Fuel Injection System

The purpose of the fuel injection system is to precisely inject a metered amount of fuel at the correct time. Based on the input sensor signals, the ECMs programming will decide when to turn each injector on and off.

Fuel Delivery System

The purpose of the fuel delivery system is to quietly deliver the proper volume of fuel at the correct pressure. The fuel delivery system must also meet emission and safety regulations. Major components are:

- Fuel Pump.
- Fuel Pump ECU.
- Pressure Regulator.
- Fuel Pressure Control Circuit.
- Fuel Lines.
- Fuel Tank.
- Fuel Filter.
- Pulsation Damper.
- Fuel Injectors.
- Inertia Switch.

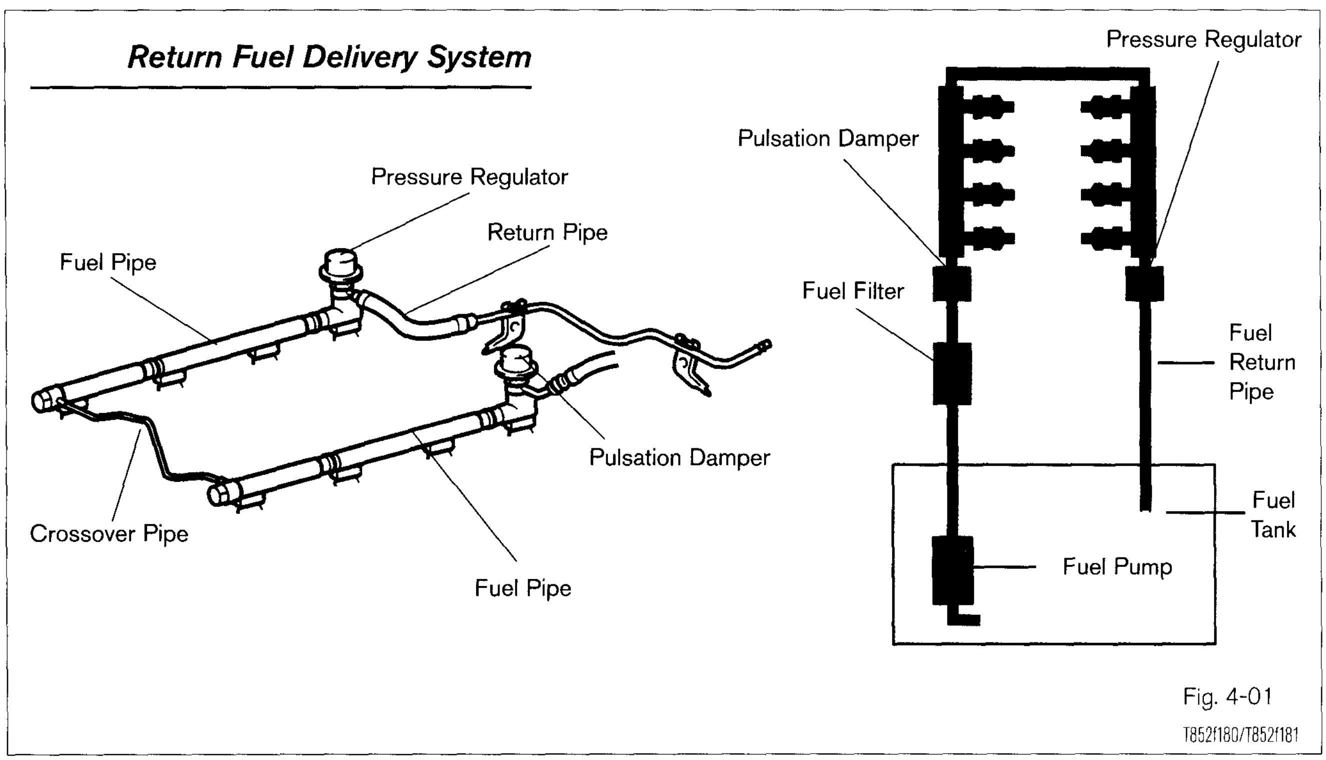


Fig. 4-01

Return Fuel Delivery System
When the fuel pump is activated by the ECM, pressurized fuel flows out of the tan, through the fuel filter to the fuel rail and up to the pressure regulator. The pressure regulator maintains fuel pressure in the rail at a specified value. Fuel in excess of that consumed by engine operation is returned to the tank by a fuel return line. A pulsation damper, mounted on the fuel rail, is used on many engines to dampen pressure variations in the fuel rail. The injectors, when turned on by the ECM deliver fuel into the intake manifold. When the fuel pump is turned off by the ECM, a check valve in the fuel pump closes maintaining a residual pressure in the fuel system.

Returnless Fuel Delivery System

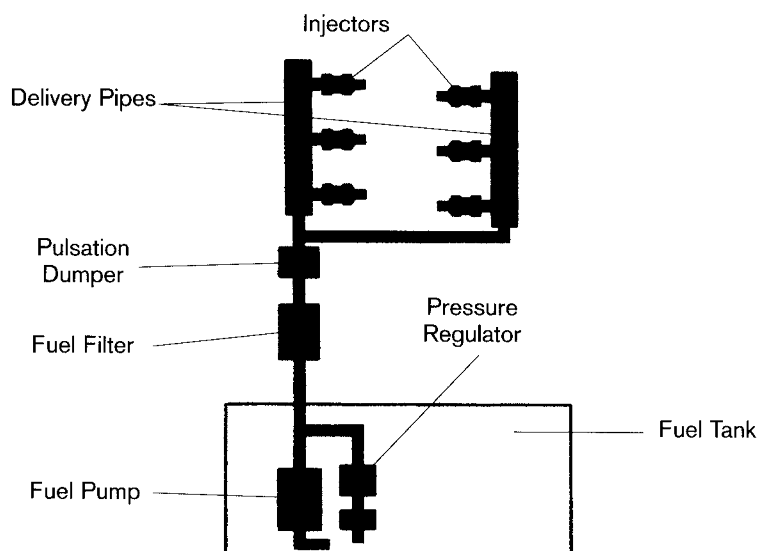


Fig. 4-02
T852f182

Returnless Fuel Delivery System
When the fuel pump is activated by the ECM pressurized fuel flows from the pump to the pressure regulator. At the pressure regulator excess fuel is directed to the bottom of the fuel tank and pressurized fuel is sent out of the fuel tank, through the fuel filter, pulsation damper, and into the fuel rail. When the ECM turns on the injectors fuel is delivered into the intake manifold.

Fuel pressure in this system is maintained at a constant and higher pressure, 44-50 psi (301-347 kPa) than the return fuel system. ECM programming and a higher fuel pressure eliminates the need for a vacuum modulated pressure regulator.

The returnless fuel delivery system was adopted because it lowers evaporative emissions since no heated fuel is returned to the fuel tank. On the return fuel delivery system, fuel heated by the engine returns to the fuel tank and has warmer fuel creating more fuel vapors.

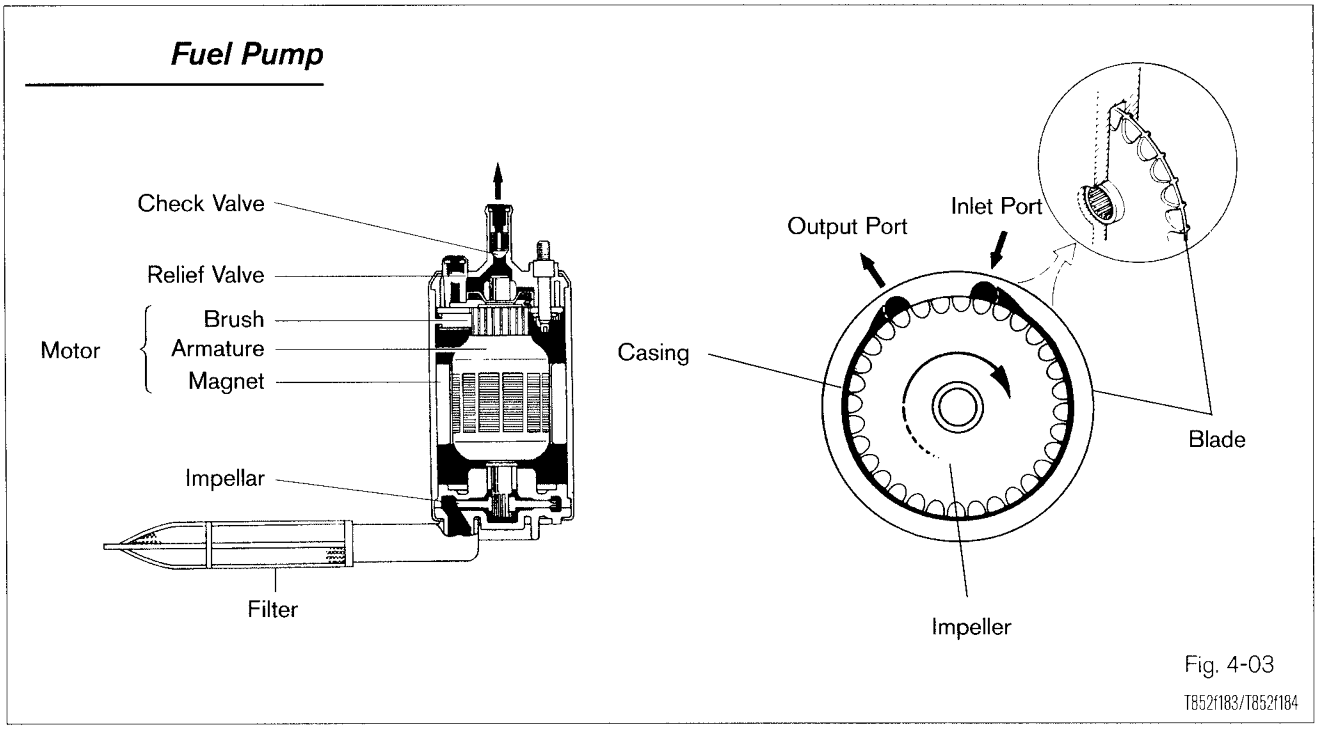


Fig. 4-03

Fuel Pump
The fuel pump is mounted in the tank and immersed in fuel. The fuel cools and lubricates the pump. When current flows through the motor, the armature and impeller rotate. The impeller draws fuel in through a filter and discharges pressurized fuel through the outlet port. The fuel pump's pumping capacity is designed to exceed engine requirements. This insures that there will always be enough fuel to meet engine demands.

