Chapter 7

Fuel Delivery Systems

Contents

1. Introduction

The fuel system delivers clean fuel under pressure to the injectors. It regulates pressure at the injectors to ensure precise control of amount injected. It provides for sensing fuel pressure. This discussion covers delivery of fuel from the tank to the injectors. Chapters 4–6 cover control of the amount of injection. Electric fuel pumps require relays and safety circuits to ensure that the pumps stop when the engine stops.

The fuel tank(s) are usually pressurized at 7–14 kPa (1–2 psi), controlled by a relief valve in the filler cap. Vapor lock is virtually eliminated because:

- The fuel is cooled by constant recirculation
- The fuel in the delivery lines is pressurized, usually at about 270 kPa (39 psi)

2. Pumps

Ford systems deliver fuel with two kinds of pump systems:

- One high-pressure in-tank pump (passenger cars and Aerostar)
- Low-pressure supply pump in tank, working with high-pressure in-line pump (larger light trucks have two tanks, each with a low-pressure pump)

All pumps are roller-cell type, where the motor operates in the fuel in the pump housing. It may seem dangerous, an electric motor running in gasoline, but it is safe because the housing never contains an ignitable mixture. There are those who, fearing a burnable mixture, say "never run out of gas with a fuel-injected car." But thirty years of electric pump experience shows they just don't catch fire that way. However, operating in gasoline is important—it cools the pump. So if you do run out of gas, just don't crank a long time or you may ruin the pump.

2.1 High-Pressure In-Tank Pump

In most EEC systems, you'll find an in-tank fuel pump assembly with an internal pressure regulator and the fuel gauge sender. The high-pressure pump in the tank pressurizes the fuel lines to reduce vapor lock, and improve hot starting. See Fig. 2-1.

In the larger light trucks, E/F-series and Bronco, the high-pressure pump is part of an In-Tank Reservoir (ITR) assembly in the fuel tank. Beginning in 1992, it is known as the Fuel Delivery Module (FDM). By either name, the assembly includes the pump, a reservoir, a fine mesh filter, a pump pressure regulator, and a fuel level sender. See Fig. 2-2.

In most vehicles, the high-pressure pump can deliver 60 liters (16 gal.) of fuel per hour—just about a whole tankful in one hour! At cruise, the engine might burn 2–3 gal/hr, so you can see that most of the fuel recirculates. That serves to cool the pump and the system. Larger engines may use a larger pump. Some deliver 80 L/hr, or 100 L/hr (21 or 26 gal/hr), and some deliver twice the standard, 120 liters (32 gal) per hour.

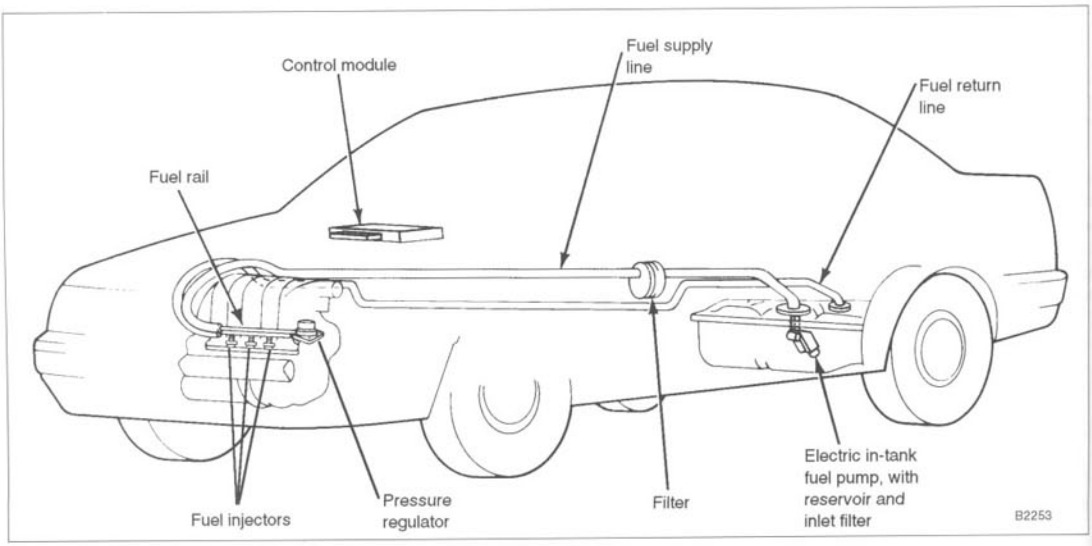


Fig. 1-1. In typical fuel delivery system, fuel is drawn from tank by an in-tank pump, filtered, and delivered to a fuel rail. A return line circulates fuel.

