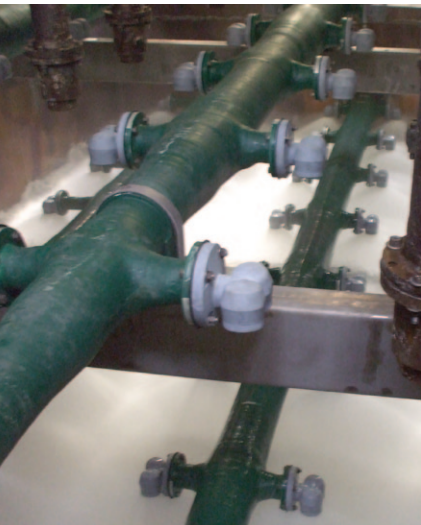


# URS

POWER

Technical Paper

## FGD Upgrades



### **New Technologies to Improve the Performance and Reliability of Older FGD Systems**

---

# **New Technologies to Improve the Performance and Reliability of Older FGD Systems**

## **Paper #129**

Gordon Maller, James Noblett, Mark Denlinger, Jonas Klingspor – URS Corporation;  
Allyn Cottemond – NRG Texas LLC

## **ABSTRACT**

The Power Industry faces the issue that most of the existing, older flue gas desulfurization (FGD) systems were not designed to meet the emissions requirements that are currently being adopted or considered. In addition, the development of technology to remove CO<sub>2</sub> from flue gas, and future emission limits for mercury and other air toxics will require that scrubbers operate at even higher removal efficiencies than is possible with older or even new FGD systems capturing higher levels of mercury and fine particulate. The performance of older FGD systems is often limited by poor reliability and/or poor design and often has significantly higher operating costs and maintenance requirements than newer systems. This is contrary to goals for most utilities to reduce operating costs and extend the time period between maintenance outages.

New advanced technology has been developed and successfully employed to upgrade the performance of older FGD systems and correct the poor design problems that limit reliability and require high levels of maintenance. This technology includes such things as advanced double hollow cone spray nozzles, high efficiency spray headers, liquid distribution rings and counter flow sieve trays all designed to enhance gas-liquid interactions and maximize the mass transfer characteristics and performance of an absorber. In addition, other technology such as CFD modeling and advanced process simulation models are being applied in novel and innovative ways, during the characterizations and design phases of the project, to analyze the performance of the scrubber, help diagnose and solve process and design problems and determine and correct the factors which limit the performance and reliability of the system.

This paper will describe and discuss the development and application of these new technologies in the upgrade of older FGD systems. These projects have been successful in significantly increasing removal efficiencies of the systems, in several cases to levels in excess of 98%, along with significant improvements in system reliability and operation. These performance gains were accomplished with minimal increases to the system pressure drop and energy requirements. In many cases, a high level of innovativeness was employed in the process design in order to achieve the goals of the project in as cost-effective a manner as possible. A case study showing how the new technology was employed in the design of modifications and improvements for the NRG Limestone Unit 1 and 2 FGD systems will be also be presented along with test results for the project to quantify the improvements that were achieved.

---

## **INTRODUCTION**

Electric utilities face the challenge of increasingly stringent environmental regulations as well as economic pressures to reduce operating costs, and improve system reliability to extend time periods between outages. As a result, existing FGD systems must operate at peak efficiency and reliability, and must provide maximum and sustainable performance to meet current and future emissions requirements. The majority of the existing U.S. fleet of FGD systems were not designed to meet these new requirements. In addition, they often suffer from poor reliability and high operating and maintenance costs due to their age or poor design. It is likely that new regulations currently being implemented or proposed, such as the Boiler MACT Rules, will require that FGD system be capable of removing additional pollutants, such as mercury and fine particulate, in addition to SO<sub>2</sub>, and operate at performance levels well beyond their original design levels.

Fortunately new technologies have been developed and successfully employed to meet these challenges. These technology includes such things as advanced double hollow cone spray nozzles, high efficiency spray headers, liquid distribution rings and counter flow sieve trays all designed to enhance gas-liquid interactions and maximize the mass transfer characteristics and performance of an absorber. In addition, technologies such as CFD modeling and advanced process simulation models can be used to analyze the performance of the scrubber, help diagnose and solve process and design problems and identify and correct the factors which limit the performance and reliability of the system. This paper will describe and discuss the development and application of these new technologies. A case study showing how the new technologies were employed in the design of modifications and improvements for the NRG Limestone Unit 1 and 2 FGD systems will be also be presented along with test results for the project to quantify the improvements that were achieved.

## **FGD UPGRADE TECHNOLOGY**

In recent years there have been a number of advances in technology which has greatly improved the performance and reliability of new FGD systems. Some of these advances include improved spray header design, improved spray nozzle technology, devices to improve the mass transfer characteristics and gas and liquid distribution within the absorber, improved materials of construction, and the development and improvement of computer based design tools. The success of these improvements in the current generation of FGD systems is evidenced by the fact that a single absorber is now capable of treating flue gas from well over 1,000 MW of generating capacity and achieve SO<sub>2</sub> removal levels which are in the high 90% range. The design approach of having multiple and spare absorbers, along with a variety of other spare equipment, to be able to achieve high reliability and availability has been abandoned.

The technology advances that have improved the performance and reliability of new FGD systems can also be applied and have been successful in improving the performance characteristics of older FGD systems, in most cases, bringing the performance of these systems to levels which are equivalent to new FGD systems. Typically, associated with the improvement in performance, the new technologies also have improved the operation and reliability of the older systems along with helping to resolve chronic process problems such as scaling and solid deposition. Much of the focus of the recent technology advances has been improvements in the gas-liquid contact characteristics of

---

the absorber, as well as improvements to achieve a uniform gas-liquid distribution within the absorber. That, along with stable and well-controlled chemistry, are the critical prerequisites required to achieve high FGD performance and reliability levels.

## **High Efficiency Spray Headers**

A problem common in older FGD systems is non-uniform and incomplete spray coverage as a result of poor recycle spray header designs. In many cases, there are significant holes in the spray coverage over the cross-sectional area of the absorber as a result of the tendency, in these older systems, to use a small number of relatively large spray nozzles. The problem is especially significant along the walls of the absorber, where gas flows tend to be higher, or in the vicinity of internal support members. The result is poor gas-liquid contact because the gas will tend to flow where the spray density and, as a result, gas-side pressure drop is the lowest. The poor design and poor coverage of the spray headers will limit the removal efficiency that can be achieved regardless of the liquid flow and L/G of the absorber. A spray coverage pattern that is typical of an older FGD system is shown in Figure 1. The location of the coverage pattern shown is 18 inches below the spray nozzle, thought to be the critical area of the absorber where most of the absorption of SO<sub>2</sub> occurs.

Achieving the very high removal efficiencies that are required to meet today's or future emission limits require a spray header design with a very dense and uniform spray coverage pattern with a high degree of overlap as illustrated in Figure 2. This allows the high degree of gas-liquid contact required for very high removal efficiencies. In addition, the possibility for gas sneakage to occur through holes in the spray pattern is eliminated. It should be noted, however, that achieving the dense spray coverage will require using a larger number of smaller spray nozzles if liquid recycle flows are not increased. The smaller spray nozzles will tend to plug easier with solids and debris compared to the older larger spray nozzles with large s free-passage. This increases the importance of minimizing operation that causes scaling and keeping solids and debris out of the header supply piping through use of suction strainers or other devices.

