ABSTRACT

This project was to design, install and test coal chemical additive treatments to low ash fusion temperature coal. The coal additive is injected into the combustion zone using targeted furnace injection nozzles whose placement is determined by computational fluid dynamic modeling. The use of high slagging and fouling index Illinois coal at Abbott Power Plant prevents operating the boilers at rated capacity. The project has demonstrated that the chemical softens the furnace slag and greatly reduces the effort of the operation staff to manage furnace slag. There is no evidence that the generating bank fouling has been ameliorated by the chemical. Although it seems there is some slight improvement in furnace heat transfer, the boiler has not operated at higher capacity with the chemical. Other changes in plant operations may be masking total capacity improvement. However, the operational improvement has reduced the amount of effort to manually deslag the furnace. Additionally, the plant avoided deslagging outages during the test program. These positive operational and economic effects of the additive have convinced the plant staff to continue operation of the system. The plant is able to burn Illinois coal with less furnace slagging.
EXECUTIVE SUMMARY

This project is to install and test coal chemical additive treatments to low ash fusion temperature coal. The current low sulfur coal has a very high slagging and fouling index. The coal boilers only run 4 to 6 weeks before requiring a shutdown for 48-72 hours to remove the fouling in the boiler and slagging in the furnace. Coal additives have been successful with slagging coals in large utility boilers. This project designed and procured a system for two coal stoker boilers. The project has demonstrated that the chemical softens the furnace slag and greatly reduces the effort of the operation staff to manage furnace slag. There is no evidence that the generating bank fouling has been ameliorated by the chemical. Although it seems there is some slight improvement in furnace heat transfer, the boiler has not operated at higher capacity with the chemical. Other changes in plant operations may be masking total capacity improvement. However, the operational improvement has reduced the amount of effort to manually deslag the furnace. Additionally the plant avoided deslagging outages during the test program. These positive operational and economic effects of the additive have convinced the plant staff to continue operation of the system. The plant is able to burn Illinois coal with less furnace slagging.
OBJECTIVES

This project was to design, install and test coal chemical additive treatments to low ash fusion temperature Illinois coal. The project was to select and install a complete coal treatment additive system without adversely affecting plant operations. The high slagging and fouling Illinois coal effectively derates the coal boilers at Abbott Power Plant. The project was to test a full implementation of coal additive technology to increase the production rate of the coal boilers thereby reducing the need to burn natural gas to meet the campus steam load. The current low sulfur coal has a very high slagging and fouling index. The project was on a compressed time schedule to specify, procure and install the system. The University provided engineering, procurement, construction management and operational labor to implement the project. The project provided funds to award a construction contract to install the technology and provide at least part of the first 6 months of fuel additive.

INTRODUCTION AND BACKGROUND

This project is to install and test coal chemical additive treatments to low ash fusion temperature coal. The coal boilers only run 4 to 6 weeks before requiring a shutdown for 48-72 hours to remove the fouling in the boiler and slagging in the furnace. Additionally, the coal boilers cannot run at rated load without exceeding a thermal design limit of the coal boiler. If the boiler is run at excessive temperatures the pollution control equipment performance degrades.

In March 2004 Abbott Power Plant conducted a test run of 1000 tons of coal on Boiler 7 (200,000 pound per hour steam, Spreader Stoker Boiler) with low slagging and fouling coal from Indiana. As there had been severe slagging problems and the associated heat transfer degradation on boiler 7, the test burn was done to see what improvement in performance could be achieved by switching coals. The boiler was shutdown to clean the furnace from slag. However, all of the other heat transfer surfaces in the generating bank, superheater and economizer were left dirty from the coal burned that winter.
The Illinois coal normally burned (Coal A) during the winter required the plant staff to increase soot blowing to 3 times a shift to avoid excessive temperatures to the electrostatic precipitator (ESP) which degrades ESP collection performance. When the ESP performance is degraded the boiler load had to be reduced to stay below opacity limits. The Indiana coal (Coal B) with much lower slagging and fouling indices was burned for a test burn to see if the combustion performance could be improved.

The lower slagging and fouling coal (Coal B) greatly improved the performance of Boiler 7. The major effect was improving the heat transfer and thermal efficiency of Boiler 7. Even though the generating tube bank and the economizer tube bank were left “dirty”, the flue gas temperatures dramatically dropped indicating about a 2% combustion efficiency improvement. Additionally, there seemed to be less carbon loss in the ash. Measuring coal consumption over a similar 5-day period, the Indiana coal (Coal B) generated more steam per pound of fuel than the Illinois coal (Coal A) equating to a 5% fuel usage improvement.

