AMETEK®

PROCESS INSTRUMENTS

APPLICATION NOTE

CEMENT AND LIME KILNS

Cement, lime and gypsum manufacturing processes have in common the mixing of inorganic minerals calcined at high temperatures, typically using rotary or vertical kilns, and use multiple measurements for combustion control.

CEMENT

Regular Portland cements are the usual products for general concrete construction. The raw materials, limestone or chalk, together with clay or shale are mixed and fed to a large rotary kiln at temperatures up to 1427°C (2600°F). The mix can be taken through several preheater and pre-calciner stages before being charged into the rotary kiln.

Kilns are normally fired with pulverized coal or gas at one end. Raw materials are fed to the kiln at the back end, furthest from the burners. Travelling through the kiln, the ingredients are progressively heated. Here, flue gas flows in the opposite direction. The kiln can be divided into three zones – drying, calcining and burning. Drying removes the water from the mix; calcining drives off the carbon dioxide (CO_2); burning sinters and partially fuses the ingredients into lumps known as clinkers. These clinkers are then cooled and pulverized into fine powder. Some gypsum is used to control the speed of setting when water is added. After the kiln, the flue gas passes through various heat recovery stages, then to electrostatic precipitators for final clean-up before being discharged to the stack.

Some cement kilns are the wet "slurry" type. Slurry of raw materials is fed directly into the kiln. The temperature at the inlet is considerably less than the dry feed process. The kiln is also much longer to allow enough time for drying before calcination.

LIME

Lime or quicklime are the common names for calcium oxide (CaO), a gray-white powder. Either directly or indirectly lime and limestone are used in more industries than any other natural substance. It is used in the manufacture of glass, cement, brick, pulp/paper, steel, aluminum, magnesium and poultry feed. It also is used in processing cane and sugar beet juices. Lime kilns are associated with every Kraft pulp mill and often used in steel mills.

Since lime is manufactured from quarried limestone, lime plants are located near these deposits. The crushed raw material is fed to a rotary or vertical kiln where carbon dioxide is driven off to produce lime. The use of lime for any process depends on its composition and physical properties, which are controlled by the selection of the limestone and manufacturing process details. The quality and color affect the suitability of use and price.

Advantages of using Thermox analyzers in lime, cement and other industries with rotary kilns

- Measurement of oxygen (O_2), combustibles ($CO+H_2$), and methane (CH_4) in one unit
- Direct or indirect measurement
- Reliable sensor technology
- Fast response
- Ability to measure oxidizing or close to stoichiometric
- Maximized fuel efficiency via combustion control
- Increased product quality with reliable flue gas
- Many options to best fit application

WHY FLUE GAS MONITORING?

Kiln operators aim to ensure consistent product quality along with good fuel efficiency and increased production. Some reasons for flue gas monitoring include:

Efficiency

In all combustion processes, monitoring flue gas for oxygen and combustibles allows the process to be operated more efficiently. At the high operating temperature of kilns, even a small reduction in excess air gives a significant cost saving, which makes monitoring particularly important.

Product quality

Maintaining the air/fuel ratio within a specific range can be important for product quality. This can be especially true for lime kilns which use coal as a fuel. If the coal has high sulfur content, the lime product can be contaminated by sulfur dioxide unless the burner operates close to stoichiometric conditions.

Safety

Monitoring combustibles ($CO+H_2$) and methane (CH_4) can prevent build-up of explosive gases in electrostatic precipitators, bag houses, or ID fans, especially during the purge and light-off on kilns started up with natural gas.

Emissions reduction

Significant reduction in emissions of NOx and other pollutants can be achieved by maintaining good combustion control.

Process optimization and control

Reliable flue gas analysis provides information for effective control of kiln, preheater, and pre-calciner conditions.

Emissions monitoring

Continuous emissions monitoring (CEM) systems are required for reporting emissions but are not normally used for process optimization.

