

how to do combustion analysis

how to do combustion analysis is a critical process for optimizing the efficiency and safety of a wide range of thermal processes, from industrial boilers and furnaces to internal combustion engines. Understanding the principles and practical steps involved allows for significant improvements in fuel economy, reduced emissions, and prolonged equipment lifespan. This comprehensive guide will delve into the intricacies of combustion analysis, covering everything from the fundamental principles and the necessary equipment to the detailed procedures and interpretation of results. We will explore how to collect accurate data, analyze flue gas composition, and what these readings signify for the performance of your combustion system. Furthermore, we will discuss common challenges and best practices to ensure you can effectively perform combustion analysis for any application.

Table of Contents

Understanding the Fundamentals of Combustion Analysis

Essential Equipment for Combustion Analysis

Step-by-Step Guide to Performing Combustion Analysis

Interpreting Combustion Analysis Results

Common Challenges and Troubleshooting in Combustion Analysis

Best Practices for Accurate Combustion Analysis

Understanding the Fundamentals of Combustion Analysis

Combustion analysis is the process of measuring and evaluating the composition of flue gases produced during the burning of fuel. This analysis provides crucial insights into the completeness of combustion, the amount of excess air being used, and the potential for harmful emissions. By understanding these parameters, operators can fine-tune their equipment to operate at peak efficiency, minimizing fuel waste and environmental impact. The fundamental principle relies on the stoichiometry of combustion, which dictates the ideal ratio of fuel to air for complete burning. Deviations from this ideal indicate either incomplete combustion, leading to wasted fuel and the production of carbon monoxide (CO), or excessive air, which cools the flame and reduces thermal efficiency.

The primary goal of combustion analysis is to achieve a state of "balanced combustion." This means providing just enough air to ensure all combustible elements in the fuel are converted into their highest oxidation states (carbon to carbon dioxide, hydrogen to water) while minimizing the amount of excess air. Excess air is necessary to ensure complete combustion, but too much can significantly reduce efficiency by carrying heat out of the system through the flue. Conversely, insufficient air leads to incomplete combustion, producing CO, soot, and unburned hydrocarbons, which are not only inefficient but also environmentally detrimental and can pose safety risks.

The Chemistry of Combustion

At its core, combustion is a rapid chemical reaction between a fuel and an oxidant, typically oxygen from the air, producing heat and light. For common fuels like natural gas, propane, oil, and coal, the primary combustible elements are carbon (C) and hydrogen (H). The ideal complete combustion

reactions can be represented as:

- Carbon: $C + O_2 \rightarrow CO_2$ (Carbon Dioxide)
- Hydrogen: $2H_2 + O_2 \rightarrow 2H_2O$ (Water)

In reality, combustion rarely achieves perfect stoichiometry. Air, which is approximately 21% oxygen and 79% nitrogen (N_2), is used as the oxidant. Nitrogen, being largely inert at combustion temperatures, passes through the system and can react at high temperatures to form nitrogen oxides (NO_x). Therefore, a more accurate representation of complete combustion in air involves nitrogen:

- For natural gas (primarily methane, CH_4): $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- With excess air, nitrogen is also present, and some may form NO_x .

Incomplete combustion occurs when there isn't enough oxygen to fully oxidize the fuel, resulting in the formation of carbon monoxide (CO) and potentially soot (unburned carbon particles). This is a direct indicator of inefficiency and a safety hazard.

Key Parameters Measured in Combustion Analysis

Combustion analysis typically focuses on measuring several key flue gas components and related parameters that collectively paint a picture of combustion performance. These measurements allow for precise adjustments to fuel and air supplies.

