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Systems Operation

3406E Truck Engine

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Fuel System

SMCS - 1250

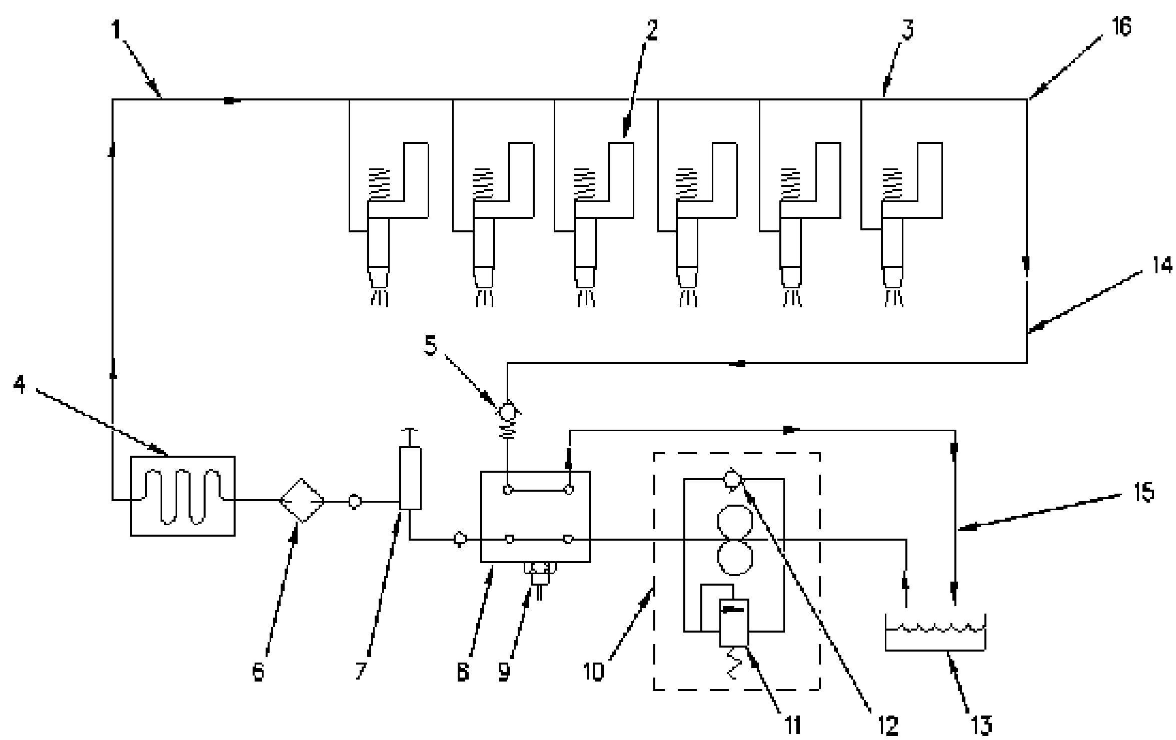

Illustration 1 g00923453

Typical fuel system schematic

(1) Fuel supply line

(2) Unit injectors

(3) Fuel gallery (fuel manifold)

(4) Electronic Control Module (ECM)

(5) Pressure regulating valve

(6) Secondary fuel filter

(7) Fuel priming pump

(8) Distribution block

(9) Fuel temperature sensor

(10) Fuel transfer pump

(11) Pressure relief valve

(12) Check valve

(13) Fuel tank

The fuel supply circuit is a conventional design for unit injector diesel engines. The system consists of the following major components that are used to deliver low pressure fuel to the unit injectors:

Fuel tank - The fuel tank is used to store the fuel.

Fuel priming pump - The fuel priming pump is used to evacuate the air from the fuel system. As the air is removed the system fills with fuel.

Fuel filter - The fuel filter is used to remove abrasive material and contamination from the fuel system.

Supply lines and return lines - Supply lines and return lines are used to deliver the fuel to the different components.

The purpose of the low pressure fuel supply circuit is to supply fuel that has been filtered to the fuel injectors at a rate that is constant and a pressure that is constant. The fuel system is also utilized to cool components such as the electronic control module and the fuel injectors.

Once the injectors receive the low pressure fuel, the fuel is pressurized again before the fuel is injected into the cylinder.

The unit injector uses mechanical energy that is provided by the camshaft to achieve pressures that can be in excess of 200,000 kPa (30,000 psi).

