State of the art temperature- and pollution monitoring

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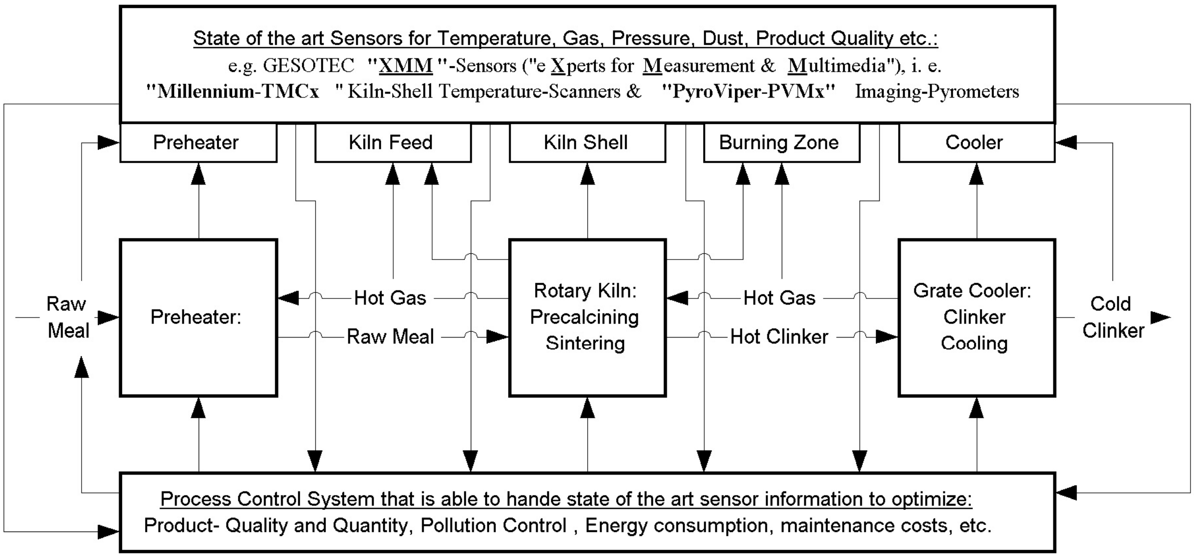
Efficient operation of a Kiln/Cooler-unit, as far as environmental protection, energy consumption and preventative maintenance are concerned, depends to a significant extent on continuous analysis of the flue gases and online temperature measurement.

The Kiln/Cooler process control is quite complex (Fig. 1). For the operation of flexible modern Process Control Systems (e.g. like the Siemens KCS) state of the art gas- and temperature sensors are imperative tools. Due to the ongoing progress of opto-electronic technology extreme powerful sensors are now available at reasonable cost. A new generation of "Infrared TV-Cameras" for the thermal and visual observation of the Kiln- & Cooler Interiors (combined visualization and temperature measurement of refractory, product bed, flame shape...) provide new aspects not only for optimizing energy- & pollution control, but also for a more efficient preventative maintenance. Especially operations that use waste fuel may substantially benefit.



The crucial importance of good, properly representative measured values are illustrated by the following examples:

A. Process Control

One of the greatest needs in the operation of a cement works, apart from making procedures easier for the control room personnel, is to improve clinker quality, reduce energy consumption and extend the service life of machines and brick-linings. The SIEMENS CEMAT-KCS system (**K**iln **C**ontrol **S**ystem) is ideal for this task because it provides the automatic control that keeps the rotary kilns of cement works working at optimum efficiency (Fig. 2).

In some respects the KCS system can be compared to an aircraft's autopilot. Both systems respond to incoming measured values. Depending on those measured values the system operates dampers and valves as necessary provides extra fuel, etc.

