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INTRODUCTION

Port fuel injection system

Electronic fuel injection systems use a powertrain control module (PCM) to control the operation of fuel injectors and other functions based on information sent to the PCM from various sensors. Most electronic fuel-injection systems share the following, Figure 1.

- Electric fuel pump (usually located inside the fuel tank)
- Fuel-pump relay (controlled by the computer)
- Fuel pressure regulator (mechanically operated spring-loaded rubber diaphragm maintains proper fuel pressure)
- Fuel injector nozzles, which are basically 12-volt solenoids

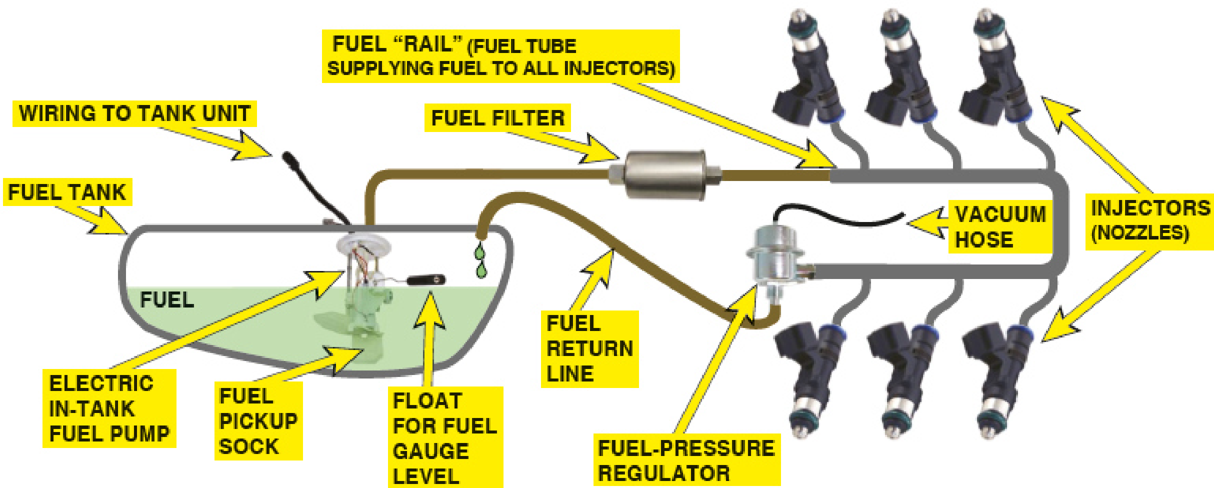

Figure 1. Typical port fuel-injection system.

Gasoline direct injection (GDI) system

Unlike a port fuel-injection system, a GDI system varies the fuel pressure to achieve greater fuel delivery using a very short pulse time, which is usually less than one millisecond. In a gasoline direct injection (GDI) system the fuel is sprayed directly into the combustion chamber. Figure 2.

- Port Fuel Injection–Constant fuel pressure but variable injector pulse-width.
- GDI–Almost constant injector pulse-width with varying fuel pressure.

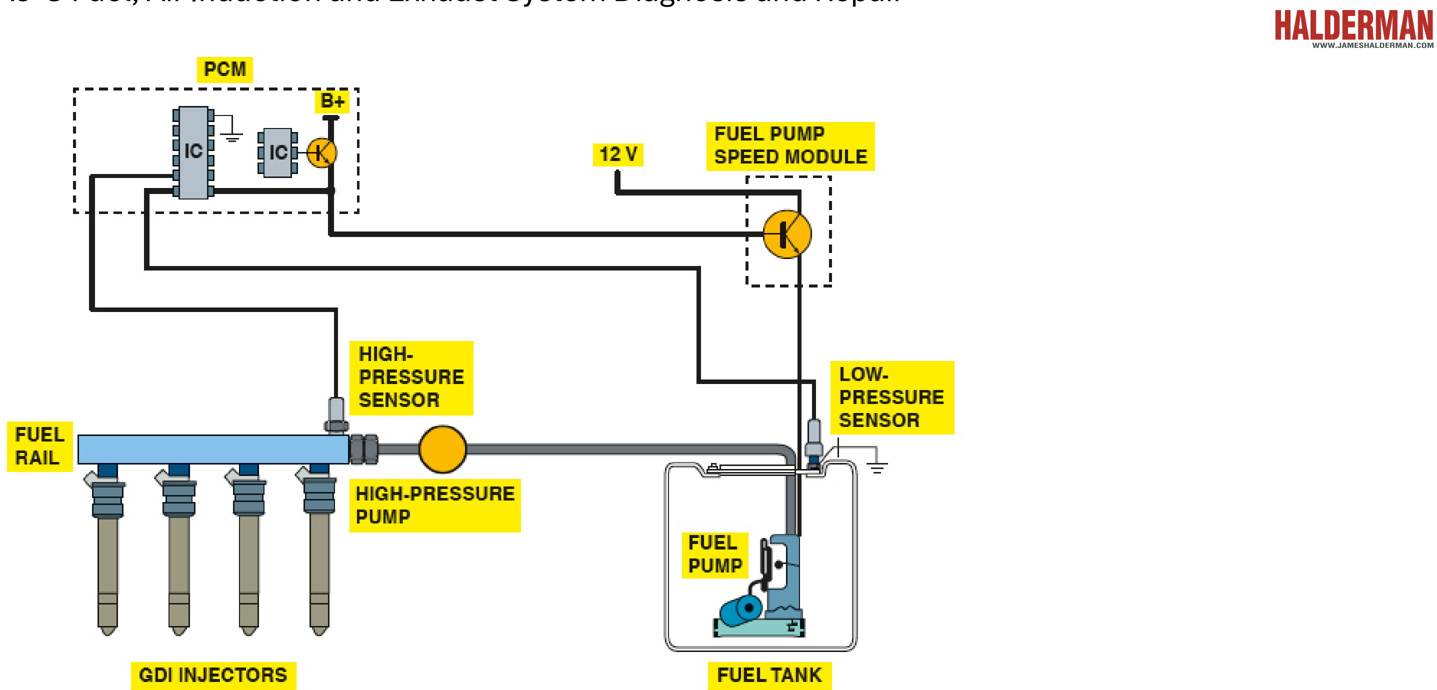

Figure 2. Typical GDI fuel injection system.

The fuel pump in the fuel tank supplies fuel to the high-pressure fuel pump at a pressure of approximately 60 PSI. The fuel filter is in the fuel tank and is part of the fuel pump assembly.

