Summary of Slagging and Fouling Mitigation Methods

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PRODUCT DESCRIPTION

This is a report on novel slagging and fouling mitigation methods in the coal-fired power generation industry. The project was identified by EPRI in response to member needs to compile a snapshot of approaches to mitigating slagging and fouling of coal-fired boilers as the industry migrates to burning off design coal.

Results & Findings

Burning off design coals in response to economic and environmental pressures has brought new challenges to control slagging and fouling. While slag mitigation in coal-fired furnaces has effectively been reactive rather than proactive, the industry has made major strides in applying techniques to maximize use of existing sootblowers, across-the-furnace cleaning devices, and advanced instrumentation. In general, this installed base constitutes a platform for implementing "next generation" slag mitigation—a proactive approach that will integrate existing technology into plant control systems and unit optimizers.

Challenges & Objective(s)

The objective of the report is to document the current status of approaches and the application of technology for slag mitigation. Corporate and plant management and engineers will find this report helpful if considering implementing strategies to improve mitigation of slagging and fouling in their coal-fired boilers. The report contains a simple review of technological offerings that will give readers an overview of various approaches available today. Use of advanced technologies such as combustion optimizers, intelligent sootblowing systems, and advanced controls continues to improve productivity with optimized staffing levels and deployment of latest techniques to maximize unit productivity.

Applications, Values & Use

Boiler fouling and slagging control continues to be identified as an area in need of improvement in today's power plants. Application of the latest mitigation technologies and methodologies will enable improved unit production and protection of boiler tubes and components. The strategy should help to overcome barriers that compromise unit availability and reliability when burning a variety of coals that differ from the plant design specification.

EPRI Perspective

This report provides a snapshot of the current slag and fouling mitigation technology applied in today's coal-fired plants. The goal was to include as much recent information as available in the public domain. The information presented is not intended to be a comparative assessment of competing technologies. As always, inclusion or exclusion of any one technology or vendor from this EPRI report is not intended as an endorsement or rejection, respectively.

Approach

The project team conducted literature searches of recent publications, gathered input from leading slag and fouling mitigation vendors in the industry, and compiled pertinent articles, papers, and web literature. Where available, references to specific past and ongoing EPRI projects have been included.

Keywords
Slagging and fouling
Intelligent sootblowing
Sonic horn cleaning
Acoustic cleaning
Fuel additive

CONTENTS

1 INTRODUCTION

In today's competitive power producing industry, fuel costs make up the largest component of a coal plant generation costs. In order to minimize production costs, many power boiler owners burn off-design fuels, including lower rank coals such as Power River Basin (PRB). Also, many units are now fitted with scrubbers to remove SO_2 and Hg. This ability to remove sulfur and other pollutants with post combustion technologies presents an opportunity for burning higher ash and sulfur fuels. Unfortunately, burning some of these coals often has led to increased slagging and fouling conditions that affect overall boiler efficiency, availability and reliability. One plant engineer's quote puts it in perspective: "*We try to burn anything that they (fuels buyers) float down the river*." In addition, a growth in demand has created added pressure to reduce outages and deratings on the units. In order to address the requirement for increased availability and to deal with increased slagging and fouling, the industry has applied a set of mitigation strategies and tools that include traditional means, such as load reduction and shedding, increased use of conventional sootblowers, improved use of existing sootblowers through intelligent sootblowing control (ISB), advanced multimedia sootblowers, across-the-furnace-cleaning, acoustic systems and fuel additives. This report provides an analysis and survey of slagging and fouling mitigation methods deployed in fossil fuel power plants today.

Objective

The objective of this project is to provide a current status of slag mitigation strategies currently deployed in the industry. The survey was initiated to provide the reader with the approaches the industry is taking to mitigate boiler slagging and fouling. The consequences of inadequately addressing increased slagging and fouling from burning lower cost fuels impact plant production derived from increased forced outages, pluggage and tube failures. Also, loss of production is increased from requirements to periodically reduce load for slag shedding.

Methodology

This report was developed by conducting literature searches of recent publications, input from leading slag and fouling mitigation vendors in the industry, and compilation of pertinent articles, papers, and web literature. Where available, references to specific past and ongoing EPRI projects have been included.

How this Report is Organized

Section 2 – Provides background information on conventional slag mitigation technologies including an introduction to intelligent sootblowing.

Section 3 – Provides information of advanced hardware technologies.

Section 4 – Discusses the available offerings and application of Fuel additives.

Section 5 – Reviews at surface treatment options such as ceramic coatings and other surface treatments.

Section 6 – Reviews other instrumentation currently used in conjunction with cleaning hardware.

2
BACKGROUND

This section provides a brief overview of conventional slagging and fouling technologies.

Load Reduction

Coal-fired boilers were originally designed to burn local fuels available at the time of construction. This geographic issue influenced the size, configuration, and type of boilers designed for the plant. However, competitive and environmental regulatory pressures have driven plant many owners to adopt a fuel switching strategy. Consequently, adverse slagging and fouling conditions result from firing off design coals. Often times, despite all other mitigation efforts, reducing load on a periodic basis becomes the most effective means to 'deslag' the boiler. This traditional method of slag mitigation involves periodically, sometimes as often as every other evening, bringing the unit to a reduced or minimal generation output to enable the combustion process to clean up the unit. Unless the unit is typically reduced in load by dispatch for economic reasons, this load reduction approach is a costly means for slag mitigation. If the unit would otherwise have been dispatched at higher load output at times needed for deslagging, the net result would be a loss of megawatts and profitability. However, the consequences of not reducing load to de-slag would be eventual pluggage of the back pass, or major slag falls in the furnace that can damage tubes. Either instance will result in considerable load loss when the units are taken offline for repair and/or removal of solidified slag.

Conventional Cleaning Technologies

This section describes the conventional methods of wall and heat surface cleaning deployed throughout the industry. These technologies have been widely applied and are briefly reviewed as background to the next sections. For a detailed and extensive description of conventional sootblower technologies, it is suggested that the reader review the EPRI Report 1004005 titled *Sootblowing Application and Maintenance Guide* (December 2001). Sections 3 and 4 of that report present detailed descriptions of traditional sootblowers and wall blowers.

Steam and Air Wall Sootblowers

Sootblowing is the removal of combustion by-product deposits with a high-velocity air, steam, or water jet. In the water wall sections of the furnace, compressed air and steam wall blowers operate similarly in that the blower lance, with a slightly greater than 90° nozzle, angled slightly toward the tube wall, is inserted just past the tube surface, the medium supply valve opened, and the lance is rotated 360° one or more times to remove deposition within the range of medium flow. Process steam from the boiler is used for steam blowers, and air from the station air compressors supplies air for the blowers. Sootblowing imposes a direct cost in energy usage. If steam is used as the blowing medium, the steam is taken from the boiler and treated water from the makeup system has to replenish the boiler. Sootblowing also affects steam temperature, convective pass and economizer outlet gas temperature, and other variables.

Water Lances and Water Cannons

The two main methods of using water for slag removal on the furnace water walls are water lances and across-the-furnace (ATF) cleaning or water cannons. Water lance technology essentially replaced or complemented existing steam and/or compressed air wall blowers. A third method used on rare and under extreme occasions while the unit is online, is manual use of external fire-hose type nozzles through an access port. This method is typically used to direct water on a specific problem slag deposit, usually in the superheat pendants, to remove the deposit before it enlarges and develops potential to fall and damage lower slope tubes.

Furnace Water Lances

Furnace water lances work similarly to steam and air blowers, where a motor driven lance is inserted through bent tube openings in the water walls. While steam and air blowers rotate typically one revolution and are then retracted, a water lance is rotated continuously as the lance is gradually inserted to its maximum penetration. The lance nozzle is directed at an angle backward toward the water wall surface such that as the lance is inserted and rotated a concentric circle water pattern, enlarging slightly with each rotation, is traced on the tube surfaces. One water lance can trace a circular pattern of up to 20 inches in diameter on the wall surface. Figure 2-1 shows a typical water lance blower. The variable speed water lance blower is used when deposits cannot be removed by conventional air or steam as the cleaning medium. The retract travel speed and rotational speed vary during the cleaning cycle to maintain an optimal water supply for cleaning and to limit the chance of thermal shock in case of excess water exposure. Nozzle designs used on the water lances and their exposure to heat requires use of process condensate water to prevent nozzle fouling and pluggage.

Figure 2-1
Model ID – K Sootblower

Across the Furnace (ATF) Cleaning – Water Cannons

ATF technology involves use of fire hose nozzle type devices for cleaning. In general, a controlled water jet is sprayed across the furnace, through the furnace plenum often crossing the combustion zone, to remove deposits from the opposite and adjacent boiler water walls. Typically there are four ATF devices installed for cleaning a furnace, one on each wall with ability to clean adjacent walls when one or more cannons are out of service. Two different vendors provide ATF devices: Clyde Bergemann water cannons and Diamond Power HydroJets. Figure 2-2 shows a photo of a typical Clyde Bergemann water cannon installation whereas

Figure 2-3 shows a Diamond Power Hydrojet. While both vendors claim advantages with their devices, in theory they function in a similar manner. Both vendors divide the water wall panels into ‘zones’, and place a heat flux sensor (detailed later) in the zone for direct feedback as to cleaning needs of that zone. A PLC based control system is used to control the ATF device, with the PLC linked to a central ISB system that directs their cleaning activations. The heat flux sensor embedded in the water wall tubes in each zone triggers cleaning when the zone slags up.

Figure 2-2
Installed Clyde Bergemann Water Cannon

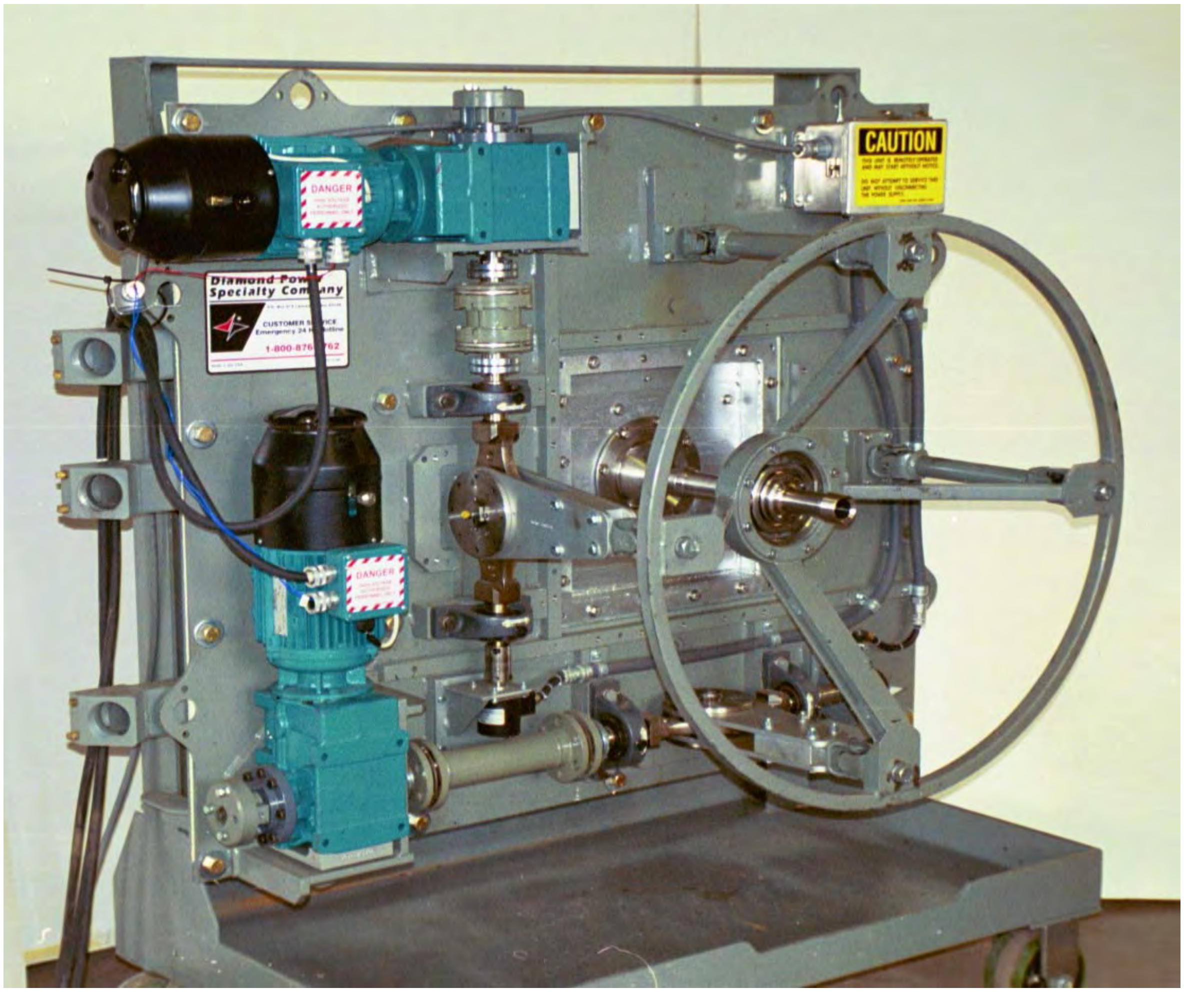

Figure 2-3
Diamond Power HydroJet (Courtesy of Diamond Power)

Figure 2-3 shows the Diamond Power HydroJet ATF. The coordinate plotting system is used to position the nozzle for directing spray onto the target zone to be cleaned. Figure 2-4 is a plot of an ATF typical cleaning cycle from a heat flux sensor. The gradual degradation in heat flux as measured by the sensor can be seen and when the control systems senses the fouling is at a level needed for cleaning the ATF device is actuated. Upon cleaning, heat flux abruptly increases as the insulating effects of the slag are removed.