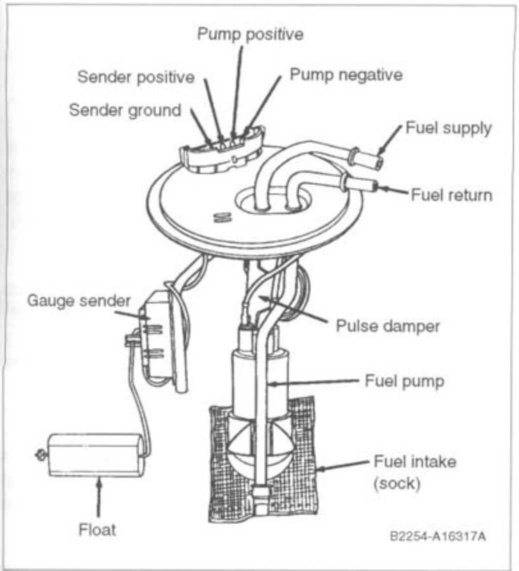


Fig. 2-1. High-pressure pump can supply 60 liters per hour (16 gal/hr) at working pressure of 270 kPa (39 psi). Check valve retains fuel pressure after shutdown.

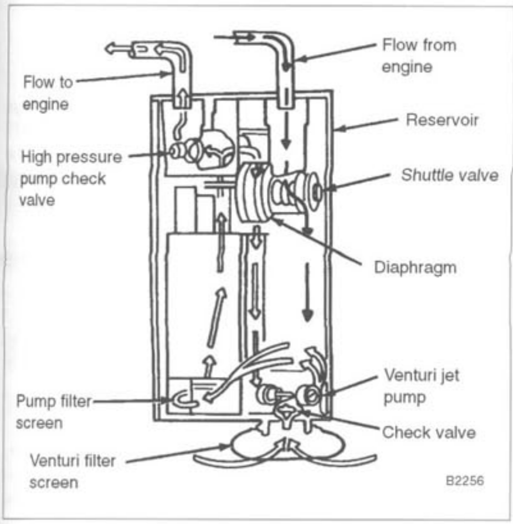


Fig. 2-2. Fuel Delivery Module (FDM) in tank includes high-pressure pump with check valve, fuel filters and reservoirs. Look for two FDM's in trucks with dual fuel tanks.

Fuel pumps on some cars vary fuel delivery according to demand by varying the voltage to the pump. The Variable Control Relay Module (VCRM) on Mark VIII and on Flexible Fuel (FF) 3.0L Taurus normally operates the pump through a high resistance wire. This reduces pump speed for quieter operation. At higher engine speeds/loads, the control module and the VCRM bypass the resistance with the high-speed fuel-pump relay. The pump runs faster, delivering more fuel. The need for the two-speed pump control differs in the two applications:

- 4.6L-4V peak output of 280 horsepower requires peak delivery of fuel. During idle and other low-demand operations, the pump operates more quietly while still delivering enough fuel
- The 3.0L Flexible Fuel Vehicle (FF) may operate on M-85 methanol-based fuel. Even though its peak output of 140 horsepower is the same with gasoline and with M-85, more gallons of M-85 must be burned because of M-85's lower energy content. The FF vehicle pump runs slower for normal cruise, and faster for full power output

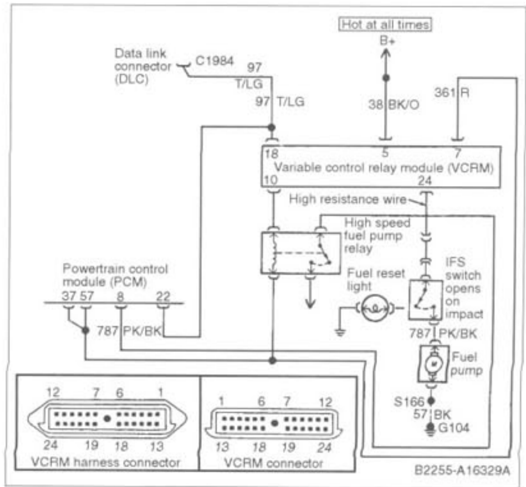


Fig. 2-3. On Mark VIII 4.6L and 1993 FF 3.0L, fuel-pump voltage control operates pump at lower speeds for normal, shifting to full voltage, higher speeds for higher fuel demand.

