WET FLUE GAS DESULFURIZATION (FGD) SYSTEMS

ADVANCED MULTI-POLLUTANT CONTROL TECHNOLOGY

B&W BABCOCK & WILCOX

RENEWABLE | ENVIRONMENTAL | THERMAL

B&W WET FGD SYSTEMS –

FLEXIBILITY OF DESIGN AND ADVANCED FEATURES TO MEET CUSTOMER NEEDS

When performance counts

SINCE 1971, BABCOCK & WILCOX's (B&W) WET FLUE GAS DESULFURIZATION (FGD) SYSTEMS, OR SCRUBBERS, HAVE OPERATED EFFICIENTLY, ECONOMICALLY AND RELIABLY, HELPING OUR CUSTOMERS MEET PERMIT REQUIREMENTS WHETHER AS A NEW SOURCE OR RETROFIT APPLICATION. CURRENT DESIGNS CAN ACHIEVE MORE THAN 99% REMOVAL OF SULFUR DIOXIDE (SO_2). IMPROVEMENTS IN B&W's WET SCRUBBER DESIGN AND AUXILIARY EQUIPMENT HAVE RESULTED IN SYSTEM AVAILABILITY GREATER THAN 99.5%. MULTI-POLLUTANT CONTROL CAPABILITIES INCLUDE FILTERABLE PARTICULATE, ACID MIST AND MERCURY.

Current B&W designs are achieving 99% SO_2 removal with system availability greater than 99.5%.

Controlling oxidation

New wet FGD systems can be supplied with either forced oxidation or inhibited oxidation.

Since the mid-1980s, limestone forced oxidation has been the leading wet FGD technology. This beneficial process converts calcium sulfite to calcium sulfate within the absorber reaction tank and improves scrubber operation while producing a marketable gypsum byproduct. B&W has more than 34,000 MW of commercial units successfully operating with forced oxidation, both in situ systems and units operating with specialized systems that are separate from the absorber reaction tank, most notably on magnesium-enhanced lime systems. We are a worldwide leader in supplying limestone forced oxidation units, and we continue to support this technology.

While limestone forced oxidation technology has proven successful in many worldwide installations, in some applications, the gypsum byproduct is no longer marketable, and wastewater treatment and discharge have become a concern. Therefore, some customers believe that a dry FGD system is the only option. However, there is an alternative: existing wet FGD technology with inhibited oxidation. In this process, emulsified sulfur, or sodium thiosulfate, is added to the reagent feed tank. The addition of emulsified sulfur reduces the oxidation rate to below 15%, thus controlling scale deposits and plugging in the tower, allows the use of less expensive materials, and eliminates the wastewater discharge stream. This process can be utilized with various reagents — limestone, lime, magnesium-enhanced lime, or sodium.

Scope of supply

B&W is a full-scope supplier. In addition to flue gas absorbers, we supply reagent preparation systems, dewatering systems and related system equipment. We also provide complete construction services through our subsidiary, Babcock & Wilcox Construction Co., Inc. (BWCC).

B&W employs an experienced staff of design engineers, graphic designers, project managers, and

As a full-scope supplier, B&W can provide complete wet FGD systems including reagent preparation, dewatering and other system equipment, as well as a wide range of multi-pollutant control technologies.

the industry's largest network of field service engineers, including wet FGD field specialists, to support project development, project execution, and long-term operation and maintenance. We also conduct extensive research and development (R&D) activities to continue product advancement.

Experience

Original Equipment Supply

At the time of publication, B&W has provided wet FGD systems for a total scrubbed capacity of more than 43,000 MW. Through licensees in China and Germany, our wet FGD technology has been utilized for an additional capacity of more than 77,000 MW.

Upgrades

B&W has also improved the performance of more than 13,000 MW of non-B&W wet FGD systems by replacing the original absorber internals with our absorption tray technology, modern spray headers, and through forced oxidation conversions. Benefits have included improved SO_2 removal, reduced absorber pump power consumption and maintenance costs, reduced limestone consumption, the elimination of costly additives, decreased landfill requirements, and the opportunity to provide a marketable byproduct.

