SECTION 2
MANUAL OPERATION MODE

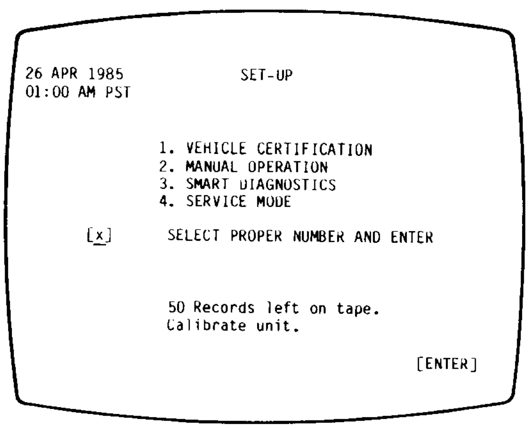
The Manual Operating Mode enables the EPA emission Analyzer to be used as a conventional exhaust analyzer and tachometer. This flexibility allows the operator to direct and expand testing as needed.

The infrared bench analyzes the exhaust sample for carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2). If an oxygen (O_2) option is installed and enabled, the sample is then analyzed by the O_2 sensor.

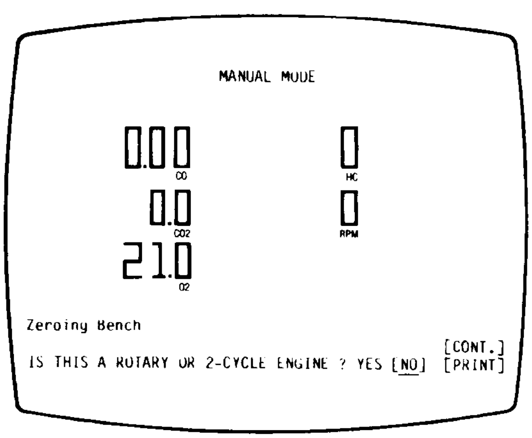
The monitor shows the exhaust gas and rpm values in a live, easy to read, digital display. The printer captures this live data on paper for later evaluation or documentation.

USING THE MANUAL OPERATING MODE

- Complete the daily Warm-up procedure to display the Set-up screen for operating mode selection.



- Press **2**, then **ENTER**; to select Manual Operation mode from the Set-up screen.
- All functions of Manual Operation are now activated.
- To purge the sample system, hang the exhaust probe on the TAS probe hook.



- Use the horizontal **Cursor** keys to indicate the engine cycle.
- Check the gas values. If the probe is out of the exhaust pipe the CO, HC and CO_2 values should be very near zero. O_2 will read 21.0%
- Press the **Zero Bench** key if the gas values are steady but still slightly different than fresh air values.
- Check for an HC hang-up if the HC is high and extended fresh air purging fails to effectively reduce it. See PTC section 4—TAS Service mode, Manual Operation—item 6, Hang-up Diagnosis.
- Connect the rpm pickup (arrow toward spark plug) to any plug wire if rpm is desired.
- Start the engine and bring it to normal idle speed and temperature.
- Insert the exhaust probe into the tailpipe.
- Press **Print** or the **Remote Button** to receive a copy of the screen values.
- Press **CONTINUE** to return to the Set-up screen.

COMBUSTION ANALYSIS

The internal combustion engine converts chemical energy stored in the fuel into heat energy. Heat increases the pressure within the engine cylinder by expanding the nitrogen in the air-fuel charge. The pressure of the nitrogen "working fluid" moves the piston and eventually the vehicle wheels.

The heat energy is released by simple combustion. Combustion is oxidation (burning) of the hydrocarbon fuel. This combustion process is the heart of engine operation. By understanding the nature of combustion and analyzing the gases left over from combustion the operator can evaluate engine performance.

Combustion Requirements

1. Induction of an air-fuel mixture that is of the proper ratio and quantity.
2. Engine mechanical integrity that enables perfect coordination of components and good sealing during compression and expansion.
3. Ignition that is correctly timed and develops good spark intensity and duration.

Engine systems try to meet these requirements under all operating conditions.

Ideal Combustion

In the laboratory, perfect combustion changes hydrocarbon fuel (HC) and air, nitrogen (N_2) plus oxygen (O_2), into carbon dioxide (CO_2) and water (H_2O). To do this, the fuel separates into hydrogen and carbon while combining with the air's oxygen. If ideal combustion conditions are maintained, all of the ingredients are converted to desirable byproducts while releasing a great amount of heat (Fig. 1).

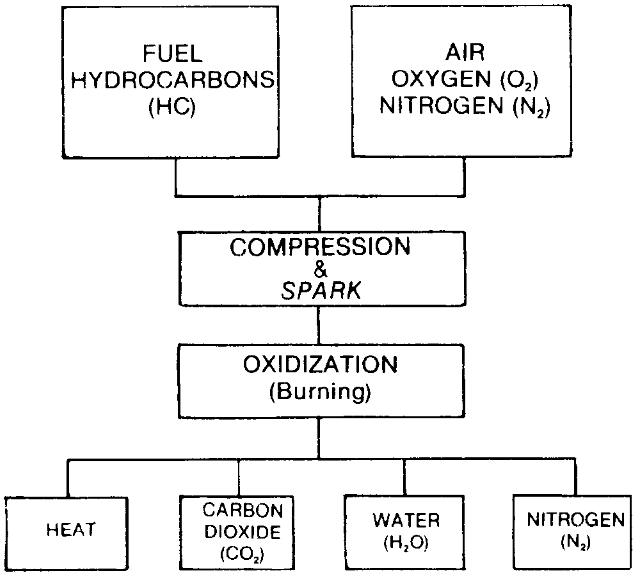


Figure 1: Perfect Combustion

Realistic Combustion

Unfortunately, perfect combustion happens consistently only in the laboratory. Even computerized engine control systems do not precisely satisfy all engine operating requirements during all operating situations. When poor combustion occurs, the vehicle exhaust contains excessive leftover ingredients and pollutants.

Three major gaseous pollutants emitted from the engine are hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NOx). In addition, the exhaust contains a trace amount of sulfur oxides (SOx), and particulates such as lead, carbon, and sulfur.

The byproducts CO_2 and H_2O, and the unused ingredients O_2 and N_2 are not considered pollutants but are important as indicators of combustion quality. Of these, CO_2 and O_2 are commonly used to analyze engine system performance.

Realistically, the engine exhaust (Fig. 2) contains varying amounts of desirable byproducts, pollutants, and unused ingredients. Understanding the nature of these exhaust emissions is the key to infrared analysis.

