Fuel Tech's Comprehensive Fireside Slag & Fouling Programs for Power Plants Firing Western Coals

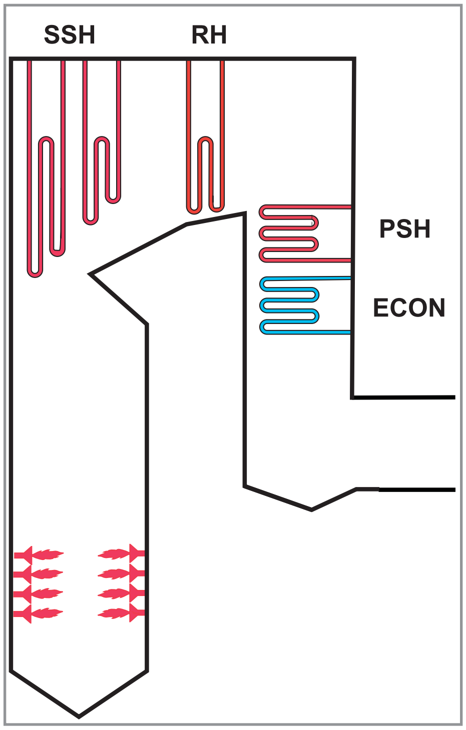
Introduction
Roughly 70% of the electric power used in the United States is produced in steam plants firing fossil fuels. Coal accounts for about 80% of this fossil-generated power, with gas and oil making up the remainder. Of these three types of fuel, coal is by far the most difficult and complicated to burn. It is also the most abundant fuel in the U.S. (and the world), and so will remain a common source of energy for many decades to come.

Utility boilers firing coal must contend with unloading, storage, size reduction, ash handling and emission control. The economics of mining and transportation, coupled with increasing environmental demands, has resulted in a dramatic increase in the use of western U.S. sub-bituminous coals. These coals place increased demands upon every aspect of their being used for power generation, but nowhere more than in regard to ash handling. These low rank coals may have 60% the heat value of eastern coals, and so must be burned at higher rates to generate similar power. The disposition of all the coal ash generated is crucial to safe, efficient and reliable operation of any coal-fired plant.

Coal Ash Chemistry
Mineral matter is always present in coal, and varies over a wide range in both quantity and composition. This incombustible material forms ash when the coal is burned, and is broadly classified as either bituminous ash or lignitic ash. Bituminous ash is characteristic of higher rank coals from the Eastern United States, and is defined as having more Fe_2O_3 than the sum of CaO and MgO. Lignitic ash typifies the Western, lower rank coals, and has less Fe_2O_3 than the sum of CaO and MgO. The relative proportions of all the constituents of a given coal ash have a marked effect on the ash fusibility, as defined by a complex eutectic chemistry. The temperature at which a coal ash melts, and its viscosity at a given temperature, have a profound effect on the design of a particular furnace. Knowing this, a furnace can be designed to accommodate nearly any coal commercially mined today. Problems arise when a new coal source must be accommodated, or even when a subtle change within a single seam of coal occurs.

Unit Description
A Fuel Tech client in a western state owns an electrical generating plant consisting of three units, each firing pulverized coal and each producing $3.3x10^6$ lbs/hr of steam at 1,005°F and 2,500 psig. At a burn rate of about 450 $x10^6$ lbs/hr, these units use four different coals, each producing strongly lignitic ash. The actual percentage of each coal burned at a particular time is achieved through a series of coal yard management techniques, to the extent that segregation and subsequent recovery allow. One coal is known to be a particular problem in regard to its fly ash fouling tendencies, but contractual obligations require its use nonetheless.

Figure 1 - Boiler Schematic



Regardless of current coal blend, the resultant coal ash tends to cause fouling and slagging of these units' Reheat, Finishing Vertical Superheat, Division Pendants and Primary Superheat sections (see Figure 1). These deposits cause flow restrictions and efficiency losses, which are marginally controlled by increased soot blowing and thermal shocking achieved by severe load swings. Ultimately, a premature outage is taken, to allow manual cleaning of the affected heat transfer surfaces. With a particularly poor blend of coals, a maximum unit run may be as short as a week, before diminished thermal efficiency favors a shut-down over continuing operation. This in the face of $500,000 to $1,000,000/day in lost revenue, added to the actual cost of physically cleaning the boiler.

