GADSDEN TECHNICAL INSTITUTE
CONTINUAL EDUCATION
COVID-19 EMERGENCY LESSONS

Teacher Name: Mr. James Weeks
Dates of Instruction: March 30 – April 13, 2020
Lesson Title: Engine Repair Technician
Grade Levels: 10 – 12; Adult
Subject Area: Automotive Service Technology 1

Assignment: After reading the material on computerized engine controls diagnosis and repair, the student will be able to: remove cylinder head; inspect gasket condition; install cylinder head and gasket; tighten according to manufacturer's specification and procedure; clean and visually inspect a cylinder head for cracks; check gasket surface areas for warpage and surface finish; check passage condition; inspect pushrods, rocker arms, rocker arm pivots and shafts for wear, bending, cracks, looseness, and blocked oil passages (orifices); determine needed action, adjust valves (mechanical or hydraulic lifters); inspect and replace camshaft and drive belt/chain; includes checking drive gear wear and backlash, end play, sprocket and chain wear, overhead cam drive sprocket(s), drive belt(s), belt tension, tensioners, camshaft reluctor ring/tone-wheel, and valve timing components; verify correct camshaft timing.

Lesson Instructions:
Week of March 30 – April 3, 2020, read pages 36 – 59.

Week of April 6 – 15, 2020, read pages 61 - 84.

Practice Activities:
Week of March 30 – April 3, 2020, answer questions 1 – 40 as they relate to the assigned reading on pages 36 - 59.

Week of April 6 – 15, 2020, answer questions 41 – 85 as they relate to the assigned reading on pages 61 – 84.

Instructional Materials:
1. Automotive Service Technology Module 1 reading packet
2. Automotive Service Technology Module 1 questions packet

Special Notes from Instructor:
ALL paper work should be kept in your folder, signed and dated to reflect completion date(s) prior to bringing them to class with you on April 16, 2020. If there are any questions, I can be reached at (850) 933-1147; or email weeksj@gcpsmail.com.

Mission Statement
The mission of Gadsden Technical Institute is to recognize the worth and potential of each student. We are committed to providing opportunities for basic and advanced instruction in a conducive learning environment. The Center encourages academic and technical curiosity, innovation and creativity by integrating applied academic skills in all occupational areas. We strive to instill the attitudes and skills necessary to produce motivated, self-sufficient individuals who are able to function effectively in our ever-changing, complex society.

Ignition System Diagnosis And Repair

IGNITION SYSTEM DESCRIPTION AND OPERATION

There are two kinds of ignition systems, Distributor Ignition (DI) and distributorless Electronic Ignition (EI).

All ignition systems are divided into two circuits, the primary and secondary. The primary circuit, or low voltage ignition circuit, is common to DI and EI systems and includes the battery, the ignition switch, the primary windings of the ignition coil(s), and a triggering mechanism (pick-up coil and reluctor, magnet and shutter vanes or slotted disc and photo optical sensor) and switching device to turn the circuit on and off.

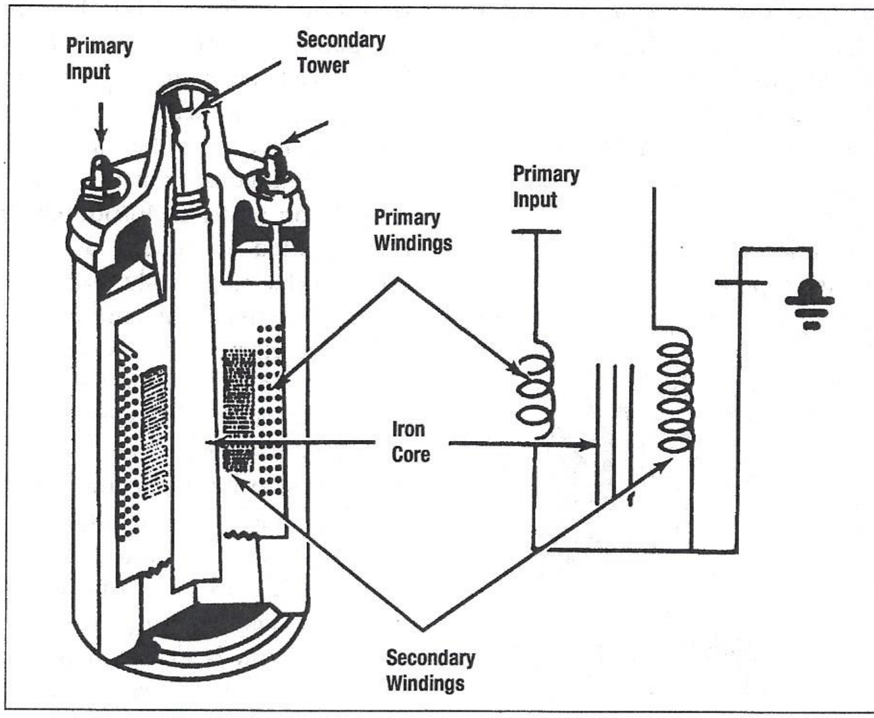
With DI systems, the secondary system consists of the secondary windings of the ignition coil, the coil wire, the distributor cap and rotor, the spark plug wires, and the spark plugs.

EI systems have no distributor and instead have a coil for each cylinder or pair of cylinders. These coils are either directly connected to the spark plugs or are connected to them with conventional spark plug wires.

Current flows from the battery, through the ignition switch, through the coil primary, and through the switching device to ground.

Functionally, the ignition coil is a transformer and its primary side is wound with about 200 turns of relatively heavy wire. When the circuit is closed and current is flowing through the primary circuit, a powerful magnetic field builds up on the coil's primary windings.

The secondary windings, which usually sit inside the primary windings, consist of about 22,000 turns of very fine wire. When the circuit is opened by the switching device (the ignition control module and/or PCM/ECM), primary current stops flowing. Then the energy stored in the primary windings collapses across the secondary windings, inducing a voltage in them. Depending upon how the primary system and the coil are designed, secondary voltage potential can range from 25,000 to 50,000 volts. Some modern systems produce 80,000 volts.



Internal construction and schematic of a conventional oil-filled coil.

On DI systems, the secondary voltage goes out through the coil's secondary terminal, through the coil wire to the distributor cap center terminal, from the center terminal to the rotor spring arm, across the rotor to one of the distributor cap terminals, through the plug wire to the spark plug, and the plug fires. As the distributor turns, the rotor distributes the voltage from the coil to each distributor terminal in the vehicle's firing order.

On EI systems the coils are signaled to fire in the proper order by the ignition control module and/or PCM/ECM, which also controls the spark timing and advance.

IGNITION SYSTEM INSPECTION

Overall, ignition systems suffer from the same problems that afflict any electrical circuit. They are hurt by high resistance connections, open circuits, wire-to-wire shorts, and shorts to ground. In addition, they are often damaged by the same things that hurt electronic circuits: reversed polarities, and static discharges. Such problems cause weak spark or no spark at the spark plugs. The result is symptoms such as no-start, hard start, misfire or stumble under acceleration. When troubleshooting an ignition system, always check for DTCs related to ignition system operation.

Perform a visual inspection of the

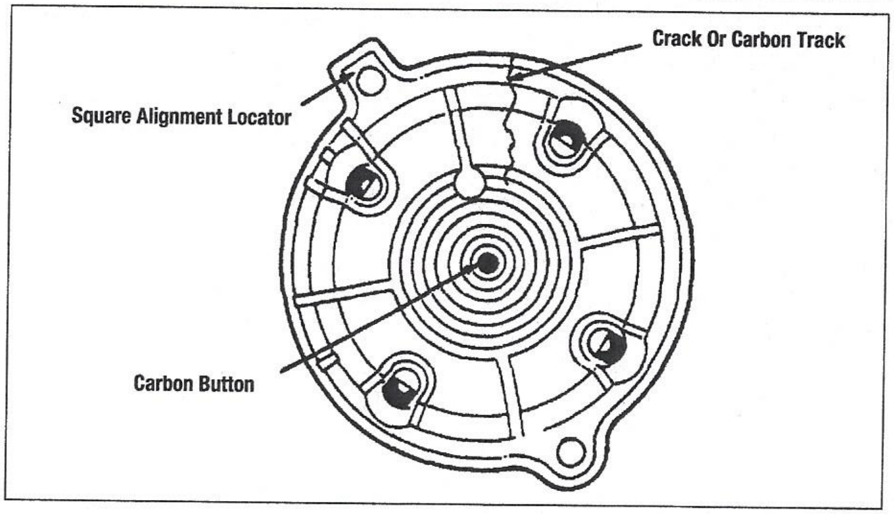
ignition wiring and components. Make sure the spark plug wires are securely connected to the spark plugs, distributor cap and/or coil(s). Inspect the wires and wire boots for wear and cracking and replace as necessary. Check that the firing order is correct on DI systems and make sure that wires from consecutively firing cylinders cross rather than run parallel, to prevent crossfiring. Check the coil(s) for cracks, carbon tracking, oil leakage or other damage.

Check the primary circuit wiring for damage, corrosion and poor connections, which can cause voltage drops. If there is an intermittent problem, you may have to wiggle or gently tug on the wiring, including the connection at the ignition switch, with the engine running to find the cause.

Damaged or worn out distributor caps and rotors can cause a variety of problems, such as a no start condition, hard starting, missing, lack of power, rough idle, high emissions, and poor fuel economy. Inspect the distributor cap for cracks, wear or other damage. Check the spark plug wire and coil wire terminals for corrosion. Check the locating tab and hold-downs to make sure the cap is secured properly to the distributor.

Remove the distributor cap and check the rotor contact terminals for wear, corrosion or other damage. Look for cracks or evidence of carbon tracking. A carbon track is a small line of carbon that conducts electricity. A carbon track can cause coil voltage to short to ground or to the wrong plug wire, causing a misfire or causing a plug to fire at the wrong time.

Inspect the rotor for cracks, carbon tracks and erosion or other damage to the rotor tip and spring arm contact. Check the rotor locating tab and hold-downs to make sure the rotor is properly positioned on the distributor shaft. Remove the rotor and look for discoloration in the center at the top and bottom. Such discoloration is evidence of 'rotor burn through'; indicating the high voltage from the coil has burned through the rotor and is grounding on the distributor shaft.



Typical location for crack or carbon track in a distributor cap.
(Courtesy: Ford Motor Co.)

Inspect the condition of the triggering mechanism and wiring. These components are inside the distributor on DI systems and mounted on the engine near the crankshaft on EI systems. The triggering mechanism components seldom require service, although the pickup air gap can be adjusted on some systems. A nonmagnetic feeler gauge must be used when checking the gap between the pickup and the tips of the reluctor wheel. Try to move the distributor shaft from side-to-side to check the condition of the distributor bushings before performing this adjustment. Excessive play could change the pickup gap and cause a misfire.

IGNITION SYSTEM DIAGNOSIS

The following are common problems and possible ignition system related causes:

No Start or Hard Start
- low or no primary voltage at the coil
- defective coil
- open coil wire
- defective distributor cap and/or rotor
- defective triggering mechanism
- defective ignition module
- fouled spark plugs

Engine Misfire
- low primary voltage
- defective coil
- defective distributor cap and/or rotor
- worn distributor
- high resistance in spark plug wires
- incorrectly routed spark plug wires
- defective spark plugs

Power Loss
- defective coil
- late ignition timing
- not enough timing advance
- engine misfire

Spark Knock
- spark plug heat range too hot
- incorrectly routed spark plug wires
- ignition timing too far advanced

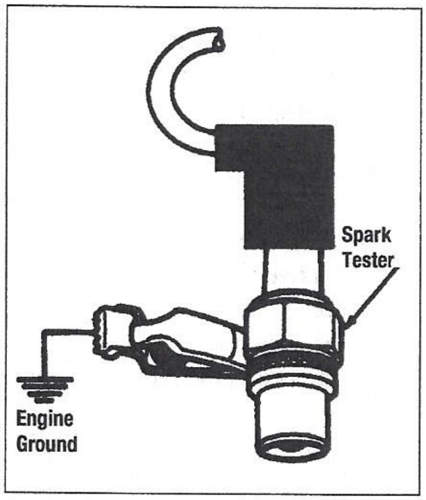
Poor Mileage
- engine misfire
- late ignition timing
- not enough timing advance

No-Start Diagnosis

If the vehicle will not start because of a no-spark condition, then perform the following tests.

Connect a 12-volt test light to the coil negative terminal and ground, then turn the ignition key to the ON position. The test light should be on. If not there is an open in the coil primary windings or in the circuit from the ignition switch to the coil battery terminal.

Watch the test light while cranking the engine. If the light flickers, the signal from the pickup coil and module are OK. If the light does not flicker when the engine is cranked, test the pickup coil with an ohmmeter. If the pickup coil tests OK, then the module is defective.



Typical spark tester.

If the test light flickered, disconnect the coil wire from the distributor cap and connect a spark tester to the wire. Ground the tester and crank the engine. If the spark tester fires, the ignition coil is OK. If the spark tester does not fire, then the coil is defective.

The spark tester can be used at each of the spark plug wires. If the tester then fails to fire when the engine is cranked, there is a problem with the spark plug wire, distributor cap or rotor.

Performance Diagnosis With A Scope

An oscilloscope converts the electrical signals from the ignition system into a visual image showing voltage changes over a period of time. This voltage line is called a pattern. The technician can study these patterns and compare with known good ones to determine what is happening in the ignition system.

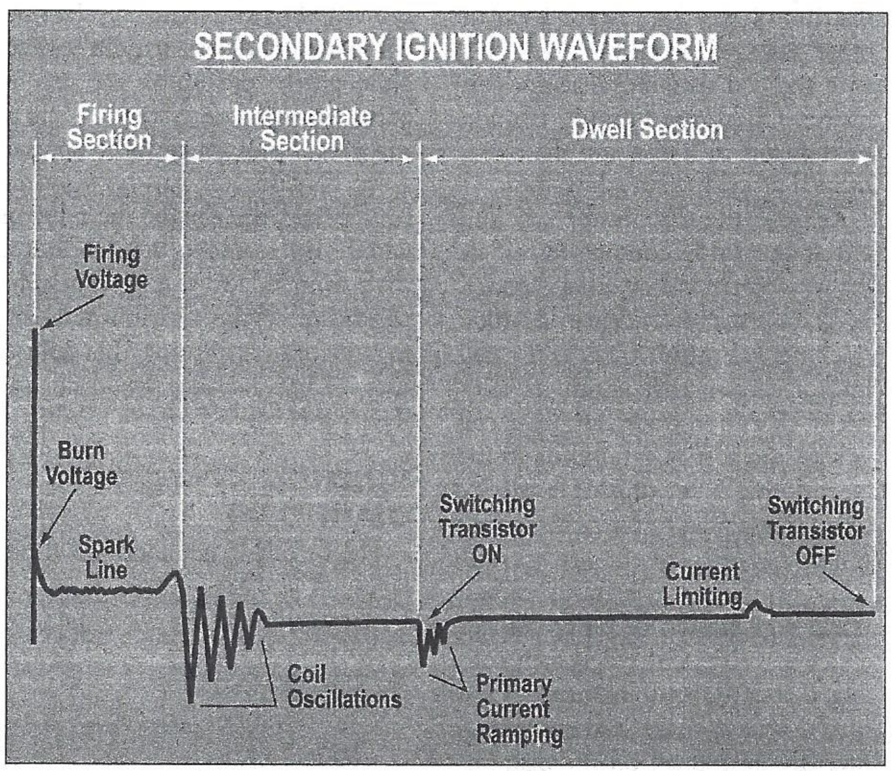
The primary scope pattern shows the low voltage changes in the primary circuit of the ignition system. However, since the secondary ignition circuit is dependent upon a properly functioning primary circuit, and any primary circuit problems are reflected in the secondary circuit, it is the secondary scope pattern that is checked more often.

The secondary scope pattern has three sections: firing, intermediate and dwell. The firing section starts on the left side of the screen. Problems with the spark plugs, plug wires, distributor cap and rotor will be indicated here.

The firing section begins with the firing line. The firing line represents the amount of voltage required to jump the spark plug gap. The firing line should be 7-13kV, with no more than 3kV variation between cylinders. Once the spark has been initiated, a horizontal line will be displayed about three quarters of the way down on the firing line. This is called the spark line. The burn voltage is the height on the voltage scale of the spark line. The burn voltage indicates the amount of energy required to sustain the flow of current across the plug electrodes.

The intermediate section shows a series of diminishing oscillations that represents residual coil energy. This residual energy gradually dissipates between the switching device and coil. Problems with the ignition coil(s) will be indicated in this section.

The dwell section begins when the switching device turns on to allow



Typical secondary ignition scope pattern.

current flow to the ignition coil. There should be a short downward drop followed by small oscillations. The dwell section is where the magnetic field builds up in the ignition coil. Problems with the triggering mechanism and ignition module will be indicated in this section.

An oscilloscope can display patterns in different ways for diagnostic purposes. The patterns for all cylinders can be superimposed (placed on top of one another) to check for uniformity. Any pattern that does not align with the others can indicate a problem with that cylinder. For example, if one cylinder has a firing line and burn time that is different from the other cylinders, there is most likely a problem with the spark plug or spark plug wire in that cylinder.

Patterns can also be lined up in a parade display, where the pattern for each cylinder is shown side by side. This display is useful for comparing firing voltages. Tall firing lines indicate high resistance while short firing lines indicate low resistance.

The raster, or stacked display places all cylinder patterns on top of one another. This display is used to check timing or dwell variations between cylinders.

COMPONENT TESTING

Ignition Switch

A defective ignition switch or ignition switch wiring may not allow enough power to the ignition module or ignition coil. The switch can be tested with a Digital Multimeter (DMM).

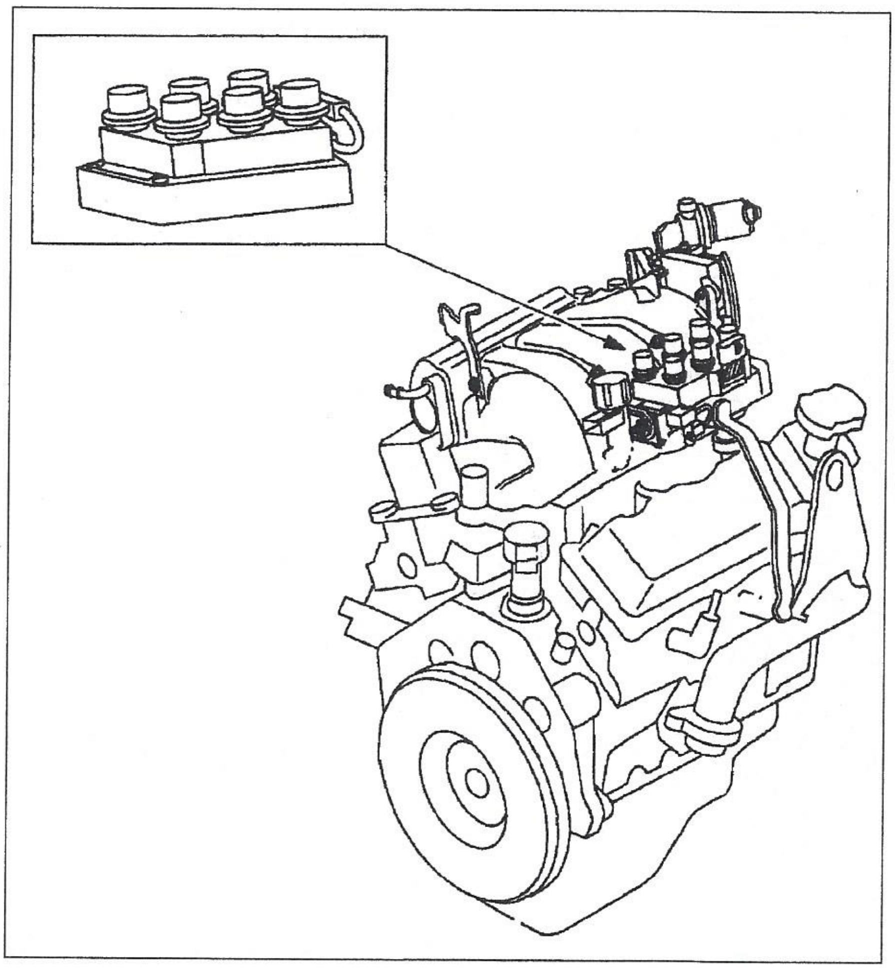
Ground the negative lead of the DMM to the distributor base. With the ignition switch in the OFF position, connect the positive lead to the power wire at the module. Turn the ignition switch to the run or start position, as required, and measure the voltage. The voltage reading should be at least 90% of battery voltage.

Ignition Coils

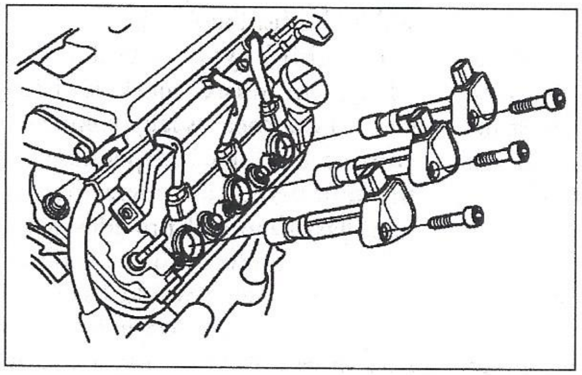
Ignition coils have advanced beyond the conventional cylindrical type of coil that was used for many years. Today there are four types of ignition coils: external, which covers the conventional coils as well, internal, EI system (distributorless) waste spark ignition coils and direct ignition Coil On Plug (COP) coils. The external coil is referred to as such because, depending on the manufacturer, the coil will be located either on the engine, firewall or strut tower (anywhere outside the distributor).

The second type is the internal ignition coil, which is located inside or is a part of the distributor cap or distributor. The GM High Energy Ignition (HEI) system ignition coil is an internal type coil, because it is located within the distributor cap.

The third type of coil is the EI system waste spark ignition coil. These coils usually come as a two- or three-pack depending on the number of cylinders the engine has. One coil provides spark for two cylinders. For example, a 4-cylinder engine would have two coils in a pack and a 6 cylinder would have three coils in a pack. The coils are grouped according to companion cylinders—cylinders whose pistons are at TDC at the same time. The spark plug fires in each cylinder simultaneously, but most of the available energy goes to the cylinder that is on the compression stroke, the 'event' cylinder, because there is little resistance from the other cylinder, which is on the exhaust stroke.



Typical distributorless waste spark EI system coil pack on a 6-cylinder engine. *(Courtesy: Ford Motor Co.)*

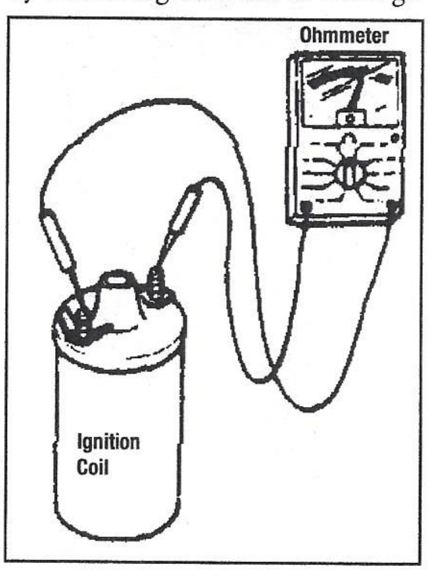


An example of Coil On Plug (COP) ignition coils.
(Courtesy: Honda Motor Co., Ltd.)

The last type of coil, the COP coil, is used in a distributorless system where the coil is mounted directly to the spark plugs. Secondary resistance is minimized with this design because the spark plug wires have been eliminated.

In any event, each type of ignition coil performs the same function: to convert a low primary voltage (battery) into a high secondary voltage and supply that voltage to the spark plug.

Test ignition coil resistance using an ohmmeter. To measure primary resistance, connect the ohmmeter leads to the positive and negative terminals. Measure secondary resistance by connecting the leads to the negative terminal and high tension wire terminal. A basic primary coil resistance for DI system coils should be approximately 0.5 to 15 ohms; the secondary side will range between 800 to 10,000 ohms. For EI system coils resistance will be slightly lower: the primary resistance will range between 0.2 to 2.0 ohms. The secondary side would typically fall between 4,000 to 7,000 ohms. Consult the vehicle service manual for specifications.



Measuring ignition coil primary resistance with an ohmmeter.
(Courtesy: Ford Motor Co.)

Resistance tests may not always determine if a coil is faulty. Careful visual inspection of the coil and testing of the ignition system under load may be the only accurate way of ascertaining if a coil is defective. Some defects will only reveal themselves during scope testing.

Coils usually used on distributorless systems are designed to fit mechanically one way. Sometimes, the electrical leads in coil packs are color coded, and must be replaced one wire at a time to ensure that the leads do not become misplaced. On older systems and new, remember to respect the intended polarity of the ignition coil during replacement. Using the 'one wire at a time' method will help to prevent problems.

Bad wires are the prime causes of coil failure on modern engines. They create either a low resistance short or a high resistance open. A low resistance wire insulation, which allows spark voltage to flow to ground, causes a miss and makes the coil overheat, shortening its life. An open wire (high resistance) forces the coil to find an alternative path to ground, often through the coil case, ruining the integrity of the unit and bleeding coil energy to ground. If the module is mounted below the coils, it may be damaged as the energy finds its way to ground. Always check your wires when replacing coils for this reason.

Primary Circuit Triggering

Various methods are used to turn the primary circuit on and off:

Distributor Pick-Up Coils

The distributor pick-up coil is better known as a magnetic pick-up coil assembly, or stator. There are different designs. On some designs, the pick-up contains a permanent magnet, a pole piece with internal teeth and a pick-up coil. A rotating timer core is used with this type. On others, it contains a permanent magnet and a single tooth pick-up coil. A reluctor or armature is used with this type. Some use a photocell, Light Emitting Diode (LED) and a wheel with slits to provide an rpm signal to a light sensitive photoreceptor.

The more common magnetic pick-up coil design will be described. When the teeth of the rotating timer core and pole piece align, or the reluctor and the single tooth of the pick-up, an induced voltage in the pick-up coil signals the electronic module to open the coil primary circuit. As the primary current decreases, a high voltage is induced in the secondary winding of the ignition coil, directing a spark through the rotor, which in turn fires the spark plugs. The pick-up coil is located inside the ignition distributor.

Before testing, check to see if spark is evident. If there is spark, the pick-up assembly is not the problem.

To test the pick-up coil, first disconnect the pick-up coil electrical leads from the module. Set the ohmmeter on the high scale. Connect one lead of the ohmmeter to ground and probe each lead of the pick-up coil connector. For this test, any resistance measurement less than infinity requires the replacement of the pick-up coil.

Pick-up coil continuity is tested using an ohmmeter (on low range) between the pick-up coil connector leads. Normal resistance is 500 to 1500 ohms. Use the specifications for the unit you are testing. If a vacuum unit is used, move the vacuum advance arm while performing this test. This will detect any break in coil continuity. Such a condition can cause intermittent misfiring. Replace the pick-up coil if the reading is outside the specified limits.

If no defects have been found at this time, and a problem still exists, the module will need to be checked.

On some distributors, the pickup coil gap requires adjustment, however usually only when components are replaced. The gap between the pick-up coil and reluctor must be adjusted using a non-magnetic feeler gauge. Pick-up coil gap that is too small or too large may cause engine misfire. A larger than specified gap may also keep the engine from starting.

Hall Effect Triggering

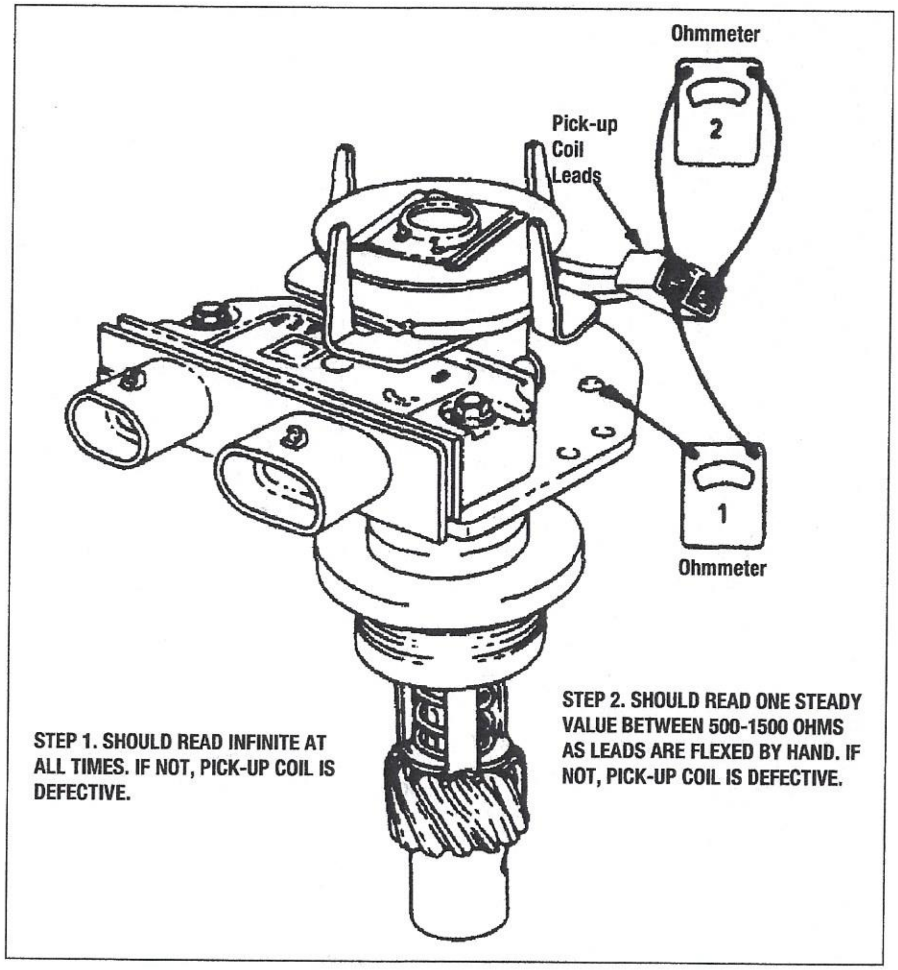
Hall Effect ignition triggering is similar to the magnetic-impulse design. However, where the magnetic-impulse voltage signal is a speed-sensitive AC pulse, the Hall effect uses a clean square-wave signal that remains constant regardless of engine speed. Only the width of the pulse changes with rpm.

Placing metal or a magnet near the system and then removing it, which makes the system change from one voltage to another, accomplishes signal switching. For example, one Hall system produces a square wave pattern that switches between 12 volts and 0 volts.