A check valve at the pump retains fuel pressure in the line after the pump shuts off. An internal pressure relief valve releases fuel into the tank if pump pressure exceeds 850 kPa (125 psi) because of a clogged filter or line.

2.2 High-pressure In-line Pump with Low-pressure In-tank Pump

Some 1988 and later Ford light trucks use two kinds of pumps. The low-pressure pump(s), often called the supply pump, in the tank(s) delivers fuel to a fuel reservoir. The high-pressure pump in the line delivers pressurized fuel to the injectors. See Fig. 2-4. The reservoir carries enough fuel to meet extra demands such as wide open throttle running. Line pumps operate at deliveries and pressures similar to those of high-pressure pumps in the tank. See Fig. 2-5.

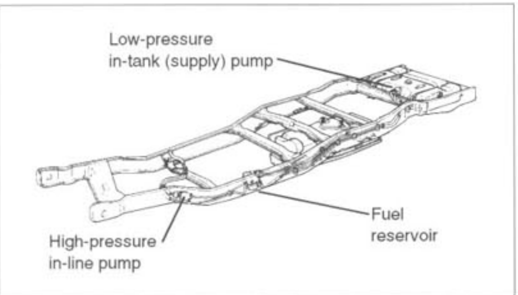


Fig. 2-4. Some light truck fuel systems operate low-pressure pump(s) in the tank(s) to supply the reservoir for the high-pressure pump in the line.

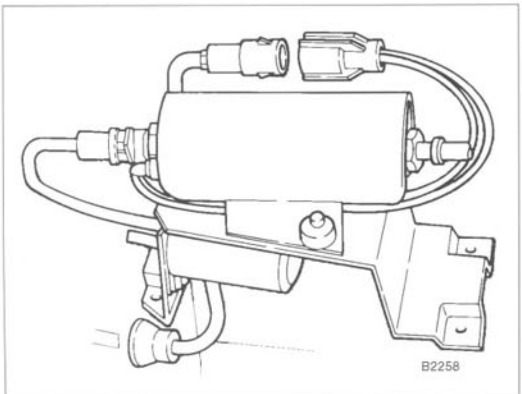


Fig. 2-5. High-pressure in-line pumps can deliver 60–100 L/hr (16–26 gal/hr) at working pressures of 270 kPa (39 psi), with relief valve set at 850 kPa (125 psi).

2.3 Pump Control by the Control Module

The control module runs the pump(s) for one second when it receives an IGNITION-ON signal. It also runs the pumps as long as it receives a CRANK signal from the ignition switch. When it receives a PIP signal from the Hall-effect devices, it continues pump operation even after the key is released from START. If the PIP signal falls below 120 rpm, the control module cuts off the signal to the Fuel Pump Relay, or the Integrated Relay Control Module. The pump will also run when the terminals of the fuel-pump test connector are jumped.

- The control module signals the pump when it receives a CRANK signal, and when the control module gets PIP signals that the engine is running;
- The pump does not run if the PIP indicates the engine is not running, even with ignition ON (except for that first one second).

MECS-I fuel-pump relays are normally controlled by a switch in the Volume Air Flow Sensor (VAF). This is similar to early Bosch systems. During cranking, the control module grounds the circuit to the fuel-pump relay.

During rapid deceleration, with closed throttle, air flow falls to near zero. The VAF flap closes, sending a false "shut-off" signal to the fuel pump relay. MECS uses two methods to keep the engine from stalling during deceleration:

- On 2.2L turbo engines, the ECA grounds the fuel-pump relay during deceleration to keep the pump running
- On 1.6L engines, a resistor and capacitor in the fuel-relay supply current into the pump relay coil

MECS-II (1993 Probe 2.0L and 2.5L V-6) fuel-pump relays operate just like EEC system relays, running with the START position of the ignition key, or by the rpm signals from the crankshaft position sensor(s).

