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Gas Analysis

By the Numbers

The Planet 5G-10 is a tool that has valuable uses far beyond just "checking emissions". The content of a vehicle's exhaust is not a random occurrence, although at times it may seem so! You will soon see that there is an orderly relationship between the readings displayed by the 5G-10 and what is happening inside the engine. When you know what those relationships are and the relative values of the separate gases, you will be able to make a knowledgeable diagnosis of the engines fuel delivery system and ignition system. And best of all, it's not difficult!

First Things First

All of us know this, but we are going to say it anyway. Verify the basics first. If they aren't right, no amount of gas analysis will be effective. It should be obvious that the engine must be in good mechanical operating condition. Make sure the vehicle's air and fuel filters are good. Vacuum leaks are not your friend. Emission components must be connected and working.

The Core Principle (or) "The Big Word"

Engines are happiest when they are operated within an optimum air/fuel ratio range. Since we tend to name most things, it follows that this range has a name. Unfortunately, the person that assigned the name happened to be a chemist. For that reason, we are stuck with the name "stoichiometric range". It's a big word and hard to pronounce, but it essentially means "an air/fuel ratio of 14.7 to 1". The term we are using to measure by is pounds. Hence 14.7:1 means 14.7 pounds of air mixed with 1 pound of fuel.

Lambda

We just talked about air/fuel ratio under "The Big Word". Lambda is another and arguably simpler way to express air/fuel ratio. By definition, lambda is the actual air/fuel ratio divided by 14.7:1. Remember, 14.7:1 is the magic stoichiometric number. It sounds pretty simple, and it is. However, computing the actual air/fuel ratio requires a formula that gives chemists delusions of grandeur.

Fortunately, to use lambda, we don't have to do the math. As noted, lambda is the actual air/fuel ratio divided by 14.7:1. That means if we have an engine running in the proper stoichiometric range, we will have a figure of 1 (14.7 divided by 14.7). In real life, the values don't vary much above or below 1. The Planet 5G-10 carries the figure out to three decimal places so that small changes can be viewed. Numbers above 1 indicate a lean condition. Numbers below 1 indicate a rich condition. A lambda reading of 0.900 to 1.100 is considered ideal.

When this fuel delivery ratio is tightly controlled throughout the engine operating range, engine performance and economy is optimal. At the same time, undesirable exhaust emissions are kept to a minimum.

The Gases

We will take a brief look at the various gases. We will then see how they relate to each other.

HC (Hydrocarbon)

Gasoline is a hydrocarbon (HC). It follows that when we see an HC reading, we are seeing unburned fuel. If it had burned, we would not be seeing it! This unburned fuel is mixed in with the exhaust.

At first, it doesn't seem logical that if we have combustion, we could also have unburned fuel. Unfortunately, it's not a perfect world. It's only possible to get complete combustion in a laboratory environment. We'll never see it in a vehicle. In the combustion chamber, there is always some fuel (hydrocarbons) that stick to the combustion chamber surfaces that the flame front just can't reach. The flame front itself may also give out before it can burn the majority of the fuel. The most obvious example of HC riding along with the exhaust would be a misfiring spark plug. If the plug doesn't fire, an entire cylinder of air/fuel is dumped into the exhaust pipe where it mixes with the (hopefully) burned mixture from the other cylinders.

Anything that can cause a spark plug to misfire will result in high HC. High HC can be caused by mechanical problems (low compression, valve problems), ignition problems, or excessively rich or lean mixtures. The mixture can become so lean that it will no longer ignite. This phenomenon is called "lean misfire".

We measure HC in parts per million (ppm).

CO (Carbon Monoxide)

CO (which we measure in percentage) is produced when combustion is not complete. This is the stuff that kills you. It makes sense that we reduce it as much as possible.

High CO indicates a rich air/fuel ratio. If the air/fuel ratio is just slightly richer than the stoichiometric range (there's the Big Word again!), CO will increase rapidly.

CO2 (Carbon Dioxide)
As before, we measure CO2 in percentage. CO2 is the product of complete combustion. It would follow then, that as combustion efficiency increases, so would CO2. And in fact, it does. If the mixture falls below or rises above stoichiometric, CO2 will decrease. CO2 is not affected by the catalytic converter.

O2 (Oxygen)
O2 is measured in percentage. The O2 we are reading is the amount of O2 remaining after combustion. With a lean condition, we have incomplete combustion and there is O2 left over. So, with a lean condition, O2 rises. On the other hand, if the mixture is rich, there will be too much fuel in the cylinder for the amount of oxygen. The result is that all of the O2 in the cylinder will be used up. So far, then, a lean condition gives us high O2 and a rich condition gives us low O2.