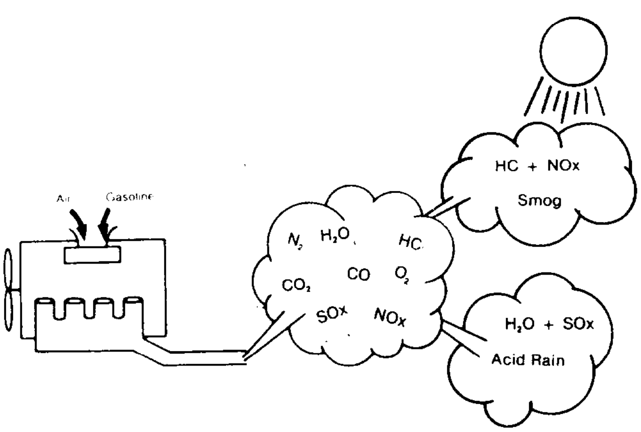


Figure 2: Imperfect Combustion

Stoichiometry

Combustion is most efficient, with regards to pollution and economy, when the air and fuel are mixed at a ratio of 14.7 lbs. of air to 1 lb. of fuel (14.7:1). This chemically ideal air fuel ratio (AFR) is called "stoichiometric"—hydrogen and carbon combines with the oxygen to produce maximum H_20, CO_2, and heat. Also this AFR is the best compromise for efficient operation of three gas catalytic converters. Modern automotive fuel systems strive to maintain a stoichiometric AFR under all engine operating conditions.

EXHAUST GASES

Lets look at the gases of major interest (CO, HC, CO_2, and O_2) to see how they form during combustion and relate to exhaust analysis. This information is the foundation for accurate testing and diagnosis.

Hydrocarbons (HC)

Hydrocarbons, measured is parts per million (ppm), contribute to air pollution. When sunny, still air conditions exist; HC combines with oxides of nitrogen (NOx) to form photo chemical smog. High HC in the exhaust is caused by fuel that was not oxidized (burned) during combustion. Depending on the ppm this can indicate moderately rich air-fuel ratios, or misfiring do to major air-fuel quality or ignition problems.

When the AFR is too rich, there is not enough O_2 available to convert all the HC into H_2O and CO_2. This leaves unburned HC.

When the air-fuel charge is excessively lean or contains too much exhaust gas, the HC molecules are spaced too far apart for normal flame propagation. Lean misfires (Fig. 3) and exhaust gas related misfires are more common than rich ones.

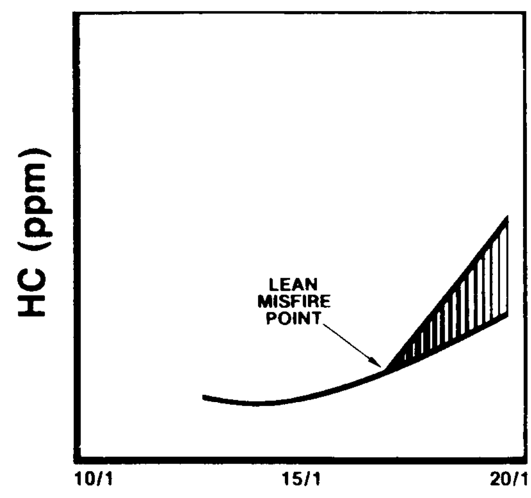


Figure 3: Lean Misfire & Unused HC

The most noticeable HC increase occurs when poor spark production or delivery causes one or more cylinders to misfire (Fig. 4). Electrical misfire will cause a dramatic (400 ppm to full scale) rise in HC emissions. Therefore, HC is an excellent indicator of ignition problems.

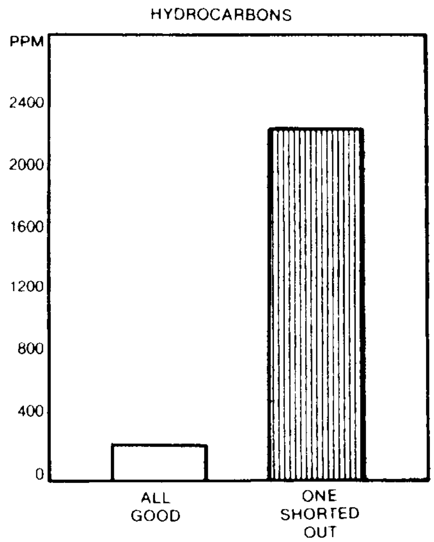


Figure 4: Spark Plug Misfire & Unused HC

Carbon Monoxide (CO)

Carbon Monoxide, measured in % by volume, is a pollutant produced by partial combustion. It forms when one carbon from the HC combines with only one oxygen. CO is an oxygen-hungry compound that upon release to the environment will eventually attract another oxygen molecule to become CO_2.

When the AFR is richer than 14.7:1, the CO production increases—there is an oxygen shortage per carbon.

When the AFR is leaner than 14.7:1, CO decreases—there is plenty of O_2 per carbon and available carbons usually join two oxygens to produce CO_2. Figure 5 shows CO production decreasing as AFR gets leaner.

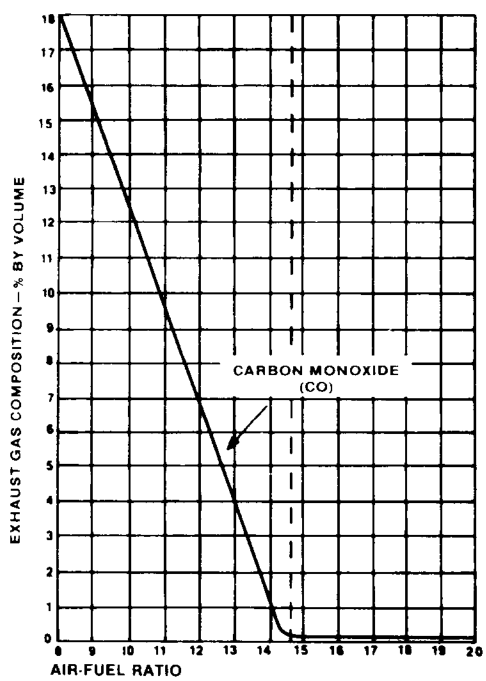


Figure 5: AFR & CO Production

It should be noted that some form of spark must occur to make conditions possible for the production of CO. However, HC is a better indicator of ignition problems than CO. CO is best used as an indicator of AFR related problems because of its sensitivity to mixture changes, especially on the rich side of 14.7:1 (Fig. 5).

Carbon Dioxide (CO_2)

Carbon Dioxide is measured in % by volume, and is a desirable combustion byproduct. CO_2 production is highest when the carbon and oxygen availability are balanced and the engine is operating efficiently. CO_2 is a good indicator of combustion efficiency.

CO_2 production will decrease when the AFR is richer or leaner than the optimum 14.7:1 ratio (Fig. 6). Thus, CO_2 can be used to indicate stoichiometric AFR.

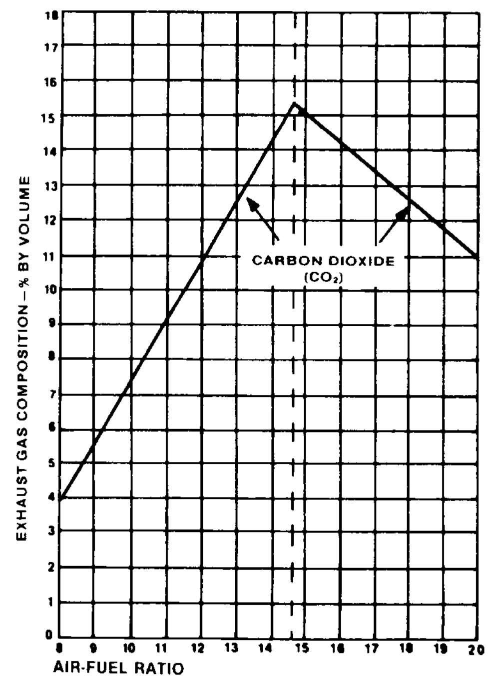


Figure 6: AFR & CO_2 Production

When the AFR is richer than 14.7:1, there is an oxygen shortage per carbon—this causes only one oxygen to join the carbon (CO) instead of two (CO_2).

