



## **Optimizing Catalyst Performance Aids in Lowering Operational & Management Costs**

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### **Abstract**

*Catalyst costs can be more than \$2 million per layer, and customers are seeking ways to better manage their budgets while maximizing catalyst performance. There are several factors that can negatively impact catalyst performance. Fuel characteristics, combustion, furnace gas flow characteristics, unit design and performance, Selective Catalytic Reduction (SCR) reactor design, Ammonia Injection Grid (AIG) performance, and the ammonia control system all can have negative or positive impacts on catalyst life. This paper discusses several of these key factors that need to be managed to be able to maximize catalyst life.*

*As we begin to unravel the negative consequences of several of these key factors, it becomes apparent that managing slag, fouling, sulfur trioxide ( $SO_3$ ), and ammonium bisulfate (ABS) are critical to successfully optimizing catalyst life. Certain fuel characteristics in combination with poor combustion can increase reducing conditions. Ultimately, slag and fouling can influence furnace gas flow and large particle ash (LPA) formation. Once these conditions begin to occur, it is very difficult to optimize catalyst performance. Blocked flow paths can concentrate furnace gas flow through smaller cross sectional areas of the catalyst. Catalyst poisons even in low concentrations can lead to premature shortening of catalyst life in sections of the catalyst. This sets up conditions for high ammonia slip and increased air heater fouling, and once this cycle begins, it is very difficult to manage. Increased air heater washes and unit down time force earlier catalyst replacement that would normally not be necessary with optimization.*

*Fuel Tech's TIF® Targeted In-Furnace Injection™ technology aids in the optimization of catalyst performance by managing slag, fouling,  $SO_3$ , and ABS. Minimizing the negative impact of poor combustion while managing slag and fouling maintains optimized gas flow paths. Reducing the potential for LPA formation improves the cross sectional contact area for  $NO_x$  removal. If ABS or  $SO_3$  forms, it can be managed effectively to prevent a negative impact on air heater performance by preventing air heater fouling.*

*Santee Cooper Cross Generating Station provides a case study of the positive effects of Targeted In-Furnace Injection technology on Optimization of Catalyst Performance.*



## **Introduction**

In 2008 Fuel Tech began to work closely with Santee Cooper to help optimize slag, fouling SO<sub>3</sub>, and ABS control. The ultimate goal was to ensure fuel flexibility without any negative impact to environmental systems. This became very important on Units 3 and 4 because they would be burning up to 4.5 lb. SO<sub>2</sub> per MMBtu sulfur coal. Fuel Tech's SCR Consulting Services group became involved in 2010 to help optimize catalyst life and lower operation and maintenance costs. Higher sulfur fuels in combination with catalyst SO<sub>2</sub> to SO<sub>3</sub> conversion rates of 1.0 percent led to significant increases in SO<sub>3</sub> generation and ABS formation. The need to optimize both catalyst performance and minimize SO<sub>3</sub> generation led to further development of injection strategies to improve overall SO<sub>3</sub> and ABS control. Targeted In-Furnace Injection (TIFI) has successfully controlled slag, fouling, and SO<sub>3</sub> related opacity for several years on coal units with Selective Catalytic Reduction (SCR). The additional modeling and injection strategies focused on catalyst generated SO<sub>3</sub> and ABS. The control and clean-up of SO<sub>3</sub> and ABS fouling at the air heater is discussed in detail.

As economic conditions require utilities to consider higher slagging fuels to lower electrical generation costs, catalyst performance and optimization has become a critical part of successfully managing fuel flexibility. Fuel Tech's SCR Consulting Services in conjunction with TIFI technology have allowed Santee Cooper to optimize unit and catalyst performance while lowering overall fuel costs. This paper provides a case study demonstrating the effectiveness of TIFI at controlling slag, fouling, furnace and Catalyst generated SO<sub>3</sub>, and ABS fouling. Ultimately, Santee Cooper was able to run an additional 8,000 hours on a catalyst that had been recommended for replacement a year earlier.

## **Selective Catalytic Reduction (SCR)**

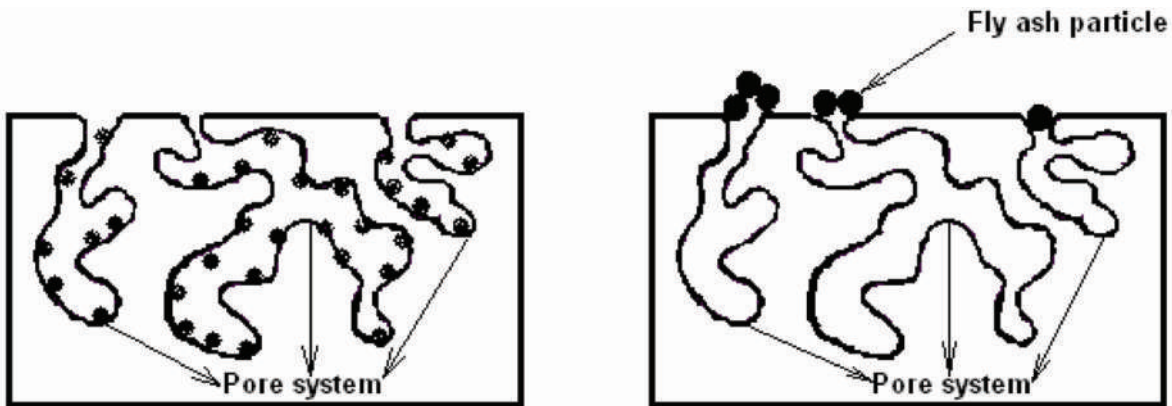
SCR is the most efficient post-combustion NO<sub>x</sub> reduction technology and entails injection of ammonia (NH<sub>3</sub>) into the flue gas downstream of the boiler and reaction with NO<sub>x</sub> upon a catalytic substrate at temperatures generally within the range of 550° to 750°F.

In general, the following reactions are responsible for NO<sub>x</sub> reduction.

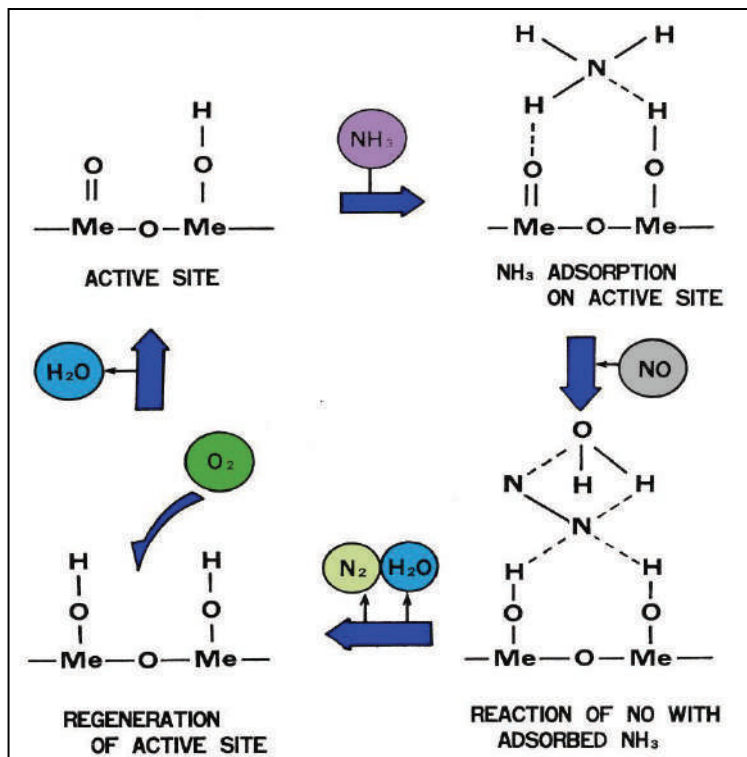
- $2\text{NH}_3 + 2\text{NO} + \frac{1}{2}\text{O}_2 \rightarrow 3\text{H}_2\text{O} + 2\text{N}_2$
- $4\text{NH}_3 + 2\text{NO}_2 + \text{O}_2 \rightarrow 6\text{H}_2\text{O} + 3\text{N}_2$

NO<sub>x</sub> reduction efficiencies as high as 95% have been achieved in the most favorable cases.

