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Technical Paper

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G.J. Nakoneczny, R.S. Conrad, I. Vulicevic, and K. A. Larson
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Barberton, Ohio, U.S.A.

K.L. Noel
MidAmerican Energy Company
Muscatine, Iowa, U.S.A.

M.W. Carlisle
Alabama Power Company
Quinton, Alabama, U.S.A.

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G. J. Nakoneczny, R. S. Conrad, I. Vulicevic,
K. A. Larson
The Babcock & Wilcox Company
Barberton, Ohio, USA

K. L. Noel
MidAmerican Energy Company
Louisa Generating Station
Muscatine, Iowa, USA

M. W. Carlisle
Alabama Power Company
Plant Miller
Quinton, Alabama, USA

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Abstract

To achieve optimum boiler operation and performance it is necessary to control the cleanliness and limit the fouling of the heat transfer surfaces. Historically, the heating surfaces were cleaned by air-blowing, steam-blowing, or water-blowing sootblowers on a scheduled time-based interval. With the advent of fuel switching strategies such as changing from bituminous to Powder River Basin coals to reduce emissions, the control of heating surface cleanliness has become more problematic for many steam generator owners. A scheduled cleaning approach does not easily address changes in operation. Also, as power plant operators push to achieve greater efficiency and performance from their boilers, the ability to more effectively optimize cleaning cycles has become increasingly important. Sootblowing only when and where it is required to maintain unit performance can reduce unnecessary blowing, save on steam utilization, and reduce tube erosion and wear.

B&W's core technology for boiler design is based on modeling of boiler heating surfaces to establish heating surface requirements and performance. The modeling process also must consider fuel types and the combustion requirements. This same technology is used to model the expected performance of existing units. By establishing the boiler model it is possible to accurately determine when and where heating surfaces are experiencing diminished performance due to ash buildup and fouling.

The ability to model the heating surface and determine real-time cleanliness indexes is important in developing a system that can more accurately initiate the cleaning cycle of the boiler heating surfaces. The performance of the individual convection pass banks is interrelated; consequently, determining the best sootblowing program must not only rely on the cleanliness of the specific bank to initiate or trigger blowing. By coupling the real-time cleanliness index data with the measured operating parameters of the boiler it is possible to establish rule-based logic to drive sootblower operation.

Presented in this paper is the approach taken by The Babcock & Wilcox Company in developing the Powerclean™ system, a sootblowing optimization system. Also presented are the performance improvements made with the Powerclean™ system at two utilities in the USA – MidAmerican Energy's Louisa Generating Station and Alabama Power's Plant Miller.

Power Generation from Coal

Coal continues to be the dominant fuel source for fossil fuel steam generation in the US electric utility industry, accounting for more than 50% of the power generated. With ever increasing pressure from environmental groups and others to reduce the emissions of SOx, NOx, mercury and now CO_2, coal-fired generation continues to seek cost effective strategies to meet regulations. An option being used by more and more utilities is the use of low sulfur western fuels such as Powder River Basin (PRB) coals, which produce less SOx emissions and can avoid the need to install high cost wet or dry scrubbers. However, this western fuel also contains greater amounts of moisture with less heating value on a per pound as-received basis. Western fuels can also have lower ash softening temperatures and produce greater fouling and slagging of the boiler surfaces. Increased slagging on furnace walls and greater ash loading to the convection pass place a premium on effective use of sootblowers to control the build up of ash deposits. Improved blowers and increased numbers of sootblowers may be part of the strategy when burning a western fuel; however, improved use of the blowers by better determination of where and when to blow and clean heating surfaces is also important. Historically, a program of monitoring the unit is implemented to develop a set of "best practices" for use of the blowers based on load, fuel source, etc. Now, improved control systems are available to allow "intelligent" cleaning of heating surfaces.

B&W Boiler Modeling Technology and Intelligent Sootblowing

The Babcock & Wilcox Company (B&W) has been modeling boilers and the combustion process for many decades. A common misconception about B&W's technology is that it only applies to B&W designed boilers. In fact, B&W has modeled and improved on the designs of many other boiler manufacturers.

B&W's technology is based on the effective development of heat transfer, fluid flow and combustion principles. However, much of what makes B&W's modeling technology effective has been the application of this technology to operating units. B&W has been using software versions of its boiler performance program on operating units since the 1970s. Commercial versions of these same programs have been deployed on operating units since the early 1980s. This deployment first took the form of performance monitoring programs that allowed plant engineers and operators to track the real time performance of the unit.

Even in those early days, users of B&W's programs used the performance and cleanliness data to optimize the sootblowing process. These users found that an accurate first-principles model of the boiler provided repeatable cleanliness factors that they could use to make changes to better optimize sootblowing. One of the drawbacks of these early systems was that they were advisory such that a plant engineer needed to use the data to track and manually alter the sootblowing schedules. Today, B&W's commercial version is the Heat Transfer Manager™ (HTM) performance program.

Heat Transfer Manager™ Performance Modeling

The Heat Transfer Manager™ (HTM) program is the core of the Powerclean™ system. The HTM program is applicable to boilers manufactured by B&W as well as those designed by other manufacturers. The HTM program is based on the heat transfer analysis programs that B&W has developed over many years of designing boilers, upgrading boilers, and analyzing their performance. The heat transfer analysis begins with combustion and efficiency calculations in accordance with ASME PTC 4 procedures. The data obtained from the plant historian, DCS or data acquisition system includes the data necessary to calculate total boiler output as well as the absorption of each major boiler component.

In a typical installation, the HTM model consists of the following components: furnace, economizer, primary superheater, furnace platens, secondary superheater, and reheater. Fuel input is calculated from measured boiler output and efficiency. Flue gas weight is calculated stoichiometrically from fuel input and excess air which is determined from measured oxygen in the flue gas.

With the above information, a detailed computer model of the unit is used to analyze unit operating data. The computer model includes the furnace as well as the convection surface. The furnace portion of the model divides the furnace into volumes whereby the location and input of burners and changes in furnace shape such as the furnace arch are described. The furnace model calculates the expected furnace exit gas temperature (FEGT) for comparison to the FEGT value determined analytically.

The convection portion of the boiler model consists of tube banks, gas cavities between the tube banks, and the steam/water cooled enclosure surface surrounding the banks and cavities. Tube banks are modeled in detail and include parameters such as tube diameter, tube side and back spacing, heating surface, gas free flow area, steam/water flow per tube, etc. Starting at the air heater gas inlet (economizer gas outlet), the gas temperature entering each component is calculated by heat balance based on calculated gas weight and measured absorption of each boiler component. For units with parallel gas paths for reheat steam temperature control, it is also possible to calculate gas splits between the reheater and superheater gas paths, if the gas temperature leaving each path is measured.

Utilizing the measured steam/water temperature entering and leaving each component and the calculated gas temperatures, the actual as well as expected overall heat transfer coefficient is determined for each boiler component. The relative measure of the actual versus expected heat transfer coefficient provides the cleanliness index that is critical to intelligent sootblowing decisions. Since the HTM program is based on the technology used by B&W for boiler design and performance evaluation, there is extensive empirical data and validation of the accuracy of the program for predicting heat absorption within tube banks. This is true for boilers originally supplied by B&W as well as units by other manufacturers.

In configuring the boiler model, B&W reviews the complete Input/Output (I/O) list of plant data available from the data acquisition system (DAS), DCS or historian to select the points needed for HTM analysis and for use in setting sootblowing strategy. In general, all the critical data used by the HTM model is part of the normal measured operating data for the boiler controls. Once the boiler model is established, the system is installed at the site and interfaced with both the sootblower controls and the plant DAS, DCS or historian. The HTM model provides the critical boiler performance and heating surface data that is used by the Powerclean module when setting up strategies that guide sootblowing. HTM model results are displayed on the Powerclean graphical interface in a boiler sideview for a comprehensive view of cleanliness by boiler region (Figure 1).

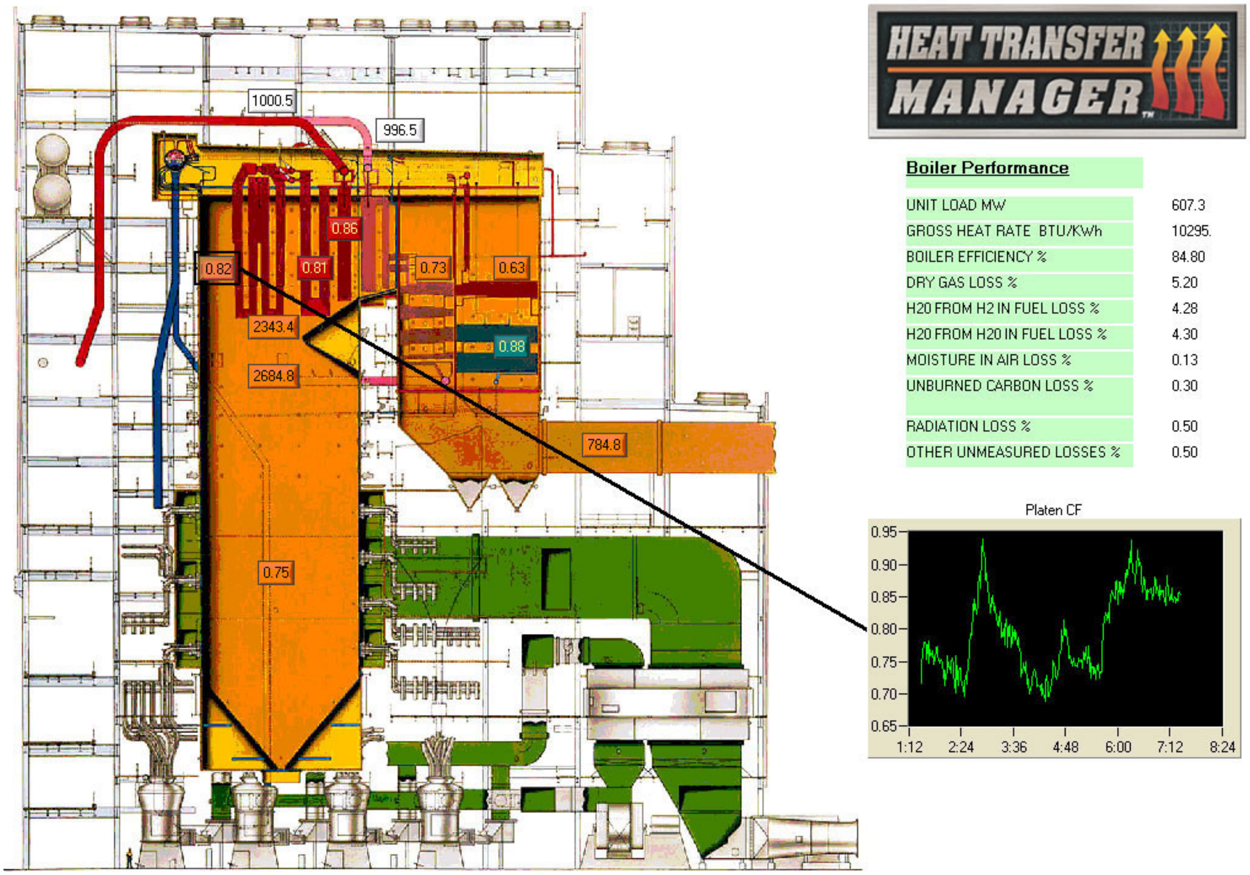

Figure 1 HTM Boiler Sideview

Fuel Analysis

HTM requires an analysis for the typical fuel being used. It is commonly thought that a different fuel analysis is required for all variations of fuel used in a boiler. In fact, when using a reliable first-principles model such as HTM, different fuel analyses are only required when major changes are made to the fuel source. As an example, one representative fuel analysis is needed for firing many different coals of the same rank such as bituminous coal from more than one source. However, if rank changes are made, such as the use of a sub-bituminous coal, then a different fuel analyses is used to ensure accurate performance modeling results. Since B&W uses the modeling behind Heat Transfer Manager for boiler design, we have extensive data on coal types and their impact on boiler performance. When determining the coal analyses for use in HTM, all coals used by the plant are considered. The program can be configured so that a different fuel analysis is substituted when a significant fuel switch (e.g. change of coal rank) is made.

Furnace Gas Temperatures

As noted above, the HTM program calculates upper furnace exit gas temperatures (FEGT) for use in the Powerclean system. This is an important feature of the B&W system since it eliminates the need for installing field instrumentation for this purpose. Upper furnace temperature measuring devices such as optical pyrometers or acoustic pyrometers can be costly to install and difficult to maintain in reliable operation. Field installed devices are also dependant on the installation location and field of view such that determining an expected temperature for making cleaning decisions is best done by a period of operation and learning in the specific unit. By contrast, HTM calculates a thermodynamic average FEGT in a specific plane of the boiler which is consistent with FEGT values used by B&W for design. This allows use of an FEGT value that can be compared to an expected value based on historical empirical data. Not only does this calculated FEGT provide important information to aid in optimizing performance but it also allows calculation of a furnace cleanliness factor that is used to help determine when best to clean the furnace walls.

The Powerclean intelligent sootblowing system has been installed on boilers with instrumentation for measuring furnace gas temperatures. Figure 2 shows a comparison of the platen inlet gas temperature (PIGT) and FEGT as determined by HTM versus the upper furnace temperature as measured by two optical furnace pyrometers. The furnace pyrometers were installed on the East and West sides of the boiler in the upper furnace. Note that the temperatures behave similarly in response to actual furnace conditions. The values are not in exact agreement since the HTM values are thermodynamic average temperatures in a specific plane of the boiler while the pyrometers detect the average peak temperature based on their physical location with a heavier weighting toward the near field in its field of view.