When the AFR is leaner than 14.7:1, a carbon shortage per oxygen exist. There is enough oxygen to convert the carbon to CO_2, but not much carbon is available.

Any AFR, ignition, or mechanical problem that degrades combustion efficiency will cause a reduction in CO_2.

Oxygen (O_2)

Oxygen is measured in % by volume and is a necessary ingredient of the combustion process. About 21% of the atmosphere at sea level is occupied by O_2. The O_2 level at the tailpipe depends on the amount delivered to the cylinders and exhaust system (air injection), and the amount used for combustion.

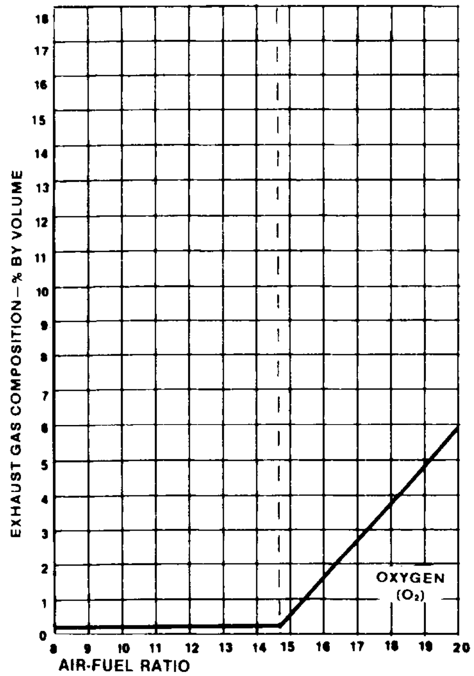


Figure 7: AFR & Unused O_2

At each AFR leaner than 14.7:1 the exhaust O_2 level increases sharply (Fig. 7). This occurs because the O_2 supply has increased while the demand has decreased (less fuel to be converted to CO, CO_2, and H_2O). O_2 is a good indicator of a lean AFR because it increases when other gases are decreasing to a barely detectable level.

Poor combustion, caused by a cylinder with a lean or ignition misfire, will release plenty of unused O_2. This is especially true with four cylinder engines. The per cylinder contribution of a four cylinder engine is about twice that of an eight cylinder engine. The leftover O_2 can ignite the converter, even with the air injection disabled, and reduce the HC to quite a low level.

Insufficient probe insertion, enabled air injection, and air leaks into the vehicle exhaust system or the analyzer sample system can dilute the gas sample and cause high O_2 readings. Stop these sources of O_2 for valid test results.

GAS ANALYSIS TIPS

When evaluating exhaust gas readings, consider the following items.

- Amount: Is the gas value higher or lower than normal?
- Stability: Is the gas value steady or does it vary at a given engine speed?
- Repeatability: Upon return to idle from cruise, is the gas value the same as before?
- Correlation: Is an abnormal reading obvious only during a certain operating condition like idle, transition, cruise, power, etc.
- Sample quality: Is the gas sample masked by the converter, air injection, or a leaking exhaust; or does it represent true combustion gases.
- Gas sensitivity: All gases may respond to a particular combustion or emission control problem. However, it is better to evaluate each gas for the type of problem it is most sensitive to.

Gas Log

Precise exhaust gas values are useful to diagnose performance problems with a specific vehicle. Normal gas values can vary greatly depending on the year, manufacturer, model, equipment options, emission controls, and operating environment. The values given in this book are general in nature and attempt to define typical situations that are likely to occur. For more accurate diagnosis, maintain a gas log that shows normal values for each vehicle listed. The log can be categorized by the year, manufacturer, model, emission control equipment etc.

Catalytic Converters

With the proper supply of oxygen and adequate warm-up time, an oxidation converter can reduce HC and CO to a barely detectable level at the tailpipe. To combat this problem, disable the air injection and try one of the following options.

- If the vehicle has a removable plug upstream of the converter, sample the gases there.
- Stop the engine and allow the converter to cool 10 minutes. Restart the engine and complete the test quickly (2 minutes) before the converter has a chance to relight.

General Tips

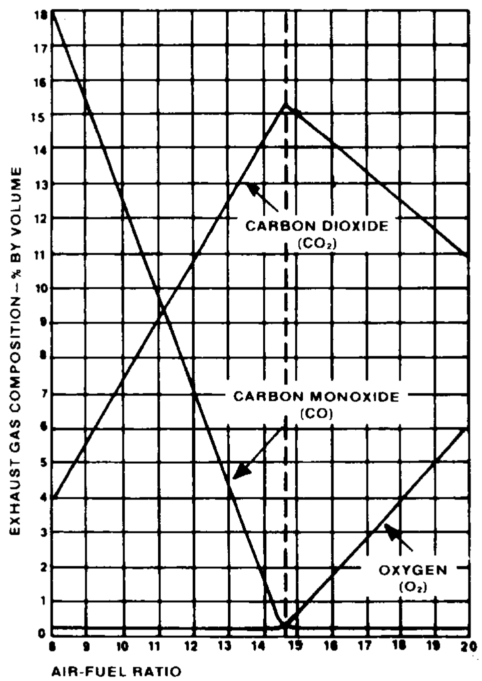
- A catalytic converter that is not active can give gas readings like a non converted engine.
- Any HC reading 1000 PPM or above indicates a severe misfiring problem.
- Unstable CO readings indicate AFR problems.
- Bad fuel distribution can cause high unstable HC readings, normal to high CO readings, and low CO_2 readings.
- Unstable HC and CO_2 readings can indicate intermittent misfiring problems.
- Small air leaks become less significant at higher RPMs.
- A lean misfire problem can cause the RPM to increase 10% or more during artificial enrichment.
- Combustion efficiency increases with throttle opening. This causes HC and CO to reduce up to 50% while CO_2 increases.

TESTING AND DIAGNOSIS

The following tests use exhaust gas and rpm to identify problem areas. The previous topics on Combustion, Exhaust Gas, and Gas Analysis Tips will aid the technician in performing these tests.

Locating an Exhaust System Air Leak

Use the Leak Test to identify air leaks into the vehicle exhaust system. Air leaks will cause sample dilution and invalid test results.



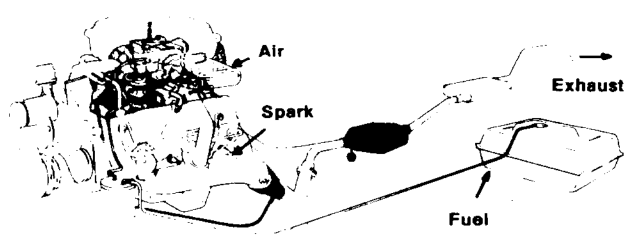
If engine performance is smooth, and HC is low, the sum of the CO and CO_2 readings should be less than 7 or 8%—if more, dilution is indicated. During efficient combustion, the chemical interrelationship of the exhaust gases shows it is unlikely an engine could operate at the AFR required (22:1) to produce a CO + CO_2 sum of 7 or 8%.