Fuel Experience

Our operating experience encompasses a complete range of fuels including bituminous, subbituminous, Powder River Basin (PRB), lignite and brown coals, as well as various coal blends. We have also provided systems for heavy oil and Orimulsion fuels.

Large, Single Absorbers

As the technology of wet FGD systems has improved, typical units have a single absorber module. B&W absorber modules have been installed on boilers up to 1,300 MW. Absorber design and reliability allow many utilities to treat the flue gas from multiple boilers with one absorber. To reduce project costs B&W and our licensees have provided systems with two to four smaller boilers feeding one absorber and three larger units feeding two absorbers.

Choice of reagents

We have designed FGD systems using a variety of reagents. While most of our experience is with limestone, designs have utilized lime, magnesium-enriched lime, and waste soda ash. Limestone-based systems using organic acid enhancement have also been provided.

Advanced design benefits

We continue to optimize our FGD systems by refining the technology to improve SO_2 removal efficiency, improve long-term operating reliability, and reduce capital and maintenance costs. As an indication of our constant efforts to improve our designs, we currently have more than 40 patents involving wet FGD technology.

B&W's wet FGD systems operate efficiently, economically and reliably on a variety of worldwide fuels to help our customers meet permitting and operating requirements.

The B&W Absorber

A proven design for high SO_2 removal

B&W's absorber design features provide the highest levels of SO_2 removal, reduced operating costs and significant reductions in maintenance costs compared to other technologies. These benefits allow our customers to stay competitive with today's increasingly more stringent environmental requirements.

Absorber design

Our absorber module is a counter-current flow design. Slurry is sprayed downward from a series of headers and nozzles and scrubs the flue gas as it moves upward through the absorption tray and spray zone. The control system automatically adjusts the feed of fresh reagent to achieve an outlet SO_2 emission limit or the required SO_2 removal efficiency.

Absorber tray system

Our absorber tray system serves the dual purpose of providing gas-liquid contact for SO_2 absorption and more uniform distribution of flue gas across the tower. The gas rises through the absorber, contacting a froth of slurry on the tray. This action results in efficient contact of gas and reagent throughout the absorber.

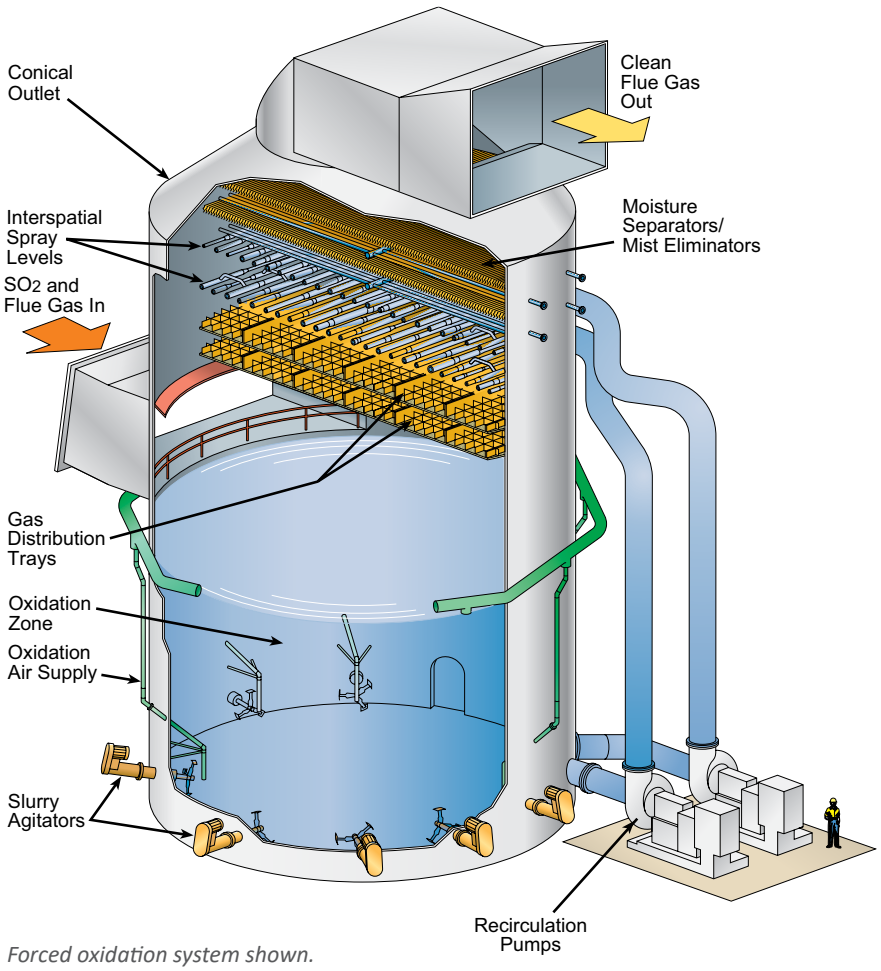
Our absorbers use one or two trays depending upon the fuel and specified requirements for SO_2 removal and operating parameters. The tray provides uniform gas distribution and effective gas-slurry contact. Table 1 summarizes the benefits of the B&W tray absorber tower design.

