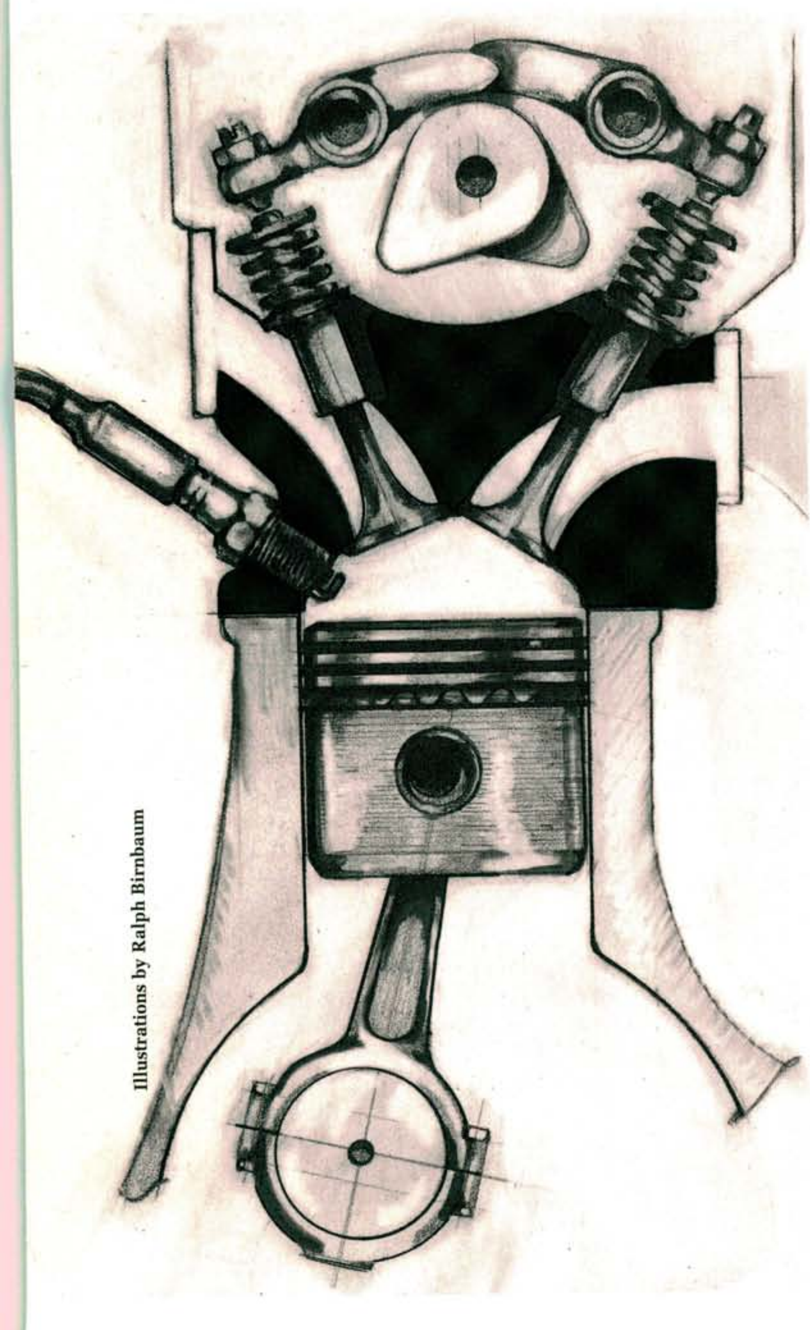
IMPORT SERVICE

Driveability Clinic

Four Gas Fundamentals

Part Two



Illustrations by Ralph Birnbaum

Welcome to **Part Two** of **Four Gas Fundamentals.** Last month we started you off with a look at common problems you'll encounter as you troubleshoot with a four gas analyzer.

We started with CO and HC because those of you familiar with two gas analysis are already accustomed to dealing with these two gases. But in **Part One** of this article, you probably noticed that the other two gases, O_2 and CO_2, started to work their way into the emission puzzle.