An outlet check valve, located in the discharge outlet, maintains a residual fuel pressure in the fuel system when the engine is off. This improves starting characteristics and reduces vapor-lock. Without residual fuel pressure, the system would have to be pressurized each time the engine was started and this would increase engine starting (cranking) time. When a hot engine is shut off, fuel temperature in the lines around the engine increases. Keeping the system pressurized increases the boiling point of the fuel and prevents the fuel from vaporizing.

A pressure relief valve will open if the fuel system becomes restricted. This is a safety device to prevent the fuel lines from rupturing and damage to the pump.

On many models the fuel pump is part of the fuel pump assembly. This assembly contains the filters, pressure (fuel system only), sending unit, and fuel pump. Many of the components can be serviced separately.

Typical Fuel Pump Assembly

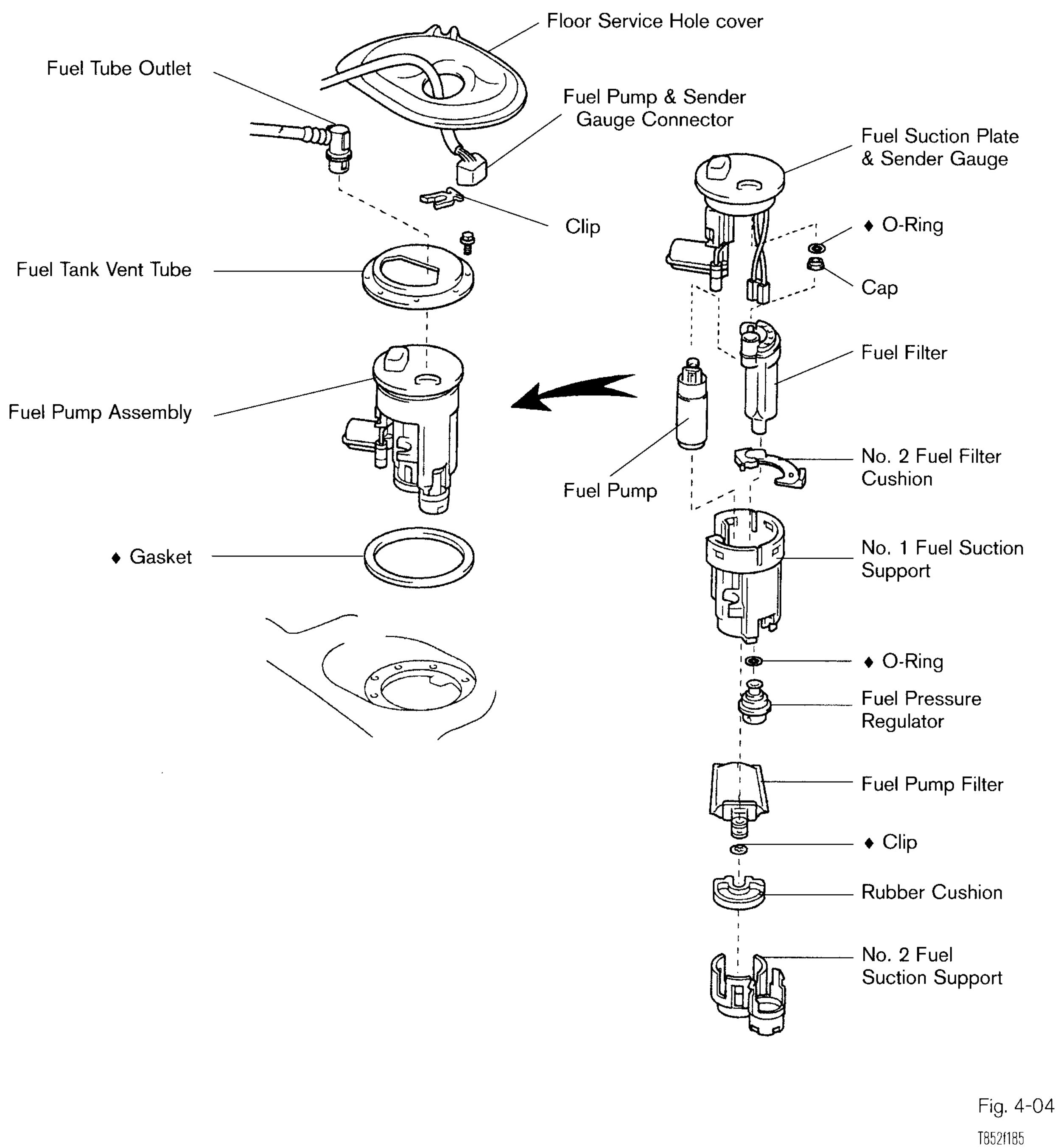
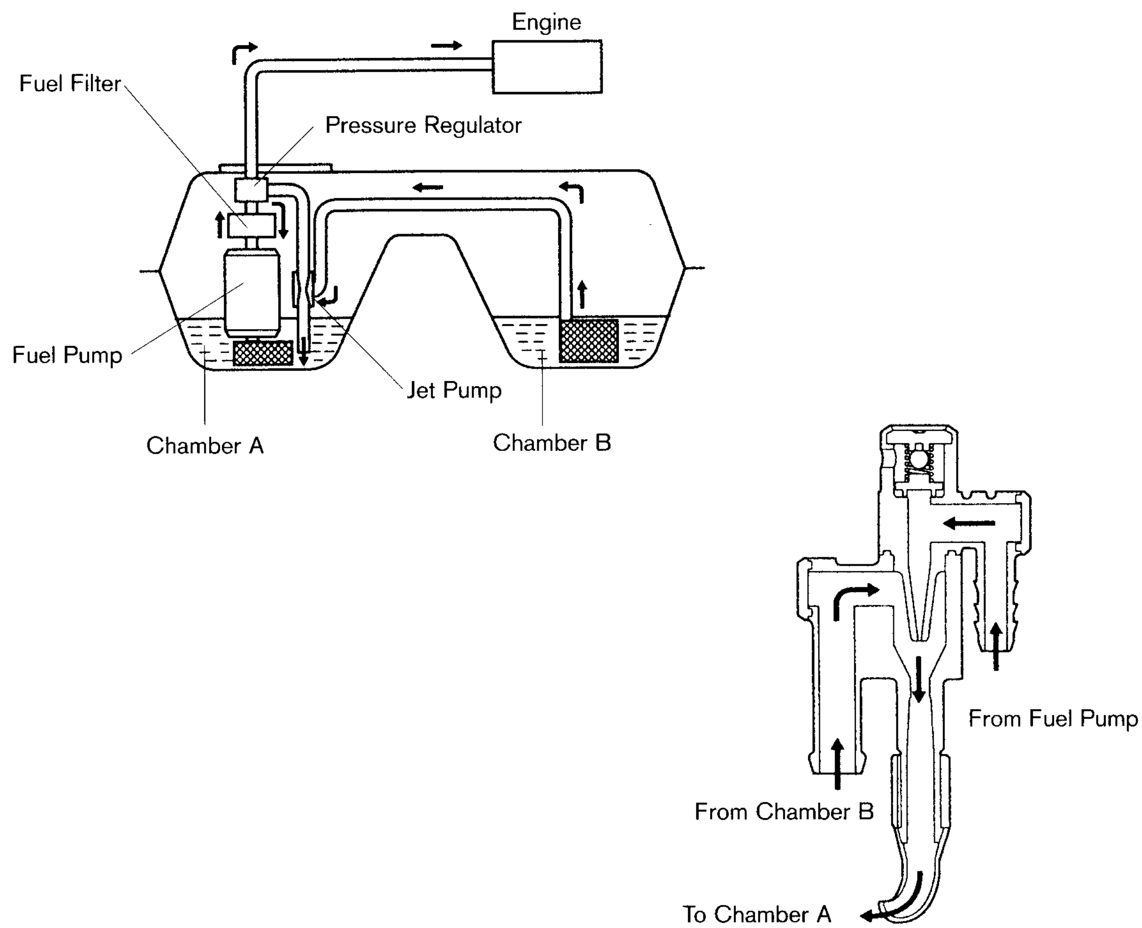


Fig. 4-04

Jet Pump



Jet Pump

Fig. 4-05

T852f186/T852f187

Jet Pump

The jet pump is an additional pump used when the fuel tank bottom is divided into two chambers. Excess fuel flowing through the fuel return passes through a venturi. This creates a low pressure area around the venturi, and this action will draw the fuel out of Chamber B, and sends it into Chamber A.

