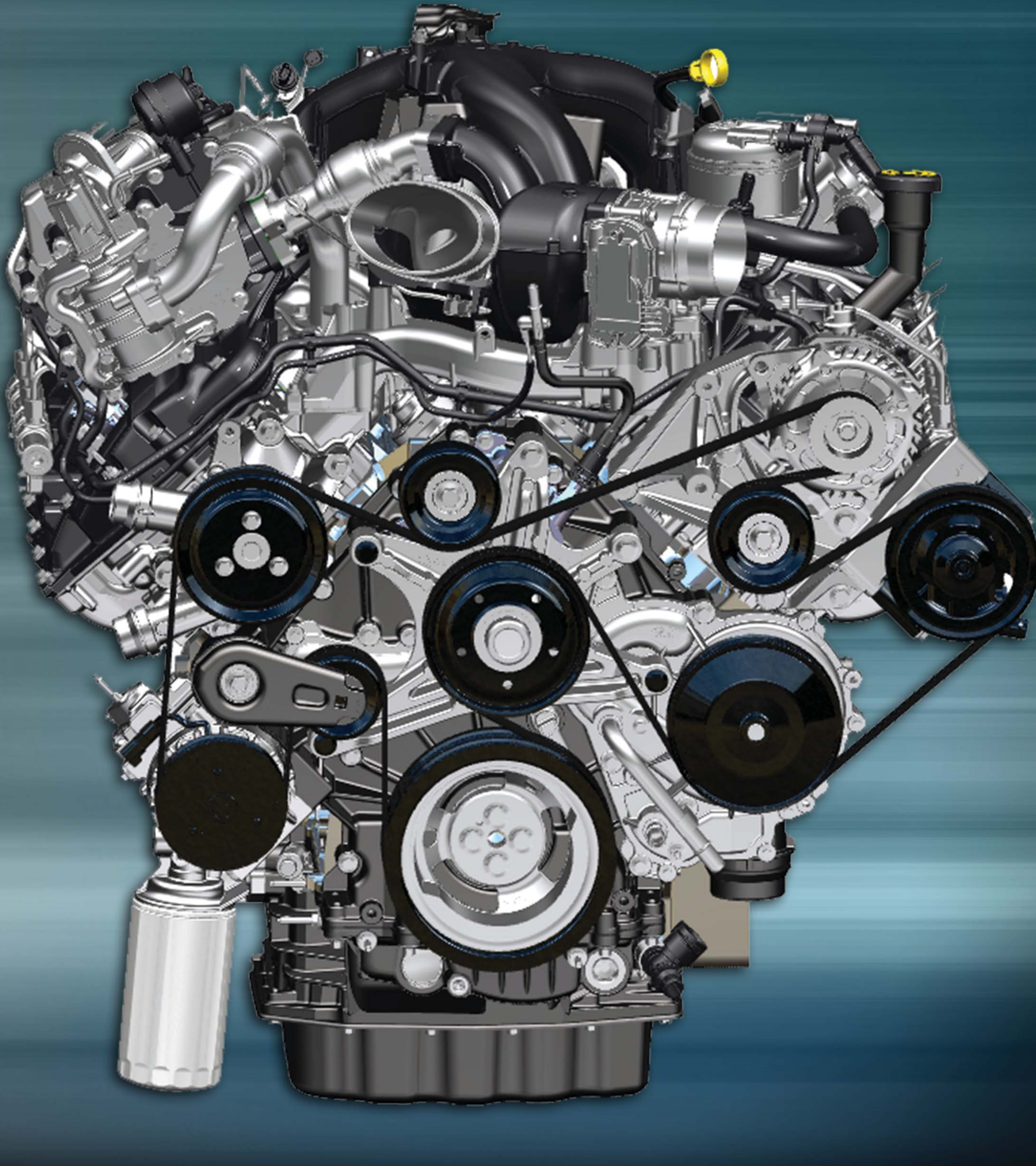
2023 6.7L Power Stroke® V8 Turbo Diesel Engine



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 helps ensure 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.

NOTE: The descriptions and specifications contained in this manual were in effect at the time this manual was approved for printing. Ford Motor Company reserves the right to discontinue models at any time, or change specifications or design without notice and without incurring any obligation.

6.7L Power Stroke®
V8 Turbo Diesel Engine

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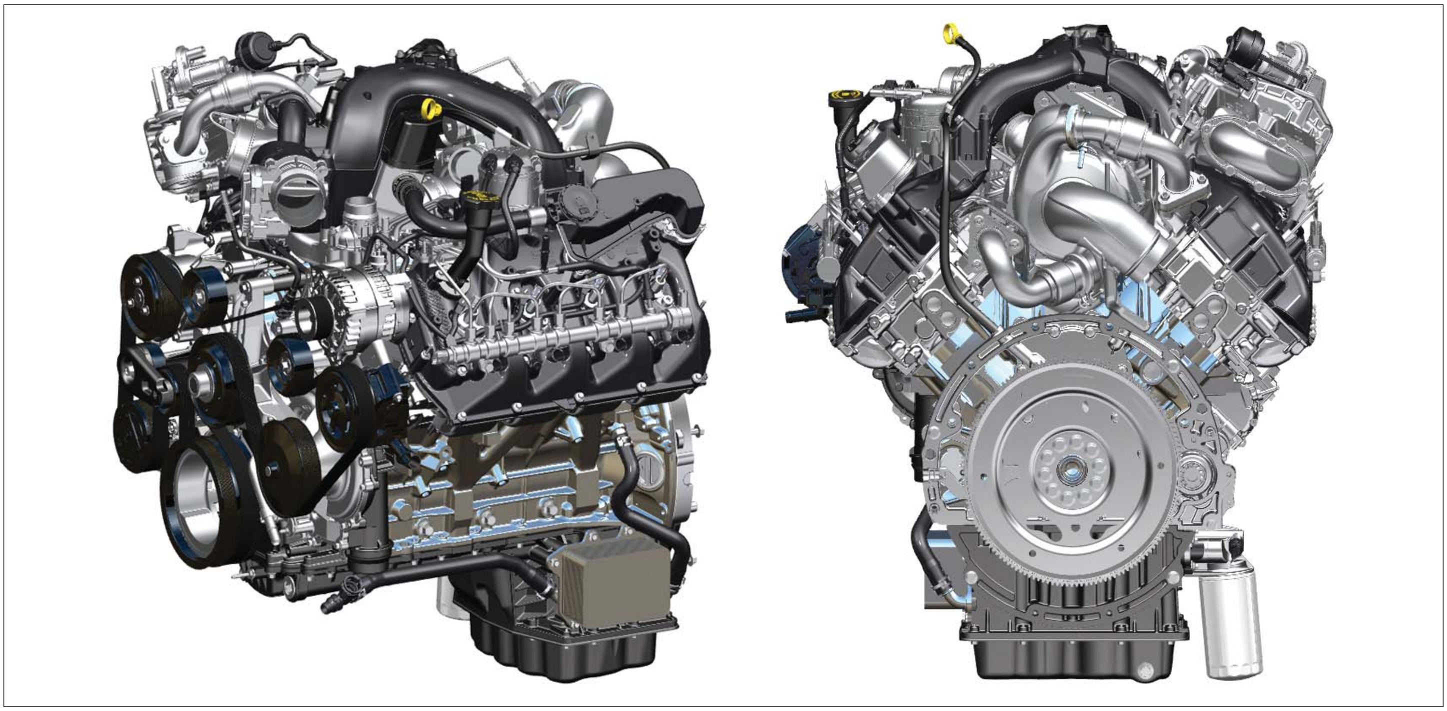
Engine Overview



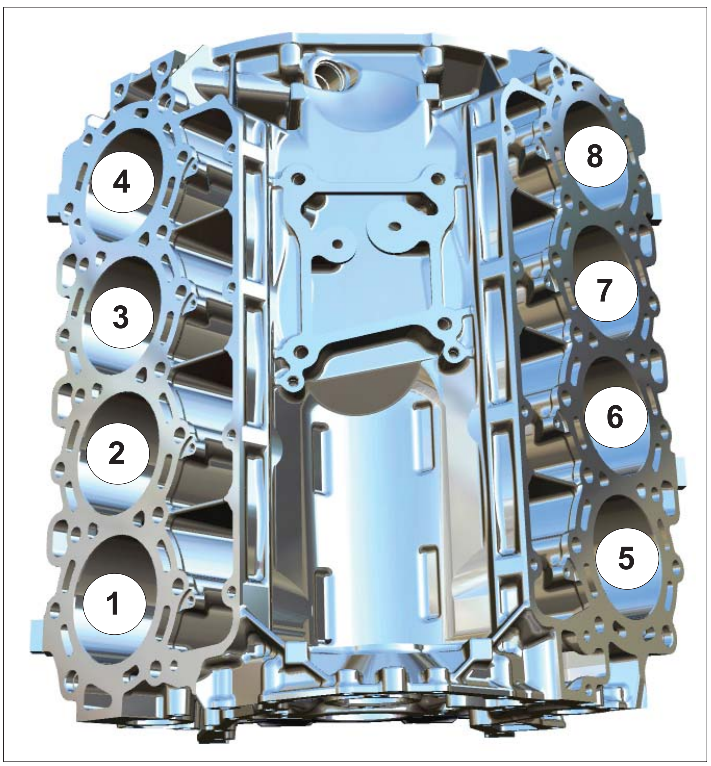
The 6.7L Power Stroke® V8 Turbo Diesel engine has been upgraded for the 2023 model year. It features a 2500 BAR (36,000 psi) fuel injection system utilizing injectors that can deliver fuel up to eight times per stroke for optimal combustion. The high output engine features a newly redesigned, electronically controlled variable geometry turbocharger, resulting in improved torque and horsepower. It also features a strengthened cylinder block, updated cylinder heads, and connecting rods. Combined with its forged-steel pistons, the 6.7L Power Stroke® V8 Turbo Diesel engine proves itself capable by producing up to 475 horsepower and 1,050 lbs.-ft. of torque with a high output option that produces 500 horsepower and 1,200 lbs.-ft of torque.

The 6.7L Power Stroke® V8 Turbo Diesel engine has the following features:

- High compression ratio interference design engine
- 4 valves per cylinder
- Aluminum upper intake manifold
- Composite lower intake manifold
- Aluminum cylinder heads
- Compacted Graphite Iron (CGI) cylinder block
- Common rail fuel system with color coded injectors for left or right-side installations
- Electronically controlled water jacketed variable geometry turbocharger with a liquid cooled compressor section (high output option)
- Stainless steel exhaust manifolds and up-pipes
- Crankcase ventilation system upgraded to new active dual stage powered impactor
- Glow Dosing Module (GDM) controlled glow plugs
- Dual thermostat system, mechanically actuated by coolant temperature
- Secondary coolant system for fuel and air charge cooling
- Gen 4 Selective Catalytic Reduction System (SCR) with Diesel Exotherm Catalyst (DEC) and Diesel Particulate Filter (DPF)
- Deeper oil pan available for heavy duty vehicles 17 qt for F650/750

6.7L Power Stroke® V8 Turbo Diesel Engine Specifications

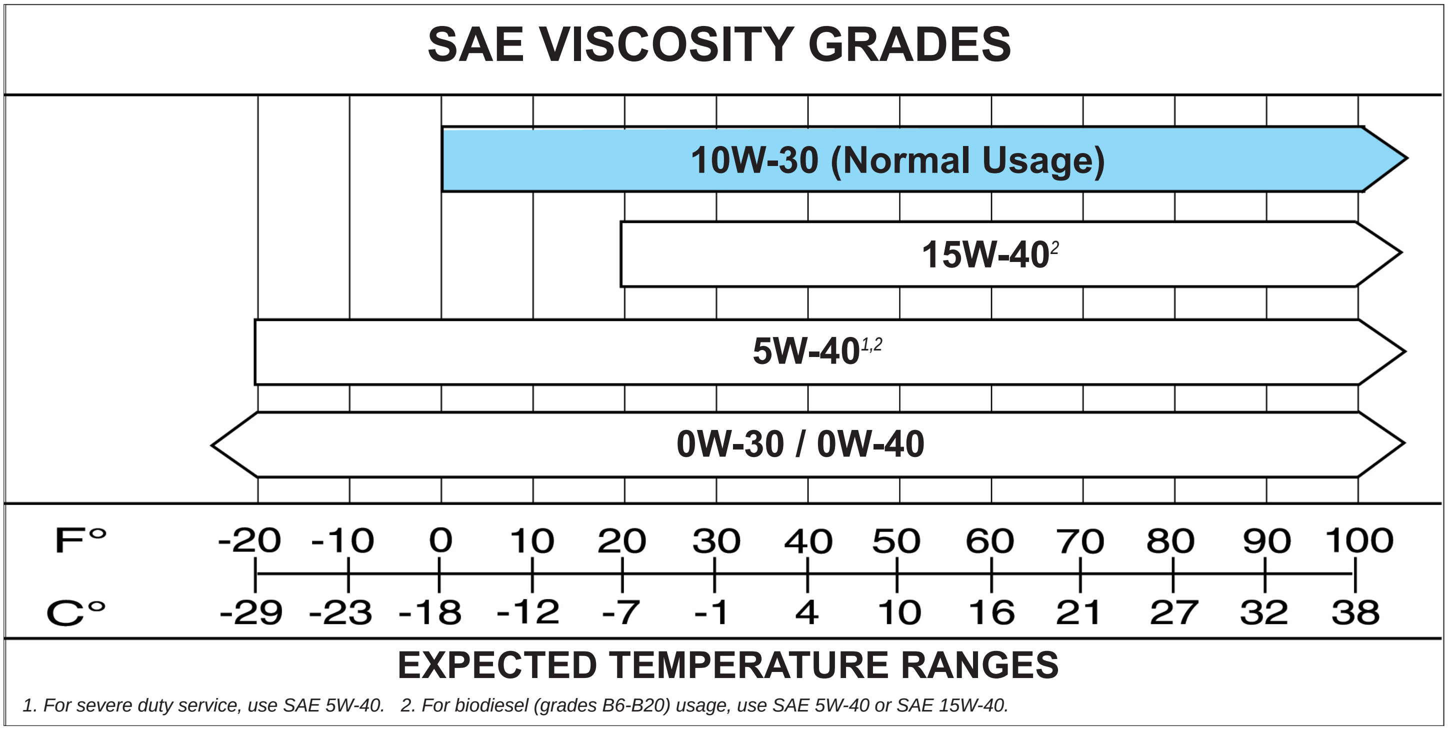
Engine Type	Common Rail Direct Injection Turbo Diesel
Configuration	V-Type 8 Cylinder Cam-in Block Diesel 4 OHV per cylinder
Displacement	6.7L (409 cu in.)
Bore and Stroke	99 mm x 108 mm (3.9 in x 4.3 in)
Compression Ratio	15.2:1
Induction	Electronically Controlled Variable Geometry Turbocharger
Rated Power @ RPM	475 hp @ 2,600 rpm (H.O. 500 hp @ 2,600 rpm)
Peak Torque @ RPM	1,050 ft.-lb. @ 1,600 rpm (H.O. 1,200 ft.-lb. @ 1,600 rpm)
Engine Rotation, Facing Flywheel	Counterclockwise
Combustion System	High Pressure Common Rail Direct Injection
Engine Cooling System and Heater	30.0L (31.7 qt.)
Powertrain Secondary Cooling	7.7L (8.13 qt.)
Lube System Capacity (including filter)	14.2L (15 qt.) {16L (17 qt) for F650/750 with deep oil pan}
Firing Order	1-3-7-2-6-5-4-8



Cylinder order

The 6.7L Power Stroke® V8 Turbo Diesel cylinders are numbered from the front:

- 1, 2, 3, and 4 on Bank 1
- 5, 6, 7, and 8 on Bank 2



SAE Viscosity Grades Chart

Engine Oil Requirements

The 6.7L Power Stroke® V8 Turbo Diesel engine is designed to operate over a wide range of operating conditions. It is important to perform regular engine oil service and match the viscosity of the engine oil to the vehicle operating conditions. Use the SAE Viscosity Grades chart and the following information to make sure the oil viscosity chosen is compatible with the expected vehicle operating conditions.

- Use an engine block heater for temperatures below -23°C (-10°F). The engine coolant reaches maximum temperature after approximately 3 hours of engine block heater operation.
- Use the same engine oil and filter change intervals when using synthetic engine oil.
- **Use Motorcraft® oil or an equivalent oil conforming to Ford specification WSS-M2C171-F1/API service category** CK-4.

When using biodiesel fuels (grades B6-B20), use SAE 5W-40 or SAE 15W-40 engine oil.

The service interval for the engine oil depends on the vehicle operating conditions. Vehicles equipped with the 6.7L Power Stroke® V8 Turbo Diesel engine utilize an Intelligent Oil Life Monitor™ system that calculates the proper oil change service interval. When OIL CHANGE REQUIRED appears in the Instrument Panel Cluster (IPC) message center, change the engine oil and oil filter within two weeks or 800 km (500 mi).

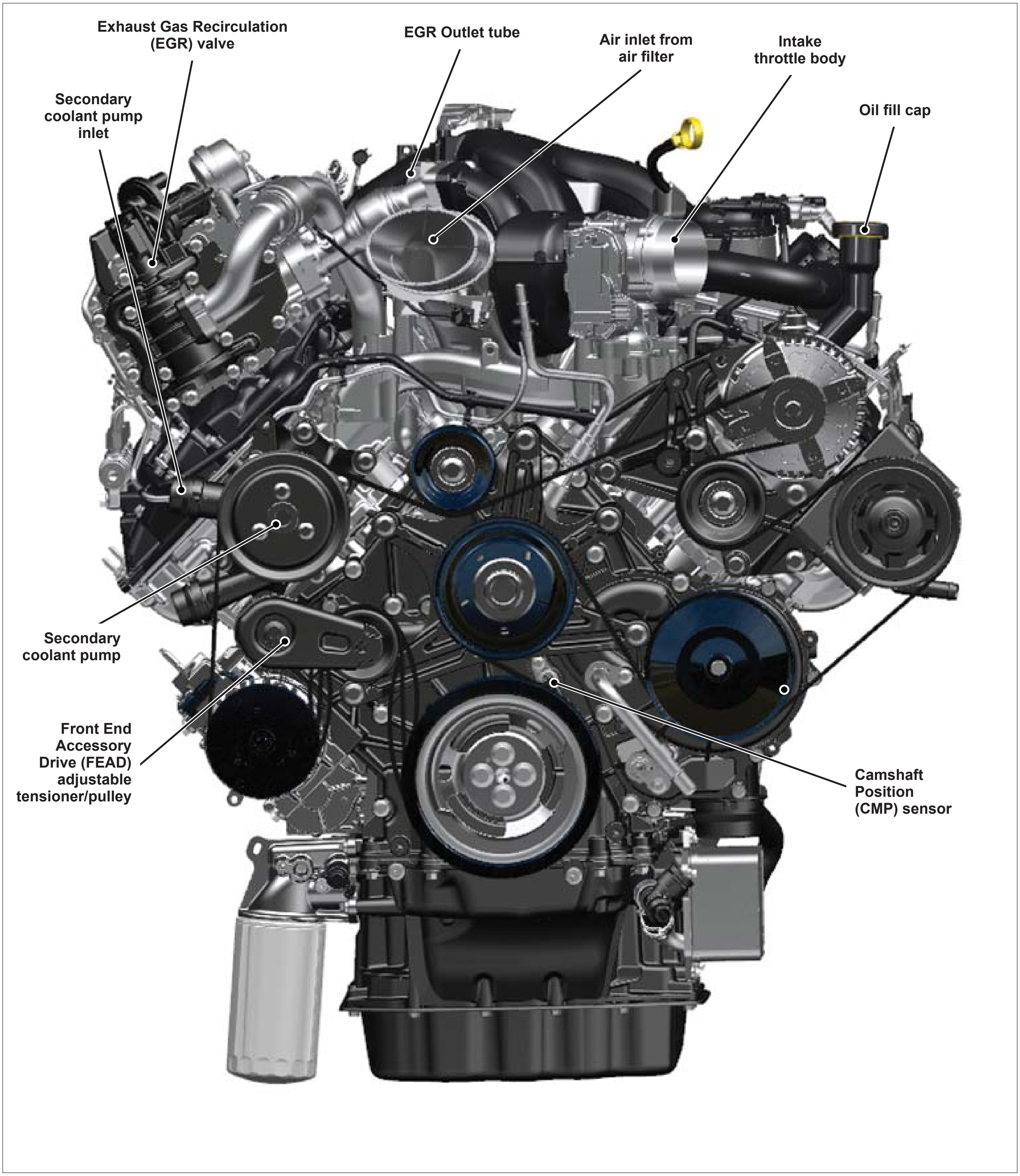
If the information display resets prematurely or becomes inoperative, change the engine oil at six months or 5,000 mi (8,000 km) after the previous oil change. Never exceed one year or 10,000 mi (16,000 km) between oil change intervals.

In severe operating conditions, the engine oil and filter change intervals may occur as frequently as every 4,000-8,000 km (2,500-5,000 mi). Engines operating in severe duty service require the use of SAE 5W-40 engine oil.

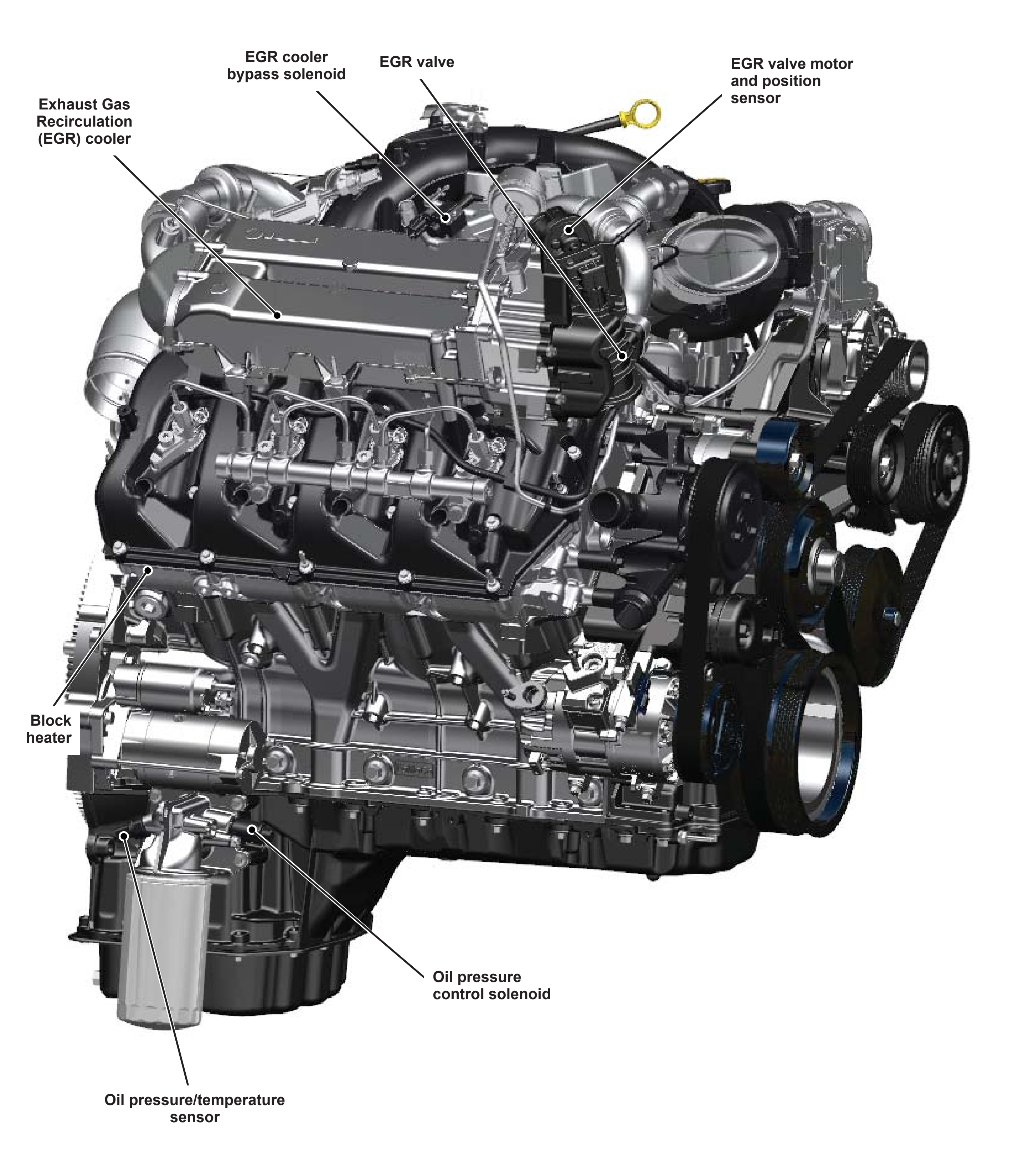
The following operating conditions are considered severe duty service:

- Sustained operation with payload at or near Gross Vehicle Weight (GVW).
- Sustained operation at or near maximum towing capacity.
- Operation in extreme hot or cold conditions.
- Frequent use of high sulfur diesel fuels.
- Frequent or extended idling (over 10 minutes per hour of normal driving).
- Frequent low speed operation, consistent heavy traffic less than 40 km/h (25 mph).
- If the vehicle is operated in sustained ambient temperatures below -23°C (-10°F) or above 38°C (100°F).
- Frequent operation in severe dust or off-road conditions.

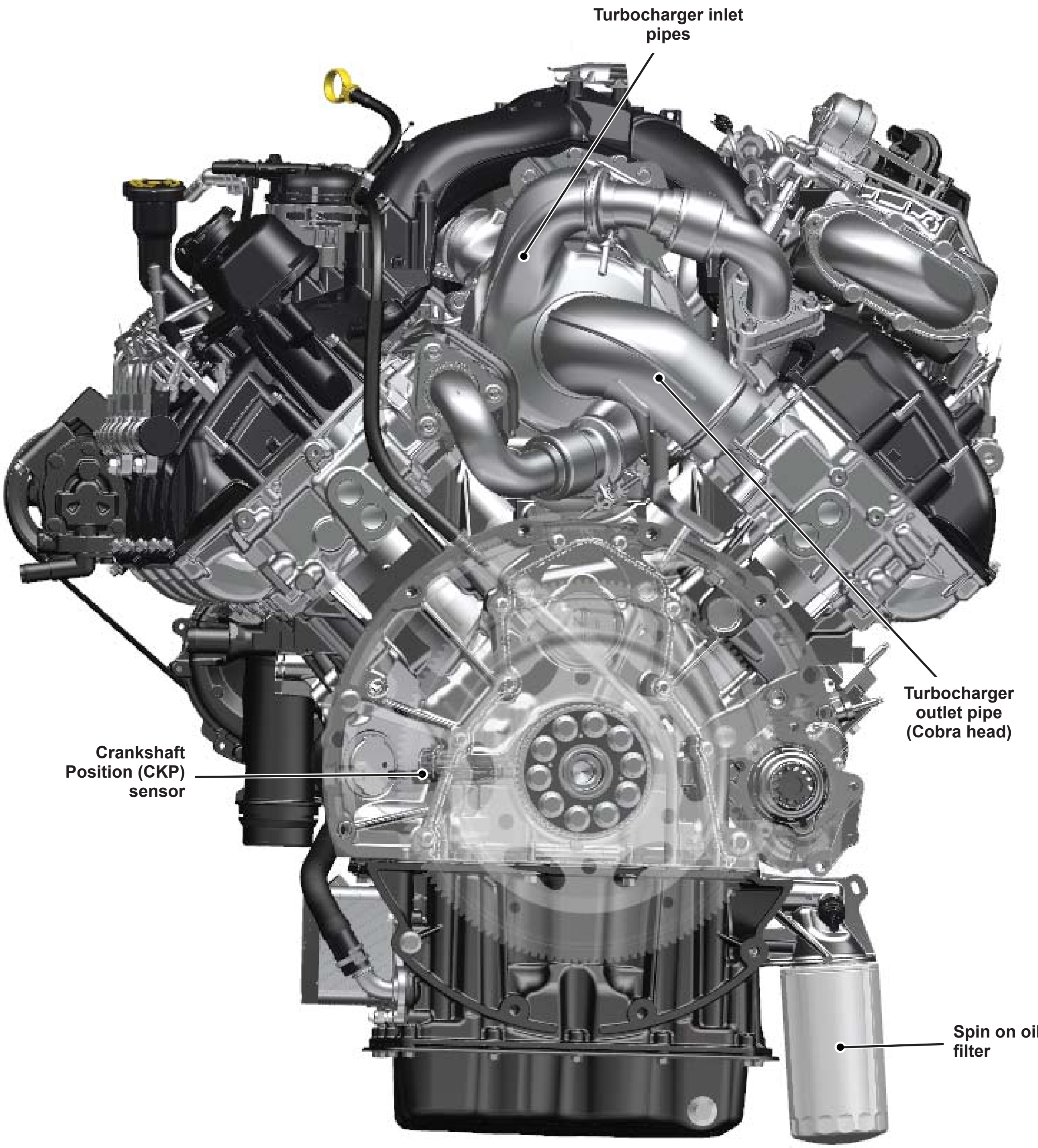
Engine Component Locations



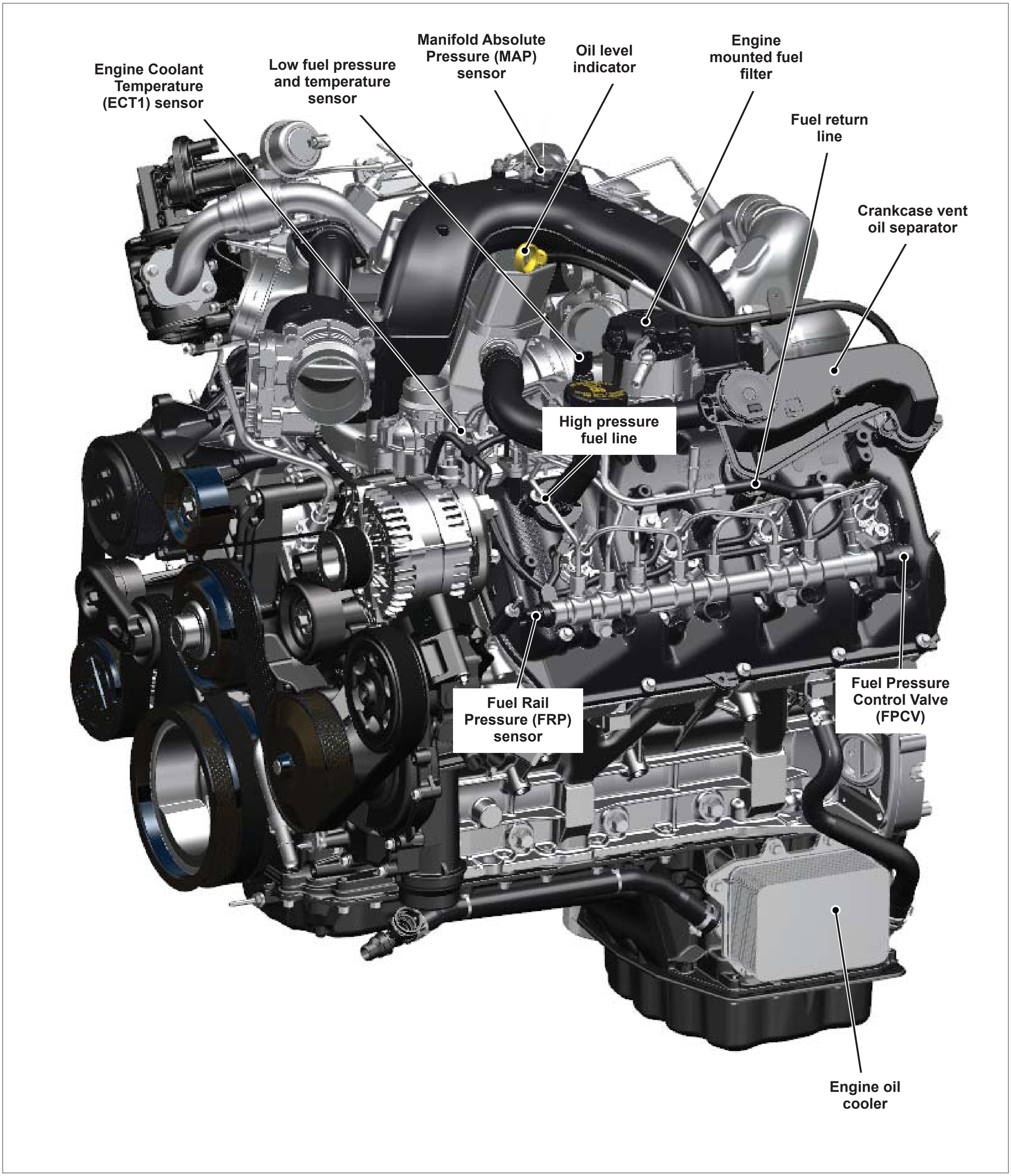
Front of engine



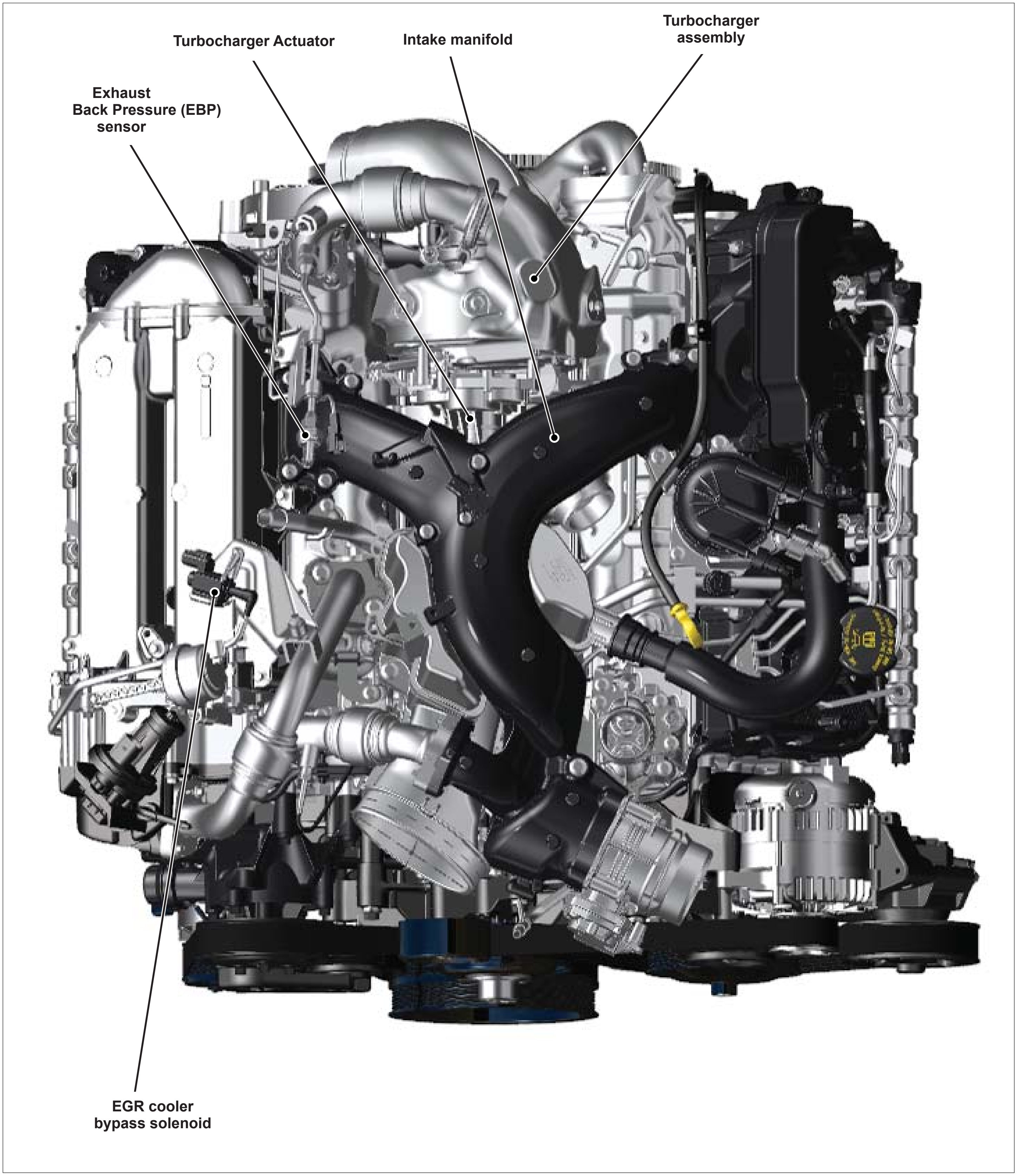
Right of engine



Rear of engine



Left of engine



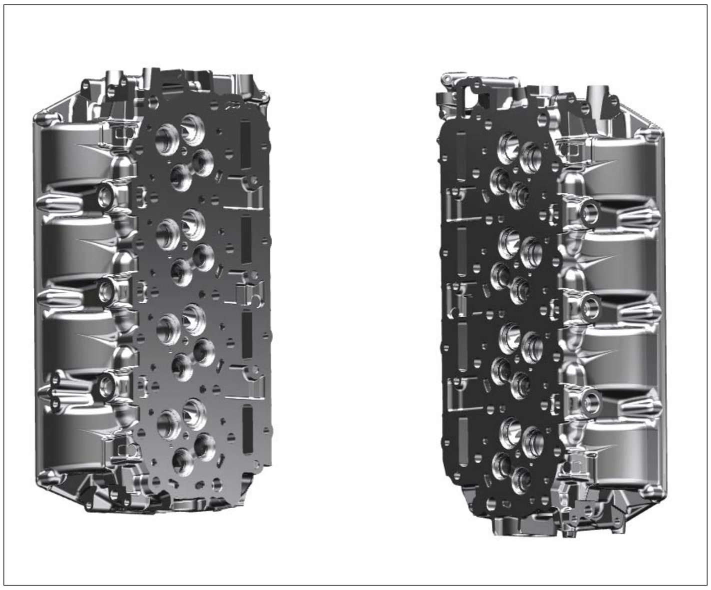
Top of engine

Upper Engine Components

Cylinder Heads

The cylinder heads are all aluminum and mount to the engine block using a combination of M8 and M12 bolts. The M12 cylinder head bolts are torque-to-yield bolts, and cannot be reused. The left side cylinder head attaches with 23 head bolts, while the right side cylinder head attaches with 22 head bolts.

These cylinder heads are designed to handle the increased torque and horsepower. Each cylinder head features four valves per cylinder, two exhaust and two intake, maximizing airflow in and out of the 6.7L Power Stroke® V8 Turbo Diesel. The valve geometry makes this an interference engine.

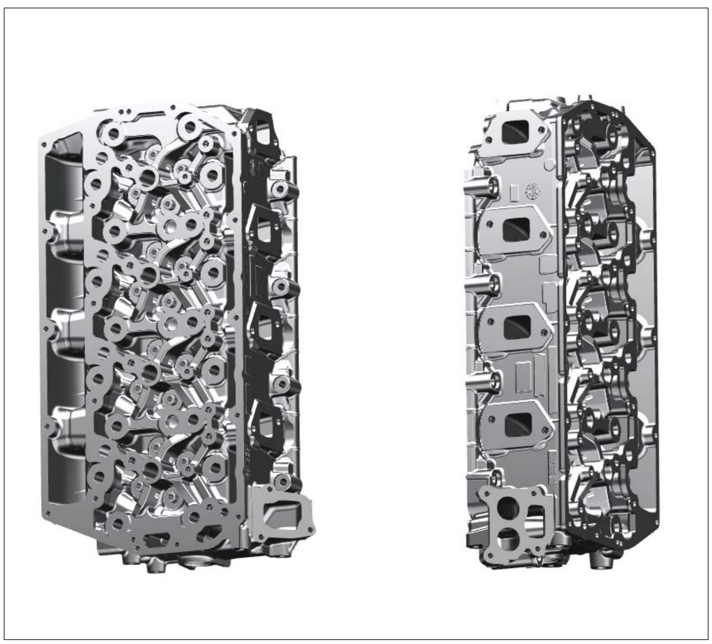


Cylinder heads

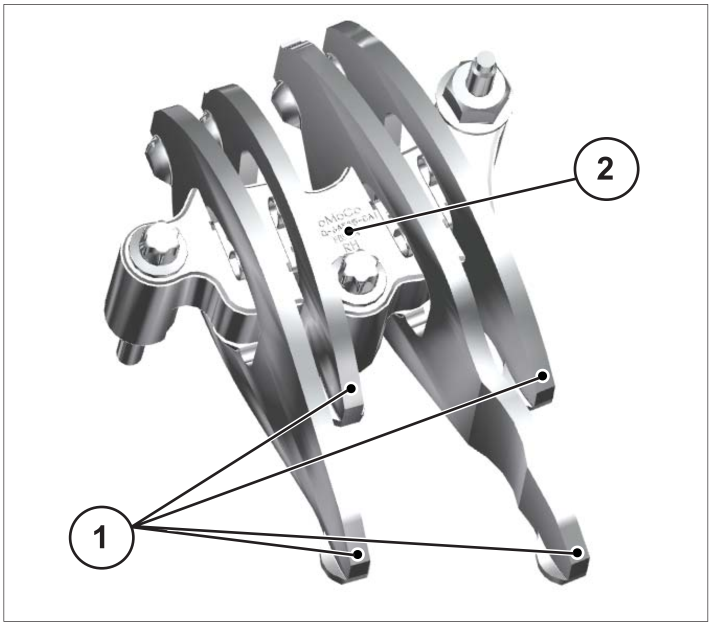
The intake ports are located on the outboard side of the cylinder heads. Specialized intake manifolds integrated into the valve covers feed the intake ports.

This allows the centrally located turbocharger's left and right inlet pipes to mount closer to both exhaust manifolds, shortening the distance exhaust gases flow to enter the turbocharger. The result is increased efficiency while reducing the transfer of radiant heat.

Note:	The cylinder heads were updated for the 2023 model year and, although they look very similar, they are **not** compatible with previous model years.



Cylinder heads



Rocker arm

Rocker Arms

Each valve has its own rocker arm and pushrod. These simple, stamped rocker arms allow for efficient packaging, robust quality, and reliable motion.

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

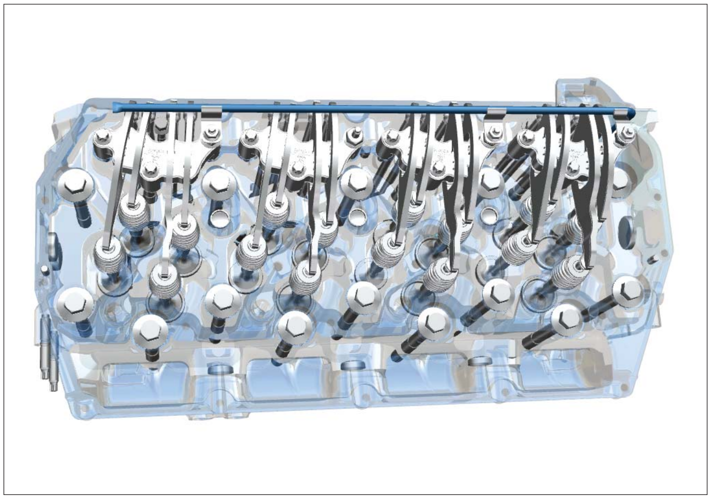
The rocker arms (**1**) for each cylinder ride on their own common fulcrum (**2**). The fulcrums attach to the cylinder heads using three bolts.

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

Valve tappet assembly

Camshaft Followers

The camshaft followers are uniquely designed and patented by Ford Motor Company. Each roller lifter/tappet individually actuates a valve through its own pushrod and rocker arm. They are packaged as pairs in the valve tappet guides. Within the assemblies, two hydraulic lash adjusters per each roller lifter/tappet are used.



Rocker arm oiling manifold

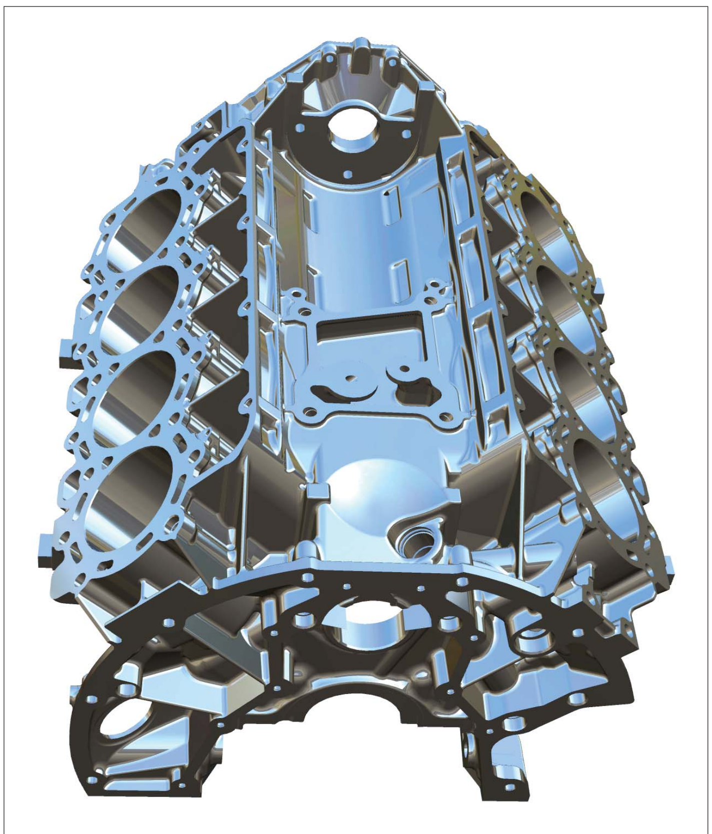
Rocker Arm Oiling Manifold

Both cylinder heads have a rocker arm oiling manifold, or oil spray bar, that cools and lubricates the valves and rocker arms.

Lower Engine Components

Engine Block

The 6.7L Power Stroke® V8 Turbo Diesel Engine utilizes a Compacted Graphite Iron (CGI) cylinder block, enhancing strength while reducing weight. The engine is cam in block design with an open, dry intake valley. The block design allows for direct mounting of the high pressure fuel pump and Variable Displacement Oil Pump (VDOP). Cylinder heads are sealed to the block using six head bolts per cylinder. To handle the best in class horsepower and torque, the crankshaft main caps feature six bolts per main bearing cap.



Engine block (top)

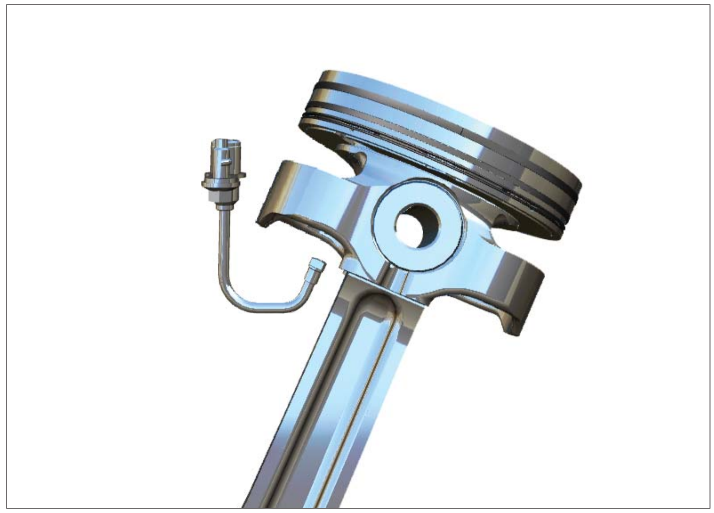
Engine block (side)

Steel pistons

Pistons

The all-steel pistons are designed with a short length skirt, resulting in a strong, lightweight piston capable of handling the horsepower and torque output of the 6.7L Power Stroke® Turbo Diesel engine.

The pistons are oil cooled. Individual block-mounted oil jets spray pressurized oil into a hole in the bottom of each piston. The oil flows through the piston and exits from a second hole on the opposite side of the piston.



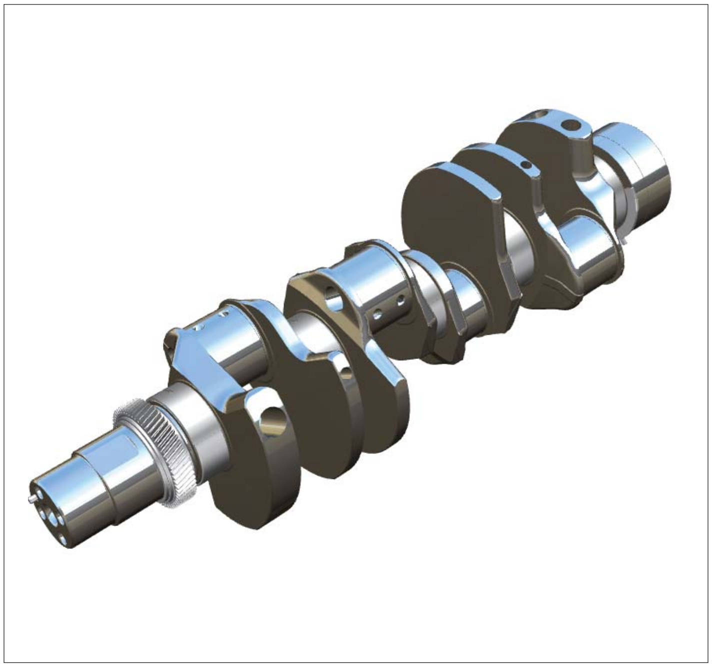
Oil jet flow through

Connecting rod

Connecting Rods

The connecting rods are powdered metal cracked rods. Make sure the connecting rod and cap are installed as a set or engine damage may occur. Proper orientation of the connecting rod and cap is also critical.

