The Importance of Exhaust Gas Diagnostics

Introduction

The goal of this presentation is to demonstrate the importance of the 5-gas analyzer in diagnostics.

We do not intend to change your opinion on emissions standards, but rather to show accepted diagnostic procedures to determine why a vehicle may fail an emissions test, why certain trouble codes are set, and why there is a drivability issue.

The gas analyzer can be a frontline diagnostic tool when used to make the first high level assessment of whether a vehicle is in fuel control and if that agrees with the Scan Tool PIDs.

But it can also be used later in a diagnosis to see if what the PCM 'thinks' is happening is really happening. Any mismatch can direct you to check feedback sensors (O2/AFS), air injection systems, and exhaust components (for leaks).

In summary, a 5-gas analyzer is an awesome addition to any collection of diagnostic tools. We do know that the PCM is acting on what it THINKS it knows, but a gas analyzer can be used to see if the PCM is being lied to!

A simple comparison of the PCM fuel control PIDs to the actual tailpipe readings can solve a lot of faults. A proper understanding of gas relationships will narrow down many faults into a testable list and made easier with the ANSED Exhaust Gas Diagnostics Software.

A gas analyzer is great for finding the effects of fuel leaks, including leaky injectors, head gasket leaks, exhaust leaks, and misfiring (fuel or ignition/mechanical), and underlying issue for premature catalytic converter failure.

Goals:

- Demonstrate the importance of the 5 Gas Analyzer in Drivability Diagnostics.
- Explain the 5 Gases and their origin in such a way as to make sense of tailpipe readings.
- Explain what, if any, effect the Seasons have on combustion.
- Explain the effect of different fuel blends
- Define both ***Lambda*** and ***Stoichiometric*** in useable terms.

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The 5 Gases:

- Hydrocarbons (HC)
- Carbon Monoxide (CO)
- Carbon Dioxide (CO2)
- Oxygen (O2)
- Oxides of Nitrogen (NOX)

Hydrocarbons (HC)

- Gasoline (Raw Fuel) is a mixture of different Hydrocarbon (HC) chains. These chains should be almost completely broken apart during complete combustion.

- In the real world, there are always variations in combustion, which allows some HC molecules to stay together during combustion.

- "Perfect Combustion" is very illusive, and it is not always 14.7:1 or Lambda. Cold starts and heavy acceleration are two examples of when these mixtures would not result in best performance. Even during very steady conditions, Short Term Fuel Trim varies in about an 8% range, so that's like Lambda 0.096 to 1.004. STFT switches fast enough that in our 8% range example the tailpipe Lambda would be an average of 1.000.

- Hydrocarbons coming out of the tailpipe is not a byproduct of combustion. They went in as a Hydrocarbon and that is how they came out. They are a result of lack of complete combustion.

- There will always be some HC in the exhaust, but on a modern vehicle with a functional exhaust with Lambda between 0.98-1.020, it should be well under 40 ppm. On a good running engine, HC will be about double on a cold start (though there may be an initial burst into the 100's). It's not uncommon to have single digit HC if the mixture is 1-2% lean (Lambda 1.010 – 1.020) because there's more than enough O2 in the exhaust to oxidize the H and C into H2O and CO2.

- During a misfire, the unburned HC and O2 get into the exhaust, so high HC and O2 are great indicators of a misfire. Partial misfiring can lead to tailpipe reading in the 100's (HC ppm), though a complete single cylinder misfire with a cold converter can yield 2500-3500 HC ppm. A hot converter can take this high HC content and oxidize much of it, so the numbers could be lower.

Carbon Monoxide (CO)

- Carbon Monoxide is a colorless, odorless, and tasteless gas that is toxic to humans when concentrations are greater than 35 ppm (parts per million).

- It is produced during combustion when there is not enough oxygen present to produce CO2.
- Understanding what Carbon Monoxide is and how it is created is critical in understanding what is going on in the combustion chamber.

- CO is simply a compound on its way to becoming CO2, so it occurs in large quantities when the mixture is just a bit too rich and all the O2 is used up before all the fuel is oxidized.

- High CO levels can be present in the exhaust due to poor combustion even when the mixture delivered to the cylinder was “perfect”.

- There are numerous possible causes of poor combustion. Weak spark, excessive EGR, etc. However, it’s still most common to have high CO when the mixture is too rich as explained on the previous slide.

- Emissions test limits vary, usually between 0.1% and 0.4% on newer vehicles, though 0.1% and 0.0% are common results. What little gets out of the engine is quickly oxidized into CO2 in the converter. During a cold start, brief periods over 1% are common.

Carbon Dioxide (CO2)

- CO2 is also generated during combustion of carbon-based fuels as carbon is oxidized.

- The better an engine runs, the more oxidation of carbon occurs, so CO2 will be higher. Therefore, CO2 is an ‘efficiency indicator’.

- A good running engine can produce over 14% CO2, but catalyst function can push this up to 15-16%.

- CO2 emissions are a concern relating to the global warming discussion, but, the more CO2 an engine produces, the better it’s running.

