

IMPROVED DSI PERFORMANCE WITH OPTIMIZED HYDRATED LIME

Jim Dickerman
Lhoist North America
650 Buena Vista Way
Laguna Beach, CA 92651

Mike Schantz*
Lhoist North America
623 West Hickory Court
Lewisville, CO 80027

ABSTRACT

Over the past year Lhoist North America (LNA) has participated in several demonstration tests to evaluate how Dry Sorbent Injection (DSI) systems can become an integral part of our customer's emission control strategy. DSI systems were initially of interest due mainly to their low capital cost for controlling SO₃, but technical advances with improved reagent physical properties, coupled with improved system reliabilities have increased the application of DSI for the control of HCl, HF, and SO₂. This paper will present data from multiple demonstration tests for multiple pollutants; and will illustrate how the physical characteristics of hydrated lime impact the overall performance of DSI systems.

INTRODUCTION

Environmental regulations currently under development by the EPA, as well as certain consent decree agreements made with several state and local environmental agencies, are requiring reduced emission levels for a number of pollutants including acid gas species (i.e. SO₂, HCl, HF) as well as Mercury (Hg) and particulate matter.. As a result of the need to comply with these new and more stringent emission limits, there is a growing use of dry sorbent injection technology (DSI) which is a low capital cost approach for controlling acid gas emissions.

Over the past few years there have been significant improvements in the performance of DSI systems such that their overall reliability and availability have greatly increased. Concurrently there has also been developments to improve the performance of some DSI sorbents such that a given removal level can be achieved at lower dosage rates, or alternatively an improved performance can be achieved at a given dosage rate. This paper discusses the development and application of Sorbacal[®]SP and Sorbacal[®]SPS, optimized hydrated lime products that have been developed and engineered specifically for acid gas emission control applications, and how the performance of these optimized hydrated lime products compare against the standard hydrated lime products that have historically been available in the US.

SORBACAL[®] DEVELOPMENT

The Lhoist R&D staff is continually working to develop and improve the company's products for specific applications. Sorbacal[®]SP (and Sorbacal[®]SPS) are examples of hydrated lime products that have been developed and engineered specifically for acid gas capture applications. Chemically, these products are very similar to other high quality hydrated lime products; but what differentiates Sorbacal[®] products from other hydrated lime products are their physical characteristics. Sorbacal[®]SP and Sorbacal[®]SPS have specific surface areas of >40 m²/gram and pore volumes of >0.20 cm³/gram whereas good quality hydrated lime products produced here in the US typically have a specific surface area of 18-20 m²/gram and a porosity of ~0.07cm³/gram. It is the combined aspects of increased pore volume and surface area coupled with an

optimized particle pore distribution that makes the Sorbocal® products more reactive. These physical properties provide added reaction sites, and the optimized pore structure prevents the reaction products from blocking the pores and keeping the surfaces below the blockage from being able to react.

Figure 1 illustrates graphically the differences in physical properties of the Sorbocal® products as compared to a more standard hydrated lime. The Sorbocal®SPS has the same physical properties as Sorbocal®SP – the difference is that Sorbocal®SPS has a promoter to assist with SO₂ removal.

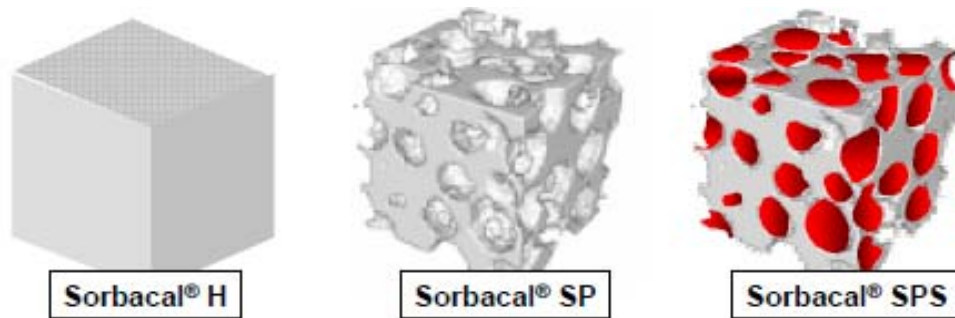


figure 1 – Graphical Representation of Hydrated Lime Products.

The Sorbocal® products have been produced and used in Europe and Asia for over 10 years, and during this time improved performance for many different applications has been demonstrated. In 2013, LNA commissioned a hydrator in the US this year to produce the Sorbocal® products, and results of demonstration tests conducted in the US are presented below to validate the performance of this material.

SO₂ REMOVAL

Full-scale demonstration and lab tests have been conducted at coal-fired boilers, and a wide variety of industrial facilities to evaluate SO₂ capture with Sorbocal®SP and SPS. Results of these various tests are discussed below and demonstrate that for some specific industrial applications, SO₂ removal well in excess of 90% is achievable with Sorbocal®SPS at reasonable reagent injection rates. Because the effectiveness of hydrate for SO₂ capture is very much dependant on specific industrial process and the flue gas properties, these results for individual industrial processes are summarized below.

Coal-fired Boiler Data Summary

Figure 2 presents data taken from a pilot-scale coal combustion furnace. The coal fired during these tests produced a flue gas SO₂ concentration of ~2000 ppm. The tests were set-up to challenge the performance of Sorbocal®SPS, as a boiler firing a coal that would produce a flue gas with this high of an SO₂ concentration would likely have a post combustion FGD system of some type for SO₂ control. The pilot plant had an ESP for particulate control during this test, which also added to the challenge. Two hydrated lime products were injected near the boiler nose at a temperature of ~2000°F.