- **Oxygen (O_2):** The percentage of oxygen in the flue gas indicates the amount of excess air. Higher O_2 levels mean more excess air.
- **Carbon Monoxide (CO):** A direct indicator of incomplete combustion. Elevated CO levels signify inefficient burning and a potential safety hazard due to its toxicity.
- **Carbon Dioxide (CO_2):** In ideal complete combustion, CO_2 is a direct measure of the fuel burned. However, it's also affected by excess air. A high CO_2 reading can indicate good combustion, but only when correlated with low CO.
- **Flue Gas Temperature:** Measures the temperature of the gases leaving the combustion appliance. This is crucial for calculating heat loss and efficiency.
- **Draft:** The pressure difference between the combustion chamber and the surrounding atmosphere, essential for ensuring proper venting and airflow.
- **Combustion Efficiency:** Calculated based on the measured flue gas parameters and fuel input, this represents how effectively fuel energy is converted into useful heat.
- **Excess Air:** The amount of air supplied beyond what is stoichiometrically required for complete combustion.

Essential Equipment for Combustion Analysis

Performing an accurate combustion analysis requires specialized equipment designed to measure the various flue gas components and temperature with precision. While older methods might have involved manual sampling and laboratory analysis, modern combustion analysis is predominantly carried out using portable electronic combustion analyzers. These devices have revolutionized the process, providing real-time data and simplifying calculations.

Portable Combustion Analyzers

A modern portable combustion analyzer is the cornerstone of any combustion analysis. These handheld devices typically include a probe that is inserted into the flue, a sensor module to detect gas concentrations, a temperature sensor, and a display unit. They are designed to be rugged, portable, and user-friendly, making them suitable for field use.

- **Gas Sensors:** The heart of the analyzer, these sensors detect and quantify specific gases like O₂, CO, and sometimes NO_x. Electrochemical sensors are common for these gases.
- **Temperature Probe:** Measures the flue gas temperature accurately.
- **Pressure Sensor:** Measures draft and sometimes inlet gas pressure.
- **Data Logging and Display:** Modern analyzers feature digital displays that show readings in real-time and often have the capability to log data for later analysis and report generation.
- **Rechargeable Batteries:** Essential for portable operation in various environments.

Flue Gas Probe

The flue gas probe is the interface between the combustion appliance and the analyzer. It must be robust enough to withstand high temperatures and constructed from materials that won't corrode or degrade in the flue gas environment. The probe typically has a nozzle that allows for the collection of a representative sample of the flue gas.

- **Insulated Tubing:** Connects the probe to the analyzer, often insulated to prevent condensation of water vapor in the flue gas, which can affect readings and damage the instrument.
- **Filter:** Some probes include a particulate filter to prevent soot and debris from entering the analyzer, which can clog sensors and reduce accuracy.
- **Length and Diameter:** The probe length should be sufficient to reach the center of the flue for a representative sample, and its diameter should be appropriate for the appliance's flue size.

Other Supporting Tools

In addition to the primary combustion analyzer, several other tools can be beneficial for a thorough combustion analysis and system inspection.

- **Infrared (IR) Thermometer:** Useful for measuring surface temperatures of the appliance and surrounding components to identify heat leaks or hot spots.
- **Manometer:** A simple device to measure pressure differences, useful for verifying draft readings or checking gas pressure at the appliance inlet.
- **Combustion Test Caps/Ports:** These are often installed in appliance flues to provide a standardized, sealed point for inserting the combustion probe, ensuring an accurate sample and preventing dilution by ambient air.
- **Gas Leak Detector:** Essential for safety checks, especially when working with natural gas or propane appliances.

Step-by-Step Guide to Performing Combustion Analysis

Performing a combustion analysis is a systematic process that requires careful attention to detail to ensure accurate and reliable results. Following a well-defined procedure will help you gather the necessary data and avoid common pitfalls. The process involves preparing the equipment, sampling the flue gas, and recording the measurements.

Preparation and Safety Checks

Before commencing any combustion analysis, safety must be the top priority. This includes ensuring the work area is well-ventilated, checking for gas leaks, and confirming the functionality of safety equipment. The combustion analyzer itself should also be checked for calibration and battery life.