Fuel Chem® Program Description

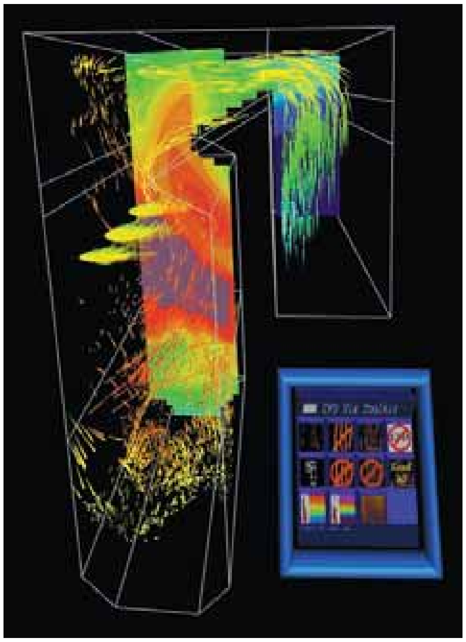
Fuel Tech Inc. can reduce or eliminate fireside slagging, fouling, corrosion and erosion problems with its comprehensive Fuel Chem® treatment programs. Utilizing both bench-top and computer laboratory facilities, and drawing upon years of fireside experience, Fuel Chem® programs include:

- Problem Analysis
- Computational Fluid Dynamics (CFD) Modeling
- Virtual Reality Visualization
- Process Design
- Customized Equipment
- Application Specific Reagent
- Project Engineering
- On-Going Service to Document and Insure Long-term Performance

Targeted In-Furnace Injection

Conventional fuel treatment programs attempt to reduce slagging and fouling by altering the bulk chemistry of the coal ash. To this end, liquid or dry chemical is added to the fuel, or blown into the combustion area of the furnace. This approach requires very large quantities of chemical in order to try and alter the eutectic chemistry of the coal ash in a positive way. Aside from being economically unfavorable, this approach is generally only marginally effective, as the majority of the applied chemical is either lost to bottom ash or rendered inert by passage through the combustion zone of the furnace. In addition, bulk treatment of a solid material like coal, subject to subsequent conveyance, crushing, pulverization and suspension firing, is an inexact science. In practice, chemical treatment is often sporadic and incomplete. The resultant hit and miss deposition of adherent fly ash is non-recoverable, and the program fails.

__Figure 2__
__Computational Fluid Dynamics__



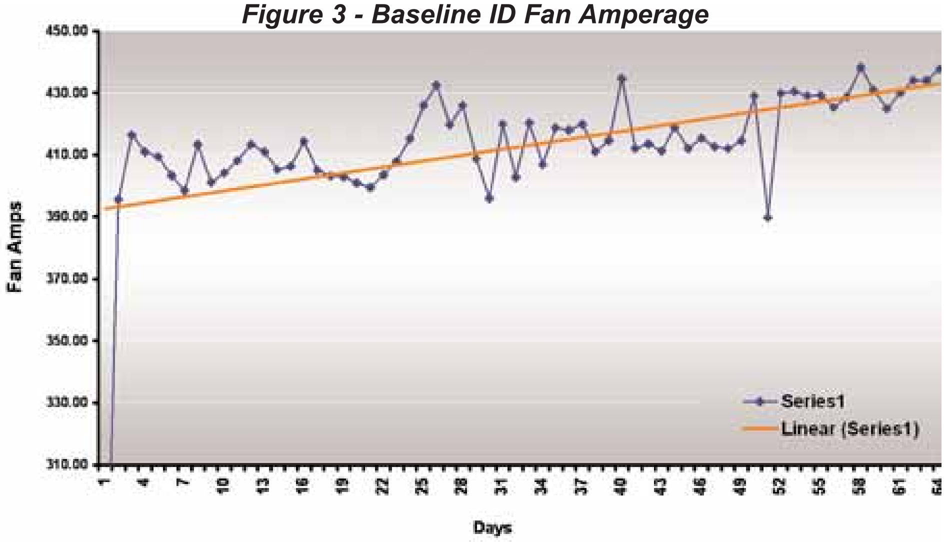
On the other hand, Fuel Chem® "Targeted In-Furnace Injection" Programs are driven by Computational Fluid Dynamics computer models. This unique, patented (#5,740,745 & #5,894,806) approach allows for the precise placement of a liquid chemical directly into the furnace gases, using flow dynamics to target and reach the problem areas (see Figure 2). Fuel Tech Inc.'s Fuel Chem® programs allow for full utilization of applied chemical, while maintaining maximal chemical activity. The result is excellent program performance and economics that yield a favorable return on investment (ROI).

