

## **Introduction**

The Kittiwake Procal P2000 is a proven analytical instrument that provides continuous emission measurements for operators of numerous flue gas desulphurisation (FGD) systems across the world. The simple in-situ design allows the P2000 to be installed quickly and integrated easily into plant data handling control systems. The in-situ method of the P2000 allows this robust instrument to be located in key positions both downstream and upstream of the FGD system. By comparison of the upstream and downstream measurements the efficiency of the FGD system can be monitored and controlled. Together with the facilities available at Procal and the services of our professional technicians analysers can be configured for FGD systems on a site-by-site basis. Gas concentration ranges can be set to span ranges covering both boiler exhaust (pre FGD) or scrubbed flue gas expected values recorded on site.

The Procal 2000 analyser operates on the proven, single beam, dual-wavelength IR light principle. Mid IR Pulses, at two specific wavelengths per monitored component, are transmitted through the sample cell. The 'measure' pulse is partially absorbed by the gases being measured while the 'reference' pulse remains unaffected. Up to eight wavelengths are available, sometimes sharing reference wavelengths, allowing up to six gas-phase component concentrations to be monitored simultaneously.

Power stations that burn fossil fuels such as coal and oil have flue gas desulphurisation (FGD) systems installed that remove sulphur dioxide from the exhaust flue gases. This is an important anti-emissions technology as fossil fuels contain significant amounts of sulphur and in the combustion process approximately 95% of the sulphur is converted to sulphur dioxide (SO<sub>2</sub>). Further oxidation to sulphur trioxide (SO<sub>3</sub>) produces sulphuric acid mist (H<sub>2</sub>SO<sub>4</sub>) in the form of a liquid droplet aerosol that is precipitated as acid rain. An optimised FGD system can remove up to 95% of the SO<sub>2</sub> emitted from the furnace of the boiler. The Procal P2000 can measure SO<sub>2</sub>, which has two infrared absorption spectrums, at wavelengths located at 3.98µm or 7.35µm in the mid Infra Red spectrum. The measurement wavelength is selected depending on the presence of other gases in the flue stream. For example carbon dioxide (CO<sub>2</sub>) has an absorption spectrum between 4.18µm and 4.5µm and so CO<sub>2</sub> overlaps at the spectrum of 3.98µm with SO<sub>2</sub>. Equipped with both knowledge and experience Procal technicians are able to select appropriate measurement wavelengths to minimise cross sensitivity effects caused by other gases present in the flue gas stream. Procal's advanced software algorithms allow the input of coefficients to further reduce cross sensitivity below 2%. The P2000 provides a measurement accuracy of ±2% of the full-scale range of the gas being measured.

The number of FGD units has steadily increased due to more stringent worldwide environmental regulations. FGD units have been applied to combustion units ranging in size between 5 and 1500 MW. By the year 2000 FGD was being used in over 27 countries covering 678 power stations with a total capacity of 229 GWs. The P2000 meets both CEM - US EPA 40 CFR

part 60 & 75 and AMS - Europe QAL 3 of EN 14181 approvals. The P2000 has also been approved under the UK environmental agencies MCERTS scheme. This monitoring certification scheme is built on proven international standards and provides industry with a framework for choosing monitoring systems and services that meet the UK environmental agency performance specifications. The MCERTS P2000 has been thoroughly tested both in laboratory and industrial environments where its reliability and measurement performance have been proven and its design specifications realised.

### **FGD Technology**

In general, FGD systems employ two stages: one for fly ash removal and the other for SO<sub>2</sub> removal. Systems that remove both the fly ash and SO<sub>2</sub> in one scrubbing vessel exist but suffer from low removal efficiency and high maintenance costs. In the majority of power stations lime or limestone wet scrubbing is the dominant technique with smaller numbers (up to 300MW capacity) using spray-dry scrubbers or sorbent injection systems.

