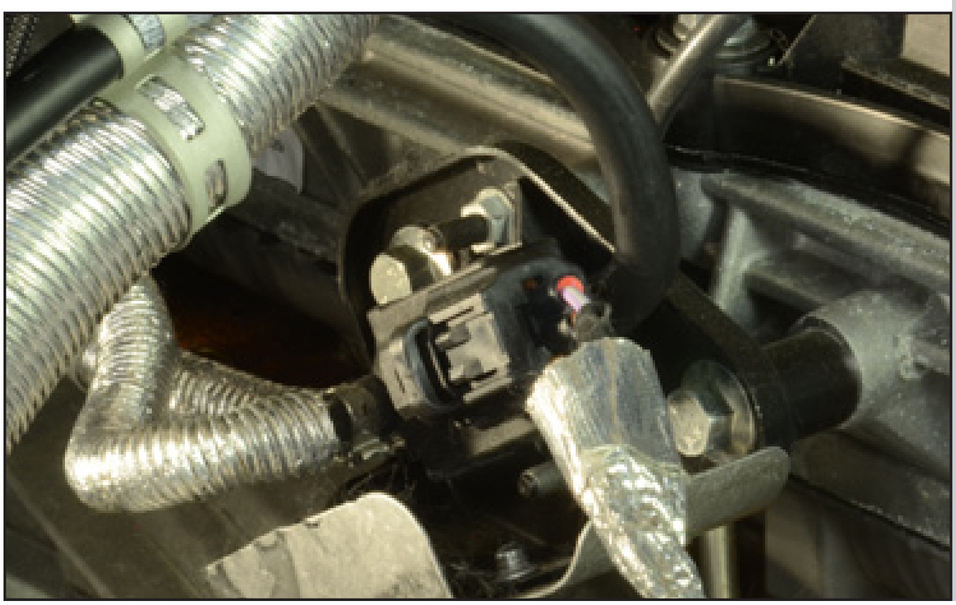
The EGR system allows cooled (inert) exhaust gases to re-enter the combustion chamber, which lowers combustion temperatures and Oxides of Nitrogen (NO_x) emissions.

EGR system control is based off an air system model to estimate the percentage of exhaust gases in the cylinder. The PCM looks at engine temperature, intake pressure, modeled exhaust pressure, RPM, and engine load to determine the EGR flow rate. The PCM uses the ratio of Manifold Absolute Pressure (MAP) and Exhaust Back Pressure (EP) to estimate a desired EGR valve position. The desired position is compared to the actual position 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 valve 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 gases are introduced into the intake manifold the amount of air measured by the Mass Air Flow and Temperature (MAFT) sensor is decreased.

The 3.2L has a cold side EGR valve due to it being after the EGR cooler. Once past the EGR valve, the exhaust gases are directed to the intake manifold.

The PCM controls the EGR cooler bypass solenoid which turns vacuum on or off to the actuator on the bypass door. The Exhaust Gas Recirculation Temperature (EGRT) Bank 1 Sensor 2 measures the temperature of the exhaust gases leaving the system for cooler effectiveness, bypass control and other hardware protection.





EGR Cooler Bypass Solenoid

The EGR cooler bypass valve solenoid controls the EGR cooler bypass valve position by applying vacuum to the EGR cooler bypass valve actuator.

EGR cooler bypass solenoid operation:

- When the EGR cooler bypass solenoid is on the EGR cooler is bypassed.
- When the EGR cooler bypass solenoid is off the EGR gases flow through the EGR cooler.

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 a single valve. When the EGR valve opens exhaust gases flow around the valve and to the EGR valve outlet pipe connected to the intake manifold.

EGR Cooler

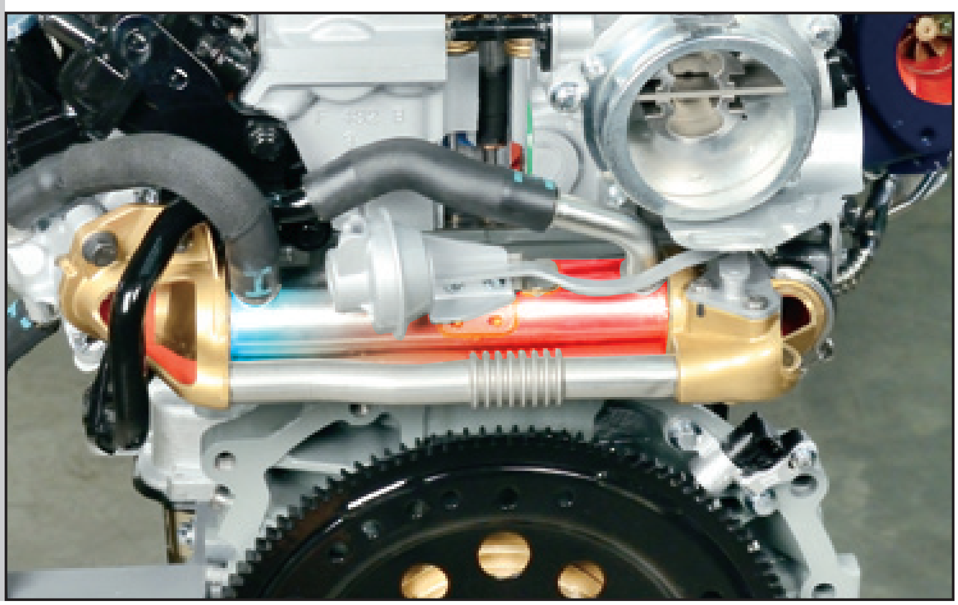
The EGR system uses an EGR cooler before the EGR valve.

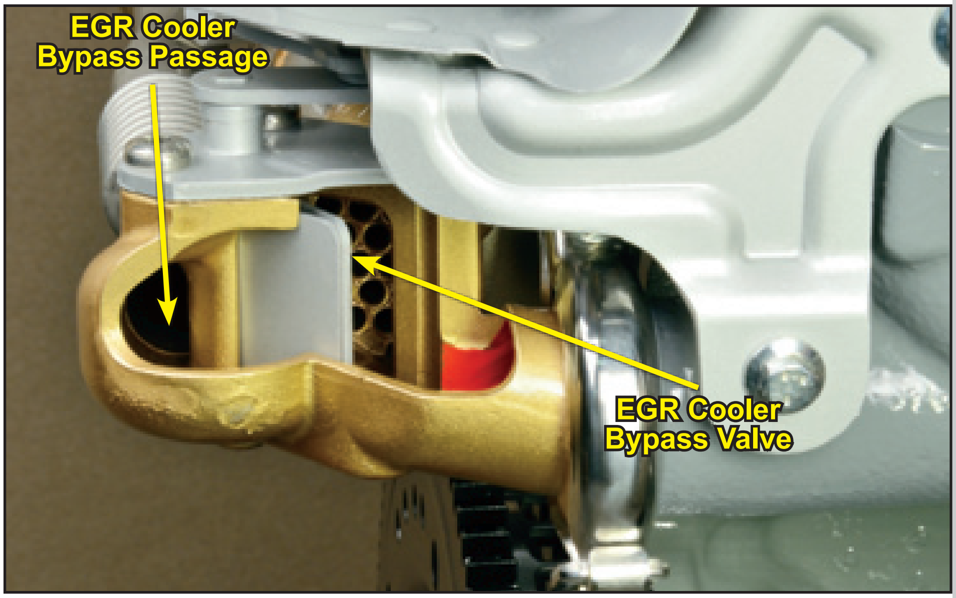
The EGR cooler wraps around the rear of the engine.

The cooler EGR temperature reduces NO_x emissions.

EGR Flow

Exhaust gases enter the EGR cooler bypass area where the bypass door directs the gases through the EGR cooler or through the bypass. Exiting the EGR cooler/bypass the gases enter the EGR valve. If the EGR valve is open the gases proceed to the intake manifold for mixing with fresh air.

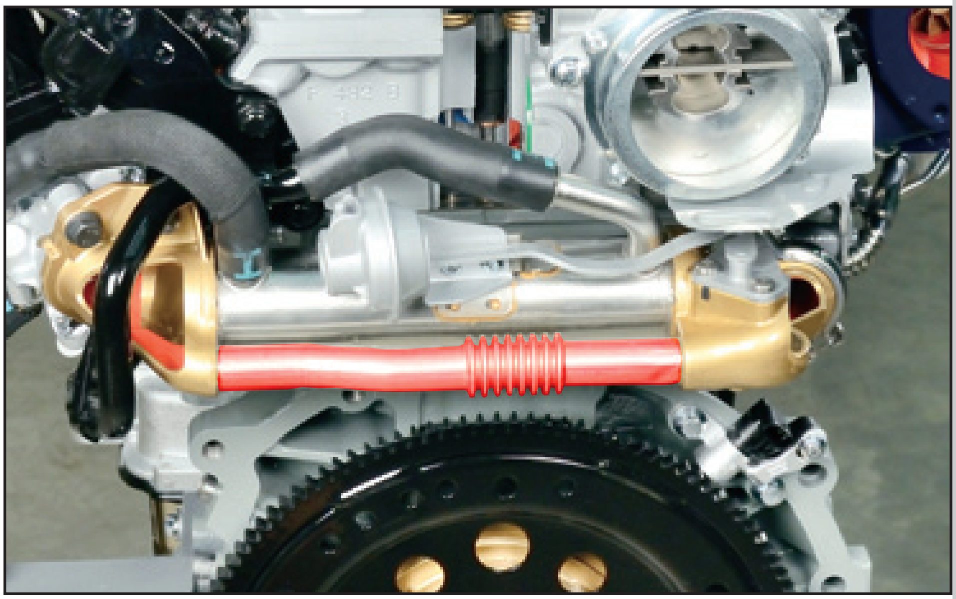




EGR Cooler Bypass Valve

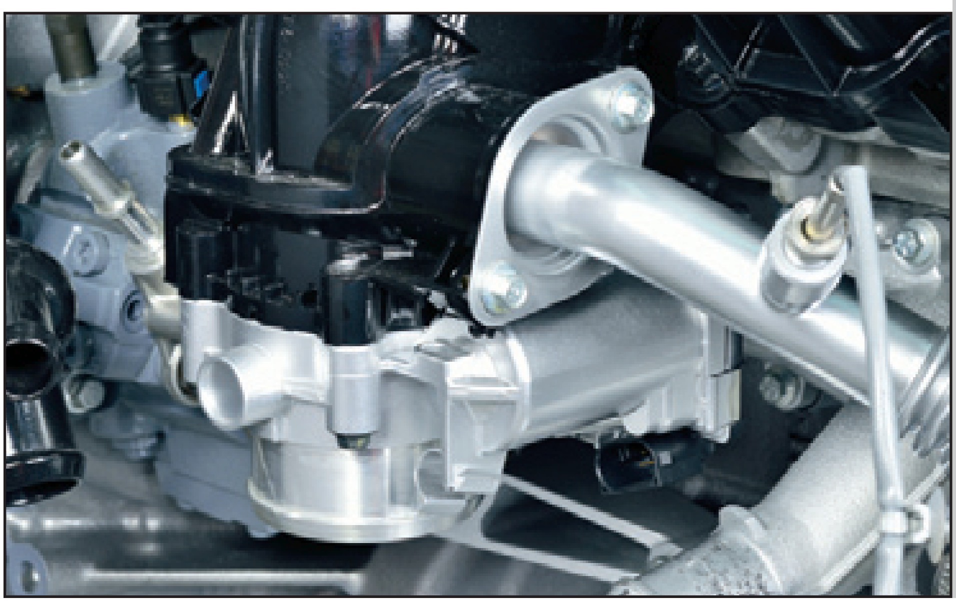
The EGR cooler bypass valve alters the flow of EGR gases to bypass the cooler at all engine speeds and low engine torque. The vacuum controlled valve is solenoid controlled by the PCM.

If the PCM determines that it does not need to cool the exhaust gases, it commands the Vacuum Solenoid Valve (VSV) to close the bypass valve and route the exhaust gases through the bypass tube to the EGR valve.



EGR Cooler Bypass Flow

The EGR cooler bypass valve is at the front of the EGR cooler/bypass tube. When the EGR cooler bypass valve solenoid is commanded on by the PCM, vacuum is applied and the EGR cooler bypass valve closes. When the EGR cooler bypass valve is closed, the exhaust gases go through the bypass tube avoiding the cooler to the EGR valve. When the EGR cooler bypass valve solenoid is commanded off by the PCM, vacuum is vented and spring pressure from the bypass actuator opens the EGR cooler bypass valve. When the EGR cooler bypass valve is open, the exhaust gases pass through the EGR cooler to the EGR valve.



Intake Throttle Body

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

NOTES

FUEL SYSTEM

The Diesel Delivery Module (DDM) located in the fuel tank contains a turbine electric fuel pump that delivers fuel flow at low pressure to the fuel filter.

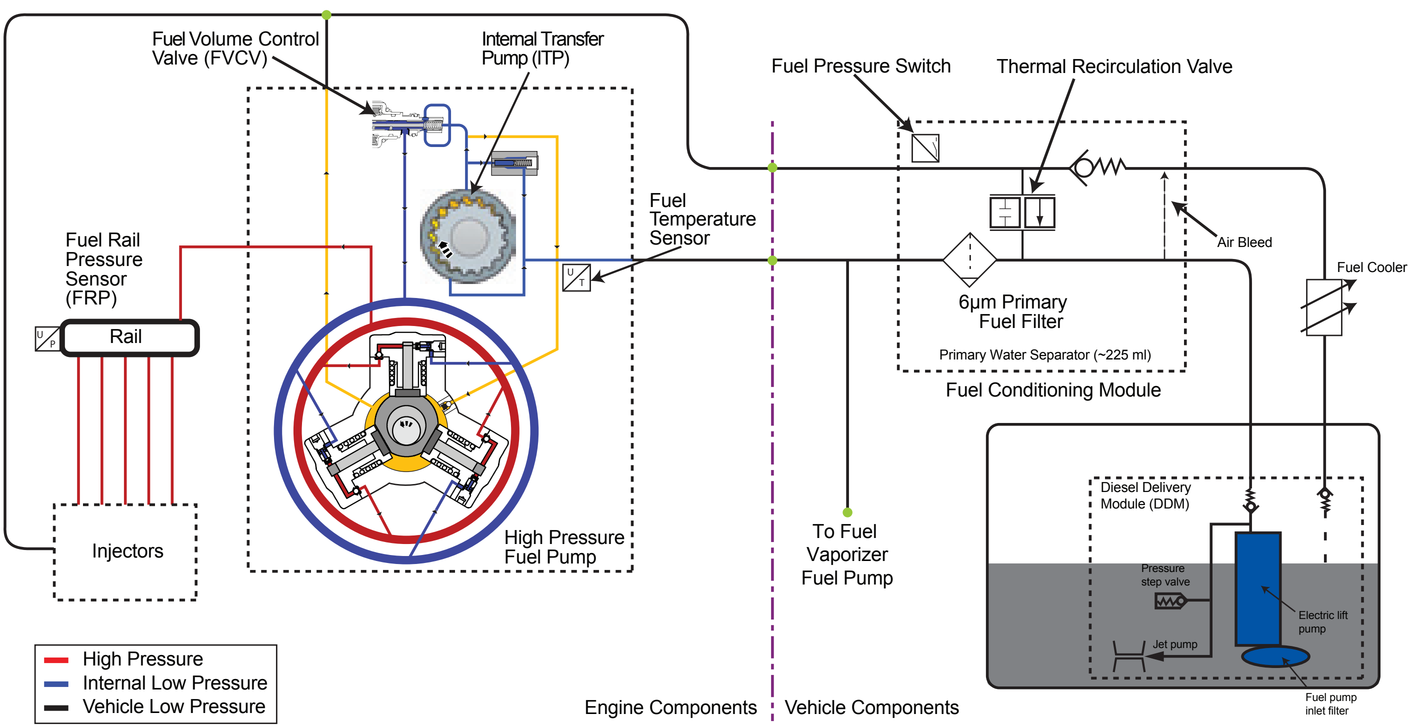
The Fuel Conditioning Module (FCM) contains a fuel filter, water separator, injector back pressure valve, low pressure switch and a thermal recirculation valve. The fuel filter cleans the fuel and separates water. The fuel filter housing contains an air bleed on the dirty side of the filter that allows air to escape back to the fuel tank return line. The filter also houses a bi-metal thermal recirculation valve that allows warm fuel from the engine to enter directly to the dirty side of the filter to help melt paraffins that can deposit and plug the filter in cold conditions. Filtered fuel will pass through a fuel pressure switch to make sure proper fuel pressure is being supplied to the high pressure fuel pump and the fuel vaporizer (exhaust injector) fuel pump. The low pressure switch warns the driver when the fuel pressure falls below a preset limit which can be caused by a malfunctioning electric pump or restriction in the supply line including a dirty filter. This protects the engine fuel injection equipment from damage

When fuel reaches the high pressure fuel pump, the Internal Transfer Pump (ITP) ensures the fuel is delivered to the high pressure pump with a specified mass flow. The fuel temperature is read while the fuel is in (or exiting) the high pressure pump. The Fuel Volume Control Valve (FVCV) meters the flow of fuel to the fuel rail. A single high pressure fuel line to the high pressure fuel pump transports fuel to the fuel rail. Individual high pressure fuel lines connect the fuel rail to the five fuel injectors. At the end of the fuel rail is the fuel rail pressure sensor. The sensor reading is used by the PCM to adjust the FVCV to meet the fuel pressure demand. Injector return fuel meets with fuel return out of the high pressure fuel pump and goes back to the fuel filter/water separator. The fuel filter/water separator element housing contains a pressure valve to generate back pressure for proper injector operation. If the return fuel temperature is greater than 38˚C (100˚F) then the thermal re-circulating valve sends the fuel through a fuel cooler and back to the tank. If the fuel is cooler, the thermal recirculating valve supplies return fuel to the fuel filter inlet.

*The 3.2L engine does not use a pressure control valve. The fuel pressure is completely regulated by the FVCV.

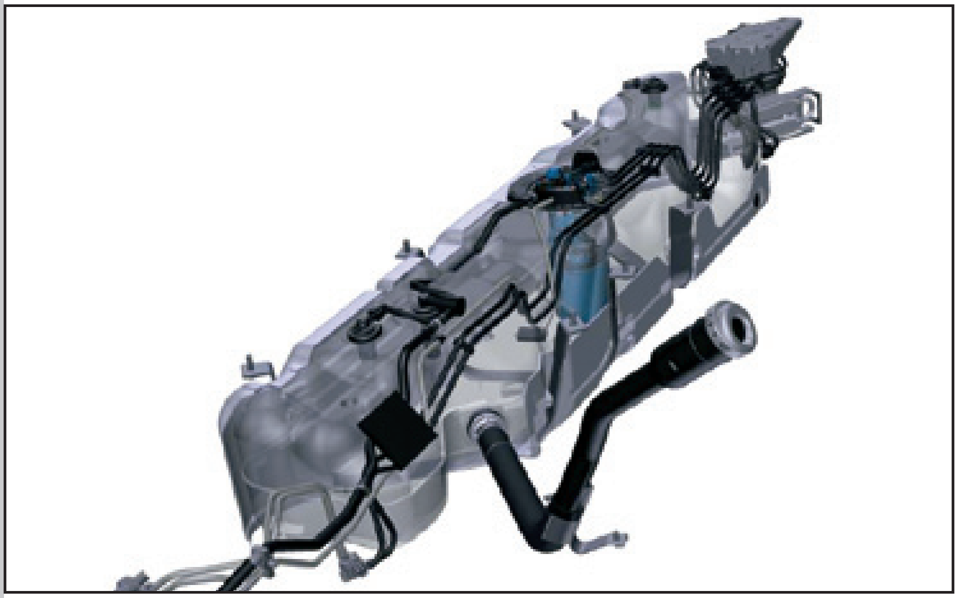
High pressure fuel system operating mode:

- Thermal recirculation valve is fully open below 33°C (91°F) and closed at 43°C (109°F) (all fuel goes back to tank)



Fuel Supply System Components

- Diesel Delivery Module (DDM)
- The Fuel Conditioning Module (FCM)
- Schrader valve
- Fuel Rail Temperature (FRT) sensor
- Fuel cooler
- Exhaust fuel injector fuel pump
- Injector low pressure lines

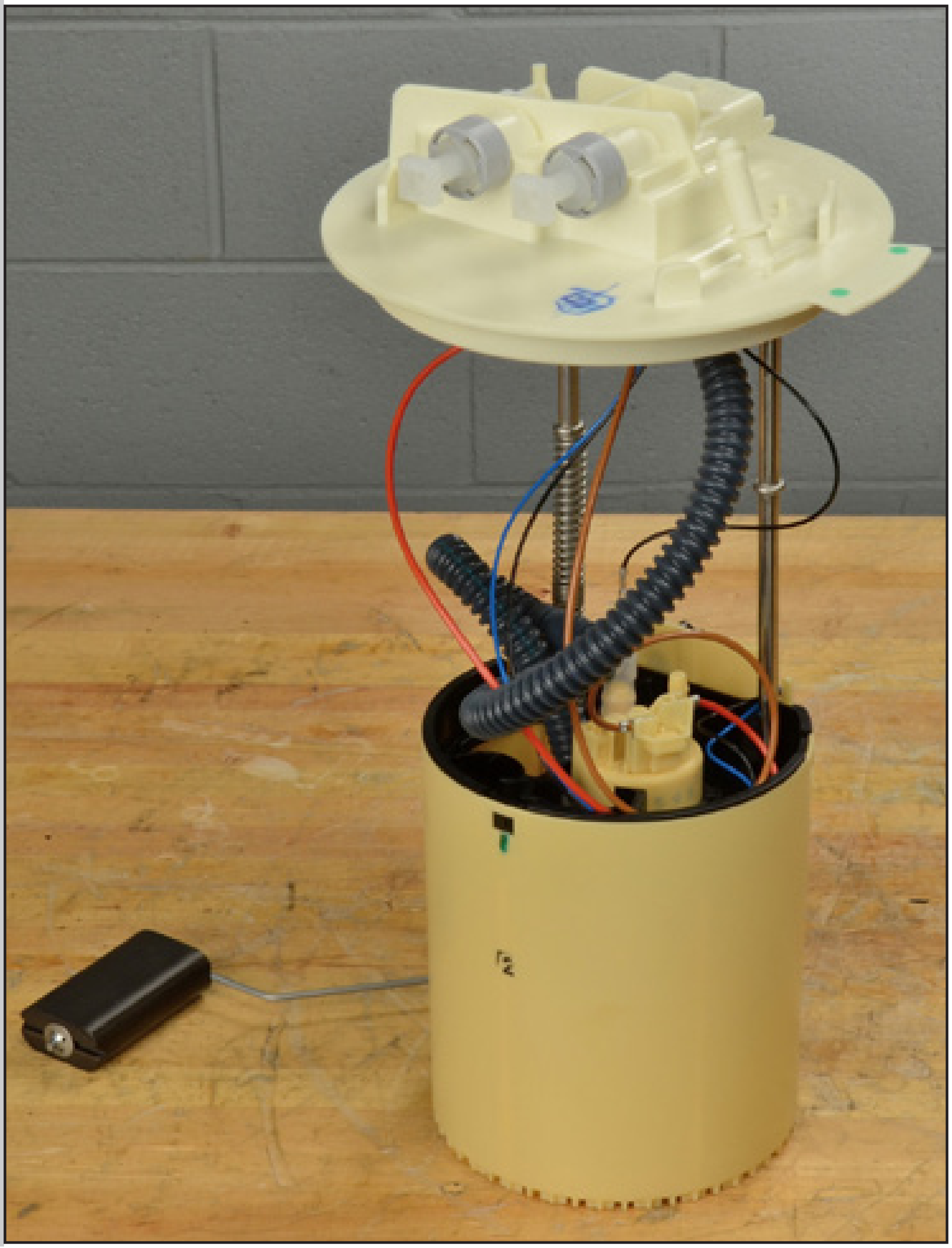


DDM Components

- Low pressure fuel lift pump
- Pressure regulator
- Jet pump

The 3.2L diesel engine has an in-tank mounted fuel pump with a separate fuel filter.