Note: Connecting rods have been updated for the 2023 model year and are not backwards compatible.



Crankshaft

Crankshaft

The crankshaft is a forged micro-alloyed medium carbon steel. An undercut rolled fillet radius is present on each journal and the crankshaft pins are fully lightened.

The crankshaft incorporates four rod journals, with two connecting rods mounting to each rod journal. Two radiused counterweights are utilized for balance.

A one piece rear flange:

- increases torque capabilities.
- improves sealing and balance.

A shrink fit installed front drive gear allows for direct drive timing gears, improving NVH.

A specialized, single mode torsional crankshaft damper, tuned to operate in harmony with the steel pistons and 10R140 transmission, is used.

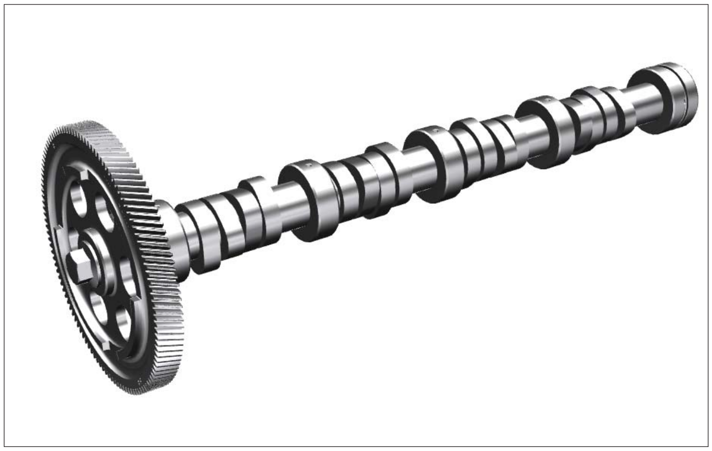
Main and Rod Bearings

Crankshaft Main and Connecting Rod Bearings

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

The lower, load-carrying halves of the crankshaft main bearings are a dark gray while the upper half are a bright metal finish with a lubrication groove and slot for the oil to flow through.

The upper half of the connecting rod bearings are a dark gray matte finish, while the lower half (installed into the cap) is a shiny, bright metal with no grooves.



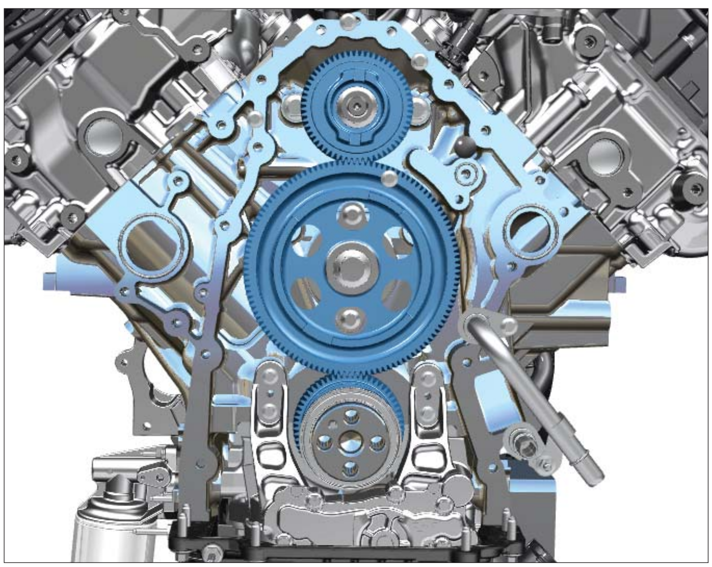
Camshaft

Camshaft

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

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

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



Timing gears

Timing Gears

Engine timing is achieved using helical cut timing gears. The crankshaft drives the camshaft, which in turn drives the high-pressure fuel injection pump. The timing gears are accessible after removing the engine front cover.

- The timing gears are marked to aid with setting proper engine timing during service.
- The crankshaft gear contains a single timing mark.
- The camshaft gear contains a single and a double-timing mark.
- The high-pressure fuel injection pump drive gear contains a double-timing mark.

Additionally, a keyway on the high-pressure fuel injection pump drive gear must be at 12 o'clock position during assembly.

Engine timing is correct when the single mark on the crankshaft gear is aligned with the double mark on the camshaft gear, and the single mark on the camshaft drive gear is aligned with the double mark on the high-pressure fuel injection pump drive gear.

The Workshop Manual contains specific images and procedures for setting engine timing.

Engine Front Cover

The engine front cover adds structural rigidity and allows for the mounting of various accessories and components.

Engine front cover

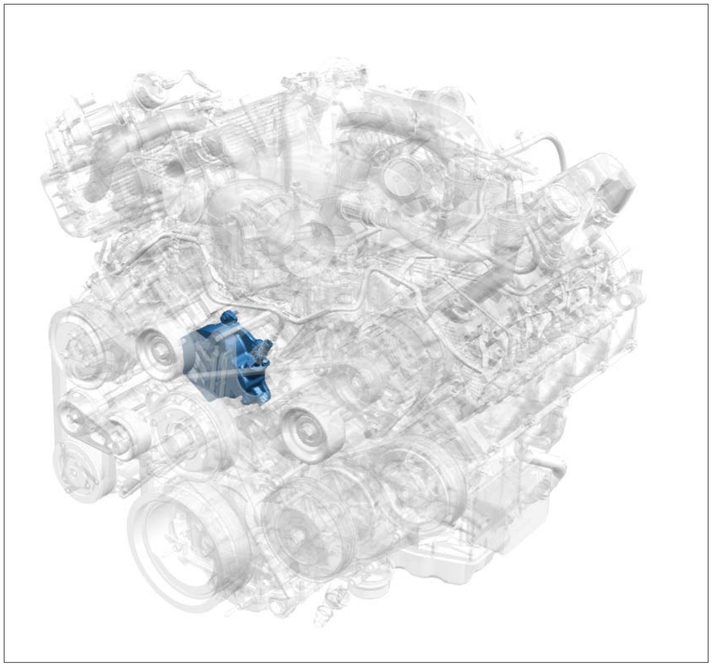
Engine front cover (back side)

Engine front cover slinger

The front crankshaft seal is a springless design and installs with the front oil slinger into the front engine cover. Casting design allows clearance for the block-mounted Variable Displacement Oil Pump (VDOP).

The vacuum pump, driven by the high pressure fuel injection pump, mounts at the top of the cover and utilizes an integrated seal in the mounting hole.

Note:	Mark the location of the engine front cover bolts prior to removing them.



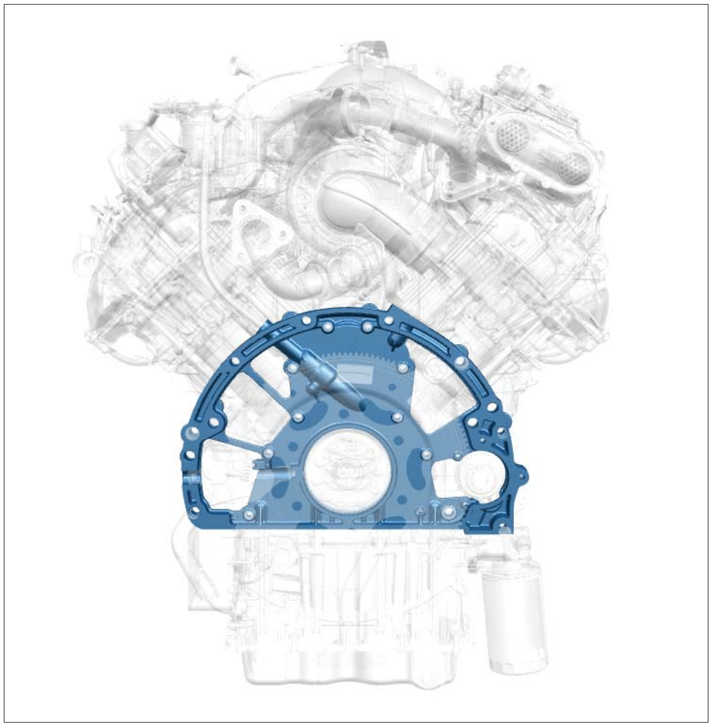
Vacuum pump location

Vacuum Pump

The vacuum pump is located on the upper portion of the front cover and is driven by the high pressure fuel pump.

Vacuum is used by the EGR cooler bypass system, the brake booster on vehicles equipped with vacuum operated power brakes, and the 4x4 locking hubs on 4-wheel drive vehicles.

Vacuum pump



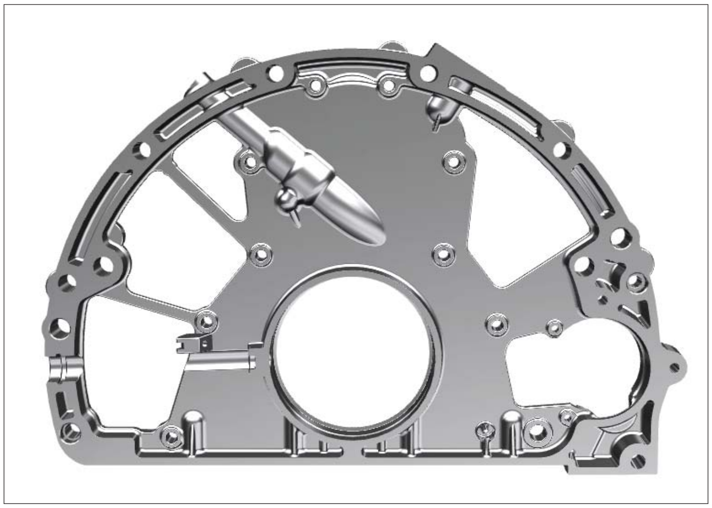
Rear cover location

Rear Cover

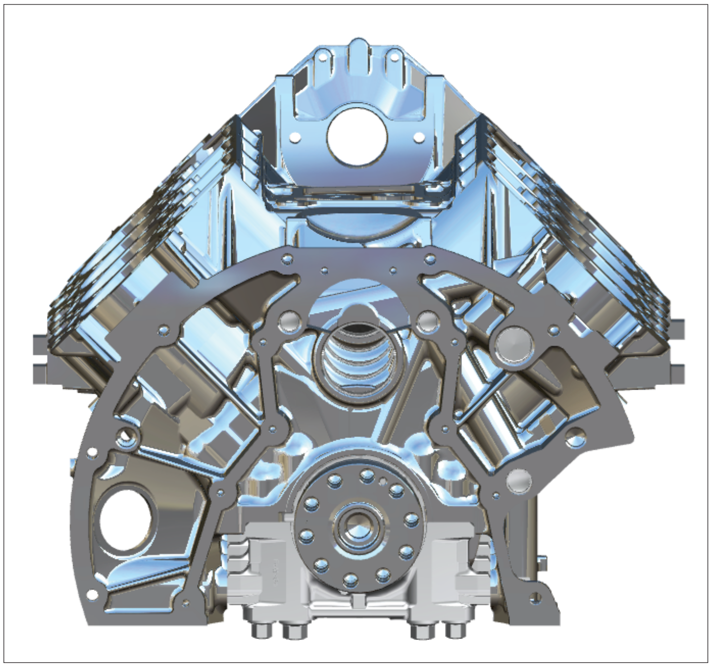
The rear cover provides additional rigidity and seals the rear of the engine block. The rear cover also provides an adaptive mounting point for the transmission.

The engine oil level indicator tube passes through the rear engine cover.

Note:	Some applications may use different oil level indicators and tubes and are **not** interchangeable**.**



Rear cover



Rear cover

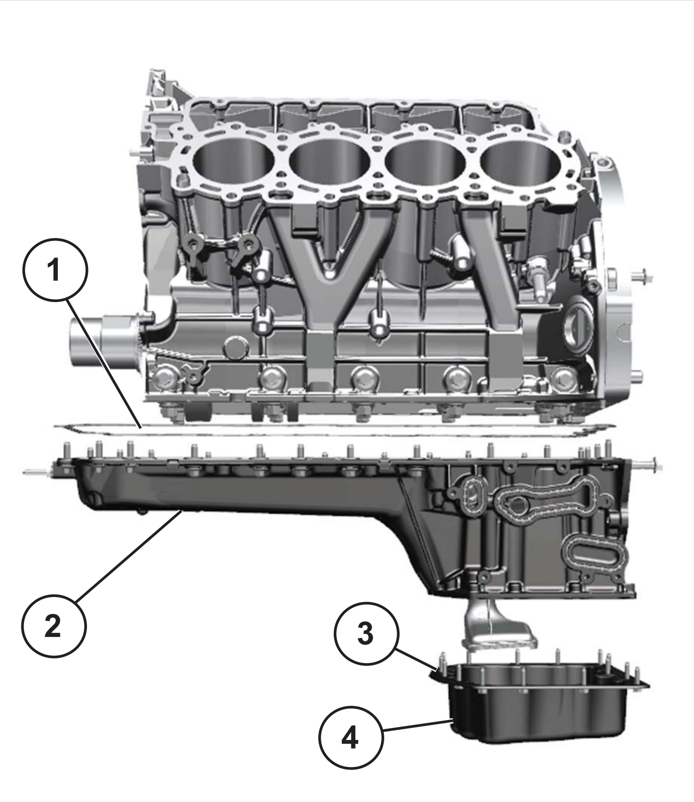
Rear Crankshaft Seal

The rear crankshaft seal is installed in the rear engine cover. The rear crankshaft seal has no sealing sleeves.

Flexplate

Flexplate

The torque converter attaches to an improved flexplate utilized on vehicles equipped with the 10R140 automatic transmission.



Oil pan

Oil Pan

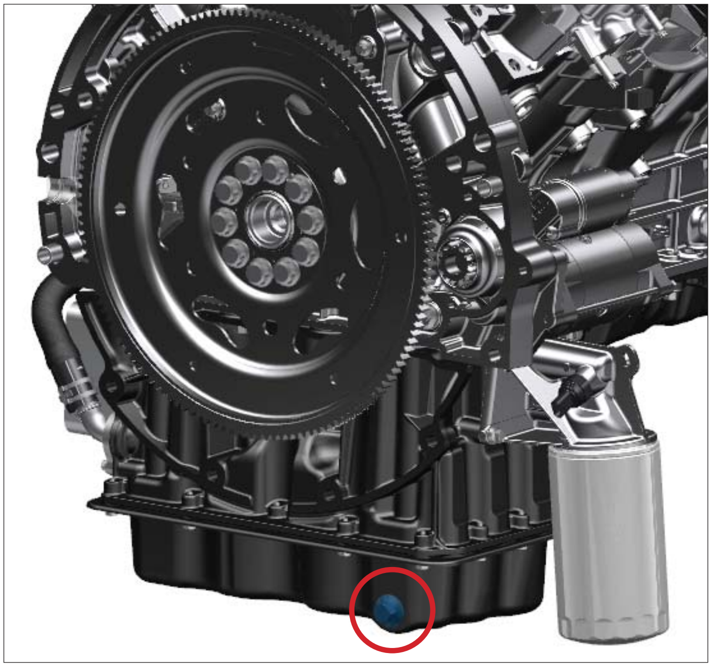
A two-piece oil pan assembly seals the lower engine. The upper oil pan acts as a block stiffener, increasing lower engine block rigidity. It also provides mounting locations for the oil cooler and the oil filter adapter. Oil tubes are integrated into the upper oil pan to route oil to the cooler and filter. The upper oil pan seals to the engine block using a non-reusable gasket.

The oil filter adapter is mounted to the right rear of the upper oil pan and contains the Variable Displacement Oil Pump (VDOP) control solenoid, Engine Oil Pressure (EOP) and Engine Oil Temperature (EOT) sensors. The oil cooler is mounted to the left rear of the oil pan.

The upper oil pan has been updated for the 2023 model year and is not backwards compatible.

The lower oil pan acts as a sump for the oil pump pickup. There are 2 lower oil pans available, the standard depth and a deeper one used in heavy duty models. It mounts to the upper oil pan and seals using RTV.

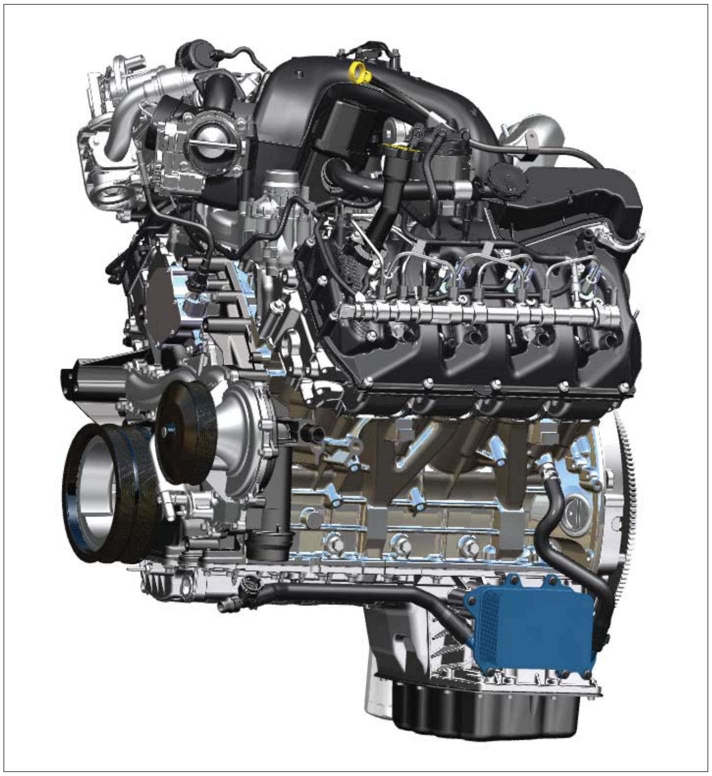
1.	Upper oil pan gasket
2.	Upper oil pan
3.	Lower oil pan sealing surface
4.	Lower oil pan



Oil drain plug

Oil Drain Plug

A conventional drain plug is utilized with the steel lower oil pan. It is located at the right rear corner of the oil pan.



Oil cooler location

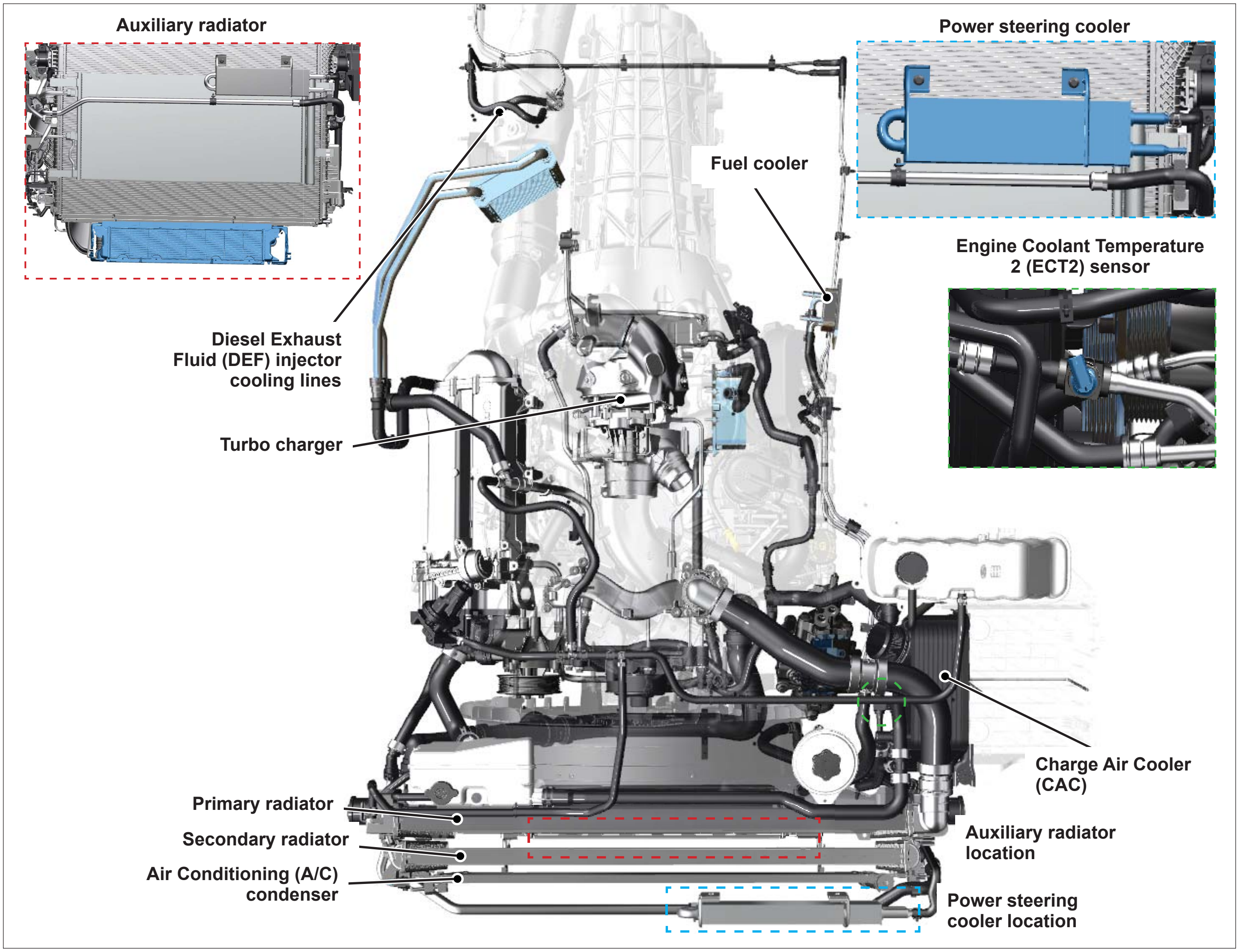
Oil Cooler

The oil cooler is mounted on the upper oil pan. The oil cooler is a heat exchanger, using engine coolant to dissipate heat from the engine oil. The capacity of the oil cooler is optimized to adequately cool 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 oil pan to the oil filter.

Oil cooler

Engine Cooling System



Cooling system

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

- The engine cooling system, called the primary or high temperature cooling system.
- The powertrain secondary cooling system, a low temperature system that cools the Charge Air Cooler (CAC), fuel cooler, Diesel Exhaust Fluid (DEF) injector, and on the High Output engine, the turbocharger compressor housing.

Each cooling system uses an independent radiator, belt-driven coolant pump, thermostats, and degas bottle. The EGR cooler uses the primary cooling system to reduce exhaust gas temperatures. The fluid coolers located at the front of the grille opening include:

- Primary radiator
- Secondary radiator
- Air Conditioning (A/C) condenser
- Power steering cooler (separate from the primary or secondary cooling systems)

The secondary radiator is located in front of the primary radiator to allow the powertrain secondary cooling system to operate at a lower temperature than the primary cooling system. On models designed to carry heavy loads such as dual rear wheel vehicles and ambulances an auxiliary radiator is mounted under the other radiators and is part of the primary cooling system. This radiator is connected to the upper and lower radiator hoses using T connections.

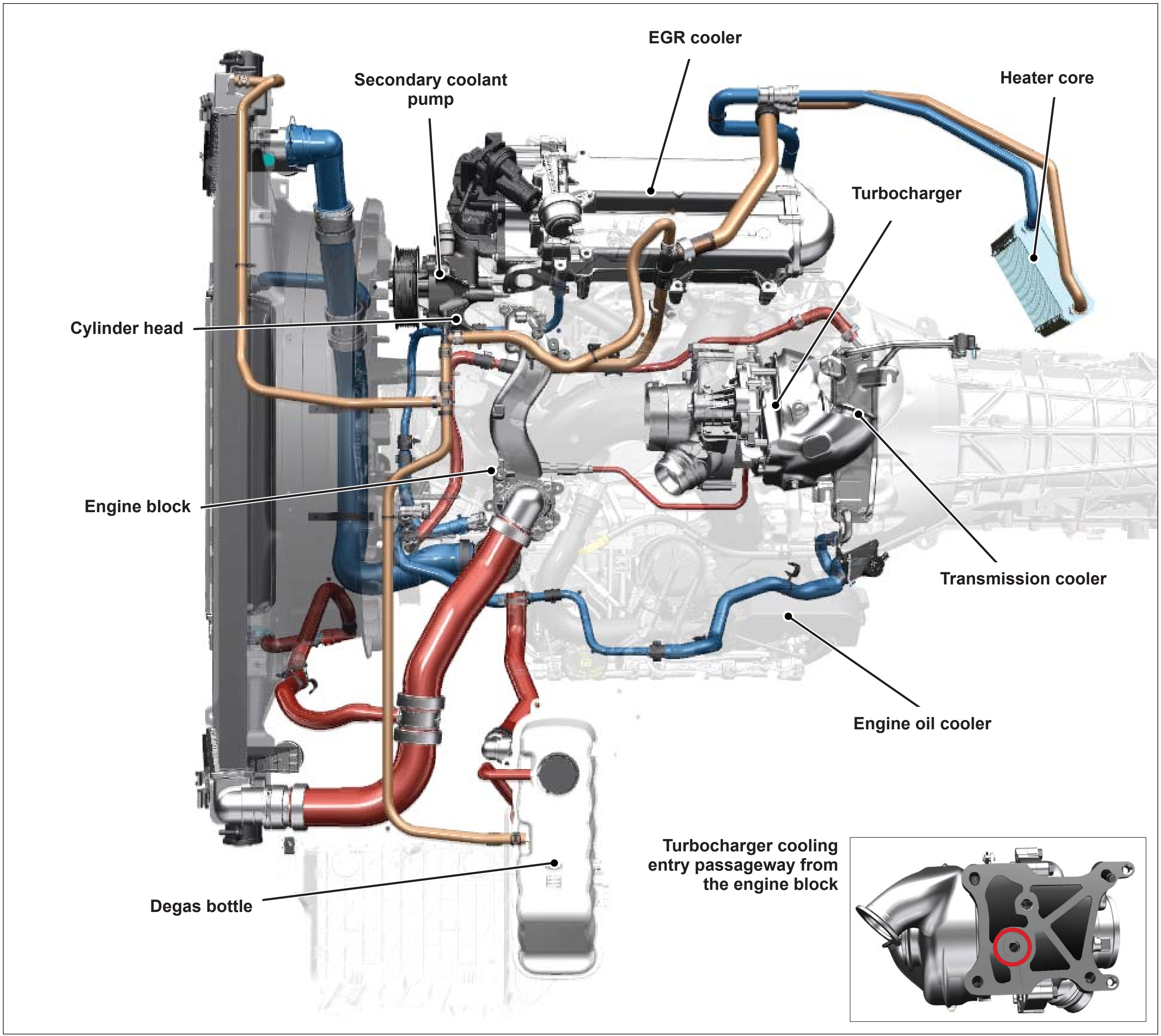
The ECT2 sensor has been relocated but is still near the charge air cooler.

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

Use only Motorcraft® Yellow Concentrated Antifreeze/ Coolant (VC-13-G) mixed with 50/50 by volume distilled water in the primary and secondary cooling systems of the 6.7L Power Stroke® Turbo Diesel engine. Motorcraft® Yellow Prediluted Antifreeze/Coolant / VC-13DL-G may also be used. Refer to the Workshop Manual section 303-03A for cooling system testing and maintenance procedures.

Quick connect fittings

Primary Cooling System Flow



Primary cooling system flow

The primary cooling system cools the following components:

- Engine block
- Turbocharger
- Engine oil cooler
- Transmission cooler
- Cylinder heads
- EGR cooler

The majority of engine coolant flows through the engine block and cylinder head to the radiator circuit and back by the coolant pump. The coolant pump operates by engine rotation through the accessory drive belt to circulate the coolant.

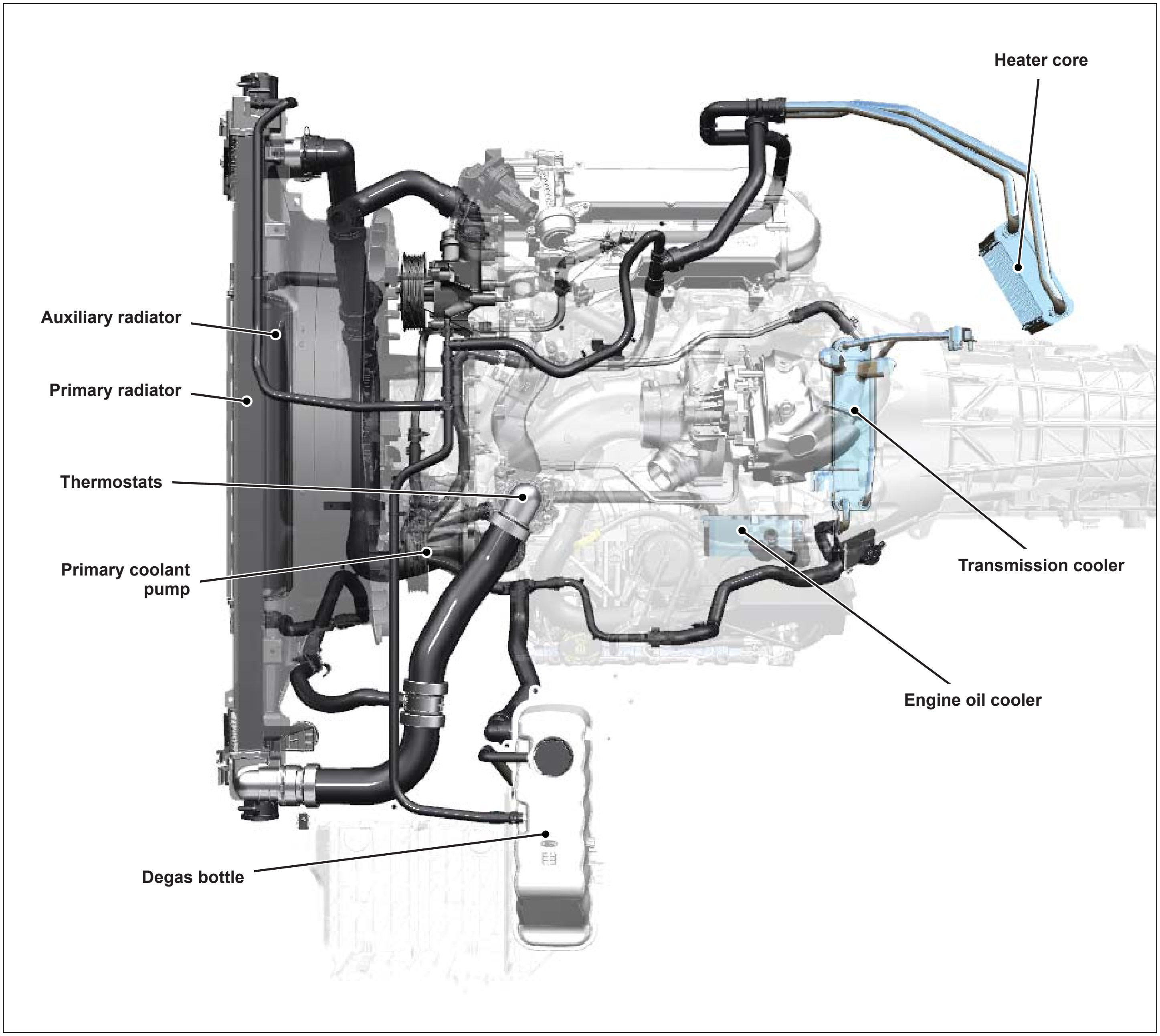
- Coolant is drawn from the bottom radiator port into the coolant pump inlet, located in the front cover, then flows from the coolant pump through the front cover and enters the engine block.
- From the engine block, the coolant is routed to the cylinder heads, turbocharger, engine oil cooler and the heater core.
  - The coolant enters the turbocharger from a passageway in the engine block. The coolant exits by a tube mounted on the left side of the turbocharger and goes into the water crossover at the front of the engine.
  - Coolant is routed through the right valve cover to the EGR cooler and the EGR valve. Most of the coolant returns to the right valve cover, but there is a small passage that allows a small amount of coolant to flow to the degas bottle.

- The inlet for the heater core runs from the front water crossover. The outlet goes into the bottom radiator hose where it attaches to the radiator.
- The inlet for the engine oil cooler comes out of the left side of the engine block. The outlet goes into the bottom radiator hose where it attaches to the front cover.

The primary cooling system uses dual temperature actuated thermostats. The two thermostatic devices do not open at the same coolant temperature, but are staggered with the back thermostat opening at a lower temperature. When both thermostats are closed, coolant flow bypasses the radiator circuit and returns to the coolant pump. When one or both thermostats are open, coolant flows through the radiator circuit to transfer engine-generated heat to the outside air. A thermostat monitor function, programmed into the PCM, verifies correct thermostat operation.

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 service fill location.

Primary Cooling System Components



Engine cooling system

Front cover coolant passage (back side)

Front Cover

Coolant is sealed using O-ring seals.

- Coolant is directed through two passages in the front cover. One for the right bank of cylinders and one for the left bank of cylinders.
- During warm up the thermostat blocks coolant flow to the radiator and the coolant is routed back to the pump through the bypass circuit.
- When one or both thermostats are open, coolant flows through the radiator circuit to transfer engine-generated heat to the outside air.

Primary coolant pump

Primary Coolant Pump

The primary coolant pump operates via the accessory drive belt to circulate the coolant through the engine.

The coolant pump is mounted to the front cover, on the left front of the engine.

Primary thermostat location

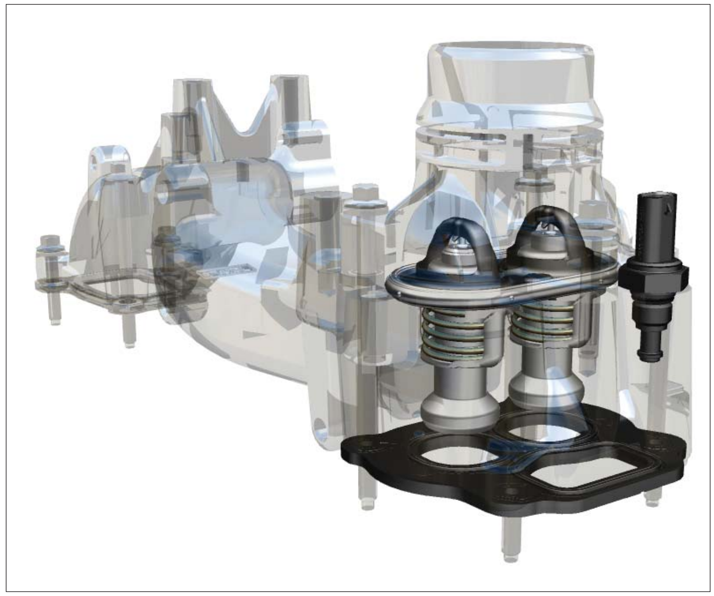
Primary Thermostats

The primary thermostat is located in the coolant crossover at the front of the engine and contains two thermostatic devices in one assembly.

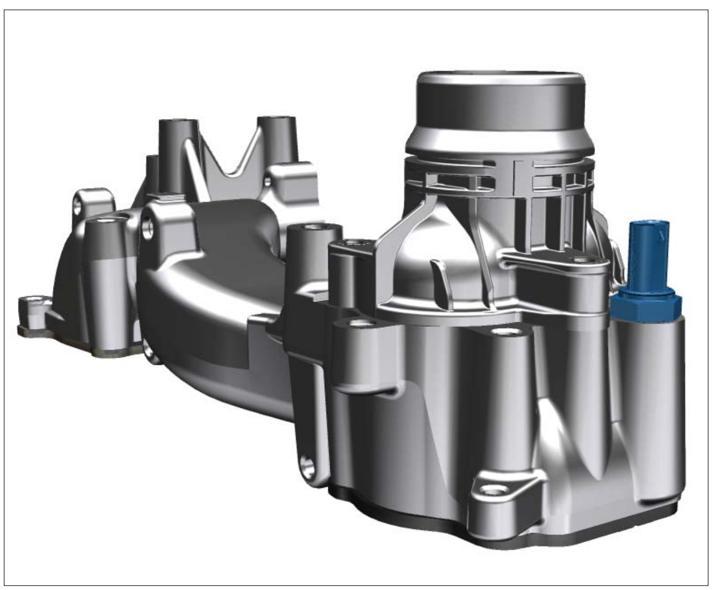
The thermostat regulates the engine coolant temperature by controlling coolant flow through the primary radiator.

The two thermostatic devices do not open at the same coolant temperature.

The opening temperatures are staggered with the rear thermostat opening at 90°C (194°F), and the front thermostat opening at 94°C (201°F).



Primary thermostat



Engine Coolant Temperature (ECT) sensor

Engine Coolant Temperature (ECT1) Sensor

The ECT1 sensor is located in the coolant crossover, above the coolant pump and next to the thermostat housing.

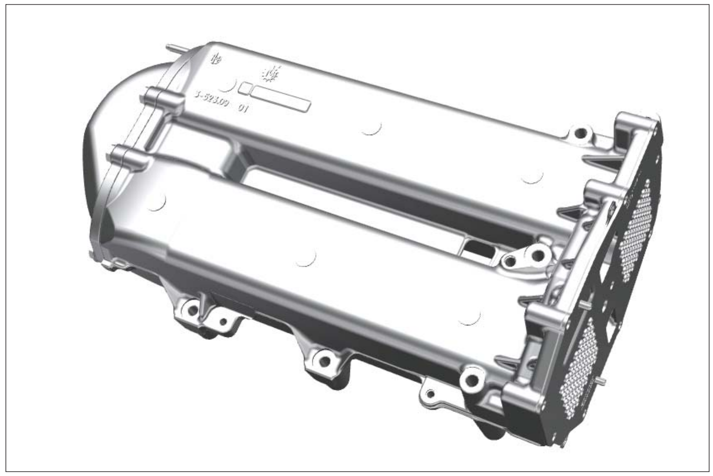
EGR cooler location

EGR Cooler

The exhaust gases are directed through the EGR cooler to lower the exhaust gas temperature before entering the intake manifold. Engine coolant reduces the exhaust gas temperature when the gases are directed through the EGR cooler by a normally closed EGR bypass valve.

The primary cooling system performs all EGR cooling functions.

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



EGR cooler

Engine cooling fan

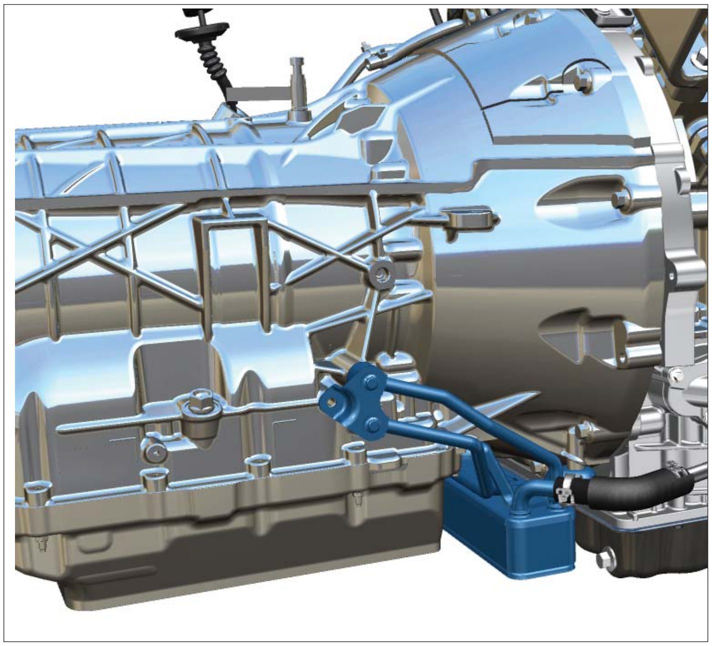
Engine Cooling Fan

The cooling fan and viscous drive actuator valve controls the fluid flow from the reservoir into the working chamber. Once the viscous fluid is in the working chamber, shearing of the fluid results in fan rotation. The valve is activated by a Pulse Width Modulated (PWM) output signal from the PCM. By opening and closing the fluid port valve, the PCM controls the fan speed. Fan speed is measured through a Hall-effect sensor and is monitored by the PCM during closed loop operation. The PCM optimizes the fan speed based on the engine coolant temperature, the engine oil temperature, the fuel rail temperature, the transmission fluid temperature, the intake air temperature, or air conditioning requirements. If a fan speed increase is required, the PCM outputs the PWM signal to the fluid port, providing the required fan speed increase.

Heater core

Heater Core

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



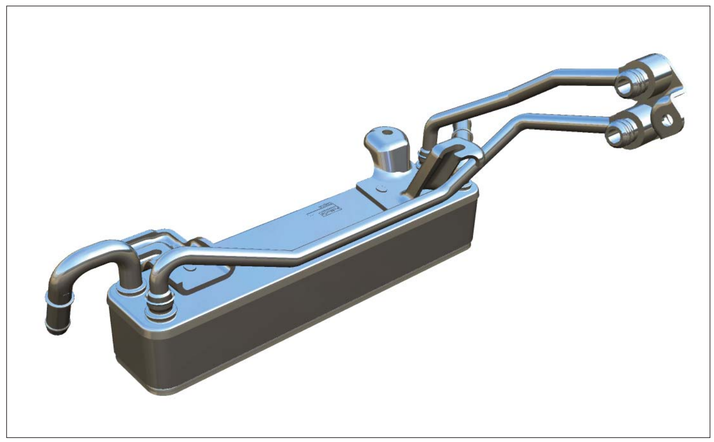
Transmission cooler location

Transmission Cooler

The 10R140 automatic transmission cooling system utilizes a heat exchanger mounted to the lower front of the transmission.

The heat exchanger has both transmission fluid and engine coolant flowing through it in separate chambers. To warm the transmission fluid, engine coolant flows through the heat exchanger during the engine warm-up period. A coolant control valve attached to the coolant return hose allows coolant flow when the transmission fluid is cold. At a predetermined temperature, the PCM signals the valve to close, shutting off coolant flow to the heat exchanger. The heat exchanger begins to work as a fluid cooler at this point.

Once at operating temperature, a fluid bypass valve on the heat exchanger directs transmission fluid through or around the cooler depending on fluid temperature.



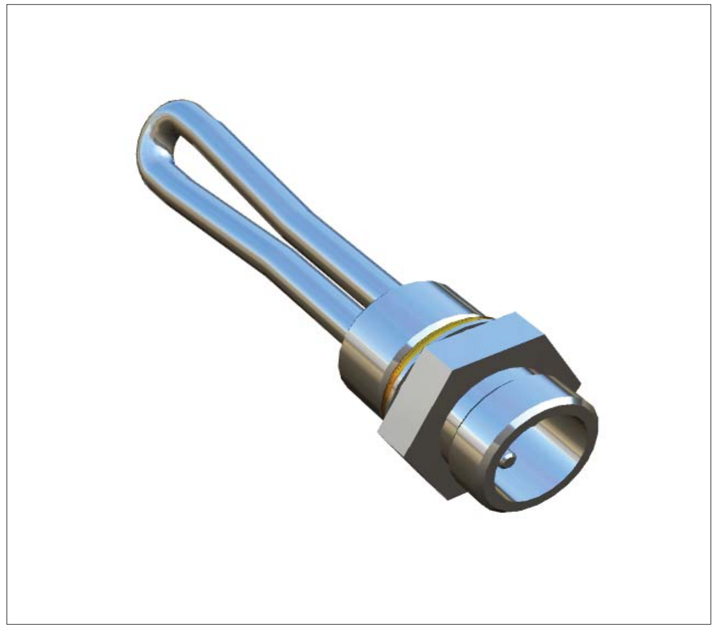
Transmission cooler

Engine block heater location

Engine Block Heater (if equipped)

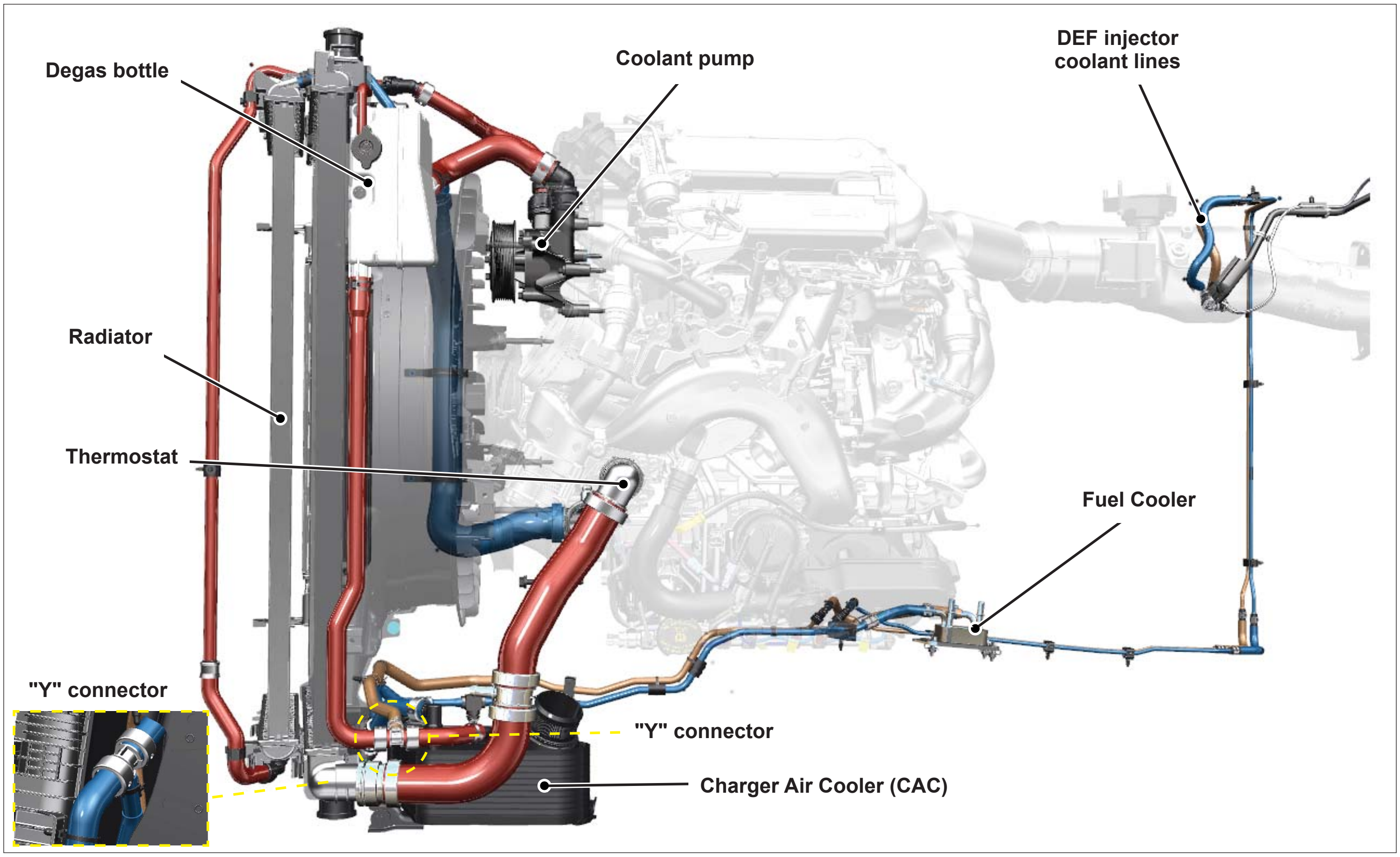
The engine block heater uses 110V AC to heat the engine coolant in cold weather climates. The block heater wiring connects to a standard 110-volt AC household outlet. Use the engine block heater whenever ambient temperatures are at or below -23°C (-10°F).

Note: For the model year 2023, vehicles equipped with a factory block heater also have a grille cover as part of the package.



Engine block heater

Powertrain Secondary Cooling Flow



Powertrain secondary cooling system flow

The secondary cooling system uses coolant flowing in a circuit separate from the primary engine cooling system.

