ASE 8 - Engine Performance

Module 16
6.5L EFI Diesel Engine Performance

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Module 16 – 6.5L EFI Diesel Engine Performance

Introduction

The focus of this module is the electronic fuel system operation and diagnosis on the 6.5L EFI V8 diesel engine. This course is intended for students who have diesel engine mechanical training but may be less familiar with the electronic engine management system related to it. At the end of this course, you should have a good understanding of the 6.5L engine management system and related components.

Pre-requisites: You should already have a thorough understanding of gasoline engine performance and OBD II prior to taking this course.

Every attempt will be made to present this information within the context of existing 6.5L EFI V8 knowledge and experience.

This module will be delivered in the following lessons:

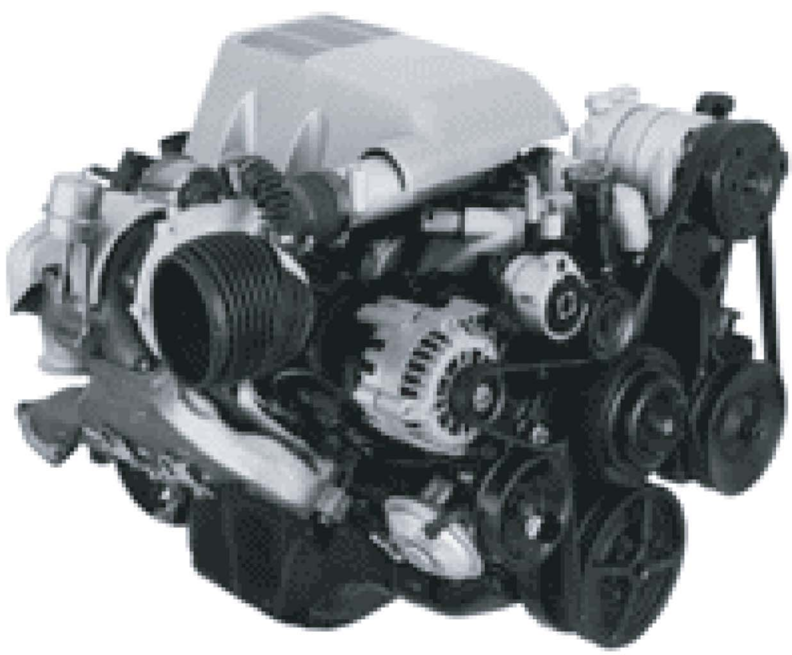
Lesson 1: General Information

Lesson 2: Air Induction/Exhaust System

Lesson 3: Fuel System

Lesson 4: Engine Management

Lesson 5: Diagnosis and Repair



Lesson 1: General Information

In this lesson you will learn about 6.5L applications, identification and design features. You will also learn about basic diesel engine operation.

Objectives:

- Identify engine applications
- Identify engine and pump identification labels
- Identify engine design features
- Understand basic diesel engine operation

At the end of this lesson there will be a short exercise.

6.5L V8 Diesel Introduction

Electronic Fuel Injection Control System: Both the normal and heavy-duty emissions certified versions of GM's 6.5L turbo diesel engine utilize an electronic fuel-injection control system. This major technological enhancement incorporates a powertrain control module (PCM) that controls the engine and transmission, an electronic throttle control and an electronically controlled fuel-injection pump. The adaptation of electronics to the rotary injection pump yields almost complete freedom to schedule fuel quantity and timing at optimal values for every speed and load point. What does all of this mean to the customer? Increased fuel economy, the elimination of black and white exhaust, improved cold weather starting, enhanced idle quality and reduced noise levels. The electronic fuel delivery system also helps protect the engine from overheating and other abuses, and allows GM to be fully compliant with current emissions standards. GM was the first manufacturer to introduce an electronically controlled fuel injection system in diesel pickup trucks. The fuel injection pump was upgraded in 1997 and again in 1999 for improved durability by improving the Optical Sensor Tracking Encoder (OSTE) circuit board. In addition, the steel rollers in the pump were replaced with ceramic rollers for longer life.

Turbocharging: When GM set out to design the 6.5L V8 diesel engine, the goal was to build an engine that was reliable and durable with unparalleled performance. From the start, the 6.5L was designed specifically for turbocharging, even though not all applications are. The secret weapon behind the 6.5L turbo diesel is the GM computer controlled wastegate. This wastegate allows the turbocharger rotor speed and boost to be electronically adjusted as altitude and engine speed changes, and as torque is needed. The wastegate helps the engine work harder, but only when it needs help. When you need torque, it's there; when it's not required, the wastegate does not overwork the engine. This uniquely designed wastegate turbocharger delivers quick throttle response during acceleration and reduces turbo-boost pressure after obtaining maximum torque. The wastegate is designed to prolong turbo life and help manage the overall stress on internal engine components.

On-Board Diagnostics Second Generation (OBDII): As with all GM vehicles, GM's L65 turbo diesel engine is fully OBDII compliant. This required significant enhancements to the powertrain control module (PCM). The PCM, a highly sophisticated on-board computer, received a 50 percent increase in memory and improved diagnostic capabilities in 1996. The PCM, which began controlling the fuel-lift pump and air conditioner in 1996, also monitors sensor systems such as coolant temperature, fuel temperature, air temperature, barometer, exhaust gas recirculation (EGR) pressure, turbo boost pressure and the thermostat diagnostic. This technology helped GM vehicles meet the new, more stringent emissions regulations, as well as improve idle stability. Misfire detection was added to OBDII in 1998.

Turbocharging System: On the G-van application of the L65, a center mounted turbocharging system shortens the air and oil passages and provides direct flow from the block. This design eliminates the need for oil lines, which increases reliability, durability, and serviceability. Oil is fed and drained directly from the block mount.

Fuel-Manager Filter System: Each of GM's diesel engines features the fuel-manager filter system. This system is a double-filtration fuel filter that incorporates the filter, a water separator and a fuel heater all in one canister. The top-load vertical design and location simplify filter cartridge replacement.

Common Serpentine Accessory Belt Drive: The 6.5L V8 diesel engine features a single serpentine belt for all the driven components. Its automatic tension adjuster improves belt life and makes servicing easier.

Fuel Economy: Among the many superior characteristics of the 6.5L turbo is its exceptional fuel economy. When matched against a comparably performing big-block V8 gasoline engine, this diesel has the potential for 25 to 80 percent better fuel economy. The improved fuel economy is a result of precise control of combustion and more precise transmission control, both due to electronic control.

Crankshaft Bearings: The crankshaft bearings used in the 6.5L are made of a fatigue-resistant material that promotes a higher bearing stress life. The rear crankshaft seal is a one piece seal to reduce the chances of leakage.

Bulkhead: The 6.5L diesel engine bulkhead area is designed to handle the higher-cylinder firing pressures of a turbocharged engine. In addition, the coolant passages and the oil galleries are sized to provide the increased flow required by a turbo engine.

Combustion Chamber: To provide smokeless performance and meet stringent emissions standards without sacrificing power, the 6.5L is designed with an optimized combustion chamber. This design provides an optimum balance of air in the pre-chamber, head and cylinder that ensures a more even and complete burning of fuel. For 1999 the compression ratio was reduced to 19.5:1 and an exhaust pressure regulator system was added to eliminate white smoke.

Modulated EGR System: In addition to having an optimized pre-combustion chamber, some 6.5L turbo engines utilize an electronically controlled modulated exhaust gas recirculation system. This allows for more precise control over the flow of exhaust gas and also helps to meet stringent emissions standards.

Adaptive Cylinder Balance: Adaptive cylinder balance is included on the 6.5L turbo diesel. This process measures the horsepower of each cylinder at idle and directs fuel to each cylinder accordingly. This results in smoother operation of the vehicle by minimizing the vibration of the engine.

Cylinder Block: The cylinder block incorporates piston spray cooling for increased engine life. This is accomplished by installing spray nozzles in the block that spray oil at the underside of the piston. An increased flow oil pump and lubrication system ensures sufficient oil pressure during all running conditions. The oil cooler lines and oil coolers have increased in size so that they provide a 100% increase in flow through the oil cooler.

Cooling System: The cooling system has been upgraded with an increased flow water pump and new water crossover and dual full-blocking thermostats. For 1999 the water pump bearing has been improved for greater durability.

Catalytic Converter: The catalytic converter was removed for 1999 while continuing to meet all emission requirements.

Oil Pan Capacity: In 1999 the oil pan capacity increased to eight quarts, which reduces maintenance.

Type:
6.5L V8 Turbo Diesel
Displacement:
6468 cc
Compression Ratio:
19.5:1
Valve Configuration:
Overhead Valves
Manufactured:
Moraine, OH
Valve Lifters:
Hydraulic Roller
Firing Order:
1-8-7-2-6-5-4-3
Bore x Stroke:
103.00 x 97.03 mm
Fuel System:
Indirect Electronic Fuel Injection
Horsepower:
215 hp @ 3400 rpm
195 hp @ 2600 rpm (C/K, G, P)
Torque:
430 lb-ft @ 1800 rpm
430 lb-ft @ 1800 rpm (C/K automatic)
420 lb-ft @ 1800 rpm (C/K manual)
Max. Governed Engine Speed:
3000 rpm

Materials:
Block: Cast Iron
Cylinder Head: Cast Iron
Intake Manifold: Cast Aluminum
Exhaust Manifold: Cast Nodular Iron
Main Bearing Caps: Cast Nodular Iron
Crankshaft: Cast Nodular Iron
Canmshaft: Forged Carbonized Steel

ADDITIONAL FEATURES:
- Extended Life Coolant

APPLICATIONS:
- Chevrolet & GMC C/K-truck (option engine)
- Chevrolet & GMC G-van (option engine)
- Chevrolet & GMC MD-truck (option engine)
- Chevrolet & GMC P32 - Motorhome Chassis (option engine)

6.5L Engine Application

From the 1994 model year to the 2000 model year, an electronically fuel injected version of the 6.5L V8 diesel engine has been available. This engine can be teamed with either a 5 speed manual or two different 4 speed automatic transmissions. It was also available with heavy-duty and light-duty emissions packages and came with or without a turbocharger, depending upon the application.

The 6.5L V8 diesel has been available in C/K trucks ranging from 1500 to 3500HD chassis. It has also been available in the G-Van and P Chassis trucks, as well as Hummers and other applications.

By the end of its production in light duty GM vehicles in 2000, the 6.5L Turbo Diesel had a peak torque output of 430 lb/ft and 215 hp.

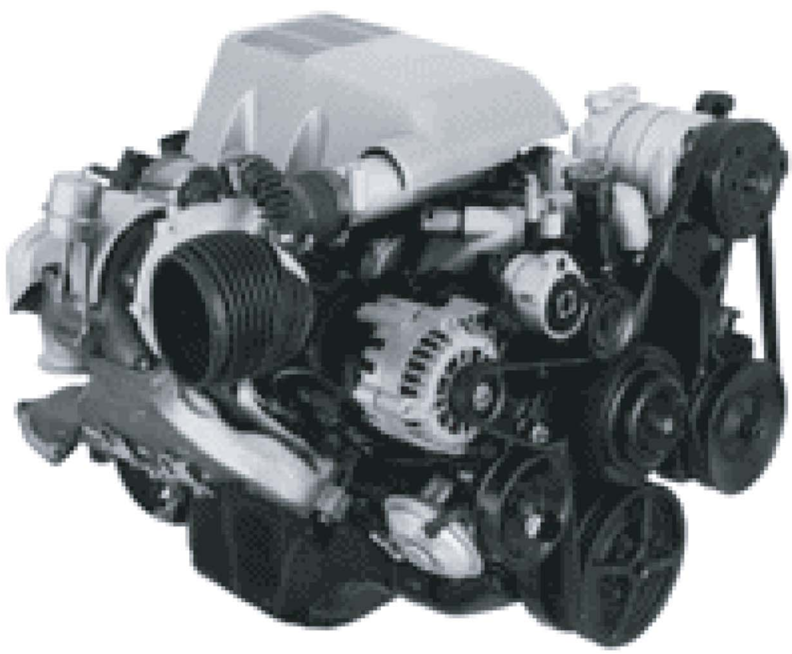


Figure 16-1, 1999 G-Van 6.5L

Identification Labels

The 6.5L diesel has had the VIN designation of F, P, S, and Y. Each engine is unique in emissions and application.

The 6.5L diesel engine has a seven-character identification code stamped on the upper surface of the cylinder case near the #1 cylinder intake manifold runner. The stamping contains a broadcast code that describes the engine configuration of the vehicle and a digital code that describes engine manufacturing information.

The fuel injection pump also has an identification code. It is contained on a metal plate riveted to the back end of its housing. The model and serial numbers are stamped on the plate. This information may be needed when ordering parts or a replacement pump.

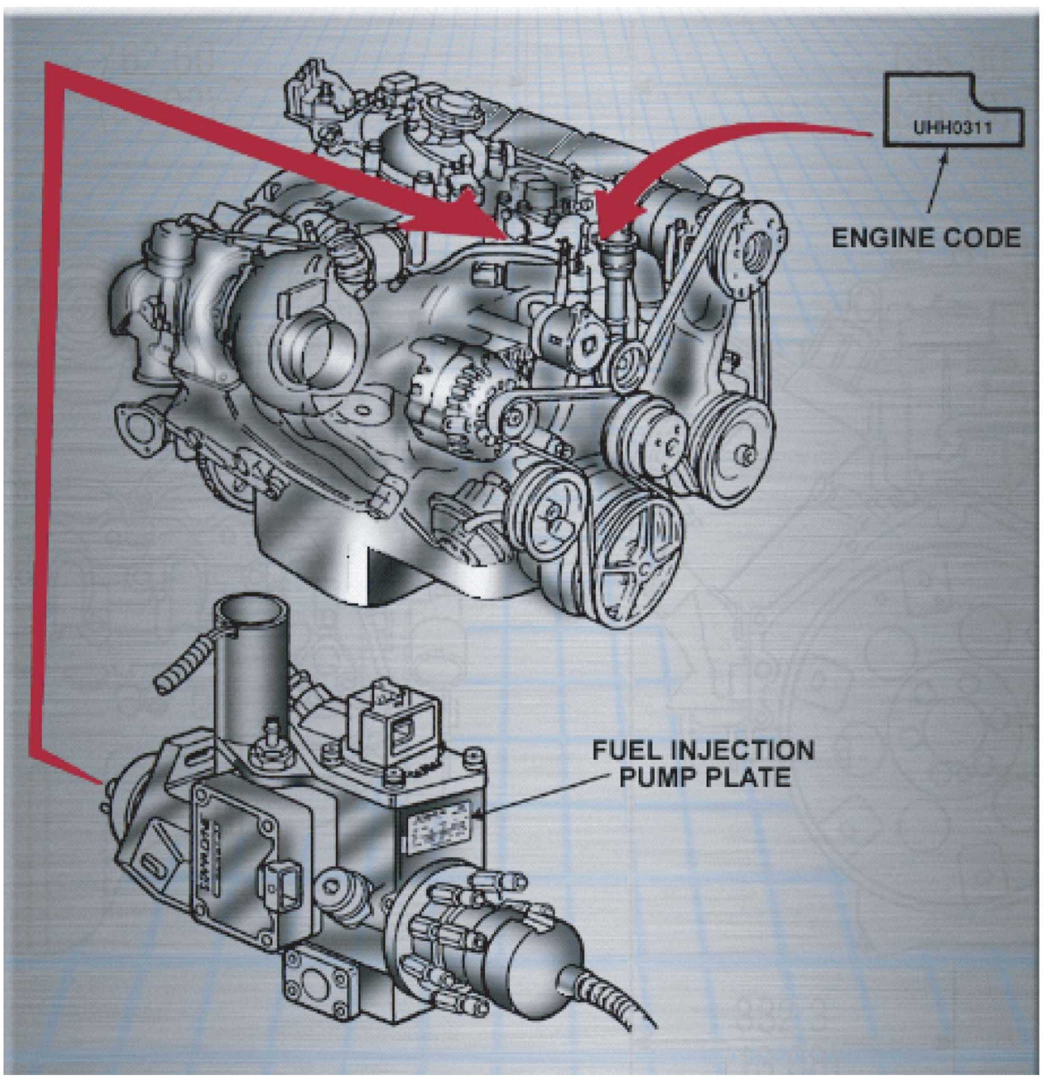


Figure 16-2, Engine and Pump Identification Labels

Design Features

The 6.5L EFI V8 diesel is derived from the same block as the pre-1994 non-EFI 6.5L engine. All 6.5L EFI engines share the following attributes:

- A four-stroke cycle.
- A compression ratio of 19.5:1 to 21.5:1 (depending upon year and application).
- Eight cylinders, each with a bore measurement of 103mm (4.055 in.) and piston stroke of 97mm (3.818 in.).
- Oil spray nozzles in the block for piston cooling.
- High-swirl pre-combustion chambers to mix fuel and air efficiently, resulting in low exhaust emissions.
- Controlled turbocharged air intake pressure of between 2 and 8 psi at peak torque, based on engine speed, load, and other conditions (turbo models).
- Power output varying from 275 lb/ft to 430 lb/ft depending on year and model.

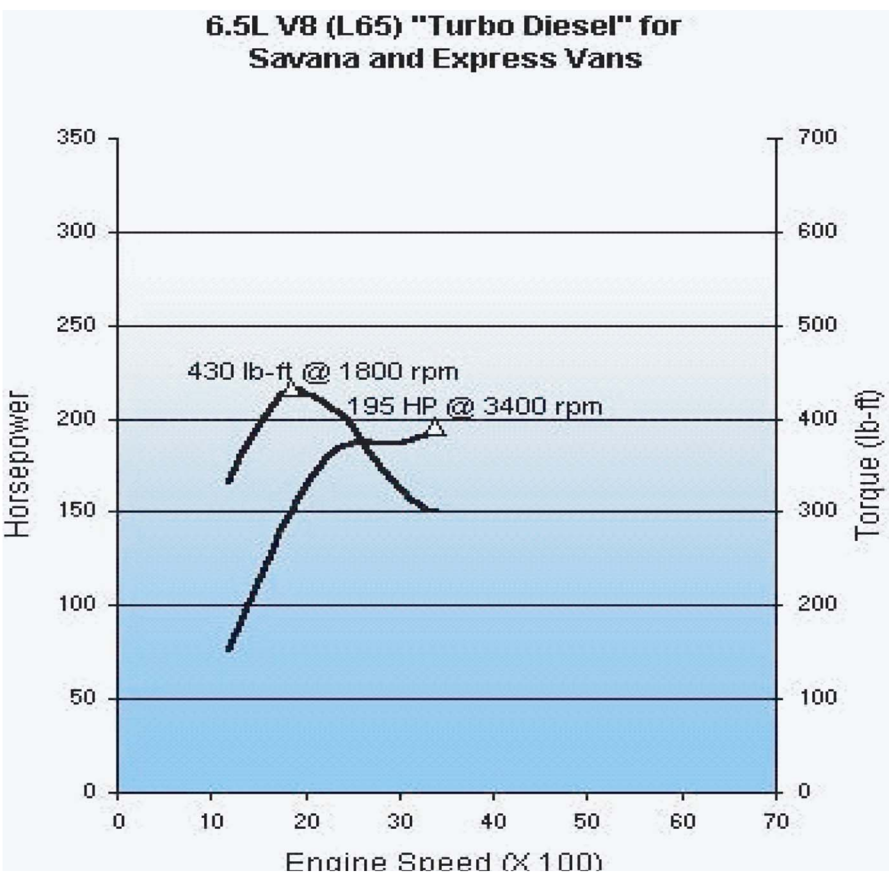


Figure 16-3, Power Chart for 2000 G-Van

Basic Diesel Operation

Four stroke diesel engines share many of the same characteristics of the four stroke gasoline engine. However, there are a few major differences in operation.

Diesel engines do not mix the air and fuel prior to entering the cylinder. Fuel is injected into the cylinder rather than into the intake manifold or into the intake runner. The air/fuel ratio of diesel engines varies by how much fuel is injected. This, in turn, controls engine speed and power. Unlike the gasoline engine, it does not attempt to maintain a 14.7:1 ratio.

Diesel engines do not require the use of a spark to ignite the air/fuel charge. Instead, the intense temperature generated by the compression ratio (up to 21.3:1) of the 6.5L diesel is all that is required to ignite the air/fuel charge. Also, timing of diesel engines is controlled by timing the injection of the fuel into the cylinder.

As with other diesel engines, the 6.5L engine does not use a throttle blade to control the amount of air entering the engine. Rather, diesel engines use the amount of fuel that is injected into the cylinder to control engine speed or power output. In a sense, diesel engines operate at wide open throttle continuously. Because of this design characteristic, there is always a large amount of air flowing through the engine in comparison to a gasoline engine. This will put a higher demand on the air filter, which will typically require more service.

There are basically two ways that fuel is injected into the cylinder. One way is known as direct injection, meaning the fuel is injected directly into the combustion chamber. The other way, which is used by the 6.5L diesel, is known as indirect injection, or pre-chamber injection. This design incorporates a pre-combustion chamber with a passage-way to the main combustion chamber. The pre-combustion chamber is where the fuel injector and glow plug are located. This design allows for a more controlled combustion rate, slightly quieter engine operation, and more controllable emissions.

Glow plugs are used in many diesel engines to aid in cold starting of the engine. Since diesel engine operation relies on the temperature of the compressed air to ignite the fuel, glow plugs can be essential for warming the cylinder in cold ambient temperatures. The glow plugs may operate before cold engine starting and during the first few seconds of run time.

Refer to figure 16-4 on the following page for cylinder component identification.

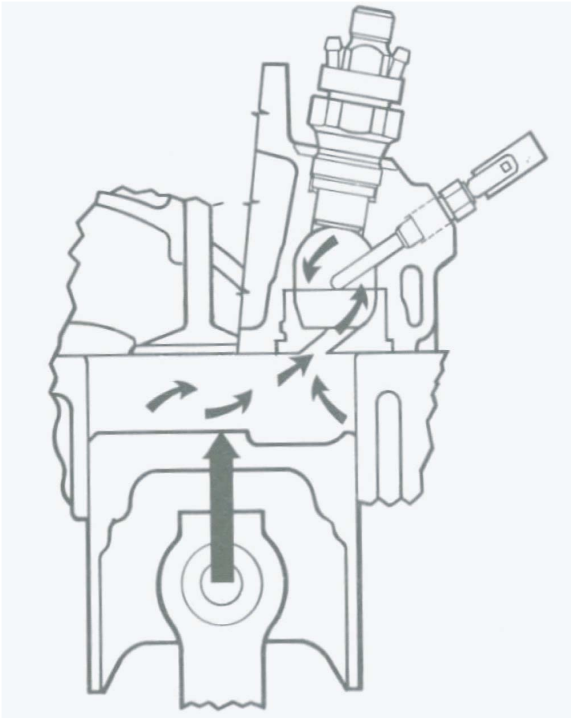


Figure 16-4, Diesel Combustion Chamber Components

Diesel engines typically don't have a combustion chamber as part of the head. Instead, they use a dished piston that acts as the combustion chamber. Diesel cylinder heads are typically flat in the combustion chamber area (Figure 16-5).

Each cylinder has a pre-combustion chamber to mix fuel and air efficiently, resulting in lower exhaust emissions. An insert made of nickel-based cast alloy forms one half of the pre-combustion chamber, while the casting of the cylinder head forms the other half. The shape and size of the insert is specific to each 6.5L diesel engine and is the key factor in determining compression ratio.

During service, the insert may be removed with a brass punch and hammer after the injector and glow plug have been removed. Installation height must be checked after replacement.

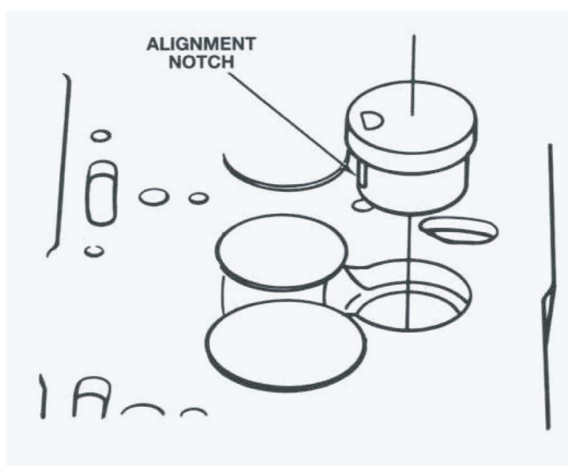


Figure 16-5, Pre-Combustion Chamber Insert

Intake Stroke

The following events occur during the intake stroke for any of the cylinders on the 6.5L diesel engine:

- At the end of the exhaust stroke, the rotating crankshaft also rotates the camshaft. The intake lobe for the cylinder pushes a hydraulic lifter upward.
- The lifter operates a rocker arm using a hollow push rod, which pushes open the intake valve.
- As the crankshaft rotates it pulls the connecting rod/piston for the cylinder in a downward direction.
- The action of the piston and the turbocharger (if equipped) causes the air induction system to allow air to move into the combustion area of the cylinder.

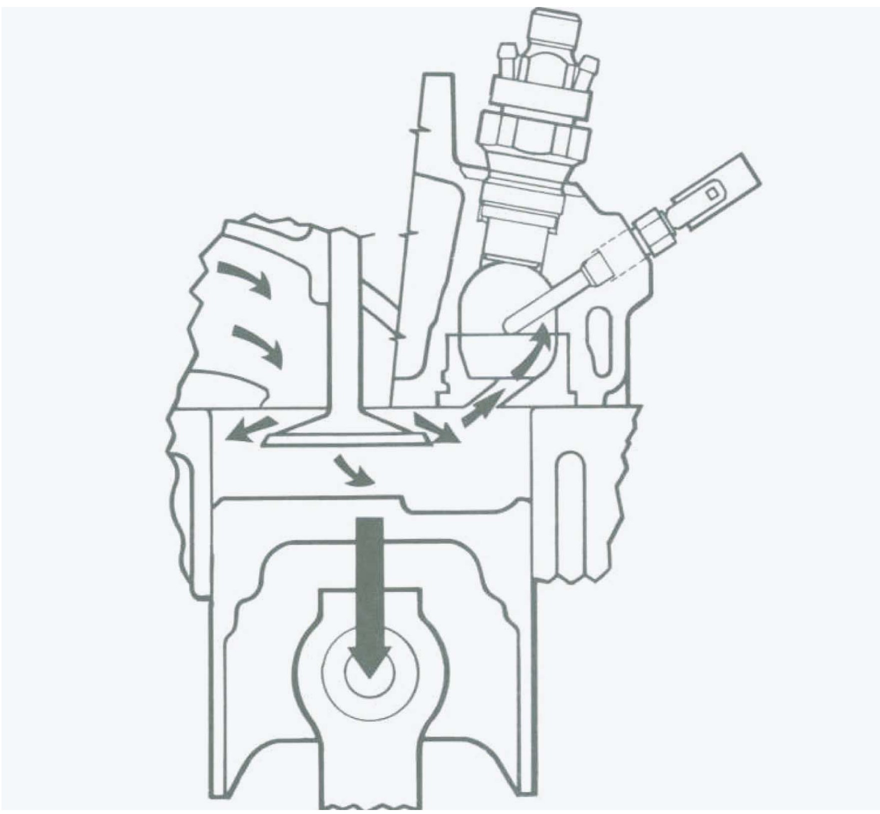


Figure 16-6, Intake Stroke Operation

Compression Stroke

The following events occur during the compression stroke for any of the cylinders on the 6.5L diesel engine:

- At the end of the intake stroke, the rotating crankshaft also rotates the camshaft. The intake lobe for the cylinder allows downward movement of the hydraulic lifter.
- Intake valve spring pressure pushes the intake valve closed and also operates the rocker arm which moves the push rod and lifter downward.
- As the crankshaft rotates, it pushes the connecting rod/piston for the cylinder in an upward direction.
- The action of the piston causes the air in the combustion area of the cylinder to be greatly compressed and the temperature of the air to greatly increases.

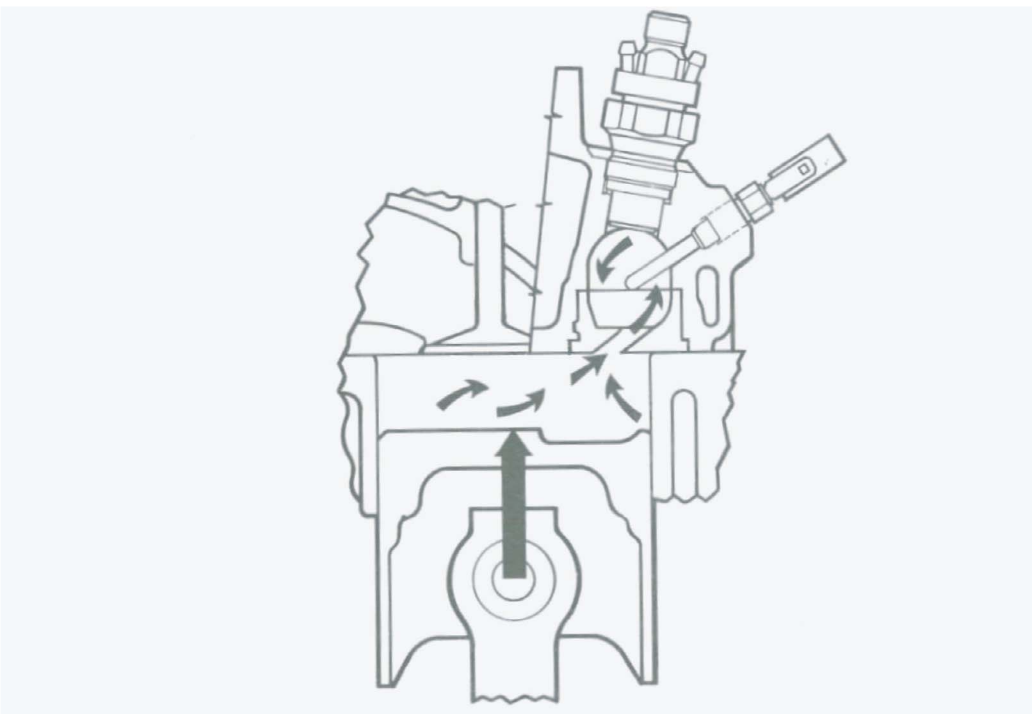


Figure 16-7, Compression Stroke Operation

Power Stroke

The following events occur during the power stroke for any of the cylinders on the 6.5L diesel engine:

- Towards the end of the compression stroke, the fuel injection pump (operated at camshaft speed by a gear set) delivers fuel through a pipe to a nozzle positioned in the combustion area of the cylinder.
- The nozzle opens, spraying fuel into the hot, swirling air in the pre-combustion chamber. This will occur at or just before TDC on the compression stroke, depending on operating conditions.
- The heated air/fuel mixture achieves combustion and expanding gases push the connecting rod/piston for the cylinder in a downward direction.
- The connecting rod/piston provides rotating force for the crankshaft.