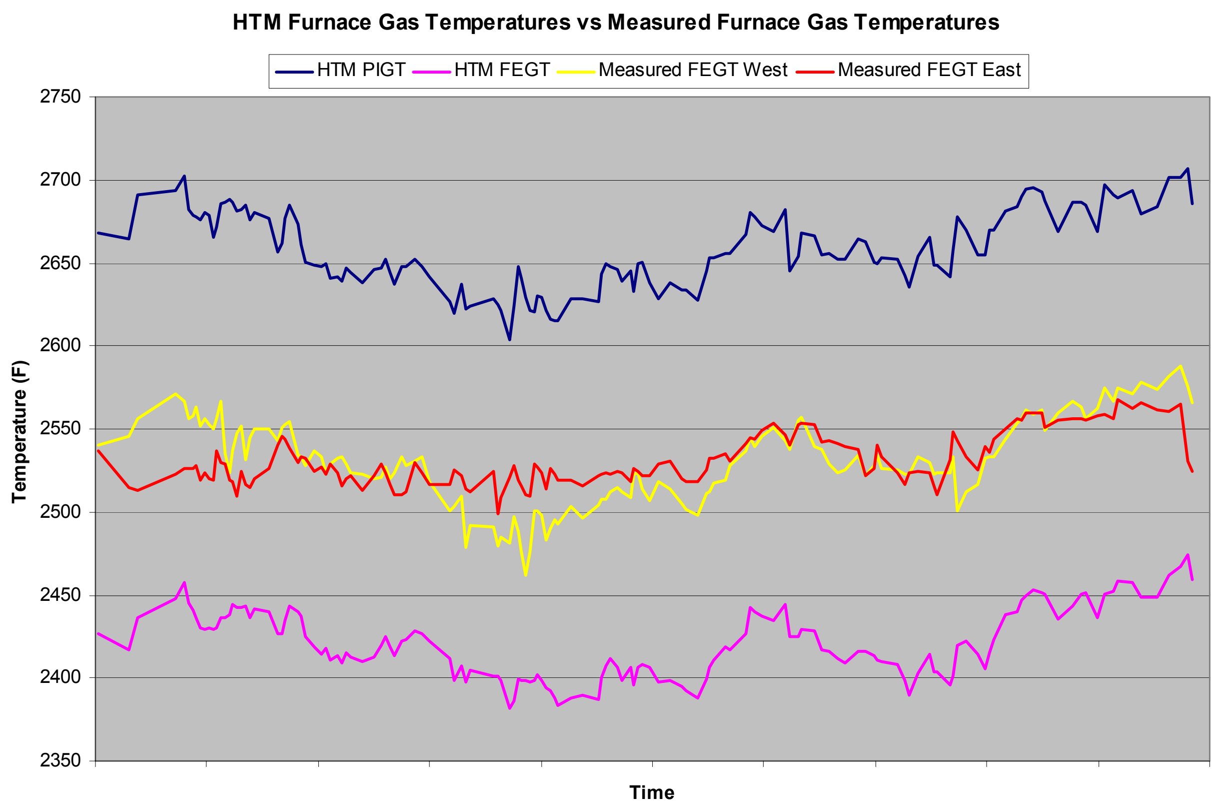

Figure 2 HTM Furnace Gas Temperatures versus Measured Temperatures

The Powerclean™ Sootblowing Optimization Program

Because boiler heating surface performance may not be the only reason to clean or not clean an area of the boiler, B&W combines the performance diagnostic capabilities of HTM with an expert system to capture and implement strategies for cleaning the unit. The Powerclean Expert System and the HTM program form the foundation of the Powerclean™ sootblowing optimization system.

When developing the Powerclean system, B&W realized that other parameters, in addition to how dirty tube surfaces have become, must be considered when deciding to clean a given region of the boiler. As an example, a plant may want to set a lower limit on cleanliness (i.e. let the surface get dirtier) for the secondary superheater (SSH) outlet sections if the unit is operating below a threshold for reheat outlet temperature. This may be necessary as increased absorption in the SSH would further reduce attainable reheat temperature.

In general, the goal in creating Powerclean was to give the system enough flexibility such that the observations of the plant engineer, operator or a B&W service engineer could be incorporated into cleaning strategies as needed. With the rule-based expert system designed to capture and implement unit-specific knowledge about sootblowing, the Powerclean approach provides the engineer or operator with significant flexibility to set different strategies for cleaning the unit under different conditions. For instance, separate strategies can be developed for multiple operating load ranges. The Powerclean system also serves as a useful tool to evolve cleaning strategies and practices over time. The user can update and modify the expert system as needed when changes occur. One example is a significant change in fuel source.

Powerclean™ System Experience: MidAmerican Energy Louisa Unit 1

MidAmerican Energy Company's Unit 1 at the Louisa Energy Center installed the Powerclean intelligent sootblowing system in early 2002. Louisa's Unit 1 is a B&W subcritical radiant boiler that began operation in 1983. The unit has a maximum continuous rated (MCR) steam capacity of 5,283,000 lbs/hr at 2,640 psi, 1005F at the superheater outlet, with reheat capacity of 4,535,000 lbs/hr steam flow at 546 psi reheat outlet pressure and 1000F. The unit was designed to make MCR steam flow while burning either Illinois bituminous or western (Wyoming) sub-bituminous coals.

The convection pass heating surfaces are arranged with a platen (radiant) superheater followed by the pendant secondary superheater (SSH) banks and pendant reheat superheater outlet bank in the upper horizontal pass (Figure 3). The convection pass is then split between parallel back end vertical passes that allow biasing of the flue gases to aid reheat steam temperature control. Arranged in the front vertical pass is the horizontal reheat surface and in the rear vertical pass are the horizontal primary superheater (PSH) banks followed by the economizer. In addition to gas biasing dampers, steam temperature from the superheater is controlled by multiple stage spray attemperation; steam temperature from the reheater is controlled by single stage attemperation. To control slagging and fouling of the furnace and convection pass tube surfaces, the unit employs Copes-Vulcan sootblowers (SB) and Diamond Power® waterlances. The furnace waterwalls have a combination of waterlances (27), Selective Pattern® waterlances (2) and steam sootblowers (34). The convection pass surfaces are cleaned by retractable steam sootblowers with 34 blowers and 2 Selective Pattern waterlances covering the SH platens, pendant SH and pendant RH, and 20 blowers in the vertical passes to clean the horizontal tube banks.

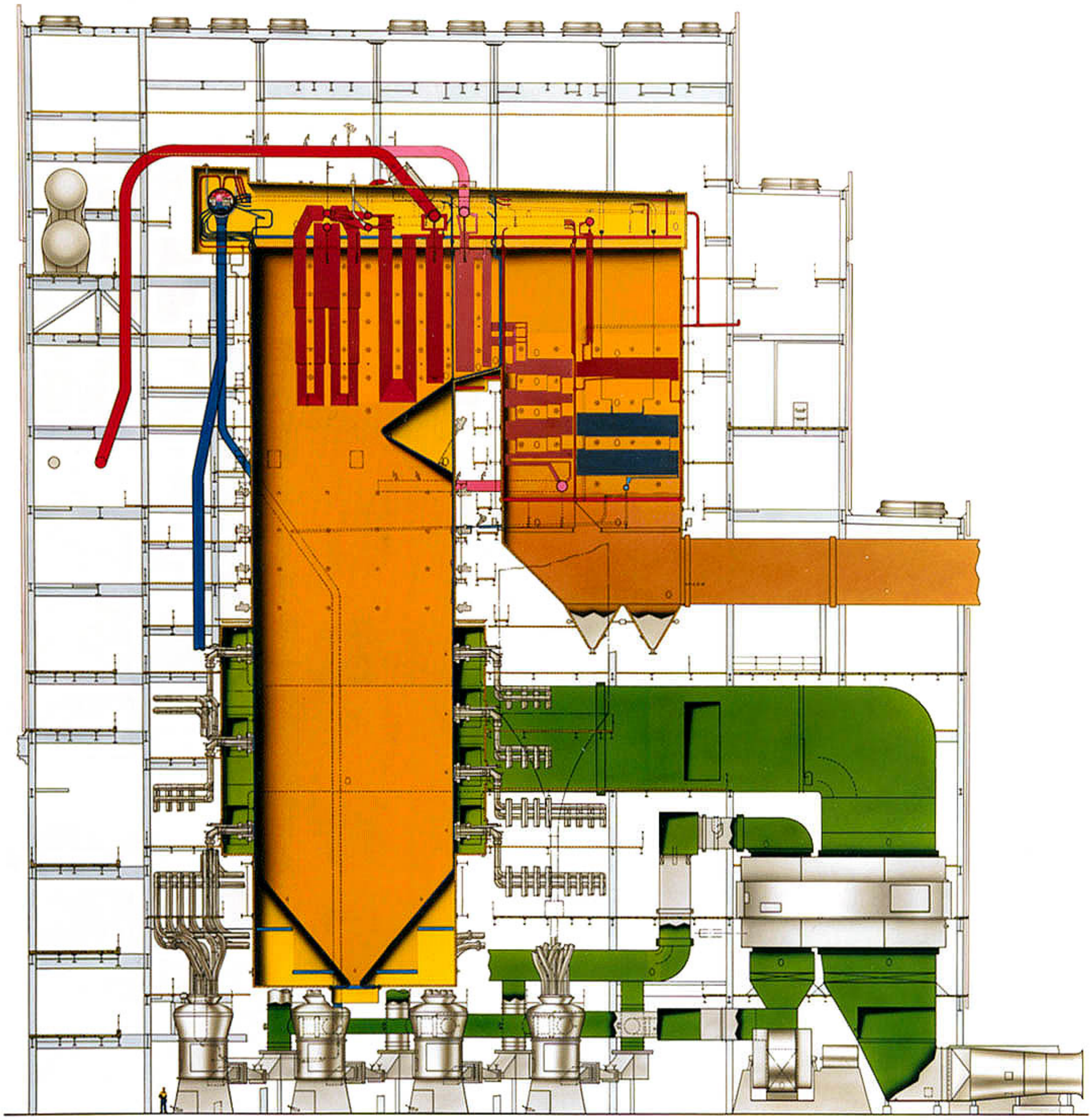

Figure 3   MidAmerican Energy Company Louisa Energy Center

Louisa 1 – Operating History

Louisa Unit 1 has burned western fuel since original startup. In general, the unit has had an excellent operating history with good availability. Normal preventive maintenance has been performed over the years to address component wear and deterioration as required including the burners, pulverizers and sootblowers. No major upgrades or equipment replacements have been required to date. B&W Field Service has supported the inspection program of the Louisa station since the unit began operations and has documented changes in conditions where monitoring was recommended. After the first years of operation, inspections began to document polishing and wear of tube surfaces throughout the convection passes in the areas of sootblowing. In general, the tube wear was not excessive. Tube shielding was installed and/or pad welding was done in selected areas where SB erosion was a concern.

In 1999, MidAmerican Energy Company (MEC) contracted with B&W to conduct a unit performance and heating surface cleanliness study. MEC was working with B&W to determine the cause of increased boiler exit gas temperature and determine whether an improved SB program could mitigate the problem. B&W performed testing of the unit over a two-day period and modeled the unit performance in B&W's heat transfer design program. The boiler modeling program made it possible to compare expected performance of the heating surface with actual performance to calculate a cleanliness factor for each bank. The testing indicated that the furnace exit gas temperature was higher than expected and the convective surfaces were not being cleaned to the extent desired for optimum performance.

Based on the study, Louisa implemented changes to their sootblowing regimen which included more frequent blowing of the vertical surfaces and less blowing of the horizontal surfaces. The updated program of sootblowing was done on a scheduled and/or parameter basis that relied on shift operators following defined blowing sequences and frequencies. B&W and Diamond Power International, Inc. (DPII) recommended the installation of Selective Pattern® waterlances to clean the lower side of the upper nose arch. This upgrade was implemented in 2003. DPII also performed a unit evaluation with their thermography technology and provided recommended blowing frequencies for the wall waterlances based on boiler load.

Louisa 1 – Powerclean System Installation and Operation

The Powerclean installation on Unit 1 was initially installed with a communications link to the Honeywell® historian that interfaced to the analog control system. Closed loop control was implemented through a communications link to a PLC based sootblowing control system. In 2003, the plant control system was updated to DCS control with an Emerson Company Ovation® system. In turn, the Powerclean system was upgraded and OPC links were established with the Ovation system for closed loop sootblowing.

Once communications were established and the I/O points were configured into Powerclean, the system was configured for the components, regions and blower sequences on the unit. For Louisa, many of the sootblowing regions were already well established as a result of their prior sootblowing optimization program. For example, the regions, blower sequences and predetermined load-based waterlance-blowing frequencies for cleaning furnace waterwalls were not changed when implementing Powerclean.

Although Louisa had done more than is typical to analyze and optimize sootblowing, the practice of drawing on the experience of plant personnel and their operating history is always an integral part of installing the Powerclean system. The initial configuration of Powerclean also utilizes the experience of B&W with similar unit types and fuels. During the configuration of regions, the initial blowing strategies are also developed.

After initial corrections were made to the HTM program it was run in advisory mode over a one-month period so that test data could be collected and evaluated. During the initial run period MEC operators found that the calculated furnace exit gas temperature correlated well with their existing furnace exit gas temperature probes. This consistency in trending of the two methods helped give the operators confidence in the system. The Powerclean system is designed to allow for remote access such that B&W was able to monitor, collect data, and make changes to the system from offices in Barberton, Ohio during the initial startup evaluation period. Data was evaluated to determine where surfaces were dirtiest, rate of degradation of heat transfer, and effectiveness of specific blower sequences. As a result of the testing, changes were made to some of the convection pass sequences to address areas that were more sensitive to sootblowing. An example was to divide the secondary superheater outlet into two regions since it was seen that the lower blowers had a much greater effect on cleanliness than the upper blowers. This allowed for less frequent blowing of the upper blowers to save on tube wear and steam use while cycling the blowers with the greatest impact more frequently.

Once the regions and rules were set up and evaluated, B&W returned to the Louisa site to implement the Powerclean system in closed loop for automatic control of the sootblowers. After the closed loop control was in operation and monitored for effectiveness, B&W provided operator training on use of the system. One aspect of the Powerclean application is that the status of blower recommendations and operation is displayed in an easy to follow graphical interface such that learning to monitor the system is not difficult (Figure 4). The additional benefit of maintaining remote access to the system is that B&W is able to provide continuing support without the delay and expense of traveling to the site.

