31

Engine Performance Diagnosis and Testing

OBJECTIVES: After studying Chapter 31, you should be able to:

1. Prepare for the interprovincial Red Seal certification examination in Appendix VIII (Engine Performance) on the topics covered in this chapter.
2. List the steps of the diagnostic process.
3. Describe the simple preliminary tests that should be performed at the start of the diagnostic process.
4. List six items to check as part of a thorough visual inspection.
5. List the six fundamental troubleshooting principles.
6. List the precautions that should be taken when working on computerized engine control systems.
7. Explain the troubleshooting procedures to follow if a diagnostic trouble code has been set.
8. Explain the troubleshooting procedures to follow if no diagnostic trouble codes have been set.
9. Discuss the diagnosis of a vehicle equipped with the second generation of on-board diagnostics (OBD II).
10. List acceptable levels of HC, CO, CO_2, and O_2 with and without a catalytic converter.
11. List four possible causes of high readings for HC, CO, and NO_x.

It is important that all automotive service technicians know how to diagnose and troubleshoot engine computer systems. The diagnostic process is a specific method that eliminates known good components or systems in order to find the root cause of automotive engine performance problems. All vehicle manufacturers recommend a diagnostic procedure, and the plan suggested in this chapter combines most of the features of these plans plus additional steps developed over years of real-world problem solving.

THE EIGHT-STEP DIAGNOSTIC PROCEDURE

Many different things can cause an engine performance problem or concern. The service technician has to narrow the possibilities until the cause of the problem is found and corrected. A funnel is a way of visualizing a diagnostic procedure. See Figure 31–1. At the wide top are the symptoms of the problem; the funnel narrows as possible causes are eliminated until the root cause is found and corrected at the bottom of the funnel.

All problem diagnosis deals with symptoms that could be the result of many different causes. The wide range of possible solutions must be narrowed to the most likely and these must eventually be further narrowed down to the actual cause. The following section describes eight steps the service technician can take to narrow the possibilities to one cause.

Step #1. Verify the Problem

Before one minute is spent on diagnosis, be certain that a problem exists. If the problem cannot be

Figure 31–1 A funnel is a visual method of thinking of the diagnostic process. The goal, of course, is to find the root cause and to repair it in order to achieve customer satisfaction.

verified, the problem cannot be solved or tested to verify that the repair was complete. See Figure 31–2.

The driver knows the vehicle and how it is driven. *Before* diagnosis is started, always ask the following questions:

- Is the malfunction indicator light (check engine) on?
- What was the temperature outside?
- Was the engine warm or cold?
- Was the problem during starting, acceleration, cruise, etc.?
- How far had the vehicle been driven?
- Were any dash warning lights on? If so, which one?
- Has there been any service or repair work performed on the vehicle lately?

NOTE: This last question is very important! Many engine performance faults are often the result of something being knocked loose or a hose falling off during repair work, etc. Knowing that the vehicle was just serviced before the problem began may be an indicator.

TECH TIP

"Original Equipment" Is Not a Four-Letter Word

Many problems can be traced to the use of an aftermarket part that has failed early in its service life. Technicians who work at dealerships usually go immediately to an aftermarket part that is observed during a visual inspection. It has been their experience that simply replacing the aftermarket part with the factory original equipment (OE) part often solves the problem.

Original equipment parts are *required* to pass quality and durability standards and tests that are not required of aftermarket parts. The technician should be aware that the presence of a new part does not necessarily mean that the part is good.

After the nature and scope of the problem are determined, the complaint should be verified before further diagnostic tests are performed. A sample of a form that customers could fill out with details of the problem can be seen in Figure 31–3. Perform a thorough test drive under similar conditions to verify the complaint (problem or concern).

Step #2. Perform a Thorough Visual Inspection and Basic Tests

The visual inspection is the most important aspect of diagnosis! Most experts agree that between 10 and 30% of all engine performance problems can be found simply by performing a *thorough* visual inspection.

NOTE: The purpose of any fault diagnosis is the elimination of known good components.

The inspection should include the following:

- **Check for obvious problems.**
  Fuel leaks
  Vacuum hoses disconnected or split (see Figure 31–4)
  Corroded connectors
  Unusual noises, smoke, or smell
  Check the air cleaner and air duct for restrictions. See Figure 31–5.

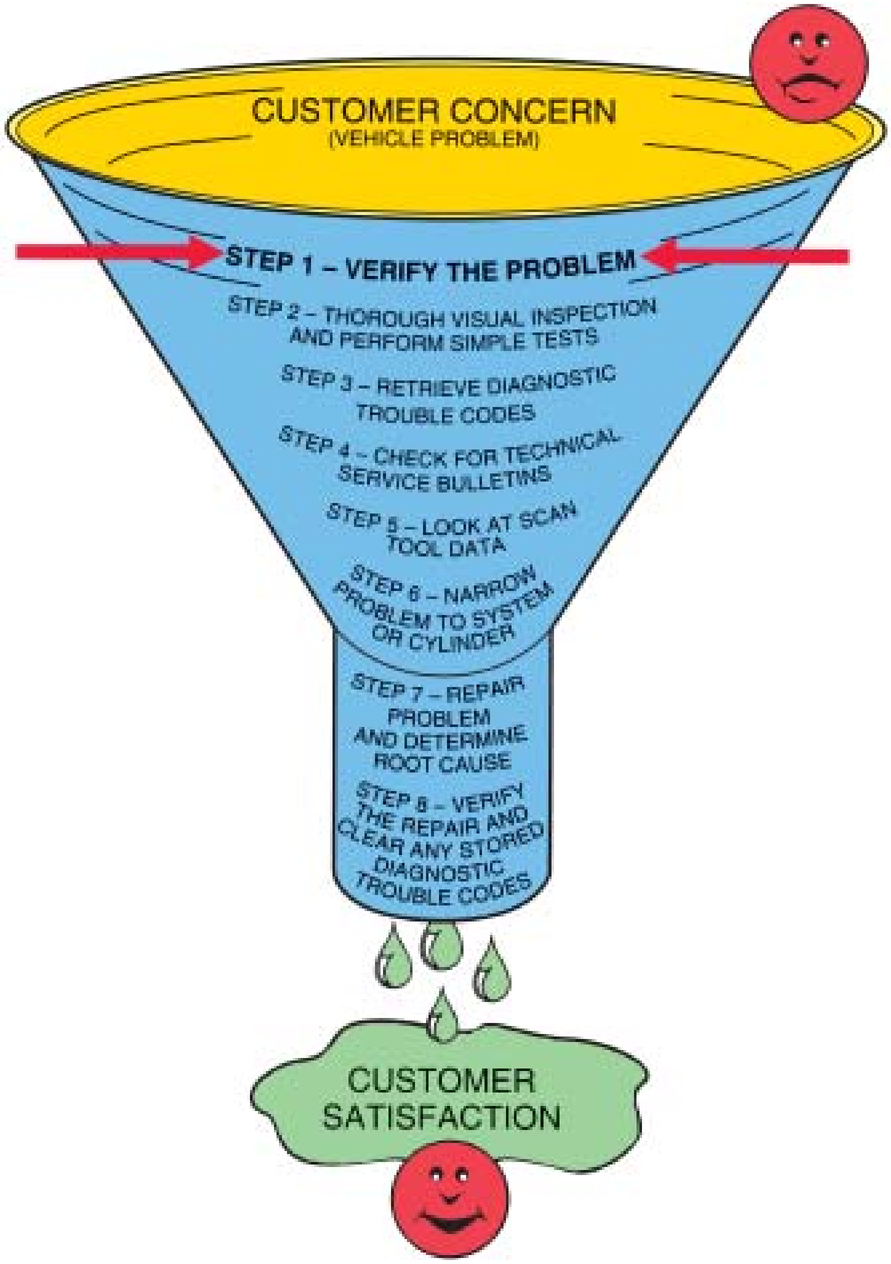


Figure 31–2 Diagnostic funnel. Step #1 is to verify the problem. If the problem cannot be duplicated, obviously the repair cannot be performed.

- **Check everything that does and does not work.** This step involves turning things on and observing that everything is working properly.
- **Look for evidence of previous repairs.** Any time work is performed on a vehicle, there is always a risk that something will be disturbed, knocked off, or left disconnected.
- **Check oil level and condition.** Another area for visual inspection is oil level and condition.
  Oil level—Oil should be to the proper level.
  Oil condition—Using a match or lighter, try to light the oil on the dipstick; if the oil flames up, gasoline is present in the engine oil. Drip some engine oil from the dipstick onto the hot exhaust manifold. If the oil bubbles or boils, coolant (water) is present in the oil. Check for grittiness by rubbing the oil between your fingers.

NOTE: Gasoline in the oil will cause the engine to run rich by drawing fuel through the positive crankcase ventilation (PCV) system.

- **Check coolant level and condition.** Most mechanical engine problems are caused by overheating. The proper operation of the cooling system is critical to the life of any engine.

ENGINE PERFORMANCE DIAGNOSIS WORKSHEET

(To Be Filled Out By the Vehicle Owner)

Name: ______________________ Kilometres (Mileage): ____________ Date: ____________

Make: ____________ Model: ____________ Year: ____________ Engine: ____________

(Please Circle All That Apply in All Categories)	
Describe Problem:	
When Did the Problem First Occur?	• Just Started • Last Week • Last Month • Other ____________
List Previous Repairs in the Last 6 Months:	
Starting Problems	• Will Not Crank • Cranks, but Will Not Start • Starts, but Takes a Long Time
Engine Quits or Stalls	• Right after Starting • When Put into Gear • During Steady Speed Driving • Right after Vehicle Comes to a Stop • While Idling • During Acceleration • When Parking
Poor Idling Conditions	• Is Too Slow at All Times • Is Too Fast • Intermittently Too Fast or Too Slow • Is Rough or Uneven • Fluctuates Up and Down
Poor Running Conditions	• Runs Rough • Lacks Power • Bucks and Jerks • Poor Fuel Economy • Hesitates or Stumbles on Acceleration • Backfires • Misfires or Cuts Out • Engine Knocks, Pings, Rattles • Surges • Dieseling or Run-On
Auto. Transmission Problems	• Improper Shifting (Early/Late) • Changes Gear Incorrectly • Vehicle Does not Move When in Gear • Jerks or Bucks
Usually Occurs	• Morning • Afternoon • Anytime
Engine Temperature	• Cold • Warm • Hot
Driving Conditions During Occurrence	• Short—Less Than 3 km (2 mi) • 3–15 km (2–10 mi) • Long—More Than 15 km (2–10 mi) • Stop and Go • While Turning • While Braking • At Gear Engagement • With A/C Operating • With Headlights On • During Acceleration • During Deceleration • Mostly Downhill • Mostly Uphill • Mostly Level • Mostly Curvy • Rough Road
Driving Habits	• Mostly City Driving • Highway • Park Vehicle Inside • Park Vehicle Outside **Drive Per Day:** • Less Than 15 km (10 mi) • 15 to 80 km (10–50 mi) • More Than 80 km (50 mi)
Gasoline Used	**Fuel Octane:** • 87 • 89 • 91 • More Than 91 **Brand:** ____________
Temperature When Problem Occurs	• 0–13° C (32–55° F) • Below Freezing 0° C (32° F) • Above 13° C (55° F)
Check Engine Light/ Dash Warning Light	• Light On Sometimes • Light On Always • Light Never On
Smells	• "Hot" • Gasoline • Oil Burning • Electrical
Noises	• Rattle • Knock • Squeak • Other

Figure 31–3 Form that can be given to a customer to be filled out before attempting to diagnose an engine performance problem.

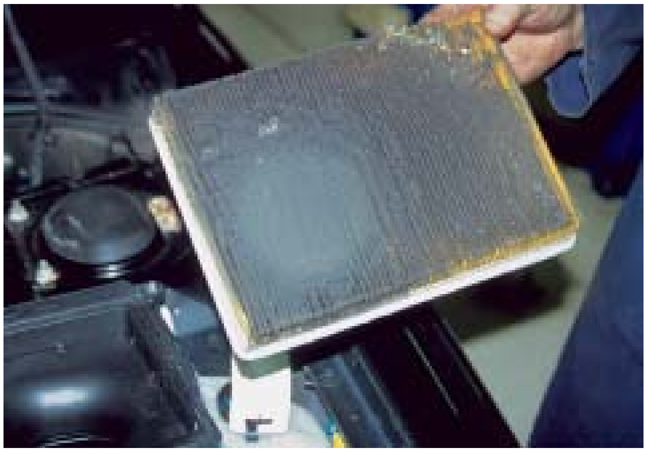
Figure 31–4 All vacuum hoses should be checked to see if they are cracked, swollen, or split.

TECH TIP

Smoke Machine Testing

Vacuum (air) leaks can cause a variety of driveability problems and are often difficult to locate. One method that works well is to use a machine that generates a burst of smoke. Connecting the outlet of the machine to the hose removed from the vacuum brake booster allows smoke to enter the intake manifold. Any vacuum leaks will be spotted by observing smoke coming out of the leak. See Figure 31–6. A theatre smoke machine works well.

(a)



(b)

Figure 31–5 (a) This is what was found as the air filter housing was opened during service. The nuts were obviously deposited by squirrels (or some other animal). (b) Not only was the housing filled with nuts, but this air filter was extremely dirty, indicating that this vehicle had not been serviced for a long time.

