

Comparison of Dry Injection Acid-Gas Control Technologies

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ABSTRACT

Boilers, furnaces, metals and ceramics manufacture, and similar processes produce waste off-gases containing acidic species that, if released uncontrolled, are harmful to human health and the environment. The acid gases of primary concern are oxides of sulfur (SO_x) and hydrogen halides (HX). Alkaline gas scrubbing is generally employed to reduce emissions of these acid gases. Various different scrubbing technologies have been well proven in operation. The least expensive to implement and simplest to operate are the “dry scrubbing” or dry injection (DI) systems. In DI systems a dry powdered alkaline material is injected into the hot gas stream to neutralize the acidic species, and the resulting solid salts and remaining excess alkaline material is collected by a downstream particulate capture device. These systems are capable of high levels of acid gas reduction. Various alkaline materials, both chemically processed and naturally occurring, have seen application in dry scrubbing. Dry hydrated lime, a calcium based alkaline sorbent, is in wide use in dry scrubbing, largely because of its moderate cost and availability. However, sodium based alkaline sorbents such as sodium bicarbonate, nacholite, and trona can provide particular advantages that make them a superior choice in certain applications. This paper summarizes the advantages of DI systems and of dry injection of sodium based alkaline sorbents in particular.

INTRODUCTION

The most common industrial sources of SO_x and HX are combustion or other high-temperature processes involving materials containing sulfur and/or halides. These processes include fossil and waste fuel fired boilers and incinerators, primary and secondary metallurgical production processes, petroleum refinery catalyst regeneration, foundry operations, brick kilns, and other furnaces associated with production of various mineral products.

When materials being processed in oxidizing atmospheres contain sulfur, the off-gases contain sulfur dioxide (SO_2) and small quantities of sulfur trioxide (SO_3) arising from excess O_2 and incidental catalysis. The SO_2 is present as a gas and the SO_3 , which hydrolyzes with moisture in the gas stream, is usually present as an aerosol (sulfuric acid mist). When the materials being processed contain halides, such as fluorine, chlorine, or bromine, the off-gases will contain HF, HCl, or HBr. As with SO_3 these gases will also hydrolyze with available moisture to form acid

aerosols. Depending on the process and the chemical composition of the feed materials, acid gases or mists can range in concentration from a few hundred parts per million (ppmv) to upwards of 10 percent by volume (100,000 ppmv).

SO₂ is a criteria pollutant that effects both public health and the natural environment, and as such it has both primary and secondary National Ambient Air Quality Standards (NAAQS). In addition, Title IV of the 1990 Clean Air Act Amendments mandates reductions in SO₂ emissions from electric utilities. Phase I of this “acid rain” control program went into effect in 1995. Phase II, which went into effect in 2000, requires even greater levels of SO₂ control.

HF and HCl are classified by the USEPA as hazardous air pollutants (HAPs) and are regulated under the Clean Air Act (CAA). In addition, in many states SO₃, H₂SO₄ and HBr are classified as HAPs and their discharge must be controlled to comply with a state air toxics program.

DISCUSSION

Although technologies exist for “cleaning” fuels or other materials before processing to remove acid gas precursors (sulfur and halides) and thereby limit acid gas emissions, pre-treatment is generally not economically viable. The release of acid gases to the environment is most often controlled by “scrubbing” the waste gases from the processes prior to release through a stack or other process vent.

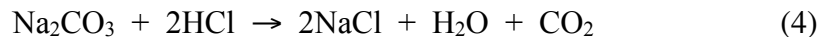
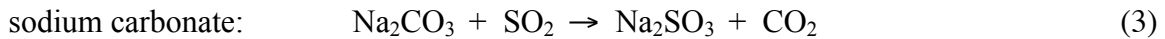
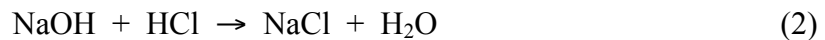
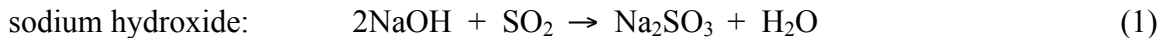
Acid Gas Scrubbing Technologies

