# Circulating fluidised bed scrubber technology

A low-cost dry flexible multi-pollutant emissions control option for the Indian power market

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Tighter control of sulphur oxides ($SO_x$), nitrogen oxides ($NO_x$) and particulate matter (PM) has become a priority for many countries around the world. As an example, India's Ministry of Environment & Forests (MOEF) has issued stringent regulations that affect an estimated 140 GW of operating coal-fired power plants and all new plants built in the future. By 2022, $SO_2$ emissions for all operating plants in India that are 500 MWe or larger must not exceed 200 mg/ $Nm^3$ and all new coal plants regardless of rating and other special category plants must meet even tighter $SO_2$ limits of 100 mg/$Nm^3$ (Table 1). In other words, for an existing coal plant with baseline $SO_2$ emissions ranging from 1200 to 1400 mg/ $Nm^3$ this amounts to an 80-90% $SO_2$ emissions reduction from uncontrolled levels.

## Competing FGD technologies

The flue gas desulphurisation (FGD) system selected for an Indian power plant can be a wet, dry or semi-dry system depending on the level of $SO_x$ removal needed and the plant specifics. The conventional approach to remove $SO_2$ from coal-fired power plant flue gases has been wet flue gas desulphurization (wFGD) technology, or, to a lesser extent, spray dryer absorber (SDA) technology.

Another technology worth consideration, which may be suitable in certain circumstances, especially for Indian power plants, is circulating fluidised bed (CFB) based technology, a dry FGD process that achieves increased $SO_2$ removal with a much more fuel flexible treatment process that is not dependent on wet chemistry.

Each of these alternatives is discussed in the following sections and prospective owners must evaluate them with respect to their current site conditions, initial & lifecycle costs, and possible future regulation of additional pollutants.

- **Wet flue gas desulphurisation.** Until now, wFGD technology has been the incumbent FGD option selected by Indian power plants largely due to its track record on large scale units, limestone cost, and its ability to produce gypsum as a byproduct for possible sale. The wFGD process uses a wet slurry produced from milled limestone mixed with water that is pumped through banks of spray headers in the absorber vessel. Flue gas enters the bottom of the absorber vessel, below the spray nozzles. The slurry droplets created by the sprays flow countercurrent to the incoming flue gas in order to mix the $SO_2$ with the calcium-rich reagent. The resulting wet chemical reaction produces a mixture of calcium sulphite and calcium sulphate ($CaSO_4$), also known as gypsum. A portion of the slurry is continuously removed from the absorber, collected by a separate recovery process, and then dewatered with drum or belt filters. The gypsum recovered, if not commercially recycled, must be properly and permanently stored either on-site in containment facilities or transported to an offsite location.

There are several expensive drawbacks of wFGD technology, such as process equipment that requires a large footprint near the boiler island, very high water usage to make the slurry used for sulphur removal, and significantly increased auxiliary power consumption necessary to run the wFGD. Some Indian plants that selected wFGD expecting to offset increased O&M expenses with gypsum sales have been disappointed. The quality of gypsum produced in the typical Indian power plant has been poor due to the low purity (<80%) of local limestone. Additionally, the Indian market for gypsum is also saturated so the expected income stream from the sale of gypsum has been replaced with a recurring expense of large-scale gypsum disposal.

The wFGD plant also requires a long-term, reliable source of high quality limestone as large quantities of limestone must be regularly delivered to the plant.

In addition, water usage by wFGD is 30% to 40% higher than either the SDA or dry CFB scrubber options, which poses a challenge for plants built in drier parts of India such as Rajasthan, Gujarat, and Tamil Nadu, where water supplies for power generation are limited. Furthermore, a plant with a wFGD system must significantly increase operating, maintenance, and laboratory testing staff because the wFGD option is much more manpower intensive, particularly with respect to routine maintenance. For a country like India that has little to no experience with the installation, maintenance, or operation of modern air quality control systems, particularly FGD, this can be a challenge.