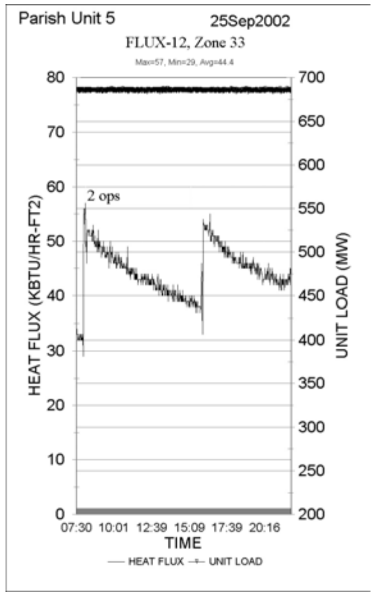

Figure 2-4
Heat Flux Meter Response to a Cleaning Event from Water Cannon

Adverse Effects of Traditional Methods

In all of the above methods, there are performance penalties associated with the cleaning strategy in that the blowing medium is a direct plant cost. Overusing a sootblower, especially on an already clean section, causes tube erosion and induces thermal transients that contribute to tube damage in the form of circumferential cracking or quench cracking as depicted in Figure 2-5. If the blowing medium is water, excessive thermal quench cracking can be induced.

Circumferential Water Wall Cracking

Circumferential water wall cracking (CWWC) generally takes place in the highest heat flux areas of the furnace in supercritical boilers (although it has also been found in non-supercritical units to a much smaller degree). The supercritical design is a factor because of high heat flux coupled with thick-walled tubes required by the high water-side operating pressures. In general, a heavy oxide layer is found on the tube interior. High heat flux, supercritical design, and an insulating oxide layer are factors in the formation of CWWC but are not sufficient to produce CWWC alone. The additional factor is thought to be associated with cyclic thermal conditions. Another contributing factor is the deposition of coal-derived corrosive species on the tube fireside. The latter mechanism seems to use the crack locations to deposit corrosive material (2).

Quench Cracking

Quench cracking occurs when water is inadvertently applied to clean tube surfaces. The sudden quenching of the water wall causes alligator skin type cracking as shown in Figure 2-6 (2).

Figure 2-5
Typical Tube Quench Cracking from Spraying Water on Clean Tube Surfaces (1)

Figure 2-6
Metallographic Cross Section of Circumferential Cracks Showing Typical Sharp Pointed Characteristic and Oxide (Dark) and Sulfide (Light) Deposits (3)

The phenomenon underscores the need to carefully control sootblowing and activate blowers only when and where needed – the definition of Intelligent Sootblowing. This technique aids to control the temperature spike amplitude and reduce the number of fatigue cycles. Applying water to a tube panel area without the protective slag coating creates a quenching effect that drives the tube temperature down before the immediate upward spike when the tube is again exposed to the fireball, resulting in tube damage described above.

Enhanced Use of Existing Sootblowers

A traditional approach has been the use of existing sootblowers with some novel control applications. Under the concept that an efficient boiler is a clean one, the original design of sootblower controls in early boiler design typically consisted of a stepper switch configuration that operated sootblowers sequentially. For instance, a motor driven rotating drum sequentially triggered sootblowers to operate on a fixed schedule without regards or indication as to whether the target area was in need of cleaning. This fixed schedule approach results in unnecessary use of cleaning medium, accelerated heat transfer tube wear damage from erosion and cracking, and regularly scheduled sootblower maintenance costs. Programmable Logic Controls (PLC) technology enabled replacement of the stepper switches and the process typically involved duplicating the stepper switch sequential logic in the PLC's that carried forward the same problems. However, in the late 1990s, deregulation, environmental, and competitive pressures prompted the industry to begin directing attention to the original control logic, and sootblower maintenance and reliability improved sootblower operation via changes and application of sequence control using the new control systems. In addition to sequential control issues, there was a somewhat novel approach in redeployment of existing sootblower controls such as enhanced insertion and rotational control to adapt to cleaning needs unique to each blower. But these enhancements still did not address the issue of cleaning the furnace only when and where it was needed, as the concept of a clean boiler is the most efficient one still existed.

Intelligent Sootblowing

Intelligent sootblowing (ISB) was defined as an EPRI initiative in the first Intelligent Sootblowing Workshop held at the EPRI I&C Center, Harriman, TN, in November 1998. Representatives at the workshop from member power producers, vendors, and academia identified sootblowing issues as a need in the industry. Improved automated control and optimization of the sootblowing process, improved training, etc. were some of the issues identified. Since that workshop, six additional ISB workshops have been sponsored by EPRI with the latest in Shreveport, LA in 2008. From needs identified in the series of workshops, the EPRI *Intelligent Sootblowing Guidelines* (4) was published. Several ISB demonstration projects were initiated, including TVA's Bull Run Station, Texas Genco's W. A. Parish (WAP), Dairyland's J.P. Madgett, and SCS's Plant Scherer. The EPRI flagship ISB project was W. A. Parish which evolved from a 1999 EPRI project established to assess available ISB technology for the site. In 2000, the assessment initiative was expanded to implement ISB on W. A. Parish Unit 8, and in June 2002 increased in scope to a five year Test and Demonstration project of ISB and boiler cleaning technologies on all four units. A final report on the project, *Intelligent Sootblowing at NRG Texas W. A. Parish Plant* (5) detailed the implementation of the ISB systems.

ISB Definition

The following definition derives from the previously referenced EPRI ISB Guidelines Report (4): Intelligent sootblowing (ISB) optimizes the cleaning of the furnace walls and convection pass elements to maintain high heat transfer while regulating steam temperatures and pressures and minimizing erosion or corrosion of tubes. ISB enables boiler operators to achieve a balance between not cleaning enough (risk reduction in heat transfer and boiler efficiency) and cleaning too frequently (waste of blowing medium, potential loss in efficiency, and increased tube and hardware wear damage). Ideally, an ISB system should determine not only when and where to blow—as well as the pressure and duration of the blowing event. ISB can also work in accordance with other operational goals such as NO_x emissions control. The objectives on an ISB system can be summarized as follows:

1. Assist in maintaining steam temperature control
2. Control economizer outlet gas temperature
3. Minimize steam temperature swings during a sootblowing event
4. For steam sootblowing, ISB should reduce the use of demineralized boiler water
5. Require less maintenance of sootblowing hardware
6. Improve boiler tube life
7. Indirectly stabilize pollutant emissions for NO_x or opacity

An ISB system requires a central controller that integrates either a model, a neural network, or an expert system. Ideally, an optimizer would combine these elements. The optimizer is supported by direct measurement methods from the lower furnace, furnace exit, convective pass process variables, economizer exit and blowing hardware process variables. The system is typically designed to operate in open-loop or advisory mode where the operator can decide whether or not to implement the ISB system cleaning cycle recommendation. Distributed Control Systems (DCS) vendors offer control of sootblowing as a component of their systems. Four major providers of ISB systems offer sootblower controls based on a combination of direct measurement of slagging in the furnace area with indirect thermal modeling of the boiler convection components. Appendices A, B, C, and D, respectively, present the approaches offered by the leading ISB vendors: NeuCo, Diamond Power Inc., Clyde Bergemann, Inc., and URS/Synerco.

3
ADVANCED SYSTEM COMPONENTS

This section describes novel or advanced technologies for monitoring and cleaning of slagging and fouling in the various areas of the boiler. The review was completed by surveying the public domain information and by interviewing various vendors and suppliers of the technologies. As stated earlier, variations of compressed air, steam, and water are used as media for keeping fossil fuel boiler tube surfaces clean. The choice of the medium is usually a function of the initial boiler manufacturer design configuration and preferences, coal quality, type of furnace (wall, tangentially fired, etc.), and the availability of the blower medium in the plant. Compressed air and process steam are effective in removing ash deposition except for some coal types, such as PRB, which exhibit unique slagging characteristics. Ash from this coal, molten and ‘sticky’, typically cannot effectively be removed by air or steam blowers because they tend to push the slag around on the surface rather than successfully removing it. As ash particles from this type of coal combine and sinter on tube surfaces in the higher temperature sections of the furnace, a molten deposit results for which the application of water is the only successful way to remove the slag. Applied at the correct time in the sintering process, water quenches the slag, causing fracture and weakening of the slag. However, if water is not sprayed on the surface at the correct time, typically just as the sintering begins to form a coating, and the slag is allowed to accumulate too thickly, removal even with water may be difficult. Repeated applications may not successfully remove the slag. Under these extreme conditions in difficult to clean areas, a combination of water and steam blowers can be used, with the water applied first followed by a local steam blower. The water ‘fractures’ the slag so the steam cycle then can remove it.

Multimedia Sootblowers

A novel approach to applying a combination of water and steam in a single blower, or long retract, is offered by Clyde Bergemann, Inc. These devices replace and/or complement steam blowers in the pendant sections, and through use of cameras and strain gage technology. In concept, these sootblowers enable focused use of water on large deposits, usually those deposits that bridge two or more pendants. Figure 3-1 shows a sketch of the multi-media long retract.

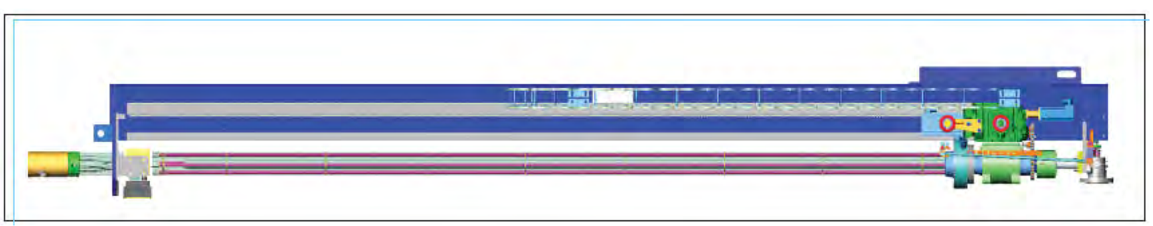

Figure 3-1
Multimedia Sootblower (Courtesy Clyde Bergemann, Inc.)

The long retract blower is a standard steam blower, but combines the ability for spraying with water in high slag deposit areas. Figure 3-2 shows the motor configuration and water connections for the blower. Variable rotation and insertion drives and the ability to selectively spray with water enable cleaning of specific areas. For instance, steam is used for cleaning and cooling on insertion and retraction, and water is injected directly on the slag buildup problem areas. Separate nozzles exist for insertion and retraction, such that upon insertion water is directed upon the slag deposit in the ahead of the lance movement. Figure 3-3 shows a diagram of the water cleaning concepts in the pendant or superheater area. The general concept is that the sootblower operates as a normal steam blower until a major deposit is identified that requires water to dissolve. This device is in operation in some US plants but their performance is yet to be documented by EPRI. Figure 3-4 shows a photo of an installed multimedia sootblower.

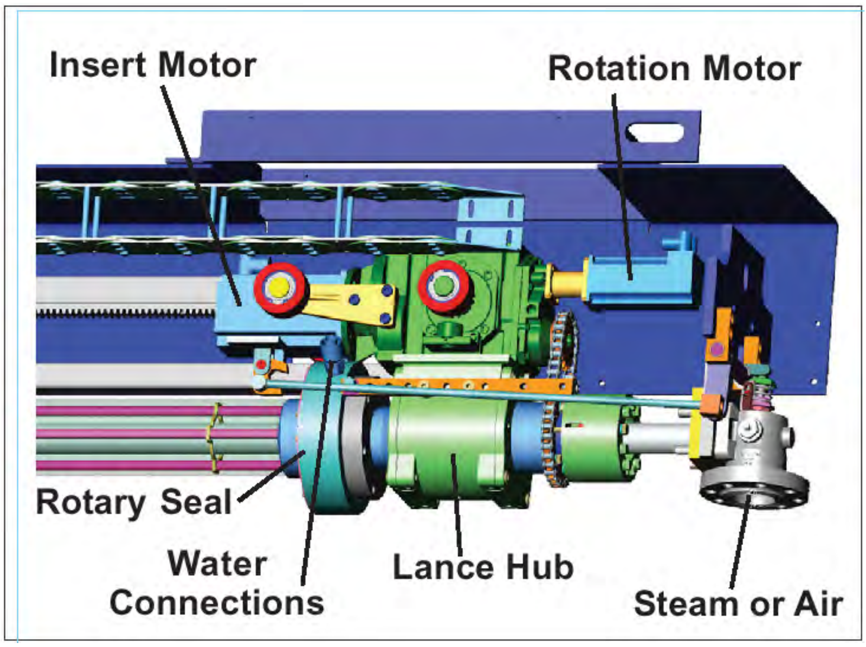

Figure 3-2
Motor Drive Assembly for the Multimedia Sootblower (Courtesy Clyde Bergemann)

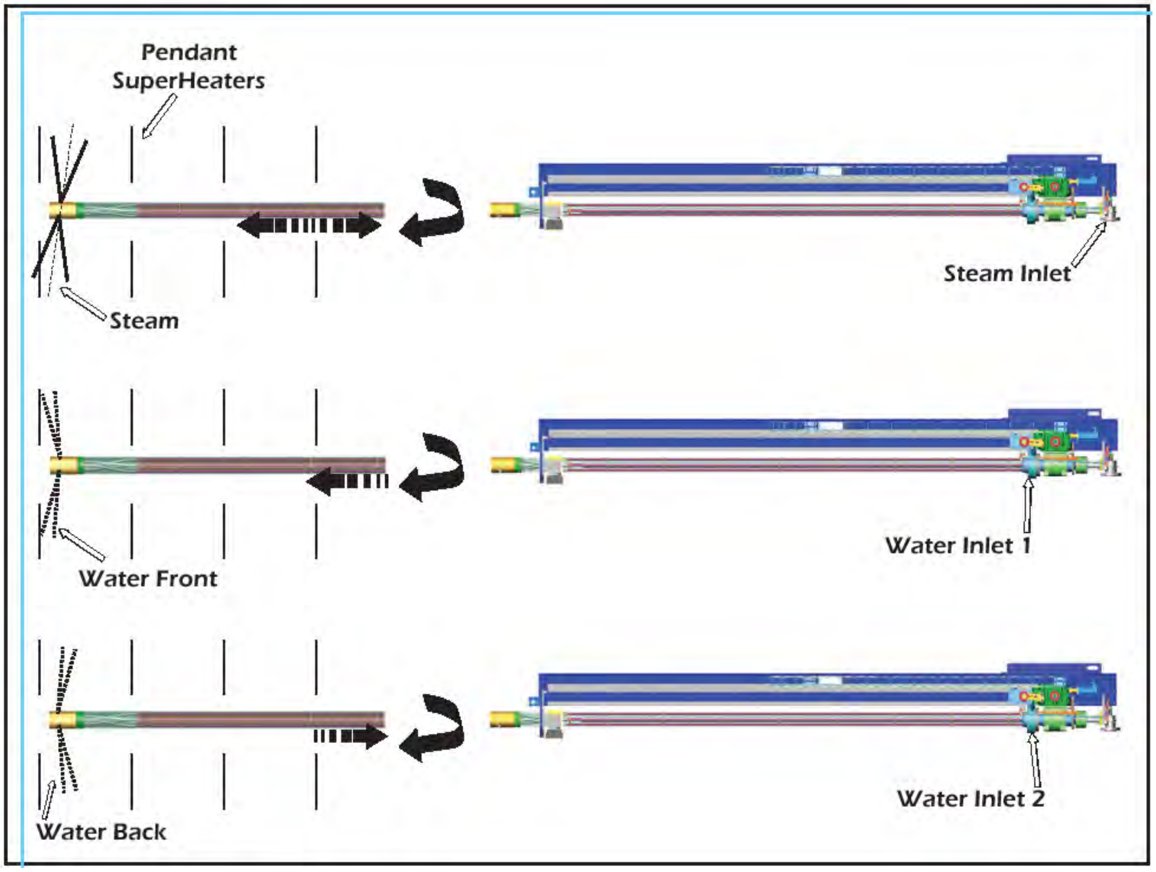

Figure 3-3
Insertion and Rotation for Multimedia Blower (Courtesy Clyde Bergemann, Inc.)