(a)

(b)

Figure 31–6 (a) A shot of smoke from a smoke machine. In actual use, this outlet is connected to a disconnected vacuum hose on the engine being tested. A convenient hose to use is the hose at the vacuum brake booster. The machine forces smoke into the intake manifold through the hose. (b) To keep the smoke from escaping through the throttle plate opening, a plastic bag can be used to seal the opening. Here a rubber glove is used, and while it looks strange, it worked well.

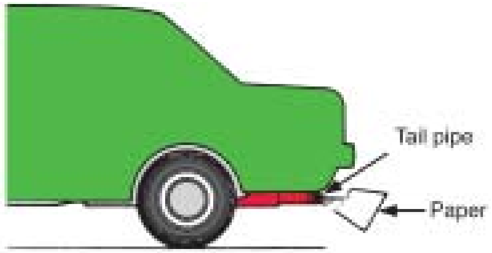


Figure 31–7 The paper test involves holding a piece of paper near the tailpipe with a warm engine at idle. A good engine should produce an even, outward flow of exhaust. If the paper is sucked in toward the tailpipe, a burned valve is a possibility.

NOTE: Check the coolant level in the radiator only if the radiator is cool. If the radiator is hot and the radiator cap is removed, the drop in pressure above the coolant will cause the coolant to boil immediately, which can cause severe burns because the coolant expands explosively upward and outward from the radiator opening.

- **Perform the paper test.** A soundly running engine should produce even and steady exhaust at the tail pipe. Hold a piece of paper or a 75 × 125 mm (3 × 5 in.) card within 25 mm (1 in.) of the tail pipe with the engine running at idle. See Figure 31–7. The paper should blow evenly away from the end of the tail pipe without puffing or being drawn inward toward the end of the tail pipe. If the paper is at times drawn *toward* the tail pipe, the valves in one or more cylinders could be burned. Other reasons why the paper might be drawn toward the tail pipe include the following:
  1. The engine could be misfiring because of a lean condition or an ignition system fault such as a bad spark plug wire.
  2. A faulty fuel injector.
  3. Pulsing of the paper toward the tail pipe could also be caused by a hole in the exhaust system. If exhaust escapes through a hole in the exhaust system, air could be drawn—in the intervals between the exhaust puffs—from the tail pipe to the hole in the exhaust, causing the paper to be drawn toward the tail pipe.
- **Ensure adequate fuel level.** Make certain that the fuel tank is at least one-fourth to one-half full; if the fuel level is low it is possible that any water or alcohol at the bottom of the fuel tank is more concentrated and can be drawn into the fuel system.

(a)

(b)

Figure 31–8 (a) A typical spark tester that uses a clear plastic shield that protects the spark from igniting any flammable substance that may be near while testing for spark. (b) A spark tester that is adjustable for different voltages. Most electronic ignition systems should be able to jump a 25 mm (1 in.) gap, which is equal to about 40 000 volts.

- **Check the battery voltage.** The voltage of the battery should be at least 12.4 volts and the charging voltage (engine running) should be 13.5 to 15.0 volts at 2000 rpm. Low battery voltage can cause a variety of problems including reduced fuel economy and incorrect (usually too high) idle speed.
- **Check the spark using a spark tester.** Remove one spark plug wire and attach the removed plug wire to the spark tester. Attach the grounding clip of the spark tester to a good clean engine ground, start or crank the engine, and observe the spark tester. See Figure 31–8. The spark at the spark tester should be steady and consistent. If an intermittent spark occurs, then this condition should be treated as a no-spark condition. If this test does not show satisfactory spark, carefully inspect and test all components of the primary and secondary ignition systems. See Chapter 24 for details.

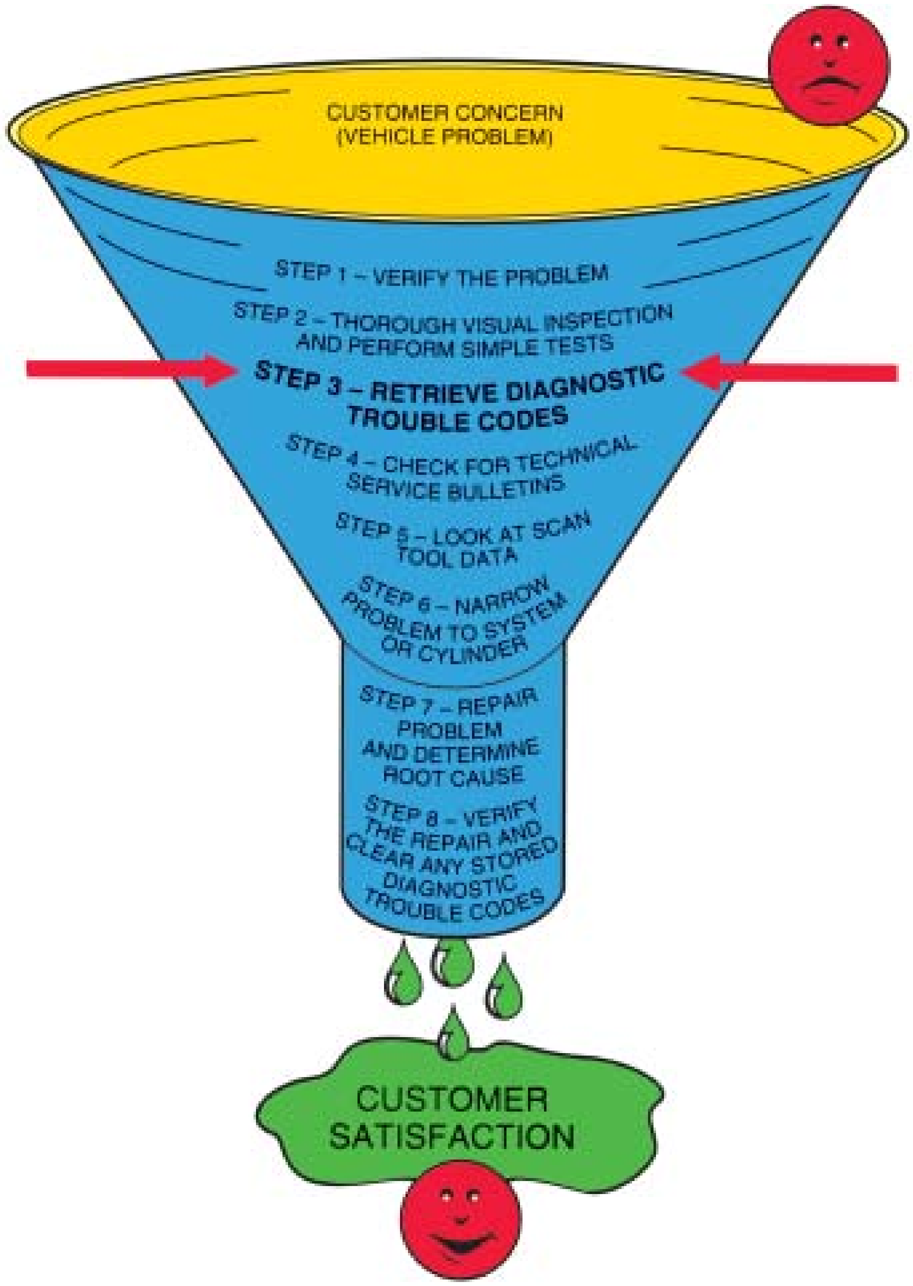


Figure 31–9 Step #3 in the diagnostic process is to retrieve any stored diagnostic trouble codes (DTCs). The vehicle computer is constantly monitoring all sensors and control devices and, therefore, if a DTC was stored, it makes sense to use the ability of the vehicle computer to help narrow the focus of what could be wrong.

NOTE: Do not use a standard spark plug to check for proper ignition system voltage. An electronic ignition spark tester is designed to force the spark to jump about 20 mm (0.75 in.). This amount of gap requires between 25 and 30 kilovolts (kV) at atmospheric pressure, which is enough voltage to ensure that a spark can occur under compression inside an engine.

- **Check the fuel pump pressure.** Checking the fuel pump pressure is relatively easy on many port fuel-injected engines. Often the cause of intermittent engine performance is due to a weak electric fuel pump. Checking fuel pump pressure early in the diagnostic process eliminates low fuel pressure as a possibility.

Step #3. Retrieve the Diagnostic Trouble Codes

If a diagnostic trouble code (DTC) is present in the computer memory, it is signalled by illuminating a malfunction indicator lamp (MIL), commonly labelled "check engine" or "service engine soon." See Figure 31–9. The code(s) displayed if the MIL is on is called a **hard code.** Any code(s) that is displayed when the MIL is *not* on is called a **soft code.** A soft code is sometimes called an **intermittent code** and indicates that the computer detected a fault in the circuit represented by the DTC. Because the MIL is not on, this indicates that the fault is no longer present. Although this soft code is helpful to let the technician know that a fault has, in the past, been detected, further testing will be needed to find the root cause of the problem. Most vehicle manufacturers state that the diagnostic procedure for a DTC is for a hard code only.

Step #4. Check for Technical Service Bulletins (TSBs)

Check for corrections in bulletins that match the symptoms. See Figure 31–10. According to studies performed by automobile manufacturers, as many as 30% of vehicles can be repaired following the information, suggestions, or replacement parts found in a service bulletin. (DTCs must be known before searching for service bulletins because bulletins often include information on solving problems that involve a stored diagnostic trouble code.)

Figure 31–10 After checking for stored diagnostic trouble codes (DTCs), the technician checks to see if there are any technical service bulletins (TSBs) that relate to the vehicle being serviced.

Step #5. Look at Scan Tool Data

Starting in 1981, General Motors and Chrysler vehicle manufacturers have been giving the technician more and more data on a **scan tool** connected to the **data link connector** or **DLC.** See Figure 31–11. Beginning technicians are often observed scrolling through scan data without a real clue to what they are looking for. When asked, they usually reply that they are looking for something unusual, as if the screen will flash a big message "LOOK HERE—THIS IS NOT CORRECT." That statement does not appear on scan tool displays. See Figure 31–12. The best way to look at scan data is in a definite sequence and with specific, selected bits of data (also called **parameter identification** or **PID**) that can tell the most about the operation of the engine such as:

1. Engine coolant temperature (ECT) is the same as intake air temperature (IAT) after the vehicle sits for several hours.
2. Idle air control (IAC) valve is being commanded to an acceptable range.
3. Oxygen sensor (O2S) is operating properly:
   - Readings below 200 millivolts at times
   - Readings above 800 millivolts at times
   - Rapid transitions between rich and lean
   - At least eight cross counts on a fuel-injected engine

Step #6. Narrow the Problem to a System or Cylinder

Narrowing the focus to a system or individual cylinder is the hardest part of the entire diagnostic process.

TECH TIP

The Five Whys

Whenever a problem is detected, the smart technician should ask, "Why did this part or component fail?" For example, consider a vehicle that misfired under load. A thorough inspection revealed a cracked spark plug. Replacing the spark plugs solved the misfire problem but only for a few weeks. Again, a spark plug was found to be cracked. Now the technician has to ask, "why?" Obviously, the cause of the engine misfire has been determined, but what can cause the recurring cracked spark plug? A missing inner-fender splash shield could be letting water splash onto a hot spark plug, causing it to crack. If the shield is missing, the technician could ask why it was missing. Perhaps some other body parts have been damaged by an accident or other cause.

Usually by the time the technician has asked "why" five times, the root cause of the problem has been determined. Asking yourself the five whys is being truly professional. Customers expect their vehicle to be repaired right the first time. Correcting the root cause is the key to customer satisfaction.

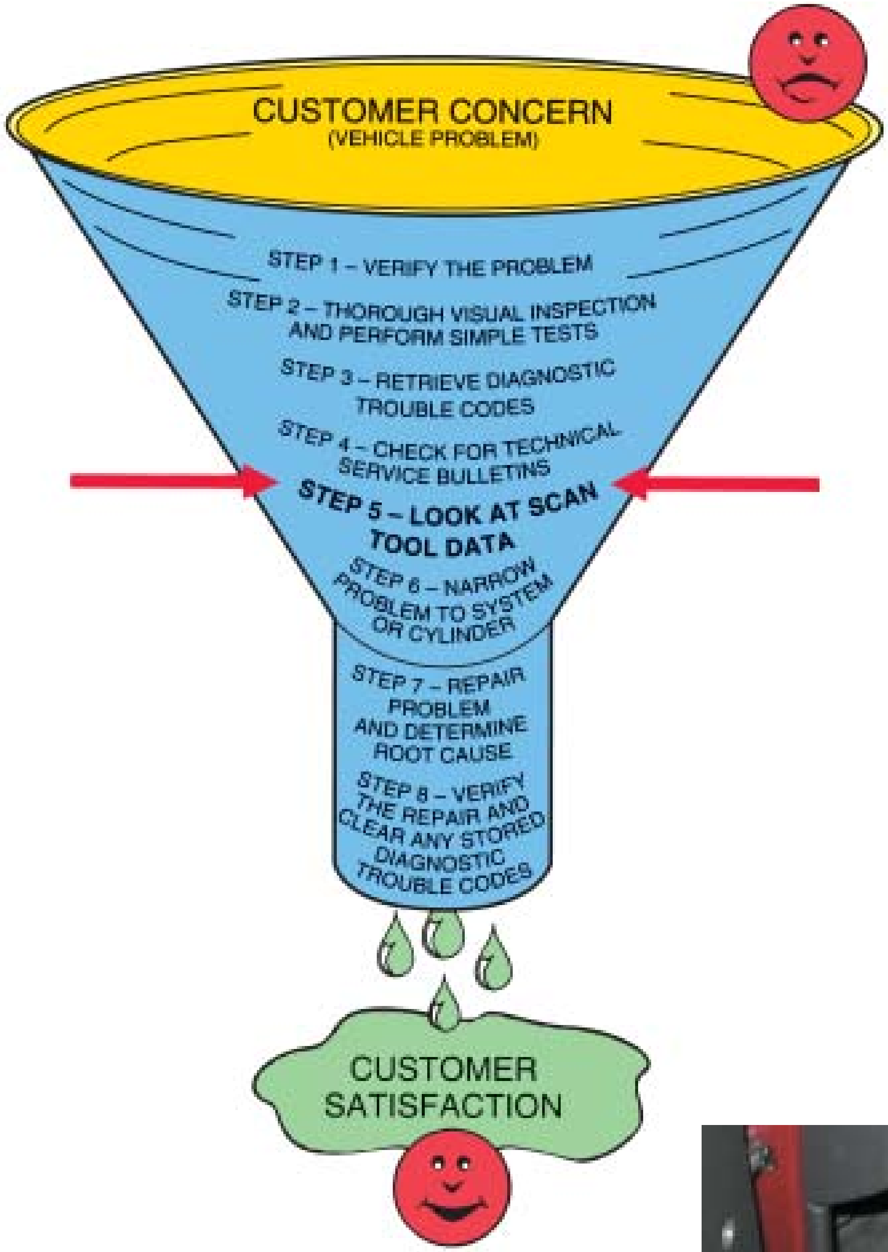


Figure 31–11 Scan tool data is a powerful tool to use to find engine performance malfunctions.

