**Unique Retrofit of Forced Oxidized Lime Wet FGD Technology**

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## INTRODUCTION

During the 1980's and 1990's approximately 16,000 MW of lime-based FGD systems were built in the United States. Most of these FGD systems used magnesium enhanced lime (MEL) technology and operated in the Ohio River Valley. With the emergence of forced oxidized technology for wet limestone FGD, this reagent became the dominant choice over the same time period.

Since the completion of the Phase I Clean Air Act FGD program, lime has been used almost exclusively in dry and semi-dry FGD systems on lower sulfur FGD systems where the high reactivity of the lime has excluded the use of limestone. As the sulfur content of the fuel increased, the differential in cost between lime and limestone (although site specific) tended to dominate the economic evaluation. When that differential is large enough and the sulfur high enough, it begins to favor limestone's lower sorbent cost. Another additional reason for the shift to limestone is because early lime-based systems did not produce quality gypsum for potential reuse and in fact, produced a sloppy, wet, thixotropic sulfite material that needed to be co-disposed of with fly ash to produce a stable disposal product. Since most of the lime-based systems utilized MEL, in-situ oxidation was not an option. The magnesium sulfite and bisulfite would be oxidized to magnesium sulfate long before the calcium sulfate, thereby losing the benefits of the soluble magnesium. These systems would need ex-situ oxidation. This is not the case with high calcium lime-based FGD, and in fact, in Germany Babcock Power's licensee built over 5,000 MW of high calcium lime-based FGD systems that produced high quality gypsum.

In 2004, PacifiCorp decided to retrofit a new FGD on their Huntington #2 plant. Huntington is a 500 MW unit firing a relatively low sulfur western bituminous coal. Unit #1 has an existing, natural oxidation lime FGD system. After evaluating a number of alternatives for Unit 2, including dry FGD and wet limestone FGD at the plant, it was decided to provide a new wet, forced oxidized lime FGD system for Unit 2. As part of the project it was decided to provide a new, common lime reagent storage and preparation facility and waste disposal facility to cover both Units 1 and 2. The old, poorly operating detention type slakers were replaced with ball mill slakers.

Other unique aspects of the overall project were to raze the existing precipitator down to its hoppers during an outage and convert it to a pulse jet baghouse. The existing acid brick chimney was converted to a wet stack allowing it to be reused for the new FGD system. Additionally, new booster fans were supplied to overcome the additional pressure drop.

Lime-based FGD systems offer several capital cost advantages over limestone as follows:

1. The reaction tank portion of the absorber vessel can be smaller than a limestone system due to the lime's higher reactivity.

2. The L/G, and the proportionate amount of horsepower required to operate the recirculation pumps, is smaller than a comparable limestone system; again due to the higher reactivity of lime.

## DESCRIPTION OF THE HUNTINGTON UNIT 2 BOILER WFGD SYSTEM

Babcock Power Environmental Inc. (BPEI) designed, fabricated, and delivered a WFGD system to Huntington Environmental Partners (HEP), a joint venture of Zachry Construction and Burns & McDonnell, for the Unit 2 boiler at the Huntington Power Station in Huntington, Utah. The Pacific Electric Operations Group, Salt Lake City, Utah, is operating the new WFGD system. Sargent & Lundy, LLC (S&L) was PacifiCorp's engineer.

In summary, BPEI supplied the WFGD absorber system downstream of the Unit 2 boiler at the Huntington Power Station. The Unit 2 WFGD system includes the absorber vessel, recycle system, absorber bleed system, a primary dewatering system (hydroclones), a mist eliminator system, oxidation air system, and an antifoam system. The absorber vessel and spray headers are constructed of 2205 alloy. The Unit 2 WFGD system also includes an auxiliary storage system for storing absorber slurry during outages. BPEI supplied a common lime preparation facility that supplies lime reagent for the new Unit 2 WFGD system and also the existing Unit 1 boiler WFGD system. HEP supplied a new Pulse-Jet Fabric Filter (PJFF) baghouse upstream of the WFGD system and the WFGD waste handling system.

The Unit 2 boiler is a balanced draft boiler producing 2.2 million pounds per hour of steam with a gross power production of 475 MW firing various low and medium sulfur coals. The flue gas path is described as follows: The boiler flue gas flows from the economizer outlet through the air heater, the new PJFF baghouse, and two ID fans. Figure 1 shows the flue gas path through the ID fans and through the new Unit 2 WFGD system to the stack. Booster fans (supplied by HEP) are installed downstream of each ID fan to increase the flue gas static pressure to overcome the WFGD system pressure loss. The two flue gas streams combine into one stream that passes through the absorber vessel and out to the single stack for Unit 2.

The Unit 2 WFGD system uses a 20% solids lime slurry reagent to remove $SO_2$ from the flue gas and maintain absorber slurry pH. The oxidation air system oxidizes the solids in the absorber slurry to calcium sulfate (gypsum). The primary dewatering system produces 45% solids gypsum slurry. HEP supplied equipment to send the gypsum slurry from the primary dewatering system to a common station waste handling system. The waste handling system combines the waste slurry streams of the Unit 2 WFGD and the existing Unit 1 WFGD. The waste slurry is combined with fly ash from the Unit 1 and 2 boilers to produce a dry solid product that is disposed in a landfill.