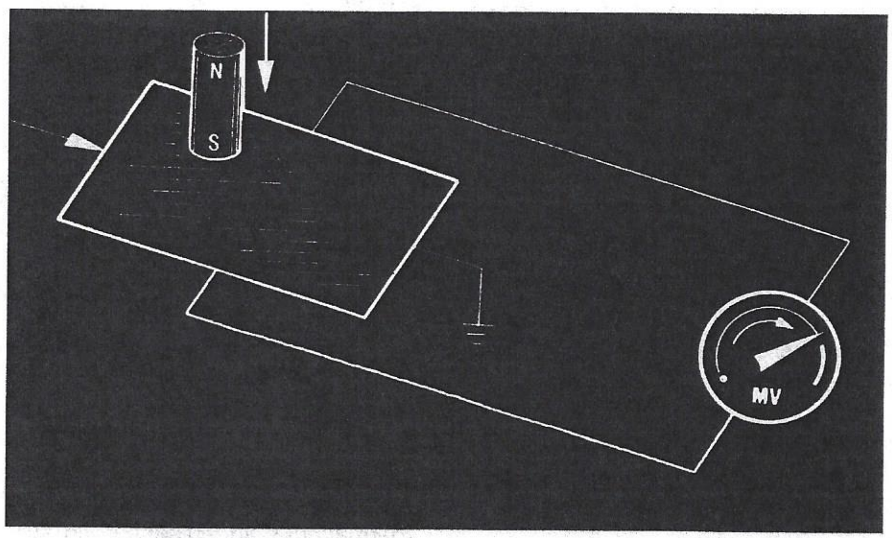
You can test a Hall effect system with a DMM (Digital Multimeter) and/or an oscilloscope. Procedures vary, however, so always consult the appropriate service manual before you test a Hall effect triggering device.

Crankshaft Position Sensor (CKP)

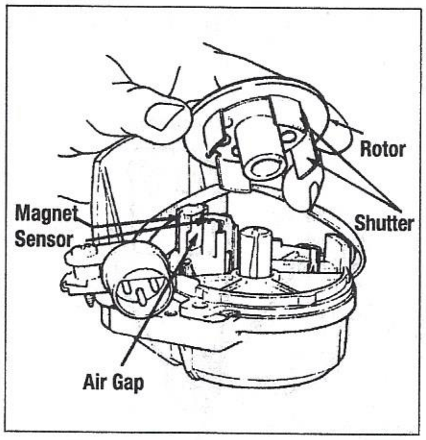
EI systems also use permanent magnet generator or Hall effect triggering. However, the reluctor component or Hall-triggering component is a gear-shaped wheel mounted on the crankshaft.



Testing a distributor pick-up coil using an ohmmeter. *(Courtesy: GM Corp.)*



If current is flowing through a thin wafer of semiconductor material, and a magnetic field crosses it at a right angle, a voltage known as a Hall effect voltage will be generated at the edge of the material. Interrupting the magnetic field turns off the voltage. This is the principle used by Hall effect sensors



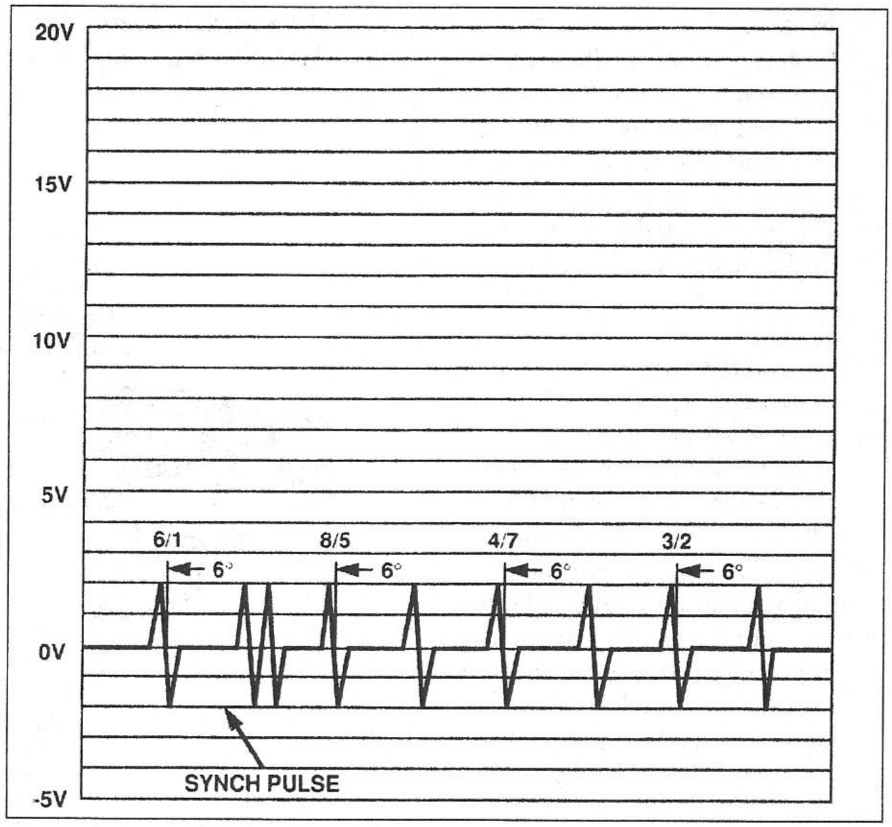
On this Hall effect ignition trigger, the shutter vanes on the distributor's rotor pass between a permanent magnet and the Hall sensor, causing the sensor to change states repeatedly. Regardless of rpm, Hall sensors produce consistent square-wave patterns of equal height (voltage)

Some crankshaft triggering components have one tooth per engine cylinder; others have as many as 36 teeth. The greater number of teeth improves the frequency and accuracy of the triggering signal.

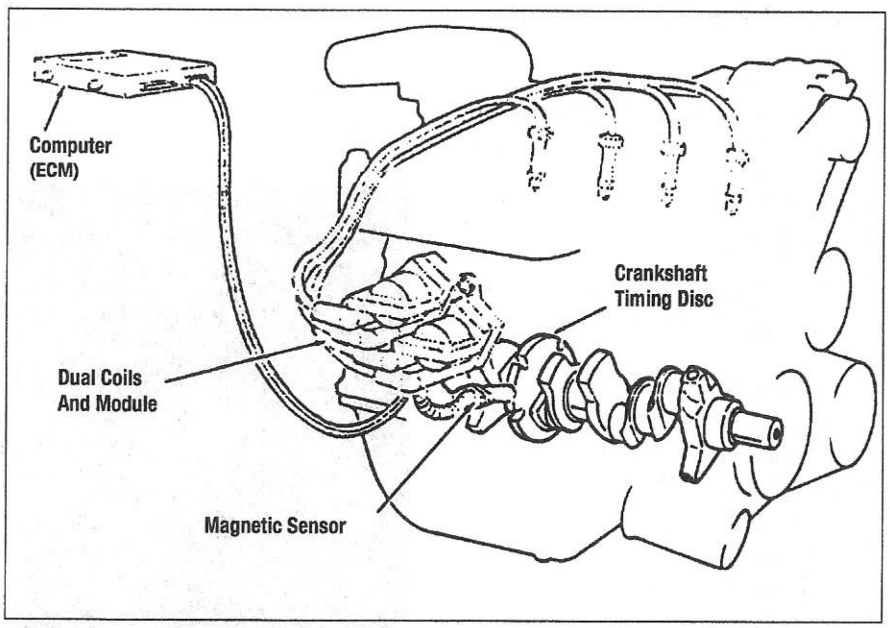
Depending on engine design, the pickup coil or Hall effect sensor may be located in its own receptacle inside the engine block. On other engines, you may find the pickup coil or Hall effect sensor mounted on an external bracket near the crankshaft.

Both permanent magnet and Hall effect sensors can be diagnosed using a scope. The typical pattern for a magnetic sensor is shown in the accompanying illustration. The pattern will vary according to the position and number of slots machined into the trigger wheel. The wheel shown has nine slots. Eight are evenly spaced with the ninth right next to one of the eight. This slot is for the synch pulse. On some systems a CMP (Camshaft Position Sensor) is used instead of a synch pulse from the CKP.

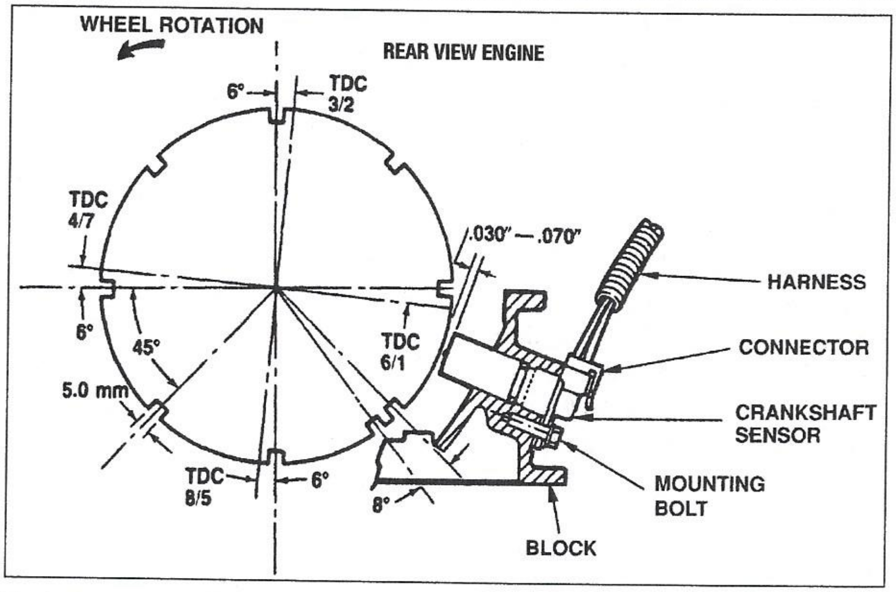
The triggering signal is the almost instantaneous drop from maximum positive voltage to maximum neg-



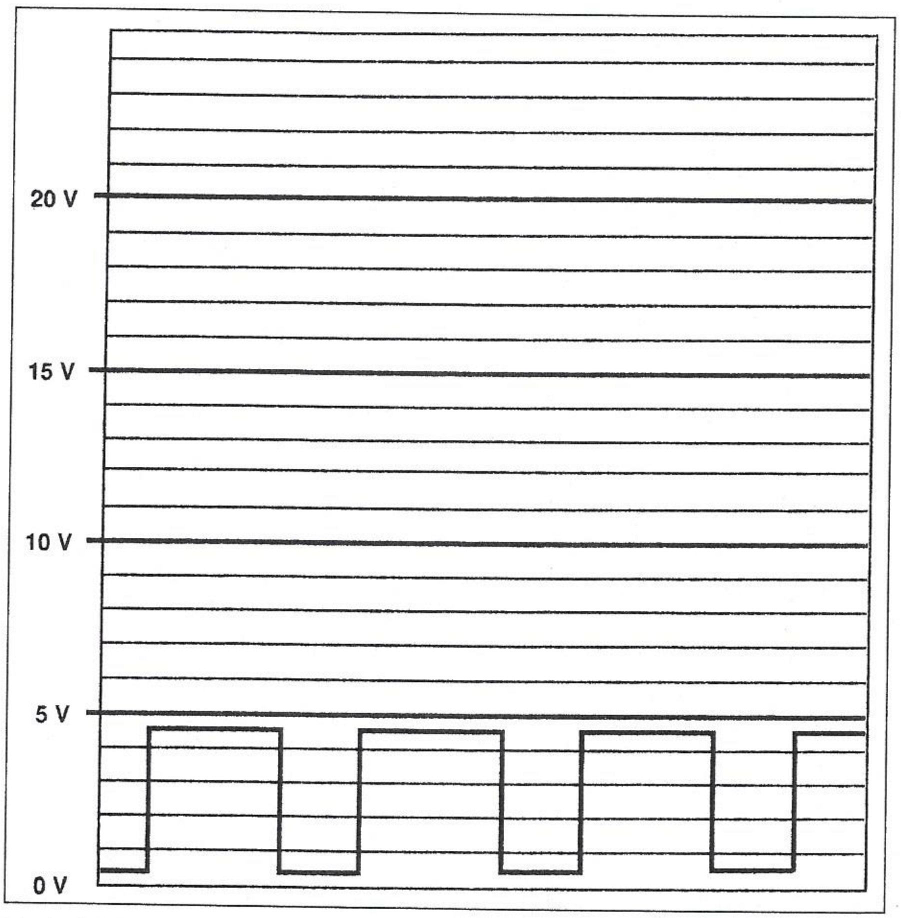
Typical permanent magnet generator crankshaft sensor waveform. *(Courtesy: GM Corp.)*



On this EI (distributorless) system, the reluctor is a timing disc built into the center of the crankshaft. As the disc's notches pass by the tip of the PM (permanent magnet) sensor, an AC voltage pulse is generated in the shape of a sine-waveform. This system is polarity sensitive, so if you replace the harness connector be certain the wires don't get reversed. In that case, the engine will only crank and produce no spark



Typical permanent magnet generator crankshaft sensor. *(Courtesy: GM Corp.)*



Typical Hall effect crankshaft sensor waveform. *(Courtesy: GM Corp.)*

ative voltage. Low amplitude (low voltage) from the CKP sensor, which can cause a no-start condition, may indicate a weak magnet or a spacing problem with relation to the crankshaft.

A typical Hall effect sensor pattern is shown in the accompanying illustration. Each pulse should be identical in shape, amplitude and spacing. The top of the trace represents the feed voltage; a clean solid line here indicates a good power source. When the sensor turns on, the voltage drops to zero. The downward and upward lines should be straight. If the upward line rises at an angle, the voltage is rising too slowly, which could cause a no-start condition.

The relationship between the CKP sensor and the ignition module can be seen on a dual trace scope. A fixed amount of timing advance is used for starting purposes. This is the result of where the notches are physically machined.

Electronic Ignition Module

The ignition module fires the ignition coil after the magnetic pickup coil submits an electrical pulse or signal to it. The ignition module interrupts the ignition primary circuit, thus causing the ignition coil to provide spark. The ignition module turns the ignition coil on and off, like mechanical ignition points did on older vehicles. The ignition module turns off the primary circuit to the coil that begins the induction of the magnetic lines of force from the primary side of the coil into the secondary side of the coil. This induction provides spark to the spark plugs.

The advantages of this system are that the transistors in the control unit can make and break the primary ignition circuit much faster than ignition points can, and higher primary voltage can be utilized, since this system is designed to handle higher voltage without adverse effects. On earlier systems, the ignition module governed the ignition dwell, whereas on later systems the PCM/ECM controls dwell.

Due to the many styles and configurations of ignition modules, there is no one easy test that will work universally. However, several steps can be taken to determine whether the ignition module is defective.

First, check for spark at the spark plug wire. This can be done using a spark tester, which looks like a regular spark plug with a ground clip attached to one side. It allows the ignition system to be checked for spark without damaging the electronics. If the engine is getting spark, the ignition module is most probably functioning correctly. Testing the ignition system for spark without the use of a spark tester can damage the ignition module.

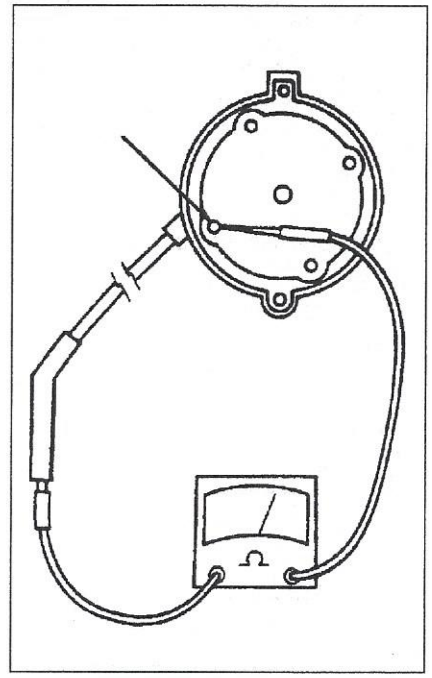
If the engine is not getting spark, check the ignition coil, ignition trigger (usually a magnetic reluctance or Hall effect switch) and all associated wiring. If all other components are functioning properly, the ignition module is probably defective. As a final test, an ignition module tester may be used to check the module circuitry. A handheld tester for the TFI family of ignition is very valuable for time saved and accuracy of diagnosis.

A simple test involves the use of a test light or logic probe. Locate the ignition coil in the engine compartment. On some ignition systems, the coil is located inside the distributor cap. Connect a test light or logic probe between the negative side of the coil and ground. Crank the engine using the starter motor. As the engine cranks the test light or logic probe bulb should flicker. This indicates the module is triggering the coil to fire. If the light does not flicker, the module is most likely at fault. Be certain you have eliminated the power up circuit and the ground as a cause of module failure.

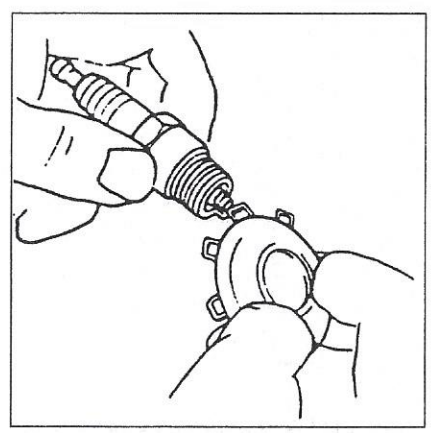
Secondary Circuit Components

Problems with spark plug wires and spark plugs are most easily seen on an engine analyzer or oscilloscope. Wires with excessively high resistance will be indicated by an abnormally high firing line on a scope pattern. The resistance of suspect wires can be checked using an ohmmeter.

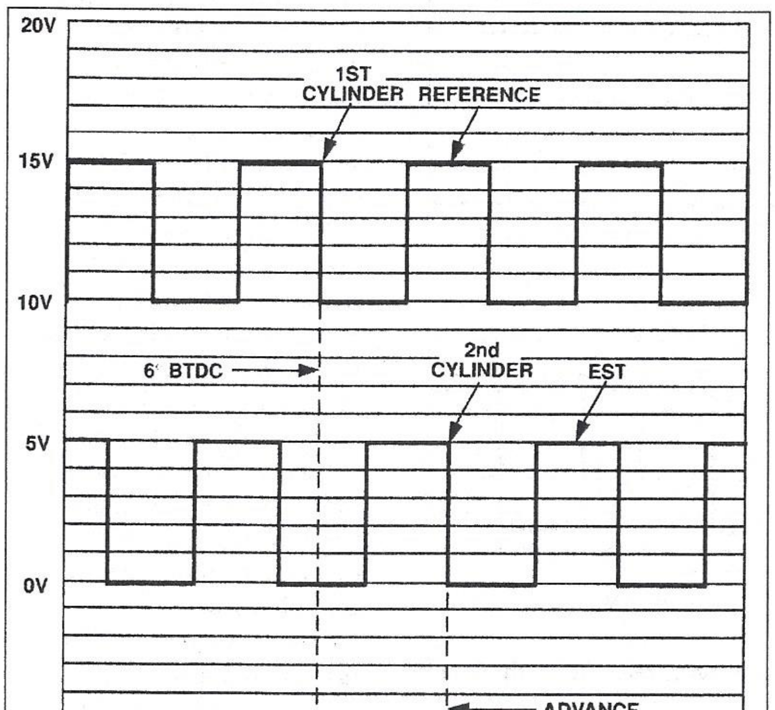
Check spark plugs for appearance and spark plug gap. The spark plug electrodes should be squared off and the insulator should be a light tan. Check spark plug gap using a wire gauge and bend the side electrode to adjust to specification. A gap that is too tight will cause a lower firing voltage resulting in incomplete combustion. If the gap is too wide, the coil may not generate enough voltage to bridge the gap for the required time.



Checking the resistance of a spark plug wire using an ohmmeter. *(Courtesy: Ford Motor Co.)*

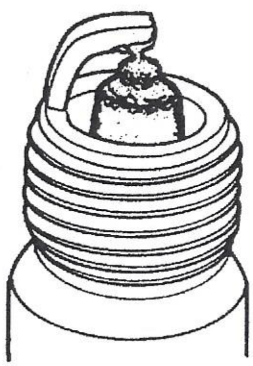


Keep in mind that wider plug gaps are just one of several factors that can increase the level of required firing (secondary) voltage; narrower gaps reduce required voltage



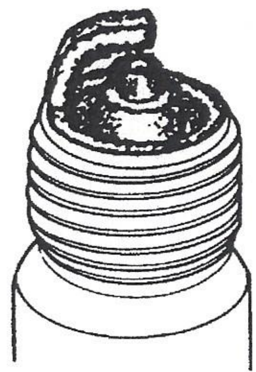
EST and crankshaft sensor signals. *(Courtesy: GM Corp.)*

Gap Bridged



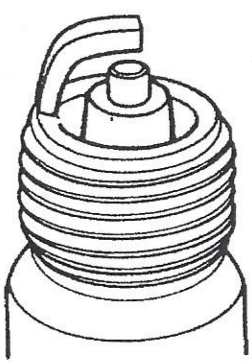
Identified by deposit build-up closing gap between electrodes. Caused by oil or carbon fouling. Replace plug, or if deposits are not excessive, the plug can be cleaned.

Oil Fouled



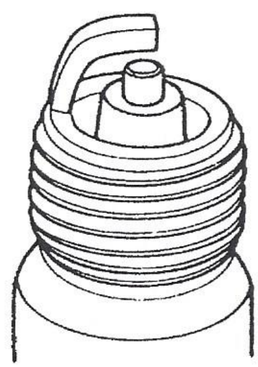
Identified by wet deposits on the insulator shell bore electrodes. Caused by excessive oil entering combustion chamber through worn rings and pistons. Excessive clearance between valve guides or worn or loose bearings. Correct oil problem. Replace the plug.

Carbon Fouled



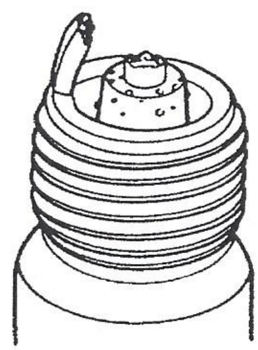
Identified by black, dry fluffy carbon deposits on insulator tips, exposed shell surfaces and electrodes.
Caused by too cold a plug, weak ignition, dirty air cleaner, defective fuel pump, too rich a fuel mixture, improperly operating heat riser or excessive idling. Can be cleaned.

Normal



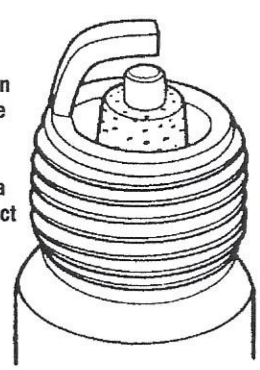
Identified by light tan or gray deposits on the firing tip.

Pre-Ignition



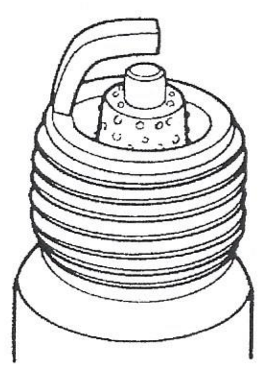
Identified by melted electrodes and possibly blistered insulator. Metallic deposits on insulator indicate engine damage.
Caused by wrong type of fuel, incorrect ignition timing or advance, too hot a plug, burnt valves or engine overheating. Replace the plug.

Overheating



Identified by a white or light gray insulator with small black or gray brown spots and with bluish-burnt appearance of electrodes.
Caused by engine overheating, wrong type of fuel, loose spark plugs, too hot a plug, low fuel pump pressure or incorrect ignition timing. Replace the plug.

Fused Spot Deposit



Identified by melted or spotty deposits resembling bubbles or blisters.
Caused by sudden acceleration. Can be cleaned if not excessive, otherwise, replace the plug.

Spark plug diagnosis chart

Notes

Fuel, Air Induction And Exhaust Systems Diagnosis And Repair

FUEL DELIVERY SYSTEM

An insufficient amount of fuel delivered to the engine can cause a no-start condition or a lean mixture. Low fuel pressure can be caused by a clogged fuel filter, a defective pressure regulator or a restricted fuel line.

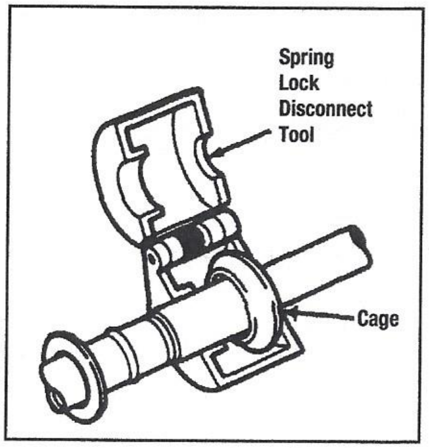
Excessive fuel pressure can cause a rich mixture. High fuel pressure can be caused by a restricted fuel return line or a defective pressure regulator.

WARNING: Fuel injection systems remain under pressure, even after the engine has been turned OFF. The fuel system pressure must be relieved before disconnecting any fuel lines. Failure to do so may result in fire and/or personal injury.

System Inspection

Inspect the general condition of the fuel system. Look for dented, damaged or corroded lines, cracked or swollen hoses and leaks. Make sure all connections are secure and all lines and hoses are securely mounted so they can't rub against other components.

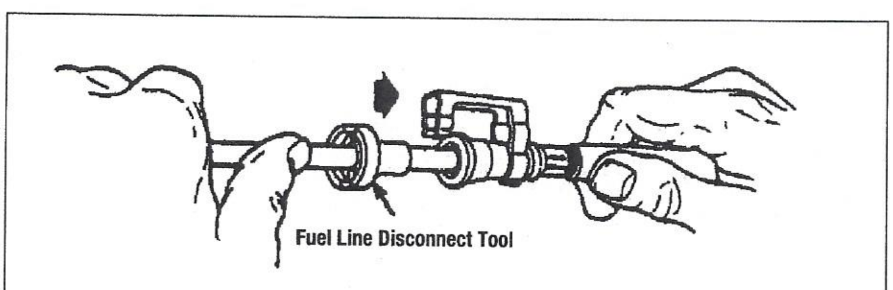
Check the fuel tank for damage and leaks, and make sure it is securely mounted. Inspect the hoses, lines and wiring at the tank, making sure they are properly connected. Make sure the fuel tank neck and cap are secure.



A special tool for separating spring-lock fittings. Always check the spring in this type of fitting prior to reassembly and replace if missing or damaged.
(Courtesy: Ford Motor Co.)

When replacing a fuel line, use only steel tubing, never copper, and make sure the line is properly attached to the frame. When replacing fuel hoses, make sure they are approved for fuel system use.

Fuel lines and components are connected using various types of fittings, many of which require special tools to disconnect. If specified, always use the special tool to prevent damaging fittings and fuel system components. Many fittings use O-rings, which should never be reused. Always replace O-rings with those specified for fuel system use.



Using a special tool to disconnect a fuel line push-connect fitting.
(Courtesy: Ford Motor Co.)

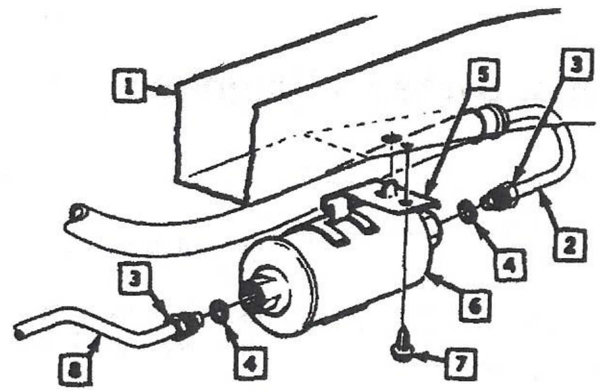
When replacing an in-line fuel filter, first properly relieve the fuel system pressure and then position a drain pan under the filter to catch any spilled fuel. Properly disconnect the fuel lines from the filter and remove the filter from its mounting. Make sure the new filter is installed in the proper fuel flow direction.

Relieving Fuel System Pressure

Fuel system pressure can be relieved in several ways. A special gauge with a drain hose can be attached to a Schrader valve on the fuel rail, with another hose from the gauge placed in a suitable container. A button on the gauge is then pressed to release the pressure and allow the fuel to drain into the container. Another way involves removing the fuel pump fuse, starting the engine and letting it run until it stalls. When in doubt as to what method to use, consult the vehicle service manual for the manufacturer's recommended procedure.

Alcohol Contamination

Oxygenated fuel that contains up to 10% alcohol (ethanol) is used in many areas of the U.S. So called 'flex fuel' vehicles have a sensor that detects the percentage of ethanol in the fuel and the system adjusts the air/fuel mixture accordingly, which allows them to use E85, which is 85% ethanol. However, most other vehicles cannot tolerate alcohol in fuel that exceeds 10%. If an excessive amount of alcohol is mixed with gasoline on these vehicles, it can degrade



1. BAR
2. FUEL FEED PIPE
3. FITTING – BACK-UP WRENCH REQUIRED AT THIS ATTACHMENT
4. O-RING SEAL
5. FUEL FILTER BRACKET
6. FUEL FILTER
7. SCREW – FULLY DRIVEN, SEATED AND NOT STRIPPED
8. FUEL PIPE ASSEMBLY

When replacing fuel system components like this fuel filter, always use new O-rings designed for fuel system use. *(Courtesy: GM Corp.)*

rubber fuel system components, clog the fuel filter and cause a lean air/fuel mixture. These defects can cause a no-start condition, stalling and other driveability complaints.

If you suspect an excessive amount of alcohol in gasoline, fill a graduated 100mL container to the 90mL mark with the suspect gasoline. Add water to bring the level of the liquid to the 100mL mark. Close the container and shake vigorously for 10-15 seconds, then allow the contents to settle. Any alcohol that is in the gasoline will be absorbed by the water and settle to the bottom of the container. For example, if there is now 20mL of water, there was 10% alcohol in the gasoline.

There are commercially available test kits that perform this test. Be aware that this test will not remove all of the alcohol from the gasoline, so the percentage of alcohol in the gas may be higher than indicated.

Fuel Pump Volume and Pressure Tests

An engine that misfires or surges under heavy load or at higher speeds may be starved for fuel. An engine that will not start may have no fuel pressure. The traditional test sequence for any fuel pump is to check its volume first and pressure second.

