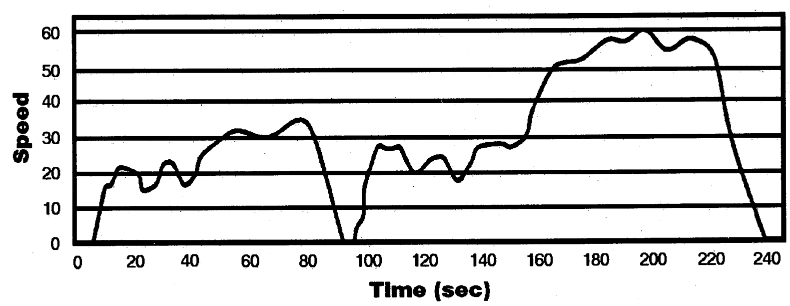
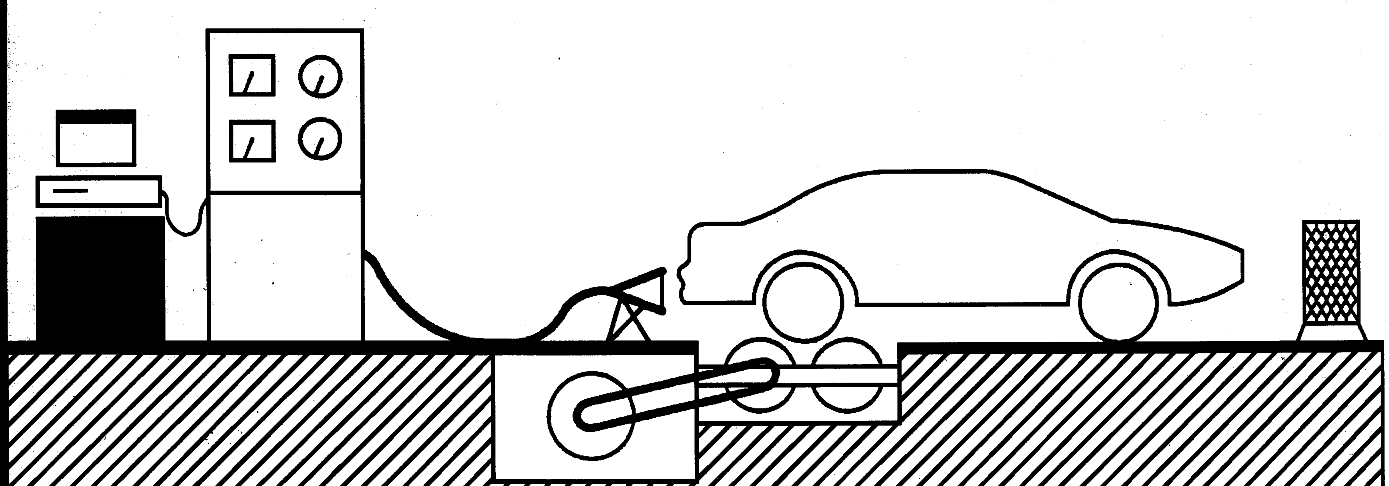
CHRYSLER CORPORATION

Emissions: Inspection, Testing, and Maintenance



Student Workbook



SAFETY NOTICE

This publications purpose is to provide Technical training information to individuals in the automotive trade. All test and repair procedures must be performed in accordance with manufacturers service and diagnostic manuals. All ***warnings***, ***cautions***, and ***notes*** must be observed for safety reasons. The following is a list of general guidelines:

- Proper service and repair is critical to the safe, reliable operation of all motor vehicles.
- The information in this publication has been developed for service personnel, and can help when diagnosing and performing vehicle repairs.
- Some service procedures require the use of special tools. These special tools must be used as recommended throughout this Technical Training Publication, the diagnostic Manual, and the Service Manual.
- Special attention should be exercised when working with spring-or tension-loaded fasteners and devices such as E-Clips, Cir-clips, Snap rings, etc., careless removal may cause personal injury.
- Always wear safety goggles when working on vehicles or vehicle components.
- Improper service methods may damage the vehicle or render it unsafe.
- Observe all ***warnings*** to avoid the risk of personal injury.
- Observe all ***cautions*** to avoid damage to equipment and vehicle.
- ***Notes*** are intended to add clarity and should help make your job easier.

Cautions and ***Warnings*** cover only the situations and procedures Chrysler Corporation has encountered and recommended. Chrysler Corporation cannot know, evaluate, and advise the service trade of all conceivable ways in which service may be performed, or of the possible hazards of each. Consequently, Chrysler Corporation has not undertaken any such broad service review. Accordingly, anyone who uses a service procedure or tool that is not recommended in this publication, must be certain that neither personal safety, nor vehicle safety, is jeopardized by the service methods they select.

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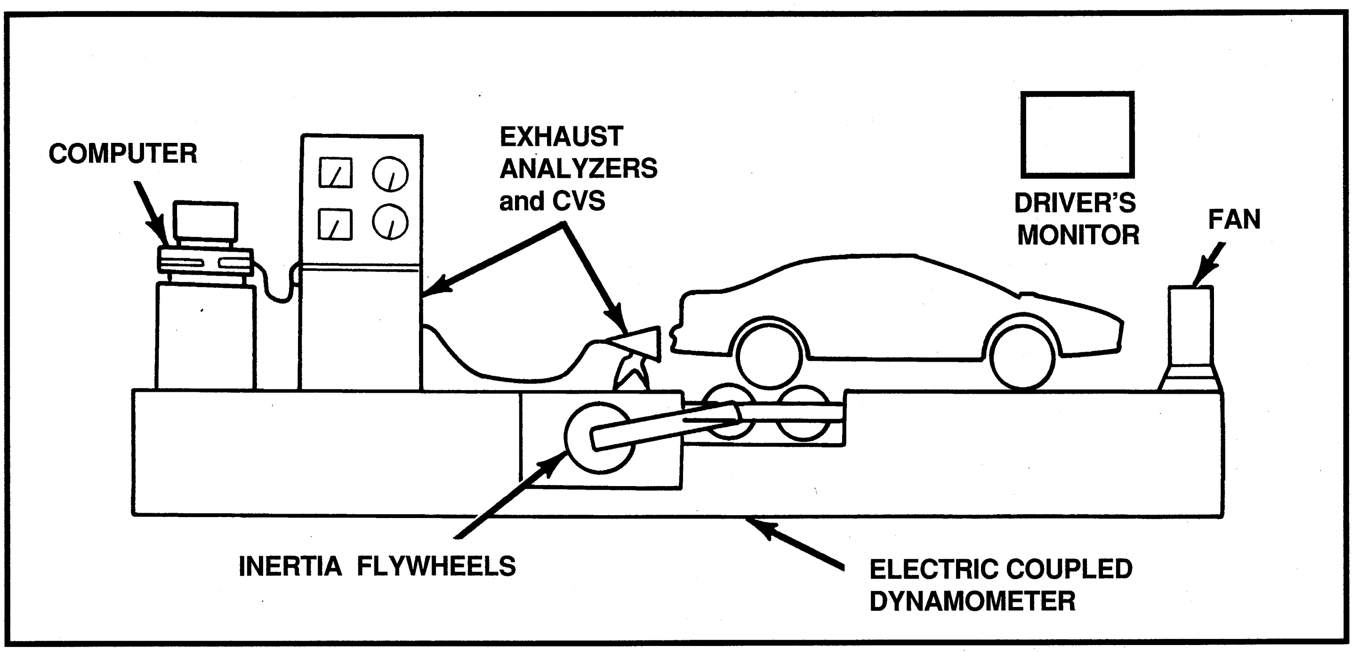
COMPUTER
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DYNAMOMETER

Emissions: Inspection, Testing, and Maintenance

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STUDENT LEARNING OBJECTIVES

After completing this course, you will be able to:

- Understand the laws governing automotive pollution control.
- Identify the components of, and difference between, basic and enhanced emissions Inspection and Maintenance (I/M) programs in your state.
- Gain experience in analyzing Basic I/M and generic IM240 test results.
- Identify the following vehicle emissions (or exhaust gases) and the relationships between them:
  - Hydrocarbons (HC)
  - Carbon Monoxide (CO)
  - Oxides of Nitrogen (NO_x)
  - Carbon Dioxide (CO_2)
  - Oxygen (O_2)
- Identify, inspect, or diagnose the following emissions control system components, and understand how they operate and what vehicle emission they affect:
  - Evaporative Emission Control System
  - Crankcase Ventilation System
  - Air Injection
  - Exhaust Gas Recirculation
  - Catalytic Converter
  - Heated Air Inlet System
  - Ignition Control System
  - Computerized Engine Control Systems
- Use a four-gas or five-gas exhaust analyzer to test vehicle emissions and diagnose failures of both the basic and enhanced emissions inspections.

FROM LEGISLATION TO ENGINEERING

Automotive emissions control systems have been with us in one form or another for the better part of three decades. In order for the technician to properly understand and maintain these systems, especially in the face of increasing governmental regulations, he or she should have some knowledge of what automotive emissions are, the conditions that cause them, and how they have been legislated and controlled in the past.

INSPECTION AND MAINTENANCE (I/M) TESTING

New vehicles must be certified to comply with Environmental Protection Agency (EPA) regulations as of the date of manufacture. As a result of EPA regulations, today's cars emit less than a twentieth of the pollutants of early-1960s cars.

While emissions-related auto parts are designed to be long-lived, they retain full efficiency over the life of the car only if they are properly maintained. According to an October, 1992, EPA Fact Sheet, approximately 30% of five-year-old cars, and 55 percent of seven-year-old cars (the average age of passenger cars in the United States) emit excessive pollution. It becomes obvious that something must be done to ensure that older vehicles don't fall into a state of disrepair which would cause them to become excessive polluters.

To address this issue, the EPA has identified certain areas of the country as being "non-attainment" areas for ground-level ozone pollution, or smog (fig. 1). As a condition of being able to obtain future federal highway funding, those areas were required to implement inspection and maintenance (I/M) testing programs to ensure that vehicles on the road were staying within federal emissions standards.

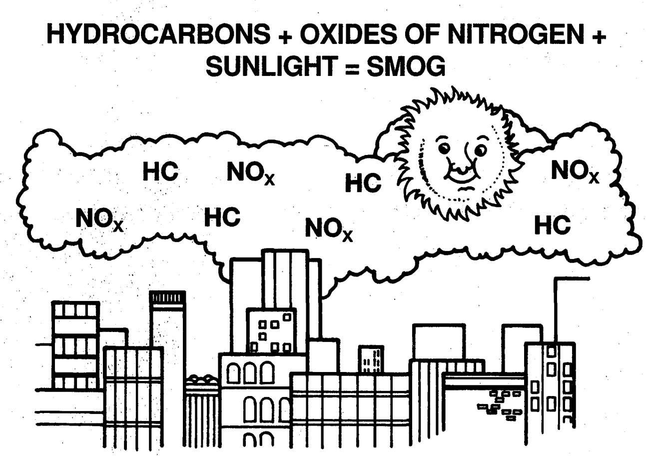


Figure 1 The Effects of Uncontrolled Emissions

Emissions: Inspection, Testing, and Maintenance

I/M is a way of checking whether the emission control system on a vehicle is working correctly. Through periodic vehicle checks and required repairs for vehicles failing the I/M test, I/M encourages proper vehicle maintenance and discourages tampering with emission control devices.

States design and operate I/M programs in accordance with guidelines established by EPA policy, although the kinds of tests vary considerably between different areas of the country according to specific needs to reduce air pollution. Two basic tests are performed: An exhaust emissions test, where a probe inserted into the vehicle's tailpipe allows an emissions analyzer to measure pollution levels in the exhaust; and a visual check of critical emissions control components, to ensure that all are present and operational.

Each individual state has the responsibility of establishing the most appropriate type of I/M testing to resolve its particular emissions problems. States consider vehicle design in setting the pass/fail cutoff limits for I/M tests. Older vehicles are not held to the same standard as newer models with more sophisticated emission controls.

The cost of a basic I/M test varies from state to state and ranges from $5 in Arizona to $44 in California. The average test costs $8 in states with inspection-only programs and $18 in states where repair shops perform inspections. Average repair costs for vehicles failing the I/M test range from $50 to $70.

In essence, the ***basic*** I/M regulations require light-duty vehicles from model years 1981 and later to meet a limit of 220 parts per million of hydrocarbon (HC) and 1.2% carbon monoxide (CO). This testing is usually performed by independent contractors using the familiar two-gas analyzer with a tailpipe probe. Individual states have the option of setting stricter requirements by including more model years or establishing tighter emission limits. There are also more involved ***enhanced*** I/M regulations which will be described later in more detail. States also have the responsibility of determining what to do with non-complying vehicles.

THE CLEAN AIR ACT AMENDMENTS OF 1990

In spite of the tremendous progress that has been made in new-car emissions levels, the total U.S. vehicle population continues to be a significant source of air pollution. This is because the number of vehicle-miles traveled on American roads has doubled in the last 20 years to 2 trillion miles per year. The total volume of emissions offsets a lot of the technological progress made over the same period. As the number of vehicle-miles continues to increase, continuing efforts will have to be made to reduce emissions levels from individual vehicles.

Emissions: Inspection, Testing, and Maintenance

The Clean Air Act Amendments of 1990 attack this problem from four different angles, by providing for the following approaches:

- Cleaner new cars (TeVan)
  - TLEV-Transitional Low Emitting Vehicles
  - LEV-Low Emitting Vehicles
  - ZEV-Zero Emitting Vehicles
- Cleaner fuels (compressed natural gas; methanol)
- Improved I/M testing to control:
  - Evaporative emissions
  - HC and CO emissions
  - NO_X emissions
- Second-generation On-board Diagnostics (OBD II)

The first two points are an evolution of a process that has been going on for more than two decades. Modern technology allows us to build cleaner-burning cars without having to go through the same learning curve that was experienced in the early years of pollution control. Cleaner vehicle and fuel technology have already helped to reduce tailpipe exhaust emissions and gasoline evaporation. In some parts of the country, oxygenated fuels are already in use, particularly during the winter months when atmospheric conditions tend to keep pollutants closer to the ground.

Most of the publicity surrounding the Clean Air Act Amendments of 1990 centers on the third point to improved I/M testing of vehicles on the road. Increased I/M testing requirements are important because, despite all the improvements in new car emissions and fuel quality, it will be many years before these cleaner cars dominate the overall population of vehicles in the U.S.

In many cities, vehicles contribute 35-70% of hydrocarbon emissions and at least 90 percent of carbon monoxide emissions. Concentrations of one or both of these pollutants exceed air quality standards in almost every major city in the United States.

Under the new law, more cities will begin I/M programs, and some cities that already have testing programs in place will have to institute more comprehensive checks. With the Clean Air Act Amendments of 1990, 154 areas require either basic or enhanced I/M testing.

GASOLINE/OXYGENATE BLENDS (CLEAN AIR GASOLINE)

Many gasolenes are now being blended that contribute to cleaner air, especially in those areas of the country where pollution levels are high. These new blends provide a cleaner-burning fuel and some are referred to as reformulated gasoline. In areas of the country where carbon monoxide levels are high, gasolenes are being treated with oxygenated materials such as ETBE, MTBE, and ethanol.

These materials are called oxygenates because they increase the amount of oxygen in the fuel. The type and amount of oxygenate used in the blend is important. The following are generally used in gasoline blends:

- ***Ethanol*** — Ethanol (ethyl or grain alcohol) properly blended, is used as a mixture of 10% ethanol and 90% gasoline. Gasoline blended with ethanol may be used in Chrysler vehicles.
- ***Methanol*** — Methanol (methyl or wood alcohol) is used in a variety of concentrations when blended with unleaded gasoline. You may find fuels containing 3% or more methanol along with other alcohols called cosolvents. ***Do not use gasolenes containing methanol.*** The use of gasoline/methanol blends may result in starting and driveability problems and damage to critical fuel system components. Problems that are the result of using gasoline/methanol blends are not the responsibility of Chrysler Corporation and may not be covered by the new vehicle warranty.
- ***MTBE/ETBE*** — Gasoline and MTBE (methyl tertiary butyl ether) blends are a mixture of unleaded gasoline and up to 15% MTBE. Gasoline and ETBE (ethyl tertiary butyl ether) are blends of gasoline and up to 17% ETBE. Gasoline blended with MTBE or ETBE may be used in Chrysler vehicles.

Oxygenates cause the engine to run slightly lean. In modern engines, this enleanment is well within the adaptive capability of the PCM and O_2 sensor. If a fuel contained excessive amounts of oxygenates, the PCM might not be able to adapt and the engine would show symptoms of excessive leanness (rough idle, stalling, etc.) Figure 2 shows the maximum permissible levels of common oxygenates.

Note: *Refer to the Service Manual of Owner's Manual for information on fuel usage.*

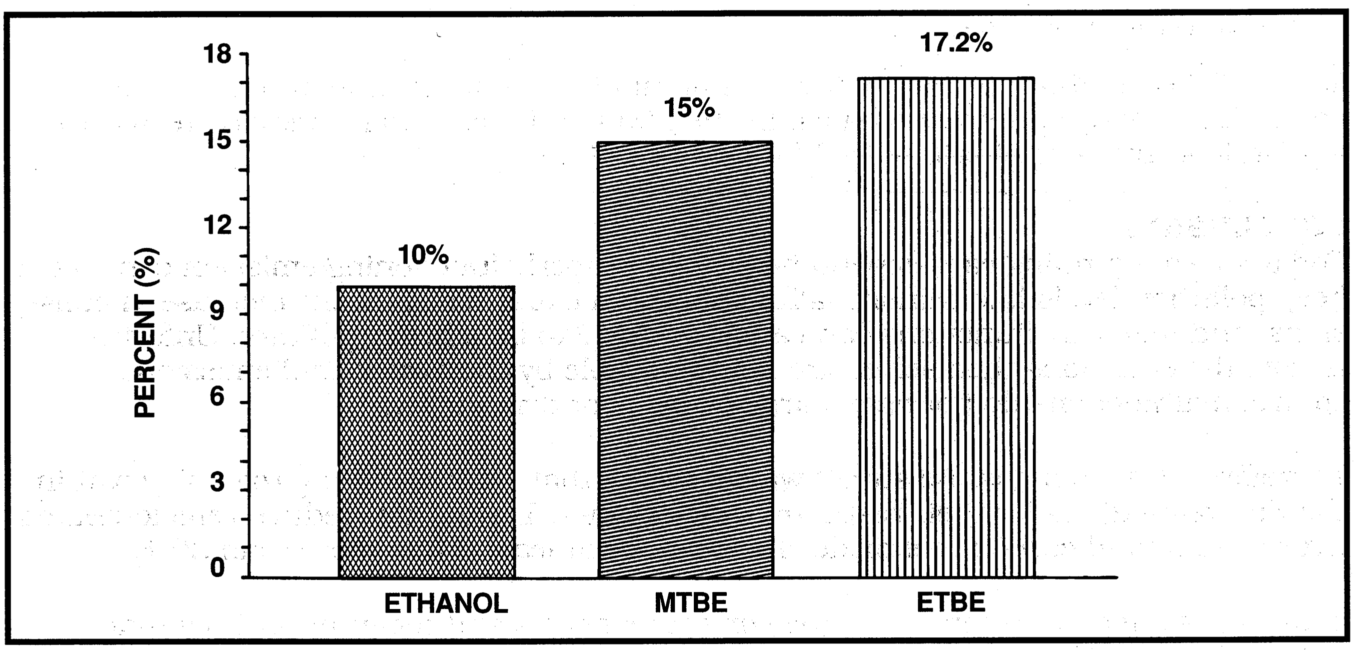


Figure 2 Maximum Permissible Amounts of Oxygenates (by Volume)

SECOND-GENERATION ON-BOARD DIAGNOSTICS (OBD II)

There is one new technical issue that carmakers have had to address as a result of the Clean Air Act Amendments of 1990. The Act calls for the standardization of computerized diagnostic capabilities in new vehicles. This new standard is called Second-Generation On-Board Diagnostics, or ***OBD II.***

Implemented in phases throughout the 1994 to 1996 model years, OBD II requires all manufacturers to make the same diagnostic information available in a standard form on a standard connector. The connector is located in the same place on every vehicle, regardless of make or model. For a technician troubleshooting an emissions-related problem, OBD II helps to eliminate the differences between diagnostic systems on different vehicles. With OBD II, every vehicle has the same diagnostic information expressed in the same format, and the malfunction indicator lamp (MIL lamp or Check Engine lamp) will be turned ON under the same conditions from one model to another. While manufacturers may continue to develop and use scan tools of their own design for special features, basic OBD II data must be readable by any generic scan tool.

OBD II calls for the following essential elements to be available for display on a generic scan tool:

- Engine misfire detection
- Monitor catalyst efficiency
- Monitor oxygen (O_2) sensors and heater functions
- Monitor fuel system operation
- Monitor evaporative control system
- Monitor EGR system function
- Monitor secondary air system function
- Monitor comprehensive components
- Maintain stored trouble codes on these systems
- Mandatory readouts

Much of the monitoring activity involves actual functional testing of the various components on an automatic basis. In the I/M test lane, vehicles may be tested with a generic scanner to obtain stored fault information.

CONCLUSION

Today's clean-running cars depend heavily on properly functioning emission controls to keep pollution levels low. Minor malfunctions can cause a significant increase in emissions, and major malfunctions can cause a vehicle to be a heavy polluter. Unfortunately, the emissions themselves are not noticeable by the owner, and emissions control malfunctions do not necessarily cause poor driveability.

Therefore, I/M testing is the surest way of seeing that vehicles on the road stay within the EPA regulations for their respective model years. Testing can reduce vehicle-related hydrocarbon and carbon monoxide emissions by at least 5% to more than 30%.

Your job as a technician includes the correct diagnosis and repair of vehicles that have failed an I/M test.

INSPECTION/MAINTENANCE (I/M) TESTS

TYPES OF I/M TESTS

The EPA provides each test area with a basic guideline to assist them in developing their particular I/M programs. Then, each area adopts the test(s) that are the most appropriate for their level of attainment. Four different types of program that can be used are:

1. Visual tampering inspections

2. Basic I/M Tests (if currently in force, may be modified)
   - Two-speed Idle Test
   - Loaded Mode Test
   - May include evaporative (pressure and purge) tests

3. Enhanced I/M Tests
   - IM240 Transient Test
   - Evaporative (pressure and purge) System Check

4. Other Tests
   - Remote Sensing
   - Acceleration Simulation Mode (ASM)
   - Random roadside visual inspection

Each of these tests is discussed below:

1. VISUAL TAMPERING INSPECTIONS

Many states may require test vehicles to undergo a visual inspection prior to being emissions tested. Some states will not require a visual inspection if an IM240 program is being enforced and includes functional testing of emissions control components.

In a visual inspection, certain systems and components are checked to assure that they are not missing, disconnected or otherwise tampered with. Visual inspections involve ensuring that "obvious" vacuum and electrical components are connected. If any system or component fails the visual inspection, the vehicle will not receive an emissions test until all failing conditions are corrected.

Some of the items that states include in their tampering inspections are:

- The fuel filler restrictor
- The gas cap
- The PCV valve
- The secondary air system
- The EGR system
- The evaporative emissions system
- The exhaust system
- The "Check Engine" lamp — is it ON?
- Quick test for leaded fuel
- Vacuum lines (already tested in some states' safety inspections)

If any tampering has occurred, the tampered condition must be corrected, and waiver amounts do not apply.

2. BASIC I/M TESTS

Two Speed Idle Test

This I/M exhaust test, the most common of the basic tests, reads hydrocarbon (HC) and carbon monoxide (CO) emissions concentrations of vehicles at two idle speeds (fig. 3). The test is performed as follows:

- Engine is held at 2500 rpm
- Emissions readings are taken for 30 to 90 seconds
- Engine is allowed to return to idle (must be below 1100 rpm) for 30 to 90 seconds
- Second set of readings is taken at idle

Some test areas only take emissions readings during the idle portion of the test. The 2500 rpm portion of the procedure is used to warm up (or precondition) the vehicle for the idle test.

To pass, the emissions concentration must be below the standard set by the state for that particular test area. The pass/fail standards can vary depending on such things as the age and technology of the vehicle, whether it is a car or a truck, and so on. Present Federal and State of California standards for basic I/M testing as of the date of this publication are shown in Table 1.

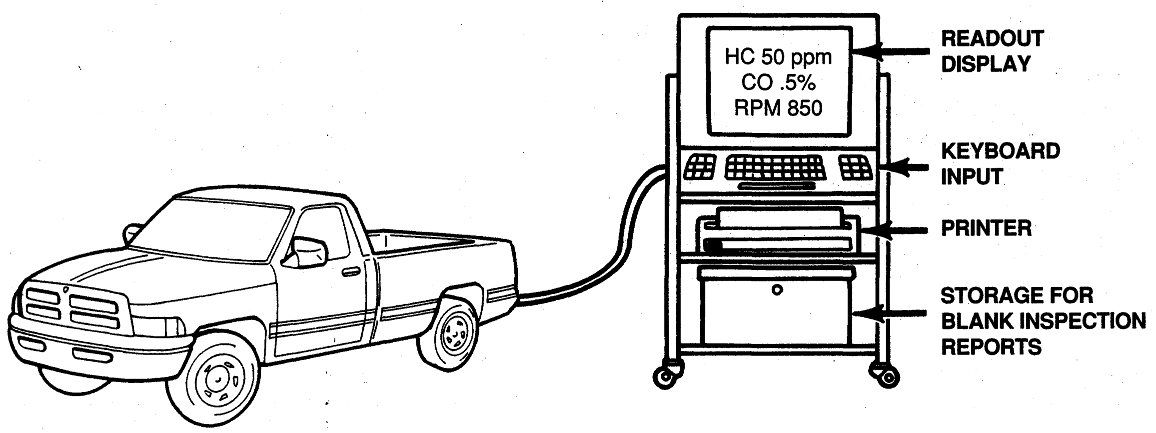


Figure 3 Equipment Used in a Basic I/M (Two-Speed Idle) Test

Table 1 Emissions Standards for Basic I/M Testing

GEOGRAPHIC AREA	*HC (ppm)*	*CO (%)*
Federal	220	1.2
California	100	1.0

When a customer has an emissions test, the passing standards will be printed on his/her emissions result slip. Table 2 shows typical test results for pre-1975 and post-1975 vehicles with various emission control systems. Note that these are not engineering standards or EPA limits; they are merely typical readings that may be expected of these categories of vehicles.

Table 2 Typical Basic I/M Idle Readings[1]

MODEL YEAR	*CONTROL SYSTEM*	*HC (ppm)*	*CO (%)*
Pre-1975		50-300	0.5-1.5
Pre-1975	Air injection	less than 50	0.5
1975 and newer	Catalyst and air injection	less than 50	less than 0.05
1975 and newer	Computerized feedback controls (air/fuel ratio control)	less than 50	less than 0.05

1 Source: "Colorado Automobile Inspection and Readjustment Program Emissions Inspection Handbook," Doug Decker & Craig McMillan, Nov. 1987 (Page 17-18).

Loaded Mode Test

This I/M test reads the emissions of vehicles that are driven on a "single weight" dynamometer. Emissions readings are taken while the vehicle is driven at a constant speed in a "loaded" condition on the dynamometer (fig. 4). The load varies based upon vehicle speed. In order to produce an equivalent amount of power to overcome the dyno load, small-engined cars are driven slower on the dyno, while large-engined cars and trucks are driven faster (Table 3). Then, a second set of readings is taken when the vehicle is allowed to return to idle.

Table 3 Vehicle Speed vs. Cylinders for Loaded Mode Test

CYLINDERS	***SPEED ON DYNO (±1 mph)***
4 or fewer	24 mph
5 or 6	30 mph
7 or more	34 mph

Here again, some areas only require the vehicle to have passing values at idle. The load caused by the dynamometer is used only as a means to precondition the vehicle for the idle test.

This test checks for HC and CO concentrations. Federal limits for these pollutants, as mandated by the EPA are shown in Table 4:

Table 4 Current Federal Limits for Loaded Mode Testing

HYDROCARBONS (HC)	***CARBON MONOXIDE (CO)***
220 ppm	1.2%

Like the two speed idle test, the pass/fail standards for a loaded mode test depend on the vehicle being tested. This information is included on the result slip supplied to the owner at the time of the test.

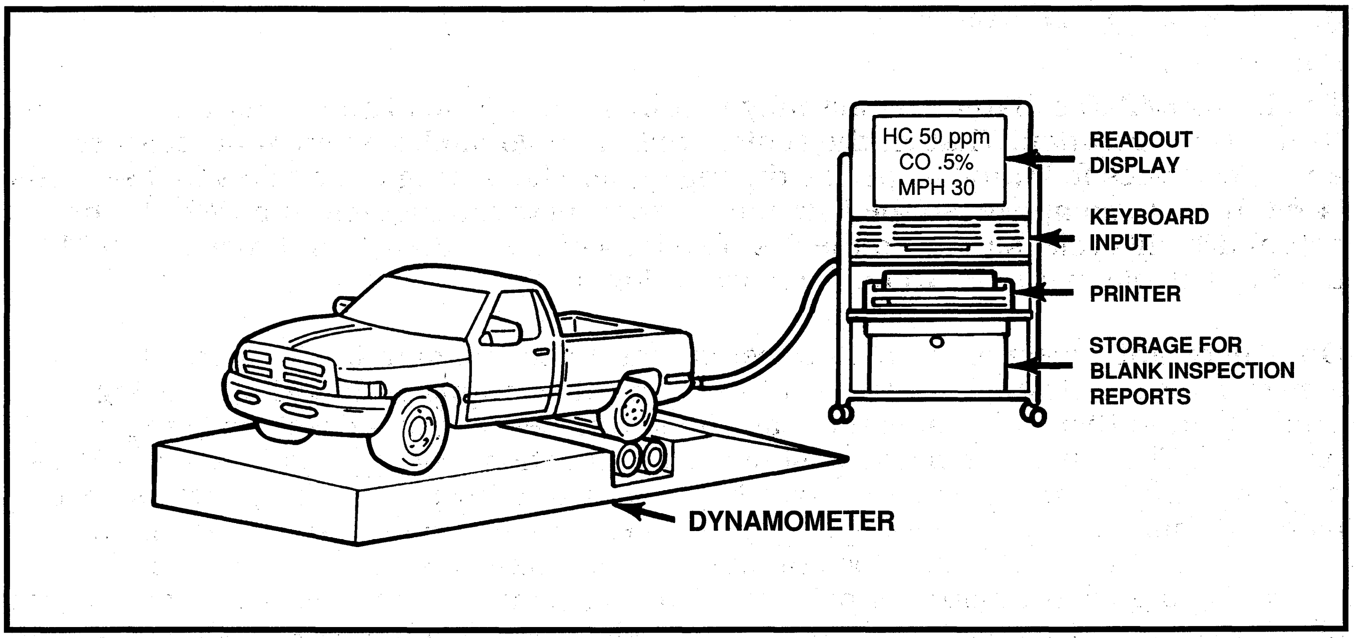


Figure 4 Equipment Used in a Loaded Mode I/M Test

Note: *The Two-speed Idle test and the Loaded Mode test are both referred to as Basic I/M tests by the EPA. They get this name from their basic (simple) procedure for reading emissions.*

3. ENHANCED I/M TESTS

IM240 Test

The EPA's IM240 exhaust test actually requires the vehicle to go through a "transient" operation. That is, the vehicle will undergo modes where it accelerates and decelerates following a specific driving cycle. The driving cycle takes 240 seconds (4 minutes) to complete, so the EPA named their new exhaust test the IM240. The actual driving cycle, similar to the first two hills of the Federal Test Procedure (FTP) used by vehicle manufacturers, is shown in Figure 5.

One important aspect of the IM240 test is that it does more than simply read emissions concentrations; it takes into account the volume of the exhaust being produced and then calculates the mass (in grams per mile) of emissions being produced. The difference between simple concentration readings, as taken in a Basic program, and the mass emissions readings, as taken during an IM240 test, is best pictured this way: Imagine sampling the concentration of both a small car and a large truck. Even if their tailpipe readings are the same, it's obvious that the truck is producing a greater amount of pollution. That's because it produces a greater volume of exhaust than does the small car and therefore it yields a higher emissions reading if we calculate the actual mass of the exhaust being produced.

The following table shows how the same concentration of pollutant in three different engines produces three different volumes of that pollutant:

Table 5 Exhaust Gas Volume vs. Engine Size at Same Concentration

ENGINE DISPLACEMENT	*EXHAUST GAS CONCENTRATION*	*EXHAUST GAS VOLUME (cu.in. per engine rev.)*
2.0L (122 cu. in.)	1.0%	0.6
5.9L (360 cu. in.)	1.0%	1.8
8.0L (488 cu. in.)	1.0%	2.4

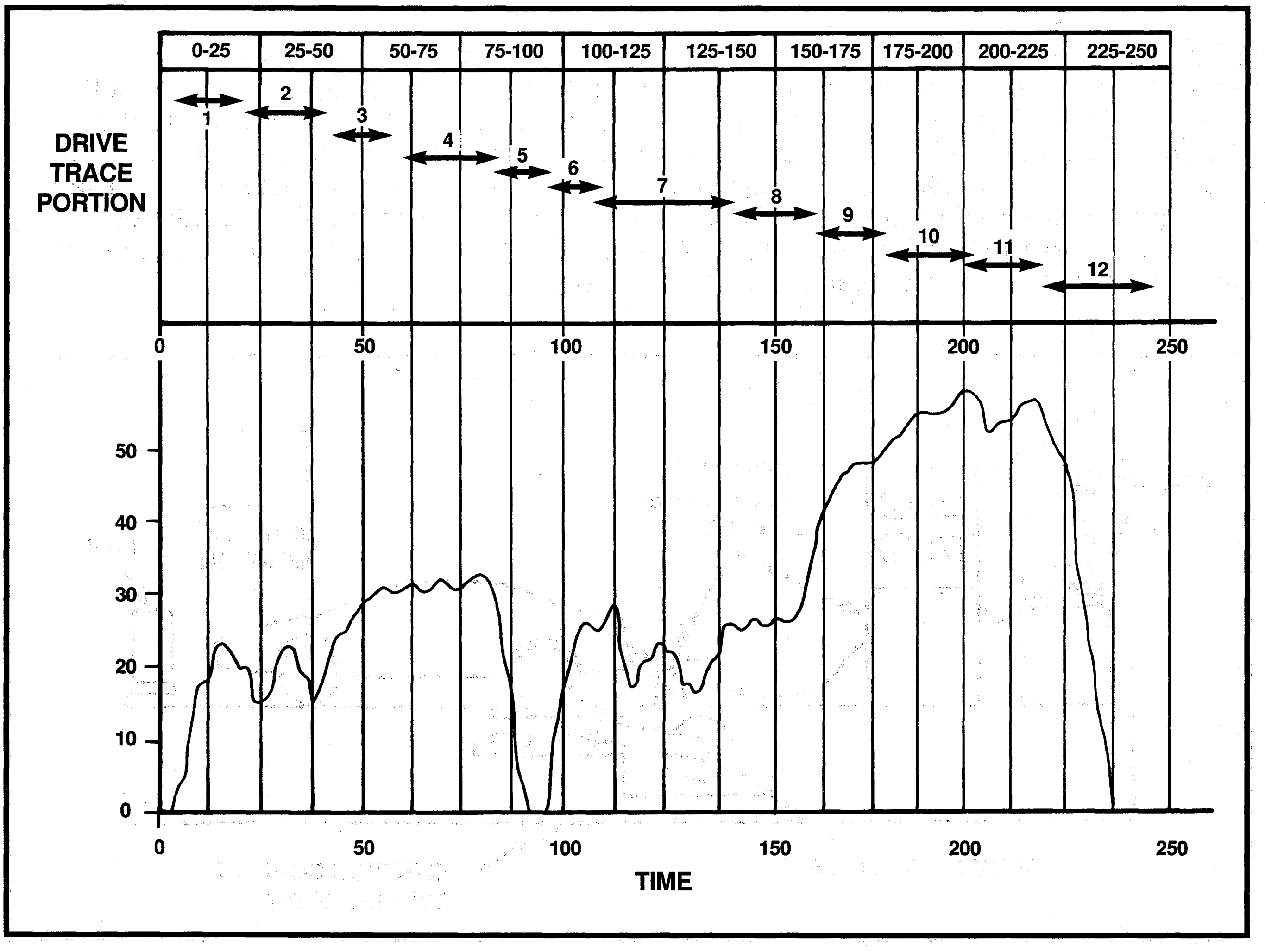
In addition to sampling HC and CO emissions, the IM240 test also reads oxides of nitrogen (NO_x). Like the two basic exhaust tests described earlier, the pass/fail standards for an IM240 test also vary depending on the age and type of the vehicle being tested. The standards will vary from one test area to another. The EPA suggested waiver rate is $450, which may vary from state to state. This amount is in 1990 dollars and can be adjusted for inflation.

UNDERSTANDING DRIVE TRACE ANALYSIS

To better understand the cause of emission levels, the driving trace shown in Figure 5:

1. First acceleration (0-23 mph)
2. Rolling deceleration and acceleration (23-17 mph)
3. Rolling light acceleration (17-32 mph)
4. Part throttle cruise (32 mph)
5. First deceleration (32-0 mph)
6. Second acceleration (0-26 mph)
7. Rolling deceleration and acceleration (26-23 mph)
8. Part throttle cruise (23 mph)
9. Rolling moderate acceleration (23-48 mph)
10. Rolling high-speed acceleration (48-53 mph)
11. High-speed deceleration and acceleration (53-50 mph)
12. Final deceleration (50-0 mph)

Figure 5 IM240 Driving Trace



EQUIPMENT USED DURING AN IM240 TEST

As you might assume, any test that can measure the volume of exhaust gases will require some high-tech equipment (fig. 6). The dynamometer used in an IM240 test, for example, must be capable of producing a very specific load on each test vehicle. (It would not be a fair test to force a small car to drive with the same load placed on a large truck.) Also, a very sophisticated device is required to measure the exhaust volume. This specialized device is called a Constant Volume Sampler (CVS).

The CVS dilutes the exhaust with fresh air and measures the flow rate of the mixture. Mass emissions (for each second) are calculated by multiplying this flow rate by the measured concentration of pollutants in the mixture. To arrive at the official test value in grams per mile, the mass emissions for each second are added together; this sum id then divided by the distance (number of miles) traveled over the 240-second test cycle.

The fresh air dilution is vital because it preserves the integrity of the sample and because it protects the emission analyzers from high concentrations of water vapor produced by the vehicle. The dilution process also allows the measurement system to accommodate the differences in exhaust flow between small engines and large engines while measuring the true amount of emissions from each type of engine.

Finally, the computer used for an IM240 must have advanced capabilities. It must generate the driver's trace and project it on a video screen for the driver to follow. It must take all of the exhaust gas information (read on high-tech analyzers) and gas volume information from the CVS and continuously calculate the mass emissions. Like the computer in the Basic I/M program, it must determine if the vehicle passes or fails and print out this information for the vehicle owner. Finally, it must store this test information for further analysis. The EPA estimates that one IM240 test lane will cost about $170,000. A typical test site might have several test lanes.

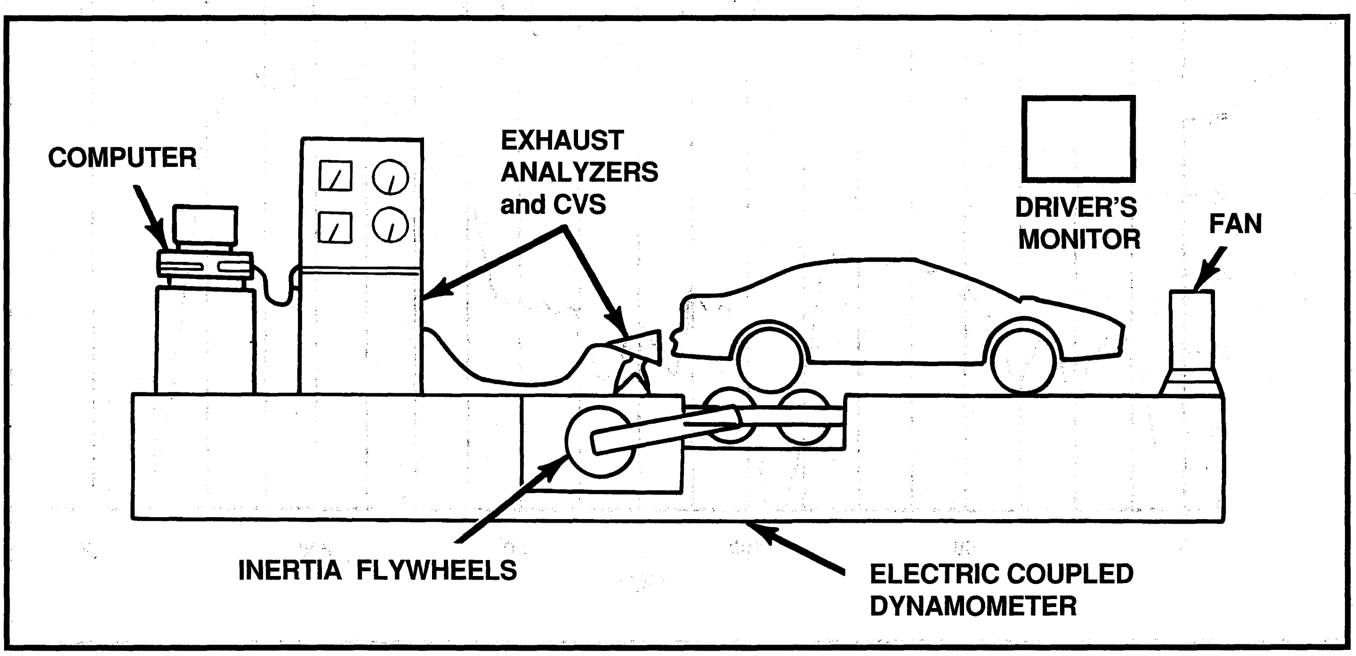


Figure 6 IM240 Test Set-up

IM240 Implementation

- Based on EPA air quality monitoring, 23 states are currently required to adopt IM240 testing.

- This involves approximately 60 million vehicles.

- So far, all states with IM240 programs are using the recommended EPA standards (Table 6):

Table 6 EPA Passenger Car Standards for IM240 Programs[2]

REGULATORY SCHEDULE	*HC Grams per mile*	*CO Grams per mile*	*NO_x Grams per mile*
Phase-In	.80	15.0	2.0
Final	.60	10.0	1.5

4. OTHER TESTS

Remote Sensing

Remote sensing is an up-and-coming technology that is being tested in a number of areas. Similar to a radar speed trap, remote sensing utilizes advanced sensing techniques to measure the pollutant levels of a moving vehicle. Roadside equipment shoots a beam of infrared light through the exhaust stream of a passing vehicle. The reflected beam is analyzed to determine the pollutant levels while the vehicle's license plate is videotaped. This technology allows a high level of inspection and may be useful in identifying heavy polluters.

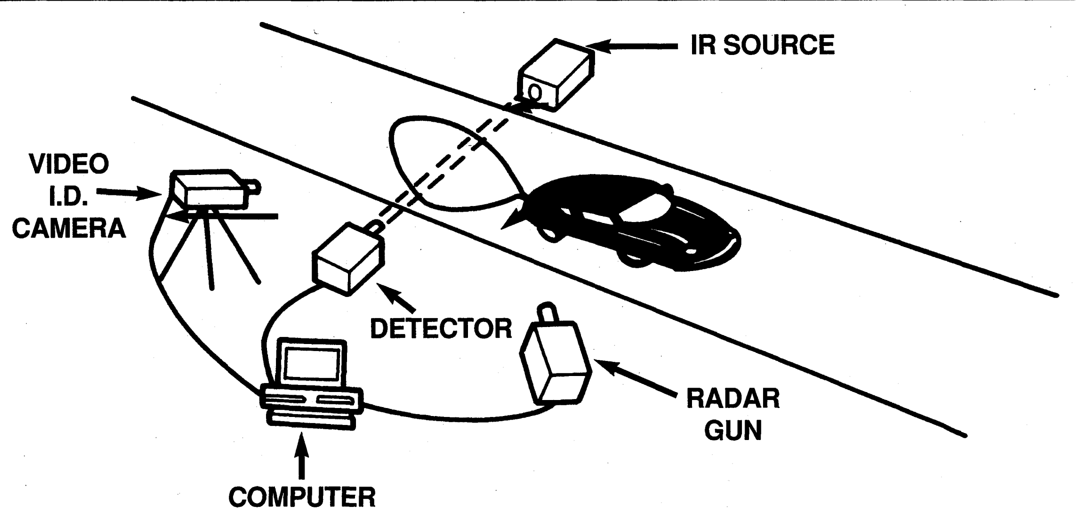


Figure 7 Remote Sensing

2 Figures accurate as of publication date, for model years 1986 and later.

ACCELERATION SIMULATION MODE (ASM)

The ASM test utilizes a dynamometer to apply a very heavy load to the test vehicle during a steady state driving cycle. HC, CO and NO_x emissions are sampled with a "garage type" analyzer. The emissions readings are in concentrations.