- **Ventilation:** Ensure the area where the appliance is operating is adequately ventilated to prevent the buildup of combustion gases.
- **Gas Leak Detection:** Use a gas leak detector to check for any signs of fuel leaks around the appliance and gas supply lines.
- **Personal Protective Equipment (PPE):** Wear appropriate PPE, including safety glasses, gloves, and sturdy footwear.
- **Analyzer Calibration:** Verify that the combustion analyzer has been recently calibrated according to the manufacturer's recommendations. Check battery levels.
- **Appliance Inspection:** Visually inspect the appliance for any obvious signs of damage,

corrosion, or blockages.

Sampling the Flue Gas

The accurate sampling of flue gas is critical for obtaining meaningful data. The probe must be inserted into the flue at the correct location and depth to ensure a representative sample, avoiding dilution from ambient air.

1. **Locate the Sampling Point:** Ideally, use a dedicated sampling port or test cap installed in the flue pipe downstream of the appliance but upstream of any draft diverters or fans if possible. If no port is available, select a straight section of the flue pipe, at least three times the diameter of the pipe away from any elbows or transitions.
2. **Insert the Probe:** Insert the combustion probe into the flue, ensuring it is positioned in the center of the flue diameter to get a representative sample. Some analyzers recommend inserting the probe to a specific depth indicated on the probe or by the appliance manual.
3. **Seal the Sampling Point:** Ensure the sampling point is as airtight as possible around the probe to prevent ambient air from being drawn into the sample. This is crucial for accurate O₂ and CO readings.
4. **Start the Analyzer:** Turn on the combustion analyzer and allow it to stabilize according to the manufacturer's instructions. Select the appropriate fuel type (natural gas, propane, oil, etc.).
5. **Begin Measurement:** Once the analyzer is stable and the probe is in place, start the data acquisition process. The analyzer will begin drawing flue gas through the probe and sensors.

Recording Measurements

As the analyzer collects data, it will display real-time readings. It's important to record these values accurately, noting any fluctuations. Many modern analyzers can automatically log these measurements.

- **Stable Readings:** Wait for the readings for O₂, CO, CO₂, and temperature to stabilize. This may take a few minutes depending on the appliance and the analyzer.
- **Record Key Parameters:** Note down the stabilized values for:
 - Oxygen (O₂)
 - Carbon Monoxide (CO)
 - Carbon Dioxide (CO₂)
 - Flue Gas Temperature

- Draft (positive or negative pressure)
- **Note Ambient Conditions:** If possible, record ambient temperature and pressure, as these can sometimes influence calculations.
- **Multiple Readings:** It is often advisable to take readings at different operating points of the appliance (e.g., low fire and high fire for modulating appliances) and at different times to ensure consistency.
- **Document Observations:** Make notes of any unusual sounds, smells, or visual observations related to the appliance's operation.

Interpreting Combustion Analysis Results

Once the data has been collected, the next crucial step is to interpret the results to understand the combustion system's performance. This interpretation involves comparing the measured values against acceptable ranges and understanding what each parameter signifies. Effective interpretation allows for informed adjustments to optimize efficiency and safety.

Understanding Acceptable Ranges

The ideal combustion parameters vary depending on the type of fuel being used and the specific appliance. However, general guidelines and target ranges exist for common fuels like natural gas and oil. These ranges are established to balance efficiency, emissions, and safety.

- **Oxygen (O₂):** For natural gas, a common target range for O₂ is between 3% and 7%. For oil, it might be slightly higher, around 5% to 9%. Low O₂ suggests insufficient air, leading to incomplete combustion and high CO. High O₂ indicates excessive air, reducing efficiency.
- **Carbon Monoxide (CO):** Ideally, CO levels should be very low, often below 50 parts per million (ppm) for natural gas and below 100 ppm for oil. Readings significantly above these levels are a strong indicator of incomplete combustion and require immediate attention. Any reading above 400 ppm is considered dangerous.
- **Carbon Dioxide (CO₂):** For natural gas, a CO₂ reading of around 8% to 12% is typically desirable. For oil, it might be in the range of 10% to 14%. Higher CO₂ generally indicates more complete combustion, but it must be evaluated in conjunction with CO levels.
- **Flue Gas Temperature:** This is compared against the temperature of the incoming air or the boiler water temperature. A large differential indicates significant heat loss up the flue. Ideal temperature differences depend heavily on appliance type and design.
- **Draft:** A slight positive draft is usually desired for natural draft appliances to ensure proper venting. Forced draft appliances will have different pressure characteristics. Consistent and

appropriate draft is vital for safe operation.

