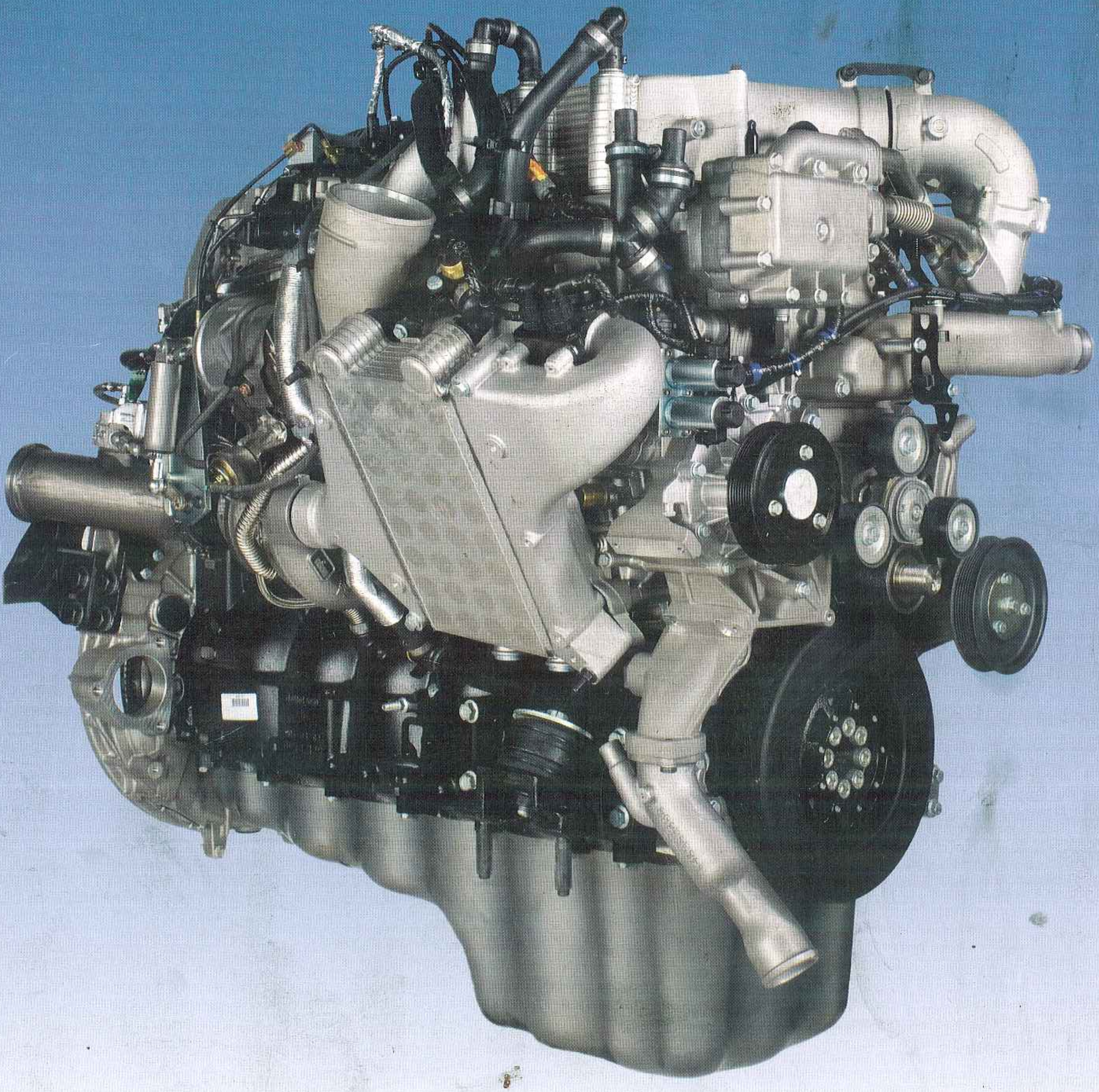
MAXXFORCE®

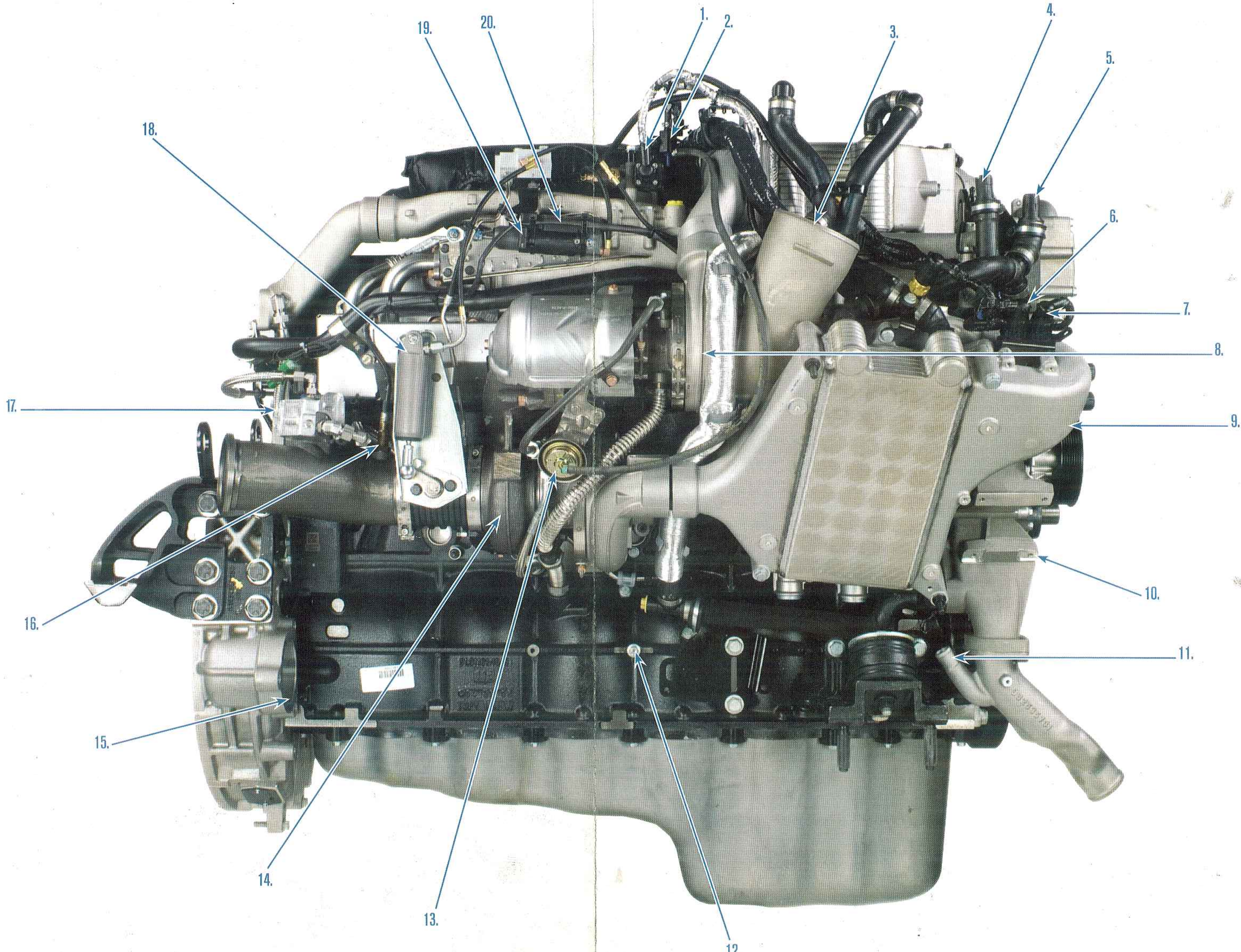
ADVANCED DIESEL POWER



MAXXFORCE® 11 AND MAXXFORCE 13 MODEL YEAR 2009
FEATURES, DESCRIPTIONS, AND UNIQUE REPAIR PROCEDURES

COMPONENT LOCATIONS - RIGHT SIDE

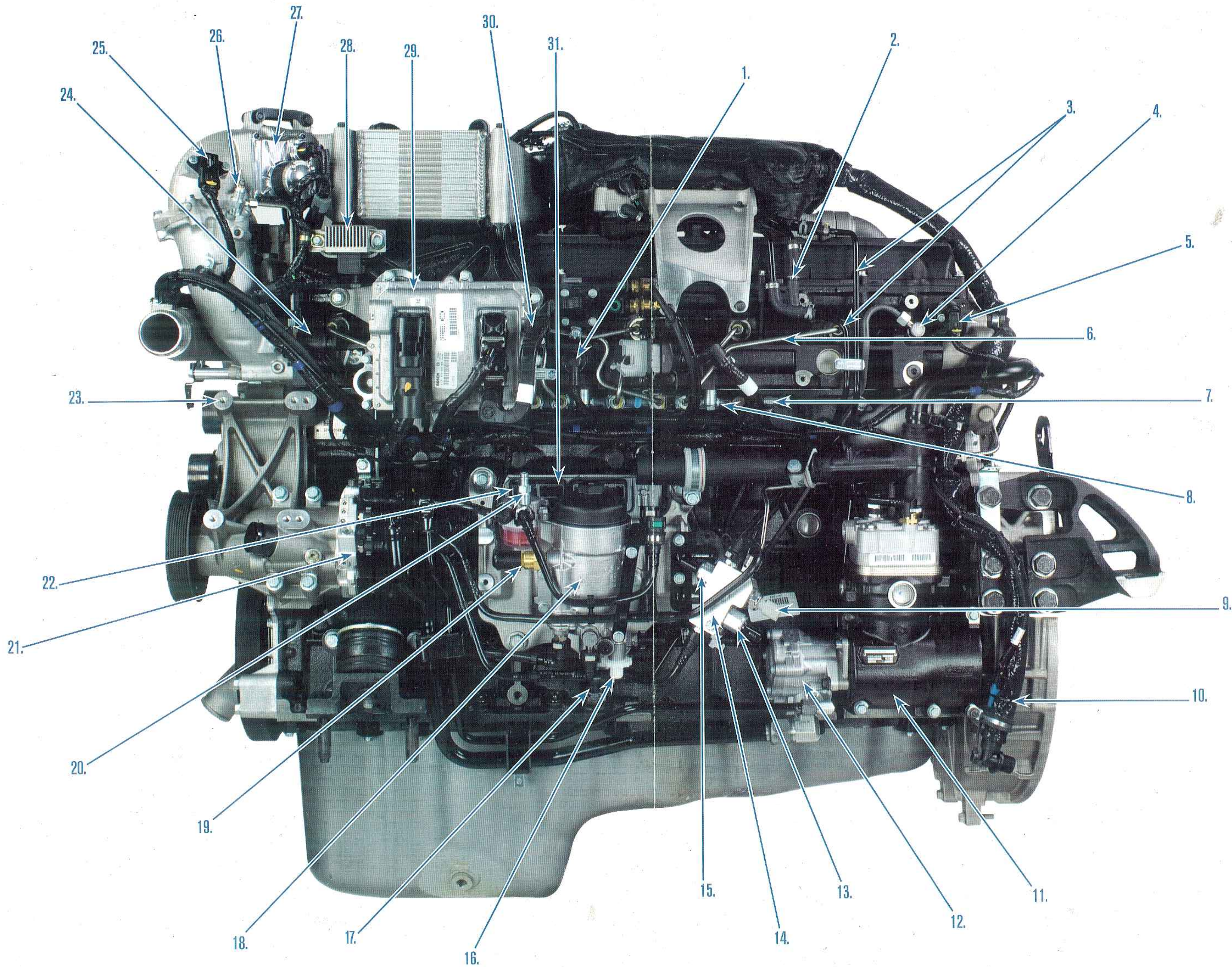
13. BOOST CONTROL ACTUATOR
14. LOW-PRESSURE TURBOCHARGER
15. STARTER MOTOR MOUNTING LOCATION
16. EXHAUST LAMBDA SENSOR
17. AFTERTREATMENT FUEL INJECTOR
18. ENGINE RETARDER ACTUATOR
19. EGR VALVE ACTUATOR
20. EGR VALVE POSITION SENSOR



1. EGR CONTROLLER
2. BOOST CONTROL SOLENOID VALVE
3. AIR INLET
4. COOLANT OUTLET TO LTR
5. COOLANT RETURN FROM LTR
6. ENGINE OIL TEMPERATURE SENSOR
7. ENGINE OIL PRESSURE SENSOR
8. HIGH-PRESSURE TURBOCHARGER
9. LOW-PRESSURE CHARGE-AIR-COOLER
10. A/C COMPRESSOR MOUNTING PAD
11. COOLANT INLET FROM DEAERATION TANK
12. GROUND STUD

COMPONENT LOCATIONS - LEFT SIDE

1. MANIFOLD AIR TEMPERATURE SENSOR
2. CRANKCASE BREATHER OIL CHECK VALVE
3. BREATHER OIL DRAIN TUBES
4. CYLINDER HEAD FUEL RETURN
5. CAMSHAFT POSITION SENSOR
6. HIGH-PRESSURE FUEL LINE (#6 CYLINDER)
7. PRESSURE-LIMITING VALVE
8. HIGH-PRESSURE COMMON RAIL
9. AFTERTREATMENT FUEL PRESSURE SENSOR
10. CRANKCASE BREATHER ROAD DRAFT TUBE
11. AIR COMPRESSOR
12. POWER STEERING PUMP
13. AFTERTREATMENT FUEL SUPPLY VALVE
14. AFTERTREATMENT CUT-OFF VALVE ASSEMBLY
15. AFTERTREATMENT FUEL DRAIN VALVE
16. WATER DRAIN VALVE
17. CRANKCASE BREATHER OIL DRAIN TUBE RETURN
18. FUEL FILTER MODULE
19. ENGINE FUEL PRESSURE SENSOR
20. DIAGNOSTIC FITTING
21. HIGH-PRESSURE FUEL PUMP
22. FUEL PRIMER PUMP
23. ALTERNATOR MOUNTING PAD
24. COLD START SOLENOID
25. MANIFOLD ABSOLUTE PRESSURE/INTAKE AIR TEMPERATURE 2 SENSOR
26. COLD START ASSIST GLOW PLUG
27. INTAKE THROTTLE VALVE
28. COLD START RELAY
29. ENGINE CONTROL MODULE
30. INJECTOR HARNESS
31. ENGINE INTERFACE MODULE



FORWARD

This publication is intended to provide technicians and service personnel with an overview of technical and features of the 2007–2009 MaxxForce® 11 & 13 engine. The information contained in this publication will supplement information contained in available service literature. Consult the latest SERVICE and DIAGNOSTIC manuals before conducting any service or repairs.

Safety Information

This manual provides general and specific service procedures and repair methods essential for your safety and the reliable operation of the engine. Since many variations in tools, procedures, and service parts are involved, advice for all of the possible safety conditions and hazards cannot be stated.

Departure from the instructions in this manual or disregard of warnings and cautions can lead to injury, death, or both, and damage to the engine or vehicle.

Read the safety instructions below before doing service and test procedures in this manual for the engine or vehicle. See related application manuals for more information.

Safety Instructions

Vehicle

Make sure the vehicle is in neutral, the parking brake is set, and the wheels are blocked before you perform any work or diagnostic procedures on the engine or vehicle.

Work Area

- Keep the work area clean, dry and organized.
- Keep tools and parts off the floor.
- Make sure the work area is ventilated and well lit.
- Make sure a First Aid Kit is available.

Safety Equipment

- Use the correct lifting devices.
- Use the proper safety blocks and stands.

Protective Measures

- Wear protective glasses and safety shoes (do not work in bare feet, sandals, or sneakers).
- Wear the appropriate hearing protection.
- Wear the correct clothing.
- Do not wear rings, watches, or other jewelry.
- Restrain long hair.

Tools

- Make sure all tools are in good condition.
- Make sure all standard electrical tools are grounded.
- Check for frayed power cords before using power tools.

Fire Prevention

NOTE: Check the classification of each fire extinguisher to ensure that the following fire types can be extinguished:

1. Type A—Wood, paper, textiles, and rubbish
2. Type B—Flammable liquids
3. Type C—Electrical equipment

- Make sure that charged fire extinguishers are in the work area.

Batteries

- Batteries produce highly flammable gas during and after charging.
- Always disconnect the main negative battery cable first.
- Always connect the main negative battery cable last.
- Avoid leaning over batteries.
- Protect your eyes.
- Do not expose batteries to open flames or sparks.
- Do not smoke in workplace.

Compressed Air

- Limit shop air pressure for blow gun to 207 kPa (30psi).
- Use approved equipment.
- Do not direct air at body or clothing.
- Wear safety glasses or goggles.
- Wear hearing protection.
- Use shielding to protect others in the work area.

Fluids Under Pressure

- Use extreme caution when working on systems under pressure.
- Follow approved procedures only.

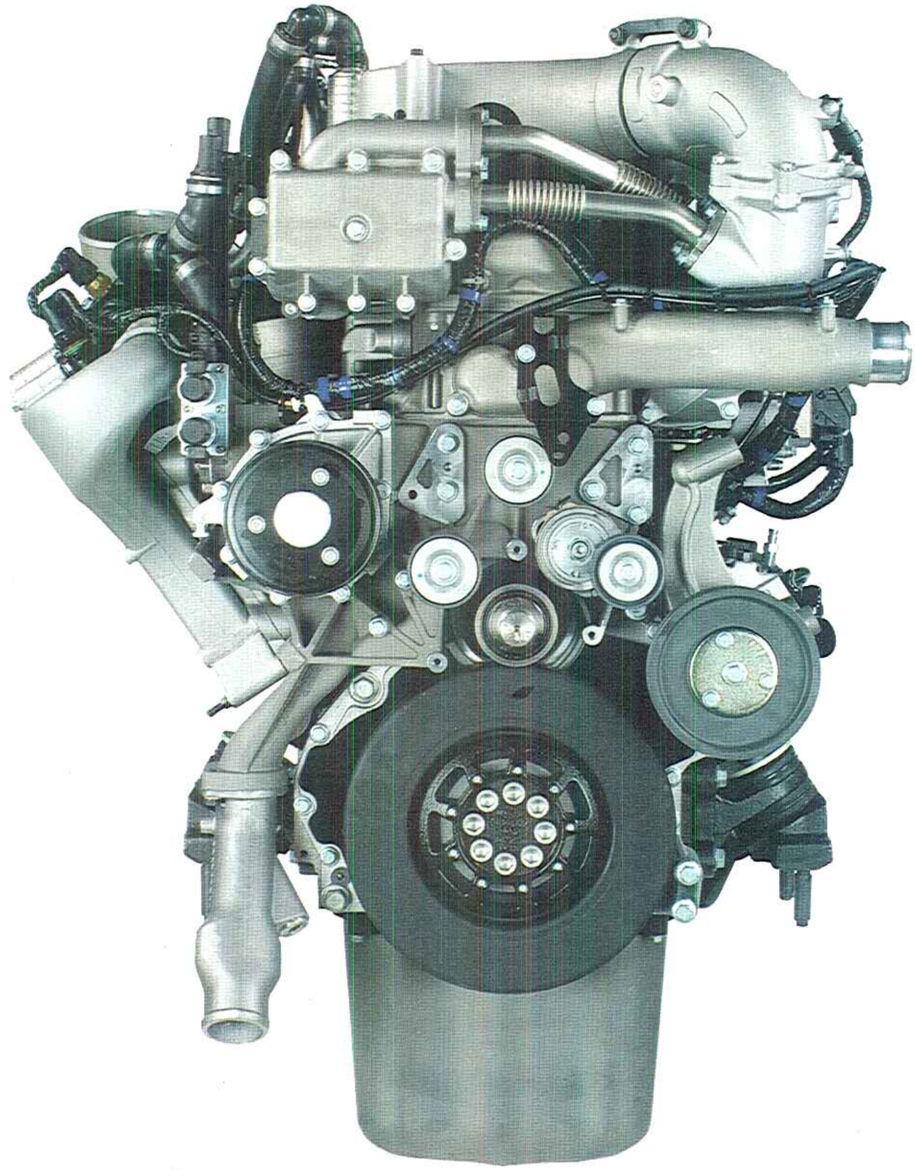
Fuel

- Do not over fill fuel tank. Over fill creates a fire hazard.
- Do not smoke in the work area.
- Do not refuel the tank when the engine is running.
- Removal of Tools, Parts, and Equipment
- Reinstall all safety guards, shields and covers after servicing the engine.
- Make sure all tools, parts, and service equipment are removed from the engine and vehicle after all work is done.

Removal of Tools, Parts, and Equipment

- Make sure all tools, parts, and service equipment are removed from the engine and vehicle after all work is done.

TABLE OF CONTENTS



Direct Injection Turbocharged Diesel Engine

ENGINE FEATURES

- High-Pressure Common Rail Fuel System
- Dual Turbochargers
- Dual Air-to-Water Charge-Air-Coolers
- Integrated Engine Retarder
- Cracked Main Bearing Caps
- Aftertreatment

ENGINE SPECIFICATIONS

Engine Configuration . . . . 4 Cycle, in-line six cylinder diesel

Valve Configuration. . . . . 4 valves per cylinder

Displacement . . . . MaxxForce 11: 10.5L (641 cu in) MaxxForce 13: 12.4L (757 cu in)

Bore . . . . MaxxForce 11: 120 mm (4.72 in) MaxxForce 13: 126 mm (4.96 in)

Stroke . . . . .MaxxForce 11: 155 mm (6.10) MaxxForce 13: 166mm (6.54 in)

Aspiration. . . . . Dual turbocharged and dual charge-air-coolers

Engine Rotation . . . . .Counterclockwise when facing the flywheel

Fuel System. . . . . High-Pressure Common Rail Fuel System

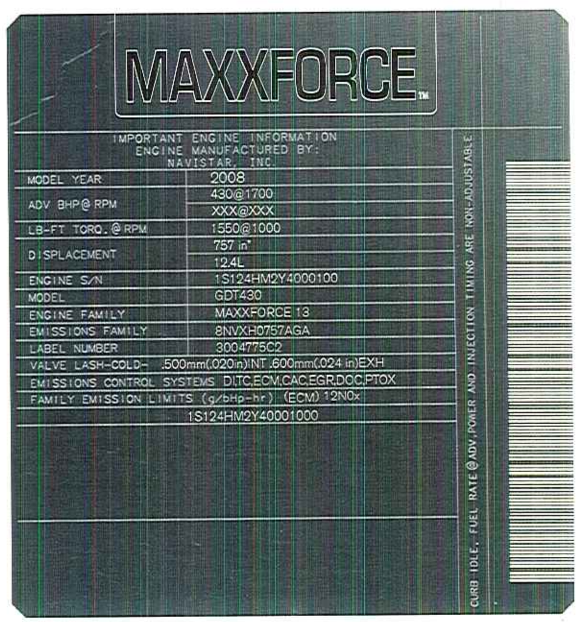
Engine Weight (including oil and accessories) . . . . .1018 kg (2244 lbs)

Firing Order. 1-5-3-6-2-4

Emissions Label

The emission label is located on top of the valve cover, towards the front of the engine. The emission label contains the following information about the engine:

–Model Year
–Horsepower Rating
–Torque Rating
–Engine Displacement
–Engine Serial Number
–Model
–Engine Family
–Valve Lash
–Engine Emission Information

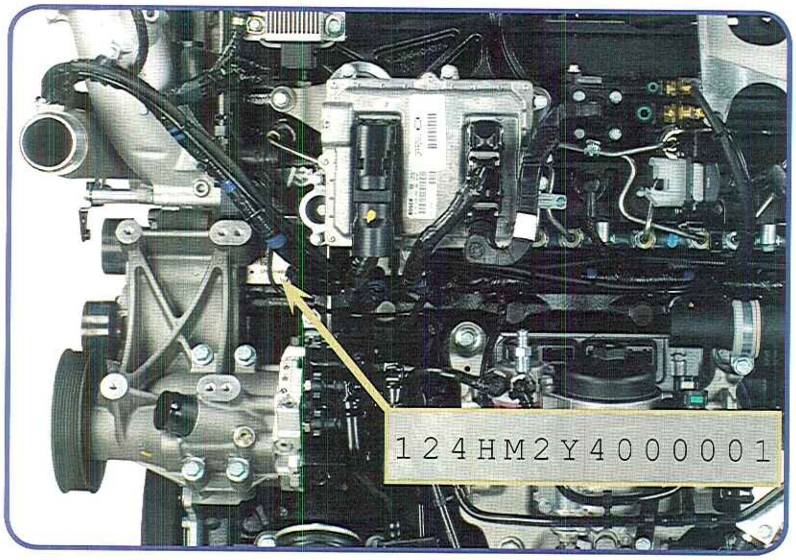


Engine Serial Number

- The engine serial number is located on the upper left side of the crankcase just above the high-pressure fuel pump.

Engine Serial Number Codes

105–Engine displacement (11L)
124–Engine displacement (13L)
H–Diesel, turbocharged, Charge-Air-Cooler and electronically controlled
M2–Motor truck
D–Germany
Y–United States, Huntsville
7 digit suffix–Engine serial number sequence



MaxxForce® 11 Horsepower and Torque

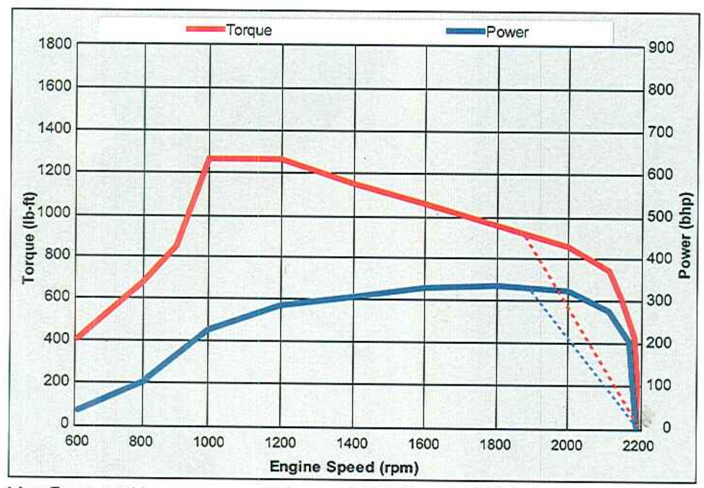
- The MaxxForce 11 engine features a base horsepower and torque rating of 330 HP at 1700 RPM and 1250 lb-ft of torque at 1000 RPM. This rating has a clutch engagement torque of 660 lb-ft at 800 RPM.

- The following two additional ratings are available:

  370 HP at 1700 RPM and 1350 lb-ft of torque at 1000 RPM. Clutch engagement torque is 760 lb-ft at 800 RPM.

  390 HP at 1700 RPM and 1400 lb-ft of torque at 1000 RPM. Clutch engagement torque is 830 lb-ft at 800 RPM.

330 HP



MaxxForce 11 Horsepower and Torque: 330 HP and 1250 lb-ft of torque for the base engine.

MaxxForce 13 Horsepower and Torque

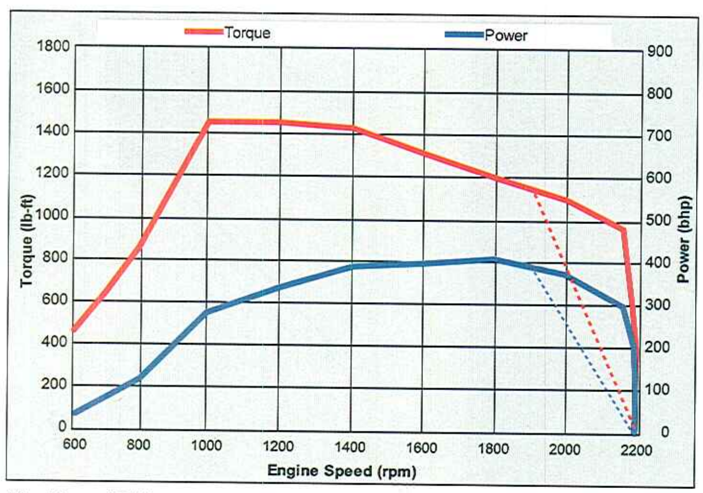
- The MaxxForce 13 engine features a base horsepower and torque rating of 410 HP at 1700 RPM and 1450 lb-ft of torque at 1000 RPM. This rating has a clutch engagement torque of 830 lb-ft at 800 RPM.

- The following two additional ratings are available:

  430 HP at 1700 RPM and 1550 lb-ft of torque at 1000 RPM. Clutch engagement torque is 830 lb-ft at 800 RPM.

  475 HP at 1700 RPM and 1700 lb-ft of torque at 1000 RPM. Clutch engagement torque is 830 lb-ft at 800 RPM.

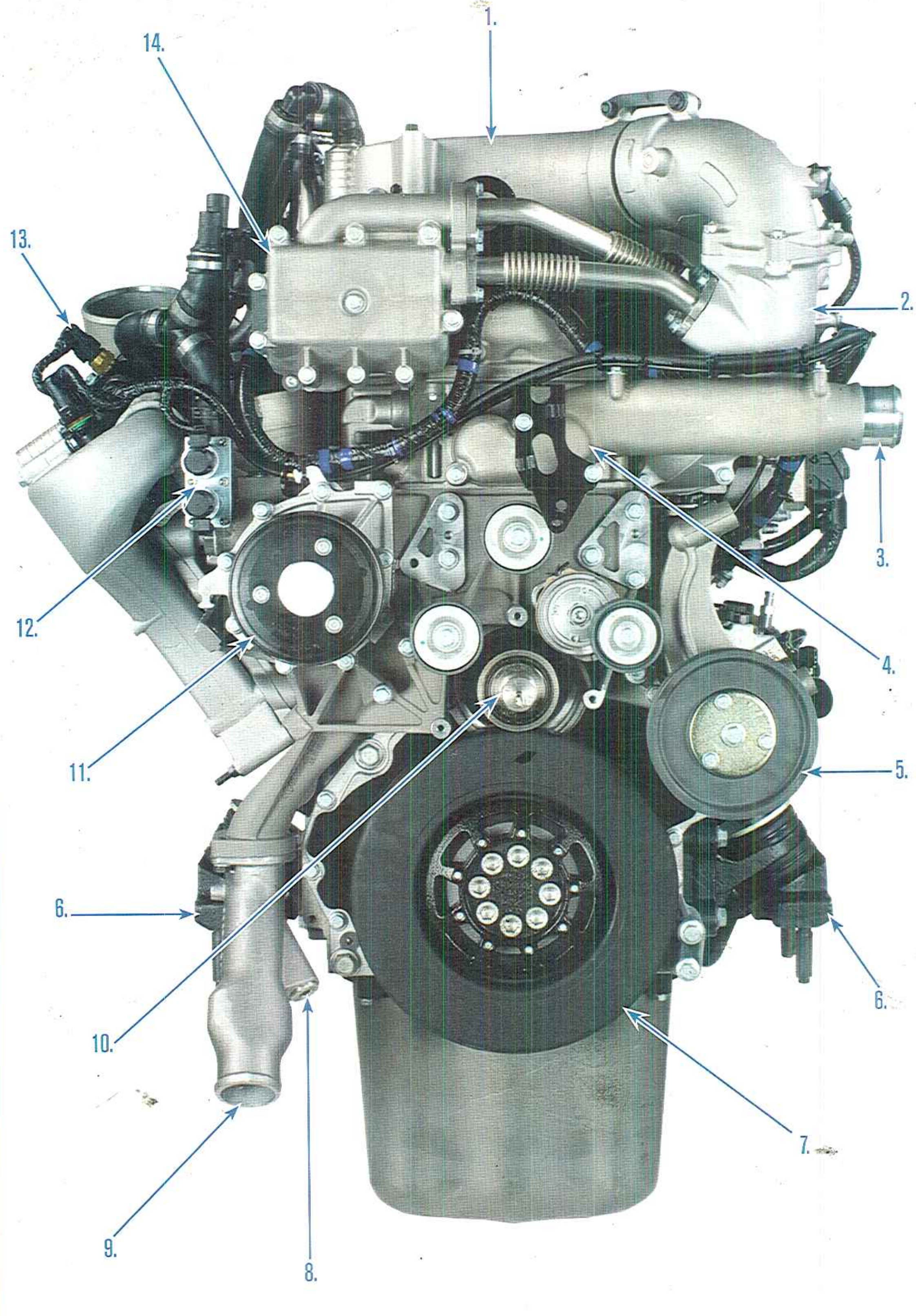
410 HP



MaxxForce 13 Horsepower and Torque: 410 HP and 1450 lb-ft of torque for the base engine.

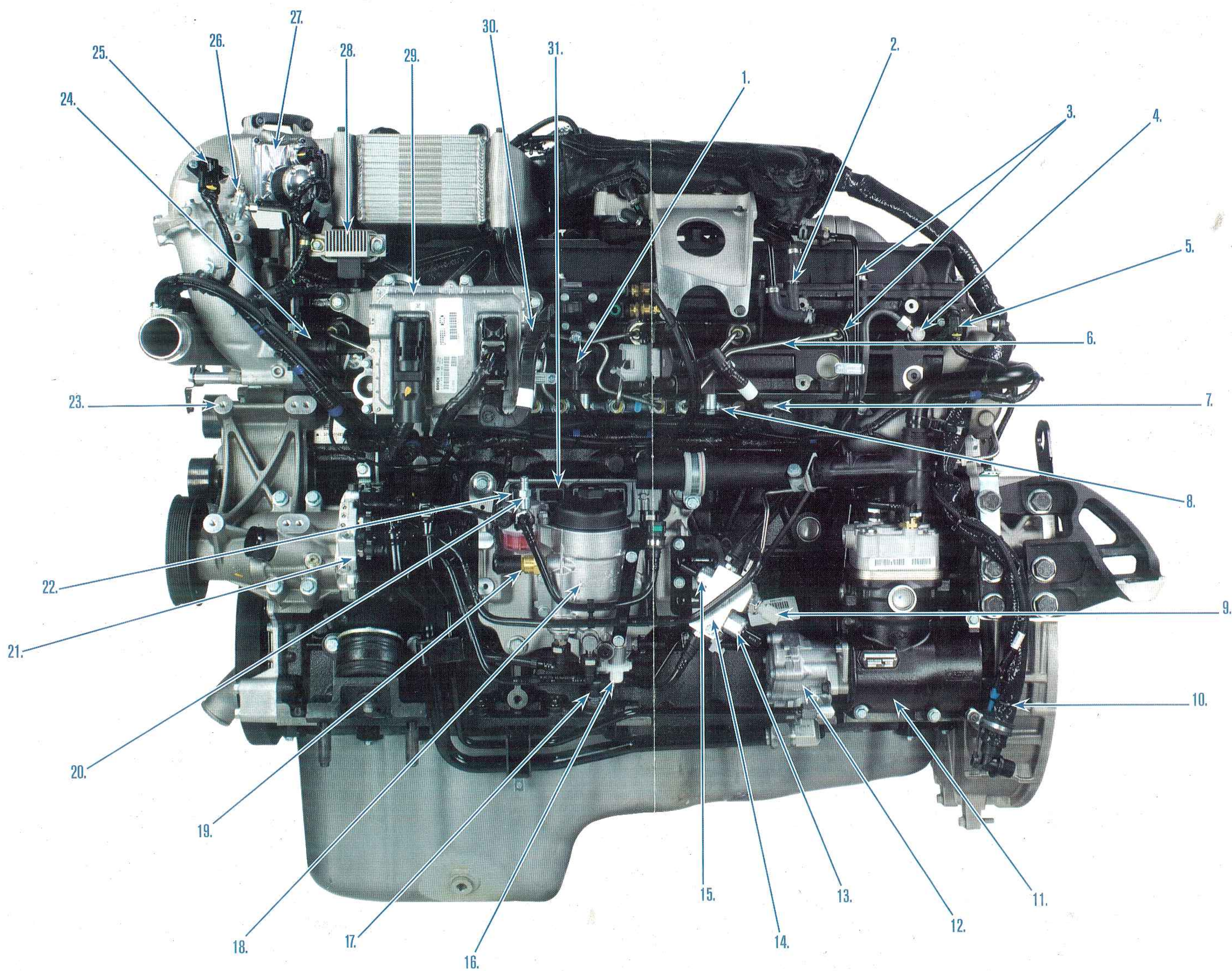
COMPONENT LOCATIONS - FRONT

1. HIGH-PRESSURE CHARGE-AIR-COOLER
2. INLET MIXING DUCT
3. COOLANT OUTLET
4. THERMOSTAT HOUSING
5. ACCESSORY DRIVE PULLEY
6. FRONT ENGINE MOUNTING BRACKET
7. VIBRATION DAMPER
8. OPTIONAL COOLANT HEATER LOCATION
9. COOLANT INLET
10. LOW MOUNT FAN DRIVE
11. WATER PUMP PULLEY
12. COOLANT CONTROL VALVE
13. ENGINE COOLANT TEMPERATURE 2 SENSOR
14. EGR COOLER MODULE



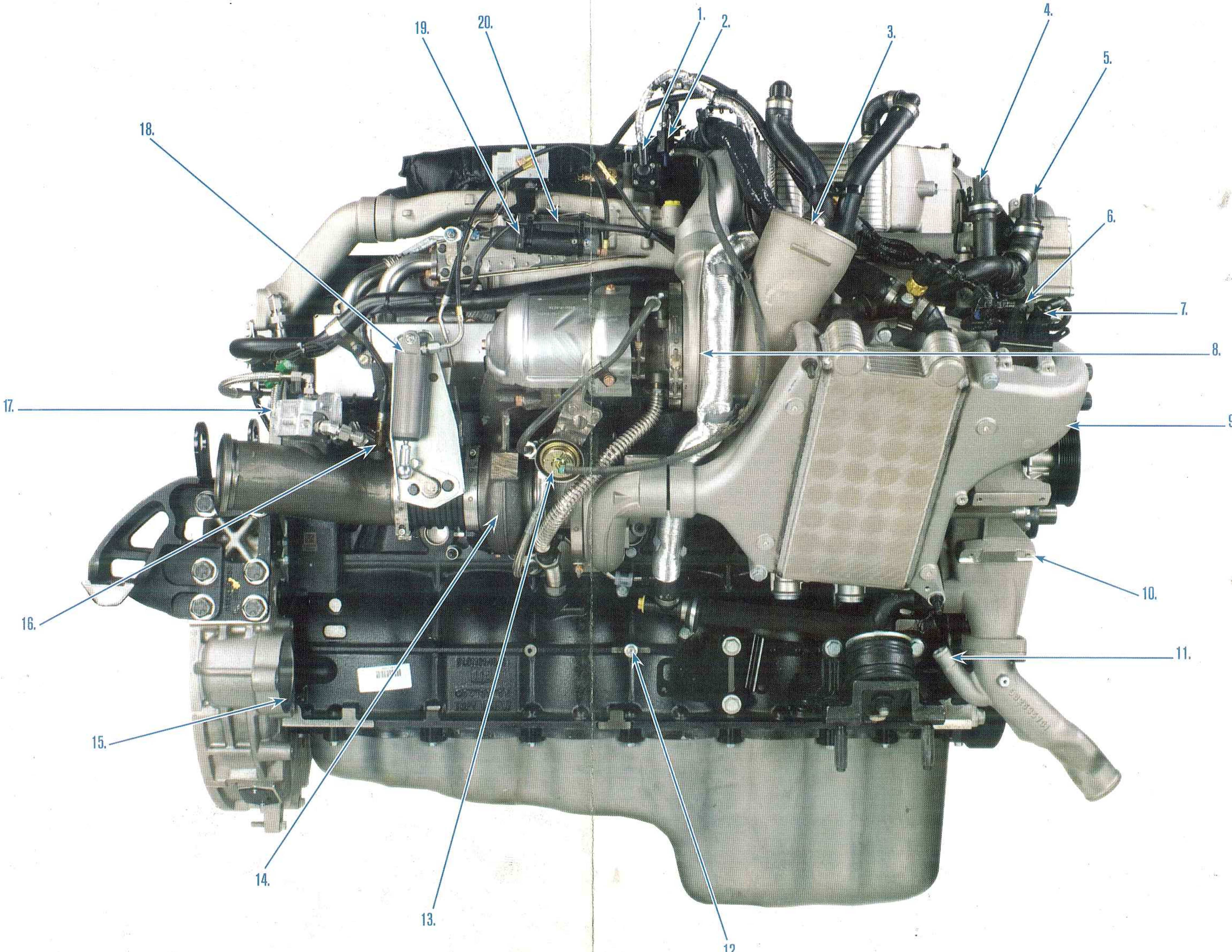
COMPONENT LOCATIONS - LEFT SIDE

1. MANIFOLD AIR TEMPERATURE SENSOR
2. CRANKCASE BREATHER OIL CHECK VALVE
3. BREATHER OIL DRAIN TUBES
4. CYLINDER HEAD FUEL RETURN
5. CAMSHAFT POSITION SENSOR
6. HIGH-PRESSURE FUEL LINE (#6 CYLINDER)
7. PRESSURE-LIMITING VALVE
8. HIGH-PRESSURE COMMON RAIL
9. AFTERTREATMENT FUEL PRESSURE SENSOR
10. CRANKCASE BREATHER ROAD DRAFT TUBE
11. AIR COMPRESSOR
12. POWER STEERING PUMP
13. AFTERTREATMENT FUEL SUPPLY VALVE
14. AFTERTREATMENT CUT-OFF VALVE ASSEMBLY
15. AFTERTREATMENT FUEL DRAIN VALVE
16. WATER DRAIN VALVE
17. CRANKCASE BREATHER OIL DRAIN TUBE RETURN
18. FUEL FILTER MODULE
19. ENGINE FUEL PRESSURE SENSOR
20. DIAGNOSTIC FITTING
21. HIGH-PRESSURE FUEL PUMP
22. FUEL PRIMER PUMP
23. ALTERNATOR MOUNTING PAD
24. COLD START SOLENOID
25. MANIFOLD ABSOLUTE PRESSURE/INTAKE AIR TEMPERATURE 2 SENSOR
26. COLD START ASSIST GLOW PLUG
27. INTAKE THROTTLE VALVE
28. COLD START RELAY
29. ENGINE CONTROL MODULE
30. INJECTOR HARNESS
31. ENGINE INTERFACE MODULE



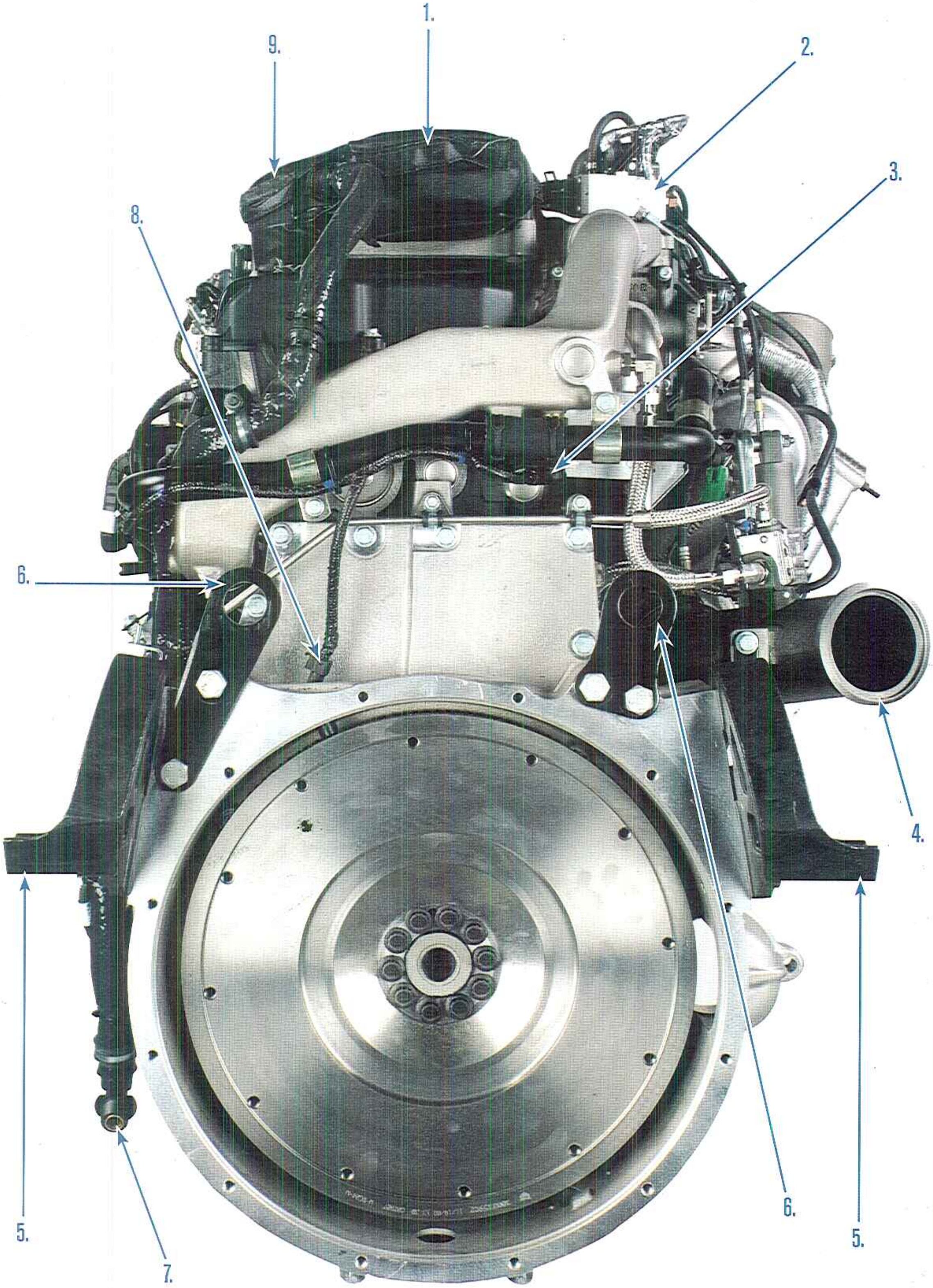
COMPONENT LOCATIONS - RIGHT SIDE

13. BOOST CONTROL ACTUATOR
14. LOW-PRESSURE TURBOCHARGER
15. STARTER MOTOR MOUNTING LOCATION
16. EXHAUST LAMBDA SENSOR
17. AFTERTREATMENT FUEL INJECTOR
18. ENGINE RETARDER ACTUATOR
19. EGR VALVE ACTUATOR
20. EGR VALVE POSITION SENSOR



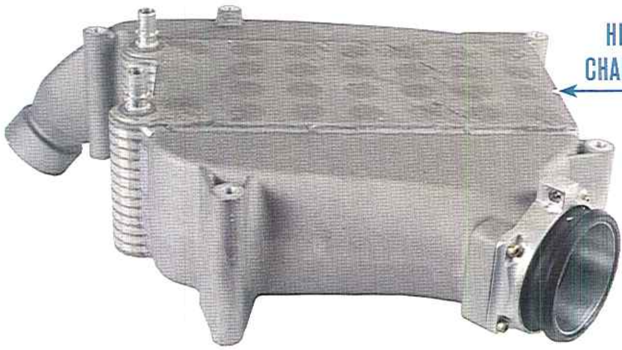
1. EGR CONTROLLER
2. BOOST CONTROL SOLENOID VALVE
3. AIR INLET
4. COOLANT OUTLET TO LTR
5. COOLANT RETURN FROM LTR
6. ENGINE OIL TEMPERATURE SENSOR
7. ENGINE OIL PRESSURE SENSOR
8. HIGH-PRESSURE TURBOCHARGER
9. LOW-PRESSURE CHARGE-AIR-COOLER
10. A/C COMPRESSOR MOUNTING PAD
11. COOLANT INLET FROM DEAERATION TANK
12. GROUND STUD

COMPONENT LOCATIONS - REAR



1. CRANKCASE BREATHER FILTER HOUSING
2. RETARDER CONTROLLER
3. ENGINE COOLANT TEMPERATURE SENSOR
4. TURBO EXHAUST OUTLET
5. REAR ENGINE MOUNTING BRACKETS
6. LIFTING EYES
7. ROAD DRAFT TUBE HEATER
8. CRANKSHAFT POSITION SENSOR
9. CRANKCASE BREATHER CYCLONE

DESIGN FEATURES



Air-To-Water Charge-Air-Coolers

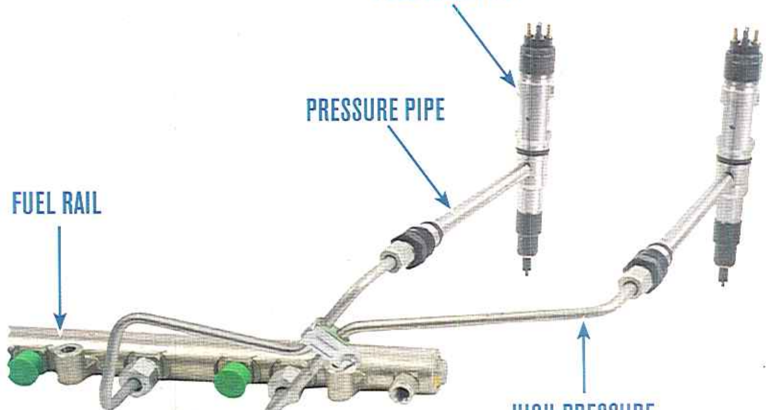
- MaxxForce® 11 and 13 engines feature dual air-to-water CACs (Charge-Air-Coolers). The LPCAC (Low-Pressure CAC) is mounted to the right side of the engine and the HPCAC (High-Pressure CAC) is mounted to the top of the engine over the front of the valve cover. Both coolers are fed coolant from the engine's water pump.

- The low-pressure cooler lowers the charge-air temperature as air passes between the low-pressure turbo compressor and the high-pressure turbo compressor. The high-pressure CAC reduces the temperature of the charge-air as it leaves the high-pressure compressor. Charge-air leaving the HPCAC enters the inlet mixing duct.

Engine Retarder

- MaxxForce 11 and 13 engines feature an optional engine retarder to provide additional braking performance. The engine retarder is a compression release brake system that uses exhaust backpressure to open the exhaust valves at the proper time.

- The system uses the exhaust rocker arm, exhaust valve-bridge, and the counterpiece under the valve cover to mechanically control the valve opening process. The ECM uses the retarder controller and the retarder actuator located on the right side of the engine to regulate the exhaust back pressure for proper brake operation.



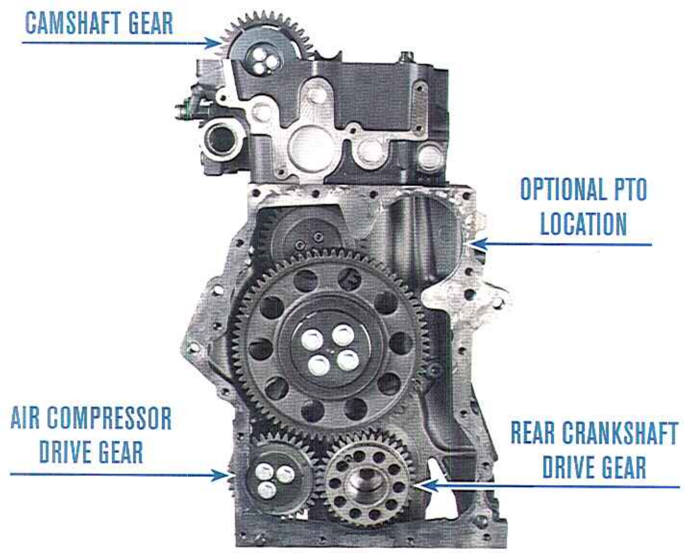
High-Pressure Common Rail

- MaxxForce 11 and 13 engines have a direct injection, high-pressure common-rail diesel fuel system. This system includes a high-pressure fuel pump driven off the front gear train, a common fuel rail mounted to the left side of the cylinder head, and fuel injectors centrally located in relationship to the combustion chamber.