The load that is applied to the test vehicle is based on the load that is applied during the acceleration phase of the second hill of an FTP driving cycle. (That acceleration rate is 3.3 mph/sec.)

For example, in one version of ASM known as ASM 25/25, the vehicle is driven at 25 mph against a load of 25% of the horsepower required to simulate FTP acceleration. This method produces relatively high HC and CO emissions. In ASM 50/15, the vehicle is driven at 15 mph against a load of 50% of the horsepower required to simulate FTP acceleration. This method produces relatively high levels of NO_x.

The advantage of ASM is that it produces a rigorous test environment without the need for costly constant volume sampling (CVS). Its chief disadvantage is that the results do not correlate well with the FTP, so it is not widely accepted by the car companies or the EPA.

RANDOM ROADSIDE VISUAL INSPECTION

This is a spot check of vehicles at roadside inspection lanes. At a roadside inspection, randomly-selected vehicles are visually checked to see that all emissions control devices are in place and have not been tampered with. While roadside inspections may be able to identify some problem vehicles, many drivers are not supportive of this type of inspection.

Activity 1

EMISSIONS-TESTING REGULATIONS AND EMISSIONS BASICS

You were given some background regarding the automotive pollution problem, as well as legislative efforts to reduce automotive emissions. This review will reinforce your understanding of this material.

DIRECTIONS:
From the word list below, choose the word or phrase that best completes each following sentence. Fill in the blanks.

Parts per million (ppm)	IM240	mass emissions
basic I/M	enhanced I/M	hydrocarbons
grams per mile	percent (%)	tailpipe concentration

1. A ________________ emissions test is an idle-speed test that measures tailpipe concentrations of HC and CO.
2. Tailpipe concentrations are typically measured in__________________ and ________________.
3. A test that measures the total weight of contaminants produced by a vehicle over a given distance is a ________________ test.
4. An________________ emissions test is a transient-speed test that measures mass emissions, visually inspects tampering, and tests the evaporative emissions control system.
5. The ________________ test is a federally-proposed enhanced exhaust test for modern vehicles.
6. A mass emissions test expresses the total weight of contaminants in __________ ____________.

7. A ____________________ test measures the concentration of contaminants in a given volume of exhaust.

8. Under certain conditions, ______________ combine with NO_x in the presence of sunlight to form smog.

TRUE OR FALSE
(Circle the answer that is most correct.):

1. The Environmental Protection Agency is the federal agency that establishes vehicle emissions limits in the United States. T F

2. Individual states can adopt emissions standards that are less stringent than the federal standards. T F

3. Areas of the United States with the worst air quality problems have been designated "enhanced" testing areas by the Environmental Protection Agency. T F

4. Excessive NO_x emissions are suspected of depleting the ozone layer. T F

5. NO_x testing takes place during basic I/M testing. T F

6. IM240 testing requires a loaded dynamometer. T F

7. I/M testing is important because clean modern vehicles do not yet dominate the overall vehicle fleet in the U.S. T F

8. Carbon dioxide (CO_2) and oxygen (O_2) are automotive pollutants which are currently being regulated by the EPA. T F

9. A vehicle can be exempted from enhanced I/M testing after repair costs exceed a predetermined amount. T F

10. Second-generation On-Board Diagnostics (OBD II) will eventually be required on all vehicles under the Clean Air Act Amendments of 1990. T F

AUTO EMISSIONS FORMATION

TWO SOURCES

Harmful automotive emissions originate from two general sources:

- Evaporative emissions from the fuel system
  - Evaporative emissions are also known as passive emissions because they can potentially be formed at any time, even when the vehicle is not being operated. They are not the result of the combustion process.
    (A third potential source of automotive emissions, crankcase gases, is effectively controlled by positive crankcase ventilation, which will be discussed later).

- Exhaust (tailpipe) emissions, which are a product of combustion
  - Exhaust emissions are produced when the engine is running, as a by-product of combustion or incomplete combustion.

  The exhaust by products we are concerned with controlling are:
  - HC
  - CO
  - NO_x

EVAPORATIVE EMISSIONS

Evaporative emissions are unburned fuel vapors that drift into the atmosphere. This evaporation is a direct result of the property of gasoline to vaporize at low temperatures. Just as water evaporation fills the atmosphere with vapor, gasoline evaporation can fill the atmosphere with fuel vapors.

Evaporative emissions (fig. 9) come from the direct release of fuel vapors into the atmosphere during refueling, parking, engine operation, and, in carbureted vehicles, fuel evaporation from the float bowl. Gasoline is a volatile substance. Besides being highly flammable, it also evaporates quite readily. Prior to the use of evaporative controls, the fuel system (including the fuel tank and carburetor float bowl) was vented directly to the atmosphere. This was necessary to prevent unsafe pressure levels inside the system. This simple type of atmospheric venting leads to hydrocarbon pollution in the air, which, in turn, can lead to the production of photochemical smog.

The evaporative emission control system performs the following functions:

- Contain liquid during a vehicle rollover
- Trap fuel vapors
- Store fuel vapors
- Deliver vapors to the engine for burning

Figure 8 illustrates a typical supply/evaporative emission control system. Individual schematics are contained in the Service Manual for each model and year, and on the underhood schematic for each vehicle.

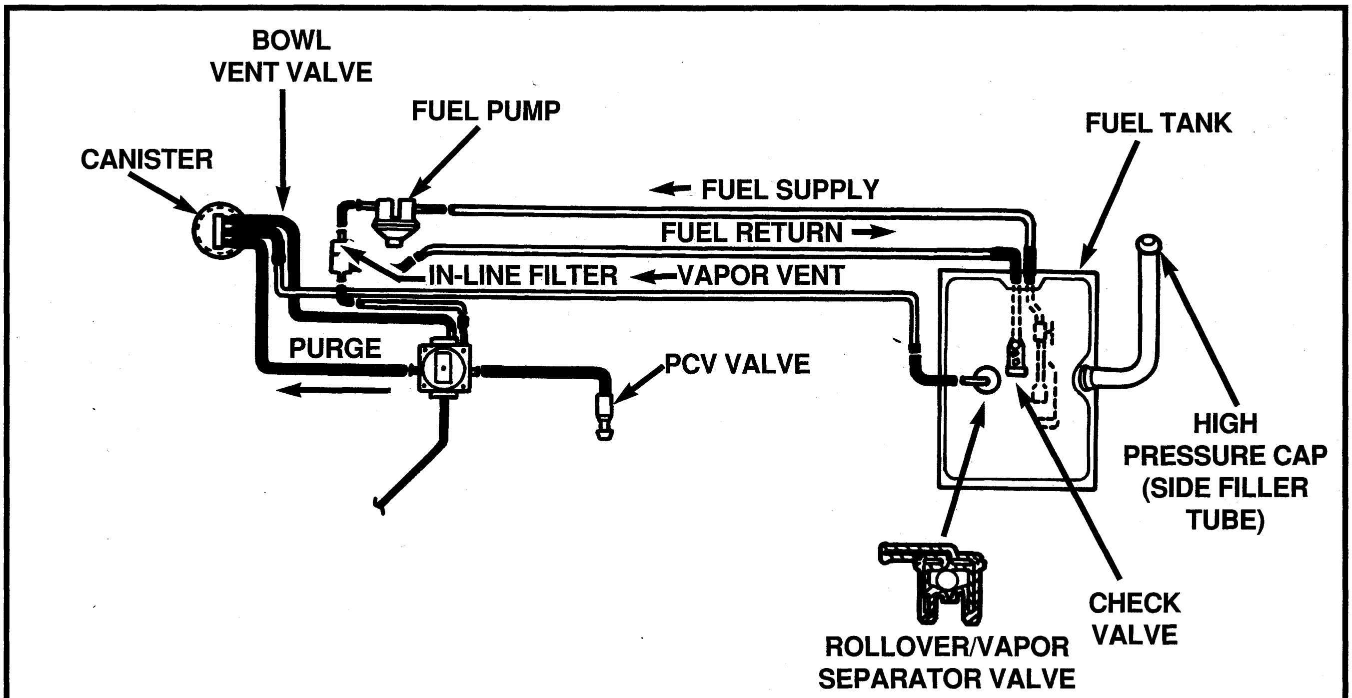


Figure 8 Evaporative Emission Control System 2.2 Liter Carbureted Engine)

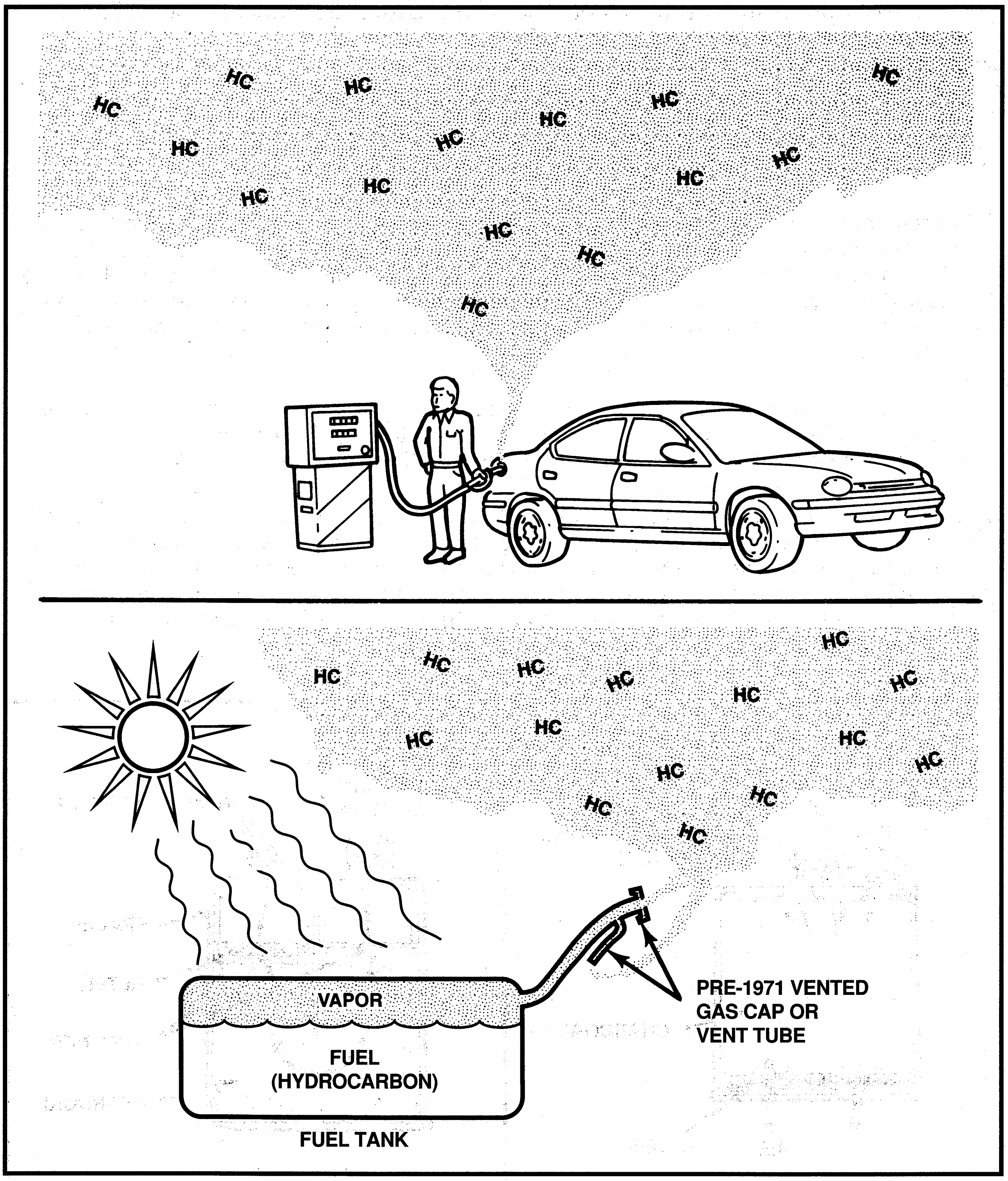


Figure 9 Evaporative Emission of Hydrocarbons

Evaporative controls (fig. 11) trap fuel vapors and reduce the tendency for fuel to evaporate. The fuel tank is sealed with relief valve filler caps to raise the fuel boiling point. The pressure/vacuum filler cap releases to the atmosphere at 44" of water column and draws air in at a system vacuum of 4" water column. Hoses route internal vapors for storage in charcoal-filled containers (fig. 10). The charcoal absorbs fuel vapors until a control valve "purges" vapors from the charcoal. The vapors are then burned in the engine instead of evaporating to the atmosphere.

This pre-combustion system is designed to keep vapors in a closed system and out of the atmosphere. When fuel is drawn from the tank to be used by the engine, a slight negative pressure (vacuum) is created in the tank. To prevent the tank from collapsing, it needs to be vented to allow air to enter it and replace the fuel. Evaporative controls allow this ventilation to take place within a closed circuit so that the hydrocarbons stay in the fuel system.

The main component of the evaporative emissions control system is the vapor canister. The sealed fuel system is vented into this charcoal-filled canister which retains the vapors until they can be drawn into the intake manifold and burned as fuel.

An evaporative line runs from the fuel tank to the canister, which is filled with activated charcoal granules to trap the vapors. A purge valve is normally used to control the flow of vapors into the intake system. On carbureted vehicles, a line also runs from the carburetor fuel bowl to the canister. The purpose of this system is to eliminate the discharge of unburned hydrocarbons into the atmosphere while providing pressure relief for the fuel system (fig. 10).

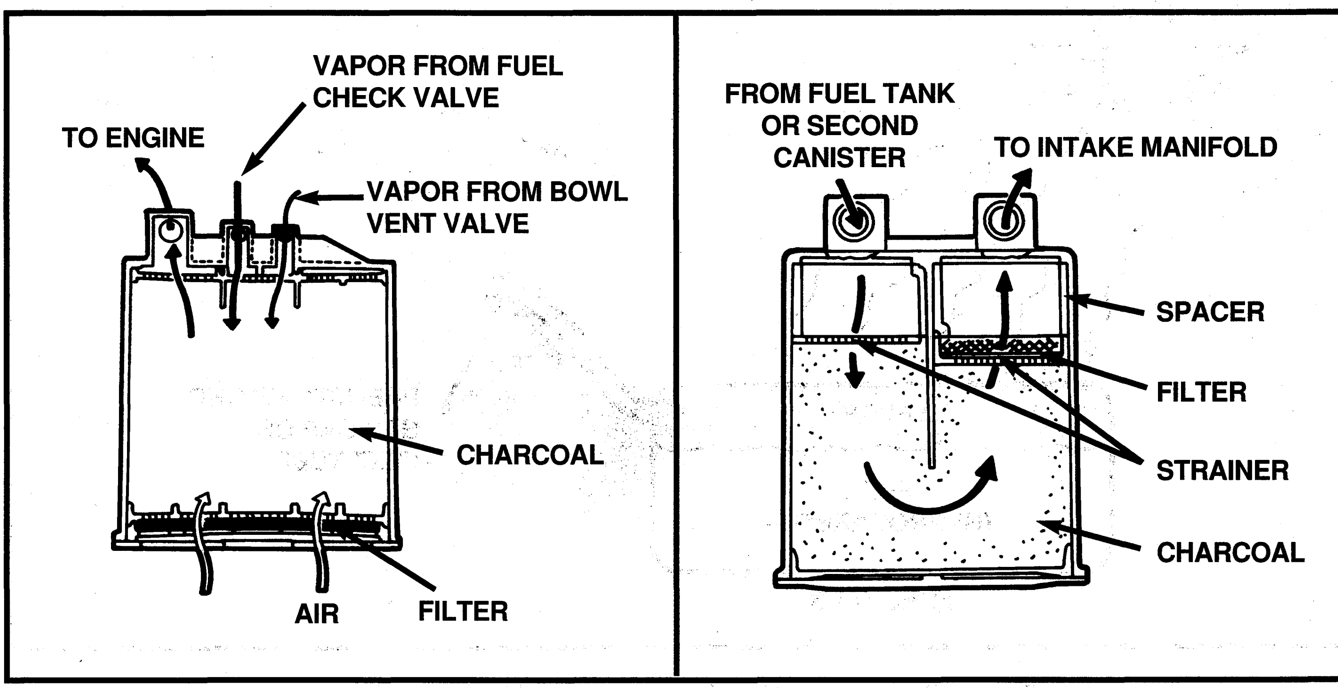


Figure 10

Charcoal Canister (Opened Bottom) Charcoal Canister (Closed Bottom)

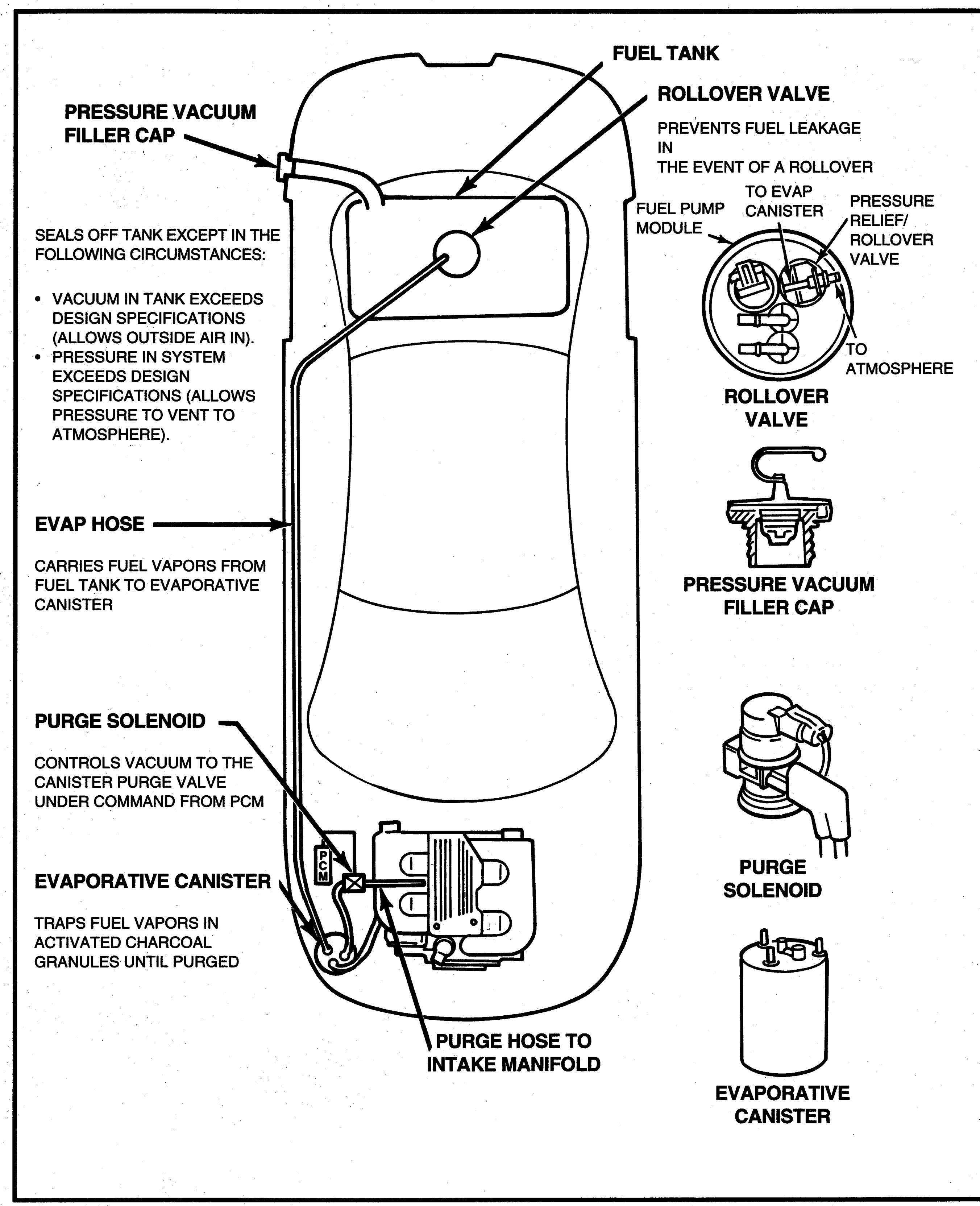


Figure 11 Typical Evaporative Emissions Controls (LH Shown)

CANISTERED CONTROL SYSTEMS

Chrysler vehicles have used several types of canister purging systems. Some of these are:

- Pressure Purge
- Tri-Level Purge
- Venturi Purge
- Vacuum Purge
- Bi-Level Purge

The function of the purge system is to apply vacuum or pressure forces to the canister contents and force them into the engine under certain conditions.

Figure 12 is an example of the bi-level purge system found on a 2.5L 1987.5 AS Body.

The system operates as follows:

- The 1987.5 2.5L uses a Bi-Level Purge system similar to earlier LP TBI's and 1986 and later Turbo's.
- Bi-Level Purge simply means that if the Purge Solenoid is ungrounded, the Canister is purged at idle (manifold vacuum through a .020" restrictor in the White Vacuum Tee). If the throttle is opened, the Canister will be purged by the normal ported vacuum. The ported vacuum for the purge is restricted by a .040" restrictor in the Blue Vacuum Tee.
- Bi-Level Purge is used to eliminate the possibility of fuel vapor leaving the Purge Canister under idle conditions.
- The Purge Solenoid is grounded (no purge) at any Coolant Sensor reading less than 145.4°F. Above 150.8°F, purge is allowed.
- In between 145.4°F and 150.8°F the Purge Solenoid can be on or off depending on whether the engine is heating up or cooling down into this temperature range.

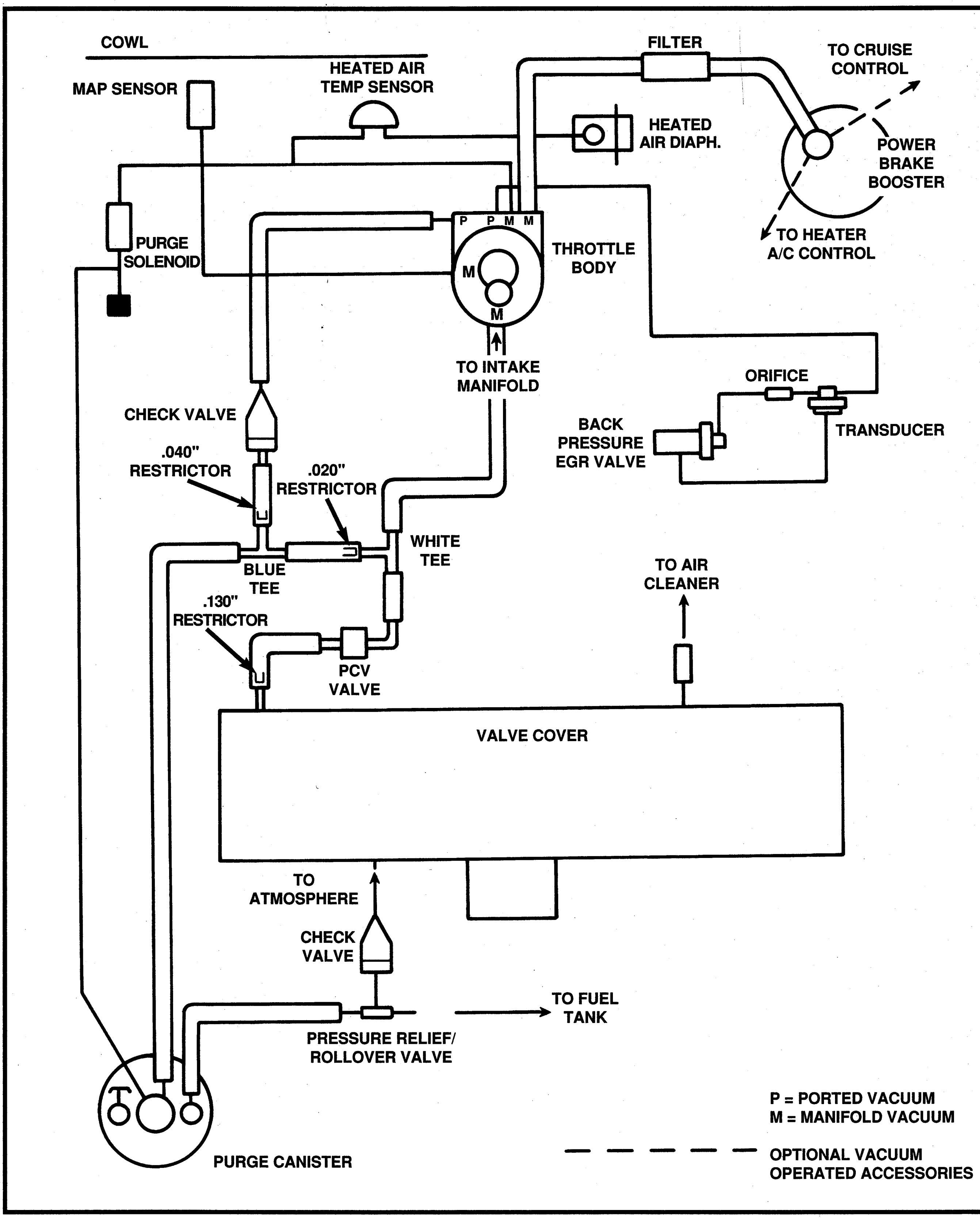


Figure 12 1987.5 2.5L SMEC Vacuum Hose Routing Schematic

EVAPORATIVE (PRESSURE AND PURGE) SYSTEM CHECK

CANISTER PURGE TEST

Fuel vapors are captured by the evaporative canister. These vapors are later "purged" from the canister into the engine when the vehicle is being operated. Periodic inspection and maintenance is required to prevent the canister from becoming overloaded, which would allow fuel vapors to escape into the atmosphere.

The purge test, which is required for all enhanced IM240 programs, verifies that this operation is working correctly. During a purge test, the purge flow rate from the vehicle's evaporative canister is measured (fig. 13). For many vehicles, the greatest amount of canister purge operation occurs when the vehicle is being driven under a transient load. Therefore, purge tests are usually conducted during an IM240 test.

Just prior to the IM240 test, a flow transducer is placed in the purge flow line between the canister and the intake vacuum source of the engine. Then, during the IM240 driving cycle, the flow transducer measures the amount of purge flow from the canister and sends this information to the computer. The present standard for all test vehicles is that it must flow at least one liter during the four minute IM240 test. Any properly operating vehicle will easily flow many times this amount.

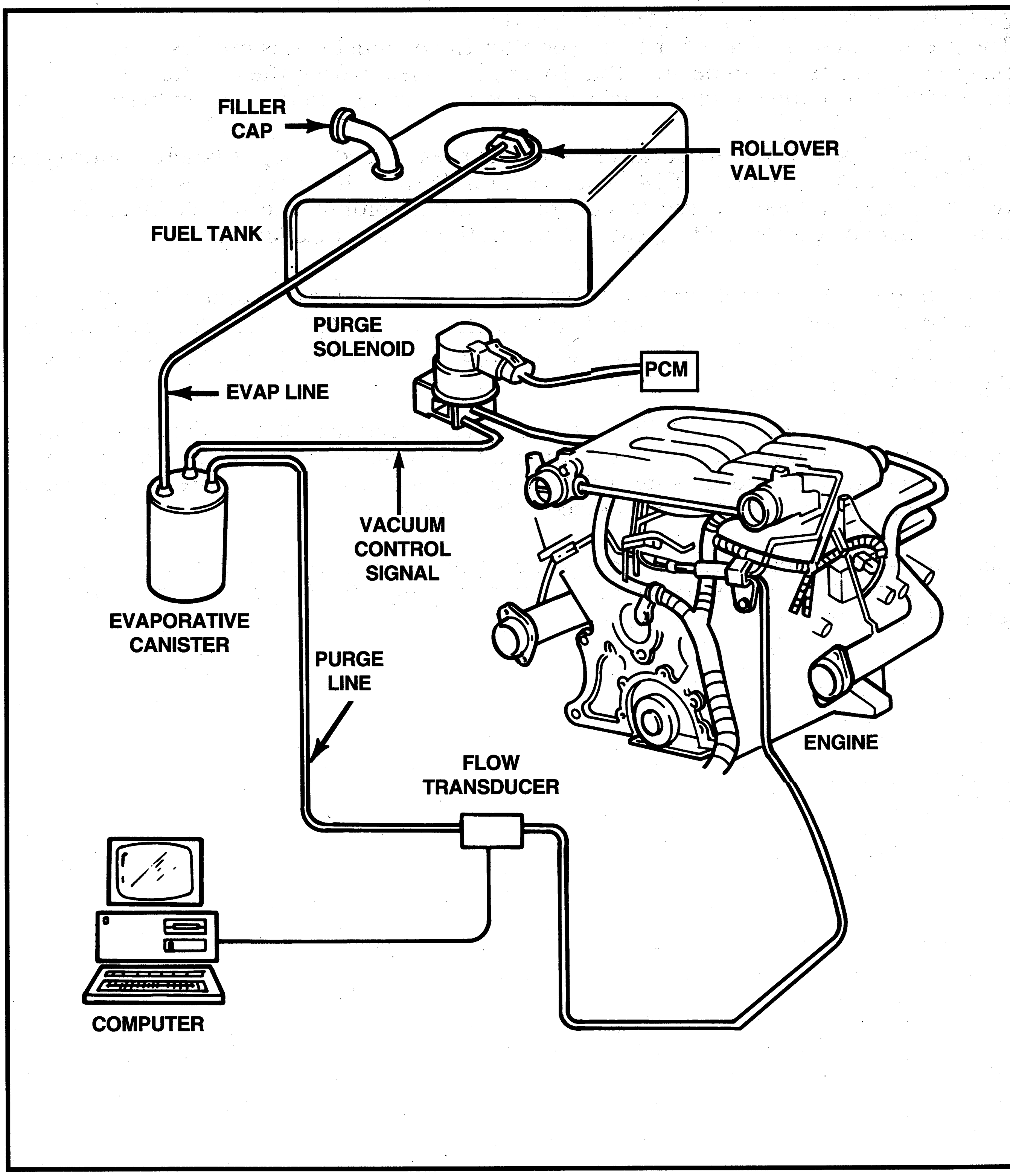


Figure 13 Test Lane Purge Test Schematic

EVAPORATIVE SYSTEM PRESSURE TEST

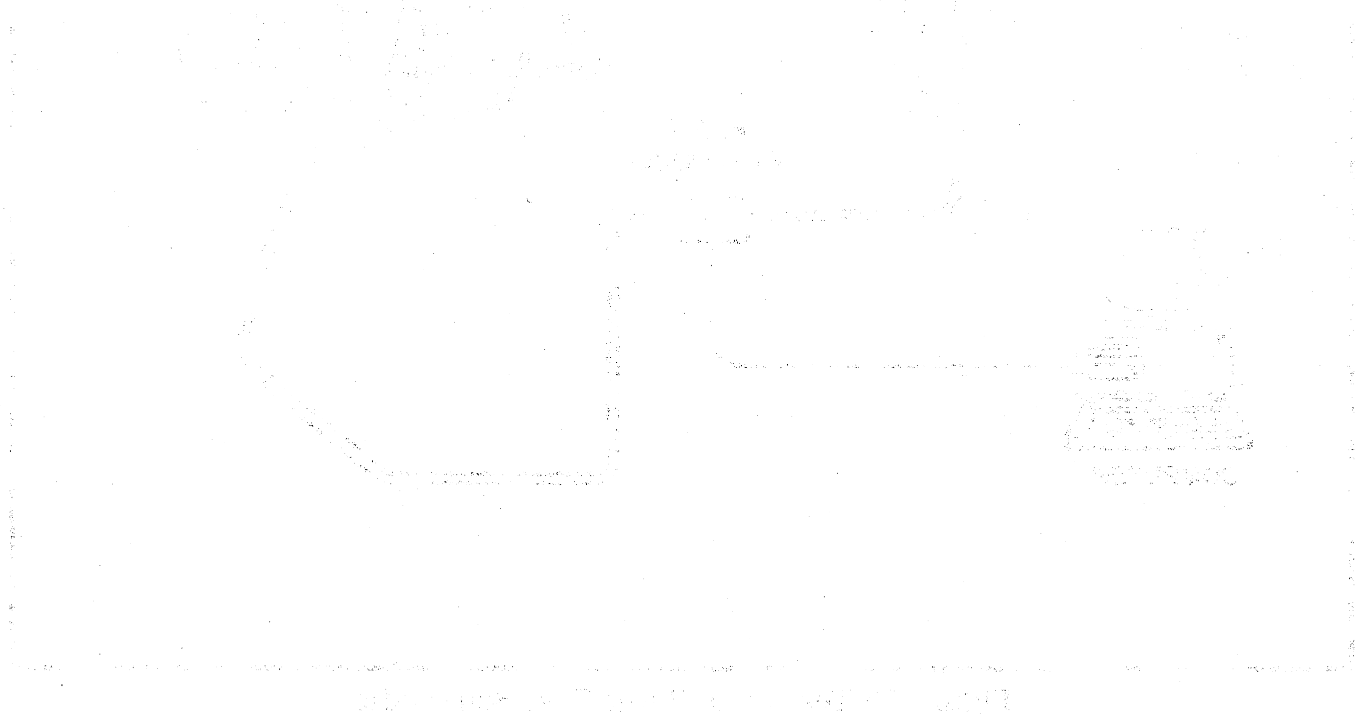
The pressure test is run either before or after the exhaust emissions test. The purpose of this test is to be sure that there are no leaks from the fuel tank to the evaporative canister where fuel vapors could escape into the atmosphere.

In this test (fig. 14), the evaporative system is pressurized by a gas (such as nitrogen) until it reaches a pressure of 14" water column.[3] Then, the pressure is monitored for two minutes. If it bleeds down to less than 8" water column, the vehicle fails. (This test will also be discussed in greater detail in the Diagnostics Manual.)

Note: *In the EPA's guidelines for I/M programs, they propose that any state using an IM240 may include both an Evaporative Emissions Purge and a Fuel System Pressure test. This combination of an IM240 with a purge and a pressure test is referred to by the EPA as an* ***Enhanced I/M Test****.*

Enhanced I/M testing doesn't begin and end at the tailpipe. EPA studies have found that proper repairs of fuel systems (evaporative emissions systems) can double the reduction of HC emissions. Appropriate testing (and repair) is therefore recognized as a required element of all new Enhanced I/M programs.

Because both the mass emission and evaporative system tests do such a thorough job of testing the vehicle's "performance", visual tampering inspections may no longer be required for all programs.



[3] "Water column" (w.c.) is a way of expressing relatively low pressure. 14" w.c. equals about 1/2 psi.

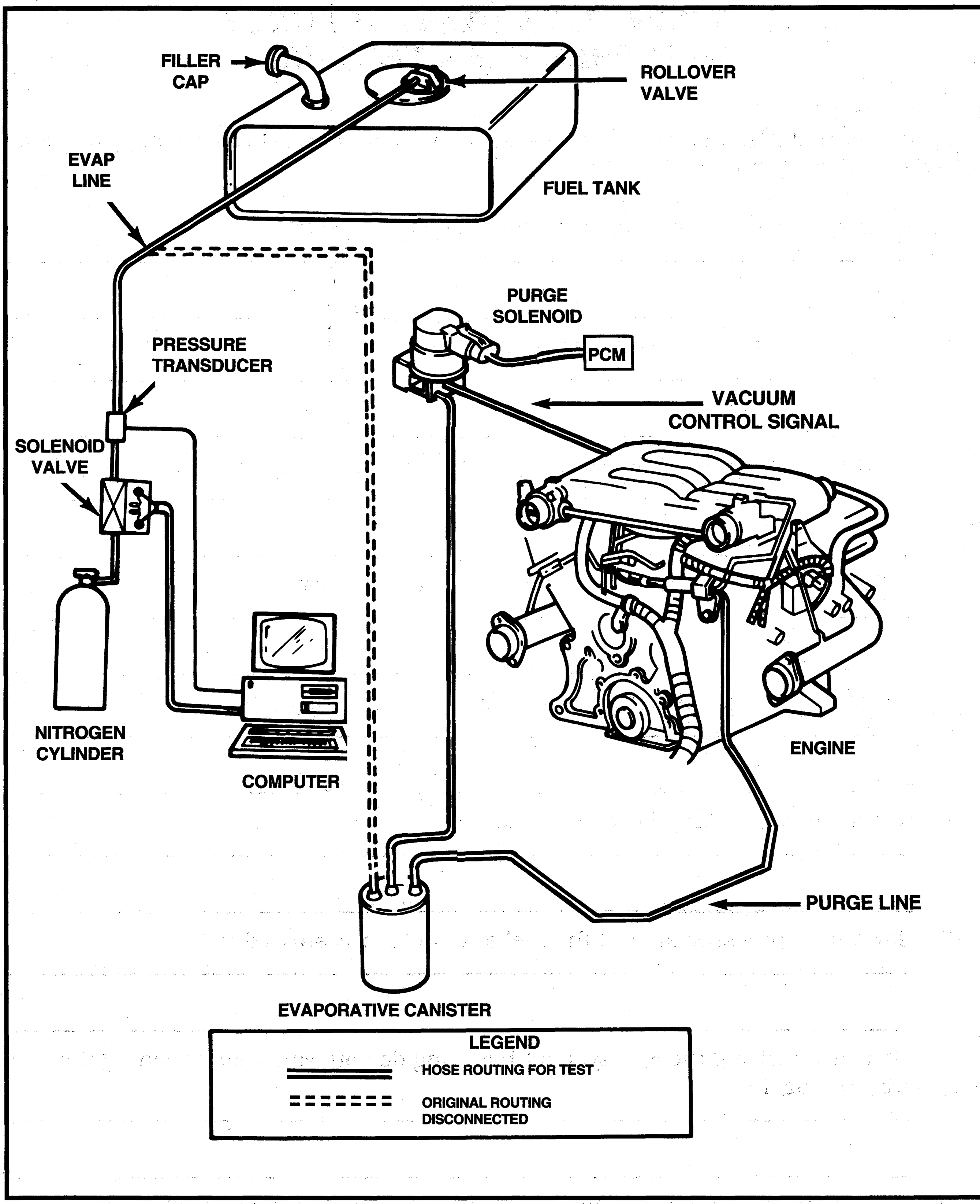


Figure 14 Test Lane Pressure Test Schematic

Activity 2

EVAPORATIVE SYSTEM PURGE AND PRESSURE TESTING

DIRECTIONS:
After the Instructor Demonstrates evaporative purge and pressure systems, complete the following questions.

1. What type of purge system is on the classroom vehicle?

2. What special tool is used to test the purge system?

3. What results should be expected in a properly-operating vehicle?

4. What special tool is used to pressure-test the fuel system?

5. What are some of the hazards to beware of when using this system?

6. Where does the pump hose attach to the vehicle?

7. How much pressure should the fuel system be pressurized to?

8. After pressurizing the fuel system, how long do you wait before reading the pressure again?

9. What is the minimum allowable pressure after the waiting period?

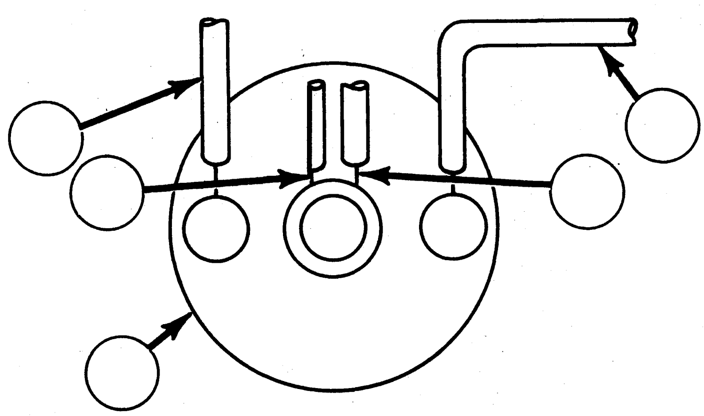
Activity 2

EVAPORATIVE CANISTER PURGE TEST

The following diagram from the Diagnostic Manual shows the components involved in an evaporative purge test.

DIRECTIONS:

1. Label each component.
2. Draw the missing hoses with the correct routing.
3. Use arrows to indicate the direction of flow of vapors and vacuum.



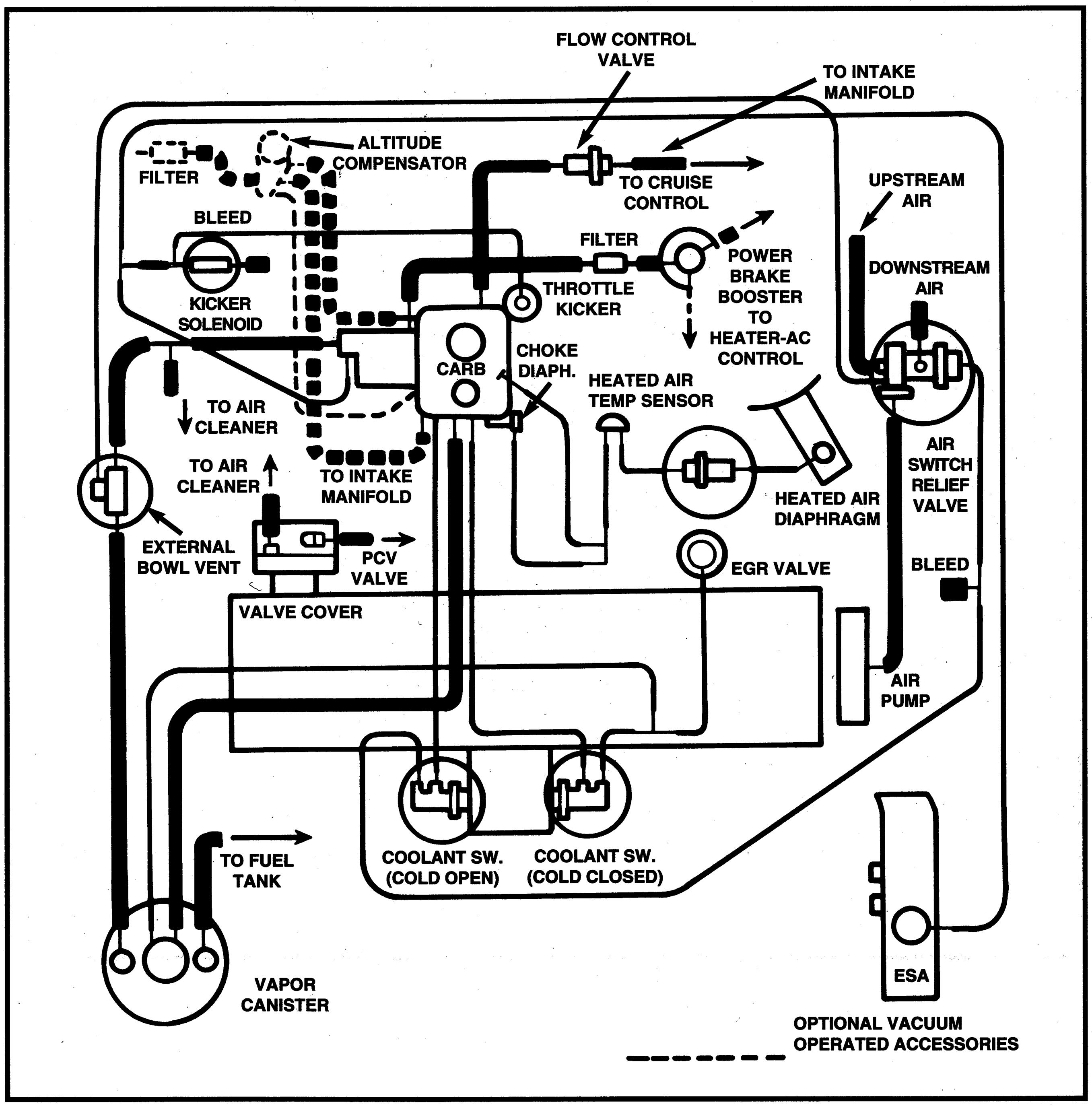
1. TO BOWL VENT
2. EVAPORATIVE CANISTER
3. TO FUEL TANK VENT
4. TO PURGE SOLENOID
5. TO INTAKE MANIFOLD

Activity 2

DIRECTIONS:

Use the 1984 Passenger Car Service Manual(s) to complete the following activity.