Calculating Efficiency and Excess Air

Modern combustion analyzers often perform these calculations automatically, but understanding how they are derived is beneficial. Efficiency is typically calculated using a "high-efficiency" or "low-efficiency" method, based on the measured flue gas composition and fuel type.

- **High-Efficiency Method:** This method accounts for the latent heat of vaporization of water produced during combustion. It provides a more accurate efficiency calculation, especially for modern condensing appliances.
- **Low-Efficiency Method:** This method ignores the latent heat of water, providing a less precise but still useful efficiency figure, often used for older, non-condensing appliances.
- **Excess Air Calculation:** Excess air is calculated based on the measured O₂ and CO₂ levels, using specific formulas that depend on the fuel type. For instance, for natural gas, a CO₂ of 10% with 5% O₂ implies a certain percentage of excess air, while a CO₂ of 12% with 3% O₂ implies a different, lower percentage of excess air.

Identifying Problems from Readings

The combination of readings provides a diagnostic tool for identifying specific combustion issues. For example, high CO and low O₂ strongly indicate a lack of air, while low CO and high O₂ suggest an excess of air or a less severe combustion problem.

- **High CO, Low O₂:** Indicates insufficient combustion air. The fuel is not burning completely. Causes include clogged air intakes, a blocked flue, or incorrect burner adjustment.
- **Low CO, High O₂:** Indicates excessive combustion air. While this ensures complete combustion, it leads to poor efficiency as excess air carries heat up the flue. This might be due to an incorrectly set air damper or a leaky appliance casing.
- **High Flue Gas Temperature:** Suggests significant heat is being lost up the flue. This could be due to excessive air, poor heat exchanger design or condition, or scale buildup.
- **Low CO₂, Low O₂:** This combination is unusual and might indicate a problem with the analyzer or sampling, or potentially a very rich fuel-air mixture with incomplete combustion.
- **Negative Draft:** This is a serious safety issue, meaning combustion gases are being drawn into the building instead of being vented outdoors. It requires immediate investigation and correction.

Common Challenges and Troubleshooting in Combustion Analysis

Even with the best equipment and procedures, certain challenges can arise during combustion analysis. Understanding these potential issues and knowing how to troubleshoot them is essential for obtaining accurate and reliable data. Many problems relate to sample integrity, equipment functionality, or appliance-specific quirks.

Sample Dilution

One of the most common issues is sample dilution, where ambient air mixes with the flue gas sample before it reaches the analyzer's sensors. This leads to artificially low CO and CO₂ readings and artificially high O₂ readings, making the system appear more efficient or less problematic than it is.

- **Causes:**

- Leaky sampling ports or test caps.
- Worn or damaged seals on the probe or sampling adapter.
- A negative draft situation, where ambient air is drawn into the flue.
- Inadequate sealing around the probe insertion point.

- **Troubleshooting:**

- Ensure the sampling port is clean and the test cap is securely fastened.
- Inspect and replace any worn gaskets or seals.
- Verify that the draft is positive; if negative, address the venting issue first.
- Use a sealant or gasket material to ensure a tight fit around the probe.

Sensor Drift and Calibration Issues

Combustion analyzer sensors, particularly electrochemical ones, can drift over time and require regular calibration to maintain accuracy. Failure to calibrate can lead to significantly incorrect readings.

- **Causes:**

- Normal sensor aging.
 - Exposure to contaminants in the flue gas.
 - Temperature extremes.
 - Lack of regular calibration.
- **Troubleshooting:**
 - Follow the manufacturer's recommended calibration schedule.
 - Perform zeroing and span calibrations using the appropriate calibration gases.
 - Store the analyzer in a suitable environment when not in use.
 - Replace sensors when they reach the end of their service life or if calibration becomes impossible.