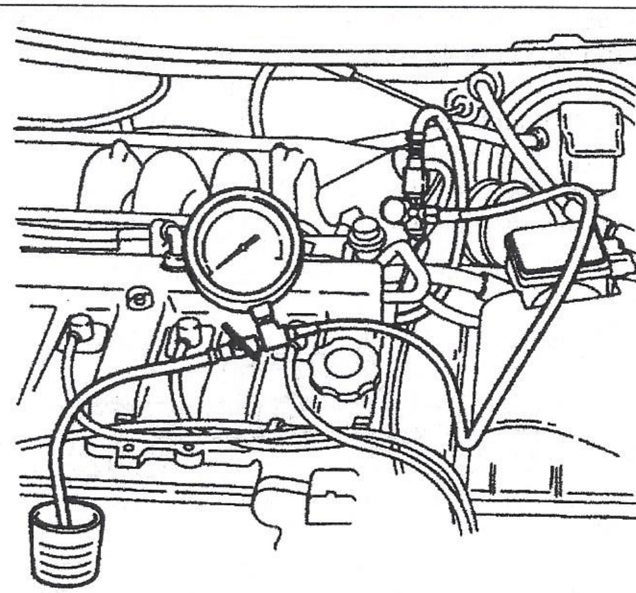
First make sure there is an adequate amount of fuel in the tank. Just because the gauge reads a quantity of fuel, doesn't mean that enough fuel is present; the gauge or gauge sending unit could be defective.

Listen for noise from the pump when the key is turned on. If no noise is heard, check for voltage at the pump and check for excessive ground resistance using a DMM. If there is adequate voltage and the ground is good but the pump does not run, it is probably defective and should be replaced.

If there is no voltage when the key is on and the engine is cranking, check the pump fuse, relay and wiring. Sometimes an oil pressure switch is incorporated in the fuel pump circuit. Bypass the switch with a jumper wire; if there is now power to the pump, replace the switch.

For a volume test, disconnect the fuel pressure feed line and insert it into a graduated container. On systems with electric fuel pumps, you usually must operate the pump with a jumper wire for a specified period. It should flow at least a half-pint of fuel in 30 seconds. If not, before condemning the pump, check the external and in-tank fuel filters and the fuel lines for restriction. Also, perform a voltage drop test on the power and ground circuits to the pump.

If fuel delivery volume is OK, reconnect the pressure feed line, con-

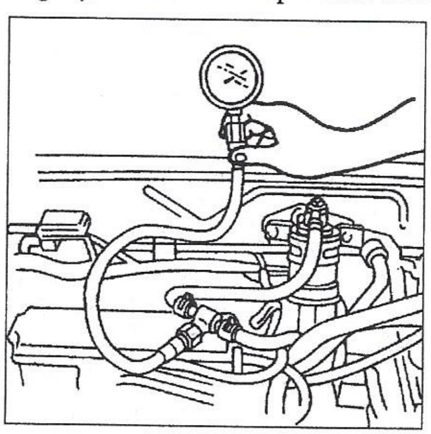


Checking fuel delivery volume *(Courtesy: Ford Motor Co.)*

nect a suitable pressure gauge and turn the key to the ON position. Compare the pressure reading with specifications. Pressure that is lower than specifications could be caused by a restricted filter, a faulty fuel pump or a faulty pressure regulator. Pressure that is higher than specifications could be caused by a faulty pressure regulator or a restricted fuel return line.

If the pressure is within specifications, wait five minutes while watching for a considerable pressure drop. If a drop occurs, block off the return line from the pressure regulator and recycle the key. If the pressure now holds, you have a defective regulator. If the pressure still drops, block off the feed line from the fuel pump and recycle the key. If the pressure holds steady, the fuel pump check valve is leaking and the pump must be replaced. If there is still a pressure drop and there are no external leaks, suspect one or more injectors of leaking.

If fuel pressure was OK and there was no pressure drop, start the engine and let it idle. With the vacuum line connected to the fuel pressure regulator, fuel pressure should be lower than with the line disconnected. If not, disconnect the vacuum line from the pressure regulator and apply vacuum to the regulator (consult the vehicle service manual for the specified amount). If the fuel pressure drops slightly, then there is a problem with the vacuum source to the regulator. If the fuel pressure does not drop, the fuel pressure regulator is faulty.



Checking fuel pressure
(Courtesy: Ford Motor Co.)

Fuel Pump Replacement

Most electric fuel pumps are installed in the fuel tank and are incorporated with the fuel gauge sending unit, however there are some vehicles that use external electric fuel pumps mounted on the frame.

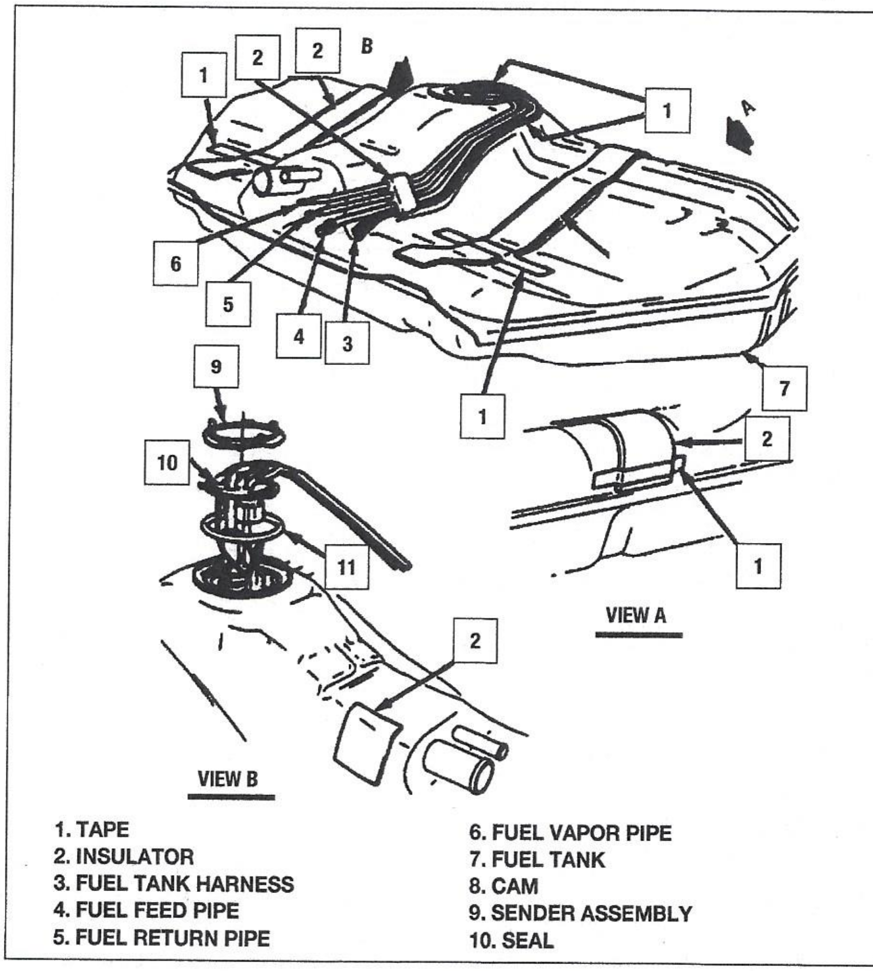
Tank-Mounted Pumps

Properly relieve the fuel system pressure. If fuel tank removal is necessary to gain access to the pump, drain or siphon the fuel from the tank, then support the tank and disconnect all wiring, lines and hoses from the tank. Remove the fuel tank fasteners and lower the tank from the vehicle.

Clean the area around the pump opening to prevent dirt from entering the tank. Remove the bolts or retaining ring and remove the pump from the fuel tank. Install the new pump using a new seal. Raise the tank into position, as required, and secure the tank with the fasteners. Connect all lines, hoses and electrical connectors. Fill the tank with fuel, turn the key to the ON position to pressurize the fuel system and check for leaks.

Frame-Mounted Pumps

Properly relieve the fuel system pressure and then position a drain pan under the fuel pump to catch any spilled fuel. Remove any covers or other components, as necessary, to gain access to the fuel pump. Disconnect all lines, hoses and wiring from the fuel pump, remove the fuel pump fasteners and remove the fuel pump



Typical fuel tank and fuel pump installation. *(Courtesy: GM Corp.)*

from the vehicle.

Place the new fuel pump in position and secure it with the fasteners. Connect the lines, hoses and wiring, as required. Install any components or covers that were removed. Turn the ignition key to the ON position to pressurize the fuel system and check for leaks.

FUEL INJECTION

There are two types of fuel injection: Throttle Body Injection (TBI) and Multiport Fuel Injection (MFI). On a TBI system, one or two injectors are located in a throttle body assembly that is mounted on a conventional intake manifold. The fuel is delivered above the throttle plates, mixes with air and is distributed to the intake ports by the intake manifold.

On an MFI system, the fuel is delivered to each intake port by individual injectors. The intake manifold in a multiport injection system is used only for air induction.

All TBI systems and most MFI systems are electrically operated. Sometimes, systems that use electrically operated injectors are generically called EFI or electronic fuel injection systems. One multiport system, the Bosch CIS (Continuous Injection System) uses hydraulically operated injectors. CIS injectors open at a pressure of about 35 to 45 psi. The CIS system is also known as the K-Jetronic system.

Electronic MFI systems can also be categorized according to injector firing strategy. Some early MFI systems fired their injectors in groups. Each injector in a group fired simultaneously and each group fired alternately. However, in a Sequential Fuel Injection (SFI) system, each injector is fired one at a time in the engine's spark plug firing order. All newer vehicles use the SFI system.

Note that on any multiport injection system, air leaks around the injectors can cause rough idle, hesitation, backfiring and poor fuel economy.

Diagnosis

When troubleshooting the fuel injection system, always check for DTCs related to fuel system operation. Also, use a scan tool to check the short term and long term fuel trims under different conditions.

The Short Term Fuel Trim (SFT) and Long Term Fuel Trim (LFT) strategies monitor the oxygen sensor signal on OBD II vehicles. The information is used by the PCM/ECM to change the amount of fuel delivered to the cylinders during closed loop operation according to operating conditions.

During open loop, the PCM/ECM operates the fuel injectors at a preprogrammed pulse width. When the engine goes into closed loop, the injector pulse width is changed in response to the oxygen sensor signal to maintain the correct air/fuel mixture. A rich mixture will increase the voltage signal from the oxygen sensor, which will in turn decrease the SFT and shorten the injector pulse width. A lean mixture will decrease the voltage signal, increase the SFT and lengthen the injector pulse width.

Increase and decrease to the SFT are represented on the scan tool as values above and below the number one when the vehicle is in closed loop. An SFT value of 1.10 means the pulse width was lengthened by 10% and will be displayed as +10. An SFT of 0.90 means the pulse width was shortened by 10% and will be shown on the scan tool as –10.

The SFT is used to modify the LFT. The LFT is stored in the PCM/ECM's memory and is part of the basic injection duration calculation. The PCM/ECM will change the LFT if the SFT remains higher or lower for longer than expected.

If the SFT numbers go back and forth between positive and negative, above and below one, the fuel system is operating properly. Correspondingly, numbers that remain on either side of one indicate a problem. A vacuum leak, which would cause a lean condition, would result in a LFT above one. Leaking injectors, which would cause a rich condition, would result in a LFT below one.

The fuel trims should be checked under different conditions because trims that are OK at idle but correct for a lean condition at highway speeds could indicate low fuel volume or a fuel restriction. Fuel trims that correct for a rich condition at idle, but are OK at higher rpms, could indicate a leaking or sticking injector(s).

Fuel Injectors

When the solenoid inside a fuel injector is turned on, it lifts a valve off its seat and the injector sprays fuel. The solenoid coil inside an injector has two terminals. When the ignition is on, power is usually fed to one injector terminal. When the control computer wants the injector to spray, it grounds the other terminal, completing the circuit to ground.

The longer the computer grounds the injector, the longer the injector sprays. The longer the injector sprays, the richer the mixture becomes. The less the injector sprays, the leaner the mixture. Injector 'on' time, which is also known as injector pulse width, is usually measured in milliseconds (ms). Mechanical problems include stuck open, stuck closed and leaking injectors.

Fuel Injector Testing

When an EFI-equipped engine won't start, you can usually determine if the injectors or their circuits are at fault without using a lot of sophisticated equipment. Connect a high-impedance test light (a 'noid' light) across an injector's terminals and crank the engine. If the light blinks consistently while you're cranking the engine, you know that, electrically at least, the injector and its circuit are working properly.

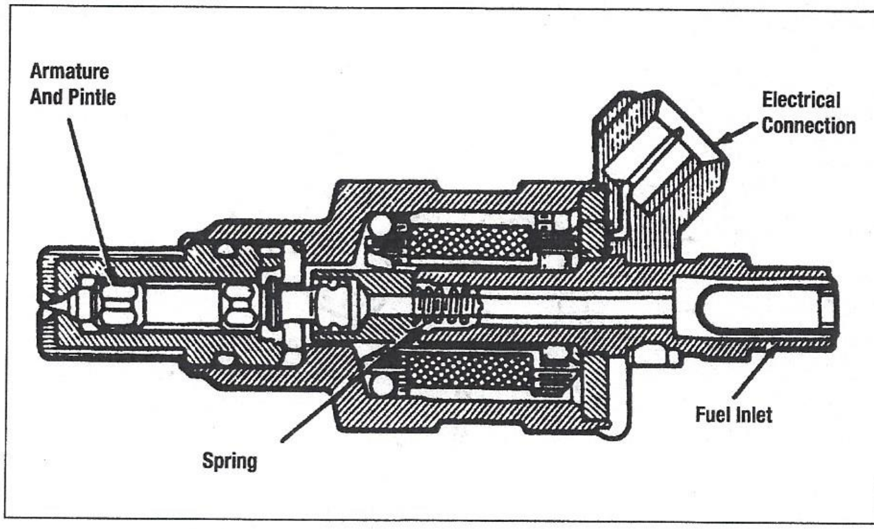
If the test light doesn't light up,

check the circuit between the injector and its power source. If the light comes on but won't blink, the injector driver circuit back at the computer has shorted, or the computer isn't telling the injectors to operate. Check the resistance of the injector solenoid. Injector resistances are generally in a very narrow range, and low values draw too much current through the injector driver transistors, and can cause failure of these drivers. If these parts are working properly, and the computer is supposed to be operating the injectors, then the computer is bad, as the drivers are not repairable in the shop. Check all of the injector resistance values before installing the new computer. Most computer rebuilders have a checklist to follow to reduce the possibility of ruining the new unit with a defective output device, which will draw too much current through the drivers in the output section. Be certain there is no condition, such as a missing input pulse from cam or crank sensors, which might be causing the computer to refuse to ground the injectors in turn for operation.

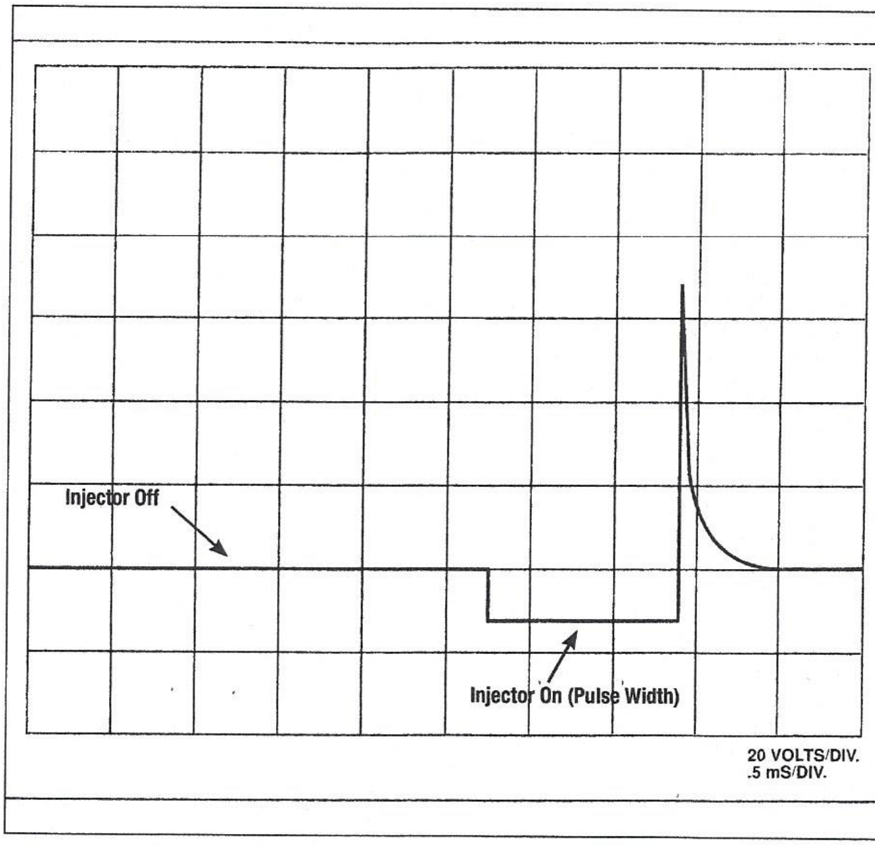
Checking static resistance sometimes is not enough to prove that an injector is operating properly. For example, on multiport injectors that are group fired, the PCM/ECM has a driver for each bank or pair of injectors. A V8 with multiport would have one driver for cylinders 1,3,5,7 and another for cylinders 2,4,6,8. A 4 cylinder might have separate drivers for cylinders 1,2 and 3,4. Fuel is delivered on both the compression and exhaust strokes of the affected cylinders. It is easy to misdiagnose this type of system when attempting to locate the cause of a misfire condition.

Suppose we have a V6 with group fired injectors and we find cylinders No. 2 and No. 6 are misfiring. After careful testing, we pin it down to the injectors in those two cylinders not spraying a sufficient amount of fuel. This will create a lean condition in cylinders No. 2 and No. 6. We reason that the PCM/ECM driver is OK as we have no problem with No. 4 cylinder. The resistance has been checked and is found to be in factory specification. However, after installing two new injectors the same problem remains.

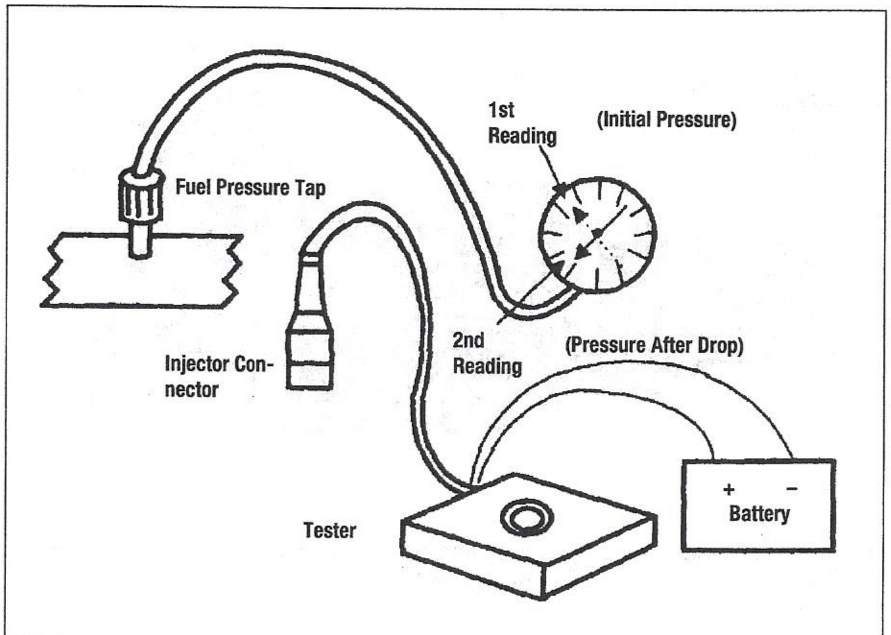
What has happened here is that the injector with the least resistance is drawing most of the current when the circuit is energized. In this case,



When the computer energizes the electromagnet inside a fuel injector, the magnet pulls the pintle off its seat, allowing the high-pressure fuel to spray out the end of the injector



Typical fuel injector voltage pattern on an oscilloscope.
(Courtesy: GM Corp.)



An example of an injector balance test. *(Courtesy: GM Corp.)*

No. 4 injector has low resistance, causing No. 2 and No. 6 cylinders to misfire by robbing current from its companion injectors.

But why did we not find this on the resistance test? Static resistance tests will generally pinpoint a shorted or open injector. However, many injectors will only short or draw excessive current when they are under load or stress. The problem in the V6 was diagnosed quickly and efficiently with a digital storage oscilloscope (DSO). The scope pattern produced a low voltage spike in the No. 4 injector.

Leaking injectors cause poor fuel economy, high emission levels, and a loss of rest pressure. In order to isolate the leaking injector, remove all the spark plugs, disable the ignition system and crank the engine until all fuel in the cylinders is removed. Allow the engine to sit for about 10 minutes. Turn the key ON and place the probe tip from your exhaust analyzer to each spark plug hole. Bump the starter to open the intake valve. An HC reading in any cylinder would indicate the presence of raw fuel. That's the cylinder with the leaking injector.

Dirty or restricted fuel injectors tend to lean the mixture and cause rough idling, generally sluggish performance, poor fuel economy, and misfiring under load. To determine if the injectors are restricted, perform an injector balance test. Disconnect one injector and connect an injector balance tester and a fuel pressure gauge. Cycle the ignition key to the ON position. The gauge must hold pressure. In some vehicles, you may have to jumper the fuel pump relay (refer to the service manual), activate the tester and record the pressure drop. Repeat this test on all injectors, making sure that the starting pressure remains the same. Total the differences in pressure and divide by the number of injectors tested. Each injector's pressure drop should be within 1.5 psi of the average. To prevent flooding, the engine should be started between individual injector tests.

A larger drop in pressure indicates a leaking injector; less indicates a restricted one. An attempt to clean the injectors should be made and the test repeated, before any injectors are condemned.

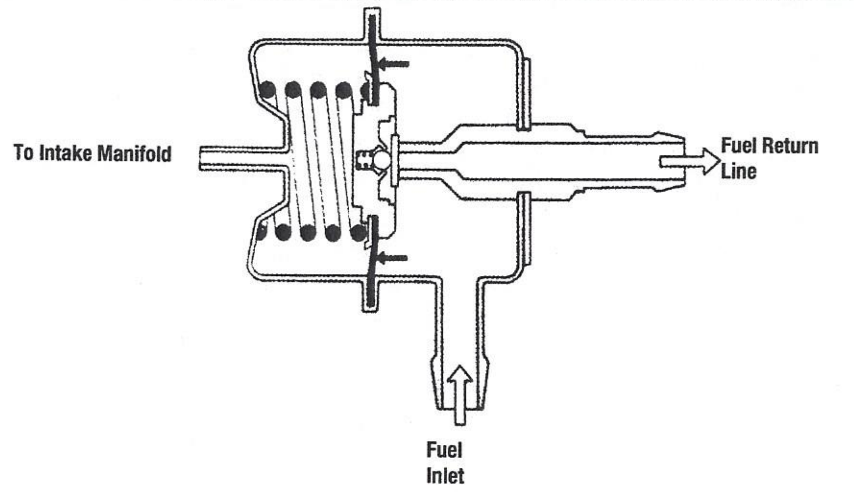
Cold Start Injector

Fuel injection systems do not have chokes. Instead, they lengthen the injector pulse width for cold enrichment. Some fuel injection systems also improve cold start-up by using a separate injector called a cold-start injector. The cold-start injector sprays only during cranking when the engine is cold. Because the cold-start injector sprays only when the engine is cranking, it doesn't affect

SAMPLE INJECTOR BALANCE TEST

INJECTOR	STARTING PRESSURE	ENDING PRESSURE	DIFFERENCE
#1	44 psi	36 psi	8 psi
#2	44 psi	37 psi	7 psi
#3	44 psi	34 psi	10 psi
#4	44 psi	35 psi	9 psi
#5	44 psi	38 psi	6 psi
#6	44 psi	37 psi	7 psi

- Total of pressure drops = 47
  Average pressure drop = 7.8 psi
- Pressure drop acceptable range per injector = 6.3 to 9.3
- Injectors #3 and #5 fall outside of range.
  Clean and retest.



On most fuel injection systems, the fuel pressure regulator reacts to changes in manifold pressure (vacuum), which helps the regulator tailor the fuel pressure to engine load, and helps keep the fuel supplied to the injectors constant.

cold driveability.

Difficult cold starting often indicates a problem with the cold-start injector or with the circuit that controls it. Loss of rest pressure, poor fuel economy and high CO levels can indicate a leaking cold-start injector. Be certain that the switch that controls the cold injector passes its diagnostic tests before blaming the injector.

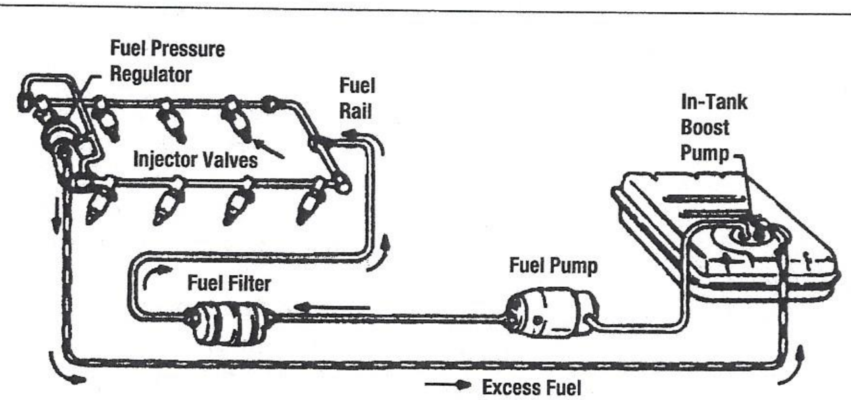
Fuel Pressure Regulator

Generally speaking, higher fuel pressure tends to make any TBI or port injection system run richer. Lower fuel pressure tends to make them run leaner.

A few fuel injection pressure regulators are adjustable; most of them are not. When fuel pressure is out-of-specification and the regulator is non-adjustable, you must replace the regulator.

Although they aren't externally adjustable, most fuel pressure regulators are connected to manifold vacuum and vary the fuel pressure according to engine load. Consequently, problems such as air leaks or a restricted vacuum sensing hose can upset the operation of a good pressure regulator.

When fuel pressure is too high, disconnect the fuel return line from the pressure regulator outlet. If disconnecting the return line brings the pressure down within specifications, you know there's a restriction somewhere in the return line. Some regulators can suffer from a ruptured diaphragm, allowing fuel to be sucked into the intake manifold through the vacuum line, which operates the regulator, causing a rich running condition. If you pull off the vacuum line from the regulator and find liquid fuel, replace the regulator.



This is a typical EFI fuel circuit. Most systems use a fuel pump submerged in fuel in the tank, and some have a second electric pump closer to the engine. Note how the fuel pressure regulator routes unused fuel back to the tank. A restriction in the return line can raise fuel pressure

Throttle Body

The throttle body on multiport fuel injected engines is susceptible to contamination that can restrict air flow and in turn cause idle speed problems. This contamination can be caused by dirt from a faulty air filtration system and by sludge buildup caused by the Positive Crankcase Ventilation (PCV) system.

The PCM/ECM bases idle speed calculations on a set amount of air that bypasses the throttle plates. If this air flow is reduced by accumulated deposits, these calculations will be incorrect and may result in stalling.

Sometimes these deposits can be cleaned off with a spray cleaner or wiped off with a cloth and solvent after the air duct is removed. However, if these methods prove ineffective, it may be necessary to remove the throttle body for more thorough cleaning.

Clean the throttle body with a soft brush and approved cleaning agent. Blow out the air passages with compressed air. Before submerging the throttle body in any kind of cleaner, components like the Throttle Position (TP) sensor and Idle Air Control (IAC) valve must be removed.

When reinstalling the throttle body, make sure all of the mounting surfaces are clean and use a new gasket. Torque the mounting bolts to specification. Adjust the TP sensor, as necessary.

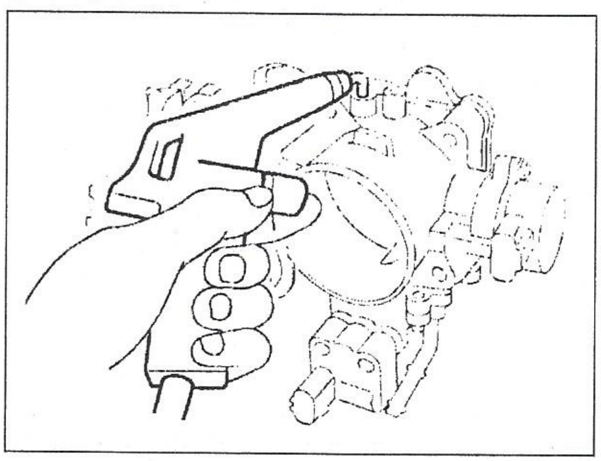
Idle Control Devices

On most electronic fuel injected engines, engine idle speeds are controlled by the PCM/ECM through the Idle Air Control (IAC) valve. On most engines, the IAC valve is mounted on the throttle body; others may be mounted on the engine near the throttle body. IAC valves that are located on the throttle body operate as follows:

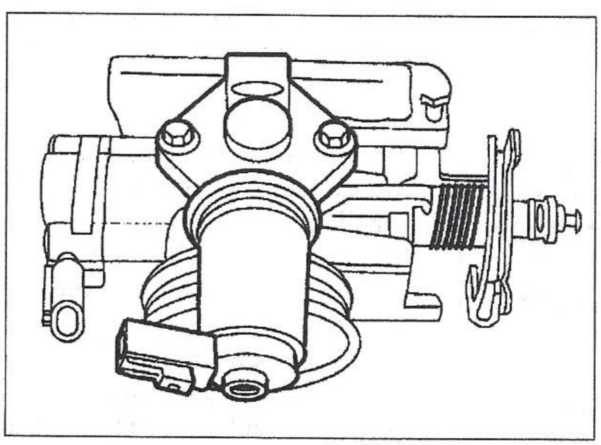
The PCM/ECM sends voltage pulses to the IAC motor windings causing the IAC motor shaft and pintle to move in or out a given distance (number of steps) for each pulse (called counts). The movement of the pintle controls the air flow around the throttle plate, which in turn controls engine idle speed. IAC valve pintle position counts can be observed using a scan tool. Zero counts correspond to a fully closed passage, while 140 counts or more corresponds to full flow.

IAC valves that are mounted separately from the throttle body operate this way: Based on information the PCM/ECM receives from the coolant temperature sensor, intake air temperature sensor and throttle position sensor, it adjusts the opening of the IAC valve accordingly. When the engine is first started, it opens the IAC valve to its full amount. This causes the engine to run at a fast idle. As the engine temperature warms up the PCM/ECM signals the IAC valve to close and open, as increased air is needed. This maintains the idle speed at proper specification.