PROCEDURE

1. Disable the air injection system.
2. Insert the probe at least 12 inches into the tailpipe.
3. Start the engine and record the gas values.
   - Add the values of the CO and CO_2. If the sum is less than 7% and the HC is quite low, dilution is indicated.
   - If the O_2 value is high (4-12%) and the engine idle quality is good, dilution is indicated.
4. Return the air injection system to its pretest status.
5. Repair and retest the vehicle.

Dead Engine Test

Use the dead engine test to identify the system (air-fuel metering, ignition, or compression) causing a no-start problem. This test checks the exhaust to verify that fuel is being delivered to and pumped through the engine cylinders during cranking.



PROCEDURE

1. Insert the exhaust probe at least 12 inches into the tailpipe.
2. Partially block the air horn with your hand and crank the engine for several seconds. Feel for a strong vacuum and record the HC value.
   - If the HC value is high (1600-2000) and the vacuum is strong, fuel is available and the engine has the mechanical integrity for pumping. Test for spark at the spark plug.
   - If the HC value is zero or very low and the vacuum is weak, verify spark to the plugs then check the engine for compression, large air leaks, and the condition of the valve train parts.
   - If the HC value is zero or very low and the vacuum is strong, activate the accelerator pump, fuel injectors, or cold start valve to check for fuel delivery.
3. Repair and retest.

For no fuel on injected vehicles, check:

- Pump safety switch.
- Oil pressure switch.
- No rpm signal.
- Pressure regulator.
- Pump, filters, or relay.

Locating a Fuel Leak

If the vehicle has a fuel odor or poor mileage, use the exhaust probe to trace the fuel system and locate leaks.

PROCEDURE

1. Start the engine and raise the vehicle a few feet.
2. Use the exhaust probe to trace the fuel tank, lines, pump, filter, etc.
3. Note any change in the HC value.
   - The HC will increase as the probe approaches the leak.
4. Repair and retest.

Locating Vacuum Leaks

Air leaks into the intake manifold can cause poor idle quality and surging. Low CO and high unstable HC are symptoms of a lean misfire. When propane is injected into an air leak, the gas values and idle quality will improve.

PROCEDURE

1. Disable the EGR valve, air injection, and closed loop system.
2. Note the rpm and gas values.
3. Trace around suspected air leaks with the hose from a propane enrichment tool. Make sure to check all gaskets, hoses, and diaphragms that must hold vacuum.
4. Note the rpm and gas values.
   - When a leak is located the idle quality will improve, rpm and CO increase, and HC decrease.
   - If no vacuum leak is found and the engine still idles poorly, test the EGR system.

Exhaust Leaks into the Passenger Cabin

Air cooled engines obtain passenger heat from a heat exchanger within the vehicle exhaust system. If the exhaust system leaks into the heat exchanger, the heater ducts can deliver lethal carbon monoxide into the passenger compartment.

PROCEDURE

1. Note HC and CO readings with the probe sampling room air.
2. Open one window slightly and bring the probe into the passenger compartment.
3. Start the engine and turn on the heater and blower controls.
4. Insert the probe into heater and defroster outlets to check for HC and CO.
   - Any increase indicates an exhaust leak.
5. Repair and retest.

Air Injection System Test

The air injection system pumps fresh air into the exhaust system at a point where the exhaust gases are still very hot. This provides O_2 for extended combustion of the exhaust gases. Some systems can switch the air flow into the converter or upstream. When the air injection system is disabled, the exhaust emissions will show a noticeable change if the system works properly.

PROCEDURE

1. Warm the engine and note the gas values with the air injection system enabled.
2. Disable the air injection and note the gas values. Injection systems can be mechanically or electrically disabled, depending on their design.
   - A significant reduction in O_2 and an increase in the HC and CO should occur when the system is disabled.

Catalytic Converter Efficiency Test

Oxidation converters change CO and HC into CO_2 and H_20. When combustion is efficient, the exhaust O_2 is sufficient, and the converter is good; the CO and HC emissions are nearly zero. When combustion in a cylinder is temporarily stopped, a good converter should have the capacity to clean up nearly all the additional HC from the dead cylinder.

PROCEDURE

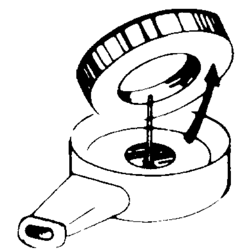
1. Start the engine and allow a ten minute warm-up to activate the converter.
2. Verify that the air injection is on.
3. Verify that the CO is less than 1% and the HC is less than 200 ppm.
4. Interrupt the ignition to one spark plug for ten seconds or less.
5. Note the gas values.
   - The converter should be able to oxidize most of the HC from the dead cylinder.
   - The HC value should be less than 800 ppm if the converter is operating properly.
   - During ignition interruption, four cylinder engines can have higher readings than six or eight cylinder engines because their per cylinder contribution is greater.
6. Repair and retest.

Air Filter Test

An air cleaner with a dirty filter element will restrict the air flow to the intake manifold and cause a rich mixture. The filter element can look good when backlighted by a shop light yet still restrict the air flow, especially at higher engine rpms. The filter test compares the gas values taken at cruise speed with the filter installed and removed.

PROCEDURE

1. Set the engine speed at a steady 2000 rpm.
2. Record the gas values with the filter and housing assembled.
3. Remove the filter and install the housing lid.



4. Record the gas values.
   - The gas values with the filter out should match those with the filter installed. If the CO drops with the filter out, it indicates more O_2 is available then—replace the filter.

PCV Valve Test

The PCV valve meters crankcase vapors into the intake manifold to be burned. These vapors are a result of cylinder blow-by and would otherwise accumulate in the crankcase and cause engine damage.

Most engines today have a positive-flow closed-loop ventilating system. This system uses manifold vacuum to move filtered air through the crankcase to purge the vapors. The vapors usually exit the engine at the valve cover and are routed to the intake manifold and combustion chamber, completing the loop. A malfunction in this system can greatly affect the air-fuel mixture.

This test will verify that PCV system is operating by checking the flow and gas values with the valve isolated from the crankcase.

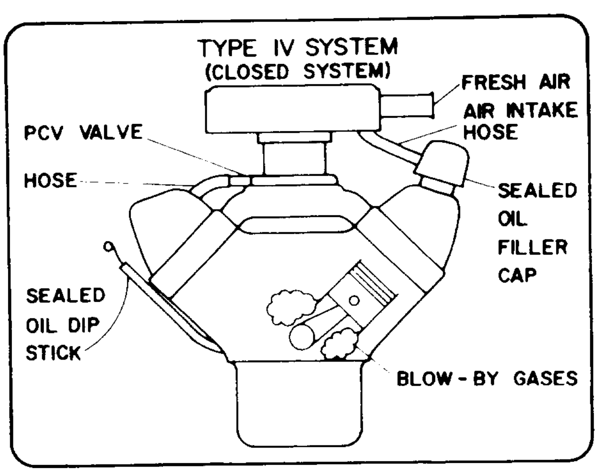
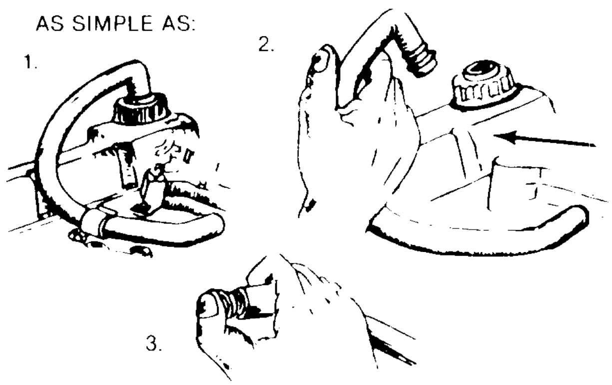


Figure 8 — PCV system

PROCEDURE

1. Start the engine and note the rpm and gas values when they stabilize.
2. Disconnect the PCV valve from the engine so the valve can meter fresh air.



