Particulate CEMs for Wet and Dry FGD applications

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1) Introduction

This paper overviews the challenges of monitoring particulate in wet and dry stack conditions found after wet and dry FGD arrestment plant fitted to coal fired power plant. It describes the techniques used for monitoring particulate in these applications and provides results and incites from the operation and calibration of PCME's wet stack PM-CEM in a wet FGD installation.

The uptake of wet Flue Gas Desupherisation (FGD) technology in the power industry has created a new demand to continuously monitor particulate emissions due to the challenge of low dust concentration measurement and, in applications without reheat, the need for operation in 'wet stack' conditions. Wet conditions are more challenging to continuously monitor than 'dry or non condensing' stack conditions due to problems of overcoming interference from water droplets. Traditional particle measurements cannot be used in these applications due to interference from condensed Water vapour.

There are essentially two core techniques for monitoring particulate emission concentration with high accuracy in wet stacks and both are extractive in nature (ie a sample is drawn continuously from the stack in a representative fashion) and passed through the analyser before return to the stack.

1) Beta Attenuation
2) Extractive light scatter

In the second type, the extracted stack sample is heated to evaporate any residual water droplets. Thus the sample becomes effectively dry so that it may be analysed by a standard dry measurement technique.

2) Emission limits for S02, NOx and Particulate in Coal fired Power Plant

Power plant have always operated in an environment where emission limits are set by regulatory bodies. These emission limits play a key role in defining the type of pollution abatement equipment fitted to the plant.

In Europe, emission limits are set by the European Parliament through the Large Combustion Plant Directive and more recently by the Industrial Emissions Directive. Emission limits for SO2 from large coal fired power plant are currently 400mg/m3 (for plant without operating lifetime constraints , and as a result of the Industrial Emissions Directive (IED) will fall to 150 mg/m3 in the medium term.

Pollutant	Plant size	Future IED limit	Current LCPD limit	Implication for control technology Comment
Particulate	50 -500MW >500MW	30mg/m^3 20mg/m^3	100mg/m^3 (50 new plant) 50mg/m^3 (50 new plant)	Bagfilters/ FGD
SO_2	50 -100MW 100 – 500MW >500MW	400mg/m^3 400 -150 150mg/m^3	2000mg/m^3 (850 new) 2000- 400 mg/m^3 400mg/m^3	FGD plant
NO_X	Up to 500MW >500MW	300mg/m^3 200mg/m^3	600mg/m^3 500mg/m^3 (200mg/m^3 in 2016)	Need SCR to meet new limits

Pollution Abatement equipment is installed before the final stack emissions to control emissions and the implications of these new limits and specifically for SO2 is that all plant will be required to install and operate efficient Flue Gas Desulpherisation (FGD) plant.

In the US similar changes to emission limits are being proposed through new Maximum Control Technique (MACT) standards which support the National Emission Standards for Hazardous Air Pollutants (NESHAP) from the plant. The proposed Utility MACT which will apply to large coal fired utilities

3) Implication of emission limits on control equipment and PM -CEMS

The trend to lower emission limits is similar world wide and therefore the installation of FGD, SCR and modern particulate control equipment is the likely direction for most Coal Fired Power Plant.

The type of arrestment plant has direct influence on the flue gas conditions and therefore the selection and applicability of Continuous Emission Monitoring (CEM) systems. One of the most important characteristics in relation to the selection and operation of PM (particulate) CEMs is whether the flue gas is wet or dry, since water droplets and condensed steam is an interferant on all types of in-situ PM CEMS

3.1) Controlling SO2 with FGD

The principle of the FGD process is to absorb SO2 with a powder or slurry sorbent injected into the flue gas.

1) Wet FGD systems

In wet FGD processes, flyash is first removed with a wet collector and/or Electrostatic precipitator before the fluegas is passed into a S02 absorber stage where a sorbent or alkali(e.g. a slurry of limestone, CaO or Mg2O, sea water) absorbs the SO2. The flue gas is saturated with water on exit from the reactor and still contains some SO_2 and is therefore highly corrosive to downstream equipment such as fans and stacks.