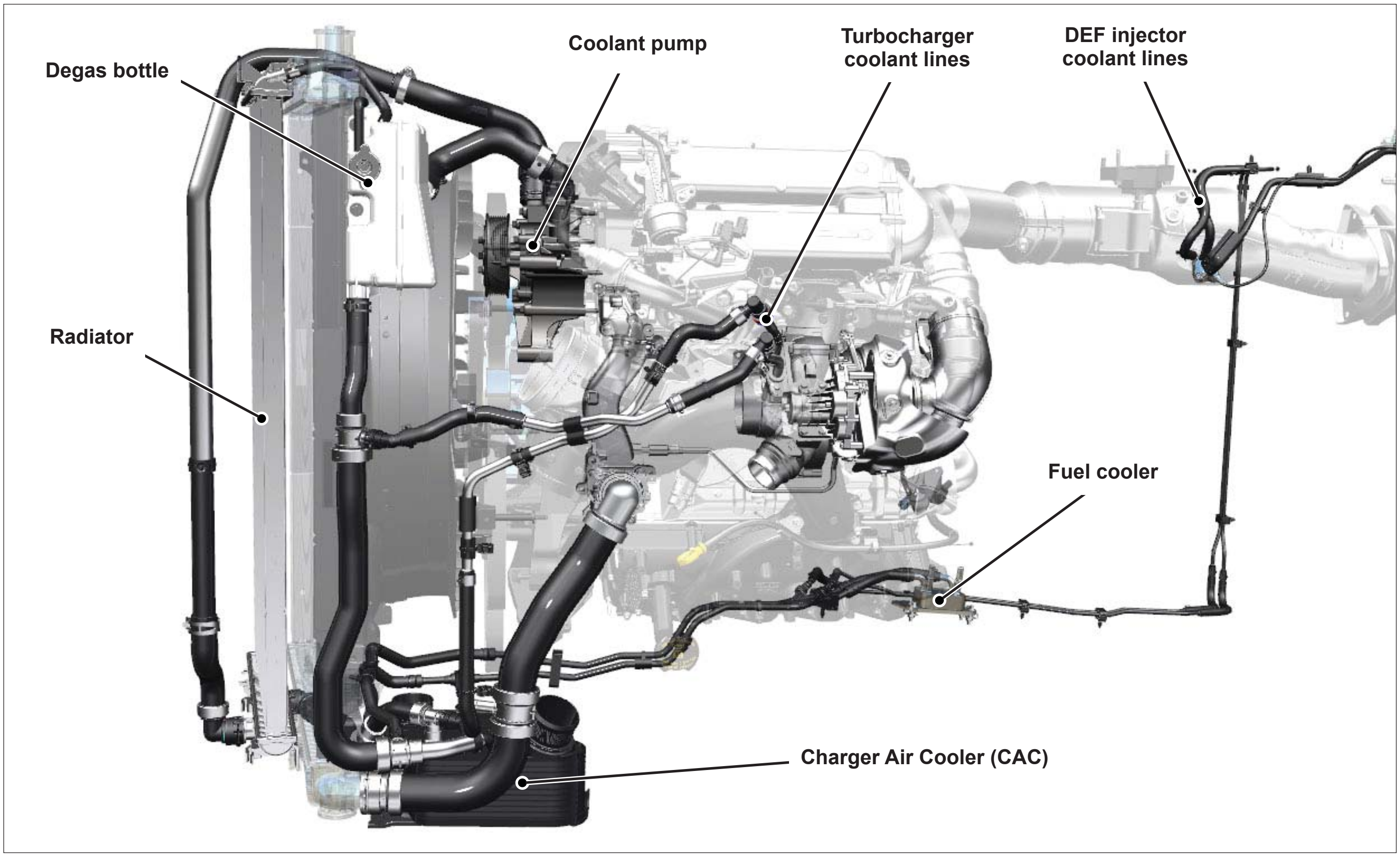
The powertrain secondary cooling system cools the following components:

- Charge Air Cooler (CAC)
- Fuel cooler
- Diesel Exhaust Fluid (DEF) injector
- Turbocharger Compressor Housing (High Output only)

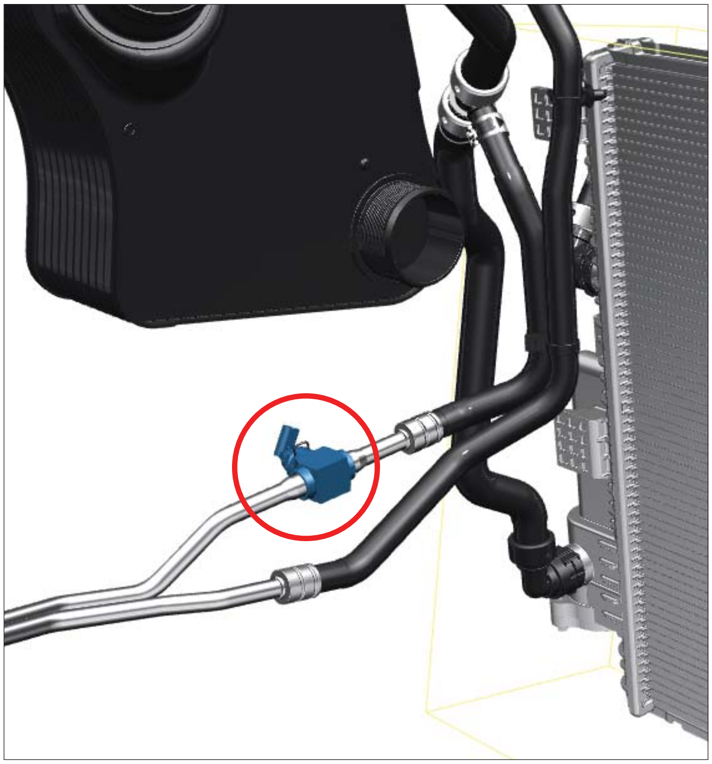
The coolant flows from the degas bottle to the coolant pump. The coolant pump delivers the coolant to the secondary radiator mounted in front of the primary engine cooling system radiator. A thermostat mounted on LH side of the secondary radiator regulates the temperature of the coolant flowing to the CAC and the fuel cooler.

- When the thermostat is closed, coolant flows from the top tank on the LH side of the engine to the thermostat housing, and then out of the thermostat housing via a single hose.
- A "Y" connection allows the coolant to flow through separate hoses to the CAC and the fuel cooler.
- When the thermostat opens, coolant entering the thermostat housing from the upper tank is blocked and the coolant flows through the radiator before flowing to the CAC and the fuel cooler.
- The coolant flows from the CAC and the fuel cooler via separate hoses to a "Y" connection, and then via a single hose to the degas bottle.
- The secondary cooling system on HO engines uses larger hoses and tubes to accommodate the added heat load from the turbocharger.

Powertrain Secondary Cooling Components High Output

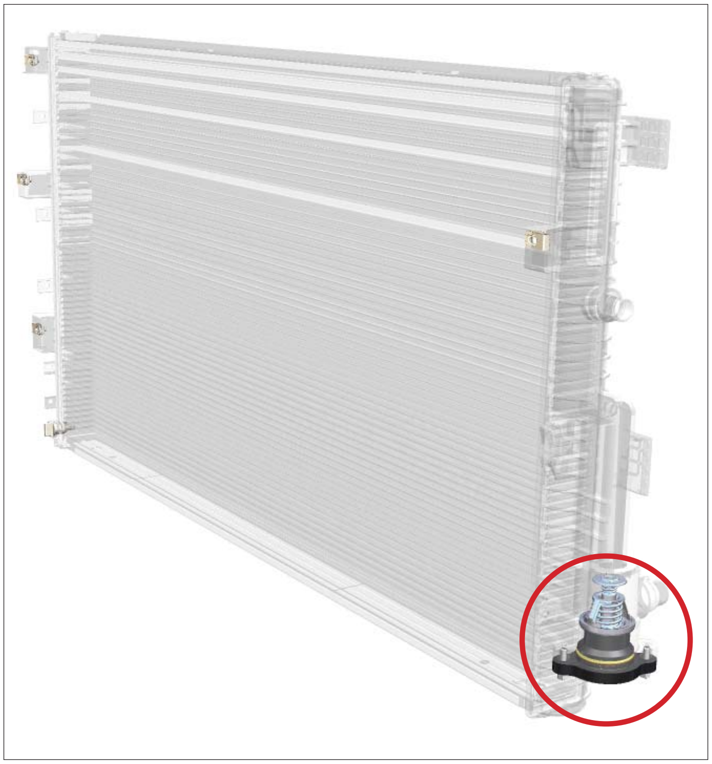


Powertrain secondary cooling system components high output


ECT2 sensor

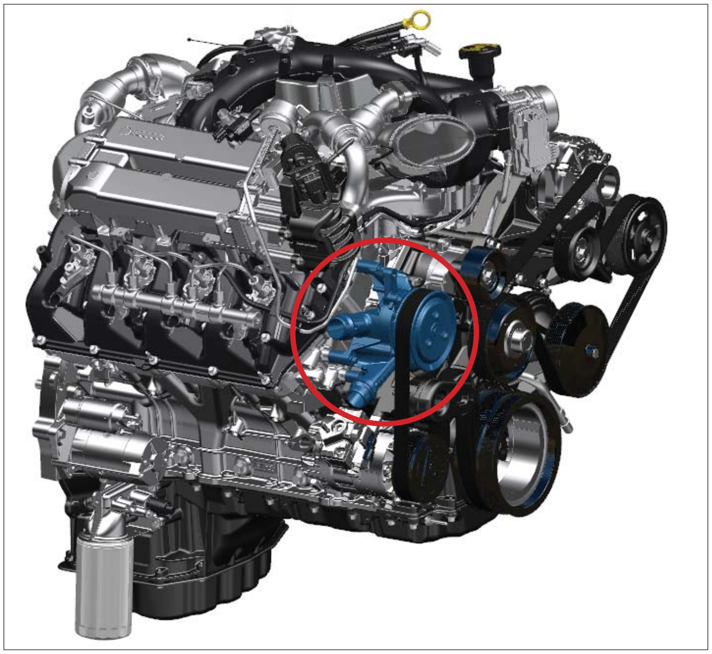
Engine Cooling System Temperature (ECT2) Sensor

The sensor is now mounted in a “T” fitting in a coolant line located in the left front engine compartment.


Secondary thermostat

Secondary Thermostat

The secondary thermostat, located on the left side of the radiator, starts to open at 20°C (68°F) and regulates the lower radiator temperature to approximately 45°C (113°F). This thermostat controls coolant flow to the CAC and the fuel cooler.



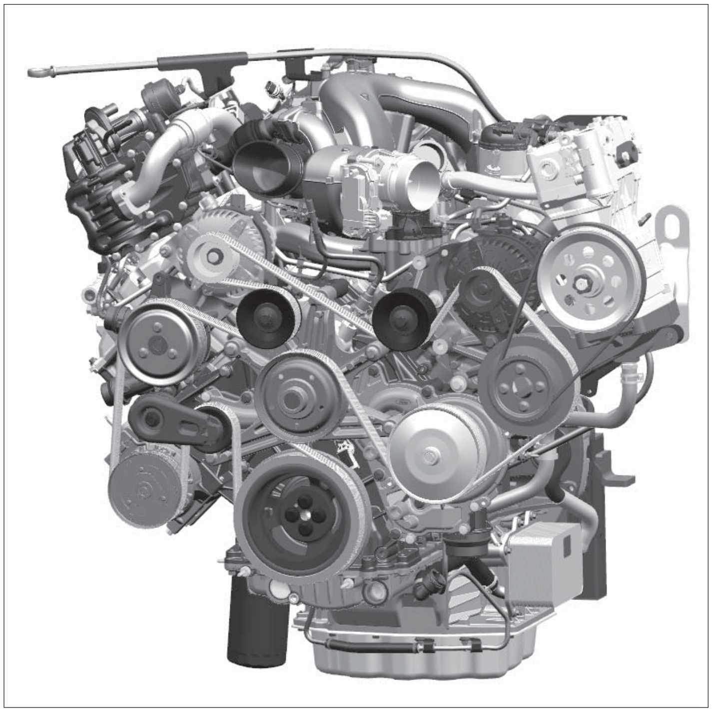
Secondary coolant pump location

Secondary Coolant Pump

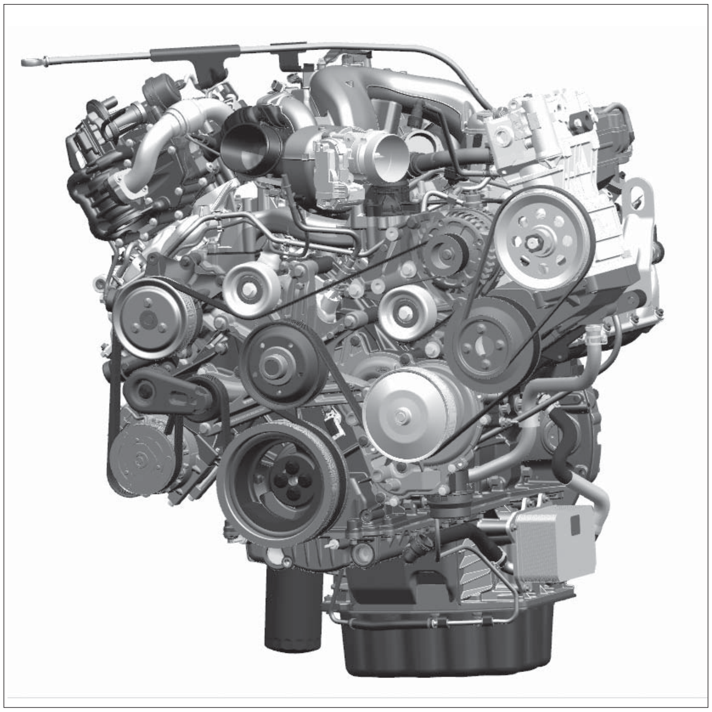
The secondary coolant pump is located on the right front of the engine and driven by the serpentine drive belt.

Note: 2023 there are 3 different water pumps single Alternator, dual Alternator, and with air compressor.

Secondary coolant pump



Dual alternator with air compressor



Single alternator with air compressor

Oil Flow

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 upper oil pan and then to the oil pump inlet.

- From the oil pump, oil is first sent across the upper oil pan to the oil cooler.
- The main oil passage in the rear of the engine block feeds the right, left and camshaft galleries.
- Right oil gallery feeds:
  - Rocker arm oiling manifold for the right cylinder head
  - Cam followers and hydraulic lifters on the right side
  - Piston cooling jets on the right side
  - Crankshaft main bearings (via a separate oil passage for each main bearing)
  - Connecting rod bearings
  - Turbocharger
- Left oil gallery feeds:
  - Rocker arm oiling manifold for the left cylinder head
  - Vacuum pump
  - Meshed gears of the crankshaft, camshaft, and high-pressure fuel pump
  - Cam followers and hydraulic lifters on the left side
  - Piston cooling jets on the left side
- A camshaft oil gallery feeds the camshaft bearings.

Components

Oil Pressure Control Solenoid

The oil pressure is electronically regulated via the Variable Displacement Oil Pump (VDOP) pressure control solenoid. This results in continuous oil pressure control which reduces engine load and improves fuel economy.

Note:	This solenoid is located in the oil filter adapter, a new location for the 2023 model year.

Oil pressure control solenoid location

Oil pressure control solenoid

Checking The Engine Oil Level

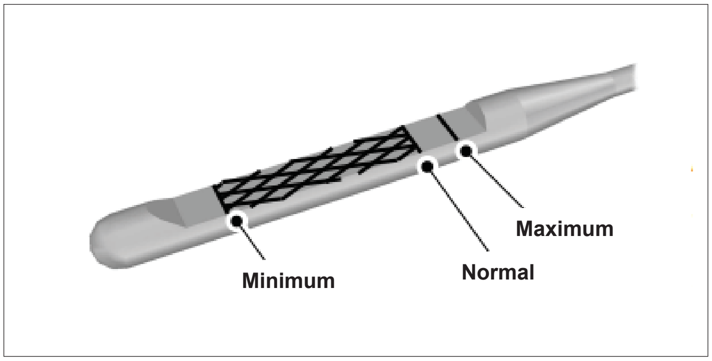
Make sure that your vehicle is on level ground. Check the coil level before starting the engine, or switch the engine off after warm up and wait 15 minutes for the oil to drain into the pan.

Note:	Checking the oil level too soon could result in an inaccurate reading.

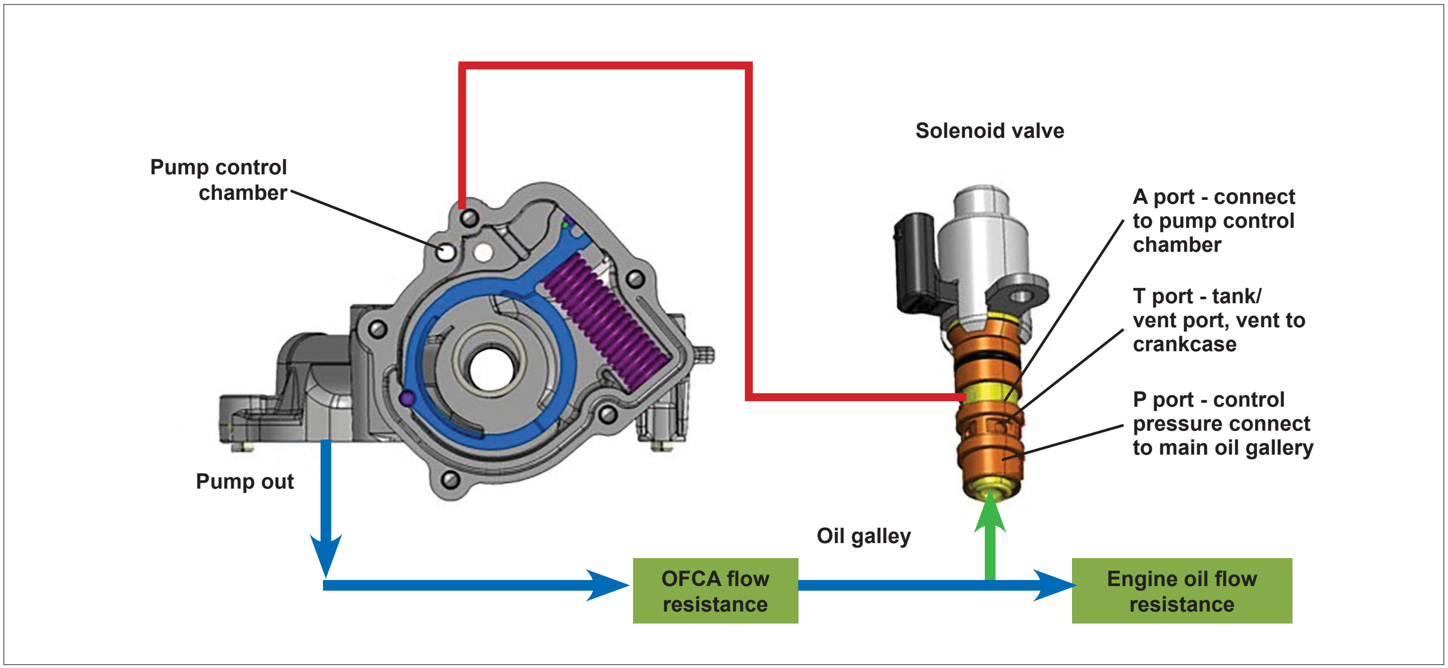
Remove the dipstick and wipe it with a clean, lint-free cloth. Reinstall the dipstick and make sure it is fully seated. Remove the dipstick again to check the oil level.

Note:	If the oil level is between the maximum and minimum marks, the oil level is acceptable. Do not add oil

If the oil level is at the minimum mark, immediately add oil. Reinstall the dipstick. Make sure it is fully seated.



Diesel engine oil dipstick



Electronic oil pressure regulator operation

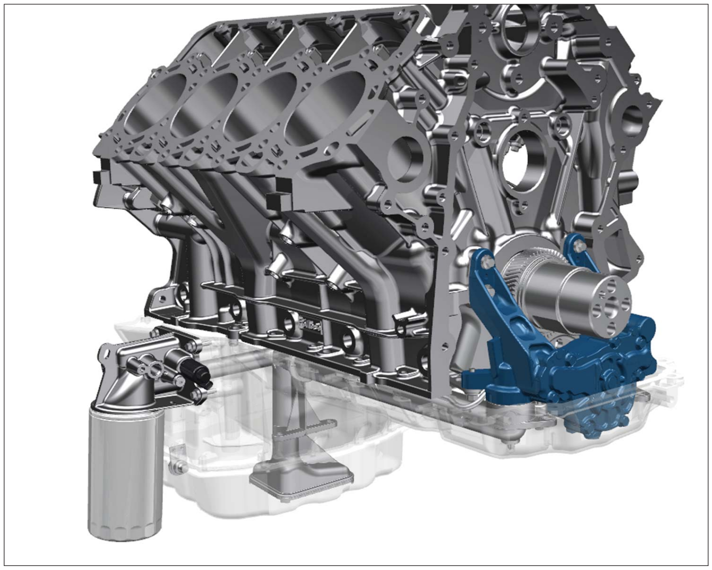
Electronic Oil Pressure Regulator Operation

Regulating oil pump displacement provides varying oil volume, ensuring correct oil pressure both at hot idle and maximum speed. Operation of the oil pump is controlled by the oil pressure control solenoid switches the pump between high and low mode operation. The solenoid mounts into the main oil galley of the engine block.

The solenoid has 3 ports:

- P - Pressure
- A - Actuation/feedback (connected to pump)
- T - Tank (dump to sump)

Oil flow pressure/flow regulation is based on engine load and temperature. The PCM commands the duty cycle power for the solenoid, changing the position of the solenoid. Pressure regulation is achieved by passing oil through the A-port, directing oil to the control chamber the of the pump and de-stroking the pump. Oil passes through the T-port during excessive pressure and high viscosity conditions.

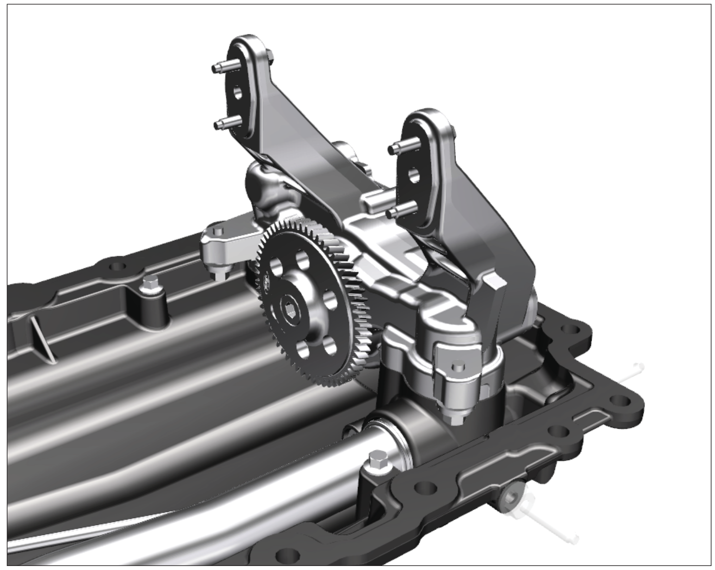


Oil pump

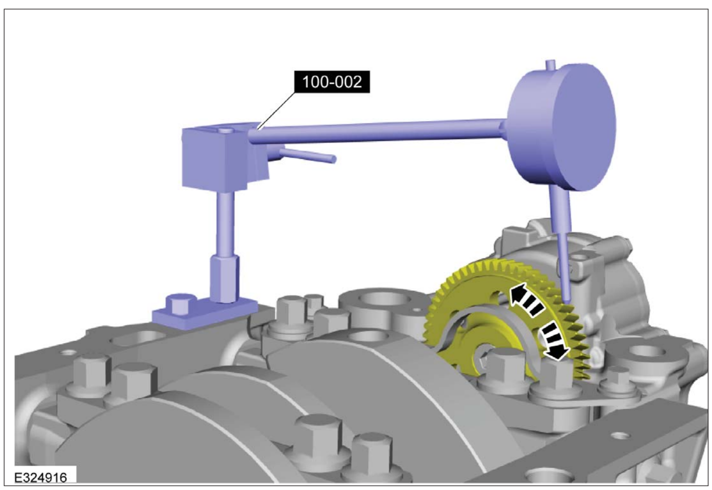
Oil Pump

The VDOP is a separately serviceable unit mounted to the front of the engine block, behind the front cover.

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



Oil pump



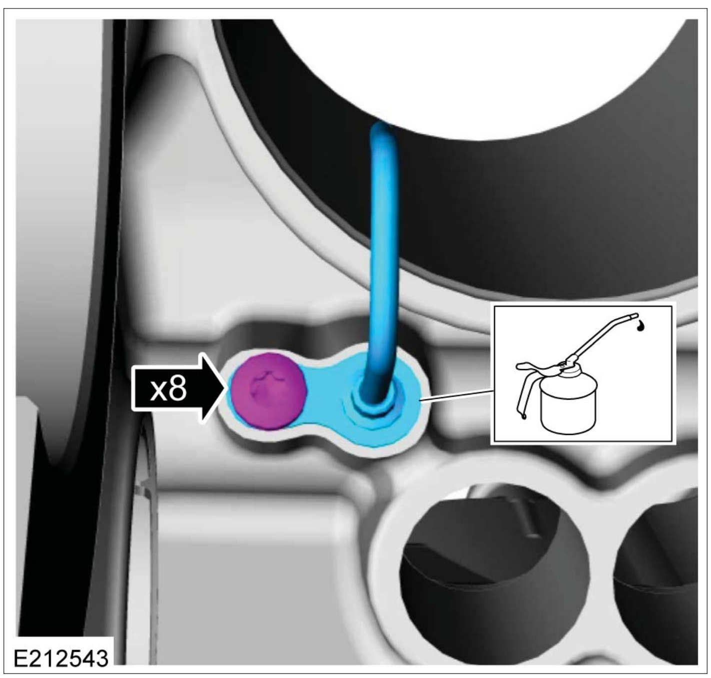
Oil pump backlash

Always check the oil pump drive gear backlash with a dial indicator during the 6.7L Power Stroke® Turbo Diesel service.

Piston cooling jet

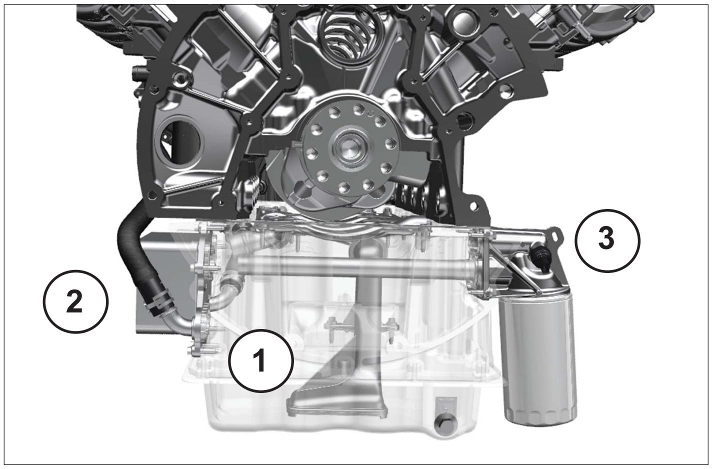
Piston Cooling Jets

The 6.7L Power Stroke®Turbo Diesel incorporates piston cooling jets that spray oil into a hole in the bottom of the piston. The oil flows internally through the piston, cooling the top of the piston.



Piston cooling jet mounting

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



Oil cooler mounting

Oil Flow Through Oil Cooler Passages

The oil pump draws oil from the lower oil pan pickup (**1**). From the oil pump, pressurized oil is fed through integrated passages in the upper oil pan and directed to the oil cooler (**2**). Oil exits the oil cooler into another integrated passage and passes across the oil pan to the oil filter adapter (**3**). After exiting the oil filter, the cooled, filtered oil is directed to the engine block main oil galley.

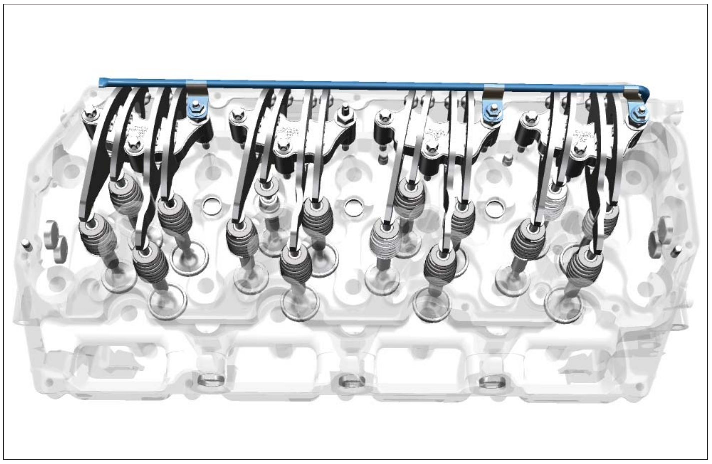
Oil filter adapter

Oil Filter Adapter

The oil filter is a spin-on style mounted on the right side of the oil pan. The oil filter mounts to a removable oil filter adapter mounted to the block stiffening upper oil pan.

The Engine Oil Temperature (EOT) and Engine Oil Pressure (EOP) sensors are integrated into a single unit mounted to the oil filter adapter and send data to the PCM via SENT protocol.

The Variable Displacement Oil Pump (VDOP) solenoid has been moved from the upper oil pan to the oil filter adapter for the 2023 model year.

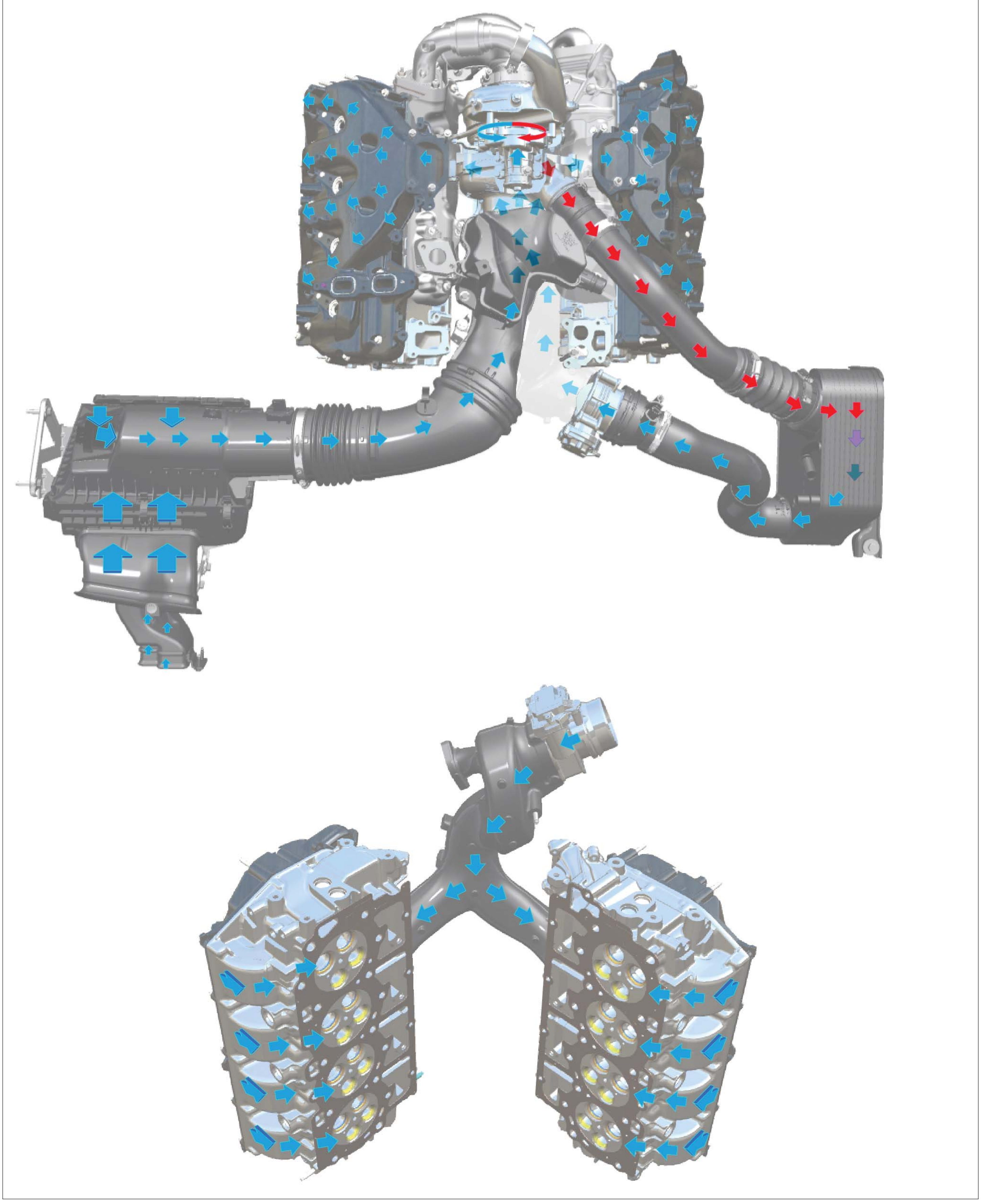


Oil spray bar

Valvetrain Lubrication

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

Air Flow



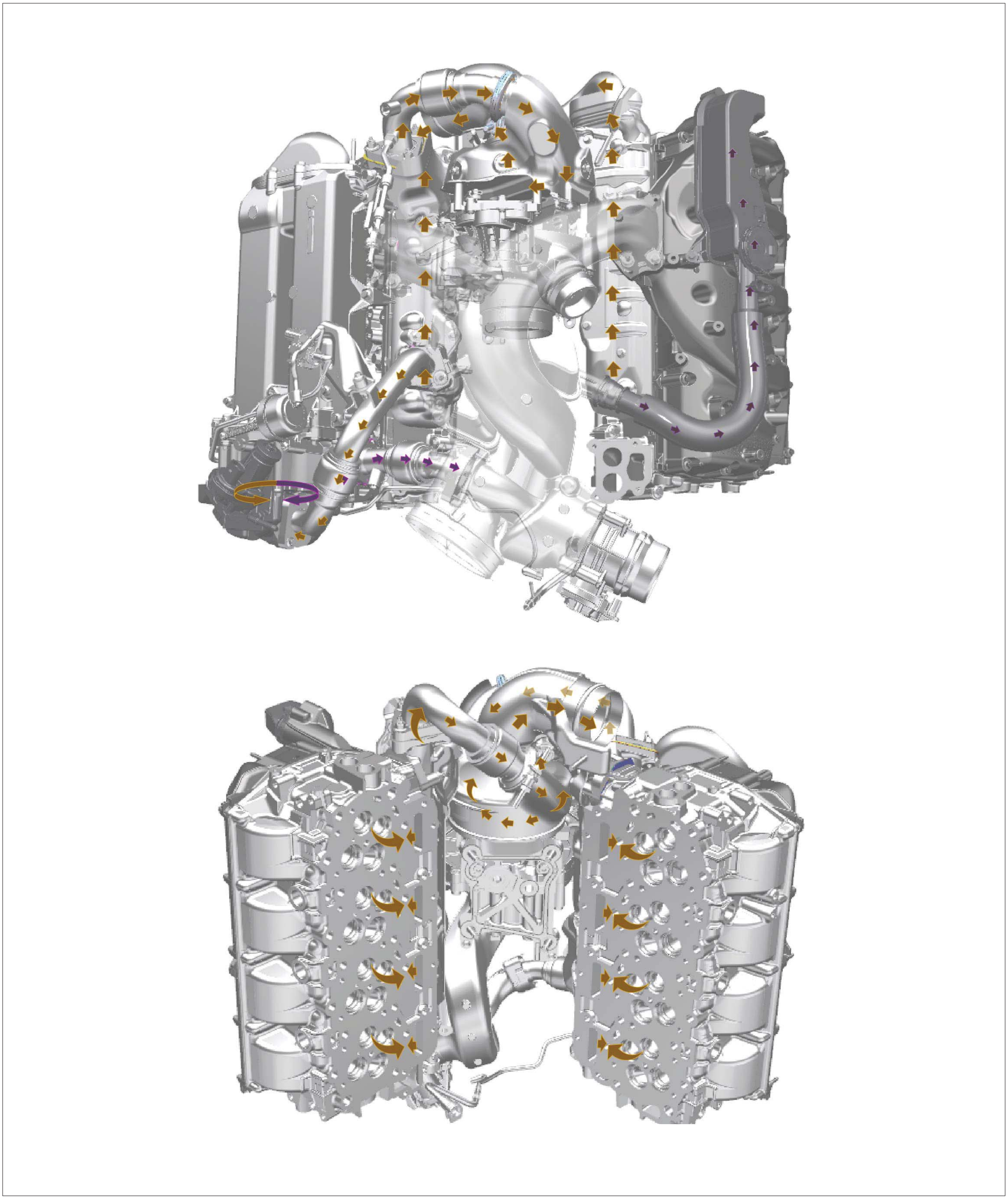
Intake

Air Flow - Intake Side

The air intake system cleans intake air with a replaceable, dry-type engine air cleaner element made of treated, pleated paper. The air cleaner element must be replaced with a new component when necessary. Engine performance and fuel economy are adversely affected when maximum restriction of the air cleaner element is reached.

Air is drawn through the air filter and through the Mass Air Flow (MAF)/Intake Air Temperature (IAT)/Turbocharger Inlet Pressure (TCIP)/Humidity Sensor assembly, which houses the MAF sensor wire. The MAF sensor measures the mass of the air entering the engine, and the IAT sensor monitors the air temperature. The pressure sensor is used to detect a restricted air filter.

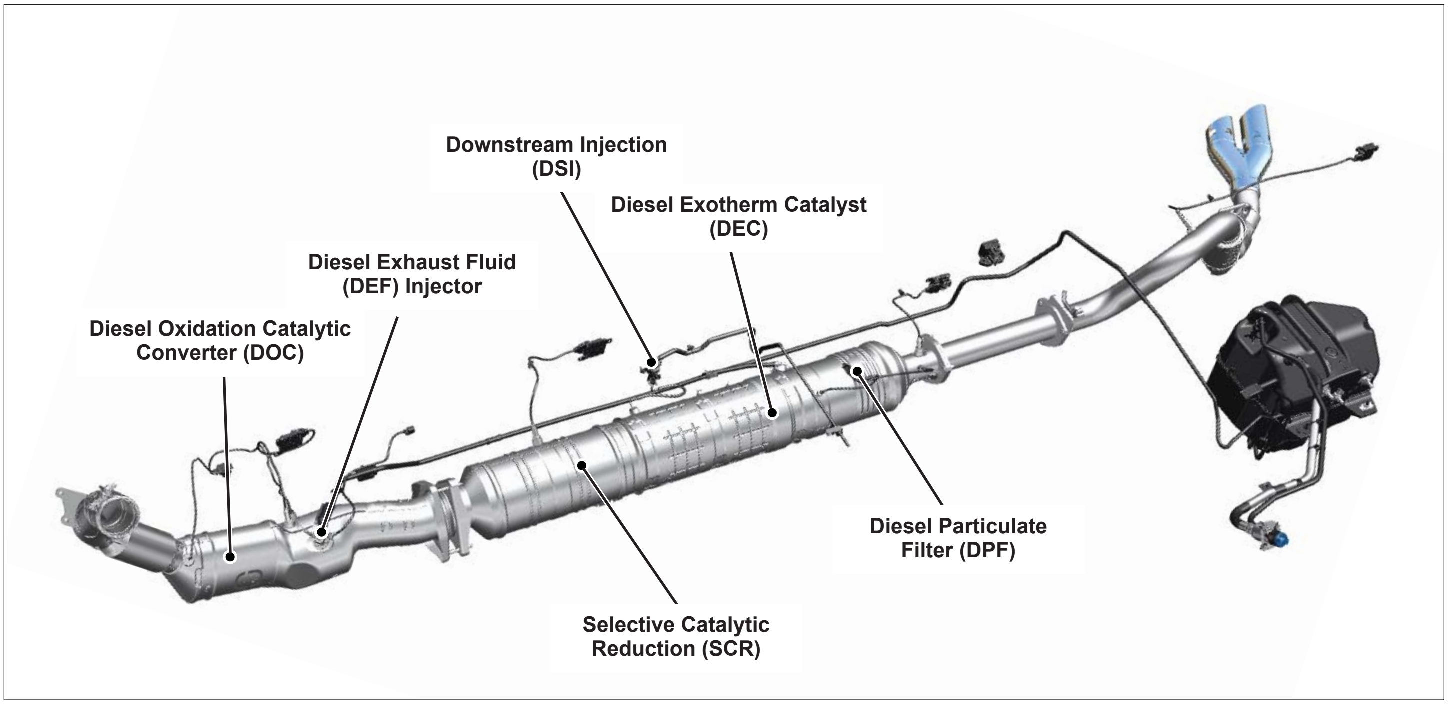
Next, the air enters the compressor side of the turbocharger through the lower intake manifold. The air is compressed above atmospheric pressure, causing the air to heat up. The hot, pressurized air is routed through an air-to-liquid Charge Air Cooler (CAC), cooling the charge, and increasing the density of the compressed air. From the CAC the air passes the Charge Air Cooler Temperature (CACT) sensor, through the intake throttle body, and into the other side of the lower intake manifold. Inside the lower intake manifold the air mixes with EGR gases (if the EGR valve is open), travels to the upper intake manifold, and through the right and left side rocker covers to the intake ports of the cylinder heads.



Exhaust

Air Flow - Exhaust Side

Exhaust gases exit the cylinder head exhaust ports into the inboard exhaust manifolds and are directed away from the cylinders. Exhaust gases flow to the dual inlet of the turbo through the right and left side up pipe. The exhaust spins the turbine wheel inside the turbocharger. The turbine wheel spins the compressor wheel through their common shaft. Some of the exhaust from the passenger side manifold is directed to the EGR valve through the EGR inlet pipe. When the EGR valve is operating, the exhaust gases can either flow through the EGR cooler or bypass it. This is done by the EGR cooler bypass valve. The exhaust gas bypassing or flowing through the EGR cooler enters the lower intake manifold and combines with the fresh intake air.



Exhaust

The hydrocarbon (HC) and carbon monoxide (CO) exhaust gas emissions are reduced to acceptable levels as the exhaust gas passes through the Diesel Oxidation Catalytic Converter (DOC). The reduced emissions exhaust gas and any soot or particulates continue to the Selective Catalytic Reduction System (SCR). As the exhaust gas enters the SCR catalyst,

Diesel Exhaust Fluid (DEF) is mixed into the stream and thermally decomposes to ammonia and carbon dioxide. The ammonia and Oxides of Nitrogen (NOx) components of the exhaust gas is chemically reduced, and the exhaust gas and particulates continue flowing through the Diesel Exotherm Catalyst (DEC) to the Diesel Particulate Filter (DPF). In the DPF, the exhaust gas and particulates flow through the channels of substrate filter. As the exhaust gas passes through the filter, most particulates are removed from the exhaust gases and trapped until DPF regeneration occurs. The reduced emissions exhaust gas and any remaining particulates flow through the muffler and tail pipe into the atmosphere. The heat needed for DPF regeneration is created by fuel injected by the Downstream Injector (DSI) just in front of the DEC. The DEC reduces the HC in the fuel resulting in an increase in exhaust temperatures so regeneration can occur.

Air Intake Components

Air filter

The air filter is located on the passenger side of the engine compartment in front of the battery on the low side pressure system (turbo intake).

Air filter

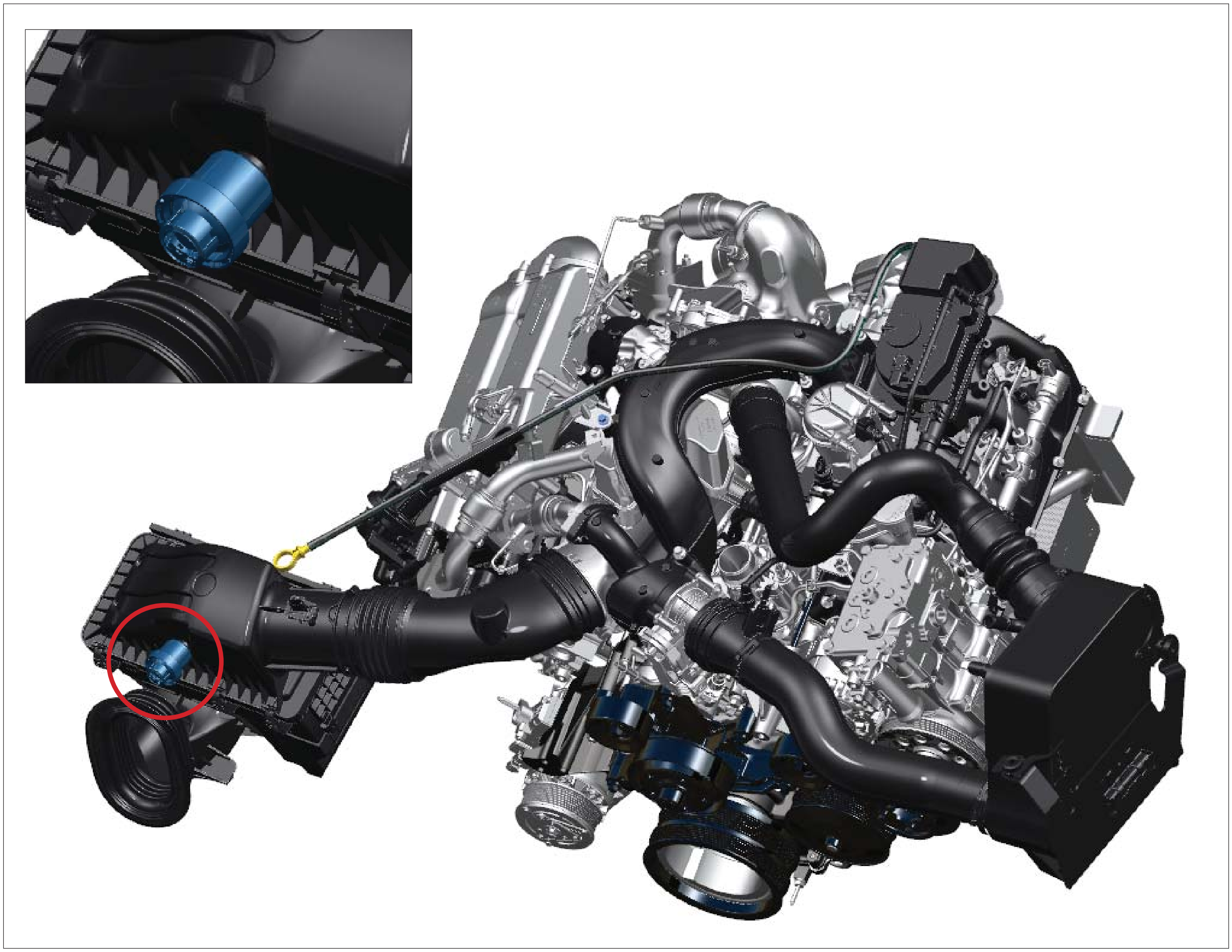
Mass Air Flow/Intake Air Temperature (MAF/IAT) Sensor

The air intake system includes Mass Air Flow (MAF) and Intake Air Temperature (IAT) sensors integrated into one unit with the humidity sensor and the Turbocharger Inlet Pressure (TCIP) sensor. The humidity sensor measures relative humidity of the incoming air. The TCIP senses if there is an air inlet restriction. The assembly uses Single Edge Nibble Transmission (SENT) protocol to transmit data to the PCM.

The MAF/IAT sensor is located in the air inlet tube after the air filter.

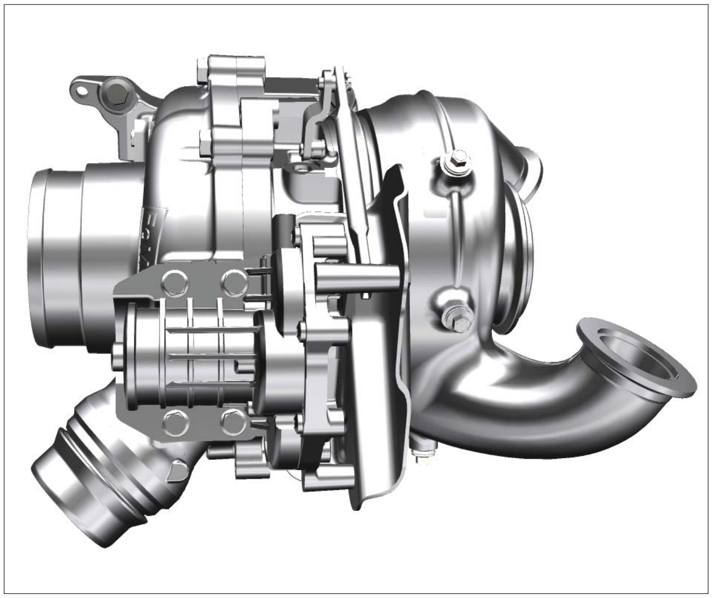
MAF/IAT location

MAF/IAT



Filter minder F650/750 (only)

The air filter housing includes a mechanical filter minder to measure inlet restriction. When the filter element becomes contaminated beyond useful limits, the filter minder visually indicates the need for replacement. The filter minder also sends an electrical signal to the PCM which then sends a message to the Instrument Panel Cluster (IPC) to notify to driver.



Turbocharger

Variable Geometry Turbocharger

The turbocharger uses variable vanes that surround the turbine wheel to dynamically adjust turbocharger speed. The PCM controls the variable turbocharger geometry using an electronic turbocharger actuator. In response to engine speed, load, manifold pressure, and barometric pressure, the PCM controls the turbocharger actuator position to match manifold boost to the requirements of the engine. The turbocharger provides up to approximately 206.84 kPa (30 psi) boost at up to 130,000 RPM. Ball bearings support the turbine/impeller shaft, allowing the turbocharger to operate under high speed and high heat conditions.

Separate oil and water feeds flow through the turbocharger mounting pedestal to lubricate and cool the turbocharger, eliminating multiple external connections. High output engines have a turbo with coolant from the secondary cooling system flowing around the compressor housing.

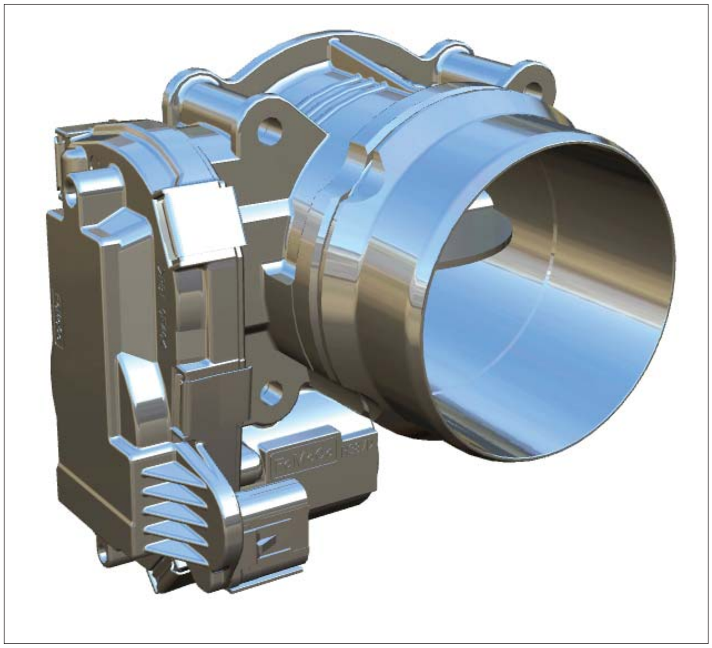
This turbocharger does not incorporate a wastegate.