SCR functionality is challenged by chemical and physical processes, which can interrupt efficient NO<sub>x</sub> performance. Chemical deactivation of the catalyst is caused by chemical attack on the active sites of the catalyst, and small scale plugging of catalyst micro-pores is caused by the agglomeration of very fine scale ash, aerosols and condensate. These two types of poisoning are diagrammed in the following Figure 1.<sup>1</sup> Additionally, LPA can completely cover large sections of catalyst sites preventing even distribution of furnace flow and NO<sub>x</sub> reduction. Ultimately, this results in less catalyst surface area available for the NO<sub>x</sub> reduction process.



**Figure 1**  
*Two Pathways to Deactivation: Chemical Attack of Catalyst Active Sites and Physical Blinding/Plugging of Catalyst Micro-Pores<sup>1</sup>.*



**Figure 2**  
*NO<sub>x</sub> removal process and effect of poisons on active sites. Arsenic replaces the Metal (Me), poisoning the site and preventing NO<sub>x</sub> removal. The site is permanently lost, and the available catalyst surface area is reduced.*



## **Factors That Can Affect SCR Performance**

There are many factors that can affect catalyst performance, and this paper will discuss some of the factors that the TIFI process can help improve.

- **Fuel Characteristics**

Many higher slagging coals have characteristics that are both less than ideal due to high slag and fouling characteristics, and their potential for increasing catalyst fouling. Chemical poisons such as arsenic present in the coal can permanently reduce the NO<sub>x</sub> removal efficiency of a catalyst.

- **Furnace Gas Flow Distribution**

Furnace gas flow distribution can be affected by many factors; however two areas commonly seen include the challenges associated with retrofitting SCR systems on older units. Some unit retrofits have less than ideal flow distribution. Secondly, higher slagging conditions in the furnace and fouling in the convective pass can prevent good furnace gas flow distribution. LPA fouling of the catalyst exacerbates flow distribution and efficient catalyst performance and NO<sub>x</sub> removal.

- **Ammonia Injection Grid (AIG) and the Ammonia Control System**

Poor furnace gas flow distribution and fouling can negatively affect ammonia distribution. This can cause higher levels of ammonia slip and inefficient NO<sub>x</sub> removal. To overcome these issues, the ammonia control system increases ammonia injection rates to overcome poor ammonia distribution and facilitate NO<sub>x</sub> removal. These actions often cause greater levels of ammonia slip, ABS formation, and air heater fouling. ***This is one of the reasons that catalyst is sometimes prematurely replaced – even if there is still a lot activity available.***

## **TIFI® Targeted In-Furnace Injection™ Technology**

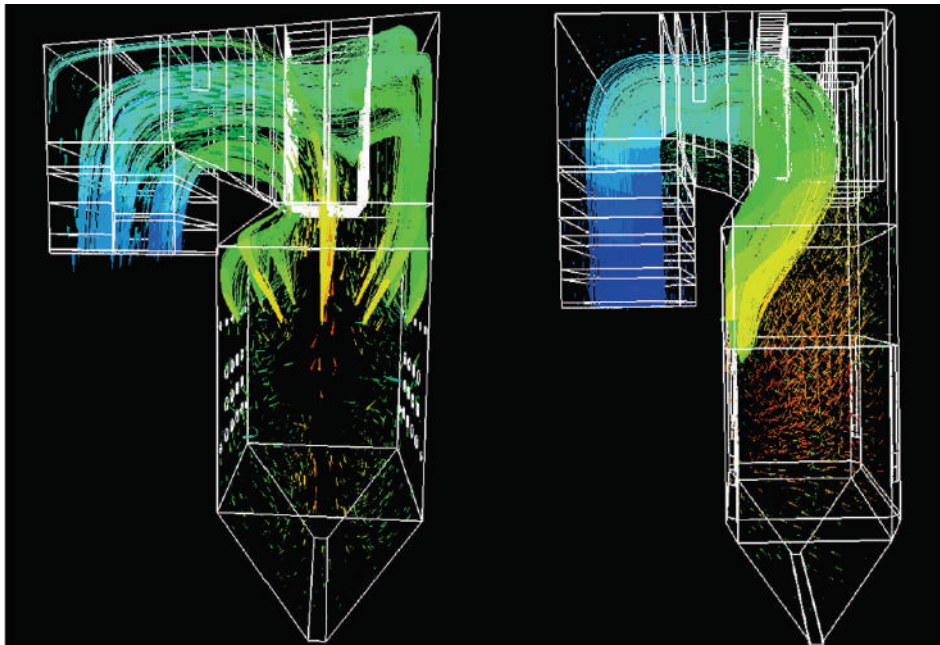
The TIFI process was initially designed as a slag and fouling control program that specifically targets areas of the radiant and convection sections of a boiler. Targeting the problem areas of the furnace, instead of simply applying chemical to the fuel, produces higher performance and cost effectiveness. Recent developments include the use of TIFI to control SO<sub>3</sub> formation and reduce high stack opacity (caused by sulfuric acid), and Air Pre Heater (APH) fouling related to these conditions.

Treatment chemicals are mixed with air and water and then injected into the flue gas stream. The areas that are targeted are based on Computational Fluid Dynamics (CFD) modeling to ensure maximum coverage where the problem areas are known to exist.

The chemical is added to the flue gas stream to treat problem heat transfer surfaces or regions where chemical reactions favor SO<sub>3</sub> formation. This targeted injection assures that the chemical reaches the problem areas ensuring effective utilization. The chemical reacts with slag as it is forming and penetrates existing deposits to affect their physical crystal characteristics. In short the slag deposits are more friable and therefore easier to remove.

### **CFD Modeling**

TIFI technology utilizes multiple CFD models coupled with a proprietary virtual reality based visualization software system. Advanced visualization brings these simulation methods to life and creates a detailed virtual model of the furnace. Injection overlays and dosage maps are used to predict where the chemical is going and to ensure effective coverage of the targeted zones. The immersive and interactive nature of the simulation enables the designers to intuitively discern problems and to improve the design. Moreover, the customer can experience the visualizations and provide input based on years of experience with the real unit. Treatment programs are designed with a customized injection scenario that is built virtually and then evaluated.

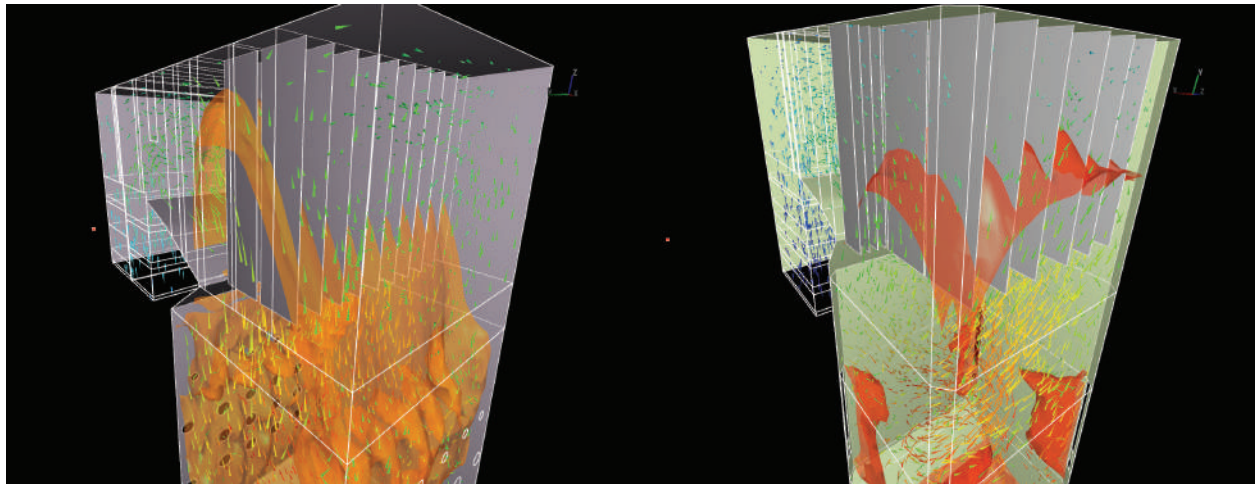


**Figure 3** CFD Visualizations of droplet trajectories. Note how injection is targeted to ensure proper coverage in the furnace, including the back pass.