- The injectors are installed in the cylinder head under the valve cover but the pressure pipes and high-pressure fuel lines connect the fuel rail to the injectors.

Rear Gear Train

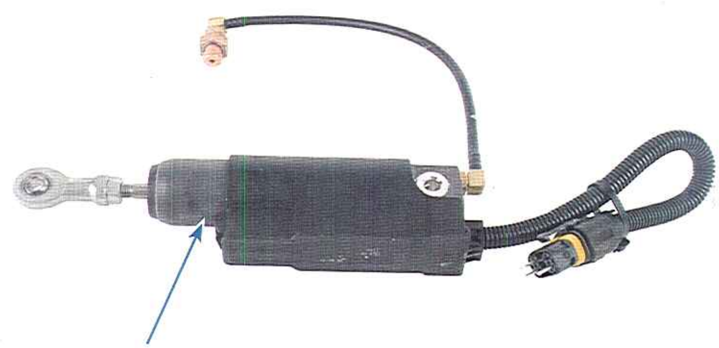
- The rear gear train on the MaxxForce®11 and 13 engines is located behind the flywheel housing cover. This gear train has seven gears: the crankshaft gear, the air compressor drive gear, the large two-piece intermediate gear, the small intermediate gear, the cylinder head mounted gear, and the cam shaft gear.
- The rear gear train drives the camshaft, air compressor, and optional PTO. An additional gear set on the front of the engine drives the accessories.



REAR GEAR TRAIN

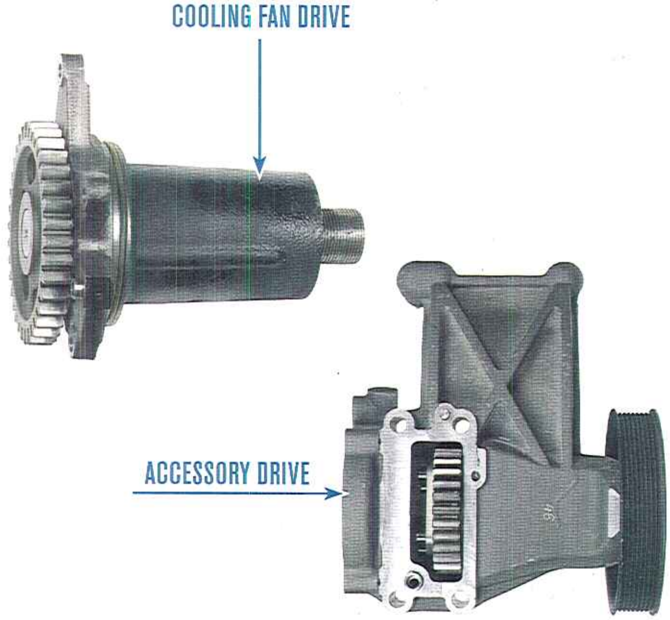
Pneumatic Actuators

- The MaxxForce 11 and 13 engines utilize pneumatic actuators to position the EGR valve, the turbocharger diverter valve, and the engine retarder exhaust flap. All engine mounted pneumatic actuators use the vehicle's air supply system. The engine receives air from the dryer after the brake system pressure reaches 90 psi. Air to the EGR controller and the retarder controller is non-regulated. Air to the boost control solenoid must be regulated to a lower psi by a pressure regulator mounted to the left front chassis rail.
- These actuators are controlled by the ECM and are used to control the EGR flow, boost, and the engine retarder operation.

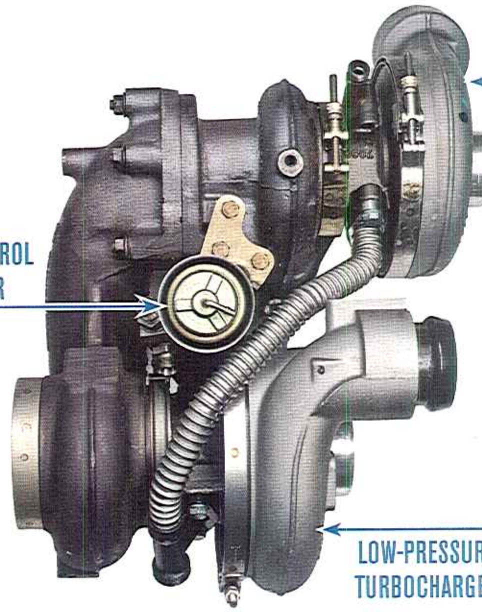


Cooling Fan Drive and Accessory Drive

- On vehicles with a low-mount cooling fan, the fan drive is gear driven by the front gear train. The fan drive is lubricated by pressurized oil from the lubrication system. On vehicles requiring a high-mount fan, the fan is powered by a serpentine belt driven by a pulley mounted to the front of the crankshaft damper.
- Both low and high mount fan drive vehicles use an additional serpentine belt driven off the accessory drive to power the alternator, A/C compressor and water pump. The accessory drive is driven by the front intermediate gear in the front gear train. This accessory drive also drives the high-pressure fuel pump.

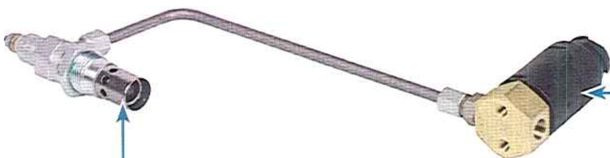


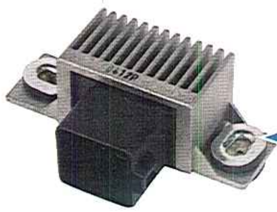
DESIGN FEATURES



Dual Turbochargers

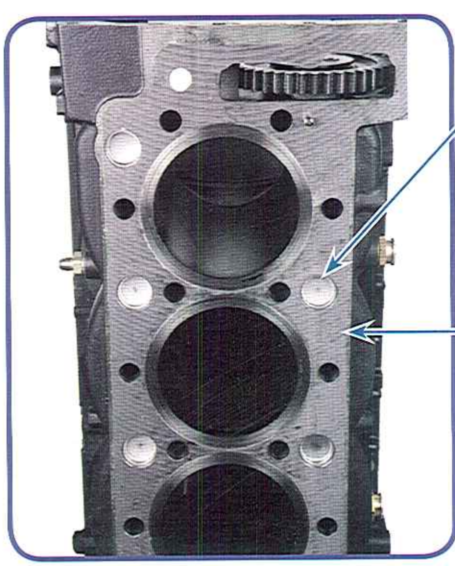
- MaxxForce® 11 and 13 engines use dual turbochargers. The smaller turbo, called the high-pressure turbo, is quick to spool up and is used to achieve quick engine response. The larger turbo, called the low-pressure turbo is used at higher speeds to prevent the high-pressure turbo from over speeding.
- The high-pressure turbo has an exhaust diverter valve used to divert exhaust flow past the high-pressure turbine when required. The ECM controls the boost control solenoid which then uses regulated vehicle air pressure to position the boost control actuator.





Cold Start Assist

- The optional cold start assist aids in cold weather and high altitude starts. The cold start assist uses a glow plug, and low-pressure fuel to heat the intake air and vaporize fuel in the intake manifold during cranking.
- When starting the engine in ambient temperatures below 52° F, the EIM (Engine Interface Module) energizes the cold start relay to provide power to the glow plug. When the Wait to Start lamp begins to blink off and on, the engine is ready to crank. While cranking, the EIM will open the cold start solenoid allowing the fuel supply pump to provide low-pressure fuel to the glow plug. The glow plug will vaporize the fuel and warm the air entering the intake manifold.



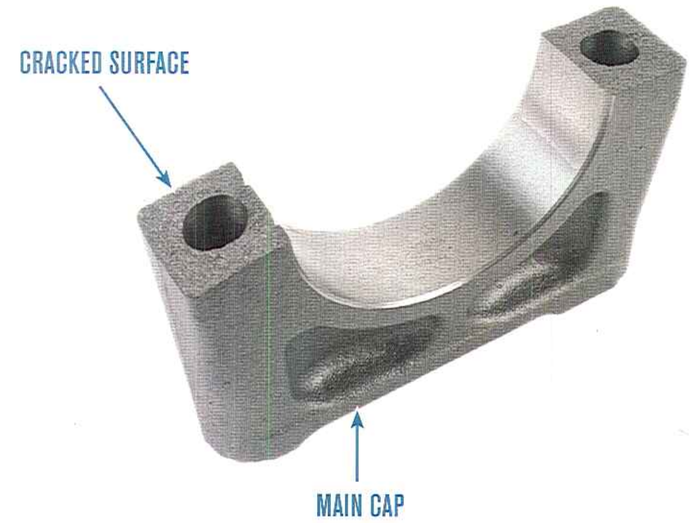
Dry Deck Surface

- MaxxForce 11 and 13 engines have a dry-deck design. This means that no coolant or pressurized oil flows through the cylinder head gasket. Instead, coolant flows from the water pump through the coolant manifolds, which branch off to the cylinder head and the crankcase separately. Coolant is piped to the crankcase and the cylinder head in parallel.
- Oil is provided to the cylinder head through a port on the top of the oil filter/cooler module. Oil from the cylinder head can drain at the front of the head or the opening for the gear train at the rear of the head.

Cracked Main Caps

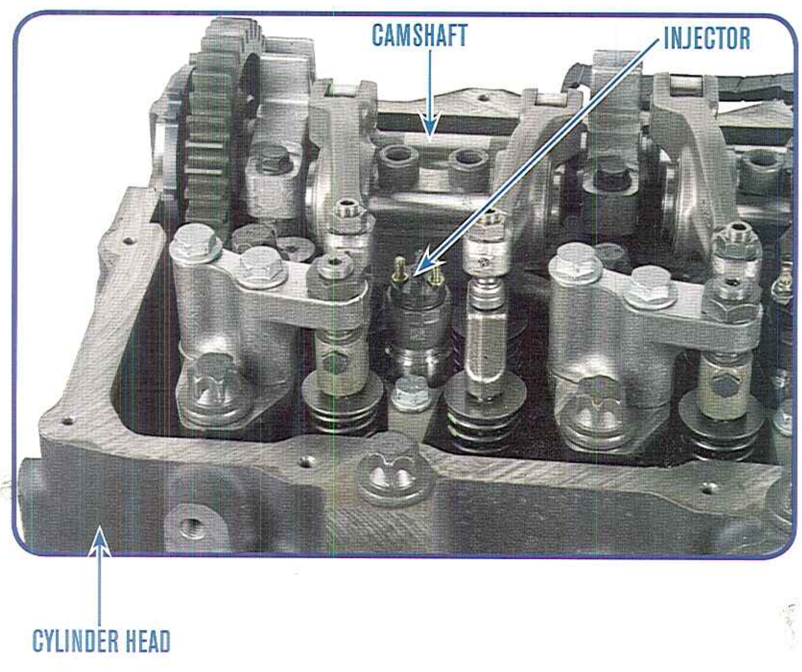
- The crankshaft main bearing caps feature a cracked design. Care must be taken when handling the cracked caps to prevent damage to the mating surfaces. Before assembly, clean cap with solvent and air dry. When properly assembled, the stamped end of the main bearing cap should be on the left side of the engine.

- The crankcase is made from compacted-graphite iron, rather than the traditional gray iron. This allows for the crankcase to be lighter weight, yet very durable.



4 Valve Cylinder Head With Camshaft

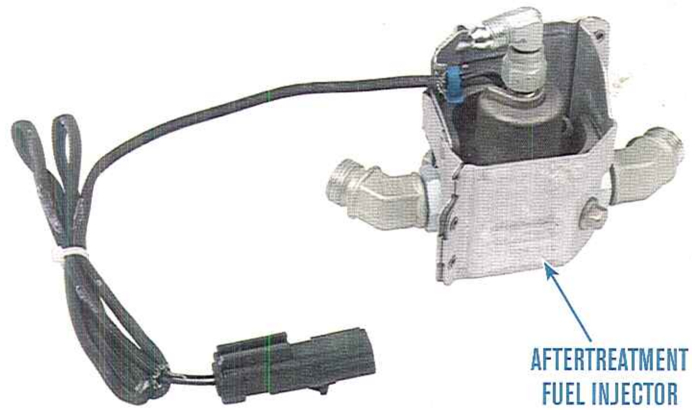
- The MaxxForce® 11 and MaxxForce 13 engine cylinder head has four valves per cylinder with centrally located fuel injectors. This design improves performance and reduces emissions. The cylinder head also has an integral intake manifold, and features an overhead camshaft with roller rockers. The camshaft rides on seven bearings in the cylinder head, and is driven by the rear gear train.



Exhaust Aftertreatment

- The Aftertreatment system consists of the DPF (Diesel Particulate Filter), the DOC (Diesel Oxidation Catalyst), the AFI (Aftertreatment Fuel Injector), the ACV (Aftertreatment Control Valve), the four exhaust system mounted sensors, and the ACM (Aftertreatment Control Module).

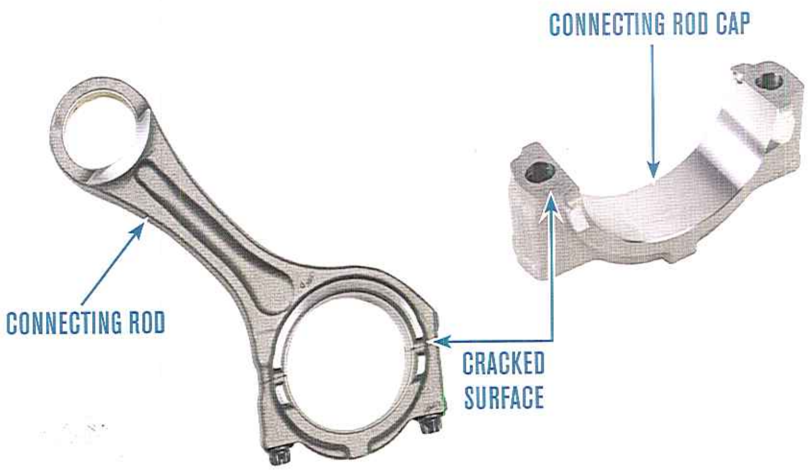
- During engine operation, the DPF stores the soot particles from the exhaust. During active regeneration of the filter the ACM commands the ACV and the injector to inject fuel into the exhaust gas. The fuel is oxidized in the DOC. This increases the exhaust temperature sufficiently for DPF regeneration. The AFI and ACV are both engine mounted. The other Aftertreatment components are chassis mounted.

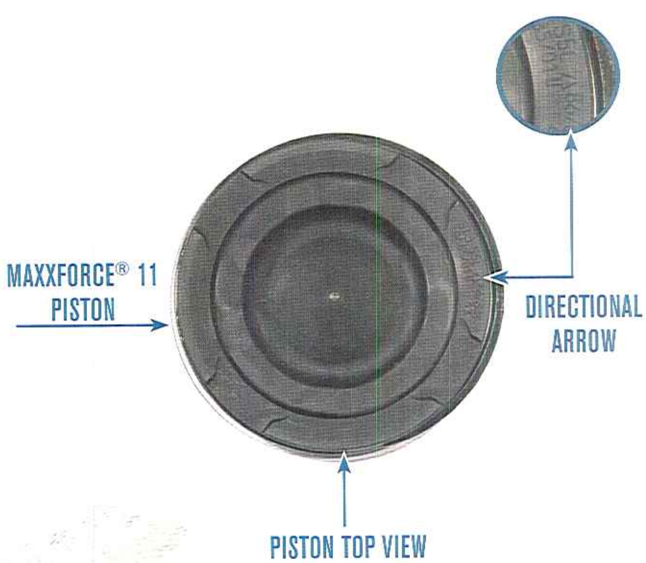


MAXXFORCE

BASE ENGINE: MECHANICAL, LUBRICATION, AND COOLING

- Overhead Camshaft with Roller Rocker Arms
- Cracked Connecting Rod and Main Bearing Caps
- MaxxForce® 13 Pressurized Piston Pin Lubrication
- Internal Piston Cooling Passage
- Gerotor Oil Pump
- Low Temperature Radiator
- Air-to-Water Charge-Air-Coolers





Connecting Rod

- The connecting rods are precision forged with a cracked mating surface design. Care must be used when handling both the rod and cap to prevent damage to the mating surfaces. The rods have identifying numbers laser-etched into the cap and rod. Never install a non-matching cap and rod together and tighten the rod bolts. The mating surface will be damaged and the rod assembly must not be reused. When installed, the connecting rod bolt heads must face the right (turbo) side of the engine. Be certain that the longer leg of the connecting rod is positioned on the left (fuel) side of the engine.

- The MaxxForce 13 connecting rods have a drilled oil passage that feeds pressurized oil from the crankshaft journal to the piston pin for additional lubrication.

Directional Piston

- An arrow is stamped on the top of the piston for proper positioning. This arrow points to the front of the engine when the piston is properly installed.

Piston Cooling

- The MaxxForce® 11 engine has an aluminum piston and the MaxxForce 13 has a steel piston. Both pistons have internal oil passages in the crown for increased cooling. The piston cooling nozzles feed oil to these passages.

- The oil fed into the passage flows around the bottom of the piston bowl. This oil removes heat from the bowl. The oil is then drained to the crankcase from a drilling opposite of the inlet. Some of the oil is also directed to the piston pin for lubrication on the MaxxForce 13.

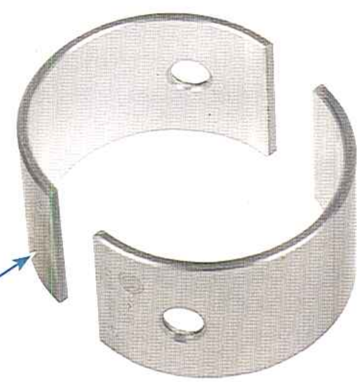
Cylinder Sleeves

- The MaxxForce 11 and MaxxForce 13 engines have replaceable wet cylinder sleeves. The bottom of the sleeve is sealed with two O-rings located in the crankcase.

Camshaft Bearings

- The camshaft is located in the left side of the cylinder head. The camshaft rides on seven precision insert bearings. The upper and lower inserts are identical. Each bearing is held in place with an aluminum cap. There are no location tabs on the bearing inserts, so during repair the inserts must be positioned carefully to locate the bearing oil hole with the oil passage in the cylinder head.

- The cam gear has a white dot on the rear of the gear. Before removing the cam or head, bar the engine over until the white dot is level with the cylinder head valve cover gasket surface on the left side of the cam. The cam will now be in the #1 cylinder TDC compression position. See the *Unique Service Procedures* area of this book for details on checking cam to crank timing.



BASE ENGINE: MECHANICAL, LUBRICATION, AND COOLING

Camshaft Gear

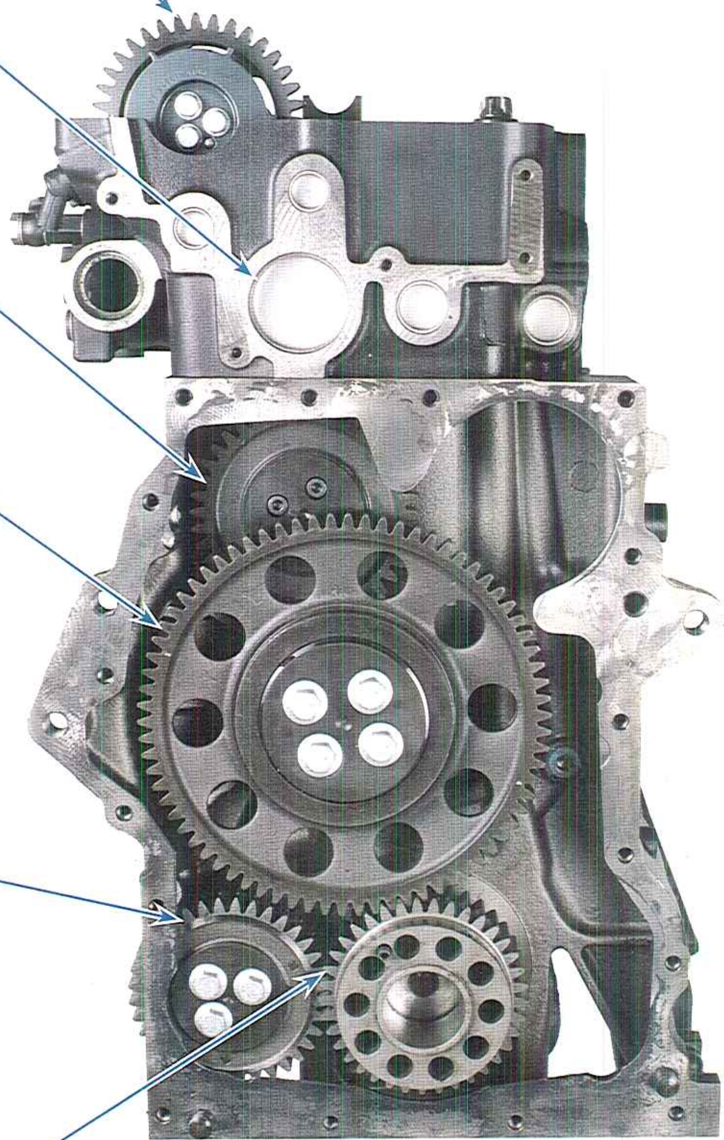
- The rear gear train drives the camshaft, the air compressor, and the optional PTO (Power Take-Off). The cam shaft, cam gear, and pulse wheel are located by a 6 mm dowel pin and attached with three 8 mm bolts. The cam gear is driven by the cylinder head gear.

Cylinder Head Gear Location

- The cylinder head gear rotates on a bearing called a stud. This gear can be accessed by removing the large diameter cup plug at the rear of the head.

Crankcase Intermediate Gear

- The crankcase intermediate gear is driven by the small gear on the rear of the large intermediate gear and drives the cylinder head gear. Each of the gears in the rear gear train rotates on a large bearing surface called a stud. Each stud is attached to the crankcase with 3 or 4 bolts.



Large Intermediate Gear

- The largest gear in the rear gear train is the large intermediate gear. This gear is a large diameter gear with a small diameter gear pressed on the back. The large diameter gear is driven by the crankshaft timing gear and the small diameter gear drives the crankcase intermediate gear. One of the two timing marks on the large intermediate gear must be in time with the crankshaft gear to achieve proper camshaft gear timing.

Air Compressor Intermediate Gear

- The air compressor is mounted on the left rear of the engine and is gear driven by the compressor intermediate gear. The compressor intermediate gear is actually two gears mounted side by side and connected with three rubberized drive pins. The gears are preloaded slightly offset to each other to eliminate backlash between the gear on the compressor and the compressor intermediate gear.

Crankshaft Timing Gear

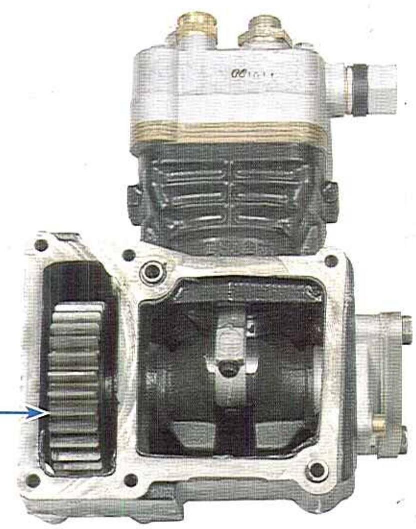
- The crankshaft timing gear is a light press fit onto the crankshaft. The gear can be removed with a gear puller and reinstalled using a hammer and brass drift. The gear has a dowel pin that aligns with an alignment hole in the crankshaft to guarantee the proper location. The crank gear must be located correctly to position the flywheel timing holes in the proper relationship to #1 cylinder TDC.

Rear Gear Train

- The 37 tooth rear crank gear drives the 36 tooth air compressor drive gear. The air compressor drive gear is then in mesh with the 29 tooth gear on the crankshaft of the air compressor. This overdrives the compressor at a 0.78:1 ratio.
- The 37 tooth rear crank gear also drives the 74 tooth large intermediate gear. The gear pressed on the back of the two-piece large gear has 37 teeth. The 37 tooth gear drives the 40 tooth crankcase intermediate gear, the 38 tooth head gear and then the 36 tooth camshaft gear for a 2:1 ratio.

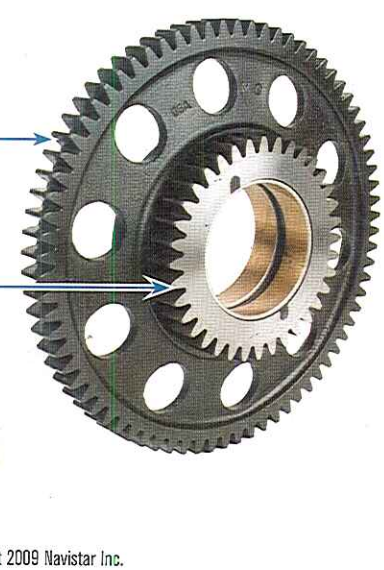
Air Compressor

- The compressor provides the vehicle and the engine actuators with pressurized air supply. This compressor is continuously running, and has no unloader valves. Vehicles are equipped with a frame mounted pressure regulator that reduces the frequency that the air dyer purges.



Large Intermediate Gear

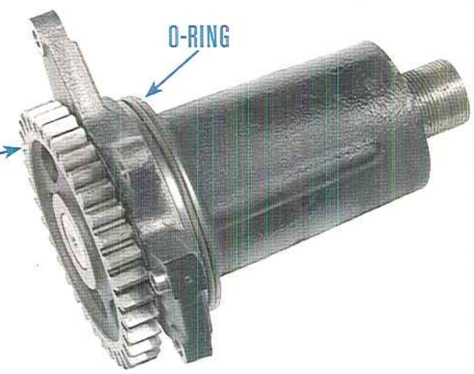
- The Large Intermediate Gear is a two piece gear. The large gear has 74 teeth while the small gear pressed on the back has 36 teeth. The relationship of the two gears is essential to maintain the correct camshaft timing. A procedure to check the camshaft timing is described in the *Unique Repair Procedures* section of this book.
- The large gear has two timing marks, either of which can be aligned with the mark on the crank gear to set the timing. The large gear and the crank gear must be timed to achieve the proper camshaft timing.



BASE ENGINE: MECHANICAL, LUBRICATION, AND COOLING

Front Gear Train

- The MaxxForce® 11 and 13 engines feature a front gear train consisting of the fan drive gear, the accessory drive gear, the oil pump outer rotor, the front intermediate gear, and the crankshaft drive gear.



Fan Drive Gear

- The fan drive gear is driven by the front intermediate gear. The 36 tooth fan drive is mounted directly to the crankcase, and the front cover is mounted over it. The fan drive housing has an o-ring to seal the front cover and the fan drive housing. The crankshaft to fan ratio is 0.80:1.

Front Intermediate Gear

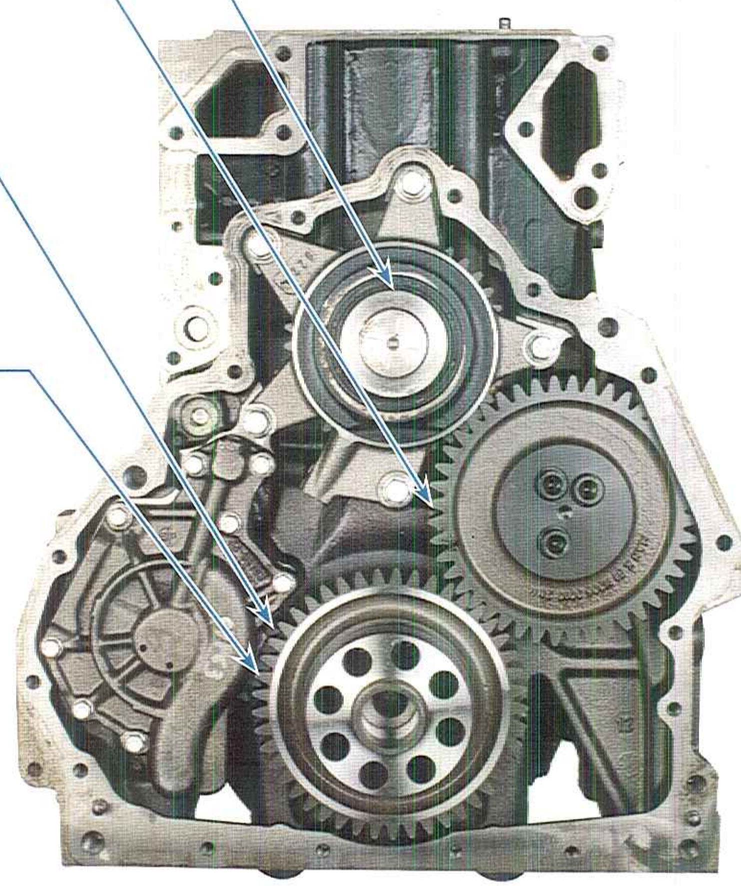
- The front intermediate gear is installed on the crankcase with a pin and three bolts. This 44 tooth gear drives the gear in the accessory drive housing and the fan drive gear. The accessory drive then turns the high-pressure fuel pump and the serpentine belt for the A/C compressor, water pump and the alternator. The crankshaft to accessory drive ratio is 0.6:1.

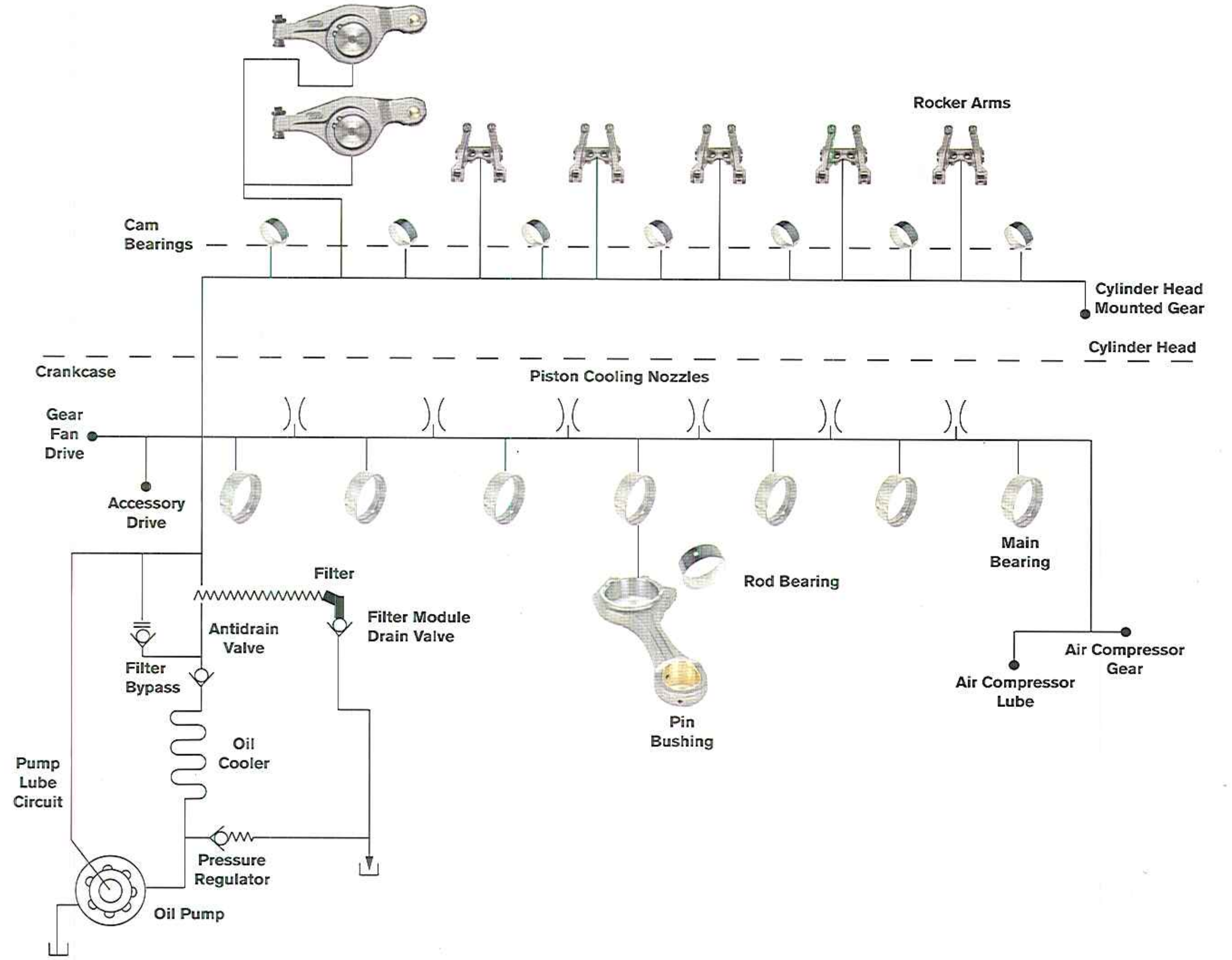
Oil Pump Outer Rotor with Gear

- Teeth cast into the outer rotor of the oil pump mesh with the front crankshaft drive gear. The 34 tooth oil pump outer rotor rides in a bushing in the crankcase. The crank to oil pump ratio is 0.75:1.

Front Crankshaft Drive Gear

- The front crankshaft drive gear is a light press-fit onto the end of the crankshaft. The 45 tooth gear drives both the front intermediate gear and the oil pump. The crank gear to intermediate gear ratio is 0.97:1.





Lubrication Operation

- Engine oil pressure is generated by a gerotor oil pump located behind the front cover. The pump gear has 34 teeth and is driven directly off of the 45 tooth crankshaft gear.

- Oil from the pump enters the oil filter module located on the right side of the engine. The module consists of the oil filter element, the oil cooler assembly, the oil pressure and temperature sensors, and the oil pressure regulator.

- Filtered oil passes from the oil filter element to the cylinder head through an external flange elbow. Oil from the cylinder head can drain back to the oil pan through a separate passage in the external flange elbow. Oil from the head can also drain into the crankcase through the gear train opening at the rear of the cylinder head.

- Inside the cylinder head, oil flows through drilled passages to lubricate the camshaft bearings, rocker arms, exhaust valve bridges, and the cylinder head intermediate gear.

- Clean oil enters the crankcase passages directly from the oil filter module. This oil lubricates the crankshaft, the high-pressure fuel pump, the air compressor, the oil pump, and the intermediate gears. Oil is also directed to the piston cooling jets where a continuously stream of oil is directed at the bottom of the piston crowns.

- At the crankshaft, oil is directed through drillings from the main bearing journals to the rod bearing journals. On MaxxForce® 13 engines a drilled passage in each connecting rod takes oil from the rod journal and pressure lubricates the piston pin.

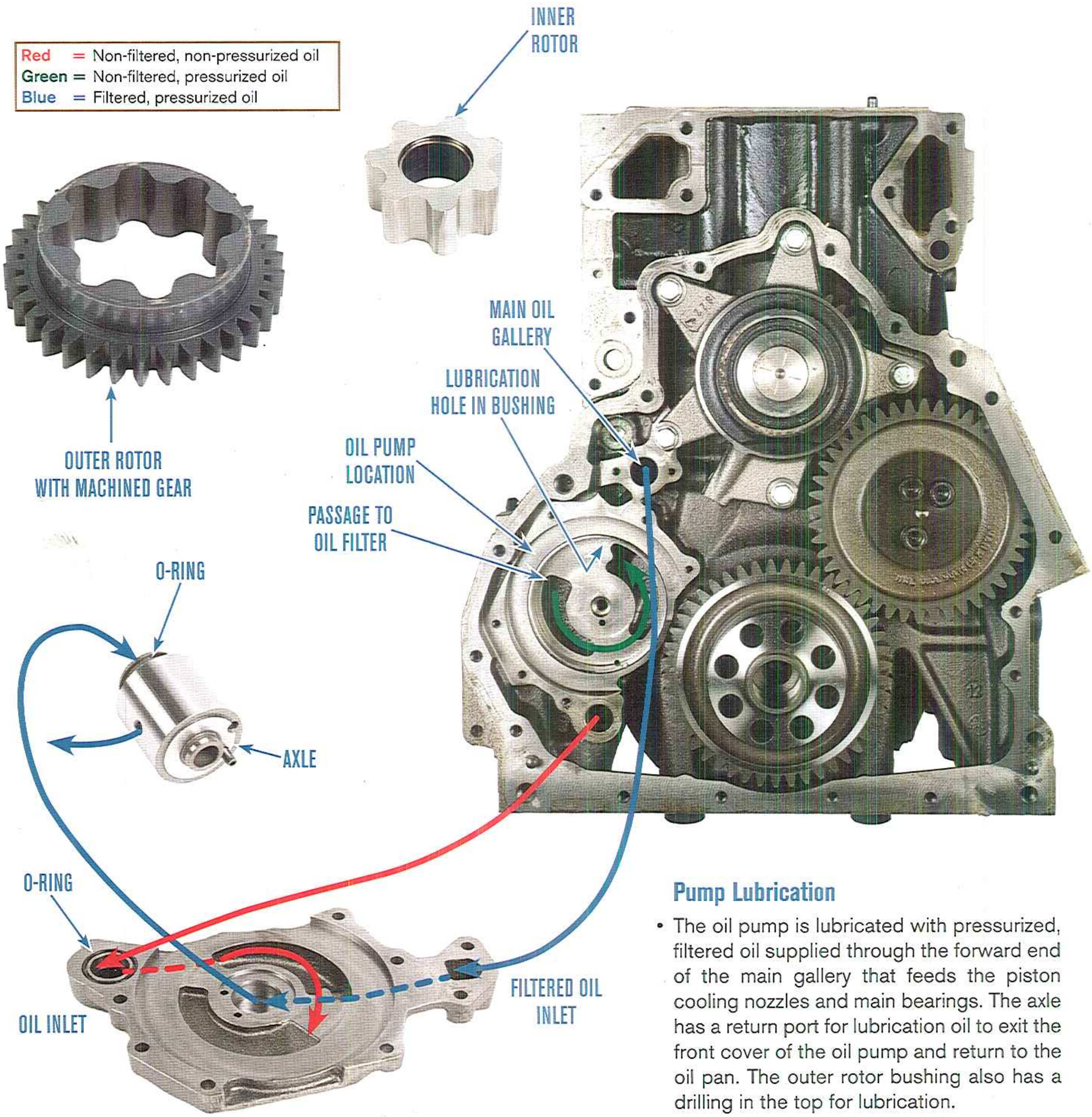
- The turbochargers are lubricated with filtered oil from an external supply tube that connects the main oil gallery from the crankcase to the center housing of each turbocharger. Oil drains back to the oil pan through the low and high-pressure turbocharger oil return pipes connected to the crankcase.

Pump Location

- The gerotor oil pump is located behind the front cover and is mounted directly to the crankcase. The oil pump housing consists of a cover and the machined area of the crankcase.
- There are two different pump sizes. The MaxxForce® 13 has a larger inner and outer rotor, as well as different housing machining. These parts cannot be interchanged between the MaxxForce 11 and the MaxxForce 13.

Pump Drive

- The crankshaft gear drives the pump through teeth machined into the outer pump rotor. The outer rotor has a machined surface that rides on a bushing located in the crankcase.
- The outer rotor turns the inner rotor, which rides on an axle. This axle is lubricated with filtered oil. There is an o-ring on the end of the axle to seal the surface between the axle and the cover.



Pump Lubrication

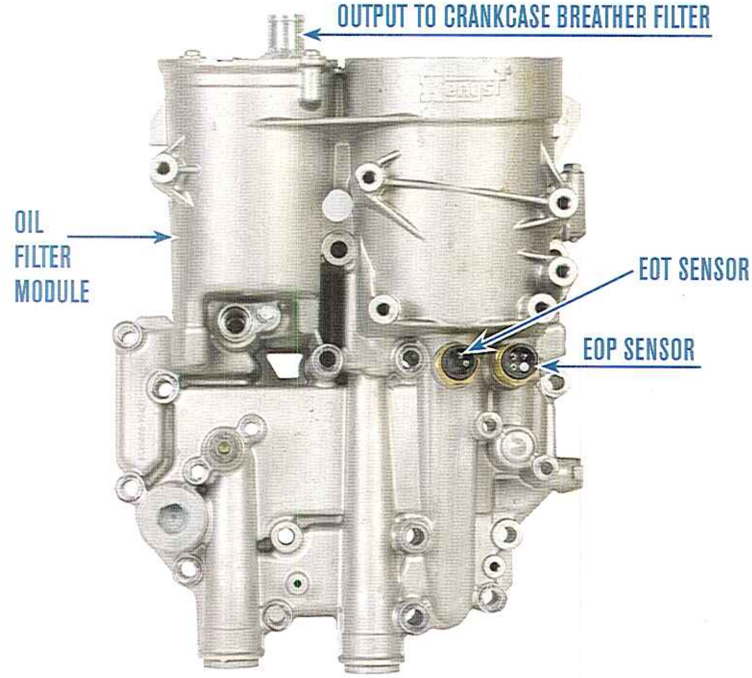
- The oil pump is lubricated with pressurized, filtered oil supplied through the forward end of the main gallery that feeds the piston cooling nozzles and main bearings. The axle has a return port for lubrication oil to exit the front cover of the oil pump and return to the oil pan. The outer rotor bushing also has a drilling in the top for lubrication.

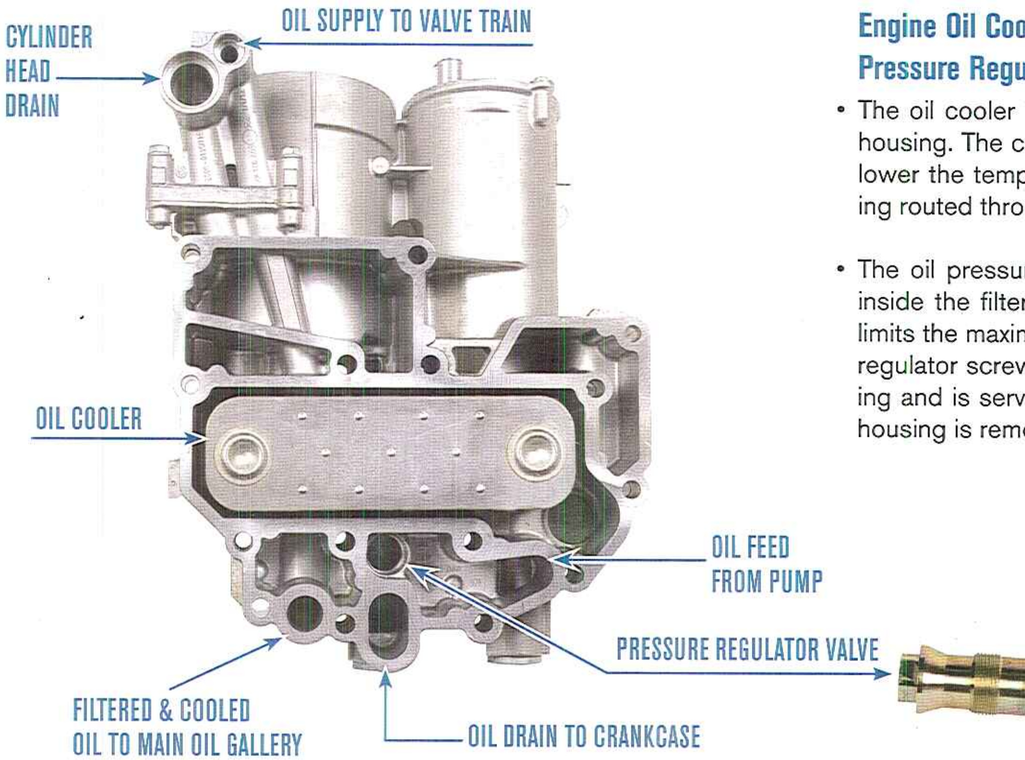
Engine Oil Pressure and Temperature Sensors

- The EOP (Engine Oil Pressure) and the EOT (Engine Oil Temperature) sensors are located on the oil filter/cooler housing. The module is located on the right side of the engine, behind the low-pressure charge-air-cooler. Replacement of the sensors requires the low-pressure charge-air-cooler to be removed. The EOP sensor must be installed in front of the EOT sensor because they do not use a common thread. These sensors are connected to the main engine harness through a jumper harness allowing sensor diagnostics to be performed without removing the charge-air-cooler. The harness connection is located on the upper front of the low-pressure charge-air-cooler.

- The EOP signal is monitored for operation of the instrument panel pressure gauge and optional engine protection system.

- The ECM monitors the EOT sensor for cold start assist, EGR control valve operation, and engine fueling calculations.





Engine Oil Cooler and Pressure Regulator Valve

- The oil cooler is located in the filter/cooler housing. The cooler uses engine coolant to lower the temperature of the oil before being routed through the rest of the engine.

- The oil pressure regulator valve is located inside the filter/cooler assembly. The valve limits the maximum engine oil pressure. The regulator screws into the filter/cooler housing and is serviceable after the filter/cooler housing is removed.

Oil Filter

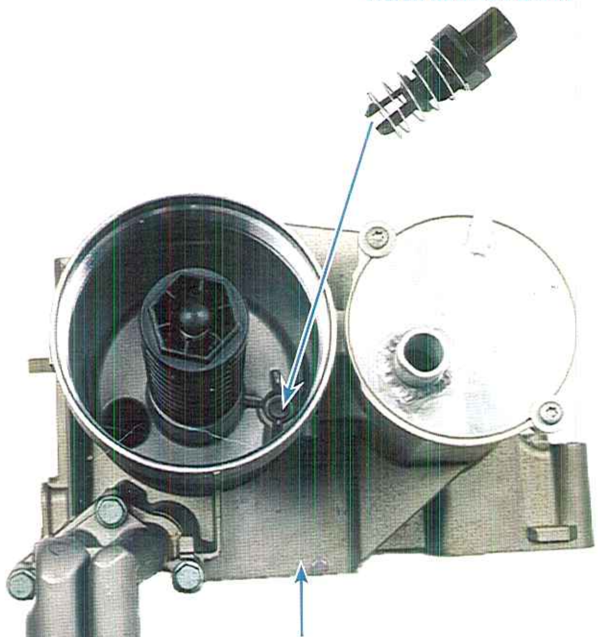
- The oil filter is located in the filter/cooler housing. The filter is a cartridge-type filter and is serviced by removing the threaded cover on the top of the filter housing. This filter has a micron rating of 17.

OIL FILTER

Oil Filter Bypass

- The oil filter bypass is located in the top of the filter standpipe within the filter/cooler assembly. The valve allows oil to pass through the engine if the filter becomes restricted.

FILTER HOUSING DRAIN



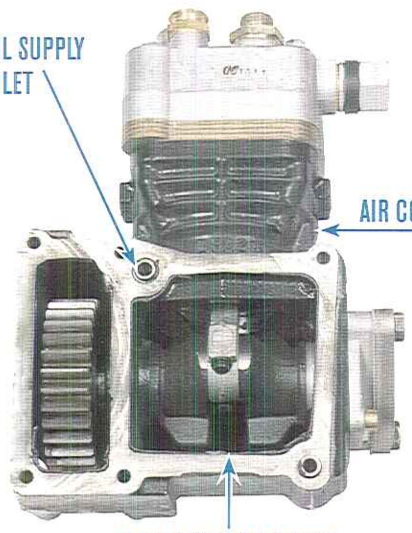
OIL FILTER MODULE
(Top View)

Filter Housing Drain

- The filter housing drain is a valve located in the bottom of the filter cavity. When the filter cap is loosened and the filter is lifted, the valve opens and allows the oil in the housing to drain back into the oil pan.

- When servicing, remove the oil filter first. This allows the oil filter module to drain into the oil pan before the oil pan drain plug is removed.

BASE ENGINE: MECHANICAL, LUBRICATION, AND COOLING

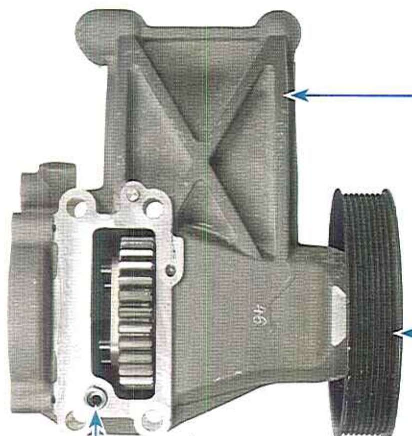


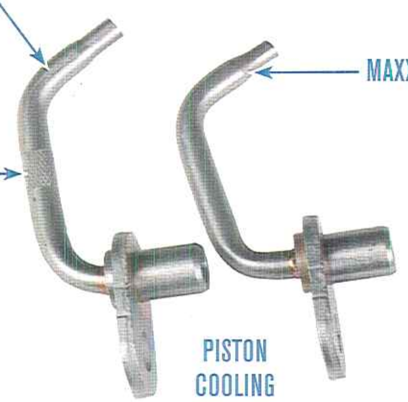
Air Compressor

- The air compressor bolts to the left rear of the engine crankcase. The compressor is supplied oil from a machined port in the crankcase. Oil drains back to the oil pan directly from the opening in the compressor.

Accessory Drive Housing

- The accessory drive housing is located on the left front of the engine. Oil is supplied to the housing through a machined port in the crankcase where the drive attaches. Oil drains back to the oil pan through the gear opening, to the front gear train.

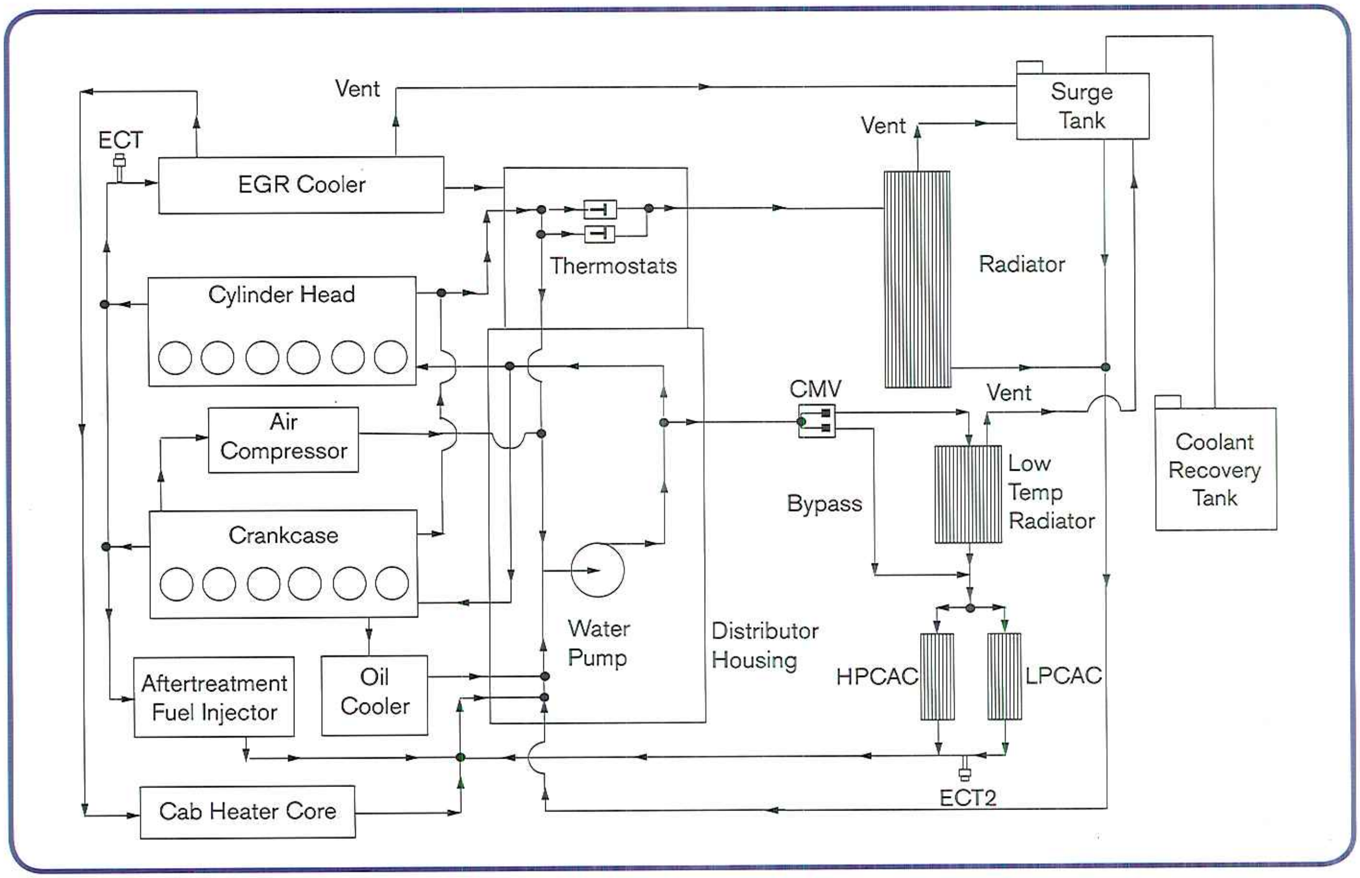




Piston Cooling Nozzles

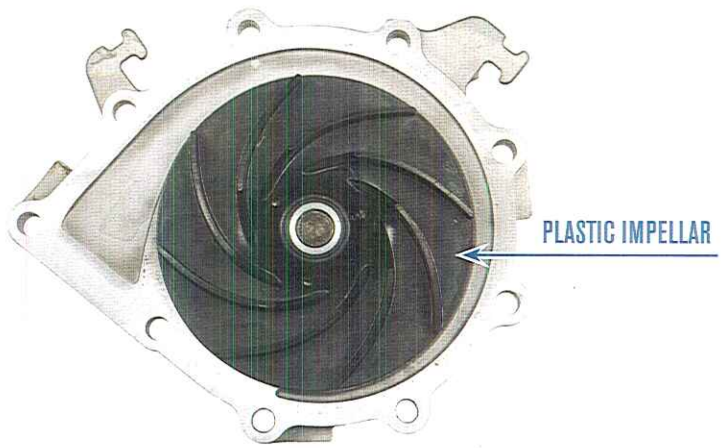
- The piston cooling nozzles connect to the main oil gallery at the bottom of the cylinders. Each nozzle provides a stream of oil to reduce the temperature of the piston's crown, and to help lubricate the connecting pin for the piston.

