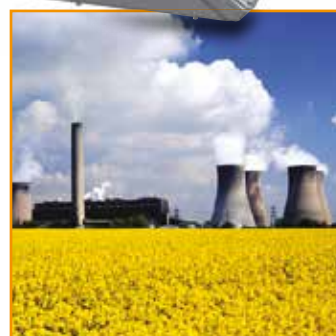
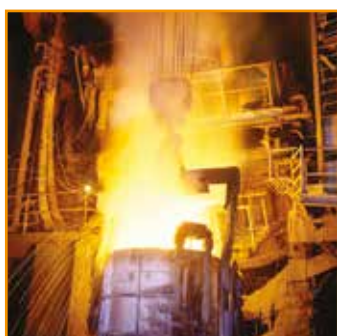


Comparison Continuous Emission Monitoring Techniques



Overview

The requirements for continuous emission monitors has changed significantly over the last 30 years. This has been brought about by the increase in use of flue gas treatment systems, reducing the levels of pollutant to be monitored, and Environmental Agencies worldwide requiring smaller processes to be monitored.

The Environmental Agencies have insisted that continuous emission monitors meet more stringent specifications, including repeatability and the capability to be fully challenged to demonstrate compliance. In addition, reporting regimes necessitate maximum availability. Pressure from the market place also requires the modern CEM system to have a low cost of ownership, which, in effect, means that high reliability must be a design criteria.

Typical Specification

There are many applications for continuous emission monitors, covering a variety of industries. The specification of the CEM system will depend on, not only the type of process, but also the pollutant gases that are required to be measured.

Typical CEM System		
Pollutants to be monitored, typical ranges:		
Range 1	0 - 200 ppm CO	0 - 250 mg/m ³ CO
Range 2	0 - 240 ppm NO	0 - 270 mg/m ³ NO
Range 3	0 - 250 ppm NO ₂	0 - 500 mg/m ³ NO ₂
Range 4	0 - 300 ppm SO ₂	0 - 850 mg/m ³ SO ₂

Other gases to be monitored:

Range 1: 0 – 20% CO₂

Range 2: 0 – 20% H₂O

Regulatory Authorities: The choice of the CEM system will depend on many factors, including the monitoring and reporting requirements of the local Environmental Authority.

Stack Temperature	80-350°C
Stack Width	0.5-10m
Performance Required	Accuracy < ± 2% FSD
	Repeatability < ± 2% FSD
	Linearity < ± 2% FSD
	Zero drift per 24 hours < 0.5% FSD non-cumulative
	Span Drift per 24 hours < 0.5% FSD non-cumulative
Reporting	Operational test period greater than 8760 hours (1 year) (hours without maintenance)
	Display concentrations of all Requirements: measurements gases to be displayed in ppm, mg/m ³ or %.
Output	Concentration to be transmitted as a 4-20 mA signal, in addition to this a serial digital link should be available to connect the CEM system to a supervisory computer



Approvals

Several countries have developed Continuous Emission Monitoring Approval Schemes. Three of the schemes are outlined, and have the following main points.

The various monitoring schemes have their small differences, but typically, as in MCERTS (EN14181), they cover the following.

- Linearity
- Cross Sensitivity
- Sample Pressure and Temperature
- Environmental Conditions
- Standard Reference Methods
- Availability
- Zero and Span Drifts

The European Monitoring Certification Schemes requires lab tests followed by field tests.

Monitoring Certification Scheme European Lab Performance Standard

	SO ₂	NO _x	CO	CO ₂	Hcl
Accuracy	+ 2%	+ 2%	+ 2%	+ 2%	+ 2%
Linearity	+ 2%	+ 2%	+ 2%	+ 2%	+ 2%
Cross Sensitivity	< 4%	< 4%	< 4%	< 4%	< 4%
Response Time Max	200 _s	200 _s	200 _s	200 _s	200 _s
Repeatability	+ 2%	+ 2%	+ 2%	+ 2%	+ 2%

Summary

The selection of the CEM system will depend very largely on the application. It has been demonstrated that the enveloped folded beam technique resolves many of the problems associated with extractive and a cross stack systems. It can also be shown that it complies with the stringent requirements of Environmental Agencies and it should be seriously considered when selecting a continuous emission monitoring system.