## **Injection Technology**

Injection is simulated with proprietary models that evaluate the distribution of the reagent in the flue gas. An interactive injector model enables quick optimization of the needed droplet trajectories and resulting penetration. A rigorous model is then used in the CFD solution to precisely determine the distribution of the chemical treatment. The TIFI injection strategy utilizes a variety of injector designs to provide treatment on the walls, the convective pass and inlet to the SCR and air heater, as noted in Figure 3.

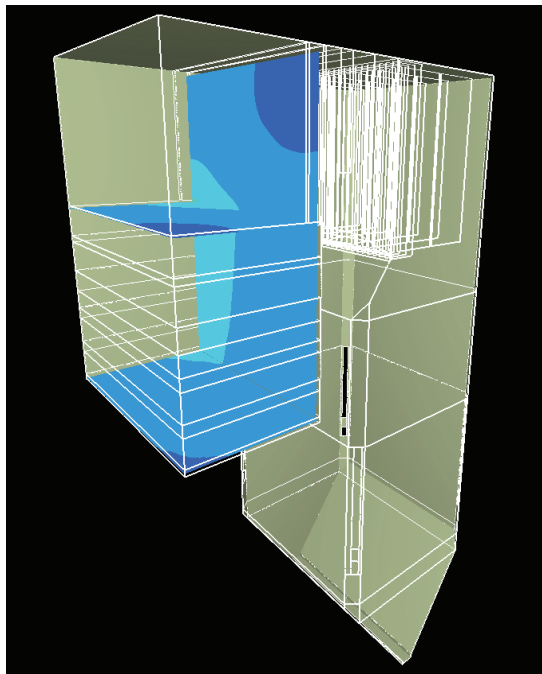
The visualization tools are also used to illustrate the likely slag and fouling fronts in the furnace. In Figure 4, the translucent reddish orange iso-surface has been created to visualize a potential ash fusion temperature of 2,150°F. The model shows the operators and designers quite clearly where slag and fouling are likely to first occur. When chemical injection is targeted, this unique and powerful approach can control slag and fouling to a degree not possible before.



**Figure 4** CFD Visualizations of Temperature Surfaces

### **CFD Modeling Includes Optimizing Backend Chemical Coverage**

To ensure adequate chemical coverage for both SO<sub>3</sub> and ABS control, backend modeling and visualization are performed to ensure adequate chemical concentration and distribution prior to the SCR and air heater. The horizontal and vertical planes in Figure 5 are color coded for chemical concentration. Light blue is indicative of the nominal amount of chemical, and teal green indicates a little more than nominal. Dark blue areas indicates less than ideal chemical concentration. When targeting certain areas there are situations when less than ideal chemical is desirable. The visualization confirms very good coverage at the inlet and outlet of the SCR to support distribution at the APH.



**Figure 5**  
*Backend Chemical Concentration Visualization*

### **Reagent Chemistry**

The TIFI reagent is a stable chemical slurry with high reactivity due to its high relative surface area. The high activity results in better performance at recommended treatment dosages while its high stability eliminates many of the handling and feeding problems associated with un-stabilized compounds.

The chemical reagent arrives at the customer site in the form of suspended slurry of 5-8 micron sized particles. Chemical injection distribution systems, guided by the CFD and injection model results, provide the desired reagent coverage of the walls, the convective pass, and the furnace gases.



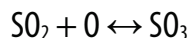
In this case, the TIFI process uses Magnesium Hydroxide to change slag characteristics and also to mitigate  $\text{SO}_3$  and ABS formation. As Magnesium Hydroxide, in the form of a slurry, travels into the furnace it becomes superheated and ultimately forms nanometer size particles of Magnesium Oxide ( $\text{MgO}$ ). These very small particles behave almost like a gas and travel with the flue gas stream. This becomes an important aspect regarding not only slag control, but also  $\text{SO}_3$  and ABS mitigation.

Enhanced by the rapid heating,  $\text{MgO}$  quickly begins to interact with the existing deposits and the deposit formation mechanisms to control the slag accumulation and downstream fouling. This slag control leads to a decrease in  $\text{SO}_3$  formation. In addition, the gas stream treatment, through acid-base neutralization reactions, reduces much of the  $\text{SO}_3$  that is formed. Control of the  $\text{SO}_3$  reduces sulfuric acid and ammonium bisulfate concentrations, air heater fouling and stack opacity issues.

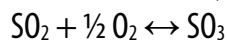
### Chemistry of $\text{SO}_3$ Formation

The formation of sulfur oxides ( $\text{SO}_x$ ) is dependent on reaction kinetics, combustion temperatures, fuel sulfur content, ash composition and the level of excess air ( $\text{O}_2$ ). Most fuel bound sulfur oxidizes to  $\text{SO}_2$  in the combustion zone. The further oxidation of  $\text{SO}_2$  to  $\text{SO}_3$  is brought on by three mechanisms.

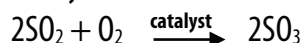
1. Oxidation of  $\text{SO}_2$  in flame by atomic oxygen.



2. Oxidation of  $\text{SO}_2$  by molecular oxygen.

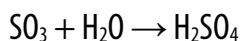


3. Catalytic oxidation via molecular oxygen.



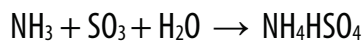
The third mechanism is significant, and results in the catalytic conversion of  $\text{SO}_2$  to  $\text{SO}_3$ . This is primarily due to metal oxides present in the furnace as well as in the catalyst itself. Typical metals include iron and vanadium, which are found in the ash particles, slag deposits, fouled metal heat transfer surfaces, as well as in the SCR.

$\text{SO}_3$  in the post-combustion gases will react with the moisture in these gases to form sulfuric acid in the air pre-heater (APH).

