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Exhaust Gas Analyzer Accuracy – Calibration, Warm-up, Zero Drift and Span Errors.

About gas analyzer accuracy:

Gas analyzer accuracy is comprised of two components – absolute error and relative error – commonly referred to as zero drift and span error. Zero drift is generally caused by thermal factors as the analyzer is warming up – and span error is generally caused by gas dilution (air leaks), pressure rarefaction (altitude) or uncompensated temperature factors. In general, NDIR analyzers show no long-term aging effects that require periodic correction.

However, the gas analyzer is only as the care taken to make sure that it is operated properly – and for the maximum accuracy should be initially gas-calibrated in the environment of use, and then checked periodically – about once every 90 days is generally sufficient.

In essence, the accuracy of the analyzer may only be determined by checking the complete system using known-good calibration gas. Comparison to other analyzers (even ‘BAR-Qualified’ systems) may not yield acceptable results – unless both analyzers are checked for accuracy before the comparison is made. The only way to determine the accuracy of a gas analyzer is by comparing the gas analyzer readings to the values of a gas of known (certified) accuracy. If a gas analyzer is compared to another machine and they do not agree, the question of the accuracy of each analyzer comes into question. Attempting to determine the accuracy of a gas analyzer by comparing gas analyzers is a fruitless task – unless the same known gas is measured by both analyzers, and the accuracy of each compared to the standard. Fortunately, there is a readily available and cost-effective solution.

Using BAR-certified calibration gas cylinders:

There are working standard gas blends available which is generally within 2% relative accuracy, manufactured by BAR-certified gas blenders. These cylinders are universal in design, comprising a disposable (non-refillable steel cylinder containing 12.74 Liters of gas at 300 psi pressure, and having a standard valve and SAE 45 degree male flare output interface. This gas should be delivered to the gas analyzer probe tip in a controlled atmosphere and pressure, and at a flow rate somewhat greater than the sampling rate of the analyzer to prevent air dilution. This is usually accomplished by means of a restricting orifice, regulator and adapter.

This delivery system should fit-up to the standard SAE 45 degree male fitting on the valve of the calibration gas cylinder to form a gas-tight seal. Once the gas cylinder valve is opened, the orifice and regulator should deliver calibration gas at a fixed flow at atmospheric pressure, which the gas analyzer samples and measures in the same manner as vehicle exhaust.

Then, the gas analyzer readings can be compared to the ‘TAG’ values of the calibration gas cylinder, and their accuracy determined.

Using Oxygen to assess air dilution:

The calibration gases do not generally contain oxygen – which is found in ambient air at 20.9%. As the oxygen reading in calibration gas should be zero – this provides a convenient way to confirm that the gas being measured by the analyzer is supplied to it at a greater rate than the analyzer flow rate, and that there are no air leaks in the sampling system.

For example, a 10% relative dilution of the calibration gas will show up not only as 10% low relative readings for the CO, HC, and CO₂ (and NO_x) channel, but can be assessed by the unexpected appearance of 2.1% additional oxygen. When the expected reading is zero, and the analyzer shows 2.1%, this is a much easier error to see than the relative dilution of the other gases.

In essence, the oxygen reading should be no greater than 0.6% when measuring calibration gas containing no oxygen to assure the operator that ambient air dilution is less than 3% relative.

Note: It may take up to 90 seconds for the oxygen reading to stabilize at its final value due to the slow time response of the oxygen sensor. Be patient when using this method.

The HC problem – Measurement of Propane as ‘Equivalent Hexane’:

The hydrocarbon gas in the calibration cylinder is propane, and the gas analyzer generally measures hexane. This is problematical, as hexane is a molecule that is about twice as large as propane. This means that the typical HC reading on the gas analyzer (hexane) should be about ½ the propane value on the calibration cylinder tag. That is, if the tag states that the cylinder contains 1200 ppm propane, then an analyzer measuring HC as hexane will report HC at about 600 ppm.

The propane in the calibration gas cylinder may be converted to equivalent hexane by multiplying it by the Propane Equivalence Factor (PEF) for the analyzer, or by setting the analyzer in propane HC measurement mode, whereby a measurement curve for propane is initiated.

NOTE:

Bridge series gas analyzers automatically enter the propane HC mode when the calibration mode is actuated – so this problem is automatically handled by Bridge analyzers. (Other manufacturers may have different methods to take care of this issue. Consult the users documentation for the analyzer in question to determine the appropriate method to take care of propane to hexane conversion.)

The other gases (CO, CO₂, O₂, NO_x) do not have this problem, and so the readings may be used directly.

Gas Use – The Number of Gas Calibrations provided by one BAR-certified Cylinder:

The number of gas calibrations contained in one BAR cylinder is a function of the gas flow rate and the flow time required for calibration confidence. As the cylinder contains 12.74 Liters of gas at 300 psi, it will provide about 500 minutes of gas flow at 500 ml/min (adequate for Bridge analyzers, but others may require more gas flow – consult users documentation to determine the appropriate calibration gas flow rate for other than Bridge analyzers.)

If calibration gas is flowed for 5 minutes during a typical calibration procedure (very conservative value), then there is enough gas in one cylinder for 100 calibrations – or 25 years worth at 4 calibrations per year! Clearly, one cylinder can last a long time.