References: Hutchinson, RJ "Spectroscopy in Smoke Gas Stacks"

Monitoring Certification Scheme Field European Standard

	SO ₂	NO _x	CO	CO ₂	Hcl
Availability	≥95%	≥95%	≥95%	≥95%	≥95%
Minimum Maintenance Interval	8 days	8 days	8 days	8 days	8 days
Zero Drift	≤3%	≤3%	≤3%	≤3%	≤3%
Span Drift	≤3%	≤3%	≤3%	≤3%	≤3%
Determination Coefficient of Calibration Function R²	≥95%	≥95%	≥95%	≥95%	≥95%
Lack of Fit	≤2%	≤2%	≤2%	≤2%	≤2%
Reproducibility	≤3.3%	≤3.3%	≤3.3%	≤3.3%	≤3.3%

* Within Maintenance Interval

MCERTS Monitoring Scheme Standards Used

Standard Used	Component
EN 14791	SO ₂
EN 15058	CO
EN 14792	NO
EN 1911	HCl
EN 13284-1	Dust



Continuous Emission Monitoring: A Brief History

Extractive

Until recently, the extractive CEM system was dominant in most applications. The majority of these systems fit into the following three categories.

Cold Extractive (Continuously)

In this type of system, a sample is continually drawn from the stack and transported via a heated line to system housing, which, in addition to the analyser or analysers, contains all the necessary sample preparation components. Part of the sample preparation is to remove the water vapour, by rapidly chilling the sample, before analysing the sample. Obviously, the system requires a significant amount of maintenance to ensure that all the sample preparation components are operating correctly.

The major drawback with this type of CEM system is that a significant percentage of any soluble gas, such as NO_2 , SO_2 , and, to a lesser extent, NO , is removed along with the water vapour.

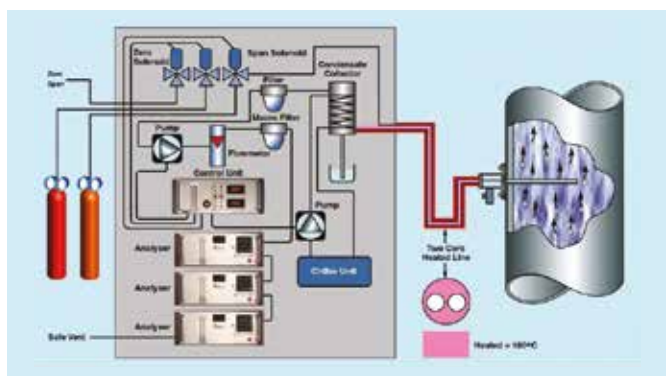


Fig. 1 Cold Extractive System

Hot Extractive

Again, a sample is continually removed from the stack and transported through a heated line to the system housing where the analysis of the stack gas is carried out hot.

This is achieved by ensuring that all the sample wetted parts are maintained well above the temperature at which condensation would occur. In many applications, this would be approximately 200°C , however, in several applications, for example the monitoring of ammonia, the temperature would have to be maintained at approximately 325°C to ensure that ammonium chloride does not form. Obviously, all the components coming into contact with the sample have to be suitable to operate at the elevated temperature, including solenoid valves, filters, pump heads, and, indeed, the analyser sample cell.

Dilution System

To avoid the need to remove the water vapour and to ensure condensation does not occur in the sample line or analyser components, a technique of diluting the sample at the take-off was developed. Protection against condensation is achieved by diluting the sample to a level at which even the lowest ambient temperature would not cause any condensation to form. The sample is transported from the take-off point to the system housing, where additional sample preparation components and the analysers are mounted.

The major drawback of this system is that, in addition to maintaining the dilution system, the analyser has to be significantly more sensitive to monitor the diluted gas.

Cross Duct and Reflective Cross Duct Analysers

This was a significant step forward in continuous emission monitors, negating the need for expensive, bulky, and a high maintenance sample systems. The disadvantages soon became clear with the inability to directly zero and calibrate the instruments. There are also restrictions on the size of stacks which could be reliably monitored with this type of system. The Cross Stack and Reflective Cross Stack rely on the stack as the sample cell, sending pulses of infrared or UV light through the stack to either a receiver or a reflector, which is then returned to the stack mounted transmitter / receiver unit. A benefit is that the analysed samples are true and unmodified.