The engine control module (ECM) controls the output of the high-pressure pump, which has a range between 500 PSI (3,440 kPa) and 2,900 PSI (15,200 kPa) during engine operation. The pump consists of a single-barrel piston pump, which is driven by the engine camshaft. Figure 3.

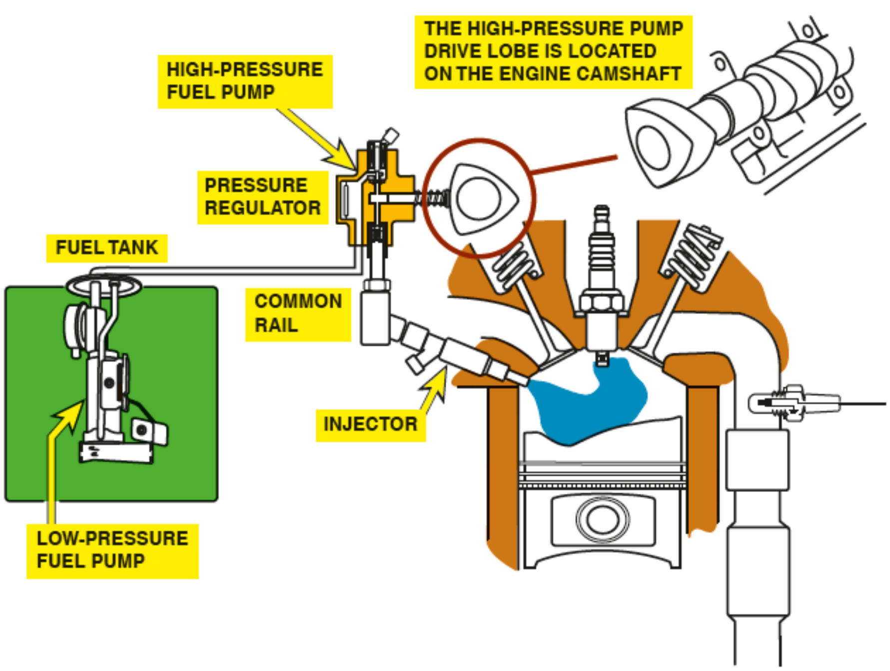

Figure 3. GDI systems use two fuel pumps.

Many vehicles use an electronic throttle control system that eliminates any mechanical linkage between the throttle pedal and the throttle body. The throttle pedal is connected to the APP sensor. The electronic throttle body includes a throttle position sensor to provide throttle angle feedback to the vehicle computer. Some systems use a throttle actuator control (TAC) module to operate the throttle blade (plate). Figure 4.

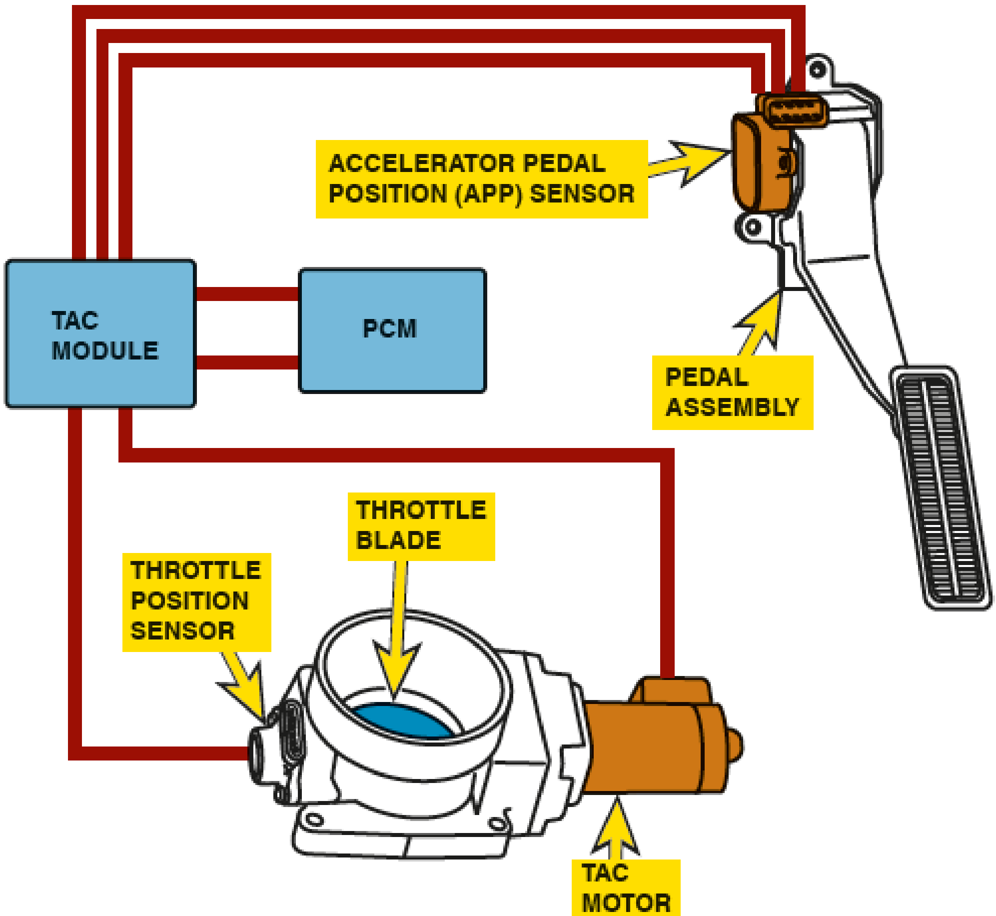

Figure 4. Electronic throttle control. Most systems use the PCM to control the throttle, but early systems had a separate throttle actuator control (TAC) module.

ASE TEST TOPICS

ASE NOTE: Fuel injection system diagnosis and repair questions will include vehicles equipped with multiport, gasoline direct injection (GDI), or a combination of both systems. These systems may be either speed density, based on rpm and manifold absolute pressure (MAP), or mass airflow (MAF). When appropriate, the fuel system type will be identified in the ASE test question.

1. Diagnose fuel system-related problems, such as: hot or cold no starting, hard starting, poor driveability, incorrect idle speed, poor idle, incorrectly delivered air/fuel ratio, hesitation, surging, engine misfire, power loss, stalling, poor mileage, and emissions problems; determine root cause; determine needed action.

All fuel-injection systems require the proper amount of clean fuel delivered to the system at the proper pressure and the correct amount of filtered air. The following items should be carefully inspected before proceeding to more detailed tests:

- Check the air filter and replace as needed.
- Check the air induction system for obstructions.
- Check the conditions of all vacuum hoses. Replace any hose that is split, soft (mushy), or brittle.

