WELLS Counter Point

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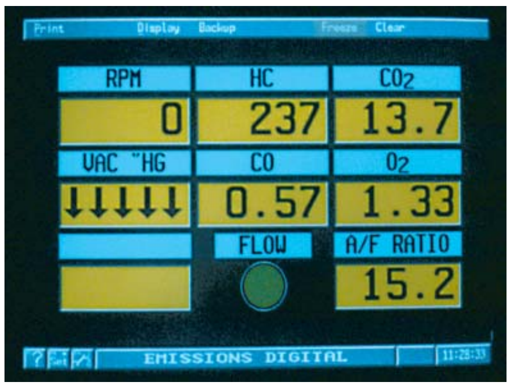
THE ELECTRONIC, DIAGNOSTIC AND DRIVEABILITY RESOURCE.

Exhaust Gas Analysis – Part One

Exhaust gas analysis is a powerful tool that should be a part of your diagnostic arsenal.



We've used the past few *Counter Point* issues to explore OBD II vehicle systems and OBD II diagnosis. While a vehicle's OBD II system can be a powerful tool, there may be situations when it becomes necessary to employ other diagnostic tools. One of these tools is the four (or five) gas exhaust analyzer.

An exhaust gas analyzer offers several diagnostic advantages:
- It's a dynamic test. The information from your analyzer is collected in real time, while the engine is running.
- Once you learn how to interpret the data, exhaust gas analysis can speed up your troubleshooting.
- After the repairs are made, a follow-up exhaust gas analysis allows you to determine whether those repairs were successful.

Before we go any further in our discussion of exhaust gas analysis, let's define our terms. By now, you've heard (or read) the word *stoichiometry*. If we sound it out phonetically, it reads 'STOY key OM e tree.' Perhaps you already know the definition of this strange-sounding word, perhaps not.

We also often see the main components of vehicle exhaust referred to by their periodic table notations, such as CO, HC and so on. Let's begin with a definition of the five measured components of the vehicle exhaust. The level amounts in the following descriptions are general statements.

- **CO_2** is carbon dioxide. Carbon dioxide is formed when the carbon in the fuel and oxygen in the air are combined during combustion. An acceptable level of CO_2 in the exhaust is above 12 percent. A high CO_2 reading indicates an efficiently operating engine.

- **CO**, or carbon monoxide, is an unstable byproduct of combustion that will easily combine with any oxygen available to form stable carbon dioxide (CO_2). This instability is why CO is a poisonous gas. If inhaled, it combines with oxygen in the lungs to form CO_2, which deprives the brain of oxygen. CO levels of a properly operating engine should be less than 0.5 percent.

- **HC**, or hydrocarbons, are unburned fuel molecules that have not been consumed during combustion. HC is measured in parts per million (PPM). A correctly operating engine should burn almost all the gasoline, leaving very little HC in the exhaust. Acceptable HC levels are 50 PPM or less.

- **O_2** is any oxygen not consumed during the combustion process that has reached the exhaust stream. About 21 percent of our atmosphere is composed of oxygen. Most of this oxygen should be used during the combustion process as it oxidizes the hydrocarbons in the gasoline. O_2 levels in the exhaust should be very low (about 0.5 percent).

- **NO_x**, or oxides of nitrogen, are formed at abnormally high combustion temperatures, when nitrogen and oxygen are able to combine.

And what about stoichiometry? Stoichiometry is the point at which the air/fuel mixture in the combustion chamber burns most efficiently. This occurs at an air/fuel ratio of approximately 14.7 parts of air to 1 part of fuel. HC, CO and O_2 emissions are nearly equal and at their optimum, lowest levels at stoichiometry. At the same time, CO_2 readings are at their highest point. Refer to **Figure 1** on page 3 for a visual explanation.

Interpreting Exhaust Gas Readings

Normal Combustion

Let's begin with an engine that is running normally and has good combustion. What should the exhaust gas readings look like?