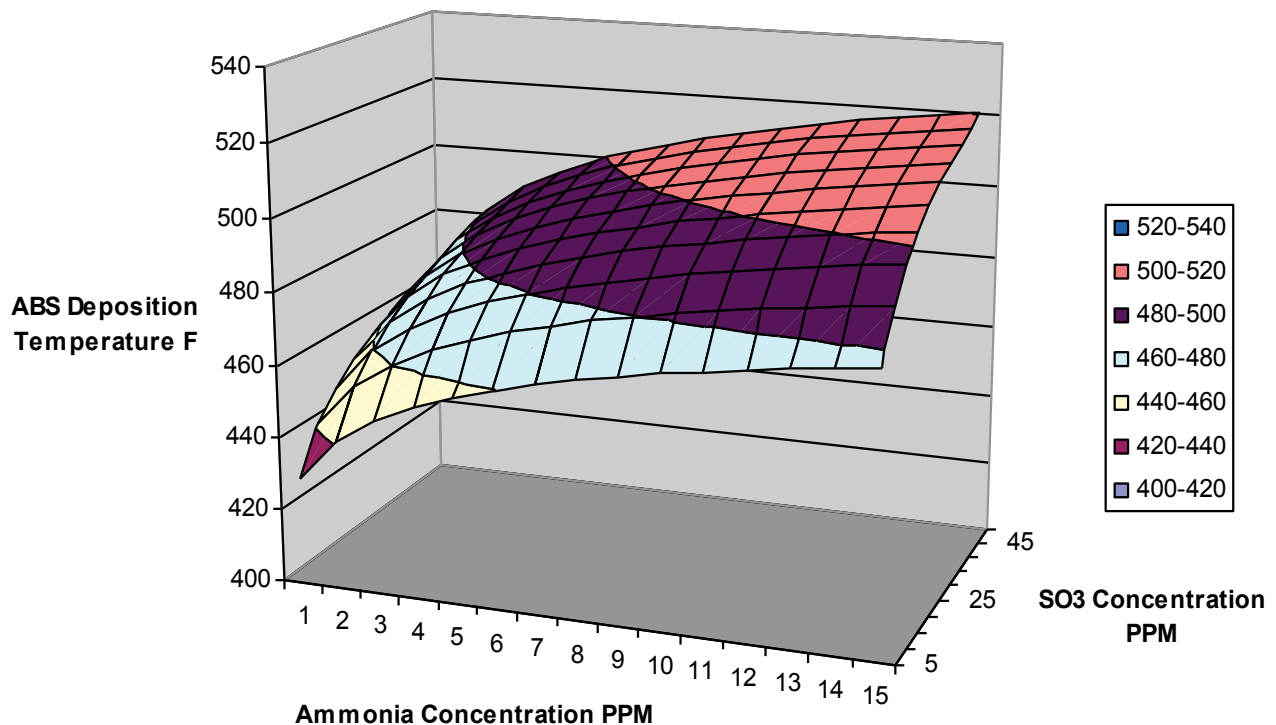


The sulfuric acid condenses on the cold metal surfaces of the APH or downstream equipment. This condensed acid can cause corrosive damage or simply provide a site for ash buildup and eventual APH pluggage that may cause an unplanned outage.

In units equipped with ammonia or urea-based NO<sub>x</sub> reduction systems, interaction between residual ammonia and SO<sub>3</sub> is an important factor in determining system performance. High concentrations of SO<sub>3</sub> prior to the APH will limit the available NO<sub>x</sub> reduction. This is because residual NH<sub>3</sub> reacts with SO<sub>3</sub> to produce ABS in the APH at approximately 400°F.



ABS deposits are sticky, difficult to remove, accelerate corrosion and create significant air heater fouling. The greater the ammonia slip and fuel sulfur concentration, the faster the ABS deposition temperature will rise (Figure 6). An increase in APH differential pressure (dP) will follow shortly after formation occurs. In particular, this becomes more significant with sulfur content greater than 1.5%.



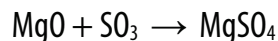
**Figure 6** Catalyst Life Cycle – Air Heater Fouling



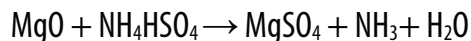
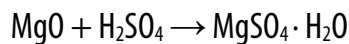
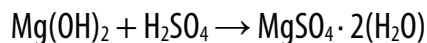
## Chemistry of TIFI - SO<sub>3</sub> & ABS Control

The TIFI reagent treatment strategy controls SO<sub>3</sub> formation by both limiting the catalytic opportunities for oxidation and by providing a clean and efficient furnace that can function well at lower levels of excess oxygen. In addition, TIFI technologies provide SO<sub>3</sub> capture to limit or eliminate the effects of sulfuric acid and ABS impacts downstream at the APH.

Magnesium oxide reacts with SO<sub>3</sub> to form Magnesium Sulfate as:



In addition, the same environment that causes the formation of sulfuric acid also allows for a classic acid–base reaction between magnesium hydroxide and magnesium oxide with sulfuric acid and ABS.



## TIFI Improves Arsenic Control

Arsenic is one of the metals that will significantly degrade catalyst life by poisoning the active site where NO<sub>x</sub> removal occurs. Once the active site is replaced by arsenic, it is not available for NO<sub>x</sub> reduction. This permanent poisoning of the catalyst shortens catalyst life and allows more ammonia slip to occur. The diagram in Figure 2 demonstrates the NO<sub>x</sub> removal process. If the active site metal (Me) is replaced by arsenic, the site is permanently lost and NO<sub>x</sub> performance will degrade.

The TIFI process has several positive effects on catalyst life and reducing the negative effects of poisons.

- Minimizing slag and fouling reduces LPA formation and improves furnace gas flow distribution prior to the catalyst
- Magnesium and calcium react directly with gaseous arsenic minimizing poisoning
$$\text{As}_2\text{O}_3 (\text{g}) + 3\text{CaO} + \text{O}_2 \rightarrow \text{Ca}_3(\text{AsO}_4)_2 (\text{s})$$
$$\text{As}_2\text{O}_3 (\text{g}) + 3\text{MgO} + \text{O}_2 \rightarrow \text{Mg}_3 (\text{AsO}_4)_2 (\text{s})$$
- MgO reacts directly with SO<sub>3</sub>, and this minimizes the opportunity for calcium to also react with SO<sub>3</sub> to form calcium sulfate. As a result, there is more calcium made available to tie up gaseous arsenic.<sup>3</sup>

TIFI has several positive effects on arsenic control. Better management of slag, fouling, LPA, SO<sub>3</sub> and ABS reduce furnace gas flow imbalances prior to the SCR. Furnace gas flow imbalances from slag, LPA fouling of the catalyst, and air heater fouling can change the flow balance to less than optimal distribution. Blocked flow paths can concentrate furnace gas flow through smaller cross sectional areas of the catalyst. Catalyst poisons even in low concentrations can lead to premature shortening of catalyst life in sections of the catalyst.

### **TIFI Effect on Slag**

TIFI makes ash more friable in both reducing and oxidizing conditions. This is because MgO has a melt point of approximately 5000°F. MgO interspersed in slag prevents strong fusion of the inorganic constituents typically found in coal and the subsequent ash. (i.e. iron, calcium, sodium, etc.). With the deposits friable, they are easily removed by soot blowing from the radiant and convective sections of the boiler. TIFI has shown that performance improves even on units with less than optimal combustion. This allows units to successfully burn non-design fuels that have lower fusion temperatures. Ultimately, TIFI provides greater fuel flexibility on many different types of units.



**Figure 7**

*Before TIFI Treatment*

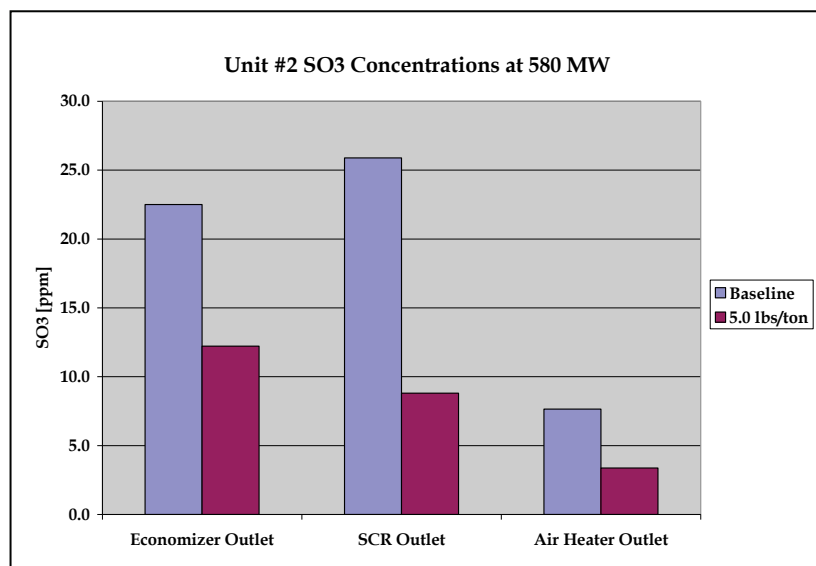
*After TIFI Treatment*

## Cross Station - Background Information

### Unit 1

Santee Cooper Cross Station Unit 1 is a 600 MW opposed wall fired unit that started commercial operation in January 1995. Cross 1 was equipped with staged combustion low NO<sub>x</sub> burners. The unit had issues with "popcorn ash" (LPA) formation from the time of initial operation.