The slurry and the flue gas must be uniformly distributed across the absorber tower's cross-section for optimum SO_2 removal. An efficient spray header and nozzle system is used to evenly distribute the liquor, while the tray distributes the gas flow. As determined by both physical and computer modeling, the gas-side pressure drop induced by the slurry sprays is not sufficient alone to adequately distribute the flue gas at the base of the spray zone. In open spray towers, uniform gas distribution is not achieved as effectively.

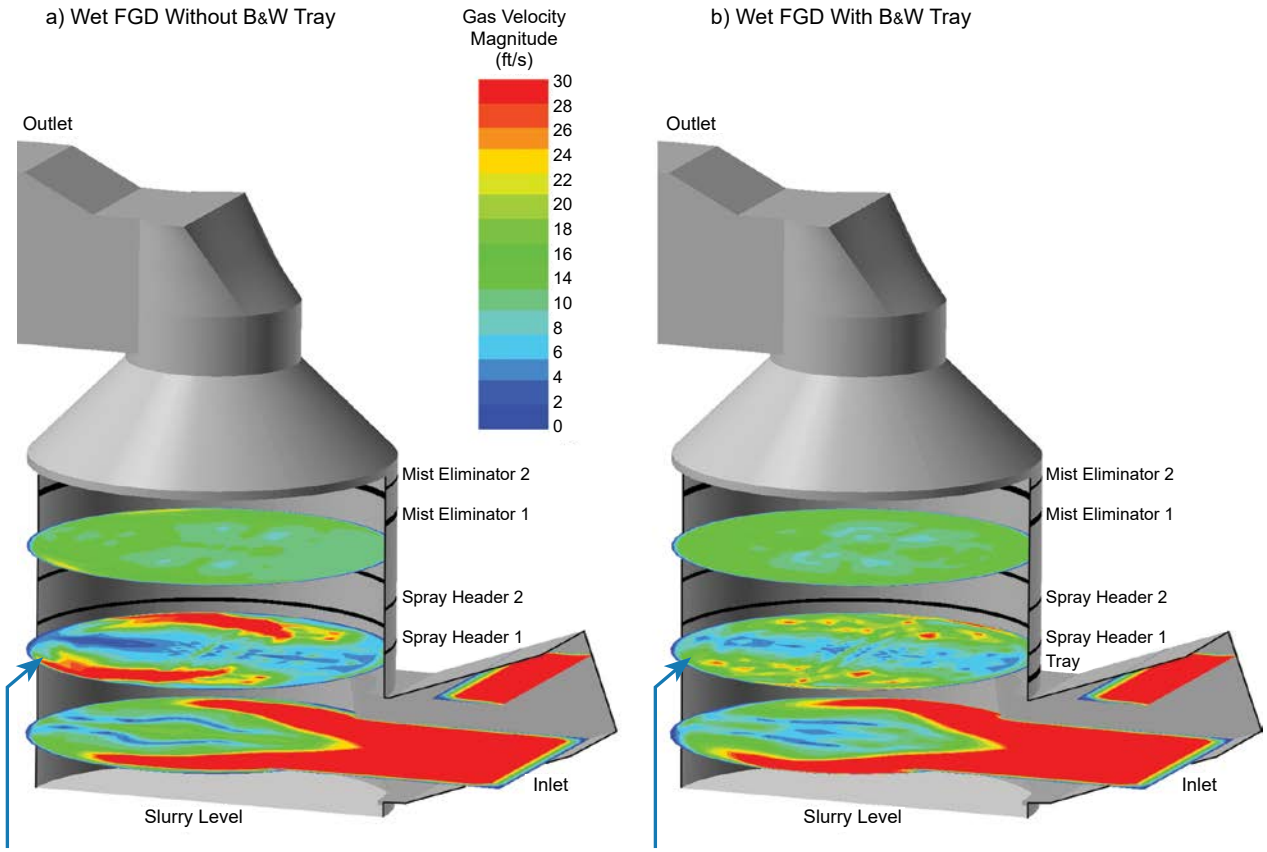
The B&W tray design effectively achieves uniform gas distribution, which becomes even more critical in larger diameter spray absorber towers. Without a tray, some zones of the absorber have poor gas distribution, which results in zones of either inadequate or excess slurry and reactant. With the tray, flue gas is uniformly distributed for the most efficient SO_2 removal.

