ACK Cement Analysis System
Dry Gas Sampling and Multi-Component Analysis for Monitoring Process Gas in Rotary Kilns and Calciners

System Description

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Overview

Application

The ACK (Advance Cement Kiln) cement analysis system is used for monitoring the process gas in cement plants. The analysis system is designed for continuous, quantitative measurement of gas concentrations:

• during the primary firing at the gas outlet of the rotary kiln and
• during the secondary firing at the gas outlet of the calciner.

Measuring Components and Measuring Procedures

The analysis system is suitable for measuring the components CO, NO, CO₂, CH₄, SO₂ and O₂.

The infrared-active components are measured using the infrared analyzer AO2000-Uras14.

The process photometer AO2000-Limas11 UV (with quartz measuring cell) is used for SO₂ measurement.

An electro-chemical oxygen sensor is used for O₂ measurement; alternatively, the AO2000-Magnos17 oxygen analyzer can be used.

Modules

The analysis system modules can be subdivided into three categories according to their function:

<table>
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<th>Functional Category</th>
<th>Modules</th>
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| Gas sampling        | • Probe H or probe 60S with probe cooling  
                    |   • Probe retractor with control box  
                    |   • Sample gas line |
| Gas conditioning    | • SCC-C sample gas cooler  
                    |   • SCC-F sample gas feed unit  
                    |   • SCC-K NO₂/NO converter |
| Gas analysis        | • AO2000-Uras14 infrared analyzer  
                    |   • AO2000-Limas11 UV process photometer  
                    |   • AO2000-Magnos17 oxygen analyzer or O₂ sensor |

Continued on next page
Principle of Operation (see Fig. 1)

Two separate types of probe are available for sampling the sample gas: Probe H is used in situations where the properties of the process gas and the sampling conditions lead one to expect hard encrustations to form on the probe. In situations where no hard encrustations are to be expected, probe 60S is used.

The probe, along with the pneumatic probe retractor, forms a single unit. The probe is built into a closed cooling-water circuit with a heat exchanger. It can be moved via the control box.

The sample gas is filtered in the probe, and passes through the heated or unheated sample gas line into the sample gas cooler, where the water vapor content of the sample gas is reduced to +3 °C dew point.

The sample gas feed unit transports the sample gas to the gas analyzer. An NO₂/NO converter can optionally be connected upstream of the gas analyzer.

The built-in PLC unit controls and monitors all the functions of the system.

Fig. 1
Functional Diagram
The sample gas is sucked in through opening 1 at the tip of the probe. The plunger 2, which is welded onto the cylindrical filter 3, is located in this opening. The filter is attached to pipe 4, which is connected to a cylinder of compressed air 6 through the gas-tight stainless steel bellows 5. The filtered sample gas flows through the electrically-heated gas pipe 7 to the gas outlet 8.

An air shock blower can be connected to connection point 9 on the mounting pipe 10. The air shock blower is not included as part of the standard system as delivered.

The probe is attached to the probe retractor with the mounting flange 11 (DN 150/ PN 10). It has a compressed-air connection 12 for cleaning the filter and two cooling-water connections 13 for cooling the probe. The tube-sealing device 14 can be adjusted in any position on the probe tube.
Scope of Delivery and Technical Data

- **Probe H**
  - Stainless steel Mat. no. 1.4571 (AISI 316 Ti)
  - Sample gas temperature approx. 180 °C (in probe tube)
  - Internal metal sinter filter (electr. heated)
  - Weight approx. 90 kg (without cooling water) for 3.0 m-long probe

- **Connecting components H**
  - Water tube, 39/25 x 7 mm, L = 50 m, with connections (incl. Pt 100)
  - Compressed-air tube, 18/14 x 2 mm, L = 50 m, with connections
  - Compressed-air tube, wire-braiding, L = 6 m
  - Weight approx. 75 kg

- **Cleaning unit H**
  - 2 solenoid valves and compressed-air tank, 5 l, attached to the probe retractor
  - Weight approx. 15 kg

- **Exhaust unit H**
  - 1 filter
  - 2 solenoid valves
  - 1 pump 4N
  - Terminal box