- The MaxxForce® 11 & 13 engines have different cooling nozzles. The MaxxForce 11 cooling nozzle has a smaller opening. The MaxxForce 13 cooling nozzle is taller, has a larger opening, and is identified with a knurled section on the tube. There are no o-rings or sealing washers between the nozzles and the crankcase.



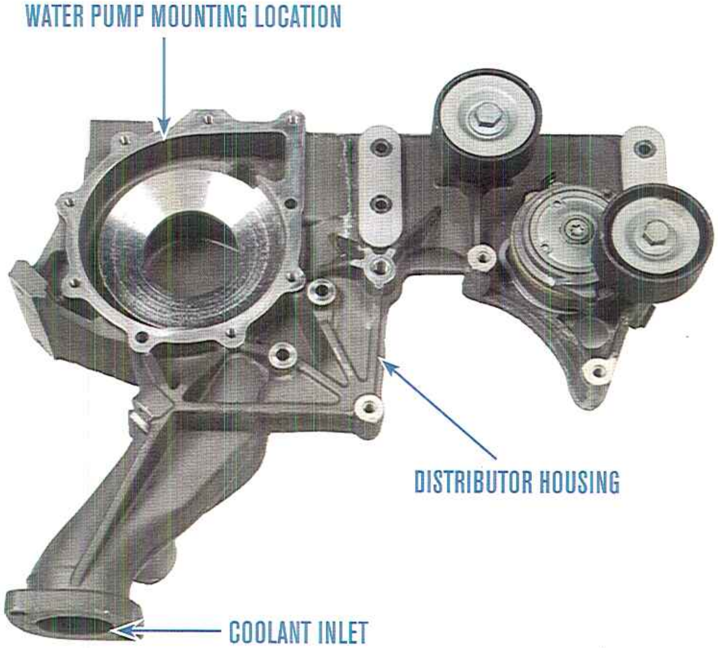
Cooling System Flow

- The water pump is located on the distributor housing and draws coolant from the radiator through the coolant inlet at the lower right side of the distributor housing.
- The MaxxForce® 11 and 13 engines have no coolant passages between the crankcase and cylinder head through the cylinder head gasket.
- Coolant in and out of the crankcase and cylinder head is directed through external passages. Coolant flows through the crankcase and cylinder head from front to rear. This coolant flows around the cylinder liners and combustion chamber to absorb heat from combustion.
- Coolant exiting the crankcase and cylinder head at the rear of the engine is directed through an external coolant elbow to the EGR cooler. A portion of this coolant is directed to the Aftertreatment fuel injector. Coolant passes between the EGR cooler plates, travels in parallel to the exhaust flow, and exits into the distributor housing.
- A deaeration port on the top of the EGR cooler directs coolant and trapped air towards the coolant surge tank.
- Coolant from the water pump also flows through the HPCAC (High-Pressure Charge-Air-Cooler) and the LPCAC (Low-Pressure Charge-Air-Cooler) to regulate the charge-air temperature. At the start of production, flow through the charge-air-coolers was controlled by the CMV (Coolant Mixer Valve) and the CFV (Coolant Flow Valve). The CFV is no longer used.
- Depending on the coolant temperature, the CMV sends coolant through the CACs, or indirectly to the CACs after going through the LTR (Low Temperature Radiator) located in front of the main coolant radiator. When the charge-air temperature is too low, the CMV bypasses the LTR and directs all the coolant through the CACs.
- When the charge-air temperature increases, the CMV directs a percentage of coolant to the LTR before it enters the CACs to cool the charge-air. If the engine coolant temperature is too high, the CMV sends all of the coolant flow through the LTR and through the CACs to help cool the charge-air faster.



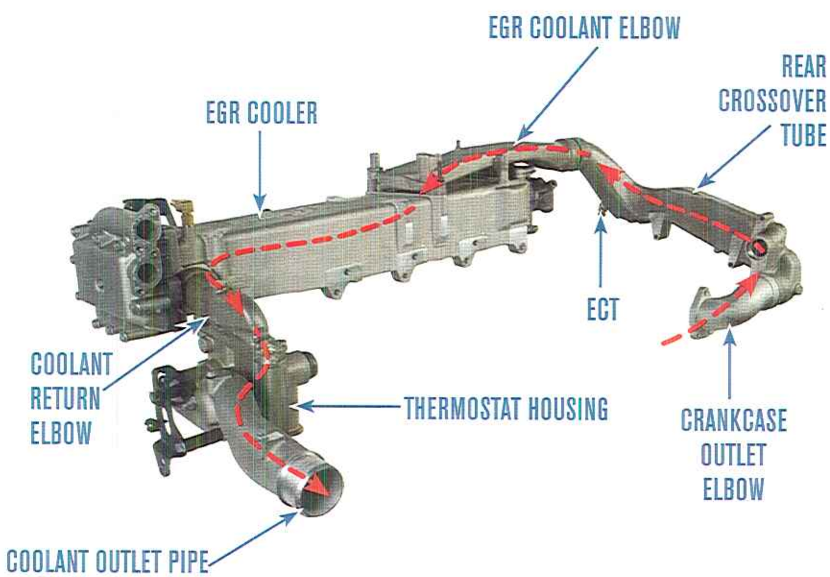
Water Pump

- The water pump is mounted to the distributor housing and is driven by the serpentine accessory drive belt. The water pump impeller is made of plastic; handle it carefully when servicing the pump.



Distributor Housing

- MaxxForce® 11 and MaxxForce 13 engines have a dry deck engine design. Coolant does not flow through the cylinder head gasket. Instead, coolant flows from the distributor housing to the crankcase and to the cylinder head independently. The distributor housing is the mounting location for the water pump. There is also an internal passage to supply coolant to the CCV (Coolant Control Valve).



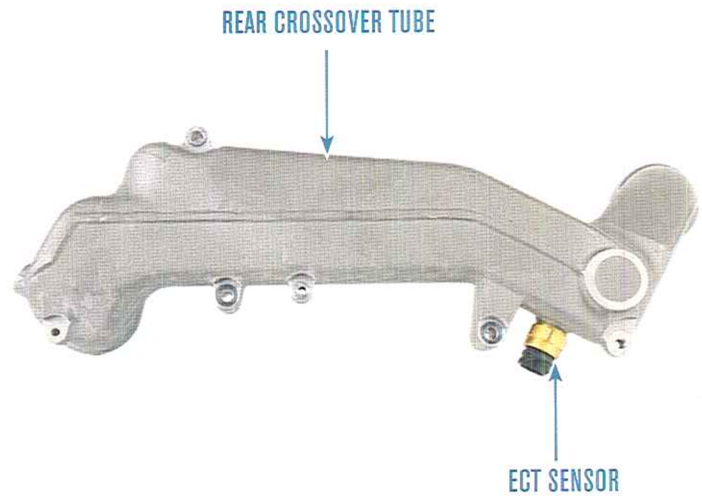
Crankcase Outlet Elbow, Rear Crossover Tube, Coolant Return Elbow

- After flowing through the crankcase and cylinder head, coolant enters the coolant outlet elbow. The rear crossover tube receives coolant from the crankcase outlet elbow and the cylinder head. This tube also has the ECT (Engine Coolant Temperature) sensor. Coolant flows from the EGR coolant elbow, to the EGR cooler, and to the thermostats through the coolant return elbow. When the thermostats open, coolant enters the coolant outlet pipe and flows to the radiator.

BASE ENGINE: MECHANICAL, LUBRICATION, AND COOLING

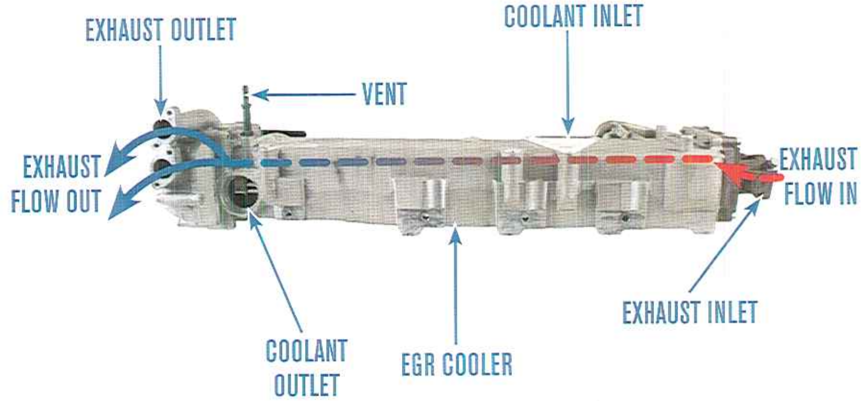
Engine Coolant Temperature Sensors

- Proper operation of the engine requires that the ECM measures coolant temperature at the rear crossover tube and at the coolant return pipe for the charge-air-coolers.
- The ECT (Engine Coolant Temperature) sensor is installed in the back of the engine on the rear crossover tube, and the ECT2 (Engine Coolant Temperature 2) sensor is installed in the CAC coolant return pipe.
- The ECT and ECT2 signals are inputs for operation of the coolant control valve, coolant temperature compensation, cold start assist, and the optional engine warning protection system. The ECT signal input is also used for the instrument panel temperature gauge.



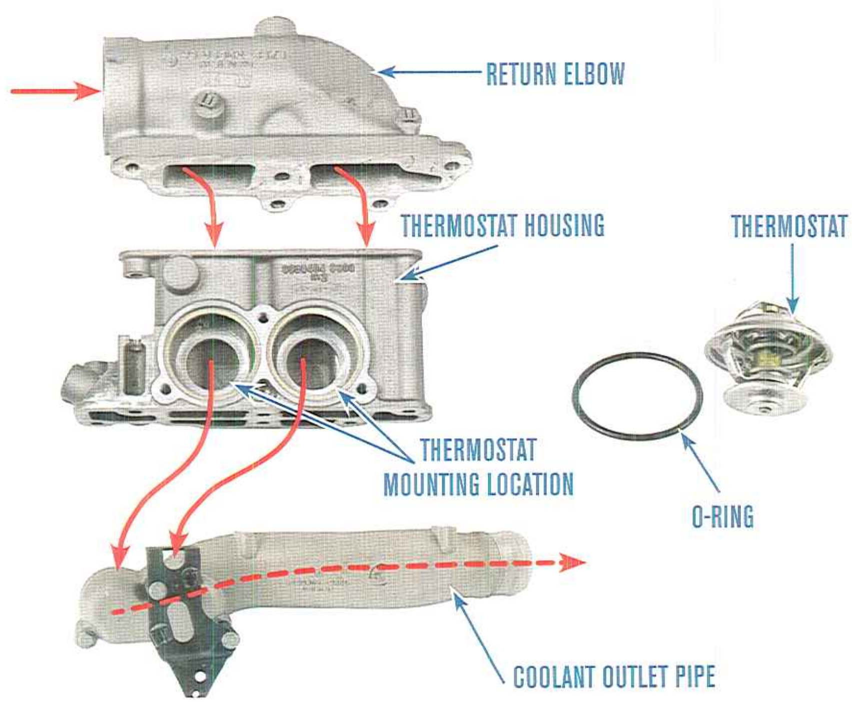
EGR Cooler

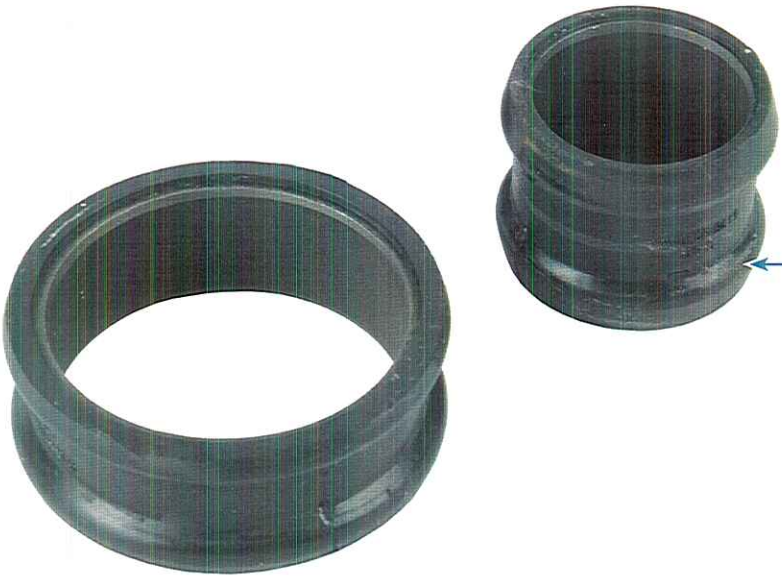
- The coolant flow from the crankcase and the cylinder head is supplied to the EGR coolant elbow on the right side of the engine via the rear crossover tube.
- All of the coolant from the EGR coolant elbow enters the EGR cooler. This is used to reduce the temperature of the exhaust gas before it enters the cylinders.
- The coolant vent at the top of the EGR cooler purges air to the surge tank.



Thermostats

- Coolant flows from the EGR cooler through the coolant return elbow to the thermostats.
- The thermostats are located in the thermostat housing behind the coolant outlet pipe. The engine has two thermostats for increased reliability and higher flow capacity. Both thermostats open at 83°C (about 180°F).
- When the thermostats open, coolant flows to the radiator. At the same time, the thermostats close off coolant flow from returning to the water pump. When the engine is cold and the thermostats are closed, the coolant returns to the water pump and is not routed to the radiator.



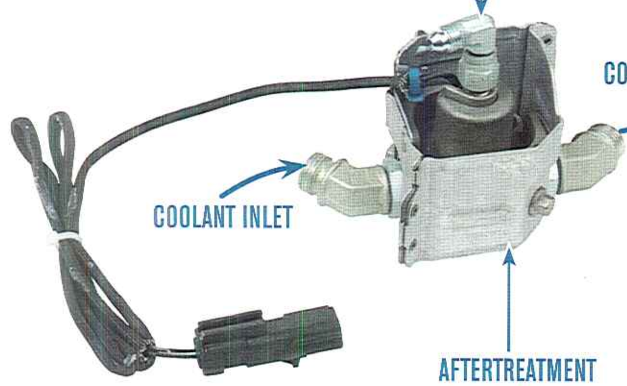


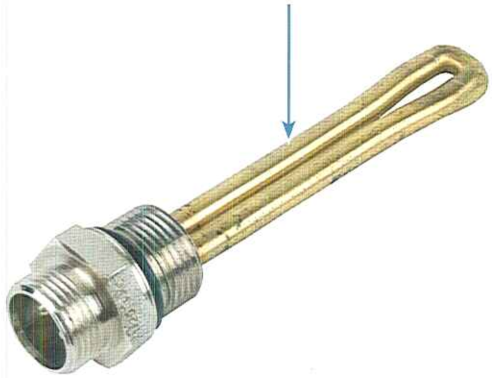
Rubberized Pipe Connectors

- The cooling system uses rubberized pipe connectors at many of the system's connections. Lubricate these connectors with petroleum jelly before inserting in the cavity.

Aftertreatment Fuel Injector

- A portion of the coolant from the rear crossover tube flows to the AFI (Aftertreatment Fuel Injector). The coolant then returns to the water pump inlet with the CAC coolant return. This reduces the temperature of the injector to increase its durability.





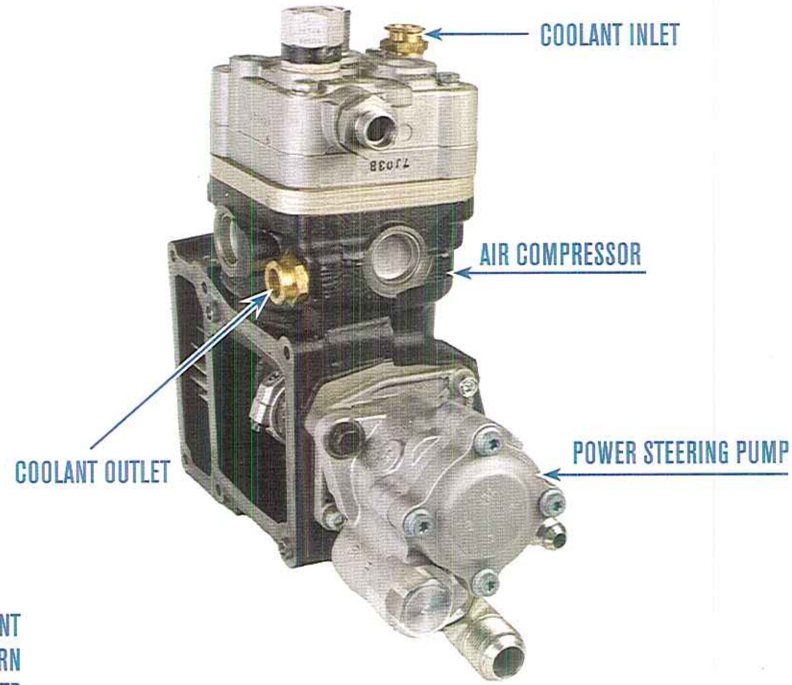
Coolant Heater

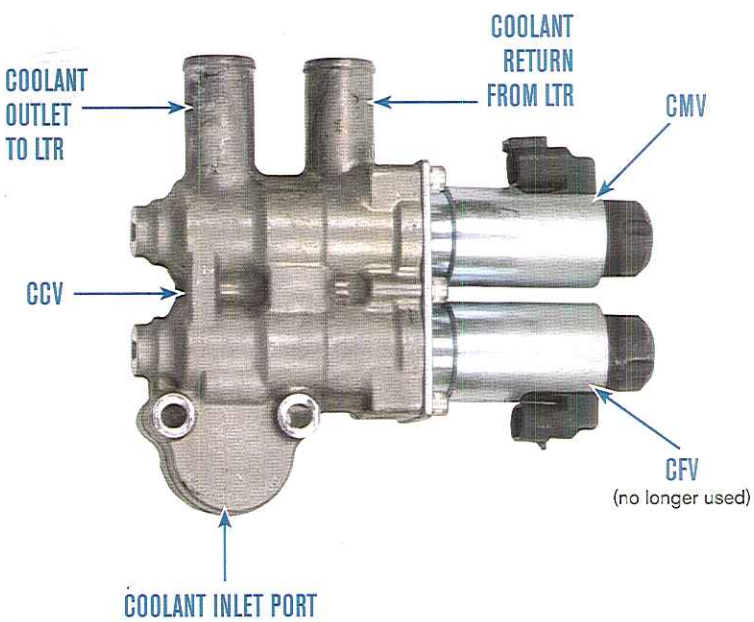
- An electric coolant heater is available as optional equipment to aid in cold weather starting. In vehicles equipped with this option, it is installed in the coolant inlet pipe.

BASE ENGINE: MECHANICAL, LUBRICATION, AND COOLING

Air Compressor

- Coolant reduces the temperature of the engine-mounted air compressor. Coolant flows into the top of the compressor from a quick-disconnect fitting below the manifold air temperature sensor. Coolant returns to the crankcase through a quick-disconnect fitting next to the crankcase outlet elbow from the back of the compressor.





Coolant Control Valve

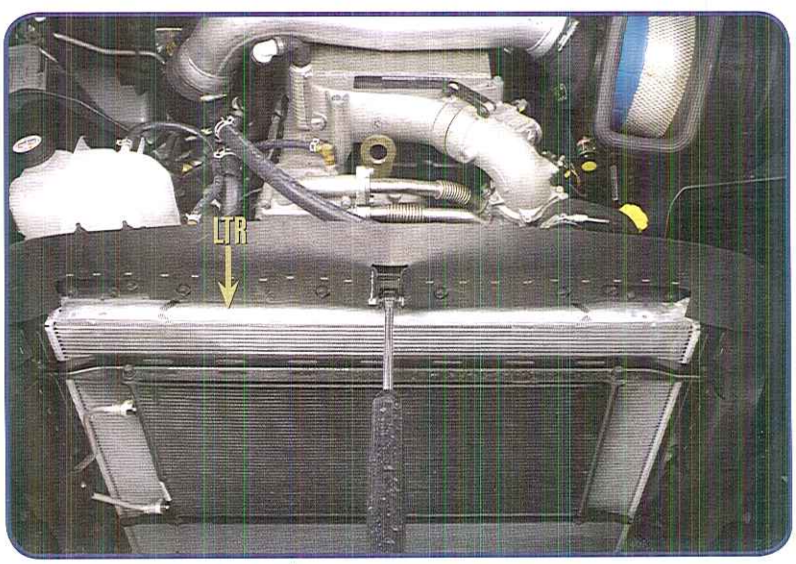
- The CCV (Coolant Control Valve) assembly is mounted at the front of the engine. At the start of production, it had two solenoids. The valve assembly regulates coolant flow and temperature through the two charge-air-coolers. As of 2009, the CFV (Coolant Flow Valve) which operates the flow valve, was disabled. The CMV (Coolant Mixer Valve) operates the mixer valve. The solenoid is controlled by PWM signals from the ECM. This valve is serviced as an assembly.

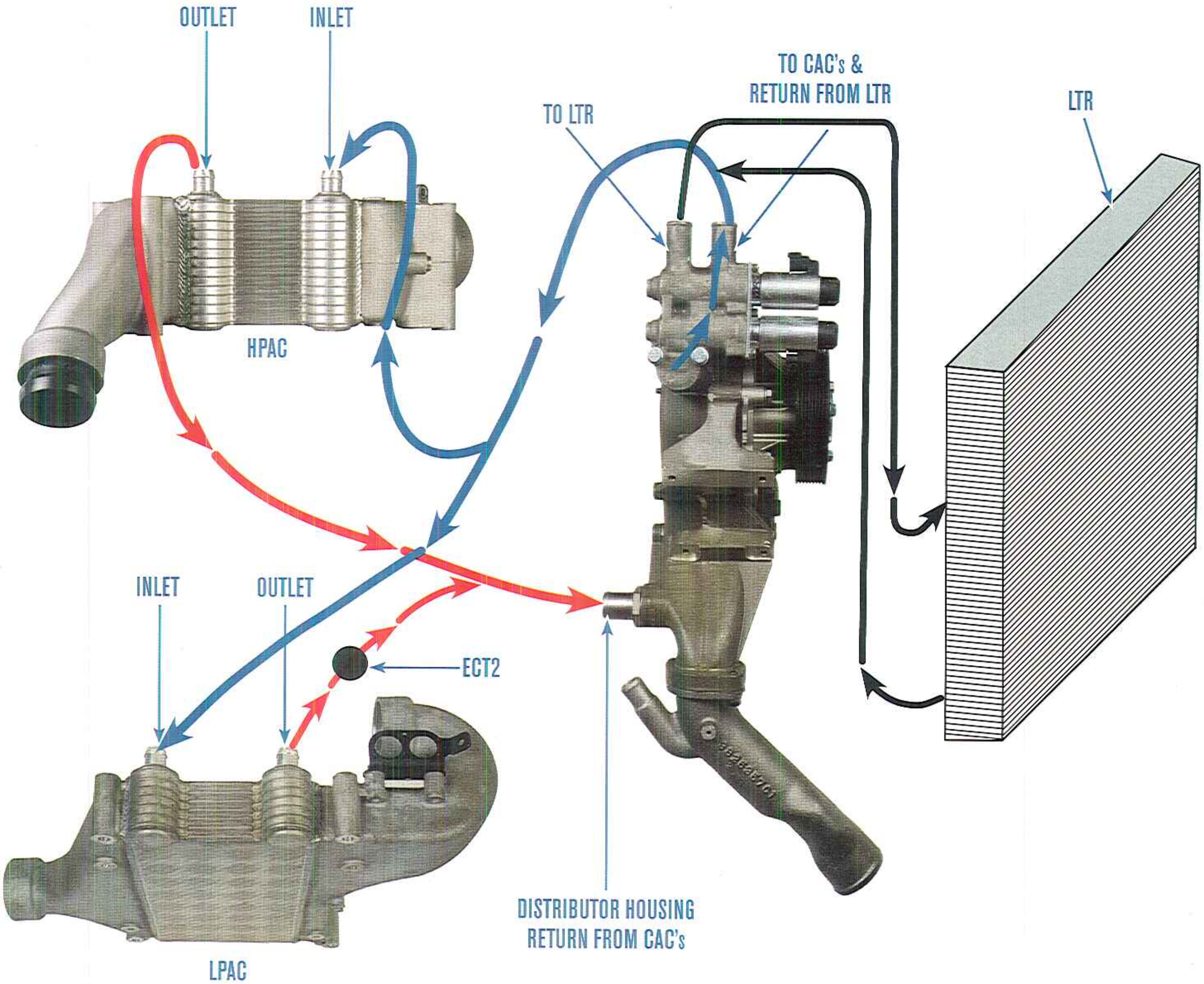
- The CCV assembly receives its coolant directly from the water pump via an internal passage in the distributor housing.

Low Temperature Radiator

- On the Class-8 truck, the LTR (Low Temperature Radiator) is mounted in the front of the conventional radiator and behind the A/C condenser. The LTR provides lower coolant temperature to the charge-air-coolers.

- Coolant that flows to the charge-air-coolers will either pass through the LTR for additional cooling, or bypass the LTR and go directly to the CACs. This cooling process allows each CAC to remove heat from the charge-air.





Cold Engine

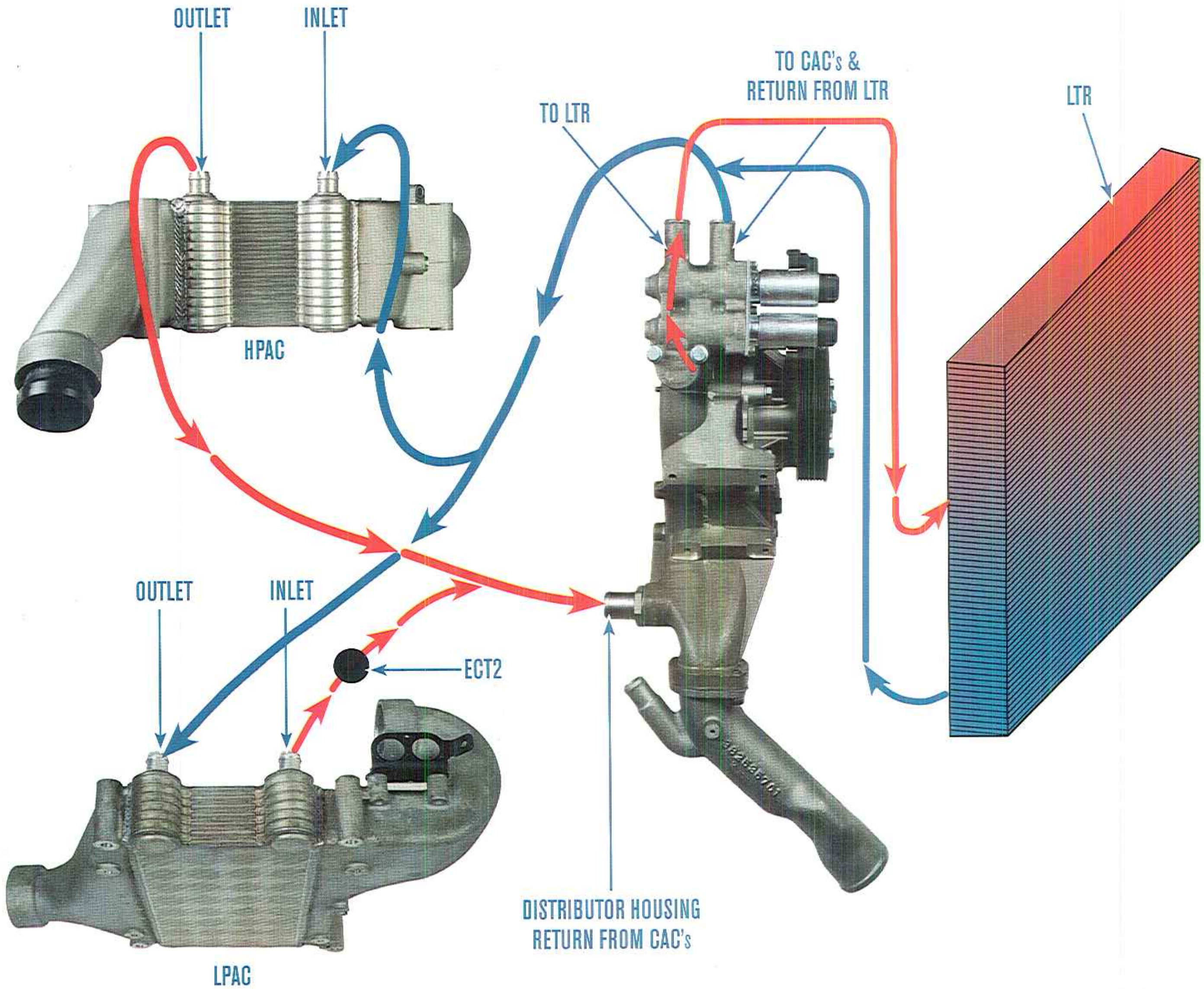
- The mixing valve in the CCV (Coolant Control Valve) assembly controls the percent of coolant flow through the LTR (Low Temperature Radiator). Coolant is always flowing through the two CAC (Charge-Air-Coolers) but the flow through the LTR is variable.

- At the start of production the flow control valve within the CCV regulated the flow through the coolers. After the start of production the action of the flow control valve was changed so that the valve always flows 100% through both coolers. This allows coolant to always flow to the CACs regardless of the temperature of the engine.

- Fresh coolant from the radiator is directed to the CCV via the water pump and an internal passage in the distributor housing. At low coolant temperatures, the mixing valve directs coolant to bypass the LTR and flow directly to both the high-pressure and low-pressure charge air coolers. Coolant that exits the coolers returns to the water pump via a connection on the back of the distributor housing

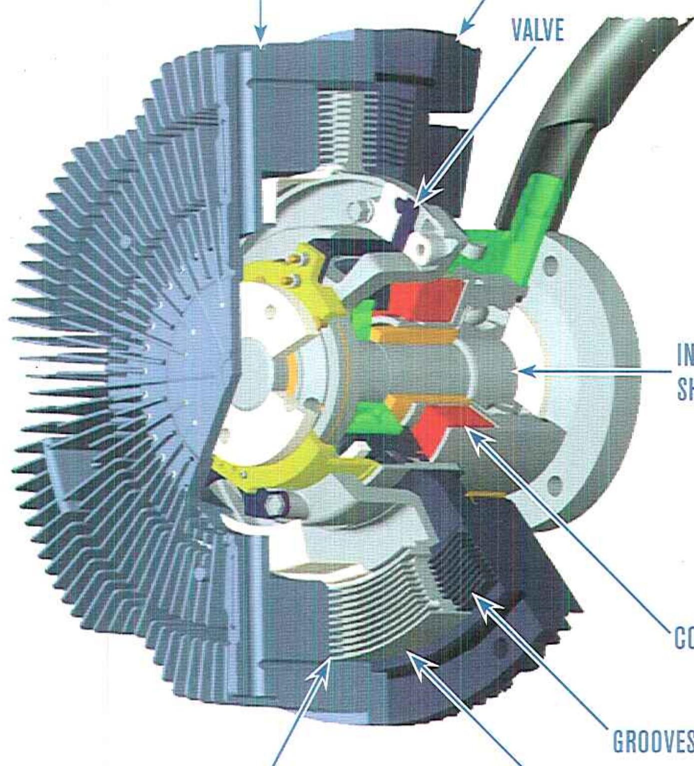
- The system flow will continue to bypass the LTR until the ECT2 sensor signal reaches a point where the ECM directs the mixing valve to change position.

BASE ENGINE: MECHANICAL, LUBRICATION, AND COOLING



Warm Engine

- The ECT2 sensor is located in the outlet coolant hose of the low-pressure charge-air-cooler. As the ECT2 sensor signal value increases, the ECM positions the mixing valve for proper CAC performance.
- When the engine is at operating temperature, the mixing valve will pass 100% of the CAC cooler flow through the LTR first. Passing the coolant through the LTR first will further reduce the coolant temperature. The lower temperature coolant then passes through the CAC's allowing the coolant to absorb the maximum amount of heat energy.
- After passing through the CAC, the hot coolant returns to the back of the distribution housing and then to the water pump for redistribution through the engine's cooling system.



Variable Electronic Fan

- Engines with a low-mount fan feature an EIM controlled variable speed viscous fan drive. Since the fan drive is gear driven on the low-mount application, the torque from the engine to the fan must be controlled when engaging the fan; the variable speed viscous feature allows for this torque control.

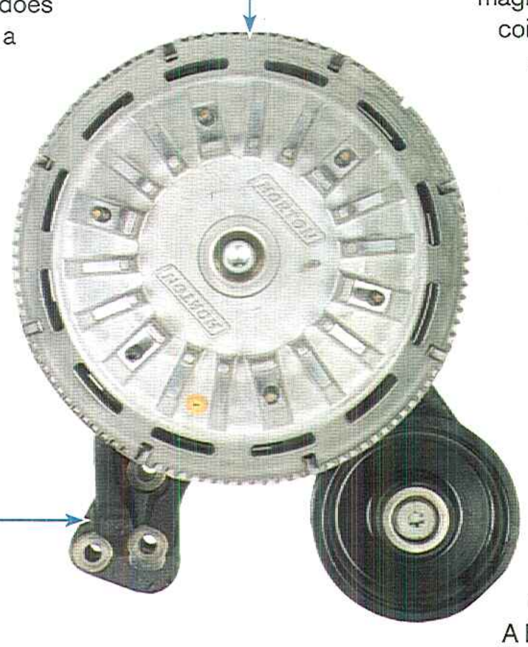
- The viscous fan drive consists of aluminum front and rear outer case halves that bolt together around an inner rotor. The inner rotor threads onto the spindle of the geared fan drive and is the point of torque input. Addition components are the input shaft, control valve, coil, and the speed sensor.

- The outer cases and the inner rotor both have a series of matching grooves that interlock together. While fitting closely together, the outer housing is free to rotate around the inner rotor. As oil is allowed to move from the reservoir and enter the space between the grooves, the friction between the two components increases. The amount of oil allowed to enter the groove area controls the rate of torque transmission from the input shaft to the outer case.

- A valve located on the inner rotor controls the oil flow from the reservoir area to the grooves. This valve is activated by an EIM powered magnetic coil mounted on the input shaft. The coil is mounted on a bearing and does not rotate with the fan. A hall-effect sensor internal to the coil assembly transmits a signal back to the EIM where fan speed is calculated. This allows the EIM to have direct variable control of the fan speed.
  - If more fan speed is required, a lower PWM signal is sent to the coil. The valve then opens and more oil enters the grooved area. If less fan speed is required, a higher PWM signal is sent, the valve closes, and oil drains from the grooved area. The default state of the variable fan is ON. A low PWM signal to the coil will result in a high torque transmission. A high PWM signal to the coil will result in low torque transmission.

High-Mount Fan Drive

- Some applications for the MaxxForce® 11 and 13 engines require a high-mount fan drive. This type of fan drive does not use the gear drive. Instead, a pulley is attached to the front of the vibration damper and a serpentine belt is used to drive the fan pulley. The high-mount uses an additional mounting bracket fastened to the front cover to increase the height of the fan pulley. This type of fan drive uses a pneumatic clutch.



ENGINE RETARDER

- ECM Controlled
- Pneumatic Powered Actuator
- Simplified Mechanical Components
- Reduced Noise Level

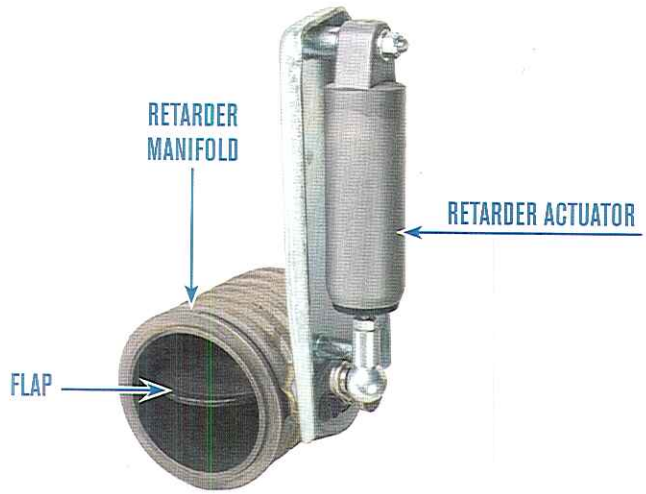
Features

- The MaxxForce® 11 and 13 engines feature an optional engine retarder. This optional feature provides braking assistance, with very little noise. This system uses the vehicle's air supply, exhaust flap and valve train components located under the valve cover to operate.

- The ECM monitors the exhaust back pressure and controls the engine retarder for proper braking performance.

Retarder Actuator

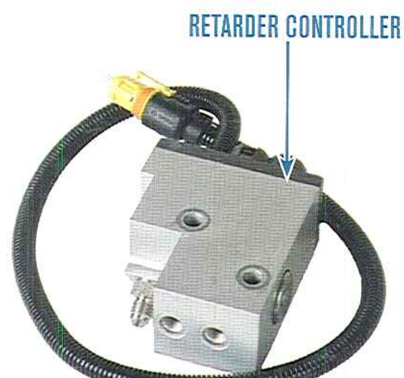
- The retarder actuator is a pneumatic cylinder that positions a butterfly valve or flap mounted in the retarder manifold. The flap is in the exhaust stream after the low pressure turbocharger outlet. When closed, the flap increases the exhaust back pressure and activates the brake mechanism in the exhaust valve bridge. The ECM closes the valve only when activating the engine brake.



Engine Retarder Controller

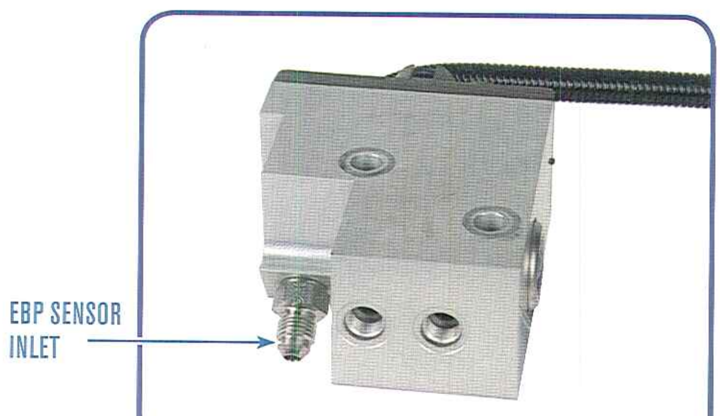
- The engine retarder controller is used to control the retarder actuator. The controller is mounted above the EGR cooler on the top right of the engine. The controller has two inputs: a signal from the ECM and air pressure from the vehicle's air supply. The ECM controls the retarder controller with a PWM signal. The retarder controller also contains an exhaust back pressure sensor. This sensor allows the ECM to command the controller to regulate the air pressure applied to the retarder actuator.

- When the retarder controller is activated, the retarder actuator restricts flow and increases exhaust back pressure. The increased back pressure activates the engine retarder. When the flap is opened, the back pressure is released and the exhaust valves return to normal operation.

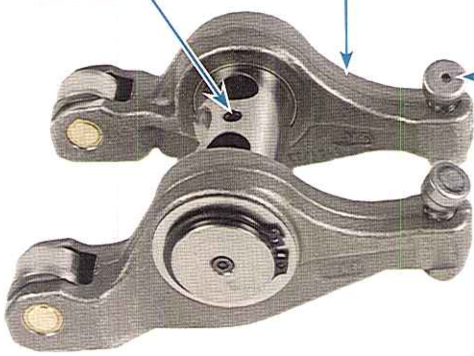


Exhaust Back Pressure Sensor

- The EBP (Exhaust Back Pressure) sensor is combined with the engine retarder controller. A steel line from the retarder manifold, allows the sensor to measure exhaust back pressure. The sensor provides feedback to the ECM on the effect of the flap position during retarder operation.



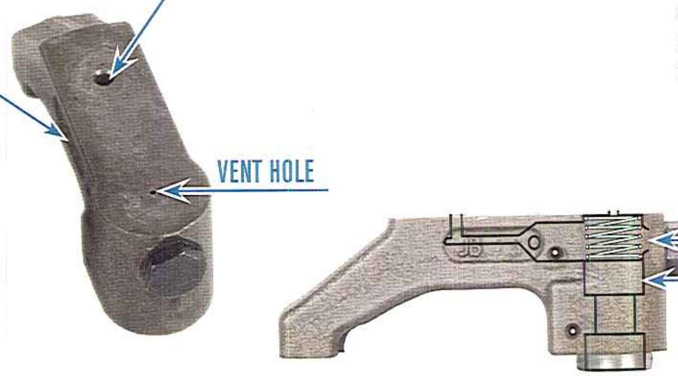
ENGINE RETARDER



(Rocker Arm Assembly Shown Upside Down)

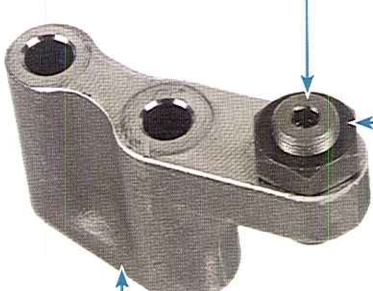
Exhaust Rocker Arm

- The exhaust rocker arm has a drilled oil passage that extends from the rocker shaft to the adjusting screw. The adjusting screw is also drilled from the swivel foot that contacts the valve bridge to a groove in the screw. The groove allows oil in the rocker arm to pass through the foot to reach a hole in the exhaust valve bridge.



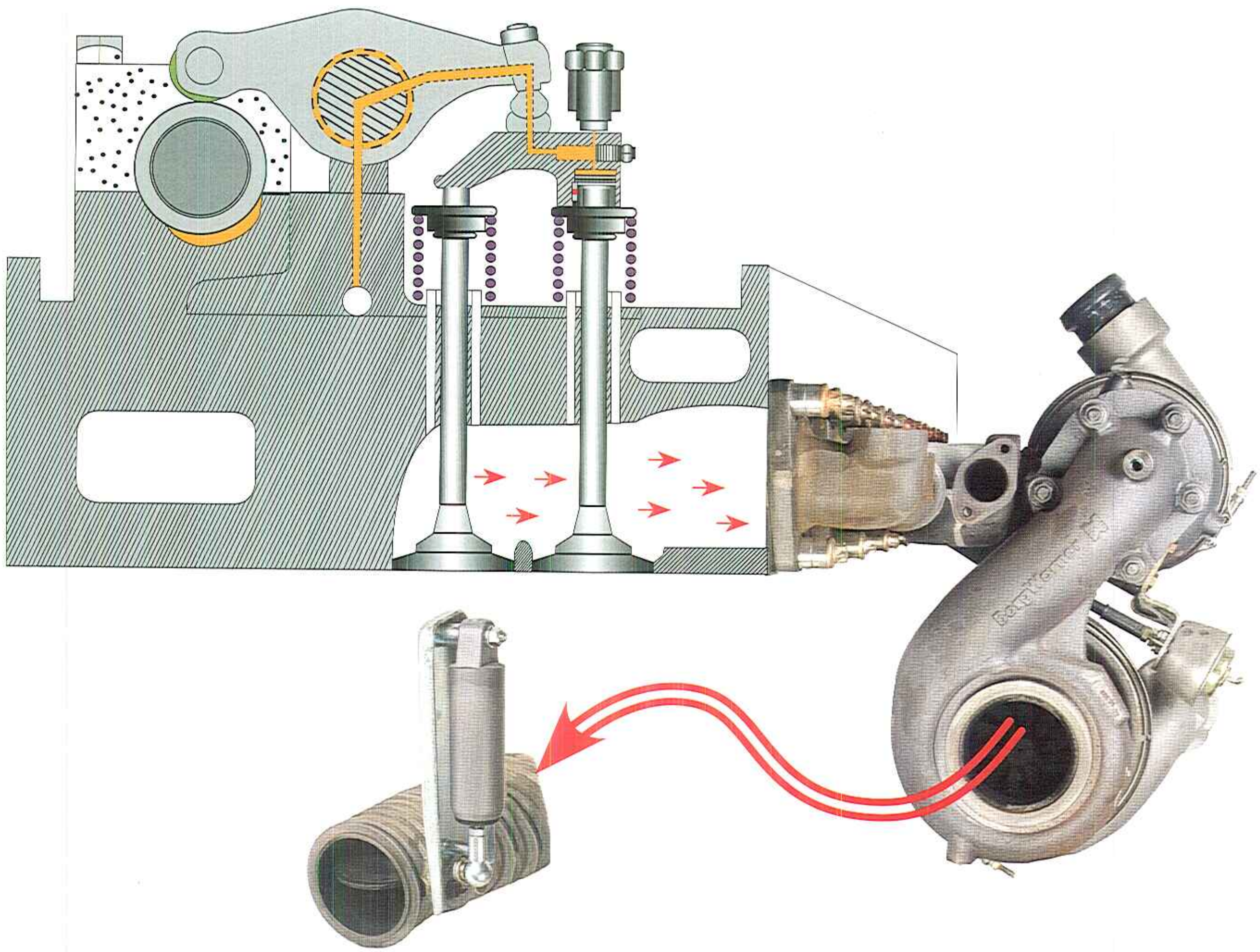
Exhaust Valve Bridge

- The exhaust valve bridge has a small spring loaded piston. When the engine is running, oil fed from the rocker arm fills the space above the piston. When the exhaust valves begin to open, a vent hole in the bridge allows the oil to escape.



Counterpiece

- The brake adjusting assembly consists of a cast iron counterpiece, adjusting stud, and locknut. The counterpiece positions the stud over the vent hole in the valve bridge. This stud must be adjusted whenever the exhaust valve clearance is set.



Engine Retarder Operation: Retarder On

- The ECM activates the engine retarder by signaling the retarder controller. The controller sends vehicle air pressure to the retarder actuator. The air pressure acts on the cylinder to close the flap and restrict the exhaust flow out of the turbos.

- The operation of the exhaust valves is the same as retarder-off until the valves close. At the end of the exhaust stroke, the high exhaust back pressure causes the exhaust valve and bridge piston to open slightly. Oil from the rocker arm fills the space above the piston and holds the valve open as long as the counterpiece covers the vent hole.

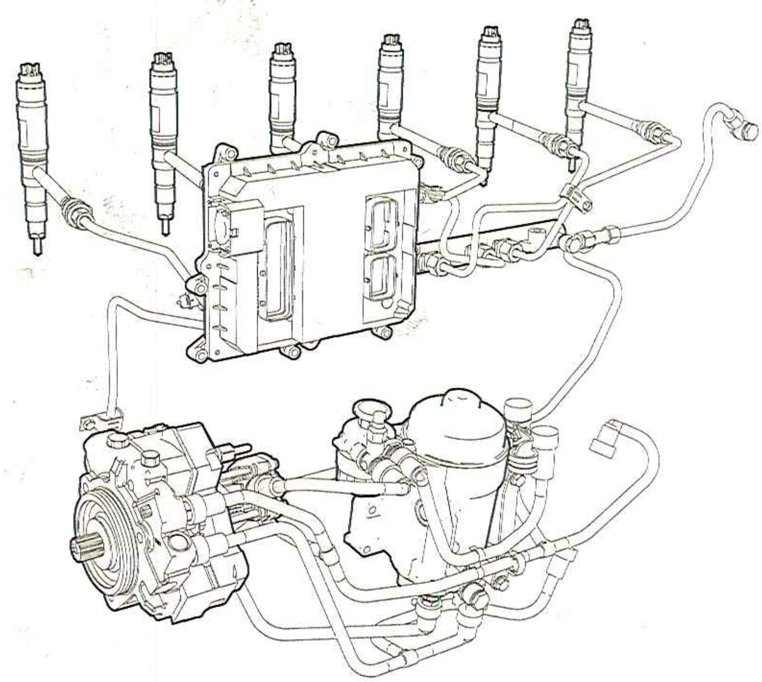
- With the valve off its seat by a few thousandths of an inch, compression still builds on the next compression stroke, but is vented quickly as the piston reaches the top of the compression stroke. When the camshaft opens the exhaust valves again, the oil above the piston vents as soon as the bridge is depressed. This allows the piston in the bridge to be pushed in and the valve then maintains proper valve-to-piston clearance.

Engine Retarder Operation: Retarder Off

- With the retarder off, the exhaust rocker arm feeds pressurized oil to a passage in the valve bridge. When the valves are closed, the oil pressure forces the piston to contact the valve stem and the bridge to contact the counterpiece stud. As the camshaft lobe pushes the rocker arm down, the exhaust valves begin to open. The bridge moves away from the counterpiece and the oil in the bridge is vented. The exhaust valves continue to open in the normal manner.