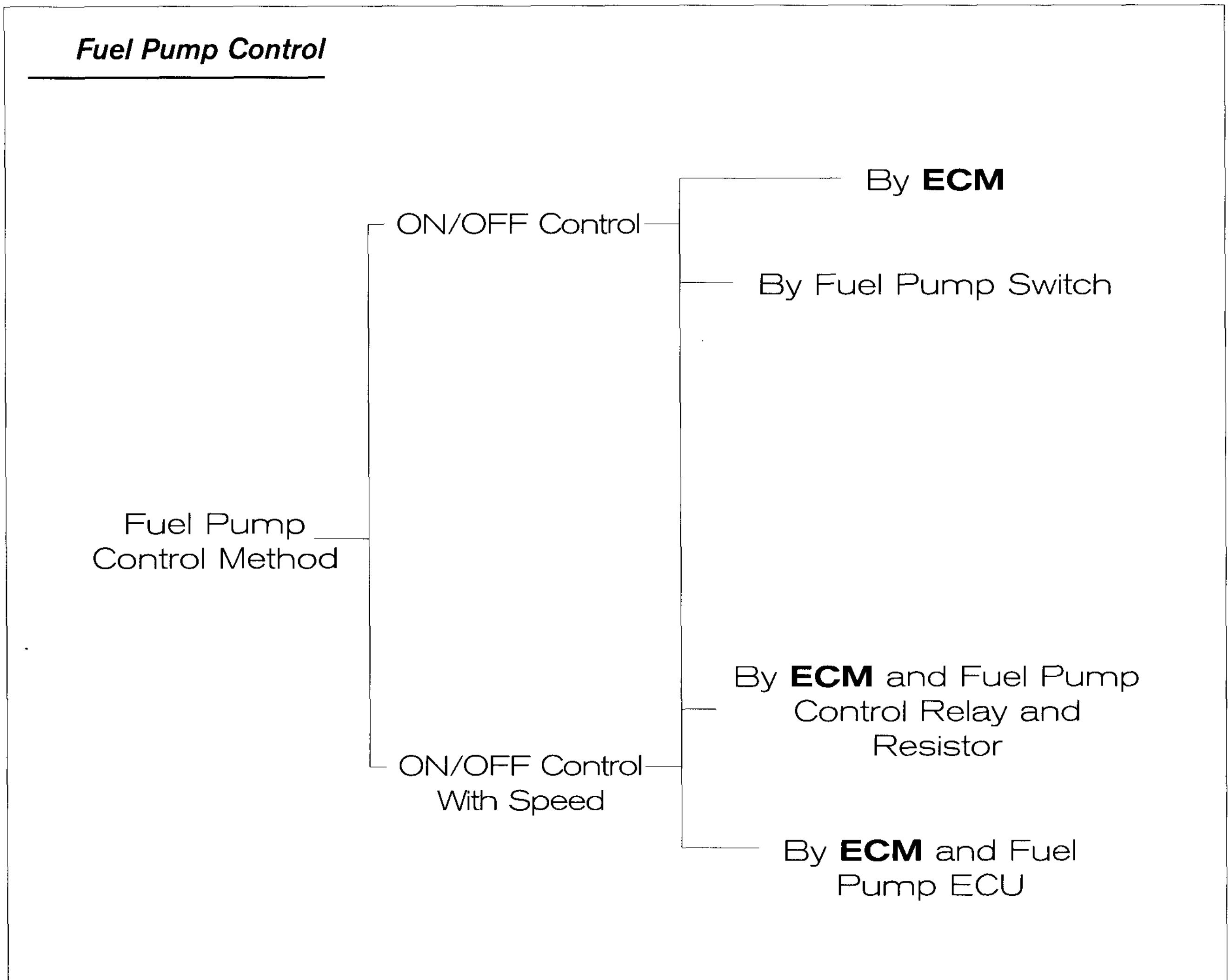


Fig. 4-06

Fuel Pump Controls
A variety of fuel pump control circuits and controls have been used over the years. The following basic methods are:

- ON/OFF Control by ECM.
- ON/OFF Control by Fuel Pump Switch.
- ON/OFF Two Speed Control with a Resistor.
- ON/OFF Two Speed Control with Fuel Pump ECU.
- ON/OFF Three Speed Control with Fuel Pump ECU.

The most accurate way of determining the type of fuel control circuit is to look up the circuit in the appropriate EVVD.

The following describes the basic methods of fuel pump control. An essential point to remember is that the fuel pump operates only when the engine is cranking or running.

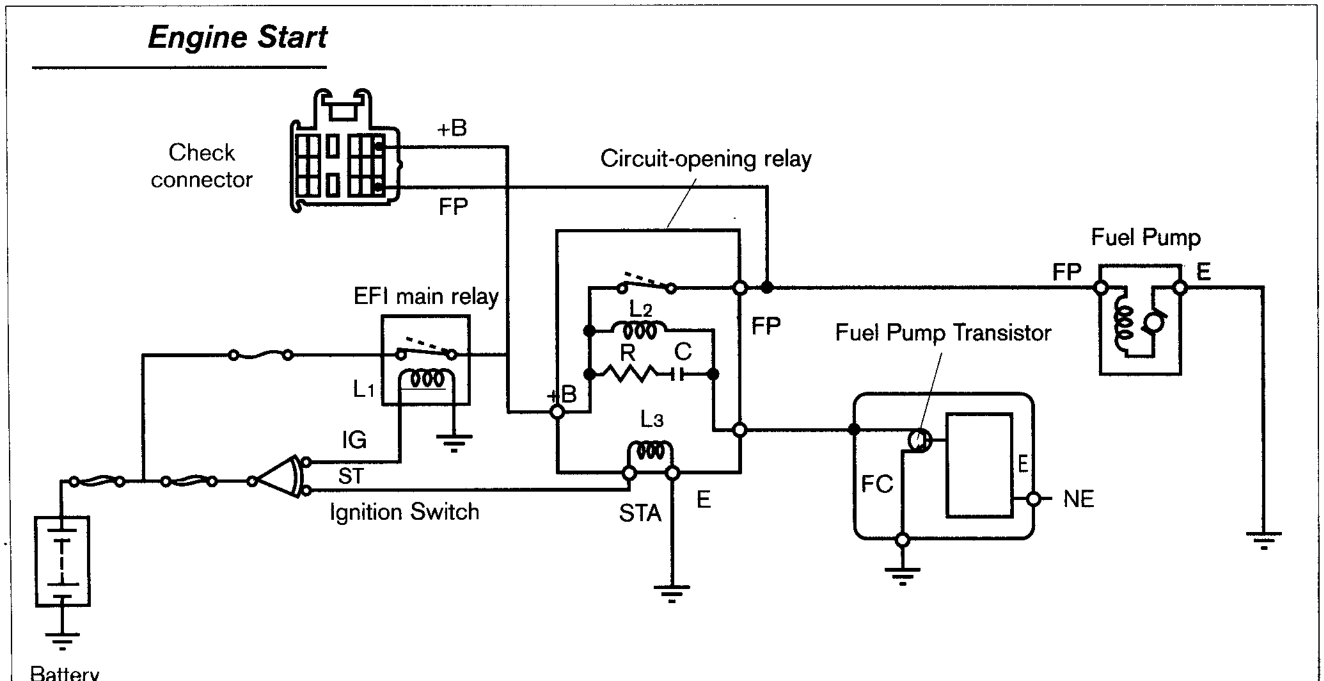


Fig. 4-07

T852f188

ON/OFF Control by ECM

The following is an explanation of how the fuel pump circuit is activated.

Engine Start

When the engine is cranking, current flows from the IG terminal of the ignition switch to the L1 coil of the EFI main relay, turning the relay on. At the same time, current flows from the ST terminal of the ignition switch to the L3 coil of the circuit opening relay, turning it on to operate the fuel pump. The fuel pump is now supplying fuel to the fuel injection system.

Note: The circuit opening relay in this example is ground side switched.

Engine Running

Once the engine starts and the ignition key is moved to the ON (IG) position, current to the L3 coil is shut off, but the ECM will keep the fuel pump on through coil L2 as long as the ECM receives an NE signal. If the NE signal is lost at any time after starting, the ECM turns the fuel pump off.

Engine Stopped
When the engine stops, the NE signal to the ECM stops. This turns off the transistor, thereby cutting off the flow of current to the L2 coil of the circuit opening relay. As a result, the circuit opening relay opens turning off the fuel pump.

Note: The resistor R and the capacitor C in the circuit-opening relay are for the purpose of preventing the relay contacts from opening when current stops flowing in coil L2 due to electrical noise (fuel pumps controlled by the ECM) or to sudden drops in the intake air volume (fuel pumps controlled by fuel pump switch). They also serve to prevent sparks from being generated at the relay contacts. On some models, an L3 coil is not provided in the circuit-opening relay.

Fuel Pump Control Switch

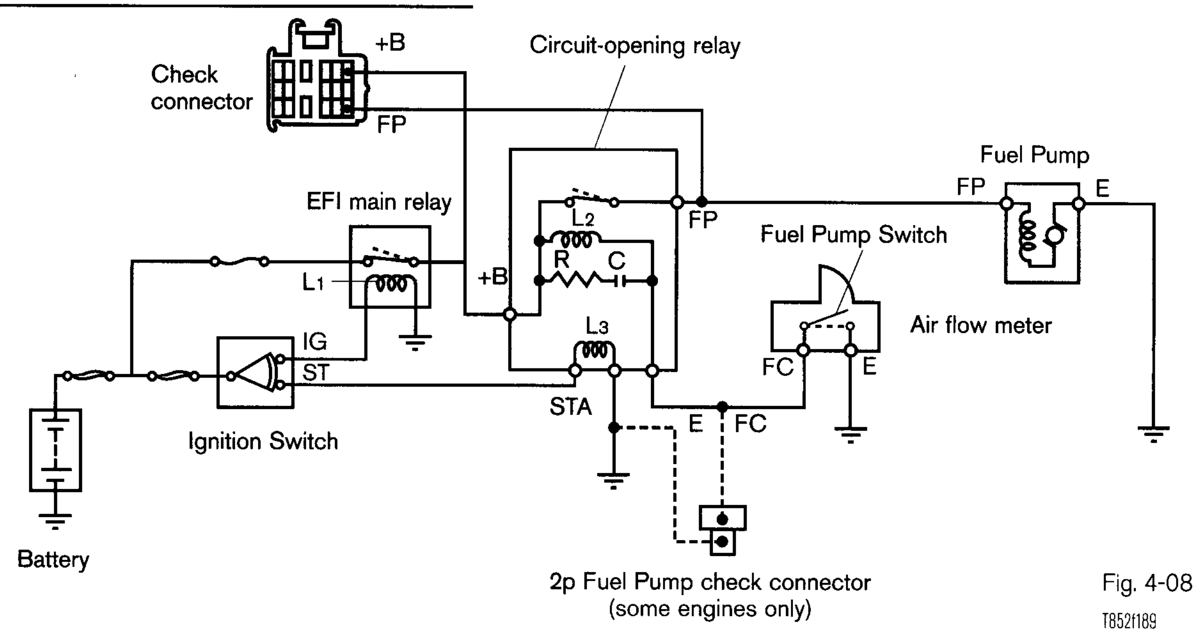


Fig. 4-08
T852f189

ON/OFF Control by Fuel Pump Switch

The fuel pump switch is found on older vehicles using a Vane Air Flow Meter. The air moves the vane when the engine is running closing the fuel pump switch. The following is an explanation of circuit operation.