Oxygen (O_2) and CO_2 were always present in exhaust, you just couldn't measure them with your old two gas analyzer. On cars without catalytic converters, or those equipped with an upstream test point ahead of the catalyst, the old two gas did a pretty good job of isolating common problems.

But more and more we find ourselves limited to sampling exhaust gases at the tailpipe, after the catalyst has cleaned them up. And catalytic converters can withhold a lot of evidence.

That's why we'll be concentrating on O_2 and CO_2 emissions in the second part of this article. These two gases will give us the information we need to paint a complete picture of an engine's combustion efficiency.

As we proceed, please note that we'll be comparing all four gases at certain points to make a diagnosis. Using only one, or even two of the four gas readings can lead us to the wrong assumptions.

Whenever possible, fall back on your understanding of how an engine burns fuel, and ask yourself which component or components are most likely to cause a certain combination of emissions.

Once again, we'd like to thank the technical staffs at OTC and at MPSI for their assistance in the preparation of these articles. They have more technical assistance available to you when it comes to better using your four gas analyzer as a valued diagnostic tool.

OTC, Circle No. 142.
MPSI, Circle No. 143.

— **By Ralph Birnbaum**

Air Injection and Catalysts

Air pumps and pulse air systems are used on many cars to inject atmospheric air into the exhaust upstream, and directly into the catalyst downstream. This added oxygen helps clean up any unburned fuel in the exhaust, and it also increases the efficiency of the catalyst.

So before we start evaluating tailpipe levels of O_2, we need to answer a couple of questions:

- Is the air injection system working, and if so, how much of our O_2 reading at the tailpipe is coming from the air injection system?
- Is the catalyst working?

Before and After Pictures

Before we can tell how much the air injection system and catalyst are affecting emissions, we need to see what emissions look like without them. To do this, start and fully warm the engine. After it reaches normal operating temperature, shut it off and disable the air injection system.

Then let the car sit for 15 minutes or so to allow the catalyst to cool below its operating temperature.

When you restart the car, the engine will still be very close to operating temperature, but the catalyst will have to heat up again before it starts working.

Take your readings before the catalyst heats up and starts working, and write them down. Here is a sample set of readings:

- **HC = 90 PPM**
- **CO = 0.8 percent**
- **O_2 = 0.4 percent**
- **CO_2 = 13.5 percent**

This is a good running engine. Harmful emissions are low, and the high CO_2 reading tells us that we have high combustion efficiency. Even without the catalyst, emissions are low.

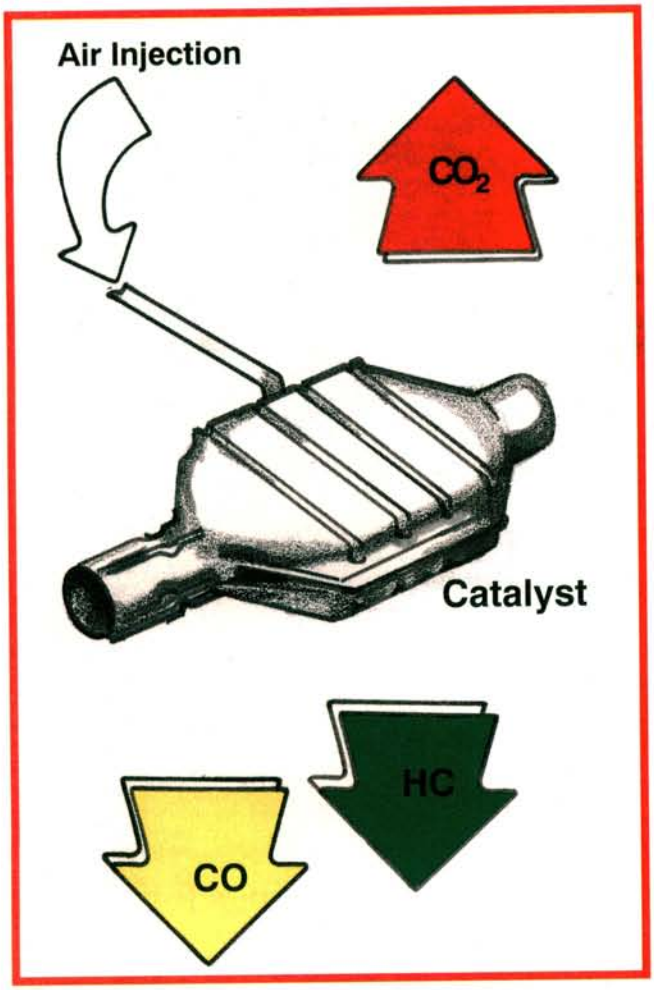
Now we can reconnect the air injection system, start the engine, and warm up the catalyst to operating temperature.

