The Evaluation of "SO_3" Measurement technologies and their applicability for their use in the control of hydrated lime injection feed rates.

Paper # 102 Presented at the Power Plant Pollution Control and Carbon Management "MEGA" Symposium

August 16-19, 2016

Baltimore, MD

Authors: Haley Turner[1], Daniel T. Menniti[2]; [1]LG&E & KU, Trimble County Generating Station, KY, [2]Breen Energy Solutions, Carnegie, PA

ABSTRACT

In the Hydrated Lime injection process, the measurement of "SO_3" is a key parameter to quantify to allow the plant operations to control the Hydrate injection rate. Breen Energy participated with LGE-KU and an independent third party to evaluate the available "SO_3"measurement technologies and determine their applicability for the control of the lime injection feed rates. The project established both baseline operating conditions, as well as multiple parametric changes to understand the impact of such changes on the measurement device repeatability, relative accuracy and operation and maintenance. This testing was performed by LGE-KU and independent third party, project management and flue gas testing companies. The following presentation outlines the project scope and results of the measurement technology evaluation and real life data sets showing the application for of such technologies.

INTRODUCTION

Within multiple industries, there are fossil fuel fired boilers and process heaters that are used for power and steam generation, as well as process heating. Within these generating units there are multiple process locations where the level SO_3 and flue gas dewpoint is of interest. Specifically the interest falls under the following categories:

1. In units with SCR and SNCR NOx reduction, Ammonia combines with the free SO_3 and water to form ammonium Bi-sulfate (AbS). Knowing the Condensables formation temperature allows the operator to control or mitigate the levels of AbS formation to avoid deposition on Air Heater Tubes and Baskets, where it can cause plugging.

2. Both AbS and Sulfuric acid have corrosive characteristics. By knowing the SO_3 levels and acid dew point temperatures the operator can control or mitigate it to levels below the cold end metal temperatures, thus avoiding cold end corrosion of the downstream metal work.

3. In processes with a Wet Flue Gas Desulfurization, Sulfuric Acid Mist ("SO_3") levels above >5ppm have been known to form "blue plumes". There are well know algorithms to covert Sulfuric Acid Dewpoint Temperature to SO_3 or H_2SO_4 ppm, thus allowing for the control and mitigation of the plume acid levels to <5ppm.

In this particular application the terminology for the sulfuric acid vapor concentration in the flue gas is typically referred to as "SO_3", which will be used throughout the paper.

BACKGROUND

The SO_3 Analyzer Testing was performed on Trimble County 2. Trimble County 2 is an 810 MW Supercritical generating Unit burning a blend of Eastern Bituminous coal and Powder River Basin Coal (PRB). The plant has downstream AQCS Equipment; Selective Catalytic Reduction (SCR), a Dry Electrostatic Precipitator (DESP), Pulse Jet Fabric Filter (PJFF), Wet Flue Gas Desulfurization (WFGD) and a Wet Electrostatic Precipitator (WESP). In addition to the OEM supplied AQCS, Trimble County 2 has installed Dry Sorbent Injection Systems (DSI) injecting Hydrated Lime at the air heater inlets and outlets.

Figure 1 – Trimble County 2 AQCS and HLIS

The Hydrated Lime Injection System (HLIS) serves three purposes;

1. The Mitigation of Ammonium Bi-sulfate (AbS) upstream of the Air pre-heater to reduce the levels of AbS formation temperatures and the potential for Air heater fouling.

2. The mitigation of SO_3/H_2SO_4 downstream of the air pre-heater to reduce these sulfur based species prior to their Activated Carbon Injection (ACI), enhancing the capture of mercury by the Powder Activated Carbon (PAC).

