WELLS Counter Point
Volume 7 Issue 2, April 2003
THE ELECTRONIC, DIAGNOSTIC AND DRIVEABILITY RESOURCE.

Exhaust Gas Analysis – Part Two

Adding O_2 and CO_2 to exhaust gas analysis greatly increases your chances of diagnostic success.

In the last *Counter Point*, we looked at common troubleshooting problems you may encounter while working with a four gas analyzer. We started with CO and HC analysis because these gases are used for basic two gas analysis. But you probably noticed that the other two gases — O_2 and CO_2 — also started to work their way into the discussion.

On cars that were not equipped with catalytic converters, or with a test point before the catalyst, a two gas analyzer did a pretty good job of helping you to isolate common problems. On today's vehicles, we are usually limited to sampling the exhaust gases at the tailpipe, after the catalyst has done its job. That's why we'll be concentrating on O_2 and CO_2 emissions here. Combined with CO and HC, these additional gases give us the information we need to paint a more complete picture of an engine's combustion efficiency.

Please note that we'll be comparing the relationship between all four gases at certain points to make a diagnosis. Using only one or even two of the four gas readings can lead to incorrect assumptions. Whenever possible, use your understanding of how an engine burns fuel, combined with scan tool data, to determine which component or components are most likely to cause a certain combination of exhaust gas readings.

Air Injection and Catalysts

Especially on earlier vehicles, air pumps or pulse air systems may be used to inject atmospheric air into the exhaust upstream, and/or directly into the catalyst downstream. This added oxygen helps clean up any unburned fuel in the exhaust and increases catalyst efficiency. Before we can evaluate O_2 levels at the tailpipe and determine whether the catalyst is working, we need to disable the air injection system on these vehicles.

After disabling the air injection system (if equipped) start and fully warm the engine. After it reaches normal operating temperature, shut it off. Let the car sit for about 15 minutes to allow the catalyst to cool below its operating temperature. Now restart the engine. The engine should still be very close to operating temperature, but the catalyst will have to heat up again before it starts working. Use the gas analyzer to immediately take your readings, before the catalyst starts working. Here is a sample set of readings collected using this testing method:

HC = 90 PPM
CO = .8 percent
O_2 = .4 percent
CO_2 = 13.5 percent

This engine is running normally. Harmful emissions are low, and the high CO_2 reading indicates high combustion efficiency. Emissions are acceptable, even without the catalyst's help.

Reconnect the air injection system (if equipped). Start the engine and warm up the catalyst to operating temperature. On a system with a properly functioning catalyst, the readings should look more like these:

- HC should be very low, at less than 100 parts per million (PPM). It may drop to 5, 10 or even zero (PPM) on a good-running engine.
- CO should also be very low. This reading should be less than .5 percent. It may be below .1 percent, or even zero on a good-running engine.
- The change in O_2 levels may not tell you much. Increased catalyst oxidation may consume more of the available oxygen after it lights, causing no change, or a decrease in O_2 emissions. On a good-running engine, the O_2 reading should be between .3 and 1.3 percent. Note what change occurs, if any. Use this information as a baseline for your O_2 readings during the remaining tests.
- CO_2 should be more than 13.5 percent and will likely increase by a percent or more over your earlier "cold cat" readings as the catalyst begins to oxidize the remaining HC and CO.

Interpreting O_2 Readings

The oxygen sensor reveals the limitations of looking at just one of the four gases. If the only oxygen in the exhaust is the result of combustion, the oxygen sensor does a good job of tracking the air/fuel ratio. But false air from a manifold vacuum leak or exhaust leak ahead of the O_2 sensor, for example, can fool

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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 just replaced the intake manifold gasket on a 1997 Chevrolet pickup with a 5.7L engine, to repair a coolant leak. I started the engine after I finished the job and it seemed to run fine. I let the engine warm up to make sure there was no air in the cooling system, then re-filled it. When I went to turn the key off, I noticed the MIL was on. I connected my scan tool and found a DTC P1345 was stored in the PCM's memory. Could this have anything to do with the work I just performed?"

David Habert
Patin's Repair
New Iberia, LA

A: David, DTC P1345 is a factory-specific code pertaining to the synchronization between the CKP and CMP sensor signals. When you replaced the intake manifold gasket, the distributor also needed to be removed. The CMP sensor is located inside the distributor housing. The distributor is driven by the camshaft via helical gears. If the distributor gear is installed a tooth off in relation to the camshaft gear, a DTC will set after start-up.