If the air injection system and cat are working, our readings should change and look like these:

- **HC = Very low, in fact HC may drop to tenths of a percent, or even zero with a good catalyst.**
- **CO = Very Low again, probably below 0.1 percent, or even zero.**
- **O_2 = This is one time when the change in O_2 levels may not tell you much.**

O_2 levels will rise on most cars when the air injection system is reconnected. On other cars, increased oxidation by the catalyst may consume more of the oxygen, causing no change, or even a reduction of O_2 emissions.

The important part is noting what change if any occurs. Then use that information to adjust your O_2 readings for the remaining tests.
• **CO_2 should increase by a percent or more as the catalyst begins to oxidize the remaining HC and CO.**



O_2—A Part of the Puzzle

The O_2 content of the exhaust brings up the importance of viewing the relationships between each of the four gases being measured.

A car's oxygen sensor is a good example of the limitation of looking at only one of the four gases.

The O_2 sensor measures oxygen and nothing else. And it doesn't care where that oxygen comes from. If the only oxygen in the exhaust is the result of combustion, the O_2 sensor does a pretty good job of tracking the air/fuel ratio.

But false air from an exhaust leak ahead of the O_2 sensor, or even from a manifold vacuum leak, can fool the sensor.

We, on the other hand, have more information to work with, since we're watching not only oxygen but the other exhaust gases as well.

Combo Platter

Here are some possible combinations and probable causes in a quick combination platter. Note that while each item on the menu includes High O_2, the added information about CO and HC helps us narrow down our list of probable causes.

High O_2 + High HC + High CO = a misfire caused by an over-rich fuel mixture.

High O_2 + High HC + Low CO = a misfire caused by a very lean mixture (a lean miss).

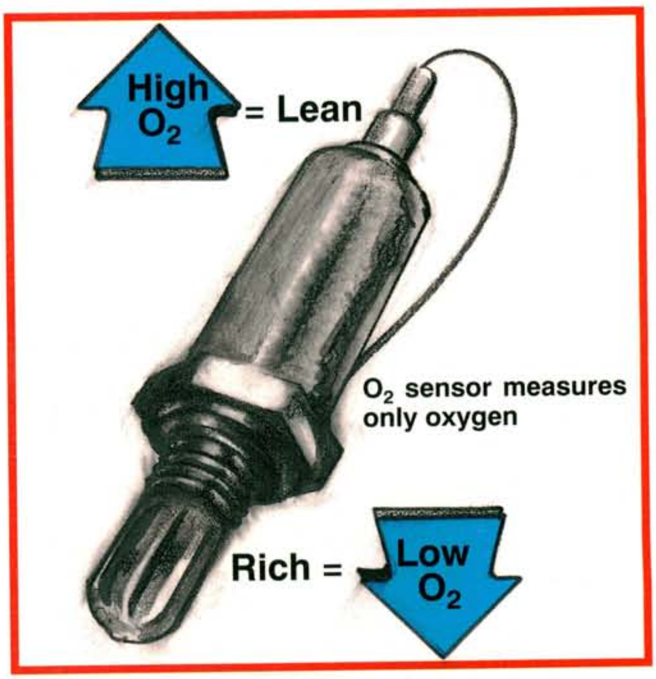
High O_2 + High HC + Normal CO = a misfire caused by an engine mechanical problem or a problem in the secondary ignition.