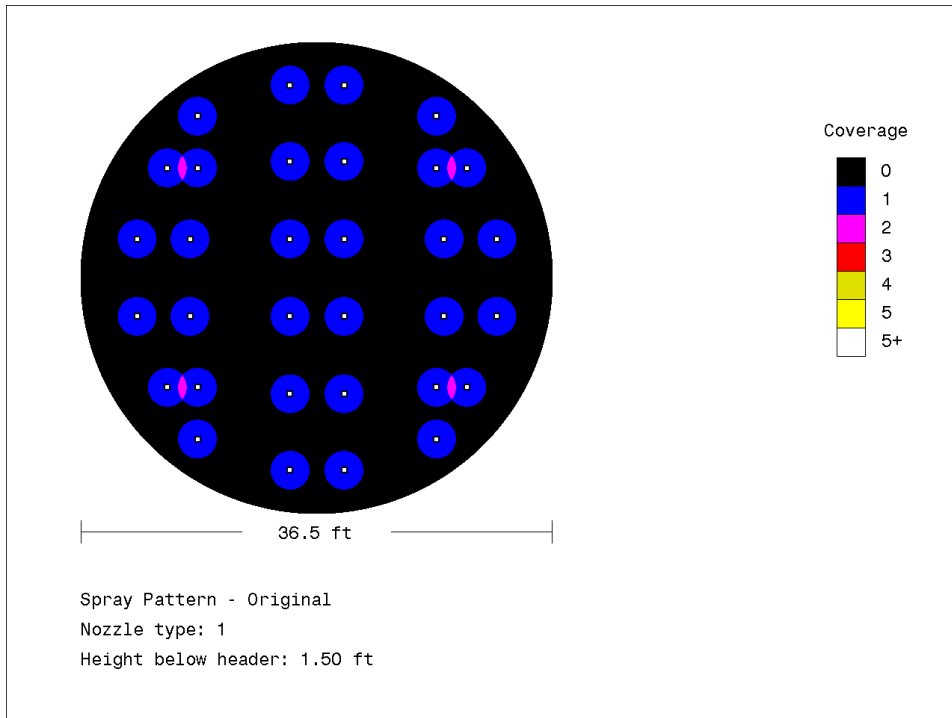
There are a number of advantages, in terms of improving spray coverage, eliminating gas flow disturbances, and eliminating possible locations for scale and solid deposits, if the spray headers can be designed to be self-supporting, meaning that the internal support members for the headers are not used. There are a number of alloys available that exhibit good corrosive properties and high tensile strength which have been used for self-supporting headers. Depending on market conditions, these materials may also be cost-competitive with the lower cost polymer materials such as FRP. Depending on the size of the absorber and spray headers, an FRP spray header may also be designed to be self-supporting.

## **Double Hollow Cone Spray Header**

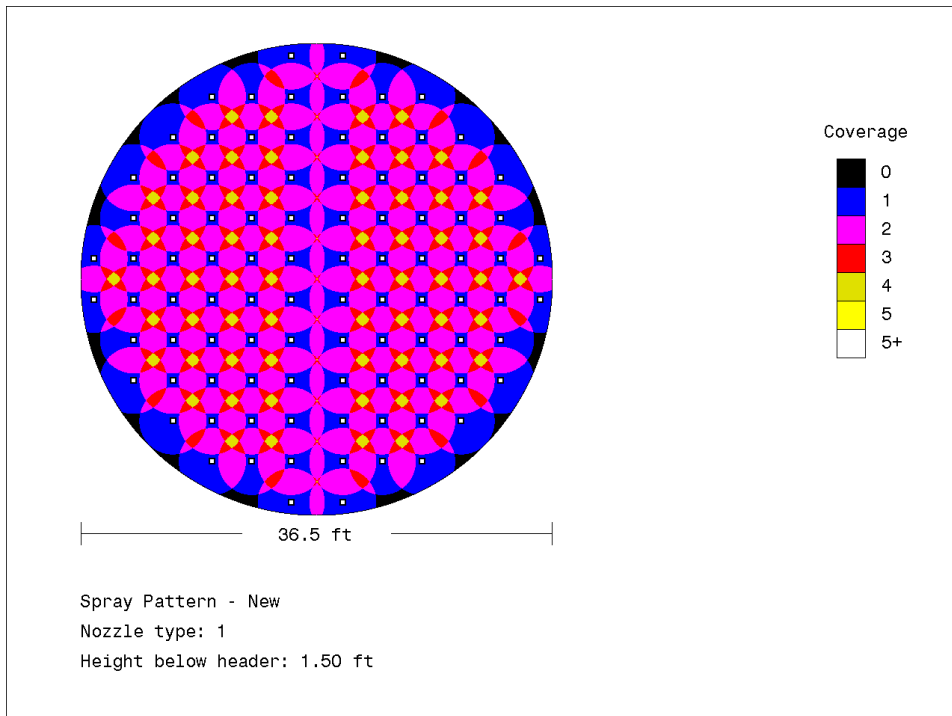
Side-by-side double hollow cone (DHC) spray nozzles are a relatively new technology which has been demonstrated, in a number of projects, to significantly enhance the SO<sub>2</sub> removal efficiency of the scrubber compared to using single hollow cone (SHC) spray nozzles. The removal enhancement is a result of the interactions and collisions that occur between the spray droplets from the two side-



**Figure 1: Recycle Slurry Spray Coverage for an Older FGD System**



**Figure 2: Spray Coverage Following Upgrade**



---

by-side spray nozzles. This is referred to as secondary atomization and results in generation of finer droplets along with replenishing the alkalinity on the surface of the droplets.

The amount of enhancement that is achieved is illustrated in the figure presented in Figure 3. This figure presents a comparison of predicted SO<sub>2</sub> removal efficiency, as a function of L/G, for both conventional SHC and the side-by-side DHC spray nozzles in a limestone, forced oxidation scrubber. The design assumptions used for the predictions, which were done using the EPRI FGDPRIISM process simulation model, included an inlet SO<sub>2</sub> concentration of 5.0 lb/MMBtu, a reagent stoichiometric ratio of 1.04, a chloride concentration of 20,000, and no performance enhancing additives. As shown in the figure, use of the DHC spray nozzles resulted in an enhancement of over 10% at lower L/G levels and moderate removal efficiencies to about 4% at high L/G and removal efficiency levels. The accuracy of the predicted removal efficiencies for both the SHC and DHC spray nozzles were confirmed in a project recently completed which involved the replacement of SHC spray nozzles with DHC spray nozzles. The project allowed a direct comparison of the performance of the two types of spray nozzles because the spray nozzle replacement was the only work performed.

