Lime Usage Reduction at the Delaware Valley Resource Recovery Facility

Stewart Nicholson
Primex Process Specialists, Inc.
P.O. Box 571
Doylestown, Pennsylvania 18901

John Clark
American Ref-Fuel
155 Chestnut Ridge Rd.
Montvale, New Jersey 07645

Introduction

Waste to Energy facilities in the U.S. collectively spend over $20 million per year on lime for flue gas treatment. Individually, most plants spend between $300,000 and $1 million per year on lime. This expense is often the plant’s largest for a consumable material and is expected to increase as emission limits become more stringent.

American Ref-Fuel’s Delaware Valley Resource Recovery Facility is a 3300 ton per day waste to energy plant located near Philadelphia, PA. The plant is equipped with dry scrubber type flue gas treatment technology using slaked quicklime as the primary reagent. This facility is typical of many waste to energy plants using dry scrubber systems as shown in Fig. 1.

Recent research and practical experience has shown that lime usage in dry scrubbers can be significantly reduced by optimization of flue gas treatment processes. In addition to reduced lime consumption, other financial and operational benefits may include reduced corrosion in downstream components, greater safety and system dependability.

This paper describes a theory of scrubber performance optimization and successful application of that theory to reduce lime usage and achieve other benefits at the Delaware Valley Facility.

Scrubber Performance Theory

Gas temperature in the absorber is known to have a significant effect on acid absorption and removal efficiency. This sensitivity can be modeled by assuming a relationship between acid absorption rate and drying time.

Referring to Figures 1 and 2, reagent initially enters the gas stream (at point A) as a slurry of solid calcium hydroxide particles suspended in liquid water. In waste to energy applications, gas temperature at this point is approximately equal to boiler outlet temperature, typically ranging from 450°F to 550°F.

Evaporation of the liquid water begins immediately at point A. During the dry evaporation phase (between points A and B), ion exchange through the liquid water enables the solid lime to dissolve and react rapidly with the acid gas. This rapid absorption process continues until the liquid water is fully evaporated (at point B). In waste to energy applications gas temperature at this point typically ranges from 290°F-340°F. While acid continues to be absorbed in the dry phase (between points B and C) the absorption rate is substantially diminished.

The effect of gas temperature on lime consumption is predicted by this model. Decreasing absorber gas temperature (shifting the evaporation point B to the right in Fig. 2) prolongs the rapid reaction liquid phase, thereby increasing acid absorption to greater levels (further along the dashed line). Similarly, increasing absorber gas temperature shortens the liquid phase (shifting evaporation point B left), thereby decreasing acid removal.

The effect of temperature on acid absorption (SO2 removal) discussed above and illustrated in Fig. 2 has been observed at numerous dry scrubber installations.
Scrubber Performance and Lime Slurry Reactivity

While temperature can be readily measured and controlled in dry scrubber systems, the factors affecting absorption rate are not so clearly defined or understood. However, recent experiments and results at facilities such as the Delaware Valley RRF show that a significant relationship exists between lime slurry reactivity and scrubber performance.

Lime slurry reactivity is a laboratory measurement of acid absorption rate. In most cases lime slurry reactivity can be measured directly by reaction with acid in the liquid phase. As reactivity reaches very high rates, however, more sophisticated methods are required including measurement of hydrated lime particle size, shape and porosity. Settling rate (of lime slurry solids) can also provide some useful indication of slurry reactivity.

By assuming that lime slurry reactivity measured in the laboratory reflects acid absorption rate in the scrubber, Figure 3 illustrates how a substantial absorption and efficiency gain may be realized as lime slurry reactivity is optimized. In this scenario, the more rapid absorption rate of the optimized lime slurry enables substantially more acid absorption (between points A and B) in the liquid slurry phase.

The actual scrubber performance gains observed when lime slurry reactivity is increased validate the assumption that reactivity measured in the laboratory reflects acid absorption rate in the scrubber.

Figure 3 illustrates another important possibility. The absorption curve is flatter at the evaporation point (C) therefore absorption should be less sensitive to temperature changes. From this illustration we may conclude that increasing lime slurry reactivity may not only reduce lime consumption but also enable higher operating temperatures to reduce corrosion and solids buildup.