Another issue for the wet desulfphurisation process is that it requires expensive glass or plastic liners or stainless steel for the absorber vessel, not required by the other two $SO_2$ removal processes, which increases the capital cost, particularly for a single vessel system. The Indian power market is very price sensitive so the much higher capital cost of wet FGD compared to other technology options, remains an important evaluation factor.

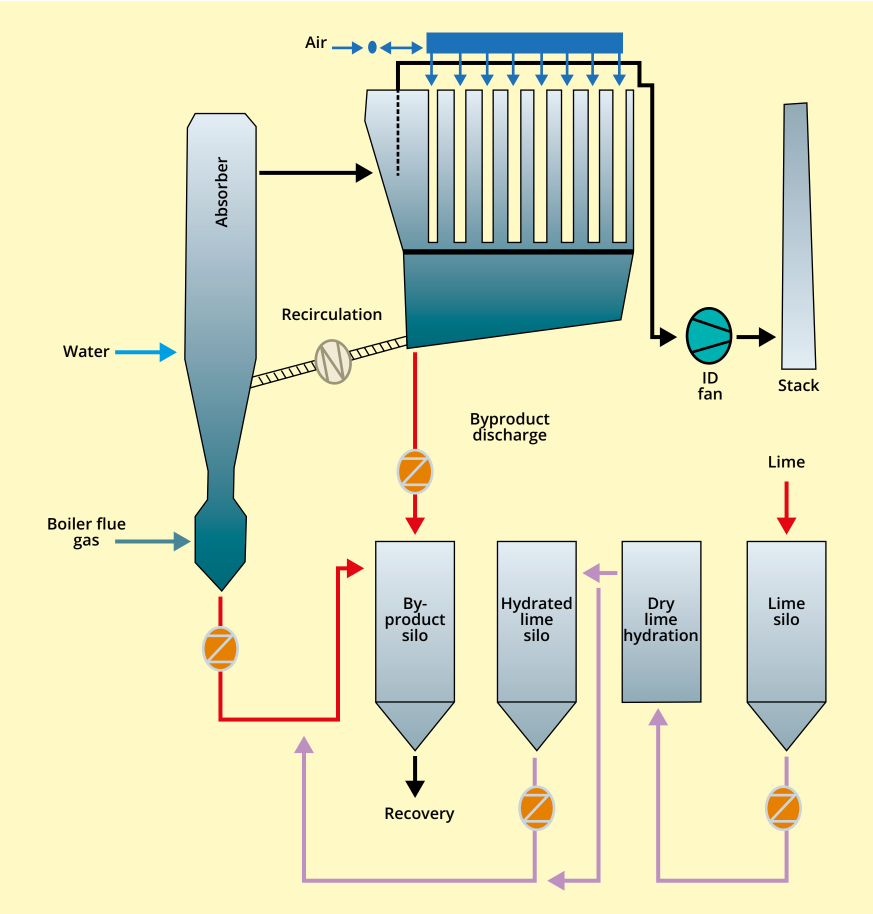
- **Spray drier absorber.** Spray drier absorber sulphur removal systems are typically employed on plants that burn low-to-medium-sulphur (<2%) coal. SDA systems generally achieve sulphur removal efficiencies in the range of 90% to 95%, depending on inlet conditions. Higher sulphur removal rates require the addition of a fabric filter that provides the reaction and mass transfer time needed for the sorbent and $SO_2$ to react, in a surface filter cake.

The SDA process begins with a lime sorbent, usually quicklime (CaO), that is slaked with water to form a slurry reagent. Lime is typically stored in silos much like the wFGD process. Slurry preparation can also use recycled dust from the plant's particulate collection system to increase the solid content of the slurry to improve $SO_2$ removal efficiency. The reagent slurry is pumped to the top of the SDA absorber vessel and is led through one or more high-speed spinning wheels within rotary atomisers located at the top of the absorber vessel to produce a spray cloud of reagent. The flue gas mixes with the spray cloud and the sorbent reacts with $SO_2$ and $SO_3$ to form calcium sulphite and calcium sulphate while simultaneously cooling the flue gas. The