Charge Air Cooler (CAC)

Charge Air Cooler (CAC)

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

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

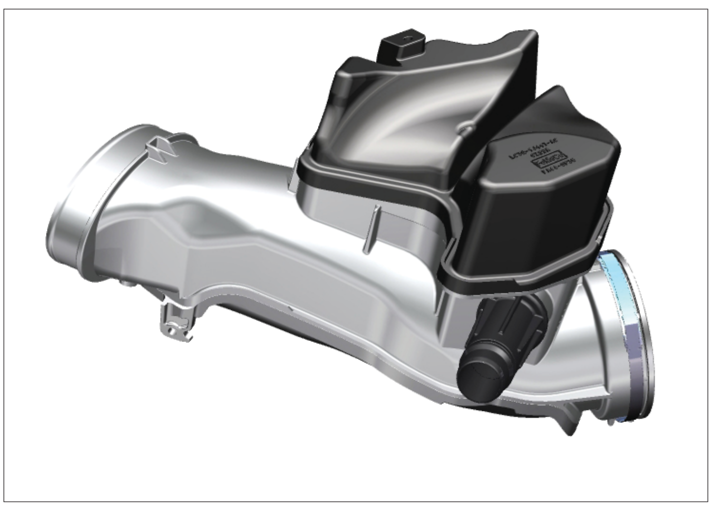


Intake throttle body

Intake Throttle Body

The intake throttle body is located on the top of the engine attached to the lower intake manifold. The throttle body is normally open, but closes to control airflow into the intake air system.

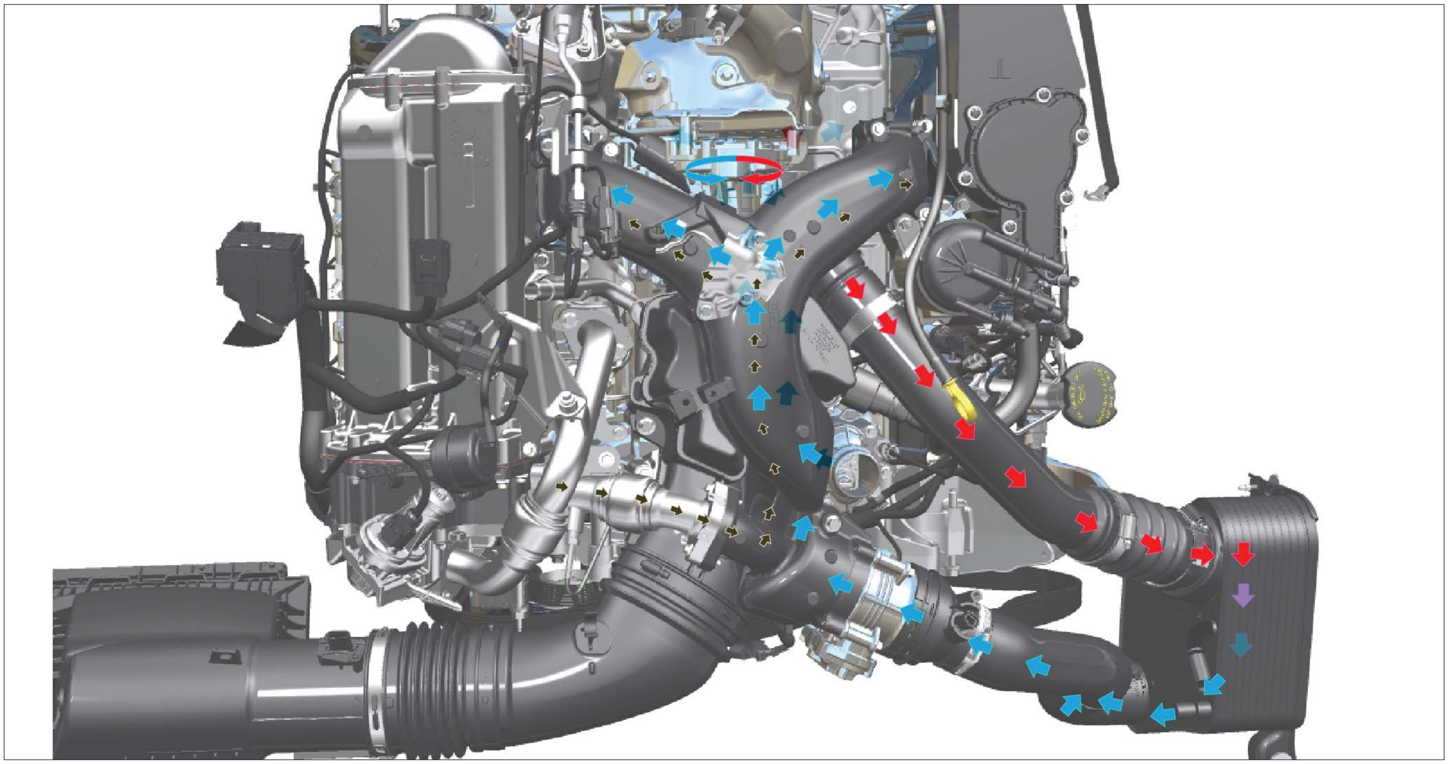
The intake throttle body promotes the flow of EGR gases to the intake manifold by creating a negative pressure differential between exhaust gas pressure and intake air pressure.



Lower intake manifold

Lower Intake Manifold

The lower intake manifold is on the top of the engine and intake air passes through it to the turbocharger. As air flows through the lower intake manifold it pulls crankcase vapors from the oil separator which mixes with the air on its way to the turbocharger.



Airflow through CAC

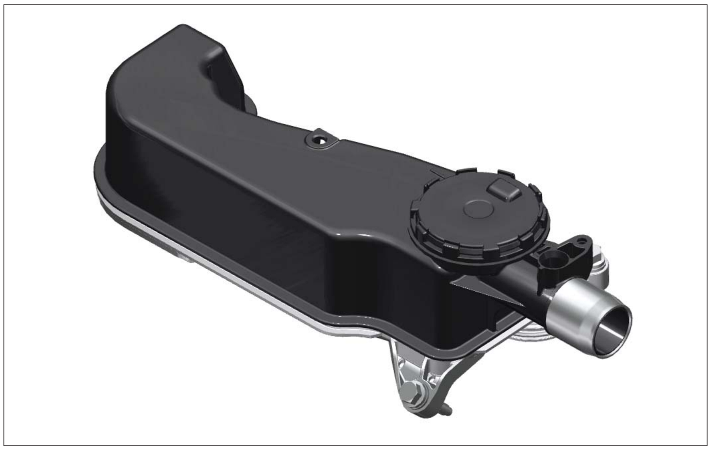
Lower Intake Airflow after the CAC

After leaving the turbocharger outlet, the air goes through the CAC and then through the intake throttle body before it is mixed with exhaust gases from the EGR valve. The blue arrows represent the flow of cooled intake air and the brown smaller arrows represent the flow of EGR gases.

Upper intake manifold

Upper Intake Manifold

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



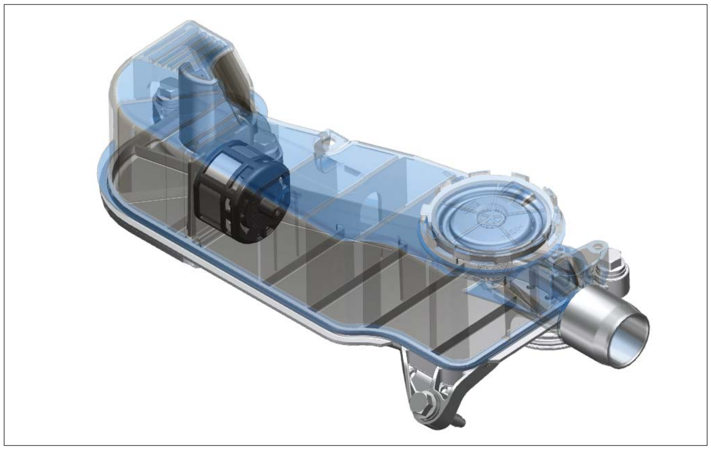
Crankcase vent oil separator

Crankcase Vent Oil Separator

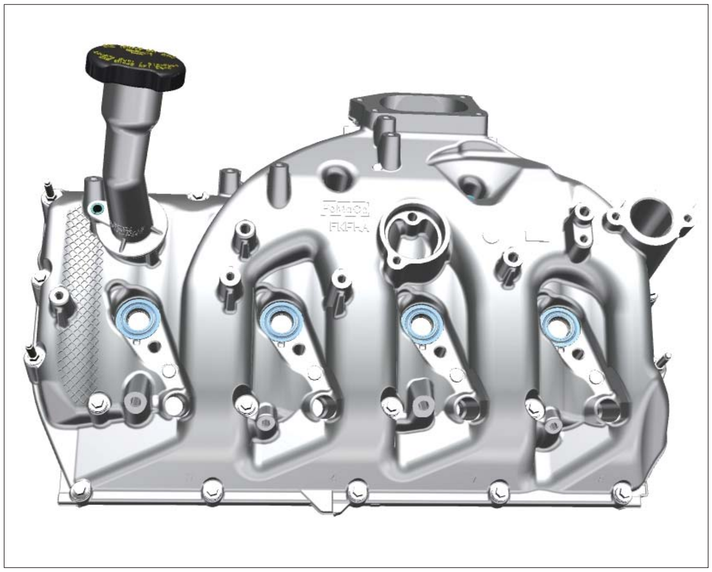
The crankcase vent oil separator is attached to the left valve cover.

The engine crankcase vent oil separator separates the oil from crankcase vapors and returns it to the crankcase through the valve cover.

The vapors are routed into the intake ducting at the lower intake before the turbo inlet. This unit is serviced as an assembly.



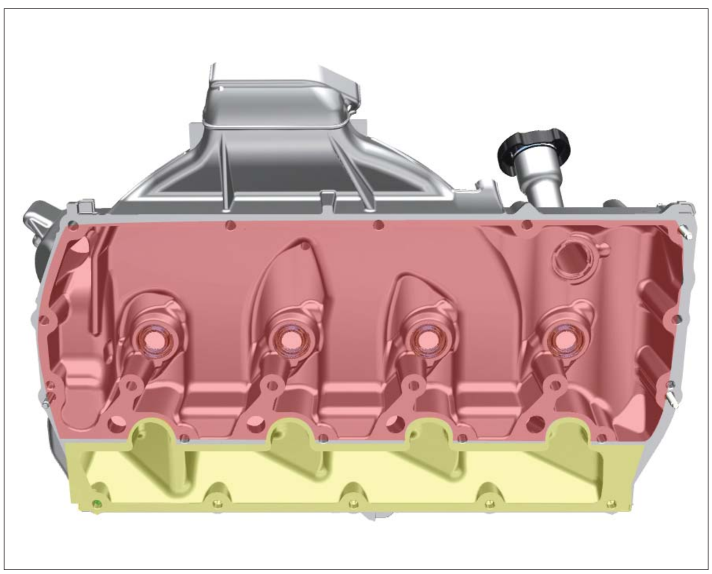
Crankcase vent oil separator



Intake manifold/valve cover assembly

Intake Manifold/Valve Cover

The intake manifold/valve cover for each cylinder head is incorporated into one piece. The air flows from the upper intake manifold into the top of the valve cover and across to the intake ports. Because the intake manifold is integrated with the valve cover, engine oil temperature affects temperature of the air entering the intake ports.

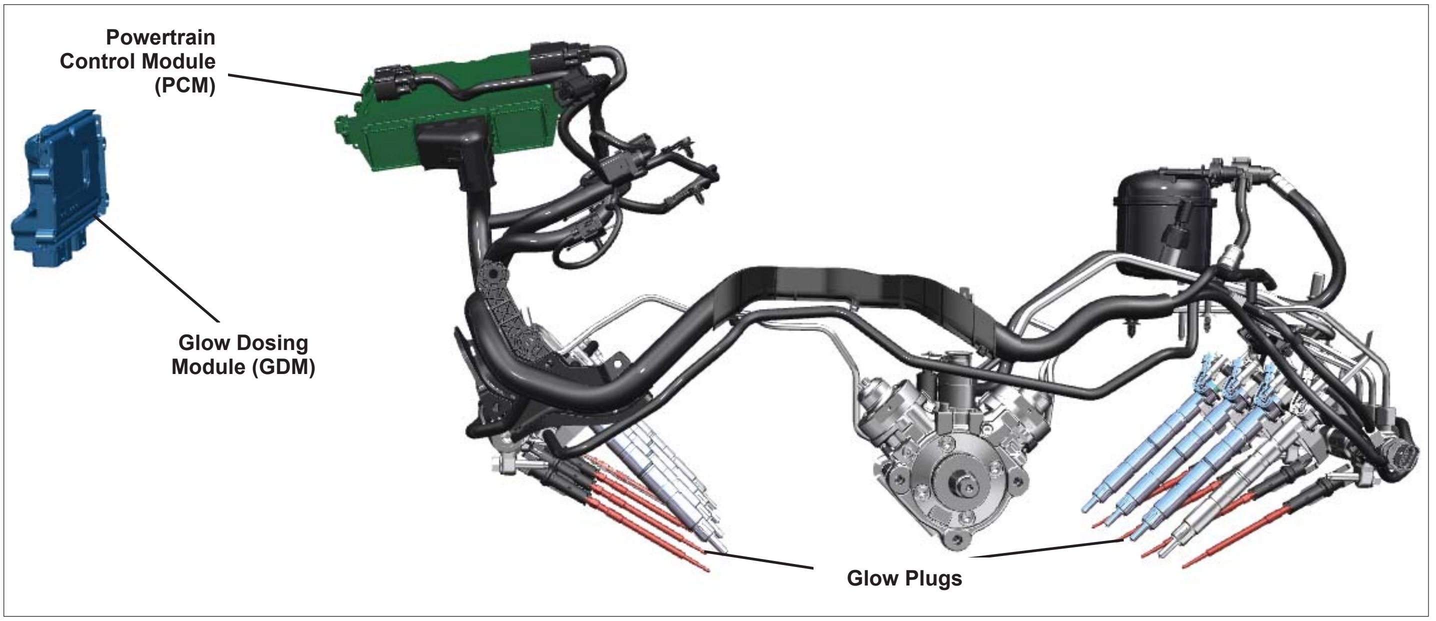


Underside - intake manifold/valve cover assembly

Underside of Valve Cover

In the picture you can see the intake manifold port on the bottom (indicated in yellow) and the valve cover cavity on the top (indicated in red).

Glow Plug System Components

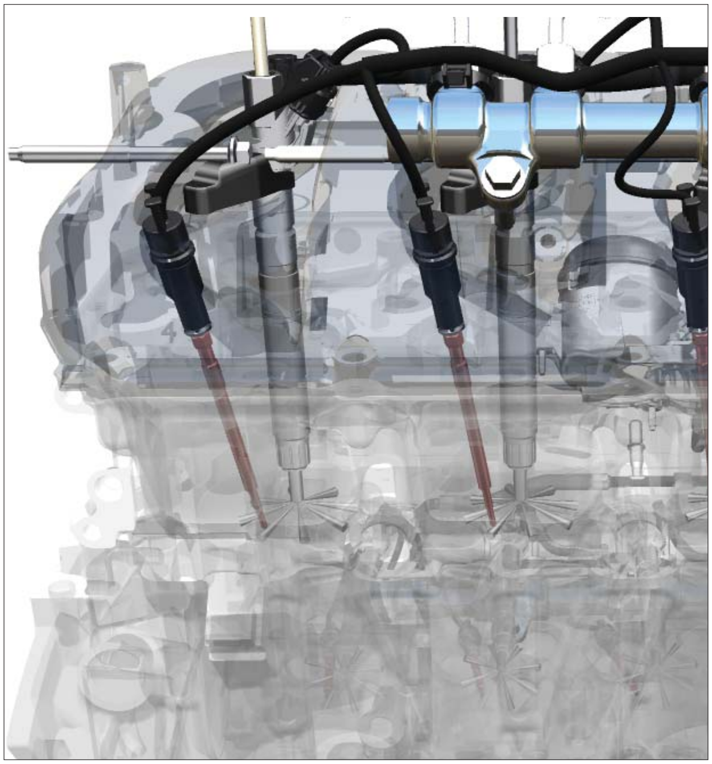


Glow dosing module

Glow Dosing Module (GDM)

The Glow Dosing Module (GDM), *formerly known as the Glow Plug Control Module (GPCM)*, is located under the passenger side battery box. The GDM controls the glow plugs, DEF pump, DEF injector and DEF heaters. The PCM receives and processes all exhaust temperature and NOx data then sends the information to the GDM which then activates the circuits. Data regarding DEF level, quality, and temperature are sent to the GDM. The GDM and the PCM communicate on HS-CAN2.

The glow plug system is electronically controlled by the PCM by monitoring the Ambient Air Temperature (AAT), Engine Coolant Temperature (ECT), and Barometric Pressure (BARO) sensors to determine if glow plug operation is needed.

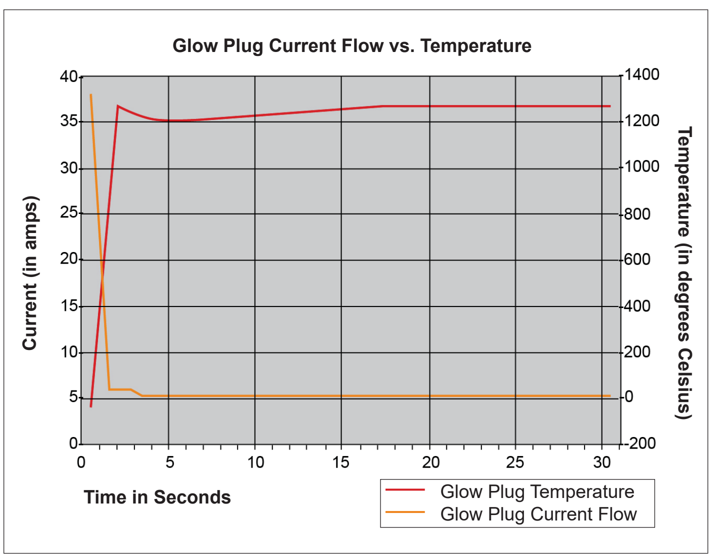


Glow plugs

Glow Plugs

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

The GDM supplies the required current to each glow plug.. Ground is provided through the glow plug body to the cylinder head.



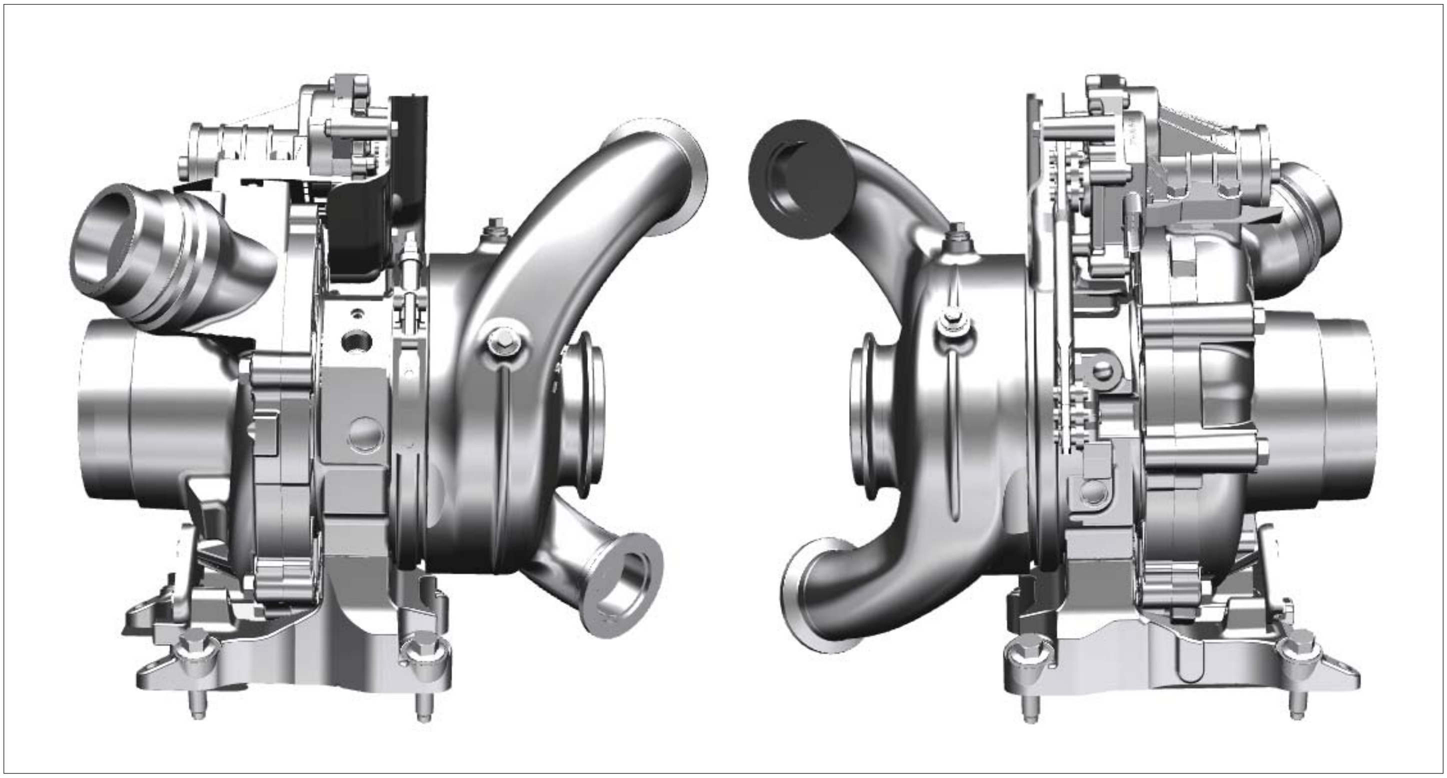
Glow plug current flow vs. temperature

Glow Plug Operation

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

- End of compression temperature is high enough to auto-ignite the fuel.
- The ceramic glow plugs can reach 1,250°C (2,282°F) in 2 seconds.
- The tip of the glow plug is closer to the rim of the piston than the injector. This causes the heat from the glow plug to contact the rim zone of the fuel spray.

Variable Geometry Turbocharger



Variable geometry turbocharger

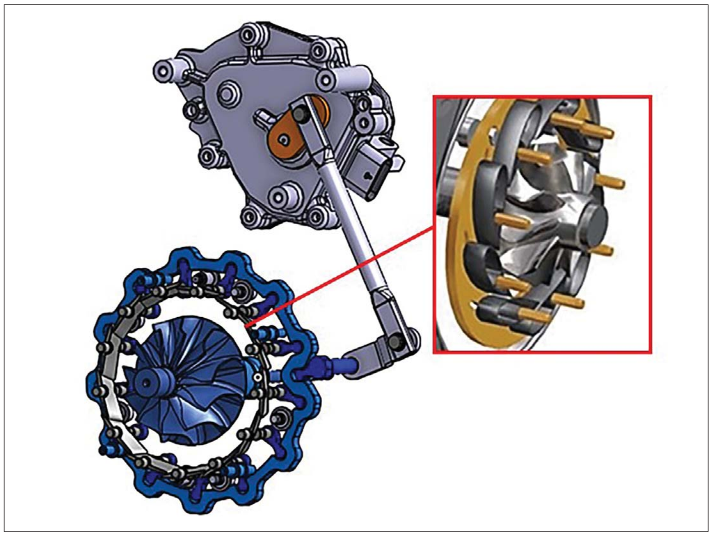
Turbocharger control is based on an air system model that produces a desired intake system pressure to meet the power requirements requested by the operator. The variable geometry turbocharger is electronically controlled by the PCM. Electronic control provides boost control at low and high speeds for improved throttle response. The PCM monitors a feedback loop in the intake system and controls the turbocharger to achieve the desired intake pressure, meeting the driver's needs. The air system model considers engine temperature, air temperature, EGR operation and throttle pedal position. High output engines have a turbo with coolant flowing around the compressor housing from the secondary cooling system.

The variable vanes surround the turbine wheel. Vane position is electronically controlled using a turbocharger actuator motor. During engine operation at low speeds and load, the vanes are closed to accelerate exhaust gases across the turbine wheel to help quickly increase the turbocharger wheel speed. At high speeds the vanes open to prevent turbocharger overspeed conditions, eliminating the need for a wastegate. A position sensor integrated into the turbocharger actuator monitors vane position.

Variable Geometry Turbocharger Operation

Turbocharger Closed

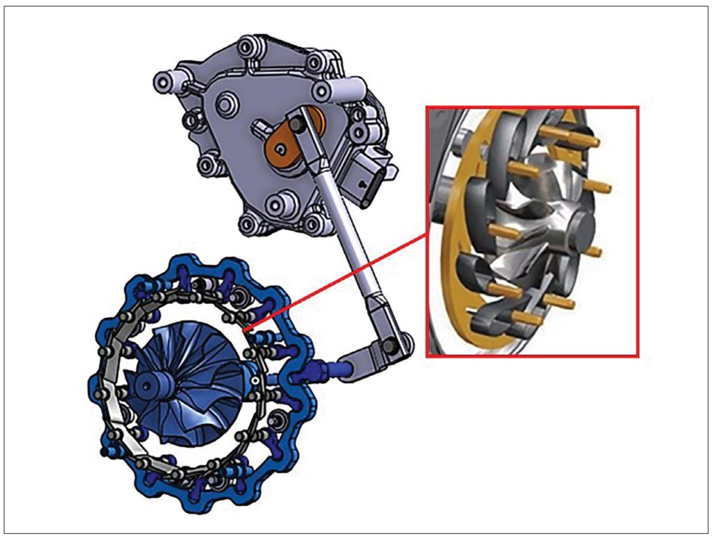
When the variable geometry turbocharger is closed it maximizes the use of the energy that is available at low speeds. Closing the variable geometry turbocharger accelerates exhaust gas flow across the vanes of the turbine wheel. This allows the turbocharger to behave as a smaller turbocharger. Closing the vanes also increases the exhaust pressure in the exhaust manifold, which aids in pushing exhaust gas into the intake. This is also the position during engine start-up in low ambient temperatures, helping the engine reach operating temperature faster.



Turbocharger closed

Turbocharger Partially Open

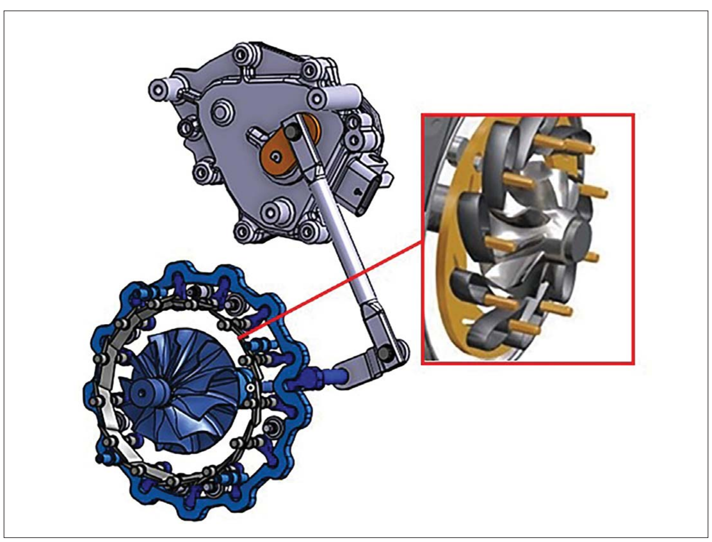
During engine operation at moderate engine speeds and load, the vanes are commanded partially open. The vanes are set to this intermediate position to supply the correct amount of boost to the engine for optimal combustion, as well as providing the necessary exhaust pressure to assist in EGR flow.



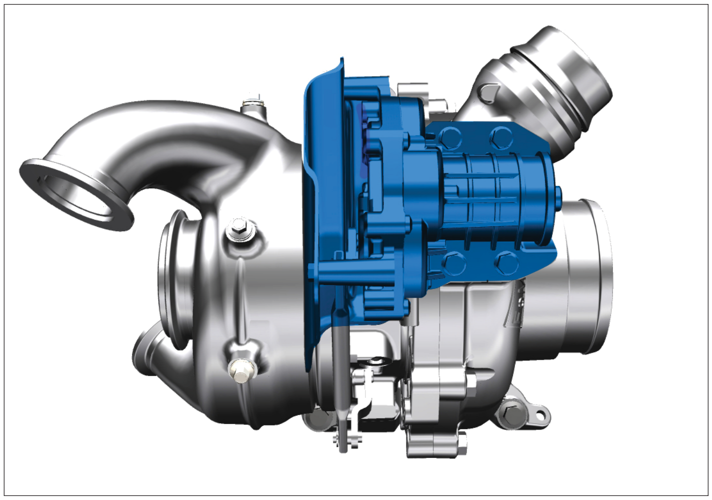
Turbocharger partially open

Turbocharger 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 operate at maximum capacity.



Turbocharger open

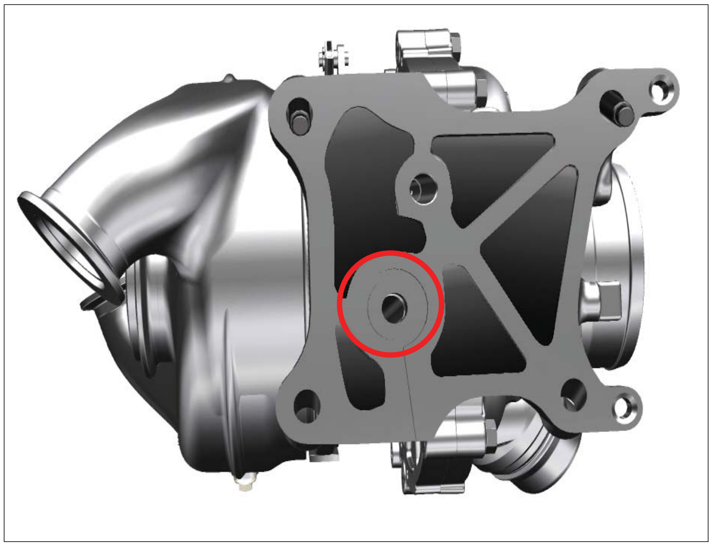


VGT actuator

Turbocharger Actuator

The PCM controls the variable turbocharger geometry using the turbocharger actuator. The turbocharger actuator contains a stepper motor that moves the VGT vanes to the commanded position with a mechanical linkage

The turbocharger actuator also contains a position sensor for feedback to the PCM. A closed-loop system provides feedback to the PCM. In response to engine speed, load, manifold pressure and barometric pressure, the PCM controls the turbocharger actuator position to match manifold boost to the requirements of the engine.

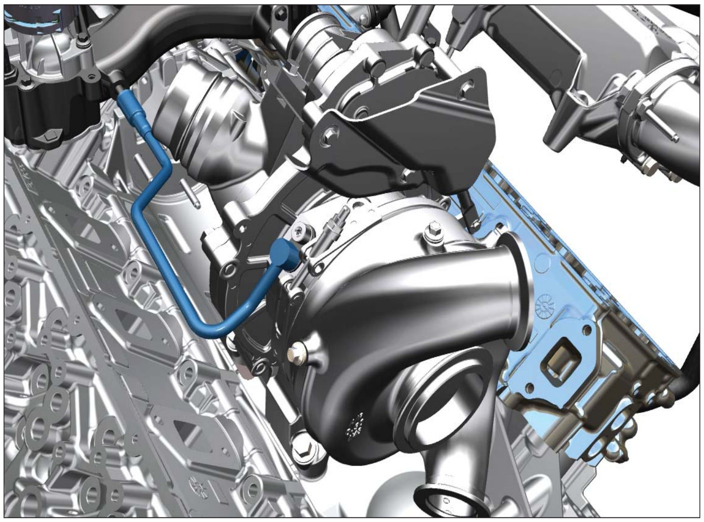


Turbocharger cooling passages

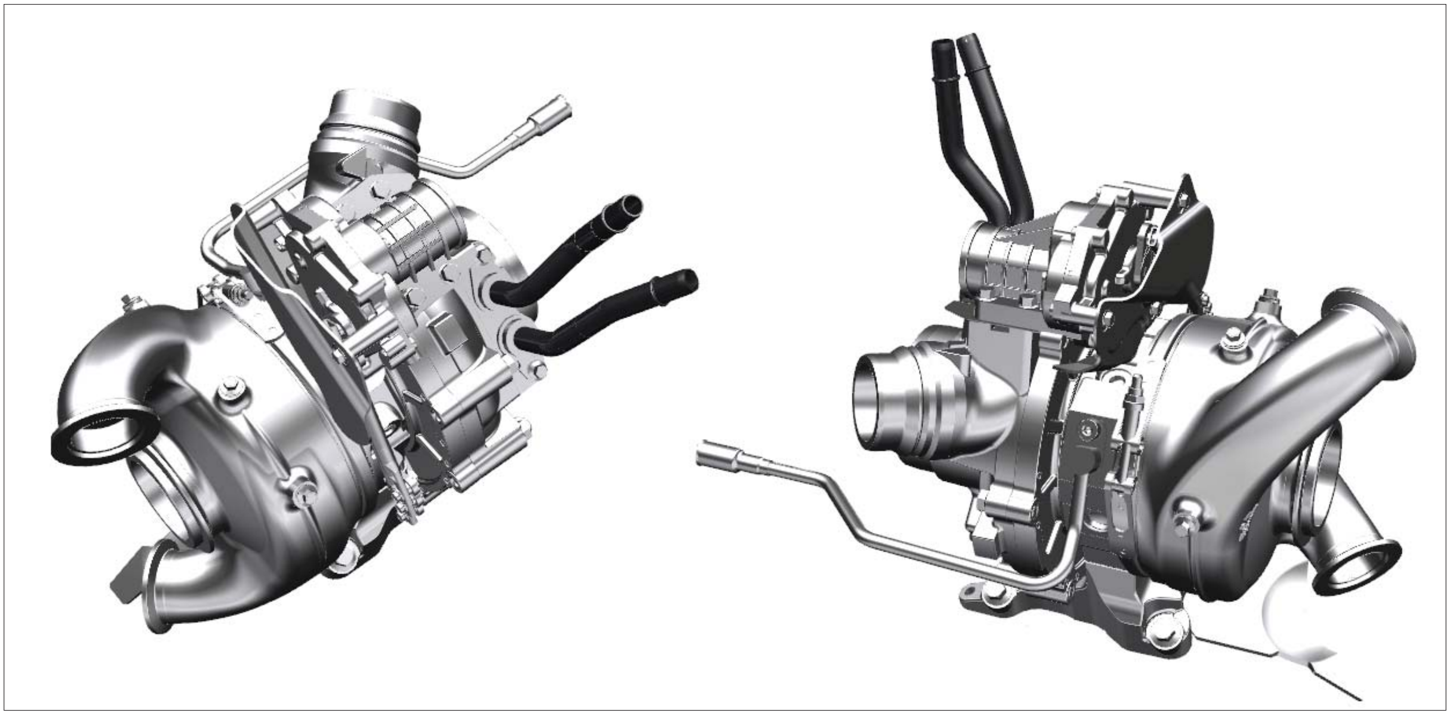
Turbocharger Cooling Passages

The turbocharger is cooled using coolant from the primary cooling system.

Coolant enters the turbocharger from the block on the bottom of the turbocharger, flows through the turbocharger, then out the top of the turbocharger through a line to the coolant crossover tube.



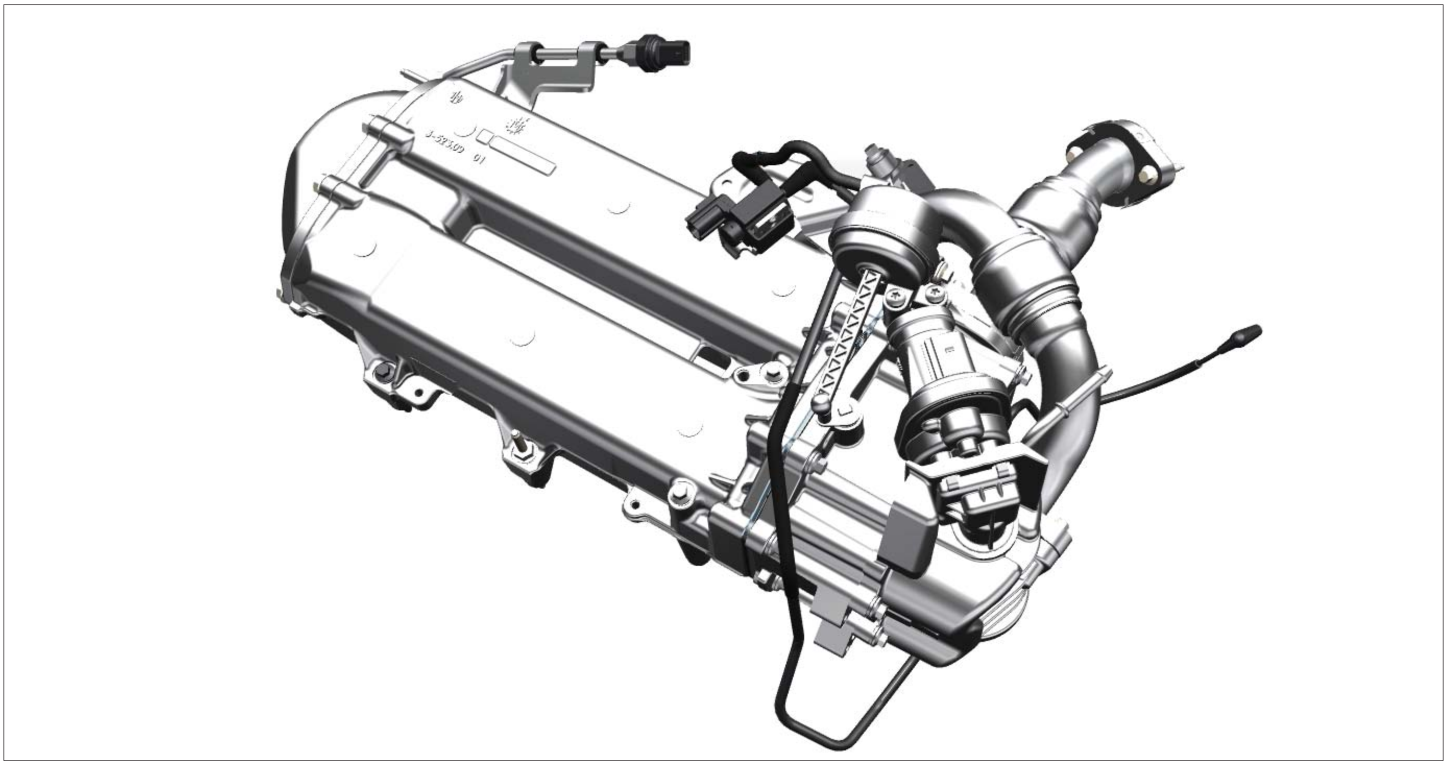
Turbocharger coolant crossover tube



High output turbocharger

High Output Turbocharger Compressor Cooling

The high output turbocharger has a cooled compressor housing using coolant from the secondary cooling system to reduce the temperature of the air coming out of the turbocharger which increases efficiency and power.



Exhaust Gas Recirculation (EGR)

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 (NOx) emissions.

EGR system control is based off an air system model to estimate the percentage of exhaust gas in the cylinder. The PCM looks at engine temperature, intake pressure, exhaust pressure, RPM, and engine load to determine the EGR flow rate. The PCM uses the ratio of manifold absolute pressure and exhaust pressure 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 gas is introduced into the intake manifold the amount of air measured by the Mass Air Flow (MAF) sensor is decreased.

The 6.7L Power Stroke® Turbo Diesel has a hot side EGR valve due to it being before the EGR cooler. Once past the EGR valve, the exhaust gas is either directed through or bypasses the EGR cooler. This is done by the PCM controlling the EGR cooler bypass solenoid which turns vacuum on or off to the actuator on the bypass door. The Exhaust Gas Recirculation Temperature (EGRT11) sensor measures the temperature of the exhaust gas leaving the system, allowing the PCM to monitor cooler eff effectiveness and bypass control.

EGR valve

EGR Valve and Actuator

The EGR valve actuator receives a duty cycled signal from the PCM. An integrated EGR position sensor provides a variable voltage signal to the PCM, indicating actual valve position.

Internally, it has two valves connected by a common shaft. Exhaust gases are routed from the right exhaust manifold to the center of the valve.

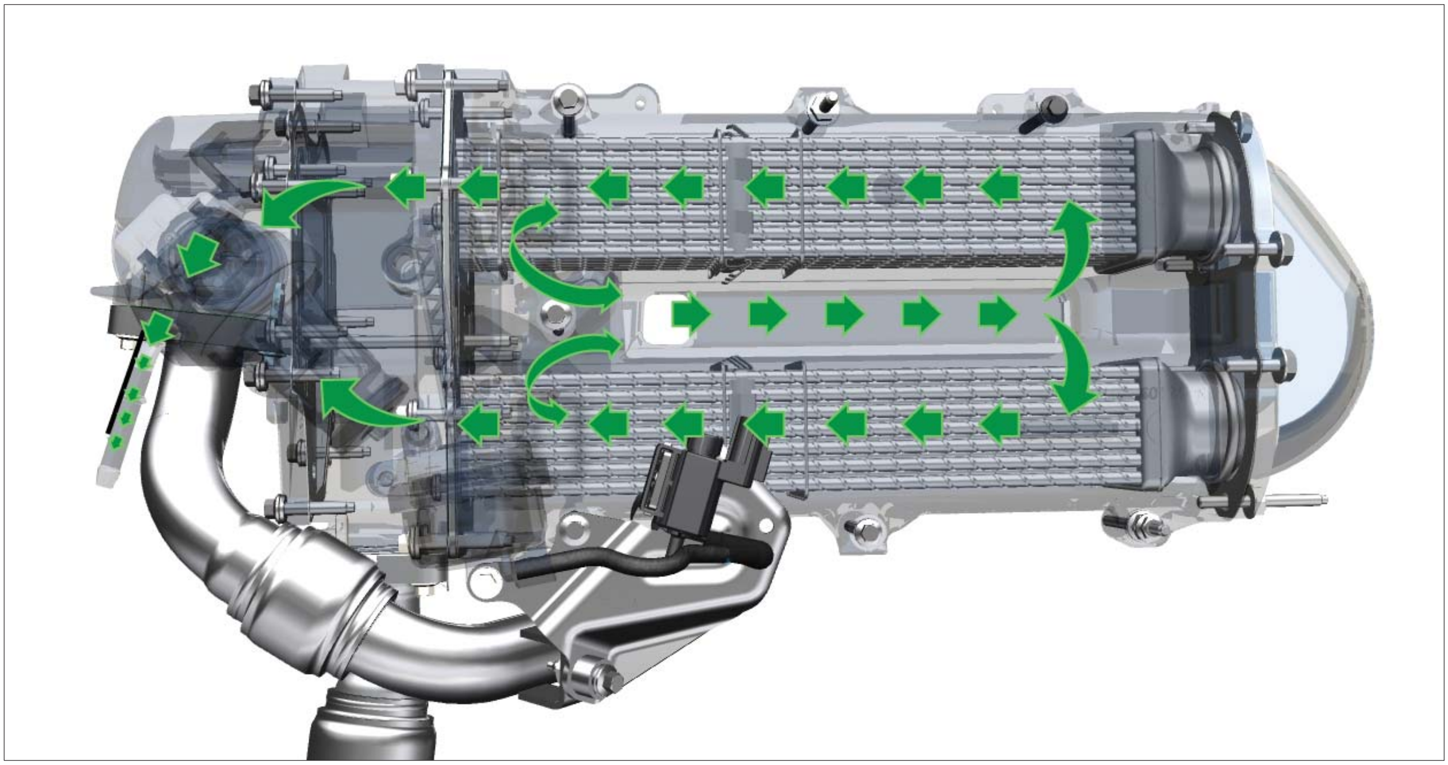
When the valve opens, exhaust gases flow out the top and bottom poppet valves.

EGR cooler

EGR Cooler

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

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

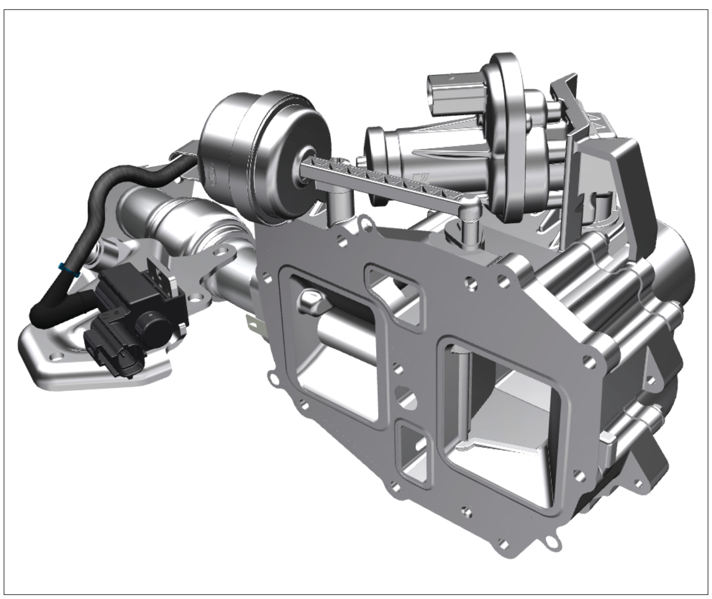


EGR coolant flow (primary system)

EGR Coolant Flow (Primary System)

The EGR cooler is cooled by the primary cooling system.

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

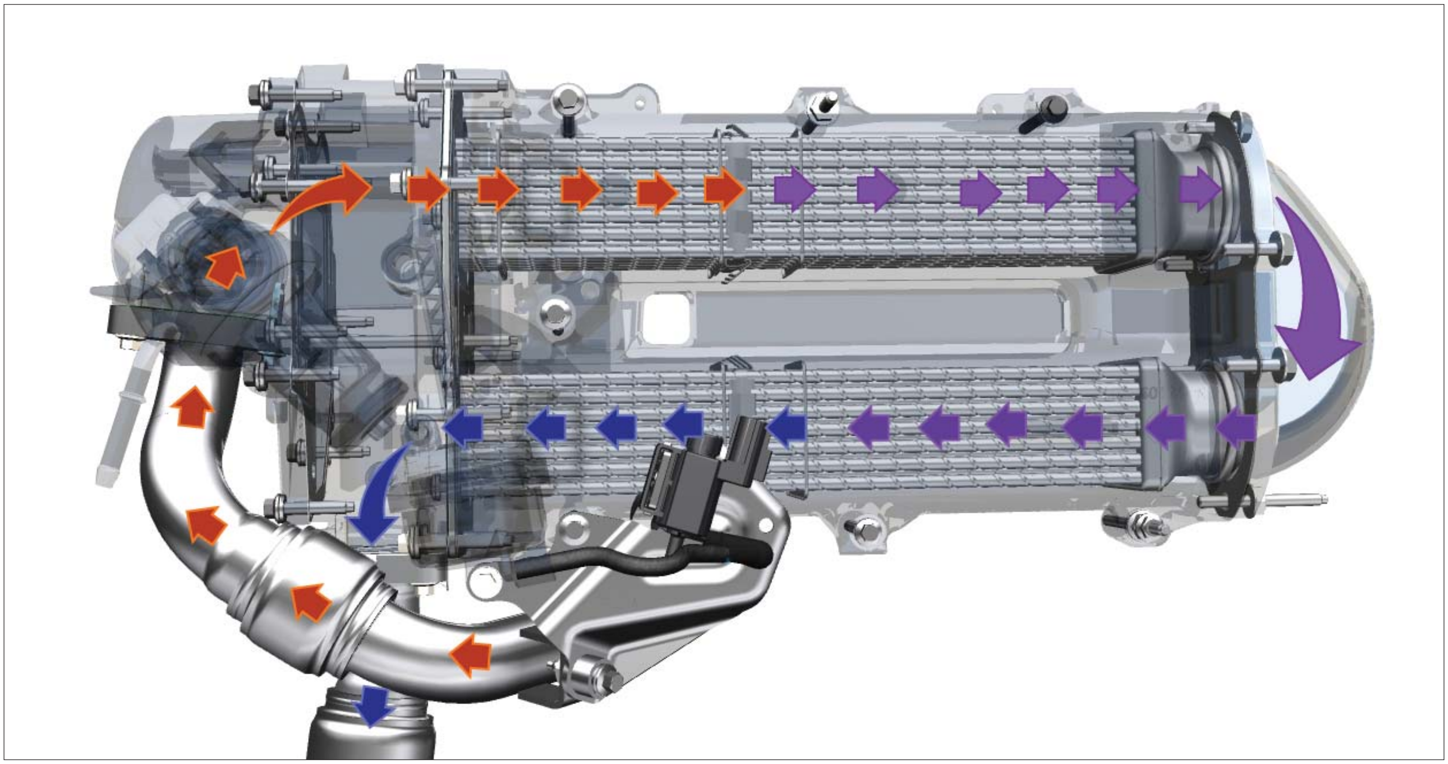


EGR cooler bypass valve

EGR Cooler Bypass Valve

The EGR cooler bypass valve alters the flow of EGR gases to bypass the cooler at low engine speeds and during periods of low EGR flow. The vacuum controlled valve is operated by a solenoid controlled by the PCM.