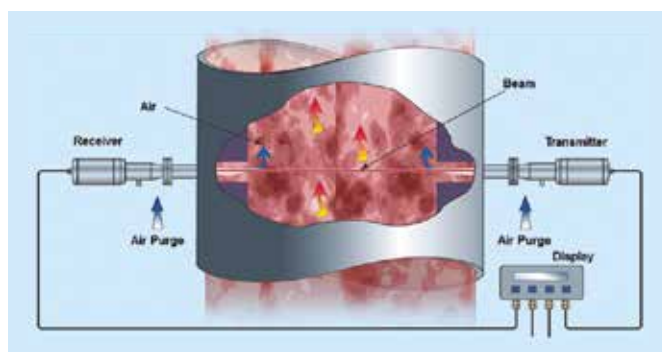


Fig. 2 Cross Duct Analyser

In-Situ Open Path Analyser

In this configuration, the reflector is mounted on the probe, a slot in the probe allows the gas to pass between the in-stack window and the reflector. In an attempt to zero and calibrate the instrument, a second reflector is swung in front of the in-situ stack window and the system zeroed.

In addition, test gas can be passed into the enclosed portion of the probe, enabling the instrument to verify calibration.

The major problem with this configuration is that the full system is not challenged, i.e., a second reflector is used and effects on the first reflector are not taken into account.

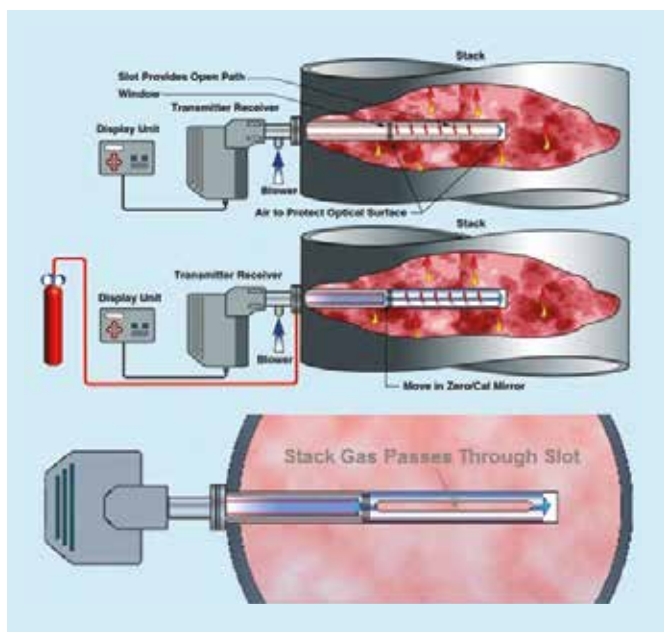


Fig. 3 In-situ Open Path Analyser

Enveloped Folded Beam

In this configuration, the transmitter and receiver are mounted in one enclosure and the pulses of infrared or UV light passed out through a tube containing two lenses, one on the exit of the optical housing, the second, a process lens, mounted in the stack. The pulses of infrared or UV then pass through a second portion of the probe, which is fitted with sintered panels, allowing the flue gas freely to pass into the cell. The pulses of infrared / UV light strike a retroreflector and are returned through the same path to the transmitter receiver.

Auto Zero /Auto Cal

To comply with various Environmental Agency requirements, in particular, US EPA 40 CFR Part 60 & 75, the instrument has to be challenged on a daily basis. Clearly, extractive instruments can be challenged by diverting zero and then test gas into the sample cell, enabling the instrument to be recalibrated and any errors reported. This is also possible in the enveloped folded beam. Normally, the flue gas passes through the sintered panels, filling the in-situ gas cell, where the absorption of infrared or ultraviolet light takes place. Periodically, either automatically or on demand, a solenoid valve can be activated by allowing instrument air to be discharged into the in-situ cell, forcing out the flue gas, enabling the instrument to check zero and adjust if necessary. In the same way, certified test gas, traceable to a National Standard, can be introduced into the sample cell, enabling the instrument to check, and, if necessary, adjust calibration. It is recommended that the auto-zero is carried out on a daily basis, however, experience has shown that calibration verification need only be carried out every three months or so. Under US EPA 40 CFR Part 60 & 75, it is a requirement to carry out these checks on a daily basis. If the instrument is outside $\pm 2.5\%$ on either the zero or the span, the instrument is deemed to be out of calibration for that day.