Control of the fuel delivery is managed by the engine's Electronic Control Module (ECM). Data from several of the engine systems is collected by the ECM and processed in order to manage these aspects of fuel injection control:

- Injection timing
- Fuel injection timing advance
- Injection duration
- Engine cold mode status

The mechanical electronic fuel system relies on a large amount of data from the other engine systems. The data that is collected by the ECM will be used in order to provide optimum performance of the engine.

Low Pressure Fuel Supply Circuit

The flow of fuel through the system begins at fuel tank (13). Fuel is pulled from the tank by fuel transfer pump (10). The fuel transfer pump incorporates a check valve (12) that will allow fuel to flow around the gears of the pump during hand priming of the fuel system. The fuel transfer pump also incorporates a pressure relief valve (11). The pressure relief valve is used in order to protect the fuel system from extreme pressure.

The fuel transfer pump is engineered in order to produce an excess fuel flow throughout the fuel system. The excess fuel flow is used by the system to cool the fuel system components. The excess fuel flow also purges any air from the fuel system during operation. Air that can become trapped in the fuel system can cause cavitation that may damage the components of the unit injector.

The fuel travels from the fuel transfer pump to distribution block (8). A fuel temperature sensor (9) that is installed in the distribution block is used to sample the fuel temperature. A signal that represents the fuel temperature is sent to the electronic control module (ECM) for processing.

The fuel is then pumped in to the fuel filter base. In most applications, fuel priming pump (7) is located on the fuel filter base. The fuel filter base also incorporates a siphon break that prevents fuel from draining from the fuel system when the engine is not in operation. The priming pump utilizes a series of check valves in order to direct the flow of fuel during the priming pump's operation. The check valves work with the fuel priming pump in order to produce a pumping action. The check valves also prevent fuel from being forced back into the fuel transfer pump. The fuel flows through a two micron fuel filter (6). The filtered fuel then flows out of the fuel filter base.

If a fuel cooled ECM is installed on the engine, the fuel is pumped into the ECM. The fuel travels through the cored passages of the electronic control module housing in order to cool the control module's electronics.

The fuel is transfered by fuel supply lines (1) to fuel gallery (3) in the cylinder head or to fuel manifold (3). Only a portion of the fuel that is supplied to the fuel injectors is used for engine operation.

The fuel that is unused by the engine is provided for cooling purposes. This unused fuel is discharged into the return passages of the fuel gallery. The fuel is returned to the fuel tank by the fuel return lines. A continuous flow of fuel is experienced within the low pressure fuel system.

During engine operation, fuel injectors (2) receive fuel from the low pressure fuel system. The injector pressurizes the fuel to high pressure. The fuel is then injected into the cylinder. The excess fuel is returned to the tank. Refer to Systems Operation, "Unit Injector" for a complete explanation of the injection process.

A pressure regulating valve (5) is located in the fuel return. The pressure regulating valve allows the low pressure fuel system to maintain a constant pressure. A flow control orifice is also located in the fuel return. The flow control orifice maintains a system back pressure that is constant. The orifice allows the flow of fuel through the system to be constant. This prevents excessive heating of the fuel.

Fuel Heaters

Fuel heaters help to prevent the plugging of the fuel filters in cold weather. This plugging is called waxing. In cold ambient conditions, the cold engine does not dissipate enough heat into the fuel system in order to prevent waxing. Heaters that are not thermostatically controlled can heat the fuel in excess of 65° C (149° F). Excessive temperatures in the fuel system will drastically reduce the efficiency of the engine. The fuel system's reliability is also affected by high fuel temperatures.

Note: Never use fuel heaters without some type of temperature regulator. Ensure that fuel heaters are turned OFF during warm weather conditions.

Fuel System Electronic Control Circuit

The fuel system's electronic control circuit can be viewed as two distinct control circuits: engine control logic and electronic governor control.

Refer to Illustrations 2 and 3 for typical examples of the engine control logic. Refer to Illustrations 4 and 5 for typical examples of the electronic governor control.

