

# Use of process analyzers in cement plants

## Solutions from Siemens

### Cement

Cement represents the main binding ingredient to produce concrete which is the most common construction and building material.

Cement was first made early in the 19th century by burning powdered limestone and clay. Today, the cement industry is an important and significant part of any economy. The world consumption of cement is estimated to exceed 2 Mt in 2004, with China (45%) being the largest producer, followed by India and the USA. Cement production is rather decentralized in more than 1,600 cement plants worldwide, because most cement plants are located close to the source of raw materials to minimize transportation costs.

Cement, mostly Portland Cement, is made from a mixture of calcium carbonate (generally in the form of limestone), silica, iron oxide and alumina. A high-temperature kiln fuelled by coal, natural gas or alternative fuels (waste tires, oils or solvents) heats the raw materials to a partial melt at 1450 °C, transforming them chemically and physically into clinker. This grey-green material comprises the special compounds that give cement its binding properties. Clinker is then ground with gypsum, flue ash and/or sand to make cement.

Process optimization, operating conditions control and emissions monitoring are tasks that require the use of efficient measurement techniques. For this purpose, devices and systems of *process analytics* perform indispensable services at many locations and measuring points in a cement plant.

# cement INDUSTRY

Cement is a hydraulic binding agent to produce concrete. Due in part to the fast growth of the Asian economies, world consumption of cement is currently growing at an annual rate of 8%. Therefore, cement production is expanding and, at the same time, production processes need to be optimized to ensure maximum efficiency. In this context, process analytics plays an important role: It determines reliable and exact data from the processes and thereby allows their optimization.

Siemens is a leading provider of process analytics. Over decades, Siemens has proven its ability to successfully and reliably implement analysis systems for cement plants, with services ranging from planning and commissioning through to maintenance.

This case study provides an overview of the cement production processes and describes how Siemens solves defined analysis tasks with its broad portfolio of instruments and systems engineering as well as its experience with applications.

# SIEMENS

# The cement production process

## Cement Production

Cement production (Fig. 1) involves the fusing together of precisely controlled blend of calcium, silicon, aluminum, iron and small amounts of other ingredients at high temperatures. Common among the materials used are limestone, shells and chalk or marl, combined with clay, silica sand, blast furnace slag, and iron ore. Lime and silica make up about 85% of the mass. The three basic process steps in cement manufacturing are

- *Preparation, blending and milling* of the raw material to raw meal that is used as kiln feed.
- *calcination and burning (sintering)*. This conversion process takes place within the cement kiln and its associated equipment.
- *Finish milling*, the grinding of clinker to produce cement.

Cement manufacturing is an energy intensive process because raw materials must be dried and heated to temperatures of about 1400 °C to initiate the chemical reaction that produces cement clinker.

## Kiln technologie

The core technology of a cement plant is the *cement kiln* (Fig. 2). This is the area where investment costs are highest, fuel demands are largest, and process control is the most crucial. All kilns rely on the same basic process - raw feed passing through the kiln is heated to very high temperatures and transformed chemically and physically into clinker.

Kiln technology has developed over years from vertical shaft to rotating kilns and from wet to dry processes. There are wet rotary kilns, rotary kilns with grid preheaters and rotary kiln with cyclone preheaters (with or without precalciners). Wet process kilns are generally older than dry kilns. Long wet and dry kilns have only one combustion zone, whereas kilns with a precalciner have a second combustion stage upstream the kiln inlet.

Preheaters and precalciner have been introduced to improve the energy efficiency of the process. Energy savings are estimated to reach 50 %.



Fig. 2: Cement and rotary kiln

## Preliminary processing

The main raw material for the manufacture of clinker is lime-bearing material. Limestone consisting almost entirely of calcium carbonate ( $\text{CaCO}_3$ ) and shale containing a high proportion of silica ( $\text{SiO}_2$ ) and lesser amounts of alumina ( $\text{Al}_2\text{O}_3$ ) and ferrous oxide ( $\text{Fe}_2\text{O}_3$ ) provide the essential constituents for the manufacture of cement. Mined or dredged from the quarry (Fig. 3) and separately crushed, the materials are stored and then blended to the required mixture. The proportions are governed by the chemical properties of the materials and the desired product. Moisture content of the raw materials is important because energy is required to dry them before the chemical conversion reaction can start.

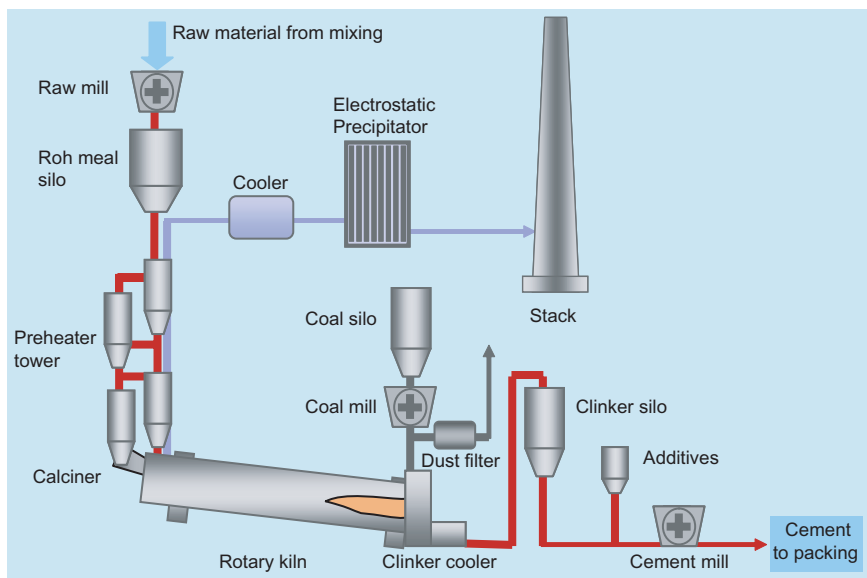


Fig. 1: Cement plant flow chart



Fig. 3: Quarry



## Feeding the raw mix

### Wet processes

In wet processes, the raw materials, ground in the slurry mill and properly blended in water basins, are fed into the kiln in form of a slurry. This process type is very energy consuming and requires a relatively long rotary kiln because the drying process must be carried out in the kiln itself before the chemical conversion reaction can start.

### Dry processes

In dry processes, the raw materials are ground (Fig. 5), mixed and then - in new or revamped plants - passed through units called *preheater* and *precalciner* before being fed to the kiln. These units are arranged in tall towers (Fig. 4) upstream from the kiln inlet.

