EVAP CODE BLUES

UNDERSTANDING HOW FORD, GM AND CHRYSLER ENHANCED ON-BOARD EVAP MONITORS WORK IS JUST AS IMPORTANT AS USING THE PROPER TOOLS TO TROUBLESHOOT THEM.

BY JACQUES GORDON, TECHNICAL EDITOR

IN THE NEWEST GENERATION OF ENHANCED EVAPORATIVE EMISSION CONTROLS, THE PCM CAN MONITOR EVERY COMPONENT AND FUNCTION OF THE EVAPORATIVE EMISSION (EVAP) SYSTEM. THIS IS GOOD NEWS, BECAUSE IT MEANS THE POWERTRAIN CONTROL MODULE (PCM) CAN PROVIDE USEFUL DIAGNOSTIC INFORMATION FOR WHAT MAY BE THE MOST DIFFICULT SYSTEM TO TROUBLESHOOT. EVEN BETTER, NOW THERE IS A SERVICE PORT THAT MAKES IT EASIER TO SEARCH FOR LEAKS USING SMOKE. BUT IN ADDITION TO TOOLS AND TRAINING, TROUBLESHOOTING EVAP CODES ALSO REQUIRES AN UNDERSTANDING OF HOW THE SYSTEM IS SUPPOSED TO WORK. SO HERE GOES …

BACKGROUND

The enhanced evaporative emission control system is a result of California emissions regulations that went into effect for the 2000 model year. Most new vehicles sold in all 50 states met those requirements that first year, and today they all do. You can tell the difference by looking for a service port cap under the hood, sometimes marked "EVAP." Like the earlier systems, the enhanced EVAP system captures fuel tank vapors and sends them to be burned in the engine. The two "enhancements" refer to the on-board diagnostic (OBD) system's ability to detect leaks as small as 0.020 of an inch (0.5mm) and to monitor canister purge flow. The former is required by law to monitor the health of the EVAP system, and the later is needed by the PCM to control tailpipe emissions and preserve driveability during canister purge. There are several different ways to accomplish these tasks, and of course the automakers have used them all. Fortunately, they're not hard to understand.

There are two different ways for an OBD system to leak test an enhanced EVAP system: pressurize it or put it under vacuum. Each has its advantages. Vacuum testing is mechanically simpler, requiring only two solenoid valves and a fuel tank absolute-pressure sensor. But because the vacuum comes from the intake manifold, the drive cycle (the engine operating conditions needed for the test) is very precise, so there's no guarantee the test will actually run during any given trip.

Leak-testing with pressure requires a pump and extra plumbing, but the drive cycle is less exacting. Ford Motor Co., General Motors (GM) and some Asian models use vacuum tests, while DaimlerChrysler, some Asian and most European models use pressure tests.

In either case, leak testing an EVAP system requires sealing the system at each end. The purge control solenoid valve is used to seal the system at the intake manifold end, and another solenoid valve seals the canister's fresh air inlet. This canister vent valve is normally open, and on several models a clogged fresh air inlet has caused problems that turn on the malfunction indicator lamp (MIL), but more on that later.

Ford and General Motors EVAP systems have a similar layout. In this Ford schematic, the purge valve is called the Vapor Management Valve.

VACUUM TESTING

The vacuum leak test used by Ford and GM has two phases – large-leak and small-leak detection. In both phases, the PCM will close the vent valve, pulse the purge valve to draw a vacuum on the system and monitor a pressure/vacuum sensor in the fuel tank. The PCM is looking for how quickly the vacuum builds to a predetermined level, and then with both valves closed, how quickly it decays. The basic difference between the large- and small-leak tests is the amount of time for the test, and, of course, different algorithms are used to calculate the results.

Assuming all the enable criteria have been met, the first step in the test is to calculate how much fuel vapor is being generated in the tank. The PCM does this by closing both the purge and vent valves and looking at the tank pressure sensor. If the rate of vapor generation (tank pressure rise) is too great, the PCM may draw a slight vacuum on the tank and/or purge the system to "precondition" it, and then check again. If the PCM still thinks fuel tank vapor pressure is rising too quickly for a valid test, it will abort the test.