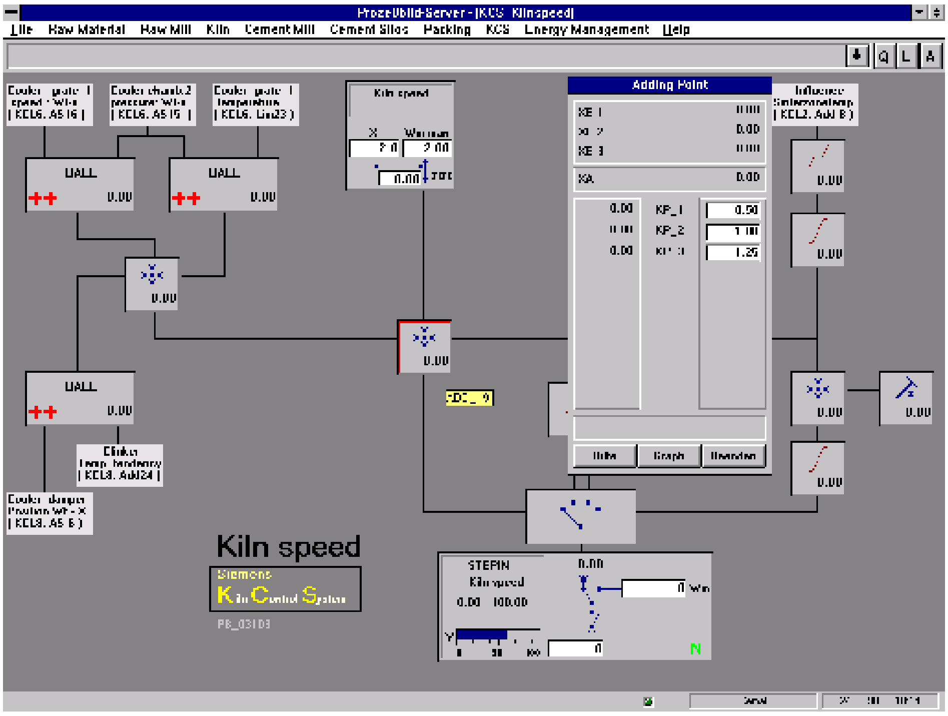
In order to get some idea of how things are going, a human pilot can glance out of the window occasionally and the kiln operator can take a quick look inside the kiln. An autopilot or kiln control system, however, does not have that option. In order to respond correctly it has to be supplied with relevant and reliable measured values. In fact, the performance of any system can only be as good as the measured data.

From between 30 and 40 different measured values the KCS system produces a picture of the actual status of the kiln at any moment. Some of the most important measured values are sintering zone temperature, CO, secondary air temperature, kiln speed, etc. Depending on the values measured, the KCS system continuously calculates revised, optimized set points. Some typical set points are “increase raw material feed to 125 t/h”, “reduce coal feed to 6.3 t/h”, “change stroke rate of cooler grate to 9 per minute”, etc. At variable preset intervals these values are fed as external set points to the subordinated controllers already installed in the plant.

The sintering zone temperature is one of the most important variables and it is the KCS system’s main job to keep it as constant as possible. Amongst other things it is also used for deducing certain characteristic kiln states which enable the KCS system to respond with varying degrees of “vigor”.

The KCS system has parameters, which allow it to respond with the necessary “vigor” while at the same time performing uniformly and with low stress levels and in a manner, which allows it to minimize certain flue gases such as CO and NO_x. The sensitivity of any of the control functions depends entirely on the accuracy of the process data received, i.e. the measured values. Parameter adjustment is performed with the aid of password-protected operator windows from the PC, which also provides the KCS visualization function. No specialized knowledge of computer programming is needed.

Visualization is clear and legible and its format simulates the way in which the kiln operator thinks: each sub-area (e.g. raw material feed, primary coal, etc.) has its own control scheme, a so-called “kiln control loop”. All the data of a kiln control loop is visualized on one PC display on the control console. The latest KCS systems are SIMATIC- based with visualization (Visual Basic) under Windows NT.



All system variables (inputs, outputs and all internal values) are displayed on the operator PC and are continuously updated in real time.

