
RELIABLE AND EFFICIENT STEAM GENERATION SYSTEMS FOR MODERN UTILITY SERVICE



SUPERCritical BOILER TECHNOLOGY



ENERGY | ENVIRONMENTAL

The safe, reliable and efficient generation of steam has challenged boiler designers since steam was first harnessed for power. As market conditions and customer demands have changed through the years, The Babcock & Wilcox Company (B&W) has met those challenges with constant innovation and engineering know-how.

Today's demand for highly efficient, variable pressure steam conditions has brought out the best in B&W's engineers. Both our proven supercritical designs and natural circulation boilers offer the flexibility to meet the most demanding needs of our customers. We have designed boilers to burn nearly every fossil fuel imaginable.

Since 1867, when George Babcock and Stephen Wilcox patented the first water tube boiler, B&W has drawn from its wealth of engineering experience and incorporates the best available technology into each new design. We are well prepared to continue our leadership role in the design, engineering and construction of the most reliable and efficient steam generating systems available.

Supercritical for today's power demands

Many factors continue to drive improvement in pulverized coal-fired system performance. Key trends include increased thermal efficiency, improved environmental performance, increased availability and the overall reduction of the cost of electricity. Deregulation of the worldwide power industry, the desire for energy supply diversity plus the high cost of imported fuels make high efficiency systems more attractive.

Higher plant efficiency with reduced emissions

At supercritical pressures, steam turbine efficiency improves significantly compared to the typical subcritical cycle. This efficiency improvement leads to reductions in both fuel input and emissions outputs. The cycle efficiency improvement of approximately 2.5% is associated with a pressure increase from the typical 2400 psi (167 bar) throttle to the typical supercritical throttle pressure of 3600 psi (250 bar).

The combination of the increase to supercritical throttle pressure and an increase in throttle temperature to 1110 F/1110 F (600 C/600 C) provides an overall 5.5% increase in plant efficiency compared to the 2400 psi, 1000 F/ 1000 F (167 bar, 538 C/538 C) cycle common in North America. These improvements result in overall cost reductions in fuel handling and usage, flue gas treatment, and ash disposal.

B&W's supercritical boiler has been designed to take full advantage of variable pressure turbine operation. Specific advantages include:

- The load change rate capability of the system is not restricted by the turbine
- Steam temperature at the inlet and outlet of the reheater is nearly constant over a wide load range
- The boiler feedwater pump power is significantly reduced at lower loads
- Short startup times
- Higher plant efficiency over the entire load range



B&W's proven boiler designs offer the flexibility to meet the most demanding needs of our customers. Shown are two B&W 420 MW variable pressure, supercritical (spiral wound universal pressure, SWUP™) units with boiler terminal conditions of 3596 psi, 1054 F/1105 F (248 bar, 568 C/596 C).

Efficiency and flexibility are key to B&W's supercritical designs

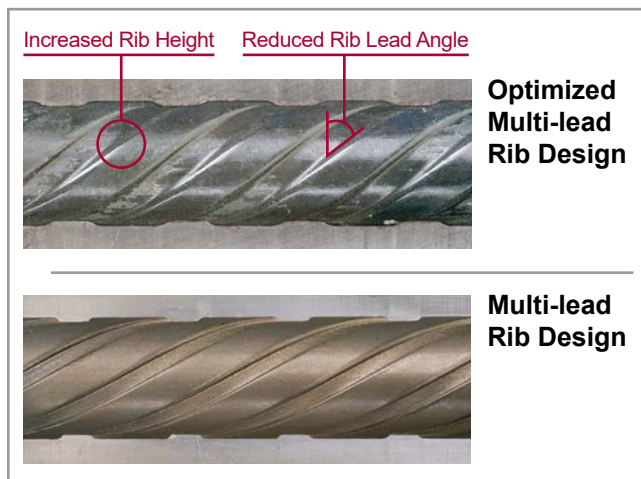
Several technologies are currently available for once-through supercritical boiler designs. The Universal Pressure (UP[®]) boiler with vertical, multi-pass furnace was developed by B&W to meet the base load and load cycling needs of U.S. utilities for supercritical boiler applications from the 1950s to the 1980s. When variable pressure and on/off cycling are required modes of operation, the B&W[®] Spiral Wound Universal Pressure (SWUP[™]) boiler is the appropriate design choice. The Vertical Tube Universal Pressure (VTUP[™]) boiler with the Siemens' optimized multilead ribbed (OMLR) tubing is also being developed for variable pressure and on/off cycling applications. B&W's supercritical experience, coupled with the Benson[®] technology, gives us a unique experience base for meeting the customer's various requirements.