**Preheaters** comprise a series of vertically aligned cyclones. Hot kiln exhaust gases flow up through the cyclones. As the raw meal travels down through the cyclones, it is heated by the exhaust gas in counterflow to a temperature of about 800 °C while the gas is cooled to about 350 °C. Caused by the high temperatures of the raw mix, the calcination process is initiated. Thus, calcination is the process of heating solid material to



Fig. 5: Raw meal grinder

drive off volatile chemically combined components, e.g. carbon dioxide. In the lowest cyclone of the preheater, a partial calcination of 20-40 % is already achieved at gas temperatures of about 850 °C.

In **precalciners**, the calcination process is continued up to a 90 % level at temperatures of 950 °C.

Accordingly, evaporation, preheating and some calcination occur in the preheater, calcination is largely completed in the precalciner, and the kiln is used mainly for the sintering stage. Preheater and precalciner technology saves fuel, allows shorter kilns and increases kiln capacity.



Fig. 4: Preheater/Precalciner-Tower

## Burning the clinker

Burning of the raw mix to clinker takes place in the rotary kiln. This is a large, long welded steel tube lined with refractory materials and inclined slightly towards one end. It rotates slowly and is fired from the lower end by powdered coal, oil, gas and waste-derived fuels. The rotation of the kiln conveys the raw meal powder from the inlet towards the firing zone.

Principally, the burning process is structured into three stages:

- During *evaporation and preheating* moisture is removed and temperature of the raw mix raised (in wet processes only).
- *calcination* takes place at 800-900 °C and breaks the calcium carbonate down into CaO and CO<sub>2</sub> which evolves.
- As the temperature continues to rise approaching 1500 °C, the process of *sintering* starts where lava-like mass with a complex chemical composition is produced.
- The clinker is discharged from the lower end of the kiln into an air cooler under the burner floor for *cooling*. The heated air from the coolers is returned to the kiln. After cooling, the product has the appearance of dark grey gravel and is called cement clinker.

The process of producing clinker is critical to the quality of cement and requires accurate control of the energy input. Insufficient heat will cause the clinker to contain unconverted lime, excess heat will shorten the life of the refractory bricks, may damage the kiln shell and diminish product reactivity.

## Finish milling the clinker

Finish milling is the grinding of clinker (Fig. 6) to produce a fine grey powder. Gypsum ( $\text{CaSO}_4$ ) is blended with the ground clinker, along with other materials, to produce finished cement. The gypsum controls the rate of hydration of the cement in the cement-setting process.

Significant amounts of electric power are required to operate the clinker mills depending on the fineness of the product and the distribution of particle size. The finer the grind, the more reactive is the finished cement.

## Plant efficiency

The cement industry has boosted efficiency by concentrating new capital investments in plants that use the dry process of cement manufacture, and by phasing out operations that rely on the more energy-intensive wet process. Currently, about 80% of the cement produced in the United States is manufactured using dry process technology.

With the development of preheater and precalciner technology, energy efficiency within cement production has reached remarkably high levels, approaching the limits of thermal efficiency. Further improvements are likely to focus more on refinements in exact process monitoring and control.

As cement manufacturing is based on a number of chemical reactions running at high temperatures, the **chemical analysis of the process gas** at all important stages of the manufacturing process provides essential information

- to optimize combustion conditions and reduce fuel consumption
- to improve and secure product quality
- to increase plant service-time and availability and
- to reduce maintenance requirements.

## Optimized combustion

It is well known that the kiln is the heart of the cement plant but it is not always appreciated that a delicate balancing act is required between combustion, energy consumption, and product quality.

Energy efficiency and emission behaviour in industrial furnaces depend largely on the correct distribution of fuel and air supplies to the combustion process. The oxygen required for the combustion is fed as part of the combustion air. In an ideal (stoichiometric) combustion, the amount of oxygen supplied to the process is just sufficient to burn all combustibles completely. In real combustion, however, an excess volume of oxygen (air) must be supplied due to insufficient mixing of fuel and oxygen. Too low oxygen content will cause an increase of CO emissions due to incomplete combustion. Too high oxygen content will cause increased NO<sub>x</sub> content and energy losses through dilution with cool air. Every 1% of excess oxygen content causes an increase in energy consumption of 15 kcal per kg clinker, which results in more than 50 million kcal per day higher energy demand for a kiln with 3,500 t/day output.

Therefore, gas analysis at the kiln inlet (Fig. 7) is essential for the entire process optimization. Despite the very difficult conditions, gas samples are extracted directly from the kiln inlet by a high-tech sampling probe technology. Read more on page 9.

## Environmental impact

Historically, emission control regulations for cement plants have focused on particulate emissions only. Over the past decades, however, regulations for the control of NO<sub>x</sub> and other hazardous pollutants have been also adopted.

A major increase of the number of regulated pollutants is due to the increasing use of co-incineration of waste materials such as tires, used oil, etc. in addition to conventional fuels.



Fig. 6: Finishing mill



Fig. 7: FLK gas sampling probe at the kiln inlet

Today, air pollutants associated with cement manufacturing (regulated and non-regulated) include particulate matter, NO<sub>x</sub>, SO<sub>x</sub>, CO, CO<sub>2</sub>, hydrocarbons, HCl, HF, Hg, heavy metals and other substances. Some of the pollutants, however, may not be present at significant mass rates or measurable concentration levels for the respective plant.

*Gas analysis at the stack* assures the compliance of the entire plant operation with the emission regulations set by the governmental or local authorities.

Read more on pages 8 and 11.

# Process gas analysis in cement plants

## Gas analysis objectives

In cement plants, the use of continuously measuring gas analyzers and measuring instruments is required at many locations. The measurement results are used to provide

- **Performance data** for the cement plant through continuous monitoring of all process steps and optimization measures, resulting in energy savings and helping to safeguard product quality.
- **Safety for personnel and equipment** through monitoring for risks of explosion or fire (electrostatic filter and coal silo/mill).
- **Environmental protection** through the control of the systems used for exhaust gas purification (filters, scrubbers) and monitoring the residual concentrations of limited substances in the exhaust gas to maintain the permitted limit.

