Adding a Tray to a Wet FGD Absorption Tower: A Simple but High-Impact Upgrade for an Existing Absorber

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ABSTRACT

Wet flue gas desulfurization (FGD) is an established technology with hundreds of installations worldwide. Many of these installations became operational more than a decade ago and have plenty of opportunity for performance improvements. With more stringent emissions requirements (SO_2 and particulate matter), it often becomes necessary to upgrade these wet FGDs in an economical manner. The Babcock & Wilcox Company (B&W) has recently used its tray technology to upgrade two wet FGDs on coal-fired power plants. The first plant had an existing spray tower wet FGD achieving less than 97% SO_2 removal with dibasic acid (DBA) addition. B&W added one tray to this installation and was able to achieve 99% SO_2 removal while also eliminating the need for DBA. The second plant is an existing single tray spray tower wet FGD in which B&W added a second tray to allow for a higher fuel sulfur and increase overall SO_2 removal efficiency. The equipment changes, operational changes, and performance will be discussed. The paper will also review wet FGD spray tray tower design, which can be optimized for particulate removal.

INTRODUCTION

The cornerstone of modern air emissions regulation in the United States (U.S.) is the Clean Air Act of 1970. This legislation chartered a government agency dedicated to monitoring and regulating emissions of pollutants by industry. Amendments to the Clean Air Act passed in 1990 included a requirement that point sources undergo a review and renewal of their permits every five years, and that the allowable emission levels for regulated pollutants be periodically reevaluated in the light of advancing technologies. The history of air emissions regulation in the U.S. is therefore one of progressively tightening requirements.

Utilities have been installing air quality control (AQC) systems since the 1980s to comply with emissions limits, and have periodically found themselves in a position where existing AQC systems no longer meet new permit requirements and must be replaced or modified. This has led AQC system suppliers, like B&W, to develop new technologies for improving the performance of older AQC systems in a cost-effective way.

One simple, yet very effective modification for an existing wet FGD AQC system is to install a tray in a spray absorber tower, or to install a second tray in an absorber that already has a tray. This change involves installing a support grid in the absorber tower just above the inlet or first tray, then installing the tray sections in the support grid. The addition of a tray improves absorber performance by enhancing gas liquid contact and interaction, improving gas distribution, and adding residence time in the gas/liquid zone. This paper will discuss two recent project case studies using such modifications and will present the results of the tray upgrades on each system's performance.

Figure 1 shows the inside of a typical spray tower with no gas distribution devices. Figure 2 shows the inside of a spray tower after installation of a B&W tray.

Figure 1: Interior of a spray tower (non-B&W) with no gas distribution devices.

Figure 2: Interior of a spray tower retrofitted with a B&W tray

TRAYS AND WET FGD DESIGN

Scrubber Design and SO_2 Absorption

High performance removal of SO_2 from flue gas by a wet flue gas desulfurization absorber depends on two basic parameters. First, the physical absorber must be designed to provide adequate contact between the gas and liquid phases to facilitate mass transfer of SO_2 from the gas phase to the liquid. Second, adequate alkalinity must be present to neutralize the acid formed when SO_2 is absorbed. Optimizing these two parameters enables a wet FGD absorber to achieve very high SO_2 removal rates.

Some wet FGD absorbers are designed with many spray levels to distribute the slurry. This is because the key to effective performance in a spray tower is to get a uniform gas and slurry spray distribution across the cross section of the tower. When there is maldistribution, there is uneven contact between the gas going up the tower and the liquid falling countercurrently. The result of maldistribution is that some of the gas is overscrubbed and some of the gas is underscrubbed, depending on where the flux is located in the absorber cross section. When this occurs, absorber performance is compromised. This may not be a problem when only moderate SO_2 removal is required, but can become a major limitation when higher removal requirements and/or low SO_2 emissions are required. Figure 3 shows the effect of maldistribution in a spray tower with inadequate gas distribution devices and the smoothing effect of a gas distribution tray.