The unit also had issues with tube thinning in areas of the furnace adjacent to the burners due to reducing conditions in that area. There were persistent problems with burner eyebrows, burner fires, furnace imbalance, and air heater pluggage. The air heater pluggage was attributed to LPA. Unit 1 was subsequently modified by the addition of an SCR in 2003.



Subsequently, LPA also blinded the SCR and protective screens. Year round SCR operation began June 2004. In April 2006, Fuel Tech began a TIFI program that was very successful at controlling SO<sub>3</sub>, slag, fouling and preventing LPA formation as well as SCR fouling. The graph in Figure 8 is data reported in the 2008 Santee Cooper Case Study presented at EUEC in 2008<sup>2</sup>.

**Figure 8** SO<sub>3</sub> test results from Santee Cooper Case study presented at EUEC January 2008<sup>2</sup>

The typical fuels used during this study had the following characteristics:

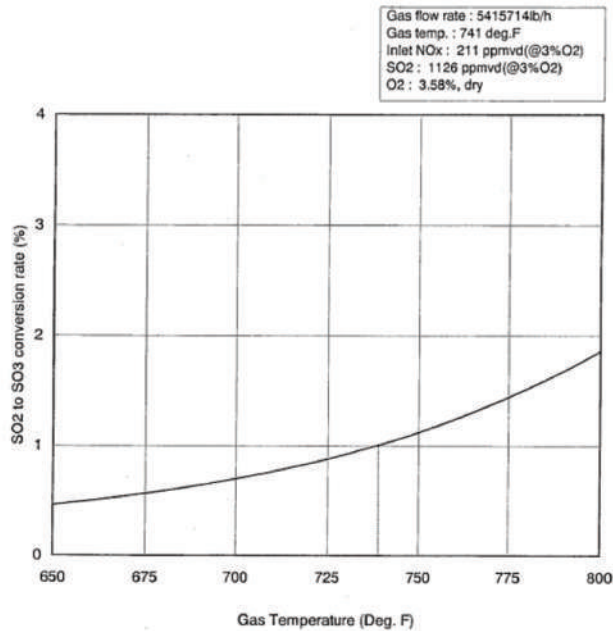
- **Sulfur**
  - U1: 3.3 lb. SO<sub>2</sub> per MMBtu
  - U3,U4: 4.5 lb. SO<sub>2</sub> per MMBtu
- **Iron**
  - U1: 23% Iron
  - U3,U4: 25% Iron

### Units 3 and 4

Unit 3 and 4 are identical tangentially-fired units. Unit 3 went into commercial operation on January 2007, and TIFI began in January 2008. TIFI began on Unit 4 in August 2008, and the unit went commercial in October 2008. They were both installed with two layers of Babcock Hitachi catalyst with a SO<sub>2</sub> to SO<sub>3</sub> conversion rate of 0.5% per layer. The total conversion rate on startup was 1.0% for 2 layers. This was based on a design SCR inlet Temperature of 741°F. Figure 9 indicates the SO<sub>2</sub> to SO<sub>3</sub> conversion rate chart from Babcock Hitachi. It should be noted that conversion of SO<sub>2</sub> to SO<sub>3</sub> at 760°F with 3.58% (dry) excess O<sub>2</sub> increases by 25%. At 775°F and 3.58% (dry) excess O<sub>2</sub>, an additional 50% more SO<sub>3</sub> would be expected. With 4.5 lb. SO<sub>2</sub> per MMBtu sulfur in the coal (approximately 1800 ppm SO<sub>2</sub>), the catalyst will generate 18 - 30 ppm SO<sub>3</sub> at various operating conditions. These units operated above 741°F SCR inlet temperatures on a regular basis due to various fuels and operating conditions. TIFI successfully controlled SO<sub>3</sub> and ABS formed under these conditions.

Babcock-Hitachi K.K.

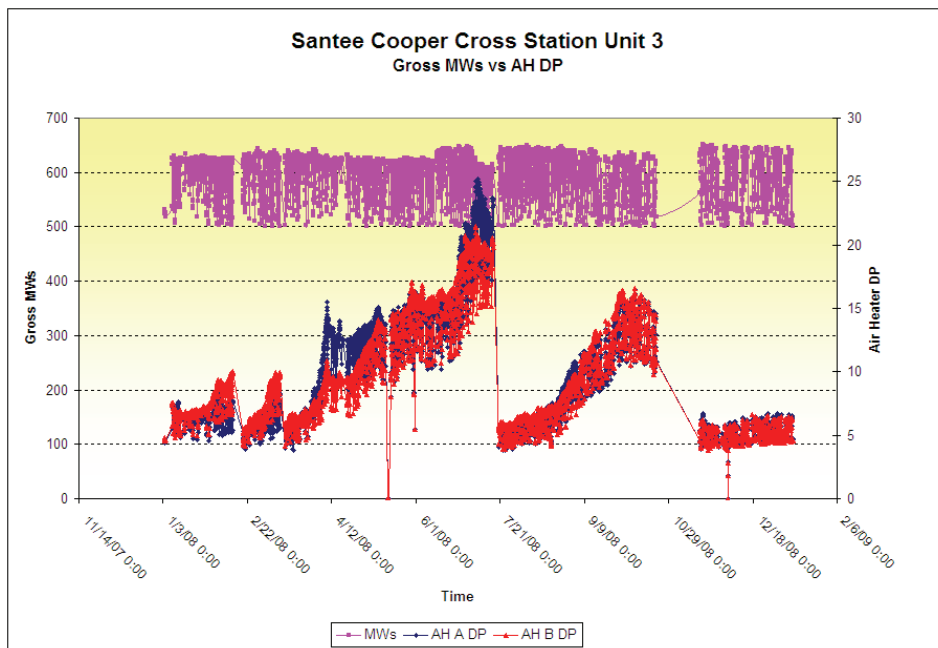
EE-CROSS3-N-002 (r3)  
SHEET No. 8 of 1



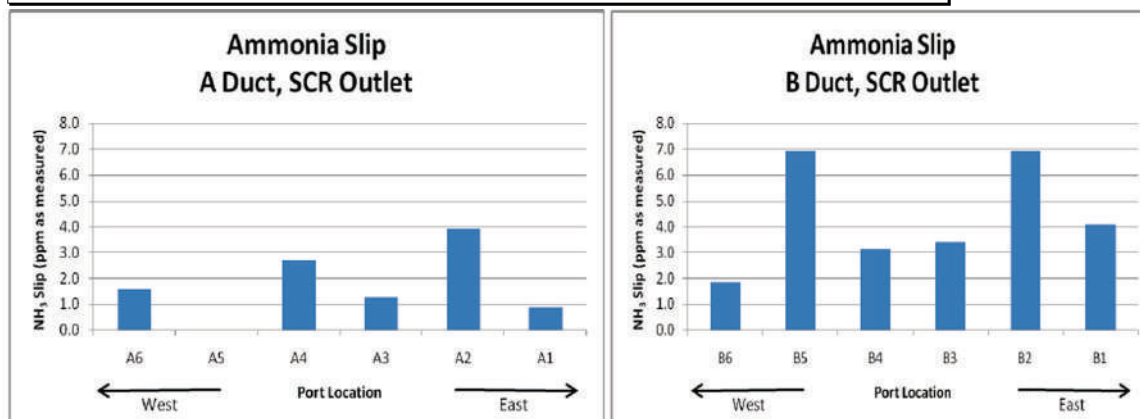
**Figure 9** SO<sub>2</sub> to SO<sub>3</sub> Conversion Rate Curve vs. Temperature for 2 installed layers

### Initial Demonstration of ABS Control

In February 2008, Unit 3 had various issues with ammonia control that led to excessive ammonia slip and air heater fouling. TIFI was installed in January 2008 with the initial goals to control slag, fouling, and SO<sub>3</sub> related opacity. The variability in ammonia slip caused challenges that required Fuel Tech to incorporate new control and injection strategies to ensure fuel flexibility and control of air heater fouling. ABS control was initially demonstrated in July 2008, and the TIFI program allowed Unit 3 to make it to the October outage. The first successful demonstration of a clean-up of an air heater fouled with ABS occurred in September 2008. The successful clean-up led to a drop in air heater differential pressure of 2.5 inches (Figure 10). Fuel Tech performed ammonia testing on Unit 3, and determined ammonia slip levels as high as 7 ppm in the B duct SCR outlet (Figure 11).