3. Pressure Regulator

The fuel pressure regulator, shown in Fig. 3-1, is important to the precise metering of fuel from the injectors. To ensure that fuel delivery varies only with changes in injector open time, relative fuel pressure at the injector must be kept constant.

Relative fuel pressure is the difference between fuel pressure pushing the fuel out of the injector, and manifold pressure pushing back at the tip. See Fig. 3-2 and 3-3. As you'll see, for each millisecond of injector pulse time, the amount of fuel delivered through the injector tip depends on the relative pressure.

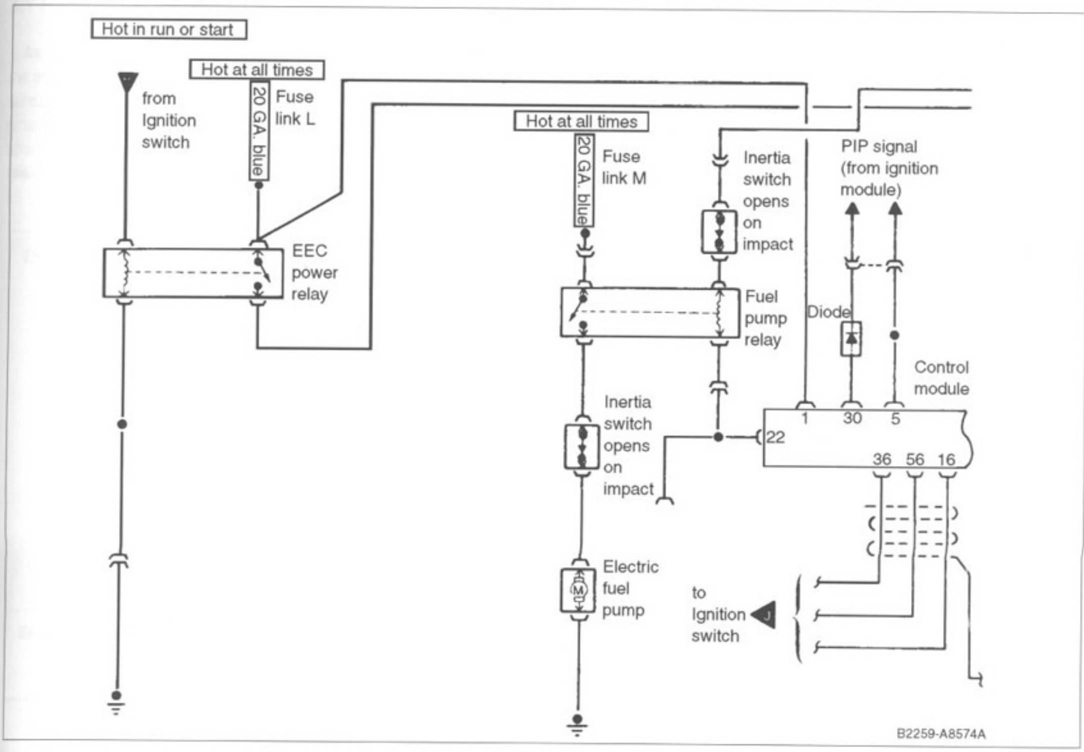


Fig. 2-6. Control Module grounds Fuel Pump Relay to run fuel pump. Control based on input signals from ignition switch in CRANK, and from PIP indicating crankshaft revs of over 120.

Fig. 3-1. Pressure regulator (arrow) at end of fuel rail controls fuel pressure by controlling fuel return flow to tank. Hose connection leads to intake manifold.

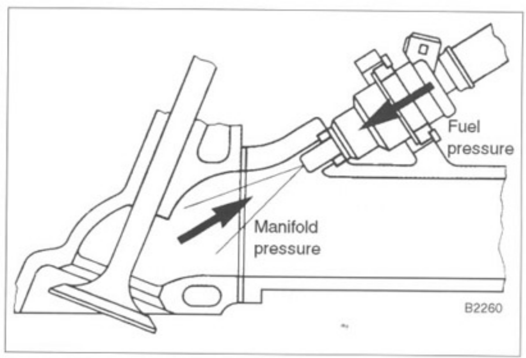


Fig. 3-2. Precise delivery depends on relative pressure—the difference between fuel pressure in the injector, and Manifold Absolute Pressure (MAP) pushing back.

