CHAPTER 17

EMISSION CONTROL DEVICES OPERATION AND DIAGNOSIS

OBJECTIVES

After studying Chapter 17, the reader will be able to:

1. Prepare for the ASE Engine Performance (A8) certification test content area "D" (Emission Control Systems).
2. Describe the purpose and function of the exhaust gas recirculation system.
3. Explain methods for diagnosing and testing for faults in the exhaust gas recirculation system.
4. Describe the purpose and function of the positive crankcase ventilation and the air injection reaction system.
5. Explain methods for diagnosing and testing faults in the PCV and AIR systems.
6. Describe the purpose and function of the catalytic converter.
7. Explain the method for diagnosing and testing the catalytic converter.

KEY TERMS

AIR (p. 298)
Backpressure (p. 307)
Blowby (p. 294)
Catalyst (p. 304)
Catalytic Converter (p. 303)
Cerium (p. 309)
Check Valves (p. 299)
Digital EGR (p. 289)
DPFE (p. 291)
EGR (p. 286)
EVP (p. 288)
EVRV (p. 292)
HO2S (p. 305)
Inert (p. 286)
Infrared Pyrometer (p. 307)
Light-Off (p. 305)
Linear EGR (p. 290)
LOC (p. 305)
Mini Converter (p. 305)
Negative Backpressure (p. 288)
NO_X (p. 286)
OSC (p. 305)
Palladium (p. 304)
PCV (p. 294)
PFE (p. 288)
Platinum (p. 304)
Positive Backpressure (p. 288)
Preconverter (p. 305)
Pup Converter (p. 305)
Rhodium (p. 304)
Smog Pump (p. 298)
Tap Test (p. 306)
Thermactor Pump (p. 298)
TWC (p. 304)
Washcoat (p. 303)

EXHAUST GAS RECIRCULATION SYSTEMS

Exhaust gas recirculation (EGR) is an emission control that lowers the amount of **nitrogen oxides (NO_X)** formed during combustion. In the presence of sunlight, NO_X reacts with hydrocarbons in the atmosphere to form ozone (O_3) or photochemical smog, an air pollutant.

NO_x Formation

Nitrogen N_2 and oxygen O_2 molecules are separated into individual atoms of nitrogen and oxygen during the combustion process. These then bond to form NO_X (NO, NO_2). When combustion flame front temperatures exceed 2,500°F (1,370°C), NO_X formation increases dramatically.

CONTROLLING NO_X

The amounts of NO_X formed at temperatures below 2,500°F (1,370°C) can be controlled in the exhaust by a catalyst. To handle the amounts generated above 2,500°F (1,370°C), the following are some methods that have been used to lower NO_X formation:

- **Enrich the air–fuel mixture.** More fuel lowers the peak combustion temperature, but it raises hydrocarbon (HC) and carbon monoxide (CO) emissions. The reduction in fuel economy also makes this solution unattractive.
- **Lower the compression ratio.** This decreases NO_X levels somewhat but also reduces combustion efficiency. When the compression ratio becomes too low, HC and CO emissions rise.
- **Dilute the air–fuel mixture.** To lower emission levels further, engineers developed a system that introduces small amounts of exhaust gas into the engine intake. This lowers combustion temperatures by displacing some of the air and absorbs heat without contributing to the combustion process. Currently, this is one of the most efficient methods to meet NO_X emission level cut-points without significantly affecting engine performance, fuel economy, and other exhaust emissions. The EGR system routes small quantities, usually between 6% and 10%, of exhaust gas to the intake manifold.

Here, the exhaust gas mixes with and takes the place of some intake charge. This leaves less room for the intake charge to enter the combustion chamber. The recirculated exhaust gas is **inert** (chemically inactive) and does not enter into the combustion process. The result is a lower peak combustion temperature. As the combustion temperature is lowered, the production of oxides of nitrogen is also reduced.

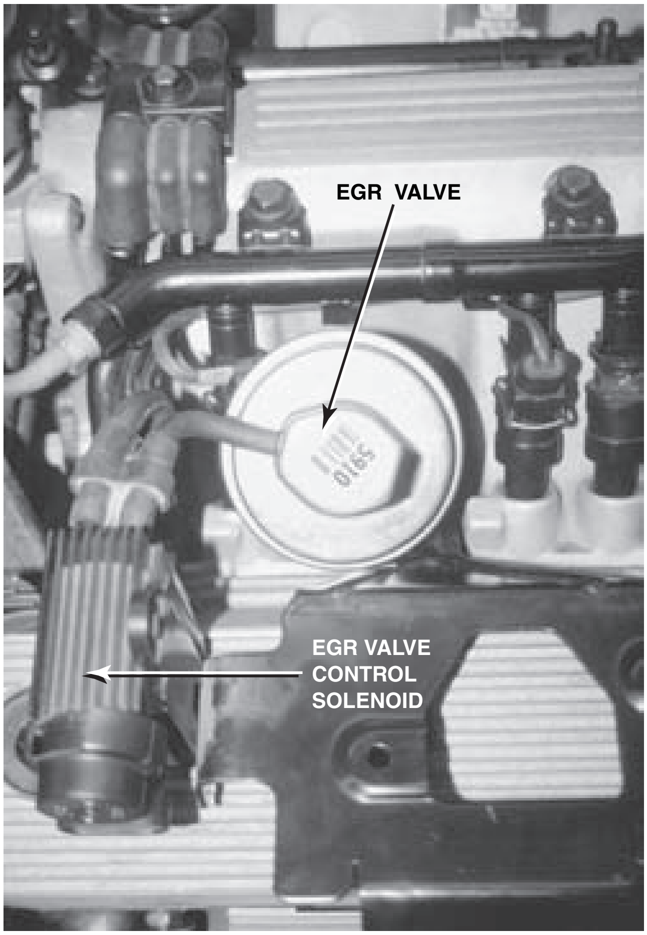

FIGURE 17-1 Typical vacuum-operated EGR valve. The operation of the valve is controlled by the computer by pulsing the EGR control solenoid on and off.

The EGR system has some means of interconnecting the exhaust and intake manifolds. See Figure 17-1. The interconnecting passage is controlled by the EGR valve. On V-type engines, the intake manifold crossover is used as a source of exhaust gas for the EGR system. A cast passage connects the exhaust crossover to the EGR valve. The gas is sent from the EGR valve to openings in the manifold. On inline-type engines, an external tube is generally used to carry exhaust gas to the EGR valve. This tube is often designed to be long so that the exhaust gas is cooled before it enters the EGR valve.

NOTE: **The amount of EGR is subtracted from the mass air flow calculations. While the EGR gases do occupy space, they do not affect the air–fuel mixture.**

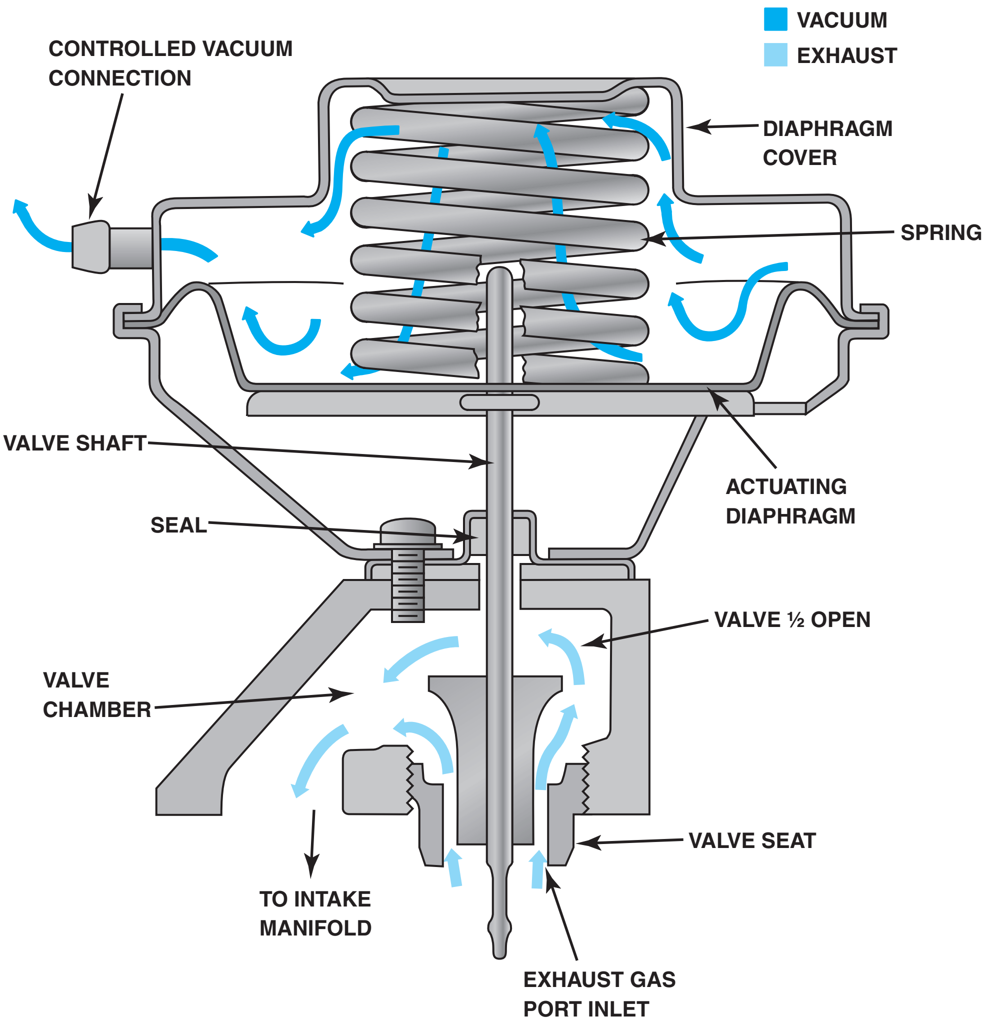

FIGURE 17-2 When the EGR valve opens, exhaust flows through the valve and into passages in the intake manifold.

EGR SYSTEM OPERATION

Since small amounts of exhaust are all that is needed to lower peak combustion temperatures, the orifice that the exhaust passes through is small. See Figure 17-2.

Because combustion temperatures are low, EGR is usually not required during the following conditions:

- Idle speed
- When the engine is cold
- At wide-open throttle (WOT)

The level of NO_X emission changes according to engine speed, temperature, and load. EGR is not used at wide-open throttle (WOT) because it would reduce engine performance and the engine does not operate under these conditions for a long period of time.

In addition to lowering NO_X levels, the EGR system also helps control detonation. Detonation, or ping, occurs when high pressure and heat cause the air–fuel mixture to ignite. This uncontrolled combustion can severely damage the engine.

Using the EGR system allows for greater ignition timing advance and for the advance to occur sooner without detonation problems, which increases power and efficiency.

POSITIVE AND NEGATIVE BACKPRESSURE EGR VALVES

Some EGR valves used on older engines are designed with a small valve inside that bleeds off any applied vacuum and prevents the valve from opening. These types of EGR valves

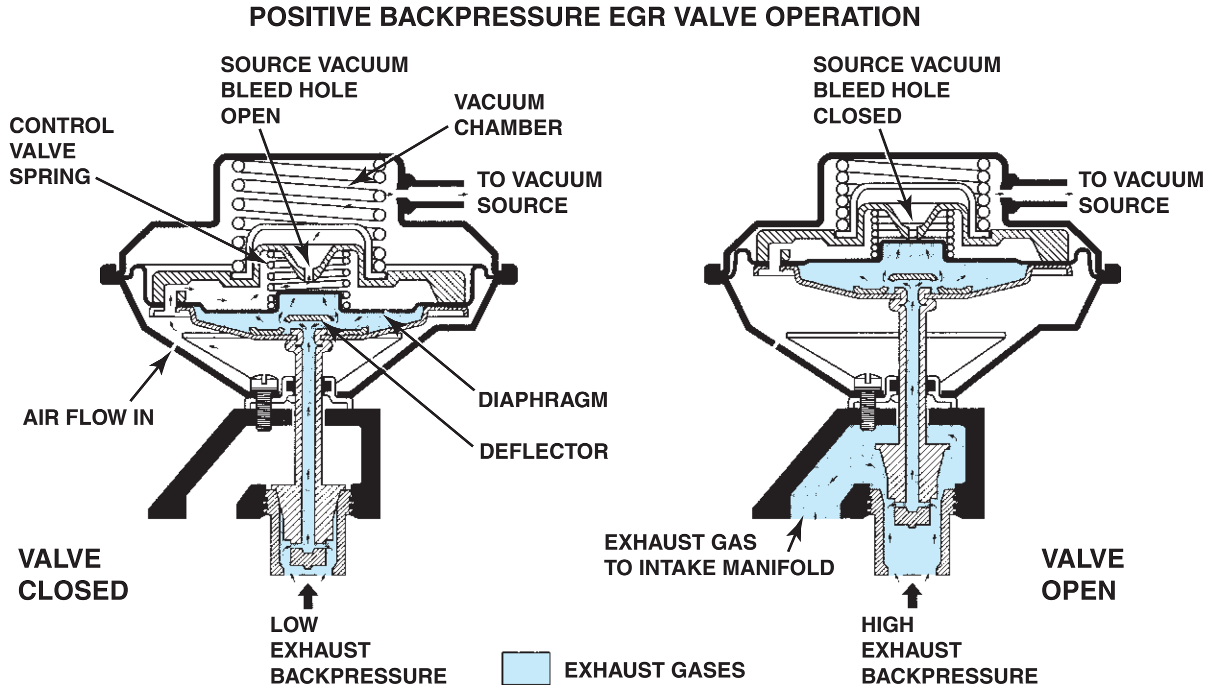

FIGURE 17-3 Backpressure in the exhaust system is used to close the control valve, thereby allowing engine vacuum to open the EGR valve.

require a positive backpressure in the exhaust system. This is called a **positive backpressure** EGR valve. At low engine speeds and light engine loads, the EGR system is not needed, and the backpressure in it is also low. Without sufficient backpressure, the EGR valve does not open even though vacuum may be present at the EGR valve.