Acid gas scrubbing technologies are usually based on multi-phase acid-base neutralization reactions. Neutralization reactions are typically fast and exothermic, and equilibrium conversions are high. However, in practice acid gas scrubbing neutralization reaction rates are mass-transfer limited and equilibrium conversions are not reached because the processes are continuous and available reaction times are limited. The effective rate of reaction and thereby the extent of acid neutralization realized in the available interfacial contact time (generally on the order of a few seconds in all types of scrubbers), depends largely on the rate of interfacial mass-transfer. The mass transfer rate, in turn depends largely on the physical and chemical form of the acid gases and the alkaline (basic) scrubbing reagents, and the physical characteristics of the systems used to bring them into contact with each other. The following sections outline the three most common approaches to alkaline scrubbing of acid gases.

Wet Scrubbing

Wet scrubbing is physically an *absorption* process, in which the gas-phase acid is dissolved in a scrubbing liquid (usually water) as a result of differential solubility. The rate and extent to which it dissolves depends on the departure from phase equilibrium, which is maintained by using a mass-transfer device such as a packed-tower, and further enhanced by the presence of an alkaline material in the scrubbing liquid. The alkaline material neutralizes the acid in solution, reducing the equilibrium partial pressure of the dissolved gas, and maintaining the driving force for *absorption*. With both reactants in solution as ionic species in the same phase, the neutralization reaction is very fast and only a small stoichiometric excess of alkaline material is needed to achieve high acid removal efficiencies (95-99+ percent). The rate-limiting step in wet scrubbing is the *absorption* of the acid gas into the liquid solution. The designs of mass transfer

devices for this purpose focus on facilitating this *absorption* by maximizing the departure from phase equilibrium through counter-current gas/liquid flows, by maximizing interfacial area (between gas and liquid films), and by maintaining turbulent liquid and gas flow regimes. With the exception of large FGD (flue-gas desulfurization) systems on utility boilers, which employ limestone (CaCO₃) slurries, the alkaline materials used in wet scrubbing are generally sodium based, since sodium salts are highly soluble in water. Calcium sorbents are generally not used in wet scrubbing, since they are not highly soluble in water and result in suspended solids that clog interstitial spaces and interfere with liquid film distribution and flow in packed columns. In large FGD systems this is avoided by contacting the limestone slurry with the process gas in a spray tower. The most commonly used alkaline reagents for wet scrubbing and their overall reactions with SO₂ and HCl are:



Gas exiting a wet scrubbing system is generally saturated with moisture from the scrubbing liquid. In addition to acid gases, a combined a high-pressure drop venturi scrubber and packed-tower system can also achieve high particulate removal efficiencies. However, high inlet loadings of insoluble particulate matter can be problematic for such systems. Salts of acid gases removed by wet scrubbing systems are purged in scrubber blow-down and generally disposed as dissolved solids in wastewater. Depending on the process being controlled, this wastewater may also contain significant levels of insoluble, suspended solids.

Semi-dry Scrubbing

In semi-dry scrubbing the gas phase acid is also *absorbed* into a scrubbing liquid. However, rather than being a solution of sodium alkaline material, it is typically a hydrated lime slurry prepared immediately prior to use, by “slaking” lime



After being absorbed into the slurry liquid the acid is chemically neutralized by the suspended alkaline material according to the following overall reactions with SO₂ and HCl:



Because of the limited solubility of calcium species in aqueous solution most of the neutralization reaction occurs between the acid gas dissolved in the liquid of the slurry particles and the alkaline material suspended in the slurry particles. Hence, the reaction conditions are multi-phase and not as ideal as in a wet scrubber. A spray-dryer is typically employed as the contact device to avoid the problems of suspended solids in the liquid phase that occur in a packed tower. Interfacial area within the spray-dryer is maximized by mechanically atomizing the alkaline slurry into an open (usually vertical down-flowing) vessel in which gas flows are maintained in the turbulent regime, to facilitate mass transfer. Simultaneous heat and mass transfer from the hot gases to the slurry liquid transforms the aerosol particles of slurry into solid