Appliance-Specific Factors

Different types of combustion appliances have unique operating characteristics that can affect combustion analysis. For example, modulating burners, condensing boilers, and draft-induced fans can present challenges.

- **Modulating Burners:** These burners can operate at multiple firing rates. It's crucial to perform analysis at different rates (e.g., low fire and high fire) as settings may vary significantly.
- **Condensing Appliances:** These appliances extract more heat from the flue gases, leading to lower flue gas temperatures and water vapor condensation. This requires specialized probes and analyzers that can handle moisture and potentially acidic condensate. Ensure the analyzer is rated for condensing applications.
- **Draft-Induced and Forced Draft Fans:** The fan's operation can influence pressure readings and potentially introduce turbulence, affecting sample homogeneity. Understanding the appliance's airflow system is important for proper probe placement.
- **Soot Buildup:** Heavy soot buildup in the heat exchanger or flue can restrict airflow and affect combustion. While combustion analysis itself doesn't directly measure soot, high CO and low O₂ can be indicators of a sooting problem that requires cleaning.

Best Practices for Accurate Combustion Analysis

To ensure the most accurate and valuable combustion analysis, adhering to best practices is paramount. These practices go beyond the basic procedural steps and involve a holistic approach to equipment maintenance, data management, and understanding the context of the appliance being analyzed. Consistent application of these principles will lead to more reliable performance tuning and troubleshooting.

Regular Equipment Maintenance and Calibration

The accuracy of any measurement is directly tied to the quality and maintenance of the measuring instrument. For combustion analyzers, this means a proactive approach to calibration and upkeep.

- **Scheduled Calibration:** Adhere strictly to the manufacturer's recommended calibration schedule, typically annually or more frequently depending on usage and environmental conditions.
- **Zeroing and Span Checks:** Before each use, perform zeroing (using clean air) and, if possible, a span check with known calibration gases to confirm the analyzer is functioning correctly.
- **Filter Replacement:** Regularly inspect and replace any particulate filters within the probe or analyzer to prevent sensor contamination and maintain airflow.
- **Probe and Tubing Inspection:** Check the probe for damage, corrosion, or blockages. Inspect the tubing for kinks, leaks, or signs of degradation.
- **Battery Management:** Ensure batteries are adequately charged and replaced as needed to avoid analyzer shutdown during critical measurements.

Accurate Fuel Identification

The type of fuel being burned significantly impacts the ideal combustion parameters. Using the wrong fuel profile in the analyzer can lead to incorrect efficiency calculations and misinterpretation of results.

- **Confirm Fuel Type:** Always verify the exact type of fuel being used (e.g., natural gas, propane, 2 fuel oil, kerosene).
- **Select Correct Settings:** Ensure the combustion analyzer is programmed with the correct fuel type. Most analyzers have pre-set options for common fuels.
- **Understand Fuel Properties:** Be aware that even within a category like "natural gas," there can be variations in composition (e.g., methane content) that can slightly alter combustion characteristics. For highly specialized fuels, custom settings may be required.

Consistent Sampling Techniques

The method of sampling flue gas is arguably the most critical factor for accurate readings. Consistency in technique ensures that measurements are repeatable and representative of the actual combustion process.

- **Standardized Sampling Location:** Whenever possible, use a dedicated sampling port. If not, establish a consistent location and depth for probe insertion, documented in your standard operating procedure.
- **Adequate Purge Time:** Allow sufficient time for the analyzer to purge its internal lines and for the sample to stabilize before taking readings.
- **Minimize Air Ingress:** Take all necessary precautions to seal the sampling point and prevent ambient air from diluting the flue gas sample. This is especially important in drafty environments or with appliances experiencing negative draft.
- **Representative Sample:** For appliances with multiple burners or complex airflow, consider if multiple sampling points might be necessary to get a truly representative picture of combustion.
- **Record Observations:** Note any factors that might have influenced the sampling process, such as strong drafts, unusual appliance operation, or environmental conditions.