On each exhaust stroke, the engine emits an exhaust "pulse." Each pulse represents a positive pressure. Behind each pulse is a small area of low pressure. Some EGR valves react to this low pressure area by closing a small internal valve, which allows the EGR valve to be opened by vacuum. This type of EGR valve is called a **negative backpressure** EGR valve. See Figure 17-3. The following conditions must occur:

1. Vacuum must be applied to the EGR valve itself. This is usually ported vacuum on some TBI fuel-injected systems. The vacuum source is often manifold vacuum and is controlled by the computer through a solenoid valve.
2. Exhaust backpressure must be present to close an internal valve inside the EGR to allow the vacuum to move the diaphragm.

NOTE: The installation of a low restriction exhaust system could prevent the proper operation of the backpressure-controlled EGR valve.

COMPUTER-CONTROLLED EGR SYSTEMS

Many computer-controlled EGR systems have one or more solenoids controlling the EGR vacuum. The computer controls a solenoid to shut off vacuum to the EGR valve at cold engine temperatures, idle speed, and wide-open throttle operation. If two solenoids are used, one acts as an off/on control of supply vacuum, while the second solenoid vents vacuum when EGR flow is not desired or needs to be reduced. The second solenoid is used to control a vacuum air bleed, allowing atmospheric pressure in to modulate EGR flow according to vehicle operating conditions.

EGR Valve Position Sensors

Late-model, computer-controlled EGR systems use a sensor to indicate EGR operation. On-board diagnostics generation-II (OBD-II) EGR system monitors require an EGR sensor to do their job. A linear potentiometer on the top of the EGR valve stem indicates valve position for the computer. This is called an **EGR valve position (EVP)** sensor. See Figure 17-4. Some later-model Ford EGR systems, however, use a feedback signal provided by an EGR exhaust backpressure sensor which converts the exhaust backpressure to a voltage signal. This sensor is called a **pressure feedback EGR (PFE)** sensor.

FIGURE 17-4 An EGR valve position sensor on top of an EGR valve.

TECH TIP

FIND THE ROOT CAUSE

Excessive backpressure, such as that caused by a partially clogged exhaust system, could cause the plastic sensors on the EGR valve to melt. Always check for a restricted exhaust whenever replacing a failed EGR valve sensor.

The GM-integrated electronic EGR valve uses a similar sensor. The top of the valve contains a vacuum regulator and EGR pintle-position sensor in one assembly sealed inside a non-removable plastic cover. The pintle-position sensor provides a voltage output to the PCM, which increases as the duty cycle increases, allowing the PCM to monitor valve operation. See Figure 17-5.

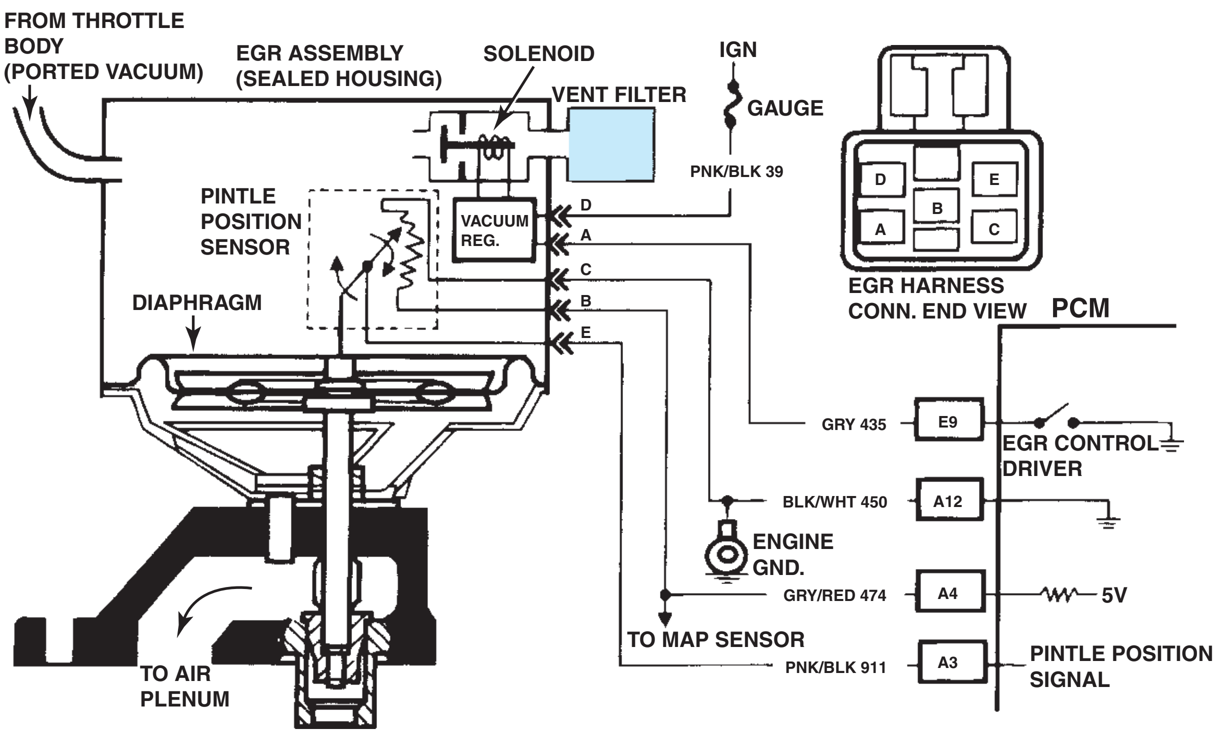

FIGURE 17-5 An integrated EGR valve system showing the pintle-position sensor and vacuum diaphragm.

Digital EGR Valves

GM introduced a completely electronic, **digital EGR** valve design on some 1990 engines. Unlike the previously mentioned vacuum-operated EGR valves, the digital EGR valve consists of three solenoids controlled by the PCM. See Figure 17-6. Each solenoid controls a different size orifice in the base—small, medium, and large. The PCM controls each solenoid ground

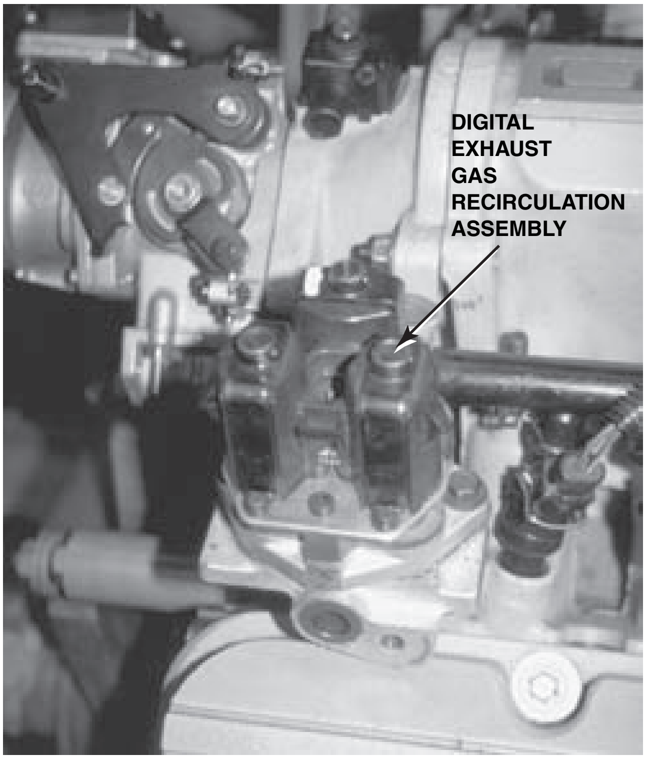

FIGURE 17-6 This 3,800 V-6 uses three solenoids for EGR. A scan tool can be used to turn on each solenoid to check if the valve is working and if the exhaust passages are capable of flowing enough exhaust to the intake manifold to affect engine operation when cycled.

individually. It can produce any of seven different flow rates, using the solenoids to open the three valves in different combinations. The digital EGR valve offers precise control, and using a swivel pintle design helps prevent carbon deposit problems.

Linear EGR

Most General Motors and many other vehicles use a **linear EGR** that contains a solenoid to precisely regulate exhaust gas flow and a feedback potentiometer that signals the computer regarding the actual position of the valve. See Figures 17-7 and 17-8.

FIGURE 17-7 A General Motors linear EGR valve.

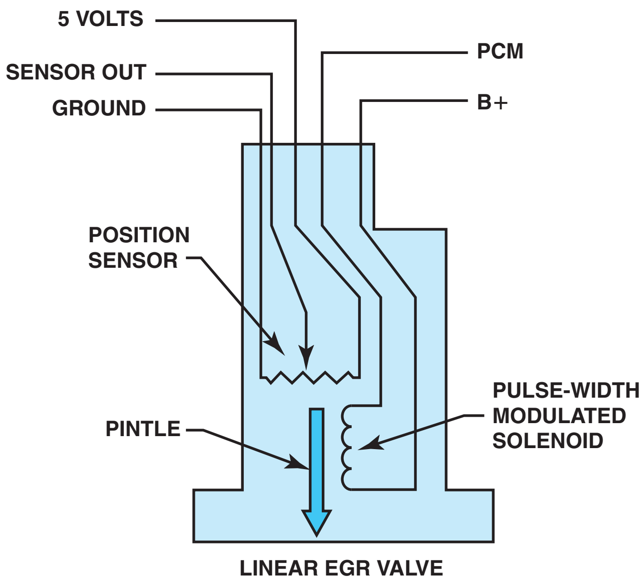

FIGURE 17-8 The EGR valve pintle is pulse-width modulated and a three-wire potentiometer provides pintle-position information back to the PCM.

OBD-II EGR MONITORING STRATEGIES

In 1996, the U.S. EPA began requiring OBD-II systems in all passenger cars and most light-duty trucks. These systems include emissions system monitors that alert the driver and the technician if an emissions system is malfunctioning. To be certain the EGR system is operating, the PCM runs a functional test of the system, when specific operating conditions exist. The OBD-II system tests by opening and closing the EGR valve. The PCM monitors an EGR function sensor for a change in signal voltage. If the EGR system fails, a diagnostic trouble code (DTC) is set. If the system fails two

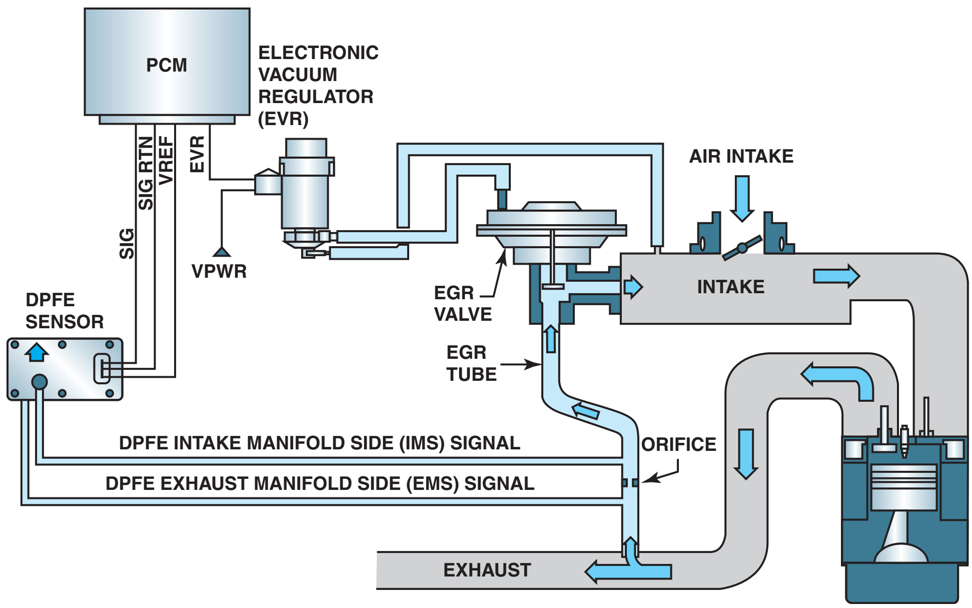

FIGURE 17-9 A DPFE sensor and related components.

consecutive times, the malfunction indicator light (MIL) is lit.