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

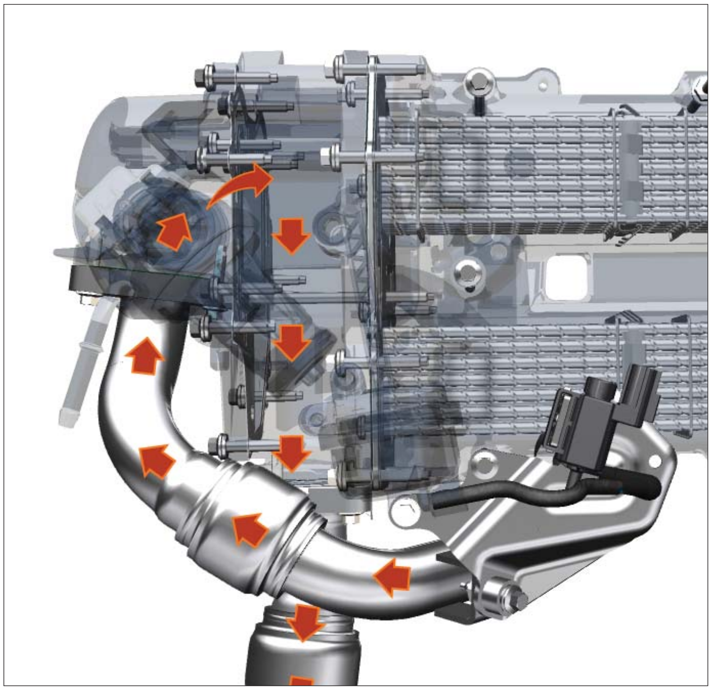


EGR cooler flow

EGR Flow (Through EGR Cooler)

Exhaust gas enters the intake manifold through the EGR valve by either passing through the EGR cooler or bypassing the EGR cooler (depending on the position of the EGR cooler bypass valve).

When exhaust gas flows through the EGR cooler, cooling is performed by the primary cooling system before gases enter the intake system. Engine coolant reduces the exhaust gas temperature when the gases are directed through the EGR cooler.

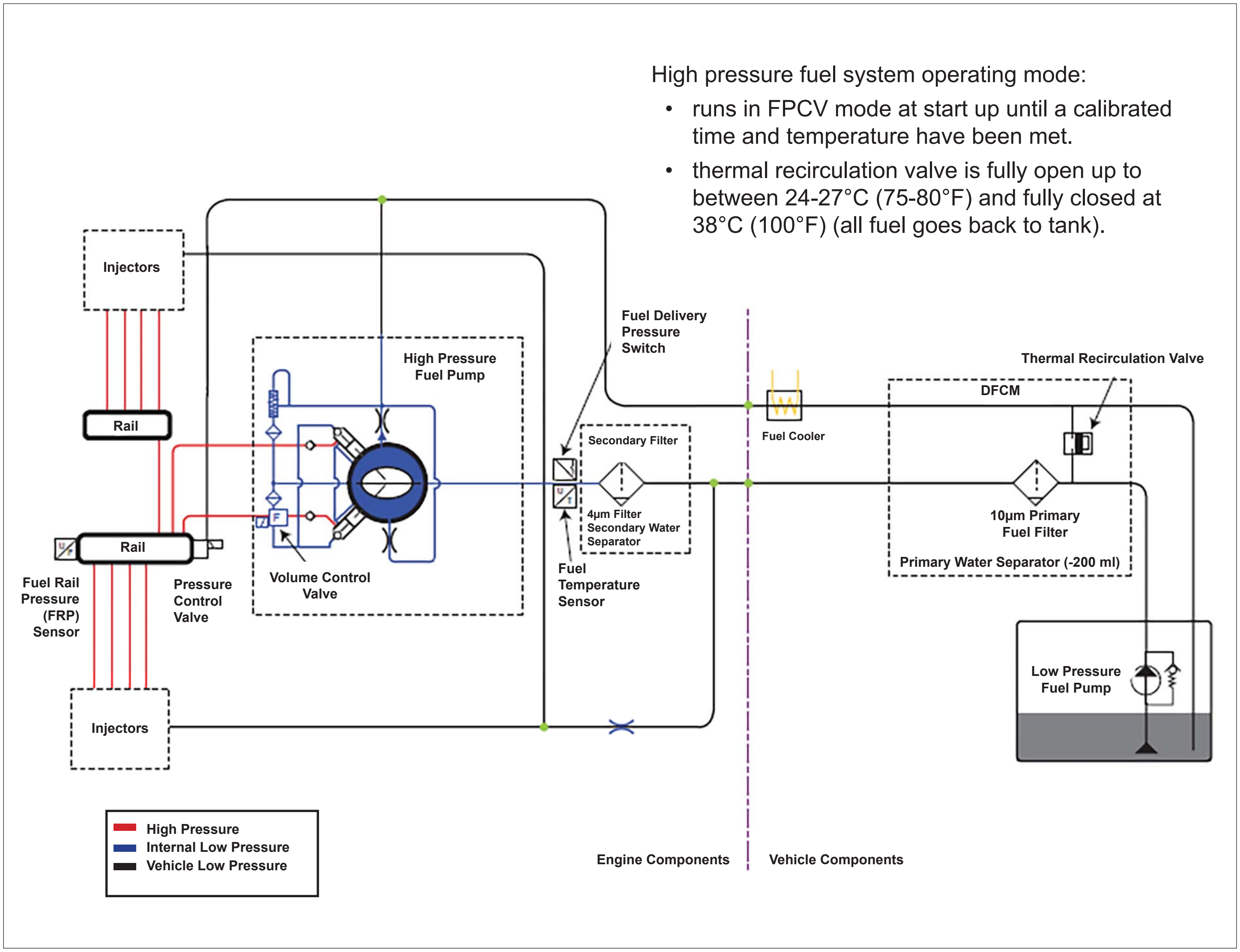


EGR cooler bypass flow

EGR Flow (Cooler Bypass)

During certain engine operating conditions, the EGR cooler is bypassed. When the EGR cooler bypass valve is commanded open, the exhaust gases go through the bypass tube avoiding the cooler to the intake manifold.

Operation



Fuel system operation

The fuel system for the high-pressure common rail direct injection turbocharged diesel engine is controlled by the PCM. The PCM energizes the fuel pump relay to power the Fuel Pump Control Module (FPCM) and regulates its operation. At key on, the electric fuel pump within the main fuel tank is powered on, pressurizing the low-pressure fuel system. If the engine is not started, the pump runs for up to 30 seconds. During light load operation the fuel pump is commanded to a low speed. When engine load increases above a pre-determined level the FPCM commands a higher speed.

The PCM obtains information from the Ambient Air Temperature (AAT), Engine Coolant Temperature (ECT), Engine Oil Temperature (EOT), and Fuel Rail Temperature (FRT) sensors for fuel delivery calculations. The Fuel Volume Control Valve (FVCV) and Fuel Pressure Control Valve (FPCV) are open.

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

Once the Fuel Rail Pressure (FRP) sensor detects the required fuel pressure, about 34,470 kPa (5,000 psi), the PCM begins fuel injection operation to meet the desired idle RPM based upon the temperature sensors and engine load. During this initial start-up mode, the high-pressure fuel system runs in FPCV mode for a calibrated amount of time. The FVCV is set to a specified point while the FPCV is duty cycled to meet the desired fuel rail pressure.

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

During acceleration, the FVCV and FPCV are commanded to meet the driver's demand (accelerator pedal input/ engine load). The PCM's commands to the FVCV and FPCV are based upon: fuel rail temperature, engine coolant temperature, engine oil temperature, ambient air temperature, engine load, and regeneration state.

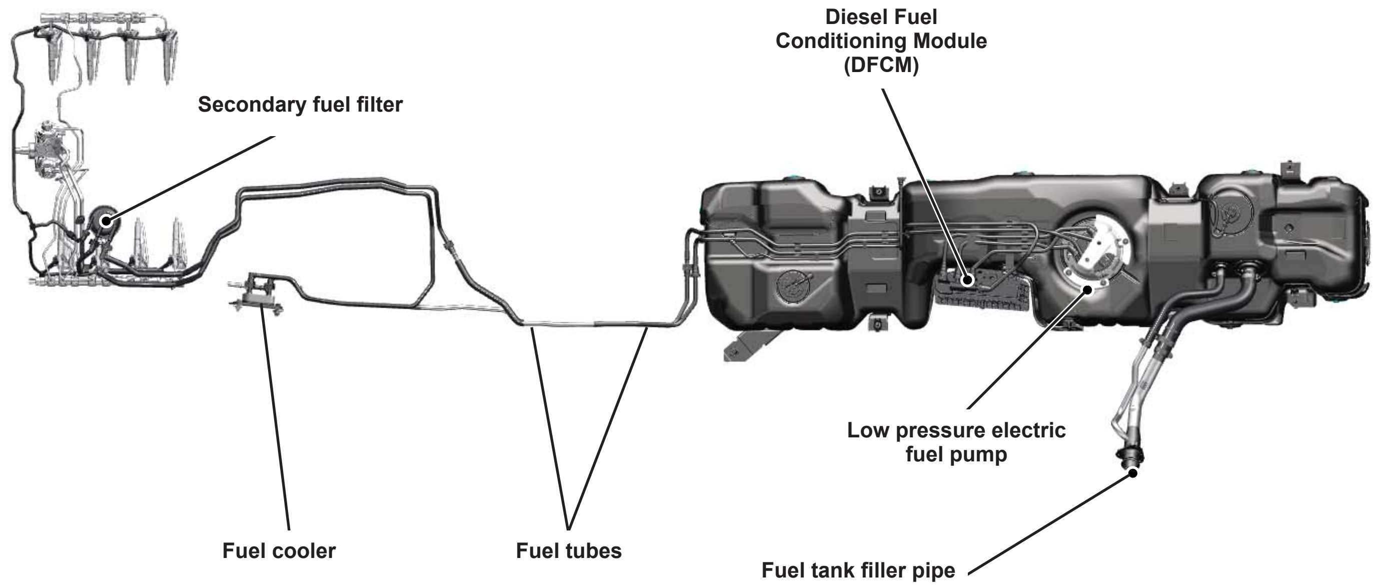
On deceleration, the FVCV is closed and the FPCV is opening to maximum position to reduce fuel pressure. When RPM is approaching the desired idle speed, the FVCV begins opening to prepare for injector usage.

During stage 2 regeneration the PCM commands a late injection in the cylinders of the engine during the exhaust stroke as well as firing the DSI for DPF regeneration. This causes the DOC to create more heat burning off the buildup and cleaning the SCR.

Note: That the Chassis Cab trucks use this type approach for their normal DPF regeneration except they command the late fuel injection to just the left bank of the engine.

Under certain conditions, like battery disconnect and fuel system reset, the fuel system operates in Adaptive Fuel Pressure Control Valve (AFPCV) mode on the first start. In the AFPCV mode, the PCM is learning the duty cycle needed for the FPCV to achieve the desired fuel pressure.

Components



Low pressure fuel system components

The diesel fuel system consists of the following low-pressure components:

- Fuel tank - 3 types available:
  - Midship fuel tank (mounted to the LH frame side rail)
  - Aft-of-axle fuel tank (mounted at the rear of the frame between the side rails)
  - Dual fuel tank setup with fuel tanks mounted midship and aft-of-axle, using a draft style fuel transfer system to draw fuel from the rear tank to the front tank as the level in the front tank reduces due to consumption
- Fuel tank filler pipe (without restrictor plate)
- Fuel tubes
- One quarter turn fuel tank filler cap (green for ultra-low sulfur diesel)
- Fuel Pump Control Module (FPCM) controls the low-pressure electric fuel pump
- Diesel Fuel Conditioning Module (DFCM) is mounted on the fuel tank and consists of the following:
  - Fuel filter and water separator to protect the fuel injectors
  - Water in fuel sensor and water drain valve
  - Internal check valve
- Secondary fuel filter

Low pressure electric fuel pump
(shown with fuel tank float at full and empty)

Low Pressure Electric Fuel Pump

The low-pressure electric fuel pump is located inside the fuel tank. Low pressure is pumped out of the fuel tank, then passes through the 10-micron primary fuel filter and water separator before flowing through the fuel lines to the engine mounted secondary fuel filter. The fuel pump pressure relief valve is integral to the fuel pump and cannot be serviceable separately. The fuel pump pressure relief limits fuel pressure to 827 kPa (120 psi).

The low-pressure fuel pump supplies approximately 3 times the maximum amount of fuel required for combustion. The excess fuel lubricates and cools the high-pressure fuel pump.

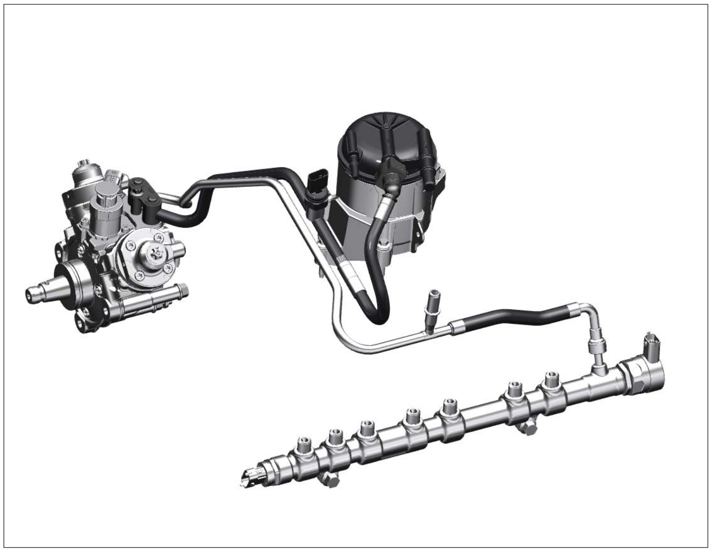
Secondary fuel filter location

Secondary Fuel Filter

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

The secondary fuel filter utilizes three ports. Fuel line design and routing prevents stress at the secondary filter connections.

Secondary fuel filter



Low pressure to high pressure fuel supply

Low Pressure Fuel Supply to High Pressure Fuel Pump

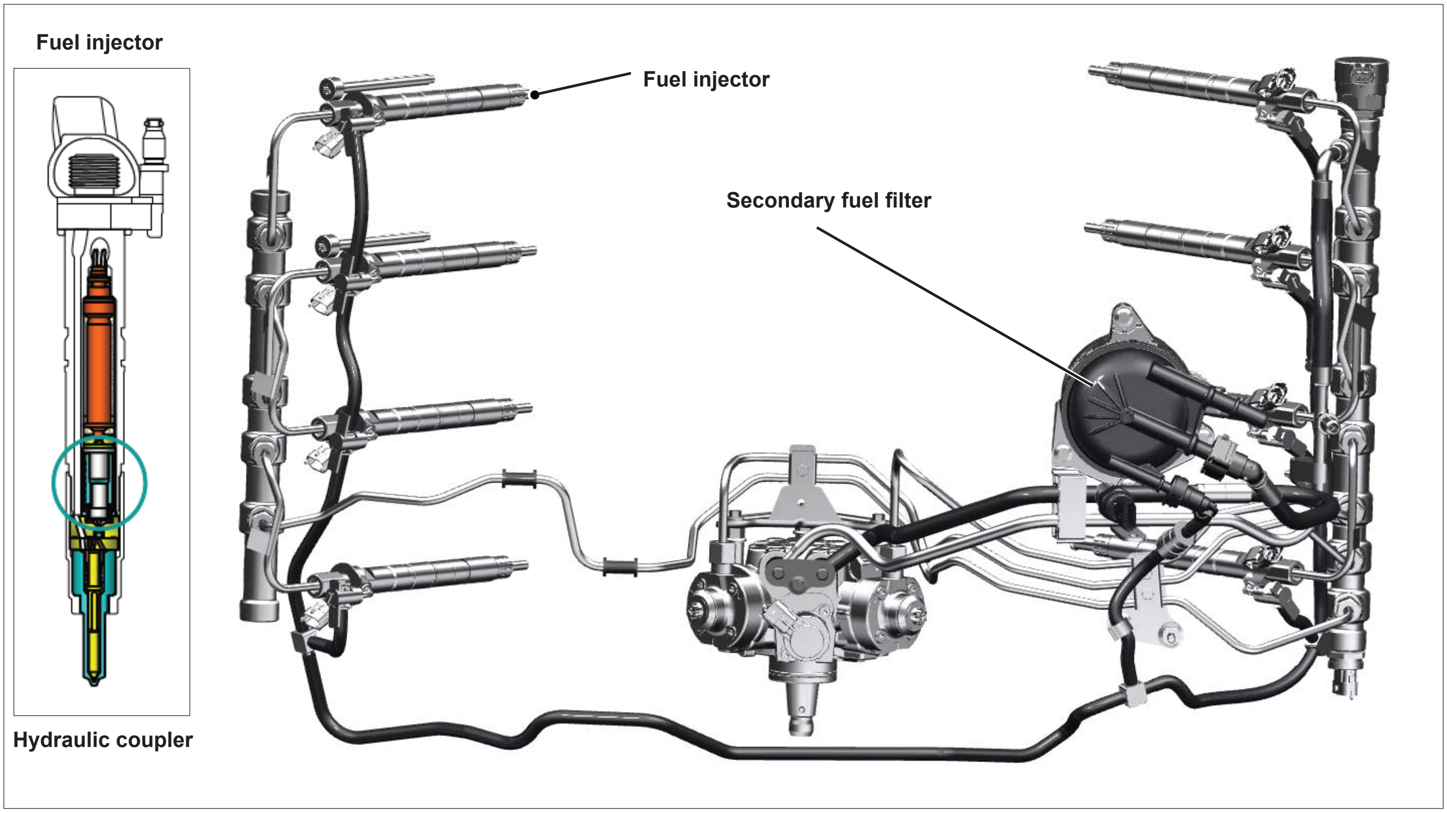
A low pressure fuel line runs between the secondary fuel filter and the high pressure fuel pump. This low pressure fuel supply line uses an integrated fuel pressure and temperature sensor to calculate fuel delivery, helping to protect the high pressure fuel system.

Fuel Pressure and temperature Sensor

Fuel Pressure and Temperature Sensor

The fuel pressure and temperature sensor is mounted in the fuel line running between the secondary fuel filter and the high-pressure fuel pump.

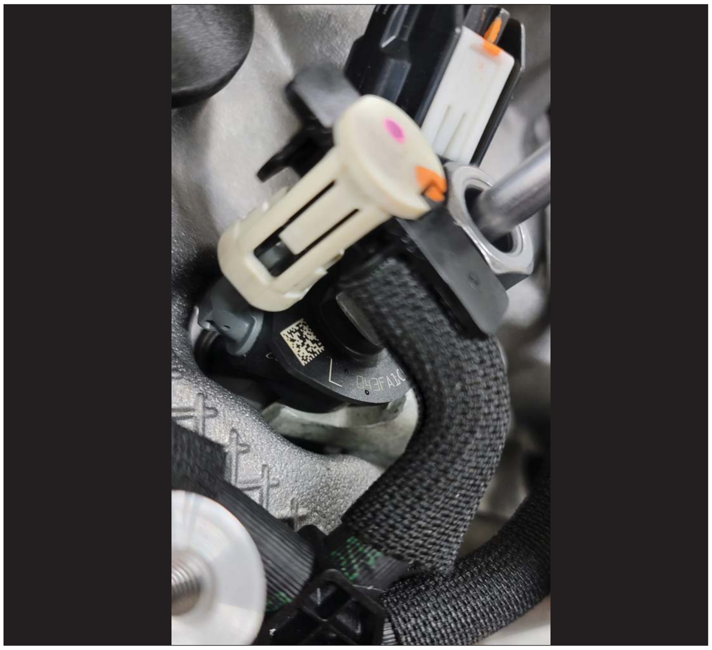
The PCM uses the pressure sensor input to protect the high-pressure fuel system from damage due to low fuel pressure supply. The PCM de-rates the engine’s power if a low-pressure threshold is not met. LOW FUEL PRESSURE displays in the message center to advise the customer of a low fuel pressure concern.



Low pressure connectors

Injector Low Pressure Connectors

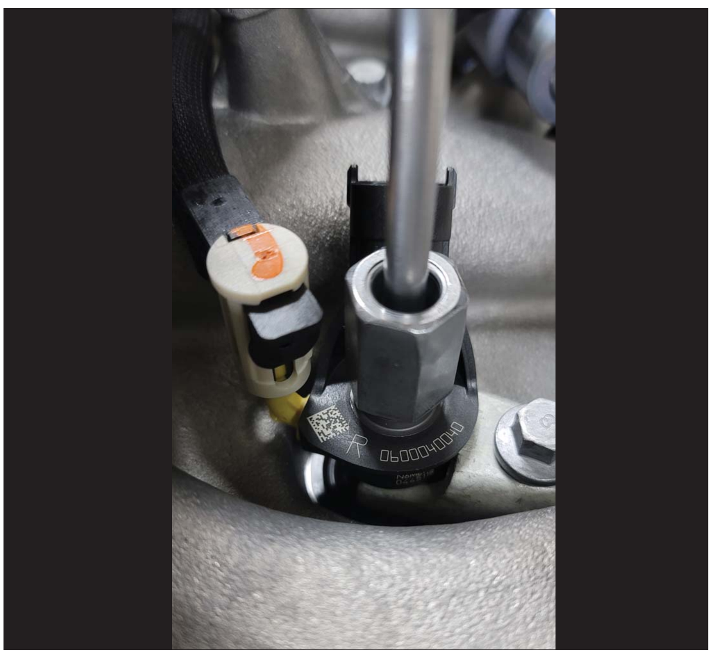
The injector low pressure connectors have a dual purpose. First, they are a low pressure back feed to keep fuel pressure inside the injector hydraulic coupler. Without fuel pressure in the hydraulic coupler, the injector does not deliver fuel.
The other purpose of the low-pressure connectors is they function as a return. The fuel that passes through the injector during the injection process exits the injector through the low-pressure connectors and is returned through a port on the secondary fuel filter.



Fuel injector left side (gray)

Left Side Fuel Injector

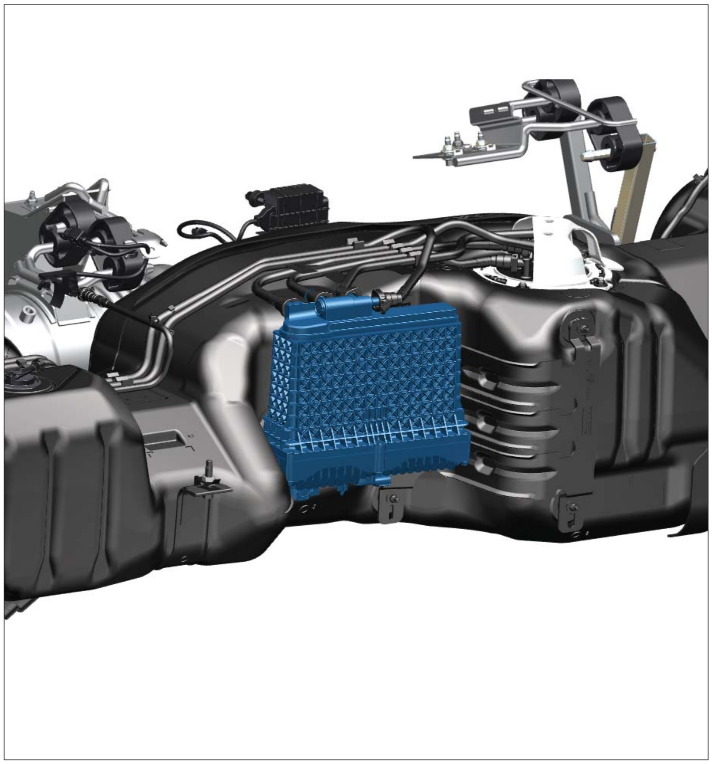
The left side fuel injector has the letter "L" stamped on it and has a gray fuel return port.



Fuel injector right side (yellow)

Right Side Fuel Injector

The right side fuel injector has the letter "R" stamped on it and has a yellow fuel return port. The electrical connectors on these injectors are also different.



Diesel delivery module location

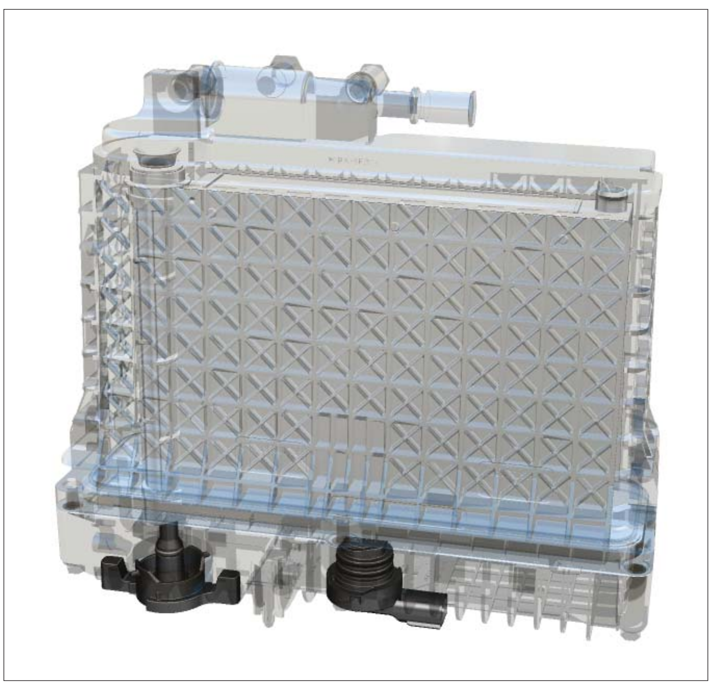
Diesel Fuel Conditioning Module (DFCM)

The 6.7L Power Stroke® Turbo Diesel engine employs an externally mounted Diesel Fuel Conditioning Module (DFCM). The DFCM mounts on the fuel tank.

The DFCM filters and separates water from the fuel. It also allows unused fuel from the engine to return to the fuel tank. Fuel returned from the fuel rail combines with fuel returned from the high-pressure fuel injection pump and passes through the frame mounted fuel cooler to the DFCM. The DFCM contains a thermal recirculating valve that, based on fuel temperature, allows fuel to return to the tank or back to the engine.

The DFCM includes the following components:

- 10 micron primary fuel filter
- Thermal recirculation valve
- Water fuel separator (~400ml total capacity)
- Water in Fuel (WIF) sensor
- Water drain valve (manual operation)



Primary fuel filter

Primary Fuel Filter

The primary fuel filter is located in the DFCM and removes particulates larger than 10 microns from the fuel. The DFCM has a recessed nut on the bottom to remove the fuel filter. The service interval of the fuel filter varies with usage. Refer the Owner's Literature or Workshop Manual for service intervals.

Water drain valve

Water Drain Valve

The water drain valve is located at the bottom of the DFCM. To drain water that has accumulated in the DFCM, turn the water drain valve to the open position and drain into a suitable container.

WIF sensor

Water-In-Fuel (WIF) Sensor

The DFCM also includes a WIF sensor that provides an input to the PCM. The WIF sensor measures the water level in the water separator reservoir. When approximately 200 mL of water is present in the reservoir, an indicator lamp illuminates and a message appears in the message center. The WIF sensor is serviceable separately from the DFCM.

Biodiesel

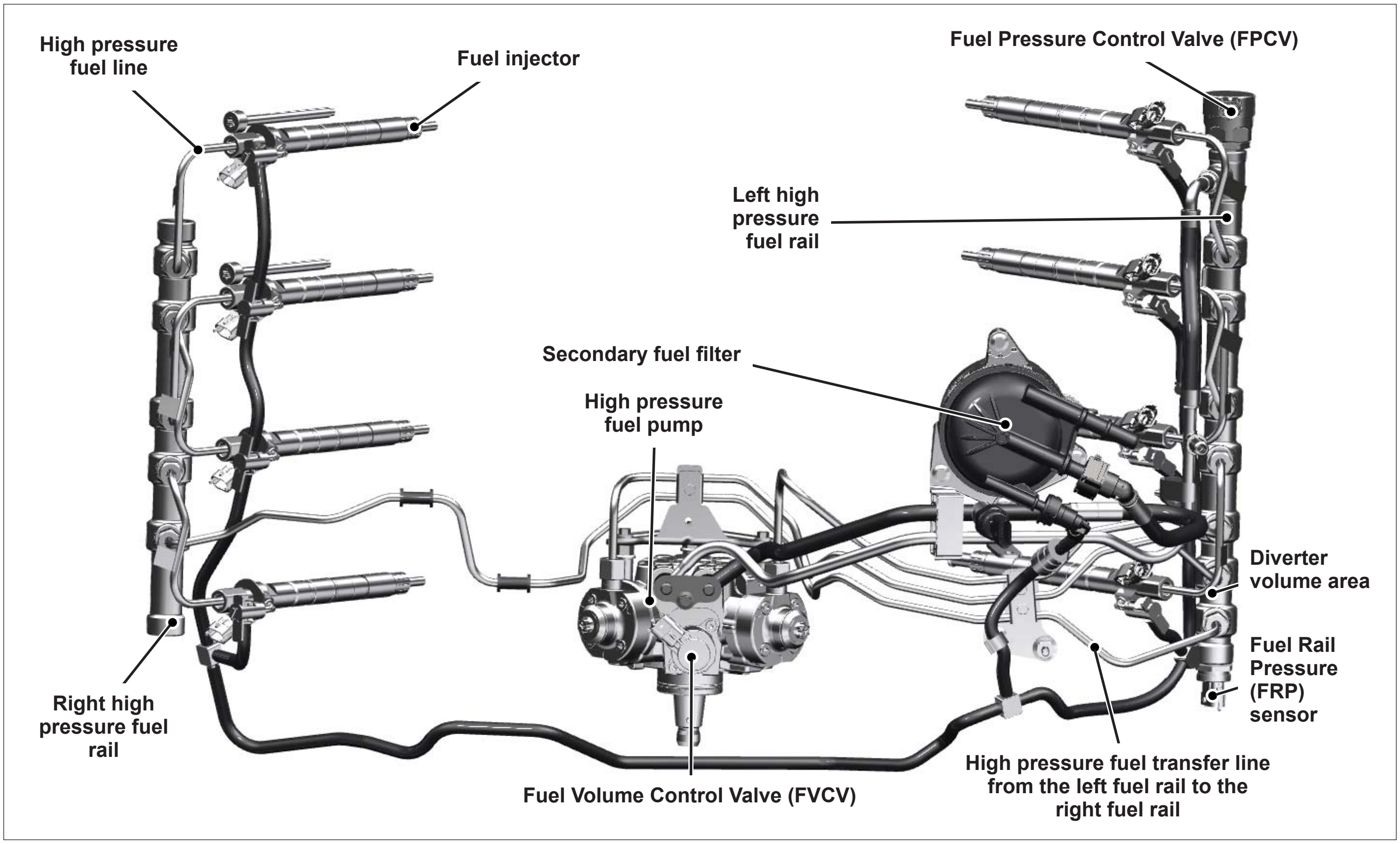
Biodiesel

The 6.7L Power Stroke® Turbo 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:

- Be alert to fuel gelling/waxing.
- Flush the fuel system with regular diesel fuel if the vehicle is going to be stored for more than a month.
- Only use good quality biodiesel fuel 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 non- warrantable conditions and warrantable conditions. The use of biodiesel or renewable fuels requires increased maintenance including more frequent oil changes and fuel filter replacements.

Fuel Management System



Fuel management system

The Fuel Volume Control Valve (FVCV) controls how much fuel enters the two high pressure pump pistons. The fuel flow to the high-pressure fuel pump is restricted as required by the PCM. Under varying conditions, the fuel system operates in pressure or volume control valve mode.

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

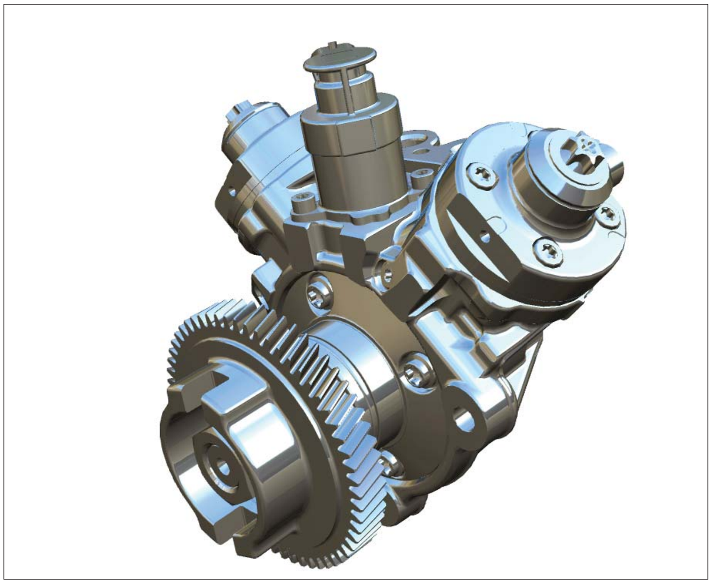
Excess fuel from the high-pressure fuel pump is routed back to the DFCM/fuel tank through the fuel cooler. The left fuel rail supplies fuel to the 4 injectors in the left cylinder head via high pressure fuel lines and it supplies fuel to the right-side fuel rail via another high-pressure fuel line.

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

The high-pressure fuel pump is capable of producing up to 250 MPa (36,259 psi), or 2,500 BAR, to the fuel injectors.

Each fuel rail has 4 individual high pressure fuel lines to supply fuel to the injectors. Injector return fuel is directed back to a port on the secondary fuel filter. The injector return line assembly contains a single throttle (orifice) to increase backflow pressure at the injector for proper operation.

Fuel Management System Components

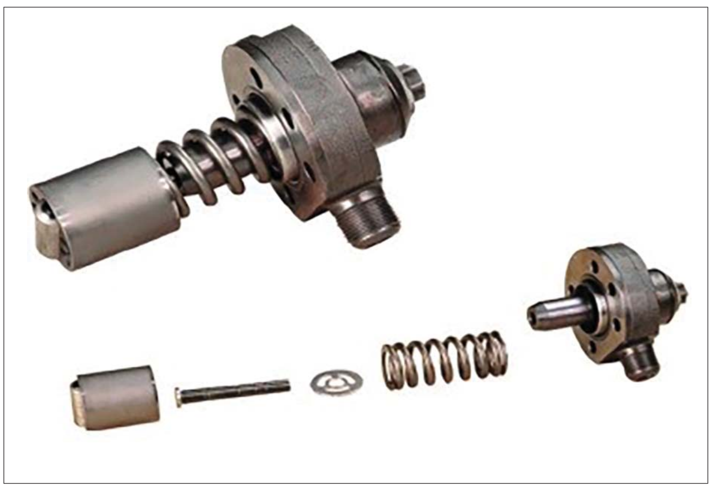


High pressure fuel pump

High Pressure Fuel Pump

The high-pressure fuel pump is mounted in the front valley of the engine and is gear driven by the camshaft. It is timed to the crankshaft and camshaft to optimize the effects of the high-pressure fuel pulses. The diesel fuel lubricates the high-pressure fuel pump.

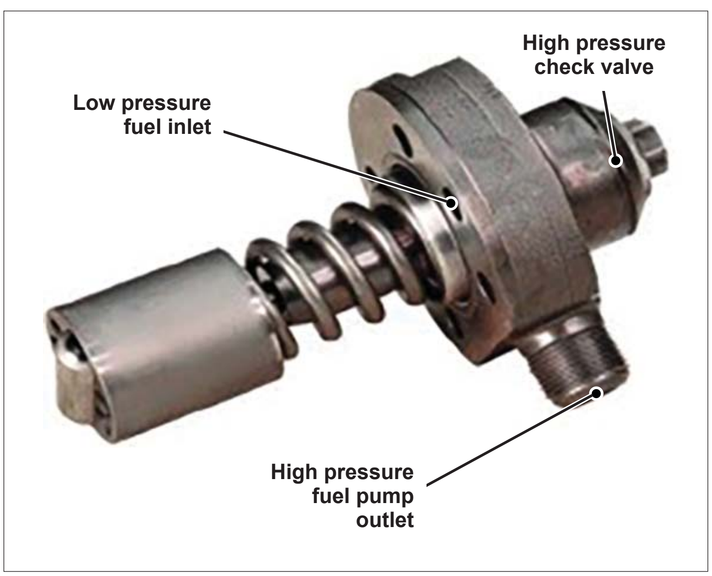
The high-pressure fuel pump is a 2-cylinder design. The main shaft has two actuating lobes that are offset 180 degrees from each other. Each pump piston is actuated twice per crankshaft revolution. The pump can create up to 2,500 Bar of pressure required by the high-pressure injection system.



Fuel pump pistons

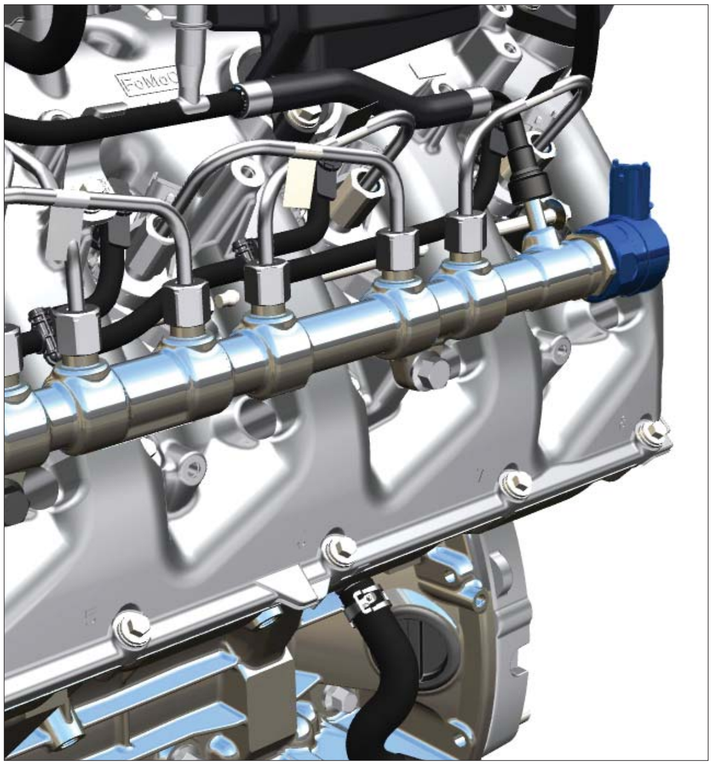
Piston Assembly

The pistons are actuated via the actuating lobes 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 valve

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 Pressure Control Valve (FPCV)

Fuel Pressure Control Valve (FPCV)

The FPCV is threaded into the rear of the left fuel rail. The FPCV is a 2-wire normally open Pulse Width Modulated (PWM) solenoid. The PCM relay supplies system voltage to one wire of the solenoid. The PCM pulse width modulates the ground to control the FPCV until the desired fuel pressure is reached. The higher the duty cycle, the higher the pressure.

Using the FPCV, the PCM regulates fuel rail pressures to meet specific operating conditions. The PCM operates the FPCV using information from the FRP sensor.

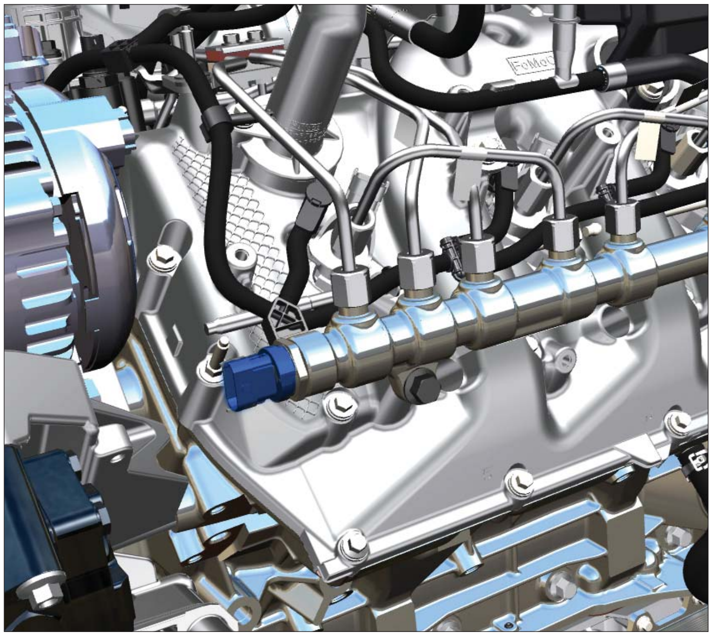
Fuel Volume Control Valve (FVCV)

Fuel Volume Control Valve (FVCV)

The FVCV is mounted on the top of the high pressure fuel pump. The PCM regulates fuel volume by controlling the duty cycle of the fuel volume control valve.

The fuel volume control valve is a normally open valve.

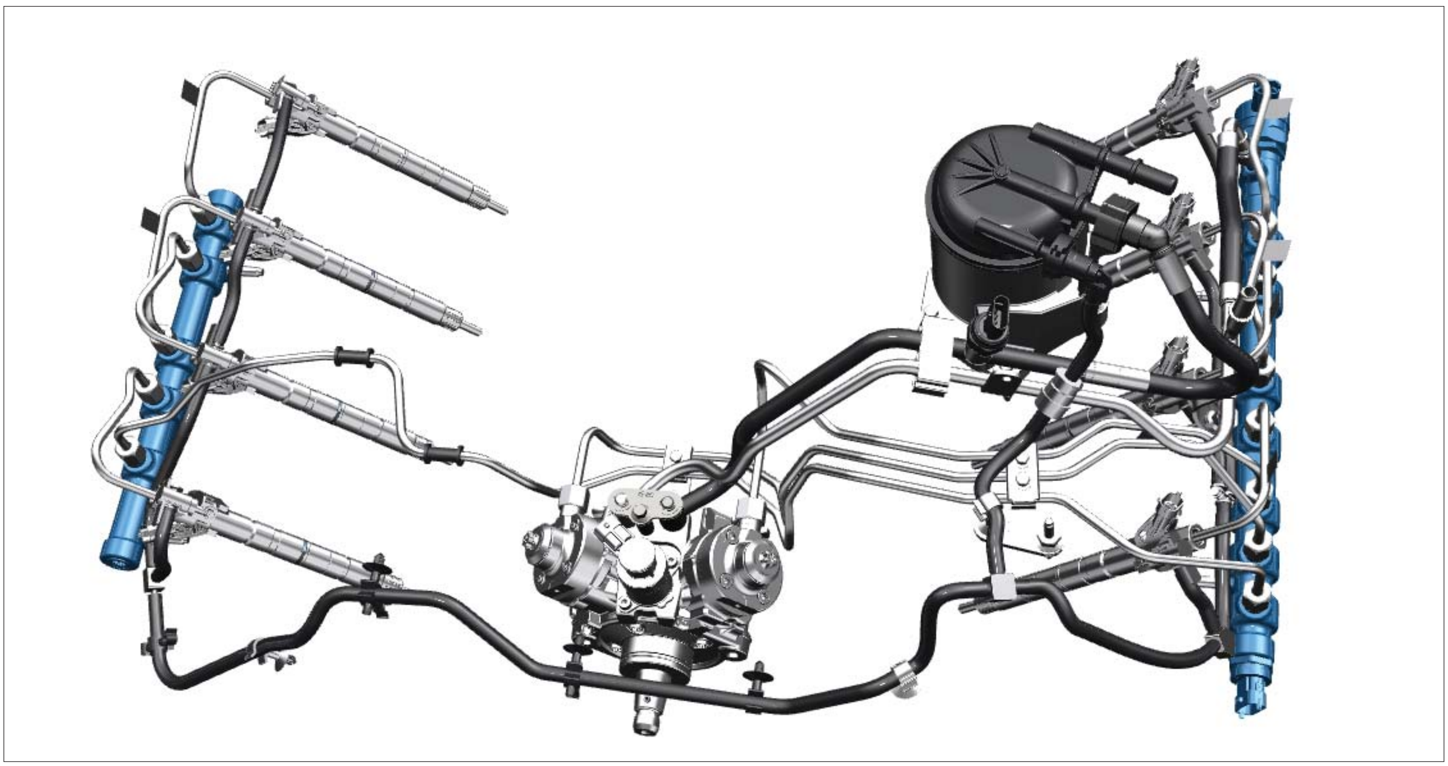
A high duty cycle indicates low fuel volume. A low duty cycle indicates high volume.



FRP sensor

Fuel Rail Pressure (FRP) Sensor

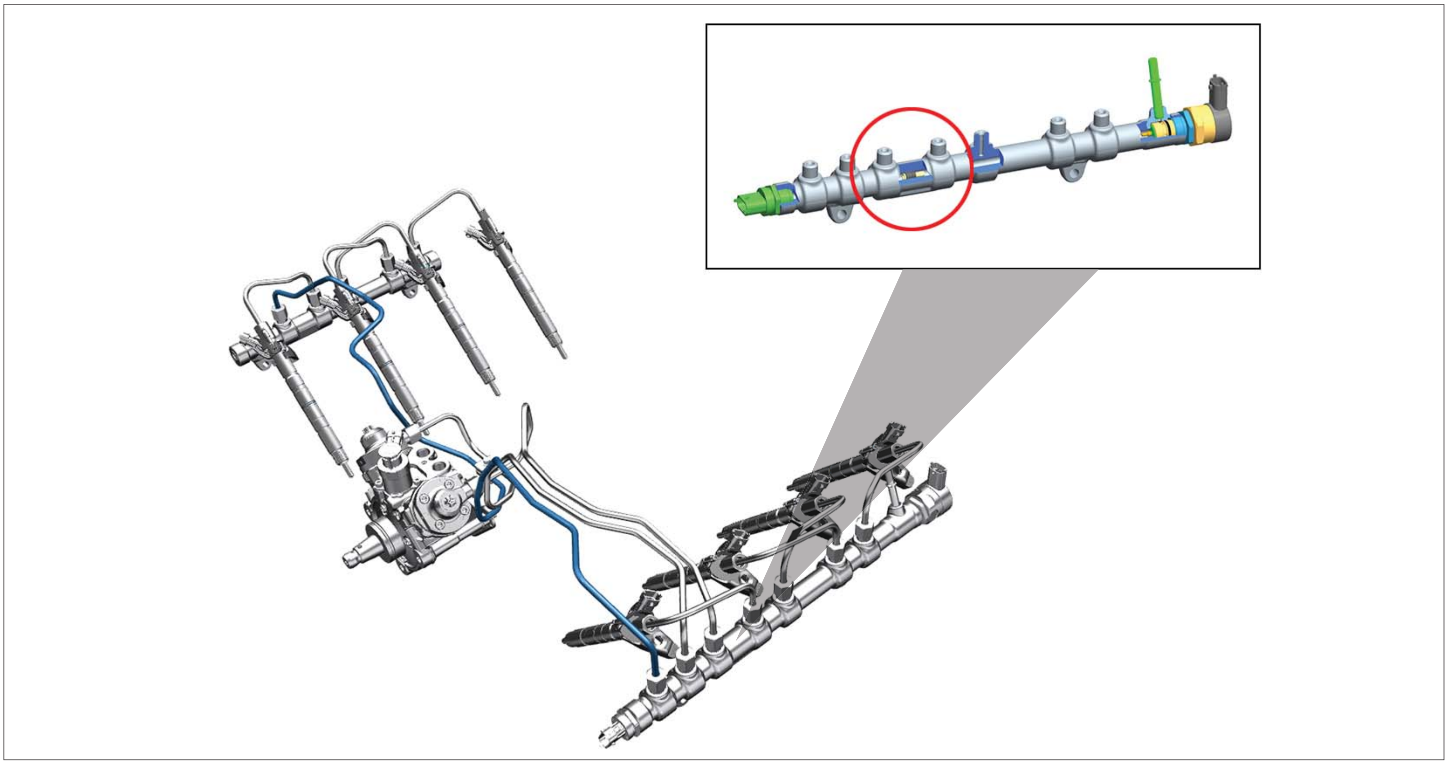
The FRP sensor is threaded into the front of the left fuel rail. The FRP sensor is a 3-wire variable capacitance sensor. The PCM supplies a 5 volt reference signal which the FRP sensor uses to produce a linear analog voltage that indicates pressure. The PCM actively monitors fuel rail pressure via the FRP sensor feedback signal.



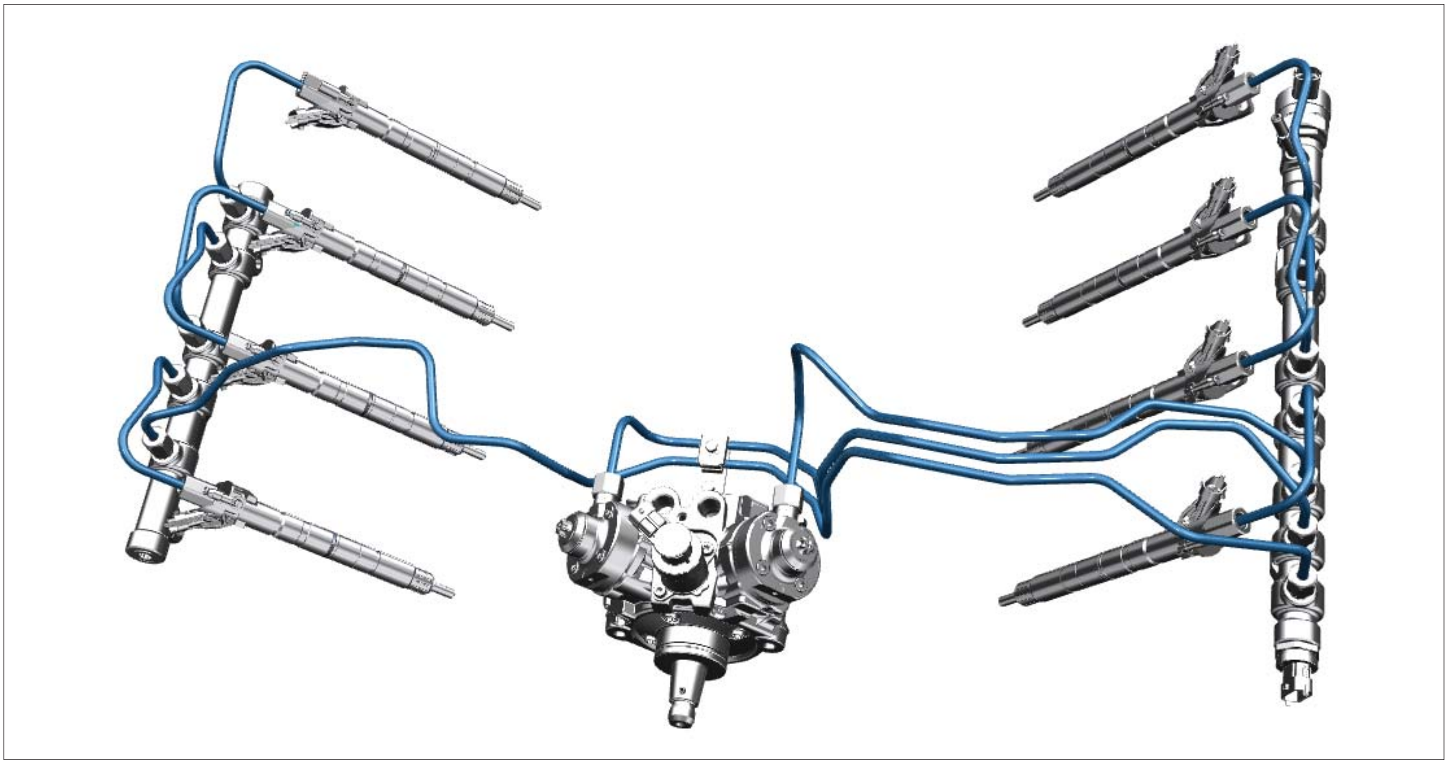
Fuel rails

Fuel Rails

The left fuel rail is longer due to the presence of the diverter. The diverter allows pressure equalization for both fuel rails, resulting in equal pressure present at all fuel injectors.