Figure 3-4
Photo of an Installed Multimedia Sootblower (Courtesy of Clyde Bergemann)

Impulse Cleaning Devices

There are multiple methods currently in use that use the principle of impulse to remove deposits. Some of these approaches include the use of horns with compressed air forced through membranes to inject acoustic energy directly into the flue gas stream. Other approaches use a combustible mixture to generate pulse energy in a combustion chamber that exits through a diverging nozzle or horn. Another application of pressure pulse concept is being tested under an EPRI project that uses existing sootblower lances in the combustion chamber to direct the impulses locally in the boiler. This section presents an overview of these various technologies.

Acoustic Cleaners

Acoustic cleaners are being successfully used for fouling mitigation in boiler sections downstream where the gas temperatures are below ash fusion temperatures. Acoustic energy from devices emitted directly into the gas path can dislodge ash dust particles from tubes and banks, and keep ash entrained in the gas path to prevent deposition on surfaces. Acoustic cleaning is most effective in sections affected by low temperature fouling such as the economizers and air preheaters.

WaveMaster Acoustic Cleaning (www.soniccleaning.com)

The WaveMaster Cleaning system is offered by Advanced Acoustic Technologies, Inc. According to the vendor's web site, the principle of operation for the WebMaster system uses the analogy of sound waves traveling through flue gas (compressible media) "like waves travel in the ocean". The ocean water moves up and down as a result of the wave passing by, but there is no transverse movement of the water. Sound waves are pressure oscillations (from plus to minus pressure values) that travel at the speed of sound. Flue gas molecules, exposed to these pressure waves, migrate toward the low pressure zones. Since numerous pressure cycles per second travel past any given point, the flue gas molecules oscillate back and forth. The amplitude of this displacement is very small, but increases as frequency drops. This scrubbing action and particle displacement is responsible for two effects: The first effect is prevention of particle settling on surfaces as these remained entrained in the flue gas. The second effect is the re-entrainment of particles that have already accumulated on the heating surfaces. Because the pressure forces are miniscule, they affect only the small ash particles and are claimed to have little or no effect on internal structures. Since the sound field is uniform throughout the target cleaning area, the cleaning is more uniform as well. The vendor suggests that cleaning with low frequency sound results in volume cleaning as in through several tube banks or the entire air preheater rotor. Figure 3-5 depicts a schematic of the WaveMaster system components.

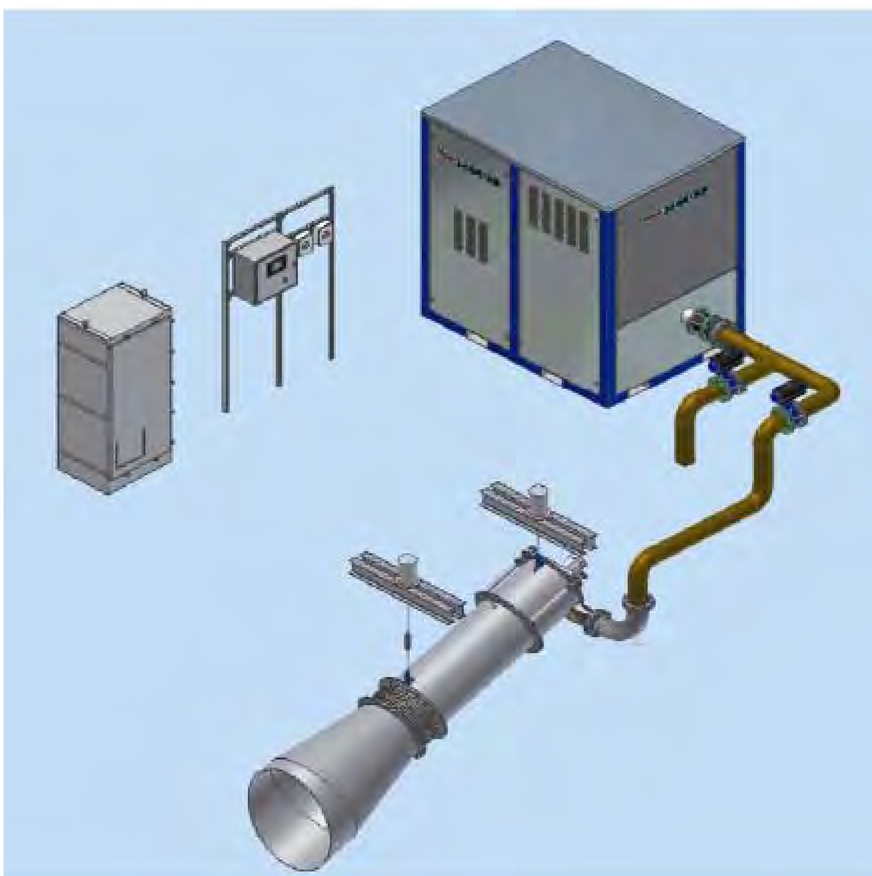

Figure 3-5
Diagram of WaveMaster Acoustic Cleaning Technology (6)

Acoustic modeling using Finite Element Analysis at CPS Deely Station was used to optimize the operating parameters and location of the cleaning devices in the economizer and air preheater sections of the unit(6). Some of the claimed advantages of the WaveMaster System include, boilers kept clean on a continuous basis, reduces sootblower use, prevents accumulation of large ash piles, reduces offline cleaning requirements, one or two cleaners cover a large volume area including extended surfaces and tube banks, requires low operating air pressure (6 psi) and the system can run continuously with an adjustable operating range. EPRI has not conducted an independent assessment of this technology in the field.

SHOCKSystem Online Detonation Cleaning (www.shock-system.com)

The SHOCKSystem was developed by Pratt & Whitney exclusively for online removal of fouling deposits on coal fired boilers. The system applies the concept of pulse detonation that creates a controlled gaseous explosion in a confined combustor that is located outside the boiler (23). The combustor blast wave propagates throughout the inside of the boiler. The wave expands in all directions reaching areas that are not necessarily in the line-of-sight of the combustor. The system does not require steam or high-pressure air. The system has been installed at multiple boilers in the US. A paper presented at EPRI's 7th ISB Workshop (6) lists two US plants that have installed these systems. These include DTE's Monroe Plant and AEP's Rockport Plant. EPRI has not conducted an independent assessment of the technology.
Figure 3-6 shows a photo of an installed SHOCKSystem at AEP's Rockport Plant.

Figure 3-6
Photo of a Bent Tube SHOCKSystem Installed at AEP's Rockport Plant (6)

GE PowerWave+ (http://ge.ecomagination.com/products/powerwave-cleaning.html)

This technology utilizes a shock wave generated by the detonation of a small amount of gaseous fuel and air in a right-angle tube where the wave generated is expelled through a divergent nozzle. These small pressure wave bursts occur at short time intervals and cause the deposits to crack and dislodge from the tubes. The claimed benefits of impulse cleaning such as the GE Powerwave+™ technology include the development of high magnitude and high energy shock impulses that fracture the ash deposits, a multi-directional wave propagation resulting in non-line-of-site cleaning, the ability to clean deeper into the tube banks with stronger pressure waves, and the relatively small size of the horns permits multiple installation points with minimal intrusions. Figure 3-7 is a picture of one of the GE Powerwave+™ pulse detonation cleaning system.

Figure 3-7
Photo of One GE PowerWave Pulse Detonation Cleaning System (6)

This system has been tested and its performance documented in EPRI's report *Slag Management at FirstEnergy's Ashtabula Plant* (7). Three pairs of PowerWave Units were installed on three elevations in the boiler's backpass: at the top of the upper low temperature superheater, at the top of the lower low temperature superheater and at the top of the economizer. The system was successful at removing deposits under normal operation when starting with a clean boiler. In this case study, the use of this technology helped to circumvent the need for the traditional annual spring outage for backpass cleaning.

EPRI Impulse Deposit Removal System (IDRS) (Bagel Blaster)

The IDRS uses the 'natural environment' of boiler flue gas in a unique way, generating and transmitting mechanical energy through release of chemical energy. The device, developed by EPRI, uses pulsed combustion to remove deposits in the furnace. Figure 3-8 shows the IDRS device installed at a utility boiler for test and demonstration (8).

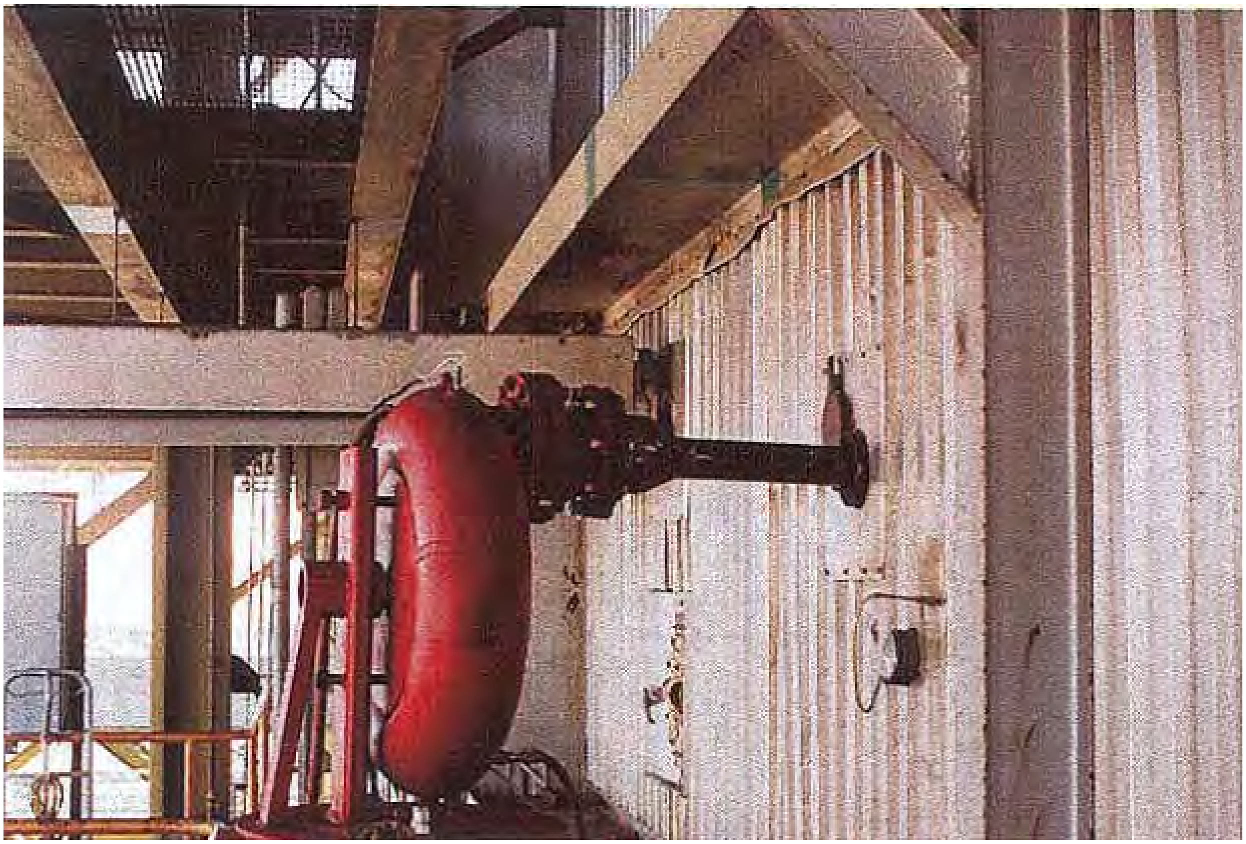

Figure 3-8
EPRI's Impulse Deposit Removal System (8)

The IDRS injects an impulse through a boiler port directed at tube fouling. The impulse originates in the device by mixing combustion air and gas under pressure. This type of combustion is self-sustaining as long as fuel and air are supplied. It does not require use of continuous or intermittent ignition. Standing (resonant) waves are generated by the pulse combustor. The combustion also is described by achieving oscillating acoustic flame velocities in the range of 20-300 ft/s and generated pressure of oscillations is in the range of 0.04 – 10 psig inside the combustion chamber. When the explosive limit of air-fuel mixture is achieved within the chamber, deflagrative combustion generates velocities in the range of 100-3000 ft/sec and pressures from 3 to 35 psig. This process is characterized by high, almost spontaneous increase of combustion gases (3-300 psig) as well as high propagation flame speed, in gaseous fuels from 3000 ft/sec to 12,000 ft/sec. These impulse energies are directed toward slag deposits and tests have shown are effective in deposit removal.

Sonic Horns

Sonic horn technology has proven effective for removal of ash in dust form at the downstream boiler sections, such as the economizer, air preheater, baghouse, ESP and SCR (22). Sonic Horns can be classified as Infrasonic acoustic cleaners or audible acoustic cleaners. Sonic horns use compressed air to vibrate a membrane in the horn to inject sonic impulses into the flue gas stream to agitate and remove ash deposits entrained in the boiler. Figure 3-9 shows a sonic horn installed at the W.A. Parish plant as part of the multi-year ISB test and demonstration project (5).