The change in coal also allowed the boiler generating tube bank to operate back at its design limit at full load. The design basis for the boiler is that the boiler outlet temperature should stay below 681 deg F at full load. Coal A would cause the boiler to exceed that temperature limit even at 55-60% load. In contrast, Coal B allowed the boiler to stay below the design limit at all loads.
Figure 2. Boiler 7 Outlet Temperatures.

Pollution control performance improved with the coal change as well. The change in coal allowed the ESP operation to be improved by lowering the flue gas temperature below the ESP operational temperature limit of 350 deg F. When the ESP flue gas temperature exceeds 350 deg F the collection efficiency drops. Additionally, the incidence of ash hopper fires increases at the higher flue gas temperature. When a hopper fire becomes too severe and cannot be cleared from the outside, the boiler has to be shutdown for 2 to 4 days.
Air Preheater Temperature, Boiler 7, March 2004

The combined effects permitted higher total steam production displacing natural gas consumption. On Coal A Boiler 7 could not operate above 120 Kpph steam load without causing the ESP performance to deteriorate due to high flue gas temperature. On Coal B Boiler 7 could run up to 160 Kpph during the test burn. The extrapolated temperatures indicate the boiler could run up to the full design load or until the boiler ran out of combustion air. Usually the boiler could not run over 187 Kpph before running out of fan capacity provided the other temperature limits were not being exceeded. Running Boiler 7 on Coal B at a base load 50 Kpph higher than that of Coal A will displace about 63 Decatherms per hour of gas usage on a gas boiler. The effect on Boiler 6 is unknown but the higher quality coal could permit sustained operations at 20 Kpph higher loads thus displacing an additional 25 Decatherms per hour gas usage. Using December 2005 natural gas prices of over $13/Decatherm this increased coal production would yield a fuel bill savings of almost $1000 per hour.
Figure 4. Boiler 7 Clean Tube Condition.

Figure 5. Boiler 7 Typical Backwall Slag – Illinois Coal.
Figure 6. Boiler 7 Typical Backwall Slag - Illinois Coal.

The effect of low slagging coals motivated the University and the Illinois Department of Commerce and Economic Opportunity, Office of Coal Development (ICDEO/OCD) to test technology that would reduce the slagging and fouling effects of Illinois coal.

The coal additives have been successful with slagging coals in pulverized coal boilers. It is not certain that coal additives will reduce boiler fouling in stoker boilers. This project is to test coal additives to determine if coal additives can improve the combustion performance of Illinois stoker coals by reducing slagging and fouling.

EXPERIMENTAL PROCEDURES

In large utility boilers burning high ash and slagging coals, targeted injection of Magnesium Hydroxide solutions have increased boiler efficiency and reduced the frequency of deslagging outages. The University had investigated implementing fuel additives as one of several options to improve coal boiler performance. Vendors of products had visited the plant proposing furnace injection or fuel stream treatment. Some vendors model the furnace to target the injection while others rely on an iterative method to optimize fuel treatment control.

An IDCEO/OCD grant in June 2005 enabled the University to pursue implementing a test toward improving the utilization of Illinois coal. A specification to design, install,
maintain and support a system on Boiler 7 and Boiler 6 was written by Abbott Engineers in June 2005.

The project required the vendor to demonstrate successful experience with coal stoker boilers as well as complete system support. As the plant is the sole source of heat for campus, the plant did not want to expose the university to the risk of a technology demonstration by a supplier without a proven history. Additionally, the vendor would have to provide a system fully integrated with the existing plant controls. The plant did not want to burden the operators with a scaled up benchtop system that would require constant attendance.

Vendors were to establish a range of dosing rates that may be needed for the test. For feedstock cost analysis Boiler 7 has a maximum coal usage rate of 11 tons per hour and Boiler 6 has a maximum coal usage rate of 8 tons per hour. Chemical additive tanks/hoppers and injection nozzles were to be fabricated and installed on Boilers 6 and 7 by the vendor.