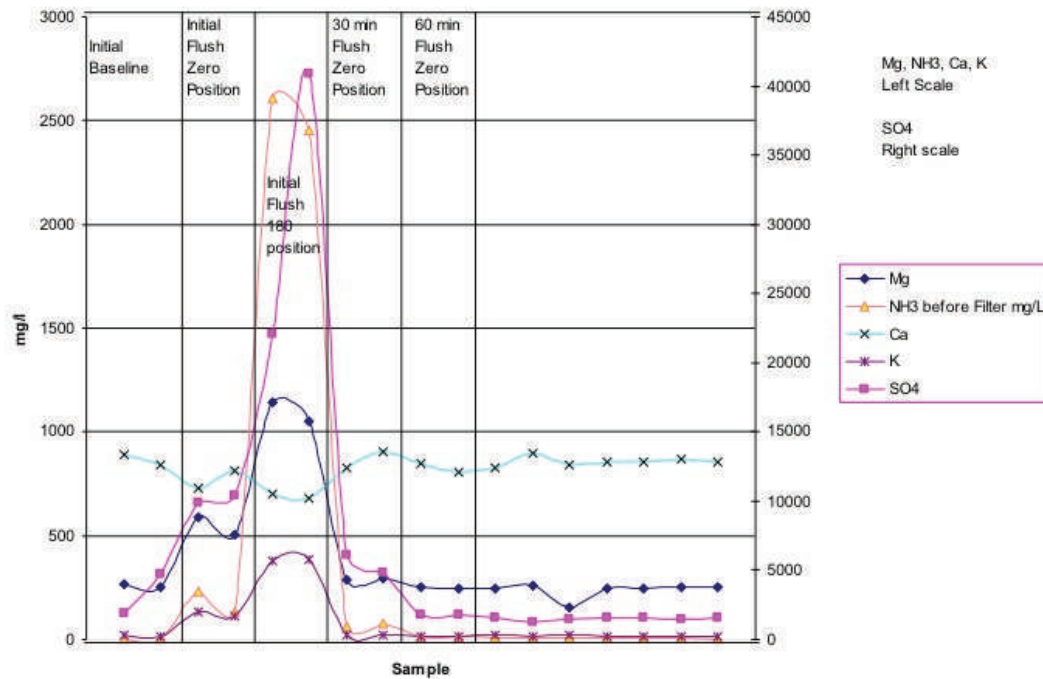


**Figure 10** Unit 3 – 2008 Demonstration of ABS Control/Air Heater Clean-Up (dP dropped 2.5 inches)



**Figure 11** Unit 3 Ammonia Slip - September 2008

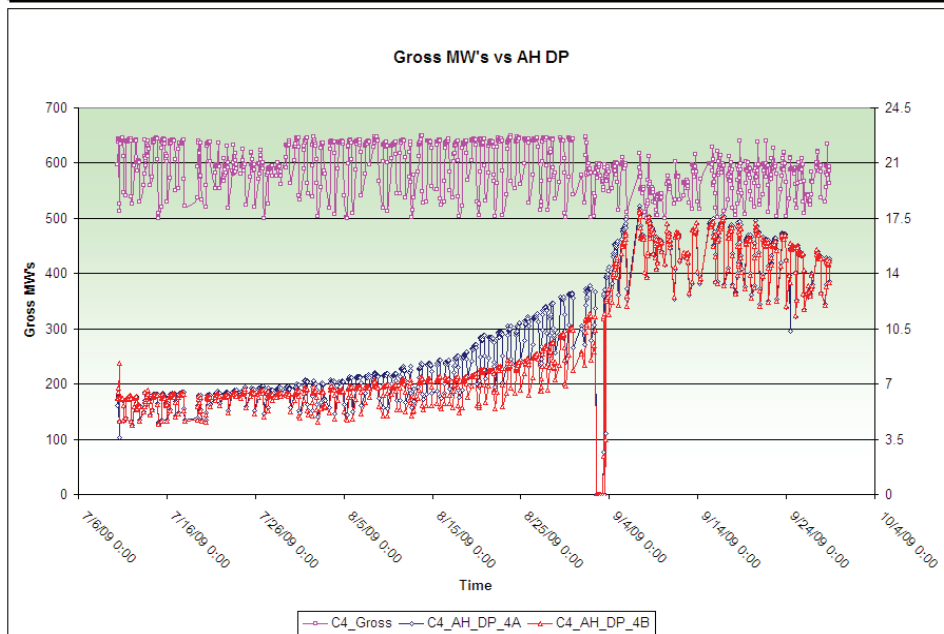
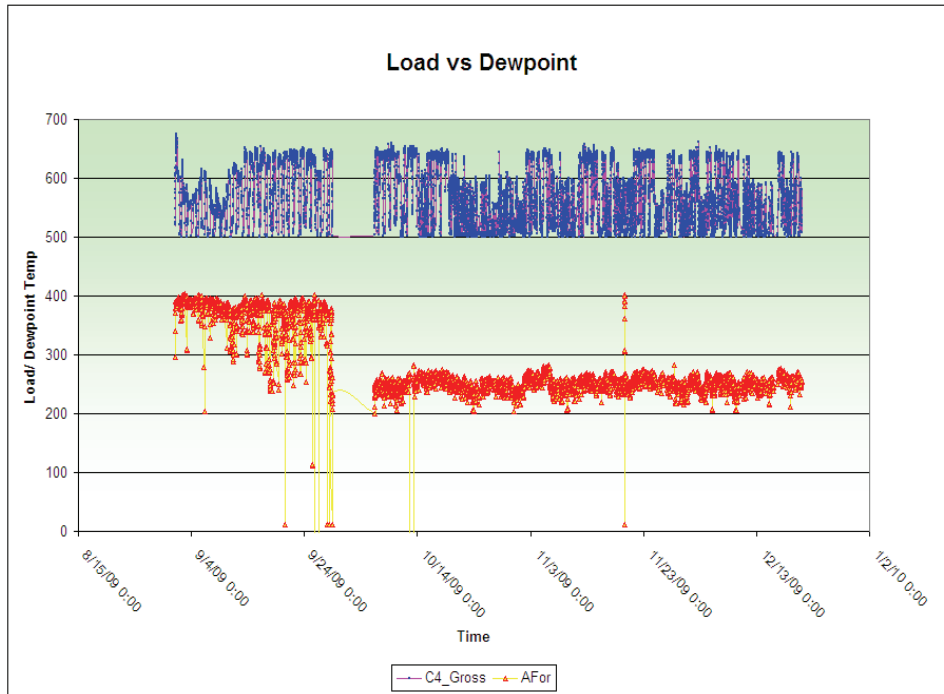
During the October 2008 outage, air heater wash water samples were collected and analyzed to determine the various foulants present. The analysis confirmed the presence of ABS, and its conversion to magnesium sulfate as shown in Figure 12. The total Mg content in the fuel ash prior to TIFI is less than 1.0%. The water analysis shows high levels of magnesium, due to the TIFI process. This analysis and the reduction in air heater differential pressures provided proof of ABS conversion to magnesium sulfate. This success led to additional optimization strategies.