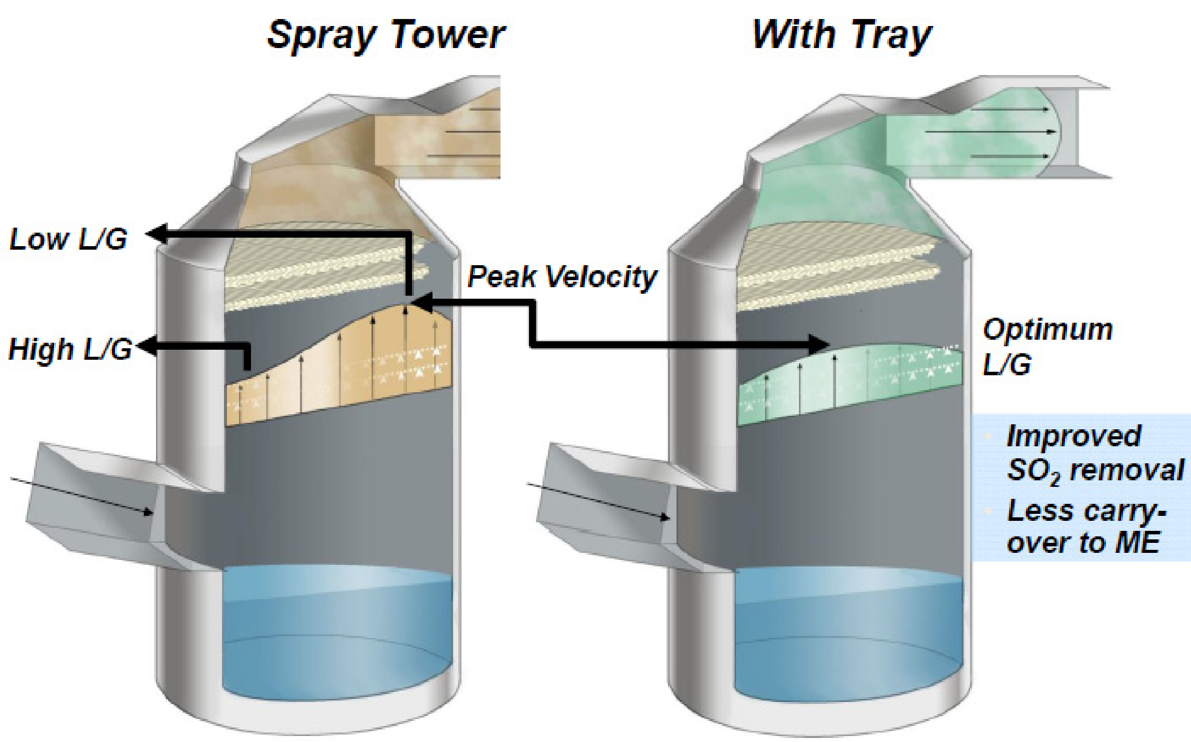

Figure 3: Liquid-to-gas (L/G) distributions in a spray tower with inadequate flow distribution and a spray tower with a gas distribution tray

The installation of a tray into a spray tower can greatly improve the performance of a wet FGD absorber. The tray acts as additional contact area for liquid-gas interaction. The turbulence that results when the gas and liquid pass through the same tray openings greatly promotes mass transfer and improves SO_2 removal. Also, the froth level that forms on the tray provides some additional residence time in the absorption zone for limestone dissolution and SO_2 absorption in the slurry.

In addition to adding contact area to an absorber, the tray also acts as a flow distributor for the gas, as shown in Figure 3. The small pressure drop incurred as the gas passes through the tray openings forces the gas to distribute more evenly across the tower cross section. This produces more uniform contact between the gas and liquid flows, which results in optimized contact, improved SO_2 removal, and better utilization of alkali in the slurry. Finally, the turbulent contact of gas and liquid promotes the capture of particulate matter from the gas, so the tray acts as an additional stage of particulate removal along with the spray and mist eliminator. Increasing the pressure drop across the tray by reducing open area leads to increased particulate removal through more vigorous contact between the liquid and gas.

Figure 4 shows actual operating data from a wet FGD absorber before and after the addition of a tray. The plot shows how the addition of a tray allows a given SO_2 removal level to be achieved with a lower recirculated liquid rate than could be achieved without the addition of the tray.

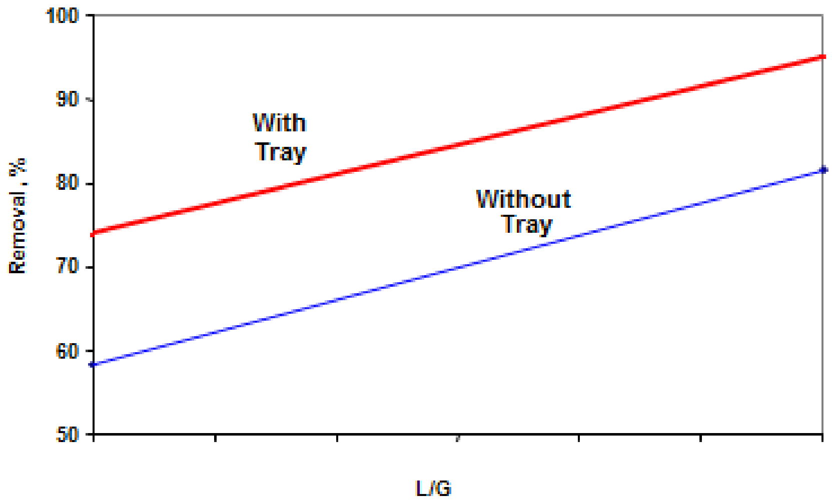

Figure 4: Wet FGD absorber tower performance, with and without a tray

Similarly, Figure 5 shows operating data from a wet FGD absorber with tray before and after the addition of a second tray. Again, the plot shows clearly that the addition of a second tray allows a given SO_2 removal to be achieved with a lower liquid rate than could be achieved with only a single tray.