particles of acid salts and excess alkaline material, that are collected downstream by a particulate capture device. Evaporation of the free water in the slurry results in quenching of the gases. Hence, waste gases can be treated in a lime spray dryer at the high temperature they leave the process. Spray dryers using electrostatic precipitators (ESPs) as the downstream particulate capture device have been proven in operation. However, the most effective systems employ a fabric filter baghouse as the particulate capture device (SD/FF). In addition to providing the highest overall particulate capture efficiency, use of a fabric filter also increases the conversion of the alkaline sorbent material by increasing available reaction time. Unconverted alkaline material in the suspended particulate matter leaving the spray dryer becomes part of the filter cake on the bag filters and provides additional acid-base contact time as the cake accumulates on the bags between baghouse cleaning cycles. Salts of acid gases removed by semi-dry scrubbing systems are purged as solids with other captured particulate matter.

Dry Scrubbing

Acid gas removal by dry scrubbing also requires inter-phase mass transfer, but it occurs between the gas phase and the solid phase, rather than between the gas phase and the liquid and solid phases, as with wet and semi-dry scrubbing. The acid gas must first be *adsorbed* onto the solid surface of the dry alkaline material (as a result of inter-molecular attractive forces), rather than being *absorbed* (dissolved) in a scrubbing liquid or slurry. Once *adsorbed*, the acid gas molecule is neutralized by the alkaline material to form a solid salt that remains as part of the solid particle of alkaline material. Chemically, these are less ideal neutralization reaction conditions than in wet or semi-dry scrubbers, since one reactant is in the gas phase and the other is in the solid phase. As a result, dry scrubbers usually require the greatest stoichiometric excess of alkaline material to achieve high acid removal efficiencies (95-99+ percent).

The dry injection (DI) contact device can be a mixing chamber designed specifically for the purpose or simply the gas duct between the source and the downstream particulate capture device. The key system performance factors are turbulent mixing of alkaline powder with hot gas, and maximizing the time that the alkaline powder is suspended in the hot gas stream. Although there are systems in operation where DI has been employed in conjunction with an ESP for particulate capture, a fabric filter provides the best overall performance by maximizing acid-base contact time. With an ESP the available acid-base contact time is limited to the time the alkaline powder and gas are in contact between the point of injection and the fields of the ESP. In a dry injection/fabric filter (DI/FF) system, as with the SD/FF combination, unconverted alkaline material in the suspended particulate matter becomes part of the filter cake on the bag filters and provides additional acid-base contact time as the cake accumulates on the bags between cleaning cycles.

Unlike wet and semi-dry scrubbing, evaporation of free water in scrubbing liquor and quenching of gases is not inherent in the dry scrubbing process. Hence cooling, either upstream or downstream of sorbent injection, may be necessary to protect a downstream fabric filter. Salts of acid gases and excess alkaline material removed by a DI system are purged as solids with other captured particulate.

A variant of dry scrubbing is dry furnace injection (DFI) where the dry alkaline material is injected directly into the process furnace at high temperature. The advantages of furnace injection are greater overall reaction time and higher reaction temperatures, producing faster reaction rates.

Technology Comparison

Each of the technologies described in the previous sections is capable of removing high percentages of both SO_x and HX from the inlet gas (95-99+ percent). Hence, the choice of which technology to apply is usually driven by a combination of cost and ease of operation & maintenance. The primary operating objective is to maintain conformance with the applicable regulatory limits for acid gas release, while incurring the minimum annualized total cost. The annualized total cost comprises both capital and operating & maintenance (O&M) costs. The annualized capital cost is the repayment of principal and interest on the funds borrowed to purchase and construct the acid gas scrubbing system. The largest component of the annualized O&M cost is typically the cost of the alkaline reagent, but it also includes energy costs associated with fans and pumps, and the costs of treatment and disposal of liquid and solid residues. The following Table 1 summarizes and qualitatively compares the various characteristics of the different acid gas scrubbing technologies.