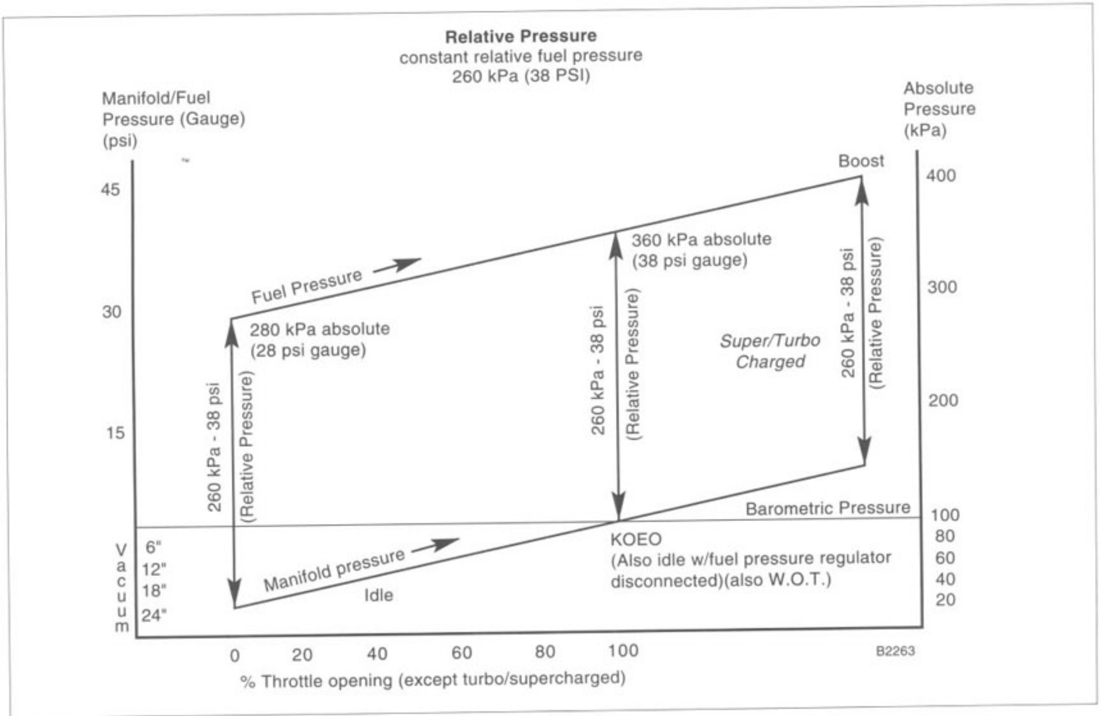


Fig. 3-3. Fuel pressure regulator keeps fuel pressure 260 kPa above pressure at the injector tips. As manifold pressure rises, fuel pressure rises. Absolute measurement is 100 kPa (barometric pressure) above gauge measurement.

The pressure regulator, usually mounted on the fuel rail, holds relative fuel pressure constant. See Fig. 3-4. All fuel from the fuel pump flows into the fuel rail at one end, then through the pressure regulator valve and back to the tank. A spring presses down on the regulator diaphragm so the valve restricts return flow to the tank. Pump pressure pushes on the diaphragm and spring until the valve opens at a set pressure. Spring pressure determines basic fuel pressure. Air pressure from the intake manifold affects the spring pressure (and therefore fuel pressure) via the diaphragm. When the engine is off, spring pressure keeps the regulator valve closed, maintaining pressure in the system.

Most Ford systems operate (engine Off, pump On) at a nominal 270 kPa (39 psi) gauge pressure—that is, pressure above barometric. Exceptions:

- Higher pressure in some engines, such as the 4.9L and 1993 and later 2.3L HSC, with more tendency to boil fuel in the rails, operate at 380 kPa (55psi)
- Lower pressures in the SHO engines, with greater range of rpms and therefore different injectors, operate at 210 kPa (31 psi)