Engine Start
When the engine is cranking, current flows from the IG terminal of the ignition switch to the L1 coil of the EFI main relay, turning the relay on. Current also flows from the ST terminal of the ignition switch to the L3 coil of the circuit-opening relay, turning it on to operate the fuel pump. After the engine starts, the cylinders begin drawing in air, causing the measuring plate inside the air flow meter to open. This turns on the fuel pump switch, which is connected to the measuring plate, and current flows to the L2 coil of the circuit-opening relay.

Engine Running
After the engine starts and the ignition switch is turned from ST back to IG, current flowing to the L3 coil of the circuit-opening relay is cut off. However, current continues to flow to the L2 coil while the engine is running due to the fuel pump switch inside the air flow meter being on. As a result, the circuit-opening relay stays on, allowing the fuel pump to continue operating.

Engine Stopped
When the engine stops, the measuring plate completely closes and the fuel pump switch is turned off. This cuts off the flow of current to the L2 coil of the circuit-opening relay. As a result, the circuit-opening relay goes off and the fuel pump stops operating.

Two Speed Fuel Pump Control
Large displacement engines require a higher volume of fuel during starting and heavy load conditions than small displacement engines. High capacity fuel pumps are used to meet the demand, but they produce more noise and consume more power. To overcome these disadvantages and increase pump life, a two speed fuel pump control is used.

ON/OFF Two Speed Control with a Resistor

This type uses a double contact relay and a series limiting resistor.

Two Speed Fuel Pump Control with Resistor at Low Speed

When the engine is idling, or under normal driving conditions (when a small amount of fuel is required), the ECM turns on the fuel pump control relay. The relay switches to contact B, sending current through the resistor. This reduces the available current and voltage to the fuel pump, causing it to run at low speed.

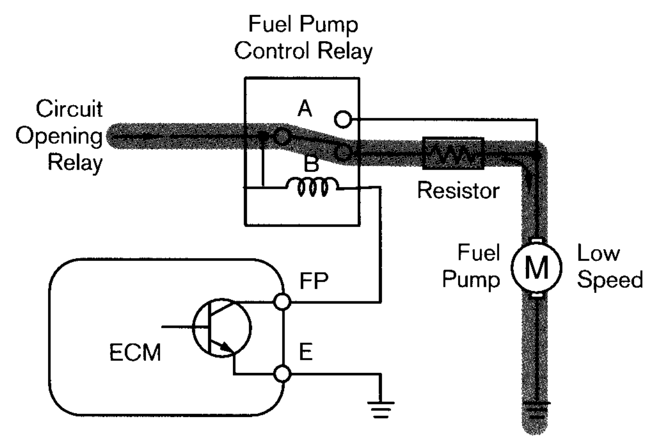


Fig. 4-09

T852f190

High Speed

When the engine is operating at high speeds or under heavy loads, the ECM turns off the fuel pump control relay. The relay switches to contact A, and the current to the fuel pump flows directly to the pump bypassing the resistor, causing the fuel pump to run at high speed.

The fuel pump also runs at high speed while the engine is starting.

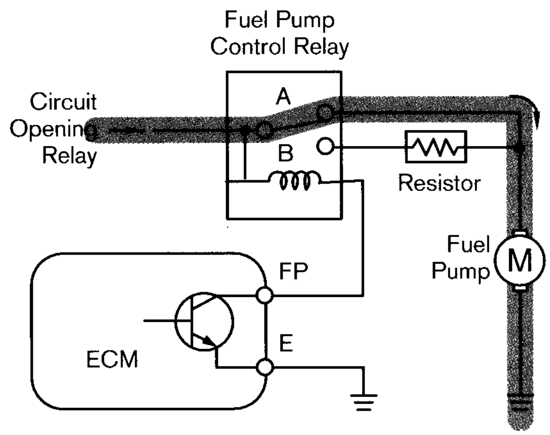


Fig. 4-10
T852f191

Two Speed Control with Fuel Pump ECU

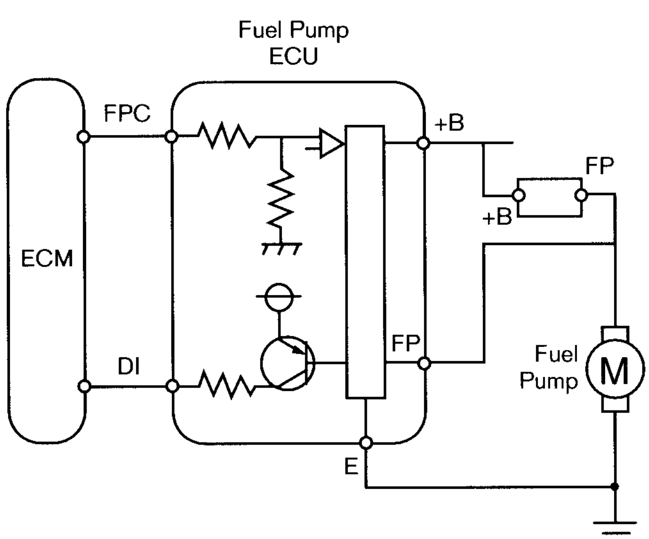


Fig. 4-11
T852f192

ON/OFF Two Speed Control with Fuel Pump ECU

This type is similar to other systems, but uses a Fuel Pump ECU. In this system, however, ON-OFF control and speed control of the fuel pump is performed entirely by the Fuel Pump ECU based on signals from the ECM. In addition, the Fuel Pump ECU is equipped with a fuel pump system diagnosis function. When trouble is detected, signals are sent from the D1 terminal to the ECM.

High Speed
During starting and heavy load condition, the ECM sends a HI signal (about 5 volts) to the FPC terminal of the Fuel Pump ECU. The Fuel Pump ECU then supplies full battery power to the fuel pump.

Low Speed
After the engine starts, during idle and light loads, the ECM outputs a low signal (about 2.5 volts) to the Fuel Pump ECU. Then, the Fuel Pump ECU supplies less voltage (about 9 volts) to the fuel pump.

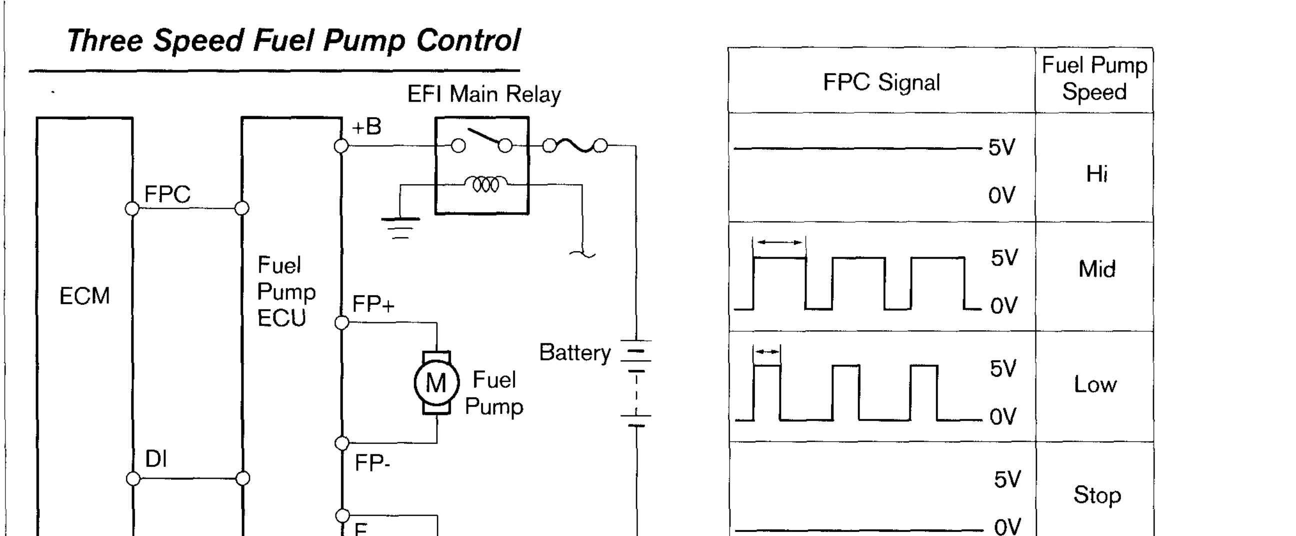


Fig. 4-12
T852f193/T852f194

Three Speed Fuel Pump Control

With this system, the fuel pump is controlled in 3 steps (high speed, medium speed, and low speed).

High Speed
When the engine is operating under a heavy load at high RPM or starting, the ECM sends a 5 volt signal to the fuel pump ECU. The fuel pump ECU then applies battery power to the fuel pump causing the fuel pump to operate at high speed.

Medium Speed
Under heavy loads at low speed, the ECM sends a 2.5 volt signal to the fuel pump control. The fuel pump ECU applies about 10 volts to the fuel pump. This is considered medium speed.

Low Speed
When idling or under light loads, the ECM sends a 1.3 volt signal to the fuel pump ECU. The fuel pump ECU applies 8.5 volts to the fuel pump, preventing excessive noise and decreasing power consumption.