3. Note the rpm and gas values.

- The CO should drop 1-1.5% when the valve is open to air making the AFR slightly leaner. The HC reading may become unstable if a lean misfire begins.
- If no change is noticed, the valve or plumbing could be clogged.
- If the CO value is reduced more than 1.5%, it indicates excessively rich crankcase vapors and fuel contaminated oil. Repair the contamination source and change the engine oil. Fuel in the crankcase can damage the engine and makes idle mixture adjustment inaccurate.

For contamination check for:

- Prolonged cylinder misfire
- Malfunctioning fuel evaporation system (sucks raw fuel into intake manifold).
- Sunken float or leaky needle and seat.
- Short trip driving (engine doesn't reach a desirable temperature).
- Leaky fuel pump (can drip gasoline directly into the crankcase).
- Choke opening improperly.
- Leaking fuel injector.
- Leaking cold start valve.
- Defective fuel pump, or pressure regulator on fuel injection systems.

4. Block the valve with your thumb and note the suction and rpm.

- No suction can indicate a plugged system.
- The engine speed should drop 50-150 rpm. If the rpm increases and the idle quality improves, an excessively lean AFR is indicated.

For lean misfire check:

- Air leaks.
- PCV valve for wrong flow rate.

PCV System Flow Test

The vacuum at the PCV valve can feel strong as the vacuum builds under your thumb, however, the flow should also be tested. A restriction in the system can cause engine blow-by to exceed the system's designed flow rate during engine loading. This will cause excessive oil and vapors to exit via the air inlet for the PCV system. Use a 3x5 card to test the flow at the air cleaner end of the fresh air hose.

PROCEDURE

1. Separate the fresh air hose from the air cleaner housing, then start the engine.
2. With the engine at idle, hold a 3x5 card close to the end of the hose.

- The flow should draw the card to the end of the hose. the vacuum should hold it there.

If the card falls off, check for:

- Air leaks between the PCV valve and air inlet. This includes engine gaskets and seals.
- System restrictions
- Too much engine blow-by.

EGR Valve Test

The exhaust gas recirculation (EGR) valve opens a passage to meter a small amount of exhaust gas into the intake manifold. If the combustion is efficient, the exhaust gas contains very little HC or O_2 and has little effect upon the air-fuel ratio. It merely takes space normally occupied by the air-fuel charge. With less air-fuel charge to burn, the heat of combustion is cooler, producing less NOx emissions.

The exhaust gas entering the cylinder must be metered in proportion to the air-fuel charge. Too little gas causes increased heat and NOx. Too much causes poor flame propagation (travel) because there is not enough air-fuel charge to bridge the exhaust gas molecules. This causes misfires.

Misfires caused by exhaust gas are similar to misfires caused by lean AFR in that the engine is likely to idle rough or surge at cruise. Artificial enrichment (adding fuel) of a lean misfire will improve idle quality and reduce HC emissions because it improves AFR. Artificial enrichment of an exhaust gas related misfire is less likely to improve idle quality or reduce HC emissions because the problem is associated with not enough air-fuel charge rather than ratio of the air-fuel charge. Adding HC without adding O_2 may only complicate the problem by causing excessive richness.

The exhaust gas entering the cylinder must also suit the engine operating conditions. Most gasoline engines will tolerate EGR at part throttle acceleration and cruising under moderate load conditions—engine operating quality is less likely to suffer then. Few engines use EGR at idle—they breathe poorly then. Nor do they during cold operation—more air-fuel charge is needed to offset poor fuel vaporization and suspension. At wide open throttle (WOT), EGR is generally by-passed for best power conditions of high air-fuel density.

The EGR valve operates as the throttle plate opens. Carburetor ported vacuum (above throttle) is applied to the top of the EGR diaphragm. Ported vacuum overcomes the EGR closing spring and the valve opens (Fig. 9). This vacuum makes the EGR valve sensitive to throttle position and engine load. Closed throttle and heavy loads reduce vacuum to the valve.

Some EGR valves incorporate a backpressure sensor. Ported vacuum is bled off until exhaust back pressure reaches a specified amount. This makes the valve sensitive to exhaust restrictions.

EGR valve cold operation is controlled by temperature sensitive vacuum switches, or by the on-board computer and vacuum solenoid.

Leaky EGR systems can cause lean AFR or exhaust gas related misfires. Use the Internal and External leak test to identify which.

Internal leak test—gas misfire

EGR systems that direct exhaust gases at idle can exhibit engine performance symptoms similar to those associated with vacuum leaks and lean misfiring. The engine idles roughly and HC levels in the exhaust are high and wavering.

PROCEDURE

1. Start the engine and note gases, rpm, and idle quality.
2. Inject propane into the air horn to artificially enrich the AFR.
3. Note changes in gas, rpm and idle quality.
   - If the idle quality is better and HC decreases, look for an air leak using the external leak test.
   - If the idle quality and HC are about the same, look for an EGR related problem.

Check for:

- Stuck open EGR valve.
- Burned through passage.
- Improper vacuum source to valve.

4. Repair and retest.

Exhaust gas related misfires can also be caused by valve train problems like sticking or leaky intake and exhaust valves, worn camshafts, and camshaft timing. These problems are likely to reduce the amount of AF charge entering the cylinder and/or increase the amount of exhaust gases left in the cylinder. Identify valve related problems using vacuum and rpm tests. Serious valve leaks will cause a steady pulse in the vacuum and rpm readings. An EGR problem makes the vacuum drift up and down with a random roughness or engine roll at idle.

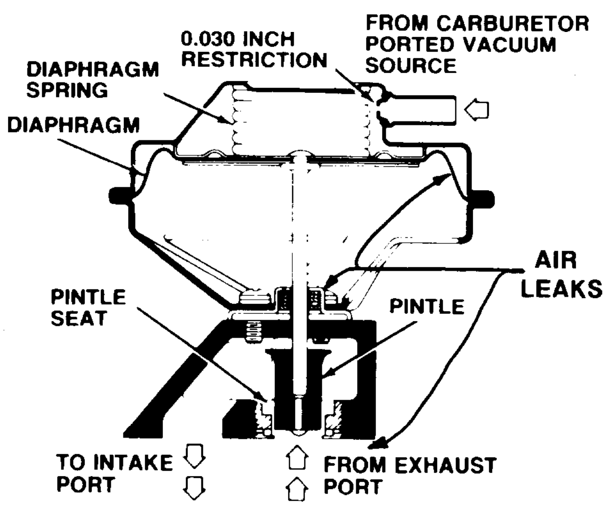


Figure 9.