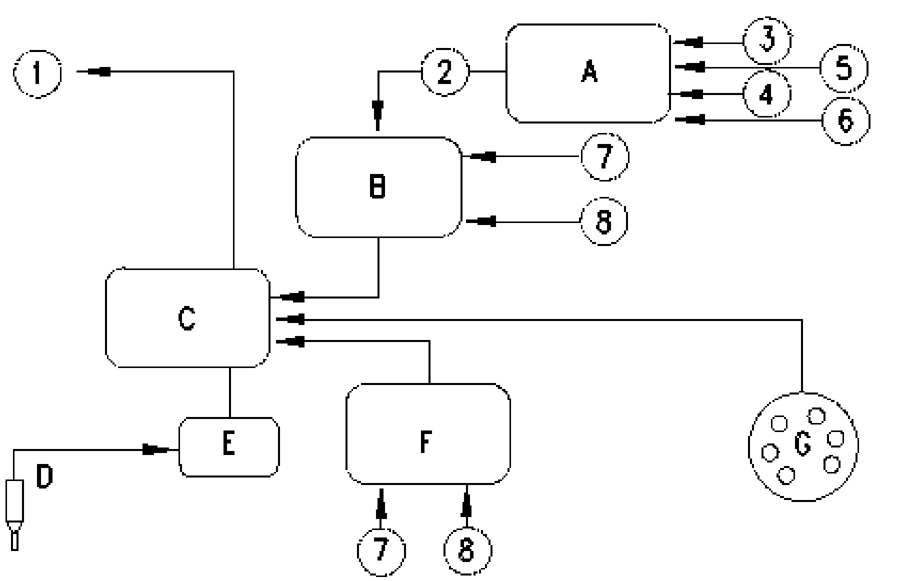

Illustration 2 g00597197

Typical logic for engine speed control (truck applications)

(A) Logic for CRUISE/PTO

(B) Control for CRUISE/PTO

(C) Engine control logic

(D) Coolant temperature sensor

(E) Cold mode operation

(F) Customer parameters

(G) Accelerator pedal position sensor

(1) Signal for enabling the engine retarder

(2) Cruise control (mph) or PTO (rpm)

(3) Transmission clutch/brake pedal

(4) Cruise control set/resume switch

(5) Cruise control on/off switch

(6) PTO on/off switch

(7) Vehicle speed (mph)

(8) Engine speed (rpm)

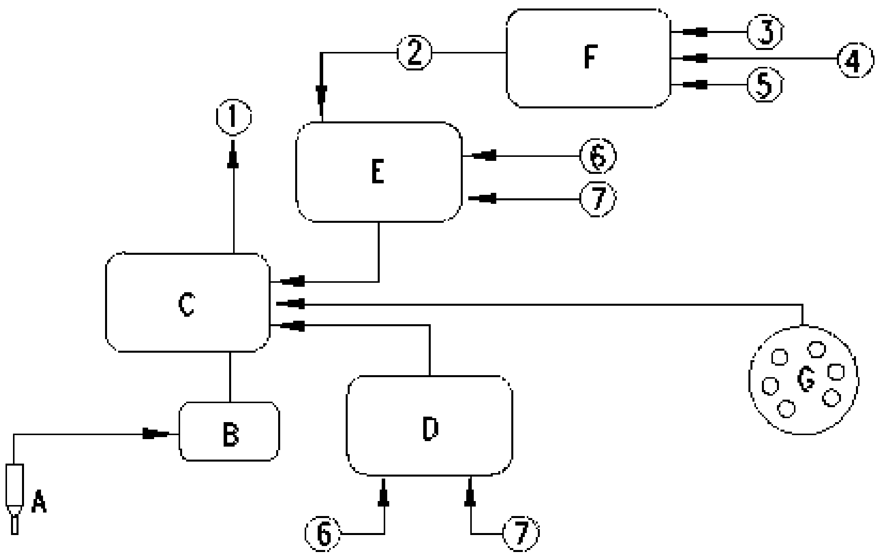

Illustration 3 g00418418

Typical logic for engine speed control (machine and industrial applications)

(A) Coolant temperature sensor

(B) Cold mode operation

(C) Logic for engine control (Desired RPM)

(D) Customer parameters

(E) Control for PTO

(F) Logic for PTO

(G) Throttle position sensor

(1) Retarder enable signal (signal to the retarder controls)

