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INTELLIGENT BOILER CLEANING CAN IMPROVE THE BOTTOM LINE

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Deregulation of electric generation has forced plant managers to think more like business people. "Dispatch or die" might be an appropriate slogan for the new paradigm. Maximizing a plant's revenue stream and profit is a challenging assignment because you have to produce more electricity at less cost than your competition and minimize, to the extent possible, the number of forced outages.

Every plant that generates electricity is your competitor. If you manage coal-fired resources in a region with significant hydro and/or nuclear generation, your job is particularly demanding. The production costs of nuclear and hydro plants may be inherently lower than for your units, placing them higher in the dispatch order. This means you have to strive to be "best in class" if you are to sell all the power your plant is capable of producing.

But you know all that. You and your staff have invested countless hours figuring out how to keep the turbine/generator, condenser, and feedwater heaters at peak efficiency; eliminating leaks to minimize makeup water; upgrading boiler heat traps; retrofitting more efficient burners and more responsive plant controls; tuning environmental controls; etc. And the headquarters staff has used its considerable negotiating skills to buy fuel at the lowest cost.

Is this enough to make you best in class or is there more you can do? In most cases, the answer is an unequivocal "yes, there is more you can do." Consider the boiler cleaning system. Most plant operators don't think of a sophisticated system here, but rather some sootblowers and brute force removal of deposits. There are many wall blowers and convection-pass retractables in the average coal-fired boiler. Sometimes water lances, water cannons, and sonic horns are found as well. Getting these devices to work in concert and remove deposits with the minimum amount of blowing medium is a challenge that often escapes the busy plant operator.

WRING MORE PROFIT FROM YOUR BOILER

The impact a state-of-the-art intelligent boiler cleaning system can have on your bottom line is astounding. For example, the real-world example presented in the sidebar for an 800 MW unit increased profit by one-third with an investment of only $1.2 million. It took only six weeks to recoup the full cost of the project. According to Dominick Garton, Director of Clyde Bergemann Inc.'s Systems & Solutions Div., Atlanta, "In almost all cases where a 300 MW or larger boiler is still operating with its original cleaning equipment and the as-designed fuel specs have changed, an investment of about $1 million will be returned within six months."

Second Generation Water Cannon installed at Southern Company's Miller Plant on an 800 MW B&W front/rear wall-fired unit burning Power River Basin coal.

Good ideas in the electric generation business usually germinate at the plant. To see if an intelligent boiler cleaning system is worth investigating for your plant, Charlie Breeding, a Senior Boiler Engineer at Clyde Bergemann, suggests asking yourself four questions:

- *Has your plant had a significant fuel change during its operating lifetime — for example, switching from bituminous to PRB (Powder River Basin) subbituminous coal?*
- *Has your boiler been retrofitted with low-NO_x burners?*
- *Does excessive slagging adversely impact operations—that is, do you reduce load a couple of times weekly, or more often, to dislodge accumulations?*
- *Is the flue gas temperature at the air heater outlet 50 F or more above design?*

If you have three or four yeses, your plant is a candidate for more detailed analysis. The time investment is minimal. In fact, if you can jot down on a sheet of paper the information necessary to run the calculation (see sidebar), Breeding can estimate within an hour the profit that can be recovered by more effective cleaning.

If the results are sufficiently attractive, the next step would be a plant visit and unit walkdown to verify the information used in the preliminary analysis, rerun the numbers if necessary, and select the optimum intelligent cleaning system for your particular situation.

NEW TECHNOLOGY

Accumulation of slag in the furnace and deposit buildup in the convection pass represent dynamic processes that sometimes escape notice until removal of this material becomes a big problem — one that dictates a reduction in load to sufficiently cool the interface between boiler tubes and the deposit to induce a slag fall or one that requires a unit shutdown to permit manual removal with jackhammers or dynamite.