Figure 31–12 Using a Snap-On scan tool to check for engine data that may give an indication as to the root cause of the problem.

Figure 31–13 An engine analyzer can also be used to help narrow the problem to a particular cylinder or system.

- Perform a cylinder power balance test. See Figure 31–13.
- If a weak cylinder is detected, perform a compression and a cylinder leakage test to determine the probable cause (see Chapter 5 for details).

Step #7. Repair the Problem and Determine the Root Cause

The repair or part replacement must be performed following vehicle manufacturer's recommendations. Read the Tech Tip "The Five Whys" to be certain that the root cause of the problem has been found. Also follow manufacturers' recommended repair procedures and methods.

Step #8. Verify the Repair and Clear Any Stored DTCs

See Figure 31–14.

1. Test drive to verify that the original problem (concern) is fixed.
2. Verify that no additional problems have occurred during the repair process.
3. Clear all diagnostic trouble codes. (This step ensures that the computer will not make any changes based on any stored DTC.)
4. Before returning the vehicle to the customer double check that
   - The vehicle is clean.
   - The radio is turned off.
   - The clock is set to the right time and the radio stations have been restored if the battery was disconnected during the repair procedure.

TECH TIP

One Test Is Worth 1000 "Expert" Opinions

Whenever any vehicle has an engine performance or driveability concern, certain people always say:

"Sounds like it's the ignition coil."

"I'll bet you it's a bad computer."

"I had a problem just like yours yesterday and it was a bad EGR valve."

Regardless of the skills and talents of those people, it is still more accurate to perform tests on the vehicle than to rely on feelings or opinions of others who have not even seen the vehicle. Even your own opinion should not sway your thinking. Follow a plan and perform tests and the test results will lead to the root cause.

DIAGNOSING USING DIAGNOSTIC TROUBLE CODES

Pinning down causes of the actual problem can be accomplished by trying to set the opposite code. For example, if a code indicates an open throttle position (TP) sensor (high resistance), clear the code and create a shorted (low-resistance) condition. This can be accomplished by using a jumper wire and connecting the signal terminal to the 5 volt reference terminal. This should set a diagnostic trouble code.

- *If the opposite code sets,* this indicates that the wiring and connector for the sensor is okay and the sensor itself is defective (open).
- *If the same code sets,* this indicates that the wiring or electrical connection is open (has high resistance) and is the cause of the setting of the DTC.

Methods for Clearing Diagnostic Trouble Codes

Clearing diagnostic trouble codes from a vehicle computer is an important procedure. The DTCs should be cleared whenever any of the following conditions exist.

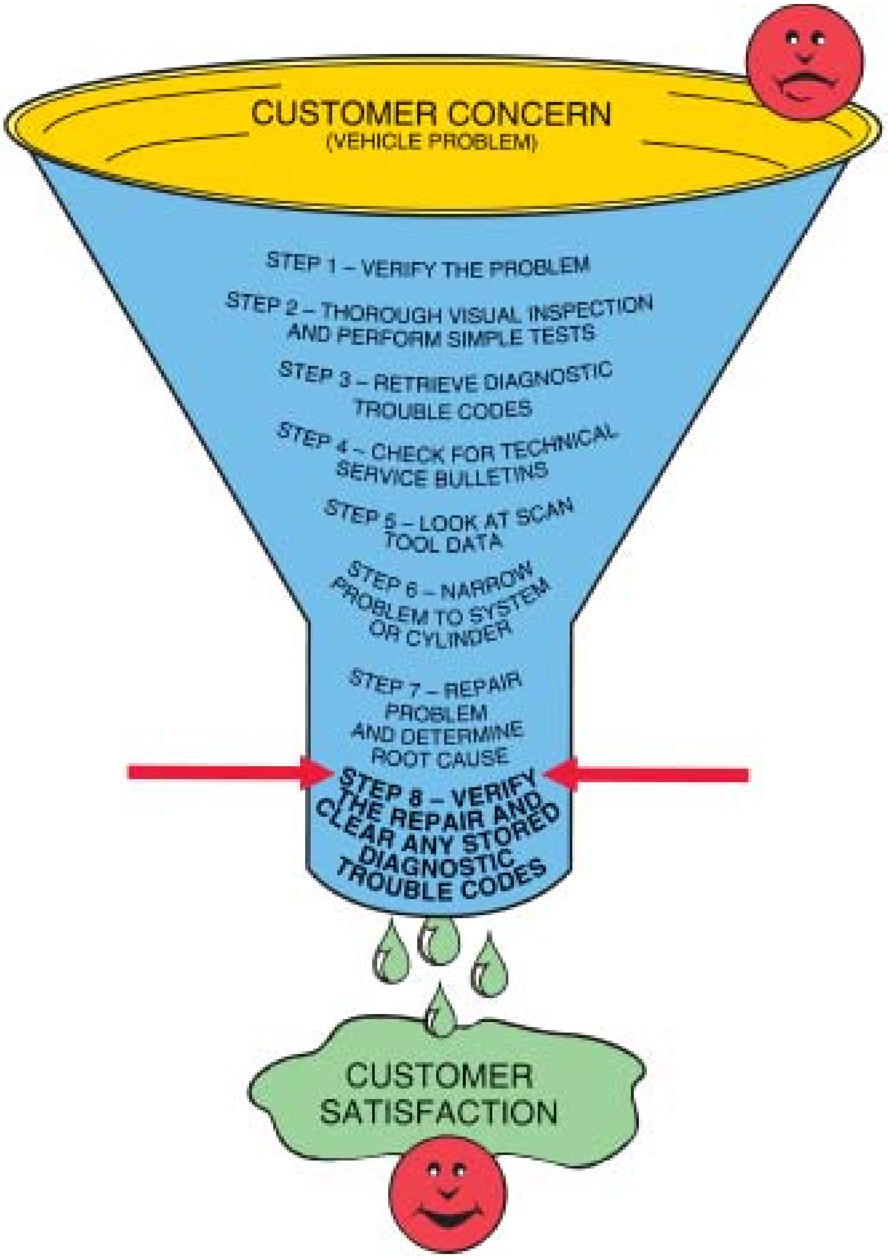


Figure 31–14 Step #8 is very important. Be doubly sure that the customer's concern has been corrected.

Before a Repair DTCs are often cleared before starting the diagnostic procedure to determine if the DTC will reset verifying the problem and the code. There are three methods that can be used to clear stored diagnostic trouble codes.

- **Clearing codes method #1.** The preferred method of clearing codes is by using a scan tool. This is the method recommended by most vehicle manufacturers if the procedure can be performed on the vehicle. The computer of some vehicles cannot be cleared with a scan tool.
- **Clearing codes method #2.** If a scan tool is not available or a scan tool cannot be used on the vehicle being serviced, the power to the computer can be disconnected.
  1. Disconnect the fusible link, if so equipped, that feeds the computer
  2. Disconnect the fuse or fuses that feed the computer

DIAGNOSTIC STORY

"Check Engine" Light On, But No Codes

A customer brought a GM vehicle to an independent service facility because the amber-coloured "check engine" light (malfunction indicator lamp or MIL) remained on all the time that the engine was running. This usually indicates a hard failure (a failure that is definite, not intermittent, and that affects the ability of the computer to properly operate the engine).

No trouble codes were found and no code 12 either, which would indicate a possible computer (**electronic control module [ECM]**) problem. After several hours of troubleshooting for loose or defective computer terminals, another technician came along and found that the 3 ampere fuse for the ECM was blown. After replacing the fuse, the computer (and the MIL) returned to normal operation. The customer later admitted that he may have been guilty of blowing the fuse when he attempted to install his own sound system into the existing wiring and fuses.

NOTE: The fuse may not be labelled as a computer fuse. For example, many Toyotas can be cleared by disconnecting the fuel-injection fuse. Some vehicles require that two fuses be disconnected to clear any stored codes.

- **Clearing codes method #3.** If the other two methods cannot be used, the negative (−) battery cable can be disconnected to clear stored diagnostic trouble codes.

NOTE: Because of the adaptive learning capacity of the computer, a vehicle may fail an exhaust emissions test if the vehicle is not driven enough to allow the computer to relearn.

CAUTION: By disconnecting the battery, the radio presets and clock information will be lost and they should be reset before returning the vehicle to the customer. If the radio has a security code, the code must be entered before the radio will function. Always check with the vehicle owner to be sure that the code is available *before* disconnecting the battery.

After a Repair DTCs should be cleared after a repair to prevent the computer from making adjustments to the operation of the engine as a result of a stored DTC.

TECH TIP

The Brake Pedal Trick

If a scan tool is not available and you must disconnect the battery to clear diagnostic trouble codes, it is more likely to be successful if an electrical load is applied to the electrical system of the vehicle to discharge any capacitors that are in the system. It is common for these capacitors to be able to supply the small amount of current needed to keep the memory from being erased. To safely discharge the capacitors, simply depress the brake pedal after removing the negative (−) battery cable. The brake lights will quickly drain any capacitors and the DTCs will be cleared.

FLASH CODE RETRIEVAL ON GENERAL MOTORS VEHICLES

Since 1981, many computer systems have had built-in on-board diagnostic capability. By checking the trouble codes, the technician can determine where the problem is located in most cases.

The GM system uses a "check engine" or "check engine soon" MIL to notify the driver of possible system failure. Under the dash (on most GM vehicles) is a **data link connector (DLC),** previously called an **assembly line communications link (ALCL)** or **assembly line diagnostic link (ALDL).** To retrieve DTCs, first locate the data link connector (DLC). Most DLCs on General Motors vehicles from 1981 to the present are underneath the dash to the left or right of the steering column.

Most General Motors diagnostic trouble codes (non OBD II vehicles) can be retrieved by using a metal tool and contacting terminals A and B of the 12-pin DLC. This method is called **flash code retrieval** because the MIL will flash to indicate diagnostic trouble codes. The steps are as follows:

1. Turn the ignition switch to on (engine off). The "check engine" light or "service engine soon" light should be on.
2. Connect terminals A and B at the DLC.
3. Observe the MIL. A code 12 (one flash, then a pause, then two flashes) reveals that the computer is receiving no engine speed indication because the engine is not running. This simply indicates that the computer diagnostic system is working correctly.
4. After code 12 is displayed three times, the MIL will flash any other stored DTCs in numeric order starting with the lowest-number code. If only code 12 is displayed another three times, the computer has not detected any other faults.

Typical General Motors Diagnostic Trouble Codes (DTC) (OBD-I)

DTC	Definition
13	O_2 sensor circuit
14	Engine coolant temperature (ECT)—high
15	ECT—low
16	Low voltage
17	Camshaft sensor circuit
21	TP sensor (voltage high)
22	TP sensor (voltage low)
23	Intake air temperature (IAT) sensor (low)
24	Vehicle speed (VS) sensor
25	IAT sensor (high)
26	Quad driver module circuit (MIL and gauges)
27	Quad driver module circuit (EVAP, SOL, and TCC)
28	Transmission range (TR) pressure switch assembly (4L80-E); or Quad driver module circuit (A/C clutch relays)
29	Quad driver module circuit for 4T60
33	MAP sensor circuit (low vacuum)
34	MAP sensor circuit (high vacuum)
35	Idle air control (IAC)—idle speed error
36	24 X signal circuit error (3.4 SFI)
37	Brake switch stuck on
38	Brake switch stuck off
39	Torque converter clutch (TCC) stuck off
42	Ignition control circuit error
43	Knock sensor (KS) circuit
44	O_2—lean exhaust
45	O_2—rich exhaust
51	EPROM error
52	System voltage high
53	Battery over voltage
54	Low voltage to fuel pump
55	Power enrichment too lean
58	Transmission fluid temperature (high)
59	Transmission fluid temperature (low)
65	Fuel injector (low current)
66	A/C refrigerant pressure sensor circuit (low)/or 3-2 shift control
67	TCC solenoid circuit fault
68	Transmission slipping
69	TCC stuck on
70	A/C refrigerant pressure sensor circuit (high)
72	Loss of transmission output speed signal
73	Transmission pressure control solenoid circuit
74	Transmission input speed (TIS) sensor circuit
75	Digital EGR #1 error/or system voltage low
76	Digital EGR #2 error
77	Digital EGR #3 error
79	VSS (high)/or transmission fluid over temperature
80	VSS (low)
81	Brake switch error/or 2-3 shift solenoid circuit
82	Ignition control 3 X signal error/or 1-2 shift solenoid circuit
83	TCC pulse width modulation (PWM) solenoid circuit fault
85	PROM error/or transmission ratio error
86	Transmission low ratio error
87	A/D error/or transmission high ratio error
87	Electronically erasable programmable read-only memory (EEPROM) error

See the OBD II DTCs for 1996 or newer vehicles. Refer to factory service information for a description of General Motors specific alphanumeric DTCs.