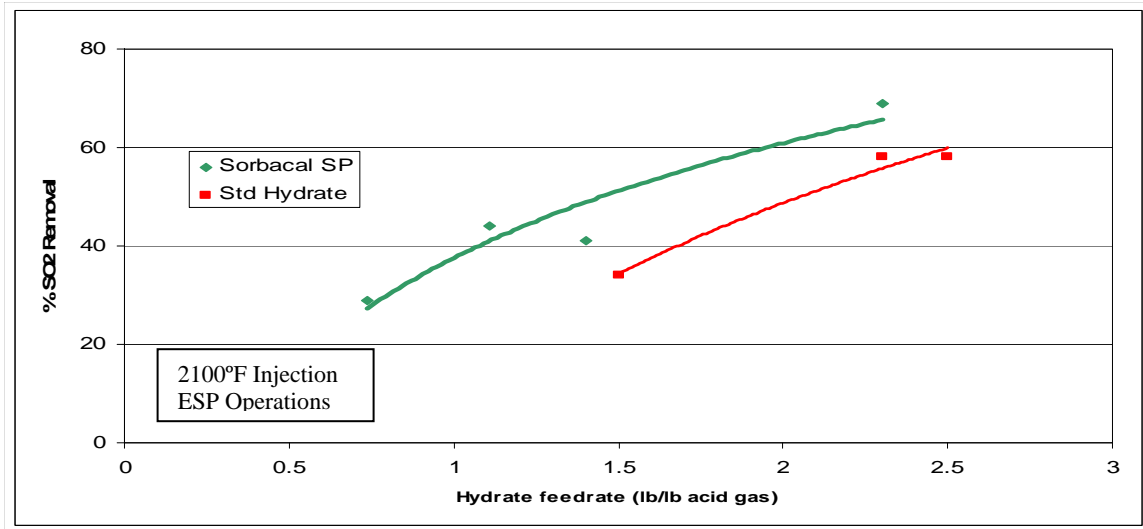


Figure 2 – SO₂ Removal for Sorbacal® SPS vs. Standard Hydrate At High Temperature Injection

As shown in Figure 2 Sorbacal® SPS required about 30% less material than the standard hydrated lime to achieve a given removal level. A removal of over 70% was achieved at a sorbent feed rate of ~2.4 lb Sorbacal® per lb of SO₂. Higher SO₂ removals would be expected at increased sorbent dosage rates or if a baghouse particulate collection device was used. It should also be noted that this trial work confirmed that the efficacy of hydrated lime for SO₂ capture is highly dependant on the temperature at the injection location.

The next data plot, Figure 3, is data from an operating coal-fired utility boiler that had a baghouse particulate collection device. The data shown in Figure 3 were taken from an injection location upstream of the air heater at a temperature of ~650°F. Data were also taken from an injection location downstream of the air heater at a temperature of ~300°F, predictably, the SO₂ removals measured at this lower temperature injection location were all ~25% or less. The coal fired at this plant was a mix of Powder River Basin and Central Appalachian coal that had a flue gas SO₂ concentration of ~600 ppm which is representative of a boiler that would consider DSI as an SO₂ mitigation approach.

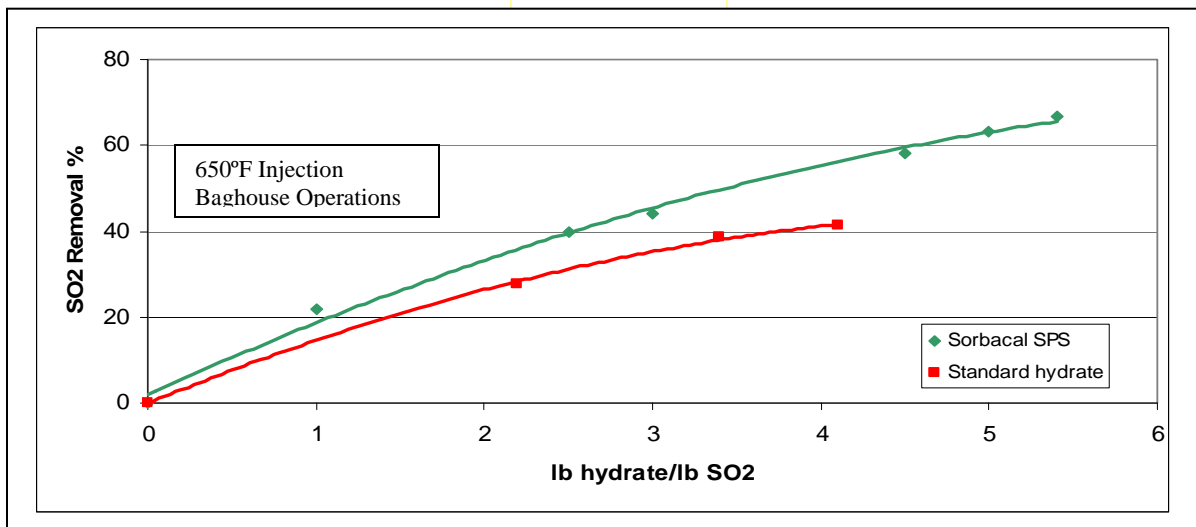


Figure 3 – SO₂ Removal for Air Heater Inlet Injection Location

The data plotted in Figure 3 show that DSI with Sorbocal®SPS can achieve greater than 60% SO₂ removal when injected at a location upstream of an air heater. When compared to the standard hydrated lime, Sorbocal®SPS achieved a 40% SO₂ removal rate at a dosage rate of 2 pounds Sorbocal®SPS per pound of SO₂, whereas the standard hydrated lime required a dosage rate of >3:1 to reach the same removal level.