External leak test—lean misfire

Another problem associated with EGR valves can be external air leaks into the intake manifold. These leaks can originate at the mounting surface, at cracked bases and diaphragms, or at the control rod for the diaphragm. This rod passes through a gasket and an intake manifold passage on its way to the pintle valve, Figure 9.

PROCEDURE

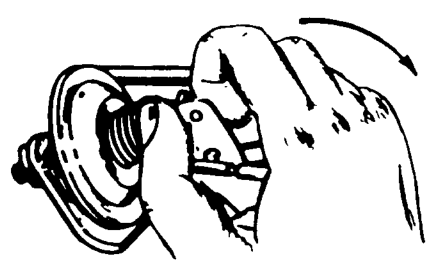
1. Start the engine and note gas, rpm, and idle quality.
2. Artificially enrich the environment around the EGR valve with propane by directing the hose at the desired location.
3. Note the change in gas, rpm, and idle quality.
   - If the HC becomes stable and CO increases with improved idle quality, an air leak is indicated.
4. Repair and retest.

Accelerator Pump Test

A carburetor accelerator pump mechanically delivers a small spray of fuel during acceleration from idle to cruise. Mechanical delivery is needed because the heavier fuel cannot respond as quickly as the air when the throttle is opened. This fuel lag would cause a temporary lean spot and hesitation. The acceleration system can be checked by noting the gas values while jabbing the throttle.

PROCEDURE

1. Set the engine speed at fast idle, approximately 1200 RPM.
2. Note the gas values after they stabilize.
3. Quickly jab the throttle without raising the engine rpm.



4. Note the CO and HC readings.
   - If the fuel delivery is about right, the CO will increase at the same time or slightly ahead of the HC. The CO should increase 1% over the original reading. The HC should increase up to 600 ppm.
   - If the fuel delivery is too little, the engine can hesitate, the HC can respond before the CO, and the CO may even decrease.

Check for:

- Fuel spray by opening the throttle.
- Bent or misadjusted linkage.
- A stuck plunger.
- A defective inlet or outlet check valve.
- A cracked plunger or diaphragm.

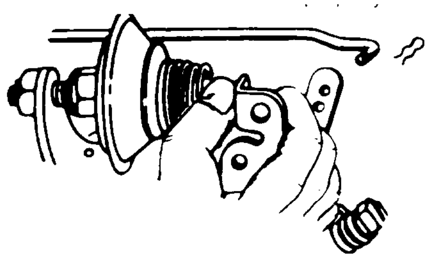
Power Valve Test

The power valve opens to supplement main metering fuel delivery. A richer AFR allows all the oxygen in the combustion chamber to be used, and develops maximum power. When the intake manifold vacuum decreases the power valve opens. Valve operation can be checked by jabbing the throttle, to drop the vacuum, and noting the gas values.

It is important to verify the power valve opens and closes. If the valve fails to open, the engine can surge and hesitate. If it fails to close, poor fuel mileage and rough idle occurs.

PROCEDURE

1. Disconnect the accelerator pump linkage.
2. Use the fast idle cam to block the throttle at 1500 rpm. Note the gas values when stable.



3. While holding the fast idle cam in one hand, quickly open and return the throttle to the same cam position.

   It is important to return to the same fast idle cam setting in order to check for proper reseating of the power valve. This test may be repeated several times to check for consistency.

- The CO should momentarily increase (1-2%), then return to the original reading.

Cylinder Power and Balance Test

For good combustion each cylinder needs the proper air-fuel ratio, good mechanical integrity to provide proper sealing during compression and expansion, and ignition that is correctly timed and develops good spark voltage and duration. When these needs are properly fulfilled, all cylinders deliver equal and adequate power.

When combustion is stopped in a cylinder by interrupting the ignition, the change in rpm and exhaust gas values can be analyzed to evaluate the cylinder's power contribution. All cylinders should show the same change when killed. A weak cylinder will show very little rpm loss, or it could show a gain. A misfiring cylinder will contribute very little additional HC during ignition interruption. Depending on the nature of a problem, one cylinder or a group of related (companion) cylinders could be affected.

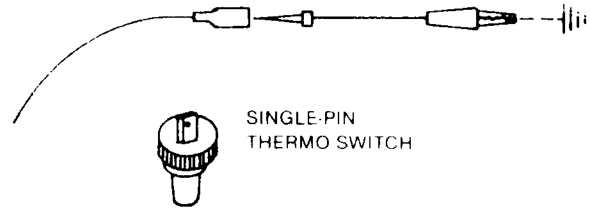
To ensure a valid cylinder power test, all other factors affecting the engine's operating status must remain steady-state. That way, only the dead cylinder is affecting the rpm and gas values. A change in spark or air-fuel mixture by electronic engine control systems, or a change in engine load by engine driven accessories will affect rpm and gas values, and may cause an invalid diagnosis.

TEST PREPARATION

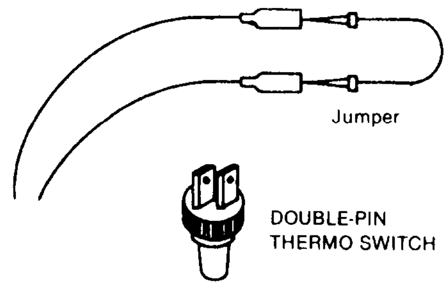
1. Disable the EGR valve to ensure even manifold distribution of the air-fuel charge. Block the vacuum to the EGR valve, or electrically disable the vacuum solenoid.
2. Electrically enable the engine's cooling fan motor to run continuously. This prevents intermittent electrical loading of the engine.

   Fan circuit designs will vary. However, they all have a thermo-switch to sense engine temperature. This switch can complete the motor circuit, energize a relay, or signal a computer that controls the fan motor. Generally, the easiest place to enable the fan motor is at the thermo-switch. Separate the harness at the thermo-switch and use one of the following options to allow the fan to energize when the key is turned on.

- A few fans are enabled when the harness is removed from the thermo-switch. Try this method first.
- If the thermo-switch has a single terminal, use a jumper wire to ground the harness.



- If the thermo-switch has a double terminal, use a test light to check if both wires in the harness are hot (+). If they are, use a jumper to ground one of the harness wires. If only one is hot, the other is likely to be ground—join the two harness wires with a jumper wire.



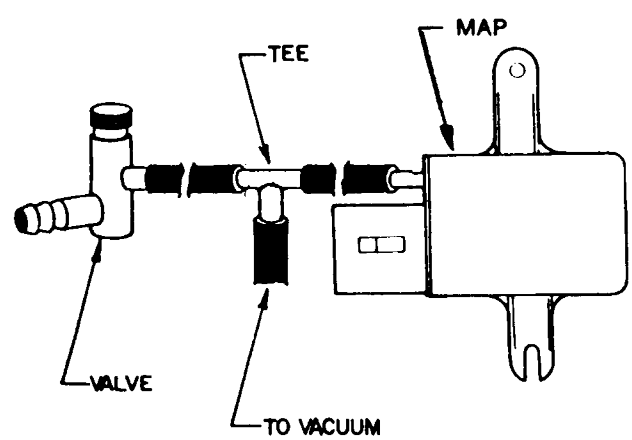
If the thermo-switch is hard to access, the operator may want to energized the fan at the motor terminal once the harness is removed.