Along with fuel sloshing and heat, vacuum in the fuel tank makes fuel evaporate, so the deepest vacuum draw is rarely more than 10 inches of water. The PCM may abort the test if fuel tank pressure changes by only 1 inch of water during the vapor check. It takes more pressure than that to blow out a match. Testing for such small changes requires very stable vehicle operating conditions, aka enabling conditions, which is why the small-leak test (0.020 inch leak) is so difficult for the PCM to run.

Although each model of car has very specific test requirements, the following enabling conditions will give you an idea of how the PCM uses vacuum to leak-test the EVAP system. These are general enabling criteria; they are not a complete list of what is needed to actually run the test:

• The PCM needs to know **fuel temperature.** But unless there is a fuel tank temperature sensor, the test runs after cold-start when the coolant temperature is near ambient, indicating the engine has not been running for a long period of time and returning warm fuel to the tank.

• The test requires a **steady speed and load condition.** GM's first small-leak test and Ford's small-leak validation (second) test require the engine to be at idle with zero or near-zero vehicle speed. The idea is to test with steady manifold vacuum and no fuel tank sloshing.

• **Ambient temperature** must be between 40°F and 100°F so the fuel tank vapor pressure remains stable during the test. On some models, the upper limit is only 86°F.

• **Fuel level** must be between 15 percent and 85 percent, and the PCM must be getting a stable signal from the tank

level sender so it can calculate how long it should take for vacuum to build and decay. On some models, if fuel level increases between engine starts or while the engine is running, which indicates the vehicle has been refueled, it may run a large-leak test right away to see if the filler cap has been tightened properly.

• **Barometric pressure** must be above 22 in.Hg on Fords and 19 in.Hg on GM vehicles. Put another way, altitude must be less than 8,000 feet or 10,000 feet respectively.

There's one other thing needed for the EVAP monitor to run: There must be no engine fault codes. There are two reasons for this. First, while the EVAP system is important for reducing overall vehicle emissions, controlling engine emissions is more important, so engine malfunctions have priority.

The second reason has to do with the way the PCM detects and controls canister purge flow. Earlier Fords use a sensor to detect temperature drop in the hose between the purge control valve and intake manifold when purge air is flowing. The earlier GM system uses a vacuum switch between the purge control valve and the EVAP canister. Neither of these devices can measure purge flow; they only confirm that flow is or is not happening as commanded. But with the enhanced systems, the PCM can calculate purge flow using data from the MAF sensor or by comparing MAP sensor readings with the tank pressure sensor reading. The amount of fuel vapor in the purge flow can also be calculated using the fuel trim correction data.

INTAKE AIR PLENUM

THROTTLE BODY

LEAK DETECTION PUMP (LDP)

LDP SOLENOID

EVAPORATIVE CANISTER

LDP VENT VALVE

EVAPORATIVE SYSTEM AIR FILTER

SERVICE PORT

EVAPORATIVE PURGE ORIFICE (MODEL SPECIFIC)

TO FUEL TANK

EVAPORATIVE PURGE SOLENOID

Chrysler's EVAP system uses manifold vacuum to power the LDP, controlled with the LDP solenoid.

CHARCOAL CANISTER

Fuel tank vapors are stored in a charcoal canister, sometimes called a carbon canister. Charcoal is made by heating wood to about 1,000°F in a sealed container. With no oxygen, the wood can't burn, but the volatile organic compounds will be driven off, leaving nothing but pure carbon.

After it cools, the charcoal granules are sealed in another container and pressurized with oxygen. This opens tiny pores in the carbon molecules, creating what's called "activated charcoal."