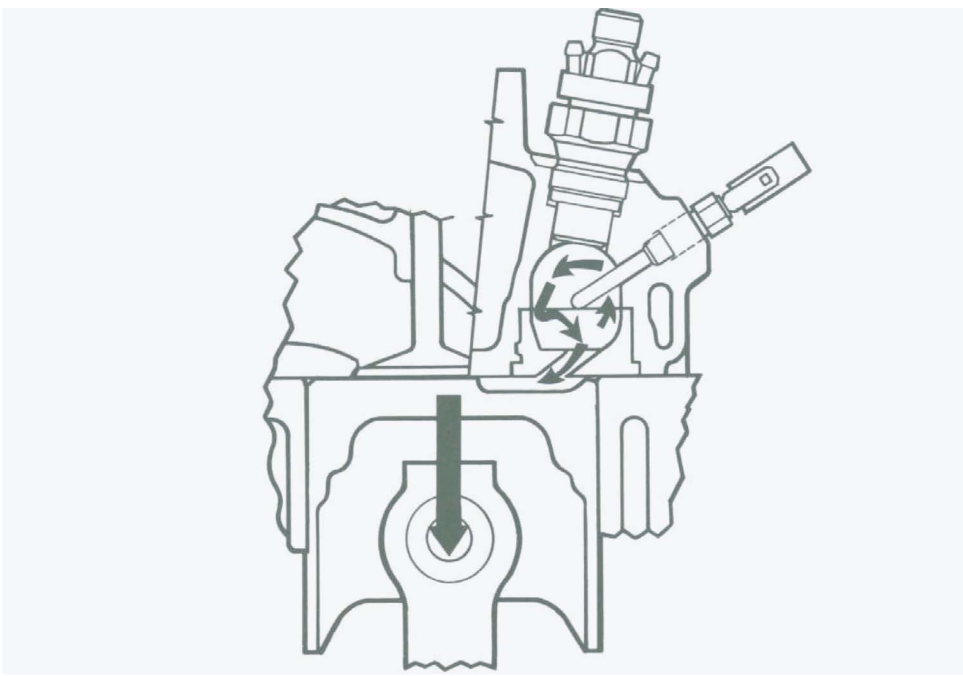


Figure 16-8, Power Stroke Operation

Exhaust Stroke

The following events occur during the exhaust stroke for any of the cylinders on the 6.5L diesel engine:

- At the end of the power stroke, the rotating crankshaft also rotates the camshaft. The exhaust lobe for the cylinder pushes a hydraulic roller lifter upward.
- The lifter operates a rocker arm using a hollow push rod, which pushes open the exhaust valve.
- As the crankshaft rotates, it pushes the connecting rod/piston for the cylinder in an upward direction.
- The action of the piston pushes post-combustion gases out of the cylinder combustion area through the exhaust system.
- At the end of the exhaust stroke, the rotating crankshaft also rotates the camshaft. The exhaust lobe for the cylinder allows downward movement of a hydraulic roller lifter.
- Exhaust valve spring pressure pushes the exhaust valve closed and also operates the rocker arm which moves the push rod and lifter downward.

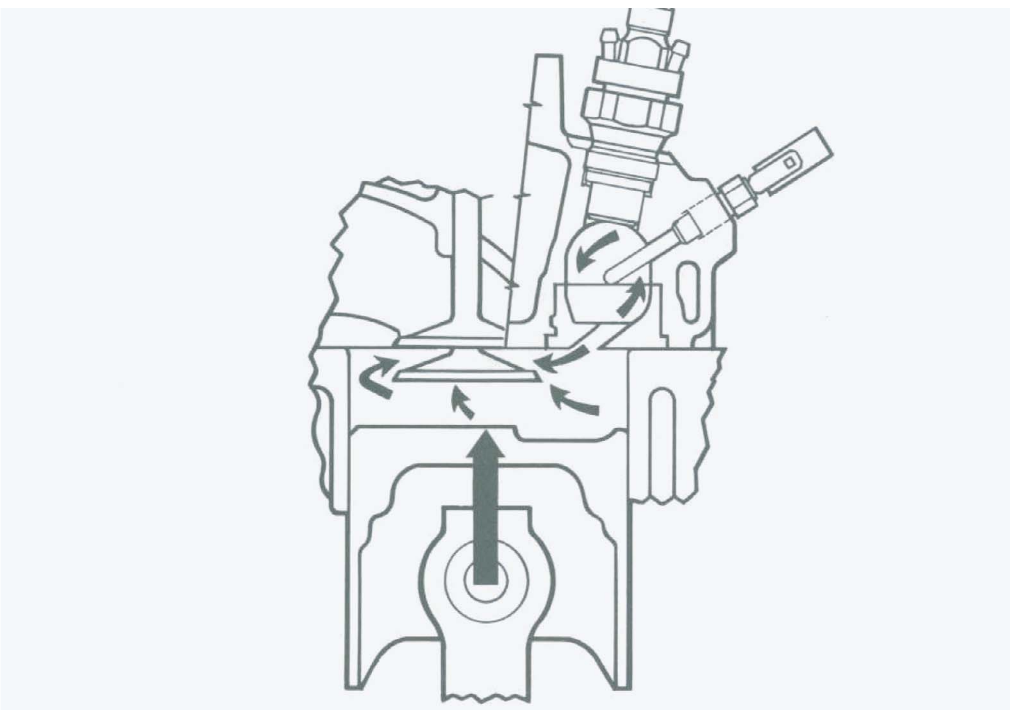


Figure 16-9, Exhaust Stroke Operation

Exercise 16-1

Read each question carefully and choose the most correct response.

1. Fuel is typically injected into the cylinder on which stroke?
   a. Intake
   b. Compression
   c. Power
   d. Exhaust

2. The 6.5L diesel uses a pre-combustion chamber for all of the following reasons except:
   a. Reduce emissions.
   b. Increase power.
   c. Control combustion rates.
   d. Reduce noise.

3. All of the following statements are true except:
   a. The 6.5 diesel is direct injected
   b. The 6.5L diesel uses pre-combustion chambers
   c. The 6.5L diesel uses glow plugs
   d. The 6.5L diesel can be equipped with a turbo

4. What is the rated torque output of the 6.5L diesel in a 2000 G-Van?
   a. 275 lb/ft.
   b. 290 lb/ft.
   c. 385 lb/ft.
   d. 430 lb/ft.

5. Glow plugs are used to __________________.
   a. Ignite the air/fuel
   b. Provide quieter operation
   c. Reduce emissions at all times
   d. Aid in cold starting of the engine

Exercise 16-1 (continued)

6. Diesels use __________ to ignite the fuel.
   a. Glow plugs
   b. Compression
   c. The turbocharger
   d. Valves

7. The intake and exhaust valves are closed furing which stroke?
   a. Compression
   b. Power
   c. Intake
   d. Compression and power

Notes:

Lesson 2: Air Induction/Exhaust System

In this lesson you will learn about the air induction and exhaust system components and their operation.

Objectives:

- Identify the location and service of the air filter
- Identify the air inlet duct components
- Understand the use and operation of the turbocharger
- Understand the use and operation of exhaust system components
- Understand the use and operation of the crankcase ventilation system

At the end of this lesson there will be a short exercise.

Air Induction/Exhaust Systems

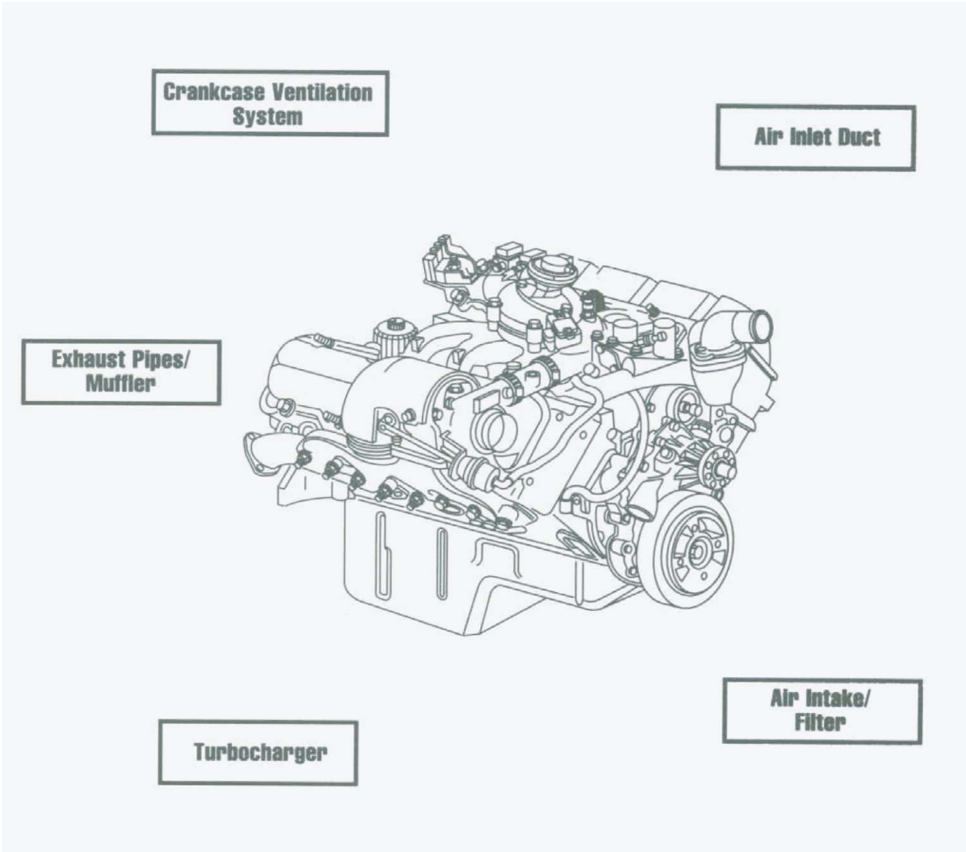


Figure 16-10, Air Induction/Exhaust System

The air induction system consists of the air filter housing, air filter, turbocharger, intake manifold and ducts. It also consists of necessary components that evacuate crankcase gasses. All of these components are essential for the proper operation and life of the engine.

The exhaust system consists of the exhaust pipe and muffler and on some vehicles a catalytic converter. This is a standard exhaust system that does not require much explanation.

Air Filtration System Description and Operation

The air filter housing is located on the right inner fender. It draws air in from between the inner and outer fender. It has a duct that connects directly to the turbocharger inlet (if equipped).

The condition of the air intake system for the 6.5L turbo diesel is very important to the life of both the engine and its turbocharger. At intervals of every 10,000 miles, the ducts, fasteners, and clamps of the air intake system should be inspected for wear or damage.

The maintenance schedule requires that the air filter be changed every 30,000 miles. It may require more frequent service in dusty environments. Air filter service is critical for engine life as well as power. A plugged air filter can have a dramatic affect on engine power output.

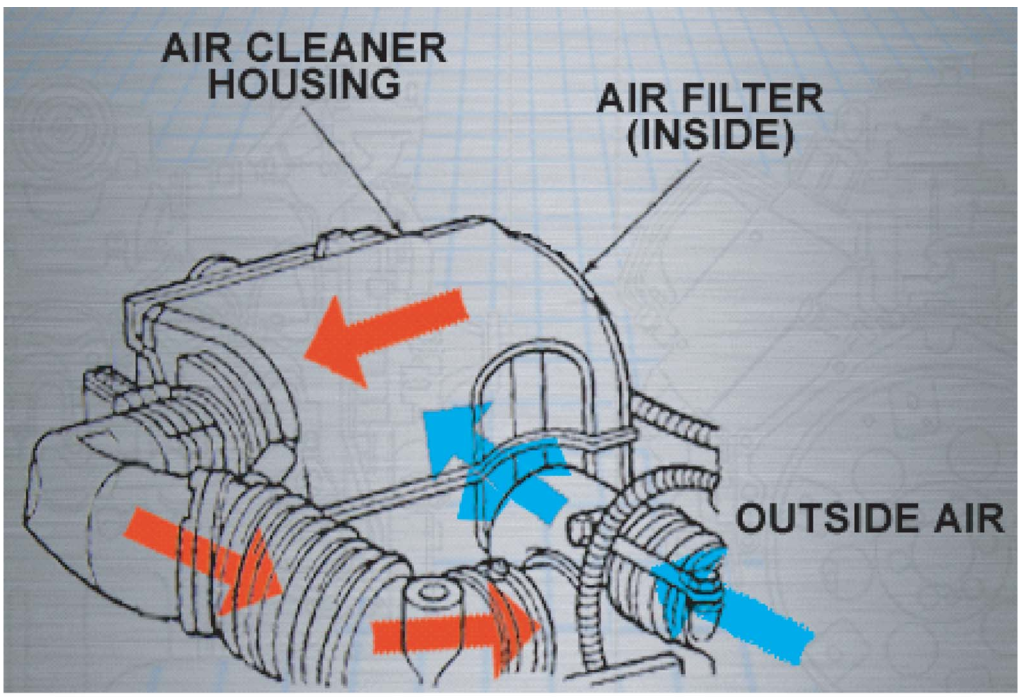


Figure 16-11, Air Filter Housing and Duct

Caution:

Never operate the engine with the air inlet duct removed from the turbo inlet. The turbo blades are spinning any time the engine is running and contact with them will result in bodily harm and/or damage to the compressor blades.

Turbocharger Assembly

The 6.5L EFI diesel turbocharger provides a variety of benefits. It increases engine response and power while also reducing exhaust emissions. The 6.5L diesel engine has a turbocharger for the following reasons:

- To provide an increase in engine power without adding a substantial increase in weight.
- To provide consistent power at all altitudes by compensating for changes in air density.
- To increase combustion turbulence and air/fuel mixing efficiency, resulting in greater fuel economy.
- To reduce exhaust emissions (especially smoke).

The 6.5L turbo diesel engine provides quick power response at low engine speeds due to the wastegated design, which is tailored to the 6.5L output requirements. Under less than full-load conditions the turbocharger works with the engine to provide varying levels of power under a broad range of speeds.

Basic Construction and Operation

The turbocharger assembly has a turbine housing, a compressor housing and a bearing housing. A turbine wheel/shaft connects to the compressor wheel and the assembly rotates inside the housing.

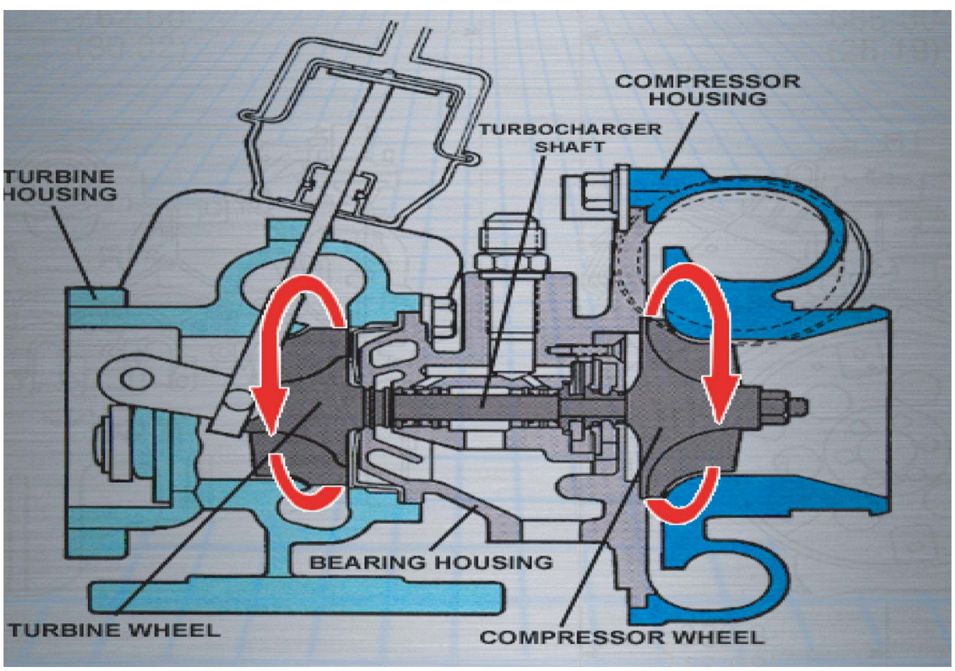


Figure 16-12, Turbocharger Major Components

Basic turbocharger operation starts with exhaust gases entering the turbine housing from both exhaust manifolds which causes the turbine wheel/shaft to rotate. As the exhaust gases spin the turbine wheel/shaft, the compressor wheel also spins. The action of the compressor wheel increases the pressure and flow of the air intake charge. The amount of pressure and flow is dependent on exhaust gas flow.

The power of the engine provides the exhaust gas pressure needed to take air under atmospheric pressure and provide air under boost pressure in the engine intake manifold. Since exhaust gas pressure varies with engine speed and load, the amount of boost also varies accordingly.

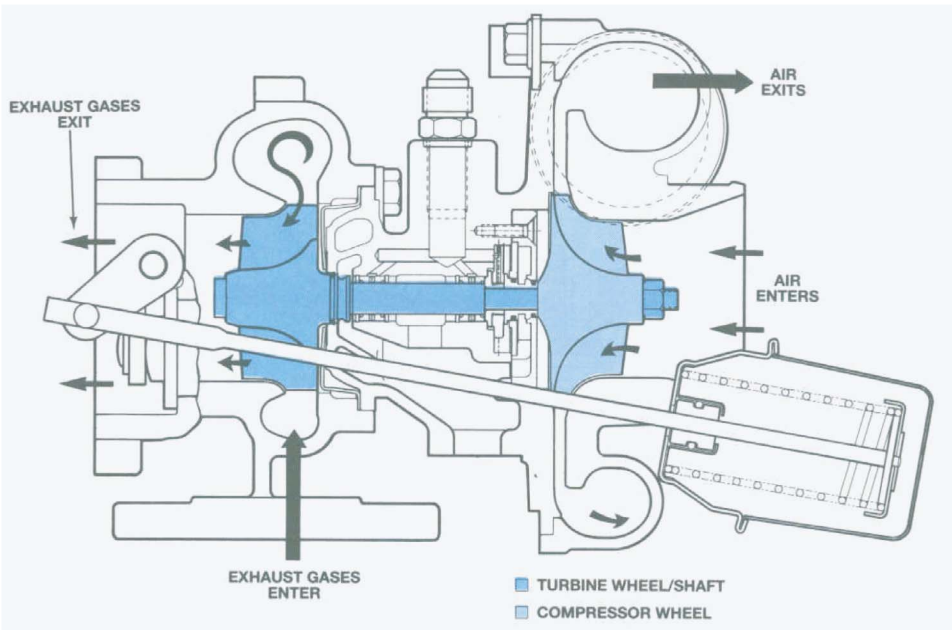


Figure 16-13, Basic Turbocharger Operation

The fitting in the center of the turbocharger is for an oil feed line. The turbocharger is cooled and lubricated by the engine oiling system. The oil returns to the engine through the return tube mounted under the turbocharger. The return tube bolts to the right side of the engine where a mechanical fuel pump on a carbureted engine would be.

Turbocharger Mounting

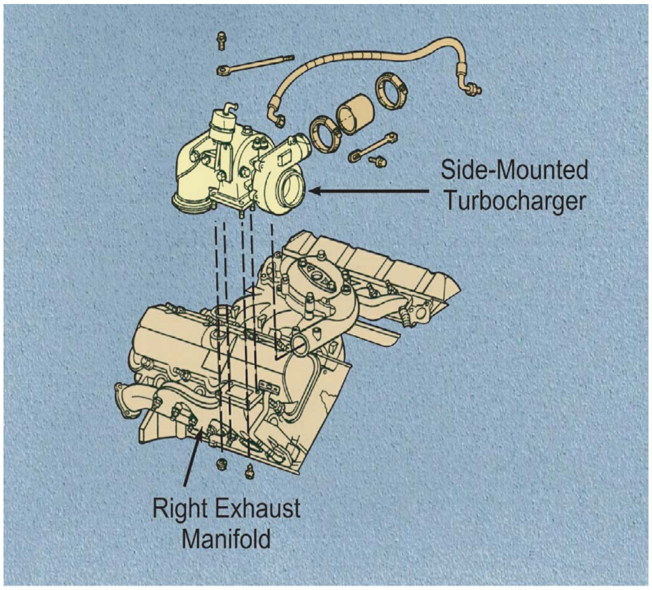


Figure 16-14, Side-Mounted Turbocharger

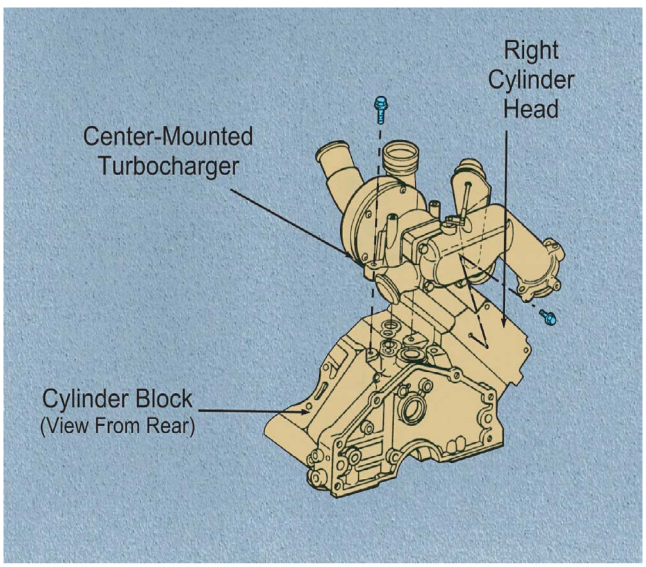


Figure 16-15, Center-Mounted Turbocharger

The engine supports the turbocharger using the right exhaust manifold on trucks and the engine valley on vans.

On trucks, exhaust gases from the left cylinder head flow through a pipe to the right exhaust manifold. There, exhaust from the left and right cylinder heads enter into the turbine housing and the gases exit the turbine housing into the exhaust pipe and muffler.

On vans, the left and right exhaust manifolds connect at the turbocharger rather than going through a crossover pipe.

The turbocharger does offer some resistance to exhaust flow, but makes up for this resistance by providing boost, which makes more power than it looses.

The compressor housing of the turbocharger has an inlet connected to the air filter assembly. The outlet of the turbocharger is connected to the intake manifold through a duct and pipe. All intake air to the engine flows into and out of the compressor housing.

Turbocharger Wastegate Valve and Actuator Assembly

The turbocharger turbine housing has a wastegate valve that allows exhaust gases to bypass the turbine wheel and directly enter the exhaust pipe. It acts like a turbine-wheel speed governor to limit the maximum amount of boost pressure (2-8 psi).

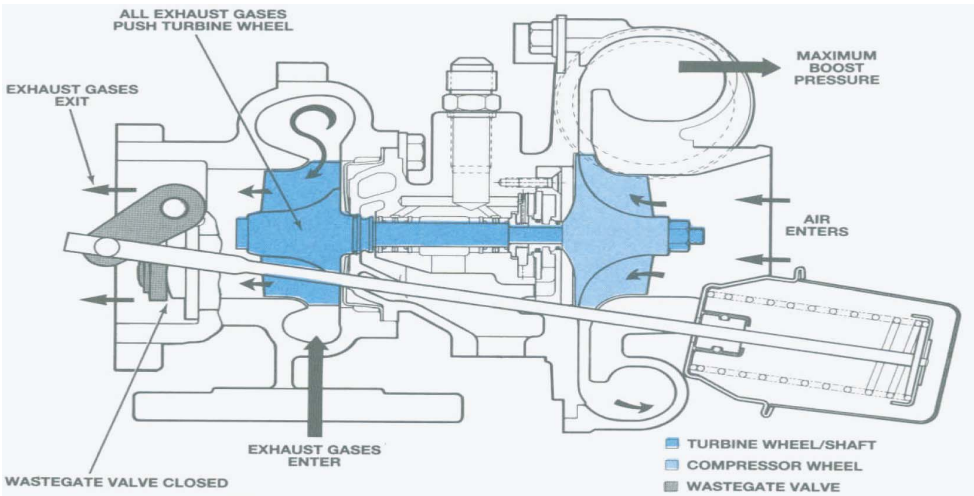


Figure 16-16, Turbocharger Wastegate and Actuator (Closed)

An actuator assembly, controlled by the PCM, controls the opening and closing of the wastegate, which in turn, controls the amount of exhaust pressure that drives the turbine. In this way, the PCM controls the amount of turbo boost to the engine. The wastegate actuator is the only component of the turbocharger that can be serviced separately.

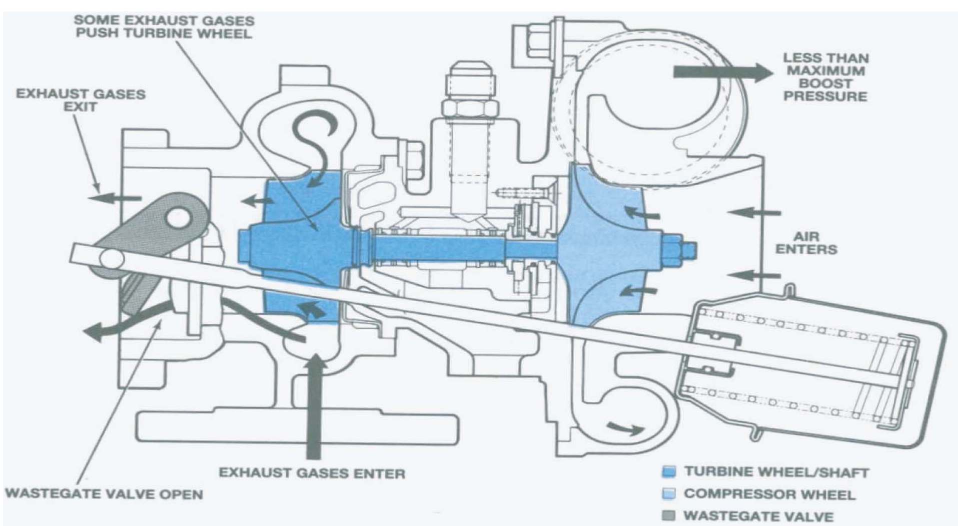


Figure 16-17, Turbocharger Wastegate and Actuator (Open)

GM ASEP BSEP

Crankcase Depression Regulator Valve (CDRV)

The crankcase depression regulator valve, or CDRV, is used on the 6.5L diesel to evacuate blow-by from the crankcase. It has a similar purpose as the PCV valve used on gasoline engines; however, its operation is somewhat different.

The crankcase ventilation system used on the 6.5L diesel engine is designed to maintain a slightly negative (vacuum) crankcase pressure across the speed range. The system consists of a crankcase depression regulator valve (CDRV), located on the right valve cover, and attaching vent hose/pipes to the engine inlet system before the turbo inlet. The CDRV is used to regulate the crankcase pressure to approximately 1-5 in. of H_2O depression over the entire engine speed range. The CDRV is NOT an oil separator or a crankcase effluent flow regulator. Therefore, the CDRV DOES NOT prevent oil droplets/mist from entering the intake system.

Figure 16-18, Crank Case Depression Regulator Valve

A slight vacuum is created at the turbo inlet duct due to air cleaner restriction and turbo compressor suction. The amount of vacuum is proportional to air inlet restrictions and turbo compressor suction.

The air inlet vacuum acts against a spring loaded diaphragm in order to control the flow of the crankcase gases. Higher inlet vacuum or high inlet restriction (e.g., plugged air filter) levels pull the diaphragm closer to the outlet tube. This prevents the vacuum level from getting too high in the crankcase. As the inlet vacuum decreases the spring pushes the diaphragm away from the outlet tube which prevents the crankcase pressure from going positive.

CDRV Operation

Inside the CDRV, a spring holds open a valve plate that connects to the CDRV body with a flexible diaphragm. The valve plate is capable of restricting the outlet passage to the turbocharger air inlet duct when airflow pulls it closed against the force of the spring.

When the engine is running at idle speed, the airflow past the CDRV outlet passage may not be great enough to pull the valve towards the closed position and crankcase pressure could be 1 inch H2O (View A).

At higher engine speeds, the valve closes to provide more restriction (View B). This prevents the movement of excessive oil vapors into the intake manifold by limiting the crankcase vacuum (measured at 2,000 rpm to be between 2 to 5 inches H2O).

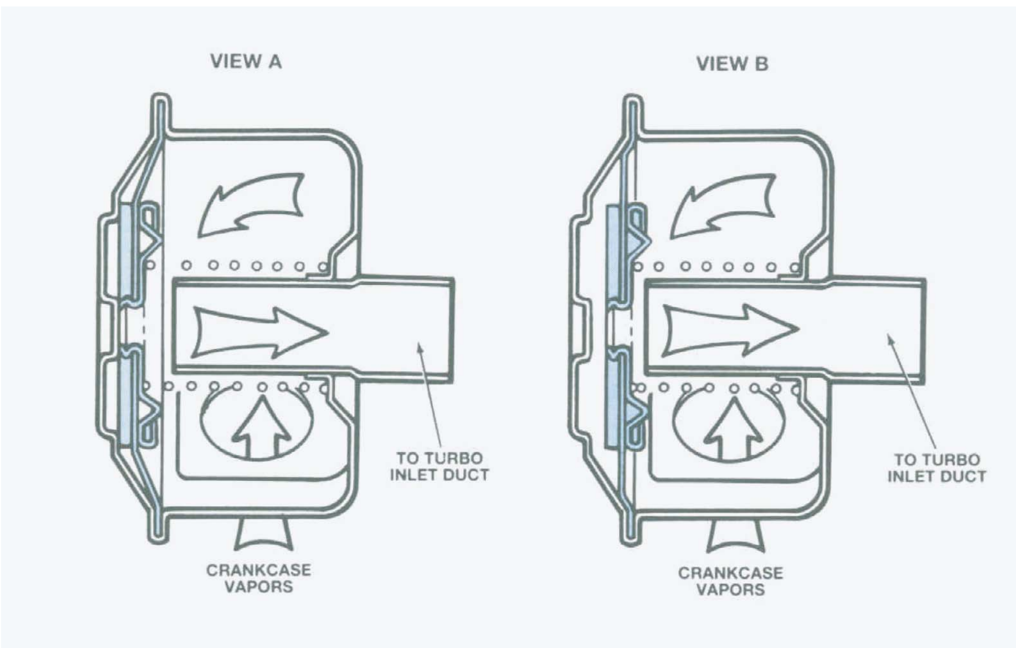


Figure 16-19, Crank Case Depression Regulator Valve Operation

The operation of this system does not include a fresh air inlet such as that used in a gasoline engine PCV system.