**Table 1. New Indian air emission standards for coal fired power plants.**
Source: MOEF

| Pollutant | Units installed before 31 December 2003 | Units installed after 1 January 2004 up to 31 December 2016 | Units installed after 1 January 2017[2] |
|---|---|---|---|
| PM | 100 mg/$Nm^3$ | 50 mg/$Nm^3$ | 30 mg/$Nm^3$ |
| $SO_2$ | 600 mg/$Nm^3$ for units < 500 MW[1]<br>200 mg/$Nm^3$ for units ≥ 500 MW | 600 mg/$Nm^3$ for units < 500 MW[1]<br>200 mg/$Nm^3$ for units ≥ 500 MW | 100 mg/$Nm^3$ |
| $NO_x$ | 600 mg/$Nm^3$ | 300 mg/$Nm^3$ | 100 mg/$Nm^3$ |
| Mercury | 0.03 mg/$Nm^3$ for units ≥ 500 MW | 0.03 mg/$Nm^3$ | 0.03 mg/$Nm^3$ |

**Notes:** 1. Units < 500 MW located in or within a 300 km radius of non-attainment areas (densely populated areas in excess of 400 people/$km^2$) must meet the ≥ 500 MW $SO_2$ standard.
2. Includes units under construction as of December 2015.




Above: **Figure 1. The CFB dry desulphurisation process (with fabric filter).** Source: Sumitomo SHI FW

cooled flue gas leaves the absorber and enters the particulate collection system, such as a fabric filter or electrostatic precipitator.

- **Circulating fluidised bed scrubber.** The circulating fluidised bed (CFB) scrubber is growing in popularity, with plants up to approximately 600 MW. Indian plant owners, who are highly sensitive to construction costs, will be pleased to learn that the CFB scrubber has an installed cost approximately 60% of a similarly sized wFGD system. In India, the average installed cost of a wFGD system has averaged \$65/kW, this would translate into immediate savings of almost \$25/kW in favour of a CFB scrubber.

The operating essentials of the CFB scrubber and its up flow absorber are substantially different from the SDA process (Figure 1). Flue gas with fly ash enters the bottom of the absorber, flowing upward through multiple venturis to accelerate the gas causing turbulent flow. There is no need for external lime preparation so all the slurry mixing and handling equipment is eliminated. Instead, dry hydrated lime, $Ca(OH)_2$, is directly injected into the CFB absorber along with the boiler flue gas and fly ash. An optional dry lime hydrator produces hydrated lime on-site from lower cost quick lime.

Recycled solids, reagents, and water mix with the turbulent flue gas providing gas cooling, reactivation of ash, and capture of pollutants. In short, unlike the other technologies, the sulphur removal process in a CFB scrubber is independent of water usage.

The design of the absorber produces highly turbulent mixing of the flue gas, solids, and water to achieve high efficiency capture of the vapour phase acid gases and metals contained within the flue gas, unlike the wFGD or SDA processes. The gas and solids typically enter a fabric filter where solids are captured and recycled back to the absorber to capture more pollutants. Unique to the CFB scrubber, reactive absorbents, such as sodium carbonates, hydrated lime, and activated carbon, may be added to target specific pollutants such as acid gases and organic compounds for capture first within the CFB absorber vessel and then again in the fabric filter as the flue gas passes through the filter cake.

There are other important cost advantages with the CFB scrubber. Because it does not need high-speed rotary atomisers within the absorber (requiring a high frequency of maintenance since they are prone to erosion, scale formation, and plugging) or lime slurry preparation equipment, so annual maintenance is reduced by a factor of four compared to the SDA and even more so compared to the wFGD.

CFB scrubber systems have been employed at plants worldwide firing coal with a wide range of sulphur levels with no technical limit on the entering fuel sulphur content, unlike the alternative technologies discussed above.

Fuel ash content seen in Indian fuels, up to 40-45%, is perfectly acceptable to a CFB scrubber.

Also, the flue gas temperature does not limit the amount of lime injection as it does when using an SDA. This feature allows a significant increase in acid gas scrubbing performance, should future air emissions regulations require it.

