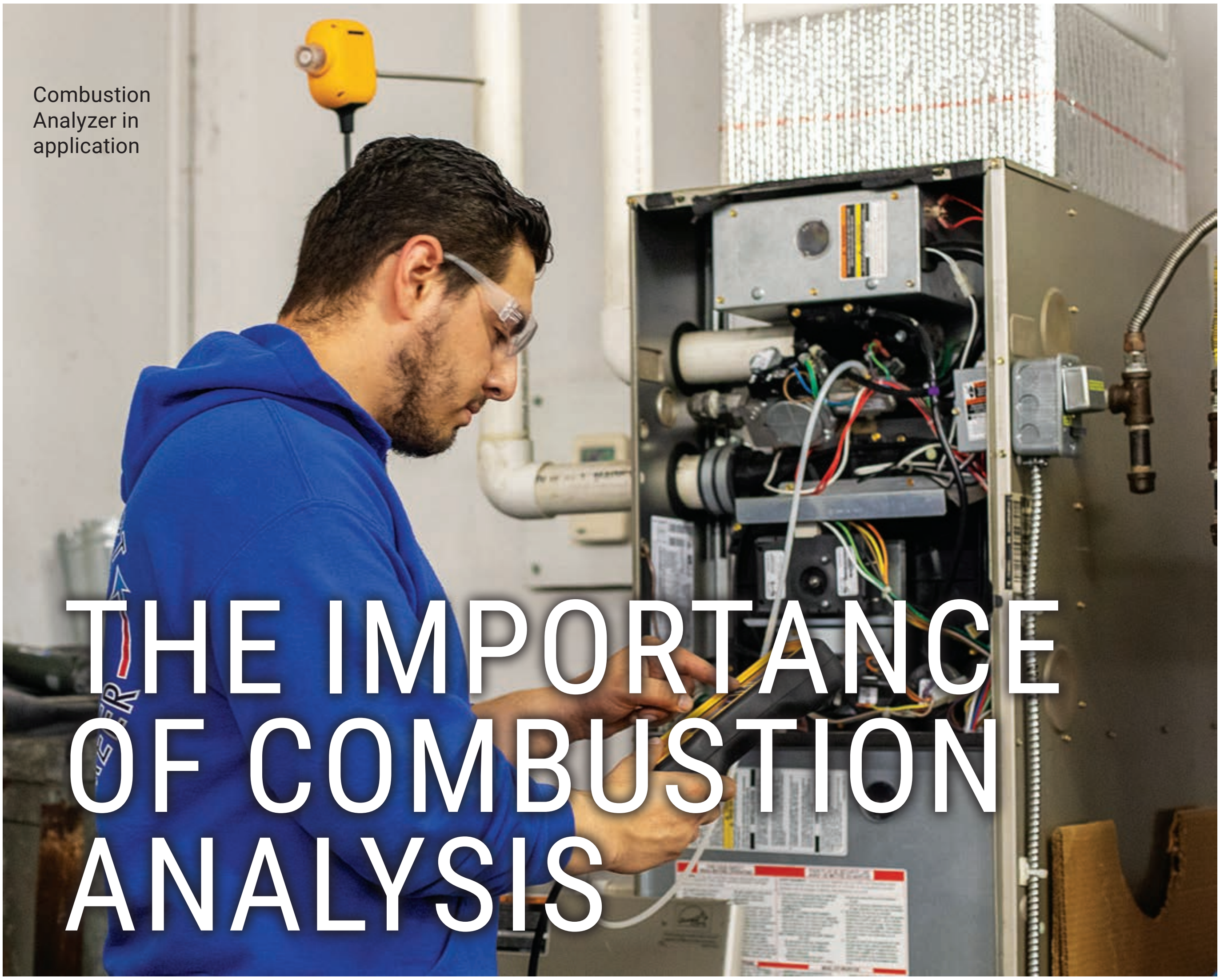

Combustion Analyzer in application

THE IMPORTANCE OF COMBUSTION ANALYSIS

Learn why the critical step of combustion analysis is essential to servicing fuel-fired heating appliances.