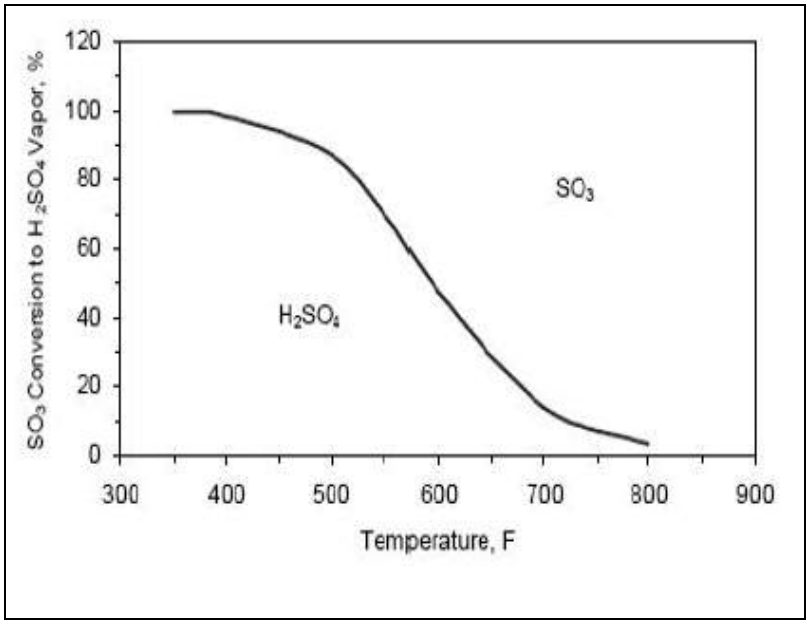
3. The mitigation of SO_3/H_2SO_4 downstream of the air pre-heater to minimize the effects of sulfuric acid mist on the visible emissions ("blue plume").

In order to minimize the use of hydrated lime, while maintaining sufficient reduction in SO_3, LGE-KU set out to compare commercially available SO_3 analyzers and finalize a decision to procure them for fleet wide use.

Process Background

In the Combustion process the SO_3 first appears in gaseous form. As the flue gas temperatures decrease throughout the process, the SO_3 combines with water and form sulfuric acid vapor. At a location downstream of the air pre-heater the flue gas temperatures are at a level where 99% of the free SO_3 combines with flue gas moisture(above 5% H_2O) to form sulfuric acid vapor, represented chemically by $SO_3 + H_2O \longleftrightarrow H_2SO_4$ and graphically by Figure 2.

Figure 2 – SO_3 conversion to H_2SO_4 vapor Vs. Flue Gas Temperature ^oF



The Fuel that was burned during this evaluation was a blend of Eastern Bituminous and PRB coals as seen in the fuel analysis below.

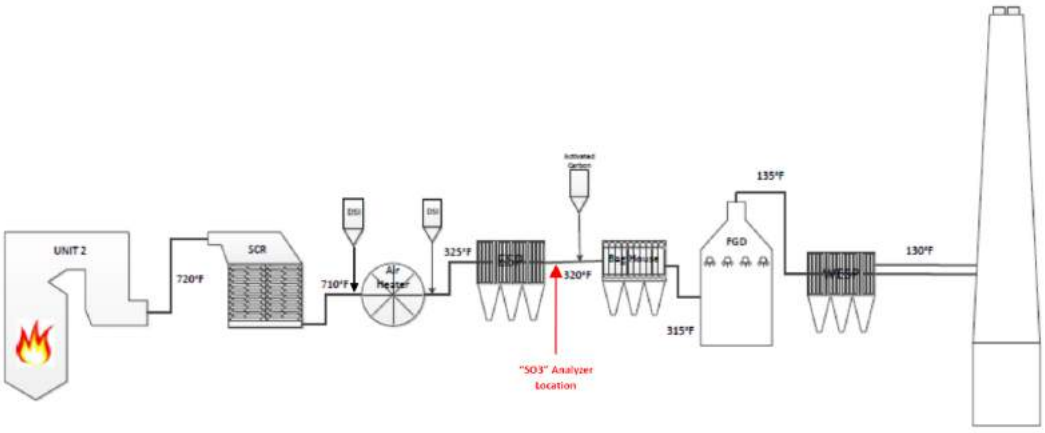
Figure 3 – Trimble County 2 as received fuel analysis

