POWER Engineering

# Increasing Wet FGD $SO_2$ Removal Efficiency

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## 1. A Dual Flow Tray at its 24-month Inspection


*Source: Amec Foster Wheeler*

New $SO_2$ emission regulations in the U.S. and EU require some utility and power producers to retrofit new flue gas desulfurization (FGD) units to existing plants. Amec Foster Wheeler's Dual Flow Tray Technology can provide a cost effective solution for both new and upgrades to existing wet FGD plants to achieve new these new emission standards.

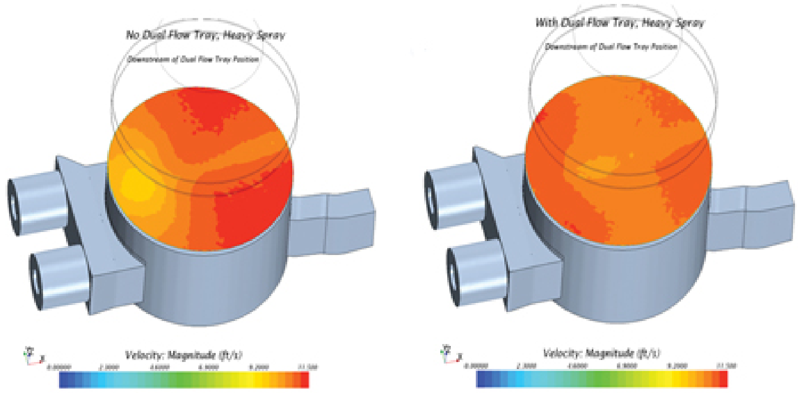
Acid gas removal efficiency (mainly $SO_2$) in a power plant's limestone-based wet flue gas desulfurization (WFGD) system absorber is governed by two processes: the absorption of $SO_2$ via gas/liquid contact and the rate at which the scrubbing liquor neutralizes the liquid phase acids collected. Improving either process generally enhances $SO_2$ capture.

The rate of $SO_2$ absorption into the absorber liquor is controlled by the mass transfer coefficient, the surface area available for mass transfer, and the difference between the $SO_2$ partial pressure in the flue gas and the vapor pressure of $SO_2$ at the gas/liquid interface. WFGD system designers can generally influence only the contact surface area and the dissolved alkalinity in the absorber slurry, which, in turn, determines interface vapor pressure. The surface area for mass transfer is determined by the selected liquid-to-gas ratio (L/G) in conjunction with the spray nozzle droplet size distribution.

Improving $SO_2$ removal performance for existing open tower designs is generally limited to increasing L/G ratio or creating smaller droplet sizes via higher pressure drop nozzles, either of which increase auxiliary pump power. Additionally, smaller spray droplet sizes are only marginally effective due to significant droplet coalescence within the spray zone of the tower.

Flue gas/slurry contact can be significantly enhanced with the use of internal contacting devices. In the past, packing material has been used but has proven unreliable in limestone WFGD systems and is not favored by the U.S. utility industry. Further development has produced the Dual Flow Tray (DFT) technology that has found favor in U.S. utility applications for over 30 years for new and retrofit applications. In general, the DFT consists of one or more levels of perforated plates that span the entire absorber cross-section. The DFT's $SO_2$ removal efficiency is improved due to its increased and more effective gas-to-liquid contact area compared to a typical open tower design that relies only on spray droplet surface area.

# 2. Fluid Dynamic Flow Model




**A computational fluid dynamic flow model shows the improved gas flow distribution of an existing Amec Foster Wheeler DFT installation over a comparable side entry wet FGD design. The flue gas distribution is illustrated at 1.5 m above the inlet duct.**

*Source: Amec Foster Wheeler*

DFTs improve WFGD performance by improving flue gas distribution at the beginning of the gas-to-liquid contact zone, which takes full advantage of the L/G provided by the slurry sprays. Flue gas distribution in a DFT absorber is markedly better than an open spray tower WFGDs designed with side flue gas entry where momentum pushes the flue gas to the far wall thus delaying optimal flue gas / absorber liquor contact. For open spray tower designs, optimal flue gas distribution doesn't occur until the gas is well into the absorption zone (Figure 2).