Fuel Pump Inertia Switch

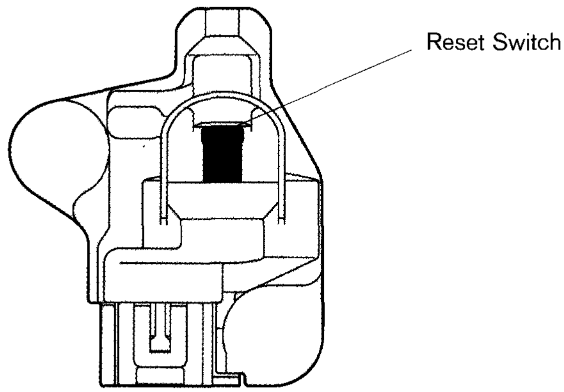
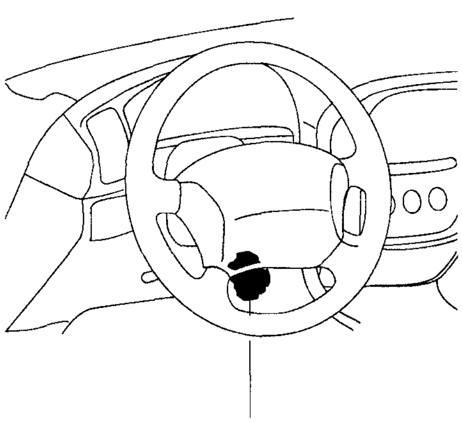


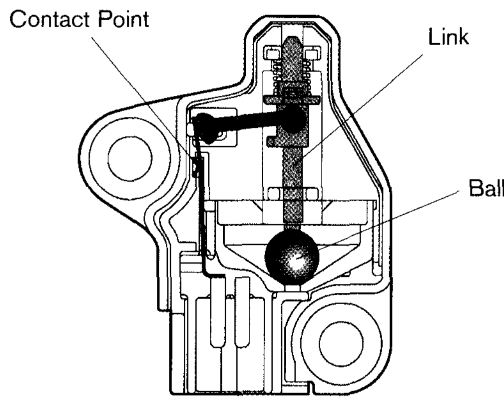
Fig. 4-13
T852f195

Inertia Switch
The fuel pump inertia switch shuts off the fuel pump when the vehicle is involved in a collision, minimizing fuel leakage.

Inertia Switch Location

The inertia switch is mounted on the floor pan.





Cross Section

Fig. 4-14
T852f196/T852f197

Fuel Pump Inertia Circuit

Electrically, the fuel pump inertia switch is located between the ECM and Fuel Pump ECU.

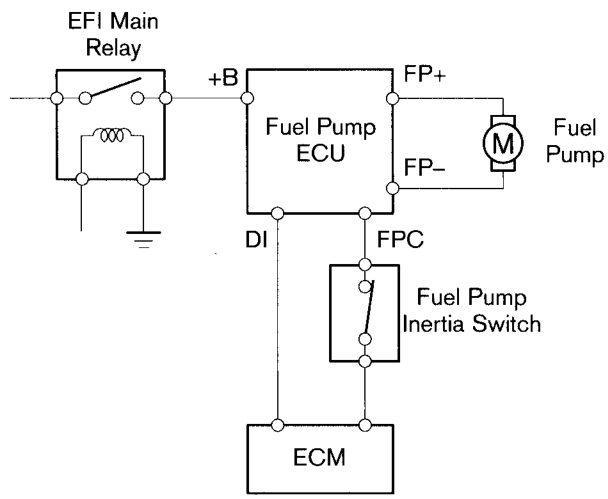


Fig. 4-15
T852f198

Inertia Switch Operation

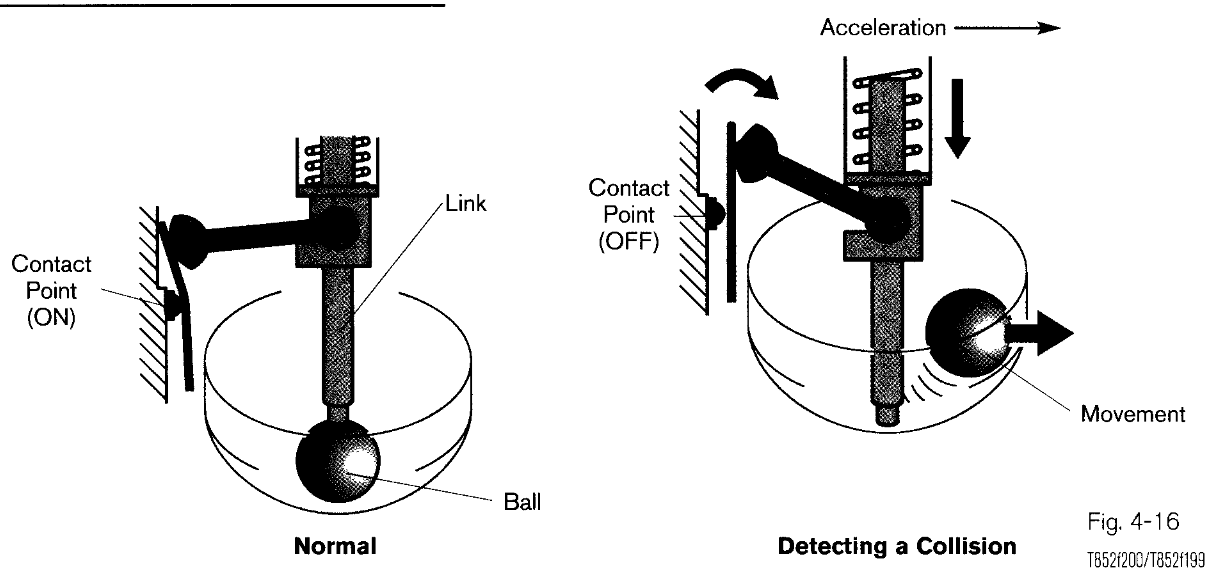


Fig. 4-16
T852f200/T852f199

Operation
The inertia switch consists of a ball, spring loaded link, contact point, and reset switch. If the force of the collision exceeds a predetermined value, the ball will move causing the spring loaded link to drop opening the contact point. This opens the circuit between the ECM and Fuel Pump ECU causing the fuel pump to turn off. If the fuel pump inertia switch has been tripped, it can be reset by pushing up on the reset switch for at least 1 second.

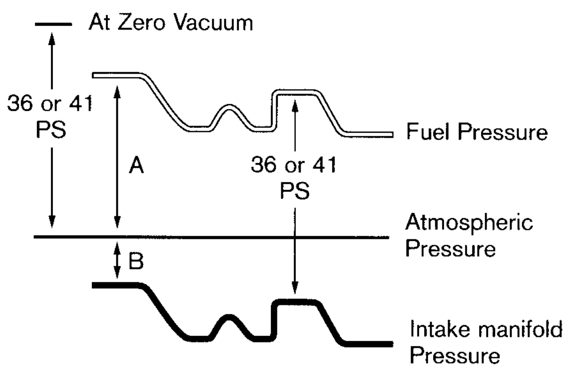
Pressure Regulators

The pressure regulator must consistently and accurately maintain the correct fuel pressure. This is important because the ECM does not measure fuel system pressure. It assumes the pressure is correct. There are two basic types of pressure regulators.

Modulated Pressure Regulators

The return fuel delivery system uses a pressure regulator located on the fuel pressure rail between the fuel pressure rail and the return line to the fuel tank. There are two types of pressure regulators. One type is modulated by vacuum, the other by atmospheric pressure.

Vacuum Modulated Pressure Regulator



Intake Manifold Pressure	Low	High
Effective Spring Tension	Small	Large
Fuel Pressure	Low	High
Injection Volume	Same	Same

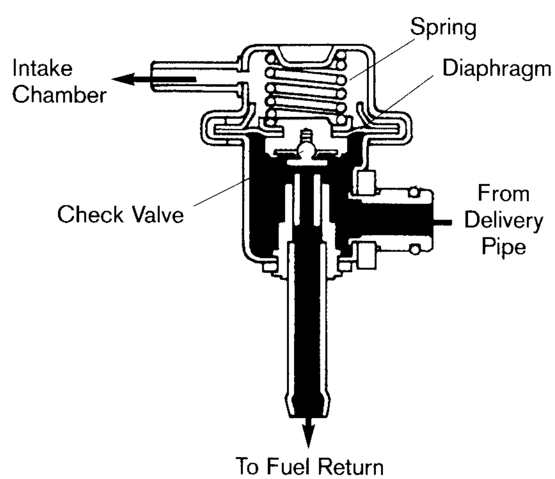


Fig. 4-17
T852f201/T852f202

Vacuum Modulated Pressure Regulator

To maintain precise fuel metering, the vacuum modulated pressure regulator maintains a constant pressure differential across the fuel injector. This means that fuel rail pressure will always be at a constant value above manifold absolute pressure.

Low intake manifold pressure (idle for example) pulls on the diaphragm decreasing spring pressure. This allows more fuel to return to the fuel tank decreasing pressure in the fuel rail. Opening the throttle increases manifold pressure. With less vacuum on the diaphragm spring pressure will increase restricting fuel flow to the fuel tank. This increases pressure in the fuel rail.

Atmospheric Modulated Pressure Regulator

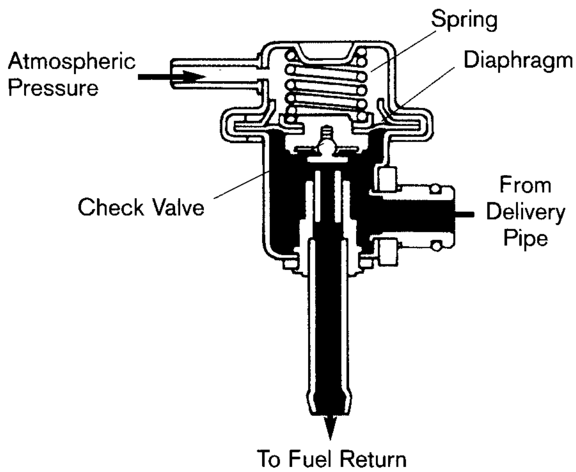


Fig. 4-18
T852f202

Atmospheric Modulated Pressure Regulator

The atmospheric modulated pressure regulator modifies fuel pressure with changes in atmospheric pressure. A hose is connected from the pressure regulator to the air intake hose between the air filter and throttle plate. Spring pressure and atmospheric pressure keep the fuel pressure at a constant value, 226-265 kPa (38-44 psi). As air pressure changes, such as climbing from low to high altitude, fuel rail pressure decreases because there is less force on the diaphragm.

Constant Pressure Regulator

The O-Ring must be properly seated to prevent leakage.