Hydrocarbons of all kinds, especially vaporized gasoline, will stick to activated charcoal like a balloon sticks to the wall after rubbing it on a wool shirt. Air moving across the charcoal can strip the hydrocarbons away again, just like blowing the balloon off the wall.
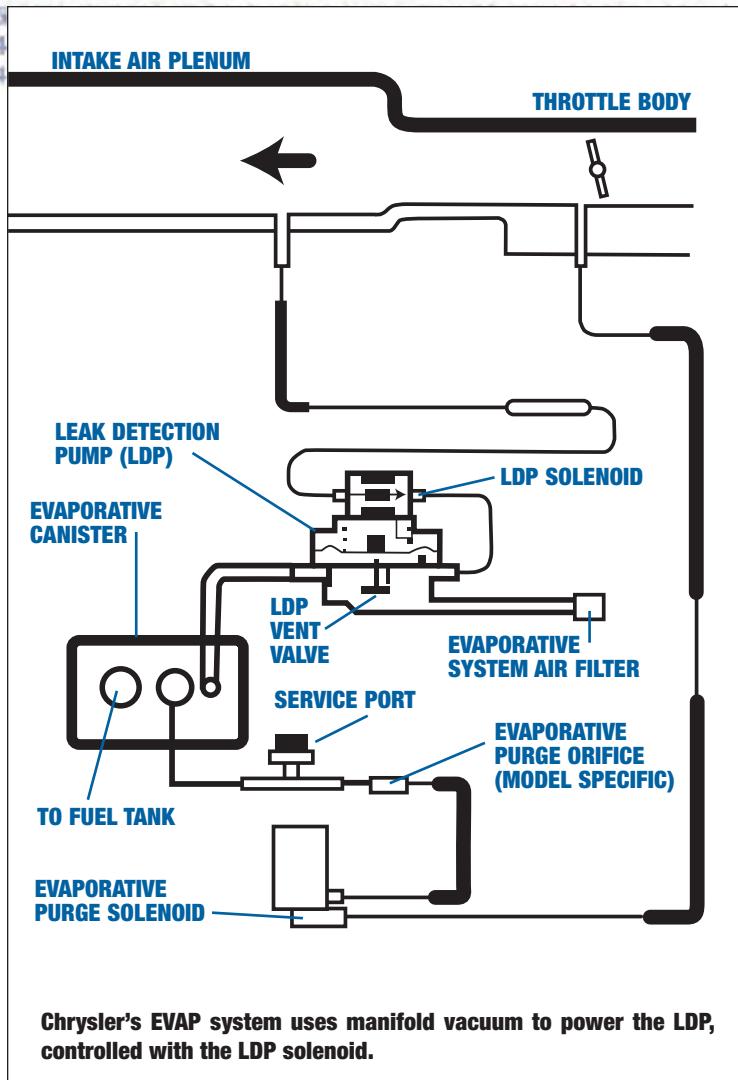
LARGE-LEAK TEST

The large-leak test always runs first. With the vent valve closed, the purge valve is pulsed to pull a target vacuum on the system.

• If the target vacuum cannot be reached and fuel level has not increased, the PCM will store a hard code and turn on the MIL.

• If the target is reached but vacuum will not hold, the PCM will store codes indicating a large leak, but it won't turn on the MIL until it fails the test a second time.

• If the vehicle has been refueled since the last engine-start or during this drive cycle (in-flight refueling) and the target vacuum cannot be reached, the PCM will assume the cap has not been tightened properly. It will set a pending code and turn on the MIL or a "Check Fuel Cap" light. If the system passes the next large-leak test, it will clear the code and turn off the light.

• If the target vacuum is surpassed quickly, the PCM will assume a plugged vent hose or faulty vent valve. If this hap-

Illustration: Michael Stassus. Source: DaimlerChrysler

pens over two tests in a row, it will set a hard code and turn on the MIL.

• If vacuum increases after the purge valve is commanded closed, the PCM will assume a leaking purge valve. If this happens over two tests in a row, it will set a hard code and turn on the MIL.

SMALL-LEAK TEST

The small-leak test takes longer. After completing the large-leak test, the PCM monitors and records the time it takes for vacuum to decay or bleed up to a second target level. The acceptable bleed-up time is calculated anew for each test to account for conditions that generate fuel tank vapors, such as ambient temperature and fuel level.

• If measured bleed-up time is between the calculated minimum and maximum, the test passes. The test must be passed twice for the monitor status to indicate "complete."

• If bleed-up time is shorter than the minimum allowed, the test is failed. A pending code is stored and the test is repeated at idle the next time all the other enable criteria are met.

• If bleed-up takes too long, the PCM assumes a leaking purge control valve or a blocked vent valve or tube. It will store a pending code and repeat the test at idle the next

time all the other enable criteria are met.

