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Dynamic Control of DSI for SO$_3$ Management

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Robert Branning and Phil Reeves, Breen Energy Solution, 104 Broadway Street, Carnegie, PA 15106

Brian Moore and Matt Blankner, OUC, Stanton Energy Center, 5100 S Alafaya Trail, Orlando, FL 32831

ABSTRACT

The combination of condensable and filterable particulate into a single reporting category has changed the way dry sorbent is applied to sulfuric acid mist mitigation. It is increasingly important to understand the dynamic location of the sulfuric acid concentration and only apply sufficient dry sorbent in response to that need. During the fall of 2011 a Stanton Energy Center explored the effects and alternatives of moving from its historical, low sulfur, compliance coal to a potential 100% reliance on Illinois Basin coal. Data was taken on both concentration and species of various sulfate based condensable compounds from the SCR outlet through the ESP outlet on both ducts as the coal blend migrated. This paper will present the results from that 3-month program, detailing observed balance of plant effects, stratification effects and the hydrate usage impacts of dynamic control.

INTRODUCTION

Orlando Utilities’ Stanton 2 is a nominal 465 MW, opposed fired unit built by B&W and commissioned in 1996. The unit is equipped with an SCR for NOx control, a cold side ESP for particulate control and a wet FGD for SO2 control.

At the start of the project Stanton 2 was burning a compliance level coal in the range of 1.5 Lb/mmBTU SO2. Annual capacity factor for Stanton 2 was 81.7%.

With emissions control systems in place, Stanton generating station was looking to lower its fuel cost by burning higher sulfur, higher iron Illinois Basic coal. Since higher sulfur/iron coal leads to higher SO2, higher SO3 and potentially lower fusion temperature compounds in the flue gas, it is important for the plant to understand the effects of the higher sulfur coal and how to mitigate those effects.

In summary the project consisted of the following functional items:
1. Development of a profile of baseline condensable species/concentration present during combustion of low sulfur compliance coal. Locations to be examined include:
   a. Air Heater Inlet A & B duct
   b. ESP Inlet A, B, C and D duct

2. Sample the ducts at each location to find the location of the highest SO3 concentration

3. Install a temporary hydrated lime injection (DSI) system with sufficient capacity and injection location flexibility to mitigate the effects of the proposed higher sulfur coal combustion. As a minimum the system will be capable of injecting sorbent at the air heater inlet and ESP inlet locations separately or in parallel.

4. With the DSI system in place, begin test burns of higher sulfur coal in the following pattern:
   a. 2 weeks at 25% ILB coal
   b. 4 weeks at 50% ILB coal (2 weeks each using different coal sources)
   c. 2 weeks at 75% ILB coal

5. At each fuel blend, determine the condensable profile, species/concentration at each of the functional test points without hydrated lime injection

6. At each fuel blend explore the relative effectiveness of varying lime injection rates between the two injection locations to achieve a moving average of 5-10 ppm SO3 vapor at the ESP Outlet

This paper will cover focus on the variability of acid presence between the ducts, the effects of varying lime injection rates between the ducts and the effects of varying lime injection rates between Air Heater Inlet and Outlet locations.

**Baseline Unit Characterization**

Beginning in mid-August 2011, Breen AbSensor Condensable Monitoring instruments were placed in multiple locations within the Unit 2 flue gas duct. These instruments were intentionally placed in service ahead of the sorbent injection program to develop a baseline of data representative on acid/ABS levels at variable load and fuel conditions consistent with normal plant operating practices.

The first section below is intended to provide a background in the operation of the instrument and the terminology that will be used throughout the balance of the report

**Condensable Probe Background**

Breen Energy Solutions (BES) has developed and commercialized an instrument capable of detecting process parameters associated with vapor condensable in utility flue gas
streams. The term condensable applies to any of the H$_2$O/SO$_3$ derived vapors present in the flue gas stream between the economizer outlet and the inlet to a wet scrubber. These vapors include water, sulfuric acid, ammonium bisulfate, and sodium bisulfate predominantly.

The instrument consists of a 2 meter long probe with a sensor tip for condensation detection on one end. The sensor tip has a glass surface with a thermocouple and a circular electrode embedded in the center. Compressed air is directed from the flanged end of the probe through an internal tube to cool the sensor tip in a controlled manner. A picture of the probe is shown in Figure 4-1.

![Figure 01 Breen Condensable Probe](image)

In operation, the instrument varies the temperature of the sensor tip by varying the cooling-air flow to the probe. Three different temperatures are determined: the formation, evaporation and dew point temperatures. This is illustrated in Figure 3-2, where the yellow line represents the cooling-air flow rate, the pink line represents the probe temperature and the blue line represents the probe current. The hot probe is precisely cooled until a condensation current is detected. This is defined as the formation temperature. During this time, the condensation is greater than the evaporation. After the condensation current is detected, the probe is allowed to heat until the current goes below a predetermined threshold. This is defined as the evaporation temperature. During the approach to the evaporation temperature, the evaporation is greater than the condensation. The point at which the condensation and evaporation are equal is defined as the equilibrium dew point, or dew point temperature.
At temperatures below 310°F, the dewpoint can be directly correlated with SO$_3$ concentrations using long standing, industry accepted calculations.