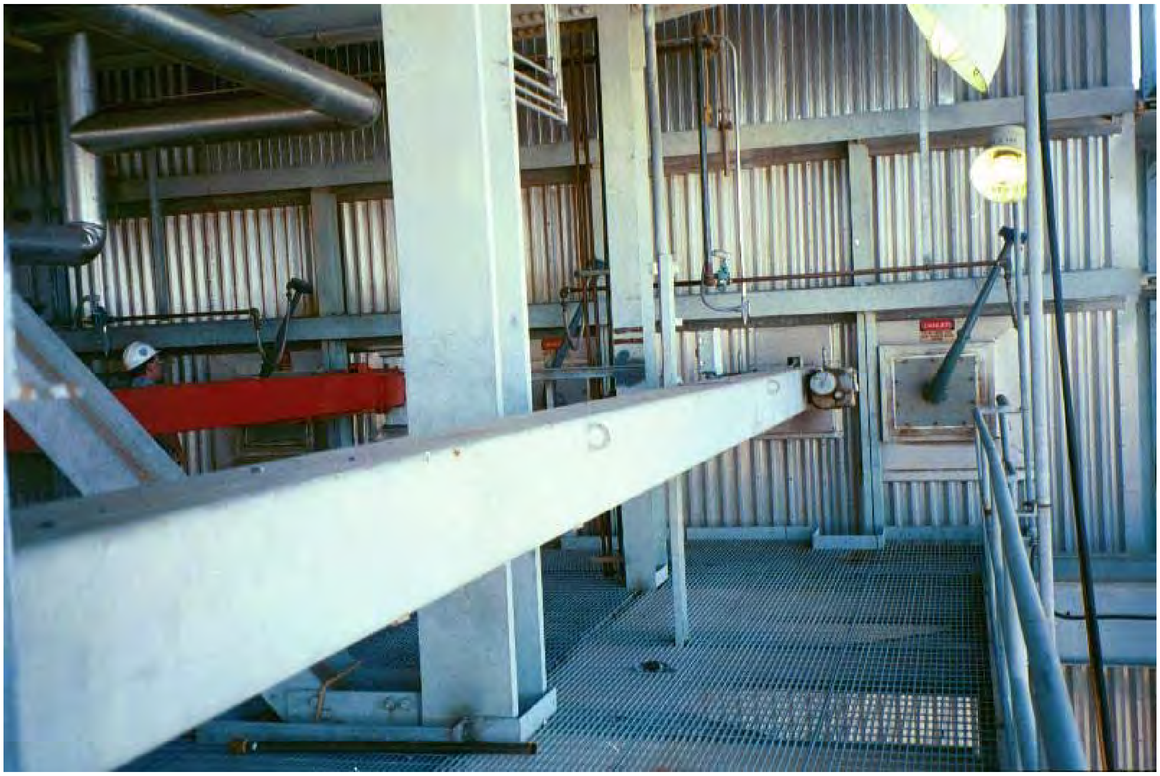

Figure 3-9
Three of Twelve Sonic Horns Installed in an Economizer through Existing Access Ports

Operation of the sonic horns is typical cyclical, controlled by a PLC that opens air valves to the horns. At Parish, the horns were cycled on in banks every two minutes for ten second intervals of operation. These cycles are variable in general, and are designed into specific needs of the boiler being cleaned. The horns shown in Figure 3-9 were installed in available human access ports in the boiler. It should be noted that sonic horn technology is most effective when adequate design places them in positions where the acoustic energy can best be directed at particle buildup. Sometimes, horns are placed completely inside the boiler to achieve that goal. Sonic horn technology has proven effective in keeping ash particles entrained in the gas path as long as the ash is dry. Another installation reported at the 7th ISB workshop (6) showed the application of sonic horns from GE installed to clean the backpass, air preheater and baghouse at the Deseret Power Cooperative Bonanza Power Station. Other public sources (9) report the GE, formerly BHA Group, Powerwave DC-75 Sonic Horn was demonstrated at Mirant's 250MW Birchwood Power Facility. The horns were installed at the top layer of the SCR inlet with satisfactory results. Another test was also conducted at TVA's Paradise Plant also at the SCR between the 1st and 2nd catalyst layers. The sonic performance was benchmarked to conventional steam sootblowers. The primary advantage of the sonic horns over steam sootblower is the ability to clean a larger volume area and overall lower operating cost. A public web search reveals a number of sonic horn vendors including Primasonics (http://www.sonic-horns.com/power_generation_industry.htm) and Acousi-clean (http://www.acousticlean.com).

Diamond Power Pulse Sootblower (Non-Commercial)

The following are excerpts from product descriptions provided by Diamond Power Corporation, explaining their pulse sootblower cleaning technology. These devices are in the product testing phase including a demonstration project with an EPRI member. Diamond Power's Pressure Pulse™ Cleaning System combines the cleaning effect of supersonic pressure pulse technology with proven sootblower retraction technology, resulting in an efficient and cost effective way to remove non-sintered ash in hard to clean back pass regions. Because it is shock wave-based, the Pressure Pulse™ Cleaning System combines the cleaning advantages of a supersonic energy pulse with the reduced risk of induced boiler tube erosion. In addition, the added value of cleaning areas where traditional sootblowers are unable to reach is realized. This patent-pending technology is claimed to provide a winning combination to increase boiler efficiency while reducing operational costs. The supersonic pressure waves are generated by simply filling a conventional lance tube with an air-fuel mixture and igniting it as illustrated in Figure 3-10. Pressure pulses from the initial combustion run ahead of the flame and gradually preheat unburned gases inside the lance tube thus increasing to the speed of sound. As pressure pulses start traveling at sonic speed, they coalesce and further heat up the unburned gases. A pocket of unburned gas reaches the auto-ignition temperature and produces a local detonation. Rapidly expanding gases produce a sharp shock wave which exits the lance tube at supersonic speed. The pressure rises by several factors across the traveling shock wave. As the emanating shock wave impacts the first tube in the line of site, it partially reflects and strikes the next tube. This process continues until the shock wave is dissipated. This unique feature of supersonic shock waves provides deeper penetration into a tube bundle in comparison to conventional subsonic air/steam jets which are greatly impaired by obstructions. A Pressure Pulse™ cleaning event starts with a request initiated by a DPII intelligent sootblower control system. The local controller checks all alarms for the sootblower in question to ensure that all parameters are within the required control band. Next, the carriage starts advancing the lance tube into the boiler. Once the lance tube reaches the designated cleaning area, the injectors and igniters are actuated at a preprogrammed frequency. For each cycle, the injectors are opened long enough to allow enough propane and air to fill the lance up to the desired length. Then the ignition is triggered at the proper time allowing the combustion process to take place and thereby producing a powerful pressure pulse. The intensity and the frequency of the pressure waves can be varied depending on the tenacity of the deposits. The magnitude of the pressure pulse delivered by the sootblower is roughly the same as that of a conventional sootblower but the energy is spread out over a wider area instead of being focused on a local spot. In addition, the shock wave energy decays at a slower rate compared to conventional jets, especially as the wave moves away from the discharge point. This feature allows the pressure pulse to reach deeper into the tube bundle. Figure 3-11 shows a diagram of a Pressure Pulse Sootblower assembly.

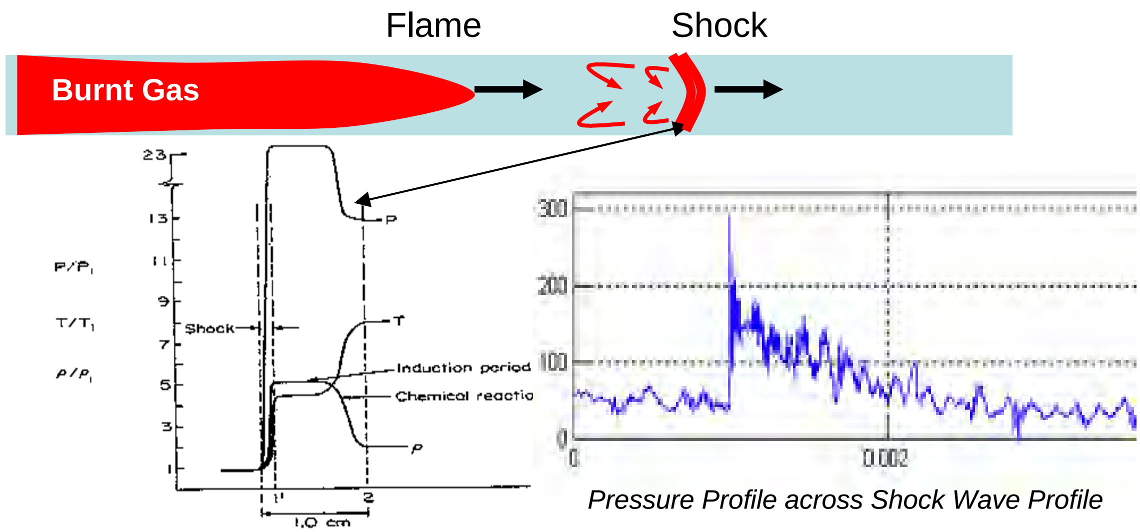

Figure 3-10
Pressure Pulse Detonation Sootblower Process Description (Courtesy of Diamond Power)

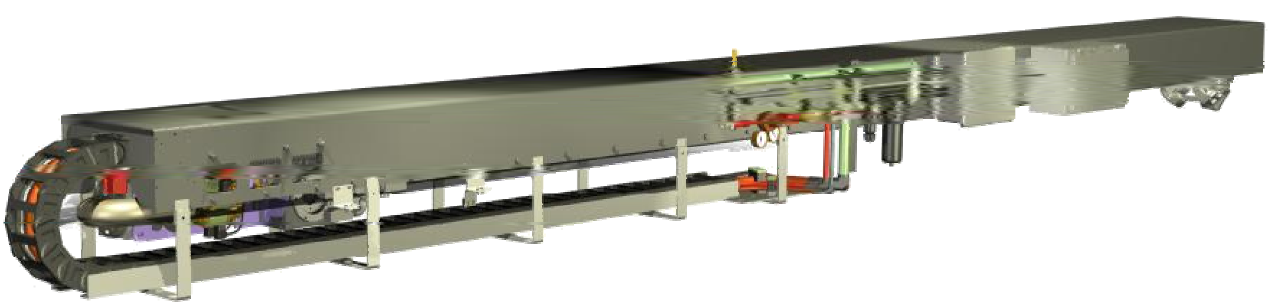

Figure 3-11
DPII's Full Carriage Assembly for Pulse-detonation Sootblower (Courtesy of Diamond Power)

4
FUEL ADDITIVES

Background

Fuel additives have been used extensively for many purposes in coal-fired boilers including efforts to mitigate slagging and fouling. In the EPRI report *Operations Guide for the Use of Combustion Additives in Utility Boilers* (10), a detailed compilation of the background, theory, application and experience with fuel additives used in the oil and coal fired boiler industry was documented. In the case of slagging and fouling for pulverized coal-fired boilers, the objective for the use of additives is to alter the chemistry of the inherent mineral matter reactions undertaken during combustion such that more friable, less tenacious and more easily removed deposits result from the process. The fuel additives can be classified by their physical form, active chemical agent, cost or method of application. Additives can be dry powders, dispersions, emulsions or gases.

Considerations for Fuel Additive Selection

Because the pulverized coal-fired combustion process involves many complex homogeneous and heterogeneous chemical reactions, the application of fuel additives should include a holistic view of plant operations beyond the furnace waterwalls and convective surfaces. The guideline report suggests the following general areas for consideration of additive usage:

1. Boiler Design: a fuel additive that works on one particular boiler may not have the same effect on a similar boiler because of the many variables that influence the combustion process.

2. Coal Composition: variability in the coal composition, which is inherent of most coals, may play a role in the effectiveness of an additive. Similarly, differences in coal rank will need to be taken into consideration for specifying a particular additive.

3. Deposit Composition: consideration to actual furnace or tube deposit compositions should provide additional insights into defining a fuel additive.

4. Coal Particle Size or Fineness: This parameter influences the combustion processes of combustible burnout, particle burnout, particle radiative heat transfer and particle aerodynamics. All of these factors will also influence the mineral matter transformations, ability to deposit on surfaces, and their interaction with an additive.

5. Precipitator Design: In some instances, an additive may cause physical properties of the fly ash such as resistivity or cohesiveness to change such that their collection efficiency may be positively or negatively affected on downstream collection equipment.

Current Industry Offerings

Some recent offerings of in-furnace type fuel additives currently in the market include GE FuelSolv, Fuel Tech, Inc. FuelChem, Environmental Energy Services CoalTreat and Flame Technologies' EcoBik among many others. Other fuel additives such as Chem-mod, are added to the coal during transport from the coal yard to the boiler house. The following subsections provide publicly available information on these additives and where available some recent EPRI experience is also briefly presented.

Fuel Tech's FuelChem (www.ftek.com)

Fuel Tech, Inc. incorporated in 1987, is an integrated company that uses a suite of technologies to provide boiler optimization, efficiency improvement and air pollution reduction and control solutions to utility and industrial customers worldwide. Fuel Tech's special focus is the worldwide marketing of its nitrogen oxide (NO_x) reduction and FUEL CHEM processes. The NO_x reduction technology segment, which includes the NOxOUT, NOxOUT CASCADE, NOxOUT ULTRA and NOxOUT-SCR processes, reduces NO_x emissions in flue gas from boilers, incinerators, furnaces and other stationary combustion sources. The FUEL CHEM technology segment claims improvements to the efficiency, reliability and environmental status of combustion units by controlling slagging, fouling, corrosion, opacity, acid plume and loss on ignition, as well as the formation of sulfur trioxide, ammonium bisulfate, particulate matter (PM2.5), carbon dioxide and NO_x through the addition of chemicals into the fuel or via TIFI programs. The company has other technologies, both commercial and in the development stage, which are related to the NOxOUT and FUEL CHEM processes or are similar in their technological base.

