

## Cement and Lime Kilns

### PROCESS DESCRIPTION

Cement, lime and gypsum manufacturing processes have in common the mixing of inorganic minerals calcined at high temperatures typically using rotary kilns (vertical kilns are also used).

#### 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 2600°F (1427°C). The mix can be taken through a number of preheater and precalciner 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;

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. Also the kiln is much longer to allow sufficient time for drying before calcination. Figure 1 is a schematic of a typical cement plant.

The tremendously high temperature sustained by cement kilns and the long transit time are ideal for the disposal of material such as tires or hazardous wastes.

#### 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 particular 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

- Measure O<sub>2</sub>, Combustibles (CO + H<sub>2</sub>), and Methane
- Direct or indirect measurement
- Reliable sensor technology
- Fast response
- Ability to measure oxidizing or close to stoichiometric
- Maximize fuel efficiency and product quality with reliable flue gas measurement
- Many options allow choice of analyzer style for optimum performance

# WHY FLUE GAS MONITORING?

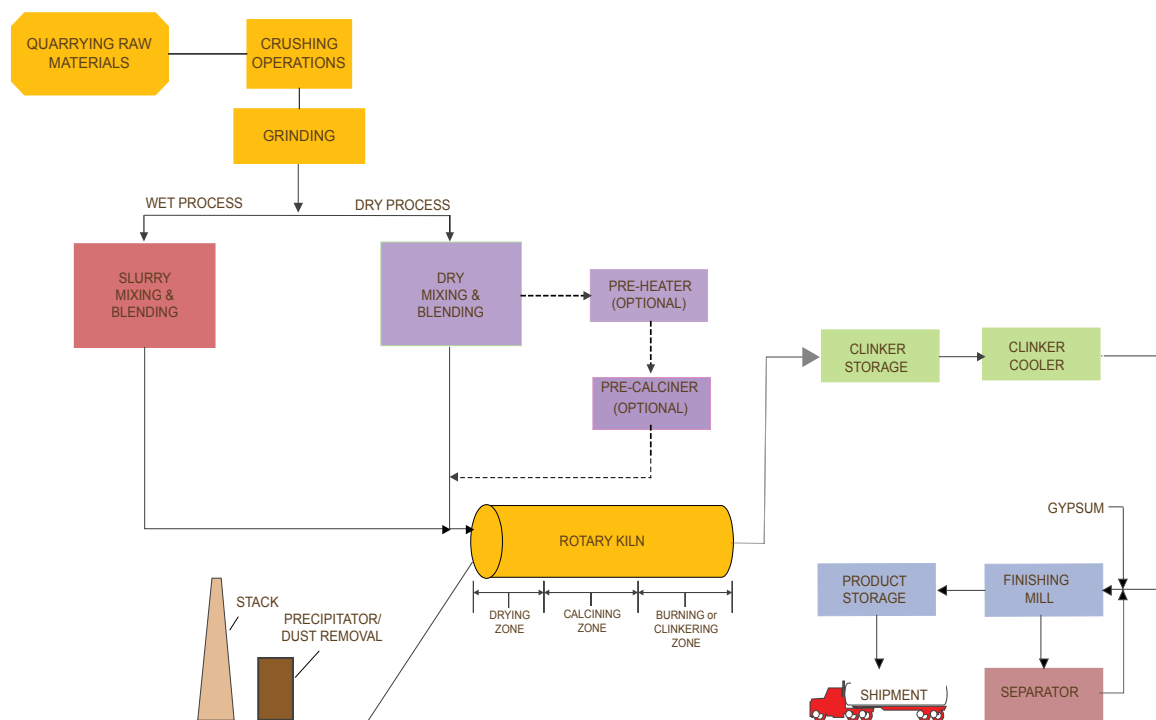


Figure 1. Typical Cement Plant

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 (or CO) 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 savings which makes monitoring particularly important.

## ■ Product Quality

Maintaining the air/fuel ratio within a specific range can be important for product quality. For example, lime kilns use coal whenever possible due to the high temperature and high cost of firing with natural gas. If the coal has a high sulfur content, it is necessary to operate the kiln close to stoichiometric to avoid contamination of the lime with SO<sub>2</sub>. This is important for lime used in steel manufacture or as a neutralizing agent for SO<sub>2</sub> removal plants.