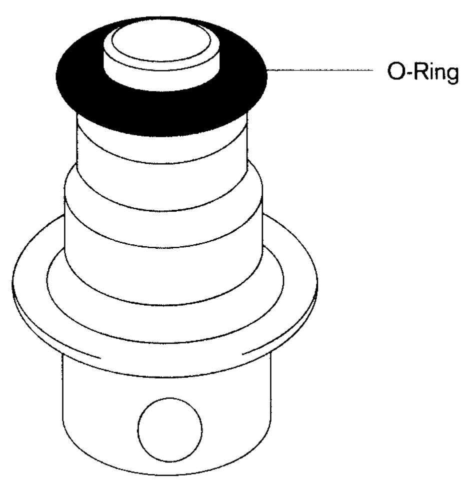


Fig. 4-19
T852f203

Constant Pressure Regulator Returnless Fuel Delivery System)
The Returnless Fuel Delivery System uses a constant pressure regulator located above the fuel pump in the fuel tank. This type of regulator maintains a constant fuel pressure regardless of intake manifold pressure. Fuel pressure is determined by the spring inside the regulator. Fuel from the fuel pump overcomes spring pressure and some fuel is bypassed into the fuel tank. Fuel pressure is non-adjustable.

High Temperature (Pressure Up) Fuel Pressure Control

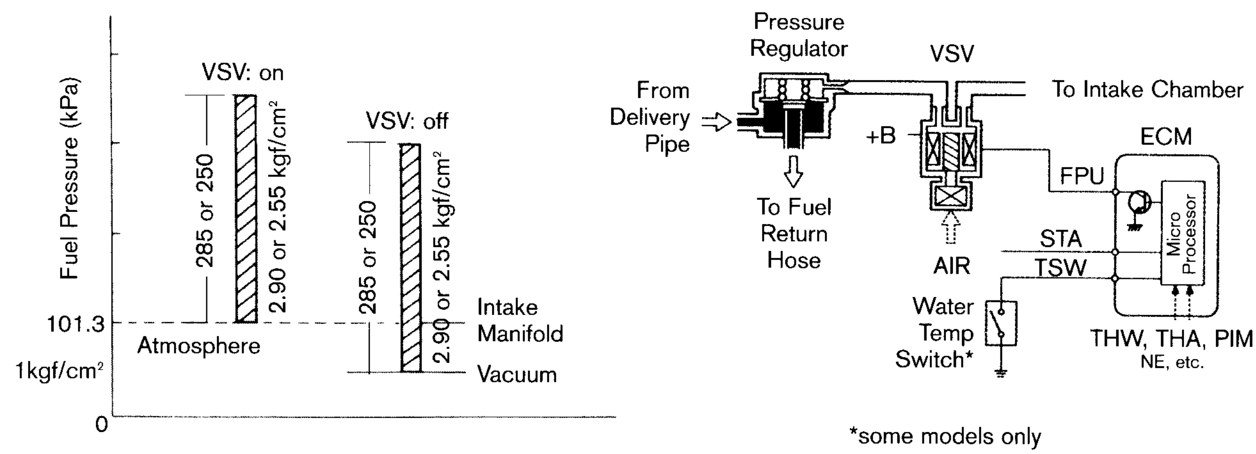


Fig. 4-20
T852f204/T852f205

High Temperature (Pressure Up) Fuel Pressure Control
Some engines are equipped with a high temperature fuel pressure control to prevent vapor lock for easier starting and better driveability. A three way VSV is connected to the fuel pressure regulator vacuum line. Under normal conditions, the VSV is off and engine vacuum regulates the pressure regulator. If the engine is started when the coolant temperature is 85'C (185'F) or higher and the intake air temperature is above predetermined level, the ECM will turn on the VSV. Engine vacuum is closed off and atmospheric pressure is applied to the pressure regulator diaphragm. This increases fuel pressure preventing vapor lock. Once the engine is started, the VSV may remain on for about 120 seconds.

Fuel Delivery Components Fuel Lines And Connectors

Today's vehicles use a variety of materials and connectors for fuel lines. Steel and synthetic materials are used, depending on location and model year. It is critical that the correct procedures be followed when servicing the fuel lines.

Connectors can be the threaded type or the quick connector style.

Styles of Quick Connectors

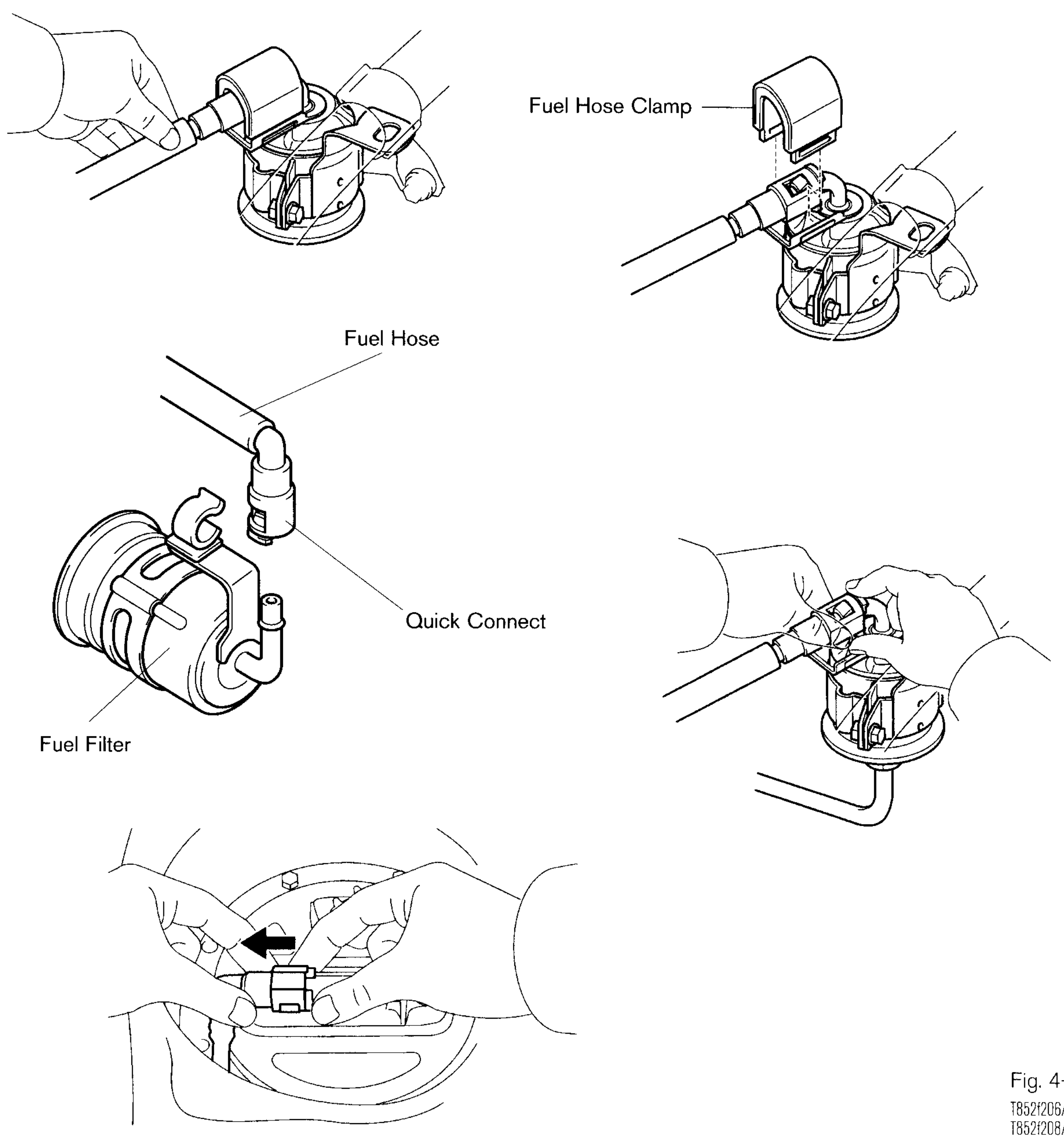


Fig. 4-21
T852f206/T852f207
T852f208/T852f209
T852f210

Fuel Tank

The fuel tank is designed to safely contain the fuel and evaporative emissions. Typically, it houses the fuel pump assembly and rollover protection valves.