NOTE: Trouble codes can vary according to year, make, model, and engine. Always consult the service literature or service manual for the exact vehicle being serviced.

RETRIEVING FORD DIAGNOSTIC CODES

The best tool to use during troubleshooting of a Ford vehicle is a **self-test automatic readout (STAR)** tester or another scan tool with Ford capabilities. If a STAR tester or scan tool is not available, a needle (analog) type of voltmeter can be used. Connect a jumper lead and an analog voltmeter as illustrated in Figure 31–15. to obtain flash codes. A 12 volt test light may be substituted if a voltmeter is not available. See Figure 31–16. The test connector is usually located under the hood on the driver's side. See Figure 31–17.

Key On–Engine Off Test With the ignition key on (engine off), watch the voltmeter pulses, which should appear within 5 to 30 seconds. (Ignore any initial surge of voltage when the ignition is turned on.) The computer will send a two- or three-digit code that will cause the voltmeter to pulse or move from left to right. For example, if the voltmeter needle pulses two times, then pauses for 2 seconds, and then pulses three times, the code is 23. There is normally a 4-second pause between codes. The codes are then repeated. These are current (hard) faults.

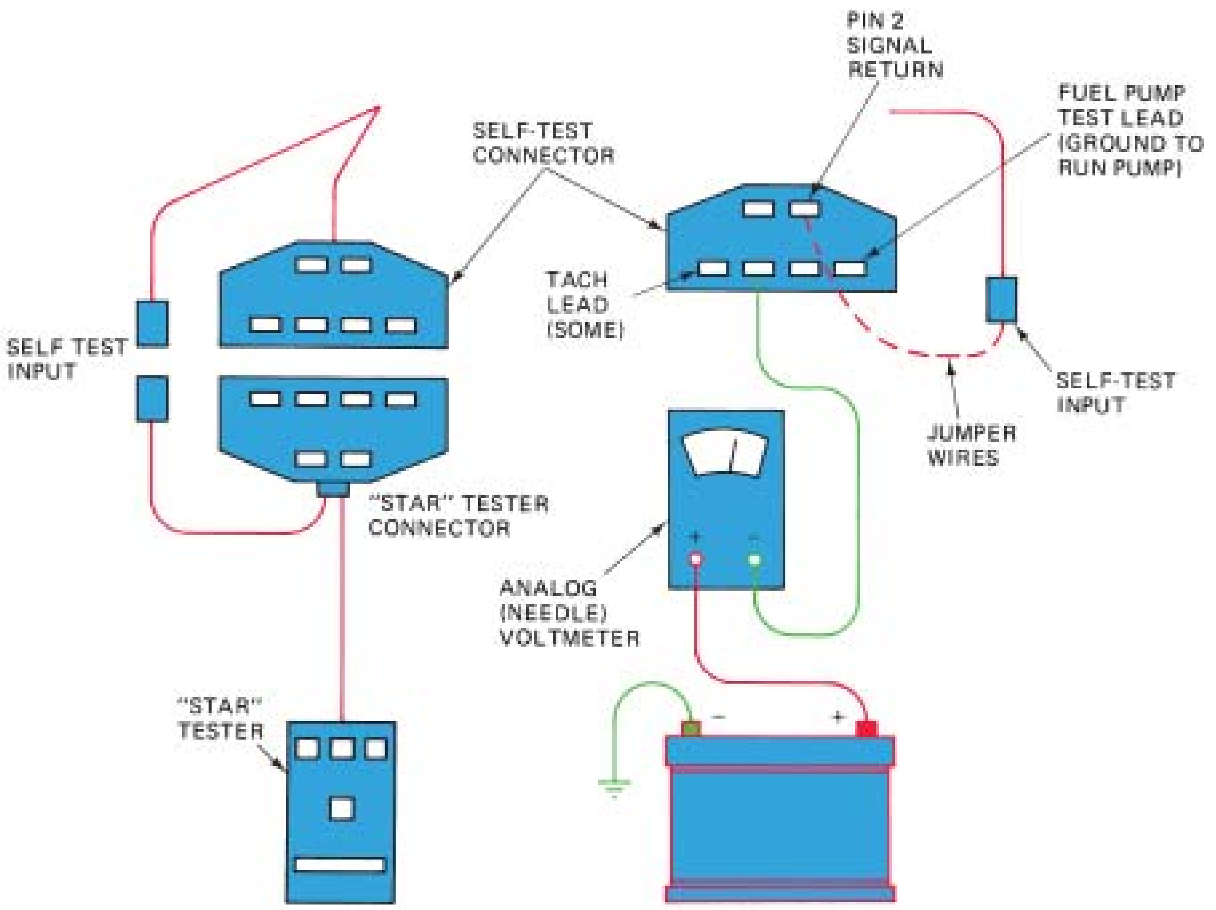
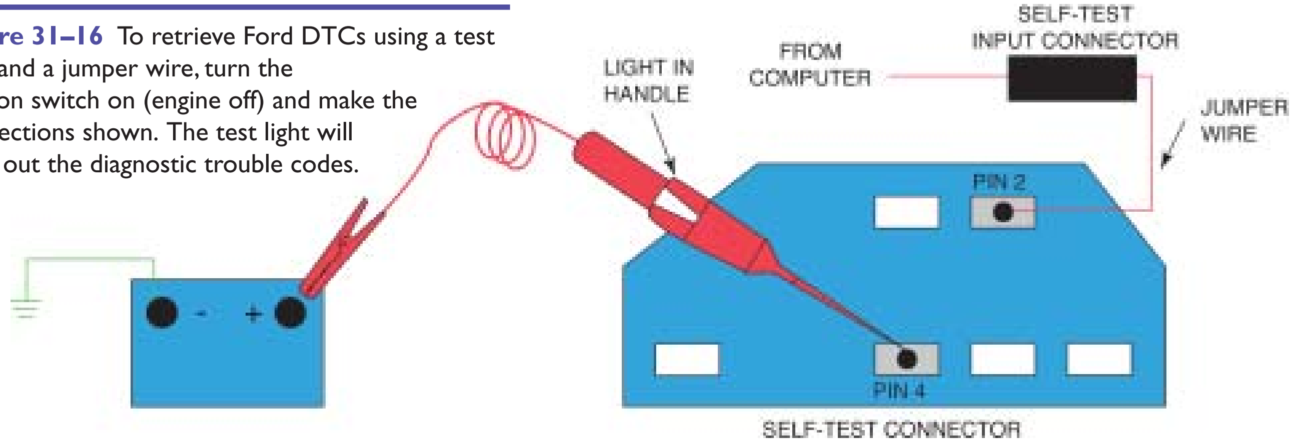


Figure 31–15 Typical connections needed to obtain Ford diagnostic trouble codes.

Figure 31–16 To retrieve Ford DTCs using a test light and a jumper wire, turn the ignition switch on (engine off) and make the connections shown. The test light will blink out the diagnostic trouble codes.



After all the codes have been reported, the computer will pause for about 6 to 9 seconds, then cause the voltmeter needle to pulse once (code 10), and then pause for another 6 to 9 seconds. This is the normal separation between current trouble codes and continuous memory codes (for intermittent problems). Code 11 is the normal pass code, which means that no fault has been stored in memory. Normal operation of the diagnostic procedure, using a voltmeter, should indicate the following if no codes are set: 1 pulse (2-second pause), 1 pulse (4-second pause), 1 pulse (2-second pause), and finally, 1 pulse. These two pulses separated by a 4-second interval represent a code 11, which is the code used for a "system pass." The code 11 was repeated twice.

After 6 to 9 seconds, the needle sweeps once. This is the separator (code 10), which precedes the continuous memory (soft) codes. Code 11 in contin-

TECH TIP

The "Unplug It" Test

If a sensor is supplying *incorrect* data to the computer, the computer may respond with incorrect fuel delivery or ignition timing. The result is a poorly operating engine, possibly with no trouble codes stored in the computer. A common example involves the mass air flow (MAF) sensor used on many vehicles. If the MAF sensor is unplugged and the engine runs better (or starts, whereas it would not start before the sensor was unplugged), then the problem is a defective MAF sensor. As long as the sensor is supplying data within the parameters (guidelines) of the computer, the data will be processed. But if the suspected unit is unplugged, no data is received from the sensor and the computer substitutes a replacement value based on values of other related sensors. For example, the throttle position sensor and/or MAP sensor may back up a defective (or unplugged) MAF sensor. Therefore, if the engine does not start, but then starts if the MAF sensor is unplugged, the MAF sensor is defective.

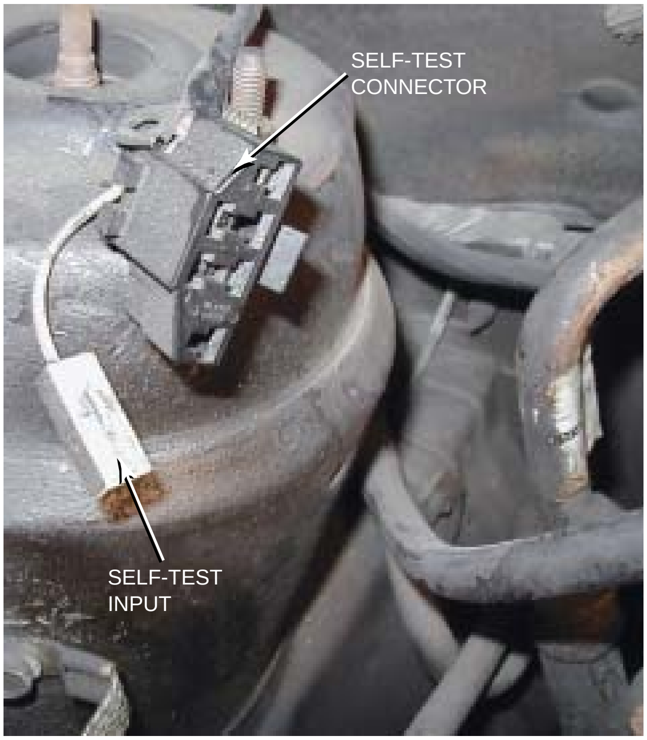


Figure 31–17 A Ford self-test connector. The exact location of this underhood connector varies with model and year of manufacture.

uous memory indicates the computer has not detected any faults in the past.

Engine Running Test Start the engine and raise the speed to 2500 to 3000 rpm within 20 seconds of starting. Hold a steady high engine speed until the initial pulses appear (2 pulses for a four-cylinder engine, 3 pulses for a six-cylinder, and 4 pulses for an eight-cylinder). Continue to hold a high engine speed until the code pulses begin (10 to 14 seconds). If any trouble codes appear, you must use the factory pinpoint tests (diagnostic flow charts) to trace the problem.

Refer to factory service information for a description of Ford-specific DTCs.

RETRIEVING CHRYSLER DIAGNOSTIC CODES

To put the computer into the self-diagnostic mode, the ignition switch must be turned on and off 3 times within a 5-second period (on-off-on-off-on). The computer will flash a series of fault codes in a manner similar to the GM system. Most Chrysler products flash the "power loss," "power limited," or "check engine" lamp on the dash. Refer to service information for a description of Chrysler-specific DTCs. See Figure 31–18 for the underhood Chrysler data link connector that is used to connect to a scan tool prior to OBD II.

NOTE: Unlike other makes, most Chrysler vehicles equipped with OBD II can still display codes (on the instrument cluster) by cycling the ignition key as previously performed on older vehicles.

Figure 31–18 An underhood Chrysler data link connector used from 1981 until 1995 on OBD I vehicles.