Exhaust System

The 6.5L exhaust system is basically the same as other exhaust systems. It may or may not have a catalytic converter, depending on the emission requirements. The only real difference in the exhaust system is that it hooks directly to the turbocharger instead of the exhaust manifolds.

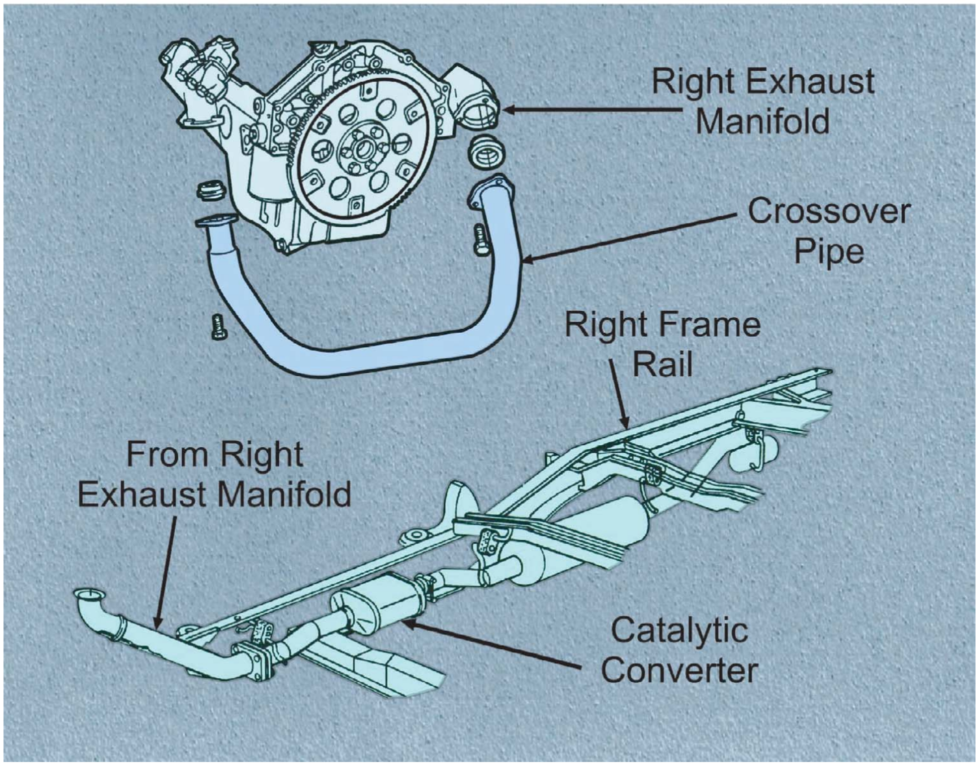


Figure 16-20, Exhaust System

Catalytic Converter

As part of its emission controls, some early 6.5L EFI engines used a palladium-oxidation catalytic converter. This type of converter differs somewhat from traditional gasoline vehicle converters. Its primary function is to oxidize the organic elements of the exhaust gas before it is passed through the exhaust system. It is not intended to oxidize hydrocarbons or carbon monoxide or reduce NOx. The converter operates at normal diesel engine exhaust temperatures and requires low-sulphur diesel fuel which has been the only type of diesel fuel available in the U.S. since 1994.

As of 1999 the catalytic converter is no longer used on the 6.5L diesel, but the engine is still able to meet emission standards.

Exercise 16-2

Read each question carefully and choose the most correct response.

1. A turbocharger is used for all of the following reasons except?
   a. Reduce emissions
   b. Reduce exhaust smoke
   c. Compensate for changes in altitude
   d. Reduce power

2. The CDRV is used for ______________________.
   a. Control EGR
   b. Evacuate the crankcase
   c. Increase crankcase pressure
   d. Circulate oil

3. The turbocharger wastegate controls ______________________.
   a. Exhaust pressure
   b. Engine speed
   c. Turbo boost
   d. Exhaust noise

4. The _____________ drives the _____________ in the turbocharger.
   a. Turbine, compressor
   b. Compressor, turbine
   c. Pump, turbine
   d. Turbine, pump

5. Boost pressure operates between ______ and ______ psi.
   a. 5, 10
   b. 3, 7
   c. 1, 10
   d. 2, 8

Exercise 16-2 (continued)

6. The exhaust pipe/muffler connects to the ________________.
   a. Exhaust manifolds
   b. Turbocharger
   c. Cylinder heads
   d. Intake manifold

7. What year was the catalytic converter removed from the 6.5L diesel?
   a. 1997
   b. 1998
   c. 1999
   d. 2000

Notes:

Lesson 3: Fuel System

In this lesson you will learn about fuel system components and their operation.

Objectives:

- Understand the lift pump operation
- Understand the fuel filter assembly operation
- Identify the fuel injection pump assembly and components
- Understand the operation of the fuel injection pump
- Identify and understand fuel injection nozzle operation
- Identify the fuel return system

At the end of this lesson there will be a short exercise.

Fuel System Components

The fuel control system delivers fuel from the fuel tank to the injectors via a series of pumps, a filter, passageways, and ports. System components include:

- Fuel Tank Assembly
- Lift Pump Assembly
- Fuel Filter Assembly
- Fuel Injection Pump Assembly
- Fuel Injection Lines
- Fuel Injection Nozzles
- Fuel Return System

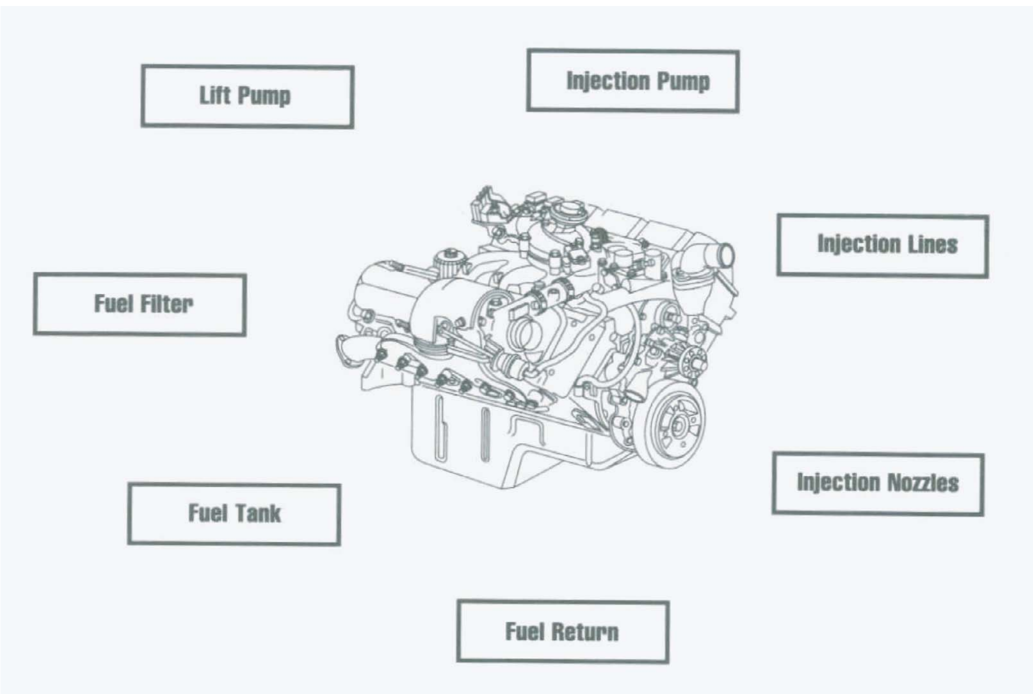


Figure 16-21, 6.5L EFI Fuel System Component Groups

Fuel Tank Assembly

The fuel supply system can have either one or two fuel tanks on some applications. If equipped with two tanks, the system has a balance pump that will pump fuel from the secondary tank to the primary tank.

This action is control by a module that measures the resistance of the sending units in both tanks, averages the readings and sends it on to the fuel gauge. When the secondary tank has approximately 2 gallons more that the primary tank, the module will energize the balance pump until the primary tank has approximately 2 more gallons than the secondary tank.

The fuel sender assembly in the tank contains only the fuel level sender, pick-up screen and necessary lines. The lift pump is located on the frame rail where the fuel filter is typically located on a gasoline vehicle.

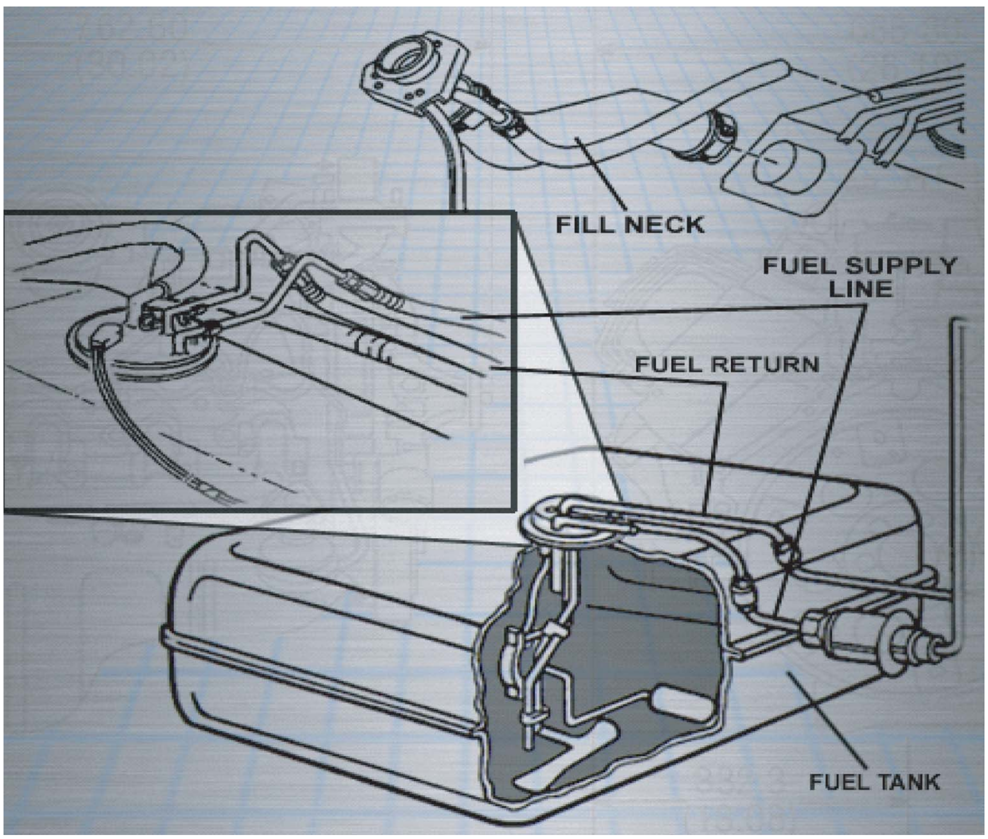


Figure 16-22, Fuel Tank Assembly

Note: When a vehicle is equipped with dual tanks and there is a malfunction with the balance pump or circuit, it is possible for the fuel gauge to read as high as ½ full while the primary tank could be empty. The fuel supply system is designed to pull fuel from the primary tank only. If the primary tank is empty, the engine will not run.

Lift Pump

The lift pump is designed to move fuel under a low (suction) pressure from the fuel tank and deliver it through the filter to the transfer pump inside the fuel injection pump. In order for the lift pump to operate correctly the fuel tank must have fuel, the lines between the tank and pump must not have leaks, and the fuel fill cap must be operating properly.

The inlet fitting of the lift pump connects to the fuel tank pick-up/sending unit fuel supply fitting using a pipe/hose assembly with o-rings. The outlet fitting of the lift pump connects to the inlet fitting of the fuel filter assembly on the engine using another pipe/hose assembly.

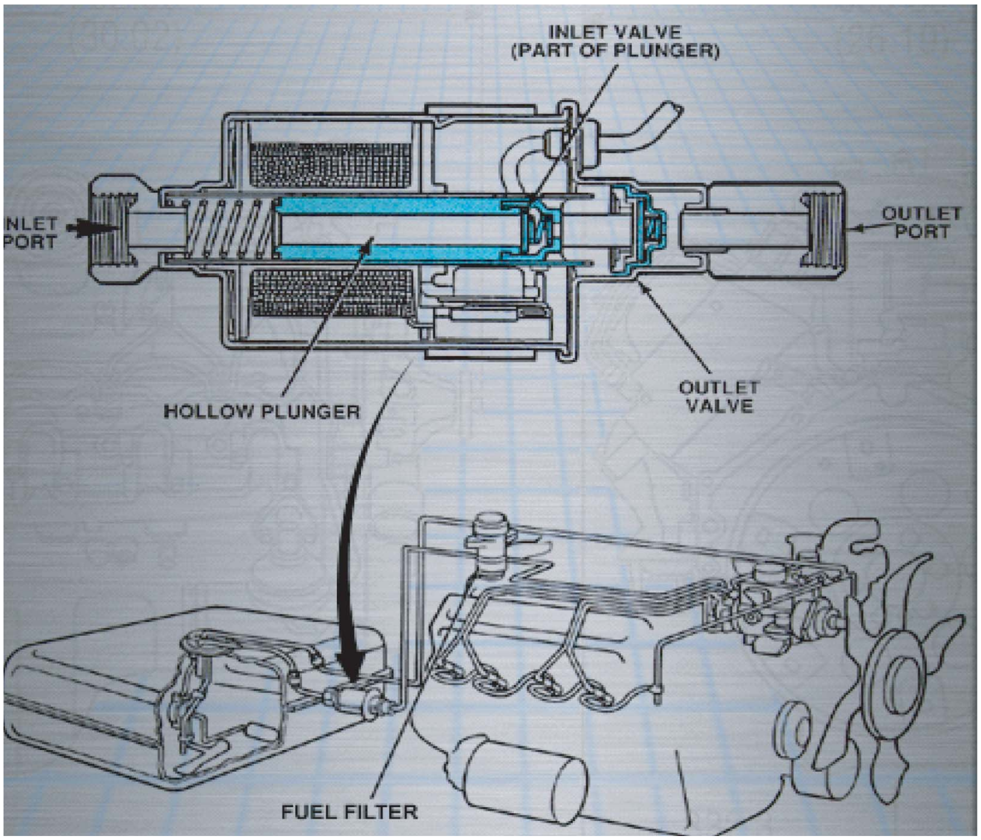


Figure 16-23, Lift Pump Construction

The electric lift pump has a hollow plunger that slides in a bore located in the center passage between the inlet and outlet ports. An inlet valve is mounted on one end of the hollow plunger, and an outlet valve is positioned at the outlet end of the center passage. Both valves are closed by spring force.

Note: Vehicles equipped with dual tanks also have a balance pump between the two tanks. Its construction and operation is the same as the lift pump.

Lift Pump Operation

When the pump is at rest a spring pushes the hollow plunger in the direction of the outlet. Both the inlet and outlet valves are closed, keeping fuel in the supply line from draining back to the fuel tank (Figure 16-24).

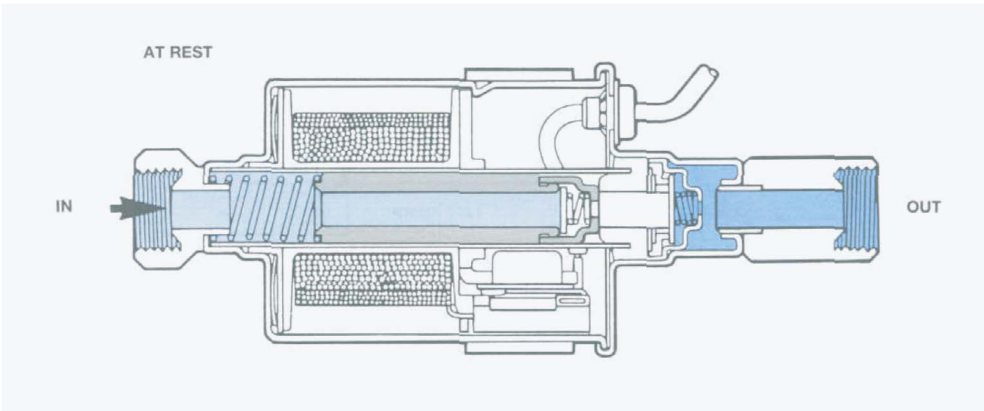


Figure 16-24, Lift Pump - At Rest

When the pump has electrical power, a solenoid turns ON and pulls the hollow plunger toward the inlet port against spring force (Figure 16-25). This action causes the inlet valve to open which allows fuel to enter the pumping chamber.

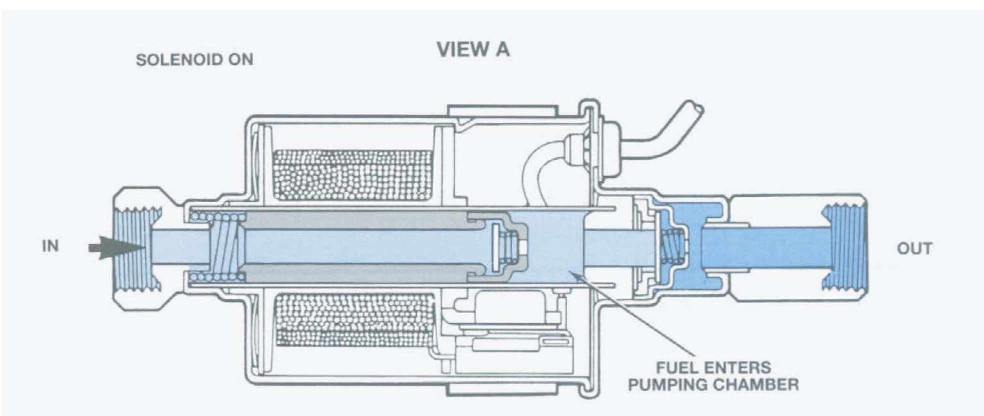


Figure 16-25, Lift Pump - Solenoid On

Lift Pump Operation Continued:

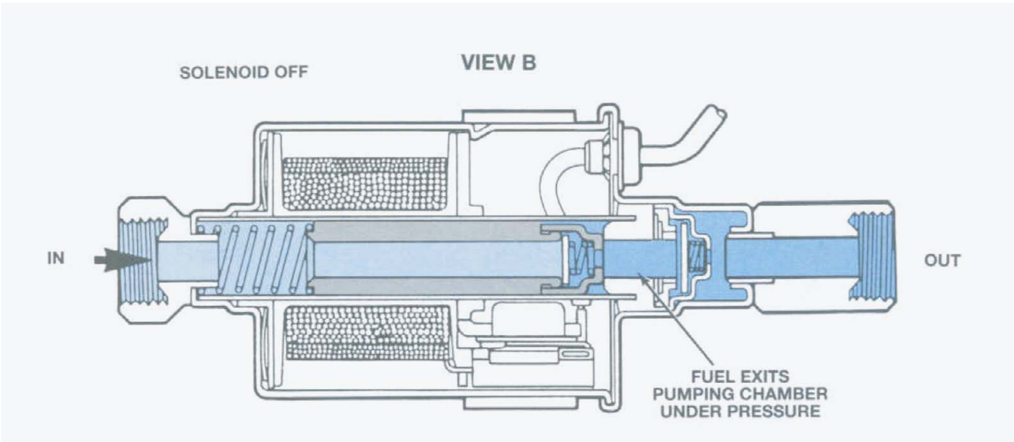


Figure 16-26, Lift Pump - Solenoid Off

As the hollow plunger reaches full travel in the direction of the inlet port, the solenoid is turned OFF and spring force pushes the plunger toward the outlet port (Figure 16-26). This action closes the inlet valve (causing fuel to be drawn from the fuel tank into the pump) and pressurizes the fuel in the pumping chamber (opening the outlet valve to allow fuel to travel to the fuel filter).

As long as the fuel pump has electrical power the solenoid ON/OFF cycle causes the movement of the hollow plunger and valves necessary to deliver a fuel supply to the filter and injection pump.

The cycling of the solenoid is controlled by a switch internal to the lift pump. The switch turns the pump on and off by the action of the plunger.

If a failure occurs in the operation of the lift pump, the customer may complain about a no-start, stall or low power condition. The injection pump must have a continuous supply of fuel without the presence of excessive air bubble in order to operate correctly.

Fuel Filter

The fuel filter assembly mounts on the rear of the intake manifold. Two bolts hold the assembly in place. The filter housing has the following fittings:

- An inlet fitting connecting to the pipe/hose from the lift pump.
- An outlet fitting connecting to the fuel injection pump with a hose.
- A third fitting connects through a hose to a drain valve mounted on the water crossover/thermostat housing.

The filter assembly has a replaceable element with integral seals. A threaded nut retains the element in the housing. The element has an air vent valve on its top surface that is used to purge air during a filter element replacement procedure. Filter and housing are keyed so that the filter will fit one way only.

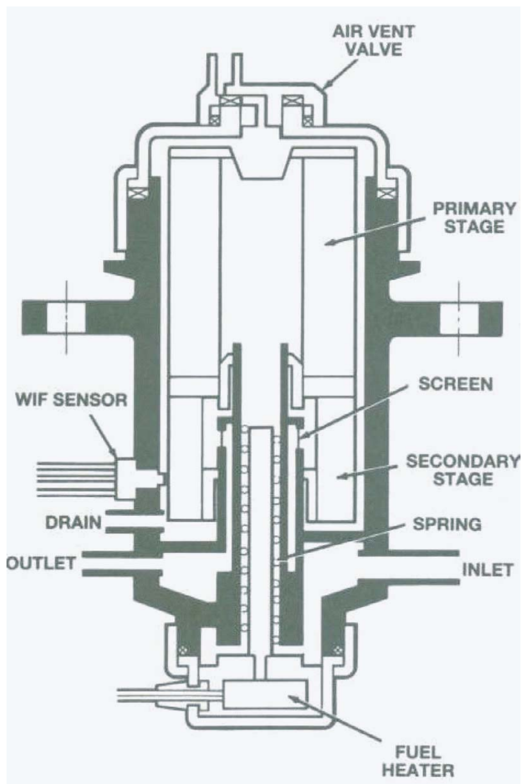


Figure 16-27, Fuel Filter Section View

The design of the fuel manager/ filter includes an area (secondary stage) that allows water droplets (as small as one micron) to separate from the fuel and collect in a lower portion of the housing. This water is collected in the bottom of the filter housing and should be drained periodically, especially when the "Water-In-Fuel" lamp is illuminated on the IPC.

Another part of the fuel filter assembly is a Water-In-Fuel (WIF) sensor. The WIF sensor has an o-ring seal and two mounting screws. Three wires connect the WIF sensor to a power supply circuit as well as to an instrument cluster-mounted amber warning lamp.

The fuel filter assembly has a fuel heater mounted to its bottom end that is retained with a threaded nut and seal ring. The fuel heater is controlled by a thermostatic switch that is integral to the heater assembly. The fuel heater turns on when fuel temperature is below 46°F to prevent fuel gelling or waxing. When fuel gelling or waxing occurs, fuel is not able to pass through the filter element and will cause a poor running condition, no start, or a stall condition.

Fuel Control System Operation

The electronic injection pump is the heart of the fuel control system. The rotary distributor pump uses an electromagnetic control valve to regulate fuel flow inside the pump. Four plungers in the pump pressurize fuel for distribution to the injectors. A PCM-controlled electronic stepper motor controls plunger timing via an advance piston.

The PCM uses information regarding engine coolant temperature, engine speed, accelerator position, fuel temperature, the optical sensor, and air conditioning status to calculate when to energize the fuel solenoid driver. The PCM illuminates the "Service Throttle Soon" lamp and/or Malfunction Indicator Lamp (MIL) in the instrument panel to alert the driver to conditions requiring service.

The PCM also has the capability to interrupt fuel supply when conditions warrant. It does this by de-energizing the normally closed engine shutoff (ESO) solenoid. When de-energized, the solenoid plunger prevents fuel from entering the charging passages in the pump.

The operation of the PCM inputs and outputs will be covered in Lesson 4.

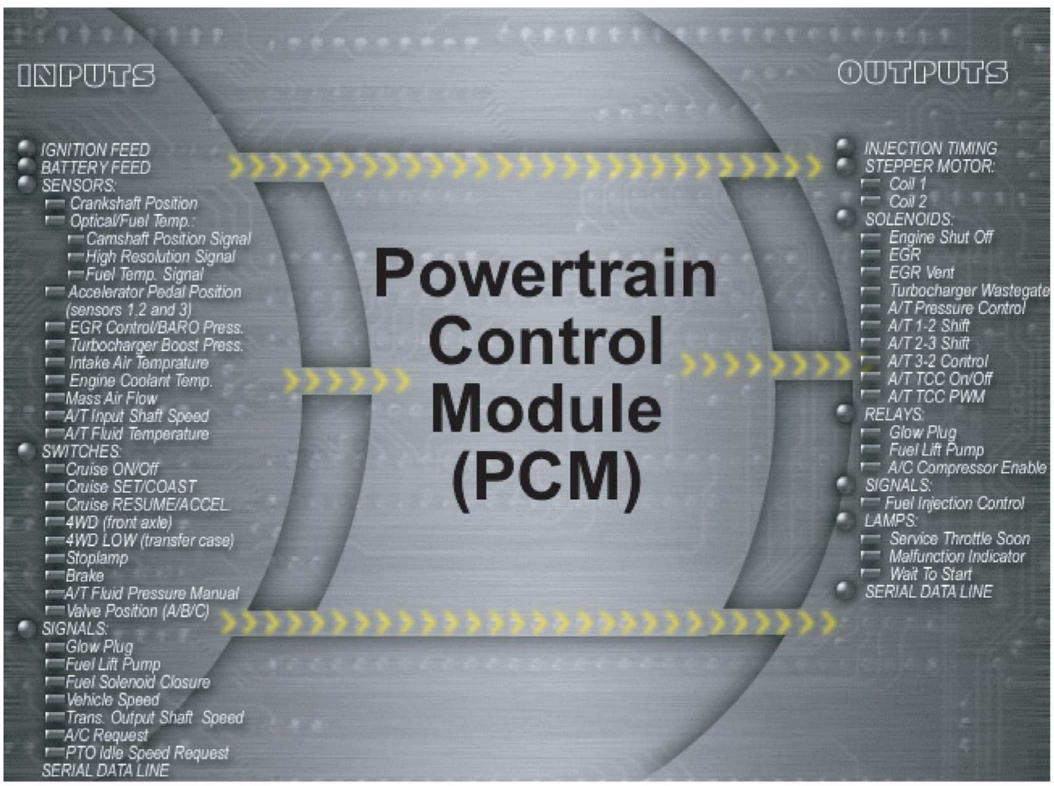


Figure 16-28, PCM Inputs and Outputs

Fuel Injection Pump

The 6.5L EFI diesel engine uses the Stanadyne model DS rotary distributor fuel injection pump consisting of the following components:

- A fuel solenoid driver that controls the fuel solenoid.
- An optical/fuel temperature sensor that supplies the PCM with pump speed, rotor position, cam ring position, and fuel temperature information.
- An engine shutoff (ESO) solenoid located on top of the pump.
- An injection timing stepper (ITS) motor located on the side of the pump that controls injection timing advance and retard.
- A fuel control solenoid that opens and closes a control valve for pump fill and spill activity.
- Inlet and outlet ports for fuel to and from the pump.

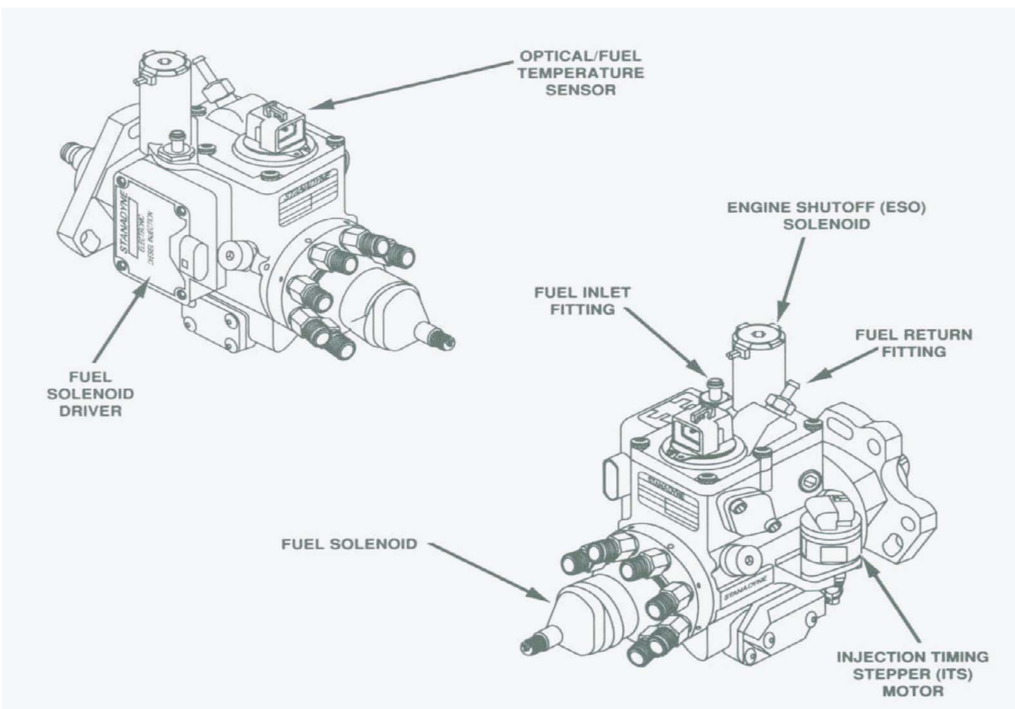


Figure 16-29, Stanadyne Model DS Electronic Fuel Injection Pump

The PCM-controlled injection pump is mounted on top of the engine, under the intake manifold. The pump is driven by the camshaft through two gears. One gear attaches to the front of the camshaft and the other attaches to the end of the pump shaft. Because these gears are the same size and have the same number of teeth, the injection pump shaft turns at the same speed as the camshaft.