- **Components for commissioning H**
  - 1 metal sinter filter
  - 1 stainless steel bellows
  - 1 compressed-air cylinder
  - Weight approx. 3 kg

- **Heat exchanger**
  - Cooler block made from copper/brass
  - Dimensions (W x H x D) 900 x 1005 x 590 mm
  - Electric, speed-controlled motor
  - Power supply with 3-phase connection 230/400 V, 50 Hz (internal)
  - Power consumption 1.5 kW
  - Weight approx. 120 kg

- **Tube-sealing device**
  - For sealing between probe tube and sampling opening, fitted to the probe tube
  - Weight approx. 8 kg

- **Installation instructions**
  - With safety information for installing the probe in the kiln gas exit or in the calciner gas exit
The sample gas is sucked in through the two side openings 1 at the tip of the probe. The sample gas flows through the gas pipe 2 and the filter unit FE2 3 to the gas outlet 4.

The filter unit FE2 has two compressed-air connections 5. It is electrically heated by the ring heater 6. Inside the filter unit is the ceramic filter 7. The filter unit is housed in a protective casing 8.

An air shock blower can be connected to connection point 9 on the fitting sleeve 10. The air shock blower is not included as part of the standard system as delivered.

The probe is attached to the probe retractor with the mounting flange 11 (DN 150/ PN 10). It has two cooling-water connections 12 for cooling the probe. The tube-sealing device 13 can be adjusted in any position on the probe tube.

Fig. 3
Structure of Probe 60S

1 Sample gas suction openings 8 Protective casing
2 Gas pipe 9 Connection for air injector
3 Filter unit FE2 10 Mounting pipe
4 Gas outlet 11 Mounting flange
5 Compressed-air connections 12 Cooling-water connections
6 Ring heater 13 Tube-sealing device
7 Ceramic filter

Continued on next page
Probe 60S, continued

Scope of Delivery and Technical Data

- Probe tube 60S
  - Stainless steel Mat. no. 1.4541 (AISI 321)
  - Sample gas temperature approx. 80 °C (in gas pipe)
  - Weight approx. 50 kg (without cooling water) for 3.0 m-long probe

- Filter unit FE2
  - with ceramic filter, filter housing and flange made from stainless steel Mat. no. 1.4571, connection for cleaning with compressed air, weight approx. 8 kg
  - Ring heating element: unregulated, weight approx. 1 kg
  - Protective casing for probe 60S: Galvanized, insulated, weight approx. 3 kg

- Connecting components 60S
  - Water tube, 39/25 x 7 mm, L = 50 m, with connections (incl. Pt 100)
  - Compressed-air tube, 18/14 x 2 mm, L = 50 m, with connections
  - Compressed-air tube, wire-braiding, L = 6 m
  - Weight approx. 75 kg

- Cleaning unit 60S
  - 2 solenoid valves and compressed-air tank, 5 l, attached to the probe retractor
  - Weight approx. 18 kg

- Components for commissioning 60S
  - 1 ceramic filter 135 x 50/20 mm
  - 1 O-ring set
  - 1 flange gasket
  - Weight approx. 1 kg

- Heat exchanger
  - Cooler block made from copper/brass
  - Dimensions (W x H x D) 900 x 1005 x 590 mm
  - Electric, speed-controlled motor
  - Power supply with 3-phase connection 230/400 V, 50 Hz (internal)
  - Power consumption 1.5 kW
  - Weight approx. 120 kg

- Tube-sealing device
  - For sealing between probe tube and sampling opening, fitted to the probe tube
  - Weight approx. 8 kg

- Installation instructions
  - With safety information for installing the probe in the kiln gas exit or in the calciner gas exit
Cooling the Probe

Why does the probe need to be cooled?
Due to the extremely high gas temperatures at the gas outlet from the rotary kiln (approx. 1300 °C) or the calciner (approx. 1000 °C), the gas-sampling probe needs to be protected by a cooling system.

Cooling the Probe (see Fig. 4)
The probe is cooled by water circulating in a totally closed system.