Numerous comparisons have been conducted plotting traditional controlled condensate measurements with acid vapor measurements taken with the Breen Instrument. At temperatures consistent with the outlet of the ESP, average differentials between the methods are less than 1 ppm. It has been argued in scientific conferences that the human inconsistencies in CCM testing often exceed that level.

During installation of the demonstration feed system, the probes will be re-located to mutually agreed locations to best identify the results derived from the test protocol.

**Figure 32** Representative Operating Curve for the Breen AbSensor

**Findings of Baseline Testing**

The following graph shows the baseline condensable conditions at the AH Inlet as measured prior to the outage in August/September 2011.
Items of note include:

1. Probe data at the SCR Outlet/AH Inlet location revealed condensable formation temperatures in the acid temperature range with very few exceptions,
2. However, evaporation temperatures which initially showed ammonia influence only at higher loads began to display this influence at all loads beginning around August 20,
3. Data from this period suggests AH Inlet SO3 value in the 10 - 18 ppm range at full load. Considering our understanding of SO2 levels in the 600 ppm range, this would suggest combined SO2:SO3 conversion rates in the 1.7 – 2.5 range, with the higher conversion rates following the higher gas temperatures.

The following graph shows the baseline measurement data of condensable material at the ESP Inlet location (B Duct):

Items of note include:
1. A visual inspection of the data suggests that the typical SO3 passing the air heater at full load and AH Out temperature below the ABS freezing point is in the 7 – 10 ppm range.

With AH Inlet values of 10 – 18 ppm and AH Outlet values of 7 – 10, it would appear that the AH transition is removing roughly 30% of the free acid vapor from the flue gas. This material is likely ending up as condensate on the fly ash since air heater differential pressure has never been a material problem.

**ESP Inlet Variability**

Stanton Unit 2 employs a single, large, rotary air heater with twin exit ducts. Each duct is then split into two ducts providing material to four ESP boxes for particulate removal. A single line drawing of the equipment layout is below:
Since condensable material leaving the air heater tends to follow gas temperature, an initial investigation was made between the A and B ducts. These two ducts are on the hotter part of the AH rotation. Initial analysis revealed that the B duct showed higher levels of sulfuric acid vapor and was selected for initial data collection.
Following the baseline characterization work documented above, an additional instrument was brought to site and moved between the other three ESP inlet ducts. The comparative data is shown below:

The red trace is the data from the original “B” duct probe. The blue highlighted section shows a comparison between the “hot” side AH ducts “A” & “B” with “B” still exhibiting higher condensable values.

The mobile probe was then moved to the two “cold” side AH ducts with “D” exhibiting almost no condensable levels and “C” showing levels lower than “B” and roughly similar to “A”. It should be understood by the reader that the data shown at the beginning of the tan highlighted section reflects zero lime feed. As can be seen, the untreated acid level in the “B” duct is seriously higher than the “C” duct. All data shown after that spike, starting at roughly 11/4/2011 reflects lime injection on the “hot” side AH Outlet duct only.

With the on-line measurement system in place, and a target of maintaining 5-10 ppm at the ESP inlet, no further treatment was required on the “cold” side. Had there been a change in plant conditions, treatment of the “cold” side could have been started within minutes.

**Lime Injection Location Variability**

**Total Injection Data by Fuel Blend**

Referring to the single line diagram above, eight injection lances were located at each functional location (1N, 1S, 2N, 2S).
The following charts present the lime injection rates (total for all locations) on a daily basis:

**Stanton 2 Demonstration Lime Feed Rate, 25% ILB**

**Stanton 2 Demonstration Lime Feed Rate, 50% ILB**
Lime feed rate was controlled manually until the week of December 5th when a basic control algorithm with sensor feedback was placed in service. In general, lime feed rate was controlled to a level supporting an average of 7-10 ppm sulfuric acid vapor at the ESP Outlet.

At various times during the demonstration the lime feed rate was held intentionally low to allow manual measurement of acid concentration levels using wet chemistry methods.