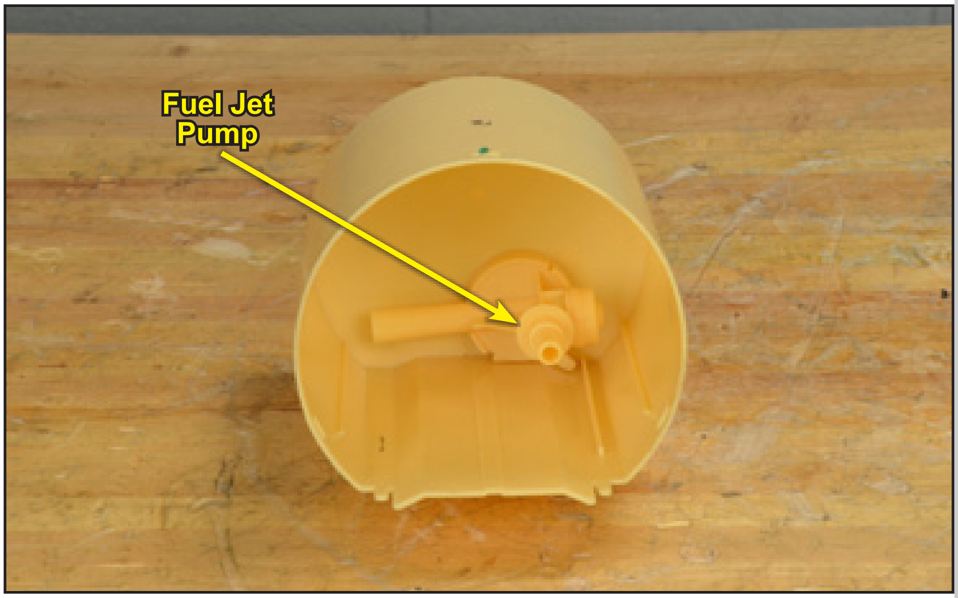
The in-tank electric fuel pump delivers fuel at 28-76 kPa (4-11 psi) to the mechanical ITP on the high pressure pump. The ITP performs the final pressurization to the high pressure piston pump



Low Pressure Fuel Lift Pump and Pressure Regulator

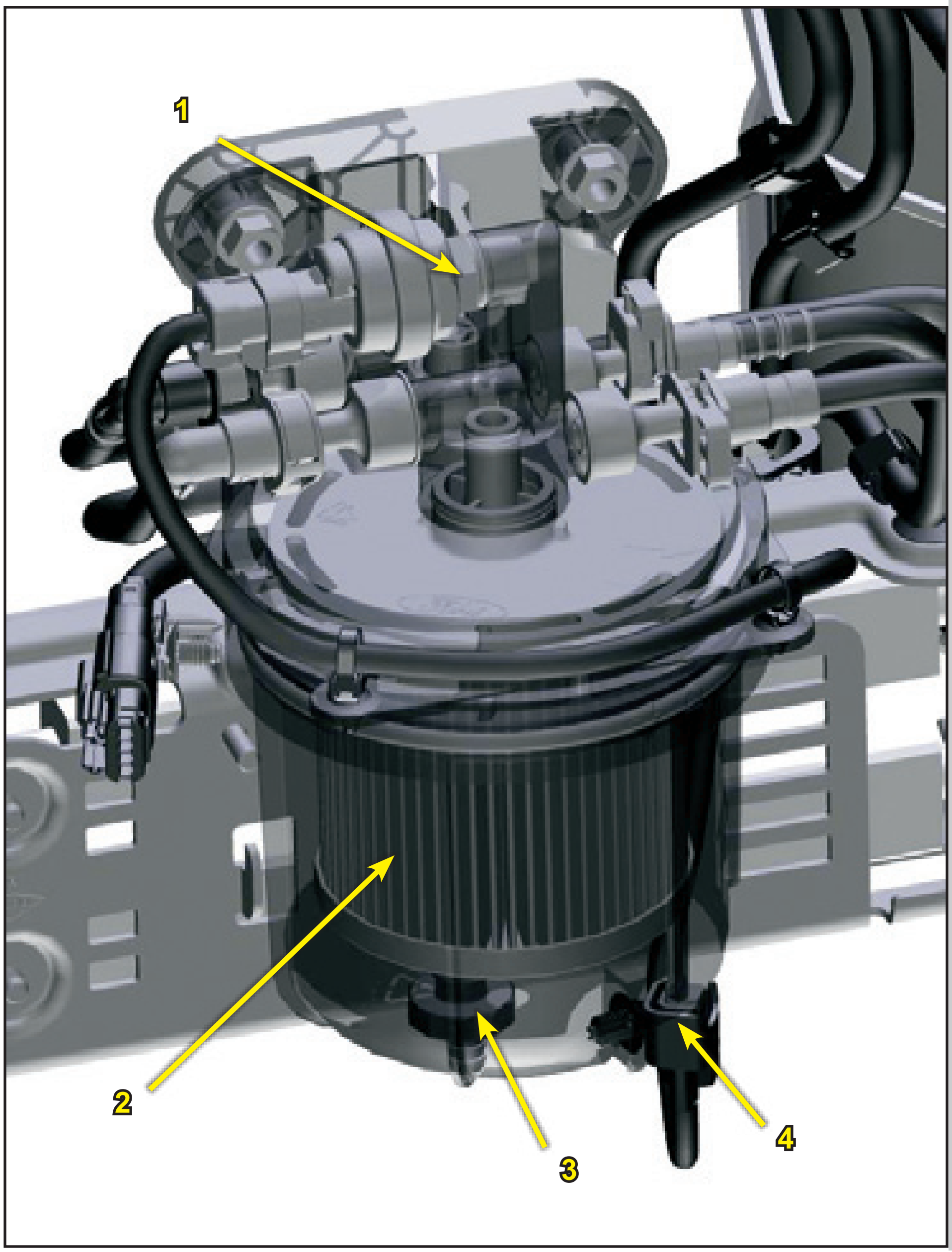
The low pressure fuel lift pump is located in the fuel tank and secured by a locking ring and seal. The pump pulls fuel from the tank through a 300 micron screen. The fuel pressure supplied to the engine is 28-76 kPa (4-11 psi).

The fuel pressure is regulated at the pump outlet by an overflow valve/ pressure regulator.



Fuel Jet Pump

The fuel pump assembly also incorporates a fuel jet pump. Fuel from the electric pump is passed through a venturi in the jet pump which causes a pressure drop across an open orifice. This draws in fuel through the base of the unit which then passes through the sock filter to the fuel pump and filling the reservoir of the DDM.



FCM Components

1. Fuel pressure switch
2. Fuel filter/water separator
3. Water in Fuel (WIF) sensor
4. Water drain valve (manual operation)

Fuel Filter

The diesel fuel filter separates air, water and other contaminants from fuel, in addition to maintaining system back pressure. The upper section of the filter incorporates the recirculation valve, return valve and a fuel pressure switch. The lower section of the filter houses the filter element, water separator, WIF sensor and drain.

Fuel Pressure Switch

The fuel pressure switch monitors fuel pressure at the FCM. The switch closes at approximately 17 kPa (2.5 psi).

Water Drain Valve

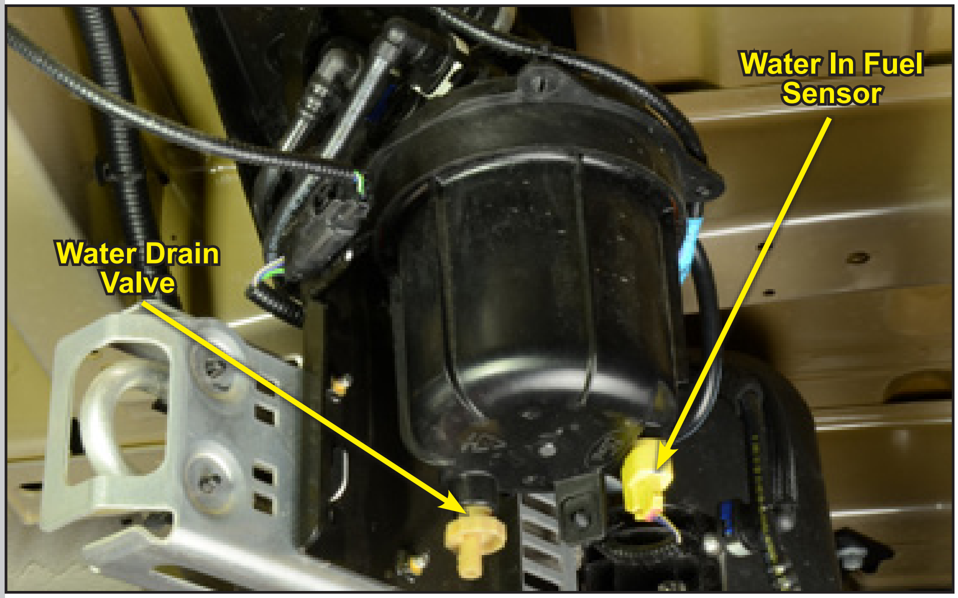
The water drain valve is located on the bottom of the FCM.

Water In Fuel (WIF) Sensor

The WIF sensor is integral to the fuel conditioning module bowl.

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

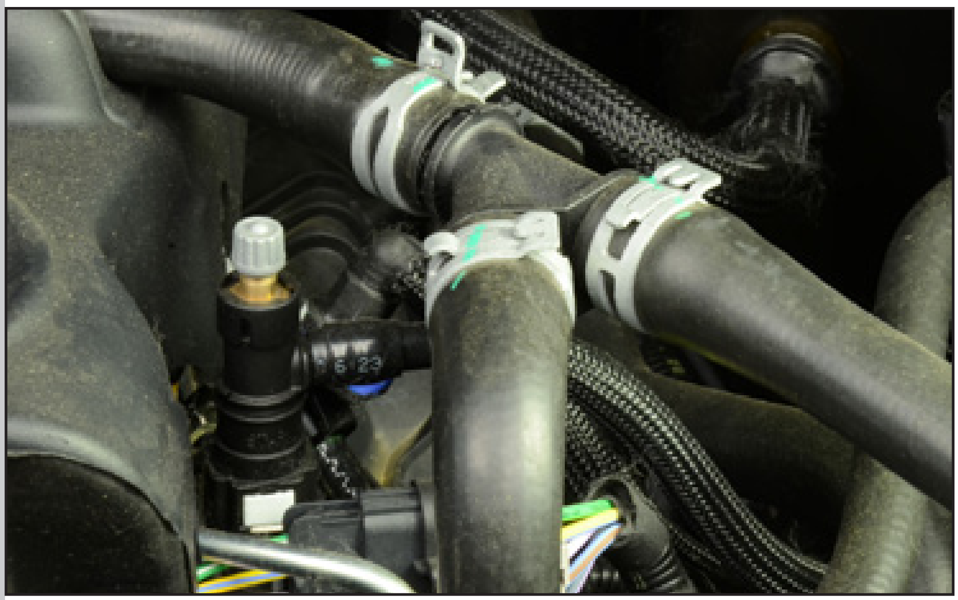
The WIF indicator is illuminated at 100 ml and has a capacity of 225 ml.



Schrader Valve

The Schrader valve is located on the supply line going to the high pressure fuel pump.

The Schrader valve can be used to measure the fuel pressure going to the high pressure fuel pump, and it may be used to drain air/fuel from the low pressure fuel system.

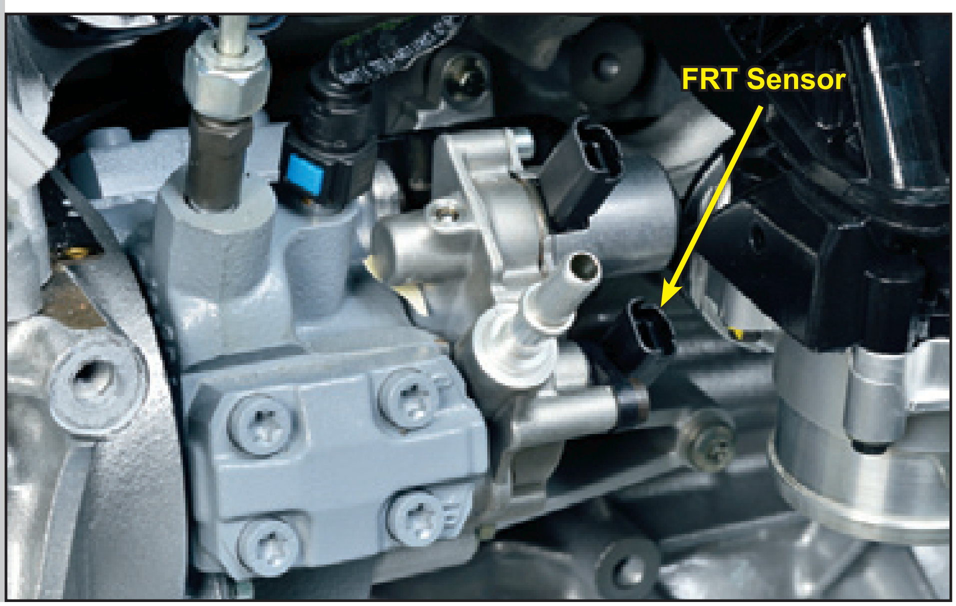


Fuel Rail Temperature (FRT) Sensor

The FRT sensor is mounted on the back of the high pressure fuel pump.

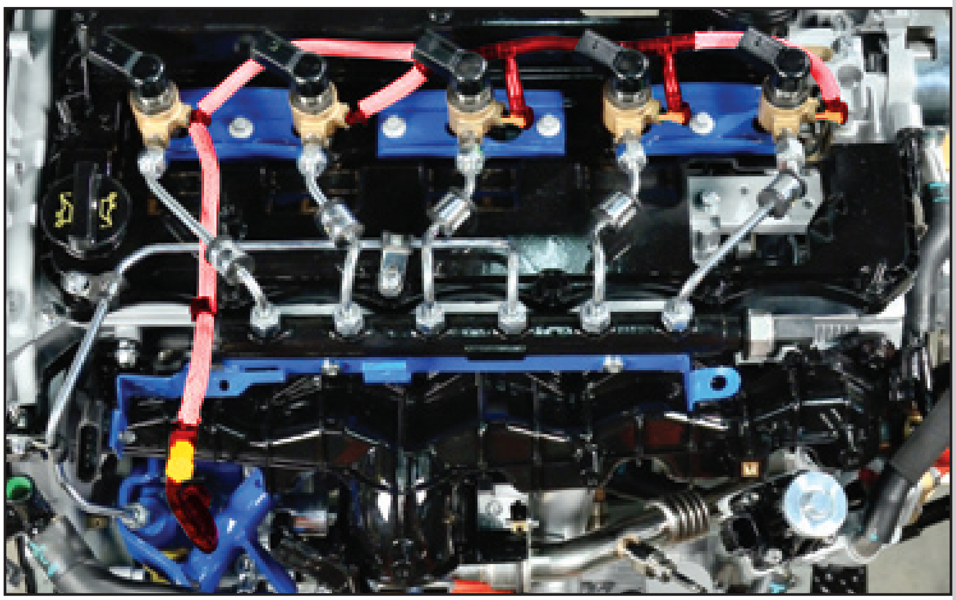
The PCM monitors the fuel temperature using the FRT sensor before the fuel enters the high pressure fuel pump.

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



Fuel Cooler

A fuel cooler is located behind the fuel tank in between the FCM and the frame. Depending on the temperature of the fuel from the injectors/High Pressure Fuel Pump (fuel return is a combination of injector return and High pressure fuel pump). The fuel cooler is an air to liquid cooler.



Injector Low Pressure Connectors

The injector low pressure connectors allows bleed off fuel to return to the FCM, along with fuel from high pressure fuel pump.

Vaporizer Fuel Pump

The exhaust fuel injector fuel pump is located just behind transmission in the center of the vehicle and supplies fuel to the fuel vaporizer.

Flitered fuel from the low pressure fuel supply line supplies fuel to the vaporizer fuel pump.

Biodiesel

The 3.2L 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.
- Flush the fuel system 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.

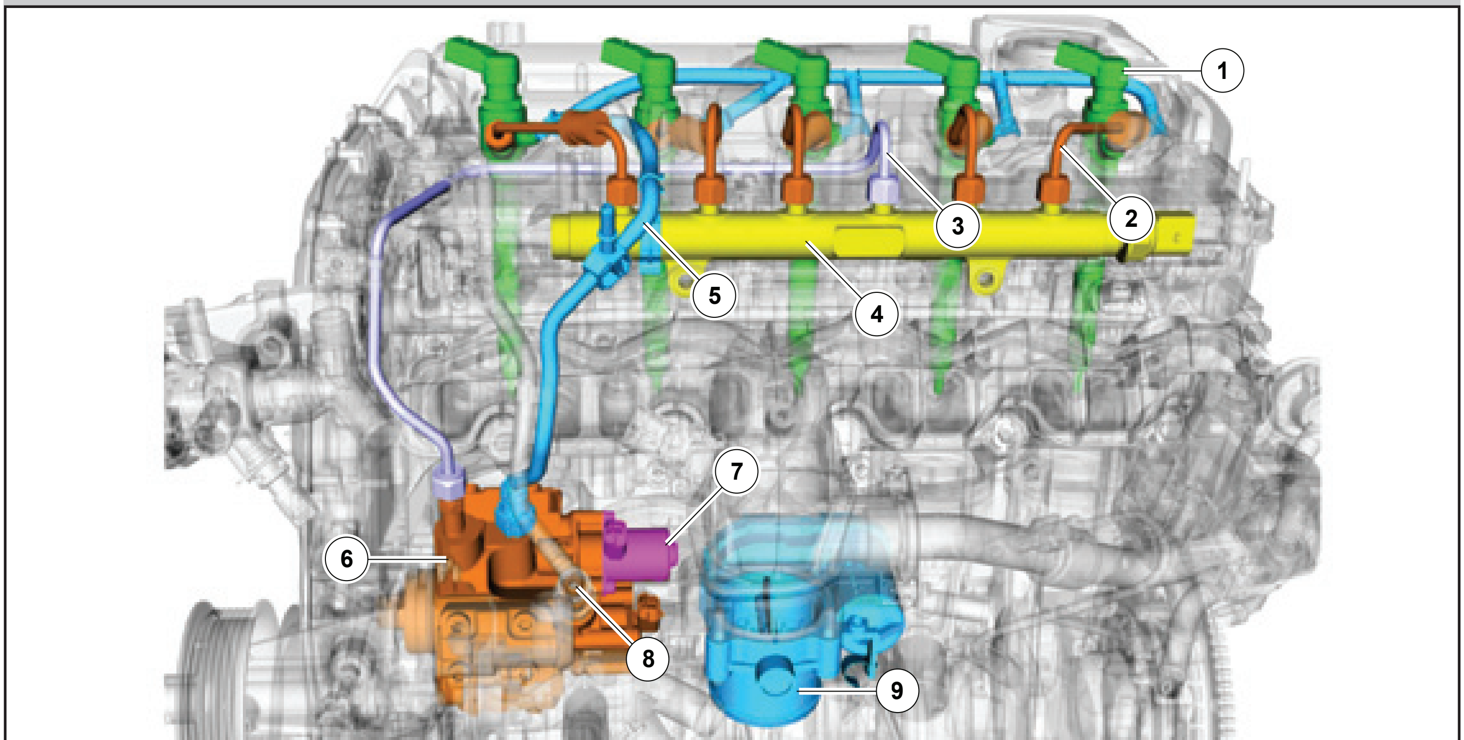
Using fuels containing more than 20% biodiesel can damage the engine and fuel system components, resulting in a non-warranty condition.

Fuel Management System

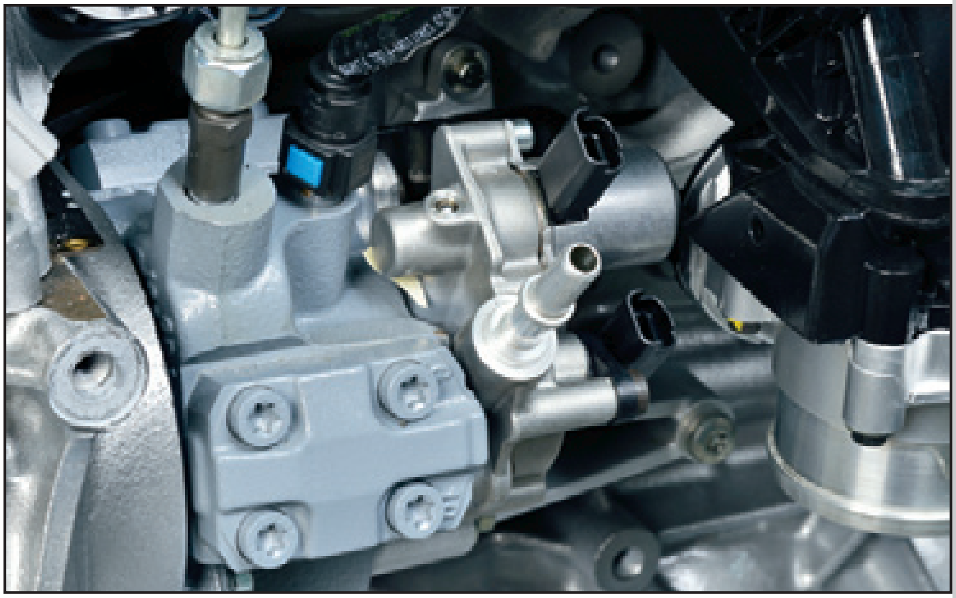
The Fuel Volume Control Valve (FVCV) controls how much fuel enters the three high pressure pump pistons. The fuel flow to the high pressure fuel pump is restricted as required by the PCM.

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

The fuel rail has 5 individual high pressure fuel lines to supply fuel to the injectors. Injector return fuel is directed back to the FCM along with fuel return from the high pressure fuel pump. The FCM has a pressure regulator on the return fuel side to keep pressure against the injectors for operation. Fuel returned to the FCM and going back to the fuel tank will go through a fuel cooler.



Number	Component	Number	Component
1	Fuel injector	6	Fuel injection pump
2	Fuel injector supply tube	7	Fuel metering valve
3	Fuel rail supply tube	8	High pressure pump fuel supply line
4	Fuel rail	9	Throttle Body (TB)
5	Fuel injector fuel return line		

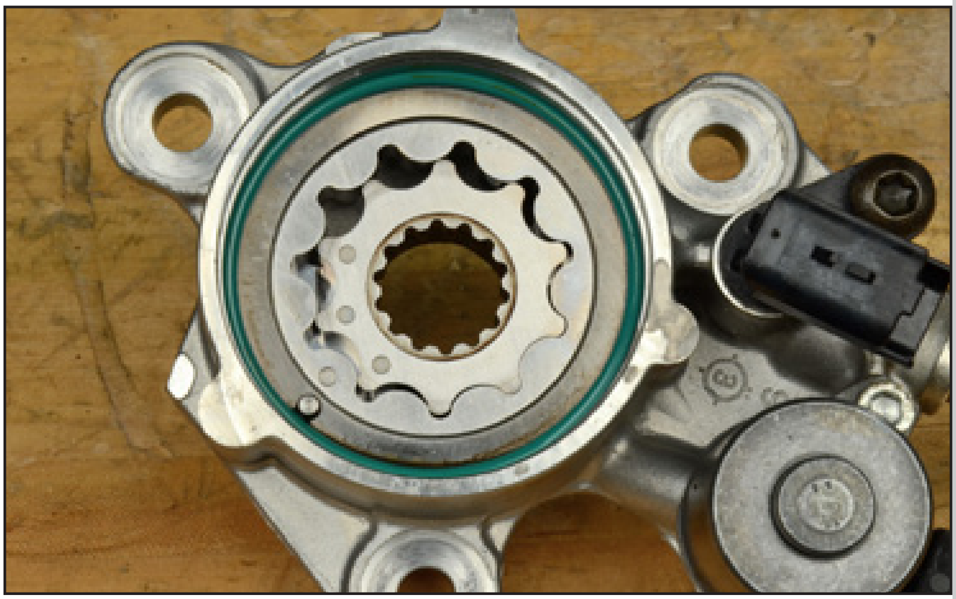


High Pressure Fuel Pump

The high pressure fuel pump is mounted in the left/front of the engine and is driven by the timing chain.

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.