## ■ Safety

Monitoring CO, combustibles and methane can prevent build-up to the levels that can cause an explosion in electrostatic precipitators, bag houses or ID fans. CH<sub>4</sub> is measured during the purge and light-off on kilns started up with natural gas.

## ■ Emissions Reduction

Significant reduction in emissions of NO<sub>x</sub> 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 precalciner conditions.

## ■ Emissions Monitoring

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

Recent advances in sensor technology combined with alternative methods of mounting flue gas analyzers have allowed much more dependable measurement of oxygen and carbon monoxide or combustibles in the flue gas from rotary kilns.

As desirable as it is to measure for the above reasons, it is also very difficult to measure the flue gas in cement and lime kilns. This is due to the combination of high temperature, heavy particulate loading, and the tendency of the material to aggregate. It is preferable to measure in the kiln ahead of the rotary seal so that air leakage does not affect the reading. This often necessitates a long probe, typically 9 ft. (2.7 m), which further compounds the difficulty. Figure 2 shows a schematic of the flue gas/burning section of the plant.

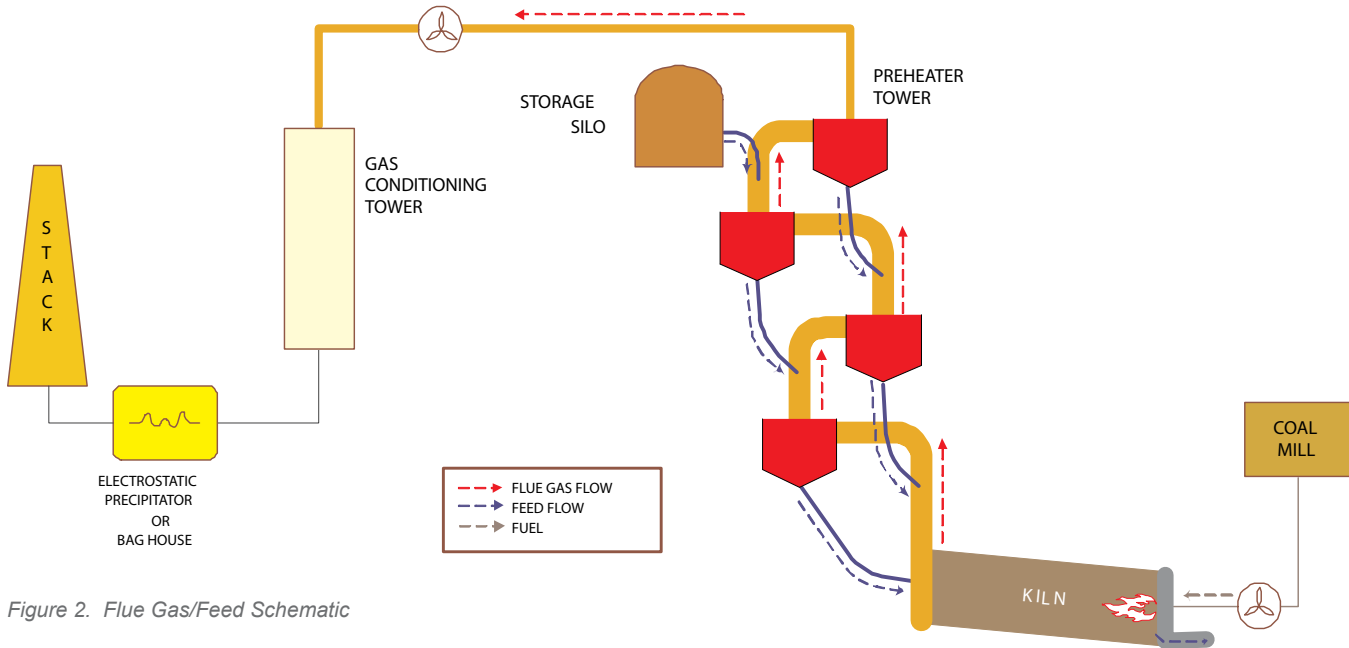


Figure 2. Flue Gas/Feed Schematic

## Oxygen (O<sub>2</sub>)

Zirconium oxide-based oxygen analyzers can be used either directly on the flue gas or connected to the end of a sample conditioning system. Paramagnetic or fuel cell-based oxygen analyzers must have a clean dry sample and therefore can be used only after a sample conditioning system.