There are therefore two approaches to avoiding the issues related to corrosion each which are considered on a site by site basis based on cost and visual impact grounds

1) To design the downstream equipment with special alloy steels (eg Hastalloy) and composite materials which are tolerant to attack by sulphuric acid. In such cases the flue gas exiting the stack is still below dew point creating a water vapour plume and as such is considered as a 'wet' gas.
2) To heat the flue gas above dew point with a heat exchange system using the hot flue gas ahead of the FGD. This ensures that the main stack plume is without steam on initial exit from the stack and that standard steels can be used for ducting the flue gas to atmosphere. This type of process is defined as one with reheat and the flue gas is above dew point (dry stack conditions)

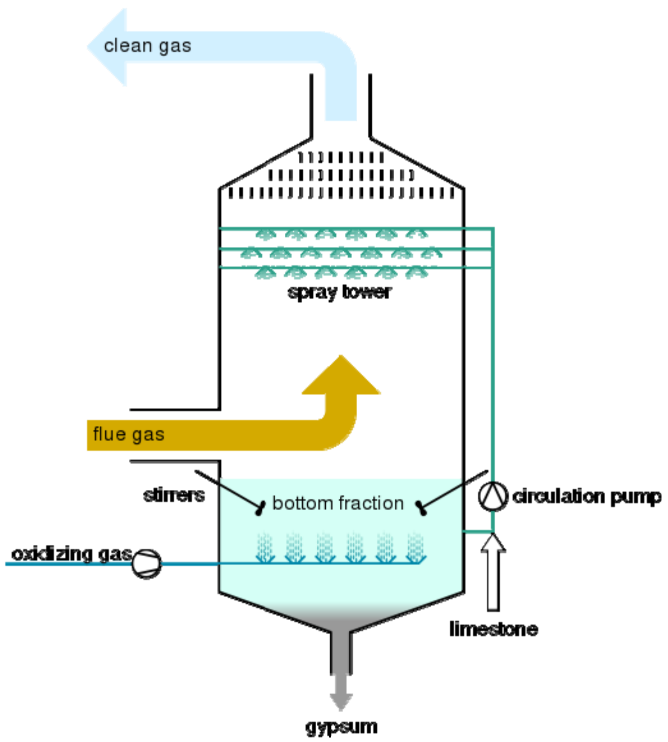


Diagram of FGD process: source: Wikipedia (31/8/11)

2) Controlling SO2 with dry FGD

In dry injection processes the SO_2 sorbent is injected as a powder and in spray drying processes the sorbent is sprayed as a solution into the hot flue gas and evaporates to form a powder. In both case the powder reacts with and absorbs the SO_2. The sorbent powder and flyash are then separated from the flue gas with large filter plant (baghouse) before the flue gas, which is above dew point, passes as a 'dry gas' up the stack. These stack are characterised as having dry stack conditions.

3.2) Controlling NOx with SCR

The control device fitted to coal fired power plant to control NOx is the Selective Catalytic Reactor (SCR) and this is required on an increasing number of coal fired power plant to meet new lower emission limits for NO and NO2. This equipment is fitted in addition to FGD and particulate control equipment.

In an SCR reactor, NOx is abated by introducing Ammonia to react with any surplus NOx to form Ammonium Nitrate. This Salt is removed in a downstream process, but is also present in the gaseous phase in the flue gas. This has implications for the maintenance of any downstream instrumentation which heats the flue gas (common in wet PM measurement) since salts will form on heated surfaces.

3.3) Implications of flue gas conditions after different arrestment plant on CEM selection

The conditions of key importance in the selection of particulate CEMs is whether the flue gas is 'wet' or 'dry' where 'wet' is defined as below dew point. A summary of these conditions based on different types of arrestment plant is given in table 1

FGD type	***Reheat***	***SCR fitted***	***Downstream bagfilter***	***Flue gas conditions***
Wet	Yes	Yes	Optional	'Dry', salts, low dust
		No		'Dry' ,no salts, low dust
	No	Yes	Not applicable	'Wet' salts, low dust
		No		'Wet', no salts, low dust
Dry	Not applicable	Yes	Yes	'Dry' , salts, low dust
		No	Yes	'Dry, no salts, low dust

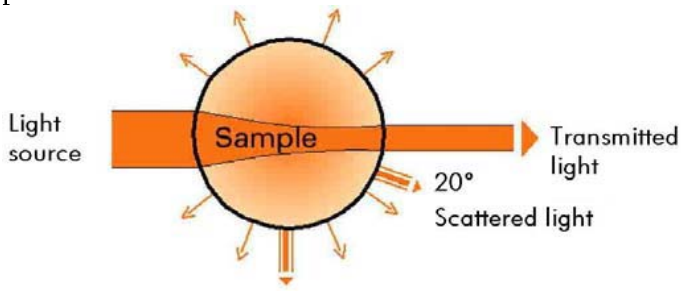
Wet FGD with reheat (common in Europe) have similar dry stack conditions as dry FGD plant whereas Wet FGD plant without reheat (common in North America) have wet stack conditions. Different types of particulate CEMs are required for these conditions.