Internal Transfer Pump (ITP)

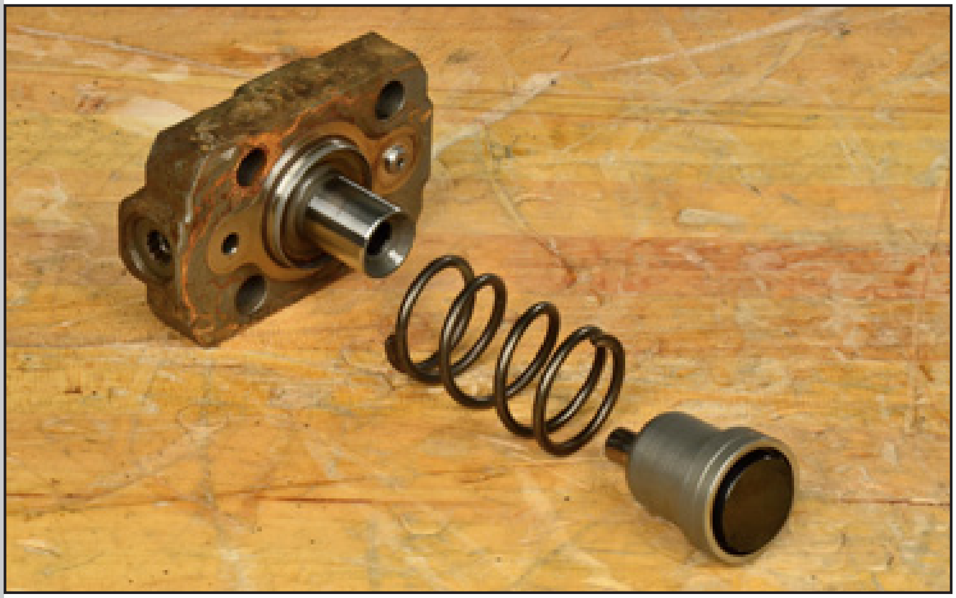
The ITP is part of the high pressure fuel pump and is used to increase the fuel pressure supplied to the high pressure fuel pump.

High Pressure Fuel Pump Operation

The high pressure fuel pump is a 3-cylinder design. The main shaft has an eccentric lobe that actuated the pistons of the high pressure pump.

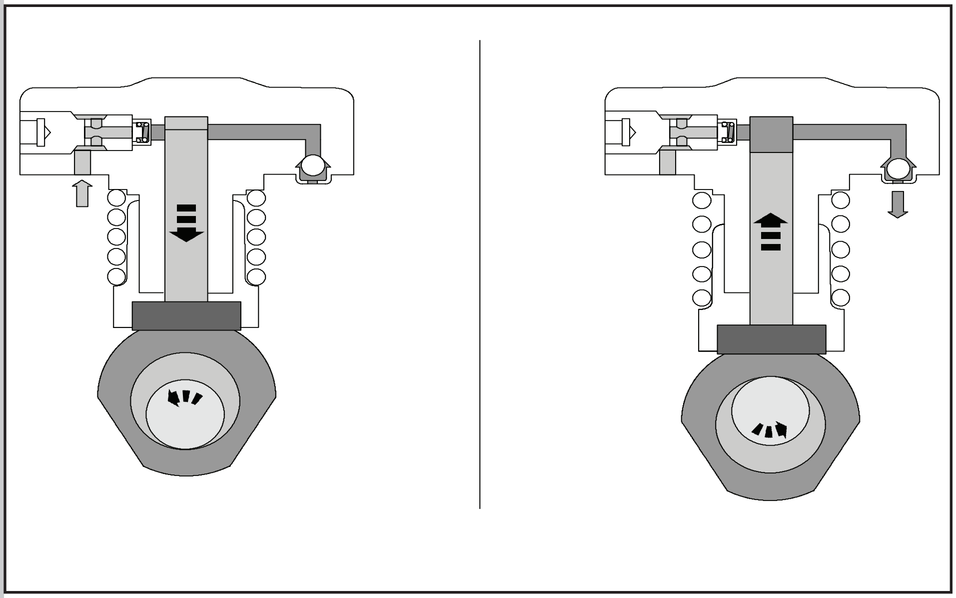
Piston Assemblies

The pistons are actuated via an eccentric lobe and are returned to rest via spring pressure. The pistons receive fuel from the 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 FVCV.



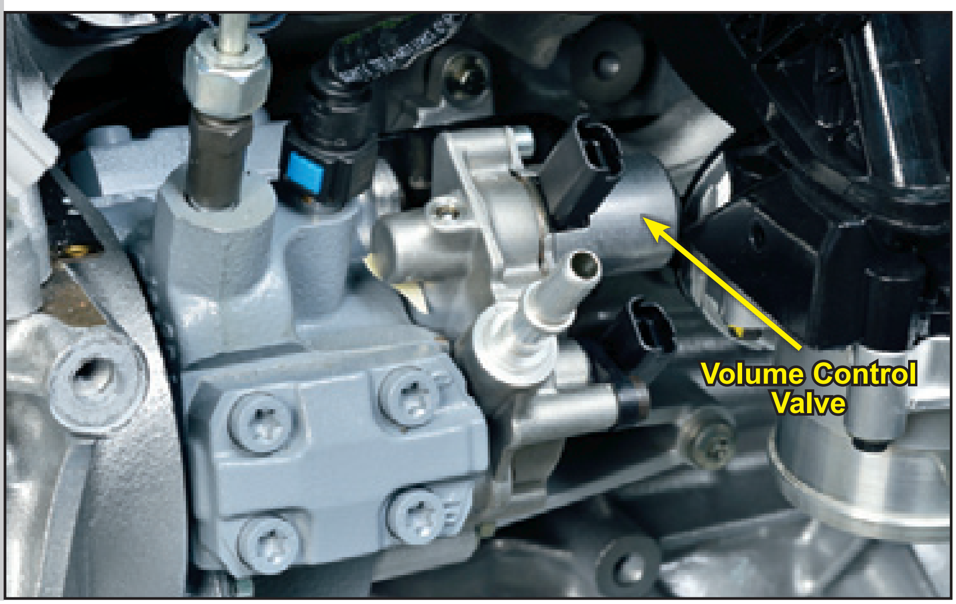
Piston Assembly Check Valves

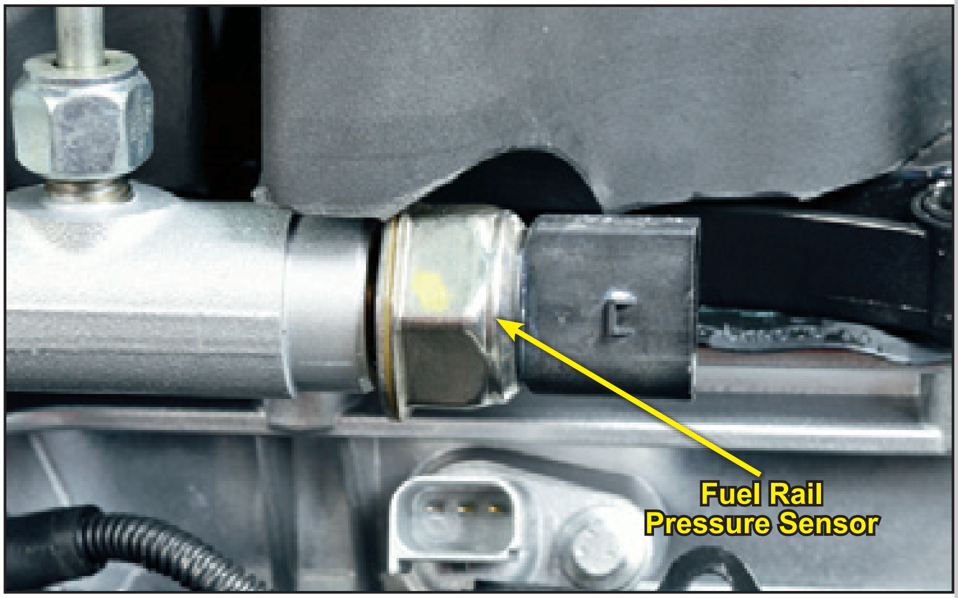
The outlet check valve closes while fuel is being drawn in due to a pressure difference on the two sides of the check valve. Once the piston starts its compression stroke, the inlet check valve closes via the spring and fuel pressure and the outlet check valve opens due to increasing fuel pressure, forcing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



Fuel Volume Control Valve (FVCV)

The fuel FVCV is mounted on the back of the high pressure fuel pump. The FVCV is pulse width modulated by the PCM to control the amount of fuel that enters the high pressure fuel pump. The FVCV regulates the fuel rail pressure. As the engine is switched off the FVCV shuts off the fuel supply to the high pressure fuel pump.



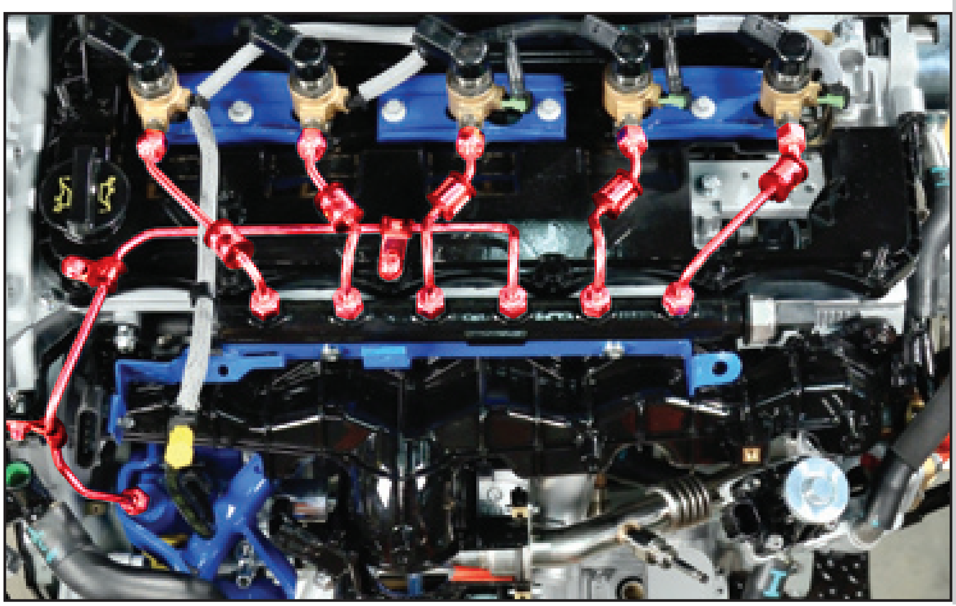


Fuel Rail Pressure (FRP) Sensor

The FRP sensor is threaded into the rear of the 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 rail on the 3.2L Power Stroke® diesel engine is on the outside of the valve cover.



High Pressure Fuel Lines

The high pressure fuel lines run between the:

- High pressure fuel pump and fuel rail.
- Fuel rail and the fuel injectors on the outside of the valve covers.

Piezo Fuel Injectors

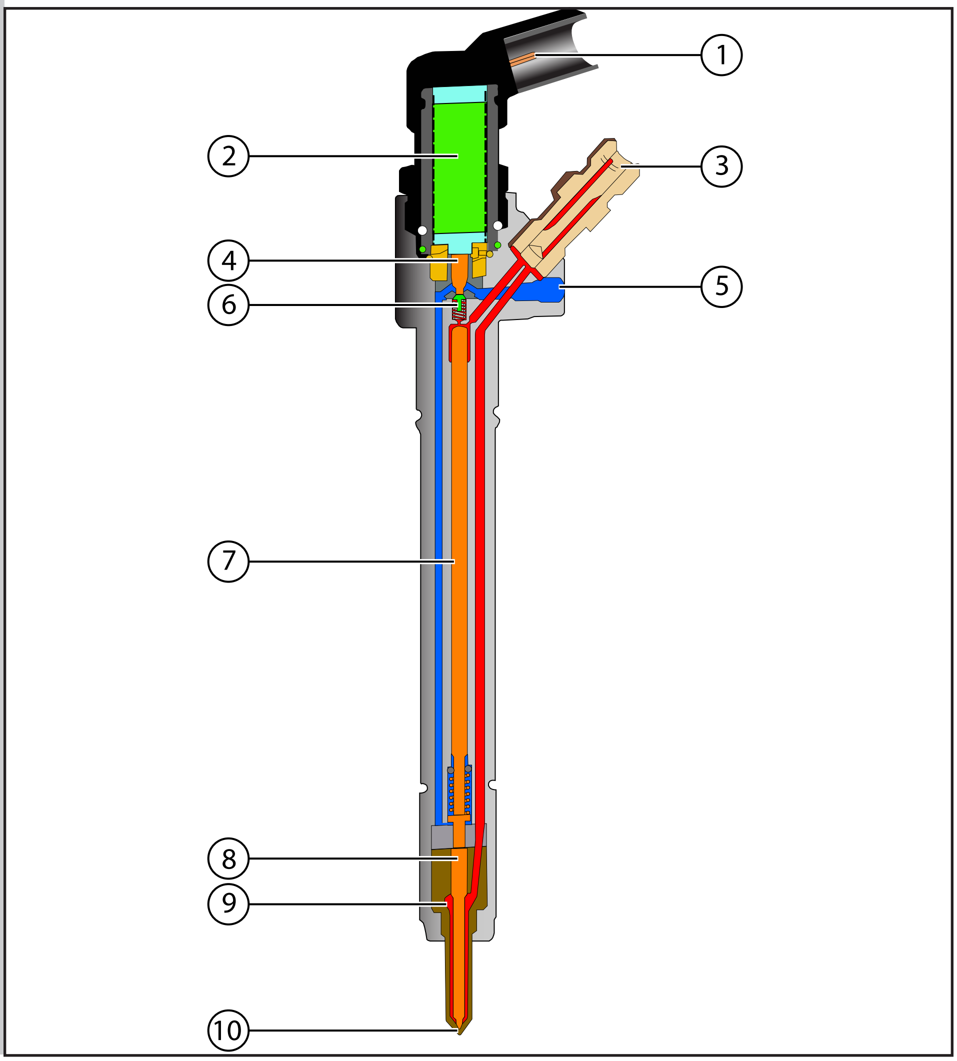
The Piezo fuel injectors inject the necessary amount of fuel into the combustion chamber for all operating conditions of the engine. The injected amount per stroke is constituted from a pre-injection amount and a main-injection amount. This distribution brings about a soft combustion operation of the diesel engine.

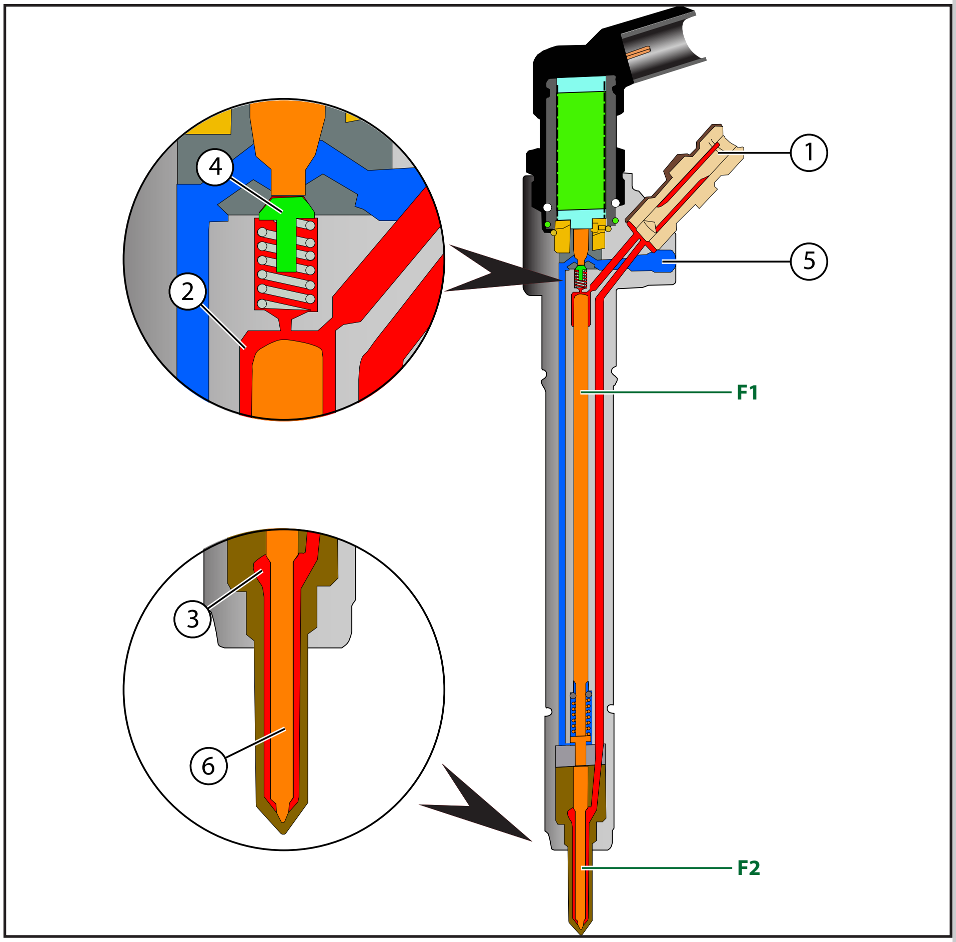
The use of the Piezo actuators allows for:

- Extremely quick response times.
- The injection on and off time can be acutely controlled.
- Repetition is quick and accurate.

Piezo Fuel Injector Cutaway

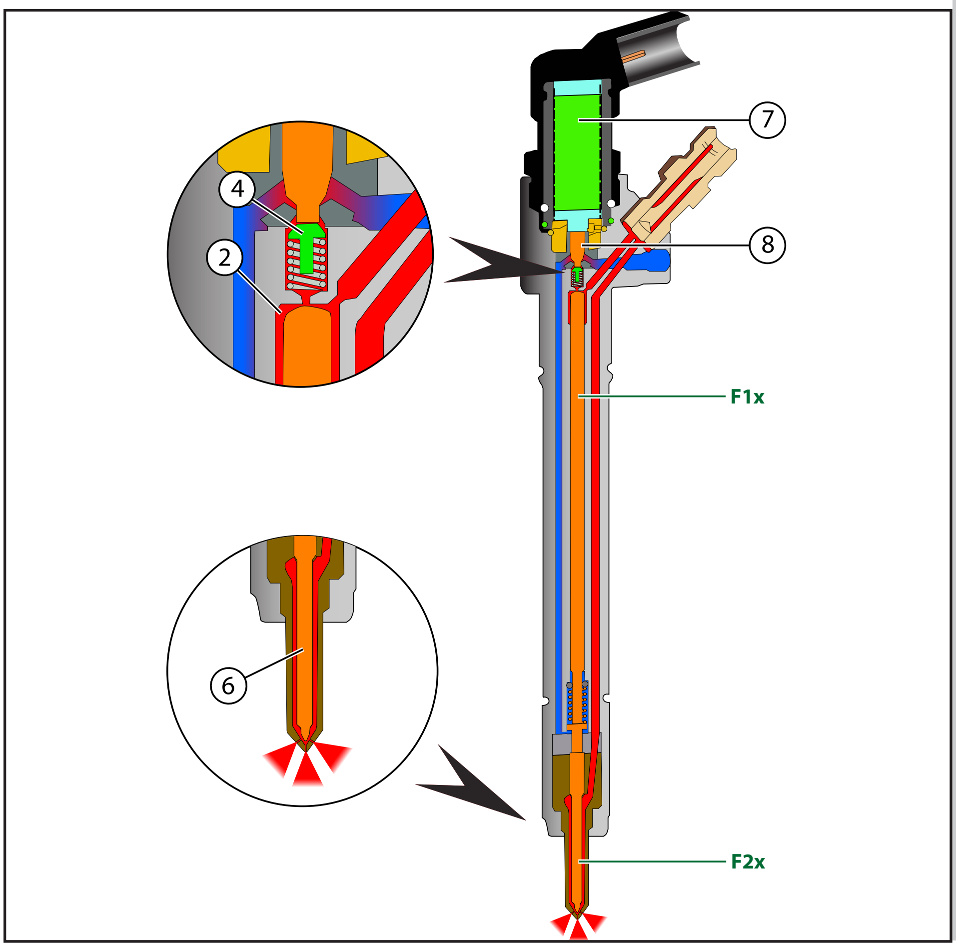
1. Connector to Powertrain Control Module (PCM)
2. Piezo actuator
3. High pressure delivery connection
4. Valve piston
5. Fuel return
6. Valve mushroom
7. Control piston
8. Nozzle needle
9. High pressure fuel chamber
10. Spray hole (6 each)





Injector Non-Injection

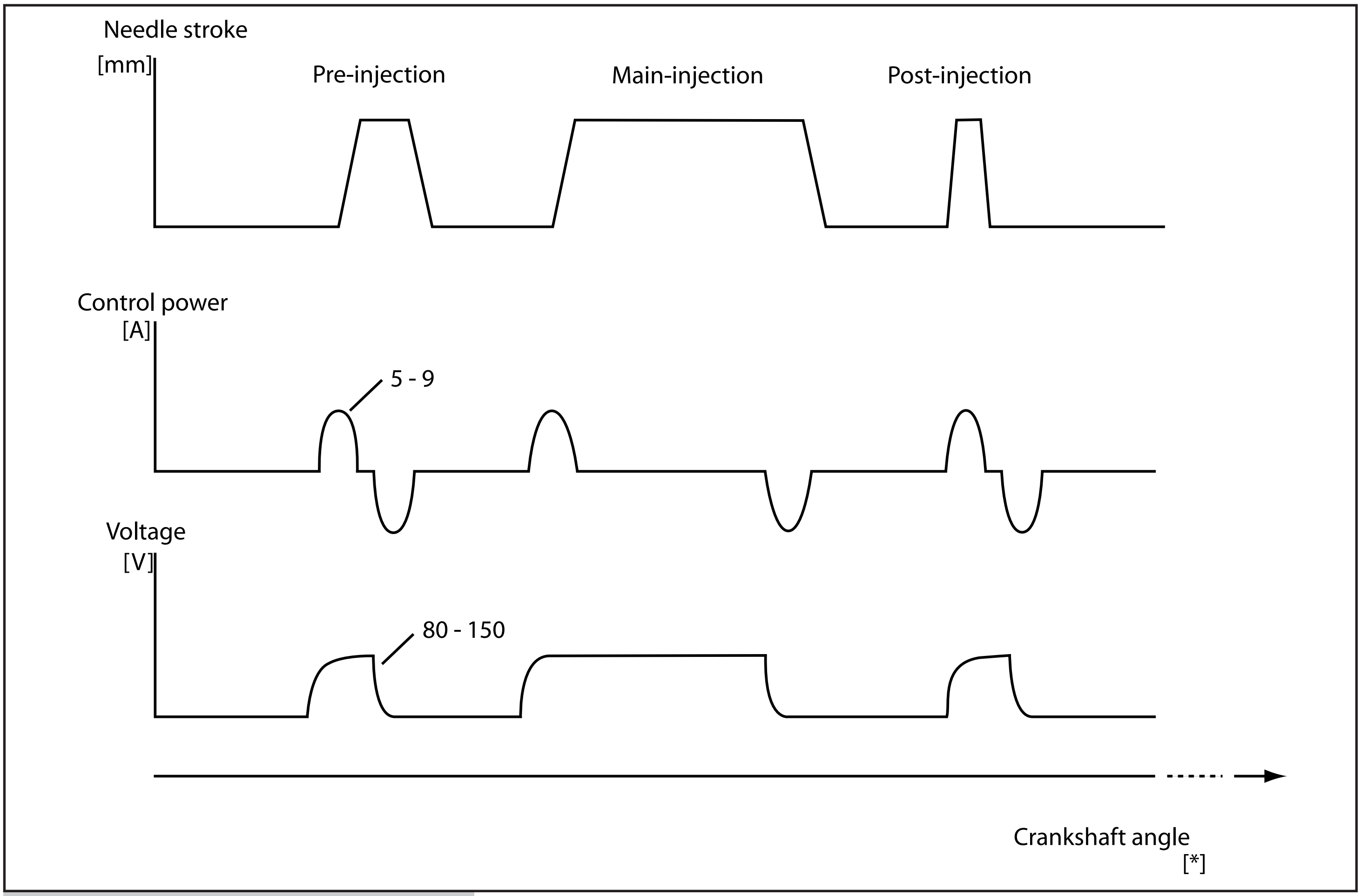
The fuel, which comes from the rail under high pressure, reaches the control chamber (2) and the high pressure chamber (3) of the injector via the high pressure fuel delivery port (1). The passageway to the fuel return line (5) is blocked by the mushroom valve (4). High pressure fuel and a spring keep the mushroom valve closed. The hydraulic force, exerted (F1) through the high pressure of the fuel on the nozzle needle (6) in the control chamber (2), is greater than the hydraulic force which is exerted on the tip of the nozzle (F2), since the surface of the control piston in the control chamber is greater than the surface of the tip of the nozzle. The injector nozzle remains closed.



