

Developments in Sorbent Injection Technology for Sulfuric Acid Mist Emissions Control

Paul S. Nolan

Chemical Lime Company, 3700 Hulen Street, Fort Worth, TX 76109

E-mail: paul.Nolan@chemicallime.com; Telephone: (817) 806-1546; Fax: (817) 732-8144

Summary

As the U.S. electric power industry faces increasingly stringent emission control regulations, the economic benefits of using integrated solutions requires due consideration of the impacts of applying a given set of process technologies for the site-specific conditions of any given plant. The widespread application of selective and non-selective catalytic reduction (SCR and SNCR, respectively) for the control of nitrogen oxides (NO_x) has resulted in attendant impacts on equipment and processes downstream of the economizer, leading to increased formation of sulfur trioxide (SO_3) and subsequent potential emission of undesirably high concentrations of sulfuric acid mist. Moreover, the increased use of fuels or fuel blends with higher vanadium content (a catalyst for SO_3 formation) has also contributed to the phenomenon. In the absence of direct federal regulatory measures and under some sets of circumstances, the effect can be minimal or even self-controlled, but for many mitigation has effectively become essential. With the pressure to address mercury and fine particulate emissions at the same time, utilities are seeking solutions cost-effective solutions with synergetic effects.

The particular combinations of fuels burned, the combustion conditions, the selection and design of the NO_x control technology, and the types of particulate collection and desulfurization techniques employed all contribute to the ultimate physical characteristics and chemical composition of the flue gas leaving the stack. Within the past three years, Chemical Lime has had several opportunities to work with industrial and utility customers on trials and demonstration tests of hydrated lime injection as a means of reducing flue gas SO_3 concentration and/or opacity resulting from the formation of sulfuric acid mist. The nature of the tests have ranged from one extreme of being very short (several hours) “proof of concept” trials to extended demonstrations lasting a week or more that have been planned with the customer to explore potential longer term impacts and compatibility with other emission control systems, especially dry electrostatic precipitators (ESP).

The specific results of the individual tests have usually been considered confidential as the tests have been exploratory in design or directed at potential performance of competing technological approaches at a given plant. It can generally be said, however, that the not-too-surprising primary conclusions are that, properly applied, calcium hydroxide as the strong chemical base in commercial hydrated lime is an effective sorbent for the capture of strongly acidic, gas-phase SO_3 , and that the removal is primarily a function of the feed stoichiometry and the residence time available for diffusion of the gas to the reactive sites on and within the lime sorbent. Several published studies¹ over the past decade have established this acid-base relationship as fundamental. The apparent “ease” with which one can remove SO_3 soon becomes more complex as choices must be made regarding which approach and technology might prove to be most cost-effective for a given set of site-specific conditions. For this reason, the overall significance of the various tests conducted points to the value of assessing the following considerations, some of which are necessarily interrelated, as part of the decision-making process.

Basic Objective Identification of the performance actually required – one must consider the mechanism(s) of SO_3 formation and conversion to sulfuric acid via reaction and dilution with water as the flue gas passes through the time-temperature profile(s) associated with the boiler and its chemistry (including the use of alkaline additives for slag control), SCR catalysis or SNCR chemistry, and potential “inherent” capture as a result of localized condensation and/or physicochemical processes further downstream – each of which may affect where the sorbent injection may most effectively be utilized. It is also important to consider the mechanisms of sulfuric acid condensation, the significance of aerosol droplet size distribution particularly as it relates to opacity, and potential neutralization by alkaline components of the fly ash.²

Injection Location Selection of the injection location(s) can have a substantial impact on overall sorbent utilization. Sorbent effectiveness is severely diminished when injection is directed at areas where the gas-phase SO_3 has already condensed into aerosol droplets. Once this occurs, reactions can essentially only take place as a result of inertial impaction between the droplet and the lime particle, a process that requires a much higher pressure drop than occurs in a typical flue gas path. It therefore becomes important to consider that SO_3 concentrations can be easily altered by the degree of uniformity of

ammonia or urea injection for the SNCR or SCR processes that results in some neutralization by excess ammonia, variation of catalyst activity with respect to SO₂ oxidation to SO₃ over a period of time, and condensation due to potentially significant temperature gradients, particularly near the “cold end” of air preheaters and as a result of air in-leakage near expansion joints. Understanding the concentration profile at the injection plane can permit one to bias the injection accordingly to improve utilization.

One other aspect of sorbent injection location that may prove to be worth considering is the possibility of selecting more than one injection location. While not widely practiced to date, it may be advantageous to direct some of the material into areas where an initial partial reduction is deemed advisable, for example, as a means of minimizing ammonium bisulfate formation while maintaining a relatively low particulate loading to lessen potential impacts on heat transfer surfaces. Additional sorbent can then be directed as needed to a downstream location, perhaps even between an ESP and a wet flue gas desulfurization system that, if operational conditions permit, will capture and use the residual alkalinity.

Sorbent Dispersion Effective dispersion of the sorbent at whatever locations are selected is critical to achieving high utilization. For smaller applications, it is often most cost effective to provide a simple blower arrangement to inject the sorbent into the flue. Because hydrated lime is a fine powdery material, it generally follows the gas path and readily disperses into the gas within a few feet of the injection port or lance, forming a cloud several feet wide. As the application becomes larger, however, it becomes increasingly important to understand both the means of injection and the velocity (and sometimes temperature) profile of the flue gas into which the sorbent is injected. For such larger applications, multiple injection lances become necessary in order to deliver reasonable portions of the sorbent to selected areas of desired coverage. Consideration of flow imbalances that may depend on ductwork geometry and varying load conditions become important, as well as an understanding of the effective residence time of the dispersed sorbent required to accommodate the diffusion and reaction kinetics. Generally speaking, minimum residence times of two or three seconds are conducive to higher removals at reasonable stoichiometric feed rates. The use of cold flow models or computational fluid dynamic (CFD) models can be instructive in identifying not only how the sorbent will disperse under various sets of load conditions, but also areas where eddy currents, recirculation patterns, and other geometric boundaries are liable to give rise to conditions that can affect performance either positively or negatively.

Downstream Effects on Dry ESPs Applications involving dry ESPs must be carefully considered due to the potential for developing a “back corona” condition that can lead to significantly diminished particulate collection. Dry ESP design parameters need to be reviewed with respect to the unit’s ability to capture higher resistivity ash. For some, the designs may be able to accommodate the relatively minor increase in ash alkaline components, while for others minimal levels of humidification to temperatures still above the acid dewpoint might be expected to restore, if not improve, performance.

Sorbent Properties In preceding studies, consideration of sorbent properties has been relegated to being one of lower importance due to the perception that, for the most part, they are commodity chemicals that have relatively low variability beyond basic purity levels. This is changing, however, as Chemical Lime and its parent company, Lhoist, are in the process of developing calcium hydroxide-based SO₃ sorbents with physicochemical properties that appear to provide improved reactivity and utilization. On-going bench-scale and small pilot studies that indicate perhaps 50 to 100 percent improvement in sorbent utilization is expected to translate into lower feed stoichiometric requirements that will also lessen the potential impact of the downstream effects on dry ESPs. A more extensive, full-scale evaluation of these sorbents is planned for this summer.

References

1. R.K. Srivastava, *et al.*, “Emissions of Sulfur Trioxide from Coal-fired Power Plants,” Paper presented at POWER-GEN International 2002, Orlando, FL, December 2002, and references therein
2. W.P. Buckley and B. Altshuler, “Sulfuric Acid Mist Generation in Utility Boiler Flue Gas,” Power Engineering, November 2002