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APPLICATION NOTE: CARBON MONOXIDE MEASUREMENTS IN COAL FIRED POWER PLANTS

Industry: Power Generation
Product: Model IR PMIF based Extractive analyzer
Bulletin: AN24-081224

Background Information

There are currently 1470 generators at 617 facilities in the United States alone that use coal as the major source of energy to generate electricity. Of these facilities, 141 are considered industrial, institutional or commercial sites that consume most of the electricity produced on-site. The remaining 476 sites are identified as "power plants" owned by electric utilities and independent power producers that generate and sell electricity as their primary business. The primary goals that drive these power plants are increasing efficiency and throughput, reducing emissions of pollutants, and maintaining a high level of safety. Obtaining these goals ensures that the power plants generate the highest profits, while complying with environmental regulations and assuring workplace and community safety.

Introduction

An accurate measurement of the carbon monoxide (CO) concentration in the boiler flue gas can be used to achieve the goals of combustion efficiency, pollutant emissions reduction, and safe operation. By measuring the concentration of CO, power plants are able fine tune the air to fuel ratio used on the burners to obtain the highest combustion efficiency. Measuring the CO concentration allows the power plants to reduce the amount of combustion air used while ensuring complete combustion, reducing the production of the pollutant NOx. The concentration of CO in the flue gas is also the most sensitive indicator of unburned combustibles in the process and can indicate the emergence of an unsafe situation.

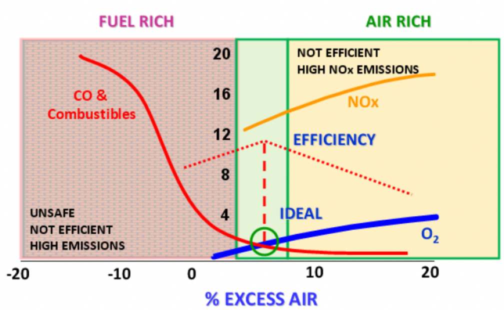
Efficiency, Emissions, Safety

Given complete mixing, a precise or stoichiometric amount of air is required to completely react with a given quantity of fuel to produce complete combustion. In real world applications, conditions are never ideal so additional or "excess" air must be supplied to completely burn the fuel.

Too little excess air will result in a "fuel rich" situation producing a flue gas containing unburned combustibles (carbon monoxide, soot, smoke, coal). This situation results in a loss of efficiency because not all of the potential energy of the coal is captured in the combustion process resulting in fuel wastes. Combustion processes that run fuel rich are "running dirty" meaning an increase in pollutant emissions. Also, this is not a safe situation as the unburnt fuel could possibly come into contact with an ignition source further down the process resulting in an uncontrolled explosion.

Too much excess air results in an "air rich" situation, resulting in complete combustion and safety, but also produces undesirable effects. Efficiency is lost in an air rich process because the increased flue gas flow results in heat loss. More fuel is required to generate the same amount of heat, so fuel is wasted in this low "boiler fuel-to-steam" efficiency situation. Since air is comprised of over 78% nitrogen, increasing the air used for combustion significantly increases the concentration of nitrogen. Nitrogen exposed to temperatures above 1600°C (2912°F) may result in the formation of "thermal NOx" (NO, NO2). These substances are major contributors to the formation of acid rain and their release into the atmosphere is heavily regulated by environmental agencies.

The ideal situation is to provide just enough excess air to produce complete combustion, but not any more than that. This will produce the highest efficiency, lowest emissions of pollutants, and maintain a high level of safety. The question is: How is the excess air setpoint determined?



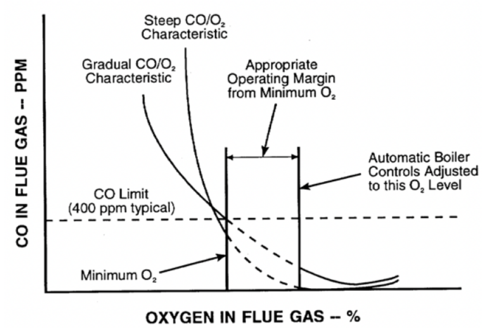
Using CO to trim excess O2

The amount of excess air in the flue gas is determined by measuring the concentration of oxygen (O2). The ideal excess O2 level (the lowest possible that allows complete combustion) depends on several factors: the fuel type, the burner type, humidity changes in the air, moisture content changes in the fuel, varying boiler loads, fouling of the burner system, and mechanical wear of combustion equipment. Since many of these factors are continuously changing, the ideal amount of excess oxygen continuously changes as well.

Measuring carbon monoxide (CO) can help to determine the excess oxygen setpoint.