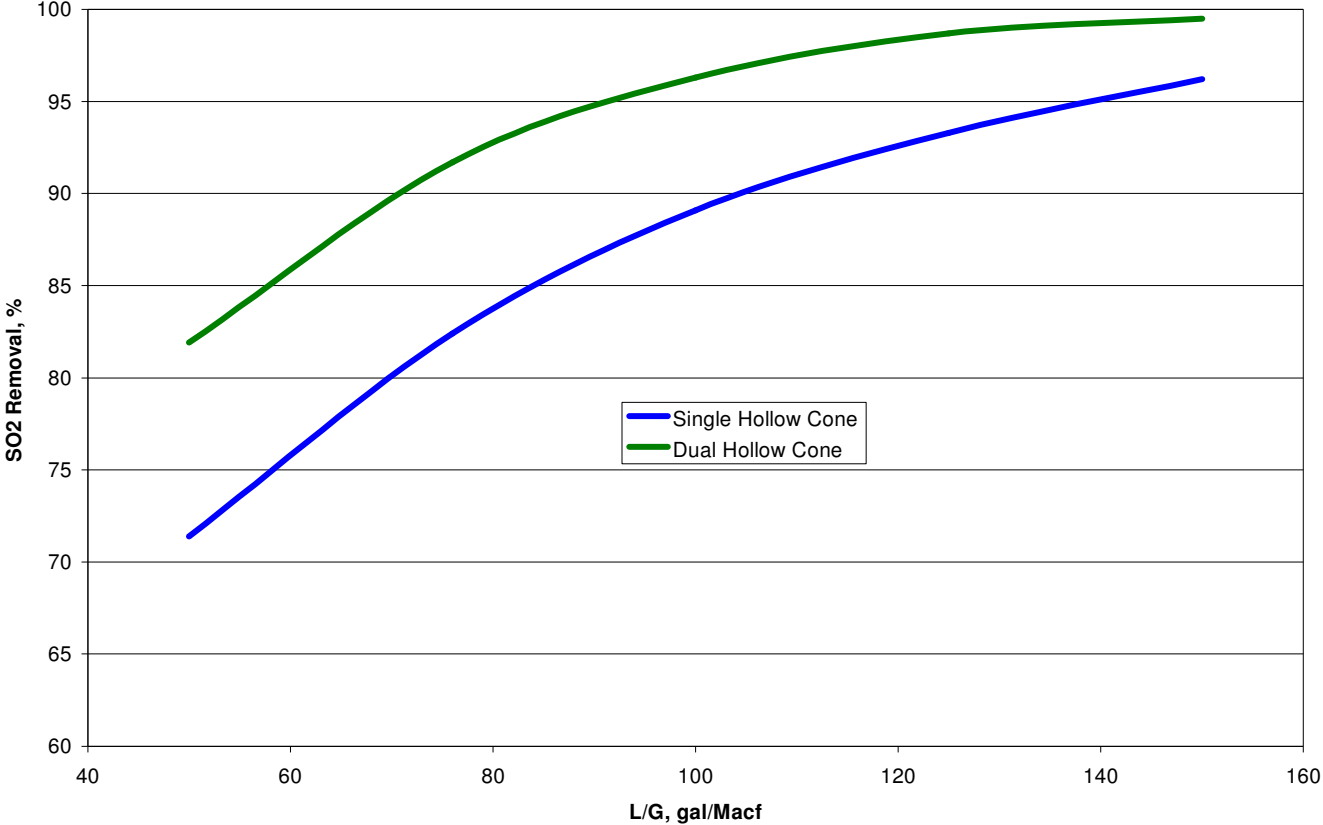
## **Liquid Distribution Rings**

Inherent in the design of any absorber which circulates and sprays slurry to provide the alkalinity required to absorb an acidic gas constituent is a region of low spray density and high gas flow along the absorber walls. The reduction of spray density in this region is the result of spray that impinges on and flows down the wall as well as the tendency in the design for nozzle placement to locate the nozzles away from the walls to minimize direct wall impingement and possible damage. The increase in gas flow in the vicinity of the wall is a direct result of the lower spray density. Liquid distribution rings (LDR) or wall rings were developed to correct this problem by both reintroducing the slurry that is running down the absorber walls back into the gas flow, and moving the gas that is running along the walls into the spray zone. This is illustrated in the CFD modeling graphic shown in Figure 4. CFD modeling is often used to determine the optimum location and placement of the wall rings. The number of projects that have successfully used wall rings to boost removal efficiency has become substantial over the last few years. The experience includes both round and rectangular absorber towers as well as large and small towers. Small round towers and rectangular towers tend to benefit the most from installation of wall rings. This is because the area of low spray density and high gas flow represent a higher percentage of cross-sectional area in a small tower compared to larger towers. The rectangular towers benefit because the corners represent a particular challenging area to obtain the dense spray coverage required for good performance. The addition of wall rings will result in a small increase in pressure drop, on the order of 0.1 to 0.4 in-wc, depending on the number of wall rings and volume of gas flow. This increase LDR is significantly lower than the increase imposed by the addition of a tray, which is discussed next.

## **Trays**

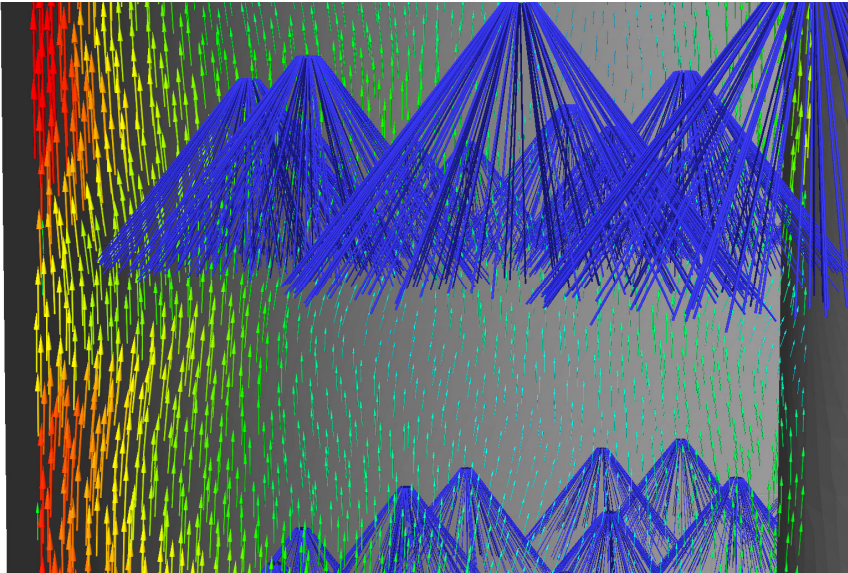
Counter flow trays are another tool available that can be added to an older scrubber to increase removal efficiency. A tray can effectively offset the additional L/G (additional slurry recycle flow)

Figure 3: Predicted Removal for SHC and DHC Spray Nozzles as a Function of L/G

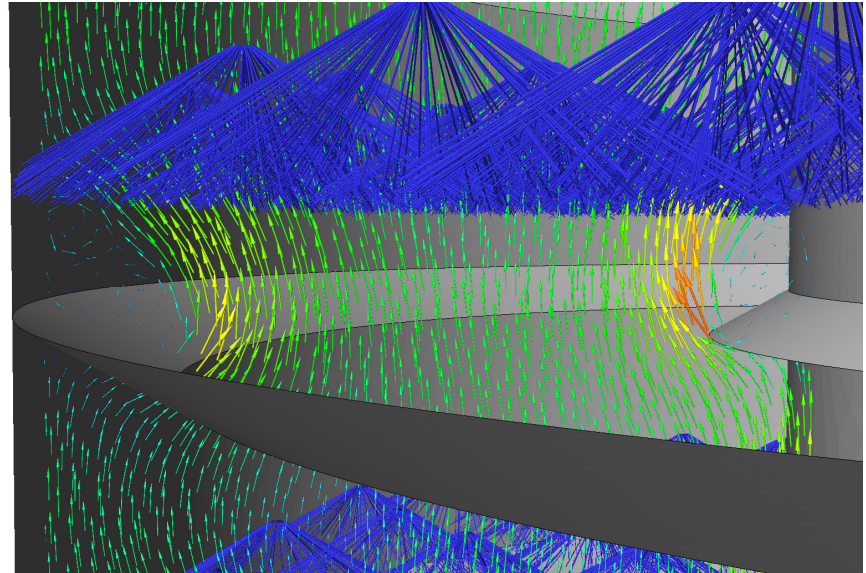


---

**Figure 4: CFD Modeling Showing Gas Streamlines Before and After Upgrade With LDR**



**Spray Tower Without LDR**



**Spray Tower With LDR**

---

that would be required to increase removal efficiency for a system. In some cases, the benefit obtained from the addition of a tray is equivalent to what would be gained from adding an additional spray level. A secondary benefit from a tray is the improvement in gas distribution within the absorber as a result of the back-pressure imposed by the tray. A uniform gas distribution is a key requirement for obtaining high removal efficiency, and good performance of the mist elimination system. There is a trade-off, however, between the advantages of a tray and the fact that a tray will increase the pressure drop of the system. The exact amount is a function of design and operating conditions but is typically on the order of 1.5 to 2.5 in-wc. The increased pressure drop and the affect on fan capacity must be considered in an evaluation of a tray for a scrubber upgrade.

The design of a tray, in terms of hole size, number of holes and pressure drop, can affect the performance and reliability of the scrubber, especially if tray rain, the liquid flowing through the tray, is to be used to cool and saturate the inlet flue gas. If the tray, or for that matter the spray header supplying liquid to the tray, is not designed correctly, the liquid coverage and liquid flow beneath the tray may be inconsistent. This will not only hurt the tray performance, it will also make it difficult to cool and saturate the flue gas before the gas reaches the tray. This type of operation can result in fairly significant scaling on the tray due to the presence of a wet-dry interface at the tray. This phenomenon is illustrated by the CFD modeling results shown in Figure 5 for a project that was recently completed. The graphic on the left shows the temperature profile of the scrubber at the start of the project. At this time, the plant was experiencing fairly severe scaling problems on the tray and throughout the absorber. The temperature profile for a re-designed tray is shown on the right. Operation with a new, re-designed tray was successful in solving the scaling problem.