The tray is rugged and can be used as a convenient inspection and maintenance platform when using appropriate planking. Costly and time-consuming scaffolding from the bottom of the reaction tank is not required.

Our tray design has been proven through extensive laboratory testing and modeling and many years of successful operation.



Forced oxidation system shown.



High gas velocity in spray area is less effective.

Uniform gas distribution through spray zone(s) results in more effective and efficient SO_2 removal.

B&W uses both advanced numerical modeling and physical modeling to design the most efficient wet flue gas desulfurization systems.

TABLE 1

EXAMPLE ABSORBER COMPARISON

Unit Size: 617 MW SO_2 Inlet: 1,100 ppmdv
Reagent: Limestone SO_2 Removal: 97.6%

	2 Trays	1 Tray	Open Tower
L/G	56	82	108
Δ P, in. wc	10.2	8.2	7.0
Pump Flow, gpm	34,500	50,000	66,000
Fan/Pump Power, kw	6,470	6,560	7,470
Δ Power	Base	+90	+1,000
Pump/Header Cost	Base	+$400k	+$700k

B&W's absorption tray provides uniform gas flow and maximizes SO_2 removal. This photo shows a tray after two years of continuous service.

Two levels of moisture separators effectively prevent slurry carryover and deposition in the downstream flue.

Patented interspatial headers

Achieving overlapping spray coverage with an effective spray header design is critical for optimal SO_2 removal performance. B&W's patented interspatial header technology allows the location of two spray headers at the same elevation while maintaining full overlapping coverage with one or both spray headers in service. The use of interspatial spray headers results in a shorter absorber tower, reduced pump power, lower building height, less external recirculation piping, and easier nozzle inspection and maintenance.

Moisture separator

Efficient moisture separation is essential to prevent slurry carryover and deposition in the flue downstream of the module. Our absorbers utilize two or three levels of moisture separators that are rugged in design and have a history of low replacement. We have performed extensive R&D to optimize gas flow distribution, develop velocity profiles, and test the performance of moisture separators in our hydraulic model. We also work closely with our suppliers in the development of advancements to moisture separator technology.

Multiple side-entering agitators on B&W's absorber tower provide uniform slurry mixing.

Patented inlet awning

B&W's patented inlet awning design prevents the buildup of deposits in the absorber inlet flue. The awning deflects the falling slurry away from the inlet, shifting the wet-dry interface out into the absorber away from the inlet flue. This design provides high reliability and lower maintenance costs.