Demo at FirstEnergy's Eastlake Plant

An EPRI project at FirstEnergy's Eastlake Plant focused on tests of the Fuel Tech Targeted-in-Furnace-Injection (TIFI) system and Fuel Tech 8261 additive. The application utilized a magnesium hydroxide [$Mg(OH)_2$] slurry diluted with water and atomized with air. The mixture of micron sized particles is sprayed into the upper furnace area injection points. A Computational Fluid Dynamics (CFD) model of the furnace was developed to define the optimum injector configuration and location. .The project team collected data including observations of slag, deposit properties such as color, density, coverage, and form, thermal performance/heat uptake by the furnace, and sootblowing requirements. The 25-week program was divided into two Phases, each with its own objectives. The findings of this project will be documented in the EPRI report *Utilization of Magnesium Hydroxide Additive at First Energy's Eastlake Station* (11).

General Electric - FuelSolv (http://www.gewater.com/pdf/Case%20Studies_Cust/Americas/English/CH1057EN.pdf)

GE Infrastructure Water & Process Technologies introduced FuelSolv FMG2960, an oil-based magnesium slurry product to control slag deposition and fouling. GE's description of the product suggests that it works by increasing the melting point and friability of deposits formed from the ash constituents in the coal during the combustion process. Thus, the additive claims to make boiler deposits easier to remove during normal sootblowing and out-of-service cleaning. The catalyst contained in FMG2960 is also claimed to improve coal combustion efficiency. EPRI has not conducted an independent field assessment of this specific fuel additive.

Environmental Energy Services Corporation (EES) – CoalTreat™ (http://www.eescorp.com/coal_coaltreat.htm)

EES has serviced the oil-fired boiler industry since 1991. The CoalTreat additive claims to inhibit the formation of slag deposits as well as to react with existing deposits to alter their tenacity while alleviating the effect of reflective ash deposits. There is little information on the public domain concerning its application, results and experience base to coal-fired plants. EPRI has not conducted an independent field assessment of this specific fuel additive.

Kubik – EcoBik™ and Flame Technologies Inc. - Magnexid

ECOBIK™ combustion enhancement technology was developed in Romania for oil fired units as a boiler cleaning agent and to improve thermal efficiency. The technology was introduced to the United States market by Avogadro Environmental and Opris Engineering with application to coal fired units (12). Until late 2008, the EcoBik system was licensed to Flame Technologies Inc., a subsidiary of Avogadro Environmental. The process is a front end combustion optimization system that is claimed to provide online boiler cleaning to remove slag buildup (13). The system uses a proprietary aerosol injected by a very low pressure constant volume system into the combustion air (primary or secondary) or into the fuel. Primary claims on the company website include shortening and concentration of the flame, oxidation of aromatic, poly-nucleatic and cyclic hydrocarbons, and separation of some heavy metals and their deposits on internal surfaces. Indirect effects claimed include removal of existing deposits on heat exchangers, protection of surfaces from new deposits, useful oxidization of unburned molecules, emissions reductions SO3, CO, NOx and VOC's, reduction of greenhouse gases, inhibition of oxidation of the heat exchangers' metal surfaces, and protection of refractory. The experience base with EcoBik in the US is limited to vendor supplied published information. Improvement claims on a 156Mw plant in the referenced presentation include reduced sootblowing by 75%, removal of 'old' slag buildup in corners, reduced corrosion of boiler tubes, excess air reduction from 35% to 10%, small reduction in SO2 and NOX emissions, and improved heat rate by 1% based on CO2 data. More recently, Flame Technologies and Opris Engineering have developed a new process called Magnexid that is similar to the EcoBik process but uses a modified injection system and additive. A demonstration project of this new process is ongoing at a mid-size pulverized coal boiler firing PRB with the primary objective of slag mitigation, according to George Wagner II, President of Flame Technologies (24). EPRI has not conducted a field assessment of EcoBik or the Magnexid technology.

The Chem-Mod Solution – Chem Mod LLC (www.chem-mod.com)

This technology consists of a dual-sorbent system that is added to the coal during the transport from the coal yard to the pulverizer hopper bins. The primary product claim is reduction of pollutants such as mercury, SO_x and NO_x. The web information also claims a reduction in slag formation. Test result data from five commercial demonstrations is presented on the web site but only for emissions reductions and not for slagging reduction. EPRI has not conducted an independent field assessment of this technology.

Energy Efficient Combustion Technology (EECT)

A start-up company venture is found in the public domain with a product for the control of mercury emissions as well as slag management by injection with a dry sorbent. EECT is a joint-partnership with the University of North Dakota's Energy and Environmental Research Center (EERC). There is little information in the public domain about results from this technology at this time. EPRI has not conducted a field assessment of this dry sorbent system.

5
TUBE COATINGS

Background

This section reviews passive methods of prevention for the formation of slagging and fouling such as the application of surface coatings on areas known to experience waterwall or tube wastage. EPRI has conducted studies on these and other material coatings under various research projects with primary focus on boiler tube life. This section presents a brief overview of some surface treatment technologies that are primarily designed for protection against tube wastage from erosion, corrosion and abrasion but that are claimed to also reduce the strength of adhesive bonds at the tube surface and ash deposit interface. EPRI's experience to date with boiler tube surface treatment for reductions in slagging tendency is not as well documented as the performance and reductions in erosion and corrosion of tubes. While these tendencies can be positive for the industry, further consideration should be given to the overall thermal effect these technologies may have on the boiler efficiencies and operation. EPRI has conducted laboratory tests of some ceramic materials primarily for wastage resistance but not as a slag mitigation option (14). Further research is needed to determine the impact of each of these processes on heat transfer, the ability to maximize steam temperature control, and the overall boiler efficiencies. A brief description of these technologies is presented in the following sub sections.

Ceramic Coatings

Cetek Limited (http://www.ceteklimited.com/)

Cetek Limited offers a range of efficiency enhancing services, including the application of Cetek's Ceramic Coating Technology, High Temperature inspection services using IR thermography or cameras, and refractory maintenance services. The ceramic coating technology, a plasma spray, can be either applied to boiler tubes in the field during a maintenance outage or on new panels that are coated and cured offsite or 'shop-applied'. Cetek technology claims include prevention of slag adherences and deposit forming sites and reduction of sootblower cycle frequency. Cetek's first application of its ceramic coating product on a power boiler occurred in 2005. An online article from Cetek presents a summary of two case studies conducted on full-scale coal-fired boilers. The first was an application of a 2800 ft^2 shop-applied waterwall segment on a 544 MW supercritical boiler. The coated segment was applied to the left side boiler wall whereas the right side wall was deslagged and cleaned. A comparison between both wall areas is reported to have shown less deposition on the coated walls. An increase in heat absorption was also reported for the coated wall segment based on steam outlet temperatures. The second case study discussed was for a tangential supercritical boiler rated at 650 MW but fired at 720 MW. The unit had experienced accelerated tube wastage in the front and rear waterwalls of the lower furnace. Cetek coating coverage areas totaled 5000 ft^2 in both the front and rear walls. Inspections conducted at 3 and 8 month intervals documented a decrease of wall deposits in the Cetek treated areas. There are ongoing EPRI projects at two full-scale boilers that aim to assess the performance of this ceramic coating.

Oxistop (http://www.oxistopinternational.com/)

OXISTOP Specialized Coatings Systems, LLC. Boardman, Ohio, was formed in the spring of 2004 by a number of partners with extensive power generation maintenance problem solving experience. The company is the exclusive distributor and installer of Oxistop PROCERA line of coatings. Figure 5-1 shows the distribution of Oxistop applications as presented in the May 2008 EPRI Boiler Tube and HRSG Tube Failures & Inspections International Conference in Alberta, Canada (15). The coating is a chemical spray product that is applied to tube surfaces during regular maintenance outages and that thermally cures during initial boiler firing after the outage. In a technical paper (16), Oxistop claims a line of coating materials has been proven to stop or minimize the damage caused by the destructive nature of slag, oxidation, corrosion, erosion and abrasion. Further claims include that boiler tubes coated with Oxistop coatings will maintain optimum heat transfer into boiler wall tubes by replacing the iron oxide protective (and insulating) layer and residue buildup that occurs when boiler tubes are subjected to high heat and coal combustion. This protective ceramic barrier is said to resist slag buildup that will also decrease heat transfer through the boiler tube. The tube surface is prepared by grit blast prior to coating. The coating is then sprayed on during a scheduled unit outage and cures to a hard ceramic coating as the unit is brought up during start-up. The public web site claims installation of this coating on 6 supercritical and 23 subcritical boilers. EPRI has not conducted a field assessment of this coating for its slag adherence properties.

Figure 5-1
Oxistop Being Applied to a Boiler Surface

Furnace Mineral Products (http://www.fmpcoatings.com)

Furnace Mineral Products (FMP) is a Canadian company that produces a proprietary ceramic coating product known as GreenShield. The public web site information suggests that the coatings are custom designed for each application. The primary functions of the coating are to protect tube surfaces from abrasion, corrosion and slag adhesion. Application description includes surface preparation by sandblasting the tube to a white metal finish in order to create a 2 to 3 mil profile. The water-based coating is applied in layers. The coating requires a drying and curing period at a rate of 200°F (93ºC) per hour which is accomplished with the use of portable heaters. Once cured the coating is said to prevent the adherence of slag because of its low porosity quality that enables isolation of the waterwall tube material. The GreenShield application rate is stated as 1500 ft^2 of coating per shift. A relative cost estimate is provided by the vendor as approximately one fifth of the least expensive metal spray. EPRI has not conducted an assessment of this technology on the field.

6 MONITORING INSTRUMENTATION

Process instrumentation has been developed and deployed in conjunction with processes and systems used to control and mitigate boiler fouling and slagging. Gas temperature measurement throughout the boiler enables effective ISB operation, heat flux sensors provide a potential indication of slagging and fouling deposits and camera technology enables visual indication of deposit formation on surfaces. Further, the range of process parameters used for boiler control in the DCS provides additional input to an ISB system's modeling and control system. This instrumentation is necessary to support systems and processes for slag mitigation. This section presents an overview of these auxiliary components.

Camera Technology

Use of camera technology for in-situ monitoring of slag deposits has become common in the industry (17). Video displays are mounted in the control room connected in a continuous fashion to enable the operator to visibly watch for slag buildups in the furnace. Figure 6-1 shows one of three cameras installed at TVA's Cumberland plant to monitor slag deposits pendants.

Figure 6-1
Diamond Power Flue Gas Temperature Camera

There are three general types of camera systems available to the boiler industry: visible spectrum, infra-red (IR) spectrum and visible near-IR spectrum. Each camera type has its advantages and associated costs. Visible spectrum cameras provide an actual color photograph much like a standard home digital camera. IR spectrum cameras present a black and white picture with a grey scale visible range or an artificially colored color map. The visible-near IR systems produce color enhanced versions enhanced with some feedback from the IR filters. The following is a nonexclusive list of camera suppliers: BoilerCam, Diamond Power, Enertechnix, Flir, IST-Quadtek, Lenyx, Lonox Instrument Co., Mikron, and Syn-Fab. As camera technology evolves, portable cameras are increasingly becoming useful tools in monitoring, recording and analyzing slagging problems. These cameras can be useful to record and/or benchmark slag conditions when undertaking slag mitigation efforts. The camera lens is typically mounted in a probe cooled by temporary connection to instrument air. Lenses can be configured to capture images straight forward, or at angles which enable views of adjacent walls, etc. Available access ports, either human access, sootblower ports, or any port into the boiler sufficient to accept the probe, can be used for photo gathering and/or video capturing through available human access ports in the boiler.

Furnace Exit Gas Temperature (FEGT) Measurement

FEGT indicates the temperature of the gas stream as it exits the furnace and enters the first pendant sections. Measuring FEGT has become a significant element of boiler control systems and ISB systems because it is an important indicator of the quality of heat transfer within the boiler's furnace section. Each boiler is designated with an operation heat transfer distribution that corresponds to a specific design temperature. But boiler combustion profiles change continuously during operation due to variations in the coal quality, boiler loading, ash deposition, and other process parameters. The temperature is a key indicator of the potential behavior of the coal ash as it passes into the convection platens. Coals with ash fluid temperatures in the range of 2000-2300°F (1093-1260°C) have a strong tendency for deposit accumulation in the inlet pendants whenever this temperature threshold is exceeded. Therefore, it is essential to limit high temperature excursions and to maintain a stabilized and balanced flow of furnace gas passing through the convection sections of a boiler. In this way, ash deposition occurs in predictable locations that can be managed with proper cleaning operations.

Implementing continuous online measurement of FEGT enables the operators to monitor furnace trends and to react to undesirable conditions. As an input to the ISB systems, FEGT provides a direct basis for indication of furnace heat loading as compared to the convection region. Where available, all ISB vendors utilize FEGT in their models, and one vendor has as a requirement that FEGT monitors be installed as part of their system. Economizer exit gas temperature coupled with economizer gas out temperature measurement and process steam temperature and pressure measurement enables accurate determination of fouling levels of each element of the convection region. Figure 6-2 shows a Diamond Power Gas Temp FEGT device at TVA's Cumberland Plant.

The FEGT instruments can be categorized in three groups according to measurement principle: optical pyrometry, acoustic pyrometry and tunable diode laser absorption spectroscopy (TDLAS). The EPRI report *Comparison of Furnace Flue Gas Temperature Monitors* (18) presents the results of field tests at one large boiler for multiple gas temperature measurement instruments. The list of technologies tested included SpectraTemp, Infra-View, PyroMetrix and ZoloBoSS. Table 6-1 presents a summary of these technologies.