(2) PTO set speed

(3) PTO enable

(4) PTO ramp up/down switch

(5) Remote shutdown

(6) PTO interrupt

(7) Engine speed in rpm

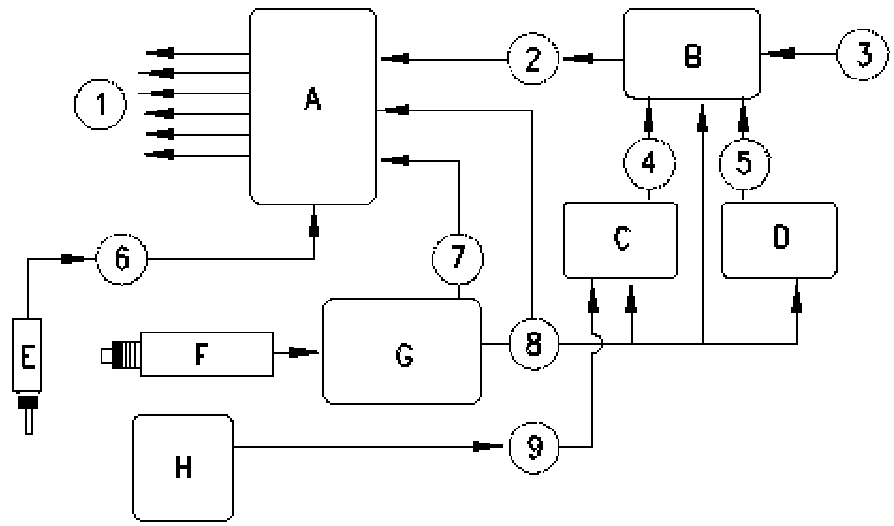

Illustration 4 g00597207

Typical control for electronic governor (truck applications)

(A) Fuel injection control

(B) Electronic governor

(C) Fuel ratio control maps

(D) Torque maps

(E) Coolant temperature sensor

(F) Engine speed/timing sensor

(G) Engine speed signal interpreter

(H) Boost pressure sensor

(1) Signals to unit injectors

(2) Fuel position

(3) Desired engine speed (rpm)

(4) FRC fuel position

(5) Rated fuel position

(6) Coolant temperature

(7) Top center for number one cylinder

(8) Engine speed (rpm)

(9) Boost pressure

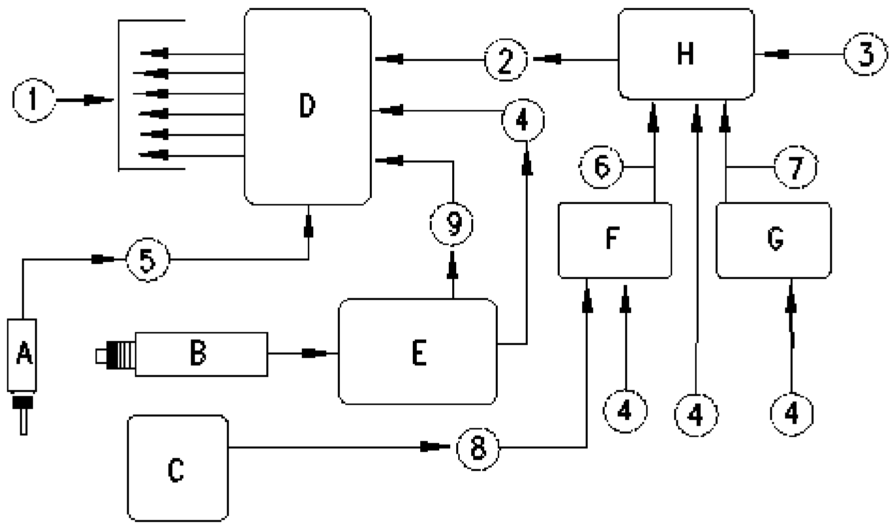

Illustration 5 g00418438

Typical control for electronic governor (machine and industrial applications)

(A) Coolant temperature sensor

(B) Engine speed/timing sensor

(C) Boost pressure sensor

(D) Fuel injection control

(E) Engine speed signal interpreter

(F) Fuel ratio control maps

(G) Torque maps

(H) Electronic governor

(1) Signals to unit injectors

(2) Fuel position

(3) Desired engine speed (rpm)

(4) Engine speed (rpm)

(5) Coolant temperature

(6) FRC fuel position

(7) Rated fuel position

(8) Turbocharger outlet pressure

(9) Top center for number one cylinder

Electronic Controls

There are two major components of the electronic control system that are necessary in order to provide control of the mechanical electronic unit injectors:

- ECM
- Personality module (storage for the ECM flash file)

The ECM is the computer that is used to provide control for all aspects of engine operation. The personality module contains the software that defines the characteristics of the engine control. The personality module contains the operating maps. The operating maps define the following characteristics of the engine:

- Horsepower
- Torque curves
- Engine speed (rpm)
- Other characteristics

The ECM, the personality module, the engine sensors, and the unit injectors work together in order to control the engine. Neither of the four can control the engine alone.

The ECM maintains the desired engine speed by sensing the actual engine speed. The ECM calculates the amount of fuel that needs to be injected in order to achieve the desired engine speed.