Typical As Received Coal Proximate and Ultimate Analysis

Coal	70% Ebit 30% PRB
Proximate Analysis	
Moisture	13.75
Ash	8.37
Volatiles	38.08
Fixed Carbon	41.80
Total	100.00
Btu/lb	11,163
Ultimate Analysis	
Moisture	13.75
Carbon	61.81
Hydrogen	4.33
Nitrogen	1.13
Sulfur	2.35
Ash	8.37
Oxygen (by diff)	8.26
Total	100.00

Based on the fuel analysis, and using typical conversion rates from economizer outlet and through the SCR the resultant SO_3 levels were expected to be in a range between 1-58ppm at the air heater outlet, dependent of horizontal duct location, load, SCR inlet temperatures and HLIS feed rates. In order to achieve the results outlined in the background Trimble County has installed a two HLIS, one at the air heater inlets and one at the air heater outlets.

Figure 4 – Trimble County 2 – DSI Locations and SO_3 Analyzer Locations



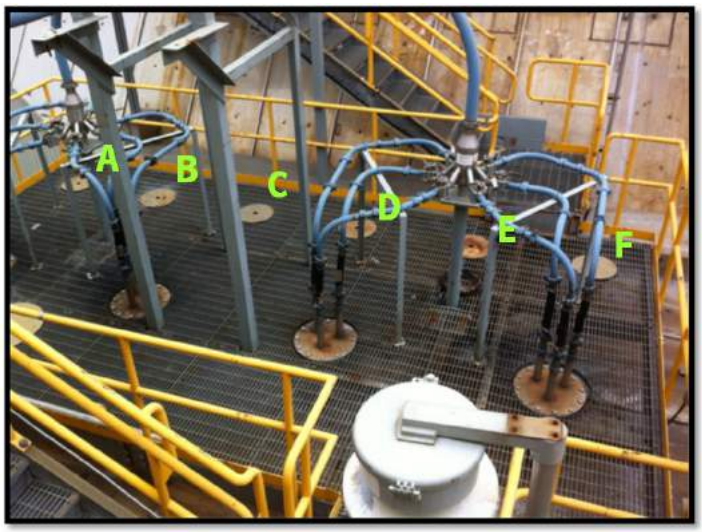
Testing Program

There were three phases of testing performed at Trimble County. The First two phases involved three vendors and the third phase involved a standalone test for a fourth vendor. The SO_3 analyzers were installed downstream of the DESP and upstream of the ACI system.

Figure 5 – ACI Injection Inlet – Analyzer Test Ports

The individual analyzer technologies were installed in alternating ports with a US EPA Method 8A(CTM-013) port available next to each technology.

Figure 6 – Port Locations for testing



A – Vendor A
B – Method 8A
C – Vendor B
D –BREEN
E – Method 8A

For the third phase, the fourth vendor technology was installed in Port E and the RM8A was performed in Port D.

Figure 7 – Port Locations for Fourth Vendor and RM8A

During the first week of testing all vendors were provided with the opportunity to compare their system outputs against the RM8A testing results with the opportunity to make any field adjustments to ensure proper commissioning of their systems in the application.

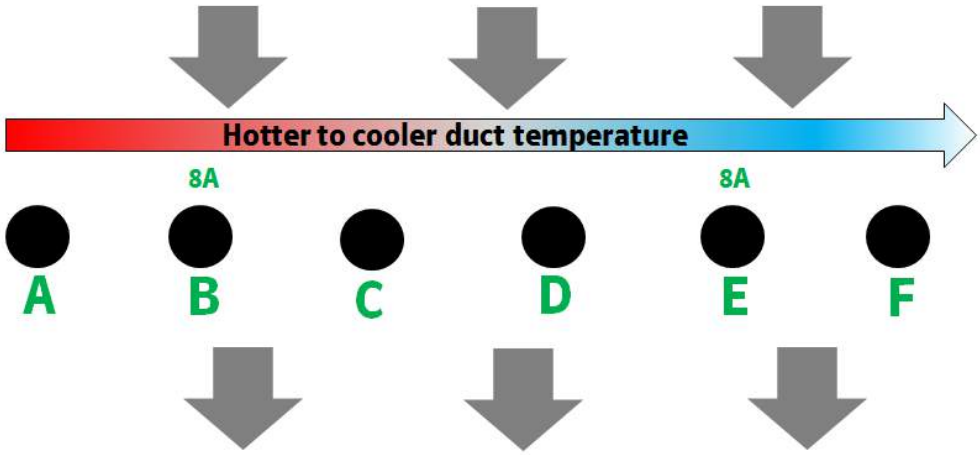
During the second week of testing, all analyzers were to run unattended while the plant varied HLIS feed rates, Load conditions and DESP operation (particulate loading). Subsequently the fourth vendor was allowed the same opportunity during their test week.