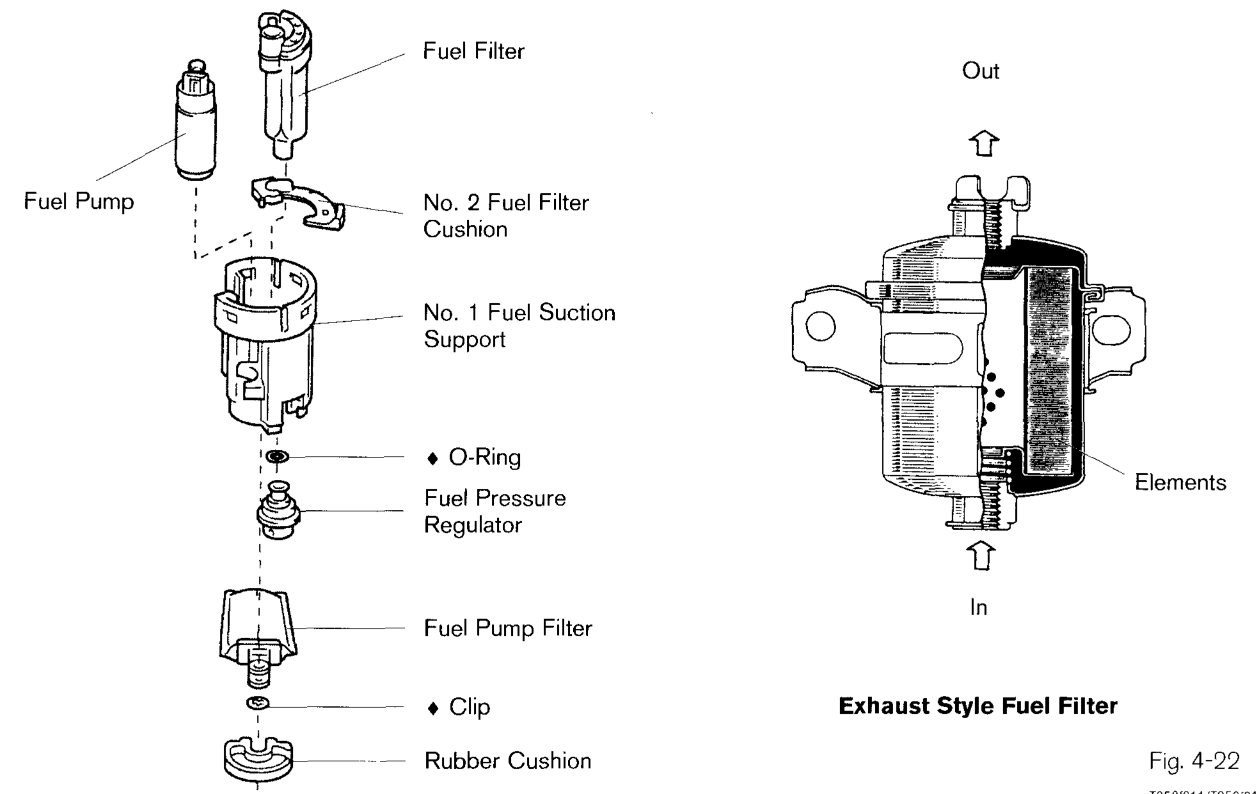


Fig. 4-22

T852f211/T852f212

Fuel Filters

Typically, there are two fuel filters in the fuel delivery system. The first filter is the fuel pump filter located on the suction side of the fuel pump. This filter prevents debris from damaging the fuel pump. The second filter, located between the pump and fuel rail, removes dirt and contaminates from the fuel before it is delivered to the injectors. This filter removes extremely small particles from the fuel, the injectors require extremely clean fuel.

The filter may be located in the fuel tank as part of the fuel pump assembly or outside the tank in the fuel line leading to the fuel rail. The filter is designed to be maintenance-free with no required service replacement.

A restricted fuel filter will prevent fuel from reaching the injectors. Therefore, the engine may be hard starting, surge, or have low power under loads. A completely clogged filter will prevent the engine from starting.

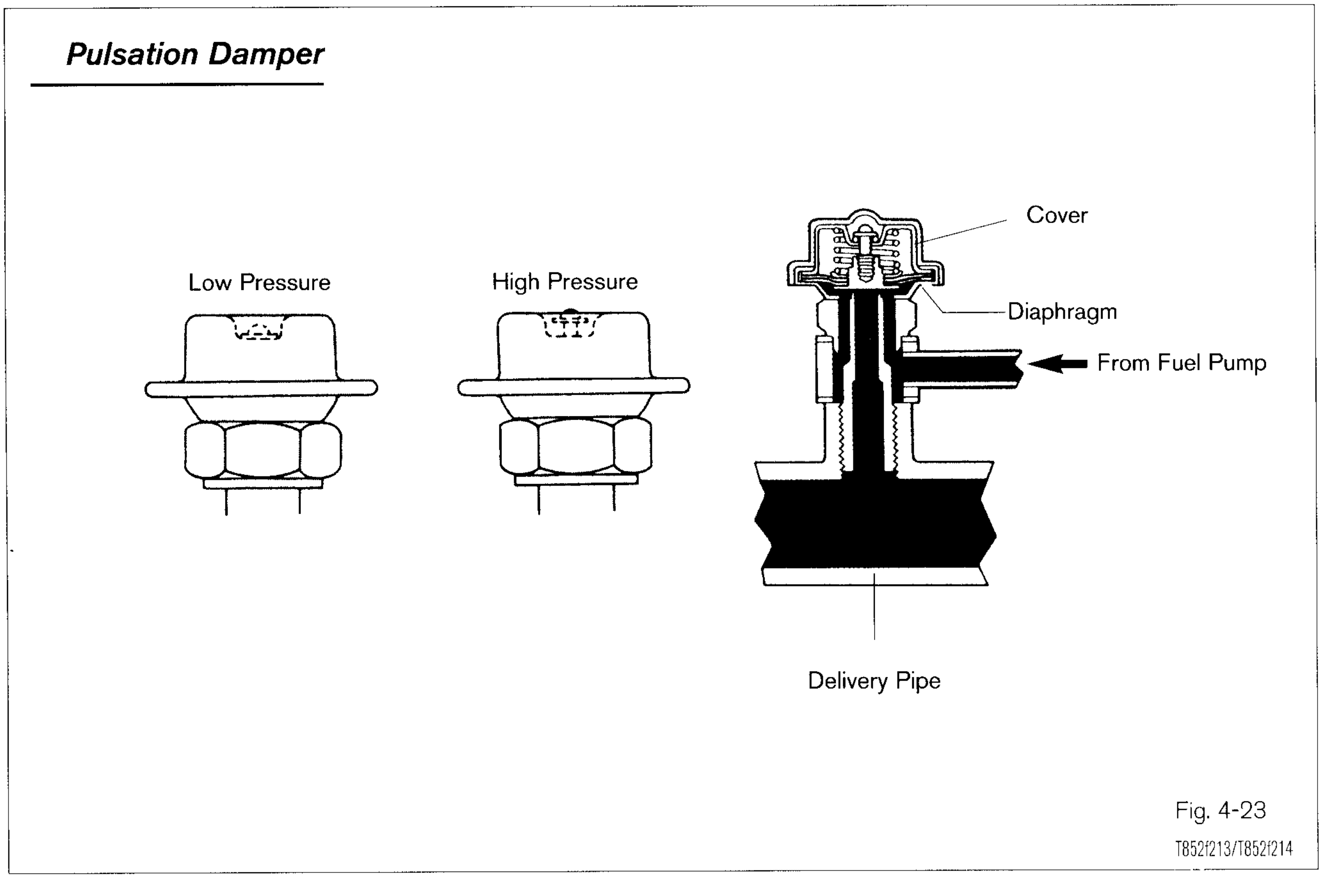


Fig. 4-23

Pulsation Damper
The rapid opening and closing of the fuel injectors cause pressure fluctuations in the fuel rail. The result is that the amount of injected fuel will be more or less than the desired amount. Mounted on the fuel rail, the pulsation damper reduces these pressure fluctuations. When pressure suddenly begins to increase the spring loaded diaphragm retracts slightly increasing fuel rail volume. This will momentarily prevent fuel pressure from becoming too high. When pressure suddenly begins to drop, the spring loaded diaphragm extends, slightly decreasing effective fuel rail volume. This will momentarily prevent fuel pressure from becoming too low. Not all engines require the use of a pulsation damper.

The screw mounted at the top of the damper provides an easy check for fuel system pressure. When the screw is up it means the fuel rail is pressurized. Under most conditions, this check is adequate. The screw is nonadjustable and it is used to calibrate the damper at the factory.

Fuel Injector

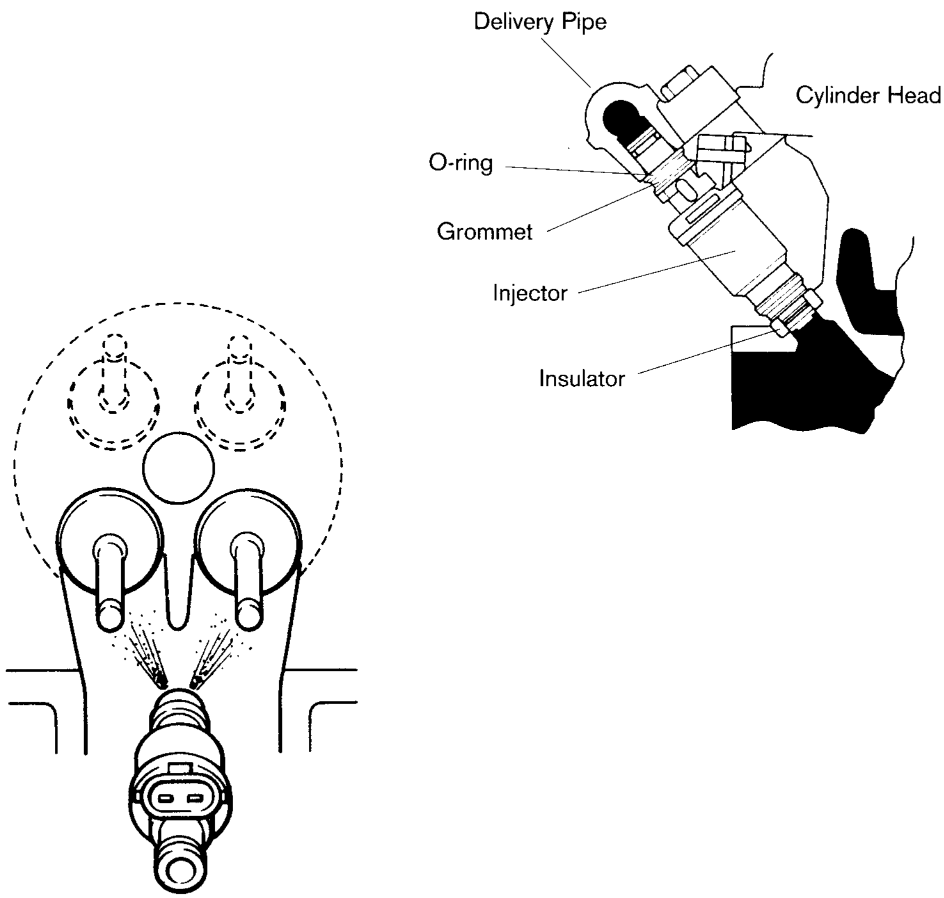


Fig. 4-24
TB52f215/TB52f216

Fuel Injection Operation

The fuel injector, when turned on by the ECM, atomizes and directs fuel into the intake manifold.

Fuel Injectors

There is one injector per cylinder mounted in the intake manifold before the intake valve(s). The injectors are installed with an insulator/seal on the manifold end to insulate the injector from heat and prevent atmospheric pressure from leaking into the manifold. The fuel delivery pipe secures the injector. An O-ring between the delivery pipe and injector prevents the fuel from leaking.