1. Using a highlight marker and arrows label the flow of evaporative fuel emissions.
2. Indicate where a purge flow tester would be installed on this system.
3. Indicate where the pressure tester would be installed on this system. (use an arrow to indicate the pressure flow)



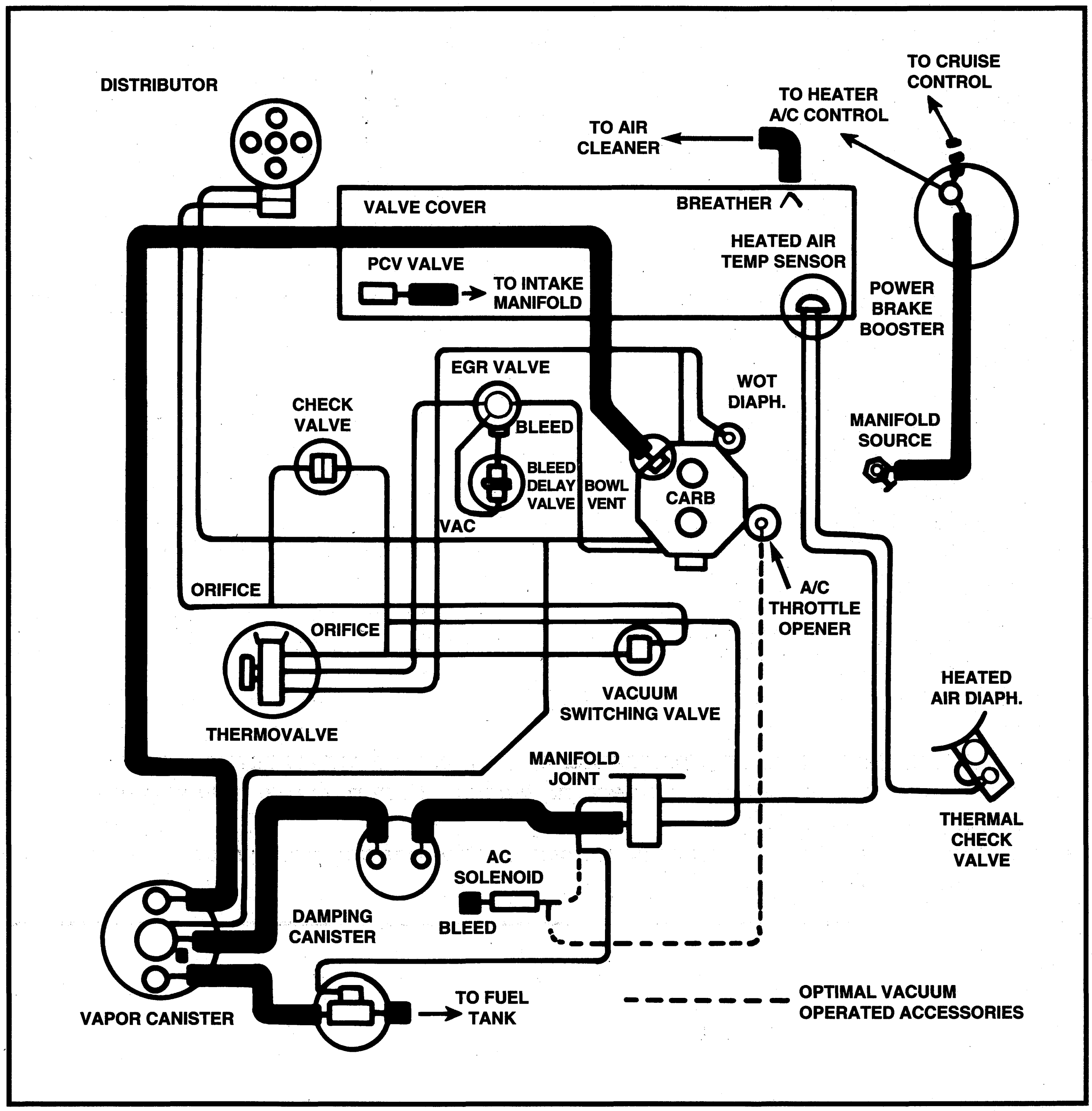
1984 Passenger Car Hose Routing Label 2.2L Federal

Activity 2

DIRECTIONS:

Use the 1986 Passenger Car Service Manual(s) to complete the following activity.

1. Using a highlight marker and arrows label the flow of evaporative fuel emissions.
2. Indicate where a purge flow tester would be installed on this system.
3. Indicate where the pressure tester would be installed on this system. (use an arrow to indicate the pressure flow)



1986 Minivan Federal 2.6L Vacuum Hose Routing Label

Activity 2

AT THE VEHICLE:

1. Locate the evaporative canister.
2. Remove the purge signal hose at the canister.
3. "Tee" the vacuum gauge between the canister and the purge solenoid.
4. Remove the purge hose.
5. Connect the purge flow indicator (Special Tool #6890) "in series" with the purge hose (i.e., between the canister and the intake manifold).
   Note: *This does not apply to 3.0L Eagle Premier, which has no purge signal hose.*
6. Start the engine and wait until it has reached normal operating temperature and has been running for at least two minutes.
7. Note flowmeter response. Flow should be at maximum.
   Note: *For vehicles with venturi vacuum (e.g.: 3.0L Eagle Premier), test should be conducted at 2500 rpm.*
8. Remove vacuum gauge and flowmeter and reconnect hoses to their original positions.

Warning: *Take the following precautions to prevent personal injury while using the Evaporative System Pressure Pump, Special Tool #6872:*

- *Keep lighted cigarettes, sparks, flames, and other ignition sources away from the test area to prevent the ignition of explosive gases. Keep the test area well ventilated.*
- *This equipment is designed to be used on the vehicle evaporative system only. Using the equipment in a manner for which it was not designed could be a dangerous procedure.*
- *The vehicle fuel tank must contain at least three gallons of gasoline when conducting this test procedure. Pressurizing a tank containing less than three gallons of gasoline could result in the ignition of fumes, causing an explosion.*
- *Wear protective eyewear that meets the requirements of OSHA and ANSI Z87.1-1968.*
- *When using the battery as a power source, connect the red (+) battery clip to the positive battery terminal and connect the black (–) battery clip to a good ground away from the battery.*
- *If the vehicle being tested is not on a hoist, set the parking brake and block the wheels before starting the test.*

Activity 2

DIRECTIONS:

> ***Warning:*** *Verify that the vehicle fuel tank contains at least three gallons of gasoline.*

1. Connect the evaporative system pressure pump (Special Tool #6872) supply hose to the vehicle.
2. Set PRESSURE/HOLD to OPEN and set VENT to CLOSED.
3. Turn pump timer ON.
4. Watch the gauge. When pressure reaches 14 in. H_2O, turn PRESSURE/HOLD to CLOSED. Note the time.
5. Turn pump timer OFF.

   - What was the pressure reading after two minutes? __________
   - What is the minimum acceptable reading? __________
   - Did this vehicle pass the evaporative system pressure test? __________

6. Repressurize the system to 14 in. of H_2O and loosen the fuel filler cap.

   - What was the pressure reading after two minutes? __________
   - What is the minimum acceptable reading? __________
   - Did this vehicle pass the evaporative system pressure test? __________

EXHAUST EMISSIONS

Vehicle exhaust emissions result from the combustion process (fig. 15):

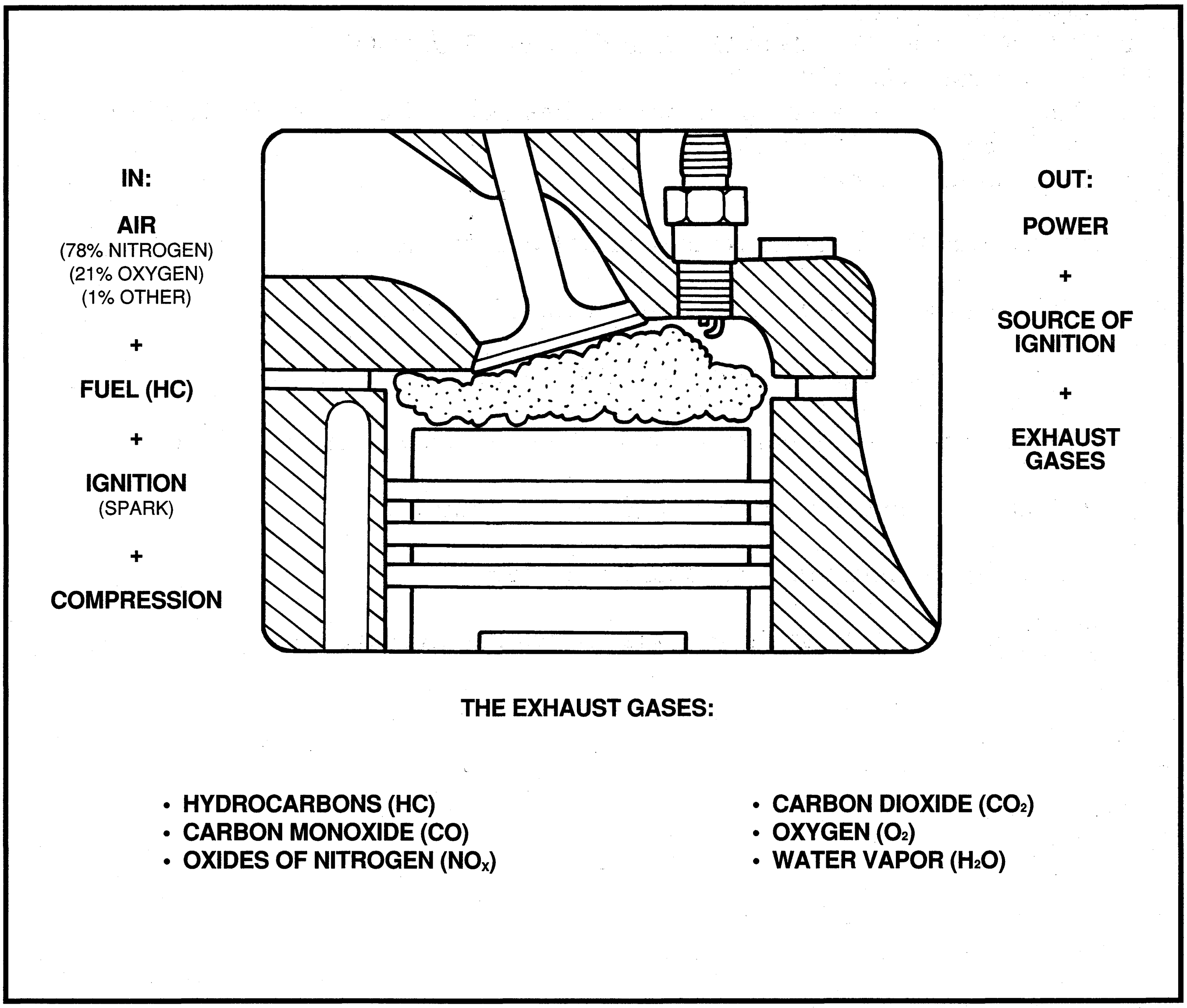


Figure 15 The Combustion Process Produces Vehicle Emissions

To meet Federal regulation for exhaust emissions and fuel economy, the goal of the combustion process is to ***completely*** burn the fuel while using up all of the oxygen. This will result in the highest power output, best fuel economy and the least amount of pollutants.

THE COMBUSTION PROCESS AND EXHAUST GASES

THE COMBUSTION PROCESS

The power of a gasoline engine is derived from the controlled combustion, or burning, of fuel in the combustion chamber. As with any other burning process, three things are required: fuel, oxygen, and heat. Remove any one of these things, and combustion will not occur.

In your fireplace, the fuel is wood, oxygen comes from the air, and heat is usually provided by a match or lighter. You can adjust the rate of burning, and even the amount of smoke given off, by adjusting the opening of the fireplace doors or louvered vent.

In an internal-combustion engine, the same three things are required:

- Fuel (a hydrocarbon called gasoline)
- Oxygen (from the air)
- Heat (from the spark plug)

When the combustion reaction is perfect (fig. 16), exactly three things are produced:

- Heat
- Carbon dioxide (CO_2)
- Water vapor (H_2O)

Carbon atoms from the hydrocarbon fuel (HC) combine with oxygen from the atmosphere (O_2) to form CO_2. Hydrogen atoms from the hydrocarbon fuel combine with oxygen from the atmosphere to form H_2O. No excess fuel remains, and all the available oxygen is used up. In other words, there is exactly the right amount of oxygen to burn the existing fuel, and exactly the right amount of fuel to consume the existing oxygen.

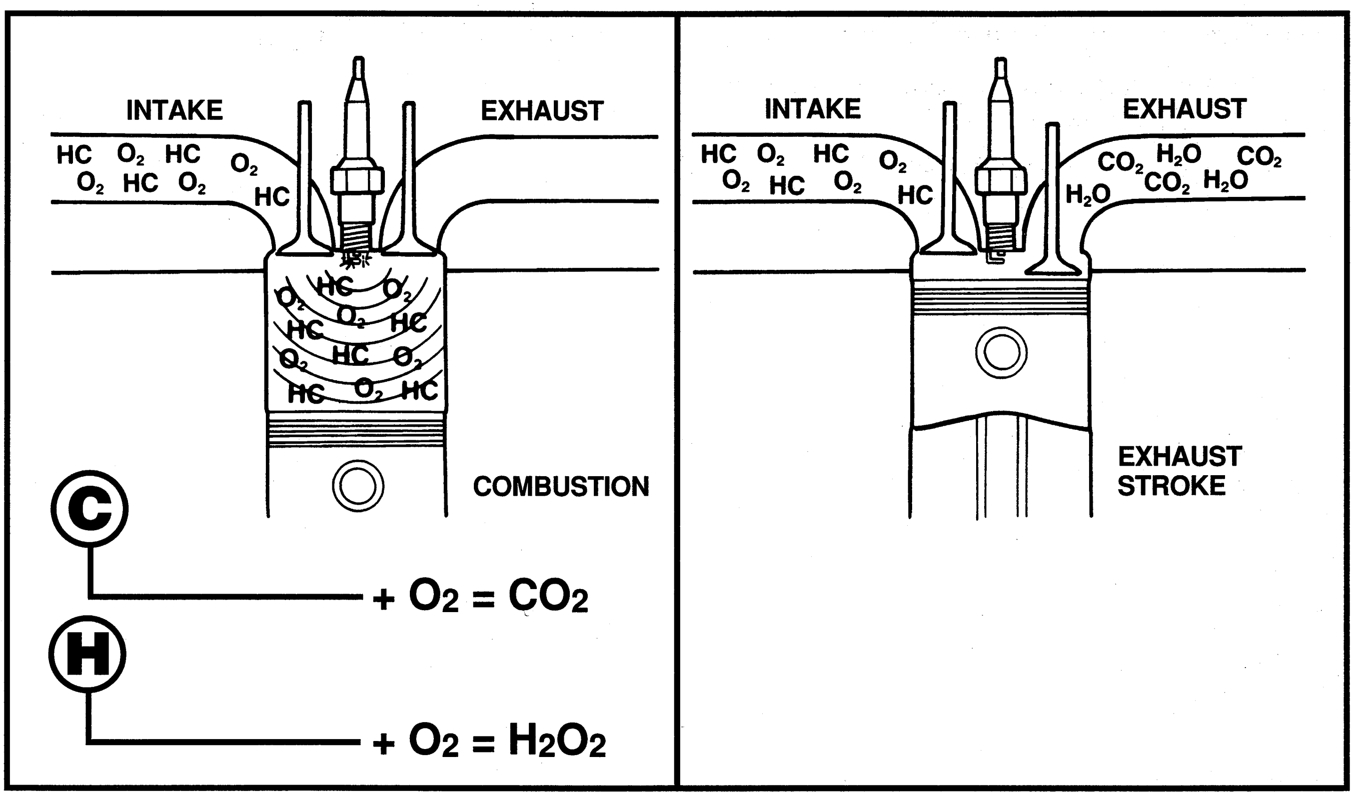


Figure 16 Perfect Combustion Reaction

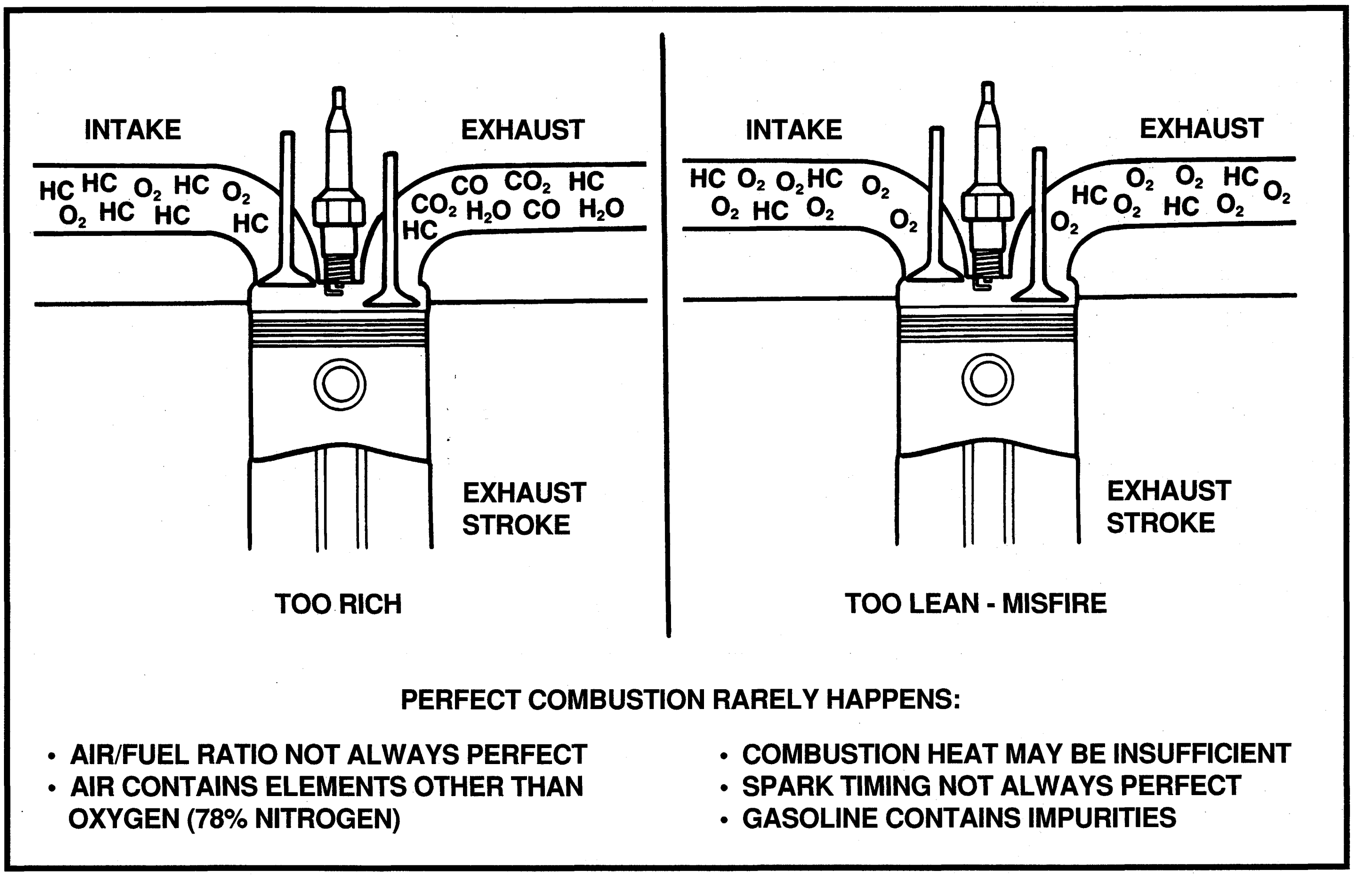


Figure 17 Incomplete Combustion

If perfect combustion could take place, the emissions controls that have been developed over the last 30 years would not have been necessary. After all, the only exhaust gases would be harmless carbon dioxide and water vapor.

Perfect combustion rarely happens, however (fig.17). The ratio of air to fuel, although controlled more precisely now than ever before, is not always perfect. Even the highest-quality gasoline has impurities that travel along with the hydrocarbons. Also, the air that gets drawn into the combustion chamber contains more than just oxygen—infact, it's about 78% nitrogen, which, under certain conditions, can produce harmful NO_X.

Even when the proper ratio of air to fuel exists, the fuel may not always be completely burned—the heat of combustion might not be sufficient, and the timing of the spark could be less than perfect. These conditions lead to incomplete combustion and the production of carbon monoxide and hydrocarbons in the exhaust.

THE EXHAUST GASES

There are generally five exhaust gases being observed in today's automobile. Three of them are pollutants which are observed for testing purposes:

- Carbon monoxide (CO)
- Hydrocarbons (HC)
- Oxides of nitrogen (NO_x)

The other two gases are not pollutants, but are informational gases which are observed for diagnostic purposes:

- Carbon dioxide (CO_2)
- Oxygen (O_2)

Studies indicate that the automobile accounts for about 50% of the hydrocarbons, over 75% of the carbon monoxide, and nearly 50% of the oxides of nitrogen that pollute our atmosphere (fig. 18). Current (and future) legislation places limits on how much of these pollutants can be produced by vehicles sold in this country.

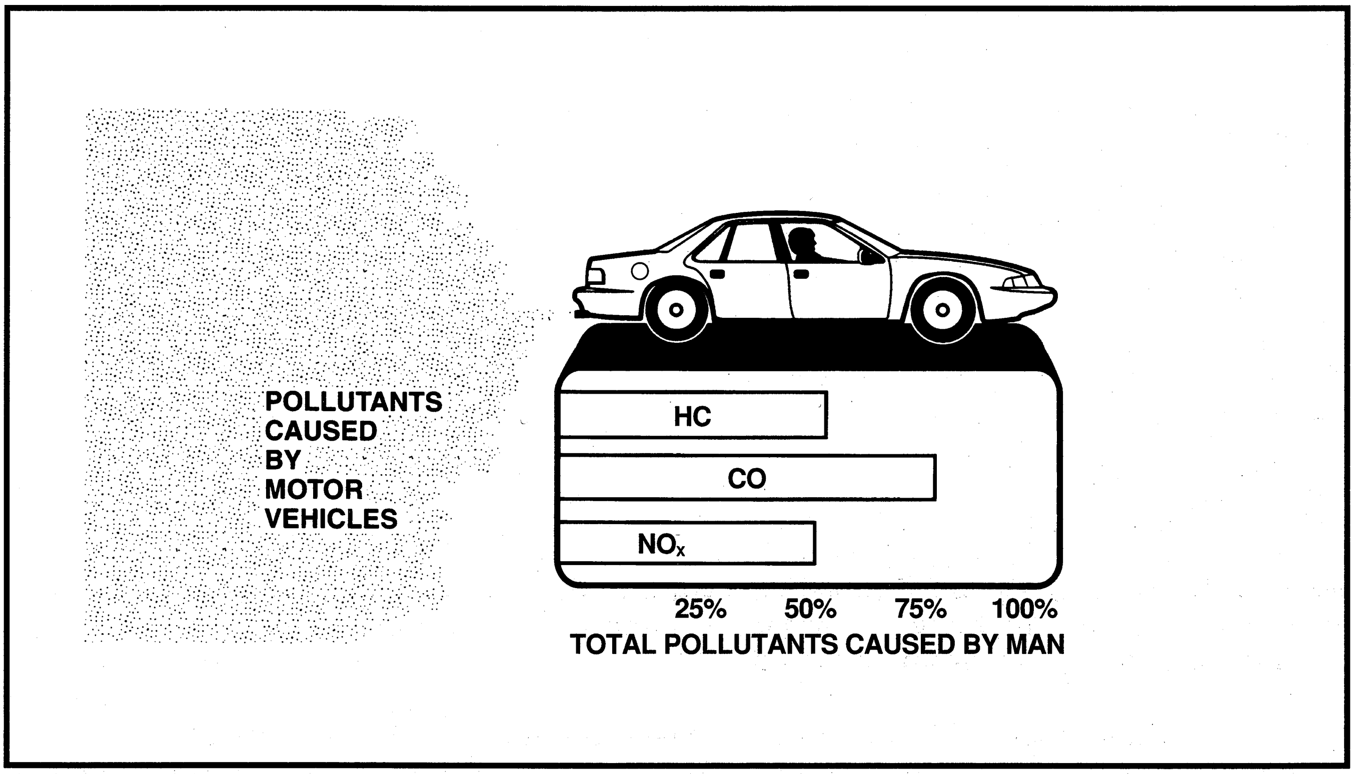


Figure 18 Exhaust Gases as Sources of Pollution

Hydrocarbons

Consist of hydrogen and carbon atoms in various combinations. Gasoline is a hydrocarbon fuel and is the source of automotive hydrocarbon emissions. Hydrocarbons, in combination with other compounds, can produce ground-level ozone, or photochemical smog.

As a tailpipe pollutant, hydrocarbon (HC) emissions are caused by partially-burned and by unburned fuel. This could occur under several different circumstances, including:

- Low compression
- Misfire, caused by:
  - Inaccurate spark timing
  - Improper spark duration
  - Ignition system problem
  - Improper air/fuel ratio

High HC emissions are also caused by the "quenching" effect inside the combustion chamber. Temperatures are not consistent throughout the combustion chamber. Near the cylinder head and engine block, metal surfaces absorb much of the heat of combustion, making this area much cooler than the rest of the chamber (fig. 14). The combustion flame tends to extinguish, or quench, in this area, allowing unburned hydrocarbons to pass through the exhaust. Quenching is primarily controlled through combustion chamber design.

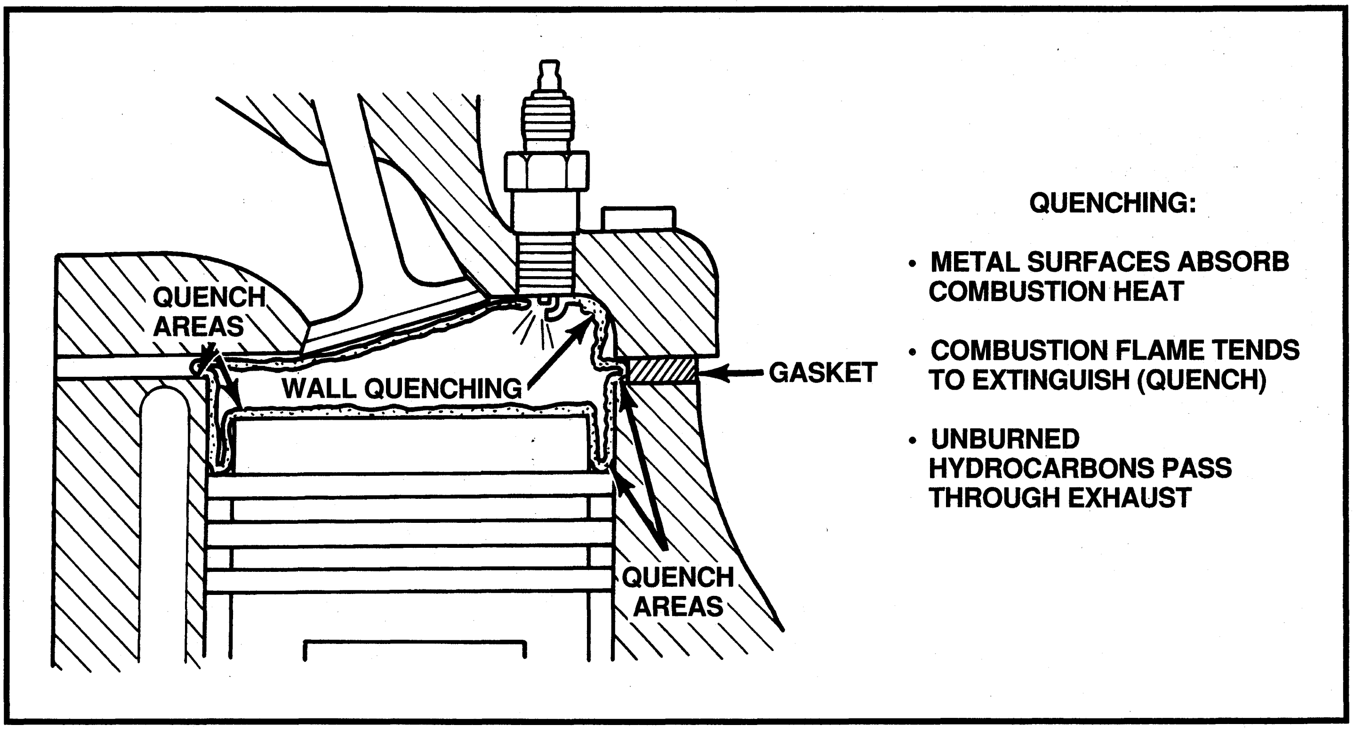


Figure 19 Quenching Effect

Hydrocarbon emissions are decreased by combining the hydrocarbons with sufficient oxygen during the combustion process. This is known as oxidation, and results in the creation of harmless carbon dioxide and water. This oxidation takes place when the air/fuel ratio is correct (fig. 20).

Figure 20 shows that hydrocarbons:

- Are high when the mixture is rich.
- Are lower at ideal mixtures (14.7:1).
- Are lowest at a slightly lean mixture.
- Increase as the mixture gets leaner.

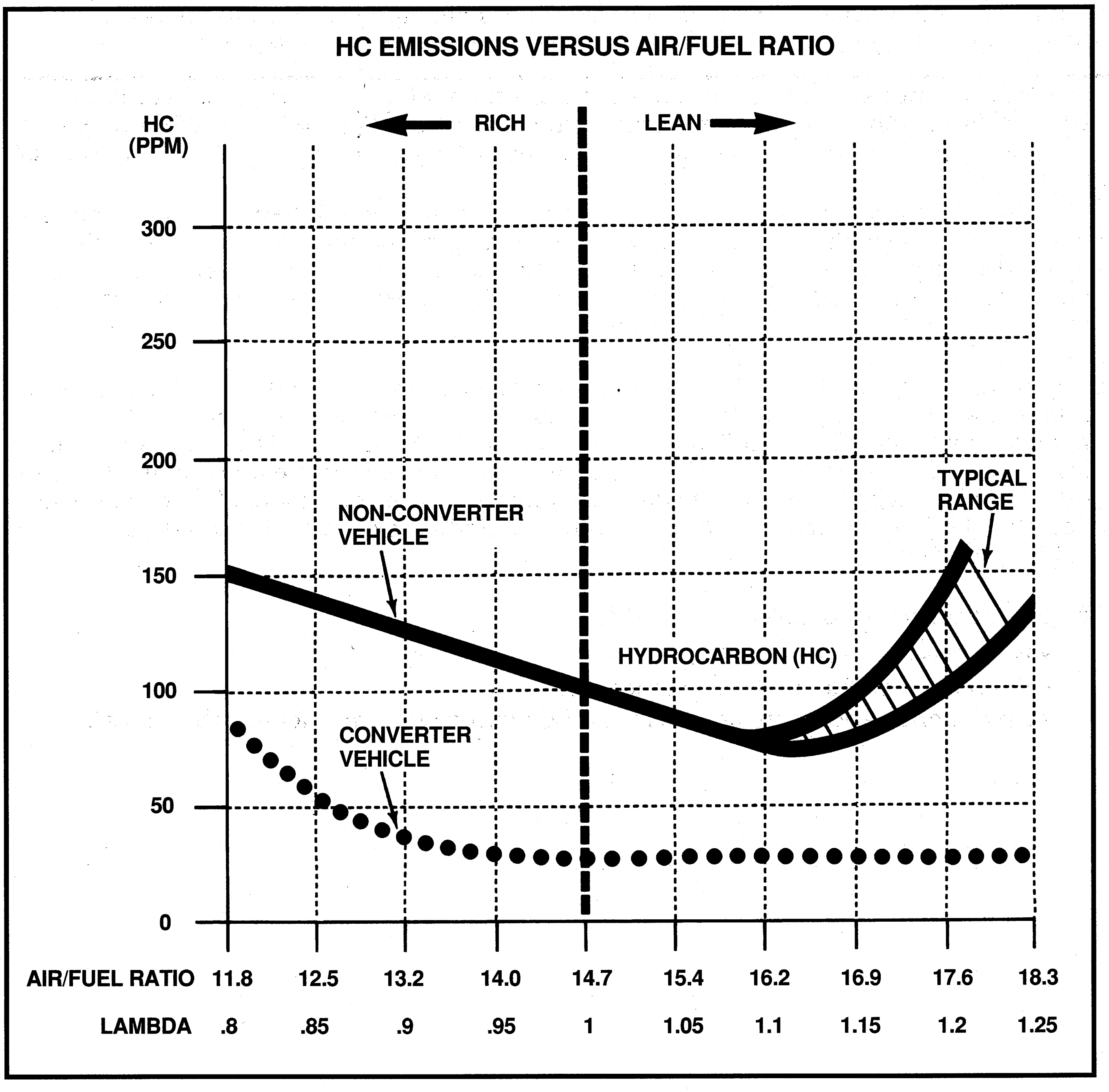


Figure 20 HC Emissions versus Air/Fuel Ratio

Carbon Monoxide

Exists as a molecule containing one carbon atom and one oxygen atom. It is a colorless, odorless, and very poisonous gas which results from incomplete combustion of the fuel mixture.

> ***Warning:*** *Inhaled carbon monoxide enters the bloodstream and takes the place of oxygen in the red blood cells. Carbon monoxide "absorbs" oxygen ten times more readily than the red blood cells do. Oxygen is essentially blocked from the body, possibly resulting in headaches, reduced mental alertness, and death.*

In perfect combustion, one carbon atom from the fuel (the "C" from HC) combines with O_2 (atmospheric oxygen) to form harmless carbon dioxide (CO_2). What do you suppose would happen if there were a shortage of oxygen in the combustion process?

That is what happens when the air/fuel mixture is too rich. When there is a shortage of oxygen in the combustion chamber, the burning of the fuel stops prematurely when the oxygen is used up. The result is that one atom of carbon combines with only one atom of oxygen to form harmful carbon monoxide (CO), which, by weight, makes up more than 40% of air pollution.

Anything that restricts air flow to the combustion chamber, such as a blockage in the intake manifold or cylinder heads, can cause high CO emissions levels. Carbon monoxide is also a direct indication of the air/fuel mixture (fig. 21). Generally, the lower the CO reading on an exhaust-gas analyzer, the leaner the air/fuel mixture. In other words, high CO levels indicate a rich mixture. Carbon monoxide emissions are decreased by increasing the air/fuel ratio (i.e., adding oxygen). This is also an oxidation process.

Figure 21 shows that carbon monoxide:

- Is highest at rich mixtures.
- Decreases as the mixture gets leaner.
- Approaches and stays near zero as the mixture becomes leaner than ideal.

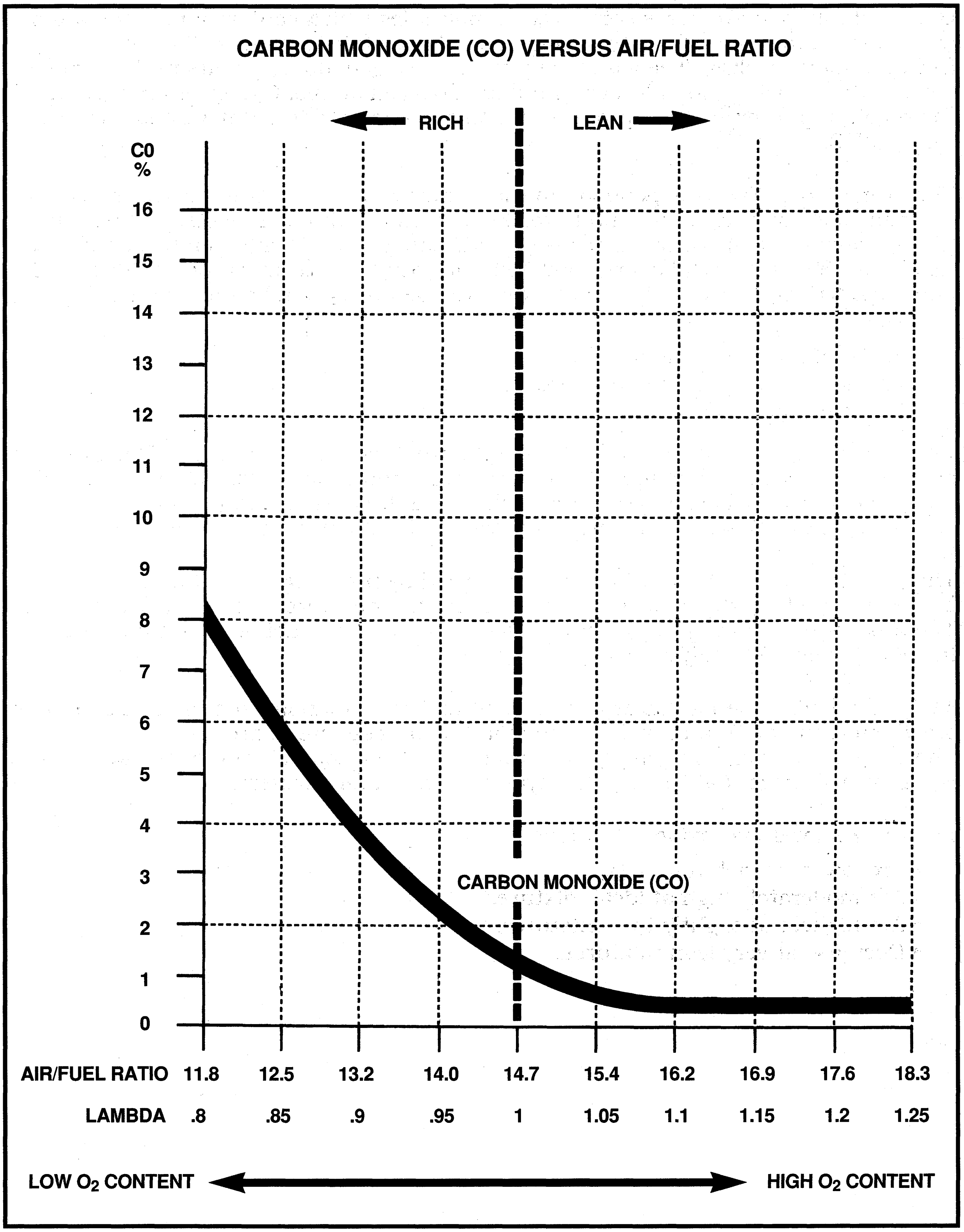


Figure 21 CO Emissions versus Air/Fuel Ratio

Oxides of nitrogen are gases composed of molecules which contain a nitrogen atom and a varying number of oxygen atoms, usually one (nitric oxide, NO) or two (nitrogen dioxide, NO_2). The variable number of oxygen atoms results in the formula "NO_x" with "x" being the unknown number of oxygen atoms. Oxides of nitrogen are the result of the combustion process, but they are formed in a different fashion from CO and HC.

The formation of NO_x is dependent on the combustion temperature. Nitrogen is normally inert and does not tend to readily combine with other elements, but when the combustion temperature exceeds approximately 2500°F, nitrogen (which makes up about 78% of the intake air), combines with oxygen to form various oxides, most notably nitric oxide (NO). High combustion temperatures can be the result of:

- Heavy loads
- High compression ratios
- Excessively lean air/fuel mixtures (fig. 22)
- Early ignition timing

NO_x emissions are controlled by lowering the combustion temperature. This has been achieved through lower compression ratios, camshaft timing adjustments, air/fuel mixture control, and exhaust gas recirculation (EGR) systems. Prior to these controls, combustion temperatures in excess of 4000°F were not uncommon.

The NO_x that is still produced can be minimized by breaking the connective bonds between the nitrogen and oxygen elements, or, in other words, removing the oxygen. The process of removing the oxygen is called a reduction reaction, and takes place inside a three-way catalytic converter.

NO_x is an environmental hazard because ultraviolet radiation from the sun acts upon a combination of NO_x and hydrocarbons in the atmosphere to produce photochemical smog. This smog, once thought to be a combination of smoke and fog, is a brownish haze that irritates the eyes and respiratory system.

Figure 22 shows that oxides of nitrogen:

- Are lowest at rich mixtures.
- Are moderately high at ideal mixtures.
- Are highest at slightly lean mixtures.
- Decrease at very lean mixtures.

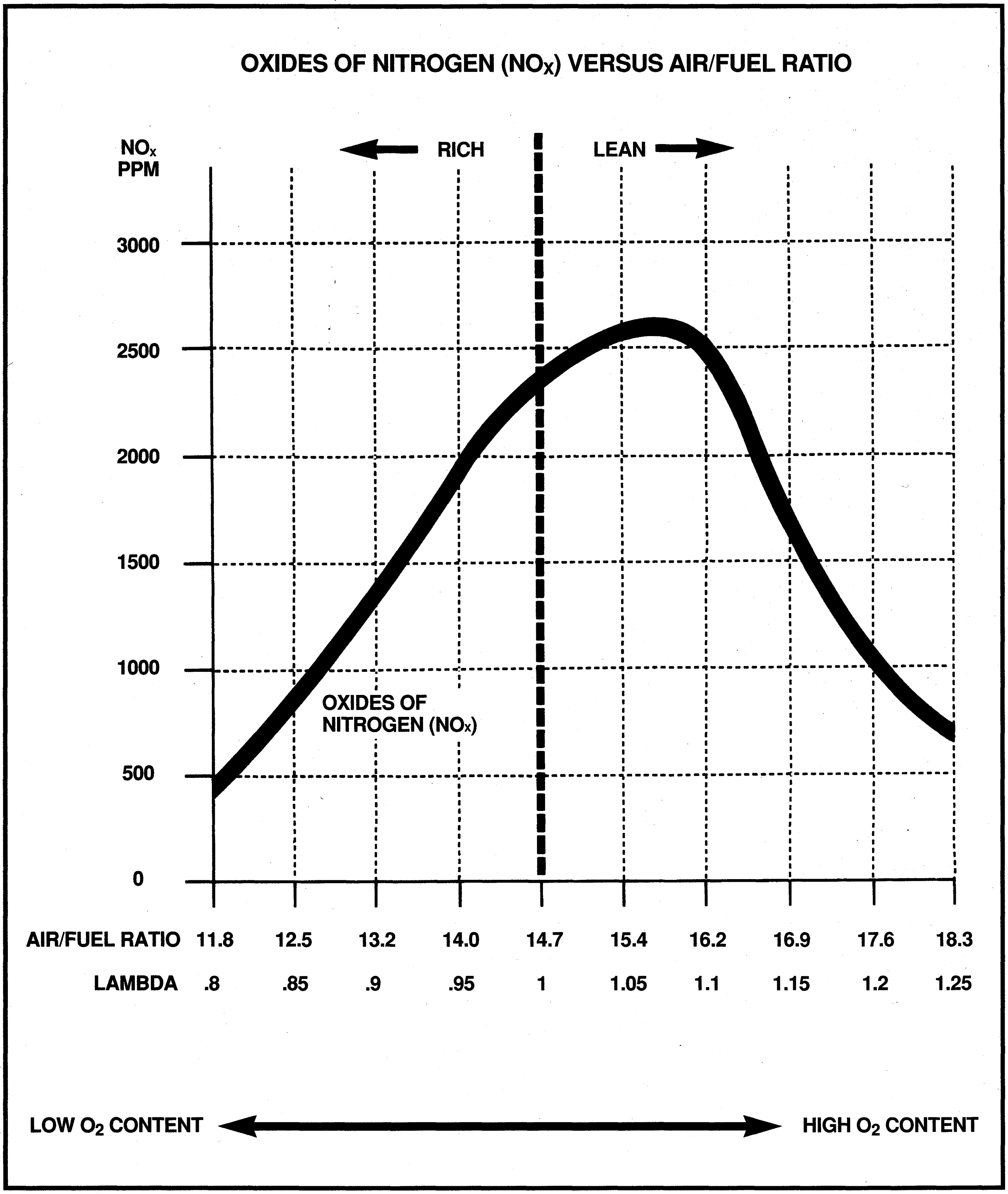


Figure 22 NO_x Emissions versus Air/Fuel Ratio

NON-POLLUTANT EXHAUST GASES

There are two major exhaust gases which are not health hazards, but whose presence helps us to diagnose certain engine conditions by determining combustion efficiency. They are:

- Carbon Dioxide (CO_2)
- Oxygen (O_2)

Carbon Dioxide (CO_2)

An essentially harmless gas, is present at levels of 14 to 15% in the exhaust of a properly-running vehicle. Carbon dioxide is a by-product of perfect combustion, formed when one atom of carbon (from the hydrocarbon fuel) bonds with two atoms of oxygen from the air during combustion. Carbon dioxide is also produced when carbon monoxide is oxidized in the catalytic converter.

The amount of carbon dioxide in the exhaust is directly related to the correctness of the air/fuel ratio. As the fuel mixture approaches stoichiometric (14.7:1), the level of CO_2 peaks. It decreases when the mixture becomes richer or leaner. This fact makes CO_2 in the exhaust an excellent reference that can help determine how efficiently the engine is combusting its fuel. The higher the CO_2 reading, the higher the efficiency of combustion.

Figure 23 shows that carbon dioxide is:

- Low at rich mixtures.
- Highest at stoichiometric (i.e. 14:7 or optimum combustion).
- Low at lean mixtures.