Table 1 – Acid Gas Scrubbing Technology Comparison									
TECHNOLOGY		CHARACTERISTICS							
		Capital Cost to Install	Efficiency (reagent utilization)	Neutralizing Reagent Cost	Energy Cost	Process/Maintenance Complexity	Ease of Retrofit	Waste Water	Visible Plume
Wet Scrubbing	Calcium-based	HIGH	MEDIUM	LOW	HIGH	HIGH	LOW	YES	YES
	Sodium-based	HIGH	HIGH	HIGH	HIGH	HIGH	LOW	YES	YES
Semi-Dry Scrubbing	Calcium-based	HIGH	MEDIUM	MEDIUM	HIGH	HIGH	LOW	NO	NO
Dry Scrubbing	Calcium-based	LOW-MED	LOW-MED	MEDIUM	LOW	MEDIUM	MEDIUM	NO	NO
	Sodium-based	LOW	LOW-MED	MED-HIGH	LOW	LOW	HIGH	NO	NO

These advantages and disadvantages and their associated economics, form the basis for selection of an acid gas scrubbing system. Each type of system is best suited to a particular set of process and economic circumstances. The following paragraphs describe the dry injection technology in greater detail and outline the circumstances under which it is likely to be the best process technology choice.

Aspects of Dry Scrubbing

When compared with wet scrubbing or semi-dry scrubbing, the primary disadvantage of dry scrubbing or dry injection, is lower alkaline sorbent utilization. The wet scrubber brings the acidic and basic species together at a molecular level and therefore the main factor that limits conversion and necessitates a slight stoichiometric excess of alkaline reagent, is the need for the continuous phase contactor (eg. packed column) to maintain a slight departure from equilibrium to provide a driving force for the reaction. The semi-dry scrubber also brings the acidic and basic species together at a molecular level, but to a more limited extent, since this occurs only at the fluid-solid interface between the lime slurry liquid and the slightly soluble solid particles of calcium hydroxide in the slurry. The solid particles in the slurry are several orders of magnitude

larger than individual molecules of the calcium hydroxide and as a result, unconverted alkaline reagent remains within the solid particles and a greater stoichiometric excess of alkaline is required than with a wet scrubber. In dry scrubbing, the molecule-particle size disparity, combined with the inherent disadvantages of heterogeneous gas-solid reactions, potentially causes even greater internal sequestration of unconverted alkaline material, resulting in the greatest requirement for stoichiometric excess of alkaline reagent.

Despite this disadvantage and the potential operating cost penalty, DI systems are extremely simple to install and operate. The only rotating equipment required is a small blower for dilute phase pneumatic conveying of the dry alkaline sorbent to the process gas ducting. The following are examples of circumstances in which a dry scrubber is better suited to an application than either a wet scrubber or a semi-dry scrubber:

- ◆ The annualized cost of a dry injection system is lowest, or close enough to the other options to be influenced by factors to which costs cannot easily be assigned.
- ◆ The process throughput is not large enough to make semi-dry scrubbing economical (gas flows are less than approximately 100,000 acfm).
- ◆ Wastewater discharges from a wet scrubber cannot be permitted or are uneconomical to treat.
- ◆ Local electric power rates are high, making the higher system pressure drops associated with wet and semi-dry scrubbers too costly to operate.
- ◆ Moisture saturated exhaust gas or a visible steam plume from the stack are unacceptable.
- ◆ The process operation and maintenance complexity of wet and semi-dry scrubbers are incompatible with the facility operator's organization.
- ◆ Handling hazardous chemicals such as sodium hydroxide, calcium oxide, and calcium hydroxide are not acceptable.
- ◆ Particulate capture equipment (eg. ESP or fabric filter) is already in operation and acid gas controls need to be retrofitted.

