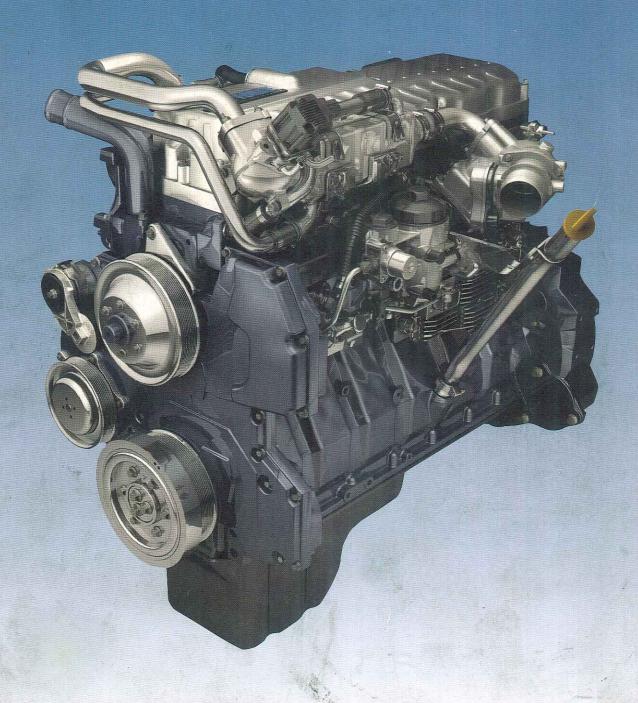
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INTERNATIONAL DIESEL POWERT

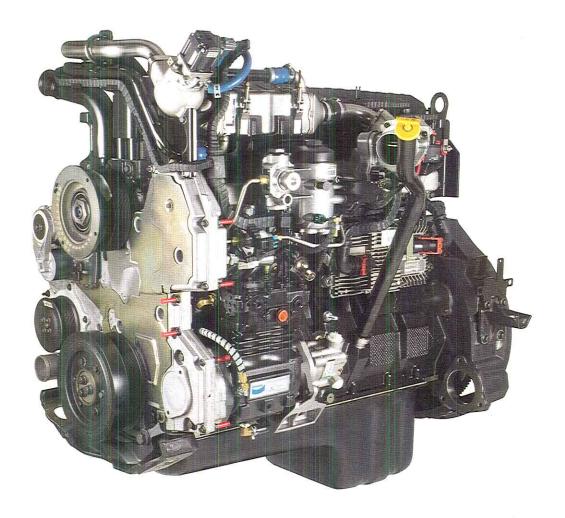


MAXXFORCE® DT, MAXXFORCE 9, AND MAXXFORCE 10
MODEL YEAR 2007 FEATURES, DESCRIPTIONS, AND UNIQUE DIAGNOSTICS AND REPAIR PROCEDURES

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# DIRECT INJECTION TURBOCHARGED DIESEL ENGINE



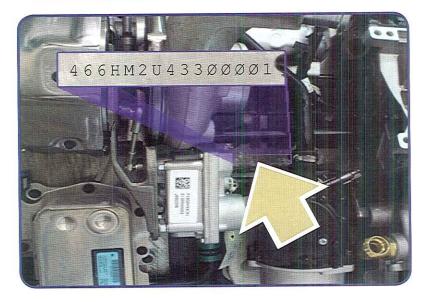
# MAXXFORCE® DT, 9, AND 10 FEATURES

- Single Engine Control Module
- Closed Crankcase Breather
- Dual EGR Coolers
- Foam Protected Wiring Harness
- Integrated Engine and Exhaust Brake
- Exhaust Aftertreatment
- Simplified Injector Wiring
- Dual A/C Compressor Compatible

# SPECIFICATIONS AND IDENTIFICATION

#### **ENGINE SPECIFICATIONS**

Engine Configuration	4-stroke, in-line six cylinder diesel
Valve Configuration	
Displacement MaxxForce® DT: 7.6 L (466 in³)	MaxxForce 9 and 10: 9.3 L (570 in <sup>3</sup> )
Bore	
Stroke MaxxForce DT: 199 mm (4.68 in) Ma	axxForce 9 and 10: 146 mm (5.75 in)
Aspiration Variable geometry	y turbocharger and charge air cooled
Engine Rotation Count	erclockwise when facing the flywheel
Fuel System Electro-	-Hydraulic Generation 2 fuel injection
Engine Weight (dry) MaxxForce DT: 671kg (1,480)	MaxxForce 9 and 10: 708 kg (1,560)
Firing Order	1-5-3-6-2-4





#### **Engine Serial Number**

- The Engine Serial Number is located on the right hand side of the crankcase in the front of the turbocharger. The engine serial number identifies the engine family, build location, and the sequential build number.
- The first serial number for the 2007 model year is 3000000
- Sample serial number: 466HM2U3300001
- · 466/570 is the engine family identifier
- · HM2U is the manufacturing designer
- The sequential build number is comprised of the last seven numbers

#### **Emissions Label**

- The Environmental Protection Agency emission label is located on the valve cover. The label information includes the following information:
  - -Horsepower rating
  - -Engine model code
  - -Service application
  - -Emission family and control system
  - Year of engine's emissions standard certification

# HORSEPOWER AND TORQUE CURVES

#### MaxxForce DT Horsepower and Torque

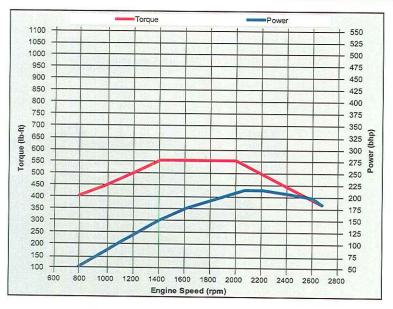
- The MaxxForce® DT is offered in nine different horsepower and torque ratings for the 2007 model year. The base rating creates 210 horsepower at 2300 rpm and 560 lb-ft of torque at 1400 rpm. The engine has a high idle speed of 2775 rpm with a manual transmission.
- The highest rating for the MaxxForce DT is 300 horsepower at 2300 rpm and 860 lb-ft of torque at 1400 rpm. Clutch engagement torque is 400 lb-ft at 800 rpm for the base rating and 420 lb-ft for the highest rating.

# MaxxForce 9 Horsepower and Torque

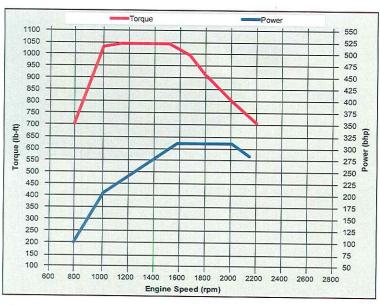
- The MaxxForce 9 is offered in three different horsepower and torque ratings for the 2007 model year. The base rating creates 300 horsepower at 2000 rpm and 800 lb-ft of torque at 1200 rpm. The engine has a high idle speed of 2425 rpm with a manual transmission.
- The highest rating for the MaxxForce 9 is 330 horsepower at 2000 rpm and 950 lb-ft of torque at 1400 rpm. Clutch engagement torque is 700 lb-ft at 800 rpm for all MaxxForce 9 ratings.

#### MaxxForce 10 Horsepower and Torque

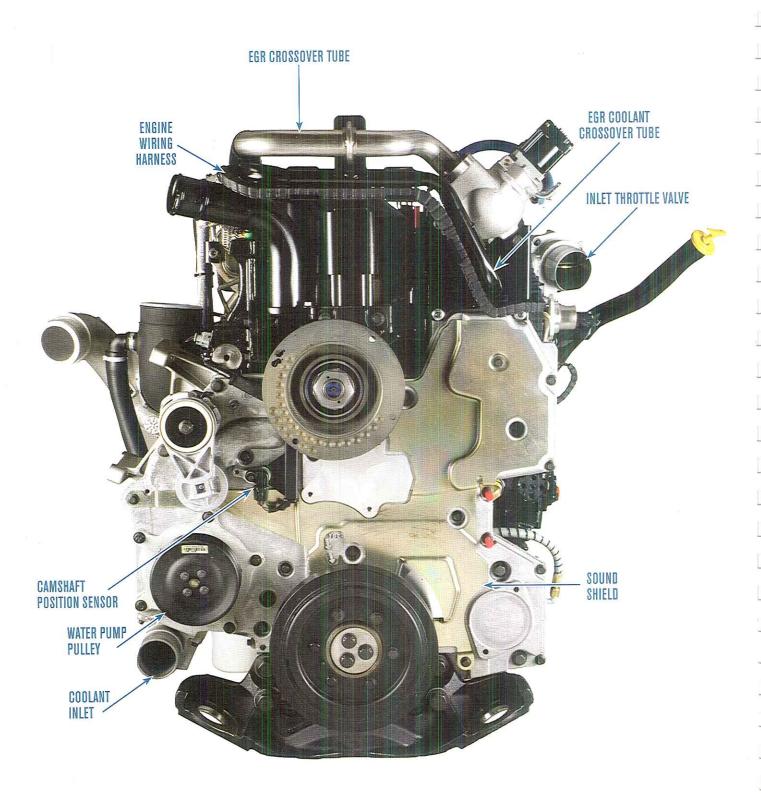
- The MaxxForce 10 is offered in three different horsepower and torque ratings for the 2007 model year. The base engine creates 310 horsepower at 2000 rpm and 1050 lb-ft of torque at 1200 rpm. The engine has a high idle speed of 2425 rpm with an automatic transmission.
- The highest rating for the MaxxForce 10 is 350 horsepower at 2000 rpm and 1150 lb-ft of torque at 1400 RPM. Clutch engagement torque is 700 lb-ft at 800 rpm for all MaxxForce 10 ratings.



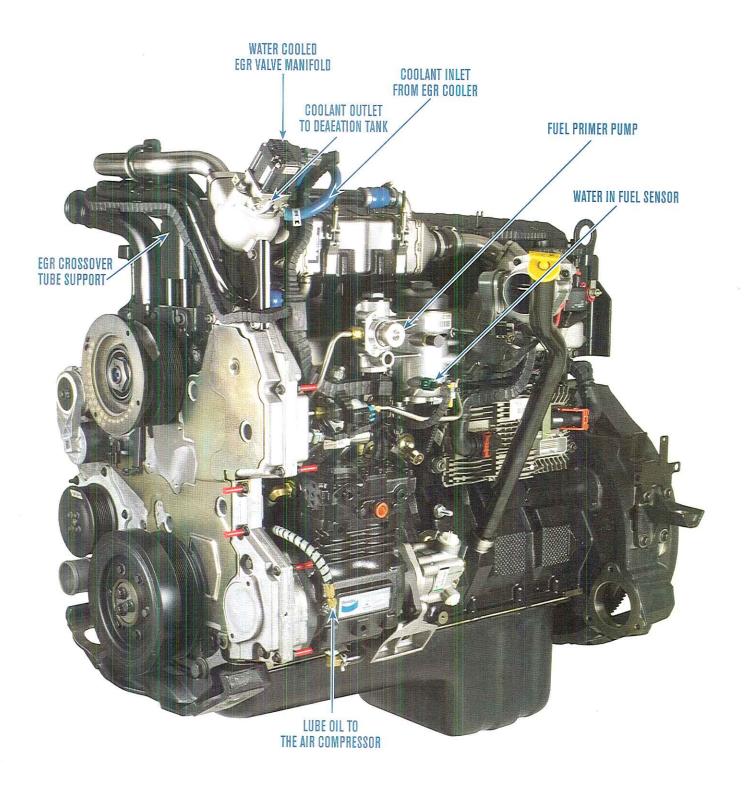




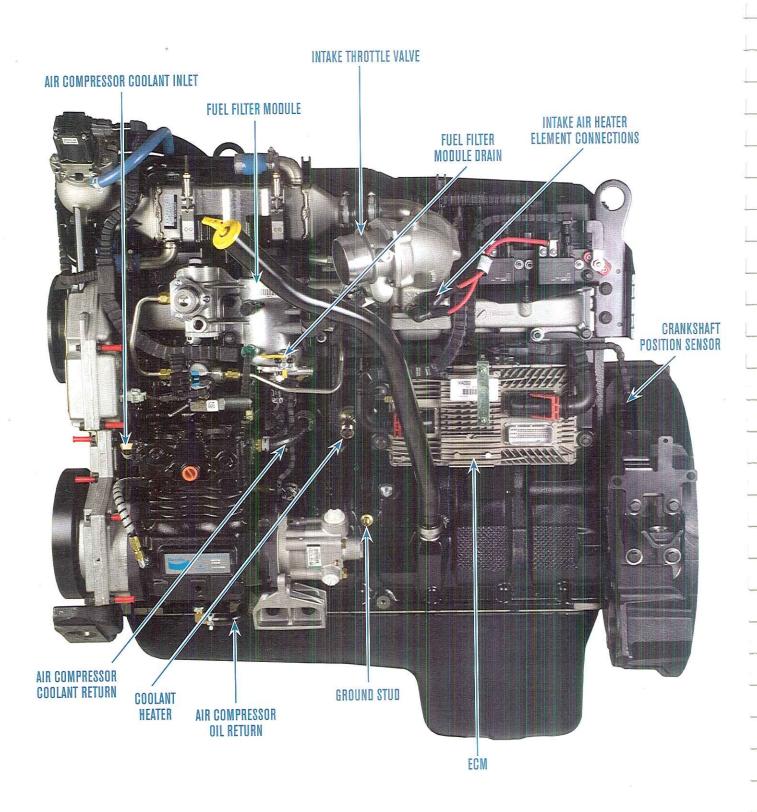
# **COMPONENT LOCATIONS - FRONT**



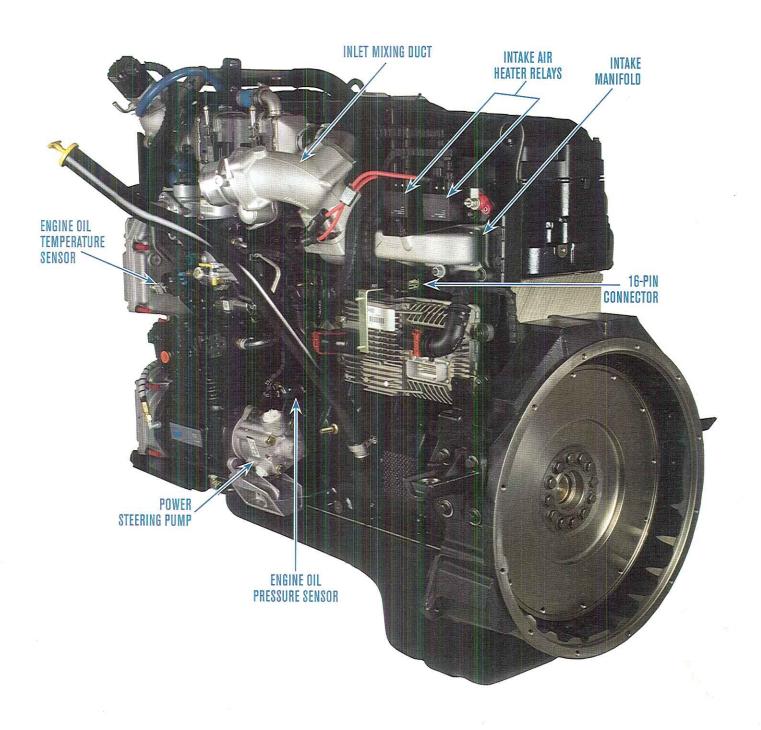
# **COMPONENT LOCATIONS - LEFT FRONT**



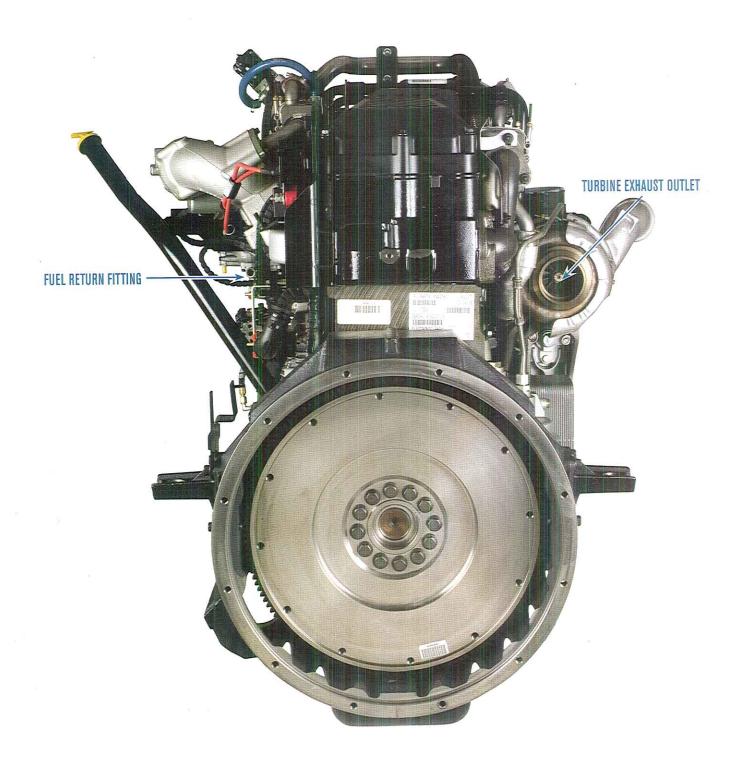
# **COMPONENT LOCATIONS - LEFT SIDE**



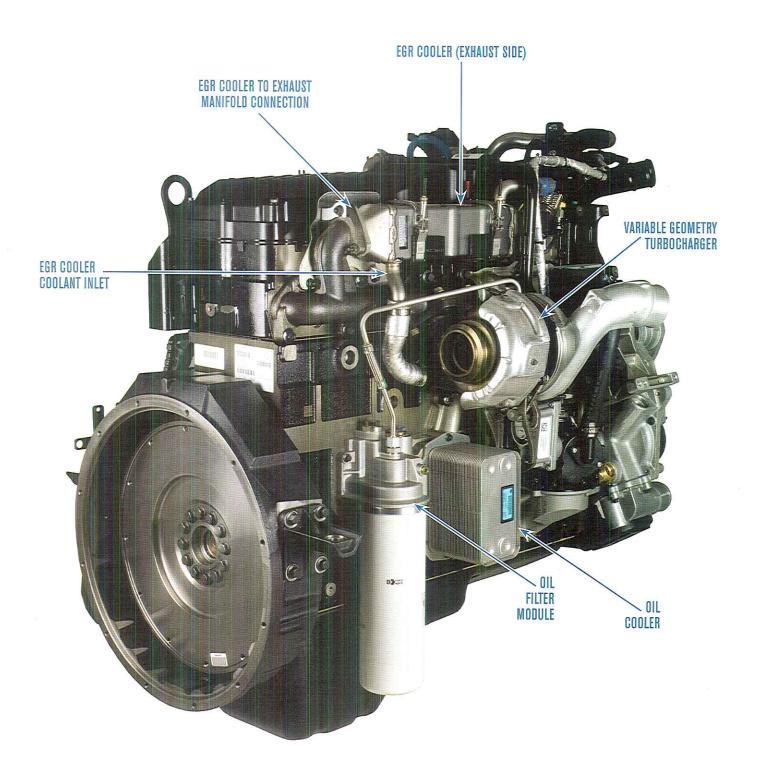
# **COMPONENT LOCATIONS - LEFT REAR**



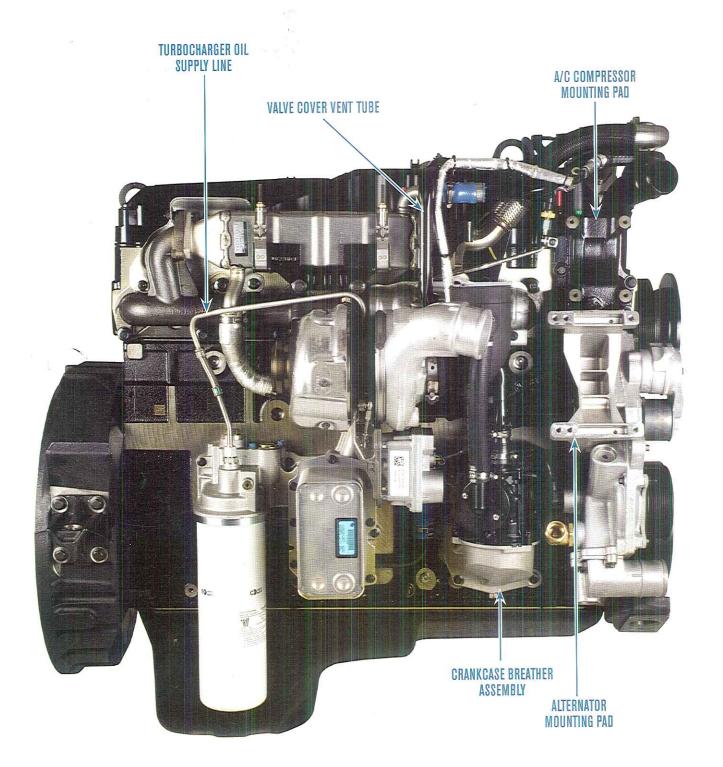
# **COMPONENT LOCATIONS - REAR**



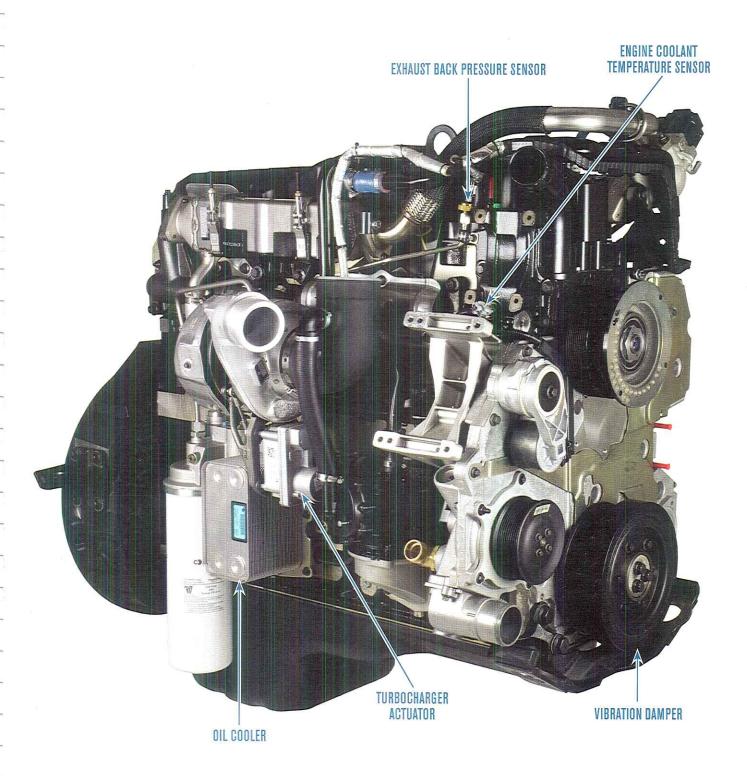
# COMPONENT LOCATIONS - RIGHT REAR



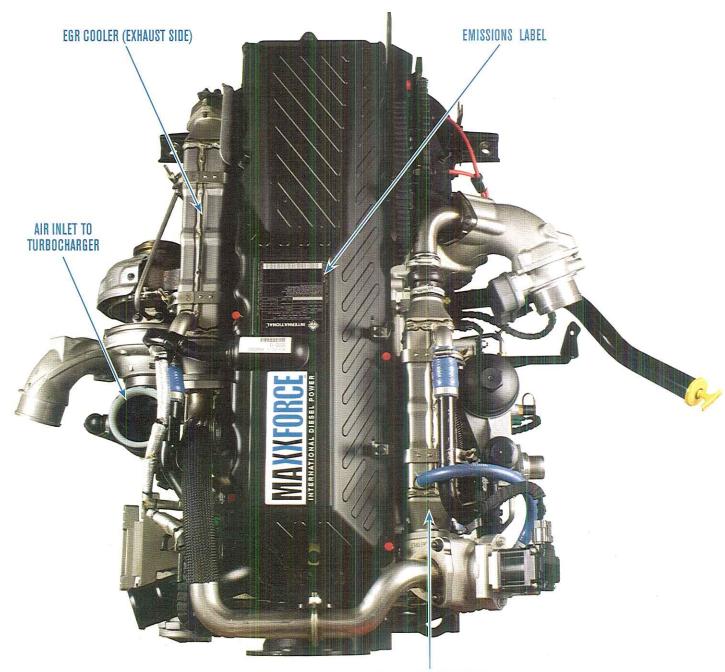
# **COMPONENT LOCATIONS - RIGHT SIDE**



# **COMPONENT LOCATIONS - RIGHT FRONT**



# **COMPONENT LOCATIONS - TOP**



EGR COOLER (INTAKE SIDE)

# **DESIGN FEATURES**

#### **Engine Control Module**

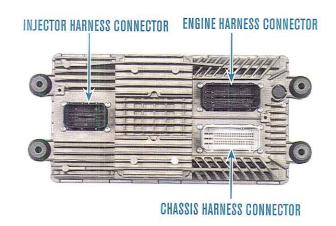
- The ECM is located on a bracket mounted to the left rear of the crankcase. Although this location requires removal of the dog house to service the ECM, its advantage is space utilization and protection of the ECM.
- The ECM uses sensor inputs to control both the fuel management and air management systems. The ECM has three connections compared to seven in the previous design. The three connectors serve to output injector signals, receive engine mounted sensor inputs, and receive chassis inputs.