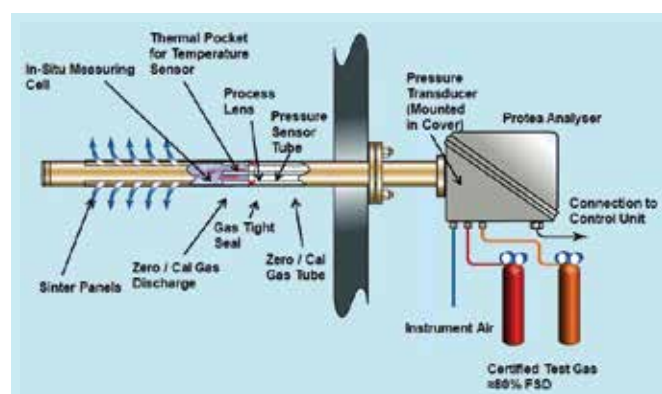


Fig. 5. Auto Zero / Auto Cal Assembly



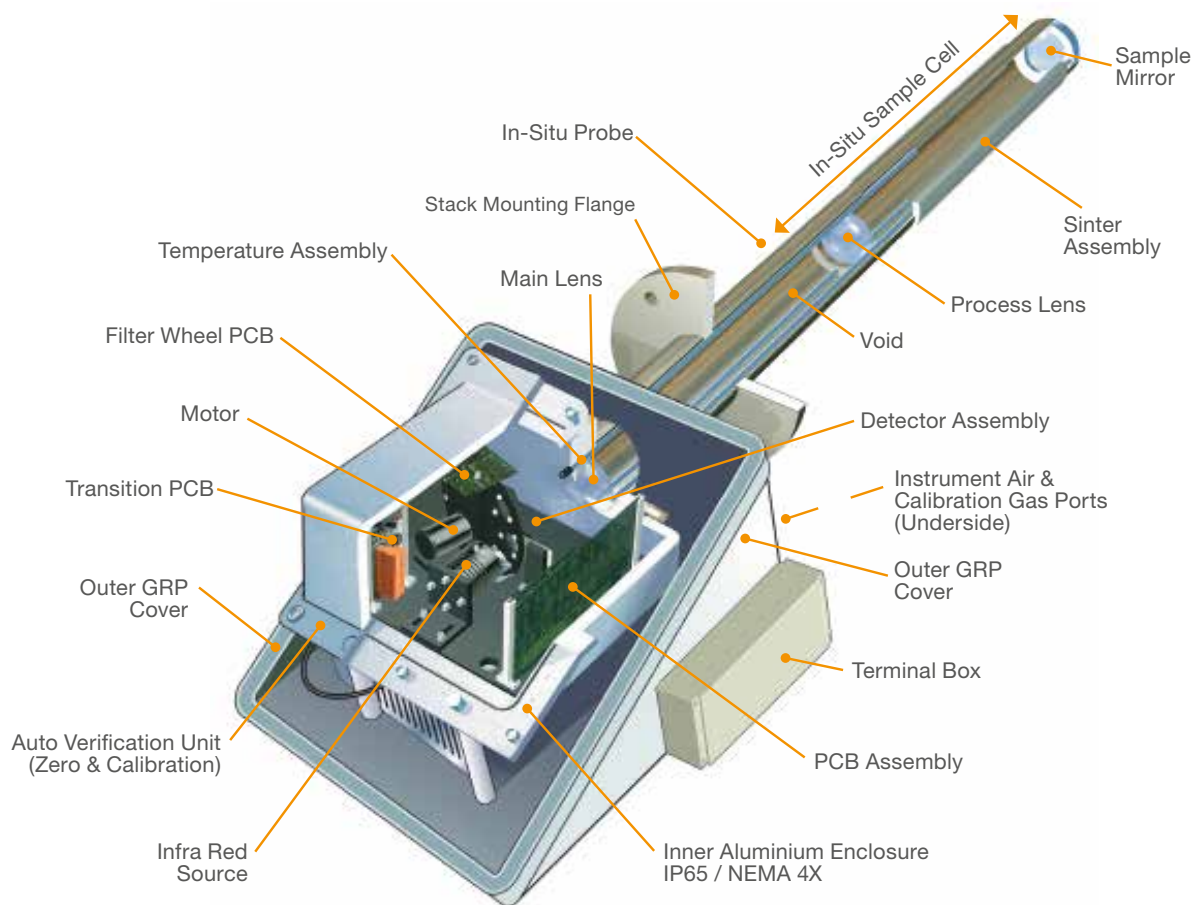


Fig. 4 Enveloped Folded Beam

Multi Component Analysis

Traditionally, analysers were designed to monitor a single gas species if multiple gas analysis was required then a series of analysers was used. With the requirement to monitor and report several pollutant gas emissions the modern CEM system is capable of simultaneously monitoring and displaying concentrations of five or six species.

Analyser Selection

The type of analyser selected will depend on the species and concentrations to be monitored.

	Species	CO	NO	SO ₂	NO ₂	CO ₂	H ₂ O
Photometer	IR	X	X	X	X	X	X
	UV		X	X	X		
Spectrophotometer	IR	X	X	X	X	X	X
	UV		X	X	X		X
Chemiluminescence			X		X		

Fig. 6

Cross Sensitivity

For many years, the only way of reliably monitoring several flue gas components, such as NO, NO₂, SO₂ and HCl was to remove the water vapour from the stack gas sample prior to carrying out the analysis. This was due to the cross sensitivity between water vapour and the components to be monitored, as can be seen from the chart, water vapour absorption occurs at the wavelengths the pollutant gases are measured. Two techniques have been applied to reduce cross sensitivity. By using gas filter correlation (GFC) the prime sensitivity is improved and cross sensitivity dramatically reduced. In addition, by monitoring