During cement production, the largest share of production costs results from the amount of fuel used. Complete combustion at sufficient oxygen content level is important for reducing toxic materials in the exhaust gas. An excess of oxygen, however, means a waste of resources. Therefore, in addition to dust as major pollutant, the following gaseous compounds must be determined

- **Carbon monoxide (CO) and oxygen (O<sub>2</sub>)** concentrations allow the plant operator to optimize the combustion in the rotary kiln with respect to clinker quality compliance, toxic emissions reduction, and fuel consumption minimization.
- **Nitrogen oxide (NO)** is a strong indicator for the combustion temperature. As a constant temperature in the sintering zone is of great significance for the clinker quality, NO analysis is an appropriate means for achieving optimal kiln operation.

- **Sulfur dioxide (SO<sub>2</sub>)** arises from the sulfur content of the raw material and of the fuel. Its determination becomes increasingly important because of the increasing use of alternative fuels with high sulfur content. High concentration of SO<sub>2</sub> in the gas circuits results in increased corrosion and unwanted caking of material. In addition, a fast rise of the SO<sub>2</sub> content is an early warning of a combustion fault.
- **Other gas components** considered as pollutants with regulated limit values such as hydrocarbons, HCl, HF, Hg.

## Sampling system demands

Extremely difficult environmental conditions in the rotary kiln of a cement plant put very high demands on the sampling system. Gas temperatures up to 1400 °C, dust concentration up to 2000 g/m<sup>3</sup> and the high content of alkali, sulfate and chloride are typical sampling conditions. High concentrations of sulfur and alkali very frequently result in blockages in the gas paths requiring high maintenance of the gas sampling equipment.

## Measuring principles of gas analysis

Analysis instruments are not "universal devices". Suitable instruments and measuring principles must be selected for each application, which requires experience and expert knowledge.

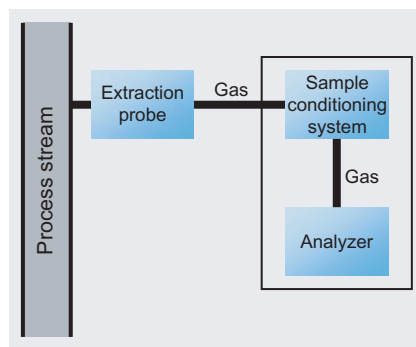


Fig. 8: Extractive measuring principle

For this purpose, analytical requirements as well as economic considerations or local conditions are important. A general distinction must be made concerning the measuring principles:

**The extractive measuring principle** (Fig. 8) is based on the measurement of a sample taken from the process flow and suitably prepared (among other things by defined drying through cooling) outside of the process atmosphere. Here, measurements are taken under optimal measurement conditions, but without being „real-time“.

**The in-situ measuring principle** (Fig. 9) means measurement directly in the gas channel, isochronous with the process and with the possibility of a very fast response. However, parts of the measuring instrument are directly subjected to often harsh conditions in the process. Furthermore, the measurement is performed with a generally wet process gas which must be taken into account in a comparison of measurement results with those of other methods.

Both measuring principles have useful application areas. They complement each other and a supplier of both measuring principles can offer the user the best solution for his specific tasks.

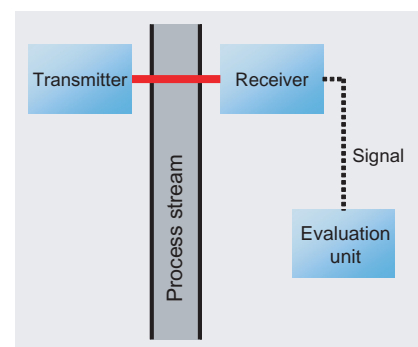


Fig. 9: In-situ measuring principle

# Typical measuring points and measuring components

## Typical measuring points

Fig. 10 shows the positions of typical measuring (sampling) points in a cement plant. Fig. 11 lists the respective measuring components and measuring ranges together with the Siemens analyzers which are particularly suited for the respective task.

Real systems may be designed differently depending upon the plant supplier and the specific requirements of the plant owner or operator.

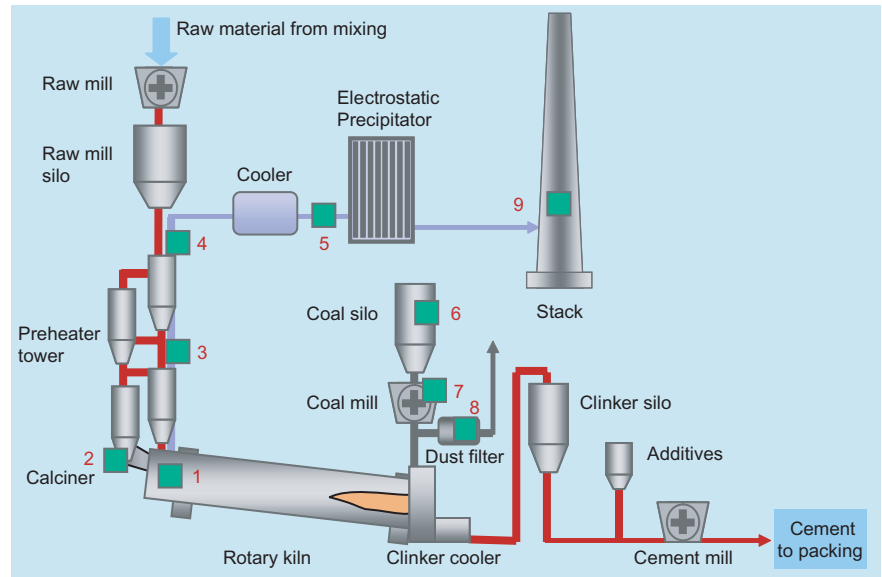


Fig. 10: Gas analysis measuring points in a cement plant

MP	Sampling location	Component	Typical measuring range	Measuring task	Siemens equipment	Siemens solution
1	Rotary kiln inlet	CO O <sub>2</sub> NO SO <sub>2</sub>	0 ... 1 % 0 ... 5 % 0 ... 1500 vpm 0 ... 2 %	Combustion control Combustion control Thermal conditions; emission control Combustion disturbance	ULTRAMAT 23 OXYMAT 6 FLK sampling probe	Page 9
2	Calciner	CO O <sub>2</sub>	0 ... 1 % 0 ... 5 %	Combustion control Combustion control	ULTRAMAT 23 OXYMAT 6	
3	Cyclone preheater	CO O <sub>2</sub> NO	0 ... 1 % 0 ... 5 % 0 ... 1500 vpm	Combustion control Combustion control Thermal conditions; emission control	ULTRAMAT 23 OXYMAT 6	
4	Preheater exit	CO CO <sub>2</sub>	0 ... 1 % 0 ... 50 %	CO monitoring Calcination level	ULTRAMAT 23	
5	Upstream electrostatic filter	CO O <sub>2</sub>	0 ... 1 % 0 ... 5 %	CO monitoring False air	LDS 6 ULTRAMAT 23	Page 10
6	Coal silo	CO	0 ... 3 %	CO monitoring	LDS 6 ULTRAMAT 23	Page 10
7	Coal mill	O <sub>2</sub>	3 ... 10 %	False air	OXYMAT 6 ULTRAMAT 23	
8	Dust filter after coal mill	CO	0 ... 3 %	CO monitoring	LDS 6 ULTRAMAT 23	
9	Stack	CO CO <sub>2</sub> NO <sub>x</sub> SO <sub>2</sub> O <sub>2</sub> THC HCL HF, Hg Dust		Emission monitoring	ULTRAMAT 6 ULTRAMAT 6 ULTRAMAT 6 ULTRAMAT 6 OXYMAT 6 FIDAMAT 6 LDS 6 LDS 6 NN	Page 11