Industrial Facility Data Summary

Figure 4 presents a data summary comparing three hydrated lime products for removing SO₂ from an industrial plant with relatively high sulfur conditions and high temperature flue gas. The injection location for all of the testing was upstream of a ceramic filter particulate collection device at an injection temperature of ~660°F.

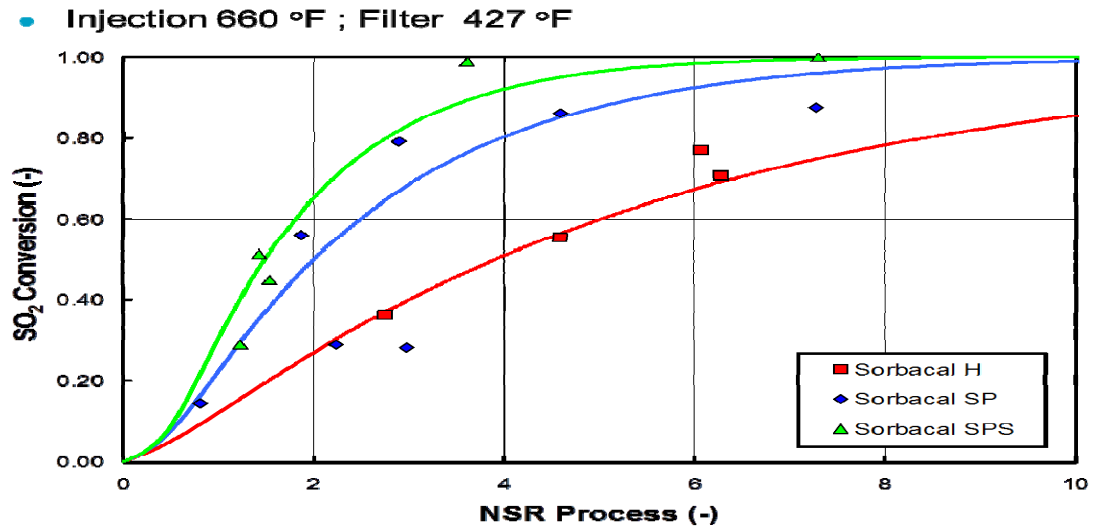


Figure 4 – SO₂ Removal Data from Industrial Facility

As shown in Figure 4, Sorbocal®SPS performed better than the other hydrated lime products, and achieved a 65% SO₂ removal at a 2:1 dosage rate, and over 90% removal at a 4:1 dosage rate. Also as shown, 99% SO₂ removals are achievable if needed with Sorbocal®SPS at increased dosage rates. While these impressive results may not be achievable at utility applications, very high capture of SO₂ is possible in some industrial applications with the Sorbocal®SPS product.

SO₃ REMOVAL

A wealth of data exists regarding the ability of hydrated lime DSI systems for controlling SO₃ emissions from coal-fired boilers. There are over 50 hydrated lime DSI systems operating on utility boilers today that are being used for reducing SO₃ emissions to desired levels. However, the potential resistivity impacts of hydrated lime within an ESP environment have sometimes limited the use of these materials for higher SO₃ applications. Therefore being able to achieve a given SO₃ level with less hydrated lime can mitigate these potential impacts.

Sorbocal®SP was recently evaluated in an existing full scale utility DSI system to compare its SO₃ removal performance with that of the hydrated lime product currently being used. Breen Environmental Services was contracted to monitor the SO₃ emissions during the test to compare the performance of the two products. Figure 5 is a summary of the data taken from the air heater inlet injection location, and shows both the sorbent injection rates as well as the SO₃ concentrations measured during the tests.