Factors Affecting Lime Slaking and Slurry Reactivity

The technical factors affecting the lime slaking process and their effect on certain lime slurry properties have been well documented. These factors include:

- Reactant Properties
- Slaking Water Temperature
- Water to Quicklime Ratio

More recent research has shown these same factors significantly affect lime slurry reactivity.

Delaware Valley RRF Scrubber Optimization

Situation

The Delaware Valley facility is equipped with a dry scrubber system consisting of six individual trains each equipped with spray dryer absorber vessel, rotary atomizer and a fabric filter baghouse arranged as shown in Fig. 1. Quicklime is received in bulk shipments and stored in the onsite lime silo. Lime slurry is prepared by slaking quicklime in a paste type slaker as shown in Fig. 4. Slurry flowrate to each atomizer is controlled automatically to maintain the required emission limit. Absorber outlet temperature is also controlled automatically by addition of process water to the atomizer feed line.

While performance at the Delaware Valley facility was amongst the best of the American Ref-Fuel plants, historical performance suggested potential for improvement. In addition, the reagent preparation process had become less stable and was requiring increasing maintenance and operator attention.

Evaluation

A comprehensive evaluation of scrubber operation was performed at the Delaware Valley facility in February 2002. The principal findings of that evaluation were:

- Absorber outlet temperature was exceptionally low (approximately 290°F) for waste to energy systems and stable.
- The lime slaking process was unstable, with large variations in water to lime ratio, temperature and solids content.


During slaking the material reject rate was excessive with substantial amounts of partially slaked lime entrained in the reject material.

Lime slurry reactivity was substantially lower than expected for the quicklime properties and slaking technology in use.

**Evaluation Conclusions and Actions**

The evaluation report concluded that absorber outlet temperature and stability were ideal for optimum scrubber performance. As well as this aspect compared, however, the report also concluded that the reagent preparation process and lime slurry reactivity could be improved significantly. A plan was then developed and implemented consisting of the following actions:

**Initial Training** - Personnel from the maintenance and instrumentation groups and all Operations personnel were given classroom training on lime chemistry, slaking and scrubber performance optimization. The training included introduction to the plan for changes to the reagent preparation system and expected operating procedure changes.

**Continuous Performance Measurement** - A program was established to measure and report on a monthly basis the following key performance indicators:

- Lime Use (as % of MSW processed)
- Adjusted Lime Use (% of MSW processed normalized to 100 ppm SO₂ removed)
- Quicklime Available Lime Index (ASTM C25)
- Quicklime Slaking Rate (ASTM C110)
- Quicklime Particle Size Distribution
- Lime Slurry Reactivity

**Results**

The slaking process changes and improved knowledge enabled more precise control of the slaking process and reduced the batch (slaker on/off) cycle frequency from 4-6 per day to less than 1 per day.

Slurry reactivity improved substantially. As measured in bench tests, acid absorption rate of the lime slurry after implementation was approximately three time greater than before.

Lime consumption dropped substantially. In the five month period following implementation, lime consumption (as % of MSW processed) dropped approximately 22% as compared to the preceding five month period.

Reduced lime expenditure enabled the cost of implementation to be recovered in less than six months. Going forward, this performance improvement is expected to save approximately $125,000 per year at the Delaware Valley facility.

Additional benefits have been realized since implementation. The slakers can now be operated unattended for much longer time periods. The period between switchover from operating to standby slaker has been extended. The reject material (grit) volume is reduced and contains less entrained lime.

The performance measurement and training have enabled potential problems to be identified and addressed more efficiently. The quicklime and lime slurry reactivity tests have been particularly useful for assuring quicklime supplier quality and troubleshooting scrubber performance issues. These aspects should enable the cost savings to be sustained on a long term basis.

**For More Information**

For more information about lime slaking process optimization, contact Primex Process Specialists, Inc. PO Box 571, Doylestown, PA 18901. Tel (215) 340 3648 or on the web at [www.primexprocess.com](http://www.primexprocess.com)