On some vehicles fuel pressure and internal leaks can be evaluated with a pressure gauge. Figure 5.

Figure 5. Fuel pressure test port.

1. Attach a fuel-pressure gauge to the Schrader valve on the fuel rail.

2. Turn the ignition key on or start the engine to build up the fuel pump pressure (to about 35 to 45 PSI).

3. Turn off the engine and wait 20 minutes and observe the fuel pressure retained in the fuel rail and note the PSI reading. The fuel pressure should not drop more than 20 PSI (140 kPa) in 20 minutes. If the drop is less than 20 PSI in 20 minutes, everything is okay; if the drop is greater, there is a possible problem with the following:

- The check valve in the fuel pump is not holding pressure. Can cause long cranking time.
- Injectors, lines, or fittings leaking. Leaking injectors can cause hard starting (flooded engine). Also, poor milage and possible poor idle or stalling.
- A fuel-pressure regulator not holding pressure. Causes long cranking time when starting.

Diagnosing a faulty fuel system can be a difficult task. However, it can be made easier by utilizing the information available via the serial data stream. By observing the long-term fuel trim and the short-term fuel trim, a determination can be made on how the fuel system is performing.

2. Interpret fuel or air induction system-related diagnostic trouble codes (DTCs); analyze fuel trim and other scan tool data; determine needed action.

Fuel and air induction DTCs are usually P0100 or P0200 series codes. Some examples are:

- P0100 Mass or Volume Air flow Circuit Malfunction
- P0120 Throttle Pedal Position Sensor/Switch A Circuit Malfunction
- P0131 O2 Sensor Circuit Low Voltage (Bank 2 Sensor 1)
- P0170 Fuel Trim Malfunction (Bank 2)
- P0200 Injector Circuit Malfunction
- P0230 Fuel Pump Primary Circuit Malfunction

Short-term fuel trim and long-term fuel trim can help zero in on specific areas of trouble. Readings should be taken at idle and at 3,000 RPM. Figure 6.

CONDITION	LONG-TERM FUEL TRIM AT IDLE	LONG-TERM FUEL TRIM AT 3,000 RPM
System normal	0% ± 10%	0% ± 10%
Vacuum leak	HIGH	OK
Fuel flow problem	OK	HIGH
Low fuel pressure	HIGH	HIGH
High fuel pressure	*OK or LOW	*OK or LOW

*High fuel pressure will affect trim at idle, at 3,000 RPM, or both.

Figure 6. Fuel trim levels and possible causes if not within 10%.

3. Inspect fuel tank, filler neck, and fuel cap; inspect and replace fuel lines, fittings, and hoses; determine needed action.

A vehicle fuel tank is made of corrosion-resistant steel or polyethylene plastic. Some models, such as sport utility vehicles (SUVs) and light trucks, may have an auxiliary fuel tank. Fuel enters the tank through a large tube extending from the tank to an opening on the outside of the vehicle. Figure 7.

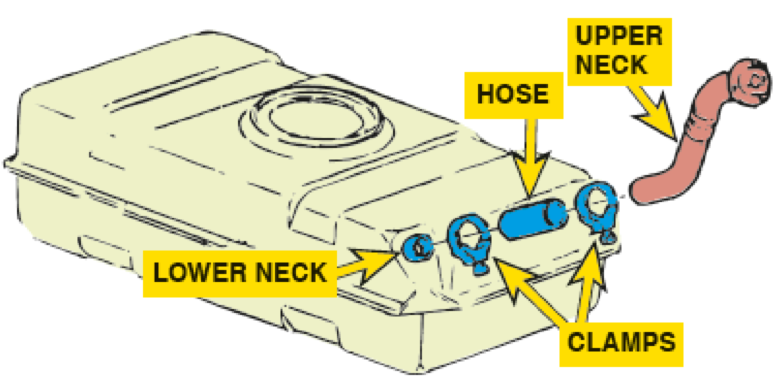

Figure 7. Fuel tank and filler neck.

Onboard refueling vapor recovery (ORVR) systems have been developed to reduce evaporative emissions during refueling. These systems add components to the filler neck and the tank. ORVR systems utilize a tapered filler neck with a smaller diameter tube. Figure 8.

Figure 8. Filler neck for an ORVR-equipped vehicle, used with enhanced evaporative vapor systems.

Fuel and vapors are sealed in the tank by the filler cap. The fuel cap must release excess pressure or excess vacuum. Typically, the cap will release if the pressure is over 1.5 to 2.0 PSI (10 to 14 kPa) or if the vacuum is 0.15 to 0.30 PSI (1 to 2 kPa).

Fuel and vapor lines made of steel, nylon tubing, or fuel-resistant rubber hoses connect the parts of the fuel system. Fuel lines supply fuel to the throttle body or fuel rail. They also return excess fuel and vapors to the tank. Depending on their function, fuel and vapor lines may be either rigid or flexible.

Because of their operating pressures, fuel-injection systems often use special kinds of fittings to ensure leakproof connections. Unlocking the metal connectors requires a special quick connector separator tool; plastic connectors can be released without the tool. Figure 9.

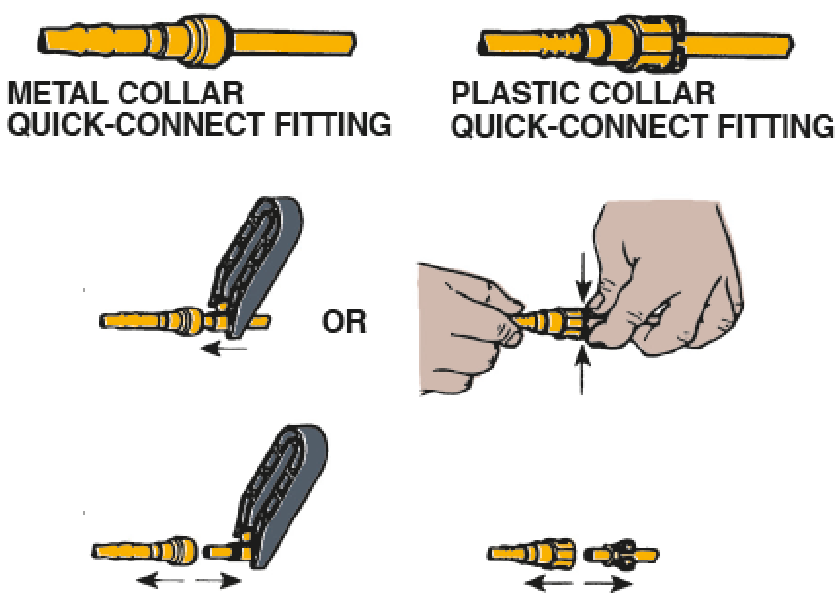

Figure 9. Fuel line connectors.