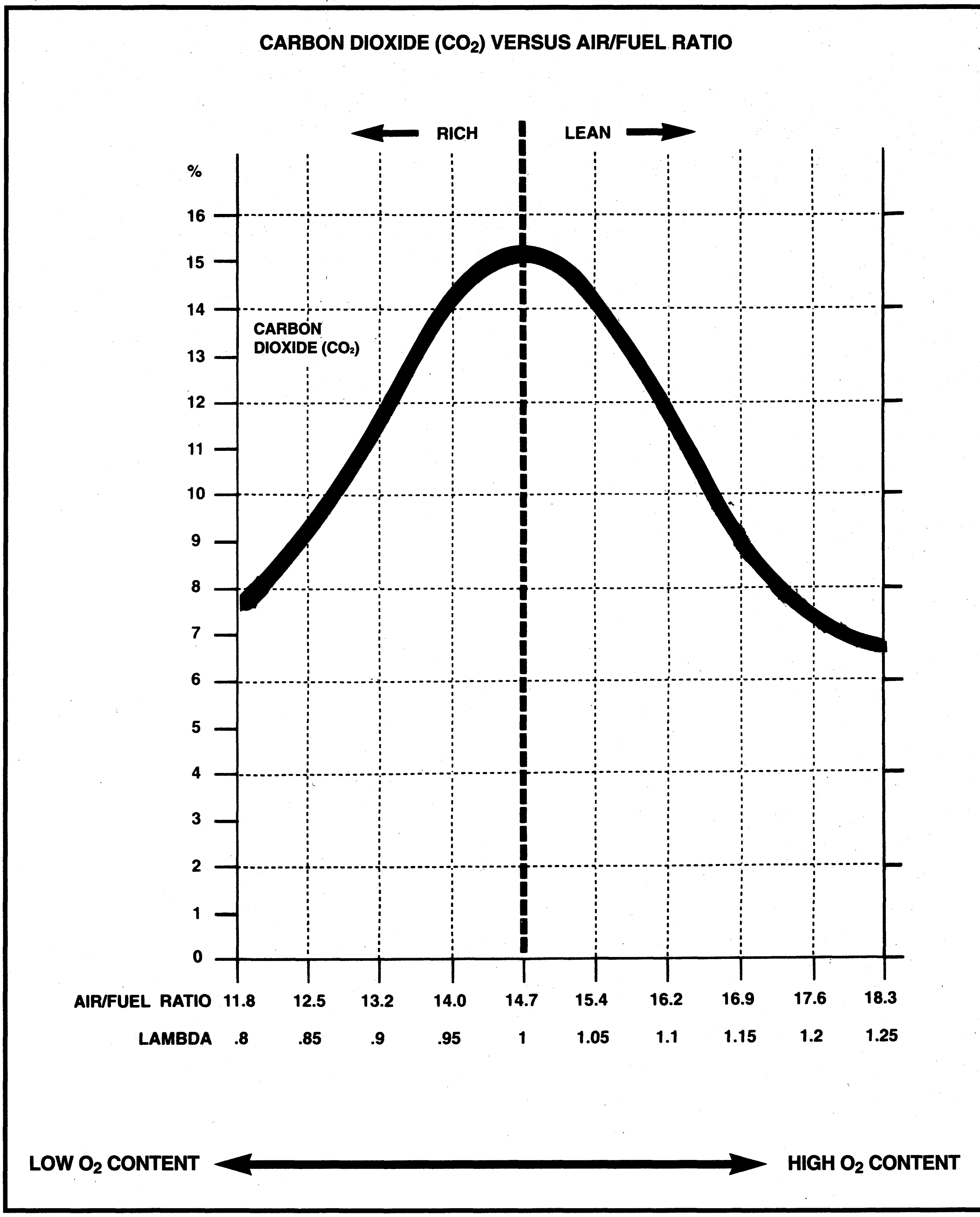


Figure 23 CO_2 versus Air/Fuel Ratio

Oxygen (O_2)

Makes up about 21% of the air we breathe and is mixed with gasoline for combustion in the cylinders. Oxygen is consumed during the combustion process. When there is a relatively great amount of fuel (a rich mixture), all of the available oxygen is used up, resulting in low reading in the exhaust.

As the mixture gets leaner, the amount of oxygen in the exhaust steadily increases, because less of it is being used in combustion. In other words, when the small amount of fuel in a lean mixture is burned up, there is still some oxygen left, which exits through the exhaust system. Therefore, higher levels of O_2 in the exhaust are a direct indication of leaner air/fuel ratios.

When the air/fuel mixture is either rich or lean, the levels of oxygen and carbon monoxide will be opposite one another (when O_2 is high, CO is low, and vice versa). At the stoichiometric air/fuel ratio, the levels of O_2 and CO in the exhaust are approximately equal, that is, they are both near zero.

Figure 24 shows that oxygen is:

- Low at rich mixtures.
- Slightly higher at stoichiometric (about 1%-2%).
- Highest at lean mixtures.

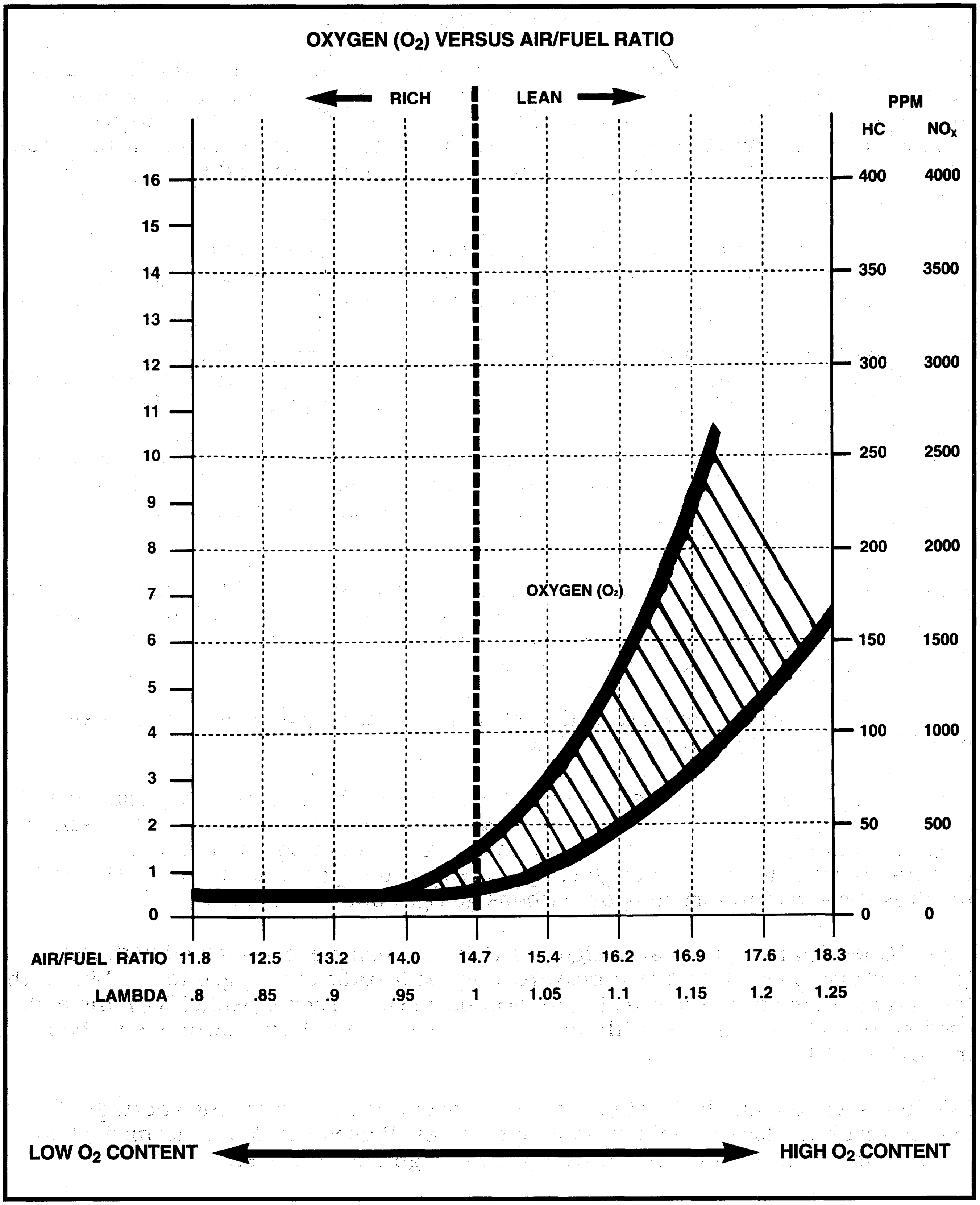


Figure 24 O_2 versus Air/Fuel Ratio

THE IMPORTANCE OF THE AIR/FUEL RATIO

You may have noticed a common element in the formation of each of the three main pollutant gases (HC, CO, and NO_x). Each of these emissions can be caused by an improper ratio of air to fuel in the combustion process. Maintaining the correct air/fuel ratio has therefore become one of the main goals of emissions control system design, and has ultimately resulted in today's computer-controlled fuel injection systems.

A "lean" mixture is one in which there is an excess of oxygen mixed with the gasoline. Depending on other circumstances, a lean mixture can be responsible for excess levels of hydrocarbons and oxides of nitrogen.

An excessively lean mixture can cause "lean misfire", in which a given volume of fuel mixture simply doesn't contain enough gasoline to ignite. What little fuel there is passes through the exhaust system unburned, resulting in high HC levels.

When the fuel mixture is lean, but not too lean to burn, the excess oxygen produces such a hot flame that combustion temperatures become excessive. These high temperatures cause nitrogen in the intake air to combine with oxygen to form harmful oxides of nitrogen (NO_x).

A lean mixture results in low-to-zero levels of carbon monoxide (CO). This is because there is sufficient oxygen to burn all of the fuel. (Remember that carbon monoxide is a by-product of partially burned fuel.) A condition that reduces the level of one pollutant can increase the level of another.

A rich mixture can lead to increased levels of hydrocarbons and carbon monoxide, but NO_x emissions will generally be low.

Curiously, hydrocarbon emissions can be caused both by an excessively lean or an excessively rich mixture. In the case of a lean mixture, there is not enough gasoline to ignite, and it passes unburned through the exhaust system. In a very rich mixture, there may not be enough oxygen present to support combustion. The end result is the same unburned hydrocarbons go right out the tailpipe.

High CO levels are a pretty sure sign of a rich fuel mixture, especially if high HC levels are also present. In a rich mixture, there is insufficient oxygen to combine with the carbon atoms from the gasoline to form harmless carbon dioxide (CO_2). Instead, each carbon atom combines with only one oxygen atom to form poisonous carbon monoxide (CO).

NO_x levels will usually be low in a rich-mixture situation because the shortage of oxygen results in lower combustion temperatures. Remember, NO_x is formed when nitrogen from the air combines with oxygen at high temperatures.

THE STOICHIOMETRIC RATIO

You've probably figured by now that there must be an optimum air/fuel ratio, one at which the three pollutant gases will be at their lowest levels. There is, of course. At that point, you will have exactly enough oxygen atoms to combine with the fuel molecules in the combustion chamber. This perfect ratio, under most conditions, is 14.7:1. In this mixture, there will be 14.7 parts of air for every part of fuel. A "part" could be any unit of weight (not volume) you wish to use pounds, grams, etc. As long as there are 14.7 units of air for every one (of the same units) of fuel, you will have the optimum ratio.

This mixture has a special name. It's called the stoichiometric (pronounced stoy-kee-o-MET-ric) ratio. The name comes from Greek words meaning "measured element." Mixing air and fuel at the stoichiometric ratio of 14.7:1 is the single most important technique that is used to control emissions levels. When the air/fuel ratio is at stoichiometric, every fuel molecule combines with every oxygen molecule, with nothing left over (theoretically, at least).

The first number in the air/fuel ratio is always the amount of *air* in the mixture. The second number is always the amount of *fuel*. A ***lean*** mixture is one that has a relatively high amount of air or oxygen (such as 16:1) and a ***rich*** mixture is one that has a relatively low amount of air or oxygen (such as 12:1).

In working with air/fuel ratios, you may occasionally see the term "lambda". This is simply a number that compares the actual air/fuel ratio to the stoichiometric ratio.

$$\text{Lambda} = \frac{\text{Actual ratio}}{\text{Stoichiometric ratio}}$$

When the actual air/fuel ratio is at stoichiometric, lambda = 1. When the actual mixture is rich, lambda is less than one. When the actual mixture is lean, lambda is greater than one.

Figure 25 shows that when the air/fuel ratio is near the stoichiometric level (about 14.6:1 to 14.8:1, or a lambda of 0.99 to 1.01), the following exhaust concentrations will occur:

- ***CO_2*** will be ***high*** (10-15%)
- ***CO*** and ***O_2*** will be about equally ***low*** (0.2-1.5%)
- ***HC*** will be ***low*** (200 ppm or less)

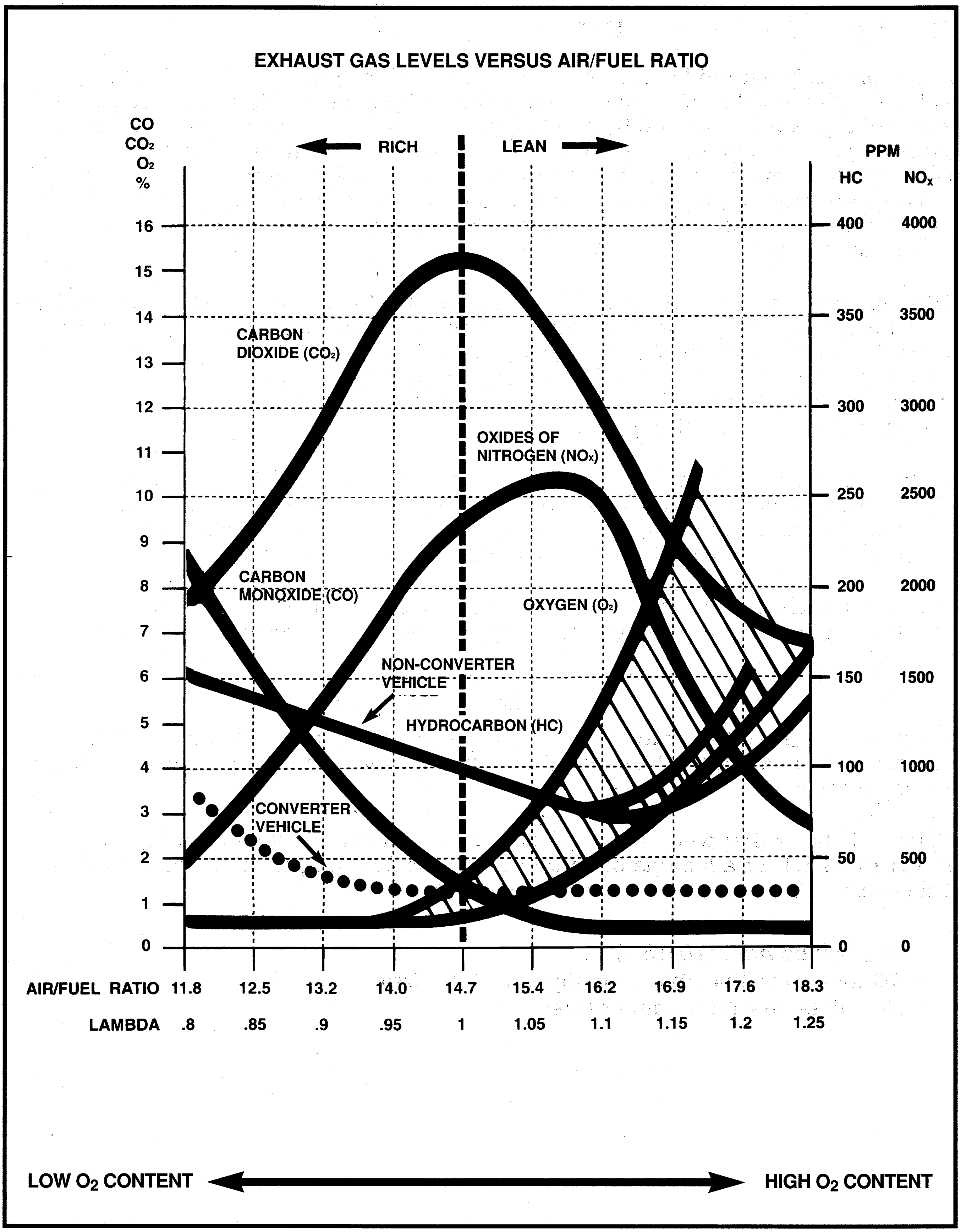


Figure 25 Exhaust Gases versus Air/Fuel Ratio

As the air/fuel mixture moves away from stoichiometric (either too lean or too rich), a number of conditions could occur, including emissions test failures and engine problems. Table 7 lists some of these relationships:

Table 7 Effects of Air/Fuel Ratio on Emissions and Performance

AIR/FUEL MIXTURE	***EFFECT ON VEHICLE***
Too Lean	Increased NO_x emissions Poor engine power Misfiring at cruising speeds Burned valves Burned pistons Scored cylinders Spark knock or ping
Slightly Lean	Low exhaust emissions High gas mileage Reduced engine power Slight tendency to knock or ping
Stoichiometric	Best all-around performance and emissions levels
Slightly Rich	Increased CO emissions Increased HC emissions Maximum engine power Higher fuel consumption Less tendency to knock or ping
Too Rich	Increased CO emissions Increased HC emissions Poor fuel mileage Misfiring Oil contamination Black exhaust

The quest for a reliable method of achieving stoichiometry (stoy-kee-OM-et-tree) has led to the evolution of fuel delivery systems from simple carburetion to today's computer-controlled multi-port fuel injection. Along the way, there have been interim developments such as electronic feedback carburetors and mechanical fuel injection.

Activity 3

AIR/FUEL MIXTURE AND INTERRELATIONSHIP BETWEEN EXHAUST GASES

You have been introduced to the various emissions gases and how their production is affected by the air/fuel mixture. The following quiz, based on the Student Workbook, lecture, and Diagnostic Manual, will reinforce your knowledge of that material.

1. Suppose that an engine is burning a fuel mixture that has an air/fuel ratio of 14.8:1. The larger number, 14.8, refers to the amount of ________________ in the mixture. The smaller number (always 1) refers to the amount of ________ ____________ in the mixture.

2. To the nearest tenth, the optimum air/fuel ratio for controlling exhaust emissions is______________.

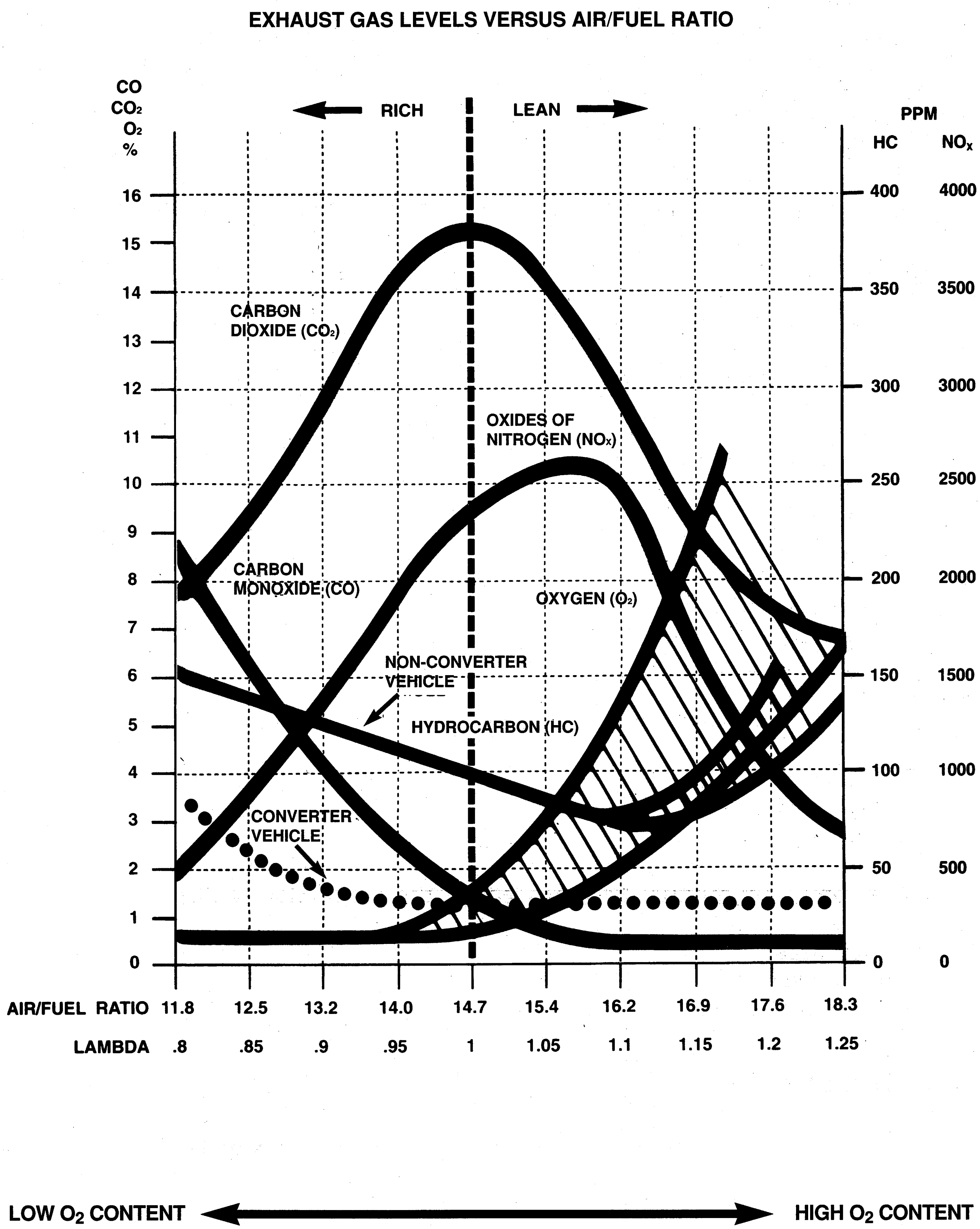
3. This optimum mixture is known as the __________________ mixture (or ratio).

4. Circle One: An air/fuel ratio of 16:1 would be considered a (rich) (lean) mixture.

5. Circle One: An air/fuel ratio of 14:1 would be considered a (rich) (lean) mixture.

The following four-gas chart graphically illustrates the relationships between various exhaust gases at different air/fuel ratios. Use the chart to answer the following questions about the air/fuel ratio and its effect on emissions levels.

Activity 3



EXHAUST GAS LEVELS VERSUS AIR/FUEL RATIO
CO
CO2
O2
%
RICH
LEAN
PPM
HC
NOx
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
400
350
300
250
200
150
100
50
0
4000
3500
3000
2500
2000
1500
1000
500
0
CARBON DIOXIDE (CO2)
OXIDES OF NITROGEN (NOx)
CARBON MONOXIDE (CO)
OXYGEN (O2)
NON-CONVERTER VEHICLE
HYDROCARBON (HC)
CONVERTER VEHICLE
AIR/FUEL RATIO 11.8 12.5 13.2 14.0 14.7 15.4 16.2 16.9 17.6 18.3
LAMBDA .8 .85 .9 .95 1 1.05 1.1 1.15 1.2 1.25
LOW O2 CONTENT
HIGH O2 CONTENT

Activity 3

CIRCLE THE MOST CORRECT ANSWER:

1. The optimum air/fuel ratio for reducing exhaust emissions is:

   a) 14:1
   b) 14.7:1
   c) 17:1

2. As a rich mixture approaches 14.7:1, the production of HC and CO:

   a) Increases.
   b) Decreases.
   c) Stays the same.

3. As a rich mixture approaches 14.7:1, the production of CO_2:

   a) Increases.
   b) Decreases.
   c) Stays the same.

4. As an optimum mixture becomes leaner, the production of CO:

   a) Increases.
   b) Decreases.
   c) Stays the same.

5. As an optimum mixture becomes leaner, the production of HC:

   a) Increases.
   b) Decreases.
   c) Stays the same.

6. As an optimum mixture becomes leaner, the production of CO_2:

   a) Increases.
   b) Decreases.
   c) Stays the same.

FILL IN THE BLANKS:

1. At a rich air/fuel ratio of 10:1, the level of carbon monoxide is about ______%.

2. At the same ratio (10:1), the level of oxygen is about _______%.

Activity 3

3. At stoichiometric (14.7:1), the level of carbon monoxide is about _________%.

4. At the same ratio (14.7:1), the level of oxygen is about _________%.

5. At a lean air/fuel ratio of 17:1, the level of carbon monoxide is about _______%.

6. At the same ratio (17:1), the level of oxygen is about _________%.

CLASS DISCUSSION:

1. As the air/fuel ratio becomes leaner than optimum, why does oxygen increase while carbon monoxide stays at a minimum?

____

____

____

____

____

2. Why do the curves for carbon dioxide and hydrocarbons travel in opposite directions?

____

____

____

____

____

Activity 3

EXHAUST GASES

Circle the most correct answer:

1. The three primary exhaust gases being controlled in today's automobile are:

   a) Hydrocarbons, carbon dioxide, and oxygen.
   b) Carbon monoxide, hydrocarbons, and oxides of nitrogen.
   c) Carbon monoxide, carbon dioxide, and hydrocarbons.
   d) Oxygen, carbon dioxide, and oxides of nitrogen.

2. The source of automotive hydrocarbon emissions is:

   a) Quenching.
   b) Improper air/fuel ratio.
   c) Inaccurate spark timing.
   d) Gasoline.

3. The poisonous gas which can replace oxygen in the bloodstream is:

   a) Carbon monoxide.
   b) Carbon dioxide.
   c) Hydrocarbon.
   d) Oxides of nitrogen.

4. A high level of carbon monoxide usually indicates:

   a) Excessive combustion temperatures.
   b) Rich fuel mixture.
   c) A vacuum leak.
   d) Low-octane gasoline.

5. The exhaust gas formed by excessive combustion temperatures is:

   a) Hydrocarbon.
   b) Carbon dioxide.
   c) Oxides of nitrogen.
   d) Carbon monoxide.

6. The two main non-pollutant gases in the exhaust stream are:

   a) Carbon monoxide and oxygen.
   b) Carbon dioxide and oxygen.
   c) Oxygen and hydrocarbons.
   d) Octane and methane.

7. The most important factor in controlling the three main pollutant gases is:

   a) Proper air/fuel ratio.
   b) Lowering combustion temperatures.
   c) Computerized engine management.
   d) Government regulation.

8. The stoichiometric ratio is the:

   a) Leanest practical air/fuel ratio.
   b) Richest air/fuel ratio allowed by law.
   c) Result of fuel injection.
   d) Optimum air/fuel ratio for efficient combustion.

9. Carbon dioxide and oxygen are considered "informational gases" because they:

   a) Tell us about combustion efficiency.
   b) Indicate the potential cause of certain engine problems.
   c) Are useful for diagnosis.
   d) All of the above.

10. At stoichiometric, the ratio, by weight, of air to fuel is approximately:

   a) 14:1
   b) 14.7:1
   c) 17:1
   d) 147:1

11. A high level of oxygen (O_2) in the exhaust is a good indication of:

   a) Restricted intake.
   b) Rich air/fuel mixture.
   c) Lean air/fuel mixture.
   d) Defective catalyst.

12. A high level of carbon dioxide (CO_2) in the exhaust is a good indication of:

   a) Good combustion efficiency.
   b) Rich air/fuel mixture.
   c) Lean air/fuel mixture.
   d) Leaky fuel injector.

CATALYTIC CONVERTERS

The following discussion of "Types of Catalysts" refers to the three pollutants described earlier in this manual. If necessary, review how the three pollutants — Hydrocarbons (HC), Carbon Monoxide (CO) and Oxides of Nitrogen (NO_x) — develop as a result of the combustion process.

There are two main types of catalytic converter, which differ in the chemical reactions that take place and in the number of pollutants that they minimize. The two types are:

- Oxidation catalysts (or two-way catalysts)
- Three-way catalysts

IMPORTANCE OF AIR/FUEL MIXTURE
Effective catalytic control of all three pollutants is possible only if the exhaust gas contains a very small amount of oxygen. It is necessary, therefore, to maintain precise control of the air/fuel mixture entering the engine, and to keep it very close to the stoichiometric level.

CURVE OF EFFICIENCY SHOWS A NARROW WINDOW EXISTS
The curve of efficiency as a function of air/fuel ratio indicates that when the air/fuel ratio is lean (excess of oxygen), the control of HC and CO is very good, but control of NO_x is poor. On the other hand, when the air/fuel ratio is rich (deficiency of oxygen), the control of NO_x is very good but control of HC and CO is poor. At the chemically correct mixture, a narrow window exists where the control of all three pollutants is quite good. Maintaining the exhaust contents at this precise value at which the three-way catalyst is most effective is the purpose of the O_2 Feedback System.

EFFECT OF AIR/FUEL RATIO ON CATALYTIC CONVERTER EFFICIENCY
The purpose of the three-way converter is to help clean up the NO_x, HC and CO emissions in the engine exhaust (hence the term: three-way). The process occurs in two stages. In the first stage, the catalyst encourages NO_x to break down into free nitrogen (N_2) and free oxygen with the Oxygen portion encouraged to further oxidize CO into harmless carbon dioxide (CO_2). In the second stage, additional air is injected into the exhaust gases. The Oxygen-enriched emissions pass over a second catalyst that encourages further oxidation of HC and CO into water vapor and carbon dioxide. Like the engine, the three-way catalytic converter is quite sensitive to air/fuel ratio, providing maximum overall (HC,CO and NO_x) conversion efficiency when a stoichiometric air/fuel ratio is being supplied to the engine. Using a richer than stoichiometric ratio will reduce HC and CO converter efficiency ***more*** than it increases NO_x converter efficiency. Using a leaner than stoichiometric ratio will reduce NO_x converter efficiency ***more*** than it increases HC and CO converter efficiency. Accordingly, the Oxygen Feedback System will command a stoichiometric air/fuel ratio whenever engine and driving conditions permit.

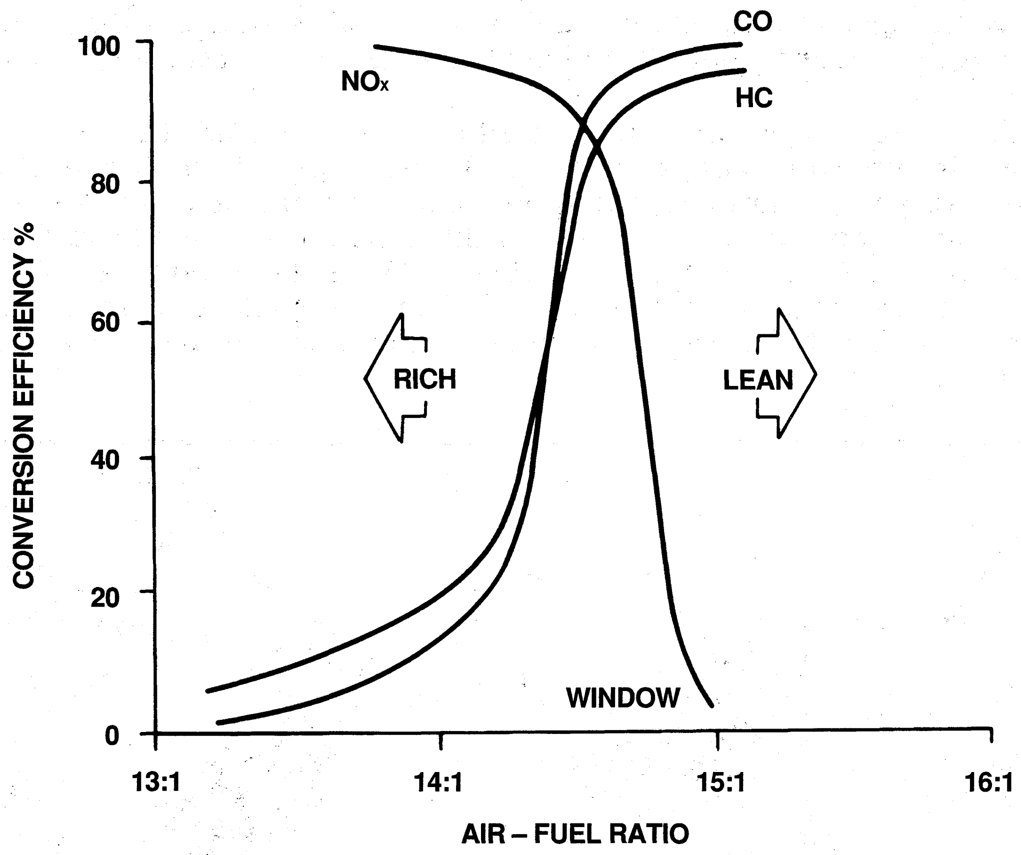


Figure 26 Characteristic Conversion Efficiencies Three-Way Catalyst

The catalytic converter is a unique emissions controlling device. It has no moving parts. It is not dependent on engine vacuum, mechanical devices or any other special control technology. It is designed for the sole purpose of decreasing exhaust emission levels. As the name implies, a catalyst triggers a chemical reaction that changes the exhaust gases that pass through it (fig. 27). A "catalyst" is an agent that causes a chemical change to occur without itself being changed by the reaction.

The catalyst is a monolith (commonly referred to as the "biscuit") that is thinly coated by certain "precious metals," such as platinum, palladium and/or rhodium. Internally, one very important design requirement of a catalytic converter is to expose the exhaust gases to the greatest possible amount of catalytic surface area without causing an excessive exhaust restriction. Thus, the biscuit has a honeycomb shape. To protect the fragile biscuit, it is cradled in a stainless steel mat (fig. 27). The mat protects the catalyst element from road shock and acts as an insulator from rapid temperature changes.

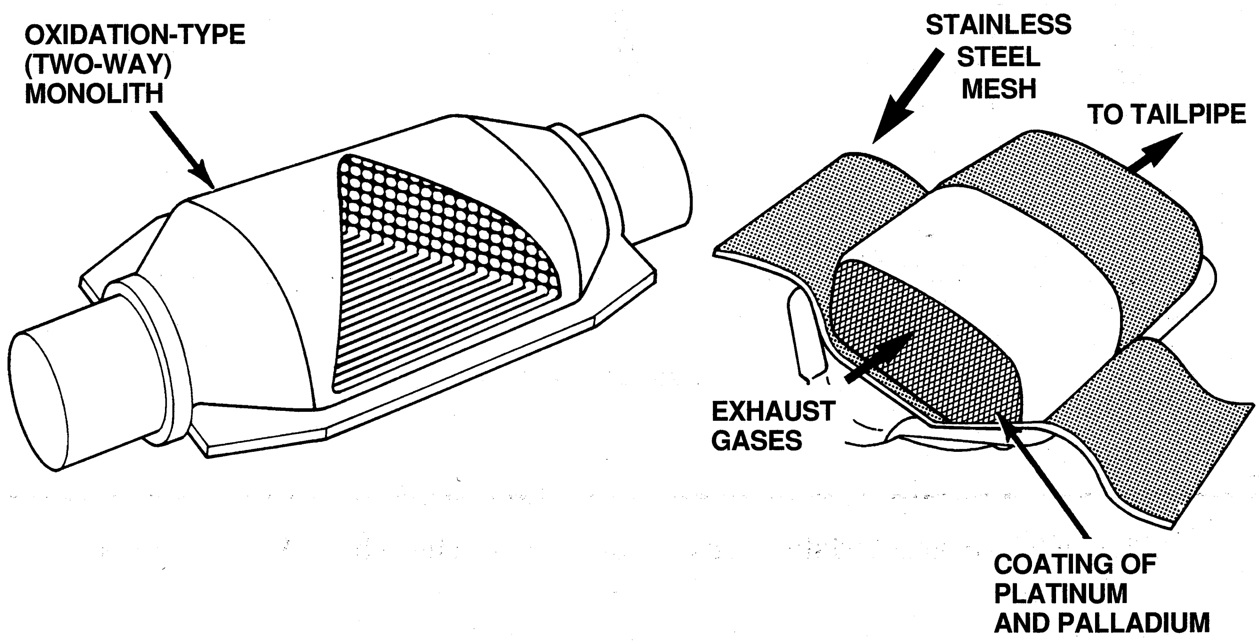


Figure 27 Oxidation-Type Monolith Converter

TYPES OF CATALYSTS

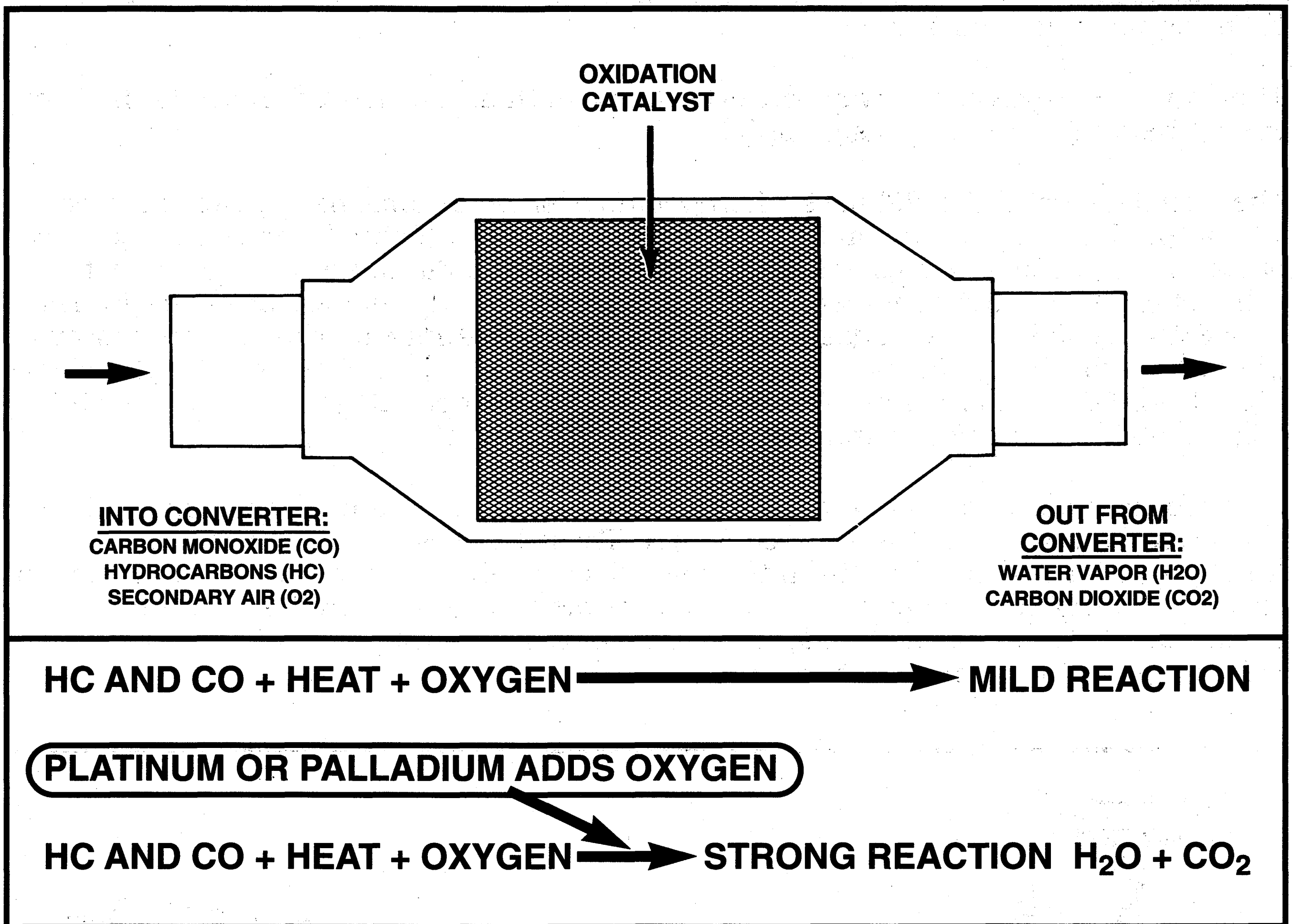


Figure 28 Oxidation Reaction

OXIDATION CATALYSTS

Oxidation converters were designed specifically to change hydrocarbon (HC) and carbon monoxide (CO) emissions into CO_2 and water vapor. Commonly called "two-way converters", the name refers to the number of pollutants affected by the converter. By supplying a sufficient amount of oxygen to HC and CO in the presence of heat and the right catalytic material (either platinum or palladium), a chemical reaction will occur (fig. 28). That reaction actually breaks the HC and CO bonds and results in the formation of harmless carbon dioxide (CO_2) and water (H_2O).

Oxygen is required to cause the reaction, so this process is referred to as ***oxidation.*** In some engine systems, the needed oxygen is supplied by an air pump or aspirator from the secondary air system.

There are two types of two-way converters, monolith and pelletized. Both do the same thing, the difference is in design only.

The monolith design (fig. 29) uses a honeycomb of small ceramic passageways coated with a thin layer of platinum and palladium as catalysts. Pelletized converters use a bed of aluminum oxide pellets coated with platinum and palladium. Both designs direct exhaust gases over the honeycomb or the pellets, where they contact the catalysts. The temperatures of the exhaust gases increase, and they continue to oxidize. This converts the hydrocarbon (HC) and carbon monoxide (CO) into water (H_2O) and carbon dioxide (CO_2) before they enter the muffler. Reaching the proper operating temperature for this (approx 500°F) reaction is commonly known as "lighting off."

Two special types of oxidation catalyst are known as the mini-oxidation, or ***mini-ox*** converter, and the ***close-coupled*** converter. These have essentially the same function, and get their name from their small size and the fact that they are installed close to the engine. The mini-ox and close-coupled converters are fast-lightoff oxidation catalysts that help reduce start-up emissions and pre-treat the exhaust before it reaches the main converter.

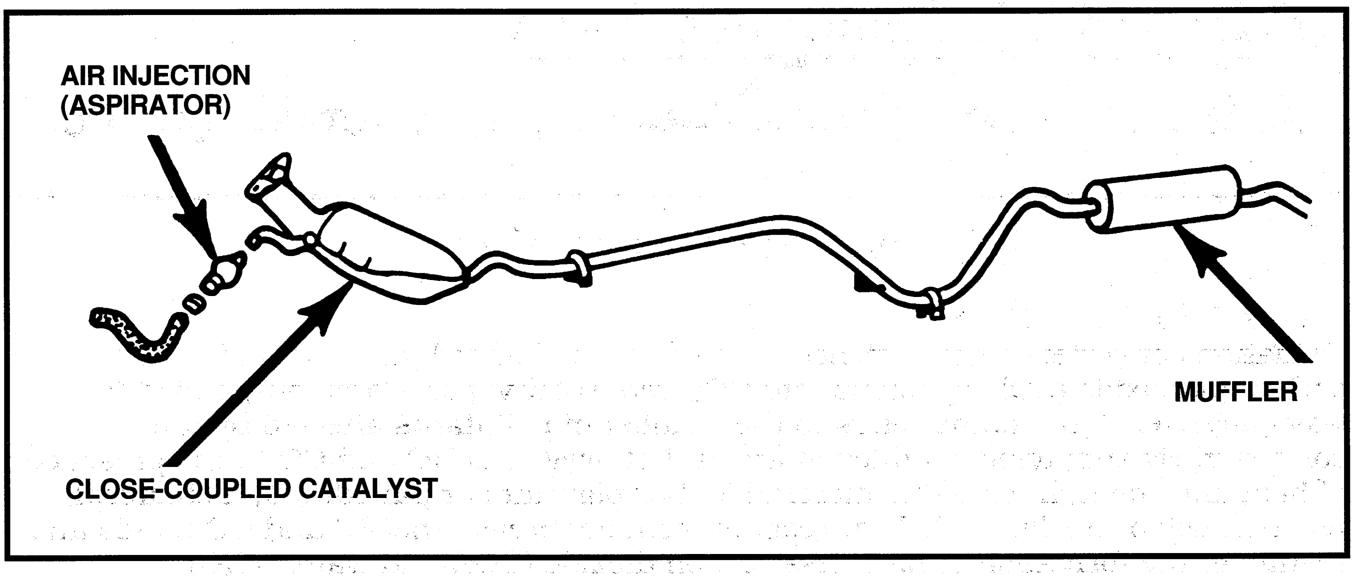
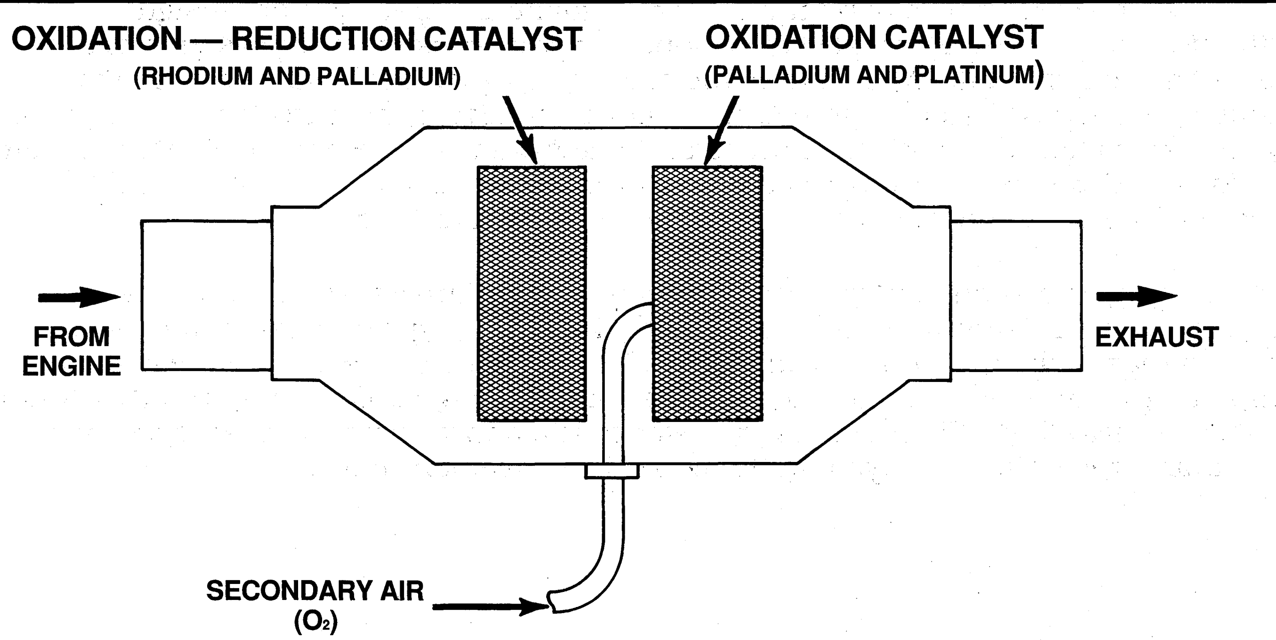


Figure 29 Close-Coupled Converted

OXIDATION AND REDUCTION (THREE-WAY)

As government regulations became more stringent, automobile manufacturers needed a more effective means to reduce the third type of pollutant, namely oxides of nitrogen (NO_X). To solve this problem, three-way catalysts (fig. 30) were introduced in the late 1970s. Three-way converters use the metal rhodium, an effective catalyst for NO_X pollutants. The chemical reaction that occurs is quite different than the oxidizing process used to control HC and CO. In this process, the NO_X is "reduced" to harmless nitrogen and oxygen. Instead of oxygen being added, it is taken away. Thus, this chemical reaction (called a "reduction" reaction) is just the opposite of the oxidation reaction described above. Excessive amounts of oxygen in the exhaust stream could actually inhibit the reduction process. To decrease all three pollutants, the three-way catalyst relies heavily on proper fuel/air control. It is the most common type of catalyst used today.