CO is the most sensitive indicator of incomplete combustion. As the amount of excess O2 is reduced, the emergence of CO will occur before other combustibles appear (unburnt fuel). When the concentration of CO reaches the desired setpoint (typically around 400 ppm), the excess O2 concentration is at the desired level and becomes the new excess O2 setpoint. As the concentration of CO increases or decreases, the excess O2 setpoint can be trimmed accordingly. CO trim control of excess O2 concentration assures minimal energy loss, maximum efficiency, and reduced NOx emissions independent of boiler load, fuel type, humidity, moisture content of fuel and other variables that make excess O2 control difficult.

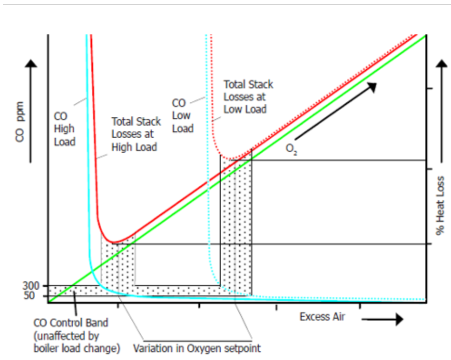
The key to obtaining these benefits is an accurate and reliable measurement of CO in low ppm levels.



Combustion Efficiency

Incomplete combustion of carbon-based fuels, including coal and oil will always result in the formation of Carbon Monoxide (CO). Increased CO concentration equates to insufficient or inefficient combustion. It is not uncommon to have varying boiler loads and fuel quality. The greater the variation the most advantage can be gained by controlling with continuous monitoring of the levels of CO.

The graph illustrates the relationship between CO, Oxygen and minimum heat loss. The Carbon Monoxide control band is load independent.



Typical Fuel savings from Secondary Trim in Coal Power Plants

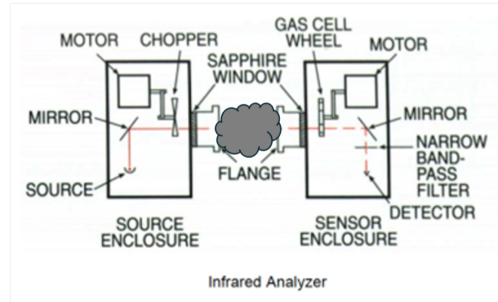
While it is challenging to provide a specific numeric value without detailed information about a particular power plant, studies have shown that secondary trim can lead to fuel savings of 1 ~ 3 % in coal fired power plants.

Example: Let's assume a coal-fired power plant consumes 1 million tons of coal per year. A 2% improvement in fuel efficiency through secondary trim could result in a fuel savings of 20,000 tons per year. Cost benefit by fuel savings can be computed accordingly.

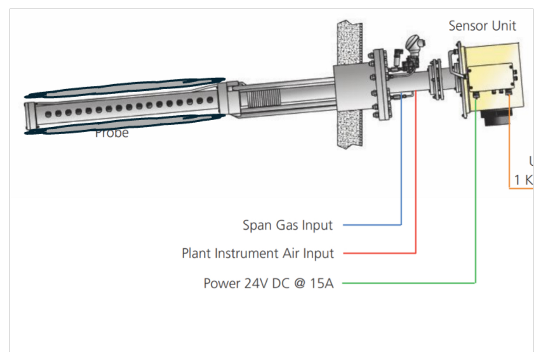
Obstacles to Measuring CO in Coal Fired Boilers

Measuring CO accurately and reliably in coal fired applications has traditionally been extremely challenging. Some of the obstacles that must be overcome:

- Flue gas laden with very high fly ash particulate, typical APH / Economizer process location has > 80 Grams / Nm3
- High temperature in the optimal measuring location
- Stratification of gas concentrations
- Presence of SO2 in the flue gas
- Insitu cross-duct installations can not perform as the optical path is heavily obstructed by the fly ash, and coats the windows completely blocking the optical path (as below)



-Probe type Insitu installations cannot perform as the sample cell filter gets clogged due to heavy fly ash load and does not allow flue gas to enter the measuring sample cell. Even very frequent auto purging may not be effective to blow out the heavy fly ash deposits. But calibration gases get trapped inside the cell to show false calibration pass, in reality the probe is not measuring any flue gas (as below)



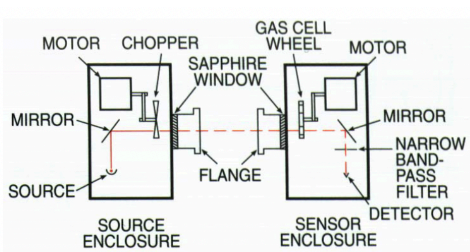
-Traditional extractive analyzer use in-line filters to remove the heavy fly ash, but these filters get clogged within a very short time

Current measuring technologies that are employed to measure CO (or combustibles in general) are Catalytic Bead sensors, Thick/Thin-Film thermistors, and IR spectroscopy.