After gaining a thorough understanding of the customer's fireside problems and goals, the Fuel Tech® team begins the problem analysis phase. Unit design and operational data are collected for the CFD computer model inputs. These data, combined with unit mapping information, enables the model to develop precise injection locations and reagent injection characteristics. This is then presented to the customer as a Virtual Reality Visualization, and the Fuel Chem® team uses this information to develop the process design, equipment specifications and layout, reagent demand, and expected program performance. With this information, resultant ROI is estimated, and the next step is a commercial demonstration.

Program Demonstration

For one of the two units described on the first page, a severe test of product efficacy was devised. After modeling the unit under moderate and full load conditions, a custom chemical application system was designed, built and installed. It was decided that a 60-day trial would be sufficient to prove program efficiency

__Figure 3 - Baseline ID Fan Amperage__



and economics. Burning an "average" blend of the four available coals was certain to cause measurable fouling and slagging during regular operation. As a final "worse case scenario" demonstration, the last four days of the trial would be on a burn consisting of 100% of only the most problematic coal. In the past, when forced to burn this unblended problem coal, the unit had always become irreversibly fouled in just a matter of hours. Four days would prove a most difficult challenge.

To establish a baseline for comparison, operating data and written reports of visual inspection for a 60-day period prior to the start-up of the demonstration trial were compiled. Plant personnel considered this two-month period to be an average to good run, not forcing an unscheduled outage. Interviews with Operators, and review of shift log sheets, showed that, starting with a clean furnace, there was a steady but tolerable accumulation of slag on the aforementioned superheat and reheat tubes. At first regular, and then accelerated, soot blowing proved to be only marginally effective in removing accumulations. The deposits on the Reheat, Finishing Vertical Superheat, Division Pendants and Primary Superheat sections of the furnace were described as "like taffy". The soot blowing could remove some of the slag, but actually spread the remainder around the tubes. In time, the deposits grew, but bridged tubes in only isolated spots. Still, the effect on unit performance was pronounced, and easily documented by increased fan amperage, exit gas temperature and delta P across superheater banks. The effect on ID Fan amperage is shown in Figure 3. The blue diamonds and line represent the actual recorded data, while the orange line is a linear regression of all the data. An average upward slope of roughly 4.43 amps/week of operation is established. Similarly, the change in flue gas pressure across the secondary superheater is shown in Figure 4. Linear regression establishes a weekly average increase in superheater delta P of 0.0163 in. WC.