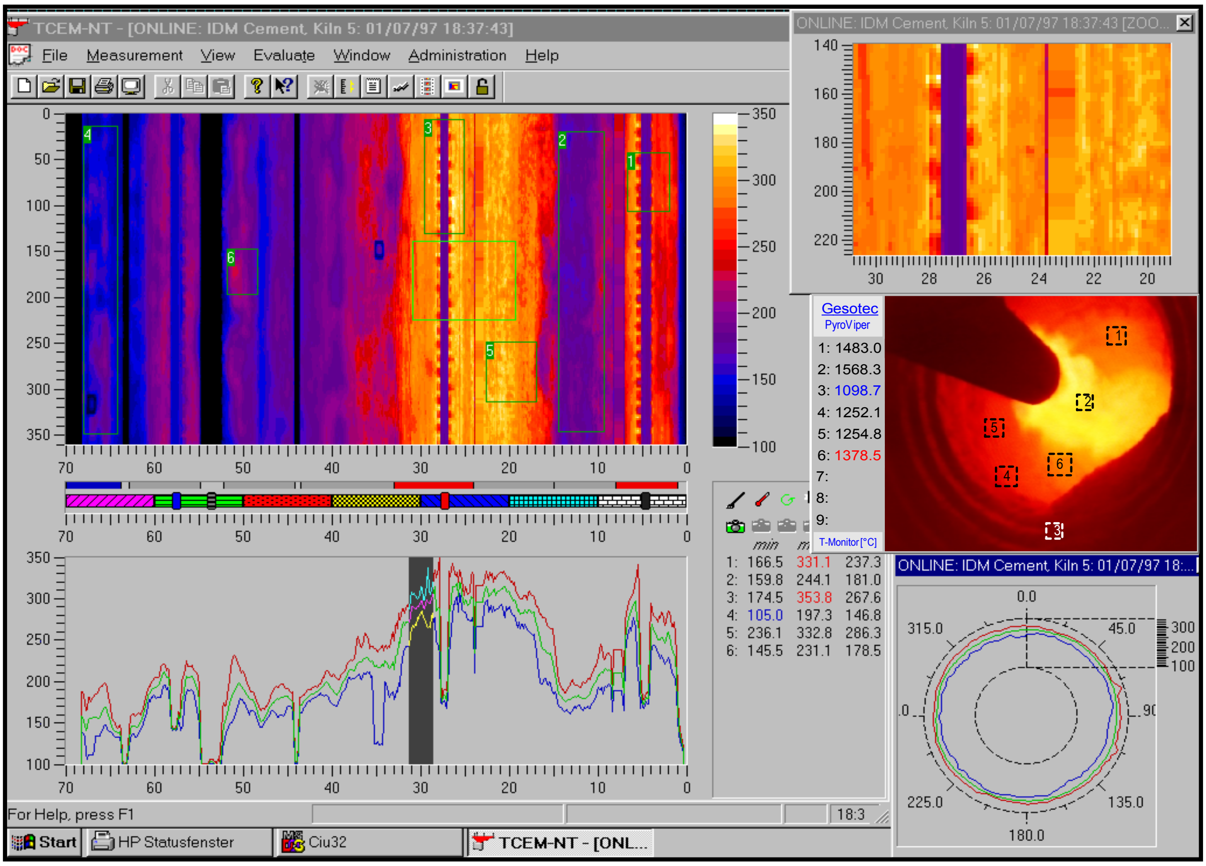
The KCS system is in service in many cement works all over the world. Each system is tailored individually for the particular conditions at each works in order to ensure that it can operate kiln and cooling plant in the most efficient manner possible. The fundamental configuration of the KCS system is also based on SIEMENS’ long experience in the cement industry.

In order to satisfy both of the above-mentioned requirements, i.e. to produce an effective marriage between accumulated practical experience and customizing features for specific works, the KCS system is of modular design and construction. It comprises a range of technological modules that can be linked together in any appropriate object-orientated configuration.
This offers optimum adaptability to suit the technological needs of customers as well as requiring the absolute minimum of engineering. At the same time it ensures, regardless of the modifications made, that only well tested and proven to be reliable software is used.

B. State of the art Sensors for Temperature and Flue Gases

The most important measuring points involved are as follows:

1. Sensors for Kiln Shell-, Burning Zone- and Cooler- Temperatures

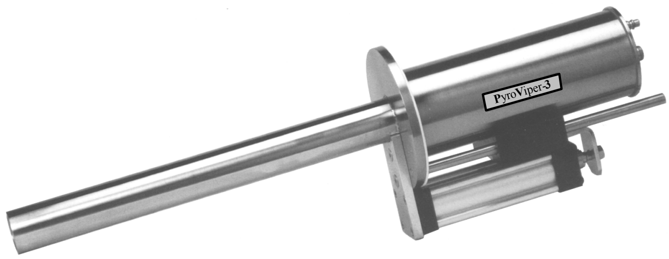


1.1 Kiln Shell Temperature Scanning

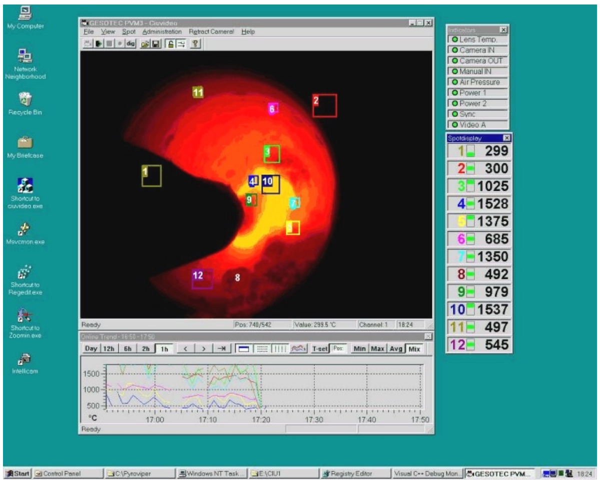
Gesotec's Millennium-TMCx series of high performance infrared line-scanners define a new industrial performance standard for mechanical-scanning electro-optical pyrometers. With the unique modular design for easy maintenance and customizing the Millenium scanners incorporate state of the art components for non-contact infrared linescanning, allowing both, high speed and high resolution continuous process monitoring. Eight standard versions of the TMCx- scanners are available, with a variety of temperature ranges, thermal- and spatial resolutions, and with spectral filtering adapted to the specific application. The modular design of the TMCx sensors allows Gesotec to customize every unit individually at reasonable cost to the users technical- and commercial advantage.

