

# OPTIMISING DRY SORBENT INJECTION TECHNOLOGY

**MELISSA SEWELL AND JERRY HUNT, LHOIST NORTH AMERICA, DISCUSS THE OPTIMISATION OF DRY SORBENT INJECTION TECHNOLOGY TO ACHIEVE HCL OR SO<sub>2</sub> REDUCTIONS WITHIN THE CEMENT INDUSTRY.**

## **Introduction**

The landscape of environmental regulations in the US is complex and continues to develop. It includes compliance deadlines for various hazardous air pollutants via the Portland Cement NESHAP (National Emission Standard for Hazardous Air Pollutants), NSPS (New Source Performance Standards) for new and significantly modified facilities, and site specific requirements based on consent decree agreements made with state and local environmental agencies or permit modifications that

result in increased emission reductions for a number of acid gas species (i.e. SO<sub>2</sub>, HCl, HF, SO<sub>3</sub>), as well as mercury (Hg) and particulate matter. As a result of the need to comply with these stringent emission limits, there is a growing desire for a low cost/easy-to-install solution. Dry sorbent injection (DSI) technology can offer just that; a low capital cost solution with a relatively small equipment footprint, low power consumption and easy to retrofit to a majority of existing facilities, compared to alternative technologies such as wet and dry flue gas desulfurisation (FGD).

Generally, it is advantageous to utilise calcium hydroxide (commonly known as hydrated lime) as the sorbent of choice for DSI applications for the following reasons:

- Calcium-based sorbents are also found to provide little or no impact to residual properties in regards to heavy metal leaching, and provide greater opportunities for reuse or resale.
- In cement production specifically, alternative sorbents such as sodium cannot be added in any significant quantity due to the negative effect on the finished product.
- Calcium-based sorbents do not require onsite milling as typically required by sodium-based sorbents; therefore, calcium-based sorbents offer a lower capital and operating cost solution with

a smaller equipment footprint and lower power consumption than sodium-based sorbents.

- Calcium-based sorbents do not generate  $\text{NO}_2$ , as is the case with several applications with sodium-based sorbents.  $\text{NO}_2$  has been shown to negatively impact Hg emissions and powdered activated carbon (PAC) efficacy for Hg removal, resulting in increased PAC usage.
- There are a number of hydrated lime manufacturing facilities throughout the US; therefore most customer plants are within a close geographic proximity to allow for reasonable freight costs and rapid deliveries.

Over the past few years there have been significant design improvements to DSI systems based on operating experiences, which have increased DSI

system design reliability and availability.

Concurrently there have been developments to improve the performance of DSI sorbents (i.e. enhanced hydrated lime sorbents), such that a given level of acid gas removal can be achieved at lower sorbent injection rates, or alternatively an improved performance previously unattainable by past generation of DSI sorbents can now be achieved.

Additionally, better understanding of the key factors in the effectiveness of DSI technology outside of the sorbents has resulted in significant improvements in the performance for DSI applications. This article discusses the development and application of Sorbocal® SP and Sorbocal® SPS, enhanced hydrated lime products that have been developed and engineered by Lhoist specifically for acid gas emission control

applications, and how the performance of enhanced hydrated lime sorbents coupled with optimisation in the use of DSI technology have created effective compliance solutions within the cement industry for various acid gas control requirements.

### Key factors in DSI performance and optimisation

The key factors in DSI effectiveness can be generalised into three main areas: sorbent properties, DSI system design configuration, and the site specific flue gas composition and operating conditions. All three factors together play a significant





Sorbent	Standard Hydrated Lime	Sorbocal® H	Sorbocal® SP	Sorbocal® SPS	Units
Figure					–
Typical Available $\text{Ca}(\text{OH})_2$	92 – 95	93	93	93	%
Typical Surface Area	14 – 18	> 20	~40	~40	$\text{m}^2/\text{g}$
Typical Pore Volume	~0.07	0.08	~0.20	~0.20	$\text{cm}^3/\text{g}$

Figure 1. Illustration of various hydrated lime particles and properties.