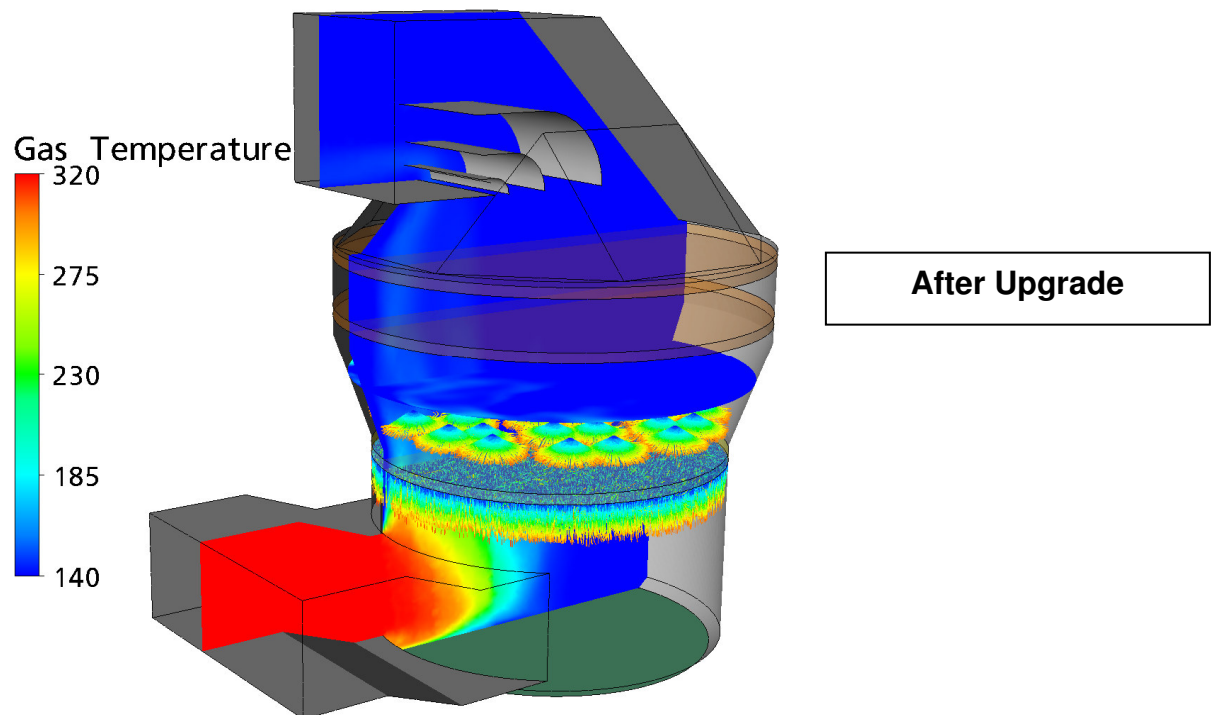
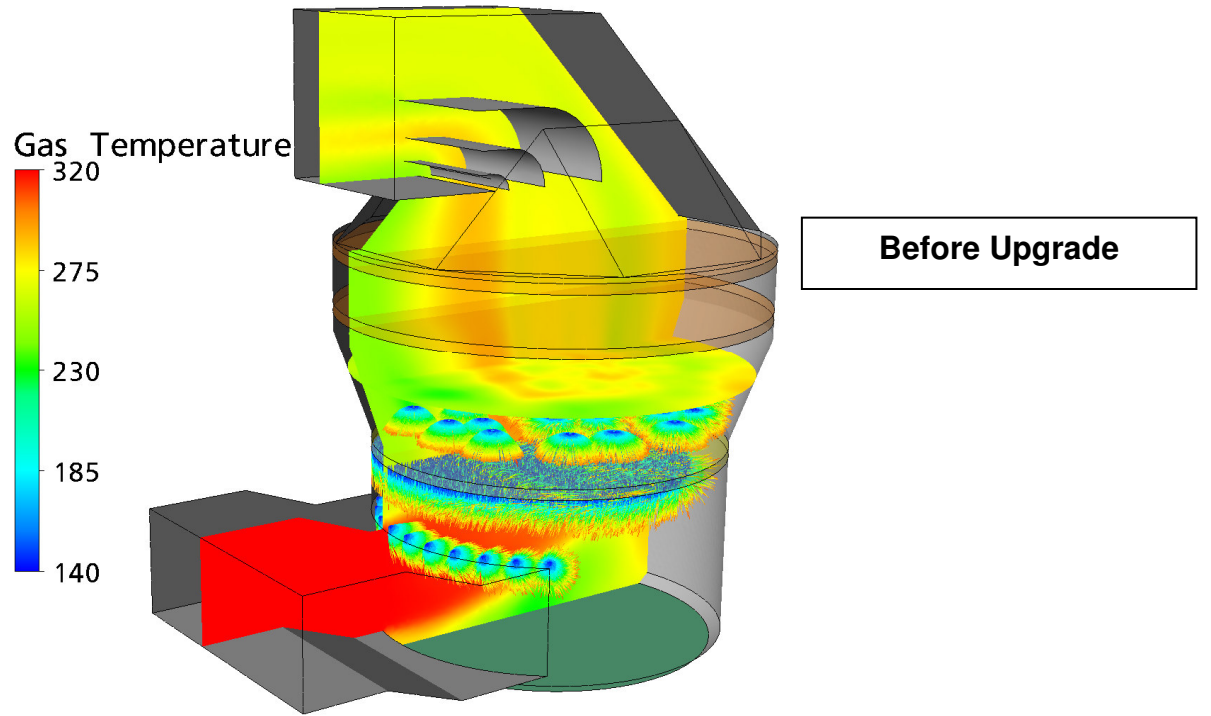
## **CFD Modeling**

Computational fluid dynamics (CFD) flow modeling is a powerful design tool used at the front-end of an FGD upgrade project to aid in identifying and evaluating the best options for the upgrade. It is also useful in identifying the aspects of the original system design that limit performance, such as poor gas-liquid contact or poor gas distribution, or cause process or operational problems such as solids deposition or poor mist eliminator performance. CFD can be used to predict and evaluate system performance for such parameters as pressure drop, gas velocity profile, and mist eliminator liquid loading following any modifications to the system. The model can analyze flow patterns and interactions within the FGD system for both gas and liquid phases, with two-way coupling of heat, mass and momentum transfer between the phases. Some examples of how CFD modeling is used for FGD upgrade projects are presented in the paragraphs below.

### ***Analysis of Gas Distribution at the Absorber Inlet***

An even and uniform gas distribution at the absorber inlet, and a balanced gas distribution between operating absorber modules, for FGD systems with multiple modules, are important requirements for efficient FGD performance. CFD modeling is commonly used to analyze the gas flow distribution at the inlet and between modules, as well as being used to design and evaluate flow control devices to correct flow maldistribution problems when they are present. These concepts are illustrated in Figures 6 and 7. Figure 6 presents the FGD inlet flue gas flow and slurry droplet flow profile for an existing multi-module FGD system. The high gas velocity region on the right side of the middle

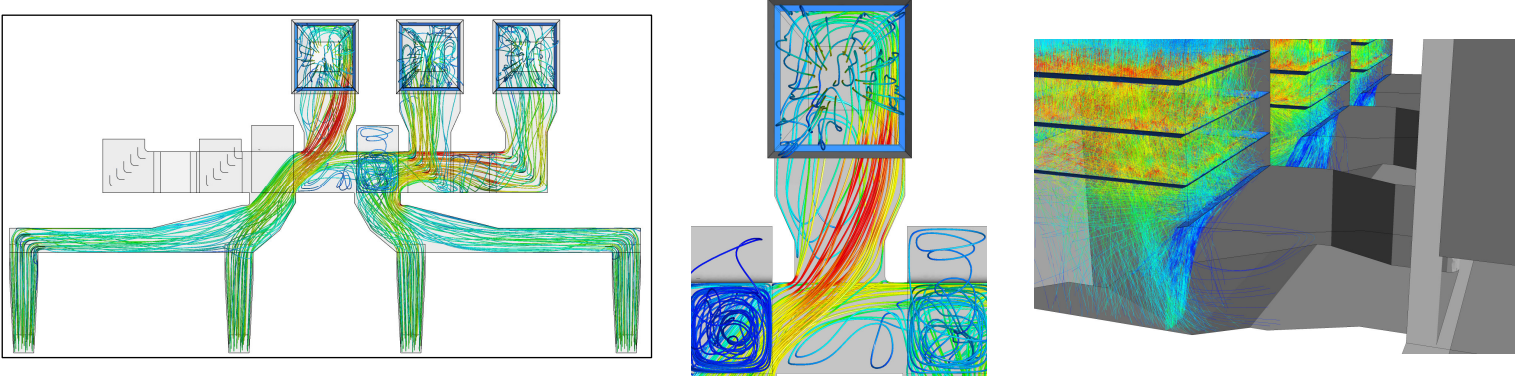
**Figure 5: Gas Temperature Profile Before and After Tray and Spray Header Redesign**