After installing the distributor, the camshaft retard offset must be set. To set the offset, attach a scan tool to the DLC. Start the engine and observe the camshaft retard. The specification is 0 ±2 degrees. To compensate for a negative reading, turn the distributor counterclockwise. Turn the distributor the opposite direction if the reading is positive.

On a side note, this distributor was designated as non-serviceable when it was first introduced. Things have changed since then and the internal parts are now available, including the internal CMP sensor.

Results: David moved the distributor one tooth back, then set the camshaft retard offset and the DTC did not reappear.

The "Fine Tuning" question in the January 2003 *Counter Point* concerned a 1992 Olds Delta 88 that has experienced multiple ignition module failures. Along with the ignition modules, the ignition coil, ignition wires, and spark plugs have also been replaced. All system grounds have also been checked for excessive voltage drops. What could cause these ignition modules to fail?

There are three causes for repeat ignition control module failures. The first and most common cause is high resistance in the secondary ignition. On this vehicle, this would include the ignition coil(s), ignition wires, spark plugs and cylinder compression. All of the ignition components mentioned have either been recently replaced or tested, so we should be able to rule them out. There was no mention of a compression increase, so for now I will assume all is well there.

The next most common cause for repeat module failure would be a bad system ground. Voltage drop tests have been performed on the system and no problems were found, so I am also going to assume everything is okay in this area.

The last possible cause has to do with the charging system. As the rotor in the alternator turns, it generates an AC current in its windings. It is the job of the rectifier bridge to convert this AC voltage to DC voltage. If the rectifier is beginning to fail, it will allow an unhealthy amount of AC voltage to enter the vehicle's electrical system. Given enough time, this AC voltage will cause an ignition control module failure. It may also damage other vehicle electronics.

To measure the amount of AC voltage that is present in the electrical system, attach a digital voltmeter to the battery and select the AC voltage scale. While the engine is running you should not see more than .5 AC volts on your meter.

Results: Tom checked and found .9 AC volts at the battery. He replaced the alternator. The ignition control module has been working fine ever since.

Although we did receive a large number of replies to last issue's "Fine Tuning" question, we did not receive any *correct* answers. Most of the answers we received pointed to an intermittent crank sensor as the cause of the problem, which I find interesting. Within the next few issues, we will take a look at different crank sensor designs, including how they function, what happens when they become intermittent and how to test them.

Diagnose The Problem Win A Shirt

Q: "I am working on a 1995 Olds Cutlass Supreme with a 3.1L engine and 132,000 miles on the odometer. The problem is, the engine cuts out whenever it exceeds 2100 RPM. When this happens, it feels like the rev limiter is cutting in and the PCM is shutting off the fuel injectors.

"I have checked fuel pressure and volume and both are perfect. I have replaced the 24X crank sensor, ignition wires, ignition control module, ignition coils, ECM (twice), MAP sensor and spark plugs. I have performed voltage drop tests on all the related wiring with excellent results. Do you have any idea what could cause this problem?"

Art Rauls
Fond du Lac Tire & Service
Fond du Lac, WI

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.

Important Dates To Remember

The National Institute for Automotive Service Excellence (ASE) will offer forty-plus certification tests for repair professionals and parts specialists on May 6, 8 and 13, 2003, beginning at 7:00 p.m. The tests will be given at over 700 U.S. and Canadian locations. If you've already registered, mark your calendar with these important dates.

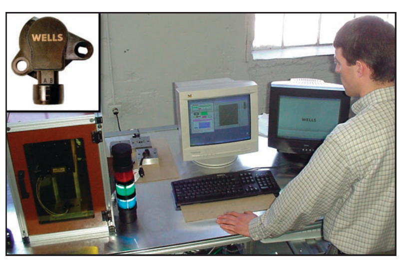
Wells Manufacturing Corp. encourages professionalism through technician certification.

Quality Points

Throttle Position (TP) Sensor Automated Test System

Wells takes measures during every step of our manufacturing processes to ensure that you always receive the highest quality parts possible. During our TP sensor manufacturing process, quality assurance begins in the Wells Clean Room (see the October 2001 *Counter Point*). This is where we build the circuit boards to fit every TP sensor we manufacture. After the circuit boards are completed, 100 percent of the production run is individually tested.

Next, the TP sensors are assembled, followed by a full function test of 100 percent of the completed sensors. The test is conducted on an innovative system designed by Wells engineers (shown here) and begins by mounting the TP sensor in a cradle that is exactly like the spot on the throttle housing where it will ultimately be mounted. One of the reasons we inspect 100 percent of our TP sensors in this way is to ensure a perfect fit.