FUEL MANAGEMENT SYSTEM

- Bosch High-Pressure Common Rail
- Top Loaded Fuel Filter
- Hand Primer Pump
- Cold Start Assist

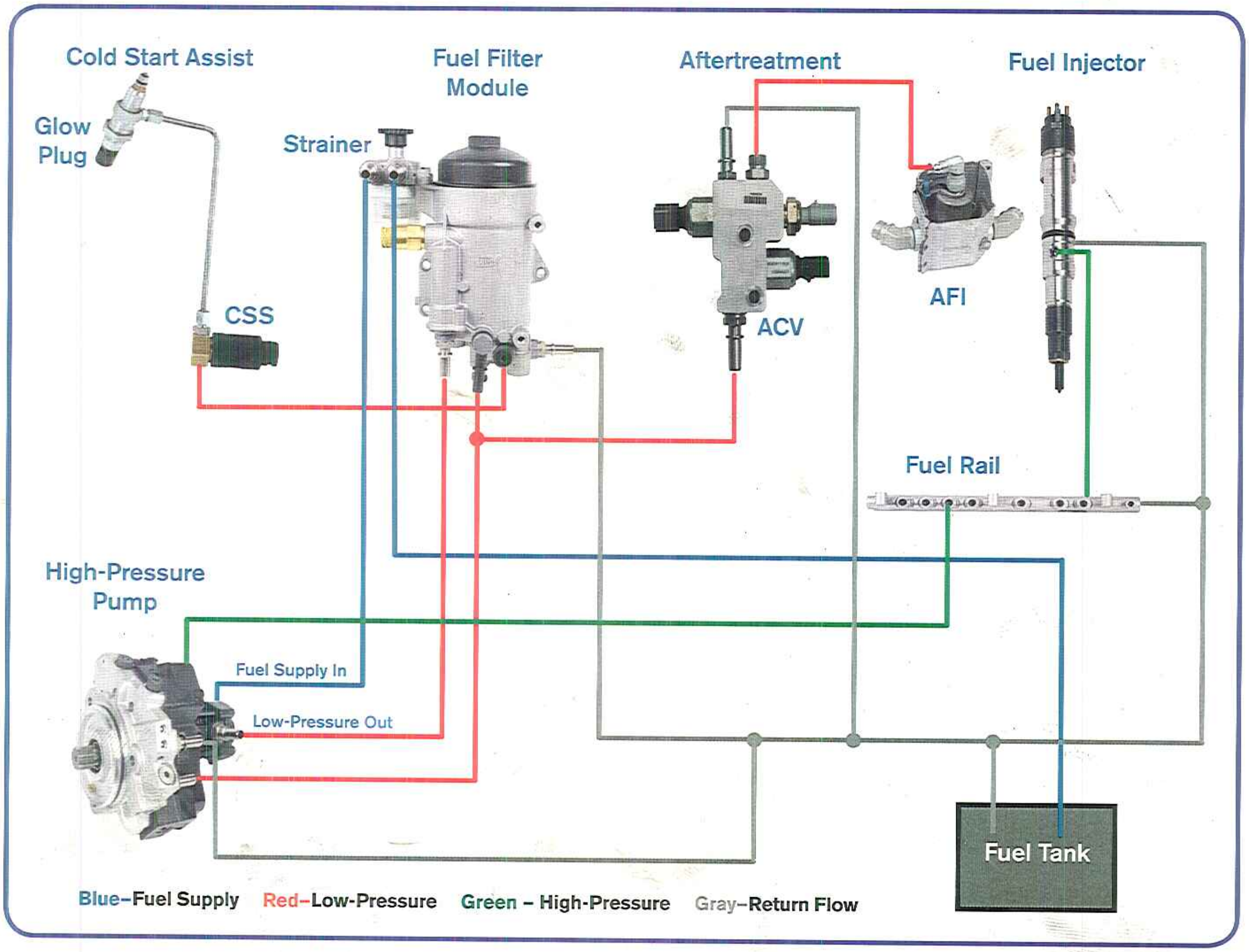


System Features

- The MaxxForce® 11 and 13 engines feature a Bosch high-pressure common rail fuel system. Fuel from the tank passes through two filters before entering the high-pressure pump. The strainer filter is mounted on the fuel filter module and contains a hand primer pump. The second filter is top loaded and is the main fuel filter element. Fuel from the high-pressure pump passes through steel lines to a common rail.

- Steel lines transfer fuel from the rail to the injectors. After passing through the system, return fuel passes through drillings in the cylinder head and to the return lines back to the fuel tank.

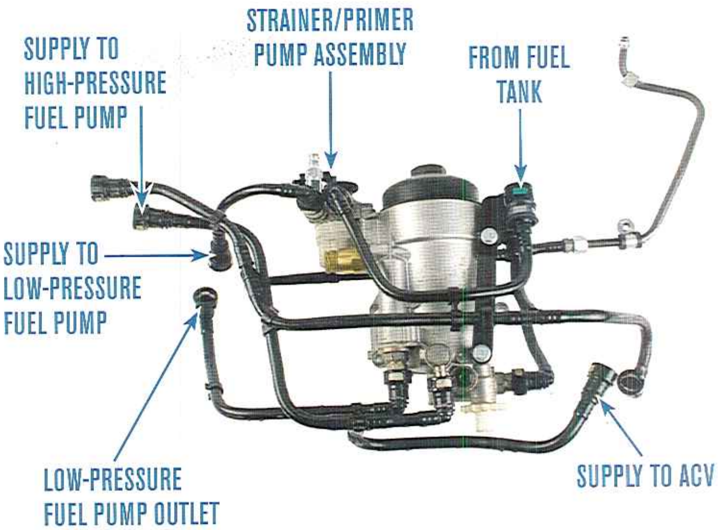
- The cold start assist option uses filtered low-pressure fuel to be vaporized in the aid of cold start conditions.



Fuel System Operation

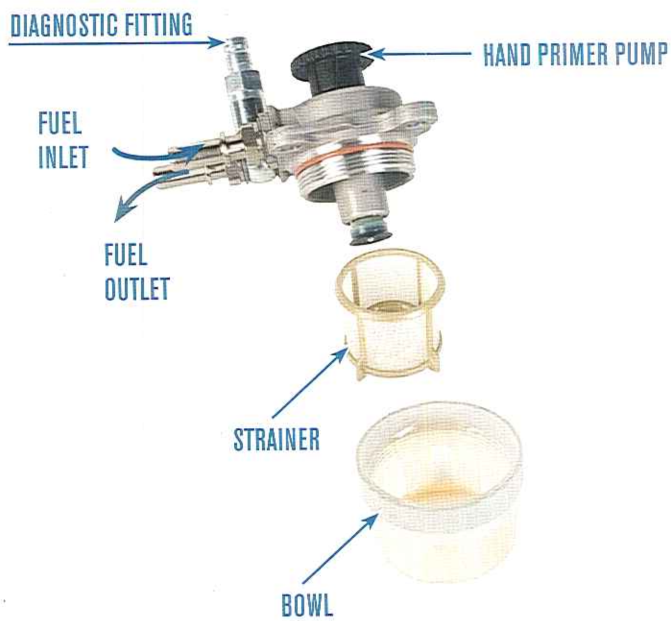
- Fuel is drawn from the tank through a fuel strainer element by a low-pressure fuel pump mounted on the high-pressure pump. Fuel flows from the low-pressure fuel pump through the fuel filter housing to the high-pressure pump. The high-pressure pump supplies fuel to the rail mounted to the cylinder head. Individual lines feed fuel from the rail to pressure pipes that deliver fuel to a port in the side of the injector.
- Fuel used to control the opening point of the injectors is collected within a passage in the cylinder head and returned to the tank.
- The ECM controls the fuel pressure with a PWM signal to the FPCV (Fuel Pressure Control Valve). Low pulse width PWM signals equal high pressure and high pulse width signals equal low pressure. To protect the system, a PLV (Pressure Limiting Valve) is installed in the end of the fuel rail. When pressure exceeds 1850 bar, the PLV opens and reduces pressure to 800 bar.
- The ACV (Aftertreatment Cut-off Valve) takes filtered fuel from the fuel filter module at supply pressure. The AFV controls the fuel flow to the Aftertreatment injector.
- Supply system pressure is regulated by a pressure regulator valve located in the supply pump. An orifice and an additional regulator located within the fuel filter module work together to reduce fuel pressure to 8 psi for the cold start system solenoid. Fuel relieved to achieve the pressure reduction joins return fuel from the cylinder head, the high pressure pump, and the ACV to return to the tank.
- The fuel system is controlled by the ECM. Various engine sensors are input into fueling calculations. The ECM then controls the FPCV and the injectors for proper engine operation. The ACM controls the AFI and ACV for regeneration, while the EIM controls the cold start solenoid.

FUEL MANAGEMENT SYSTEM



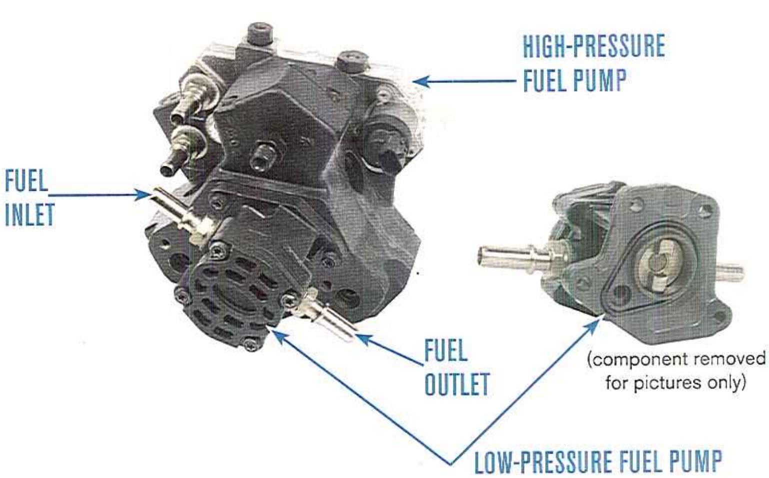
Fuel Supply Lines

- The fuel supply line comes from the tank to the strainer/primer pump assembly. Fuel in this section is on the suction-side of the system.
- Fuel flows from the strainer/primer pump to the low-pressure fuel pump under suction, unless the system is being primed. When priming the fuel system, this line has pressure.



Fuel Strainer/Primer Pump Assembly

- The fuel strainer/primer pump assembly is located on the fuel filter module assembly. Fuel flows through this assembly to the low-pressure fuel pump. On the inlet side of the primer pump, there is a check valve. When priming the system, this valve prevents pressurized fuel from entering the fuel tank
- The strainer consists of a clear plastic removable bowl, and a removable strainer filter. The strainer filter rating is 300 micron. Both components are serviceable.
- At the start of production the diagnostic fitting was located on the filtered side of the strainer. After the start of production the fitting was relocated to the non-filtered side of the fitting.

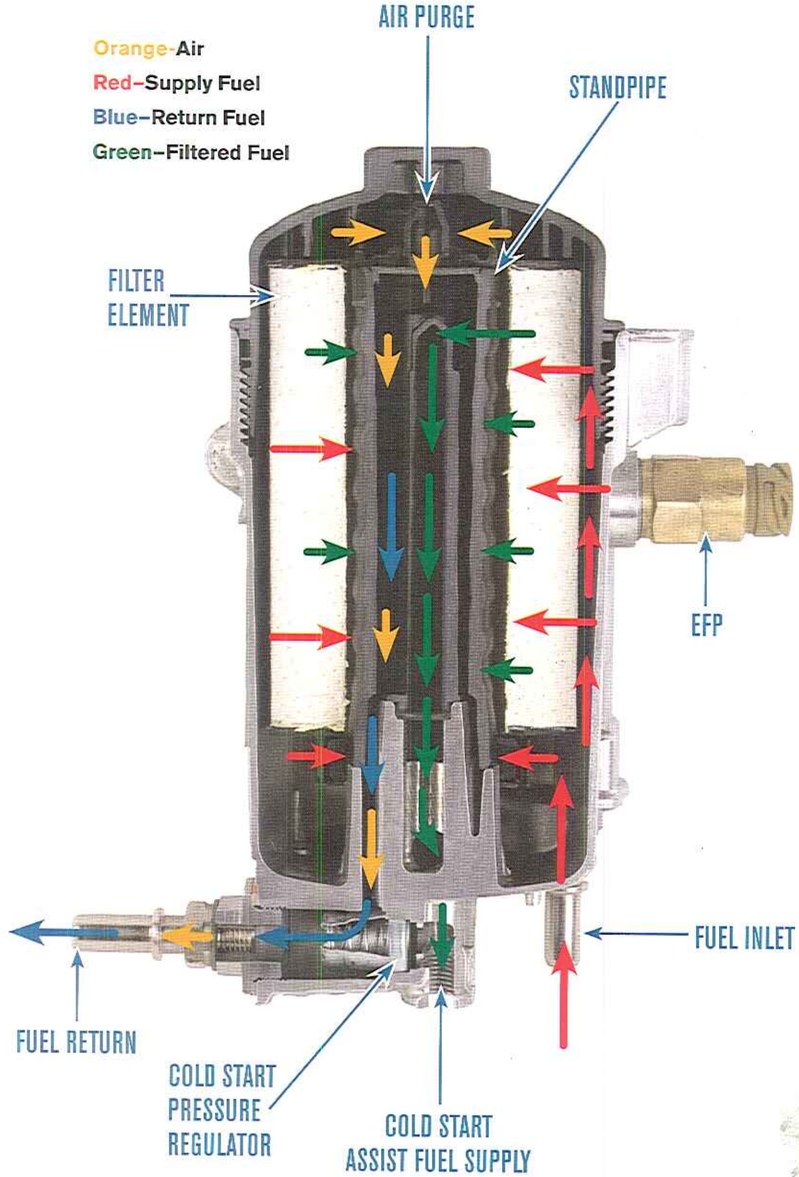


Low-Pressure Fuel Pump

- The low-pressure fuel pump is bolted to the high-pressure fuel pump on the left side of the engine. Driven by the high-pressure fuel pump, the low-pressure pump produces an internally regulated feed to the high-pressure system. The low-pressure fuel pump is serviced as part of the high-pressure fuel pump assembly.

Fuel Filter Module

- The fuel filter module mounts on the left side of the engine. Fuel flows through the fuel filter, to the high-pressure fuel pump, to the cold start solenoid and the Aftertreatment cut-off valve.
- The fuel filter is top loaded and is located in the filter module. The filter is accessed by removing the threaded cap. The filter is rated at 3-5 microns. A drain in the fuel filter housing allows water and dirty fuel to be removed prior to service.
- In addition, the air purge in the filter standpipe continuously directs a portion of the fuel and trapped air to the fuel return line.

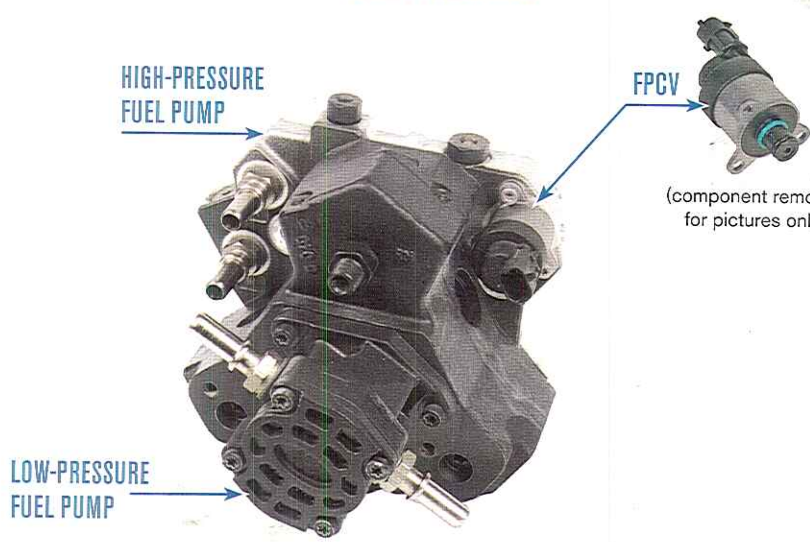


Engine Fuel Pressure Sensor

- The EFP (Engine Fuel Pressure) sensor is installed in the front of the fuel filter module. The sensor monitors fuel pressure on the unfiltered side of the system. It does not measure the pressure of the filtered side that feeds the high-pressure pump.
- The EFP sensor is used by the ECM to warn the operator of low fuel pressure and allow the ECM to determine when the fuel filter needs to be changed.

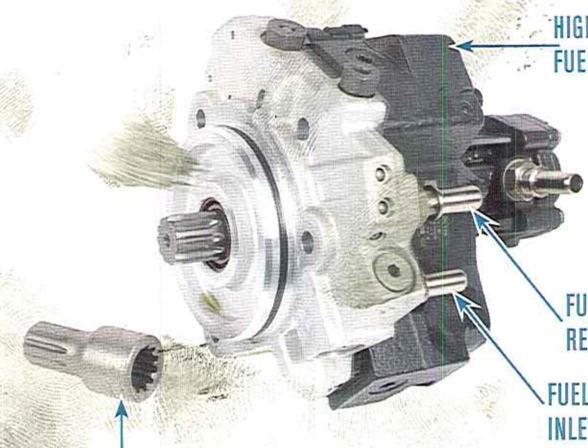
Fuel Pressure Control Valve

- The FPCV (Fuel Pressure Control Valve) is mounted on the high-pressure pump. This valve controls the fuel rail pressure by limiting the volume of fuel supplied to the inlet side of the pump. The FPCV constantly drains away fuel, which lubricates and cools the pump before it goes to the fuel return line.
- The FPCV is controlled by a PWM signal from the ECM. The higher the signal duty cycle, the lower the pressure in the rail. The lower the signal duty cycle, the higher the fuel pressure is in the rail.
- The ECM monitors the fuel rail pressure sensor to verify that its commands to the FPCV resulted in the desired changes in rail pressure.
- The FPCV is serviced as part of the high-pressure fuel pump assembly.



(component removed for pictures only)

FUEL MANAGEMENT SYSTEM

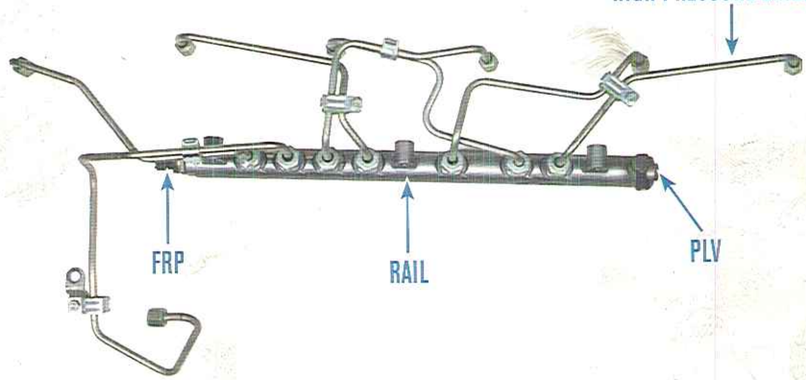


High-Pressure Fuel Pump

- The high-pressure fuel pump is bolted to the accessory drive housing on the left front of the engine. The accessory drive is driven by the front gear train; whenever the crankshaft is rotating, the fuel pump also rotates.
- The high-pressure fuel pump is a 3 cylinder radial piston fuel pump. In this application, the accessory drive is lubricated with engine oil, but the fuel pump is lubricated by the fuel. The fuel-lubricated pump creates up to 1,930 bar (28,000 psi) in the fuel rail.
- A single line from the high-pressure fuel pump feeds the fuel rail. Fuel lines are single-use only; they must be replaced when removed from the engine.

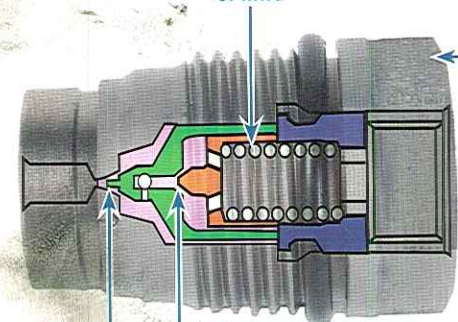
High-Pressure Fuel Rail

- The high-pressure fuel rail bolts to the cylinder head on the left side of the engine. High-pressure fuel accumulates in the rail to be supplied to the injectors.
- Six separate lines deliver fuel to the six fuel injector pressure pipes. Fuel lines and pressure pipes are single-use only; they must be replaced when removed from the engine. These lines are replaced in sets; there are three sets.
- The FRP (Fuel Rail Pressure) sensor threads into the front of the fuel rail assembly. It sends a signal based on pressure in the fuel rail to the ECM. This allows the ECM to monitor the pressure and vary the signal to the FPCV based on current pressures. This sensor can be replaced without replacing the entire fuel rail assembly.



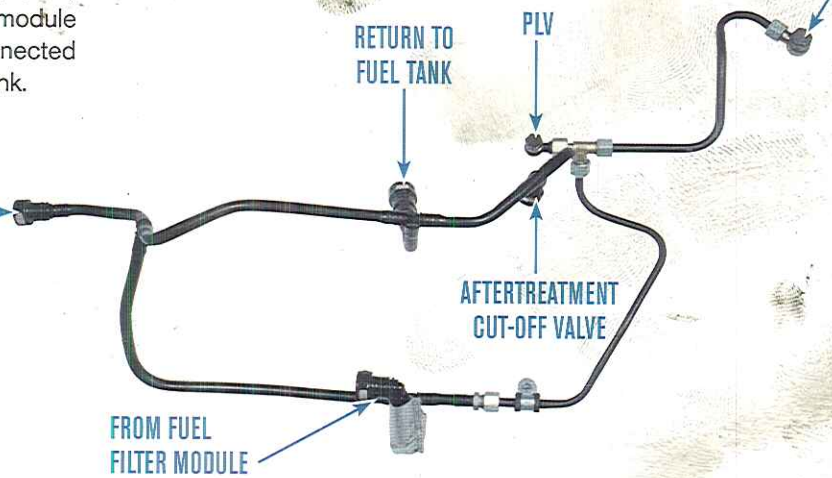
Pressure-Limiting Valve

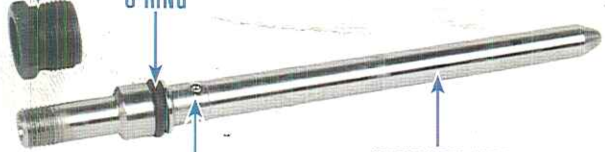
- The PLV (Pressure-Limiting Valve) is located on the end of the high-pressure fuel rail. This valve acts as a pressure relief valve if the fuel rail pressure exceeds 1,930 bar (28,000 psi). The PLV contains two pistons, which are held in place by a high-tension spring.
- The first piston moves to allow the pressure to push against a larger-diameter surface on the next piston. That piston moves, allowing a maximum fuel pressure of 800 bar 11,600 psi). The valve stays in this position until the engine is shut down and the valve resets. Excess fuel from the valve enters the return side of the system. This valve can be replaced without replacing the entire fuel rail assembly.



Fuel Return Lines

- Return fuel from the high-pressure pump, Aftertreatment cut-off valve, fuel injectors, pressure limiting valve, and fuel filter module returns to the fuel tank. This fuel is connected into one return line back to the fuel tank.





Fuel Pressure Pipe

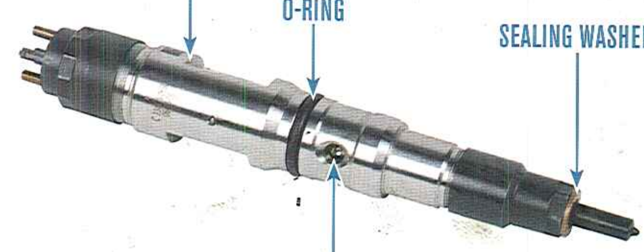
- The fuel pressure pipe connects the high-pressure fuel lines to the injectors. Each pipe is held in the cylinder head with a pressure pipe nut and provides a passage for the fuel to flow from the high-pressure fuel lines to the injectors. The end of the pressure pipe enters a small dimple in the side of the injector. When tightened, the pressure pipe is deformed to seal against the injector, keeping the high-pressure fuel from leaking.

- The fuel pressure pipe can be used only once, since it deforms during installation. The pressure pipe has two locating surfaces that must be in the vertical position for the pressure pipe to fully enter the cylinder head.

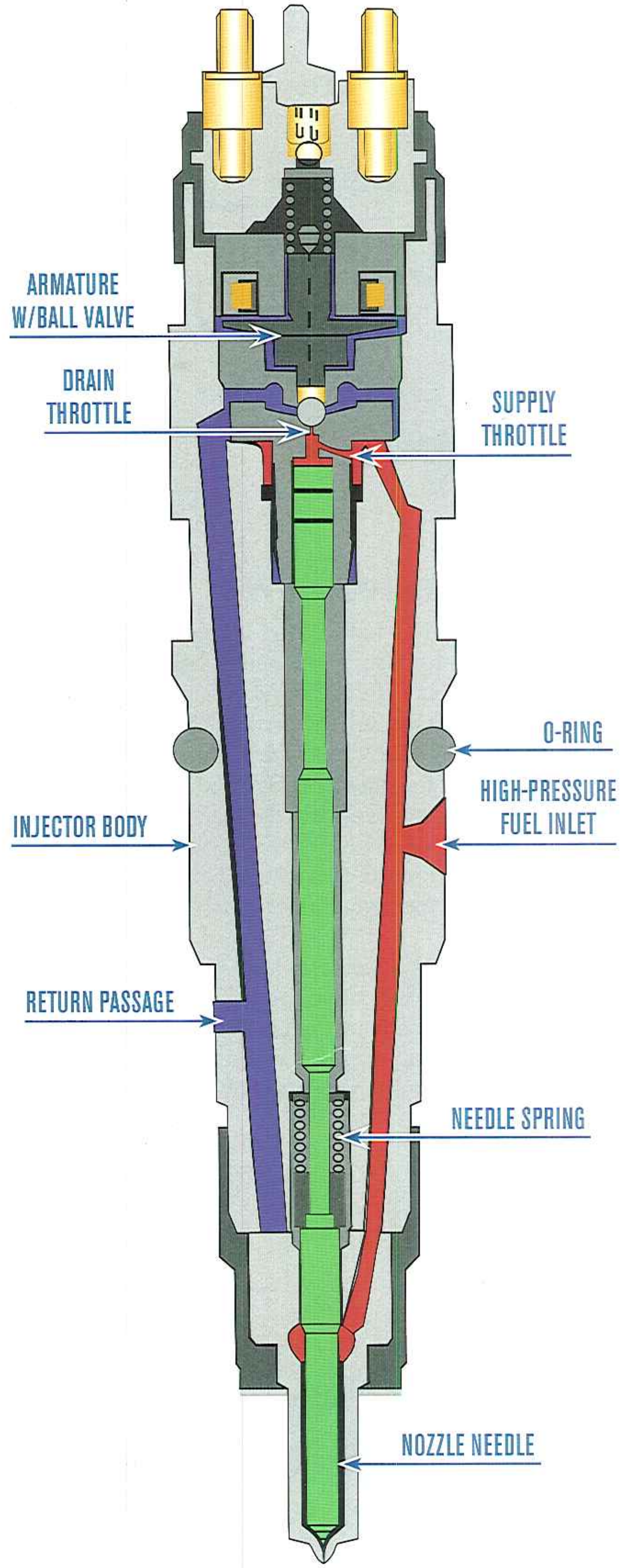
Injector Sealing

- Each injector has a single o-ring that seals the low-pressure return fuel within the lower part of the injector bore. Return fuel that exits the injector, enters the drilled passage in the cylinder head and reconnects to the fuel system through a banjo bolt at the back of the cylinder head. A sealing washer on the nozzle stops combustion gases from entering the return side of the fuel system. Each injector is held in place with a hold down clamp.

- Fuel lines and pressure pipes are single-use only; they must be replaced when removed from the engine.



FUEL MANAGEMENT SYSTEM



Magnetic Coil and Armature with Ball Valve

- Whenever the magnetic coil is energized, the armature and ball valve is lifted. The high-pressure fuel that is above the needle passes through the drain throttle to the fuel return passage. When the magnetic coil is not energized, a spring above the armature and ball valve closes the drain throttle.

Supply and Drain Throttle

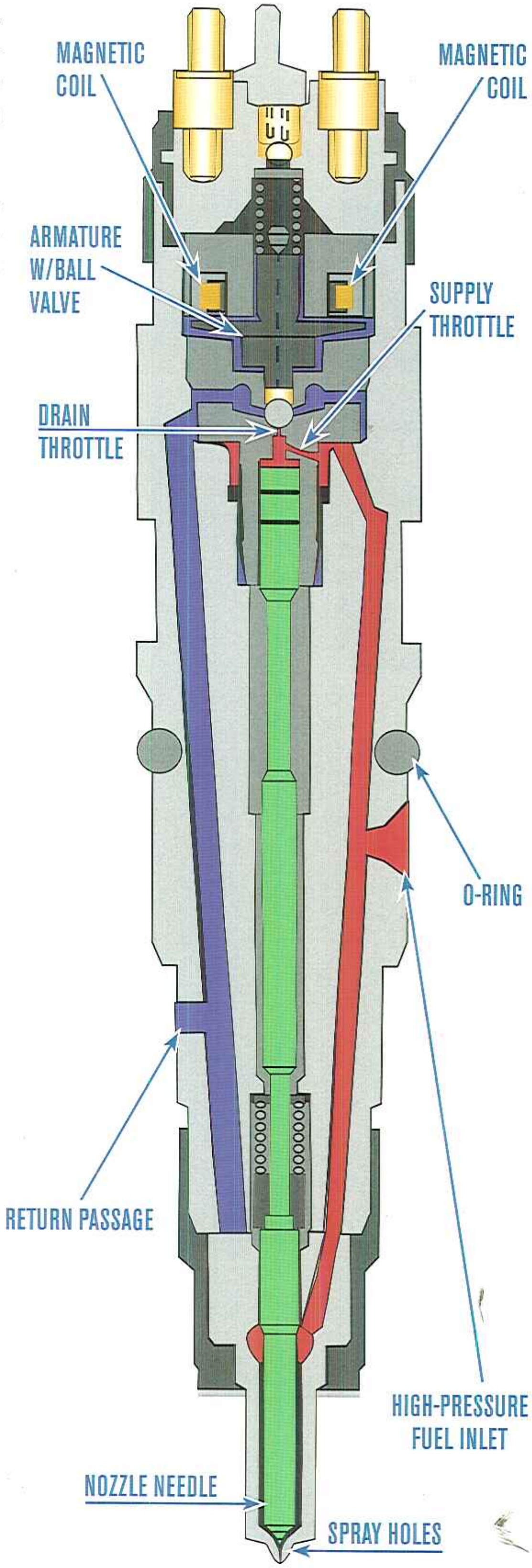
- With the ball valve closed, high-pressure fuel enters through the supply throttle above the needle. When the armature and ball valve is lifted, the drain throttle is opened draining that portion of the fuel. The pressure drop above the needle allows fuel that is pushing on the chamfer to lift the needle.

Nozzle Needle

- Fuel from the common rail enters the injector and surrounds the nozzle needle. The nozzle needle is an inwardly, opening-type which lifts off its seat every time the force on the needle bevel exceeds the force from the nozzle spring, plus the force acting on top of the needle. When the needle opens, fuel is atomized at high-pressure as it sprays through the nozzle tip's six spray holes.

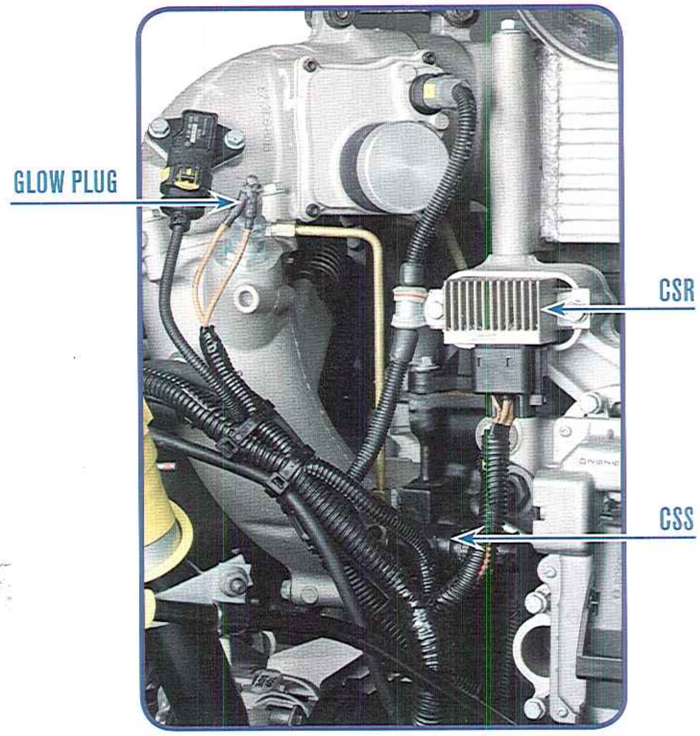
Fill Stage

- The fuel injector is constantly being filled with fuel via the high-pressure fuel pump during both the fill stage and the injection stage.
- In the fill stage, fuel from the pump enters the supply throttle and the area that surrounds the nozzle needle. The magnetic coil has no voltage applied during the fill stage. This makes the armature and ball valve placed in the closed position.
- With the armature and ball valve closed, fuel from the common rail enters the supply throttle. Pressure in the supply throttle equalizes with the pressure in the common rail.
- The surface area on the top of the needle is larger than the area of the bevel on the lower part of the needle. With fuel pressure in the supply throttle equal to the pressure around the needle, the force pushing down on the needle is greater than the upward force acting on the needle bevel. The nozzle needle is kept closed by the downward force and fuel cannot reach the nozzle spray holes.



Injection Stage

- When power is supplied to the magnetic coil, the armature and ball valve are lifted up. The drain throttle opens allowing a small amount of high-pressure fuel to enter the fuel return line passage, effectively dropping the pressure above the needle.
- The pressure drop is enough for the force on the nozzle needle to overcome the force from the supply throttle. This allows the nozzle needle to move upward, uncovering the six spray holes and allowing high-pressure fuel to atomize and enter the combustion chamber. When the ECM determines that injection should end, the voltage at the magnetic coil is removed. Without voltage applied, the spring above the armature forces the armature and ball valve down, sealing the drain throttle.
- With the ball valve closed, the fuel pressure above the needle from the supply throttle increases. When the downward force on top of the nozzle needle exceeds the upward force on the bevel, the needle closes and injection stops.
- The high-pressure fuel that is allowed to escape past the drain throttle enters into the fuel return passage. The fuel is routed down a drilled passage to the drain hole in the side of the injector just below the O-ring seal in the middle of the injector. The fuel is then routed through the cylinder head.



Cold Start Assist Operation

- The cold start assist system is located on the left front of the engine. This system is designed to heat the intake air to provide easier starting in cold-start conditions.

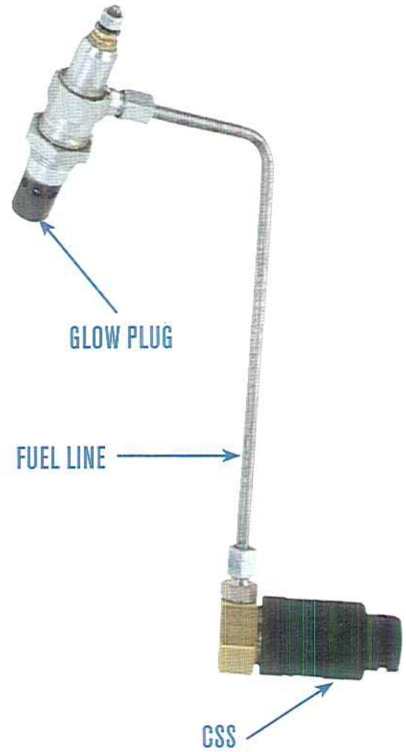
- The cold start assist system operates only if commanded by the EIM based on temperature and altitude inputs. When the operator turns the ignition key ON, the wait-to-start lamp in the instrument cluster illuminates. Based on barometric pressure, coolant temperature, oil temperature, and intake air temperature, the ECM determines if the cold start assist is required. If cold start assist is needed, the EIM activates the cold start relay. The relay then energizes the glow plug. Once the glow plug is heated, the wait-to-start lamp begins to flash, telling the operator to crank the engine. During cranking, the cold start solenoid opens and fuel dribbles on the glow plug. The fuel is vaporized by the heat of the glow plug and the solenoid will remain energized while the wait-to-start lamp is flashing. When the lamp is no longer illuminated, the operator can drive the vehicle.

Cold Start Solenoid and Fuel Lines

- The CSS (Cold Start Solenoid) is mounted to the air inlet duct on the left front of the engine. The CSS controls the fuel flow to the glow plug via a signal from the EIM.

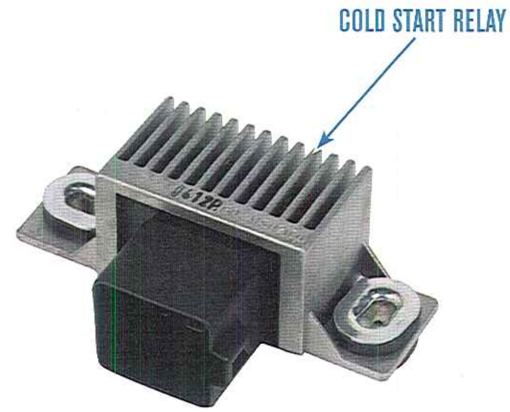
- CSS fuel is regulated by a 0.5mm orifice and a pressure relief valve located in the fuel filter module. The excess fuel that passes the valve is routed back to the fuel tank.

- The regulated pressure flows through a supply line to the cold start solenoid and on to the glow plug.



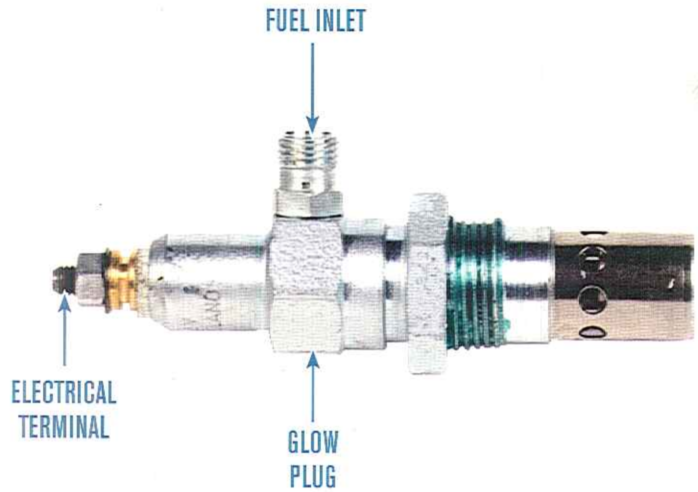
Cold Start Relay

- The CSR (Cold Start Relay) mounts on the ECM bracket on the left front of the engine. The CSR controls the output current to the glow plug via a command signal from the ECM.



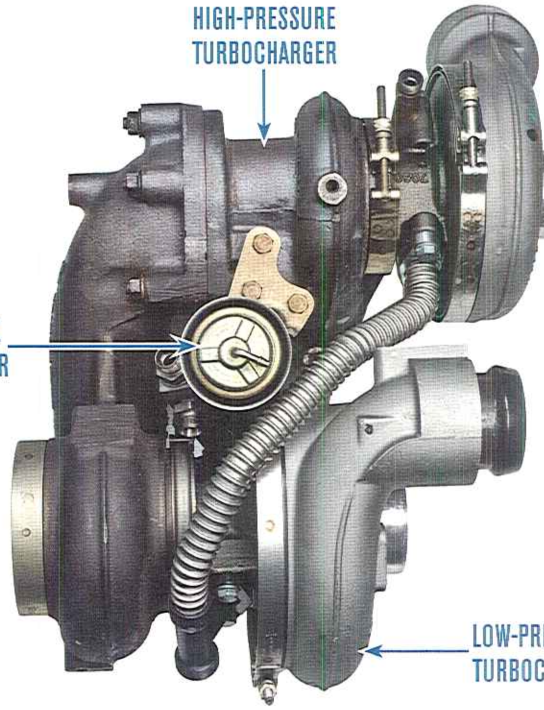
Glow Plug

- The glow plug mounts to the air inlet duct on the left front of the engine. The glow plug acts both as a glow plug and as a fuel injector for the fuel supplied to the cold start assist system.



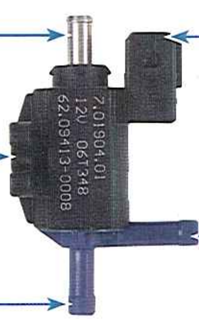
NOTES

AIR MANAGEMENT SYSTEM



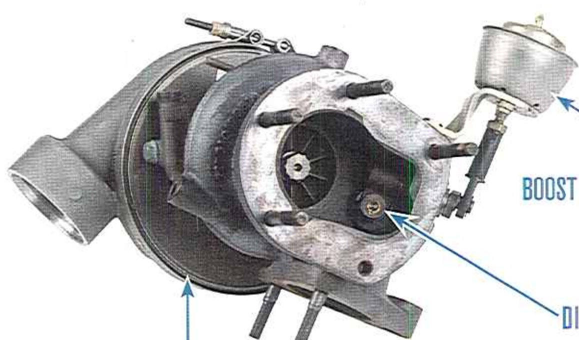
Turbochargers

- The high-pressure and low-pressure turbochargers are mounted to the exhaust manifold. The exhaust enters the turbine housing and exits to the low-pressure turbo. An ECM-controlled diverter valve in the high-pressure turbocharger allows a portion of the exhaust to bypass the high-pressure turbine and travel directly to the low-pressure turbo. The high-pressure turbo receives pressurized air from the low-pressure turbo, increases the pressure, and directs it to the high-pressure charge-air-cooler.



Boost Control Solenoid Valve

- The BCS (Boost Control Solenoid) valve indirectly controls the position of the diverter valve within the high-pressure turbo. The BCS is mounted to the top right of the engine. The BCS has two inputs: air pressure from the vehicle's air tanks, and a signal from the ECM.

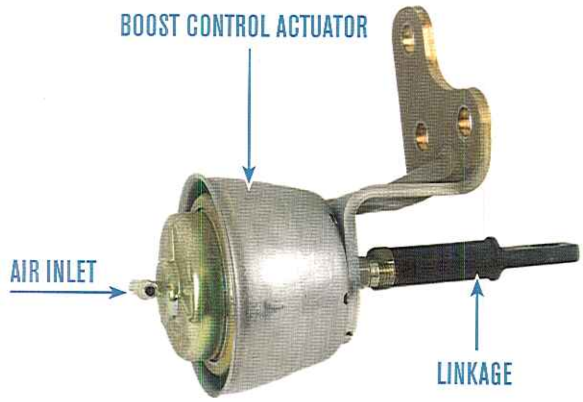


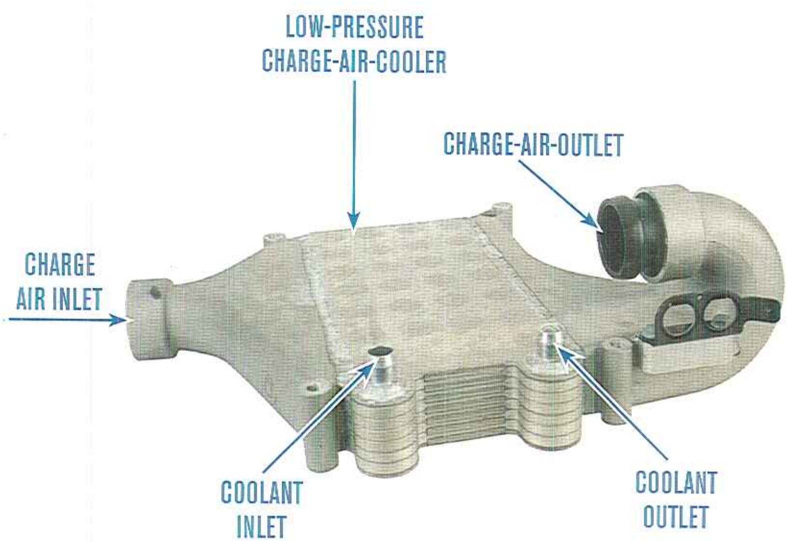
Boost Control

- The ECM controls the boost control solenoid valve. When the BCS is open, air pressure to the boost control actuator pushes the diverter valve open, bypassing a portion of the exhaust past the high-pressure turbine. When the ECM wants to close the diverter valve, the BCS closes and vents the actuator pressure to the atmosphere. The diverter valve spring pressure returns the diverter to the closed position.

The Boost Control Actuator

- The boost control actuator is pneumatic and is mounted to the turbocharger assembly. Linkage connects the actuator to the diverter valve in the high-pressure turbo. When air pressure from the BCS enters the actuator, the diverter valve is opened. The air pressure for this actuator must be regulated to 40–50 psi. However, the vehicle's air supply must be a minimum of 90 psi for this actuator to operate.



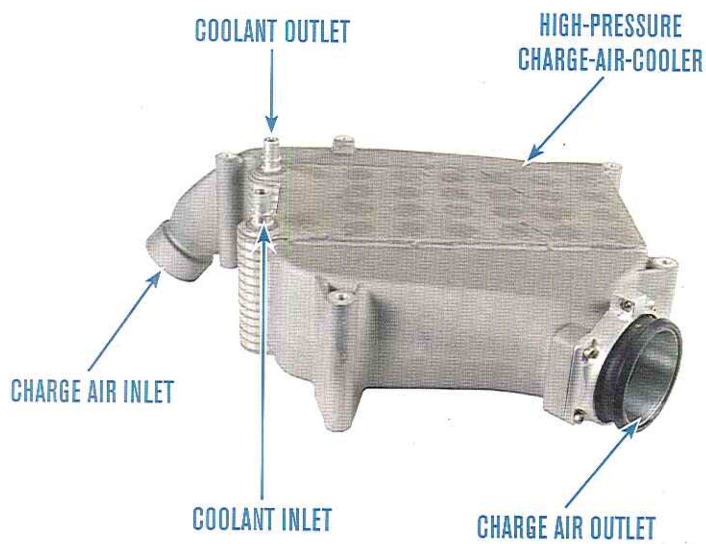


Low-Pressure Charge-Air-Cooler

- The LPCAC (Low-Pressure Charge-Air-Cooler) is mounted between the low-pressure and the high-pressure turbochargers on the right side of the engine. Charge air flows through the cooler releasing excess heat to the engine coolant.

High-Pressure Charge-Air-Cooler

- The HPCAC (High-Pressure Charge-Air-Cooler) is installed between the high-pressure turbo and the ITV (Intake Throttle Valve) above the valve cover. Charge air flows through the cooler releasing heat to the coolant before entering the air inlet duct.



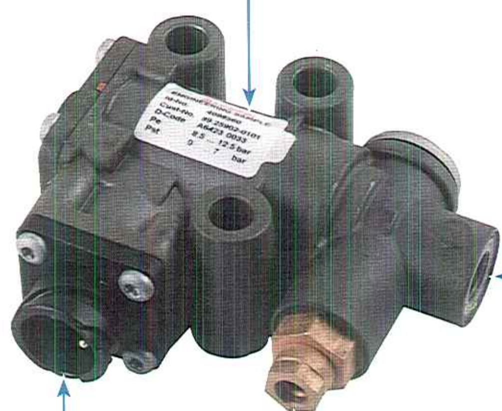
AIR MANAGEMENT SYSTEM

EGR Valve and Cooler

- The EGR (Exhaust Gas Recirculation) valve is mounted to the inlet of the EGR cooler. A control valve mounted to the cooler controls air pressure to the EGR actuator. The pneumatic cylinder moves a set of butterfly valves that control the flow of exhaust gases into the cooler.
- The EGR cooler is a heat exchanger that uses engine coolant to remove heat from the exhaust.

EGR Control Valve

- The EGR control valve is supplied with air pressure from the vehicle's air system. The valve receives a PWM (Pulse Width Modulated) signal from the ECM to open and allow pressurized air to the actuator. The ECM monitors the ELS (Exhaust Lamboda Sensor) to help determine what the EGR valve and ITV (Intake Throttle Valve) positions need to be.

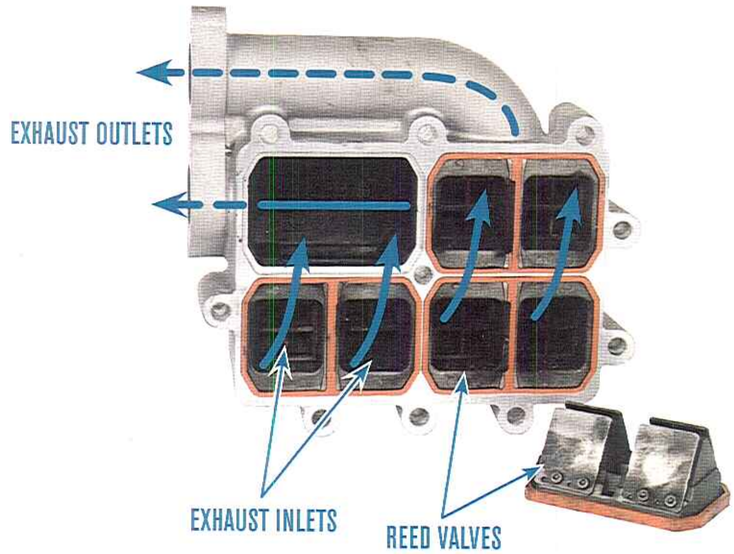


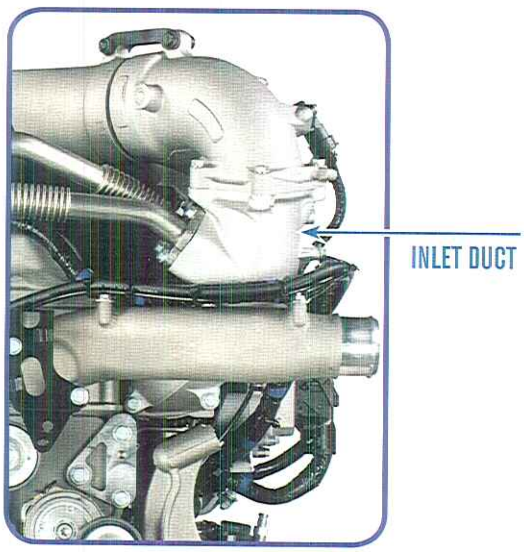
EGR Actuator and Position Sensor

- The EGR pneumatic actuator receives air pressure through the EGR control valve. When activated, the actuator opens the EGR butterfly valves. The EGRP (Exhaust Gas Recirculation Position) is a potentiometer sensor and is integral to the actuator and provides feedback to the ECM regarding the position of the actuator.
- The signal from the sensor allows the ECM to determine the air pressure required to maintain the proper position of the EGR valve.

EGR Reed Valves

- The EGR reed valves are located at the outlet of the EGR cooler. These valves are used to prevent backflow into the EGR cooler.
- The EGR reed valves are serviceable.



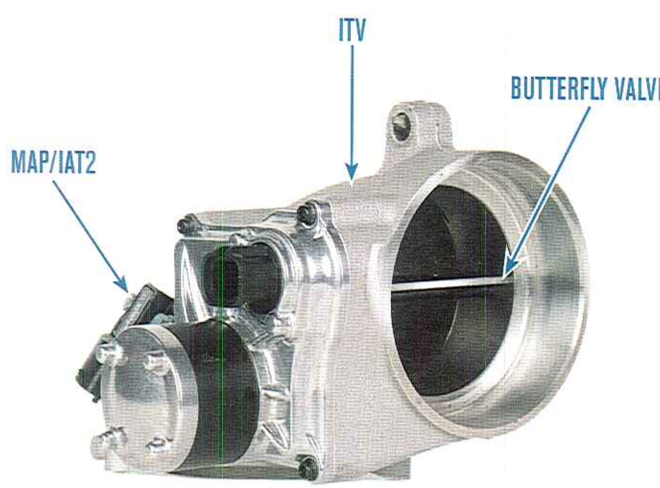


Air Inlet Duct

- The air inlet duct feeds air into the intake manifold. This is where EGR flow enters the intake system. The cold start glow plug is also mounted on the air inlet duct.