Bridge P/N and costs for calibration gas components:

Model 9003 / 9004	P/N 000688	BAR-90 (CO, HC, CO ₂ , BAL N ₂ Blend)	Cost \$95.00
Model 9005	P/N 000689	BAR-97 (CO, HC, CO ₂ , NO, BAL N ₂ Blend)	Cost \$175.00
P/N 000690	Regulator and adapter for cylinders above		Cost \$110.00

(See Appendix A below for enumeration of the gasses contained in the blends specified above.)

Zero Drift – Minimizing the Absolute Error:

The Absolute Error component is known as ‘Zero Drift’ – and is the main component of error for values close to zero, or during the first 15 minutes of analyzer operation. It is a small + or – absolute error that is added or subtracted to the gas value.

Remember that regardless of the situation, the best way to ensure that the analyzer is measuring as accurately as it can is to Zero the analyzer (**you do not have to remove the probe from the exhaust - just push the 'Zero' button**) before you take a critical reading. After about 15 minutes of operation, this is less critical than at first - but it is just good practice to Zero the analyzer before you measure gas. You will find that taking the 30 seconds to do this will improve the accuracy of any analyzer - which is why we went to the trouble of making it convenient to do so.

The analyzer ‘Zeros’ on ambient air by drawing room air into the ‘Zero Port’ on the left side of the analyzer. While this gas may contain small amounts of CO, CO₂, and HC, the levels of the gases are much smaller than they are in exhaust gas, and so the residual errors introduced by this method are generally trivial. Still, it is wise to keep the analyzer away from exhaust gas (or the users breath – which contains up to 5% CO₂) during the zero process.

When the analyzer is purged of test gas and a new zero gas reference level is obtained, the gas analyzer switches back to sampling gas from the probe – a process which takes about 25 seconds.

Warm-up Compensation:

The analyzer monitors internal temperature gradients, and performs real-time zero level temperature correction as it warms-up – a process that is reset to the actual level when the analyzer is Zeroed. This means that Zero drift is removed by the Zero process – and the analyzer may gradually accumulate Zero Drift error until it is re-Zeroed. For this reason, when measuring gas values close to zero, it is wise to Zero the analyzer before a critical measurement is made, and more Zero’s may be required to maintain analyzer accuracy during the first 20 minutes of use, where the greatest warm-up thermal effects occur. After 20 minutes, the analyzer is essentially thermally stable and this component of zero drift reduces substantially.

Span Error:

This is a relative error, meaning it is a percent of the gas being measured. For example, a +5% relative error will cause 1.00% CO to read 1.05%, and 3.00% CO to read 3.15%. Clearly, this error component is small and converges to zero when measuring gas levels close to zero. This is the dominant error component when measuring gas values above 50% of full scale and can only be corrected by using calibration gas.

It is wise to gas-calibrate the analyzer initially at the altitude and thermal environment of use – and to introduce the calibration gas into the same probe and hose that will be used for tailpipe gas measurement. (Altitude rarefaction is about 3.5% relative every 1,000 ft above sea level – so altitudes below 2,000 feet or so generally show such small relative errors that they are imperceptible to the user.)

Then, the gas analyzer reading is corrected to match the ‘tag values’ of the calibration gas itself – thus correcting any residual gas measurement values that may exist.

It is noteworthy to remind the reader that the gas analyzer should be gas calibrated using test gas that is between 50% and 75% of full scale – as this provides the best correction for relative errors, and minimizes any residual effects caused by zero errors during the calibration process. Even though the actual gas measured in the application may be less than 10% of full scale, the gas analyzer should be span calibrated using substantial gas.

It should also be noted that gas measurement errors due to air leaks, etc will be hidden by recalibration – and so this is a potentially dangerous process. An analyzer that shows ‘drifty’ operation when periodically checked with calibration gas (will not ‘hold calibration’) probably has some other problem that should be corrected first before another gas calibration is performed.

In addition, gas calibration should really not be performed until an analyzer is fully thermally stable, which generally is about 30 minutes after power-up.

Once the gas analyzer reads the values on the calibration gas cylinder, it is considered gas calibrated –although the user should remember that most calibration gas is certified accurate to about 2% of value – so this residual span error is not correctable. For practical purposes, however, this level of residual error is trivial.

Appendix A

Gas Contents in various BAR-Certified Calibration Gas Blends:

Nominal (target) gas values:

Gas	Bar-90 Mid	Bar 97 High	Bar 90 Low	Bar 97 Low	Units of Measure
(Propane) HC	1200	3200	300	200	ppm
CO	4.00	8.00	1.00	0.50	Percent
CO2	12.00	12.00	6.00	6.00	Percent
NO	0	3000	0	300	ppm
O2	0	0	0	0	Percent

Note: Gas blending of BAR Certified gas mixtures is required to be accurate within +/- 2% relative to gas value.

The actual (within blending accuracy) value of each gas contained in each cylinder is given on a ‘Tag’ affixed to each cylinder. The ‘Tag’ value (not the values above) is what should be used for gas analyzer calibration.

Bridge does NOT recommend calibrating the analyzer on ‘Low’ gas mixes (in blue above) due to their proximity to the Zero point. The ‘Low’ gas readings are predominantly effected by the accuracy of the Zero, not the gas calibration of the instrument.