Chrysler monitors the difference in the exhaust oxygen sensor's voltage activity as the EGR valve opens and closes. Oxygen in the exhaust decreases when the EGR valve is open and increases when the EGR valve is closed. The PCM sets a DTC if the sensor signal does not change.

Depending on the vehicle application, Ford uses at least one of two types of sensors to evaluate exhaust-gas flow. The first type uses a temperature sensor mounted in the intake side of the EGR passageway. The PCM monitors the change in temperature when the EGR valve is open. When the EGR is open and exhaust is flowing, the sensor signal is changed by the heat of the exhaust. The PCM compares the change in the sensor's signal with the values in its look-up table.

DPFE EGR Sensor Chart

PSI	Pressure In. Hg	kPa	Voltage Volts
4.34	8.83	29.81	4.56
3.25	6.62	22.36	3.54
2.17	4.41	14.90	2.51
1.08	2.21	7.46	1.48
0	0	0	0.45

The second type of Ford EGR monitor test sensor is called a **Delta Pressure Feedback EGR (DPFE) sensor.** This sensor measures the pressure differential between two sides of a metered orifice positioned just below the EGR valve's exhaust side. Pressure between the orifice and the EGR valve decreases when the EGR opens because it becomes exposed to the lower pressure in the intake. The DPFE sensor recognizes this pressure drop, compares it to the relatively higher pressure on the exhaust side of the orifice, and signals the value of the pressure difference to the PCM. See Figure 17-9. When the EGR valve is closed, the exhaust-gas pressure on both sides of the orifice is equal.

The OBD-II EGR monitor for this second system runs when programmed operating conditions (enable criteria) have been met. The monitor evaluates the pressure differential while the PCM commands the EGR valve to open. Like other systems, the monitor compares the measured value with the look-up table value. If the pressure differential falls outside the acceptable value, a DTC sets.

Many vehicle manufacturers use the manifold absolute pressure (MAP) sensor as the EGR monitor on some applications. After meeting the enable criteria (operating condition requirements), the EGR monitor is run. The PCM monitors the MAP sensor while it commands the EGR valve to open. The MAP sensor signal should change in response to the sudden change in manifold pressure or the fuel trim changes created by a change in the oxygen sensor voltage. If the signal value falls outside the acceptable value in the look-up table, a DTC sets. See Figure 17-10. If the EGR fails on two consecutive trips the PCM lights the MIL.

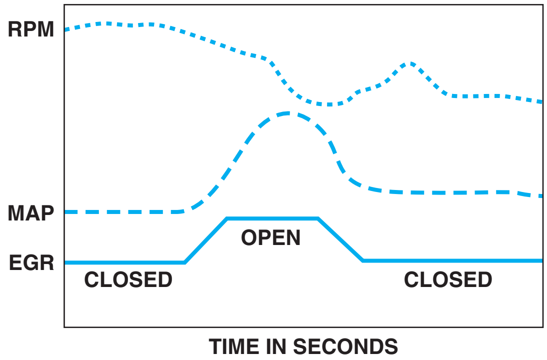

FIGURE 17-10 An OBD-II active test. The PCM opens the EGR valve and then monitors the MAP sensor and/or engine speed (RPM) to meet acceptable values.

DIAGNOSING A DEFECTIVE EGR SYSTEM

If the EGR valve is not opening or the flow of the exhaust gas is restricted, then the following symptoms are likely:

- Ping (spark knock or detonation) during acceleration or during cruise (steady-speed driving)
- Excessive oxides of nitrogen (NO_X) exhaust emissions

If the EGR valve is stuck open or partially open, then the following symptoms are likely:

- Rough idle or frequent stalling
- Poor performance/low power, especially at low engine speed

TECH TIP

WATCH OUT FOR CARBON BALLS!

Exhaust gas recirculation (EGR) valves can get stuck partially open by a chunk of carbon. The EGR valve or solenoid will test as defective. When the valve (or solenoid) is removed, small chunks or balls of carbon often fall into the exhaust manifold passage. When the replacement valve is installed, the carbon balls can be drawn into the new valve again, causing the engine to idle roughly or stall.

To help prevent this problem, start the engine with the EGR valve or solenoid removed. Any balls or chunks of carbon will be blown out of the passage by the exhaust. Stop the engine and install the replacement EGR valve or solenoid.

REAL WORLD FIX

THE BLAZER STORY

The owner of a Chevrolet Blazer equipped with a 4.3-L, V-6 engine complained that the engine would stumble and hesitate at times. Everything seemed to be functioning correctly, except that the service technician discovered a weak vacuum going to the EGR valve at idle. This vehicle was equipped with an EGR valve-control solenoid, called an **electronic vacuum regulator valve** or **EVRV** by General Motors Corporation. The computer pulses the solenoid to control the vacuum that regulates the operation of the EGR valve. The technician checked the service manual for details on how the system worked. The technician discovered that vacuum should be present at the EGR valve only when the gear selector indicates a drive gear (drive, low, reverse). Because the technician discovered the vacuum at the solenoid to be leaking, the solenoid was obviously defective and required replacement. After replacement of the solenoid (EVRV), the hesitation problem was solved.

NOTE: The technician also discovered in the service manual that blower-type exhaust hoses should not be connected to the tailpipe on any vehicle while performing an inspection of the EGR system. The vacuum created by the system could cause false EGR valve operation to occur.

The first step in almost any diagnosis is to perform a thorough visual inspection. To check for proper operation of a vacuum-operated EGR valve, follow these steps:

1. Check the vacuum diaphragm to see if it can hold vacuum.

   NOTE: Because many EGR valves require exhaust backpressure to function correctly, the engine should be running at a fast idle.

2. Apply vacuum from a hand-operated vacuum pump and check for proper operation. The valve itself should move when vacuum is applied, and the engine operation should be affected. The EGR valve should be able to hold the vacuum that was applied. If the vacuum drops off, then the valve is likely to be defective.

   If the EGR valve is able to hold vacuum, but the engine is not affected when the valve is opened, then the exhaust passage(s) must be checked for restriction. See the Tech Tip "The Snake Trick." If the EGR valve will not hold vacuum, the valve itself is likely to be defective and require replacement.

REAL WORLD FIX

I WAS ONLY TRYING TO HELP!

On a Friday, an experienced service technician found that the driveability performance problem with a Buick V-6 was a worn EGR valve. When vacuum was applied to the valve, the valve did not move at all. Additional vacuum from the hand-operated vacuum pump resulted in the valve popping all the way open. A new valve of the correct part number was not available until Monday, yet the customer wanted the vehicle back for a trip during the weekend.

To achieve acceptable driveability, the technician used a small hammer and deformed the top of the valve to limit the travel of the EGR valve stem. The technician instructed the customer to return on Monday for the proper replacement valve.

The customer did return on Monday, but now accompanied by his lawyer. The engine had developed a hole in one of the pistons. The lawyer reminded the technician and the manager that an exhaust emission control had been “modified.” The result was the repair shop paid for a new engine and the technician learned to always repair the vehicle correctly or not at all.

TECH TIP

THE SNAKE TRICK

The EGR passages on many intake manifolds become clogged with carbon, which reduces the flow of exhaust and the amount of exhaust gases in the cylinders. This reduction can cause spark knock (detonation) and increased emissions of oxides of nitrogen (NO_X) (especially important in areas with enhanced exhaust emissions testing).

To quickly and easily remove carbon from exhaust passages, cut an approximately 1-foot (30-cm) length from stranded wire, such as garage door guide wire or an old speedometer cable. Flare the end and place the end of the wire into the passage. Set your drill on reverse, turn it on, and the wire will pull its way through the passage, cleaning the carbon as it goes, just like a snake in a drain pipe. Some vehicles, such as Hondas, require that plugs be drilled out to gain access to the EGR passages, as shown in Figure 17-11.

FIGURE 17-11 Removing the EGR passage plugs from the intake manifold on a Honda.

3. Connect a vacuum gauge to an intake manifold vacuum source and monitor the engine vacuum at idle (should be 17 to 21 in. Hg at sea level). Raise the speed of the engine to 2,500 RPM and note the vacuum reading (should be 17 to 21 in. Hg or higher). Activate the EGR valve using a scan tool or vacuum pump, if vacuum controlled, and observe the vacuum gauge. The results are as follows:
   - The vacuum should drop 6 to 8 in. Hg.
   - If the vacuum drops less than 6 to 8 in. Hg, the valve or the EGR passages are clogged.

EGR-Related OBD-II Diagnostic Trouble Codes

Diagnostic Trouble Code	Description	Possible Causes
P0400	Exhaust gas recirculation flow problems	▪ EGR valve ▪ EGR valve hose or electrical connection ▪ Defective PCM
P0401	Exhaust gas recirculation flow insufficient	▪ EGR valve ▪ Clogged EGR ports or passages
P0402	Exhaust gas recirculation flow excessive	▪ Stuck-open EGR valve ▪ Vacuum hose(s) misrouted ▪ Electrical wiring shorted

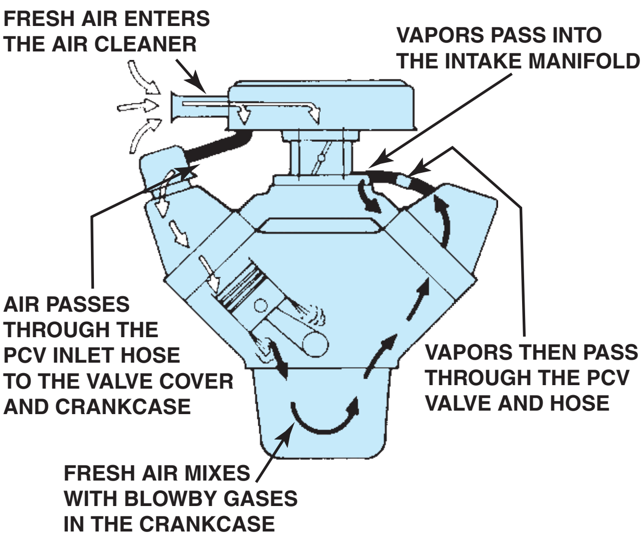

FIGURE 17-12 A PCV system includes a hose from the air cleaner assembly so that filtered air can be drawn into the crankcase. This filtered air is then drawn by engine vacuum through the PCV valve and into the intake manifold, where the crankcase fumes are burned in the cylinder. The PCV valve controls and limits this flow of air and fumes into the engine and the valve closes in the event of a backfire to prevent flames from entering the crankcase area.

CRANKCASE VENTILATION

The problem of crankcase ventilation has existed since the beginning of the automobile, because no piston ring, new or old, can provide a perfect seal between the piston and the cylinder wall. When an engine is running, the pressure of combustion forces the piston downward. This same pressure also forces gases and unburned fuel from the combustion chamber, past the piston rings, and into the crankcase. This process of gases leaking past the rings is called **blowby,** and the gases form crankcase vapors.

These combustion by-products, particularly unburned hydrocarbons caused by blowby, must be ventilated from the crankcase. However, the crankcase cannot be vented directly to the atmosphere, because the hydrocarbon vapors add to air pollution. **Positive crankcase ventilation (PCV)** systems were developed to ventilate the crankcase and recirculate the vapors to the engine's induction system so they can be burned in the cylinders.

Closed PCV Systems

All systems use a PCV valve, calibrated orifice or separator, an air inlet filter, and connecting hoses. See Figure 17-12. An oil/vapor or oil/water separator is used in some systems instead of a valve or orifice, particularly with turbocharged and fuel-injected engines. The oil/vapor separator lets oil condense and drain back into the crankcase. The oil/water separator accumulates moisture and prevents it from freezing during cold engine starts.

The air for the PCV system is drawn after the air cleaner filter, which acts as a PCV filter.

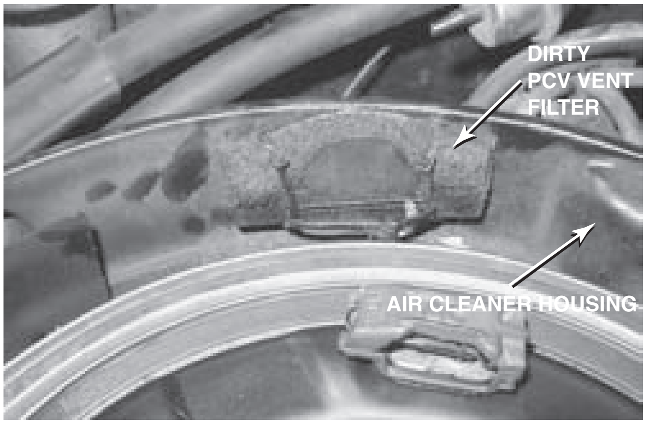

FIGURE 17-13 A dirty PCV vent filter inside the air cleaner housing. The air enters the crankcase through this filter and then is drawn into the engine through the PCV valve.