## Carbon Monoxide (CO) and Combustibles (CO+H<sub>2</sub>)

Carbon monoxide analyzers are infrared and can either be across-the-stack or at the end of a sample conditioning system. The across-the-stack version can be used only after a sample clean up device such as an electrostatic precipitator. Combustibles detectors (CO and H<sub>2</sub>) are typically catalytic bead and are usually combined with the oxygen measurement in the same analyzer. Most analyzers used on sample conditioning systems are based on paramagnetic, infrared, ultraviolet or electrochemical technology and require a perfectly clean, dry sample gas. If the sample conditioning system fails to operate correctly, the cells of these analyzers become coated or contaminated and are very expensive to repair.

## Methane (CH<sub>4</sub>)

Neither combustibles nor carbon monoxide detectors are able to measure methane, the primary constituent of natural gas. Before ignition of a natural gas burner, a purge and light-off cycle aims to ensure that no gas is present, but explosions still occur. An on-line methane measurement detects the presence of natural gas before ignition independently of the purge cycle. Once the burners are lit, methane no longer exists - only CO and H<sub>2</sub>. This measurement can be combined with oxygen and combustibles in the WDG-IVCM 3-in-1 analyzer. Due to the physical nature of gas-fired rotary kilns, which can channel explosive energy, methane detection can be of particular importance.

There are many different ways of measuring the flue gas from rotary kilns. All have been developed by customers through many years of trial and error with their own process. The customer knows the characteristics of the flue gas – temperature, stickiness of the particulate, corrosivity, fluidity, and abrasiveness. He or she will generally know which kind of system is most likely to survive in the process. There are as many different solutions as there are plants. It is important to work within the framework of the customer's experience. Most customers prefer to measure at a point ahead of the rotating seal for precise control of the kiln firing conditions without errors caused by the ingress of air from the seal. However, analysis can be made at any point between the kiln and the final stack. Direct measurement works for lower temperature, dry applications where ceramic is not required and the particulates do not stick to the probe to build a large "beehive". Making use of an existing sample system or a bypass is preferred for high temperature applications, although some customers are measuring directly in the kiln with varying degrees of success and maintenance frequency. There is no single "best" way to monitor in kiln applications, but here are some approaches.

## 1. Direct Measurement

### *Direct Measurement Before the Seal*

Direct measurement in the kiln ahead of the seal is the most difficult. Temperatures here are typically 1900° – 2200°F (1038° – 1204°C) on a dry cement process and 800° – 1800°F (427° – 982°C) on a wet slurry cement process or a lime kiln. An insitu can be used if oxygen-only measurement is required and the temperature is under 1250°F/677°C. In many dry cement kilns, the temperature is high enough that only water-cooled probes can survive for extended operation. Some customers use a type of deflector pipe installed in the process with the analyzer mounted directly to this. 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 3, Probe 2).

### *Direct Measurement After the Seal*

A WDG-HPIIC (O<sub>2</sub> and combustibles, less than 1875°F/1024°C) or a WDG-Insitu (O<sub>2</sub> only, less than 1250°F/677°C) can be used in the kiln hood or at any point in the flue gas flow path between the kiln and the final stack. The difficulty at the kiln hood is accessibility for cleaning of the probe and service of the analyzer. The measurement in the hood can be influenced by air leakage past the rotating seal and hence many customers prefer to have a sample taken from before the seal. However it is often useful to measure at other points in the process for good combustion control and comparison. Both the WDG-Insitu and WDG-HPIIC are diffusion-based analyzers and can be used directly in high particulate applications (see Figure 3, Probes 3 and 4).