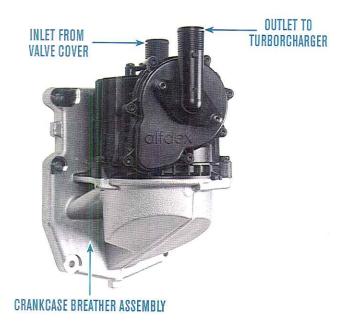


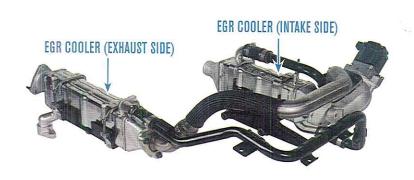
• 2007 I-6 engines are equipped with a closed crankcase ventilation system. The system uses a centrifugal crankcase breather to remove oil from the crankcase gases. The breather is mounted to the right front of the crankcase and is driven by lube oil pressure. During operation, the crankcase gases exit the valve cover and move through the breather before entering the turbocharger inlet. Centrifugal force generated within the breather by the rotating element causes the heavy oil particles to be removed and returned to the crankcase.

#### **Dual EGR Coolers**

- The MaxxForce® DT, 9, and 10 engines utilize dual EGR coolers to meet the increased demand of exhaust gas recirculation. The two EGR coolers are needed to meet the 2007 emission standards. Unlike the previous design, the dual EGR design uses a parallel flow cooling system which helps reduce coolant boiling in the EGR coolers.
- The exhaust side EGR cooler is mounted to a flange on the exhaust manifold and supported by a cradle bolted through the exhaust manifold to the cylinder head. This provides greater stiffness for the system and improves assembly issues. The intake side cooler is mounted to both the EGR valve manifold assembly and to the inlet air mixer duct with 3-bolt flanges. The intake cooler is also supported by a cast iron cradle.







### **DESIGN FEATURES**





# HIGH PRESSURE OIL RAIL BRAKE CONTROL PRESSURE SENSOR BRAKE CONTROL VALVE

#### **Foam Wiring Harness**

- The engine wiring is now contained within a foam cover. The robust foam construction helps resist chaffing of the wires while maintaining clearance from moving components. This harness is not serviceable. To avoid damage the foam sections should not be bent more than 90 degrees.
- The harness is made in two sections. One section is for under valve cover inputs and outputs. The other section is for engine mounted sensors and actuators.

#### Damper and New Accessory Drive Belt and Pulleys

- The damper and hub are two piece. The MaxxForce<sup>®</sup> 9 and 10 damper has a steel pin that protrudes from the front. The DT damper pin is flush. The dampers ability to control torsional vibrations in the crankshaft are different and should not be interchanged. The MaxxForce 9 an 10 also has a POSE seal on the back of the hub.
- The accessory drive pulley size has been increased to match a new 10 groove belt. The increase from an eight groove belt to a ten groove allows the belt to carry greater loads without compromising durability.

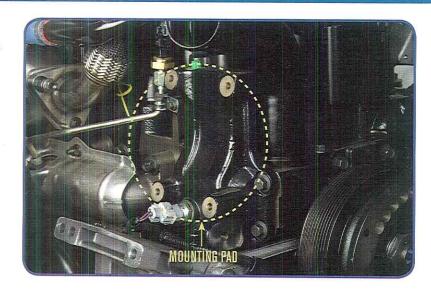
#### **Integrated Engine and Exhaust Brake**

• The Diamond Logic® Engine Brake and the Diamond Logic® Exhaust Brake are both available as an option for all engine displacements. Both brakes allow the operator to adjust for current driving conditions. The exhaust brake works commanding the turbocharger to produce exhaust back pressure. The engine brake is a compression release brake system combined with the turbo control to provide additional braking performance.

# **DESIGN FEATURES**

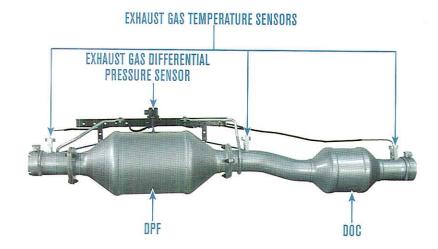
#### Dual Pad Mount A/C Compressors

- A new auxiliary bracket allows for dual A/C compressors to mount at the same location.
   The water supply housing serves as the mounting bracket for the single compressors. If the optional dual mount is selected, an additional bracket with idler allows the second compressor to piggy back on top of the first unit.
- Pad mounting allows a single belt to drive the alternator, water pump and either single or dual A/C compressors resulting in lower maintenance costs.



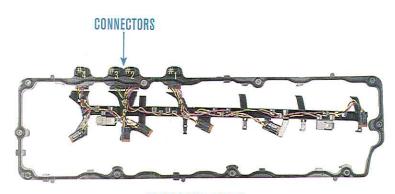
#### **Exhaust Aftertreatment**

- 2007MY engines require an aftertreatment system to reduce the amount of particulate matter in the exhaust. The Aftertreatment system is made up of a Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), Exhaust Temperature Sensors, and an Exhaust Pressure Differential Sensor.
- Both the DOC and DPF are constructed of ceramic materials with a coating of precious metals. The DOC has a series of small passages that maximize the contact between the exhaust and the precious metals. The DOC reacts with unburned fuel creating heat. The DPF is used to catch and store the ash and particulate matter leaving the engine.



#### Valve Cover Gasket

• The valve cover gasket has been redesigned. The previous design had a connector for each electrical device under the valve cover. The new gasket allows connections for all under valve cover electrical components to route through four connectors. The four connectors are located on the left rear of the valve cover gasket. The four connectors are numbered one through four with number one at the front of the engine. Injectors 1 and 2 pass through connector 1. Injectors 3 and 4 pass through connector 2. The ICP, BSV, and BCP pass through connector 3. Injector 5 and 6 pass through connector 4.



**VALVE COVER GASKET** 



# BASE ENGINE

- Cracked Rod Caps
- Oil Cooled Piston
- Large Geometry Valve Train
- Closed Crankcase Breather



# OIL OUTLET OIL INLET

#### **Cracked Rod Caps**

- The MaxxForce® DT, 9, and 10 engines starting with serial number 3004733 use a new connecting rod. MaxxForce engines from 3000000 to 3004732 use the same rod as the 2004–2006 466 and 570 engine. The new connecting rod is lighter. Both are available for service and should not be mixed in the same engine.
- Because the connecting rods have a fractured surface, the rod serial number and the cap serial number must match and be on the same side. If either cracked surface is damaged or the rod bolts are inadvertently tightened while the cap is in the wrong position, the fractured mating surfaces will be damaged and the connecting rod assembly must be replaced.

#### Steel Piston

• MaxxForce 9 and 10 engines use one piece steel pistons. Steel pistons are used to increase the engine's durability. The piston pin is not offset, but the piston is directional due to the location of an under crown oil hole that provides oil to the pin joint. The piston is marked CAM-SIDE on the crown for assembly purposes. The piston also has an oil gallery in the crown to help transfer heat from the piston to the oil. Fresh oil is constantly sprayed from the piston cooling jet to a port in the bottom of the piston. Oil circulates through the passage removing heat from the piston and then exits a second port.

#### MaxxForce® DT Piston

- The MaxxForce DT uses a one piece aluminum piston with an offset pin to reduce piston slap. The crown is marked with an arrow that must point to the damper when the piston is installed. The DT piston only has one relief notch for the piston cooling jet. If the piston is assembled with the arrow facing the flywheel, both the piston and the piston cooling jet may be damaged when the crankshaft is rotated.
- Both engine displacements, MaxxForce DT (466 in³) and the MaxxForce 9 and 10 (570 in³.), share a common bore size of 116.6 millimeters. The additional displacement on the MaxxForce 9 and 10 comes from increasing the stroke from 119 mm to 146 millimeters.



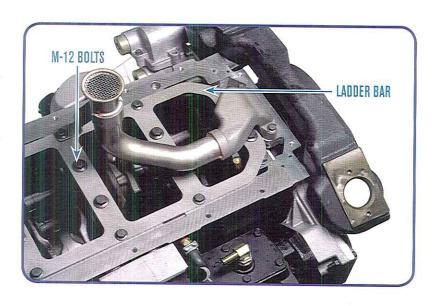
- Design changes were made to the valve train prior to the start of MaxxForce production. The cup size of the lifters, the ball size of the push tubes, and the valve clearance adjusting screw were increased in size.
- Engines with these components can be identified by the hex shape of the valve clearance adjusting screw and the lack of the large spacer under the rocker shaft bolt. Use the engine serial number to get the correct service parts when performing repairs. Do not mix components in an engine. Do not change from large geometry to small geometry as this will complicate future engine service.

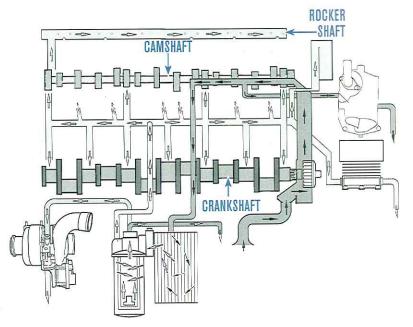
#### Ladder Bar

- Depending upon the horsepower, some Maxx-Force DT, 9, and 10 engines use a ladder bar.
   The ladder bar is a quarter inch thick steel plate bolted to both the main bearing caps and the pan rail of the crankcase. The ladder bar ties the main bearing caps and the crankcase sides together for increased rigidity.
- The ladder bar is bolted to the main bearing caps with two M12 bolts per cap. The main bearing bolts do not go through the cap, so the bar can be removed without disturbing the main bearings.









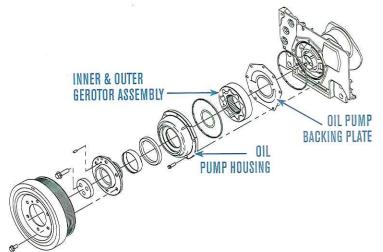
#### **Lube System Operation**

- Unfiltered oil is drawn from the oil pan through the pickup tube and front cover passage. Pressurized oil is forced through a front cover passage and the crankcase to the filter/cooler module. Oil in the module is controlled by a thermal valve, pressure regulator and a filter bypass valve. After the filter, oil then enters the main oil gallery and is distributed to the moving components.
- Oil is also supplied by external hose to the air compressor. Drain oil from the compressor returns to the crankcase by a hose. Oil is also supplied to the turbocharger by a steel line. Drain oil from the turbo returns to the crankcase by a steel tube.



#### **Pump Suction Tube**

 All engine displacements are offered in both front sump and rear sump oil pans. A short suction tube is used on the front sump pan and a longer tube is used on the rear sump pan. The suction port for the pump is located at the bottom of the outer half of the front cover. The suction tube bolts to the cover at that point. Removing the front cover requires that the pan be dropped so the suction tube can be unbolted from the front cover.



#### Lube Oil Pump

• The Maxxforce® DT, 9, and 10 engines use a gerotor style oil pump. The DT engine has a pump with a 1½ wide rotor set. The Maxxforce 9 and 10 engines use a 1½ inch wide rotor set. The oil pump is mounted externally on the front cover and is driven by the engine crankshaft. The pump draws unfiltered oil through a passage in the outer half of the front cover and forces the oil through the cover to the unfiltered gallery in the crankcase. When removing a pump that will be reused, mark the inner and outer rotors with a permanent marker so direction of gear rotation can be maintained during reassembly.

#### Oil Filter/Cooler Module

- The oil filter/cooler module is mounted to the right side of the crankcase. The module cools, filters, and regulates the flow of oil.
- Oil from the non-filtered oil gallery enters the oil cooler/ filter module through a port in the crankcase. After the oil is filtered and cooled the oil re-enters the crankcase at the filtered oil gallery.
- All of the lubrication system control valves are mounted within the module. The valves control the flow of oil through the filter and cooler and regulate the pressure.

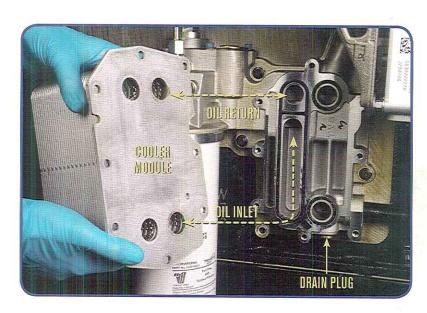
#### **Cooler Module Oil Flow**

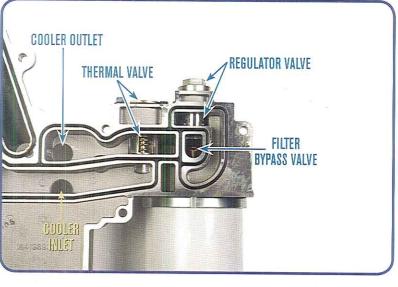
- Oil entering the filter/cooler module is directed to either the filter or the plate style cooler depending upon the oil's temperature. Oil traveling through the cooler dissipates heat to the engine's coolant. Coolant input is through a port in the crankcase. Coolant return is through an external pipe to the back half of the front cover where the coolant is directed to the water pump.
- A coolant drain plug is provided in the bottom of the filter/cooler module. This allows the coolant to be drained before the oil cooler is removed from the filter/cooler base. This feature protects the oil side of the cooler from possible contamination with coolant during removal.

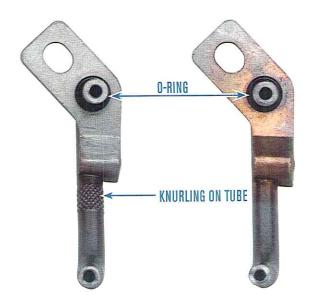
#### **Control Valves**

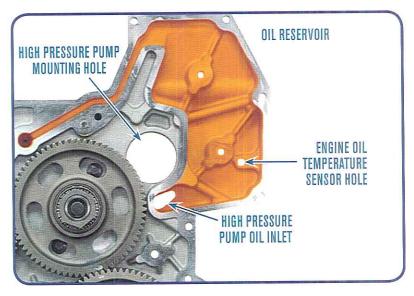
- The oil filter/cooler assembly has three valves: a thermal valve, a pressure regulator valve, and a filter bypass valve. The thermal valve allows cold unfiltered oil to bypass the oil cooler and flow directly to the oil filter. As the oil temperature increases, the thermal valve begins to open allowing unfiltered oil to flow through the oil cooler before entering the oil filter.
- If the oil filter is restricted and the pressure differential across the filter reaches 345 kPa (50 psi) the filter bypass begins to open and allow oil to bypass the filter to maintain engine lubrication. After the filter, oil travels past the oil pressure regulator. The regulator directs excess oil back to the crankcase in order to limit maximum oil pressure.

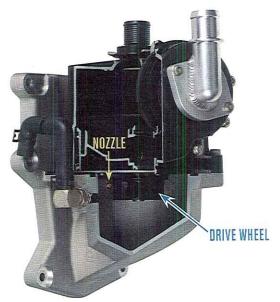












#### **Piston Cooling Tubes**

- The MaxxForce® DT, 9, and 10 engines use piston cooling tubes. The continuous flow of pressurized oil from the main oil gallery is sprayed through the tubes to reduce the temperature of the piston crown. There are two orifice sizes, the MaxxForce 9 and 10 use the larger orifice. The jet for a Maxx-Force 9 and 10 are identified with a knurling on the tube.
- During service, do not reuse the bolt that attaches the tube and do not substitute a different part number bolt.

#### High Pressure Oil Reservoir

- The oil reservoir for the high-pressure pump is cast in the front cover. The reservoir receives oil under pressure from the crankshaft driven lube oil pump. The high pressure pump draws oil from the reservoir for the injection control pressure system. Oil drained from the ICP system by the IPR does not re-enter the reservoir. Instead, drain oil exits the pump from behind the pump gear and enters the gear train area.
- The engine oil temperature sensor, mounted in the back of the front cover, is used to measure the temperature of the oil in the reservoir. Removing the sensor allows the technician to verify there is oil in the reservoir.

#### **Closed Crankcase Breather**

- The closed crankcase breather system uses a centrifugal breather to extract oil from the crankcase gases. The crankcase breather attaches to the right front of the crankcase. The back of the breather has a port which receives oil from the unfiltered oil gallery. The oil passes through a nozzle inside the breather. Pressurized oil exits the nozzle and strikes a drive wheel, forcing the wheel to turn at high speed.
- Oil separated from the crankcase gases and oil striking the drive wheel are both returned to the crankcase through a drain port in the rear of the breather.

#### **Cooling System Flow**

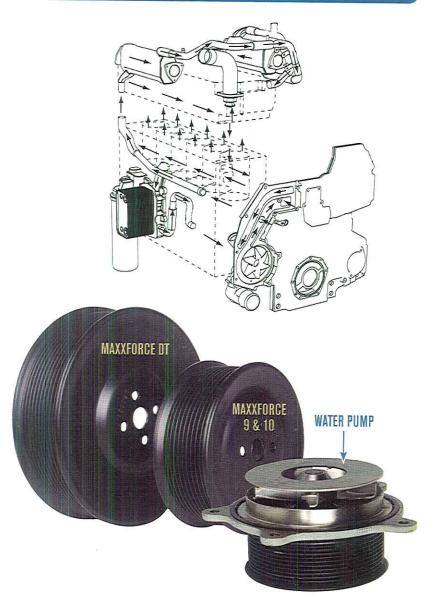
- Coolant is drawn from the radiator into the front cover by the water pump. The pump pushes coolant into the crankcase where coolant flows around the cylinder liners to absorb the heat from combustion.
- Coolant passes through the head gasket and enters the cylinder head. Coolant flows through the cylinder head water jackets towards the thermostat cavity at the front of the cylinder head.
- Coolant is also used to cool the air compressor, remove heat from oil passing through the oil cooler, remove heat from exhaust passing through the EGR coolers, and cool the EGR valve.

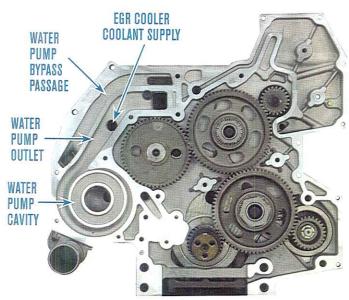
#### **Water Pump**

- The MaxxForce® DT and MaxxForce 9 and 10 use a different pump pulley to match pump flow to engine speed. The DT uses a 67/s inch diameter pulley and the MaxxForce 9 and 10 use a 41/4 inch diameter pulley.
- The MaxxForce 9 and 10 both use a premium bearing water pump during production. During service only the premium bearing pump is available for both the MaxxForce DT and the MaxxForce 9 and 10.

#### Front Cover Coolant Flow

- The impeller of the water pump sits in a cavity fed by the water inlet elbow, the thermostat bypass valve, and the oil cooler return line. Impeller rotation pushes coolant up a passage in the cover to a port where coolant enters the crankcase. Coolant in this passage also feeds the exhaust side EGR cooler.
- If the thermostat is closed, coolant will exit the cylinder head and return to the back of the pump via a second passage in the cover. This allows for circulation in the engine when coolant is not circulating through the radiator.