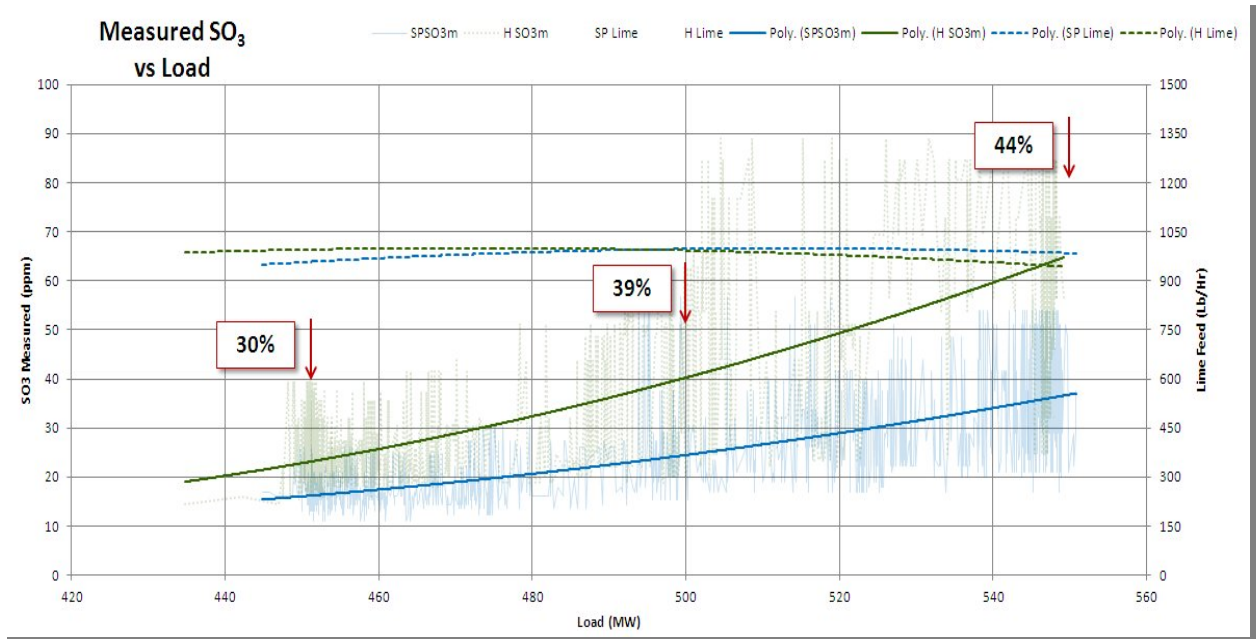


Figure 5 – Comparison of SO₃ Performance on a Coal-Fired Boiler

The top two traces on the graph show the sorbent injection rates and as shown, both products were being injected at a rate of ~950 lb/hr throughout the test. The bottom two traces show the SO₃ levels in the flue gas as a function of boiler load (the green trace is the standard hydrate and the blue is Sorbacal®SP) and this graph shows that the SO₃ concentrations were at least 30% lower when the Sorbacal®SP was being injected than they were with the standard hydrate.

HCl REMOVAL

Flue gas HCl measurements and emission control have not historically been a compliance issue. However recent air toxic regulations (Utility Boiler MATS as well as several industry specific MACT standards) have created a need for industry to understand their emission levels and how to best reduce the levels in order to meet the new emission standards. Consequently LNA has participated in several demonstration projects to evaluate how DSI with hydrated lime can effectively control these emissions; and results of several of these tests are summarized in this section.

Coal-fired Boiler Data Summary

Figure 6 is a data summary for tests conducted while burning a high chloride coal. The coal had a chloride concentration of 0.33% which resulted in a flue gas concentration of ~200 ppm. These data were collected at an injection temperature of ~330°F, and the HCl concentrations were measured downstream of a baghouse.

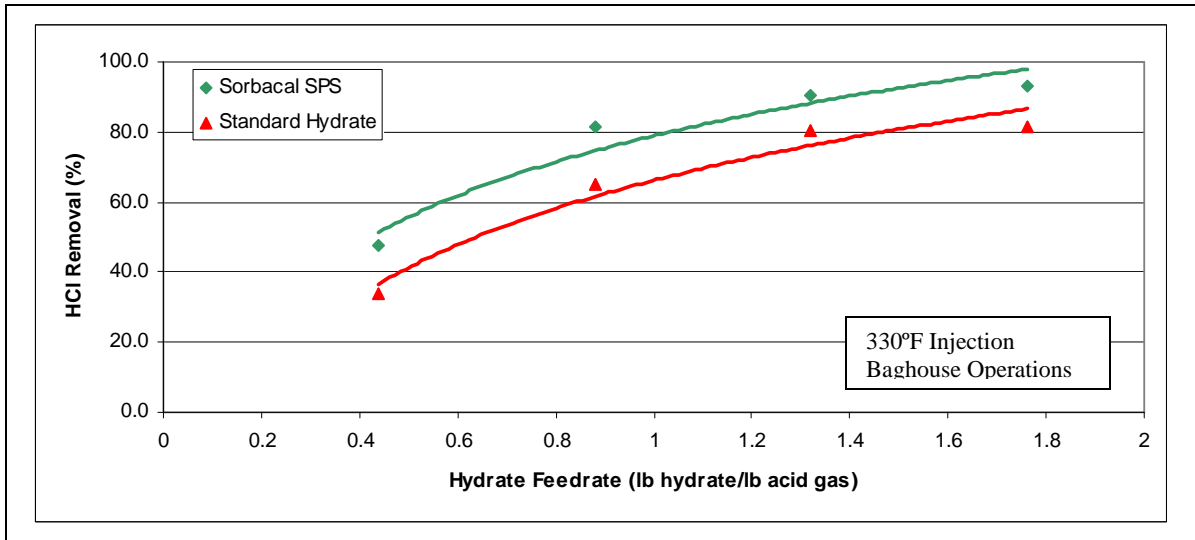


Figure 6 – HCl Removal for High S, High Cl Coal

The demonstration tests showed that Sorbacal®SPS performed about 30% better than the standard hydrate, and that greater than 97% HCl removal (from 200 ppm down to 4 ppm) could be obtained with this very high chloride coal when using the optimized Sorbacal®SPS reagent. Given that any unit burning such a high chloride fuel would be scrubbed, the goal for this trial was process water related. With the development of water intake rules and process water discharge requirements, the potential to remove chlorides in the solid phase, thereby allowing for higher recirculation rates is very attractive. These data demonstrate that DSI can be a viable approach for reducing these concerns.

The impact of the particulate collection device on HCl removal was also evaluated and Figure 7 shows these effects.