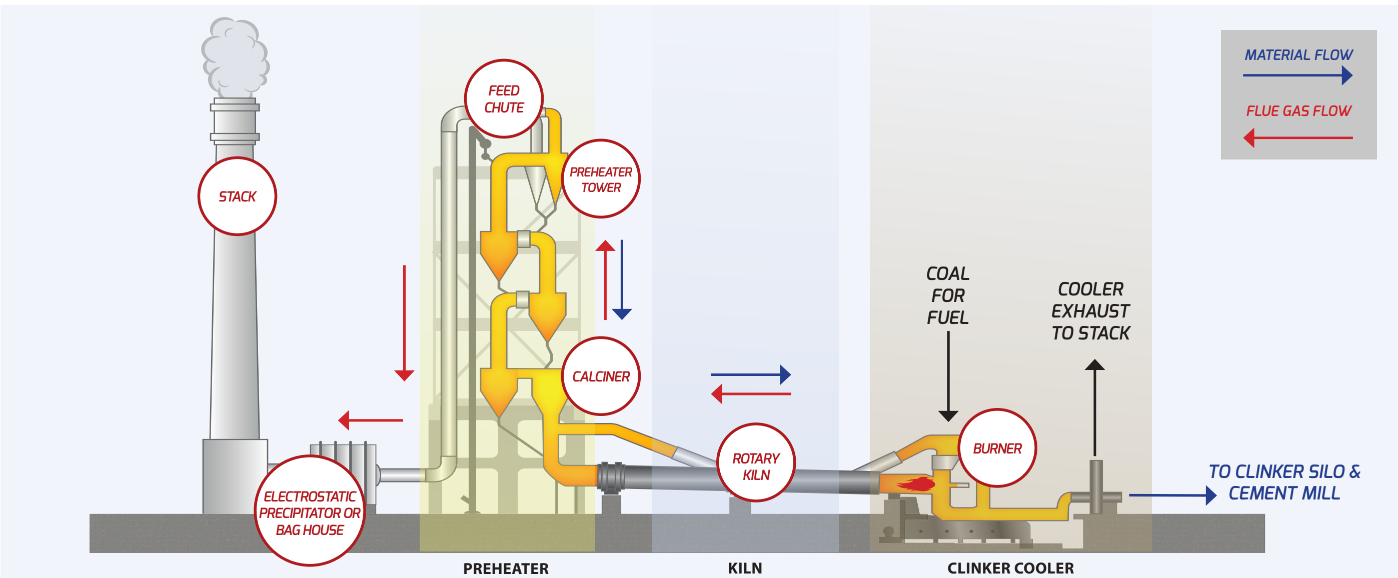

Figure 1. Cement lime process diagram

MEASURED GASES

Oxygen (O_2)

Zirconium oxide-based O_2 analyzers can be used either directly on the flue gas or connected to the end of a sample conditioning system. Paramagnetic, infrared, ultraviolet and fuel cell-based O_2 analyzers must have a perfectly clean dry sample and therefore can be used only after a sample conditioning system. If the sample conditioning system fails to operate correctly, the cells of these analyzers become coated or contaminated and are very expensive to repair.

Combustibles ($CO+H_2$)

Combustibles ($CO+H_2$) detectors are typically catalytic bead and are usually combined with the O_2 measurement in the same analyzer. Carbon monoxide (CO) alone may be measured using an infrared analyzer, but either requires sample conditioning or an across-the-stack approach downstream of the electrostatic precipitator or baghouse.

Methane (CH_4)

Measuring CH_4 provides an additional layer of safety that neither $CO+H_2$ nor CO analyzers can detect. CH_4 is the primary constituent of natural gas, and explosions have occurred from gas leaks prior to light off and burner flame-outs. Before ignition of a natural gas burner, a purge and light-off cycle aims to ensure that no gas is present, yet gas leaks can still occur, and measuring CH_4 provides a preventative safety measurement independent of the purge cycle. Even after the burners are lit, CH_4 measurement provides an early detection of a potential flame-out. Due to the physical nature of gas-fired rotary kilns, which can channel explosive energy, CH_4 detection can be a particularly important safety measurement.

METHODS OF FLUE GAS MONITORING

Although kilns are a difficult application, customer trial and error has driven several effective approaches to measure flue gas in rotary kilns. Knowing the flue gas characteristics – temperature, stickiness of the particulate, corrosivity, fluidity, and abrasiveness – helps to determine which methods may be suitable. Direct measurement often works better for low temperatures and dry, non-sticky particulate while sampling systems or bypasses support higher temperatures and wet applications. Although there is no single "best" way, the following are common approaches.