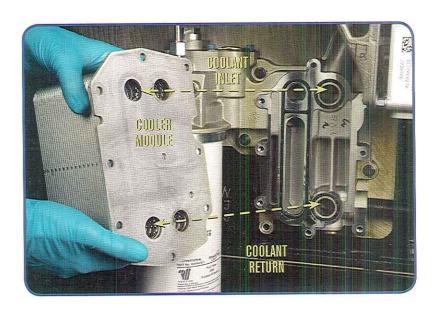






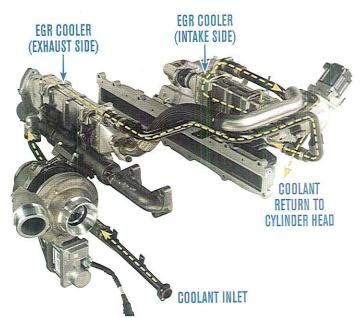
#### **Thermostat**

• When engine coolant temperature is below 88°C (190°F) the thermostat is closed, blocking the flow of coolant to the radiator. Coolant is forced to flow through a bypass port back to the water pump. When coolant temperature reaches the nominal opening temperature 88°C (190°F) the thermostat opens allowing some coolant to flow to the radiator. When coolant temperature exceeds 96°C (205°F), the lower seat blocks the bypass port directing full coolant flow to the radiator.



#### **Coolant Flow: Oil Cooler**

• All MaxxForce® DT, 9, and 10 engines use an oil cooler to reduce oil temperature. Oil flow through the cooler is controlled by the thermal valve but coolant always flows through the cooler when the engine is running. Coolant flows from the crankcase through the module to the cooler. Coolant then flows through the cooler and back into the module. Then coolant is directed into external piping that returns the coolant to the front cover. The front cover port feeds coolant directly to the water pump.



#### **Coolant Flow: EGR Coolers**

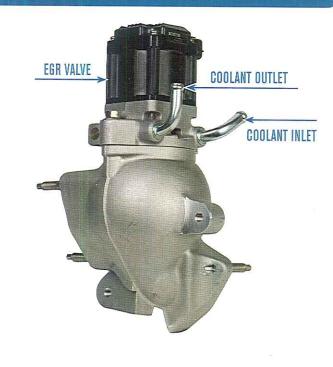
 EGR coolant flow originates at a port on the rear of the front cover. Coolant passes from the front cover through a steel line to the rear of the exhaust side cooler. Coolant then passes by steel piping to the front of the intake side cooler. After passing through the intake side cooler, the coolant returns to the engine through a pipe connecting to a port at the front of the cylinder head.

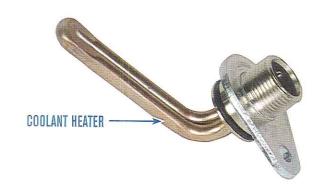
#### Coolant Flow: EGR Valve

- The MaxxForce<sup>®</sup> DT, 9, and 10 all use a water cooled EGR valve. Coolant flow protects the electronic section of the valve from excessive heat. Coolant from the valve comes from the front section of the intake side EGR cooler. Coolant passes through a hose to a port on the valve, circulates through a passage in the valve, and then flows by hose to the deaeration tank.
- The valve is designed with a weep hole that will drain any coolant leakage if the valve were to be damaged. This feature will keep coolant from entering the cylinders.

#### **Coolant Heater**

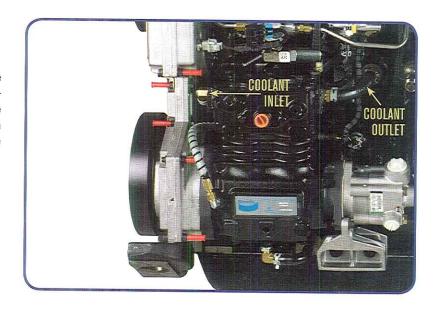
• Available cold climate features include an optional oil pan heater, coolant heater, and fuel heater. All three heaters use an electric element to warm the engine fluids in cold weather conditions. The fuel heater is DC powered from the vehicle's electrical system while both the oil pan heater and the coolant heater are AC powered and are active only when plugged into a 110 volt circuit. The coolant heater warms engine coolant surrounding the cylinders. The coolant heater warms engine coolant surrounding the cylinders. Warmed engine coolant aids in starting a cold engine.





#### **Coolant Flow: Air Compressor**

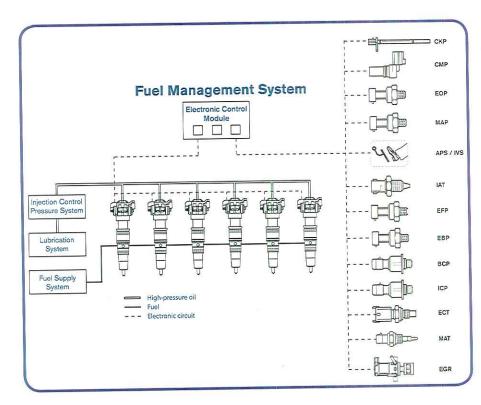
 The air compressor is cooled with engine coolant. Coolant is supplied to the compressor through a hose from the left side of the crankcase. Coolant passes through the compressor and returns through a hose back to the crankcase.





# FUEL MANAGEMENT SYSTEM

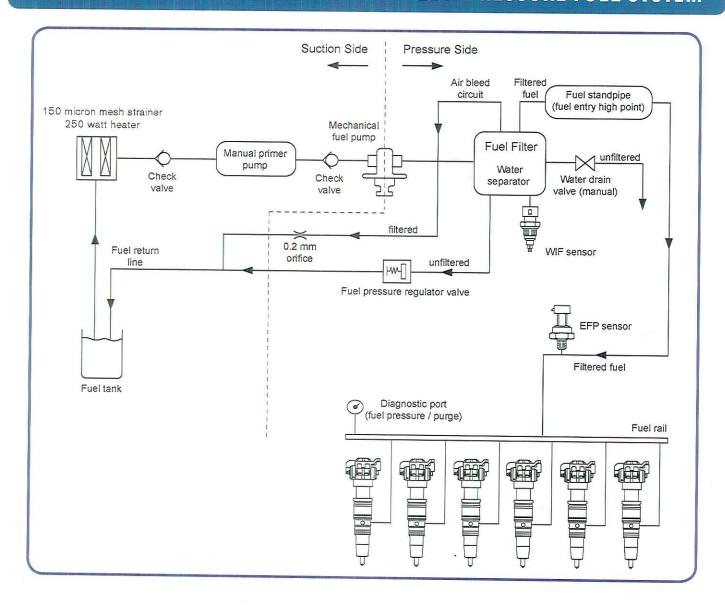
- · Water-in-fuel Detection
- Optional Electric Fuel Heater
- Top Mounted Fuel Filter And Strainer
- Larger Hand Primer Pump
- Cast Iron High Pressure Pump
- Internally Mounted High Pressure Rail



#### **System Features**

- The fuel filter module features water-infuel detection. When the water-in-fuel sensor detects water, the vehicle's instrument cluster notifies the operator. An optional electric fuel heater at the inlet port of the fuel filter module monitors fuel temperature and automatically activates when needed. Both top mounted fuel filter and fuel strainer allow easy access to service the elements.
- A new larger hand primer pump is used for easier hand priming.
- The high pressure system uses a cast iron high pressure pump with an internal throttle to regulate oil fed to the pistons of the pump. This feature reduces the power required to drive the pump.
- The high pressure oil system uses a high pressure rail mounted under the valve cover. Mounting the rail under the cover eliminates the potential for external oil leaks.

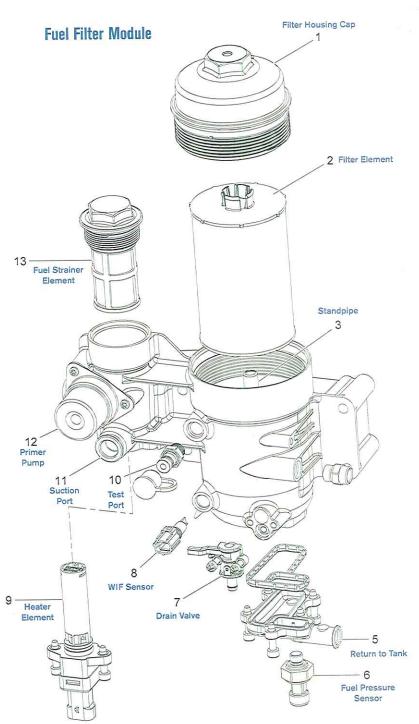
# **LOW PRESSURE FUEL SYSTEM**



#### System Operation

- The fuel supply system draws fuel from the vehicle's tank with a low pressure fuel pump. The fuel pump is mounted on the high pressure pump. Rotation of an eccentric within the high pressure pump drives the piston of the supply pump.
- Fuel from the tank is drawn into the fuel strainer where it passes through a 150 micron element. Fuel then passes through a steel line to the suction side of the fuel pump. The pump passes fuel under pressure to the fuel filter housing. After passing through the fuel filter element, fuel enters the top of the stand pipe. If
- the fuel pressure exceeds the regulator crack pressure, the regulator in the bottom of the filter housing opens and a portion of the fuel on the non-filtered side of the filter is returned back to the fuel tank.
- The fuel filter element features an air bleed circuit to keep air from entering the injectors. A cavity built into a stand pipe within the filter allows a small volume of fuel to constantly bleed from the clean side of the filter. This fuel and air is returned to the tank through a passage that combines the flow of fuel and air with the fuel released from the pressure regulator valve.
- Fuel under pressure passes through the module stand pipe and exits a passage at the back of the filter module. Fuel then enters a drilling in the intake manifold. A drilled passage in the intake manifold runs the length of the manifold and matches up with drilled passages in the cylinder head. Fuel exiting the intake manifold enters the individual cylinder head passages where the fuel then flows to each injector. This system makes fuel under pressure available to each injector's barrel and plunger during the fill stage of the injector.

## LOW PRESSURE FUEL SYSTEM



#### **Engine Fuel Pressure Sensor**

The EFP (Engine Fuel Pressure) sensor is installed in the bottom of fuel filter module. The sensor is used to monitor engine fuel pressure on the "clean side" of the filter. The ECM uses the pressure sensor signal to determine the condition of the filter and warn the operator with an instrument cluster lamp if the filter needs to be serviced.

#### **Fuel Strainer**

The fuel strainer is mounted in the filter module under the fuel strainer cap. The 150 micron element removes coarse sediment from the fuel before it enters the supply pump. The element can be removed and cleaned.

#### Water-In-Fuel Sensor

The WIF (Water-in-Fuel) sensor is installed in the fuel filter module. The WIF sensor provides a feedback signal to the ECM when water is detected in the fuel supply. If water is detected, the ECM will alert the operator by illuminating the water-in-fuel lamp.

#### **Fuel Heater**

An optional heater warms the fuel in cold weather to avoid fuel waxing. The fuel comes in contact with the heater when it enters the module. A thermostat within the heater switches on when the temperature is below 33°F and turns off when the fuel temperature reaches 75°F.

#### **Primer Pump**

A manual primer pump is mounted to the fuel filter module and is used to prime the system if the engine has run out of fuel or the system has been serviced.

#### **Test Port**

A quick disconnect coupling is provided to allow technicians to measure non-filtered fuel pressure. Filtered fuel pressure can be measured at the Schrader<sup>TM</sup> valve on the intake manifold.

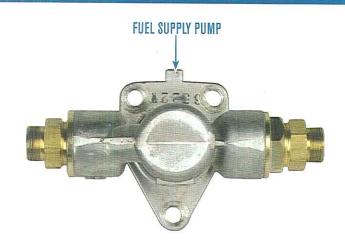
#### Water Drain

The water drain allows the operator to drain water and/or contaminated fuel from the fuel filter housing if the water-in-fuel lamp is activated by the ECM.

# LOW PRESSURE FUEL SYSTEM

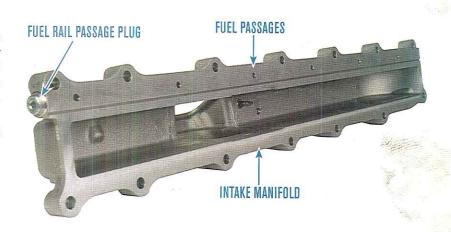
#### **Fuel Supply Pump**

The fuel supply pump is a piston type pump.
The pump is mounted on the high pressure
pump. The high-pressure pump has an internal eccentric that drives the piston within the
pump. The eccentric drives the piston on the
suction stroke and a spring within the pump
drives the piston on the pressure stroke.



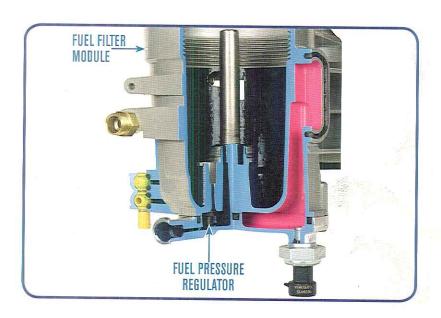
#### **Fuel Rail**

• The fuel rail is a drilled passage in the intake manifold. A passage in the rear of the filter module feeds the fuel rail. Fuel exits the rail through the back of the manifold and enters individual passages in the cylinder head to feed each injector. Fuel pressure in the rail can be measured through the Schrader™ valve at the front of the manifold. The Schrader™ valve also provides a point to bleed air from the system.

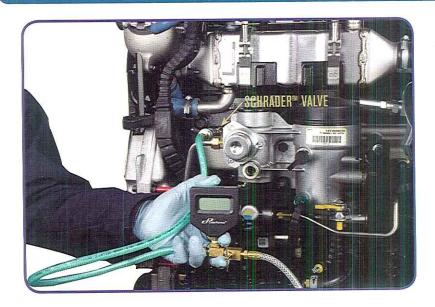


#### **Pressure Regulator**

• The fuel pressure regulator is located at the bottom of the filter cavity of the filter module. The regulator is on the non-filtered side of the system. Pressure released from the filter housing is returned to the fuel tank. The regulator is a serviceable part that can be replaced without replacing the module itself. The regulator is accessed by removing the small cover that is part of the return fuel port. The cover is bolted to the bottom of the filter housing.

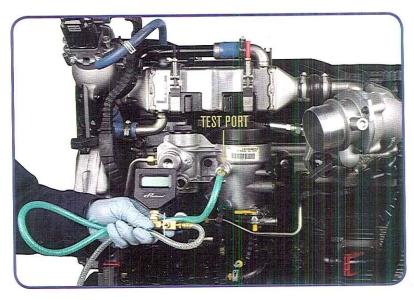


# FUEL SUPPLY SYSTEM DIAGNOSTICS



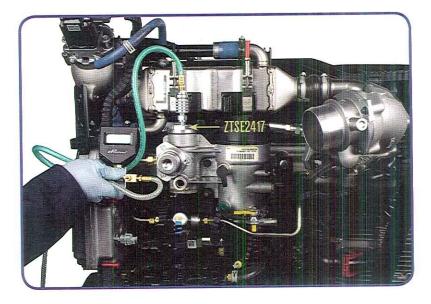
#### Measuring Clean Side Pressure

• The filtered or 'clean side' fuel pressure can be measured at the Schrader™ valve on the forward end of the intake manifold. Use adapter kit ZTSE4657 to connect a 0-160 psi gauge to the port. Engine fuel pressure will be approximately 20 psi during cranking, 40-70 psi at low idle, 40-75 psi at high idle, and 40-75 psi at rated speed under 100% load. These are approximate values; consult the appropriate service literature for the specifications.



#### **Measuring Dirty Side Pressure**

- The non-filtered or 'dirty side' fuel pressure can be measured at the test port on the front of the fuel filter module. Measuring pressure on the clean side and the dirty side of the fuel filter allows the technician to determine if the filter is restricted.
- Use fuel/oil pressure test coupler ZTSE4626
  to adapt 0-160 psi fuel pressure gauge
  ZTSE4681 to the test port. If the clean side
  pressure is low but the dirty side meets the
  specification, the filter should be replaced.



#### **Measuring Inlet Restriction**

• Replace the fuel strainer cap with fuel inlet restriction adapter ZTSE2417. Attach a 0-30 in/hg vacuum gauge to the adapter then crank the engine for 15 seconds while watching the gauge. The gauge reading should be less than 6 in/hg while cranking. Restrictions in the system can cause the flow of fuel to be limited. If the inlet restriction is greater than 6 in/hg, there is a restriction between the point in the suction side of the system where the gauge is inserted and the fuel in the tank. It is normal to have some restriction at the inlet. A restriction of zero can indicate an air leak on the suction side of the system.

# FUEL SUPPLY SYSTEM DIAGNOSTICS

#### **Checking for Aeration**

• The fuel system can be checked for aeration through the test port on the front of the fuel filter module. Use fuel/oil pressure test coupler ZTSE4626 to adapt fuel pressure gauge ZTSE4681 to the test port. With the engine cranking or running, open the valve on the pressure gauge and take a sample of fuel into a clean container. If the fuel is aerated in the sample hose, the engine either has an air leak on the suction side of the system or compression or combustion gases leaking back into the system.



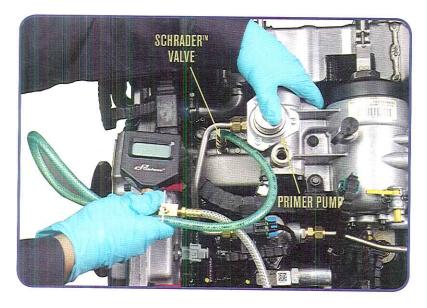
#### **Checking Pump Pressure**

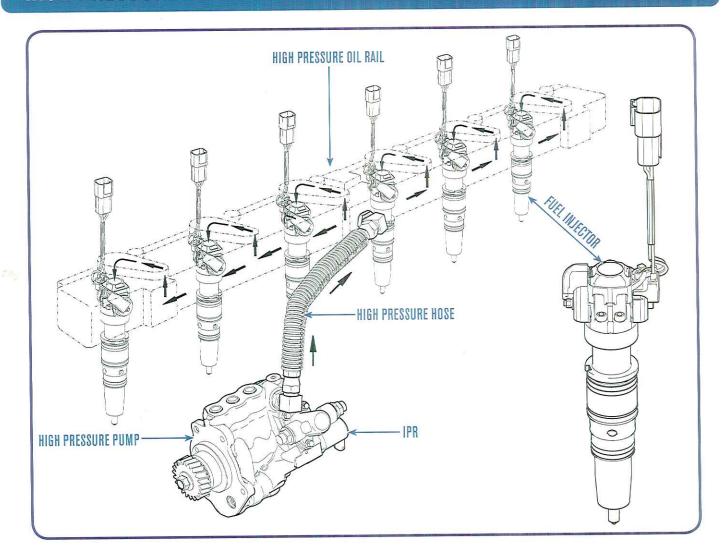
• The fuel pump can be deadheaded by removing the fuel line from the output side of the pump. Using a spare line, adapt a pressure gauge to the pump. Crank the engine and read the output pressure. If the dirty side pressure is low, the fuel is not aerated, the inlet restriction is not above specification, and the deadhead pressure is low, the pump is at fault. If all the conditions exist except that deadhead pressure meets the cranking specifications, a pressure regulator kit needs to be installed.



#### **Priming the System**

- If the engine runs out of fuel or the fuel filter header has been drained, it is important that the system be primed before attempting to start the engine. Starting the engine with air in the system can damage the injectors.
- Use fuel pressure test kit ZTSE4657 to adapt Pressure Gauge ZTSE4681 to the intake manifold test port. Insert the gauge hose into a container to catch the fuel. Open the shut-off valve and pump the primer pump until an air-free stream of fuel comes out the hose. Close the valve then start the engine and check for fuel leaks. Turn off the engine and remove the fuel pressure gauge and the adapter.



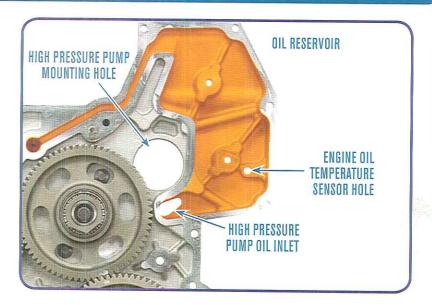


#### **High Pressure Oil System Operation**

- The high pressure oil system consists of the following components:
  - Supply reservoir
  - High pressure pump
  - High pressure hose
  - High pressure manifold
  - ICP sensor
  - IPR
- The high-pressure oil pump mounts on the back of the front cover. The pump draws oil from a reservoir contained within the two halves of the front cover. The pump can develop pressures up to 5,200 psi, but normal operating pressure is approximately 800 to 4,500 psi depending upon operating conditions.
- The IPR (Injection Pressure Regulator) is mounted on the high pressure pump. The ECM controls the regulator. If the pressure is high, the IPR drains oil from the output of the pump. If the pressure is low, the IPR restricts the drain oil from the pump.
- Oil from the pump is forced through the high-pressure hose to a passage in the cylinder head and then to the high-pressure oil manifold or what is often called the rail. The oil is delivered to each injector by the high flexible oil inlet adapters. High-pressure oil increases the fuel pressure inside each injector by applying pressure to an amplifying piston in the injector. After exerting force on the piston
- within the injector, the oil exits the injector and drains to the sump through the cylinder oil return passages.
- The high pressure oil system is a closed loop system. The ECM constantly corrects the position of the IPR based off current operating conditions and the signal value of the ICP sensor.
- The EOT (Engine Oil Temperature) signal is an input into the operation of the high pressure oil system. Oil temperature in the reservoir is constantly measured so the ECM can compensate for changes in oil viscosity due to temperature changes. Oil viscosity effects the injector operation and therefore can have an effect on injection timing.

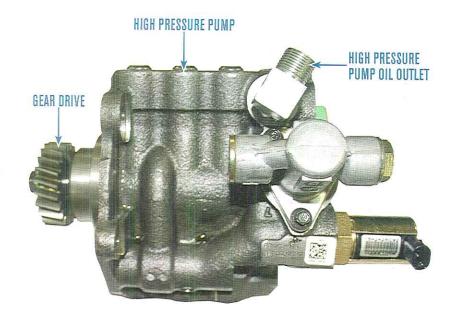
#### High Pressure Oil Reservoir

- The high pressure pump draws oil from a reservoir formed from the two halves of the front cover. The reservoir is fed under pressure by the lube oil pump in order to keep the reservoir filled. The reservoir capacity is approximately two quarts.
- The back half of the front cover has a hole that the engine oil temperature sensor threads into. This allows the technician to check the level of oil in the reservoir if required during hard start no start diagnostics.