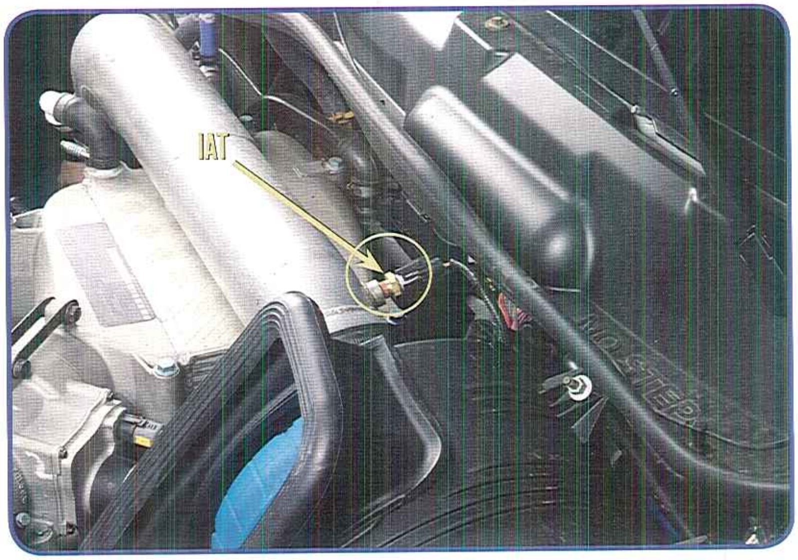
Intake Throttle Valve

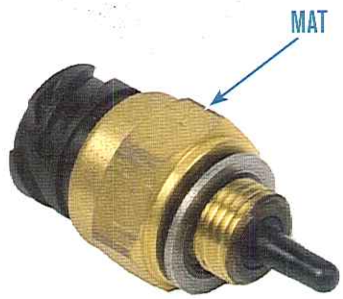
- The ITV (Intake Throttle Valve) is mounted on the air inlet duct on the top front of the engine. This has a variable-position actuator that moves a butterfly valve that restricts intake airflow. The ITV contains an internal position sensor that monitors valve position and transmits that signal to the ECM. The ITV changes butterfly valve position according to signals from the ECM control. Mounted on this component is also the MAP/IAT2 (Manifold Absolute Pressure/Intake Air Temperature 2) sensor.



Intake Air Temperature Sensor

- The IAT (Intake Air Temperature) sensor is located in the intake tube assembly. This tube connects the air filter housing to the low-pressure turbocharger inlet. The IAT sensor is an input to the engine interface module. The sensor's value is used in the control of injection timing and fuel rate during cold starts. The signal is also used as an input to control the EGR and the intake throttle position.





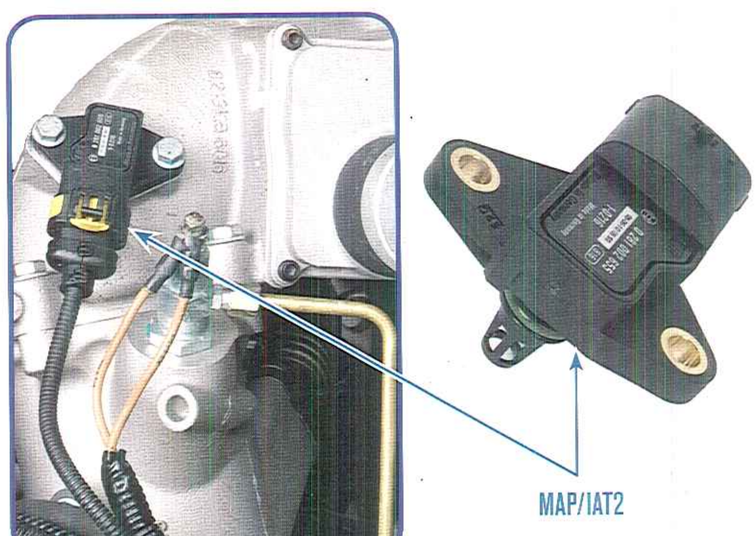
Manifold Air Temperature Sensor

- The MAT (Manifold Air Temperature) sensor is a thermistor that monitors EGR function and for operation of the cold start assist system. This sensor is installed in the intake channel of the cylinder head and is located just to the rear of the ECM, below the point where the injector harness enters the cylinder head. Certain temperature conditions cause the EGR to shut down to prevent sulphurous acids from condensing under cold charge air temperatures. This EGR shutdown also protects the engine from excessively hot intake air when an EGR fault occurs.

Manifold Absolute Pressure/Intake Air Temperature 2 Sensor

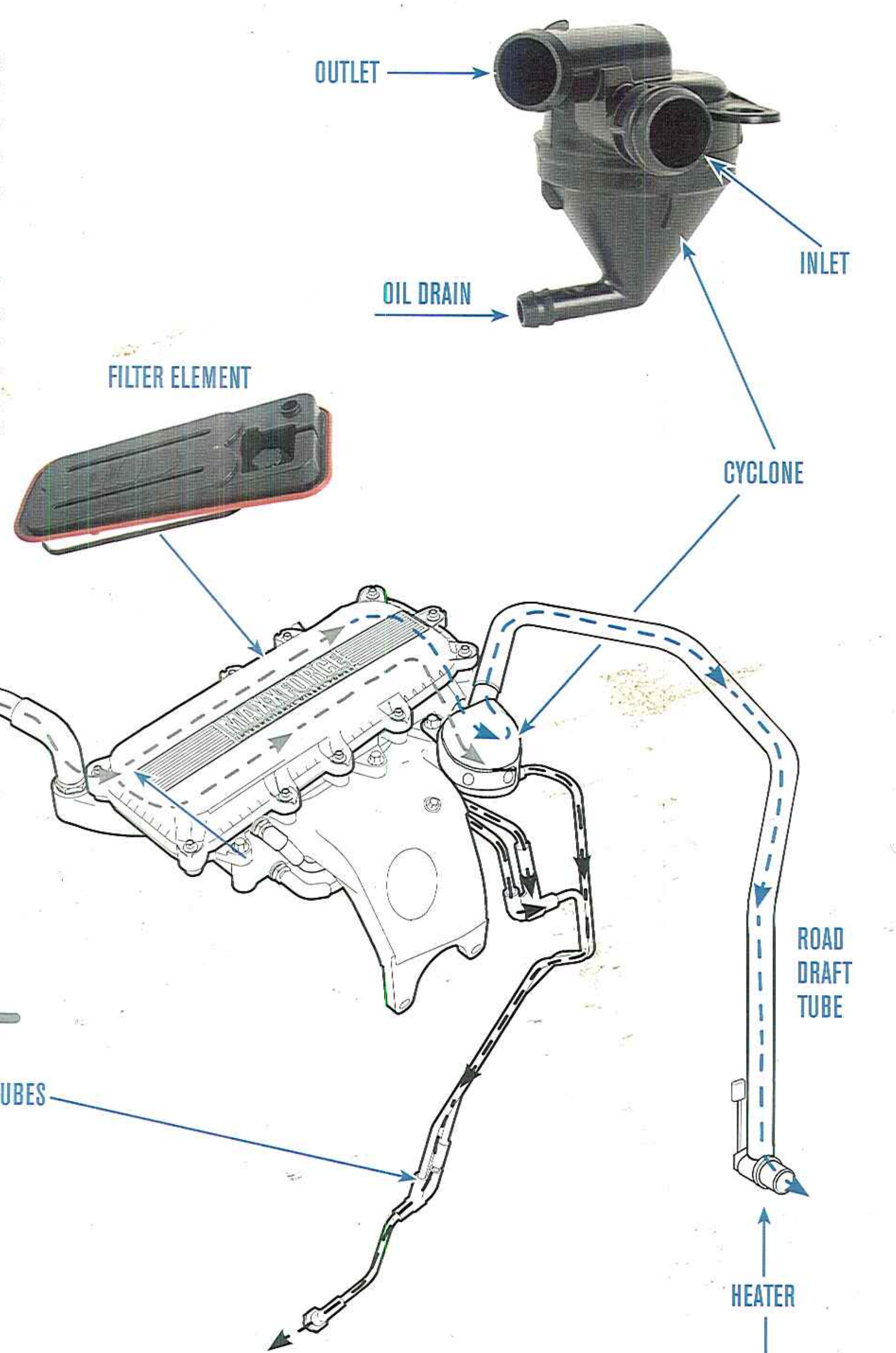
- The IAT2 (Intake Air Temperature 2) sensor is combined with the Manifold Absolute Pressure sensor. The combined sensor is mounted to the left of the inlet throttle valve on the intake elbow. This elbow directs the charge air from the turbochargers and the exhaust from the EGR cooler to the intake manifold. The IAT2 measures the temperature of the charge air before it is mixed with the EGR gases.

- The MAP (Manifold Absolute Pressure) sensor is used to measure the absolute charge air (boost) pressure. The ECM uses this data to control boost pressure and EGR operation based on pre-programmed parameters.



Crankcase Breather Operation

- The MaxxForce® 11 and MaxxForce 13 breather system consists of a cyclone, oil drain tubes, check valves, serviceable filter and a heater element. Crankcase gases generated by combustion are filtered, and released back to the atmosphere.
- As crankcase gases are generated, they must be separated and disposed of. The crankcase gases are routed and flow through a portion of the oil filter/cooler module. The gases flow up to the serviceable filter. This filter will separate most of the oil from the gases and drain the oil back to the crankcase. The gases then flow to the breather cyclone.

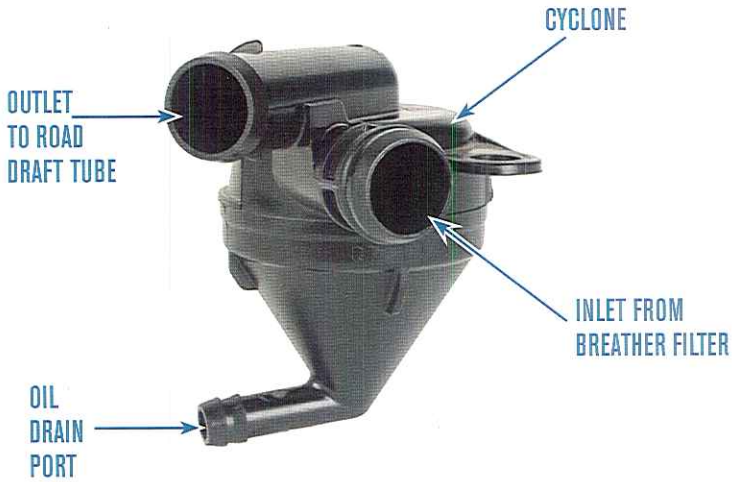


Black	=	Oil
Blue	=	Separated Gases
Grey	=	Un-Separated Gases

Breather Oil Drain Tubes

- The oil drain tubes direct the oil that has been separated from the crankcase gases back to the crankcase. These tubes are connected to the bottom of the cyclone, and the filter assembly.
- The check valves are located in the oil drain tubes. These valves prevent crankcase gases going up through these tubes. If this was to happen, the gases and oil would not be separated and oil would leak out of the road draft tube.

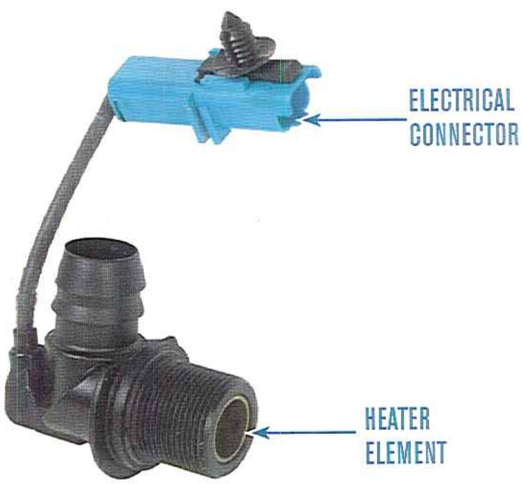
AIR MANAGEMENT SYSTEM



Cyclone Oil Separator

- The cyclone helps spin out the fine oil mist from the crankcase gases before the gases are released to the atmosphere. There is an oil drain tube located at the bottom of the cyclone to drain the separated oil back to the crankcase.

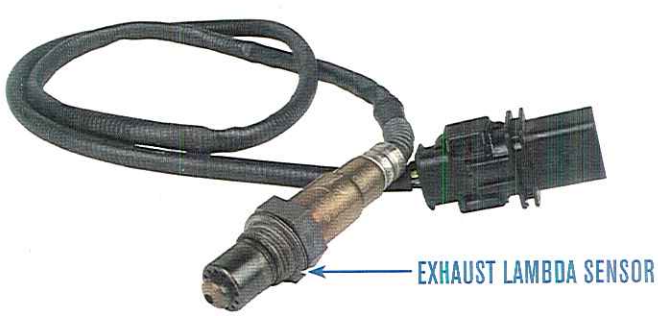
- The gases are then routed to the road draft tube and released to the atmosphere.



Heater Element

- The heater element is located at the opening of the road draft tube. This is used to prevent moisture in the crankcase gases from freezing at the outlet of the road draft tube.

- The heater element receives power from Chassis harness connector C Pin-21 and a ground from Pin-7 of the same connector. Pin-21 is the VIGN circuit, the heater has power whenever the ignition key-switch is in the On position.



Exhaust Lambda Sensor

- The ELS (exhaust Lambda Sensor) is used to monitor the oxygen level of the exhaust gases. The ELS is installed in the exhaust pipe in front of the Aftertreatment fuel injector. The ceramic material used in the construction of the ELS acts as an insulator when cold, but a semi-conductor when at operating temperatures. The ELS has a heater element that heats the sensor to its normal operating temperature of 780°C (1,436°F). During initial engine warm-up the ELS heater element is activated only after the engine coolant reaches 40°C (104°F) and the exhaust gas temperature exceeds 100°C (212°F) for more than 30 seconds. The EGR system operates in open loop until the ELS becomes active.

Exhaust Lambda Sensor

- The ELS (Exhaust Lambda Sensor) is installed in the turbo exhaust pipe. The ELS is a wide band oxygen sensor that determines the oxygen levels in the exhaust gases. The ECM uses the ELS value to position the EGR valve.

Lambda = 1

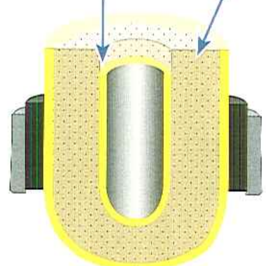
- To achieve complete combustion, a pound of diesel fuel requires 14.7 pounds of air. This ideal ratio is known as stoichiometric. The ratio of the actual mixture in the cylinder when compared to stoichiometric is known as Lambda, or λ. When the ratio is ideal, it is said that $\lambda = 1$.

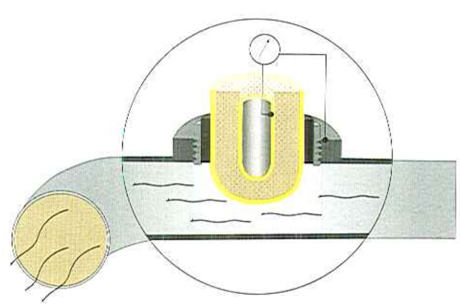
- The diesel engine normally operates in the range of $\lambda = 1.3$ to $\lambda = 10$. Lambda = 1.3 occurs when the engine is making maximum power with maximum fuel. Lambda = 10 at idle where the mixture is very lean. These numbers indicate that diesel combustion always has an excess amount of air.

EGR Effect on Fuel Ratios

- Adding EGR affects the air-fuel ratio in the cylinder and the amount of excess oxygen in the exhaust. This occurs because the recirculated exhaust displaces air (20% oxygen) in the cylinder. With more EGR and less air, the exhaust will have less oxygen content. This allows the lambda sensor to be used to monitor the EGR system.

- Ideal EGR rates are calculated and programmed into the ECM. Then the lambda sensor detects the oxygen level in the exhaust stream and the ECM adjusts the Air-Fuel-EGR mixture by adding or subtracting from the EGR flow.





Basic O_2 Sensor Cell Operation

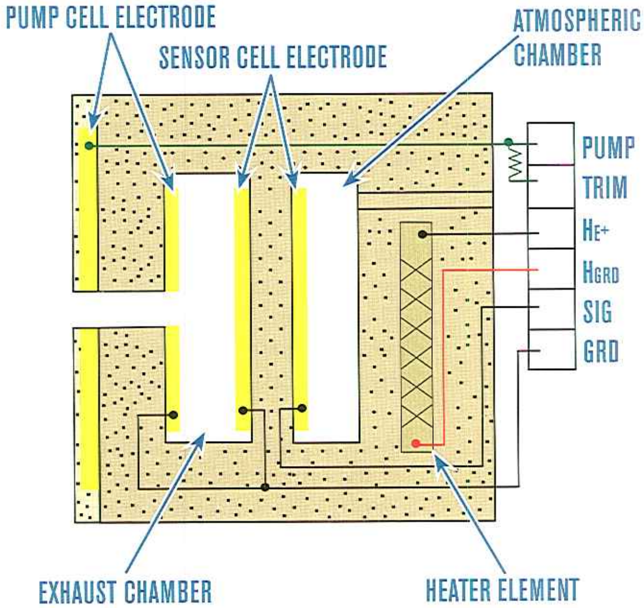
- The easiest way to understand how an Oxygen Sensor works is to compare it to a lead-acid truck battery. In a truck battery, there are two electrodes; one electrode is made of lead the other electrode is made of lead dioxide. Both electrodes are suspended in a sulfuric acid and water electrolyte. During operation, when a load is placed across the two electrodes, electrons pass from one electrode through the electrolyte to the other electrode. This creates a voltage.

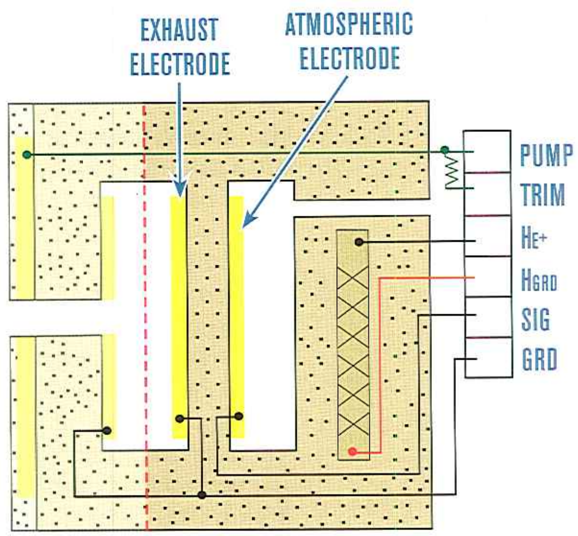
- In an O_2 sensor, the electrodes are made of porous platinum while the electrolyte is a solid ceramic material. In operation, the oxygen in the engine's exhaust is exposed to the exhaust side electrode and a sample of the atmosphere is exposed to the other electrode. The level of oxygen in the air on the atmospheric side is approximately 20%, while the oxygen level in the exhaust depends upon the O_2 consumed in the cylinder during to combustion.

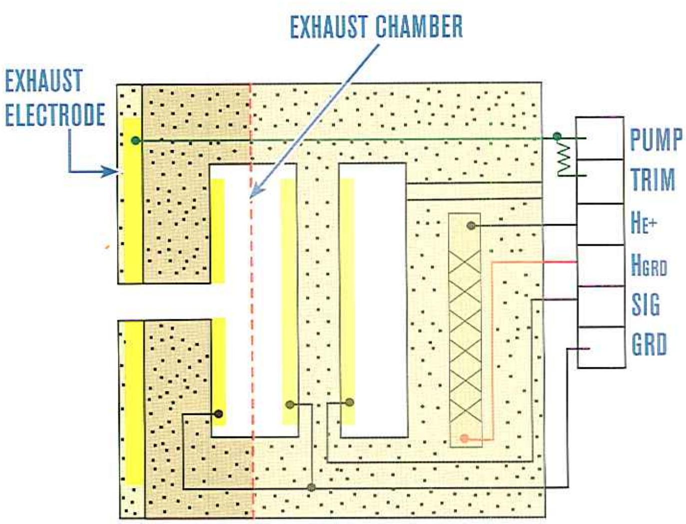
- With the engine running, a difference in oxygen level will exist between the exhaust side electrode and the atmospheric side electrode. With the O_2 sensor's ceramic material at operating temperatures, this difference causes oxygen ions to flow through the ceramic electrolyte, producing a voltage.

- Voltages produced by the O_2 sensor are affected by the amount of oxygen in the exhaust. Mixtures with very little excess oxygen result in low oxygen levels on the exhaust side electrode and create about 1,000 millivolts in the O_2 sensor circuit. Mixtures with a large excess level of oxygen result in high oxygen levels on the exhaust side electrode and create about 100 millivolts.

- The ECM measures the sensor's signal voltage and determines if the mixture was rich (uses all the oxygen during combustion) or lean (excess oxygen passes through the cylinder to the exhaust system).







Lambda Sensor Construction

- O_2 sensors used in most engines have the ability to detect rich mixtures or lean mixtures, but not the actual air-fuel ratio. The O_2 sensor used in the MaxxForce® 11 and 13 engines is a wide-band sensor that can detect the degree of lean and rich. This allows the ECM to calculate the lambda value and adjust the EGR flow accordingly.

- Lambda sensors are constructed of two O_2 sensor cells. The lambda sensor has a sensor cell, a pump cell, an exhaust chamber, heater element, and an atmospheric chamber. The sensor cell is used to compare engine's exhaust to an atmospheric sample. The pump cell and sensor cell work together to detect the exact level of O_2 in the exhaust.

- The lambda sensor has six wires: Pump current, Trim, GRD, Signal, Heater B+, and Heater GRD.

Sensor Cell

- The exhaust chamber constantly receives exhaust from the cylinders. The sensor cell reacts to the exhaust sample and produces a voltage based off the sample's oxygen content. If the sample has excessive oxygen, a low voltage signal is produced. If the exhaust has insufficient oxygen, a higher voltage signal is produced.

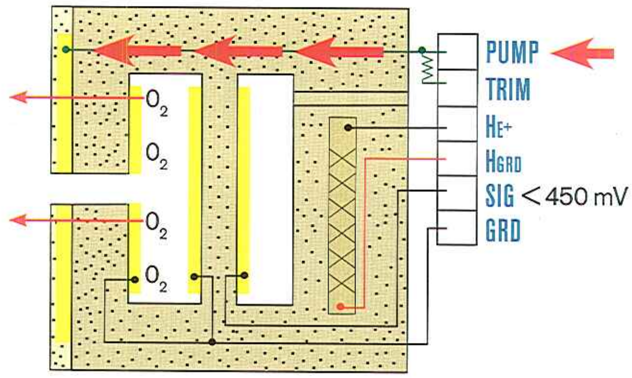
Pump Cell

- The pump cell's construction is similar to the sensor cell. But the pump cell is utilized in the opposite way. The ECM applies a voltage to the pump cell electrode. The voltage causes the cell to transport oxygen from one electrode to the other. By reversing the polarity of the current, the oxygen flow between the electrodes can be reversed.

- The ECM strategy is to keep $\lambda = 1$ in the sample chamber. During normal diesel operation the engine always runs with an excess amount of air in the cylinders. So the Lambda sensor is used by the ECM to determine how much of the excess air is being displaced by EGR. Adding too little EGR could mean the engine is no longer meeting emissions. Adding too much EGR could displace the oxygen in the cylinder required to achieve complete combustion.

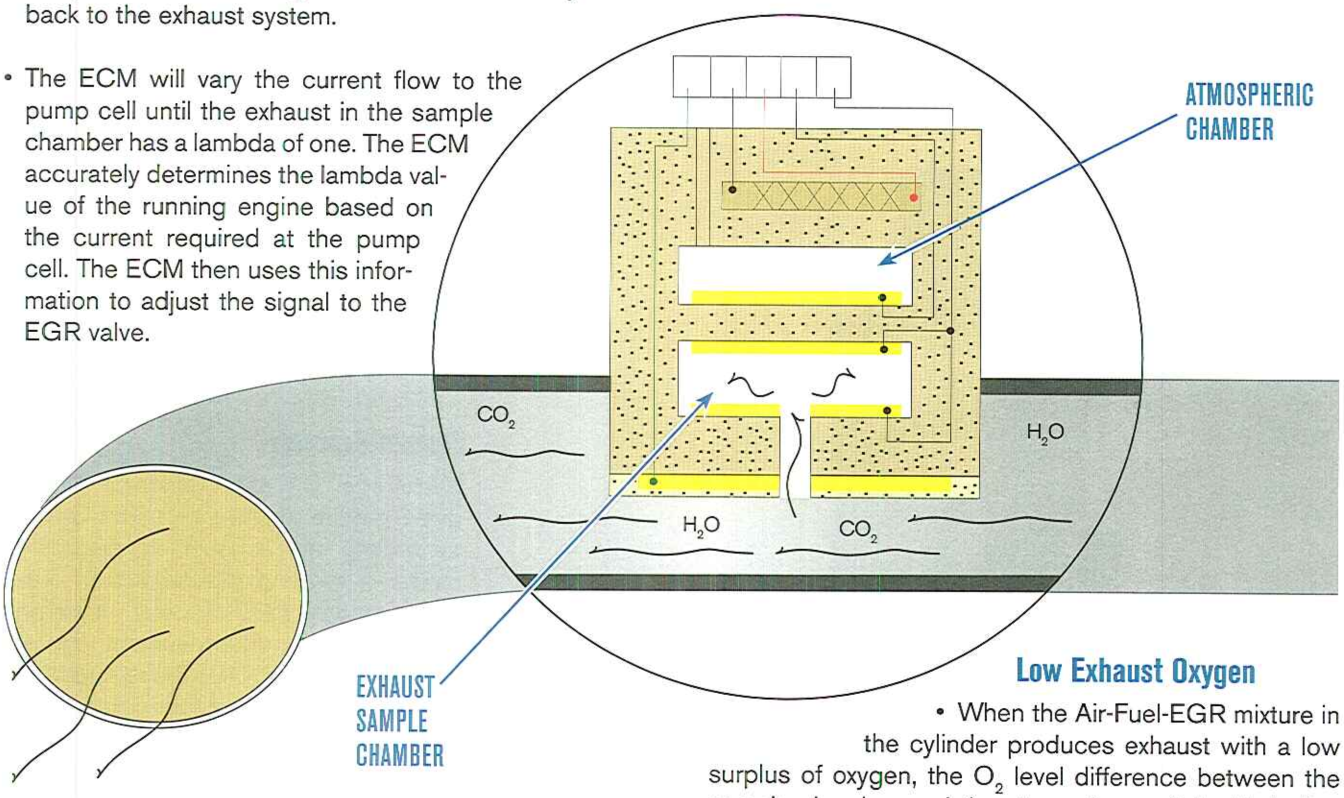
Excessive Exhaust Oxygen

- When the Air-Fuel-EGR mixture in the cylinders produces exhaust with a high surplus of oxygen, the O_2 level difference between the exhaust sample chamber and the atmosphere chamber will be low. Because of the excess O_2 in the exhaust, the sensor's signal voltage will be less than 450 mV.



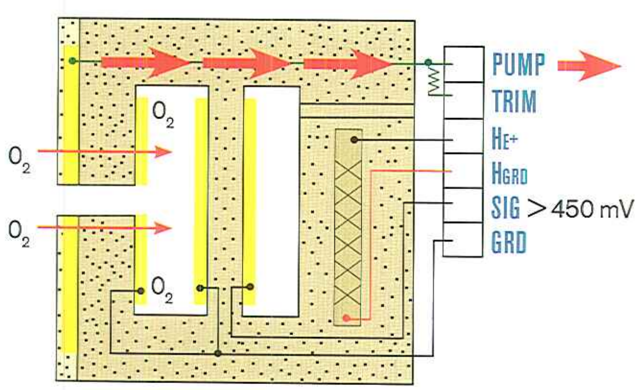
- The ECM will compare the signal voltage to a reference voltage. The signal will be lower than the reference allowing the ECM to determine that the exhaust has high surplus of oxygen. The ECM then applies a current to the pump cell, forcing oxygen to travel from the exhaust sample chamber through the ceramic electrolyte and back to the exhaust system.

- The ECM will vary the current flow to the pump cell until the exhaust in the sample chamber has a lambda of one. The ECM accurately determines the lambda value of the running engine based on the current required at the pump cell. The ECM then uses this information to adjust the signal to the EGR valve.



Low Exhaust Oxygen

- When the Air-Fuel-EGR mixture in the cylinder produces exhaust with a low surplus of oxygen, the O_2 level difference between the sample chamber and the atmosphere will be high. Because of the low levels of O_2 in the exhaust, the sensor's signal voltage will be greater than 450 mV.



- Since the signal is greater than the reference, the ECM determines that the exhaust has a low surplus of oxygen. The ECM applies a current to the pump cell, but reverses the polarity. This causes oxygen to travel from the exhaust through the ceramic material to the sample chamber.

- The ECM will vary the current flow to the pump cell until the exhaust in the sample chamber has a lambda of one. The ECM then accurately determines the lambda value of the running engine based on the current and polarity the pump cell required to achieve a lambda of 1 in the sample chamber. The ECM then uses this information to adjust the signal to the EGR valve.

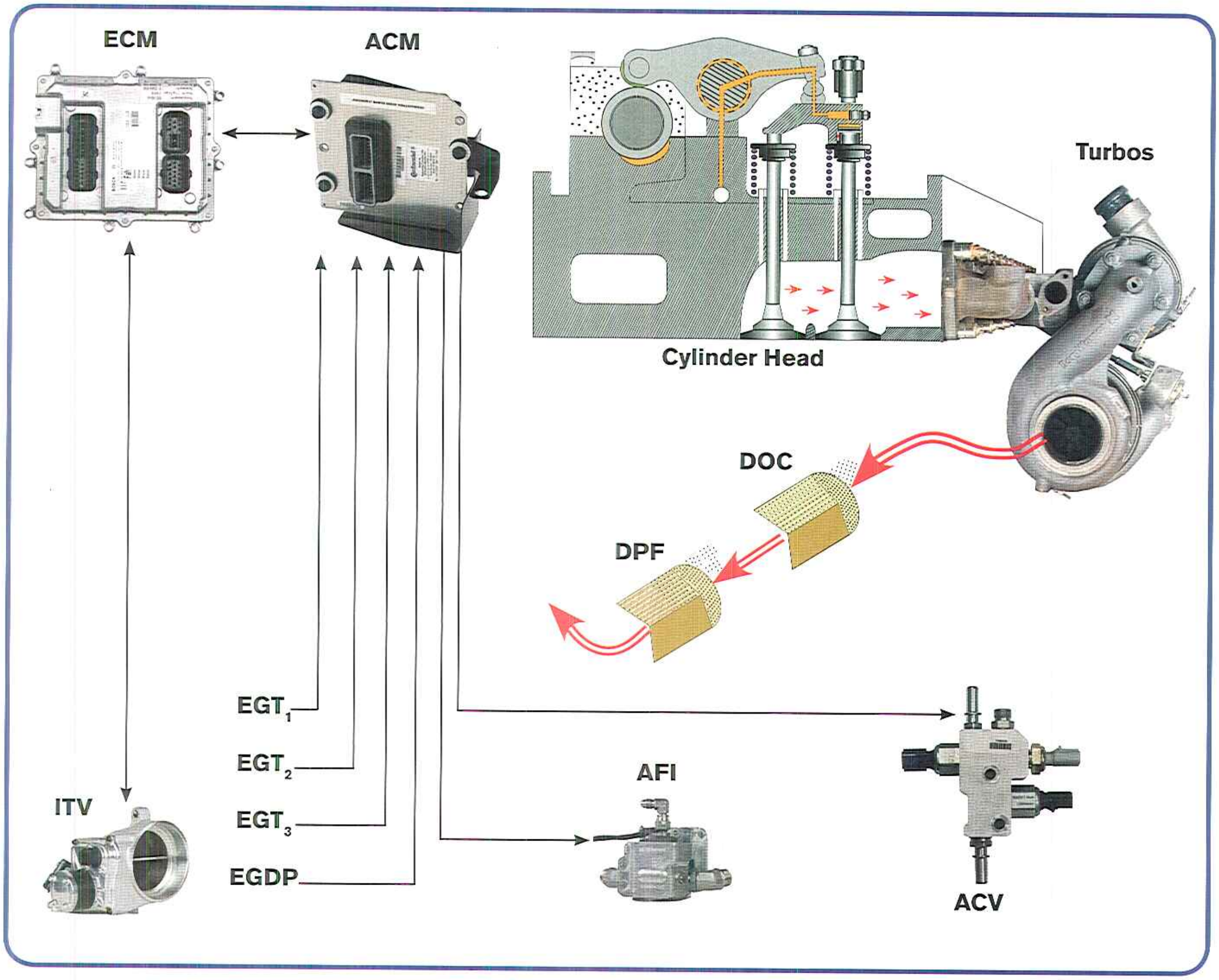
MAXXFORCE

AFTERTREATMENT SYSTEM

- Aftertreatment Fuel Injector
- Aftertreatment Control Module
- DPF
- DOC
- ACV

System Features

- MaxxForce® 11 and MaxxForce 13 engines require an Aftertreatment System to reduce the amount of particulate matter in the engine's exhaust in order to meet the 2007 Federal emissions standards. The Aftertreatment System is made up of a DOC (Diesel Oxidation Catalyst), DPF (Diesel Particulate Filter), ACM (Aftertreatment Control Module), ACV (Aftertreatment Cut-Off Valve), AFI (Aftertreatment Fuel Injector), EGT (Exhaust Gas Temperature) sensors, and an EGDP (Exhaust Gas Differential Pressure) sensor.



Aftertreatment System Operation

- The vehicle mounted Aftertreatment system components consists of the ACM, the DPF, the DOC, and the four exhaust system sensors. The engine mounted Aftertreatment components consists of the ACV, the AFI, and the ITV.

- During engine operation PM (Particulate Matter), or soot, is filtered out of the exhaust by the DPF (Diesel Particulate Filter). When exhaust temperatures are high, the soot is reduced to ash within the DOC (Diesel Oxidation catalyst) and DPF. This reduction is called passive regeneration.

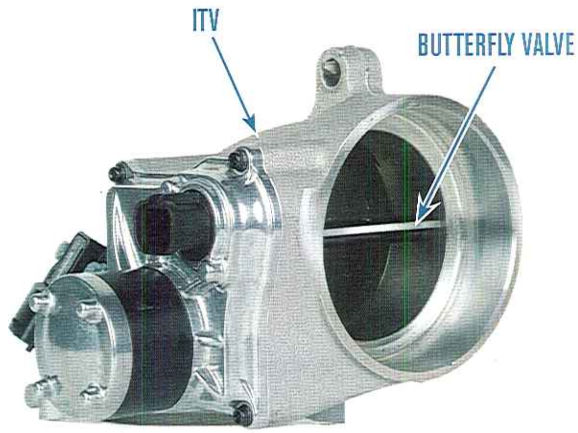
- When driving at low speeds or while under light load the exhaust temperature may not be hot enough to reduce the soot. As the soot builds up in the DPF, the EGDP (Exhaust gas Differential Pressure) sensor will sense a restriction.

- When soot builds in the DPF, the system must go through the regeneration process. If exhaust gas temperature is insufficient to reduce the soot, the ACM will manipulate the ITV (Inlet Throttle Valve) and the ACV (Aftertreatment Cut-off Valve) to control fuel and oxygen levels in the exhaust.

The exhaust will then enter the DOC where the added fuel will be burned increasing the exhaust temperature sufficient to reduce the soot. This is known as active regeneration.

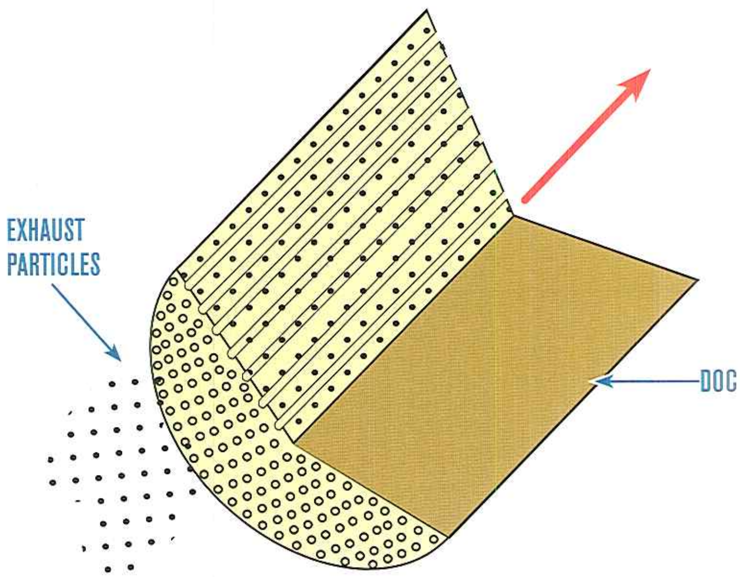
- A third type of regeneration occurs when the operator performs a stationary regen. Stationary regeneration is used when neither active nor passive can keep up with the production of soot. In a stationary regen, the driver pulls off the roadway and initiates the regen with a button on the dash. The ECM and EIM then take control of engine speed and the ITV and AFI to reduce the soot enough that the vehicle can be operated on the road again.

AFTERTREATMENT SYSTEM



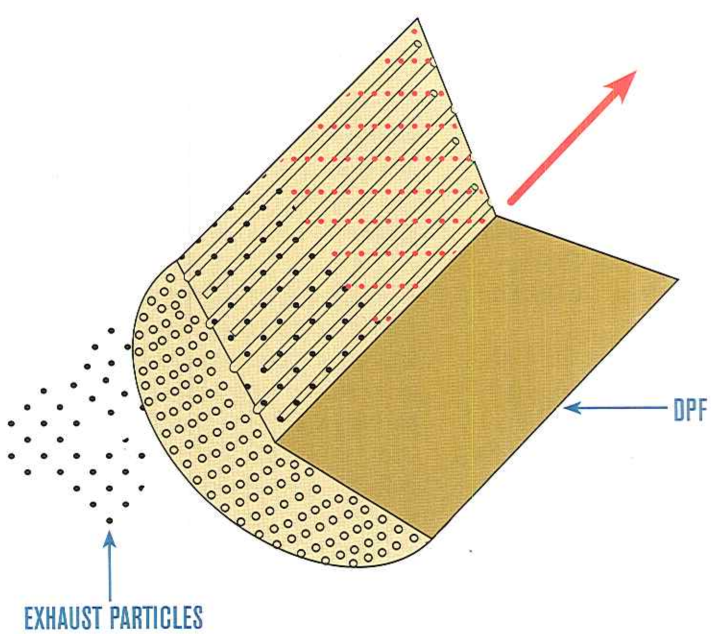
Intake Throttle Valve

- The ITV (Intake Throttle Valve) is installed on the air intake, between the high-pressure charge-air-cooler and the inlet mixing duct. The ITV is used to control the air/fuel mixture in the cylinders to aid the regeneration process.



Diesel Oxidation Catalyst

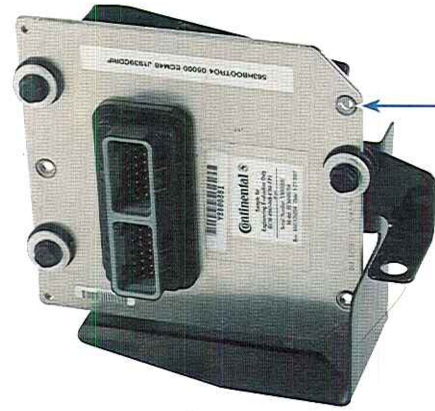
- The DOC is located in the exhaust pipe, downstream of the turbocharger and just before the DPF. The DOC is constructed of a ceramic honeycomb and uses a series of small passages coated with precious metals. As exhaust passes through the passages, unburned hydrocarbons are oxidized through a reaction with the metals and the remaining oxygen in the exhaust. This process can be used to increase the temperature of the exhaust system during regeneration of the DPF.



Diesel Particulate Filter

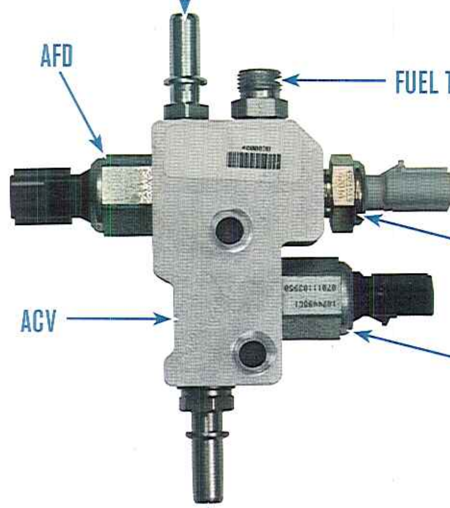
- The DPF (Diesel Particulate Filter) is located after the DOC and is also constructed of a ceramic honeycomb with a precious metals coating. Within the DPF, exhaust gases are forced to flow through small passages in the ceramic material. This allows the DPF to catch the soot (ash and particulate matter) in the exhaust. The DPF allows for the oxidation of the soot particles to save space in the DPF. The process of reducing the soot to ash is called regeneration or regen. Regen can be active, passive, or stationary.

Aftertreatment Control Module



- The ACM (Aftertreatment Control Module) is mounted on the chassis of the vehicle. The ACM controls the regeneration process for the DPF by activating the AFI and the Aftertreatment cut-off valve.

Aftertreatment Cut-Off Valve

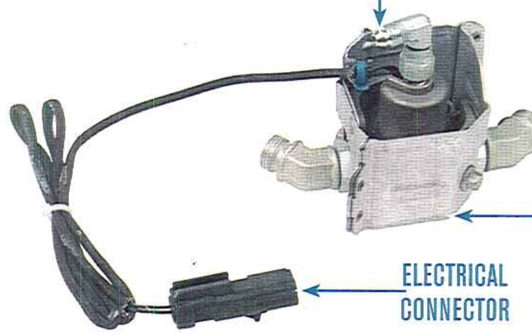


- The ACV (Aftertreatment Cut-Off Valve) assembly consists of two valves and a sensor mounted in an aluminum housing on the left side of the engine:

  1. The AFS (Aftertreatment Fuel Supply) valve provides fuel to the AFI when regeneration is requested by the ACM.
  2. The AFD (Aftertreatment Fuel Drain) valve relieves pressure from the fuel line to the AFI.
  3. The AFP (Aftertreatment Fuel Pressure) sensor monitors fuel pressure in the fuel line that feeds the AFI.

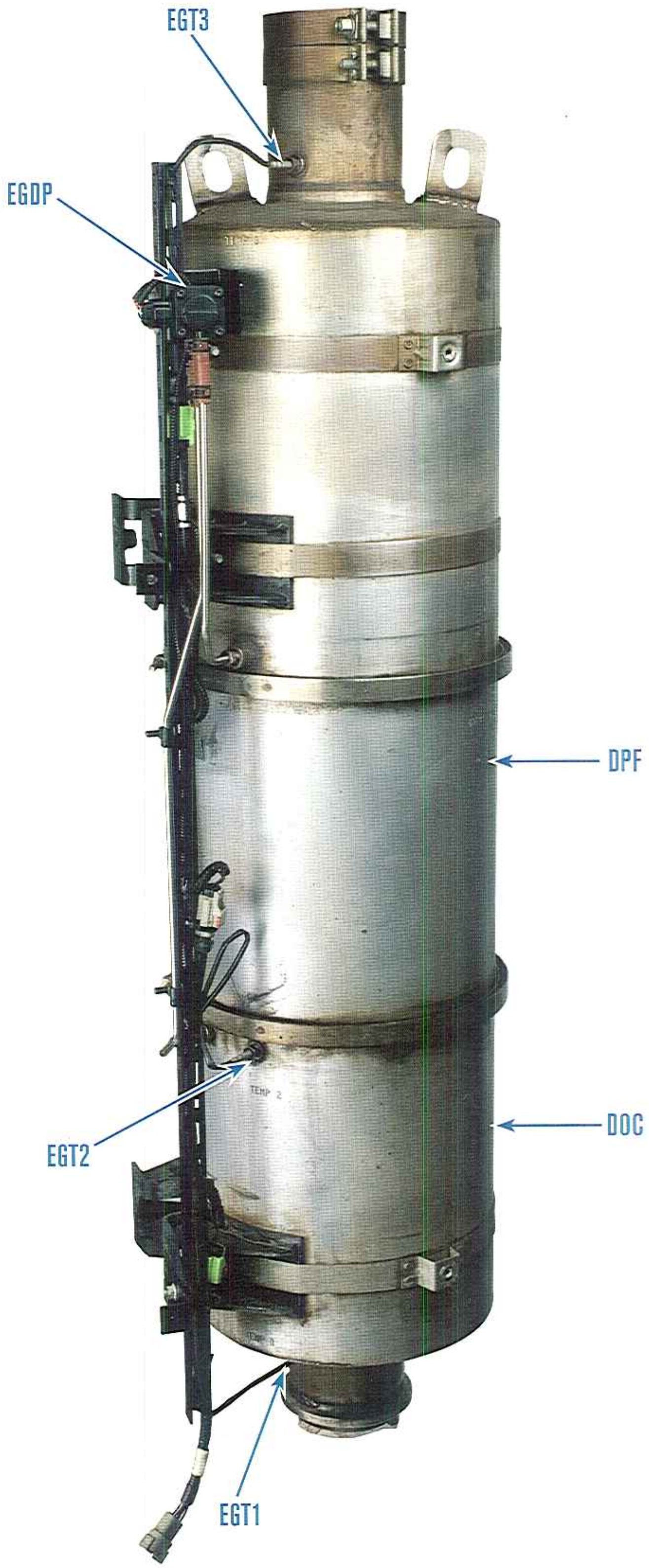
- Thermal expansion can cause excessive fuel pressure inside the AFI fuel supply line. When the AFP indicates excessive fuel pressure, the ACM commands the AFD to open and drain into the fuel return line.

Aftertreatment Fuel Injector



- The AFI (Aftertreatment Fuel Injector) is located on the exhaust pipe after the ELS (Exhaust Lambda Sensor). The Aftertreatment cut-off valve supplies pressurized fuel to the AFI. During regeneration, the ACM sends a signal to open the AFI to inject fuel into the turbo exhaust pipe.

AFTERTREATMENT SYSTEM



Exhaust Sensors

- The EGDP (Exhaust Gas Differential Pressure) sensor measures pressure in the exhaust system in two places. The first is between the DOC and the DPF. The second location is after the DPF. The EGDP sensor provides a feedback signal to the ACM indicating the pressure difference between the inlet and outlet of the DPF. This signal is used to calculate the soot level in the DPF. When the soot load is high, the passages in the DPF are restricted and the pressure differential is high.

- Three temperature sensors are used in the Aftertreatment system. EGT1 (Exhaust Gas Temperature) is inserted into the exhaust system just in front of the DOC. EGT2 is located immediately before the DPF, and EGT3 is located just after the DPF. The EGT signals are sent to the ECM where the values are used to regulate the Aftertreatment function.

Regeneration

- **Passive Regeneration,** or Regen, of the Aftertreatment System occurs when the exhaust system gets hot enough to ignite the soot particles in the DOC and the DPF. This automatically cleans, or regenerates, the ceramic material in the DPF. The advantage of passive regen is that soot is burned to ash without additional fuel being introduced into the system.

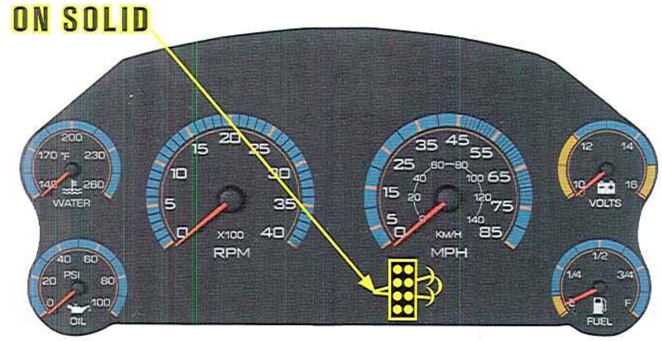
- **Active Regeneration** occurs when the ACM commands the aftertreatment fuel injector to inject extra fuel into the exhaust. The catalytic reaction between the fuel and the precious metals in the DOC creates heat, causing the soot particles in the DPF to be turned to ash.

- There is a third, driver-initiated method referred to as **Parked Regen.** When Passive and Active strategies aren't adequate enough to reduce the soot level, Parked Regen is required. Parked Regen will raise the engine RPM, inject extra fuel into the exhaust, and close the intake throttle valve as required to raise exhaust temperatures and then reduce the soot to ash.

Low Soot Load

When the DPF reaches the Low Soot Load level, the DPF lamp will illuminate, indicating that DPF Regeneration is required or start Parked Regeneration to prevent loss of engine power.

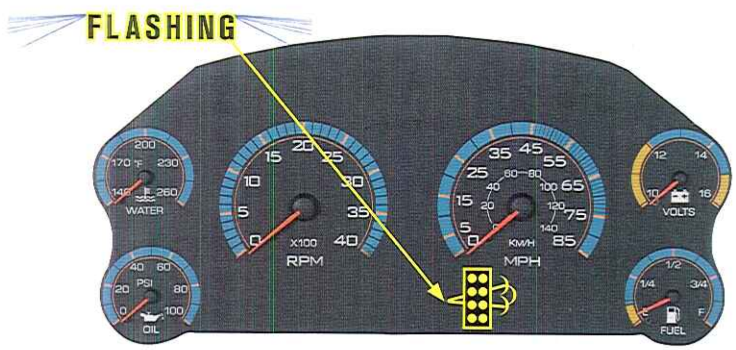
DPF Lamp



Moderate Soot Load

When the DPF is almost full, the DPF lamp will begin to flash. The operator should pull the vehicle safely off the roadway and start Parked Regeneration to avoid a loss of engine power.

DPF Lamp

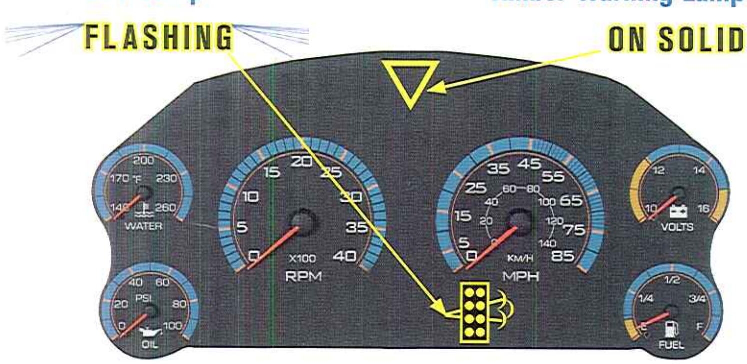


Full Soot Load

When the DPF becomes so full that it causes engine performance to be limited, the yellow "AMBER WARNING" lamp will illuminate and the DPF lamp will continue to flash. The engine may moderately de-rate or lose power. The operator should pull the vehicle safely off the roadway and start Parked Regeneration to prevent the engine from stopping.