Figure 6-2
Diamond Power Gas Temp FEGT at TVA's Cumberland Plant

Table 6-1
Basic Features of Some Upper Furnace Temperature Measurement Instruments

Supplier AMETEK	Process Instruments	JNT Technical Services	Enertechnix Zolo	Technologies
Technology Ash	radiation in visible spectrum	CO_2 radiation in infrared spectrum	Acoustic TDLAS	
Pieces of Equipment	1 2 3			5
Equipment Description	Self contained instrument	Instrument and Power Supply/digital read	Sound generation, sound reception and signal processing	Transmitter, Receiver, distribution node, distribution cabinet, and control cabinet
What gets measured	Line of sight, 6° Field of View	Line of sight, 2° field of view	Average Path Temperature	Average Path Temperature along with O_2, CO, CO_2 and H_2O
Measurement Range	675°-2900°F (357-1593°C)	250°-4000°F (121 – 2204°F)	0°-3500°F (-18 – 1927°C)	500°-3000°F (260-1649 °C)

Heat Flux Monitoring of Waterwalls

In both water lances and ATF devices, heat flux sensors provide direct input into the ATF control system to provide an indication of the water wall thermal status. Use of heat flux sensors when using water to clean has become somewhat an industry standard because spraying water on clean tube surfaces causes extremely high thermal stresses that lead directly to tube quench cracking. There are several types of instruments designed to provide an indication of heat flux. These can be characterized as direct or indirect measurement methods. Some instruments provide a point measurement whereas others provide a composite contour average based several nodes. In the recent EPRI report *Heat Flux Measurement: Requirements, Characterization and Technologies* (19), a detailed review of several heat flux instruments is presented.

Direct Methods

Direct measurement technologies include Chordal thermocouples, Crown-type heat flux sensors and membrane-type heat flux sensors. Chordal thermocouples are generally installed by boiler OEM's. The thermocouples and installation design are generally customized based on tube size and application and provide a tube surface temperature that can be coupled with other furnace parameters to estimate a heat flux. Crown-type devices are more widely used for waterwall heat flux measurement as they provide both a surface temperature and heat flux indication albeit at higher installation cost. Several vendors offer variations of this type of instrument including Clyde Bergemann, Diamond Power, BMS International, and Hukseflux. Lastly, membrane type sensors are considered a lower cost solution as they install in the wall membrane. The thermocouples are installed at the waterwall membrane, between tubes, to infer a crown heat flux. Calibration and correction factors can be used although deposition differences between the tube crown and the tube membrane are a concern for properly interpreting the heat flux data. Clyde Bergenmann offers a commercial device and B&W has a prototype version of this type of instrument.

Indirect Methods

Indirect methods can be further classified into calculated or instrumented methods. The calculated methods provide a bulk indication of the heat flux from available plant process data. The instrumented method includes a number of nodes across a larger waterwall area. Rowan Technologies Ltd offers their Rowan VTER furnace wall corrosion monitor to detect tube wastage damage. In test phases, the technology is not yet integrated into ISB systems for monitoring slag deposition, but holds potential for such applications. The Rowan Technologies approach configures water wall tube panels with a matrix of sensors that inject a small current and measure resistance variances within the matrix to sense changes in tube conditions from erosion/corrosion. The sensors are spaced within the matrix such that a profile of the tube panel conditions can be derived. This technology, while currently being tested for tube damage control, holds potential to yield fouling and slagging condition variations within the sensor matrix. Multiple ongoing EPRI projects are currently testing this technology.

Strain Gages

Strain gages are being used to sense the formation of slag deposits in the superheat radiant sections. The concept of defining the amount of slag on tube elements works by measuring weight increases as the deposits grow over time. Data from each gage is converted to weight using the stress strain relationship:

$S = E\varepsilon$

S = Stress in pounds per square inch

E = Modulus of elasticity (30×10^6 for steel)

ε = strain in micro inches per inch

Using the diameter of the rod a cross sectional area can be calculated, and the stress is multiplied by the area of the rod. According to Clyde Bergemann Inc., the weight measurement can be started at any time within the process and any subsequent readings indicate the change in weight from starting conditions. Thus, it is not necessary to start from a totally unloaded rod. In a demonstration project at the TVA Cumberland plant, strain gages were placed on the secondary superheater. There are 73 pendants across the boiler with eight pendants each attached to a steel beam inside the penthouse as shown in Figure 6-3, and each beam is suspended from the two rods upon which the strain gages are attached.

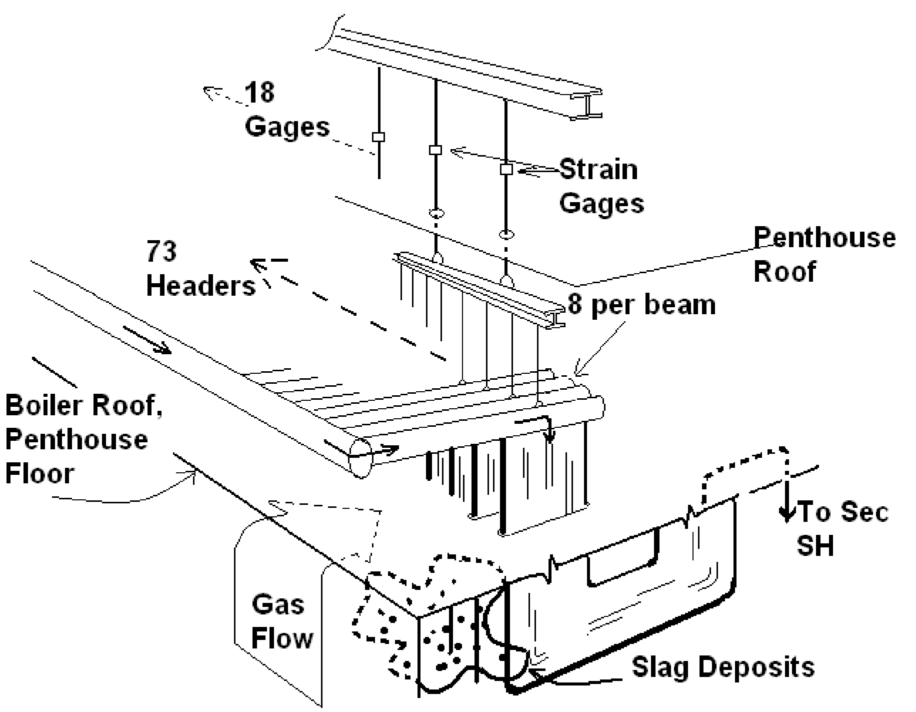

Figure 6-3
TVA Cumberland Pendant Support Configuration (20)

Figure 6-4 shows the strain gages attached to the rods above the penthouse. Each gage was wired to a PLC multiplexing cabinet housed on the penthouse roof, from which an Ethernet cable routed strain gage signals to the control room.

Figure 6-4
Strain gages on the Superheat Support Rods (20)

Strain gage data is now used to complement boiler modeling in the Clyde Bergemann ISB systems. Figure 6-5 is a screen capture showing the status of strain gages connected to the ISB system. The six shaded pendant bars, three each on the North and South sides, indicate level of total weight reported by the gages, which is used in combination with furnace modeling to determine cleanliness levels of the furnace components. EPRI Report *Slag Deposition Monitoring Using Strain Gage Technology* (20) presents a through description of the strain gage system applied at three coal-fired units.

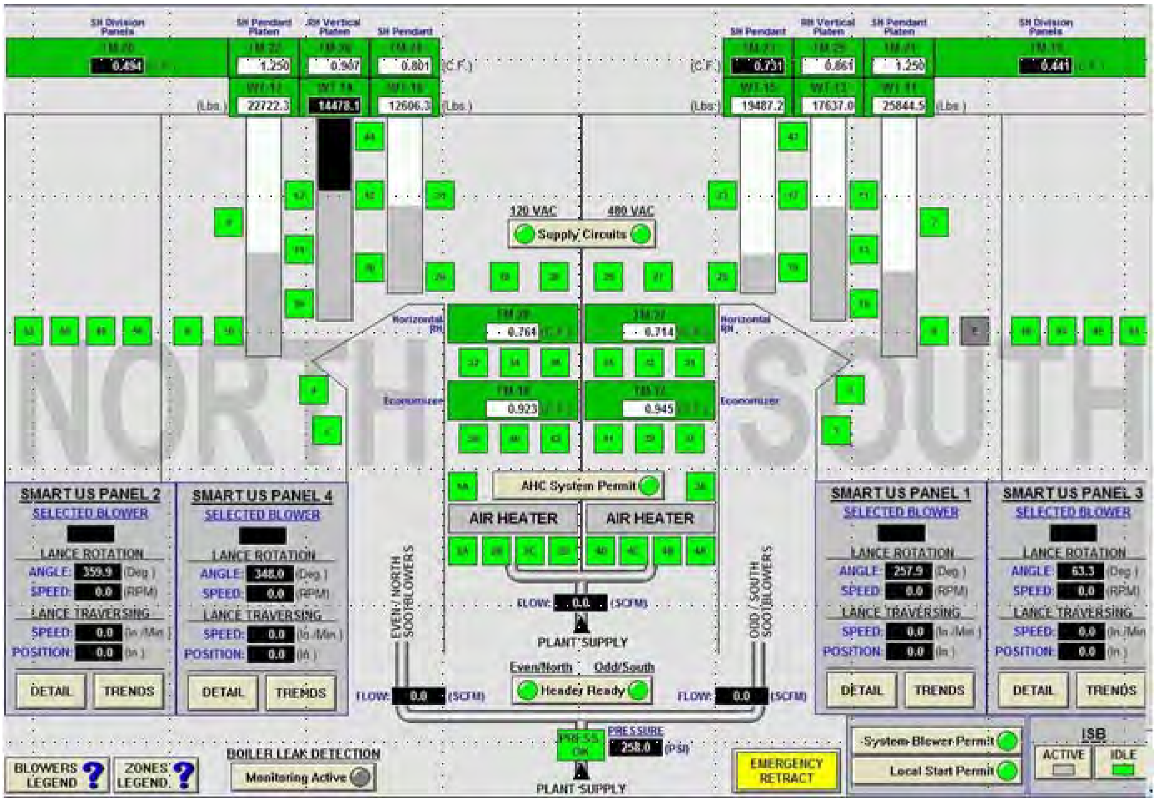

Figure 6-5
Screen Capture of Strain Gage Status (Courtesy Clyde Bergemann, Inc.)

7 CONCLUSION

In general, slag mitigation in coal fired furnaces has effectively been in a reactive role rather than proactive for many power boiler operators. EPRI has sponsored several projects to advance technological solutions to optimizing boiler heat transfer optimization, and the industry has made major strides in applying techniques to maximize use of existing sootblowers, ATF devices, and advanced instrumentation to mitigate slagging. In general, this installed base constitutes a platform for implementing the 'next generation' slag mitigation and productivity optimization.

Combustion optimizers for generation output and controlling emissions to required standards while achieving maximum production have been or are being installed in some coal fired generating plants. While some installations have implemented ISB in the DCS for convenience of operator interface, integration of proactively controlling boiler fouling conditions in conjunction with combustion optimizers and control systems could further improve plant productivity while maintaining optimal emissions compliance, representing the 'next generation' of optimized slag mitigation and fouling control optimization.

Recommendations Summary

- Evaluate the long term potential savings on boiler tube life impacts and balance of plant components from the implementation of various slag mitigation options.
- Assess the impact of coatings and claddings on combustion optimization.
- Assess the effects on the ability of the DCS and ISB systems to work in concert to maintain optimal steam temperature and pressure control, and impacts on add-on systems such as combustion optimizers, etc.
- Continue to investigate and test existing and new fuel additives as an alternative option to hardware component options.
- Another potential option for defining a proactive strategy is the adoption and where needed advancement of technologies for real-time measurement in the areas of:
    - Air and coal flow measurement either online or manually
    - Pulverized coal flow distribution control for mills
    - Online coal fineness determination
    - Online determination of coal elemental analysis
    - Flue gas constituent and temperature measurement
    - Waterwall temperature and heat flux

8
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A
NEUCO

NeuCo Inc. is located in Boston, MA with facilities in Austin, TX, Chardon, OH, and Beijing, China. According to their website, www.neuco.net, NeuCo, Inc. was formed in 1997 with the goal of bringing advanced artificial software solutions to bear on the power industry's mounting emissions and competitive market pressures. Their claim is that today NeuCo is recognized as the leading provider of real-time asset optimization solutions that improve electric power plants' emissions, efficiency and availability profiles.

In 2006, NeuCo acquired Pegasus Technologies, and early optimization visionary that has been providing boiler optimization solutions to the electric power industry for more than 20 years. According to claims on their website, the combined entity is the industry's only dedicated optimization software solutions company with the most experienced team of optimization experts, the largest worldwide customer base, and the most advanced optimization technology solutions and platforms.

Neuco offers SootOpt ISB as part of their fleet of optimization software which includes Boiler Optimization, SCR Optimization, Combustion Optimization, Maintenance Optimization, and Performance Optimization. According to the NeuCo website, SootOpt dynamically determines boiler cleaning actions that optimally balance the unit's heat rate, reliability, and NO_x objectives. A closed-loop optimization software application, SootOpt directs existing sootblowing control systems to take action in real-time to best meet the unit's overall heat rate, reliability, and emissions goals.

SootOpt works in conjunction with existing soot blowing controls and instrumentation – from simple PLC-based controls to advanced ISB systems. SootOpt uses adaptive modeling and expert rules or heuristics to optimize the activity of these systems with respect to their effect on multiple simultaneous global performance objectives. The expert rules also ensure that all applicable unit-specific constraints are considered. Within the boundaries defined by these rules, SootOpt's adaptive neural network models identify the equipment and actions most effective for achieving the plant's efficiency, reliability, and emissions objectives, and bias control activity toward those objectives. The neural models constantly learn from and adapt to changes in boiler operations, so that model quality remains high as conditions change.

Neuco claims the benefits include:

- Improves heat rate by minimizing attemperation sprays and exit gas temperatures, and boiler controlling reheat and superheat steam temperatures.
- Improves reliability by avoiding soot cleaning activities that cause tube erosion and excessive thermal shocking, and by avoiding plugging and fouling events.
- Reduces NO_x by correctly proportioning heat transfer and reducing 'hot spots' that results from ineffective cleaning.
- Reduces opacity violations by better managing the time between cleaning events and consistently applying rules for cleaning zones associated with opacity events.

The NeuCo approach to slag mitigation does not require heat flux sensors in the furnace for direct input as to slagging, but if the heat flux sensors already exist, they can be used by SootOpt as an input into their system. SootOpt utilizes all available process inputs for slag mitigation.

B
DIAMOND POWER

The following is provided courtesy of Diamond Power.

HydroJet Water Cleaning Devices

Each HydroJet will be configured to permit a ± 45° range of motion, both horizontally and vertically. Each surface to be cleaned will be programmed for the highest jet progression velocity, which provides effective cleaning in order to minimize thermal shock. The specific programs will also avoid tube bends and other boiler components subject to accelerated damage by water cleaning.