Jason Strange checks the operation of the TPS tester. A laser-engraved TP sensor is in the inset.

The test system then fully sweeps the TP sensor twice to check for mechanical imperfections. The sensor is then slowly rotated through the full functional range, and the voltage slope is compared to OEM specifications stored in the adjoining computer. If the TP sensor passes these tests, a laser prints the Wells logo, part number, date code and serial number on the sensor face.

Once again, Wells steps forward to give you the confidence and peace of mind you deserve.

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Exhaust Gas Analysis - Part Two

the sensor. The oxygen sensor measures oxygen and nothing else, and it can't tell where that oxygen comes from. We have more information to work with when we can watch the oxygen, along with the other exhaust gases. This illustrates the importance of the relationships between each of the four gases.

Mix and Match

Below are some exhaust gas combinations and possible causes. The complete list of possible causes would be too long for this article. The examples given here should give you a feel for the diagnosis. While each item includes high O_2, the added CO and HC information helps to narrow things down.

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 (possibly a partially plugged fuel filter).

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

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

This last combination of High O_2 with normal HC and CO suggests a number of possibilities. In this case, CO is not low enough to reveal a lean miss. But there will be more unused oxygen left after combustion if the mixture is leaner than normal. Alternately, the extra oxygen may be coming from a vacuum leak, or an exhaust leak that is pulling in atmospheric oxygen.

Interpreting O_2 Readings

In general, low O_2 levels indicate a rich mixture. There isn't enough O_2 to combine in combustion when the air/fuel ratio gets too rich. But keep the following in mind to avoid incorrect conclusions:

- 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, a misfire will result. Oxygen in the exhaust will increase when combustion stops or is incomplete.

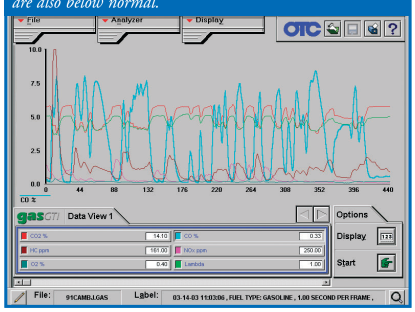
When thinking of the engine as a huge vacuum pump, the diagnostic importance of the O_2 readings intensifies. The engine doesn't care whether it's inhaling intake air, crankcase fumes from the PCV system, extra fuel vapors from the charcoal canister or exhaust gas from an open EGR valve. Alternately enabling and disabling these components while watching the O_2 readings should yield some 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 PCV system is working.
- Run the engine at a very high idle — between 2000 and 2500 RPM. Remove the PCV valve and place your finger over the valve inlet. If O_2 doesn't change, check for a collapsed PCV hose, plugged PCV or plugged vacuum port at the intake manifold.
- Place the tip of the exhaust analyzer probe near the engine oil filler hole after removing the fill cap. If the crankcase oil is fuel-saturated, excessive crankcase vapors will cause a very noticeable increase in HC and possibly CO. Change the engine oil and filter, and retest.

Figure 1: *This exhaust gas trace illustrates elevated CO and HC levels, caused by a defective injector. O_2 and CO_2 are also below normal.*



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. But a valve that's partially stuck open can cause problems that are harder to pinpoint. Even an EGR valve in good working condition can get a control signal at the wrong time, opening it far enough to cause rough running.

To test the EGR, remove its vacuum hose at idle. O_2 levels should not change. If O_2 levels change more than .1 percent, the EGR valve is allowing exhaust gas to enter the intake, affecting combustion. You will need to check why the EGR is getting vacuum at idle.

There's also the possibility that the EGR is being held in a partially open position by a piece of carbon. In some cases, the EGR will be open just far enough to cause a poor idle, but not far enough to make the engine stall. Low manifold vacuum, map voltage that is high and high O_2 readings are good indicators of this condition.

CO_2

High CO_2 readings indicate that the engine is running as efficiently as possible. Low CO_2 readings aren't quite as useful as the other three exhaust gas readings when it comes to isolating a specific problem. But CO_2 can still be useful when the other readings get out of whack. Just remember, when it comes to combustion efficiency, the higher the CO_2 reading, the better.

CO_2 Catalyst Test

Now repeat the catalyst test, while watching CO_2 to determine whether the catalyst is working.