Fig. 11: Measuring points, components and measuring ranges, according to Fig. 10



# Cement kiln exhaust gas

## Exhaust Gas

Burning of organic material such as coal, oil or waste in the kiln generates exhaust gas that can not be released into the atmosphere because of environmental protection, without a purifying secondary treatment (exhaust gas purification). International and national authorities specify concentration limits for dust and certain chemical compounds in guidelines and regulations that must not be exceeded in the exhaust gas prior to leaving the stack. Regulations may differ depending on whether kiln firing is based on the waste co-incineration principle or not.

## Exhaust gas contents

The exhaust gas of a cement kiln is composed of the following major components. Some of them are treated as air pollutants with lowest permissible concentration values specified in relevant international and national directives and regulations (Fig. 12 and page 8).

### Cement dust

Cement dust emissions are generated mainly in the kiln. Two methods are used to capture the dust, bag filters or electrostatic precipitators (ESP). ESP filters use the action of force on charged particles in an electric field for dust removal.

The dust particles, which are charged through the collection of negative ions, are guided to a receiving electrode in an electric field where they are collected. Electric filters generally pose an explosion hazard by an explosive gas mixture entering the electric field. To prevent such an explosion, the CO concentration in front of the filter is monitored (see page 10).

The collected kiln dust is returned to the kiln as part of the raw mix or used in a variety of applications in industry.

### Nitrogen

Due to the fact that the main part of the combustion air nitrogen also represents the main part of the exhaust gas. Nitrogen it is not a pollutant.

## CO, CO<sub>2</sub> and O<sub>2</sub>

- Carbon monoxide (CO) is formed by an incomplete burning of fuel, i.e. through lack of oxygen, which can be minimized by controlling the air supply accordingly.
- Carbon dioxide (CO<sub>2</sub>) is created during the combustion and calcination processes and is known as significant contributor to the greenhouse effect.
- Oxygen (O<sub>2</sub>) is required for the combustion process and is supplied as a part of the combustion air. Because the combustion process is operated with excess of air, some oxygen is still contained in the exhaust gas. It is used as reference value when monitoring the pollutants at the stack.

## Nitrogen oxides

There are two significant sources of nitrogen oxides in cement plants: Oxidation of the molecular nitrogen present in the combustion air and oxidation of the nitrogen compounds in the fuel used. The NO<sub>x</sub> concentration depends largely on the combustion temperature.

Control strategies to reduce NO<sub>x</sub> formation are:

- Control of temperature and excess air supply through continuous monitoring of O<sub>2</sub> and CO.
- Process modifications such as staged air supply, low NO<sub>x</sub> burner, exhaust gas recirculation, secondary catalytic reduction (SCR) etc.

## Sulfur dioxide

Sulfur dioxide arises from the sulfur content in the fuel and traces of sulfide ores in the raw mix. In the past, most of the SO<sub>2</sub> emissions have been related to sulfides in the raw mix which are driven off in the upper stages of the preheater.

These days, because of the increasing share of liquid or solid waste-derived alternative fuels, some of which have high sulfur concentrations, the monitoring of SO<sub>2</sub> becomes increasingly more important.

## Other compounds

In case of the use of co-incineration of waste materials for kiln firing other compound such as HCl, HF, Hg and hydrocarbons (specified and measured as THC, total hydrocarbon content) must be monitored additionally.

Gas component	Emission limit values [mg/m <sup>3</sup> ]		
	European 2000/76/EC Waste Incineration Directive Daily average value	German 17. FEPL Co-incineration in cement kilns Half hour average value	German TI Air (new) Cement and clinker Half hour sampling
CO		100	
NO <sub>2</sub> *	500	1000	500
CO <sub>2</sub>			
SO <sub>2</sub>	50	200	350
THC	10	20	
HCl	10	60	30
HF	1	4	3
Hg	0.05	0.05	0.05
Dust	30	40	20

(\*) NO<sub>2</sub> is usually measured as NO (conversion factor NO<sub>2</sub>/NO=1,53)

Fig. 12: List of pollutants according to different European regulations

# Emission monitoring

## Emission Monitoring Regulations

### Europe

In the European Community, depending on whether the kiln is fired with or without the addition of waste-derived alternative fuels, different emission regulations apply.

The new *Directive 76/2000/EC on the incineration of waste* requires the continuous measurement of total dust, SO<sub>2</sub>, NO<sub>x</sub>, THC, CO, HCl, HF and O<sub>2</sub> (as reference value) emissions in the exhaust gases of **co-incineration plants**, i.e. a cement kiln which uses secondary fuels. However, the directive provides for certain exemptions and as a consequence the requirements can differ from one European country to another. In addition some other exhaust gas parameters have to be recorded as well, such as pressure, temperature and water vapor. Besides these continuous measurements, periodic measurements of trace elements, dioxins and furans, and in some cases polycyclic hydrocarbons or other pollutants have to be carried out. The given limit values are defined as daily or half hour average values.

In Germany, the Directive 76/200/EC has been converted into national law by the 17th BImSchV, Federal Emission Protection Law, FEPL, as of August 14, 2003. Cement plants without waste co-incineration must comply with the regulations of the „Technical Instruction Air (TI Air)“, published as a rule first in 1986 and revised in July 2002 setting lower limit values, e.g. 500 mg/Nm<sup>3</sup> NO<sub>2</sub>.

Fig. 12 shows lowest limit values specified for major pollutants according to different regulations.

### Quality assurance through CEN standards

From its very beginning, the 17th FEPL demanded the mandatory use of relevant EN standards as existing. Today, since EN 14181 and EN 14956 have been put into force in 2002 and have become a national standard in all CEN member states, both must be considered.