FROM ENGINE (TYPICAL VALUES)	
CO	0.1 - 1.0%
HC	50 - 200 PPM
CO_2	13.6 - 14.3%
O_2	0.3 - 0.7%
NO_X	1200 PPM

BETWEEN CHAMBERS (TYPICAL VALUES)	
CO	0 - 0.5%
HC	0 - 50 PPM
CO_2	14.7 - 15.5%
O_2	0 - 0.5%
NO_X	120 PPM

EXHAUST (THEORETICAL VALUES)	
CCO	0
HC	0
CO_2	9.6 - 12%
O_2	2.5 - 5.5%
NO_X	120 PPM
WATER VAPOR	
NITROGEN	

PLATINUM OR PALLADIUM ADDS OXYGEN

HC AND CO + HEAT + OXYGEN → H_2O + CO_2

RHODIUM REMOVES OXYGEN

NO_X + HEAT → NO_X (LOWER LEVELS)

} LOWER LEVELS OF HC, CO, NO_X PLUS H_2O, CO_2, OTHER GASES

Figure 30 Oxidation-Reduction Reaction (Three-Way Catalyst)

There are two types of three-way converters: without air and with air. A three-way converter without air looks like a two-way converter inside, but the substrate is coated with rhodium and palladium. Because of varying loads on the vehicle, additional air may sometimes be required to provide enough oxygen for the catalyst to work. To effectively reduce all three pollutants, a three-way converter with air is used. This converter has two chambers, separated by an inlet tube from the air injection system or aspirator (described later in this course). The front chamber is coated with rhodium and palladium, to reduce NO_x emissions. A second chamber, coated with palladium and platinum and located downstream of the air inlet, uses the additional air to oxidize hydrocarbons and carbon monoxide. Thus, the amount of all three pollutants — HC, CO and NO_x — is decreased.

EXHAUST SYSTEM CONFIGURATIONS

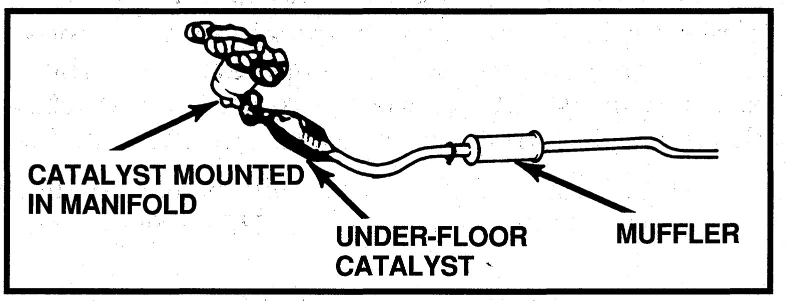
Catalyst types vary, not only by their internal make-up, but by their design configurations as well. Examples of various car and truck exhaust systems are shown on the next page. Note that some catalysts, which are mounted near the engine, are referred to as "close-coupled". Other catalysts, mounted further from the engine, are called "under-floor" catalysts. Some systems have only one catalyst, some have two or three. Some catalysts require air injection, some do not. One catalyst (used on 2.6L vehicles) was mounted in the exhaust manifold.

Even with these obvious differences, you may find exhaust systems that have incorrect parts. It is quite possible to find that a wrong type of catalyst has been installed (particularly with the availability of "after-market" parts). Further, some components (such as secondary air system components) could be incorrectly routed, damaged or missing. When necessary, refer to the appropriate manual to verify a particular application. Always use the correct replacement parts.

EXAMPLES OF EXHAUST SYSTEM CONFIGURATIONS USED ON CHRYSLER VEHICLES

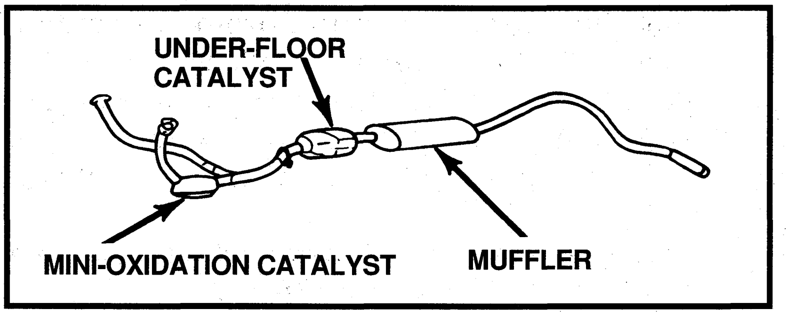
1983 2.6L Passenger Car

Two catalysts; one in manifold, one under-floor.



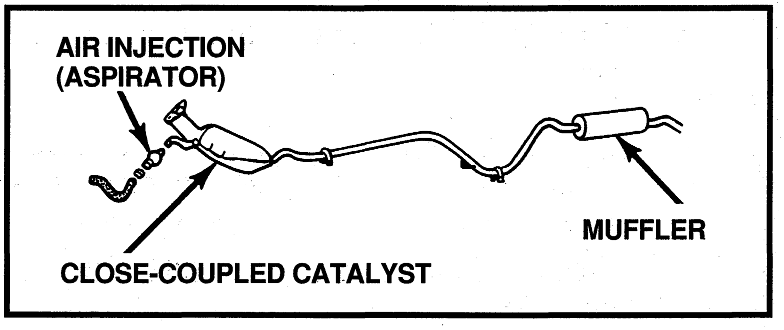
1985 5.2L B-250 Van

Two catalysts; small (Mini-Ox) near engine, larger catalyst under-floor.



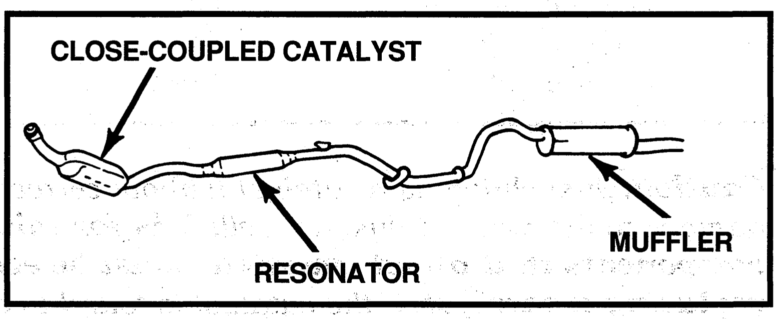
1990 2.2/2.5L TBI Passenger Car
Manual Trans)

Single catalyst with aspirator air injection.



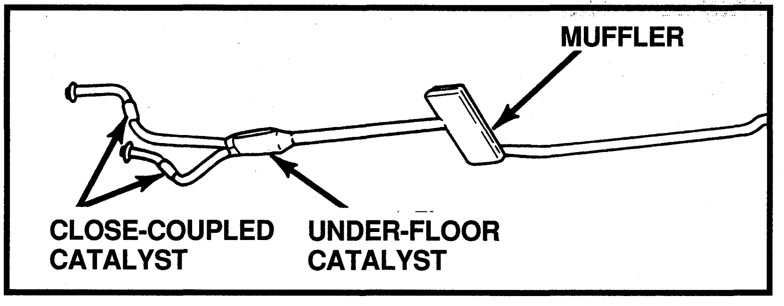
1993 3.0L Passenger Car

Single catalyst; without air injection, resonator after catalyst.



1993 3.3L and 3.5L LH

Three catalysts; one on each engine bank (Y-pipe) and one under-floor.



THE EFFECTS ON CATALYST REACTION

Exhaust temperatures are extremely important to the function of catalytic converters. The desired chemical reactions most readily occur at high temperatures. In fact, the catalyst starts to operate when the exhaust temperatures reach about 500°F. Catalytic Converters experience reductions in conversion efficiency through the normal course of operation. The three primary causes of these reductions are:

- High temperatures, which will oxidize rhodium (Rh) irreversibly affecting the conversion of hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NO_x)

- Contamination - While high temperatures accelerate oxidation of the catalyst material, low temperature promotes contamination or poisoning of catalyst materials. Contaminants collect on the catalyst surface restricting exhaust gases to and from active catalyst sites where the metals are located. Hydrocarbons are primarily affected because they are larger molecules than carbon monoxide (CO) and oxides of nitrogen (NO_x) molecules.

- Inadequate air/fuel control, which can result in lean mixtures and high temperatures. A lean air/fuel ratio promotes irreversible reactions of rhodium (Rh) with other metal oxides when the converter bed exceeds temperatures of 500°C (932°F). Also, base metals are irreversibly converted to a different, less reactive form.

COMMON CONTAMINANTS

CONTAMINANT	MAJOR SOURCE	GAS MOST AFFECTED
Lead (Pb)	Fuel	HC
Phosphorus (P)	Oil	HC, CO
Silicone (Si)	Fuel	HC, CO, NO_x
Sulfur (S)	Fuel	HC, CO, NO_x (esp. Rich)

Caution: *Just changing a catalyst without correcting the real problem could result in damage to the new catalyst as well.* ***It is for this reason that all other components that affect emissions must be evaluated first, before ever replacing a catalyst.*** *If the catalyst is found to be bad, it cannot be repaired; it can only be replaced.*

Activity 4

EXHAUST TEMPERATURE VERSUS CATALYTIC CONVERTER ACTIVITY

This activity demonstrates the effect of catalytic conversion (oxidation) on exhaust system temperatures. You will measure the difference in exhaust temperature before and after the catalytic converter twice, once before the converter is working and once after the converter is working.

Directions:

1. Make sure the engine is cold (off for at least 15 minutes).
2. Check the engine coolant temperature (ECT) with a scan tool before starting the engine, and record in the table below.
3. Start the engine.
4. Immediately after starting the engine, measure the surface temperature of the exhaust pipe just before the converter and just after the converter, using a digital thermometer. Record both readings in the table below.
5. Wait at least 3 minutes for the engine to enter closed loop operation.
6. Check the ECT again with the scan tool and record in the table below.
7. Again measure the surface temperature of the exhaust pipe just before the converter and just after the converter. Record both readings in the table below.
8. Calculate the temperature difference before and after the converter (cold engine) and record in the table below.

	COLD ENGINE	***WARM ENGINE***
Engine coolant temperature		
Exhaust pipe temp. after converter		
Exhaust pipe temp. before converter		
Difference in temp. (After-Before)		

9. Calculate the temperature difference before and after the converter (warm engine) and record in the table below.
10. Using the exhaust gas analyzer, test the emissions at idle and record the results:

HC __________ ppm

CO __________ %

CO_2 __________ %

O_2 __________ %

NO __________ ppm

Activity 4

1. What is the difference in exhaust pipe temperature before and after the converter WHEN THE ENGINE IS COLD? ____________________

2. What is the difference in exhaust pipe temperature before and after the converter WHEN THE ENGINE IS WARM? ____________________

3. What does this tell you about the relationship between catalyst operation and temperature?

____

____

____

____

4. How would additional oxygen from an air pump affect catalyst temperature?

____

____

____

____

5. If O_2 is above 0.5%, the catalyst is getting sufficient oxygen to function properly. If CO is above 0.5%, the catalyst is not oxidizing fuel from the engine. Did the emission test indicate that the catalytic converter is working properly? Why or why not?

____

____

____

____

Notes:

____

____

____

____

PRE-COMBUSTION AND POST-COMBUSTION CONTROLS

All regulated auto emissions result from the properties and combustion of fuel. Three sources have been identified and are regulated by federal and state governments — evaporative emissions, crankcase emissions and exhaust emissions.

All three sources produce HC. Crankcase and exhaust emissions also include CO and NO_x. Various designs have evolved to control emissions.

All of the systems described in this course can be grouped into two general types. The first group consists of those systems which prevent the formation of harmful emissions. This is the preferred approach to pollution control, because it's more effective to prevent the formation of pollutants right up front than it is to get rid of them after they've been produced. The methods and devices in this first group are known as ***pre-combustion*** systems.

The systems in the second group have the job of reducing the level of pollutants after they have been formed. They are known as ***post-combustion*** systems.

Table 8 identifies the major emissions-control systems, classifies them as pre-combustion or post-combustion, and shows what pollutants they control.

Table 8 Pre-Combustion and Post-Combustion Control Systems

SYSTEM	*CLASSIFICATION*	*POLLUTANT CONTROLLED*
Engine design/operation	Pre-combustion	HC, CO, NO_x
Computerized engine control	Pre-combustion	HC, CO, NO_x
Spark control	Pre-combustion	HC, CO, NO_x
Exhaust gas recirculation	Pre-combustion	NO_x
Evaporative controls	Pre-combustion	HC
Air injection	Post-combustion	HC, CO
Catalytic converters	Post-combustion	HC, CO, NO_x

Let's take a brief look at each of these systems to see why they're categorized as they are, and how each helps to reduce emissions:

ENGINE DESIGN/OPERATION

The ultimate pre-combustion "technique". Assuming that it's better to prevent emissions than it is to treat them later, this is the best possible approach to automotive pollution control. A well-designed engine reduces the need for add-on devices and post-treatment methods. In the 1970s, engineers scrambled to meet federal and state emissions regulations with a host of devices and techniques that reduced performance along with emissions levels.

In the 1980s, the trend shifted toward starting with a clean sheet of paper and designing new engines with the express intent of having low emissions levels and uncompromised performance. Advances in the areas of manifold design, combustion chamber design, fuel injection, and computerization have enabled new cars to be solid performers while being environmentally responsible.

CO, for example, can be controlled by fuel system design. Delivering less fuel reduces the chance for partial combustion. A major consideration for CO is equal fuel distribution. This is controlled by intake manifold design and the use of fuel injection. Leaner air/fuel mixtures assure enough air for complete oxidation to CO_2 during normal driving. The heated air inlet causes better vaporization of fuel in a cold engine. Advanced ignition timing allows more time for complete burning. However, this can raise HC, and it also raises combustion temperatures, which leads to the formation of NO_x.

NO_x forms at high combustion temperatures. These occur with lean mixtures and advanced timing (which also produces high power output and good fuel economy). Cooler combustion is provided by fuel control and moderate ignition timing advance. It is also achieved through the use of exhaust-gas recirculation to dilute the fresh air/fuel mixture with exhaust gases.

When diagnosing emissions problems, verifying base engine performance should be your first consideration. This is especially true when no trouble codes are being set. Any mechanical problem can lead to excess emissions, and the following items should be checked as possible causes:

- Engine Vacuum — must be above the minimum specified for your engine refer to the Service Manual for specifications.
- Engine Valve Timing — must be within specifications.
- Engine Compression — must be within specifications.
- Engine Exhaust System — must be free of any restrictions.
- Engine PCV System — must be the correct application.
- Engine Drive Sprocket — must be properly positioned.
- Torque Converter Stall Speed — must be within specifications.
- Power Brake Booster — no internal vacuum leaks.
- Fuel — must be of proper quality and free of contamination.
- Fuel Injectors — check for plugged, leaking, or restricted injectors, or control wire not connected to correct injector.

The following vacuum gauge readings (fig. 31) are indicators of possible mechanical engine problems:

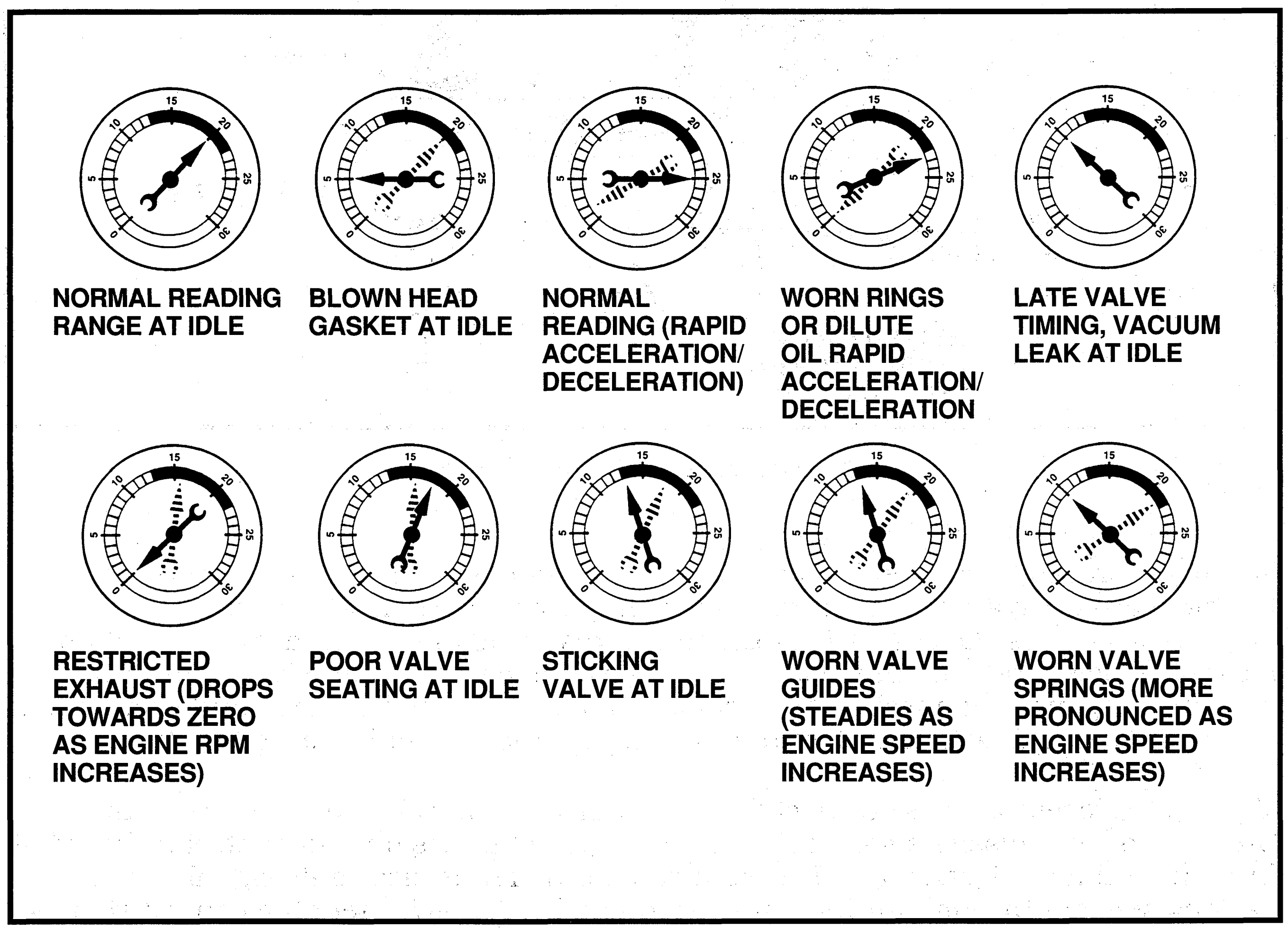


Figure 31 Typical Vacuum Readings (3.9L/5.2L/5.9L SFI)

One way of controlling emissions through engine design is by use of a ***heated air inlet.*** Also called a thermostatic air system, the main component in most of these systems is the Thermostatic Air Cleaner (TAC). Traditionally, a cold engine required a rich mixture because the fuel does not vaporize well when it is mixed with cold air. A thermostatic air cleaner (fig. 32) takes warm air from around the exhaust manifold and directs it through a hot air duct to the air cleaner. This achieves the following results:

- Heated inlet air provides better fuel vaporization.
- Better vaporization means leaner mixtures can be used.
- Leaner mixtures result in reduced levels of HC and CO.

Note: *Earlier six and eight cylinder vehicles used a heated crossover to assist in fuel atomization during cold engine operation.*

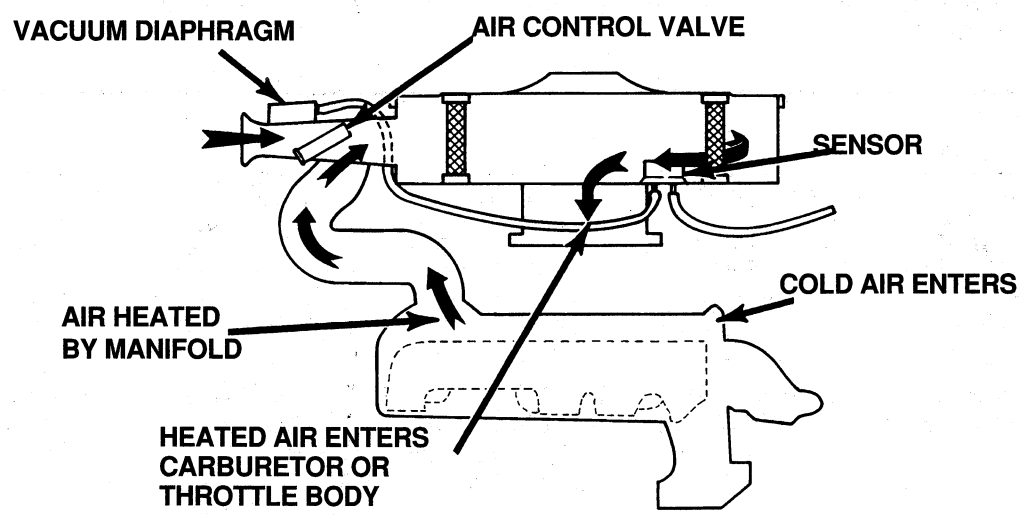


Figure 32 Heated Air Inlet System

COMPUTERIZED ENGINE CONTROL

The microprocessor can be considered a pre-combustion device, but its role as an engine manager places it in an entirely different league from EGR valves and charcoal canisters. As regulations tightened, resulting in more and more pollution control devices, the one thing lacking was a way to control it all. Pre-computerized systems responded to mechanical feedback such as vacuum signals, and there was a lot of conflict as to which devices and which conditions should take precedence.

The microprocessor, these days called a Powertrain Control Module (PCM), has brought to the emissions control system a degree of precision and control unheard of little more than a decade ago. The PCM constantly reads electronic signals from various sensors throughout the powertrain and responds by sending control signals to various devices as needed.

Technicians should be careful not to assume that the PCM is at fault in all repair situations. Items not monitored by the computer that can affect driveability include:

- Engine mechanical condition
- Ignition system condition
- Exhaust system condition
- Basic timing
- Routing of hoses and tubing

One computerized engine control device, the ***oxygen (O_2) sensor***, is located in the exhaust manifold and detects the amount of oxygen in the exhaust stream (fig. 33). This information tells the computer whether the fuel mixture is too rich or too lean. The computer can then have the fuel injectors or electronic feedback carburetor adjust the fuel mixture as necessary.

Vehicles with O_2 sensors (essentially every modern passenger car and light truck on the road today) operate in one of two modes – open loop or closed loop. When a cold engine is first started, it is said to be operating in open loop. This means that the computer is not yet responding to signals from the O_2 sensor, but is operating from a pre-programmed set of instructions instead. These instructions tell the computer how to control fuel delivery for optimum performance and emissions control.

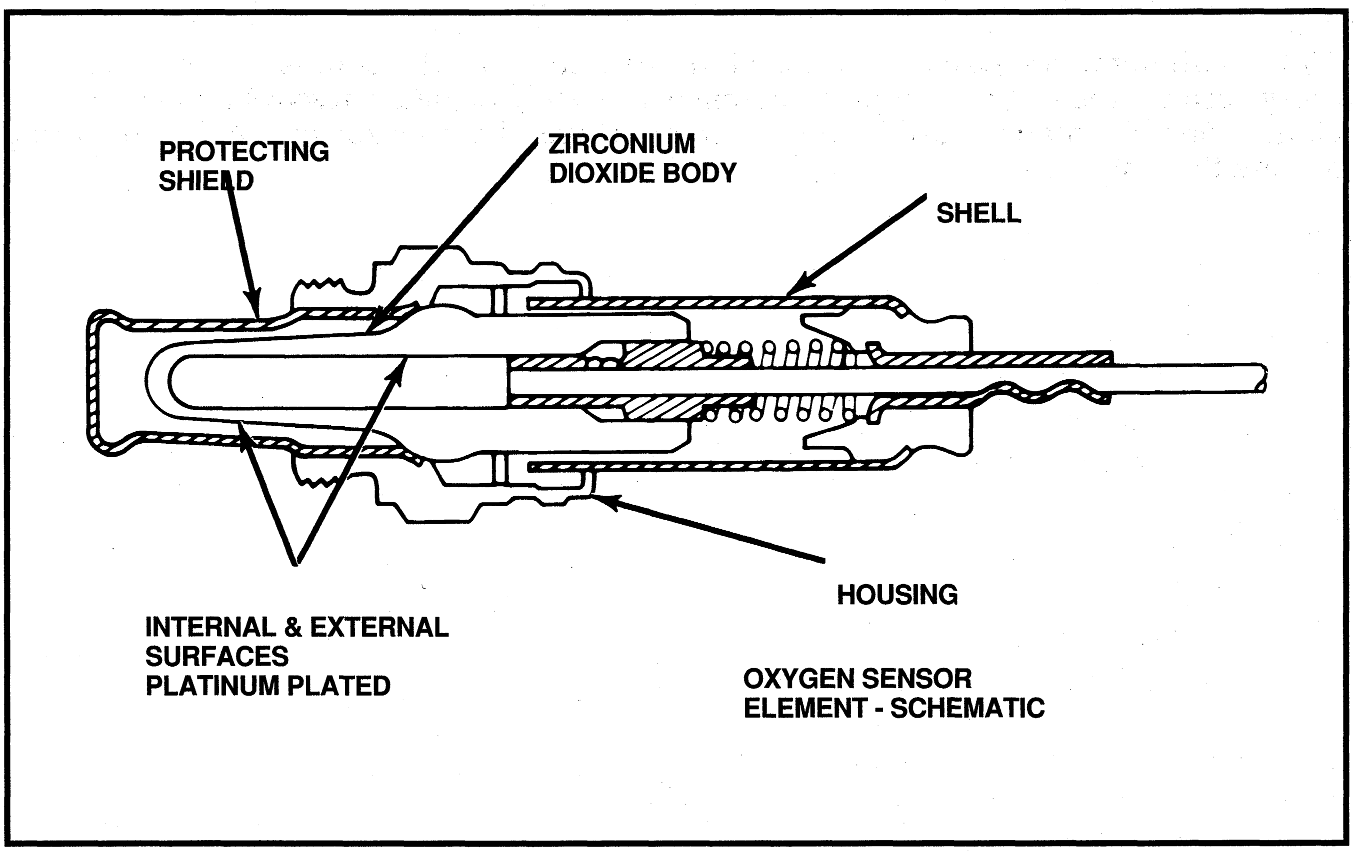


Figure 33 Oxygen Sensor

After the engine has warmed up, the O_2 sensor is sending reliable signals to the PCM, and the system goes into closed loop. In closed loop, the PCM controls fuel delivery based on signals from the O_2 sensor rather than from a predetermined program. Depending on the engine package, close loop operation is triggered in several ways. Timers, coolant temperature sensors, vehicle operation, and O_2 sensor voltages are some of the parameters used by the computer to initiate closed loop operation.

Computerized adjustments to the base fuel delivery are referred to as fuel trim, or "adaptive memory". This system uses a short term and a long term ***fuel trim***. The short term is updated only in closed loop, based on the O_2 sensor signal. The short term fuel trim will, in turn, update the long term fuel trim, which affects fuel delivery in open or closed loop. The short term can increase or decrease fuel by about ±17%, while the long term can increase or decrease fuel by about ±25%.

With an ability to analyze thousands of inputs and make thousands of decisions every second, the engine computer (along with well-designed software) has almost single-handedly made possible the design of smaller, high-performance, low-polluting automotive engines.

IGNITION CONTROL

Also known as ignition timing, this pre-combustion system has a tremendous effect on overall emissions output. Ignition timing determines the precise moment at which the electrical impulse is sent to the spark plug to ignite the air/fuel mixture. By controlling this function as precisely as possible before combustion, harmful emissions are avoided so that they don't have to be treated later.

The optimum moment for this ignition has long been a subject of debate, and different engineers in the past have relied on contradictory theories to achieve the same desired balance between efficiency, power, and clean emissions. When pollution-control research was in its infancy, some systems were designed to advance the spark during deceleration, while other systems eliminated advance under the same condition.

Improper ignition timing can affect the levels of:

- CO.
- HC.
- NO_X.

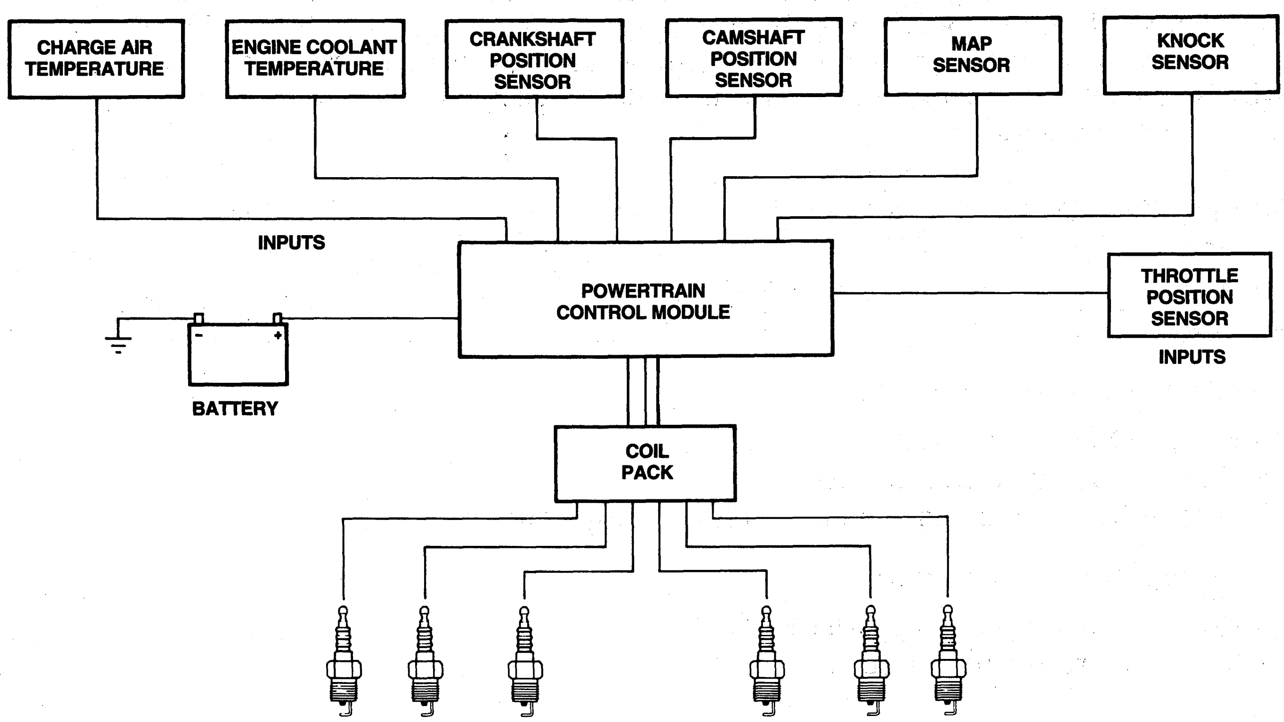
Excessive advance can cause:

- High CO from partially burned fuel.
- High HC from unburned fuel.
- High NO_X from excessive combustion temperatures.

Excessive retarding can cause:

- High CO from partially burned fuel.
- High HC from unburned fuel.

Modern technology has refined the theories of ignition control, and the system can now be managed entirely by electronic means. The engine computer responds to various sensors and is programmed with instructions that tell it how to change the ignition timing for different situations. The newest technique, called Distributorless Ignition System (DIS) (fig. 34), replaces the distributor entirely and gives the computer direct control.



SPARK PLUG CONDITIONS THAT AFFECT EMISSIONS

LOW VOLTAGE	MISFIRE	HEAT RANGE
• Partial combustion	• Caused by very low voltage or fouling	• Too cold — partial combustion; high CO and HC
• High CO, HC	• High HC	• Too hot — High NO_x

Figure 34 Computer-Controlled (Distributorless) Ignition

EXHAUST GAS RECIRCULATION

The exhaust gas recirculation system (EGR), consists of the EGR valve, a control mechanism, and related hoses and passages. Knowledge of this system is particularly important because EGR directly affects driveability.

The EGR system does not operate below a specified temperature. The system also varies operation depending on engine load (throttle position). When operating, the system directly mixes exhaust gases with the combustion mixture (in the intake manifold). This interferes with efficient combustion and power output. The result sometimes causes rough engine performance that appears to be the result of a lean carburetor. So EGR malfunctions must be diagnosed carefully to avoid unnecessary carburetor repairs.

"Cooler" Combustion

Since NO_x forms in high-temperature combustion, the problem solution is cooler combustion. Unfortunately, lean mixtures which reduce HC and CO increase NO_x. Advanced timing which improves fuel economy also increases NO_x. So NO_x is controlled through the dilution of the air/fuel mixture.

Air/Fuel Dilution

Dilution means to make weaker or watered-down. A glass of orange juice diluted with 25% water, will have weaker flavor than 100% orange juice. The EGR system dilutes the air/fuel mixture with exhaust gases. Burned exhaust gases are basically inert or "dead" air. They won't react chemically or burn anymore. A percentage of exhaust gases mixed with the air/fuel fixture "dilutes" the strength. The result is less fuel for the same volume of mixture, and reduced combustion temperature and pressure. Which means less NOx.

EGR and Driveability

The dilution of the air/fuel mixture by EGR interferes with combustion. This causes some engine roughness. The more dilution, the lower the NO_x and the rougher the engine performance.

The EGR system meters a portion of exhaust gases into the intake manifold. The gases dilute the fuel charge to control NO_x. The system is well-designed to add just enough EGR to control NO_x, and yield the best driveability. Some basic guidelines for controlling EGR are shown in Table 9.

EGR Valve

The exhaust gas recirculation (EGR) valve is a vacuum operated, poppet-type (fig. 35). The valve fastens to the intake manifold delivery port. The mounting block has two passages: one for exhaust gas into the valve, and one for metered exhaust gas flow out of the valve. The stem operates the poppet valve which seats in the mounting block to close off EGR flow.

The upper part of the valve contains a vacuum diaphragm, which is attached to the stem. The diaphragm and stem are spring-loaded to close the poppet valve against the seat. The valve can move from closed to open, or to metering positions in between, depending on the amount of vacuum applied to the diaphragm.

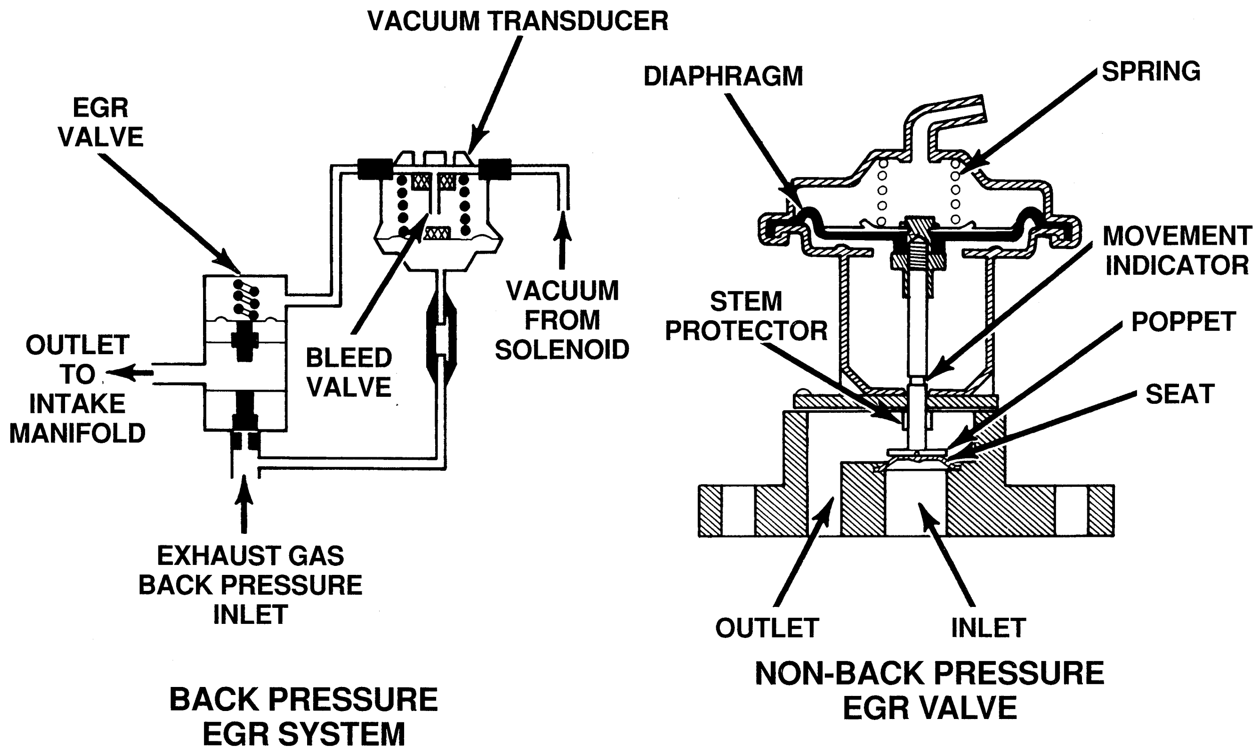
EXHAUST GAS RECIRCULATION

Table 9 EGR Control

DON'T WANT EGR @	BECAUSE
Idle	Causes roughness
WOT	Reduces maximum power
Cold Start / Light Throttle	Engine not hot enough to produce much NO_X; causes hard starting, roughness, hesitation, stalls

Table 10 EGR Flow

ENGINE CONDITION (HOT)		HOW MUCH FLOW
Off Idle / Light Throttle	Minimum Air fuel mixture, low combustion temperatures	Very little off idle Small amount at light throttle
Medium Throttle —	Moderate air/fuel mixture and combustion temperatures	Moderate amount proportional to air/fuel flow
Heavy Throttle (Not WOT) —	Rich mixtures, high power, high combustion temperatures	Maximum flow
Acceleration —	Need smooth engine performance and rich mixtures	Very little until speed stabilizes



EXHAUST-GAS RECIRCULATION SYSTEM

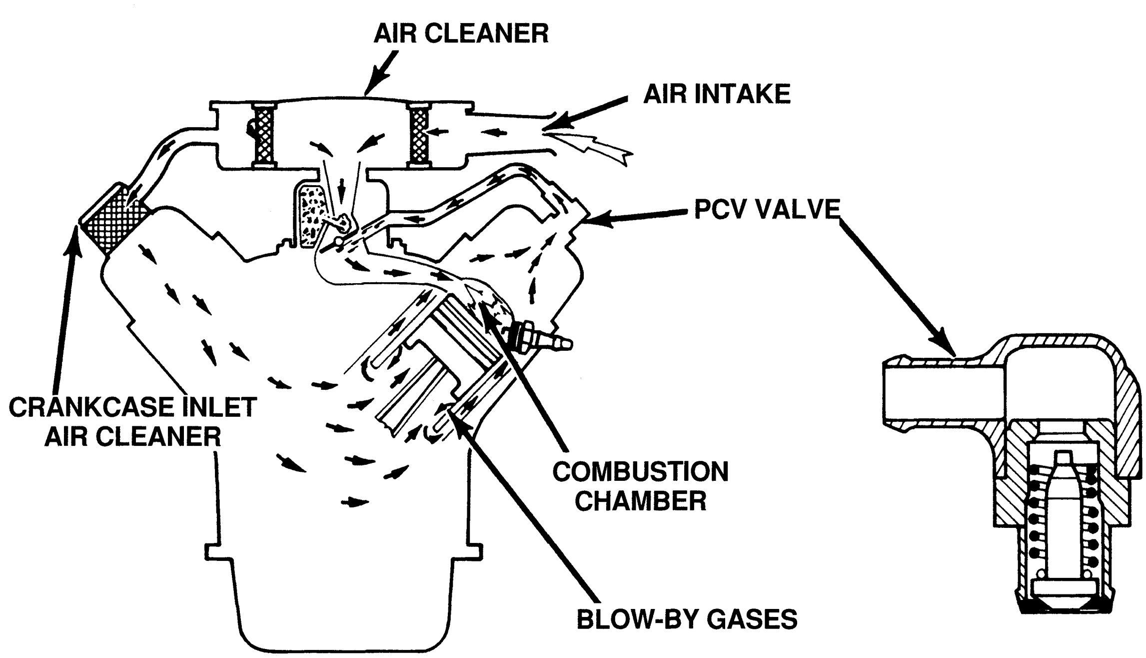
- REDUCES NO_x BY REDUCING COMBUSTION TEMPERATURE
- REDUCES TEMPERATURE BY DILUTING INTAKE CHARGE WITH SMALL AMOUNT OF EXHAUST GAS
- OPERATES UNDER THE FOLLOWING CONDITIONS (TYPICAL):
  - — WARM ENGINE
  - — NOT AT IDLE
  - — NOT AT WIDE-OPEN THROTTLE
- POSSIBLE PROBLEMS:
  - — STUCK CLOSED: KNOCKING (DETONATION) AND EXCESSIVE NO_x
  - — STUCK OPEN: ROUGH IDLE OR STALLING FROM TOO MUCH EXHAUST IN THE INTAKE CHARGE. HIGH HC, CO.

Figure 35 Exhaust Gas Recirculation (EGR) System

Crankcase Ventilation

Crankcase emissions are engine vapors escaping past the piston rings, out of the engine, and into the atmosphere. In modern vehicles, the engine crankcase is sealed by gaskets and caps to minimize vapors leaking to the atmosphere. Vapors are re-routed into the engine intake manifold for burning in the engine. Fresh air ventilates the crankcase. This positive ventilation is controlled by the positive crankcase ventilation (PCV) valve (fig. 36).

In keeping with the general sense of "not needing further treatment" which describes pre-combustion devices, crankcase ventilation fits in here. Crankcase ventilation is actually an environmental "bonus" in the sense that it was developed as an engineering necessity before the harmful environmental effects of crankcase gases were even known. The only adaptation that had to be made from the original crankcase ventilation systems is that the present-day systems are completely closed. Crankcase vapors are continuously recirculated, with nothing being discharged into the atmosphere.



CONDITIONS FOR CRANKCASE VAPOR FLOW

- ENGINE OFF OR ENGINE BACKFIRE — NO VAPOR FLOW
- HIGH INTAKE MANIFOLD VACUUM — MINIMAL VAPOR FLOW
- MODERATE INTAKE MANIFOLD VACUUM — MAXIMUM VAPOR FLOW

Figure 36 Positive Crankcase Ventilation (PCV) System

Related to positive crankcase ventilation is the issue of fuel in the crankcase. Some common causes of fuel in the crankcase include:

- Engine in poor mechanical condition.
- Leaking fuel injector.
- Defective fuel pressure regulator.