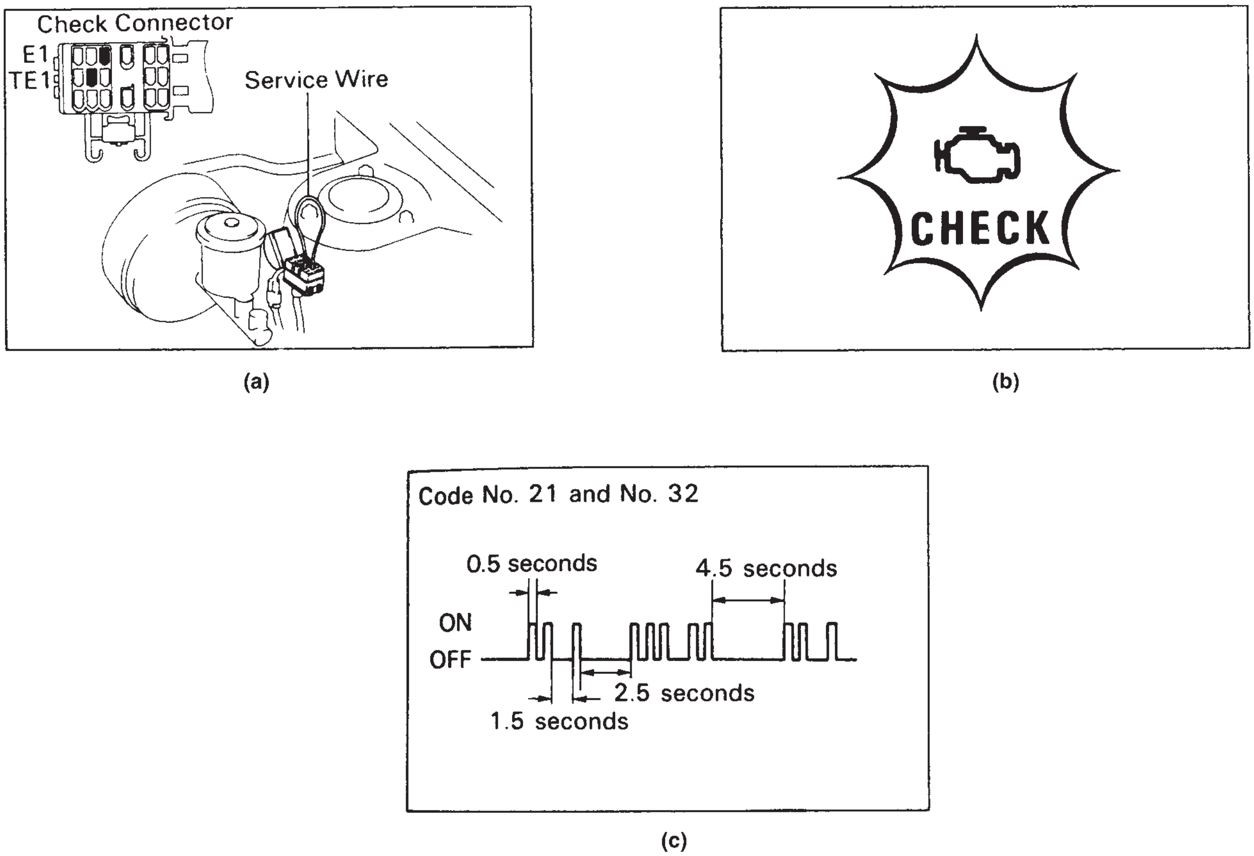


Figure 31–19 Many imports use a service wire (a) to connect the diagnostic terminals. The malfunction indicator lamp (MIL) will begin to flash (b). Read and note the number of flashes, and the spacing (c). (Courtesy Toyota Canada Inc.)

RETRIEVING DIAGNOSTIC CODES IN IMPORT VEHICLES

Early OBDI import and domestic vehicles use similar methods of retrieving DTCs. Generally a jumper wire is placed across two terminals of a diagnostic connector (see Figure 31–19) and a dash light flashes or a voltmeter (connected into the circuit) needle will rise and fall. Count the number of light flashes or needle sweeps to determine the code. See Figure 31–20. Follow the diagnostic routines in the shop manual. Import OBDII diagnostic systems are almost the same as domestic systems.

RETRIEVING OBD II CODES—16 PIN

A scan tool is required to retrieve diagnostic trouble codes from an OBD II vehicle. Every OBD II scan tool will be able to read all generic Society of Automotive Engineers (SAE) DTCs from any vehicle. Manufacturers' specific codes may require an adaptor (personality keys) for some scan tools. See Figure 31–21 for a typical OBD II data link connector (DLC) location. Except for Chrysler vehicles, all OBD II DTCs must be read using a scan tool. See Figure 31–22 for OBD II generic DTCs.

OBDII freeze-frame data such as "calculated load," "short and long-term fuel trim," and "cylinder identification for misfire" are invaluable for diagnosing problems.

When the repair is completed and the DTC is cleared, road test the vehicle again to confirm that the code does not reset. Although some OBDII codes require two or three trips to set, many scan tools have a program that allows codes to register with only one trip.

NOTE: Although OBD II requires that just one freeze-frame of data be stored, the instant an emission-related DTC is set, vehicle manufacturers usually provide expanded data about the DTC beyond that required. However, retrieving this enhanced data usually requires the use of the vehicle-specific scan tool.

DIAGNOSTIC CODES

Code No.	Number of check engine blinks	System	Diagnosis	Trouble area	See page
—	ON OFF FI1401	Normal	This appears when none of the other codes (11 thru 71) are indentified.	—	—
11	FI1388	ECU (+B)	Wire severance, however slight, in +B (ECU)	● IG switch circuit ● IG switch ● Main relay circuit ● Main relay ● ECU	FI-34
12	FI1389	RPM Signal	No NE or G signal to ECU within several seconds after engine is cranked.	● Distributor circuit ● Distributor ● Starter signal circuit ● ECU	IG-4
13	FI1390	RPM Signal	No NE signal to ECU when the engine speed is above 1000 rpm.	● Distributor circuit ● Distributor ● ECU	—
14	FI1391	Ignition Signal	No IGF signal to ECU 4 — 5 times in succession.	● Ignition circuit (+B, IGT, IGF) ● Igniter ● ECU	FI-44
21	FI1609	Oxygen Sensor Signal	Detection of oxygen sensor deterioration.	● Oxygen sensor circuit ● Oxygen sensor ● ECU	FI-48
22	FI1392	Water temp. Sensor Signal	Open or short circuit in water temp. sensor signal (THW).	● Water temp. sensor circuit ● Water temp. sensor ● ECU	FI-42
24	FI1611	Intake air Temp. Sensor Signal	Open or short circuit in intake air temp. sensor signal (THA).	● Intake air temp. sensor circuit ● Intake air temp. sensor ● ECU	FI-41
*25	FI2562	Air-fuel Ratio Lean Malfunction	When air-fuel ratio feedback compensation valve or adative control value continues at the upper (lean) or lower (rich) limit renewed for a certain priod of time.	● Injector circuit ● Injector ● Oxygen sensor circuit ● Oxygen sensor ● ECU ● Fuel line pressure ● Air flow meter ● Water temp. sensor ● Ignition system ● ECU	—
*26	FI2563	Air-fuel Ratio Rich Malfunction		● Injector circuit ● Injector ● Fuel line pressure ● Cold start injector ● Air flow meter ● Water temp. ensor ● ECU	—
*27	FI3294	Sub-oxygen Sensor Signal	Open or short circuit in sub-oxygen sensor signal (OX2)	● Sub-oxygen sensor circuit ● Sub-oxygen sensor ● ECU	FI-48
31	FI1394	Air flow Meter Signal	Open circuir in VC signal or short circuit between VC and E2 when idle contacts are closed.	● Air flow meter circuit ● Air flow meter ● ECU	FI-39
32	FI1395	Air flow Meter Signal	Open circuit in E2 or short circuit between VC and VS.	Same as 31, above.	FI-39

*CALIF. only

Continued on next page

Figure 31–20 A typical OBD I diagnostic trouble code (DTC) chart for an import vehicle. Import OBD II charts are the same as generic fault codes for domestic vehicles. (Courtesy Toyota Canada Inc.)

DIAGNOSTIC CODES

Code No.	Number of check engine blinks	System	Diagnosis	Trouble area	See page
41	 FI1396	Throttle Position Sensor Signal	(w/o ECT) IDL and PSW signals being output simulaneously for several seconds. (w/ ECT) Open or short circuit in throttle position sensor signal (VTA).	● Throttle position sensor circuit ● Throttle position sensor ● ECU	FI-36 or FI-37
42	 FI1397	Vehicle Speed Sensor Signal	No SPD signal for several seconds when engine speed is between 2500–5500 rpm and coolant temp. is below 80°C (176°F) except when racing the engine.	● Vehicle speed sensor circuit ● Vehicle speed sensor ● ECU	–
43	 FI1398	Starter Signal	No STA signal to ECU when behicle stopped and engine running over 800 rpm.	● IG switch circuit ● IG switch ● ECU	FI-43
*71	 FI2622	EGR Malfunction	EGR gas temp. below predetermined level for during EGR control.	● EGR system (EGR valve, EGR hose etc.) ● EGR gas temp. sensor circuit ● EGR gas temp. sensor ● BVSV for EGR ● BVSV for EGR circuit ● ECU	FI-49
51	 FI1399	Switch Signal	No IDL signal or A/C signal to ECU, with the check terminals TE1 and E1 connected.	● A/C switch circuit ● A/C amplifire ● Throttle position sensor circuit ● Throttle position sensor ● Accelerator pedal and cable	–

*CALIF. only

Figure 31–20 continued

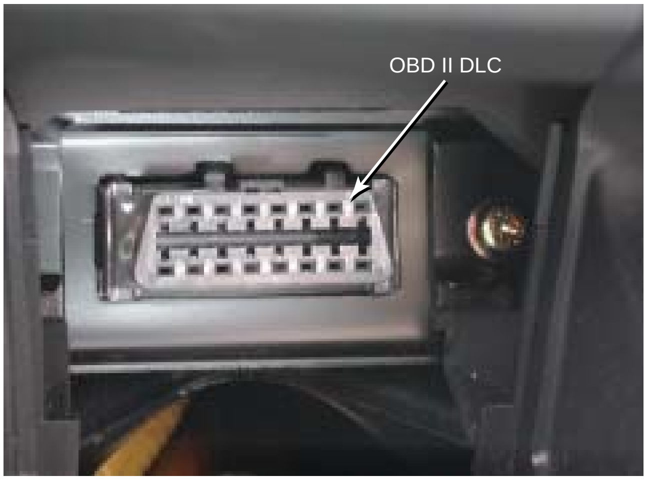


Figure 31–21 An OBD II data link connector (DLC). It is located under the dash and could be covered by a snap-in cover such as on this Acura TL.

EXHAUST ANALYSIS AND COMBUSTION EFFICIENCY

A popular method of engine analysis involves the use of five-gas exhaust analysis equipment. See Figure 31–23. The five gases analyzed and their significance are as follows.

Hydrocarbons

Hydrocarbons (**HC**) are unburned gasoline and are measured in parts per million (ppm). A correctly operating engine should burn (oxidize) almost all of the gasoline; therefore, very little unburned gasoline should be present in the exhaust. Acceptable levels of HC are 50 ppm or less. High HC levels are an indicator of poor combustion or a misfire. The most common cause of excessive HC emissions is a fault in the ignition system or a lean condition. Items that should be checked include:

- Spark plugs
- Spark plug wires
- Distributor cap and rotor (if the vehicle is so equipped)
- Ignition timing
- Ignition coil
- Vacuum leaks

Carbon Monoxide

Carbon monoxide (**CO**) is unstable and will easily combine with any oxygen to form stable carbon dioxide (**CO_2**). CO is a very poisonous gas. CO levels of a properly operating engine should be less than 0.5%.