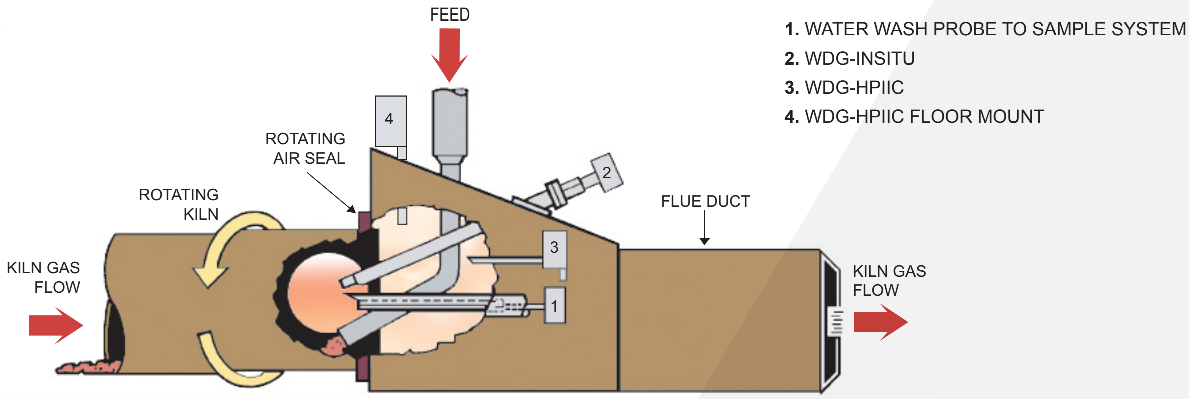

Figure 2. Various kiln measurements

1. Direct measurement

Direct measurement before the seal

Although the most difficult approach, direct measurement in the kiln ahead of the rotating seal is also preferred by customers for precise control of the kiln firing to avoid errors from ingress air from the seal itself. Temperatures here are typically 1038° to 1204°C (1900 to 2200°F) on a dry cement process and 427° to 982°C (800 to 1800°F) on a wet slurry cement process or lime kiln. Under 677°C (1250°F), an insitu can be used for an oxygen (O_2)-only measurement. In many dry cement kilns, only a water-cooled probe can survive the high temperatures for extended operation. Some customers install a type of deflector pipe to the process and mount the analyzer directly onto it. The analyzer probe extends almost to the end of the deflector pipe, which is open in the direction opposite of the gas flow shielded by the deflector. Others use a standard probe and filter with variable success rates (see Figure 2, Probe 2).

Direct measurement after the seal

Several analyzers can be used in the kiln hood or at any point in the flue gas path between the kiln and the final stack, including the WDG-HPIIC (< 1024°C to measure O_2 & combustibles ($CO+H_2$) and the WDG Insitu (< 677°C for O_2 only). The difficulty at the kiln hood is accessibility to clean the probe and service the analyzer. Past the rotating seal, the measurement in the hood can be influenced by air leakage, which is why direct measurement before the seal is often preferred. However, multiple measurement points are often useful for comparison and ensure good combustion control throughout the process. Both the WDG Insitu and WDG-HPIIC are diffusion-based analyzers and can be used directly in high particulate applications (see Figure 2, Probes 3 and 4).

Direct measurement in the pre-heater

Within the preheater, process temperatures are normally cooler (< 677°C/1250°F), and both the WDG-HPIIC and WDG Insitu can be directly mounted at a suitable point in the ductwork.

2. Sample conditioning systems

Sample systems are often connected to a water-cooled probe or automated/motorized probe ahead of the seal (refer to Figure 2, Probe 1). This presents a cleaned, cooled flue gas sample to a bank of analyzers located in an analyzer shelter. The analyzers may include O_2, CO, and at times, CO_2 to ensure process and combustion control. These analyzers can be easily damaged by sample system upsets and require frequent, if not daily, calibration. A separate probe from the final stack is used for continuous emission monitoring of O_2, CO, NOx, and SO_2. The WDG-VC or WDG-VCM can replace the O_2 and CO analyzers used for process control on an existing sample system, and the unistrut option allows for convenient mounting of the analyzer on a wall or panel.