Fuel rail diverter



High pressure fuel lines

High Pressure Fuel Lines

The high-pressure fuel lines run between the:

- High pressure fuel pump and left fuel rail
- Right and left fuel rails
- Fuel rails and the fuel injectors on the outside of the valve covers

The lines are not reusable and must be replaced if loosened or removed

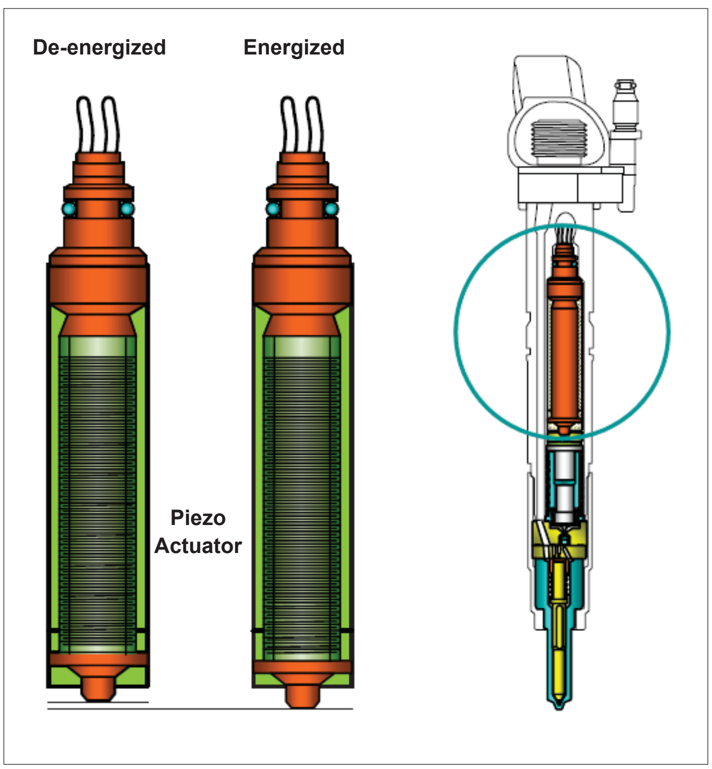
Piezo fuel injectors

Piezo Fuel Injectors

There are eight fuel injectors: four mounted in each cylinder head. They are serviced without removing the valve covers. The Injector Quantity Adjustment (IQA) must be programmed into the PCM when a new injector is installed. The injector is a 19 mm piezo-actuated injector with an 8-hole nozzle.

Each fuel injector is retained with a single clamp and bolt through the rocker cover to the cylinder head and are designed for the left or right bank. On the top of the injector body there is either an R or an L indicating which bank the injector is designed for. Also, the right bank has a yellow-spigot and the left bank has a gray spigot. Each bank uses a different electrical connector.

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



Piezo actuators

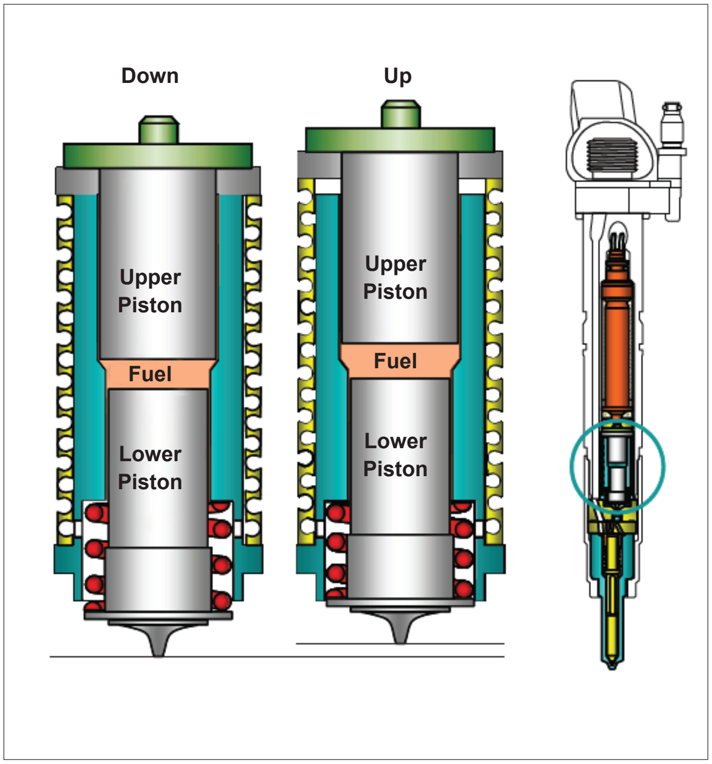
Piezo Actuator

The piezo actuator is a stack of piezo crystals. When current is applied to the crystals, the crystals expand. When the PCM supplied current is removed from the piezo crystals, they contract.

When the crystals contract, they create voltage (current flow reverses). The PCM supplies current to the piezo stack and when the injector is de-energized the current is removed from the piezo stack and stored by the PCM to actuate the injector in a companion cylinder.

The use of the piezo actuators allows for:

- Extremely quick response times.
- Accurately controlled injection on and off time.
- Quick and accurate repetition.

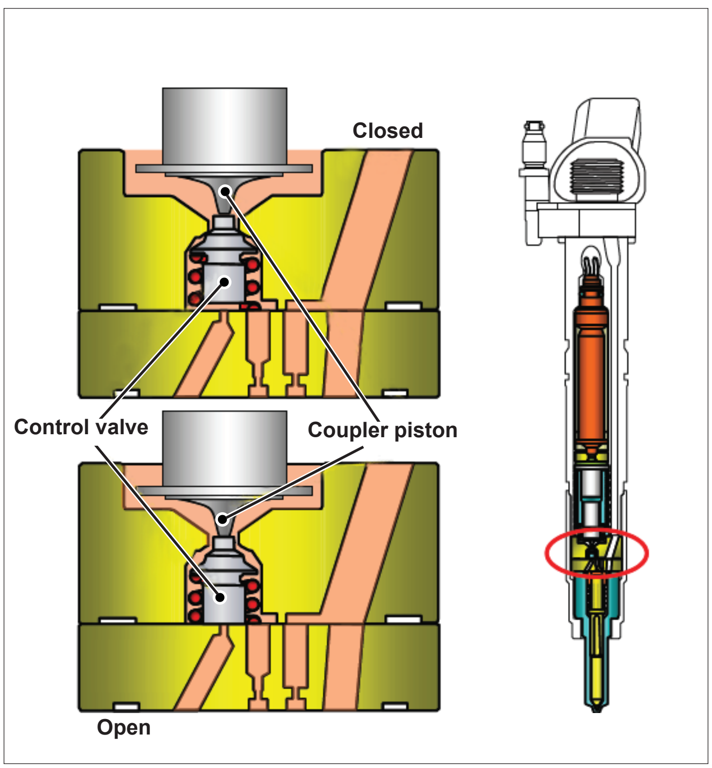


Hydraulic coupler

Hydraulic Coupler

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

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

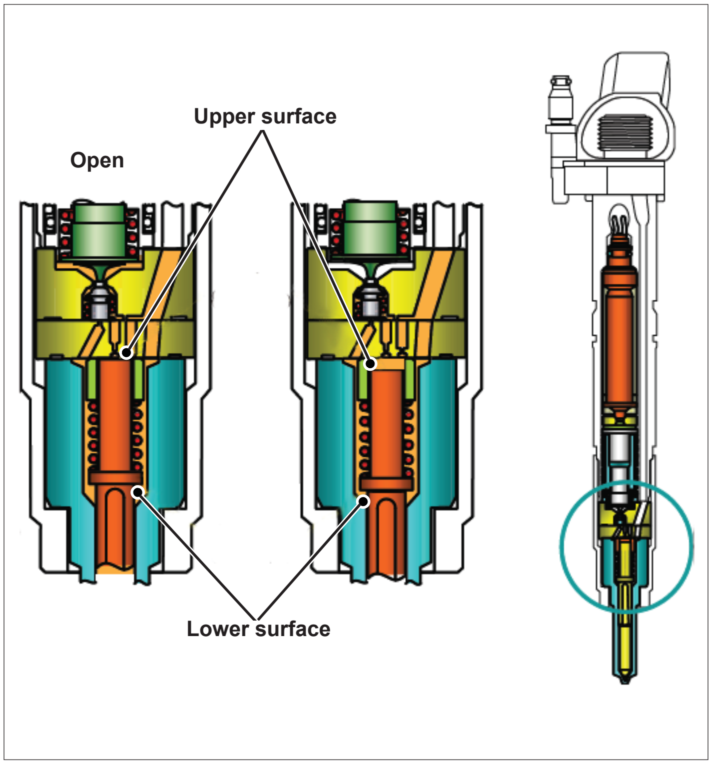


Fuel injector control valve

Control Valve

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

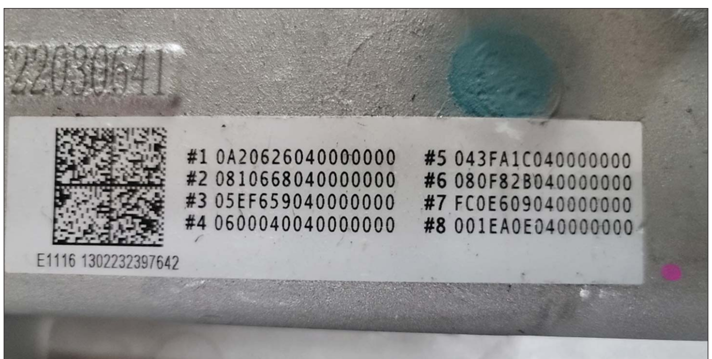
When the control valve is pushed fully down, it seals off an orifice in the intermediate plate, stopping the flow of high pressure fuel to the top of the nozzle needle. Fuel is allowed to flow past the control valve, removing pressure from the top of the nozzle needle.



Injector nozzle needle

Injector Nozzle Needle

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



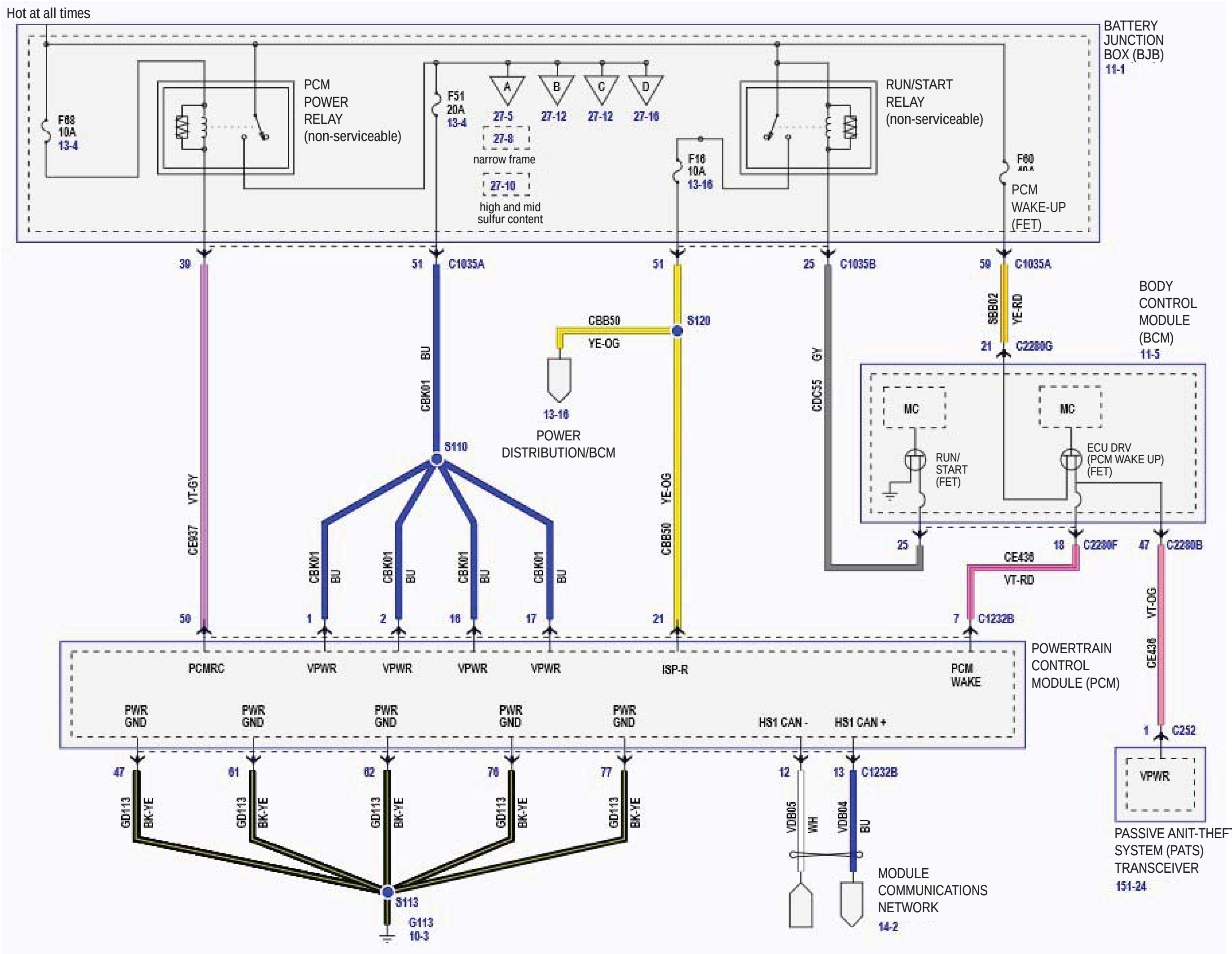
Fuel Injector Control Factors (FICF)

Fuel Injector Control Factor (FICF) Code

Each injector has a unique 10 digit code representing the fl ow characteristic of that injector. The Fuel Injector Control Factors (FICF) code is located on each injector head and is also printed on a factory label located on the engine. The factory-installed label indicates the FICF data for all of the original injectors installed at the factory. In addition, there are individual injector FIFC labels provided with each service replacement injector. Refer to both the factory label and the individual service labels to obtain the latest FIFC data. If the labels are missing or damaged retrieve the FIFC data from each injector head. When an injector is replaced, program the FIFC code for the injector using the FDRS. The FDRS automatically clears the keep alive memory values associated with the old injector when the new injector IFC code is entered. Affix the new injector FIFC sticker next to the old sticker.

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

Components



Powertrain Control Module (PCM) schematic

Powertrain Control Module (PCM)

Powertrain Control Module (PCM)

The PCM is located on the top right side of the bulkhead. The PCM receives battery power from the PCM power relay through the chassis connector. Ground is provided through the chassis connector and also includes a case ground.

Single Edge Nibble Transmission (SENT) Sensors

Single Edge Nibble Transmission (SENT) sensors were developed in 2005 and incorporated into Society of

Automotive Engineers (SAE) protocol J2716. They combine digital precision with low cost and have very fast transmission speeds of up to 390 microseconds (1,000,000 microseconds = 1 second). The sensors have a high resolution, are very reliable, and immune to electromagnetic interference.

The SENT sensor uses a point-to-point protocol. This standardizes the interface between numerous inputs and the PCM, such as position, pressure, mass air flow, and temperature sensors. With this standardization, multiple sensors can be combined and housed in one assembly.

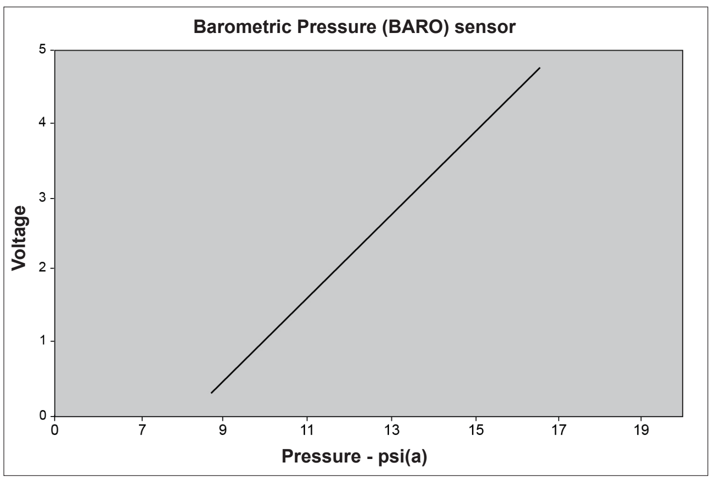
The sensors are unidirectional. They only send information to the PCM and do not receive data (output only). The sensor emits data continuously over a signal line while the PCM receives and processes the data.

SENT sensors utilize a 3-wire design: Signal circuit (0.5V-4.1V), VREF (5V), and a ground circuit (SIGRTN).

Pressure Sensors

Barometric Pressure (BARO) Sensor

The BARO sensor is internal to the PCM. The PCM supplies a 5 volt reference (VREF) signal 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.

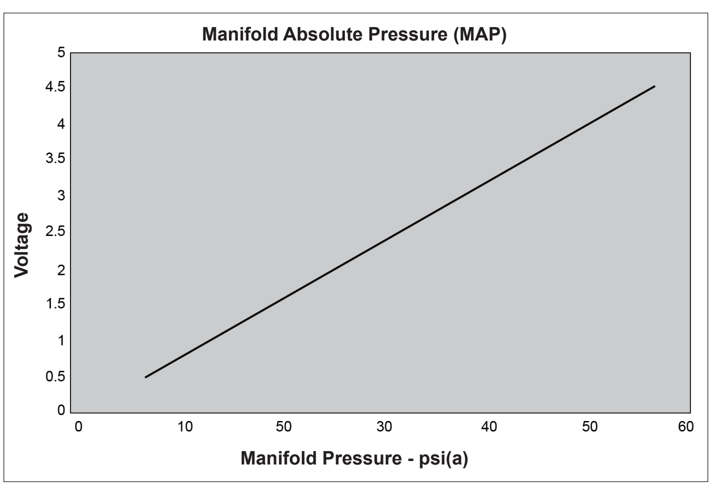


Barometric Pressure (BARO) sensor

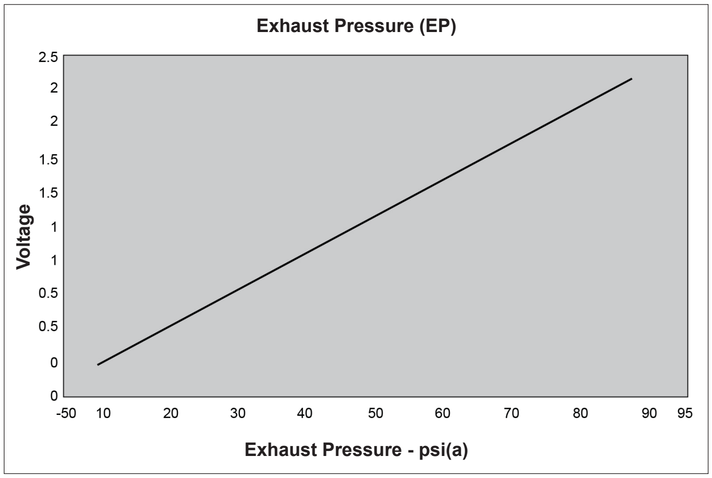
Manifold Absolute Pressure (MAP) Sensor

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, fuel control, and regeneration control.



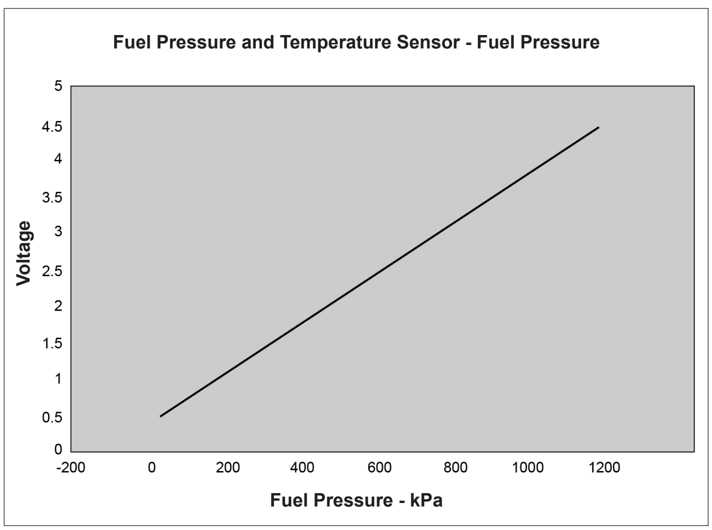
Manifold Absolute Pressure (MAP)



Exhaust Pressure (EP)

Exhaust Back Pressure (EBP) Sensor

The EBP sensor is a 3-wire variable capacitance sensor. The PCM supplies a 5 volt reference (VREF) signal which the EBP sensor uses to produce a linear analog voltage that indicates pressure. The PCM monitors the EBP sensor as an input for EGR operation for the delta pressure calculation.



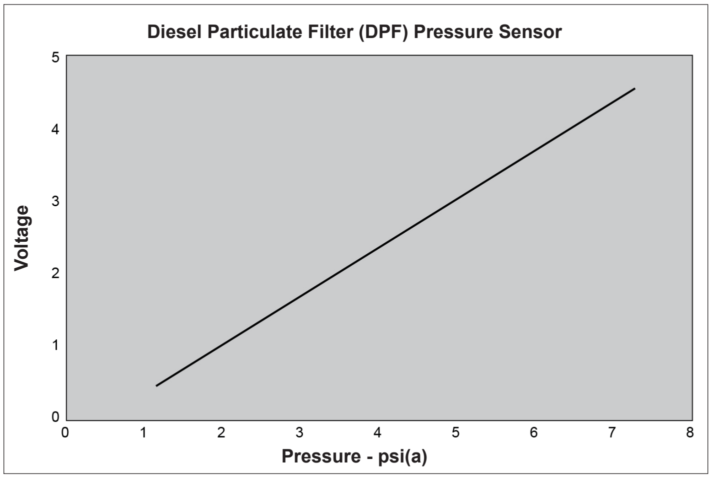
Fuel Pressure and Temperature Sensor - Fuel Pressure

Fuel Pressure and Temperature Sensor

The fuel pressure and temperature sensor monitors the fuel system pressure and temperature in the low pressure fuel supply line to the high pressure fuel injection pump.

The pressure component of the sensor provides a signal to the PCM to alert if low Fuel Line Pressure (FLP) occurs. The PCM supplies a 5 volt reference (VREF) signal, each has dedicated VREF, independent signal return. As pressure increases, the sensor signal voltage decreases.

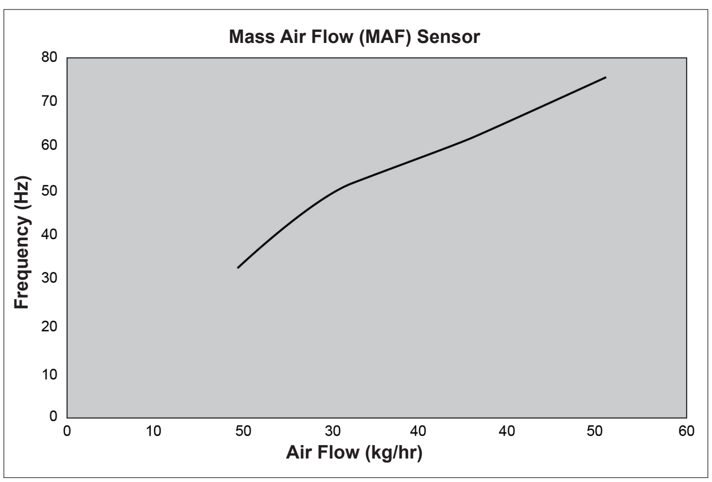
LOW FUEL PRESSURE displays in the message center to advise the customer of a low fuel pressure concern.



Diesel Particulate Filter (DPF) Pressure Sensor

Diesel Particulate Filter (DPF) Pressure Sensor

The DPF pressure sensor is an input to the PCM and measures the pressure before the diesel particulate filter. The sensor is a single port digital sensor that transmits data using SENT protocol. The Diesel Particulate Filter Pressure Sensor Bank 1, sensor 1 (DPFP11) is referenced to atmospheric pressure and is located at the exhaust system upstream of the diesel particulate filter. At ignition ON, engine OFF the DPF pressure sensor pressure value reads 0 kPa (0 psi). The range of the sensor is 0-80 kPa (0-11.6 psi). The PCM calculates soot load based on the DPF pressure and initiates a regeneration when the soot load reaches a threshold.



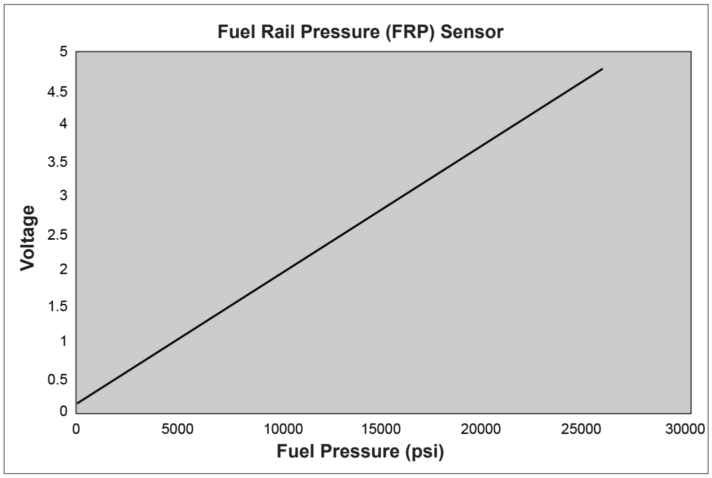
Mass Air Flow (MAF) Sensor

Mass Air Flow (MAF) Sensor

The MAF sensor provides a signal to the PCM proportional to the intake air mass. The sensor uses a hot wire sensing element to measure the amount of air entering the engine. The hot wire is maintained at a constant temperature above ambient. Air passing over the hot wire cools the wire. The current required to maintain the temperature of the hot wire is proportional to the airflow.

The MAF sensor is a digital sensor that provides an output signal of varying frequency. The signals time period is proportional to the flow rate crossing the sensor. The greater the airflow the shorter the time period. The time period varies from 1480 microseconds at a low flow or idle condition, to 106 microseconds at a high flow rate condition. The MAF sensor provides a signal to the PCM using SENT protocol.

The MAF is part of the MAF/IAT/TCIP/RHS Sensor.

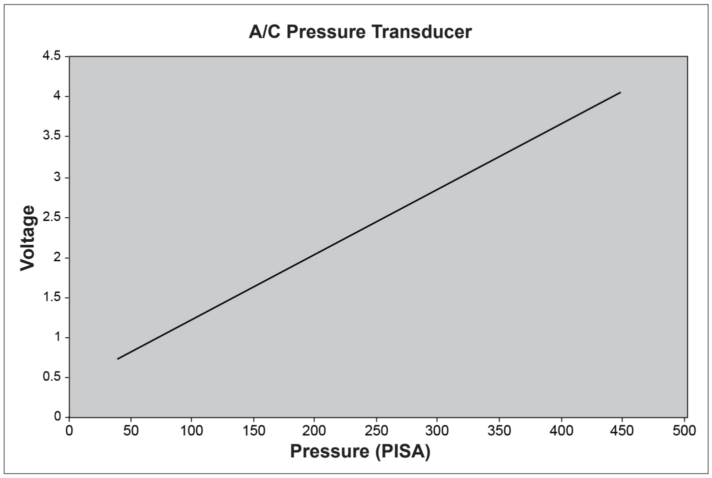


Fuel Rail Pressure (FRP) Sensor

Fuel Rail Pressure (FRP) Sensor

The FRP sensor is a 3-wire variable capacitance sensor. This sensor is separate from the fuel pressure and temperature sensor. The FRP sensor is located at the front of the left hand side fuel rail.

The PCM supplies a 5 volt reference (VREF) signal which the FRP sensor uses to produce a linear analog voltage that indicates high fuel pressure. The primary function of the FRP sensor is to provide a feedback signal to the PCM indicating the pressure of the fuel in the fuel rail. 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 engine load, speed and temperature.



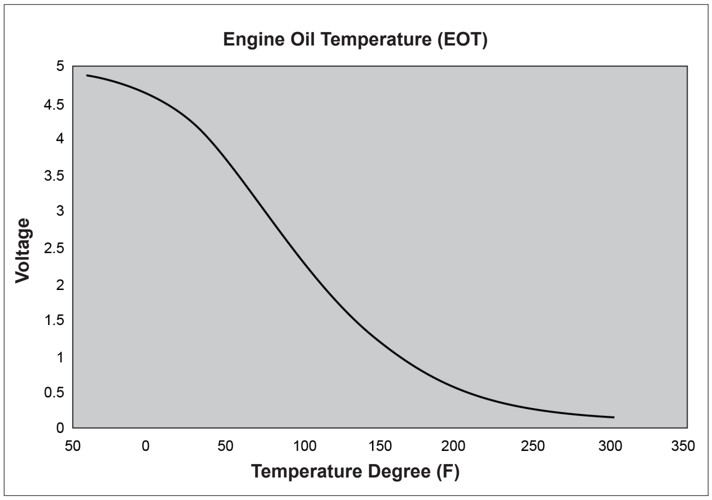
A/C Pressure Transducer

A/C Pressure Transducer

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

Temperature Sensors

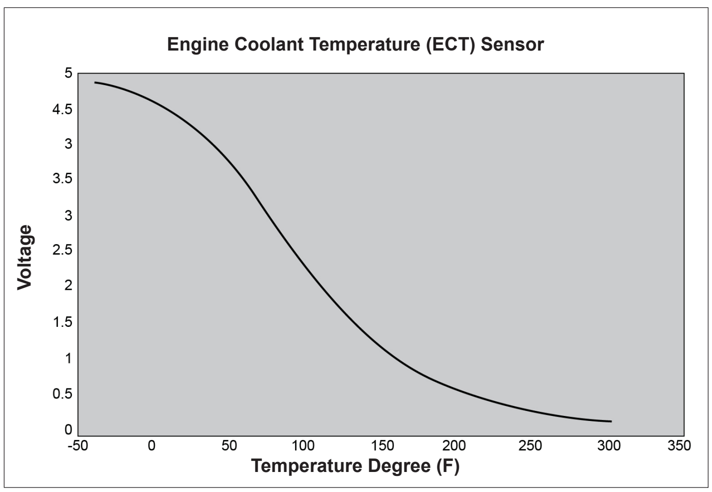
Temperature sensors are thermistor devices in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals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



Engine Oil Temperature (EOT) Sensor

Engine Oil Temperature (EOT) Sensor

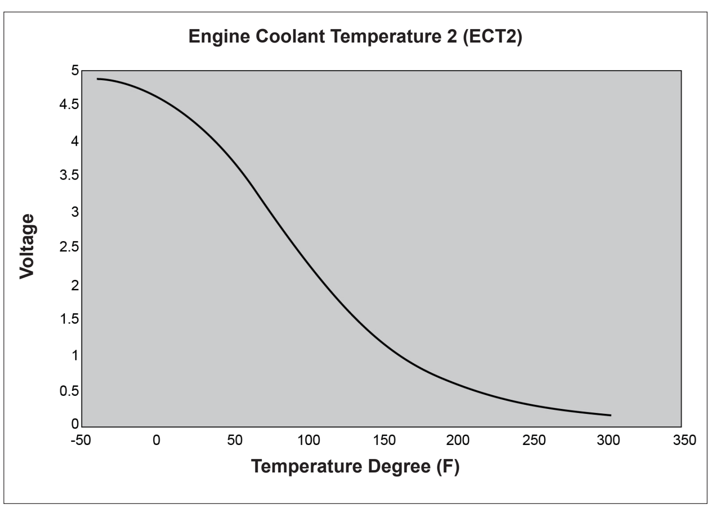
The EOT sensor is a 2-wire thermistor type sensor located in the Engine Oil Pressure (EOP) sensor and uses SENT protocol. The sensor changes the internal resistance as engine oil temperature changes. The EOT sensor is an input for the cooling fan operation, VGT command, and engine control as well as diagnostics. The EOT sensor signal allows the PCM to compensate for temperature changes in the operating environment.



Engine Coolant Temperature (ECT) Sensor

Engine Coolant Temperature (ECT1)

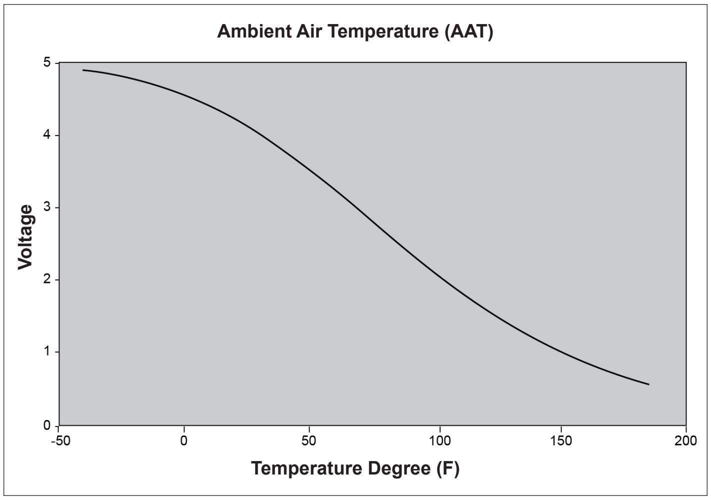
The ECT sensor is a 2-wire thermistor-type sensor. The sensor changes the internal resistance as the coolant temperature changes. The PCM uses the ECT sensor for engine temperature protection, input for EGR function, fuel control, and engine fan operation. The ECT sensor measures the temperature of the primary cooling system.



Secondary Cooling System Engine Coolant Temperature 2 (ECT2) Sensor

Secondary Cooling System Temperature 2 (ECT2) Sensor

The ECT2 sensor is a 2-wire thermistor-type sensor that measures coolant temperature in the powertrain secondary cooling system. The PCM applies 5 volts to the ECT2 sensor circuit. The sensor's internal resistance changes as the coolant temperature changes.

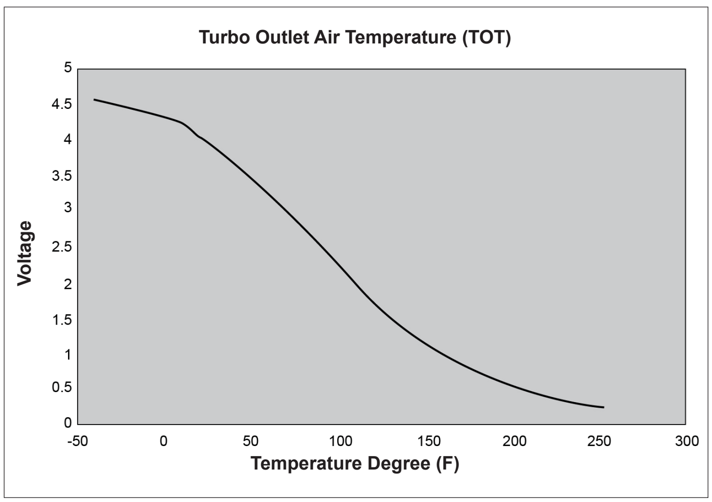


Ambient Air Temperature (AAT) Sensor

Ambient Air Temperature (AAT) Sensor

The AAT sensor is a 2-wire thermistor-type sensor. The sensor changes the internal resistance as the ambient air temperature changes.

The AAT sensor provides ambient air temperature information to the PCM which is used for the temperature sensor correlation tests and controls the glow plug operation reductant heaters. The PCM also communicates the AAT sensor information to all other modules on the controller area network (CAN).The AAT sensor is located in the passenger mirror.

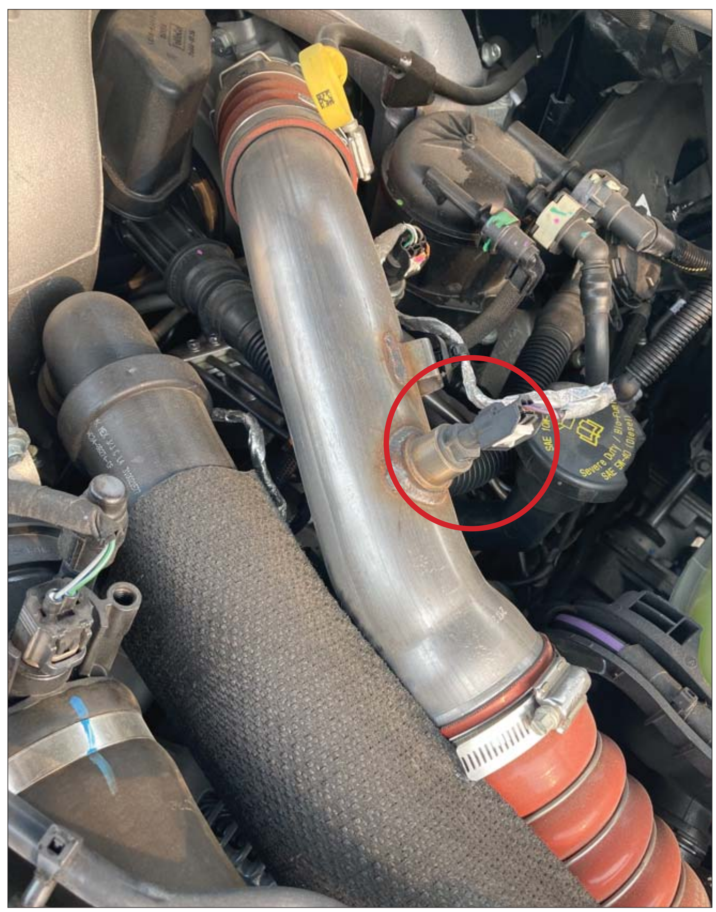


Turbo Outlet Air Temperature (TOT) Sensor (high output engine only)

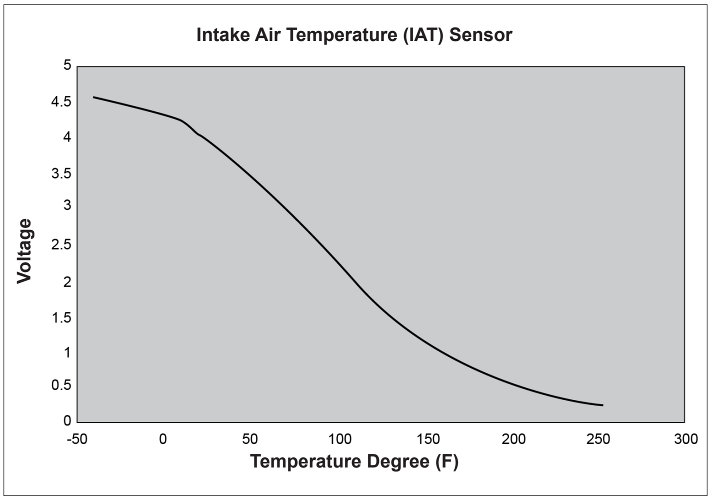
Turbocharger Outlet Air Temperature Sensor

The turbocharger outlet air temperature sensor is a 2-wire thermistor-type sensor. The sensor changes the internal resistance as the turbo outlet air temperature changes.

The turbocharger outlet air temperature sensor provides the PCM with temperature data of the air leaving the turbocharger on its way to the Charge Air Cooler (CAC).



Turbo Outlet Air Temperature (TOT) Sensor

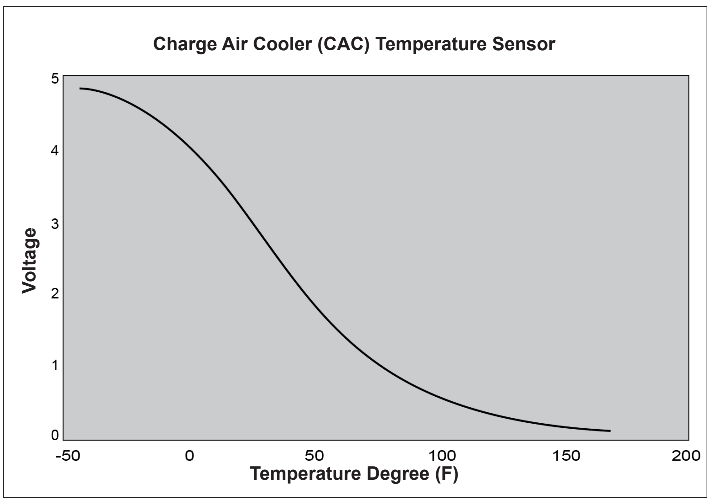


Intake Air Temperature (IAT) Sensor

Intake Air Temperature (IAT) Sensor

The IAT sensor is a thermistor-type device 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 voltage signals to the PCM corresponding to temperature.

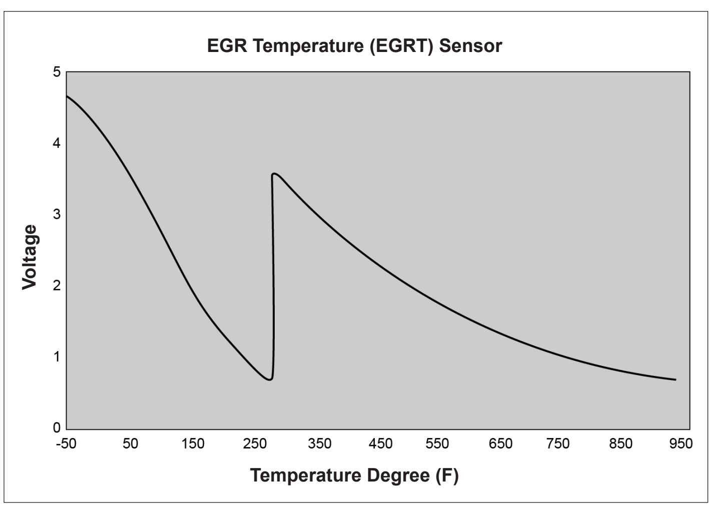
The IAT is part of the MAF/IAT/TCIP/RHS Sensor.



Charge Air Cooler (CAC) Temperature Sensor

Charge Air Cooler (CAC) Temperature Sensor

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



EGR Temperature (EGRT11) Sensor

EGR Temperature (EGRT11)Sensor

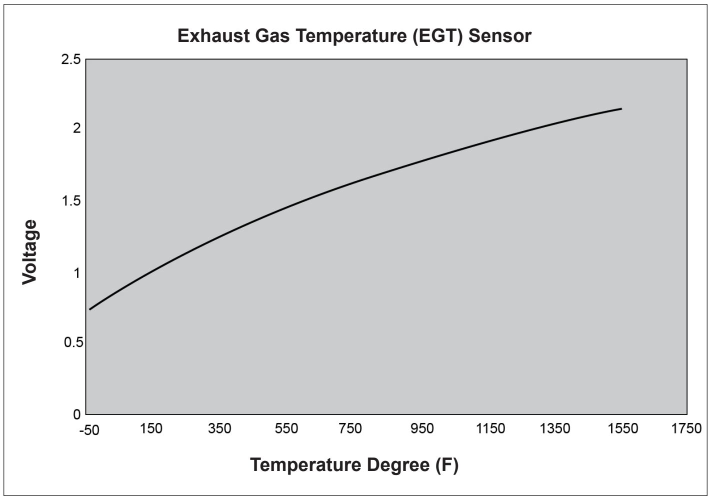
The EGRT11 sensor is a 2-wire thermistor-type sensor. The sensor changes the internal resistance as the temperature changes. This sensor has a two-step pull-up resistor internal to the PCM and the PCM controls the switch point.

Notice the two temperature curves with voltage. The PCM uses the EGRT sensor as an input in determining EGR cooler bypass actuator function, cooler effectiveness, turbocharger, EGR, fuel and regeneration control.

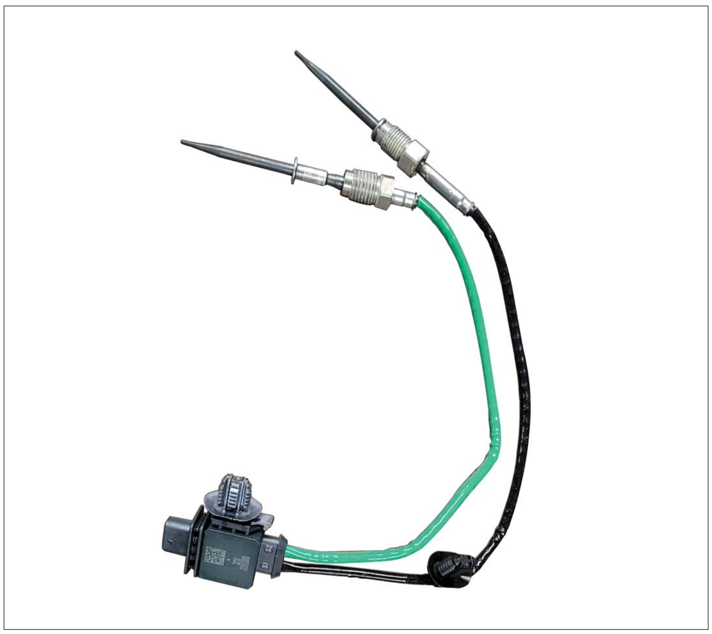
Exhaust Gas Temperature (EGT) Sensors

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 five EGT sensors used as part of the aftertreatment system. Except EGT11 which is a stand alone RTD sensor, the sensors are paired, and use SENT protocol to send data to the PCM. Sensors EGT12 and 13 are paired and EGT14 and EGT15 are paired. Each pair uses one connector for the pair. Each sensor uses a different size thread to prevent installation in the wrong location. EGT configuration may vary based on vehicle design. Not all vehicles use all possible EGTs.



Exhaust Gas Temperature (EGT) sensor



Exhaust Gas Temperature 12-13 (EGT12-13) sensor

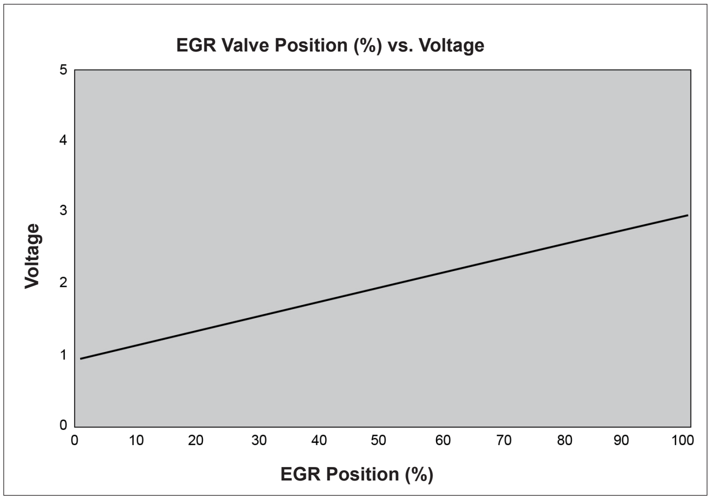
Exhaust Gas Temperature 14-15 (EGT14-15) sensor

Position Sensors

Exhaust Gas Recirculation Valve Position (EGRVP) Sensor

The EGRVP sensor is a 3-wire non- contacting position sensor. 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 exhaust gas recirculation valve position sensor to determine exhaust gas recirculation valve position and compares it to the calculated desired position.