Vertical tube multi-pass furnace (B&W UP) boiler

The high mass flux vertical tube furnace supercritical design features a furnace design that operates above the critical pressure. The high mass flux in the high absorption areas of the furnace is achieved by arranging the enclosure tubing in multiple passes. A throttling valve located between the primary and secondary superheater enables the boiler to maintain supercritical operation in the furnace throughout the operating load range while operating in the variable pressure mode at full steam temperature at the superheater outlet. This arrangement has proven to be ideal for base load and load cycling operations.

Spiral wound furnace (B&W SWUP) boiler

The two keys to once-through boiler furnace water side design are maintaining uniform tube-to-tube temperatures and maintaining adequate heat transfer on the inside of the tubes in high heat flux areas. The spiral wound furnace has a proven record of achieving both of these goals. As shown in Figure 1, the spiral furnace design allows the fluid in the tubes to pass through the various heat flux zones around the furnace providing a more uniform outlet enthalpy. The layout of the spiral tubes provides for fewer parallel flow paths than vertical tube arrangements. This arrangement produces a high mass flux to maintain adequate heat transfer on the inside tube wall. B&W's spiral furnaces utilize multi-lead ribbed tubing to allow once-through operation at lower minimum loads. This design is ideal for on/off cycling requirements and, unlike the vertical tube high mass flux



▲ An optimized multi-lead ribbed tube design provides the necessary combination of heat transfer and pressure drop for a low mass flux once-through boiler design to function properly.

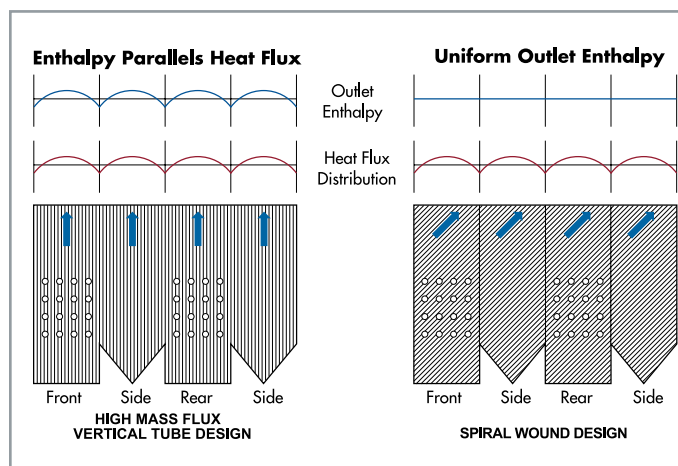
designs, permits variable pressure operation in the furnace.

Vertical tube universal pressure (B&W VTUP) boiler

While the spiral furnace is well suited for daily on/off and variable pressure

operation, it is somewhat more costly to fabricate and erect. The low mass flux vertical tube variable pressure furnace with OMLR tubing combines the advantages of variable pressure operation with the fabrication and erection simplicity of a vertical tube furnace.