Both standards deal with the definition of measures for quality assurance (Quality Assurance Levels, QAL) for the use of automated measuring systems.

For cement plants, it is still under discussion when these CEN standards will become finally effective.

#### EN 14181

The EN 14181 *“Stationary source emissions - Quality assurance of automated measuring systems”* mandates which features automated measuring systems must have and how they must be installed, calibrated and maintained. The standard describes the necessary procedures of quality assurance so that automated measuring systems (AMS) can maintain the requirements on the uncertainty of measured values defined by authorities or guidelines.

To reach this goal, the standard defines three quality assurances levels (QAL 1-3) and a functional check (AST)

- **QAL 1**  
Basic suitability of the measuring system for the measuring task (details in EN ISO 14956)
- **QAL 2**  
Installation and calibration of the AMS, determination of measurement uncertainty and check for ensuring maintenance of permitted measurement
- **QAL 3**  
Regular drift control of the AMS during operation
- **AST**  
Annual Surveillance Test

### EN ISO 14956

The EN ISO 14956 *“Air quality - Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty”* deals with the definition of the suitability of an automated measuring system and the measurement procedure, which corresponds to quality assurance level QAL 1. The procedure described is based on the calculation of the total uncertainty of the measured values of the measuring system on the basis of individual procedure characteristics contributing to the uncertainty.

### USA

In the US, under the clean Air Act are the Code of Federal Regulations (CFR), which comprise many different titles. The title that applies to the cement industry is *Title 40, Protection of the Environment*. The part of title 40 that deals with cement plants is part 60, section 60. So **40CFR60** applies specifically to Portland Cement plants.

Each state can add to the CFR, but cannot take away from the CFR.

According to EPA, SO<sub>x</sub>, and NO<sub>x</sub> as well as dust must be measured continuously in the stack together with temperature, flow and O<sub>2</sub> as reference values. In the future, more demand for the measurement of HCl and HF may arise.

### Asien

Most Asian countries follow US EPA regulations, but European regulations are also applied by some countries or companies.



# Solutions from Siemens Process Analytics

## Gas analysis at the cement kiln inlet

### Rotary kiln gas analysis

Continuous analysis of oxygen (O<sub>2</sub>), carbon monoxide (CO) and nitrogen oxide (NO) in the rotary kiln is essential for the quality of the produced cement clinker, the efficient use of fuel, and the protection of the environment from toxic emissions:

- The analysis allows detailed assessment of the combustion processes and is therefore a prerequisite for burner control, determining fuel requirements and product quality.
- Malfunctions can be detected early and prevented through appropriate countermeasures.
- Stable kiln control prevents the emission of toxic materials thus supporting environmental protection.

### Sampling system demands

Extremely difficult environmental conditions in the rotary kiln put very high demands on the sampling system. Gas temperatures up to 1400 °C, dust concentration up to 2000 g/m<sup>3</sup>, and the high alkali, sulfate and chloride content, portray the typical sampling conditions. High concentrations of sulfur and alkali very frequently result in blockages in the gas paths requiring high maintenance of the gas sampling equipment. In addition, the system is subject to high mechanical stress resulting from falling material or inflowing raw meal.

### FLK sampling system

The Siemens FLK sampling system (Fig. 13), allows the direct extraction of sample gas from the intake area (Fig. 14) of the rotary kiln. The FLK sampling system is a very effective and well proved unit which is operated in more than 150 cement plants all over the world.

Read more about the FLK sampling system on page 14.

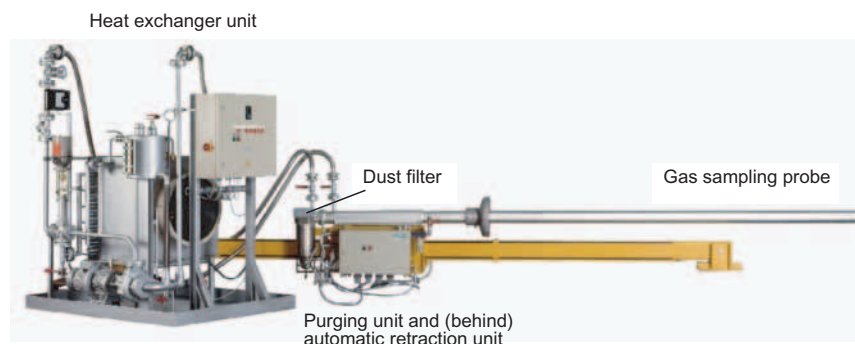


Fig. 13: FLK sampling system

### User benefits

- The high gas sampling temperature of 200 °C reduces condensation effects such as blockages in the gas paths significantly compared to water cooled systems operated at 90 °C.
- The use of a high quality synthetic heat exchanger prevents precipitation or corrosion in the cooling circuit and saves costs for a water treatment system.
- Caking on the probe jackets is removed by automatic retraction of the probe and the resultant drop in ambient air temperatures, and is further supported by compressed air.
- Maintenance intervals are extended to approx. 3 months because of the high sample gas temperature and the efficient cleaning procedures of the sampling probe and the gas paths.
- Adaption of the control parameters, such as purging frequency and duration, can be carried out at any time using the integrated operator panel.
- The internal sample tube can easily be replaced in case of persistent clogging which may result from increasing use of alternative fuels.

### Sample gas preparation

The process gas is sampled by the probe, purified by a dust filter and a pre-condensation trap and finally passed through the sample conditioning unit to the gas analyzers.

### Gas analysis

Typically, the gas analyzers are mounted in a cabinet (Fig. 17) that is installed in an analyzer house.



Fig. 14: Measuring area at the kiln inlet

# Solutions from Siemens Process Analytics

## Explosion protection of coal silo and ESP

### Protection of coal silo

A major threat in running coal silos is the random occurrence of partial self-ignition of the coal. This leads to elevated CO concentrations inside the head-space of the silo creating the danger of explosions and toxic impacts. This self-ignition is hard to predict, since its occurrence depends on several parameters. An effective measure of protection is to monitor the CO concentration in the headspace of the silo. Enhanced CO concentrations indicate a chance of fire and require immediate counter measures.