Uncatalyzed CO_2 levels in the 13 percent range or above indicate efficient combustion. CO_2 levels should increase when the catalyst starts scrubbing the exhaust. A catalyst that is working efficiently will combine oxygen with CO 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 even higher when the catalyst lights, the catalyst is doing its job.

Here are some guidelines for CO_2 readings:

- If CO_2 is low (below 10 percent), the exhaust is dirty, the catalyst isn't working — or both. Use the CO and O_2 readings to help complete the diagnostic picture.
- If CO is above .5 percent, and O_2 is greater than CO, the catalyst might not be oxidizing the unburned CO and HC to form CO_2 and water. If the catalyst is oxidizing the unburned fuel as it should, there usually isn't as much O_2 left over.
- If CO is higher than .5 percent, but O_2 is lower than CO, the catalyst is probably doing its job.

This last combination suggests two additional possible causes of high CO readings:

- The air injection system is not supplying enough O_2 to the catalyst. The catalyst may be doing the best it can with the air it's getting.
- The engine or the cat or both are in bad shape. The exhaust is too dirty for the catalyst to clean. The catalyst has reduced CO levels somewhat, but the low oxygen content is a sign that there is still too much CO in the exhaust for the catalyst to handle.

More To Come

In future *Counter Point* issues, we'll continue our investigation of exhaust gas theory and diagnosis. We plan to bring NOx and Lambda into the picture too, and to explain how information from a scan tool can be combined with an exhaust gas analyzer to speed up the diagnostic process.

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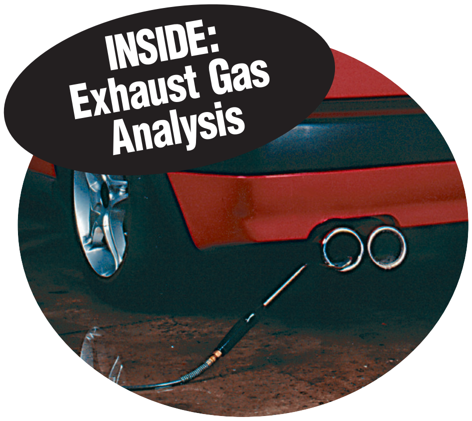

Hot off the Wire

Wells Manufacturing Corp. Achieves ISO 14001 Certification

In the October, 2001 *Counter Point*, we announced that Wells Manufacturing Corp. was pursuing ISO (International Organization for Standardization) 14001 certification. Today, we are pleased to inform our readers that we have successfully completed the program and have been granted certification for our plants located in Fond du Lac, WI, home of our corporate headquarters.

ISO 14001 certification requires Wells Manufacturing Corp. to monitor and control the environmental effects of its activities, products and services. ISO 14001 also assesses energy usage, waste creation disposal and general environmental awareness. The buildings and manufacturing equipment have been evaluated to ensure all drains and ventilation systems are properly installed and maintained. All materials entering our plants are evaluated as to their potential environmental effects (positive or negative). ISO 14001 also considers the final disposition of products when their useful life has ended.


CERTIFICATE OF REGISTRATION
ISO 14001 REGISTERED FIRM
This is to certify that
WELLS MANUFACTURING CORP.
26 South Brooke Street, Fond du Lac, WI 54936
385 W. Rolling Meadows Drive, Fond du Lac, WI 54937
has successfully implemented an environmental management system
entela
2625 Buchanan S.W., Grand Rapids, MI 49548-1039 USA
Phone (616) 222-7979, Fax (616) 222-7999
Certification Number: 03-062
In Accordance with Standard(s): ISO 14001: 1996
Scope: Management of Environmental Aspects for the Design and Manufacture of Electronic and Electro-Mechanical Engine Management Systems, Charging Systems, Sensors and Components
SIC Code: 36, 37
Date of Registration: 03/17/03
Date of Registration Expiration: 03/17/06
Ford - W429
GM - 006070320
CORPORATE SEAL
Certification Manager
Vice President of Registration Services

Recently, General Motors, DaimlerChrysler, Ford Motor Company and most European automakers have stated they will require their suppliers to achieve ISO 14001 certification during 2003. We are proud to say that Wells is one of the first engine management component manufacturers to attain this very important certification.

Publisher's Information

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Counter Point is a quarterly publication of Wells Manufacturing Corp., P.O. Box 70, Fond du Lac, WI 54936-0070. Letters and comments should be directed to: *Counter Point* Editor, c/o Wells Manufacturing Corp., P.O. Box 70, Fond du Lac, WI 54936-0070.