water vapour and applying a cross sensitivity correction, the effect of water vapour can be eliminated, ensuring that the accuracy of the instrument is within the 2% requirement. These techniques can be used to remove the cross sensitivity of other species.

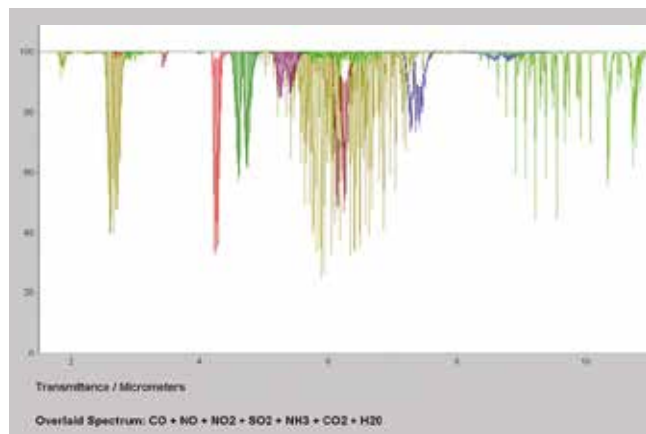


Fig. 7 IR Spectrum of Gases

Pressure and Temperature Compensation

To ensure that the instrument is within $\pm 2\%$ accuracy, it is necessary to carry out automatic correction for changes in sample temperature and pressure. This is achieved by continually monitoring the temperature and pressure within the sample cell and compensating for any changes.

The pressure compensation deals with changes in barometric and flue gas pressure, in addition, if the certified test gas applied to the probe causes a pressure increase, pressure compensation would remove the effect.

Typical Installation

The in-situ CEM system is flange mounted, with the in-situ sample cell protruding into the stack. The analyser is connected via a serial link to the analyser control unit, which displays, data logs and re-transmits the concentrations of the monitored flue gas components. In addition, the auto zero / calibration unit, fitted with three solenoid valves, and controlled by the microprocessor in the analyser, allows the periodic zero and calibration to be carried out. Several analyser can be connected to a single Analyser Control Unit.