Injector During Injection

The Piezo actuator (7) presses on the valve piston (8). The valve mushroom (4) opens the passageway which connects the control chamber (2) with the fuel return line. In this manner, a reduction in the pressure occurs in the control chamber and the hydraulic force, which is exerted at the tip of the nozzle (F2x), is greater than the force on the control piston (F1x) in the control chamber. The nozzle needle (6) moves upwards and the fuel reaches the combustion chamber via the 6 spray holes.

For lubrication purposes, a small amount of fuel is directed between the nozzle needle and the guide from the high pressure side, directly into the return line.

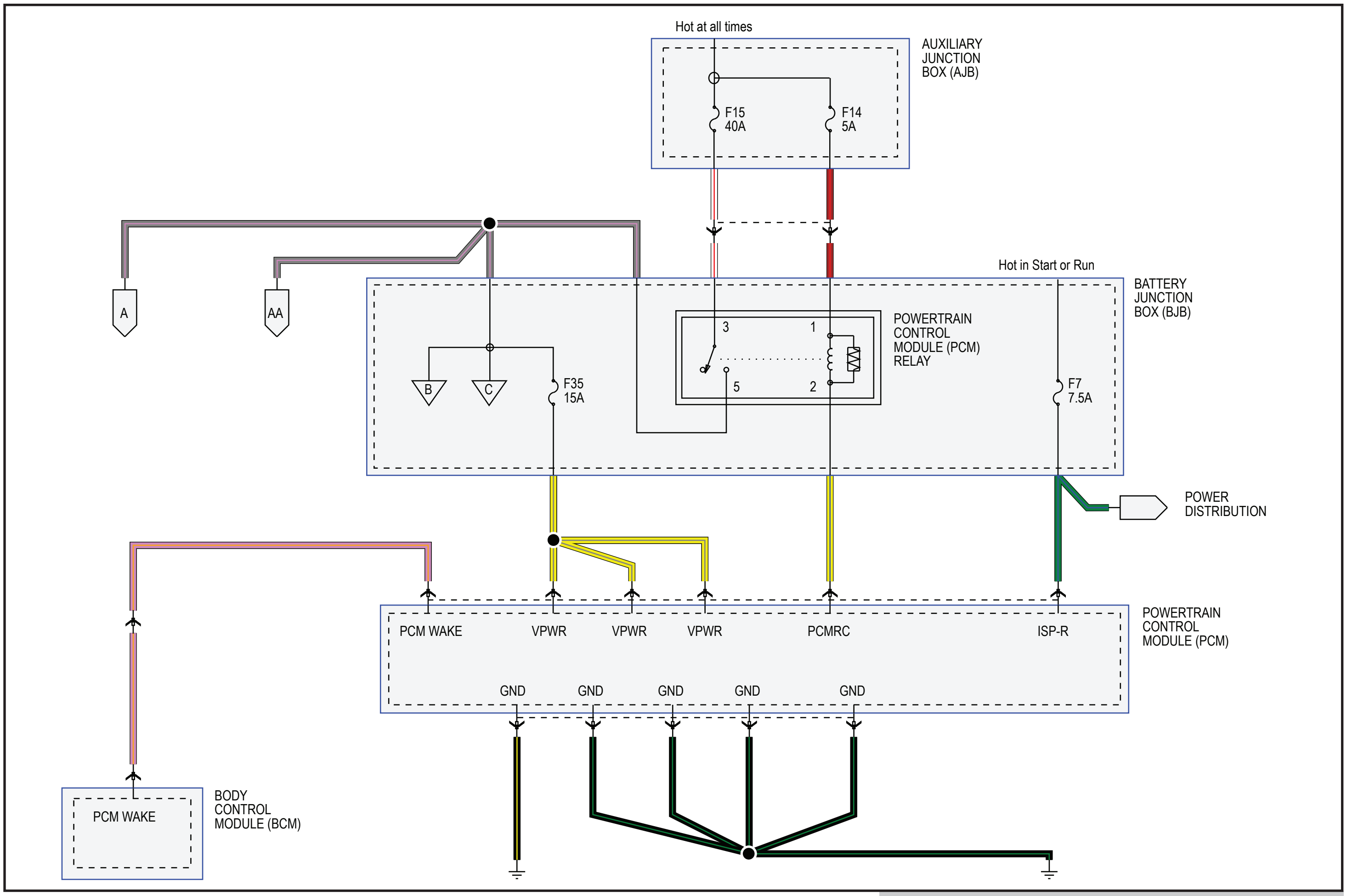


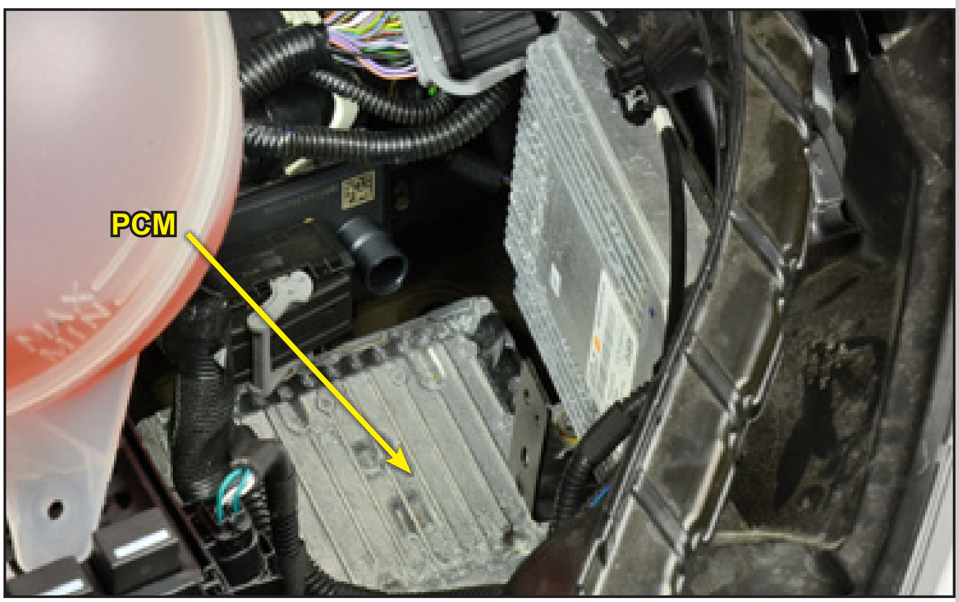
Injector Quantity Adjustment (IQA) Codes

The IQA codes for the injectors can be found on either the injectors or the sticker on the engine front cover.

The PCM uses the IQA code to adjust injector on and off time.

ELECTRICAL COMPONENTS





Powertrain Control Module (PCM)

The Powertrain Control Module (PCM) is located on the drivers side, behind headlight and below degas bottle.

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.

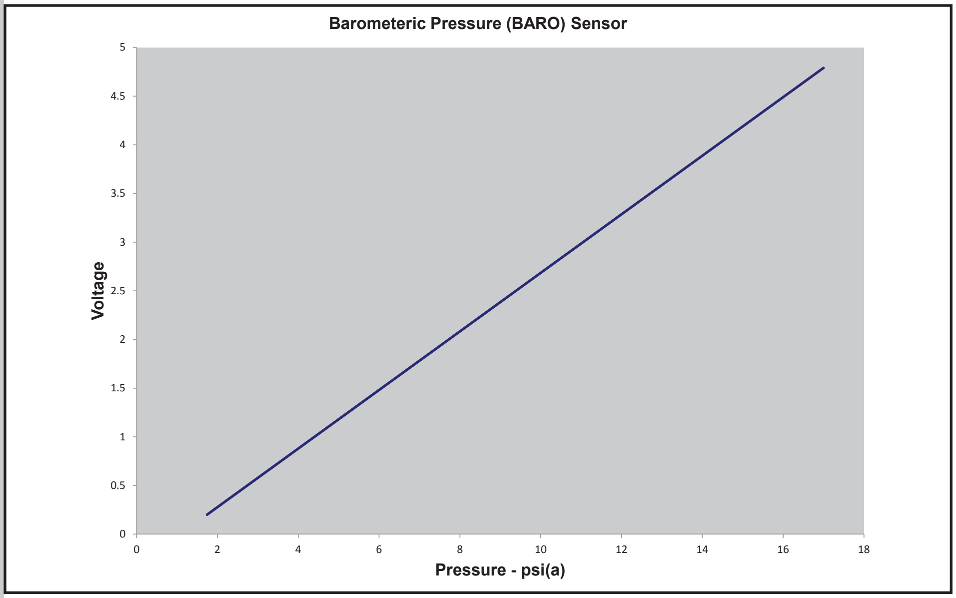
Pressure Sensors

Barometric Pressure (BARO) Sensor

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.

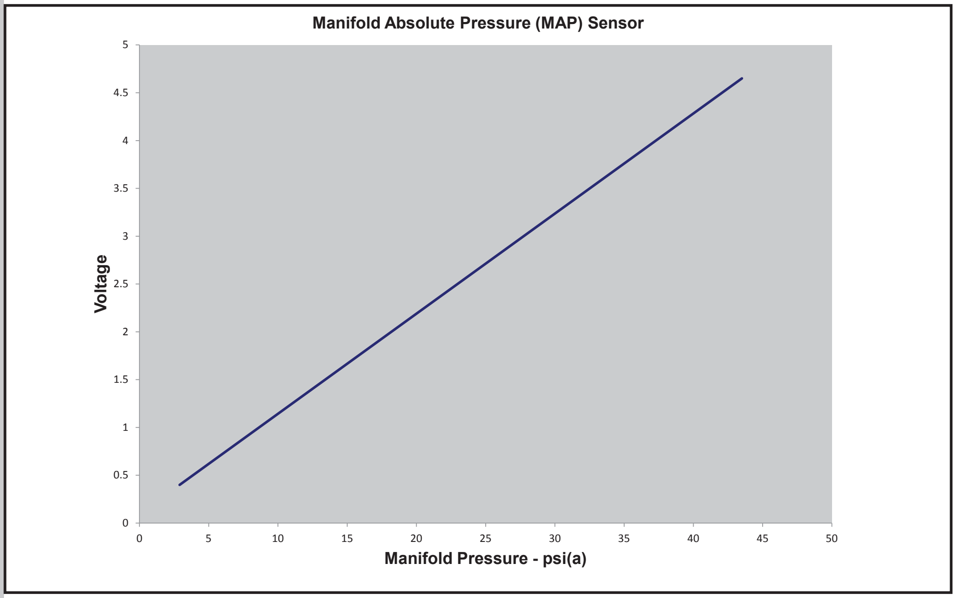
The PCM uses the BARO sensor to determine atmospheric pressure for fuel control, timing, and turbocharger control.



Manifold Absolute Pressure (MAP) Sensor

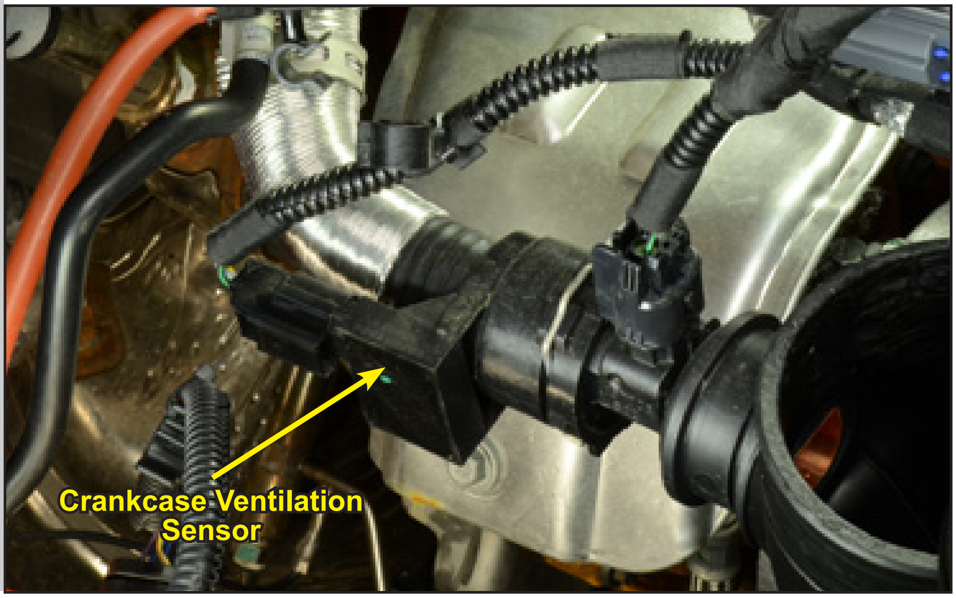
The MAP sensor is a 3-wire variable capacitance sensor. The PCM supplies a 5 volt reference (VREF) signal which the MAP sensor uses to produce a linear analog voltage that indicates pressure.

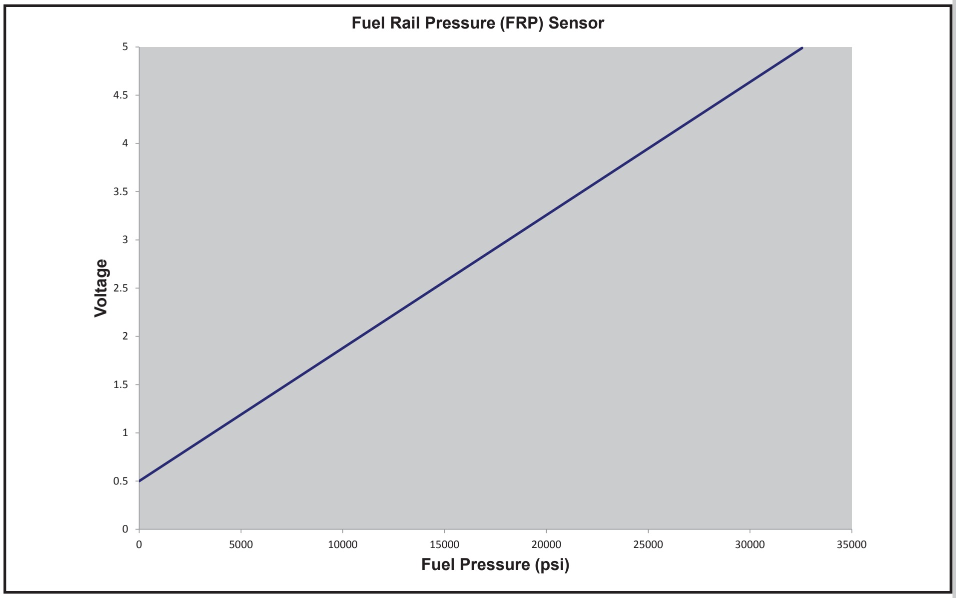
The MAP sensor is used for turbocharger, EGR, and regeneration control.



Crankcase Ventilation Sensor

The crankcase ventilation sensor is a Hall-effect sensor mounted on the crankcase ventilation hose at the air inlet connection. The crankcase ventilation separator is integral to the rocker cover. The crankcase ventilation hose on the air inlet side has a tamper proof connector. The crankcase ventilation sensor monitors the crankcase ventilation hose connection at the fresh air inlet. The crankcase ventilation sensor signal to the PCM indicates if the crankcase ventilation hose is connected or disconnected.

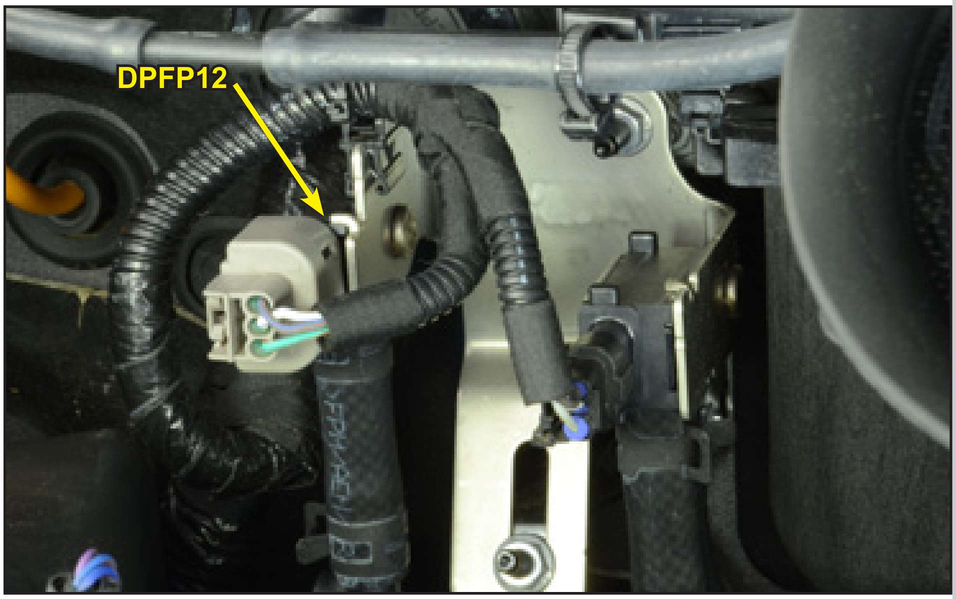




Fuel Rail Pressure (FRP) Sensor

The FRP sensor is a 3-wire variable capacitance sensor. The FRP sensor 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.



Diesel Particulate Filter Pressure (DPFP) Bank 1, Sensor 2

The DPFP12 pressure sensor is a 3-wire variable capacitance sensor. The PCM supplies a 5 volt reference (VREF) signal which the DPFP12 sensor uses to produce a linear analog voltage that indicates pressure.

The DPFP12 sensor measures the exhaust pressure upstream of the diesel particulate filter and is used in the calculation to determine when regeneration is required.

Mass Air Flow and Temperature (MAFT) Sensor

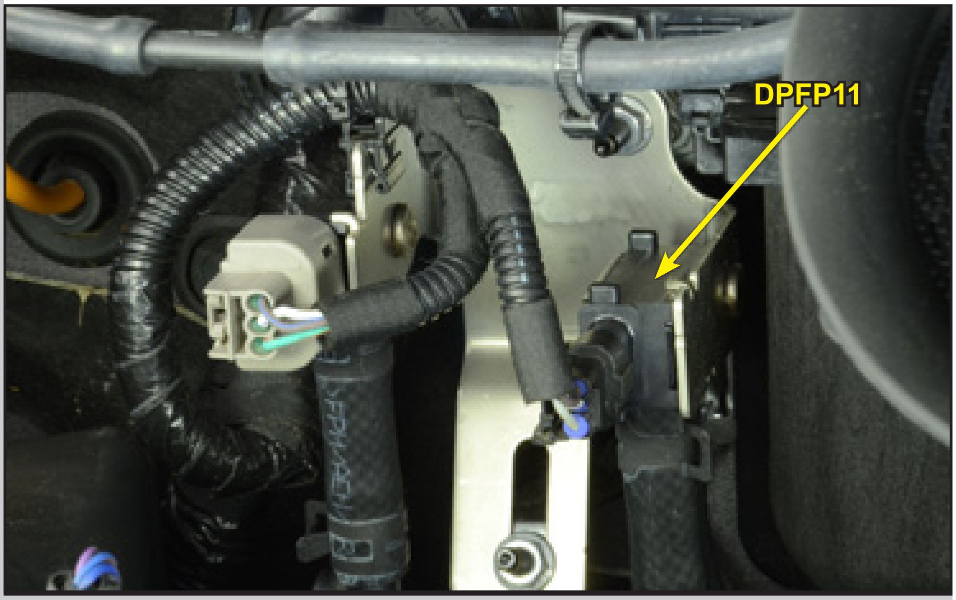
The MAFT sensor uses a hot wire sensing element to measure the air flow rate entering the engine. The hot wire is maintained at a constant temperature. The temperature of the hot wire changes with varying air flow. The current required to keep the constant temperature is measured and converted to a frequency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

PCM uses the MAFT sensor to measure the air flow into the engine. MAFT sensor input is used for EGR, fuel system, and regeneration control.

Diesel Particulate Filter Pressure (DPFP) Bank 1, Sensor 1

The DPFP11 is a delta pressure sensor that is located at the exhaust system and measures pressure both before and after the diesel particulate filter.

The DPFP11 is used in diagnosing the integrity of the Single Brick System (SBS).



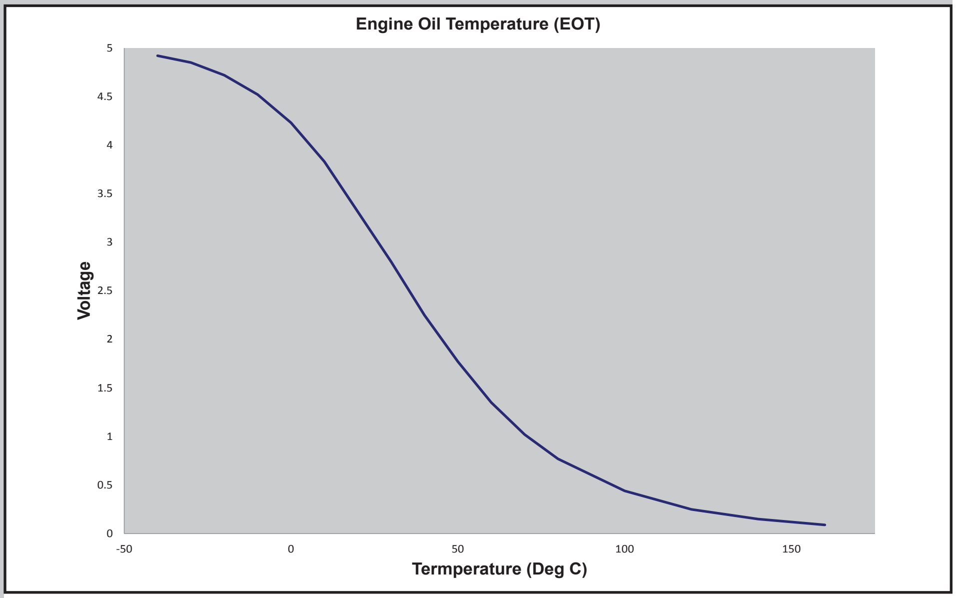
Temperature Sensors

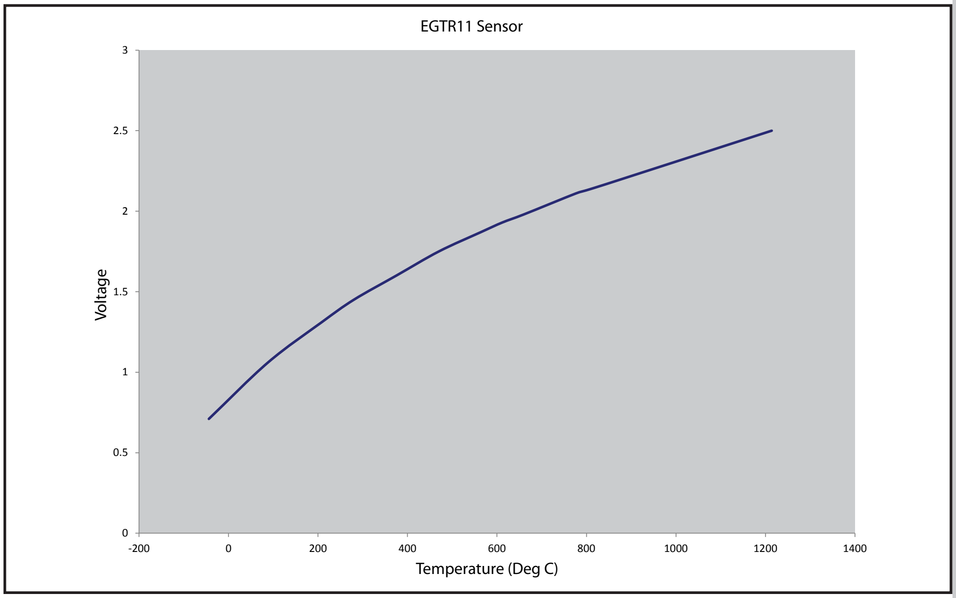
Temperature sensors are thermistor devices in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals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

Engine Oil Level and Temperature Sensor

The Engine Oil Temperature (EOT) sensor is a 2-wire thermistor-type sensor that is part of the engine oil level 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 an input for the cooling fan operation, VGT command, and engine control as well as diagnostics.