- ***CO_2 should be high.*** Carbon dioxide is produced when carbon (C) and oxygen (O_2) combine during the combustion process. When combustion efficiency increases, CO_2 levels also increase.
- ***CO and O_2 should be equal.*** The CO level indicates whether the mixture is rich or lean. If CO is high, the mixture is rich. When the engine is at stoichiometry, CO and O_2 levels should be almost equal, indicating balanced combustion.

continued on page 3

Fine Tuning

Fine **Tuning** *questions are answered by Mark Hicks, Technical Services Manager. Please send your questions to: Mark Hicks c/o* ***Wells Manufacturing Corp., P.O. Box 70, Fond du Lac, WI 54936-0070*** *or e-mail him at* ***technical@wellsmfgcorp.com.*** *We'll send you a Wells shirt if your question is published. So please include your shirt size with your question.*

Q: "I have been working on a 1999 Ford F-150 with a 4.6L V-8 engine. The number 6 cylinder has a misfire. Could this cause a long cranking time before the engine starts?"

Matt Lange
Goodyear
Irving, TX

It depends on how long the engine has been misfiring. If the cylinder misfire has just started, it is unlikely that it is the cause of the long cranking condition. But if the misfire has been going on for some time, then yes, this definitely could be the cause.

When a misfire occurs, the oxygen in the combustion chamber is not used in the combustion process. This unused oxygen is pushed through the exhaust system and past the oxygen sensor, along with unburned hydrocarbons. The high concentration of oxygen passing over the oxygen sensor causes it to report a lean running condition to the powertrain control module (PCM). In an attempt to correct the mixture, the PCM increases injector pulse width. The engine ends up receiving more fuel than it can consume. This problem is not as common on today's vehicles as it was in the past. However, it can still happen.

On an OBD II compliant vehicle like your customer's, the main purpose of the engine management system is to maintain a 14.7:1 air/fuel ratio. If the PCM has made several adjustments to the long term fuel trim in an attempt to correct the fuel mixture, and if the condition shows no improvement, the PCM will switch to a set of learned values. This scenario will occur only if the misfire is not severe. During a severe misfire the PCM will immediately change to learned values. This means the timing and fuel trim will be set to parameters that are stored in its memory. To determine the correct parameters, the PCM looks at the engine coolant temperature, cylinder head temperature, intake air temperature and mass air flow sensor inputs. However, the engine will run rich until the PCM enters the learned mode, increasing the possibility of saturating the cylinders and the oil with unburned fuel.

Results: After replacing the ignition wires, spark plugs and changing the oil, the engine started as normal.

The "Fine Tuning" question from the last *Counter Point* concerned a 1999 Ford Escort with a 2.0L engine. The vehicle was brought to the shop due to a cylinder number 2 misfire. Replacing the coil repaired the problem at that time. Two weeks later, the customer returned with the same cylinder misfiring. Could the PCM (Powertrain Control Module) be causing this problem?

To answer this question, we need to determine what type of ignition system this vehicle utilizes. It's a DIS (distributorless ignition system), with the coil primary circuit controlled and energized by the PCM. Crankshaft position information is relayed to the PCM by a magnetic reluctance crankshaft position sensor. The system has a DIS coil with four secondary terminals. This is actually two separate coils in one package.

The coil incorporates three primary pins. One of these pins is connected to a 15 amp fuse and carries the positive current for both coil primary windings. The other two pins are connected directly to the PCM. The PCM alternately provides ground to each of these pins, which power the primary winding of the respective coils.

The secondary winding of the powered coil is energized via magnetic induction. When the circuit resistance is overcome, the PCM opens the circuit, discharging the coil and simultaneously firing two spark plugs in a loop.

Considering only one cylinder is misfiring and its mate sharing the ignition coil secondary windings is not, it appears you have a problem in the secondary ignition system, the fuel system or the mechanical engine. The problem is not in the primary ignition, which also rules out the PCM.