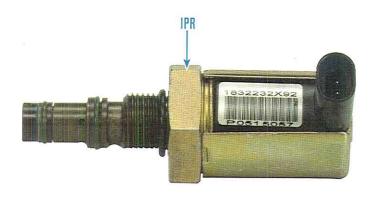
#### **High Pressure Pump**

- The high pressure pump is mounted to the rear of the front cover and is driven by the gear train. A passage on the front of the pump connects the pump to the reservoir.
- Drain oil from the injection pressure regulator is directed against a shuttle valve in the pump. The shuttle valve controls the flow of oil to the pump pistons. If drain oil is high, the shuttle restricts the oil flow to the pistons. This results in less parasitic drag on the engine.



#### Injection Pressure Regulator

• The IPR valve is mounted in the body of the high-pressure pump. The IPR valve maintains desired injection control pressure by dumping excess oil back to the crankcase through the front cover. The IPR solenoid receives a current control signal from the ECM. Increased current flow raises the injection control pressure. Lowering the current flow lowers the injection control pressure. Excess oil drained by the system exits the pump behind the drive gear and enters the front cover area.







#### BRAKE CONTROL VALVE ASSEMBLY



#### **Injection Control Pressure Sensor**

- The ICP sensor is mounted at the right rear of the high pressure oil rail. The sensor is part of a closed loop system that uses the ICP sensor to continuously provide injection control pressure feedback to the ECM. The ECM commands the IPR duty cycle based on that feedback in order to adjust ICP pressure to match engine requirements.
- The ICP sensor is a micro-strain gauge sensor that is supplied with a reference voltage and a ground. The sensor returns a variable voltage signal to the ECM based on the pressure in the rail. The circuit the sensor is attached to is a pull up circuit meaning the voltage on the signal wire will go to five volts (out of range high) when the sensor is disconnected.

#### High Pressure Oil Manifold/ Oil Inlet Adapter

• The high pressure oil manifold is cast iron and is mounted under the valve cover of the engine. The oil passage that connects the cylinder head to the manifold is sealed with an o-ring. The manifold has six oil inlet adapters that supply oil to the injectors. The outlet pipes have replaceable o-rings to seal into the top of the injectors. An internal oring in the inlet adapters is not serviceable. If the internal o-ring fails, the inlet adapter must be replaced.

#### **Brake Control Valve**

- There are two main passages in the high pressure rail on engine brake equipped engines: the injector passage and the brake piston passage. These two passages are divided by the brake control valve. During normal engine operation the valve is closed and injector pressure can not reach the brake pistons. When the brake is activated, the control valve opens and high pressure oil pump flow reaches the brake piston passage.
- The ECM controls the control valve with a two wire circuit. The connection is made through connector three of the valve cover gasket. The connectors are numbered starting from the front of the engine.

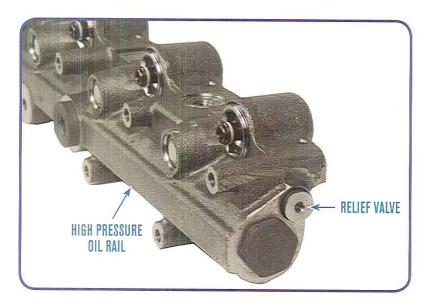
#### **Brake Actuator Piston**

 When equipped with an engine brake, the high pressure oil rail is machined to hold six brake pistons. When the ECM activates the brake, high pressure oil pushes each piston down in contact with the exhaust valve bridge. An internal mechanism in the piston limits piston travel, yet allows the piston to hold open one exhaust valve in each cylinder approximately 0.035".



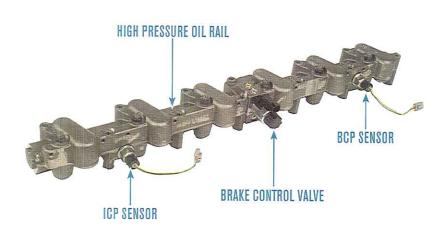
#### **Brake Pressure Relief Valve**

• The brake pressure relief valve is mounted at the forward end of the oil rail. When the brake is in operation and the operator applies the throttle, the ECM closes the brake control valve. With the oil supply cut off from the brake passages in the rail, normal leakage around the pistons causes oil pressure in the brake passage to drop rapidly. When the pressure drops below 1000 psi, the brake pressure relief valve opens and vents the remaining pressure under the valve cover.

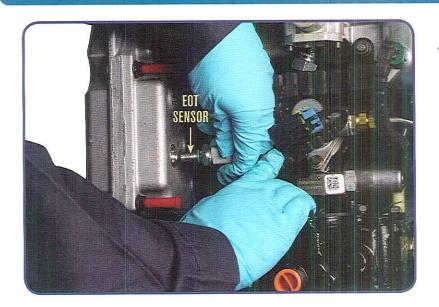


#### **Brake Control Pressure Sensor**

• The engine brake uses the BCP (Brake Control Pressure) sensor for fault detection. The sensor is mounted on the right front side of the high pressure rail. The sensor measures brake pressure and sends a voltage signal proportional to the pressure back to the ECM. The ECM compares the BCP value to the desired value during both brake-on and brake-off operation. The BCP pressure should be high when the brake is activated and low when the brake is off. If BCP does not match the desired value a DTC is set and engine fueling is reduced to prevent possible engine damage



# LOW ICP NO-START DIAGNOSTICS



#### **Checking Reservoir Level**

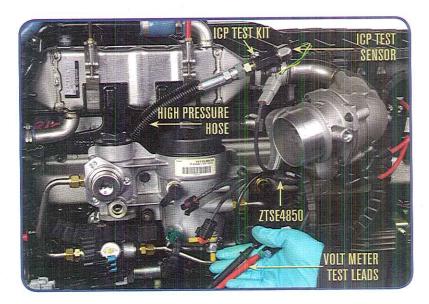
 Check the oil pressure during cranking with the dash gauge or the EST. If the oil pressure meets the cranking specification, the reservoir should be full. If the pressure is low, or you want to check the level, unthread the EOT sensor from the rear of the front cover. If the reservoir is full, the oil will begin to leak out between the threads before the sensor is fully removed.



#### **IPR Control Test**

• The ECM must be able to control the injection pressure regulator. If an engine with low ICP will not start, attach breakout harness ZTSE4484 to the IPR but do not connect the engine harness to the breakout harness. Full field the regulator by connecting B+ to one lead and a good ground to the other lead. If the engine starts when full fielded, check the fuse for the IPR, check the IPR connector for corrosion or damage, then check the harness for opens or shorts to ground. If the harness is good, check the ECM output to the IPR.

**NOTE:** Do not leave the IPR powered for more than two minutes.



#### **Pump Deadhead Test**

Deadhead the pump to determine if the pump can produce the correct pressure when disconnected from the high pressure rail and injectors. Remove the high pressure hose from the cylinder head and install the ICP test kit with ICP sensor PN# 1875784C91 (use this sensor on ESN 3,000,001 and up) or equivalent into the end of the hose. Use pressure sensor breakout harness ZTSE4850 to connect the test sensor to the MAP sensor harness lead. Use a volt meter to measure the signal voltage while cranking. The pump should create at least 1.2v or 870 psi for the engine to start with the engine harness connected to the IPR.

# LOW ICP NO-START DIAGNOSTICS

#### **IPR Block-off Test**

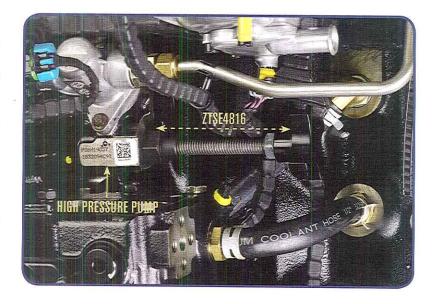
- Retain the hose, the ICP sensor, and the breakout harness as installed in the deadhead test. Remove the IPR and install the IPR block-off tool ZTSE4816 in its place. Measure the signal voltage while cranking. The pressure should exceed 4000 psi if the pump is good.
- Note: If the engine is equipped with an air compressor, a head bolt on the compressor may interfere with removal of the IPR. Do not remove the compressor head bolt; instead, break the connector off the IPR before removal.

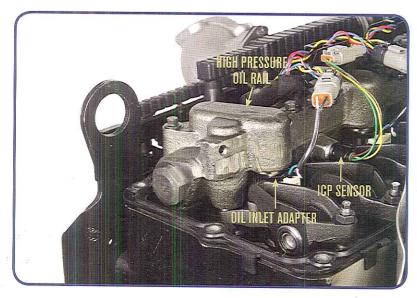


- Remove the valve cover. Re-attach the high pressure hose to the cylinder head and crank the engine while watching for an oil leak. Possible leak areas:
  - BCP (Brake Control Pressure) sensor
  - Six oil inlet adapters
  - Abnormal flow at injector drain ports
  - ICP (Injection Control Pressure) sensor
  - BCV (Brake Control Valve)
- The BCP sensor and the brake pressure relief valve should only be pressurized during brake operation. It would require a failure of the brake control, a BCV circuit failure, or a casting flaw in the rail to pressurize these during non-brake operation.

#### **ICP Sensor and Sensor Circuit Test**

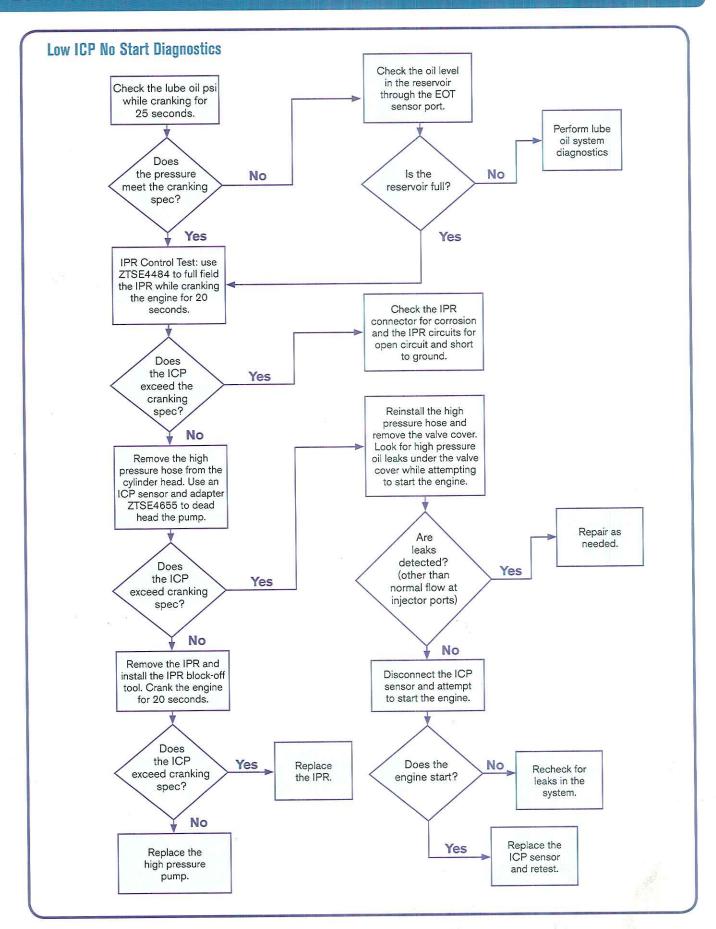
- Return all of the parts to the engine including the IPR, IPR connector, and the high pressure hose. Disconnect the ICP sensor and crank the engine. If the engine starts with the sensor disconnected, either the sensor is biased and needs to be replaced, or the circuit is biased. An out of range high or low DTC will not act as a biased sensor.
- The ECM will not signal the spool valves of the injectors if the ICP is below a programmed value. If the sensor is biased and the ECM detects that this value is not being reached, the engine will not start. When you disconnect the sensor, you induce a DTC and the ECM then ignores the ICP sensor value and runs off of programmed values.







# LOW ICP NO-START DIAGNOSTICS



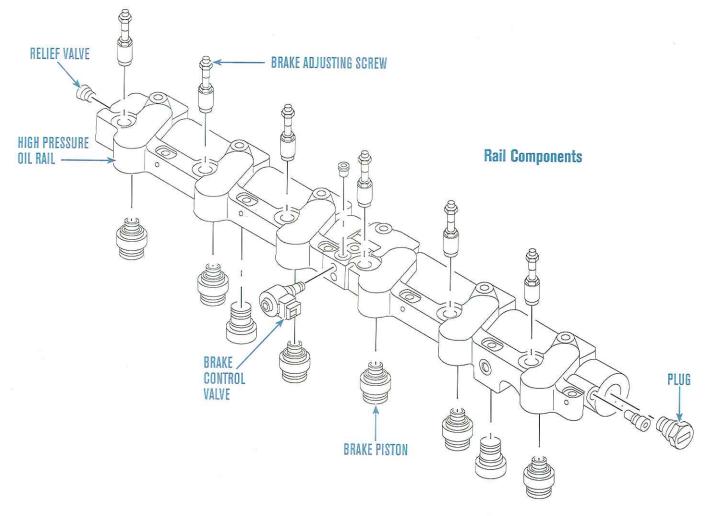
# LOW ICP NO-START DIAGNOSTICS

#### Rail Installation and Repair

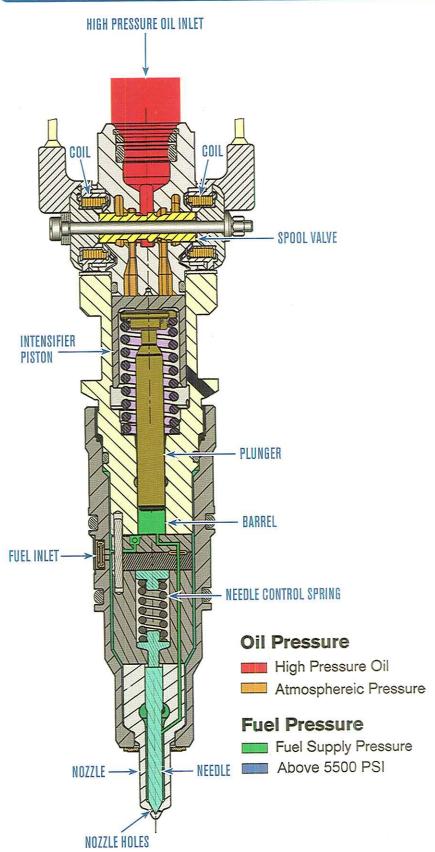
- Use clean engine oil on the oil inlet adapter seals when assembling the high-pressure oil rail to the cylinder head. This reduces the chance of a seal rolling or being cut during installation. To assist in the installation of the oil rail, use two mounting bolts as guides.
- The oil inlet adapters are flexible to allow the rail to engage in the injectors. Because the inlet adapters can move, you must make sure the inlet adapters are started into the injector opening before pushing the rail into place. During installation, guide all six oil inlet adapters into the opening of the injectors. Forcing the rail into place can damage the oil inlet adapter's internal o-ring. This damage will not be visible and will only be discovered when high pressure oil leaks past the internal o-ring during start up. The high-pressure oil rail should seat against the surface of the cylinder head. Never draw the high-pressure oil rail into place with mounting bolts.

#### Oil Inlet Adapter Replacement

 All of the high pressure rail components can be serviced separately. Do not replace the entire rail to repair a leak at one of the rail's components. When replacing an oil inlet adapter, use injector adapter removal tool ZTSE4725. Inspect the new injector adapter. Make sure the o-rings are not twisted, damaged, or missing. Install the adapter and torque to manufacturer specifications.



# INJECTOR OPERATION



#### **Spool Valve**

• The ECM changes the position of the spool valve by sending electrical current to the open and close coils. Current in the coil, produces a magnetic force that pulls the spool into place. The spool has two positions. When the spool valve is open, oil from the rail flows into the injector. When the spool valve is closed, oil exits from ports on top of the injector and drains back to the crankcase.

#### Intensifier Piston and Plunger

The intensifier piston and plunger work together to increase supply pressure to the levels needed for injection. During operation, high pressure oil contacts the upper surface of the plunger, while the plunger contacts the fuel in the barrel. When the spool valve is open, high-pressure oil enters the injector forcing the intensifier piston and plunger down.

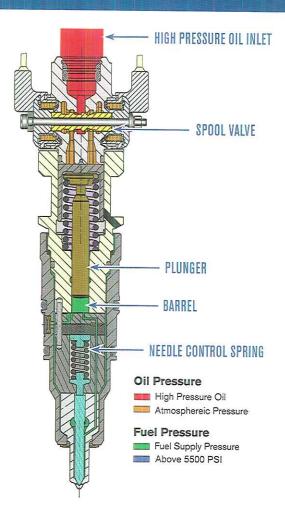
#### **Barrel** and Plunger

• The barrel and plunger of the injector is where fuel injection pressure is generated by the movement of the plunger. Since the intensifier piston surface area is approximately seven times greater than the plunger, the injection pressure created in the barrel is seven times greater than the oil pressure above the intensifier piston. The plunger is coated to reduce the possibility of scuffing.

#### Nozzle

The nozzle needle opens when fuel pressure, pushing on the bevel of the needle, is greater than the spring pressure holding the needle closed. At that point, the needle lifts and fuel under high pressure passes through the nozzle holes.

# **INJECTOR OPERATION**

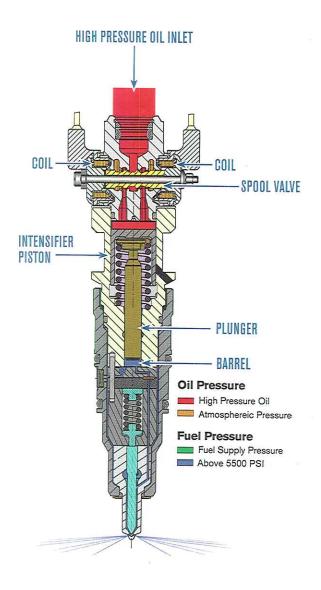


#### Injection

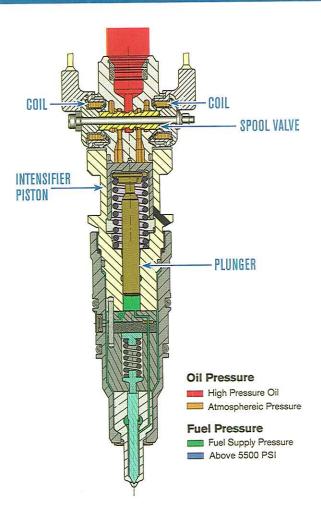
- The Engine Control Module (ECM) energizes the OPEN coil to move the spool valve. With the valve open, high pressure oil flows to the intensifier piston. Fuel pressure in the barrel builds when the plunger begins to move downward. This causes the fuel inlet valve to seat. As the intensifier piston continues to move downward the fuel pressure rises until it raises the nozzle needle off its seat.
- The injector also acts as part of the After-treatment system. During a regen the ECM commands the injectors to add fuel to the cylinder during the exhaust stroke. This causes unburned fuel to enter the Aftertreatment system. The fuel and catalyst produces high amounts of heat in the diesel oxidation catalyst and the diesel particulate filter. The higher exhaust temperatures causes soot particles in the DPF to be reduced to ash. This phase is called post injection.

#### Fill Stage

 During the fill stage, the spool valve is in the closed position. High pressure oil from the High-pressure oil manifold cannot pass through the spool valve. The plunger is high in the barrel which allows low pressure fuel to pass through the fuel inlet check valve and fill the barrel and plunger cavity. The needle control spring holds the needle on its seat so fuel cannot enter the combustion chamber.



# INJECTOR OPERATION

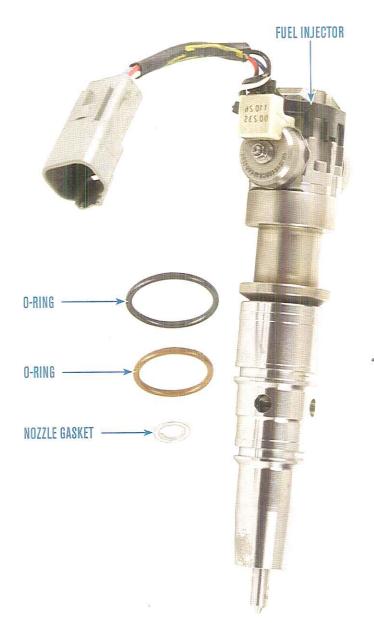


#### **End of Injection**

• When the Engine Control Module (ECM) determines that the correct injector on-time has been reached (the correct amount of fuel has been delivered), the ECM sends a voltage signal to the CLOSE coil of the injector. The electrical current energizes the CLOSE coil and magnetic force pulls the spool valve closed. High-pressure oil is deadheaded against the spool valve. The intensifier piston and plunger begin to return to their initial positions. Fuel pressure in the barrel and passage to the needle decreases until the needle control spring forces the needle back onto its seat and injection stops.

#### **Injection Sealing**

• The injector has two replaceable o-rings on the outside of the body. These o-rings seal the fuel inlet area. In addition, the injector has a nozzle gasket where the nozzle passes through the cylinder head into the combustion chamber. The nozzle gasket has a raised portion or bump on one side. The bump can face either direction when installed on the injector.



## **INJECTOR DIAGNOSTICS**

#### **KOEO** Injector Test

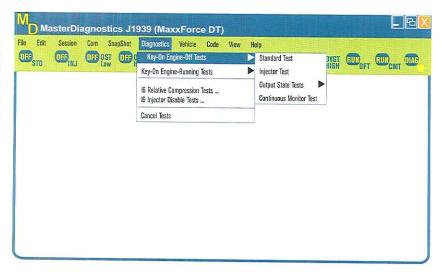
 The KOEO Injector Test checks for electrical faults in the injector circuits and allows the technician to check for mechanical movement of the spool valves by listening for spool movement. During the test, the ECM activates the injectors in the pre-cycle mode then activates the injectors in the firing order.

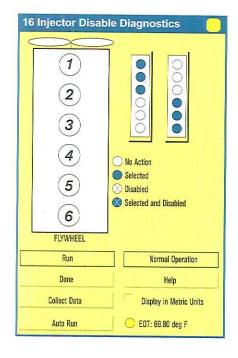
#### Possible Causes

- · Open or short in injector circuits
- · Poor ECM power or ground
- · Failed injector coil
- · Failed ECM



· The Injector Disable Test allows the technician to shut off injectors to determine the cause of rough engine idle. To test a cylinder, first note the tone or sound of the engine. Then select the cylinder you wish to disable. Now select the RUN button. The injector for that cylinder will be disabled. Listen for a change to the tone or sound of the engine. Select Normal Operation to enable the injector. When a good cylinder is disabled, the remaining cylinders must do more work to maintain the set speed. This causes a tone change in the engine. When a weak or dead cylinder is disabled, the remaining cylinders are not required to do more work to maintain the set speed. This results in little or no tone change.





