ABSTRACT

The study investigated the capabilities of the #2 boiler at the Southern Illinois University Carbondale (SIUC) Steam Plant. The study focused on an inspection of the boiler tubes and a vibration analysis of the #2 boiler. The results of the study and analysis will be used to enhance the operation of the Water Cooled Oscillating Grate (WCOG) technology installed at the #2 boiler. Further retrofit activities will investigate the blending of biomass with a base load of coal.

The boiler tubes were inspected in order to determine the #2 boiler’s current operational condition, to recognize opportunities for improvements in the #2 boiler’s operations and maintenance procedures, and to identify any deteriorating conditions. The inspection and evaluation included visual inspection, nondestructive examination, remote field eddy current testing, and a review of previous operation, maintenance, and repair data. The inspection found some areas that needed improvement in the operation and maintenance of the boiler. It was also determined that boiler tubes needed replacement. In general, the condition of the boiler was within allowable tolerances and should be able to continue operation for at least ten more years.

The vibration analysis of the #2 boiler was conducted in order to determine if excessive resultant vibrations from the Water Cooled Oscillating Grate occur during operation. The transmission of vibrations to the surrounding structures were identified and eliminated, if possible, or recommendations were given. Data was collected using a spectrum analyzer and vibration transmissions were identified and eliminated. In addition, it was determined that the foundation and support structure of the WCOG were not adversely affected by any resultant vibrations and were within normal parameters. Several causes of vibrations were found and isolated. The main area of vibration was in the upper part of the grate was found to be a metal rod that was welded to the edges of the grate in order to hold in fuel material.

The inspection of the boiler tubes and the vibration analysis of the #2 boiler determined that some operational and maintenance procedures should be modified. There were also some components that need to be replaced or modified. For the most part, the WCOG in the #2 boiler is capable of normal operation supported by the findings of these studies.
EXECUTIVE SUMMARY

The Water Cooled Oscillating Grate (WCOG) was installed in the #2 boiler at Southern Illinois University Carbondale (SIUC) Steam Plant in 2007, and has demonstrated that the grate is effective in combustion of run-of-mine coal. The WCOG replaced a different failed attempt to convert the #2 unit so a bare-bones approach was used to install the WCOG until the technology was proven to be effective in burning non stoker grade Illinois coal. This was especially prudent in that another technology was tried, did not perform and was subsequently removed. A decision was made early in the project to use the existing primary air fan, even though it was thought to be marginal in size for the application. Additionally, manual valves were put on the inlet to wind boxes to hold down cost and a manual once through potable water system was used for supply of water through tubes that cool the grate plates. All of these cost saving measures have made the tuning of the boiler difficult and as a result the unit is not as efficient.

This study of the #2 Boiler focussed on boiler furnace tube thickness. The boiler furnace tube study ensured that the aging #2 boiler is capable of continued service and available for use by SIUC as a main line boiler. The furnace tube study included a visual inspection of the boiler and a series of nondestructive examination tests on the tubes, drums, and furnace box. The study found that 156 furnace tubes needed replacement. There were some other minor operational and maintenance improvements that were recommended. Overall, the condition of the #2 Boiler was found to be satisfactory for continued service.

The other focus of the study involved a vibration analysis that ensured the #2 boiler is adequately isolated from the rest of the plant. Any undue vibrations were identified and if feasible, corrections incorporated. One major source of vibration transmission was identified to be a steel cylindrical bar attached to the side grate plates. Other minor sources of vibration transmission were found at ineffective flex joints in the plumbing system. The minor source modifications can easily be incorporated by the steam plant staff into their routine maintenance program. The complete Boiler Furnace Tubes Report from BIS is attached as Appendix 1 to this report, and the Vibration Analysis from Riley is attached as Appendix 2.
OBJECTIVES

The main objectives of this study was to be able to determine the condition and the operational capabilities of the furnace boiler tubes in the #2 boiler and to identify and analyze any abnormal vibration in the #2 boiler that would adversely affect its operation. Upon completion of this study, a separately funded scope of work is planned for this unit in order to enhance and optimize its performance and operation. The study was composed of two tasks which are described below.

TASK 1: Boiler Furnace Tubes – The furnace tubes in the #2 boiler were mapped throughout the boiler in order to determine tube thickness loss. The boiler tubes are mostly the original boiler tubes in the #2 boiler. The mapping identified the tubes that are in need of repair or replacement in order to be able to run the boiler consistently. Boiler Inspection Services Company (BIS) of Wheaton, Illinois conducted the Furnace Boiler Inspection under the supervision of Sterling Energy and the University staff.

BIS reviewed existing information such as maintenance and repair records, operating logs, original drawings, feed water treatment methods and ASME data sheets. They conducted a visual examination of the #2 boiler and conducted a series of nondestructive examinations. BIS conducted ultrasonic thickness measurements, dry magnetic particle testing, remote field eddy current tests.

TASK 2: Vibration Analysis – A vibration analysis of the #2 boiler was conducted to determine if the #2 boiler is adequately isolated from the steam plant. Since the installation of the WCOG, minor cracks and spalling had occurred in the steam plant. The vibration analysis will determine and/or rule out if the WCOG is the cause of the cracking and spalling. The analysis will also help determine if there is a separate cause. Remedies to the analysis will be discussed with SIUC.