NOTE: **Some older designs drew from the dirty side of the air cleaner, where a separate crankcase ventilation filter was used. See Figure 17-13.**

PCV VALVES

The PCV valve in most systems is a one-way valve containing a spring-operated plunger that controls valve flow rate. See Figure 17-14. Flow rate is established for each engine and a valve for a different engine should not be substituted. The flow rate is determined by the size of the plunger and the holes inside the valve. PCV valves usually are located in the valve cover or intake manifold.

The PCV valve regulates air flow through the crankcase under all driving conditions and speeds. When manifold vacuum is high (at idle, cruising, and light-load operation), the PCV valve restricts the air flow to maintain a balanced air–fuel ratio. See Figure 17-15. It also prevents high intake manifold vacuum from pulling oil out of the crankcase and into the intake manifold. Under high speed or heavy loads, the valve opens and allows maximum air flow. See Figure 17-16. If the engine backfires, the valve will close instantly to prevent a crankcase explosion. See Figure 17-17.

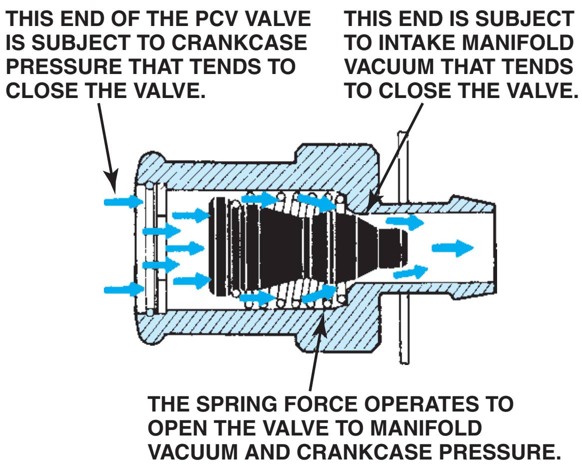

FIGURE 17-14 Spring force, crankcase pressure, and intake manifold vacuum work together to regulate the flow rate through the PCV valve.

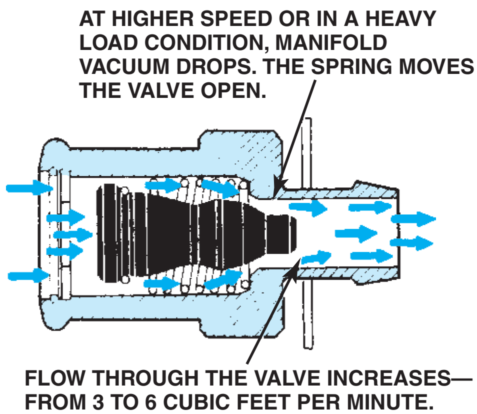

FIGURE 17-16 Air flows through the PCV valve during acceleration and when the engine is under a heavy load.

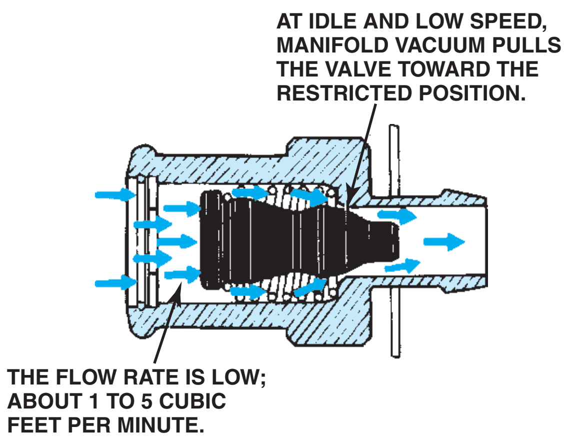

FIGURE 17-15 Air flows through the PCV valve during idle, cruising, and light-load conditions.

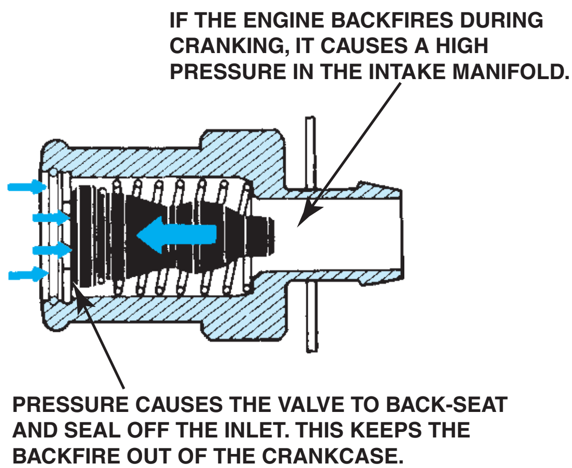

FIGURE 17-17 PCV valve operation in the event of a backfire.

ORIFICE-CONTROLLED SYSTEMS

The closed PCV system used on some 4-cylinder engines contains a calibrated orifice instead of a PCV valve. The orifice may be located in the valve cover or intake manifold, or in a hose connected between the valve cover, air cleaner, and intake manifold.

While most orifice flow control systems work the same as a PCV valve system, they may not use fresh air scavenging of the crankcase. Crankcase vapors are drawn into the intake manifold in calibrated amounts depending on manifold pressure and the orifice size. If vapor availability is low, as during idle, air is drawn in with the vapors. During off-idle operation, excess vapors are sent to the air cleaner.

At idle, PCV flow is controlled by a 0.050-inch (1.3-mm) orifice. As the engine moves off-idle, ported vacuum pulls a spring-loaded valve off of its seat, allowing PCV flow to pass through a 0.090-inch (2.3-mm) orifice.

Separator Systems

Turbocharged and many fuel-injected engines use an oil/vapor or oil/water separator and a calibrated orifice instead of a PCV valve. In the most common applications, the air intake throttle body acts as the source for crankcase ventilation vacuum, and a calibrated orifice acts as the metering device.

REAL WORLD FIX

THE WHISTLING ENGINE

An older vehicle was being diagnosed for a whistling sound whenever the engine was running, especially at idle. It was finally discovered that the breather in the valve cover was plugged and caused high vacuum in the crankcase. The engine was sucking air from what was likely the rear main seal lip, making the "whistle" noise. After replacing the breather and PCV, the noise stopped.

POSITIVE CRANKCASE VENTILATION (PCV) SYSTEM DIAGNOSIS

When intake air flows freely, the PCV system functions properly, as long as the PCV valve or orifice is not clogged. Modern engine design includes the air and vapor flow as a calibrated part of the air–fuel mixture. In fact, some engines receive as much as 30% of their idle air through the PCV system. For this reason, a flow problem in the PCV system results in driveability problems.

A blocked or plugged PCV system is a major cause of high oil consumption, and contributes to many oil leaks. Before expensive engine repairs are attempted, check the condition of the PCV system. See Figure 17-18.

PCV System Performance Check

A properly operating positive crankcase ventilation system should be able to draw vapors from the crankcase and into the intake manifold. If the pipes, hoses, and PCV valve itself are not restricted, vacuum is applied to the crankcase. A slight vacuum is created in the crankcase (usually less than 1 in. Hg if measured at the dipstick) and is also applied to other areas of the engine. Oil drainback holes provide a path for oil to drain back into the oil pan. These holes also allow crankcase vacuum to be applied under the rocker covers and in the valley area of most V-type engines. There are several methods that can be used to test a PCV system.

The Rattle Test

The rattle test is performed by simply removing the PCV valve and shaking it in your hand. See Figure 17-19.

- If the PCV valve does *not* rattle, it is definitely defective and must be replaced.

FIGURE 17-18 A visual inspection found this deteriorated PCV vacuum hose.

TECH TIP

CHECK FOR OIL LEAKS WITH THE ENGINE OFF

The owner of an older vehicle equipped with a V-6 engine complained to his technician that he smelled burning oil, but only *after* shutting off the engine. The technician found that the rocker cover gaskets were leaking. But why did the owner only notice the smell of hot oil when the engine was shut off? Because of the positive crankcase ventilation (PCV) system, engine vacuum tends to draw oil away from gasket surfaces. But when the engine stops, engine vacuum disappears and the oil remaining in the upper regions of the engine will tend to flow down and out through any opening. Therefore, a good technician should check an engine for oil leaks not only with the engine running but also shortly after shutdown.

- If the PCV valve *does* rattle, it does not necessarily mean that the PCV valve is good. All PCV valves contain springs that can become weaker with age and heating and cooling cycles. Replace any PCV valve with the *exact* replacement according to vehicle manufacturers' recommended intervals (usually every 3 years or 36,000 miles, or 60,000 km).

The 3 × 5 Card Test

Remove the oil-fill cap (where oil is added to the engine) and start the engine. See Figure 17-20.

FIGURE 17-19 A typical PCV valve. A defective or clogged PCV valve or hose can cause a rough idle or stalling problem. Because the air flow through the PCV valve accounts for about 20% of the air needed by the engine at idle, use of the incorrect valve for an application could have a severe effect on idle quality.

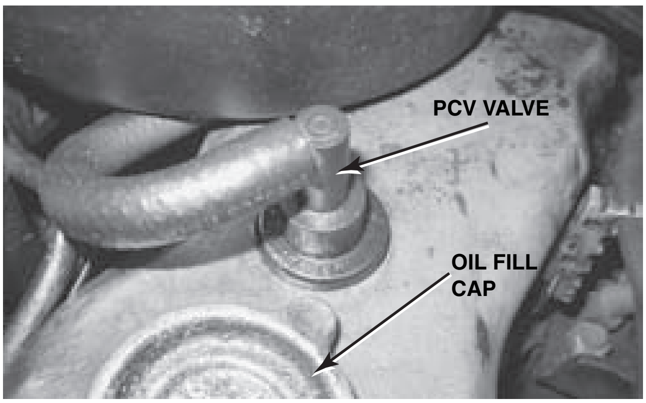

FIGURE 17-20 A typical PCV valve installed in a rubber grommet in the valve cover.

NOTE: **Use care on some overhead camshaft engines. With the engine running, oil may be sprayed from the open oil-fill opening.**

Hold a 3 × 5 card over the opening (a dollar bill or any other piece of paper can be used for this test).

- If the PCV system, including the valve and hoses, is functioning correctly, the card should be held down on the oil-fill opening by the slight vacuum inside the crankcase.
- If the card will not stay, carefully inspect the PCV valve, hose(s), and manifold vacuum port for carbon buildup (restriction). Clean or replace as necessary.

NOTE: On some 4-cylinder engines, the 3 × 5 card may vibrate on the oil-fill opening when the engine is running at idle speed. This is normal because of the time intervals between intake strokes on a 4-cylinder engine.

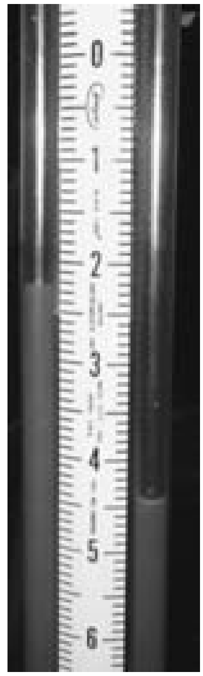

FIGURE 17-21 A water manometer being used to check for a slight vacuum when testing at the oil dipstick tube.

The Snap-Back Test

The proper operation of the PCV valve can be checked by placing a finger over the inlet hole in the valve when the engine is running and removing the finger rapidly. Repeat several times. The valve should "snap back." If the valve does not snap back, replace the valve.

Crankcase Vacuum Test

Sometimes the PCV system can be checked by testing for a weak vacuum at the oil dipstick tube using an inches-of-water manometer or gauge as follows:

Step 1 Remove the oil-fill cap and cover the opening.
Step 2 Remove the oil level indicator (dipstick).
Step 3 Connect a water manometer or gauge to the dipstick tube.
Step 4 Start the engine and observe the gauge at idle and at 2500 RPM. See Figure 17-21.

The gauge should show some vacuum, especially at 2500 RPM. If not, carefully inspect the PCV system for blockages or other faults.

PCV MONITOR

Starting with 2004 and newer vehicles, all vehicles must be checked for proper operation of the PCV system. The PCV monitor will fail if the PCM detects an opening between the crankcase and the PCV valve or between the PCV valve and the intake manifold.

PCV-Related Diagnostic Trouble Code

Diagnostic Trouble Code	Description	Possible Causes
P1480	PCV solenoid circuit fault	▪ Defective PCV solenoid ▪ Loose or corroded electrical connection ▪ Loose defective vacuum hoses/connections

AIR PUMP SYSTEM

An air pump provides the air necessary for the oxidizing process inside the catalytic converter. See Figure 17-22.