Examine the secondary ignition circuit closely. If the ignition wires or spark plugs have high resistance or an extended gap, a premature ignition coil failure will result. Remember, when checking the spark plugs at least one firing in a positive direction needs to be examined to determine center electrode wear. The companion cylinder spark plug will show wear on the outside electrode.

Results: After closely examining the spark plugs, they were determined to be worn beyond acceptable service limits, and they were replaced. The ignition coil has been holding up since, and cylinder number two has never run better.

The first correct e-mail or fax answer was from:
Rick Panganiban
Firestone Tire
Colonie, NY

The first correct postal answer received was from:
Gary Curtis
Car Care Doctors, Inc.
Pomeroy, OH

Diagnose The Problem Win A Shirt

Q: "I have been working on a 1992 Olds Delta 88 off and on for the last month. To correct a no-start condition, I have installed three ignition control modules over this period of time and can't find a reason for the repeat failures.

"The ignition coil, ignition wires and spark plugs were replaced along with the module the first time the vehicle was towed in. I have rechecked them and they all look good. I have performed voltage drop tests on all the ground circuits and they are in good shape. I just don't understand what else could cause these ignition modules to fail."

Tom McCabe
J&R Repair
Tallahassee, FL

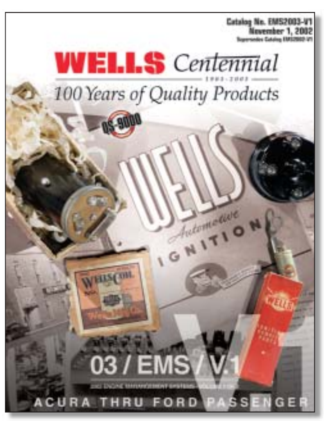
The first reader to respond with the most accurate answer via e-mail or fax, and the first reader to respond with the most accurate answer via snail-mail, will receive a Wells golf shirt. The answer will appear in the next issue.

Hot off the Wire

Wells Manufacturing Corp. 100th Anniversary 1903 - 2003

In 1903, Robert Wells opened the doors of a new business. His goal was to manufacture the highest quality products for an emerging industry—the automobile. Through an acquaintance with Henry Ford, Wells Manufacturing Corp. received its first contract to manufacture coils for the Model T.

To ensure the success of his new business, Mr. Wells knew he would need reliable employees to produce high quality products at sensible prices. One hundred years later, those values are still alive within every Wells employee. Our commitment to quality is exemplified by the fact that all of Wells' facilities are QS-9000 certified. We are the only full-line manufacturer of engine management components to earn that distinction. In 1903, our founder had a dream that became a reality. Today, all of Wells' employees enjoy the privilege of perpetuating that dream.



As we begin our 100th year of doing business, we are proud to announce the arrival of our 2003 Engine Management Systems Applications Catalog and Illustrated Parts Guide. More than 2,000 new part numbers have been added since last year's catalog, which helps to explain why Wells continues to lead the industry with the most comprehensive engine management parts coverage.

continued from page 1

Exhaust Gas Analysis - Part One

• *HC should be low.* A low HC level indicates that the air/fuel mixture is burning efficiently. All (or nearly all) of the fuel (HC) is being consumed during combustion. There's one thing to keep in mind, however. A properly functioning catalytic converter can reduce higher than normal levels of HC and CO, and possibly mask a problem. This is why O_2 is a better indicator of combustion efficiency. We'll delve deeper into the relationships between the exhaust gasses as we go along.

Poor Combustion

Now let's assume the engine is not running properly and has poor combustion. How do we interpret the abnormal exhaust gas readings we see on the analyzer?

The CO reading may be high. CO is an indicator of the air/fuel ratio, so anything that affects that ratio can cause a change in CO.