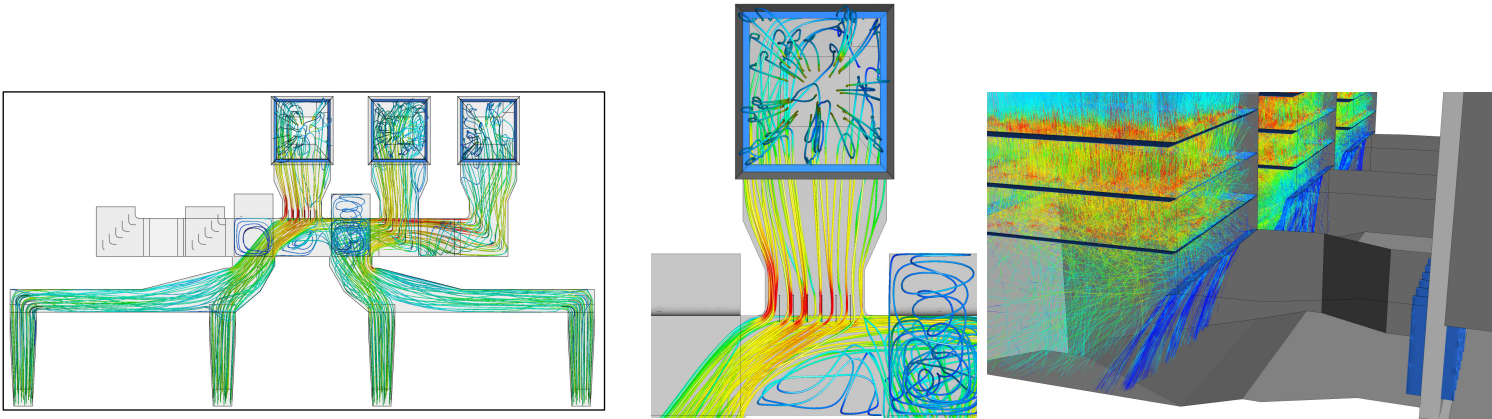


---

**Figure 6: Gas and Slurry Streamlines at Absorber Inlet Without Flow Control Device**



**Figure 7: Gas and Slurry Streamlines at Absorber Inlet With Flow Control Device**



---

absorber module is clearly evident. This high velocity region is caused by a poorly-designed inlet plenum which allows gas to take a line of sight path into the module. The result is a significant level of reverse gas flow (recirculation) at the inlet duct, in addition to increased system pressure drop, and an uneven gas distribution between modules. At the time this modeling was performed, the plant was experiencing a significant level of inlet duct solid deposition in this module. The slurry droplets that are being pulled into the inlet duct as a result of the recirculation are evident in the figure. CFD modeling was used to identify and evaluate a fix for the problem, installation of a flow straightening control device at the entrance to the inlet duct. The improved gas velocity profile and elimination of slurry recirculation into the inlet is evident in Figure 7. The flow control device allows the gas to use the entire inlet duct cross section, reducing the gas velocity at the inlet, decreasing pressure drop, and eliminating or significantly reducing gas recirculation.

### ***Mist Eliminator Performance***

The multi-phase CFD model is useful in evaluating liquid loading and gas velocity profiles at the front of a mist eliminator and can be used to identify problems related to high velocity break-through or excessive liquid loading. CFD modeling can also be used to help design and evaluate the performance of devices that can be installed to improve the performance of a mist eliminator such as a bulk entrainment separator. Figure 8 presents the CFD model prediction for the liquid flow profile upstream of the mist eliminator in a horizontal scrubber. The significant reduction in liquid loading at the front of the mist eliminator that results from installation of a bulk entrainment separator is clearly evident in the CFD graphic on the right.

### ***Reaction Tank and Air Sparger Performance***

CFD can be used to characterize reaction tank performance including mechanical and air agitation configurations. Performance is evaluated based on the model predictions for liquid residence time and distribution, floor velocity profile, air entrainment rate into pump suctions, air and reagent feed mixing and residence time, and air-liquid contact. An example is illustrated in Figure 9 which presents the model prediction for air sparger bubble trajectories in a reaction tank before and after the relocation of a liquid return line. Prior to relocating the line, the model predicts that the air bubble plume will be pushed to the far wall of the tank allowing the air bubbles to escape with little air-liquid contact (graphic on left). The improved air bubble plume profile and air-liquid contact is evident in the graphic on the right associated with relocating the return line. Similar to this is Figure 10 which shows the liquid velocity profile for a mechanically-agitated tank prior to conversion to forced oxidation, and the liquid velocity profile and air bubble plume profile following the conversion.

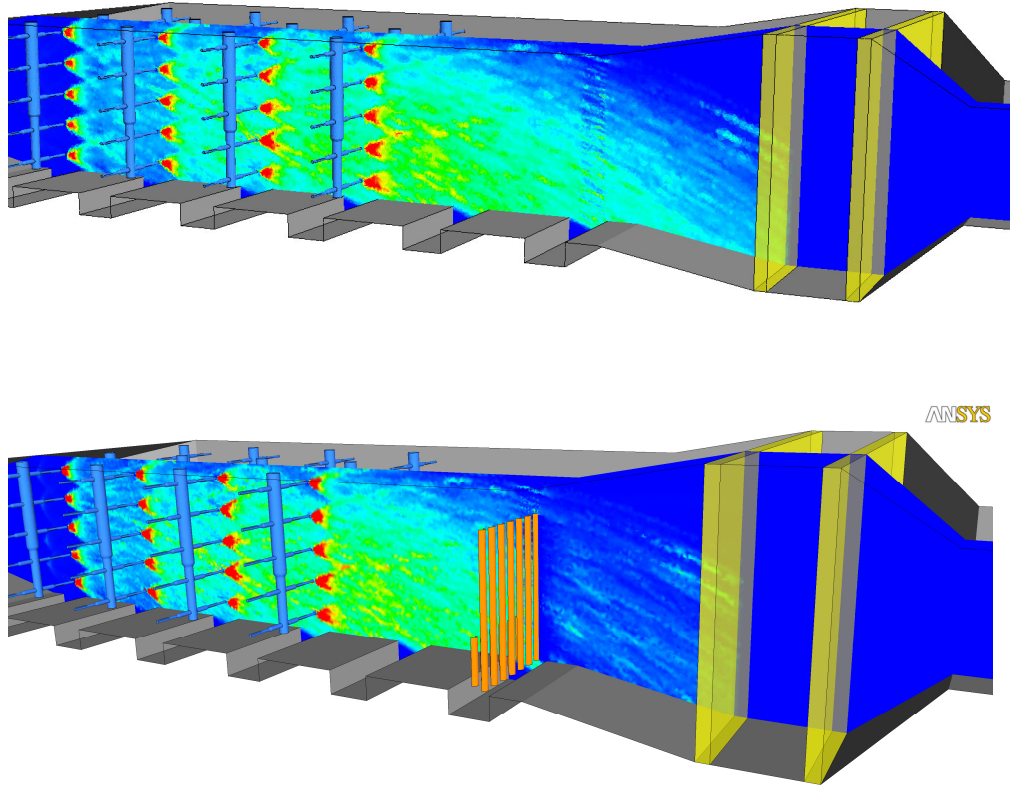
## **Process Simulation Modeling**

A major computational tool used by URS in designing and evaluating FGD system upgrades is FGDPRISM (Flue Gas Desulfurization Process Integration and Simulation Model). FGDPRISM is a process simulation model that was developed by URS under contract to EPRI. A chemical equilibrium program, ACAPP (Aqueous Chemical And Physical Properties), that was developed internally, is also used for predicting aqueous solution properties such as SO<sub>2</sub> vapor pressure, and