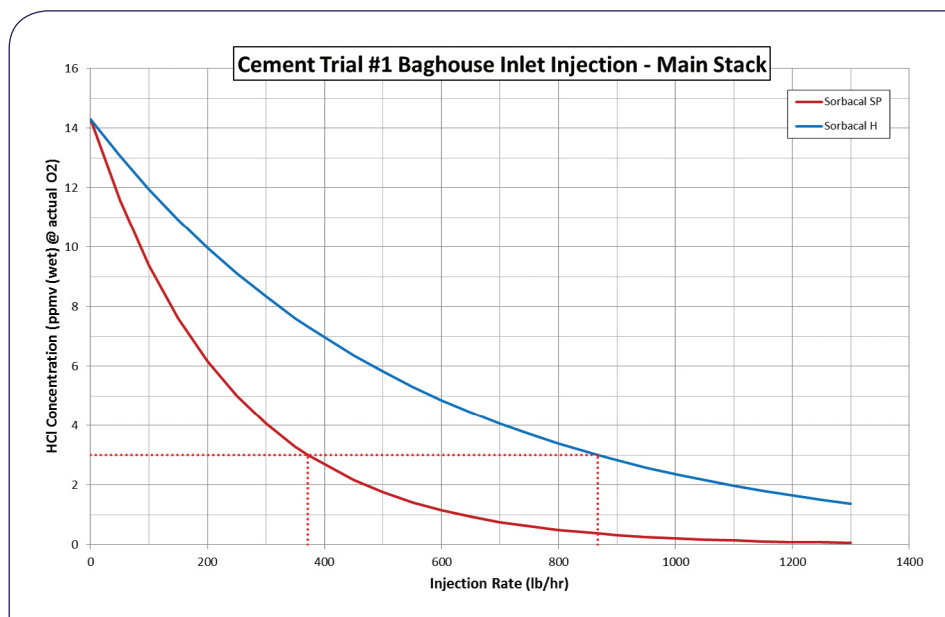


Figure 2. Comparison of standard hydrated lime versus enhanced hydrated lime sorbents.

role in optimising the performance of any DSI system and are variables that should be considered on a case-by-case basis when evaluating DSI technology.

### Sorbent properties and development

The first generation of enhanced hydrated lime sorbents (designated by Lhoist as Sorbocal® A) was developed in the 1980s by increasing the surface area to about 40 m<sup>2</sup>/g, which was twice that of a high quality hydrated lime. The high surface area combined with a small particle size gave Sorbocal® A a significant performance enhancement compared to standard hydrated lime.

During the acid removal reaction the rate is slowed down because the reaction product CaSO<sub>4</sub> forms a diffusion layer on the fresh unreacted Ca(OH)<sub>2</sub> material. More importantly, the reaction product CaSO<sub>4</sub> has a higher molar volume and thus gradually fills up the porosity of the sorbent.

Extensive research by the Lhoist group in the 1990s showed that indeed both the capture capacity and the reactivity of the sorbent scales directly with the pore volume. In contrast, the surface area was found to be contributing to a lesser extent. This research led to the development of a second generation of sorbents with both a higher pore volume >0.2 cm<sup>3</sup>/g (i.e. three times that of standard hydrated lime) and an even higher surface area >40 m<sup>2</sup>/g, which Lhoist designated as Sorbocal® SP. Laboratory scale, pilot scale and commercial scale tests have demonstrated that the reactivity of Sorbocal® SP can be up to twice that of high quality hydrated lime.

The third generation of sorbents is designated as Sorbocal® SPS and combines the exceptional pore structure properties of Sorbocal® SP with a chemical reaction enhancement obtained by surface coating. Sorbocal® SPS enables reaction rate enhancement of up to 30 to 50% over that of Sorbocal® SP. Today, Lhoist operates six Sorbocal® SP/SPS manufacturing locations in Europe, has licensed the technology to five Japanese plants and has one manufacturing location in the US, with plans for an additional two facilities to be operational in 2016. Figure 1 shows the characteristics of the different sorbents in graphical form and the main sorbent properties important in DSI applications.

One recent case study outlining the performance differences of standard hydrated lime (in this case Lhoist North America's Sorbocal® H) versus

Sorbocal® SP enhanced hydrated lime is shown in Figure 2. In this example, DSI at a cement facility was applied at the inlet to the baghouse and the graph shows the reduction of HCl using various injection rates of two hydrated lime sorbents. This DSI trial demonstrated that, for similar HCl removal performance, more than double the amount of standard hydrated lime was required compared to the enhanced hydrated lime product, Sorbocal® SP.

