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INTRODUCTION

FUEL SYSTEM The fuel system includes the following components and systems:

- Fuel tank
- Fuel lines and filter(s)
- Fuel injectors
- Electronic control of the fuel pump and fuel injection

The fuel injectors are designed to atomize the liquid gasoline into small droplets so they can be mixed with the air entering the engine. This mixture of fuel and air is then ignited by the spark plug.

AIR INTAKE SYSTEM All engines, both gasoline and diesel engines, draw air from the atmosphere. The air must be drawn where deep water in the road cannot be drawn into the engine. The air is then filtered by a replaceable air filter. After the air is filtered, it passes through a throttle valve and then into the engine through an intake manifold.

STARTING AND CHARGING SYSTEM Engine starting and charging systems include the battery, starting (cranking) system, charging system components, and circuits.

IGNITION SYSTEM The ignition system includes the ignition control module (ICM or PCM) and ignition coil(s), which create a high-voltage spark by stepping up battery voltage. The arc across the electrodes of the spark plug ignites the air–fuel mixture in the combustion chamber and the resulting pressure pushes the piston down on the power stroke.

EXHAUST SYSTEM Exhaust systems are especially designed for the engine–chassis combination. The exhaust system length, pipe size, and silencer are designed, where possible, to make use of the tuning effect within the exhaust system. Components include:

- Exhaust manifold. 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.
- Catalytic converter. The catalytic converter is placed as close to the engine as possible so that the heat can help the converter work most efficiently.
- Exhaust pipes. The exhaust pipes from the catalytic converter rearward are used to conduct the hot exhaust gases to the rear of the vehicle. The pipes are usually constructed of aluminized or stainless steel to resist rust and corrosion.
- Muffler. The muffler catches the large bursts of - high-pressure exhaust gas from the cylinder, smoothing out the pressure pulses and allowing them to be released at an even and constant rate.

ASE TEST TOPICS

1. Diagnose engine problems caused by faults in the fuel system; determine needed action.

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:

- 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 nozzle or nozzles which are basically 12-volt solenoids. Fig. 1.

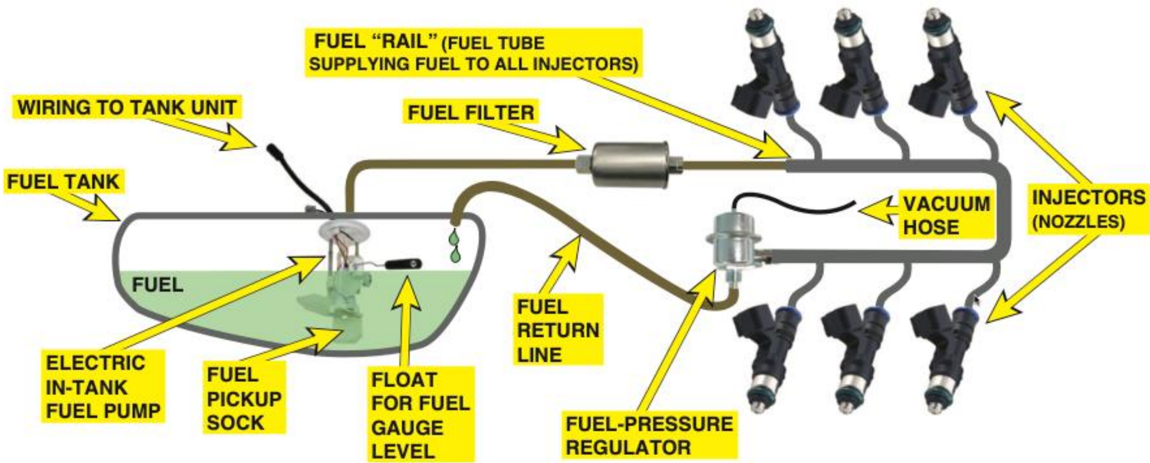

Figure 1. Typical port fuel injection system.

Gasoline direct injection GDI system varies the fuel pressure to achieve greater fuel delivery using a very short pulse time, which is usually less than one millisecond. A direct-injection system sprays high-pressure fuel , up to 2,900 PSI, into the combustion chamber as the piston approaches the top of the compression stroke.