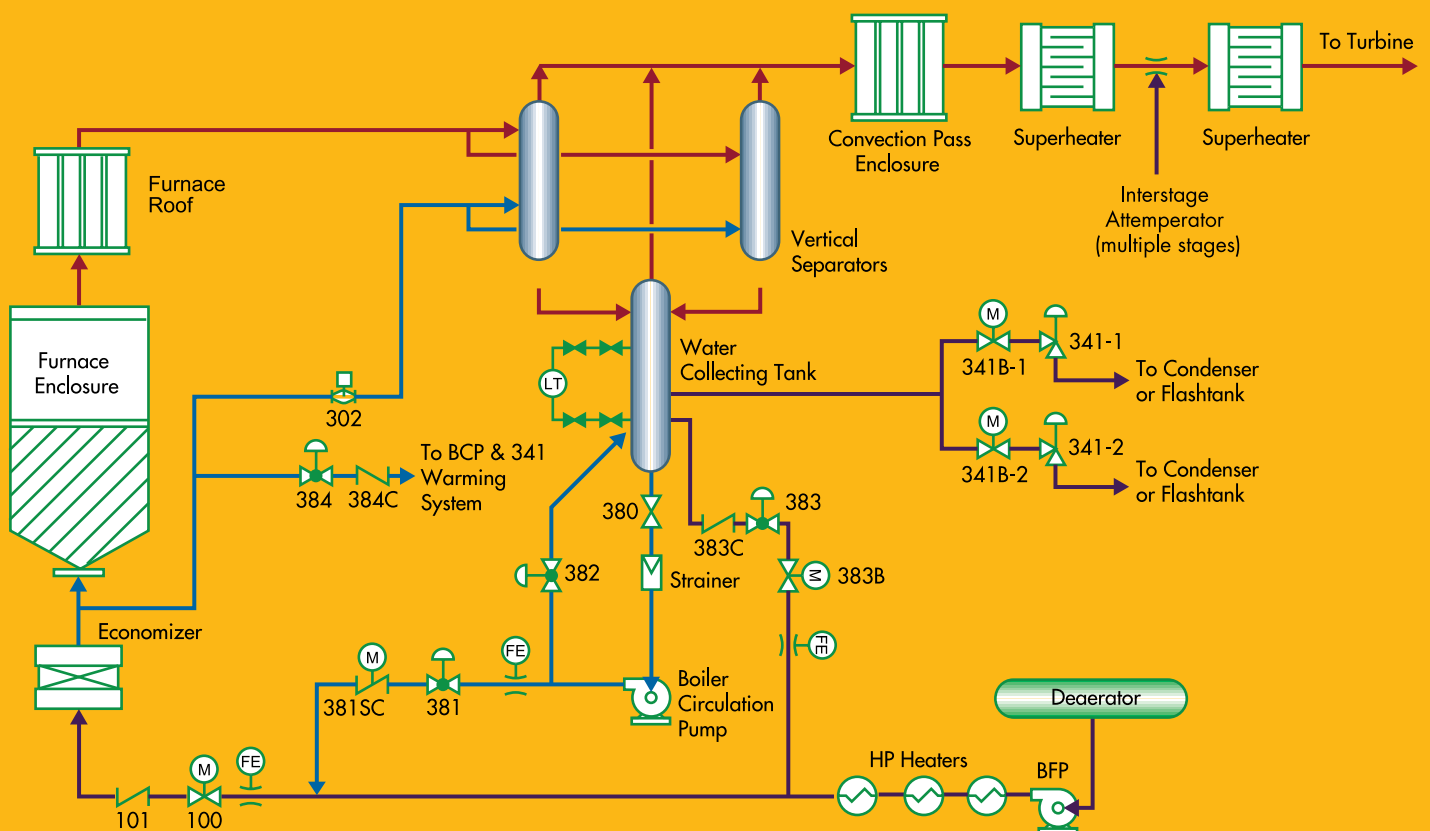
While the multi-pass and spiral furnaces are designed to operate in a high mass flux, forced circulation mode, the vertical tube furnace design takes advantage of natural circulation characteristics similar to a drum boiler. The OMLR tubing makes this design possible. Through years of laboratory testing, an optimized ribbed tube has been designed to provide the combination of heat transfer and pressure drop required for a low mass flux once-through boiler design to function properly. B&W continues to develop this promising design for application in future power plants.



▲ Figure 1: The spiral furnace design permits true variable pressure operation.



Figure 2: B&W's once-through boiler startup system allows for rapid startups with the least amount of thermal stress on the components.





From the first supercritical boiler in the U.S. to units up to 1300 MW, B&W has the proven experience to provide the world's most efficient steam generating systems.

Rapid startup systems

During startup of a once-through boiler, the water-side components must have a minimum water flow maintained to ensure adequate cooling. B&W startup systems are well proven to provide reliable flow to the waterside components to produce short startup times and low thermal stresses.