### DSI system configuration

Key design parameters include the sorbent distribution system and the particulate control device. DSI system operations rely on the hydrated lime particles making intimate contact with the acid gas distributed throughout the flue gas stream. If the sorbent distribution within the flue gas stream is not well balanced, some of the flue gas will not make contact

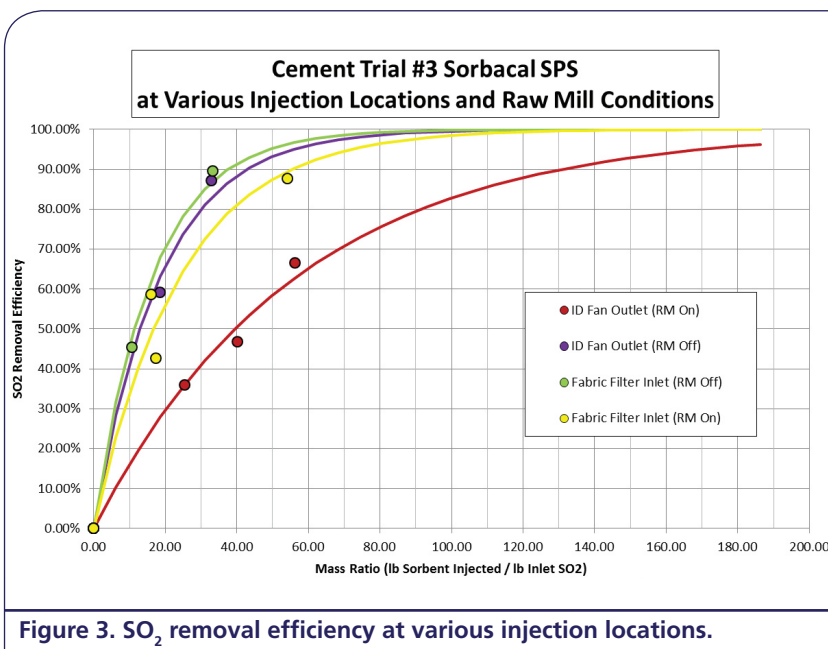


Figure 3. SO<sub>2</sub> removal efficiency at various injection locations.

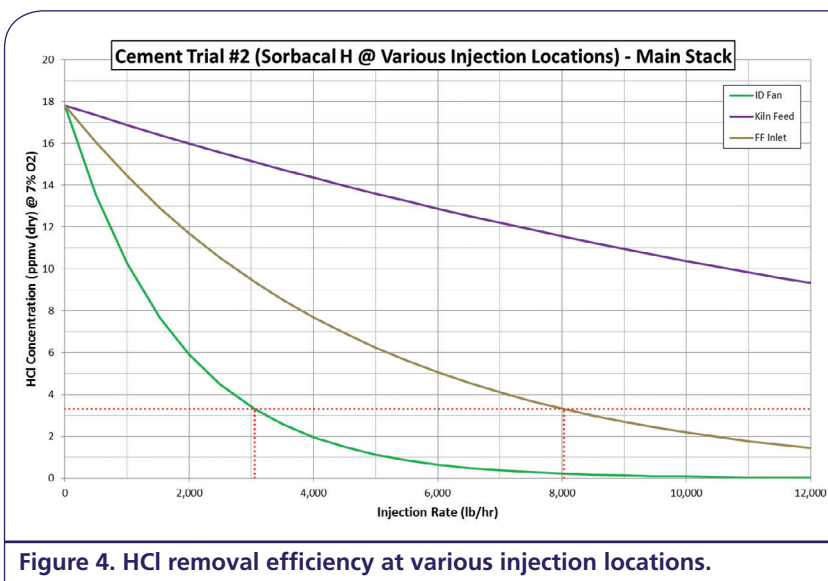


Figure 4. HCl removal efficiency at various injection locations.



with the hydrated lime, and therefore that portion of flue gas will be poorly treated or possibly untreated. Optimal injection location considerations are an important part of designing a successful DSI system; determination of the optimal location(s) may provide more opportunities for better mixing and/or may provide additional residence time leading to maximum sorbent utilisation possible. Improving the sorbent distribution through the use of a multi-injection lance grid, which is appropriately spaced across the width of the duct and at appropriate penetration depths into the duct, increased mixing using static mixers (or similar technologies), as well as increasing the residence time in a system, are all tools to improve the DSI system design to promote better removal performance. Tools such as computational fluid dynamic (CFD) modelling can also help to ensure optimisation of lance design and positioning, as well as identify any trouble areas within the flue gas path that may not be adequately mixed with the sorbent stream. In addition, baghouse particulate control devices provide added gas-solid contact over an electrostatic precipitator and therefore typically will have improved performance.