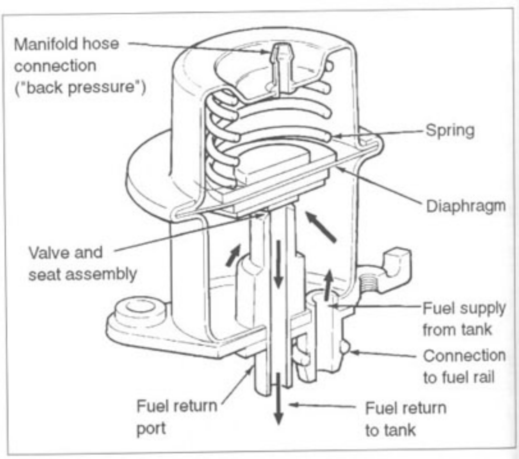
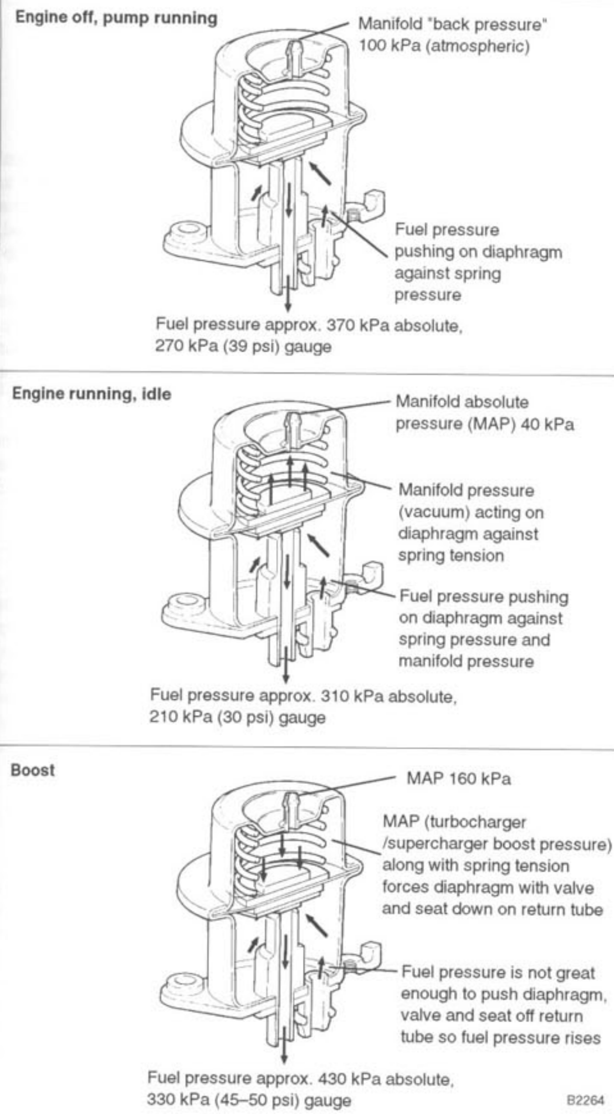


Fig. 3-4. Fuel pressure regulator with pump running. Fuel pressure enters from fuel rail, raises diaphragm against spring and manifold air pressure. Excess fuel is returned to tank.

3.1 Relative Fuel Pressure and Fuel Delivery

As you know, manifold pressure and therefore pressure at the injector tip changes with throttle opening. If the fuel pressure were constant for all manifold pressures, then at low engine loads, with the throttle partly closed, reduced manifold absolute pressure would increase fuel delivery. To keep that relative pressure constant as the throttle is opened and closed, the fuel-pressure regulator is connected to the intake manifold by a hose. Manifold pressure acts on the diaphragm to hold the relative pressure constant. See Fig. 3-5.

Remember back in Chapter 2, I told you fuel injection is easier to understand when you think positive, also when you keep in mind the difference between barometric pressure and absolute pressure, usually about 100 kPa at or near sea level. Your



- With engine off, pump running and barometric pressure 100 kPa, fuel pressure is 370 kPa, absolute. Fuel pressure would be about the same at Wide Open Throttle (WOT) when the throttle allows MAP to approach barometric pressure. Pressure would also be the same with the engine idling with vacuum hose to regulator disconnected. Relative pressure at the injector tips is 270 kPa (370 minus 100).