Fuel Injection

The ECM controls the amount of fuel that is injected by varying the signal to each of the unit injectors. The unit injectors will inject fuel only while the unit injector solenoid is energized. The ECM sends a 105 volt signal to the solenoid in order to energize the injector solenoid. By controlling the timing of the 105 volt signal, the ECM controls injection timing. By controlling the duration of the 105 volt signal, the ECM controls the amount of fuel that is injected.

The ECM sets certain limits on the amount of fuel that can be injected. The FRC fuel position is a limit that is based on boost pressure in order to control the fuel air mixture for the emission control. When the ECM senses an increase in the boost pressure, the ECM increases the FRC fuel position. The rated fuel position is a limit that is based on the horsepower rating of the engine. The rated fuel position is similar to the rack stops and the torque spring on a mechanically governed engine. The rated fuel position provides the horsepower and the torque curves for a specific engine family. The rated fuel position provides the horsepower and the torque curves for a specific horsepower rating. The limits are programmed by the factory into the personality module. The limits are not programmable in the field.

The injection timing relies on the following engine parameters: engine speed, engine load and other engine data. The ECM senses the top center position of number one cylinder from the signal that is provided by the engine speed/timing sensors. The ECM decides when the injection should occur relative to this top center position. The ECM provides the signal to the unit injector at the desired time.

Unit Injector Mechanism

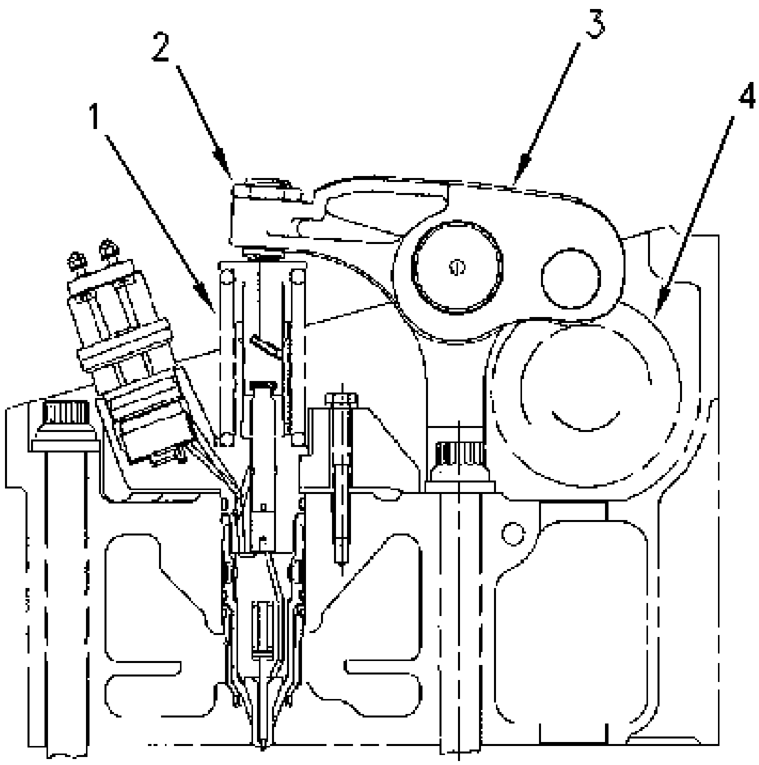

Illustration 6 g00291269

Typical unit injector mechanism

(1) Unit injector

(2) Adjusting nut

(3) Rocker arm assembly

(4) Camshaft

The unit injector mechanism provides the downward force that is required to pressurize the fuel in the unit injector. When a signal is received from the ECM, the unit injector (1) injects the pressurized fuel into the combustion chamber. The camshaft gear is driven by an idler gear which is driven through the front gear train by the crankshaft gear. The gears of the front gear train that are timed must be aligned in order to provide the correct relationship between the piston and valve movement. During assembly of the front gear train, care must be taken in order to correctly align the timing marks of the gears. The camshaft has three camshaft lobes for each cylinder. Two lobes operate the inlet and exhaust valves, and one operates the unit injector mechanism. Force is transferred from the unit injector lobe on camshaft (4) through rocker arm assembly (3) to the top of the unit injector. The adjusting nut (2) allows setting of the unit injector adjustment. Refer to the section on adjustment of the injector in Testing and Adjusting for the proper setting of the unit injector.