In Figure 3, a case study demonstrating the difference in SO<sub>2</sub> removal performance for two injection locations can be observed. In this trial, testing also included evaluation of the raw mill, when it was in operation and when it was down. In this specific trial, the removal performance was improved when injecting at the baghouse inlet, as compared to the ID fan outlet, which appeared counter-intuitive given the lower residence time at the baghouse inlet location. This may not always be the case, which exemplifies the importance of doing testing prior to designing and installing a permanent DSI system. In this example the performance of this injection location may be attributed to additional mixing opportunities due to some site specific process configurations as well as some reduction in particulate loading, as compared to the ID fan outlet condition.

To further illustrate the importance of upfront testing and evaluating each system on a case-by-case basis, Figure 4 shows that unlike the system configuration for the cement plant in Figure 3 the ID fan injection location was more efficient than the baghouse inlet injection location.

#### **Site specific conditions: flue gas properties and operating conditions**

The key flue gas properties of importance are the concentrations of acid gas species and moisture. Figure 3 compares the relative performance of the raw mill on versus the raw mill off. It can be seen that the raw mill off condition provided better removal than when the raw mill was on (i.e. lower mass ratio required to achieve the same SO<sub>2</sub> removal efficiency). During the raw mill off condition the flue gas is bypassed around the raw mill; therefore a lower baseline SO<sub>2</sub> concentration is observed compared to the raw mill on condition. Additionally, when the raw mill is bypassed the quench spray system upstream of the ID fans was turned on for flue gas temperature control, but also increased flue gas moisture content. Figure 3

illustrates that the higher SO<sub>2</sub> concentration and high flue gas moisture content conditions occurring when the raw mill was not operating proved to provide better sorbent performance than when the raw mill was in operation, emphasising the importance of understanding how flue gas properties and operating conditions will directly impact the overall DSI system performance. Additionally, the flue gas temperature at the point of injection is also a critical parameter in determining the effectiveness of DSI technology as the relative performance of the sorbents is directly impacted by the flue gas temperature, and not all sorbents are impacted identically.

Understanding all of the acid gas species present in the flue gas is important in that sorbents react preferentially with the varying acid gas pollutants. In general, calcium hydroxide (hydrated lime) will first capture SO<sub>3</sub>, then HCl, followed lastly by SO<sub>2</sub>. This means that when evaluating the amount of sorbent required to achieve a given acid gas control level, sorbent utilised to capture the other pollutants must be considered.

#### **Conclusion**

Lhoist North America (LNA) has conducted multiple full-scale DSI demonstrations using enhanced hydrated lime products for acid gas control within the cement industry, specifically for SO<sub>2</sub> and/or HCl control, and proved that during short-term parametric testing these products coupled with DSI technology were successful in achieving the desired acid gas abatement over a wide range of process conditions. Based on these demonstrations, LNA concludes the following;

- DSI with hydrated lime sorbents has the ability to achieve high SO<sub>2</sub> and HCl removal efficiencies and the relative performance is dependent on the flue gas properties, including temperature of the flue gas, as well as moisture and the concentration of the acid gas species.
- Enhanced hydrated lime sorbents, such as Sorbocal® SP and Sorbocal® SPS, allow for higher removal efficiencies or lower sorbent usage as compared to standard hydrated limes and are available worldwide, including in the US for upcoming regulations, such as the Portland Cement NESHAP.
- Flue gas moisture appears to be a key factor in sorbent utilisation for SO<sub>2</sub> removal and the relative impacts on performance for SO<sub>2</sub> removal should be studied further.
- Hydrated lime sorbent utilisation for acid gas removal with DSI technology can be optimised by improved sorbent-to-gas contact via in-duct static mixers and/or injection lance design.
- Due to the many differences in site-specific conditions when considering DSI technology, a short-term demonstration test is usually very beneficial in determining the optimal injection location(s), sorbent options for a given removal target, and the range of removal efficiencies that can be expected over the range of site operating conditions tested. 🌐