Fuel in the crankcase leads to a rich mixture. The following responses may occur:

- Fuel vapors are drawn into intake through PCV system.
- Mixture is rich because of increased fuel amount.
- O_2 sensor detects rich mixture and adjusts accordingly.

One way of detecting fuel in the crankcase is through exhaust gas testing. The procedure is as follows:

- Test the exhaust gas ahead of the catalytic converter and with the air pump (if equipped) disconnected.
- Record CO reading.
- Test the exhaust gas again with the PCV valve removed from the engine valve cover.
- Record CO reading again.
- If CO decreases by more than 1.5%, the crankcase is probably contaminated with fuel.

Note: *Similar test results could occur if the catalytic converter is contaminated or otherwise nonfunctional.*

FUEL PROPERTIES

There are several properties of fuel which could affect the production of exhaust emissions, including:

- Volatility -
  - Summer blend.
  - Winter blend.
- Presence of oxygenates (clean air gasoline).
- Presence of lead or other additives.

Volatility

Volatility is a basic fuel property. It indicates how easily a fuel will evaporate, or vaporize (change from liquid to vapor). You can't do anything in the field to change the basic volatility of the fuel supply. It is controlled by the blending of various hydrocarbons during the manufacture of the gasoline. But it is helpful to understand how volatility relates to performance and emissions control.

Gasoline is blended differently for various regions and seasons to improve cold-weather starts and warm-ups as well as hot-weather operation. At designated times of the year, the fuel supply to retail dealers is changed. This changeover takes place in accordance with temperature records for the various regions. As cooler months approach, more volatile winter fuels are supplied. When warm weather nears, less volatile fuel is supplied. Normally, this shift causes no problems. However, there are certain times when volatility problems could affect emissions.

If summer fuel stays in the tank for a long time (such as during storage), the light ends of the fuel will eventually evaporate. Remember that summer fuel is not as volatile as winter fuel. After several months, all of the light ends will evaporate and the remaining fuel in the tank will not be very volatile. If the car is operated with that fuel, and an early cold day occurs, the fuel won't be able to vaporize or start the engine. Even if the engine starts, the warm-up could be rough. Spark plugs can become wet with fuel and not ignite the mixture. This leads to excess hydrocarbons going out the exhaust. In this case, you simply have to replace the old fuel supply with fresh fuel blended for the current season. Table 11 summarizes how improper volatility can affect emissions.

Table 11 Effects of Fuel Volatility on Emissions

VOLATILITY TOO LOW:	*VOLATILITY TOO HIGH:*
• Poor cold performance, resulting in increased HC and CO emissions. • Increased deposits in crankcase, combustion chamber, and spark plugs, resulting in increased HC emissions.	• Higher evaporative emissions, resulting in increased HC in the atmosphere. • Canister overload, resulting in high HC emissions.

Leaded Fuel

In the days before catalytic converters, regular leaded fuel was the standard for automotive use. Leaded fuel is composed of gasoline and a lead additive (tetra-ethyl lead). Lead reduces knock by slowing down the burning rate of gasoline and raising the octane rating. Fast burning is more like an explosion, which results in knock. Slower burning reduces the tendency to knock. Premium leaded gasoline contained a higher lead content and a correspondingly higher octane rating. It was commonly used in high-compression, high-performance engines.

Unfortunately, lead deposits coat the inside of the catalytic converter and render it useless. As little as one tank of leaded fuel can ruin a catalytic converter. For this reason, all vehicles which have catalytic converters must run on unleaded fuel. Fuel additives not recommended by the manufacturer can also cause converter problems. Consult the Service Manual and instruct owners to consult their Owner's Manual to see what's recommended for their vehicle.

Unleaded Fuel

Vehicles with catalytic converters run on unleaded fuel, whose anti-knock characteristics are provided by the basic composition of the gasoline instead of by lead-based anti-knock compounds. As with premium leaded fuel, premium unleaded fuel has additional anti-knock properties to raise the octane rating. Unleaded fuels are cleaner-burning than leaded fuels. However, the absence of the lubricating property of lead requires hardened engine valve components to resist wear.

Table 12 summarizes some of the properties of leaded, unleaded, and oxygenated fuels.

Table 12 Fuel Properties

TYPE OF FUEL	***PROPERTIES***
Leaded (Regular and Premium)	High octane Good lubricating properties Creates lead deposits Coats catalyst and renders it useless
Unleaded (Regular and Premium)	Cleaner engine oil than leaded Cleaner combustion chamber than leaded Lower octane than leaded Excessive valve train wear (without hardened materials)
Gasohol (10% Ethanol, 90% Gasoline)	Energy alternative Higher octane Cleaner combustion chamber Cleaner engine oil Lean mixture/hot vapor properties (in some engines) Attraction to water

Activity 5

IDENTIFYING COMPONENT LOCATION AND FUNCTION

AT THE VEHICLE

Directions:

For each of the emissions control components in the table below, briefly describe its location on the vehicle (for example, "on the left side of the engine compartment near the battery," or "on the passenger side dash panel in the engine compartment") and state whether the component is a pre-combustion control ("Pre") or a post-combustion control ("Post").

Note: *The "right" and "left" sides of the vehicle always refer to facing forward. In other words, the driver's side is the left side and the passenger side is the right side.*

Note: *If the component does not exist on your vehicle, write "NA" (Not Applicable) in the LOCATION column.*

COMPONENT	***LOCATION***	***PRE OR POST***
Air Pump		
Catalytic Converter		
EGR Valve		
Heated Air Inlet		
O_2 Sensor(s)		
PCV Valve		
Purge Solenoid		
Vapor Canister		

Activity 5

REVIEWING COMPONENT FUNCTION

DIRECTIONS:

Choose the most correct answer for each question.

1. Failure of this component is likely to result in rough idle or high NO_x production:

   a) PCV valve.
   b) EGR valve.
   c) Air pump.
   d) O_2 sensor.

2. Failure of this component could result in excessive hydrocarbons being drawn in from the vapor canister:

   a) EGR valve.
   b) Vapor canister.
   c) Purge solenoid.
   d) PCV valve.

3. An air pump failure is likely to result in excessive levels of these gases:

   a) HC only.
   b) CO only.
   c) HC and CO.
   d) HC, CO, and NO_x.

4. An O_2 sensor is sending a false rich signal to the PCM. This is most likely to result in:

   a) High NO_x.
   b) High CO.
   c) Low HC.
   d) Low O_2.

5. An exhaust leak has developed downstream of the O_2 sensor. This is likely to result in:

   a) False lean signals to the PCM.
   b) False rich signals to the PCM.
   c) Erratic O_2 signals to the PCM.
   d) No effect.

Activity 5

6. High HC readings, combined with contaminated oil in the crankcase, most likely indicate a failed:

   a) EGR valve.
   b) Vapor canister.
   c) PCV valve.
   d) Purge solenoid.

7. An obstructed air supply to a three-way catalyst is most likely to result in:

   a) High HC, CO, and NO_x.
   b) High NO_x only.
   c) High HC and CO.
   d) High CO and NO_x.

8. A scan tool indicates that the engine is not going into closed loop when expected. This could be due to:

   a) A faulty engine coolant temperature sensor.
   b) A bad ground in the O2 sensor circuit.
   c) A faulty PCM.
   d) All of the above.

9. A slipped timing belt could lead to high emissions levels because:

   a) It could cause advanced timing and pre-ignition.
   b) It could cause retarded timing and incomplete combustion.
   c) Both (a) and (b).
   d) Neither (a) nor (b).

10. An air injection system supplies additional oxygen to:

   a) Hot exhaust gases.
   b) The second stage of a dual-bed catalytic converter.
   c) Both (a) and (b).
   d) Neither (a) nor (b).

POST-COMBUSTION CONTROLS

Post-combustion controls are those that reduce emissions levels after combustion has taken place. There are only two such systems commonly found in vehicles on the road today. They are:

- Air injection
- Catalytic converters

Air Injection

One of the earliest of the post-combustion devices for controlling HC and CO emissions was ***air injection*** (also called Air Injection Reaction, or AIR). In most air injection systems, an engine-driven air pump is used to take air from the atmosphere and force it into the exhaust stream. The additional oxygen that is introduced causes unburned fuel to continue burning in the exhaust manifold.

Secondary air systems are also used to supply oxygen to the second stage of a dual-bed catalytic converter. The oxygen supplied by the air pump enhances the reaction by which HC and CO are converted to harmless carbon dioxide and water. Chrysler uses three types of secondary air systems, which differ by the method in which they supply air to the exhaust system:

- ***Air pump systems*** (fig. 37) employ a belt-driven air pump to inject air into the exhaust system.

- ***Aspirated systems*** (fig. 38) utilize negative pressure from the exhaust system to "pull" air into the system.

- ***Pulse Air Feeder systems*** (fig. 39) use engine crankcase pressures acting on a diaphragm to draw air from the air cleaner.

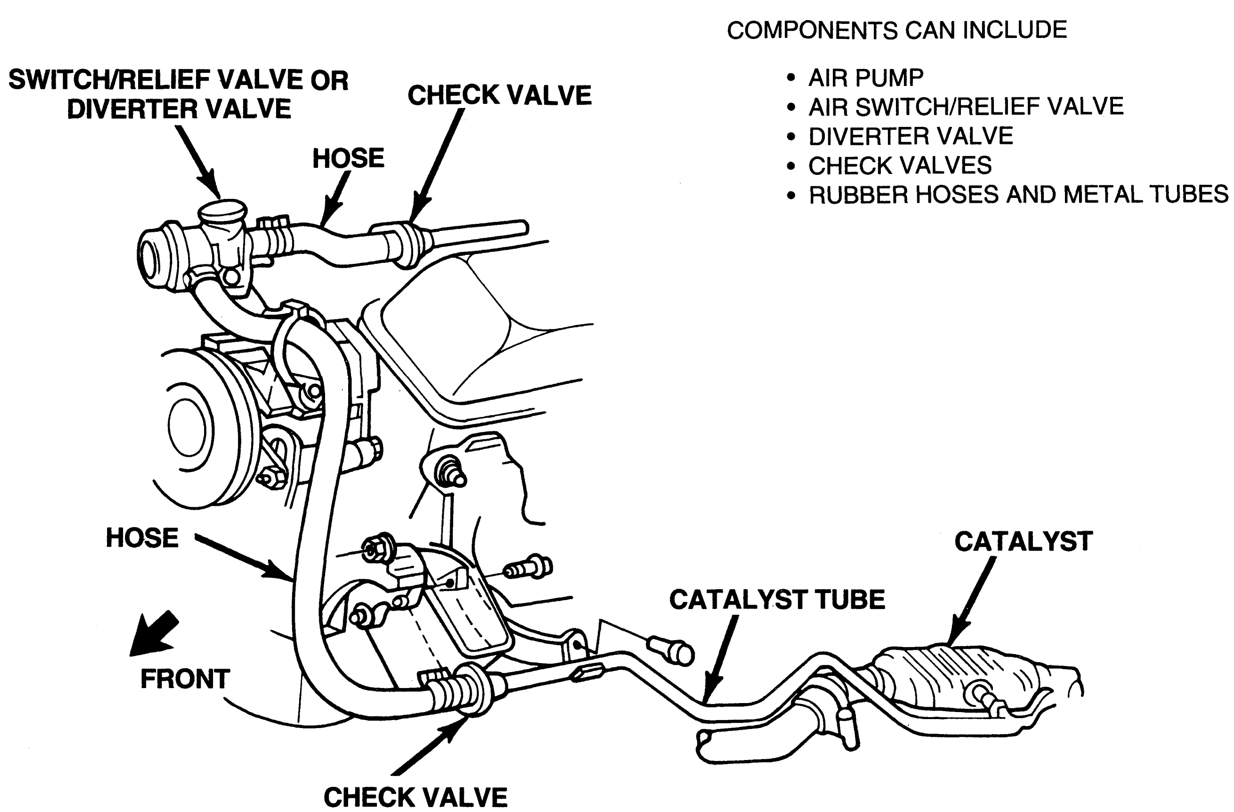


Figure 37 Air Pump System 1987 5.2L Light Duty Truck

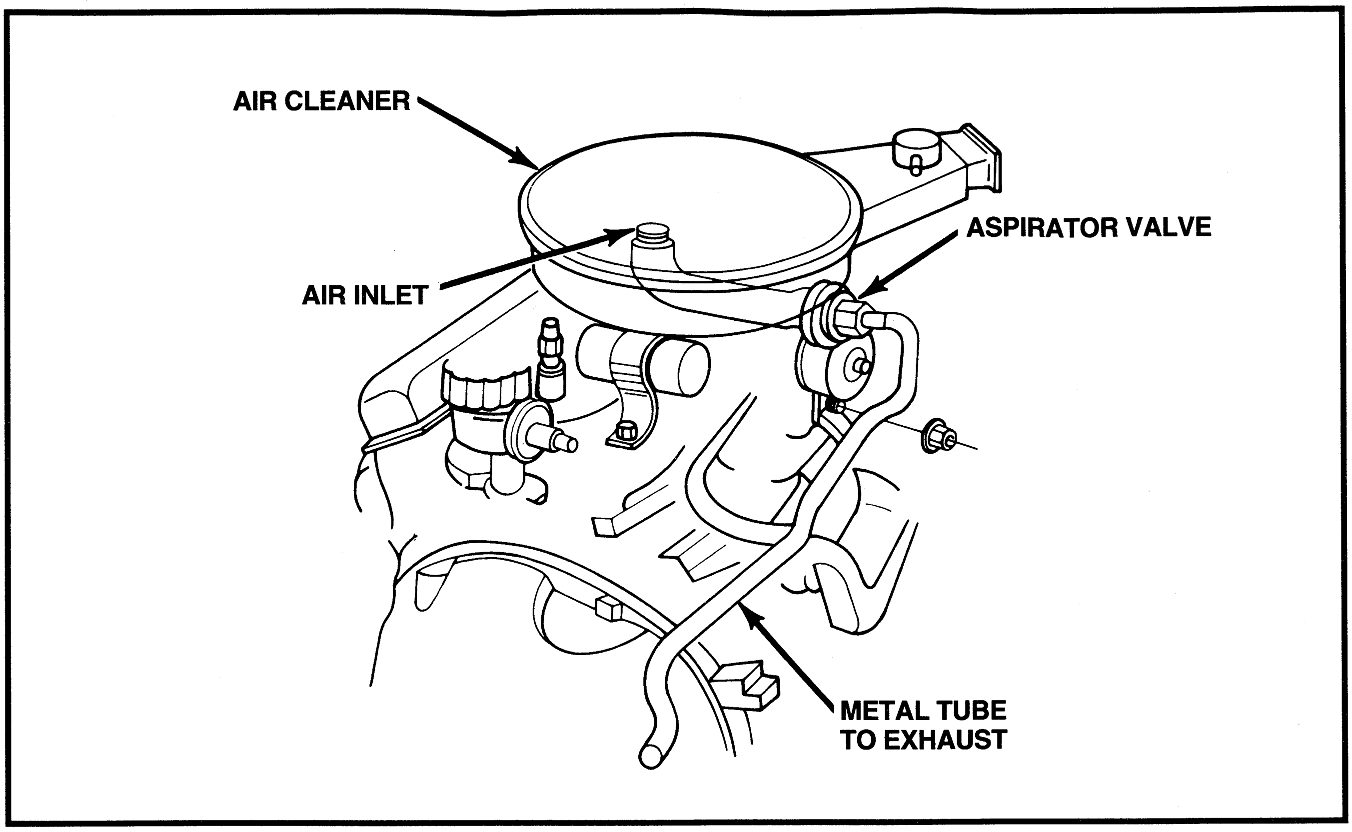


Figure 38 Aspirated Secondary Air System

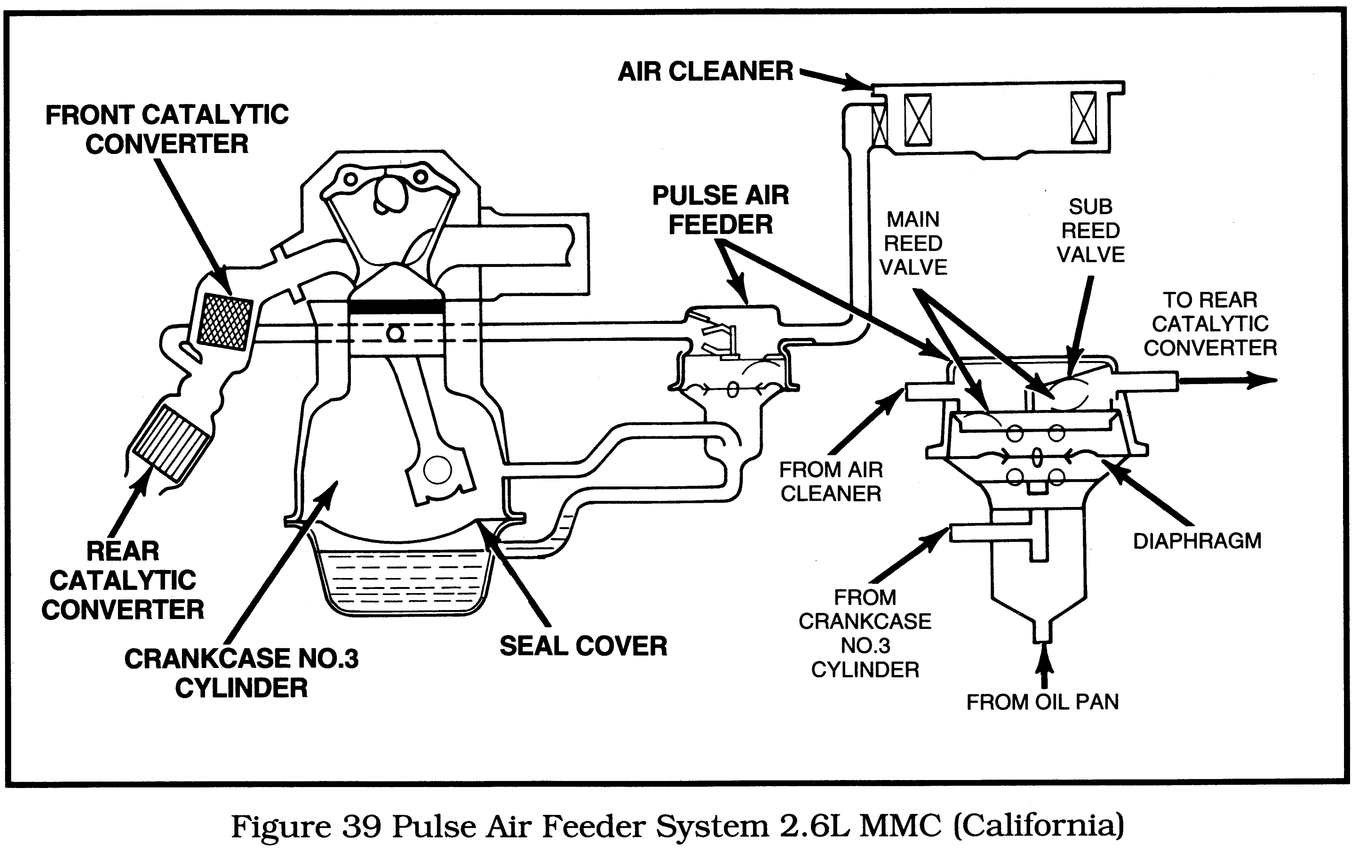


Figure 39 Pulse Air Feeder System 2.6L MMC (California)

In air pump systems, an air switching/relief valve directs the air pump output upstream while the vehicle is cold, and downstream to the catalyst after the vehicle has warmed up. This switching activity is controlled by a CVSCO (coolant vacuum switch, cold open) and/or an air switching solenoid. Manifold vacuum is applied to the air switching/relief valve at start-up and when the vehicle is cold. The vacuum supply is discontinued when the vehicle is warm, causing the air pump output to be directed downstream.

Field observations have shown that, in many instances, secondary air systems have been disabled or totally removed. This is particularly true where a non-original catalytic converter (without air tube fittings) has been installed. When working on these systems, inspect all components of the system. Make sure all hoses and tubes are correctly routed and free of defects. Review the underhood hose routing diagram to verify the installation and type of secondary air system for that particular engine package.

As an add-on system, air injection does an especially effective job of reducing pollutants without costing much in the way of performance. Its only burden on the engine is a small amount of drag from the air pump. Even though air injection is one of the older emissions-control technologies, its effectiveness is such that it's still in use in many vehicles on the road today.

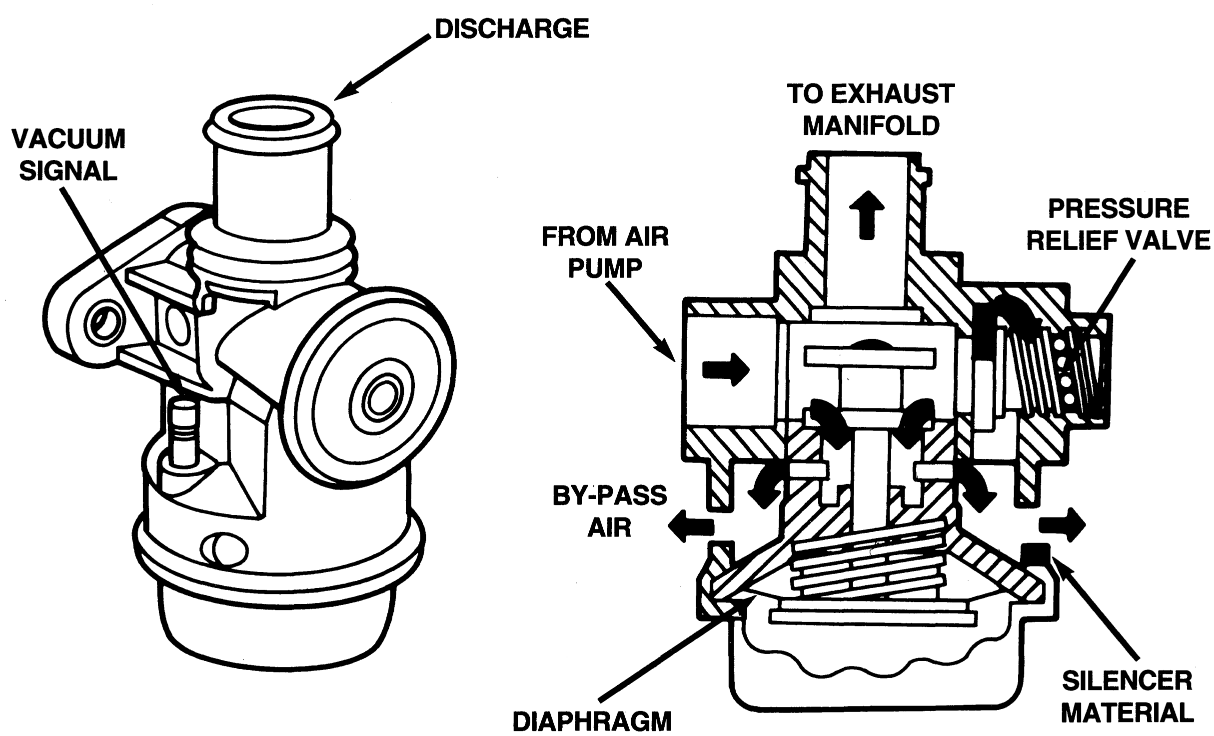


Figure 40 Diverter Valve

Catalytic Converter
Potentially harmful amounts of the three pollutant gases still enter the exhaust system. The catalytic converter is the "last chance" to render these gases harmless before they enter the environment. Refer to the section on catalytic converters for more details on this post-combustion system.

Note: *Continuous operation of upstream air from the air pump decreases the efficiency of the reduction catalyst portion of the catalytic converter.*

Note: *Readings form vehicles with secondary air systems will have about 2% to 4% CO.*

Activity 6

OBSERVING THE EFFECT OF THE AIR PUMP ON VEHICLE EMISSIONS

In this activity you will observe the effect of the air pump by measuring the emissions levels with and without the air pump operating. You will also observe the differences between upstream and downstream air injection.

DIRECTIONS:

1. Start the engine and allow to warm up for two to three minutes.
2. Test the exhaust gases and record the readings in the table on the next page, in the "Downstream Air" column.
3. Using a scan tool, read the injector pulse width and the O_2 sensor state (rich/lean) and record in the table.
4. Shut the engine off.
5. Create a condition on your vehicle that would force upstream air to flow from the air pump.
6. Start the engine again and allow to warm up for two to three minutes.

Caution: *Do not attempt to drive the vehicle under this condition. Do not run the engine any longer than necessary to perform the tests. Possible backfiring and vehicle damage may result.*

7. Test the exhaust gases and record the readings in the table, in the "Upstream Air" column.
8. Using a scan tool, read the injector pulse width and the O_2 sensor state (rich/lean) and record in the table.
9. Shut the engine off and remove the condition that was created to force upstream air.
10. Remove the air output hose to the check valve and plug the hose.
11. Start the engine again and allow it to warm up for two to three minutes.
12. Test the exhaust gases and record the readings in the table, under the "Air Pump Disconnected" column.

Activity 6

13. Using a scan tool, read the injector pulse width and the O_2 sensor state (rich/lean) and record in the table.

14. Shut the engine off and reconnect the air output hose.

WARM ENGINE			
	DOWNSTREAM AIR	UPSTREAM AIR	AIR PUMP DISCONNECTED
CO			
HC			
NO_x			
CO_2			
O_2			
INJ. PULSE WIDTH			
O_2s STATE			

1. What happened to the CO and HC readings after the air pump was disconnected?

____

____

2. What effects were noted when there was downstream air injection?

____

____

3. What effects were noted when there was upstream air injection?

____

____

____

____

Activity 6

4. What does this tell you about air pump operation?

5. Air injection should supply 2-5% more oxygen when operational. Based on the exhaust gas test, did this happen? Why or why not? What could cause the O_2 reading to vary from the expected result with a functioning air injection system?

Notes:

USING THE EXHAUST GAS ANALYZER

INTRODUCTION

The increased importance of pollution control over the last two decades has led to the need for test equipment that allows government inspection agencies, car manufacturers, and dealership technicians to accurately measure the exhaust gas composition of a vehicle.

Gas analysis can do more than just determine if a car passes or fails government emissions tests. As a diagnostic tool, gas analysis is a quick and accurate way to determine the general health of an engine, just as a doctor determines your general health with a blood test.

The most common piece of equipment for testing the level of harmful emissions in exhaust gas is the infrared gas analyzer (fig. 41).

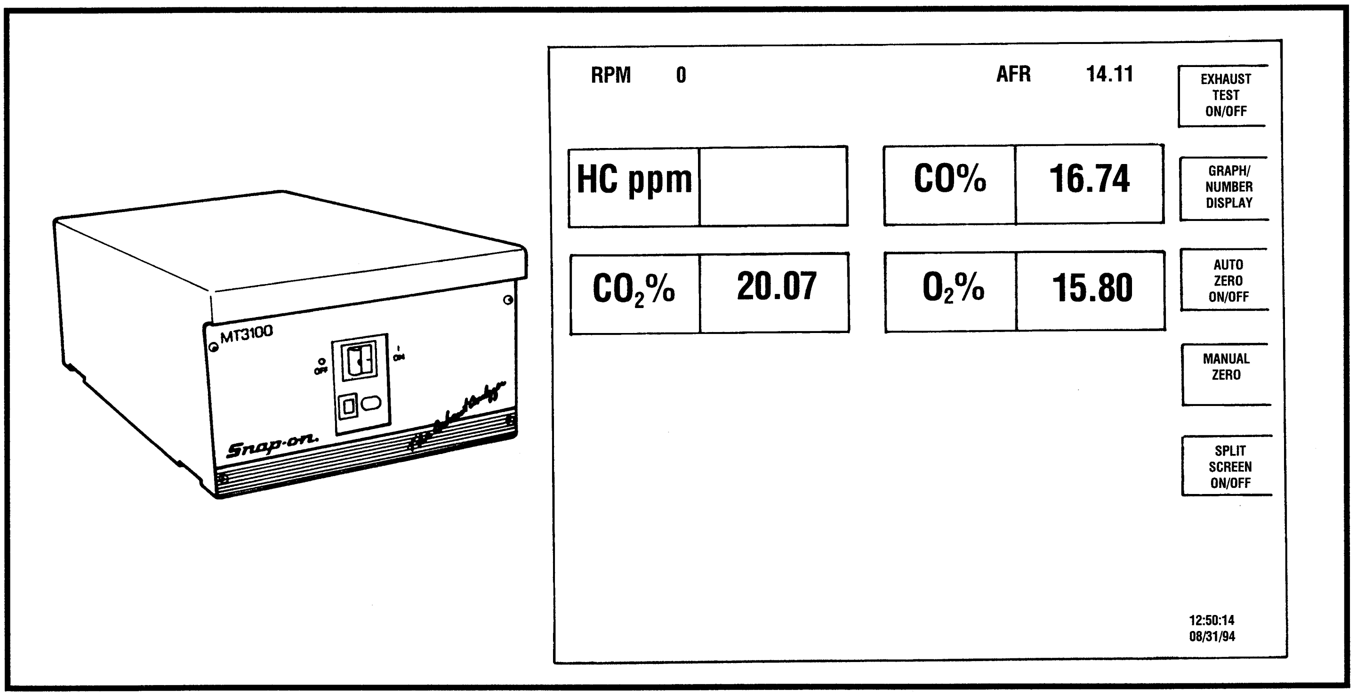


Figure 41 Four-Gas Analyzer And Sample Readout (Snap-On MT3100A)

With the gas analyzer, you measure the efficiency of the engine's combustion system by measuring the emissions levels of the gases at the tailpipe. You can determine which components in the vehicle are defective or misadjusted by seeing which gas readings are too high or too low. Then the defective or misadjusted components can be repaired or brought back within specifications. The gas analyzer comes in three basic types:

- The two-gas analyzer, which measures hydrocarbons (HC) and carbon Monoxide (CO).
- The four-gas analyzer which, in addition to measuring HC and CO, also measures carbon dioxide (CO_2) and oxygen (O_2).
- The five-gas analyzer, which also measures nitric oxide (NO). Nitric oxide is a major component of oxides of nitrogen (NO_x).

While the two-gas model is still usable for basic emissions testing, the use of the four-gas and five-gas analyzers is becoming more widespread because their ability to measure CO_2 and O_2 makes them valuable diagnostic tools for driveability complaints and other engine concerns outside of the emissions arena. Although commonly available gas analyzer cannot measure oxides of nitrogen (NO_x), this ability may become available on more and more machines in the near future.

An infrared analyzer does its job by sending a beam of infrared light through the exhaust sample. Before the beam reaches the sample, it is split into three parts and passed through optical filters which balance the light to the wavelengths that are absorbed by HC, CO, and CO_2. The exact method of filtration varies from one manufacturer to the next. After having passed through the exhaust sample, the returning beam is analyzed electronically to determine the levels of HC, CO, and CO_2 present in the exhaust.

Oxygen is not measured with the infrared beam, but with an elctrochemical sensor similar to the O_2 sensor in the vehicle. The four-gas levels are displayed in the following units:

- HC in parts per million (ppm)
- CO in percentage (%)
- CO_2 in percentage (%)
- O_2 in percentage (%)

WHAT ABOUT NO_X?

Presently, only a five-gas analyzer can detect oxides of nitrogen, and even those don't measure NO_x directly. Instead, they measure one of the components of NO_x, nitric oxide (NO). The NO reading is NOT an accurate measurement of the amount of NO_x, but a high NO reading does indicate that there is an NO_x problem.

For our purposes, then, NO_x levels are determined by assumption and can only be measured with the vehicle under load. Make sure the vehicle doesn't have any driveability problems, particularly anything that might cause a lean condition (such as a vacuum leak). Then, if HC and CO levels are acceptable, and if the vehicle's emission control systems are in good working order (especially the EGR system and three-way catalytic converter), NO_x levels can be assumed to be acceptable also.

USING THE GAS ANALYZER

Calibration

Before testing a car's exhaust, the technician needs to be sure that the analyzer will display accurate information about the sample. To do this, he or she will have to check the calibration of the analyzer. Although the details of this procedure vary among manufacturers, calibrating the analyzer is typically done by ***zeroing*** the analyzer with clean air, and then ***calibrating*** it with known concentrations of HC, CO, and CO_2.

Zeroing is the simplest part of the procedure. Zeroing purges the analyzer with fresh air, samples the air, then adjusts all the readings to zero (except for O_2, which will read about 21%, its normal level in clean air). Follow the manufacturer's instructions for this procedure.

The composition of the calibrating gas, which can be used for a two-gas or four-gas analyzer, will be something like this:

- HC 300 ppm
- CO 1%
- CO_2 6%

Calibrating the analyzer (fig. 42) is done by connecting a bottle of standardized calibrating gas which is commercially available for this purpose. A typical calibrating gas contains known concentrations of hydrocarbons, carbon monoxide, and carbon dioxide, and is known as a "tri-blend" gas.

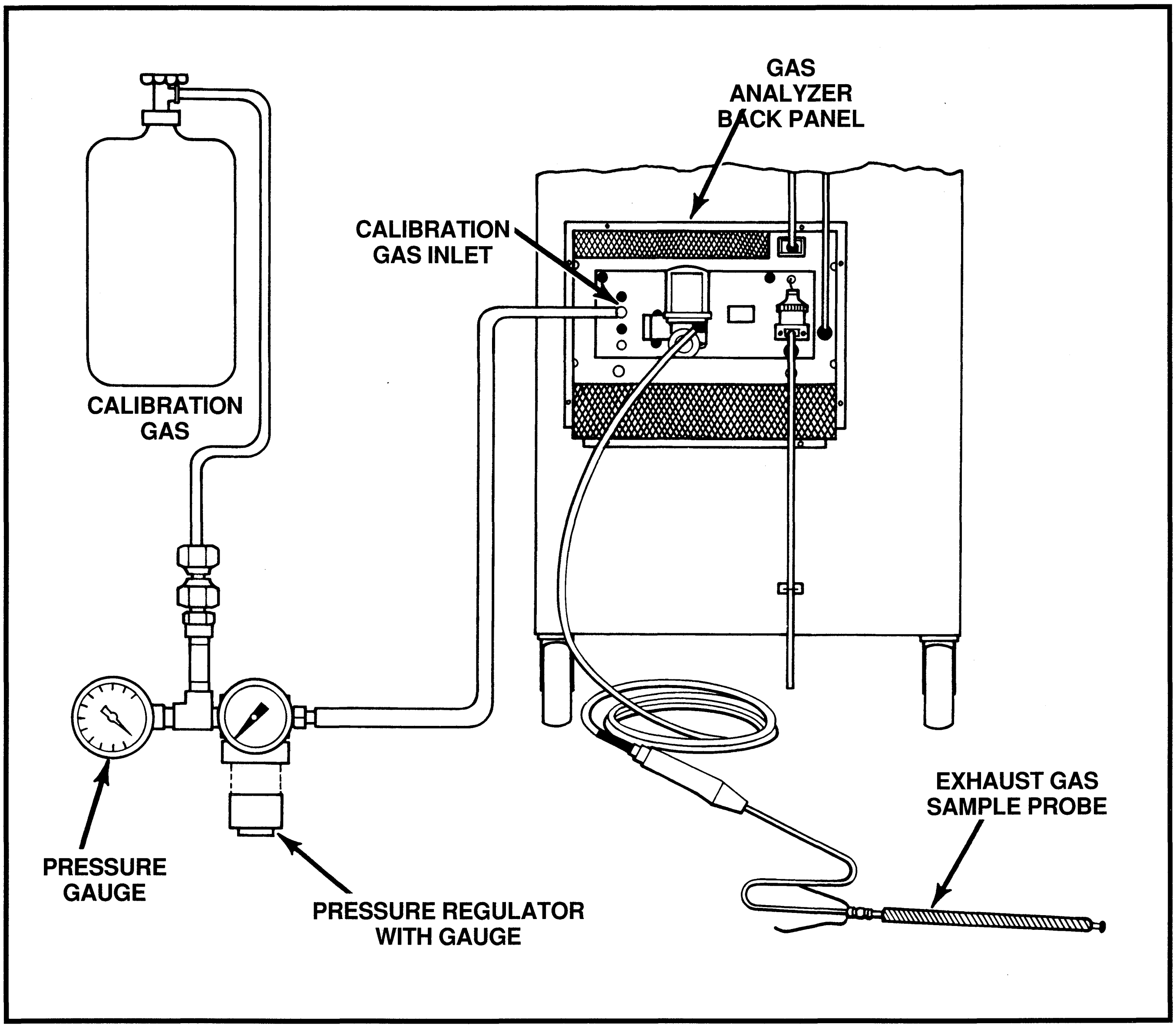


Figure 42 Typical Calibration Setup

While the calibration procedure varies from one manufacturer to the next, it will contain these basic elements:

- Connect a hose from the calibration gas bottle regulator to the calibration port on the analyzer.
- Select the calibration mode on the analyzer.
- Open the valve on the calibration gas bottle and adjust the pressure to the manufacturer's recommendation.
- Wait for the gas readings on the analyzer to stabilize.
- After the readings stabilize, issue the calibration command. This is usually done by making a menu selection and/or pressing the appropriate button on the keyboard.
- When the analyzer indicates that the calibration is complete, turn off the calibration gas and disconnect the gas bottle.

Although not necessary for normal diagnostic use, some analyzers allow for a two-gas calibration. In a two-gas calibration, the procedure described above is repeated with another tri-blend calibration gas containing higher concentrations of the three emissions gases. This composition might be as follows:

- HC 1200 ppm
- CO 4%
- CO_2 12%

By calibrating at both the high and low ends of the scale, the analyzer can be more accurate throughout the emissions testing range.

PURGING

After repeated use, small amounts of exhaust gas might remain in the analyzer's detection chamber. This lingering gas needs to be removed to prevent false readings. Purging is a method of drawing fresh air through the system to clear out the analyzer. It is normally done when the analyzer shows HC readings above a certain level, say 20 ppm, when sampling fresh air. Refer to the manufacturer's instructions for details.

FLUSHING

The three normal by-products of combustion are heat, CO_2, and water vapor. The water vapor produced during combustion can condense in the analyzer, producing moisture in the sampling system.

Caution: *Moisture in the sampling system will give erroneous readings and could damage the analyzer.*

Flushing the system blows this moisture out through a drain hose. Again, consult the manufacturer's information for details.

PREPARING FOR EXHAUST GAS TESTING

Visual Inspection

The visual inspection is an important part of emissions diagnosis. Technicians, as well as state inspectors, can benefit from a thorough visual inspection of the emissions control system.

Check the following items and correct as necessary before testing. Make sure all systems are in good condition:

- Air filter.
- Air leaks/vacuum hoses.
- Damaged or discolored catalytic converter.
- Dirty carburetor.
- Distributor cap.
- Fuel filter and hoses.
- Open or damaged sensor wires.
- PCV valve.
- Spark plug wires.
- Tampering to any emissions system component.
- PCM-
  - Check for proper operation (is the MIL on, are there any DTCs).
  - Check for fault codes and correct as necessary before testing.

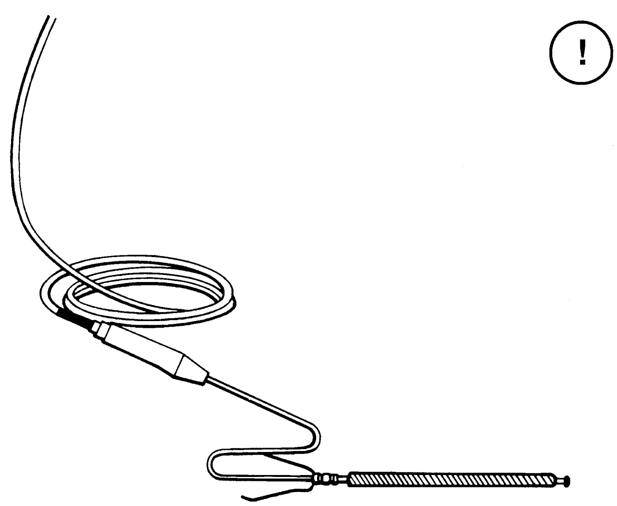
When the visual inspection has been completed, and any problems corrected, the vehicle is almost ready to be tested. The final preliminary step is to precondition the engine.

PRECONDITIONING THE ENGINE

This is an important step to take before doing the exhaust test. Omitting this procedure can lead to false failures of the vehicle being tested. The purpose of preconditioning the engine is to warm it up to the point where the O_2 sensor is performing properly, the catalytic converter is hot enough to do its job, and the other components of the emissions control system have stabilized. Technicians should pass this information along to the vehicle owner, because it could help avoid a state emissions test failure.

Exhaust gas analyzers have two primary diagnostic functions engine performance and emissions compliance. The instruction manual for your analyzer may contain one preconditioning procedure for diagnosing engine performance, and another one for emissions compliance. Make sure you ***do not*** use the preconditioning procedure intended for diagnosing engine performance. This involves disabling the vehicle's air pump and catalytic converter so that the gases can be tested before they've been treated by the catalyst. (If you are specifically analyzing CO_2 for engine performance, you should disable the air injection system. Air injected into the catalytic converter combines with CO to form CO_2. This gives false CO_2 readings and is especially noticeable with rich mixtures.)

For emissions compliance, you want to test the final exhaust product ***after*** all treatment has taken place. Preconditioning for emissions compliance does not involve disabling any components, just warming up the engine.



BEFORE TESTING...

PRECONDITION THE ENGINE:

- **MAKE SURE ENGINE IS WARM (CLOSED LOOP).**
- **PLACE GEAR SELECTOR IN PARK (AUTOMATIC) OR NEUTRAL (MANUAL).**
- **WITH YOU LEFT FOOT ON THE BRAKE PEDAL, INCREASE ENGINE SPEED TO 1500-2000 RPM.**
- **HOLD THIS ACCELERATED IDLE FOR AT LEAST ONE MINUTE.**
- **RELEASE ACCELERATOR AND CONDUCT THE TEST.**

Figure 43 Precondition the Engine

TIPS FOR EXHAUST GAS ANALYSIS

When evaluating any given exhaust gas reading, these points should be considered:

- ***Magnitude:*** Is the reading higher or lower than normal?
- ***Stability:*** Is the reading steady, or does it change with different engine speeds?
- ***Repetition:*** After returning to idle from cruise, does the reading change?
- ***Correlation:*** Does the reading relate only to certain conditions? Can the abnormal reading be related to idle speed, transition, cruise, power, etc.?
- ***Sample quality:*** Is the gas sample masked or affected by air injection, catalytic converter, or a leaking exhaust?
- ***Gas sensitivity:*** Certain gases are more sensitive to some problems than others. When diagnosing a particular emissions problem, analyze the most sensitive gas.

Carburetion versus fuel injected vehicles react differently to system components that have failed.

In addition to the gas relationships presented elsewhere in this course, keep these points in mind when evaluating exhaust gases:

- High HC readings usually indicate excessive unburned fuel caused by lack of ignition or by incomplete combustion. Common causes include:
  - Faulty ignition system.
  - Vacuum leaks.
  - Fuel control problems.
- High HC is an indicator of leanness and misfires.
- Any HC reading of 1000 ppm or more indicates a serious misfiring problem.
- Unstable HC and CO_2 readings can indicate intermittent misfiring problems.
- Bad fuel distribution can cause:
  - High unstable HC readings.
  - Normal to high CO readings.
  - Low CO_2 readings.
- Combustion efficiency improves as the throttle opens (primarily with carbureted vehicles), causing HC and CO to decrease up to 50%, and causing CO_2 to increase.
- High CO readings usually indicate a fuel mixture richer than ideal, caused by fuel control problems.
- If CO goes up, O_2 goes down.
- CO and O_2 are about equal at the stoichiometric air/fuel ratio.
- Unstable CO readings indicate air/fuel ratio problems.
- High CO_2 (maximum about 15%) indicates a nearly ideal air/fuel ratio and efficient combustion.
- Low CO_2 indicates a too rich or too lean fuel mixture, exhaust system leaks, or sample dilution.

- High O_2 readings indicate too lean an air/fuel ratio.
- Low O_2 indicates a rich mixture.
- High O_2 is a better indicator of leanness and misfires than is high HC.
- If O_2 goes up, CO goes down.
- Analyzing HC and CO together with the diagnostic gases CO_2 and O_2 can be useful for checking catalytic converter efficiency.
- O_2 is essential for proper operation of the catalytic converter. Its concentrations are essentially unchanged by the catalytic converter. O_2 levels are higher on vehicles with properly operating air injection systems.
- With the air injection system disabled and the CO above 1%, the catalytic converter is oxygen-starved. Without O_2 it does not fire, allowing exhaust concentrations to be more like readings taken ahead of the converter.
- A vehicle with an inactive catalytic converter can give gas readings similar to a non-converter vehicle.
- Small air leaks become less significant at higher rpm.
- A lean misfire problem can cause the rpm to increase 10% or more during artificial enrichment.