4. Inspect, test, and replace fuel pump(s) and/or fuel pump assembly; inspect, service, and replace fuel filter(s).

The electric fuel pump is a pusher unit. When the pump is mounted in the tank, the entire fuel supply line to the engine can be pressurized. All electrical pumps are driven by a small electric motor, but the turbine pump turns at higher speeds and is quieter than the others. Figure 10.

Figure 10. A typical fuel-pump module assembly, which includes the pickup strainer and fuel pumps, as well as the fuel pressure sensor and fuel level sensing unit.

The following recommendations should be followed whenever replacing an electric fuel pump:

- The fuel-pump strainer (sock) should be replaced with the new pump.
- If the original pump had a deflector shield, it should always be used to prevent fuel return bubbles from blocking the inlet to the pump.
- Always check the interior of the fuel tank for evidence of contamination or dirt.
- Double-check that the replacement pump is correct for the application.
- Check that the wiring and electrical connectors are clean and tight.

The inline filter is located in the line between the fuel pump and fuel rail. Fuel filters should be replaced according to the vehicle manufacturer's recommendations, which range from every 30,000 miles (48,000 km) to 100,000 miles (160,000 km) or longer. Fuel filters that are part of the fuel-pump module assemblies usually do not have any specified service interval. Figure 11.

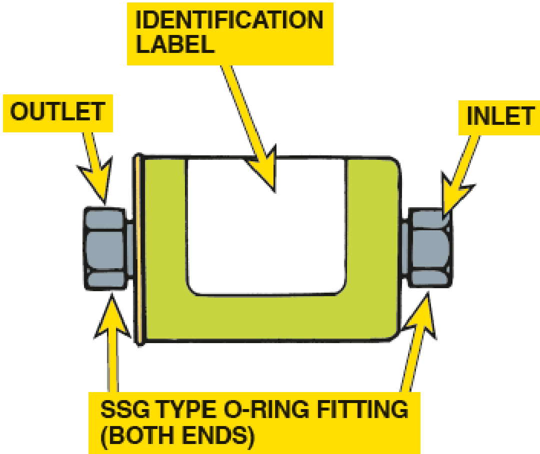

Figure 11. A typical in-line fuel filter.

The useful life of many filters is limited, but vehicles that use a returnless-type fuel-injection system usually use filters that are part of the fuel pump assembly and do not have any specified interval. This means they should last the life of the vehicle.

5. Inspect and test fuel pump control circuits and components; determine needed action.

Fuel-pump circuits are controlled by the fuel-pump relay. Fuel-pump relays are activated initially by turning the ignition key on, which allows the pump to pressurize the fuel system. As a safety precaution, the relay de-energizes after a few seconds unless the key is moved to the crank position.

For testing, the scan tool can command the pump relay on and off while listening for pump operation. Figure 12.

Figure 12. Listening to confirm pump operation.

On some systems, once an ignition coil signal, or “tach” signal, is received by the engine control computer, indicating the engine is rotating, the relay remains energized even with the key released to the run position. Figure 13.

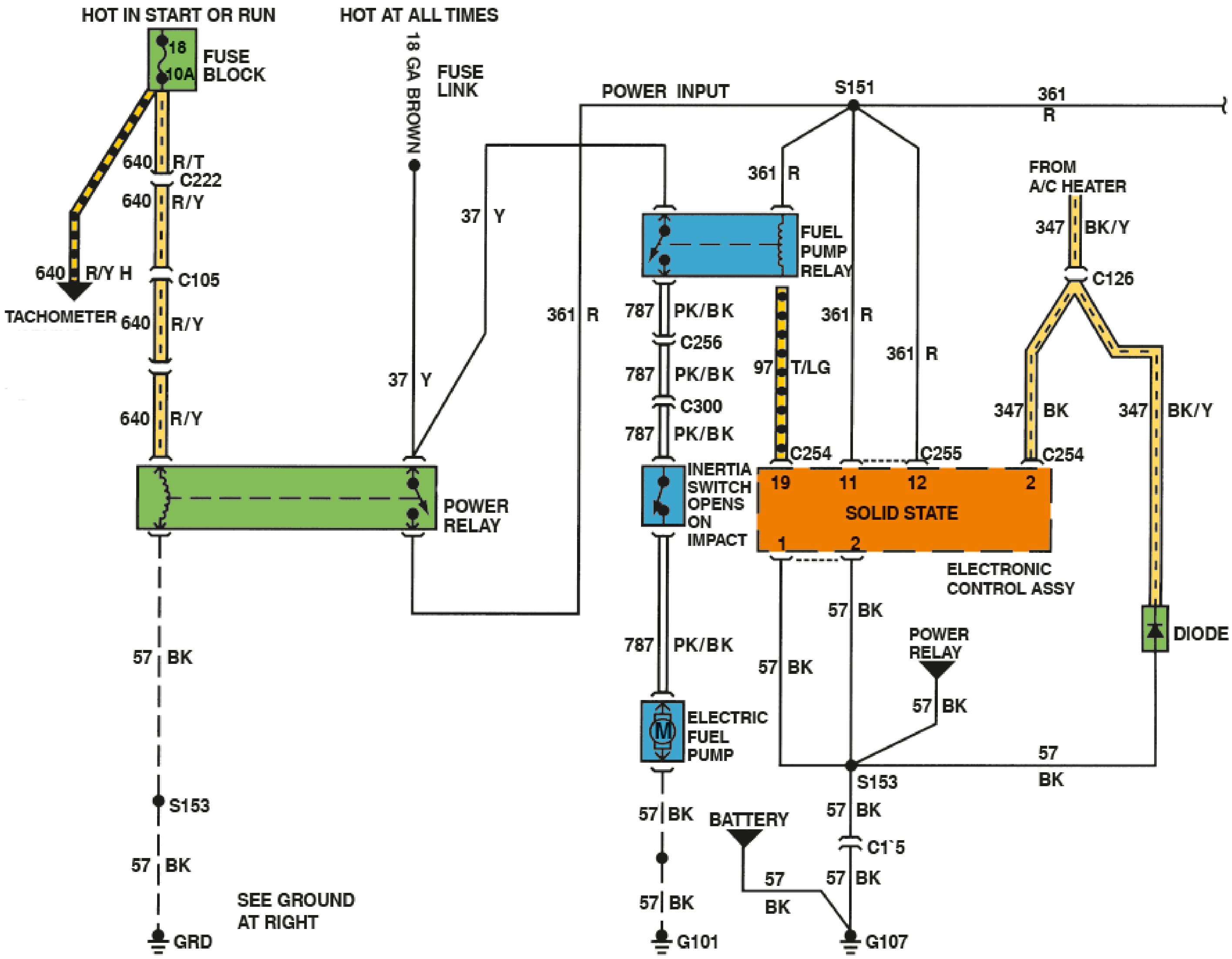

Figure 13. Fuel pump control circuit showing the pump relay. Most vehicles do not use the inertia switch.