Low dust (< 10mg/m3) applies to all conditions where FGD are fitted, and salts are of relevance for extractive CEMS using heating systems.

4)Technologies for monitoring Particulate monitoring after FGD

4.1 Dry Stack conditions

Where the flue gas is dry (above dew point), it is always more effective to use an insitu instrument to avoid the maintenance associated with extractive instruments and it is increasingly relevant to use particulate CEMs using light scattering technologies, since these can measure emissions at the low levels (< 10mg/m3) found after modern FGD plant.



The traditional opacity or extinction transmissometer is not relevant for these applications since their inherent zero drift limits its stable resolution to 25mg/m3 even in larger stacks.

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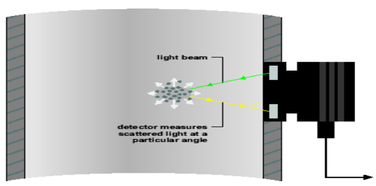
Light scattering instruments measure the light scattered or reflected by the particles and are available in 3 forms of implementation

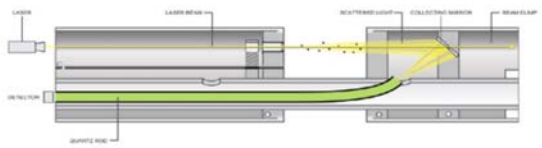
Back scatter instruments

Back scatter instruments shine a light (typically a laser) into the stack and measure the light reflected back towards a receiver positioned close to the light source. Modern instruments tend to position the receiver very close to the transmitter and in the same enclosure, so that the instrument can be mounted to the stack with a single standard flange connection. The minimum resolution of back scatter instruments can be as low as 1mg/m3 but is typically 10mg/m3.



Forward scatter probe instruments

Forward scatter probe instruments measure the light scattered by a laser in the forward direction collected by receiver optics embedded in the far end of a probe which is inserted in the stack. Such instruments are capable of measuring emission levels as low as 0.1 mg/m3



Measurement mode

Forward scatter cross stack instruments

In these cross stack instruments a laser light source is directed across the stack and the light that is reflected in the forward direction by particles at a certain position in the stack, is measured by a detector which is mounted on the far side of the stack, but offset from the incident beam. Similar to light scatter probes, cross stack light scatter instruments can measure emissions as low as 0.1mg/m3 at a particular point in the stack.They have the corrosion advantage of having no ‘wetted’ parts exposed to flue gas, but must maintain alignment to ensure stable readings.

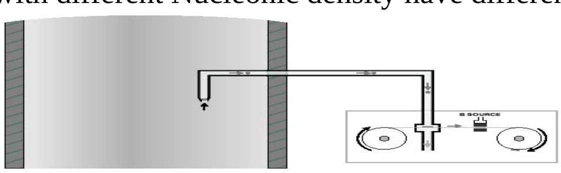
4.2) Wet stack conditions

When the flue gas is below dew point it is not possible to use an insitu PM CEM, since water droplets and condensed steam give an interfering response in the CEM (water droplets absorbs and scatter light similarly to particulate). Hence it is not possible to differentiate in an insitu PM CEM between the signal coming from particulate and water.

An extractive approach is therefore required to measure PM continuously in a wet stack. This necessitates the use of techniques which do not suffer interference from water (Beta absorption) or work on the basis of evaporating the water ahead of measurement with a ‘dry’ light scattering CEM.

Beta absorption systems

The principle of operation of Beta absorption systems is that the flue gas stream is sampled iso-kinetically and the sample of particulate collected onto a filter. The filter is advanced periodically (typically every 15 mins) into a measurement chamber, so that radioactive Beta particles can be passed through the sample and the amount of Beta particles transmitted through the sample is measured. The amount of transmitted signal is related to the amount of particles by the Bear Lambert law. The main advantage of this technique is that the absorption of radioactivity is not significantly effected by the type of particle (although particles with different Nucleonic density have different responses)



Practical Issues: The major practical issues relate to the difficulties of sampling the particulate:

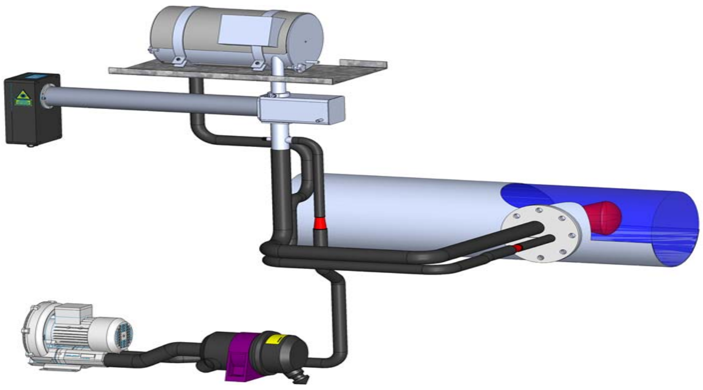
- High maintenance is required for the sampling train and the mechanical filter advancing system.
- A radioactive source is commonly used in the Beta device and as such many countries require a defined health and safety procedure for the device which can stipulate installation issues.

Extractive Light scattering systems

In extractive light scatter instruments a sample of flue gas is sampled under isokinetic conditions and then passed into an external light scattering chamber. A forward light scattering technique is normally used in the measurement chamber and a heater unit can be fitted before the chamber to evaporate and eliminate water from a wet or humid application. The same problematic issues of sample handling are as relevant with these instruments as for Beta attenuation devices.

5)Results with PCME Instruments in wet applications

PCME's wet stack instrument (PCME Stack 181 WS) has been developed over a 4 year period and is derived from a proven insitu light scatter probe (PCME QAL 181). It is as an extractive light scatter system, which controls extraction from the stack to maintain isokinetic conditions (based on input from a separate flow meter). The sample passes into a vapourising chamber in which the centrifugal motion of the flue gas against the heated (220'C) cylindrical walls evaporates any water droplets and takes the flue gas above dew point. Measurement of the particulate under dry conditions is made in a measurement chamber in which the PCME QAL 181 sensor is installed. A venturi pump is used to power the sampling system.

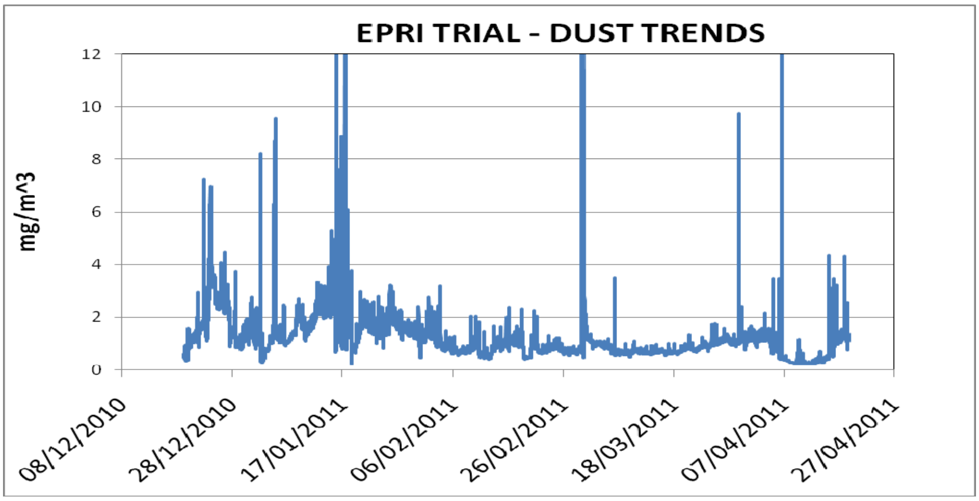


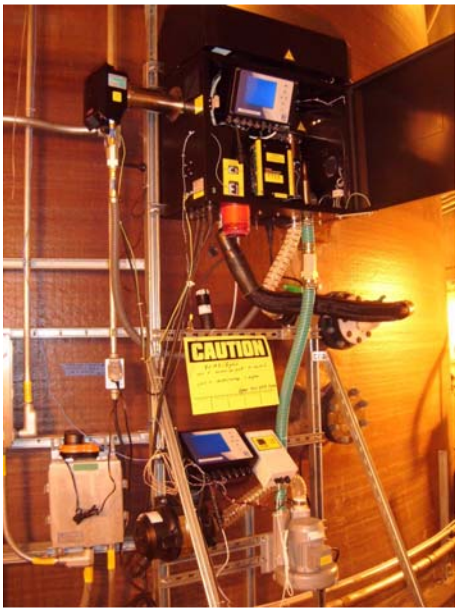
The system, unlike some others in development, is not a 'dilution' system, meaning that a much larger sample of flue gas is sampled and the sampling pipework is therefore larger meaning it is less likely to plug and block between scheduled maintenance.