Different Styles of Fuel Injectors

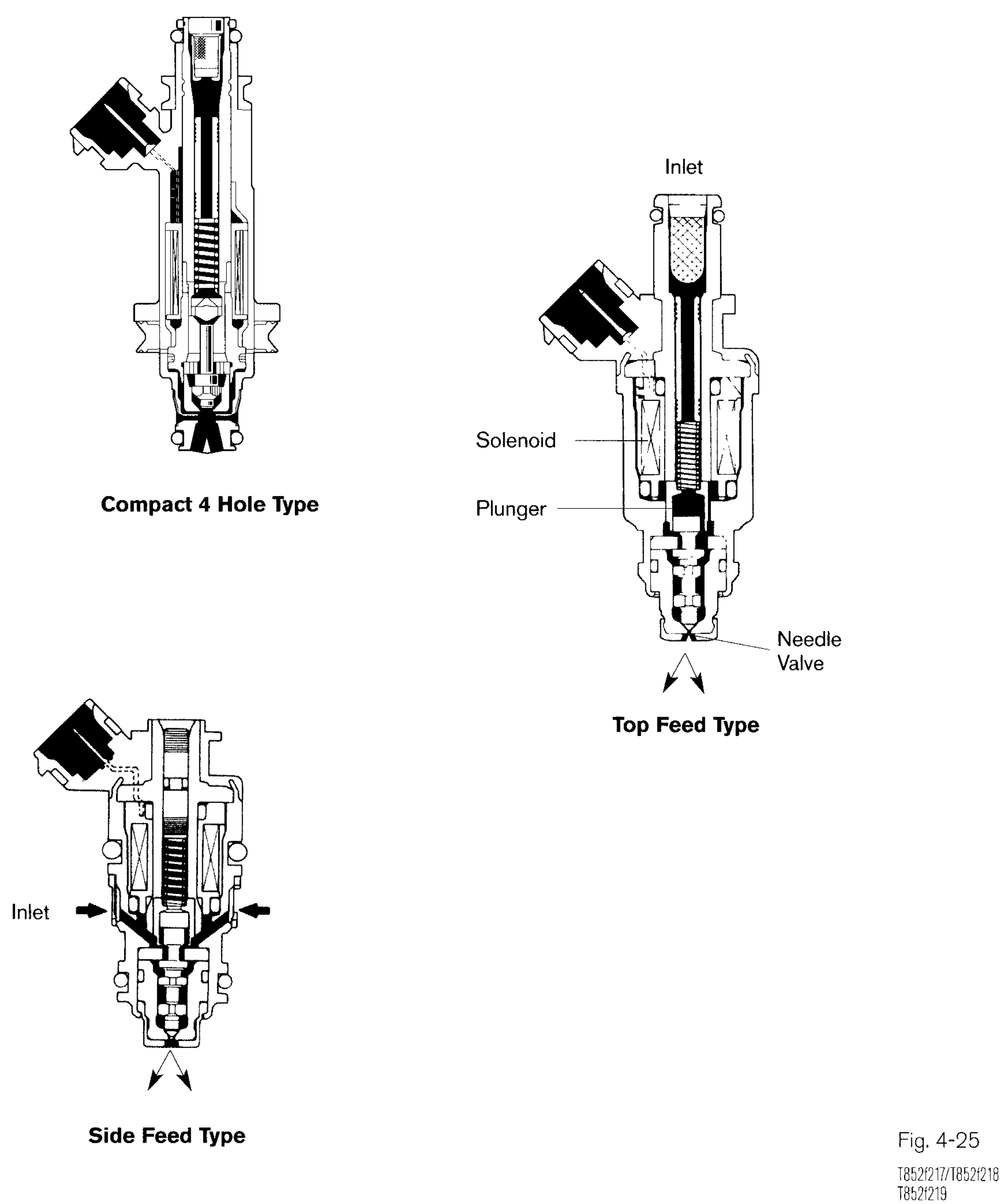


Fig. 4-25

Different engines require different injectors. Injectors are designed to pass a specified amount of fuel when opened. In addition, the number of holes at the tip of the injector varies with engines and model years. When replacing an injector it is critical that the correct injector be used.

Air Assist Fuel Injector

The one on the right is for the air assist system. During idle air is directed Into the air gallery. The smaller tubes increase the air velocity and therefore mixes easily with the fuel for better combustion.

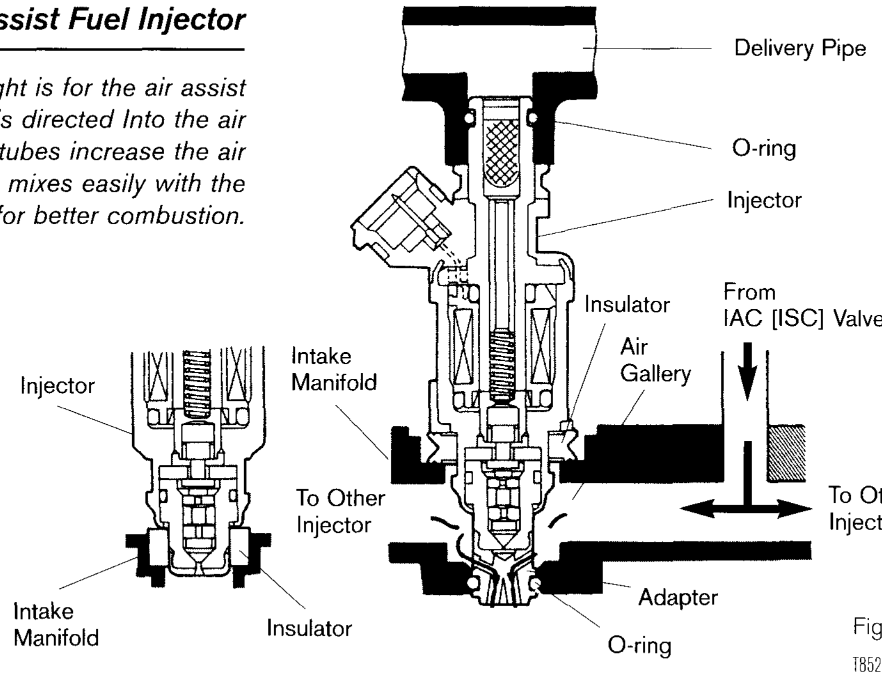


Fig. 4-26
T852f220

Inside the injector is a solenoid and needle valve. The fuel injector circuit is a ground switched circuit, To turn on the injector, the ECM turns on a transistor completing a path to ground. The magnetic field pulls the needle valve up overcoming spring pressure and fuel now flows out of the injector. When the ECM turns off the circuit, spring pressure will force the needle valve onto its seat, shutting off fuel flow.

Grouped Injection

This is one style of grouped injection.

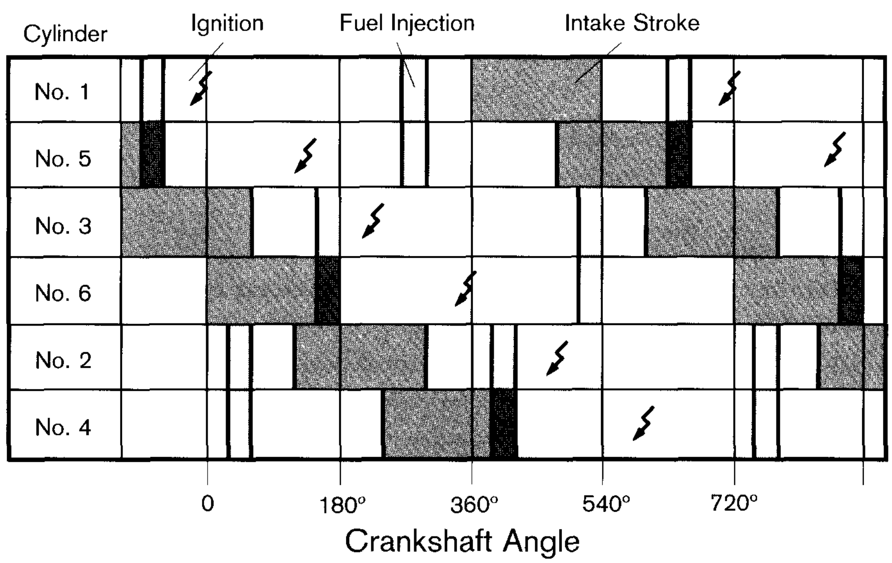


Fig. 4-27
T852f221

Sequential Injection

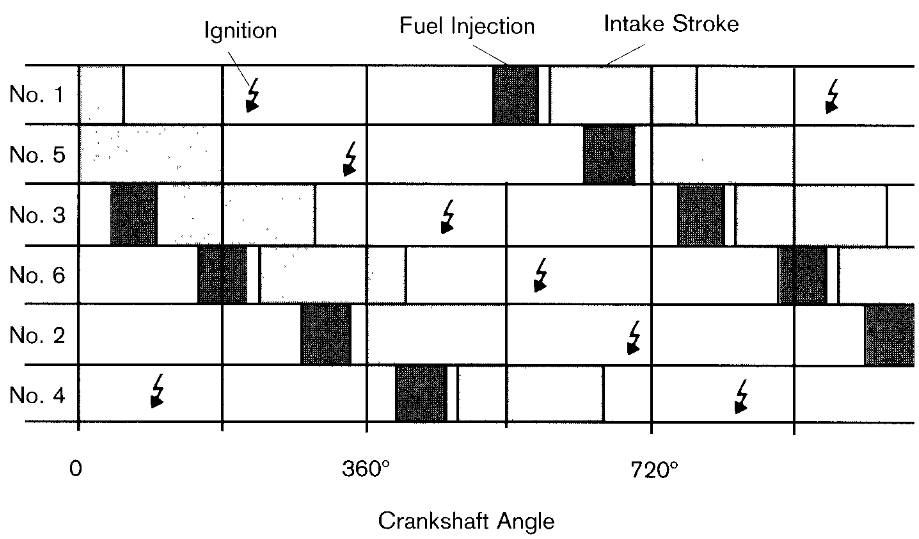


Fig. 4-28

T852f222