• In either case, if the next test is passed, the pending code will be erased. On some models, it must be passed twice in a row. If the second test fails, the PCM will set a hard code and turn on the MIL.

Steady conditions are needed for the small-leak test, and most GM vehicles will only run it at idle. On all vehicles, if vehicle speed, engine load or fuel tank pressure changes too much during the test, indicating fuel slosh, the test will be aborted. The PCM keeps track of the number of aborts, and Ford's Mode $06 data will display zeros in each Test ID that did not complete due to an aborted test.

PRESSURE TESTING

Since 1996, Chrysler has been leak testing the EVAP system with air pressure generated by an on-board pump. This has several advantages, the greatest being that because manifold vacuum plays a different role in the test, the drive cycle is much simpler. Manifold vacuum is used only to power the on-board Leak Detection Pump (LDP), and is controlled with a solenoid valve. Here's how it works:

• The PCM opens a vacuum solenoid valve inside the LDP, admitting vacuum to the top of the LDP diaphragm.

• As the diaphragm is pulled up against a spring, filtered air is drawn through a check valve and into the chamber below the diaphragm.

• The PCM closes the solenoid valve, venting vacuum above the diaphragm and allowing the diaphragm spring to push the diaphragm back down.

• The air under the diaphragm is pushed through an exit check valve and into the EVAP system through the canister.

• The PCM continues cycling the vacuum solenoid valve to operate the pump, but the diaphragm stops moving and is held in the full-up position when EVAP system pressure equals diaphragm spring pressure.

The diaphragm spring exerts a pressure of only 7.5 in.H_2O, about 0.25 psi, and that's the pressure used to leak-check the EVAP system. When this pressure is reached, the PCM stops cycling the vacuum solenoid valve. How does it know when the system is pressurized? The key to the whole EVAP monitor system is the reed switch inside the LDP.

Above the diaphragm is a simple on-off reed switch that the PCM uses to monitor the position of the diaphragm. The switch is open when the diaphragm is up and closed when the diaphragm is down. When the reed switch stays open, the PCM knows the system is

EVAP Codes

Code	Description
P0441:	INCORRECT OR UNCOMMANDED PURGE FLOW (PURGE VALVE LEAK)
P0442:	SMALL LEAK
P0443:	PURGE SOLENOID ELECTRICAL FAULT
P0446:	BLOCKED CANISTER VENT (HIGH SYSTEM VACUUM)
P0449:	CANISTER VENT SOLENOID ELECTRICAL FAULT
P0452:	TANK PRESSURE SENSOR VOLTAGE LOW
P0453:	TANK PRESSURE SENSOR VOLTAGE HIGH
P0454:	TANK PRESSURE SENSOR VOLTAGE NOISY
P0455:	LARGE LEAK (LOW SYSTEM VACUUM)
P0456:	VERY SMALL LEAK
P0457:	GROSS LEAK (CAP OFF)
P0460:	FUEL LEVEL CIRCUIT
P0461:	FUEL LEVEL SENSOR STUCK/NOISY
P0462:	FUEL LEVEL SENSOR VOLTAGE LOW
P0463:	FUEL LEVEL SENSOR VOLTAGE HIGH
P0464:	FUEL LEVEL SENSOR VOLTAGE NOISY AT IDLE
P1443 (FORD):	GROSS LEAK, NO FLOW
P1450 (FORD):	EXCESSIVE VACUUM
P1451 (FORD):	VENT VALVE CIRCUIT FAULT
P1486 (CHRYSLER):	PINCHED HOSE
P1494 (CHRYSLER):	LDP FAULT
P1495 (CHRYSLER):	LDP SOLENOID CIRCUIT

pressurized and will stop cycling the vacuum solenoid valve. At this point, the PCM measures the amount of time it takes for the switch to close again, meaning the system pressure has fallen below diaphragm spring pressure. If the system builds and holds pressure in the correct amount of time, the test is passed.

The PCM calculates the correct amount of bleed-down time before beginning each test, based on conditions similar to those used by Ford and GM. Enable conditions for the leak test are:

• Cold start.

• Ambient temperature between 40°F and 86°F.

• Fuel level between 30 percent and 85 percent for small-leak test; 15 percent to 85 percent for large-leak test.

• Vehicle speed less than 35 mph.