When suspecting an IAC valve problem, first perform a visual inspection. Most problems can be found in wiring harnesses and connectors. An unstable idle or stalling condition could be caused by a vacuum leak or faulty PCV valve. In some cases, just dirty electrical connections at the IAC valve can cause a problem. Proper diagnosis can only be accomplished by systematic testing procedures.



Cleaning a typical throttle body assembly.
(Courtesy: Toyota Motor Corp.)



A Throttle body mounted IAC valve.
(Courtesy: Ford Motor Co.)

To test the IAC valve, begin with a cold engine. Start the engine. Using a voltmeter, check the voltage reading by probing the feed circuit to the IAC valve. Allow the engine to warm up while observing the voltmeter reading.

The initial reading should be high, close to battery voltage. As the engine warms up the voltage reading should gradually decrease to almost 0 volts.

Another test that can be made is by checking the resistance between the terminals of the IAC valve for an open circuit, or checking the positive feed terminal to ground to see if the valve is shorted. These resistance values may vary, but should never be an open circuit.

CIS

As mentioned earlier, CIS is a mechanical port injection system. The CIS air flow sensing and mixture enrichment process, which appears on some older European vehicles, differs from EFI systems.

The CIS system has an air flow sensor plate mounted on a pivoted lever. As the engine draws in air, the sensor plate moves and the lever pivots with it. A device called the fuel distributor sits on the opposite end of the pivoted lever from the air sensor plate. As air flow moves the lever, the lever moves a valve in the center of the fuel distributor called the control plunger. The greater the air flow, the greater the control plunger travel and the more fuel the plunger allows each injector to have.

Fuel pressure, also called control pressure, balances movement of the control plunger. The air sensor lever works on one end of the plunger, and control pressure works on the other end. Remember, the greater the control pressure, the less the control plunger moves. And, the less the plunger moves, the less fuel flows to the injectors.

In short, high control pressure equals lean mixture, and vice versa.

Warm-Up Compensator

The warm-up compensator is a heated device that varies control pressure according to temperature. If a CIS-equipped engine runs poorly when cold, check control pressure. Control pressure should vary from a relatively low pressure (about 8 psi) on a cold engine to a higher pressure (about 50 psi) when the engine warms up. When in doubt, refer to the compensator pressure/temperature chart in the service manual.

Be sure the warm-up compensator heater hasn't open-circuited, and that it has power going to it. Then, beginning with a cold start-up, watch control pressure as the engine warms up. Replace the warm-up compensator if the pressure falls out of the range shown on the pressure/temperature chart.

AIR INDUCTION SYSTEM

A dirty or clogged air filter will restrict air flow into the throttle body, possibly causing an overly rich air/fuel mixture and resulting in reduced engine performance, poor fuel economy and excessive HC and CO exhaust emissions. Remove the air filter from its housing and gently tap it on a hard surface to dislodge dirt. Visually inspect the filter for holes and other damage. Hold the filter up to a light source to check the filter. If the filter is clean, light will pass through all areas. Dark areas on a filter element will not allow light to pass through; the filter is dirty and must be replaced.

When replacing the filter element, wipe any dirt from the housing and make sure the filter seals fit properly. Check and replace the crankcase breather filter. Check the air intake ducting for cracks and poor joint sealing that could allow air into the engine other than through the filter. This is especially important on vehicles with remote mounted MAF (Mass Air Flow) or VAF (Vane Air Flow) sensors. These sensors measure the amount of air entering the engine and the PCM/ECM uses this information in calculating the proper air/fuel mixture. Air entering the throttle body other than through the MAF or VAF sensor will not be accounted for in these calculations, causing a lean condition.

A lean condition can also be caused by a vacuum leak. When inspecting the air induction system, check vacuum lines, throttle body mounting and intake manifold sealing areas for vacuum leaks. Vacuum leaks can be found using propane. The engine will run smoother and there will be an engine rpm change when propane is discharged near a vacuum leak.

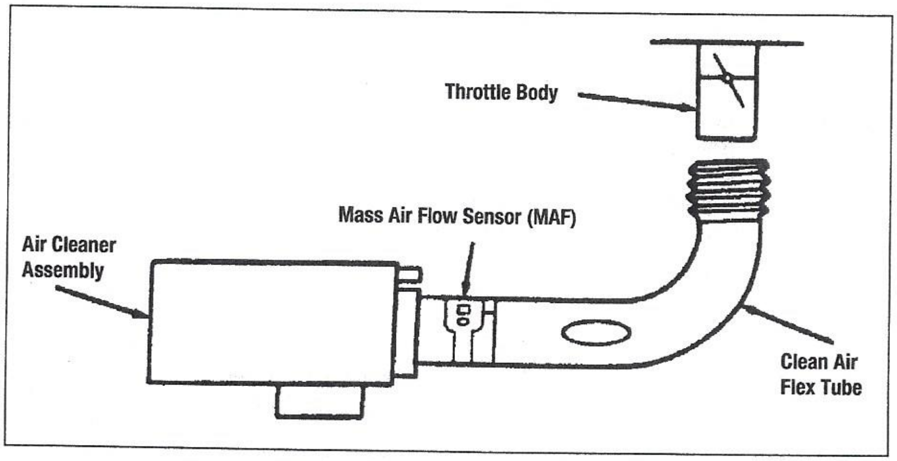
EXHAUST SYSTEM

Exhaust system components can fail due to physical or chemical damage. Since it is located under the vehicle, the exhaust system is subject to damage and wear from dirt, stones, water and other road hazards. The components in the system can also rot out from the inside. When the engine is started from cold, combustion gases mix with condensation that forms when the hot exhaust contacts the colder exhaust parts, forming acids that corrode the metal. This type of failure is common on vehicles that are driven short distances, since the exhaust system never gets warm enough to evaporate the moisture.

Whether it is caused by physical or chemical damage, the result is cracks, holes or other damage to the exhaust system that cause excessive noise and can allow harmful exhaust gases to enter the passenger compartment. Engine exhaust contains CO, which can cause headache, nausea and drowsiness, and if enough is ingested, can even result in unconsciousness and death. Any exhaust system damage that results in exhaust leakage must be repaired immediately.

Damage to the exhaust system can also result in a restriction in the system. A blockage can be caused by physical damage, such as a dent in a pipe, or a clogged muffler or catalytic converter. A restriction can also be caused by a collapsed exhaust pipe. Some vehicles use double wall tubing for exhaust pipes. The inside tube can collapse or rust inside the outer tube and cause a restriction, even though the outer tube looks OK. Tap on the exhaust pipes with a mallet and listen for rattling or rust breaking loose, which would indicate a problem inside the pipe. A restricted exhaust system can cause a lack of power, poor fuel economy, backfiring, and if completely clogged, the engine may not run at all.

Begin exhaust system inspection by raising and safely supporting the vehicle. Visually inspect the exhaust system for physical damage, holes, cracks, separated components, bulging muffler seams, and broken or missing clamps and hangers. A catalytic converter that appears bluish or brownish indicates that it is overheating.



Typical air intake system. Makes sure there are no air leaks downstream from the MAF sensor or a lean condition could result.
(Courtesy: Ford Motor Co.)

Wiggle the exhaust system at various points to check for excessive movement caused by broken or cracked connections or broken or missing hangers. Tap on the exhaust system components with a mallet. A part that is in good condition will make a solid metallic sound, while a part that is worn out will have a dull sound. Rattling noises can be caused by loose heat shields, loose clamps or an exhaust pipe interfering with another component.

When tapping on the muffler, listen for the sound of loose rust particles. Mufflers usually rot out from the inside, so even if the outside of the muffler appears OK, it still may be ready for replacement.

A telltale sign of exhaust leakage is black streaks or soot on the outside of a component. However, if the source of exhaust leakage is not evident, you may have to start the engine and listen carefully for leaks at all joints. Do not overlook welded connections, as these can crack. A small exhaust leak will make a whistling, hissing or popping noise. A tapping sound that may sound like a valvetrain noise can actually be caused by an exhaust leak at the exhaust manifold/cylinder head juncture. Keeping in mind that the exhaust system will be very hot, carefully pass your hand close to a suspected leak area to see if escaping exhaust can be felt.

To check for a restricted exhaust system, connect a vacuum gauge to the intake manifold and start the engine. At idle, there should be approximately 17-21 in. Hg. vacuum. Accelerate the engine gradually to 2000 rpm. The vacuum should momentarily drop to zero and then return to normal without delay; if the exhaust is restricted, as the engine rpm is increased the vacuum will slowly drop to zero and slowly rise to normal. When closing the throttle, the vacuum should momentarily increase and then resume the normal reading; if the exhaust is restricted the vacuum will not increase when the throttle is closed. Accelerate the engine to 2500 rpm and hold. If the vacuum reading drops 3 in. Hg below the original reading after a few minutes, there is a restriction in the exhaust system.

A backpressure test can also be used to check for a restricted exhaust system. Remove the front oxygen sensor and install a suitable pressure gauge in the sensor hole. Start the engine and compare the pressure reading with specifications for the vehicle in question. A pressure reading that is higher than specifications indicates an exhaust restriction.

TURBOCHARGERS AND SUPERCHARGERS

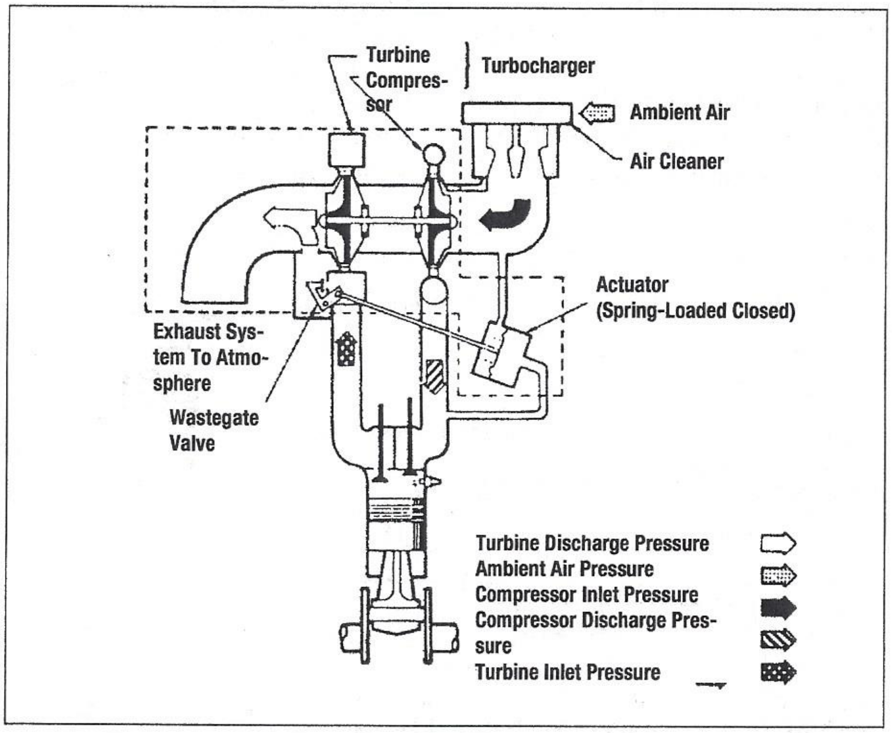
In a normally-aspirated engine, when the piston moves down the cylinder on the intake stroke, a vacuum is created that draws the air into the cylinder. The air moves into the cylinder because the pressure in the cylinder is lower than the atmospheric pressure outside the engine. The more air that can be packed into the cylinders (along with a corresponding amount of fuel), the more power an engine will make, however, cylinder filling is limited in this type of engine because it is restricted to the amount of air that can be pushed by atmospheric pressure alone. This is why normally-aspirated engines are also known as atmospheric engines.

A supercharger or turbocharger is an air pump that forces air into the combustion chamber. In effect, a supercharger or turbocharger raises the pressure inside the intake manifold, so that when the intake valves open, more air (along with fuel on a gasoline engine) flows into the cylinders, resulting in an increase in power.

Superchargers are driven off the engine's crankshaft by a belt or gears, so some of the increased power that the supercharger generates is used to drive the supercharger itself. Turbochargers are driven by the engine's exhaust, so the power increase is said to be 'free' horsepower, since the turbocharger does not use any of the horsepower it creates.

Turbochargers

A turbocharger is divided into two sections, the turbine and the com-



Turbocharger operation. *(Courtesy: GM Corp.)*

pressor. The turbine is attached to the exhaust manifold, where a turbine wheel inside the turbine housing is driven by the exhaust gas pressure and heat energy. The turbine wheel is connected by a shaft to the compressor wheel inside the compressor housing. The spinning of the turbine wheel causes the compressor wheel to spin, drawing in air to the compressor housing where it is compressed and pumped through ducts into the intake manifold. As the speed of the turbine increases, so does the pressure output, or boost, of the compressor.

Boost pressure must be limited to prevent engine damage. Boost is controlled by a wastegate or by shutting off the fuel supply to the engine.

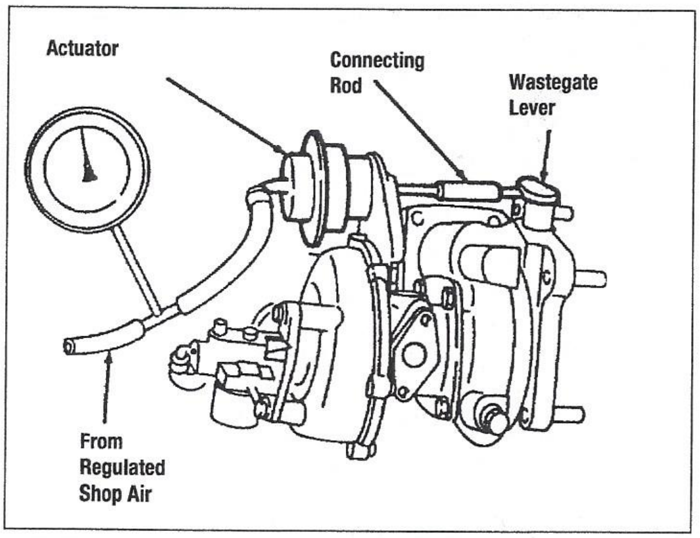
A wastegate is a valve activated either by a diaphragm or a boost control solenoid. Wastegates are either integral to the turbine housing or are remotely mounted in the exhaust system. If controlled by a diaphragm, when a preset boost limit is reached, the diaphragm moves a rod that opens the wastegate. If controlled by a boost control solenoid, which is operated by the PCM/ECM, the wastegate opens and closes in response to sensor inputs to the PCM/ECM. When the wastegate is opened, excess exhaust pressure is released from the turbine housing, directed to the exhaust system and expelled into the atmosphere.

The fuel supply to the engine can be shut off by the PCM/ECM in response to inputs regarding intake manifold pressure or engine speed. The MAP (Manifold Absolute Pressure) sensor sends a signal to the PCM/ECM when a specified intake manifold pressure is reached. The PCM/ECM then cuts the fuel supply to the engine, causing boost and engine speed to decrease. When intake manifold pressure falls below the limit, fuel delivery resumes. When boost is controlled in response to engine speed, the PCM/ECM will cut the fuel supply when inputs are received that a specific engine speed has been reached. Fuel delivery resumes when engine speed drops below the limit.

Inspection

Turbocharger related engine performance problems are caused by too little boost pressure or by overboost. These problems can usually be traced to a malfunction in the boost control system however, other components should also be inspected before any are condemned. If there is a lack of power, check for a dirty air cleaner, loose or restricted intake ducting or restricted exhaust system. Also check for exhaust leaks; if exhaust can escape before it reaches the turbine wheel, less boost (and power) will be produced. Listen for unusual noises coming from the turbocharger that could be an indication that the rotating assembly is binding or dragging.

A wastegate actuator that is stuck can be the cause of too little boost and low power if it is stuck open, or overboost if it is stuck closed. Overboost can cause detonation and possible engine damage. A wastegate can stick or bind due to carbon buildup or be inoperative due a leaking diaphragm or vacuum hose. Check for free movement of the actuator by hand if possible and check for obstructions that could prevent free movement or closure. Wastegate operation can be checked using air pressure and a pressure gauge. Consult the appropriate service manual for testing procedures and pressure specifications.

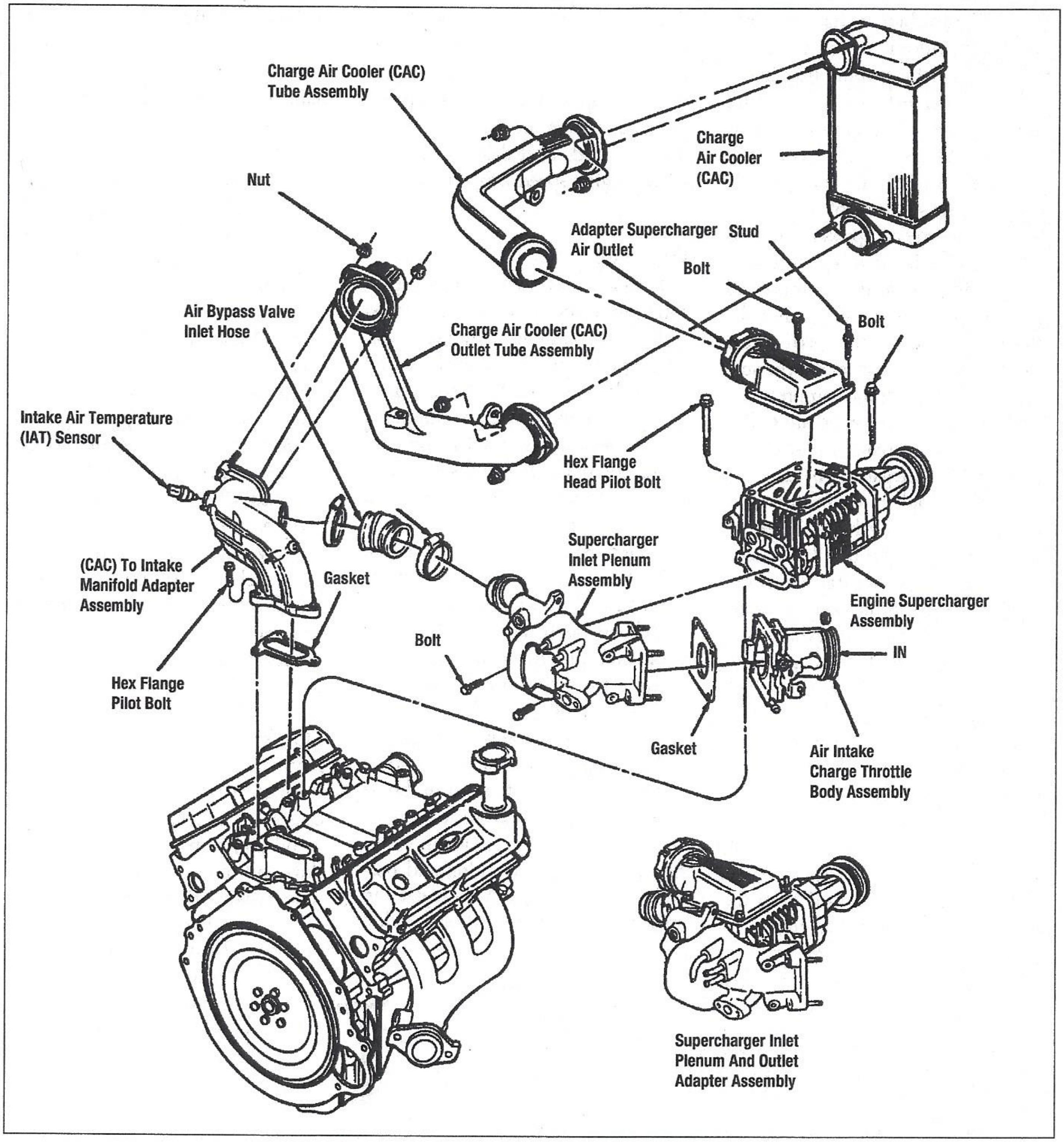


Testing wastegate operation using air pressure. *(Courtesy: Ford Motor Co.)*

***WARNING:** Turbochargers operate at extremely high temperatures. Do not touch the turbocharger while the engine is operating. Allow the turbocharger to cool sufficiently after the engine has been turned off before performing testing or servicing procedures.*

If a wastegate problem is suspected, always check the ignition timing, knock sensor and vacuum lines before replacing the wastegate. If the wastegate is controlled by a boost control solenoid and the solenoid fails, a DTC should set in the PCM/ECM's memory and the MIL may illuminate.

Most turbocharger failures are caused by lubrication problems such as oil lag, restriction or lack of oil flow and foreign material in the oil. The exhaust flow past the turbine wheel creates extremely high temperatures, which creates a harsh operating environment for the turbocharger shaft bearings. Some manufacturers connect coolant lines to the turbocharger to cool the shaft bearings, but others rely on engine oil to lubricate and to cool. With the latter design, it is a good idea to let the engine idle for about a minute before shutting it off, particularly if the vehicle has been run hard, to let oil cool the turbocharger. If the engine is shut off immediately,



Typical supercharger installation.

the oil may burn causing hard carbon particles to form, which in turn will destroy the bearings.

When replacing a turbocharger, use new gaskets and torque all fasteners to specification. The unit should be preoiled prior to installation and the engine should not be revved before proper oil pressure has been established.

To prolong turbocharger service life, the oil and filter should be changed at regular intervals and the air filter should be inspected regularly. Inspect the routing and integrity of the oil supply and oil drain lines and check for oil leaks.

Superchargers

The amount of boost pressure a supercharger generates is determined by the size of the pulleys or gears on the crankshaft and supercharger, and by engine speed. The size of the pulleys or gears can be varied in order to get the desired boost. It may be necessary to drive the supercharger at a speed faster or slower than crankshaft speed. If the supercharger turns the same speed as the engine it is driven 1:1. If it's geared to turn faster for more or quicker boost, it is over-driven. If it's set up to run slower than the engine, it is under driven. Otherwise, boost increases as engine speed increases.

To prevent supercharger cavitation, reduced performance and increased temperatures, a bypass valve is installed at the supercharger outlet. This bypass valve allows a controlled amount of air flow from the supercharger outlet back into the supercharger.

Proper supercharger performance depends on there being no vacuum leaks, which could cause a lean operating condition. Vacuum leaks can be detected using a propane cylinder as described in the Air Induction section.

Notes

Emissions Control Systems Diagnosis And Repair

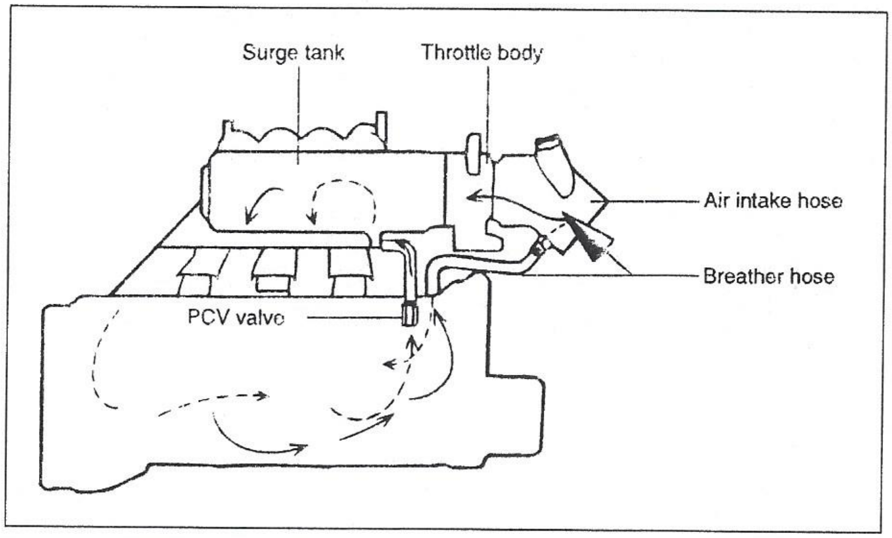
POSITIVE CRANKCASE VENTILATION

Description And Operation

During engine operation, some combustion gases leak past the piston rings into the crankcase. These gases are commonly known as 'blowby'. The PCV (Positive Crankcase Ventilation) system vents crankcase gases into the engine air intake where they are burned with the air/fuel mixture.

The PCV system keeps pollutants from being released into the atmosphere, and also helps to keep the engine oil clean by ridding the crankcase of moisture and corrosive fumes. It also keeps crankcase pressure from building up and causing oil leaks as the pressure forces its way past seals and gaskets.

The PCV system is basically a controlled air leak from the crankcase into the intake manifold. Fresh air enters the crankcase through the breather cap or the ventilation filter inside the air cleaner. Atmospheric pressure pushes crankcase blow-by vapors toward the low-pressure point offered by the PCV valve and the intake manifold.



PCV system functional diagram *(Courtesy: Hyundai Motor Co.)*

Inspection, Diagnosis And Testing

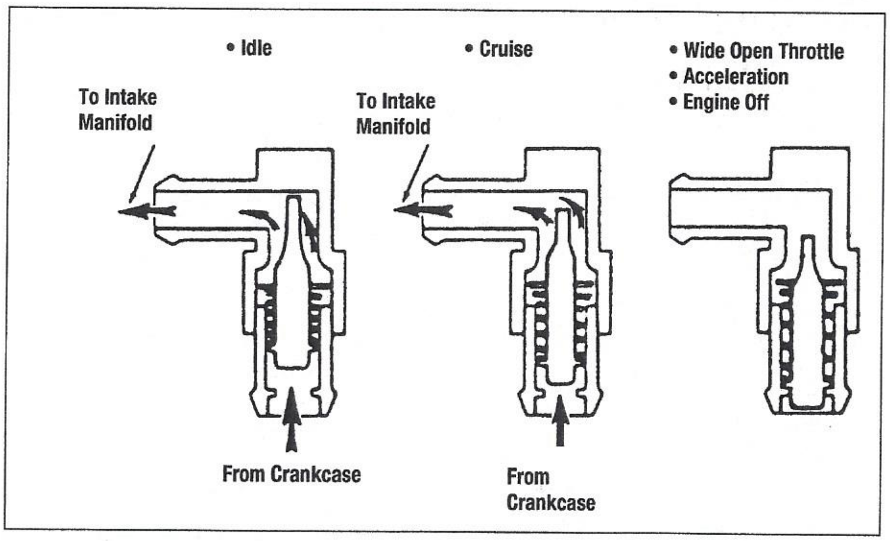
Inspect all PCV system hoses for cracks or other damage. Check the crankcase inlet air filter and replace as necessary.

Inspect the engine air cleaner. If the air cleaner is oil soaked and there is oil in the air cleaner, it may because the PCV valve or hoses are clogged. If the PCV valve and hoses are OK and these conditions are found, then the engine may be worn to the point it creates more blowby than the PCV system can handle.

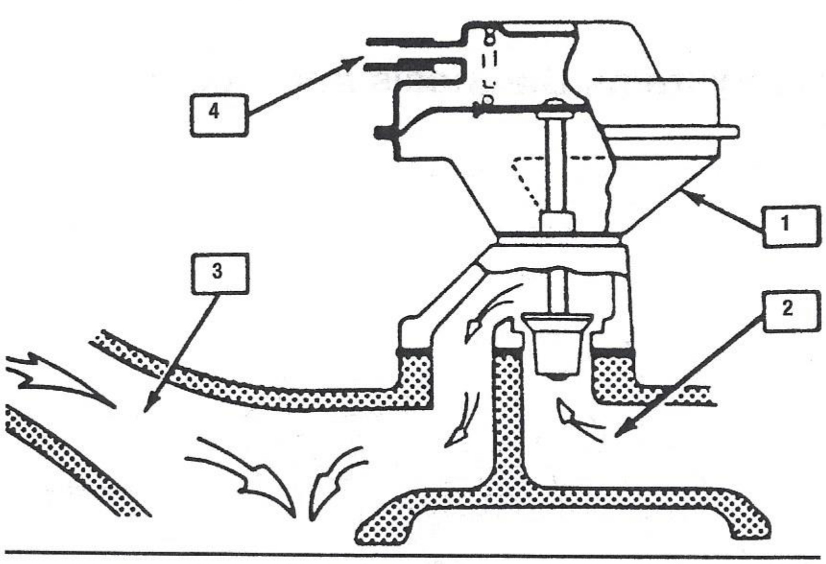
Start the engine and let it idle. Being careful not to damage the hose, use a suitable tool to pinch the hose between the intake manifold and the PCV valve. If the PCV valve is OK it should make a clicking sound when the hose is pinched and released.

Disconnect the PCV valve from its mounting grommet and listen at the valve. It will make a hissing noise if it is not clogged. Place your finger over the valve to check for vacuum. If there is little or no vacuum, check for a clogged or restricted hose.

Turn off the engine, remove the PCV valve from the engine and shake it. Listen or feel for the rattle of the valve plunger within the valve body. If it rattles the valve is not stuck



PCV valve operation.



Vacuum operated EGR valve

open or closed. If it doesn't rattle, the valve must be replaced.

Make sure the PCV valve is replaced with the correct one for the application. The spring inside the valve is calibrated for a specific flow rate. If the wrong valve is used, the engine can draw in excessive air, possible causing a high idle speed on vehicles with speed density fuel injection systems.

EXHAUST GAS RECIRCULATION

Description And Operation

Most of the air around us is made up of harmless nitrogen. Ordinarily, nitrogen cannot combine with oxygen. However, under very high heat conditions, such as those that occur inside an engine's combustion chamber, where temperatures can exceed 2500°F (1371°C), nitrogen molecules can bond with oxygen molecules and form oxides of nitrogen (NOx). When NOx leaves the tailpipe and is struck by sunlight, photochemical smog is formed.

A simple way to reduce NOx would be to lower the temperature of combustion. This could be accomplished by running rich air/fuel mixtures, which contain a high level of cool liquid gasoline, or also by lowering thermostat temperatures. Unfortunately, both methods would produce high levels of HC and CO emissions and lower fuel economy, and are contradictory to the objective of using the minimum amount of fuel necessary for combustion. Burning leaner mixtures produces high temperatures.

The solution is to introduce a metered amount of an inert gas into the intake air stream. The gas takes up space that would otherwise be occupied by the regular incoming air/fuel charge, which contains 21% oxygen. Oxygen would contribute to combustion, and subsequently raise temperature. Replacing the oxygen with inert gas slows and cools the combustion burn.