Fuel Flow

Similar to other fuel delivery systems on diesel engines, fuel delivery on the 6.5L EFI power plant consists of four stages:

- Pressurization
- Distribution
- Metering
- Lubrication

Pressurization

Fuel is drawn from the tank by a lift pump. From the lift pump, fuel is carried to the transfer pump. The vane-type transfer pump located inside the injection pump varies the pressure of the fuel depending on the speed of the engine. At idle, the transfer pump outlet pressure is approximately 20 to 30 psi. At full engine speed, the transfer pump outlet pressure may be over 100 psi with a maximum of 125 psi.

A regulator valve controls transfer pump outlet pressure. The valve uses a viscosity-compensating orifice. This regulator valve is at the end of the hydraulic circuit rather than directly at the transfer pump. The pressure regulator valve spills fuel back to the transfer pump inlet.

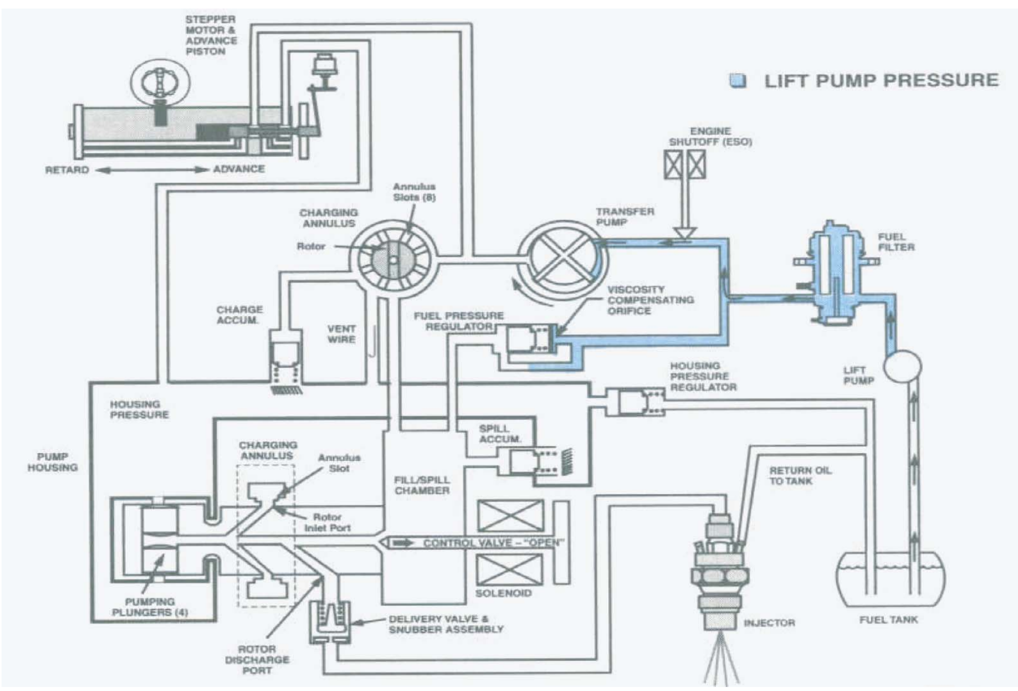


Figure 16-30, Fuel System Diagram - Pressurization

Distribution

Fuel pressurized at the transfer pump travels to the charging annulus. The annulus has eight slots. From the charging annulus, fuel is distributed to two places:

- The pump housing.
- The pumping plungers of the rotor.

Fuel delivery to the plungers is most important for the understanding of injection pump operation. Fuel reaches the plungers from two sources:

- The first is through two inlet ports in the rotor. As the rotor spins, these ports align with two of the eight annulus slots. Pressurized fuel passes from the slots through the rotor inlet ports. Passages in the rotor carry fuel from the ports to the plungers.
- The second source of fuel distribution to the plungers occurs at the front of the rotor, in the fill/spill chamber. Fuel enters through the open control valve. The valve's movement is controlled by the fuel solenoid. When the solenoid is off, the spool-type control valve unseats to allow fuel to pass through.

Fuel in the rotor is metered for delivery to the injection nozzles.

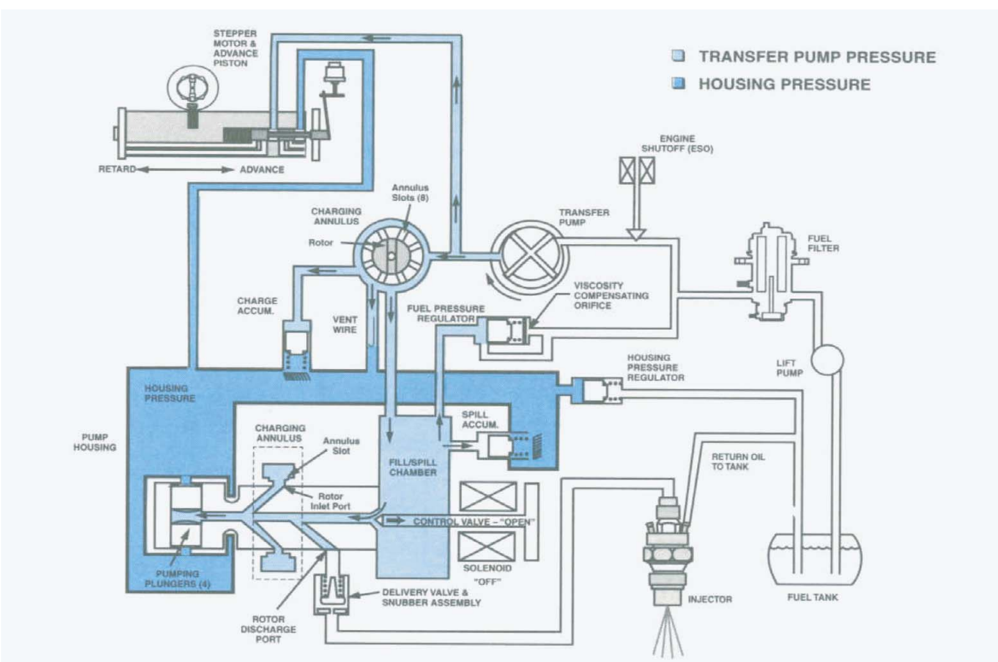


Figure 16-31, Fuel System Diagram - Distribution

Metering

Metering is a four-stage process consisting of:

1. Fill
2. End of fill
3. Pumping
4. Spill

These stages are the result of changes in cam ring, plunger, and control valve positions. The plungers are housed in the rotor. A cam ring surrounds the plunger area of the rotor. The inner surface of the cam has eight lobes (high points) and valleys (low points).

The plungers don't directly contact the cam. Instead, there are four shoe/roller assemblies that ride on the cam's inner surface to reduce friction. The flat shoe surfaces contact the plungers. As the rotor spins, the shoe/roller assemblies rise and fall on the cam surface. When they do, the plungers move inward and outward. The in-and-out movement of the plungers pushes high pressure fuel to the injectors.

Metering occurs eight times in one revolution of the rotor. Each pair of inlet ports goes through the complete metering process once per revolution. The pumping chamber is always completely filled with fuel. Injection quantity is controlled by fuel spill at the end of injection.

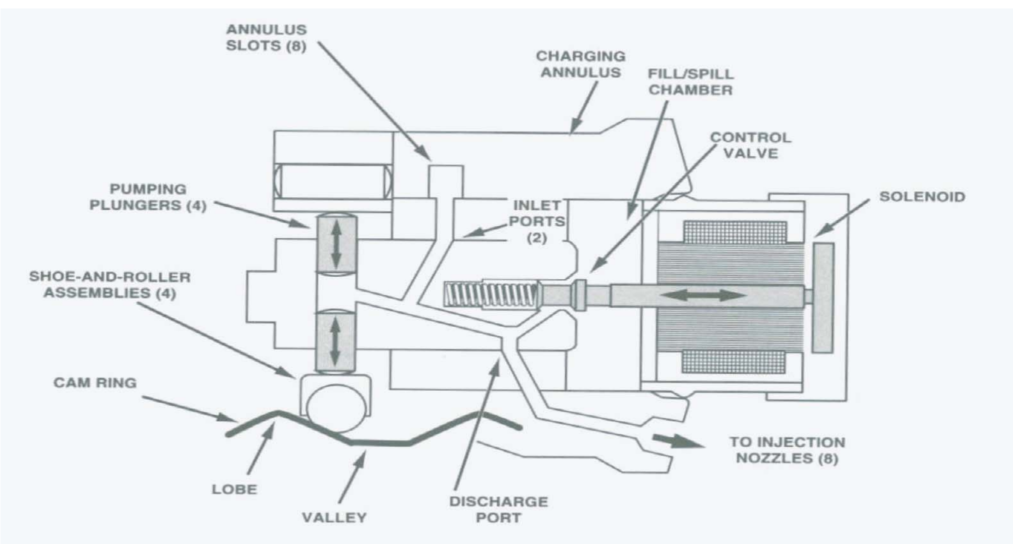


Figure 16-32, Pumping Chamber Components

Cam ring, plunger, and control valve activity at each metering stage are described on the following pages.

Fill

During fill:

- The two rotor inlet ports align with the charging annulus slots. This allows transfer pump pressure into the rotor passages.
- The fuel solenoid is off, releasing the control valve. Fuel passes around the valve head.
- The shoe/roller assemblies are entering the valleys of the cam, causing the plungers to move outward and fill with fuel.

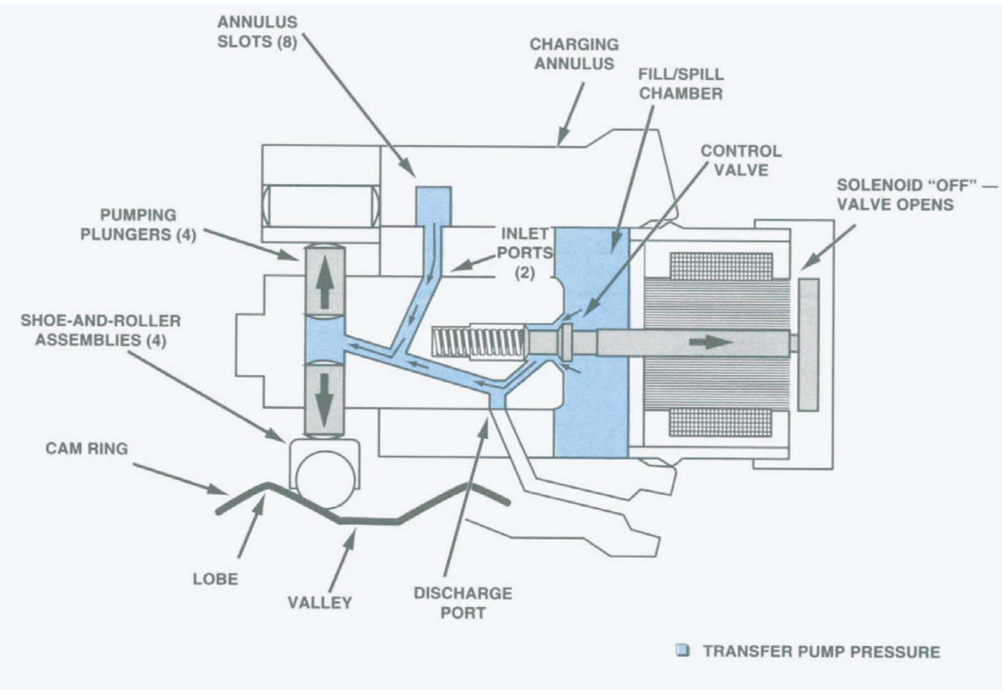


Figure 16-33, Fuel Metering - Fill

End of Fill

During end of fill:

- The rotor inlet ports are out of alignment with the annulus slots. Fuel is prevented from entering the rotor.
- The fuel solenoid energizes to close the control valve. Fuel cannot enter or exit around the control valve.
- The shoe/roller assemblies are in the valleys of the cam. As a result, the plungers are in the maximum outward position.

At the end of this stage, pressurized fuel is trapped in the rotor waiting to be sent to the injection nozzles.

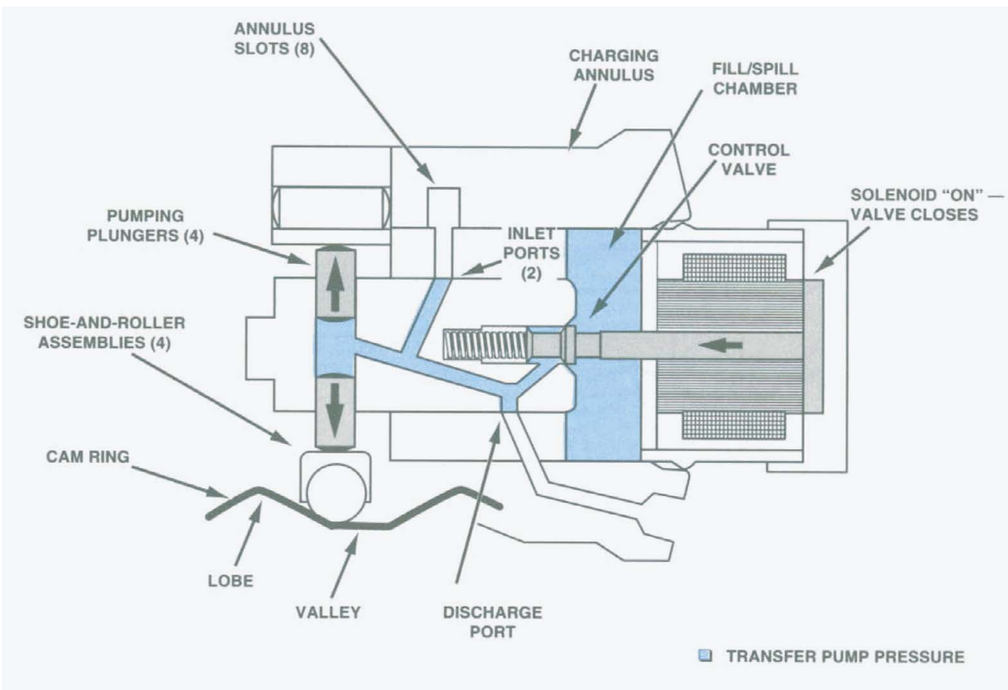


Figure 16-34, Fuel Metering - End of Fill

Pumping

During pumping:

- The shoe/roller assemblies begin up the next cam lobe ramp. This pushes the plungers inward creating high injection pressure (1500-1700 psi) that flows to the discharge ports.
- High fuel pressure in the injection pump and line overcome injector nozzle spring pressure and allow fuel to be injected into the pre-combustion chamber area.
- The solenoid remains energized to prevent fuel from escaping at the control valve opening.

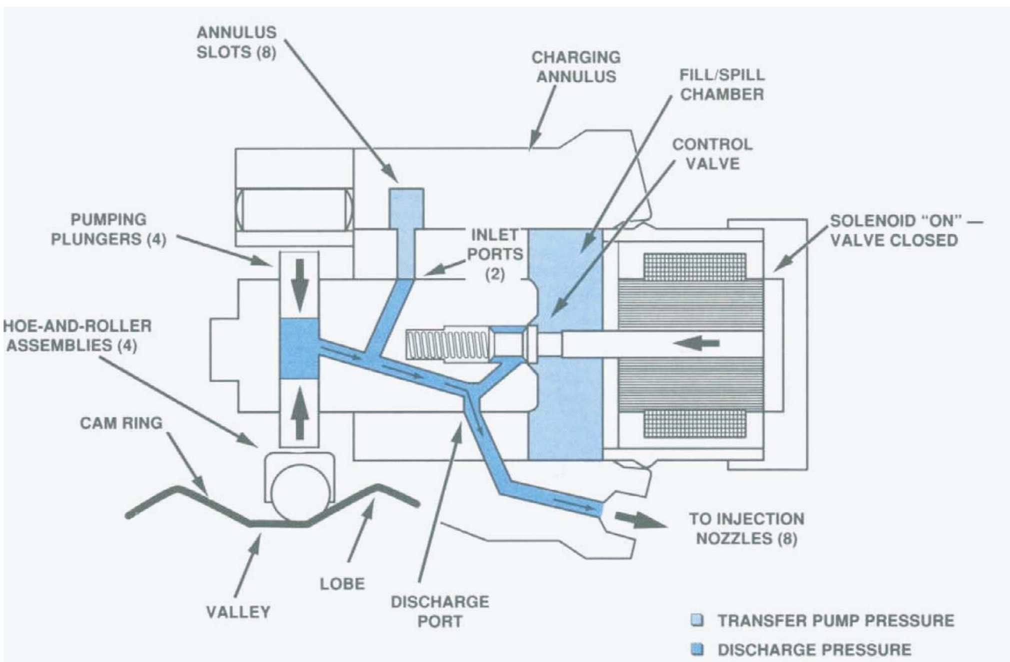


Figure 16-35, Fuel Metering - Pumping

Spill

Spill signals the end of injection. This is when the PCM controls the amount of fuel that is injected into each cylinder:

- The fuel solenoid, as commanded by the PCM, de-energizes. This opens the fuel control valve. Excess fuel spills out the control valve opening and returns to the fill/spill chamber.
- Fuel from the injection lines spills back into the rotor through the discharge ports. Near the end of the spill cycle, the rotor spins to close the discharge ports.
- The shoe/roller assemblies are at the top of the cam lobe which forces the plungers in the maximum inward position.

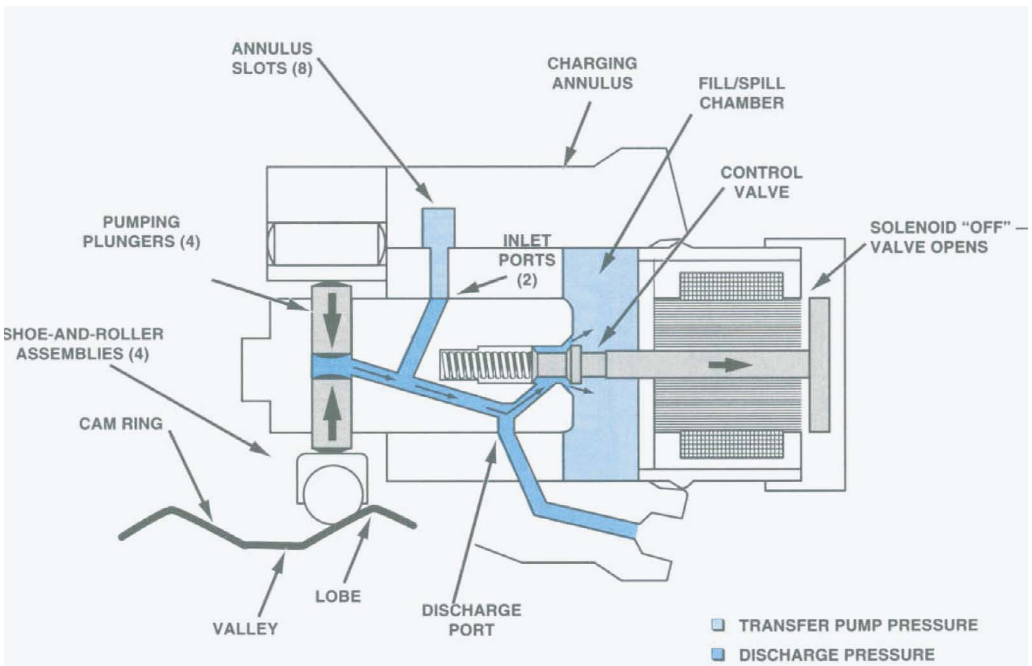


Figure 16-36, Fuel Metering - Spill

Note: Keep in mind that all of these things happen for every cylinder and they happen very quickly

Lubrication

The outlet of the transfer pump connects to a threaded restrictor known as the vent wire assembly. The assembly includes a wire with hooked ends. The vent wire assembly is a restriction with a vibrating wire in its orifice that causes a drop in pressure and reduces air bubbles in the fuel.

Fuel passing through the vent wire assembly flows inside the pump housing to cool and lubricate most of the injection pumps internal components. This fuel is under pressure which is controlled by the housing pressure regulator. The housing pressure regulator maintains enough pressure to ensure that fuel moves around and between the parts that need to be cooled and lubricated.

Fuel exits the housing by going around the housing pressure regulator and returning to the tank through the fuel tank return line.

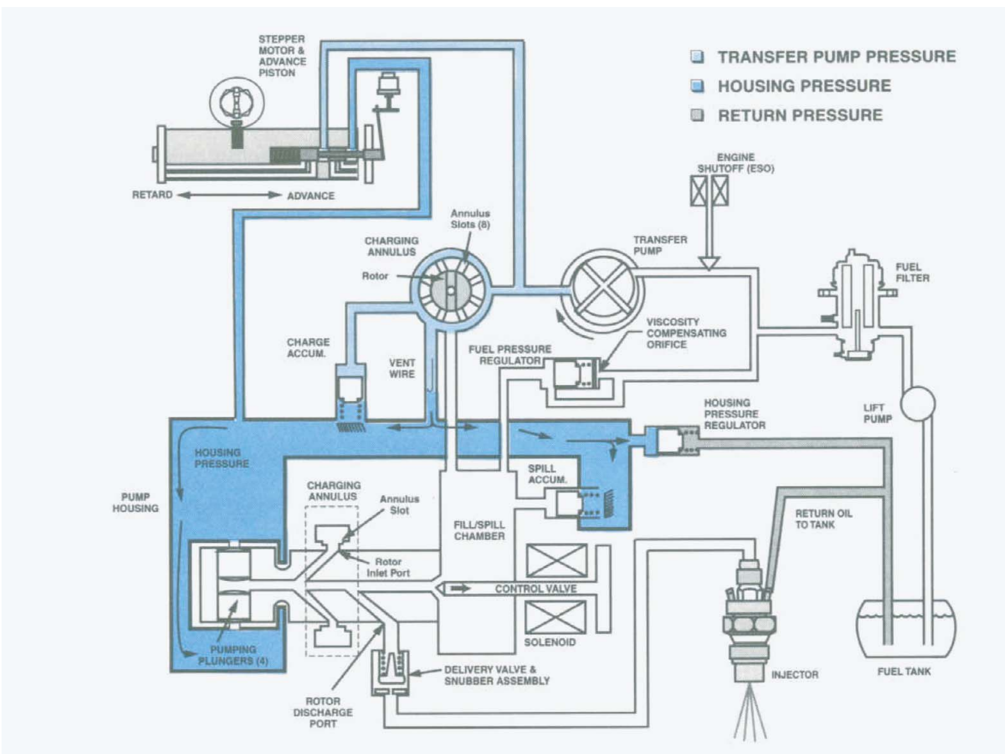


Figure 16-37, Fuel System Diagram - Lubrication

Injection Timing

Timing on the electronic pump is managed by the injection timing stepper motor. It uses a sliding piston that connects to the cam ring with a pin. The stepper motor controls the position of the advance piston servo valve. This valve controls the flow of pressurized fuel which causes the piston to move. As the piston slides in its housing bore, it causes the pin to rotate the cam ring and changes injection timing.

There is an outlet passage from the charging annulus to the advance piston. The pressurized fuel in this passage is used to move the advance piston. There are also drain passages in the piston housing.

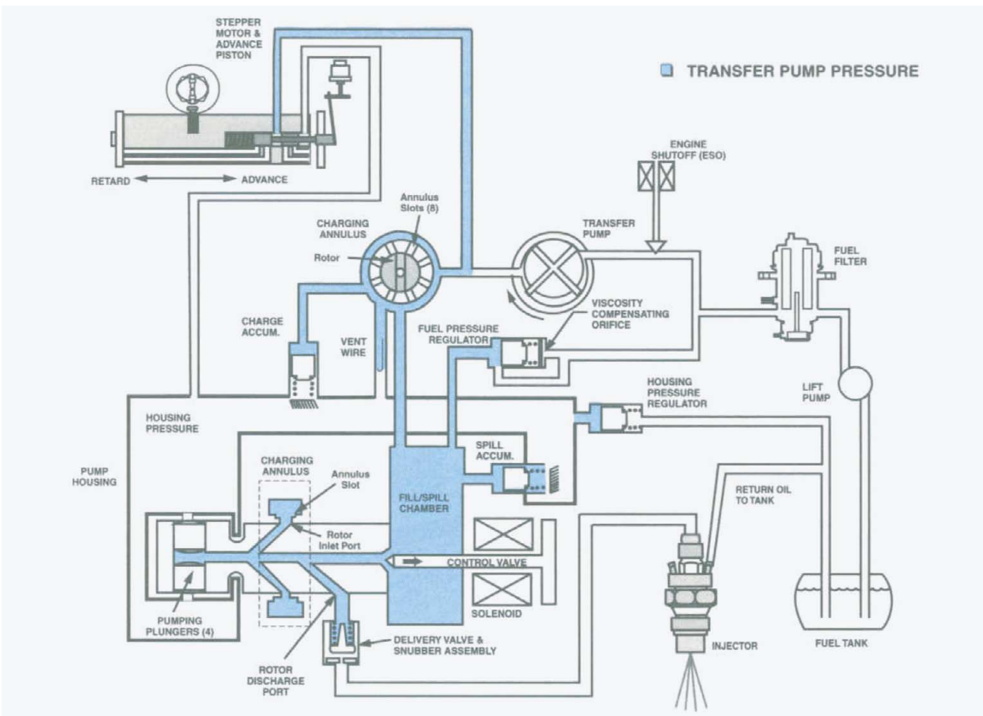


Figure 16-38, Fuel System Diagram - Timing

Stepper Motor/Advance Piston Components

The mechanical advance/retard components of the stepper motor and piston assembly include:

- Lever Spring (Motor Activated)
- Pivot Shaft
- Control Lever
- Servo Valve
- Cam Pin
- Advance Piston
- Servo Valve Return Spring

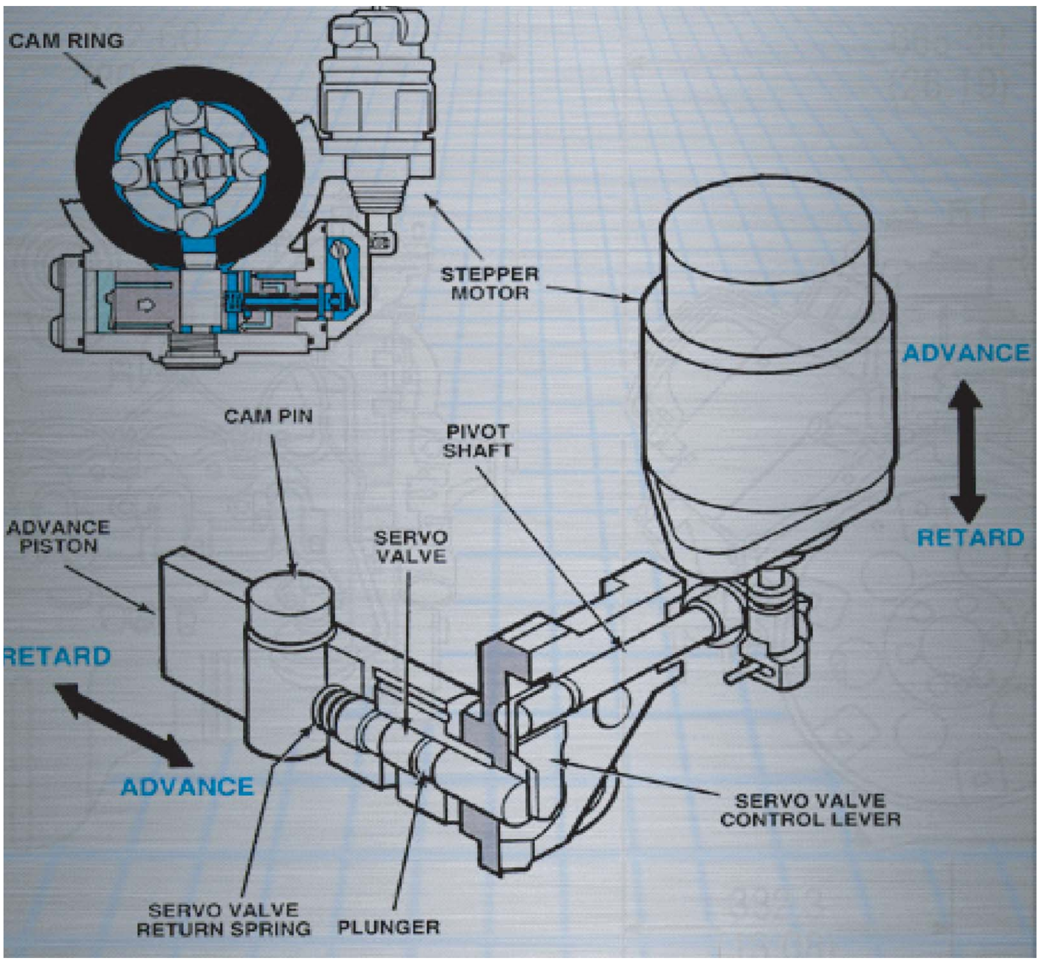


Figure 16-39, Injection Timing Stepper Motor/Advance Piston Components

Advance Piston Operation

The advance piston uses fuel pressure that is generated by the transfer pump to move and hold the cam ring. Advance and retard are accomplished in the following ways:

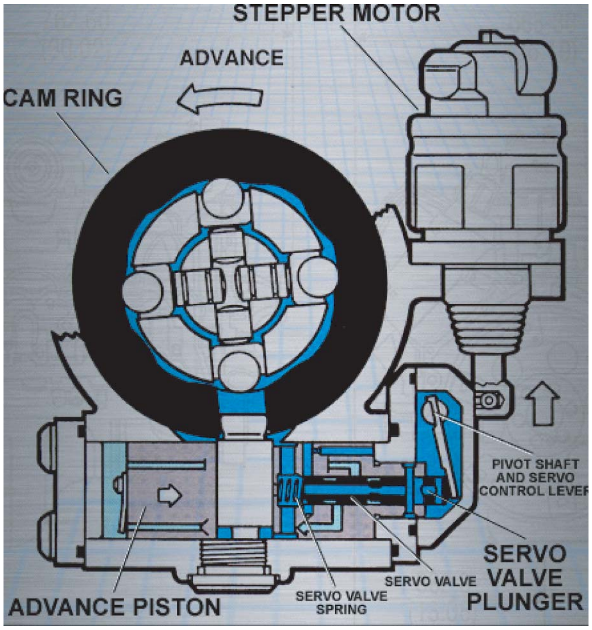


Figure 16-40, Piston Operation - Advanced

- In advance mode, the stepper motor arm retracts in steps. This causes the pivot shaft to rotate. As it does, it swings the paddle-like control lever away from the servo valve. Spring pressure pushes the valve off the advance passage. Pressurized fuel enters the advance passage and pushes the advance piston in the advanced direction.