In wet scrubbing systems the fly ash is normally removed first by passing the gas through an electrostatic precipitator or wet scrubber before entering the SO<sub>2</sub> absorber. Unlike higher maintenance extractive systems, Procal's patented, sintered metal technology removes the need for gas filtering or sample conditioning. The sintered panels of the P2000 allow flue gases to enter the in-situ sample cell whilst preventing the entry of fly ash. On exiting the absorber the flue gas is saturated with water and still contains some SO<sub>2</sub> that is highly corrosive to any downstream equipment such as fans, ducts, and stacks. Optional accessories are available for the P2000 to extend the analyser's capability in such cases of extreme process or ambient variations. Typical P2000 accessories would be a probe heater to ensure the in situ gas cell operates above process gas dew point, a gas flow bypass for high thermal stress applications and a analyser cooler for operation in high ambient temperature conditions

### **Types of wet scrubbers used in FGD**

To promote maximum gas-liquid surface area and residence time, a number of wet scrubber designs have been used, including spray towers, venturis, plate towers, and mobile packed beds. Because of scale build-up, plugging, or erosion, which effect FGD dependability and absorber efficiency, the trend is to use simple scrubber designs such as spray towers.

### **Spray towers**

The P2000 system, which requires very little maintenance and achieves a class beating up-time of 98%, has been installed on several spray tower FGD systems including that at the Drax Power Station in the United Kingdom.



Figure 1 Drax Power Station UK with a capacity of 4000MW

The Drax power station is the largest in the UK with a capacity of 4000MW. Flue gases from the six boilers are measured by twelve P2000 analysers with two analysers fitted at the exit of each boiler. Each P2000 is equipped with an in-situ heater keeping the sample compartment above the dew point at 150°C. The P2000s at the exit of the boilers are configured to measure the following gases SO<sub>2</sub> 0-3000ppm, NO 0-800ppm, CO 0-300ppm (dry basis) and H<sub>2</sub>O 0-20%.

In the FGD system fly ash is first removed by passing the flue gas through the electrostatic precipitators. The boiler flue gas is increased in pressure and then cooled from between 115°C-130°C to 80°C. The gas then enters the lowest part of the absorber tower and is further cooled by water that washes the inlet duct and prevents a build up of solids. The spray tower consists of a tower equipped with spray nozzles arranged at five separate levels that generate the droplets and interact with the gas absorbing SO<sub>2</sub>. The spray washes out of any remaining pulverised fuel ash, and the gas is 'scrubbed' by the re-circulating limestone slurry.

The two most important alkaline sorbents used for scrubbing flue gases are lime and sodium hydroxide (caustic soda). Lime is typically used on large coal or oil fired boilers as found in power plants, as it is less expensive than caustic soda. However, using lime results in a slurry being circulated through the scrubber instead of a solution as in the case with caustic soda.