The typical variable pressure boiler startup system is shown in Figure 2. The main components of the system are the vertical steam separators, water collecting tank and boiler recirculation pump. The steam separator acts similar to a drum in a natural circulation boiler. The fluid from this separator is recycled to the economizer inlet where it mixes with feedwater to maintain the minimum flow through the

boiler furnace. Once minimum load is achieved, the startup system is put in warm standby for quick use when required. The steam from the separator passes through to the superheater and then on to the turbine. The startup operation parallels that of a drum boiler. This system provides the maximum amount of heat recovery back to the boiler during startup allowing for rapid startups with the least amount of thermal stress on the components.

The continued advancement of ultra supercritical technology

Current designs are for steam cycles of 3500 psi (241 bar), with overpressure, and temperatures in the range of 1110 F/1110 F (600 C/600 C). B&W continues the quest for higher plant efficiencies through the development of

advanced materials. Under sponsorship from the U.S. Department of Energy and the Ohio Coal Development Office, we have been conducting field testing of advanced materials for several years and are a major participant in the ongoing ultra supercritical materials development program.

The goal of this program is to develop boiler materials which will allow plant efficiencies to be boosted to nearly 50%. Attainment of these high efficiencies requires turbine throttle temperatures near 1400 F (760 C). These conditions require materials with significant improvements in fatigue and creep strength, as well as fireside and steamside corrosion resistance. B&W's involvement in this program underscores our dedication to improving coal-fired boiler technology.

The experience of B&W

Having supplied more than 140 once-through boilers, including 91 supercritical units ranging in size up to 1300 MW capacity, B&W has the expertise to design the world's highest quality boilers. B&W designed the first supercritical boiler in the United States which went into operation in 1957. From this initial 125 MW unit, B&W's proven once-through boiler size capability increased to 1300 MW in just 15 years. Today, nine B&W 1300 MW steam generating units have combined for more than 200 years of operation, including one unit that, at the time, set a world record of 607 consecutive days without shutting down.

Radiant boilers

The B&W natural circulation drum boiler design, or radiant boiler (RB), provides the advantages of low initial capital cost, wide flexibility (including multiple fuels), “forgiving” operation and very high reliability and availability.

The basic design features include a completely water-cooled furnace, balanced draft design, and horizontal and vertical convection passes to minimize initial capital cost and dry ash removal. B&W has supplied more than 700 RB boilers worldwide up to a capacity of 900 MW.

Recent design improvements have been incorporated in a number of areas, including pulverizers, low NO_x combustion systems, startup/low load systems, superheater header stress reduction and material upgrades, post-combustion environmental systems, and advanced control systems to optimize overall performance.



Auxiliary equipment

Auxiliary equipment plays an important role in a power plant’s long-term availability and reliability. The same high quality standards that are built into B&W boilers go into all of our auxiliary and related equipment.

B&W Roll Wheel™ pulverizers

B&W has designed, constructed and placed in operation more than 1,100 roll wheel pulverizers grinding a wide range of worldwide coals. Features such as a rotating throat, Auto-Spring™ loading system, DSVS® rotating classifier, and WEARESTOR® roll wheel tires offer improved boiler load-following capability, optimal pulverizer performance, and reduced operating and maintenance costs. These benefits contribute to stable steam generator performance regardless of station duty. The B&W Roll Wheel pulverizer has set the standard in the industry for value.

Total-scope capability

As a one-stop source for total boiler island supply, construction services, environmental equipment and aftermarket services, B&W helps minimize your project and performance risks.

Manufacturing and procurement

B&W has put in place a worldwide procurement process for world sourcing and has prequalified equipment suppliers. In addition, we operate manufacturing facilities to serve the power generation and industrial boiler market with unique capabilities. From specialized plant components to the largest steam systems, B&W is your most reliable source of equipment for your boiler. We provide our customers with the best value – quality products delivered on schedule.

Environmental equipment

When it comes to clean steam generation from fossil fueled boilers, no other company has the experience of B&W. We have been at the technological forefront in providing cost-effective solutions to tough emission-control standards. Our continued research and commercial applications of NO_x, SO₂, particulate and mercury reduction have led to many advancements in air pollution control technology.