6. Inspect, test, and repair or replace fuel pressure regulation system and components of fuel injection systems; check fuel for contaminants, composition, and quality; perform fuel pressure/volume test.

The fuel-pressure regulator typically consists of a spring-loaded, diaphragm-operated valve in a metal housing. Fuel pressure is modulated by a combination of spring pressure and manifold vacuum acting on the diaphragm. Figure 14.

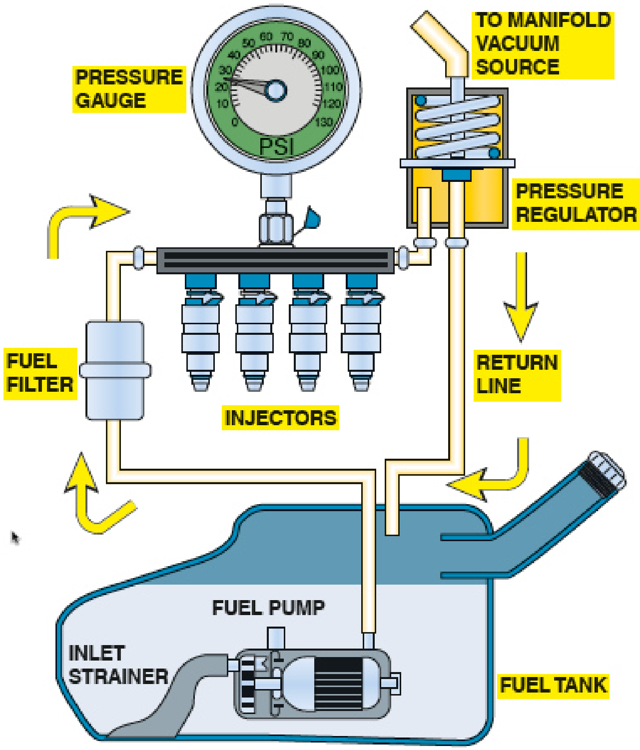

Figure 14. A fuel injection system that uses a vacuum-biased mechanical pressure regulator.

Some systems do not use a mechanical valve to regulate rail pressure. Fuel pressure at the rail is sensed by a pressure transducer, which sends a low-level signal to a controller. The controller contains logic to calculate a signal to the pump power driver. The power driver contains a high-current transistor that controls the pump speed using pulse width modulation (PWM). This system is called an electronic returnless fuel system (ERFS). Figure 15.

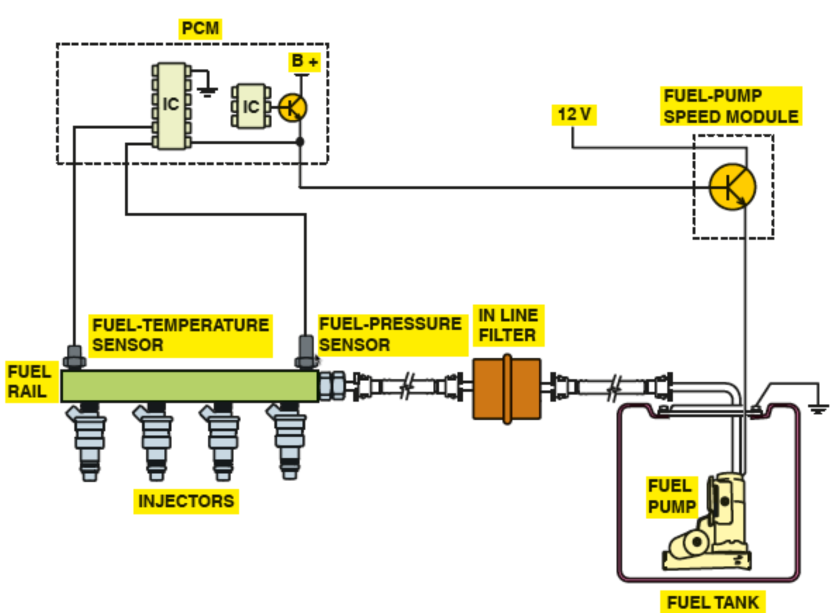

Figure 15. A returnless fuel pump system controls the speed of the pump to control pressure.

Fuel pressure alone is not enough for proper engine operation. Sufficient fuel capacity (flow) should be at least 2 pints (1 L) every 30 seconds or 1 pint in 15 seconds. Fuel flow specifications are usually expressed in gallons per minute. A typical specification would be 0.5 gallons per minute or more. Figure 16.

Figure 16. A tester that measures both pressure and volume.

7. Inspect, test, service and/or replace throttle assembly; make related adjustments and/or perform initialization or relearn procedure as required.

The only service that an electronic throttle control (ETC) system may require is a cleaning of the throttle body. Throttle body cleaning is a routine service procedure on port fuel-injected engines and is still needed when the throttle is being opened by an electric motor. Some points to consider:

- Some vehicle manufacturers add a nonstick coating to the throttle assembly and warn that cleaning could remove this protective coating.
- Do not spray cleaner into the throttle body assembly. The liquid cleaner could flow into and damage the TP sensors.

STEP 1 With the ignition off and the key removed from the ignition, remove the air inlet hose from the throttle body.

STEP 2 Spray throttle body cleaner onto a shop cloth.

STEP 3 Open the throttle body and use the shop cloth to remove the varnish and carbon deposits from the throttle body housing and throttle plate. Figure 17.