With the combination of high-pressure swirl injectors and modified combustion chamber, almost instantaneous vaporization occurs. This combined with a higher compression ratio allows a direct-injected engine to operate using a leaner-than-normal air–fuel ratio, which results in improved fuel economy with higher power output and reduced exhaust emissions. Fig. 2.

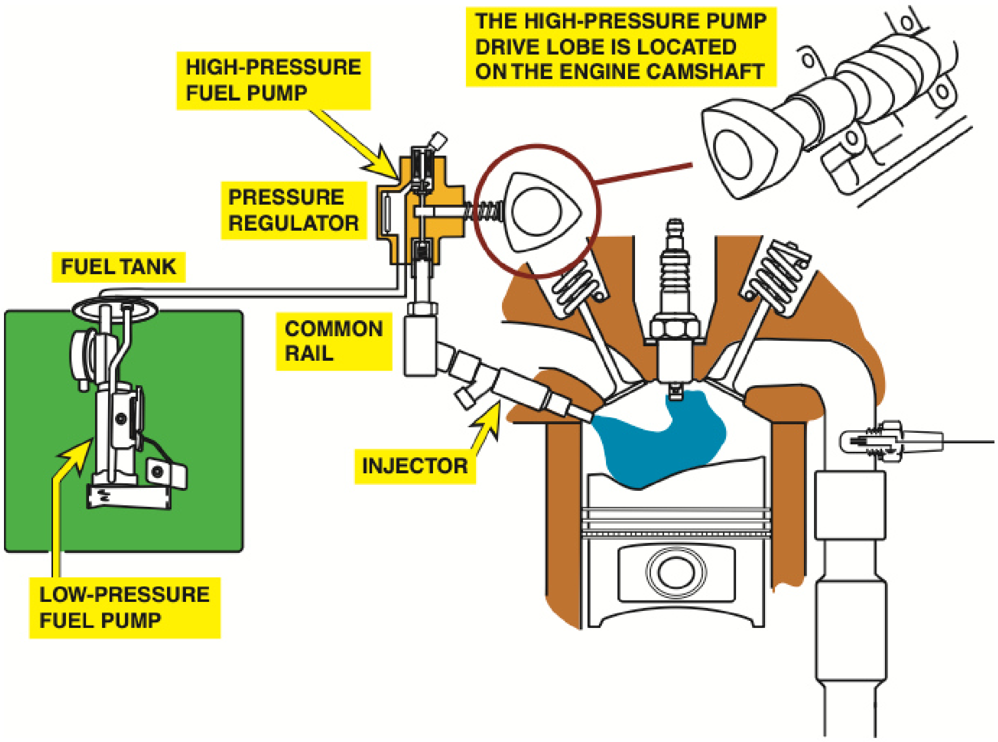

Figure 2. Direct injection system.

A typical direct-injection system uses two pumps-one low-pressure electric pump in the fuel tank and the other a high-pressure pump driven by the camshaft. The high-pressure fuel system operates at a pressure as low as 500 PSI during light load conditions and as high as 2,900 PSI under heavy loads.

2. Inspect, test, repair and/or replace components of the fuel system.

A fuel pressure gauge can be connected to many older fuel injection systems at the threaded port on the fuel rail. Attach a fuel-pressure gauge to the Schrader valve on the fuel rail. Turn the ignition key on or start the engine to build up the fuel pump pressure (to about 35 to 45 PSI). Fig. 3.

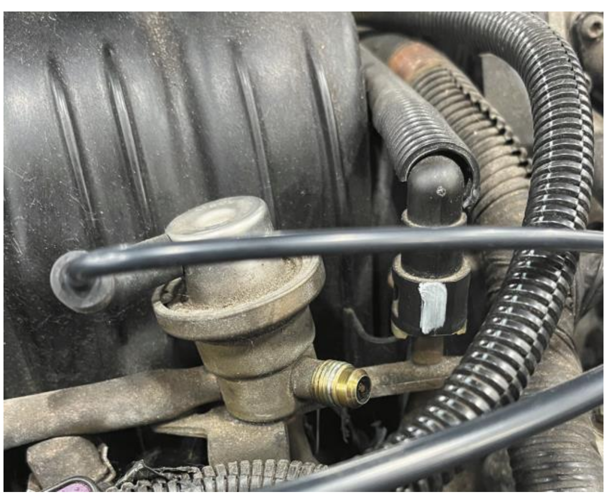

Figure 3. Fuel pressure test port.

