COMBUSTION ANALYZERS

BY BILL SPOHN

CLEVER DESIGNS AND SMART FEATURES

Drawing on my 30-year background in the industry working for such fine companies as Bacharach Inc. (as Engineering Manager) and Testo Inc. (as North American Product Manager) and working amidst combustion gurus like Jim Davis, Jim Bergmann, Rudy Leatherman and Bob Dwyer, I propose to give you a succinct update on where things stand in the market for combustion analyzers.

As a combustion analyzer engineer and patent holder, I will reveal many things only insiders know and understand. Let's start with some background.

While wet chemistry testing kits are still made (the modified Orsat method or Fyrite wet test kits by Bacharach Inc. were launched in 1939), the market has converted to using digital analyzers for combustion testing. The prices have come down, the features have come up and the quality continues to get better and better.

And with good reason: digital analyzers provide real-time analysis, or moving pictures if you will, of the dynamics of the combustion process. Additionally, digital data unleashes many options for your combustion analyzer to serve you: real-time calculations, printed results, on screen graphics, shared data via email and now data streaming into smart device apps and in any format they can produce.

If you are looking for good, free resources on the broader topics of why and how to test, along proper processes and target values for common combustion systems, please consider these resources: *TruTech Tools Combustion Applications Guide* (https://www.trutechtools.com/Downloads) and the *Accutools Combustion Quick Start Guide* (https://accutools.com/combustion-quick-start-guide).

SIMILAR SENSORS

Most combustion analyzers have two similar sensors built inside and one at the tip of the flue gas probe. The inside sensors you will find include oxygen (O_2), temperature and carbon monoxide, with the temperature sensor at the tip of the probe. There are, however, a few analyzers that have only O_2 and temperature sensors.

There is at least one brand that uses a Non-Dispersive Infrared (NDIR) Carbon Dioxide (CO_2) sensor in place of an O_2 sensor. That is because combustion efficiency is directly tied to stack CO_2 and temperature—the more CO_2 produced with a lower stack temperature means more complete combustion and heat transfer, hence higher efficiency. How do you get CO_2 measurement from the majority of the analyzers on the market that do not have a CO_2 sensor? How do they go from O_2 reading to CO_2 reading?

Combustion analyzers typically are packaged in rigid cases with plenty of room for accessories.

It's simple. If you know the type of fuel you are burning, and you "tell it" to the analyzer, it will calculate the amount of CO_2 in the stack using an industry recognized table of values based on decades old chemistry. That and excess air values are pretty much the only reason why you set a fuel code when you are doing combustion analysis—all the other basic readings O_2, CO, temperature and draft are all direct readings off of their respective sensors. All analyzers have the basic fuel codes in them (e.g. natural gas, propane, wood, etc.); some models have a more extensive list and some manufacturers will program custom fuel codes if the user provides a chemical analysis of the fuel.

The temperature reading is collected from a thermocouple (usually K Type) that is sitting at the tip of the flue gas probe to sample the combustion gases that are being drawn into the probe.

The CO sensor, buried inside the analyzer, detects CO concentrations in the flue gas sample. And of course, the O_2 sensor (inside the unit) detects oxygen concentrations in the flue gas.

It should be noted that all of these concentration measurements are made on a volume concentration basis. For example, out of a million "parts" of sample gas, there are 100 "parts" of CO, so the CO concentration is 100 parts per million (PPM).

A pressure sensor is very common amongst most combustion analyzers. The range and resolution of most of these sensors are tuned for use in sensing fuel pressure, stack draft, and static pressure drops across system components or filters. Some models have finer resolution sensors that may be used with pitot tubes to measure air velocity and zonal pressures, such as combustion air zone depressurization.

The Building Performance Institute (BPI) has developed a solid knowledge base on this topic, some of which you will find in their standards (some of which are ANSI standards, all of which are free to download): https://www.bpi.org/standards/current-standards.

GOOD READINGS

Let's cover some factors involved to achieving the best quality of flue gas measurement.