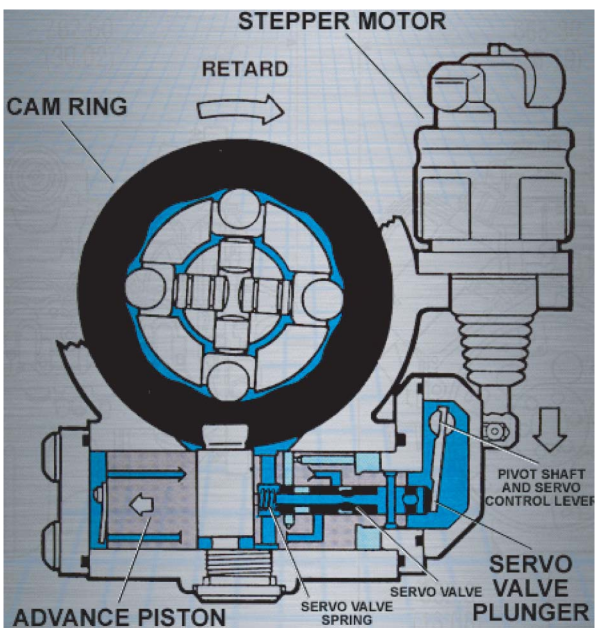


Figure 16-41, Piston Operation - Retard

- In retard mode, the stepper motor arm extends downward. This rotates the pivot shaft in the other direction, causing the control lever to press on the servo valve to overcome spring pressure. The valve opens the drain passages but blocks the advance passage. The lack of pressure at the piston causes it to move in the retarded direction.

Injection Lines

The high-pressure discharge fittings on the head of the injection pump connect to the injection nozzles with steel lines of equal length and interior volume for precise fuel delivery. The ends of the injection lines have special fittings and nuts.

When the engine is not running fuel is contained in the injection lines. During operation a residual pressure of approximately 500 psi is maintained in each injection line. As injection occurs in each line a small amount of fuel enters the line. This creates a pressure wave that pushes a similar amount of fuel into the nozzle at the other end of the line.

Diesel engines require a much higher fuel pressure than that of gasoline engines due to the fact that fuel is injected into the cylinder against several hundred pounds of compression pressure initially and even higher pressure once combustion begins. Therefore, the high pressure fuel lines are made of seamless steel tubing and must be replaced and not repaired when service is required.

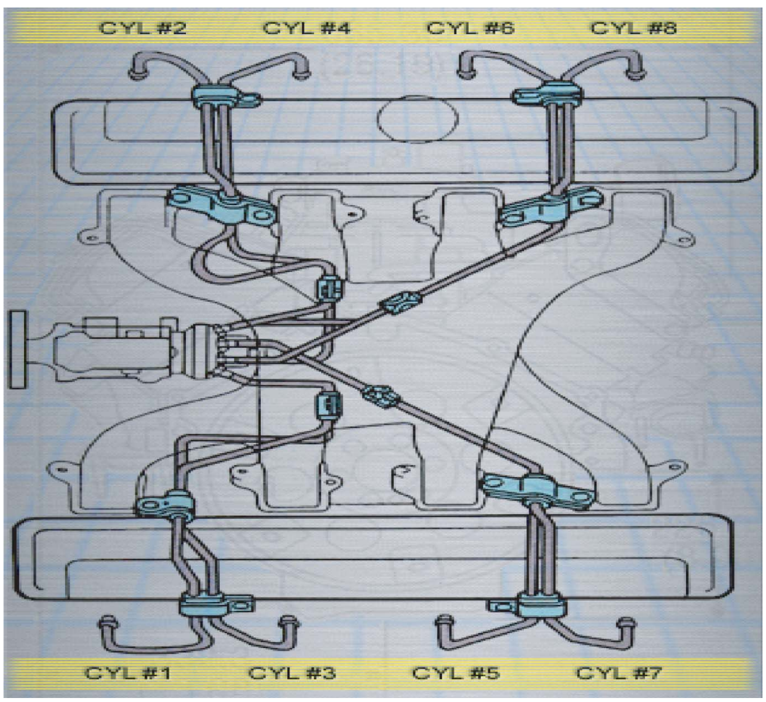


Figure 16-42, Injection Lines

Caution:

Diesel fuel injection systems operate under very high fuel pressure. You should never open a line with the engine running and you should always wear eye protection around a running engine.

Injection Nozzles

Each cylinder has an identical fuel injection nozzle mounted in the pre-combustion chamber. The nozzles are secured with threads and copper sealing gaskets to ensure long-term seating and durability under high-pressure operation.

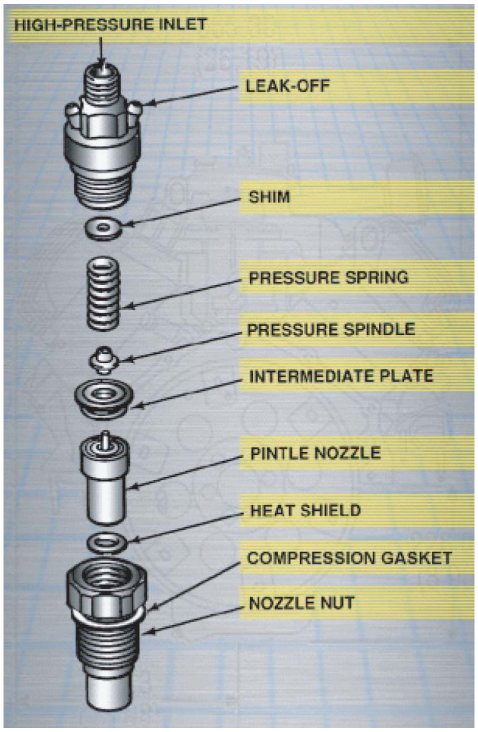


Figure 16-43, Injector Nozzle Components

Each nozzle consists of a two-piece body. The upper body element includes the high-pressure inlet and a pair of leak-off ports. The lower body element consists of the nozzle nut. Each nozzle body houses the following components:

- A selective shim.
- A pressure spring.
- A pressure spindle.
- An intermediate plate.
- A pintle nozzle.
- A heat shield.

As the pressure wave of injection reaches a nozzle the needle valve is lifted by fuel pressure against spring force and fuel exits into the pre-combustion chamber of the cylinder as an atomized spray.

A small amount of fuel also travels between the needle valve and pintle nozzle to provide lubrication. Two passages inside the upper half of the nozzle body allow fuel that has lubricated the needle valve to exit into the fuel return system. Fittings on the nozzle connect with hoses and clamps to the return system pipes.

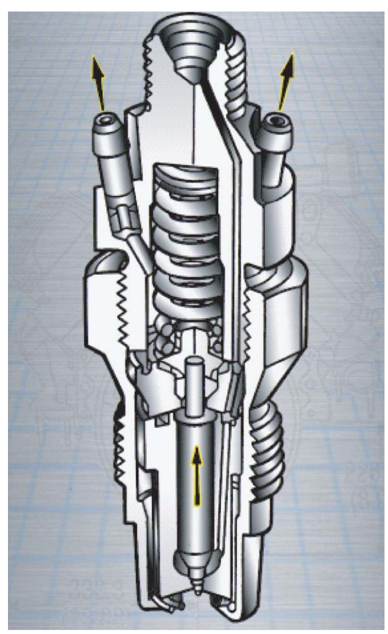


Figure 16-44, Injector Assembly

Fuel Return System

The fuel return system uses the following hoses and pipes:

- The two-stage housing pressure regulator is connected to the return system by a hose and two clamps.
- Injection nozzles are connected to each other and then to a return pipe by short lengths of hose.
- The rear fittings of nozzles for cylinder 7 and 8 have caps and clamps.
- The return hoses for cylinder injectors 1 and 2 connect to a center pipe.
- The injection pump return hose connects to the same center pipe as cylinders 1 and 2. The injection return hose also connects to a pipe mounted under the right side of the intake manifold.
- The return system pipe under the intake manifold connects to a series of hoses and pipes that send fuel back to the fuel tank.

During diagnosis of the injection pump, the return system should be checked for restrictions. Any blockage in the path of fuel leaving the injection pump will cause housing pressure to increase, which will greatly affect the performance of the engine.

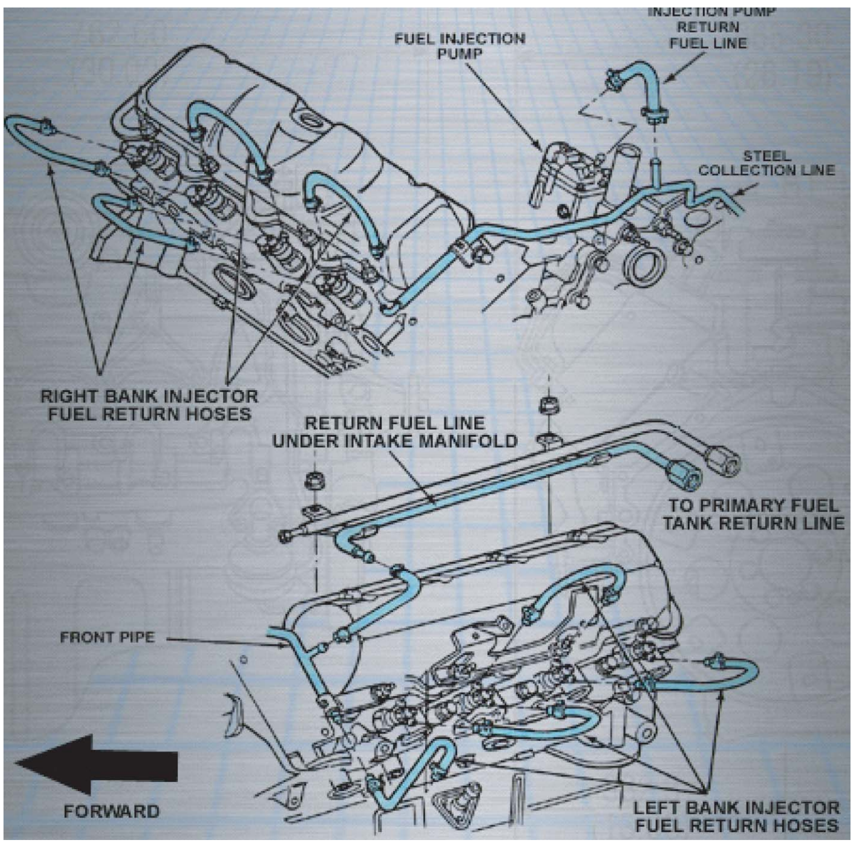


Figure 16-45, Fuel Return System

Exercise 16-3

Read each question carefully and choose the most correct response.

1. The fuel heater is located _____________________.
   a. In the injection pump
   b. In the fuel filter element
   c. In the lift pump
   d. In the fuel filter housing

2. The fuel filter assembly is located _____________________.
   a. On the left frame rail
   b. On the front of the intake manifold
   c. At the rear of the intake manifold
   d. In the fuel tank

3. Fuel is used to lubricate the injector components and then exits to the _____________________.
   a. Return system
   b. Lift pump
   c. Fuel filter
   d. Injection pump

4. The fuel solenoid releases fuel pressure during the __________ stage.
   a. Fill
   b. End of fill
   c. Pumping
   d. Spill

5. Water is separated from the fuel in the _____________________.
   a. Lift pump
   b. Injection pump
   c. Fuel filter housing
   d. Injectors

GM ASEP BSEP

Exercise 16-3 (continued)

6. During operation, a residual pressure of approximately _______ psi is maintained in the injection lines.
   a. 250
   b. 500
   c. 750
   d. several thousand

7. If the fuel return system is blocked, what will result?
   a. Engine will run normally
   b. The lift pump will shut off
   c. Housing pressure will increase
   d. Nothing

Notes:

Lesson 4: Engine Management

In this lesson you will learn about the PCM operation, inputs, and outputs of the 6.5L diesel engine.

Objectives:

- Identify and understand PCM operation
- Identify inputs and outputs for PCM control
- Understand the use and operation of input sensors
- Understand the operation of output functions

At the end of this lesson there will be a short exercise.

PCM Overview

The Powertrain Control Module (PCM), located in the passenger compartment, controls the EFI system.

Internally, the PCM is programmed with calibration information specific to the vehicle. This program tells the PCM what the normal operating parameters are for fuel delivery, timing, emissions control, and transmission control for automatic transmissions.

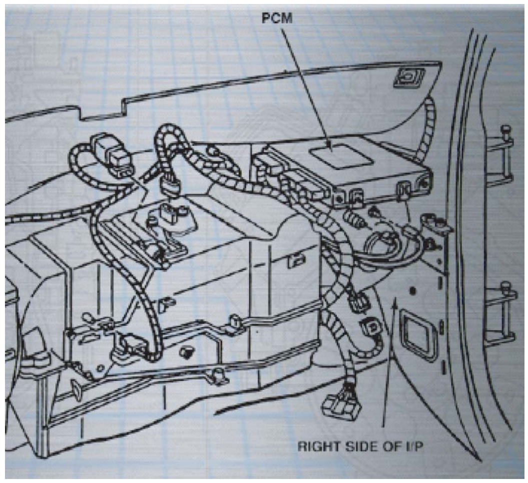


Figure 16-46, PCM Location

Externally, the PCM is hard-wired to numerous sensors known as inputs, as well as to solenoids, relays and indicator lamps, known as outputs.

The PCM constantly receives and interprets information from the inputs. It processes this information and compares it to the nominal values with which it is programmed. The PCM then either sends or inhibits electrical responses to output devices in order to control fuel delivery, timing, and other emission control systems.

The input-output relationship within the PCM isn't one-to-one. The information from a particular input might be used as part of the PCM's decision making for several outputs. For this reason, if one input fails it can affect the operation of more than one system. Understanding these relationships can improve your diagnostic skills.

When input data doesn't correspond to PCM parameters or when output devices don't respond as they should, one or more Diagnostic Trouble Codes (DTCs) can be set. These codes are stored in the PCM memory. Under many code conditions the PCM will substitute default values that provide the driver with vehicle operation.

Using the on-vehicle Data Link Connector (DLC) and a "Scan" tool, a technician can access stored codes in order to determine the causes of a driveability condition. DTCs are designed so that each one relates to a specific component or system. By using the DTC's corresponding diagnostic trouble-tree chart in Service Information, a technician can systematically pinpoint and correct the condition.

Note: The PCM has a learning ability that allows it to make corrections for minor variations in the fuel system to improve driveability. If the battery is disconnected for repairs, the learning process resets and begins again. A change may be noted in the vehicle's performance. To "teach" the PCM, ensure that the engine is at operating temperature. The vehicle should be driven at part throttle with moderate acceleration and idle conditions until normal performance returns.

PCM Control

PCM control can be divided into eight subsystems:

- Fuel control
- Timing control
- Glow plug control
- Boost control
- EGR control
- Cruise control
- Transmission control
- Diagnostic request

We will only be discussing the engine management related systems in this course. The operation of many of these systems is similar to gasoline fuel injection systems, so not a lot of detail will be involved with some of the descriptions.

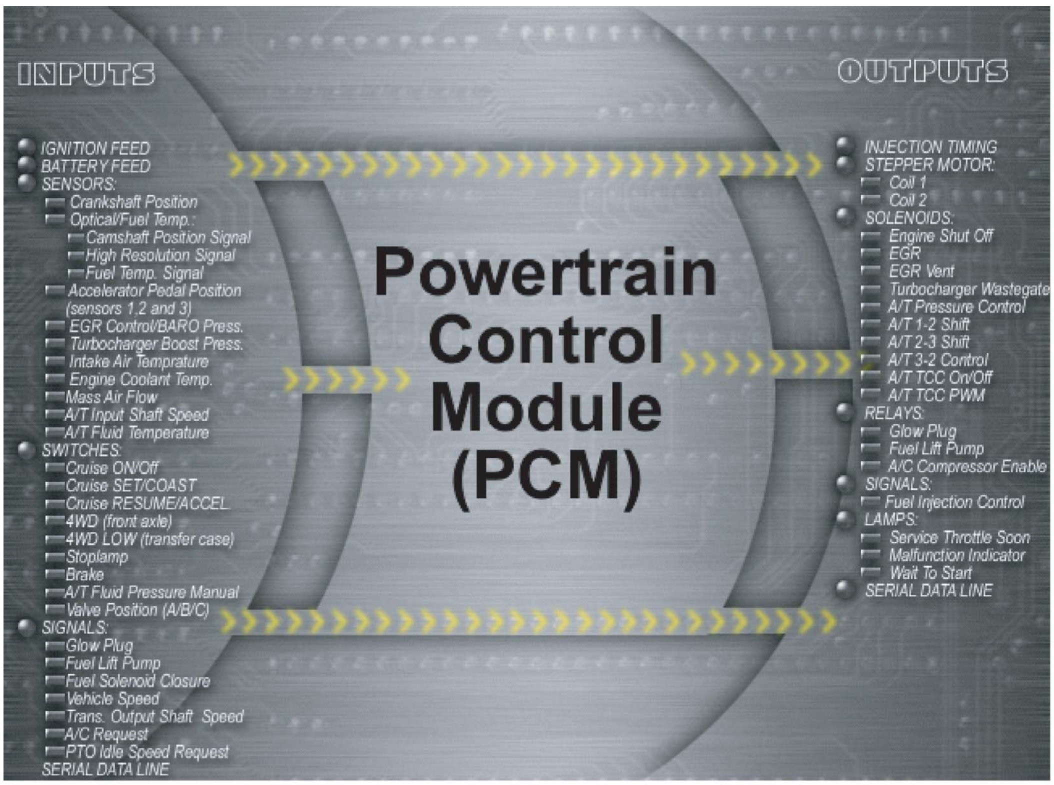


Figure 16-47, PCM Inputs and Outputs

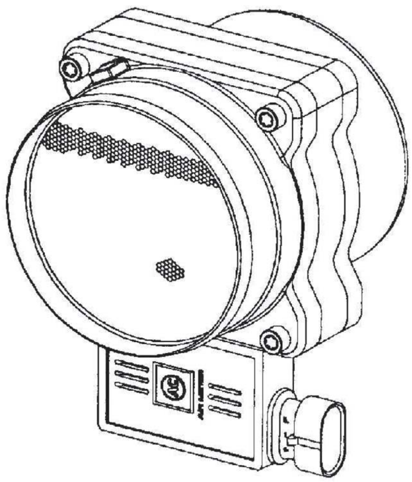


Figure 16-48, Mass Air Flow Sensor

Mass Air Flow Sensor Description and Operation

A mass air flow sensor was added to the 6.5L EFI diesel engine in 1997 and newer vehicles equipped with EGR. The mass air flow (MAF) sensor measures the amount of air which passes through it. The PCM uses this information to determine the operating condition of the engine and to control EGR operation. A large quantity of air indicates acceleration. A small quantity of air indicates deceleration or idle.

The scan tool reads the MAF value and displays it in Grams per Cylinder, Grams per Second (gm/s), and Hertz (Hz). Values should change rather quickly on acceleration but should remain fairly stable at any given RPM. When the PCM detects a malfunction in the MAF sensor circuit, one of three DTCs can set.

Engine Coolant Temperature (ECT) Sensor Description and Operation

The Engine Coolant Temperature (ECT) sensor is mounted in the engine coolant stream. The PCM uses coolant temperature as an indicator of engine temperature. The operation of the ECT circuit is the same as GM gasoline engine vehicles.

The ECT sensor receives a 5 volt signal from the PCM. ECT sensor resistance changes inversely according to temperature. Low coolant temperature causes high sensor resistance, which results in higher voltage as seen by the PCM.

The ECT is an important input to the PCM because coolant temperature is used to determine the operation of most systems controlled by the PCM.

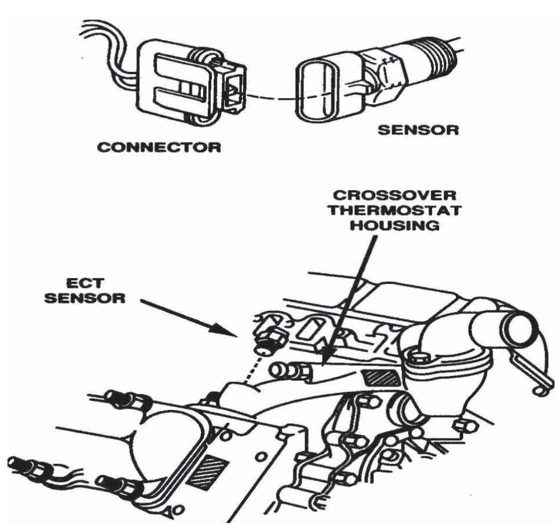


Figure 16-49, Engine Coolant Temperature Sensor

Intake Air Temperature Sensor Description and Operation

The Intake Air Temperature (IAT) sensor is mounted in the intake manifold. Like the ECT sensor, the IAT is a thermistor that changes value based on temperature.

The intake air temperature sensor receives a 5 volt signal from the PCM. IAT sensor resistance changes inversely according to temperature.

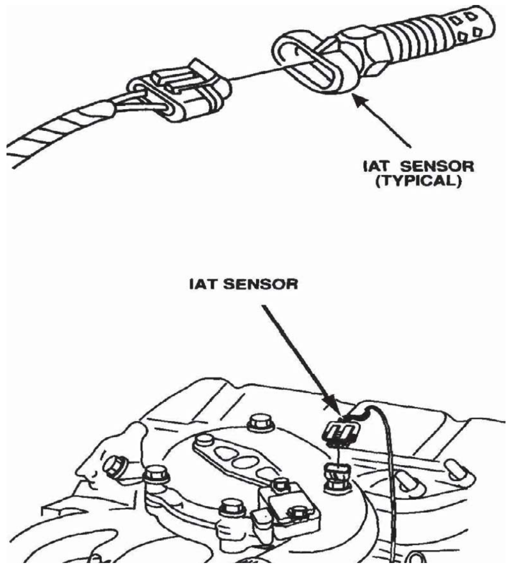


Figure 16-50, Intake Air Temperature Sensor

The PCM uses the IAT sensor signal to adjust fuel delivery according to incoming air temperature. The IAT shares a common ground with the ECT sensor, crankshaft position sensor, and boost sensor.

Accelerator Pedal Position Module Description and Operation

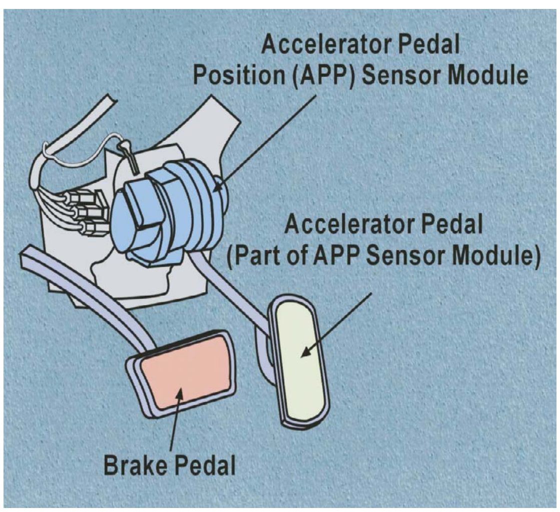


Figure 16-51, Accelerator Pedal Position Sensor

The 6.5L EFI PCM uses Accelerator Pedal Position (APP) sensors to control fuel delivery as requested by driver demands at the accelerator pedal. Three APP sensors are located in a module at the base of the accelerator pedal.

The APP module replaces the throttle linkage found on non-EFI 6.5L diesel engines. While it was new to GM diesel engines, similar "drive by wire" technology has been in use for several years on diesel engines from other manufacturers.

The APP sensors are each potentiometer type sensors similar to a TPS. Each sensor receives its own 5 volt reference signal from the PCM. The PCM provides a ground for each sensor to complete the circuit.

Accelerator Pedal Position Module Description and Operation (continued)

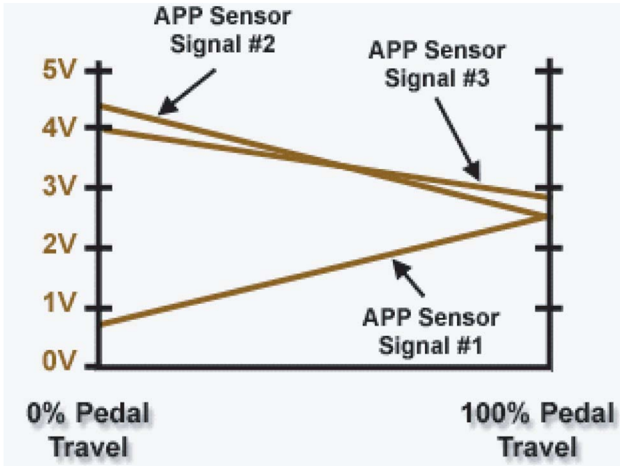


Figure 16-52, APP Voltage Output

Resistance in each sensor changes as the accelerator pedal is depressed. By monitoring the output voltage from the APP module, the PCM can calculate proper fuel delivery as required by acceleration needs. Each of the three sensors produces varying voltage at different levels. The PCM compares all of these signals with each other to ensure accuracy of each signal. A fault with the APP system could result in the illumination of the STS lamp and reduced engine power.

Optical Sensor Description and Operation

The optical sensor is located in the fuel injection pump and includes the fuel temperature sensor. It operates by using an infrared light and optical sensor. As the light is blocked and un-blocked by the disc, signals are generated by the optical sensor. The optical sensor sends the pulses emitted by the disc in the injection pump to the PCM. The disc is a silver-colored film-like ring with two sets of notches:

- The outer diameter consists of 512 notches that provide the PCM with pump speed information. (256X signal)
- The inner diameter uses eight notches, one for each cylinder, to send cam reference information. (4X signal)

The high resolution sensor (256X) generates 64 equally spaced pulses per cylinder combustion stroke from the slotted disc mounted on the injection pump timing cam ring. The pulses are counted by the PCM and used to measure the angular pump displacement. Fuel is metered by using the angular indication and timing is measured by counting the angular pulses between the pump cam signal and the crankshaft position sensor signal.

The pump cam signal (4X) generates one pulse per cylinder combustion stroke from a slotted disc mounted on the injection pump timing cam ring. The pulse is used to locate the start of injection event for each cylinder (i.e. timing) with respect to the crankshaft position sensor. The number one cylinder is identified with a wider pulse (larger slot in disc). The PCM uses this information to adjust idle fuel, timing, trigger real time events and is used in the diagnostics of the crankshaft position sensor and the high resolution circuit.

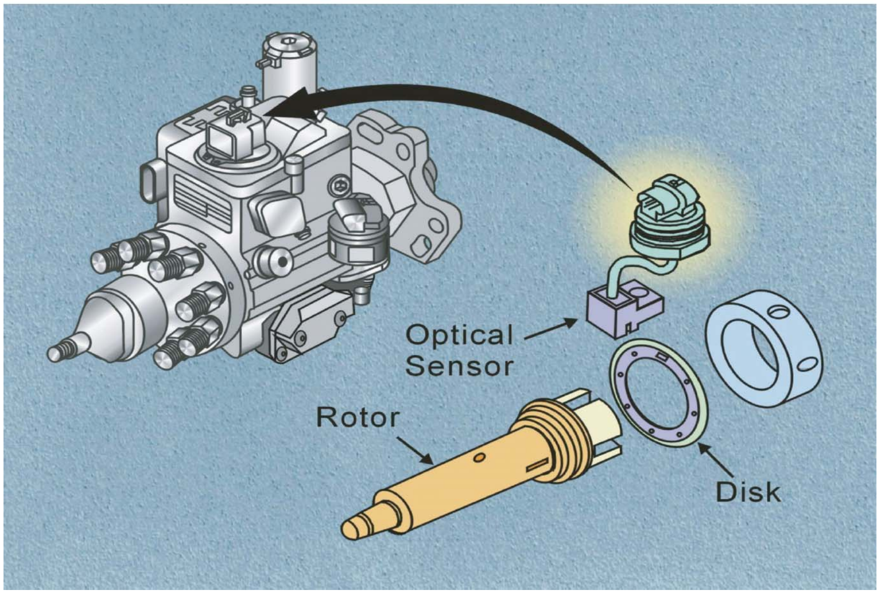


Figure 16-53, Optical/Fuel Temperature Sensor and Disc

The PCM sends a 5 volt reference signal to the optical sensor. The sensor returns two signals to the PCM: a high resolution signal and a cam signal. Both are regulated-current signals read by the PCM. The high resolution signal pulses 512 times per one revolution of the injection pump. The cam signal pulses 8 times per one revolution of the pump.

The signals are considered 256X and 4X because the pump is rotating at camshaft speed. The signals are actually counted by crankshaft revolution. One revolution of the crankshaft equals ½ revolution of the camshaft.

When the signal on either circuit to the PCM is out of calibration, the PCM sets a Diagnostic Trouble Code (DTC). Also, excessive air bubbles present in the fuel system can cause false signals to be generated by the optical sensor which may set a DTC or cause a driveability concern.

Fuel Temperature Sensor Description and Operation

The fuel temperature sensor is part of the optical sensor. It is a thermistor that controls signal voltage to the PCM. Voltage from the sensor will vary inversely to fuel temperature (i.e. high temperature equals low voltage; low temperature equals high voltage).

The PCM provides a reference signal to the fuel temperature sensor. As fuel temperature changes, the sensor will alter the strength of the voltage. Through monitoring, the PCM knows fuel temperature and can take this into consideration when determining fuel delivery rates. Fuel temperature relates to fuel viscosity, which can affect fuel delivery rates.