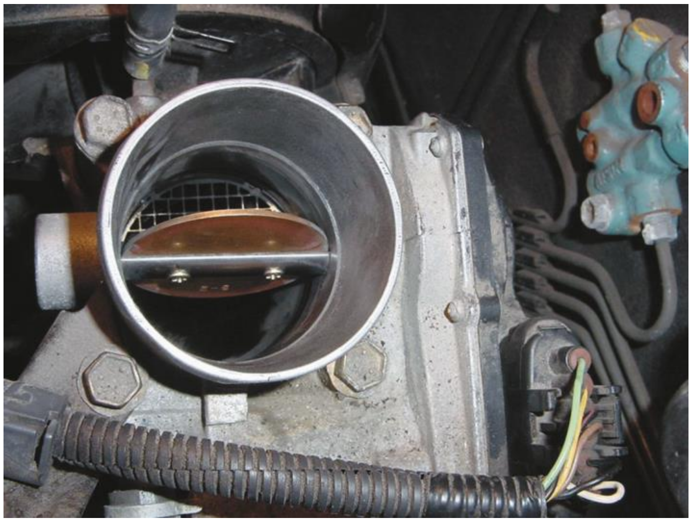

Figure 17. Clean the throttle body using a shop cloth wetted with solvent.

When installing a new throttle body or PCM or sometimes after cleaning the throttle body, the throttle position must be learned by the PCM. After the following conditions have been met, a typical throttle body relearn procedure includes the following:

- Accelerator pedal released
- Battery voltage higher than 8 volts
- Vehicle speed must be zero
- Engine coolant temperature (ECT) higher than 40°F (5°C) and lower than 212°F (100°C)
- Intake air temperature (IAT) higher than 40°F (5°C)
- No throttle DTCs set

If all of the above conditions are met, perform the following steps:

STEP 1 Turn the ignition on (engine off) for 30 seconds.

STEP 2 Turn the ignition off and wait 30 seconds.

STEP 3 Start the engine and the idle learn procedure should cause the engine to idle at the correct speed.

8. Inspect, test, clean, and replace fuel injectors, high-pressure lines, and fuel rails.

For best engine operation, all injectors should have the same electrical resistance. With an ohmmeter, measure the resistance across the injector terminals. Check service information for the resistance specification of the injectors. Measure the resistance of all the injectors. Replace any injector that does not fall within the resistance range of the specification. Figure 18.

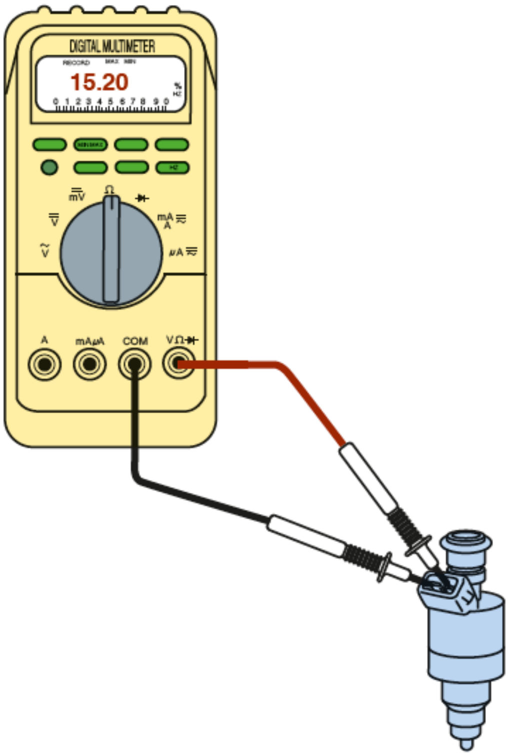

Figure 18. Measuring injector resistance.

A pressure balance test involves using an electrical timing device to pulse the fuel injectors on for a given amount of time, usually 500 milliseconds or 0.5 seconds, and observing the drop in pressure that accompanies the pulse. If the fuel flow through each injector is equal, the drop in pressure in the system will be equal. The general procedure is:

- Attach the pressure gauge to the fuel delivery rail on the supply side.
- Turn the ignition key to the on position to prime the fuel rail. Note the static fuel-pressure reading.
- Activate the pulser tool for the timed firing pulses.
- Note and record the new static rail pressure after the injector has been pulsed.
- Sample results:

	1	2	3	4	5	6
Initial pressure	40	40	40	40	40	40
Second pressure	30	30	35	30	20	30
Pressure drop	10	10	5	10	20	10
Possible problem	OK	OK	Restriction	OK	Leak	OK

If a defective injector is found, it is usually recommended that all of injectors be replaced along with the other one that tested as being defective.

GDI Systems. Because of the high pressures involved, it is important to adhere to safety precautions when working on GDI system which include the following:

- Don’t reuse high-pressure lines. The ball-ends deform when tightened and will not seal if reused. Figure 19.

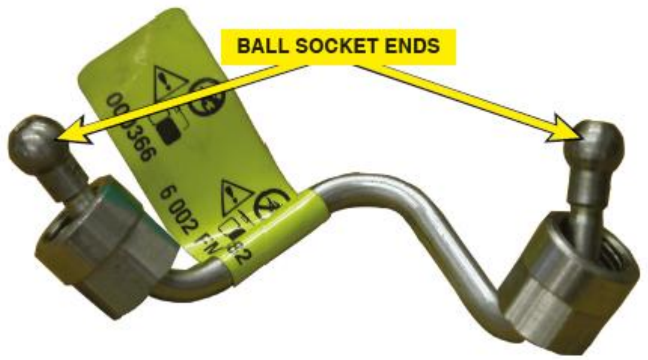

Figure 19. A GDI high pressure line.

- Always use a torque wrench when tightening fuel line fittings.
- Do not loosen any fuel fittings with the engine cranking or running.
- Always replace the Teflon seal whenever replacing or reinstalling an GDI injector. Figure 20.

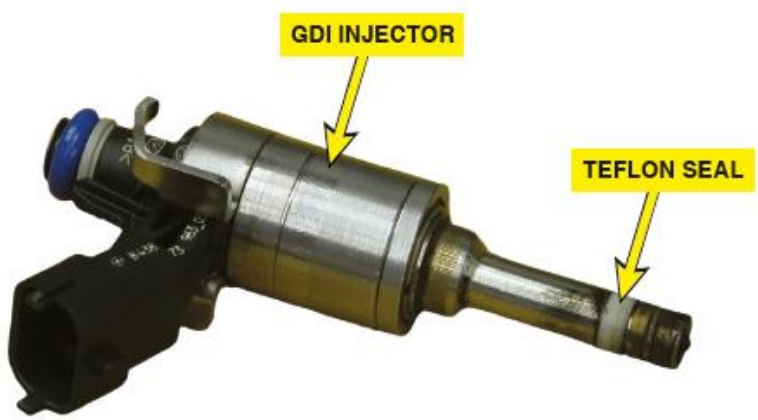

Figure 20. GDI injector and seal.