Here are some factors that can contribute to high CO:
• High fuel pressure.
• A leaking fuel injector (or injectors).
• A faulty input or inputs to the PCM. This may cause the PCM to keep the injectors open too long. For example, a bad coolant temperature sensor can fool the PCM into thinking the engine is cold. This increases injector ON time, causing an abnormally rich mixture.
• A plugged air filter or other restriction in the air intake limits the amount of air available for combustion.
• A saturated charcoal canister or faulty purge valve.
• A fuel-saturated crankcase. Fuel vapors will be drawn into the intake through the PCV system. Infrequent oil changes and short-trip driving may cause fuel-saturated oil. Any of the previously mentioned defects could also cause a fuel-saturated crankcase.

Accurate exhaust gas analysis depends on your ability to interpret the readings *as they relate to one another*. For example, slightly higher than normal CO levels may occur without a corresponding increase in HC. The engine may be able to burn a slightly rich mixture without an apparent loss of performance. If CO gets too high, however, a miss will result and HC levels will rise.

Catalytic converters can also mask small problems with the air/fuel mixture by lowering the levels of CO and HC your analyzer sees. This is one reason why the two gas exhaust analyzers that were common a generation ago are no longer adequate. For a more accurate diagnosis we need to be able to see the other exhaust gasses too. For example, O_2 is a better indicator of a rich condition than CO. If O_2 emissions drop too low, this indicates that there isn't enough oxygen available for the amount of fuel being delivered.

The CO reading may be low, while O_2 is high. A low CO reading by itself is not enough to determine whether the mixture is lean. The low reading may be the result of catalyst efficiency, rather than a lean condition. However, if O_2 is also high, the extra oxygen left in the exhaust when a lean mixture burns will give you an added clue that the pre-catalyst CO is too low. This is why an intrusive test that samples the exhaust stream before the catalytic converter is often the best.

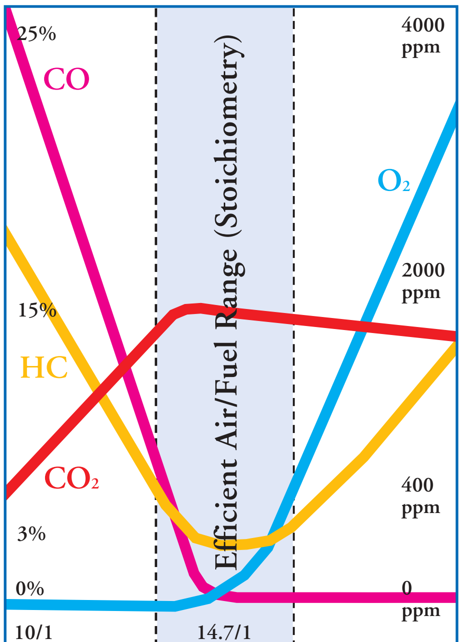


Figure 1: *HC, CO, CO_2 and O_2 at or near stoichiometry.*

Possible Causes of a Lean Mixture

Lean mixtures are caused by too little fuel, too much air, or a combination of the two. The following are possible causes of low CO:
• Low fuel pressure. Check for a plugged fuel filter, weak fuel pump or restriction in the fuel inlet hose.
• Restricted fuel injectors.
• Engine vacuum leaks.
• A defective O_2 sensor.

Exceptions

We've been using CO and O_2 to evaluate a lean condition. However, there are a couple of exceptions to be aware of:
• High O_2 accompanied by high HC indicates a mixture that is so lean that it is causing a lean misfire.
• High O_2 can also be caused by an exhaust leak that is drawing air into the exhaust system. This will fool the exhaust gas analyzer (and possibly the oxygen sensor) and produce abnormally high O_2 readings at the tailpipe. This in turn could cause the injector pulse width to increase, leading to high CO and HC readings.

High HC

The air/fuel ratio can vary within limits, without causing a misfire. But when fuel mixtures go beyond these limits, the results are incomplete combustion and high HC emissions. Other factors can also cause incomplete combustion. In fact, anything that prevents complete combustion will cause an increase in HC.