- With engine idle, MAP is 40 kPa, so fuel pressure is regulated to be about 310 kPa absolute. The MAP pushing the pressure-regulator diaphragm is only 40 kPa instead of 100. The reduced MAP on the diaphragm allows it to move away from the opening, returning more fuel to the tank. Gauge fuel pressure drops to about 210 kPa. The relative pressure at the injector tip is still 270 kPa (310 absolute minus 40).

- At boost of 160 kPa MAP (about 10 psi gauge), fuel pressure is regulated to be 430 kPa absolute. The MAP pushing the pressure-regulator diaphragm is 160 kPa. The increased MAP on the diaphragm forces it toward the opening, returning less fuel to the tank. Gauge fuel pressure increases to about 330 kPa. The relative pressure at the injector tip is still 270 kPa (430 absolute minus 160).

Fig. 3-5. Relation of fuel pressure, absolute and gauge, to manifold absolute pressure (MAP).

fuel pressure gauge reads "gauge pressure"—that is, fuel pressure above barometric; or fuel pressure, gauge. This relates to a fuel pressure regulator set for 260 kPa. (Some engines differ, but follow an example of a system operating at relative fuel pressure of "260kPa (38psi)".)

Now perhaps you see the importance of the fuel pressure regulator. Its job is to insure that fuel delivery per injection is not affected by changes in manifold pressure. When you understand this principle of relative fuel pressure, injection pressure versus manifold pressure, you'll understand the checking of fuel pressures. You'll also understand how greater delivery for off-road performance operation may be increased by increasing fuel pressures.

Fuel Pressure Regulator Control

On some engines, EEC and MECS, you'll find a Fuel Pressure Regulator Control (FPRC) system. See Fig. 3-6. It prevents percolation of the fuel during idle after restarting a warm engine. Some FPRCs operate to raise fuel pressure during crank, idle, neutral, and wide open throttle (WOT), depending on input signals to the Powertrain Control Module.

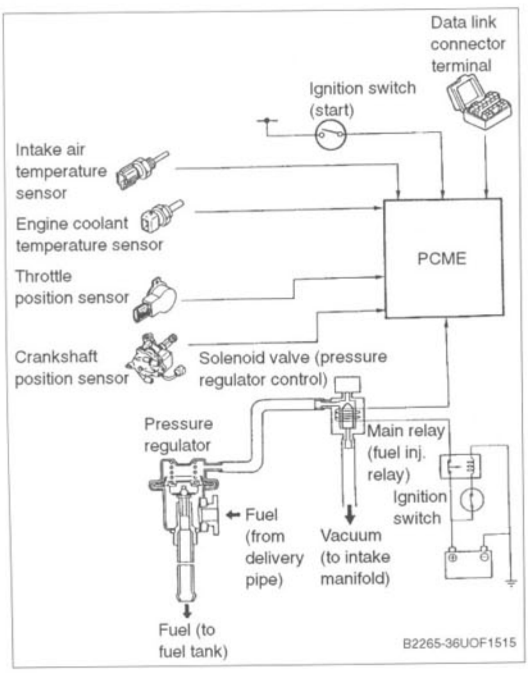


Fig. 3-6. MECS Fuel Pressure Regulator Control (FPRC) solenoid valve closes passage from pressure regulator to manifold when engine is warm, raising idling fuel pressure to prevent percolation.

Coolant temperature signals, or intake air temperature signals cause the engine control module to ground a circuit from the main relay. The solenoid valve closes the line connecting the pressure regulator to the manifold, and vents the pressure regulator to atmosphere. This has the effect of raising the fuel pressure of a warm engine from a normal idle pressure of 33 psi (230 kPa) to 41 psi (280 kPa). A timer in the control module releases the solenoid after a measured time, (10 to 120 seconds, depending on the engine). This returns the fuel pressure regulation to normal. In most controls, the TPS must signal closed throttle, CKP signal low rpm, and Clutch or Park/Neutral signal engine not driving car.

4. Fuel Filters

The fuel-injection fuel filter is much larger than the usual carburetor fuel filter because clean fuel is so important to fuel-injection systems. Also, in contrast to carburetor-engine pumps, fuel-injection pumps deliver more fuel than is burned, so the filter handles up to 10 times the actual fuel consumption. Fuel-injection filters are also finer. Replace the filter as a complete unit, not as an insert. In most high-pressure fuel-injected cars, look for the fuel filter next to the fuel pump. In some trucks, check in the fuel reservoir. When the truck has in-tank high-pressure pumps, look for the filter on the frame near the fuel tank.