The Catalytic Bead and Thick/Thin Film thermistors utilize the thermal properties of combustion to change the resistance of an active element compared to that of an inactive reference element. The active element is coated with metal that acts as a catalyst for combustion when exposed to air and a hydrocarbon. The other element is left in a natural state without a coating to act as a reference against background changes that would affect both elements (i.e. process temp, gas thermal conductivity etc). Combustion on the surface of the active bead increases the temperature of the bead in effect raising its resistance. The difference between the reference and active resistance values is proportional to the concentration of combustibles in the process gas.

Catalytic Bead Sensor

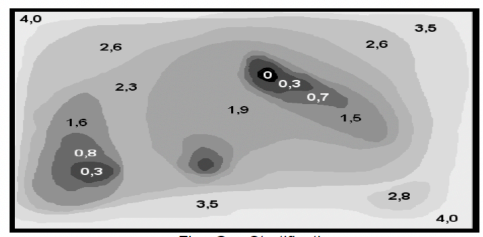
Infra-red Analyzers use an infrared source mounted directly on the flue gas duct or stack on the side opposite from the receiver. Infrared energy is radiated by the source, through the flue gas, to the receiver. The receiver employs gas filter correlation and narrow band pass optical filtration with a solid-state detector to determine the absorption of radiation by CO in the flue gas. The magnitude of the absorption is proportional to the concentration of CO in the flue gas.



Infrared Analyzer

These measuring technologies are prone to the following problems:

- The catalytic sensors require sample extraction installations. These sample extraction systems are prone to plugging and fouling with fly ash in coal fired applications. They require frequent preventative maintenance and the filters they require cause slow response times.
- The catalytic sensors are discreet or point measurements. They do not provide a path or average measurement across the firebox. They are subject to stratification errors, may not detect isolated areas of CO breakthrough, and require multiple points of installation to provide adequate coverage.



Flue Gas Stratification

- IR analyzers cannot make the measurement in particulate laden (fly ash) flue gas. This combined with temperature limitations prevents IR installation directly across the fire box. They must be installed further down the process, at lower temperatures after particulate removal (precipitators). This introduces more lag time in detecting CO breakthrough. Also CO that reacts after the fire box will not be detected (CO quenching).

- IR analyzers are subject to interference from CO2 and water vapor in the flue gas. Catalytic sensors are subject to interference from NO2 and water vapor, and quickly deteriorate in the presence of SO2. This mandates frequent calibrations, replacements, and suspect accuracy.

These problems prevent these traditional measurement technologies from providing an accurate and reliable CO measurement.

Solution to Measuring CO in Coal Fired Boilers

Dual Beam IR Spectroscopy (NDIR) manufactured by ILLC has been proven in the field to be a solution for this difficult measurement. IR measurements are based on absorption spectroscopy. The Model IR Analyzer is a NDIR system and operates by measuring the amount of laser light that is absorbed (lost) as it travels through the gas being measured. In the simplest form a NDIR analyzer consists of a laser that produces infrared light, optical lenses to focus the laser light through the gas to be measured and then on to a detector. The detector and electronics that control the laser then translate the Detector signal into a signal representing the CO concentration.

The Model IR Analyzer utilizes powerful lasers that are highly sensitive and selective for CO. This results in many benefits over traditional IR analyzers and catalytic sensors:

- The Model IR Analyzer measures CO directly in the closed loop of the high velocity flue gas flow. This means negligible lag time in detecting CO breakthrough and no false low reading due to CO quenching after the fire box.
- The Model IR Analyzer measures CO from a dust free flue gas sample from the PMIF Inertial filter probe. There is no traditional extractive sample system induced maintenance or lag time.
- The Model IR Analyzer is an inertial based measurement (single inertial probe pulls flue gas at a very high velocity). This provides an average reading that ensures isolated areas of CO breakthrough are detected. Multiple installations are not required.