- For a motor with one terminal, use a jumper wire to apply battery plus (+) to the motor terminal.
- For a motor with two terminals, apply battery plus (+) to one motor terminal to see if the motor will run. If the motor fails to run, apply battery minus (-) to the other terminal.

3. Disable full-time air conditioning systems to ensure stable rpm. Disconnect the harness from the compressor clutch.
4. Disable the air injection system to help deactivate the converter and make the gas values easier to read.
5. Electronic engine control systems (closed loop, feedback, etc.) can change throttle position, idle bypass air, AFR, or timing during cylinder kill. Disable electronic engine control system to ensure a valid power analysis.

Ford systems with a MAP sensor:

- Locate the MAP sensor and introduce a small vacuum leak (use an aquarium valve) to lower the vacuum. Open the valve slowly until the vacuum is 7-12 inches of mercury or until the rpm rise and stabilize.

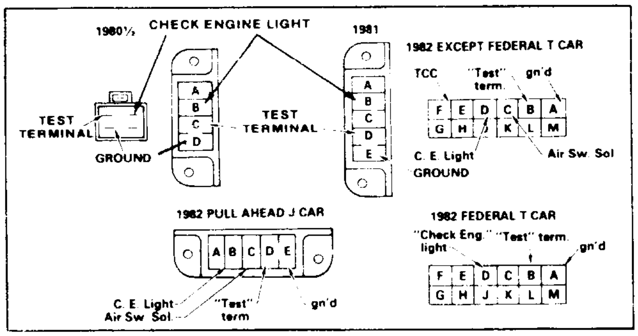


Ford systems without a MAP sensor:

- Disconnect the O_2 sensor.

GM Closed Loop Carbureted systems: (CCC, Min T)

- Turn the key off and disconnect the O_2 sensor.
- Short between the Ground terminal and the Test terminal at the ALDL connector.



- Restart the engine.

GM Close Loop Fuel Injected systems: (TBI, PFI)

- Slowly bleed off vacuum (use an aquarium valve) to the MAP sensor until the rpm rise and stabilize.

Other systems:

- Most closed loop systems can be disabled by turning off the engine, disconnecting the O_2 sensor, then proceeding with the test.

TEST CONSIDERATIONS

The rpm and gas values recorded at idle and cruise should be evaluated for:

- Amount: Are the values low, normal or high?
- Equality: Are all the values the same?
- Correlation: Is there anything common only to abnormal reading cylinders? Like the same intake plenum or the EGR is located closer. Is an abnormal reading obvious only during a specific operating condition like idle, or cruise?

Given enough oxygen and warm-up time, the oxidation converter can make the gas sample unstable and difficult to evaluate. Disabling the air injection may not keep the O_2 level low enough to obtain a valid gas sample. If a cylinder is currently misfiring, or the ignition is interrupted longer than a few seconds, the O_2 from the dead cylinder can be enough to intermittenly ignite the converter.

When the idle quality indicates a misfire, yet the HC value is low; use rpm drop to evaluate the cylinders. If no misfire is suspected, use gas and rpm for analysis. Kill the cylinder for less than 10 seconds and wait 30 seconds between kills to allow the O_2 to purge from the system.

Artificial enrichment of the AFR with propane may also counteract high O_2 in the exhaust and keep the converter extinguished. Prior to testing, enrich the mixture until the CO is 3%. Keep the valve at the same setting during testing. Enrich at the air intake, to ensure even distribution. Even though the AFR is enriched and the readings abnormal, the change in rpm and gas values can be compared to evaluate the cylinder's power contribution. Again it is important to kill for only a few seconds and allow time between each kill to purge the unused oxygen. If rpm, idle quality, and exhaust gases improve when enrichment begins; a lean misfire should be suspected.

PROCEDURE

1. Enable or disable the appropriate systems to prepare the vehicle for the cylinder power test.
2. Set engine speed to 1000-1200 RPM.
3. Kill the cylinders in any order but record the change in rpm and gas values in the idle test box that corresponds to the cylinder number.
4. Set engine speed at 2300-3000 rpm.
5. Repeat step 3 but record the values in cruise test boxes.

	Rank	1st	2nd	3rd	4th	5th	6th	7th	8th
Firing Order									
Idle	RPM								
	HC								
	CO								
	CO_2								
	O_2								
Cruise	RPM								
	HC								
	CO								
	CO_2								
	O_2								

- A slight HC increase (400-800 ppm) can be expected from each cylinder that is killed.
- The HC can increase 800 ppm to full scale if:

  The vehicle has no oxidation converter.

  The gases are sampled upstream of the converter.

  The oxidation converter is damaged.

  The converter efficiency is reduced because the oxygen level is too low or the warm-up time was too short.
- The rpm should decrease an equal and adequate amount for each cylinder. An eight cylinder engine will provide a 6-7% rpm drop; a six cylinder, 8-9%; and a four cylinder, 12-14% drop.

HC EMISSIONS	LIKELY PROBLEM
1. Every other cylinder reads higher than the average.	Unbalanced carburetor, carburetor base or manifold air leak.
2. Two cylinders on the same intake runner read low.	Vacuum leak, check for hoses off, intake manifold leak.
3. One or two cylinders low.	Sticky or poorly seated valve, intake manifold restriction...intake manifold restriction will likely be true at higher RPM as well. A sticky valve may show normal at high RPM.
4. All cylinders reading equal but RPM reading low on some cylinders.	Not related to fuel, check scope for ignition if OK, check compression

Use the following chart to compare low and high speed readings. Depending on engine performance, these readings will respond in a predictable way.

SPEED	RPM CHANGE	HC INCREASE	LIKELY PROBLEM
LOW SPEED	LOW TO EQUAL	LOW	AIR LEAK
HIGH SPEED	EQUAL	EQUAL	
LOW SPEED	LOW	LOW	VALVE OPENING OR
HIGH SPEED	LOW	LOW	RESTRICTION, COMPRESSION
LOW SPEED	EQUAL	ALL HIGH	EXTREMELY RICH
HIGH SPEED	EQUAL	ALL HIGH	CARBURETOR SETTING
LOW SPEED	EQUAL	ALTERNATE HIGH/LOW	UNBAL CARBURETOR
HIGH SPEED	EQUAL	ALTERNATE HIGH/LOW	
LOW SPEED	EQUAL	EQUAL	OK
HIGH SPEEDS	EQUAL	EQUAL	

Air-Fuel Metering Performance

The air-fuel metering system must be able to compensate for changing engine operating conditions. This ensures that the cylinders will receive the proper air-fuel charge for economy, power, and emissions. The system performance can be tested when throttle position or engine load is changed to simulate driving conditions.

PROCEDURE

1. Disable the air injection system.
2. Start the engine and allow the engine to idle.
3. Note the rpm and gas readings.
- The idle quality should be smooth and the rpm within the manufactures specs.
- The gas values should be normal and stable.
4. Set the engine speed at 2500 rpm and note the gas readings.
- The HC and CO should decrease while the CO_2 increases. This is due to better combustion efficiency.
- A rich condition will cause the CO to increase while the HC remains about the same or only slightly lower.
- A lean misfire will cause high HC and O_2 , and low CO and CO_2.
5. Release the throttle to allow the engine to idle. Then note the rpm and gas values. This step should be repeated several times to verify valid results.
- The rpm and gas values noted in step 3 should recur if the air-fuel metering is consistent.