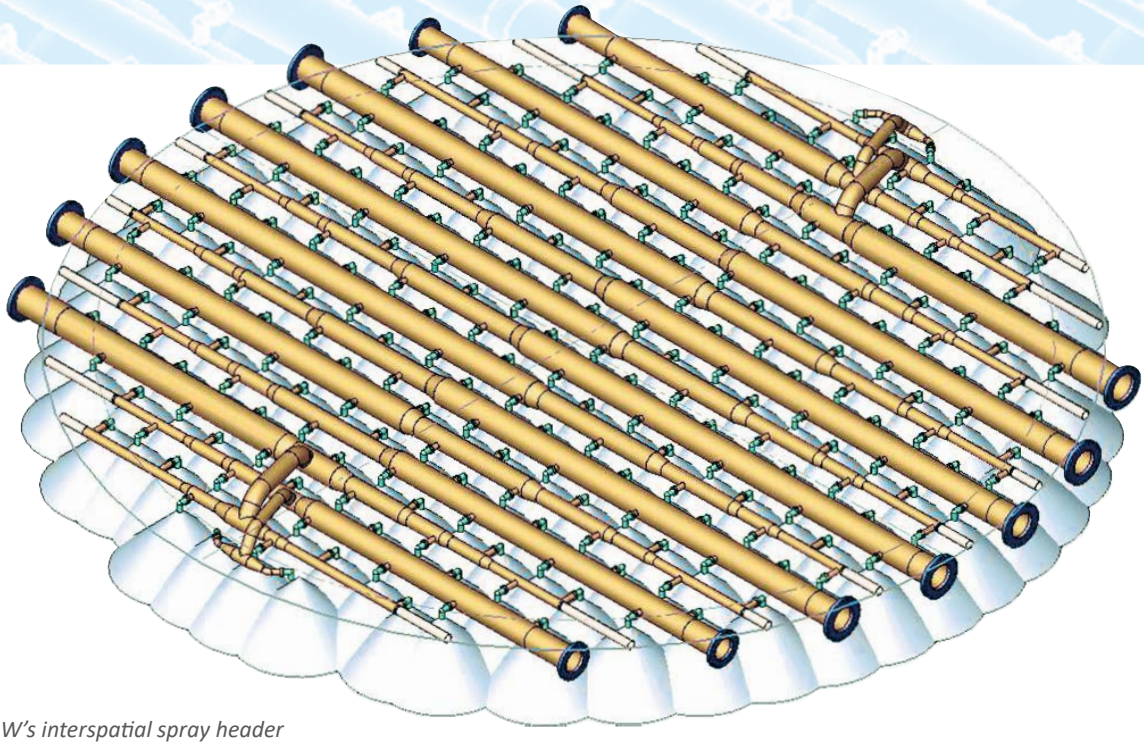
Deposit buildups in the absorber inlet flue are reduced by B&W's patented inlet awning.

Tank agitators

Slurry in the recirculation tank is agitated to keep the solids in suspension. Our standard design allows for operation with one of the agitators out of service for high system reliability.

Materials of construction

We can supply absorber modules in a variety of materials for dependable operation and reliability: rubber and flake glass lined, tile-lined concrete, tile-lined carbon steel, stainless steel, and other specialty alloys. Abrasion-resistant fiberglass reinforced piping (FRP) or alloy piping can be used for internal spray headers. Abrasion-resistant materials are used for the spray nozzles. External piping is typically FRP or rubber-lined carbon steel.



B&W's interspatial spray header design provides complete spray coverage for optimal performance and easier maintenance.

Multi-pollutant capability

As a multi-pollutant control device, B&W's wet scrubber provides control of several pollutants in addition to SO_2.

Filterable (solid) particulate is removed in the wet scrubber. The wet scrubber removes 40 to 90% of the flyash entering the scrubber, depending upon the ash inlet loading and the type of upstream particulate collector.

Acid mist (H_2SO_4) is removed in the wet scrubber. The removal is dependent upon a number of operating conditions such as gas temperature, gas humidity, inlet concentration, etc. H_2SO_4 removal in wet scrubbers ranges from 35 to 70%.

Mercury is also removed in the wet scrubber. Using B&W's patented and proprietary additives that are injected directly into the absorber, a minimum of 90% removal of oxidized mercury can be achieved. Recognizing that oxidized mercury is water soluble and elemental mercury is not, we developed the Absorption Plus (Hg)™ system, a patented technology to inhibit mercury re-emission and to increase the total mercury captured and retained in a wet FGD system.