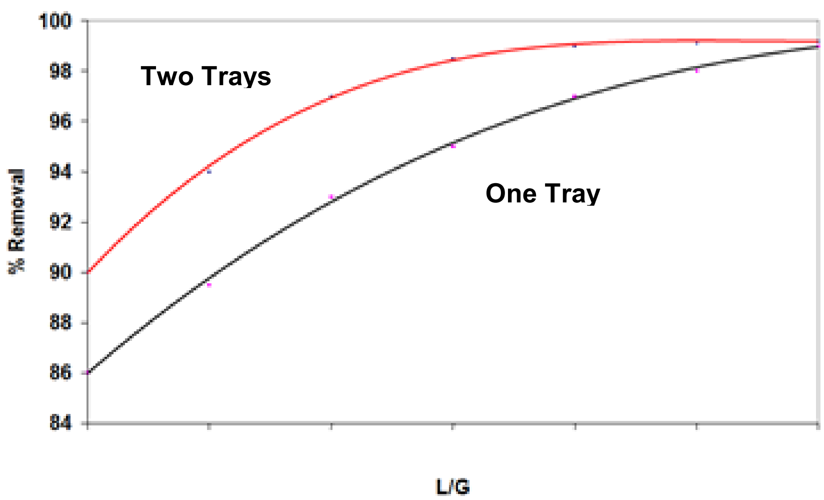

Figure 5: Wet FGD absorber tower performance, with single and dual tray

The addition of a tray is B&W's preferred upgrade for existing wet FGD absorbers. It is a straightforward installation which can typically be completed in a 4- to 6-week outage. It provides a significant return on investment in terms of performance improvement. The use of a tray in wet FGD units was patented by B&W in 1981. Since then, B&W has provided more than 150 units that are operating with at least one absorber tray, and over 25 retrofits of our competitors' units. B&W has retrofitted trays into packed towers, spray towers, and has installed a second tray in towers with single trays. The design of the B&W absorber with one tray or two trays is based on empirical data from multi-variable testing of field units and from pilot plant testing.

To summarize, the absorber tray promotes intimate contact between the gas and slurry, and provides the following benefits when compared to spray towers alone:

1. Improved performance. Retrofit of tray achieves higher removals in an existing absorber, and can provide the ability to run on higher sulfur coals while maintaining low emissions. A tray upgrade can also eliminate the expense of using DBA, or some other organic acid for performance enhancement.
2. Reduced power consumption as a result of lower L/G ratios. Fewer recirculation pumps are required to reach a given emissions level. Typically, the pump power saved on slurry recirculation more than offsets the additional fan power required for the tray pressure drop.
3. Even distribution of gas across the tower cross section leads to more uniform contact between slurry and gas, better absorption performance, and better alkali utilization.
4. Longer slurry residence time in the absorption zone leading to better absorption performance, and better alkali utilization.
5. More vigorous liquid-gas contact increases particulate removal through the absorber.
6. Fewer spray headers and large recirculation pumps are required for a given SO_2 removal requirement in a new absorber tower.
7. Reduced maintenance of absorber recirculation pumps, piping, headers and nozzles
8. New absorber towers can be shorter, with reduced foundation, steel, platform, wiring, motor control centers (MCCs) piping, instrumentation, I/O count and building requirements
9. Tray support grid, when using wooden support planks, can be used as a maintenance platform for inspection/cleaning of spray nozzles.

RECENT PROJECT CASE STUDIES

Case #1: Retrofit of a Single Tray to Increase Performance and Eliminate Need for DBA

The first case study is of a power plant in the midwestern U.S. with two 900 MW boilers. The existing AQC system includes low NO_x burners and electrostatic precipitators (ESP) upstream of a limestone forced oxidized wet FGD system. Each wet FGD system is comprised of two spray tower absorbers operating in parallel on a common gas stream for each boiler. The spray tower absorbers were installed in the mid-1990s and were not supplied by B&W. The wet FGD systems were originally designed for 95% SO_2 removal, but at the time of the upgrade, were achieving 97% SO_2 removal with the use of approximately 580 kg/day of DBA per system.

The goal of the upgrade project was to increase the SO_2 removal to 99%, eliminate the need for the costly DBA chemical, replace deteriorated equipment, and increase reliability of the wet FGD system. B&W used its advanced variable open area tray design to meet the project goals and minimize the scope of required changes for a cost-effective solution.