Data Interpretation and Context

Collecting data is only half the battle; understanding what that data means in the context of the specific appliance and its operating conditions is crucial for effective troubleshooting and optimization.

- **Compare to Manufacturer Specifications:** Always refer to the appliance manufacturer's recommended operating parameters and efficiency targets.
- **Trend Analysis:** Instead of relying on a single set of readings, track combustion parameters over time. Changes can indicate developing problems.
- **Correlate with Appliance Performance:** Link combustion analysis data with observable appliance performance, such as heat output, noise, or fuel consumption.
- **Document Everything:** Keep detailed records of all combustion analyses performed, including date, time, appliance details, fuel type, all measured parameters, calculated values, and any adjustments made. This historical data is invaluable for troubleshooting and warranty claims.
- **Consider Safety First:** Always prioritize safety. If readings indicate dangerous levels of CO or other hazards, take immediate steps to mitigate the risk and inform the responsible parties.

FAQ

Q: How often should a combustion analyzer be calibrated?

A: Combustion analyzers should be calibrated regularly, typically annually, or more frequently if recommended by the manufacturer, if the unit is dropped, or if its accuracy is in question. Regular calibration is essential to ensure accurate readings and reliable performance diagnostics.

Q: What is the difference between O₂ and CO₂ readings in combustion analysis?

A: Oxygen (O₂) in flue gas is a measure of the excess air available for combustion. A higher O₂ reading indicates more excess air. Carbon Dioxide (CO₂) is a product of complete combustion of carbon. While higher CO₂ can indicate good combustion, it's only a reliable indicator when correlated with low Carbon Monoxide (CO) levels, as excess air can reduce CO₂ output.

Q: Why is carbon monoxide (CO) a critical reading in combustion analysis?

A: Carbon Monoxide (CO) is a colorless, odorless, and highly toxic gas produced by incomplete combustion. Elevated CO levels in flue gas indicate that the fuel is not burning completely, leading to wasted energy and a significant safety hazard for occupants of the building. Low CO readings are a primary goal of efficient combustion.

Q: Can I perform combustion analysis on any type of fuel?

A: Yes, most modern combustion analyzers are designed to handle a variety of fuels, including natural gas, propane, butane, heating oil (various grades), and even some solid fuels. However, it is crucial to select the correct fuel type on the analyzer's settings for accurate calculations of efficiency and other parameters.

Q: What is considered "good" efficiency for a residential boiler?

A: For modern, high-efficiency condensing boilers, efficiencies can exceed 90%. Older, non-condensing boilers typically operate at efficiencies in the range of 75-85%. Combustion analysis helps determine the actual operating efficiency and identify areas for improvement.

Q: What are the risks of insufficient air in combustion?

A: Insufficient air leads to incomplete combustion, producing high levels of Carbon Monoxide (CO), soot, and unburned hydrocarbons. This results in significant fuel waste, reduced heating output, potential soot buildup within the appliance and chimney, and a severe risk of carbon monoxide

poisoning.

Q: How does draft affect combustion analysis?

A: Draft is the pressure difference that causes flue gases to flow out of the appliance and up the chimney. Proper draft is essential for ensuring a consistent and representative sample of flue gas. Negative draft can draw ambient air into the flue, diluting the sample and leading to inaccurate readings. Conversely, excessive draft can pull too much air through the system, reducing efficiency.

Q: What should I do if my combustion analyzer shows very high CO readings?

A: If your combustion analyzer shows very high CO readings (e.g., above 200 ppm for natural gas), it indicates a serious combustion problem. You should immediately stop the appliance from operating, ensure the area is well-ventilated, and cease further testing until the issue is diagnosed and corrected by a qualified technician. Safety is paramount in such situations.

[How To Do Combustion Analysis](#)

How To Do Combustion Analysis

Related Articles

- [how hard is the cppb exam](#)
- [how to be a drug dealer](#)
- [how do i fix my relationship with my boyfriend](#)

[Back to Home](#)