



## Increasing SO<sub>x</sub> removal efficiencies in Dry Sorbent Injection Systems

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### Introduction:

Over half the electric power used in the United States is generated by coal-fired power plants, consuming about a billion metric tons of coal a year, which emit about a 1/3<sup>rd</sup> of the SO<sub>2</sub> gas from all sources. As such, the roughly 1,500 coal-burning power plants are the single biggest polluters of this acid-rain causing gas. Conversion from coal to biomass is a growing trend but, the problem of emission of green-house and acid-rain gases such as CO<sub>2</sub>, SO<sub>2</sub> and mercury from power generation or from other industrial coal-burning applications, are an ever-present and growing danger to our way of life. With increased scrutiny of late on the human-hand in global warming and with the move toward “going green”, the Environmental Protection Agency (EPA) is expected to come up with regulations on limiting green house gas emissions, and/or the US Congress is expected to pass legislation on what has come to be known as “cap and trade” and “carbon tax” laws, which would allow current polluters such as utility companies, some leeway in how they manage the many pieces of this multifaceted problem. Over time, several industrial equipment manufacturers have developed equipment and systems that address one or more aspects of this issue. Given its complexity, flue gas desulfurization (FGD) is usually handled in two-stages. Remove the fly-ash and then the SO<sub>2</sub>. This current article focuses on this second aspect of FGD and examines the use of an innovative grinding system that dramatically increases the efficiency of SO<sub>2</sub> removal, thereby bringing cost savings to the many utilities that use this system.

### Overview of FGD:

While FGD has been around in England since before World War II, its evolution in the US and Japan into large scale commercial FGD systems, has occurred mostly since the 1970s. The technology for FGD has broadly been:

- (A) wet-scrubbing systems
- (B) wet sulfuric acid systems
- (C) spray-dry scrubbing systems
- (D) dry-sorbent injection systems

Even if the chemistry behind each system is more or less the same, using a sorbent (usually, limestone or lime or carbonates of sodium) to react with and remove the SO<sub>2</sub>, each has its own benefits and disadvantages. Wet-based systems using sorbent slurries, still constitute the vast bulk of FGD systems in use today, whereas dry-sorbent injection (or DSI) or spray-dry scrubbing systems account for about 20%. However, recent trends have pointed many power producers away from wet-based systems toward DSI systems,



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largely due to the extra complexities, concerns and costs associated with the post-reaction handling and treatment of the waste water and reaction by-products of wet-sorbent systems.

### **Elements of a Dry Sorbent Injection (DSI) System.**

A Dry Sorbent Injection (DSI) system is, as the name implies, a dry process in which a sorbent is pneumatically injected into the furnace or ducting downstream of where the coal is combusted and flue gas produced. The dry waste product of reaction is removed using particulate control such as an electrostatic precipitator or dust collector.

While somewhat higher sulfur dioxide removal efficiencies can be achieved using wet scrubbing, with removal rates greater than 90%, DSI systems come with two distinct advantages. First, the capital cost of DSI systems is much lower compared to wet scrubbers or semi-dry systems. Second, DSI systems take up much less space which is especially important when considering retrofit or upgrades to existing systems.

Traditionally, DSI systems can achieve removal efficiencies as high as 80%; however, for quite a number of smaller industrial applications we can expect removal efficiencies greater than 90%. With further adjustments to the process, higher removal efficiencies can be achieved, thereby using even less reagent.

### **Sodium Sesquicarbonate, (“Trona”)—the future of FGD in the US:**

Two primary sorbents are utilized in DSI systems - Sodium Sesquicarbonate, or Trona, and sodium bicarbonate. Trona, a naturally occurring mineral, is mined from a vast formation in the Green River, WY area, and certain areas of California.

Sodium bicarbonate, on the other hand, is a chemical compound primarily manufactured using the Solvay Process. This salt is obtained from a reaction of calcium carbonate, sodium chloride, ammonia and carbon dioxide in water.

There are several notable differences between these materials. First, sodium bicarbonate simply put is more effective in removing sulfur dioxide emissions than trona. Hence, less sodium bicarbonate is required for an equivalent removal. Next, however, sodium bicarbonate is much more expensive in the U.S. Finally, trona, as noted earlier, is a naturally occurring mineral in the U.S., so it is in abundant supply. However, for plants outside the U.S., logistical costs may prohibit its use despite the fact that trona is approximately half the cost of sodium bicarbonate for an equivalent particle size.

### **Particle size –the impact on SO<sub>2</sub> removal efficiency:**



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The effectiveness of sulfur dioxide reduction is based on the following factors, not ranked in any particular order. 1) sorbent injection rate, 2) sorbent residence time in flue gas stream, 3) sorbent penetration and mixing with flue gas, 4) particulate control device, such as a dust collector or electrostatic precipitator, 5) flue gas temperature, and 6) sorbent particle size.

### **The Hosokawa DSI system-- a cut above the rest:**

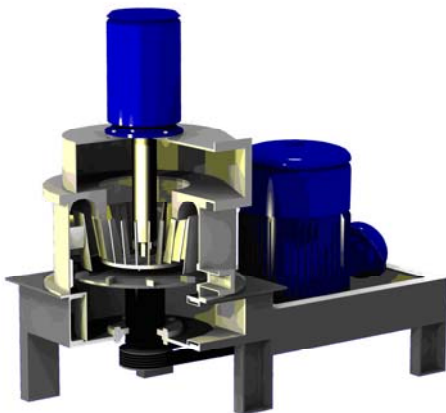
As a particle is broken down into smaller pieces, its net surfaces area increases, which in turn, increases the particles' ability to react with its environment. Therefore, sorbent particle size has a direct impact on sulfur dioxide reduction, as smaller particle size sorbent contributes to greater reaction with sulfur dioxide and hence, further reduction. In order to achieve the new level of fineness required, an Air Classifying Mill (ACM) is an excellent choice for effective and efficient size reduction of either trona or sodium bicarbonate for Dry Sorbent Injection Systems.

Facts and features of the air-classifying mill include:

- High tip speeds in the range of 115 m/s.
- ACM equipped with an internal dynamic air classifier with controls particle top size.
- One other important feature is that, as the name suggests, this is an air-swept mill. Airflow is an extremely important parameter, which affects size reduction / classification efficiency.

It not only affects size and efficiency but also serves to cool the material being processed. Everything else being equal, the amount of airflow as compared to a pin mill is higher. Therefore, there is a natural cooling effect and a lower product outlet temperature can be achieved.

The main principle of this mill type is to use air to convey material to the mill, classify the product into a fine and coarse fractions, convey the fines out of the mill and then



return the coarse fraction to the grinding chamber for further size reduction. This is a continuous process. The unique feature of this type of mill is that the classification step takes place inside the mill and is not a separate or external operation. This design allows these mills to be relatively compact. The primary airflow is introduced from underneath the main rotor disc.

Material is introduced into the grinding chamber at the grinding zone and is impacted by the rotating hammers. Processed material is then carried by the air stream to the classification zone.

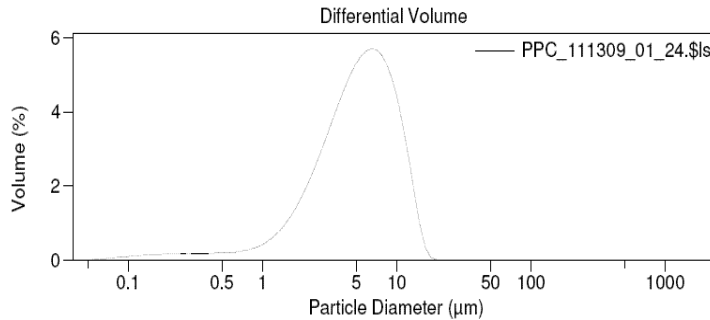
Correctly sized material passes the classifier and exits the mill at the top. Oversize



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material is rejected by the classifier and is returned to the grinding zone. The grinding and classification zones are normally separated by a shroud and baffle assembly.

Shown below is a size distribution curve of trona, produced by an air-classifying mill. Particle size was measured using a laser diffraction analyzer, the method of which is laser light scattering, and produces a probability density function as shown.

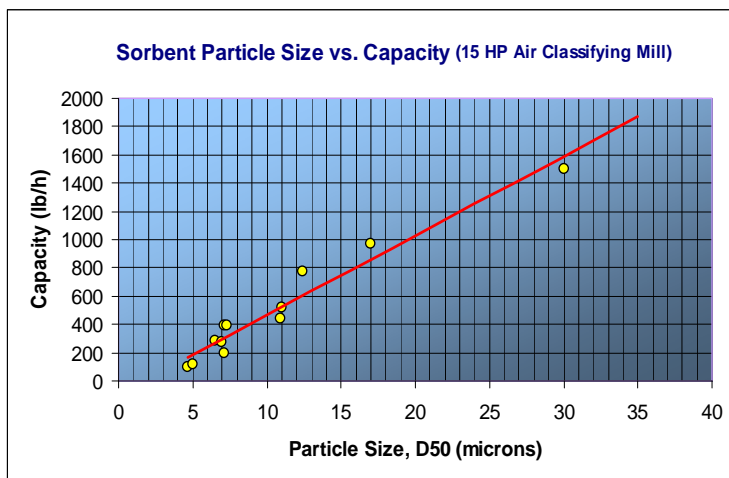


This actually represents the smallest particle size achieved and supplied for this application. As the graph shows, this application required a product with a median particle size, or D50, of approximately five µm, with a D90 or nominal top size of 10.6 µm.

Volume Statistics (Arithmetic)		PPC_111309_01_24.\$ls					
Calculations from 0.040 µm to 2000 µm							
Volume:	100%	S.D.:	3.401 µm				
Mean:	5.771 µm	Variance:	11.57 µm <sup>2</sup>				
Median:	5.264 µm	Skewness:	0.609 Right skewed				
Mean/Median ratio:	1.096	Kurtosis:	-0.109 Platykurtic				
Mode:	6.452 µm						
<10%	<25%	<50%	<75%	<90%	<97%	<99%	<100%
1.764 µm	3.166 µm	5.264 µm	7.970 µm	10.62 µm	13.07 µm	14.76 µm	20.71 µm

This is a typical curve, or profile, generated by an air classifier mill. Note the very steep coarse tail. This is a feature of the air classifying mill. By utilizing an internal dynamic classifier to control particle top size, a narrow particle size distribution can be achieved.

The next graph shows the effect of particle size on energy requirement, in other words, relationship between particle size (in this case, median particle or D50) versus capacity of a 15 HP air classifying mill.



This graph more or less shows the full workable range of an air-classifying mill. For Dry Sorbent Injection applications utilizing an air classifying mill, most common particle size ranges are in the 10 to 20 µm median size range. However, in recent years there has been an increase in demand for finer grades of sorbents. In the case of the



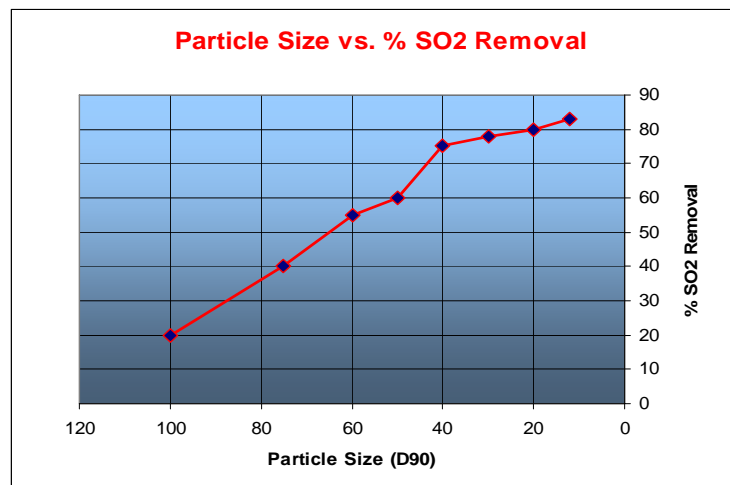
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particle size distribution outlined in the previous slide with a median size of 5.2  $\mu\text{m}$ , a 15 HP mill can achieve on average 100 to 120 lb/h. However, for a 15  $\mu\text{m}$  median product, throughput dramatically increases between six- to seven-folds, to almost 750 lb/h.

The energy requirement can be expressed differently, in terms of output of product per unit of grinding energy input. Energy input is electrical energy required for grinding, in terms of HP or kW. Output can be expressed in terms of lb/h or kg/h. In producing a 5.2  $\mu\text{m}$  material, for example, approximately 7 lb/hp-h can be obtained. However, in the case of the 15  $\mu\text{m}$  median material, 50 lb/hp-h is achieved indicating that the particle size of the product has a significant effect on capacity. A 20  $\mu\text{m}$  median-sized sorbent requires almost double the energy than a 30 micron product. As end-products get smaller, the increase in specific energy required gets steeper.

While a finer sorbent particle size increases sulfur dioxide removal efficiency, it is done so at a cost. The plant would require less 20 $\mu\text{m}$  product than 30  $\mu\text{m}$  product to remove nearly the same percentage of sulfur dioxide, but the energy requirement is higher to do so. So, in fact there exists a trade-off between particle size, the amount of material required (hence material costs) and operating costs. The trick is to find the point where particle size, energy input and sulfur dioxide removal is optimized, the “sweet spot” where utilities must operate.

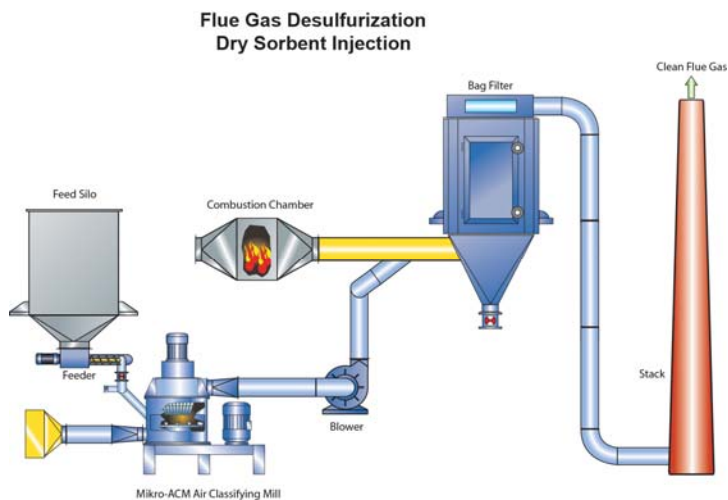
The graph above shows the relationship between sorbent particle size and sulfur dioxide removal efficiency. The graph is based on data compiled from a multitude of lab tests as well as real-life field results or feedback received from our customers utilizing air classifying milling technology. On the x-axis is particle size, referred by the term D90, the size (expressed in  $\mu\text{m}$ ) at which 90% of the particles are finer than. On the y-axis is sulfur dioxide removal efficiency.



The data shows, with finer particle size distribution, sulfur dioxide removal efficiency increases. Traditionally, power plants have utilized coarser grades of sorbent, mostly in the D90 range of 75 to 100  $\mu\text{m}$ . For these applications, removal efficiency is low as compared to other types of FGD systems. However, when injecting finer sorbents, say in the 20 to 30  $\mu\text{m}$  D90 range, removal efficiencies approach alternate technology results.



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Pictured here is a typical ACM size reduction system for dry sorbent injection. Feed material is transported from rail cars or trucks to one or more feed silos that hold a campaign of material. The feed metering system typically includes a screw conveyor, which meters the material into the air classifying mill, as well as a rotary airlock which serves as a suction / pressure isolator. Air inlet filters are recommended to

avoid contaminants. The ground sorbent is conveyed from the air classifying mill by means of a material handling fan and is injected at a controlled rate into the flue gas stream. Once reacted, the reaction product and the de-sulfurized flue gas go to the dust collector where the solids are captured and cleaner gas is emitted out of the exhaust stack.

### Results & Conclusions:

It is certain that governmental regulations are forcing lower and lower emissions standards. It is matter of time before new, tighter regulations are set or more importantly new legislation is enacted. DSI systems have demonstrated significant advantages over other incumbent technologies and may be a lower capital cost alternative for sulfur dioxide reduction.

Evidence has shown that reagent particle size greatly affects sulfur dioxide removal efficiency. Utilizing finer-sized sorbents may drive capital and materials costs even lower, with less quantities of sorbent being required to meet removal efficiency. An air-classifying mill is an excellent choice for continuous, energy-efficient production of very fine particle sizes and hence higher removal efficiencies. Higher sulfur dioxide removal efficiencies go hand-in-hand with further tightening of emissions standards.