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

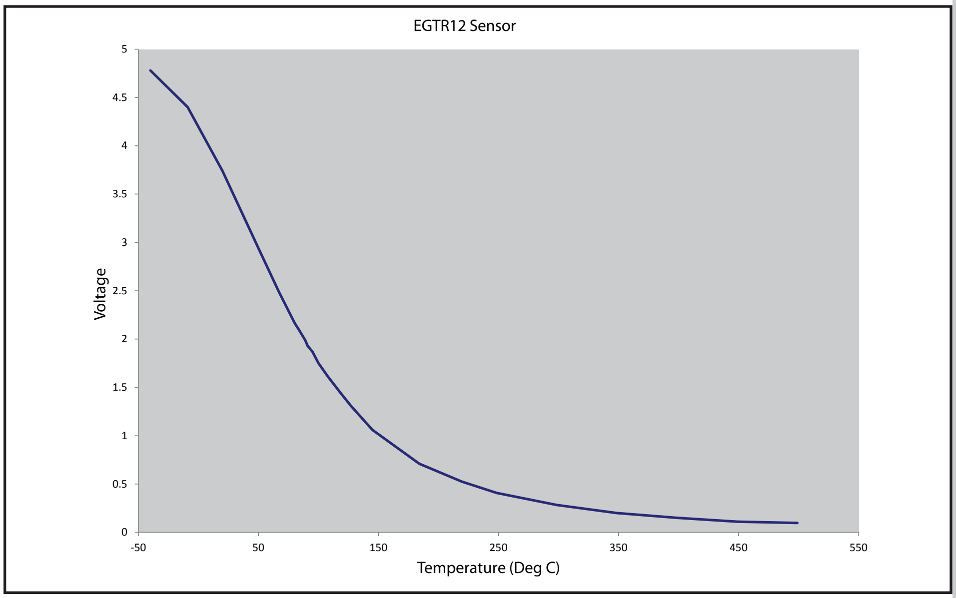




Exhaust Gas Recirculation Temperature (EGRT) Bank 1 Sensor 1

The EGTR11 sensor is a Resistance Temperature Detector (RTD) type sensors. The electrical resistance of the sensor increases as the temperature increases, and resistance decreases as the temperature decreases.

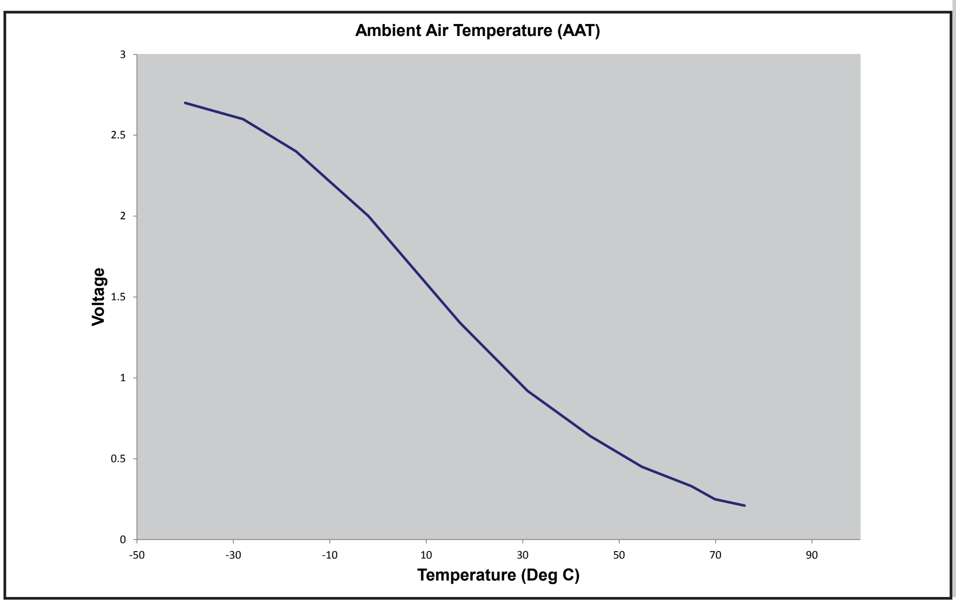
The EGRT11 sensor is used to monitor the exhaust temperature before the EGR cooler and also for engine hardware protection.



Exhaust Gas Recirculation Temperature (EGRT) Bank 1 Sensor 2

The EGRT12 sensor is a 2-wire thermistor-type sensor. The PCM supplies 5 volts to the EGRT sensor circuit. The sensor changes the internal resistance as the temperature changes.

The PCM uses the EGRT12 sensor as an input in determining EGR cooler bypass actuator function, cooler effectiveness.



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.

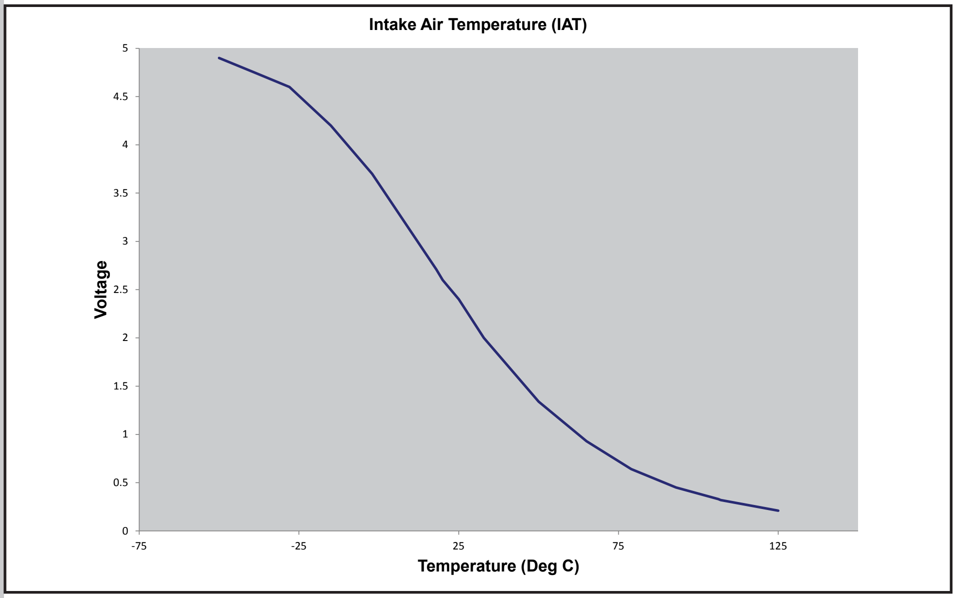
The AAT sensor is used as an input for engine control, particularly engine coolant fan operation, glow plug system control and diagnostics.

The AAT sensor is located in the at the front of the vehicle.

Intake Air Temperature (IAT) Sensor

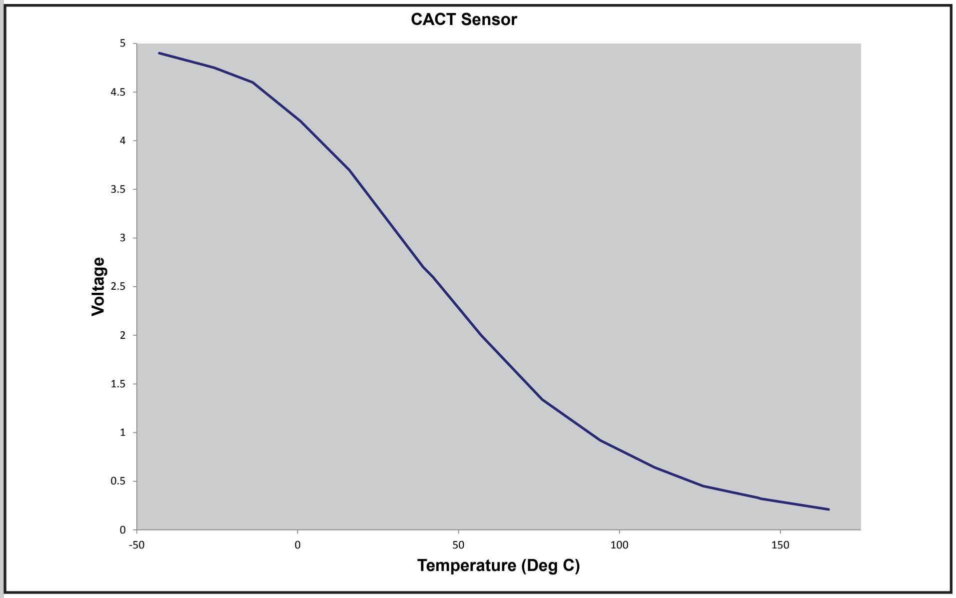
The IAT sensor is a 2-wire thermistor-type sensor. The PCM applies 5 volts to the IAT sensor circuit. The sensor changes the internal resistance as the intake air temperature changes.

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



Charge Air Cooler Temperature (CACT) Sensor

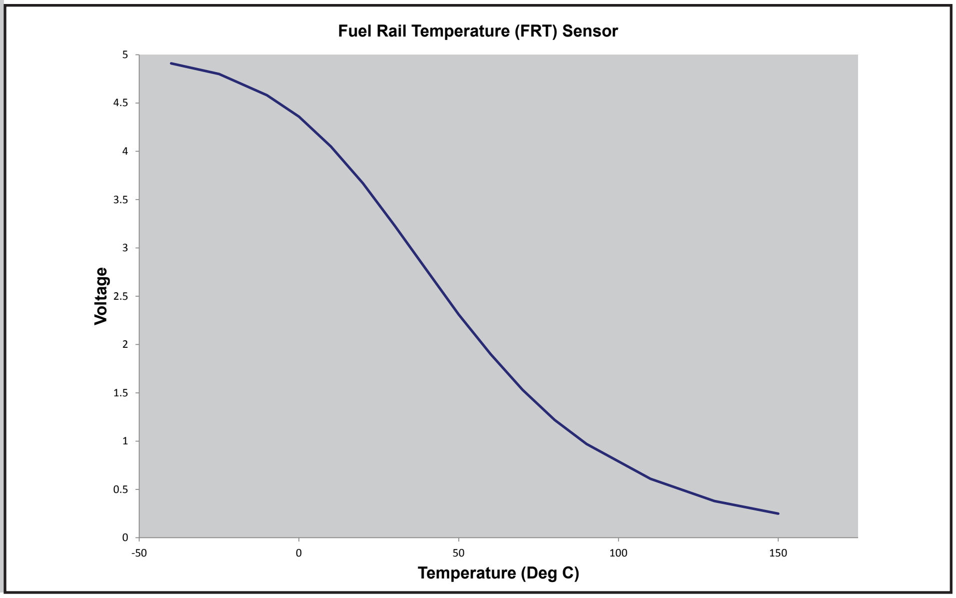
The CACT sensor is a 2-wire thermistor-type sensor. The PCM applies 5 volts to the CACT sensor circuit. The sensor changes the internal resistance as the air temperature changes. The PCM uses the CACT sensor as an input in determining turbocharger vane and EGR position, as well as fuel and regeneration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

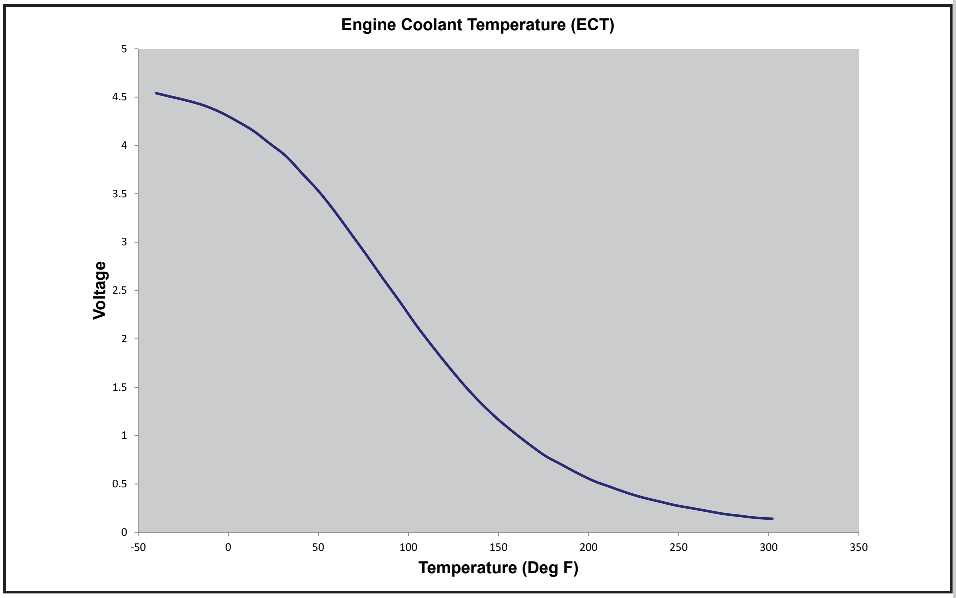


Fuel Rail Temperature (FRT) Sensor

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

The PCM uses the fuel temperature for fuel delivery.

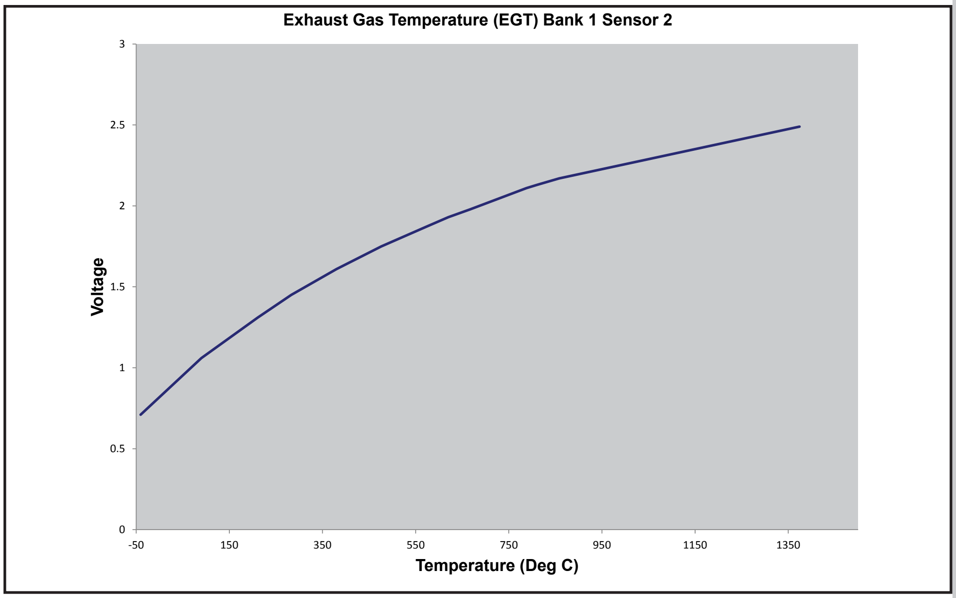




Engine Coolant Temperature (ECT) Sensor

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.

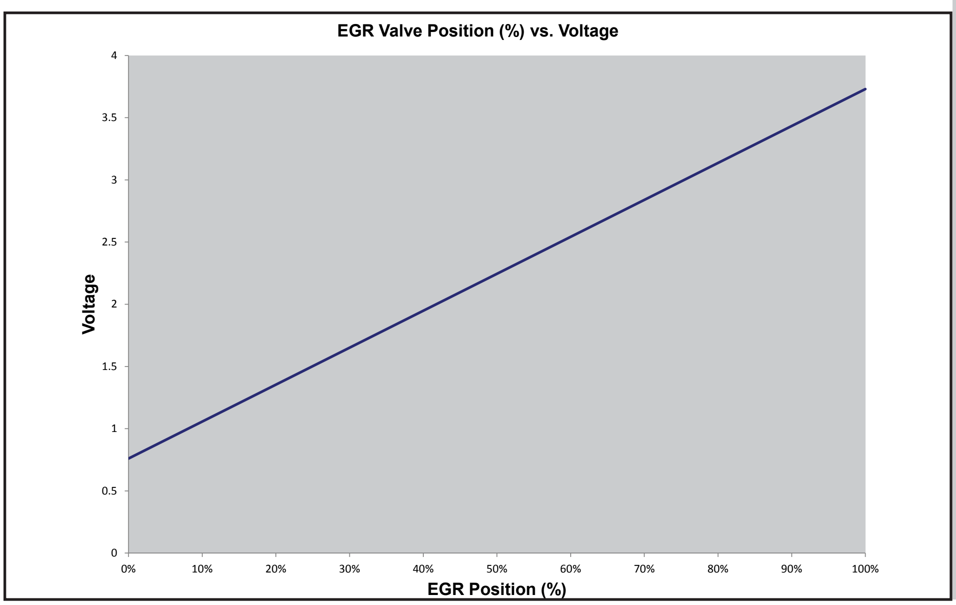
The ECT sensor measures temperature of the cooling system.



Exhaust Gas Temperature (EGT) Sensor

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

There are three EGT sensors used as part of the regeneration reductant injection strategy.



Position Sensors

Exhaust Gas Recirculation Valve Position (EGRVP)

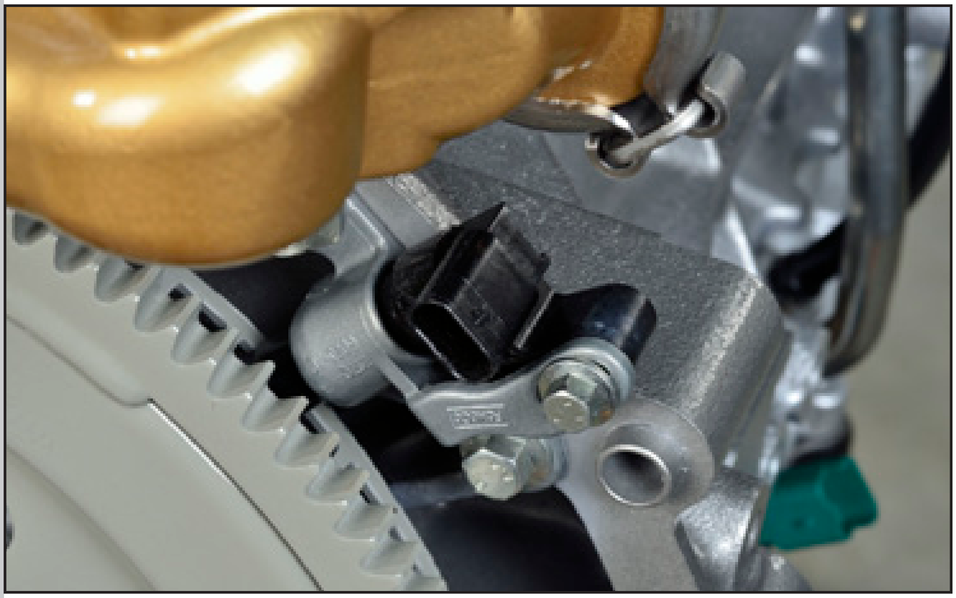
The EGRVP sensor is a 3-wire non-contacting position sensor based upon the magneto-resistive effect (that is, a non-contacting Hall-effect). The PCM supplies a 5 volt reference (VREF) signal which the EGR position sensor uses to produce a linear analog voltage indicating EGRVP.

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

Crankshaft Position (CKP) Sensor

The CKP sensor is a Hall-effect sensor. The PCM filters the information from the sensor which indicates the tooth edges of the magnetic trigger wheel. There are 2 teeth removed to allow the PCM to determine the crankshaft and piston position.

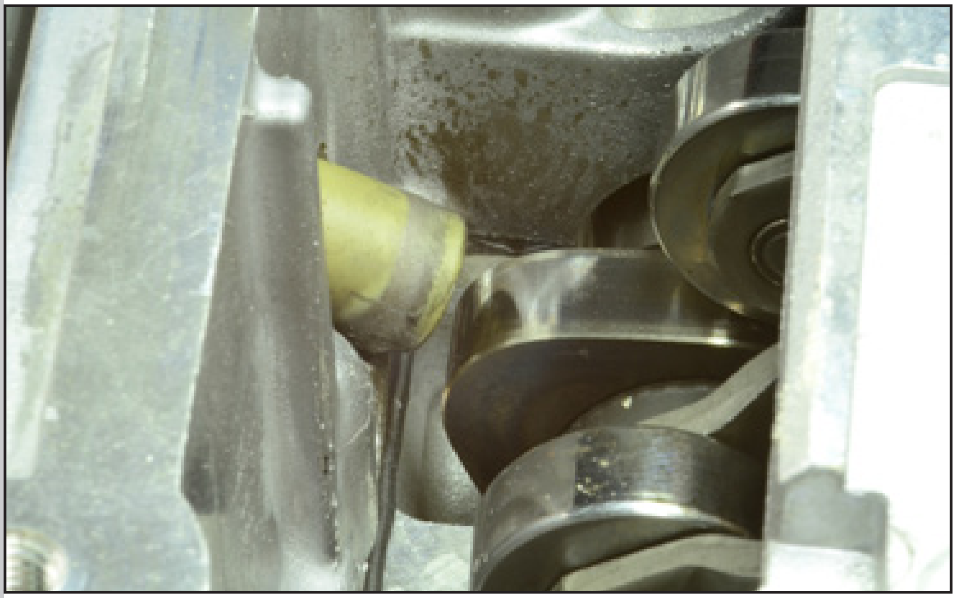
The PCM uses the CKP sensor for engine speed and crankshaft position calculation.



Camshaft Position (CMP) Sensor

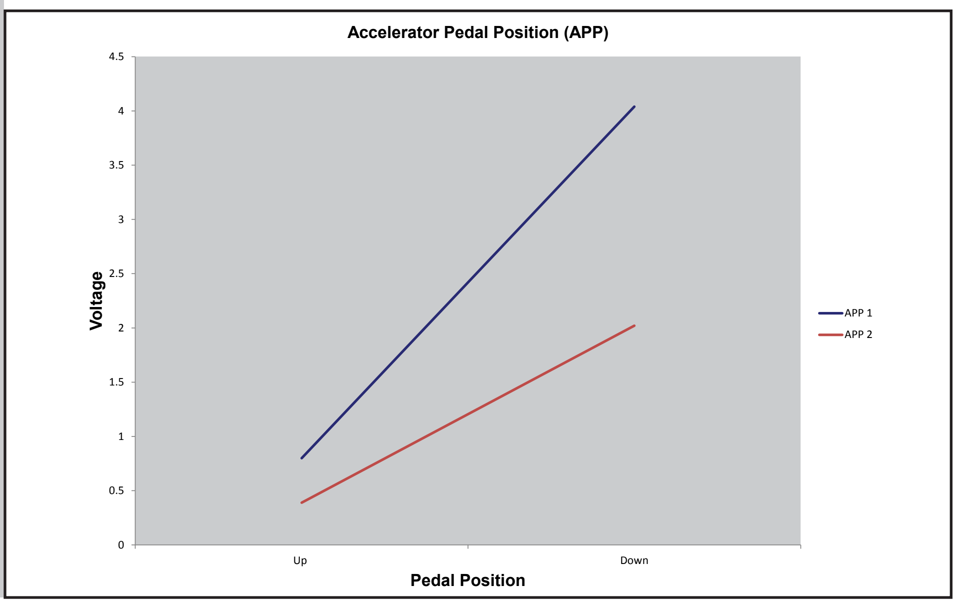
The CMP sensor is a Hall-effect sensor. The PCM filters the information from the sensor which reads a camshaft lobe off the intake camshaft.