Fuel and Air Metering System

P0100 Mass or Volume Airflow Circuit Problem
P0101 Mass or Volume Airflow Circuit Range or Performance Problem
P0102 Mass or Volume Airflow Circuit Low Input
P0103 Mass or Volume Airflow Circuit High Input
P0105 Manifold Absolute Pressure or Barometric Pressure Circuit Problem
P0106 Manifold Absolute Pressure or Barometric Pressure Circuit Range or Performance Problem
P0107 Manifold Absolute Pressure or Barometric Pressure Circuit Low Input
P0108 Manifold Absolute Pressure or Barometric Pressure Circuit High Input
P0110 Intake Air Temperature Circuit Problem
P0111 Intake Air Temperature Circuit Range or Performance Problem
P0112 Intake Air Temperature Circuit Low Input
P0113 Intake Air Temperature Circuit High Input
P0115 Engine Coolant Temperature Circuit Problem
P0116 Engine Coolant Temperature Circuit Range or Performance Problem
P0117 Engine Coolant Temperature Circuit Low Input
P0118 Engine Coolant Temperature Circuit High Input
P0120 Throttle Position Circuit Problem
P0121 Throttle Position Circuit Range or Performance Problem
P0122 Throttle Position Circuit Low Input
P0123 Throttle Position Circuit High Input
P0125 Excessive Time to Enter Closed-Loop Fuel Control
P0130 O2 Sensor Circuit Problem (Bank 1* Sensor 1)
P0131 O2 Sensor Circuit Low Voltage (Bank 1* Sensor 1)
P0132 O2 Sensor Circuit High Voltage (Bank 1* Sensor 1)
P0133 O2 Sensor Circuit Slow Response (Bank 1* Sensor 1)
P0134 O2 Sensor Circuit No Activity Detected (Bank 1* Sensor 1)
P0135 O2 Sensor Heater Circuit Problem (Bank 1* Sensor 1)
P0136 O2 Sensor Circuit Problem (Bank 1* Sensor 2)
P0137 O2 Sensor Circuit Low Voltage (Bank 1* Sensor 2)
P0138 O2 Sensor Circuit High Voltage (Bank 1* Sensor 2)
P0139 O2 Sensor Circuit Slow Response (Bank 1* Sensor 2)
P0140 O2 Sensor Circuit No Activity Detected (Bank 1* Sensor 2)
P0141 O2 Sensor Heater Circuit Problem (Bank 1* Sensor 2)
P0142 O2 Sensor Circuit Problem (Bank 1* Sensor 3)
P0143 O2 Sensor Circuit Low Voltage (Bank 1* Sensor 3)
P0144 O2 Sensor Circuit High Voltage (Bank 1* Sensor 3)
P0145 O2 Sensor Circuit Slow Response (Bank 1* Sensor 3)
P0146 O2 Sensor Circuit No Activity Detected (Bank 1* Sensor 3)
P0147 O2 Sensor Heater Circuit Problem (Bank 1* Sensor 3)
P0150 O2 Sensor Circuit Problem (Bank 2 Sensor 1)
P0151 O2 Sensor Circuit Low Voltage (Bank 2 Sensor 1)
P0152 O2 Sensor Circuit High Voltage (Bank 2 Sensor 1)
P0153 O2 Sensor Circuit Slow Response (Bank 2 Sensor 1)
P0154 O2 Sensor Circuit No Activity Detected (Bank 2 Sensor 1)
P0155 O2 Sensor Heater Circuit Problem (Bank 2 Sensor 1)
P0156 O2 Sensor Circuit Problem (Bank 2 Sensor 2)
P0157 O2 Sensor Circuit Low Voltage (Bank 2 Sensor 2)
P0158 O2 Sensor Circuit High Voltage (Bank 2 Sensor 2)
P0159 O2 Sensor Circuit Slow Response (Bank 2 Sensor 2)
P0160 O2 Sensor Circuit No Activity Detected (Bank 2 Sensor 2)
P0161 O2 Sensor Heater Circuit Problem (Bank 2 Sensor 2)
P0162 O2 Sensor Circuit Problem (Bank 2 Sensor 3)
P0163 O2 Sensor Circuit Low Voltage (Bank 2 Sensor 3)
P0164 O2 Sensor Circuit High Voltage (Bank 2 Sensor 3)
P0165 O2 Sensor Circuit Slow Response (Bank 2 Sensor 3)
P0166 O2 Sensor Circuit No Activity Detected (Bank 2 Sensor 3)
P0167 O2 Sensor Heater Circuit Problem (Bank 2 Sensor 3)
P0170 Fuel Trim Problem (Bank 1*)
P0171 System Too Lean (Bank 1*)
P0172 System Too Rich (Bank 1*)
P0173 Fuel Trim Problem (Bank 2)

Figure 31–22 Generic OBD II powertrain DTCs.

P0174 System Too Lean (Bank 2)
P0175 System Too Rich (Bank 2)
P0176 Fuel Composition Sensor Circuit Problem
P0177 Fuel Composition Sensor Circuit Range or Performance
P0178 Fuel Composition Sensor Circuit Low Input
P0179 Fuel Composition Sensor Circuit High Input
P0180 Fuel Temperature Sensor Problem
P0181 Fuel Temperature Sensor Circuit Range or Performance
P0182 Fuel Temperature Sensor Circuit Low Input
P0183 Fuel Temperature Sensor Circuit High Input

Fuel and Air Metering (Injector Circuit)

P0201 Injector Circuit Problem—Cylinder 1
P0202 Injector Circuit Problem—Cylinder 2
P0203 Injector Circuit Problem—Cylinder 3
P0204 Injector Circuit Problem—Cylinder 4
P0205 Injector Circuit Problem—Cylinder 5
P0206 Injector Circuit Problem—Cylinder 6
P0207 Injector Circuit Problem—Cylinder 7
P0208 Injector Circuit Problem—Cylinder 8
P0209 Injector Circuit Problem—Cylinder 9
P0210 Injector Circuit Problem—Cylinder 10
P0211 Injector Circuit Problem—Cylinder 11
P0212 Injector Circuit Problem—Cylinder 12
P0213 Cold Start Injector 1 Problem
P0214 Cold Start Injector 2 Problem

Ignition System or Misfire

P0300 Random Misfire Detected
P0301 Cylinder 1 Misfire Detected
P0302 Cylinder 2 Misfire Detected
P0303 Cylinder 3 Misfire Detected
P0304 Cylinder 4 Misfire Detected
P0305 Cylinder 5 Misfire Detected
P0306 Cylinder 6 Misfire Detected
P0307 Cylinder 7 Misfire Detected
P0308 Cylinder 8 Misfire Detected
P0309 Cylinder 9 Misfire Detected
P0310 Cylinder 10 Misfire Detected
P0311 Cylinder 11 Misfire Detected
P0312 Cylinder 12 Misfire Detected
P0320 Ignition or Distributor Engine Speed Input Circuit Problem
P0321 Ignition or Distributor Engine Speed Input Circuit Range or Performance
P0322 Ignition or Distributor Engine Speed Input Circuit No Signal
P0325 Knock Sensor 1 Circuit Problem
P0326 Knock Sensor 1 Circuit Range or Performance
P0327 Knock Sensor 1 Circuit Low Input
P0328 Knock Sensor 1 Circuit High Input
P0330 Knock Sensor 2 Circuit Problem
P0331 Knock Sensor 2 Circuit Range or Performance
P0332 Knock Sensor 2 Circuit Low Input
P0333 Knock Sensor 2 Circuit High Input
P0335 Crankshaft Position Sensor Circuit Problem
P0336 Crankshaft Position Sensor Circuit Range or Performance
P0337 Crankshaft Position Sensor Circuit Low Input
P0338 Crankshaft Position Sensor Circuit High Input

Auxiliary Emission Controls

P0400 Exhaust Gas Recirculation Flow Problem
P0401 Exhaust Gas Recirculation Flow Insufficient Detected
P0402 Exhaust Gas Recirculation Flow Excessive Detected
P0405 Air Conditioner Refrigerant Charge Loss
P0410 Secondary Air Injection System Problem
P0411 Secondary Air Injection System Insufficient Flow Detected
P0412 Secondary Air Injection System Switching Valve or Circuit Problem
P0413 Secondary Air Injection System Switching Valve or Circuit Open
P0414 Secondary Air Injection System Switching Valve or Circuit Shorted
P0420 Catalyst System Efficiency Below Threshold (Bank 1*)
P0421 Warm Up Catalyst Efficiency Below Threshold (Bank 1*)
P0422 Main Catalyst Efficiency Below Threshold (Bank 1*)
P0423 Heated Catalyst Efficiency Below Threshold (Bank 1*)
P0424 Heated Catalyst Temperature Below Threshold (Bank 1*)
P0430 Catalyst System Efficiency Below Threshold (Bank 2)
P0431 Warm Up Catalyst Efficiency Below Threshold (Bank 2)
P0432 Main Catalyst Efficiency Below Threshold (Bank 2)
P0433 Heated Catalyst Efficiency Below Threshold (Bank 2)
P0434 Heated Catalyst Temperature Below Threshold (Bank 2)
P0440 Evaporative Emission Control System Problem
P0441 Evaporative Emission Control System Insufficient Purge Flow

Figure 31–22 continued

P0442 Evaporative Emission Control System Leak Detected
P0443 Evaporative Emission Control System Purge Control Valve Circuit Problem
P0444 Evaporative Emission Control System Purge Control Valve Circuit Open
P0445 Evaporative Emission Control System Purge Control Valve Circuit Shorted
P0446 Evaporative Emission Control System Vent Control Problem
P0447 Evaporative Emission Control System Vent Control Open
P0448 Evaporative Emission Control System Vent Control Shorted
P0450 Evaporative Emission Control System Pressure Sensor Problem
P0451 Evaporative Emission Control System Pressure Sensor Range or Performance
P0452 Evaporative Emission Control System Pressure Sensor Low Input
P0453 Evaporative Emission Control System Pressure Sensor High Input

Vehicle Speed Control and Idle Control

P0500 Vehicle Speed Sensor Problem
P0501 Vehicle Speed Sensor Range or Performance
P0502 Vehicle Speed Sensor Low Input
P0505 Idle Control System Problem
P0506 Idle Control System RPM Lower than Expected
P0507 Idle Control System RPM Higher than Expected
P0510 Closed Throttle Position Switch Problem

Computer Output Circuit

P0600 Serial Communication Link Problem
P0605 Internal Control Module (Module Identification Defined by J1979)

Transmission

P0703 Brake Switch Input Problem
P0705 Transmission Range Sensor Circuit Problem (PRNDL Input)
P0706 Transmission Range Sensor Circuit Range or Performance
P0707 Transmission Range Sensor Circuit Low Input
P0708 Transmission Range Sensor Circuit High Input
P0710 Transmission Fluid Temperature Sensor Problem
P0711 Transmission Fluid Temperature Sensor Range or Performance
P0712 Transmission Fluid Temperature Sensor Low Input
P0713 Transmission Fluid Temperature Sensor High Input
P0715 Input or Turbine Speed Sensor Circuit Problem
P0716 Input or Turbine Speed Sensor Circuit Range or Performance
P0717 Input or Turbine Speed Sensor Circuit No Signal
P0720 Output Speed Sensor Circuit Problem
P0721 Output Speed Sensor Circuit Range or Performance
P0722 Output Speed Sensor Circuit No Signal
P0725 Engine Speed Input Circuit Problem
P0726 Engine Speed Input Circuit Range or Performance
P0727 Engine Speed Input Circuit No Signal
P0730 Incorrect Gear Ratio
P0731 Gear 1 Incorrect Ratio
P0732 Gear 2 Incorrect Ratio
P0733 Gear 3 Incorrect Ratio
P0734 Gear 4 Incorrect Ratio
P0735 Gear 5 Incorrect Ratio
P0736 Reverse Incorrect Ratio
P0740 Torque Converter Clutch System Problem
P0741 Torque Converter Clutch System Performance or Stuck Off
P0742 Torque Converter Clutch System Stuck On
P0743 Torque Converter Clutch System Electrical
P0745 Pressure Control Solenoid Problem
P0746 Pressure Control Solenoid Performance or Stuck Off
P0747 Pressure Control Solenoid Stuck On
P0748 Pressure Control Solenoid Electrical
P0750 Shift Solenoid A Problem
P0751 Shift Solenoid A Performance or Stuck Off
P0752 Shift Solenoid A Stuck On
P0753 Shift Solenoid A Electrical
P0755 Shift Solenoid B Problem
P0756 Shift Solenoid B Performance or Stuck Off
P0757 Shift Solenoid B Stuck On
P0758 Shift Solenoid B Electrical
P0760 Shift Solenoid C Problem
P0761 Shift Solenoid C Performance or Stuck Off
P0762 Shift Solenoid C Stuck On
P0763 Shift Solenoid C Electrical
P0765 Shift Solenoid D Problem
P0766 Shift Solenoid D Performance or Stuck Off
P0767 Shift Solenoid D Stuck On
P0768 Shift Solenoid D Electrical
P0770 Shift Solenoid E Problem
P0771 Shift Solenoid E Performance or Stuck Off
P0772 Shift Solenoid E Stuck On
P0773 Shift Solenoid E Electrical

Figure 31–22 continued

(a)

(b)

Figure 31–23 (a) Typical portable 5-gas exhaust analyzer. This particular unit can be removed from its stand and placed inside the vehicle to monitor the exhaust emission while driving. (b) A typical partial stream sample type of exhaust probe used to measure exhaust gases in parts per million (ppm) or percentage (%).

High CO is a good indicator of richness. High levels of CO can be caused by clogged or restricted crankcase ventilation devices such as the PCV valve, hose(s), and tubes. Other items that might cause excessive CO include:

- Sticking fuel injector
- Clogged air filter
- Incorrect idle speed
- Too-high fuel pressure
- Fuel saturated carbon canister
- Any other items that can cause a rich condition

Carbon Dioxide (CO_2)

Carbon dioxide **(CO_2)** is the result of oxygen in the engine combining with the carbon of the gasoline. An acceptable level of CO_2 is between 12 and 17%. A high reading indicates an efficiently operating engine. If the CO_2 level is low, the mixture may be either too rich or too lean. CO_2 emissions are considered a contributor to "greenhouse gases."

Oxygen

There is about 21% oxygen (**O_2**) in the atmosphere, and most of this oxygen should be used up during the combustion process to oxidize all the hydrogen and carbon (hydrocarbons) in the gasoline. Levels of O_2 should be very low (about 0.5%). O_2 readings are a good indicator of the air/fuel ratio (high O_2 = lean, low O_2 = rich).

Frequently Asked Question ???

What Do All These Emission Labels Mean?

TLEV	Transitional Low-Emission Vehicle, car exhaust hydrocarbon (HC) limited to 0.125 gram per mile (gpm).
LEV	Low-Emission Vehicle, car exhaust HC 0.075 gpm.
ULEV	Ultra Low-Emission Vehicle, car exhaust HC 0.040 gpm.
SULEV	Super Ultra Low-Emission Vehicle, car exhaust HC 0.010 gpm.
ZEV	Zero-Emission Vehicle.
CEV	City Electric Vehicle, a miniature car, which could earn minor credit against ZEV quota.
NEV	Neighborhood Electric Vehicle, very similar to golf cart, could earn minor credit against ZEV quota.
PZEV	A near-zero emissions category, P is for "partial." A PZEV would earn "partial credit" against manufacturers' ZEV quotas.
AT-PZEV	A near-zero-emissions category. AT is for "advanced technology," meeting PZEV requirements using, for example, a low-emissions fuel cell running on methanol or an internal-combustion engine running on natural gas.