• Engine run time greater than 10 seconds.

• Battery voltage between 10 and 15 volts.

• MAP (BARO) sensor reading 22 in.Hg or more.

As you can see, while the drive cycle is not as critical, it's still important to avoid generating fuel tank vapor pressure. That's why more and more vehicles are built with a return-less fuel system.

There are two phases to the leak test. First the PCM measures the amount of time needed to pressurize the system. If pressure never builds, a gross leak is assumed. If pressure builds within a few pump strokes, this indicates a pinched or plugged hose between the LDP and the canister. Next, it will measure the size of the leak by measuring the amount of time between turning off the vacuum solenoid valve and the reed switch closing as the diaphragm falls. In general, it takes 1.2 seconds to pass the large-leak test and six seconds to pass the small-leak test.

The Leak Detection Pump also includes the canister vent valve. The diaphragm still has a bit of downward travel left after the reed switch closes. If the PCM doesn't open the vacuum solenoid valve to pull the diaphragm up again, the diaphragm will continue down and bottom out. At this
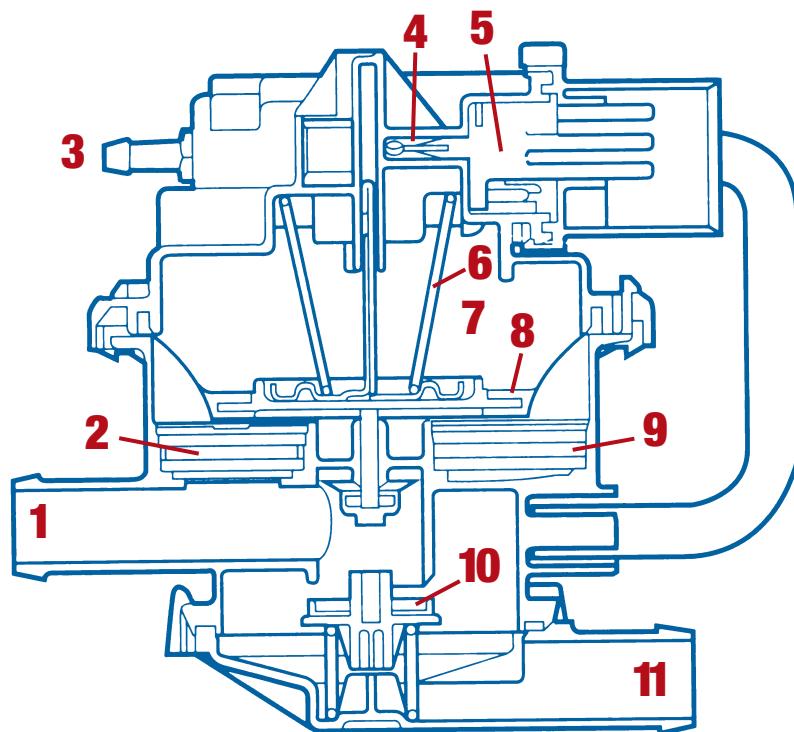
The key to Chrysler's LDP is the reed switch. When the diaphragm is all the way down, the vent valve is pushed open.

1. To canister
2. One-way check valve outlet
3. Vacuum from intake manifold
4. Reed switch
5. Pressure/vacuum solenoid
6. Diaphragm spring
7. Pump cavity
8. Diaphragm
9. One-way check valve (inlet)
10. Vent valve
11. To air filter

point, a shaft attached to the bottom of the diaphragm pushes the spring-loaded canister vent valve open. That means the vent valve is closed only when the LDP diaphragm is pulled up with vacuum.

It's easy to see from the enabling criteria that cars driven in extreme hot or cold weather may not run the EVAP monitor for months, and cars that never leave the high country might never test the system at all. With a bidirectional scan tool, the purge and vent valves can be commanded closed for testing with smoke, and on any vehicle a scope or graphing meter can be used to monitor the tank pressure sensor or LDP reed switch during a drive cycle. This can be helpful in states that use the vehicle's own onboard diagnostic system for emissions inspection. Just remember that the PCM is looking for stable testing conditions, correct operation of the solenoid valves and/or LDP, and the time needed to build, hold and release system pressure or vacuum.

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