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



Accelerator Pedal Position (APP) Sensor

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



Miscellaneous Sensors

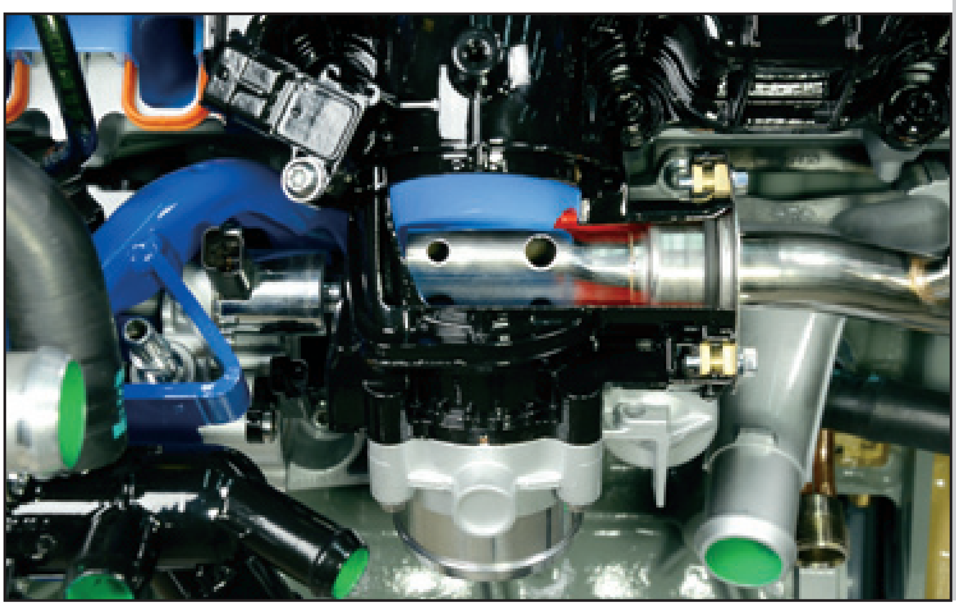
NO_x Sensor

The NO_x sensor is mounted next to the EGT13 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 indicate the effectiveness of the Selective Catalyst Reduction (SCR) system.

Water In Fuel (WIF)

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

The PCM notifies the customer through the Instrument Panel Cluster (IPC) when the water needs to be drained from the FCM to protect the high pressure fuel system.



Outputs

Intake Throttle Body

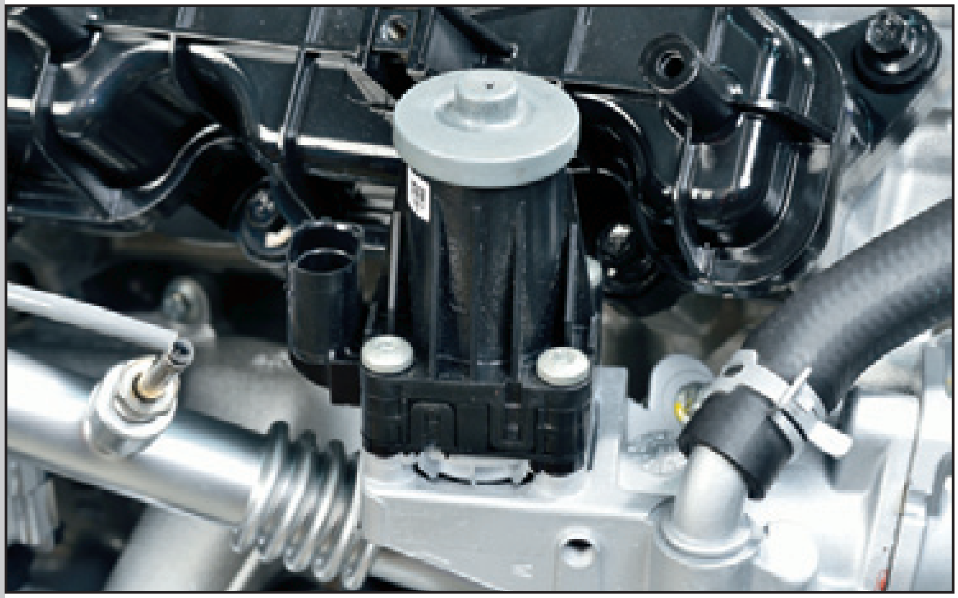
The intake throttle body has an electric DC motor to move the throttle plate. The intake throttle body is controlled by the PCM. The valve is powered in both the open and closed positions.

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

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.

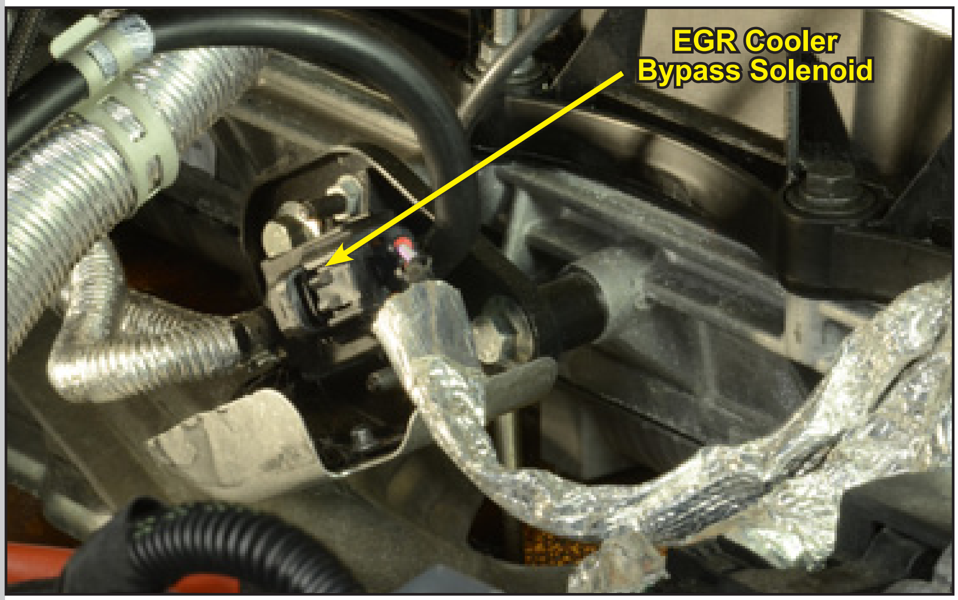
The EGR valve is opened to allow exhaust gases to mix with the intake air for NO_x emissions purposes.



Exhaust Gas Recirculation (EGR) Cooler Bypass Solenoid

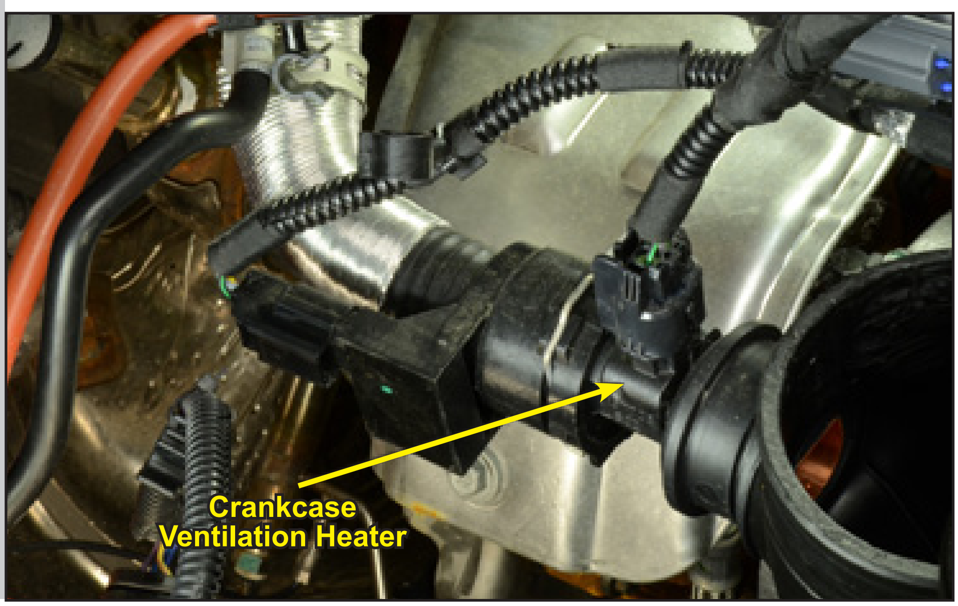
A duty cycle is applied to the solenoid from the PCM to turn vacuum to the actuator on or off. This change causes the EGR cooler bypass door to move.

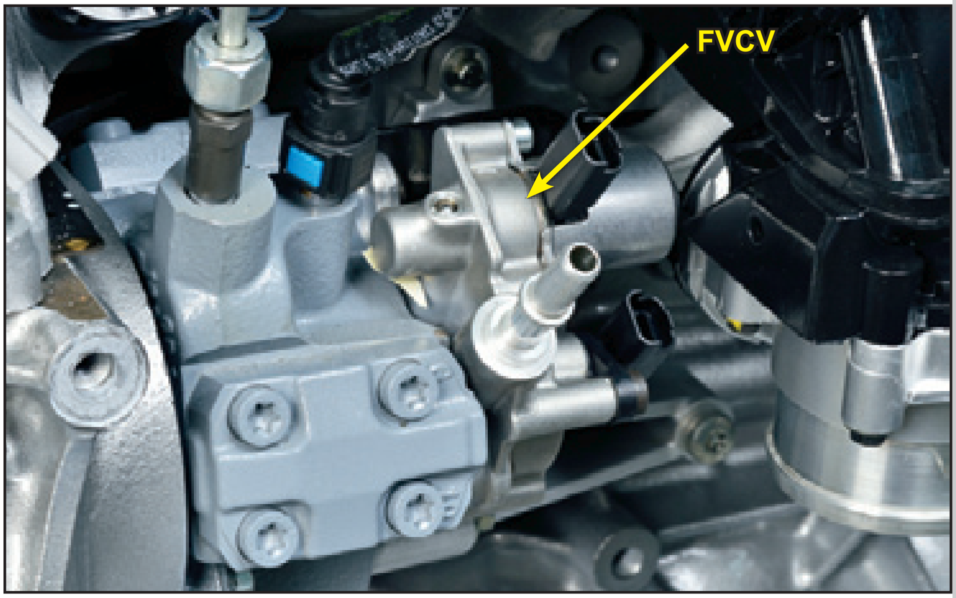
The EGR cooler bypass solenoid changes the state of the EGR cooler bypass door to allow either exhaust gases to bypass the EGR cooler or direct the gases through the EGR cooler.



Crankcase Ventilation Heater

The crankcase ventilation heater heats the crankcase ventilation system vapor to keep any oil that may be present from sludging in the Charge Air Cooler (CAC), turbocharger and intake manifold. The crankcase ventilation heater is located on the crankcase ventilation hose, between the crankcase ventilation sensor and the fresh air inlet. For additional information on the crankcase ventilation system, refer to Crankcase Ventilation System in this section.





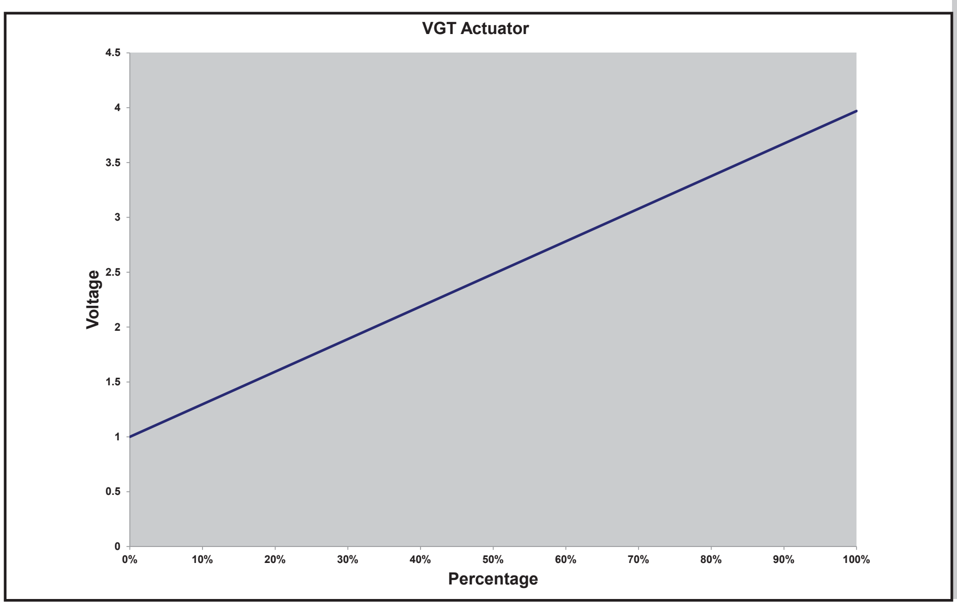
Fuel Volume Control Valve (FVCV)

The fuel FVCV 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 FVCV.

The PCM regulates fuel volume by controlling the on/off time of the fuel FVCV 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 PCM controls on and off time of the fuel injectors. The piezo actuator device allows extreme precision during the injection cycle.

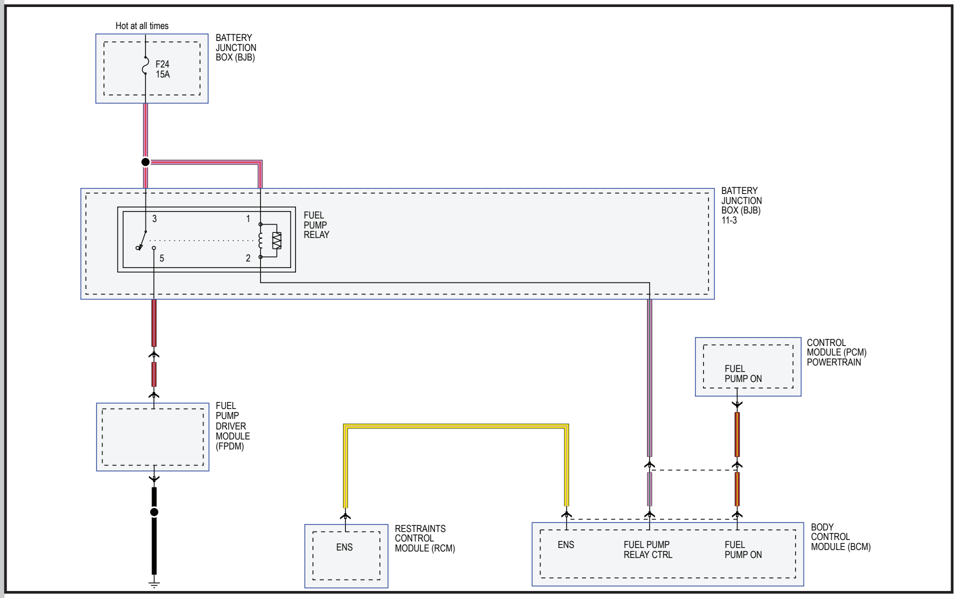


Variable Geometry Turbocharger (VGT) Actuator

The VGT actuator is mounted in between the turbocharger and the engine. The VGT actuator is commanded by the PCM based on engine speed and load. A servo motor is used to adjust the VGT vanes to the correct position.

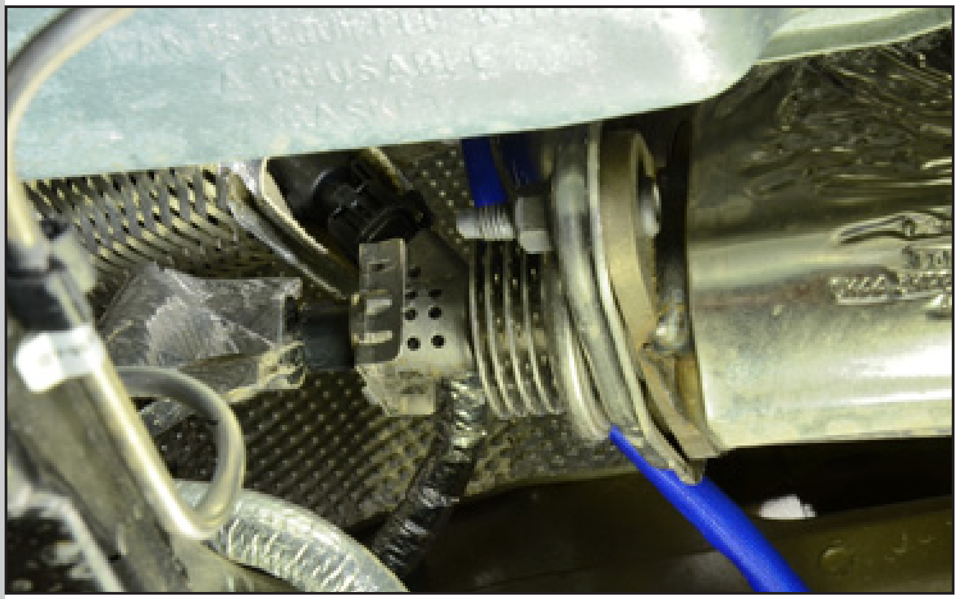
Fuel Pump Relay

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

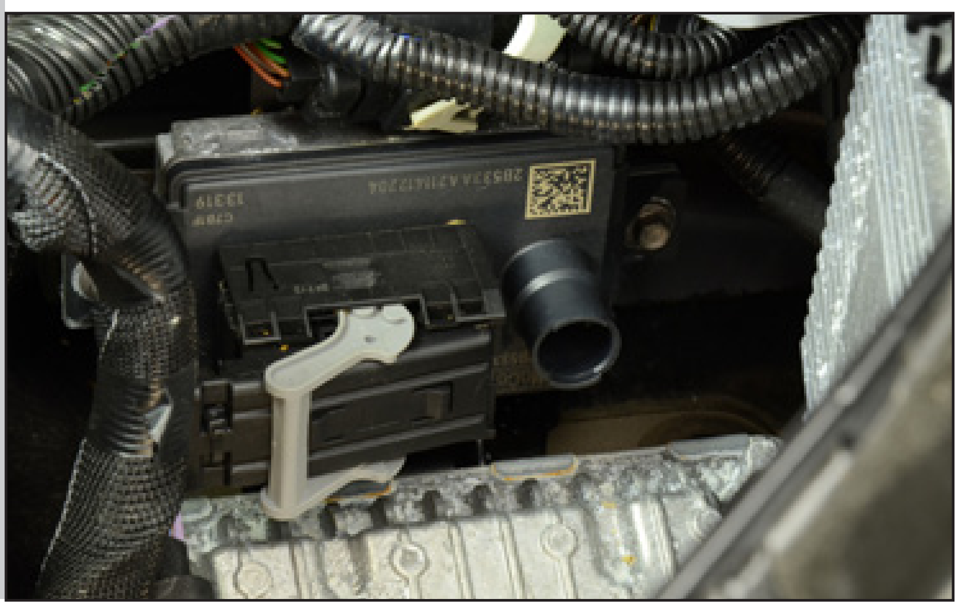
The reductant dosing module is mounted in between the Single Brick System (SBS) and Selective Catalyst Reduction (SCR) catalysts. The reductant dosing module is the part that injects the Diesel Exhaust Fluid (DEF) into the exhaust system.

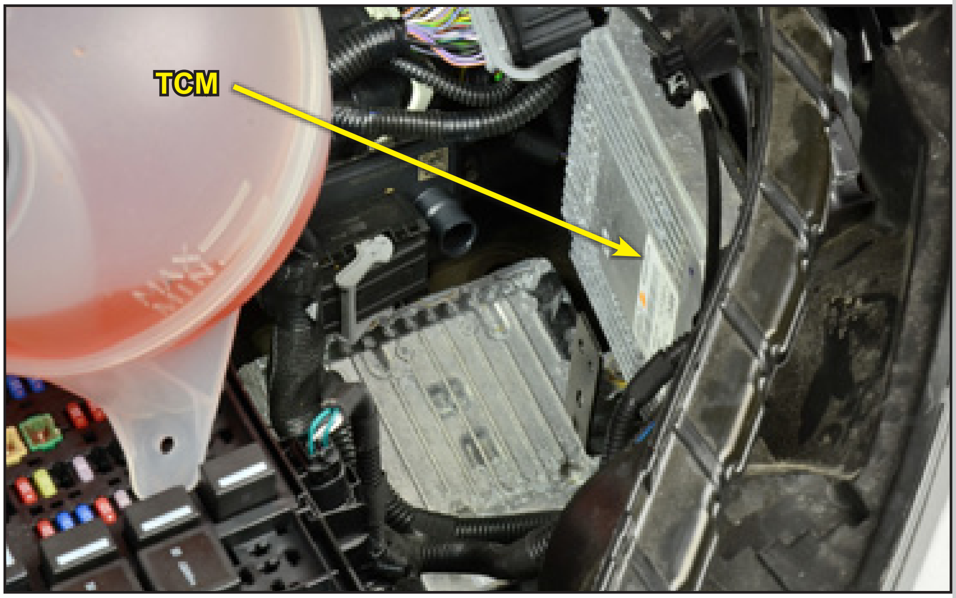


Glow Plug Control Module (GPCM)

The GPCM is located behind the driver side headlight and under the cooling system degas bottle.

The PCM commands the GPCM to power the individual glow plugs, which the GPCM does by providing battery voltage.

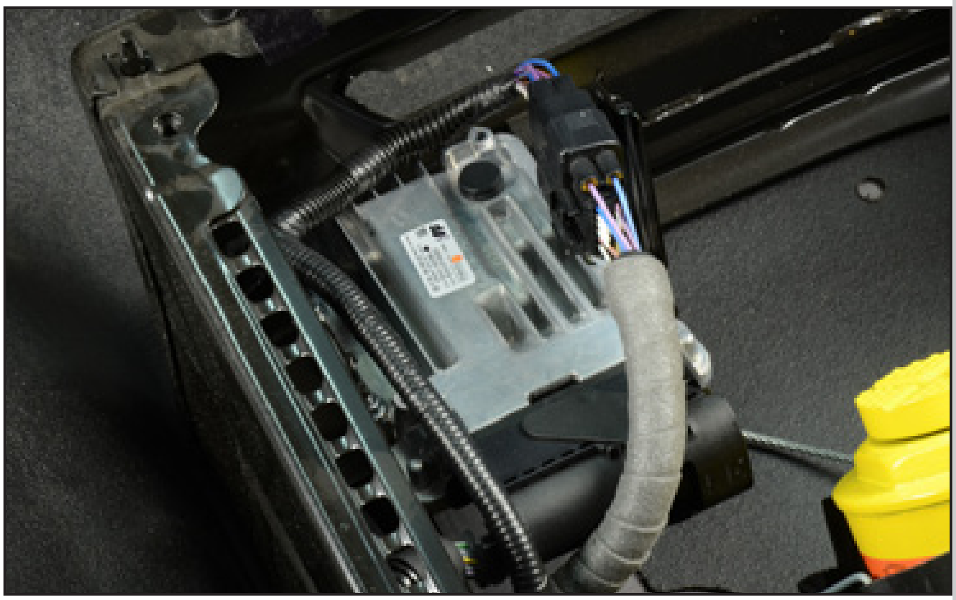




Transmission Control Module (TCM)

The TCM is located behind the driver side headlight and under the cooling system degas bottle.

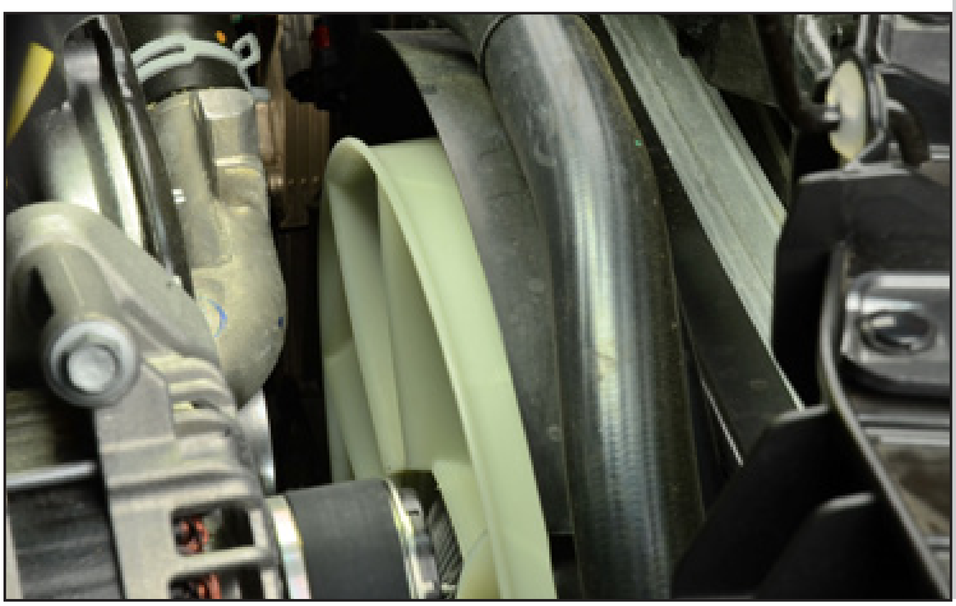
The TCM controls the operation of the transmission.