3. Bypass Systems

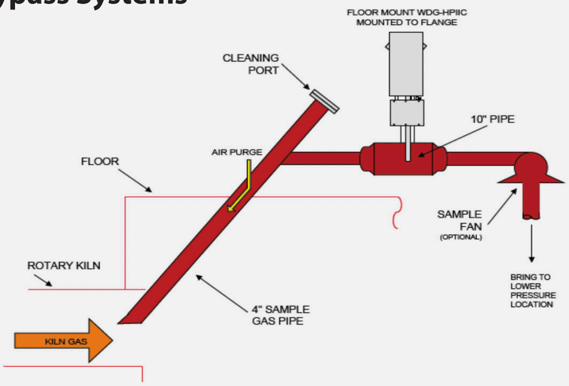

Figure 3. Bypass vertical probe

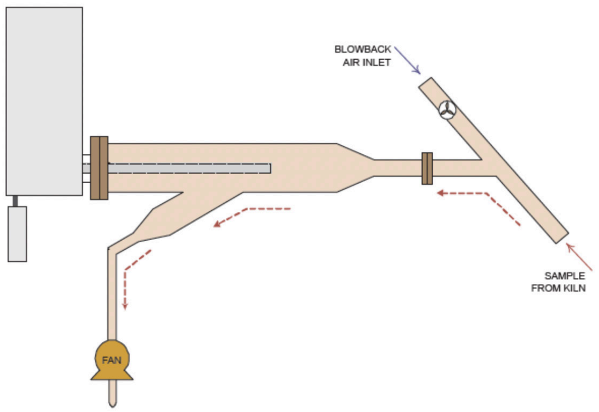

Figure 4. Bypass horizontal probe

In a bypass system, the sample pipe is inserted into the kiln behind the seal and routed out of the kiln to a part of the ductwork at a slightly lower pressure. This causes the sample to flow through the bypass and the analyzer can be located at a suitable position. A fan may be required to assist the flow. A bypass system still requires regular maintenance to keep it clean, but the system can be designed with easy access ports.

Figure 3 shows the analyzer mounted vertically on a larger diameter section of the bypass. The version shown in Figure 4 uses a Y-shaped pipe with the probe mounted horizontally in one of the arms of the Y. Another approach brings the pipe to a large sample box upon which the analyzer (or multiple analyzers) can be mounted (Figure 5).

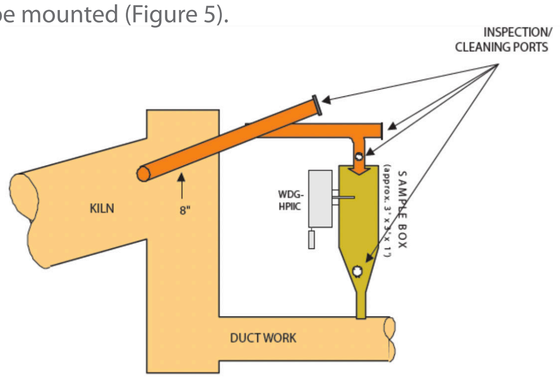

Figure 5. Bypass sample box

ELECTROSTATIC PRECIPITATOR PROTECTION

For electrostatic precipitator protection, we recommend the WDG-VCM and WDG-HPIICM. Normally the combustibles ($CO+H_2$) high alarms are set to 0.8%, at which point the precipitator or other devices can be shut down. Since a standard catalytic $CO+H_2$ detector does NOT respond to methane (CH_4), high levels of CH_4 which may have leaked into the burner chamber at start up can lead to an explosion. A useful precaution in this case is to use an analyzer fitted with the additional CH_4 detector.

RELATED INDUSTRIES WITH KILNS

In addition to cement and lime, rotary kilns are used for other applications. Some of the applications have considerable vibration which would damage the analyzer.
A flexible mount, shown in Figure 6, can be used to minimize the effect of vibration. An anti-vibration furnace is also recommended.

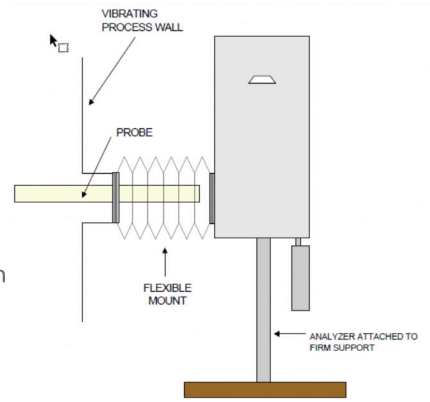

Figure 6. Flexible mount

SUMMARY

AMETEK's Thermox line of products has a large installed base in rotary kiln measurement in the cement, lime, pulp and paper, steel, minerals, and waste disposal industries. These analyzers offer flexibility in design and options and can be adapted to practically any situation.

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