#### LDS 6 based solution

The LDS 6 is installed to measure the concentration of CO right inside the coal silo. Typically, the sensors are mounted at the silo walls (Fig. 15) in a distance of several meters. The sensor pair is connected via fiber optic cables to the central unit. In this way, up to three silos can be monitored simultaneously with only one LDS 6 analyzer. The central unit can be separated up to 1000 m from the measurement point. The sensors themselves are ruggedly designed and fully suitable for the operation conditions at the silo. The sensors are intrinsically safe and suitable for the use in any EEx-zones including those for dust. The LDS 6 analyzer has a dynamic dust load compensation.

Therefore it is capable of determining the correct CO concentration values, at any time.

In the case of a significant increase of the CO level, the instrument immediately gives out a warning that indicates a seat of fire inside the coal silo. This reaction time is very short, since there are no extractive gas paths and the instrument itself delivers the concentration values in real-time.

#### ULTRAMAT based solution

For accurate and reliable continuous CO monitoring in coal silos, the extractive gas analyzers ULTRAMAT 6 (field or plug-in version) and ULTRAMAT 23 (Fig. 22 and 23) have proved best in countless installations world wide. Combined with a suitable gas sampling and gas conditioning equipment these analyzers build an analyzing system that complies best with the requirements of this application.

### Protection of ESP

Electrostatic filters (ESP) are standard in cement plants. Because of the high field strength used, electrostatic filters are basically endangered by electric spark-overs. Provisions must be taken to avoid exhaust gases with too high CO content to enter the filter, since the gas is flammable and could be ignited by electric sparks.

Therefore, fast and continuous *monitoring of the CO content* of the exhaust gas upstream the filter (Fig. 16) is a key issue for safe filter operation.

#### LDS 6 based solution

LDS 6 is a diode laser-based in-situ gas analyzer for measuring specific gas components directly in a process gas stream. It is capable of measuring CO directly in or before the ESP. A pair of sensors is measuring in-situ and delivering data to the central unit, which can control up to three measurement points simultaneously. Since LDS 6 provides the concentration data very fast in real-time and with high accuracy, a smaller safety margin can be applied, and thus the number of filter shut-downs can be minimized. LDS 6 is measuring CO concentration levels of higher significance, since the measuring point is much closer to the hazardous area. Therefore, in the case of too high CO concentrations close to the explosion endangered level, a fast and automatic shut-down of the filter is realized.

More user benefits are listed in Fig. 26, page 13.

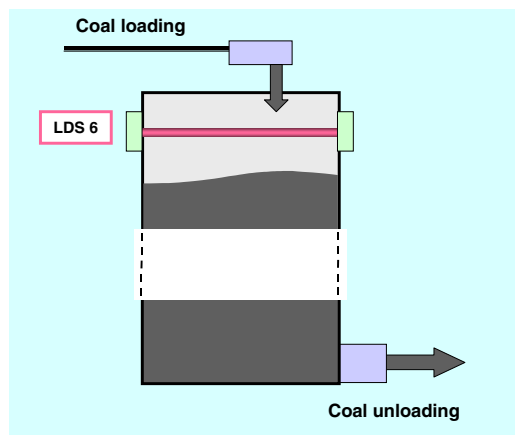


Fig. 15: LDS 6 for coal silo protection

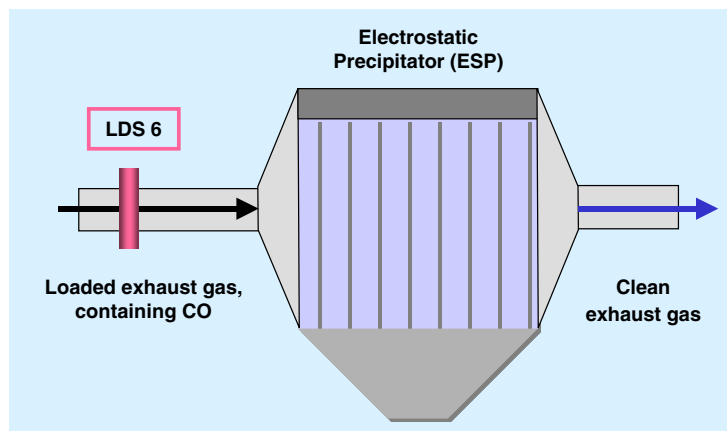


Fig. 16: LDS 6 for ESP protection

# Solutions from Siemens Process Analytics

## Emission monitoring at the stack

### Continuous emission monitoring at the stack

Depending on the kind of fuel used and following the provisions of the relevant international or national regulations a number of specified gas components (mainly CO, NOx and SO<sub>2</sub>, but increasingly also THC, HF, HCl and Hg) and dust must be monitored continuously at the stack of a cement plant (see also Fig. 11 on page 6).

Siemens Process Analytics is able to deliver different solutions for that task thus providing the user with the most economical solution corresponding to the actual requirements.

#### Solution for plants without waste co-incineration

In the case of no waste-derived fuels being used to fire the cement kiln, the ULTRAMAT 23 (Fig. 23) fits best for emission monitoring of the required components (CO, NO and SO<sub>2</sub>) with just one analyzer.

Particular features and user benefits of the ULTRAMAT 23 include

- Compact and very cost effective design
- High selectivity and measuring accuracy because of the single beam design with double and triple layer detectors
- Highest long term stability without the need of expensive calibration gases by means of auto-calibration using ambient air
- Compliance with the requirements of EN 14181 and 14956 standards.

#### Package-solution for plants with waste co-incineration

In the event that waste-derived fuels are a part of the fuel mix, an analyzer system (Fig. 17) will meet best the requirements of stack monitoring. The system package includes

- One ULTRAMAT 6 to monitor CO, NO and SO<sub>2</sub> in one analyzer
- One FIDAMAT to monitor THC

- One OXYMAT 6 to monitor O<sub>2</sub> as reference value
- Two LDS 6 to monitor HF and HCl
- One Hg-analyzer (third party)
- Equipment for gas sampling, sample gas preparation, data processing, etc.

For particular features and user benefits of the ULTRAMAT 6 and OXYMAT 6, see page 12.  
The analyzers have been approved regarding availability of lowest measuring ranges required for emission monitoring (Fig.18).