Figure 4 Powerclean™ Results Screen

Louisa Results

The Powerclean system has had a very positive impact on the operation and maintenance of Louisa Unit 1. In addition to improving the operation and maintenance of the unit, the system has proven to be a valuable engineering tool for plant personnel. For example, two Selective Pattern® waterlances were added to the unit in the upper furnace to improve cleanability and eliminate the need to operate four waterlances. Using Powerclean, Louisa engineering personnel were able to confirm the improved operation of the furnace due to these new blowers. The improvement was reflected in a rise in the furnace cleanliness factor from a previous maximum of 0.85 to a new maximum of 1.00.

Additionally, two Selective Pattern® waterlances replaced two retractable sootblowers on the leading edge of the pendant secondary superheater to improve slag removal capabilities. This proved to be more effective as reflected in the Powerclean response and blowing frequencies by half in this area.

Operational Improvements

Operations personnel have found the system to be very helpful since it manages the task of scheduling sootblowing so that the operators do not have to focus on this activity and manually initiate the sequences. Blowing the right regions at the appropriate times has also reduced boiler exit gas temperature concerns, which often resulted in overblowing already clean areas. Although results and the impact of the system will vary from unit to unit, the data from Louisa has indicated improvements in both steam usage and unit efficiency (heat rate).

Data was available from the plant historian for the periods before and after the Powerclean system was implemented (Figures 5 through 7). Evaluation of the data indicated that the steam utilization was reduced because blowers were cycled more efficiently in that the areas of greatest impact on component cleanliness were blown more often while areas that had less significant impact could be blown less. Overall sootblowing at high boiler load has been reduced but has actually increased at lower loads. The implication is that surfaces were not kept as clean as desirable at lower loads when using a time-based and/or parameter-based approach, which restricted the ability of the blowers to clean surfaces as loads increased.

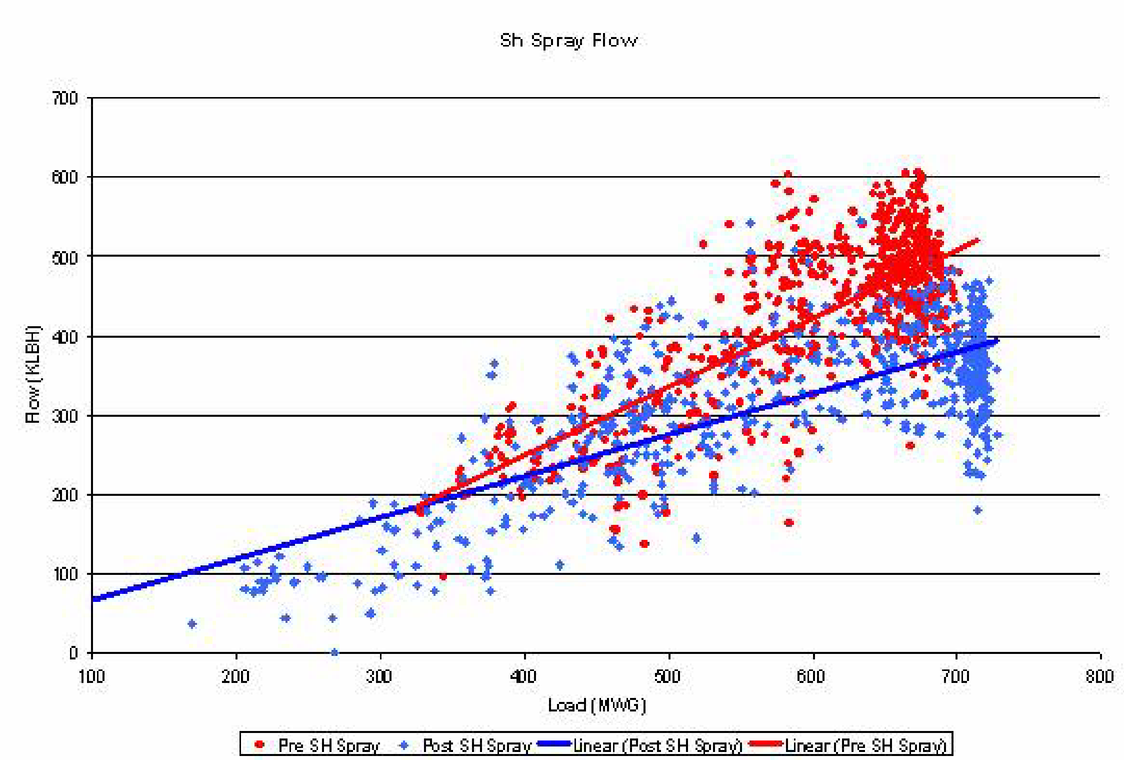

Figure 5 Superheater Spray Flow

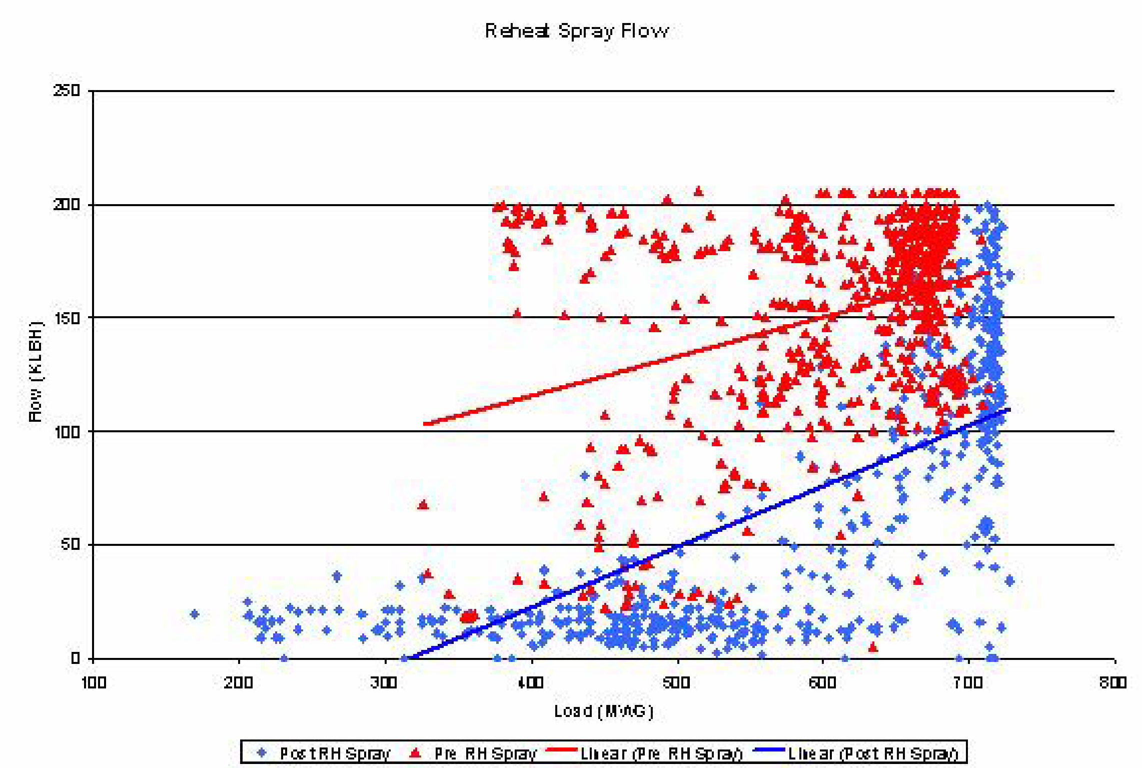

Figure 6 Reheater Spray Flow

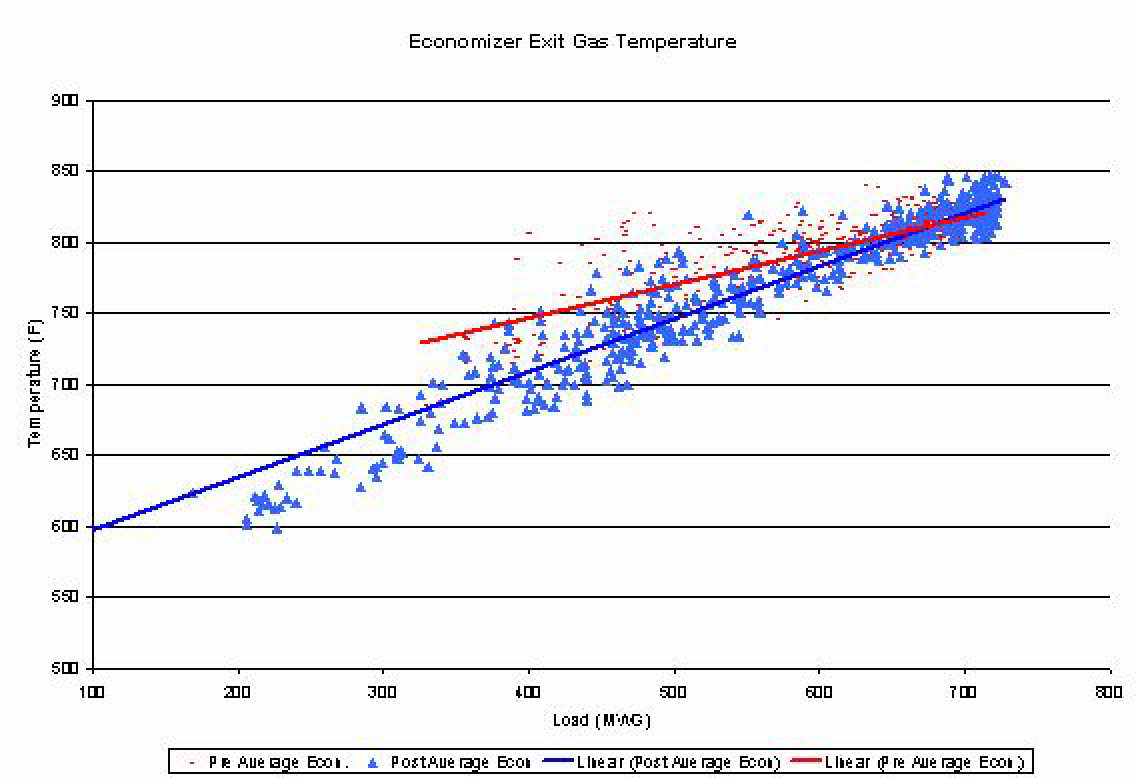

Figure 7 Economizer Exit Gas Temperature

Overall, better targeting of where to blow has resulted in less total blowing. At the same time the economizer gas outlet temperature has trended down and the reheat spray flow has been reduced – both of which impact efficiency and heat rate. Based on historical capacity factors MEC estimates a savings of about $250,000 annually as a result of improved efficiency and reduced heat rate.

Still Effective After One Year

In the past with many optimization systems it was all too common for the benefits first gained during installation to diminish over time. After a year of operation, a study was conducted to determine whether the Powerclean system was still effective. For this study, Powerclean was run in manual and automatic modes under similar conditions during full load operation. When Powerclean was in manual mode, the operators would use their experience and judgment to run the cleaning system. In automatic mode, the Powerclean system was in closed loop and ran all of the sootblowers and waterlances automatically based on the current cleaning strategies.

After the data was collected, the comparison of Powerclean closed loop control to operator control revealed the following.

With Powerclean in closed loop control:

- The platen inlet gas temperature (PIGT) was lower by 63F. (Figure 8)
- There was less variation in superheater and reheater outlet temperatures. In closed loop, the SH/RH temperatures did not exceed 1005/1010F. In manual mode, the temperatures reached 1010/1025F. (Figure 9)

- Superheater and reheater attemperator spray flows were lower. In manual mode, the reheater spray flow often reached its maximum flow rate. (Figure 10)
- The average economizer outlet temperature was lower by 5F with the Powerclean system in automatic control of sootblowing. Also, use of Powerclean showed the ability to get lower economizer outlet temperatures than were achievable with the system off. (Figure 11)