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. 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. Fig. 4.

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

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

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

Figure 4. Fuel trim chart.

For best engine operation, all injectors should have the same electrical resistance. To measure the resistance, carefully release the locking feature of the connector and remove the connector from the injector. With an ohmmeter, measure the resistance across the injector terminals. The resistance value of a most injectors is usually 12 to 16 ohms. Figure 5.

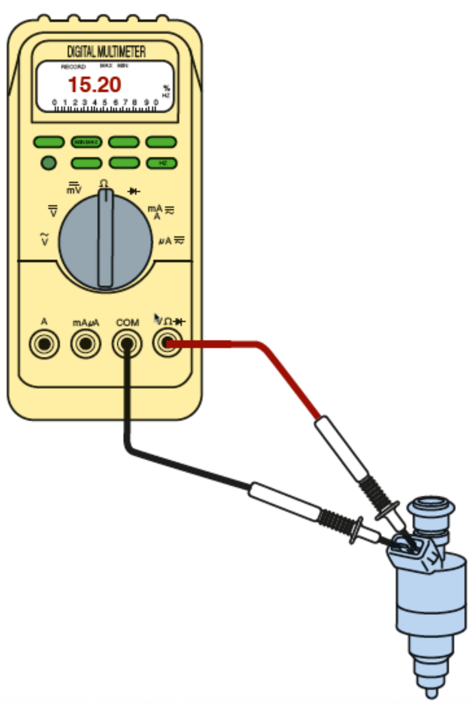

Figure 5. Measuring injector resistance.

GDI Diagnosis.

- Connect a scan tool and select the data parameters for desired fuel pressure and actual fuel pressure.
- With the key on, engine off (KOEO), the fuel pressure sensor should read low pressure pump pressure, approximately 50 to 75 psi. If the fuel pressure is below specification, focus on the low pressure pump circuit and components.
- With the key on engine running (KOER), monitor the desired fuel pressure and actual fuel pressure data parameters. The actual fuel pressure should be a close match to the desired fuel pressure in all operating conditions.
- If the actual fuel pressure is too low or too high, the pressure regulator data parameter should be monitored for a higher or lower than normal value. This information will help determine if this issue is related to the high pressure pump, low pressure pump or high pressure pump control circuit.

GDI Service.

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.
- 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 a GDI injector. Fig.6.

Figure 6. A GDI injector.

3. Diagnose engine problems caused by faults in the air induction system; determine needed action.

Without proper filtering of the air before it enters the engine, dust and dirt in the air can seriously damage engine parts and shorten engine life. 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. The filter that cleans the intake air is in a two-piece air cleaner housing made of composite (usually nylon-reinforced plastic) materials.

Vehicles generally use a horizontally mounted throttle body with a mass airflow (MAF) sensor between the throttle body and the air cleaner. Because placing the air cleaner housing next to the throttle body would cause engine and vehicle design problems, it is more efficient to use a remote air cleaner placement. Fig. 7.

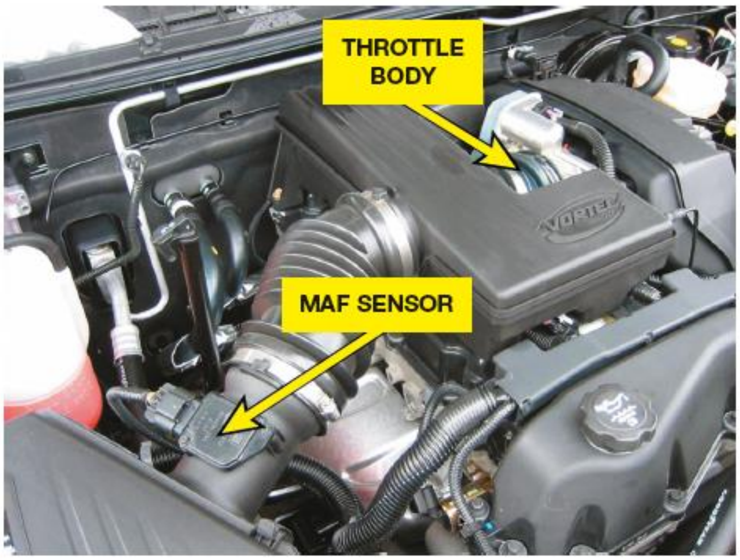

Figure 7. Air filter, lower left.