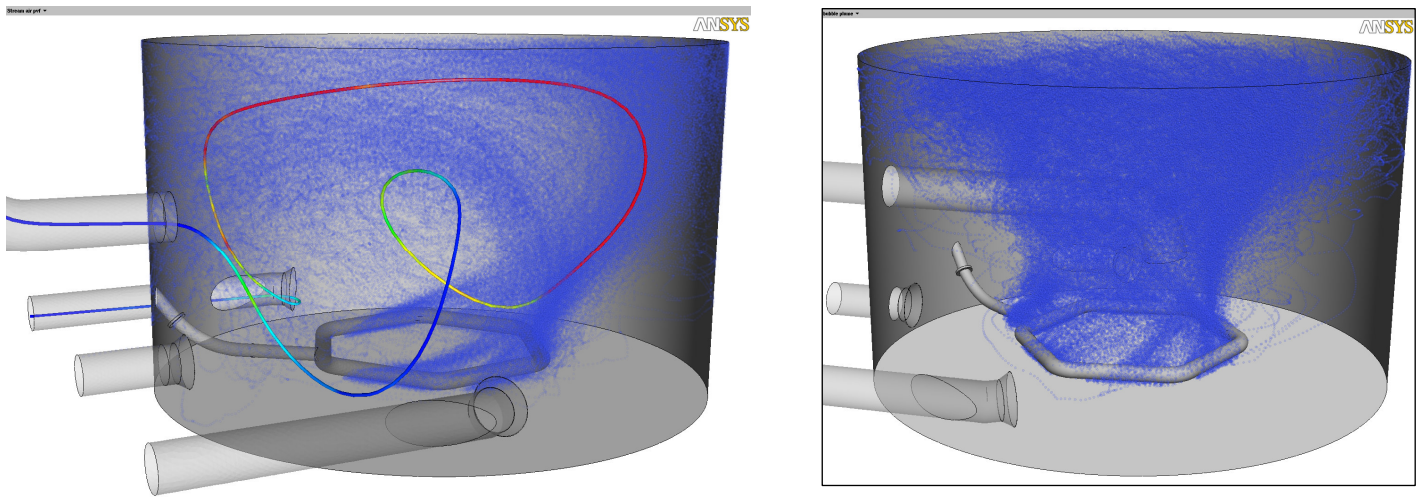


---

**Figure 8: Change in Liquid Loading at Mist Eliminator With bulk Entrainment Separator**

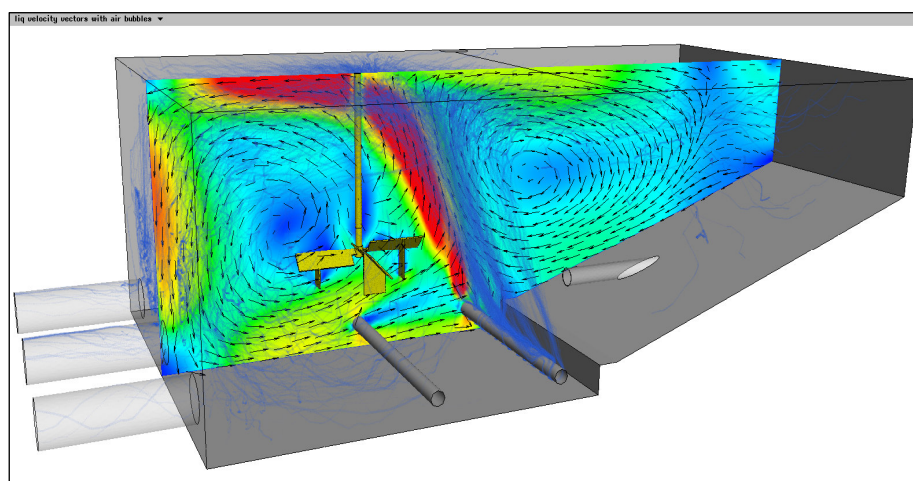
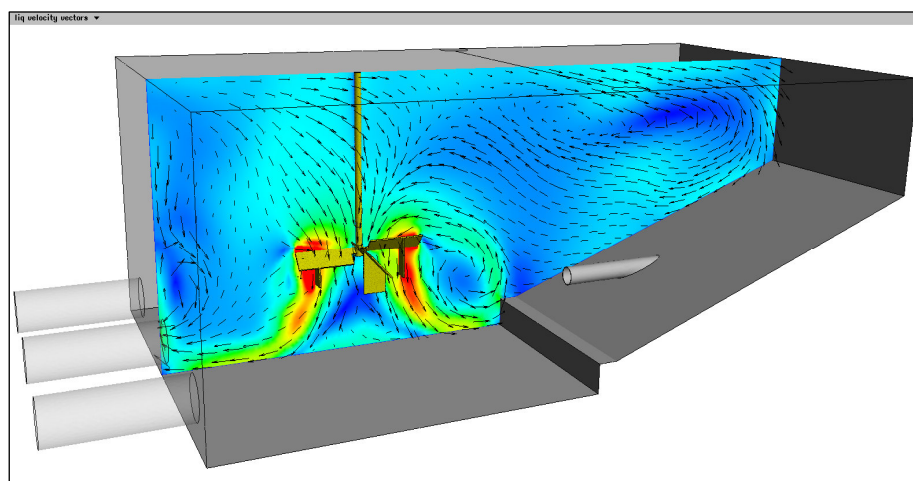


**Figure 9: Examples of Bad and Good Air Sparger Bubble Dispersion**



---

**Figure 10: Improved Liquid Dispersion Following Conversion to Forced Oxidation**



---

gypsum scaling potential. The FGDPRISM model is a first-principles model that can predict FGD system performance, given inputs that define the physical dimensions of the system, as well as operating characteristics, such as L/G, limestone grind, reagent ratio, composition, and reactivity, inlet flue gas or coal parameters, nozzle characteristics (droplet size and exit velocity), makeup water composition, and others. A critical input to FGDPRISM is the set of mass transfer coefficients (implemented as “film thicknesses” in the model) for SO<sub>2</sub> vapor-liquid mass transfer calculations. On an ongoing basis, the correlations for the mass transfer coefficients are reviewed and refined as new data is obtained for such parameters as flue gas velocity, nozzle type, mass transfer devices and other variables. Results are useful in predicting performance levels that can be achieved associated with a proposed modification as well as evaluating tradeoffs for upgrade options in terms of cost and benefits.

To illustrate the accuracy of FGDPRISM predictions, Figure 11 shows a plot of an actual FGD system performance as a function of DBA concentration. As shown, the model predictions are very good at low DBA concentration, and somewhat conservative at the higher DBA values. However, the tests that were performed at the higher DBA concentrations had a lower inlet SO<sub>2</sub> concentration than was used for the prediction curve and, as would be expected, the actual performance is greater than predicted. This model accuracy has been shown to hold up for a variety of system types (tray towers and spray towers), spanning a wide range of coal sulfur levels, forced oxidation and inhibited oxidation systems, and a wide range of absorber gas velocities.

The capability of FGDPRISM to take into account all operating variables is critical to optimizing the upgrade options for a particular system. For example, the model can accurately predict scrubber performance over a range of fuel properties such as sulfur level, to provide information for current coal sulfur level and possible future levels. Figure 12 illustrates how different coal sulfur levels can dramatically influence system performance, and can result in significantly different levels of additive required to maintain removal. The modeling tool must also be capable of accurately evaluating tradeoffs for various upgrade options, for example tray tower versus spray tower. This comparison is illustrated in Figure 13. The model is also useful in optimizing the tray design in terms of evaluating removal performance and the impact of the tray on system pressure drop.

In addition to evaluating upgrade options, there are other factors that must be evaluated to determine the optimum upgrade scenario. These include such things as the amount of excess limestone to use (limestone utilization or reagent ratio), the amount of SO<sub>2</sub> that is absorbed per liter of scrubbing slurry as it passes through the absorber, gypsum and other species scaling potential, and gas velocity considerations. The FGDPRISM model and ACAPP programs are used in evaluating these alternate factors. The amount of excess limestone not only affects the SO<sub>2</sub> removal performance, but can be an issue in the ability of the system to produce wallboard quality gypsum. The FGDPRISM model performs material balances that take into account the amount of inerts from fly ash and from the limestone, as well as the amount of excess limestone that reduce the quality of the product gypsum with respect to meeting wallboard specifications. Increased excess limestone in the circulating slurry reduces the mass transfer requirements of the absorber (tray pressure drop, or L/G) but too much can result in the product gypsum not meeting wallboard specifications. The FGDPRISM model is used to determine how much excess limestone can be used, and then what the absorber mass transfer requirements are for that level of excess limestone.