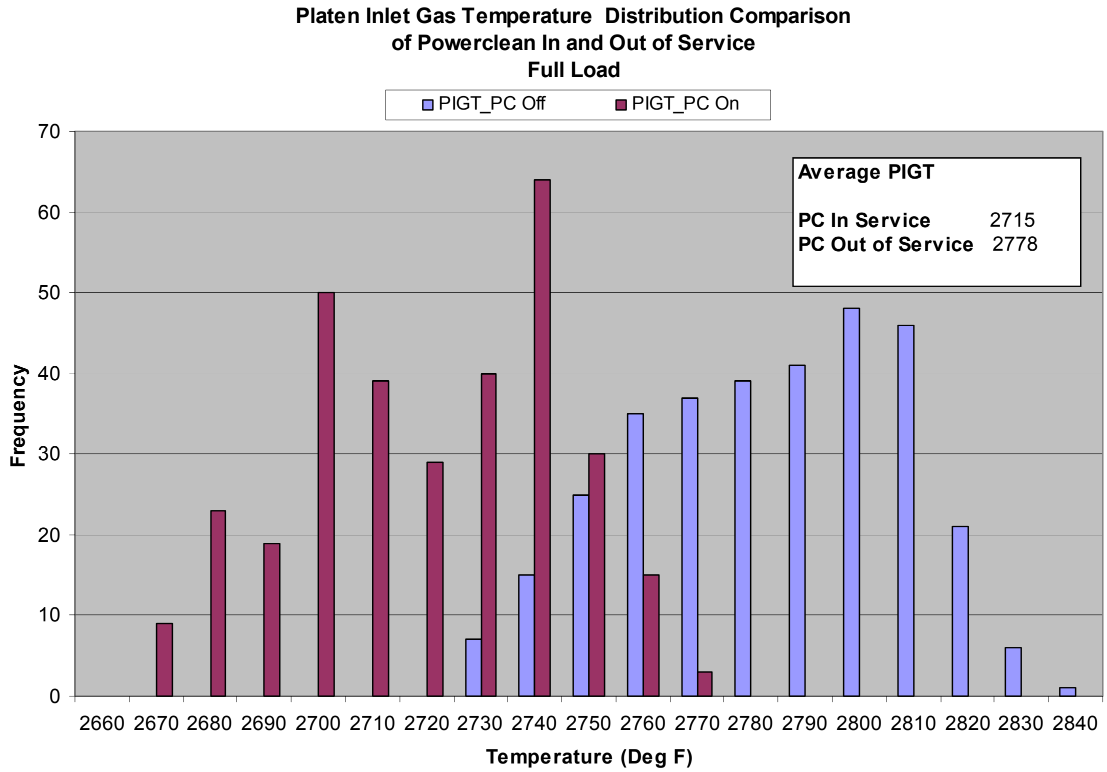

Figure 8 PIGT Distribution Comparison, Powerclean™ System In and Out of Service

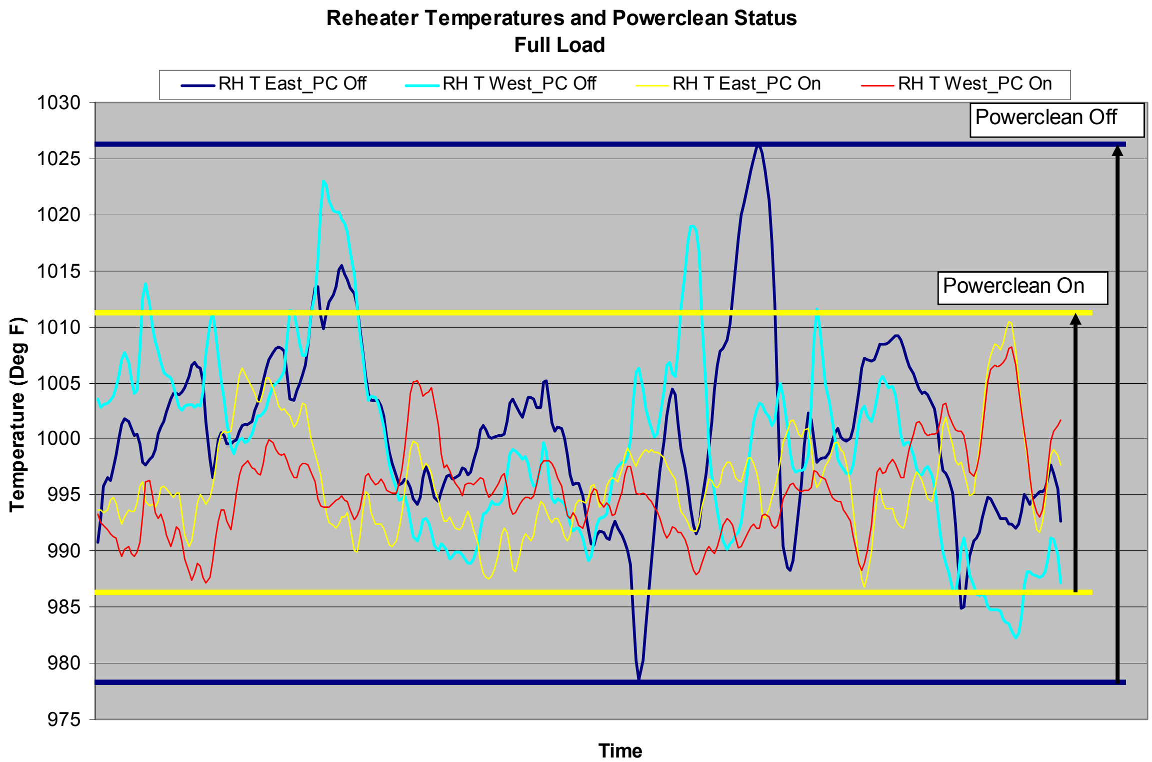

Figure 9   Reheater Temperatures, Powerclean System In and Out of Service

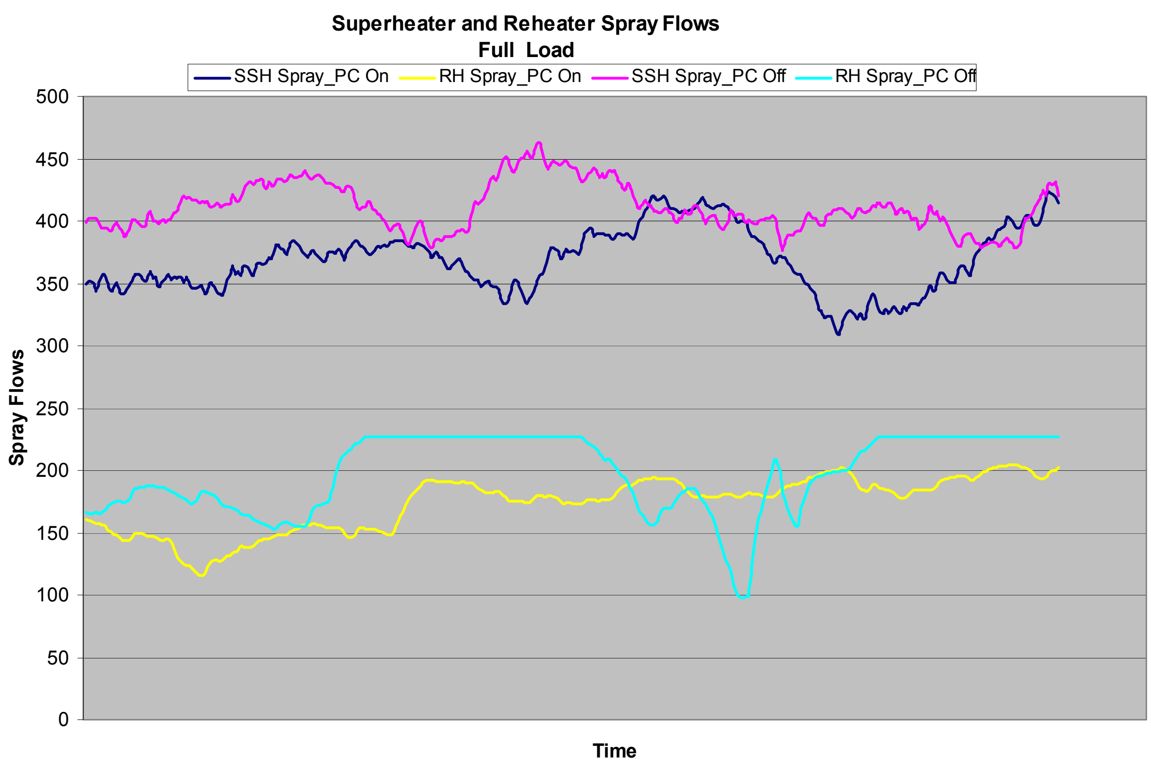

Figure 10   Superheater and Reheater Spray Flows, Powerclean In and Out of Service

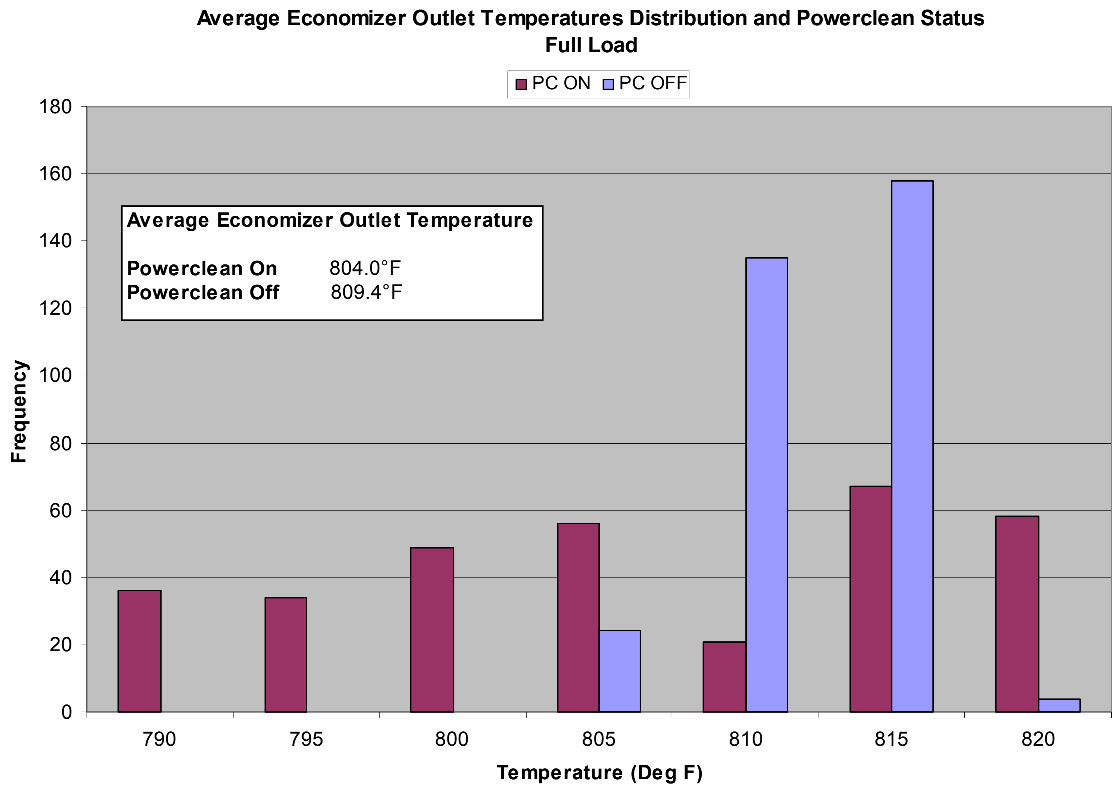

Figure 11 Average Economizer Gas Outlet Temperatures, Powerclean System In and Out of Service

Maintenance Improvements

With the application of the Powerclean system, Louisa has experienced lower overall sootblower maintenance. With knowledge of each blower's effectiveness and its value in keeping the unit clean, Operations and Maintenance personnel know which blowers are critical. These critical blowers are given priority status for maintenance to ensure they are operable – nine blowers in particular have had much higher maintenance than other blowers due to their higher usage and effectiveness.

Originally, this boiler was outfitted with steam wall blowers. Subsequently, waterlances were added to the furnace along with the original steam wall blowers with both remaining in use. It had been long suspected that the blowing frequency of the steam wall blowers could be reduced but there was lack of objective data to guide operations on how to best implement these changes. The Powerclean system provided the data in the form of the Furnace Cleanliness Factor and Platen Inlet Gas Temperature to assure operations personnel that the waterlances were cleaning effectively when reducing the steam wall blower cleaning frequencies. As a consequence, maintenance was reduced substantially on these blowers.

After 13 months of operating with the Powerclean system, the unit was taken offline for an outage. The unit was found to be much cleaner than during previous outages. In the past it normally took 24 hours to de-slag the unit via blasting. During this outage, with the unit being much cleaner, this time was reduced to 8 hours. Additionally, while the unit was cleaner, the rate of erosion seen previously on horizontal tube banks was reduced since Powerclean allowed for decreasing blowing frequency without loss of unit performance.

Louisa Conclusions

The use of the Powerclean intelligent sootblowing system was proven successful and fulfilled its promised benefits of providing better control of heating surface cleanliness. It has also proven to be a valuable tool for plant personnel. Improved control of the heat transfer function in the convection passes and furnace resulted in measurable savings in steam usage, improved unit efficiency (fuel savings) and lower maintenance.

Powerclean™ System Experience: Alabama Power – Miller Unit 1

Alabama Power Plant Miller Unit 1 is a 710 MW, subcritical radiant boiler supplied by The Babcock & Wilcox Company. Unit 1 is a balanced draft, opposed-wall fired boiler equipped with seven (7) B&W-89 Roll Wheel™ Pulverizers. The unit is designed for MCR main steam flow of 4,921,000 lb/hr at 2625 psig and 1000F. Reheat steam flow is 4,511,250 lb/hr at 559 psig and 1000F. The unit was switched from firing bituminous coal to Western (PRB) sub-bituminous coal in 1999.

The convection pass heating surfaces are arranged with a platen (radiant) superheater followed by the pendant secondary superheater (SSH) banks and pendant reheat superheater outlet bank in the upper horizontal pass (Figure 12). The vertical pass consists of horizontal primary superheater (PSH) followed by the horizontal reheater bank and the economizer. Superheater and reheater steam temperature are controlled by spray attemperation.

The furnace is equipped with four water cannons, 24 waterlances and 22 steam wall blowers. Typically, if the water cannons are used then the waterlances and wall blowers are not used. The convection pass is equipped with 70 retractable steam sootblowers to control fouling and slagging.