### NOTES



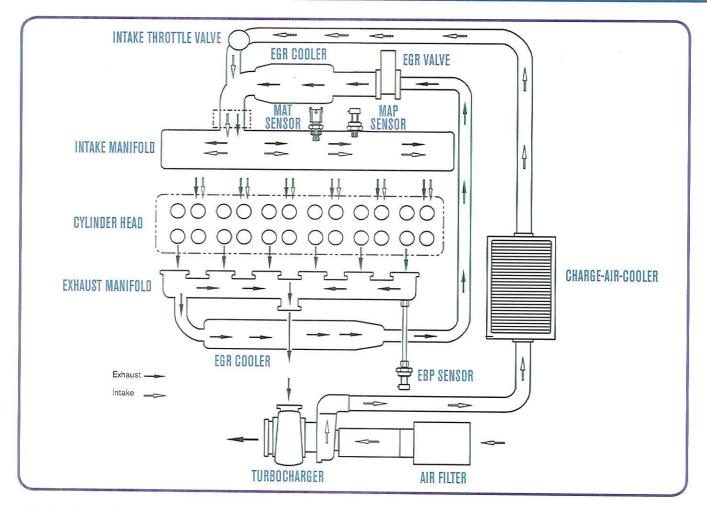
# AIR MANAGEMENT AND AFTERTREATMENT SYSTEMS

- VGT Turbocharger
- Dual EGR Coolers
- DC Motor Driven EGR Valve
- Inlet Throttle Valve
- Diesel Oxidation Catalyst
- Diesel Particulate Filter



#### System Features

- The 2007 I-6 engine features an improved Air Management System. The internal components of the variable geometry turbocharger have been improved to resist the effects of corrosion. Dual EGR coolers and an EGR driver integrated into the EGR valve allow for further incylinder reductions in NOx.
- The 2007 engine is equipped with an Aftertreatment system consisting of a diesel oxidation catalyst and a diesel particulate filter. The aftertreatment system regeneration process is aided by the inlet throttle valve and post injection.



#### System Operation

- Air flows through the air filter assembly and enters the variable geometry turbocharger. The turbo compressor increases the pressure, temperature, and density of the intake air before it enters the charge-air-cooler.
- Cooled compressed air flows from the charge-air-cooler into the inlet throttle valve and EGR mixer duct. If the EGR control valve is open, exhaust gas will pass through the EGR system and mix with the intake air. This mixture flows through the inlet air heater and into the intake manifold. If the EGR control valve is closed only intake air will flow through the inlet air heater and into the intake manifold.
- After combustion gases exit through the exhaust valves and ports, the gas is forced through the exhaust

manifold to the EGR system and the turbo. Some gas flows through the EGR system, which is controlled by the EGR valve. The remaining gas flows to the turbocharger turbine.

- The movable vanes within the turbocharger control flow and pressure of the exhaust gases. This controls the speed of the compressor wheel, which is connected to the turbine wheel by a shaft.
- Exhaust gases exit the turbocharger, flow into the exhaust piping to the aftertreatment system, and are then released from the exhaust tail pipe.
- The ECM monitors the exhaust back pressure, the manifold absolute pressure, and the manifold air temperature

in order to control the turbo, intake throttle valve, and the EGR valve.

During engine operation, the ECM monitors the Aftertreatment sensors for proper operation. When the soot level increases, the pressure before the diesel particulate filter increases. The exhaust gas pressure differential pressure sensor measures the pressure difference and the ECM activates a series of dash lamps to indicate to the driver that action must be taken to cause the system to regen. The ECM continues to monitor the sensors during passive, active, or parked regeneration.

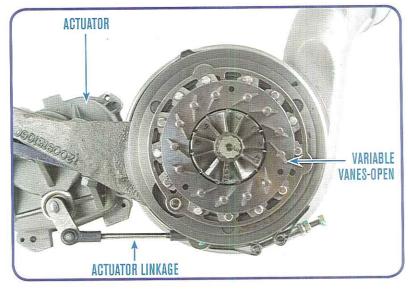




- The variable geometry turbocharger has the ability to change the internal geometry of the turbine side in order to modify exhaust gas flow. Changing exhaust flow allows the turbo to adapt for various engine speeds and load conditions.
- The turbo uses moveable vanes mounted on a unison ring inside the turbine housing.
   The vanes are positioned in order to control boost pressure, or manifold absolute pressure, for various engine speeds and load conditions. The turbocharger is part of a closed loop system which uses the EBP (Exhaust Back Pressure) sensor to continuously provide feedback to the ECM.

#### **Turbo Actuator**

- The turbocharger was serviceable only as an entire component at the start of 2007MY production. The actuator and linkage can now be replaced as a unit. The linkage can be disconnected from the turbo but not from the actuator.
- The ECM commands the turbocharger actuator with a digital signal over the private CAN link (Controller Area Network). A DC motor in the actuator controls the movement of the internal components that change the flow of exhaust.

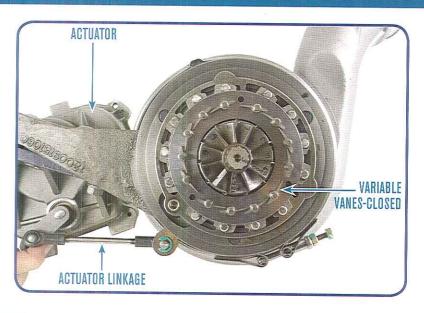


#### Vanes Open

 During high engine speeds with high load, there is a great deal of energy available in the exhaust. Excessive boost under high speed and high load conditions can negatively affect component durability. The ECM monitors both the EBP and the MAP (Manifold Absolute Pressure) signal values. If the EBP is too high, the actuator is commanded to reduce the pressure. The actuator then moves the vanes to a more open position to prevent turbocharger over-speed. The open vanes result in slower exhaust gas speed and lower boost pressure.

#### **Vanes Closed**

• During low rpm or low load conditions, little energy is available from the exhaust to generate boost. In order to maximize the use of the energy that is available, the vanes are moved towards the closed position. Closed vanes cause the exhaust gases to accelerate between the vanes and strike the turbine with greater force resulting in higher turbine speeds and higher boost pressure. Closing the vanes also increases the backpressure in the exhaust manifold. Exhaust back-pressure is used to drive the exhaust gases through the EGR Valve and into the intake manifold.



# EGR VALVE IRON CRADLE IRON CRADLE IRON CRADLE

#### **EGR Coolers**

• Both EGR coolers sit in cast iron cradles that are bolted through the manifolds to the cylinder head. The exhaust side cooler receives exhaust from the rear portion of the exhaust manifold. When the EGR valve is open, the gases travel through the cooler to the exhaust crossover tube. Gas enters the EGR valve and exits into the intake side EGR cooler where the temperature is further reduced. The reduction in gas temperature allows the EGR system to cool the combustion process.

#### **EGR Valve**

- The EGR system is used to reduce nitrogen oxide engine emissions. When the EGR valve is commanded open, cooled exhaust gas from the exhaust side EGR cooler enters the intake side EGR cooler. The exhaust gas temperature is further reduced and then directed into the EGR mixer duct.
- The EGR valve is part of the inlet mixing duct. Do not remove the valve from the inlet mixing duct.



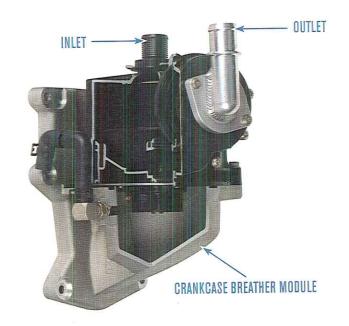
#### Inlet Throttle Valve

 The Inlet Throttle Valve is installed on the inlet mixing duct. The ITV is used to control the air flow during the regeneration process of the after-treatment system. Closing the valve during a stationary regen restricts excessive air flow into the cylinders.



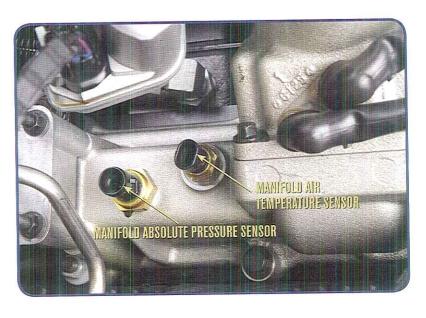
#### **Closed Crankcase Breather**

 The closed crankcase breather system uses an engine mounted centrifugal oil separator to return oil stripped from the engines' blow-by to the crankcase. Oil removed from the crankcase gases is routed to the inlet side of the turbocharger. Stripping oil from the blow-by prevents coking of the turbocharger compressor wheel.



#### **MAP and MAT Sensors**

- The MAP sensor is installed in the intake manifold in front of the MAT sensor. The ECM monitors the MAP signal to determine the pressure in the intake manifold, or what is commonly called boost pressure. The MAP sensor signal is used to calculation to determine the required position of the EGR valve and turbocharger vanes.
- The MAT sensor provides a signal to the ECM indicating manifold air temperature.
   The ECM controls the EGR system based on the air temperature in the intake manifold.



# AFTERTREATMENT SYSTEM

#### 1. Diesel Particulate Filter

The DPF (Diesel Particulate filter) is located in the exhaust system after the DOC (Diesel Oxidation Catalyst). 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.

#### 2. EGDP

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 ECM 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.

#### 3. EGT Sensors

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 DPT. The EGT signals are sent to the ECM where the values are used to regulate the Aftertreatment function.

#### 4. Diesel Oxidation Catalyst

The DOC is located in the exhaust pipe, downstream of the turbocharger and just before the DPF. The DOC 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.

#### Regeneration

Passive Regeneration, or Regen, of the AFT 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 ECM commands the injectors to inject extra fuel into the cylinders during their exhaust strokes. 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 cylinders, and close the intake throttle valve as required to raise exhaust temperatures and then reduce the soot to ash.



# AFTERTREATMENT SYSTEM

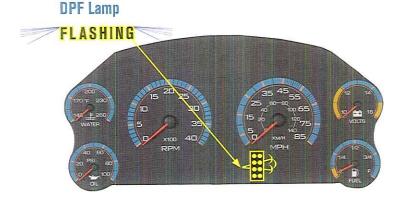
#### **Low Soot Load**

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.

# 

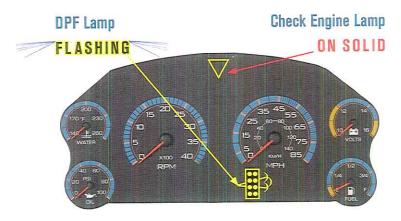
#### **Moderate Soot Load**

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.



#### **Full Soot Load**

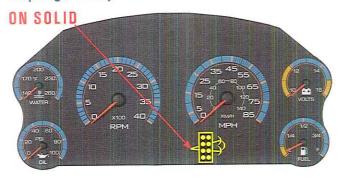
When the DPF becomes so full that it causes engine performance to be limited, the yellow "WARN ENGINE" lamp will illuminate and the DPF lamp will continue to flash. The engine may moderately de-rate or lose power. The operator should pull the vehicle safely off the roadway and start Parked Regeneration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



#### Over-Full Soot Load

If the DPF is allowed to become full, the red STOP ENGINE lamp will illuminate, and the engine may shut down soon. The operator should drive at highway speeds under load so regeneration occurs.

#### Stop Engine Lamp



# AFTERTREATMENT SYSTEM

#### Failed or Plugged DPF Diagnostics

When ever it is necessary to either replace or clean a plugged DPF, the technician should investigate possible reasons for failed or plugged DPF. The following are reasons why a DPF may be plugged:

- 1. Loaded with ash
- 2. Loaded with soot caused by coolant, oil, or excessive fuel in the exhaust system that has caused the PDF to fail or prematurely plug-up
- 3. Operator failed to perform parked regeneration when required

After replacement the technician should perform the following steps to avoid a repeat failure.

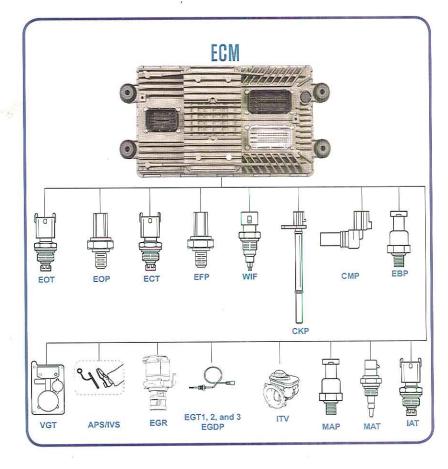
STEP	TEST POINT	CHECK	RESULTS	COMMENT
1.	Vehicle Operator	Does the driver understand the dash lamps and the required actions? How is the vehicle used?		Vehicle operator ignores Dash lights and fails to run a Stationary Regen.  Vehicle may operate in a city environment, with no chance of a passive regen.
2.	Exhaust System	For external exhaust leaks prior to the DOC		Leaks may cause low exhaust temps and interfere with regeneration.
3.	DTC's	Check for current AMS, Fuel System, and AFT DTC's		Stuck EGR valve and/or ITV may cause DPF plugging.
4.	KOER Std test	Perform KOER Std test and check for DTC's related to ICP, ITV, and EGR		Failed EGR valve and/or failed ITV can reduce efficiency of the engine, resulting in a higher soot production.
5.	KOER AMS test	Perform KOER AMS test and check for DTC's related to EGR and VGT		Failed EGR can cause premature soot loading.
6.	AFT Cleanliness test	Perform Cleanliness test		Resets soot level data in the ECM.
7.	Inlet restriction	Check for restrictions in the Intake System		Restrictions may inhibit regeneration.
8.	DOC	Check DOC inlet pipe or turbo outlet for signs of coolant		Coolant from a failed EGR cooler can cause a DPF failure <sup>1</sup> .
9.	DOC	Check DOC inlet pipe or turbo outlet for signs of oil		Excessive oil from a failed turbo or damaged cylinder can cause a DPF failure².

Investigate for coolant leaks if there are dark soot rings on the outlet face of the DPF indicates excessive water concentration in the exhaust. Investigate for coolant leaks or water intrusion into the exhaust system if there is visible water in the DPF. Investigate for coolant leaks if there is a dark streak on outlet side of the filter

<sup>&</sup>lt;sup>2</sup> Deformed or melted Cells within the DPF are caused by excessive fuel or oil in the exhaust. Investigate for failed injectors, oil leaks (Turbor-Charger damage, worn piston rings, or scored cylinder liners). Concentration of ash, with a dark wet surrounding ring and uneven soot streaks across the face of the inlet side of the DPF are caused by excessive oil in the exhaust. Soot stains on the outlet side of the DPF are caused by fuel or engine oil in the exhaust.
Cracks across the face of the DPF are caused by excessive fuel or oil in the exhaust gas, creating high temperatures.



- Single Engine Controller
- Turbo CAN Communications
- EGR Valve CAN Communications
- CMP Failure Limp Mode
- Foam Protected Harness
- Inlet Air Heater



#### **System Features**

- The 2007 engine has several major changes to the electronic system. The MaxxForce® DT, 9, and 10 engines all feature a single box controller to reduce wiring complexity. The ECM receives inputs from the engine and chassis side sensors and controls the injectors and engine mounted actuators.
- The 2007 engine's wiring harness is encased in a protective foam cover.
- The 2007 engines use the CAN link to control both the turbocharger and the EGR valve.
- The 2007 engines feature a limp home mode for the cam position sensor. If the sensor fails, the engine will still start but the crank time will be longer.
- The inlet air heater 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 turns off, the engine can be started.

#### Single Engine Controller

 The MaxxForce® DT, 9, and 10 engines all use a single box electronic control system.
 The ECM monitors and controls the engine to ensure maximum performance while meeting emissions standards. The ECM is mounted on the left rear of the crankcase.

The ECM performs the following functions:

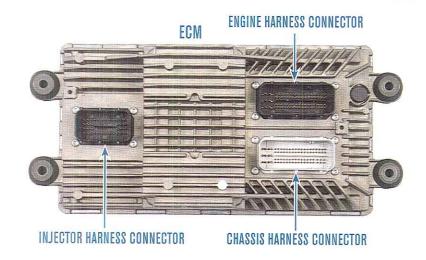
- Provides Reference Voltage (VREF)
- Condition input signals
- Processes and stores control strategies
- Controls the AFT system

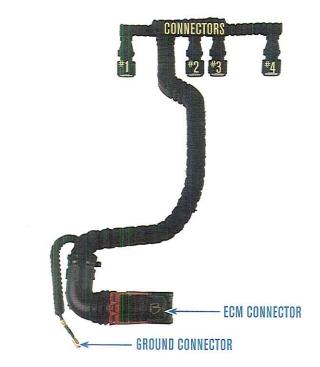
#### **Foam Protected Harness**

- The engine wiring is now contained within a molded form fitted flexible foam cover. The robust foam construction helps resist chaffing of the wires while maintaining clearance from moving components. This harness is not serviceable. To avoid damage, the foam sections should not be bent more than 90 degrees.
- The engine harness is divided into two sections. One section connects the ECM to all of the engine mounted sensors. The other section connects the ECM to the injectors.

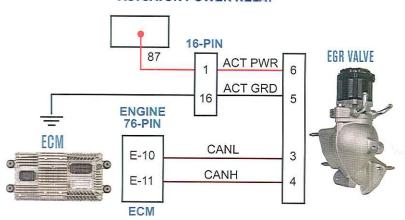
#### EGR Valve

- The EGR valve is installed in the EGR manifold. The valve has four major components:
   a dual poppet valve assembly, a DC motor,
   controller circuits, and three Hall-effect position sensors.
- The EGR valve has a 6-way connector populated with 4 pins. The actuator receives power at Pin 6 from the actuator power relay. Ground is supplied at Pin 5. The ECM controls the EGR actuator through the CAN circuits; CANH to EGR Pin 4, and CANL to EGR Pin 3. The electronics within the EGR valve communicates failures back to the ECM through the CAN network.





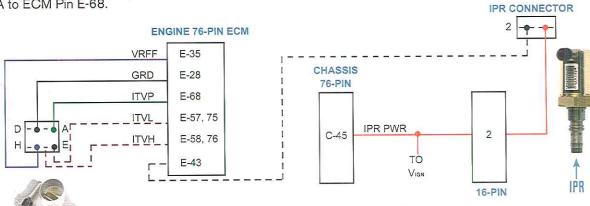
#### **ACTUATOR POWER RELAY**

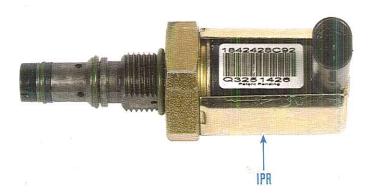


#### **Inlet Throttle Valve**

- The inlet throttle assembly is mounted on the EGR and inlet air mixer duct. The throttle is a variable position actuator used to restrict intake air flow during Aftertreatment regeneration.
- The throttle changes position in response to an H-Bridge circuit in the ECM. The throttle has an 8-way connector populated with 5 pins. Three pins for the position sensor and two pins for control. To position the DC motor, the ECM connects one of the two control pins, F or E, to voltage and the other ground. To rotate the motor in the opposite direction, the ground pin is connected to voltage and the positive pin is connected to ground.
- The inlet throttle valve position sensor is a potentiometer sensor within the ITV. The ECM supplies a 5 voltage reference at Pin G from ECM Pin E-35. The sensor is grounded at Pin C from ECM Pin E-28. The sensor returns a variable voltage signal from Pin A to ECM Pin E-68.





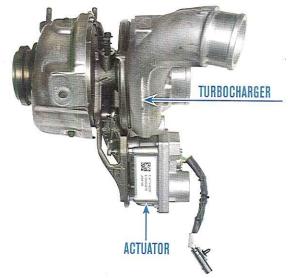


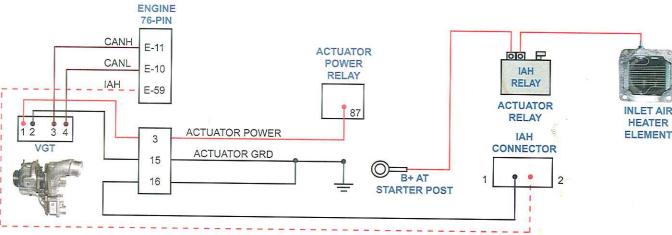
#### IPR

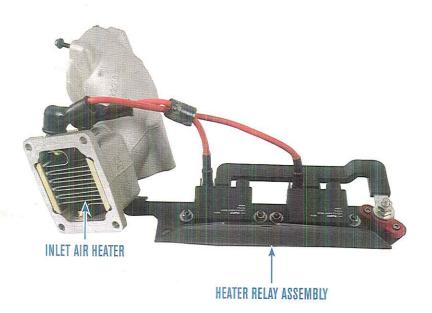
· The IPR valve regulates oil pressure in the high-pressure injection control system. The ECM uses the ICP sensor to monitor system pressure and then adjusts the current flow to the IPR valve in order to match the current engine requirements. Power to the IPR is fused within the vehicle. The power circuit goes to pin 1 of the IPR and to pin C-45 of the ECM. Pin 2 of the IPR is the control side. The ECM provides a ground to the control side through pin E-43. When a higher injection control pressure is required, the ECM increases the on-time of the circuit which allows higher current flow through the IPR coil. When a lower injection control pressure is required, the ECM decreases the on-time of the circuit which allows lower current flow through the IPR coil.

#### **Turbocharger Actuator**

The turbocharger actuator is used to allow the ECM to accurately position the vanes surrounding the turbine. The actuator has a 4-way connector. The actuator receives power at Pin 1 from the actuator power relay. Ground for the actuator is supplied at Pin 2. The ECM controls the actuator through the private CAN circuits; CANH to Pin 3, and CANL, to Pin 4. The electronics within the actuator communicates failures back to the ECM through the CAN network. At the start of production, the actuator and linkage were not serviceable. Later in production, the linkage was modified to allow the actuator and linkage to be replaced as a unit.