The project scope included installing the tray and support grid, installing a new awning at the absorber inlet, replacing the discharge piping of the absorber recirculation pumps, installing new absorber bleed pumps, and refurbishing the primary hydroclones. No changes were made to the large absorber recirculation pumps, nozzles or spray headers which was a significant cost savings for the multiple absorber towers. In addition, no changes were made to the ID fan because the low additional pressure drop of the second tray was within the fan's capability. Once this work was completed and the absorbers were brought back online in the summer of 2013, an independent stack tester was engaged to measure the performance of the modified systems. The results from the performance tests are shown in Table 1. The addition of a tray in all of the absorbers allowed the wet FGD systems to achieve 99% SO_2 removal and eliminate the need and associated cost for the DBA additive.

Table 1: Average Performance of Absorber Towers per Boiler Unit During Testing

	Sulfur Loading Percent of Design	Percent Removal	DBA Addition (kg/day)	Additional Pressure Drop (mm H_2O)	Pump Flow (L/G Ratio)	Limestone Feedrate
Before Upgrade (Each)	100%	97%	580	0	Design	Design
Unit 1	103%	99%	0	39	No Change	No Change
Unit 2	104%	99%	0	53	No Change	No Change

Case #2: Retrofit of a Second Tray to Allow Use of Higher Sulfur Fuel and to Increase Overall SO_2 Removal

The second case study involves a power plant in the southeastern U.S. The plant has one 350 MW boiler with two wet FGD systems. Each wet FGD system is comprised of two B&W spray towers with one tray just above the inlet in each tower. The absorbers in each system operate in parallel and are fed by a common plenum. Each absorber handles approximately 50% of the overall gas stream. A fifth, common spare absorber tower is connected to both systems, but is only used when one of the primary towers is offline for service. The outlet fluework from the two absorbers in each system are combined before exiting through a common stack. The absorbers were designed by B&W in the late 1970s, and extra height was included in anticipation of tightening emissions regulations and the need for a future second tray.

Facing higher SO_2 and particulate removal requirements in 2014, the owner approached B&W for options. B&W proposed modifications to improve the SO_2 removal performance from a pre-upgrade emissions level of 167 mg/dry Nm^3 at 6% O_2 while burning 2.2% sulfur coal to less than 52 mg/dry Nm^3 at 6% O_2 while burning 3.4% sulfur coal. The upgrade project involved modifying the existing tray in each absorber to reduce open area, then adding a second tray above the first. Reducing the open area in the first tray increased turbulence and promoted better gas-liquid contact. The addition of a second tray further increased turbulent contact between gas and liquid, and increased residence time of the liquid in the absorption zone. The effect of increasing turbulent contact was to improve SO_2 capture and particulate capture in the absorber. The additional residence time of the liquid on the second tray also contributed to better SO_2 capture and provided the ability to maintain high removal performance when the higher sulfur coal was burned. Also, a third (spare) pump was pressed into continuous service to increase liquid rate.

The upgrade project was completed in spring 2015. Performance data from the plant's continuous emissions monitoring system (CEMS) showed that the new configuration was able to meet the target levels. The results of testing are shown in Table 2.

Table 2: Measured SO_2 in Common Stack During Testing

	Calculated Inlet SO_2 (kg/kJ x 10^6)	Measured Outlet SO_2 (kg/hr)	Percent Removal	Additional Pressure Drop (mm H_2O)	Pump Flow (L/G Ratio)	Number of Pumps in Service
Before Upgrade	1.6	0.32	80%	0	Design	2
After Upgrade	2.0	0.06	97%	140	150%	3

Table 2 shows that the upgrade project successfully improved the performance of the originally designed absorber and allowed the wet FGD system to achieve the emissions levels required even when burning higher sulfur fuel.

SUMMARY

Adding a gas distribution tray to a wet FGD absorber is a simple and effective upgrade that can be used to improve the performance of most systems. The tray is a particularly good fit for upgrading spray towers where the benefits of an improved flow distribution will be realized as well as the enhanced gas-liquid contact a tray (or an additional tray) provides. The enhanced liquid contact comes at the expense of a small additional pressure drop, but the benefit of being able to reach higher removals without the capital, space requirements, and energy costs of a major recirculation pump upgrade more than offsets this expense, in most cases. A tray upgrade is a cost-effective strategy for improving performance of older absorbers that would otherwise need replaced or decommissioned. It is also a way to reduce operating costs by eliminating the need for organic acid performance enhancers, or being able to achieve desired emissions levels with fewer recirculating pumps online. This approach is a viable option worthy of consideration for any wet FGD system owner who faces continually decreasing emissions requirements.

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KEYWORDS

Wet flue gas desulfurization, WFGD, WFGD Upgrades, Tray Tower Absorber, Spray Tower Absorber