The polar opposite of allowing slag to accumulate — which can incur operating penalties and possible damage to tubes during physical removal or from heavy slag falls — is clean-tube paranoia that leads to tube damage from over-blowing. Bear in mind that over-cleaning can be as costly, or even more costly, than under-cleaning.

Excessive deposits and over-cleaning are avoidable by retrofitting one or more smart solutions developed over the last several years and tested successfully under demanding operating conditions. For example, Clyde Bergemann's SmartClean series of solutions, which rely on advanced cleaning hardware, software, and process controls, include the following individual products: SmartCannons, the Furnace Fouling Monitor using SmartSensors, SmartControls, the Superheater Fouling Monitor using SmartGauges, and SmartConvection.

MAINTAINING A CLEAN FURNACE

A boiler is divided into three main areas with respect to slag and deposit formation — the furnace proper, the steam-generation section of the convection pass, and the back pass (economizer and air heater). An intelligent system cleans the furnace based on feedback from SmartSensors — specifically, heat-flux sensors and instruments designed to accurately measure furnace exit gas temperature. FEGT is an especially critical measurement because it is indicative of both furnace cleanliness and the potential for deposition in the convection pass (the higher the temperature the more likely deposits will form).

Heat-flux sensors, consisting of paired thermocouples installed in furnace waterwall tubes, are the preferred method for pinpointing slag buildup. They offer

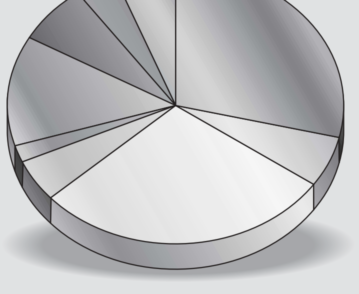
Pegging the Profit

It is relatively easy to compute the return on investment you can expect from modernizing a boiler cleaning system. The first step is to gather design and operating data and some business-related information:

- *Unit capacity and heat rate.*
- *Boiler manufacturer and boiler type.*
- *Furnace geometry and design data (dimensions, waterwall heating surface, etc.).*
- *Annual power sales and revenue.*
- *Flow rates for steam, feedwater, and desuperheater spray.*
- *Arrangement of boiler cleaning system, media (air, steam, and/or water) consumption and cost.*
- *Coal type, heating value, cost, consumption.*
- *Flue-gas temperatures at furnace outlet, air heater and economizer inlets and outlets.*
- *NO_x flow rate entering/leaving SCR or SNCR, reagent cost, length of ozone season, value of NO_x credits, NO_x emissions restrictions (if any).*
- *Operating costs—total, variable, fixed, boiler cleaning.*
- *Boiler modifications planned—for example, fuel switch, burner replacement, scrubber retrofit, etc.*
- *Financial impacts of poor boiler cleaning—for example, load shedding duration and frequency, forced outages and deratings caused by slagging/fouling, wear and tear on heat-transfer surfaces attributed to excessive sootblowing.*

Step 2 is to enter the information into Bergemann's Boiler Cleaning Evaluation Program and quantify the savings.

FIGURE 1
INTELLIGENT CLEANING RECOUPS $9.7 MILLION IN LOST PROFIT



Example: Calculate the potential profit gain from upgrading OEM-supplied sootblowers on an 800 MW, 25-year-old tangentially fired boiler to a state-of-the-art intelligent boiler cleaning system. The unit burns a nominal 90/10 blend of PRB and bituminous coal that averages 9000 Btu/lb and has the potential to dispatch 97% of the rated power output at $25/MWh.

The plant is operating significantly below its potential, in part because of an outdated boiler cleaning system. Air at 200 psig is the cleaning medium at this 34%-efficient facility located in a region where the ozone season extends for 3650 hr/yr and NO_x credits are worth an average of $4500/ton. Flue gas temperatures at the furnace exit and air heater outlet are 2600 F and 375 F, respectively.