Fig. 17: Gas analyzer systems for emission monitoring in European (left) and US design (right)

Analyzer	Component	Lowest approved measuring ranges	
ULTRAMAT 23		Device equipped for 1-2 components	Device equipped for 3 components
	CO	0 - 150 mg/m <sup>3</sup>	0 - 250 mg/m <sup>3</sup>
	NOx	0 - 100 mg/m <sup>3</sup>	0 - 400 mg/m <sup>3</sup>
	SO <sub>2</sub>	0 - 400 mg/m <sup>3</sup>	0 - 400 mg/m <sup>3</sup>
ULTRAMAT 6		Device equipped for 1 component	Device equipped for 2 components
	CO	0 - 50 mg/m <sup>3</sup>	0 - 75 mg/m <sup>3</sup>
	NOx	0 - 100 mg/m <sup>3</sup>	0 - 200 mg/m <sup>3</sup>
	SO <sub>2</sub>	0 - 75 mg/m <sup>3</sup>	

Fig. 18: Lowest measuring ranges of ULTRAMAT 23 (acc. TI Air) and ULTRAMAT 6 (acc. 17. FLP)

# Siemens Process Analytics at a glance

## Siemens Process Analytics

Siemens Process Analytics is one of the worldwide leading suppliers of instruments, systems and services of process analytics with competence centers in Germany, Singapore, the United States and China. The scope of services includes planning and engineering, manufacturing, assembly, commissioning and subsequent maintenance.

Siemens develops and manufactures systems tailored to specific application demands, thereby supporting the user, his individual system and the operation of his process as economical as possible.

In cement plants, continuously operating gas analyzers (with extractive sampling or in-situ measuring principle, see page 5) are the most important class of analysis instruments.

## Continuous gas analyzers Extractive principle

### Series 6 gas analyzers

Most of the series 6 gas analyzers use the proven extractive sampling principle with device installation separate from the process, e.g. in analyzer cabinets or shelters, under user configurable ambient conditions. As they are based on diverse measurement and detection principles, the analyzers can be used universally for a variety of applications. Specific variants are available for certain application areas or operating conditions, e.g. plug-in or field devices, corrosion-resistant or explosion-proof versions (Fig. 22) as well as with different communication interfaces such as Ethernet or Profibus. Features and user benefits of two series 6 analyzers are shown in Fig. 20 and 21.

Siemens Process Analytics for use in cement plants	
<b>Continuous Gas Analyzers</b>	<ul style="list-style-type: none"> <li>Series-6 gas analyzers, comprising OXYMAT 6/61, ULTRAMAT 6, CALOMAT 6 and FIDAMAT 6</li> <li>ULTRAMAT 23 multicomponent gas analyzer</li> <li>LDS 6 in-situ diode laser gas analyzer</li> </ul>
<b>Gas sampling</b>	<ul style="list-style-type: none"> <li>Devices for sample gas extraction and conditioning</li> <li>FLK sampling probe for cement kiln measurements</li> </ul>
<b>System Integration</b>	<ul style="list-style-type: none"> <li>Full capability to plan, engineer, implement and service process analytical systems worldwide</li> <li>Workshops in Germany, Singapore and the US</li> </ul>

Fig. 19: Products and services of Siemens Process Analytics

Features ULTRAMAT 6	User Benefits
Dual-layer detector with variable optical path length setting (optocoupler)	Maximum selectivity and thus measuring precision; can be optimized for actual analysis
Detector uses microflow sensor with no moving parts to generate the measuring signal	No microphony: Very low signal noise High measuring accuracy
Extremely stable mechanical design Electronic and physical parts separated gas tight in one robust IP 65 housing (Field unit)	Very high operating reliability and life time
Easy cleaning of gas cell (on site possible)	Minimum maintenance costs
Remote control by SIPROM GA software tool Interface to PROFIBUS PA (option)	Easy integration into automated systems
Can be extended for simultaneous measurement of 1-4 NDIR gas components Available in one housing together with an OXYMAT 6 oxygen analyzer	Lower investment costs due to processing of several measuring tasks with one device

Fig. 20: Features and user benefits of ULTRAMAT 6

Features OXYMAT 6	User Benefits
Simple and robust design without moving parts	High operating reliability, availability, and service life; very low maintenance and spare part requirements
Strictly linear measuring principle	High precision and flexibility
Very short signal response time	T90 time < 2 s provides optimum reaction to process variations
Measuring principle allows differential measurement of two different gas streams in one analyzer with one bench No electronic zero elevation required	Very small measuring ranges for high (absolute) concentrations and thus very high measuring precision
Minimum drift (0.5% of span in 3 months)	Very high measuring precision Very little needs for recalibration
Remote control by SIPROM GA software tool Interface to PROFIBUS PA (option)	Easy integration into automated systems
Available in one housing together with an ULTRAMAT 6 NDIR analyzer	Very economic operation

Fig. 21: Features and user benefits of OXYMAT 6



### Gas analyzer ULTRAMAT 23

With its multi-component design with NDIR technology for the measurement of up to three IR active components such as CO, NO, SO<sub>2</sub> and electrochemical oxygen measurement, the ULTRAMAT 23 (Fig. 23) is extremely economical and space saving. The integrated automatic calibration function using ambient air is a unique advantage. A check with calibration gas is necessary once a year only.

Menu-guided operation in plain text allows users and service personnel to operate the device immediately. The information in the logbook allows for preventive maintenance.

The multi-layer detectors used guarantee high selectivity and reduced steam cross sensitivity. The measuring cells used are robust and resistant and can easily be cleaned in case of pollution, induced by faults in the sample preparation. Features and user benefits are shown in Fig. 25.



Fig. 22: Series 6 gas analyzer (Field unit)



Fig. 23: ULTRAMAT 23 gas analyzer

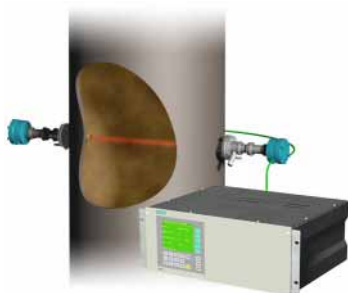


Fig. 24: LDS 6 In-situ laser gas analyzer

Features ULTRAMAT 23	User Benefits
Single beam measuring principle together with AUTOCAL ambient air adjustment and multilayer NDIR detector technology	High level of selectivity and accuracy No provision of test gas required Easy adjustment by using ambient air
Modular design with 1-3 IR channels and additional oxygen measurement using an electrochemical cell	High efficiency by measuring up to 4 components in one device Long life time of the O <sub>2</sub> cell
Easy cleaning of gas cell Long life time of electrochemical cell	Minimum maintenance requirements
Remote control by SIPROM GA software tool Interface to PROFIBUS PA (Option)	Easy integration into automation systems

Fig. 25: Features and user benefits of ULTRAMAT 23

### Continuous gas analyzers In-situ principle

The LDS 6 analyzer is part of the series 6 but uses the in-situ measuring principle to determine components directly in a process flow.