9. Inspect, service, and repair or replace air filtration system components.

Air contains dirt and other materials that cannot be allowed to reach the engine. Just as fuel filters are used to clean impurities from gasoline, an air cleaner and filter are used to remove contaminants from the air.

The paper air filter element is the most common type of filter. It is made of a chemically treated paper stock that contains tiny passages in the fibers. Most air filters are capable of trapping dirt and other particles larger than 10 to 25 microns in size. One micron is equal to 0.000039 inch.

Manufacturers recommend cleaning or replacing the air filter element at periodic intervals, usually listed in terms of distance driven or months of service. The distance and time intervals are based on so-called normal driving. More frequent air filter replacement is necessary when the vehicle is driven under dusty, dirty, or other severe conditions.

Some vehicles, especially pickup trucks that are often driven in dusty conditions, are equipped with an air filter restriction indicator. Figure 21.

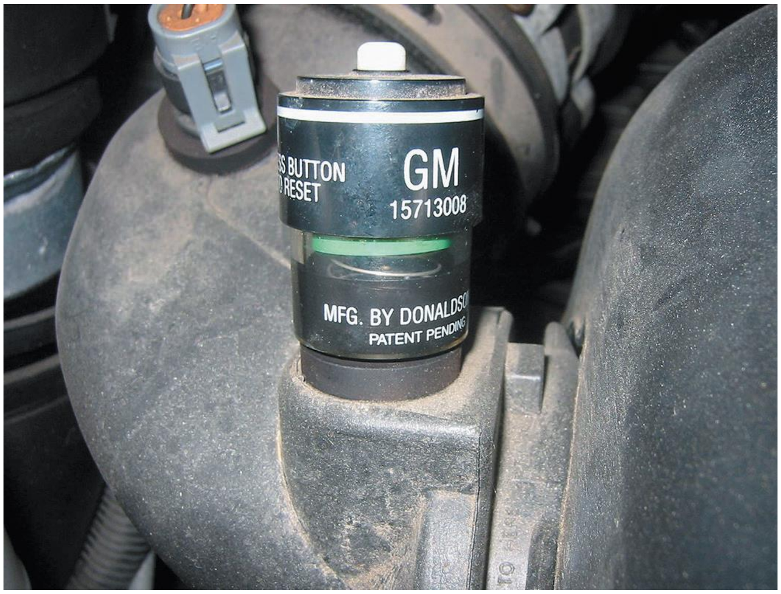

Figure 21. An air filter restriction indicator turns red when it detects enough restriction to require a filter replacement.

10. Remove, clean, inspect, test, and repair or replace throttle assembly, vacuum pump(s), air induction system, variable intake runners, intake manifold, and gaskets.

Air cleaner and duct design depend on a number of factors, such as the size, shape, and location of other engine compartment components, as well as the vehicle body structure. A mass airflow (MAF) sensor is placed between the throttle body and the air cleaner.

Remote air cleaners are connected to the turbocharger air inlet elbow or fuel-injection throttle body by composite ducting that is usually retained by clamps. The ducting used may be rigid or flexible, but all connections must be airtight.

Most intake manifolds are made from thermoplastic molded from fiberglass-reinforced nylon by either casting or by injection molding. Some manifolds are molded in two parts and bonded together.

When replacing the intake manifold gasket, always check service information for the exact procedure to follow. Some important steps are:

- Loosen all fasteners in the reverse order of the tightening sequence. This means that the bolts should be loosened starting at the ends and working toward the center.
- Thoroughly clean the area and replace the intake manifold if needed.
- Install the intake manifold using new gaskets as specified.
- Torque all fasteners to factory specifications and in the proper sequences. The tightening sequences usually start at the center and work outward to the ends. Many intake manifolds use fasteners that are torqued to values expressed in pound-inches and not pound-feet.
- Start the engine and check for leaks and proper engine operation.
- Reset or relearn the idle if specified, using a scan tool.

11. Diagnose air induction system for air/vacuum leaks, restrictions, and/or unmetered air.

Mass airflow (MAF) sensors are designed to measure all the air entering the engine. If an air inlet hose was loose or had a hole, extra air could enter the engine without being measured. This extra air is often called false air or unmetered air. Figure 21.

Figure 21. Inspect ducting for cracks and splits.

12. Inspect, service, and replace exhaust manifold, exhaust pipes, oxygen sensors, air/fuel ratio sensors, mufflers, catalytic converters, resonators, tailpipes, and heat shields.

The exhaust manifold is designed to collect high-temperature spent gases from the individual head exhaust ports and directs them into a single outlet connected to the exhaust system. The hot gases are sent to an exhaust pipe, then to a catalytic converter, to the muffler, to a resonator, and on to the tailpipe, where they are vented to the atmosphere. Figure 22.

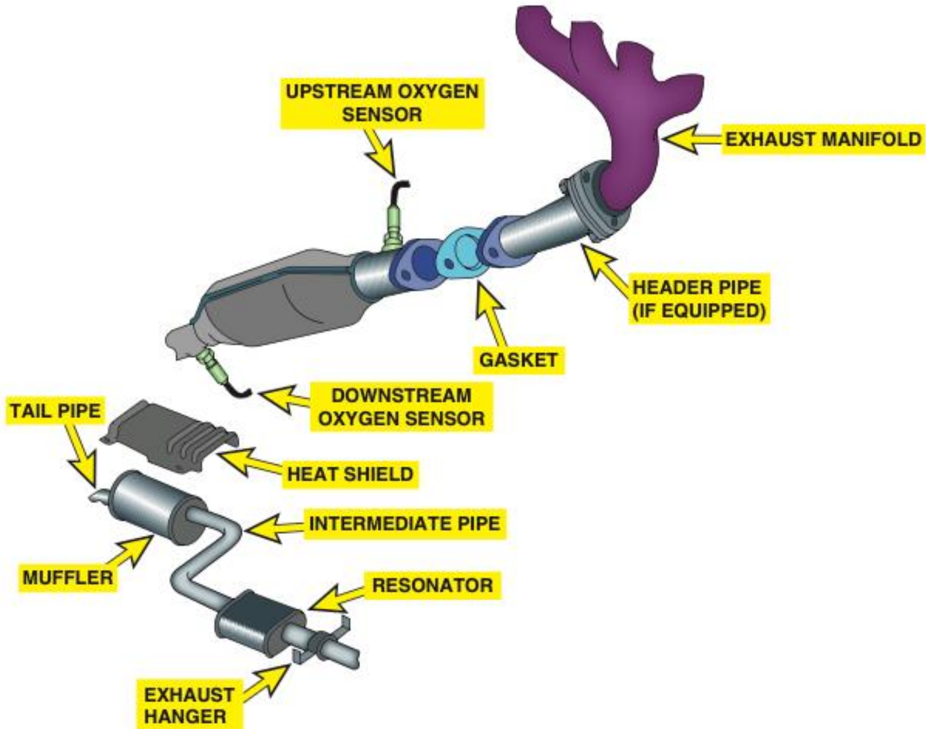

Figure 22. Exhaust system.