One factor is sampling system integrity. Since the flue gas sample moves from the probe tip, through a hose, a water trap and usually through some filters, under the negative pressure of a pump, it is absolutely critical that all components in the sampling chain are sealed so no "room air" gets inside the sample stream and dilutes the flue gas sample, messing up your measurement of O_2 (by increasing the value) and CO (by decreasing value). Some models actually include a built-in test for sampling system integrity.

It's also important to use and maintain the particulate filter in the sampling system, especially if you are testing oil or wood fuel based systems.

Something else to note, some of the new models with shorter hoses improve the responsiveness of the flue gas readings, as there is a shorter transit in the hose between and actual change in the flue gas at the probe tip and the time it is measured back at the sensors inside the unit.

A lesser known factor is that all common CO sensors actually react to other gases. One gas in particular is nitric oxide (NO) gas. There are actually several "species" of oxides of nitrogen (NO, NO_2, N_2O5, etc.) and the one in highest concentration in flue gas is typically NO. So, in general we talk about NOX interference when we mean NO interference. The impact is that 100 PPM of NO looks like about 50 ppm of CO to a CO sensor (and all typical CO sensors share the same chemistry, hence the same reaction to NO).

Sensors and batteries can often be accessed from the same compartment.

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Something to keep in mind, NO production is independent of CO production. If you have one gas at certain levels there is no guarantee you will have similar levels of the other.

NOX FILTERS MAKE A DIFFERENCE

I have seen NO readings (using more advanced analyzers with these sensors) ranging from 40 to 200 PPM NO. That means a typical CO sensor sample 80 PPM CO could read 100-130 PPM CO if it does not have a NOX filter. Combustion analyzer manufacturers have been adding either integral (in sensor) or external NOX filters to their products for years. However, the practice is not uniform. One very popular model does not have a NOX filter built in.

I have been involved in many CO debates that end in a showdown: "My analyzer is reading LOW on CO, so it's broken/wrong." What it boils down to is the reference product is using an unfiltered CO sensor and reading "fake CO", and the "compared to" product has a NOX filter and is actually reading the correct concentration of CO. The filtered product reads low, sometimes close to zero and users find it hard to believe, so they cast a shadow of doubt on it.

It's also important to recognize that in addition to the flue gas concentrations and temperature varying over time, both factors can vary in space: that is the flue gas most often moves in waves and currents in the stack/vent system. The best way to handle this is to make your testing as repeatable as possible. Try to "search" with the probe until you find a point of maximum temperature across the stack. Use that location to take your readings. Some call it the "core flow."

One final factor to consider is that sensors, just like people, can get stressed. And in the case of a CO sensor, it can get drunk! The CO sensor is actually a little chemical bench. The materials inside react with CO in the sample to produce a minuscule current which is read by the electronics in the analyzer. In the most basic sense, the CO sensor "drinks" CO and processes out CO_2—yep, carbon dioxide.

If the CO sensor drinks too much CO for its ability to process, the chemistry gets overwhelmed (drunk) and immediately requires some fresh air to recover. If the CO over range is not severe, and fresh air purge is started quickly, the sensor will often recover. In some cases, recovery is not possible and the sensor must be replaced.

Some manufacturers have CO over-range warnings built in to their analyzers, where it either sends you a message or actually shuts off the pump to protect the sensor. If the pump shuts off, it is still very important to pull the probe from the stack and re-set the pump to begin sampling fresh air, as when the pump stopped there is still some CO-rich gas sitting on top of the sensor. You need to take that "last glass of spirits" out of your sensor's "hands"!

Other, more advanced analyzers actually have a second pump built in. Usually it is used to dilute the sample with fresh air to allow extended operating range (of about 10x) on sensors. It can have secondary purpose (with some internal valving) to run fresh air over a sensor that has reached its point of over-range. Experienced techs will know, CO can be humming along at a tolerable level and in rapid fashion rise to

Note the magnetic disks above the battery-sensor bay. They allow the analyzer to mount to the appliance, yielding hands-free operation.

extreme levels. Bottom line: watch for over-ranging your CO sensor and know how your analyzer handles the situation.