The size and shape of engine intake manifolds can be optimized because the only thing in the manifold is air. The runner length and shape are designed for tuning only. Intake manifold runners are tuned to improve engine performance.

- Long runners build low-RPM torque.
- Shorter runners provide maximum high-RPM power.

Many intake manifolds are constructed in two parts. The use of a two-part intake manifold allows for easier manufacturing, as well as assembly, but can create additional locations for leaks. If the lower intake manifold gasket leaks, not only could a vacuum leak occur, affecting the operation of the engine, but a coolant leak or an oil leak can also occur if the manifold has coolant flowing through it.

4. Inspect, test, repair and/or replace components of the air induction system.

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. Fig. 8.

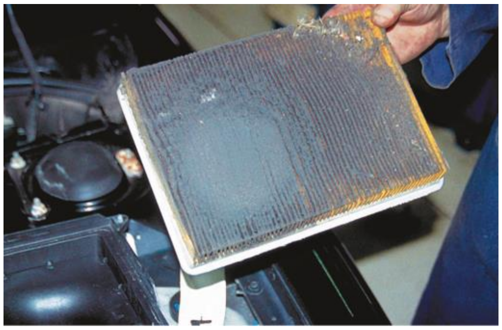

Figure 8. Air filter replacement needed.

5. Diagnose engine problems caused by faults in the electrical system; determine needed action.

Battery. The primary purpose of an automotive battery is to provide a source of electrical power for starting and for electrical demands that exceed alternator output. The battery must be in good (serviceable) condition before the charging system and the cranking system can be tested.

Cranking system. The cranking circuit includes those mechanical and electrical components required to crank the engine for starting. The engine is cranked by an electric motor that is controlled by a key-operated ignition switch or the PCM on vehicles equipped with electronic starting. The ignition switch will not operate the starter unless the automatic transmission is in neutral or park. Fig. 9.

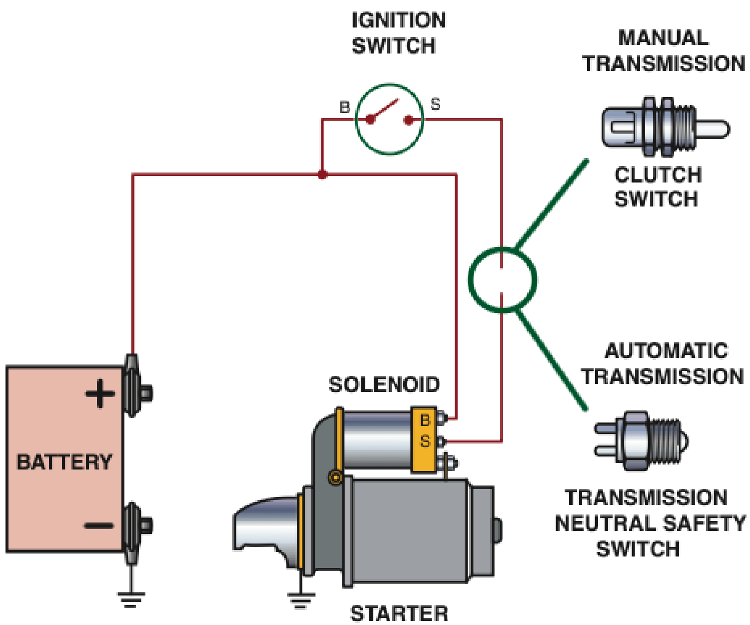

Figure 9. Basic cranking system..

Charging system. It is the purpose and function of the charging system to keep the battery fully charged and to provide power for the vehicle when the engine is running. The Society of Automotive Engineers (SAE) term for the unit that generates electricity is **generator**. The term alternator is most commonly used in the trade. Fig. 10.