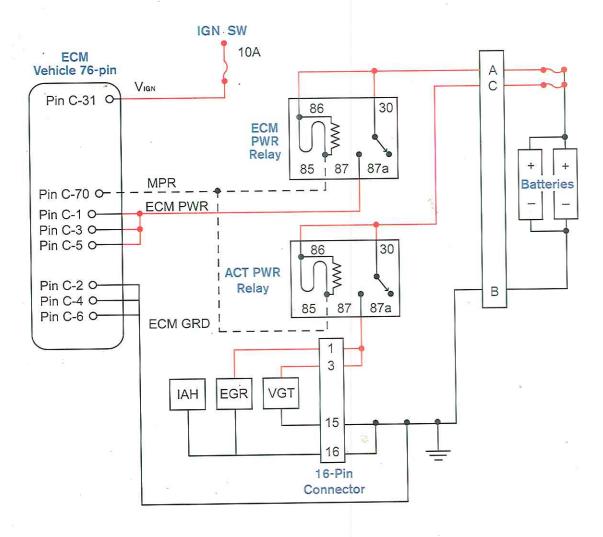






#### Inlet Air Heater

- The IAH (Inlet Air Heater) system warms the incoming air supply to aid cold engine starting. The system will initially illuminate the WAIT TO START lamp located on the instrument panel. When the lamp turns off, the engine can be started. There are two heater grids mounted within the inlet elbow on early models, and one grid on later models. Each grid has one external electrical connector.
- Both IAH relay's mount on a bracket bolted to the rear of the intake manifold. Each relay supplies current to one grid. The relay is controlled by a high side driver in the ECM that switches voltage to the control side of the relay. The relay delivers battery voltage to the heater elements for a set time, depending on engine coolant temperature and altitude. The ground circuit for the grids is supplied through the inlet elbow.

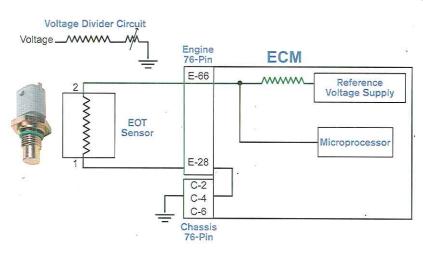


#### **ECM** Relay

- The ECM requires battery power during engine operation to power the electronic control system. In addition, the ECM performs maintenance after the ignition switch is turned to the Off position. To do this, the ECM must control its own power supply.
- Battery voltage is always available at pin 86 of the ECM relay. Current goes through the relay coil to pin 85 of the relay and then to pin C-70 of the ECM. Internally the circuit is switched open. When the ECM receives the VIGN signal at pin C-31, the ECM internally switches the circuit closed to a ground connection. This provides a ground to pin C-70. The relay coil now has a current flowing through it and the relay switches.
- When the ignition switch is turned to the off position, the engine is shut down, but the ECM stays powered up. The ECM performs internal maintenance, and then disables the ECM relay by removing the ground from Pin C-70.

#### **Actuator Power Relay**

 The actuator power relay supplies the engine mounted actuators with switched battery voltage. When the ECM receives the VIGN signal from the ignition switch, the ECM will provide a ground to the actuator relay coil through the MPR circuit. The ground enables the relay to power-up. When switched, the relay provides current to the control portion of inlet air heater relay, the ERG valve, and the actuator on the variable geometry turbocharger.

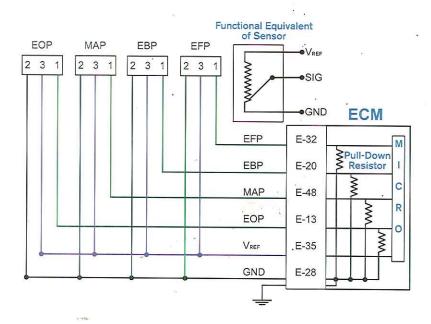


#### Variable Capacitance Pressure Sensors

- Variable capacitance sensors measure pressure. The pressure measured is applied to a ceramic material that bends proportional to the pressure being measured. The pressure forces the ceramic material closer to a thin metal disk. 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 disk. The thicker the ceramic disk the more pressure the sensor can measure. The variable capacitance sensors are used in pull-down circuits which results in an out-of-range low DTC when the signal wire is open and the ECM detects the zero voltage. Variable capacitance sensors include the following:
  - Exhaust Gas Differential Pressure sensor
  - Engine Fuel Pressure sensor
  - Engine Oil Pressure sensor
  - Exhaust Back Pressure sensor
  - Manifold Absolute Pressure sensor

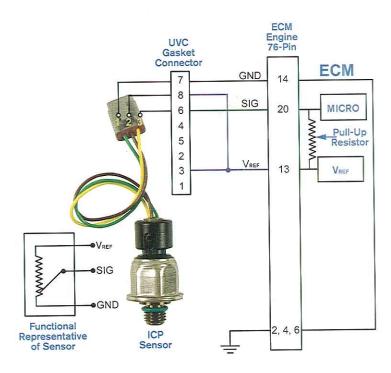
#### Temperature Sensor

- 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. Thermistor type sensors include the following:
  - Aftertreatment temperature sensors
  - Engine Coolant Temperature sensor
  - Engine Oil Temperature sensor
  - Inlet Air Temperature sensor
- Manifold Air Temperature sensor



#### Micro-strain Gauge Pressure Sensors

- · Micro strain gauge sensors measures pressure. Pressure to be measured exerts force on a small container within the sensor. The container stretches as pressure is applied and contracts as pressure is released. A micro strain gauge bonded to the surface of the container changes resistance as the container changes shape. Sensor electronics measure the resistance changes and convert the changes to a voltage signal. The sensor is connected to the ECM by the ground, the signal, and the VREF wires. The sensor is powered by VREF received from the ECM and is grounded through the ECM to a common sensor ground. The ECM compares the voltage with pre-programmed values to determine pressure.
- Micro strain gauge type sensors are used to measure BCP (Brake Control Pressure) and ICP (Injection Control Pressure). The ICP and BCP sensors are used in pull-up circuits which results in an out-of-range high DTC when the signal wire is open and the ECM detects the five volt value. The ICP and BCP are micro-strain gauge pressure sensors.





#### **Magnetic Pickup Sensor**

Magnetic pickup sensors contains permanent magnet that is surrounded by a coil of wire. The sensor generates a small AC voltage when a metal trigger moves through the magnetic field. Magnetic pickup sensors include the CKP, CMP, and VSS sensors

#### CKP

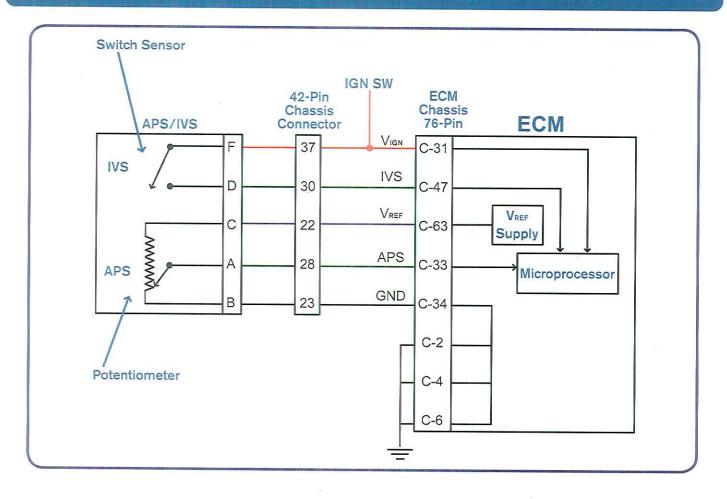
• The CKP (Crankshaft Position) sensor provides the ECM with a signal that indicates crankshaft speed and position. As the crankshaft turns, the CKP sensor detects a 60 tooth timing disk on the crankshaft. Teeth 59 and 60 are missing. By comparing the CKP signal with the CMP signal, the ECM calculates engine rpm and timing requirements. The CKP sensor is installed in the top left side of the flywheel housing. The CKP trigger wheel is pressed on to crankshaft before the flywheel is installed.

#### CMP

The CMP (Camshaft Position) sensor provides the ECM with a signal that indicates camshaft position. As the cam rotates, the sensor identifies the position of the cam by locating a peg in the face of the cam gear. The CMP sensor is installed in the front cover.

#### VSS

 The VSS (Vehicle Speed) sensor provides the ECM with transmission tail shaft speed by sensing the rotation of a 16 tooth gear on the rear of the transmission. The detected AC signal allows the ECM to count the trigger wheel pulses. Pulse count is used with tire size and axle ratio to calculate vehicle speed.



#### **Switch Sensors**

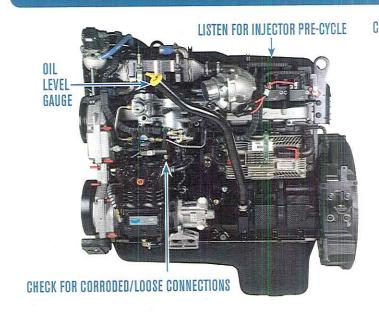
- Switch sensors indicate position, level, or status. They operate open or closed, regulating the flow of current. A switch sensor can be a voltage input switch or a grounding switch. A voltage input switch supplies the ECM with a voltage when it is closed. A grounding switch grounds the circuit when closed, causing a zero voltage signal. Grounding switches are usually installed in series with a current limiting resistor.
- The IVS sensor is a switch type sensor. The ignition switch supplies 12 volts to pin F of the switch. When the switch is closed, the ECM senses 12v on Pin C-47. If the switch is open, the ECM senses 0v on C-47.

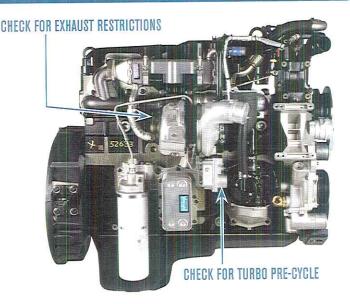
- · Switches include the following:
  - Driveline Disengagement Switch (DDS)
  - Engine Coolant Level (ECL)
  - Idle Validation Switch (IVS)
  - Water-In-Fuel (WIF)

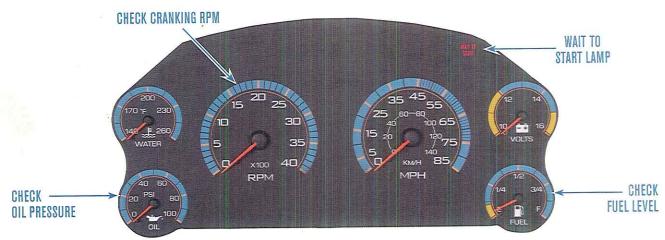
#### APS/IVS

The APS (Accelerator position Sensor) is a potentiometer. The potentiometer is a variable voltage divider that senses the position of a mechanical component. A reference voltage is applied to one end of the potentiometer. Mechanical rotary or linear motion moves a wiper along the resistance material, changing voltage at each point along the material. The signal voltage is proportional to the amount of mechanical movement.

 The APS provides the ECM with a analog voltage signal indicating the operator's demand for power. The APS is installed in the cab on the accelerator pedal. The IVS is a redundant sensor that verifies when the APS is in the idle position.







# 1. Initial Key-On (Is the ECM Powered Up?)

Turn the ignition switch to ON; check or listen for the following:

- · Injector pre-cycle
- · Turbocharger pre-cycle
- · Water-in-Fuel lamp
- Wait-to-Start lamp

If the turbocharger and injector pre-cycle, and the Wait-to-Start lamp or the Water-in-Fuel lamp comes on after the dash cycle, the ECM is powered up.

If injector and turbo pre-cycle do not occur, the ECM may not be powered up. If the EST is not communicating with the ECM, check for power at the fuses and ECM relay.

# 2. Engine Cranking (Is the cranking RPM correct?)

Crank the engine for 20 seconds; use the instrument panel gauges to check for the following:

- · Cranking speed
- · Lube oil pressure

The cranking speed must be at least 120 RPM. If engine speed is below specification, check the batteries, battery cables, and the starter motor.

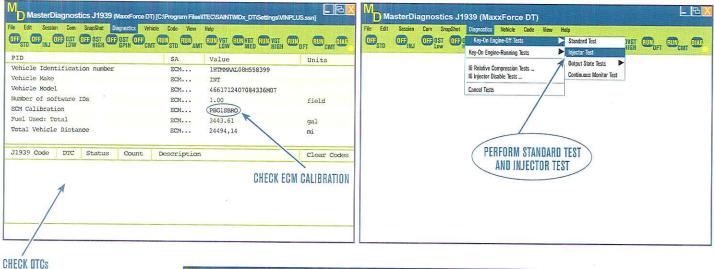
If the oil pressure does not build while cranking, the engine may not be feeding the high-pressure oil system. Check the oil level and diagnose the lube oil system if required.

# 3. Visual Inspection (Are the fluid levels correct?)

Access the engine and perform a visual inspection of the following:

- · Engine oil level
- · Surge tank level
- CAC system
- · Engine harness
- · Exhaust system

If the oil level is low, inspect for leaks. If level is above specification, inspect for dilution. If the coolant level is low, inspect for leaks, coolant in the oil, and coolant in the exhaust. Inspect the electrical system for poor or loose connections. Inspect the CAC system for leaks and inspect the exhaust system for damage that could cause a restriction.



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# 4. Calibration (Is the ECM calibration correct?)

Use the EST to check for the following:

- ECM calibration
- Diagnostic Trouble Codes (DTCs)

Verify that the engine has the correct calibration. Check for DTCs. With the ignition switch on, active indicates a DTC for a condition currently in the system. Inactive indicates a DTC for a condition during a previous key cycle. Correct any active DTC that will affect the ability of the engine to start.

#### EST Data List (Are the engine systems working correctly?)

Use the EST to check the following while cranking the engine for 15-20 seconds:

- · Battery volts (VBAT)
- · Engine speed (RPM)
- Injection control pressure (ICP)
- Fuel delivery pressure (EFP)

If VBAT readings are not in specification, check the ECM power relay and the ECM power and grounds. If RPM readings are not in specification, check vehicle starter system. If ICP readings are not in specification, perform the Low ICP Diagnostics.

If EFP readings are not in specification, perform the Low Fuel Pressure Diagnostics test.

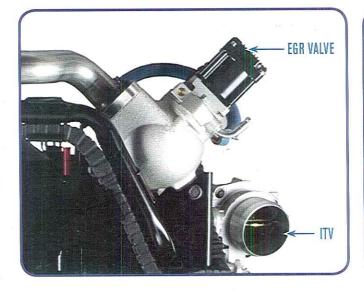
# 6. KOEO Tests (are the electrical circuits free of faults?)

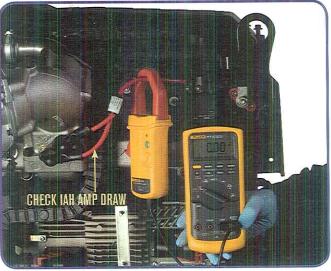
Use the EST to perform the following tests:

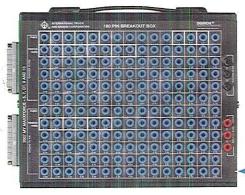
- KOEO Standard Test
- KOEO Injector Test

After the Standard test is completed, check for DTCs related to electrical components.

During the KOEO Injector Test the ECM tests the electrical portion of the injector by energizing them in order of cylinder position. Listen again for injectors to pre-cycle, cycle in cylinder numbering order. Listen for the spool valves cycling and check for DTCs when the test is completed.







ECM PWR = C1, 3, 5 ECM GND = C2, 4, 6 Vign = C31

180 PIN BREAKOUT BOX

# 7. EGR Valve and ITV Operation (Is the ITV open and EGR valve closed?)

Use the EST to check to perform the following tests:

- Output State High Test
- · Output State Low Test.

Use the EST to read each valves position during both tests. Both valves should open and close during the tests. During cranking the EGR valve should be closed and the ITV should be open. If readings are not in specification correct the issue before continuing.

#### **Special Test Procedures**

The following tests should only be completed if a prior test leads you to believe there is a problem in the system.

# 8. ECM Voltage (Is there sufficient voltage at the ECM?)

Use the Relay Breakout Harness and/ or the ECM Relay Breakout harness to measure the voltage available at the ECM. Install the relay breakout harness between the relay and the power distribution box. If the relay does not function, correct that issue and retest.

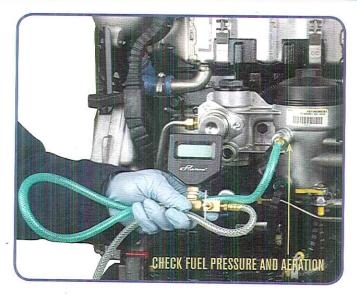
If the relay does function, Install ECM breakout box between the ECM and the chassis harness. Measure the voltage to ECM PWR pins while cranking for 20 seconds.

#### 9. Inlet Air Heater (IAH) System

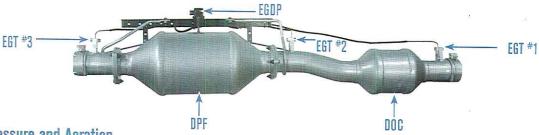
Use the EST, DVOM, and an Amp Clamp to perform the following tests:

- IAH current draw
- IAH Voltage

Install the Amp Clamp around one IAH element feed wires. Turn the ignition switch to ON. Use the EST to perform the Glow Plug/Inlet Air Heater test. Measure the amperage at the wires and compare to the specifications. If the amp draw meets the specs, the system is working correctly. If the amp draw is low, measure the voltage at the terminals on the EGR valve elbow. If battery voltage is available at the terminal and the amperage is low, the heater element is defective.







#### 10. Fuel Pressure and Aeration

Use the fuel pressure gauge and fuel pressure test kit to measure the following: Filtered Fuel Pressure and Non-filtered fuel pressure; Compare filtered side and non-filtered side pressure to determine if the filter is restricted. Replace the filter is the pressure drop across the filter is excessive.

Inlet restriction; Measure the fuel inlet restriction. If inlet restriction is high check the system for a restriction between the strainer and the fuel tank. Aeration; If the fuel is aerated, check for a leak on the suction side of the system. Pump output; Check the pump output by deadheading the pump. If the pressure is good with the pump deadheaded, install a new pressure regulator kit. If the pressure is still low, replace the pump.

#### 11. Aftertreatment System

Use the EST to measure the following:

- EGT sensor values
- EGDP sensor value

Record the AFT sensor values. Verify temperature sensors EGT1, EGT2, and EGT3 (Exhaust Gas Temperature) are operating at similar values and that the EGDP (Exhaust Gas Differential Pressure) sensor is near zero. If results are satisfactory, run the On-Board Filter Cleanliness Test.

#### 12. ICP System Test

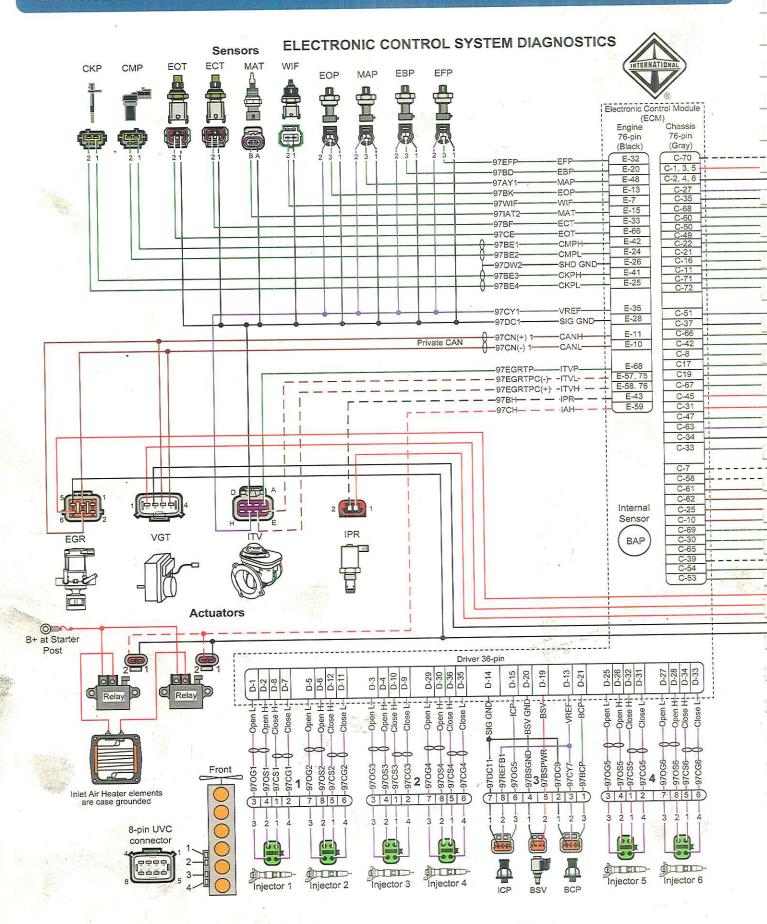
Use the EST, IPR breakout harness, ICP test adapter, pressure sensor breakout harness, and the IPR block-off tool to perform the following tests.

- Reservoir level
- IPR Control
- Pump Deadhead
- IPR Block-off
- Under valve cover Leak
- ICP Sensor

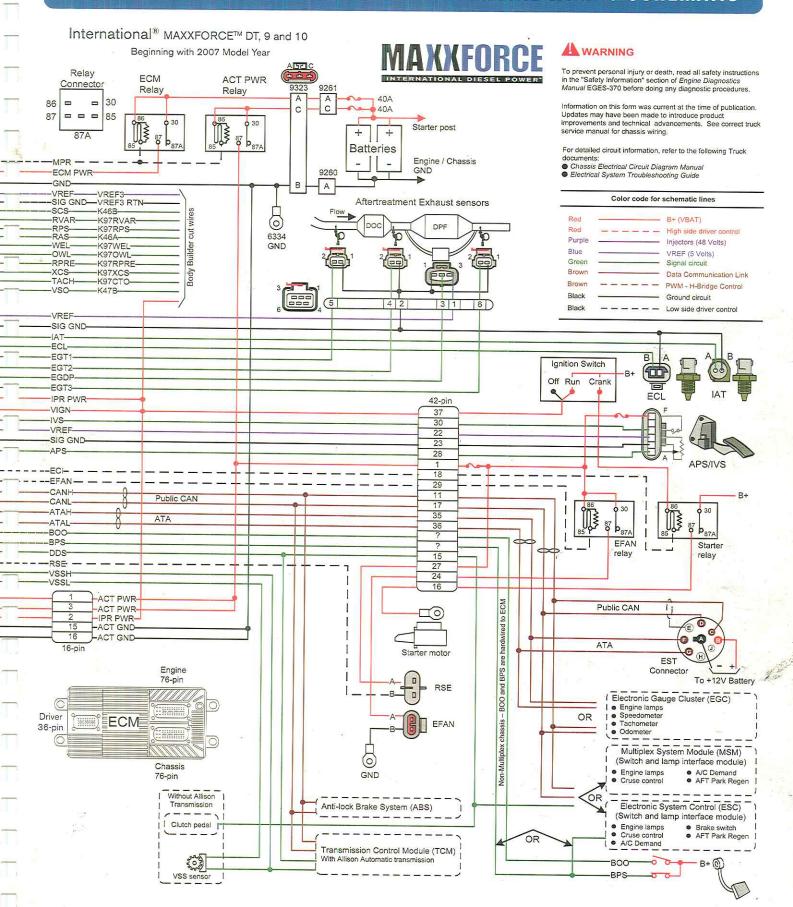
If the engine has good lube oil pressure the reservoir should be full. The EOT sensor can be removed to verify the oil level. Remove the IPR harness connector. Inspect for connection problems. Use the IPR breakout harness to apply battery voltage and ground to the IPR. If the engine starts, check the IPR circuits.

