

Mark Warren

smwarren@motor.com

explaining why you need an exhaust gas analyzer for diagnostics. irst, some review and clarifications. The first column (December 2009) can be found at www.motormagazine.com. In that column, we referred to the

A good diagnostician may not know the answers, but he knows what

questions to ask to get them. This is the second of a three-part series

Brettschneider formula, which calculates Lambda by accounting for all of the fuel and air molecules passed through the engine. You do not need to understand the formula or do the complex calculations; your gas analyzer likely does this for you in real time. Or, you can record the gases and plug the numbers into an online calculator.

Lambda accuracy is unaffected by combustion, misfire, catalytic converters, etc. What goes in the engine must come out. Assuming no exhaust leaks or dilution, Lambda will be correct.

There are some other assumptions to be made. The Lambda calculation is based on a gasoline chemistry of typical carbon to hydrogen ratios. Gasoline is made up of many different molecular compounds; also, oxygenated additives like ethanol may be

Misfiring Cylinders	НС РРМ	CO2%	<b>O</b> 2%	CO%	Lambda
6-Cyl Expected Gas Values (Pre-Catalyst)					
1	3900	12.50	3.50	?	1
Actual Measured Pre-Catalyst					
1	2482	11.83	3.94	1.16	1.052
Actual Measured Post-Catalyst					
1	817	15.37	0.44	0.44	0.98
Baseline Pre-Catalyst Before Misfire					
0	200	14.40	1.12	0.58	1.028
Baseline Tailpipe Before Misfire					
0	0	15.84	0.48	0.02	1.023

added. Typically, in my experience in Tucson, on a correctly running engine, Lambda is  $\pm 5\%$  of 1. When looking for a fuel delivery problem, I don't consider ±5% much of an issue.

When diagnosing driveability problems, Lambda can be used to quickly determine if the problem is in the fuel delivery system. The ability of Lambda to positively identify or eliminate fuel delivery as a problem with a simple exhaust probe connection is one of the fastest and most reliable tests a diagnostician can run.

The primary air/fuel ratio controller is the O<sub>2</sub> or wide-range-air/fuel ratio sensor in the exhaust. What happens if this sensor is incorrect? How does the on-board diagnostic system know? There are two possible indicators.

The first is if fuel injector on-time is increased or decreased by more than the "normal" on-time (comparative data stored in the PCM). Fuel trim values will increase or decrease accordingly. Fuel trim might

put you on to a skewed sensor; Lambda will find it fast.

Second, we depend on the onboard system to compare the postcatalyst sensor values with the precatalyst sensor values and do a rationality test. Generally, it can be assumed that the postcatalyst sensor is less likely to skew or fail because it resides in a more favorable environment. Any contaminant that will react with the platinum in the sensor has easy access to the precatalyst sensor. The postcat-alyst sensor sits behind a catalytic converter that will likely attract most of the contamination before it reaches the postcat sensor. The precatalyst sensor is also sub-ject to far greater thermal excursions. The heavy engine load while climbing a hill causes high exhaust temperaplatinum in the sensor has easy access

## **Driveability Corner**

tures, and topping the hill and shutting off fuel causes a rapid temperature decline. While the postcatalyst sensor is located behind a hot catalytic converter, when topping the hill, the converter is still hot. The postcatalyst sensor temperature excursions are buffered by the catalytic converter.

So, the theory is that the onboard system will use both pre- and postcatalyst sensors to determine if the precatalyst sensor reading is correct. The problem is that too often a driveability problem shows long before the on-board system flags a skewed sensor.

Go to www.motormagazine.com and check out my August 2001 column. The Mitsubishi Galant I wrote about had a cracked exhaust manifold bleeding air onto the  $O_2$ sensor. The sensor shifted lean and actual fuel delivery was pig rich. There were no  $O_2$  sensor codes and no actual problem with the sensor. Fuel trim codes showed +50% total fuel trim correction. Despite the black tailpipe and poor fuel economy, the tech working on the Galant was looking for a lean running/fuel delivery problem, based solely on the fuel trim data. Lambda or a more perceptive eye would have saved him here.