### *Direct Measurement in the PreHeater*

As the temperature is normally cooler here (less than 1250°F/677°C), a WDG-HPIIC or a WDG-Insitu can be used directly mounted at a suitable point in the ductwork.

## 2. Sample Conditioning Systems

A water-cooled probe or an automated/motorized probe ahead of the seal is often connected to a sample system (refer to Figure 3, Probe 1). This presents the cleaned, cooled flue gas to a bank of analyzers located in an analyzer shelter. The analyzers are oxygen, carbon monoxide and sometimes carbon dioxide used for process and combustion control. They are 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. The gases measured include oxygen, CO, NO<sub>x</sub>, and SO<sub>2</sub>.

The ThermoX WDG-IVC or WDG-IVCM can replace the oxygen and CO analyzers used for process control on an existing sample system. The unistrut option allows the analyzer to be mounted on a wall or panel in a convenient location.

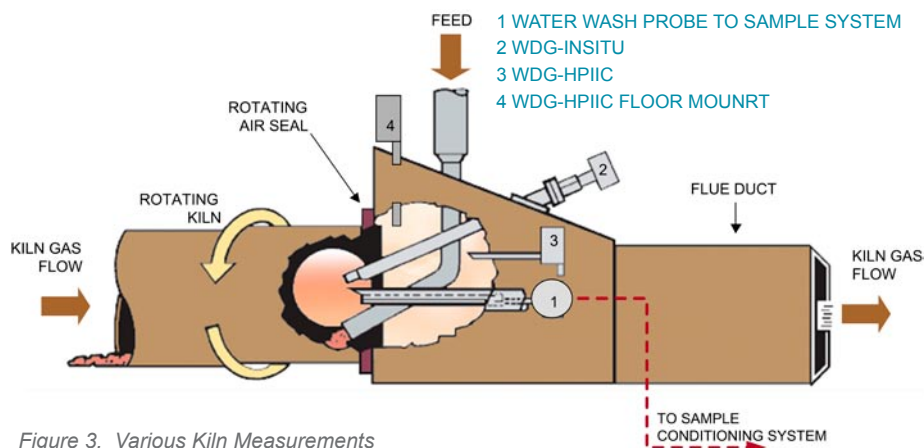
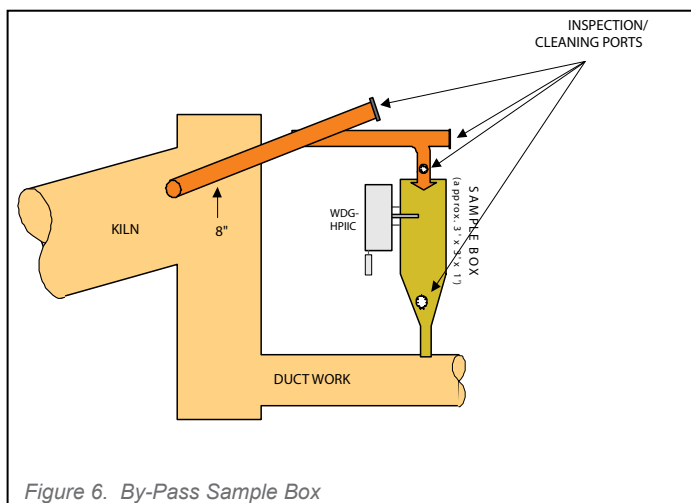
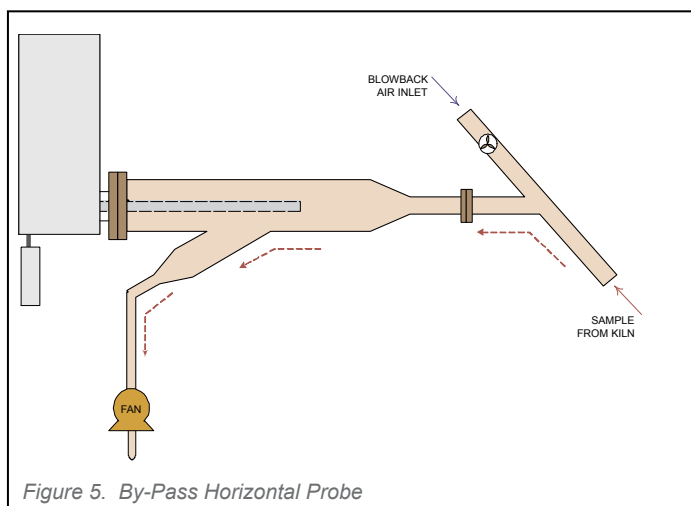
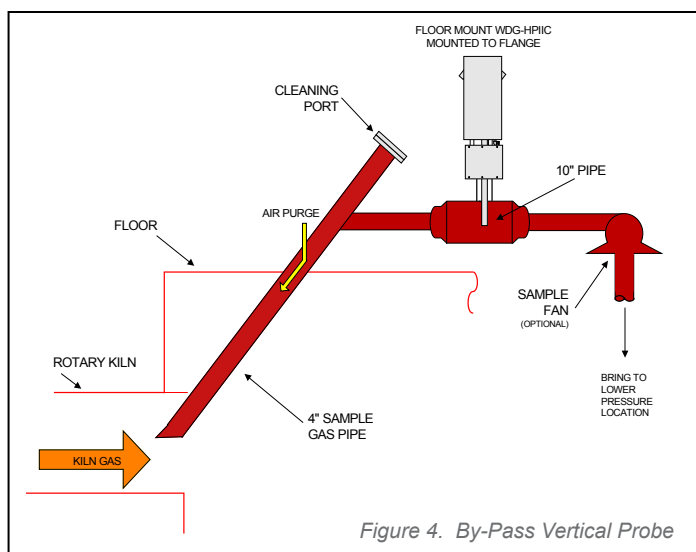