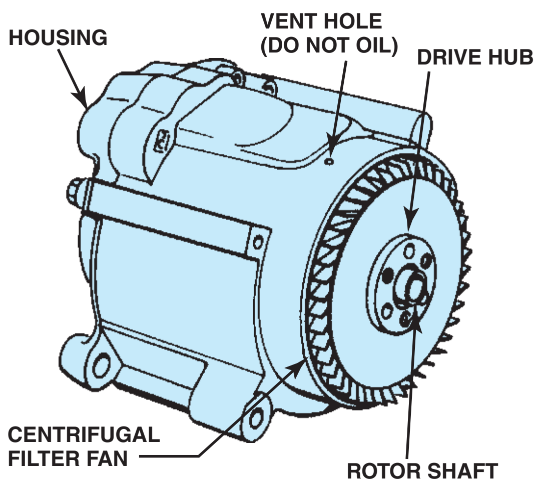

FIGURE 17-22 A typical belt-driven air pump. Air enters through the revolving fins. These fins act as a moving air filter because dirt is heavier than air, and therefore the dirt in the air is deflected off the fins at the same time the air is drawn into the pump.

NOTE: This system is commonly called **AIR**, meaning **air injection reaction**. Therefore, an AIR pump does pump air.

The AIR pump, sometimes referred to as a **smog pump** or **thermactor pump,** is mounted at the front of the engine and driven by a belt from the crankshaft pulley. It pulls fresh air in through an external filter and pumps the air under slight pressure to each exhaust port through connecting hoses or a manifold.

- A belt-driven pump with inlet air filter (older models); or,
- An electronic air pump (newer models)
- One or more air distribution manifolds and nozzles
- One or more exhaust check valves
- Connecting hoses for air distribution
- Air management valves and solenoids on all newer applications

With the introduction of NO_x reduction converters (also called dual-bed, three-way converters, or TWC), the output of the AIR pump is sent to the center of the converter where the extra air can help oxidize HC and CO into H_2O and CO_2.

The computer controls the air flow from the pump by switching on and off various solenoid valves. When the engine is cold, the air pump output is directed to the exhaust manifold to help provide enough oxygen to convert HC (unburned gasoline) and CO (carbon monoxide) to H_2O (water) and CO_2 (carbon dioxide). When the engine becomes warm and is operating in closed loop, the computer operates the air valves so as to direct the air pump output to the catalytic converter. When the vacuum rapidly increases above the normal idle level, as during rapid deceleration, the computer diverts the air pump output to the air cleaner assembly to silence the air. Diverting the air to the air cleaner prevents exhaust backfire during deceleration. See Figure 17-23.

AIR DISTRIBUTION MANIFOLDS AND NOZZLES

The air-injection system sends air from the pump to a nozzle installed near each exhaust port in the cylinder head. This provides equal air injection for the exhaust from each cylinder and makes it available at a point in the system where exhaust gases are the hottest.

Air is delivered to the exhaust system in one of two ways:

- An external air manifold, or manifolds, distributes the air through injection tubes with stainless steel nozzles. The

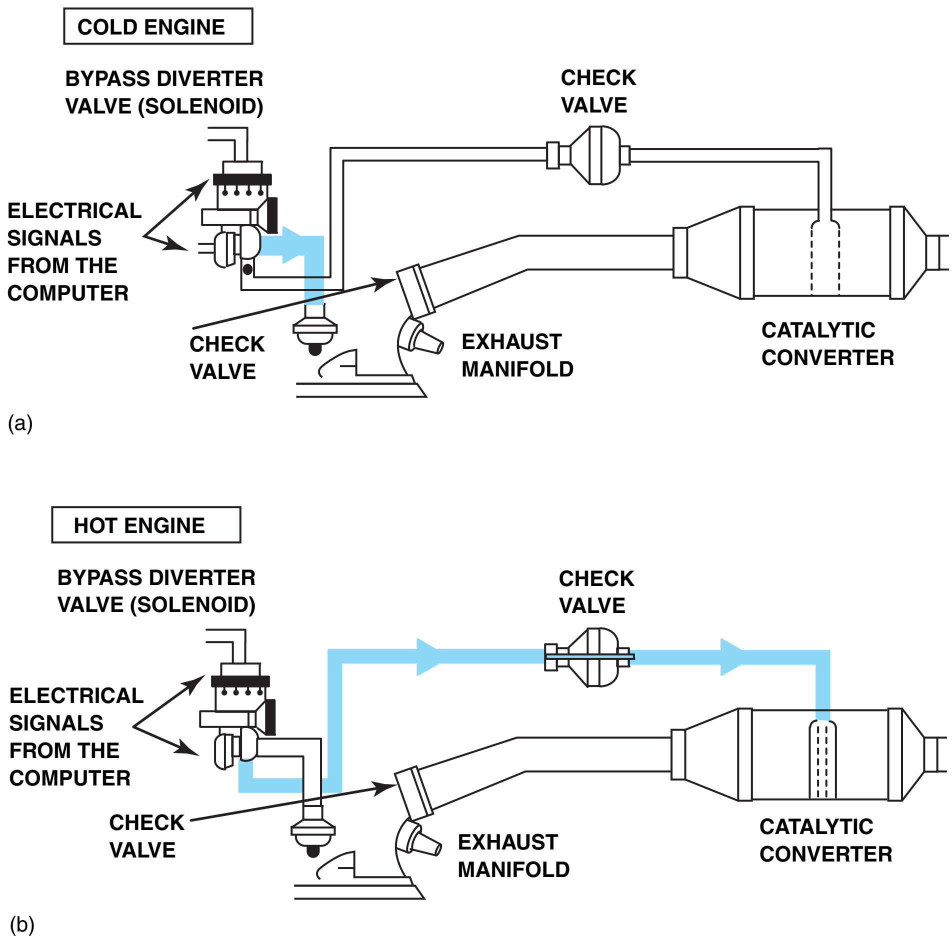

FIGURE 17-23 (a) When the engine is cold and before the oxygen sensor is hot enough to reach closed loop, the air flow is directed to the exhaust manifold(s) through one-way check valve(s). These valves keep exhaust gases from entering the switching solenoids and the air pump itself. (b) When the engine achieves closed loop, the air flows through the pump, is directed to the catalytic converter, and then moves through a check valve.

nozzles are threaded into the cylinder heads or exhaust manifolds close to each exhaust valve. This method is used primarily with smaller engines.

- An internal air manifold distributes the air to the exhaust ports near each exhaust valve through passages cast in the cylinder head or the exhaust manifold. This method is used mainly with larger engines.

Three basic types of air pumps are the belt-driven air pump, the pulse air-driven air pump, and the electric motor-driven air pump.

Exhaust Check Valves

All air-injection systems use one or more one-way check valves to protect the air pump and other components from reverse exhaust flow. A **check valve** contains a spring-type metallic disc or reed that closes the air line under exhaust backpressure. Check valves are located between the air manifold and the diverter valve. See Figure 17-24. If exhaust pressure exceeds injection pressure, or if the air pump fails, the check valve spring closes the valve to prevent reverse exhaust flow. See Figure 17-25.

All air pump systems use one-way check valves to allow air to flow into the exhaust manifold and to prevent the hot exhaust from flowing into the valves on the air pump itself.

NOTE: *These check valves commonly fail, resulting in excessive exhaust emissions (CO especially). When the check valve fails, hot exhaust can travel up to and destroy the switching valve(s) and air pump itself.*

Belt-Driven Air Pumps

The belt-driven air pump uses a centrifugal filter just behind the drive pulley. As the pump rotates, underhood air is drawn

FIGURE 17-24 An AIR exhaust check valve between the rubber air hose and the metal discharge tubes.

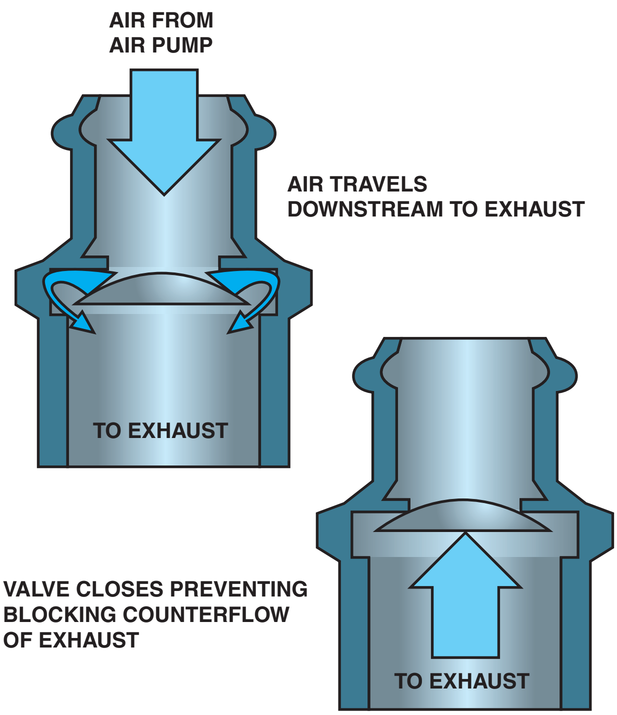

FIGURE 17-25 Exhaust check valves in the AIR system allow air to flow in only one direction.

into the pump and slightly compressed. See Figure 17-26. The air is then directed to:

- The exhaust manifold when the engine is cold to help oxidize CO and HC into carbon dioxide (CO_2) and water vapor (H_2O).

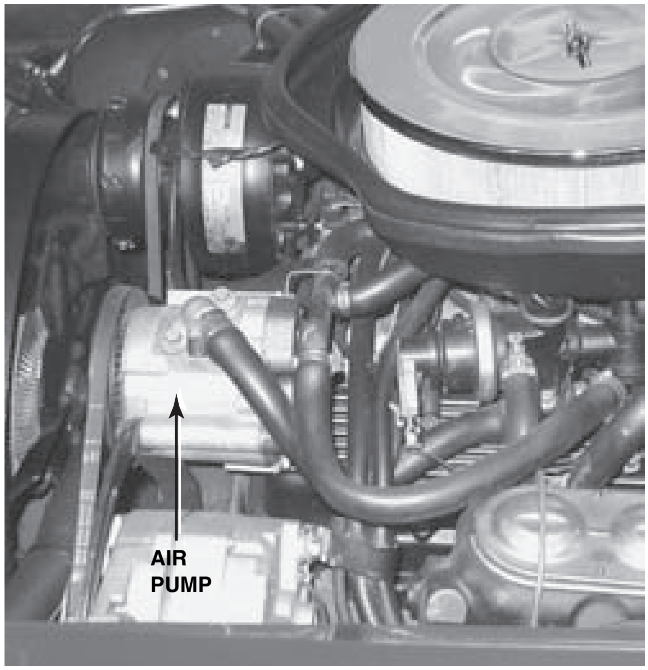

FIGURE 17-26 A typical belt-driven air pump used on an older model Chevrolet Corvette.

- The catalytic converter on many models to help provide the extra oxygen needed for the efficient conversion of CO and HC into CO_2 and H_2O.
- The air cleaner during deceleration or wide-open throttle (WOT) engine operation. See Figure 17-27.

Electric Motor-Driven Air Pumps

This style of pump is generally used only during cold engine operation and is computer controlled. The air injection reaction (AIR) system helps reduce hydrocarbon (HC) and carbon monoxide (CO). It also helps to warm up the three-way catalytic converters quickly on engine start-up so conversion of exhaust gases may occur sooner.

The AIR pump and solenoid is controlled by the PCM. The PCM turns on the AIR pump by providing the ground to complete the circuit which energizes the AIR pump solenoid relay. When air to the exhaust ports is desired, the PCM energizes the relay in order to turn on the solenoid and the AIR pump.

The PCM turns on the AIR pump during start-up any time the engine coolant temperature is above 32°F (0°C). A typical electric AIR pump operates for a maximum of 240 seconds, or until the system enters closed-loop operation. The AIR system is disabled under the following conditions:

- The PCM recognizes a problem and sets a diagnostic trouble code.
- The AIR pump has been on for 240 seconds.