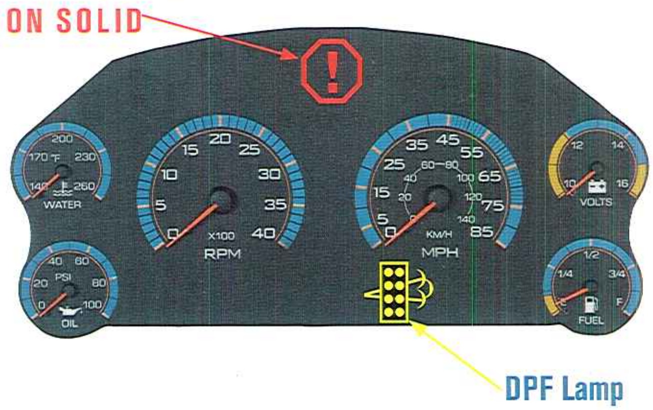
DPF Lamp

Amber Warning Lamp



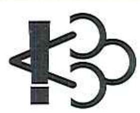
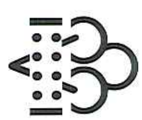
AFTERTREATMENT SYSTEM

Red Stop Lamp



Over-Full Soot Load

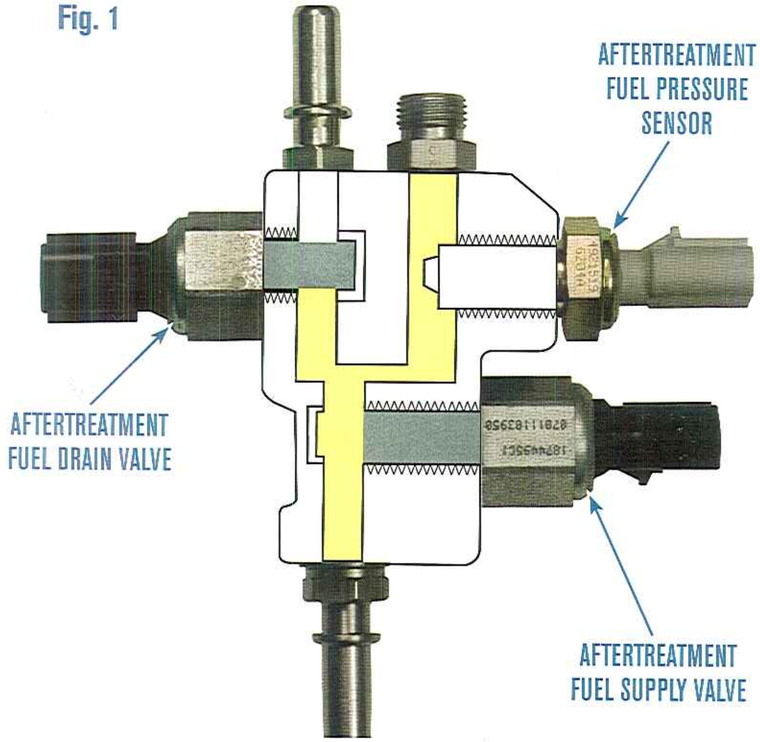
If the DPF is allowed to become full, the RED STOP lamp will illuminate, and the engine may shut down soon. Pull vehicle off roadway and stop the engine. Do not use Parked Regeneration. Call for service.

Name	Warning Lamps	Comments
Amber Warning Lamp (AWL)		The Amber Warning Lamp will illuminate when a non-emissions fault is detected in the engine control system. **Note: The amber triangle will also illuminate for chassis related faults.**
Malfunction Indicator Lamp (MIL)		The Malfunction Indicator Lamp will illuminate when an emissions fault is detected in the engine control system.
Red Stop Lamp (RSL)		The Red Stop Lamp will illuminate when a critical engine condition is detected by the engine control system. (Coolant over temp, Low oil pressure, Low coolant level, Critically Over-Loaded DPF).
DPF Regeneration Lamp (Regen)		The DPF regeneration lamp will illuminate when the DPF is reaching various stages of overloading. The lamp will not be illuminated when the system is performing an ordinary active or inactive DPF Regeneration. This light being on is a requirement to enable a stationary regeneration.
HOT Exhaust Lamp		The HOT Exhaust Lamp will illuminate when the exhaust system temperature goes above 400°C with vehicle speed less then 5 mph.

Aftertreatment Cut-Off Valve: AFI Flow Test

- This test verifies the condition of the Aftertreatment Fuel Injector (AFI). The positions of the two valves on the ACV (Aftertreatment Cut-Off Valve) are shown in figure 1. This test is activated through the electronic service tool. During the test, the AFS (Aftertreatment Fuel Supply) valve is open, the AFD (Aftertreatment Fuel Drain) valve is closed, and the AFI (Aftertreatment Fuel Injector) is energized.
- Before performing this test, remove the AFI from the exhaust system and place a clean clear container under the injector nozzle. The test runs for 60 seconds and injects fuel in a pulsing mist pattern. During this test the AFI injects approximately 177 ml (6 oz.) of fuel.

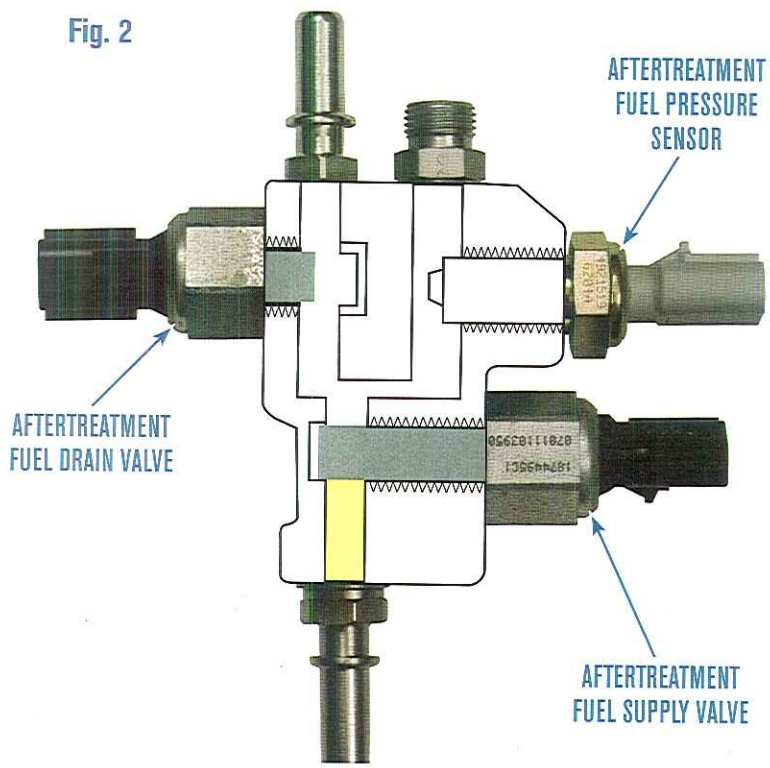
Fig. 1



AFT System Leak Test

- This test verifies the AFI and the AFI fuel supply lines do not leak. The valve's positions are shown in figure 1. This test runs for 120 seconds. Once started, the AFS valve is energized for 60 seconds. The AFP sensor may be monitored to verify fuel pressure is supplied to the AFI. During these 60 seconds, the AFI nozzle and the AFI fuel supply lines can be monitored for any signs of leakage.
- At the end of the first 60 seconds, the AFS valve is de-energized and the AFD valve is energized for 60 seconds. The valve's positions are shown in figure 2. During this time, the Aftertreatment fuel pressure must drop to less than 6.9 kPa (1psi).

Fig. 2



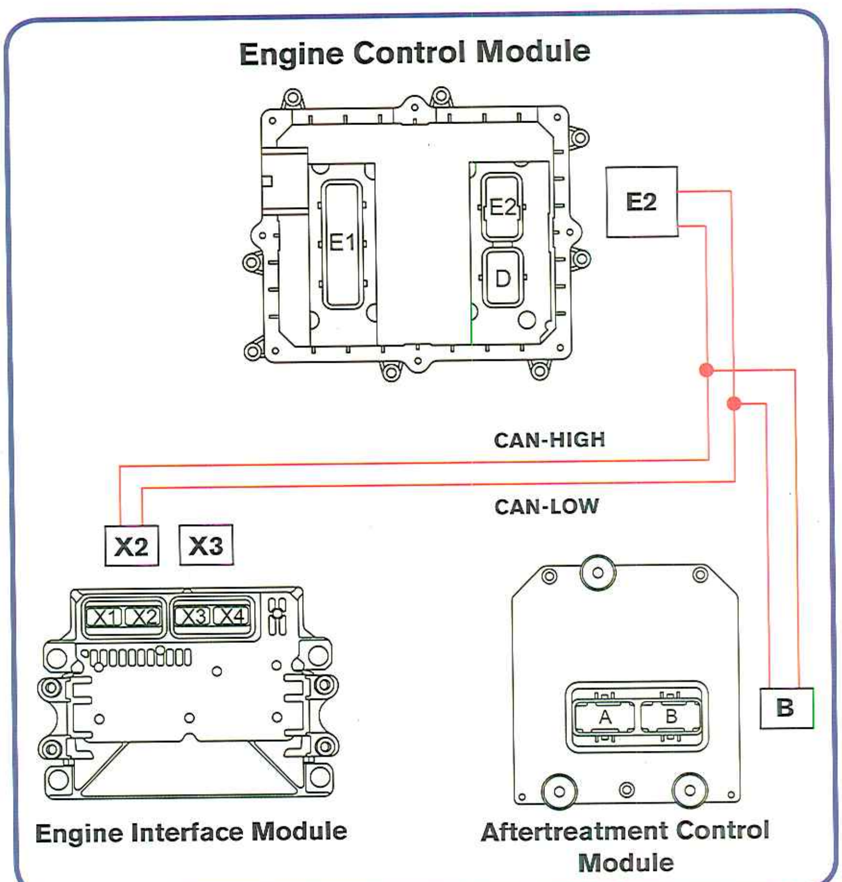
AFS Leak Test

- This test verifies the AFS valve does not leak after it is closed. The valve's positions are shown in figure 2. This test runs for 60 seconds, during which time AFS valve and the AFI are closed, and the AFD valve is opened. Before performing this test, remove the drain line from the ACV assembly. Watch for leakage from the line while the test is in progress. Leakage indicates the supply valve is leaking.

MAXXFORCE

ELECTRONIC CONTROL SYSTEM

- Three Module System with CAN Communications
- Cold Start Assist Control
- Aftertreatment Control

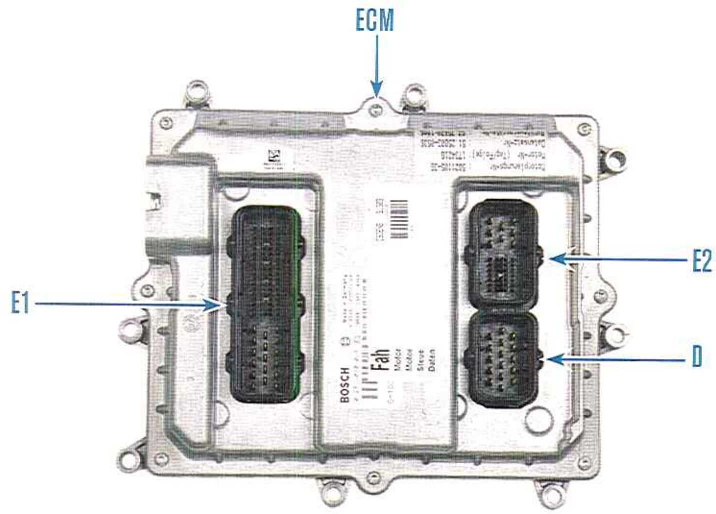


System Features

- The MaxxForce® 11 and 13 engines are equipped with three control modules: ECM (Engine Control Module), EIM (Engine Interface Module), and the ACM (Aftertreatment Control Module).
- The cold start assist system warms the incoming air supply prior to cranking to aid cold engine starting. The system will initially illuminate the WAIT-TO-START lamp located on the instrument panel. When the lamp begins to flash, the engine can be cranked.
- The Aftertreatment system reduces the emissions in the exhaust. This system consists of several sensors and an Aftertreatment fuel injector. The sensors are monitored by the ACM for proper Aftertreatment management. When necessary, the ACM will command the Aftertreatment fuel injector on to initiate certain regeneration cycles

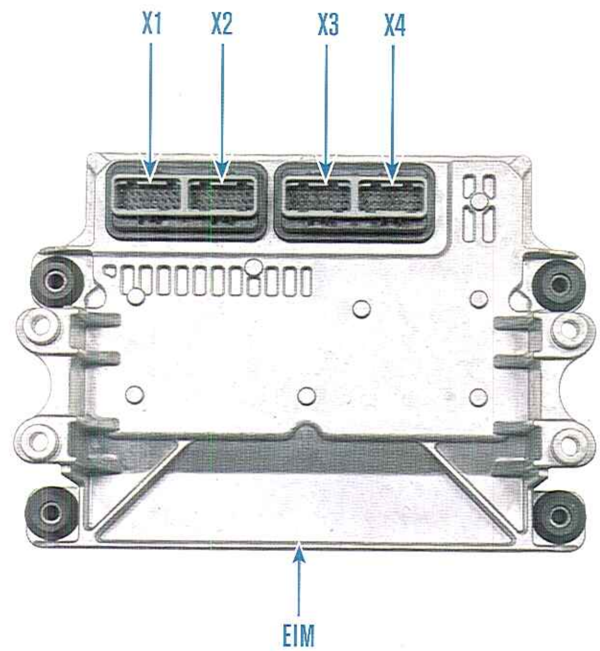
Engine Control Module

- The ECM (Engine Control Module) controls the injectors and the engine-mounted actuators based on inputs received from the engine and chassis-mounted sensors. The ECM is located on the upper left side of the engine near the front. The ECM has three electrical connectors: E1, E2, and D. The ECM communicates with the EIM and the ACM over a private CAN line.



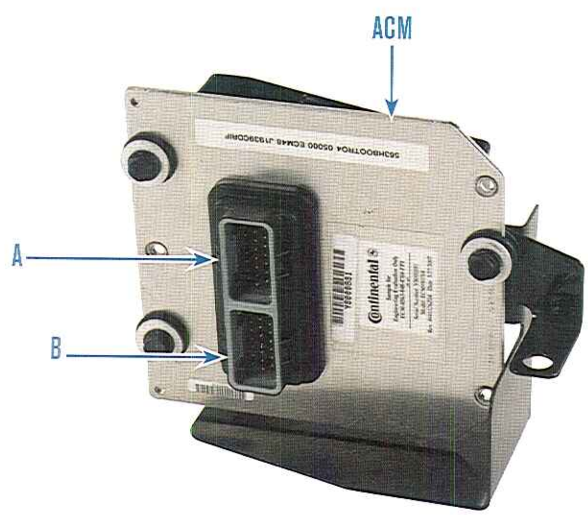
Engine Interface Module

- The EIM (Engine Interface Module) acts as an interface between the engine and the chassis. The EIM receives the chassis inputs and communicates the information over the CAN line. The EIM is located behind the fuel filter module and has four electrical connectors: X1, X2, X3, and X4. The EIM communicates with the ECM and the ACM over a private CAN line.



Aftertreatment Control Module

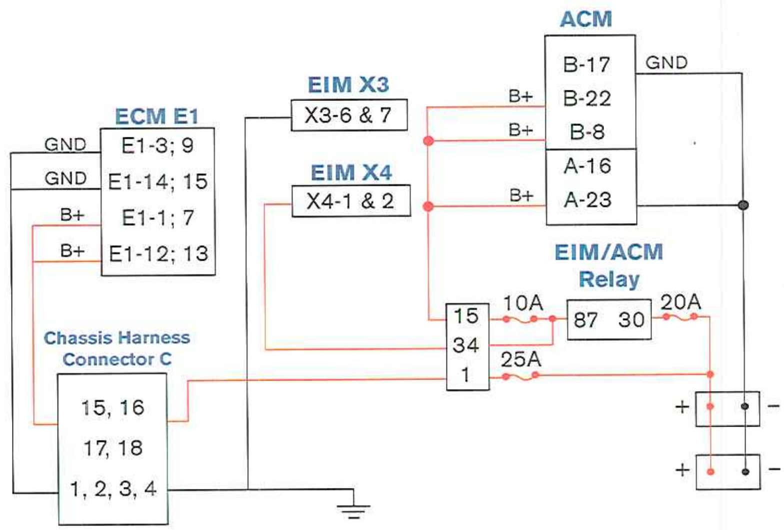
- The ACM (Aftertreatment Control Module) receives inputs from the Aftertreatment System sensors and controls the Aftertreatment injector and the cut-off valve. The ACM is located behind the driver's side frame rail, just to the rear of the front cab mount. The ACM has two electrical connectors: A and B. The ACM communicates with the ECM and the EIM over a private CAN line.



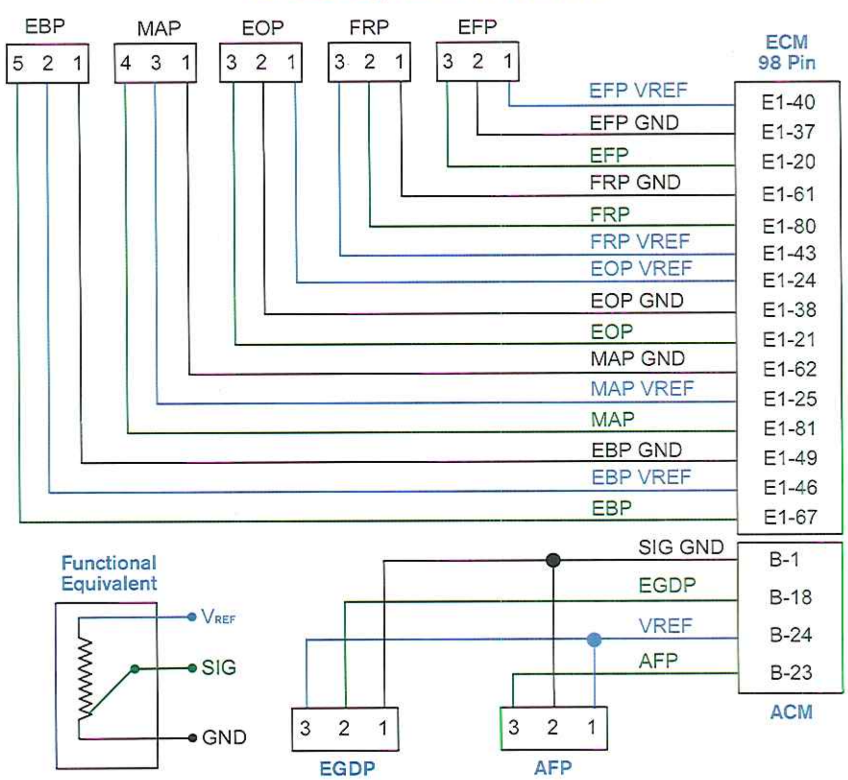
ECM Power-Up

- The MaxxForce® 11 and MaxxForce 13 engines are equipped with three control modules: ECM (Engine Control Module); EIM (Engine Interface Module); and the ACM (Aftertreatment Control Module).

- When the Ignition Switch is turned on, the EIM/ACM relay closes. B+ is then sent to the ECM, EIM, and ACM. The ECM has an internal relay which powers the engine mounted actuators. The control modules communicate over a CAN line.



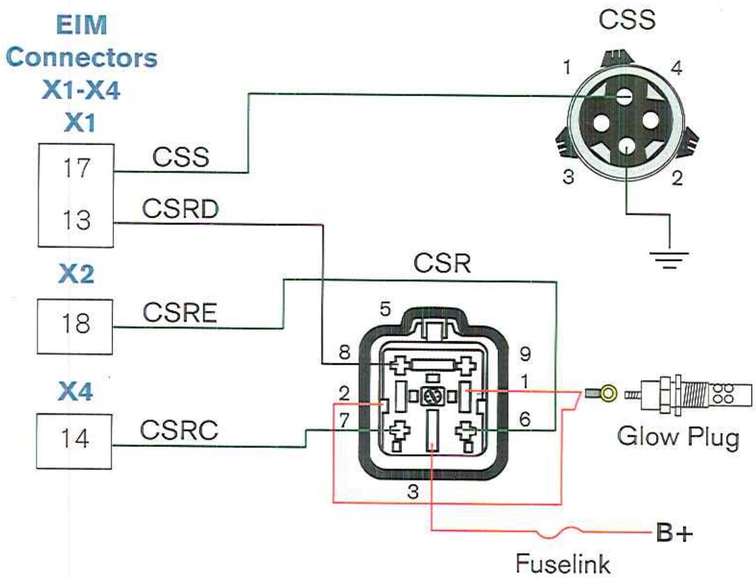
Variable Capacitance Sensors



Variable Capacitance Pressure Sensors

- Variable capacitance sensors measure pressure. The measured pressure is applied to a ceramic material that bends proportional to the pressure. When the pressure bends the disc, the ceramic is forced closer to a thin metal disc. This action changes the capacitance between the two materials. Integrated circuits within the sensor body convert the capacitance value into an analog signal voltage proportional to the pressure. Each pressure sensor is connected to the ECM by the VREF, signal, and ground wires. The sensor receives the VREF and returns a signal voltage to the ECM. The ECM compares the voltage to programmed values in order to determine the pressure. The operational range of a variable capacitance sensor is linked to the thickness of the ceramic disc. The thicker the ceramic disc, the more pressure the sensor can measure.

- The variable capacitance sensors are used in pull-down circuits. This type of circuit results in an out-of-range low DTC when the signal wire is open and the ECM detects the zero voltage.

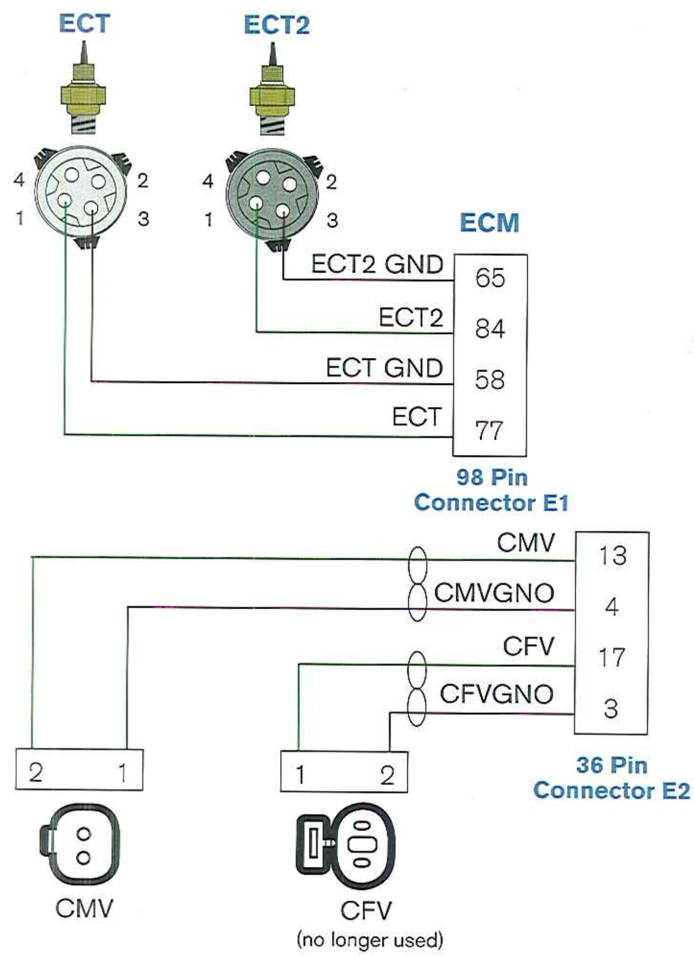


Glow Plug

- The glow plug is installed on the left front side of the engine in the air inlet duct. The function of the glow plug is to heat the intake air by vaporizing fuel in the air inlet duct. When commanded on, the CSR supplies power to the glow plug. This allows the glow plug to heat up, which must be done before fuel is supplied. Once the glow plug is heated, the CSS (Cold Start Solenoid) is then powered on to allow fuel to the glow plug.
- The CSR (Cold Start Relay) is located on the left side of the engine above the ECM. The CSR provides voltage to the glow plug and is controlled by the EIM.

Coolant Control Valve

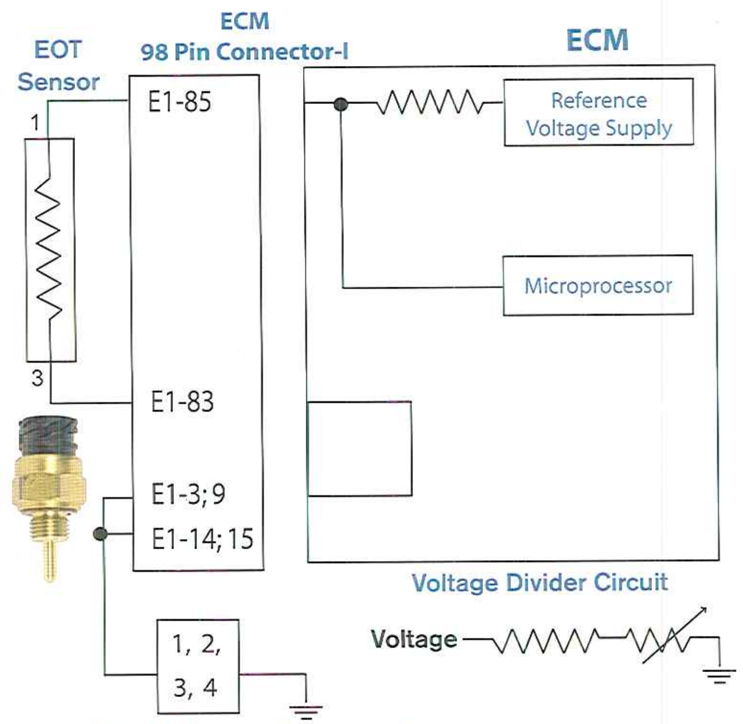
- The CCV (Coolant Control Valve) assembly is located on the right side of the front cover and consists of the CMV (Coolant Mixer Valve); at the start of production the CFV (Coolant Flow Valve) was also used. This combined solenoid assembly regulates coolant flow and temperature through the CACs (Charge-Air-Coolers). The CFV used to control the rate of coolant flow through the CACs, but is no longer used. Now the CFV is disconnected and now flows 100%, and the CMV regulates the temperature of the coolant, by directing the coolant either through the low temperature radiator or through an internal bypass. The CMV valve is controlled by the ECM via PWM signal.
- The ECM uses the inputs from the ECT and ECT2 sensors to control the CMV. Pin 2 on the CMV connects to pin 4 on the ECM connector E2. Pin 2 is connected to Pin 13 on the ECM connector E2.

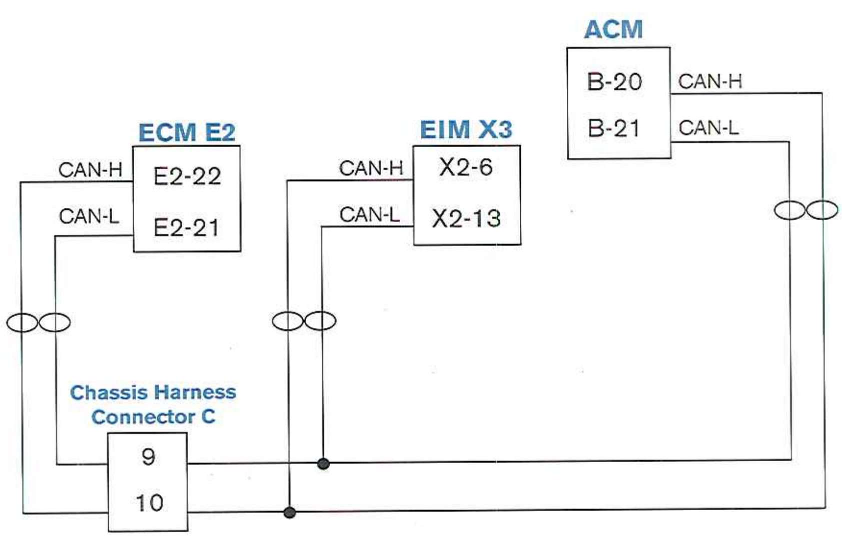


Temperature Sensors

- The working element within a temperature sensor is a thermistor. A thermistor changes its electrical resistance with changes in temperature. Resistance in the thermistor decreases as temperature increases, and increases as temperature decreases.
- Thermistors are part of a voltage divider circuit. The top half of the voltage divider is a current limiting resistor inside the ECM. The bottom half of the circuit is the thermistor.
- The ECM supplies a reference voltage to the top half of the circuit and a ground to the bottom half. The thermistor and resistor in series divide the voltage depending upon the current resistance of the thermistor. The ECM measures the voltage between the two devices and compares that value to a table that converts the voltage to a temperature value.
- The temperature sensor has two electrical connectors, signal return and ground. The output of a thermistor sensor is a nonlinear analog signal.

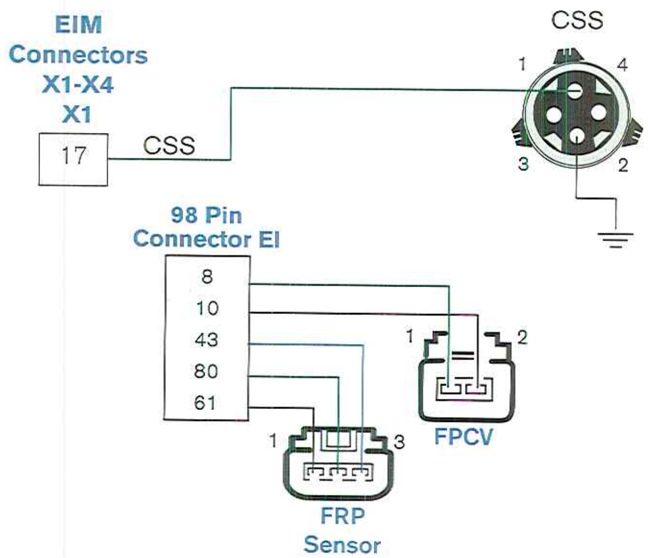
Temperature Sensor





ECM Communications

- The ECM receives inputs from the engine-mounted sensors and controls engine operation through the engine-mounted actuators. The EIM receives the chassis inputs and communicates the information over the CAN line; and the ACM receives inputs from the Aftertreatment sensors and controls the Aftertreatment fuel injector.
- The private CAN line allows the ECM, EIM and ACM to communicate to each other. On this line, the communication signals are direct to each module and eliminates possible interpretations.



Fuel System Actuators

- The FPCV (Fuel Pressure Control Valve) regulates fuel pressure to the fuel injectors. The ECM uses the FRP sensor to monitor system pressure and adjust the duty cycle of the valve to match engine requirements (starting, engine load, speed and temperature). When the ignition switch is turned on, the ECM commands a 50% duty cycle to the FPCV for 60 seconds, then turns it off if the engine is not started. NOTE: The Actuator Test does not cycle this valve.

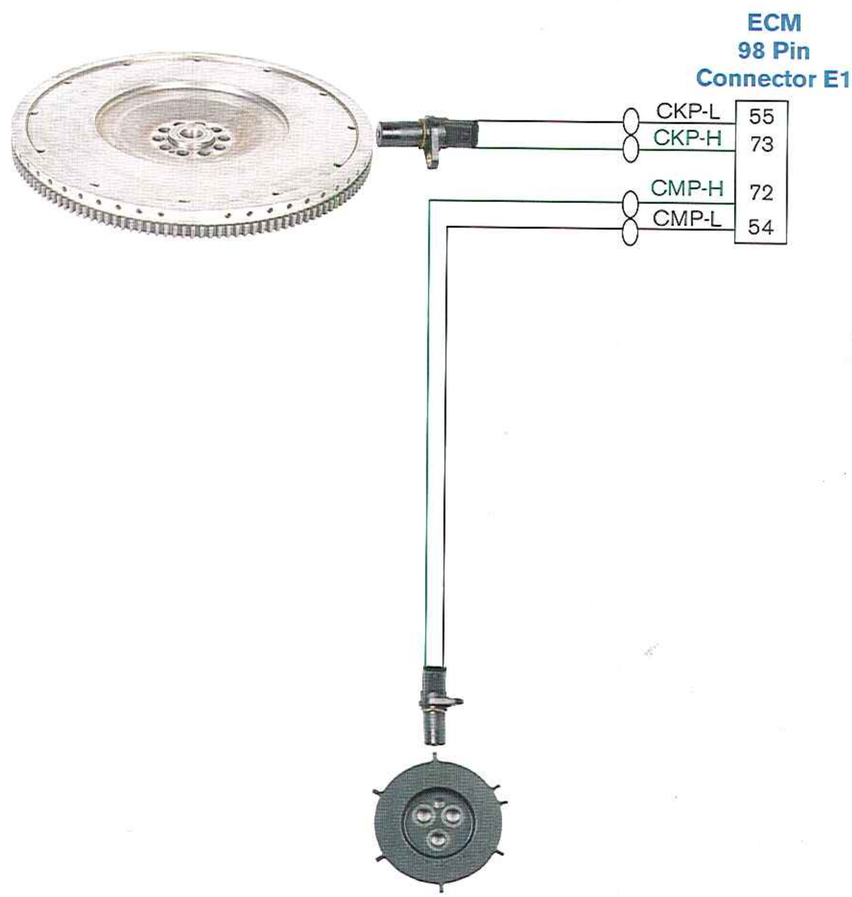
- The CSS (Cold Start Solenoid) valve is part of the cold start assist. This valve controls the fuel sent to the glow plug. Pin 1 of the CSS valve is driven by a switched B+ output from the EIM module, pin X1–17. Pin 2 of the CSS valve is grounded. The solenoid is held on for a fixed duration of time allowing fuel to enter the glow plug.

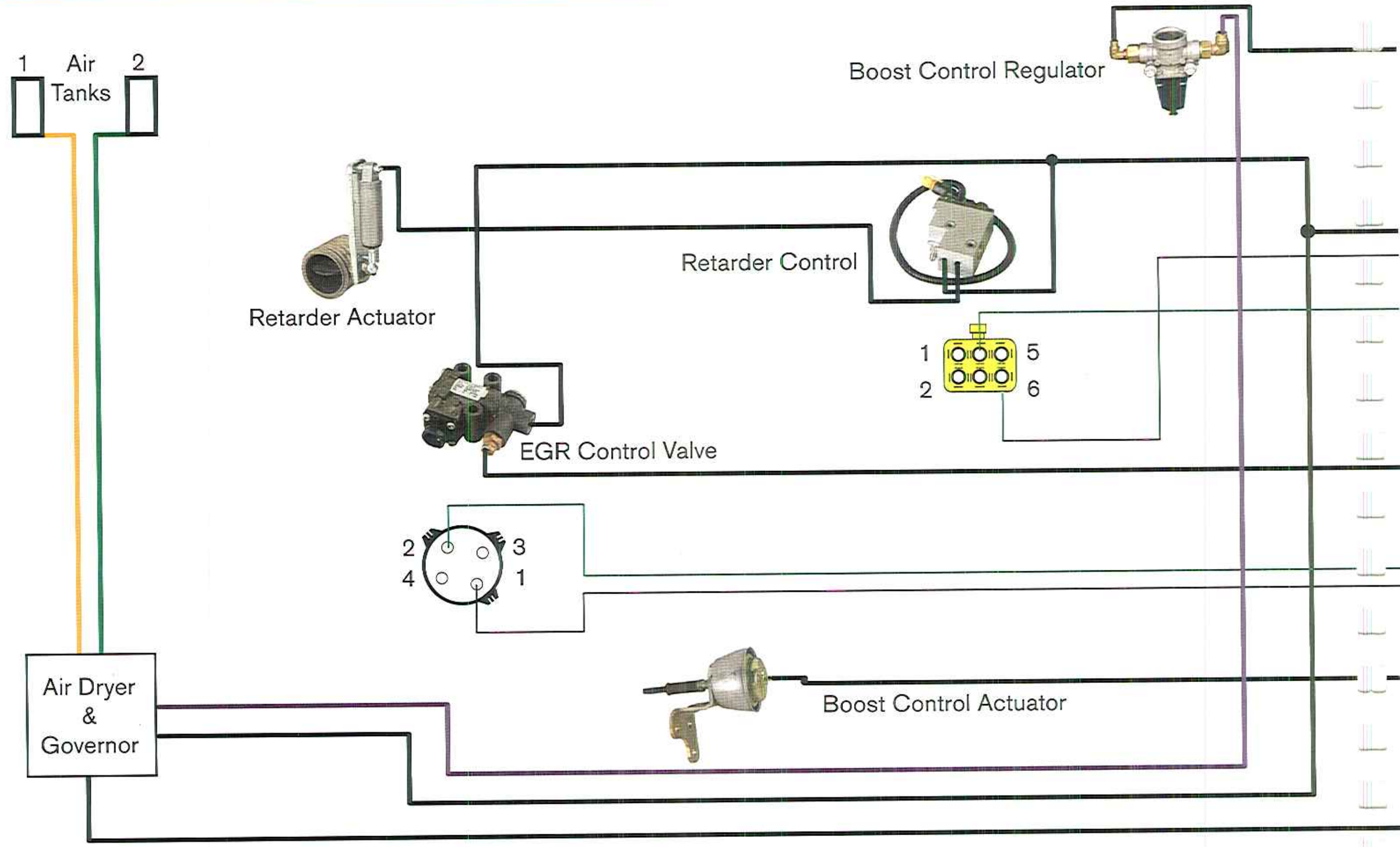
Magnetic Timing Sensors

- The CKP (Crankshaft Position) sensor is mounted on top of the flywheel housing and is used to detect crankshaft speed and position. The CKP trigger is a series of holes drilled in the edge of the flywheel. If the CKP sensor fails, the engine will still start, but will have a longer crank time.

- As the crankshaft turns, the CKP sensor detects timing hole drillings on the flywheel. Two holes are not drilled, so the ECM calculates and identifies the position of the crankshaft based on the signal gap. The CKP sensor produces pulses for each hole edge that passes it. Crankshaft speed is derived from the frequency of the CKP sensor signal. From the CKP signal frequency, the ECM can calculate engine rpm. By comparing the CKP signal with the CMP (Camshaft Position) signal, the ECM calculates engine rpm and timing.

- The CMP sensor provides the ECM with a signal that indicates camshaft speed and position. The signal is created when a tooth timing disk on the camshaft rotates and breaks the magnetic field. As the cam rotates, the sensor identifies camshaft position. By comparing the CMP signal with the CKP signal, the ECM calculates engine rpm and timing.





Electro-Pneumatic Control Valves

- The MaxxForce® 11 and MaxxForce 13 engines are equipped with up to three pneumatic actuators. To control and operate these actuators, there are up to three electronic control valves. These controllers are: the boost control solenoid valve, the EGR controller, and the retarder controller.

BCS Valve

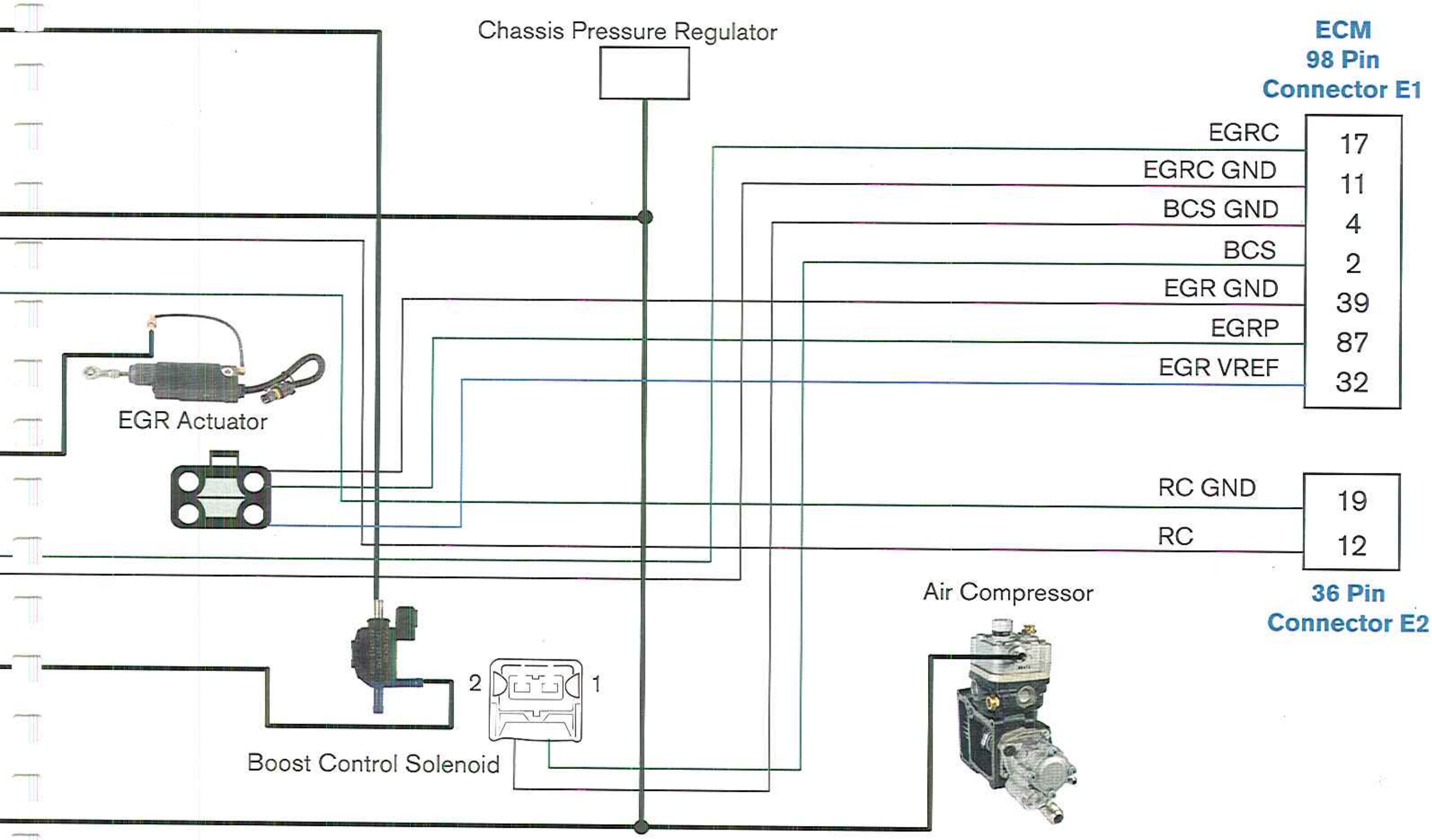
- The BCS (Boost Control Solenoid) valve controls the boost control actuator position by regulating the compressed air based on a PWM signal received from the ECM. With no PWM signal, the BCS valve is open and air is supplied to the boost control actuator maintaining the diverter valve in the turbo in the open position. When an increase in the charge air pressure is required, the ECM supplies PWM voltage to close the BCS valve. When the BCS valve closes, it interrupts the air supply to the boost control actuator and at the same time it relieves the air pressure from the boost control actuator by opening the vent to the atmosphere. The boost control actuator then closes the diverter valve, resulting in increased charge air pressure.

EGR Control Valve

- The EGR control valve is supplied with air pressure from the vehicle's air system. The controller receives a PWM signal from the ECM to open and allow air to the EGR actuator. When the ECM commands the controller to close the EGR valve, air is not supplied to the actuator, and the remaining air in the actuator is vented via the control valve. A spring in the actuator will close the butterfly valves.

Retarder Controller

- The retarder controller is supplied with air pressure from the vehicle's air system. The controller receives a PWM signal from the ECM to open and allows air to the retarder actuator. The actuator closes the butterfly valve to increase exhaust back pressure in the exhaust to activate the engine retarder. The retarder controller monitors the exhaust back pressure through a pressure line connected to the retarder manifold. This allows the ECM to determine how much air pressure the controller needs to send to the actuator to achieve the desired braking assistance. When the ECM commands the controller to open the retarder butterfly valve, air is not supplied to the actuator, and the remaining air in the actuator is vented via the control valve. A spring in the actuator will open the butterfly valve.



Pneumatic Actuators

- The pneumatic actuators are operated by the vehicle's air supply, and controlled by the ECM. These actuators are: the boost control, the EGR, and the engine retarder.

Boost Control Actuator

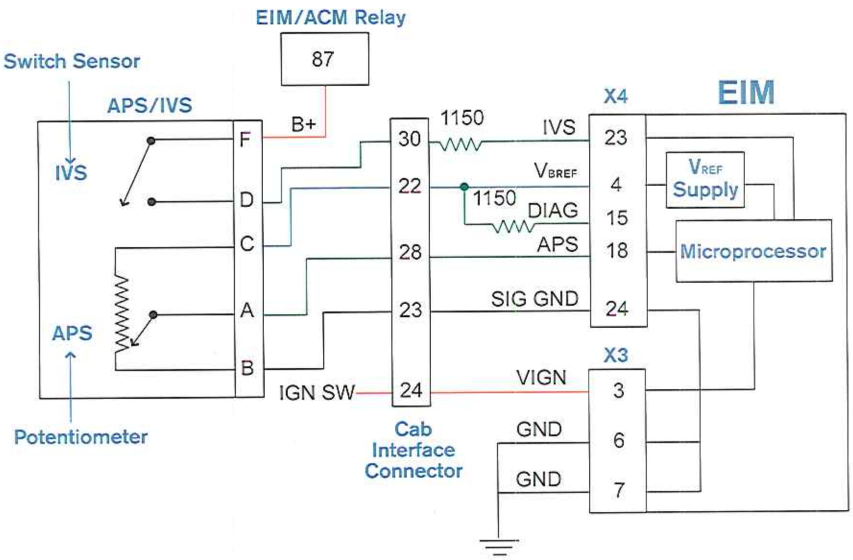
- The boost control actuator operates the diverter valve in the high-pressure turbo. This actuator must have a regulated air pressure of 40-50 psi. The boost control regulator is chassis mounted, and is supplied with vehicle air pressure. This reduces the vehicle air pressure used to operate this actuator only. The vehicle's air supply must be at a minimum of 90 psi for the actuator to operate. When the ECM commands the diverter valve to be open, there is no signal sent to the BCS. This allows regulated air pressure to the actuator, forcing the linkage to move opening the diverter valve. When the ECM commands the diverter valve closed, the ECM sends a PWM signal to the BCS. This signal stops the air supply from entering the actuator. Instead, it allows the remaining air pressure in the actuator to be vented. The spring in the actuator then allows the diverter valve to close.

EGR Valve Actuator

- The EGR valve actuator operates the butterfly valves at the exhaust inlet of the EGR cooler. This actuator also contains a position sensor. The ECM monitors the position of this actuator to determine what position the valve is in. When the ECM commands the EGR valve to open, the controller sends the necessary amount of vehicle air pressure to the actuator for the proper valve position. When the ECM commands the EGR valve to close, no air is supplied to the actuator. The remaining air pressure in the actuator is then vented through a port located on the control valve. After the air pressure is vented, an internal spring in the actuator closes the butterfly valves.

Retarder Actuator

- The retarder actuator operates the butterfly valve in the retarder manifold. When the ECM commands the retarder on, the retarder controller allows air pressure to the retarder actuator. The actuator then closes the butterfly valve. The ECM monitors the exhaust back pressure sensor, located internally in the retarder controller, to determine how much air pressure is needed to properly position the butterfly valve. When the ECM commands the retarder off, no air is supplied to the actuator. The remaining air pressure in the actuator is then vented through a port located on the retarder controller. After the air pressure is vented, an internal spring in the actuator opens the butterfly valve.

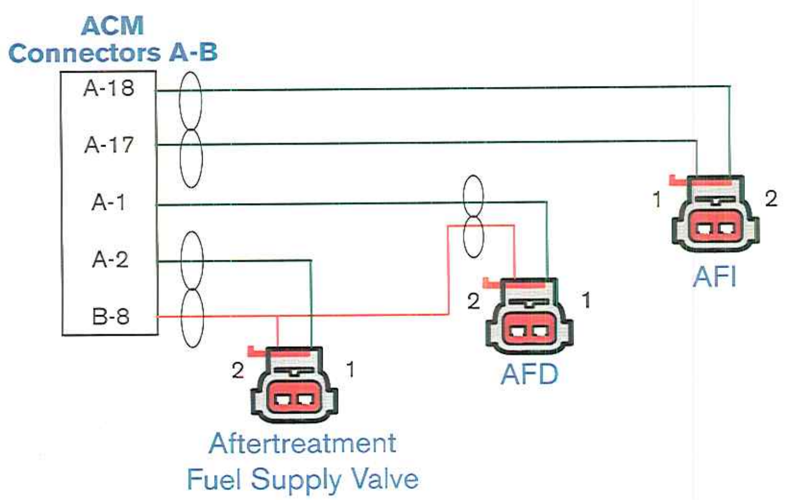


APS/IVS

- The APS/IVS is integrated into one component and mounted on the accelerator pedal. The APS/IVS switch can be replaced without replacing the complete assembly. The EIM determines accelerator pedal position by processing input signals from the APS and the IVS.
- The APS provides the ECM with an analog voltage signal indicating the operator's demand for power. The APS is a potentiometer sensor that is supplied with a 5 V reference voltage at Pin C from EIM Pin X4-4 and is grounded at Pin B from EIM Pin X4-24. The sensor returns a variable voltage signal from Pin A to EIM Pin X4-18.
- The IVS sensor is a switch type sensor that verifies when the APS is in the idle position. The ignition switch supplies 12 volts to pin F of the switch. When the switch is closed, the ECM senses 12v on pin X4-23. If the switch is open, the ECM senses 0v on X4-23.

Aftertreatment Control Valves

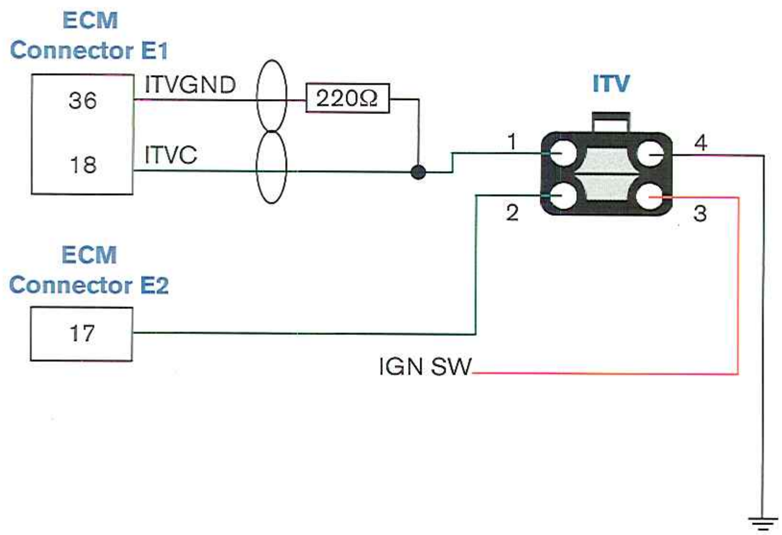
- The AFI (Aftertreatment Fuel Injector) is located on the right side of the engine and is installed on the turbo exhaust pipe after the ELS (Exhaust Lambda Sensor). Pressurized fuel is supplied to the AFI from the Aftertreatment cut-off valve through the fuel filter housing assembly. When regeneration is required, the ACM sends voltage to the AFI to open and inject fuel into the turbo exhaust pipe.
- The AFD (Aftertreatment Fuel Drain) valve is used to relieve the pressure from the Aftertreatment fuel system. A fuel overpressure can occur due to thermal expansion of the fuel inside the AFI fuel supply line. When the fuel pressure increases, the ACM commands the AFD to open and relieve the fuel pressure into the fuel return line.

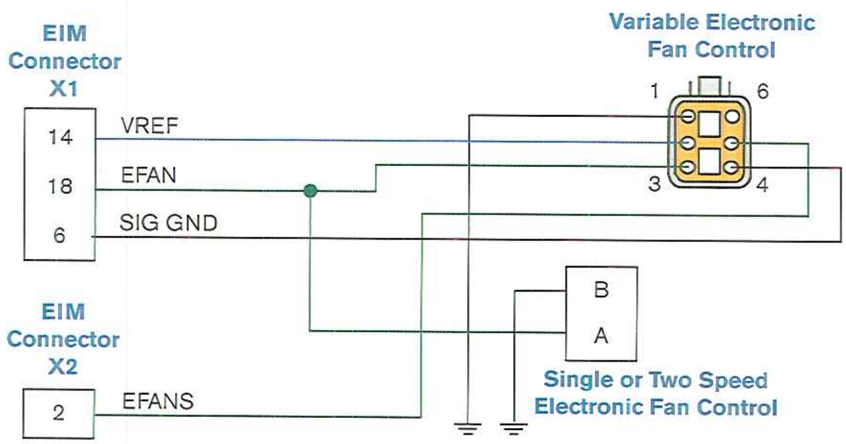


ITV Circuit Operation

- The ITV is a variable position actuator that restricts intake air flow by way of an internal butterfly valve to help heat the exhaust after-treatment during regeneration, and to assist when heavy EGR is requested.