PERFORMANCE STANDARDS

The European Union has long had a standard in place for the performance rating of combustion analyzers (BS EN 50379). Over 10 years ago, I helped from a committee of U.S. manufacturers that eventually launched the ANSI/AHRI 1260 standard in 2017. You can learn a lot by downloading a free PDF of the standard at this link: http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/AHRI/AHRI_Standard_1260_2017_IP.pdf.

As of this writing, I know of only two manufacturers, Accutools (BluFlame) and Bacharach that state alignment with this standard. This is a very important step forward to legitimize and, in some cases, mandate to the public for the use of combustion analyzers when doing appliance installation and service. The standard will even make uniform the calculation of combustion efficiency, which has caused unnecessary complications and debate in the use of combustion analyzers in the past.

ADVANCED MODELS

Digital combustion analyzers can be purchased for anywhere from $500 to more than $10,000. The most expensive ones are referred to as emissions analyzers and usually contain advanced sensors for Nitric Oxide (NO), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), CO_2 (via precise Non-Dispersive Infrared Sensors), Hydrogen (H_2), Hydrogen Sulfide (H_2S), and unburned hydrocarbons (HC).

Advanced product designs include special sample treatment and heated hoses made of non-reactive materials to keep the sample hot and pure before you remove the water vapor from the sample (with electronic chillers and peristaltic pumps), as water can absorb the gases you are trying to measure. Additionally, some have heated sensors as the sensor chemistry is more stable and accurate at controlled temperatures.

A new entrant to the emissions class analyzers is the extremely modular and extremely affordable PCA 400 by Bacharach. They have incorporated touch screen, Bluetooth, a rugged, single connection hose system, with optional sample conditioner, smart O_2, CO, NO and SO_2 sensors and a dilution pump.

WHAT'S NEW?

Bluetooth communication is sweeping through the measurement industry like wildfire. Combustion analyzers are no exception. Most analyzers communicate to smart phones and tablets (smart devices) via custom apps. There is one company that has created a free universal app, www.MeasureQuick.com that is gaining rapid acceptance in various parts of the HVACR measurement world.

Bluetooth data features provides several great attributes, including the ability to remotely view data and, in some cases, control the analyzer. It allows you to tap into the power of the "connected computer in your pocket."

This gives you the ability to see streaming info displayed as if you had a digital strip chart recorded running on all channels of measurement and calculations! In addition, some apps include helpful troubleshooting advice and real time training on topics you may be rusty on, or never learned in the first place.

This advanced analyzer does not have a display or keypad and is controlled only via an app.

This analyzer has room for a third (NO) sensor to be installed.

For an interesting overview on connected tools, listen to the www.HVACRSchool.com podcast on this topic: https://hvacrschool.com/the-future-of-app-based-diagnosis-w-jim-bergmann-podcast/.

The connected nature of a smart device allows for rapid communication of your data via email or even real-time with a colleague or other support person for advice. Additionally, geo-tagging, and time stamping help to round out the reporting aspect.

Sensors are getting smarter too. Analyzers will tell you when calibration or replacement is needed. Some sensors are able to be installed with their own calibration data, eliminating down time. You will find a feature like this in Testo, Bacharach, MRU and Accutools combustion analyzers. Color displays and onscreen graphics are present on many of the mid-level analyzers enhancing the ability to "see" the combustion process in your hands.

Some manufacturers have taken the Bluetooth interface even further and removed the displays from their analyzers as is seen in the Testo 330i and the TPI DC710. These analyzers receive all their inputs from the smart device and use the smart device display to report back all information.

I've seen a real acceleration of clever design with very meaningful, robust features being added to combustion analyzers in the last few years. I look forward to what the future holds and look forward to coming back with an update!

Bill Spohn P.E., a frequent webinar presenter for RSES, is president and CEO of Tru-Tech Tools Ltd. He has worked with BPI, RESNET, GAMA, AHRI, OMA, RSES, NATE, and ACCA Technical Committees, and holds three patents. He holds BS and MS degrees in mechanical engineering from the University of Rochester.