Figure 3. Various Kiln Measurements

## 3. By-Pass Systems

In a by-pass 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 by-pass and the analyzer can be located at a suitable position. A fan may be required to assist the flow. A by-pass system still requires regular maintenance to keep it clean but the system can be designed with easy access ports. Figure 4 shows the analyzer mounted vertically on a larger diameter section of the by-pass. The version shown in Figure 5 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 6).





## ELECTROSTATIC PRECIPITATOR PROTECTION

For electrostatic precipitator protection, we recommend the WDG-IVCM, and WDG-HPIICM. Normally the combustibles high alarms are set to 0.8% at which point the precipitator or other devices can be shut down. Since a standard catalytic combustibles detector does NOT respond to methane, high levels of methane 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 methane 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 7, can be used to minimize the effect of vibration. An antivibration furnace is also recommended.

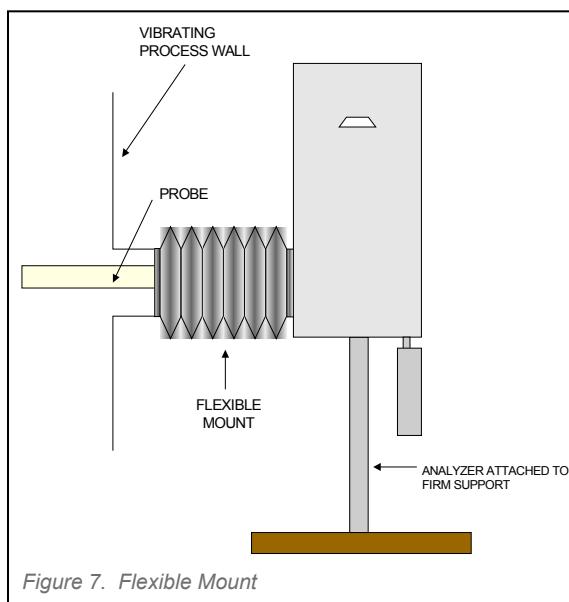


Figure 7. Flexible Mount

## SUMMARY

AMETEK/Thermox has a large installed base in rotary kiln measurement in the cement, lime, pulp and paper, steel, minerals, and waste disposal industries. The Thermox analyzers offer flexibility in design and options and can be adapted to practically any situation. We will be pleased to advise on your analytical application and invite you to contact your nearest AMETEK Process Instruments' office for assistance.



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apnote cement-lime (5/07)

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