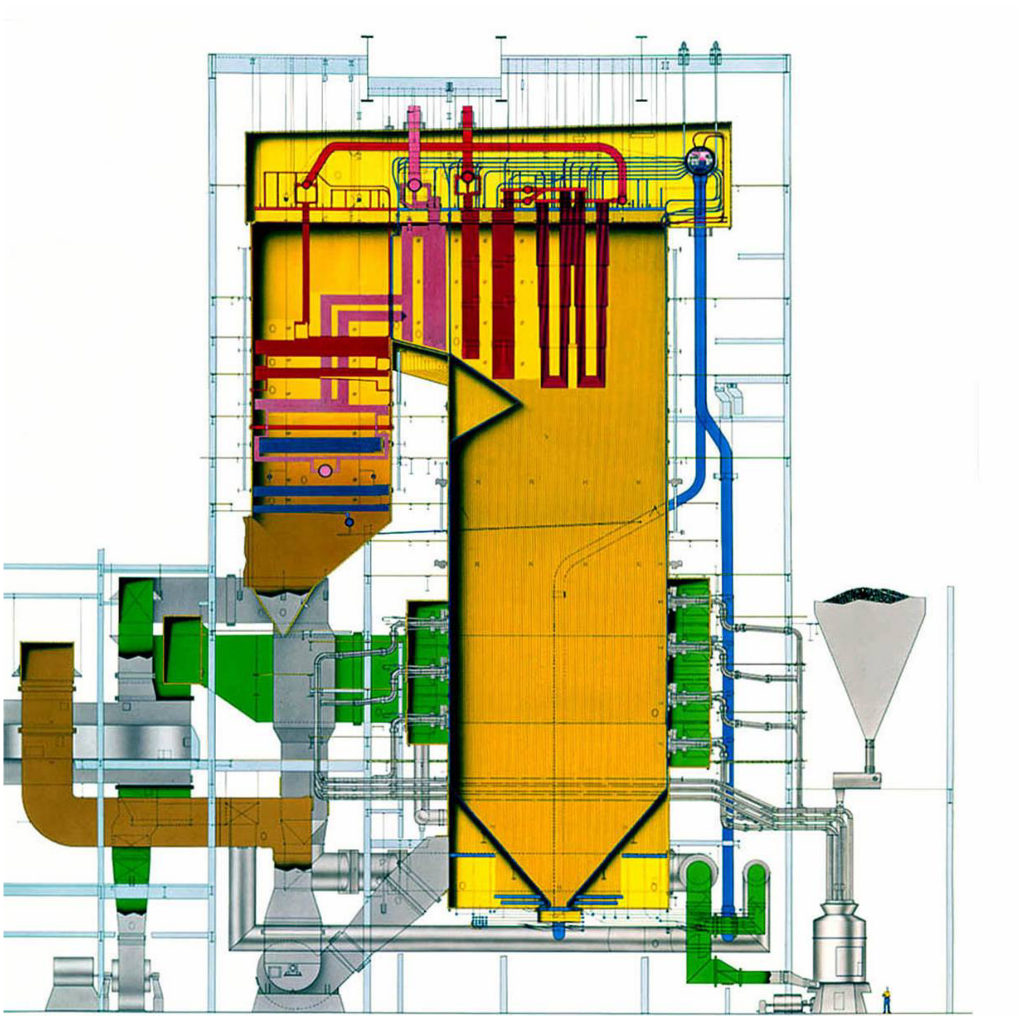

Figure 12 Alabama Power - Miller Station Unit 1

Miller 1 – Operating History

Prior to the conversion to Powder River Basin (PRB) coal, Miller 1 did not have problems with fouling and slagging. The installed sootblowing equipment, which consisted of steam wall blowers in the furnace and steam retractable blowers in the convection pass, was sufficient to keep the unit running well.

Since the conversion to PRB coal, Miller 1 has experienced significant fouling and slagging which has required changes to the equipment and operating procedures. The most severe fouling and slagging has occurred in the platen superheater and secondary superheater. Based on Alabama Power's experience with fouling problems in sister units, Unit 1 is also susceptible to heavy fouling in the pendant section of the reheater.

In an effort to address anticipated fouling problems in the furnace, waterlances were added as part of the PRB conversion. The waterlances were more effective than the steam wall blowers and were able to adequately clean the furnace. However, use of the waterlances resulted in thermal cracking of the waterwalls. In an effort to reduce the cracking associated with the waterlances, the furnace was outfitted with water cannons and tube-based heat flux sensors. It was hoped that the use of the heat flux sensors and its associated controls would prevent further furnace wall cracking.

In the past, Plant Miller had examined the sootblowing strategies for Unit 1 and attempted to developed operator guidelines to help improve overall management of unit cleanliness and sootblowing. These strategies were based on unit evaluation, review of operating data, visual observations and prior experience. However, without the right analysis tools, effective strategies were difficult to develop and implement. A further problem with the guidelines was that they had to be manually followed by operators across shifts which proved to be a problem since monitoring and implementing sootblowing schedules was one of many operator functions for the operating unit. Inconsistent cleaning day to day and across shifts is problematic for most operating utilities and one of the less tangible benefits and drivers for development of intelligent sootblowing systems such as Powerclean.

Miller 1 – Powerclean Installation and Operation

Alabama Power upgraded the core sootblowing controls while installing the Powerclean sootblowing optimization system. Applied Synergistics, Inc. (ASI), a subsidiary of Diamond Power International, Inc., was contracted to provide this upgrade. Since both the ASI sootblowing control system and the Powerclean optimization system required a personal computer interface, both systems were installed on the Powerclean workstation. By integrating the Powerclean system with the sootblowing controls on the same workstation, integration problems were minimized and space was conserved in the control room. The entire system was installed where the previous sootblowing control system had been located.

The Powerclean system was delivered, installed and placed in operation in October 2003. The system was interfaced to the plant data system via an OPC connection. Since the sootblowing control system could not be upgraded until a Spring 2004 outage, the Powerclean system was initially operated in advisory mode to establish a performance baseline and to gather data to support the development of optimization strategies.

Sensitivity Testing for Initial Setup

As part of the implementation process, each sootblower was run and its cleanliness factor response was evaluated to determine its effectiveness. The sootblowers were also run in various sequences to test their response and their interaction. Knowing the effectiveness of each blower and considering its location allowed B&W to divide the unit into regions. Some of the regions represented entire boiler components like the primary superheater. Other regions represented portions of components or particularly effective groupings of blowers. The final regions are as listed in Figure 13.

During testing, Plant Miller operations and engineering personnel were consulted to document past cleaning practices. This experience is valuable and is an important part of formulating sootblowing strategies that are implemented in the Powerclean system. The objective is to integrate past best practices, prevent bad practices, and optimize blowing and unit performance.

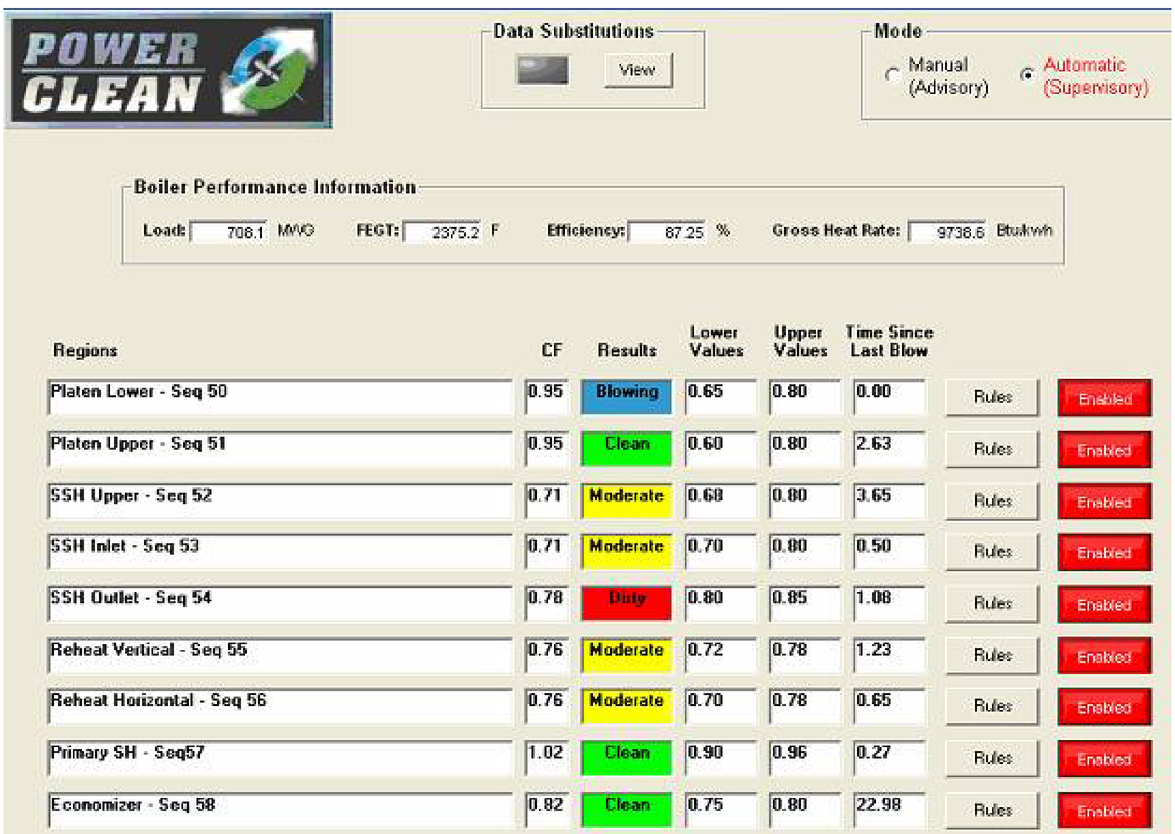

Figure 13 Powerclean Results Screen

Driving Cleaning Strategies with Performance

The Heat Transfer Manager™ program provided information critical to the evaluation and control of furnace cleanliness. The HTM calculation of platen inlet gas temperature (PIGT), furnace exit gas temperature (FEGT), and furnace cleanliness factor were important considerations in evaluating overall sootblowing. Convection pass cleanliness factors, their rate of change and the sootblowing equipment cleaning effectiveness depend in large part on the cleanliness of the furnace. The HTM Boiler Sideview (Figure 14) displays the locations, temperatures, and cleanliness factors, along with other critical boiler performance statistics. Data trends can also be selected for a given value for a quick reference during data evaluation.

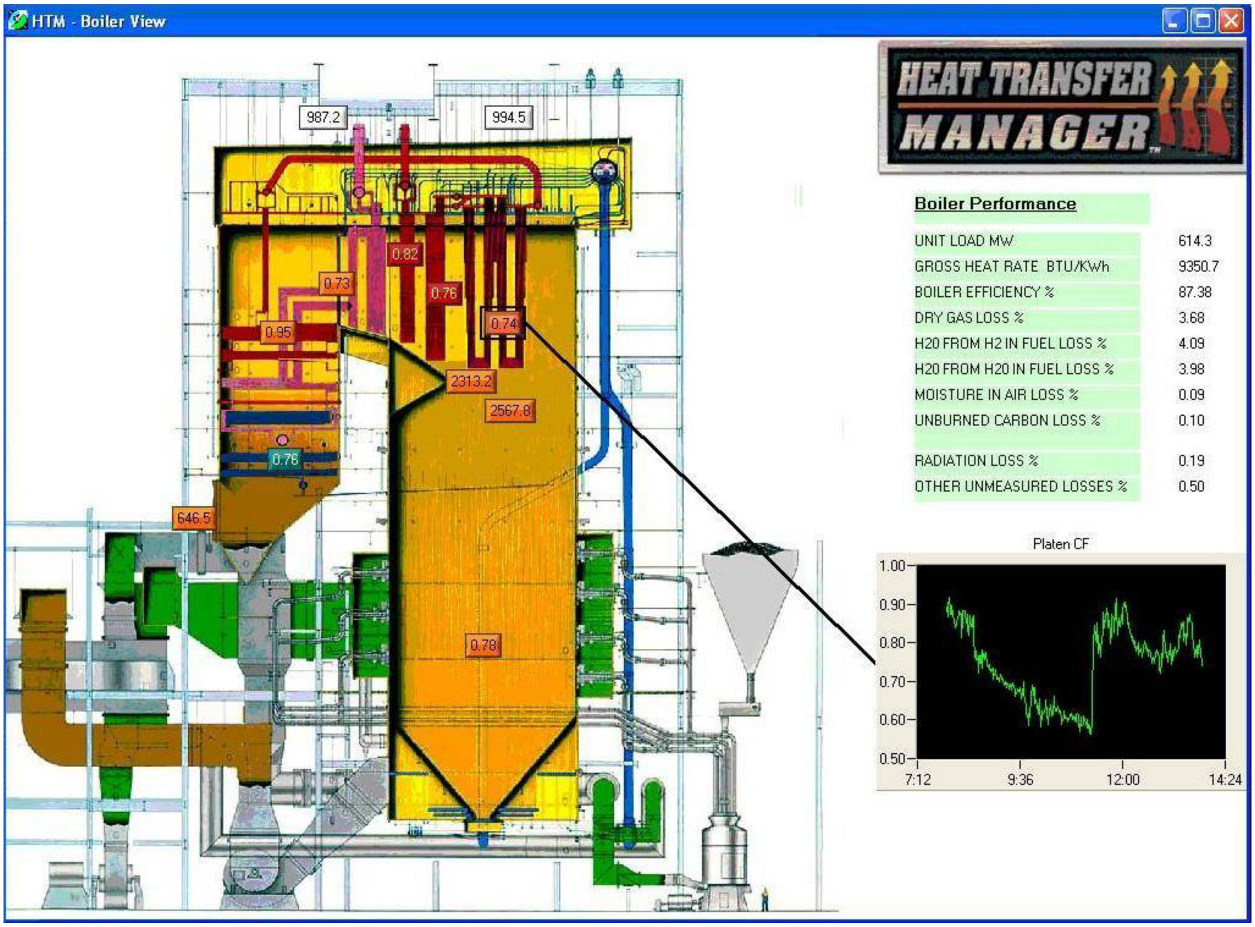

Figure 14 Powerclean Display - Boiler Sideview

On Miller 1 furnace cleaning was performed by a water cannon system that was not interfaced with the Powerclean system. Thus, the cleanliness state of the furnace as well as the PIGT could not be influenced or controlled by Powerclean directly. Instead, the Powerclean system was set up to accommodate the varying furnace conditions. B&W used the flexibility of the Powerclean system to implement strategies that allow the convection pass to anticipate the changing furnace conditions and change cleaning patterns and frequencies. In this manner, the Powerclean system was able to increase blowing in areas anticipated to foul heavier when slagging conditions worsen, and decrease blowing when slagging conditions ease.

During the Spring outage the new ASI sootblowing control system was installed. Following the outage the Powerclean system was placed into closed loop operation. Because the sootblowing controls were integrated with Powerclean on the same workstation, achieving automatic control (closed loop) was a relatively straightforward process. After the system was operating in closed loop control, B&W provided operator training on the use of the system while on site. Subsequent to site start up B&W continued to support data evaluation and sootblower optimization remotely.

Miller Results

The Powerclean system has had a positive impact on the operation of Alabama Power Miller Unit 1. Sootblowing strategies have been developed based on reliable technical data and analysis and Powerclean allowed the strategies to be implemented in a consistent manner. Plant personnel have found that Powerclean allows them to study and evaluate the effectiveness of sootblowing.

To assess the impact of the system on Unit 1, data was collected from the Powerclean historian for analysis. Baseline data, which represents how the unit was operating prior to the implementation of Powerclean, was retrieved for the time period of February 9, 2004 to February 15, 2004. Data from July 30, 2004 to August 6, 2004 was chosen to represent unit operation after the Powerclean system was operating in closed loop. Below is a discussion of the comparison of operation before and after Powerclean was operating.