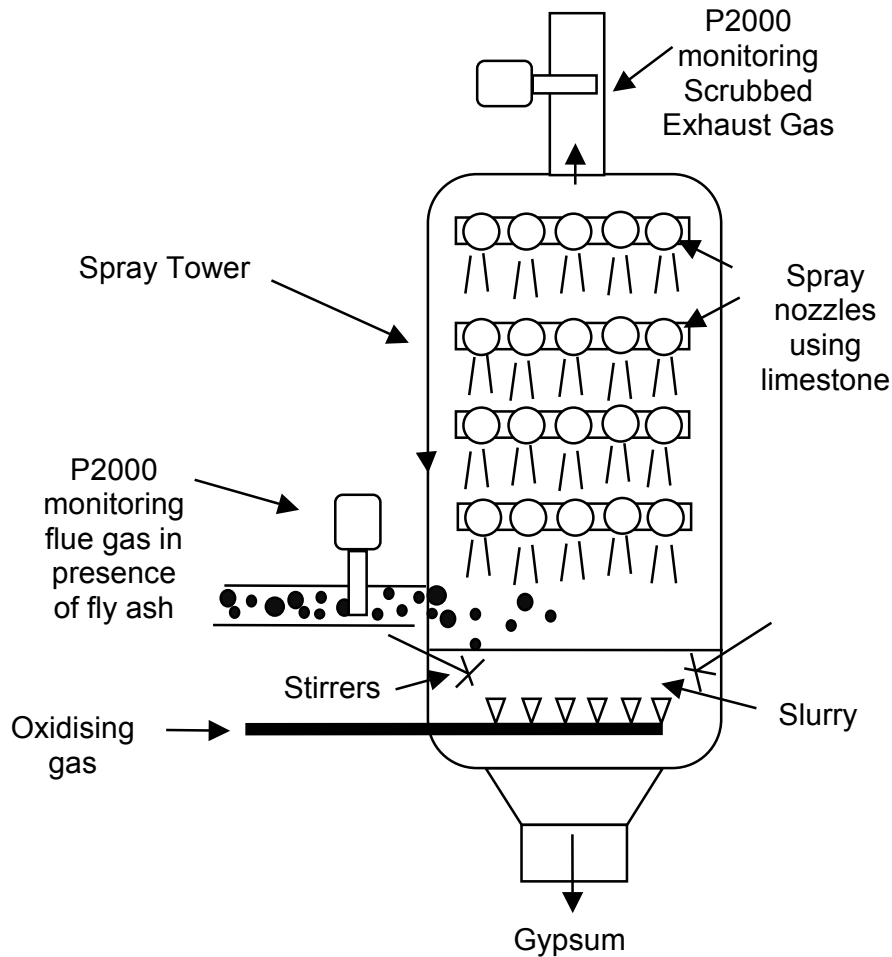
As a result of the process chemistry, the re-circulating slurry becomes predominantly gypsum and a portion is continuously pumped away for gypsum separation and the removal of water using a hydrocyclone system. A waste water treatment plant ensures any water from the FGD process returned to the river meets quality standards set by the regulatory authority.

At the exit of the FGD system the SO<sub>2</sub> gas concentration is reduced by up to 95%. A further six Procal P2000 analysers measure the cleaned flue gases with a lower SO<sub>2</sub> range up to 300ppm (other gases measured by the P2000s

at the exit are NO 0-800ppm and H<sub>2</sub>O 0-20%). The cleaned flue gas is raised in temperature and discharged up the 259 metre high chimney. By comparing the P2000 analyser readings on the input and the output of the FGD the efficiency of the FGD can be determined and controlled.

At full operation, some 280,000 tonnes of SO<sub>2</sub> per year can be removed from the chimney gases using the FGD system installed at Drax. The limestone slurry uses 10,000t of crushed limestone that produces 15,000t of gypsum per week.

Figure 2 shows a cross sectional view of a spray tower fitted with P2000s



### **Plate Tower Packed bed scrubbers**

Packed bed scrubbers take the form of a tower with a packing material inside that is shaped to maximize the contact area between the flue gas and liquid. Packed towers are cheap to operate and have a high SO<sub>2</sub> removal efficiency but have a greater tendency to plug up if particles are present in excess in the exhaust air stream.

