Technical Support Note

Title: Advantages of a 4 or 5 Exhaust Gas Analyzers over CO only or 2-Gas (CO/HC) Exhaust Gas Analyzers.
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Created by: R. Schrader
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Overview:

CO only analyzers and 2-Gas (CO&HC) gas analyzers cannot measure oxygen or CO2 in the exhaust gas sample stream. These two gases are important to measure, as they verify the quality of the exhaust gas sample – which is particularly important for short exhaust systems with pulsating exhaust under low and medium loads.

4 and 5 gas EGAs measure O2 (ambient air) and CO2 (a normal product of combustion) – so they can be used to determine the amount air dilution of the exhaust gas sample being measured by the analyzer. These two gas channels enable the tuner to protect himself against the most common cause of exhaust gas measurement error and inconsistency – ambient air dilution of exhaust gas.

Exhaust Gases – Principle of Combustion:

The purpose of the engine is to use the oxygen in ambient air (about 21%) to oxidize the hydrogen and carbon atoms in the fuel, producing heat as a result, and then to use this heat to create mechanical power. To do this, the engine intakes ambient air, mixes it with the correct ratio of fuel, intakes it into the cylinder, ignites it, and uses the heated expanding gas to create power. The air/fuel mix is balanced by the carburetor or fuel injection system so that there should be just enough oxygen in the incoming air to burn all of the fuel that is being delivered. A perfectly balanced air/fuel mixture is called Stoichiometric (Lambda = 1.000) – and spark-ignited engines seek to maintain air fuel mixtures close to stoichiometric throughout the operating range of rpm and power settings. This principle can be used to detect air dilution of the exhaust as well as to make sure the engine is operation correctly.

Delivering a good exhaust gas sample to the analyzer– the primary problem:

Often it is difficult to get a good exhaust gas sample into the analyzer for analysis – due to exhaust gas pulsations, insufficient probe insertion, low exhaust gas volume, or an extraneous air leak. When this happens, the exhaust gas is mixed with outside air and the resulting gas mix is delivered to the analyzer – reducing the apparent levels of combustion exhaust gases – CO, HC, and CO2.

The relative levels of O2 and CO2 in the measured gas can be used to qualify the exhaust gas integrity by showing the relative level of exhaust gas and ambient air being measured. Because fuel is balanced to the incoming air, the combustion process will use up almost all the oxygen being ingested by the engine, and pure exhaust gas contains very little residual O2– usually less than 0.5% for Propane fueled engines. In addition, the complete oxidation of the carbon in the fuel produces high levels of CO2 (carbon dioxide) – often referred to as a 'natural' product of combustion. This operating principle makes Oxygen and Carbon Dioxide good indicators of the purity of exhaust being delivered to the analyzer. Generally, simply looking at the level of O2 (0.50% in pure exhaust vs 20.9% in pure air) tells you if you are experiencing air dilution. This is then confirmed by looking at the level of CO2 – which is generally in the 12% to 15% range in pure exhaust.

If you see low O2 and high CO2 – you can be assured that you are looking at real exhaust gasses – and the CO and HC readings can be believed. If you see high oxygen and lower than expected CO2, further work has to be done to correct the problem before relying on the accuracy of the CO and HC values, or AFR/Lambda.

Single CO and 2-Gas Analyzers – Miss Air Dilution:

These analyzers are responsive only to CO or CO and HC. That is, they measure only the fuel-related products of incomplete combustion – the 'bad' gases in the exhaust gas. Unfortunately, this means they do not have the capability to see the main product of combustion (CO2) or how much air (O2) is in the measured gas stream. As a result, these gas analyzers may be reporting air diluted CO or CO and HC – and there is no way to tell how much the readings are air-diluted. This is why a minimum of 4-gas EGAs are required for legally implemented exhaust gas emission control programs – as they are then used to verify that the measured exhaust gas is not air-diluted.

4 and 5-Gas Analyzers – Detect Air Dilution:

Ambient air has about 20.9% O2 and 0.05% CO2 in it, while exhaust gas has 1.0% or less O2 and 12.0% (LPG) or 15.0% (Gasoline) CO2 in it. This extreme difference in the relative amounts of O2 and CO2 in exhaust gas vs ambient air can be used to tell how much of the gas being delivered to the analyzer is exhaust gas and how much is ambient air.

Bridge Analyzers, Inc. (510) 337-1605 office
PO Box 39325 (216) 274-9262 fax
Solon, Ohio 44139 USA support@bridgeanalyzers.com

Correcting Sources of Air Dilution – Look at O2 and then CO+CO2:

When the probe is first inserted in the exhaust pipe (engine running), you should expect to see the indicated O_2 reading go down from 20.9% to 1.0% or less within about 10 seconds. If the O_2 level does not go down below 1.0% or 2.0% – but stabilizes at a higher than expected reading, this is an indication that air dilution exists.

The O_2 readings can be reduced by changing the probe insertion length, position, or partially blocking the exhaust - or by increasing the throttle setting to increase the gas flow.

As stated earlier, undiluted exhaust has about 0.5% O_2 in it, so you should strive for that target – although less than 2.0% O_2 is generally acceptable.

Once you have reduced the O_2 readings to less than 2.0%, you should also confirm that the sum of the CO and CO_2 readings is close to 15% for Gasoline and 12% for LPG. If they are, you can be confident that you are measuring exhaust gas, and the gas readings you are getting are accurate.

Once you have qualified the exhaust gas, using AFR, Lambda, and Combustion Efficiency:

Once you have qualified that you are indeed measuring exhaust gas, you can use the advanced features of the 4 or 5 gas analyzer to perform advanced engine and post-treatment diagnostics using AFR, Lambda, and Combustion Efficiency:

1. AFR is automatically calculated in real time from engine exhaust gasses – and is displayed by the analyzer diagnostics screen in real time 4 times a second. The value displayed is corrected by fuel selection. There is no need to convert '14.7' (stoichiometric for gasoline) into '15.3' (stoichiometric for LPG). The analyzer does this for you.
2. Lambda is essentially identical to AFR, but it is not fuel specific. A lambda value of 1.000 is stoichiometric for all fuels. Again, there is no need to convert values – the analyzer calculates lambda correctly automatically for the fuel selected. For closed-loop systems, this is an even more important parameter, as the 'oxygen sensor' in a closed loop system is designed to keep Lambda at a very narrow range (0.980 to 1.020) for proper operation of the catalytic converter. The lambda feature in the analyzer allows you to quickly verify fuel control in either open loop or closed loop systems.
3. Combustion Efficiency is a parameter that indicates how completely the fuel is being burned – where 100.00 is complete combustion. Internal combustion engines will reach 95.0% to 97.0% (depending on the fuel) if they are

correctly tuned and maintained – so CE allows rapid determination of the quality of combustion. Catalytic Converters increase the combustion efficiency to about 99.5% - making CE a convenient and rapid way to measure the catalytic converter efficiency.

These features make the 4 or 5 gas analyzer a much more accurate and useful tool for the maintenance technician.

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