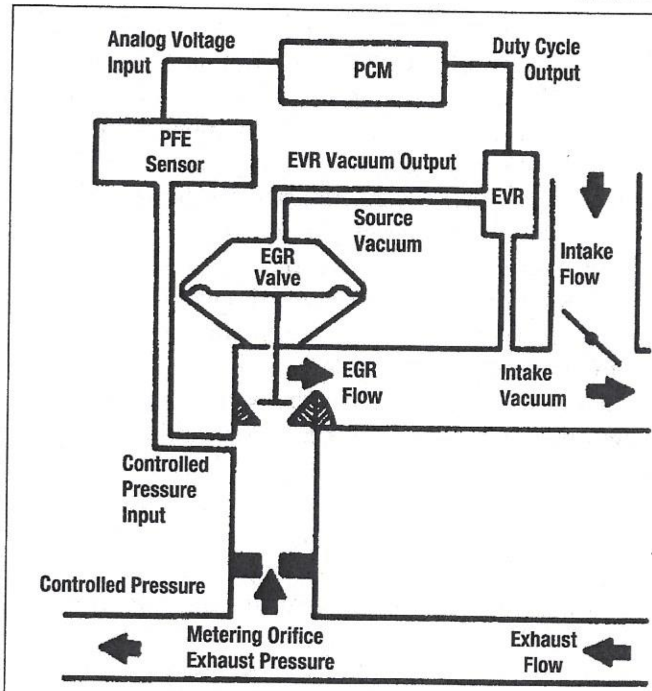
Fortunately, a running engine produces large quantities of a suitable inert gas for this purpose: exhaust. Exhaust gas should theoretically contain very little, if any, oxygen because it should have all been consumed during the combustion process.

The Exhaust Gas Recirculation (EGR) valve is used to meter the exhaust into the intake air stream. Most EGR valves consist of a vacuum operated diaphragm that is connected by a rod to a valve in its base, however on some EGR valves, control of the valve is fully electronic. The valve is located inside a connecting passage between the exhaust system and the intake manifold. When the valve opens, exhaust gas mixes with the incoming air that is to be used for combustion.

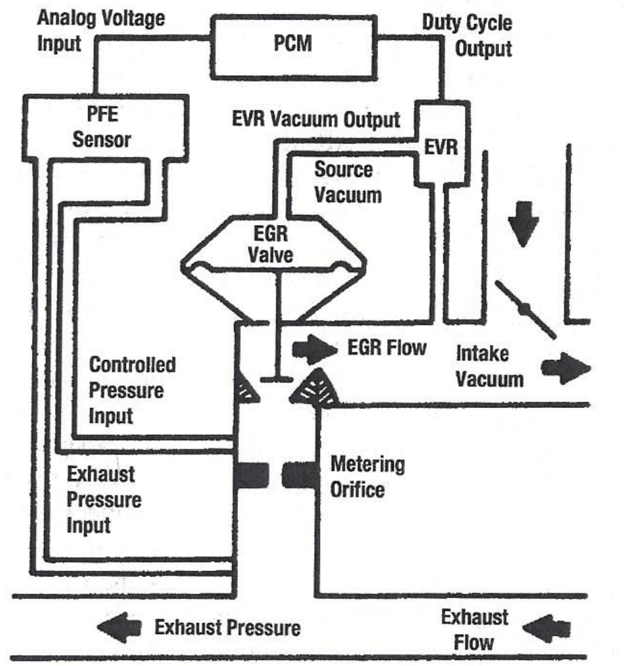
EGR function must be controlled because exhaust gas recirculation is not constantly required. EGR is not required when the engine is cold, at idle (warm or cold) and at WOT (Wide Open Throttle). Until the engine is warm, there is no need for exhaust gas recirculation because combustion is still sufficiently cool. Even when the engine is warm, there is no need for exhaust gas recirculation at idle because combustion pressures are relatively low and NOx is not formed, and exhaust gas recirculation would stall the engine because of too much dilution. At WOT, the need for power outweighs the need to control NOx emissions, and since WOT needs richer, and therefore slightly cooler mixtures, NOx formation is minimal anyway.

There are several systems currently used to control EGR function including ported, positive backpressure, negative backpressure, pulse-width modulated and electronic.

On the positive backpressure EGR valve, a control valve located in the EGR valve acts as a vacuum regulator valve. The control valve manages the amount of vacuum to the EGR diaphragm chamber by bleeding vacuum to atmosphere during certain operating conditions. When the control valve receives a backpressure signal from the exhaust through the hollow shaft of the EGR valve pintle,



Typical Pressure Feedback EGR (PFE) system.
(Courtesy: Ford Motor Co.)



Differential Pressure Feedback EGR (DPFE) system.
(Courtesy: Ford Motor Co.)

pressure on the bottom of the control valve closes it. When the EGR valve closes, the full vacuum signal is applied directly to the EGR valve diaphragm, which opens the valve and allows exhaust gas recirculation.

On the negative backpressure EGR valve, a vacuum signal is supplied through a hose connected to the upper part of the EGR valve. Manifold vacuum is also applied to the lower diaphragm through an intake port at the base of the EGR valve. When manifold vacuum in the lower chamber isn't strong enough to overcome the spring tension on the lower diaphragm, a bleed valve closes allowing vacuum in the upper chamber to open the EGR valve. Exhaust flow opens a check valve in the pintle so that vacuum bleeds to atmosphere and the valve rises, but tries to drop again. This process controls EGR flow.

The pulse-width modulated EGR system is controlled entirely by the PCM/ECM. The computer controls the flow rate by sending electrical signals to a solenoid vacuum valve between the PCM/ECM and EGR valve. The solenoid pulses up to 32 times per second. To determine pulse width, the PCM/ECM relies on a ported vacuum signal.

On computer controlled EGR systems, the PCM/ECM controls the vacuum signal to the EGR valve through a solenoid valve. The PCM/ECM uses coolant temperature, throttle position and MAP (Manifold Absolute Pressure) signals and sometimes other inputs, to determine solenoid operation. Whenever the engine is cold or idling, the solenoid valve blocks vacuum to the EGR valve. When the engine is warm and RPM is higher than idle speed, the solenoid ground is broken and vacuum opens the EGR valve.

Some systems, such as Ford Pressure Feedback EGR (PFE) and Differential Pressure Feedback EGR (DPFE) use a sensor in the exhaust stream that tells the PCM/ECM how much exhaust gas is actually flowing. With PFE, the PCM/ECM uses internal formulas to estimate the EGR flow. With DPFE, the PCM/ECM actually gets a report on the flow by measuring the pressure above and below the EGR valve. The PCM/ECM then adjusts the EGR Vacuum Regulator (EVR) to optimize the EGR flow under various conditions.

The digital EGR valve allows the precise amount of EGR flow without using manifold vacuum. The valve controls EGR flow through three different size orifices for seven different combinations of EGR flow. When the PCM/ECM energizes a solenoid, the swivel pintle is lifted to open the orifice.

Some engines have an electronically controlled EGR valve. It has a control solenoid and EGR Valve Position (EVP) sensor. The return voltage signal ranges from 0.3 volts when it is closed up to 5 volts when it is fully open. The PCM/ECM controls EGR flow by pulsing the signal to the EGR solenoid. This provides better regulation of EGR flow than with conventional vacuum controlled EGR valves.

Diagnosis And Testing

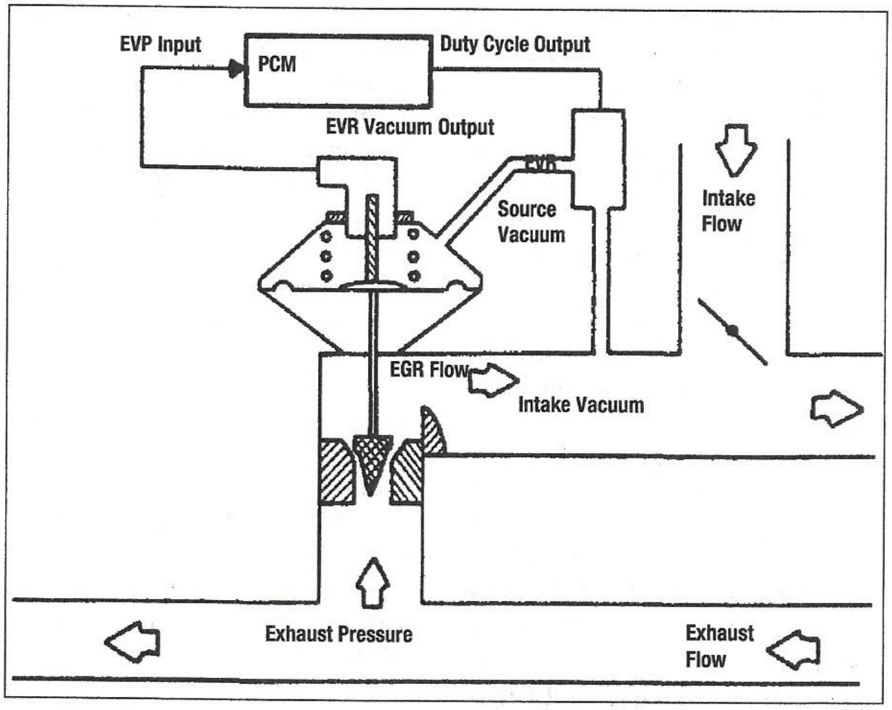
When EGR function is not controlled properly, there is either not enough EGR when it is required, or there is too much EGR or EGR at the wrong time. When there is not enough EGR, driveability problems such as spark knock or surging at cruise can occur, as well as an increase in NOx emissions that could cause a failed emissions inspection. Symptoms of too much EGR or EGR at the wrong time include poor idle, stalling, hesitation, stumble and rough running during warm up, tip-in hesitation or stumble, surge at cruise, poor acceleration, and low engine vacuum.

Before blaming EGR function for any of these symptoms, be sure to check the basics as other components and systems could also be the cause. For example, carbon buildup in the combustion chamber could be the cause for that spark knock, and vacuum leaks could be the cause of hard starting and hesitation. Check EGR related scan tool data and check for DTCs that could narrow your troubleshooting focus.

Basically, the EGR system can malfunction in four ways: problems with EGR passages, problems with the EGR valve itself, problems with the vacuum control system and problems with the computer control system.

If you lift up on the EGR valve diaphragm (after protecting your fingers with a glove or shop towel) with the engine idling and there is no effect on idle speed, the EGR passages are probably clogged with carbon. Check the NOx readings using a five-gas exhaust analyzer. Run the engine until it reaches normal operating temperature and then increase engine speed to 2000 rpm. If the EGR system is functioning properly, the NOx readings should generally be below 1000 ppm (parts per million). If the NOx reading is above 1000 ppm and the EGR valve is functioning, then the EGR passages are probably clogged.

Remove the valve and clean the EGR passages until they are clear. Carbon stuck between the pintle and seat can also cause the EGR valve to not fully close causing poor idle, stalling or stumble after cold start.



Electronically controlled EGR system. *(Courtesy: Ford Motor Co.)*

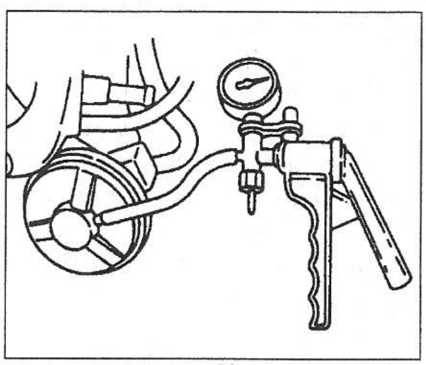
Also keep in mind that if the EGR passages are only partially clogged, enough exhaust gas can enter the combustion chamber to make the engine run rough or stall at idle, but there still may not be enough EGR flow to control NOx emissions.

Conventional ported EGR valves can be tested simply using a hand operated vacuum pump. When vacuum is applied, the EGR valve should lift and maintain vacuum.

In order to test a positive backpressure EGR valve, a restriction in the exhaust system must be created to simulate exhaust backpressure. Place a suitable object in the tailpipe to restrict exhaust flow, then connect a hand operated vacuum pump to the EGR valve and apply vacuum. The vacuum should hold providing the diaphragm is not leaking. Start the engine and place the transmission in gear. The engine should stall when the restriction created exhaust backpressure builds up enough to open the EGR valve at idle.

To test a negative backpressure EGR valve, disconnect the vacuum hose from the EGR valve and connect a hand operated vacuum pump. With the engine off, apply vacuum and feel for diaphragm movement with your finger. The diaphragm should move up and hold vacuum. Have an assistant operate the ignition key. When the engine is cranked, you should feel the diaphragm drop, closing the valve.

Note that damage to the exhaust



Testing an EGR valve with a vacuum pump. *(Courtesy: Ford Motor Co.)*

system that restricts exhaust flow (dented or collapsed pipe, clogged catalytic converter) or modifications which improve exhaust flow (after-market performance exhaust system) will affect the operation of a back-pressure EGR valve.

In order to function properly, vacuum operated EGR valves must receive the proper vacuum signal. Check for vacuum leaks caused by loose, broken, pinched or missing vacuum hoses. Check the hose routing against the schematic shown on the emissions label. Most systems use a TVS (Thermal Vacuum Switch) to prevent EGR when the engine is cold. If the switch is operating properly, it should not allow vacuum flow until the engine reaches a specific operating temperature.

Computer controlled EGR systems usually have a vacuum control solenoid controlled by the PCM/ECM. To test operation, use a tee fitting to connect a vacuum gauge into the hose at the EGR valve. With the engine warm, place the transmission in gear, apply the brakes and accelerate the engine. There should be a vacuum reading on the gauge. When the electrical connector at the solenoid is disconnected, vacuum should vent off and the gauge reading should be zero.

Some GM systems use a solenoid with a vent filter that can cause driveability problems if the filter becomes restricted, which could trap vacuum and hold the EGR valve open. Test these solenoids by covering the solenoid vent with your finger. The engine should stumble or stall. If it doesn't, the vent solenoid is probably defective.

Some Chrysler and import computer controlled systems use a back-pressure transducer. These systems are also tested in the same way as a positive backpressure EGR valve, using an exhaust flow restriction. Restrict the exhaust flow at the tailpipe, start the engine and unplug the solenoid. The engine should stall.

EGR System Service

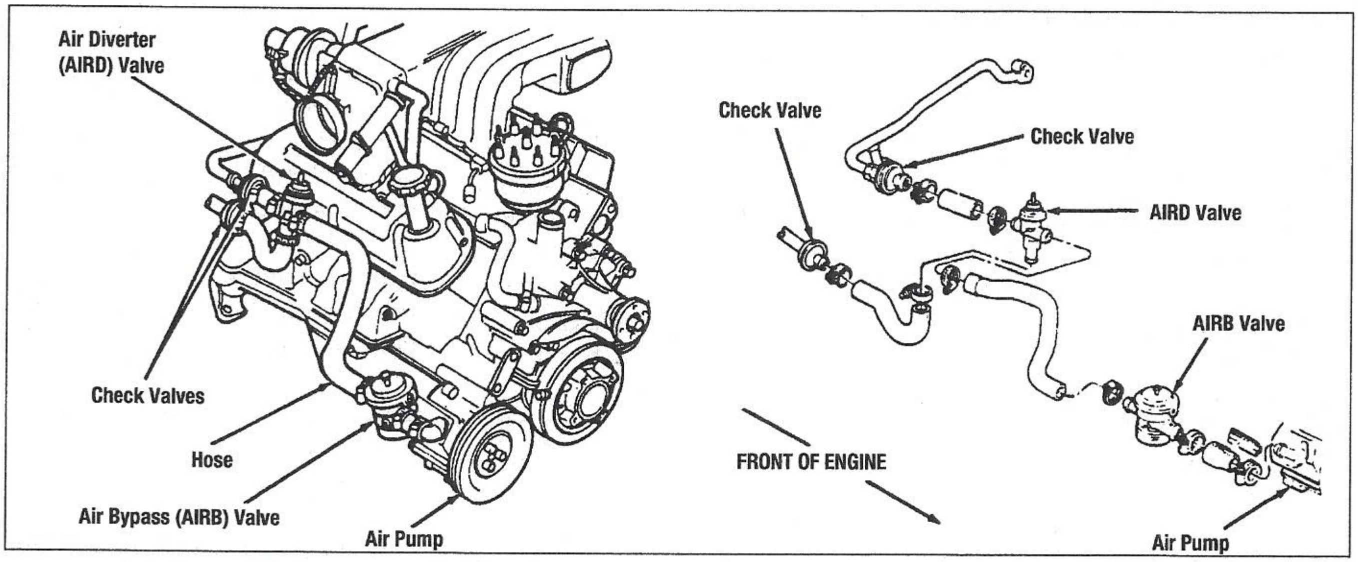
One of the most common problems with EGR systems is the buildup of combustion deposits on the valve and in the manifold passages. Even when all components of the EGR system are operating properly, the engine may exhibit faulty EGR symptoms or in some cases even set a DTC if the manifold passages are blocked or restricted. Any time that the EGR valve is removed, the manifold passages should be inspected and cleaned with a wire brush or scraper.

SECONDARY AIR INJECTION (AIR)

Description And Operation

The Air Injection Reactor (AIR) system forces fresh air into the exhaust system to reduce HC and CO emissions. The oxygen in the fresh air combines with the post-combustion HC and CO to provide secondary oxidation, converting the residual HC and CO to water vapor and CO_2. The fresh air is fed into the exhaust stream at the cylinder head exhaust ports or in the exhaust manifold just past the exhaust ports, and on some vehicles, the catalytic converter. There are two kinds of systems: pump systems, that use an engine driven or electric pump to pump air into the exhaust system, and pulse-air systems, that use the natural pulses in the exhaust system to pull air into the exhaust system.

A basic pump air injection system consists of a belt driven air pump, a diverter valve to vent pumped air to atmosphere during engine acceleration to prevent backfire, a one-way check valve to allow air flow into the exhaust manifold or cylinder head and keep exhaust out of the air pump, and hoses and tubing to route the air to the exhaust manifolds or cylinder heads. Systems that include



Typical air pump AIR system. *(Courtesy: Ford Motor Co.)*

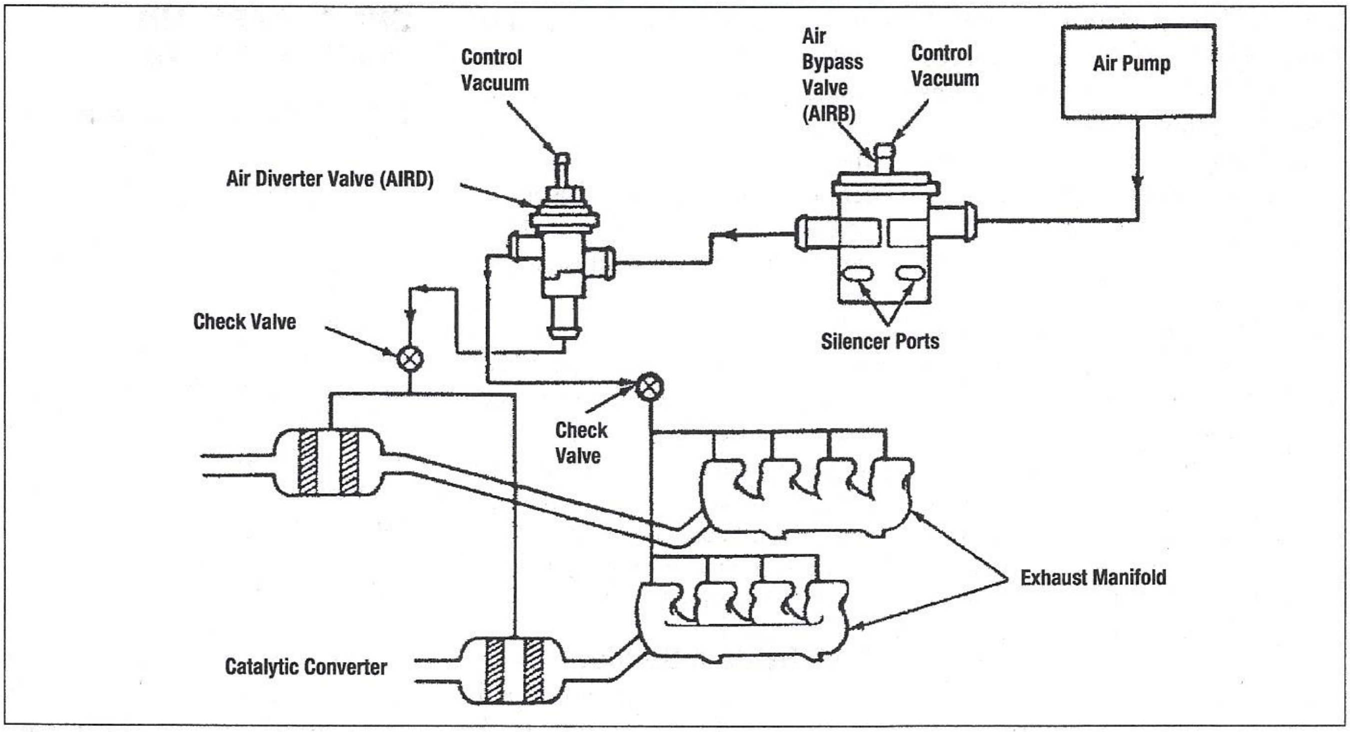


Diagram of a typical AIR system. *(Courtesy: Ford Motor Co.)*

the catalytic converter use an Air Bypass (AIRB) valve to direct pumped air to atmosphere or to an Air Diverter (AIRD) valve that directs air to the exhaust manifolds/cylinder heads or catalytic converter.

Intake air enters the pump through a centrifugal filter positioned behind the drive pulley. The filter consists of small fins that deflect airborne contaminants away from the pump as it rotates. Under certain conditions, pump air is delivered to the exhaust manifold(s), and on some vehicles, the catalytic converter. Check valves are used to prevent hot exhaust gases from backing up into the pump. When air is being supplied to the exhaust manifold for example, the check valve opens under pump pressure. When pump air is directed away from that location, exhaust system backpressure forces the check valve closed.

The AIRB and AIRD valves contain solenoids that are controlled by the PCM/ECM. These solenoids are used to direct air flow to a specific location depending on engine operating conditions. Typically, air is directed to the exhaust manifolds/cylinder heads during open loop, when the engine is warming up. At this time, the rich air/fuel mixture that is used for engine start-up results in high amounts of unburned HC and CO in the exhaust. The oxygen in the incoming air combines with the HC and CO and oxidation continues.

The air is then switched to the catalytic converter when the engine has reached normal operating temperature and gone into closed loop. The air that is injected into the converter helps with the oxidation of HC and CO.

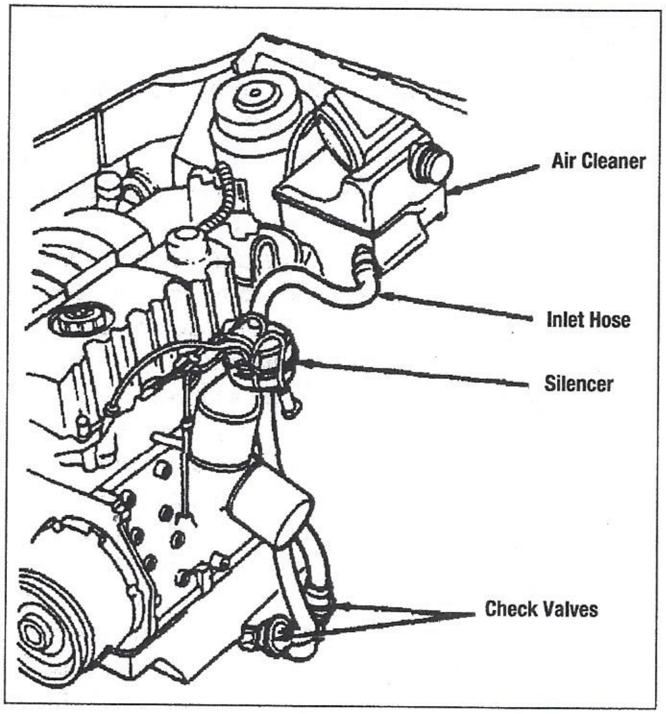
Under certain conditions, such as heavy acceleration, the addition of oxygen to the exhaust could cause a backfire. To prevent this, pump air is bypassed to the air cleaner or a remote silencer by the AIRB valve during this time.

Pulse-air systems use a reed valve, which responds to pressure pulses in the exhaust system. When an exhaust valve opens, a low-pressure area is created in the line extending from the reed valve to the exhaust system. This causes the valve to open. Under this condition, air flows from the air cleaner through the open reed valve and into the exhaust, where it oxidizes unburned fuel and CO. When the exhaust valve closes, exhaust backpressure forces the reed valve closed.

Diagnosis And Testing

A faulty secondary air system can cause several problems including backfiring, excessive HC and CO emissions, and improper fuel control. The latter occurs when pump air is delivered to the exhaust manifold(s) during closed loop. This is because the oxygen sensor interprets the additional air as a lean condition. In response, the computer commands a rich mixture. Eventually, this condition will lead to poor fuel economy, rotten egg odor, an overheated converter, and/or an illuminated MIL. Always check for secondary air system related scan tool data and DTCs.

A functional check of the AIR system can be performed using a four- or five-gas analyzer. Run the engine



Typical pulse-air AIR system. *(Courtesy: Ford Motor Co.)*

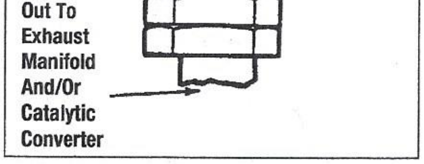
at idle and record the exhaust gas readings. Then disable the AIR system by removing the pump drive belt or pinching off the hose to the air distribution manifold. Run the engine at idle and again record the exhaust gas readings.

When the engine was run without the AIR system, there should have been 2-5% less oxygen in the exhaust and the HC and CO readings should have increased. This would mean that the AIR system was injecting air into the exhaust system and thereby functioning properly. If there was no change in the readings with and without the AIR system, then the AIR system is not functioning properly. Check the system for the cause of the malfunction.

On pump driven systems, check the vacuum hoses and wiring in the system. Check the vacuum hoses for cuts, cracks and kinks that could cause a vacuum leak or a vacuum restriction. Also check hoses for flexibility; even though a hose appears OK, it could be hardened and ready to break. Use a vacuum diagram, such as that found on the vehicle emissions control information label, to make sure all vacuum hoses are routed correctly. Carefully inspect the wiring for damage and corrosion.

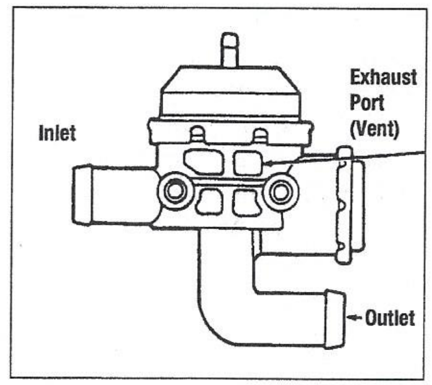
Check the hoses, tubing and connections in the system for looseness, cracks, corrosion or other damage. Make sure the hoses and tubing are properly routed and connections are secure. Inspect the condition of the air pump drive belt and make sure it is properly tensioned.

If any hoses in the system show signs of burning, inspect the check valves for leaks. Disconnect the valve's input hose and, with the engine running at fast idle, hold your hand near the valve inlet. Replace the check valve if you feel exhaust gas leaking out. The valve can also be checked for leaks with an exhaust gas analyzer. With the engine running, hold the analyzer probe near the check valve opening. If any exhaust gas is detected, then the valve is leaking.



Cutaway view of an air check valve.
(Courtesy: Ford Motor Co.)

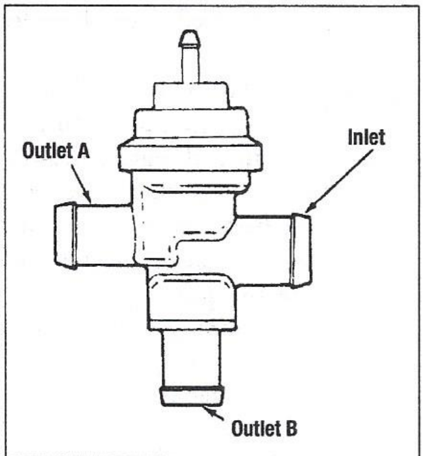
If the system passes a visual inspection, check the air pump output. Start the engine and remove the outlet hose from the pump. Air should be coming from the pump outlet. A low pressure gauge can be used to measure the pump pressure. A properly functioning pump should typically produce 1-3 psi, but always check the manufacturer's specifications for the vehicle in question. If pressure is low, check the air filter for clogging before condemning the pump.



Typical AIRB valve.
(Courtesy: Ford Motor Co.)

Start the engine and remove the vacuum hose from the Air Bypass (AIRB) valve. There should be a vacuum signal with the engine running. Reinstall the vacuum line and remove the outlet hose from the AIRB valve. Air should be coming from the hose. Reinstall the hose and open and quickly release the throttle. There should be a sudden release of air from the AIRB valve vent if there is air supply from the pump and the valve is working properly.

While the engine is warming up from a cold start, remove the hose from the Air Diverter (AIRD) valve that goes to the cylinder head or exhaust manifold. Air should be coming from the hose. If not, check for a vacuum signal at the vacuum hose to the valve. If there is an adequate vacuum signal (refer to the manu-



Typical AIRD valve
(Courtesy: Ford Motor Co.)

facturer's specifications) replace the AIRD valve. If there is no vacuum signal, check the vacuum hoses and the AIRD solenoid and wiring.

Once the engine reaches normal operating temperature, remove the hose from the AIRD valve that runs to the catalytic converter. When the engine is in closed loop, at normal operating temperature, air should be coming from the hose. If not, remove the vacuum line from the AIRD valve and check for a vacuum signal at the line. If there is no vacuum signal, replace the AIRD valve. If there is some vacuum (measured with a vacuum gauge), check the AIRD solenoid and wiring.

On pulse-air systems, visually inspect the hoses, tubes and valves of the system for damage and replace parts as necessary. Disconnect the hoses from the check valve inlet(s) and check the inside of the hoses for damage from hot exhaust gases. Replace the hoses and check valve(s), if damage is found.

Leave the inlet hose(s) disconnected and start the engine. Listen and feel for exhaust at the check valve(s). Intake air pulses should be found and the check valve(s) will make a burbling sound as air is drawn in. If exhaust is heard and/or felt, replace the valve(s).