High O_2 + Normal HC + Low-to-Normal CO = a slightly lean mixture, or false air.

This last combination of High O_2 and normal HC and CO suggests a number of possibilities.
• **In this case, CO is not low enough to cause a lean miss.** But there will be more oxygen left over after combustion when things are leaner than normal.
• **Or, the extra oxygen may be coming from a localized vacuum leak, or exhaust leak, which is pulling in atmospheric oxygen.**

Low O_2

In general, low O_2 levels indicate a rich mixture. This makes sense, since there isn't enough O_2 to combine in combustion when the air/fuel ratio gets too rich.



But keep one or two things in mind before jumping to a wrong conclusion.

- **If the mixture is richer than normal, but still burnable, O_2 levels will be low, and the catalyst may mask slight increases in CO and HC at the tailpipe.**
- **If the mixture gets TOO rich to support combustion, we end up with a misfire. Oxygen may actually increase when combustion stops.**

More Tricks With O_2

If we remember that an engine is a huge vacuum pump, the importance of the O_2 readings grows. The engine is always sucking in something, isn't it, whether it's intake air, crankcase fumes from the PCV system, extra fuel vapors from the charcoal canister, or exhaust gas from an open EGR valve.

Why not put the big pump to work? If we alternately enable and disable these components, and watch the O_2 readings as we do, we should get some really useful information.

Checking the PCV System

This simple test checks the PCV system.

- **If CO readings are too high, pull the PCV and hold it away from the engine so it can draw fresh air.** If CO goes down, and O_2 and CO_2 go up, the system is working.
- **Run the engine at high idle, between 2000 and 2500 RPM.** Pull the PCV valve and place your finger over the valve inlet. If O_2 doesn't change, check for a collapsed PCV hose or plugged vacuum port at the intake manifold.
- **You can also place the tip of the analyzer probe near the oil filler hole after removing the fill cap.** If the crankcase oil is fuel saturated, excessive crankcase vapors will cause a big increase in both CO and HC.

Change the engine oil and filter, and retest.

Checking the EGR

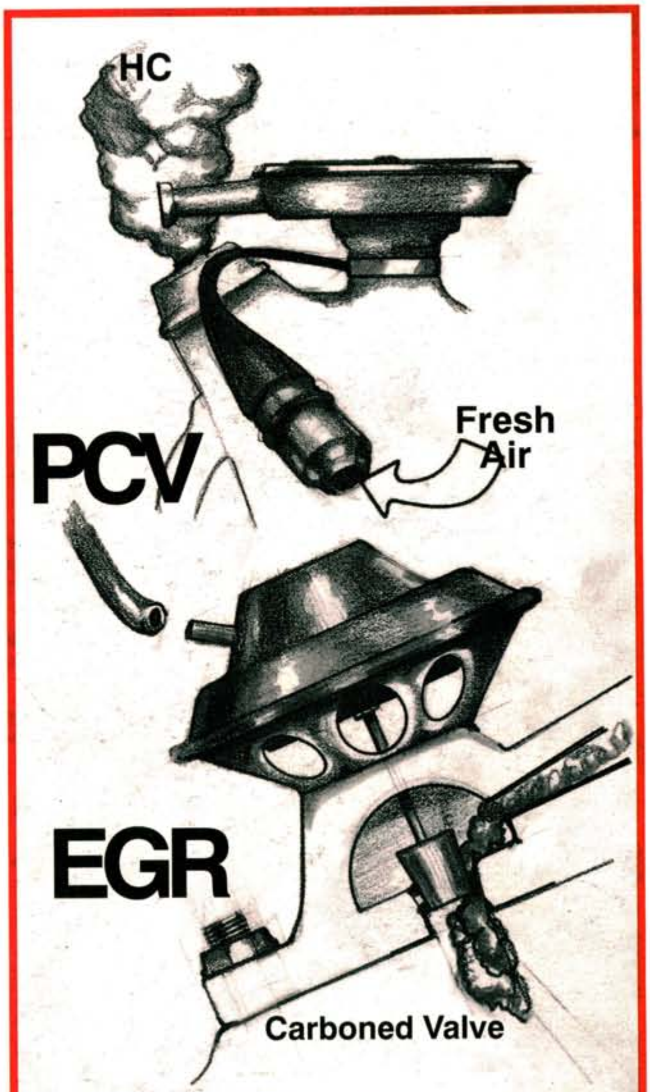
An open, or partially open EGR valve can cause a number of problems. If the EGR is stuck wide open, the car probably won't idle at all. But a valve that's stuck open just a crack can cause some weird problems. Even an EGR valve in good working condition can get a vacuum signal at the wrong time, opening it far enough to cause rough running.