RESULTS & DISCUSSION

Prior to the results discussion it is important to note that at the air heater outlet location of there is a well known variation of SO_3 concentrations across the duct which follows the temperature profile of the flue gas. This is caused by the rotation of the regenerative air heater. In Summary effects of the rotation of the air heater results in higher SO_3 concentrations on the hotter side of the duct and lower concentrations on the colder side of the duct.

This phenomenon is explained in Appendix A.

Figure 8 – Air heater outlet temperature profile relative to test ports



The air heater rotational effects were confirmed via RM8A and Breen AbSensor© testing during week one.

Figure 9 – SO3 Measurements across the air heater inlet

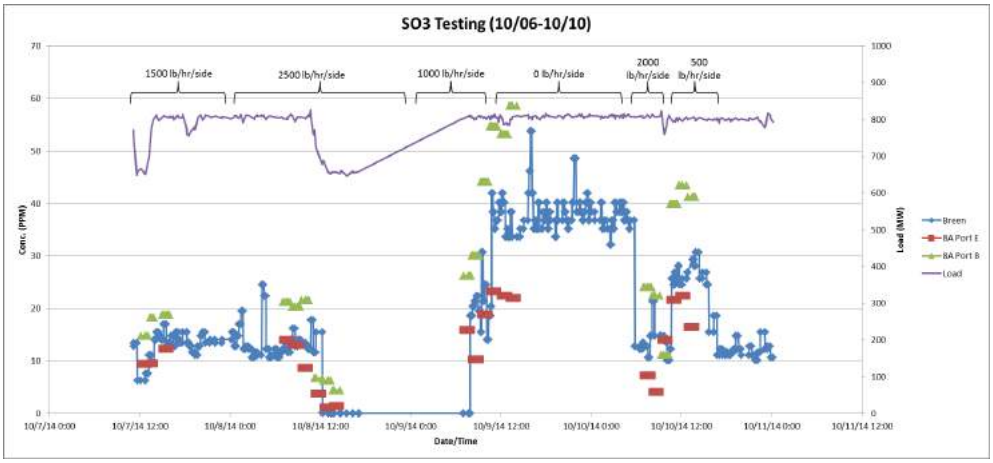


Figure 9 shows the RM8A in the hot port (port B) with the highest levels of SO3, the Breen AbSensor© results (Port D) were the mid level concentrations and the RM8A results from the coldest test port (Port E) RM8A showed the lowest measured concentrations

For consistency, the data compared during the testing was done at full load. Throughout the all test periods Analyzers A, B and C showed little, if any response to the process changes introduced (HLIS feed rate variations, particulate level changes).