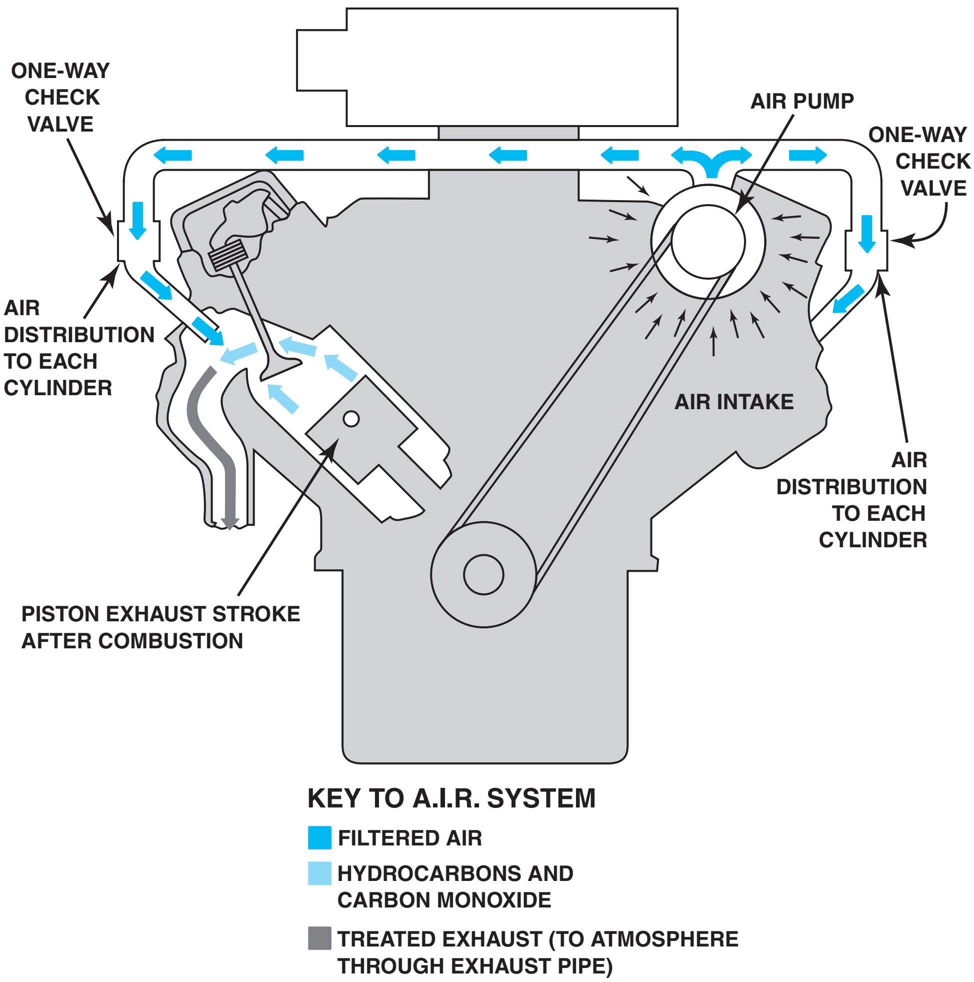

FIGURE 17-27 The air pump supplies air to the exhaust port of each cylinder. Unburned HCs are oxidized into CO_2 and H_2O, and CO is converted to CO_2.

- The engine speed is more than 2825 RPM.
- The manifold absolute pressure (MAP) is less than 6 in. Hg/20 kPa.
- Warm up three-way catalytic converters over temperature detected.
- The short- and long-term fuel trim are not in their normal ranges.
- Power enrichment is detected.

If no air (oxygen) enters the exhaust stream at the exhaust ports, the HC and CO emission levels will be higher than normal.

Air flowing to the exhaust ports at all times could increase temperature of the three-way catalytic converter.

The diagnostic trouble codes P0410 and/or P0418 set if there is a malfunction in the following components:

- The AIR pump
- The AIR solenoid
- The AIR pump solenoid relay
- Leaking hoses or pipes
- Leaking check valves
- The circuits going to the AIR pump and the AIR pump solenoid relay

The AIR pump is an electric type pump that requires no periodic maintenance. To check the operation of the AIR pump, the engine should be at normal operating temperature in neutral at idle. Using a scan tool, enable the AIR pump system and watch the heated oxygen sensor (HO2S) voltages for both bank 1 and bank 2 HO2S. The HO2S voltages for both sensors should remain under 350 mV because air is being directed to the exhaust ports. If the HO2S voltages remain low during this test, the AIR pump, solenoid, and shutoff valve are operating satisfactorily. If the HO2S voltage does not remain low when the AIR pump is enabled, inspect for the following:

- Voltage at the AIR pump when energized
- A seized AIR pump

FIGURE 17-28 Cutaway of a pulse air-driven air device used on many older engines to deliver air to the exhaust port through the use of the exhaust pulses acting on a series of one-way check valves. Air from the air cleaner assembly moves through the system and into the exhaust port where the additional air helps reduce HC and CO exhaust emissions.

- The hoses, vacuum lines, pipes, and all connections for leaks and proper routing
- Air flow going to the exhaust ports
- AIR pump for proper mounting
- Hoses and pipes for deterioration or holes

If a leak is suspected on the pressure side of the system, or if a hose or pipe has been disconnected on the pressure side, the connections should be checked for leaks with a soapy water solution. With the AIR pump running, bubbles form if a leak exists.

The check valves should be inspected whenever the hose is disconnected or whenever check valve failure is suspected. An AIR pump that had become inoperative and had shown indications of having exhaust gases in the outlet port would indicate check valve failure.

Pulse Air-Driven Devices

The pulse air-driven air pump uses the exhaust system pulses to draw in the compressed air. See Figure 17-28. Pulse air or aspirator valves are similar in design to exhaust check valves. Each valve contains a spring-loaded diaphragm or reed valve and is connected by tubing to the exhaust port of each cylinder or the exhaust manifold. Each time an exhaust valve closes, there is a period when exhaust manifold pressure drops below atmospheric pressure. During these low-pressure (slight vacuum) pulses, the pulse valve opens to admit fresh air to the exhaust. When the exhaust valve opens and exhaust pressure rises above atmospheric pressure, the pulse air valve acts as a check valve and closes. As a result, air "injection" or more correctly, ingestion, occurs without the need for a power-consuming air pump.

Pulse air injection works best at low engine speeds when extra air is needed most by the catalytic converter. At high engine speeds, the vacuum pulses occur too rapidly for the valve to follow, and the internal spring simply keeps the valve closed. Pulse air valves must be connected upstream in the exhaust system where negative pressure pulses are strongest. This means that pulse air cannot be switched downstream for use in the converter or between oxidation and reduction catalysts.

AIR PUMP SYSTEM DIAGNOSIS

The air pump system should be inspected if an exhaust emissions test failure occurs. In severe cases, the exhaust will enter the air cleaner assembly, resulting in a horribly running engine because the extra exhaust displaces the oxygen needed for proper combustion. With the engine running, check for normal operation:

Engine Operation	Normal Operation of a Typical Air Injection Reaction (AIR) Pump System
Cold engine (open-loop operation)	Air is diverted to the exhaust manifold(s) or cylinder head
Warm engine (closed-loop operation)	Air is diverted to the catalytic converter
Deceleration	Air is diverted to the air cleaner assembly
Wide-open throttle	Air is diverted to the air cleaner assembly

Visual Inspection

Carefully inspect all air injection reaction (AIR) system hoses and pipes. Any pipes that have holes and leak air or exhaust require replacement. The check valve(s) should be checked when a pump has become inoperative. Exhaust gases could have gotten past the check valve and damaged the pump. Check the drive belt on an engine-driven pump for wear and proper tension.

Four-Gas Exhaust Analysis

An AIR system can be easily tested using an exhaust gas analyzer. Follow these steps:

1. Start the engine and allow it to run until normal operating temperature is achieved.
2. Connect the analyzer probe to the tailpipe and observe the exhaust readings for hydrocarbons (HC) and carbon monoxide (CO).
3. Using the appropriate pinch-off pliers, shut off the air flow from the AIR system. Observe the HC and CO readings. If the AIR system is working correctly, the HC and CO should increase when the AIR system is shut off.
4. Record the O_2 reading with the AIR system still inoperative. Unclamp the pliers and watch the O_2 readings. If the system is functioning correctly, the O_2 level should increase by 1% to 4%.

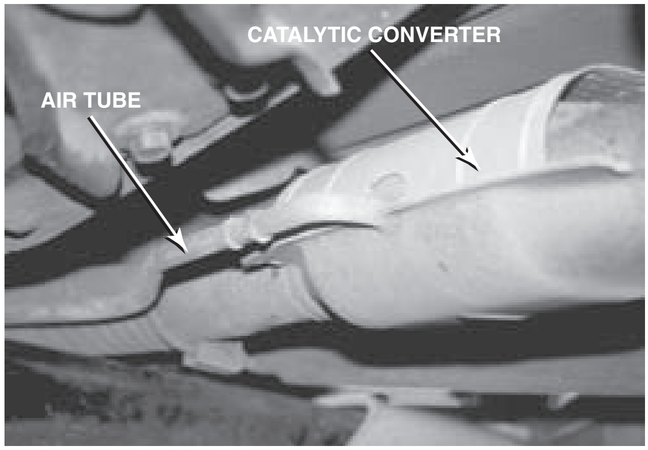

FIGURE 17-29 Typical catalytic converter. The small tube into the side of the converter comes from the air pump. The additional air from the air pump helps oxidize the exhaust into harmless H_2O and CO_2.

Air-Related Diagnostic Trouble Code

Diagnostic Trouble Code	Description	Possible Causes
P1485	AIR solenoid circuit fault	▪ Defective AIR solenoid ▪ Loose or corroded electrical connections ▪ Loose, missing, or defective rubber hose(s)

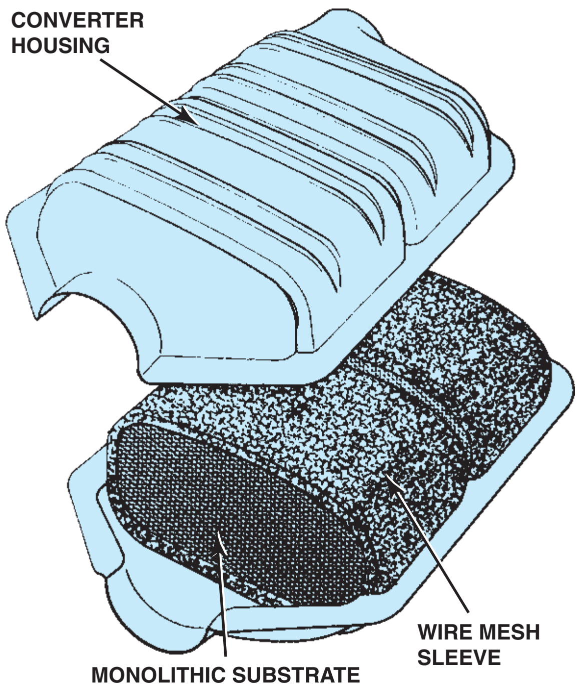

FIGURE 17-30 A typical catalytic converter with a monolithic substrate.

CATALYTIC CONVERTERS

A **catalytic converter** is an aftertreatment device used to reduce exhaust emissions outside of the engine. This device is installed in the exhaust system between the exhaust manifold and the muffler, and usually is positioned beneath the passenger compartment. See Figure 17-29. The location of the converter is important, since as much of the exhaust heat as possible must be retained for effective operation. The nearer it is to the engine, the better.

CERAMIC MONOLITH CATALYTIC CONVERTER

Most catalytic converters are constructed of a ceramic material in a honeycomb shape with square openings for the exhaust gases. There are approximately 400 openings per square inch (62 per sq. cm) and the wall thickness is about 0.006 in. (1.5 mm). The substrate is then coated with a porous aluminum material called the **washcoat,** which makes the surface rough. The catalytic materials are then applied on top of the washcoat. The substrate is contained within a round or oval shell made by welding together two stamped pieces of aluminum or stainless steel. See Figure 17-30.

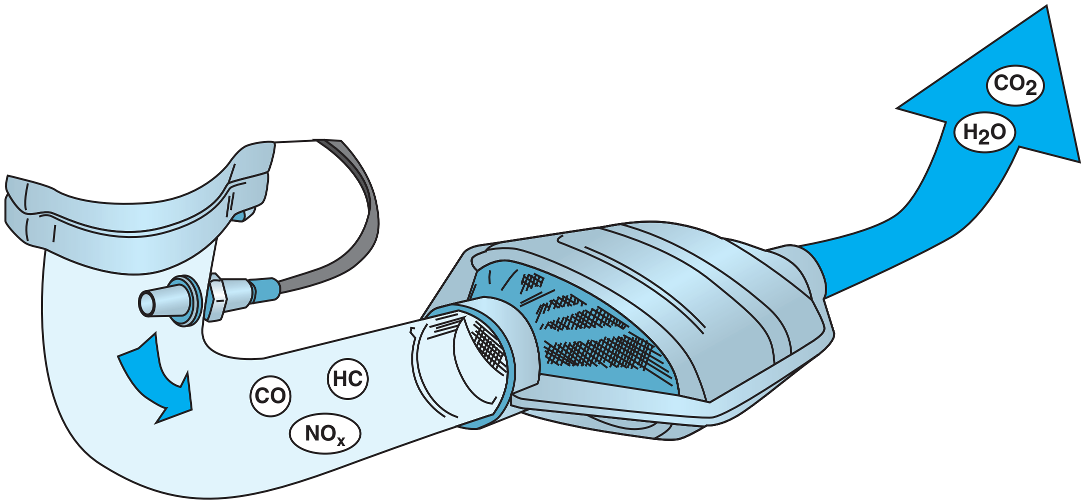

FIGURE 17-31 The three-way catalytic converter first separates the NO_X into nitrogen and oxygen and then converts the HC and CO into harmless water (H_2O) and carbon dioxide (CO_2).

The ceramic substrate in monolithic converters is not restrictive, but the converter breaks more easily when subject to shock or severe jolts and is more expensive to manufacture. Monolithic converters can be serviced only as a unit.

An exhaust pipe is connected to the manifold or header to carry gases through a catalytic converter and then to the muffler or silencer. V-type engines usually route the exhaust into one catalytic converter.