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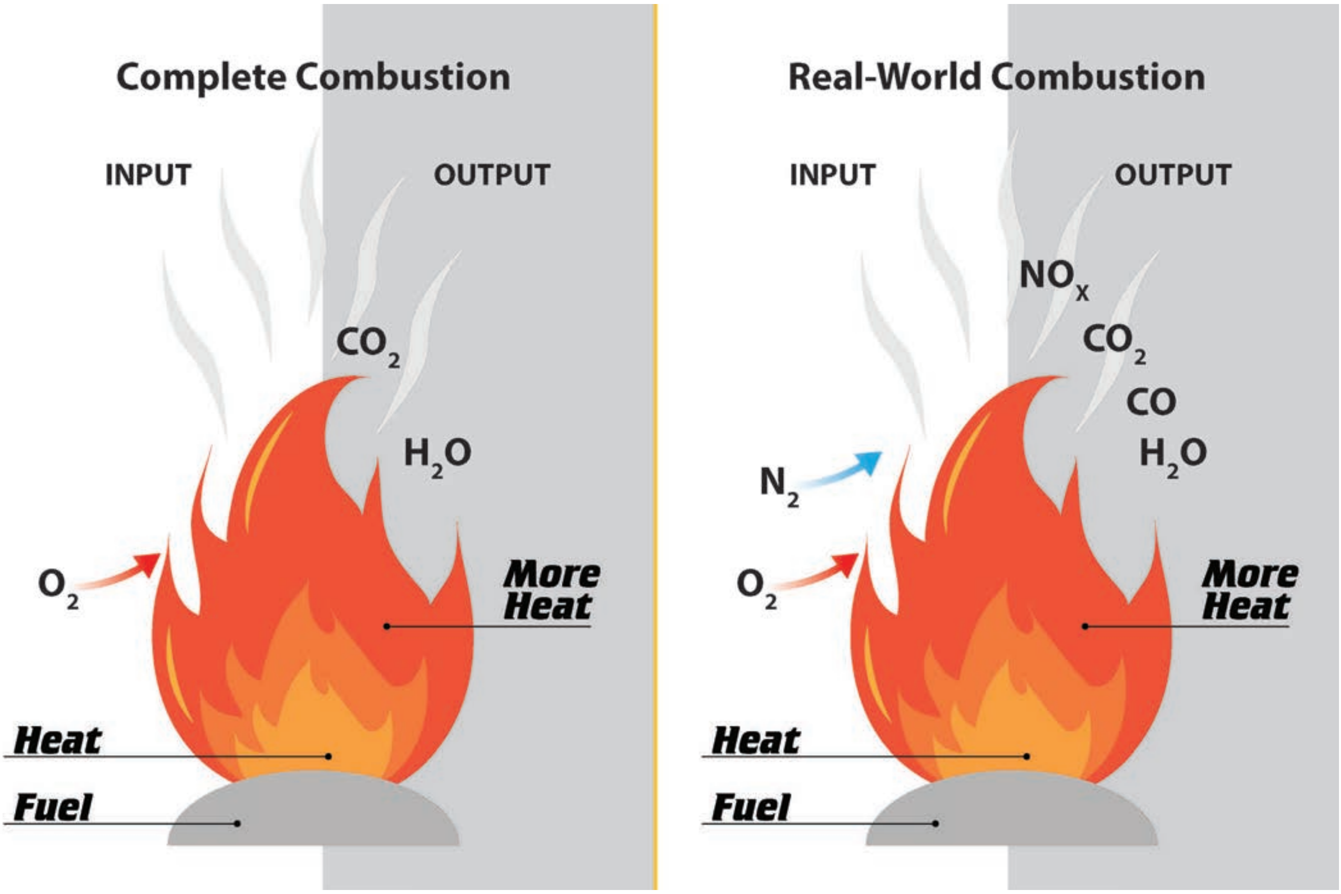
Note: The values expressed in this article are considered generic. When available, always defer to the manufacturer's recommendations and local regulations and standards.

Combustion analysis is a critical step to ensure a heating appliance operates safely and efficiently. It is a test that should be performed with the proper instruments on any gas, oil, coal, or wood-fired system during commissioning, maintenance, and repair or when any changes are made that affect the combustion process. Combustion analysis measurements and calculations help HVACR technicians optimize system performance and safety by, among other things, ensuring the gas pressure is set properly, the flue draft is correct for safe ventilation and the stack temperature is within the expected range.

Defining combustion analysis

To fully understand why combustion analysis is so important, we must first understand the process of combustion. Combustion is a chemical reaction that occurs when oxygen, fuel and an ignition source (heat) are combined, resulting in the generation of more heat. A perfect ratio of oxygen, fuel and heat delivers a clean combustion where the only byproducts are water vapor, carbon dioxide and heat. However, the air we breathe and the oxygen source for heating appliances is composed of 78% nitrogen and only 21% oxygen. With nitrogen in the mix,



Complete Combustion and Real-World Combustion

additional byproducts are also produced during combustion, including the highly toxic gas, carbon monoxide (CO) and nitrogen oxides (NOx). The more efficient the combustion process, the fewer dangerous byproducts are produced, reducing pollution and the risk of carbon monoxide poisoning for occupants.

