BULLSEYE
Leak Detector

Training

Diagnosing EVAP Systems

by Bernie Thompson

Perhaps one of the toughest jobs in the automotive field is diagnosing small leaks, especially A/C and Fuel Vapor (EVAP) leaks. Finding these leaks can be time consuming and frustrating to say the least. Small EVAP system leaks maybe the most difficult to locate because of several issues. First, the system test pressure is low at less than 1 PSI. Second, the leak sites that you must find are small at .005 to .030 of an inch. You may think you will not need to find these small .005 leaks, however you do. These small leaks can become large leaks with thermal expansion and contraction. The third issue is the EVAP system is located from one end of the vehicle to the other end of the vehicle. All of these are serious concerns and will require you to have a great understanding of EVAP systems and the test equipment used in order to find these elusive leak sites.

Why do we have EVAP systems on vehicles? In southern California air quality became an issue in the mid 1960s. In order to control the air quality for human health, emission regulations were forced on the automotive industries. California established a new organization called the California Air Resource Board (CARB) in 1967. CARB is the “Clean Air Agency" of California. This organization became the first to impose requirements on the automotive industry and still leads the nation on regulating vehicle pollutants. After CARB was established, the Environmental Protection Agency (EPA) was established in 1970 to regulate pollutants in the United States that harm human health.

At first these regulations covered the internal combustion engine’s tailpipe and crankcase emissions and in 1970 moved to regulate the fuel handling and containment system (EVAP), which includes the engine’s tailpipe, crankcase emissions and fuel vapor produce smog — an acronym for smoke and fog. Photochemical smog is a type of air pollution caused by chemical reactions that occur between the sun’s ultraviolet light and pollutants such as hydrocarbons and oxides of nitrogen. Since these pollutants, referred to as smog, are created in part by hydrocarbons in the atmosphere reacting with sunlight, it has become necessary to prevent these hydrocarbons from entering the atmosphere.

Controlling fuel vapor
In order to accomplish reduced hydrocarbons, the fuel handling and containment system was required to trap the fuel vapor and then pull this trapped fuel vapor into the engine to be burned. To trap the fuel vapor (gasoline), activated carbon is used (Fig. 1). The carbon canister provides a bed of activated carbon that allows absorption and desorption of the many different species of hydrocarbons, which are contained in gasoline. These hydrocarbons are caught in the cracks in the activated carbon when the fuel handling system is venting hydrocarbons under atmospheric pressure. The activated carbon will adsorb these fuel vapors until it becomes saturated. In this saturated condition the activated carbon cannot take on any more hydrocarbons, thus the hydrocarbons go into the atmosphere. In order for this not to occur, the activated carbon must have a desorption cycle. This is accomplished by the purge cycle and is controlled by the purge valve. The hydrocarbons are then purged (pulled out) from the activated carbon using negative pressure applied by the running engine. An early EVAP systems (Fig. 2) were controlled by mechanical valving.

fig. 1

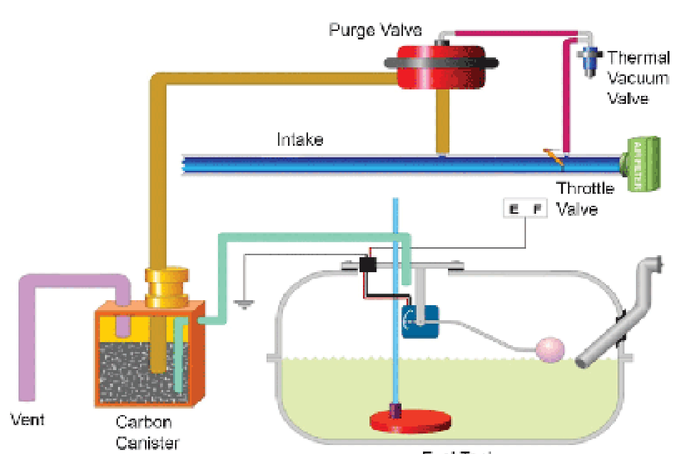

fig. 2

This purge control valve is normally closed and is opened to allow atmospheric air to enter the running engine through the carbon canister vent. As the air moves through the vent and the carbon canister, it removes the hydrocarbons from the activated carbon. This air and hydrocarbon mixture is then moved into the running engine and burned. Since this mixture of air and hydrocarbons varies, it can affect the drivability of the engine. This air/fuel mixture can affect the fuel control system and can be seen in the fuel trim. If the activated carbon has no hydrocarbons adsorbed within it, the mixture will be lean. If the activated carbon has hydrocarbons contained within it, the mixture will be rich. If you have a fuel trim issue at idle and light load where the engine produces vacuum, disconnect and plug the purge valve. This will indicate if the fuel trim issue is caused by the purge control or not.