Visual analysis of the above data suggests the following average feed rates for each of the fuel blend periods:

<table>
<thead>
<tr>
<th>IBC Blend</th>
<th>Average SO2 (ppm)</th>
<th>Average Lime Feed (Lbs/Hr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% blend</td>
<td>1000</td>
<td>400</td>
</tr>
<tr>
<td>50% blend</td>
<td>1250</td>
<td>900</td>
</tr>
<tr>
<td>75% - 100% blend</td>
<td>1600</td>
<td>1300</td>
</tr>
</tbody>
</table>

The following graphs provide some better insight into the relationship between lime feed rate and ESP Inlet SO3 vapor:
Items of note include:

- This graph plots lime feed and ESP Inlet SO3 vapor against an event number sorted by SO2 value. This approach is different from Lime Feed vs. SO3 in that it also gives some information on the amount of time during the project that the variables were at each value.
- If we break the chart into three sections, a) less than 1200 ppm SO2, b) more than 1200 ppm and less than 1400 ppm, and c: more than 1400 ppm we can arrive at the following information:
  - 0-1200 ppm, the lime feed follows the SO2 slope and ranges from 200 Lbs/Hr. at the low end to 600 pounds/hr. at the high end,
  - 1200 – 1400 ppm, again the lime feed tracks the lower SO2 slope moving from 600 Lbs/HR. at the low end to 800 Lbs./HR. at the high end. There are some peaks, however that touch up to 1000 Lbs/HR.,
  - 1400 ppm and up, the lime feed is nearly steady at 1400 Lbs./HR.
- The dashed black line is a linear trendline suggesting a very simple injection curve excluding the high feed test shown at the right hand side of the graphs.
- Tracking the ESP Inlet SO3 vs. Lime Feed and SO2,
  - 0-1200 ppm, the applied lime feed kept the ESP Inlet SO3 value to below 8 ppm,
  - 1200 – 1400 ppm, the applied lime feed was insufficient to keep the SO3 level below 10 ppm, with several peaks nearer to 14 ppm.
  - Greater than 1400 ppm, the applied lime feed was again sufficient to keep the SO3 level below 10 ppm.
  - In conclusion it seems that ESP inlet SO3 can be effectively kept below 10 ppm but that the injection rates for the middle SO2 levels needs to be higher.
Lime Feed variations vs. Location/SO2

The four graphs below represent Observation Plots for the Lime Feed vs. ESP Inlet SO3 data comparing injection location (SCR Outlet vs AH Outlet). The green traces are lime feed rate required to maintain the ESP Inlet SO3 at the value shown by the red trace. Dashed lines reflect lime injection at the AH Outlet location where solid lines reflect lime injection at the SCR Outlet location.
Items of note include:

- Be aware that the data from Injection Location 2 (AH Out) represents almost 3.5 times as many events as the data from Injection Location 1 (SCR Out).
- Visual analysis of the data by SO2 partition suggests the following:
  - Lime Injection at the SCR Outlet maintained the ESP Inlet SO3 at less than 10 ppm over the entire range of fuels and SO2 values,
  - Lime injection at the Air Heater Outlet was expected to provide better SO3 capture efficiency. In other words, less lime would be required to maintain a constant SO3 value at the ESP Inlet location. In fact, the data suggests that lime efficiency vs. location is a function of acid concentration:
    - At low levels of SO2, lime efficiency is maximized by injection at the AH Outlet location,
    - At medium levels of SO2 lime efficiency is slightly improved by injecting at the AH Inlet location
    - At high levels of SO2 lime efficiency is dramatically maximized by injection at the AH Inlet location
- The data presented reflects the middle 70% of the total data, removing the top and bottom 15%. Analysis of the edge data for the high sulfur period shows that minimal lime injection (0 – 500 Lbs./Hr.) resulted in SO3 levels that could result in blue plume generation (> 10 ppm). Additionally, higher levels of injection (> 1000 Lbs./Hr.) showed that acid levels could be controlled to safe concentrations for blue plume avoidance (< 5 ppm at the ESP Inlet).

**Conclusions and Further Work**

The work conducted at Orlando Utilities/Stanton Energy Center Unit 2 represents excellent foresight and planning on the part of plant engineering and management. Sufficient time was allowed at each fuel blend change to explore the impacts of acid distribution and hydrated lime injection variations. The results suggest the following:

1. It is well accepted that acid stratification exists following the air heater. Dry sorbent injection systems are often designed to reflect the natural acid level imbalances. However, most DSI control systems do not allow for dynamic changes in side-to-side injection rates. While executed manually here, it is clear that matching the “hot” side and “cold” side injection rates can achieve a significant reduction in total sorbent usage without negative effect on acid emissions.

2. It is general industry wisdom that hydrated lime injection ahead of the air heater will require more sorbent per pound of acid captured than injection post air heater. However, the work conducted at Stanton strongly suggests that the level of lime utilization efficiency may be related to acid concentration levels and that injection ahead of the air heater, in the presence of high acid concentration, may be preferable. Further testing will be conducted to confirm these findings.

Further work, as follow-up to these findings, would focus on automatic adjustment of hydrate feed rate between ducts and between pre and post AH locations. Of significant interest is the pre and post AH work since effective splitting of the two lime feeds could have significant impact on:

- Lime Usage Rate
- Mercury Capture improvement through reduced flue gas SO3 competition
- Dry capture of HCl and reduction in scrubber water chloride levels.
This work could not have been possible without the total support of Stanton plant management, Breen field operations staff (24/7 system operators) and Lhoist North America. Our appreciation is extended to all of them for a very interesting and successful project.