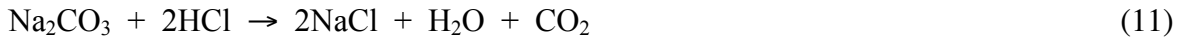
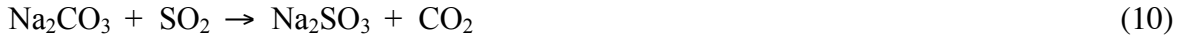
If the above factors indicate that a dry injection acid gas scrubber is the best process choice, the best alkaline reagent for the application must then be chosen. This decision is made largely on the basis of the effective alkaline reagent cost, in dollars per unit of acid gas removed. That cost is a function of the amount of alkaline material required per unit of acid gas removed and the unit cost of the material (and possibly the unit cost of solid residue disposal).

Dry Injection Chemistry

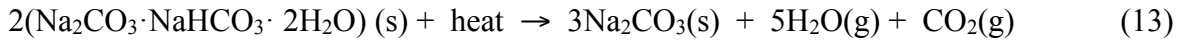
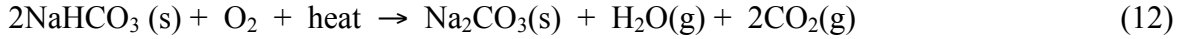
Dry injection (DI) systems can employ either calcium or sodium alkaline materials for neutralizing acid gases. With a calcium based system, dry hydrated lime (purchased and stored as $\text{Ca}(\text{OH})_2$) is directly injected and the overall neutralization reactions are essentially the same as those for the semi-dry scrubber:



With a sodium sorbent based systems the ultimate neutralization reactions derive from sodium carbonate:



The source of the carbonate can be synthetic sodium bicarbonate, naturally occurring sodium bicarbonate (nacholite), or naturally occurring sodium sesquicarbonate (trona). When these materials are injected into a hot (oxidizing) gas stream they “calcine” according to:



The theoretical stoichiometry and mass requirements for the different alkaline materials and reactions are summarized in Table 2.

Common Name	Chemical Name	MW	Neutralization Reactions	Theoretical Requirement		Purity	Practical Limit lb base lb acid
				Moles base Mole acid	lbs base lb acid		
Baking soda	Sodium bicarbonate	84.01	$2\text{NaHCO}_3 + \text{SO}_2 \rightarrow \text{Na}_2\text{SO}_3 + \text{H}_2\text{O} + 2\text{CO}_2$	2	2.62	99%	2.65
			$\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$	1	2.30		2.33
Hydrated lime	Calcium hydroxide	74.09	$\text{Ca}(\text{OH})_2 + \text{SO}_2 \rightarrow \text{CaSO}_3 + \text{H}_2\text{O}$	1	1.16	98%	1.18
			$\text{Ca}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{CaCl}_2 + 2\text{H}_2\text{O}$	½	1.02		1.04
Nacholite	Sodium bicarbonate	84.01	$2\text{NaHCO}_3 + \text{SO}_2 \rightarrow \text{Na}_2\text{SO}_3 + \text{H}_2\text{O} + 2\text{CO}_2$	2	2.62	97%	2.70
			$\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$	1	2.30		2.37
Soda ash	Sodium carbonate	105.99	$\text{Na}_2\text{CO}_3 + \text{SO}_2 \rightarrow \text{Na}_2\text{SO}_3 + \text{CO}_2$	1	1.65	97%	1.71
			$\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$	½	1.45		1.50
Trona	Sodium sesqui-Carbonate	226.03	$2(\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}) + 3\text{SO}_2 \rightarrow 3\text{Na}_2\text{SO}_3 + 5\text{H}_2\text{O} + 4\text{CO}_2$	2/3	2.35	97.5%	2.41
			$\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O} + 3\text{HCl} \rightarrow 3\text{NaCl} + 4\text{H}_2\text{O} + 2\text{CO}_2$	1/3	2.01		2.12