As the air quality continued to degrade from the mid 1960s, the need to prevent these hydrocarbons from escaping into the atmosphere has brought stringent emission regulations from CARB and the EPA. These regulations are referred to as “Enhanced EVAP.” In 1996 with the OBDII emission regulations, EVAP containment regulations required vehicle manufacturers to monitor and detect leakage for the gasoline containment system that exceeded an area equal to a hole diameter of .040 of an inch (1mm) in size (P0442). They are also required to test the function of the purge and vent valves, along with monitoring the electric circuits of the EVAP components. In order to be compliant with these stringent emission regulations, a microprocessor is used to control the EVAP system (Fig. 3).

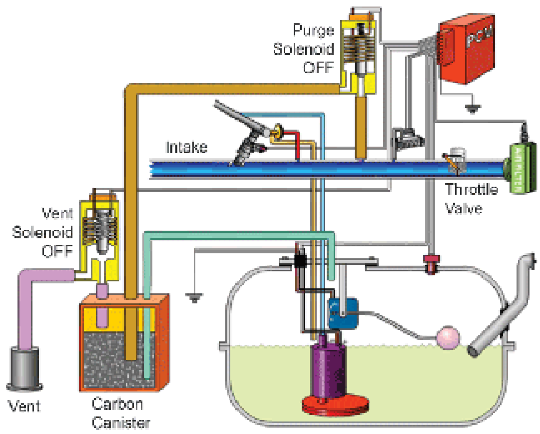

fig.3

In 2000 with the OBDII emissions regulations, EVAP containment regulations required that the vehicle manufacturer had to monitor and detect leakage for the gasoline containment system that exceeded an area equal to a hole diameter of .020 of an inch (.5mm) in size (P0456). This .020 area is not half that of a .040 area, but is one fourth of the size, as this is a product of the hole size area. A dime weighs 2.268 grams; under the right conditions, the area equal to a .020 hole size can emit about “a dime’s” worth of HCs per every two miles. This would be more than 30 times the current allowable exhaust emission standard. As you can see, the need to control leakage in these systems is important. In order for the OBDII diagnostic test results to fall under the EVAP regulations, the area of the leak size to be tested will need to be reduced. This can be seen by looking at the bell curve in Fig. 4. The testing bell curve determines the need to run the EVAP leak test at a smaller hole diameter than the standard. In this case, the standard .040 leak area will be tested at a .030 leak area and the standard .020 leak area will be tested at a .015 leak area.

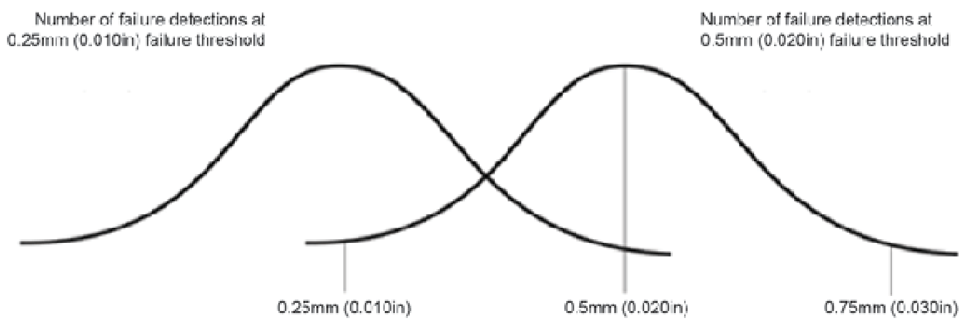

fig. 4

There are two automotive fuel containment leak detection methods used: Negative Pressure and Positive Pressure (Fig. 5). Pressure is the ratio of force to the area over which that force is distributed. Pressure is measured in any unit of force divided by any unit of area. The lb./square inch (PSI) is the traditional unit of pressure used in the US and the UK. These units can be read in absolute pressure, which is read from 0 pressure, or can be read in gauge pressure. Gauge pressure is where the pressure reading of the atmospheric pressure is not accounted for. Because the area the pressure is pushing against multiplies the force, it will be important to never adjust the testing pressure higher than the system’s operating pressure as this could cause severe damage to the system. The maximum EVAP testing pressure is 1 PSI or 27.68 inches of water column (in H2O). An example of the force being multiplied is if an area of 36 in. x 36 in. had 1 PSI applied on it, the force would be 1,296 lbs. If this pressure was increased to 10 PSI, the force would be increased to 12,960 lbs.