LDS 6 (Fig. 24 and 26) is a laser diode gas analyzer based on absorption spectroscopy. The light source is a diode laser whose wavelength is matched to an absorption line of the gas to be measured. LDS 6 consists of a central unit and up to three pairs of cross duct sensors in a transmitter / receiver configuration. The central unit is separated from the sensors by using fiber optics. Regardless how hostile the environ-

ment is, the analyzer can always be placed outside any hazardous areas. Measurements are carried out free of spectral interferences and in real time enabling proactive control of dynamic processes.

Due to its measuring principle, LDS 6 is particularly suited for real-time applications in many industrial processes. The very short response time allows very fast reaction to any unwanted variation of the process conditions.

Measuring components include O<sub>2</sub>, NH<sub>3</sub>/H<sub>2</sub>O, HF/H<sub>2</sub>O, HCl/H<sub>2</sub>O, CO/CO<sub>2</sub>, low ppm H<sub>2</sub>O, ...

Full network connectivity via Ethernet allows for remote maintenance.

Features LDS 6	User Benefits
Use of in-situ measuring principle	Very fast (real-time) response for immediate reaction
Use of fiber optic technology to convey signals from and to the sensors	Easy installation and reliable operation even in extreme environments. Up to 1000 m distance between sensor and central unit
Internal reference channel using a built-in reference gas cell	Long term stability, continuous self-calibration; automatic self-diagnosis and failure correction
Up to three sensor systems	Cost effective installation and expansion
High performance controller with remote access interface	Easy parameterization at the front panel Fast remote failure diagnosis and correction
Intrinsically safe explosion protection (option)	Easy installation and safe operation in explosion hazardous areas
Stable and modular sensor design	Adaptable to various installation conditions
Wide area of applications	Gain of synergies from different applications. Simultaneous control of very different measuring locations/process steps possible

Fig. 26: Features and user benefits of LDS 6

## FLK sampling system

The FLK sampling system is designed especially for the use at the inlet of cement kilns. It consists of the following components:

- *Liquid-cooled gas sampling probe* suitable for process gas temperatures up to 1400 °C with gas sampling entrance from the side for dust minimization
- *Air/liquid heat exchanger unit* (Fig. 27) using a synthetic heat transfer liquid with a boiling point above 300 °C which permits sampling gas temperatures of 200 °C. Closed circuit, pressure-free operation, temperature, flow and level sensor controlled.
- *Heated maintenance-free dust filter* (Fig. 28) to purify the gas/dust mixture extracted from the process area. Suitable for dust concentrations up to 2000 g/m<sup>3</sup>. Electrical heating to approx. 200 °C prevents crustation or caking on the filter tube.
- *Automatic retraction unit* to enable the probe to be removed in the event of failure, preventing thermal overload. Very robust, maintenance-free design.
- *Purging unit* to carry out the regular cleaning programs for purging the gas sampling probe. Purging can be manually initiated as well as automatically controlled by the PLC control unit.
- *PLC-based control and monitoring unit* : Siemens (SIMATIC), Alan Bradley or Schneider.



Fig. 27: Heat exchanger of FLK sampling system



Fig. 28: Dust filter of FLK sampling system

# System integration

## System Integration

Analyzers from Siemens are known for their high availability, long life cycle and measurement precision. In order to maximize the benefits of these properties, it is required to integrate the analyzers into an ideal and safe environment. This includes sample handling and conditioning, safeguarding equipment and utilities, as well as signal processing and data communication.

Siemens has been a reliable partner in the construction of analyzer systems for over 30 years. We supply front end engineering services and complete turnkey systems and shelters along with start-up, commissioning and training services.

## Blend of Expertise

As a manufacturer of analyzers and instruments and as an automation specialist, Siemens provides a unique blend of analytical expertise, process and process control knowledge. Depending on the needs of the application, Siemens can supply new and innovative solutions or can use solutions that have been of proven value for many years. As a matter of course, Siemens integrates its own analyzers as well as third-party analyzers.

Our logistic specialists have expert knowledge in handling and shipping analyzer systems and spare parts worldwide. Thanks to our worldwide service network, our specialists and spare parts can be quickly on-site.

Through all stages of the project, a designated Siemens project manager operates as your single point of communications and responsibility.



Fig. 29: CGA cabinet

Finally, our customers receive a complete analyzer system from a single source with the warranty for the whole system.

## Range of Services

Our range of services is not limited to engineering and assembly of your analytical system. We also support you in the planning and basic engineering of your analytical system and communication network. But also in the settlement of your project, you can count on us. Your project is on time and on budget – with no surprises.

At Siemens, all units exist under one umbrella. Thus, we have direct access to our workshops, our analyzer production lines as well as our R&D and application labs. This ensures high flexibility and short reaction time.

## Globally on Site

Siemens operates system integration centers in Karlsruhe (Germany), Houston and Singapore and centers of competence in Dubai and Shanghai. In this way, we are present globally and acquainted with all respective local and regional requirements, codes and standards.

Each of the system integration centers has its own support team, as well as its own engineering and assembly teams along with a sizeable workshop, service and training facilities. The centers of competence provide support, service, training and spare part supply.

Siemens has engineered, assembled and installed many analytical systems at cement plants all over the world.



Houston, Texas, USA



Karlsruhe, Germany



Singapore

# Case Study

**If you have any questions, please contact your local sales representative or any of the contact addresses below:**

Siemens AG  
A&D PI 2 Process Analytics  
Oestliche Rheinbrückenstr. 50  
D-76187 Karlsruhe  
Germany  
Tel.: +49 721 595 3180  
Fax: +49 721 595 6375

E-Mail: [processanalytics@siemens.com](mailto:processanalytics@siemens.com)  
[www.siemens.de/processanalytics](http://www.siemens.de/processanalytics)

Siemens Applied Automation  
7101 Hollister Road  
Houston, TX 77040  
USA  
Tel.: +1 713 939 7400  
Fax: +1 713 939 9050

E-Mail: [saasales.sea@siemens.com](mailto:saasales.sea@siemens.com)  
[www.sea.siemens.com/ia](http://www.sea.siemens.com/ia)

Siemens Pte. Limited  
A&D PI 2 Regional Headquarter  
The Siemens Center  
60 MacPherson Road  
Singapore 348615  
Tel.: +65 6490 8702  
Fax: +65 6490 8703

E-Mail: [splanalytics.sgp@siemens.com](mailto:splanalytics.sgp@siemens.com)  
[www.siemens.com/processanalytics](http://www.siemens.com/processanalytics)