If all the available hydrocarbons are consumed in the combustion process, HC emissions are zero. No engine is completely efficient, however, so there will always be some HC left over, even at stoichiometry. The catalyst then cleans up the remaining unburned hydrocarbons. But an engine with a serious misfire will put more hydrocarbons into the exhaust than the catalyst can handle.

High HC Causes

• *Poor secondary ignition.* A bad spark plug, plug wire, cap or rotor or a weak or cracked ignition coil may cause high HC. Over-advanced ignition timing can also cause high HC.
• *Low or no compression.* Compression loss in a cylinder or cylinders may cause a miss.
• *An EGR that is sticking open.*
• *If the mixture is too rich to burn, high HC and CO will result.* Refer to the comments on high CO causes, as they may also cause high HC.
• Any of the possible causes of extremely low CO can cause a misfire if the mixture gets too lean to burn.

Other Symptoms That Accompany High HC

• Lower than normal CO_2.
• CO and O_2 may be low, high or normal.

More To Come

Some of the scenarios we've introduced have included the O_2 level in the diagnosis. Oxygen (O_2) and CO_2 were always present in the exhaust, you just couldn't measure them with a two gas analyzer. However, these two gases provide the information we need to paint a complete picture of an engine's combustion efficiency, especially if the engine is equipped with a catalytic converter (as most are now).

Relying on only one or possibly two of the four gas readings can lead to an incorrect diagnosis. In the next *Counter Point*, we'll explain how O_2 and CO_2 readings can be combined with HC and CO readings to produce an accurate diagnosis. See you then.

WELLS

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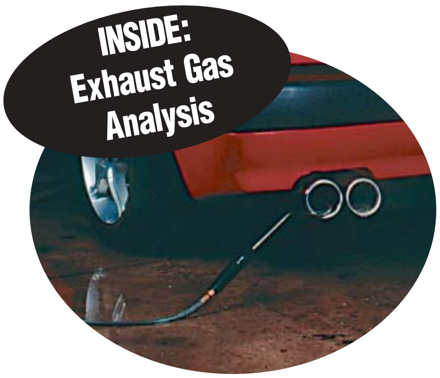
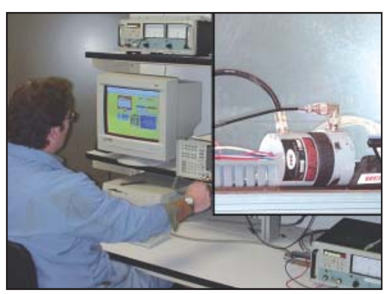


Quality Points

Bulk Current Injection (BCI) Testing Chamber

Radio frequency interference (RFI) and electromagnetic pulses (EMP), which can affect a car radio, can also affect other vehicle electronics if they are not properly shielded. For example, it is essential to route the ignition wires on today's vehicles exactly as the manufacturer intended. But what if the engine has an intermittent stumble or cuts out occasionally, even when the wires are routed correctly? Could these symptoms be caused by a poorly engineered module?

Wells Manufacturing Corp. has taken steps to ensure this does not happen to your customers' vehicles. Our totally enclosed, electromagnetically shielded, galvanized steel testing chamber is dedicated to testing our products for resistance to the influence of RFI and EMP. Each product to be tested is connected to a wiring harness suspended 50 millimeters above a copper plane table. The table simulates an automobile chassis, and the wires are suspended above it to allow a bombardment of RFI and EMP to encircle them.



Scott Waranius monitors operation of the Wells bulk current injection testing chamber. The Wells module being tested is in the photo inset.

Next, a radio frequency injection probe is clamped around the wires near the connector. Unlike the inductive spark plug wire clamp on your timing light, the injection probe injects RFI instead of absorbing it. The injection probe is connected to a spectrum analyzer on the other side of the wall, where a technician operates the controls and gathers the data.

All Wells products are subjected to the same rigorous tests as original equipment (OE) products. Our RFI/EMP testing procedures are another example of our ongoing efforts to ensure that every product we manufacture meets or exceeds OE specifications.

Publisher's Information

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