- The ITV changes butterfly valve position in response to ECM signals. The ITV contains an internal position sensor that monitors butterfly valve position and transmits a position signal to the ECM. The desired position signal is sent from ECM Pins E1-18 and E1-36 to the ITV Pin 1. After the ITV receives the request from the ECM, the ITV motor controls the throttle plate to the desired position.





Variable Electronic Fan Control

- The Variable Speed Viscous fan is electronically controlled by the EIM. If more fan speed is required, a lower duty cycle PWM signal is sent from EIM X1-18 to pin-3 of the fan connector. The lower duty cycle reduces current to the fan's control coil. A valve within the fan drive opens and allows more oil to enter the grooved area. If less fan speed is required, a higher PWM signal is sent.

- The Hall Effect sensor tracks 12 steel slugs imbedded in the outer case. The signal is sent from fan connector pin-5 to EIM X2-2.

MAXXFORCE

UNIQUE SERVICE PROCEDURES

- Injector Replacement
- Verify Camshaft Timing
- Valve Adjustment
- Coolant Fill Procedure

WARNING

- A warning describes actions necessary to prevent or eliminate conditions, hazards, and unsafe practices that can cause personal injury or death.

CAUTION

- A caution describes actions necessary to prevent or eliminate conditions that can cause damage to the engine or vehicle.

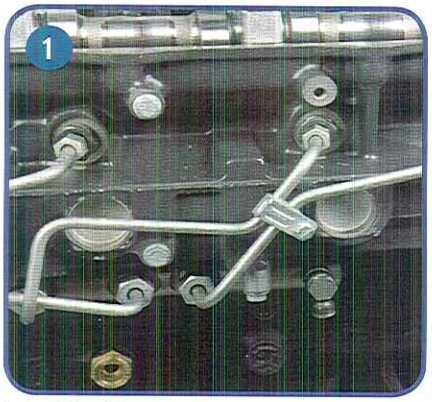
NOTE

- A note describes actions necessary for correct, efficient engine operation.

Injector Replacement Procedure

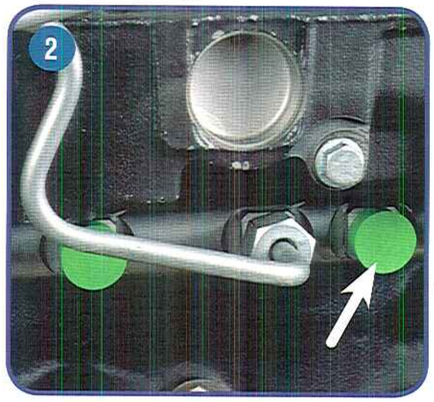
CAUTION

Incorrect removal or installation will damage the injector and other related components.



Injector Lines

Remove the appropriate injector line(s).



Fuel Connections

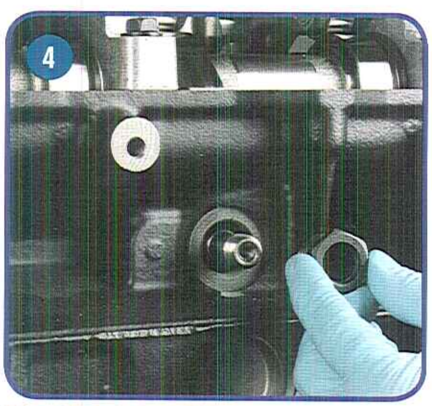
Plug the fuel connections immediately.

Electrical Leads

Disconnect the electrical leads to the injector.

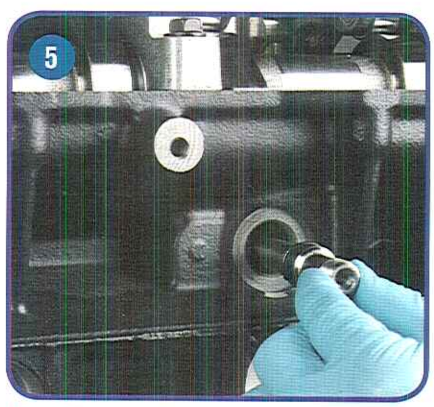
▲ NOTE

The pressure pipe must be removed before removing the injector.



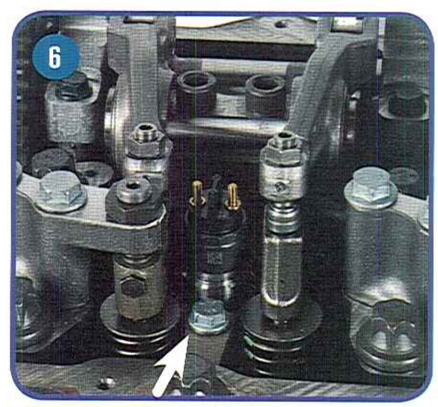
Pipe Retaining Nut

Unscrew and remove the pipe retaining nut.



Pipe Removal

Pull out the pipe from the cylinder head. Plug the bore in the cylinder head immediately with the proper plug.



Mounting Clamp

Remove the mounting clamp bolt and washer.

UNIQUE SERVICE PROCEDURES

Injector Replacement Procedure

Injector Puller

Install the special puller tool (ZTSE4770) for the injector removal.

Injector Removal

Pull the injector and mounting clamp as a unit from the cylinder head. Immediately after removing the injector, seal all the components to prevent contamination.

Cylinder Head Inspection

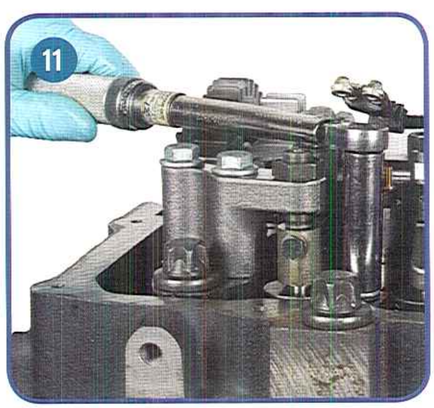
Inspect the cylinder head and make sure that the old sealing washer and O-ring have been removed and all components and mounting areas are completely clean. Slide the mounting clamp onto the injector and make sure that the injector fuel inlet opening will mate to the injector pressure pipe when installed.

▲ NOTE

The injector and the mounting clamp must be installed as a unit. The clamp cannot be installed after the injector is in place.

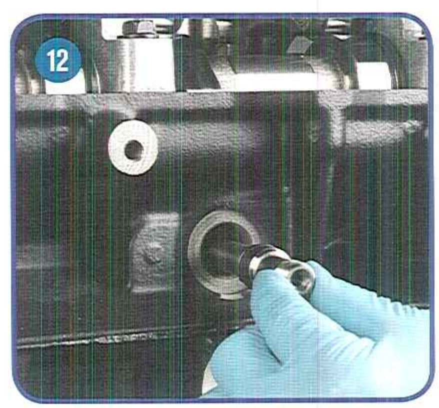
Injector Installation

Insert the injector into the cylinder head with new O-ring and new sealing washer. Press the injector fully into the cylinder head using the hand push tool (ZTSE4777).



Mounting Clamp Torque

Tighten the injector mounting clamp bolt to initial torque.



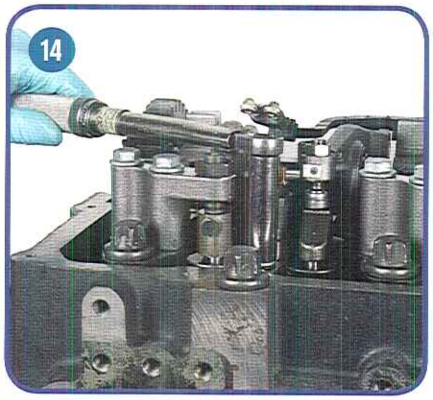
Pipe Installation

Install the pipe into the cylinder head. The locating surfaces on the pressure pipe must be vertically aligned to mate with the grooves in the cylinder head.

Injector Replacement Procedure

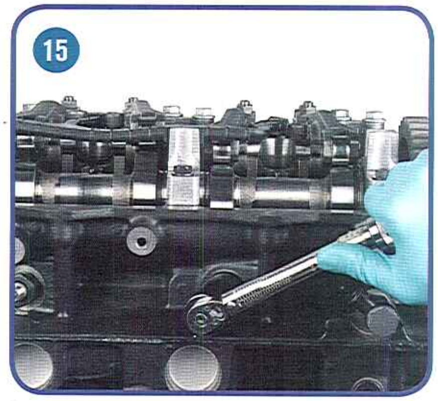
Retaining Nut Torque

Tighten the pipe retaining nut to initial torque.



Mounting Clamp Final Torque

Tighten the injector mounting clamp bolt to final torque.

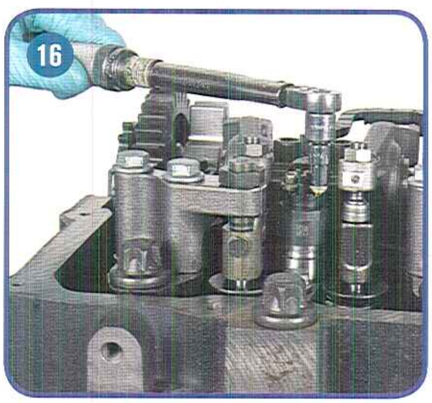


Retaining Nut Final Torque

Tighten the pipe retaining-nut to final torque.

▲ NOTE

Do not damage the injector electrical connections when tightening the harness to the injectors.



Injector Electrical Leads

Connect the electrical leads to the injector. The torque of these fasten-ers is critical. An accurate in/lb torque wrench must be used.

High Pressure Line

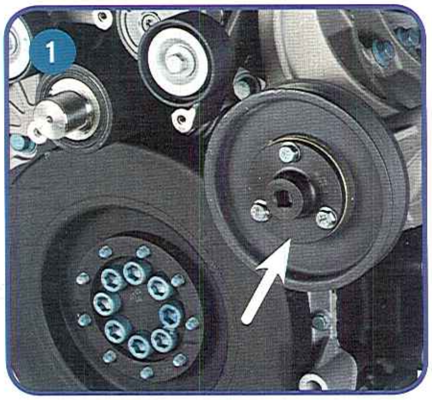
Install the new high-pressure line:

a. Install both ends of the new high-pressure injector line, finger tight.

b. Torque each line retaining nut to specification.

UNIQUE SERVICE PROCEDURES

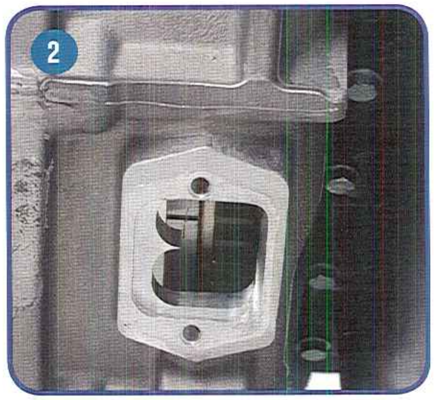
Verify Camshaft Timing



Install Baring Tool

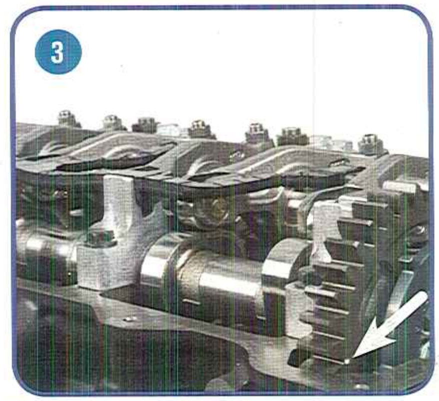
The camshaft timing should be verified if the cylinder head or camshaft is to be removed. This allows you to verify that the small gear on the back of the big intermediate gear has not slipped.

Install the baring tool (ZTSE4786) to the accessory drive pulley using the special bolts supplied with the tool.



Flywheel and Camshaft Alignment

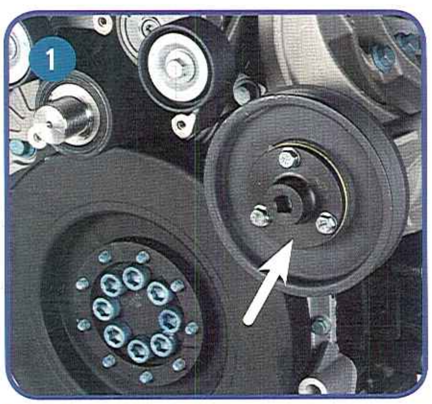
Use a breaker bar to turn the engine over until the TDC mark on the flywheel is aligned with the pointer on the flywheel housing window. With those aligned, the dot on the camshaft gear must be level with the cylinder head surface on the left side.



Verify Camshaft Timing

If the line on the flywheel is in line with the flywheel housing mark and the dot is on the left side of the cylinder head, the camshaft timing is correct. If the dot does not align with the cylinder head, either the rear gear train is miss-timed or the big intermediate gear has slipped.

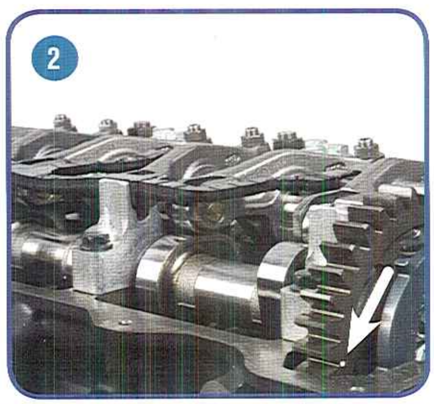
Valve Adjustment



Install Baring Tool

The valves require adjustment at set intervals and whenever any valve train components are removed from the engine. When adjusting the valves on a cylinder, the piston on that cylinder must be on top dead center compression.

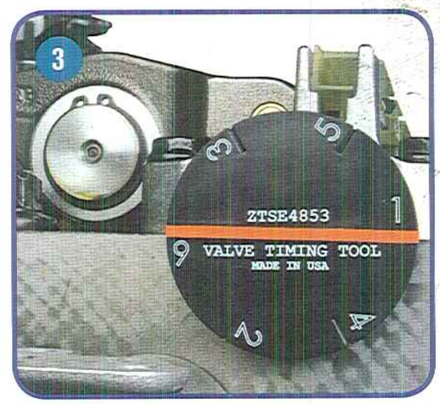
Install the baring tool (ZTSE4786) to the accessory drive pulley using the special bolts supplied with the tool.



Cylinder 1 TDC

Use a breaker bar and the rotation tool to bar the engine over until the camshaft gear timing dot is level with the cylinder head surface on the left side.

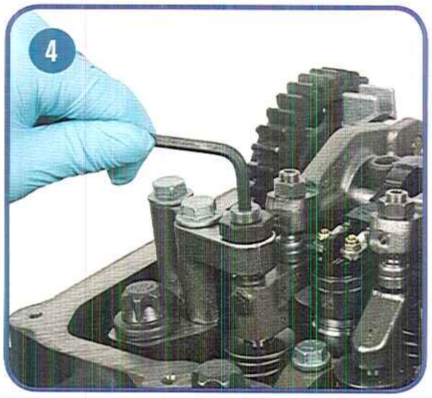
This will place number 1 piston at TDC (Top Dead Center) compression. Note the position of the cam lobes. Both lobes face slightly downward and the two valves should have clearance. This is the compression stroke.



Valve Timing Tool

Be sure that the camshaft timing dot is properly aligned. Install the Valve Timing Tool (ZTSE4853) into the front of the camshaft on the front of the engine. The number 1 on the Valve Timing Tool will be level with the cylinder head surface on the right side when #1 cylinder is on TDC compression.

Valve Adjustment



Loosen the Counterpiece Adjusting Screw

Loosen the counterpiece adjusting nut and back off the adjustment screw until it clears the bridge. Use a screwdriver to push down on the bridge several times to insure all oil has vacated the space above the piston.

Exhaust Valve Adjustment

Loosen the exhaust rocker arm adjusting nut and stud until a 0.8mm feeler gauge can be placed between the arm and the bridge. Tighten the rocker adjusting screw until the piston is collapsed into the bridge and the parts grip the feeler gauge, but not so far that the valves begin to open.

Lock Nut

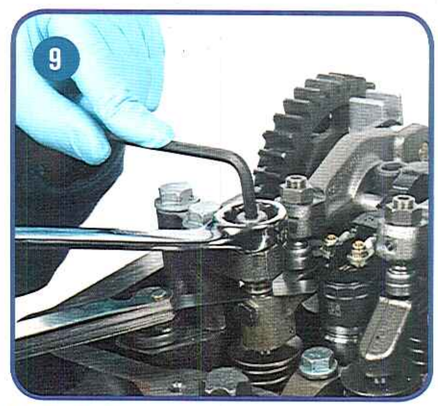
Tighten the exhaust rocker arm adjusting screw lock nut.

Counterpiece

Insert a 0.6mm feeler gauge between the counterpiece adjusting stud and the bridge.

Counterpiece Adjustment

Tighten the counterpiece adjusting screw until the piston is collapsed into the bridge and the parts grip the feeler gauge, but not so far that the valves begin to open



Lock Nut

Tighten the counterpiece adjusting stud lock nut.

If the exhaust valve and counterpiece are adjusted properly, the rocker will have free play

UNIQUE SERVICE PROCEDURES

Coolant Fill Procedure

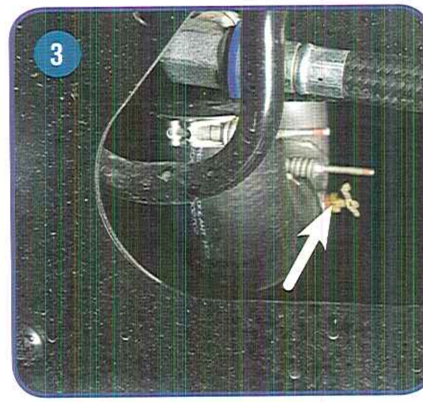
Fill Procedure With Vacuum Fill Tools

Pressure Cap

After all necessary service and repairs have been made to the cooling system, install the pressure cap on the cowl-mounted coolant recovery tank. Do not add coolant at this location.

Clamp Coolant Hose

Clamp off the hose between the deaeration tank and the coolant recovery tank. Use appropriate hose clamping tool to prevent hose damage.



Radiator Drain Valve

Close the drain valve on the lower radiator pipe.

LTR Drain Valve

Close the drain valve on the LTR.

Radiator Air Bleed

Close the air bleed on the top tank of the radiator.

LTR Air Bleed

Close the air bleed on the LTR.

Coolant Fill Procedure

Fill Procedure With Vacuum Fill Tools

Vacuum Fill Tool

Install the vacuum fill tool in the dearation tank. Attach shop air to the vacuum fill tool and turn the air supply on. Allow the system to reach a vacuum in the green zone of the tool gauge and pull the vacuum for at least five minutes. Place the coolant pickup tube on the vacuum tool into the new coolant supply. Open the blue coolant supply valve on the tool to fill the cooling system. Once the system is full and the vacuum has depleted, remove the vacuum fill tool.

Engine Warm Up

Start the engine and allow to idle for five minutes. While idling, open the LTR vent and allow air to bleed out. Maintain the coolant level in the dearation tank while bleeding.

LTR Air Bleed

Close the LTR air bleed when a steady flow of coolant is evident.

Install NON-VENTED Cap

After five minutes of idling, adjust the coolant level in the dearation tank and install and tighten the NON-VENTED dearation tank cap.

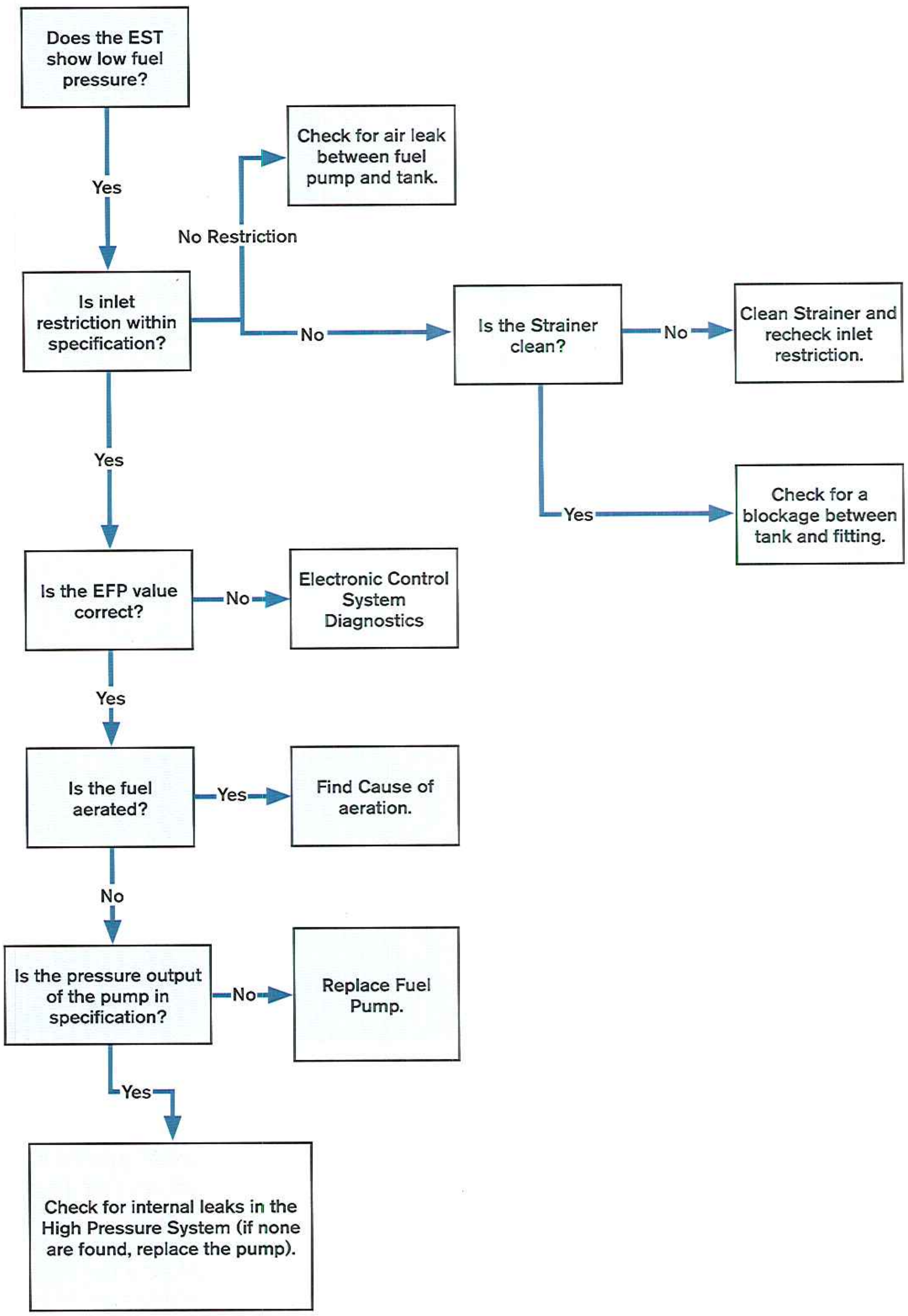
Clamp Tool

Remove the clamp tool from the coolant recovery tank hose.

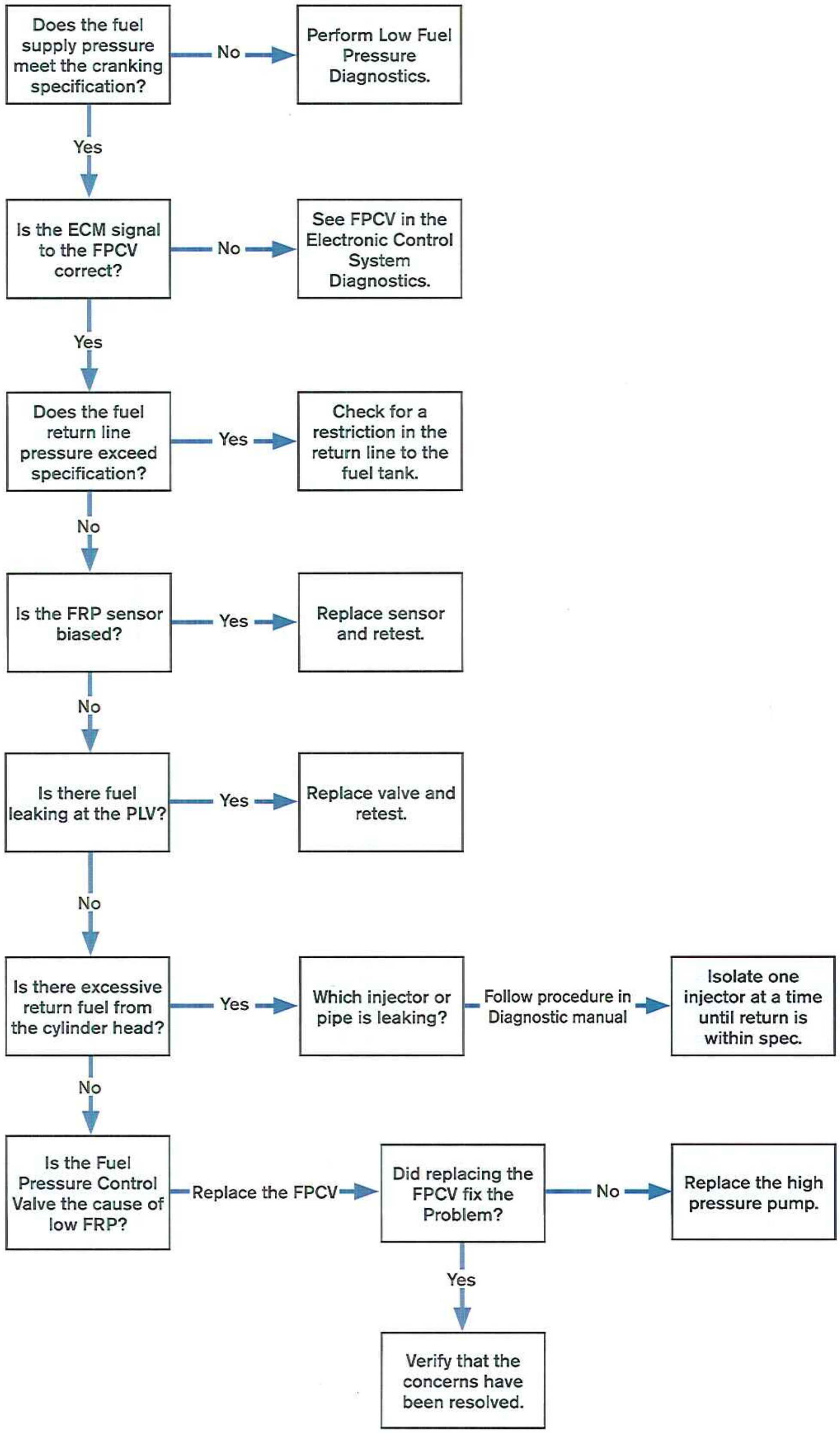
Engine Warm Up

Start and run the engine at high idle until the engine temperature reaches 190°F and the engine fan has cycled on and off once (this may require moving the vehicle outdoors and/or blocking the radiator with cardboard). Monitor the engine coolant in the dearation tank. Allow the engine to cool and carefully remove the dearation tank cap. Adjust the coolant level to the top of the dearation tank. Install and tighten the NON-VENTED dearation tank cap.

LOW PRESSURE FUEL SYSTEM DIAGNOSTICS

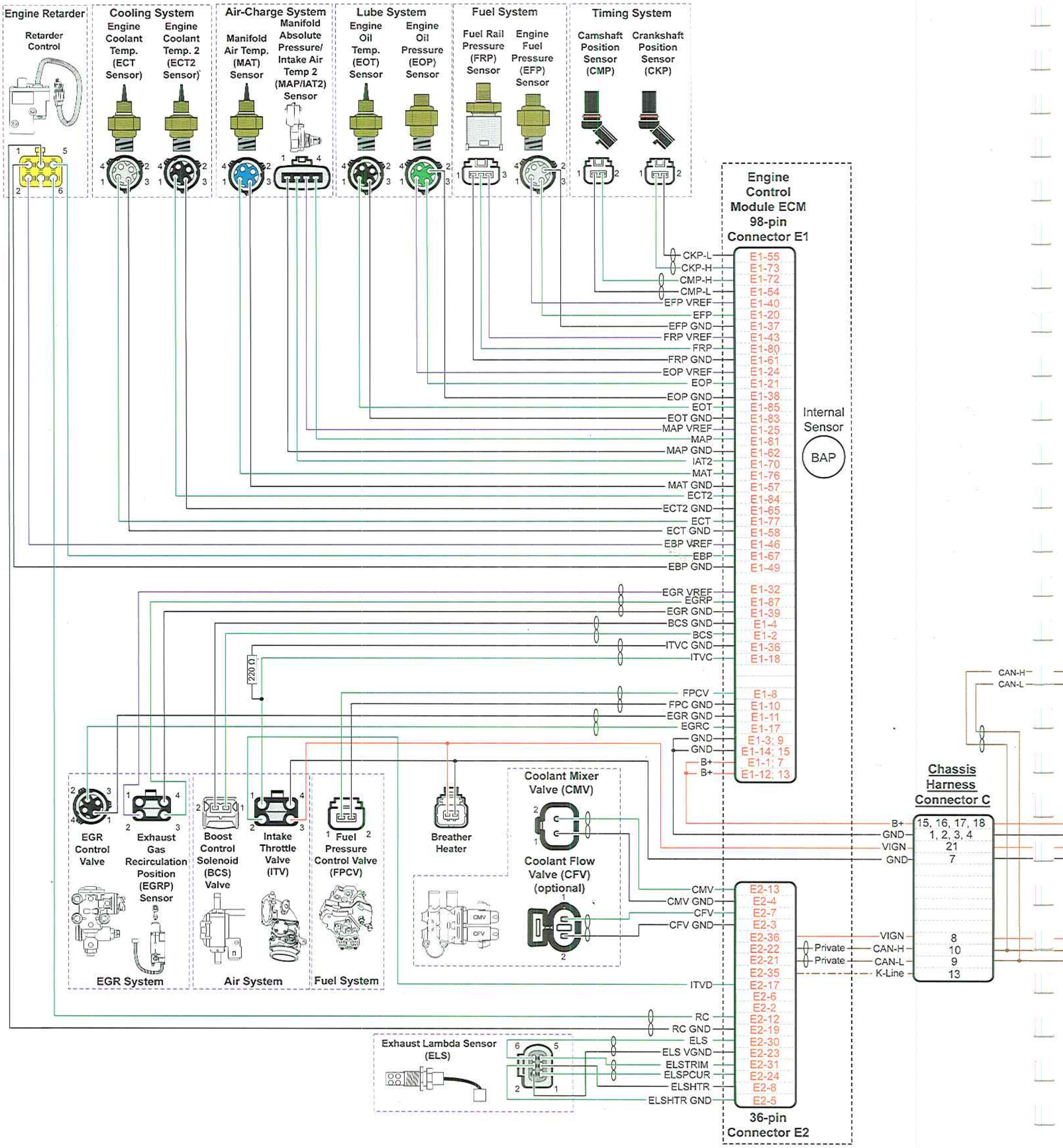


HIGH PRESSURE FUEL SYSTEM DIAGNOSTICS



ENGINE WIRING SCHEMATIC

ENGINE WIRING DIAGRAM (Side 1)



MAXXFORCE® 11 AND 13
2008 Model Year

⚠ WARNING

To prevent personal injury or death, read all safety instructions in the "Safety Information" section of *Engine Diagnostics Manual* EGES-420 before doing any diagnostic procedures.

Information on this form was current at the time of publication. Updates may have been made to introduce product improvements and technical advancements. See correct vehicle service publication for chassis wiring.

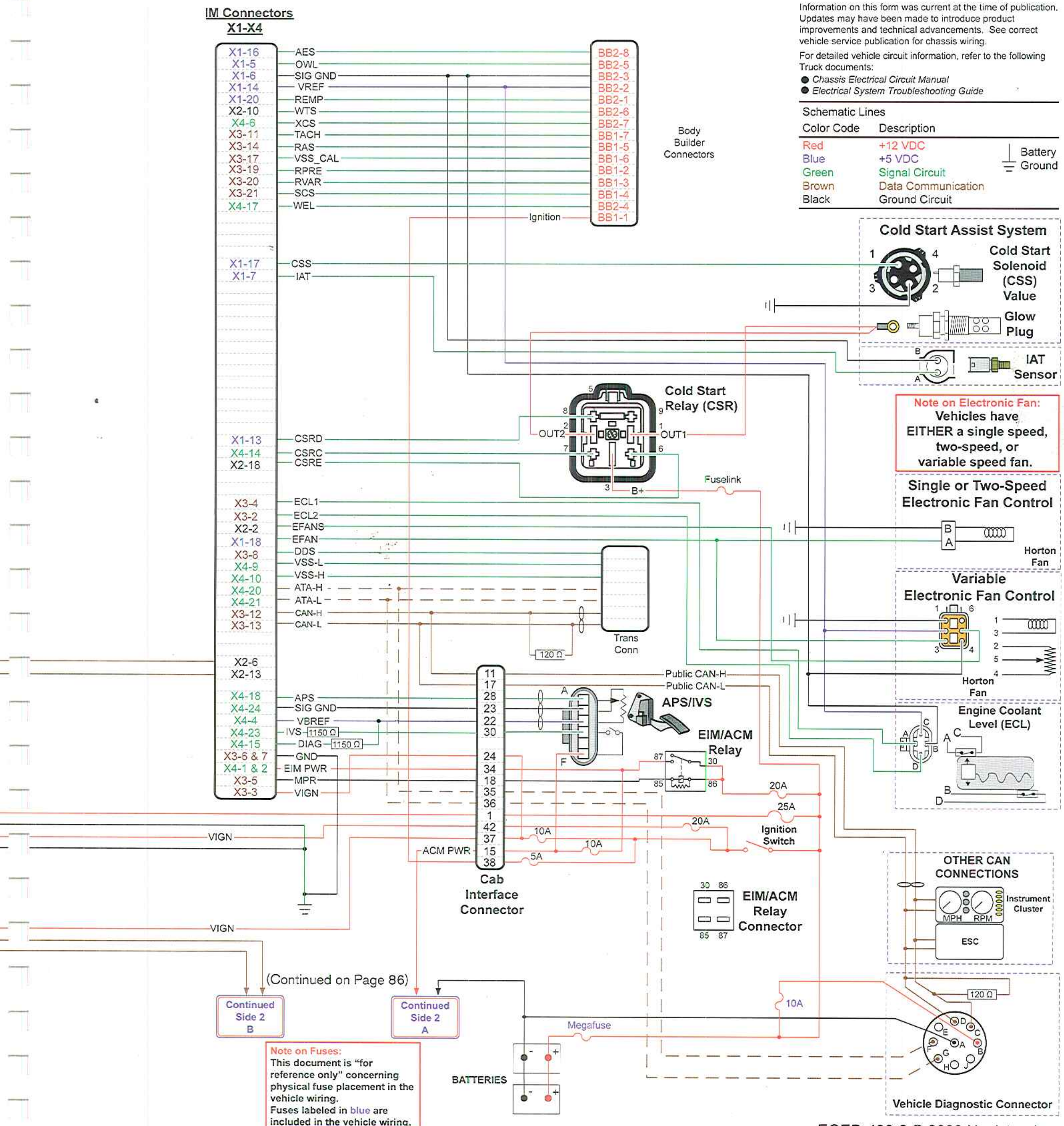
For detailed vehicle circuit information, refer to the following Truck documents:

- *Chassis Electrical Circuit Manual*
- *Electrical System Troubleshooting Guide*

Schematic Lines

Color Code	Description
Red	+12 VDC
Blue	+5 VDC
Green	Signal Circuit
Brown	Data Communication
Black	Ground Circuit

Battery Ground



(Continued on Page 86)

Note on Fuses:
This document is "for reference only" concerning physical fuse placement in the vehicle wiring.
Fuses labeled in blue are included in the vehicle wiring.

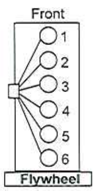
ENGINE WIRING DIAGRAM (Side 1

MAXXFORCE® 11 and 13
2008 Model Year

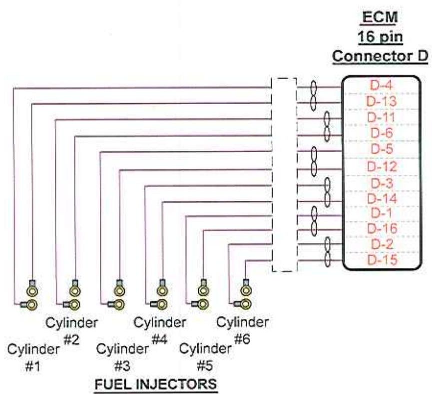
Chassis Mounted Components

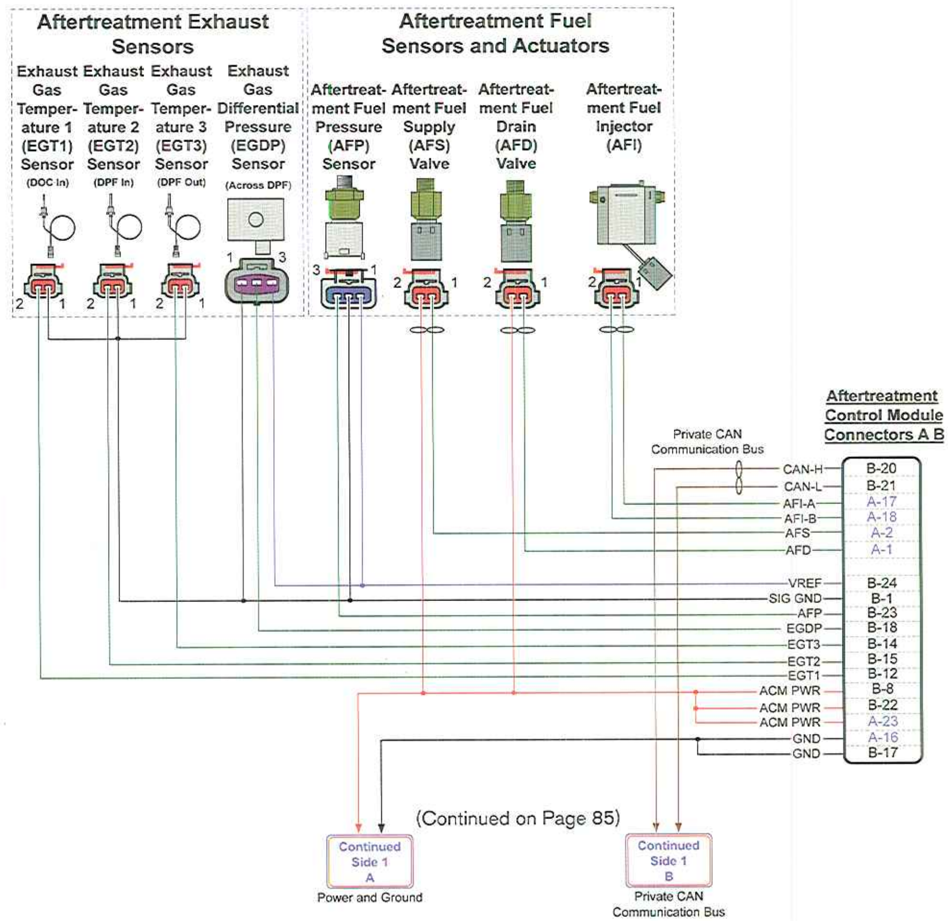
Engine Mounted Components

Chassis Mounted Components

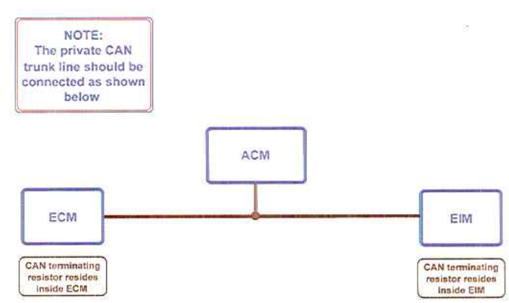


FIRING ORDER: 1 - 5 - 3 - 6 - 2 - 4



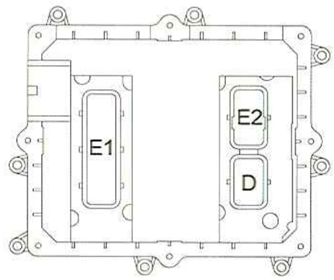


(Continued on Page 85)

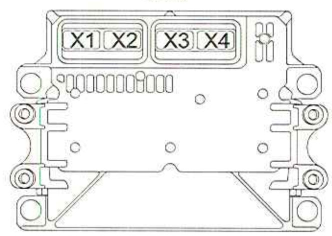


Connector Locations

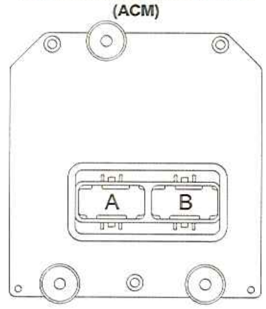
Engine Control Module (ECM)



Engine Interface Module (EIM)



Aftertreatment Control Module (ACM)



Hard Start and No Start Diagnostics 2008 Model Year MaxxForce™ 11 and 13	Technician ______	Miles ______
	Date ______	Hours ______
	Unit No. ______	VIN ______

⚠ WARNING

To avoid personal injury, death, or damage to the engine or vehicle, read all safety instructions in the "Safety Information" section of Engine Diagnostics Manual EGES-420 before doing form procedures.

Header Information and Specifications

1. Look up the VIN on ISIS for build date, engine hp, engine serial number, ECM and IDM calibration, and transmission.
2. See Performance Specifications for EFRC, injector number, and turbocharger number.
3. Use Performance Specifications to fill in the specifications needed for some tests.
4. Detailed information on these procedures can be found in Engine Diagnostics Manual EGES-420.
5. Do all tests in sequence unless directed otherwise. It is not necessary to complete the rest of the form after the problem has been found and corrected.

1. Visual Inspection

☐ Check all fluid levels.
☐ Inspect electrical connectors.
☐ Inspect air cleaner restriction indicator.
☐ Inspect for exhaust damage.

Fuel ☐	Oil ☐	Coolant ☐	Electrical ☐	Air ☐

Fuel Quality

Debris	Fuel Grade	Oil Gasoline Kerosene	Cetane Level

2. Initial Ignition Switch ON (Do not crank.)

☐ Verify 90 psi minimum truck air pressure.
☐ Look for WAIT TO START lamp to come on. (2-10 seconds, temperature dependent.)

Comments

3. Engine Cranking

☐ Cranking above 100 rpm. (Instrument panel)
☐ Oil pressure increased. (Instrument panel)

Specification ☐	☐	Actual

- If cranking rpm is below specification, check batteries and starting system.
- If oil pressure does not increase, check oil.

4. Diagnostic Trouble Codes (DTCs)

☐ Install Electronic Service Tool (EST).
☐ Use EST to read DTCs.
☐ Use EST to check KOEO values for temperature and pressure sensors.

Active DTCs	
Inactive DTCs	
Abnormal sensor values Suspect sensor/value	☐ Yes ☐ No

- Correct problem causing active DTCs before continuing.

5 Actuator Test

☐ Verify 90 psi minimun truck air pressure.
☐ Use EST to run Actuator Test.

Actuator	Status
EGR Throttle Valve Actuator	
ITV	
Retarder Control	
Boost Control Solenoid (BCS) Valve	

- If any Acuator Fails, correct Actuator Failure before continuing.

6. EST Data List

☐ Enter data in the Cranking Spec column.
☐ Monitor KOEO values and enter in KOEO column.
☐ Crank engine and monitor DATA for 20 seconds.
☐ Enter data in the Cranking Actual column.

PID	KOEO	Cranking Spec	Cranking Actual
VBAT			
RPM			
EOP			
EGRP			
IAT2			
EFP			
FRP			

- If VBAT is below spec, do "Main Power Voltage at ECM" test.
- If no rpm signal, check DTCs.
- If EOP is below spec, see "Low Oil Pressure " in Section 4.
- EGRP should equal 0.
- If IAT2 is out-of-range, see "IAT2 Sensor" in *Electronic Control System Diagnostics* section of manual.

7. Relative Compression Test

Cylinder	Time
1	
2	
3	
4	
5	
6	

Transmission Information:	Complaint ______	ACM Calibration ______	IAT temperature ______
Manual _____ Auto _____	Engine SN ______	EIM Calibration ______	Coolant temperature ______
Build date ______	Engine HP ______	ECM Calibration ______	Coolant temperature 2 ______
Calibration ______	EFRC ______	LP Turbocharger Part # ______	Manifold Absolute Temperature ______
	Injector Part # ______	HP Turbocharger Part # ______	IAT2 Temperature ______

Special Test Procedures

(Do the following tests only if instructed to do so.)

8.1 Low Pressure Fuel

☐ Test using EST monitor fuel pressure PID.

☐ Start or crank engine for 20 seconds and record results.

Pressure	Specification	Actual
EFP		
Is fuel aerated?		

- If pressure is pulsating or aerated, see "Combustion Leaks to Fuel" in Section 4 .
- If pressure is below specification and aerated, check for leaks in suction side to the pump.
- If pressure is below specification and not aerated, replace filter and test again.
- If pressure is still below specification, Test for inlet restriction.

8.2 High Pressure Fuel

- Connect a fuel pressure guage to the t-connector fuel line.

☐ Test using EST to monitor EFP and FRP PIDS while monitoring aftertreatment fuel pressure on the guage.

Pressure	Specification	Actual
FRP		
Aftertreatment Fuel Pressure		
EFP		

☐ Check the FPCV.

☐ Check the FPCV Resistance ______

☐ Measure the FPCV Duty Cycle ______

☐ Test the fuel rail pressure relief valve ☐ Pass ☐ Fail

☐ Fuel return flow

Cylinder	mL
1	
2	
3	
4	
5	
6	

9. Aftertreatment System

☐ Turn the ignition switch to ON. (Do not start engine)

☐ Open Aftertreatment session with EST.

☐ Record readings and verify similar sensor values.

☐ Verify soot and ash loading is at acceptable level.

☐ If level is unacceptable, start the engine and run the On-Board Filter Cleanliness Test.

☐ Record sensor test result readings.

Sensor	Specification	Engine ON	Test Result
EGT1			
EGT2			
EGT3			
EGDP			
Excessive soot and ash loading?			☐ Yes ☐ No

- If On-Board Filter Cleanliness Test does not detect a problem, the test will complete regeneration cycle and resume low idle.
- If On-Board Filter Cleanliness Test detects a problem, the ECM will cancel test, set a DTC, and resume low idle.

10. Cold Start Assist Operation

☐ Enter data in ECT, IAT, IAT2, MAT TEMP Column.

PID	TEMP		
	Key On	Key On + 30 sec	Engine Crank
MAT			
IAT			
IAT2			
ECT			

☐ If there is no change in MAT see Cold Start Assist in section 5.

☐ Install Amp Clamp around the two feed wires and cycle the ignition.

Test	Glow Plug Wires	
	Circuit 1	Spec
Amperage draw		20 - 50 amps
Voltage at element		VBAT
Element continuity	☐ Yes ☐ No	
Wiring harness continuity and resistance		< 5 ohms
Relay operation Battery feed Relay output		 B+ B+

Performance Diagnostics 2008 Model Year MaxxForce™ 11 and 13	Technician ______	Miles ______
	Date ______	Hours ______
	Unit No. ______	VIN ______

⚠ WARNING
To avoid personal injury, death, or damage to the engine or vehicle, read all safety instructions in the "Safety Information" section of Engine Diagnostics Manual EGES-420 before doing form procedures.

Header Information and Specifications

1. Look up the VIN on ISIS for build date, engine hp, engine serial number, ECM and EIM calibration, and transmission.
2. See Performance Specifications for EFRC, injector number, and turbocharger number.
3. Use Performance Specifications to fill in the specifications needed for some tests.
4. Detailed information on these procedures can be found in Engine Diagnostics Manual EGES-420.
5. Do all tests in sequence unless directed otherwise. It is not necessary to complete the rest of the form after the problem has been found and corrected.

1. Visual Inspection

- ☐ Check engine oil level.
- ☐ Check engine oil quality.
- ☐ Check engine coolant level.
- ☐ Check Charge Air Cooler (CAC) system.
- ☐ Check intake system.
- ☐ Check exhaust system.

2.1 Fuel Quality

	Yes	No
Water	☐	☐
Waxing	☐	☐
Sediment	☐	☐
Gasoline	☐	☐
Kerosene	☐	☐

2.2 Low Pressure Fuel System

- ☐ Test using Electronic Service Tool (EST) monitor fuel pressure Parameter Identifier (PID).
- ☐ Start or crank engine for 20 seconds and record results.

Pressure	Specification	Actual
EFP		
Is fuel aerated?		

- If pressure is pulsating or aerated, see Low Pressure Fuel System in Section 5.
- If pressure is below specification and aerated, check for leaks in suction side to the pump.
- If pressure is below specification and not aerated, replace filter and test again.
- If pressure is still below specification, test for inlet restriction.

3. Sensor Compare/DTCs & ECM Calibration

3.1 ECM and EIM Calibration

- ☐ Install Electronic Service Tool (EST).

Module	Calibration
ECM	
EIM	
ACM	

3.2 Checking For Diagnostic Trouble Codes(DTCs)

- ☐ Install Electronic Service Tool (EST).
- ☐ Use EST to read DTCs.
- ☐ Use EST to check KOEO values for temperature and pressure sensors.

Active DTCs		
Inactive DTCs		
Abnormal sensor values Suspect sensor/value	☐ Yes	☐ No

- Correct problem causing active DTCs before continuing.

3.3 Sensor Compare

Sensor	Reading
ECT	
ECT2	
IAT	
IAT2	
EOP	
MAT	
EGT1	
EGT2	
EGT3	
EFP	
FRP	
EOP	
EBP	
MAP	
BAP	

4. Actuator Test

- ☐ Truck air system pressure (621 kPa [90 PSI] minimum)

kPa	PSI

- ☐ Install Electronic Service Tool (EST).
- ☐ Use EST to run actuator test.
- ☐ Monitor actuators.

Actuator	Pass	Fail
ITV		
BCS Valve		
EGRC		
CMV		
Retarder Control		
AFI		
AFS		
AFD		
CSR		
ECI		
EFAN		
EGRP		

5. Air Supply System

- ☐ Truck air system pressure (621 kPa [90 PSI] minimum)

kPa	PSI

Air connection pressures.

Connection	kPa	PSI
EGR Throttle Valve In		
EGR Control Valve In		
Boost Control Actuator		
Boost Control Solenoid (BCS) Valve Out		
BCS Valve In		
Exhaust Manifold with Butterfly In		
Retarder Control Out		
Retarder Control In		

Transmission Information:	Complaint ______	ACM Calibration ______	IAT temperature ______
Manual _____ Auto ______	Engine SN ______	EIM Calibration ______	Coolant temperature ______
Build date ______	Engine HP ______	ECM Calibration ______	Coolant temperature 2 ______
Calibration ______	EFRC ______	LP Turbocharger Part # ______	Manifold Absolute Temperature ______
	Injector Part # ______	HP Turbocharger Part # ______	IAT2 Temperature ______

7.3 Aftertreatment Fuel Injector (AFI) Leak Test

☐ Install Electronic Service Tool (EST).
☐ Remove AFI from exhaust manifold.
☐ Using EST run AFT system leak test.
☐ Measure AFI fuel output.

Is fuel leak present?