DFTs also provide very effective gas-to-liquid contact. Flue gas flowing upward is intimately mixed with the falling absorber slurry. The flue gas velocity travelling through the tray holes causes liquid resistance, thus forming a froth layer on the tray. The froth layer, typically 150mm – 300mm deep, provides additional mass transfer surface area and contact time in the absorption zone. Each tray level provides an additional one to two seconds of contact time in the absorption zone. Full scale testing of absorber towers with and without DFTs confirm comparable performance for DFT absorbers at L/G ratios 15 percent – 30 percent below open tower designs.

# Performance Comparison

Absorber slurry liquid phase chemistry also plays a substantial role in the overall performance of the wet FGD unit. The absorber slurry needs sufficient liquid phase alkalinity to quickly neutralize the absorbed acid to maintain the driving force necessary for $SO_2$ capture. In limestone-based systems, the alkalinity is produced from dissolved calcium carbonate. The operating pH is a general indicator of the alkalinity of the absorber liquor. The higher the pH, the more dissolved alkalinity is present.

# 3. Under Construction

### The DFT can be used as a staging platform during construction.

*Source: Amec Foster Wheeler*

As the absorber slurry falls through the absorber tower, the pH of the solution falls as the acid is absorbed. For an absorber with a reaction tank pH of 5.7, the slurry pH falls to ~3.5 to 4.5 on the DFT. Since limestone dissolution rate is proportional to the pH, the lower pH on the DFT significantly increases limestone dissolution rates and provides additional dissolved alkalinity needed for further acid neutralization.

# Wet FGD New Builds and Retrofits

A comparison between a typical open spray tower design and an equivalent DFT design for a theoretical 500 MW unit illustrates the performance and equipment size differences between absorber types (Table 1 on page 14). Note that the DFT tower is smaller in size than a comparable open tower because of the lower L/G of the DFT absorber, as is the overall liquid recirculation rate. Since limestone dissolution and gypsum crystallization require a minimum retention time in the recycle tank, a lower L/G also allows for a smaller recycle tank. Because a DFT tower requires a lower L/G, it is often possible for a DFT tower to be designed with one less operating spray level and recycle pump.

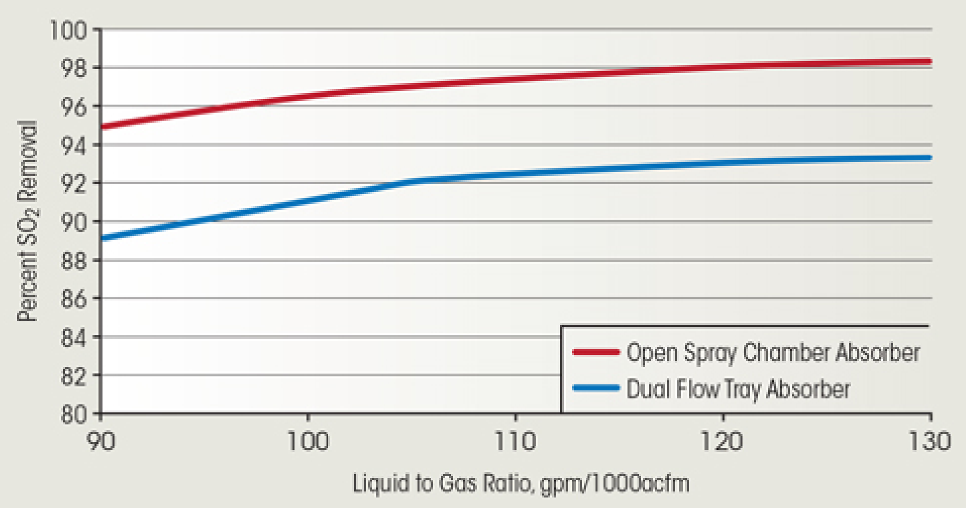
In this comparison, two operating spray levels are required for the DFT design while three operating spray levels are needed for the open tower design. Note that one less spray level reduces the overall absorber height by over one meter, which may reduce absorber shell thickness and foundation requirements, and therefore overall installation costs. The reduced absorber height will also reduce piping and electrical installation costs. Finally, the DFT can be used as a maintenance platform during construction and later as an inspection platform for the upper absorber sections (Figure 3).