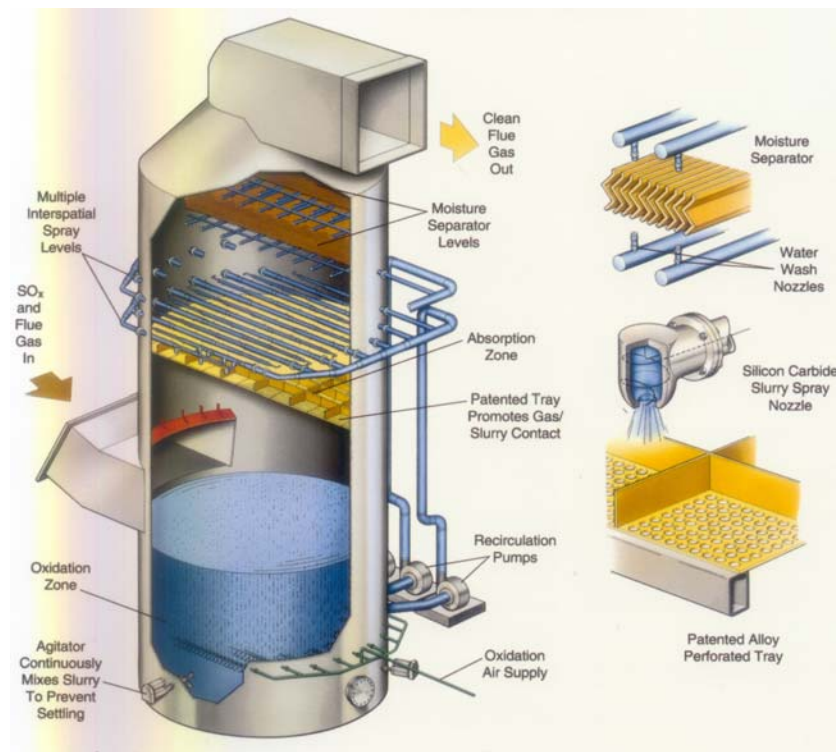
### **Venturi-rod scrubbers**

A venturi consists of a converging and then diverging section of piping with the converging section accelerating the gas stream. The liquid stream is injected at the point of smallest diameter as this is the point of maximum velocity. The turbulence caused by the high gas velocity atomizes the liquid into small droplets that provide the surface area necessary for mass transfer to take place and both fly ash and SO<sub>2</sub> can be removed simultaneously. Although removal of both particles and SO<sub>2</sub> in one vessel can be economic, the problems of high pressure drops and finding a scrubbing medium to remove heavy loadings of fly ash must be considered. However, in cases where the particle concentration is low, such as from oil-fired units, it can be more effective to remove particulate and SO<sub>2</sub> simultaneously.

### **Mobile-bed scrubbers**

Mobile-bed scrubbers, also known as moving-bed scrubbers, were developed to provide the absorption characteristics of packed and plate towers, without the plugging problems. The bed scrubber consists of plastic sphere shaped materials that rotate and rub against each other when subjected to the high velocity of the exhaust gas stream. The moving bed is sprayed with liquid creating a large absorption surface area that together with the high velocity allows larger volumes of flue gas to be scrubbed. Mobile-bed scrubbers are classified in to two groups flooded or fluidized, depending on the degree of packing movement.

Figure 3 A Cut away view of a mobile bed



### **Particulate Removal from moving bed scrubbers**

By saturating the exhaust gas steam with liquid sprayed underneath the packing course particles can be removed. Particles are also captured when they impinge on the wetted surface of the packing. Bubbles formed in the bed create a layer of froth that provides an additional surface for absorbing pollutant gases and collecting fine particles as small as 2 to 3µm.

In a fluidized-bed scrubber a high exhaust gas velocity keeps the packing suspended or fluidized in constant motion between a lower and upper retaining grid. Both particulate and gaseous pollutants are removed by a multi layer system with a froth zone above each packing section. The technique is used extensively when the exhaust stream does not contain particles in the submicron range. A major maintenance problem is the effect of abrasive wear and high temperatures on the packing balls, causing them to deteriorate.

### **Scrubbing with sodium sulphite solution**

Sulphur dioxide can also be scrubbed by using a cold solution of sodium sulphite which forms a sodium hydrogen sulphite solution. When the resulting solution is heated the reaction can be reversed and sulphur dioxide and sodium sulphite solution can be produced.

### **Radiation Chemical Processing by oxidation and reaction with ammonia**

An emerging form of flue gas desulfurization technology uses a branch of science known as radiation chemical processing. In this new technique, an accelerator produces an intense electron beam that is directed at the flue gas whilst at the same time ammonia is added to the gas. The electron beam promotes the oxidation of the sulphur dioxide to sulphur (VI) compounds which react with the ammonia to produce ammonium sulphate that can be used as a nitrogenous fertilizer. In addition, the nitrogen oxide content is also reduced.

### **Alternative techniques for reducing sulphur dioxide emissions**

An alternative to removing sulphur from the flue gases after burning is to remove the sulphur from the fuel before or during combustion. Hydrodesulphurization of fuel has been used for treating fuel oils before use. Fluidized bed combustion adds lime to the fuel during combustion. The lime reacts with SO<sub>2</sub> to form sulphates which become part of the ash.