In the cement industry infrared line-scanners have become a standard temperature-measuring tool for checking kiln shell conditions, not only for the emergency hot spot detection and preventative maintenance, but also for optimized energy- and refractory lining management...

1.2 Monitoring the Burning Zone and the Clinker Cooler



The Imaging Pyrometer system PyroViper-3, model "PVM3-SFXX" combines enhanced high temperature video imaging with state-of-the-art two-color / two-dimensional pyrometry. This sophisticated combination of two (optional three) rugged industrial infrared imaging systems has the advantage of no



"moving sensor parts". It gives the operator the ability to observe the process conditions with great visual details while simultaneously measuring the temperature of virtually any object- or region of interest within the systems field of view (FOV). The PVM3-SFXX sensor unit is mounted on the "process wall" with an automatic retracting device.

PyroViper's standard endoscopical lens assembly is air-cooled (additional water-cooling is optional) and has an usable length between 550mm and 1143mm, thus covering most installation conditions. The high quality optical system transfers the object image- and temperature information to PyroViper's Camera/2D-Pyrometer-Sensor(s). From here the information is transmitted via coax-cables or optional via fiber-optic cables over distances up to 2000 meters to PyroViper's enhanced sensor control- & display-unit, that usually is located somewhere near to the process control room.

Both, the real time image and the real time temperature information of the object are processed and displayed on a standard 21" high-resolution SVGA color video monitor. Up to 48 areas of interest of variable size and position (AOI-Windows) can be selected by the operator and are linked with a numerical display-window that shows the corresponding Max.-, Min.- and/or Avg.- temperature values. These AOI temperature values are checked for crossing HI/LO- alarm limits and are continuously recorded/stored in an easy-to-access-format (ASCII) for further analysis. The system also features a built-in digital VCR with an image-snapshot function that provides standard graphics files (BMP, JPG...) for further evaluation-, printout- or even email-transfer through the Internet.

A standard MS-EXCEL spreadsheet program is used for trend- evaluation and for graphical trend-display. PyroViper's standard Ethernet-Interface (LAN-Interface) opens the possibility to transfer all information directly to the process control system. AOI-Temperature values, alarm conditions and other significant information are available via standard 4-20ma analog output or via the built-in LAN-Interface.

1.3 Sensors for flue gas analysis

- **Measurement of the CO content upstream of the electrostatic filter**
  To protect the electrostatic filter against dangerous concentrations of CO. The most important requirements here are absolute minimum dead time and fast measurement. If necessary, twin probe systems can be used to allow measurement with practically no dead time at all.

- **Measurement of the CO_2 content upstream and downstream of the heat exchanger**

This measurement provides an indication of the deacidification of the raw material flowing into the kiln.

- **Measurement of the O_2 content at the kiln inlet**
  This measurement monitors the excess air of the combustion process and so allows a high efficiency to be achieved. At the same time, however, a certain amount of oxygen is needed in the exhaust gases from the kiln in order to prevent the formation of carbon monoxide.

An effective flue-gas analysis system brings major benefits:
- It reduces production costs thanks to the more sparing use of fuel
- It ensures consistently high product quality thanks to the early detection of abnormal operating conditions
- It enables operational problems and production outages to be avoided thanks to the early detection of critical situations
- It reduces pollutant emissions and so raises the standard of environmental protection

Unfortunately, none of the measurements mentioned above can be taken without some difficulty. The sampling technique employed must ensure that a representative sample is extracted from the flow of gas and that the adverse effect on the results of the measurement due to infiltrated air is kept to a minimum. The intermediate chamber between the heat exchanger and the kiln inlet chamber is particularly prone to problems. The processing of the gas samples should be carried out as close as possible to the point of sampling so that the gas flow path is short and rapid.
The measuring point at the inlet to the kiln is especially important with regard to operating conditions.