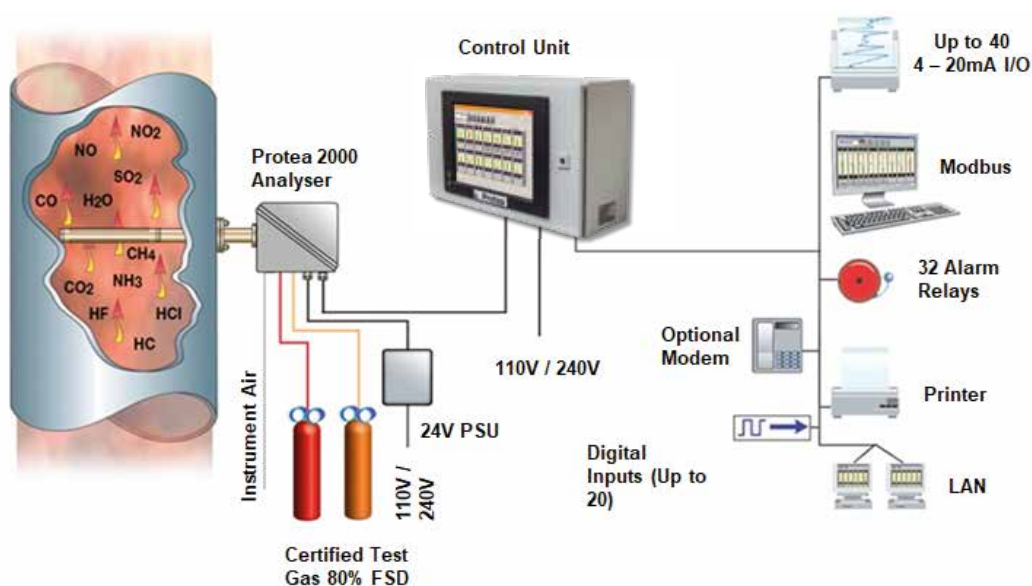


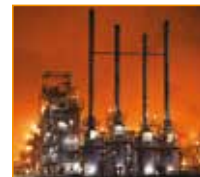
Fig. 8 Typical Installation

Analyser Control Unit (ACU)

Industrial PC displays, data logs and retransmits concentrations of monitored gas species.



Fig. 9 ACU Display



Integrated Stack Monitoring System

It is often necessary to report the pollutant measurements normalised to a level of O_2 or CO_2 . This can be achieved by connecting an oxygen analyser directly into the stack mounted infrared / UV analyser. The data from the oxygen analyser is then transmitted to the analyser control unit, and used to calculate and display a normalised concentration of pollutant gas.

Similarly, a velocity device can be connected to the optical head unit, enabling the concentrations to be displayed in mass units.

In many applications, it is also necessary to measure the opacity / dust. Again, an appropriate instrument can be connected to the P2000, and the concentrations of dust displayed on the analyser control unit.

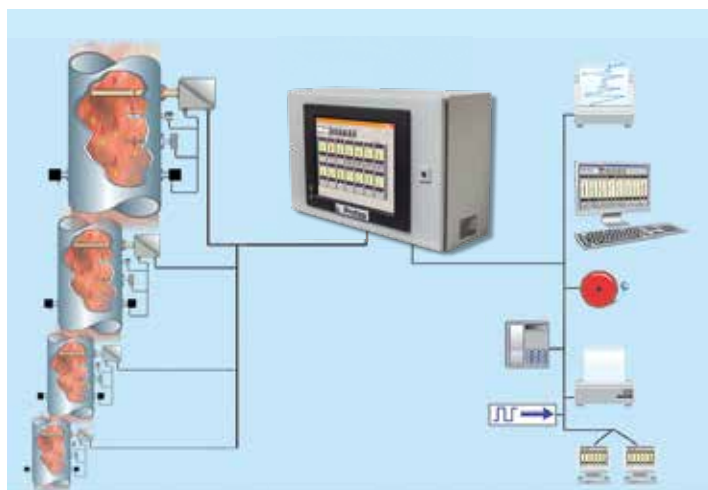
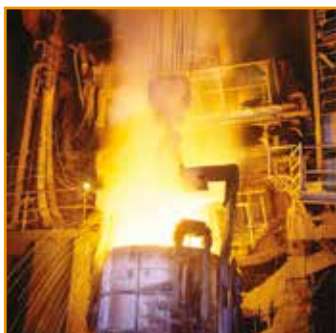


Fig. 10 Integrated Stack Monitoring System



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