The Bergemann program calculates that the potential annual profit from this plant is slightly more than $47 million, but it is netting only $29 million, in round numbers, because of various operating and regulatory constraints. However, more than half of the profit shortfall—$9.7 million—is recoverable by upgrading the boiler cleaning system (Figure 1). Here is how the savings break down on an annual basis:

Increase in profits attributed to NO_x compliance, $3.4 million. Better furnace heat transfer reduces NO_x formation, making available credits for sale (projected revenue of $2.8 million) and reducing SCR O&M costs ($0.6 million saving).

Increase in profits attributed to operation at higher efficiency, $3.4 million. A cleaner furnace means greater radiant heat absorption and a reduction in furnace exit gas temperature of 100 F ($2.8 million bottom-line impact), less attemperator flow ($0.5 million saving that includes the reduced cost of water treatment), and reduced consumption of the compressed-air blowing medium ($0.2 million saving).

Increase in profits attributed to an increase in operating hours at higher output, $3.0 million. The largest component of saving in this category is a reduction in unit derating caused by excessive slagging of the furnace and fouling of the convection section ($1.3 million). Reducing intermittent load shedding employed to remove slag by "chilling" contributes $0.4 million to the bottom line; reducing the number of outages to dislodge stubborn slag with jackhammers, high-pressure water sprays, or dynamite saves $0.7 million; and reducing the number of outages to repair or replace tubes damaged by over-cleaning boosts profits by another $0.6 million.

Bottom line — For the plant described, it is realistic to assume an increase in annual profits of about one-third with an investment of about $1.2 million for upgrading the as-supplied boiler cleaning system to a state-of-the-art intelligent system. This translates to a payback period of roughly a month and a half.

What this dramatic saving illustrates is that even if the plant manager were off-base on some data, the payback period probably would not have stretched beyond three months. And even if an SCR were not installed for NO_x control, or the value of NO_x credits were to drop dramatically, the payback period would not extend beyond six months.

direct measurement of heat flux and are able to quantify the thermal impact of the cleaning event on the waterwalls, says Clyde Bergemann's Sandeep Shah.

Having the instrumentation to guide the operation of furnace cleaning devices is only part of the solution. You must also select the proper blowers for the job at hand. A recent development to consider — one that has proven itself in commercial operation — is the SmartCannon. Its advantage over other types of water blowers is that the spray head, which moves left/right and up/down as directed by the control system, patrols a large area of waterwall surface. Plus, it interactively changes water pressure and cleaning speed to ensure that boiler performance goals are achieved, but not at the expense of waterwall damage.

SmartCannon was first tested in 2002 at Alabama Power Co.'s Miller Steam Plant, which had experienced quench cracking of waterwall tubes because of simple sequential operation of conventional water lances. The lances had been retrofitted, according to John Sorge of The Southern Company (Alabama Power's parent), Atlanta, after a switch to PRB coal in the mid 1990s. The SmartCannon demonstration project was partially financed by the Electric Power Research Institute (EPRI), Palo Alto, Calif., which provided extensive analytical and technical support. The utility's goal was to reduce the rate of tube failures without sacrificing the performance benefits gained from using water as a cleaning medium.

SmartGauges installed on hanger rods at TVA's Cumberland Plant as part of an EPRI project.

Data presented by Sorge and several colleagues at the EPRI Heat Rate Improvement Conference in 2003 revealed that the SmartCannon dramatically reduced the number of quench cycles of more than 100 F compared to conventional water lances, thereby extending waterwall life. Other advantages the SmartCannon offered over water lances included an increase in furnace heat absorption, lower average FEGT, a 10% reduction in NO_x emissions, and improved distribution of heat absorption in the furnace. Evenly distributed heat absorption is particularly important because it creates a more balanced temperature profile for flue gas entering the convection pass. Fewer "hot spots" reduce the potential for fouling those heat-transfer surfaces.