AIR FILTER TESTING

The exhaust gas analyzer can be used to evaluate CO to determine the condition of the air filter. Even a filter element that looks good can be dirty enough to restrict air flow and cause a rich mixture. The following procedure can be used to test the filter:

1. Insert the exhaust probe at least 12 inches into the tailpipe.

2. Start the engine and allow it to warm up for at least two minutes.

3. Note the CO reading at idle.

4. Remove the air cleaner filter element and reinstall the air cleaner cover.

5. Without changing the engine speed, immediately note the CO reading before the air/fuel ratio is corrected by the PCM. If the CO reading is lower, replace the filter.

OTHER USES FOR THE EXHAUST GAS ANALYZER

Because of its ability to detect various gases, the exhaust gas analyzer can be used to perform a number of useful tests not related to emissions testing. These include tests for:

- Fumes in the passenger compartment (door seals, gaskets, etc.)
- Exhaust leaks
- Fuel leaks
- Combustion gases in the cooling system
- PCV system operation
- Catalytic converter operation
- Exhaust restrictions

Details for these procedures are beyond the scope of this course, but more information can be found in the operator's manual for your exhaust gas analyzer.

Activity 7

DIAGNOSING EMISSIONS PROBLEMS WITH THE EXHAUST GAS ANALYZER

In this exercise, we will be creating an intentional emissions problem, testing the exhaust with the gas analyzer, and analyzing the results.

Before beginning the hands-on portion of this activity, record the emissions test results that your instructor obtained in the demonstration:

HC	_____ppm
CO	_____%
CO_2	_____%
O_2	_____%
NO	_____ppm

Does this vehicle pass or fail the emissions regulations for your area? (Circle One) Pass/Fail

AT THE VEHICLE–EXERCISE ONE

Directions:

1. Prepare the gas analyzer in accordance with the manufacturer's instructions or your instructor's directions.

2. Start the vehicle. The following steps are used to pre-condition the engine in the same manner that you would prior to any emissions test.

3. Engage the parking brake.

4. Make sure all accessories, such as air conditioning and cruise control, are OFF.

5. With the gear selector in PARK and your left foot on the brake pedal, gently depress the accelerator pedal with your right foot to increase the engine speed to approximately 1500-2000 rpm.

6. Maintain this accelerated idle (1500-2000 rpm) for one minute.

7. Using a Scan Tool, record the O_2 sensor voltage. ______volts.
   Is it switching? (Circle One) Yes No

8. Shut the engine off and remove the spark plug wire from one of the spark plugs.

> ***Warning:*** *The ignition system generates approximately 40,000 volts. Personal injury could result from contact with this system.*

9. Start the engine and perform the exhaust test as prescribed by the manufacturer of the gas analyzer.

Caution: *To avoid damaging the catalytic converter, do not exceed normal idle speed during this test, and do not exceed two minutes of running time.*

10. Record the results of the exhaust test:

    HC ______ppm

    CO ______%

    CO_2 ______%

    O_2 ______%

    NO ______ppm

11. Using a Scan Tool, record the O_2 sensor voltage. ______volts.
    Is it switching? (Circle One) Yes No

12. Disconnect the gas analyzer and shut off the vehicle.

13. Replace the spark plug wire to its original location.

DISCUSSION QUESTIONS:

1. Does this vehicle pass or fail the emissions regulations for your area?
   (Circle One) Yes No

2. How did the HC and CO readings compare with the original test?____________

3. How did the CO_2 and O_2 readings compare with the original test?___________

4. What affect did the dead cylinder have on the gas readings?_________________

5. Did the NO reading change between tests? Why or why not?_________________

Activity 7

AT THE VEHICLE–EXERCISE TWO

Directions:

1. Prepare the exhaust gas analyzer in accordance with the manufacturer's instructions or your instructor's directions.

2. Remove the electrical connector from one of the fuel injectors. Be sure to pull on the connector, not the wire, when disconnecting the injector.

3. Start the vehicle. The following steps are used to pre-condition the engine in the same manner that you would prior to any emissions test.

4. Engage the parking brake.

5. Make sure all accessories, such as air conditioning and cruise control, are OFF.

6. With the gear selector in PARK and your left foot on the brake pedal, gently depress the accelerator pedal with your right foot to increase the engine speed to approximately 1500-2000 rpm.

7. Maintain this accelerated idle (1500-2000 rpm) for one minute.

8. Release the accelerator pedal and perform the exhaust test as prescribed by the manufacturer of the gas analyzer.

9. Record the results of the exhaust test:

   HC ______ppm

   CO ______%

   CO_2 ______%

   O_2 ______%

   NO ______ppm

10. Using a Scan Tool, record the O_2 sensor voltage. _______volts.
    Is it switching? (Circle One) Yes No

11. Disconnect the gas analyzer, shut off the vehicle, and re-connect the fuel injector.

Activity 7

DISCUSSION QUESTIONS:

1. Does this vehicle pass or fail the emissions regulations for your area? (Circle One) Pass Fail

2. How did the HC and CO readings compare with the original test?

   ____

   ____

3. How did the CO_2 and O_2 readings compare with the original test?

   ____

   ____

4. What caused the differences in the test results?

   ____

   ____

5. Did the NO reading change after the injector was disconnected? Why or why not?

   ____

   ____

LESSON REVIEW:

1. Approximately how much hydrocarbon (HC) will be emitted by a properly-running computerized vehicle at idle?

   a) 0-80 ppm.
   b) 100-150 ppm.
   c) 200-500 ppm.
   d) 500-750 ppm.

2. What two gases are measured on a four-gas analyzer that were not measured on the older two-gas analyzers?

   a) HC and CO.
   b) HC and CO_2.
   c) CO and CO_2.
   d) CO_2 and O_2.

3. Before performing emissions test, the vehicle should be checked to ensure that:

   a) Vacuum hoses are properly connected.
   b) Electrical connectors are properly attached.
   c) There are no obvious leaks or missing components in the exhaust system.
   d) All of the above.

4. When a vehicle is in open loop, the PCM is not using the:

   a) O_2 sensor.
   b) Throttle position sensor (TPS).
   c) Vehicle speed sensor (VSS).
   d) Mass airflow (MAF) sensor.

Activity 7

5. What procedure should be done prior to entering an I/M test lane?

   a) Idling for 10 minutes.
   b) Preconditioning the engine.
   c) Holding the engine rpm at 2000 for five minutes.
   d) Shutting the engine off until it's time for the test.

6. During closed loop operation, if the O_2 sensor detects high levels of oxygen in the exhaust stream, it will tell the engine computer to:

   a) Slow the vehicle down.
   b) Lean out the fuel mixture.
   c) Switch to open loop.
   d) Enrich the fuel mixture.

7. When calibrating the gas analyzer, the O_2 reading in clean air should be approximately:

   a) 2 %
   b) 21 %
   c) 78 %
   d) 220 ppm

8. A low CO reading is an indication of:

   a) A properly-running engine.
   b) Complete combustion.
   c) A defective catalytic converter.
   d) Both (a) and (b).

9. The best indicator of an ignition misfire is:

   a) A high O_2 reading.
   b) A low CO reading.
   c) A low O_2 reading.
   d) A high HC reading.

10. The CO reading is the best indicator of:

   a) Air pump operation.
   b) EGR valve operation.
   c) Air/fuel ratio.
   d) Preconditioning.

EMISSIONS CONTROL SYSTEM SERVICE

MAINTENANCE SCHEDULE

The maintenance schedule is a convenient list of services required to keep systems operating to specification. Perform each of the maintenance services listed in the schedules for vehicles in the Unites States and Canada. In particular, follow instructions for inspections of emission control systems. Perform adjustments accurately. The inter-relationship of engine systems requires precise operation of all systems. A slight misadjustment could cause significant problems. For example, a few degrees error in base ignition timing will affect performance, economy, and emissions.

ENGINE PERFORMANCE AND EMISSION CONTROL

Sometimes engine operation is overlooked when diagnosing emission control system problems. You should always consider engine operation first when approaching these problems, because the engine is the basis for the function of all other systems. These systems depend on good mechanical engine condition for proper air flow, fuel delivery, vacuum, and exhaust gas flow. Good performance always begins with a sound engine.

ENGINE MAINTENANCE

Overall mechanical condition is vital to performance and emission control. In particular, valve clearance affects valve timing. This is critical to all engine operation. Adjust valves as scheduled.

Look for oil consumption as a sign of faulty valve seals or worn piston rings. If you have reason to suspect engine or valve wear, measure compression to verify good mechanical condition.

WARRANTY

Warranty coverage of emissions control system components varies with the individual component and vehicle. If there is a question as to warranty coverage for a particular situation, refer to Chrysler Warranty Policy and Procedures.

DIAGNOSING EMISSIONS-RELATED PROBLEMS

Your skills as a technician are tested when a customer comes in with a vehicle that has failed a state I/M test, either basic or enhanced. Older, pre-computer vehicles usually give a clue as to what the problem is, because the car will tend to have driveability troubles. Newer cars, however, may have a subtle problem revealed in the I/M test which is not obvious to the driver. There might not be a driveability problem at all, and there are usually several systems that could be related to a particular emissions failure.

When diagnosing a problem like this, it is important to look at the job logically. Randomly pulling hoses and replacing parts is no substitute for an organized approach, and may even make the problem worse. In the long run, a logical diagnostic technique is the most efficient and cost-effective way to repair a vehicle. It helps you to get the job done right the *first* time, and minimizes comebacks.

To assist the vehicle owner in avoiding unnecessary repair work, the Chrysler Corporation has prepared a notice for the Owner's Manual which informs the owner of the importance of preconditioning the engine prior to an emissions test. The notice, which is reprinted here, also tells the owner how to properly precondition the engine.

ATTENTION CHRYSLER CUSTOMERS:
YOU CAN HELP YOUR VEHICLE TO PASS
THE STATE EMISSIONS TEST!

Modern cars and trucks contain several emissions control devices which reduce the exhaust pollutants produced during normal operation. Some of these components, such as the catalytic converter, require high exhaust temperatures to chemically convert the tailpipe emissions into other harmless gases. Under normal driving conditions, a properly functioning vehicle will easily maintain the high operating temperature needed to adequately control the exhaust emissions.

During unusual circumstances, however, certain conditions can occur which could cause the exhaust temperature to drop below the optimal operating temperature range. This can happen, for example, while waiting in line for a State emissions test. As a vehicle owner, you must be aware that unless the vehicle is re-warmed prior to the emissions test, it could possibly fail. This, in turn, can lead to an unnecessary trip to a repair facility, followed by a return trip to the test site. We at the Chrysler Corporation hope to alert our customers to this possibility. Further, we have developed the following simple procedure for each vehicle owner to follow to assure that his or her vehicle is being tested under the optimal conditions. Please take time to review the procedure. Your Chrysler Dealership Technician will be pleased to answer any questions you may have.

PRIOR TO GOING TO THE TEST SITE:

- Completely warm your vehicle by driving it (preferably at freeway speeds) for at least five miles.

WHILE IN LINE AT THE TEST SITE:

- Avoid shutting the engine off unless you expect to wait more than 20 minutes in line. If you must shut the engine off, or if you idle for more than three minutes, use the following re-warming process before the car is tested:

1. Place the gear selector in the "PARK" position (or "NEUTRAL" for manual transmission vehicles).
2. With your left foot on the brake pedal, gently depress the accelerator pedal with your right foot to increase the engine speed (approximately 1500-2000 rpm for tachometer-equipped vehicles). Continue to hold this accelerated idle for at least one minute.

CAUTION: To avoid possible engine damage, never "race" the engine above 2500 rpm while in PARK or NEUTRAL.

3. Repeat this warm-up process every 3-4 minutes while waiting for your emissions test.

JUST PRIOR TO YOUR EMISSIONS TEST:

- Turn off all accessories, such as your air conditioning and cruise control.

- Repeat the warm-up steps described earlier. (Make sure the gear selector is in the "PARK" position and your left foot is on the brake pedal. Gently depress the accelerator with your right foot to increase the engine speed without "racing" the engine. Continue to hold this speed for at least one minute.)

THE CHRYSLER CORPORATION

Emissions: Inspection, Testing, and Maintenance

An important first step in diagnosing emissions-related problems is to ***get as much information from the customer as possible.*** The customer knows their vehicle and driving habits better than anyone. The customer may be able to provide additional information about other problems he or she may have been having with the car, as well as giving some insight into its maintenance history. Emissions levels can also vary depending on how the vehicle was warmed up prior to the test. An ***Owner's Questionnaire*** has been prepared which the owner should fill out in order to give the technician as much up-front information as possible about the car. This questionnaire is reprinted on the following page.

OWNER'S QUESTIONNAIRE

Test Information:

1. How was your vehicle warmed up prior to the emissions test? (Please check all answers that apply.)

☐ It was warmed up by me driving it ______ miles to the test site.

☐ It was warmed up by the test technician for ______ minutes prior to the test.

☐ It was not warmed up at the test station.

☐ Other:

____
____
____
____

2. While waiting for the test, did you turn the engine off or did you let it idle?

☐ Turned engine off ☐ Let engine idle

3. Were all accessories off? ☐ Yes ☐ No

Vehicle Information:

1. Are you presently experiencing any of the following problems? (Check all items that apply.)

☐ Poor fuel economy
☐ Rough idle
☐ "Check Engine" light is on
☐ EMR light is on
☐ Engine runs on after key has been turned to OFF
☐ Stalling, stumbling, or poor acceleration
☐ Engine knock
☐ Engine overheats
☐ Misfiring
☐ Other:

____
____
____

2. Have any of the following emissions parts been replaced?

☐ Catalytic Converter ☐ O_2 Sensor

3. How long (in months or mileage) has it been since the following items were replaced?

________	Air Filter	________	Spark Plugs
________	Engine Oil	________	Spark Plug Wires
________	Oil Filter	________	Distributor Cap
________	PCV Valve	________	Distributor Rotor

Emissions: Inspection, Testing, and Maintenance

When diagnosing a repair, be organized and thorough. A good troubleshooting procedure simplifies finding the problem and results in:

- Better organized, more efficient technicians.
- Elimination of costly unnecessary repairs.
- Improved personal credibility through professionalism.
- Improved customer satisfaction.

The *Emissions I/M Diagnostic Manual* deals with troubleshooting approaches and techniques that will enable you to repair an emissions-related problem within the framework of a logical diagnostic process. As you will see, the basic concepts of logical problem-solving will be tailored to apply specifically to an emissions-related repair.

DRIVEABILITY WORKSHEETS

The following pages contain samples of a Cold Driveability Worksheet and Warm Driveability Worksheet. Driveability problems are often related to excessive emissions problems, and these worksheets provide a good general guide as to what components to check for various conditions. More detailed procedures for this type of diagnosis are provided in the *Emissions I/M Diagnostic Manual.*

COLD DRIVEABILITY WORKSHEET

Use when the symptom occurs before engine reaches operating temperature.

(A) CHOKE: Cold start to 1 min. (carbureted only):

Visual insp. (check for binding linkage) Pass/Fail _________

	READING	***SPECS***	***PASS/FAIL***
Primary choke pull-off			
Secondary vacuum brk.			
Fast idle speed			
Fast idle cam setting			
Float level			

(B) EXHAUST GASES: Warm up 2-3 min.

READING:

HC:	CO:	CO_2:	O_2:

CONDITION:

RICH	
LEAN	
NORMAL	

(C) PCV SYSTEM: Is PCV Valve correct for particular engine application?

Visual inspection of PCV Valve and hoses
PCV valve can be verified by color and part number. Part # _________
Correct application Yes/No

	O_2 or CO_2 % BEFORE	O_2 or CO_2 % AFTER	PASS/FAIL
Remove PCV Valve from valve cover. Record exhaust gas change.			
Slowly remove PCV Valve from PCV hose. Record exhaust gas change.			

(D) EGR SYSTEM: Functional test of system

Visual inspection of vacuum hoses and EGR valve Pass/Fail _________

With engine idling apply vacuum directly to EGR valve. Record RPM change.

RPM:

BEFORE	
AFTER	

Pass/Fail _________

(If no RPM change check for defective EGR valve or clogged EGR passage.)

Tee a vacuum gauge into the EGR vacuum hose. Check for vacuum while driving at IDLE, CRUISE and WOT (in gear).

Engine Condition	Vacuum (should be 0") at IDLE & WOT	PASS/FAIL
Idle		
Cruise		
W.O.T.		

(E) CANISTER PURGE SYSTEM

Disconnect Canister Purge vacuum line from engine:

Does driveability improve? Yes/No _________

Check Canister Purge hose for fuel droplets Pass/Fail _________

Check Canister for fuel saturation Pass/Fail _________

(F) HEATED AIR INLET SYSTEM

Visual inspection of air ducts and stove pipes Pass/Fail _________

Apply vacuum to blend door vacuum motor (motor should hold vacuum and the door should operate smoothly) Pass/Fail _________

Check operation of thermostat (gently apply heat to thermostat — with vacuum applied — blend door should shift to cold air position) Pass/Fail _________

Heated crossover (warm/hot to the touch) Pass/Fail _________

WARM DRIVEABILITY WORKSHEET

AIR/FUEL MIXTURE:

Determine if engine is rich or lean during driveability symptom. Disable air pump for accurate readings.

HC:	CO:	CO_2:	O_2:

AIR/FUEL RATIO:

RICH	
LEAN	
NORMAL	

IF AIR/FUEL MIX IS NORMAL CHECK:

- Proper EGR operation — Pass/Fail ________
- Heated air induction system — Pass/Fail ________
- Clogged fuel injectors — Pass/Fail ________

FOR LEAN CONDITIONS CHECK:

- Vacuum leaks — Pass/Fail ________
- Leaking brake booster — Pass/Fail ________
- Improper vacuum hose routing — Pass/Fail ________
- Defective or improper PCV — Pass/Fail ________
- EGR system leakage — Pass/Fail ________
- Leaking purge lines — Pass/Fail ________

CARBURETOR CIRCUITS

- Low float level — Pass/Fail ________
- Leaky throttle plates — Pass/Fail ________
- Leaky secondary plates — Pass/Fail ________
- Defective accelerator pump — Pass/Fail ________
- Carburetor balance — Pass/Fail ________

FUEL INJECTED SYSTEMS

- Low fuel pressure — Pass/Fail ________
- Leaky O-rings — Pass/Fail ________
- "False Air" — Pass/Fail ________
- Clogged injectors — Pass/Fail ________
- High engine temperature — Pass/Fail ________

FOR RICH CONDITIONS CHECK:

• Gas-diluted oil	Pass/Fail ________
• Defective oxygen sensor	Pass/Fail ________
• Air management system problem	Pass/Fail ________
• Improper vacuum line routing	Pass/Fail ________
• Clogged PCV system	Pass/Fail ________
• Defective canister purge valve	Pass/Fail ________
• Air cleaner/air ducts	Pass/Fail ________

CARBURETOR CIRCUITS

• High float level	Pass/Fail ________
• Defective power valve	Pass/Fail ________
• Defective choke pull-off	Pass/Fail ________
• Rich idle mixture	Pass/Fail ________
• Computer problem	Pass/Fail ________

FUEL INJECTED SYSTEMS

• Defective fuel pressure	Pass/Fail ________
• Leaky injector	Pass/Fail ________
• Cold engine temperature	Pass/Fail ________
• Computer problem	Pass/Fail ________

COMMON CAUSES OF EXCESSIVE EMISSIONS

Earlier in this course you learned the basic causes of excessive emissions and how various vehicle conditions can lead to their formation. The following list gives specific components and systems to examine when there is an emissions problem. In each category, the excessive emission can be caused by one or more of the indicated conditions. Further details on testing these systems and components can be found in the appropriate service manual and in the *Emissions I/M Diagnostic Manual.*

HIGH HC:

- Improper ignition timing
- Ignition system malfunction (misfire)
- Excessively rich or lean mixture
- Leaky injectors
- Engine problems such as:
  - Low compression
  - Leaky gaskets
  - Defective valves, guides, or lifters
  - Defective rings, pistons, or cylinders
  - Flat camshaft
- Over-advanced timing
- Fouled spark plug
- Grounded or open spark plug wire
- PCM is compensating for a vacuum leak

HIGH CO:

- Rich mixture
- Dirty air cleaner
- Leaky injectors
- Defective choke
- Improper idle speed
- Over-advanced initial ignition timing
- Air pump inoperative
- Malfunctioning accelerator pump, power circuits
- Restricted induction system
- Clogged PCV system

HIGH HC AND CO:

- Inoperative PCV system
- Heat riser stuck open
- Air pump inoperative or disconnected
- Sticking heated air inlet door
- Excessive crankcase dilution with fuel, caused by:
  - Fuel pump diaphragm rupture
  - Power valve stuck open
  - Choke stuck closed
- Evaporative canister not purging adequately or has not had time to purge

LOW CO_2:

- Exhaust gas sample dilution caused by:
  - Leaky exhaust system
  - Leaky sample hose or probe
- Rich mixture
- Dirty air filter
- Defective choke

LOW O_2 AND HIGH CO:

- Rich mixture
- Leaking fuel injectors
- Leaking power valve
- Dirty air filter
- Defective choke
- Improper idle mixture adjustment
- Restricted air bleeds
- Improper idle speed
- Evaporative canister system not purging properly
- Evaporative canister recently subjected to high quantities of fuel and has not had time to purge properly
- Crankcase contaminated with fuel

HIGH O_2 AND LOW CO:

- Lean mixture
- Vacuum leaks/air leaks/disconnected hoses
- Idle mixture improperly adjusted
- Bad fuel injector
- Improper idle speed
- Meter rods improperly positioned
- Internal air/vacuum leak in carburetor
- Restricted idle system
- Restricted main metering system
- Air pump connected during testing that calls for disconnected air pump
- Low float level
- O_2 sensor bad or failing
- Malfunctioning PCM

SUGGESTED EMISSIONS TARGETS

The following list and table (Table 11) give target emissions values for properly-running vehicles. These are not official government limits for your area. Instead, they are a general diagnostic guide to let you know whether or not your vehicle is in good basic tune for emissions purposes.

Non-Emission-Controlled Vehicles:

- HC less than 600 ppm
- CO less than 6%
- O_2 between 0.1 and 7%
- CO_2 greater than 8%

Emission-Controlled Vehicles–refer to Table 13.

Table 13 Suggested Emissions Levels for Emissions-Controlled Vehicles

Model Year	*HC less than*	*CO_2 greater than*	*CO less than*	*O_2 in the range of*
1971-1975	400 ppm	8%	3%	0.1 - 7%
1976-1979	200 ppm	8%	2%	0.1 - 7%
1980-Present	100 ppm	8%	0.5%	0.1 - 7%

TYPICAL EXHAUST GAS READINGS FOR VARIOUS CONDITIONS

The following table (Table 12) gives typical exhaust gas readings at idle, 1500 rpm, and 2500 rpm for model years 1981 - present. Note that converter readings are taken with any air injection system disabled.

GASES	*IDLE*		*1500 rpm*		*2500 rpm*		*Condition/ Possible Cause*
	Conv.	*Non-Conv.*	*Conv.*	*Non-Conv.*	*Conv.*	*Non-Conv.*	
HC (ppm) *CO (%)* *CO_2 (%)* *O_2 (%)*	0 - 150 0.1 - 1.5 10 - 12 0.5 - 2.0	75 - 250 0.5 - 3.0 10 - 12 0.5 - 2.0	0 - 135 0 - 1.1 — 0.5 - 2.0	50 - 200 0.5 - 2.0 — 0.5 - 2.0	0 - 75 0 - 0.8 11 - 13 0.5 - 1.3	25 - 150 0.1 - 1.5 11 - 13 0.5 - 2.0	Normal gas readings—stable values.
HC (ppm) *CO (%)* *CO_2 (%)* *O_2 (%)*	0 - 150 3.0 + 8 - 10 0 - 0.5	75 - 250 4.0+ 8 - 10 0 - 0.5	0 - 135 3.0+ — 0 - 0.5	50 - 200 3.5+ — 0 - 0.5	0 - 75 3.0+ 9 - 11 0 - 0.5	0 - 100 3.0+ 9 - 11 0 - 0.5	***RICH MIXTURE:*** Idle mixture too rich/choke set too rich or not opening fully/power valve leaking/float level too high/restricted air cleaner/PCV restricted/ contaminated crankcase
HC (ppm) *CO (%)* *CO_2 (%)* *O_2 (%)*	0 - 150 0 - 1.0 8 - 10 1.5 - 3.0	75 - 250 0 - 1.0 8 1.5 - 3.0	0 - 135 0 - 0.8 10 1.0 - 2.5	50 - 200 0 - 0.9 9 1.0 - 2.5	0 - 75 0 - 0.25 11 1.0 - 2.0	0 - 100 0 - 0.75 9 - 11 1.0 - 2.0	***LEAN MIXTURE:*** Low float level/idle mixture lean/cruise mixture lean/small air leaks/cracked or disconnected vacuum lines
HC (ppm) *CO (%)* *CO_2 (%)* *O_2 (%)*	50 - 850 0 - 0.3 5 - 9 4 - 9	400-1200 0 - 0.75 5 - 9 4 - 9	50 - 850 0 - 0.3 — 4 - 9	400-1200 0 - 0.75 — 2 - 7	50-750 0 - 0.3 6 - 10 2 - 7	400-1200 0 - 0.75 6 - 10 2 - 7	***LEAN MISFIRE:*** Severe air leak/bad spark plug or wire/stuck PCV/misadjusted or defective carb
HC (ppm) *CO (%)* *CO_2 (%)* *O_2 (%)*	50 - 850 0.1 - 1.5 6 - 8 4 - 12	1000+ 0.5 - 3.0 6 - 8 5 - 12	50 - 850 0 - 1.1 — 4 - 12	1000+ 0.5 - 2.0 — 5 - 12	50 - 750 0 - 0.8 8 - 10 4 - 12	1000+ 0.1 - 1.5 8 - 10 5 - 12	***MISFIRE:*** Overadvanced timing/fouled plug/open or grounded plug wire/EGR stuck open

Activity 8

DIAGNOSING EMISSIONS-RELATED PROBLEMS

The following chart shows a list of conditions that could result in high hydrocarbon (HC) emissions. In the column labeled "Possible Causes" there are 9 blank spaces. From the word list below, fill in each blank with the most appropriate word or phrase.

fuel	Vacuum	injection
Catalytic converter	engine problems	EGR
Exhaust	computer	preconditioned

HIGH HYDROCARBONS (HC)

Over 220 ppm or over state limits (Basic I/M)

OTHER GASES	*RELATED SYMPTOMS*	*POSSIBLE CAUSES*
CO Very Low (under 0.2%) O_2 High (over 2.5%) CO_2 Low	Rough Idle. Misfire. Idle "hunting". Surging. Detonation (at cruise). Overheating. Low gas mileage.	Lean mixture __________ leak. Incorrect carburetor adjustment. Restricted/dirty ______ injector. ____________ valve leak. Bad ___________ or sensor. ________ flow at idle. Heated air inlet stuck.
CO Normal (0.5 - 1%) O_2 High (at least 2.5%) CO_2 Low	Misfire. Rough idle.	Ignition fault. Poor cylinder sealing, resulting in low vacuum. Repair ________________ before trying to diagnose emissions control defects.
CO High (over 1.5%) O_2 High (over 2.5%) CO_2 Low	Low gas mileage.	Engine not ________________. Engine cold. Air ______________ inoperative. __________________ not warmed up for testing.

Activity 8

The following chart shows a list of conditions that could result in high carbon monoxide (CO) emissions. In the column labeled "Possible Causes" there are 9 blank spaces. From the word list below, fill in each blank with the most appropriate word or phrase.

injector	vacuum	Rich
vapor canister	choke	PCV
air filter	carburetor	purge

HIGH CARBON MONOXIDE

Over 1.2% or over state limits (Basic I/M)

OTHER GASES	*RELATED SYMPTOMS*	*POSSIBLE CAUSES*
HC Low/Normal (less than 220 ppm) ***O_2*** Low/Normal ***CO_2*** Low	Low gas mileage. Sooty spark plugs. Black smoke from tailpipe. Rough idle Hesitation	Bad catalytic converter. Defective ______ valve. Dirty ____________. Carburetor or _______ needs adjustment. Fuel-contaminated crankcase. Leaking injector(s). __________________ saturated. Bad canister _________ valve.
HC High (over 220 ppm) ***O_2*** High (over 2.5%) ***CO_2*** Low	Rough idle. Low gas mileage.	__________ mixture. Failed _____________. Bad ___________ advance.
CO High/Varying (1.5%±) ***HC*** Low ***O_2*** Low to zero ***CO_2*** Low (under 9%)	Erratic idle	Sunken ______________ float. Bad fuel pressure regulator.

Activity 8

Directions:
Circle the most correct answer for each question.

1. A vehicle in your shop has failed the evaporative emissions part of an enhanced I/M test. It is a recent model fuel-injected vehicle with duty cycle purge, and the problem that has been traced to the purge system. What is the first step to take in the diagnosis of this problem?

   a) Replace the purge solenoid
   b) Check fault codes with a scan tool
   c) Inspect all hoses and connectors to verify condition and routing
   d) Check the fuel tank vent line for leaks

2. A fuel-injected vehicle has failed the NO_x part of an I/M test, but HC and CO are within limits. Which of the following is the LEAST likely to be the cause of this failure?

   a) Lean mixture
   b) Leaky injector
   c) Faulty EGR valve
   d) Excessive brake drag

3. When troubleshooting the vehicle in Question 2, what is the LAST step to consider?

   a) Replace the three-way catalyst
   b) Evaluate O_2 sensor switching
   c) Check for slipped timing belt
   d) Evaluate the engine coolant temperature sensor output

4. When diagnosing HC and CO emissions failures on any vehicle, which of the following series of steps are in proper sequence?

   a) Perform scheduled maintenance, check fault codes, do visual inspection
   b) Check fault codes, do visual inspection, perform scheduled maintenance
   c) Perform scheduled maintenance, do visual inspection, check fault codes
   d) Do visual inspection, perform scheduled maintenance, check fault codes

5. A carbureted vehicle without O_2 feedback is in the shop because of an HC/CO failure. Which of the following is LEAST likely to be the cause of the problem?

   a) Stuck choke
   b) Vacuum leak
   c) Faulty air pump
   d) Incorrect carburetor adjustment

Activity 9

ANALYZING TEST RESULTS

In this exercise, you will be taking sample I/M test data and analyzing it to see if the tested vehicle passes or fails the emissions test.

DIRECTIONS:
This part is divided into two sections, basic testing and enhanced testing. Before analyzing the basic test results, refer to the appropriate handout and determine the HC and CO cutoff points for YOUR STATE, COUNTY, OR CITY, as necessary. These will be the values used to determine if the vehicle passes or fails in your area.

For enhanced test analysis,. use the following proposed federal cutoff points for mass emissions testing:

- HC 0.80 grams/mile
- CO 15 grams/mile
- NO_x 2.0 grams/mile

For each vehicle analyzed, compare the test results against the basic or enhanced cutpoints. Indicate whether the vehicle passed or failed the test, and, if the vehicle failed, explain which part of the test was failed. Discuss in class what the possible causes might have been for these failures.

Activity 9

BASIC I/M TESTING

Federal Basic I/M Standards: HC 220 ppm
CO 1.2%

Vehicle #1

YEAR	*ENGINE*	*MODEL*	*MILEAGE*	*HCppm*	*CO %*	*CO_2 %*	*O_2 %*
87	5.2L 2V	Fifth Ave.	92850	230	1.4	8.1	3.1

1. How many parts per million (ppm) HC did this vehicle produce?____________
2. What percentage CO did this vehicle produce?__________________________
3. Did this vehicle pass the basic I/M test for your area? Yes No

Vehicle #2

YEAR	*ENGINE*	*MODEL*	*MILEAGE*	*HCppm*	*CO %*	*CO_2 %*	*O_2 %*
87	5.2L 2V	Fifth Ave.	92850	600	8.8	8.1	3.1

1. How many parts per million (ppm) HC did this vehicle produce?____________
2. What percentage CO did this vehicle produce?__________________________
3. Did this vehicle pass the basic I/M test for your area? Yes No

Activity 9

Vehicle #3

YEAR	ENGINE	MODEL	MILEAGE	HCppm	CO %	CO_2 %	O_2 %
87	2.2L TBI	Sundance	81771	90	0.7	14.2	2.2

1. How many parts per million (ppm) HC did this vehicle produce?____________
2. What percentage CO did this vehicle produce?________________________
3. Did this vehicle pass the basic I/M test for your area? Yes No

Vehicle #4

YEAR	ENGINE	MODEL	MILEAGE	HCppm	CO %	CO_2 %	O_2 %
86	2.2L TBI	Caravelle	69028	200	2.0	7.5	0.5

1. How many parts per million (ppm) HC did this vehicle produce?____________
2. What percentage CO did this vehicle produce?________________________
3. Did this vehicle pass the basic I/M test for your area? Yes No

Activity 9

ENHANCED I/M TESTING

Federal IM240 Standards: HC 0.80 grams/mile
CO 15 grams/mile
NO_x 2.0 grams/mile

Vehicle #1

YEAR	ENGINE	MODEL	MILEAGE	HC g/mile	CO g/mile	NO_x g/mile
86	2.2L TBI	Caravelle	69028	200	2.0	7.5

1. How many grams per mile HC did this vehicle produce?____________________
2. How many grams per mile CO did this vehicle produce?____________________
3. How many grams per mile NO_x did this vehicle produce?____________________
4. Did this vehicle pass the enhanced I/M test? Yes No

Vehicle #2

YEAR	ENGINE	MODEL	MILEAGE	HC g/mile	CO g/mile	NO_x g/mile
90	2.2L TBI	Sundance	68811	0.11	0.99	0.09

1. How many grams per mile HC did this vehicle produce?____________________
2. How many grams per mile CO did this vehicle produce?____________________
3. How many grams per mile NO_x did this vehicle produce?____________________
4. Did this vehicle pass the enhanced I/M test? Yes No

Activity 9

Vehicle #3

YEAR	*ENGINE*	*MODEL*	*MILEAGE*	*HC g/mile*	*CO g/mile*	*NO_x g/mile*
87	2.2L TBI	Sundance	81771	8.66	123.0	0.37

1. How many grams per mile HC did this vehicle produce?____________________
2. How many grams per mile CO did this vehicle produce?____________________
3. How many grams per mile NO_x did this vehicle produce?____________________
4. Did this vehicle pass the enhanced I/M test? Yes No

Vehicle #4

YEAR	*ENGINE*	*MODEL*	*MILEAGE*	*HC g/mile*	*CO g/mile*	*NO_x g/mile*
87	2.2L TBI	Sundance	81771	8.66	123.0	0.37

1. How many grams per mile HC did this vehicle produce?____________________
2. How many grams per mile CO did this vehicle produce?____________________
3. How many grams per mile NO_x did this vehicle produce?____________________
4. Did this vehicle pass the enhanced I/M test? Yes No

Activity 9

Vehicle #5

YEAR	ENGINE	MODEL	MILEAGE	HC g/mile	CO g/mile	NO_x g/mile
86	2.2L TBI	Dodge 600	59109	0.54	6.80	4.80

1. How many grams per mile HC did this vehicle produce?____________________
2. How many grams per mile CO did this vehicle produce?____________________
3. How many grams per mile NO_x did this vehicle produce?____________________
4. Did this vehicle pass the enhanced I/M test? Yes No

Vehicle #6

YEAR	ENGINE	MODEL	MILEAGE	HC g/mile	CO g/mile	NO_x g/mile
90	2.2L TBI	Sundance	68811	0.11	0.99	0.09

1. How many grams per mile HC did this vehicle produce?____________________
2. How many grams per mile CO did this vehicle produce?____________________
3. How many grams per mile NO_x did this vehicle produce?____________________
4. Did this vehicle pass the enhanced I/M test? Yes No

Activity 9

Vehicle Inspection Report

Arizona Department of Environmental Quality
Vehicle Inspection Program

0044227

- This test was conducted in accordance with the Federal Short Test Procedure in 207B. If your vehicle failed, it may be covered by the manufacturer's warranty (see supplemental brochure for more information).
- Vehicle registrations expire on the last day of the registration month. You will not have to pay a late registration fee provided: Your vehicle failed the first test prior to registration expiration, is repaired, retested and passed, and the registration renewal is postmarked within 30 days of the first test.
- The Arizona Vehicle Emissions Inspection Program is administered by the Arizona Department of Environmental Quality. Inspection services provided, under contract, by Gordon-Darby, Inc.

THE FINAL RESULT OF THIS INSPECTION IS: COMPLIANCE IM240

LICENSE PLATE	VEHICLE IDENTIFICATION NUMBER	MODEL YEAR/MAKE	STYLE	ODOMETER FUEL	CYL	STD	CLASS
FAST CAR	1B7GG23Y1PS177145	93 DODGE	PU	Ø23	G	Ø8	5

STATION/ANF	INSPECTOR(S)	DATE	TIME	TEST TYPE	INSPECTION NUMBER	REPRINT	FEE
MØ7 1	3333 3333	Ø1/17/95	15:Ø2	INITIAL	MØ71AØ51	NO	$16.75

EQUIPMENT OR PRESSURE & PURGE INSPECTION RESULTS

SYSTEM	RESULT	SYSTEM	RESULT
GAS CAP TEST	PASS	VISUAL EVAP- Inaccessible	OK
PURGE TEST- Inaccessible	NO TEST		

EMISSIONS INSPECTION RESULTS

TRANSIENT TEST POLLUTANT	THIS VEHICLE'S EMISSIONS	APPLICABLE STANDARD	RESULT FOR THIS POLLUTANT
HYDROCARBONS (HC) IN GRAMS/MILE	Ø.72	2.4Ø	PASS
CARBON MONOXIDE (CO) IN GRAMS/MILE	7.9	60.0	PASS
OXIDES OF NITROGEN (NOX) IN GRAMS/MILE	1.9	4.5	PASS

THIS IS AN INITIAL INSPECTION OF THIS VEHICLE.
THIS VEHICLE HAS PASSED THE EQUIPMENT INSPECTION AND THE EMISSIONS TEST.
CONGRATULATIONS! THANK YOU FOR HELPING CLEAN OUR AIR.
USE THE TEAR-OUT SECTION BELOW FOR REGISTERING YOUR VEHICLE.
KEEP THE UPPER PORTION OF THIS VIR UNTIL YOU RECEIVE YOUR NEW REGISTRATION.
IT IS YOUR PROOF OF COMPLIANCE WITH VIP REQUIREMENTS!

TEAR HERE

Questions? Call: 602-470-4646
The Arizona Department of Environmental Quality shall preserve protect and enhance the environment and public health and shall be a leader in the development of public policy to maintain and improve the quality of Arizona's air and natural resources.

OCT1994

Activity 9

VEHICLE REPAIR INFORMATION

To qualify for a retest you must complete this form and return within 60 days within 60 days of the first test.
Please see the brochure "Failed Vehicle Information"
For repair information and diagnostic assistance.

EQUIPMENT REPAIR INFORMATION

Check the appropriate boxes for those repairs performed on the vehicle.

- ☐ AIR INJECTION SYSTEM
- ☐ CATALYTIC CONVERTER
- ☐ INLET RESTRICTOR
- ☐ GAS CAP

MARICOPA COUNTY ONLY

- ☐ POSITIVE CRANKCASE VENTILATION (PCV)
- ☐ EVAPORATIVE EMISSIONS SYSTEM

PRESSURE/PURGE REPAIR COST [| |] (TO THE NEAREST WHOLE DOLLAR)

EQUIPMENT REPAIR INFORMATION - MARICOPA COUNTY ONLY

Check the appropriate boxes for those repairs performed on the vehicle.

- ☐ CANISTER
- ☐ PRESSURE / PURGE
- ☐ HOSES / FITTINGS
- ☐ GAS CAP
- ☐ CHECK VALVES
- ☐ OTHER ____________

PRESSURE/PURGE REPAIR COST [| |] (TO THE NEAREST WHOLE DOLLAR)

EMISSIONS REPAIR INFORMATION

Perform the following and make necessary repairs and adjustments in accordance with manufacturer's specifications and procedures. Check appropriate boxes for repairs performed.

A

- ☐ EMISSIONS FAILURE DIAGNOSIS
- ☐ DWELL / TIMING
- ☐ AIR INTAKE SYSTEM Air filter, Choke / Cold Start System, EFE / Heat Riser, TAC)
- ☐ PCV SYSTEM
- ☐ VACUUM LEAKS
- ☐ AIR / FUEL MIXTURE
- ☐ IDLE SPEED

B

- ☐ PLUG WIRES
- ☐ SPARK PLUGS
- ☐ SPARK CONTROL (Coil / Coil Packs, Distributor, Pickup Coil, Module, Rotor Cap, Mechanical

C

- ☐ CARBURETOR / FUEL INJECTION Clean / replace injectors or repair carburetor components (float setting, power valve, etc.)

D

- ☐ EVAPORATIVE EMISSIONS SYSTEM
- ☐ OXYGEN SENSOR
- ☐ THROTTLE POSITION SENSOR
- ☐ COOLANT TEMP. SENSOR
- ☐ AMBIENT SENSOR
- ☐ MAP / BARO SENSOR
- ☐ MASS AIR FLOW SENSOR
- ☐ RPM SENSOR
- ☐ ELECTRONIC CONTROL MODULE
- ☐ EGR SYSTEM
- ☐ AIR INJECTION SYSTEM
- ☐ CATALYTIC CONVERTER
- ☐ ELECTRICAL PROBLEMS (Connectors, broken wires, corrosion, battery, alternator)
- ☐ COOLANT SYSTEM
- ☐ FAULT CODES (List in comment section)

PRESSURE/PURGE REPAIR COST [| |] (TO THE NEAREST WHOLE DOLLAR)

DIESEL REPAIR INFORMATION

Check the appropriate boxes for those repairs performed on the vehicle.

- ☐ AIR CLEANER
- ☐ FUEL INJECTION TIMING
- ☐ FUEL INJECTORS
- ☐ FUEL PUMP
- ☐ SET AIR / FUEL RATIO
- ☐ PUFF LIMITER / ANAROID VALVE
- ☐ EGR
- ☐ ELECTRONIC FUEL / ENGINE CONTROL
- ☐ FAULT CODES (List in comment section)

PRESSURE/PURGE REPAIR COST [| |] (TO THE NEAREST WHOLE DOLLAR)

TO BE FILLED OUT BY REPAIR FACILITY OR VEHICLE OWNER

(Please print or use rubber stamp)

FACILITY PHONE NUMBER [| |]–[| |]–[| | |]

Person or Facility Performing Repairs		
Street		
City	State	Zip

Mechanic's Comments: ______________________________

____

____

Activity 9

Vehicle Inspection Report

Arizona Department of Environmental Quality — Vehicle Inspection Program

0001011

- This test was conducted in accordance with the Federal Short Test Procedure in 207B. If your vehicle failed, it may be covered by the manufacturer's warranty (see supplemental brochure for more information).
- Vehicle registrations expire on the last day of the registration month. You will not have to pay a late registration fee provided: Your vehicle failed the first test prior to registration expiration, is repaired, retested and passed, and the registration renewal is postmarked within 30 days of the first test.
- The Arizona Vehicle Emissions Inspection Program is administered by the Arizona Department of Environmental Quality. Inspection services provided, under contract, by Gordon-Darby, Inc.

THE FINAL RESULT OF THIS INSPECTION IS: FAILURE NOTICE

LICENSE PLATE	VEHICLE IDENTIFICATION NUMBER	MODEL YEAR/MAKE	STYLE	ODOMETER FUEL	CYL	STD	CLASS
FAST CAR 2	JP3CU24AØMUØ75943	91 PLYMO	HB	Ø17	G	04	3

STATION/ANF	INSPECTOR(S)	DATE	TIME	TEST TYPE	INSPECTION NUMBER	REPRINT	FEE
MØ5 1	2955	Ø1/Ø3/95	Ø8:28	INITIAL	MØ51AØØ2	NO	$16.75

EQUIPMENT OR PRESSURE & PURGE INSPECTION RESULTS

SYSTEM	RESULT	SYSTEM	RESULT
GAS CAP TEST	PASS	VISUAL EVAP-	OK
PURGE TEST	PASS		

EMISSIONS INSPECTION RESULTS

TRANSIENT TEST POLLUTANT	THIS VEHICLE'S EMISSIONS	APPLICABLE STANDARD	RESULT FOR THIS POLLUTANT
HYDROCARBONS (HC) IN GRAMS/MILE	1.Ø8	1.2Ø	PASS
CARBON MONOXIDE (CO) IN GRAMS/MILE	5.7	2Ø.Ø	PASS
OXIDES OF NITROGEN (NOX) IN GRAMS/MILE	3.Ø	2.5	FAIL

THIS IS AN INITIAL INSPECTION OF THIS VEHICLE.
THIS VEHICLE HAS PASSED THE EQUIPMENT INSPECTION AND THE EMISSIONS TEST.
REPAIRS MUST BE COMPLETED PRIOR TO HAVING THE VEHICLE RETESTED AT AN INSPECTION STATION.
SEE THE BACK OF THIS FORM AND THE SUPPLEMENTAL BROCHURE FOR MORE INFORMATION.