Only the reactions between SO₂ and HCl and the alkaline material are shown in Table 2 for comparison purposes, but the stoichiometry for SO₃/H₂SO₄ and other HX is essentially the same. Although it is not used directly as a DI alkaline material, for reasons explained later, soda ash is also included for comparison. As can be seen from this table, calcium sorbents have an theoretical stoichiometric advantage relative to sodium sorbents, due to the divalent cation (Ca⁺⁺), as compared with the monovalent cation (Na⁺). Even with differing molecular weights factored in, the approximate 2 to 1 advantage translates roughly into mass so that the theoretical mass requirement for the sodium sorbents is roughly twice the theoretical calcium sorbent requirement. However, the theoretical requirements do not account for differing reactivities and assume that equilibrium conversions are reached. The different alkaline materials used in dry

injection exhibit different reactivities and due to the nature of the processes, equilibrium conversions are never reached. A common measure of actual alkaline sorbent usage as compared with the theoretical requirement is the normalized stoichiometric ratio or NSR, defined as:

$$\text{normalized stoichiometric ratio} = \frac{\text{moles alkaline material actually injected}}{\text{moles alkaline material theoretically required}}$$

The well established axiom that combustion reactions are favored by “time, temperature, and turbulence” can also be applied to dry acid gas scrubbing. The process factors that have the most effect on alkaline reactivity and conversion are:

- ◆ available interfacial surface area,
- ◆ reaction temperature, and
- ◆ reaction time.

In this hierarchy, the effect of interfacial surface area and turbulence are functionally equivalent.

Interfacial Surface Area

In dry scrubbers available interfacial area is determined by how much powdered alkaline material is suspended in the hot gas, by the individual alkaline material particle size, and by the average available surface area of each particle. Up to the point where solid particles of alkaline material drop out of the gas stream due to insufficient velocity to keep them suspended, the amount of alkaline material in the gas is driven by inlet acid gas loading. Individual particle size for “sorbent grade” alkaline materials is generally minimized by mechanical refinement to a practical mean diameter of 20 to 30 microns. The factor that has the greatest potential to effect available surface area for reaction is the interstitial pore area of the particles. If the solid alkaline particles are porous the internal surface area can be several orders of magnitude greater than the outer surface area of the particle.

Although this characteristic is of limited importance with hydrated lime, it is significant with sodium sorbents. The reactions shown in Equations 12 and 13 above result in the explosive evolution of H₂O(g) and CO₂(g) from the source carbonate molecules, causing the solid particles to “pop-corn”, greatly increasing the available surface area of sodium carbonate within the particles of alkaline sorbent material. Sodium carbonate (soda ash) itself is rarely used in dry scrubbing because this calcining does not occur and the surface area available for neutralization reaction, even with finely milled powder, is much less than in the “pop-corned” particles formed by calcining sodium bicarbonate/sesquicarbonate in the hot process gases. The additional particle surface area available with sodium sorbents can also improve collateral removal of air toxics such as metals and trace organics, by providing sites for surface *adsorption* of these pollutants, reducing or eliminating the need for powdered activated carbon (PAC) injection.

Reaction Temperature

Although acid-base neutralization reactions are exothermic and the theoretical reactant conversion is negatively effected by temperature, as a practical matter the positive exponential

temperature dependence of the reaction rate factor is far more important relative to conversion of alkaline material. Up to a point, the higher the gas temperature the faster the neutralization reaction and the greater the conversion of alkaline material to acid salts in the available reaction time. Dry injection systems often operate in the range of 250°F to 500°F. The low end of the range is usually 250°F to 300°F to remain above the acid dewpoint of the process gas. In general, the higher the acid gas content the higher the acid gas dewpoint. The high end of the range is usually 450°F to 500°F, which corresponds to the practical limit for most baghouse filter media as well as being the bottom end of the range in which ESPs can actually become a source of dioxins and furans. As experience with ceramic filters grows at may be possible, in applications where heat recovery is not an objective, to operate a DI-filter system at much higher temperatures.

Furnace sorbent injection (FSI) is intended to take advantage of significantly higher temperatures than are typically present in gas ducting downstream from the furnace. In cases such as fluidized bed combustion of coal, furnace injection of calcium sorbent can be accomplished by feeding limestone (CaCO_3) into the bed, where it calcined and the resulting calcium oxide reacts with sulfur dioxide to form solid sulfites/sulfates. Furnace injection of sodium sorbents has been found to significantly reduce the stoichiometric excess and the NSR required to achieve high acid gas removal efficiencies. Trials at the Davis County Energy Recovery Facility in Utah and the Baltimore Regional Medical Waste Incinerator have shown that injection of trona into the furnace at approximately 1800°F can significantly increases the reactivity and conversion of the alkaline material, greatly reducing the effective NSR.