The circulating pump 1 transports at least 5 m³/h through the probe tube 2. Fitted at the water outlet on the probe tube is the resistance thermometer (Pt 100) 3, which functions as the primary detector for controlling the water temperature.

The water flows through the heat exchanger 4 and the pressure compensation vessel 5. Additional instruments are installed in the water pipe for measuring pressure 6, flow 7, and temperature 8. The pressure gauge 6 is equipped with one min. contact and one max. contact. When the water pressure is too low (p < 0.5 bar) the min. contact automatically triggers the probe to move out; when the water pressure is too high (p > 2 bar) the max. contact triggers an alarm. The flow monitor 7 is equipped with a min. contact, which again automatically causes the probe to move out when the flow rate is too low (< 20 l/min).

Fitted outside the analysis cabinet is the mechanical safety valve 10, which opens when the water pressure rises above 3 bar. When the system is first filled up with water (approx. 50 l), the water flows through the filter 9.

The measured signal from the resistance thermometer 3 is converted in the transmitter 11 and passed on to the frequency converter 12, which controls the speed of the electric motor 13 on the heat exchanger. At the frequency converter the set point is fixed for controlling the water temperature. The temperature of the cooling water is shown on the analyzer’s display.

Continued on next page
Cooling the Probe, continued

Fig. 4
Piping Diagram for Probe Cooling

1. Circulating pump
2. Probe tube
3. Resistance thermometer Pt 100
4. Heat exchanger
5. Pressure compensation vessel
6. Pressure gauge
7. Flow monitor
8. Resistance thermometer Pt 100
9. Filter
10. Safety valve
11. Transmitter for Pt 100
12. Frequency converter
13. Motor
Cleaning the Probe

(see Fig. 5)

The process of cleaning the probe incorporates the following procedures:

- Cleaning the fitting sleeve
- Cleaning the outside of the probe by retracting and inserting the probe
- Cleaning the suction opening on the probe by moving the plunger
  (only for probe H)
- Cleaning the probe filter

Cleaning the Fitting Sleeve

At the beginning of the cleaning process the PLC sets a control signal for cleaning the mounting pipe. An air shock from the air shock blower 1 breaks the material build-ups that may have blocked the area between the probe and the mounting pipe.

Cleaning the Outside of the Probe

Material build-ups and encrustations on the probe tube 2 are removed by regular movement of the probe. The retraction and insertion of the probe is controlled by compressed air from the control box 3.

Cleaning the Suction Opening on the Probe

(only for probe H)

On probe H, the sample gas suction opening is located at the tip of the probe tube. The periodic pneumatically-driven movement of the plunger has the effect of breaking up crusty deposits at the suction opening. The sampling carries on uninterrupted by this process.

Cleaning the Probe Filter

The filter, which in probe H is located in the probe tube and in probe 60S is located in the filter device FE2 (connected via a gasket), is cleaned periodically with compressed air.

Cleaning Unit

The cleaning unit 5 contains the control valves for cleaning with compressed air 6 and for moving the plunger 7 and the compressed-air cylinder 8. The cleaning unit is fitted on the probe retractor 4.
Cleaning the Probe, continued

Fig. 5
Pneumatic Diagram of Probe Cleaning

1 Air shock blower
2 Probe tube
3 Control box
4 Probe retractor
5 Cleaning unit
6 Control valve for cleaning with compressed air
7 Control valve for moving the plunger (only with probe H)
8 Compressed-air cylinder
9 Pneumatic motor
10 Control valve
11 Oil filter
12 Compressed-air tank (250 l)
## Probe Retractor with Control Box

**Probe Retractor**

- The function of the probe retractor is to move the probe regularly to prevent it from being seized or bended.
- The movements of the probe retractor are controlled by the PLC.

**Retracting the Probe**

- The probe is automatically retracted out of the kiln if the following problems occur:
  - Temperature of cooling water too high,
  - Flow rate of cooling water too low,
  - Cooling-water pressure too low,
  - Circulating pump out of operation,
  - Power supply break down.