CATALYTIC CONVERTER

Description And Operation

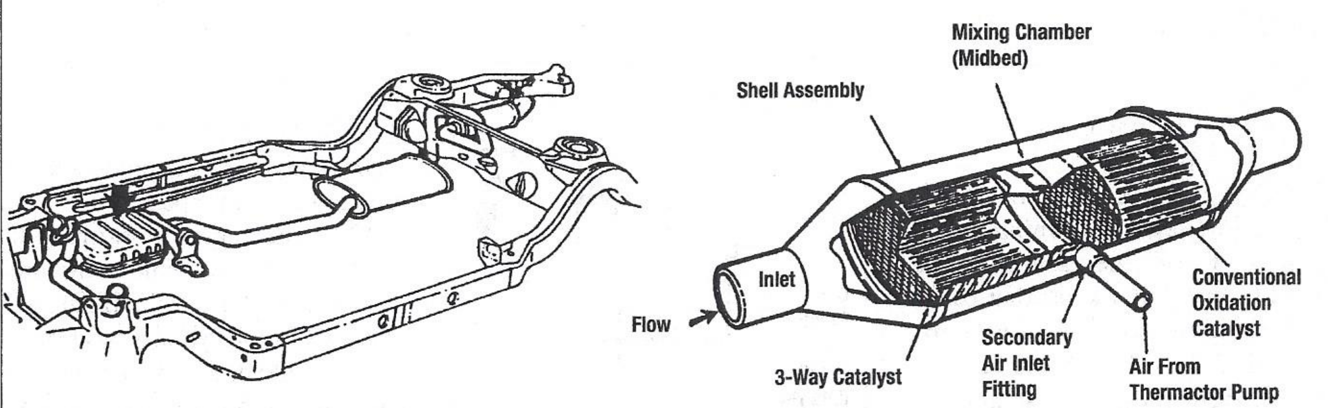
The catalytic converter contains a ceramic component coated with a catalyst. A catalyst is something that causes a chemical reaction without being part of the reaction. The catalyst agent is coated on a ceramic honeycomb structure or on small ceramic beads. A converter that uses the honeycomb structure is called a monolithic catalytic converter, while the kind that uses ceramic beads is known as a pellet catalytic converter. As exhaust flows through the converter, the catalyst agent causes a chemical reaction to take place, converting harmful exhaust gases to harmless ones.

The elements platinum, palladium and rhodium are used as catalysts in the catalytic converter. When HC and CO gases are exposed to hot surfaces inside the converter that are coated with platinum and palladium, the HC and CO combine with oxygen to become Carbon Dioxide ($CO2$) and water ($H2O$). Because platinum and palladium are called oxidizing catalysts, a catalytic converter that only reduces HC and CO is known as an oxidation converter, or two-way catalytic converter.

Three-way catalytic converters also contain the catalyst rhodium, which reduces NOx emissions. When NOx is exposed to a hot surface coated with rhodium, the oxygen is removed and only Nitrogen (N) remains. Because rhodium is called a reducing catalyst, a three-way catalytic converter is also called a reduction type converter. In a three-way converter, the oxidizing catalysts and reduction catalyst are separated in two compartments.

Most vehicles that are manufactured today also have a small catalytic converter that is part of the exhaust manifold or located just behind it. These converters are used to clean the exhaust during engine warm-up and are known as warm-up converters.

Most catalytic converters have fresh air injected into the converter by the



A three-way catalytic converter contains a reduction catalyst and an oxidizing catalyst. The reduction catalyst treats the incoming exhaust by reducing NOx into oxygen and nitrogen. The oxidation catalyst, with additional air from the AIR system, oxidizes HC and CO into CO_2 and water.

AIR system. The extra air helps in the oxidation of HC and CO. The PCM/ECM controls when the air is injected. If air is injected at the wrong time the converter could overheat or actually produce more NOx.

A catalytic converter can fail in several ways. If the engine is run with leaded gas, the catalysts in the converter can become coated with lead, making them useless. Leaded gas is no longer generally available, so this type of failure is rare.

The converter can become clogged if exposed to an overly rich air/fuel mixture, which can overheat the converter and melt the ceramic substrate.

The catalytic converter can also fail like any other exhaust system component, due to rust or physical damage. Over time, the ceramic substrate can come loose in the converter and slowly disintegrate, which is indicated by a rattling noise when the converter is struck with a mallet.

Diagnosis And Testing

A catalytic converter must be replaced if it leaks, if it is clogged or if it does not function properly. Check for catalytic converter related scan tool data and DTCs.

If exhaust leakage is suspected, visually inspect the converter for holes, cracks or other physical damage. A telltale sign of exhaust leakage is black streaks or soot on the outside of the converter. However, if the source of exhaust leakage is not evident, you may have to start the engine and listen carefully for leaks. A small exhaust leak will make a hissing or popping noise.

While inspecting the converter, tap on it with a mallet. If the converter makes a rattling sound, it means that the ceramic substrate has come loose and is disintegrating, and the converter must be replaced.

The catalytic converter can become clogged from using leaded gas or if exposed to an overly rich air/fuel mixture, which can overheat the converter and melt the ceramic substrate. A clogged converter can cause a lack of power, poor fuel economy, backfiring, and if completely clogged, the engine may not run at all.

To determine if the converter is clogged, perform the vacuum test or backpressure test described in the exhaust system inspection section of this study guide. To isolate the source of the restriction, disconnect the exhaust system one part at a time, until the vacuum or pressure readings are normal.

If a converter is being replaced because it is clogged, the cause of the clog must be determined and repaired or the replacement converter will also clog. A cylinder that is misfiring due to an ignition problem (bad plug wire, etc.) or mechanical problem (valve not seating, etc.) will allow raw fuel to enter the exhaust system, and also may cause the PCM/ECM to enrich the mixture in the other cylinders because it detects the unused oxygen from the dead cylinder. This can cause serious overheating in the catalytic converter, which can melt the ceramic substrate, clogging the converter.

A simple test for whether a catalytic converter is functioning properly is by measuring the inlet and outlet temperatures. With the engine at normal operating temperature, check the temperature of the exhaust inlet and outlet surface before and after the converter using a temperature probe and a DMM or an exhaust pyrometer. The exhaust surface temperature should be at least 100°F (38°C) hotter than the intake surface temperature. If not, the converter is probably not operating at peak efficiency. Since the converter needs oxygen to convert HC and CO into CO_2 and water, this may be caused by a problem in the AIR system.

WARNING: *Be very careful when performing this test as catalytic conversters operate at extremely high temperatures.*

Another test can be performed using a four- or five-gas exhaust analyzer. For proper results with this test, there should be no defects in the vehicle's ignition, fuel or O2 feedback systems, no leaks in the exhaust system, and the analyzer must be calibrated and working 100% properly.

Disable the air injection system, if equipped, since any extra air in the exhaust will produce unreliable results. Bring the engine to normal operating temperature and make sure it enters closed loop. Connect the analyzer to the exhaust system.

Run the engine at 2000 rpm and note the exhaust readings. If the converter is cold, the readings should continue to drop until the converter reaches full operating temperature.

When the readings stabilize, check the oxygen level; it should be close to zero, indicating that the converter is using all available oxygen. There is one exception to this however. If there is no CO left for the converter to use, there may be a little oxygen in the exhaust. If there is too much oxygen and no CO in the exhaust, stop the test and verify that the system is in control. If not, perform the necessary repairs and retest.

If the system was in control, use a propane enrichment tool to bring the CO level up to about 0.5%. The oxygen level should drop to zero, because the converter now has enough CO to convert.

Once a solid oxygen reading is being obtained, snap the throttle wide open and let it drop back to idle. Check the rise in oxygen level; it should not rise past 1.5%.

If the converter passes the above tests, it is working properly. If the converter fails the tests, its efficiency is probably compromised, if it is functioning at all.

OBD II systems use an oxygen sensor mounted downstream from the catalytic converter to check converter efficiency. This sensor checks the oxygen content of the exhaust after it leaves the converter and is known as a catalyst monitor. If the signal from the catalyst monitor is too similar to the signal from the primary oxygen sensor, it means that the converter is not functioning properly.

EVAPORATIVE EMISSIONS CONTROLS

Description And Operation

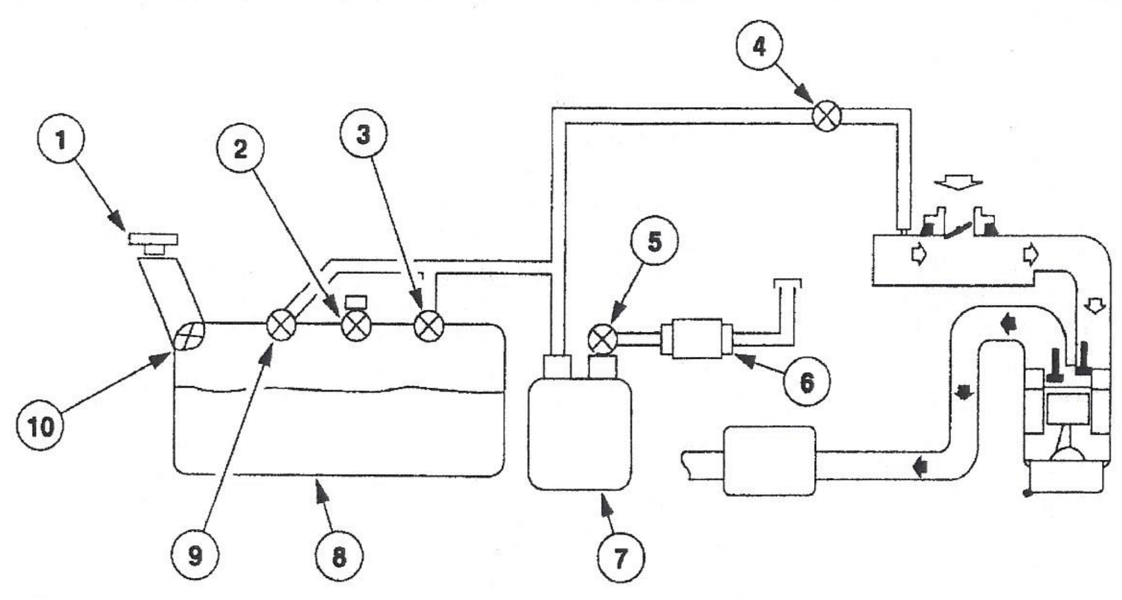
The purpose of the evaporative emissions control system (EVAP) is to prevent HC emissions from escaping the fuel system to atmosphere. Prior to the introduction of EVAP systems, fuel vaporized and was emitted to the atmosphere from vented gas caps and carburetor float bowls, polluting the environment. The EVAP system is designed to capture these vapors and route them to the engine where they become part of the air/fuel mixture and are burned during combustion.

All EVAP systems contain a pressure/vacuum relief fuel cap, vapor valve, charcoal canister, canister purge valve and the necessary plumbing connecting the fuel tank and the canister, and the canister and the engine intake.

The fuel tank cap contains a pressure and vacuum relief valve. The vacuum valve acts to allow air into the fuel tank to replace the fuel as it is used, while preventing fuel vapors from escaping the tank. The vapor valve is located on or near the fuel tank and allows fuel vapor but not liquid fuel to flow from the tank to the charcoal canister.

The charcoal canister contains activated charcoal that adsorbs the fuel vapors from the fuel tank. When something is adsorbed, it is held on the surface like a magnet, as opposed to being absorbed, which is akin to being sucked up, like with a sponge. The canister stores the fuel vapors when the engine is not running. When the engine is running, under certain operating conditions, a valve between the canister and engine opens, fresh air is drawn in through the canister air filter and the air and fuel vapors are drawn into the engine and burned, 'purging' the canister.

Where EVAP systems differ is in when and how canister purging takes place. Early systems used ported vacuum and a check valve to make sure purging would not occur at idle and thermovalves to make sure purging only occurred after the engine reached a certain operating temperature. As emissions requirements became more stringent, more sophis-



1	Fuel Filler Cap
2	Fuel Tank Pressure Sensor
3	Fuel Vapor Vent Valve
4	Evaporative Emission Canister Purge Valve
5	Canister Vent Solenoid
6	Evaporative Emission Dust Separator
7	Evaporative Emission Canister
8	Fuel Tank
9	Fuel Vapor Vent Valve
10	Fuel Filler Pipe Check Valve

Typical evaporative emissions control system *(Courtesy: Ford Motor Co.)*

ticated purging controls were called for. Today charcoal canister purging is controlled by the PCM/ECM. The PCM/ECM determines when the canister should be purged based on various sensor inputs. When purging is needed, the PCM/ECM operates a solenoid valve, which controls the vacuum to purge the canister. Generally, the purge solenoid is activated when the engine is running above idle speed and at normal operating temperature.

OBD II vehicles have enhanced EVAP systems (leak detection). A fuel tank pressure sensor and canister vent solenoid are added to the EVAP system for diagnostic purposes. The solenoid is located in the fresh air supply hose to the sealed charcoal canister. On a non-enhanced EVAP system, the canister is open to the atmosphere. The canister vent solenoid is normally open, allowing fresh air to be drawn into the canister. The PCM/ECM activates the solenoid during the EVAP leak test to block the entrance of outside air.

Diagnosis And Testing

The EVAP system can malfunction and allow fuel vapors to escape into the atmosphere or cause driveability problems like rough idle and stalling. Begin diagnostics by checking for any EVAP related scan tool data and DTCs.

Visually inspect the system, looking for cracked, broken or missing vapor hoses, which can cause vacuum leaks and fuel odors. Make sure all hoses are routed properly and connections at the tank, canister and engine are secure. Check the electrical wiring and connections for looseness, corrosion and chafing.

Inspect the fuel cap and gas tank filler neck for damage and correct fit. On OBD II vehicles, a cap that is not installed securely may set a DTC.

Inspect the canister for cracks or other damage. Be sure to inspect the canister air filter to make sure it is not clogged. If fresh air cannot be drawn into the canister, the fuel vapors cannot be purged. The filter is replaceable on some canisters, but on others the entire canister must be replaced.

To check EVAP system function, connect a scan tool to the DLC. Start the engine and let it idle. Using the scan tool, determine whether the solenoid is on or off. At idle the purge solenoid should be off.

Leave the scan tool connected and drive the vehicle. When the engine operating conditions for purging are met, again check the scan tool for purge solenoid operation. The solenoid should be on. If the solenoid is not on, check the power supply to the solenoid and the solenoid itself.

Purge solenoid valves can be tested to see if they will pass or block vacuum using a remote source of voltage and a hand vacuum pump. However, you must first determine whether the solenoid is normally closed or normally open. A normally open solenoid permits vacuum flow when de-energized. A normally closed solenoid blocks vacuum until it is activated by the PCM/ECM.

Enhanced EVAP

To test system integrity, the PCM/ECM can close the canister vent solenoid and open the purge valve. This will cause the fuel tank pressure sensor to indicate a vacuum if the system is properly sealed. If the vacuum fails to reach a certain level during two consecutive tests under the same conditions, the MIL will be illuminated and one or more DTCs will be set. The cause could be a loose fuel cap, a vapor hose loose or damaged, or a stuck open canister vent solenoid.

The system can also test for small leaks by closing the canister vent solenoid and purge solenoid and waiting for a loss of vacuum. If the vacuum drops too quickly during two consecutive tests under similar conditions, a DTC will set.

Some vehicles with enhanced EVAP systems may be able to perform additional tests and may have additional components. Always consult the vehicle service manual for information.

Notes

Computerized Engine Controls Diagnosis And Repair

ENGINE CONTROL SYSTEM OPERATION

In order to provide a combination of good overall performance, good fuel economy, and low emissions, computerized engine control systems became necessary. Simpler mechanical controls can no longer do the job alone.

Earlier automotive computers controlled only a single function, such as ignition timing or air/fuel mixture. Today's computers, commonly known as PCMs (Power-train Control Modules) or ECMs (Engine Control Modules), control air/fuel mixture, ignition timing and other functions.

All engine control systems have the same basic format of inputs, the PCM/ECM and outputs, which communicate using electronic circuits. Information is gathered by a wide variety of sensors, using several means. Some sensors vary a resistance to ground for temperature or pressure sensing. Some sensors report movement by a variable resistor. Other sensors vary a frequency output as pressure or air flow changes. All sensors supply the PCM/ECM with information on engine conditions.

Once the PCM/ECM sees what the operating conditions are, it compares what it sees to pre-programmed reference parameters in its ROM (Read Only Memory) or PROM (Programmable Read Only Memory), which it uses to adjust to changing engine conditions. Outputs are voltage commands, such as providing power or ground to circuits, or varying the pulse width of a square wave to control timing or injection.

Typical inputs are sensors such as the O2 (oxygen) sensor, ECT (Engine Coolant Temperature) sensor, MAP (Manifold Absolute Pressure) sensor, and TP (Throttle Position) sensor. On the output side of the computer, typical actuators include fuel injectors, an ignition timing module, an idle speed control motor, a cooling fan relay or an EGR control solenoid.

Most computerized engine control systems have self-diagnostic capabilities. When the ignition key is turned ON, the PCM/ECM sends out a 5-volt reference signal to its sensors and controlled devices, and examines the return signals from them as indications of the particular conditions to which they are being subjected. At the same time, the PCM/ECM is checking for problems within the system. It does this by comparing these inputs with its internal memory of what probable signals should be.

Suppose, for example, after the engine is running, the TP sensor indicates a closed throttle, the CKP (Crankshaft Position) sensor indicates 1000 RPM, but the MAP sensor registers atmospheric pressure instead of idle intake manifold pressure. By comparing these signals, the PCM/ECM recognizes an incompatibility. It knows that this is an impossible combination of signals, so it stores the information about this problem in its memory.

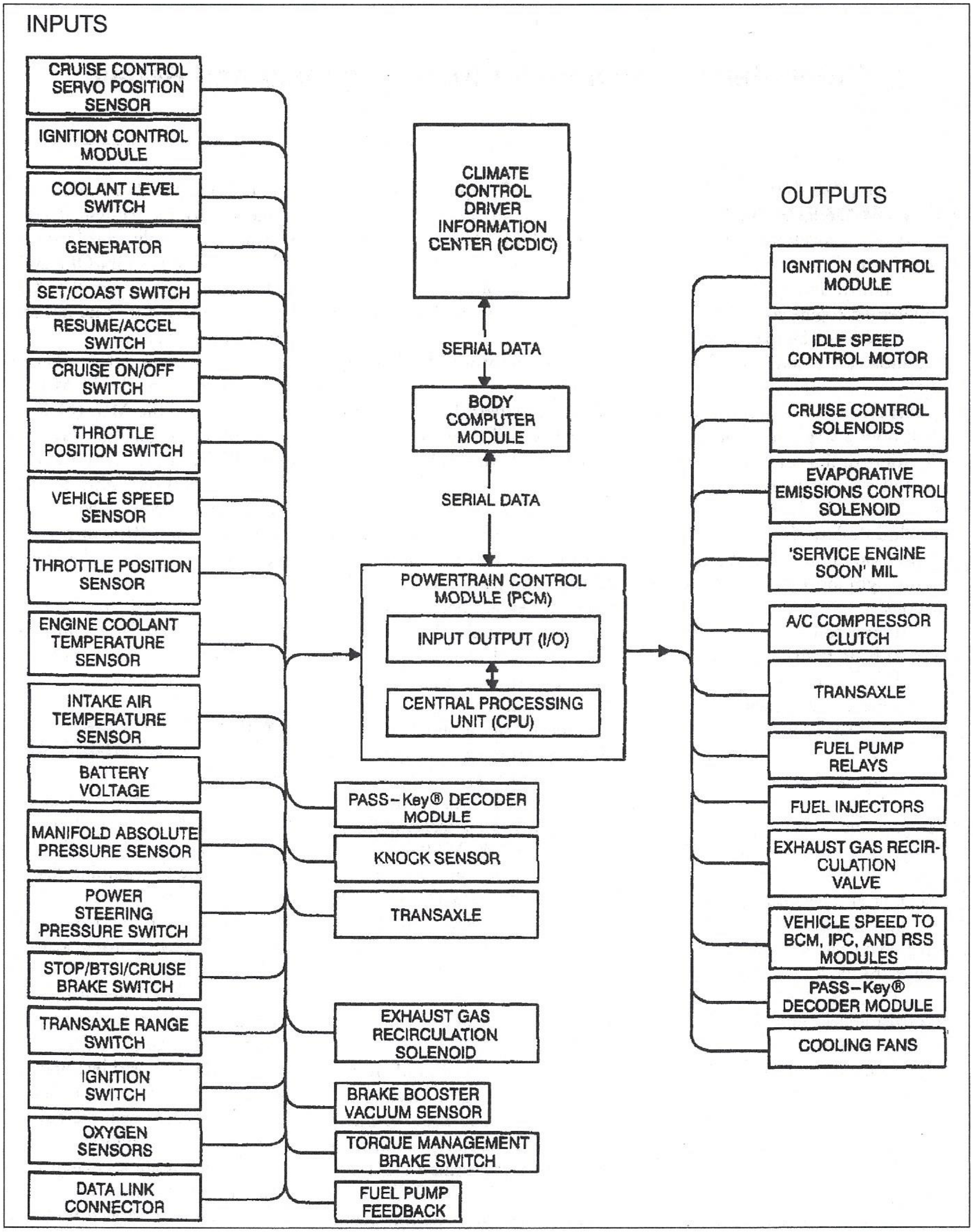
Problems that are found by the PCM/ECM during self-testing are stored as either hard faults or intermittent failures. Each type is assigned a number that represents a DTC that is stored in the PCM/ECM's memory. A hard fault is a problem that is found in the system at the time of the self-test, while an intermittent problem is a malfunction that occurred in the past, but is not present at the time of the self-test. Intermittent faults are usually stored for a specific number of key ON/OFF cycles, and are then erased from the PCM/ECM's memory if they do not reappear during that period.

Most of the time, when a DTC is stored in memory, the PCM/ECM will illuminate the MIL (Malfunction Indicator Light) (also known as the CHECK ENGINE or SERVICE ENGINE SOON light) to show that service is needed. Under normal conditions, the MIL will come on for a few seconds when the ignition key is turned ON and during engine cranking, but should go off when the engine starts. If the MIL comes back on, it means that there is probably a DTC stored in memory.

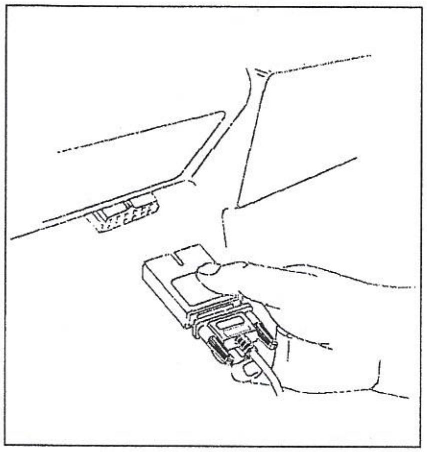
ENGINE CONTROL SYSTEM DIAGNOSIS AND TESTING

Diagnosis of electronic engine control systems should be performed in a logical manner. This begins with not automatically assuming that the problem is with the engine control system! Make sure the basic engine and related conventional systems are sound, using inspections and tests like those described elsewhere in this study guide, before getting involved with testing sensors. A driveability problem can be caused by something as simple as a broken vacuum line.

Become familiar with the capabilities of the engine control system on the vehicle you are servicing, using available service literature. Check TSBs (Technical Service Bulletins) for information about problems and fixes discovered in the field and not covered in the service manual.



Inputs and outputs in a typical electronic engine control system. *(Courtesy: GM Corp.)*

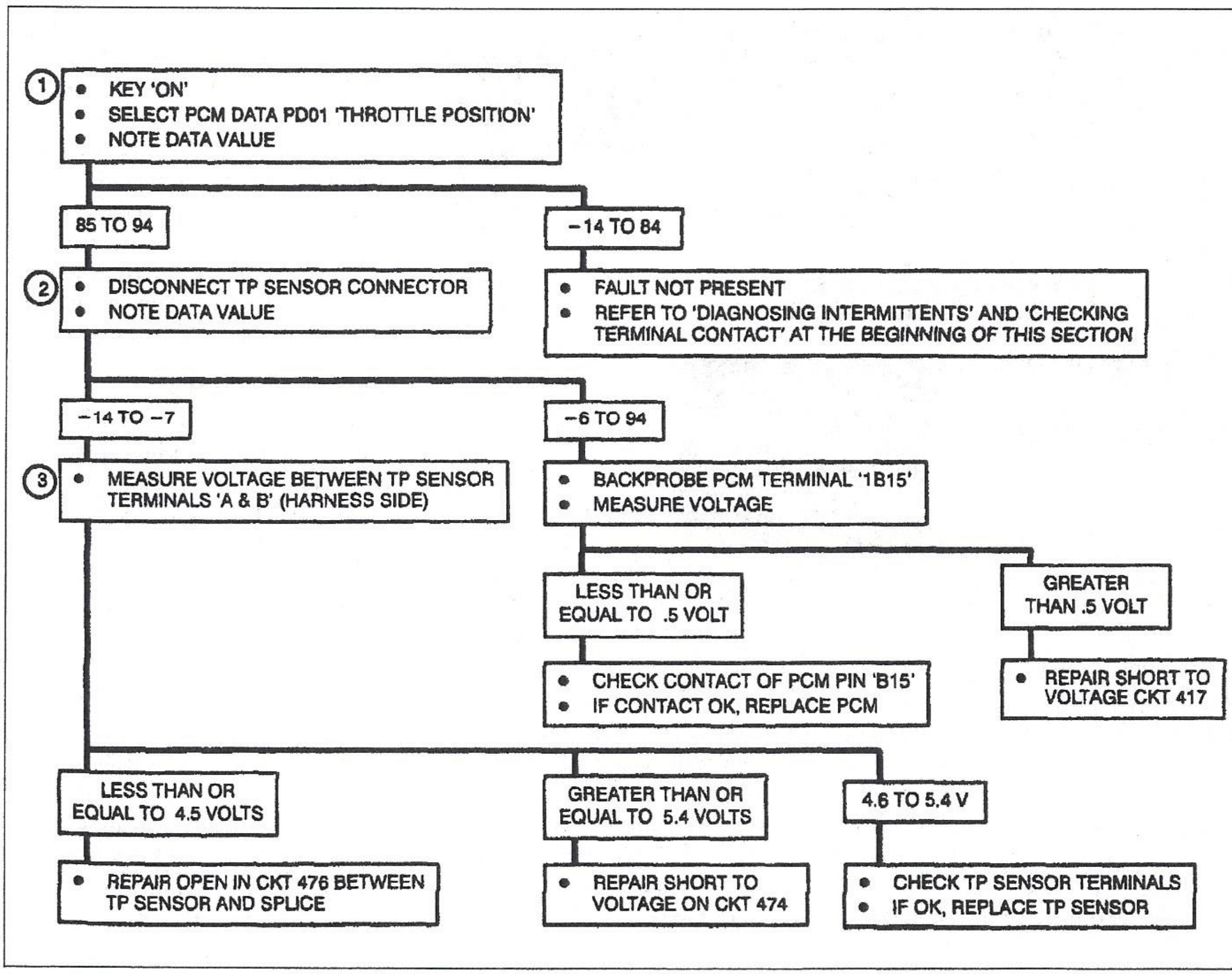


The DLC (Data Link Connector) on all OBD II vehicles is located under the dash on the driver's side of the vehicle. *(Courtesy: Snap-on Tools)*

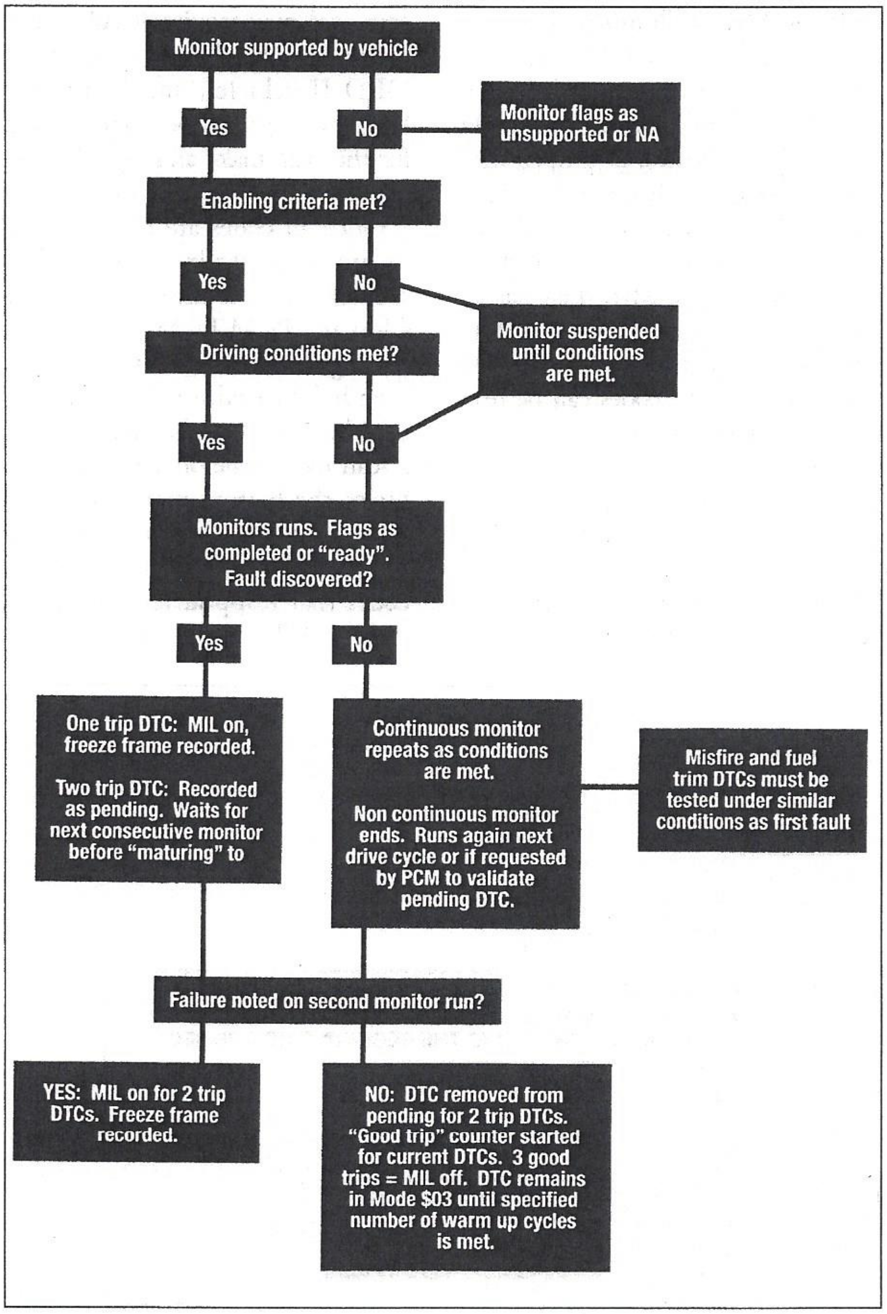
If the MIL is illuminated or you suspect that there are DTCs stored in the PCM/ECM memory, the codes can be retrieved in several ways. On some older vehicles, a jumper wire can be connected between terminals of the DLC, which causes the engine control system to go into self-diagnostic mode. The MIL then flashes and codes can be read by interpreting the flashes with a service manual. On other vehicles, the codes can be read on a digital display on the instrument panel.