Figure 4 - Baseline SH Pressure Loss

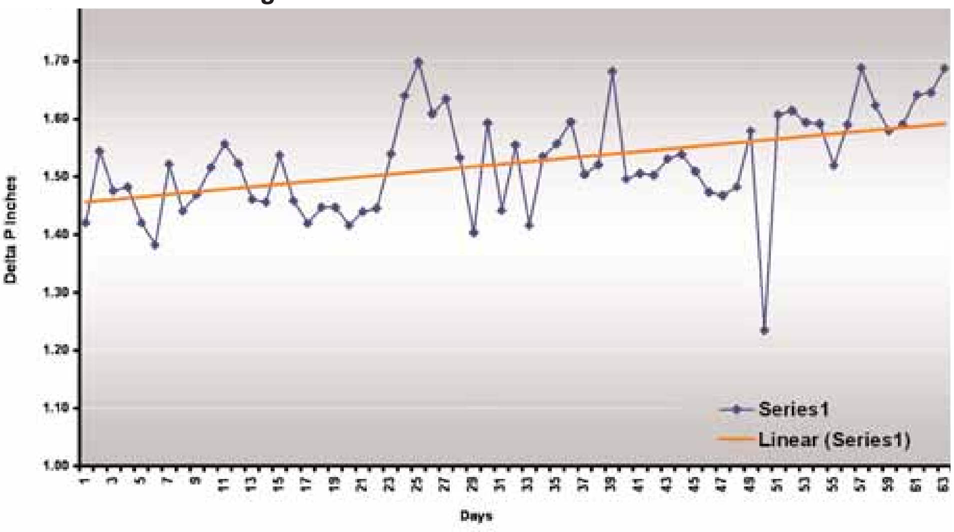


Figure 5 -Treated ID Fan Amperage

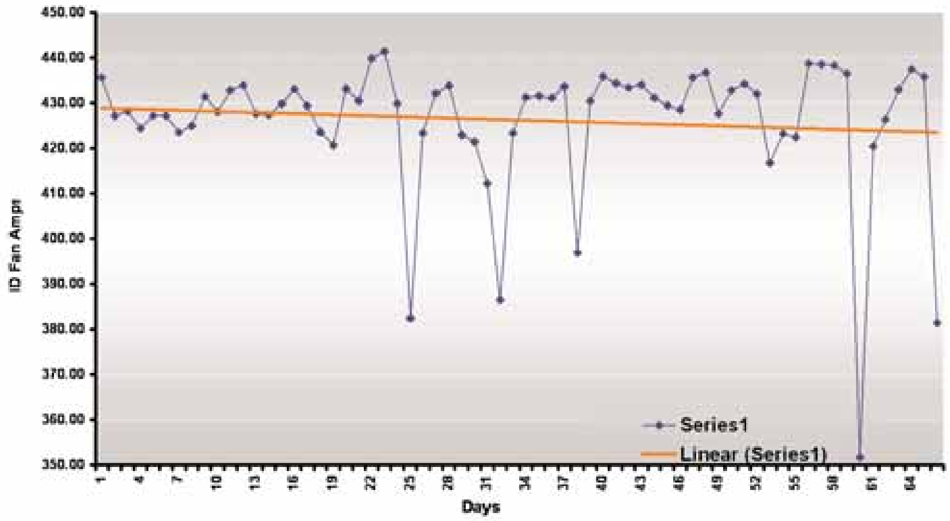
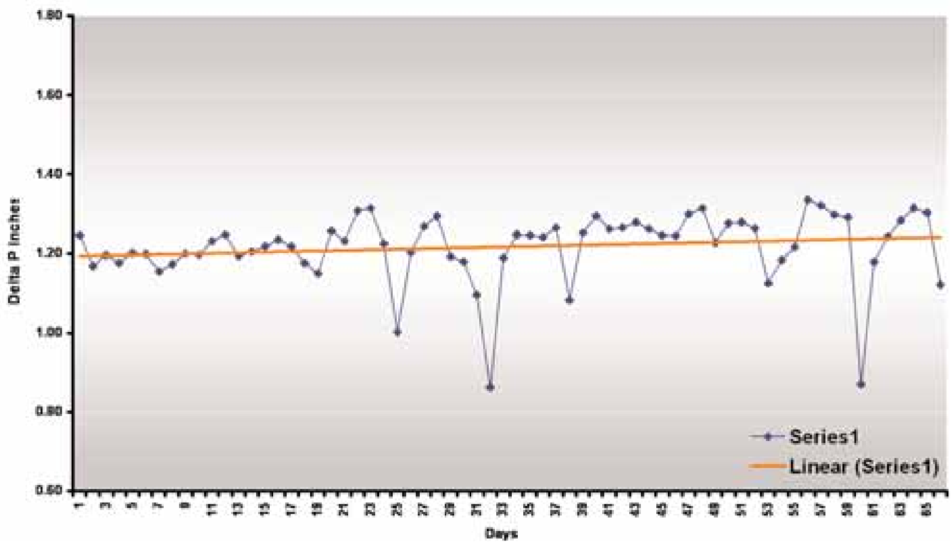