You may have noticed a possible dilemma here. Assume we start with a lean mixture. We will see a high O2 reading. As we enrich the mixture, O2 will drop. If we continue to enrich the mixture, there will be a point where it crosses over from too lean and becomes too rich. From this point on, even if we keep enrichening the mixture, O2 will read zero. Remember, an overly rich mixture uses up all the available oxygen in the cylinder.

Not to worry! Remember CO? High CO indicates a rich mixture. So, if O2 is low and CO is high, we have a rich mixture. And the opposite is true. If O2 is high and CO is low, we have a lean mixture. Here's a little secret. O2 and CO should generally be about equal. Tell all your friends about us. Here is one more useful thing. CO2 is inversely proportional to O2. In other words, if one goes up, the other goes down. If you remember, CO2 is an indicator of combustion efficiency.

Here is one last note about O2. High O2 by itself can indicate excessive air getting into the exhaust sample. This can be caused by a hole in the vehicle exhaust system, air leaks at or in the analyzer, or the probe not being inserted far enough into the tailpipe.

NOx (Oxides of Nitrogen)
NOx, which we read in ppm, is a result of high combustion temperatures. Usually NOx will be under a few hundred ppm at idle and shouldn't stray too far above 1000 when driven under a steady road load. Anything that can cause high combustion temperatures can cause high NOx readings. Defective EGR valves, advanced ignition timing and carbon deposits can all cause high NOx. Modern catalytic converters do a good job of controlling NOx, but rely on precise air/fuel management to accomplish it. A lean condition can cause NOx to increase substantially.

The Numbers
Now that we know a little about the various gases, it's time to see what some typical readings mean. Feel free to use the following chart in your interpretation of the readings and your diagnosis, but remember that there are many variables to consider and that these values are not absolute.

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	IDLE		1500 RPM		2500 RPM		Condition/Possible Cause
	Conv.	Non-Conv.	Conv.	Non-Conv.	Conv.	Non-Conv.	
HC ppm **CO %** **CO2%** **O2 %**	0 - 150 0.1 - 1.5 10 - 12 0.5 - 2.0	75 - 250 0.5 - 3.0 10 - 12 0.5 - 2.0	0 - 135 0 - 1.1 - 0.5 - 2.0	50 - 200 0.5 - 2.0 - 0.5 - 2.0	0 - 75 0 - 0.8 11 - 13 0.5 - 1.25	25 - 150 0.1 - 1.5 11 - 13 0.5 - 2.0	NORMAL GAS READING - STABLE VALUES
HC ppm **CO %** **CO2%** **O2 %**	0 - 150 3.0 + 8 - 10 0 - 0.5	75 - 250 4.0 + 8 - 10 0 - 0.5	0 - 135 3.0 + - 0 - 0.5	50 - 200 3.5 + - 0 - 0.5	0 - 75 3.0 + 9 - 11 0 - 0.5	0 - 100 3.0 + 9 - 11 0 - 0.5	RICH MIXTURE Idle mixture too rich, choke, power valve, high float level air cleaner, fuel in oil, leaking injectors
HC ppm **CO %** **CO2%** **O2 %**	0 - 150 0 - 1.0 8 - 10 1.5 - 3.0	75 - 250 0 - 1.0 8 1.5 - 3.0	0 - 135 0 - 0.8 10 1.0 - 2.5	50 - 200 0 - 0.9 9 1.0 - 2.5	0 - 75 0 - 0.25 11 1.0 - 2.0	0 - 100 0 - 0.75 9 - 11 1.0 - 2.0	LEAN MIXTURE Low float level, idle mixture, cruise mixture, air leaks, injectors
HC ppm **CO %** **CO2%** **O2 %**	50 - 850 0 - 0.3 5 - 9 4 - 9	400 - 1200 0 - 0.75 5 - 9 4 - 9	50 - 850 0 - 0.3 - 4 - 9	400 - 1200 0 - 0.75 - 2 - 7	50 - 750 0 - 0.3 6 - 10 2 - 7	400 - 1200 0 - 0.75 6 - 10 2 - 7	LEAN MISFIRE Air leak, plugs or wires, stuck PCV, carb, injectors
HC ppm **CO %** **CO2%** **O2 %**	50 - 850 0.1 - 1.5 6 - 8 4 - 12	Over 1000 0.5 - 3.0 6 - 8 5 - 12	50 - 850 0 - 1.1 - 4 - 12	Over 1000 0.5 - 2.0 - 5 - 12	50 - 750 0 - 0.8 8 - 10 4 - 12	Over 1000 0.1 - 1.5 8 - 10 0.5 - 12	MISFIRE Timing advance, plugs, wires, EGR valve

Converter readings are taken with air injection system disabled