Reheater Cleanliness and Temperature Control

Figure 15 shows a comparison between reheat temperature and reheat spray flow for full load operation with a reheat (RH) temperature setpoint of 995F. This setpoint is 5F below design temperature so that all RH outlet leg temperatures are maintained below their alarm temperatures. The before (Feb 04) and after (Aug 04) graph shows that the RH temperature was fluctuating more during the February timeframe, before the Powerclean system was in closed loop, when compared to the August timeframe. In August, the RH temperature was maintained in a tighter band around the 995F setpoint. Figure 16 is a comparison of the distribution of February and August RH outlet temperatures which shows that reheat was better controlled to set point with the variance and standard deviation significantly lower. The increase in RH spray flow from February to August, as seen in Figure 16, can be attributed to a cleaner reheater - Figure 23. In an effort to better distribute absorption and reheat temperatures across the unit, the vertical reheater sections were high pressure water cleaned during a May outage – the cleanliness was maintained by the Powerclean system in the subsequent months. The cleaner RH sections resulted in increased spray flow to maintain the RH temperature setpoint.

Optimization of the sootblowing continues. Increased RH spray flow is undesirable, so several options are being pursued to lower the spray flow. These include raising the RH setpoint, evaluating furnace cleanliness and evaluating maintainable RH cleanliness. Since the reheater is susceptible to severe fouling, allowing it to operate dirtier to lower spray flows requires careful study.

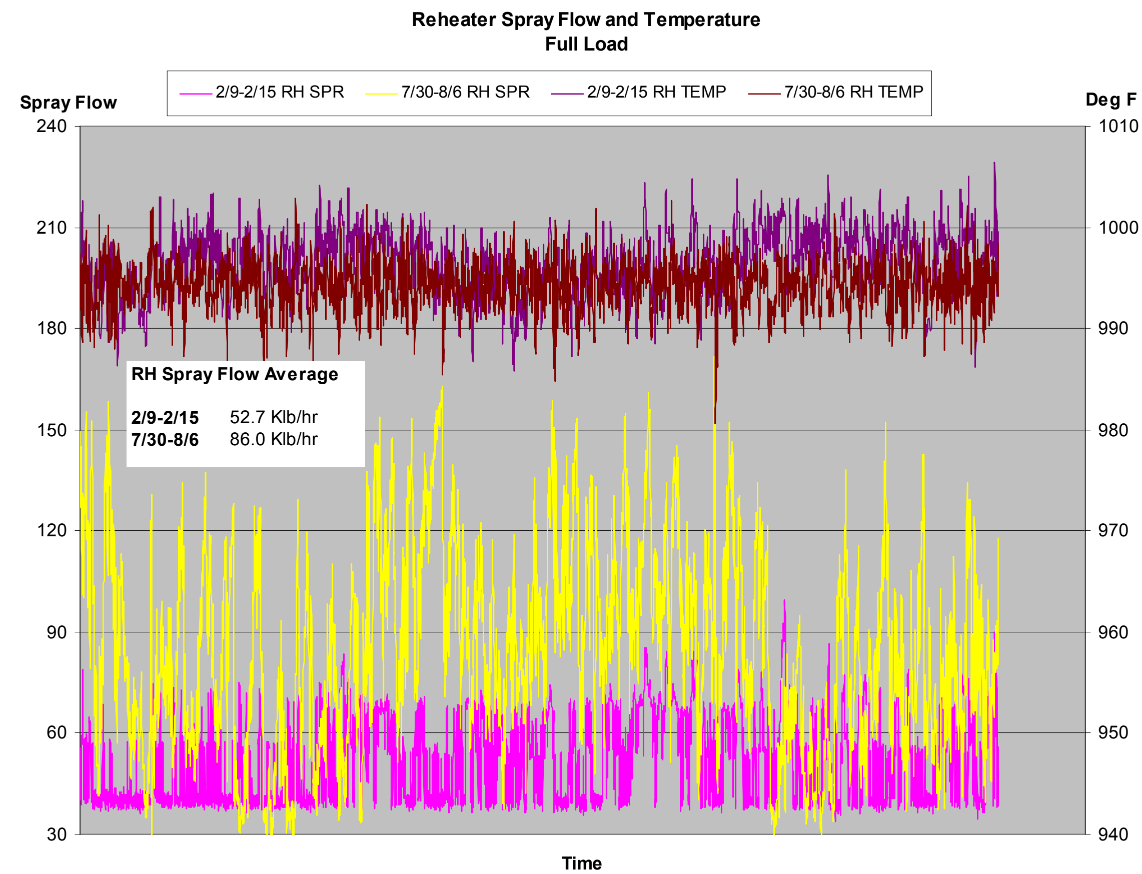

Figure 15 Reheater Spray Flow and Temperature – Set Point @ 995 °F

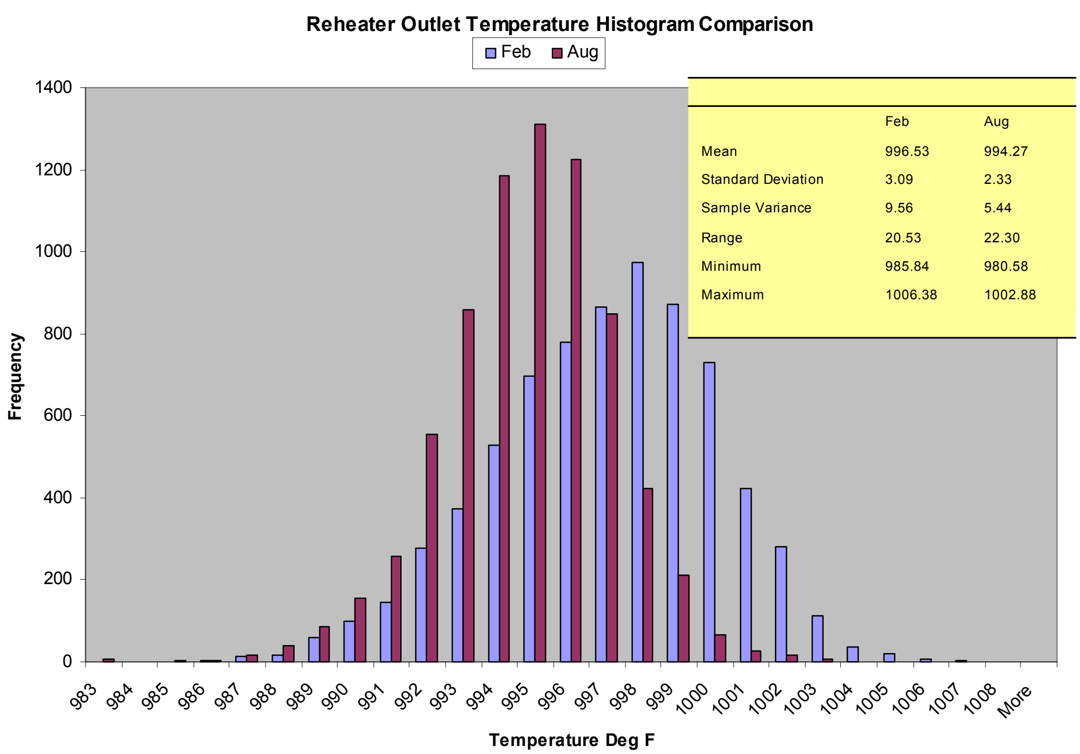

Figure 16 Reheater Outlet Temperature Distribution – Set Point @ 995 °F

Economizer Exit Gas Temperature

By keeping the convection pass cleaner, the Powerclean system was able to lower the average economizer exit gas temperature (EEGT) as indicated in Figure 17. The average temperature in August was 659F compared to the February average of 665.5F even though most of the blowers in the horizontal banks were cycled significantly less. Note that the trend line in the graph also shows that the average EEGT was held more constant in August than in February.

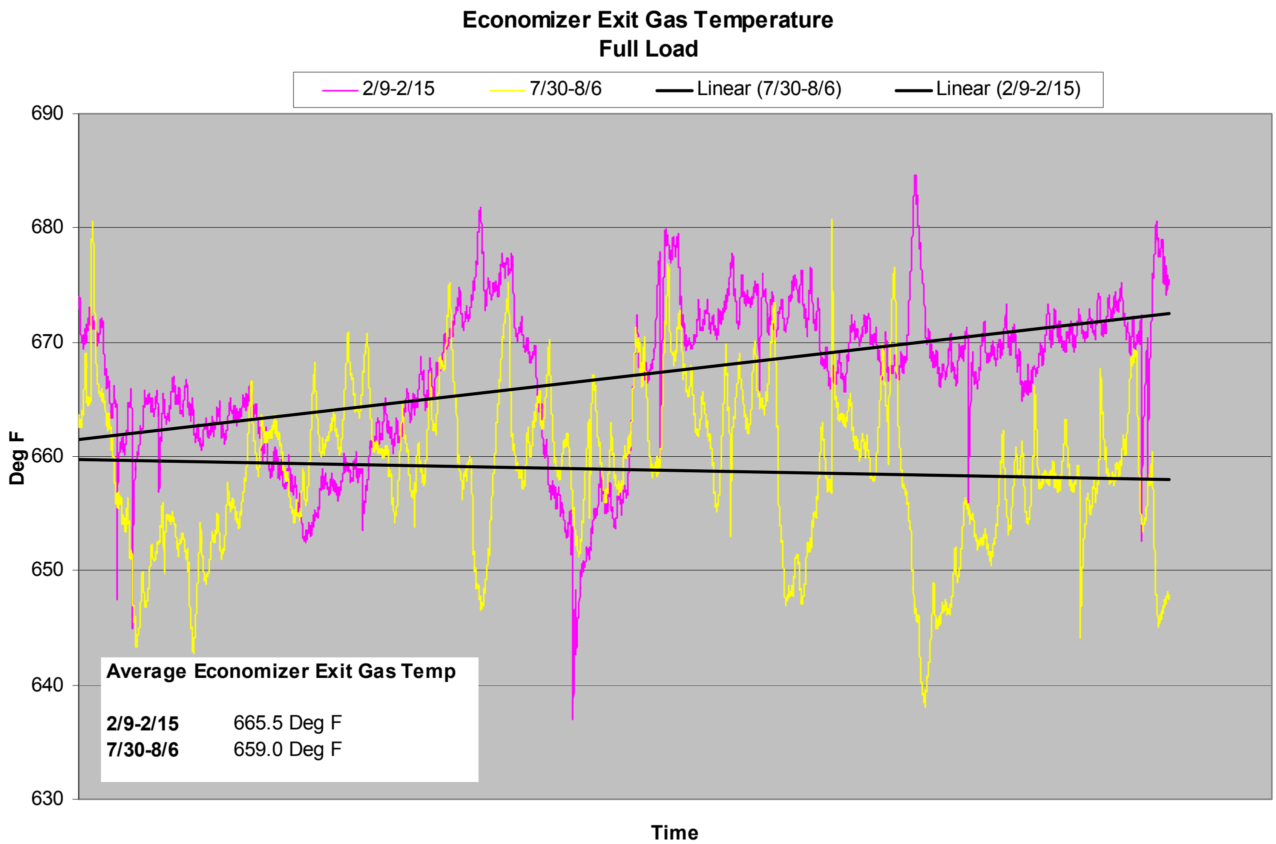

Figure 17 Economizer Exit Gas Temperature

Boiler Efficiency

The improvement in overall unit efficiency was consistent with the improvement anticipated by lowering the unit economizer exit gas temperature. As shown in Figure 18, an efficiency improvement of 0.14% was achieved in August versus February. Figure 18 shows a February average of 86.88% compared to an August average of 87.02%. Maximizing boiler efficiency minimizes fuel usage for the same output and reduces unit operating costs.

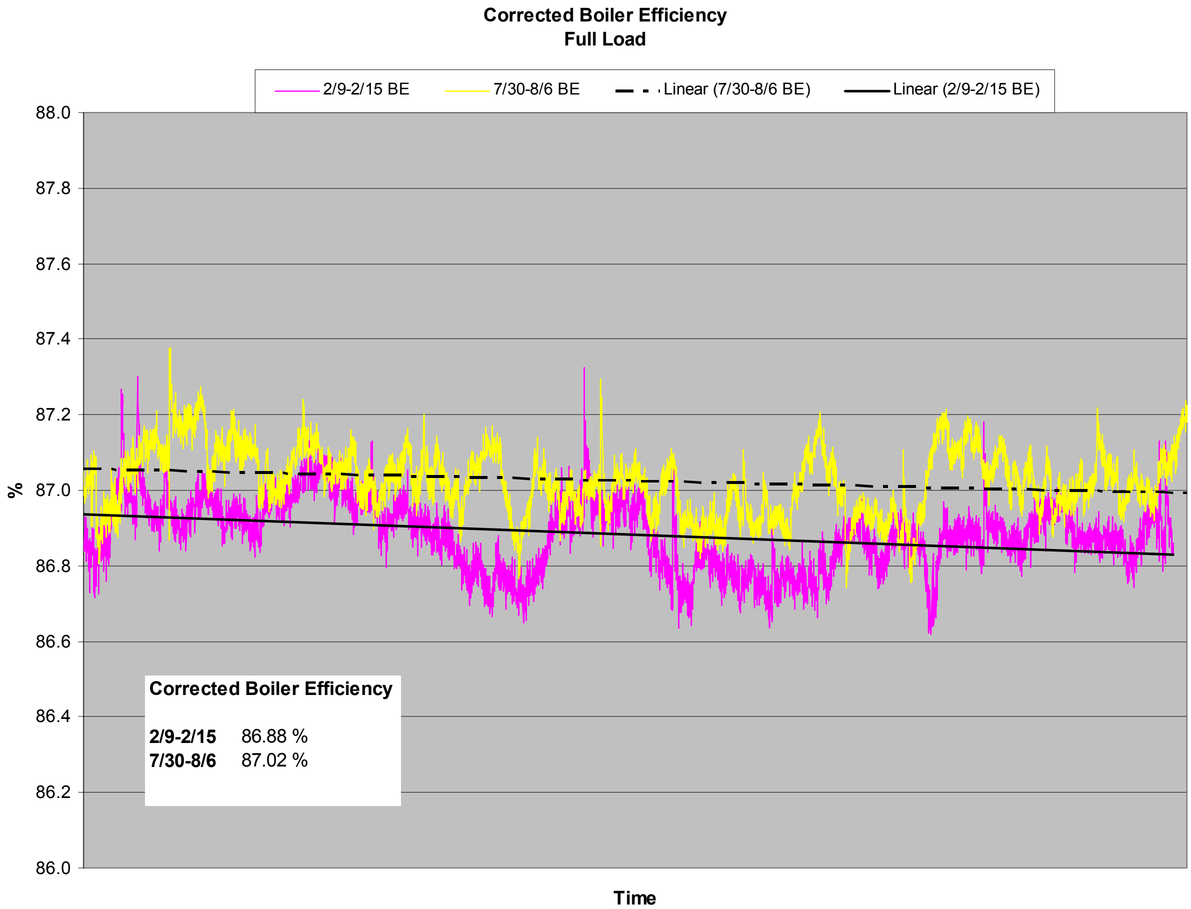

Figure 18 Boiler Efficiency

Sootblowing Steam Consumption and Blowing Frequencies

Within the Powerclean system, the unit was divided into sootblowing regions. Figure 19 shows the daily sootblowing frequencies for those regions for February and August. While the conditions entering the convection pass have remained similar, there has been a marked change in how the convection pass is being cleaned. Most of the regions of the boiler are blowing less frequently while the cleanliness factors for each component are comparable or higher. Note that the blowing frequency has increased or been maintained in the lower platen and lower secondary superheater inlet bank regions. Analysis of the unit shows that allowing excessive fouling in these banks has a significant impact on the subsequent surfaces in the convection pass. By increasing the blowing in these two regions the unit was kept cleaner with an overall reduction in sootblowing. Total sootblowing cycles for the unit were reduced from 302 to 210 which represents a 30% reduction.