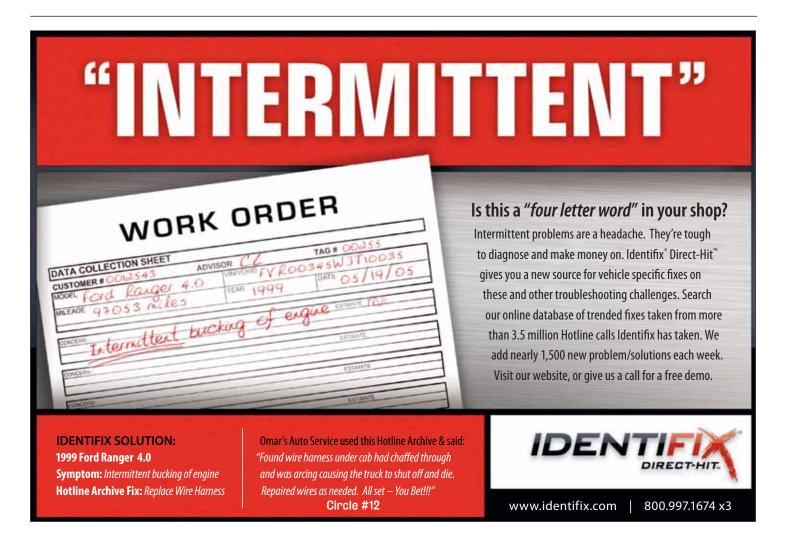
The photo on page 17 shows an  $O_2$  sensor contaminated by engine coolant and silicone. Its output skewed low, giving a false lean indication. Fuel trim shifted positive, indicated by additional injector ontime. Lambda immediately illuminated the problem, showing a richer-than-stoichiometric mixture.

Are you deep in a diagnostic conundrum, wondering if the vehicle you're working on has a fueling problem? Let Lambda be your guide. Lambda is easy to use and fast, and will identify many air/fuel ratio issues. Lambda may not be able to help with other problems; you'll need to dig deeper into the exhaust gases to solve them.

The chart on page 14 shows gas readings pre- and postcatalyst on a 2000 Honda Odyssey. I created an ignition misfire on one cylinder.

The baseline numbers in the bottom row are the tailpipe readings before the misfire. HCs are zero,  $CO_2$  is 15.84% (nice),  $O_2$  is .48% (around .5% is typical), CO is .02% (good) and Lambda is 1.023 (typical numbers for a good-running late-model engine).

Now look at the row labeled "Actual Measured Pre-Catalyst." HCs at 2482 is typical for a single-cylinder misfire,  $CO_2$  at 11.83% is way too low for a good-running engine,  $O_2$  at 3.94% is not good and typical



of a single-cylinder misfire in a 6-cylinder engine (more on that in a minute), CO at 1.16% is not good and Lambda is fairly happy at 1.052. Despite the misfire, the fuel delivery system/calculation is quite good. Lambda tells us that the misfire is not fuelrelated.

Okay, what did the  $O_2$  sensor reading in the "Actual Measured Pre-Catalyst" line tell us? Usually, a good-running engine will have about .5%  $O_2$  at the tailpipe. If the atmosphere has 21%  $O_2$  and a 6-cylinder is missing on one cylinder, then the single-cylinder  $O_2$  output should be 21% divided by 6, or 3.5%. Add the 3.5% to the normal .5% and a misfiring 6-cylinder engine should output about 4.0%  $O_2$ .



This oxygen sensor has been contaminated by engine coolant and silicone. Its output skewed low, giving a false lean indication to the PCM.

Now look at the row labeled "Actual Measured Post-Catalyst." HCs at 817 ppm is still not good but way better,  $CO_2$  at 15.37% is not bad,  $O_2$  at .44% is good, COat .44% is also not good but way better and Lambda at .98 indicates no problem with fuel delivery.

In this example, Lambda and fuel delivery were fine (within  $\pm 5\%$ ) under all conditions. The catalytic converter had very little effect on Lambda. It burned more of the unburned fuel, CO and O<sub>2</sub>, but the total carbon, hydrogen and oxygen exiting the engine remained the same.

Lambda data alone justifies the purchase price of a gas analyzer; further gas analysis gives more useful di-

agnostic information. Next month we'll discuss finding evap leaks using exhaust gas analyzer readings.