The HydroJet is based on the proven industrial hardware and controls, along with Diamond Power's thirty years of water cleaning experience. The hardware, controls and plumbing components provide the technology required for cleaning multiple patterns of various shapes and sizes, while also controlling thermal impact, achieved by maintaining constant jet progression velocity (JPV).

Design: Wallbox Rotational Joint

All portions of the HydroJet mechanical hardware have been designed with ruggedness and simplicity in mind. Water is fed to the nozzle through a lance tube, which passes through a ball and socket arrangement, thereby allowing freedom of motion in the X and Y axis directions. Because the wallbox and pivot joint are exposed to radiant heat from the furnace, they are constructed of advanced alloys which can operate at high temperature, and are highly resistant to thermal shock and corrosion, proving to be highly reliable in the field.

The wallbox pivot joint is continuously purged with air to provide cooling of components and prevention of dust accumulation. We have included seal air fans, one per HydroJet to provide the required flow and pressure for cooling / purge air.

Design: Electronics

The two resolvers for X and Y axis provide continuous real time absolute position and speed feedback of the nozzle throughout the blowing cycle. If the power is interrupted, the nozzle position is always available with absolute positioning, and therefore, no limit switches are required. These resolvers can operate at temperatures between -30°F to +250°F and be washed down for cleaning. The nearby pressure switch and electrically actuated water valve provide a quick reliable response necessary for cleaning discrete furnace areas.

Design: Motor and Gear Reducer

The two inverter duty motors are directly attached to the gear reducers, and they respond to the continuously changing speed requirements necessary for maintaining a constant jet progression velocity. When the HydroJet was designed, extensive research was done to select the HydroJet drive motor and gearbox that would give the best performance.

All components, lubricants and seals are selected for the hot and dirty environment, and are able to withstand a periodic wash down. Each gear reducer is directly linked to the nozzle position control by a heavy-duty swing arm. No drive screws are used. The X and Y axis motion is tied together by a stabilizing ring.

Diamond Power Water Cleaning Philosophy

The Diamond Power water cleaning philosophy is that water cleaning on tenacious deposits, such as most PRB or lignite fired units occurs through a combination of thermal shock and kinetic energy. The water cleaning device must deliver a coherent water stream at the point of impact on the slag deposits.

The cooling power of the coherent water jet freezes the molten outer slag layer and causes a differential thermal expansion of the ceramic slag as compared to the metallic tube wall. This weakens the bond between the deposits and the tube wall. The kinetic energy of the coherent water jet sweeps away the deposits.

This water cleaning design philosophy has long been used for cleaning success with the Diamond Power water lances, and has been carried over to the HydroJet lance and nozzle design. Significant development was performed to provide a nozzle/lance design to deliver a coherent water jet over the distances, turbulence and through hot gases required for cleaning in utility furnaces. Experience has demonstrated that a coherent jet is required for the precise delivery of the water to the targeted cleaning zone.

With non-coherent (spray) jets, the water jet is broken up, evaporated, dispersed and/or diverted. The result is limited cleaning and collateral thermal impact. If the water jet does not arrive at the targeted zone, but is diverged, the water jet may have the undesirable effect of impact on a clean zone. The result is excessive thermal shock and reduced tube life.

The superior capability of HydroJet technology has been demonstrated when applied to enhance the cleaning capability of previously installed and operating water cannons. A recent Western Fuels Conference presentation documents the results of one of these upgrades performed at the Ameren Labadie Station (Four 650 MW tangentially-fired units burning PRB coal). The conclusions were:

- The originally supplied nozzle and lance from the water cannon OEM demonstrated successful cleaning on only 1 of 6 zones tested.
- The Diamond nozzle and lance assembly met the proof of design criteria by demonstrating cleaning on 5 of 6 zones tested and repeatability >66% on 5 of 6 zones tested.
- Additionally, it was proven that HydroJet technology operated within the limitations of the water cannons and their associated water supply systems resulted in a marked improvement in cleaning capability.

- Since the completion of the study, all previously installed water cannons on Units 1, 2 and 4 have been upgraded using HydroJet technology, and a HydroJet Cleaning System was selected and purchased for Unit 2.

External to the HydroJet is a *factory-assembled* plumbing assembly consisting of an electrically actuated water valve and an electrically actuated air purge valve. After the completion of each cleaning pattern, a brief air purge of the lance and nozzle occurs to prevent residual water from draining out the nozzle onto the boiler tubes which could cause tube failures over time.

Additionally, each HydroJet comes with a small disconnect enclosure which has separate disconnects for the motor and control power. These would typically be mounted near each HydroJet. This enclosure also has a quick disconnect for attaching a hand-held control pendant to locally test HydroJet operation. Finally, each HydroJet comes with an emergency stop button.

DPII Unique Feature for Water Hammer Control

Water hammer can be a significant challenge on the HydroJet supply piping when the fast-acting valves open and close to control the cleaning events. DPII has developed a successful approach for water hammer control (Figure B-1). Our system addresses water hammer as follows.

As an option, we are including an additional fast-acting valve with downstream orificing for attachment to the ring header around the boiler supplying the HydroJets. The downstream side of the valve should be run to drain or to the source. This valve, controlled by the HydroJet PLC, is open when no cleaning event is occurring allowing water to be re-circulated off the boiler.

Figure B-1
Ring Header Recirculation Package for Water Hammer Control

DPII Unique Feature: Tube Life Monitoring Using the Tube Life Database

As with other Diamond Power water cleaning systems users, the HydroJet installation entitles the Plant to participate in the Diamond Power Tube Life Database Program. This program allows the Plant to submit tube samples or inspection reports to Diamond Power for analysis and comparison with tube crack development/growth rate data from other plants using Diamond Power water cleaning equipment. This data will be used to confirm existing crack growth rate models and to allow early corrective action if the need is indicated. Figure B-2 is a photograph of a Diamond Power HydroJet ATF cleaning device.

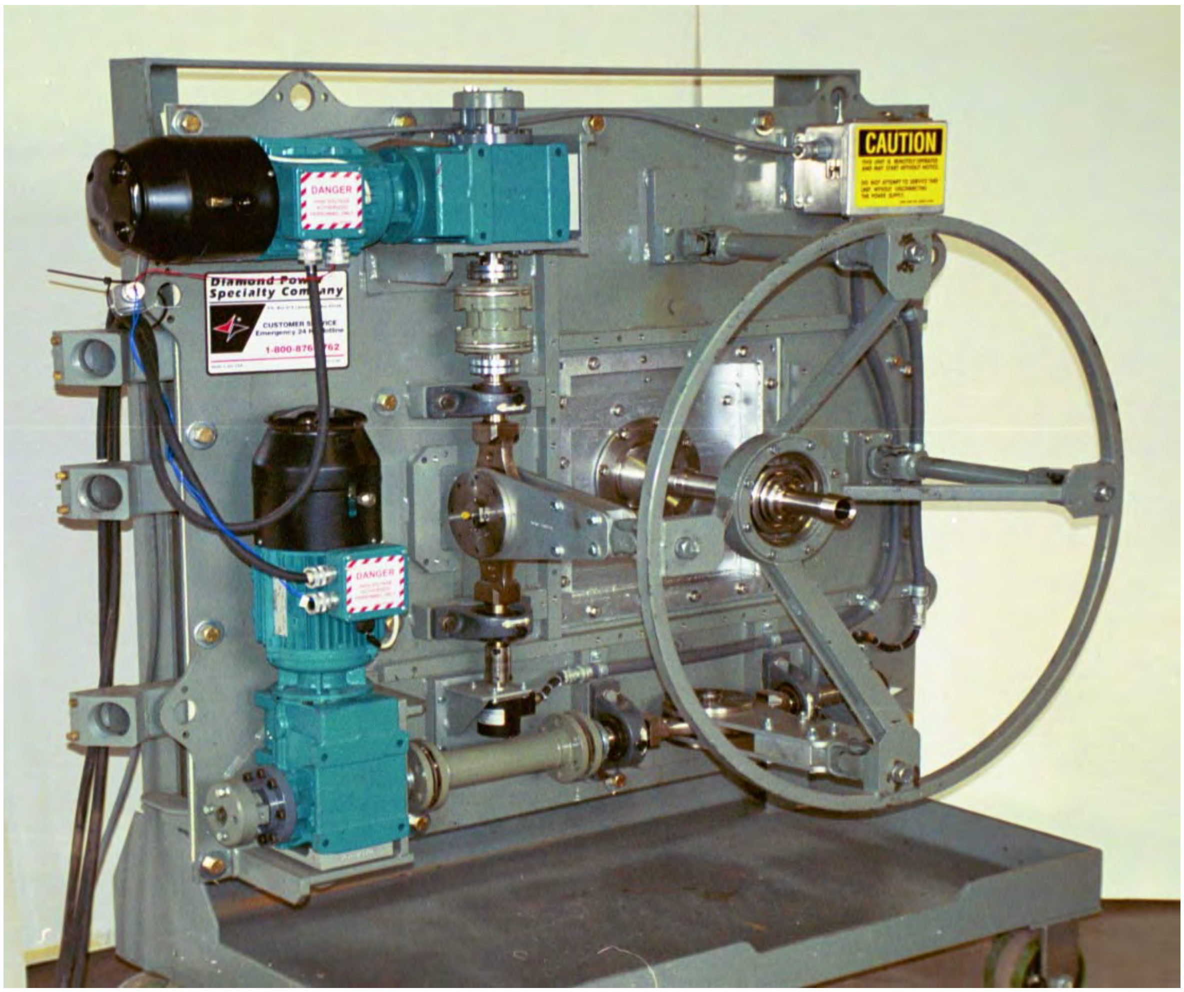

Figure B-2
HydroJet Furnace Cleaning Device

Note: The HydroJet cleaning device is protected under patent 6,655,397 and our Automatic Adaptive Module is protected under patent 6,325,025.

HydroJet Pattern Control Cabinet

The HydroJet Control Cabinet is a NEMA 12 enclosure which houses the two open-loop vector drives (latest generation for reliability and rapid response), an Allen Bradley ControlLogix PLC and the associated electrical hardware necessary to control all HydroJets, one at time. Thus, only one cabinet is required for up to six HydroJets on each unit. The control cabinet can be installed up to 1000 cable feet from the furthest HydroJet. This allows the electrical hardware, that is sensitive to heat and vibration, to be mounted in a remote location other than near the boiler. An environmentally controlled installation location is recommended.

There is a touch screen display unit for local pattern operation, calibration, alarm diagnostics, and nozzle “jogging” functions. This display unit comes in a small portable enclosure which can be attached at the control cabinet, or at the disconnect enclosure of any of the HydroJets.

Also included is a new computer for operator interface for all boiler cleaning management functions (HydroJet and ISB). The computer will have the following specifications:

- Desktop style PC located in control room (mini-tower)
- Windows XP operating system
- Dual hard drives
- Ethernet communications card
- Nineteen inch LCD desktop monitor, per specifications.
- 104 keyboard and mouse
- All operator interface screens will be developed and installed. Software is licensed to the end user per the attached agreement.
- Interface to DCS via Ethernet

Model HC1 Water Supply Station

Diamond Power has a family of water supply stations which can meet the wide range of flow rates that water cleaning equipment may require.

The Model HC1 WSS is a complete water supply station, which can boost a low pressure (45-100 psig), lower quality (non-condensate) water to the required pressure, while also providing required water supply instrumentation. All components are contained on two compact skids. The first skid contains the pump and direct drive motor set, sized to meet the pressure and flow requirements of the HydroJets while providing sufficient head to accommodate elevation and piping losses up to the cleaning devices.

The pump is a RotoJet Model 2200 S600 pump with 316 SST rotor and manifold. The pump speed is 3550 rpm, and the pump achieves a maximum flow of approximately 200 gpm at 650 psi of added head. The advantage of the pump design that we use is that its added head is very stable from the minimum flow of approximately 20 gpm to the maximum flow. A 125 hp motor is used, direct-coupled to the pump.

The second skid is a piping and control skid which is completely factory assembled at Diamond Power. The WSS is equipped with dual redundant basket strainers for particulate removal. Strainer maintenance can be performed with the WSS operational by isolating and cleaning one strainer at-a-time. Also, the WSS will be equipped with flow and pressure transducers. The control is ~ 6’ long x 5’ wide x 9’ tall.

Output pressure will be controlled via a PID in the HydroJet PLC which sets the control valve to the correct flow for the operating pattern. Flow set points will originate from the control system. Each discrete HydroJet pattern can have its own flow set point so that the correct flow is used for each area.

Furnace Cleaning Management System (FCMS) Components for Intelligent, Automatic Operation of the HydroJet System

The following sections describe the tools that are recommended for automatic HydroJet operation, thermal fatigue monitoring, and system self-tuning.

Furnace Cleanliness Module (FCM)

Diamond Power offers a well-proven Furnace Cleanliness Module as a key tool for optimizing furnace heat transfer performance. FCM is a key tool, which includes an appropriate complement of furnace heat flux sensors for each unit, and our FCM software. FCM has been installed at over 120 sites for the optimization of furnace cleaning devices and about 2000 ASI / DPII heat flux sensors are installed in the field in North America.

Furnace cleaning optimization is based on the direct measurement of furnace heat flux at spatially resolved locations within the furnace and HydroJet operation based on heat transfer need or demand. Since furnace slagging is generally not uniform, cleaning needs vary with location. By directly measuring the heat transfer at selected locations within the furnace, cleaning can be performed when and where needed.

The Furnace Cleanliness Module includes the heat flux sensors, the remote multiplexers, and FCM optimization software. All ASI heat flux sensors are ASME S Stamped devices.

Furnace sootblowing optimization is founded on the direct measurement of furnace heat flux at a number of locations within the furnace and sootblower operation directed based on heat transfer need or demand. Since furnace slagging is generally not uniform, cleaning needs vary with location. Without a direct measurement of cleaning need, some areas are over cleaned and some under cleaned. By directly measuring the heat transfer at selected locations within the furnace, sootblowers can be operated when and where needed.

Figure B-3 is a DPII operator display for a system that includes heat flux sensors and FCM software.

Figure B-3
DPII FCM Display Screen (Courtesy Diamond Power, Inc.)