A scan tool must be used to obtain codes from OBD II systems, but it is also a better choice for older vehicles as well since a scan tool can perform tests and read datastream values. The scan tool may require an adapter to connect to the DLC on older pre OBD II vehicles, and it must be loaded with the proper data cartridge for the year, make and model of the vehicle being serviced.

Once all codes are retrieved and recorded, determine whether they are hard faults or intermittent faults. Clear the PCM/ECM memory following the manufacturer's recommended procedure. On OBD II vehicles codes can be cleared using a scan tool, while on some older vehicles the battery may have to be disconnected. Drive the vehicle and watch for the MIL to illuminate. Any codes that reappear are hard faults and should be serviced first.



Typical diagnostic chart for a specific trouble code. *(Courtesy: GM Corp.)*



OBD II monitor flowchart.

Once you have the DTCs that require diagnosis, refer to the appropriate service information to identify the systems and circuits that the DTCs represent. The diagnostic charts will describe the circuit and the fault that the code represents and contain troubleshooting procedures and tests that must be performed, to determine the cause of the malfunction. These tests usually describe various voltage and resistance measurements using a DMM.

If the vehicle exhibits driveability problems like rough idle, stalling, surging or hesitation, but does not set any codes, refer to the symptom-driven diagnostic charts contained in most manufacturer's service manuals.

Scan tool datastream values can also be invaluable when there are no codes. Datastream values are the actual electrical values of the engine control system sensors and actuators measured while the engine is operating. These values can then be compared with the manufacturer's specifications. Since a value that is not within spec should in theory set a DTC, a value that is almost out of spec might not set a DTC but could indicate a problem area.

Intermittent driveability problems are usually more difficult to diagnose and repair. You may have to try to recreate conditions described by the driver to get an intermittent code to reset. Since intermittent problems are often caused by damaged wiring and connectors, tapping and wiggling wiring harnesses and connectors can also get problems to reoccur and reset codes.

A scan tool feature that is helpful for finding intermittent problems is the ability to take a 'snapshot' of the engine control system operating parameters. A vehicle with an intermittent problem can then be driven in an attempt to recreate the conditions for the problem. When the symptoms appear, the technician can then record the system electrical values. The technician can then analyze the data to see what values changed at the time of the malfunction.

OBD II Monitors

The PCM/ECM on OBD II vehicles performs continuous tests on emissions-related systems and components. These tests are known as 'monitors'. Some monitors run all the time and are called 'continuous' monitors. Others are run once per drive cycle and are referred to as 'non-continuous' monitors.

A drive cycle consists of a set of conditions necessary to run the monitor to completion. This usually involves operating the vehicle while in closed loop under specific operating conditions. Always refer to the vehicle shop manual, as each monitor has a specific 'enable criteria'—the conditions that must be met for a monitor to be completed—and the criteria varies among models and manufacturers.

There are three kinds of tests that can be performed during a monitor. The first is where the PCM/ECM tests a component's electrical circuit for opens and shorts to power or ground. The second involves comparing data between sensors to see if the information makes sense (as in our earlier CKP/MAP sensor example). In the last type of test, the PCM/ECM can check the function of output devices by commanding the component and checking the result.

If the monitor results indicate a failure, a fault will be recorded in the PCM/ECM's memory. For some faults, the PCM/ECM will set a DTC and turn on the MIL. However, for most DTCs the PCM/ECM must see the same fault occur during two 'trips'. A trip is a completed drive cycle. After the first trip, the fault is recorded as 'pending'. Once the PCM/ECM sees the same fault the next time the monitor runs, the PCM will turn on the MIL. If the same fault is not seen during the next monitor, the pending code will be cleared.

If the MIL is turned on because of a particular DTC, and the monitor responsible for that DTC runs three times in a row without seeing the failure, the PCM/ECM will then turn off the MIL. However, the DTC will remain in the PCM/ECM's memory until a certain number of warm-up cycles occur.

To check monitor status, connect a scan tool to the DLC. On some scan tools you may have to access Mode $01. 'Complete' or 'ready' indicate monitors that have run successfully. 'NA' or 'not available' indicates monitors that are not used on this particular vehicle. Monitors shown as 'not ready' or 'incomplete' means that either the drive cycle criteria have not been met and the monitor isn't finished or a related monitor has recorded a fault.

Just because a monitor has not completed does not mean that it cannot be useful in achieving a diagnosis. Examine the vehicle service information to see how the system operates. Look for information on conditions that are necessary for a monitor to complete. Here you may find that a fault derived from one monitor is keeping others from completing. Also look for what various incomplete monitors have in common. Access Mode $07 and look for pending faults that may indicate an impending failure. Being able to look at the engine operating conditions at the time a code was set can also assist with diagnosis. This 'freeze frame data' can be accessed in Mode $02.

Once repairs are completed, use Mode $04 on the scan tool to clear codes and reset all monitors. Operate the vehicle in a manner necessary to satisfy the drive cycle requirements for the monitor that set the DTC in question. Recheck the monitor status and check for pending codes to see if the fault returned.

Service Precautions

The following precautions should be observed when testing or servicing components and circuits of an electronic engine controls system:

- Never disconnect any electrical connector with the ignition switch ON. This creates high voltage spikes, known as short duration transients, which can permanently ruin delicate circuits
- Some electronic engine control circuits are designed to carry very small amounts of current. For this reason, a high-impedance (over 10 megohms) digital meter must always be used when troubleshooting computer-related circuits
- Always connect the negative lead of a voltmeter first.
- Never use a test light unless specifically instructed to do so in the manufacturer's diagnostic procedure
- To prevent damage from electrostatic discharge, always touch a known good ground before handling an electronic component. This is especially important after sliding across a seat or walking a distance
- Do not touch the terminals of an electronic component unless it is necessary, as oil from skin can cause corrosion.

Electrical Testing

In order to perform diagnostic tests, a technician must be able to measure voltage, voltage drop, amperage and resistance using a DMM.

Voltage Measurements

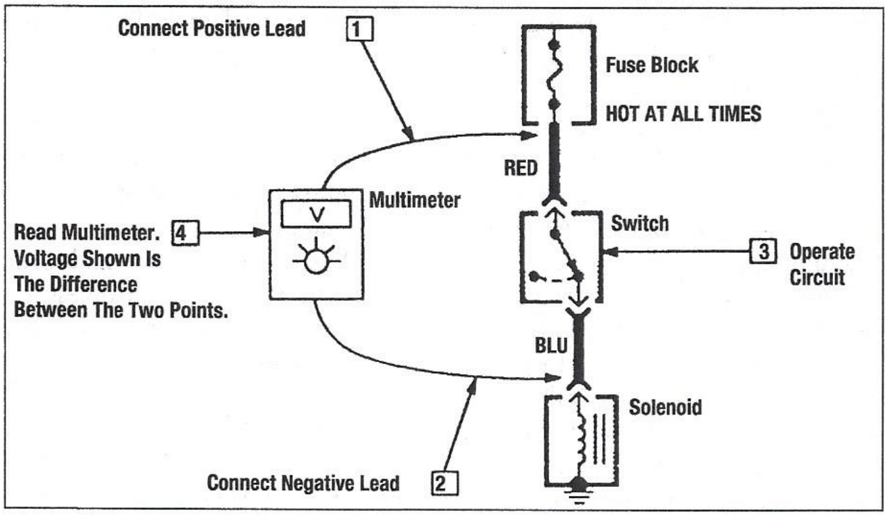
If there is a DC/AC switch, make sure it is switched to the DC position. Set the function/ range control to the desired volts position. If the magnitude of the voltage is not known, set the switch to a range that will read the most voltages seen on the vehicle. (Normally, a 20V range will be sufficient). Reduce the range until you have a satisfactory reading. Connect the test leads to the circuit being measured and read the voltage on the display.

Resistance Measurements

Set the function/range control to the desired position. If the magnitude of the resistance is not known, set the switch to the highest range, then reduce until a satisfactory reading is obtained. If the resistance being measured is connected to a circuit, turn off the power to the circuit being tested. Turn off the ignition. Connect the test leads to the circuit being measured and read the resistance on the display.

Voltage Drop

Each component in a circuit has some resistance value, and the voltage is reduced as it moves the circuit's resistive loads. The sum of all the voltage drops across a circuit will equal



Using a voltmeter to perform a voltage drop test.

the original amount of applied voltage. Voltage never disappears—it is merely converted into another form of energy by the resistance of the load or wires.

The voltage available at any point depends on the circuit resistance. The higher the resistance, the more voltage is needed to force current through the circuit. Resistance of any type will use some voltage potential, so the use of voltage is lost across any type of resistance.

To measure voltage drop, set the voltmeter switch to the 20-volt position. Connect the voltmeter negative lead to the ground side of the resistance or load to be measured. Connect the positive lead to the positive side of the resistance or load to be measured. Read the voltage drop directly on the 20-volt scale.

A high voltage reading is a sign of too much resistance. Converse-ly, if the voltage drop is too low, then that condition signifies too little resistance.

Amperage Measurements

An ammeter is connected in series with the circuit, so all the current passing through passes through the ammeter. This means that the fuse must be removed from the circuit, or a connection broken. The ammeter is then inserted into the circuit to replace the fuse or join the two halves of the circuit, observing proper polarity with an analog meter.

Connect the ammeter as you would a voltmeter, with the red or positive probe connected on the battery positive side of the circuit, and the negative lead toward the ground side of the circuit or the battery negative terminal. When working on the voltage side of the load, the negative lead would then be on the load side of the ammeter. If working on the ground side, the positive lead would be on the load side of the ammeter, and the negative lead would then be on the side away from the load.

The ammeter should always be set to the highest range before starting to take a measurement. Then, lower the setting one notch at a time until a usable reading is obtained. If the reading is more than half the scale on an analog ammeter or more than half the digital range on a digital ammeter, don't switch to a lower range. This will protect an analog unit from damage. A digital unit will not be able to give a reading if the amperage measured is out of range.

Engine Control System Sensors

Oxygen Sensor

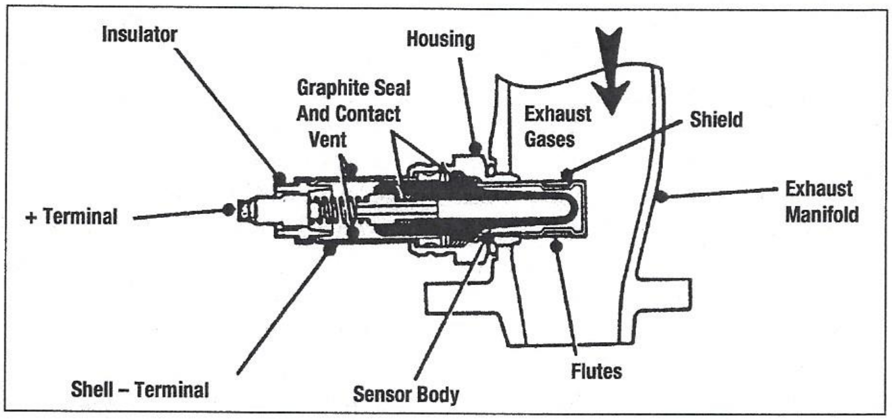
The oxygen sensor (O2S) is located in the exhaust stream, ahead of the catalytic converter, on the exhaust manifold or exhaust pipe. It is used to detect the concentration of oxygen in the exhaust gas. Input from the oxygen sensor is used by the PCM/ECM to regulate the air/fuel mixture. Using highly refined metals (zircon and platinum), the sensor uses differences between the oxygen content of the surrounding air and the oxygen content of the exhaust to generate a voltage, which is transmitted to the PCM/ECM. The computer in turn reacts to the changing voltage value by adjusting the fuel metering at the fuel injectors.

There is an opening in the oxygen sensor that is exposed to atmosphere. The atmosphere contains 21% oxygen, so this percentage is used as a reference with which to compare the oxygen content of the exhaust. The oxygen sensor's voltage signal ranges from zero to one volt. Signals below 450 mV indicate a lean condition (excessive oxygen), while readings above 450 mV point to a rich condition (little residual oxygen).

Most newer vehicles use a heated oxygen sensor (HO2S), which contains a heating element that brings the sensor to operating temperature faster. Since an oxygen sensor must be hot (at least 500°F) in order to work, the heating element allows the PCM/ECM to use the sensor's input signals sooner. The heating element also stabilizes the temperature of the sensor during cold weather.

Several oxygen sensors may be installed on a vehicle. V6 and V8 engines can have a sensor installed in each manifold. The sensor(s) that is located closest to the engine is used to check the exhaust oxygen content as the exhaust leaves the engine and is known as a primary sensor. A secondary sensor may be installed closer to the catalytic converter to monitor the oxygen content of the exhaust before it enters the converter.

OBD II systems use a sensor mounted downstream from the cata-



Cutaway view of a typical oxygen sensor.

lytic converter to check its efficiency. This sensor checks the oxygen content of the exhaust after it leaves the converter and is known as a catalyst monitor.

Since the oxygen sensor signal is used by the PCM/ECM to regulate the air/fuel mixture, a faulty oxygen sensor can cause the PCM/ECM to meter the fuel delivery incorrectly, causing overly rich or lean misfire conditions.

Inspect the oxygen sensor wiring for cuts and abrasion and contamination from oil or transmission fluid. The cavity in the sensor that senses the oxygen content in the atmosphere must be clear for the sensor to function properly. Disconnect the electrical connector and inspect the terminals for corrosion, distortion and contamination.

Start the engine and allow it to run until it reaches normal operating temperature. The oxygen sensor must be tested with the engine at normal operating temperature and the engine control system in closed loop.

Connect the positive lead of a DMM to the sensor signal wire and the negative lead to the engine ground. The voltage reading should fluctuate as the oxygen sensor detects varying levels of oxygen in the exhaust stream.

If the sensor reads above 550 mV constantly, the air/fuel mixture is probably too rich or the sensor may be contaminated from carbon caused by rich air/fuel mixtures, the use of leaded fuel, or from silicones found in antifreeze or sealers. If the sensor voltage reads below 350 mV constantly, the air/fuel mixture may be too lean, there may be an exhaust leak near the sensor, diluting the reading, there may be high resistance in the wire between the sensor and the PCM/ECM, or the sensor may be defective.

Under normal conditions, the sensor should fluctuate high and low. If the sensor voltage does not fluctuate, the sensor may be defective. However, before condemning the sensor, try forcing the system rich by restricting the air intake or injecting propane into the air inlet. The voltage reading should increase to 800-900 mV. Then, force the system lean by pulling off a large vacuum hose. The voltage reading should drop to 200-300 mV.

If the voltage did not change accordingly when the system was forced rich or lean, then the sensor is defective and must be replaced. Remove the sensor from the exhaust system and examine its appearance. Black sooty deposits on the sensor tip may indicate a rich air/fuel mixture. White gritty deposits could be an internal antifreeze leak. Brown deposits indicate oil consumption. All of these contaminants will destroy a sensor, and if the problem is not repaired the new sensor will also be destroyed.

If the catalytic converter is functioning properly, the voltage signal from the catalyst monitor will fluctuate very little in comparison to the signal from the primary oxygen sensor. If the signal from the catalyst monitor is too similar to the signal from the primary oxygen sensor, it means that the converter is not functioning properly.

Camshaft Position Sensor

The Camshaft Position (CMP) sensor determines when Top Dead Center (TDC) compression of the No. 1 cylinder occurs and then converts it into a pulse signal that is sent to the PCM/ECM. The PCM/ECM uses the signal to determine correct injection sequence. The sensor may be located in the distributor housing; it may obtain its signal from the camshaft timing gear; or, on vehicles with distributorless ignition systems, the CMP sensor may be in an assembly that replaces the distributor. Regardless of its location, in all cases this sensor reacts to the camshaft position.

Essentially, there are two types of camshaft sensors. One is a Hall effect switch and the other is a magnetic reluctance sensor, or PM generator (permanent magnet generator). The easiest way to distinguish the Hall effect switch from magnetic sensors is to remember that the Hall effect switch will have a three-wire harness and control an existing voltage and the reluctance sensors usually have two wires and create a voltage.

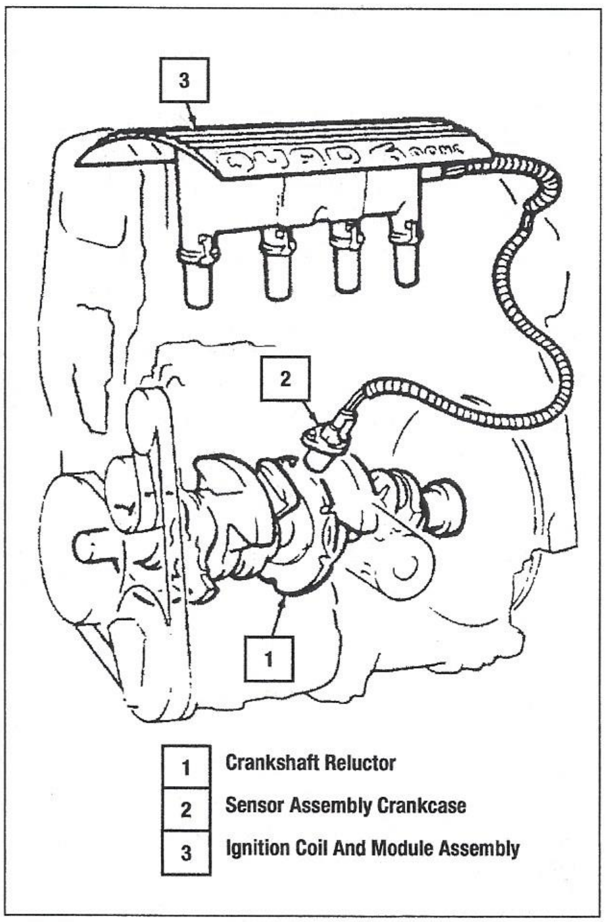
If there is spark at the coil or if the fuel injectors are injecting fuel, the problem is most likely not the cam sensor.

When suspecting a camshaft sensor problem, first perform a visual inspection; most problems can be found in wiring harnesses and connectors.

To test a Hall effect switch, set a DMM to the volts setting and check the voltage between the power and ground wires. This voltage may be 4, 6, 8 or 12 volts depending on the system. Take note of this voltage reading.

Connect the DMM between the signal terminal and the ground wire. Rotate the engine with the starter motor by tapping the ignition key. When the engine is rotated, the signal should fluctuate between 0 volts and the system voltage noted in the earlier step. While rotating the engine, check for damaged shutter blades or any indication that the shutter blades are hitting the magnet. You can use a scope to monitor the half wave pulses, which you should see on the output wire. If the hall switch is powered and grounded properly, and the mechanical parts move as intended when the engine is cranked, you should see the pulses. If not, the switch is bad.

To check a magnetic reluctance sensor, disconnect the sensor connector. Using a DMM set to the ohms setting, check resistance across the sensor terminals. The resistance should be approximately 500 to 1200 ohms at 70°F (21°C). Resistance will vary with temperature. This test should be performed with the ignition on and engine off. Using a thin piece of steel, check the tip of the sensor to be certain that it is magnetized.



Magnetic reluctance type crankshaft sensor
(Courtesy: GM Corp.)

Crankshaft Position Sensor

The Crankshaft Position (CKP) sensor generates a signal to the ignition module, which results in a reference pulse being sent to the PCM/ECM. The PCM/ECM uses this signal to calculate crankshaft position and engine speed for injector operation.

As with camshaft sensors, there are two types of crankshaft sensors. One is a Hall effect switch and the other is a magnetic reluctance sensor.

There is also a dual crankshaft or combination sensor. This design combines two sensors and is normally mounted on a pedestal on the front of the engine, near the harmonic balancer. This type of crankshaft sensor is usually a Hall effect switch, and usually requires adjustment during replacements. Failure to make this adjustment will usually allow the sensor to be struck by the rotating vanes behind the harmonic balancer, damaging both the vanes and the new sensor.

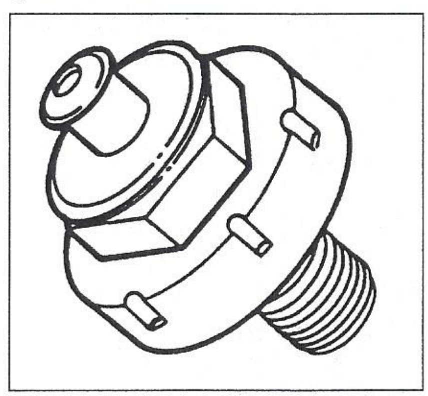
Magnetic reluctance type crankshaft sensors are usually mounted on the side of the engine, protruding into the block. You can test the voltage output of these permanent magnet sensors (PM generators) by measuring their voltage output, which varies by cranking rpm. Record some readings on known good sensors in use in vehicles you service, so you'll have benchmark values by which to judge the output of these sensors when a similar vehicle comes in with a no-start condition.

Testing of each type of crankshaft sensor is the same as testing of the camshaft sensor types.

Knock Sensor

The Knock Sensor (KS) is mounted in the engine block or manifold. When spark knock or pinging is present, the sensor produces a voltage signal that is sent to the PCM/ECM. The PCM/ECM will then retard the ignition timing based on these signals.

When suspecting a knock sensor problem, first perform a visual inspection. Most problems can be found in wiring harnesses and connectors. The voltage and resistance at the knock sensor can be checked using a DMM. Refer to the vehicle manufacturer's test procedures and specifications.



Typical knock sensor. It contains a piezoelectric crystal that produces an AC voltage under vibration

Intake Air Temperature Sensor

The Intake Air Temperature (IAT) sensor advises the PCM/ ECM of changes in intake air temperature (and therefore air density). As intake air temperature varies, the PCM/ECM, by monitoring the voltage change, adjusts the amount of fuel injection according to the air temperature. These sensors, like the similar coolant temperature sensors, are 'negative coefficient' sensors, meaning that the resistance varies inversely by temperature. More voltage is dropped across the sensor when it is cold, and less when hot. This is why you see a low voltage reading (0.5 to 0.6v) across a coolant sensor at operating temperature.

If you don't want to use live voltage readings, unplug the electrical connector from the IAT sensor. Using an ohmmeter, measure the resistance between both terminals. The resistance should be approximately 3000 ohms at room temperature (70°F, or 21°C). The intake air temperature sensor and coolant temperature sensor resistance values are usually the same. Because of this, an easy test on a cold engine (sitting overnight) is to compare the resistance values of the two sensors. If the engine is cold, and both sensors are the same temperature, the resistance values should be about the same.

Start the engine, and as it warms up check that the values change smoothly, or heat the sensor up using a hair dryer to see if the values change smoothly.

If the resistance value doesn't change, the sensor is probably defective. A thermometer and a table of expected voltages are also an easy way to test the sensor at a wide range of temperatures. Some manufacturers build the intake air temperature sensor into the air flow sensor. In this case, they are usually replaced as a unit. Since this type of sensor is expensive, careful testing should be performed to make certain that it is defective.

ECT And IAT Sensors		
Temperature vs. Resistance Values (approximate)		
°F	°C	ohms
210	100	185
160	70	450
100	38	1,800
70	20	3,400
40	4	7,500
20	-7	13,500
0	-18	25,000
-40	-40	100,700

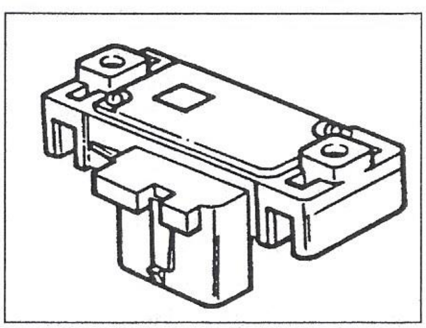
Typical resistance values of a Negative Temperature Coefficient (NTC) sensor

Engine Coolant Temperature Sensor

The PCM/ECM sends the Engine Coolant Temperature (ECT) sensor a voltage and the sensor varies the voltage according to coolant temperature. When the sensor fails, it can prevent the system from going into closed loop. Depending upon its failure mode, it can also cause poor fuel economy and hesitation or stalling when the engine is cold. The ECT sensor is also a Negative Temperature Coefficient (NTC) sensor and is tested similar to the IAT sensor.

Manifold Absolute Pressure Sensor

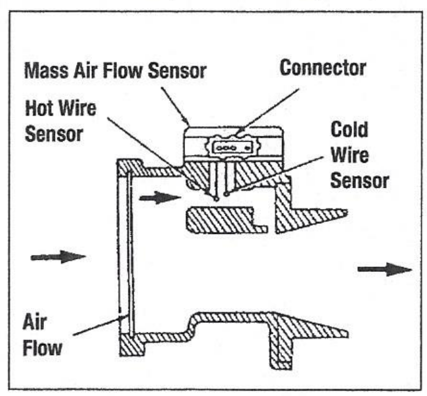
The PCM/ECM sends the Manifold Absolute Pressure (MAP) sensor a voltage and the sensor varies the voltage according to manifold vacuum or engine load. A bad MAP sensor can cause poor fuel economy, poor driveability and detonation. There are two types of MAP sensors, the analog signal type, which is tested with a voltmeter, and the frequency signal type, which is tested with a hertz meter or digital tachometer. If you are not certain with which type the vehicle is equipped, check the reference voltage (usually around 5 volts), and then check the signal voltage. If the signal voltage never changes from 2.5 volts, it is most likely a frequency type. If still not certain with which type the vehicle is equipped, check the service manual.



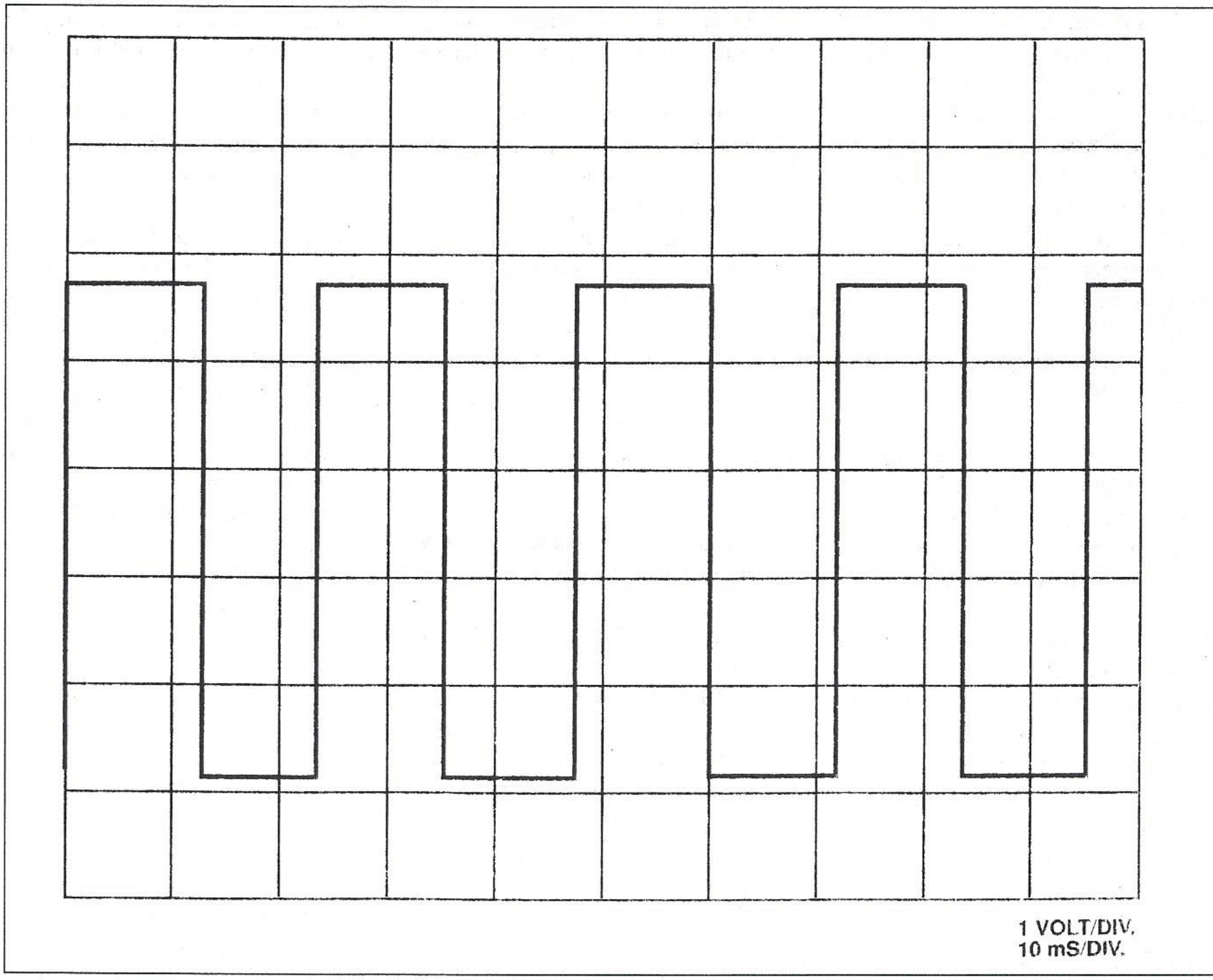
Manifold Absolute Pressure Sensor

Analog signal type sensors are usually located in the engine compartment near the air cleaner, mounted on the inner fender or firewall. They can be checked using a DMM and a hand vacuum pump. Disconnect the MAP sensor electrical connector. Connect one jumper wire from the connector to the MAP sensor's terminal A. Connect the other wire from the connector to terminal C.

Connect the positive lead of a DMM to terminal B and the negative voltmeter lead to ground. Turn the ignition key ON. If the reading falls in the range of 4.6 to 5.0 volts, the sensor is functioning properly, at this point. Start the engine and let it idle. An idling engine will produce a large amount of intake manifold vacuum, which should pull the MAP sensor's voltage down to a low reading of approximately 1 to 2 volts (reading will vary with altitude). This test indicates that the MAP sensor is responding to vacuum. Check the service manual for the specifications for the vehicle you are testing.



Cross section of a Mass Air Flow sensor



Typical MAF sensor signal on an oscilloscope. *(Courtesy: GM Corp.)*

MAP sensor frequency can be measured with a digital tachometer. Never use an analog tachometer. A tachometer is a frequency counter. It measures pulses received per second (Hz) and converts them to rpm. If in doubt, always refer to the vehicle service manual for values and testing procedures.