Reductant Dosage Control Module (RDCM)

The RDCM is mounted under the passengers seat.

The RDCM controls all aspects of the SCR system. The reductant dosage control module monitors the NO_x modules, calculates the amount of reductant required to reduce NO_x levels in the exhaust stream, and commands the reductant injector to provide the calculated amount. The reductant dosage control module also monitors and controls the reductant pump assembly, the reductant heaters and sender assembly.



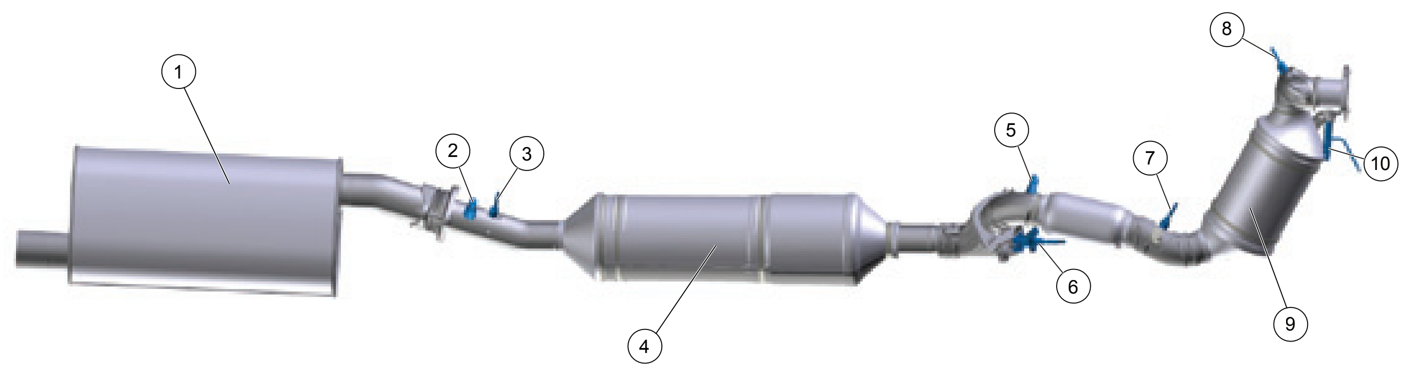
Cooling Fan

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

NOTES

EXHAUST SYSTEM

Exhaust gases exit the exhaust ports on the right side of the engine and are directed to the turbine inlet of the turbocharger and to the EGR Cooler bypass valve. The hot exhaust gas and heat spins the turbine wheel inside the turbocharger. The turbine wheel spins the compressor wheel via their common shaft. Exhaust exiting the turbine is directed to the SBS and exhaust system. Some of the exhaust from the exhaust manifold is directed to the EGR cooler or bypass via the EGR cooler bypass valve. The EGR Cooler bypass valve routes the exhaust gas flow to the EGR cooler and EGR cooler bypass. The PCM controls the operation of the valve routing the gases through either the EGR cooler or EGR cooler bypass. After the gases flow through the EGR cooler, the EGR valve controls if the exhaust gas flow goes through into the intake manifold. The exhaust gas enters the intake manifold and combines with the fresh air.



Number	Component	Number	Component
1	Muffler	6	Reductant dosing module
2	NO_x Sensor (NO_x12)	7	Exhaust Gas Temperature Sensor (EGT12)
3	Exhaust Gas Temperature Sensor (EGT13)	8	Exhaust Gas Temperature Sensor (EGT11)
4	Selective Catalyst Reduction (SCR)	9	Single Brick System (SBS)
5	NO_x Sensor (NO_x11)	10	Fuel vaporizer system glow plug

Single Brick System (SBS)

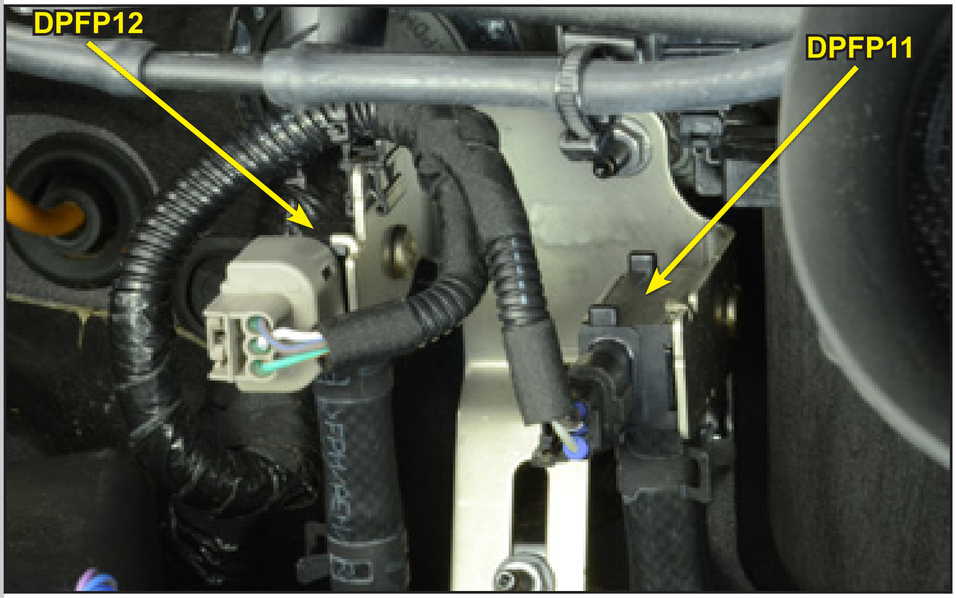
On the 3.2L Transit the Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF) have been integrated into a single catalyst called the Single Brick System (SBS). The SBS is a highly engineered aluminum titanate that both oxidize hydrocarbons in the exhaust and captures particulates.

The DOC oxidizes hydrocarbons in the exhaust and generates heat for the SCR and DPF to function properly.

The DPF is a 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.

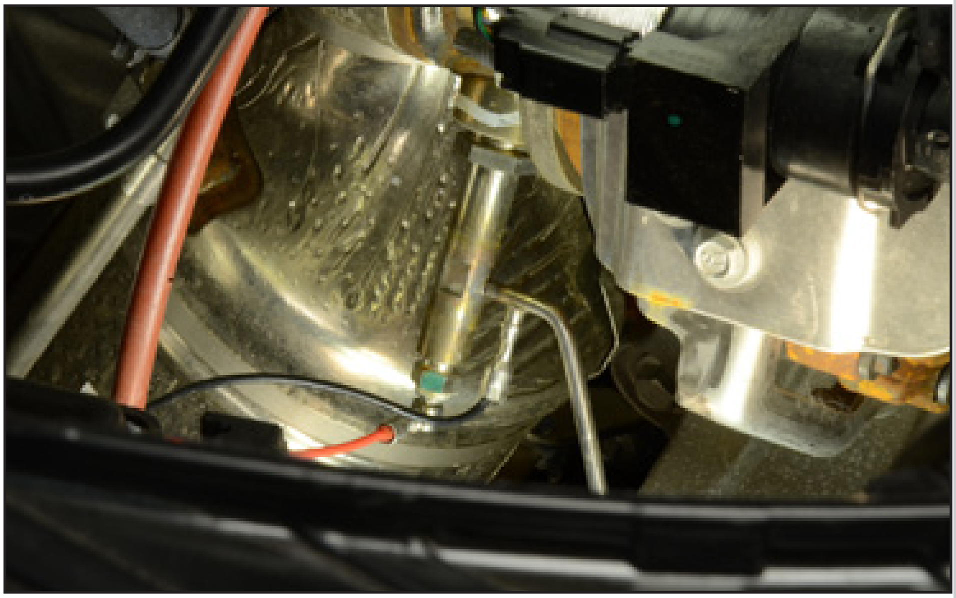
DPF Pressure Sensors

There are two DPF pressure sensors. The first sensor is a single point, Diesel Particulate Filter Pressure Bank 1 Sensor 2 (DPFP12) used in the calculation to determine when regeneration is required. The second sensor, Diesel Particulate Filter Pressure Bank 1 Sensor 1 (DPFP11) is a delta pressure sensor used in diagnosing the integrity of the SBS.



Selective Catalyst Reduction (SCR)

The SCR reduces NO_x in the exhaust. To do this the SCR system injects Diesel Exhaust Fluid (DEF) into the exhaust stream as it passes through a ceramic catalyst coated with copper and iron.



Fuel Vaporizer System Glow Plug

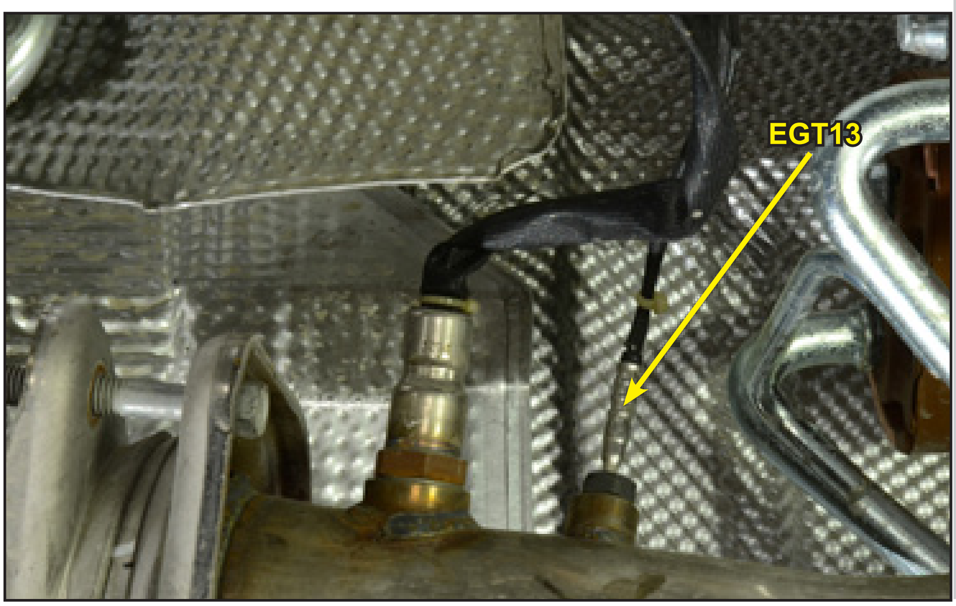
The fuel vaporizer system glow plug is mounted in the aftertreatment system before the SBS.

Fuel is delivered by the fuel vaporizer system pump and injected by the fuel vaporizer system glow plug when the PCM commands a regeneration. The fuel increases the exhaust gas temperature in the SBS to burn off particulates in the DPF.

Note that the fuel vaporizer system glow plug does not ignite the fuel it only vaporizes the fuel.

Fuel Vaporizer System Fuel Pump

The fuel vaporizer system fuel pump delivers fuel to the fuel vaporizer system glow plug when the PCM commands a DPF regeneration. The vaporizer pump is located inside the left frame rail forward of the fuel tank.

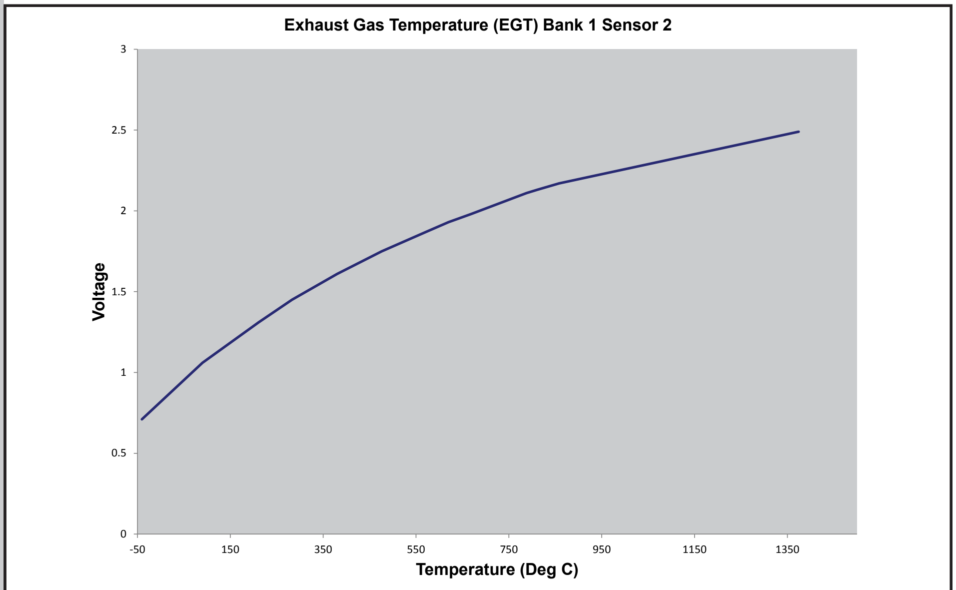


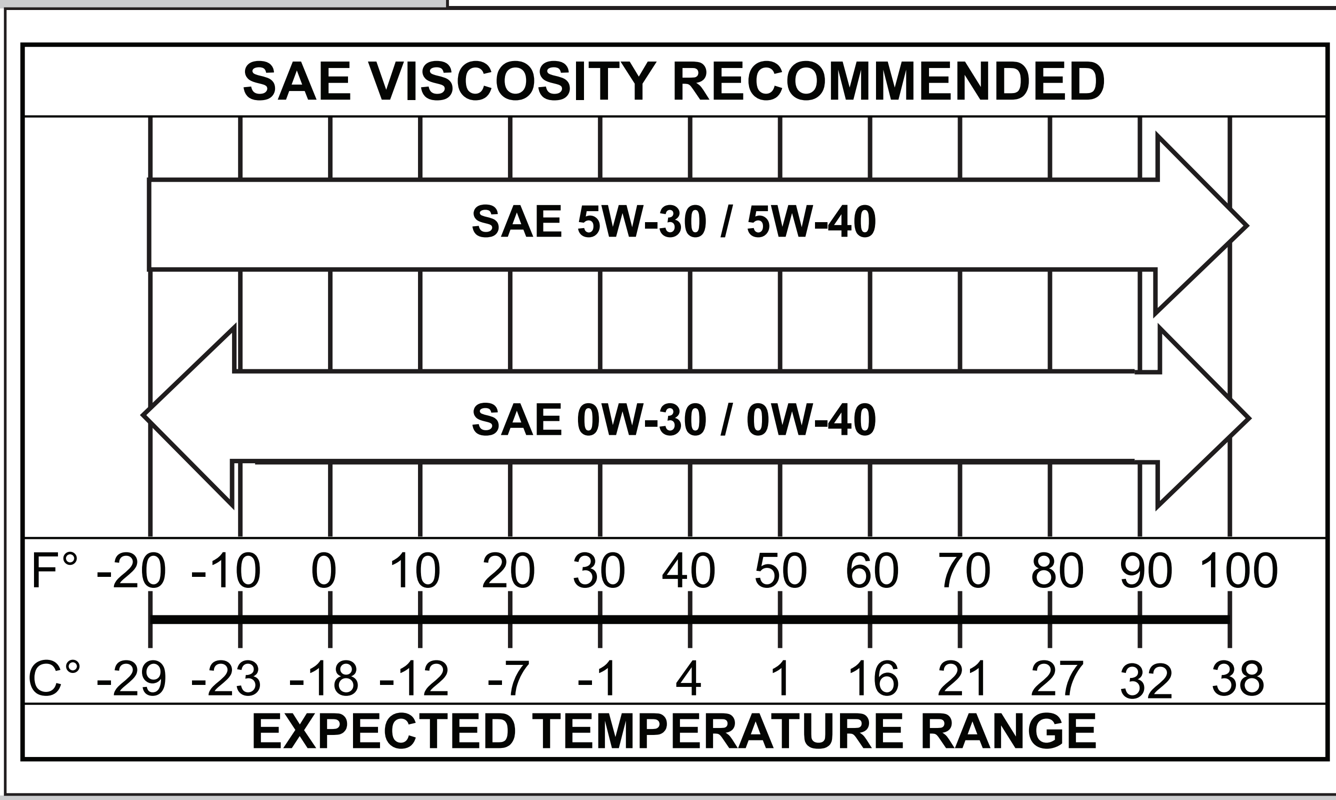
Exhaust Gas Temperature (EGT) Sensors

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 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 the EGT sensors to monitor the exhaust gas temperature.





Recommended Motor Oil

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 SBS.

The use of correct oil viscosities for diesel engines is important for satisfactory operation. Using the SAE Viscosity Grade chart, determine which oil viscosity best suits the temperature range you expect to encounter for the next service interval.

When using biodiesel (grades B5-B20), SAE 5W-40 API CJ-4 is recommended.

The service interval for the engine oil depends on the vehicle operating conditions. Change the engine oil and filter as indicated by the information display. For off road operation or operating the vehicle in dusty, or sandy conditions it is recommended to change the engine oil and filter every 8000 km (5000 miles) or six months.

Consult the maintenance schedule for the proper maintenance interval for the operating conditions.

Use the same engine oil and filter change intervals when using synthetic engine oil.

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

- Increased particulate matter in the aftertreatment system may cause more ash build up in the SBS
- More frequent DPF regenerations
- Reduction of SBS 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 SBS. Regeneration can be commanded by the PCM or the scan tool.

The PCM starts regeneration of the SBS if the soot load exceeds a calibrated value and other conditions such as engine temp, fuel temp, and in the case of active regeneration vehicle speed are met. The PCM determines the load condition of the SBS, based on the exhaust gas pressure upstream of the SBS. 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 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 PCM is indicating the need for regeneration.

The PCM automatically activates the DSI vaporizer, fuel vaporizer 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 SBS 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 SBS is necessary.

CAUTION: The manual regeneration of the SBS 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. On vehicles that are rarely are driven above 24-32 km/h (15-20 mph), the regeneration process can be temporary disabled, so it can be performed at a different time.

Post Regeneration

After regeneration, the PCM reads the pressure at the DPF pressure sensor and compares it with a calibrated value.

Non-Burnable Ash

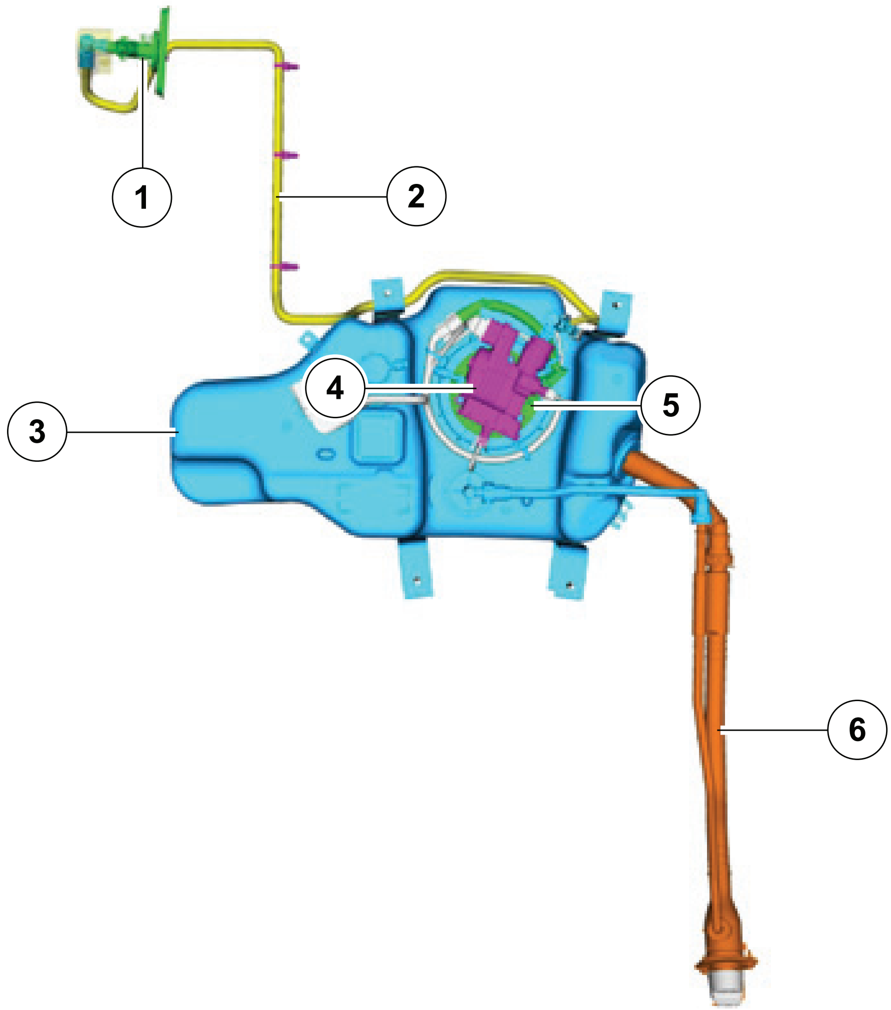
Over time a slight amount of non-burnable ash builds up in the SBS which is not removed during the regeneration process. Ash comes from the fuel, oils and other materials that remain after the DPF regeneration process. The SBS may need to be removed for ash cleaning and replaced with a new or remanufactured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

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

Selective Catalyst Reduction (SCR) System Operation

The SCR system reduces Oxides of Nitrogen (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 more efficiently because of the ability of the SCR system to eliminate high NO_x levels produced under lean conditions.



Number	Component	Number	Component
1	Reductant injector	4	Reductant pump
2	Reductant pressure line	5	Reductant heater and sender assembly
3	Reductant tank	6	Reductant tank filler hose

Selective Catalyst Reduction (SCR)

The SCR system components include:

- Diesel Exhaust Fluid (DEF)
- Reductant Dosage Control Module (RDCM)
- 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
- Pre and post NO_x sensor and module
- Exhaust mixing system

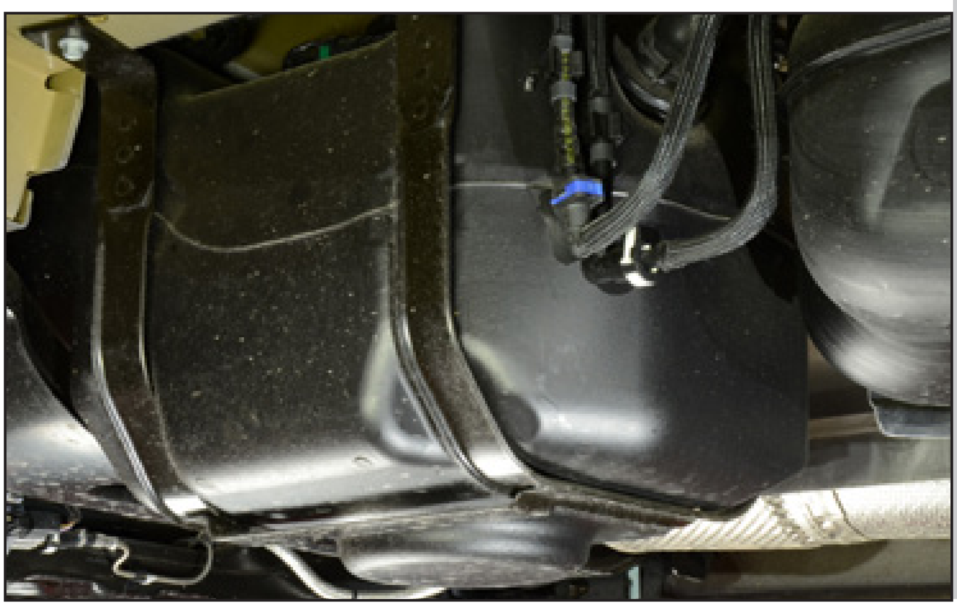
Reductant Dosage Control Module (RDCM)

The RDCM controls all aspects of the SCR system. The RDCM monitors the NO_x modules, calculates the amount of reductant required to reduce NO_x levels in the exhaust stream, and commands the reductant injector to provide the calculated amount. The RDCM also monitors and controls the reductant pump assembly, the reductant heaters and sender assembly. The RDCM communicates with the NO_x sensors and the PCM over the Controller Area Network (CAN) circuits.