- **To test the EGR, pull the vacuum hose at idle.**

O_2 levels should not change. If O_2 levels change more than 0.1 percent, the EGR valve is allowing exhaust gas to enter the intake, affecting combustion.

There's always a possibility that the EGR is stuck in a partially open position. Maybe it's being held open by a piece of carbon. Or perhaps the valve is so worn and carboned up that it just can't close all the way.

In some cases, the EGR will be open just far enough to cause a poor idle, but won't be open far enough to make the engine stall at idle. Another good indicator of this condition will be a low manifold vacuum reading.



CO_2

Whether you know it or not, you exhale CO_2 with each breath. We also get a lot of CO_2 when a healthy engine exhales. And plants inhale CO_2 as a part of photosynthesis. (Remember Biology 101?)

In order to keep the EPA and chlorophyl-laden plants happy, we look for high CO_2 readings as an indication that our engine is running as efficiently as it can.

Low CO_2 readings aren't quite as useful as the other three amigos when it comes to isolating a specific problem. But our friend CO_2 will definitely snitch on one or more of its brothers when they get out of line.

When it comes to combustion efficiency, the higher the CO_2 the better.

CO_2 as a Test of the Catalyst

Remember our earlier test of the air injection system and catalyst? Let's run it again, only this time we want to emphasize the importance of watching CO_2 as an indication that the catalyst is working.

Uncatalyzed CO_2 levels in the 13 percent range indicate efficient combustion. CO_2 levels should increase when the catalyst starts scrubbing the exhaust. An oxidizing catalyst should be combining injected oxygen from the air system with any unburned fuel to form CO_2.

In addition to watching for a reduction in CO and HC emissions with the catalyst lit, keep your eye on CO_2.

If CO_2 shoots up to 14.5 percent or higher when the catalyst lights up, you know for sure that the engine is providing a cleanable exhaust, and that the cat is finishing the job.

Here are rules of thumb for watching CO_2:

- **If CO_2 is low (below 10 percent) either the engine exhaust is dirty, the catalyst isn't working—or both. We'll go back to CO and O_2 to look for clues.**

- **If CO is above 0.5 percent, and O_2 is greater than CO, the catalyst isn't oxidizing the unburned CO and HC to form CO_2.** After all, if the catalyst were oxidizing the unburned fuel, there wouldn't be so much O_2 left over, would there?

- **If CO is higher than 0.5 percent, but O_2 is lower than CO, the catalyst probably isn't to blame.**

This last combination suggests two possibilities:

1) The air injection system is not supplying enough O_2 to the catalyst. Maybe the cat is doing the best it can with the air it's getting, but needs more air to do its job. Check for a missing downstream pipe, or other problem in the air injection system.

2) If the air injection system is intact, and working properly, then the engine is pumping out too much unburned fuel. Looks like the exhaust is so dirty that the catalyst just can't clean it all.

The catalyst has managed to reduce CO levels somewhat, but the low oxygen content is a sign that there is still too much unburned fuel in the exhaust for the catalyst to handle.

As we leave you, remember, the more CO_2 in the exhaust, the better.