NOTE: Adding 10% alcohol to gasoline (gasohol) provides additional oxygen to the fuel and will result in lower levels of CO and higher levels of O_2 in the exhaust.

OXIDES OF NITROGEN (NO_X)

An oxide of nitrogen (NO) is a colourless, tasteless, and odorless gas when it leaves the engine, but as soon as it reaches the atmosphere and mixes with more oxygen, nitrogen oxides (NO_2) are formed. NO_2 is reddish-brown and has an acid and pungent smell. NO and NO_2 are grouped together and referred to as NO_x, where x represents any number of oxygen atoms. NO_x is the fifth gas commonly tested using a 5-gas analyzer. The exhaust gas recirculation (EGR) system is the major controlling device limiting the formation of NO_x. Because the formation of NO_x occurs mostly under load, the most efficient method to test for NO_x is to use a portable exhaust analyzer that can be carried in the vehicle while the vehicle is being driven under a variety of conditions. A maximum reading of 1,000 parts per million (ppm) of NO_x under loaded driving conditions will generally mean that the vehicle will pass an enhanced I/M roller test. A reading of over 100 ppm at idle should be considered excessive. Because NO_x is a good indicator of combustion temperatures, watch for overadvanced ignition timing or lean air/fuel ratios.

BASIC EXHAUST GAS ANALYSIS

Older gas analyzers give only two readings, carbon monoxide and hydrocarbons. See Figure 31–24. Note that hydrocarbons are high with both rich mixtures

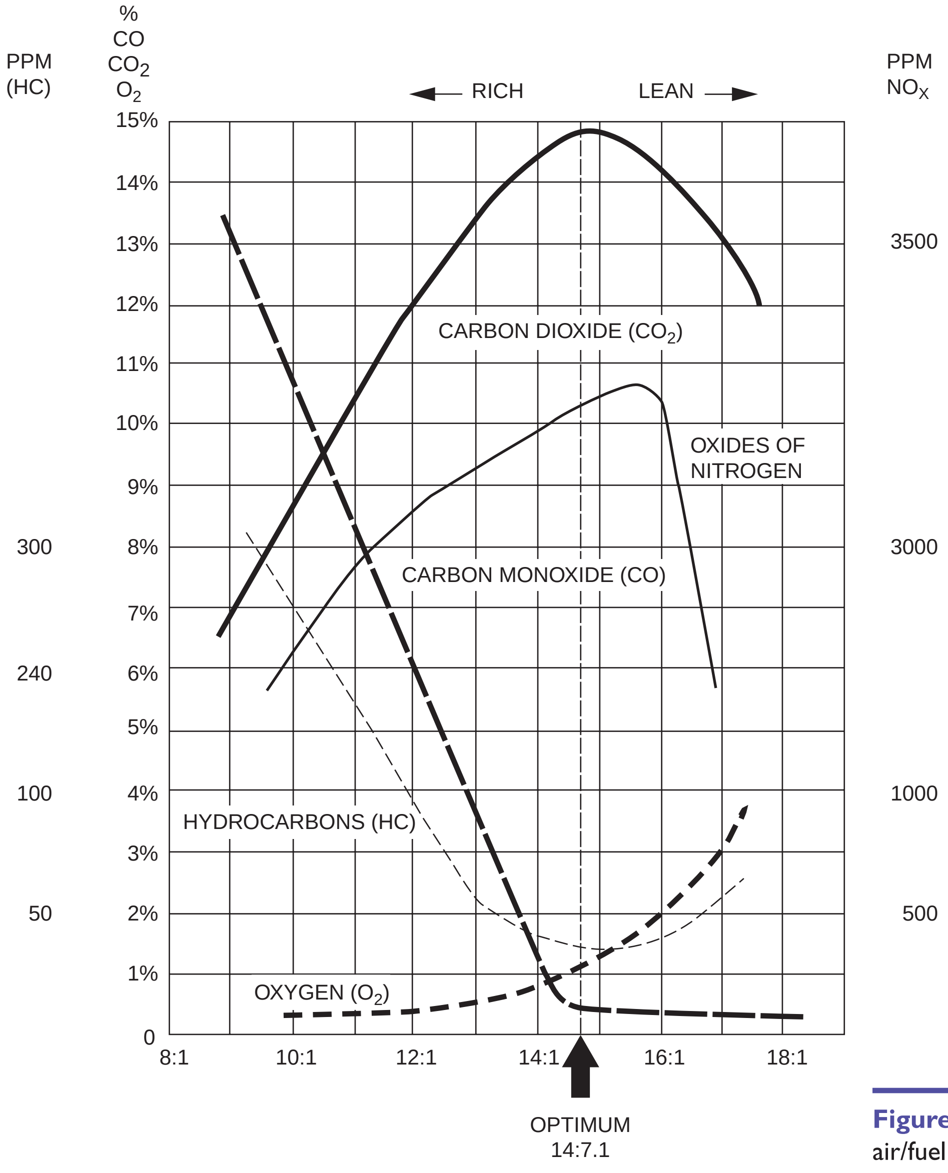


Figure 31–24 Exhaust emissions versus air/fuel ratio. (Courtesy DaimlerChrysler)

(too much fuel) and lean mixtures (not enough fuel). To determine the cause of a high hydrocarbon reading, look at the carbon monoxide reading. CO is a good indicator of richness. Therefore, if

HC and CO high	=	rich mixture
HC high, CO low	=	lean mixture
HC very high, CO low	=	possible misfire

Two-gas readings became obsolete when catalytic converters came into use; the converters mask both HC and CO. Some import vehicles have a removable plug ahead of the converter for "pre-cat" sampling, but these are not common.

Four-gas analyzers read both CO and HC, plus oxygen (O_2), which is a good indicator of rich/lean, and carbon dioxide (CO_2), an indicator of combustion efficiency.

High CO_2	=	good combustion
Low CO_2 and high O_2	=	too lean or misfire
Low CO_2 and low O_2	=	too rich

The air injection system is sometimes disabled before taking tailpipe readings. Check your analyzer manual.

Five-gas analyzers include the above four gases, plus oxides of nitrogen (NO_x). Because NO_x increases under load, a chassis dynomometer or a portable gas analyzer must be used.

High NO_x = too lean, overadvanced timing, lack of EGR, etc.

Comparing the NO_x reading with the other gases will determine the problem area. Note that NO_x decreases with extremely lean mixtures when the engine misfires.

Low NO_x, high O_2 = misfire.

Acceptable exhaust emissions include:

	Without Catalytic Converter (pre-1975)	With Catalytic Converter (post-1975)
HC	300 ppm or less	30–50 ppm or less
CO	3% or less	0.3%–0.5% or less
O_2	0%–2%	0%–2%
CO_2	12%–17% or higher	12%–17% or higher

I/M 240

I/M 240 refers to inspection and maintenance (I/M), and the 240 means that the exhaust emissions test lasts 240 seconds (4 minutes). The I/M 240 test is a shorter version of the Federal Test Procedure (FTP) that takes 505 seconds. The I/M 240 procedure tests vehicle emissions under a loaded dynamometer that simulates actual highway usage. All the exhaust is analyzed and the results are given in grams per kilometre or per mile. See Figure 31–25.

Because many locations do not use the I/M 240 test, most vehicle exhaust emissions testing is referred to as **enhanced exhaust emission testing** or **enhanced I and M,** which refers to any of the various tests and variations of the tests used in different parts of the country.

Frequently Asked Question ???

How Can My Worn-Out, Old, High-Mileage Vehicle Pass an Exhaust Emissions Test?

Age and mileage of a vehicle are generally not factors when it comes to passing an exhaust emissions test. Regular maintenance is the most important factor for passing an enhanced I/M exhaust analysis test. Failure of the vehicle owner to replace broken accessory drive belts, leaking AIR pump tubes, defective spark plug wires, or a cracked exhaust manifold can lead to failure of other components, such as the catalytic converter. Tests have shown that if the vehicle is properly cared for, even an engine that has been operating for 480 000 km (300 000 mi) can pass an exhaust emissions test.

DIAGNOSTIC STORY

The Corvette Story

A Corvette failed an enhanced exhaust emissions test repeatedly. All of the exhaust gases, except hydrocarbons (HC), were well within limits. HC emissions were off the scale and a strong smell of gasoline was apparent. All of the fuel lines and the charcoal canister were replaced and the vehicle still failed. Finally, a technician used a hydrocarbon detector and located a small rust hole in the gas tank. The fumes were escaping from the hole in the tank and were picked up by the large exhaust hose during the testing on the rollers. A temporary plug of epoxy was applied to the hole and the Corvette then passed with flying colours. The customer was informed that a new gas tank is all that would be needed to complete the emission repair. See Figure 31–26.

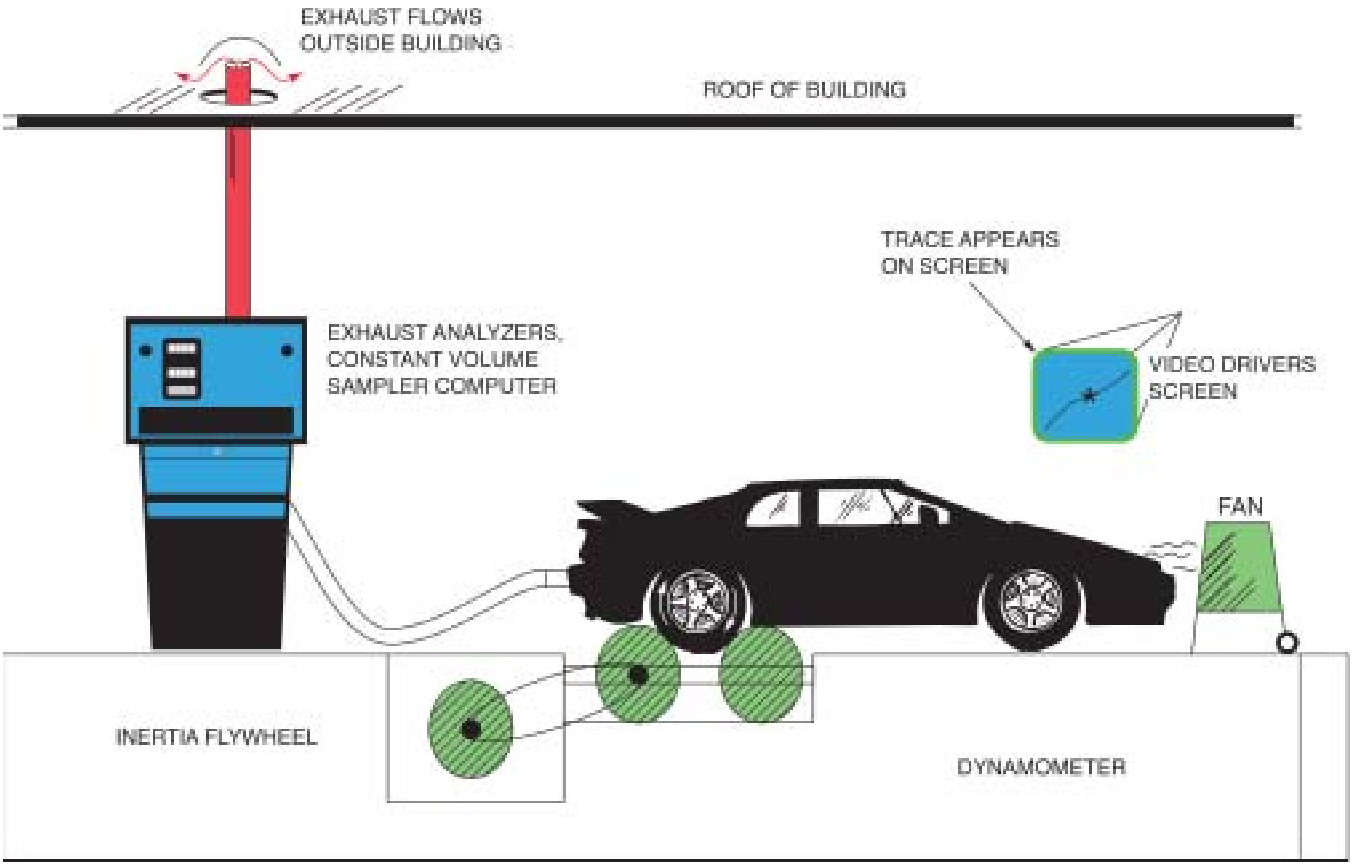


Figure 31–25 A line drawing representation of an enhanced I/M test setup. The vehicle's drive wheels rotate an inertia dynamometer that is loaded to match the inertia weight of the vehicle being tested. A driver "drives the trace," following the path deployed on an overhead monitor. The test measures all the exhaust, and the computer then calculates the amount of exhaust gases in grams per kilometre or grams per mile.


(a)


(b)

Figure 31–26 (a) The first step during the diagnosis of the exhaust emissions from the Corvette was to test drive the vehicle with the 5-gas analyzer inside the vehicle. This allows the technician to monitor the exhaust emissions under conditions similar to those during an enhanced I/M test. Care should be taken not to damage the vehicle's paint when attaching the test hose. (b) A hydrocarbon tester finally found the gas tank leak.