A variety of emission control technologies, both combustion and post-combustion, are available to meet our customer’s specific environmental strategies:

- Low NO_x burners and staged combustion systems
- Selective catalytic reduction (SCR) systems
- Wet and dry flue gas desulfurization (FGD) systems
- Fabric filter baghouses
- Electrostatic precipitators

Services

B&W’s involvement with your new power plant doesn’t end when the power is delivered to the grid. We are recognized as a highly reliable and responsive service organization. Whether through our many regional field engineering service offices, or our customer service organization, B&W can help ensure the safe, reliable and efficient operation of your steam generation assets.

Some of the many services that we provide include:

- On-site training
- Startup, testing and commissioning
- Replacement parts and inventory management programs
- Field engineering services
- Condition assessment
- Equipment or plant maintenance services

◀ *The workhorse base-loaded boiler, for many years, has been the B&W natural circulation drum boiler.*



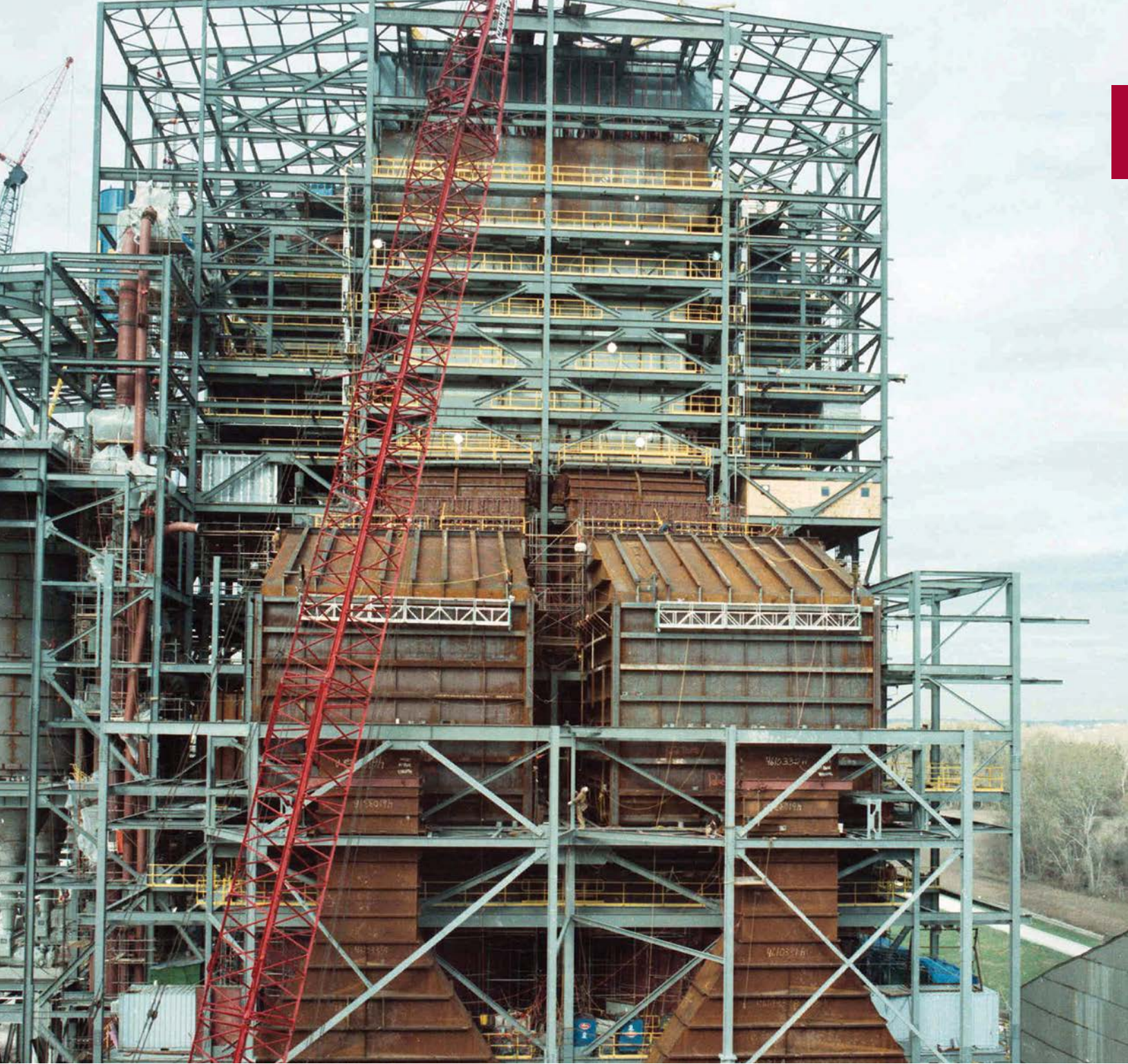
▲ The latest environmental technologies were incorporated into this power plant, including ultra-low NO_x burners, SCR system, dry FGD and fabric filter baghouse.