Figure 10. Alternator (also called a generator).

6. Inspect, test, repair and/or replace components of the electrical system.

The battery and battery cables should be included in the list of items checked during a thorough visual inspection. Check the battery cables for corrosion and tightness.

Testing the battery voltage with a voltmeter is a simple method for determining the state of charge of any battery. This test is commonly called an open-circuit battery voltage test because it is conducted with an open circuit—with no current flowing and no load applied to the battery. Fig. 11.

Battery voltage (v)	State of charge
12.6 or higher	100% charged
12.4	75% charged
12.2	50% charged
12.0	25% charged
11.9 or lower	Discharged

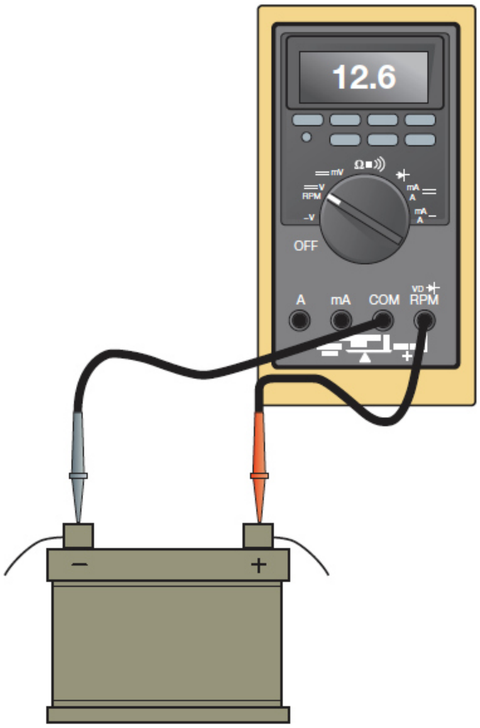

Figure 11. Battery voltage check.

A common test to determine the condition of any battery is the load test. Most automotive starting and charging testers use a carbon pile to create an electrical load on the battery. The proper electrical load used to test a battery is half of the CCA rating for 15 seconds.

For proper operation, all starters require that the vehicle battery be at least 75% charged and that both power-side and ground-side battery cables be free from excessive voltage drops. The following should be carefully checked as part of a thorough visual inspection.

- Carefully check the battery cables for tightness both at the battery and at the starter, and block connections.
- Crank the engine. Feel the battery cables and connections. If any cables or connections are hot to the touch, then an excessive voltage drop is present, or the starter is drawing too much current. The engine itself could be binding. Repair or replace the components or connections as needed.

To measure charging system voltage, connect the test leads of a digital multimeter to the positive (+) and negative (-) terminals of the battery. Set the multimeter to read DC volts. Most alternators are designed to supply between 13.5 and 15 volts at 2,000 engine RPM.

7. Diagnose engine problems caused by faults in the ignition system; determine needed action.

The ignition system includes components and wiring necessary to create and distribute a high voltage (up to 40,000 volts or more) and send to the spark plug. A high-voltage arc occurs across the gap of a spark plug inside the combustion chamber. The spark raises the temperature of the air–fuel mixture and starts the combustion process inside the cylinder.

Electronic Ignition (EI) is the term specified by the SAE for an ignition system that does not use a distributor . Types of EI systems include:

- Waste-spark system . This type of system uses one ignition coil to fire the spark plugs for two cylinders at the same time. Fig. 12.
- Coil-on-plug system . This type of system uses a single ignition coil for each cylinder with the coil placed above or near the spark plug. Fig. 13.

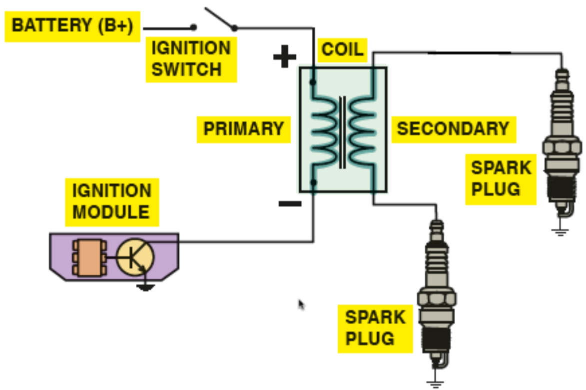

Figure 12. Waste spark system.