Experience at Unit 2 of Ohio Power Co.'s Gavin Generating Station in early 2003 confirmed the Miller results. Ohio Power is a subsidiary of American Electric Power Co., Columbus. This eastern bituminous fueled boiler was troubled by high FEGT, which contributed to excessive NO_x production, fouling problems, and poor SCR performance.

Gavin installed a SmartClean system consisting of four SmartCannons and 24 SmartSensors to solve the problem. According to Randy Sheidler, a senior coordinator at Gavin, in a presentation at POWER-GEN International 2003, the installation produced the following results while operating in automatic mode: (1) An increase in average furnace heat absorption from 56,700 to 66,500 Btu/hr-ft^2, (2) A sustainable reduction in FEGT of 112 F, (3) NO_x reductions of 5-8%, and (4) A one-third reduction in reheat attemperation spray flow (equivalent to a 17 Btu/kWh improvement in unit heat rate).

Tube quenching — so-called thermal impact — was held below the 100 F limit suggested by EPRI and other industry sources to assure acceptable waterwall life. See "Boiler Maintenance and Upgrades," in the February 2004 issue of *Power Engineering* for greater detail on the Gavin experience.

Convection Pass

There are two methods for measuring the buildup of noncombustible deposits in the convection pass. The most widely used technique is a thermodynamic model that predicts steam production rates for the superheater and reheater. Shah says this method requires that a theoretical level of performance be calculated for a clean section of the boiler and used as a baseline. Breeding adds that the actual performance level is then calculated based on measured temperatures and flow rates and compared to the baseline to gauge the extent of deposit buildup. The problem with this approach, according to the two boiler experts, is that you really don't know the amount of deposit buildup or exactly where it is located. Thus, it is virtually impossible to program a boiler cleaning system for maximum effectiveness and efficiency.

A better way to determine the extent of fouling in the convection pass is to use strain gauges to directly measure deposit accumulations on pendant sections. The gauges are mounted on the hanger rods used to suspend boiler components from building steel.

Strain gauges quantify the buildup and pinpoint its location — information that is particularly valuable for identifying the specific sootblowers to use for deposit removal. Likewise, strain gauges are used to monitor sootblower effectiveness.

Recognize that ash deposits are rarely uniform. Local temperatures (read hot spots), air/fuel ratio, performance of individual burners and pulverizers, flue-gas flow patterns, and other variables all impact the physical characteristics of deposits and their location.

Strain gauge technology has a wide array of uses in all process industries. International Paper Co., Stamford, Conn., developed and patented a method of using strain gauges to measure the load on the rods that suspend heat-transfer surfaces for use in its recovery boilers. Clyde Bergemann is the exclusive licensee of that technology for electric power industry.

The first use of what Bergemann calls its SmartGauge system to measure deposit accumulations in coal-fired boilers was on Unit 4 at Georgia Power Co.'s Plant Bowen.

A reheater pendant was selected for the trial because it is located just above the nose arch and is a known location for slag formation. Both wired and wireless strain gauges were installed. A multiplexer receives data from the strain gauges and transmits that information via an Ethernet cable to a personal computer in the control room equipped with input processing and operator-interface software.

Results of that trial, as reported by Georgia Power's Chris Bentley at the 2003 International Joint Power Generation Conference, confirmed that there is excellent correlation between sootblower operation and the reduction in weight measured by the strain gauges. Without blowing, the weight on the gauges slowly increased until another blowing event was initiated. Another conclusion of the work was that automatic control of boiler cleaning activities is viable based on direct measurement of deposits. Further, the ability to monitor deposits continuously affords plant operators the opportunity to study the impact of process variables — such as fuel/air ratio, FEGT, etc. — on convection-section fouling.

Later work at Unit 1 of the Tennessee Valley Authority's Cumberland Fossil Plant, co-sponsored by TVA and EPRI, was initiated in an attempt to prevent the buildup of large deposits in pendant sections and the resulting slag falls that had caused million-dollar outages to repair damage to the lower slopes. TVA's Ben Zimmerman and EPRI's Rabon Johnson concluded in their 2004 ASME Power paper that strain gauge technology "holds promise for optimizing early slag deposition detection at Cumberland." Additionally, "the deposit data gathered offer the potential for use in closed-loop control of sootblowers."