The University selected Fuel Tech to install a Magnesium Hydroxide targeted injection system. This vendor has experience in injecting fuel additives in stoker boilers and utility boilers to control slagging, fouling and Nitrous Oxide emissions. After modeling the furnaces the system was installed and operating by April 2006. The system has been operating successfully on Boilers 6 and 7. The University has gone forward to install injectors on Boiler 5 after observing much reduction in furnace slagging on the first two boilers.

Prior to installing the system Fuel Tech performed a computational fluid dynamics (CFD) model of both furnaces. Their analysis located the temperature profile corresponding to the ash fusion temperature of 1700 deg F. This temperature line in the flame front is the optimal injection point for the chemical. Injector locations were selected based on the CFD analysis and the structural constraints of the boiler. The chemical injection ports were installed low on the back wall and front wall of the boilers about 24 inches above the grate. No sidewall injectors were installed. The chemical injection requires high purity water and compressed air to transport and atomize the mixture in the furnace. Each boiler needs about 75 cfm (cubic feet per minute) of plant air to atomize the chemical solution. The system was installed with hydraulic high pressure hosing. A 6,500 gallon double walled chemical tank was set behind the plant to supply the system.
Figure 7. Chemical Injector Placement.
RESULTS AND DISCUSSION

The furnace slagging is greatly reduced by the chemical injection with injection rates of about 3.5 lbs/ton of coal. This is higher than the expected 1-2 lbs/ton of coal. Lower injection rates have been attempted but sidewall slagging increases. However, at this rate the boilers went all summer without a need to shutdown for furnace deslagging. The boilers took outages for other system failures but there was no need to shutdown for slag removal. Additionally, the plant did not need to hire water-blasting contractors to remove furnace slag. The cost for a 2-day deslagging outage is approximately $30,000 per boiler in natural gas fuel cost and contract labor.

The chemical injection did improve the boiler heat transfer by slightly lowering the boiler outlet temperatures. However, there is still generating bank fouling by the ash. The plant has made other operational changes in combustion air setting and equipment lineups to improve the opacity in the flue gas. These changes may have masked the improvement in the top end limit of the coal boilers. The plant did not see the maximum sustainable boiler load increase significantly due to the generating bank fouling and the plant configuration changes. The boiler steam productivity per ton of coal dropped slightly. Again, that may be due to operational changes such as high-pressure feedwater heater lineup and combustion adjustments as well as loss of heat transfer surfaces from plugging
generating bank boiler tubes. There is no evidence that the chemical injection ameliorated the generator bank fouling.

Figure 9. Boiler 7 Boiler Outlet Temperatures.

Figure 10. Boiler 7 ESP Inlet Temperatures.
CONCLUSIONS AND RECOMMENDATIONS

The use of Illinois Coal with high slagging and fouling indices in stoker boilers creates operational and environmental problems limiting the maximum capacity of a stoker boiler. The coal additive has greatly reduced the slagging in spreader stoker boilers firing high sulfur Illinois Coal. The reduction in slagging reduced the manual labor to operate the coal boilers and reduced the hazards to plant staff from breaking tenacious clinkers on front and back walls. The plant avoided boiler outages for deslagging. However, the coal additive was not observed to help control boiler fouling which reduces the maximum steaming rate of the coal boilers.

The University will continue to operate the fuel additive system as the slagging reduction has a positive economic and operational effect on the plant. The University will continue to adjust the rate to determine if lower federates can maintain the clean furnace. The University will install additional injectors on the front outboard of the coal feeders to ensure treatment of the sidewall. The University will also continue to look for methods to increase the use of coal at the plant toward reducing natural gas usage and costs to meet the campus heating and electrical load.
DISCLAIMER STATEMENT

This report was prepared by Robert Hannah, University of Illinois, with support, in part by grants made possible by the Illinois Department of Commerce and Economic Opportunity through the Office of Coal Development and the Illinois Clean Coal Institute. Neither the Robert Hannah, University of Illinois, nor any of its subcontractors nor the Illinois Department of Commerce and Economic Opportunity, Office of Coal Development, the Illinois Clean Coal Institute, nor any person acting on behalf of either:

(A) Makes any warranty of representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately-owned rights; or

(B) Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring; nor do the views and opinions of authors expressed herein necessarily state or reflect those of the Illinois Department of Commerce and Economic Opportunity, Office of Coal Development, or the Illinois Clean Coal Institute.

Notice to Journalists and Publishers: If you borrow information from any part of this report, you must include a statement about the state of Illinois' support of the project.