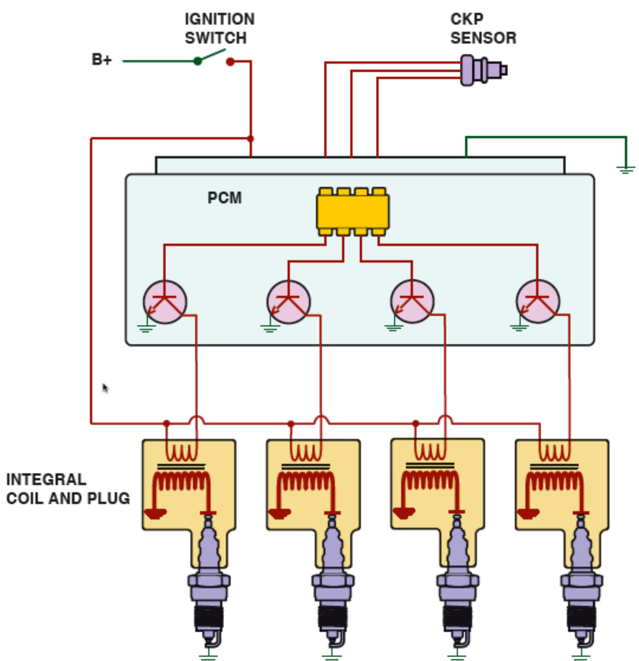

Figure 13. A coil-on-plug ignition system.

For any ignition system to function, the primary current must be turned on to charge the coil and off to allow the coil to discharge, creating a high-voltage spark. This turning on and off of the primary circuit is called switching. The unit that does the switching is an electronic switch, such as a power transistor. This power transistor can be located in the ignition control module or the powertrain module (PCM).

The device that signals the switching of the coil on and off in most instances, is called the trigger. A trigger is typically a pickup coil in some distributor-type ignitions or a crankshaft position (CKP) sensor in non-distributor systems. Fig. 14.

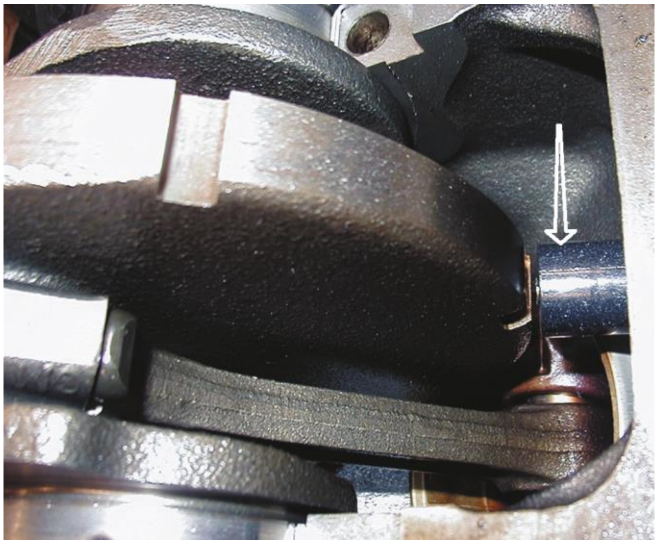

Figure 14. CKP sensor (arrow).

8. Inspect, test, repair and/or replace components of the ignition system.

In the event of a no-start condition, the first step should be to check for secondary voltage out of the ignition coil to the spark plugs. Remove the spark plug wire from the spark plug, install a spark tester, and crank the engine. A good coil and ignition system should produce a blue spark at the spark tester. Fig. 15.

Figure 15. Spark tester.

A basic step in the diagnosis process is to perform a thorough visual inspection of the ignition system, including the following:

- Check all spark plug wires for proper routing. All plug wires should be in the factory wiring separator and be clear of any metallic object that could cause damage to the insulation and cause a short-to-ground fault.
- Check that all spark plug wires are securely attached to the spark plugs and to the distributor cap or ignition coil(s).
- Remove the spark plugs and check for excessive wear or other visible faults. Replace if needed.