Crankshaft Position Sensor Description and Operation

The crankshaft sensor is located in the front cover. The sensor is positioned over the crankshaft sprocket and consists of a Hall-effect device and a magnet. The crankshaft sprocket has four teeth at 90° intervals. As the sprocket rotates, its teeth pass the sensor.

- When no teeth of the sprocket are in alignment with the sensor, the sensor's magnetic field passes through the Hall-effect device. This causes the device to turn "OFF," allowing the sensor signal line to the PCM to go high (5 volts).
- As a tooth of the crankshaft sprocket comes into alignment with the sensor, the magnetic field passes through the lower reluctance of the tooth instead of the Hall-effect device. This causes the device to turn "ON," which pulls the sensor signal line low (0 volts).

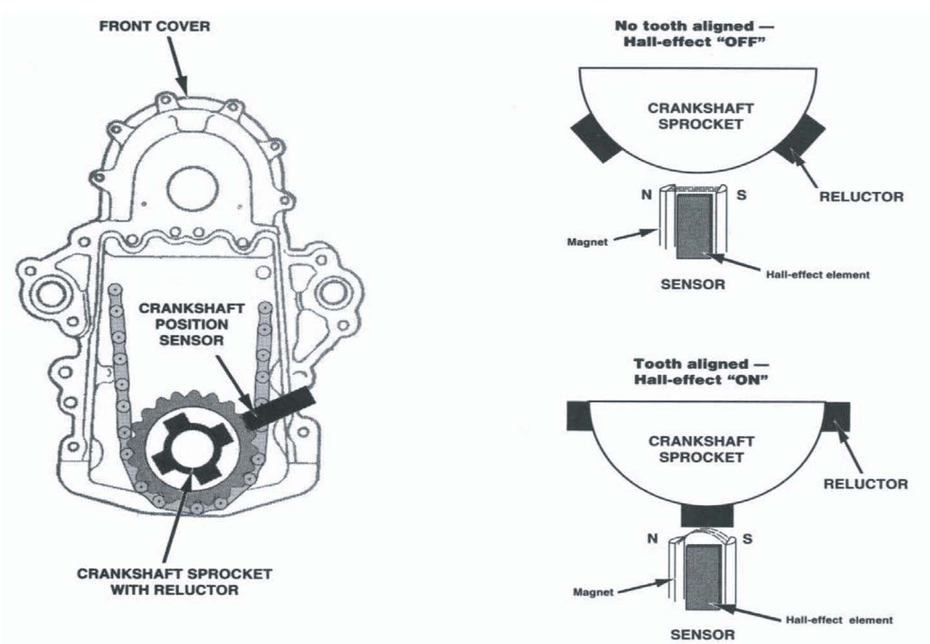


Figure 16-54, Crankshaft Sensor Operation

The crankshaft sensor high/low digital signal is monitored by the PCM to determine crankshaft/engine speed. If the crank signal is lost while the engine is running, the fuel injection system will shift to a calculated fuel injection mode based on the last fuel injection pulse and the engine will continue to run as long as there is a signal from the optical sensor.

The crank sensor signal is not only used for engine speed input, but it is also used for misfire diagnosis. The PCM watches acceleration and deceleration rates of each cylinder to determine if any cylinder is not contributing.

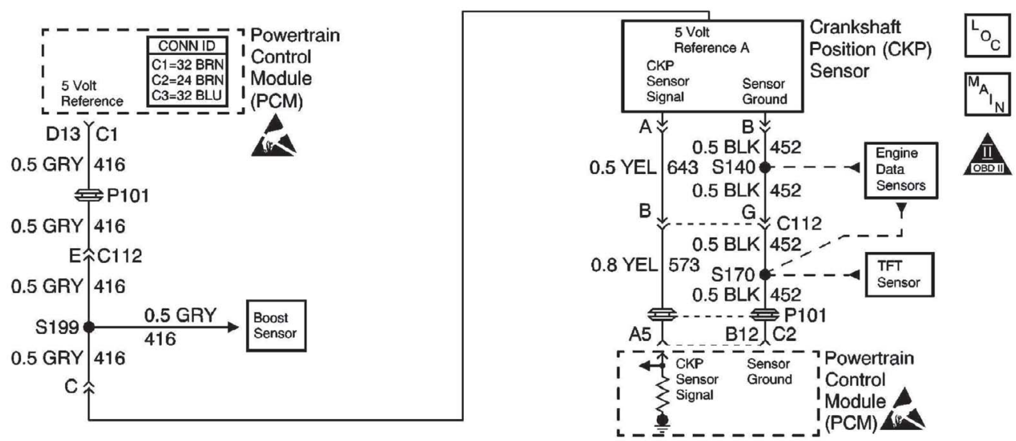


Figure 16-55, Crankshaft Sensor Circuit

The crankshaft position sensor is a Hall-effect device that receives a 5 volt reference signal from the PCM, which it shares with the boost sensor on turbo models. The sensor converts its changing magnetic field to a digital electrical signal and sends it to the PCM on the crankshaft position signal circuit.

The sensor shares a ground with the boost sensor, ECT sensor, and IAT sensor. It also shares a 5-volt reference signal with the EGR control pressure/baro sensor and boost sensor.

Boost Sensor Description and Operation

The boost sensor on turbocharged engines measures changes in intake manifold pressure and vacuum that occurs as a result of changes in engine load and engine speed. The sensor is a resistor that converts manifold pressure/vacuum into electrical signals:

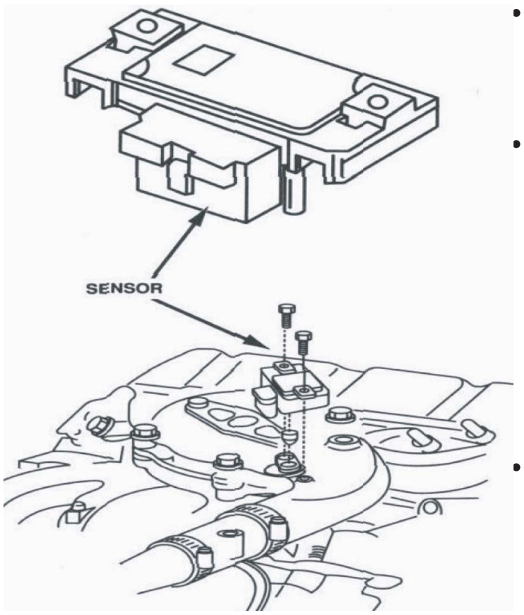


Figure 16-56, Boost Sensor

- At idle, the boost sensor displays approximately the same reading as the barometric pressure sensor.
- When the engine is at full load with wide open throttle (WOT), manifold pressure is high and vacuum is low. Under these conditions, boost sensor resistance is low. As a result, a high voltage signal is sent to the PCM telling it to deliver more fuel.
- Conversely, under low manifold pressure conditions, boost sensor resistance is high. This high resistance reduces the strength of the boost signal sent back to the PCM. The PCM then knows to deliver less fuel to the engine.

The PCM uses the boost sensor signal to determine how much pressure is being produced by the turbocharger. Boost pressure information is used to control fuel delivery and wastegate solenoid operation.

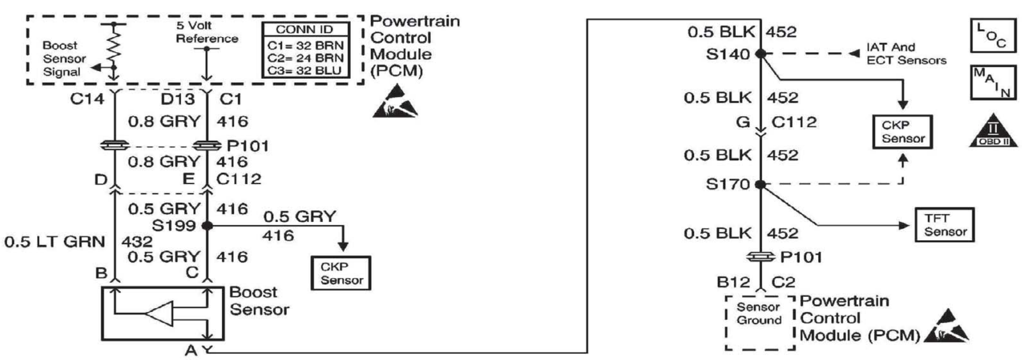


Figure 16-57, Boost Sensor Circuit

The boost sensor receives a constant 5 volt reference signal from the PCM. The sensor signal is sent back to the PCM as a boost signal.

EGR Control Pressure/Baro Sensor Description and Operation

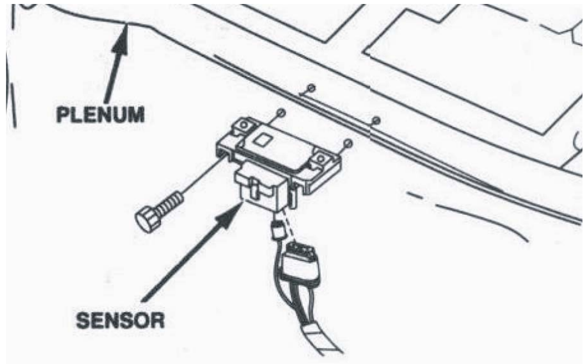


Figure 16-58, EGR Control Pressure/Baro Sensor

The EGR control pressure/baro sensor is mounted on the left side of the cowl. The sensor produces a voltage signal in proportion to the amount of absolute pressure in the EGR vacuum line. The PCM compares this actual signal to the desired EGR value it has calculated and makes minor corrections in EGR solenoid operation to compensate for the difference. If the difference between actual and desired EGR is too great for the PCM to correct, a diagnostic trouble code will set. The sensor also acts as Barometric pressure sensor. A Baro reading is taken on key up and when EGR is off.

The EGR control pressure/baro sensor receives a 5 volt reference signal from the PCM. This reference signal is shared with the crankshaft position sensor and boost sensor. Based upon EGR vacuum, the sensor sends a signal back to the PCM.

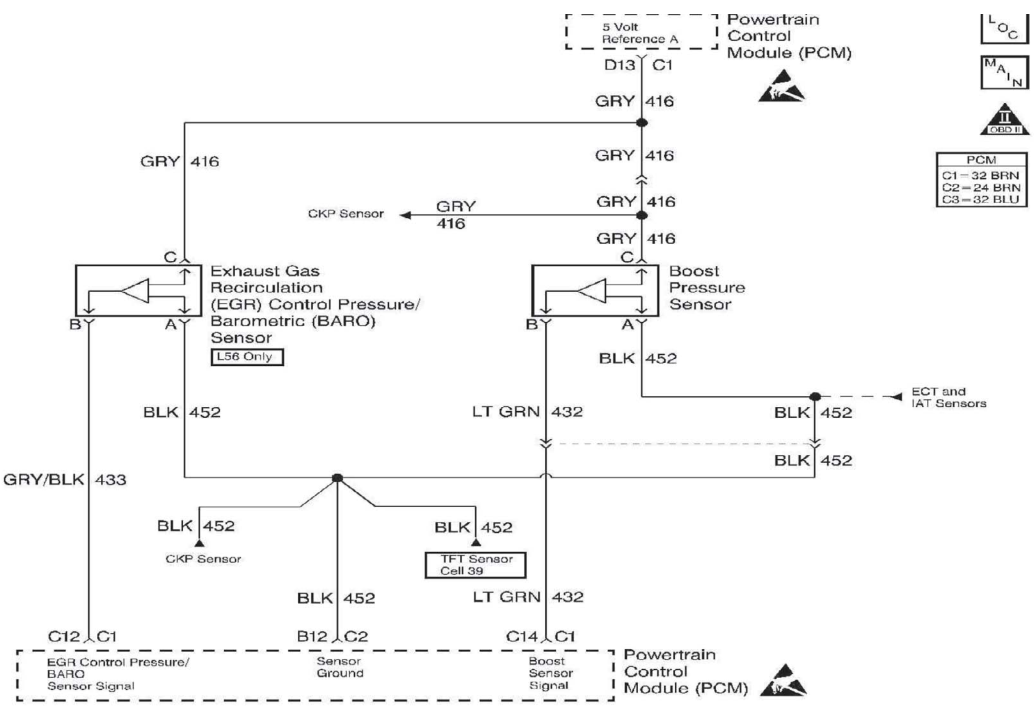


Figure 16-59, EGR Control Pressure/Baro Sensor Circuit

A/C Signal

This signal indicates whether or not the A/C compressor clutch is engaged. The PCM uses this signal to adjust the idle speed.

Cruise Control Switch

The cruise control switch is part of the multifunction turn signal lever. This switch enables the driver to control the cruise on/off, set/coast and resume/accel signals. These signals are inputs to the fuel control portion of the PCM which allow the PCM to maintain a desired vehicle speed under normal driving conditions.

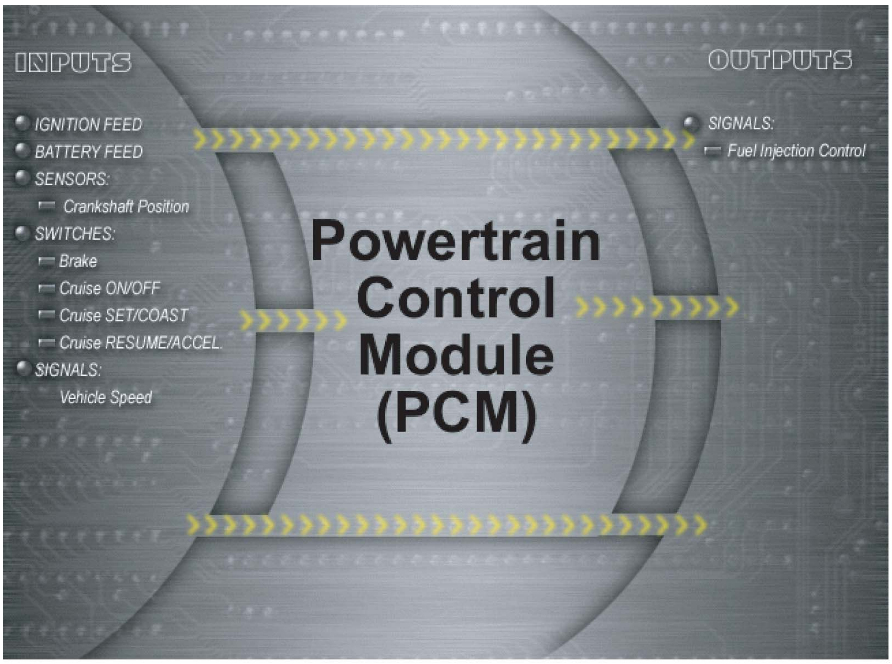


Figure 16-60, Cruise Control Inputs

Brake Switch and Clutch Pedal Position Switch

The PCM uses brake switch input information to interrupt cruise control operation when the brakes are applied. On vehicles equipped with manual transmissions, a clutch switch input is also used to interrupt cruise control operation.

Vehicle Speed Sensor

The vehicle speed sensor (VSS) signal is used by the PCM to determine speed governing operations, cruise control operation and automatic transmission control. On older models a VSS buffer module is used to interpret the VSS A/C signal and convert it into a digital signal that the PCM can use. Newer PCMs have an internal interface to convert the A/C signal.

PCM Outputs

Lift Pump Control

The electrical circuit for the lift pump involves several main components:

- A fuel pump relay.
- The PCM.
- The lift pump itself, mounted under the vehicle on the frame rail where the fuel filter on a gasoline vehicle would be located.
- The oil pressure switch/sending unit which is threaded into a lubrication system passage at the rear of the cylinder block.

When the key is turned to the ON position the PCM energizes the fuel pump relay for a 2 second prime. During cranking the PCM will also ground the fuel pump relay and continue to ground it while the engine is running. The oil pressure switch is used as a secondary power supply for the fuel pump in case of fuel pump relay failure. A minimum of 28 KPa (4 psi) is required to close the oil pressure switch contacts.

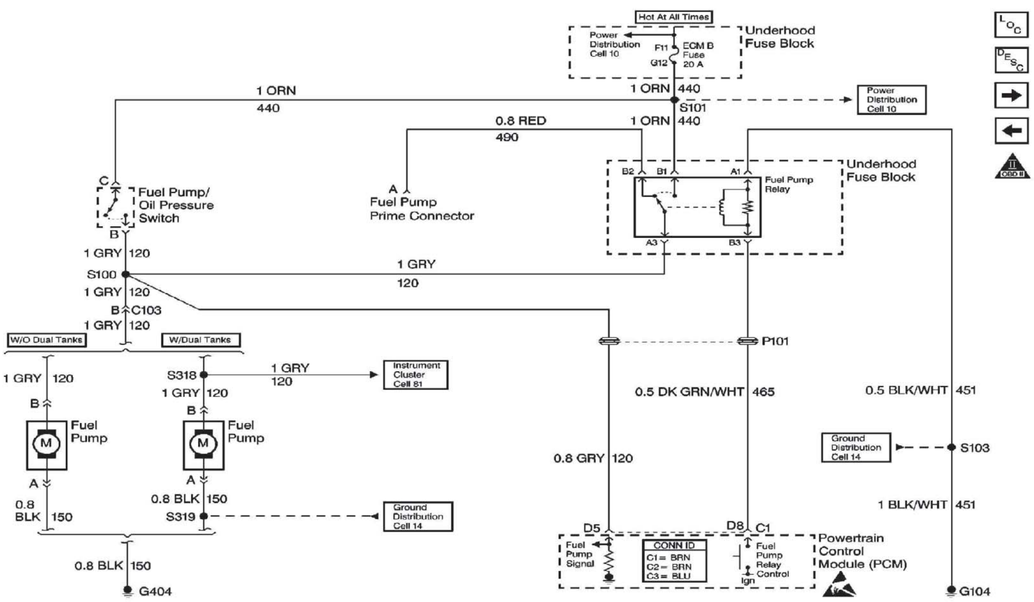


Figure 16-61, Lift Pump Control Circuit

When the ignition switch is returned to the RUN position, the oil pressure of the running engine maintains electrical power to the lift pump (up to and through 1995 trucks). If engine oil pressure drops below 28 kPa (4 psi), the engine may run poorly or stall when the lift pump circuit opens. 1996 to present trucks operate the lift pump through the fuel pump relay. The oil pressure switch is only a redundant power supply.

"Service Engine Soon" Lamp (MIL) Description and Operation

The malfunction indicator lamp (MIL) is in the instrument panel cluster. The MIL has the following functions:

- The MIL informs the driver that a fault that affects the emission levels of the vehicle has occurred and the owner should take the vehicle in for service as soon as possible.
- As a bulb and system check, the malfunction indicator lamp (MIL) comes on with the key "ON" and the engine not running. When the engine is started, the MIL turns off if no DTCs are set.

The PCM controls the lamp by providing a ground for the lamp. The lamp receives power from the ignition switch.

"Service Throttle Soon" (STS) Lamp Description and Operation:

The "Service Throttle Soon" (STS) in the instrument panel cluster alerts the driver to concerns in the accelerator pedal position (APP) circuit that require attention.

Under normal operation, the STS lamp illuminates when the ignition is "ON" and the engine is "OFF." The lamp comes on for approximately 2 seconds at key "ON" and turns off when the engine is started. If the lamp remains illuminated after the engine has started, a problem may exist in the STS or APP circuits. The appropriate diagnostics should be followed as directed by the OBD System Check.

The PCM illuminates the "Service Throttle Soon" lamp by providing a ground. The "Service Throttle Soon" lamp receives battery power through the ignition switch.

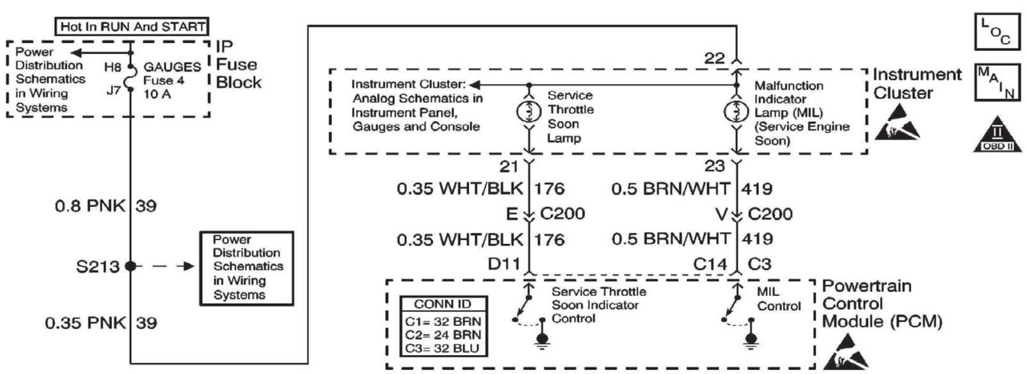


Figure 16-62, "Service Throttle Soon" Lamp Circuit

Cruise Control Operation

Operation of the cruise control is simple. The PCM is always in control of how much fuel is delivered to the injectors, so it simply maintains vehicle speed at the set point by controlling engine power output with the fuel control solenoid, which in turn controls vehicle speed.

Fuel Solenoid Driver Description and Operation

The Fuel Solenoid Driver is located on the left side of the injection pump. It is basically a slave of the PCM, much like many ignition modules used on gasoline engines. Because of the high amperage required to operate the fuel control solenoid, the PCM uses the remote driver instead of controlling the high amperage itself.

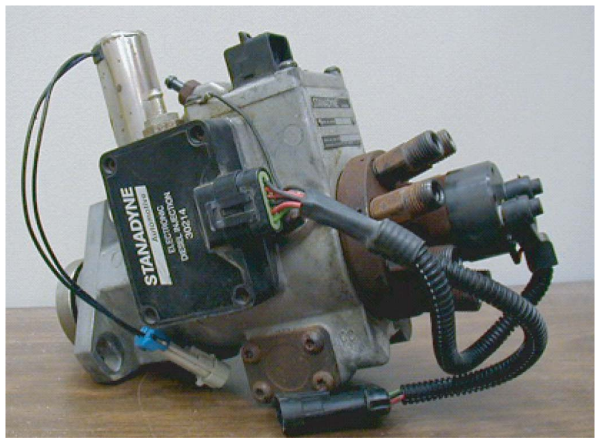


Figure 16-63, Injection Pump

The fuel solenoid driver receives an injection command signal from the PCM and then provides current-regulated output to the fuel solenoid, which controls fuel injection pump metering. The driver also returns an injection pulse-width modulated (PWM) signal back to the PCM. This signal tells the PCM when the fuel solenoid plunger seats. The PCM uses a calibrated injection pump-mounted resistor to determine fuel rates. The resistor value of the pump is stored in PCM memory. If the PCM's memory has been disrupted or the PCM has been replaced, it will relearn the resistor value on the next ignition cycle and store this value.

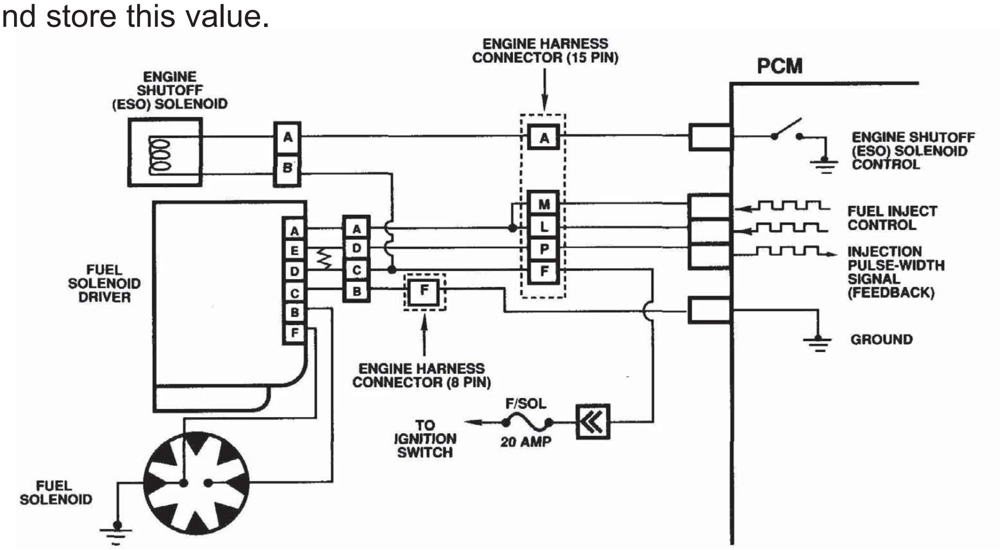


Figure 16-64, Fuel Solenoid Driver Circuit

ESO Solenoid Description and Operation

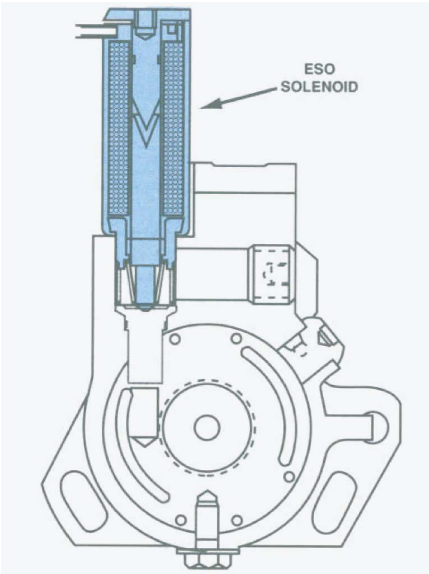


Figure 16-65, Engine Shutoff Solenoid

The Engine Shutoff (ESO) solenoid is located on the injection pump. When the ignition switch is "OFF," the ESO solenoid is in the "No Fuel" position. It prevents fuel from entering the injection pump from the filter. It can also be cycled on and off to prevent an engine over-speed condition.

The Engine Shutoff (ESO) solenoid receives power from the ignition switch. At ignition start-up, the PCM provides a ground for the solenoid. By providing a ground path, the PCM energizes the solenoid which then allows fuel to pass into the injection pump. The solenoid must remain energized by the PCM in order for the engine to continue running.

A fault with the ESO or its circuit will cause a stall or no start condition.

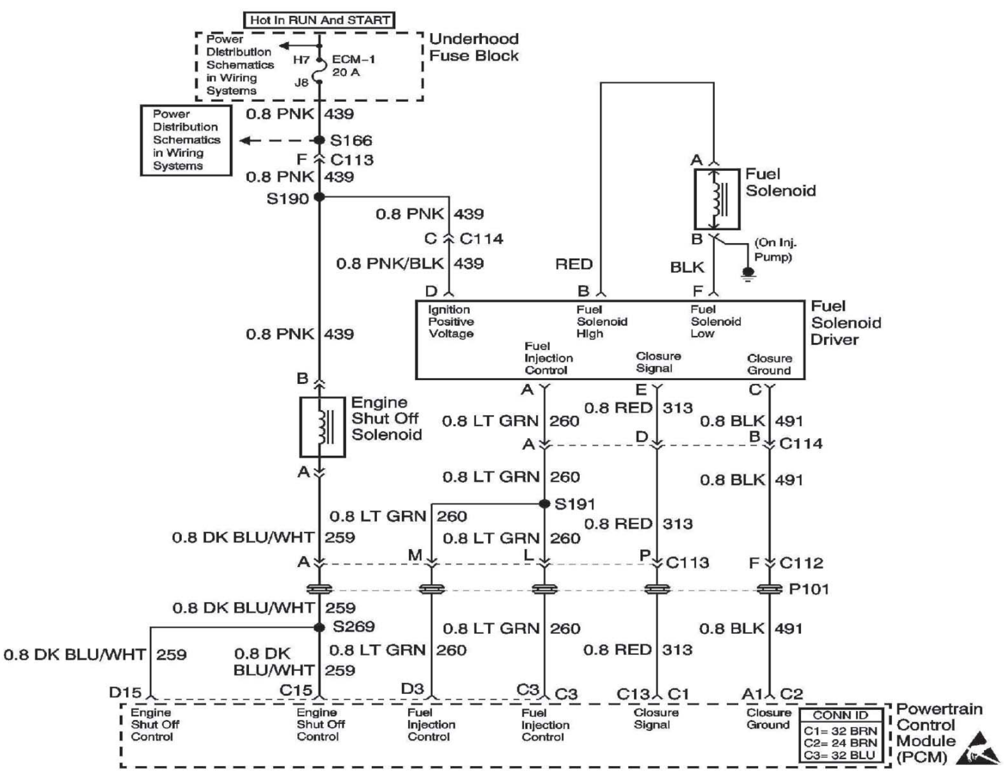


Figure 16-66, Engine Shutoff Solenoid Circuit

Injection Timing Stepper Motor Description and Operation

The injection timing stepper motor is located on the right side of the injection pump. The motor housing contains two coils that are controlled by voltage from the PCM. (See the "Timing Control" in Lesson 3 for a description of stepper motor mechanical and hydraulic operation.)

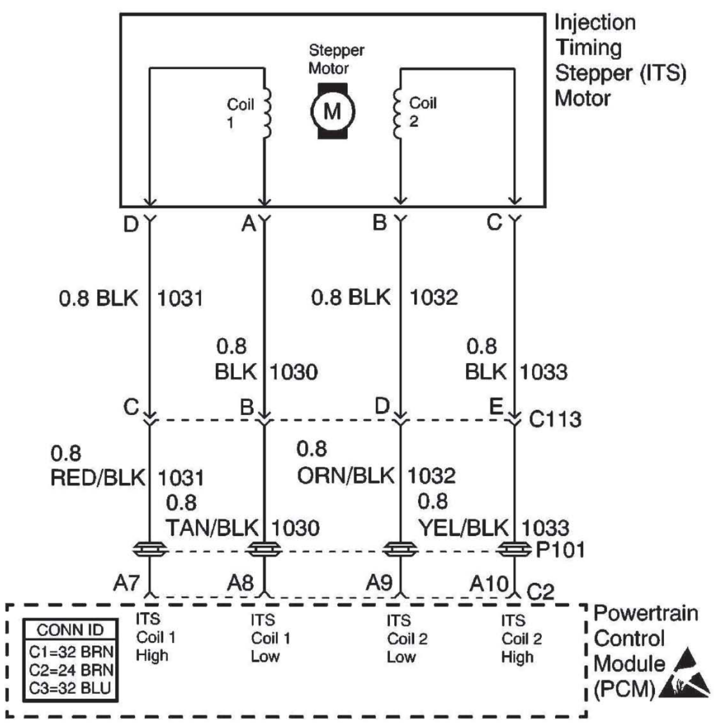


Figure 16-67, Injection Timing Stepper Motor Circuit Operation

By using a stepper motor, the PCM can control injection pump timing more precisely. The injection timing stepper motor contains two coils that control injection pump timing. The PCM controls these coils through four circuits:

- Coil 1 low position
- Coil 1 high position
- Coil 2 low position
- Coil 2 high position

High position basically means power and low position basically means ground. By using two coils the motor is bi-directional.