**Design of the Probe Retractor**

(see Fig. 5)

- The probe retractor 4 comprises two parallel bearing rails on which the carriage with the flange-mounted probe runs. When retracted, the probe can be turned to the left or to the right.
- The pneumatic motor 9 has a chain drive that makes it particularly well-suited for use in a dusty environment. The motor is attached to the probe retractor. It is designed for a pressure of approx. 700 kPa (approx. 6 bar positive pressure).
- The speed is set using the control valve 10 on the motor's compressed-air outlet.
- The compressed-air outlet is equipped with an oil filter 11.

**Control Box**

(see Fig. 5)

- The control box 3 is installed close to the probe retractor 4.
- The on-site supply of compressed air is connected to the control box. The compressed air must be dried and at a pressure of approx. 700 kPa (approx. 6 bar positive pressure). The compressed air is piped to the compressed-air tank 12 and to the probe retractor 4. Oil is added to the compressed air destined for the pneumatic motor.

**Functions of the Control Box**

- In “Automatic” operating mode, all monitoring and control functions are handled by the PLC.
- The following functions can be activated in “Manual” operating mode:
  - Retract probe,
  - Insert probe,
  - Clean probe,
  - Activate air shock blower.
- The Emergency Stop button can be used to stop the probe retractor at any time.

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Probe Retractor with Control Box, continued

Technical Data

- Probe retractor
  - Double beam design with carriage, probe and tube connection, proximity switches
  - Pneumatic flap, for max. ± 50 hPa
  - Pneumatic motor with gear, tractive power 5000 N at 700 kPa (6 bar positive pressure), chain drive
  - DN 200 mounting flange, similar to PN 6 DIN 2573, outside diameter 320 mm, 280 mm bolt circle, 8 holes of diameter 18 mm
  - Removable dust cover
  - Dimensions: L = probe length + 1500 mm; W = 750 mm; H = 600 mm
  - Weight (without probe) approx. 350 kg for 3.0 m probe length

- Control box
  - Sheet-steel box for wall mounting, color RAL 7032
  - Dimensions (W x H x D) 800 x 1000 x 300 mm
  - Compressed-air filter and pressure regulator; lubricator and pneumatic valves
  - Transformer for heating the gas tube (only for probe H)
  - Push buttons for probe control and emergency stop
  - Key-operated switch for maintenance
  - Warning light
  - Weight approx. 75 kg
### Compressed-Air and Cooling-Water Supply Requirements

#### Compressed-Air Supply Requirements

Compressed air is needed for cleaning the probe and moving the probe retractor.

The compressed air must be free from contamination as well as from oil and water droplets. It must be dried at $\leq +3 \, ^\circ\text{C}$ and have a pressure of approx. 700 kPa (approx. 6 bar positive pressure). Consumption is approx. 3 m$^3$/h.

There must be a compressed-air tank with a capacity of at least 250 l installed close to the probe retractor. This ensures that the probe can be retracted out of the kiln even when the on-site supply of compressed air is not available.

When the ambient temperature is below 0 °C, it is essential to ensure that the compressed-air supply cannot freeze.

#### Compressed-Air Supply from ABB Analytical

ABB Analytical can offer the following options for supply of compressed air:

- Compressed-air tank, volume 250 l, 3/4-inch inlet and outlet nozzles
  - weight: approx. 80 kg

- Complete compressed-air conditioning unit, comprising:
  - Screw compressor, 10 bar
  - Drier, dried down to +3 °C
  - Compressed-air tank, 280 l

  - Power supply 380/400 V, 50 Hz, 2.2 kW
  - Noise level 65 dB(A) at 1 m distance
  - Weight approx. 350 kg

#### Cooling-Water Supply Requirements

Probe H and probe 60 S are cooled with water.

The closed cooling-water circuit must be filled with approx. 50 l of drinking water (do not use anti-corrosion agents). When the ambient temperature is below 0 °C, approx. 20 l of glycol must be added.
Sample Gas Line

**Unheated Sample Gas Line**

The unheated sample gas line is only to be used in situations where the ambient temperature is higher than 0 °C.