The instrument is designed for use in all types of wet applications (eg incinerators , metal furnaces and lime kilns all with wet scrubbers) aswell as wet FGD. The following findings are taken from the ongoing evaluation of the CEM in a 500MW coal fired power plant with wet FGD as part of an evaluation on PM CEMS by the Electric Power Research Institute (EPRI) in the US.

Coal fired Power plant with wet FGD, 7m stack on which extractive 181WS is installed

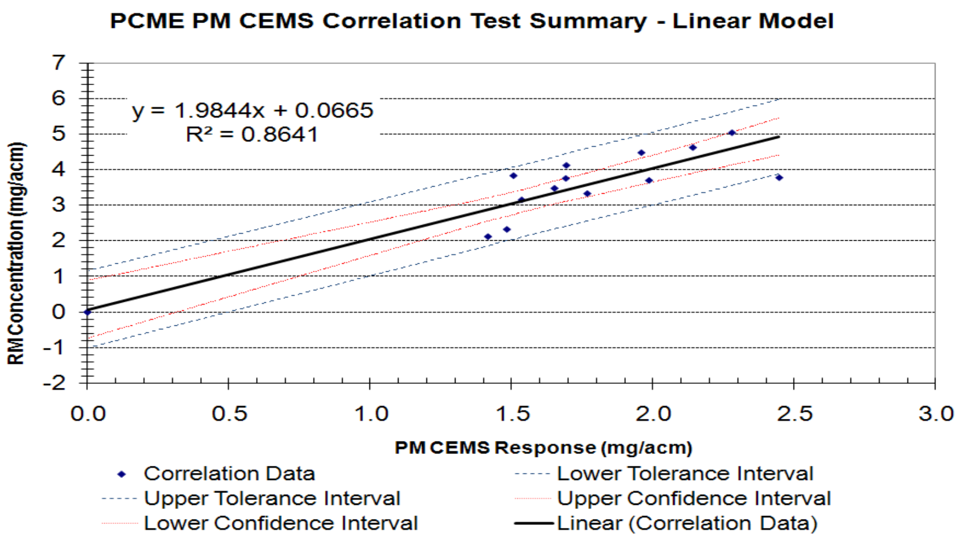
- First the instrument has the resolution to measure the low levels of emissions (<1 mg/m3) found after FGD plant



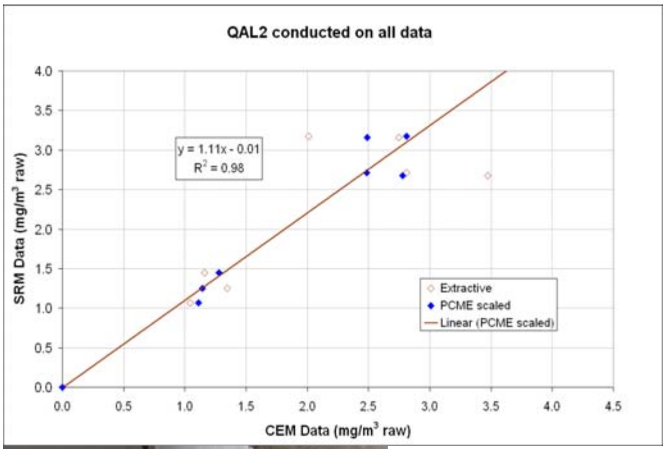


Installation of 181WS at analyser level in main stack

- The instrument can be calibrated against dust concentration as required to satisfy the calibration requirements of US EPA standard PS-11 which are similar to the QAL2 calibration requirements of EN-14181. In FGD applications it is difficult to create emission conditions which extend the calibration range beyond a cluster.