**Figure 12** Sample analysis of U3 Air Heater Wash Water confirming high Magnesium Sulfate content

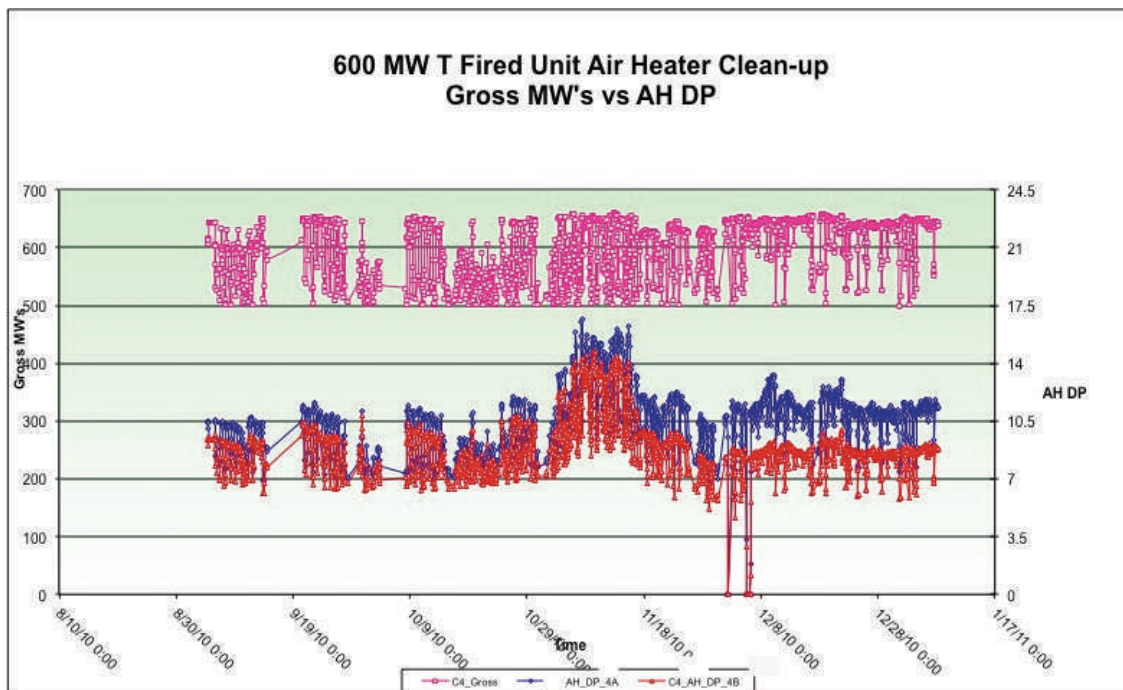
## Unit 4 – The 2<sup>nd</sup> Demonstration of ABS Control and Air Heater Clean-Up

In 2009, Unit 4 began experiencing high ammonia slip due to catalyst degradation. High arsenic levels in the coal were found to be one of the key factors. In July 2009, Fuel Tech was tasked to control ABS, and help the unit to make it to the October 2009 outage. With TIFI in operation, the air heater clean-up dropped the differential pressures 3.1 inches as noted in Figure 14.



### Unit 4 – 3<sup>rd</sup> Demonstration of On-Line Clean-Up of an Air Heater at Full load

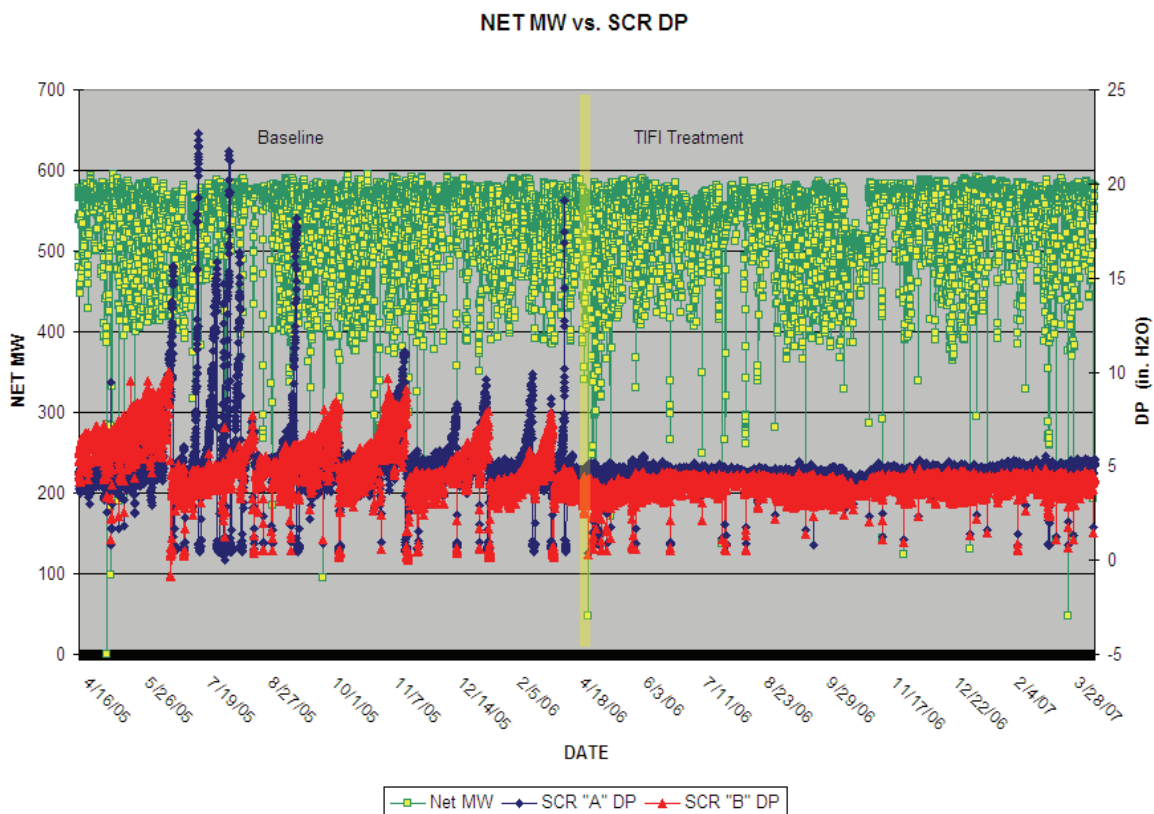
Ammonia slip caused by overfeed of ammonia due to performance problems with the ammonia controls caused a rapid rise in air heater differential pressures. An on-line air heater clean-up was implemented to reduce APH differential pressures. The successful air heater clean-up caused a differential pressure drop of 6 inches while the unit was able to maintain full load. After the air heater clean-up occurred, the ammonia control issues were resolved. Unit 4 was able to return to normal control without a need for an air heater wash (Figure 15).



**Figure 15** High ammonia slip due to Ammonia control issues cause the Air Heater differential pressure to rise rapidly. Air Heater clean-up was performed at full load, and differential pressure dropped 6 inches.