Insulation material is supplied along with the sample gas line; this should be used to insulate the sample gas line together with the cooling-water hose (probe outlet) in order to minimize the amount of condensate formation in the sample gas line. Since it is impossible to completely prevent condensation, one must be prepared to spend extra time on maintenance.

Material: PTFE 6/4 x 1 mm

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**Heated Sample Gas Line**

The heated sample gas line must be used in situations where the ambient temperature is < 0 °C, and when measuring SO₂.

Technical data: Sample gas line made of PTFE, 6/4 x 1 mm, electrically self-regulating, flexible and able to be shortened to any length, temperature approx. 110 °C at –5 °C, insulated with silicon foam, Pt-100 sensor, outside diameter approx. 48 mm.
Gas Conditioning

Layout
The gas-conditioning modules are installed in the analysis cabinet (see Figs. 6 and 7).

Cleaning the Probe
When the probe is cleaned, the solenoid valve 3 closes and allows air to flow into the analyzer system. At the end of the cleaning process the ventilation valve 2 opens for a few seconds in order to release any positive pressure which may be in the sample gas line.

Switching on the Sample Gas
If the AO2000-Magnos17 oxygen analyzer is being used for measuring O₂, then the zero gas (N₂) is passed through the solenoid valve 4.

Aerosol Filter
The aerosol filter 5 is installed upstream of the sample gas cooler. Its function is to filtrate aerosols and very fine particles.

Vacuum Monitoring
The vacuum gauge 6 monitors the pressure loss through the probe, the filter and the sample gas line. When the probe gets blocked, the vacuum gauge’s minimum contact (~0.3 bar) is activated and a cleaning process is triggered automatically.

Sample Gas Cooler
The SCC-C sample gas cooler 7 reduces the water vapor content of the sample gas. The condensate that has been separated is pumped out by the built-in condensate pump. The maximum level in the condensate-collecting bottle 8 is monitored.

Gas Feed-In
The SCC-F sample gas feed unit 10 contains a fine dust filter with condensate monitor, a flow monitor, a needle valve, a diaphragm pump and a dosing pump. The sample gas feed unit monitors the flow and the formation of condensate in the sample gas. The sample gas flow is set to 60 l/h, and the minimum switching point is approx. 30 l/h.

Reagent Dosing
The metering system is used to add H₂O₂ to the sample gas. SO₂ is thereby selectively eliminated from the sample gas, thus preventing a harmful formation of sulfuric acid. This dosing should always be carried out when coal and oil are used for kiln firing, but not for pure gas firing. The minimum level in the reagent supply bottle 9 is monitored.

NO₂/NO Converter
The SCC-K NO₂/NO converter 12 can optionally be installed upstream of the analyzer. The converter converts the NO₂ content of the sample gas (normally < 5 % of NOₓ) into NO. As the only NO-part of interest is that which has been formed thermally through the heat in the kiln, the converter does not generally need to be installed.

Continued on next page
Fig. 6
Pneumatic Diagram of Gas Conditioning

Fig. 7
Pneumatic Diagram of Gas Conditioning with Optional SO₂ Measurement

1 Sample gas inlet
2 Ventilation valve
3 Solenoid valve for connecting air (when cleaning the probe)
4 Solenoid valve for connecting zero gas (only for AO2000-Magnos17)
5 Aerosol filter
6 Vacuum gauge
7 SCC-C sample gas cooler
8 Condensate-collecting bottle
9 Reagent supply bottle
10 SCC-F sample gas feed unit
11 Condensate trap
12 SCC-K NO₂/NO converter (optional)
13 AO2000-Uras14 infrared analyzer
14 AO2000-Magnos17 oxygen analyzer (optional)
15 AO2000-Limas11 UV process photometer (optional)
Gas Analysis

Operation

The infrared analyzer AO2000-Uras14 measures the concentration of the components CO and NO. The O₂ concentration is generally measured using an electro-chemical O₂ sensor. The AO2000-Uras14 analyzer is housed along with the O₂ sensor in the casing of the central unit.

If waste products containing chlorides are combusted in the kiln, then the paramagnetic oxygen analyzer AO2000-Magnos17 should be used for measuring the O₂; this analyzer is housed in a separate casing.