Use the ICP test adapter and the pressure sensor breakout harness to check the cranking pressure with the pump deadheaded. If the pressure is greater than 870 psi, perform the Under Valve Cover Leak test. If the pressure is still low, remove the IPR and install the IPR block-off tool. If the pressure is less than 870 psi, the pump is defective. If the pressure is greater than 870 psi, the IPR is defective. Under Valve Cover Leak Test: With all the system parts reinstalled, remove the valve cover and crank the engine over. Watch for oil leaking from the rail, rail components, and the injectors. If there are no leaks under the valve cover, disconnect the ICP sensor wiring and attempt to start the engine. If the engine starts, the sensor is at fault.

# ENGINE WIRING SCHEMATIC



# **ENGINE WIRING SCHEMATIC**



DTC	SPN	FMI	MD DESCRIPTION	TEST SECTION	POSSIBLE CAUSES
1112	168	3	B+ Out of Range HIGH	ECM PWR	EIM PWR above 17 volts, Charging system fault, Low batteries
1113	168	4	B+ Out of Range LOW	ECM PWR	ECM PWR below 7.5 volts, Charging system fault, Low batteries
1114	110	4	ECT signal Out of Range LOW	ECT	ECT 0 volts, short to GND
1115	110	3	ECT signal Out of Range HIGH	ECT	ECT 4.7 Volts, Open circuit or short to PWR
1121	102	3	MAP signal Out of Range HIGH	MAP	MAP above 4.9 Volts, Open circuit or short to PWR
1122	102	4	MAP signal Out of Range LOW	MAP	MAP below 0.5 Volts, Short to GND
1124	164	4	ICP signal Out of Range LOW	ICP	ICP signal short to GND, or failed sensor
1125	164	3	ICP signal Out of Range HIGH	ICP	ICP signal OPEN circuit, short to PWR, or failed sensor
1126	7139	4	BCP signal Out of Range LOW	BCP	BCP signal short to GND, or failed sensor
1127	7139	3	BCP signal Out of Range HIGH	BCP	BCP signal OPEN circuit, short to PWR, or failed sensor
1131	91	4	APS signal Out of Range LOW	APS/IVS	APS 0 Volts, Open circuit or short to GND
1132	91	3	APS signal Out of Range HIGH	APS/IVS	APS 5 Volts, short to PWR
1133	91	2	APS In-Range fault	APS/IVS	APS signal constant while IVS has changed
1134	91	7	APS and IVS Disagree	APS/IVS	IVS signal constant while APS has changed
1135	558	11	IVS signal fault	APS/IVS	IVS circuit fault. Does not change state
1136	94	4	EFP signal Out of Range LOW	EFP	EFP 0 Volts, Open circuit or short to GND
1137	94	3	EFP signal Out of Range HIGH	EFP	EFP 5 Volts, Short to PWR
1141	84	4	VSS signal Out of Range LOW	Truck	VSS frequence below 0.25 Hz
1142	84	3	VSS signal Out of Range HIGH	Truck	VSS frequence above 4365 Hz
1143	8021	2	CMP signal incorrect for CKP sync	CMP	CMP circuit fault, or failed sensor
1144	8021	8	CKP signal noise detected	CKP	CKP circuit fault, or failed sensor
1146	8064	12	CKP Signal Inactive	CKP	CKP circuit fault, or failed sensor
1147	8064	2	CKP incorrect signal signature	CKP.	CKP circuit fault, or failed sensor
1151	108	3	BAP signal Out of Range HIGH	ECM Self	BAP voltage above max, Failed ECM
1152	108	4	BAP signal Out of Range LOW	ECM Self	BAP voltage below min, Failed ECM
1154	171	4	IAT signal Out of Range LOW	IAT	IAT below 0.2 Volts, Short to GND
1155	171	3	IAT signal Out of Range HIGH	IAT	IAT above 4.62 volts, open circuit or short to PWR
1156	102	0	MAP In-Range HIGH  -MAP above BARO at start	MAP	MAP 4.4 psi above BARO at KOEO
1157	102	1	MAP In-Range LOW  -MAP below BARO at start	MAP	MAP 4.4 psi below BARO at KOEO
1161	105	4	MAT signal Out of Range LOW	MAT	MAT 0 Volts, Short to GND
1162	0.000000	3	MAT signal Out of Range HIGH	MAT	MAT above 4.84 Volts, Open circuit or short to PWR
1178	7316	0	VGT actuator temp above high limit	VGT	VGT internal failure, check circuits and replace valve
1211	100	4	EOP signal Out of Range LOW	EOP	EOP 0 Volts, Open circuit, or short to GNE

DTC	SPN	FMI	MD DESCRIPTION	TEST SECTION	POSSIBLE CAUSES
1212	100	3	EOP signal Out of Range HIGH	EOP	EOP above 4.9 Volts, short to PWR
1213	8029	4	Remote Throttle signal Out of Range LOW	Truck	Remote Throttle signal short to GND
1214	8029	3	Remote Throttle signal Out of Range HIGH	Truck	Remote Throttle signal OPEN or short to PWR
1222	597	2	Brake Switch circuit fault	BOO/BPS	Brake switch circuit fault or failed switch
1236	111	2	ECL In-Range circuit fault		ECL switch circuit fault or failed switch
1253	97	3	WIF signal Out of Range LOW	WIF	WIF signal short to GND
1254	97	4	WIF signal Out of Range HIGH	WIF	WIF signal short to PWR
1255	97	5	WIF signal open/circuit fault	WIF	WIF signal OPEN, or Short to PWR or GND, or failed switch
1276	8366	6	IPR short to B+, over temperature	IPR	IPR control circuit short to PWR, or failed IPR
1277	8366	5	IPR short circuit	IPR	IPR control circuit short to GND, or failed IPR
1287	3464	1	ITVL OCC self-test failed/ITV position Control deviation below MIN threshold	ITV	ITVL Circuit Open or shorted to PWR or GND -Failed ITV actuator
1288	3464	0	ITVH OCC self-test failed/ITV position control deviation above MAX threshold	ITV	ITVL Circuit Open or shorted to PWR or GND –Failed ITV actuator
1292	7318	2	ITVP In-Range fault	ITV	ITV Position doesn't agree with the commanded position -ITV circuit fault, or failed valve
1293	7318	3	ITVP signal out of range HIGH	ITV	ITVP signal circuit short to PWR -Failed ITVP sensor
1294	7318	4	ITVP signal out of range LOW	ITV	ITVP signal circuit Open or Short to GND  -VREF circuit Open  -Failed ITVP sensor
1298	51	2	ITV operation fault-under Volt, over Amp, over Temp/ITV H-bridge Electrical Check	ITV	ITV circuit fault, Open, Short, over temp or failed ITV
1299	175	10	EOT In-Range fault	EOT	EOT biased circuit or sensor
1311	175	4	EOT signal Out of Range LOW	EOT	EOT 0 Volts, Short to GND
1312	175	3	EOT signal Out of Range HIGH	EOT	EOT 4.84 Volts, Open circuit or short to PWR
1328	164	2	FRP signal constant	FRP	-FRP signal too stable, should be fluctuating -FRP circuit fault, or Failed sensor
1328	164	2	ICP signal constant	ICP SYS	-ICP signal too stable, should be fluctuating -ICP circuit fault, or Failed sensor
1362	412	0	EGR valve internal high circuit failure	EGR	Failed EGR valve
1363	412	1	EGR valve internal low circuit failure	EGR	Failed EGR valve
1396	7137	12	EGRV Initialization Fault	EGR	EGR circuit fault, or failed EGR valve
1397	7137	4	EGR position In-Range fault	EGR	EGR circuit fault, or failed EGR valve
1398	8327	7	EGR unable to achieve desired position	EGR	-EGR closed-loop error deviation is not within specified limits -EGRP sensor/circuit fault
1729	3251	4	EGDP signal out of range LOW	EGDP	EGDP 0 volts, Open circuit or short to GND

DTC	SPN	FMI	MD DESCRIPTION	TEST SECTION	POSSIBLE CAUSES
1731	3251	3	EGDP signal out of range HIGH	EGDP	EGDP above 4.75 Volts, short to PWR
1737	3241	4	EGT1 signal out of range LOW	EGT1	EGT1 signal below 0.5V (Maxxforce 11 & 13 below 0.1 Volts) check for short to GND
1738	3241	3	EGT1 signal out of range HIGH	EGT1	EGT1 signal above 2.3 V (Maxxforce 11 & 13 above 5.1 Volts) check for Open or short to PWR
1741	3242	4	EGT2 signal out of range LOW	EGT2	EGT2 signal below 0.5V (Maxxforce 11 & 13 below 0.1 Volts) check for short to GND
1742	3242	3	EGT2 signal out of range HIGH	EGT2	EGT2 signal above 2.3 V (Maxxforce 11 & 13 above 5.1 Volts) check for Open or short to PWR
1744	3245	4	EGT3 signal out of range LOW	EGT3	EGT3 signal below 0.5V (Maxxforce 11 & 13 below 0.1 Volts) check for short to GND
1745	3245	3	EGT3 signal out of range HIGH	EGT3	EGT3 signal above 2.3 V (Maxxforce 11 & 13 above 5.1 Volts) check for Open or short to PWR
2159	8365	7	Brake applied while APS applied	APS/IVS	Is set when APS and brakes are applied when vehicle speed is above 10 mph and engine speed is above 1500 rpm
2174	8321	2	VGT communication fault	VGT	VGT circuit fault, or failed VGT valve
2175	8321	7	VGT performance fault	VGT	VGT circuit fault, or failed VGT valve
2176	8321	0	VGT commanded position over a threshold	VGT	VGT circuit fault, or failed VGT valve
2177	8321	1	VGT commanded position below a threshold	VGT	VGT circuit fault, or failed VGT valve
2179	97	2	Water in Fuel Detected	WIF	Water detected in primary fuel filter housing
2232	8331	7	Resume normal speed control due to momentary CAN loss	CAN Public	CAN communication fault between ECM and TCM
2242	1442	2	ICP adaptation In-Range fault	ICP SYS	Injection control pressure command 10% higher then last learned command under same conditions -Possible ICP system leak
2313	100	1	EOP below Warning Level	EWPS	EOP below threshold -dealer programmable option
2314	100	7	EOP below Critical Level	EWPS	EOP below threshold -dealer programmable option
2315	190	0	Engine Speed above Warning Level	EWPS	Engine over speed I6 -3200 rpm, V8 -3700 rpm, V6 -3600 rpm
2319	518	2	Torque limited to control engine overheat	EWPS	Engine overheating, Engine torque limited
2321	110	0	ECT above Warning Level	EWPS	EOT above 70° C, or above 75° C during Retarder control
2322	110	7	ECT above Critical Level	EWPS	EOT above threshold -dealer programmable option
2323	111	1	ECL below Warning/Critical Level	EWPS	Low Coolant level -programmable dealer option

DTC	SPN	FMI	MD DESCRIPTION	TEST SECTION	POSSIBLE CAUSES
2324	593	14	Engine stopped by IST	IST	Engine was shutdown by the Idle Shutdown Timer. (This is an alert, not a fault)
2327	164	10	ICP Abnormal Rate of Change	ICP SYS	Fault sets if ICP changes by more than 30 Mpa (4400 psi) in 0.1 second –FRP circuit fault, or failed sensor
2332	164	13	ICP above KOEO Spec	ICP	2 MPa after 0.2 sec from key on ICP biased sensor or circuit
2335	164	1	ICP Unable to Build During Engine Cranking	ICP SYS	ICP below 3.5 MPa during engine crank -Low oil supply to high pressure system -IPR circuit fault, or failed valve -High pressure oil pump failure
2351	7129	1	EBP below desired level	AMS	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	AMS	EBP above 10 psi Exhaust restriction, Plugged DPF, or Biased EBP circuit or sensor. (or MaxxForce 11 & 13 Retarder Control failure) Sticky Turbocharger Vanes
2368	8146	7	EGR valve communication fault	EGR	EGR circuit fault, or failed EGR valve
2369	1378	2	Engine Oil Service Required	Service	Engine oil service reminder -dealer programmable option
2371	94	0	Fuel Pressure above normal	EFP	Engine fuel pressure above 145 psi with engine running
2372	94	1	Fuel Pressure below normal	EFP	Engine fuel pressure below 43 psi with engine running
2388	2659	0	EGR flow excessive –possible leak to atmosphere	AMS	-EBP biased sensor or circuit -EGR valve sticking open -Sticky Turbocharger Vanes -MAP, EGRP, EBP biased sensor or circuit
2389	2659	1	EGR flow insufficient -possible plugged system	AMS	-EBP biased sensor or circuit -EGR valve sticking closed -Sticky Turbocharger Vanes -MAP, EGRP, EBP biased sensor or circuit
2391	2791	11	EGR valve internal circuit failure	EGR	EGR control circuit fault, or failed EGR
2392	7138	6	EGR duty cycle above limit	EGR	EGR control circuit fault, or failed EGR
2393	7137	2	EGR position sensor fault	EGR	EGR circuit fault, or failed EGR
2394	8146	2	EGR valve not receiving ECM CAN messages	EGR	EGR circuit fault, or failed EGR
2395	7317	3	EGRH OCC self-test failed	EGR	EGR control circuit fault, or failed EGR
2396	7317	4	EGRL OCC self-test failed	EGR	EGR control circuit fault, or failed EGR
2544	8329	7	ECM unable to send CAN messages	CAN Public	Public CAN circuit fault, or ECM fault
2545	8330	7	ECM not receiving body controller CAN messages	CAN Public	Public CAN circuit fault, or body control module fault

DTC	SPN	FMI	MD DESCRIPTION	TEST SECTION	POSSIBLE CAUSES
2546	7121	1	BCP below desired	BCP	BCP unable to reach within 650 psi of desired within 3 seconds -BCP or BSV circuit fault or failed BSV valve
2547	7121	0	BCP above desired	ВСР	BCP unable to reach within 650 psi of desired within 3 seconds –BCP or BSV circuit fault or failed BSV valve
2549	8321	12	ECM not receiving VGT CAN messages	VGT	VGT control circuit fault, or failed VGT
2673	3242	10	EGT2 not warming along with engine	EGT2	EGT2 sensor or circuit fault
2674	3242	2	EGT2 reading off compared to EGT1 and EGT3	EGT2	Biased EGT2 sensor or circuit
2675	3241	2	EGT1 temp not increasing with engine temp	EGT1	Biased EGT1 sensor or circuit
2676	3241	1	EGT1 reading off compared to EGT2 and EGT3	EGT3	Biased EGT1 sensor or circuit
2677	3245	2	EGT3 not warming along with engine	EGT3	EGT3 sensor or circuit fault
2678	3245	1	EGT3 reading off compared to EGT1 and EGT2	EGT3	Biased EGT3 sensor or circuit
2681	3242	1	EGT2 reading off compared to EGT1 and EGT3	EGT2	Biased EGT2 sensor or circuit
2687	8302	1	DPF, low flow resistance	AFT SYS	-Exhaust leak before DPF -Leaking or reversted EGDP sensor hoses -Failed DPF (open flow) -Biased EGDP sensor or circuit
2688	8302	0	DPF over temperature -possible filter damage	AFT SYS	-Restricted DPF -Restricted Exhaust -Engine over fueling -Biased EGT2 sensor or circuit
2699	3251	1	EGDP below desired level	EGDP	-EGDP sensor tube(s) retricted, open or crossed -Baised EGDP sensor or circuit -Damaged or missing DPF
2732	3251	2	EGDP stuck in range fault	EGDP	-EGDP sensor tube(s) restricted or open -Biased EGDP sensor or circuit
2733	3251	10	EGDP mismatch between key-on/off	EGDP	-EGDP sensor tube(s) restricted or open -Biased EGDP sensor or circuit
2782	8317	13	DPF Servicing Required	AFT SYS	Level 1 soot loading at 80%, DPF Regen required.
2783	8318	13	DPF load: above warning level	AFT SYS	Level 2 soot loading at 100%, DPF Regen required
2784	8319	13	DPF load: above critical level 1 -engine de-rate	AFT SYS	Critical level 1 soot loading over 100%, DPF Regen required
2785	8320	13	DPF load: above critical level 2 -further engine de-rate	AFT SYS	Critical level 2 soot loading over 100%, engine shut down enable, Replace DPF

DTC	SPN	FMI	MD DESCRIPTION	TEST SECTION	POSSIBLE CAUSES
3333	8492	0	ICP above desired level	ICP SYS	ICP was above the desired pressure by 3%  -Biased ICP sensor or circuit  -Trapped air in system (If set after system was open)  -Incorrect oil level  -Aerated, or contamination in engine oil  -IPR circuit fault, or failed (sticking) valve
3334	8492	1	ICP below desired level	ICP SYS	ICP was below desired pressure by 3%  -Biased ICP sensor or circuit  -Incorrect oil level  -Aerated, or contamination in engine oil  -IPR circuit fault, or failed (sticking) valve  -High pressure oil pump failure
3338	7129	17	KOER STD -EBP unable to build during test	AMS	I6(466): 10 psi below desired V8: 6 psi below desired -Exhaust or Intake system leaks -Biased EBP circuit or sensor -Turbocharger vanes sticking V8: 400 hPa
3339	7129	15	KOER STD -EBP too high during test	AMS	I6(466): 4 psi above desired V8: 3 psi above desired -Restricted Exhaust system -Biased EBP circuit or sensor -Turbocharger vanes sticking V8: 200 hPa
3341	1209	4	EBP signal out of range LOW	EBP	EBP signal OPEN or short to GND, or failed sensor
3342	1209	3	EBP signal out of range HIGH	EBP	EBP signal short to PWR, or failed sensor
3345	7136	0	VGT control over duty	VGT	VGT circuit fault, or failed VGT valve
3346	1209	0	AMT -EBP unable to build during EGR test	AMS	I6(466): 17 psi below desired V8:9 psi below desired -Restricted Exhaust system -Biased EBP circuit or sensor -EBP sensor or tube plugged -Sticking or inoperative EGR valve
3347	7136	1	VGT control under duty	VGT	VGT circuit fault, or failed VGT valve
3348	1209	1	AMT -EBP too high during EGR test	AMS	I6(466):3 psi above desired V8: 2 psi above desired -Exhaust or intake system leaks -Biased EBP circuit or sensor -Inoperative EGR valve -Failed turbocharger
3373	164	15	ICP too high during test	ICP SYS	ICP sensor above 8 MPa during first part of KOER Standard test  -Biased ICP sensor or circuit  -Trapped air in system (If set after system was open)  -Incorrect oil level  -Aerated, or contamination in engine oil  -IPR circuit fault, or failed (sticking) valve

DTC	SPN	FMI	MD DESCRIPTION	TEST SECTION	POSSIBLE CAUSES
3374	164	17	ICP unable to build during test	ICP SYS	ICP sensor below 20 MPa during second part of KOER Standard test  -Biased ICP sensor or circuit  -Incorrect oil level  -Aerated, or contamination in engine oil  -IPR circuit fault, or failed (sticking) valve  -High pressure oil pump failure
3786	8326	2	DPF Test -test unsuccessful	AFT SYS	Test was aboarded due to an active DTC
4411	8001	6	Cyl 1 close coil: open circuit	INJ #1	Injector 1 close coil, open circuit fault or failed Injector
4412	8002	6	Cyl 2 close coil: open circuit	INJ #2	Injector 2 close coil, open circuit fault or failed Injector
4413	8003	6	Cyl 3 close coil: open circuit	INJ #3	Injector 3 close coil, open circuit fault or failed Injector
4414	8004	6	Cyl 4 close coil: open circuit	INJ #4	Injector 4 close coil, open circuit fault or failed Injector
4415	8005	6	Cyl 5 close coil: open circuit	INJ #5	Injector 5 close coil, open circuit fault or failed Injector
4416	8006	6	Cyl 6 close coil: open circuit	INJ #6	Injector 6 close coil, open circuit fault or failed Injector
4421	8001	5	Cyl 1 open coil: open circuit	INJ #1	Injector 1 open coil or circuit fault or failed Injector
4422	8002	5	Cyl 2 open coil: open circuit	INJ #2	Injector 2 open coil or circuit fault or failed Injector
4423	8003	5	Cyl 3 open coil: open circuit	INJ #3	Injector 3 open coil or circuit fault or failed Injector
4424	8004	5	Cyl 4 open coil: open circuit	INJ #4	Injector 4 open coil or circuit fault or failed Injector
4425	8005	5	Cyl 5 open coil: open circuit	INJ #5	Injector 5 open coil or circuit fault or failed Injector
4426	8006	5	Cyl 6 open coil: open circuit	INJ #6	Injector 6 open coil or circuit fault or failed Injector
4431	8001	4	Cyl 1 open coil: short circuit	INJ #1	Injector 1 open coil short circuit fault or failed Injector
4432	8002	4	Cyl 2 open coil: short circuit	INJ #2	Injector 2 open coil short circuit fault or failed Injector
4433	8003	4	Cyl 3 open coil: short circuit	INJ #3	Injector 3 open coil short circuit fault or failed Injector
4434	8004	4	Cyl 4 open coil: short circuit	INJ #4	Injector 4 open coil short circuit fault or failed Injector
4435	8005	4	Cyl 5 open coil: short circuit	INJ #5	Injector 5 open coil short circuit fault, or failed Injector
4436	8006	4	Cyl 6 open coil: short circuit	INJ #6	Injector 6 open coil short circuit fault, or failed Injector
4441	8001	3	Cyl 1 close coil: short circuit	INJ #1	Injector 1 close coil short circuit fault, or failed Injector