### Unit 1 - Performance for LPA and ABS control

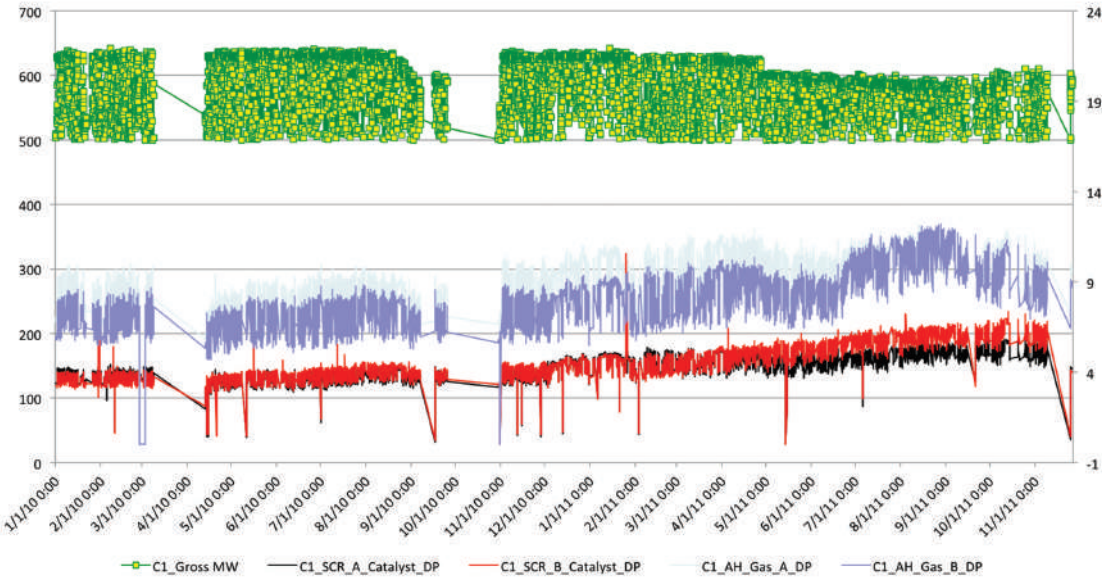
The graph in Figure 16 indicates how the SCR differential pressures (dP) were affected before and after TIFI treatment, which is noted by the yellow vertical line. This information was documented in the initial Santee Cooper Case Study in 2008.<sup>2</sup> The red and blue lines are the dP's for the A and B duct SCRs. It can be noted that the numerous cleanings by vacuuming of the catalyst were no longer required after treatment began. The TIFI program has demonstrated successful LPA control for six years, and there have been no on-line cleanings or unplanned outages related to SCR performance since April 2006. SCR Inspections continue to show the ash to be very friable without the presence of LPA.



**Figure 16** SCR dP Before and After TIFI Treatment

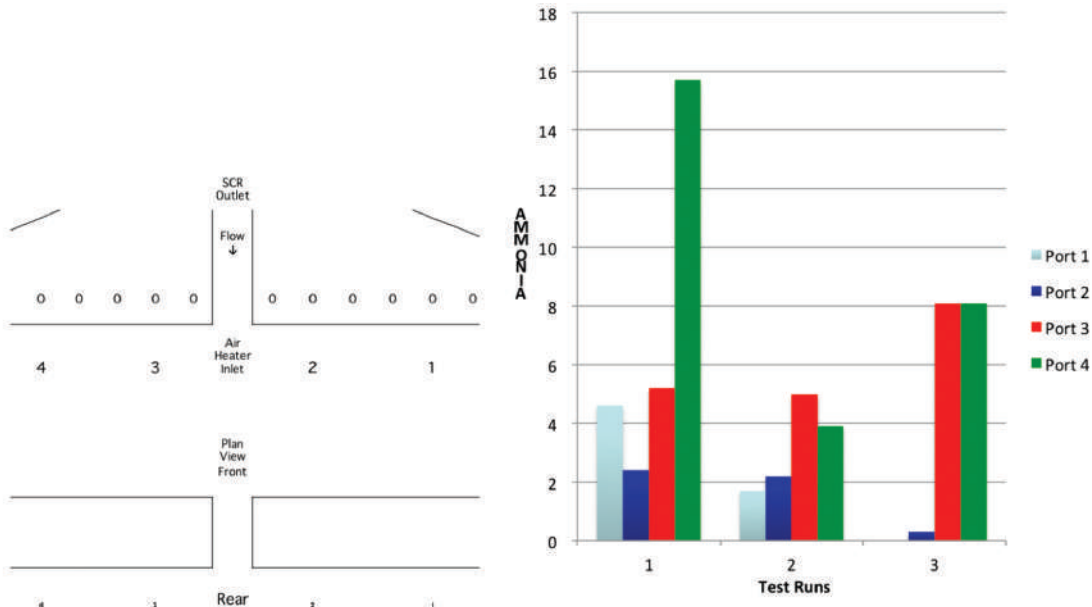
In 2005, Unit 1 had ash screens installed to help reduce SCR fouling. Screen integrity was poor, and the ash screen had consistent failures due to erosion. Prior to TIFI, SCR fouling still occurred after screen integrity became compromised. After the TIFI program demonstrated successful control and prevention of LPA, the ash screens were no longer maintained. In 2009, the decision to remove ash screens from the unit was made. With over five years of operation using TIFI, the catalyst has not had high SCR differential pressures or fouling. Moreover, the unit has operated without any ash screens for over three years. The performance data shown in Figure 17 is with no ash screens installed in the unit.

**Gross MW vs. SCR DP & AH DP**



**Figure 17** Unit 1 record 19-month run Black/Red - SCR dP's, Blue/Light Blue APH dP's

The data in Figure 17 shows that Unit 1 had a very successful run for 19 months while controlling SCR dP's. Moreover, Unit 1 began exhibiting high ammonia slip between 3 -15 ppm starting in June 2011, as shown in Figure 18. The data shows successful control of ABS, and a clean-up of the air heater in September 2011. TIFI reduced the air heater dP's preventing the need for an unplanned outage. Air heater washes were not performed on this unit.



**Figure 18** Ammonia Slip - Tests performed September 2011



The catalyst OEM had originally recommended replacement of the catalyst be completed in the Spring of 2011. The graph in Figure 17 shows very effective control of ABS and air heater differential pressures. Based on this and other data, minor adjustments in TIFI dosage control were recommended to help control ABS. Santee Cooper chose to run with Fuel Tech's ABS control strategy, and delay their outage. The new strategy was in effect from June through November 2011. In November 2011, the catalyst was vacuumed for the first time in 19 months to help extend available active surface area. The ABS control strategy was very successful, and Unit 1 was able to run one additional year. The catalyst will be replaced in the Spring of 2012. Ultimately, Cross Unit 1 has gained an additional 8,000 hours of catalyst operation without sacrificing NO<sub>x</sub> performance.

## **Conclusion**

Optimizing catalyst life and lowering operational and maintenance costs is achievable. However, combining fuel flexibility with higher sulfur and higher slagging coals provides additional challenges making it very difficult to extend catalyst life. After several years, and many successful demonstrations of ABS control on Units 3 and 4 at Cross Station, Fuel Tech has developed a very flexible strategy to extend catalyst life. A combination of SCR Consulting Services and the utilization of TIFI technology have allowed Cross Station many different options to burn lower cost fuels without sacrificing unit performance or catalyst life.

Fuel Tech's TIFI program has proven that successfully controlling slag, fouling, SO<sub>3</sub>, and ABS will extend catalyst life without sacrificing fuel flexibility. Controlling ABS with ammonia slip as high as 15 ppm with high sulfur fuels has always caused air heater differential pressures to rise due to fouling. Many times these conditions have caused the need for expensive unplanned outages. Until now, air heater washes or catalyst replacement has been the only option to overcome these challenges. Fuel Tech's Targeted In-Furnace Injection technology has given our customers an additional tool to avoid expensive premature catalyst replacement while still ensuring fuel flexibility. With today's economic challenges of cheap natural gas, lower electrical demand, and higher dispatch rates for coal units, Fuel Tech's TIFI program continues to provide options for our customers to compete and lower overall operational costs.



## **References**

1. Baxter, L Biomass Impacts on SCR Catalyst Performance IEA BioEnergy Task 32 October 2005
2. Benisvy, Boyle, Davis, Hermanas, Schulz, Toombs Controlling SO3 Slag and Fouling Resulting in Improved Heat Rates, Better Efficiency and Allowing for Fuel Flexibility January 2008
3. Guberlet, Murphy, Struckmann, Watson Arsenic Mitigation at PPL Montour Lessons Learned February 2010