Figure 11- Analyzer A response to HLIS feed rate changes

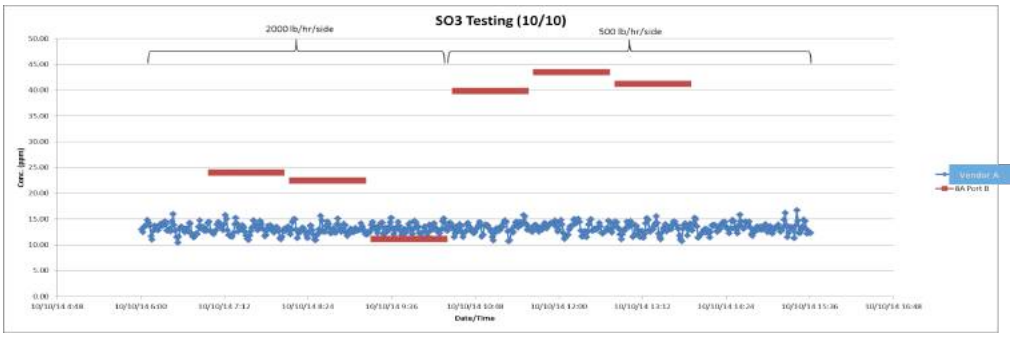
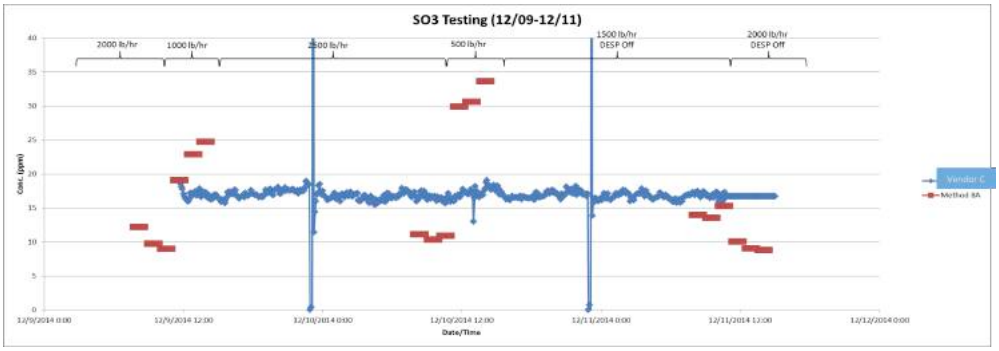


Figure 11 shows the response to process changes by the RM8A in Port B, while the SO3 measurement in Port A showed no response.

Similarly, Figure 12 below shows the same from the analyzer installed in Port A, during the last week of testing.

Figure 12 - Analyzer C response to HLIS feed rate changes



During the entire test period, The Breen AbSensor© exhibited response to the changes in the process SO_3 concentration comparable to the RM8A test results as seen in Figures 12 and 13 below.

Figure 12 – Breen AbSensor© SO_3 measurement compared to RM8A

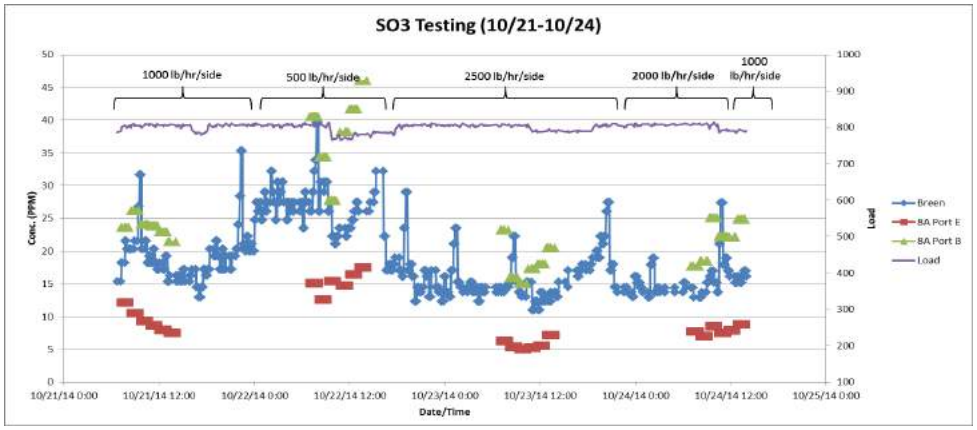
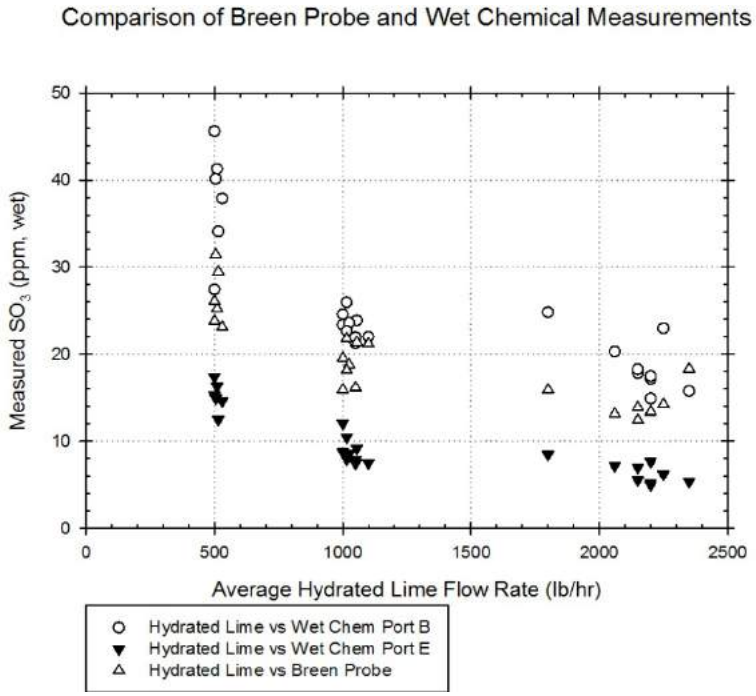