Figure 6 - Treated SH Pressure Loss



Prior to the start of the 60-day program demonstration, the unit was mechanically cleaned to restore it to a "clean" condition, as at the start of the baseline period described above. The coal yard was instructed to provide one of two "normal" blends of coal, and the unit was then fired and ramped up to full load. A normal soot blowing routine was employed.

Unit Operators found that, where visible, all the troublesome superheat and reheat tubes described earlier stayed clean with normal soot blowing. Encouraged by this observation, 30 days into the trial the soot blowing schedule was reduced by 50%. This abbreviated routine proved adequate to maintain tube cleanliness for the remainder of the 60-day demonstration. Whatever sintered ash deposited upon the tubes was easily removed through this reduced cycling of soot blowers.

In keeping with the protocol established at the onset, four days before the scheduled completion of the demonstration, the coal yard began to send up 100% of the station's most troublesome coal. In the past, when forced to burn this coal unblended with higher fusion point coals, markedly higher ash deposition rates on the superheat and reheat tubes were observed within several hours. These deposits were invariably "like taffy", and could not be completely removed, even with accelerated soot blowing. During this demonstration trial, as soon as the poor quality coal hit the burners, a huge increase in the deposition rate on target tube surfaces was observed. Unlike during previous episodes, however, the deposits remained sintered, not fused, and were easily and completely removed by soot blowing. There was no measurable increase in exit gas temperature or fan amperage. Figure 5 shows the actual ID Fan Amperage during the program demonstration. Again, a linear regression was performed, and it shows no increase at all during the 60-day trial.

Likewise, Figure 6 plots change in flue gas pressure across the secondary superheater, and linear regression shows an average weekly increase in delta P of only 0.0047 in. W.C. This is a 71.4% decrease, when compared to baseline conditions. This is all the more remarkable when one considers that the baseline period did not include four days of 100% problem coal. The data are summarized in Table 1.

The data presented below are reinforced by exit gas temperatures, fan suction on an absolute basis, efficiency calculations and personal testimony from the Unit Operators. By any measure, more Btu's from the combusted coal are finding their way into superheated steam, instead of being lost out of the stack. Just as important, the efficacy of the applied Fuel Chem® Treatment Program allows the unit to maintain full load, because the cleaner tube passages do not cause ID Fan limitation. The net results are increased availability, capacity and efficiency. Aside from these gains, the station can now, with confidence, burn a higher percentage of the poorest grade (and lowest cost) coal available to them. The savings versus cost for this client (Return On Investment) is several fold.

Other Fuel Tech Inc. Programs

Fuel Tech Inc. also offers FUEL CHEM® programs to reduce the effects of slag and corrosion on black liquor recovery boilers and municipal waste combustors, as well as programs for biomass and hazardous waste units. Other programs include plume abatement, NOx, SOx, and HCl stack emissions reduction, and a host of other preflame and fireside problem prevention programs.

Table 1 - Program Demonstration Data Summary

	Average Daily Unit Load (MW)	Starting ID Fan (amps)	Finishing ID Fan (amps)	ID Fan Increase (amps)	Starting Superheater Δp (in. W.C.)	Finishing Superheater Δp (in. W.C.)	Superheater Draft Loss (in. W.C.)
Untreated	427	394	432	38.00	1.45	1.59	0.1400
Fuel Chem Program	457	429	425	- 4.00	1.20	1.24	0.0400
Percent Reduction	N/A	N/A	N/A	**100**	N/A	N/A	**71.4**

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