# DIAGNOSTIC TROUBLE CODES

DTC	SPN	FMI	MD DESCRIPTION	TEST SECTION	POSSIBLE CAUSES
4442	8002	3	Cyl 2 close coil: short circuit	INJ #2	Injector 2 close coil short circuit fault, or failed Injector
4443	8003	3	Cyl 3 close coil: short circuit	INJ #3	Injector 3 close coil short circuit fault, or failed Injector
4444	8004	3	Cyl 4 close coil: short circuit	INJ #4	Injector 4 close coil short circuit fault, or failed Injector
4445	8005	3	Cyl 5 close coil: short circuit	INJ #5	Injector 5 close coil short circuit fault, or failed Injector
4446	8006	3	Cyl 6 close coil: short circuit	INJ #6	Injector 6 close coil short circuit fault, or failed Injector
4515	8151	5	Bank A Injector open coil short	INJ	Bank A INJ open coil high side driver short to PWR or GND,
4516	8151	6	Bank A Injector close coil short	INJ	Bank A INJ close coil high side driver short to PWR or GND,
4521	8152	5	Bank B Injector open coil short	INJ	Bank B INJ open coil high side driver short to PWR or GND,
4522	8152	6	Bank B Injector close coil short	INJ	Bank B INJ close coil high side driver short to PWR or GND,
4551	8021	12	CMP signal inactive	CMP	CMP circuit fault, or failed sensor
4552	8022	2	CMP loss of sync	CMP	CMP circuit fault, or failed sensor
4553	8022	12	CKP signal inactive	CKP	CKP circuit OPEN, or failed sensor
4554	8022	7	CKP loss of sync	CKP	CKP circuit fault, or failed sensor
4555	8064	8	CKP signal noise detected	CKP	CKP circuit fault, or failed sensor
4556	8022	8	CKP period too short	CKP	CKP circuit fault, or failed sensor
4561	8001	1	Cyl 1 Cyl Balance below min limit	Cyl Bal	Cylinder 1 imbalance  -possible mechanical fault
4562	8002	1	Cyl 2 Cyl Balance below min limit	Cyl Bal	Cylinder 2 imbalance -possible mechanical fault
4563	8003	1	Cyl 3 Cyl Balance below min limit	Cyl Bal	Cylinder 3 imbalance -possible mechanical fault
4564	8004	1	Cyl 4 Cyl Balance below min limit	Cyl Bal	Cylinder 4 imbalance -possible mechanical fault
4565	8005	1	Cyl 5 Cyl Balance below min limit	Cyl Bal	Cylinder 5 imbalance -possible mechanical fault
4566	8006	1	Cyl 6 Cyl Balance below min limit	Cyl Bal	Cylinder 6 imbalance -possible mechanical fault
4571	8001	0	Cyl 1 Cyl Balance max limit exceeded	Cyl Bal	Cylinder 1 imbalance -possible mechanical fault
4572	8002	0	Cyl 2 Cyl Balance max limit exceeded	Cyl Bal	Cylinder 2 imbalance -possible mechanical fault
4573	8003	0	Cyl 3 Cyl Balance max limit exceeded	Cyl Bal	Cylinder 3 imbalance -possible mechanical fault
4574	8004	0	Cyl 4 Cyl Balance max limit exceeded	Cyl Bal	Cylinder 4 imbalance -possible mechanical fault
4575	8005	0	Cyl 5 Cyl Balance max limit exceeded	Cyl Bal	Cylinder 5 imbalance -possible mechanical fault

# DIAGNOSTIC TROUBLE CODES

DTC	SPN	FMI	MD DESCRIPTION	TEST SECTION	POSSIBLE CAUSES
4576	8006	0	Cyl 6 Cyl Balance max limit exceeded	Cyl Bal	Cylinder 6 imbalance -possible mechanical fault
4611	8021	13	CKP signature one tooth off	CKP	CKP circuit fault, or failed sensor
4612	8021	7	CMP to CKP incorrect reference	CKP CMP	CKP or CMP circuit fault, or failed sensor
5382	1136	0	ECM Error -over temperature	ECM Self	ECM internal fault
5618	8334	2	ECM Error -SPI-BUS error1	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5619	8334	12	ECM Error -SPI-BUS error2	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5627	8333	12	ECM Error -Checksum program	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5628	8333	2	ECM Error -Checksum Dataset	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5632	8254	12	EIM Error -RAM/CPU Self Test Fault	EIM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM (EIM for MaxxForce 11 & 13)
5633	8254	0	ECM Error -CPU load above maximum	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5634	8336	12	ECM Error -MQPS daisy chain failure	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5635	8337	12	ECM Error -OCT daisy chain failure	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5636	8338	12	ECM Error -QPS daisy chain failure	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5641	86	14	ECM Error  -CC monitoring	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5642	94	14	ECM Error  -Fuel Cut Off monitoring	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5643	183	14	ECM Error  -Post Inj: monitoring	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5644	190	2	ECM Error -Engine Speed limitation	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5645	7253	7	ECM Error -EEPROM failure	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5646	190	14	ECM Error -Engine Speed: monitoring	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5647	558	14	ECM Error –PVS monitoring	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5648	976	14	ECM Error –PTO monitoring	ECM Self	If DTC is still active, replace ECM
5649	1136	14	ECM Error  -A/D conversion monitoring	ECM Self	If DTC is still active, replace ECM
5651	7132	14	ECM Error  -MFMA monitoring	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM

## DIAGNOSTIC TROUBLE CODES

DTC	SPN	FMI	MD DESCRIPTION	TEST SECTION	POSSIBLE CAUSES
5652	8240	14	ECM Error -NVMY channel	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5653	8300	14	ECM Error -PPS monitoring	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5654	8329	14	ECM Error -CAN monitoring	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5655	8332	14	ECM Error -Service Tool monitoring	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5656	8335	14	ECM Error -Processor monitoring	ECM Self	ECM internal fault, Clear DTC, cycle the key. If DTC is still active, replace ECM
5666	8339	4	VREF Engine voltage below min	VREF	VREF on the Engine E and D connector short to GND
5667	8339	3	VREF Engine voltage above max	VREF	VREF on the Engine E and D connector short to PWR
5668	8340	4	VREF Chassis voltage below min	VREF	VREF on the Chassis connector short to GND
5669	8340	3	VREF Chassis voltage above max	VREF	VREF on the Chassis connector short to PWR
5671	8341	4	VREF Body voltage below min	VREF	VREF on the Body connector short to GND
5672	8341	3	VREF Body voltage above max	VREF	VREF on the Body connector short to PWR

## Procedure for accessing Diagnostic Trouble Codes (DTC) on MaxxForce engines.

- 1. Set the Parking Brake
- 2. Turn the key switch to ON position
- 3. Press and hold the CRUISE ON and RESUME/ACCEL switches (top left and bottom right respectively) simultaneously within 3 seconds of key on. This enables Diagnostic Mode for the engine
- 4. Observe the driver information center in the middle of the dash
  - a. The screen will identify active and inactive codes
  - b. Flash codes are no longer used. The codes are identified by SPN and FMI numbers. They must be referenced on the DTC list

## Procedure for Clearing Diagnostic Trouble Codes (DTC) on MaxxForce Engines

- 1. Engine must be in Diagnostic Mode (see step 3 above if needed) with the key switch still in the ON position
- 2. Put the left turn signal on
- 3. Press and hold the CRUISE ON and Set/Cruise switches (top left and top right respectively)
- 4. All inactive DTC will be cleared. Active codes will not be

## **SPECIAL SERVICE TOOLS**

# **Diagnostic Tools**

## 3-Banana Plug Harness

#### **ZTSE4498**

The 3-Banana Plug Harness is used to diagnose sensor

## 4-Pin Actuator Breakout Harness

#### ZTSE4739

The 4-pin actuator breakout harness is used to measure voltage and resistance on circuits that go to the VGT actuator.

## 8-Pin Injector Harness

#### ZTSE4793

The 8-Pin UVC Breakout Harness is used to measure continuity of the UVC wiring, injector solenoids, ICP sensor wiring, BCP sensor wiring, and the BSV valve.

#### 16-Pin Breakout Harness

#### **ZTSE4762**

The 16-Pin Breakout Harness to diagnose circuits that pass through the 16-way connector.

#### 180-Pin Breakout Box

The 180-pin breakout box allows testing of the electronic control system components without disturbing connections or piercing wire insulation to access various signal voltages in the electronic control system. **CAUTION:** To prevent engine damage, do not use the Breakout Box to activate or control circuits. High current passing through the breakout box will burn out the internal circuitry. Use the Breakout Box for measurement only.

#### 500 Ohm Resistor Harness

#### **ZTSE4497**

The 500 Ohm Resistor Harness is used for sensor end diagnostics of sensor circuits.

## **Actuator Breakout Harness**

#### **ZTSE4484**

The Actuator Breakout Harness is used to measure voltage and resistance at the IPR valve. The harness is also used to full field the IPR during low ICP diagnostics.

## Amp Clamp

## **ZTSE**4575

The Amp Clamp is used to measure amperage draw for the inlet air heater.

## **APS/IVS Sensor Breakout Harness**

#### **ZTSE4485**

The APS/IVS Breakout Harness is used to measure voltage and resistance on APS/IVS sensor circuits.

## **EGR Valve Breakout Harness**

#### **ZTSE4758**

The EGR Breakout Harness is used to measure voltage and resistance on EGR valve circuits.

#### **Exhaust Pressure Breakout Harness**

#### ZTSE4761

The exhaust pressure breakout harness is used to measure voltage and resistance on Exhaust Gas Differential Pressure (EGDP) sensor circuits.

## **Exhaust Temperature Breakout Harness**

#### **ZTSE4760**

The exhaust temperature breakout harness is used to measure voltage and resistance on Exhaust Gas Temperature (EGT) sensors circuits.

#### **ITV Breakout Harness**

#### **ZTSE4765**

The ITV Breakout Harness is used to measure voltage and resistance on ITV actuator circuits.

## **MAT Breakout Harness**

#### ZTSE4782

The MAT Breakout Harness is used to measure voltage and resistance on MAT sensor.

## **Pressure Sensor Breakout Harness**

#### 7TSF4347

The Pressure Sensor Breakout Harness is used to measure voltage and resistance on EBP, EFP, EOP, and MAP sensors circuits.

#### Relay Breakout Harness

#### **ZTSE4596**

The Relay Breakout Harness is used to measure voltage and resistance EFAN and starter relays circuits.

## **Relay Breakout Harness**

#### 7TSF4674

The Relay Breakout Harness is used to measure voltage and resistance on actuator power relay circuits.

## SPECIAL SERVICE TOOLS

## **Temperature Sensor Breakout Harness**

#### **ZTSE4483**

The Temperature Sensor Breakout Harness is used to measure voltage and resistance on IAT sensor circuits.

## Temperature Sensor Breakout Harness

#### ZTSE4602

The Temperature Sensor Breakout Harness is used to measure voltage and resistance on ECT, EFT, EOT, and MAT sensors circuits.

## **Terminal Test Adapter Kit**

#### ZTSE4435A

The Terminal Test Adapter Kit is used to access circuits in the connector harness and allows for the use of a DMM without damaging the harness connectors. The probes may also be used as a guide to determine whether the harness connectors retaining correct tension on the mating terminal.

## **Mechanical Tools**

## Charge Air Cooler Test Kit

#### **ZTSE4341**

The Charge Air Cooler (CAC) Test Kit is used to pressurize the charge air cooler and piping to check for leaks.

## **Fuel Inlet Restriction Adapter**

#### **ZTSE**4817

The Fuel Inlet Restriction Adapter is used as a test port for measuring fuel restriction at the fuel strainer.

## Fuel/Oil Pressure Test Coupler

#### ZTSE4526

The Fuel/Oil Pressure Test Coupler is used with the fuel pressure test fitting for an easy connection to measure fuel pressure.

## **Fuel Pressure Gauge**

#### **ZTSE**4681

The Fuel Pressure Gauge is used to check for fuel pressure and aerated fuel at the fuel rail.

#### **Fuel Pressure Test Kit**

#### **ZTSE4657**

The Fuel Pressure Test Kit includes a quick disconnect check valve and fittings that can be used to make a test line to check fuel pressure at the high-pressure fuel rail.

## **Fuel Test Fitting**

#### ZTSE4692

The fuel test fitting is used to measure fuel pressure. When measuring non-filtered fuel pressure, the fittings installed at the diagnostic port of the fuel filter housing. When measuring fuel pressure, the fitting can be installed on the fuel rail instead of the Schrader® valve. The Fuel/Oil Pressure Test Coupler can then be connected to the fuel test fitting to measure fuel pressure or fuel inlet restriction.

## Gauge Bar Tool

#### ZTSE4409

The Gauge Bar Tool can be used to measure intake manifold (boost) pressure, fuel system inlet restriction, fuel pressure, oil pressure, intake restriction, and crankcase pressure.

## **ICP System Test Adapter**

#### ZTSE4594

The Injection Control Pressure (ICP) System Test Adapter used to take an oil sample or measure oil pressure at the Engine Oil Temperature (EOT) sensor port.

## **ICP** Test Kit

#### **ZTSE4655**

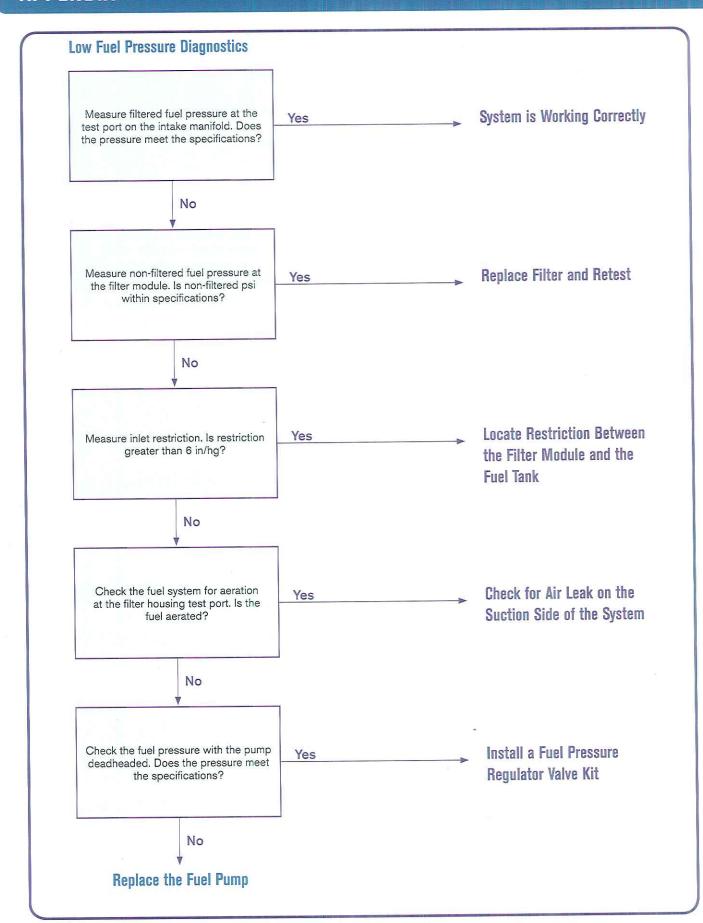
The ICP Test Kit is used to adapt an ICP sensor to the end of the high pressure hose.

## **IPR Test Adapter**

#### ZTSE4816

The IPR Test Adapter is used to check the high-pressure pump for ability to reach maximum injection control pressure.

## **APPENDIX**



## 2007 Warning Lamps

Name		Comments
Warn Engine Lamp (WEL)		The <b>WARN</b> Engine lamp will illuminate when a non-emissions fault is detected in the engine control system.
Malfunction Indicator Lamp (MIL)	43	The <b>MALFUNCTION</b> Indicator lamp will illuminate when an emissions fault is detected in the engine control system.
Stop Engine/Water and Oil Lamp (OWL)		The <b>STOP</b> engine 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 <b>DPF</b> 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 <b>HOT</b> Exhaust lamp will illuminate when the exhaust system temperature goes above 400° F with vehicle speed less then 5 mph.

## **APPENDIX**

## **Valve Adjustment**

- The crankshaft is rotated twice during the valve lash adjustment procedure.
- Six valves are adjusted when cylinder #1 is at TDC (Top Dead Center) compression and six valves are adjusted when piston #6 is at TDC compression.
- With the valve cover removed, bar the engine over until the valves for #1cylinder or #6 cylinder are in overlap. Overlap is when the exhaust valve is almost closed and the intake is just starting to open. If cylinder #6 is in overlap use chart 1 and adjust the indicated valves. If

cylinder #1 is in overlap, use chart 2 and adjust the indicated valves.

## **Engine Brake Lash**

The crankshaft is rotated twice during brake lash adjustment procedure. Three brake actuator pistons are adjusted when piston #1 is at TDC Compression and three are adjusted when piston #6 is at (TDC) compression.

**NOTE:** Valve lash adjustments are not required when adjusting engine brake lash. To adjust the brake piston lash, position the crankshaft for valve adjustment. If piston #6 is in

overlap, see Chart 1 and adjust the pistons on cylinders 1, 3, and 5. If piston #1 is in overlap, see chart 2 and adjust pistons #2, 4, and 6.

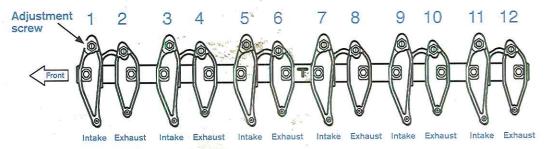
• Measure brake lash when engine is cold. Put a 0.48 mm (0.019 in) feeler gauge between the brake actuator piston and valve bridge, a light drag on the feeler gauge should be felt. If adjustment is required, loosen the actuator piston locknut and turn actuator piston screw. Once the brake lash is set, tighten the actuator piston locknut to the special torque value and remove the feeler gauge. Recheck lash with a light drag on feeler gauge. If the drag is too tight or loose, repeat the procedure.

#### Chart 1

Cylin	der 1	Cylin	der 2	Cylin	der 3	Cylin	ider 4	Cylin	der 5	Cylin	der 6
Intake 1	Exhaust 2	Intake 3	Exhaust 4	Intake 5	Exhaust 6	Intake 7	Exhaust 8	Intake 9	Exhaust 10	Intake 11	Exhaust 12
0.019	0.019	0.019	e.		0.019	0.019			0.019		
Brake	0.019		э	Brake	0.019			Brake	0.019		

#### Chart 2

Cylin	der 1	Cylin	der 2	Cylin	der 3	Cylin	der 4	Cylin	der 5	Cylin	der 6
Intake 1	Exhaust 2	Intake 3	Exhaust 4	Intake 5	Exhaust 6	Intake 7	Exhaust 8	Intake 9	Exhaust 10	Intake 11	Exhaust 12
		а	0.019	0.019		<i>y</i>	0.019	0.019		0.019	0.019
-		Brake	0.019			Brake	0.019			Brake	0.019



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## **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 an electrical input signal.

#### Aeration

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

#### **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.

#### Ampere (amp)

The standard unit for measuring the strength of an electrical current. The flow rate of a charge in a conductor or conducting medium of one coulomb per second. (SAE J1213 NOV82)

#### Analog

A continuously variable voltage.

#### **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.

#### Catalytic converter

An antipollution device in the exhaust system that contains a catalyst for chemically converting some pollutants in the exhaust gases (carbon monoxide, unburned hydrocarbons, and oxides of nitrogen) into harmless compounds.

#### 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 (usually air).

### Closed crankcase

A crankcase ventilation that recycles crankcase gases through a breather, then back to the clean air intake.

#### 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 switch

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. (SAE J1479 JAN85)

#### Diagnostic Trouble Code (DTC)

Formerly called a Fault Code or Flash Code. A DTC is a three digit numeric code used for troubleshooting.

#### 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 (high side)

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

#### Driver (low side)

A transistor within an electronic module that controls the ground 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 gasses before they enter the intake manifold.

#### **EGR Valve**

A valve that regulates the flow of exhaust gasses into the intake manifold.

#### **Engine Oil Pressure Switch (EOPS)**

A sensor that senses oil pressure.

## **Engine Oil Temperature (EOT) Sensor**

A thermistor sensor that senses engine oil temperature.

### **Engine OFF tests**

Tests that are done with the ignition switch ON and the engine OFF.

#### **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 intake air charge in order to reduce oxides of nitrogen.

### 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 strainer**

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

### 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. (SAE J1156 APR86)

#### Hall effect sensor

Type of sensor that generates a digital on/off used to signal that indicate speed and position.

#### Idle speed

- Low idle is minimum rpm at no load.
- High idle is maximum rpm at no load.

## **GLOSSARY**

## Injection Control Pressure (ICP)

High lube oil pressure generated by a high pressure pump/pressure regulator used to hydraulically actuate the fuel injectors.

#### Injection Control Pressure (ICP) Sensor

A sensor that measures injection control pressure.

#### Injection Pressure Regulator (IPR)

An ECM regulated valve that varies injection control pressure.

#### 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.

#### 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  $H_2O$ , or inches of mercury ( $H_9$ ).

#### Magnehelic Gauge

A gauge that measures pressure in inches of water (in H<sub>2</sub>O).

#### **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.

#### Oxides of Nitrogen (NOx)

Nitrogen oxides form by a reaction between nitrogen and oxygen at high temperatures.

#### Potentiometer

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

#### Pulse Width Modulate (PWM)

The time that an actuator, such as an injector, remains energized.

#### Rated horsepower

Maximum brake horsepower output of an engine as certified by the engine manufacturer. The power of an engine when configured as a basic engine. (SAE J1995 JUN90)

## Rated speed

The speed, as determined by the manufacturer, at which the engine is rated. (SAE J1995 JUN90)

#### 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.

#### 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.

## Vehicle Speed Sensor (VSS)

Normally a magnetic pickup sensor mounted in the tailshaft housing of the transmission, used to indicate ground speed.

### Volt (v)

A unit of electromotive force that will move a current of one ampere through a resistance of one Ohm.

#### VIGN

Voltage supplied to the ECM when the key is ON.