Product Recommendations

The Model IR Analyzer

System components

IR Analyzer
PMIF Inertial Probe
Flow control Panel
Calibration & Purge Panel (Option)
Probe Heater Jacket (Option)

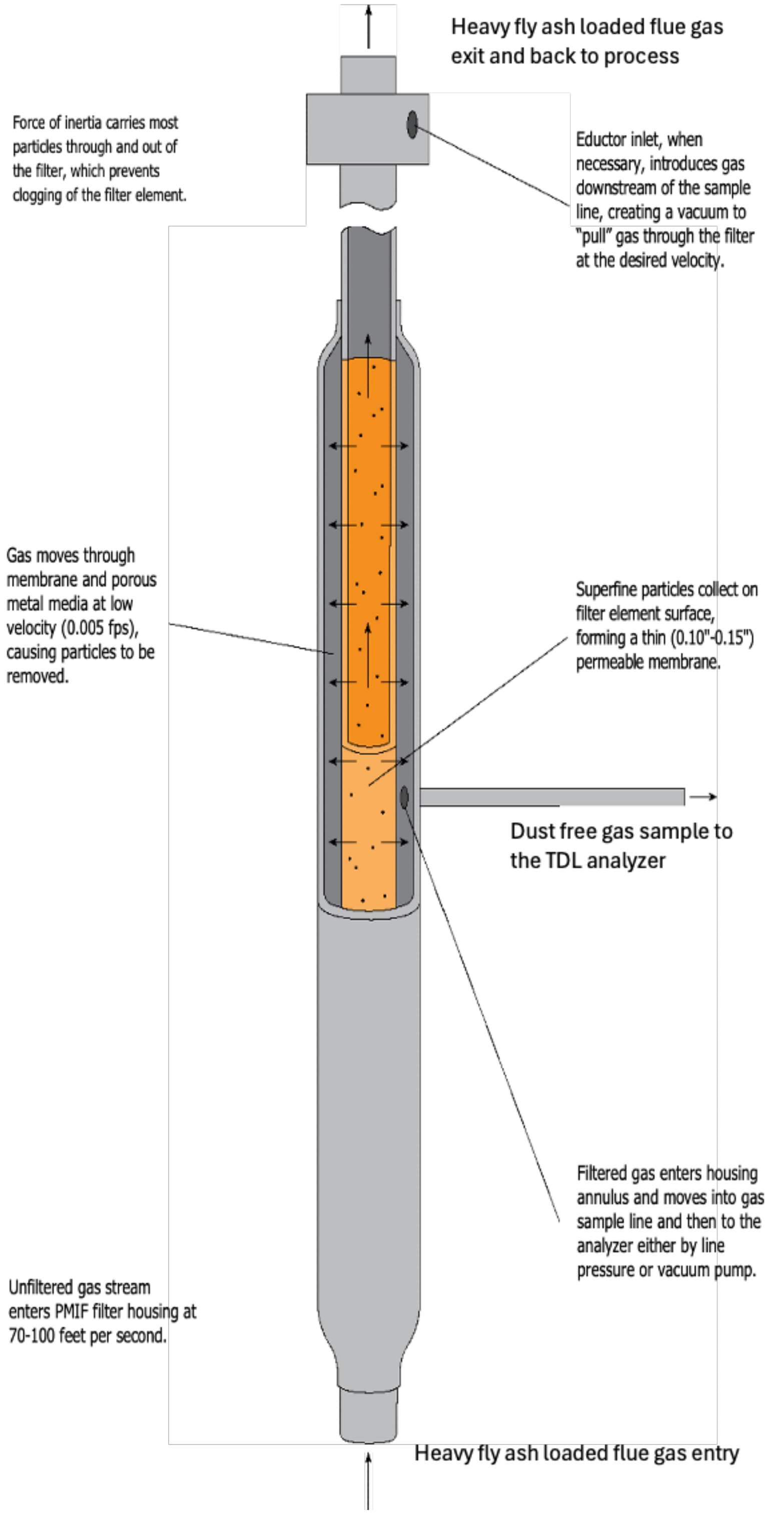
PMIF Porous Metal Inertial Filter draws high flow flue gas samples from highly dust laden process gas in Air Pre Heater inlets in coal fired power plants and diffuses a small flow, dust free gas sample into the NDIR analyzer for continuous CO measurements for combustion optimization and air fuel ratio control to increase efficiency and reduce fuel costs and emissions.

All-metal strength, plus crossflow efficiency – the PMIF (Porous Metal Inertial Filter) approach to gas filtration

All-metal, inertial gas sampling (PMIF) filters allow the collection of particle-free samples from virtually any gas stream, even those which are very hot or heavily contaminated. And, unlike other gas filters which may quickly plug and need to be thrown away, filters are designed to provide long-term – in many cases, permanent – filtration. Benefits of PMIF's exclusive design include:

- Continuous, clog-resistant
- Filtration
- Fast generation of high-purity samples.
- High temperature tolerance.
- High corrosion resistance.
- High pressure tolerance.
- Fast, efficient, in-situ cleaning.
- Wide selection of materials

0.5μm (shown here, x100) is the recommended micrometer grade for filter applications. also provides filters with all-metal media in 0.2μm, 2μm, 5μm and 10μm.