# Wet FGD Performance Upgrades

There are several techniques available to improve the performance of an existing Wet FGD system. The easiest and most cost effective is to operate the system with a higher pH. The typical limestone-based system operates at pH levels between 5.0 and 5.7. A higher operating pH will improve $SO_2$ removal efficiency up to a limit. Slower sulfite to sulfate oxidation rates and high limestone stoichiometry produce unacceptable gypsum quality when pH levels exceed 6.0. Poor oxidation may also produce gypsum scaling which is not acceptable for long-term operation.

Physical equipment changes are usually the upgrade path. Adding wall rings, improving flue gas or liquid spray distribution, smaller spray droplet spray nozzles, double spray nozzles, more L/G, or the addition of one or more DFTs, alone or in concert, are typical open tower upgrade options. Wall rings will marginally improve the efficiency of a properly designed wet FGD system. Higher-pressure spray or double spray cone nozzles will produce smaller spray droplets that should help efficiency, in theory, however droplet coalescence limits the performance improvement.

**$SO_2$ Removal Efficiency**




*The Elmer Smith Station owned by Owensboro Municipal Utilities upgraded an existing open spray chamber absorber with one DFT, thereby increasing the wet FGD's SO2 removal efficiency from 93 percent to 98 percent.*

*Source: Amec Foster Wheeler*

The remaining option for significantly improving performance of an existing open spray tower is adding L/G, in conjunction with spray header modification. Unfortunately, increasing L/G in an existing absorber is normally a challenge. Most sites do not have adequate floor space for additional recycle pumps and not enough tower height for additional spray banks. Modifications to existing pumps are possible, however recycle pump efficiency will likely be compromised and recycle pipe flow velocities could exceed design limits. Recycle tank retention times must also be considered when adding additional L/G. These solutions, although possible, generally require outages of several months and have high construction costs.

Normally the best physical upgrade option is the addition of one or more DFTs below the bottom spray bank. Many open towers have adequate space between the lowest spray bank and the inlet ductwork to allow installation of a new DFT level. Approximately 3.0 – 3.5m of vertical height is generally required. An added benefit of the DFT is that lower pressure drop nozzles can be used (spray nozzle droplet size is less critical for a DFT) to artificially increase L/G without modification to the existing recycle pump and recycle piping systems.

# Successful Retrofit Case Study

Amec Foster Wheeler’s predictive models indicate that a DFT can improve mass transfer by as much as 50 percent (1.5 times) from the current design of open tray spray towers. In many instances, the addition of one or more DFTs can achieve desired performance objectives without other modifications. For even higher levels of performance, a DFT addition in conjunction with spray nozzle modification and pH adjustment is an option. The liquid holdup and low pH on the DFT will allow higher operating pH levels without affecting limestone stoichiometry or gypsum quality.

A DFT retrofit of an existing open spray tower was recently completed at the Elmer Smith Station owned by Owensboro Municipal Utilities (OMU). Amec Foster Wheeler supplied two open spray chamber absorbers that began operation in 1995. In 2008, the existing absorber towers were operating at 93 percent $SO_2$ removal efficiency at an operating pH level of 5.7 when OMU decided to upgrade its system to reach 98 percent efficiency.

The five-point efficiency increase represented an increase in absorber mass transfer from 2.7 NTU to 3.9 NTU, a 42 percent increase. Amec Foster Wheeler’s analysis found that adding one DFT level would increased the overall absorber NTU by ~50 percent, without any additional modifications to the existing recycle pump or spray header system. Kevin Frizzel, Director of Power Production noted, “The addition of a Dual Flow Tray level on our two scrubbers was a very cost effective method for OMU to maintain our commitment to high environmental standards.” Operational testing of the completed DFT upgrade in 2009 confirmed the expected performance increase was achieved without changes to the operating pH or limestone stoichiometry (Figure 4).

### Author

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