☐ Yes ☐ No

7.4 Fuel Shut-off Valve Leak Test

☐ Install fuel inlet restriction and aeration tool.
☐ Install Electronic Service Tool (EST).
☐ Use EST to run AFS leak test.
☐ Is fuel flow present in fuel inlet restriction and aeration tool?

☐ Yes ☐ No

8. Relative Compression

☐ Install Electronic Service Tool (EST).
☐ Using EST run relative compression test.
☐ Record results.

Cylinder	Time
Baseline	
1	
2	
3	
4	
5	
6	
Baseline	

9. Engine Run-Up Test

☐ Install Electronic Service Tool (EST).
☐ Using EST run engine run-up test.
☐ Record results.

Cylinder	Seconds
1	
2	
3	
4	
5	
6	

10. Injector Disable

☐ Install Electronic Service Tool (EST).
☐ Using EST run injector disable test.
☐ Disable each cylinder and record engine noise change.

Cylinder	Change (Y/N)
1	
2	
3	
4	
5	
6	

11. High Pressure Fuel Pump Run-Up Test

☐ Install Electronic Service Tool (EST).
☐ Using EST run high pressure fuel pump run-up test.
☐ Record results.

PID	Values	Units	Status
High Pressure Pump Build up Speed 1			
High Pressure Pump Build up Speed 2			
High Pressure Pump Build up Speed 3			
High Pressure Pump Build up Speed 4			
High Pressure Pump Pressure Drop Speed 1			
High Pressure Pump Pressure Drop Speed 2			
High Pressure Pump Pressure Drop Speed 3			
High Pressure Pump Pressure Drop Speed 4			

12. High Crankcase Pressure

☐ Coking or excessive oil in intake ☐ Yes ☐ No

Flow readings

Location	Low, Normal, High
Breather Cup	
Breather Tube Outlet	
CDR In	
CDR Out	

Pressure reading

Location	PSI
Air Compressor Disconnected	
Low Pressure Turbocharger Oil Drain Disconnected	
Air Compressor & LP Turbocharger Oil Drain Connected	
Is Pressure Pulsing	☐ Yes ☐ No

13. Exhaust Restriction

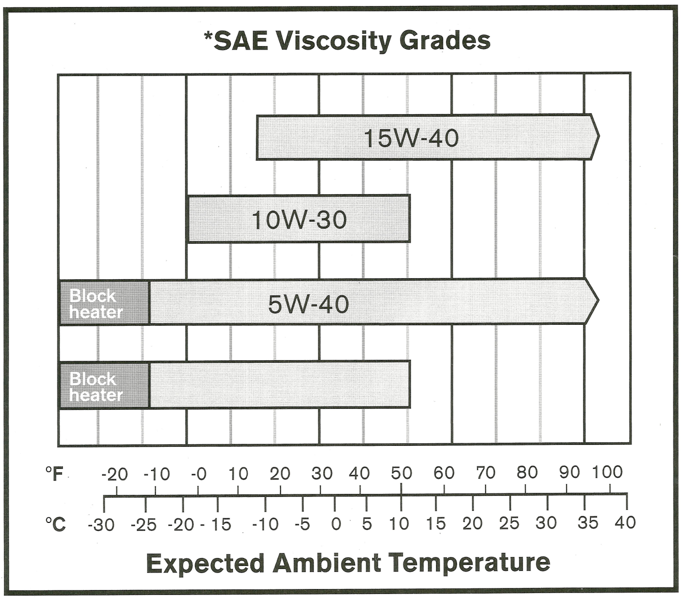
☐ Install Electronic Service Tool (EST).
☐ Monitor exhaust back pressure (EBP) Parameter identifier (PID).

Cylinder	Reading
EGR Control Valve Connector Disconnected	
Exhaust Pipe Disconnected	

SERVICE INTERVALS

Service Operation Interval–whichever comes first, kilometers (miles), months, years, hours, or liters (gallons) of fuel.

SERVICE INTERVALS	
Visual Inspection	Belt, Air Intake Piping, and Clamps **Service Interval:** 24,00 km (15,000 miles) /6 months /550 hours
Engine Oil and Filter Maintenance	**Service Interval:** 40,000 km (25,000 miles) /12 months /1,100 hours /16,000 liters (2,100 gallons) of fuel **Capacity:** 40 liters (42 quarts) API CJ-4 oils are required. See the chart in the Operator's Manual to determine the proper oil viscosity for the ambient temperatures. *
Fuel System Maintenance	**Filter Service Interval:** 40,000 km (25,000 miles) / 12 months /1,100 hours /16,000 liters (4,200 gallons) of fuel **Strainer Service Interval:** 80,000 km (50,000 miles) /24 months /2,200 hours /32,000 liters (8,400 gallons) of fuel
Crankcase Breather System Maintenance	**Filter Service Interval:** Replace the Crankcase Breather filter every 161,100 km (100,000 miles) /3,300 hours /12 months
Valve Adjustment	**400,000 km (250,000 miles):** Adjust engine valve lash **400,000 km (250,000 miles):** Adjust engine brake lash (if equipped)
Cooling System Maintenance	Shell ROTELLA® Extended Life Coolant is the standard factory fill for the cooling system. **Coolant Service Interval:** Add Shell ROTELLA® Extended Life Coolant (ELC) Extender at 500,000 km (300,000 miles) /3 years /6,000 hours. **Coolant Service Interval:** 1,000,000 km (600,000 miles) /6 years /12,000 hours



DTC = **DIAGNOSTIC TROUBLE CODES** **SPN** = **SYSTEM PARAMATER NUMBER** **FMI** = **FAILURE MODE INDICATOR**

ENGINE LAMPS: **RSL** = **RED STOP LAMP** **AWL** = **AMBER WARNING LAMP** **MIL** = **MALFUNCTION INDICATOR LAMP**

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
1112	168	3	B+ to EIM Out of Range HIGH	AWL	EIM PWR above 17 volts, Charging system fault, Low batteries
1113	168	4	B+ to EIM Out of Range LOW	AWL	EIM PWR below 7.5 volts, Charging system fault, Low batteries
1114	110	4	ECT signal Out of Range LOW	AWL	ECT signal circuit short to GND, or failed sensor
1115	110	3	ECT signal Out of Range HIGH	AWL	ECT signal circuit open or short to PWR, or failed sensor
1119	110	12	ECT Temp above Maximum	AWL	ECT above 120 C, Cooling system fault, biased sensor
1121	102	3	MAP signal Out of Range HIGH	AWL	MAP signal circuit open or short to PWR, or failed sensor
1122	102	4	MAP signal Out of Range LOW	AWL	MAP signal circuit short to GND, or failed sensor
1124	164	4	FRP signal Out of Range LOW	AWL	FRP signal circuit short to GND, or failed sensor
1125	164	3	FRP signal Out of Range HIGH	AWL	FRP signal circuit open or short to PWR, or failed sensor
1129	91	0	APS VREF out of range HIGH	AWL	APS VREF circuit short to PWR
1130	91	1	APS VREF out of range LOW	AWL	APS VREF circuit short to GND
1131	91	4	APS signal Out of Range LOW	AWL	APS signal circuit open or short to GND, or failed sensor
1132	91	3	APS signal Out of Range HIGH	AWL	APS signal circuit short to PWR, or failed sensor
1133	91	2	APS In-Range fault	AWL	APS signal unchanged while IVS has changed
1134	91	7	APS and IVS Disagree	AWL	IVS signal unchanged while APS has changed
1135	558	11	IVS signal fault	AWL	IVS circuit fault. Signal does not change state
1136	94	4	EFP signal Out of Range LOW	AWL	EFP signal circuit open or short to GND, or failed sensor
1137	94	3	EFP signal Out of Range HIGH	AWL	EFP signal circuit short to PWR, or failed sensor
1140	8551	7	Vehicle hard brake event	No Lights	Vehicle stopped abruptly. (This is an alert, not a fault)
1141	84	4	VSS signal Out of Range LOW	AWL	VSS frequence below 0.25 Hz
1142	84	3	VSS signal Out of Range HIGH	AWL	VSS frequence above 4365 Hz
1148	84	8	VSS circuit frequency out of range HIGH	AWL	VSS frequency was above normal range
1149	84	2	VSS anti-tampering fault	AWL	VSS was detected without engine speed and load
1151	108	3	BAP signal Out of Range HIGH	AWL	BAP voltage above max, Failed ECM

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
1152	108	4	BAP signal Out of Range LOW	AWL	BAP voltage below min, Failed ECM
1153	108	10	BAP signal abnormal rate of change	AWL	BAP voltage change Error, Failed ECM
1154	171	4	IAT signal Out of Range LOW	AWL	IAT signal circuit short to GND, or failed sensor
1155	171	3	IAT signal Out of Range HIGH	AWL	IAT signal circuit open or short to PWR, or failed sensor
1158	1131	0	IAT2 Temp above Maximum	AWL	IAT2 above 100 deg C, or 135 deg C w/ engine braking –Biased sensor or circuit –Engine over heating, cooling system, EFAN
1159	1131	3	IAT2 signal Out of Range HIGH	AWL	IAT2 signal circuit open or short to PWR, or failed sensor
1160	1131	4	IAT2 signal Out of Range LOW	AWL	IAT2 signal circuit short to GND, or failed sensor
1161	105	4	MAT signal Out of Range LOW	AWL	MAT signal circuit short to GND, or failed sensor
1162	105	3	MAT signal Out of Range HIGH	AWL	MAT signal circuit open or short to PWR, or failed sensor
1163	2791	4	EGRP signal out of range LOW	AWL	EGRP signel circuit short to GND, or failed sensor
1164	2791	3	EGRP signal Out of Range HIGH	AWL	EGRP signal circuit open or short to PWR, or failed sensor
1166	105	0	MAT above Maximum	AWL	MAT temp above 80 deg C at normal operation, or 90 deg C with the retarder control on.
1211	100	4	EOP signal Out of Range LOW	AWL	EOP signal circuit open or short to GND, or failed sensor
1212	100	3	EOP signal Out of Range HIGH	AWL	EOP signal circuit short to PWR, or failed sensor
1213	8029	4	Remote Throttle signal Out of Range LOW	AWL	Remote Throttle signal circuit short to GND
1214	8029	3	Remote Throttle signal Out of Range HIGH	AWL	Remote Throttle signal circuit open or short to PWR
1221	536	2	SCCS switch circuit fault	AWL	Cruise control switch fault
1222	597	2	Brake switch disagreement	AWL	Brake switch or circuit fault
1236	111	2	ECL switch circuit fault	AWL	ECL switch circuit fault or failed switch
1245	7272	0	Fan Speed above desired	AWL	Fan speed error over 500 rpm for 45 seconds
1246	7272	11	EFAN control circuit fault	AWL	EFAN circuit fault, or failed EFAN
1247	1639	3	Fan Speed Sensor Out of Range LOW	AWL	EFANS signal circuit open or short to GND
1248	1639	4	Fan Speed Sensor Out of Range HIGH	AWL	EFANS signal short circuit to PWR
1256	7312	5	Boost Control Solenoid open circuit	AWL	BCS open circuit, or failed valve
1257	7312	11	Boost Control Solenoid short circuit	AWL	BCS short circuit, or failed valve
1258	7320	5	Coolant Mixer Valve open circuit	AWL	CMV open circuit, or failed valve
1259	7320	11	Coolant Mixer Valve short circuit	AWL	CMV short circuit, or failed valve
1260	7321	5	Coolant Flow Valve open circuit	AWL	CFV open circuit, or failed valve

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
1261	7321	11	Coolant Flow Valve short circuit	AWL	CFV short circuit, or failed valve
1286	51	7	ITV unable to achieve commanded position	AWL	ITV circuit fault, or failed ITV
1289	51	0	ITV overtemperature	AWL	ITV above maxium temp. ITV Internal fault
1292	51	5	IVT Communication Error	AWL	ITV circuit fault: open or short to PWR or GND –Failed ITV actuator
1295	3464	5	Intake Throttle Valve open circuit	AWL	ITV control open circuit, or failed valve
1296	3464	11	Intake Throttle Valve short circuit	AWL	ITV control short circuit, or failed valve
1297	51	3	ITV no input signal	AWL	ITV circuit fault: open or short, or failed ITV
1298	51	2	ITV Communication fault	AWL	ITV circuit fault: open or short to PWR or GND –Failed ITV actuator
1311	175	4	EOT signal Out of Range LOW	AWL	EOT signal circuit short to GND, or failed sensor
1312	175	3	EOT signal Out of Range HIGH	AWL	EOT signal circuit open or short to PWR, or failed sensor
1371	676	18	Cold start solenoid fault	AWL	Cold start solenoid circuit fault, or failed solenoid
1372	676	17	Cold start relay control fault	AWL	Cold start relay circuit fault, or failed relay
1373	7263	11	Cold start relay fault	AWL	Cold start relay circuit fault, or failed relay
1375	7264	7	Cold start relay circuit fault	AWL	CSR circuit fault or failed relay
1377	1136	3	ECM Temp above maximum	No Lights	ECM Temp above max, Failed ECM
1378	1136	4	ECM Temp below minimum	No Lights	ECM Temp below min, Failed ECM
1379	158	0	B+ to ECM Out of Range HIGH	AWL	ECM internal fault
1380	158	1	B+ to ECM Out of Range LOW	AWL	ECM PWR below 7.5 Volts, Charging system fault, Low batteries
1381	158	3	B+ to ECM Out of Range Spiked HIGH	AWL	ECM PWR Spiked above 16 Volts, Charging system fault, or 24 V jump start
1382	158	4	B+ to ECM Out of Range Spiked LOW	AWL	–ECM PWR Spiked below 7 Volts, low battery voltage during engine crank –ECM PWR circuit fault
1607	8021	5	CMP –No signal	AWL	CMP circuit open, or failed sensor
1608	8021	7	CMP sensor angle based phase system error–disagreement	AWL	Camshaft to crankchaft timing misaligned Circuit fault or failed sensor
1609	8021	8	CMP sensor time based phase system disagreement	AWL	CMP circuit fault, or failed sensor
1610	8021	14	CMP circuits reversed	AWL	CMP circuit are reversed
1611	8021	3	CMP signal Out of Range HIGH	AWL	CMP circuit short to PWR, or failed sensor
1612	8021	4	CMP signal Out of Range LOW	AWL	CMP circuit short to GND or failed sensor
1614	8064	3	CKP signal Out of Range HIGH	AWL	CKP circuit short to PWR, or failed sensor
1615	8064	4	CKP signal Out of Range LOW	AWL	CKP circuit short to GND or failed sensor
1616	1442	5	Fuel Pressure Control Valve open circuit	AWL	FPCV open circuit, or failed valve
1617	1442	11	Fuel Pressure Control Valve short circuit	AWL	FPCV short circuit, or failed valve

DIAGNOSTIC TROUBLE CODES

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
1618	1119	0	Lambda sensor correction value above normal	AWL	Lambda correction value above 200mV for more then 2 seconds –Intermittent open or short circuit, failed sensor
1619	1119	1	Lambda sensor Not Plausible	AWL	Lambda sensor signal changed more than 5 volts within 2 seconds –Intermittent open or short circuit, failed sensor
1620	1119	2	Lambda sensor circuit intermittent contact	AWL	Lambda sensor intermittent circuit fault
1621	1119	5	Lambda sensor monitoring below lower limit	AWL	Lambda sensor circuit fault, or failed sensor
1622	1119	7	Lambda sensor circuit fault	AWL	Lambda sensor below 0.2 Volts, circuit fault, or failed sensor
1623	1119	11	Lambda heater circuit fault	AWL	Lambda heater circuit fault or failed sensor
1624	7319	16	Lambda Temp calculation above normal	AWL	Lambda above 800 C for 60 seconds
1625	7319	17	Lambda Temp calculation below normal	AWL	Lambda below 650C for 60 seconds whan it should be fully warmed up. –heater circuit, or failed sensor
1626	7319	18	Lambda Temp calibration calculation value above normal	AWL	Lambda sensor temperature correction calculation above norm. –Lambda circuit fault, or failed sensor
1627	7319	19	Lambda Temp calibration calculation value below normal	AWL	Lambda sensor temperature correction calculation below norm. –Lambda circuit fault, or failed sensor
1628	1119	22	Lambda sensor Temp above Maximum	AWL	Lambda Temp above 800 C, Plugged exhaust, over-fueling, biased sensor (Special DTC clearing procedure)
1629	1119	12	Lambda sensor not detected in exhaust system	AWL	Lambda sensor internal resistance has change more then 1500 ohms, circuit faults, or failed sensor
1630	1119	15	Lambda sensor SPI communication error status	AWL	Lambda circuit fault, or failed sensor
1635	7311	4	ECT2 signal Out of Range LOW	AWL	ECT2 signal circuit short to GND, or failed sensor
1636	7311	3	ECT2 signal Out of Range HIGH	AWL	ECT2 signal circuit open or short to PWR, or failed sensor
1729	3251	4	EGDP signal out of range LOW	AWL	EGDP signal circuit open or short to GND, or failed sensor
1731	3251	3	EGDP signal out of range HIGH	AWL	EGDP signal circuit short to PWR, or failed sensor
1737	3241	4	EGT1 signal out of range LOW	AWL	EGT1 signal circuit short to GND, or failed sensor
1738	3241	3	EGT1 signal out of range HIGH	AWL	EGT1 signal circuit open or short to PWR, or failed sensor
1741	3242	4	EGT2 signal out of range LOW	AWL	EGT2 signal circuit short to GND, or failed sensor
1742	3242	3	EGT2 signal out of range HIGH	AWL	EGT2 signal circuit open or short to PWR, or failed sensor

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
1744	3245	4	EGT3 signal out of range LOW	AWL	EGT3 signal circuit short to GND, or failed sensor
1745	3245	3	EGT3 signal out of range HIGH	AWL	EGT3 signal circuit open or short to PWR, or failed sensor
2212	175	0	EOT Temp above Maximum	AWL	EOT above 122 C, Biased EOT sensor or circuit
2243	8351	7	FRP above pressure relieve valve limitation	RSL	Pressure relief valve failed to open. Biased FRP sensor or circuit. Fail rail pressure relief valve
2244	8351	0	Fuel Rail Pressure relief valve opened (Pressure was too High)	AWL	Fuel Rail Pressure too high, FRP signal circuit open or short to PWR, or FPCV circuit open.
2245	8352	1	Fuel Pressure Controller Output High at Low Idle	RSL	FPCV command above 10 % duty cycle at low idle –Biased FRP circuit / sensor –Stuck or sticking FPCV or circuit fault –High pressure fuel system fault –Low fuel supply pressure
2246	8352	0	FRP above or below desired	RSL	FRP above or below desired for over 5 seconds –Biased FRP circuit / sensor –Stuck or sticking FPCV or circuit fault –High pressure fuel system fault
2247	8353	7	HP fuel pump erratic fuel quantity balancing	RSL	Possible Fuel system leak –Biased FRP circuit / sensor –Stuck or sticking FPCV or circuit fault –Fuel system restriction –Fuel system aeration –High pressure fuel system fault –Low fuel supply pressure
2248	8354	0	Fuel Rail Pressure above Maximum	RSL	FRP above 195 Mpa –Biased FRP circuit / sensor –Stuck or sticking FPCV or circuit fault
2310	100	10	EOP abnormal rate of change	AWL	Intermittent circuit fault, wired incorrectly Failed sensor
2311	100	0	EOP above maximum	AWL	Oil Pressure above 7 psi at engine off –EOP biased sensor or circuit
2312	100	11	EOP below minimum	RSL	Low Oil Pressure at engine idle –EOP biased sensor or circuit.
2313	100	1	EOP below Warning Level	RSL	EOP below threshold –dealer programmable option
2314	100	7	EOP below Critical Level	RSL	EOP below threshold –dealer programmable option
2315	190	0	Engine Speed above Warning Level	AWL	Engine over speed I6 –3200 rpm, V8 –3700 rpm, V6 –3600 rpm
2316	190	16	RPM above maximum at ECM	RSL	Engine over speed 2500 rpm
2317	84	0	VSS value above programmable limit 1	AWL	VSS over threshold –dealer programmable option
2318	84	14	VSS value above programmable limit 2	AWL	VSS over threshold –dealer programmable option

DIAGNOSTIC TROUBLE CODES

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
2321	110	0	ECT above Warning Level	AWL	EOT above 70 C, or above 75 C during Retarder control
2322	110	7	ECT above Critical Level	RSL	EOT above threshold –dealer programmable option
2323	111	1	ECL below Warning/Critical Level	RSL	Low Coolant level –dealer programmable option
2324	593	14	Engine stopped by IST	No Lights	Engine was shutdown by the Idle Shutdown Timer. (This is an alert, not a fault)
2325	110	14	Engine de-rate due to: ECT, ECT2, ECL, EOT, or plugged DPF	AWL	ECT, ECT2, EOT above temperature set point (dealer programmable) –Coolant below level (dealer programmable) –plugged DPF
2235	8354	1	FRP Unable to Build During Engine Cranking	RSL	FRP below 10 MPa (1450 psi) during engine crank –Low fuel supply –FPCV circuit fault, or failed valve –High pressure fuel pump failure
2351	7129	1	EBP below desired level	AWL	EBP below -10 psi Exhaust leaks, failed Turbocharger, or Biased EBP circuit or sensor. (or MaxxForce 11 & 13 Retarder Control failure)
2352	7129	0	EBP above desired level	AWL	EBP above 10 psi Exhaust restriction, Plugged DPF, or Biased EBP circuit or sensor. (or MaxxForce 11 & 13 Retarder Control failure) Sticky Turbocharger Vanes
2357	7129	7	Retarder control valve unable to achieve desired EBP	AWL	EBP below desired Failed RC valve, Exhaust Leak, Cracked DPF, Failed Turbocharger, Low engine performance
2369	1378	2	Engine Oil Service Required	No Lights	Engine oil service reminder –dealer programmable option
2370	94	17	Fuel filter change reminder	No Lights	Change fuel filter. (This is an alert, not a fault)
2371	94	0	Fuel Pressure above normal	AWL	Engine fuel pressure above 145 psi with engine running –Biased EFP sensor or circuit –Fuel system fault
2372	94	1	Fuel Pressure below normal	AWL	Engine fuel pressure below 43 psi with engine running –Biased EFP sensor or circuit –Restricted fuel filter –Low fuel supply level –Fuel system fault
2391	2791	11	EGR valve internal circuit failure	AWL	EGR control circuit fault, or failed EGR
2674	3242	2	EGT2 signal In-Range fault	AWL	Biased EGT2 sensor or circuit
2675	3241	2	EGT1 signal In-Range fault	AWL	EGT1 sensor or circuit fault
2676	3245	2	EGT3 signal In-Range fault	AWL	Biased EGT3 sensor or circuit

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
2687	8302	1	DPF, low flow resistance	AWL	–Exhaust leak before DPF –Leaking or reversed EGDP sensor hoses –Failed DPF (open flow) –Biased EGDP sensor or circuit
2698	3251	0	DPF high restriction	AWL	DPF needs to regenerate (This is an alert, not a fault)
2732	3251	2	EGDP stuck in range fault	AWL	–EGDP sensor tube(s) restricted or open. –Biased EGDP sensor or circuit
2773	8303	10	DOC unable to reach Regen temp	AWL	EGT2 not heating up during a fuel injected Regen, but EGT3 is heating up –Failed DOC
2774	8303	1	DOC efficiency –AFI Low flow	AWL	EGT2 and EGT3 not heating up during a fuel injected Regen –AFI injection fault
2775	8303	7	DOC occlusion is severe	No Lights	DOC under performing
2784	8319	13	DPF load: above critical level 1 –engine de-rate	AWL	Critical level 1 soot loading over 100%, DPF Regen required
2785	8320	13	DPF load: above critical level 2 –further engine de-rate	RSL	Critical level 2 soot loading over 100%, engine shut down enable, Replace DPF
3333	164	0	Fuel Rail Pressure above maximum	AWL	FRP above maximum –FPCV open circuit, or stuck closed valve –Biased FRP sensor or circuit
3341	7129	4	EBP signal out of range LOW	AWL	EBP signal circuit open or short to GND, or failed sensor
3342	7129	3	EBP signal out of range HIGH	AWL	EBP signal circuit short to PWR, or failed sensor
3787	8326	2	DPF Cleanliness test –Soot level too high	No Lights	DPF soot load is too high, service is required
4421	8001	5	Cyl 1 open coil, open circuit	AWL	Injector 1 open circuit fault. or failed Injector
4422	8002	5	Cyl 2 open coil, open circuit	AWL	Injector 2 open circuit fault. or failed Injector
4423	8003	5	Cyl 3 open coil, open circuit	AWL	Injector 3 open circuit fault. or failed Injector
4424	8004	5	Cyl 4 open coil, open circuit	AWL	Injector 4 open circuit fault. or failed Injector
4425	8005	5	Cyl 5 open coil, open circuit	AWL	Injector 5 open circuit fault. or failed Injector
4426	8006	5	Cyl 6 open coil, open circuit	AWL	Injector 6 open circuit fault. or failed Injector
4441	8001	3	Cyl 1, 2 or 3 Injector short circuit	AWL	Short circuit on injector 1, 2 or 3, or failed injector
4442	8002	3	Cyl 1, 2 or 3 Injector short circuit	AWL	Short circuit on injector 1, 2 or 3, or failed injector
4443	8003	3	Cyl 1, 2 or 3 Injector short circuit	AWL	Short circuit on injector 1, 2 or 3, or failed injector
4444	8004	3	Cyl 4, 5 or 6 Injector short circuit	AWL	Short circuit on injector 4, 5 or 6, or failed injector
4445	8005	3	Cyl 4, 5 or 6 Injector short circuit	AWL	Short circuit on injector 4, 5 or 6, or failed injector
4446	8006	3	Cyl 4, 5 or 6 Injector short circuit	AWL	Short circuit on injector 4, 5 or 6, or failed injector

DIAGNOSTIC TROUBLE CODES

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
4511	8358	2	Bank A Injector driver over voltage	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4512	8358	3	Bank A Injector driver under voltage	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4513	8358	4	Bank A Injector driver under current	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4514	8358	5	Bank A Injector driver over current	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4515	8358	6	Bank A Injector Low driver over current	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4516	8358	8	Bank A Injector on phase time out	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4517	8358	10	Bank A Injector time out	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4521	8359	2	Bank B Injector driver over voltage	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4522	8359	3	Bank B Injector driver under voltage	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4523	8359	4	Bank B Injector driver under current	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4524	8359	5	Bank B Injector driver over current	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4525	8359	6	Bank B Injector Low driver over current	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4526	8359	8	Bank B Injector on phase time out	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4527	8359	10	Bank B Injector time out	AWL	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4528	7253	14	ECM Error –Injector control out of normal operating range	No Lights	Check for injector circuit faults, if okay. Clear DTC, if DTC is still active replace ECM
4553	8064	5	CKP –No signal, open circuit	AWL	CKP circuit fault, or failed sensor
4554	8064	7	CKP missing gap detection error	AWL	CKP circuit fault, or failed sensor
4555	8064	8	CKP excessive pulses	AWL	CKP circuit fault, or failed sensor
4556	8064	14	CKP circuits reversed	AWL	CKP circuit are reversed
4571	8001	0	Cyl 1 Cyl Balance max limit exceeded	AWL	Cylinder 1 imbalance –possible mechanical fault
4572	8002	0	Cyl 2 Cyl Balance max limit exceeded	AWL	Cylinder 2 imbalance –possible mechanical fault
4573	8003	0	Cyl 3 Cyl Balance max limit exceeded	AWL	Cylinder 3 imbalance –possible mechanical fault
4574	8004	0	Cyl 4 Cyl Balance max limit exceeded	AWL	Cylinder 4 imbalance –possible mechanical fault
4575	8005	0	Cyl 5 Cyl Balance max limit exceeded	AWL	Cylinder 5 imbalance –possible mechanical fault
4576	8006	0	Cyl 6 Cyl Balance max limit exceeded	AWL	Cylinder 6 imbalance –possible mechanical fault
5536	8253	1	EIM Error –Manufacturing defaults were selected	AWL	Verify EIM program matches vehicle
5541	8254	8	EIM Error –Unexpected reset fault	AWL	Check for intermittent loss of B+ to EIM
5549	8240	11	EIM Error –RAM programmable parameter list corrupted	AWL	Verify EIM program matches vehicle

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
5558	7314	4	AFP VREF out of range	AWL	AFP VREF circuit open or short.
5559	7310	2	AFP sensor failed ambient pressure test	AWL	Biased AFP sensor or circuit –Open AFS valve –Closed AFD valve
5560	7310	4	AFP signal out of range LOW	AWL	AFP signal circuit open or short to GND, or failed sensor
5561	7310	3	AFP signal out of range HIGH	AWL	AFP signal circuit short to PWR, or failed sensor
5565	7313	5	Retarder control valve open circuit	AWL	Retarder control valve open circuit, or failed valve
5566	7313	11	Retarder control valve short circuit	AWL	Retarder control valve short circuit, or failed valve
5632	8254	12	EIM Error –RAM/CPU Self Test Fault	AWL	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace EIM for MaxxForce 11 & 13
5637	3511	5	ECM Error –Fuel Rail Pressure Error	AWL	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5660	3509	3	VREF (MAP, EOP, EFP) out of range HIGH	AWL	VREF (MAP, EOP, EFP) circuit short to PWR
5661	3509	4	VREF (MAP, EOP, EFP) out of range LOW	AWL	VREF (MAP, EOP, EFP) circuit short to GND
5662	3509	5	VREF (MAP, EOP, EFP) No Signal	AWL	VREF (MAP, EOP, EFP) Internal ECM fault
5663	3756	3	VREF (EGRP, EBP) out of range HIGH	AWL	VREF (EGRP, EBP) circuit short to PWR
5664	3756	4	VREF (EGRP, EBP) out of range LOW	AWL	VREF (EGRP, EBP) circuit short to GND
5665	3756	5	VREF (EGRP, EBP) No Signal	AWL	VREF (EGRP, EBP) Internal ECM fault
6233	3511	3	FRP VREF out of range HIGH	AWL	FRP VREF circuit short to PWR
6234	3511	4	FRP VREF out of range LOW	AWL	FRP VREF circuit short to GND
6258	102	7	Boost below desired	AWL	Engine performance issue –Biased MAP/IAT sensor/circuit –Engine mechincal –Low fuel pressure –Failed turbocharager –EGR stuck open
6259	2791	7	EGR valve unable to achieve commanded position	AWL	EGRP valve sticking –Air supply or linkage fault –EGRP sensor or circuit fault –EGR control valve or circuit fault
6260	2791	0	EGRP unable to detect close postion	AWL	EGRP valve sticking –Air supply or linkage fault –EGRP sensor or circuit fault –EGR control valve or circuit fault
6262	2791	5	EGR control valve open circuit	AWL	EGR control circuit open or failed valve
6270	2791	14	EGRP valve stuck open	AWL	–Air supply or linkage fault –EGRP sensor or circuit fault –EGR control valve or circuit fault
6271	2791	12	EGRP valve stuck closed	AWL	–Air supply or linkage fault –EGRP sensor or circuit fault –EGR control valve or circuit fault

DIAGNOSTIC TROUBLE CODES

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
6314	8342	7	ECM CAN message not received from EIM	No Lights	Private CAN communication fault from EIM to ECM
6315	8309	2	ACM CAN message not received from ECM	AWL	Private CAN communication fault from ECM to ACM
6316	8311	2	ACM CAN message not received from EIM	AWL	Private CAN communication fault from EIM to ACM
6317	8316	2	EIM CAN message not received from ACM	AWL	Private CAN communication fault from ACM to EIM
6318	8342	14	EIM CAN message not received from ECM	AWL	Private CAN communication fault from ECM to EIM
6319	8487	19	EFRC information not received by ECM	AWL	EIM PP file incorrect vehicle configuration
6320	8484	19	EFRC invalid value or timeout by ECM	No Lights	EIM or ECM incorrect software.
6321	7311	0	ECT2 above Warning Level	AWL	ECT2 Temperature above set point (dealer programmable option)
6322	7311	7	ECT2 above Critical Level	AWL	ECT2 Temperature above set point (dealer programmable option)
6823	7311	14	ECT2 Temp above Maximum	AWL	ECT2 Temp above 119 C, or above 135 C during engine retard operations for 10 seconds –Cooling system fault –Biased ECT2 circuit or sensor
6813	3241	0	EGT1 or EGT2 High temp without regen	AWL	EGT2 above 425 C without active regen –Engine Over-fueling –Fuel leaking into exhaust –Biased circuit or sensor
6814	3242	7	EGT2 Temp above Maximum Severe	AWL	–EGT2 above 800 C for 10 seconds –Over-fueling –Plugged DPF or exhaust system –Biased EGT2 sensor or circuit
6817	3245	7	EGT3 Temp above Maximum Severe	AWL	–EGT2 above 800 C for 10 seconds –Over-fueling –Plugged DPF or exhaust system –Biased EGT2 sensor or circuit
6835	8491	14	Auxiliary engine shutdown input circuit out of range	AWL	Auxiliary engine shutdown circuit fault EIM pin X1-16
6840	51	12	ITV broken spring or linkage	AWL	–Broken Return spring/Linkage –Failed ITV"
6841	51	8	ITV feedback outside duty cycle range	AWL	ITV circuit fault, or ITV component failure
6842	51	19	ITV feedback signal not plausible	AWL	ITV circuit fault, or ITV component failure
6900	8305	12	AFI circuit fault	AWL	AFI circuit fault, or failed AFI
6901	8306	5	AFS Valve circuit fault	AWL	AFS circuit fault, or failed AFS
6902	8307	5	AFD Valve circuit fault	AWL	AFD circuit fault, or failed AFD
6905	8306	7	Aftertreatment fuel leak: fuel line, AFD, or AFI	AWL	AFS valve fault, or AFD valve fault, or AFP sensor fault
6906	8306	14	AFS valve and AFD valve connections reversed	AWL	AFS and AFD connections reversed

DTC	SPN	FMI	DESCRIPTION	ENGINE LAMPS	POSSIBLE CAUSES
6910	8307	12	AFD valve fail to open	AWL	AFD valve or circuit fault
6912	8308	7	AFP above normal with AFS closed	AWL	–AFS valve or circuit fault –Biased AFP sensor or circuit
6913	7310	7	AFP above normal with AFD open	AWL	–AFD valve or circuit fault –Biased AFP sensor or circuit
6914	7310	1	AFP below normal during DPF regen	AWL	AFT Fuel Pressure below 43psi for 5 seconds during regen –AFD valve or circuit fault –AFS valve or circuit fault –Biased AFP sensor or circuit

Abbreviations & Acronyms

°C – Degrees Celsius

°F – Degrees Fahrenheit

A or amp – Ampere

A/C – Air Conditioner

ACM – Aftertreatment Control Module

ACT PWR GND – Actuator Power Ground

ACV – Aftertreatment Cut – off Valve

AFD – Aftertreatment Fuel Drain

AFI – Aftertreatment Fuel Injector

AFP – Aftertreatment Fuel Pressure

AFS – Aftertreatment Fuel Supply

AFT – Aftertreatment

AMS – Air Management System

API – American Petroleum Institute

APS – Accelerator Position Sensor

APS/IVS – Accelerator Position Sensor / Idle Validation Switch

B+ – Battery Voltage

BAP – Barometric Absolute Pressure Sensor

BCS – Boost Control Solenoid

CAC – Charge-Air-Cooler

CAN – Controller Area Network

CCV – Coolant Control Valve

CFV – Coolant Flow Valve

CID – Cubic Inch Displacement

CKP – Crankshaft Position

cm – Centimeter

CMP – Camshaft Position

CMV – Coolant Mixer Valve

CSR – Cold Start Relay

CSS – Cold Start Solenoid

DDS – Driveline Disengagement Switch

DMM – Digital Multi Meter

DOC – Diesel Oxidation Catalyst

DPF – Diesel Particulate Filter

DTC – Diagnostic Trouble Code

EBP – Exhaust Back Pressure

ECL – Engine Coolant Level

ECM – Engine Control Module

ECM PWR – Engine Control Module Power

ECT – Engine Coolant Temperature

ECT2 – Engine Coolant Temperature 2

EFP – Engine Fuel Pressure

EFRC – Engine Family Rating Code

EFT – Engine Fuel Temperature

EGDP – Exhaust Gas Differential Pressure

EGR – Exhaust Gas Recirculation

EGRP – Exhaust Gas Recirculation Position

EGT1 – Exhaust Gas Temperature 1

EGT2 – Exhaust Gas Temperature 2

EGT3 – Exhaust Gas Temperature 3

EIM – Engine Interface Module

ELS – Exhaust Lambda Sensor

EOP – Engine Oil Pressure

EOT – Engine Oil Temperature

ESN – Engine Serial Number

EST – Electronic Service Tool

EWPS – Engine Warning Protection System

FMI – Failure Mode Indicator

FPCV – Fuel Pressure Control Valve

FRP – Fuel Rail Pressure

ft – Foot

GND – Ground (electrical)

H_2O – Water

HC – Hydrocarbon

Hg – Mercury

hp – Horsepower

HPCAC – High-Pressure Charge-Air-Cooler

ABBREVIATIONS AND ACRONYMS

HSNS – Hard Start/ No Start

IAT – Intake Air Temperature

IGN – Ignition

in – Inch

in H_2O – Inch of water

in Hg – Inch of mercury

ISIS® – International® Service Information System

ITV – Intake Throttle Valve

IVS – Idle Validation Switch

km – Kilometer

KOEO – Key – On Engine – Off

KOER – Key – On Engine – Running

kPa – Kilopascal

L – Liter

lb – Pound

lb-ft – Pound – foot

lb-in – Pound – inch

LPCAC – Low-Pressure Charge-Air-Cooler

LTR – Low Temperature Radiator

MAP – Manifold Absolute Pressure

MAP/IAT2 – Manifold Absolute Pressure/Intake Air Temperature 2

MAT – Manifold Air Temperature

mi – Mile

ml – Milliliter

mm – Millimeter

MPa – Milli – Pascals

Nm – Newton meter

NOX – Nitrogen Oxides

oz – Ounces

PID – Parameter Identifier

PLV – Pressure Limiting Valve

ppm – Parts per million

psi – Pounds per square inch

PTO – Power Take Off

PWM – Pulse Width Modulate

qt – Quart

rpm – Revolutions per minute

S/N – Serial Number

SPN – Suspect Parameter Number

SW – Switch (electrical)

TBD – To Be Determined

TDC – Top Dead Center

V – Volt

VBAT – Battery Voltage

VIGN – Ignition Voltage

VIN – Vehicle Identification Number

VREF – Reference Voltage

VSS – Vehicle Speed Sensor

Service Tools

ZTSE2536
Cylinder Liner Puller

ZTSE4299
Fuel Injector Rack Holder

ZTSE4301
Fuel Injector Tip Cleaning Brush

ZTSE4341
Charge-Air-Cooler Tester Kit

ZTSE4751
Injector Sleeve Brushes

ZTSE4770
Injector Puller

ZTSE4776
Fan Hub Seal Installer

ZTSE4777
Injector Installer

ZTSE4778
Coolant Line Release Tool

ZTSE4786
Engine Rotating Tool

ZTSE4787
Head Bolt Torx Socket 3/4" Dr.

ZTSE4789
Engine Stand Adapter Plate

ZTSE4825
Sleeve Protrusion Hold Down Clamps

ZTSE4835
Connecting Rod Bolt Torx Socket

ZTSE4843
Exhaust Manifold Bolt Torx Socket

ZTSE4853
Valve Timing Tool

ZTSE4854
Main Bolt Bottoming Tap

ZTSE4855
Head Bolt Bottoming Tap

ZTSE4869
Cylinder Head Lifting Bracket (rear)

ZTSE4872
Valve Spring Compressor Jaws

ZTSE4873
Front Crankshaft Seal Installer

ZTSE4875
Rear Oil Seal Installer

ZTSE4892
Fuel Injector Cups (6)

ZTSE4898
Pilot Bearing Installation Tool

Diagnostic Tools

ZTSE4039
Crankcase Pressure Test Adapter

ZTSE4435
A Terminal Test Adapter Kit

ZTSE4483
IAT Sensor Breakout Harness

ZTSE4485A
APS/IVS Sensor Breakout Harness

ZTSE4497
Ohm Resistor Harness

ZTSE4498
Banana Plug Harness

ZTSE4735A
ELS Breakout Harness

ZTSE4760A
EGT, AFS, AFI and AFD 2-pin Breakout Harness

ZTSE4761A
EGDP Sensor Breakout Harness

ZTSE4772
Fuel Line Disconnect Tool 16mm

ZTSE4773
Fuel Line Disconnect Tool 11.8mm

ZTSE4827
EGR Controller, ECTs, EOT and CSS Breakout Harness

ZTSE4828
CMP, CKP and FPCV Breakout Harness

ZTSE4829
FRP Sensor Breakout Harness

ZTSE4830
MAP/IAT2 Sensor Breakout Harness

ZTSE4831
BCS Breakout Harness

ZTSE4833
EGRP and ITV Breakout Harness

ZTSE4834
Retarder Control Breakout Harness

ZTSE4844
Engine Fan Control Breakout Harness

ZTSE4845
AFP Sensor Breakout Harness

ZTSE4870
CMV Breakout Harness

ZTSE4871
CFV Breakout Harness

ZTSE4877
EGR Cooler Pressure Test Plates

ZTSE4879
Oil Cooler Pressure Test Plates

ZTSE4881
EFP Breakout Harness

ZTSE4882
EOP Breakout Harness

ZTSE4883
MAT Breakout Harness

ZTSE4885
CSR Breakout Harness

ZTSE4886
The Fuel Inlet Restriction and Aeration Tool is used to check for pressure and aerated fuel

ZTSE4887-1
The 17 mm High Pressure Return Line Tester is used to check for fuel returning from the pressure limiting valve on the end of the high-pressure rail.

ZTSE4887-2
The 19 mm High Pressure Return Line Tester is used to check for excessive fuel returning from the fuel injectors at the cylinder head fuel return port.

ZTSE4891
Disposable Air and Fuel Caps

ZTSE4893
Air Intake Guard

ZTSE4900
The High-Pressure Rail Plugs are used to isolate individual injectors by blocking the high-pressure rail pipe output.

ZTSE4904
Breakout Harness Kit

ZTSE4905
The Fuel Block Off Tool is used to block off a fuel line when measuring fuel pressure during certain tests.

ZTSE4906
The Fuel Fitting Adapter is used in conjunction with the Fuel Inlet Restriction and Aeration Tool to measure fuel pressure.

ZTSE4908
EIM Power Relay Breakout Harness

ZTSE4909
High Pressure CAC Test Plate

ZTSE4913
Fan Clutch Nut Wrench

ZTSE23842
The Plastic Surge Tank Cap Adaptor is used to block off the surge tank while performing a cooling system pressure test.

GLOSSARY

Accelerator Position Sensor (APS)
A potentiometer sensor that indicates the position of the throttle pedal.

Actuator
A device that performs work in response to a input signal.

Aeration
The entrainment of gas (air or combustion gas) in the coolant, lubricant, or fuel.

Ambient Temperature
The environmental air temperature in which a unit is operating.

American Trucking Association (ATA) Datalink
A serial datalink specified by the American Trucking Association and the SAE.

Analog
A continuously variable voltage.

BAR:
1 Bar equals 14.5 psi

Boost Pressure
The pressure of the charge air leaving the turbocharger.

Bottom Dead Center (BDC)
The lowest position of the piston during the stroke.

Calibration
The data values used by the strategy to solve equations and make decisions. Calibration values are stored in ROM and put into the processor during programming to allow the engine to operate within certain parameters.

Catalyst
A substance that produces a chemical reaction without undergoing a chemical change itself.

Charge Air
Dense, pressurized, heated air discharged from the turbocharger.

Charge-Air-Cooler (CAC)
A heat exchanger mounted in the charge air path between the turbocharger and engine intake manifold. The aftercooler reduces the charge air temperature by transferring heat from the charge air to a cooling medium.

Closed Loop Operation
A system that uses a sensor to provide feedback to the ECM. The ECM uses the sensor to continuously monitor variables and adjust to match engine requirements.

Controller Area Network (CAN)
A J1939 high speed communication link.

Coolant
A fluid used to transport heat from the engine to the radiator.

Coolant Level Sensor
A switch sensor used to indicate low coolant level.

Crankcase
The housing that encloses the crankshaft, connecting rods, and associated parts.

Crankcase Breather
A vent for the crankcase to release combustion gases that pass the piston rings.

Crankcase Pressure
The force of air inside the crankcase against the crankcase housing.

Crankshaft Position (CKP) Sensor
A magnetic pickup sensor that determines crankshaft position and speed.

Current
The flow of electrons passing through a conductor. Measured in amperes.

Damper
A device that reduces the amplitude of torsional vibration.

Deaeration Tank
A separate tank in the cooling system used for one or more of the following functions:

- Deaeration
- Coolant reservoir (fluid expansion and afterboil)
- Coolant retention
- Filling
- Fluid level indication (visible)

Diagnostic Trouble Code (DTC)
Formerly called a Fault Code or Flash Code. A DTC is a four digit numeric code used for troubleshooting.

Diesel Particulate Filter
A diesel particulate filter, sometimes called a DPF, is a device designed to remove diesel particulate matter or soot from the exhaust gas of a diesel engine.

Diesel Oxidation Catalyst
A DOC (Diesel Oxidation Catalyst) is part of the diesel exhaust Aftertreatment system. DOCs are devices that use a chemical process to break down pollutants in the exhaust stream into less harmful components. More specifically, DOCs utilize rare metals such as palladium and platinum to reduce hydrocarbon based soluble organic fraction (SOF) and carbon monoxide content of diesel exhaust by simple oxidation. The DOC can be used during an active regeneration to create higher exhaust temperatures thereby increasing soot reduction in the DPF.

Digital Multimeter (DMM)
An electronic meter that uses a digital display to indicate a measured value. Preferred for use on microprocessor systems because it has a very high internal impedance and will not load down the circuit being measured.

Disable
A computer decision that deactivates a system and prevents operation of the system.

Displacement
The stroke of the piston multiplied by the area of the cylinder bore multiplied by the number of cylinders in the engine.

Driver
A transistor within an electronic module that controls the power to an actuator circuit.

Duty Cycle
A signal that has a controlled on/off time measurement from 0 to 100%. Normally used to control solenoids.

Electronic Control Module (ECM)
An electronic processor that monitors and controls the engine.

EGR Cooler
A cooler that allows heat to dissipate from the exhaust gases before they enter the intake manifold.

EGR Valve
A valve that regulates the flow of exhaust gases into the intake manifold.

Engine Oil Pressure Sensor (EOP)
A sensor that senses oil pressure.

Engine Oil Temperature (EOT) Sensor
A thermistor sensor that senses engine oil temperature.

Exhaust Brake
A brake device using engine exhaust back pressure as a retarding medium.

Exhaust Gas Recirculation
A system used to recirculate a portion of the exhaust gases into the cylinder in order to reduce oxides of nitrogen.

Exhaust Manifold
Exhaust gases flow through the exhaust manifold to the turbocharger exhaust inlet.

Fault Detection/Management
An alternate control strategy that reduces adverse effects that can be caused by a system failure. If a sensor fails, the ECM substitutes a good sensor signal or assumed sensor value in its place. A lit amber instrument panel lamp signals that the vehicle needs service.

Fuel Inlet Restriction
A blockage, usually from contaminants, that prevents the flow of fluid through the fuel inlet line.

Fuel Pressure
The force that the fuel exerts on the fuel system as it is pumped through the fuel system.

Fuel Rail Pressure (FRP)
This is the amount of pressure in the high-pressure fuel rail.

Fuel Rail Pressure Sensor (FRP)
The FRP sensor monitors the fuel pressure in the fuel rail and sends a signal to the ECM.

Fuel Strainer
A pre-filter in the fuel system that keeps larger contaminants from entering the fuel system.

Fusible Link (Fuse Link)
A fusible link is a special section of low tension cable designed to open the circuit when subjected to an extreme current overload.

Horsepower (hp)
Horsepower is the unit of work done in a given period of time, equal to 33,000 pounds multiplied by one foot per minute. 1hp = 33,000 lb x 1 ft /1 min.

Hydrocarbons
Unburned or partially burned fuel molecules.

Intake Manifold
A collection of tubes through which the fuel-air mixture flows from the fuel injector to the intake valves of the cylinders.

Idle Speed
Low idle is minimum rpm at no load. High idle is maximum rpm at no load.

Injector Drive Module (IDM)
The electronic portion of an ECM that is the power supply for the injectors.

Intake Air Temperature (IAT) Sensor
A thermistor sensor that senses intake air temperature.

Manifold Absolute Pressure (MAP)
Boost pressure in the manifold that is a result of the turbocharger.

Manifold Absolute Pressure (MAP) Sensor
A variable capacitance sensor that measures boost pressure.

Manifold Air Temperature (MAT) Sensor
A thermistor style sensor used to indicate air temperature in the intake manifold.

GLOSSARY

Manometer
A double-leg liquid-column gauge, or a single inclined gauge, used to measure the difference between two fluid pressures. Typically, a manometer records in inches of water, or inches of mercury (Hg).

Magnehelic Gauge
A gauge that measures pressure in inches of water.

Magnetic Pickup Sensor
A sensor that creates an alternating current voltage when a magnetic field is broken.

Microprocessor
An integrated circuit in a microcomputer that controls information flow.

Normally Closed
Refers to a switch that remains closed when no control force is acting on it.

Normally Open
Refers to a switch that remains open when no control force is acting on it.

Output Circuit Check (OCC)
An on demand test done during an Engine OFF self-test to check the continuity of selected actuators.

Oxides of Nitrogen (NOx)
Nitrogen oxides form by a reaction between nitrogen and oxygen at high temperatures.

Particulate Matter
Particulate matter includes mostly burned particles of fuel and engine oil.

Potentiometer
An electro-mechanical device that senses the position of a mechanical component.

Power
Power is a measure of the rate at which work is done. Compare with Torque.

Power Take Off (PTO)
Accessory output, usually from the transmission, used to power a hydraulic pump for a special auxiliary feature (garbage packing, lift equipment, etc).

Pulse Width Modulate (PWM)
The time that an actuator remains energized.

Rated Horsepower
Maximum brake horsepower output of an engine as certified by the engine manufacturer.

Rated Speed
The speed, as determined by the manufacturer, at which the engine is rated.

Rated Torque
Maximum torque produced by an engine as certified by the manufacturer.

Reference Voltage (Vref)
A reference voltage supplied by the ECM to operate the engine sensors.

Regeneration
Regeneration is the process of removing the accumulated soot from a diesel particulate filter. This is done either passively, actively, in a parked regen, or by removing the unit from the vehicle and baking the DPF in a special oven.

Signal Ground
The common ground wire to the ECM for the sensors.

Strategy
A plan or set of operating instructions that the microprocessor follows for a desired goal. Strategy is the computer program itself, including all equations and decision making logic. Strategy is always stored in ROM and cannot be changed during calibration.

Stroke
Stroke is the movement of the piston from Top Dead Center (TDC) to Bottom Dead Center (BDC).

Thermistor
A semiconductor device. A sensing element that changes resistance as the temperature changes.

Top Dead Center (TDC)
The uppermost position of the piston during the stroke.

Torque
A force having a twisting or turning effect. Torque is a measure of the ability of an engine to do work.

Turbocharger
A turbine driven compressor mounted to the exhaust manifold. The turbocharger increases the pressure, temperature and density of the intake air.

Variable Capacitance Sensor
A variable capacitance sensor measures pressure. The pressure forces a ceramic material closer to a thin metal disc in the sensor, changing the capacitance of the sensor.

Viscosity
The internal resistance to the flow of any fluid.

Vehicle Speed Sensor (VSS)
Normally a magnetic pickup sensor mounted in the tailshaft housing of the transmission, used to indicate ground speed.

VIGN
Voltage supplied to the ECM when the key is ON.