Unit Injector

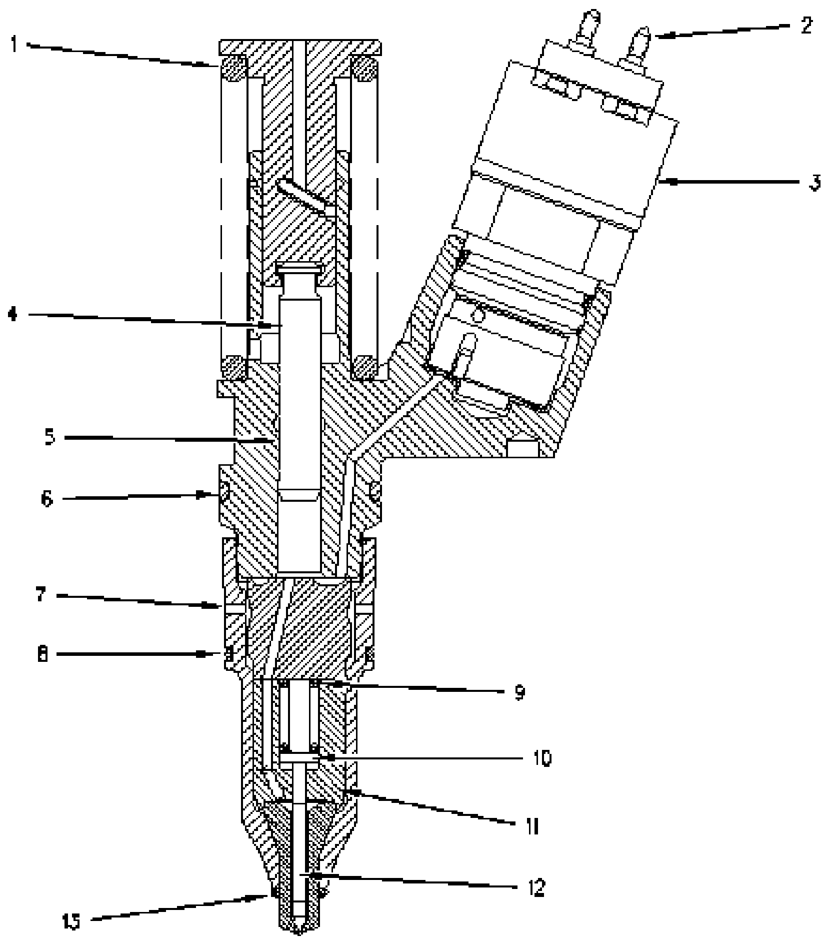

Illustration 7 g00922660

Typical mechanical electronic unit injector

(1) Spring

(2) Solenoid terminal

(3) Solenoid valve assembly

(4) Plunger

(5) Barrel

(6) Seal

(7) Fill port

(8) Seal

(9) Spring

(10) Spacer

(11) Body

(12) Check valve

(13) Seal

Fuel at low pressure from the fuel gallery (supply manifold) enters the unit injector at the fill port through passages in the cylinder head.

As the unit injector mechanism transfers the force to the top of the unit injector, the spring (1) is compressed and the plunger (4) is driven downward. This causes fuel to be displaced through the valve, in solenoid valve assembly (3), and into the fuel return port of the cylinder head. As the plunger continues to be driven downward, the fuel passage in the barrel (5) is closed by the outside diameter of the plunger. The passages to the injector tip within body (11) and along check valve (12) are filled with the fuel that is displaced by the plunger. After the fuel passage in the plunger barrel is closed, fuel can be injected at any time. The characteristics of the injection cycle relies on the software in the ECM.

When solenoid valve assembly (3) is energized by a signal across solenoid terminal (2), the solenoid valve closes and pressure in the injector tip increases. Injection begins at 37,931 kPa (5,500 psi) as the force of spring (9) is overcome. This causes the check valve to rise from the valve seat. The pressure continues to increase as the plunger cycles through the full stroke. After the correct amount of fuel has been discharged into the cylinder, the ECM discontinues the 105 volt signal. The solenoid valve assembly is de-energized and the solenoid valve is opened. The high pressure fuel is dumped through the spill port and into the fuel return port of the cylinder head. The check valve in the injector tip seats. Injection has ended as the fuel pressure decreases to 25,517 kPa (3,700 psi).

The duration of injection determines the quantity of fuel that is injected into the cylinder. Injection duration is controlled by the governor logic that is programmed into the ECM.

As the unit injector mechanism begins to retract, the force to the top of the unit injector is removed as spring (1) expands. The plunger returns to the original position. As the plunger retracts, a vacuum is created in barrel of the injector. This pulls fuel into the barrel which fills the cavity in preparation of the next injection cycle.