The second phase of the TVA project involves installing strain gauges on other sections of the Unit 1 convection pass, thereby allowing operators to monitor most of the boiler's retractable sootblowers for effectiveness. Development of a thermodynamic model to limit sootblower operation in the automatic mode is also part of the work scope.

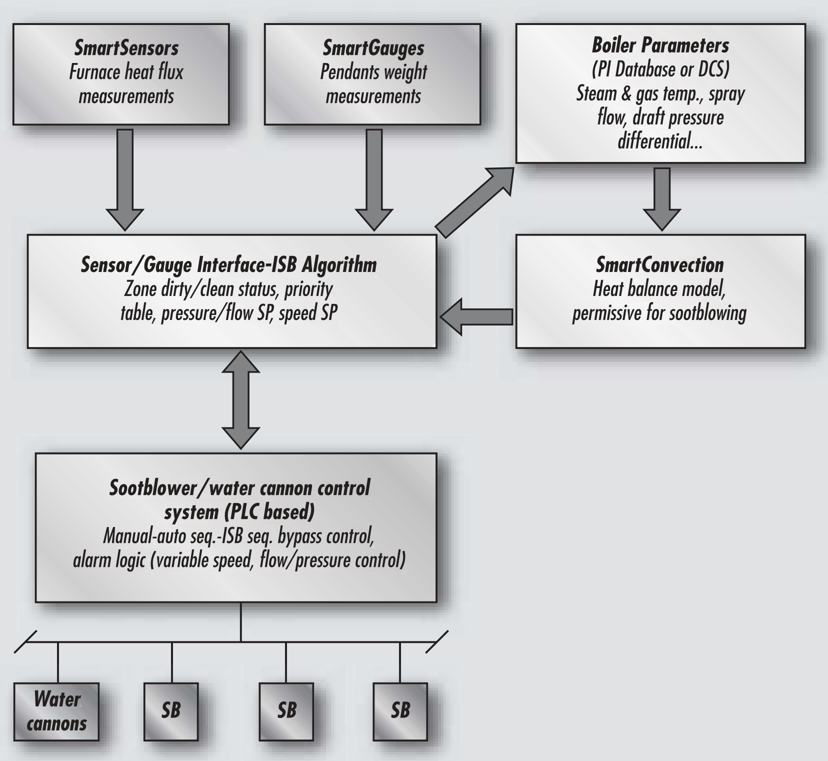
SYSTEM CONTROL

Figure 2 illustrates how various elements of the intelligent sootblowing system are arranged. The SmartSensors/SmartGauges interface provides algorithms that determine the cleanliness states of various boiler components. This interface derives priority tables that identify which sootblowers are most effective and which should be operated to achieve desired steam conditions.

For the furnace, the interface calculates SmartCannon traverse speed and water pressure from information supplied by heat-flux sensors, strain gauges in the pendant sections, and the thermodynamic model. In addition, the interface monitors plant operational variables such as unit load, steam temperature, spray flows, draft pressure, etc. The output of the intelligent sootblowing algorithm logic block are instructions that guide the operation of cleaning equipment — water cannons, retractable sootblowers, air-heater and economizer blowers, etc.

Finally, keep in mind that all this sophisticated hardware and software require human input to achieve plant-specific goals. For example, is the plant's goal best heat rate or maximum power generation? The goal will impact FEGT, steam production, attemperator spray flow, unit load, and air heater exit gas temperature, and, therefore, the amount of slagging and fouling that is permissible on heat-transfer surfaces. PE

FIGURE 2
TYPICAL SYSTEM ARCHITECTURE FOR INTELLIGENT SOOTBLOWING



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