BPEI began delivery of the FGD components to the site in November 2005. The initial FGD startup began in November 2006, and the final acceptance test was conducted in March of 2007.

## Huntington Unit #2 Design Conditions

Table 1 presents the conditions that were used in the design of the Huntington #2 FGD system and the test results of the performance test conducted in March 2007.

| | | Design | Test Conditions |
|---|---|---|---|
| Flue Gas Flow | Acfm | 1,992,000 | 1,658,000 |
| Flue Gas Temperature | °F | 280 | 243 |
| $SO_2$ Inlet loading | lb/MM Btu<br>ppm | 1.79<br>770 | 1.20<br>632 |
| $SO_2$ Removal | % | 95.6 | 96.7 |
| $SO_2$ Outlets | lb/MM Btu<br>ppm | 0.079<br>34 | 0.039<br>21 |

Table 1 – Huntington Unit #2 Design Conditions

**Lime Vs. Limestone**

During the 1980-90's approximately 16% of the FGD applications built in the US were designed to operate on lime based sorbents. Many of these FGDs were built in the Ohio River Valley using magnesium-enhanced lime. One of the key economic factors in the selection of lime in the Ohio River Valley was that the lime could be delivered by barge to a number of plants. The other technical and economical advantages to mag-lime have been published in a number of early papers.

In Germany, approximately 10% of the utility boilers use quicklime as their sorbent. However, in the most recent series of US FGD's (post 2000), three projects have been ordered. These projects are two units at APS Cholla and one unit at PacifiCorp Huntington totaling 1,090 MW. Based on recent FGD in the US, approximately 1% are lime-based projects.

Lime based FGD's would be expected to have a significant capital cost savings over limestone systems. Table 2 presents the key design differences between the Huntington FGD system as built and compared to the same scrubber if it had been built using limestone as the sorbent.

| | Units | Lime | Limestone |
|---|---|---|---|
| Vessel height from foundation to cone | Ft | 81.5 | 107.5 |
| Reactor diameter | Ft | 57.5 | 57.5 |
| Absorber pressure drop | iwg | 2.5 | 4.7 |
| Recycle pump capacity | gpm | 29,915 | 60,500 |
| Number of recycle pumps | | 3+1 | 3+1 |
| Total recycle pump horsepower | HP | 2,800 | 6,000 |
| Sorbent feed rate | T/hr | 3.9 | 7.2 |
| Ball mill power | HP | 75 | 350 |
| Oxidation air | HP | 600 | 750 |

Table 2 – Physical Comparison of Lime and Limestone Systems

This table shows the following capital cost saving features of lime-based systems:

1. The lime-based vessel has 31% smaller surface area. This would reduce the weight of the 2205 material used in the construction by 196,000 pounds. At a cost of $6.50 per pound for 2205, the capital cost savings would be $1,275,000. Additional savings would be gained in the erection of the tower and in the foundations.
2. The lime-based recycle pumps are significantly smaller than limestone sorbent pumps. This will result in significantly lower power usage and a reduction in capital cost over a limestone system of $1,400,000.
3. The ball mills (one operating and one spare) are 84% smaller for the lime design resulting in $1,800,000 capital savings.
4. Lime based system requires less power consumption for the ID fan and oxidation air blowers. The total power consumption for a lime system compared to a limestone system is estimated to be about 20% to 30% less.
5. There are numerous other material and construction cost savings, such as smaller foundations and reductions in pipe diameter that impact the total project cost, that we have not defined in this paper.

In the case of Huntington 2 there were several factors that combined which led to the selection of forced oxidized lime FGD as the technology of choice.

First, the plant was already receiving lime for the existing Unit 1 FGD system. From a convenience standpoint it would be desirable to handle only one major reagent at the facility. Since the existing Unit 1 FGD system could not be easily and economically converted to using limestone the use of lime was favored.

Secondly, the sulfur level of fuel currently burned at Huntington and the projected sulfur level was in the low to medium range. This means that on a net present value basis it takes a higher differential cost between lime and limestone to “pay back” the additional capital investment needed to utilize the limestone reagent. The lower sulfur design fuel means that reagent cost has a smaller impact on the net present value.

Thirdly, and probably most important, was that the Huntington plant is located on a high plateau in Utah south of Salt Lake City. There is no locally available limestone source in close proximity to the Huntington plant that has been identified. Consequently, both lime and limestone must be brought a significant distance by truck up over the mountain passes to the Huntington site. Thus the transportation cost for both lime and limestone is a significant percentage of the delivered cost of reagent. The consequence ~~is~~ was that based on the costs PacifiCorp had for both reagents delivered to the Huntington site, there was an insufficient differential in cost to overcome the other advantages of lime.