Figure 11: Comparison of Predicted and Actual Removal over Range of DBA Levels

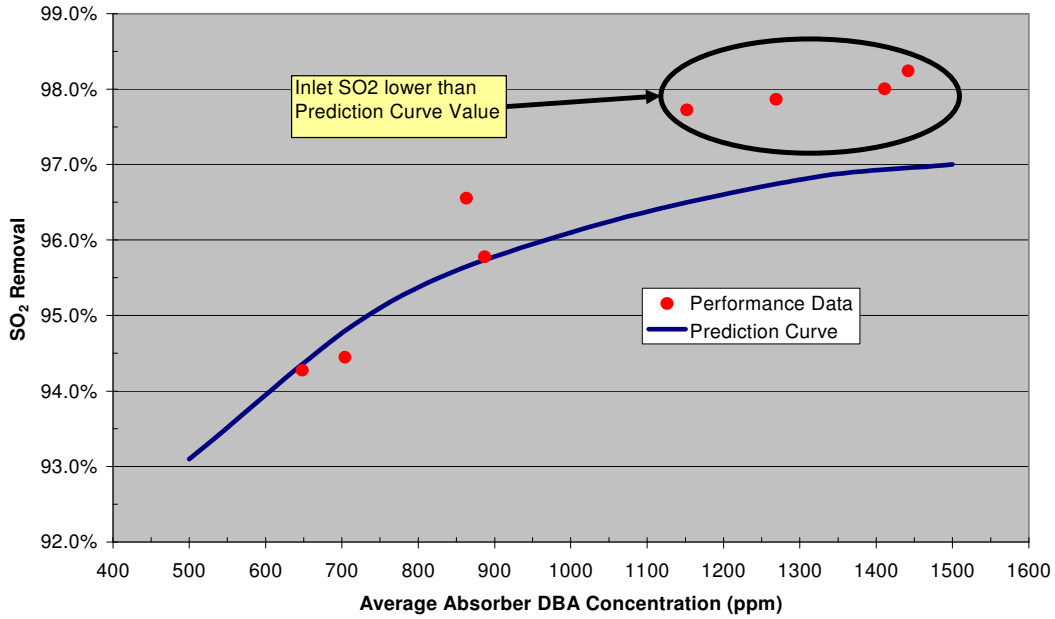


Figure 12: Comparison of Predicted and Actual Removal over Range of DBA

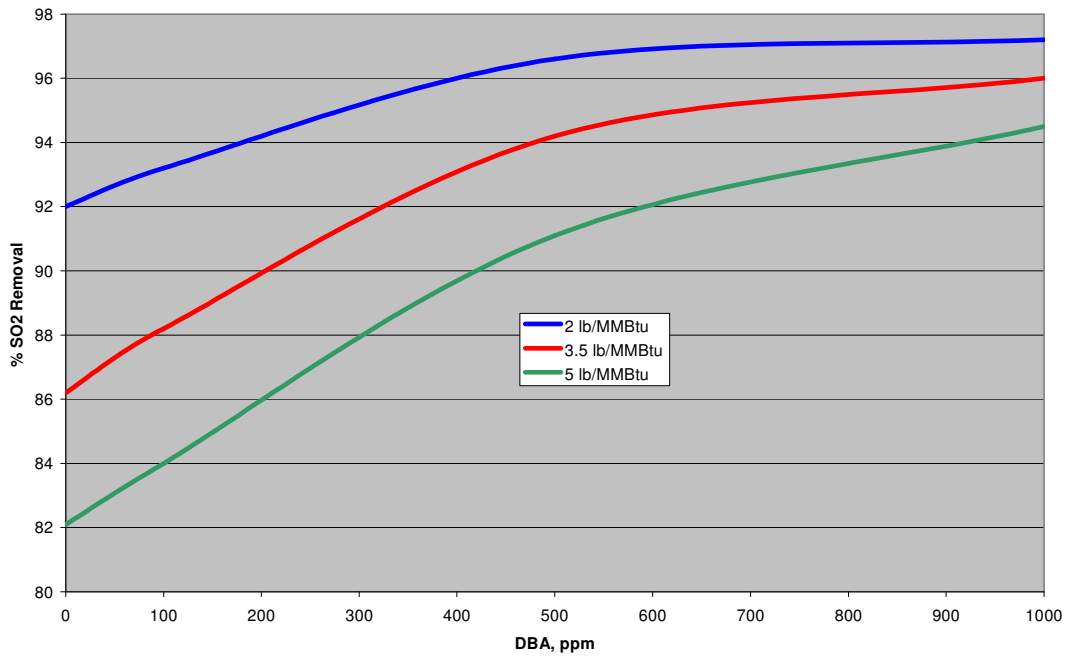
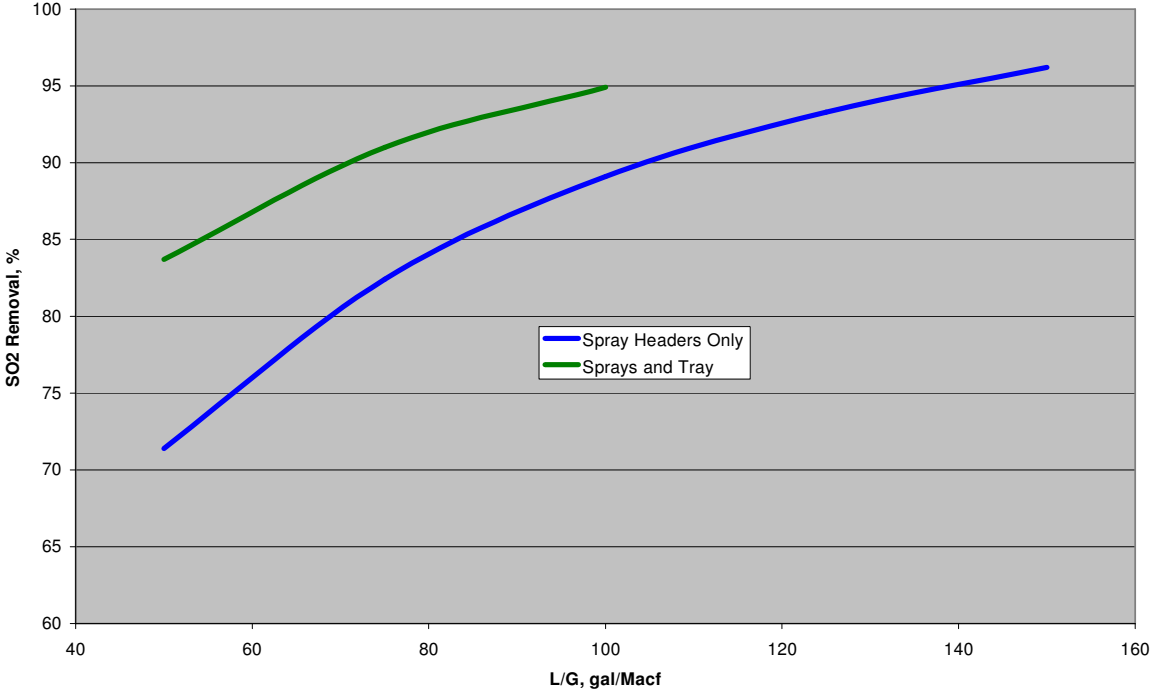


Figure 13: Comparison of Removal Performance for Spray and Tray Tower



---

The amount of SO<sub>2</sub> absorbed per liter of scrubber slurry (pickup per pass) can have a significant impact on reliability. Large quantities of additive can be used to minimize L/G, but if the pickup per pass is too large, the gypsum relative saturation ( $RS_{GYP}$ ) can become too large in the absorber resulting in scale formation on equipment surfaces. Both FGDP<sub>PRISM</sub> and ACAPP can calculate the gypsum relative saturation as a function of pickup per pass allowing tradeoffs to be evaluated between a lower cost upgrade option, such as use of an additive, and system reliability.

Another consideration in predicting scrubber performance is the gas velocity in the absorber. Some upgrade projects may involve treating additional gas by closing a bypass damper, or combining multiple units into a single existing FGD system. These options will result in a higher gas velocity in the absorber. While a higher gas velocity improves the mass transfer efficiency of the absorber and the pressure drop of a tray, it also lowers the L/G and can cause problems in the mist eliminators. The process model is useful in evaluating these various effects to arrive at an accurate prediction for performance.

## **CASE STUDY – NRG LIMESTONE UNIT 1 AND 2 FGD UPGRADE**

URS was contracted in the fall of 2007 to upgrade and make improvements to the NRG Energy (NRG) Limestone Unit 1 and 2 FGD systems located near Jewett, Texas. The two units at the plant, rated at 910 and 925 MW respectively, fire a mixture of Texas lignite and PRB fuel and include a cold-side ESP for removal of fly ash and a Combustion Engineering (CE) wet limestone FGD system, consisting of five absorber modules per unit, for removal of SO<sub>2</sub>. The FGD system originally was designed to dewater slurry bleed from the scrubber in a thickener followed by a drum filter. The dewatered calcium sulfite scrubber sludge was then mixed with fly ash and lime for final disposal in a landfill. At the beginning of the project, the FGD system was using about 2,000 ppm of an organic acid removal enhancement additive (DBA) and was capable of removing about 92% of the inlet SO<sub>2</sub>.

The key objectives of the FGD upgrade project included:

- Modifying the scrubber absorbers to increase the SO<sub>2</sub> removal efficiency of the system and eliminate the need for DBA additive;
- Redesigning the mist eliminator wash system to improve the cleanliness of the mist eliminators
- Replacing the mist eliminators with an improved design made out of polysulfone;
- Converting the FGD process from inhibited oxidation to forced oxidation producing a wallboard specification gypsum byproduct; and
- Improving the performance of the primary and secondary dewatering systems to produce a drier byproduct suitable for gypsum wallboard production.

A number of modifications were completed to achieve these objectives including redesigning and replacing the spray headers, adding high efficiency side-by-side double hollow cone (DHC) spray

---

nozzles, adding liquid distribution rings (LDR), replacing the existing retractable mist eliminator wash lances with a fixed-grid wash system, adding two-stages of new polysulfone mist eliminators, and adding a new mist eliminator wash tank for Unit 2 and converting an existing water tank so it could be used for mist eliminator wash service for Unit 1. This was done to allow the wash water supply to be segregated from the scrubber make-up water supply and allow the mist eliminators to be washed with fresh water.

Modifications were also made to convert the process from inhibited oxidation to forced oxidation. These included installing three new 1250 HP multistage air blowers rated at 14,500 SCFM @ 27.7 psia, five lance-style air spargers pipes in each module to supply oxidation air to the reaction tank; and flow meters and control valves at each module to balance the air flow between operating modules.