The reduced amount of blowing is also reflected in Figure 20 which shows the sootblowing steam flow before and after the implementation of Powerclean. On average, sootblowing steam consumption decreased from 30 klb/hr to 26 klb/hr - a reduction of 13%.

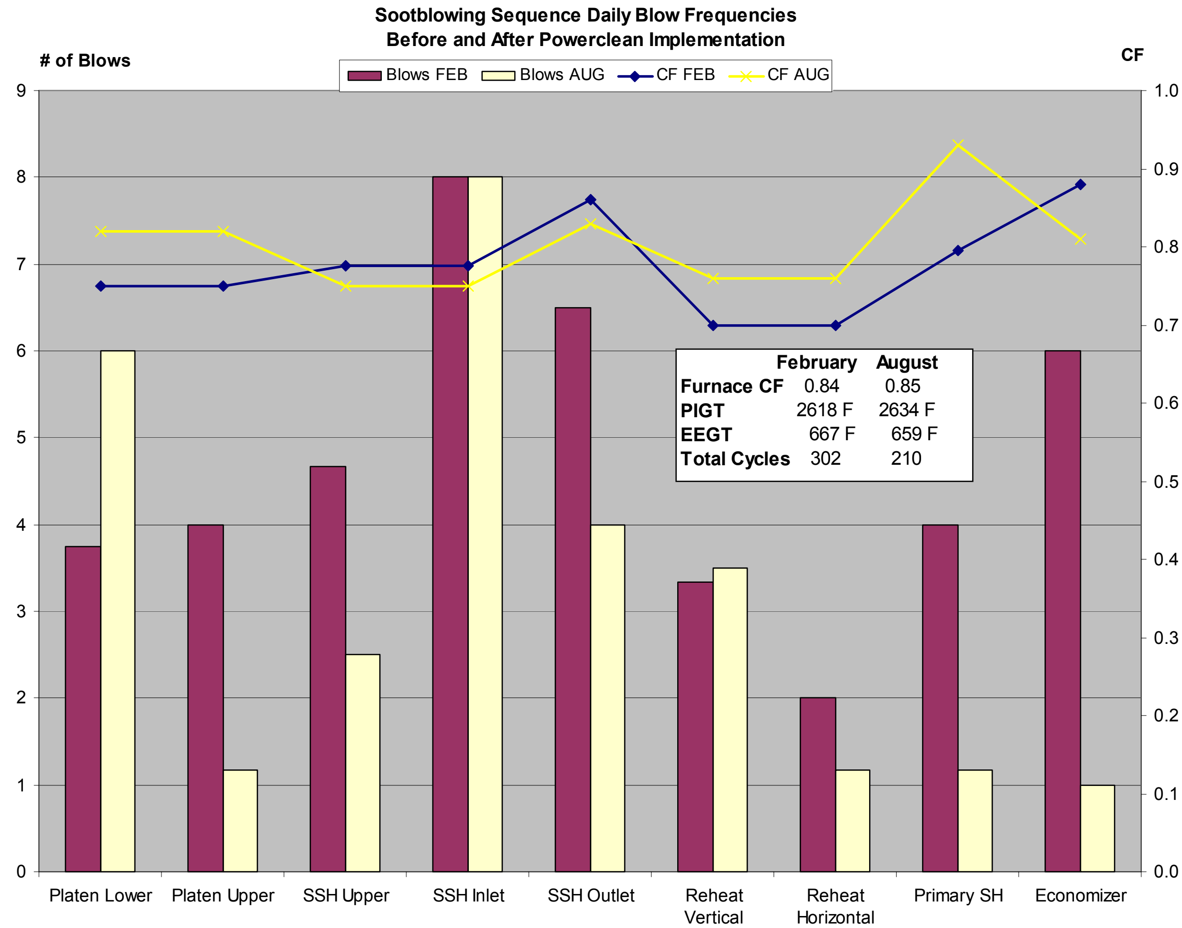

Figure 19 Sootblowing Sequence Daily Blow Frequencies February vs. August, 2004

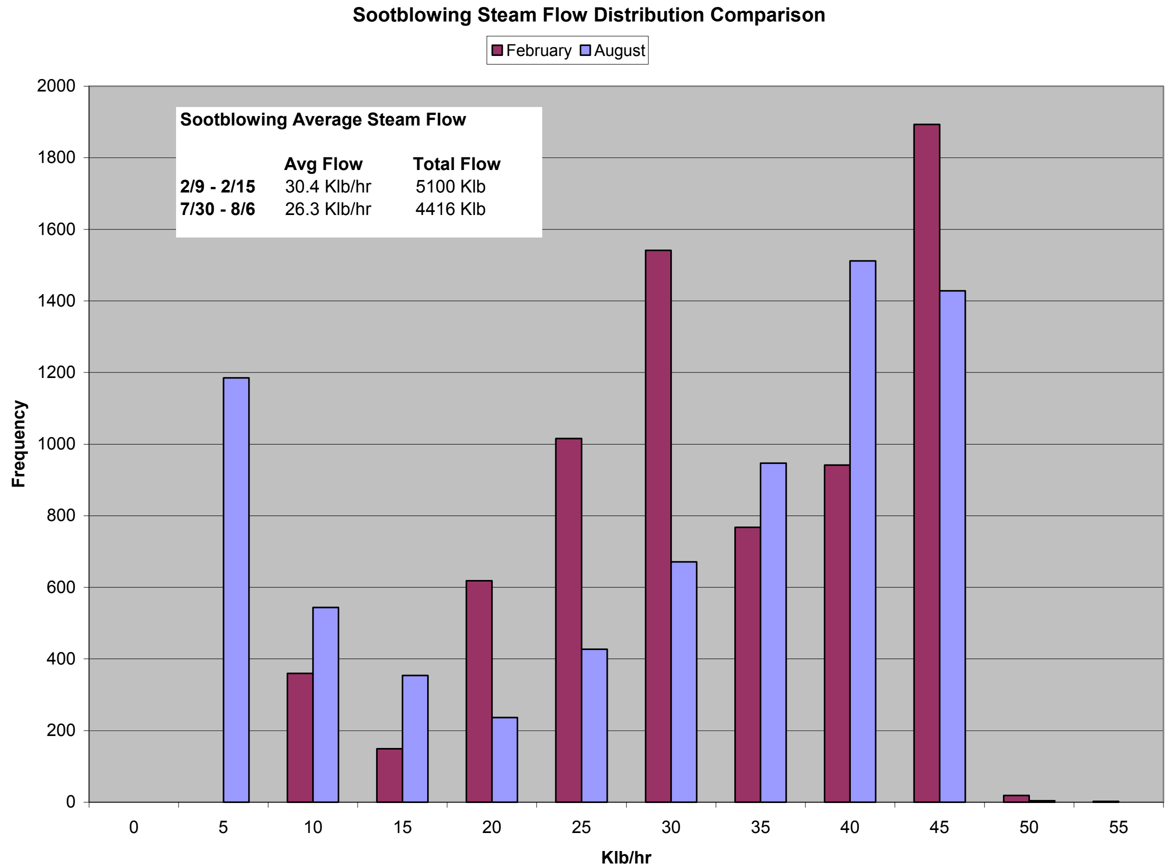

Figure 20 Sootblowing Steam Flow Distribution Comparison

This reduction in sootblowing steam was reflected in a comparison of sootblowing cycles by plant personnel (see chart below). Data was pulled from the sootblowing system for the months of June and July of 2003 and 2004 to compare the sootblowing activity before and after the Powerclean system was implemented. The reduction in sootblowing cycles is consistent with the reduction in overall steam flow. While the steam flow was reduced 13%, the sootblowing cycles were reduced between 13% and 16%.

Comparison of Total Sootblowing Cycles for 2003 and 2004

	June	July
2003	9504	10049
2004	8026	8785
Reduction in sootblowing cycles	1478	1264
Reduction in sootblowing cycles (%)	16%	13%

Heavy Slagging versus Light Slagging Comparison

During the month of June while the Powerclean system was being implemented, plant personnel reported heavy slagging conditions in the rear of the platen superheater and the front of the secondary superheater inlet bank. This condition was attributed to recent combustion tuning that had been performed. The heavy slagging needed to be mitigated and this proved to be a good opportunity to use the Powerclean system to mine data and determine the behavior of the unit as it became heavily slagged. The analysis of this behavior using Powerclean provided improved strategies that could be implemented to mitigate heavy slagging in the future.

The new strategy to deal with the slag necessitated heavier blowing at the location specific to the accumulations in the platen SH and SSH Inlet bank. The unit cleanliness improved and returned to a condition classified as light slagging (typical conditions). Figure 21 shows the comparison of the unit in June, when slagging was heavy, to the light slagging conditions present during August. As noted by earlier sootblowing versus cleanliness trends, once fouling occurred in the SSH all subsequent blowers downstream of the SSH had to be cycled more frequently to maintain cleanliness. The HTM model used in the Powerclean system provides data that allows for a much better understanding of the impact of slagging throughout the unit so that sootblowing strategies can adapt. It is noteworthy that the Powerclean system automatically responded to the improved fouling conditions in the unit by reducing the blowing frequencies elsewhere in the unit. It is expected that sootblowing frequencies will vary in the various regions of the unit as slagging and fouling conditions worsen or ease.

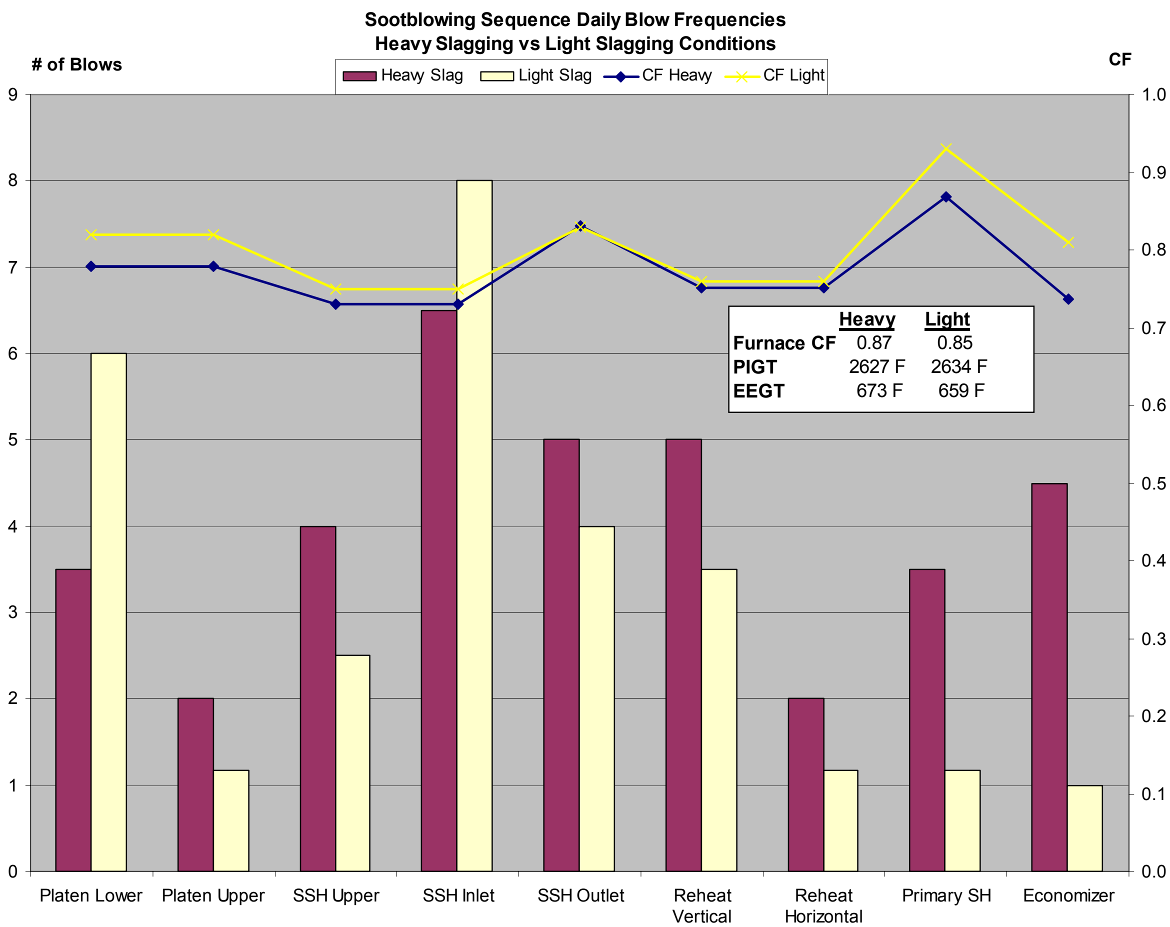

Figure 21 Sootblowing Daily Blow Frequency Heavy vs. Light Slagging

Cleanliness Factors

The component cleanliness factors that have most noticeably changed since the Powerclean installation are the primary SH, reheater, and economizer sections - Figures 22, 23 and 24. The primary SH cleanliness factor increased from 0.80 to 0.93 while blowing frequency was reduced from an average of 3.5 times per day to just over once per day. Some of this increase in cleanliness was attributed to the replacement of primary superheater sections during the May outage. However, the Powerclean system has maintained the improved cleanliness levels found after the outage.