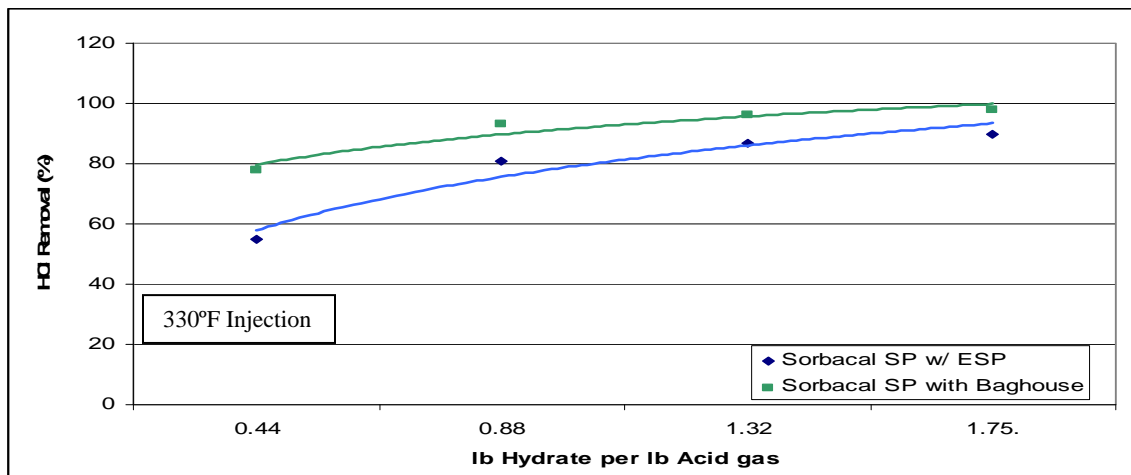


Figure 7 – Impacts of Particulate Collection Device

As one would predict, systems with a baghouse will have enhanced HCl removals for a given hydrate feed rate due to the added gas-solid contact that occurs in the baghouse as the unreacted hydrate becomes part of the filter cake.

Tests were also conducted to evaluate the performance of DSI as a potential MATS compliance strategy on a coal-fired boiler with a more moderate chloride content. The coal tested was a blend of Powder River Basin and Central Appalachian coal that had a chloride content of 0.09% and a sulfur content of 0.47%. Figure 8 illustrates the HCl removal performance for both the standard hydrate and Sorbacal® SP for a system with a baghouse particulate collector.

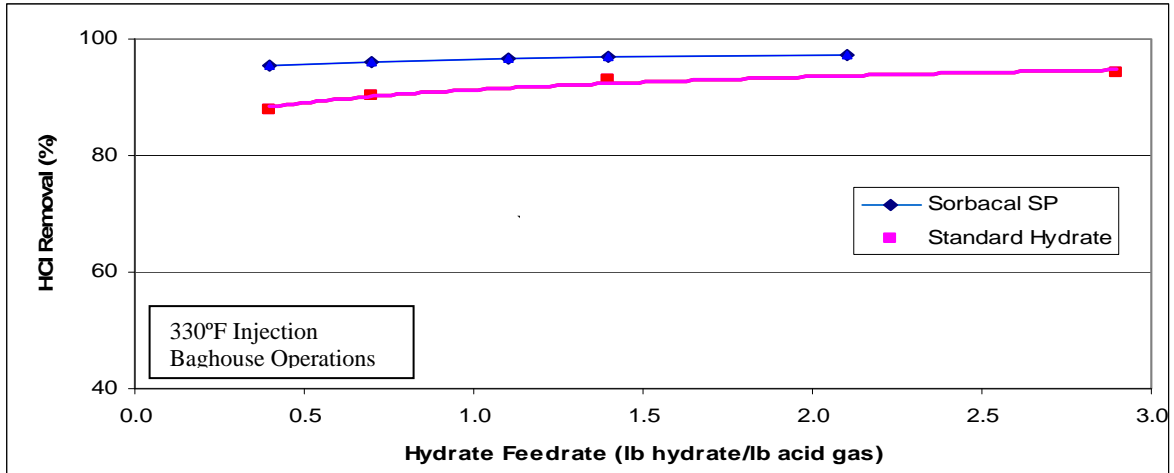


Figure 8 – HCl Removal – Baghouse Operations

As demonstrated in all prior trials, the Sorbacal® SP performed consistently better than the standard hydrate.

Figure 9 present the results from the use of the same fuel blend, but using ESP particulate collection device instead of a baghouse.

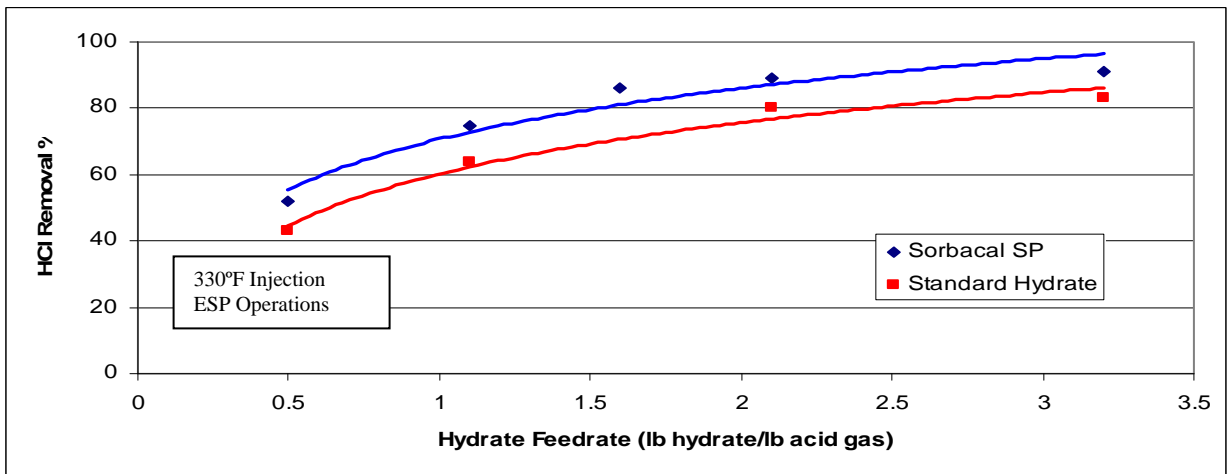


Figure 9 – HCl Removal – ESP Operations

These results suggest that in order to get the very high HCl removals that would be required for MATS compliance (>95%), a baghouse particulate collection device may be required and in many cases a high performance hydrated lime such as Sorbacal® SP will likely be necessary.