TECH TIP

Your Nose Knows

Using the nose, a technician can often hone in on a major problem without having to connect the vehicle to an exhaust analyzer. For example:

- The strong smell of exhaust is due to excessive unburned hydrocarbon (HC) emissions. Look for an ignition system fault that could prevent the proper burning of the fuel. A vacuum leak could also cause a lean misfire and cause excessive HC exhaust emissions.
- If your eyes start to burn or water, suspect excessive oxides of nitrogen (NO_x) emissions. The oxides of nitrogen combine with the moisture in the eyes to form a mild solution of nitric acid. The acid formation causes the eyes to burn and water. Excessive NO_x exhaust emissions can be created by a vacuum leak, which causes higher-than-normal combustion chamber temperatures, over-advanced ignition timing, which also increases combustion chamber temperatures, or a malfunctioning exhaust gas recirculation system (EGR). EGR problems are usually noticed at higher RPM on most vehicles.
- Dizzy feeling or headache. This is commonly caused by excessive carbon monoxide (CO) exhaust emissions. Get out of the building and into fresh air as soon as possible. A probable cause of high levels of CO is an excessively rich air–fuel mixture.

TECH TIP

Hints for Passing an Emissions Test

While these hints will not permit a poorly-maintained or defective vehicle to pass an enhanced exhaust emissions test, it will help prevent a well-maintained vehicle from failing the test.

1. Only test your vehicle on a nice day—avoid very cold or windy days/nights. Cold weather requires that the engine be run longer for the engine coolant, oil, and catalytic converter to reach and maintain optimum operating temperature.
2. The battery must be in good condition. A weak or low voltage battery causes many fuel-injected engines to run too rich (too much fuel) due to battery voltage correction programs built into the PCM.
3. Change engine oil before having the vehicle tested. Dirty or contaminated oil increases exhaust emissions.
4. Use premium gasoline to help reduce oxides of nitrogen (NO_x) emission.
5. Do not overfill the gas tank. After the nozzle "clicks off," only add fuel to the next dime's worth. If the gas tank is overfilled, liquid gasoline can be drawn into the engine through the canister purge system during the test.
6. *Drive 30 km (20 mi) before having the vehicle tested.*
7. Arrive at the test centre with only one-fourth to one-half tank of gasoline.
8. While waiting for the inspection, place the gear selector in "park" or "neutral" and keep the engine running at a fast idle (about 2500 rpm).
9. Before testing begins, turn the air conditioning/heating or defroster to the off position.

P22–1 All vehicles sold in Canada since 1998 (1996 in U.S.) use the OBDII 16-pin data link connector (DLC).

P22–2 Start the scan tool diagnosis by connecting the scan tool, a Tech 2 in this case, to the DLC. The DLC contains a 12 volt pin (Pin 16) and a chassis ground pin (Pin 4) to power the scan tool. An additional connection to the lighter plug or battery is not necessary on vehicles equipped with OBD II.

P22–3 Turn the power on to the scan tool before starting the engine. Much information can be learned if the scan tool is set up ready to go before the ignition is turned on or the engine is started.

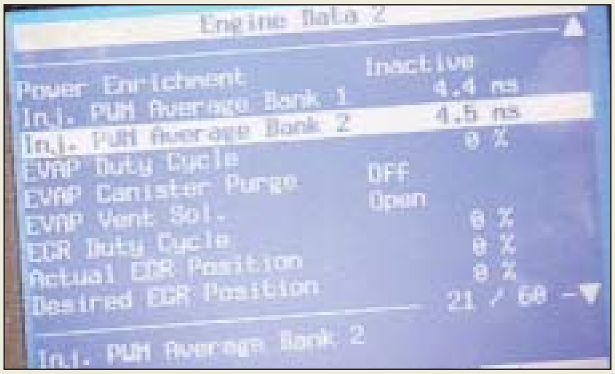
P22–4 Select heated oxygen sensor (HO2S) data before turning on the ignition.

P22–5 Turn the ignition key on (engine off) and observe the voltage readings of all the oxygen sensors. When the ignition is first turned on, the voltage of the oxygen sensors represents the bias voltage that the vehicle computer applies to the sensors.

P22–6 After waiting several minutes, notice that the voltage has been lowered on all three oxygen sensors. As the electric heaters inside the oxygen sensors heat the sensors, they become more electrically conductive. Remember: The engine is off and the oxygen sensors are simply responding normally to the oxygen in the exhaust system. There may be a possible problem with bank 2 sensor 1 because it did not drop as far as the others.

P22–7 Another item to check before starting the engine is the engine coolant temperature (ECT). The temperature should be close to the surrounding temperature. In this case, the vehicle has been in the shop overnight and the temperature displayed is the temperature inside the building.

P22–8 To help check the ECT sensor, a scan tool can be used to check the intake air temperature (IAT) sensor. The two sensors (ECT and IAT) should be within 5° of each other. In this case, both show 73°F (22°C). Also notice that the manifold absolute pressure (MAP) sensor values match the barometric (BARO) sensor reading at key on/engine off. This value will vary according to altitude.



P22–9 After checking the temperature, pressure, and oxygen sensors, the engine can be started. With the engine running, notice that the injector pulse width is about the same for each bank of this 4.3 6L V-6 engine. Normal pulse width for most engines at operating temperature is 1.5 to 3.5 ms and should be higher when the engine is cold, as shown here.

P22–10 Cylinder misfire data is available on most scan tools for vehicles equipped with OBD II. This helps determine if a fault exists in any particular cylinder.

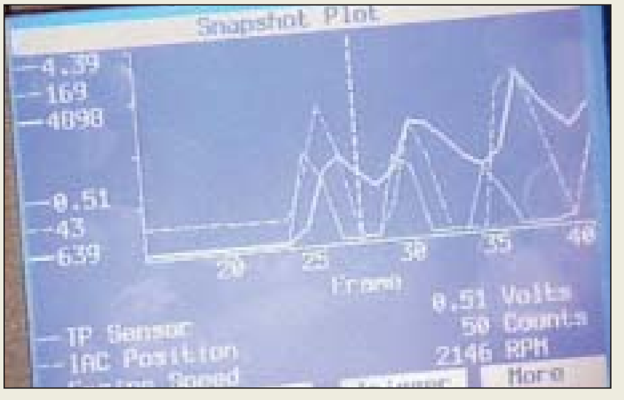
P22–11 Misfire data shows no misfires for all six cylinders on this GM vechicle.

P22–12 The pre-catalytic converter oxygen sensor (sensor 1) should fluctuate from below 200 mV to above 800 mV. The post converter oxygen sensor should be steady if the converter is okay.

P22–13 Engine speed and idle speed control can also be maintained. The difference between the desired idle speed and the actual idle speed should be within 50 rpm. The idle air control (IAC) counts should also be checked. A lower-than-normal IAC count, such as zero, indicates a possible intake manifold or vacuum leak. A higher-than-normal reading could indicate dirty throttle plates or partially clogged fuel injectors.

P22–14 The vehicle should also be checked for any stored diagnostic trouble codes (DTCs). If a DTC is stored, the engine controller (computer) could be compensating for the problem, and the scan data, also called **parameter identification data** or **PID,** could be misleading.

P22–15 The snapshot feature of most scan tools is useful to help find those intermittent problems. The scan tool can store and play back data about the engine even before the snapshot is triggered.



P22–16 When playing back snapshot data, it is useful to graph the value of several sensors to see if there is an obvious problem at one particular moment of time. The legend on the left side of the display shows the highest and the lowest value of the three sensors selected, displays which are also helpful when trying to see if a sensor is out of range.

P22–17 After use, the scan tool should be used to clear any stored DTCs and then powered down.

P22–18 Disconnect the scan tool from the DLC and store it in its protective case.

P23–1 A typical portable exhaust gas analyzer that is capable of measuring unburned hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), carbon dioxide (CO_2), and oxygen (O_2).

P23–2 After turning the unit on, most exhaust analyzers require a warmup period.

P23–3 To test the exhaust of a vehicle, select "data display" from the main menu.

P23–4 Select "gases/RPM/oil temp" from the data display menu.

P23–5 Wait again! This is the reason why many service technicians turn on the exhaust gas analyzer at the beginning of each day and leave it on all day to avoid having to wait for the unit to become operational.

P23–6 The unit is now able to display exhaust gas readings. It has been about 15 minutes from the time the unit was first turned on!

P23–7 Insert the test probe into the tailpipe.

P23–8 Start the engine.

P23–9 Use the up and down arrow keys to scroll up and down the data list to observe the gases. This unit can only display four of the five gases at a time. Because we are not concerned with NO_x until the vehicle is driven, this technician selected this display showing CO, HC, CO_2 and O_2.

P23–10 This display shows a typical engine at idle after a cold start. Notice the higher-than-normal HC reading.

P23–11 To help get the engine, oxygen sensor, and catalytic converter up to operating temperature, operate the engine at 2000 rpm for several minutes.

P23–12 After the engine has reached operating temperature, the HC readings are now 13 ppm—well within the normal allowable limit of less than 50 ppm.

SUMMARY

1. Funnel Diagnostics—Visual Approach to a Diagnostic Procedure
 Step #1. Verify the Problem (Concern)
 Step #2. Perform a Thorough Visual Inspection and Basic Tests
 Step #3. Retrieve the Diagnostic Trouble Codes (DTCs)
 Step #4. Check for Technical Service Bulletins (TSBs)
 Step #5. Look Carefully at Scan Tool Data
 Step #6. Narrow Focus of Problem to a System or Cylinder
 Step #7. Repair the Problem, Determine and Correct the Root Cause
 Step #8. Verify the Repair and Clear any Stored DTCs
2. Care should be taken not to induce high voltage or current around any computer or computer-controlled circuit or sensor.
3. A thorough visual inspection is the first step in the diagnosis and troubleshooting of any engine-performance problem or electrical malfunction.
4. If the MIL is on, retrieve the DTC and follow the manufacturer's recommended procedure to find the root cause of the problem.
5. All DTCs should be cleared after the repair.
6. OBD II vehicles use a 16-pin DLC and common DTCs.
7. Excessive hydrocarbon (HC) exhaust emissions are created by a lack of proper combustion, such as a fault in the ignition system, too lean an air–fuel mixture, or too cold engine operation.
8. Excessive carbon monoxide (CO) exhaust emissions are usually created by a rich air–fuel mixture.
9. Excessive oxides of nitrogen (NO_x) exhaust emissions are usually created by excessive heat or pressure in the combustion chamber or a lack of the proper amount of exhaust gas recirculation (EGR).
10. Carbon dioxide (CO_2) levels indicate efficiency—the higher the CO_2, the more efficient the engine operation.
11. Oxygen (O_2) is a lean indicator. The higher the O_2, the leaner the air-fuel mixture.
12. A vehicle should be driven about 30 km (20 mi), especially during cold weather, to allow the engine to be fully warm before an enhanced emissions test.

REVIEW QUESTIONS

1. Explain the procedure to follow when diagnosing a vehicle without any stored DTCs using a scan tool.
2. Discuss what the PCM does during a drive cycle to test emission-related components.
3. List three things that should be checked as part of a thorough visual inspection.
4. List the eight-step funnel diagnostic procedure.
5. Explain why a bulletin search should be performed after stored DTCs are retrieved.
6. Explain why a rich mixture is better for the engine than a lean mixture.
7. List the five exhaust gases and their maximum allowable readings for a fuel-injected vehicle equipped with a catalytic converter.

RED SEAL CERTIFICATION-TYPE QUESTIONS

1. The first step in the diagnostic process is
 - **a.** Retrieve the diagnostic trouble codes
 - **b.** Perform a thorough visual inspection
 - **c.** Verify the problem
 - **d.** Check the scan tool data
2. When testing a vehicle using a scan tool, what values should be the same before starting a cold engine?
 - **a.** O2S and IAT
 - **b.** ECT and IAT
 - **c.** MAP and TP
 - **d.** MAF and MAP
3. Before performing an exhaust gas analysis
 - **a.** The computer should be scanned for codes
 - **b.** The fuel tank should be full
 - **c.** A cylinder balance test should be done
 - **d.** The catalytic converter should be at temperature
4. After the customer complaint has been verified, what is the next step when diagnosing an engine performance problem?
 - **a.** Checking for any stored diagnostic trouble codes
 - **b.** Checking for any technical service bulletins (TSBs)
 - **c.** Performing a thorough visual inspection
 - **d.** Looking carefully at the scan tool data
5. A vehicle arrives with a DTC identifying an open TPS. The technician clears the code and installs a jumper wire between the 5 volt reference terminal and the signal terminal in the TPS wiring connector. The opposite code sets. The problem is with the
 - **a.** Computer
 - **b.** Wiring circuit
 - **c.** Sensor
 - **d.** Throttle cable
6. The preferred method to clear diagnostic trouble codes (DTCs) is to
 - **a.** Disconnect the negative battery cable for 10 seconds
 - **b.** Use a scan tool
 - **c.** Remove the computer (PCM) power feed fuse
 - **d.** Cycle the ignition key on and off 40 times

7. All OBD II vehicles use a _____ pin data link connector (DLC).
- **a.** 16
- **b.** 12
- **c.** 5
- **d.** 4

8. A port fuel-injected engine with a plugged fuel injector will show a rise in what emission?
- **a.** HC
- **b.** CO
- **c.** CO_2
- **d.** NO_x

9. HC and CO are high and CO_2 and O_2 are low. This could be caused by a
- **a.** Rich mixture
- **b.** Lean mixture
- **c.** Defective ignition components
- **d.** Clogged EGR passage

10. Which gas is generally considered to be the rich indicator? (The higher the level of this gas, the richer the air-fuel mixture.)
- **a.** HC
- **b.** CO
- **c.** CO_2
- **d.** O_2