Mass Air Flow Sensor

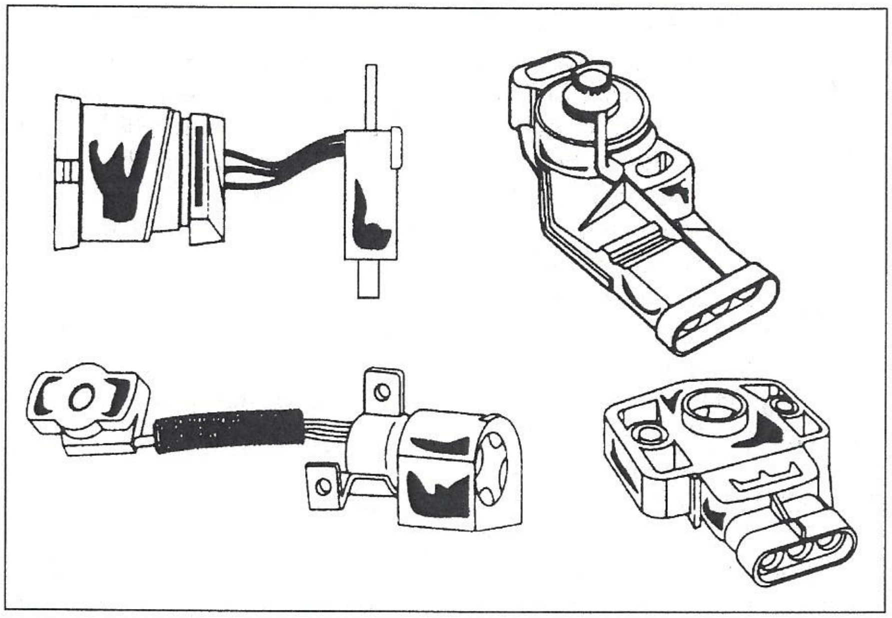
In the Mass Air Flow (MAF) sensor, incoming air flow cools a heated wire inside the sensor. The temperature, and therefore the resistance, of the heated wire varies according to changes in air flow. The PCM/ECM monitors the amount of power required to keep the heated wire at a specified temperature. The PCM/ECM uses this information to determine the operating conditions of the engine to control fuel delivery. A large quantity of air indicates acceleration, while small quantities indicate deceleration or idle. These values must correspond to the actual condition. In other words, if a large air flow is indicated, the throttle should be open and the rpm high.

You can test the MAF with a DMM or an oscilloscope. The waveform on an oscilloscope should appear as a series of square waves. The frequency should increase smoothly and proportionately when engine speed and intake air flow is increased. If the frequency is erratic, the MAF or circuit wiring is defective.

Another method of checking a MAF sensor is to measure the pulse width of the fuel injector. Pulse width is a measurement of how long the fuel injector is open, or how much fuel the fuel injector is delivering. Restrict the air intake and look for a change in fuel control. If a change in fuel delivery is noticed, the MAF sensor is most likely working properly.

Some MAF sensors are sensitive to vibration. Gently tap on the MAF; if the engine idle changes, the MAF sensor is defective.

The symptoms of a bad MAF sensor include hesitation or stumbling during acceleration, stalling or intermittent stalling during acceleration,



Various types of throttle position sensors

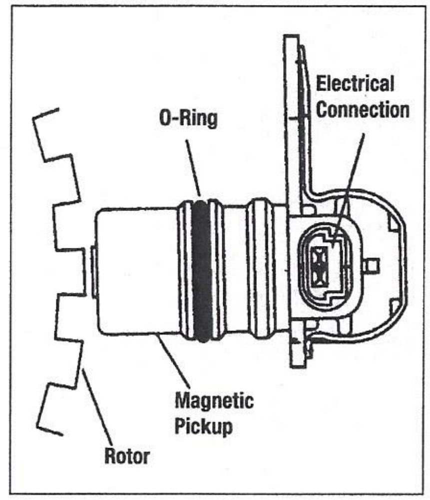


Diagram of a typical Vehicle Speed Sensor (VSS). *(Courtesy: GM Corp.)*

misfiring under load, and surging at cruising speeds.

Always be sure that the air duct from the air flow sensor to the throttle body or intake manifold is connected and in good condition. If the duct falls off or engine backfiring blows it off, the engine won't start. Furthermore, air leaks in the duct will lean out the fuel mixture and may cause lean-related performance problems. Remove the duct and inspect it closely to look for cracks in the rubber.

Throttle Position Sensor

Throttle Position (TP) sensors are usually located on the side of the fuel injection throttle body. These are most often variable resistors. TP sensors can be checked using a DMM set to the volts setting. TP sensor failure is common because it has parts that move each time the accelerator is depressed or released. This is one of the more common parts that require replacement or adjustment, due to the amount of movement this sensor endures every time a vehicle is driven. However, it is one of the easiest components to test and replace. Be certain the problem is the sensor, and not its connector.

Before testing a TP sensor, perform a visual inspection. To test most TP sensors, disconnect the TP connector and install jumper wires from the sensor connector to the wiring harness. You can attach test leads to the jumpers, or you can use 'bed of nails' test clips on the harness. This permits the sensor to operate properly during testing. Most TP sensors use three wires: a 5-volt reference wire, a signal wire to the PCM/ECM and a ground wire. Some may have additional wires, used for integral switches in the sensor.

Connect a DMM set to the volts setting between the signal wire (usually the center terminal) and the ground wire (one of the outside terminals) on the TP sensor. This test should be performed with the ignition ON and the engine OFF.

Check the voltage reading with the throttle in the idle position. Usual voltage readings are approximately 0.45 volts.

Open the throttle slowly. The voltage should increase smoothly as the throttle is moved to the WOT (Wide Open Throttle) position. Usual voltage at the WOT position is approximately 4.5 volts.

Release the throttle slowly. The voltage should decrease smoothly as the throttle is moved to the idle position. Erratic readings or a momentary infinite reading indicate a defective sensor. The voltage test of a TP sensor is best accomplished using a scope, as even the smallest dropouts can be easily seen as the throttle is moved.

Vehicle Speed Sensor

The vehicle speed sensor is a permanent magnet sensor. The VSS consists of a permanent magnet surrounded by a coil of wire. A toothed ring, also called a reluctor, is located on the transmission's output shaft. The VSS and the reluctor are positioned so that a slight air gap (generally 0.050 in.) is maintained between the two. As the output shaft turns, the reluctor causes the magnetic field of the VSS to continually change from strong to weak. This produces an alternating current output, which increases in both frequency and amplitude as vehicle speed increases.

The VSS produces its own voltage. The resistance of the coil windings in the VSS is typically around 1200 ohms. Always check the manufacturer's specification when performing diagnosis. The computer uses the VSS signal to control shift timing, TCC (Torque Converter Clutch) application, cruise control and the electronic speedometer.

To test the VSS, disconnect the wiring connector from the sensor and connect the leads of a DMM, set on the ohms position, to the sensor terminals. Compare the resistance reading with the manufacturer's specifications. High or infinite resistance readings are caused by excessive resistance or possibly an open circuit. If the resistance reading is low there is a short circuit.

Next, change the DMM to the AC volts position. Raise and safely support the vehicle so the drive wheels are off the ground. Start the engine and place the gear selector in Drive. Observe the DMM as the engine speed is increased. The voltage reading should increase smoothly as engine speed increases.

The VSS can also be checked using a lab scope. In place of the DMM, connect the lab scope leads to the sensor terminals. When the speed is constant, a sine wave pattern should appear on the scope. As speed is increased the AC signal should change in amplitude and frequency.

PCM/ECM Reprogramming

Over the years, the OEMs (Original Equipment Manufac-turers) have found it necessary in many cases to reprogram vehicles' PCM/ECMs with changes to correct various performance problems. These changes are usually detailed in TSBs. On pre-OBD II vehicles, it was common practice to replace a PROM (Program-mable Read Only Memory) or chip to update the PCM/ECM. However, OBD II vehicles do not have replaceable PROMs. OBD II PCM/ECMs have an EEPROM (Electrically Erasable Program-mable Read Only Memory) chip, which can be reprogrammed without removing the unit from the vehicle.

At first, updates could only be installed using a manufacturer-specific tool, but because the U.S. EPA (Environmental Protection Agency) wants the aftermarket to be able to perform emissions-related repairs and they cannot require shops to purchase specific brands of tools, the SAE (Society of Automotive Engineers) and the tool and equipment industry developed communication protocol J2534. This is a translator that allows a PC (Personal Computer) to communicate with the PCM/ECM on all makes and models. The translation software is contained in a pass-through device that connects to the PC and the vehicle's DLC.

Before reprogramming a PCM/ECM, the existing calibration must be identified. This can be done using Mode $09 on a scan tool and then checking a calibration list at the OEM web site.

The updates and installation programs are available through the OEM web sites. To program a PCM/ECM without using a factory scan tool, you need the software, a PC or laptop computer running the Windows 2000 or later operating system, a high-speed Internet connection and the pass-through tool. A high-speed Internet connection is essential because the programs are large and would take many hours to download using a dial-up connection. It is also recommended that a stand-alone PC or laptop be used, instead of one that is also used for other jobs in the shop. Other computer processes can interrupt or stop the reprogramming process, which can ruin the PCM/ECM.

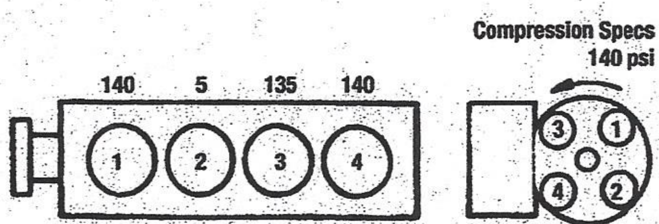
Two software packages are needed for programming, the updated PCM/ECM software and the computer program that installs the software on the PCM/ECM. These can usually be downloaded to the PC or laptop before connecting the computer to the pass-through tool, however some manufacturers require a 'live' link between the vehicle and the OEM's server while the PCM/ECM is being updated.

As stated earlier, interrupting reprogramming can cause the process to fail and possibly ruin the PCM/ECM. To avoid this, pop-up blockers, virus protection and firewall software must be turned off. E-mail programs, screensavers and all other automatic processes should be disabled.

Another way that reprogramming can be interrupted is if the vehicle's battery voltage drops. During reprogramming, battery voltage to the PCM/ECM and the pass-through tool gets power from the OBD II connector and must remain constant. The ignition switch must be turned on for part of the process, which may automatically turn on lights or other loads that could cause a significant battery voltage drop. To avoid this, connect a second fully charged battery to the vehicle battery with jumper cables. Do not use a battery charger.

Reprogramming can also be interrupted if something is accidentally turned on, like the vehicle's interior lights. Before starting the job, make sure the key is in the ignition and the driver's window is down. Make sure the security system is turned off.

Once all safeguards against interruption are in place and the software is downloaded into the PC, start the reprogramming application and follow the process step-by-step. Once reprogramming is completed, the PCM/ECM will have to undergo a relearning procedure, which may be as simple as completing a drive cycle, but could also require more reprogramming. Information on relearning procedures is usually available at the OEM web sites.



1. After the compression readings shown above were taken, a wet compression test was made. The second set of readings was almost the same as the first. Technician A says that a burned valve could cause these readings. Technician B says that a worn piston ring could cause these readings. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

2. Blue smoke is coming from the exhaust pipe of a vehicle. Technician A says that worn piston rings could be the cause. Technician B says that a bad head gasket could be the cause. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

3. A vacuum gauge is connected to the intake manifold of an engine and the engine is run at 2000 rpm. During the test, the pointer on the gauge fluctuates rapidly between readings of 10 and 22 inches of vacuum. These test results point to:
   A. a leaking intake manifold gasket.
   B. worn piston rings.
   C. worn valve guides.
   D. a weak or broken valve spring.

4. Engine detonation (knock) could be caus of the following EXCEPT:
   A. a lean air/fuel mixture
   B. retarded ignition timing
   C. excess carbon in the combustion char
   D. a stuck-closed EGR valve

5. A vehicle with electronic ignition hesitate stumbles during acceleration. The problem away when the vacuum advance hose is dis nected and plugged. Technician A says that vacuum advance mechanism could be the c Technician B says that an intermittent open pickup coil leads could be the cause. Who i
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

6. Technician A says that spark advance on a can be tested by listening to the way the engi at higher rpm. Technician B says that spark a on an engine can be tested with a timing light corporates an ignition advance meter. Who is
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

7. A regular customer presents his vehicle for He describes symptoms of poor driveability a that the vehicle has been repaired for the sam in the past. Which, of the following, should yo
   A. connect the vehicle to an engine analy
   B. check for diagnostic trouble codes
   C. check the vehicle service history and c TSBs, service campaigns and recalls
   D. perform a cylinder balance test

8. Two technicians are listening to a tapping coming from the top end of a V8 engine. Tec says the noise could be a valve needing adj Technician B says the noise could be an exh Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

9. Technician A says a high spike line on an oscilloscope indicates a disconnected or open plug wire. Technician B says a high spike line indicates a closed gap on a spark plug. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

10. A vehicle can be started with great difficulty, but lacks power, and will not idle. Technician A says that there could be a hole or tear in the duct between the mass air flow sensor and the throttle body. Technician B says that a restricted fuel filter is the problem. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

11. A vehicle is towed in with a 'cranks but won't start' condition. A 'noid' light test finds no injector pulses, and Technician A says the vehicle needs a computer. Technician B finds no spark, and says the vehicle needs an ignition module. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

12. Technician A says that evidence of cylinder wear can be found using a cylinder leakage tester. Technician B says that a blown head gasket can be found using a cylinder leakage tester. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

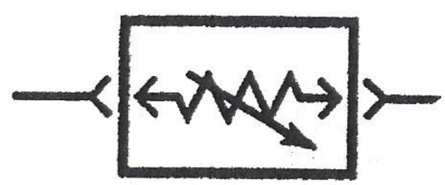
13. A poor running vehicle has low fuel volume. Technician A tests the electrical connector at the tank, and finding system voltage available, says the vehicle needs a new pump. Technician B says high circuit resistance may prevent the pump from operating properly. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

14. An engine with an electronic fuel injection
high fuel pressure at idle. This could be cause
A. low manifold vacuum.
B. leaking fuel pump check valve.
C. plugged fuel injection valve.
D. high manifold vacuum.

15. With the engine off, vacuum is applied
tive backpressure EGR valve using a hand
uum pump. Technician A says that the EGI
should open. Technician B says that the va
open unless a restriction is created in the e
the engine is started. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

16. Technician A says that valves should be
when the piston is at TDC on the compress
and both valves are closed. Technician B s
hydraulic lifters should be adjusted to zero
is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

17. While the engine is running, a technician
PCV valve out of the valve opening and plac
ger over the valve. No vacuum is felt. Techni
says that the PCV valve could be stuck clos
cian B says that the hose between the intak
and the PCV valve could be plugged. Who is
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B



18. The wiring diagram symbol shown above
A. resistor
B. variable resistor
C. transistor
D. thermistor

19. A vehicle gets poor fuel mileage and has poor heater performance. Which of the following could be the cause?
A. a bad ECT sensor
B. a defective fan clutch
C. a clogged cooling system
D. a stuck open thermostat

20. A vehicle with electronic fuel injection gets poor gas mileage. Engine tests show a rich mixture. Technician A says that a bad O_2 sensor could be the cause. Technician B says that a bad IAT sensor could be the cause. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

21. With a DMM connected, the O_2 sensor reads above 550 millivolts constantly, Technician A says that the fuel mixture is probably too rich. Technician B says the fuel mixture may be too lean or there may be an exhaust leak near the sensor. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

22. There are two types of MAP sensors: the analog signal type, which is tested with a voltmeter, and the frequency signal type, which is tested with a Hertz meter or digital tachometer. To determine which type the technician has, he performs a reference voltage and signal voltage check. The signal voltage doesn't changes from 2.5 volts. It is most likely:
A. a frequency type
B. an analog type
C. could be either type
D. none of the above

23. A vehicle has sluggish performance and high fuel consumption. Testing reveals that the vehicle fails to enter closed loop operation. Technician A says the ECT sensor may be defective. Technician B says the TP sensor may be set incorrectly. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

24. A vehicle is towed in for a no start conc
Spark tests good, and an examination of th
body shows fuel pouring from the TBI injec
the engine is cranked. Technician A says th
jector is stuck open. Technician B says the
driver for the injector is shorted out. Who is
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

25. A turbocharged vehicle performs poorly
power. All of the following could be the cau
CEPT:
A. restricted intake duct
B. a wastegate that is stuck open
C. failed turbocharger shaft bearings
D. a wastegate that is stuck closed

26. An oxygen sensor voltage is being mon
scope type analyzer. A pattern is observed
from 0.25 volts to 0.8 volts in a regular, seri
topped 'hills'. Technician A says that this is
closed loop operation. Technician B says th
dicates intermittent operation, and the sens
replacement. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

27. When troubleshooting a slow drain on t
which diagnostic tool should be used?
A. ohmmeter
B. ammeter
C. voltmeter
D. test light

28. While testing a starting circuit on a V8 e
technician finds that the engine cranks slow
starter current draw is 90 amps, and the ba
age while cranking is 11 volts. What should
nician do next?
A. check the voltage drop of the starter n
cuit
B. test the battery capacity
C. replace the starter motor, as a short is
D. determine the condition of the engine

29. A V6 engine with distributorless ignition breaks up on acceleration, but gets smoother when reaching cruise. Technician A says a bad coil pack is the problem. Technician B says the cam sensor must be replaced. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

30. Blue-gray smoke comes from the tailpipe of a vehicle during deceleration. Technician A says that this is most likely due to bad valve seals. Technician B says that the cause could be clogged oil return passages. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

31. Technician A says that an incorrect ignition pick-up coil gap can cause a misfire. Technician B says that when testing the pick-up coil with an ohmmeter, the meter should read infinity when the ohmmeter is connected to both pick-up coil leads. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

32. Hall effect sensors normally produce a:

A. sine waveform
B. triangle waveform
C. sawtooth waveform
D. square waveform

33. Technician A says that excessive resistance in the voltage side of the charging circuit can cause a low charging rate. Technician B says that too much resistance in the circuit will cause higher than normal voltage drop. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

34. The initial timing and spark advance are l checked on an older vehicle with distributor Technician A says that the engine must be a when checking how much the timing is being by the distributor vacuum advance unit. Tech says that the vacuum line to the vacuum adv be disconnected and plugged before checki tion timing. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

35. Which of the following would cause a s

A. high engine temperature
B. low fuel pressure
C. dirty throttle body and IAC
D. distributor cap carbon track

36. All of the following are symptoms of ins exhaust gas recirculation EXCEPT:

A. spark knock
B. stalling
C. surging at cruise
D. increased NOx emissions

37. When testing a catalytic converter with ar pyrometer, the difference between the surfac tures of the converter inlet and outlet should with the engine at normal operating temperat

A. 50°F (10°C)
B. 100°F (38°C)
C. 150°F (66°C)
D. 200°F (93°C)

38. The EVAP system is designed to:

A. keep fuel vapors from escaping the fu
B. capture fuel vapors and route them to lytic converter, where they are burned
C. purge fuel vapors from the charcoal ca atmosphere
D. capture fuel vapors and route them to where they become part of the air/fuel and are burned during combustion

39. Which of the following sensors can be checked by measuring the pulse width of the fuel injector?
A. TP (Throttle Position) sensor
B. VSS (Vehicle Speed Sensor)
C. MAF (Mass Air Flow) sensor
D. CKP (Crankshaft Position) sensor

40. An IAT sensor is being tested. Technician A says that the resistance should be checked on an NTC (Negative Temperature Coefficient) sensor. Technician B says that the voltage drop across the sensor should be checked on this type of sensor. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

41. The MAP sensor voltage on a vehicle is measured with the engine running at idle and found to be almost 5 volts. Technician A says that this voltage is too high for idle speed. Technician B says that this voltage will cause the engine to run extremely rich. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

42. The engine in a vehicle running at normal operating temperature has a rough idle and black smoke coming from the exhaust. All of the following could be the cause EXCEPT:
A. EGR valve stuck closed
B. EVAP canister purge solenoid stuck open
C. fuel pressure too high
D. fuel injector(s) stuck open

43. A vehicle is towed in with a 'no start' condition. The technician disconnects the coil wire from the distributor cap, connects a suitable spark tester and checks for a good spark while cranking the engine. If there is no spark, all of the following could be the cause EXCEPT:
A. a problem in the ignition primary circuit
B. a problem in the ignition secondary circuit
C. a bad coil
D. a bad distributor pick-up coil

44. A technician suspects that a faulty CMI
shaft Position) sensor is the cause of a driv
complaint. In order to test the sensor, he m
know what type it is. Since the sensor is ec
with a 3-wire connector, the sensor:
A. is a Hall effect type
B. is a magnetic reluctance type
C. creates a voltage
D. is a permanent magnet generator

45. An alternator output harness (pigtail) ne
replaced. Technician A says that a pencil sc
iron should be used to ensure a good conn
Technician B says that a butt splice sleeve
will be sufficient. Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

46. Which of the following diagnostic methc
used to determine which cylinder is leaking
tion chamber gas into the cooling system?
A. observing the radiator coolant for bubl
the engine is running
B. placing a vial of a chemical that is sen
combustion gases over the radiator fill
while the engine is running
C. holding an exhaust analyzer probe ove
ator filler neck while checking for a rea
the exhaust analyzer
D. observing the radiator coolant for bubl
performing a cylinder leakage test

47. A vehicle's tailpipe emissions are being
with a four-gas exhaust analyzer. The level
the exhaust gas is lower than normal and th
O_2 is high. Technician A says that the engin
lean condition. Technician B says that, if the
had five-gas capabilities, the NOx level wou
Who is right?
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

48. A vehicle running at normal operating temperature is idling at too high an idle speed. When checking the IAC (Idle Air Control) valve pintle counts with a scan tool, the reading is zero. Technician A says that the IAC valve is defective. Technician B says that there is a vacuum leak at the intake manifold. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

49. A vehicle's exhaust system is being tested for a restriction, using a vacuum gauge connected to the intake manifold. All of the following are indications of a restricted exhaust EXCEPT:

A. When the engine is gradually accelerated to 2000 RPM, the vacuum reading slowly drops to zero and slowly returns to normal.
B. When the throttle is closed, the vacuum does not increase.
C. When the throttle is closed, the vacuum momentarily increases and then resumes the normal reading.
D. When the engine is accelerated to 2500 RPM, the vacuum reading drops 3 in. Hg below the original reading after a few minutes.

50. Under which of the following conditions is exhaust gas recirculation required?

A. cold engine at part throttle
B. warm engine at idle
C. warm engine at part throttle
D. warm engine at wide open throttle

51. An electrical circuit is being tested using a DMM (Digital Multimeter). When measuring voltage in the circuit, Technician A says that the meter should be connected in parallel. When measuring amperage, Technician B says that the meter should be connected in series. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

52. When retrieving stored codes from a c ized engine control system, a hard fault is garding a fuel injector circuit. Technician A fuel pressure and volume tests should be Technician B says that the injectors should placed on that circuit. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

53. A sweep test is being made on a TP sen the data from a scan tool. Technician A says preferred method for greatest accuracy. Tec says that a scope will give the best results. V

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

54. A PCM/ECM is being replaced with a reb Technician A says to disconnect the negative cable prior to replacement. Technician B say vehicle driver circuits for low resistance. Who

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

55. A technician is testing the ignition on a v a 'no start' condition. He connects a test lig tween the negative side of the coil and grou has an assistant crank the engine. A test ligl ters on and off indicates all of the following

A. The pickup coil signal is OK.
B. The ignition module is OK.
C. The module is triggering the ignition coi
D. The coil is OK.

56. Which of the following is used to preven eration when the engine is cold?

A. EGR valve position sensor
B. EGR vacuum solenoid valve
C. EGR vacuum regulator
D. Thermal vacuum switch

57. Technician A says that a secondary air injection system forces air into the intake ports. Technician B says that the secondary air injection system reduces spark knock. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

58. All of the following are true statements regarding fuel pressure regulators EXCEPT:

A. With the vacuum line connected to the fuel pressure regulator, fuel pressure should be higher than with the line disconnected.
B. Most fuel pressure regulators are not adjustable.
C. Most fuel pressure regulators are connected to manifold vacuum and vary the fuel pressure according to engine load.
D. Some regulators can suffer from a ruptured diaphragm, allowing fuel to be sucked into the intake manifold through the vacuum line, which operates the regulator, causing a rich running condition.

59. When testing computer-controlled systems, a DMM (Digital Multimeter) should be used with an input impedance of at least:

A. 10k ohms
B. 100k ohms
C. 1 megohm
D. 10 megohms

60. Technician A says an oscilloscope can be used to read spark plug firing voltage. Technician B says an oscilloscope can be used to check the ignition coil. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

61. All of the following are statements desc mal mechanical fan clutch operation EXCE

A. A fan clutch has viscous drag regardl perature.
B. A fan clutch varies fan speed accordi gine temperature.
C. A fan clutch stops the fan from spinnin two seconds after turning off a hot en
D. A fan clutch varies fan speed accordi gine speed.

62. All of the following are indications of a c system that is undercharging EXCEPT:

A. slow cranking
B. dim headlights
C. short light bulb life
D. low ammeter indication

63. An engine has a light metallic knocking ing light engine loads, however, when the c with the noise is disabled during a cylinder test, the sound diminishes. Technician A sa noise is caused by excessive connecting rc clearance. Technician B says that the noise by excessive piston-to-wall clearance. Whc

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

64. All of the following are true statements r intermittent faults EXCEPT:

A. An intermittent problem is a malfuncti curred in the past, but is not present a of the self-test.
B. You may have to try to recreate condit scribed by the driver to get an intermit to reset.
C. Intermittent problems are often cause aged wiring and connectors, so tappir wiggling wiring harnesses and connec sometimes get problems to reoccur ar codes.
D. Intermittent faults should be serviced l hard faults.

65. When an EGR valve diaphragm is raised with the engine idling, there is no effect on idle speed. Technician A says that the EGR valve is bad and should be replaced. Technician B says that the EGR passages are clogged with carbon. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

66. The MIL is illuminated on a late-model vehicle that is brought in for service. A scan tool is connected to the DLC and the DTC P0107 is obtained. Technician A says that this code indicates a failure in the vehicle's powertrain. Technician B says that this code is manufacturer specific. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

67. A vehicle with an AIR system backfires during acceleration. Which of the following should the technician check?

A. operation of exhaust manifold check valve(s)
B. output pressure of the air pump
C. operation of the air bypass valve
D. the AIR manifolds for restriction

68. A vehicle with a normally closed canister purge solenoid is not purging the EVAP canister when engine operating conditions for purging are met. When the purge solenoid is removed from the vehicle for testing, it allows vacuum flow when voltage is applied. Technician A says the purge solenoid is defective. Technician B says the purge solenoid power circuit is at fault. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

69. Two technicians are inspecting an exh tem. When he taps on the muffler with a m nician A hears noise coming from inside th and says that it is most likely rotting out fr side. Technician B says that he hears nois from inside the catalytic converter when h with a mallet and says that the converter is from the inside. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

70. A technician wants to quickly compare ondary ignition patterns of each cylinder of gine. Which of the following scope patterns use?

A. primary superimposed
B. secondary superimposed
C. parade
D. raster

71. When manifold vacuum is checked on a v brought in for service it is found to be low but Technician A says that an air/fuel mixture that can cause this condition. Technician B says t fuel mixture that is too lean can be the cause. right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

72. A vehicle with multiport fuel injection ha problem. When the throttle body is inspecte found to be contaminated with sludge build nician A says that this could be caused by v Technician B says that this could be causec clogged or restricted PCV system. Who is ri

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

73. All of the following are indications of a catalytic converter problem EXCEPT:

A. The converter shell appears bluish.
B. The converter makes a rattling noise when struck with a mallet.
C. There is little difference between the inlet and outlet temperatures.
D. The catalyst monitor signal is stable.

74. All of the following are true of the EVAP canister vent solenoid EXCEPT:

A. It is activated by the PCM/ECM to allow the flow of fuel vapor from the EVAP canister to the engine.
B. It is activated by the PCM/ECM to block the entrance of outside air into the canister during the EVAP leak test.
C. It is used only on vehicles with enhanced EVAP systems.
D. It is located in the fresh air supply hose to the canister.

75. A vehicle has been towed in with a no-crank condition. The starter solenoid is being tested using a jumper wire between the battery and the solenoid 'S' terminal. Technician A says that if the engine cranks, the problem is in the starter control circuit. Technician B says that if the solenoid makes a clicking sound, it is operating properly and the starter may be defective. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

76. All of the following can cause air flow problems through a radiator core EXCEPT:

A. broken shroud
B. debris buildup
C. bent fins
D. excessive mineral deposits

77. A customer brings his car in because th on. However, when the vehicle is started in vice bay, the light is off. Technician A says cause the DTC that turned on the light is nc the PCM/ECM's memory. Technician B say because the monitor responsible for the DT three times in a row without seeing the sam Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

78. A quick way to determine if valve timing jumped is to:

A. look at the timing mark alignment on t and crank sprockets
B. check timing chain or belt slack
C. check valve movement with the pistor on the exhaust stroke
D. check valve movement with the engin on the compression stroke

79. The SFT value on a scan tool is shown ative number. Which of the following will als

A. There is less oxygen in the exhaust
B. The voltage signal from the oxygen se creased.
C. The injector pulse width was lengthen
D. The SFT value is greater than 1.

80. All of the following could cause a vehicl hanced EVAP to fail the PCM/ECM's large l EXCEPT:

A. loose fuel cap
B. cracked vapor line
C. stuck open canister vent solenoid
D. open canister purge valve

81. Two technicians are discussing alcohol in fuel. Technician A says that if any alcohol is mixed with gasoline it will cause driveability problems. Technician B says that excessive amounts of alcohol in fuel can degrade the fuel system. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

82. An alcohol in fuel test is being conducted using a 100mL container. If there is 15mL of water in the container at the end of the test, what is the alcohol content of the fuel?

A. 5 percent
B. 10 percent
C. 15 percent
D. 20 percent

83. Technician A says that a 'pending' code is recorded if monitor results indicate a failure after one drive cycle. Technician B says pending codes should be checked to verify a repair. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

84. A voltage generating Vehicle Speed Se
is being tested. Technician A says that the
sion shaft should be rotated and the DC vc
put checked. Technician B says that the se
tance should be checked. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

85. All of the following can interrupt an OBI
ECM reprogramming procedure EXCEPT:

A. getting an automatic virus protection u
B. opening a door on the vehicle
C. carrying the vehicle's key fob in your p
D. turning on the ignition key