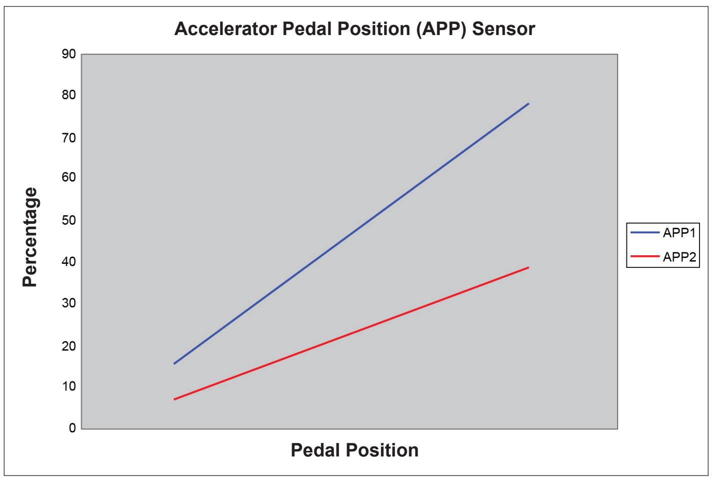


Exhaust Gas Recirculation Valve Position (EGRVP) sensor

Accelerator Pedal Position (APP) Sensor

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

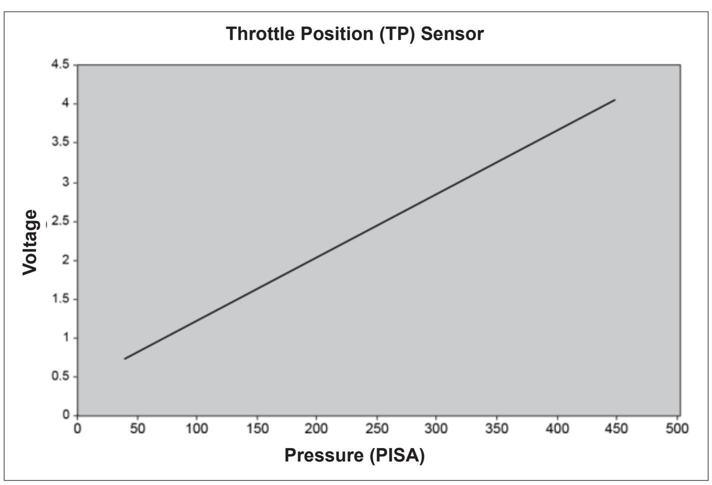
The presence of a second sensor in the same assembly is a safety feature. The two sensors must agree or the PCM will not react



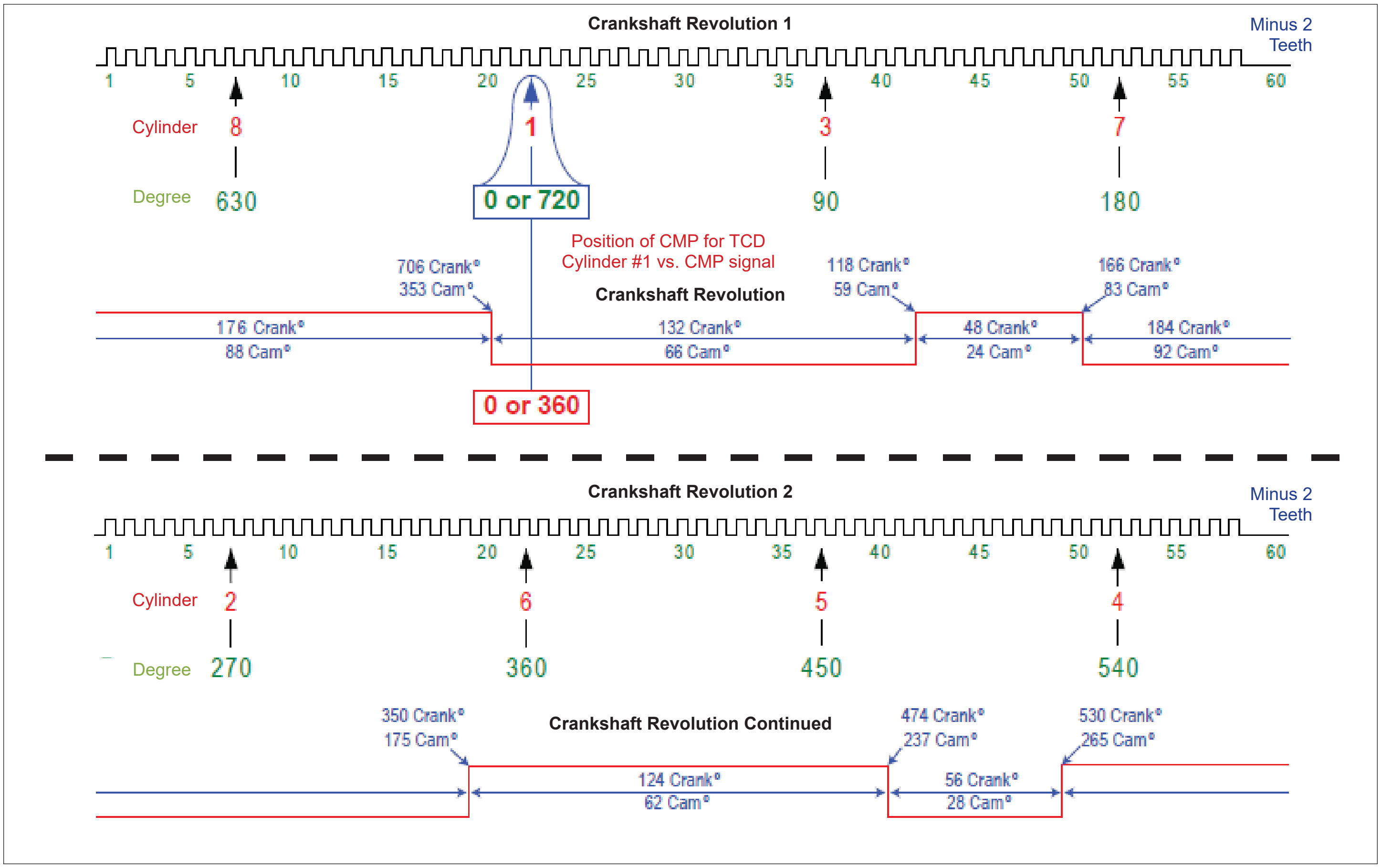
Accelerator Pedal Position (APP) Sensor

Throttle Position (TP) Sensor

The TP sensor monitors the position of the throttle plate in the throttle body and send this data to the PCM. This data is used for EGR system operation.



Throttle Position (TP) sensor



Crankshaft Position (CKP) Sensor

Crankshaft Position (CKP) Sensor

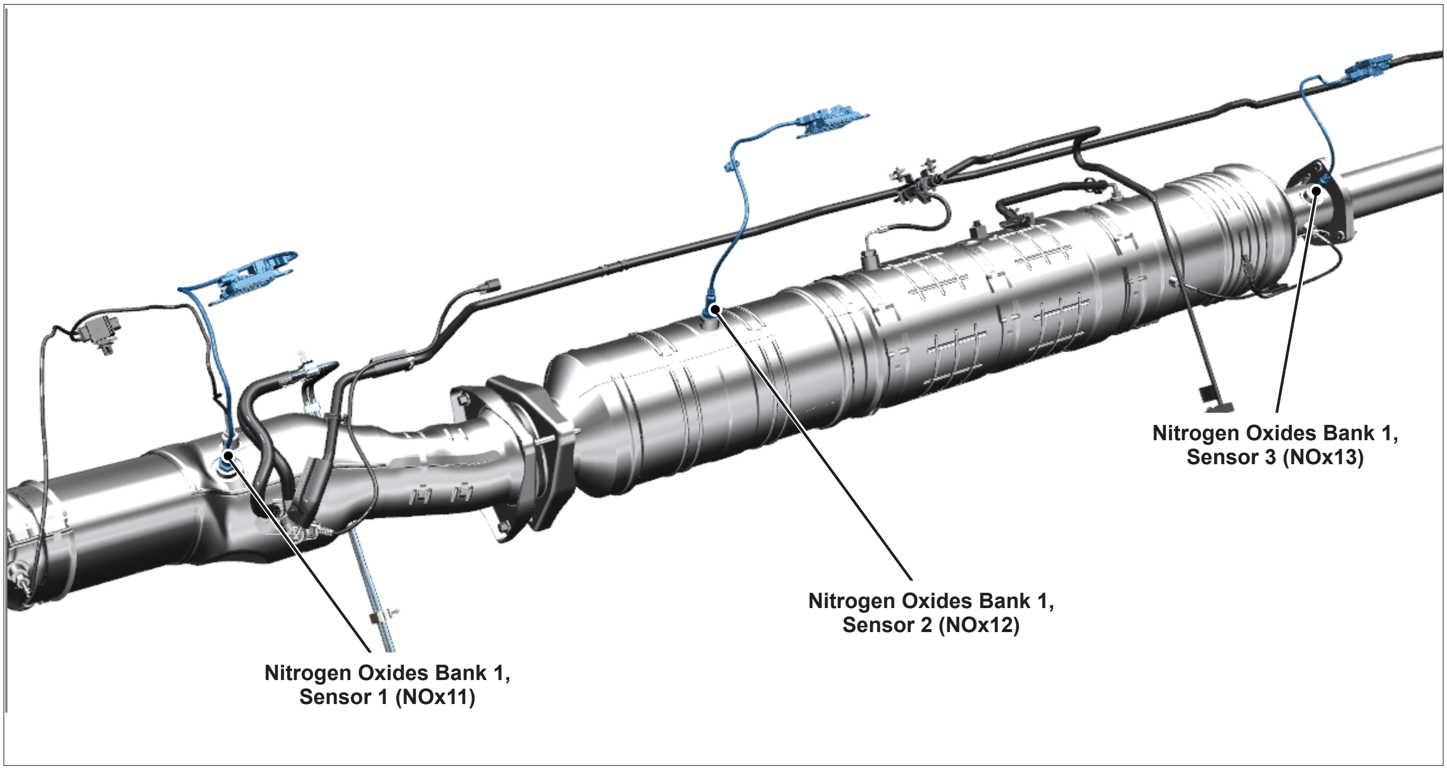
The CKP sensor is a Hall-effect sensor. The PCM filters the information from the sensor which indicates the tooth edges of the magnetic trigger wheel. There are 2 teeth removed to allow the PCM to determine the crankshaft and piston position.

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 that detects the camshaft position. The CMP sensor identifies when piston number 1 is on its compression stroke. The graphic below shows a properly timed engine. Note the position of the trailing edge of the short CMP signal to the gap in the CKP signal.

Miscellaneous Sensors



NOx sensors

NOx Sensors

There are three NOx sensors located in the exhaust system. The Nitrogen Oxides Bank 1, Sensor 1 (NOx11) sensor is located upstream of the Selective Catalytic Reduction System (SCR) catalyst and is only used to detect the presence of NOx concentrations in the exhaust system.

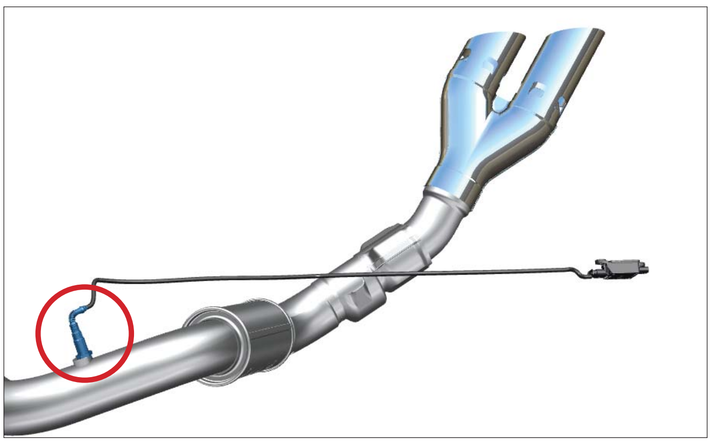
The Nitrogen Oxides Bank 1, Sensor 2 (NOx12) is located between the SCR and the Diesel Exotherm Catalyst (DEC) and is used to monitor SCR efficiency. The Nitrogen Oxides Bank 1, Sensor 3 (NOx13) is located at the outlet of the DPF and monitors the downstream injector efficiency.

The PCM uses the information to adjust how much reductant and fuel is being injected into the exhaust as well as an input for fuel trim.

DPF pressure sensor

Diesel Particulate Filter Pressure Sensor

The diesel particulate filter pressure sensor is an input to the PCM and measures the pressure before the diesel particulate filter. The sensor is a differential type of sensor. The diesel particulate filter pressure sensor bank 1, sensor 1 (DPFP11) is referenced to atmospheric pressure and is located at the exhaust system upstream of the diesel particulate filter. At ignition ON, engine OFF the diesel particulate filter pressure sensor pressure value reads 0 kPa (0 psi). The range of the sensor is 0-80 kPa (0-11.6 psi). The PCM calculates soot load based on the diesel particulate filter pressure and initiates a regeneration when the soot load reaches a threshold.



Particulate Matter Sensor

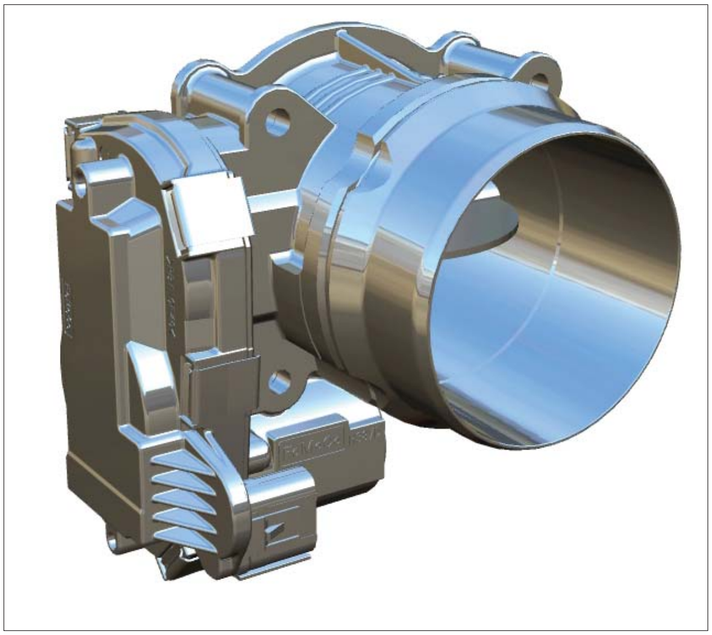
Particulate Matter Bank 1 Sensor 1 (PM11) Module

The PCM monitors the diesel particulate filter for leaks in the filter substrate, as well as for a filter substrate that has been removed. The PM11 sensor is an input used by the diesel particulate filter monitor and is located downstream of the DPF.

For the efficiency monitor test, as soot accumulates on the PM11 sensor, a current is generated within the PM11 sensor. The PCM calculates a monitoring time for the PM11 sensor based on the expected soot generated by the engine. At the conclusion of this monitoring time, the PCM strategy compares the current of the PM11 sensor to a calibrated threshold. If the current exceeds the threshold, a concern is present. At the conclusion of this test, the PM11 sensor operation is controlled to burn all of the accumulated soot off the PM11 sensor, and the measurement cycle is repeated.

Outputs

Intake Throttle Body



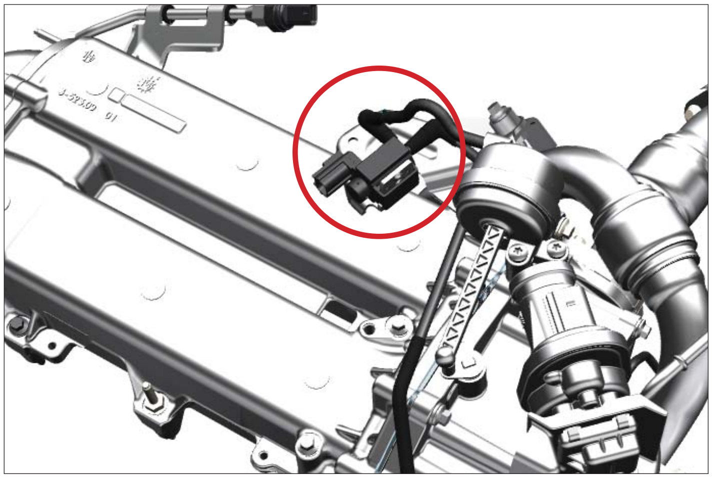
Intake throttle body

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

EGR valve

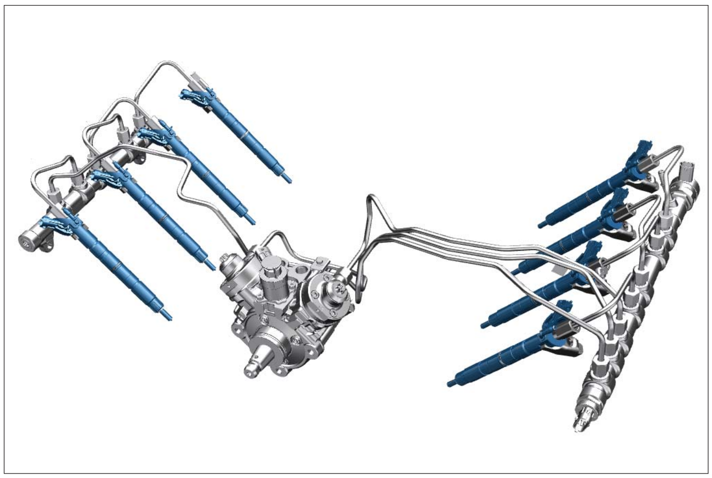
The EGR valve is an electric DC motor controlled by the PCM. The valve is powered in both the open and closed positions. The EGR valve opens to allow exhaust gases to mix with the intake air for Oxides of Nitrogen (NOx) emissions purposes. The EGR position (EGRVP) sensor is an integral part of the EGR valve and provides the PCM with EGR position data.



EGR cooler bypass solenoid

EGR Cooler Bypass Solenoid

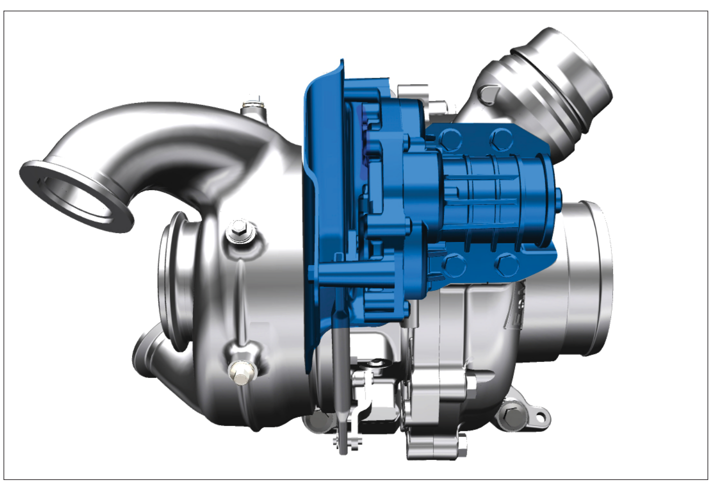
A duty cycle is applied to the solenoid from the PCM to turn vacuum to the actuator on or off. This change causes the EGR cooler bypass door to move. The EGR cooler bypass solenoid changes the state of the EGR cooler bypass door to either allow exhaust gases to bypass the EGR cooler or direct the gases through the EGR cooler.



Fuel Injectors

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. The piezo actuator is commanded on by the PCM for approximately 0-400 microseconds during the main injection stage.

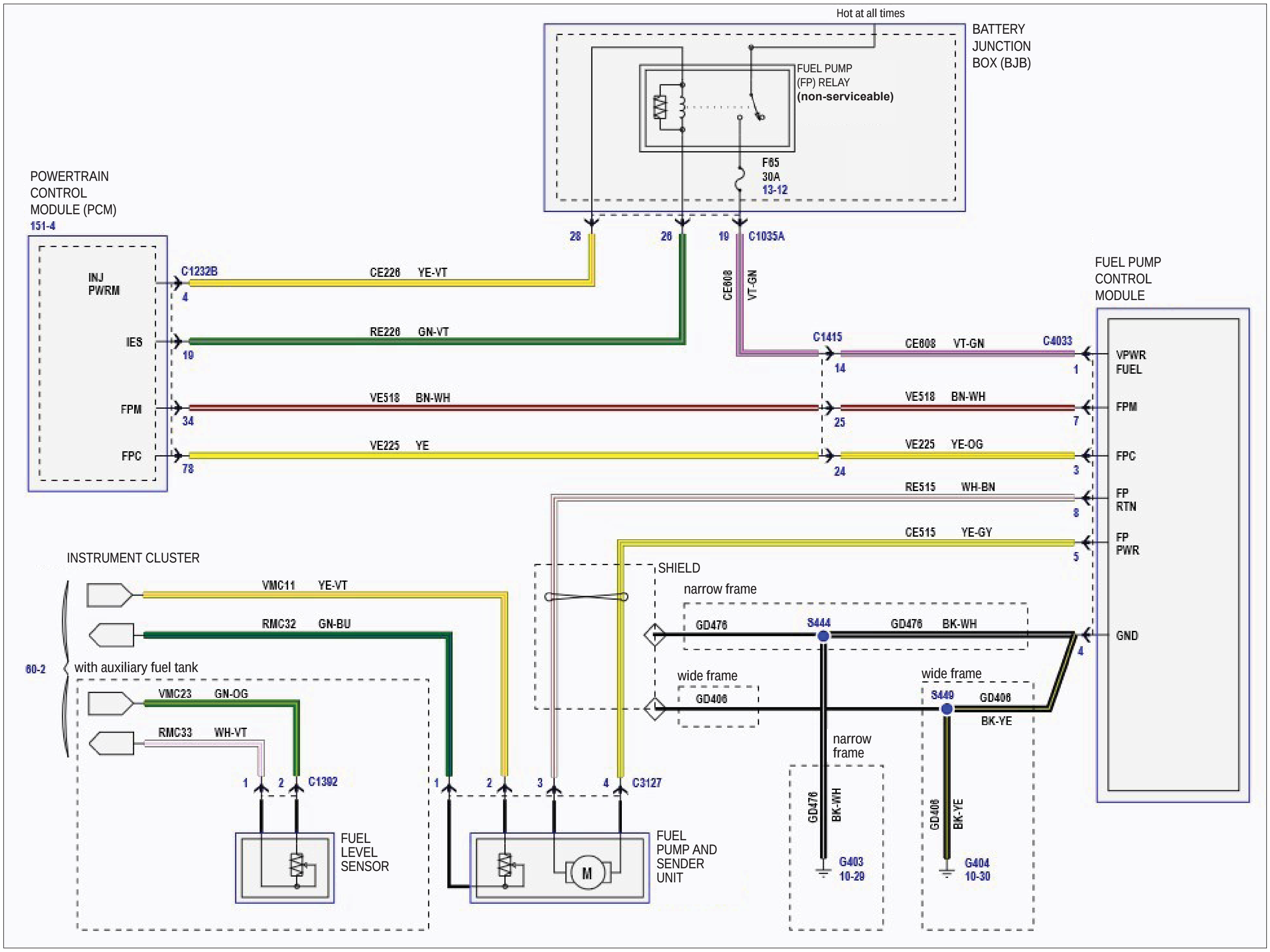


Electronic turbocharger actuator

Electronic Turbocharger Actuator

The electronic turbocharger actuator contains a stepper motor that moves the VGT vanes to the commanded position with a mechanical linkage

The electronic turbocharger actuator also contains a position sensor for feedback to the PCM. A closed-loop system provides feedback to the PCM. In response to engine speed, load, manifold pressure and barometric pressure, the PCM controls the turbocharger actuator position to match manifold boost to the requirements of the engine.

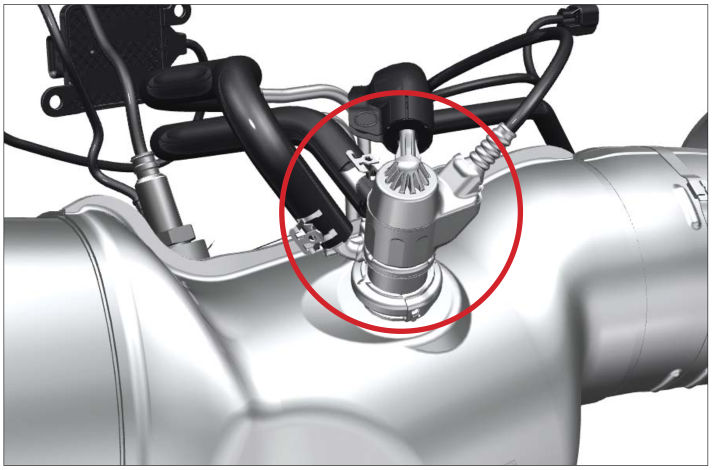


Fuel pump relay

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.

The relay then powers the fuel pump control module which turns the fuel pump on or off.



Reductant Dosing Module (Injector)

Reductant Dosing Module (Injector)

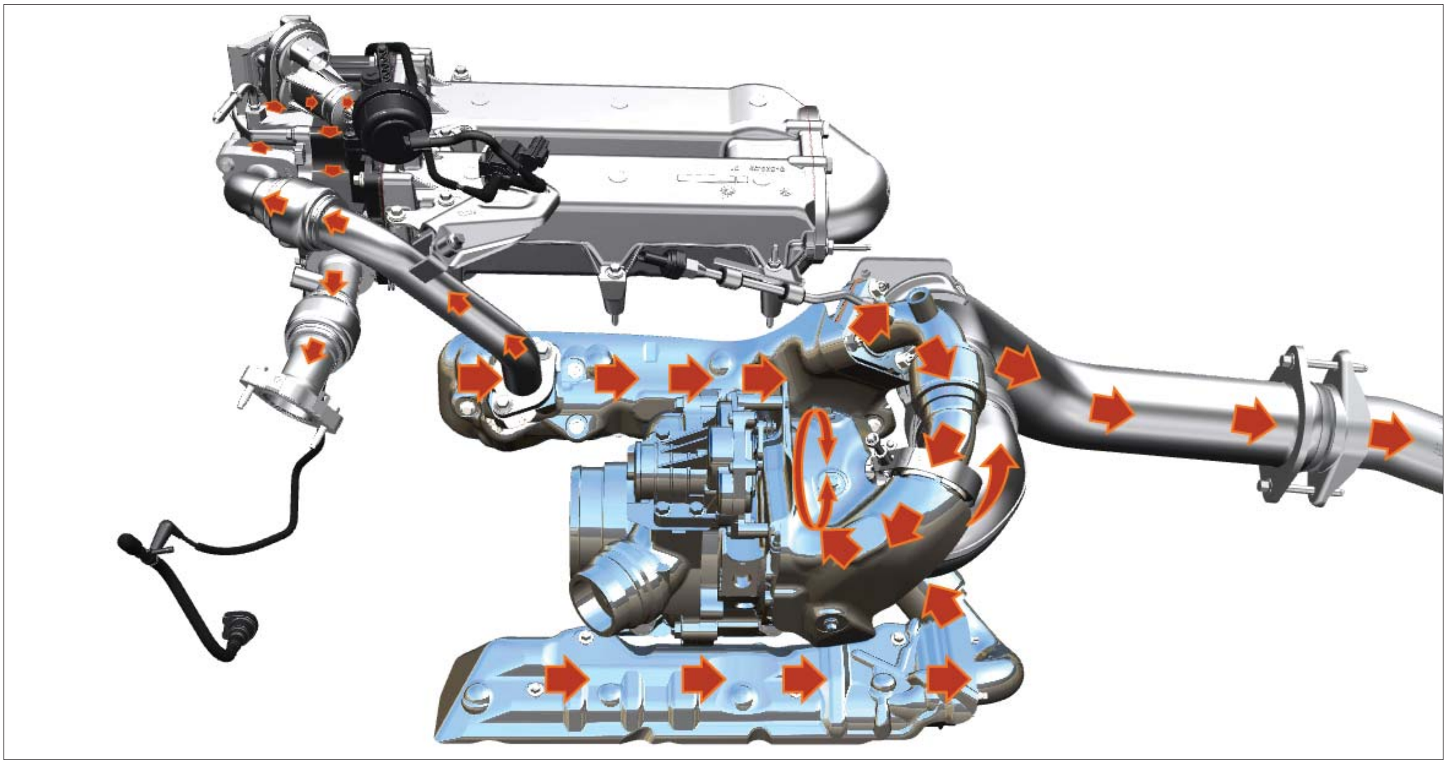
The reductant dosing module is mounted to the exhaust on the SCR next to EGT13 sensor. The reductant dosing module is the part that injects the Diesel Exhaust Fluid (DEF) into the exhaust system. The coolant lines are part of the secondary cooling system.

TCM

Transmission Control Module (TCM)

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

Operation



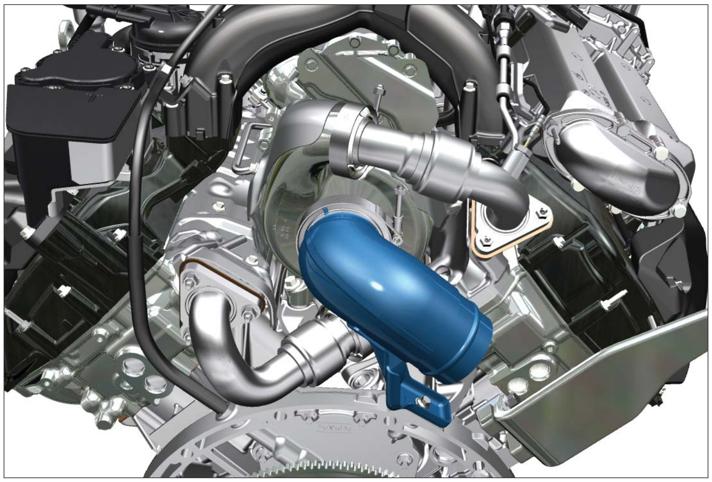
Turbocharger down pipe

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

Components (Non Chassis Cab)

Turbocharger Downpipe

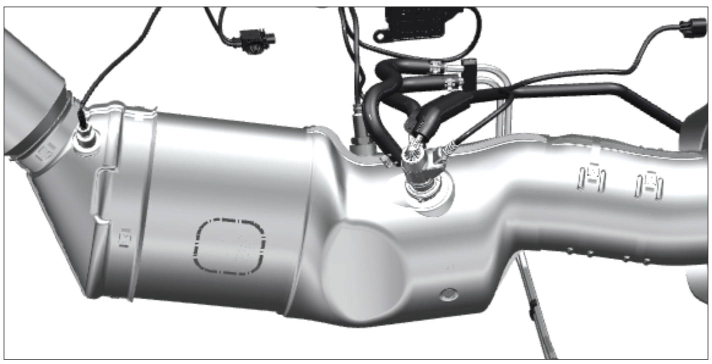
The turbocharger downpipe is double walled to help retain heat. This assists the oxidizing catalyst by maintaining high exhaust gas temperatures to optimize the effects of the aftertreatment system. It connects to the turbocharger with a V-band clamp connector.



Turbocharger down pipe

Diesel Oxidation Catalytic Converter (DOC)

The DOC is a ceramic catalytic converter which oxidizes hydrocarbons in the exhaust and generates heat for the SCR and DPF to function properly. In order to keep the DOC from excessive sulfur buildup the PCM occasionally performs a stage 2 regeneration.

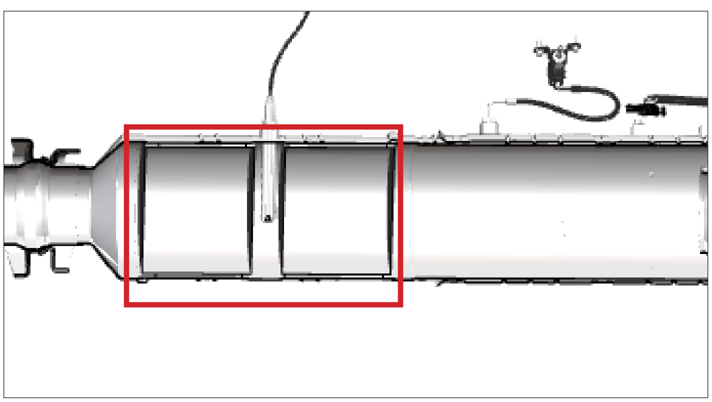


Oxidation Catalyst (OC)

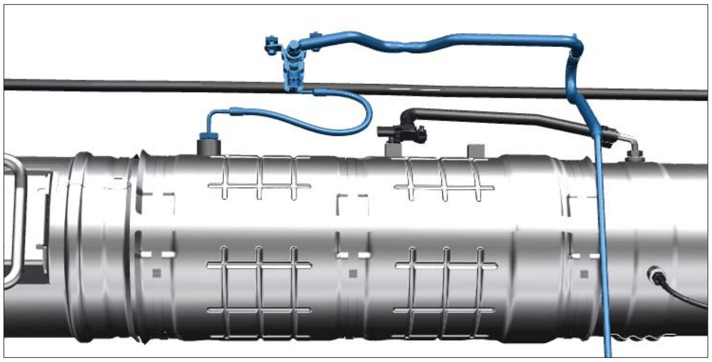
Selective Catalytic Reduction (SCR)

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

The pipes are designed with an integral twist mixer that causes the DEF fluid and exhaust gases to mix thoroughly.



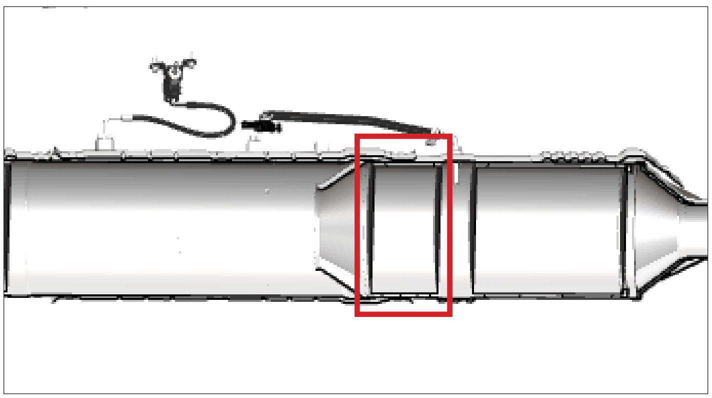
Selective Catalyst Reduction (SCR)



Diesel Downstream Injector (DSI)

Diesel Downstream Injector (DSI)

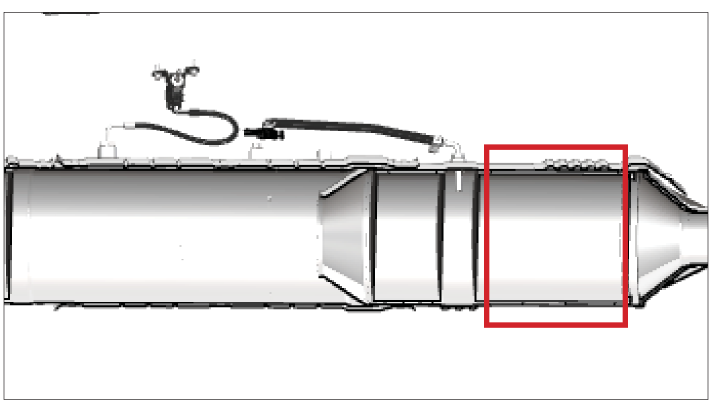
The diesel downstream injector provides fuel to the diesel exotherm catalyst to generate heat for DPF regeneration. The diesel exotherm catalyst acts similar to the DOC using the hydrocarbon in the fuel to create heat. When activated the diesel downstream injector applies fuel from the low pressure fuel system to a poppet valve located just in front of the diesel exotherm catalyst. The Hydrocarbon in the fuel oxidizes across by the diesel exotherm catalyst resulting in additional heat for DPF regeneration.



Diesel Oxidation Catalyst (DOC)

Diesel Exotherm Catalyst

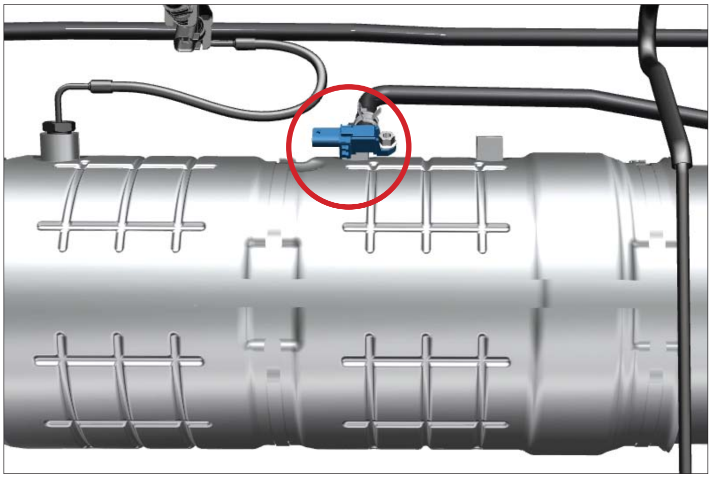
The diesel exotherm catalyst uses fuel from the downstream injector to create heat for the DPF regeneration process. It is located in front of the DPF and is monitored by EGT15 and EGT16.



Diesel Particulate Filter (DPF)

Diesel Particulate Filter (DPF)

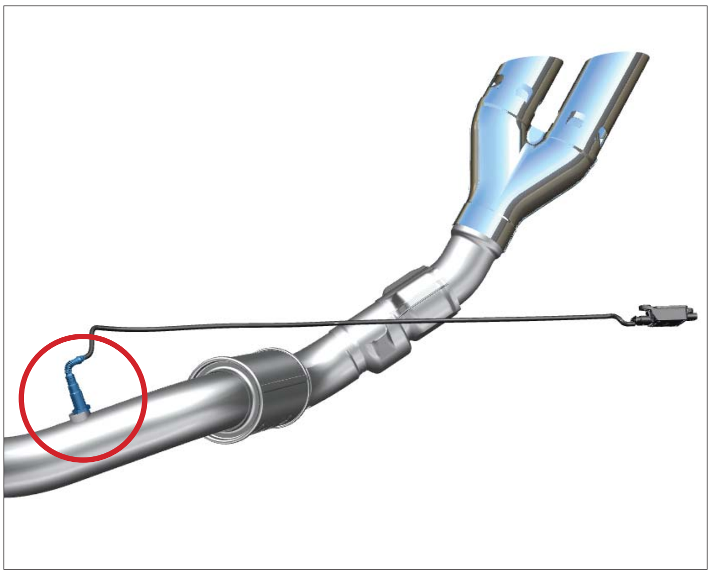
The DPF is an aluminum titanate, wall-flow catalyst that traps particulates, reducing the amount of black smoke emitted from the tailpipe. The three modes of DPF regeneration are active, passive, and manual.



DPF pressure sensor

DPF Pressure Sensor

The DPF pressure sensor is an input to the PCM and measures the pressure before the DPF. The DPF pressure sensor is a single port digital sensor that transmits data using SENT protocol. The PCM uses the DPF pressure sensor to monitor the amount of exhaust pressure produced by the DPF. An active regeneration is performed when the reading reaches a specified point.

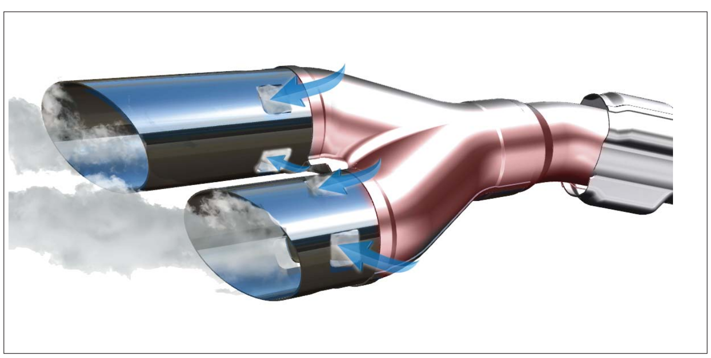


PM11 Sensor

Particulate Matter Bank 1 Sensor 1 (PM11)

The PCM monitors soot leakage after the diesel particulate filter. The PM11 sensor, located on the catalyst and particulate filter assembly, is used as an input for the diesel particulate filter monitor.

As soot accumulates on the PM11 sensor, a current is generated within the PM11 sensor. The PCM calculates a monitoring time for the PM11 sensor based on the expected soot generated by the engine. At the conclusion of this monitoring time, the PCM strategy compares the current of the PM11 sensor to a calibrated threshold. The MIL illuminates if a DPF failure is detected.

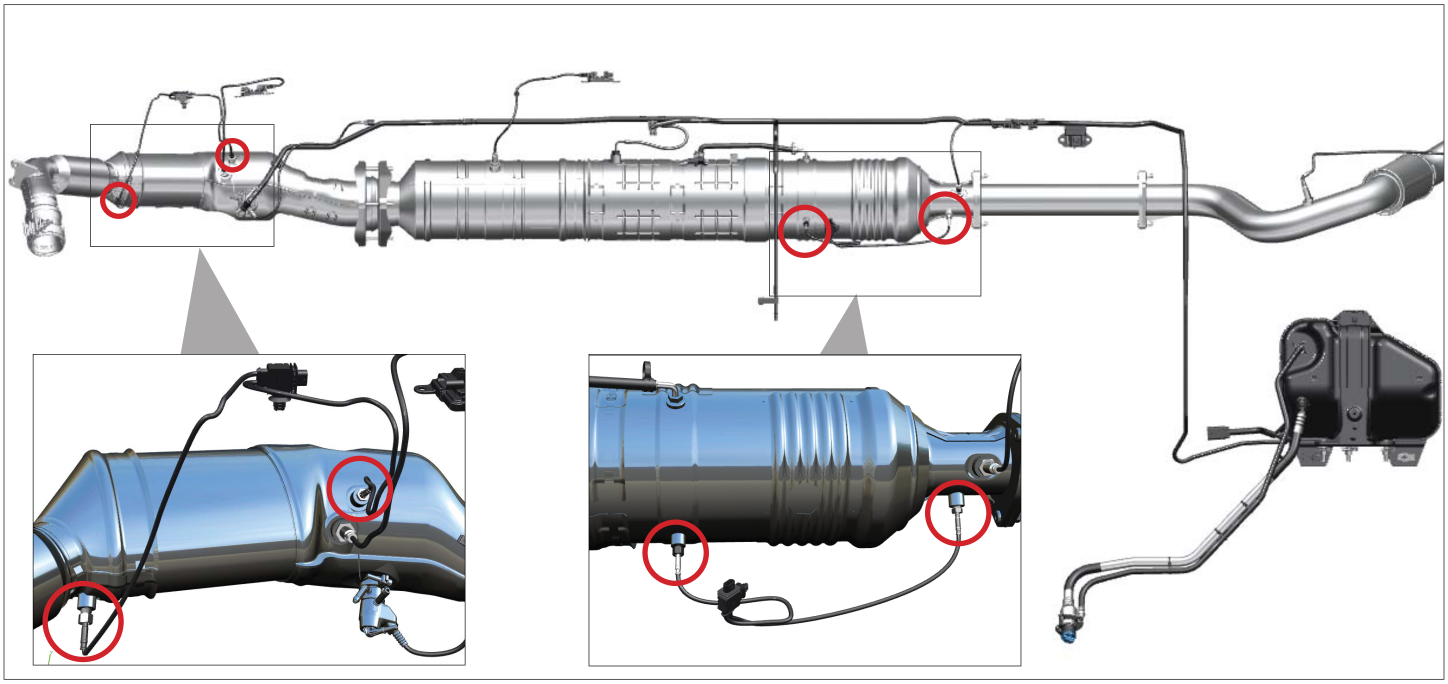


Double exhaust diffuser

Exhaust Diffusers

Exhaust diffusers use a venturi effect to draw outside air into the exhaust to help keep the outlet temperatures down

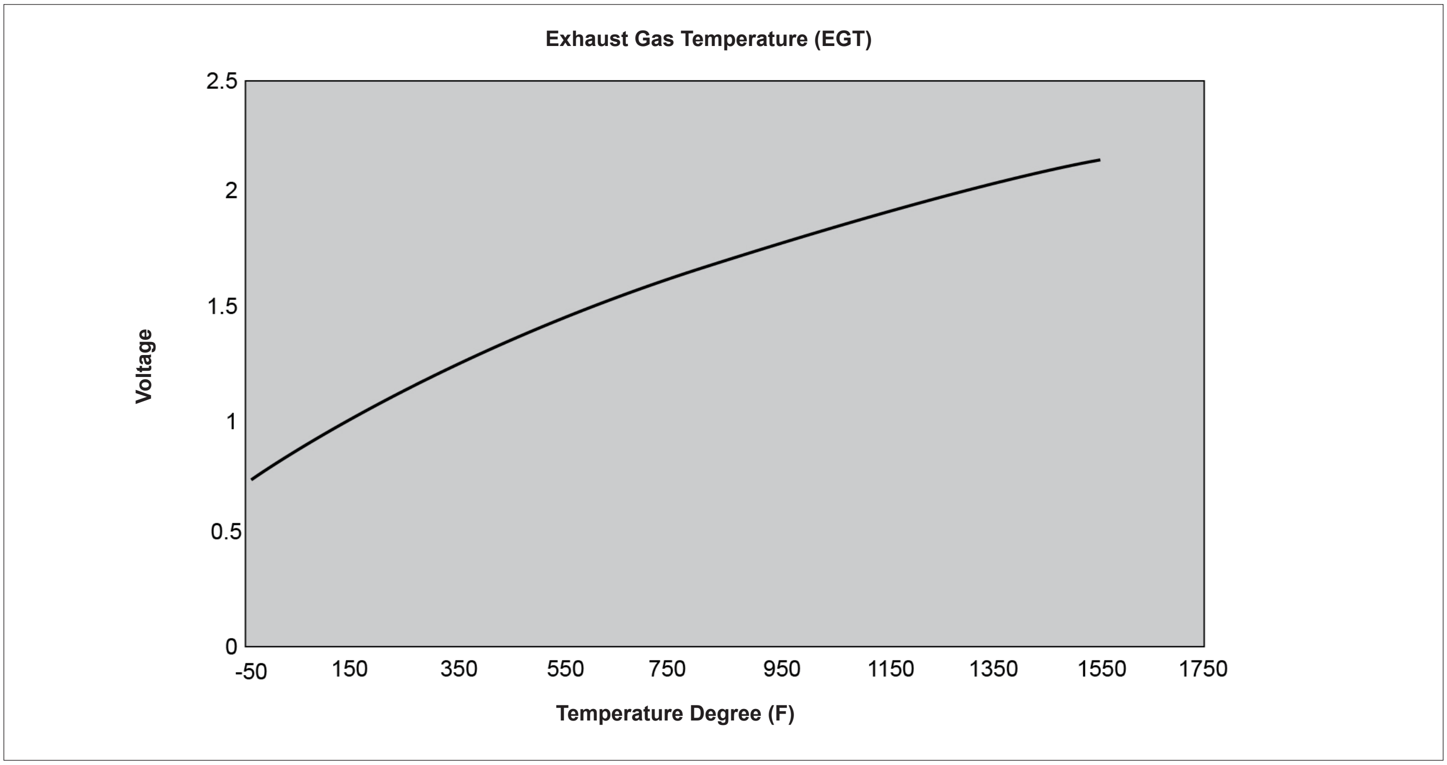
Single exhaust diffuser



EGT sensors

Exhaust Gas Temperature (EGT) Sensors

The EGT sensors are inputs to the PCM. They measure the temperature of the exhaust gas passing through the exhaust system at five different points.



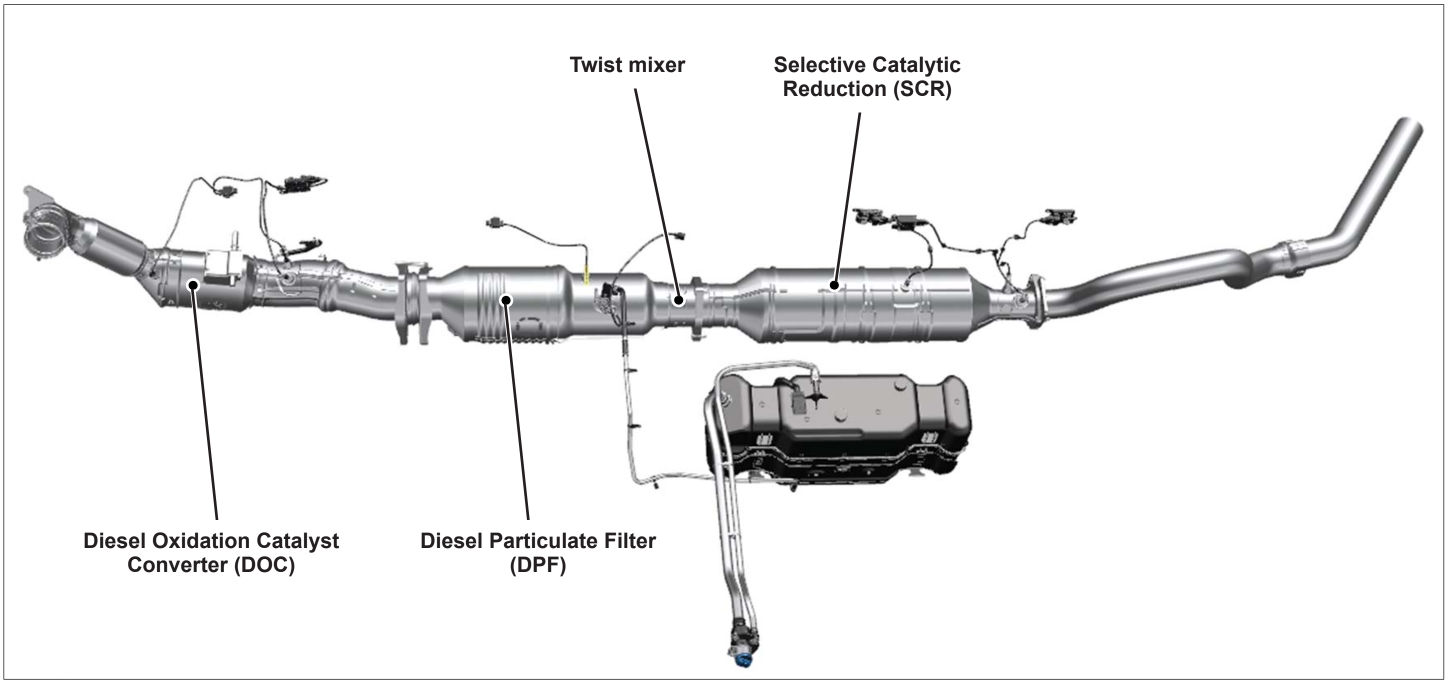
Exhaust Gas Temperature (EGT) Sensor

EGT Sensor Operation

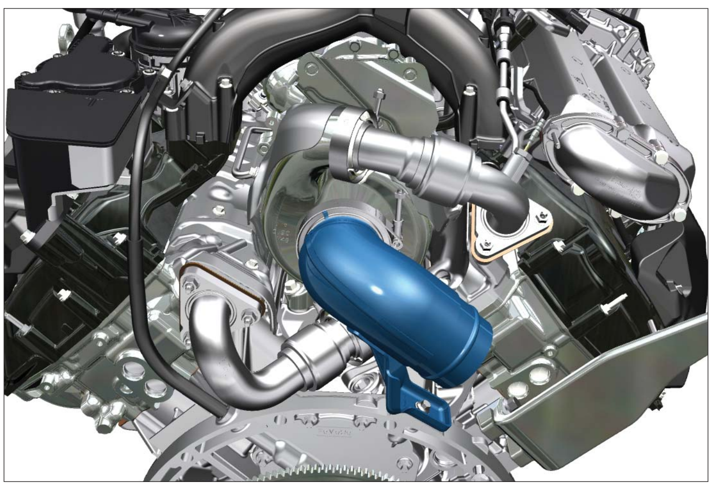
The electrical resistance of the Exhaust Gas Temperature (EGT) sensors changes with the temperature of the sensor. EGT11, located near the turbocharger turbine inlet, is a single sensor that sends a voltage signal to the PCM to indicate its temperature. EGT12 (located at the DOC inlet) and EGT13 (located at the DOC outlet) are paired together using one connector, and use SENT (Single Edge Nibble Transmission) technology to provide the PCM with temperature data. EGT14 (located near the DEC and DPF) and EGT15 (located at the DPF outlet) are also paired together and use SENT technology. Because of the SENT protocol, direct voltage readings on these sensors for diagnosis will not provide relevant information.