TEAR HERE

Questions? Call: 602-470-4646

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Activity 9

VEHICLE REPAIR INFORMATION

To qualify for a retest you must complete this form and return within 60 days within 60 days of the first test.
Please see the brochure "Failed Vehicle Information"
For repair information and diagnostic assistance.

EQUIPMENT REPAIR INFORMATION

Check the appropriate boxes for those repairs performed on the vehicle.

- ☐ AIR INJECTION SYSTEM
- ☐ CATALYTIC CONVERTER
- ☐ INLET RESTRICTOR
- ☐ GAS CAP

MARICOPA COUNTY ONLY

- ☐ POSITIVE CRANKCASE VENTILATION (PCV)
- ☐ EVAPORATIVE EMISSIONS SYSTEM

PRESSURE/PURGE REPAIR COST [| |] (TO THE NEAREST WHOLE DOLLAR)

EQUIPMENT REPAIR INFORMATION - MARICOPA COUNTY ONLY

Check the appropriate boxes for those repairs performed on the vehicle.

- ☐ CANISTER
- ☐ PRESSURE / PURGE
- ☐ HOSES / FITTINGS
- ☐ GAS CAP
- ☐ CHECK VALVES
- ☐ OTHER ________________

PRESSURE/PURGE REPAIR COST [| |] (TO THE NEAREST WHOLE DOLLAR)

EMISSIONS REPAIR INFORMATION

Perform the following and make necessary repairs and adjustments in accordance with manufacturer's specifications and procedures. Check appropriate boxes for repairs performed.

A

- ☐ EMISSIONS FAILURE DIAGNOSIS
- ☐ DWELL / TIMING
- ☐ AIR INTAKE SYSTEM
  Air filter, Choke / Cold Start System, EFE / Heat Riser, TAC)
- ☐ PCV SYSTEM
- ☐ VACUUM LEAKS
- ☐ AIR / FUEL MIXTURE
- ☐ IDLE SPEED

B

- ☐ PLUG WIRES
- ☐ SPARK PLUGS
- ☐ SPARK CONTROL
  (Coil / Coil Packs, Distributor, Pickup Coil, Module, Rotor Cap, Mechanical

C

- ☐ CARBURETOR / FUEL INJECTION
  Clean / replace injectors or repair carburetor components (float setting, power valve, etc.)

D

- ☐ EVAPORATIVE EMISSIONS SYSTEM
- ☐ OXYGEN SENSOR
- ☐ THROTTLE POSITION SENSOR
- ☐ COOLANT TEMP. SENSOR
- ☐ AMBIENT SENSOR
- ☐ MAP / BARO SENSOR
- ☐ MASS AIR FLOW SENSOR
- ☐ RPM SENSOR
- ☐ ELECTRONIC CONTROL MODULE
- ☐ EGR SYSTEM
- ☐ AIR INJECTION SYSTEM
- ☐ CATALYTIC CONVERTER
- ☐ ELECTRICAL PROBLEMS
  (Connectors, broken wires, corrosion, battery, alternator)
- ☐ COOLANT SYSTEM
- ☐ FAULT CODES
  (List in comment section)

PRESSURE/PURGE REPAIR COST [| |] (TO THE NEAREST WHOLE DOLLAR)

DIESEL REPAIR INFORMATION

Check the appropriate boxes for those repairs performed on the vehicle.

- ☐ AIR CLEANER
- ☐ FUEL INJECTION TIMING
- ☐ FUEL INJECTORS
- ☐ FUEL PUMP
- ☐ SET AIR / FUEL RATIO
- ☐ PUFF LIMITER / ANAROID VALVE
- ☐ EGR
- ☐ ELECTRONIC FUEL / ENGINE CONTROL
- ☐ FAULT CODES
  (List in comment section)

PRESSURE/PURGE REPAIR COST [| |] (TO THE NEAREST WHOLE DOLLAR)

TO BE FILLED OUT BY REPAIR FACILITY OR VEHICLE OWNER

(Please print or use rubber stamp)

FACILITY PHONE NUMBER [| | – | | – | | |]

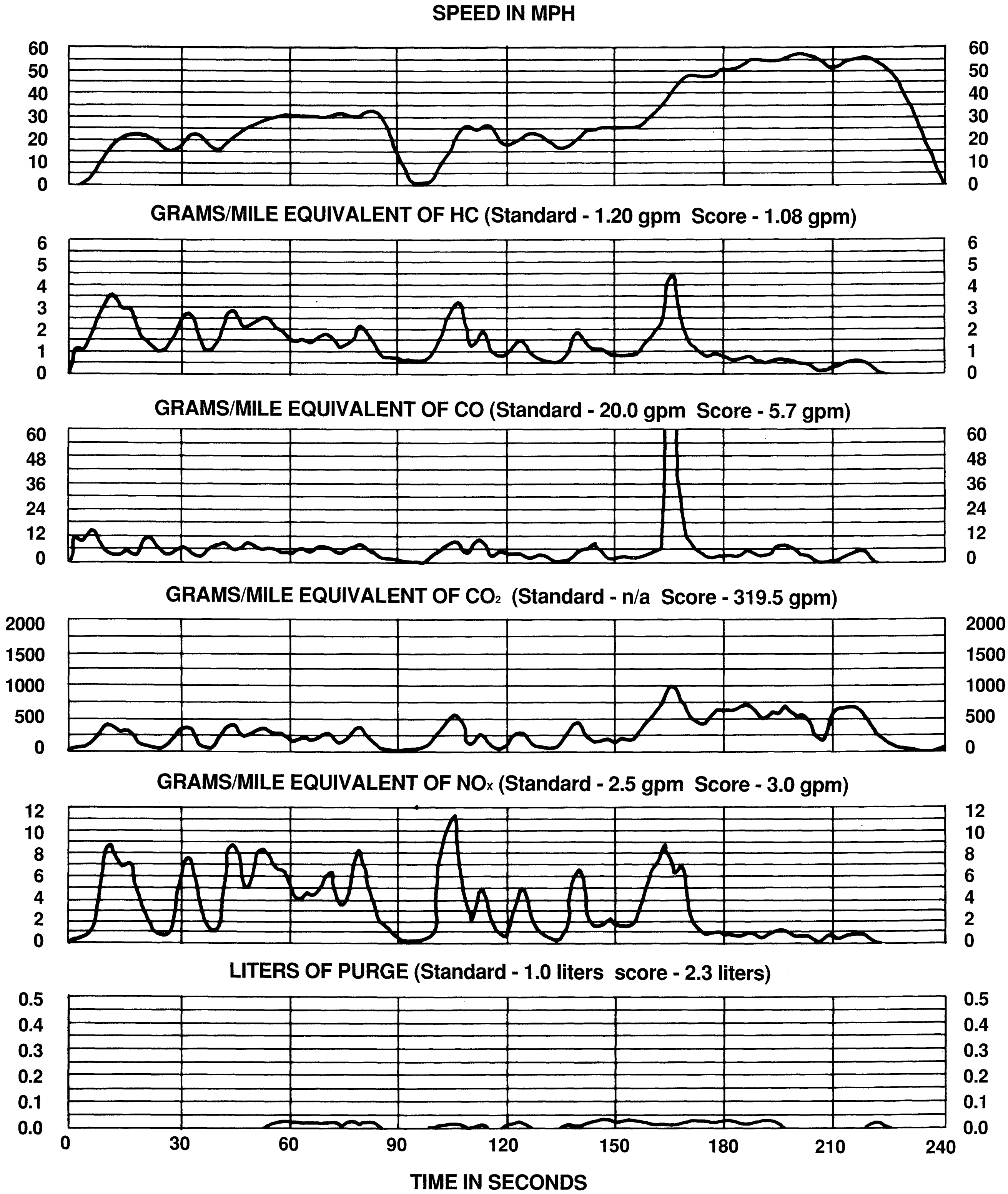
Person or Facility Performing Repairs		
Street		
City	State	Zip

Mechanic's Comments: ____

____

____

Activity 9


SPEED IN MPH
60
50
40
30
20
10
0
GRAMS/MILE EQUIVALENT OF HC (Standard - 1.20 gpm Score - 1.08 gpm)
6
5
4
3
2
1
0
GRAMS/MILE EQUIVALENT OF CO (Standard - 20.0 gpm Score - 5.7 gpm)
60
48
36
24
12
0
GRAMS/MILE EQUIVALENT OF CO_2 (Standard - n/a Score - 319.5 gpm)
2000
1500
1000
500
0
GRAMS/MILE EQUIVALENT OF NO_x (Standard - 2.5 gpm Score - 3.0 gpm)
12
10
8
6
4
2
0
LITERS OF PURGE (Standard - 1.0 liters score - 2.3 liters)
0.5
0.4
0.3
0.2
0.1
0.0
0
30
60
90
120
150
180
210
240
TIME IN SECONDS

Activity 10

INSPECTING THE PCV AND HEATED AIR INLET SYSTEMS

POSITIVE CRANKCASE VENTILATION (PCV)

AT THE VEHICLE

> ***Warning:*** *Apply parking brake and/or block wheels before performing any test or adjustment with the engine operating.*

1. Start the engine and allow to warm up at least two minutes. Perform an emissions test and record the readings:

   HC ________ ppm

   CO ________ %

   CO_2 ________ %

   O_2 ________ %

   NO ________ ppm

2. With the engine idling, remove the hose from the PCV valve. A hissing noise should be heard as air passes through the valve. A strong vacuum should also be felt when a finger is placed over the valve inlet.

3. Install hose on PCV valve. Remove the make-up air hose from the air plenum at the rear of the engine. Hold a piece of stiff paper (such as a parts tag) loosely over the end of the make-up air hose.

4. After allowing approximately one minute for crankcase pressure to reduce, the paper should draw up against the hose with noticeable force.

5. Turn the engine off. Remove the PCV valve from the intake manifold. The valve should rattle when shaken.

6. With the PCV valve still out of the intake manifold, start the engine. Test the exhaust emissions with the exhaust gas analyzer and record your results here:

   HC ________ ppm

   CO ________ %

   CO_2 ________ %

   O_2 ________ %

   NO ________ ppm

7. Shut the engine off and replace the PCV valve. Verify that all hoses are properly connected.

8. Discuss the results of this exercise with your instructor and classmates. What do the changed values indicate? Is O_2 switching taking place?

   ____

   ____

   ____

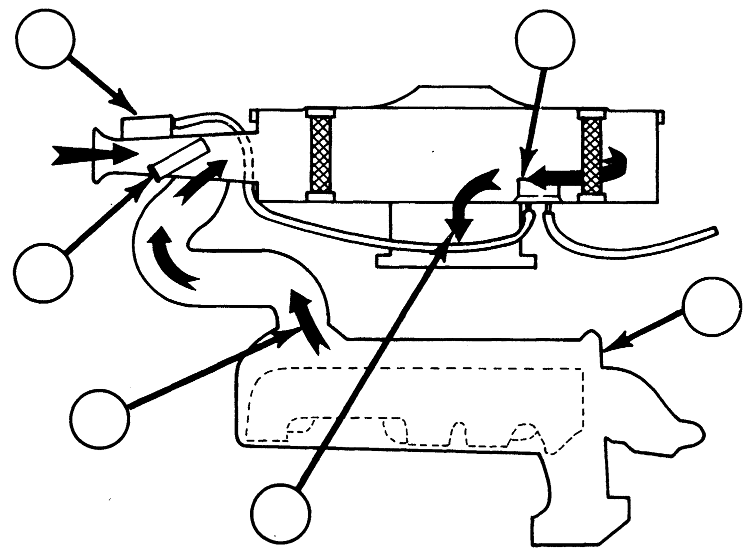
   ____

   ____

Activity 10

HEATED AIR INLET
(If classroom vehicle so equipped.)

DIRECTIONS:
Before going to the vehicle, complete the following illustration. Identify the heated air inlet system components by placing the appropriate number in each circle.



1. SENSOR
2. HEATED AIR ENTERS CARBURETOR
3. VACUUM DIAPHRAGM
4. AIR CONTROL VALVE (AIR DOOR)
5. AIR HEATED BY MANIFOLD
6. COLD AIR ENTERS

AT THE VEHICLE

Warning: *Be sure to apply parking brake and/or block wheels before performing any test or adjustment with the engine operating.*

1. With the engine off, make sure all vacuum hoses, the flexible connector between the stove and air cleaner, and the air cleaner duct are all properly attached and are in good condition.

2. Remove the air cleaner from the engine. With a hand vacuum pump, apply 20 inches of vacuum to the sensor. Within 35 seconds, the door should move to the UP or HEAT ON position.

3. Start the engine. With a cold engine and ambient temperature less than 50∞F, the heat control door (valve plate) in the snorkel should be in the UP or HEAT ON position.

4. With the engine warmed up and running, check the air temperature entering the snorkel or at the sensor. When the air temperature entering the outer end of the snorkel is 100°F or higher, the door should be in the DOWN or HEAT OFF position.

5. Shut engine off. To test the diaphragm, apply 25 inches of vacuum to the diaphragm. The vacuum should not bleed down more than 10 inches in five minutes. The door should not lift off the bottom of the snorkel at less than 5.5 inches Hg and should be in full up position with no more than 8.5 inches Hg.

6. Disconnect the vacuum pump and replace hoses.

7. Class Discussion: What do you suppose would happen to the following exhaust gases if the heated air inlet were stuck ON?

- HC ______________________________
- CO ______________________________
- CO_2 ______________________________
- O_2 ______________________________

HEATED CROSSOVER INSPECTION

1. Is the crossover passage hot to touch?

____

____

____

____

2. Does the manifold heat control valve more freely?

____

____

____

____

Activity 11

OBSERVING THE EFFECT OF A VACUUM LEAK ON EMISSIONS

In this exercise, you will create a vacuum leak to observe its effect on exhaust emissions. The vehicle will be tested for exhaust emissions before the leak is created, and the emissions will continue to be observed while the engine is running with a vacuum leak.

AT THE VEHICLE
DIRECTIONS:

1. Connect the scan tool (or MDS) to the vehicle.
2. Start the engine and run at fast idle for several minutes until closed-loop operation has been verified on the scan tool (or MDS).
3. Connect the exhaust gas analyzer to the vehicle and perform an emissions test.
4. Record your emissions readings:

   HC ______ ppm

   CO ______ %

   CO_2 ______ %

   O_2 ______ %

   NO ______ ppm

5. With the engine running, create a vacuum leak by carefully removing a vacuum hose from a convenient location, such as at the brake booster.

6. What happened to the vehicle's idle speed? Why?

   ____

   ____

   ____

   ____

   ____

   ____

6. Test the exhaust gases again and record the results:

HC ______ ppm

CO ______ %

CO_2 ______ %

O_2 ______ %

NO ______ ppm

Continue to observe the emissions readings on the gas analyzer for several minutes.

What is the immediate change in the exhaust gases? Describe in general terms (e.g., HC was up a lot, CO was down a little, etc.).

____

____

What happens to the exhaust gases during the next several minutes? Describe in general terms.

____

____

What other conditions were noted? Is O_2 switching taking place?

____

____

7. Replace the vacuum hose.
8. Using the scan tool (or MDS), check for any Diagnostic Trouble Codes.
9. Were any codes set? If yes, list them. ______________________________
10. Clear the codes, if any.

Notes:

____

____

____

____

Activity 12

OBSERVING THE EFFECT OF THE ENGINE COOLANT TEMPERATURE SENSOR ON EMISSIONS

In this exercise, you will generate a faulty ECT sensor signal by unplugging the sensor on a known clean vehicle and plugging the connector into another ECT sensor in room-temperature air. The vehicle will be tested for exhaust emissions before the sensors are swapped, and will be observed while the engine is running with the room-temperature ECT sensor connected.

AT THE VEHICLE
DIRECTIONS:

1. Connect the scan tool (or MDS) to the vehicle.

2. Start the engine and run at fast idle for several minutes until closed-loop operation has been verified on the scan tool (or MDS).

3. Connect the exhaust gas analyzer to the vehicle and perform an emissions test.

4. Record your emissions readings:

   HC _____ ppm

   CO _____ %

   CO_2 _____ %

   O_2 _____ %

   NO _____ ppm

   Injector PW _____ MS

5. Shut the engine off. Remove the connector from the coolant temperature sensor and plug it into a second ECT sensor at room temperature.

Activity 12

6. Start the engine and allow to warm up for two minutes. Test the exhaust gases again and record the results.

   HC ______ ppm

   CO ______ %

   CO_2 ______ %

   O_2 ______ %

   NO ______ ppm

   Injector PW ______ MS

Continue to observe the emissions readings on the gas analyzer for several minutes.

What is the immediate change in the exhaust gases? Describe in general terms (e.g., HC was up a lot, CO was down a little, etc.)

____

____

What happens to the exhaust gases during the next several minutes? Describe in general terms.

____

____

What other conditions were noted? Is O_2 switching taking place?

____

____

7. Shut the engine off and replace the connector on the vehicle ECT sensor.

8. Using the scan tool (or MDS), check for any Diagnostic Trouble Codes.

9. Were any codes set? If yes, list them.______________________________________

   ____

10. Clear the codes, if any.

Activity 13

OBSERVING THE EFFECT OF THE OXYGEN SENSOR ON EMISSIONS

In this exercise, you will test the exhaust emissions on a vehicle with a faulty O_2 sensor to see how the results differ from a known clean vehicle.

AT THE VEHICLE
DIRECTIONS:

1. Connect the scan tool (or MDS) to a vehicle with a faulty O_2 sensor.
2. Start the engine and run at fast idle for several minutes until closed-loop operation should have been reached. Was closed-loop operation verified on the scan tool (or MDS)?
3. Connect the exhaust gas analyzer to the vehicle and perform an emissions test.
4. Record the following readings:

   HC ______ ppm

   CO ______ %

   CO_2 ______ %

   O_2 ______ %

   NO ______ ppm

   Injector PW ______ MS

5. Continue to observe the emissions readings on the gas analyzer for several minutes.

What happens to the exhaust gases during the next several minutes? Describe in general terms.

____

____

What other conditions were noted? Is O_2 switching taking place? How many times should the O_2 sensor switch for proper operation?

____

____

____

6. Shut the engine off. Disconnect the faulty O_2 sensor. Remove the faulty sensor and install a good one. Plug the connector onto the good O_2 sensor.

7. Restart the engine and allow to warm up for at least two minutes. Test the exhaust gases again and record the readings:

   HC ______ ppm

   CO ______ %

   CO_2 ______ %

   O_2 ______ %

   NO ______ ppm

   Injector PW ______ MS

8. Shut the engine off.

9. Using the scan tool (or MDS), check for any Diagnostic Trouble Codes.

10. Were any codes set? If yes, list them. ______________________ ______________

    ____

11. Clear the codes, if any. ____

Activity 14

OBSERVING THE EFFECT OF THE MAP SENSOR ON EMISSIONS

In this exercise, you will test the exhaust emissions on a vehicle with a faulty MAP sensor to see how the results differ from a known clean vehicle.

AT THE VEHICLE

Directions:

1. Connect the scan tool (or MDS) to a vehicle with a known good MAP sensor.
2. Start the engine and run at fast idle for several minutes until closed-loop operation has been verified on the scan tool (or MDS).
3. Connect the exhaust gas analyzer to the vehicle and perform an emissions test.
4. Record the following readings:

   HC ______ ppm

   CO ______ %

   CO_2 ______ %

   O_2 ______ %

   NO ______ ppm

   Injector PW ______ MS

5. Shut the engine off. Replace the MAP sensor with a faulty sensor provided by the instructor.

Activity 14

6. Start the engine and allow to warm up for at least two minutes. Test the exhaust gases again and record the results:

   HC ______ ppm

   CO ______ %

   CO_2 ______ %

   O_2 ______ %

   NO ______ ppm

   Injector PW ______ MS

7. Continue to observe the emissions readings on the gas analyzer for several minutes.

What is the immediate change in the exhaust gases? Describe in general terms (e.g.: HC was up a lot, CO was down a little, etc.).

____

____

What happens to the exhaust gases during the next several minutes? Describe in general terms.

____

____

What other conditions were noted? Is O_2 switching taking place?

____

____

____

____

8. Shut the engine off.

9. Using the scan tool (or MDS), check for any Diagnostic Trouble Codes.

10. Were any codes set? If yes, list them. ______________________________

    ____

11. Clear the codes, if any.

Activity 15

OBSERVING THE EFFECT OF THE THROTTLE POSITION SENSOR ON EMISSIONS

In this exercise, you will test the exhaust emissions of a vehicle with the throttle position sensor (TPS) connected and disconnected, and with a faulty TPS, to see how the results differ.

AT THE VEHICLE
DIRECTIONS:

1. Connect the scan tool (or MDS) to a vehicle with a known good TPS.
2. Start the engine and run at fast idle for several minutes until closed-loop operation has been verified on the scan tool (or MDS).
3. Connect the exhaust gas analyzer to the vehicle and perform an emissions test.
4. Record your emissions readings in the table on the following page.
5. Quickly "snap" the throttle to wide open and release.
6. Immediately record the new exhaust gas readings in the table.
7. Shut the engine off.
8. Remove the electrical connector from the TPS.
9. Restart the engine and allow it to warm up for at least two minutes.
10. Record the exhaust gas readings at idle.
11. Quickly "snap" the throttle to wide open and release.
12. Immediately record the new exhaust gas readings in the table.
13. Shut the engine off.
14. Remove the TPS and install a faulty TPS provided by the instructor. Plug the electrical connector into the faulty TPS.
15. Restart the engine and allow it to warm up for at least two minutes.
16. Record the exhaust gas readings at idle.

17. Quickly "snap" the throttle to wide open and release.

18. Immediately record the new exhaust gas readings in the table.

	TPS CONNECTED		TPS DISCONNECTED		TPS FAULTY	
	Before Throttle Snap	*After Throttle Snap*	*Before Throttle Snap*	*After Throttle Snap*	*Before Throttle Snap*	*After Throttle Snap*
HC						
CO						
CO_2						
O_2						
NO						
INJ. PW						

19. Shut the engine off and reinstall the original TPS.

20. What happened to the exhaust gases (particularly CO and O_2) after each example? What does this tell you about the role of the throttle position sensor? What other conditions were noted?

____

____

____

____

____

____

21. Using the scan tool (or MDS), check for any Diagnostic Trouble Codes.

22. Were any codes set? If yes, which ones? ______________________.

____

23. Clear the codes, if any.

Notes:

____

____

Activity 16

OBSERVING THE EFFECTS OF THE EGR VALVE ON EMISSIONS

In this exercise, you will inspect the EGR system, and you will use a hand vacuum pump to force the EGR valve into an open position during an emissions test. The vehicle will be tested for exhaust emissions while the EGR valve is operating normally, and they will continue to be monitored while the EGR valve is forced open.

AT THE VEHICLE
Before testing the exhaust emissions, inspect system hoses and make sure there are no leaks. Inspect hose connections between intake manifold, EGR solenoid and transducer, and the EGR valve.

EGR Transducer Solenoid

1. Ensure that manifold vacuum flows to the electronic EGR transducer (EET). Use the scan tool (or MDS) to test the solenoid on the EET. Refer to the appropriate Powertrain Diagnostic Manual.

2. Disconnect the vacuum supply hose from the transducer. Tee a vacuum gauge between the transducer and hose. Start the vehicle. There should be a minimum of 15 inches of vacuum supplied to the solenoid. If vacuum is low, check for kinked or twisted hoses and leaking hoses or hose connections.

3. Actuate the solenoid using the scan tool (or MDS). The solenoid should click when turned ON and OFF. As the solenoid cycles, it should shut vacuum to the transducer ON and OFF. After ensuring that the solenoid operates correctly, proceed to test the transducer.

EGR Transducer

1. Disconnect the vacuum hose and back-pressure hose from the transducer. Disconnect the electrical connector from the solenoid.

2. Plug the transducer output port.

3. Apply 1 to 2 psi of air pressure to the transducer back-pressure port. Use a hand-held air pump or compressed air regulated to 2 psi.

4. Using a hand vacuum pump, apply a minimum of 12 inches of vacuum to the other side of the transducer. The transducer should momentarily hold vacuum and then slowly bleed off.

Activity 16

Emissions Testing

1. Connect the scan tool (or MDS) to the vehicle.
2. Start the engine and run at fast idle
3. Connect the exhaust gas analyzer to the vehicle and perform an emissions test.
4. Record the following readings:

   HC ______ ppm

   CO ______ %

   CO_2 ______ %

   O_2 ______ %

   NO ______ ppm

   Injector PW ______ MS

5. Remove the vacuum hose at the EGR valve and attach a hand vacuum pump to the EGR valve.
6. Gently apply just enough vacuum to the EGR valve to cause the engine to run rough. While maintaining vacuum, continue to observe the emissions readings on the analyzer for several minutes. Record the emissions readings while the engine is running rough:

   HC ______ ppm

   CO ______ %

   CO_2 ______ %

   O_2 ______ %

   NO ______ ppm

   Injector PW ______ MS

Activity 16

What happens to the four gases (especially NO and O2) during the next several minutes? Describe in general terms.

____

____

What other conditions were noted? Does the scan tool show O2 sensor switching?

____

____

7. Disconnect the hand vacuum pump and replace the vacuum hose on the EGR valve.

8. Disconnect the EGR valve by plugging the vacuum hose or by clamping it shut.

> ***Warning:*** *The next part of this Activity is conducted with the car in gear. Apply the parking brake and set wheel blocks before performing this exercise. Do not allow anyone in front of the vehicle.*

9. With the engine running, depress the brake pedal firmly with your left foot and place the car in DRIVE. While keeping the brake pedal depressed, hold the engine at a fast idle (about 1800 rpm).

10. Have another student record the emissions readings while the engine is at fast idle.

    HC ______ ppm

    CO ______ %

    CO_2 ______ %

    O_2 ______ %

    NO ______ ppm

11. Release the accelerator and place the car in PARK. Shut the engine off.

12. Re-connect the EGR valve.

13. Repeat steps 9 and 10 to take emissions readings with the engine at 1800 rpm and the EGR valve functioning normally.

    HC ______ ppm

    CO ______ %

    CO_2 ______ %

    O_2 ______ %

    NO ______ ppm

14. Release the accelerator and place the car in PARK. Shut the engine off.

15. Using the scan tool (or MDS), check for any diagnostic trouble codes.

16. Were any codes set? If yes, list them.______________________________.

    ____

17. Clear the codes, if any.

18. Discuss the results of this exercise with your instructor and classmates. What do you think your NO_x results would have been at an I/M test station?

    ____

    ____

    ____

    ____

    ____

    ____

    ____

    ____

Activity 17

TROUBLESHOOTING A PROBLEM VEHICLE

In this exercise, you will diagnose and repair a high-emissions vehicle. The customer says that the CHECK ENGINE lamp stays ON when the engine is running, and the vehicle seems to have a strong odor of gasoline coming from the tailpipe.

AT THE VEHICLE
DIRECTIONS:

1. Follow Step One of the six-step diagnostic process — verify the complaint.

   Start the engine. If the Check Engine lamp ON? Is there a gasoline odor? Record your observations:

   ____

   ____

2. Follow Step Two of the six-step diagnostic process—determine related symptoms.

   Perform an exhaust gas test with the exhaust gas analyzer. Record the results:

   HC _____ ppm

   CO _____ %

   CO_2 _____ %

   O_2 _____ %

   NO _____ ppm

What other conditions were noted?

____

____

Shut the engine off.

3. Perform Step Three of the six-step diagnostic process — analyze the symptoms.

What is the significance of the exhaust gas readings? What is the significance of the gasoline odor, if any, and any other conditions you may have noted? Discuss in class.

4. Perform Step Four of the six-step diagnostic process — isolate the trouble.

   Are any diagnostic trouble codes set?

   If so, which ones? ______________________________.

   According to the Diagnostic Manual, what circuit is most likely causing the problem? ______________________________.

   What page of the Diagnostic Manual lists the fault tree for this condition? __________.

5. Perform Step Five of the six-step diagnostic process — correct the trouble. This means perform any necessary repairs indicated by the previous steps.

6. Perform Step Six of the six-step diagnostic process — check for proper operation. Start the engine. What conditions are noted?

   Re-test the exhaust with the gas analyzer. Record the results:

   HC ______ ppm

   CO ______ %

   CO_2 ______ %

   O_2 ______ %

   NO ______ ppm

7. Are these acceptable readings for a well-tuned modern vehicle? Why or why not? If the readings are acceptable and no other symptoms are noted, the Activity is complete. Clear any trouble codes and discuss your results in class. If there is still a problem with the vehicle, return to Step 3 and continue your diagnosis.

Notes: ____

____

____

____

GLOSSARY

Air Injection — A system of feeding air into the exhaust manifold or catalytic converter to complete the combustion of unburned fuel by adding oxygen.

Air/Fuel Ratio — The ratio, by weight, of air to gasoline in the intake charge of a gasoline engine. The ideal ratio for complete combustion is 14.7 parts of air by weight to 1 part of fuel.

Basic — A type of government-mandated vehicle inspection program in which the vehicle is given an idle-speed test for tailpipe concentrations of hydrocarbons and carbon monoxide.

Carbon Dioxide — A gas whose molecules each consist of one atom of carbon and two atoms of oxygen. A relatively harmless gas which is one of the products of complete combustion. Abbreviated CO_2.

Carbon Monoxide — A poisonous gas whose molecules each consist of one carbon atom and one oxygen atom. Carbon monoxide is an automotive pollutant which is the result of incomplete combustion due to lack of oxygen. Abbreviated CO.

Catalyst — A material that promotes a chemical reaction without itself being changed by the reaction. The noble metals platinum, palladium, and rhodium are used as catalysts in catalytic converters.

Catalytic Converter — A passive device which utilizes the action of catalyst metals to convert harmful carbon monoxide, hydrocarbons, and/or oxides of nitrogen into harmless compounds.

Clean Air Act Amendments of 1990 — A body of legislation which was enacted to further reduce the level of atmospheric pollutants generated by automobiles. Included in the legislation are reductions in mass emissions, provision for enhanced inspection and maintenance (I/M) testing in designated areas, and the required use of second-generation on-board diagnostics (OBD II).

Clean Air Act of 1963 — Legislation which grew out of air pollution research conducted in the late 1950s and early 1960s and which laid the groundwork for today's emission regulations and control systems.

Closed Loop — A state in which the air/fuel mixture is being controlled by the engine computer, in response to signals from the oxygen sensor.

CO — See Carbon Monoxide.

CO_2 — See Carbon Dioxide.

Combustion — The act of burning which takes place when heat is applied to a fuel in the presence of oxygen. Takes place in the combustion chamber and produces heat and power. Perfect combustion of a hydrocarbon produces heat, carbon dioxide, and water vapor. Imperfect combustion also produces harmful carbon monoxide and oxides of nitrogen.

EGR Valve — The principal component of the exhaust-gas recirculation system. Under certain conditions, the EGR valve opens to allow a small amount of exhaust gas to be mixed with fresh fuel mixture in the intake system. This dilutes the overall fuel mixture, lowering combustion chamber temperatures and reducing levels of harmful oxides of nitrogen.

Emissions — The exhaust gases produced by combustion. Harmful emissions, or pollutants, include carbon monoxide, unburned hydrocarbons, and oxides of nitrogen.

Engine Control Module — The microcomputer or microprocessor used to control engine functions based on input signals received from various sensors. Instrumental in the development and control of modern-day emissions control systems.

Enhanced — A type of government-mandated vehicle inspection program in which the vehicle is given a transient-speed test of mass emissions of carbon monoxide, hydrocarbons, and oxides of nitrogen. Enhanced testing also includes a visual inspection and a pressure and purge test of the evaporative emissions system.

Environmental Protection Agency — The federal agency responsible for creating and enforcing anti-pollution legislation.

EPA — The Environmental Protection Agency (See Above).

Evaporative Canister—A container of activated charcoal granules used to store fuel tank vapors until they can be drawn into the engine's intake system and burned.

Evaporative Emissions—Raw hydrocarbons which escape from the fuel system.

Exhaust-Gas Recirculation—A method of reducing the levels of harmful oxides of nitrogen (NO_x) by reburning small amounts of exhaust gas with the intake charge. This dilutes the fuel mixture and lowers the combustion temperature, resulting in a reduced production of NO_x.

Federal Test Procedure—A transient-speed mass emissions test conducted on a loaded dynamometer. This is the test which, by law, car manufacturers use to certify that new vehicles are in compliance for hydrocarbon, carbon monoxide, and oxides of nitrogen emissions.

Feed Gases — Exhaust gases prior to being treated by the catalytic converter (i.e., gases entering the converter from the engine).

Four-Gas Analyzer — An exhaust-gas analyzer which determines the levels of hydrocarbons, carbon monoxide, carbon dioxide, and oxygen in the exhaust stream.

Fuel Injector — A device which injects pressurized gasoline through a nozzle and into the intake manifold. Its ability to be computer-controlled has led to much tighter control of the air/fuel ratio, and a corresponding decrease in hydrocarbon and carbon monoxide emissions.

HC — See Hydrocarbon(s).

Hydrocarbons — A family of organic fuels containing only hydrogen and carbon. Gasoline consists almost entirely of a hydrocarbon mixture. Unburned hydrocarbons in the atmosphere are considered pollutants.

Idle-Speed Test — An inspection and maintenance (I/M) test conducted at a steady engine speed at low rpms.

IM240 — An inspection and maintenance (I/M) test consisting of a transient-speed 240-second simulated drive on a loaded dynamometer. Mass emissions of carbon monoxide, hydrocarbons, and oxides of nitrogen are measured during this test.

Inspection and Maintenance (I/M) — Any of a group of government-mandated programs to regularly inspect and certify the emissions-control systems on automobiles.

Knock Sensor — An electrical device that detects spark knock from excessively advanced spark timing. The sensor contains a quartz crystal which produces a voltage when subjected to physical pressure. The vibration from a spark knock is sufficient to produce a voltage which instructs the engine computer to retard the spark timing.

Lean — Designating an air-fuel mixture that contains a relatively high amount of air or low amount of fuel (i.e., an air/fuel ratio greater than the ideal 14.7:1). A lean burn is characterized by low levels of carbon monoxide. Excessively lean burns can result in increasing levels of unburned hydrocarbons due to lean misfire.

Mass Emissions — The total quantity of pollutants produced by an automobile, usually expressed in grams per mile.

Microcomputer — Another name for microprocessor, or a computer built around such a device. In an automobile, the microcomputer receives input signals from various sensors (oxygen sensor, throttle position sensor, coolant temperature sensor, etc.), interprets the information, and sends control instructions to the appropriate devices such as fuel injectors and purge valves. Engine control modules, powertrain control modules, single-board engine controllers, and single-module engine controllers are all names given to automotive microcomputers.

Microprocessor — An electronic computer contained on a single chip. Microprocessors form the heart of microcomputer systems.

Monolithic — A type of catalytic converter construction in which a ceramic honeycomb is coated with a thin layer of the catalyst metals. Exhaust gases flow through the passages in the honeycomb.

Nitrogen — The gas which makes up 78% of the air we breathe. Under conditions of high temperature and pressure in the combustion chamber, nitrogen can combine with oxygen to form harmful oxides of nitrogen (NO_x). Oxides of nitrogen contribute to the formation of ground-level ozone and photochemical smog.

NO_x — Abbreviation for oxides of nitrogen. Harmful gases which form when nitrogen from the air is combined with oxygen under conditions of high temperature and pressure in the combustion chamber. Oxides of nitrogen contribute to the formation of ground-level ozone and photochemical smog.

O_2 — Symbol for oxygen in its normal state. Oxygen makes up 21% of the air we breathe, and is a necessary element for combustion.

OBD II — Abbreviation for second-generation on-board diagnostics. OBD II is mandated under the Clean Air Act Amendments of 1990 and requires all manufacturers to use a standardized set of data with standardized diagnostic trouble codes. This data is supplied to a standard 16-pin connector which is located in the same area on every vehicle.

Open Loop — A state in which the air-fuel mixture is being controlled by the engine computer according to a standard program and not in response to signals from the oxygen sensor. Normally encountered during the first few minutes of operation after a cold start.

Oscilloscope — A piece of electronic test equipment that displays signal voltages and shapes on a screen. Can be used to diagnose devices in which the signal voltage, waveform, or timing are important factors.

Oxidation Converter — A type of catalytic converter that uses platinum and palladium metals as catalysts to oxidize carbon monoxide and hydrocarbons into harmless carbon dioxide and water vapor.

Oxides of Nitrogen — Harmful gases which form when nitrogen from the air is combined with oxygen under conditions of high temperature and pressure in the combustion chamber. Oxides of nitrogen contribute to the formation of ground-level ozone and photochemical smog.

Oxygen — The gas that makes up about 21% of the air we breathe, and is a necessary element for combustion. When air is mixed with fuel, it provides the oxygen needed for combustion.

Oxygen Sensor — A small electrical device that installs in the exhaust manifold and produces a voltage which varies with the amount of oxygen present in the exhaust. The voltage is read by the engine computer, which uses the information to control the air/fuel mixture at the fuel injectors or carburetor.

Ozone — A gas whose molecules consist of three atoms of oxygen, instead of the usual two. Ozone is a respiratory irritant that is formed when oxides of nitrogen combine with hydrocarbons in the presence of sunlight. Abbreviated O_3.

Palladium — Rare metallic element used as a catalyst in the oxidizing part of a catalytic converter, usually along with platinum.

Pellet-Type — A type of catalytic converter construction in which aluminum oxide pellets are coated with a thin layer of catalyst metal. The pellets are contained within a shell, and the exhaust gases are directed through the pellets by baffles .

Photochemical Smog — A type of air pollution caused by the action of sunlight on certain chemicals. Consists mainly of ozone formed when sunlight reacts with hydrocarbons and oxides of nitrogen.

Platinum — A metallic element used as a catalyst in the oxidizing part of a catalytic converter, usually along with palladium.

Pollutant — Any substance, such as chemical waste, that is considered hazardous to the environment. In automotive use, refers specifically to hydrocarbons, carbon monoxide, oxides of nitrogen, and other trace compounds released to the atmosphere as a by-products of combustion.

Positive Crankcase Ventilation — A method of retaining blow-by gases within the engine rather than releasing them to the atmosphere. Achieved by recirculating these gases back through the intake system through the PCV valve.

Post-Combustion — An emissions-control device or system whose action takes place after combustion has occurred. Air injection and catalytic converters are post-combustion systems.

Powertrain Control Module — A microcomputer that controls engine operations by interpreting and responding to input signals from various sensors.

Pre-Combustion — An emissions-control device or system whose action takes place before combustion has occurred. Positive crankcase ventilation, air/fuel control, exhaust-gas recirculation, evaporative controls, spark timing, and thermostatic air cleaners are pre-combustion systems.

Preconditioning — Warming up the engine prior to an emissions test. This is a critical step to avoid false failures. Preconditioning the engine warms it up to the point where the O_2 sensor is active, the catalytic converter is working, and the rest of the emissions control system has stabilized. Typically performed by running the engine at fast idle (about 2200 rpm) for at least two minutes.

Purge — The act of transferring fuel vapors from the vapor canister to the intake system by drawing fresh air into the canister.

Quenching — A premature extinguishing of the combustion flame that occurs along relatively cool areas of the cylinder. This leads to the exhausting of unburned fuel and a correspondingly high level of hydrocarbons.

Rhodium — A metallic element used as a reduction catalyst in three-way catalytic converters. Promotes the conversion of oxides of nitrogen into carbon dioxide and nitrogen.

Rich — Designating an air-fuel mixture that contains a relatively low amount of air or high amount of fuel (i.e., an air/fuel ratio less than the ideal 14.7:1). A rich burn is characterized by high levels of carbon monoxide and hydrocarbons.

Secondary Air Injection — A method of reducing hydrocarbon and carbon monoxide levels by injecting air into the exhaust stream. The additional oxygen promotes the continued burning of unburned fuel. Also used to inject air into the oxidation section of a three-way catalytic converter to assist oxidation.

Sensor — An electrical device that typically produces a varying voltage or varying resistance based on surrounding conditions such as temperature, pressure, speed, etc. Sensors are used to send input signals to the engine computer, which interprets the signals and sends the appropriate output signal to a controlling device such as a fuel injector or purge valve.

Six-Step Diagnostic Procedure — A troubleshooting system based on the application of six logical and sequential steps, namely, Verify the Complaint, Determine Related Symptoms, Analyze the Symptoms, Isolate the Trouble, Correct the Trouble, and Check for Proper Operation.

Smog — A brownish haze of pollutants consisting chiefly of ozone. Name is derived from smoke and fog, which were originally thought to be its components.

Spark Control — Any method of controlling the timing of the ignition spark. Excessively advanced or retarded spark timing can lead to increases in hydrocarbon and carbon monoxide levels. In modern vehicles, spark timing is controlled by the engine computer in response to changes in coolant temperature, manifold vacuum, and knock sensor signals.

Stoichiometric — The chemically correct mixture of air and fuel in the intake charge, which will result in the most complete combustion achievable. The stoichiometric mixture is 14.7 parts of air to 1 part of fuel by weight.

Tailpipe Concentration — The level of pollutants in the exhaust stream, measured in percent concentration or in parts per million.

Thermostatic Air Cleaner — A system that uses an exhaust manifold "stove" and a vacuum-actuated door to preheat the intake air before it is mixed with the fuel. When the engine is cold, preheating the intake air allows the fuel to vaporize better while using a leaner mixture than would otherwise be required.

Three-Way Converter — A catalytic converter that reduces the levels of all three major automotive pollutants — hydrocarbons, carbon monoxide, and oxides of nitrogen.

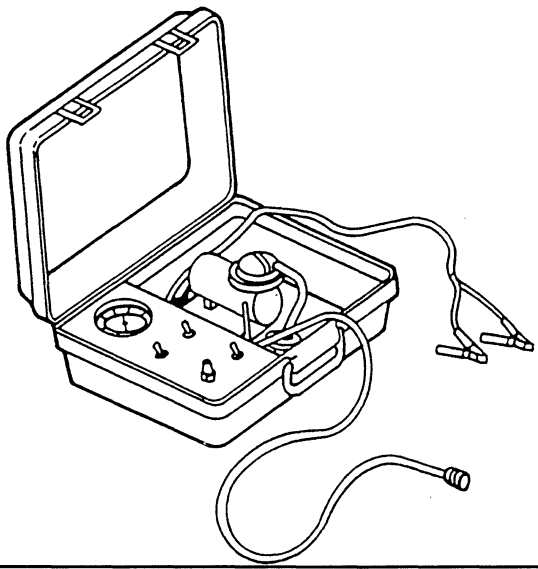
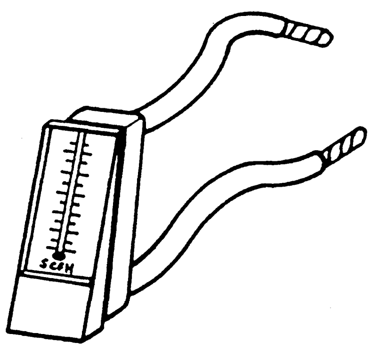
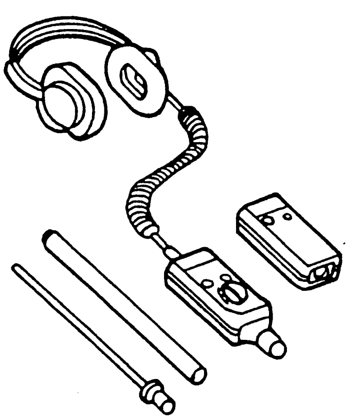
Throttle Position Sensor — An electrical device attached to the throttle, which tells the engine computer where the throttle is positioned. Consists of a variable resistor, or rheostat, which is fed a reference voltage by the computer. The sensor sends back to the computer an output voltage that varies with the throttle position.

Transient — Describes an inspection and maintenance (I/M) test in which the exhaust gases are monitored throughout numerous changes in engine speed. A transient-speed test attempts to duplicate actual driving conditions, whereas an idle-speed test does not.

Two-Gas Analyzer — An exhaust gas analyzer that measures hydrocarbon and carbon monoxide levels.

Vapor Canister — A container filled with activated charcoal granules which absorb fuel vapors from the tank instead of letting them be released into the air. Under certain conditions, the vapors are purged out of the canister and into the intake system where they are burned.

TOOL APPENDIX

6872A 	***Evaporative System Pressure Pump*** Electric pump and pressure gauge for testing the integrity of the evaporative emissions system. Part of Special Tool #6917. "Evaporative System Diagnostic Kit."
6890A 	***Flow Indicator*** Floating-ball flow meter for testing proper operation of the evaporative purge system. Part of Special Tool #6917, "Evaporative System Diagnostic Kit."
6904A 	***Ultrasonic Leak Detector*** Ultrasonic device for detecting pressure leaks in various systems. Part of Special Tool #6917, "Evaporative System Diagnostic Kit."

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