Extensive R&D activities for improved performance

B&W is continuously working to improve our wet scrubber product line. Our research center is equipped with a wet scrubber pilot plant. The flue gas is supplied by a small boiler unit capable of firing a variety of coals, liquid and gaseous fuels. We also use an advanced hydraulic model to study tray and spray fluid hydraulics and mist eliminator carryover.

Through extensive research and development, B&W scientists continually strive for product improvements to help our customers reduce emissions.

We are the only FGD supplier with a full capability construction company operating as a subsidiary on the same campus. Complete project integration, from concept to commercial operation, is necessary to control costs and schedule and is achievable through the team of B&W and BWCC.

Full-Scope Integration

Modularization

B&W designs its scrubber systems with modularization in mind. Components are manufactured to minimize on-site labor requirements, particularly in locations with limited laydown area. This technique significantly reduces both the project schedule and construction costs and represents an important advancement in manufacturing and construction technology.

Project management

Many times, a project calls for new ways of thinking. Our innovation goes beyond traditional project management and vendor/supplier relationships. Innovative approaches, such as strategic alliances, allow us to collaborate with our customers and key suppliers on ideas and solutions and ultimately share in the cost savings that can result from such an arrangement. Effective communication and trust are vital to make any project a success.

Total-scope services

B&W provides total-scope services, such as project engineering and management, component fabrication, and installation of complete environmental emissions control equipment. In addition to wet scrubbers, our environmental equipment capabilities include dry FGD systems with spray dryer absorbers or circulating dry scrubber technology, fabric filter baghouses, electrostatic precipitators, sorbent injection systems for acid gas control, various mercury mitigation technologies, low NO_x combustion systems, and selective catalytic and non-catalytic reduction systems for NO_x control. In addition, B&W provides a complete package of aftermarket services including engineered equipment upgrades, startup and commissioning, performance testing and monitoring, field engineering and replacement parts, and emissions monitoring products and services.

Our FGD systems are backed by an experienced staff of design engineers, project managers and a network of field service engineers.

Selected B&W Wet FGD Projects

DETROIT EDISON, MONROE UNITS 1 THROUGH 4

Nominal Boiler Capacity (combined)	3300 MW
Nominal Scrubber Capacity (ACFM, per unit)	2,723,000
Inlet SO_2 Concentration (ppm, per unit)	1158
Percent SO_2 Removal	97%
Commercial Operation	June 2009 (Unit 4) October 2009 (Unit 3) November 2013 (Unit 1) April 2014 (Unit 2)
Fuel	Pulverized PRB/Bituminous Coal Blend
Reagent	Limestone
Oxidation Method	Forced Oxidation

WESTERN U.S. UTILITY UNITS 1 AND 2

Nominal Boiler Capacity (combined)	397 MW
Nominal Scrubber Capacity (ACFM)	834,274 (Unit 1) 1,081,788 (Unit 2)
Inlet SO_2 Concentration (ppm)	1411 (Unit 1) 1443 (Unit 2)
Percent SO_2 Removal	97%
Commercial Operation	2011/2012
Fuel	Pulverized Coal
Reagent	Soda Liquor

GENON ENERGY, CHALK POINT, DICKERSON, MORGANTOWN UNITS 1 AND 2

Nominal Boiler Capacity (combined)	2390 MW
Nominal Scrubber Capacity (ACFM)	2,513,000 (Chalk Point) 2,146,000 (Dickerson) 2,102,000 each (Morgantown Units 1 and 2)
Inlet SO_2 Concentration (ppm)	1554 (Chalk Point) 1666 (Dickerson) 1711 each (Morgantown Units 1 and 2)
Percent SO_2 Removal	98%
Commercial Operation	2009
Fuel	Pulverized Bituminous Coal
Reagent	Limestone
Oxidation Method	Forced

Established in 1867, Babcock & Wilcox is a global leader in renewable, environmental and thermal technologies and services for power and industrial applications.

For more information or to contact us, visit our website at www.babcock.com.

HELPING OUR CUSTOMERS PROVIDE CLEAN POWER

Working with our customers, B&W provides worldwide leadership in environmental products and services by applying the best available technology through innovation, responsiveness and commitment.

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