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.

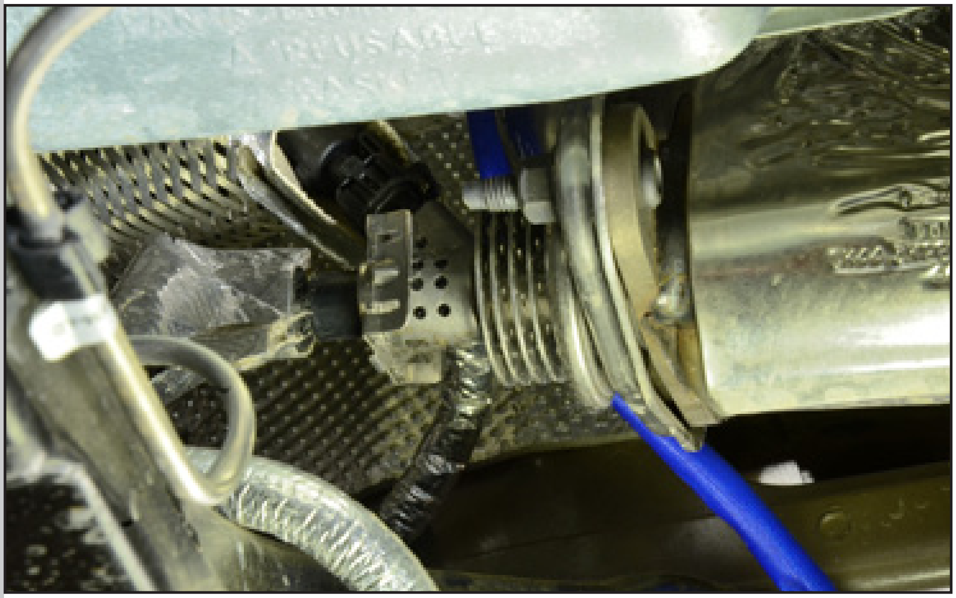


Reductant Tank

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

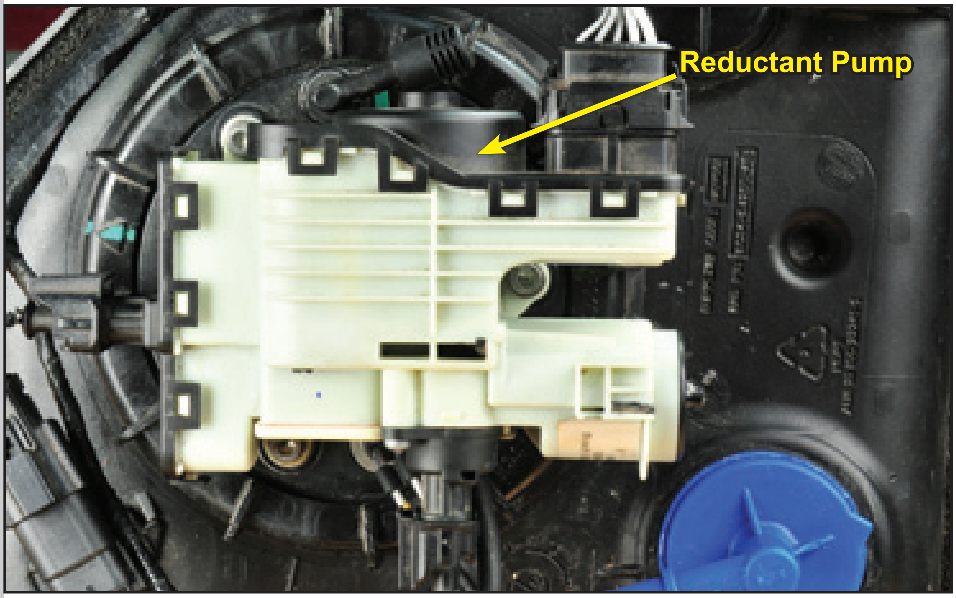
Reductant Dosing Module

The reductant dosing module is controlled by the RDCM. 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.



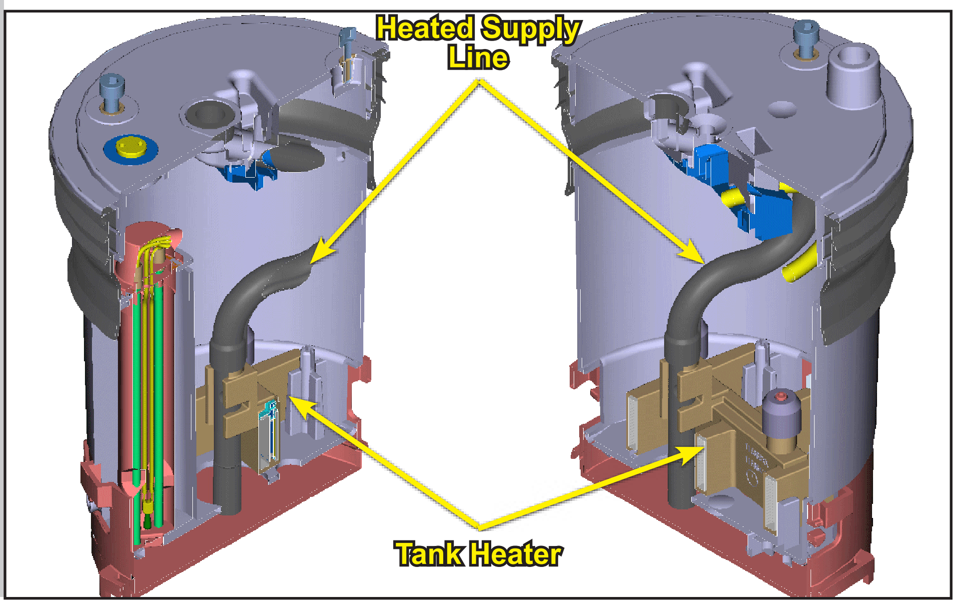
Reductant Pump

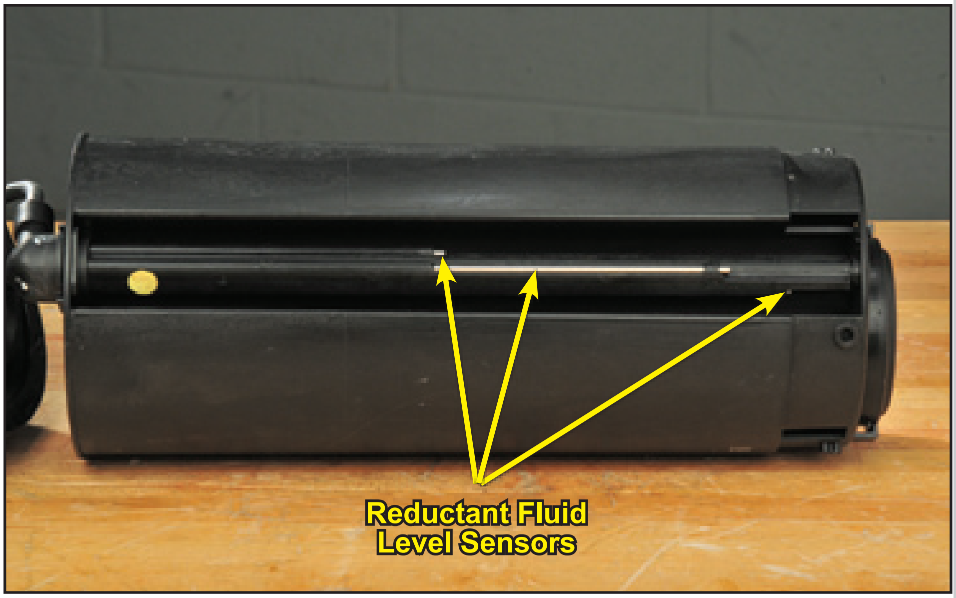
The reductant pump supplies reductant to the dosing module. One unique function of the pump is that when the ignition is turned off, the pump pulls all the reductant out of the lines. This prevents damage to the lines if the reductant was to freeze.



Reductant Heaters

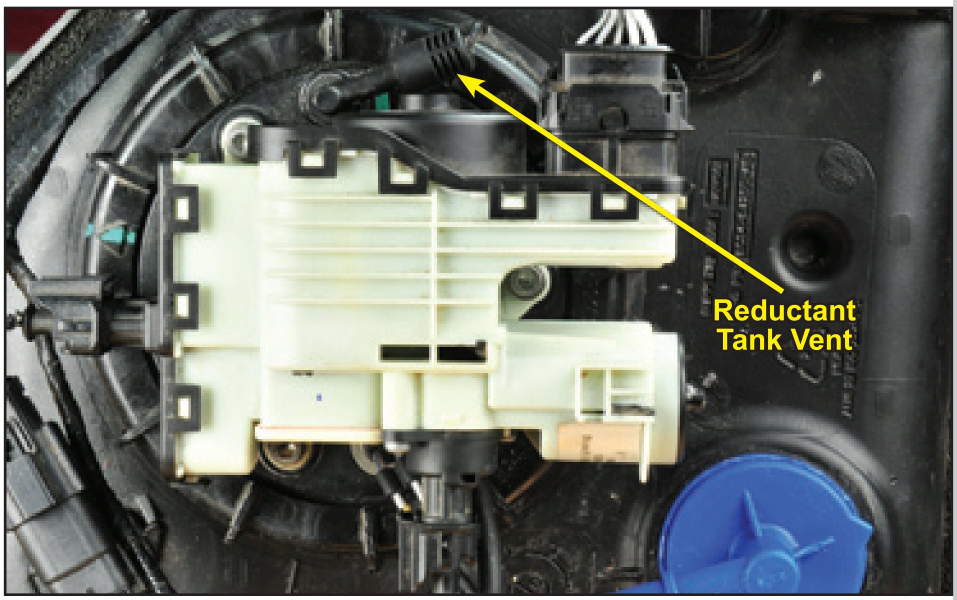
Below a specified temperature the RDCM activates the heaters in the reductant system. The reductant system has heaters in the tank, pump, and lines. The heaters in the tank thaw the DEF if it is frozen and allow it to flow to the pump without freezing. The heaters in the pump and lines allow the DEF to flow to the injector without freezing.





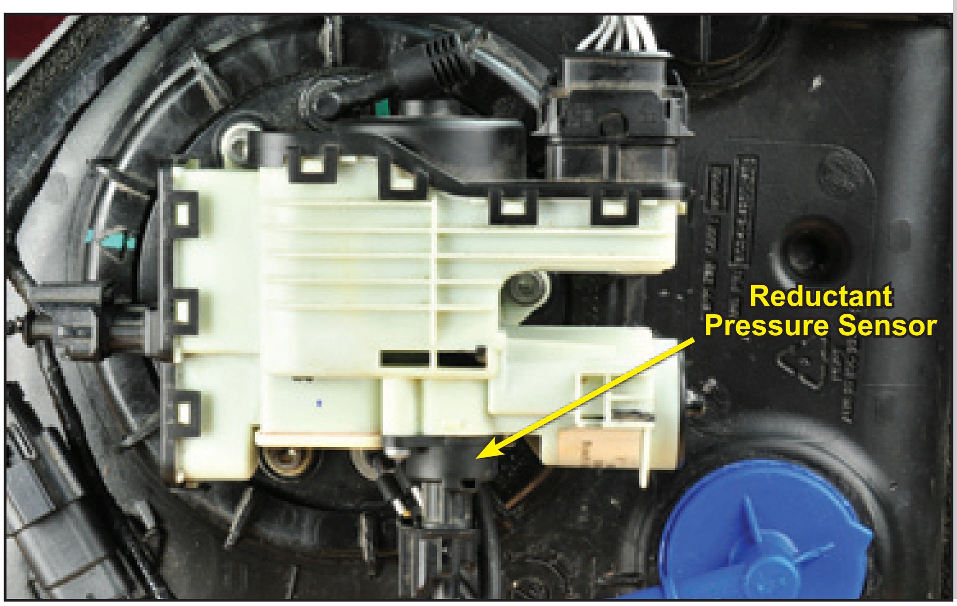
Reductant Fluid Level Sensors

The reductant fluid level sensor operates by using four electrodes (one not visible in the picture) 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 Tank Vent

The reductant tank vent allows the fluid tank pressure to equalize with atmospheric pressure. Pressure differences are caused by temperature and reductant usage.

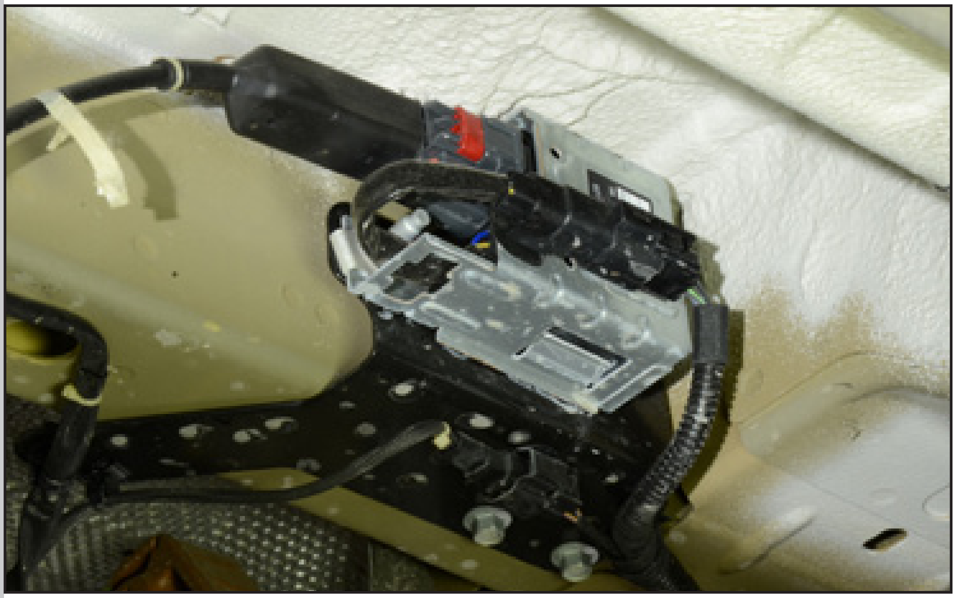


Reductant Pressure Sensor

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

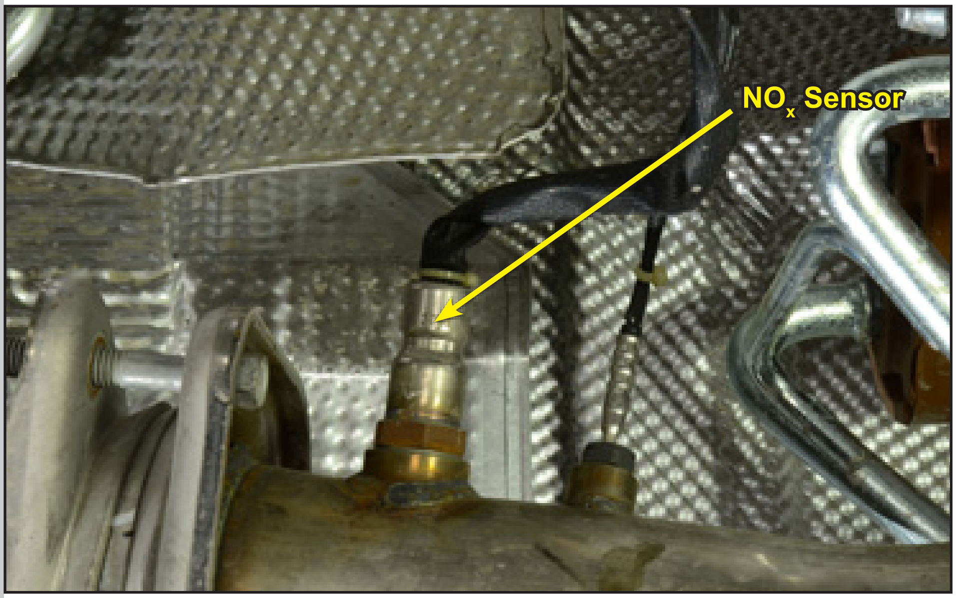
NO_x Sensor Modules

The NO_x sensor modules control the NO_x sensors mounted in the diesel aftertreatment exhaust system. There is a module for each of the two NO_x sensors. They communicate to the RDCM via the CAN2 to report NO_x and O_2 concentrations as well as sensor and controller errors.



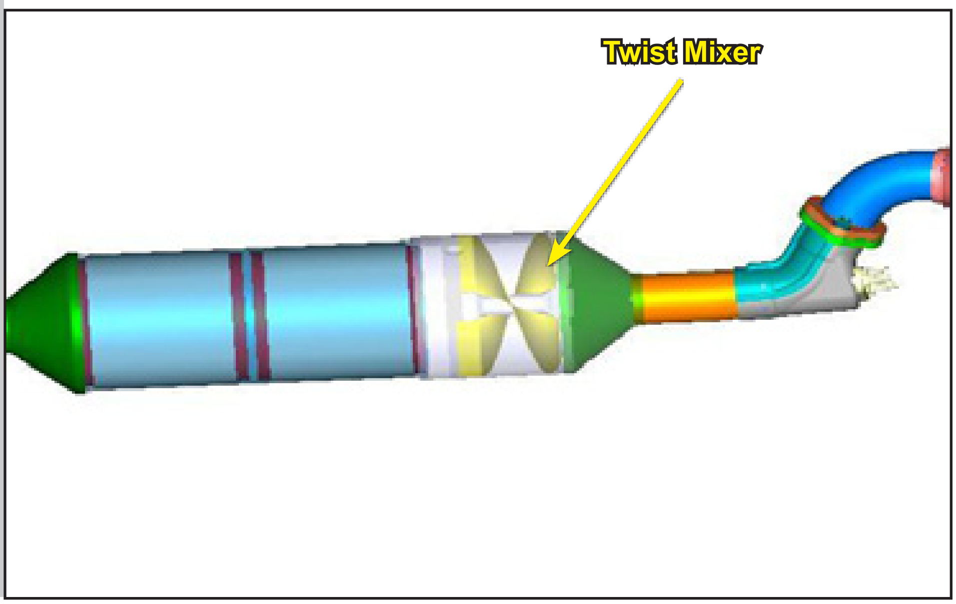
NO_x Sensors

The NO_x sensors are used primarily to detect O_2 and NO_x concentrations in diesel exhaust gas. The sensors are mounted in a vehicle's exhaust pipe, perpendicular to exhaust gas flow. One of the two sensors is mounted before the SCR catalyst and the second NO_x sensor is mounted after the SCR catalyst. Each of the sensors interface with a specific NO_x sensor module that controls the sensor and heater circuits.



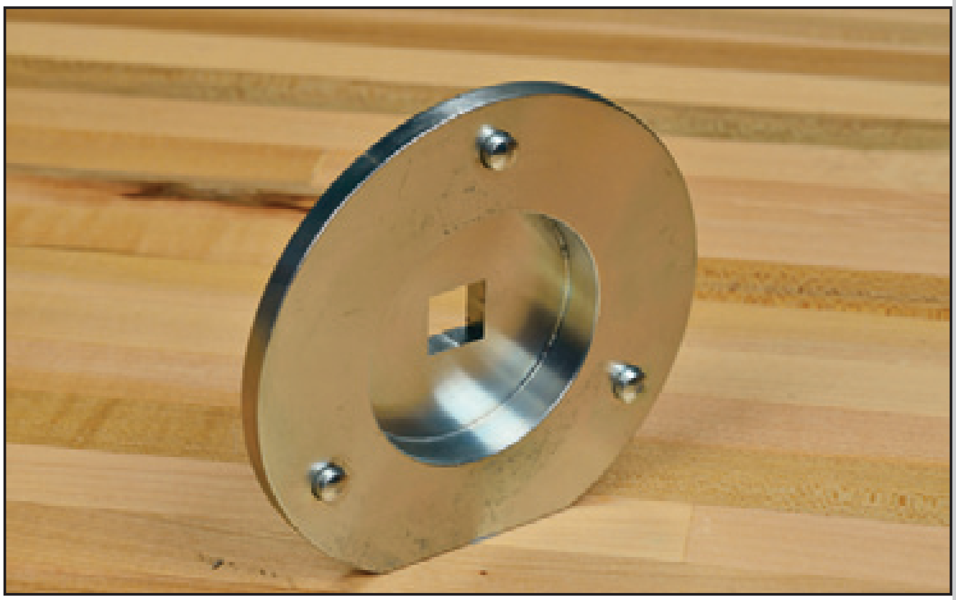
Reductant Exhaust Mixer

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.



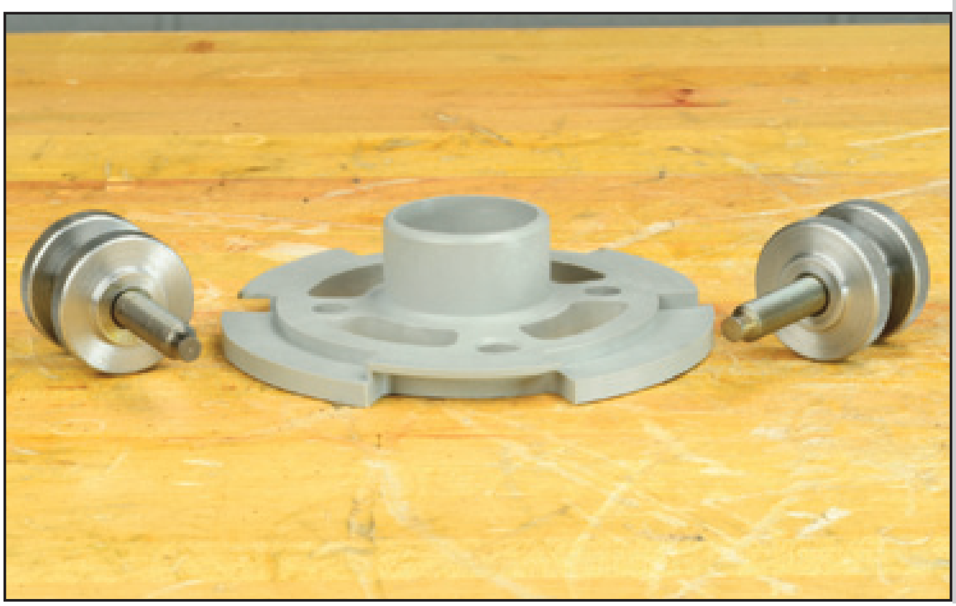
Front Engine Cover Aligner

Engine Front Cover Aligner (303-682), is used when installing the front cover.



Remover/Installer, Engine Front Cover Inspection Plate

Engine Front Cover Inspection Plate Remover and Installer (303-679A), it is used to remove or install the high pressure drive gear access cover (which is on the front cover).



Fuel Injection Pump Sprocket Locking Tool

The Fuel Injection Pump Sprocket Locking tool (303-1317) is used with Crankshaft Timing Pulley Remover (303-249) and Adapter for 303-249 (303-249-01) to press the high pressure fuel pump from the high pressure fuel pump drive gear.

Crankshaft Timing Pulley Remover

The Crankshaft Timing Pulley Remover (303-249) is used with the Fuel Injection Pump Sprocket Locking tool (303-1317) and Adapter for 303-249 (303-249-01) to press the high pressure fuel pump from the high pressure fuel pump drive gear.

Adapter for 303-249

The Adapter for 303-249 (303-249-01) is used with the Fuel Injection Pump Sprocket Locking tool (303-1317) and Crankshaft Timing Pulley Remover (303-249) to press the high pressure fuel pump from the high pressure fuel pump drive gear.

Crankshaft Timing Tool

The Crankshaft Timing Tool (303-1587) is used to hold the crankshaft when the timing chain is being installed.

Oil Pump Aligner

The Oil Pump Aligner (303-705) is used to align the oil pump drive gear, so it is aligned with the gear on the crankshaft.

Crankshaft Holding Wrench

The Crankshaft Holding Wrench (303-1310) is used to hold the crankshaft when removing and installing the crankshaft pulley bolts.

NOTES

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