Oxygen (O2)

- Oxygen supports combustion (oxidation).
- Oxygen at the tailpipe is a great "Lean" indicator.
- The accepted value of O2 before the converter is approximately 0.8% to 1.1%.
- The converter increases CO2 and H2O by oxidizing HC and CO, so tailpipe O2 is less than 0.4% if the converter is working.
- False high oxygen levels due to leaking exhaust systems have been the reason for many costly repairs that did not fix the vehicle! Oxygen is not a by-product of combustion. It went in as oxygen and came out as oxygen. It was not created in the combustion process. Any O2 present at the tailpipe that did not get through the engine simply came in through an exhaust leak.

Oxides of Nitrogen (NOx)

- NOx formed during combustion is composed mostly of NO (90-95%), with a lesser amount (5-10%) of NO2.
- The nitric oxide (NO) slowly oxidizes to nitrogen oxide in the atmosphere.
- The main source of NOx emissions is the combustion of fuels in motor vehicles. NOx forms over 2,500ºF, which occurs when:
    - The engine is overheating
    - The mixture is too lean
    - Timing is too advanced
    - Compression is too high EGR is not working
- In a perfect world we want "0" NOx coming out of the tailpipe; however, this is not possible under all conditions.
- NOx emissions are very low (often near 0 or single digits) at idle but can rise into the 100's (ppm) under load.

5 Gas Recap

- **HC:** Misfire Indicator
- **CO:** Rich Indicator
- **CO2:** Efficiency Indicator
- **O2:** Lean Indicator
- **NOx:** Lean, Timing, Temperature Indicator

What is Stoichiometric AFR? And Lambda?

- For our purposes, it is simply a value of 14.7:1 air/fuel ratio (AFR) for gasoline. And Lambda is 1.000.

- Ethanol added to gasoline will affect this ratio based on Ethanol/fuel concentrations.

- Stoichiometric AFR is different depending on the different fuels used. Propane, CNG and Diesel all have a different Stoichiometric value than gasoline. But remember Lambda is a value of 1.000 for all of these.

- Stoichiometric Ration by Fuel:

Fuel:	AFR	Lambda
Natural Gas	17.2:1	1.000
Gasoline	14.7:1	1.000
Propane	15.5:1	1.000
Ethanol	9:1	1.000
Methanol	6.4:1	1.000
Hydrogen	34:1	1.000
Diesel	14.6:1	1.000

- Lambda is the ratio of the amount of actual oxygen present in the combustion chamber in comparison to the amount that should be present to obtain 'perfect' combustion.

- A commonly accepted value for a normal running engine (to allow for proper converter function), is 0.980-1.020.

- This only explains Lambda as it relates to gasoline. It is important that you can have a tailpipe emissions failure and still have a Lambda value of near 1.00 or even 1.00. The fact that the combustion chamber or catalyst did not do their job does not mean that the sensors and computer did not do theirs. The right amount of air and fuel could be correct and tailpipe emissions be a failure for many reasons. Misfire, lack of ignition, partial ignition, incomplete combustion etc.

- The most important thing to remember about Lambda is that it is not affected by either combustion or the catalytic converter.

- One of the rules of nature is "Nothing can be either created or destroyed, it can only change forms"!

Seasonal Fuel Blends

- Each area of the country has seasonal blends that are adjusted for weather conditions.

- As the weather becomes warmer or colder the fuel blend 'Reid Vapor Pressure' (RVP) is adjusted to change the volatility.

- In cold weather the fuel needs to be more volatile to aid in cold starts.

- In warmer weather the fuel needs to be less volatile to decrease the chance of pre-ignition and detonation.

- For diagnostic purposes these changes will have little or no effect on our gas readings even (Lambda still = 1.000), though they can affect drivability.

- If volatility is a concern, use an RVP Tester.

Wrap it up!

A 5-gas analyzer is an awesome addition to any collection of diagnostic tools. It was an indispensable tool as a 2-gas tool decades ago, but with the advent of computer controls we seem to have forgotten why we loved them so much.

- The PCM is acting on what it THINKS it knows, but a gas analyzer can be used to see if the PCM is being lied to! A simple comparison of the PCM fuel control PIDs to the actual tailpipe readings can solve a lot of faults.

- A proper understanding of gas relationships will narrow down many faults into a testable list.

- A gas analyzer is great for finding the effects of:
    - Fuel leaks, including leaky injectors
    - Head gasket leaks
    - Exhaust leaks
    - Misfiring (fuel or ignition/mechanical)

ANSED introduces the KANE AUTOplus Hand-held 5-Gas Analyzer with the proprietary ANSED Exhaust Gas Diagnostics Software.

KANE AUTOplus Hand-held 5-Gas Analyzer:

- Tests HC, O2, CO, CO2, NOx, and Lambda.
- All readings LIVE, not calculated.
- Self-calibrating, no cal-gas required.
- Dyno not required for NOx testing.

ANSED Exhaust Gas Diagnostics Software:

- Effective interpretation of exhaust gas readings.
- Offers problem identification and potential solutions
- Diagnose no-code drivability & performance issues.
- Ensure catalytic converter related repairs are complete.
- Print test results reports: pre- and post-repair.
- Verify vehicle running at max efficiency after repairs and prevent comebacks.

https://www.anseddiagnostics.com/products/autoplus5-automotive-exhaust-gas-analyzer

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