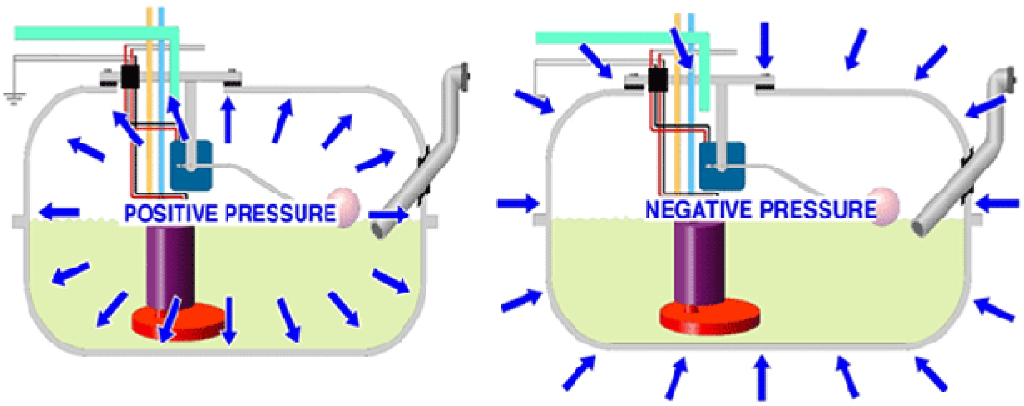

fig. 5

The OBDII EVAP diagnostic system will use the difference in pressure between what is contained within the EVAP system and that of the atmospheric pressure to determine if the system leak area is above or below the standard. Pressure differential is the difference in energy between a higher pressure and a lower pressure. High pressure, having more force, always moves to a low pressure, having less force. When the fuel containment system has a higher (positive pressure) or lower (negative pressure) contained within it and a leak is present the pressure difference will change over time.

In order for the EVAP system to be pressurized, the system must first be sealed. One of the more common OBDII leak detection methods, referred to as vacuum decay, is set up using a valve that is installed in the canister vent. This valve is called the vent valve and is normally open (Fig. 3), which allows the internal EVAP pressure to be vented to the atmosphere just as in the early EVAP systems. However, this vent valve will be closed during an ODBII diagnostic fuel containment leak test. Once the vent valve is closed, the negative pressure from the engine is used to pull the fuel containment system into a vacuum. A pressure sensor is used in order to monitor the pressure within the containment system. If there is no leak present, the pressure will remain constant. If a leak is present, the pressure will change or decay. The rate at which this pressure changes is proportional to the size of the leak. However, the vapor space volume will change this decay rate. This means the vapor space contained within the fuel containment system becomes important to know. The OBDII program checks the fuel gauge in order to calculate this vapor space. If the fuel gauge misreads the liquid fuel level, the system could set a false leak code.

Does the fuel guage read correctly?
This can be seen with an example of an 18-gallon volume with a .015 inch leak area. At 25 inH2O the system will lose 1 inH2O in 30 seconds, which will set a leak DTC. This same 18-gallon volume with a .010 inch leak area at 25 inH2O will lose 1 inH2O in 40 seconds, which will not set a leak DTC. This makes sense that a larger leak size would leak at a faster rate. However, when a smaller volume is tested, such as 9 gallons of volume with a .010 inch leak area at 25 inH2O, the system will lose 1 inH2O in 22 seconds, which would not set a leak DTC. This is a faster leak rate than the .015 leak area with 18-gallon volume by 8 seconds that would set a leak DTC. The OBDII diagnostic program looks up a leak rate table that is based on the vapor space, so if the vapor space volume is not correct, the test outcome cannot be correct.

In order to test the fuel gauge, a simple test can be run. Look at the fuel gauge in the instrument panel. Now let’s say the fuel gauge is reading one fourth of a tank and the tank has a 20-gallon volume. This is approximately 5 gallons of gas and 15 gallons of vapor space. Now add 2 gallons of volume for the hoses and carbon canister; 15 gallons + 2 gallons = 17 gallons of vapor space volume. In order to test this vapor space, take the testing equipment that you use for EVAP systems and fill an empty 5-gallon gasoline can. Time how long it takes to bring the pressure up to the maximum amount your equipment can produce or a known value; do this multiple times. Now you know how long it takes to fill 5 gallons without a leak. Use this known time-to-volume fill rate from your equipment when filling the fuel containment system on the vehicle. For example, if you are filling the system and it has 10 gallons of vapor space, double the known fill time. After you do this just one time, you will see how simple it is and you will do this each time you are filling the system when looking for a leak. If you are filling the system and the fill time is very short, suspect a restriction between the carbon canister and the fuel tank connection hose.