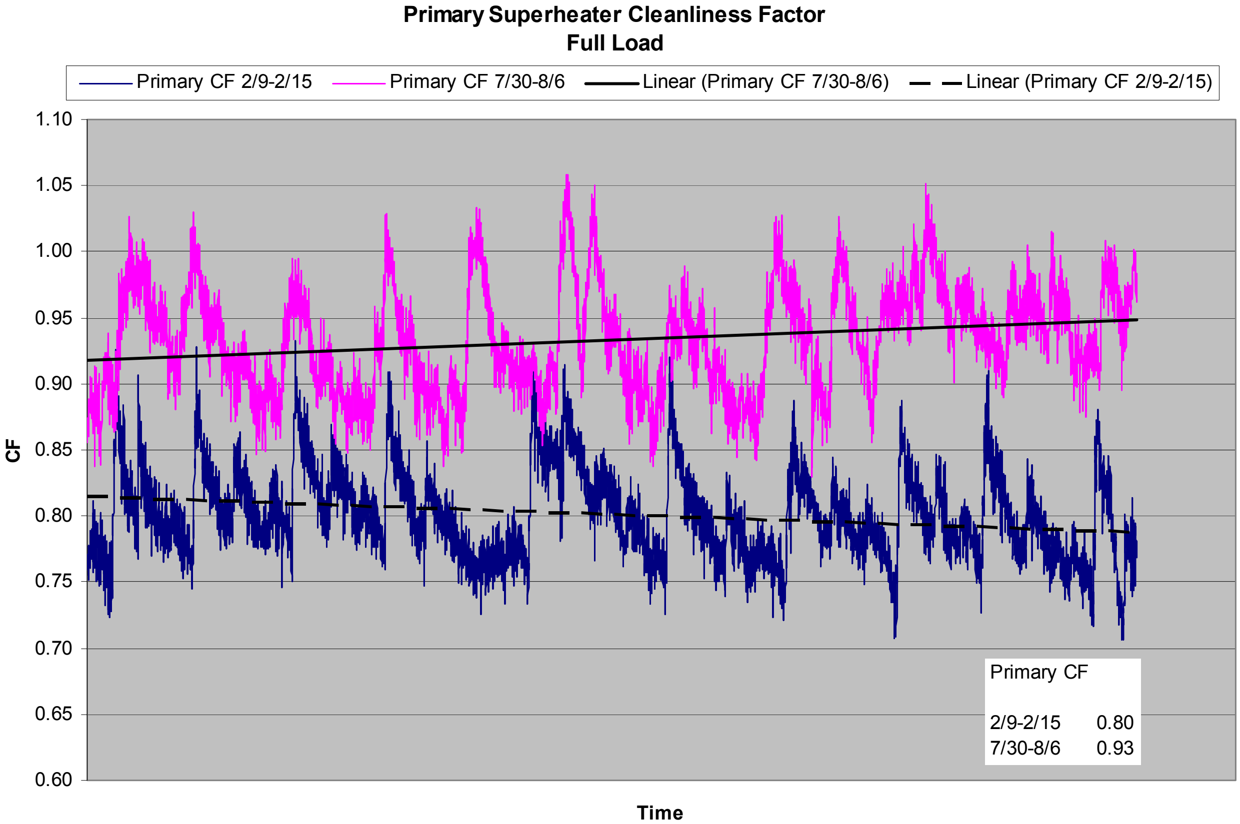

Figure 22 Primary Superheater Cleanliness Factor

Reheater cleanliness improved from 0.69 to 0.76 with similar blowing cycles in the vertical reheat bank and a decrease in horizontal reheat blowing cycles. As noted earlier, some of the increase in reheater cleanliness was due to cleaning performed during the May outage. The Powerclean system has improved sootblowing effectiveness to maintain cleanliness after the outage.

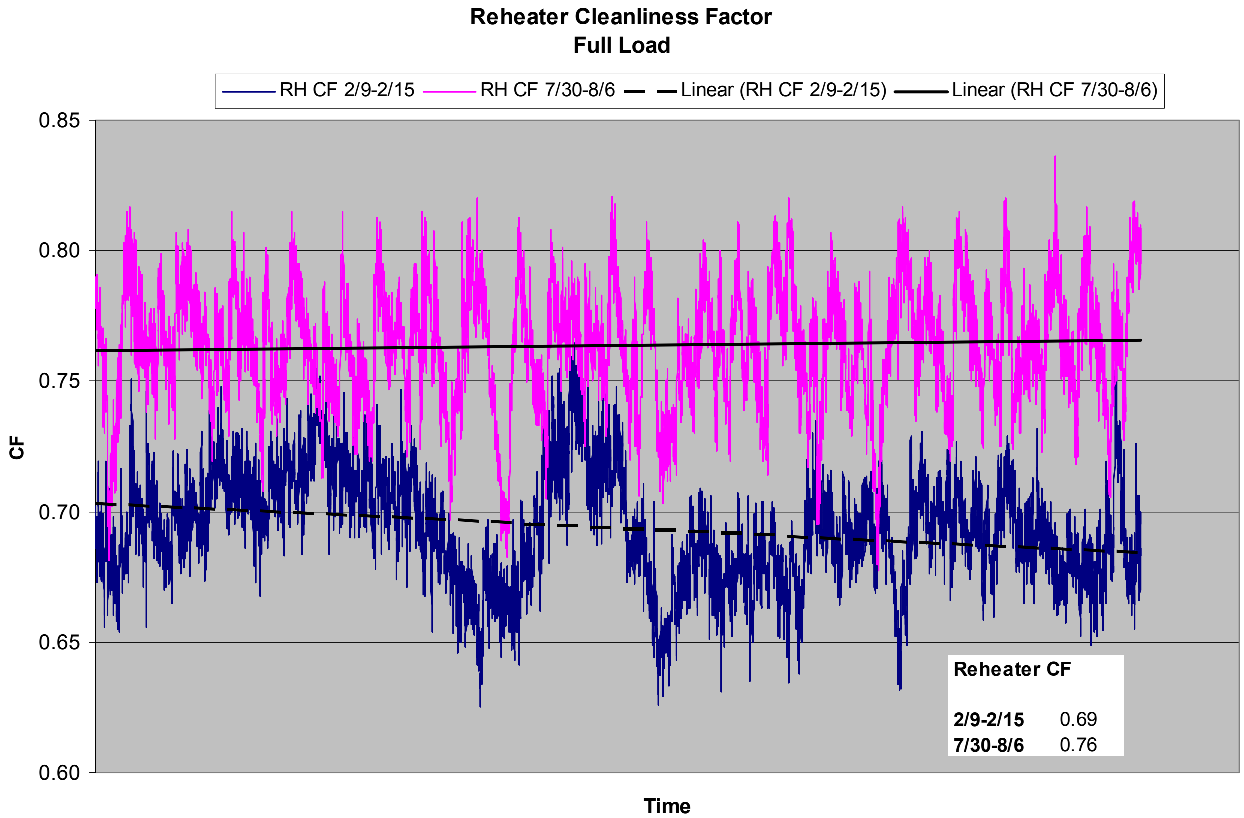

Figure 23 Reheater Cleanliness Factor

The economizer section was slightly dirtier in August with the average cleanliness value dropping from 0.89 to 0.81 (Figure 24). As a result of the Powerclean analysis it was determined that the cleanliness of the bank did not need to be as high to maintain performance; as noted previously economizer exit gas temperature had actually decreased with an increase in boiler efficiency. Shortly after the installation of the Powerclean system the frequency of blowing in the economizer was reduced from 6 times to 3.5 times per day. Subsequently, sonic horns were added to the economizer by the plant to evaluate their effectiveness as cleaning devices. The Powerclean strategy as coded in the expert rules was not changed, however, the system responded to the additional cleaning effort of the sonic horns by automatically lowering the frequency of blowing in the economizer such that steam sootblowing in the economizer eventually decreased to just once per day. The system provided data to not only evaluate the impact of adding sonic horns but also to determine acceptable cleanliness with improved performance while minimizing steam usage and the potential for wear on economizer tubes.

Plant personnel recognized that without the Powerclean system they could not have adequately assessed and responded to the impact of the sonic horns. As the sonic horns were started and contributed to the cleaning of the economizer, the cleanliness data from the Powerclean system provided plant personnel the information to assess sonic horn effectiveness as steam sootblowing in the bank was reduced. In addition, the Powerclean system reduced the use of the steam sootblowers automatically.

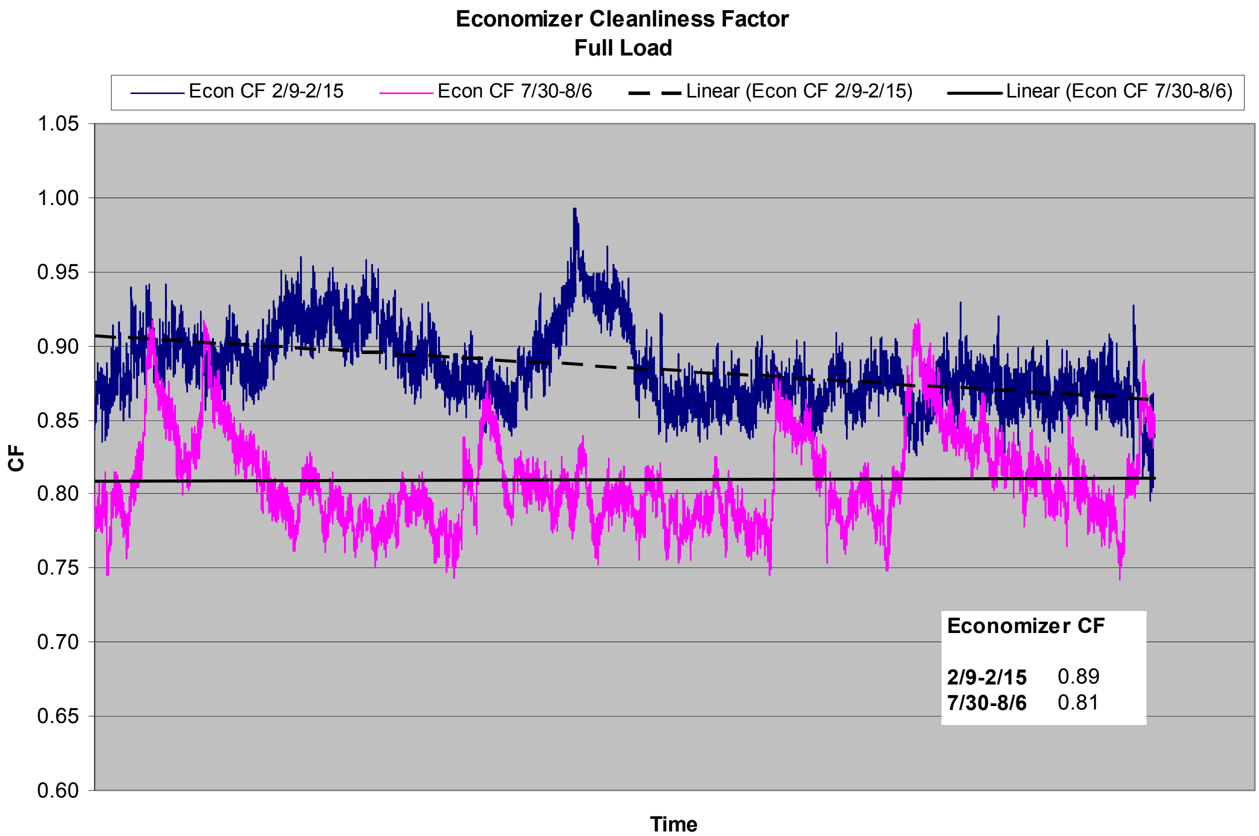

Figure 24 Economizer Cleanliness Factor

Miller Conclusions

Based on the results to date, the Powerclean system has proven to be a valuable addition to unit 1 at Plant Miller. Using the system it was possible to establish strategies that anticipate and react to the behavior of the unit. The overall cleanliness of the convection pass has improved while sootblowing has decreased. Experience to date has illustrated that cleaning in the right places at the right frequency can improve operation of the boiler even while reducing the overall use of sootblowing.

The Powerclean system with the HTM model continues to provide critical data for performance and cleanliness that enables B&W and Miller personnel to develop blowing strategies. Measurable improvements to operations are possible, including,

- Reduced sootblowing steam consumption
- Reduced economizer exit gas temperature for improved efficiency
- Improved steam temperature control

The Powerclean system allows engineers to understand the impact of slagging events so that strategies can be developed to better mitigate the recurrence of major slagging. Another benefit is the consistency of unit operation that is gained with automatic application of the same cleaning strategy. Since blowing can be reduced in many areas, plant personnel also expect a reduction in the rate of tube erosion in the future. The Powerclean application has been designed to be a dynamic system to be used by the plant as a valuable tool that will enable operations to adapt to new problems and improve on current strategies going forward.