Idle Mixture Adjustments

Idle mixture adjustment procedures differ according to the manufacturer and vehicle features. They are designed to abide by the law while complimenting the engine systems, emission controls, and available test equipment. Currently these procedures are similar and observe either rpm or exhaust gases to indicate achievement of proper AFR. The mixture screws are adjusted until:

- The rpm is affected a specific amount by propane enrichment.
- A specific gas value is reached.
- The peak rpm or gas value is attained.
- Slightly less than peak rpm or gas value is attained.

The manufacturer's adjustment procedure will give the best results, however, the following simplified procedures may work satisfactorily.

PROCEDURE—PEAK CO_2 METHOD

1. Disable Air Injection
2. Start engine, bring to operating temperature.
3. Verify that the idle quality is good and the gas values stable.
4. Lightly bottom the idle mixture screws and back them out 2 full turns.
5. Adjust curb idle speed according to the manufacturer.
6. Turn the idle mixture screws 1/8 turn at a time in the same direction until the CO_2 reaches the highest value (usually 12-15%).
7. Adjust the mixture screws equally to the leanest setting possible while maintaining the peak CO_2 value, stable readings, and good idle quality. The HC should be stable and below 400 ppm, the CO should be .5-3%.
8. Reset curb idle speed as needed.

PROCEDURE—PROPANE ENRICHMENT METHOD

Idle mixture can be checked by injecting a controlled amount of propane into the induction air and note its affect on engine speed. Some manufacturers set curb idle speed, then note the amount of rpm gain during enrichment. Others set engine speed during enrichment to an enriched idle specification, then note if the rpm drops to the curb idle speed specification when enrichment is stopped. Use the following generic procedure to check and adjust idle mixture.

1. Follow safety precautions and prepare the vehicle for idle mixture adjustment using propane. The pretest steps are usually listed on the tune-up decal. Be sure the transmission is in the proper gear.
2. Artificially enrich the mixture for highest rpm. Meter the propane into the air horn so it is evenly distributed to all the intake manifold runners. Increase enrichment slowly so rpm change is easily observed. If the propane flow is increased too fast the peak rpm will be missed because the engine becomes instantly rich—false test conclusions will result.
- When the engine is currently too rich, adding any propane will reduce rpm. If this occurs stop enrichment, adjust the idle speed screw to the enriched rpm specification (step 3), then turn the mixture screws leaner until the curb idle speed specification is reached (step 5). Then repeat steps 1-6.
3. With the engine at peak rpm (propane may be flowing), and the transmission in the proper gear, adjust the idle speed screw to the enriched rpm specification found on the tune-up decal.

   If the vehicle decal only list rpm gain, add the rpm gain and curb idle specifications to calculate the enriched rpm specification.
4. Turn off the propane, place the car in neutral, and purge the system at 2,000 rpm for 30 seconds.
5. Place the transmission in the proper gear and check the curb idle speed.
- If the curb idle speed is too low, the mixture screws are set too lean. Turn the mixture screws counterclockwise slowly and equally in 1/8 turn increments until curb idle speed is reached.
- If the curb idle speed is too high, the mixture is too rich. Set the mixture leaner until the curb idle speed specification is attained.
6. Repeat steps 1-5 until the engine speed drops to curb idle specification when the propane is turned off.

PROCEDURE—LEAN DROP METHOD

This procedure adjust the mixture slightly leaner than the mixture needed attain peak rpm.

If the adjustment is not completed within three minutes, run the engine at 2000 rpm for one minute. This will purge and stabilize the system.

1. Adjust the curb idle speed.
2. Adjust the mixture screws slowly and equally in 1/8 turn increments until peak rpm is attained.
3. Lean the idle mixture screws equally until the rpm drops a total of 5%.
4. Adjust the curb idle speed. Do not use the mixture screws for this adjustment.

PROCEDURE—CO METHOD

This method can be used when the sample probe is inserted upstream of the converter, or the vehicle does not have a converter. Some vehicles provide a special upstream port to sample non converted gas.

1. Adjust the curb idle speed.
2. Adjust the mixture screws slowly and equally in 1/8 turn increments until the desired CO reading is attained. Verify that the idle quality is good and the gas readings stable.

- Generally, 1-2% CO is acceptable for newer vehicles, and 2-3% for older vehicles.

  If the idle speed changes more than 5% while adjusting the mixture, reset the curb idle speed and repeat the mixture adjustment.

3. Adjust the curb idle speed.

GAS PARAMETER CHART
INFRARED ANALYSIS
EXHAUST GAS PARAMETERS FOR HC, CO, CO_2 & O_2

Gases	IDLE		1500 RPM		2500 RPM		Condition/ Possible Cause
	Converter*	Non-Converter	Converter*	Non-Converter	Converter*	Non-Converter	
HC (PPM) CO (%) CO_2 (%) O_2 (%)	0 - 150 1 - 1.5 10 - 12 .1 - 2.0	75 - 250 .5 - 3.0 10 - 12 .1 - 2.0	0 - 135 0 - 1.1 — .1 - 2.0	50 - 200 .5 - 2.0 — .1 - 2.0	0 - 75 0 - .8 11 - 13 .1 - 1.25	25 - 150 .1 - 1.5 4cyl - 3% 11 - 13 .1 - 2.0	NORMAL GAS READING — STABLE VALUES
HC (PPM) CO (%) CO_2 (%) O_2 (%)	0 - 150 Above 3.0 8 - 10 0 - .5	75 - 250 Above 4.0 8 - 10 0 - .5	0 - 135 Above 3.0 — 0 - .5	50 - 200 Above 3.5 — 0 - .5	0 - 75 Above 3.0 9 - 11 0 - .5	0 - 100 Above 3.0 9 - 11 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 - 10 1.5 - 3.0	0 - 135 0 - .8 — 1.0 - 2.5	50 - 200 0 - .9 — 1.0 - 2.5	0 - 75 0 - .25 9 - 11 1.0 - 2.0	0 - 100 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 - .3 5 - 9 4 - 9	400 - 1200 0 - .75 5 - 9 4 - 9	50 - 850 0 - .3 — 4 - 9	400 - 1200 0 - .75 — 2 - 7	50 - 750 0 - .3 6 - 10 2 - 7	400 - 1200 0 - .75 6 - 10 2 - 7	LEAN MISFIRE: Severe air leak; bad spark plug or wire; stuck PCV; misadjusted defective carb.
HC (PPM) CO (%) CO_2 (%) O_2 (%)	50 - 850 .1 - 1.5 6 - 8 4 - 12	over 1,000** .5 - 3.0 6 - 8 5 - 12	50 - 850 0 - 1.1 — 4 - 12	over 1,000** .5 - 2.0 — 5 - 12	50 - 750 0 - .8 8 - 10 4 - 12	over 1,000** .1 - 1.5 8 - 10 5 - 12	MISFIRE: Overadvanced timing; fouled plug; open/grounded plug wire: EGR stuck open

*Converter readings are taken with the air injection system disabled.
**Maximum digital reading HC on Analyzer = 2000 PPM.