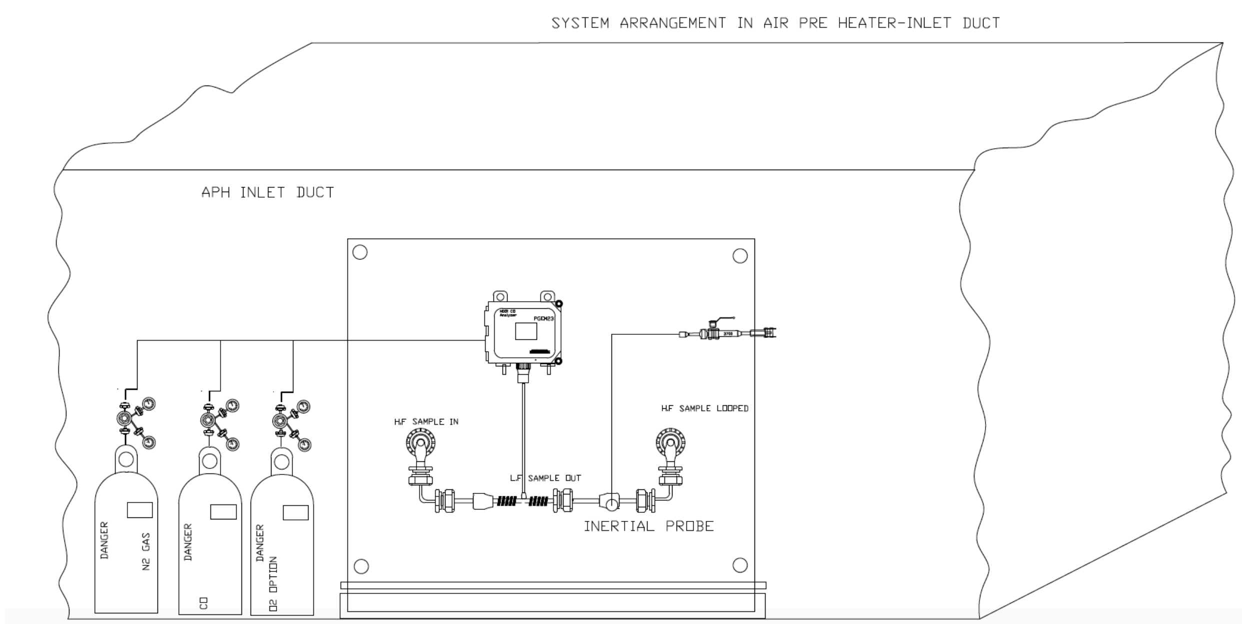
PMIF approach to gas filtration

IR ANALYZER OVERVIEW

The IR is a 19-inch panel-mounted tunable laser gas analyzer designed for "at-line" industrial analysis and environmental monitoring. Based on the optical measurement method of tunable diode laser absorption spectroscopy (NDIRAS), the analyzer scans absorption peaks of the measured gas (without background gas absorption), and the gas concentrations are calculated by high precision second harmonic algorithm.

FEATURES

- Universal structure, easy to integrate
- Adopts compact NEMA style wall-mounted / panel mounted chassis with modularized design of internal key components.
- Strong anti-interference ability, high measurement accuracy, small drift and high stability
- Utilizes the high stability and low noise semiconductor laser as the light source and adopts single line spectroscopy and laser wavelength scanning technology.
- Multiple parameters by single analyzer, rapid response
- Contain 1~4 laser transmitter modules, highly integrated in a small size; supports measurements of 1~5 customizable parameters, which are measured with short response time and high sensitivity for closed loop controls.
- Strong adaptability to working conditions
- The system adopts corrosion-resistant materials for the key components, making it applicable to petrochemical and other corrosive environments. Using extractive sampling, the system can be directly installed at the process pipeline for process and emissions control, with no moving parts with high reliability.



Model IR General Layout

Summary

Coal fired power plants can achieve the highest efficiency, lowest emission levels, and ensure safety by using CO concentration measurements to fine tune their excess O2 setpoint. These benefits are achievable only if the CO measurement is accurate and reliable. Using NDIR, the Model IR

Analyzer from ILLC can provide the accurate, reliable CO measurements in coal fired power plants

(information courtesy: www.energy.gov)