Figure 10 shows the HCl emission levels as a function of hydrate feedrate for baghouse operations with the MATS compliance level highlighted.

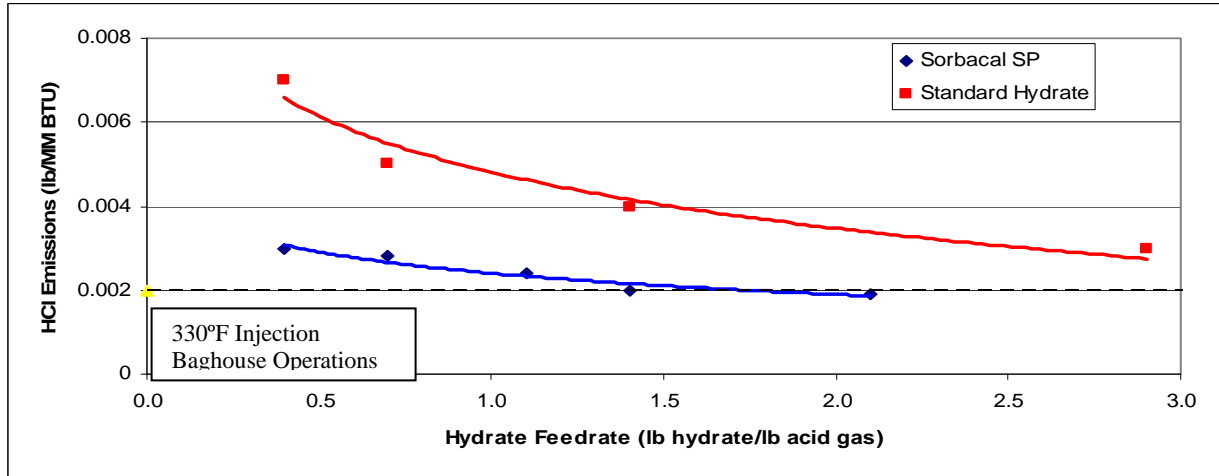


Figure 10 – HCl Emissions vs. Hydrate Feedrate

As shown, the MATS emission level was achieved with Sorbacal[®]SP at a feed rate of around 1.5 lb hydrate/lb acid gases. The MATS emission limit of 0.002 lb/MM BTU was not achieved with the Sorbacal H product.

CFB Boiler Tests

Figure 11 shows data from several tests conducted on the emissions of a full-scale fluid bed boiler. The HCl emissions from this unit were in the range of 30 ppm and as such needed to be reduced by over 90% to be able to meet the MATS emission level. Initial testing with standard hydrated lime was performed but was not able to achieve the required reduction for HCl.

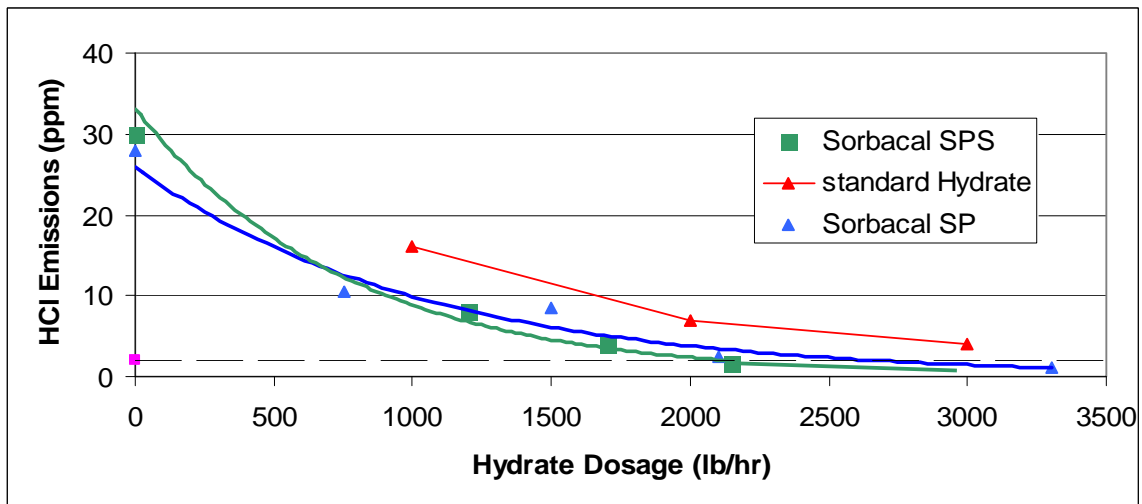


Figure 11 – HCl Emissions from CFB Boiler

Recent testing with both Sorbacal[®]SPS and Sorbacal[®]SP showed that the MATS level is achievable at an injection rate of around 1 ton/hr or these materials. This suggests that the use of DSI with Sorbacal[®] SP is a viable HCL trim control approach for CFB boilers.

Industrial Boiler Tests

Figure 12 shows the HCL removal performance of Sorbacal®SP as compared to Sorbacal®H for a moderate sulfur fuel industrial coal-fired boiler application. Both sorbents were injected into a duct prior to a baghouse at a temperature of approximately 380°F.