Combustion analysis is the measurement and calculation of variables including ambient CO, CO air-free, oxygen, carbon dioxide (CO_2), ambient temperature, stack temperature, dew point and draft. By understanding each of these values and how they relate to one another, a technician can get a clear picture of how efficiently a furnace is burning oxygen and fuel to create heat as well as how much toxic CO is being created by the combustion process.

Controlling the combustion process by precisely regulating the fuel and airflow optimizes system efficiency to safely deliver the most heat to a space. Think of a furnace as producing 100 "balls of heat" in the combustion chamber. Heating efficiency defines how many of those 100 balls of heat make it into the home, office or store to condition the space and how many are lost in the flue stack. A newer, more efficient condensing furnace has a 90% heating efficiency, meaning 90 balls of heat condition the space and 10 are lost in the flue. An induced draft system has an 80% heating efficiency, and a natural draft furnace is 70% efficient, therefore, the target flue temperature measurement to optimize heating efficiency is system dependent.

Where to take measurements

Key combustion analysis measurements are taken in the flue gas after the end of the heat exchanger and prior to any dilution of air entering the flue gas. The analyzer probe is inserted into the flue stack, ideally at the combustion test access fitting. The flue stack is where the combustion products exit the furnace and are vented to the outside. Best practice is to warm up and connect the combustion analyzer prior to firing up the furnace. All measurements should be monitored at startup, after a system has stabilized and after light out (unit turned off).

The optimal measurement location in the flue stack varies with the type of system. For a condensing furnace, measurements should be taken 6 in.–12 in. after the furnace box but can be anywhere along the exhaust line. For an induced draft system, measure 18 in.–24 in. after the furnace box. For a natural draft furnace, outside air is mixed with exhaust gases in the air hood, diluting the exhaust, so measurements should be taken before the air hood for accurate readings. If an access location must be drilled, reseal the hole with a silicone plug following testing to ensure

Combustion Analyzer Displays (Standard and Trending)

exhaust gases are not vented into the space. Silicone is resistant to heat and moisture in the flue, providing a sure seal.

Understanding the measurements/calculations

Combustion analysis measurements and calculations should be compared to the heating appliance manufacturer's recommendations to verify compliance and optimal performance. Legwork is greatly simplified with an analyzer that provides visual cues indicating compliance or non-compliance to system-specific ranges as defined by the National Comfort Institute (NCI). What follows are general guidelines as to what the measurements and calculations mean.

Flue gas temperature is measured inside of the flue at the hottest point and is used to calculate the dew point and combustion efficiency. If flue gases cool too quickly, below the dew point, in induced draft and natural gas appliances, there will be condensation in the metal flue pipes and corrosion will limit system lifetime. Acidic condensate can also affect emissions leading to non-compliance with environmental regulations. Air temperature is typically measured at the combustion analyzer body or with an external probe placed in the inlet air stream and is used in conjunction with the flue gas temperature to calculate heating efficiency.

Carbon monoxide measurements are taken both in the ambient environment as a baseline and in the flue gas. High CO levels can indicate incomplete combustion and corrective actions such as adjusting the fuel pressure and airflow must be taken to minimize the CO level in the flue. Monitor CO levels at startup, as the unit will create a peak CO that should not exceed 1,000 ppm; however, this is system dependent. Continue to measure at light out to ensure CO levels drop to near 0 ppm—exact levels are also system dependent.

A calculation of **carbon monoxide air free (COAF)** uses the CO and O_2 readings to calculate what the CO would read if there was zero excess oxygen in the flue gas. The COAF value is used as the maximum allowable limit emitted by appliances and is 400 ppm for vented heating appliances. CO emissions compliance with local regulations and standards is critical to ensure the health and safety of occupants.

In some jurisdictions, **nitrogen oxides** are also considered an air pollutant and must be measured. NOx sensors are typically an optional sensor in some residential and light commercial analyzers. It is also worth noting that some heating appliances are designed to lower NOx emissions which can cause elevated CO levels as the flame or ignition temperature tends to run lower.