Not all vehicles will use all 5 EGTs. Some vehicles will use only 4 sensors depending on the level of aftertreatment system used. On these vehicles EGT15 is not used and the sensors may not use SENT technology.

Components (Chassis Cab)



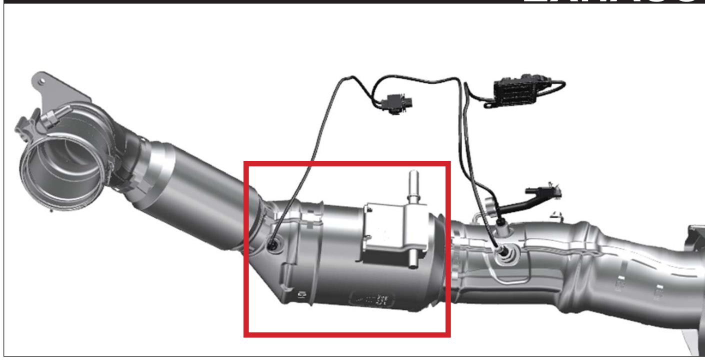
Chassis cab exhaust



Turbocharger down pipe

Turbocharger Downpipe

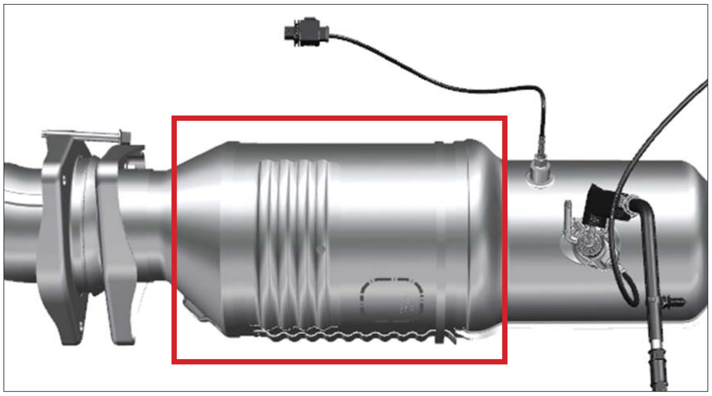
The turbocharger downpipe is double walled to help retain heat. This assists the oxidizing catalyst by maintaining high exhaust gas temperatures to optimize the effects of the aftertreatment system. It connects to the turbocharger with a V-band clamp connector.



Oxidation Catalyst (OC)

Diesel Oxidation Catalytic Converter (DOC)

The DOC is a ceramic catalytic converter which oxidizes hydrocarbons in the exhaust and generates heat for the SCR and DPF to function properly. In order to keep the DOC from excessive sulfur buildup the PCM occasionally performs a stage 2 regeneration.



Diesel Particulate Filter (DPF)

Diesel Particulate Filter (DPF)

The DPF is an aluminum titanate, wall-flow catalyst that traps particulates, reducing the amount of black smoke emitted from the tailpipe. The three modes of DPF regeneration are active, passive, and manual.

Note:	Chassis Cab Units do not have the DSI / DEC System Hardware

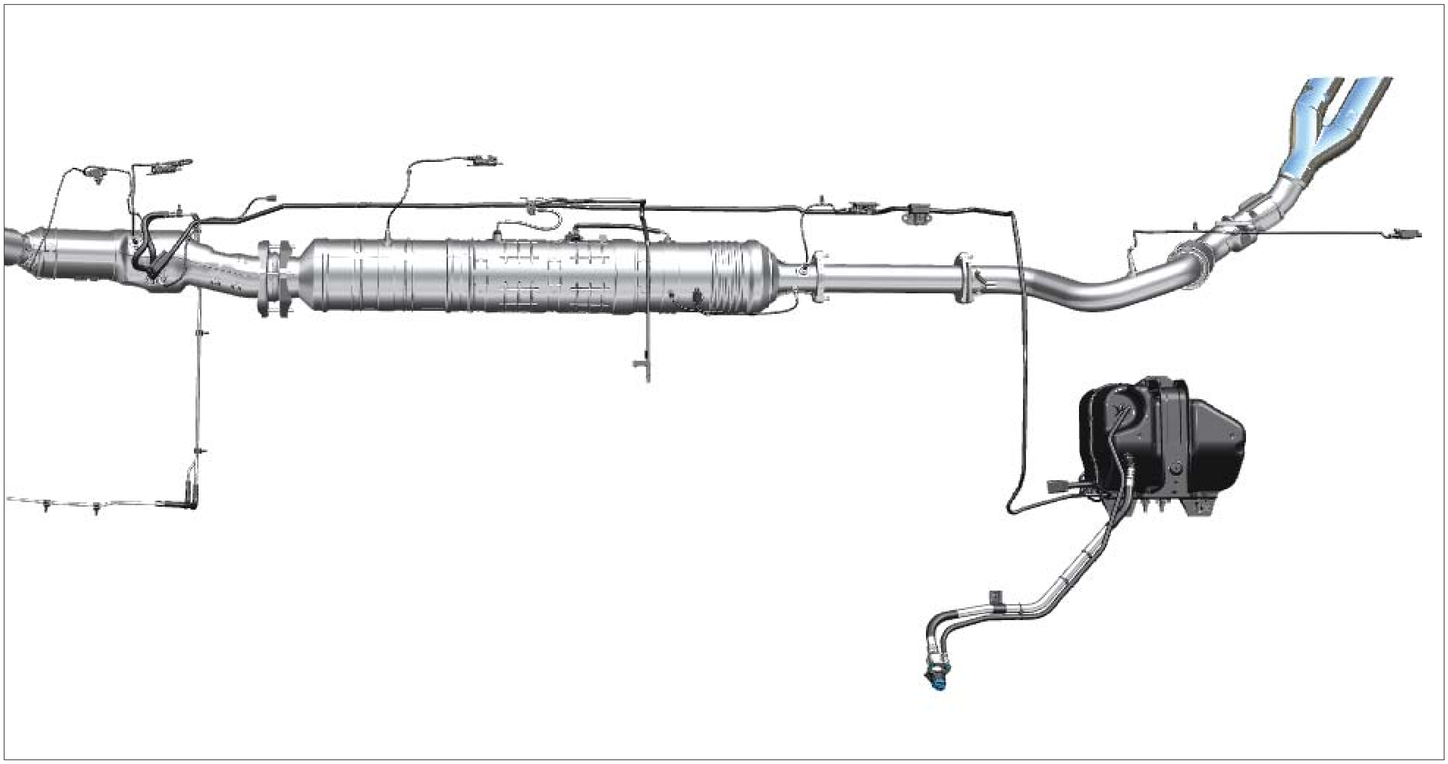
Selective Catalyst Reduction (SCR)

Selective Catalytic Reduction (SCR)

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

The pipes are designed with an intergral twist mixer that causes the DEF fluid and exhaust gases to mix thoroughly.

Regeneration Process



Regeneration process

As soot gathers in the after-treatment system, the exhaust becomes restricted. Regeneration is the process in which soot is burned off from the inside of the DPF. Regeneration can be passive, active, or manual. The PCM starts regeneration of the DPF if the soot load exceeds a calibrated value. The PCM determines the load condition of the DPF, based on the exhaust gas pressure upstream of the DPF. The DPF pressure sensor provides the pressure input to the PCM.

Passive Regeneration

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

Active Regeneration

Active regeneration occurs when exhaust temperatures are insufficient to achieve passive regeneration and the DPF pressure sensor is indicating the need for regeneration. For the Pick-Up Truck applications, active regeneration is commanded by the PCM uses the DSI system to deliver fuel to the DEC to create the need heat to clean the DPF. Engine performance is not affected by active regeneration; however, the engine or exhaust tone may change. Occasionally the Exhaust system requires a stage 2 (high temperature) regeneration to burn off any buildup of sulfur on the SCR. During stage 2 regeneration the PCM commands a late injection in the cylinders of the engine during the exhaust stroke as well as firing the DSI for DPF regeneration. This causes the DOC to create more heat burning off the buildup and cleaning the SCR.

Note: The Chassis Cab Trucks use this type approach for their normal DPF Regeneration except they command the Late Fuel injection to only the left bank of the engine.

Manual Regeneration

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

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

Frequency of Regeneration

The mileage between regenerations varies significantly, depending on vehicle usage. For the model years 2011-2022 F-Super Duty and 2016-2023 F-650/F-750, vehicles equipped with a 6.7L engine may exhibit an elevated idle condition. During prolonged idle time, vehicles may experience this elevated idle to reduce unburned hydrocarbons from the SCR. The powertrain control module estimates hydrocarbon levels in the SCR and may increase idle speed to remove them. Idle speed is increased to 1,000 RPM for ambient temperatures near 26°C (80°F) and may increase to 1,200 RPM at -40°C (-40°F). Vehicles may exhibit exhaust smoke and exhaust smell during elevated idle condition. Exhaust smoke and smell condition does not affect reliability or durability of the engine. Power take-off (PTO) use and idle set point control disables elevated speed.

It is required that the operator monitor the vehicle and adhere to any Exhaust Filter warning messages.

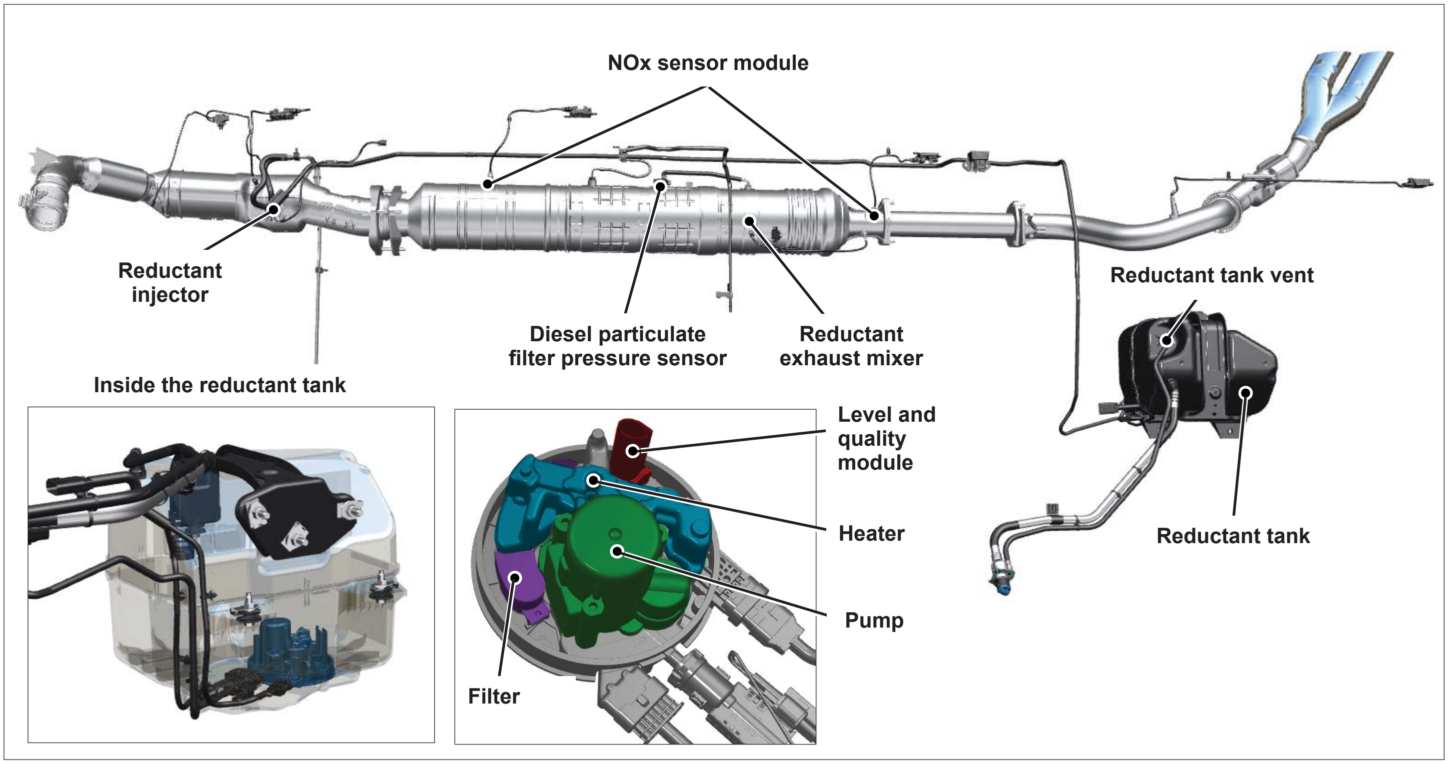
Post Regeneration

After regeneration, the PCM reads the pressure at the DPF pressure sensor and compares it with a calibrated value. This is to verify regeneration was completed successfully.

Non-Burnable Ash

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

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



SCR

Selective Catalytic Reduction System (SCR)

The SCR system components include the following:

- Reductant or Diesel Exhaust Fluid (DEF)
- Reductant tank
- Reductant Injector
- Reductant pump and heater assembly
- Reductant tank temperature sensor
- Reductant quality module
- Reductant tank vent
- Oxides of Nitrogen (NOx) sensors and modules

Reductant or Diesel Exhaust Fluid (DEF)

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 NOx into N2 and H2O. 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

Reductant Tank

The reductant tank holds the DEF and related components. Prior to refilling, turn the vehicle turned off. DEF gauge should update within a few minutes of vehicle start after a refill. The DEF gauge does not update instantly while refilling (unlike a fuel gauge). When adding DEF, fill to capacity. Do not overfill. Do not add a small quantity of DEF to determine DEF gauge accuracy. Manually draining the DEF tank is not instantly reflected on the gauge.

The DEF gauge does not move off 'F' until the tank level falls below 90% capacity. If the gauge does not match the actual level in the tank, perform a SCR refill activation test. Distance to Empty (DTE) is calculated based on the last 500 miles of driving.

It is not recommended to add DEF until the low fluid warning is present. When DEF is in liquid form, the DEF gauge uses an ultrasonic level sensor to determine the DEF level. Any debris in the tank (floating or not) may interfere with the level sensor causing the DEF gauge reading to be inaccurate or trigger a check engine light.

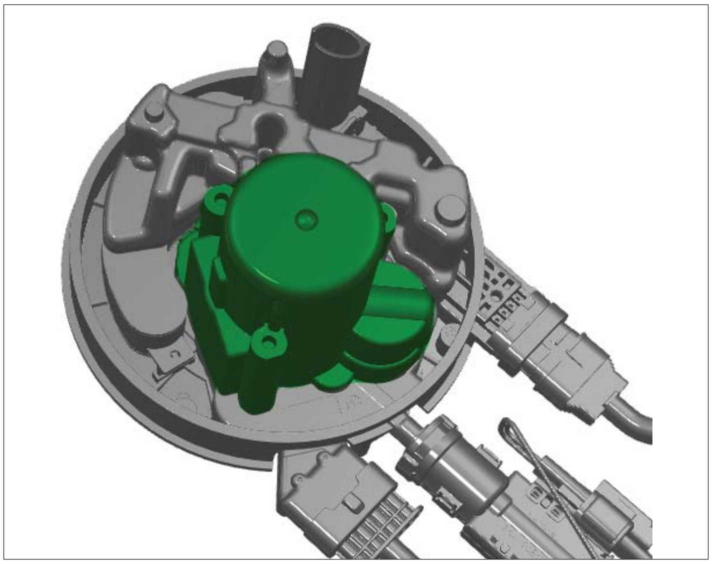
Overfilling or topping off the tank results in erroneous DEF gauge operation. If the tank is overfilled, the level sensor does not work as designed, drain some liquid from the tank and perform a SCR refill activation. A tank at 100% capacity will still has air space at top of the tank. This is needed because DEF expands as it freezes.

Reductant Injector

Reductant Injector

The reductant injector is a Pulse Width Modulated (PWM) solenoid controlled directly by the GDM. The injector receives Diesel Exhaust Fluid (DEF) from the reductant pressure line and sprays it into the exhaust stream, where it is mixed into the exhaust gases before entering the Selective Catalytic Reduction System (SCR) catalyst. The injector is cooled by the secondary cooling system.

Note: Due to new emissions regulations for model year 2023, vehicle owners may experience an increase in the amount of DEF the vehicle is using. This is considered normal.

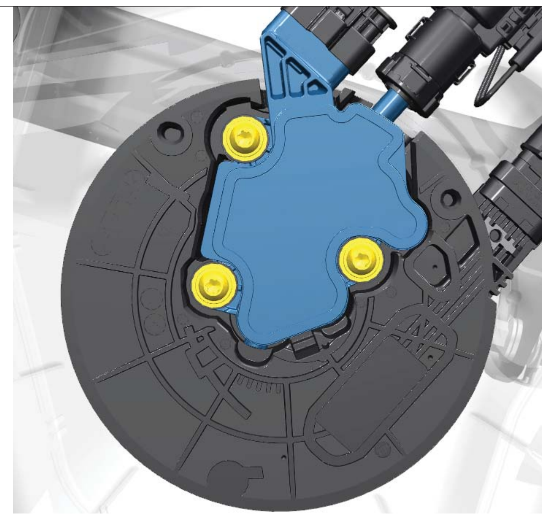


Reductant pump

Reductant Pump

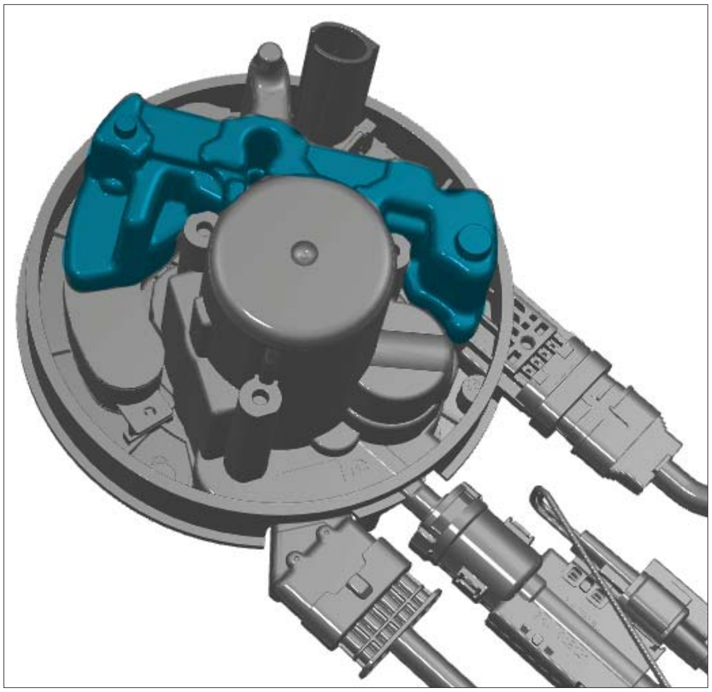
The reductant pump assembly contains 2 solenoid pumps (one pressure, one purge), a temperature sensor, and an internal heating element. When the PCM requests reductant injection, the reductant injector opens and the pump operates, filling the reductant pressure line and injector and purging air from the system. When all air is purged, the injector closes, and the pump builds pressure. The pressure reading is inferred, and no pressure sensor is used. The system is then primed, and the injector provides DEF to the SCR catalyst as requested by the PCM. The PCM requests are sent to the GDM which carries out the actions.

The reductant purge pump, which replaces the purge valve, purges the system when commanded by the PCM when the vehicle is turned off. This prevents damage to the lines if the reductant was to freeze. The pumps are serviced separately from the tank assembly.



Underneath side of the reductant pump

Reductant pump service



Reductant heaters

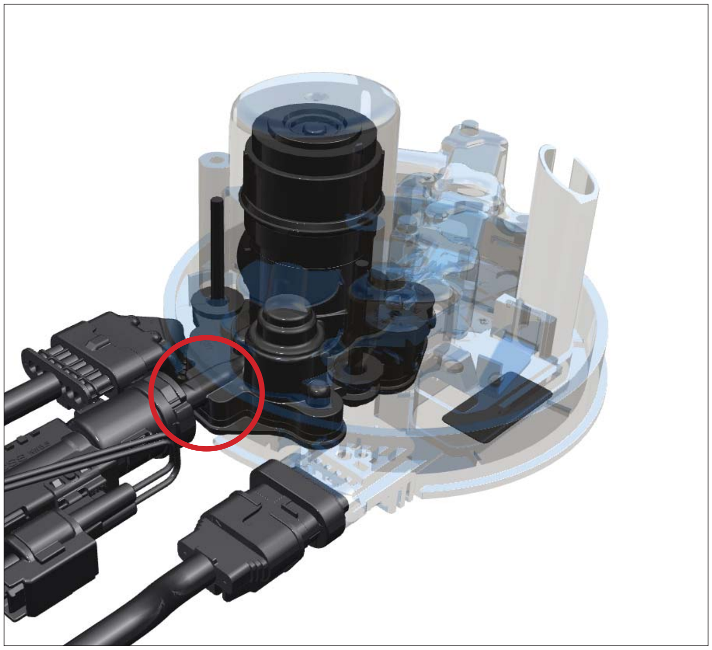
Reductant Heater

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. The DEF tank is designed with an air space for ice expansion when the DEF freezes at temperatures below 12°F (-11°C).

Do not overfill the DEF tank in freezing conditions as a blockage may occur in the fill pipe. In freezing conditions, the DEF gauge may not recognize a refill event until the DEF in the tank has completely thawed, and there is no floating ice in the tank. When DEF is frozen, the GDM uses a calculation to determine DEF level for gauge operation. The PCM knows the quantity of DEF used based on the injector duty cycle, then subtracts that calculated volume from the last known liquid DEF reading.

If DEF in the tank freezes common symptoms include erroneous DTE readings, unable to fill the DEF tank due to plugged filler pipe, floating Ice crystals or debris interfering with the level sensor and causing the DEF gauge reading to be inaccurate or cause a DTC.

A full tank of frozen DEF may take a few days to thaw out with the key off. The most effective way to thaw out a DEF tank is to have the vehicle indoors and a fan blowing on the tank overnight. Do not direct any heat source at the DEF tank. The tank heater is only required to thaw out enough of DEF required for operation. The remainder of the DEF may remain frozen during short drive cycles.

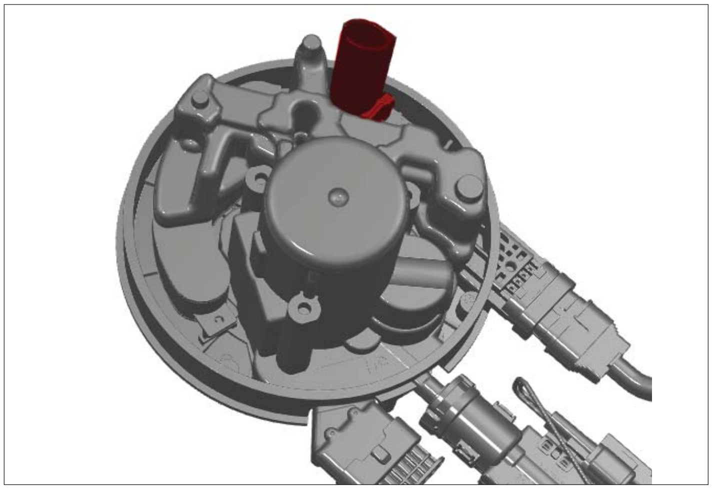


Reductant Tank Temperature Sensor

Reductant Tank Temperature Sensor

The reductant temperature sensor is a thermistor device integrated into the reductant pump assembly. The electrical resistance of a thermistor changes with temperature. The varying resistance affects the voltage drop across the sensor terminals and provides electrical voltage signals to the PCM corresponding to temperature.

The reductant temperature sensor provides feedback to the PCM through the GDM, which controls the reductant heaters to keep the reductant in a liquid state during low ambient temperatures.



Reductant Quality Module

Reductant Quality Module

The reductant quality module provides the reductant tank level and reductant concentration to the GDM using SENT technology. The reductant quality module incorporates an ultrasonic transducer and sensor assembly, located at the bottom of the reductant tank. The transducer produces timed ultrasonic sound waves through the DEF and the sensor measures the return rate of the sound waves.
As the DEF is consumed, the liquid level lowers and the return speed increases. Additionally, the sensor monitors reductant concentration percentage by calculating the speed of sound travel through the DEF, comparing it to an expected value. If this value is not met, the reductant is diluted or contaminated. The reductant quality module is integral to the reductant tank assembly.

Reductant Tank Vent

Reductant Tank Vent

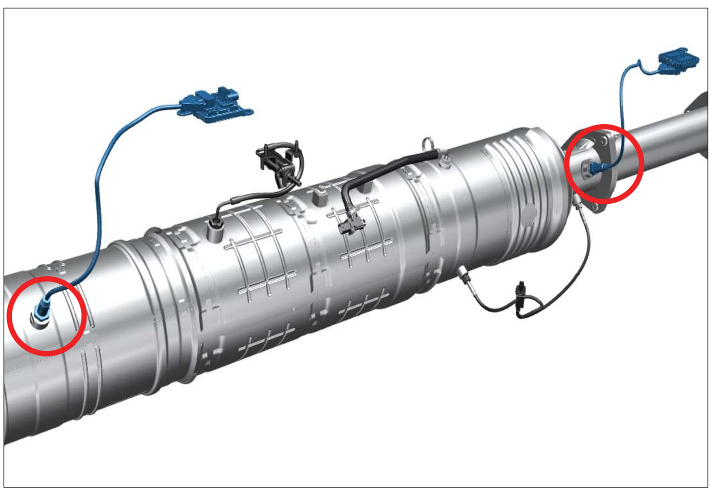
The reductant tank vent allows the fluid tank pressure to equalize with atmospheric pressure. Pressure differences are caused by temperature and reductant usage.

NOx Sensor Module

Oxides of Nitrogen (NOx) Sensor Modules

The NOx11, NOx12, and NOx13 sensor modules are mounted to the vehicle frame under the body. They control the NOx sensors mounted in the diesel exhaust after treatment system upstream and downstream of the SCR and DPF. The modules communicate to the PCM via the CAN2 to report NOx and Oxygen (O2) concentrations as well as sensor and controller errors.

Note:	Module locations are color coded and are not interchangeable.

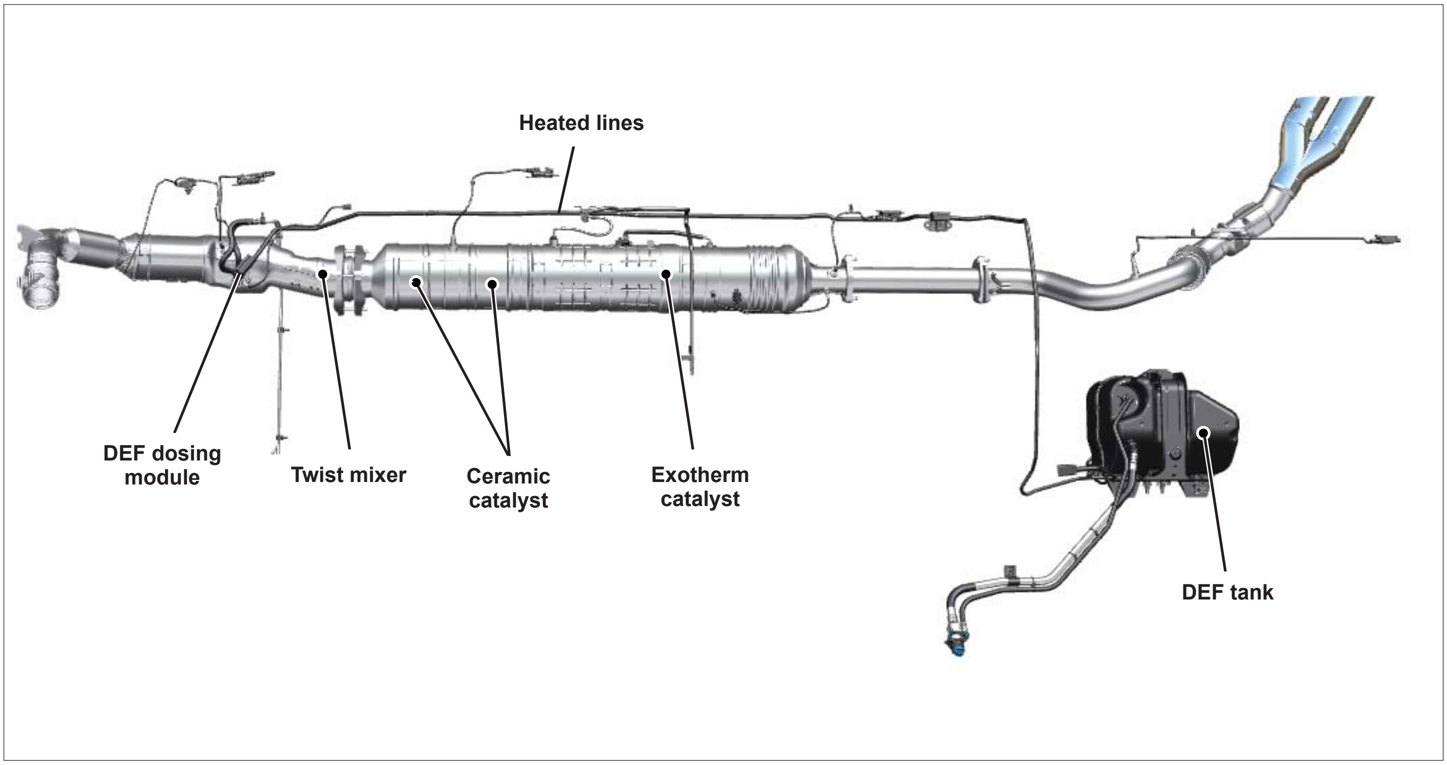


NOx Sensor

Oxides of Nitrogen (NOx) Sensors

The NOx sensors are used primarily to sense O2 and NOx concentrations in diesel exhaust gas. The NOx11 sensor is located upstream of the SCR, the NOx12 sensor is located downstream of the SCR catalyst, and NOx13 is located downstream of the DPF. The sensors interface with the NOx sensor modules that control the sensor and heater circuits.

The PCM uses the information to adjust how much reductant and fuel is being injected into the exhaust as well as an input for fuel trim. The information from the NOx sensor can also indicate the effectiveness of the SCR and diesel exotherm catalyst.

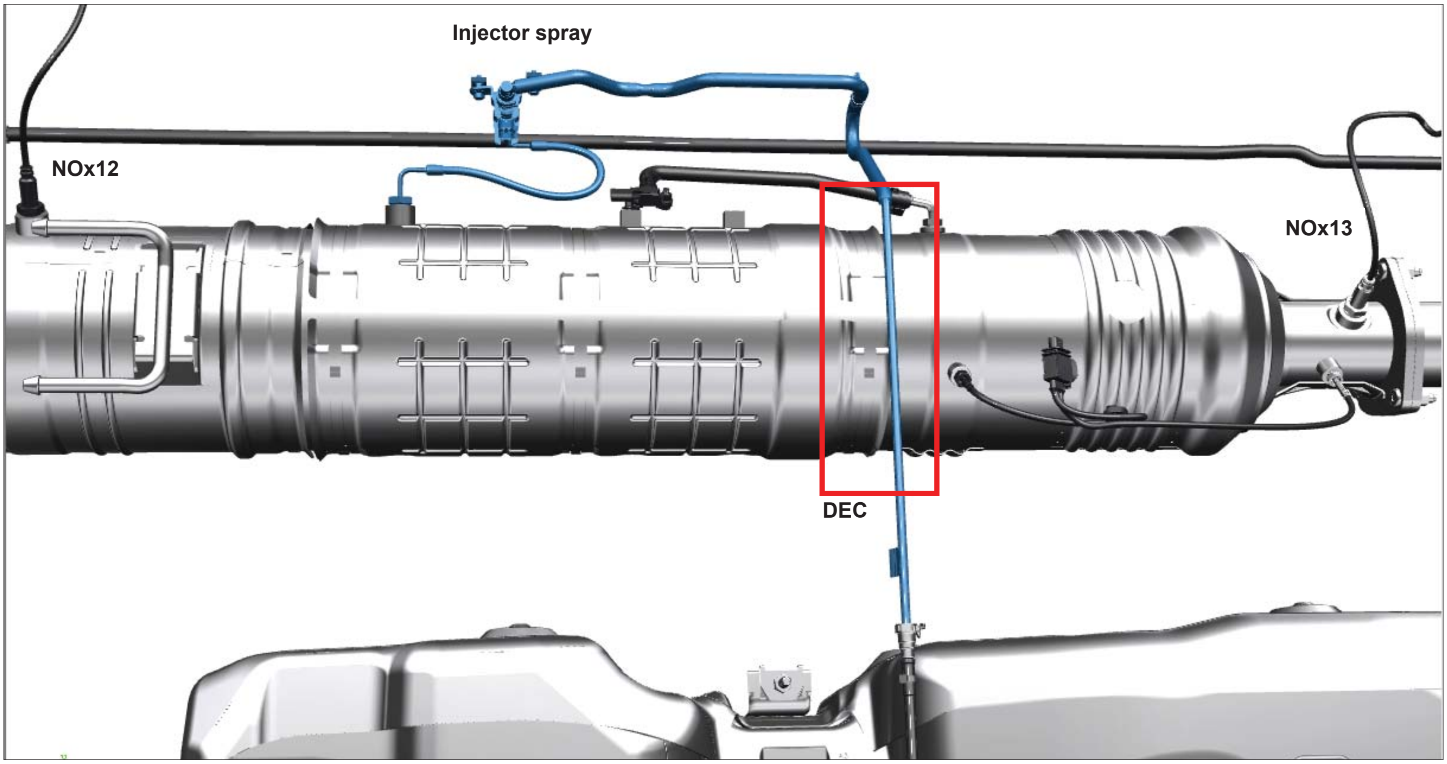


Turbocharger downpipe

Selective Catalytic Reduction System (SCR) Operation

The SCR reduces Oxides of Nitrogen (NOx) present in the exhaust stream to nitrogen (N2) and water (H2O). The SCR contains a ceramic catalyst wash coated 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 (CO2) and ammonia (NH3). As the ammonia and NOx pass through the ceramic SCR catalyst, a reduction reaction takes place, and the ammonia and NOx are converted to nitrogen and water.

The engine is able to run leaner and more efficiently because of the efficiency of the SCR in eliminating the high NOx levels produced under lean conditions.



Diesel Exotherm Catalyst

Diesel Exotherm Catalyst

When the PCM commands an active or manual regeneration it uses a PWM signal to active the downstream injector. The injector sprays fuel into the exhaust stream just before the diesel exotherm catalyst. A catalyst reaction results in more heat entering the DPF resulting in regeneration. EGT15 and EGT16 monitor the temperature of the DPF and provide feedback information to the PCM which adjusts the injector pulse width.

Derate

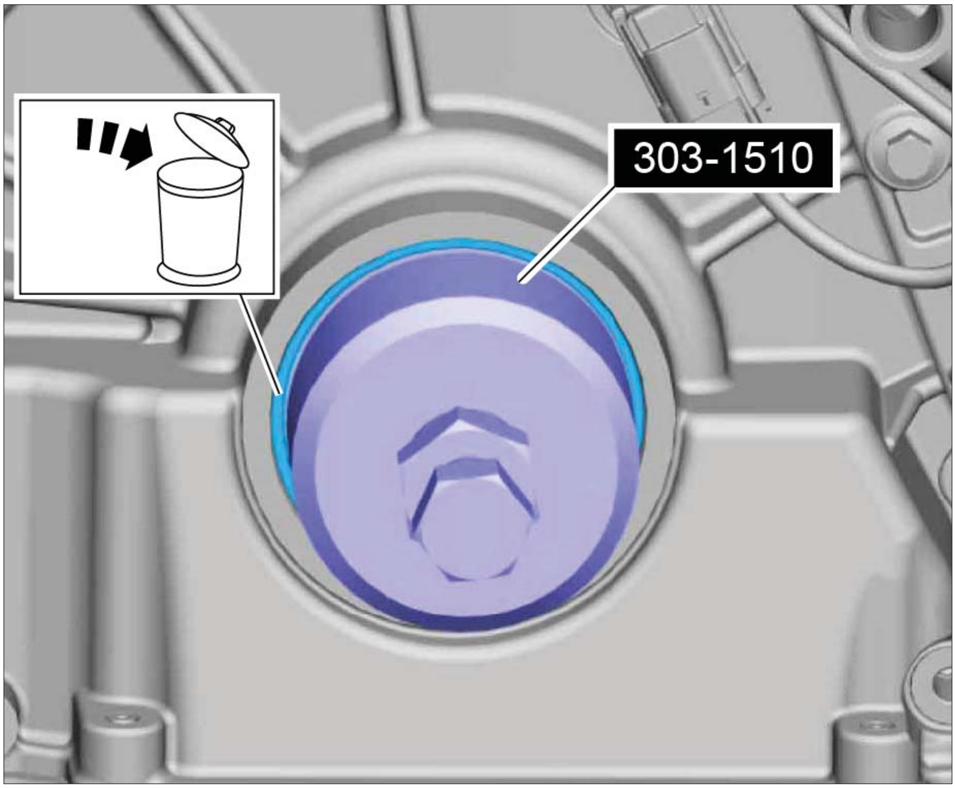
The PCM includes strategies to limit the output of the engine if it detects certain faults. There are 3 levels of derate that limit power for engine protection:

Level 1 derate is most common. It reduces the available engine power by 30%. It is possible the customer may not notice the reduced power if they are driving with the truck unloaded. Either the MIL or a message in the IPC indicates the engine is derated. Depending on the fault, a level one derate may be put into action on the first or second occurrence of the fault. An example of a fault that causes a level 1 derate is P0100 - Mass Or Volume Air Flow A Circuit. The Mass Airflow (MAF) sensor is monitored for a low sensor frequency. If the sensor frequency changes below a minimum calibrated limit for greater than 1.5 seconds the DTC is set. The faults that cause a level 1 derate, but do not flag a DTC, are a coolant over temperature or excessive fuel temperature fault.

Level 2 derate reduces the available engine power by 50%. The MIL and possibly a message in the IPC indicate the engine is derated. An example of a fault that causes a level 2 derate is P0087 - Fuel Rail/System Pressure - Too Low. The PCM regulates the fuel rail pressure by controlling the Fuel Volume Control Valve (FVCV) and Fuel Pressure Control Valve (FPCV). When the PCM is no longer capable of maintaining the fuel pressure the DTC is set.

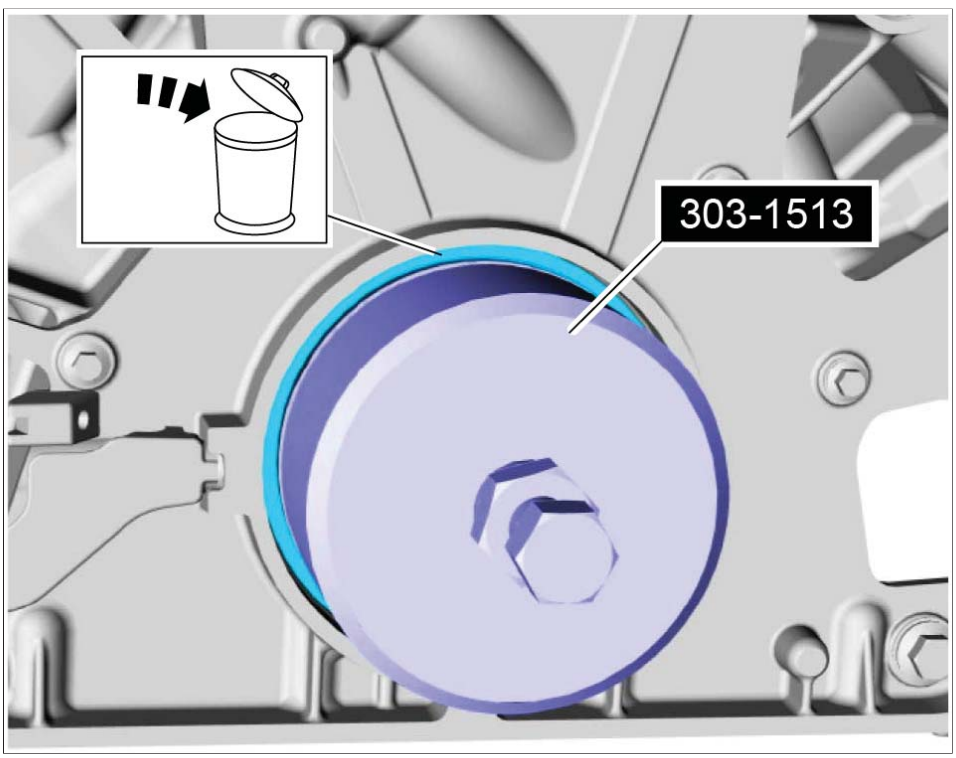
Level 3 derate reduces the available engine power by 70%. The MIL and possibly a message in the IPC indicate the engine is derated. An example of a fault that causes a level 3 derate is P2470 - Exhaust Gas Temperature Sensor Circuit Low (Bank 1 Sensor 4). The PCM flags this fault if the sensor voltage is less than 0.10 volt for more than 15 seconds.

Disassembly - Special Tool(s) / General Equipment



Front Crankshaft Seal Remover

303-1510 removes the front crankshaft seal.



Rear Crankshaft Seal Remover

303-1513 removes the rear crankshaft seal.

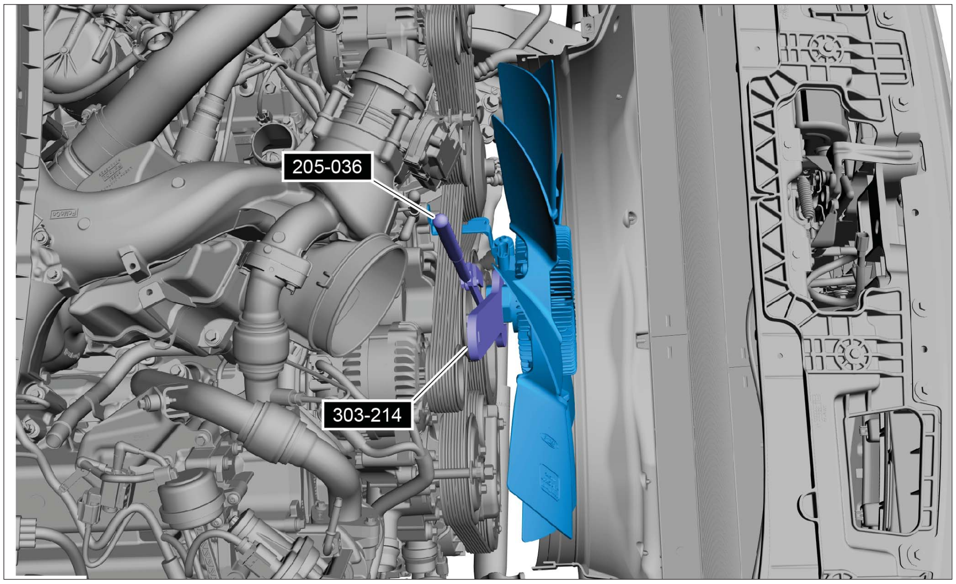
Camshaft Removal and Installation Adapter

303-1517 removes and installs the camshaft (TKIT-2009C-F, TKIT-2009C-ROW)

Engine Removal Bracket

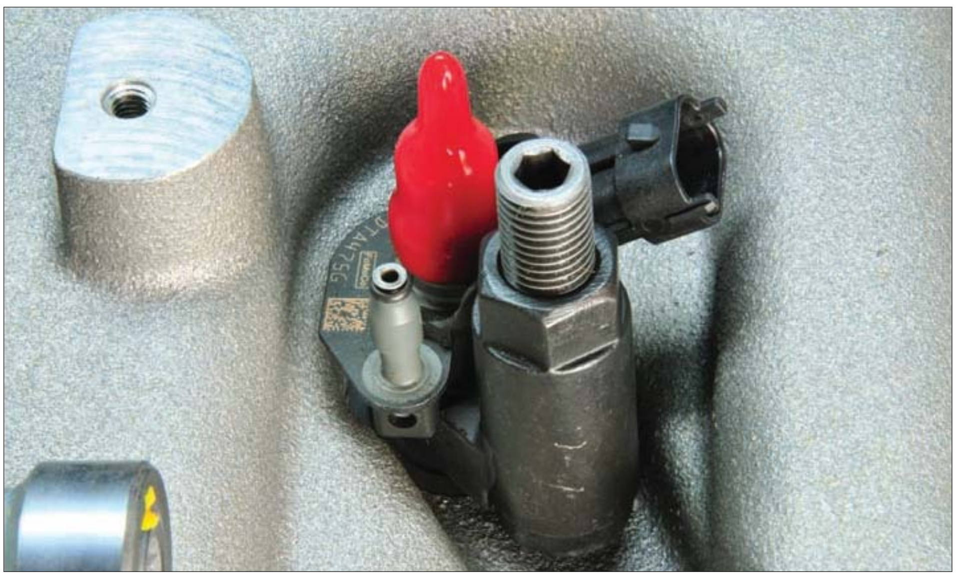
303-1518 is bolted to the engine after the turbocharger removal and is used to remove and install the 6.7L diesel engine. It is used with the Engine Lifting Brackets, 303-050.

(TKIT-2009C-F, TKIT-2009C-ROW)



Fan Clutch Wrench

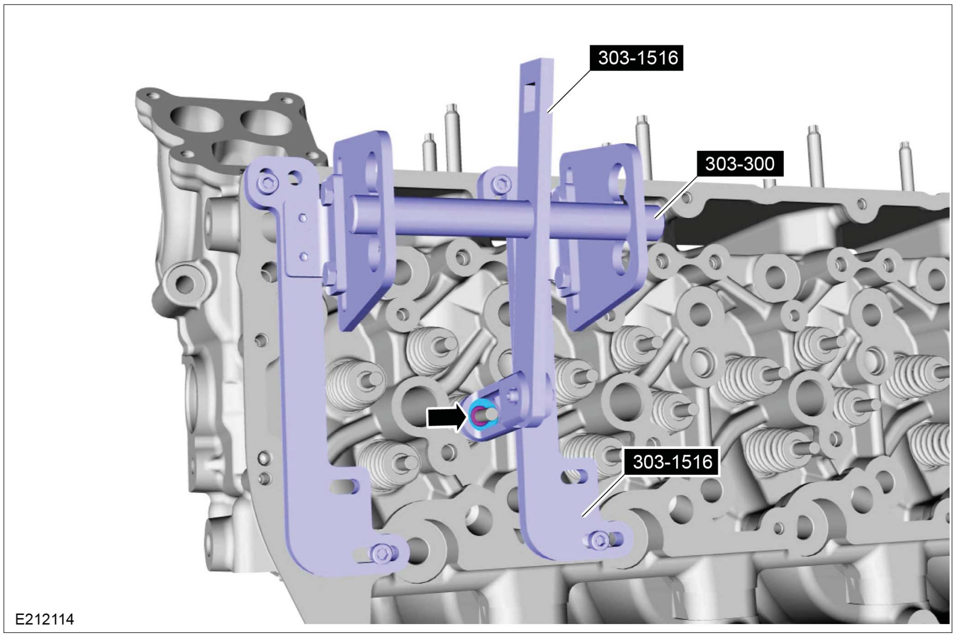
205-036 and the Fan Clutch Nut Wrench, 303-214, are used in conjunction to remove the cooling fan assembly.



Fuel Injector Remover

310-230 removes the fuel injectors from the 6.7L diesel engine.

(TKIT-2010FT-F, TKIT-2010FT-ROW)



Valve Spring Compressor

303-1516 and Valve Spring Compressor Set, 303-300, compress the valve springs to remove the valve keepers.

(TKIT-2009TC-F, TKIT-2009C-F)

Assembly - Special Tool(s) / General Equipment

Front Crank Seal Installer

303-1509 and the 6.7L Front Seal Installer, 303-1509-01, are used in conjunction to install the front crankshaft seal and slinger.

(TKIT-2009C-F, TKIT-2009C-ROW, TKIT-2019P9-F)

6.7L POWER STROKE
TURBO DIESEL