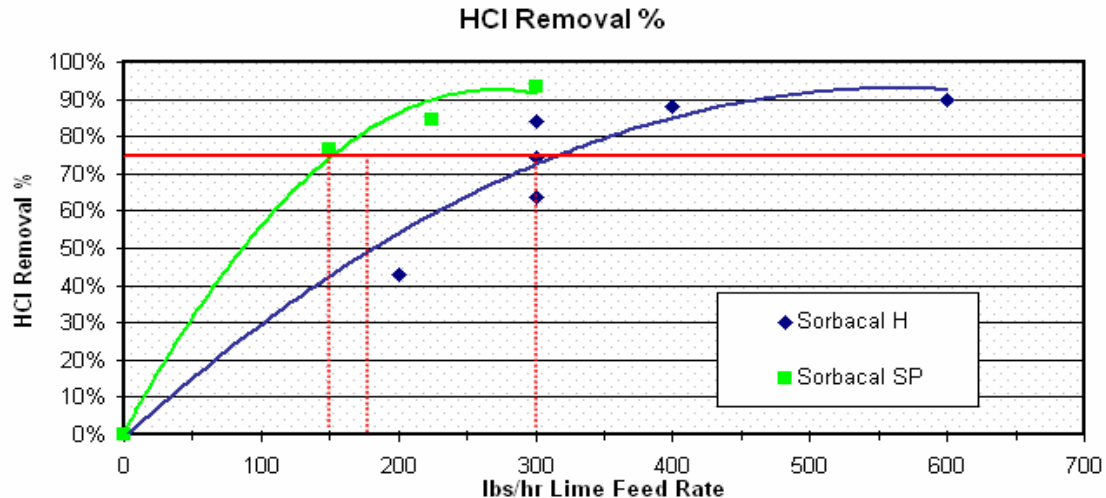


Figure 12 – HCL Removal for an Industrial Boiler

Greater than 95% HCL removal was obtained with both sorbents, however the Sorbacal®SP did so at about half the dosage rate as the Sorbacal®H. Figure 13 shows the same industrial boiler data plotted to show HCL emissions rather than the removal percentage.

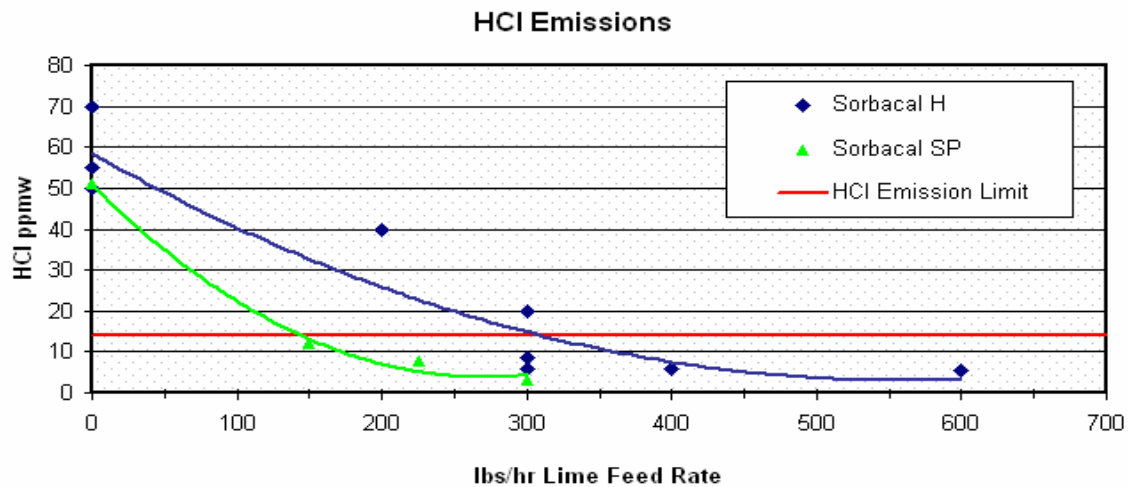


Figure 13 – HCL Emissions for an Industrial Boiler

As shown both products achieved the Industrial Boiler MATS emission level but the Sorbacal®SP had about a 50% reduction in sorbent requirements as compared to the standard hydrated lime. Such a reduction would also mean fewer trucks into a facility, less waste for disposal, and reduced impacts on downstream equipment.

Cement Plant Data

Several demonstration tests have been conducted at cement plants to evaluate the ability of hydrated lime to achieve compliance with the cement plant MACT HCL requirements. In all of these tests, DSI with hydrated

lime was shown to be effective in achieving the MACT emission limit for HCl. Figure 14 is from one of these tests and shows that both the standard hydrate product and Sorbacal®SP can reduce HCl emissions to the MACT limit, however, the Sorbacal®SP does so at a dosage rate that is about 30% less than the standard hydrated lime.