Glow Plug System Description and Operation

The glow plug system assists in providing the heat required to begin combustion during cold engine starting temperatures. The glow plugs can be activated before and during cranking, as well as during initial cold engine operation.

The glow plug system consists of the following components:

- A glow plug relay
- An instrument panel-mounted lamp
- The PCM
- The glow plugs

The PCM uses input information about engine coolant temperature and engine speed, as well as feedback information from the glow plug circuit to control the glow plug relay and lamp operation.

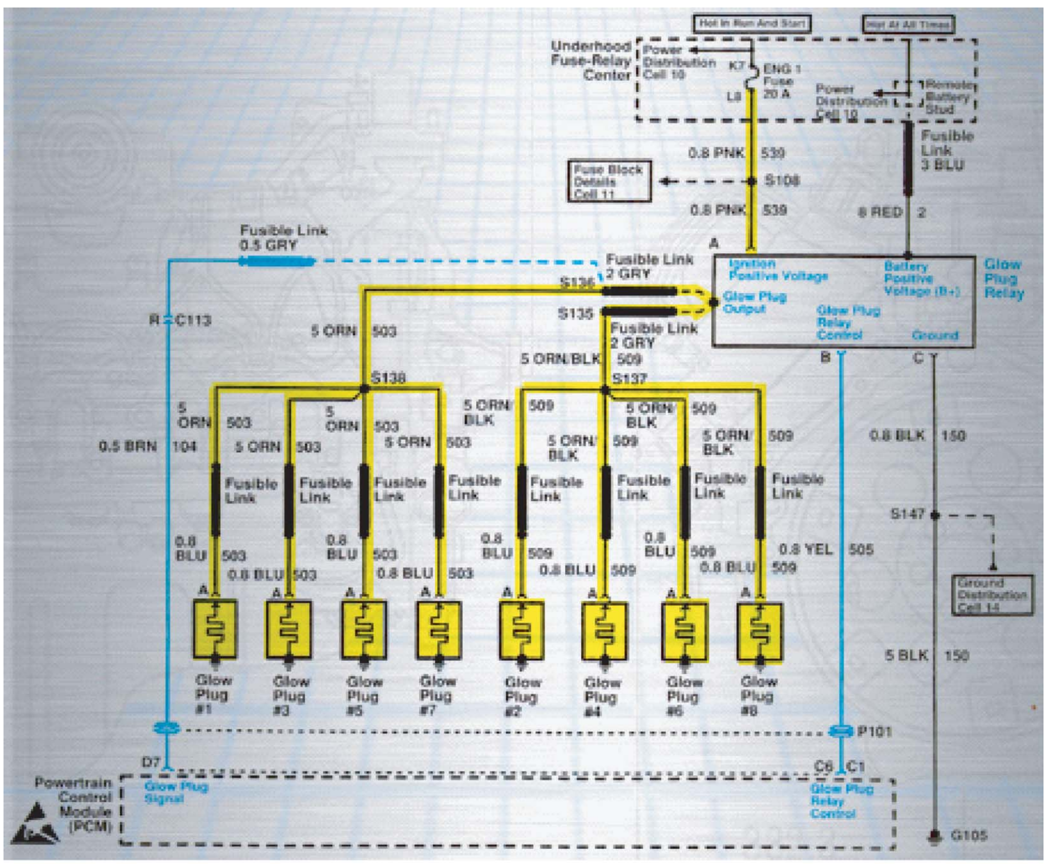


Figure 16-68, Glow Plug Circuit (1998 C/K)

Glow Plug System Description and Operation (continued)

Control of the glow plugs has been accomplished by moving the logic for controlling the heat of the plugs to the PCM. This logic incorporates the higher accuracy of digital processing compared to the previous analog controller. Additionally, logic involving engine speed and estimates of engine combustion can be added to the traditional time and temperature data used in the previous controller. This capability yields more optimum heat times for the glow plugs, thus pre-glow times can be kept to a minimum for short wait-to-crank times and maximum glow plug durability.

A normal functioning system operates as follows:

- Key "ON", engine not running and at room temperature
- Glow plugs ON for a short period of time (approximate on times may range from 1 to 16 seconds)
- If the engine is cranked during or after the above sequence, its possible the glow plugs will cycle ON/OFF after the ignition switch is returned to Run from the Crank position, whether the engine starts or not. The engine does not have to be running to terminate the glow plug cycling.

The glow plug initial on times may range from 1 to 16 seconds and cycling on/off times will vary also with system voltage and/or temperature. Lower temperature causes longer duration of cycling. The PCM also provides glow plug operation after starting a cold engine. This after-glow operation is initiated when the ignition switch is returned to "Run" from the Start position. This function helps clean up excessive white smoke and/or poor idle quality after starting.

A "Wait to Start" lamp on the instrument panel provides information on engine starting conditions. The "Wait to Start" lamp will not come on during post glow.

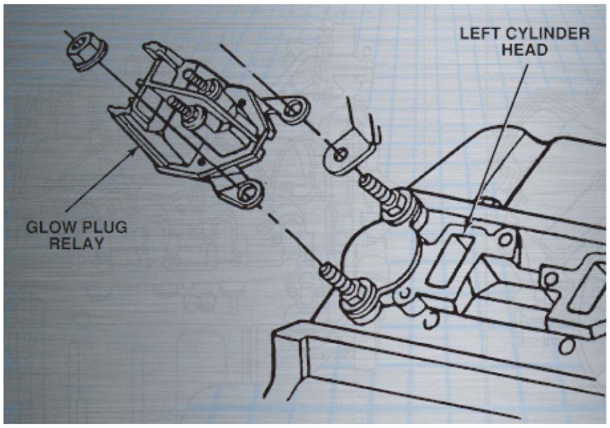


Figure 16-69, Glow Plug Relay

Glow Plug Description

Glow plugs used in the 6.5L diesel are 6-volt heaters (operated at 12 volts) that are positioned in the pre-combustion chamber. They provide heat when energized to aid in cold engine starting.

Glow Plug Relay Description

The glow plug relay is mounted at the rear of the left cylinder head. It is a solid state device which operates the glow plugs. The PCM uses an ignition voltage signal to control the solid state circuitry of the glow plug relay. When commanded by the PCM the relay contacts close allowing battery power to reach the two sets of glow plugs.

Wastegate Solenoid Description and Operation

The turbocharger uses a solenoid-controlled wastegate actuator to control turbo boost. The valve acts like a turbine wheel speed governor to limit the maximum amount of turbo boost pressure to between 2 and 8 psi. The more vacuum that is present in the wastegate actuator the more boost there will be.

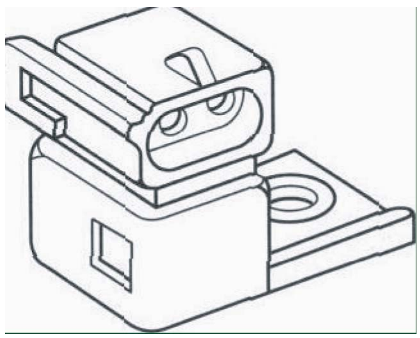


Figure 16-70, Wastegate Solenoid

The wastegate is normally closed when the engine is running, but it opens to bypass exhaust gas to prevent an over-boost condition. The wastegate will open when vacuum is vented from the actuator allowing exhaust pressure to open the wastegate. The amount of vacuum is controlled by the pulse-width modulated solenoid.

The wastegate solenoid is pulsed "ON" and "OFF" by the PCM. Under normal driving conditions and idle, the wastegate solenoid is "ON" allowing vacuum to close the actuator to build boost pressure. A boost increase will be detected by the boost sensor. The PCM will pulse the wastegate solenoid "OFF" allowing it to vent and open the wastegate to bleed off boost pressure, thereby preventing over-boost.

If an over-boost condition exists, the PCM will reduce fuel delivery to prevent engine and powertrain damage.

Wastegate Solenoid Description and Operation (continued)

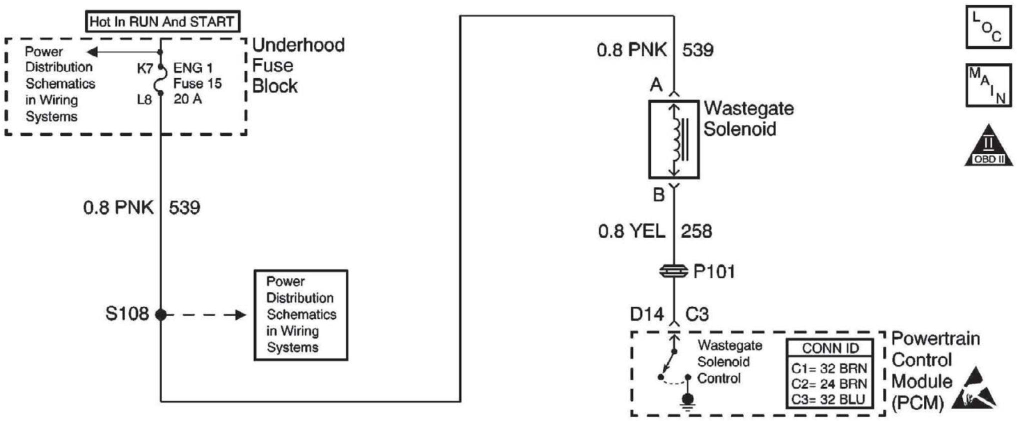


Figure 16-71, Wastegate Solenoid Circuit

The wastegate solenoid receives power through the ignition switch. The PCM controls solenoid operation by providing a ground at the PCM. The solenoid is located on the left valve cover near the cowl.

EGR Valve, EGR Solenoid, and EGR Vent Solenoid Description and Operation

The EGR valve is located atop the intake manifold in a port that is machined into the manifold. A vacuum-operated pintle in the valve controls the amount of exhaust gas that is recirculated into the intake manifold. Recirculating these gases helps reduce NOx emissions. A normally closed EGR solenoid controls the EGR valve. The solenoid allows vacuum to pass to the EGR when on. An EGR vent solenoid is used to vent vacuum from the EGR valve chamber during non-EGR conditions.

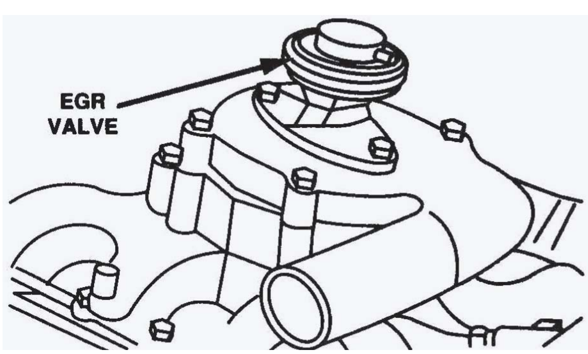


Figure 16-72, EGR Valve

EGR Valve, EGR Solenoid, and EGR Vent Solenoid Description and Operation (continued)

The PCM provides a ground path to the EGR solenoid that allows the solenoid to control vacuum to the EGR valve. The PCM also controls the EGR vent solenoid. Both solenoids receive battery power through the ignition switch. During normal operation the PCM compares the EGR duty cycle command with the EGR pressure control/baro sensor signal it receives. If there is a difference between PCM-commanded EGR and actual EGR position, the PCM makes minor adjustments in the duty cycle to correct the difference. If the difference is too great for the PCM to compensate, a DTC may set.

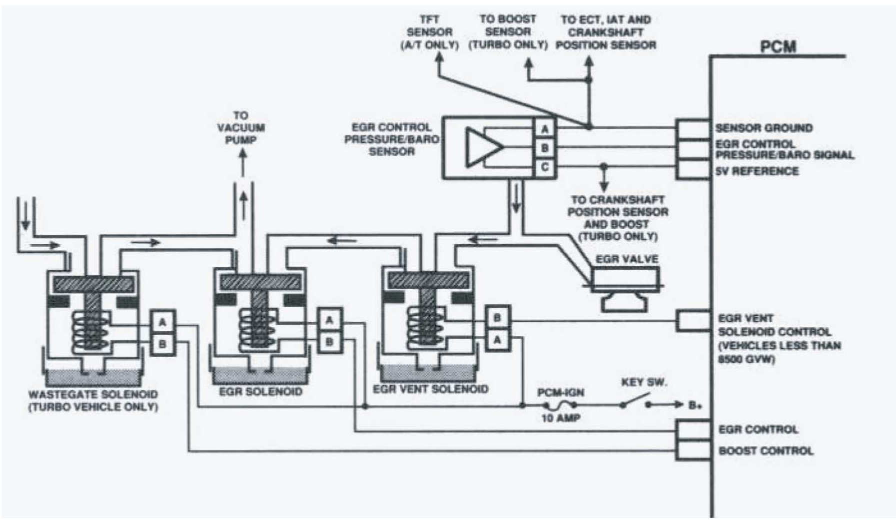


Figure 16-73, EGR Components Circuit

Note: Not all 6.5L EFI applications use an EGR system. EGR is typically found on vehicles equipped with light duty emissions.

Note: The EGR and wastegate system are vacuum operated. Since diesel engines don't have vacuum available in the intake manifold, an auxiliary vacuum pump is located on the front of the engine and is belt driven.

Exercise 16-4

Read each question carefully and choose the most correct response.

1. All of the control for engine management is in the ______________.
   a. Fuel solenoid driver
   b. Injection pump
   c. PCM
   d. TCM

2. The ________ interrupts fuel delivery to stop the engine.
   a. Fuel solenoid driver
   b. ESO solenoid
   c. Return system
   d. Fuel filter

3. The fuel solenoid driver does all of the following except.
   a. Receives inputs and makes decisions to control outputs
   b. Provides power to the fuel solenoid
   c. Provides ground for the fuel solenoid
   d. Sends the PCM information on the closing of the fuel solenoid

4. The EGR and wastegate operate using vacuum from the __________.
   a. Intake manifold
   b. Turbocharger
   c. Vacuum pump
   d. Exhaust system

5. Operation of the lift pump is controlled by the __________________.
   a. Injection pump
   b. PCM
   c. Fuel solenoid driver
   d. Fuel heater

Exercise 16-4 (continued)

6. The APP module consists of ________ potentiometers in one housing.
   a. 1
   b. 2
   c. 3
   d. 4

7. The fuel temperature sensor is located in the ______________.
   a. Fuel filter
   b. Optical sensor
   c. Fuel solenoid driver
   d. ESO solenoid

Notes:

Lesson 5: Diagnosis and Repair

In this lesson you will learn about the proper diagnostic procedures, possible DTCs, scan tool data and possible faults. You will also learn about some repair procedures associated with the 6.5L diesel.

Objectives:

- Identify proper diagnostic procedures
- Identify possible DTCs
- Identify scan tool data values
- Identify possible faults
- Identify certain repair procedures

At the end of this lesson there will be a short exercise.

Strategy Based Diagnostics

As with any other system, proper diagnostic procedures are important for minimizing the possibility of mistakes and for fixing the vehicle right the first time. Following Strategy Based Diagnostics will help ensure that no steps are skipped and nothing is overlooked.

Always use the most current information for the vehicle you are working on. When working on the 6.5L EFI diesel it is especially important to check for bulletins. There have been a number of concerns with this engine and there are numerous bulletins to address many of these issues.

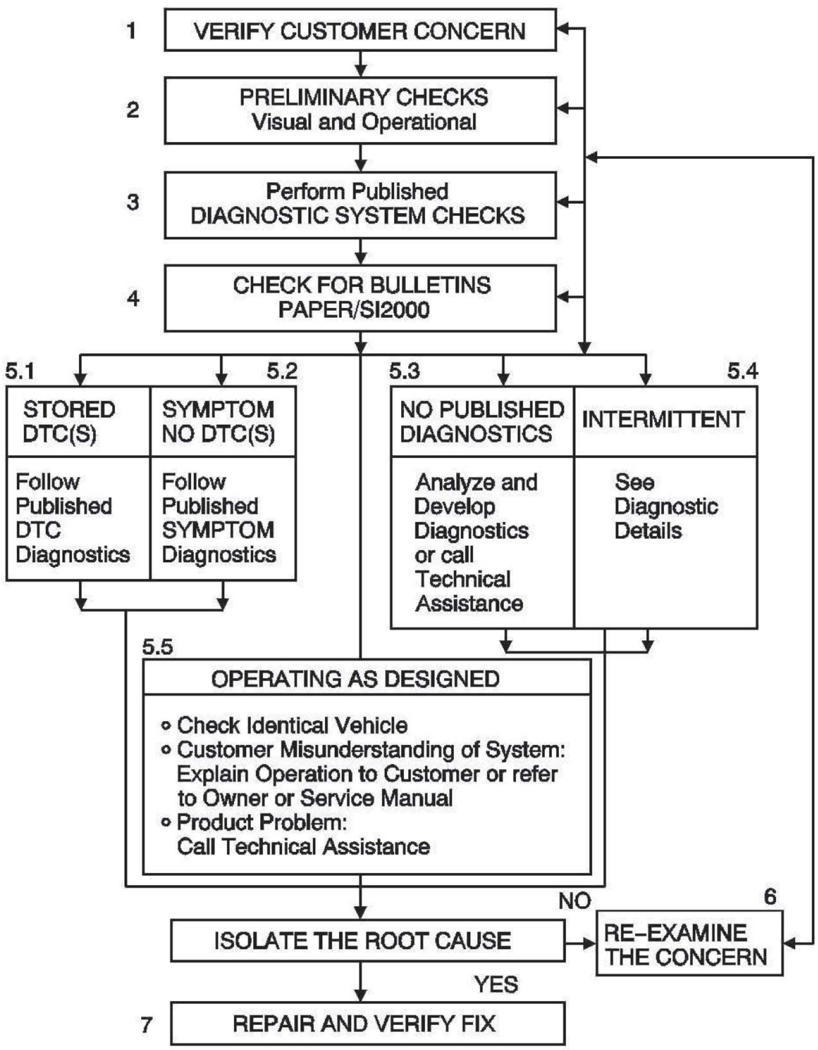


Figure 16-74, Strategy Based Diagnostic Chart

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Diagnostic Tools

The recommended diagnostic tools for working on the 6.5L V8 diesel are the TECH 1 or TECH 2 scan tools (depending upon the year of the vehicle), the J39200 Digital Multi-meter, an inductive ammeter and a test light where instructed.

Figure 16-75, Tech 2

Always follow diagnostic procedures during diagnosis, especially when jumping circuits and back probing terminals. Only do so when instructed.

Caution:

Improper diagnostic procedures can cause damage to the vehicle and possibly cause bodily harm. Always understand the procedures before performing them.

TECH 2 Use

As with gasoline powered vehicles, on the 6.5 L EFI diesels the TECH 2 can be used to:

- Retrieve Diagnostic Trouble Codes.
- Clear Diagnostic Trouble Codes.
- Display live and captured data.
- Perform snapshots.
- Perform special functions.

Figure 16-76, Tech 2

You should have a thorough understanding of the Tech 2 operation and features prior to using it for diagnosis. Since the PCM has control of basically every function of the 6.5L EFI diesel, you will find that the scan tool will be a necessity.

The TECH 2 menus will also be similar to that of gasoline powered vehicles. Only the data information that you will receive may look a little different. Also, some of the special functions available will be different. The following pages are a list of typical data display you will see on a 6.5L diesel.

Engine Scan Tool Data List

Engine Idling/Lower Radiator Hose Hot/Closed Throttle/ Park or Neutral Accessories Off				
Scan Tool Parameter	**Data List**	**Units Displayed**	**Typical Data Value**	**Reference**
A/B/C Range Switch	Engine Data 1	On On On/Off Off Off	On Off On	Automatic Transmission 4L80E
A/C Compressor	Engine Data 1	Engaged/ Disengaged	Disengaged	Engine Scan Tool Data Definitions
Accelerator Pedal Pos. 1	Engine Data 1, MAF EGR Data	Volts	0.44 - 0.95 (Idle) 0.75 - 1.25 (2500 RPM)	Information Sensors
Accelerator Pedal Pos. 2	Engine Data 1, MAF EGR Data	Volts	3.9 - 4.5 (Idle) 3.7 - 4.3 (2500 RPM)	Information Sensors
Accelerator Pedal Pos. 3	Engine Data 1, MAF EGR Data	Volts	3.6 - 4.1 (Idle) 3.5 - 4.0 (2500 RPM)	Information Sensors
A/C Relay	Engine Data 1	On/Off	Off	Engine Scan Tool Data Definitions
A/C Request	Engine Data 1	Yes/No	No	Engine Scan Tool Data Definitions
Actual EGR	Engine Data 1, MAF EGR Data	kPa	80 - 104 kPa (All RPMs)	Engine Scan Tool Data Definitions
Actual Inj. Pump Timing	Engine Data 1, MAF EGR Data	°	4 -10 (Idle) 14 - 20 (2500 RPM)	Engine Scan Tool Data Definitions
APP Angle	Engine Data 1, MAF EGR Data	%	0 (Idle) 4 - 12 (2500 RPM)	Engine Scan Tool Data Definitions
BARO	Engine Data 1, MAF EGR Data	kPa	65 - 104 (varies with altitude)	Information Sensors

Engine Idling/Lower Radiator Hose Hot/Closed Throttle/ Park or Neutral Accessories Off				
Scan Tool Parameter	**Data List**	**Units Displayed**	**Typical Data Value**	**Reference**
Boost Pressure	Engine Data 1, MAF EGR Data	kPa/PSI	60 - 170 kPa (All RMPs)	Information Sensors
Brake Switch	Engine Data 1	Open/Closed	Open	Information Sensors
Calc. A/C Load	Engine Data 1	Counts	0	Engine Scan Tool Data Definitions
Clutch Pedal Switch	Engine Data 1	Applied/ Released	Released	Information Sensors
Crank Reference Missed	Engine Data 1	Counts	0	Engine Scan Tool Data Definitions
Cruise Active	Engine Data 1	On/Off	Off	Engine Scan Tool Data Definitions
Cruise Brake Switch	Engine Data 1	Open/Closed	Closed	Information Sensors
Cruise Switch	Engine Data 1	On/Off	Off	Engine Scan Tool Data Definitions
Cylinder Air	MAF EGR Data	g/cyl	0.30 - 1.00 g/cyl (All RPMs)	Information Sensors
Desired Cylinder Air	MAF EGR Data	g/cyl	0.30 - 1.00 g/cyl (All RPMs)	Information Sensors
Desired EGR	Engine Data 1, MAF EGR Data	kPa	80 - 104 kPa (All RPMs)	Engine Scan Tool Data Definitions

Engine Idling/Lower Radiator Hose Hot/Closed Throttle/ Park or Neutral Accessories Off				
Scan Tool Parameter	**Data List**	**Units Displayed**	**Typical Data Value**	**Reference**
Desired Idle Speed	Engine Data 1, MAF EGR Data	RPM	630 - 650	Engine Scan Tool Data Definitions
Desired Inj. Pump Timing	Engine Data 1, MAF EGR Data	°	4 - 10 (Idle) 14 - 20 (2500 RPM)	Engine Scan Tool Data Definitions
DTC Set This Ignition	Engine Data 1	Counts	Yes/No	Engine Scan Tool Data Definitions
ETC	Engine Data 1, MAF EGR Data	°C/°F	85°C - 105°C/ 185°F - 220°F (varies with temperature)	Information Sensors
ECT Sensor	Engine Data 1	Volts	2 - 3	Information Sensors
EGR Adaptive Learn Matr.	MAF EGR Data	Counts	0 - 4	Information Sensors
EGR Duty Cycle	Engine 1 Data, MAF EGR Data	kPa	0 kPa (All RPMs)	Engine Scan Tool Data Definitions
EGR Loop Status	MAF EGR Data	Open/Closed	Open	Information Sensors
EGR Sensor	Engine 1 Data, MAF EGR Data	Volts	4.60 - 4.85 volts (All RPMs)	Information Sensors
EGR Vent Sol.	Engine 1 Data, MAF EGR Data	On/Off	Off	Information Sensors
Engine Load	Engine Data 1	%	1 - 15	Engine Scan Tool Data Definitions

Engine Idling/Lower Radiator Hose Hot/Closed Throttle/ Park or Neutral Accessories Off				
Scan Tool Parameter	**Data List**	**Units Displayed**	**Typical Data Value**	**Reference**
Engine Run Time	Engine Data 1, MAF, EGR Data	Hrs/Mins/Sec	Varies with engine run time	Engine Scan Tool Data Definitions
Engine Speed	Engine Data 1, MAF EGR Data	RPM	+/-100 RPM from desired	Engine Scan Tool Data Definitions
Engine Torque	Engine Data 1	ft lb	3 - 30	Engine Scan Tool Data Definitions
ESO Solenoid	Engine Data 1, MAF EGR Data	On/Off	On	Engine Scan Tool Data Definitions
Four-Wheel Drive Low	Enabled/ Disabled	Disabled	Automatic Transmission	Information Sensors
Front Axle Switch	Locked/ Unlocked	Unlocked	Automatic Transmission	Information Sensors
Fuel Rate	Engine 1 Data, MAF EGR Data	mm3	7 - 15 (All RPMs)	Engine Scan Tool Data Definitions
Fuel Temperature Sensor	Engine Data 1, MAF EGR Data	°C/°F	10°C - 90°C/ 50°F - 194°F	Information Sensors
Glow Plug	Engine Data 1	Volts	0.0 - 0.2	Engine Scan Tool Data Definitions
Glow Plug System	Engine Data 1, MAF EGR Data	Disabled/ Enabled	Enabled on key up (times varies with temperature)	Engine Scan Tool Data Definitions
IAT	Engine Data 1, MAF EGR Data	°C/°F	10°C - 90°C/ 50°F - 194°F (temperature may increase under heavy engine loads)	Engine Scan Tool Data Definitions

Engine Idling/Lower Radiator Hose Hot/Closed Throttle/ Park or Neutral Accessories Off				
Scan Tool Parameter	**Data List**	**Units Displayed**	**Typical Data Value**	**Reference**
Ignition Voltage	Engine Data 1, MAF EGR Data	Volts	12 - 14 (accuracy +/ -0.4 volts)	Engine Scan Tool Data Definitions
Inj. Pump CAM Reference Missed	Engine Data 1	Counts	0	Engine Scan Tool Data Definitions
Inj. Pump Sol. Closure Time	Engine Data 1, MAF EGR Data	mS	1.70 - 1.90 (All RPMs)	Engine Scan Tool Data Definitions
Lift Pump	Engine Data 1	Volts	12 - 16 (0.6 volts higher than ignition voltage)	Engine Scan Tool Data Definitions
Lift Pump System	Engine Data 1, MAF EGR Data	Disabled/ Enabled	Enabled	Engine Scan Tool Data Definitions
MAF	MAF EGR Data	g/s	20 - 35 g/s (Idle) 120 - 140 g/s (2500 RPM)	Information Sensors
MAF Frequency	MAF EGR Data	Hz	4000 - 4500 Hz (Idle) 7200 - 7800 Hz (2500 RPM)	Information Sensors
MIL	Engine Data 1, MAF EGR Data	On/Off	Off	Engine Scan Tool Data Definitions
Number of DTCs	Engine Data 1	Counts	0	Engine Scan Tool Data Definitions
PCM in VTD Fail Enable	Engine Data 1	Yes/No	No	Engine Scan Tool Data Definitions
Resume Switch	Engine Data 1	On/Off	Off	Engine Scan Tool Data Definitions

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Engine Idling/Lower Radiator Hose Hot/Closed Throttle/ Park or Neutral Accessories Off				
Scan Tool Parameter	**Data List**	**Units Displayed**	**Typical Data Value**	**Reference**
Service Throttle Soon Lamp	Engine Data 1, MAF EGR Data	On/Off	Off	Engine Scan Tool Data Definitions
Set Switch	Engine Data 1	On/Off	Off	Engine Scan Tool Data Definitions
Startup ECT	Engine Data 1, MAF EGR Data	°C/°F	Varies (ECT at time of engine startup)	Engine Scan Tool Data Definitions
TDC Offset	Engine Data 1, MAF EGR Data	°	+0.85 to -1.75 (factory setting varies per engine)	Engine Scan Tool Data Definitions
Trans. Fluid Temp.	Engine Data 1	°C/°F	50°C - 80°C/ 122°F - 158°F	Automatic Transmission 4L80E
Transmission Range	Engine Data 1	Park/Neutral/ Reverse/ Overdrive/Drive 3/ Drive 2/Drive 1	Park/Neutral	Automatic Transmission 4L80E
Vehicle Speed	Engine Data 1, MAF EGR Data	MPH/km/h	0	Engine Scan Tool Data Definitions
VTD Auto Learn Timer	Engine Data 1	Active/Inactive	Inactive	Engine Scan Tool Data Definitions
VTD Fuel Disable	Engine Data 1	Active/Inactive	Inactive	Engine Scan Tool Data Definitions
VTD Fuel Disable Until Ign. Off	Engine Data 1	Yes/No	No	Engine Scan Tool Data Definitions
Wastegate Solenoid	Engine Data 1, MAF EGR Data	%	50 - 70 (Idle) 20 -40 (2500 RPM)	Engine Scan Tool Data Definitions

Engine Idling/Lower Radiator Hose Hot/Closed Throttle/ Park or Neutral Accessories Off				
Scan Tool Parameter	**Data List**	**Units Displayed**	**Typical Data Value**	**Reference**
Wastegate Solenoid	Engine Data 1, MAF EGR Data	%	50 - 70 (Idle) 20 - 40 (2500 RPM)	Engine Scan Tool Data Definitions
1 - 2 Sol.	Engine Data 1	On/Off	On	Automatic Transmission 4L80E
2 - 3 Sol.	Engine Data 1	On/Off	Off	Automatic Transmission 4L80E

Possible DTCs

The following list is an example of the DTCs that can set for the Engine Management System. This is a complete list of the 6.5L EFI engine related DTCs for a 1999 K-truck.