▼ The B&W Roll Wheel™ pulverizer has demonstrated both reliable and durable operation. B&W continues to improve upon the original design to provide additional performance and cost benefits.

▼ B&W has supplied more than 700 radiant boilers worldwide.

▲ B&W DRB-4Z® low NO_x burners, along with staged combustion systems, offer the plant owner the ultimate in combustion NO_x control.





BWCC's experience and knowledge of the latest construction technology will help ensure the safe and successful execution of your project.

B&W's family of products and services

Babcock & Wilcox Construction Co., Inc

Babcock & Wilcox Construction Co., LLC (BWCC), a subsidiary of B&W, provides a full-range of field construction, construction management, advanced construction technology, and maintenance services. An experienced management team combined with skilled craftsmen will help ensure the safe and successful execution of your construction project.

BWCC continually looks for methods to reduce the overall construction span of a project. One such method is modularization. Modularization is an integrated approach to power plant construction and must be incorporated at

the earliest possible stages of a project's planning phase.

To take full advantage of new construction techniques, BWCC conducts constructability reviews throughout the project. The design for constructability process optimizes the integration of construction knowledge and experience into project planning, design, procurement and field operations to achieve overall project objectives.

Diamond Power® Boiler Cleaning Systems

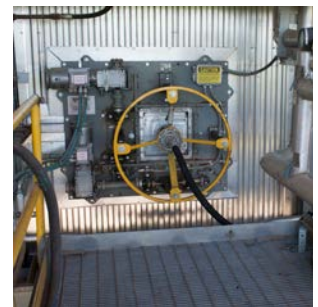
Seven out of ten power plants feature Diamond Power sootblowers from B&W. Diamond Power sootblowers remove deposits, prevent

plugging of gas passes and maintain boiler efficiency. We lead the industry in providing advanced sootblower and intelligent control designs. Our extensive experience gives us a unique perspective on the optimal, most efficient and cost-effective way to clean boilers that burn a variety of fuels, in any operating condition. We also support your aftermarket requirements and provide equipment upgrades, rebuilds and quality replacement parts.

Allen-Sherman-Hoff® Ash Handling

Through our Allen-Sherman-Hoff® (A-S-H®) ash handling product line, B&W is a leading global supplier and manufacturer of customized

material handling solutions. Our extensive knowledge of the physical and chemical properties of various material combinations has made us an integral supplier of customized solutions. We provide engineered systems for bottom ash, fly ash, reagent/byproduct transport, as well as complete aftermarket services and parts.



The Diamond Power and Allen-Sherman-Hoff brands of B&W have a long and proven successful history of boiler cleaning and ash handling technologies in the power generation industry.



▲ From boiler to stack, B&W provides products and services for the entire power plant.

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Established in 1867, Babcock & Wilcox is a global leader in advanced energy and environmental technologies and services for the power, industrial and renewable markets.

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

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The Babcock & Wilcox Company is recognized and respected worldwide for its dependable and efficient steam generation systems. We are experts in converting the energy in fuels to energy in steam.

Our total-scope capability includes boiler and boiler island supply, environmental systems, auxiliary equipment and complete construction and startup services. As a one-stop source, we minimize your project and performance risks.

No other boiler company can duplicate the engineering excellence and advanced technologies developed by The Babcock & Wilcox Company. B&W's commitment to our customers and employees continues "full steam ahead."