This flexibility is an important performance characteristic for those plants receiving coal from mines with poor coal quality and reduces or eliminates the need to burn imported coal. Sulphur dioxide removal efficiency has been demonstrated in excess of 95% (see case study, below) and up to 99% depending on the entering $SO_2$ loading. Also, unlike wFGD, CFB absorbers can be designed to remove 99% of the $SO_3$ because of the lime reagent has a high affinity for $SO_3$. Other important design features and operating advantages of the CFB scrubber that should be of interest to the Indian power market are shown in Figure 2.

## CFB scrubber case study – Dry Fork

Basin Electric's 420 MWe (520 MWe equivalent at sea level altitude) Dry Fork station, located in Gillette, Wyoming, entered commercial service in June 2011. Behind its pulverised coal boiler sits the largest single absorber dry scrubber operating in the world today.

The Sumitomo SHI FW CFB scrubber there has demonstrated very high, 98%, availability while meeting all the strict emission requirements set by the US Environmental Protection Agency and

Advantage | Neutral | Disadvantage

| Capability/requirement | Wet FGD | SDA FGD | CFB FGD |
|---|---|---|---|
| $SO_2$ capture capability | Advantage | Disadvantage | Advantage |
| Low water consumption | Disadvantage | Advantage | Advantage |
| Fuel flexibility, sulphur content | Advantage | Disadvantage | Advantage |
| Fine particulate capture | Disadvantage | Advantage | Advantage |
| High $SO_3$ capture | Disadvantage | Advantage | Advantage |
| Compact system footprint | Disadvantage | Neutral | Advantage |
| Low maintenance requirements | Disadvantage | Neutral | Advantage |
| Includes mercury capture | Disadvantage | Neutral | Advantage |
| Reduces $CO_2$ emissions | Disadvantage | Advantage | Advantage |
| Includes wastewater treatment | Disadvantage | Advantage | Advantage |
| Uses low-quality water | Disadvantage | Disadvantage | Advantage |
| Uses limestone reagent | Advantage | Disadvantage | Neutral |
| Large scale (>350 MW) | Advantage | Disadvantage | Advantage |
| Necessary for retrofit: ESP improvements | Disadvantage | Advantage | Advantage |
| Necessary for retrofit: Stack improvements | Disadvantage | Advantage | Advantage |
| Necessary for retrofit: Flue gas reheater | Disadvantage | Advantage | Advantage |

Above: **Figure 2. Advantages and disadvantages of the three desulphurisation technologies of interest to the Indian power market.** Source: Sumitomo SHI FW the state of Wyoming. The emissions regulations are designed to directly or indirectly limit a broad array of compounds designated as pollutants, such as $SO_2$, $SO_3$, HCl, $H_2SO_4$, HF, PM10, PM2.5, mercury, and other heavy metals.

Since it went into operation, the CFB scrubber at the Basin Electric plant has exceeded its design performance, reducing $SO_x$ by 95%-98%, to levels below 50-60mg/$Nm^3$. It also passed a 30-day mercury removal compliance test by meeting the permitted emission limit of 2.35µg/$m^3$ while demonstrating an Hg removal rate of over 95%.

## Make the right choice

For many plants in the Indian power market, the CFB scrubber is a compelling economic choice particularly for units rated at 600 MW or less due to its lower installed cost, auxiliary power and water usage. CFB scrubbers also offer a compact footprint with low maintenance requirements while achieving high reliability. It's a hard-learned truth that the number of regulated pollutants will increase in the future, particularly in developing countries, so multi-pollutant control capability should be included up front rather as an expensive afterthought. Also, the fuel flexible CFB scrubber allows Indian power plants to purchase lower-cost opportunity fuels, including mixes of local fuels.

For the Indian power market, 2022 is coming quickly and purchase decisions must be made very soon. Given these important characteristics, the CFB scrubber enjoys distinct and quantifiable advantages over competing flue gas desulphurisation processes. ■


Right and below: **Basin Electric Dry Fork Unit 1, with a plant electrical output of 420 MWe (or 520 MWe at sea level). The CFB scrubber at this plant, commissioned by SFW, is the largest in the world** (photos courtesy Basin Electric Power Cooperative/ Wyoming Municipal Power Agency)