- DTC P0101 Mass Air Flow (MAF) Sensor Performance
- DTC P0102 Mass Air Flow (MAF) Sensor Circuit Low Frequency
- DTC P0103 Mass Air Flow (MAF) Sensor Circuit High Frequency
- DTC P0112 Intake Air Temperature (IAT) Sensor Circuit Low Voltage
- DTC P0113 Intake Air Temperature (IAT) Sensor Circuit High Voltage
- DTC P0117 Engine Coolant Temperature (ECT) Sensor Circuit Low Voltage
- DTC P0118 Engine Coolant Temperature (ECT) Sensor Circuit High Voltage
- DTC P0121 Accelerator Pedal Position (APP) Sensor 1 Circuit Performance
- DTC P0122 Accelerator Pedal Position (APP) Sensor 1 Circuit Low Voltage
- DTC P0123 Accelerator Pedal Position (APP) Sensor 1 Circuit High Voltage
- DTC P0126 Engine Coolant Temperature (ECT) Insufficient for Stable Operation
- DTC P0182 Fuel Temperature Sensor Circuit Low Voltage
- DTC P0183 Fuel Temperature Sensor Circuit High Voltage
- DTC P0215 Engine Shutoff (ESO) Solenoid Control Circuit
- DTC P0216 Injection Timing Control Circuit
- DTC P0219 Engine Overspeed
- DTC P0220 Accelerator Pedal Position (APP) Sensor 2 Circuit
- DTC P0221 Accelerator Pedal Position (APP) Sensor 2 Circuit Performance
- DTC P0222 Accelerator Pedal Position (APP) Sensor 2 Circuit Low Voltage
- DTC P0223 Accelerator Pedal Position (APP) Sensor 2 Circuit High Voltage
- DTC P0225 Accelerator Pedal Position (APP) Sensor 3 Circuit "Voltage

- DTC P0226 Accelerator Pedal Position (APP) Sensor 3 Circuit Performance
- DTC P0227 Accelerator Pedal Position (APP) Sensor 3 Circuit Low Voltage
- DTC P0228 Accelerator Pedal Position (APP) Sensor 3 Circuit High Voltage
- DTC P0231 Fuel Pump Feedback Circuit Low Voltage
- DTC P0236 Turbocharger Boost System Performance
- DTC P0237 Turbocharger Boost Sensor Circuit Low Voltage
- DTC P0238 Turbocharger Boost Sensor Circuit High Voltage
- DTC P0251 Injection Pump Cam Sensor Circuit
- DTC P0263 Cylinder 1 Balance System
- DTC P0266 Cylinder 2 Balance System
- DTC P0269 Cylinder 3 Balance System
- DTC P0272 Cylinder 4 Balance System
- DTC P0275 Cylinder 5 Balance System
- DTC P0278 Cylinder 6 Balance System
- DTC P0281 Cylinder 7 Balance System
- DTC P0284 Cylinder 8 Balance System
- DTC P0300 Engine Misfire Detected
- DTC P0301 Cylinder 1 Misfire Detected
- DTC P0302 Cylinder 2 Misfire Detected
- DTC P0303 Cylinder 3 Misfire Detected
- DTC P0304 Cylinder 4 Misfire Detected
- DTC P0305 Cylinder 5 Misfire Detected
- DTC P0306 Cylinder 6 Misfire Detected
- DTC P0307 Cylinder 7 Misfire Detected
- DTC P0308 Cylinder 8 Misfire Detected
- DTC P0335 Crankshaft Position (CKP) Sensor Circuit
- DTC P0370 Timing Reference High Resolution System Performance
- DTC P0380 Glow Plug Feedback Circuit
- DTC P0400 Exhaust Gas Recirculation (EGR) System Performance
- DTC P0401 Exhaust Gas Recirculation (EGR) Flow Insufficient
- DTC P0402 Exhaust Gas Recirculation (EGR) Flow Excessive

- DTC P0404 Exhaust Gas Recirculation (EGR) Open Position Performance
- DTC P0405 EGR Position Sensor Circuit Low Voltage
- DTC P0406 EGR Position Sensor Circuit High Voltage
- DTC P0501 Vehicle Speed Sensor (VSS) Performance
- DTC P0567 Cruise Control Resume Switch Circuit
- DTC P0568 Cruise Control Set Switch Circuit
- DTC P0571 Cruise Control Brake Switch Circuit
- DTC P0601Control Module Read Only Memory (ROM)
- DTC P0602 Control Module Not Programmed
- DTC P0604 Control Module Random Access Memory (RAM)
- DTC P0606 Control Module Internal Performance
- DTC P1125 Accelerator Pedal Position (APP) System
- DTC P1191 Intake Air Duct Leak
- DTC P1214 Injection Pump Timing Offset
- DTC P1216 Fuel Solenoid Response Time Too Short
- DTC P1217 Fuel Solenoid Response Time Too Long
- DTC P1218 Injection Pump Calibration Circuit
- DTC P1406 Exhaust Gas Recirculation (EGR) Position Sensor Performance
- DTC P1409 Exhaust Gas Recirculation (EGR) System Performance
- DTC P1621 Control Module Long Term Memory Performance
- DTC P1626 Theft Deterrent Fuel Enable Signal Lost
- DTC P1627 Control Module Analog to Digital Performance
- DTC P1630 Theft Deterrent Learn Mode Active
- DTC P1631 Theft Deterrent Start Enable Signal Not Correct
- DTC P1635 5 Volt Reference Circuit
- DTC P1641 Malfunction Indicator Lamp (MIL) Control Circuit
- DTC P1643 Wait to Start Lamp Control Circuit
- DTC P1653 Exhaust Gas Recirculation (EGR) Vent Solenoid Control Circuit
- DTC P1654 Service Throttle Soon Lamp Control Circuit
- DTC P1655 Exhaust Gas Recirculation (EGR) Solenoid Control Circuit
- DTC P1656 Wastegate Solenoid Control Circuit

Air Induction/Exhaust System Related Service

Crankcase Pressure Check

This test is designed to check the operation of the CDRV.

1. Bring the engine to operating temperature with the air filter installed.
2. Obtain a water manometer (special tool J 23951).
3. Remove the engine oil dipstick and attach the hose of the water manometer to the oil dipstick tube.
4. Start and run the engine at idle speed, observing the water manometer reading.
    - If the reading indicates that crankcase pressure is approximately 1 inch of pressure or less, go to step 5.
    - If the reading indicates that crankcase pressure is higher than 1 inch of pressure, inspect the Crankcase Depression Regulator Valve (CDRV) and re-check crankcase pressure (if the CDRV checks good, perform a compression test).
5. Run the engine at 2,000 rpm, observing the water manometer reading
    - If the reading indicates that crankcase pressure is approximately 3 to 4 inches of vacuum, go to step 6.
    - If the reading indicates that crankcase pressure is lower than 2 inches of vacuum, inspect the CDRV and re-check crankcase pressure (if the CDRV checks good, check the air intake/exhaust systems).
    - If the reading indicates that crankcase pressure is higher than 5 inches of vacuum, inspect the CDRV and re-check crankcase pressure.
6. Separate the hose of the water manometer from the oil dipstick tube and install the engine oil dipstick.
7. Stop the engine.

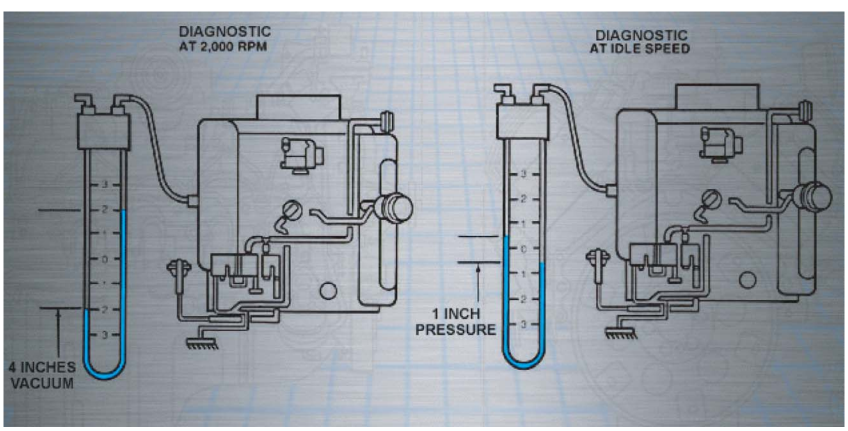


Figure 16-77, Water Manometer

Engine/Turbocharger Performance

Remember, the 6.5L V8 diesel engine has a turbocharger for several reasons:

- to provide an increase in engine power without adding a substantial increase in weight.
- to provide consistent power at all altitudes by compensating for changes in air density
- to increase combustion turbulence and air/fuel mixing efficiency, resulting in greater fuel economy
- to reduce exhaust emissions (especially smoke)

As part of the turbocharger diagnosis, a technician may test intake manifold boost pressure in these steps:

Figure 16-78, Boost Pressure Test

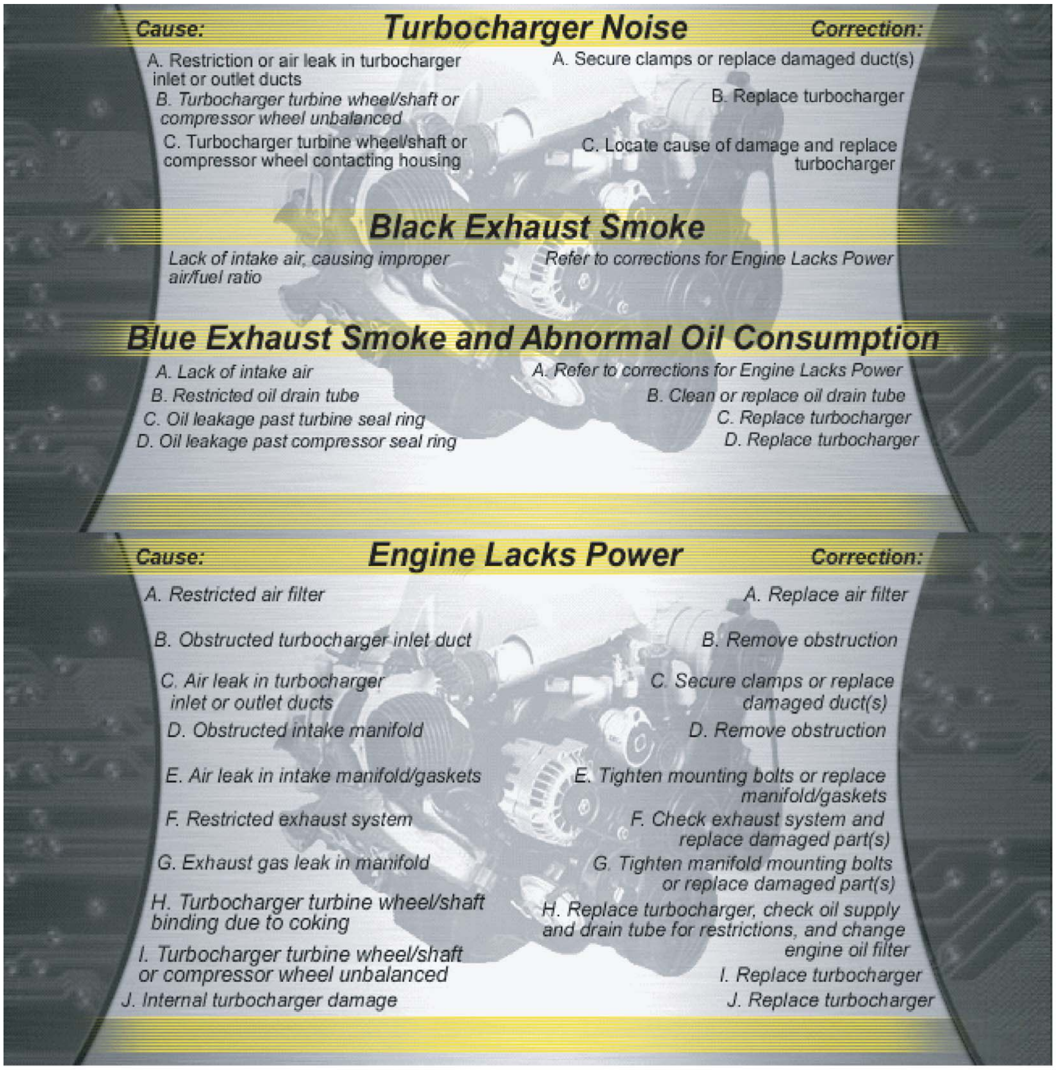
1. Remove the front center mounting bolt from the air inlet and install a J39307 adaptor with a 6 to 7 foot length of vacuum line. Run a vacuum line into the cab and connect a combination pressure-vacuum gauge to the end of the vacuum line.
2. Test drive the vehicle with a passenger watching the gauge, allow the vehicle to coast at idle in first gear, then press the accelerator pedal to the floor with the passenger noting the pressure reading. A boost reading of 2 psi or more indicates that the turbocharger is working properly.

Note: The 2 psi reading is for snap acceleration only. The pressure can climb above 2 psi under heavy loads and extended acceleration. During deceleration, the pressure reading may go slightly negative.

Caution:

Perform the turbocharger boost test in a remote area away from traffic, and have an assistant ride in the vehicle during the test.

The following charts are used to give you an idea of what to look for during certain concerns that can be caused by the air induction/exhaust system.



Note: If the turbocharger is leaking oil severely into the intake, an engine run-away condition can exist. If this occurs, leave the area until the engine has stopped.

Note: The turbocharger is not serviceable and must be replaced as an assembly. The wastegate actuator is the only part that can be replaced on the turbo.

Fuel System Related Services

Fuel Supply System Check

If the fuel supply system is not delivering enough fuel or air is being drawn into the fuel injection system, driveability could be greatly affected or a "Cranks But Will Not Run" symptom could exist. If another diagnosis indicates, or if the fuel supply system is suspected of not delivering enough fuel or drawing air, the following checks should be performed:

- Make certain that there is sufficient fuel in the tank.
- Check for air leaks or restrictions on the suction side of the fuel lift pump.
- Check for restrictions in the fuel return system.
- Check for leaks at all of the fuel connections from the fuel tank to the injection pump.
- With the engine running, check all of the hoses and the lines for flattening or kinks that would restrict the flow of fuel.

Fuel Lift Pump Flow Check

1. Remove the ECM 1 fuse from the underhood relay center to prevent engine starting.
2. Disconnect the pipe at the lift pump outlet fitting.
3. Install a hose at the lift pump outlet fitting and place a 1 liter (0.946 quart) container at the hose in order to collect fuel.
4. Crank the engine or energize the lift pump and measure the amount of fuel:
   - If more than 0.24 liters (½ pint) in 15 seconds, refer to Fuel Lift Pump Pressure Check.
   - If less than 0.24 liter (½ pint) in 15 seconds, refer to Fuel Lift Pump Suction Line Check.

Fuel Lift Pump Suction Line Check

1. Remove the fuel tank cap and repeat the Lift Pump Flow Check.
   - If the flow is more than 0.24 liter (½ pint) in 15 seconds, replace the defective fuel tank cap.
   - If the flow is less than 0.24 liter (½ pint) in 15 seconds, go to the next step.
2. Separate the lift pump suction line from the fuel sender.
3. Connect the suction line to a source of clean
   fuel by using an additional hose.
4. Repeat the Lift Pump Flow Check.
   - If the flow is more than 0.24 liter (½ pint) in 15 seconds, refer to Fuel System Air Leak Check.
   - If the flow is less than 0.24 liter (½ pint) in 15 seconds, Go to Step 5.
5. Check the lift pump suction line for a restriction.
   - If a restriction exists, repair it and recheck lift pump flow.
   - If no restriction exists, replace the lift pump and recheck the lift pump flow. Refer to Fuel Pump Electrical Circuit Diagnosis.
6. Attach the lift pump suction line to the fuel sender.

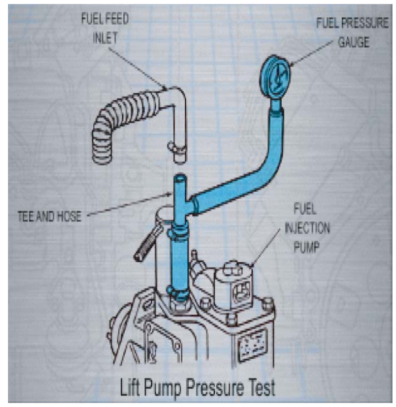


Figure 16-79, Lift Pump Test

Fuel Lift Pump Pressure Check

1. Install a tee adapter at the injection pump.
2. Connect a pressure gauge with the dial indication of 0-103 kPa (0 to 15 psi) to the tee adapter.
3. Start the engine and measure the fuel pressure.
   - If the fuel pressure is a least 4 psi (27 kPa) continue to step 4.
   - If the pressure is less than 4 psi, refer to Fuel Pump Electrical Circuit Diagnosis before replacing the lift pump.
4. Remove the pressure gauge and the tee adapter.
5. Connect the inlet pipe.
6. Clean any fuel spillage.
7. Operate the engine and check for any fuel leaks.

Fuel System Air Leak Check

1. Install a transparent hose between the filter outlet and the injection pump inlet.
2. Start and idle the engine, observing the fuel for air bubbles.
   - If air bubbles are not present, stop the engine and Go to Step 7.
   - If air bubbles are present, stop the engine and Go to Step 3.
3. Check the lift pump suction line for air leakage.
4. Check the fuel sender for air leakage.
5. Start and run the engine.
6. Observe the fuel for air bubbles.
   - If air bubbles are present, stop the engine and recheck Steps 3 and 4.
   - If air bubbles are not present, stop the engine and Go to Step 7.
7. Remove the transparent hose and connect the hose of the filter outlet to the injection pump inlet fitting.
8. Disconnect the return hose at the injection pump.
9. Install a transparent hose between the injection pump and the hose of the return line.
10. Start and run the engine.
11. Observe the fuel for air bubbles. (It is normal to see small amounts of bubbles during snap acceleration.)
    - If air bubbles are present, replace the injection pump. Refer to Fuel Injection Pump Replacement.
    - If air bubbles are not present, Go to Step 12.
12. Stop the engine.
13. Remove the transparent hose and attach the fuel return hose at the injection pump.
14. Clean any fuel spillage.
15. Run the engine to check for fuel leakage.

Fuel Injector Service and Testing

Injector nozzles are serviced by replacement. Installation involves the use of a new compression gasket, anti-seize compound on the cylinder head threads and a tightening torque of 60 to 80 N•m (44 to 59 lb-ft), using a special socket (J29873).

If an injection nozzle is not properly delivering fuel into the pre-combustion chamber of a cylinder, driveability could be greatly affected, or a DTC could be set. If other diagnosis indicates, or if the injection nozzles are suspected of not properly delivering fuel, they should be tested. Typically a nozzle failure can be detected by using the injector balance test.

Nozzle testing is comprised of the following checks:

- Injector Balance test (performed with scan tool).
- Nozzle opening pressure test.
- Leakage test.

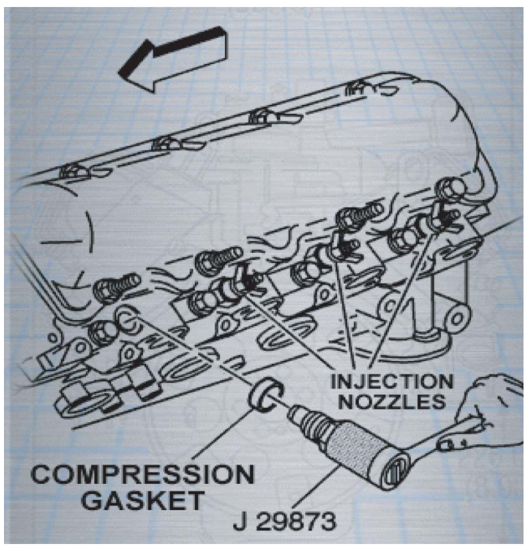


Figure 16-80, Fuel Injector Replacement

Note: Each injector test should be considered independent of the others (for example, when checking opening pressure, do not check for leakage at the same time). If all of the nozzle tests are satisfied, the nozzle assembly can be reused. If any one of the tests are not satisfied, the complete nozzle assembly must be replaced. When performing the injection nozzle tests, refer to the instructions provided with the nozzle tester J29075-B.

Injector Balance Test

An injector balance test is performed with the scan tool. This test can identify a stuck closed or noisy injector nozzle. The injector balance test is performed as follows:

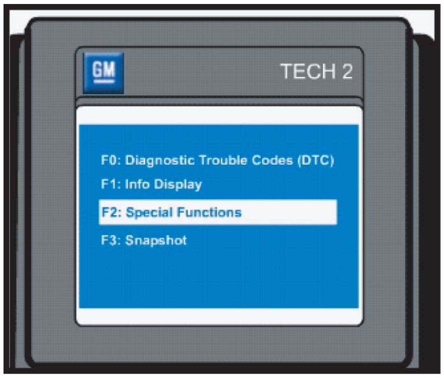


Figure 16-81, Tech 2

1. Install scan tool.
2. Start and idle engine.
3. Perform "INJ BALANCE" test on each cylinder
   - If a suspect nozzle has been located, it can be swapped with the adjacent cylinder and the balance test can be repeated as a check to positively identify a faulty nozzle.
4. Locate and replace faulty nozzle and glow plug.

Note: Injector Nozzle Opening Pressure and Leakage tests should only be performed on engines with high mileage, engines that have been over-heated, or on vehicles that pull heavy toads. False or inaccurate readings can occur if the following tests are not performed to the above criteria.

Preparation for injection nozzle test

- Position a nozzle tester on a workbench.
- Install one nozzle on the tester fitting.
- Place a container under the nozzle that will deflect the nozzle spray and absorb the test fluid.
- Install two clear plastic hoses (1 in. long) over the leak-off fittings.
- Close the shutoff valve at the pressure gauge.
- Operate the lever of the nozzle tester repeatedly and briskly to fill and flush the nozzle with test oil.

Caution:

When testing nozzles, do not place your hands or arms near the tip of the nozzle. The high pressured atomized fuel spray from a nozzle has sufficient penetrating power to puncture flesh and destroy tissue and may result in blood poisoning. The nozzle tip should always be enclosed in a receptacle, preferably transparent, to contain the spray.

Nozzle Opening Pressure Test

1. Open the shutoff valve at the pressure gage 1/4 turn.
2. Depress the tester lever slowly. Note at what pressure the needle of the pressure gauge stopped. Maximum observed pressure is the opening pressure.
   - Some nozzles may pop while other nozzles may drip down (this is not leakage).
3. The opening pressure should not fall below the lower limit of 105 bar (1500 psi) for naturally aspirated engines and 117 bar (1700 psi) for turbo-charged engines for used nozzles.
4. Replace nozzles which fall below the lower limit.

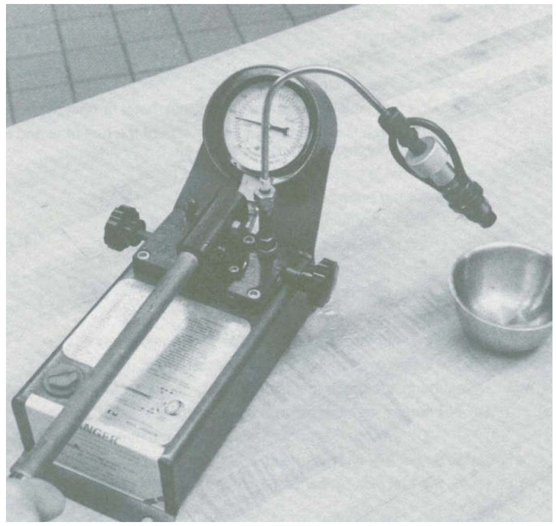


Figure 16-82, Injector Tester

Nozzle Leakage Test

1. Further open the shutoff valve at the pressure gauge (1/2 to 1-1/2 turns).
2. Blow dry the nozzle tip.
3. Depress the lever of the manual test stand slowly until the gauge reads a pressure of 95 bar (1400 psi). Observe the nozzle tip. A drop may form on the end of the nozzle but should not drop off within a period of 10 seconds.
4. Replace the nozzle assembly if a drop falls during the 10 seconds.

Fuel Return System Restriction Check

1. Disconnect the hose of the fuel return line at the fuel sender.
2. Disconnect the hose of the fuel return line at the injection pump and connect a vacuum pump with gauge to the hose.
3. Apply vacuum to the return line and observe the gauge reading.
   - If vacuum does not build and hold, go to Step 4.
   - If vacuum builds and holds, repair the return line restriction.
4. Connect the fuel return line at the injection pump and fuel sender.
5. Clean any fuel spillage.
6. Run the engine to check for fuel leakage.

Water-In-Fuel Lamp

Occasionally, the Water-In-Fuel lamp may illuminate on the IPC. When this occurs, you should drain the water from the filter housing. Removing water from the fuel filter housing can be accomplished by opening the drain valve located on the front of the engine. Make sure to place a drain pan under the front of the vehicle to catch the water/fuel that is drained. Allow fluid to flow until clear fuel is present. This procedure should be done with the lift pump running. The lift pump can be activated using a scan tool.

Once this has been completed, the light should go out. If not, refer to the proper diagnostic procedures in Service Information.

If excessive water or fungi/bacteria are present at the fuel filter, you must perform a fuel system cleaning. This is a lengthy procedure, but it must be performed thoroughly in order to be affective. Refer to Service Information for the complete procedure.

Glow Plug Testing

A fault in the glow plug system can cause a hard or no start condition. A fault with one or several glow plugs can cause a rough idle and/or white smoke on start up. The glow plugs can be tested individually or as a bank. Using an inductive ammeter, check the current flow in each bank of the system. Each bank should have at least a 55 amp draw. If either bank does not, you need to test each individual glow plug using a test lamp. Disconnect all of the injectors on the suspect bank and connect a test lamp to B+. Touch the terminal of each injector with the other end of the lamp and each one should light the test lamp brightly. If not, replace the glow plug. You can also test each glow plug with an ammeter and each one should have around 14 amps.

Engine Cranking Speed Test

Cranking speed is critical for a diesel engine to start, whether the engine is hot or cold. Some tachometers are not accurate at cranking speed. The primary method of testing cranking speed or determining the accuracy of a tachometer is to use a scan tool.

Ensure that the vehicle's batteries are in good condition, and fully charged, prior to performing this test. Remove the fuel solenoid fuse to prevent engine starting. Install the scan tool. Crank the engine for 2 to 4 seconds. This will allow the starter to reach its maximum performance. Observe the engine RPM reading on the scan tool. The minimum cold cranking speed required for the 6.5L diesel engine is 100 RPM. The minimum hot cranking speed required for the 6.5L diesel engine is 180 RPM.

Fuel Quality

Fuel quality may cause driveability problems such as hesitation, lack of power, stall, no start, etc. For best results use Number 2-D diesel fuel year-round (above and below freezing conditions) as oil companies blend Number 2-D fuel to address climate differences. Number 1-D fuel may be used in very cold temperatures (when it stays below -18°C (0°F); however; it will produce a power and fuel economy loss. The use of Number 1-D fuel in warm or hot climates may result in stalling and poor starting when the engine is hot and may damage the fuel injection system.

The fuel quality hydrometer provides a general indication of fuel quality and should not be considered scientifically accurate.

Fuel Oil Specific Gravity Requirements			
	Number 2-Diesel	**Number 1-Diesel**	**Method**
API Gravity	30 - 39	39 - 44	J38641-B
*API Gravity specification for blended fuels is on the high end of Number 2-Diesel			

Fuel Testing

1. Retrieve a fuel sample by following the steps below:
    - Stop the engine.
    - Place a container under the water drain valve exit hose at the left front side of the engine.
    - Open the drain valve.
    - Use a scan tool and command the fuel lift pump ON.
    - Fill a 1 liter (0.946 quart) container with a sample of fuel.
    - Close the drain valve.

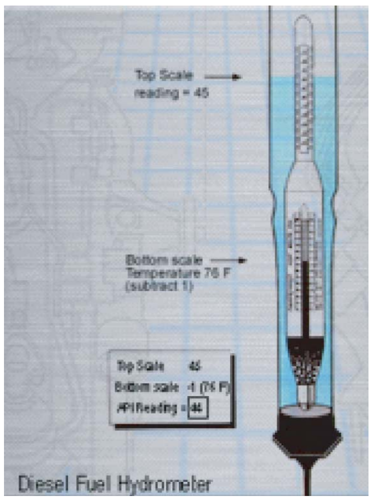


Figure 16-83, Hydrometer

2. Obtain a fuel quality hydrometer (J 38641-B).
3. Fill the hydrometer with the fuel sample by doing the following:
    - Squeeze the hydrometer bulb.
    - Submerse the hydrometer tip into the sample.
    - Release the bulb, allowing fuel to enter the glass tube until it completely floats the glass bulb inside the tube.
    - Gently spin the hydrometer to relieve the surface tension of the fuel sample. Read the scale on the glass bulb at the point where the top of the fuel sample contacts it. By reading this value, it will give an approximate fuel oil specific gravity. Refer to tool instructions on how to determine API Gravity.
4. Refer to Fuel Oil Specific Gravity Requirements table. If the correct fuel is being used in the proper conditions and meets number 1-Diesel or number 2-Diesel fuel oil specific gravity requirements, the fuel is OK. If not, the fuel should be replaced.

Exercise 16-5

Read each question carefully and choose the most correct response.

1. During diagnosis, you should probe connectors ________________.
   a. whenever possible
   b. always
   c. when instructed to
   d. never

2. If the turbocharger is leaking oil severely into the intake, what could occur?
   a. An engine run-away condition
   b. The “Service Throttle Soon” lamp will come on
   c. Nothing
   d. The engine may stall

3. If the “Water in Fuel” lamp comes on, the first thing you should do is ___________.
   a. Perform a fuel system cleaning
   b. Replace the fuel filter
   c. Add alcohol to the fuel
   d. Drain the filter housing

4. Testing fuel with a hydrometer is considered a scientifically accurate measurement.
   a. True
   b. False

5. What type of fuel should be used in the 6.5L diesel?
   a. 91 octane
   b. 2-D
   c. 1-D
   d. 85 octane

Exercise 16-5 (continued)

6. When testing injector nozzles, you should ______________________.
   a. Always keep hands and arms away from the injector tip
   b. Wear safety glasses
   c. Use the proper tools
   d. All of the above

7. A fuel injector balance test can be accomplished using a __________.
   a. Test light
   b. Scan tool
   c. Spark tester
   d. Injector testor

Notes: