Dry Sorbent Injection for SO_3 and MATS Application

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Dry sorbent injection (DSI) is a cost-effective technology for achieving emission limits on acid gases from coal-combustion flue gas. DSI technology can be used on various coal types and in existing air pollution control (APC) configurations as a retrofit technology. DSI provides other benefits such as reduced cold-end corrosion and improved mercury control. This article describes the purpose and application of DSI.

A DSI system is the chemical application of dry alkaline sorbents, injected directly into the flue gas duct and collected downstream, typically in the particulate control device or, less commonly, in the wet flue gas desulfurization scrubber. DSI systems provide a low-capital-expenditure alternative for meeting certain provisions of the Mercury and Air Toxic Standards (MATS). The systems are tailored to each location, plant, and unit to ensure optimized mitigation of targeted air pollutants.

Under the recently promulgated MATS rule for electric utility boilers, HCl was identified as a surrogate for a group of acid-gas hazardous air pollutants, and, therefore, emission limits were set for HCl. Sulfur dioxide emissions are regulated by both the state and federal government. Generally, emissions of SO_3 are not regulated, except at the state level via a restriction on condensable particulate matter. However, there are compelling reasons to reduce concentrations of SO_3 in combustion flue gas:

- (a) prevention of corrosion and / or formation of ammonium bisulfate in air preheaters
- (b) ability to lower cold-end air temperatures in the air preheater and increase boiler efficiency
- (c) better utilization of activated carbon for mercury control
- (d) reduction in corrosion downstream of air preheater
- (e) elimination of persistent plume ("blue plume") due to sulfuric acid mist

Conventional flue gas desulfurization (FGD) systems remove SO_2 and HCl efficiently. While dry FGDs remove SO_3 efficiently, wet FGDs are notoriously inefficient at removing the ultrafine sulfuric acid mist that forms from SO_3 when the flue gas is quenched at the inlet to a wet FGD. Coal-fired boiler operators who want to reduce SO_3 in the flue gas and / or reduce HCl or SO_2 emissions without using an expensive FGD system often turn to DSI for acid gas control.

Sorbents Used in DSI Technology

The primary DSI sorbents used in today's market for acid gas control are calcium-based (hydrated lime) or sodium-based (trona, sodium bicarbonate) sorbents. The applications of these sorbents are shown in Table 1.

Table 1

Applicability of Alkaline Sorbents for Acid Gas Control

Dry sorbent for control of	SO_2	HCl	SO_3
Limestone			√
$Mg(OH)_2$			√
MgO			√
Hydrated lime - $Ca(OH)_2$		√	√
Trona – sodium sesquicarbonate	√	√	√
Sodium bicarbonate (SBC)	√	√	√

The selected sorbent is injected into the flue gas anywhere from the selective catalytic reduction (SCR) inlet to the scrubber inlet, depending upon pollutants being targeted, the type of sorbents, and the operating temperatures at injection points. In addition to surface area and particle size, good sorbent dispersion is critical to achieving high utilization of the sorbents. Multiple injection lances are typically used in the duct; computational fluid dynamic (CFD) modeling is used routinely to optimize the lance arrangement for maximum dispersion.

Hydrated lime is used to remove SO_3 and/or HCl from flue gas. Efficient removal requires a high surface area (greater than 20 m^2/g) and a small particle size (2-5 microns).

Trona typically has mean particle size between 30 and 35 µm, while sodium bicarbonate is coarser (~50 µm). Both trona and sodium bicarbonate may benefit from being milled on-site before injection. Trona and sodium bicarbonate decompose at about 275°F to form sodium bicarbonate. The decomposition reaction that occurs when sodium sorbents are injected into the flue gas produces a high surface area, allowing an efficient reaction with acid gases.

The normalized stoichiometric ratio (NSR) is used to describe the ratio of moles of active sorbent element (Na, Ca) to moles of acid gases present in the duct. NSR should be calculated based on total acid gases (SO_2 +HCl+HF+SO_3) because all will react with sorbent to some extent. The ratio is not always reported this way; in some cases, the NSR of sorbent to a specific acid gas is reported. It's important to make sure the basis for NSR is known. Some sorbent vendors report sorbent usage as mass ratio (e.g., lb. sorbent/lb. acid gas). In either case, the flow rate of acid gases in the flue gas of interest must be calculated to estimate sorbent usage.

Generally, the removal of acid gases follows this trend: SO_3 > HCl > SO_2. Sodium sorbents are more reactive with SO_2 than calcium sorbents when injection occurs post-economizer. When DSI is used to remove SO_3 or HCl from the flue gas, some SO_2 also may be removed. This must be taken into account when calculating the sorbent flow rate that is needed.

Commercial Applications of DSI

The early installations of SO_3 mitigation systems were usually for reduction of a visible, persistent plume caused by sulfuric acid mist. Concentrations of SO_3 in the stack must be less than about 5 ppm by volume in order to eliminate a visible, persistent plume. According to a recent study from the Electric Power Research Institute (EPRI), there are about 100 commercial installations of reagent injection for SO_3 control, which include 30 hydrated lime injection systems, 22 trona injection systems, and three $Mg(OH)_2$ systems. Levels of SO_3 removal were 65 percent to 95 percent using NSRs of between three and five.

There is less commercial experience with DSI systems for SO_2 or HCl removal, although in the last several years many commercial demonstrations have been carried out. For efficient removal of SO_2, high-temperature (upstream of the air preheater) injection of trona or sodium bicarbonate is used. Hydrated lime or sodium sorbents are both effective for removing HCl, as has been shown in numerous demonstrations.

Integration into Existing APC Systems

DSI is a retrofit technology and integrates into a plant's current APC configurations. Whether the system uses a calcium or a sodium sorbent for removal of HCl or SO_3 is influenced by the balance-of-plant impacts of the sorbents. (Table 2). Each boiler is different, and, therefore,

Table 2

Potential Balance-of-Plant Impacts

	Hydrated Lime	Sodium Sorbents
Air Preheater	Potential solid deposition (calcium carbonate)	Potential solid deposition (sodium bisulfate)
Ductwork	No significant issues observed	Formation of molten sodium bisulfate deposits: T>350°F, SO_3 removal application
ESP	Increases PM loading to ESP Increases resistivity of fly ash, which might increase opacity	Increases PM loading to ESP But can condition ash & offset increase in resistivity associated with removal of SO_3
FF	No significant issues observed	No significant issues observed
FGD	No significant issues observed	No significant issues observed
Fly Ash	No significant issues observed	High sodium might not be suitable for selling ash. Increased leachability of As, Se in fly ash
ACI	Reduction in SO_3 increases Hg capture	Reduction in SO_3 increases Hg capture NO_2 produced by sorbent inhibits performance of PAC

balance-of-plant impacts can be more or less severe depending on specific configurations or operating conditions. Conducting full-scale testing to understand the effects of DSI in a specific application is important.

Solids injected upstream of the air preheater have the potential for deposition. Under certain conditions, the formation of sodium bisulfate (instead of sodium sulfate) can result in sticky deposits when the temperature is greater than 350°F. This has been observed in ductwork downstream of the air preheater, but no published reports of excessive deposit buildup in air preheaters have been noted to date.

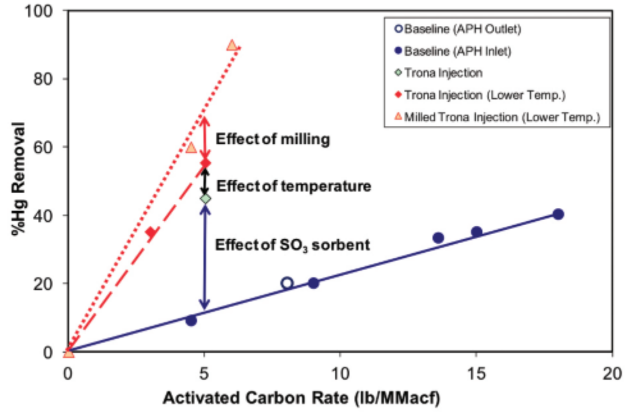
Alkaline sorbent injection can affect operation of electrostatic precipitators (ESPs) in several ways. At the most basic level, the particulate loading at the inlet to the ESP will increase. Reduction of SO_3 will increase resistivity of the ash entering the ESP. Calcium compounds also will increase resistivity, while sodium compounds decrease resistivity. On balance, calcium sorbents can result in increased opacity and reduced ESP performance depending on the size and condition of the ESP.

Adding sodium sorbents to fly ash can affect the ability to sell or dispose of it. Before contemplating the use of sodium sorbents, the leachability of fly ash containing the sorbent should be assessed. If fly ash is sold, discern in advance if there are any application-imposed restrictions on its sodium content.

The effectiveness of activated carbon injection (ACI) for mercury control increases as the SO_3 concentration in the flue gas decreases. Figure 1 illustrates the effect imparted on mercury control. The combination of DSI and ACI results in better Hg capture, particularly in bituminous-fired boilers with higher sulfur in the coal. Sodium sorbents react with NO_X as well as SO_X, and this sometimes can result in a slight decrease in total NO_X and an increase in NO_2. Laboratory studies on activated carbon have shown that increasing NO_2 concentration decreased the ability of activated carbon to capture Hg. Combined full-scale testing of ACI and sodium DSI is needed to determine if there is an impact on Hg capture.

Figure 1

Activated Carbon Injection with Trona Injection at PSNH Merrimack, Unit 2



Components of DSI Equipment

The equipment needed for a DSI system is relatively simple and consists of the following subsystems:

- Solids island
  - Storage silo
  - Feeder
  - Milling (optional)
- Air island
  - Motive air
  - Conditioning system
- Distribution system
  - Piping
  - Distribution manifold and lances

There are challenges in the design and operation of the pneumatic conveying system for alkaline sorbents. Most pneumatic systems use compressed ambient air as the motive air source. For compression, most systems use either a regenerative or a positive displacement blower. Compression inefficiencies of blowers result in heat being added to the motive air, resulting in plugging of conveying systems from either dehydration of sodium sorbents or carbonation of hydrated lime, thus the need for properly conditioned conveying air.

The temperature and dew point must be controlled in a hydrated lime conveying system because both factors affect the formation of calcium carbonate deposits, which can plug the piping. Generally, the temperature in a hydrated lime system should be kept below 110°F. Dryers and dehumidifiers are routinely used in current designs. A compressor also can be used, instead of a blower, with the result of producing drier and cooler air for the conveying system.

The flow of trona is extremely sensitive to its moisture content. Therefore, the sorbent must be very dry for handling purposes. Air for conveying trona should be maintained below 135°F to prevent loss of reactivity. Conveying and storage of trona requires more stringent moisture requirements than conveying of trona for duct injection. Consequently, conveying air must be dehumidified if the end destination is bulk storage.

Success with DSI systems can be achieved by paying attention to these factors:

- Optimization of injection system
  - Good distribution and mixing of sorbent
  - Sufficient residence time
- Proper handling of sorbent
- Mill sorbent to increase external surface area
- Proper injection location, depending on sorbent, targeted acid gas, residence time, balance-of-plant impacts

Conclusion

DSI is a low-capital-cost method for compliance with emission limits on acid gases and mercury from coal-fired boilers, with operational co-benefits such as eliminating corrosion issues and blue plume. The relatively simple equipment has a small footprint and can be integrated into a facility's existing APC configurations. Selecting the proper sorbent, injection point, and flow rate, in conjunction with a reliable DSI system, can be used to achieve compliance with MATS. **APC**

Dr. Connie Senior *is currently the director of technology development at ADA-ES, Highlands, CO, where she is responsible for research and development in control of mercury and other pollutants from coal-fired power plants and other industrial combustion systems. Senior has worked on understanding and predicting the behavior of mercury and other hazardous air pollutants for more than 15 years, and she has more than 10 years of experience with demonstrations of full-scale mercury emissions control. She has more than 25 years of experience in the behavior of ash, glasses, and ceramics in systems. Senior holds a B.S. in chemical engineering from Rice University and a Ph.D. in environmental engineering science from the California Institute of Technology.*

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