Reaction Time

One of the aspects of dry scrubbing that can significantly offset the inherent limitation on reactant conversion is reaction time. In wet scrubbers the available reaction time is the time that the gas stream and scrubbing liquor are actually in contact. This time is generally on the order of a few seconds. In SD and DI systems that use ESPs for particulate collection, the situation is analogous. The available reaction time is the time that the gas stream and alkaline material are in contact - the time between injection of the alkaline material into the hot gas and the ESP fields removing the suspended particulate material.

In DI/FF (and SD/FF) systems the neutralization reaction is a 2-phase process. Much of the conversion of alkaline material to acid salts occurs while the alkaline material is suspended in the gas but significant additional conversion can occur in the baghouse filter cakes between filter bag cleaning cycles. The typical contact time between reactants while the sorbent material is suspended in the gas stream is on the order of a few seconds. Exposure of alkaline material in the filter cakes to acid gas can range from several minutes to up to a hour, depending on the baghouse cleaning cycle and the actual system pressure drop due to inlet dust loading. This additional residence time can increase the alkaline material conversion from a “once through” value of 30 to 50 percent, up to between 60 and 80 percent.

In calcium-based DI systems, the alkaline particle surface area does not benefit from the “pop-corn” effect of sodium materials. As a means of increasing sorbent utilization, calcium based DI processes often include systems for recycling collected particulate matter containing unreacted calcium in order to increase the conversion of alkaline material. Baghouse bottoms are collected and reinjected into the hot gas stream, increasing the total alkaline residence time and thereby the

overall alkaline utilization. Depending on the system, single-pass conversions can range from 30 to 60 percent. Systems equipped with recycle can exceed 70 percent conversion of calcium. The disadvantage of sorbent recycle is that the dust loading in the hot gas going into the particulate capture device is significantly higher. With existing ESPs this may not be feasible and the particulate capture performance of existing baghouses may be significantly degraded. New baghouses designed for that dust loading will be much larger than they would be with the once-through dust loading and the greater the inlet dust loading the more frequently the bags will be cleaned. With sodium-based DI systems, the higher particle surface area available enables more of the alkaline reactant conversion to occur while the material is initially suspended in the hot gas stream and allows greater conversion in the filter cakes on the bags in the baghouse. Hence, sodium-based systems are able to achieve high alkaline conversions without recycling baghouse bottoms to the hot gas stream, reducing the inlet loading of particulate matter that includes a significant fraction of material that is essentially inert, and thereby the required sizing of the particulate capture device.

CONCLUSIONS

In certain acid gas control applications, DI is the simplest and least costly process to implement (new or retrofit), and the least costly to operate and maintain. Both calcium and sodium alkaline reagents are well proven in DI applications. However, calcium hydroxide is a hazardous chemical with potential worker exposure hazards, whereas sodium bicarbonate/sesquicarbonate are considered to be nuisance dusts from the occupational exposure standpoint. The delivered cost of calcium and sodium reagents varies with location, but is more consistent with the chemically processed materials, dry hydrated lime and sodium bicarbonate, than with the naturally occurring materials nacholite and trona, which only have natural deposits in certain parts of the country. The sodium sorbents are generally more costly than the calcium sorbents, although the material cost (less freight) of dry hydrated lime and trona are similar. Among the sodium sorbents, nacholite and synthetic sodium bicarbonate are slightly more efficient for SO_x reduction, while trona is slightly more effective for HX reduction. The delivered cost of synthetic sodium bicarbonate is significantly higher than nacholite, and nacholite is generally higher than trona.

Keywords

acid gas, alkaline sorbent, dry injection, DFI, DI, DI/FF, flue-gas desulfurization, FGD, gas scrubbing, hydrated lime, nacholite, NSR, SD/FF, sodium bicarbonate, sulfur oxides, trona

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