Thermal Impact ModulE (TIME)

Thermal Impact ModulE™ (TIME), as defined in DPII's adaptive sootblowing-cleaning patent, provides real time monitoring and assessment of each water-cleaning cycle at each cleaning location. TIME is an extremely valuable tool to water cleaning users which captures all thermal transients at every heat flux sensor location and continually advises plant staff of the progression of thermal fatigue cracking.

During operation, TIME continuously monitors all locations where heat flux sensors are installed simultaneously. When a transient is detected, TIME captures the tube metal temperature transient and calculates the impact associated with the transient based on the corrected temperature difference and the tube construction.

When the impact has been determined, an immediate indication of the transient is provided to the operator in the form of a blinking icon on the interface screen. The transient is classified as low, medium or high impact. Locations experiencing higher than desired impact are immediately identified, via an operator interface alarm, so that adjustments to the cleaning system can be made.

With Automatic Adaptive Module (AAM) and HydroJets as part of the system configuration, changes are made automatically to parameters for each HydroJet area such as jet progression velocity (JPV) or water flow rate. For example, the installation of a larger diameter nozzle or unacceptably low JPV would result in larger than desired thermal impact. The TIME module would flag this occurrence before any significant furnace wall tube damage was experienced.

For further information, the operator can select the icon and review more detailed information about the transient such as the metal temperature transient, cumulative thermal fatigue impact for the zone or number of thermal cycles for that zone. Also, previous thermal transients at all zones can be reviewed. See Figure B-4.

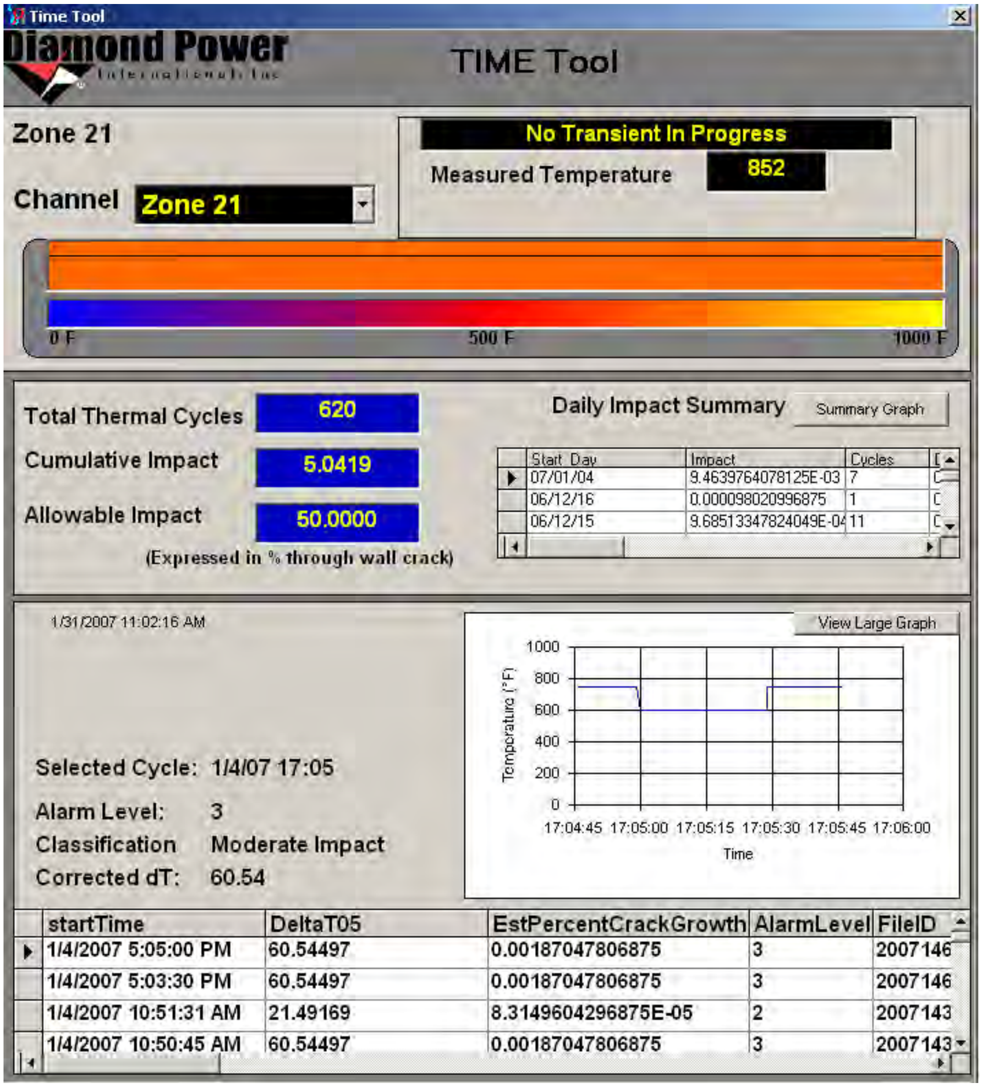

Figure B-4
DPII's Display of Thermal Transient Information

The metal temperature changes, the assessment of the cleaning cycle impact, and the number of cleaning cycles are used with a structural model to determine and compile the cumulative thermal fatigue impact. In addition to the real time information, the TIME Report program provides summary information on thermal impact, number of thermal cycles and predicted crack growth rate for user defined periods. This information is available graphically and as a spreadsheet for user defined reports. This information is extremely valuable for predicting the effects of furnace water cleaning on the boiler tubes.

Figure B-5 shows an example TIME report screen. In this example, a summary is captured for all zones over a 24 day period. The X-axis shows the number of thermal transients (green bar) for each zone, and the calculated thermal fatigue cracking (red bar) over the time period. The blue bar represents allowable cracking for the 24 day period. So, the long term goal of the HydroJet system is to sustain the red, actual cracking bar below the blue, allowable bar for all zones. The Plant Operations and Performance staff is quickly directed to zones that need to be investigated to reduce thermal fatigue impact.

The combination of the FCM and TIME ensures that water-cleaning operations are on dirty walls and with an acceptable level of thermal impact. The result is enhanced knowledge of water cleaning impact and extended useful life of furnace tubing.

With the installation of TIME and AAM, then AAM will also analyze cleaning effectiveness (from FCM) and thermal shock levels (from TIME). AAM will select the correct JPV and cleaning flow for each HydroJet area, which ensures that cleaning is effective *and* that thermal shock is controlled to an acceptable level.

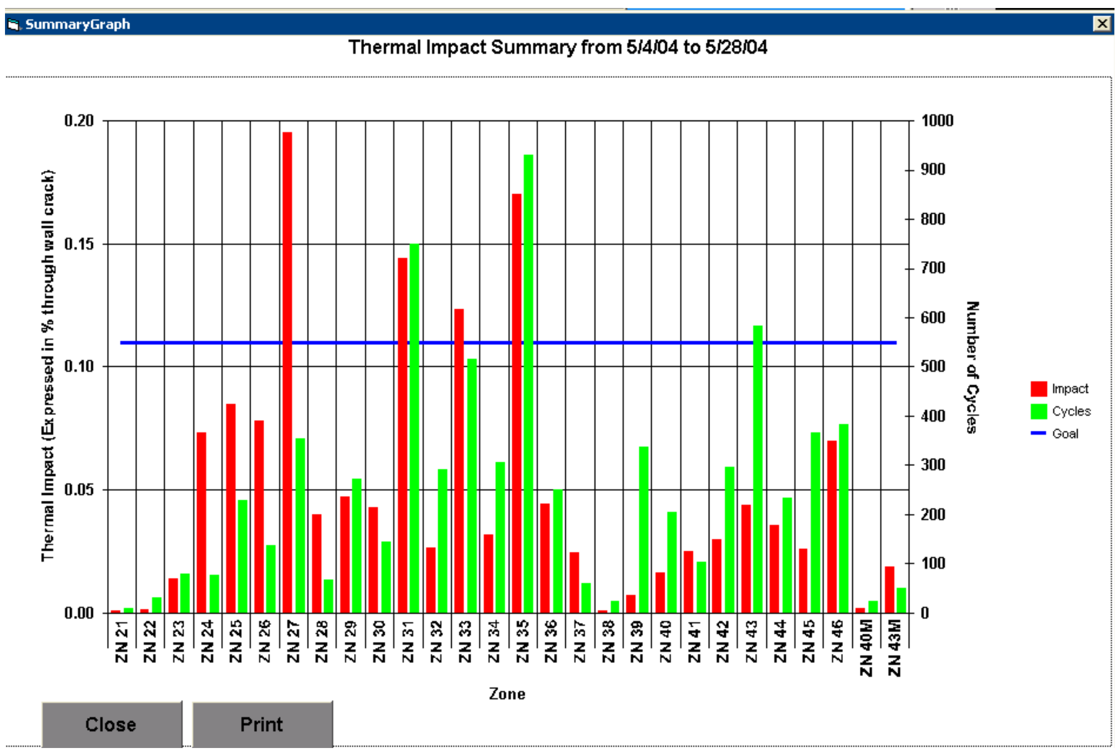

Figure B-5
Example of DPII's Thermal Impact Report Screen

Automatic Adaptive Module for Furnace Optimization

To maximize the performance benefit realized from the HydroJet cleaning option two inputs and one output are required. These are, respectively:

- determination of cleaning success,
- determination of thermal shock, and
- adjustments to the operating parameters of the cleaning device to sustain cleaning success and balance against tube damage.

The FCM will be used for determination of cleaning success and the Thermal Impact Module will be used to for the determination of thermal impact.

The AAM provides the third piece, or the output. This component automatically and continuously works with the cleaning device control system to select the HydroJet cleaning parameters to maximize the rate of successful and effective cleaning and to minimize the water usage and thermal impact damage with each cleaning cycle.

The AAM uses a deterministic algorithm to find an optimal set of cleaning device-operating parameters to achieve the required level of cleaning. Since the module is continuously searching for an optimum set of parameters, changes in fuel quality and seasonal load variations are recognized as changes in the rate of successful cleaning. This will lead to operating parameter adjustments to maintain the desired rate of successful cleaning.

The ability to change the cleaning device operating parameters on an automatic and continuous basis is critical. On-site and remote tune-ups using historical data are helpful but are random operating snapshots, which may not be representative of the current demands on the cleaning system.

The changes in operating parameters are bi-directional. For example, the module might increase water pressure during periods of sustained full load operation as cleaning effectiveness deteriorates and then decrease water pressure when obtaining clean surfaces is easier, such as, periods of lower loads and frequent load variations.

C

CLYDE BERGEMANN

Clyde Bergemann, Inc. (CBI) offers an array of technology for slag mitigation in coal fired power plants. Their system uses heat flux sensors installed in the furnace for direct measurement of heat flux to direct cleaning when and where needed. CBI supplies wall and long retract blowers as well as ATF devices for cleaning. Strain gage technology installed on the boiler support structure provides input to their ISB system to complement their convection modeling for determination of slag deposition. This summarizes the CBI product offerings from their website.

In addition to their ISB system, for furnace cleaning devices CBI provides wall blowers and water cannons (ATF). Super heat and reheat cleaning is provided by retractable sootblowers. Economizer cleaning is provided by retractable/partial retractable, rotary and rake sootblowers, as is provided for air heater cleaning with the added multimedia blowers. Selective Catalyst Reduction (SCR) cleaning is provided by SCR Rake sootblowers.

In addition to the heat flux sensors for direct measurement of water wall tube fouling, CBI offers strain gage technology to monitor and measure slag deposition buildup in the superheater headers that complement their convection pass thermodynamic modeling. The thermodynamic model uses coal combustion chemical reaction equation and CEMs data for solving for coal flow rate and boiler efficiency (loss method). Coal flow rate, excess air and boiler dimensions determine FEGT. Thermodynamic balance around individual steam generation sections of the boiler results in cleanliness factors being solved using combustion equation and heat transfer equations. Cleanliness factors are then used with gages (or without) to initiate sootblowing in the convection regions.

D
URS ISB

The URS&S ISB system provides model optimization, reporting, and a Web interface. The URS&S method of intelligent sootblowing – called the SentientSystem for ISB control – is based on algorithms developed by Synengco of Brisband, Australia. This approach allows the ISB system to be optimized for current conditions – in this case, where the boiler tubes are near the end of their life and need to be nursed along. The system is self-learning for parameters such as coal type, sootblower hardware, and boiler firing rates. It is expandable, allowing future changes to the boilers (e.g., tube metal types) to be integrated into the controls. In addition, this system allows for information to flow across the plants local area network or wide area network.

The system can accommodate objective function changes after the boiler is retubed. For example, the optimization objective could be changed from tube life expenditure minimization to thermal cycle performance improvement, with tube life expenditure balanced for optimized minimum total cost.

Another advantage of the URS&S system is its use of an open architecture in the PLC control logic, enabling plant personnel to customize the system without vendor assistance. (Systems that use proprietary software, such as the old sootblowing controls, make it difficult for plant personnel to make changes without factory assistance and the associated costs.)

The URS&S system approach is a flexible, engineered solution that uses all available plant instrumentation in implementing ISB. If water wall chordal thermocouples and/or heat flux sensors are available, they are used in conjunction with all other process system inputs. Operator interface is designed as required by the customer. For example, the operator workstation for TVA Bull Run (21) the operator workstation, located in the central control room, allows an operator to select the various modes of control. The highest level of control is ISB closed-loop automatic control. In this mode, the ISB PC continuously calculates which furnace areas require blowing, schedules blowing sequences, and initiates the sootblowing. The other three control modes are local manual, manual, and automatic (non-ISB). The ISB system incorporates safeguards, such as alarms for stuck sootblowers and low steam flow, to protect equipment from inadvertent damage.

The control room operators can view the ISB – calculating blowing sequence from their station. Selection of the particular embedded mode with the ISB is reserved for the plant engineer. (The sootblowing control system can also be operated independent of the ISB system and performs the same functions as the old system.)

To ensure operation in the even of a PC failure, and LCD control panel located at the rear of the unit control board provides operators with a backup for manual control.

In general, URS does not offer a specific product as does the other providers of ISB systems. The URS solution is an engineered solution, one that utilizes all available pertinent process parameters in the plant, and engineers the operator interface as required by the customer. The software used is the SentientSystem for ISB control, provided by Synengco of Brisbane, Australia.

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