Normally, the process photometer AO2000-Limas11 UV with quartz cell is used for SO₂ measurement. In case of gas firing and a SO₂ content < 500 ppm, also the infrared analyzer AO2000-Uras14 can be used for SO₂ measurement.

Calibration

The analyzers are always calibrated automatically. Cylinders of test gas are not generally required for the weekly calibration. The AO2000-Magnos17 oxygen analyzer requires N₂ as a zero gas.

The activation of calibration is time-controlled and cyclical, but calibration can also be started manually.

Technical Data

- AO2000-Uras14 infrared analyzer
  - Measuring ranges (examples): 0...0.5 vol. % and 0...2 vol. % CO
  - Measuring ranges (examples): 0...3000 ppm and 0...5000 ppm NO
  - Automatic calibration using calibration cells

- AO2000-Limas11 UV process photometer
  - Measuring ranges (examples): 0...5000 ppm and 0...20000 ppm SO₂
  - Automatic calibration using calibration cell

- Electro-chemical O₂ sensor
  - Measuring ranges 0...10 vol. % O₂ and 0...25 vol. % O₂
  - Automatic calibration using ambient air

- AO2000-Magnos17 oxygen analyzer
  - Measuring ranges 0...10 vol. % O₂ and 0...25 vol. % O₂
  - Zero-point calibration with nitrogen or ambient air; for this, a solenoid valve needs to be installed upstream of the sample gas cooler. The test gas cylinder is set up outside the analysis cabinet.

For further technical information see Data Sheet “AO2000 Series” (Publication No. 10/24-1.10 EN)
### Output, Input and Status Signals

**Indication**

All status signals are displayed in clear text.

| **Analog Outputs**<br>**(Current Signals)** | 1 current output 0/4...20 mA per measuring component (max. 4 measuring components), load max. 750 Ω |
| **Binary Outputs** | 3x common status 24 V, 1 A (error, maintenance mode, maintenance request) |

| **Single Status Signals**<br>**(Option)** | Output via floating relay contacts, max. load rating 230 VAC, 1 A |
| **Status signals:** |  |
| Manual | Plunger seized (only for probe H) |
| Automatic | Min. temperature sample gas line |
| Measure | Min. pressure compressed air |
| Clean | Min. pressure sample gas |
| Error | Cleaning failed |
| Probe inserted | Probe seized |
| Probe retracted | Min. pressure cooling water |
| Maintenance | Max. pressure cooling water |
| Failure | Min. temperature cooling water |
| Maintenance mode | Max. temperature cooling water |
| Maintenance request | Min. flow cooling water |
| Probe tube heating off | Cooling water pump motor protection |
|  | Frequency converter malfunction |

**Interfaces**

- Profibus DP slave RS232/RS485 (option)
- Ethernet (gas analyzer only) for remote operation and remote diagnosis with TCP/IP protocol
- Further interfaces possible on request
Analysis Cabinet

Layout

The analysis cabinet is produced in two versions: sheet steel and plastic (GRP). The analyzers are mounted in a swing frame. The electrical and gas connections are located in the left side wall.

Fig. 8
Analysis Cabinet

1 PLC unit
2 Sample gas pressure gauge
3 SCC-F sample gas feed unit
4 SCC-C sample gas cooler
5 Water filter
6 Flow monitor
7 Cooling water pressure gauge
8 Circulating pump
9 Reagent supply bottle
10 Condensate-collecting bottle
11 Pressure compensation vessel
12 Frequency converter
13 Gas analyzers

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Installation Notes

The sheet-steel analysis cabinet should always be installed in an air-conditioned room in order to protect it from dust and from ambient temperatures that are too high/low.

Ambient temperature range:
- with filter fans +5...+35 °C
- with filter fans and electric heating –10...+35 °C
- with cooler and electric heating –10...+50 °C

A plastic cabinet with filter fans, electrical heating and cooler is available for outdoor installation. In this case the filters must be cleaned on a daily basis.

Ambient temperature range: –20...+50 °C
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