To replace an oxygen sensor a special socket is usually required. Figure 23.

Figure 23. Oxygen sensor socket.

13. Test for exhaust system restriction or leaks; determine needed action.

To check for restriction exhaust system back pressure can be measured directly by installing a pressure gauge in an exhaust opening, usually by removing the upstream oxygen sensor and installing a pressure gauge. Figure 24.

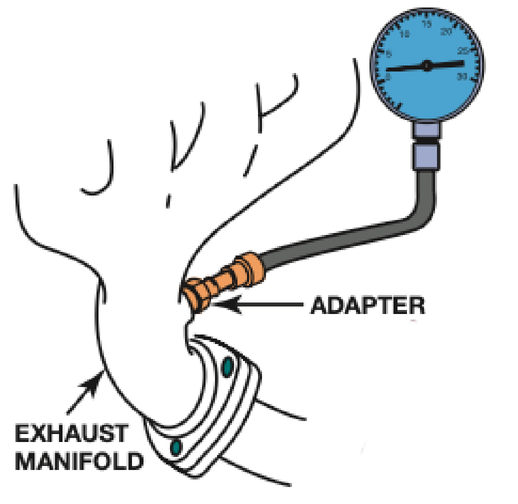

Figure 24. Measuring back pressure.

Exhaust restriction can be tested indirectly by checking the intake manifold vacuum with the engine operating at a fast idle speed (about 2500 rpm).

- Attach a vacuum gauge to an intake manifold vacuum source.
- Start the engine. Record the engine manifold vacuum reading. The engine vacuum should read 17 to 21 inch Hg when the engine is at idle speed.
- Increase the engine speed to 2500 rpm and hold that speed for 60 seconds while looking at the vacuum gauge.

If the vacuum reading is equal to or higher than the vacuum reading when the engine was at idle speed, the exhaust system is not restricted.

If the vacuum reading is lower than the vacuum reading when the engine was at idle speed, then the exhaust is restricted. Further testing will be needed to determine the location of the restriction.

14. Inspect, test, clean, and repair/replace turbocharger, supercharger, and related system components.

A turbocharger uses the heat of the exhaust to power a turbine wheel and, therefore, does not directly reduce engine power. A turbocharger gets its energy from the exhaust gases, converting more of the fuel's heat energy into useful mechanical energy. Figure 25.

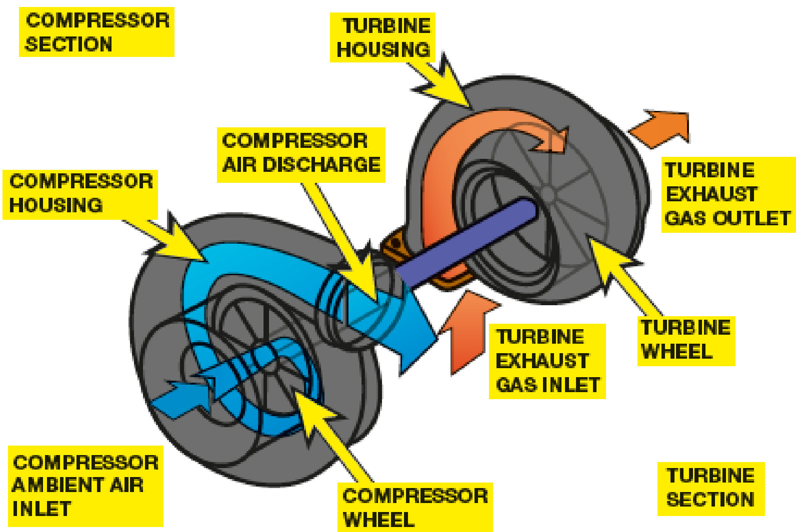

Figure 25. Turbocharger.

A supercharger is an air pump mechanically driven by the engine itself. Gears, shafts, chains, or belts from the crankshaft can all be used to turn the pump. This means the air pump or supercharger pumps air in direct relation to engine speed.

Superchargers are usually lubricated with synthetic engine oil inside the unit. This oil level should be checked and replaced as specified by the vehicle or supercharger manufacturer. The drive belt should also be inspected and replaced as necessary.

Both supercharged and turbocharged systems are designed to provide a pressure greater than atmospheric pressure in the intake manifold. As boost pressure increases, combustion temperature and pressures increase, which, if not limited, can do severe engine damage.

The wastegate is the pressure control valve of a turbocharger system. It is usually controlled by the engine control computer through a boost control solenoid.

Factory-installed superchargers are equipped with a bypass valve that allows intake air to flow directly into the intake manifold, bypassing the supercharger. The PCM controls the bypass valve actuator. Figure 26.

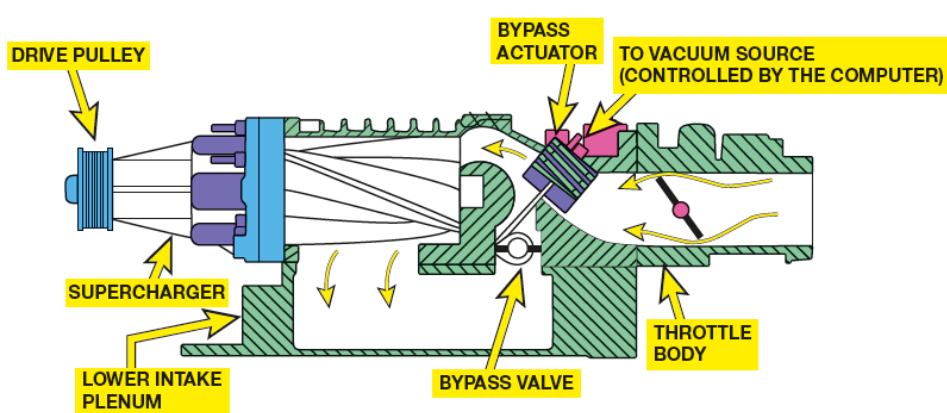

Figure 26. Supercharger and bypass valve.