For most vehicles, including MECS, look for the fuel filter under the hood. If it's not there, look for it next to the external high-pressure fuel pump, or in the line between the tank and the engine.

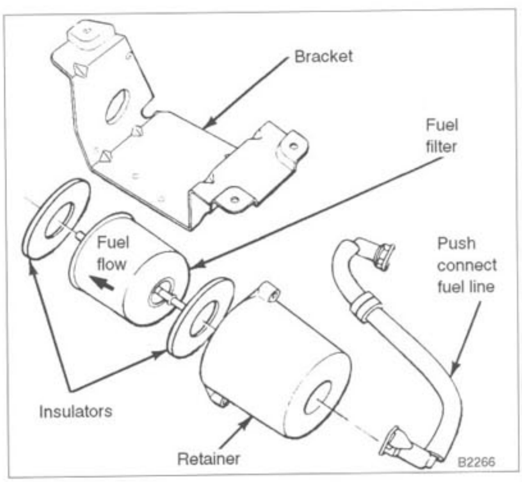


Fig. 4-1. Fuel filter for high-pressure in-tank pumps is usually located under car near fuel tank.

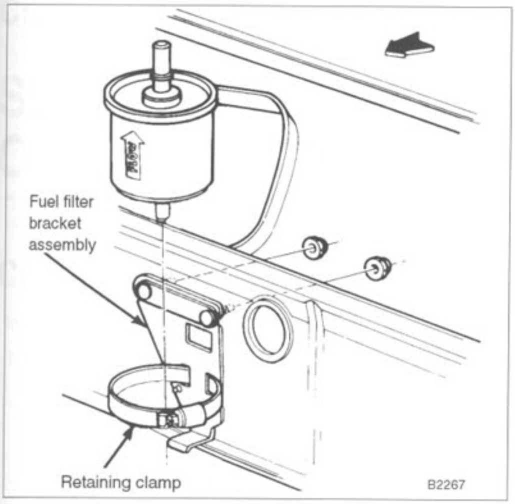


Fig. 4-2. Fuel filter for Escort, MECS, and other vehicles is located under hood.

5. FUEL RAIL

The fuel rail serves two purposes:

- Delivers fuel to the injectors
- Stabilizes fuel pressure at the injectors

The relatively large fuel supply in the fuel rail helps to minimize pressure changes or pulsations that could cause uneven fuel injection, leading to rough idle. Fuel pressures change rapidly in the fuel rail as the injectors pop open and closed. Pressure change is noticeable when two, three or four injectors open at the same time, as in ganged port injection. The pressure changes less when individual injectors open and close one at a time, as in SFI. V-6 and V-8 engines have two rails, each one feeding the injectors of that bank.

5.1 Pressure Test Point

Ford EEC systems provide a pressure test point on the fuel rail. You can read fuel pressure directly from this point by connecting a gauge, without the need to bleed the pressure and open the system.

MECS systems do not provide a pressure test point. You must release pressure before installing a pressure gauge. And, after removing the gauge and closing the system, you must prime the fuel system before starting to avoid excess cranking. More in Chapter 10 and Chapter 11.

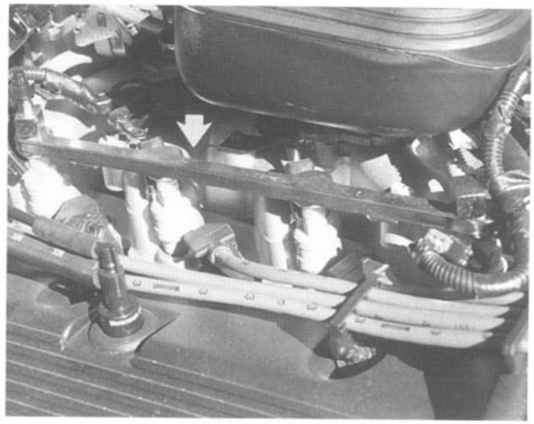


Fig. 5-1. Fuel rail (arrow) provides fuel supply to injectors and helps damp fuel pressure pulsations.

Fig. 5-2. Fuel-pressure test point provides direct access for reading of fuel pressure. System does not need to be bled and opened.

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