Catalytic Converter Operation

The converter contains small amounts of **rhodium, palladium,** and **platinum.** These elements act as catalysts. A **catalyst** is an element that starts a chemical reaction without becoming a part of, or being consumed in, the process. In a **three-way catalytic converter (TWC)** all three exhaust emissions (NO_x, HC, and CO) are converted to carbon dioxide (CO_2) and water (H_2O). See Figure 17-31. As the exhaust gas passes through the catalyst, oxides of nitrogen (NO_x) are chemically reduced (that is, nitrogen and oxygen are separated) in the first section of the catalytic converter. In the second section of the catalytic converter, most of the hydrocarbons and carbon monoxide remaining in the exhaust gas are oxidized to form harmless carbon dioxide (CO_2) and water vapor (H_2O). An air-injection system or pulse air system is used on some engines to supply additional air that may be needed in the oxidation process. See Figure 17-32.

NOTE: A two-way converter used in most vehicles from 1975 to 1980 only contained the oxidation portion.

FIGURE 17-32 A cutaway of a three-way catalytic converter showing the air tube in the center of the reducing and oxidizing section of the converter. Note the small holes in the tube to distribute air from the AIR pump to the oxidizing rear section of the converter.

Since the early 1990s, many converters also contain cerium, an element that can store oxygen. The purpose of the cerium is to provide oxygen to the oxidation bed of the converter when the exhaust is rich and lacks enough oxygen for proper oxidation. When the exhaust is lean, the cerium absorbs the extra oxygen. For most efficient operation, the converter should have a 14.7:1 air–fuel ratio exhaust but can use a mixture that varies slightly.

- A rich exhaust is required for reduction—stripping the oxygen (O_2) from the nitrogen in NO_x
- A lean exhaust is required to provide the oxygen necessary to oxidize HC and CO (combining oxygen with HC and CO to form H_2O and CO_2)

If the catalytic converter is not functioning correctly, check to see that the air–fuel mixture being supplied to the engine is correct and that the ignition system is free of defects.

Converter Light-Off

The catalytic converter does not work when cold and it must be heated to its **light-off** temperature of close to 500°F (260°C) before it starts working at 50% effectiveness. When fully effective, the converter reaches a temperature range of 900° to 1,600°F (482° to 871°C). In spite of the intense heat, however, catalytic reactions do not generate a flame associated with a simple burning reaction. Because of the extreme heat (almost as hot as combustion chamber temperatures), a converter remains hot long after the engine is shut off. Most vehicles use a series of heat shields to protect the passenger compartment and other parts of the chassis from excessive heat. Vehicles have been known to start fires because of the hot converter causing tall grass or dry leaves beneath the just-parked vehicle to ignite, especially if the engine is idling.

Converter Usage

A catalytic converter must be located as close as possible to the exhaust manifold to work effectively. The farther back the converter is positioned in the exhaust system, the more gases cool before they reach the converter. Since positioning in the exhaust system affects the oxidation process, cars that use only an oxidation converter generally locate it underneath the front of the passenger compartment.

Some vehicles have used a small, quick heating oxidation converter called a **preconverter, pup,** or **mini-converter** that connects directly to the exhaust manifold outlet. These have a small catalyst surface area close to the engine that heats up rapidly to start the oxidation process more quickly during cold engine warm-up. For this reason, they were often called **light-off converters,** or **LOC.** The oxidation reaction started in the LOC is completed by the larger main converter under the passenger compartment.

OBD-II CATALYTIC CONVERTER PERFORMANCE

With OBD-II equipped vehicles, catalytic converter performance is monitored by **heated oxygen sensor (HO2S),** both before and after the converter. See Figure 17-33. The converters used on these vehicles have what is known as **OSC** or **oxygen storage capacity.** OSC is due mostly to the cerium coating in the catalyst rather than the precious metals used. When the TWC is operating as it should, the post-converter HO2S is far less active than the preconverter sensor. The converter stores, then releases, the oxygen during its normal reduction and oxidation of the exhaust gases, smoothing out the variations in O2 being released.

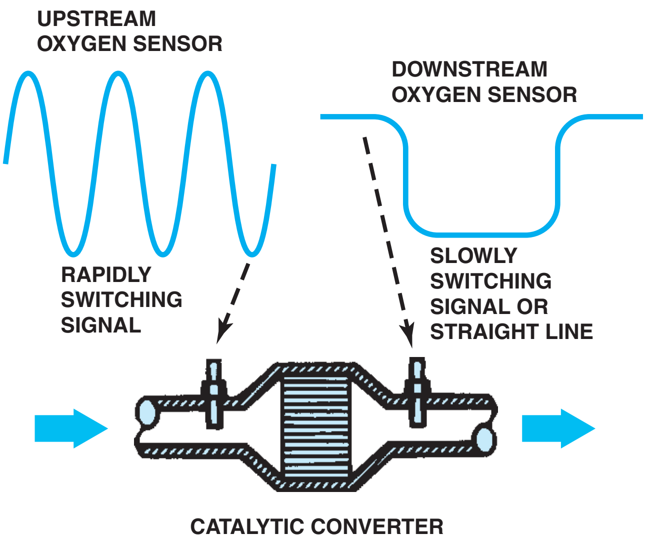

FIGURE 17-33 The OBD-II catalytic converter monitor compares the signals of the upstream and downstream HO2S to determine converter efficiency.

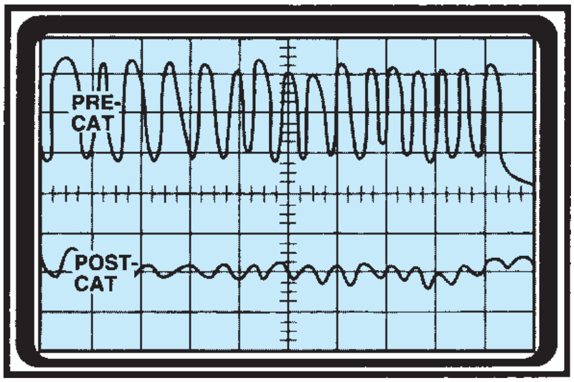

FIGURE 17-34 The waveform of an HO2S downstream from a properly functioning converter shows little, if any, activity.

Where a cycling sensor voltage output is expected before the converter, because of the converter action, the post-converter HO2S should read a steady signal without much fluctuation. See Figure 17-34. With the rapid light-off and more efficient converters used today, the air pump needs to supply only secondary air during the first few minutes of cold-engine operation.

CONVERTER-DAMAGING CONDITIONS

Since converters have no moving parts, they require no periodic service. Under federal law, catalyst effectiveness is warranted for 80,000 miles or 8 years.

The three main causes of premature converter failure are:

- **Contamination.** Substances that can destroy the converter include exhaust that contains excess engine oil,

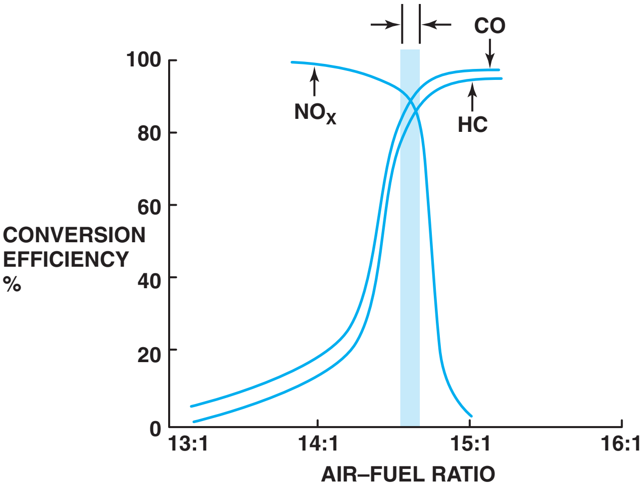

FIGURE 17-35 The highest catalytic converter efficiency occurs when the air–fuel mixture is about 14.7:1.

antifreeze, sulfur (from poor fuel), and various other chemical substances.

- **Excessive temperatures.** Although a converter operates a high temperature, it can be destroyed by excessive temperatures. This most often occurs either when too much unburned fuel enters the converter, or with excessively lean mixtures. Excessive temperatures may be caused by long idling periods on some vehicles, since more heat develops at those times than when driving at normal highway speeds. Severe high temperatures can cause the converter to melt down, leading to the internal parts breaking apart and either clogging the converter or moving downstream to plug the muffler. In either case, the restricted exhaust flow severely reduces engine power.
- **Improper air–fuel mixtures.** Rich mixtures or raw fuel in the exhaust can be caused by engine misfiring, or an excessively rich air–fuel mixture resulting from a defective coolant temp sensor or defective fuel injectors. Lean mixtures are commonly caused by intake manifold leaks. See Figure 17-35. When either of these circumstances occurs, the converter can become a catalytic furnace, causing the previously described damage.

To avoid excessive catalyst temperatures and the possibility of fuel vapors reaching the converter, follow these rules:

1. Do not try to start the engine by pushing the vehicle. Use jumper cables or a jump box to start the engine.
2. Do not crank an engine for more than 40 seconds when it is flooded or firing intermittently.
3. Do not turn off the ignition switch when the vehicle is in motion.

FREQUENTLY ASKED QUESTION

CAN A CATALYTIC CONVERTER BE DEFECTIVE WITHOUT BEING CLOGGED?

Yes. Catalytic converters can fail by being chemically damaged or poisoned without being mechanically clogged. Therefore, the catalytic converter should not only be tested for physical damage (clogging) by performing a backpressure or vacuum test and a rattle test but also a test for temperature rise, usually with a pyrometer or propane test, to check the efficiency of the converter.

FIGURE 17-36 This catalytic converter blew up when gasoline from the excessively rich-running engine ignited. Obviously, raw gasoline was trapped inside and all it needed was a spark. No further diagnosis of this converter is necessary. However, the fuel and ignition systems would need to be tested and repaired before operating the engine to prevent a reoccurrence.

4. Do not disconnect a spark plug wire for more than 30 seconds.
5. Repair engine problems such as dieseling, misfiring, or stumbling as soon as possible.

DIAGNOSING CATALYTIC CONVERTERS

The Tap Test

The simple **tap test** involves tapping (not pounding) on the catalytic converter using a rubber mallet. If the substrate inside the converter is broken, the converter will rattle when hit. If the converter rattles, a replacement converter is required. See Figure 17-36.

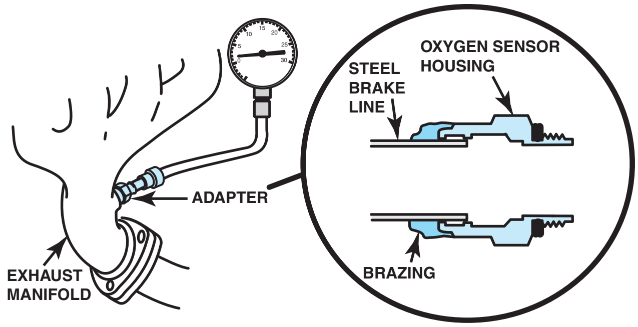

FIGURE 17-37 A backpressure tool can be easily made by attaching a short section of brake line to the shell of an old oxygen sensor. Braze or epoxy the tube to the shell.

Testing Backpressure with a Vacuum Gauge

A vacuum gauge can be used to measure manifold vacuum at a high idle (2000 to 2500 RPM). If the exhaust system is restricted, pressure increases in the exhaust system. This pressure is called **backpressure.** Manifold vacuum will drop gradually if the engine is kept at a constant speed if the exhaust is restricted.

The reason the vacuum will drop is that all the exhaust leaving the engine at the higher engine speed cannot get through the restriction. After a short time (within 1 minute), the exhaust tends to "pile up" above the restriction and eventually remains in the cylinder of the engine at the end of the exhaust stroke. Therefore, at the beginning of the intake stroke, when the piston traveling downward should be lowering the pressure (raising the vacuum) in the intake manifold, the extra exhaust in the cylinder *lowers* the normal vacuum. If the exhaust restriction is severe enough, the vehicle can become undriveable because cylinder filling cannot occur except at idle.

Testing Backpressure with a Pressure Gauge

Exhaust system backpressure can be measured directly by installing a pressure gauge in an exhaust opening. This can be accomplished in one of the following ways:

1. To test an oxygen sensor, remove the inside of an old, discarded oxygen sensor and thread in an adapter to convert it to a vacuum or pressure gauge.

   NOTE: An adapter can be easily made by inserting a metal tube or pipe. A short section of brake line works great. The pipe can be brazed to the oxygen sensor housing or it can be glued with epoxy. An 18-millimeter compression gauge adapter can also be adapted to fit into the oxygen sensor opening. See Figure 17-37.

2. To test an exhaust gas recirculation (EGR) valve, remove the EGR valve and fabricate a plate.
3. To test an air injection reaction (AIR) check valve, remove the check valve from the exhaust tubes leading to the exhaust manifold. Use a rubber cone with a tube inside to seal against the exhaust tube. Connect the tube to a pressure gauge.