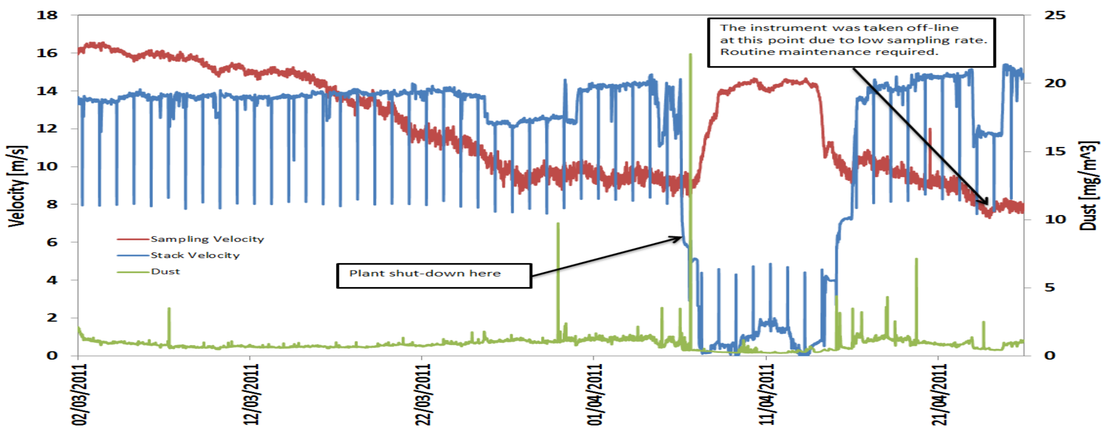


- It is challenging but possible to get good results in wet stack conditions in spite of the small sampling volume of the CEM and the increased inaccuracies of the Standard Reference Method (SRM) in wet stack conditions. However these issues do limit the quality of correlation coefficient of calibrations compared to dry applications. The following results are from the use of the same light scatter probe, but in insitu form in a wet FGD application with reheat.

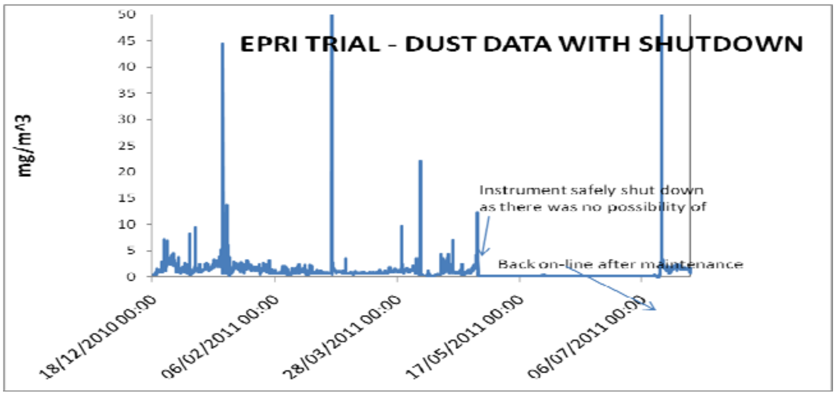


In insitu version of light scatter used on FGD with reheat

- The instrument requires regular maintenance and cleaning to give reliable results in a wet FGD application. With a monthly schedule of cleaning the sampling probe for entrained particulate and the cleaning of the vaporising chamber to remove salts coming from the SCR, the instrument will provide reliable operation. Component parts which are exposed to flue gas which has condensed below the dew point must be made of Hastalloy to provide long term protection.



- The instrument has long term stable operation. Even when shut down for an extended period of time the instrument returns to its normal response after recommissioning and cleaning.



This EPRI evaluation which is ongoing, isexpected to conclude by the end of 2011. The performance of the 181WS is representative of that shown in other wet applications.

6) Summary and Conclusion

The adoption of new lower emission limits for S02 on Coal Fired power Plant in Europe, US and the wider industrial world is encouraging the retrofit and installation of new efficient FGD plant.

FGD plant are either ‘wet’ or ‘dry’ and depending whether reheat is used after the FGD, the flue gas conditions maybe above or below dew point.

In dry stack applications, insitu light scatter systems may be used satisfactorily to monitor PM emissions on a continuous basis, however if the stack conditions are wet (ie below dew point and /or containing water droplets) then extractive PM monitors must be used to avoid interference and errors from the water.

Both Beta and extractive light scatter systems are used in these applications. The PCME QAL 181 WS is an extractive wet stack instrument which has evolved from an insitu light scatter CEM and is able to operate in a wet FGD application. Field results from a 3rd party evaluation of the instrument in this application provides encouraging evidence that the instrument is fit for purpose. The instrument is being used to satisfy European EN-14181 and US EPA PS-11 monitoring standards.