- On COP systems remove the coils and check the connecting boot for cracks, carbon tracks, or corrosion. Fig. 16.

Figure 16. Check the COP coil for arcing or corrosion.

If accessible, check the crankshaft position sensor for the correct resistance and AC voltage output using a DMM. Fig. 17.

Figure 17. Measuring CKP sensor resistance.

9. Diagnose engine problems caused by faults in the exhaust system; determine needed action.

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. Fig. 18.

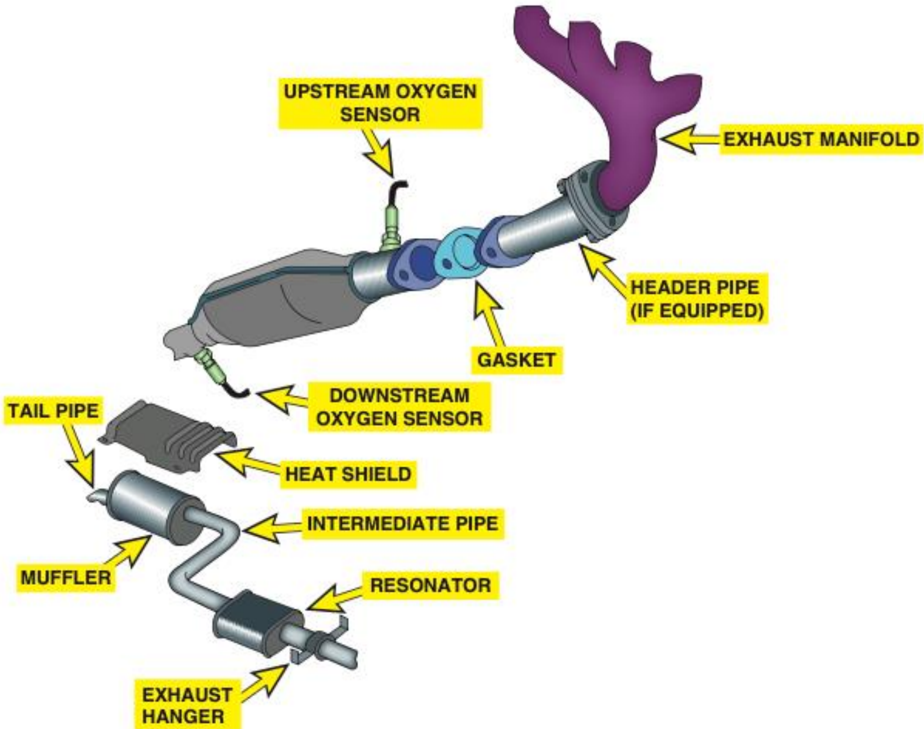

Figure 18. Exhaust system.

10. Inspect, test, repair and/or replace components of the exhaust system.

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. Fig 19.

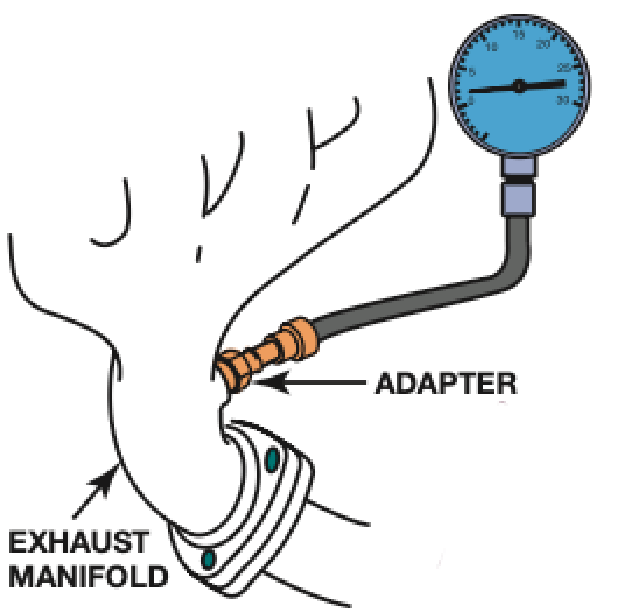

Figure 19. Measuring back pressure.

An 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.