We also compared a baghouse followed by wet lime forced oxidized FGD with a lime-based spray dry FGD with baghouse. The spray dry option would have required two dry modules versus the single wet absorber module. This additional equipment begins to erode the dry system's capital advantage. This, along with PacifiCorp's experience in mercury collection with a baghouse followed by wet FGD, favored the wet FGD selection.

**PERFORMANCE**

Flue gas was first passed through the FGD system in November 2006. Summaries of the performance test results are presented in Table 3. Sargent & Lundy reported that BPEI met all of the performance requirements during the March 2007 performance test. The plant at times burns a lower sulfur coal than the FGD system was designed for, and at these times they operate only two recycle pumps to meet their emission limits.

## REFERENCES

DePriest, William and Rajendra P. Gaikwad. “Economics of Lime and Limestone for Control of Sulfur Dioxide. May 2003 Megasymposium.

Hartenstein, Hans, Horst Rhein, and Hermann Brüggendick, “Cost Development of Single Absorber Open Spray Tower Limestone Forced Oxidation FGDs During The Last 20 Years”. STEAG’s Experience Mega Symposium. August 28-31, 2006.

“Wet Flue Gas Desulfurization Technology Evaluation”, Project Number 11311-000. Sargent & Lundy. Prepared For National Lime Association January 2003.

Figure 3 -- Huntington Unit 2 WFGD System

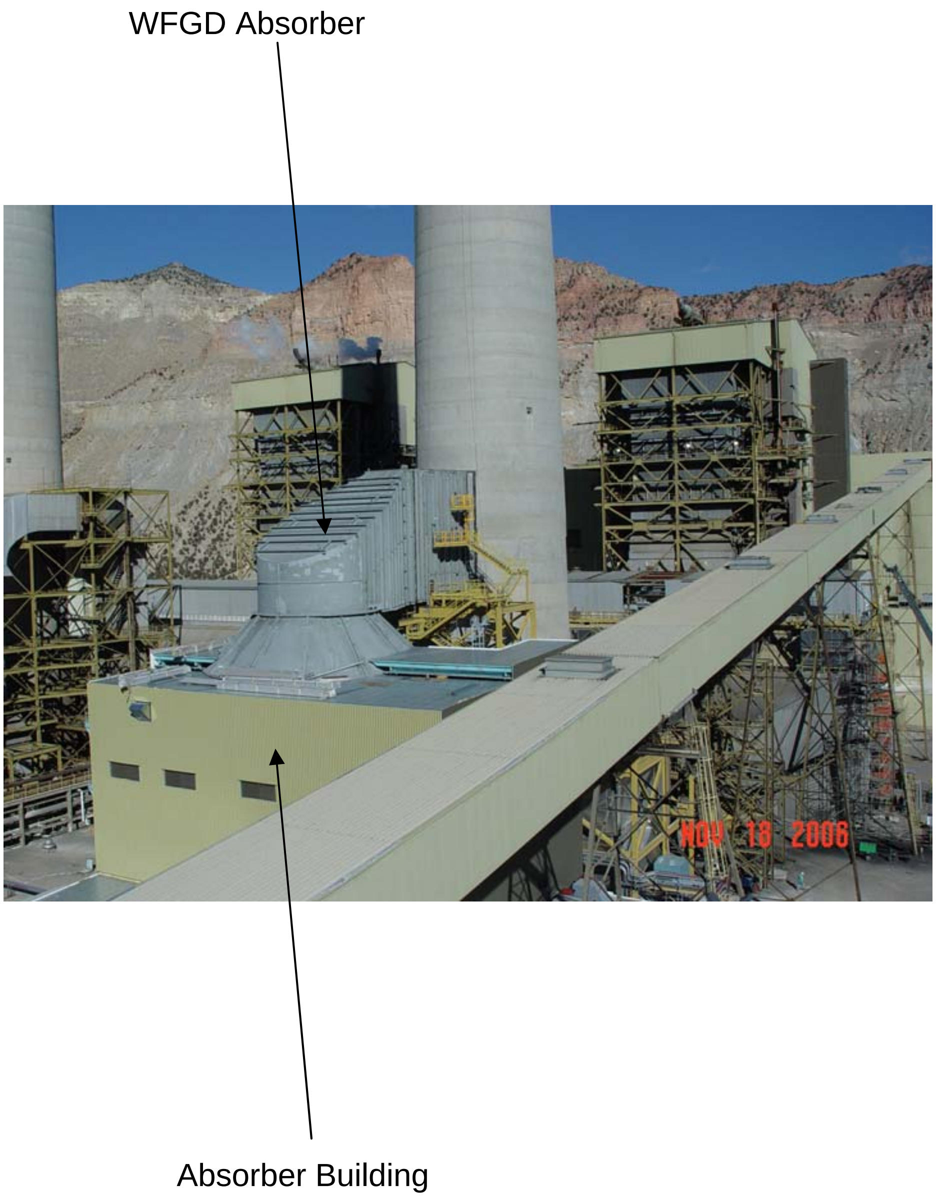

Figure 4 – Huntington FGD System Model