At idle the maximum backpressure should be less than 1.5 PSI (10 kPa), and it should be less than 2.5 PSI (15 kPa) at 2500 RPM.

Testing a Catalytic Converter for Temperature Rise

A properly working catalytic converter should be able to reduce NO_x exhaust emissions into nitrogen (N) and oxygen (O_2) and oxidize unburned hydrocarbon (HC) and carbon monoxide (CO) into harmless carbon dioxide (CO_2) and water vapor (H_2O). During these chemical processes, the catalytic converter should increase in temperature at least 10% if the converter is working properly. To test the converter, operate the engine at 2500 RPM for at least 2 minutes to fully warm up the converter. Measure the inlet and the outlet temperatures using an **infrared pyrometer** as shown in Figure 17-38.

NOTE: If the engine is extremely efficient, the converter may not have any excessive unburned hydrocarbons or carbon monoxide to convert! In this case, a spark plug wire could be grounded out using a vacuum hose and a test light to create some unburned hydrocarbon in the exhaust. Do not ground out a cylinder for longer than 10 seconds or the excessive amount of unburned hydrocarbon could overheat and damage the converter.

Catalytic Converter Efficiency Tests

The efficiency of a catalytic converter can be determined using an exhaust gas analyzer.

Oxygen level test. With the engine warm and in closed loop, check the oxygen (O_2) and carbon monoxide (CO) levels.

- If O_2 is zero, go to the snap-throttle test.
- If O_2 is greater than zero, check the CO level.
- If CO is greater than zero, the converter is *not* functioning correctly.

Snap-throttle test. With the engine warm and in closed loop snap the throttle to wide open (WOT) in park or neutral and observe the oxygen reading.

- O_2 reading should not exceed 1.2%; if it does, the converter is *not* working.

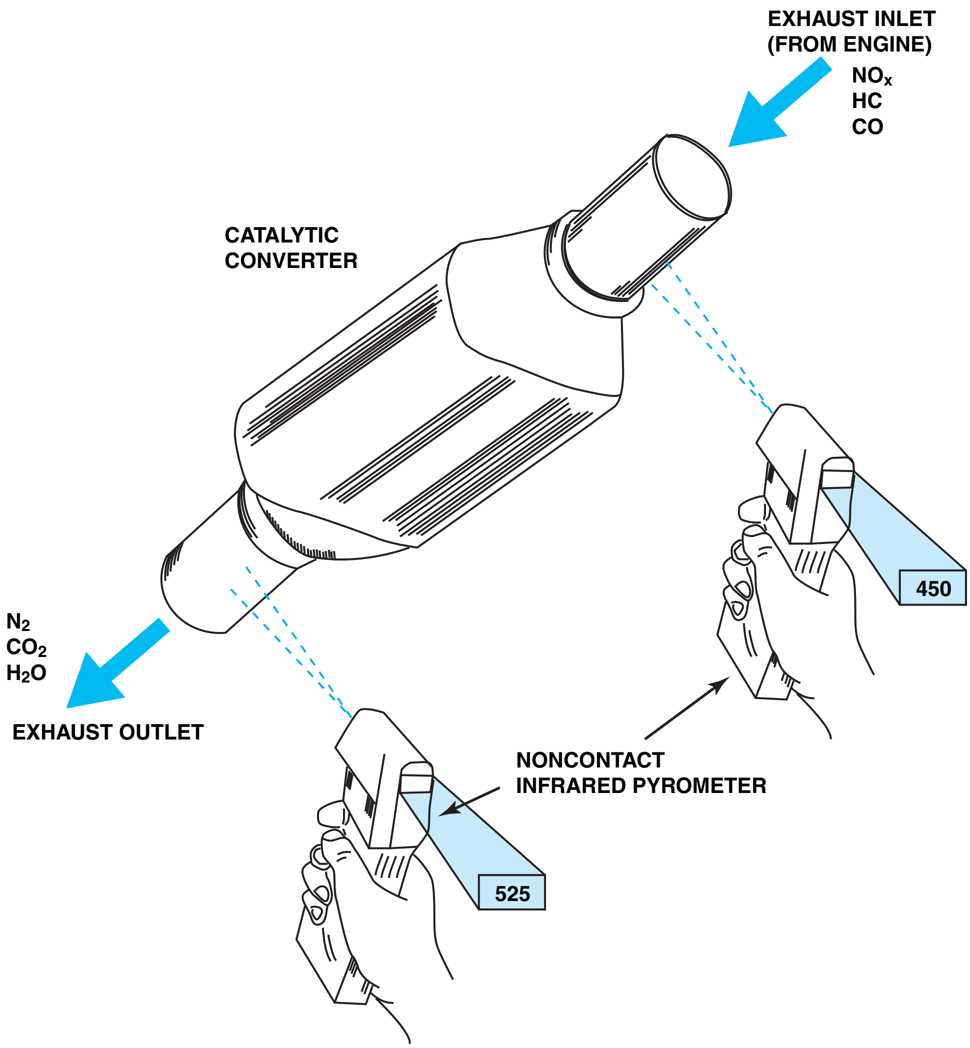

FIGURE 17-38 The temperature of the outlet should be at least 10% hotter than the temperature of the inlet. This converter is very efficient. The inlet temperature is 450°F. Ten percent of 450° is 45° (45° + 450° = 495°). In other words, the outlet temperature should be at least 495°F for the converter to be considered okay. In this case, the outlet temperature of 525°F is more than the minimum 10% increase in temperature. If the converter is not working at all, the inlet temperature will be hotter than the outlet temperature.

- If the O_2 rises to 1.2%, the converter may have low efficiency.
- If the O_2% remains below 1.2%, then the converter is okay.

OBD-II CATALYTIC CONVERTER MONITOR

The catalytic converter monitor of OBD II uses an upstream and downstream HO2S to test catalyst efficiency. When the engine combusts a lean air–fuel mixture, higher amounts of oxygen flow through the exhaust into the converter. The catalyst materials absorb this oxygen for the oxidation process, thereby removing it from the exhaust stream. If a converter cannot absorb enough oxygen, oxidation does not occur. Engineers established a correlation between the amount of oxygen absorbed and converter efficiency.

The OBD-II system monitors how much oxygen the catalyst retains. A voltage waveform from the downstream HO2S of a good catalyst should have little or no activity. A voltage waveform from the downstream HO2S of a degraded catalyst shows a lot of activity. In other words, the closer the activity of the downstream HO2S matches that of the upstream HO2S, the greater the degree of converter degradation. In operation, the OBD-II monitor compares activity between the two exhaust oxygen sensors.

CATALYTIC CONVERTER REPLACEMENT GUIDELINES

Because a catalytic converter is a major exhaust gas emission control device, the Environmental Protection Agency (EPA) has strict guidelines for its replacement, including:

- If a converter is replaced on a vehicle with less than 80,000 miles/8 years, depending on the year of the vehicle, an original equipment catalytic converter *must* be used as a replacement.
- The replacement converter must be of the same design as the original. If the original had an air pump fitting, so must the replacement.
- The old converter must be kept for possible inspection by the authorities for 60 days.
- A form must be completed and signed by both the vehicle owner and a representative from the service facility. This form must state the cause of the converter failure and must remain on file for 2 years.

Catalytic Converter-Related Diagnostic Trouble Code

Diagnostic Trouble Code	Description	Possible Causes
P0422	Catalytic converter efficiency failure	1. Engine mechanical fault 2. Exhaust leaks 3. Fuel contaminants, such as engine oil, coolant, or sulfur

TECH TIP

AFTERMARKET CATALYTIC CONVERTERS

Some replacement aftermarket (non-factory) catalytic converters do not contain the same amount of cerium as the original part. **Cerium** is the element that is used in catalytic converters to store oxygen. As a result of the lack of cerium, the correlation between the oxygen storage and the conversion efficiency may be affected enough to set a false diagnostic trouble code (P0422).

NOTE: If an aftermarket converter is being installed, be sure that the distance between the rear of the catalyst block is the same distance from the rear oxygen sensor as the factory converter to be insured of proper operation. Always follow the instructions that come with the replacement converter.

TECH TIP

CATALYTIC CONVERTERS ARE MURDERED

Catalytic converters start a chemical reaction but do not enter into the chemical reaction. Therefore, catalytic converters do not wear out and they do not die of old age. If a catalytic converter is found to be defective (nonfunctioning or clogged), look for the *root* cause. Remember this:

"Catalytic converters do not commit suicide—they're murdered."

Items that should be checked when a defective catalytic converter is discovered include all components of the ignition and fuel systems. Excessive unburned fuel can cause the catalytic converter to overheat and fail. The oxygen sensor must be working and fluctuating from 0.5 to 5 Hz (times per second) to provide the necessary air–fuel mixture variations for maximum catalytic converter efficiency.

SUMMARY

1. Recirculating 6% to 10% inert exhaust gases back into the intake system reduces peak temperature inside the combustion chamber and reduces NO_X exhaust emissions.
2. EGR is usually not needed at idle, at wide-open throttle, or when the engine is cold.
3. Many EGR systems use a feedback potentiometer to signal the PCM the position of the EGR valve pintle.
4. OBD II requires that the flow rate be tested and then is achieved by opening the EGR valve and observing the reaction of the MAP sensor.
5. Positive crankcase ventilation (PCV) systems use a valve or a fixed orifice to transfer and control the fumes from the crankcase back into the intake system.
6. A PCV valve regulates the flow of fumes depending on engine vacuum and seals the crankcase vent in the event of a backfire.
7. As much as 30% of the air needed by the engine at idle speed flows through the PCV system.
8. The AIR system forces air at low pressure into the exhaust to reduce CO and HC exhaust emissions.
9. A catalytic converter is an aftertreatment device that reduces exhaust emissions outside of the engine. A catalyst is an element that starts a chemical reaction but is not consumed in the process.
10. The catalyst material used in a catalytic converter includes rhodium, palladium, and platinum.
11. The OBD-II system monitor compares the relative activity of a rear oxygen sensor to the pre-catalytic oxygen sensor to determine catalytic converter efficiency.

REVIEW QUESTIONS

1. How does the use of exhaust gas recirculation NO_X exhaust emission?
2. How does the DPFE sensor work?
3. What exhaust emissions does the PCV valve and AIR system control?
4. How does a catalytic converter reduce NO_X to nitrogen and oxygen?
5. How does the computer monitor catalytic converter performance?

CHAPTER QUIZ

1. Two technicians are discussing clogged EGR passages. Technician A says clogged EGR passages can cause excessive NO_X exhaust emission. Technician B says that clogged EGR passages can cause the engine to ping (spark knock or detonation). Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B
2. An EGR valve that is partially stuck open would *most likely* cause what condition?
   - **a.** Rough idle/stalling
   - **b.** Excessive NO_X exhaust emissions
   - **c.** Ping (spark knock or detonation)
   - **d.** Missing at highway speed
3. How much air flows through the PCV system when the engine is at idle speed?
   - **a.** 1% to 3%
   - **b.** 5% to 10%
   - **c.** 10% to 20%
   - **d.** Up to 30%
4. Technician A says that if a PCV valve rattles, then it is okay and does not need to be replaced. Technician B says that if a PCV valve does not rattle, it should be replaced. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B

5. The switching valves on the AIR pump have failed several times. Technician A says that a defective exhaust check valve could be the cause. Technician B says that a restricted exhaust system could be the cause. Which technician is correct?

- **a.** Technician A only
- **b.** Technician B only
- **c.** Both Technicians A and B
- **d.** Neither Technician A nor B

6. Two technicians are discussing testing a catalytic converter. Technician A says that a vacuum gauge can be used and observed to see if the vacuum drops with the engine at idle for 30 seconds. Technician B says that a pressure gauge can be used to check for backpressure. Which technician is correct?

- **a.** Technician A only
- **b.** Technician B only
- **c.** Both Technicians A and B
- **d.** Neither Technician A nor B

7. At about what temperature does oxygen combine with the nitrogen in the air to form NO_X?

- **a.** 500°F (260°C)
- **b.** 750°F (400°C)
- **c.** 1,500°F (815°C)
- **d.** 2,500°F (1,370°C)

8. A P0401 is being discussed. Technician A says that a stuck-closed EGR valve could be the cause. Technician B says that clogged EGR ports could be the cause. Which technician is correct?

- **a.** Technician A only
- **b.** Technician B only
- **c.** Both Technicians A and B
- **d.** Neither Technician A nor B

9. Two technicians are discussing P1480 DTC. Technician A says that a defective PCV solenoid could be the cause. Technician B says that a corroded electrical connection on the solenoid could be the cause. Which technician is correct?

- **a.** Technician A only
- **b.** Technician B only
- **c.** Both Technicians A and B
- **d.** Neither Technician A nor B

10. Two technicians are discussing P0422 DTC. Technician A says that the engine may have mechanical faults. Technician B says that the vehicle may have exhaust leaks. Which technician is correct?

- **a.** Technician A only
- **b.** Technician B only
- **c.** Both Technicians A and B
- **d.** Neither Technician A nor B