Problems with gas sampling from a rotary cement kiln
Conventional systems often suffer from serious problems when required to operate continuously under extreme conditions such as those encountered in rotary kilns:
- Clogging of the sampling tube and the dust filter due to the products of condensation that arise as a result of the low operating temperatures, especially in the case of water-cooled probes
- Lime deposits and corrosion in systems employing water cooling
- Falsification of measurements due to water-soluble components in the gas (e.g. SO_2) caused by water vapor in the sampling system
- Overheating of the probe due to the formation of steam bubbles in the cooling circuit
- Difficult disassembly of the sampling probe while the kiln is in operation as a result of the heavy weight and high temperatures due to the absence of suitable retraction devices
- There is often no compressed-air cleaning system tailored to the particular operating conditions of the kiln

CEMAT–GAS sampling system with liquid-cooled probe
All of these problems can be avoided by using a gas sampling system that has been tailored specifically to the needs of cement making. The key to success lies in operating the sampling probe at a very high temperature of up to 230ºC - made possible by using a special eco-friendly heat-transport fluid. In this way most of the baking-on of products of condensation can be prevented. The dust filter is also operated at a temperature of approximately 230ºC so that no clogging of the filter space occurs and the filter voids do not become blocked with sludge.

Excellent availability
Since it is impossible to totally avoid the deposition of dust in a gas sampling system, and at least some degree of cooking-up, monitoring devices and independent programs for compressed-air cleaning are employed in order to ensure trouble-free operation and periods of maintenance-free service of more than three months. In the event of a malfunction the sampling probe is withdrawn from the kiln chamber automatically by means of an automatic motorized retraction device. An

auxiliary pneumatic actuator provides redundancy to cover the possibility of power failure. All control functions are performed by a highly reliable SIMATIC-S7 control system.

The component parts of the gas sampling system

The CEMAT-GAS gas sampling system is in six parts:

- Sampling probe
- Dust filter
- Compressed-air combination valve
- Heat exchanger unit
- Retraction device with electric and pneumatic actuators
- Programmable controller

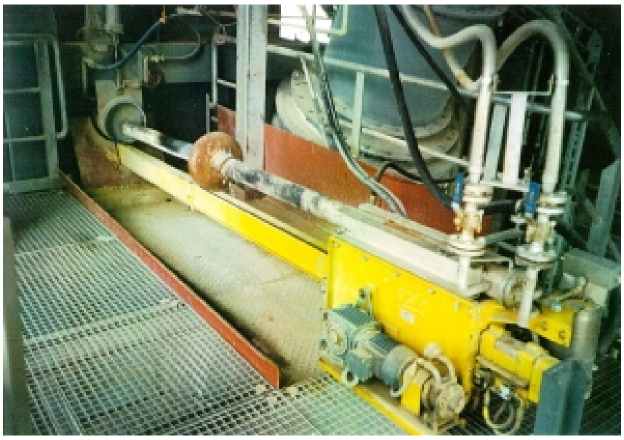


Fig.: Gas sampling probe with retraction device

The length of the *sampling probe* can be varied in order to adapt it to any particular place of installation. Having the sampling aperture at the side means that only relatively dust-free gas is drawn into the sampling chamber. The probe is cooled by means of a synthetic heat-transport fluid with a very high boiling point and high absorptivity. The very high operating temperatures that this allows means that the problems encountered with conventional sampling systems mentioned earlier can be avoided. In the event of a malfunction the probe is withdrawn from the kiln by the *automatic retraction device* which prevents it from becoming overheated.

The sample of gas taken is cleaned in the *electrically-heated dust filter* before being passed via the *compressed-air combination valve* to the analytical equipment cubicle containing the gas conditioning apparatus and the ULTRAMAT 23 gas analyzer.
The *compressed-air combination valve* works together with the SIMATIC S7-300 programmable controller to perform the cleaning programs. The scavenging cycle is initiated automatically by means of an adjustable negative pressure switch according to the degree of blockage in the system. The main feature of the combination valve is a motorized 4-way spherical cock that isolates the line to the analytical apparatus while scavenging is in progress.

The synthetic heat-transport fluid is cooled in a *heat exchanger unit* built to the highest industrial standards and able to provide adequate cooling capacity under extremes of temperature or when the cooling surface is partially fouled.

The flue gases are analyzed with the aid of the new ULTRAMAT 23 gas analyzer. This instrument is able to measure three infrared-absorbent gases (e.g. CO, CO_2, SO_2, CH_4) at the same time, and also oxygen. Automatic calibration of zero and sensitivity with ambient air make the instrument almost totally maintenance-free. Calibration with a test gas is only needed at intervals of approximately six to twelve months.