### **Other P2000s installations on FGD systems include**

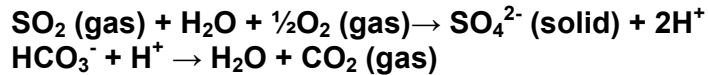
In the USA at the Florida Jackson Electric coal fired power station with a generating capacity across two combined plants of 700MW. Four P2000s measuring SO<sub>2</sub> up to 2000ppm are installed on the input to the circulating fluidised bed scrubber.



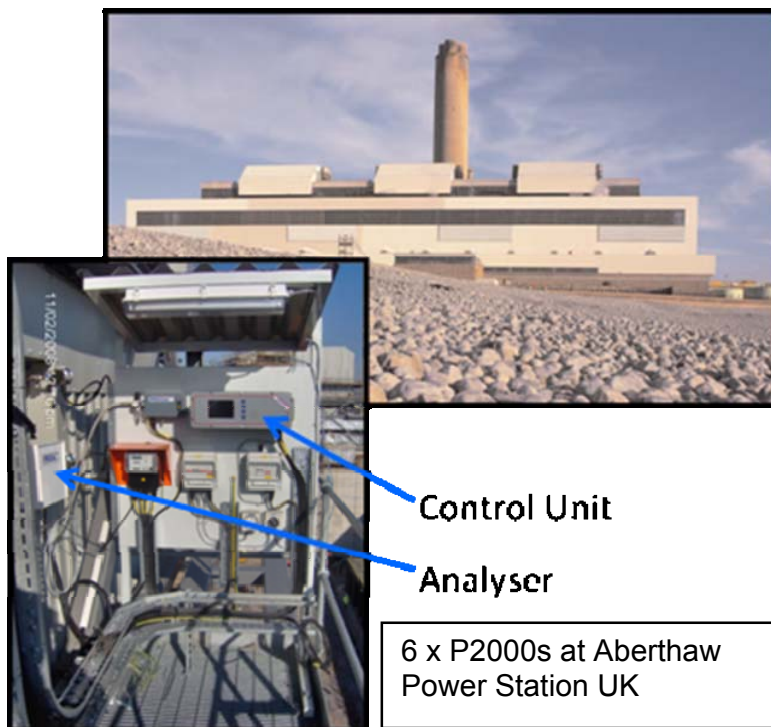
In Poland, at the Polaniec coal fired power station operated by Tractebel which has a capacity of 1800MW. Sixteen P2000s are installed on the FGD scrubber where they measure SO<sub>2</sub> 0-1500ppm, NO 0-300ppm and CO 0-200ppm.



In the UK at the Aberthaw coal fired power station operated by RWE nPower with a capacity of 1455MW. With its close proximity to the sea the power station uses salt water in the Flue Gas Desulphurisation system to scrub the flue gases. Seawater which is a natural alkaline is used to absorb SO<sub>2</sub>. The SO<sub>2</sub> is absorbed in the water, and when oxygen is added reacts to form sulphate ions SO<sub>4</sub><sup>-</sup> and free H<sup>+</sup>. The surplus of H<sup>+</sup> is offset by the carbonates in seawater pushing the carbonate equilibrium to release CO<sub>2</sub> gas:



At Aberthaw three P2000s are employed on the FGD inlet measuring SO<sub>2</sub> 0-1000ppm, NO 0-1000ppm and H<sub>2</sub>O 0-10%. Whilst at the outlet another three P2000s measure H<sub>2</sub>O 10%, CO 500ppm, NO 1000ppm and SO<sub>2</sub> 250 and 1000ppm.



Also in the UK at Longannet where another salt water based FGD is used to scrub gases clean from the 2400MW coal fired power station. This power station is equipped with nine P2000s with four on the outlet measuring SO<sub>2</sub> 0-750 and 0-3000mg/m<sup>3</sup>, NO 0-1000mg/m<sup>3</sup> (NO<sub>x</sub> 0-1600mg/m<sup>3</sup>) and H<sub>2</sub>O 0-15% and four on the inlet measuring SO<sub>2</sub> 0-300mg/m<sup>3</sup> and H<sub>2</sub>O 0-15%



9 x P2000s controlling  
the FGD at  
Longannet  
power station