When looking for a leak in the EVAP system there are two things you must know. First, you need to know if the system is leaking right now or not. The second thing you need to know is how big the leak size is. To find the answer to these questions, seal and pressurize the system with a gauge attached. Now shut off the flow going into the system. Watch the gauge for a pressure loss. If no pressure is lost, there is currently no leak present; if there is a pressure loss, a leak is currently present in the system. How fast the pressure drops in relation to how much vapor space is present will indicate the leak size.

Now before you go looking for the EVAP DTCs such as a P0456 or P0442, you will know there is a leak present right now and how large the system leak is. This information is imperative in order to find the leak site(s) location(s). The leak volume is based on the operating system pressure and the size of the leak site area. The larger the leak site the more volume will escape, or the higher the pressure the more volume will escape. If both the leak site and the pressure are low, a small amount of volume will escape from the leak site. This makes these EVAP leaks difficult to locate.

Finding the leak site
There are several ways in which you can find the locations of EVAP leak sites. There are three basic methods: Soap, Smoke and Gas. “Soap” is based on surfactants. These are chemicals that lower the surface tension of a fluid. In a state where there is less surface tension, a bubble can be produced. When the fluid is water, the surface tension of the soapy water is much lower, about a third of pure water, so the molecules of the bubble are less stressed and therefore stable. This allows the bubble to be produced and last longer. If the volume of gas escaping from the leak site is too small, there will not be enough energy, or a

pressure jump, to produce a bubble. Therefore, the leak site will not be detected. If the pressure or volume is too great, the bubble will not form. This is due to the escaping gas having enough energy to instantly break through the soap surface tension. Once the soap surface tension is broken, the escaping gas goes into the atmosphere instead of filling the area within the bubble; therefore, the leak site will not be detected. Additionally, the soap's very slick nature creates a problem when applying the soap to the surface of the sealed system. When applying the soap to a vertical surface, the soap will tend to slide off of the surface. If the surface is that of plastic, the soap will just run off. If the soap cannot stay in place over the leak site, a bubble will not be produced; therefore, no leak can be found. If the conditions are just right, the soap will produce a bubble or bubbles at the leak site, thus allowing you to locate the leak site within the sealed system.

Yet another leak detection method is using vapor or smoke. The problem here is smoke vapor is a poor visual indicator. This can best be understood by looking at water vapor in the air. A cloud is water vapor that has condensed to a point where it can distort light and thus be seen. On a day with high humidity (water vapor in the air) there may not be a cloud in the sky but the vapor in the sky is high; however, this vapor cannot be seen. This is the same as the vapor from a smoke machine. There will need to be a large amount of smoke vapor condensed together to distort light so it will be visible. When the leak site is small, there is not enough smoke vapor present to distort the light so the leak cannot be seen. Additionally, the smoke vapor is produced from oil. When using this type of leak detection equipment in a fuel containment and handling system, the gasoline will break down the oil vapor. In chemistry, likes breakdown likes, meaning the smoke being produced from heavier oil hydrocarbons will be broken down by the lighter gasoline hydrocarbons, thus smoke may not be detectable. Additionally, the carbon canisters in these systems are designed to catch hydrocarbons. The smoke being produced from hydrocarbons will be caught in the activated charcoal. So a leak at the carbon canister may not be found. The main problem with smoke is many large leaks (> .030) can be found with smoke so technicians think it works for all leaks including small leaks; but this is just not the case.

In the last few years, significant advances have been made in leak detection equipment. These new equipment developments are based on gas and can be used in all sealed systems. It can find all leak sizes small and large fast and accurately. These new leak detection systems use a new technology based on carbon dioxide (CO2) gas. CO2 is a very small molecule that moves through small leak sites with ease. The sealed system to be tested is pressurized with CO2. The sealed system now, being at a higher pressure than the surrounding atmospheric pressure, will allow the CO2 gas to escape if a leak is present. An advanced electronic CO2 leak detector is used to locate the approximate area of the leak site. Finding the exact location of the leak site can be difficult when using any gas-based electronic leak detector, especially if several connections or components are all located within a small area. Because CO2 gas can cause a specifically formulated foam to change color, pinpointing the source of the leak is simplified. The specifically formulated foam is applied to the general area identified by the advanced CO2 leak detector and the leaking CO2 gas changes the color of the foam from a pinkish-red color to yellow at the exact location of the leak site. The use of CO2 gas makes false detection a thing of the past, allowing you to be absolutely positive as to the location and size of the leak. With a good understanding of these EVAP systems and knowledge of your equipment, these EVAP leaks will be easy to locate.