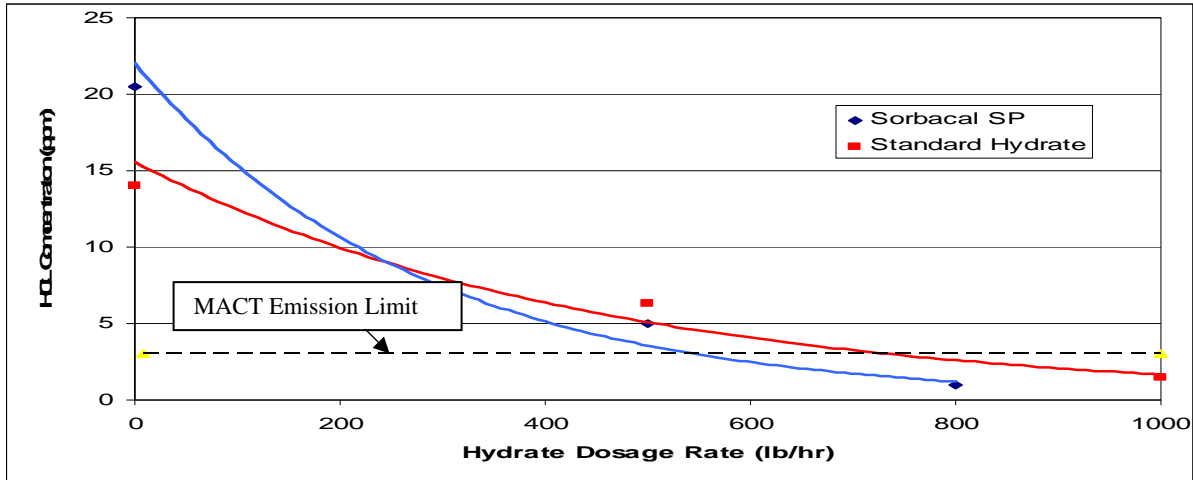


Figure 14 – HCl Emissions from Cement Plant

HF REMOVAL

Tests were performed at a glass manufacturing facility to evaluate the effectiveness of DSI with hydrated lime for reducing the emissions of HF from the flue gas. The facility was using a sodium based sorbent for SO₂ reduction, but had concerns about the HF emissions impacting their NO_x reduction catalyst. Figure 15 shows the HF emission levels achieved by the two sorbents. Both sorbents were injected at the same location with the dosage rates shown in the figure. Using Sorbacal®SP, the HF removal was greater than 98% as compared to 83% for the same rate with Soda Ash.

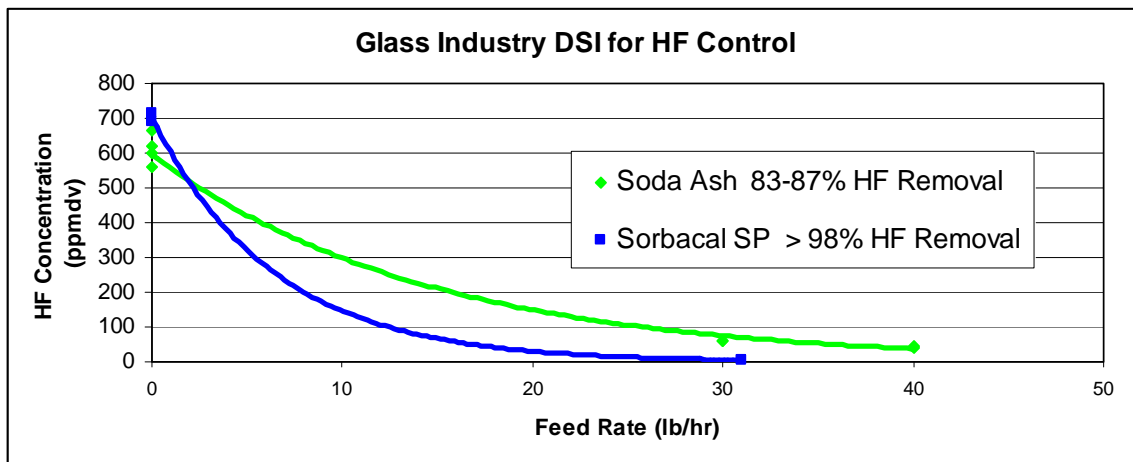


Figure 15 – Glass Plant HF Emissions

Demonstrations within other glass and brick applications have shown similar removal performance and in a number of applications Sorbacal® SP has achieved HF emission limits where sodium sorbents were not able to achieve similar results.

HF flue gas concentrations were also monitored during pilot plant tests with a coal-fired boiler. The uncontrolled HF emissions were approximately 4 ppm and as soon as hydrated lime was injected, the HF concentration decreased to less than 1 ppm and remained at that very low level throughout all of the tests.

SUMMARY

The demonstration testing results clearly show that the Sorbacal[®] products are indeed different and are more reactive with all acid gas species than other hydrated lime products produced in the United States. In all of the demonstration tests in which the performance of Sorbacal[®]SP was measured against a standard high purity hydrated lime, the Sorbacal[®]SP was shown to be at least 30% more efficient and in some cases up to 50%. This difference was seen regardless of the application or the pollutant of interest. This can be important to a potential user as the ability to achieve a given emission level by using a smaller amount of reagent would mean less truck traffic to the plant, reduced impacts on downstream particulate collection equipment, and less amount of material for disposal. All of which can have economic benefits.

A summary of the data presented for each acid gas compound follows:

1. For **SO₂** up to 99% removal was measured at an industrial plant with total sulfur emissions of nominally 1800 ppm. The hydrate/SO₂ reaction is very temperature dependant with better removals seen at higher temperatures. For coal-fired boilers, greater than 80% SO₂ removal can be expected with Sorbacal[®]SPS for furnace injection applications.
2. For **SO₃**, data collected by a 3rd party showed Sorbacal[®]SP to be at least 30% more effective than a standard hydrated lime. Both products will effectively remove SO₃, but the Sorbacal[®]SP will do so at a significantly lower dosage rate.
3. For **HCl**, data collected from various installations to include utility boilers, industrial boilers, and cement plants all show that DSI with Sorbacal[®]SP can achieve the MATS or MACT compliance levels. Depending on the emission source, a standard hydrated lime may also allow compliance with the applicable emission limit, but the use of Sorbacal[®]SP will achieve the limit at a significantly lower dosage rate.
4. For **HF**, data collected by glass and brick installations have shown greater than 98% removal of HF under relatively low feed rates. In many cases, HF limits were not able to be achieved with sodium sorbents and were replaced with Sorbacal[®] SP due to its increased effectiveness for HF control. .