Figure 13 – Comparison of Breen probe and Wet Chemistry methods



SUMMARY

Four SO3 analyzers were installed and monitored by Trimble County and an independent project management party. During the testing period all analyzer results were compared to the USEPA Reference Method 8A (CTM-013). Taking into consideration the rotational effects of the air heater, the Breen AbSensor© had the expected relative response comparable to the results of the RM8A testing. These positive results indicated the technology's applicability as an SO_3 analyzer for the control and optimization of HLIS feed rates. Subsequently, over 30 analyzers were installed in the LGE-KU fleet for the measurement of SO_3 and Ammonium bi-sulfate formation temperatures.

As a note, we are told that some of the other vendors are continuing to pursue the development of their technology for the measurement of SO_3 in combustion flue gas.

REFERENCES

SO_3 CEMS and Monitor Testing; Turner, Haley, LGE-KU Trimble County, Dry Hydrate Users Group 2015.

USEPA, METHOD 8A - DETERMINATION OF SULFURIC ACID VAPOR OR MIST AND SULFUR DIOXIDE EMISSIONS FROM KRAFT RECOVERY FURNACES, https://www3.epa.gov/ttnemc01/ctm/ctm-013.pdf

THE LATEST AVAILABLE TECHNOLOGY FOR THE MEASUREMENT OF SULFURIC ACID DEWPOINT AND OTHER CONDENSABLE GASES, IN THE COMBUSTION PROCESS STREAM, Menniti, Daniel T. ISA Analysis Division Program, April 24-28, 2016

Development of Hydrated Lime DSI at LG & E – Trimble County: Turner, Haley, LGE-KU Trimble County, Dry Hydrate Users Group 2016.

APPENDIX A

The Effects of a Rotating Air Pre-Heater (APH) on the Downstream Acid Concentrations

When an air heater first rotates into the gas stream, the basket material is at its coldest. As a result, acid will condense on the baskets and onto the ash passing through the baskets resulting in less free acid on this (cold) side of the outlet duct (AcidIN > AcidOUT).

As the air heater continues to rotate, the basket material will eventually heat to a point where acid no longer condenses and it passes straight through the air heater (AcidIN = AcidOUT). Continued rotation of the air heater provides additional heating until there is sufficient temperature to vaporize acid from baskets. This vaporized acid combines with the acid in the gas to produce an outlet acid level which exceeds the inlet level (AcidIN < AcidOUT) on this (hot) side of the duct. These effects are illustrated in Appendix A, Figure 1, below:

APPENDIX A, FIGURE 1 AIR HEATER CONDENSE AND CONCENTRATE.