Changes to the primary and secondary dewatering systems were required to be able to handle the faster settling gypsum scrubber solids and produce a dryer final byproduct material suitable for gypsum wallboard production. Originally the plant was constructed with three 180' thickeners with one operating per unit and one common spare. Following the upgrade, it was determined that only one thickener was needed for material from both of the units. As a result, one of the three thickeners was abandoned and the other used as a spare. It was also determined that only two of the four original drum filters would be required and would be upgraded to produce a filter cake with a moisture level less than 14%. In addition, two KMPT vertical centrifuges, each capable of processing 12 ton per hour of gypsum byproduct with a moisture level of less than 10% were installed. Changes that were made included replacing the three constant speed thickener underflow pumps per thickener with two VFD driven underflow pumps, making piping modifications to allow each of the thickeners to be fed from either unit, replacing the drum filter rubber coated vat agitator and drive mechanism with a heavier duty alloy agitator, replacing the constant speed drum drive with a VFD and inverter duty motor, adding new bridge blocks and air side throttling valves, and adding a new cake wash system, which was supplied by vacuum pump seal water.

## **Project Results**

The performance of the upgraded FGD system was evaluated during an initial and final performance test of each unit. A summary of the test conditions and results associated with the scrubber performance is presented in Table 1. As shown, tests for removal performance and system pressure drop were performed with either three spray levels in service, which is the design number of spray levels, or two spray levels. All of the tests were performed with four of the five available modules in operation. The initial Unit 2 test also included testing with five modules and either three or two spray levels in service. No DBA was used during any of the tests.

The design SO<sub>2</sub> removal efficiency that was predicted following the upgrade for four module and three spray levels operation ranged from 92.2% to 93.7%, depending on the absorber recycle slurry flow, which was measured during each test. As shown in the data summary, the removal efficiency that was measured for this condition far exceeded the predicted design values ranging from 96.3% to

**Table 1: Summary of Performance Test Conditions and Results for NRG Limestone FGD Upgrade**

	Unit:	1	1	1	1	1	2	2	2	2	2
Test ID		Initial	Initial	Final	Final	Final	Initial	Initial	Initial	Initial	Initial
Date		3/31/2009	3/31/2009	11/3/2009	11/3/2009	11/3/2009	5/5/2009	5/5/2009	5/5/2009	5/5/2009	5/5/2009
Unit Load	MW	895	900	881	879	879	907	912	911	906	875
Inlet SO <sub>2</sub>	lb/MM Btu	2.0	2.0	1.7	1.7	1.7	1.9	1.9	2.0	2.1	1.5
Inlet SO <sub>2</sub>	ppmd	794	794	707	707	707	722	724	744	776	656
Number Modules I/S		4	4	4	4	4	5	5	4	4	4
Number of Spray Levels I/S		2	3	2	3	3	2	3	2	3	2
Treated Gas Flow Per Module	acfm	712,650	712,650	712,650	712,650	712,650	570,118	570,118	712,650	712,650	712,650
Total Recycle Flow <sup>a</sup>	gpm	32,920	47,305	32,920	48,735	48,735	30,823	45,245	30,823	45,245	26,140
L/G	gal/1000 ACF	46	66	46	68	68	54	79	43	63	37
pH		5.4	5.4	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Limestone Stoichiometry		1.03	1.03	1.03	1.03	1.03	1.08	1.08	1.08	1.08	1.02
Sulfite Oxidation	mol %	99	99	99	99	99	99	99	99	99	99
Absorber Recycle Slurry Solids	wt%	2.5	2.5	8.7	8.7	8.7	2.6	2.6	2.8	2.8	5.0
FGD System Pressure Drop	in-w.c.	5.50	6.20	5.39	6.04	6.04	4.60	5.20	5.90	7.00	5.49
Removal Efficiency	%	94.7	96.3	94.7	98.0	98.0	97.2	98.5	93.2	97.8	92.3

<sup>a</sup> Design slurry recycle flow is 54,300 gpm



---

98.0%. In fact, the measured removal with two spray levels in operation exceeded the three spray level predicted removal ranging from 92.3% to 94.7% meaning that upgrade design removal can be achieved with only two pumps in operation. Turning off a recycle pump is worth about 1.5 MW in terms of reduced power consumption. The removal efficiency for five module operation that was measured during the testing was 98.5% for three spray level operation, and 97.2% for two spray level operation. These values compare to the design removal efficiency for five modules and three spray levels operation of 94.2%.

FGD system pressure drop was also evaluated during the tests. Prior to beginning the upgrade work, an increase of 2 in-wc over current pressure drop was estimated for full load operation with four modules and three spray level in service as a result of the re-designed spray headers, with increased spray density, and the addition of the liquid distribution rings. The additional 2 inches of pressure drop were expected to increase the total FGD system pressure drop to 6 in-wc. The testing indicated that the measured pressure drop at full load for the Unit 1 scrubber was slightly higher than the predicted value of 6 inches. The measured pressure drop for Unit 2 was about 1 inch higher than the predicted value. It is unclear why the Unit 2 pressure drop runs higher than the Unit 1 pressure drop even when the higher load rating for Unit 2 is taken into account. Possible factors may include more air in-leakage and a higher gas volume, and solids deposition in the inlet duct that was observed during a recent outage. It should be noted that for either of the units, operation with two spray levels in service or with five modules in service results in a pressure drop significantly lower than the design value of 6 inches.

The scope of the project also included the re-design and replacement of the absorber mist eliminators and mist eliminator wash systems. Prior to the upgrade, the mist eliminators were washed with a retractable lance type wash system that was a common feature of early CE scrubbers. The experience at Limestone and at other utilities that have used this wash system is that it is not capable of keeping the mist eliminators clean over a time period longer than a few months. The new wash system that was installed was a fixed-grid design capable of operating at a wash intensity and wash duration that is consistent with modern scrubbers. Observations of the mist eliminators after more than six months of operation indicated that they were clean and free of solid deposits. Recently, however, the plant has had to change to a poorer quality wash water to manage plant water supplies and this has resulted in some solid deposits and pluggage that was not observed earlier.

The quality of the gypsum byproduct, as determined by chemical tests for moisture levels, purity, sulfite oxidation and chlorides, are evaluated on a routine basis by the Limestone plant laboratory. The data from the lab indicate that the gypsum meets or exceeds all of the design parameters and is acceptable for wallboard manufacturing. At times, moisture levels have been as low as 6% for material dewatered by the centrifuges and 12% for material dewatered by the modified drum filters compared to the design values of 10% and 15% respectively.

## **SUMMARY**

Utilities will face a number of challenges in the next few years to reduce SO<sub>2</sub> emission levels and emission levels for a number of other pollutants. To efficiently and cost-effectively do this, they will need to increase the performance and reliability of their FGD systems, as well as making changes to

---

allow these systems to increase their capability to remove and control additional pollutants besides SO<sub>2</sub>. At the same time these utilities must reduce operating costs and improve unit reliability and capacity factors to remain competitive in the marketplace. A new FGD system will likely meet these performance and reliability objectives, however the cost of a new FGD system has dramatically increased over the last few years, associated with significantly higher material and equipment costs, and will likely be even more expensive in the future. Utilities who have already made a significant capital investment in an older FGD system cannot afford the costs required to replace their system to be able to comply with the new performance requirements.

Fortunately, technologies now exist to upgrade an older FGD system to the levels required to meet the new performance and reliability requirements. This upgrade can be done at a fraction of the costs of replacing the older FGD system. This paper has described and discussed a number of these technologies and has presented a case study to demonstrate how these technologies were applied in an upgrade of an older FGD system. The experience of applying the technologies described in the paper has shown that no one technology can be applied universally to solve process problems and upgrade performance. Each new project offers unique problems and design challenges and requires a unique solution. It is the innovative application of a number of technologies, as well as a deep understanding of the factors that determine and limit the performance and reliability of a system, that have made it possible to successfully upgrade and improve older FGD systems.



POWER    INFRASTRUCTURE    FEDERAL    INDUSTRIAL & COMMERCIAL

URS is a full-service organization providing engineering, procurement, project management, and construction services worldwide with annual revenues exceeding \$10 billion. URS has approximately 45,000 employees in a network of offices in major cities in the Americas, Asia-Pacific, the Middle East and Europe. Our broad-based expertise is a valued resource for federal, state, and local governmental agencies, as well as Fortune 500 and other private industry clients worldwide. The *Engineering-News Record* has ranked URS as one of the top three design firms for the past decade.

URS Corporation  
600 Montgomery Street  
26th Floor  
San Francisco, CA 94111

[www.urscorp.com](http://www.urscorp.com)