Most combustion analyzers **measure oxygen** and calculate **carbon dioxide**. The percentage of O_2 and CO_2 in the flue

Table 1: Typical Combustion Analysis Design Ranges by Furnace Type

	Condensing Furnace	Induced Draft	Natural Draft
Supply Air Temp	130°F–140°F	132°F–142°F	145°F–155°F
Flue Gas Temp	100°F–140°F	302°F–402°F	415°F–525°F
O_2	6%–9 %	6%–9%	6%–9%
CO	0–99 ppm	0–99 ppm	0–99 ppm

Source: *National Comfort Institute, Inc. (2020) Combustion Safety and Carbon Monoxide Diagnostics Field Reference Guide, Version 1.1.*

gas are also an indication of combustion efficiency. Most gas heating appliances achieve near complete combustion with around 50% excess oxygen or a measured flue gas oxygen of 7% and operate well between 6%–9% flue gas oxygen.

Another key safety measurement is **draft**, or pressure difference, across the furnace and flue stack. Draft indicates whether the exhaust gases are moving in the right direction and are properly removed from the system. The flue pressure should be -0.02 in. wc lower than the pressure in the combustion air zone.

Combustion analyzer selection and maintenance

When selecting a combustion analyzer, it is important to understand the features that will help you with your heating season jobs and to consider lifetime ownership costs. For example, a combustion analyzer with a built-in manometer means one less tool to carry. It allows for real-time draft feedback, so you can view the effects to draft due to any adjustments made to the heating system and the effect of any other heating appliances or common vented appliances (like a water heater) in the space.

Also, consider an analyzer that does not require an inline water trap. Because water vapor is a byproduct of combustion, when exhaust air is pulled into an analyzer the water must be removed or it will damage the oxygen and carbon monoxide sensors. Most combustion analyzers have an in-line water trap that condenses the vapor prior to reaching the sensors. Water traps must be monitored and emptied regularly during and following the analysis. A solution that minimizes this maintenance step is an analyzer that condenses the water vapor and returns it to the flue before it reaches the sensors - no water trap is required.

Look for long-life sensors that are field replaceable to maximize uptime. Most sensors should be replaced every year or two, and many units require the entire analyzer to be returned for sensor replacement and calibration. Regular calibration is typically recommended annually but it is important to always follow the manufacturer's guidelines and local jurisdiction regulations. There are analyzers on the market with sensors that last up to four years and when it's time for replacement, they can be swapped in the field so that you're always ready on the job.

Some jurisdictions also require that a combustion analysis report be printed and left with the owner as verification that all safety parameters are within compliance. Therefore, investing in an analyzer that pairs with a portable printer or wirelessly connects to a job reporting app may be necessary in your service area.

A critical component to the HVACR professional's job in servicing fuel-fired heating appliances is verifying that it operates efficiently, minimizes fuel waste, limits pollutant emissions and is safe for occupants. Combustion analysis makes these unseen parameters visible, helping to find and fix issues that would otherwise go unnoticed.

Tony Gonzalez, CSME, Technical Training Manager at Fieldpiece Instruments, has accumulated more than 20 years of HVAC experience and has been leading Fieldpiece training since 2020. Gonzalez presents courses nationally at conferences, partners with leading industry organizations and is recognized everywhere for his how-to videos. He is committed to sharing the best practices that make HVACR technicians' jobs easier, faster and better. For more information, visit www.fieldpiece.com or call 714-634-1844.

COMBUSTION ANALYZER USE AND MAINTENANCE TIPS

- Calibrate sensors annally or per manufacturer's recommendation.
- Drain analyzer condensate trap and check dust filter regularly.
- Store analyzers above freezing to preserve sensors and prevent freezing of any residual condensate, which can damage the analyzer.
- Always start an analyzer in fresh air away from combustion sources, including vehicle exhaust.
- If a source of high CO is not readily apparent, be aware that external sources, such as operating lawn mowers, generators, weed eaters, BBQ grills, may be the culprit.
- After the burners light, the CO should rise and fall and the O_2 should slowly fall, and both should stabilize within a few minutes.
- If CO or O_2 levels spike suddenly after the blower starts on a warm air furnace, it is a sign the heat exchanger is compromised in some way. Do not attempt to repair a heat exchanger.
- If CO sensor exceeds capacity, immediately open to fresh air and let the analyzer pump run until displayed level is at or near zero.
- When testing is complete, run the pump until CO, O_2 and temperature readings return to ambient, removing any residuals.
- Test any appliance after a repair, it should the last thing completed.