The vibration analysis was performed by/and under the supervision of Riley Power, Inc. and Kinergy Corporation, the owners of the WCOG technology. Sterling Energy and SIUC agreed to review the analysis and jointly determine the appropriate course of action if such actions are necessary. Actions could be to change operation procedures, installation of isolators to absorb vibration, etc. Any corrections as a result of the study are not included in this ICCI grant application.

INTRODUCTION AND BACKGROUND

With the goal of providing fuel flexibility that will generate lower annual operating costs while reducing outages and maintenance costs, a new technology was sought. The Water Cooled Oscillating Grate (WCOG) was developed jointly by Riley Power, Inc. and Kinergy Corporation. The WCOG is a patented product, U.S. Patent # 6,220,190, dated April 24, 2001. The WCOG was installed in the #2 boiler at Southern Illinois University Carbondale (SIUC) Steam Plant in 2007. The installation effectively demonstrated that both stoker and Run-of-Mine coals could be successfully burned on the WCOG.
The initial grant to install the WCOG on Boiler #2 at SIUC excluded many enhancements due to the fact that it was in the interest of the State of Illinois to take a bare bones approach until the technology was proven to be effective in burning non stoker grade Illinois coal. This was especially prudent in that another technology was tried, did not perform and was subsequently removed. A decision was made early in the project to use the existing primary air fan, even though it was thought to be marginal in size for the application. Additionally, manual valves were put on the inlet to wind boxes to hold down cost and a manual once through potable water system was used for flow of water through tubes that cool the grate plates. All of these cost saving measures have made it difficult to tune the boiler and created inefficiencies in the operation of the boiler.

The excluded enhancements will cost only a fraction of the installation of the original equipment, especially when the cost of the failed technology is considered. While the cost differential of run of mine vs. stoker coal at SIU is less than other parts of the State of Illinois, SIUC has always been a leader in innovation of their energy facilities. All of the enhancements provided in this project will be available for incorporation in other installations within the State of Illinois. This technology can have a far reaching effect on preservation of jobs operating coal fueled boilers at this facility and other facilities in Illinois. This positive impact is expected in both the public and private sector.

EXPERIMENTAL PROCEDURES

The SIUC #2 Boiler Study was comprised of two tasks as detailed below.

TASK 1: Boiler Furnace Tubes – The furnace tubes in the #2 boiler were mapped throughout the boiler in order to determine tube thickness loss. The tubes are mostly the original boiler tubes in the #2 boiler. The mapping will identify tubes that are in need of repair or replacement in order to be able to run the boiler consistently.

Boiler Inspection Services Company (BIS) of Wheaton, Illinois conducted the furnace boiler inspection under the supervision of Sterling Energy and the SIUC power plant staff. The BIS Project Team that performed the evaluation has the following qualifications:

The Project Manager is graduate Mechanical Engineer with twenty-five (25) years experience on project evaluation, ASME Code, and has passed the National Board Commission examination. The Project Manager also has twenty-five (25) years experience in nondestructive testing, loss prevention, inspection and engineering analysis. All BIS personnel is qualified and certified in accordance with SNT-TC-1A, Level III & Level II. In addition, the metallurgist is a graduate Metallurgist with over 30 years experience.

BIS reviewed existing information such as maintenance and repair records, operating logs, original drawings, feed water treatment methods and ASME data sheets. They conducted a visual examination of steam and mud drums, steam separator, tubes
connection, headers, economizer, superheater, burners, refractory and other boiler related parts.

BIS conducted ultrasonic thickness measurements of both of the steam and mud drums, headers, accessible economizer and superheater tubes, and firebox tubes. For the drums and headers, measurements were made at evenly spaced accessible intervals, every 45 degrees and every two (2) feet. For the tubes, measurements were made on every tube every three (3) feet elevations, closer when deemed necessary. For accessible superheater and economizer tubes, the same testing interval will applied. BIS also conducted dry magnetic particle testing of selected inside welds of the steam drum.

BIS performed Remote Field Eddy Current tests of all the generating tubes. The testing probe was inserted in the tube from steam drum all the way to mud drum to determine the range of wall thickness.

TASK 2: Vibration Analysis – A vibration analysis of the #2 boiler was conducted to determine if the #2 boiler is adequately isolated from the steam plant. Since the installation of the WCOG, minor cracks and spalling have been noticed by the power plant staff. The vibration analysis was done to determine and/or rule out if the WCOG is the cause of the cracking and spalling. The analysis also helped to determine if there is a separate cause. Remedies to the analysis were discussed with SIUC power plant staff.

The vibration analysis was performed by Riley Power, Inc. and Kinergy Corporation, the owners of the WCOG technology. The equipment used for the analysis included an accelerometer with power supply and an FFT analyzer. Frequencies were measured in potential problem areas and then measurements were made near the WCOG and other major pieces of equipment in Boiler #2 and other units in the same building. Measurements were also taken with the WCOG offline and while operating in potential problem areas. Measurements were compared to determine a frequency match between problem areas and the WCOG and/or other major pieces of equipment.

RESULTS AND DISCUSSION

The observations and findings of the study are summarized below for the Boiler Furnace Tubes and the Vibration Analysis. The complete Boiler Furnace Tubes Report from BIS is attached as Appendix 1 to this report, and the Vibration Analysis Report from Riley is attached as Appendix 2. The following paragraphs briefly summarizes the findings of the reports.

TASK 1: Boiler Furnace Tubes – The #2 boiler was visually inspected by BIS personnel on October 14, 2010. The fire box revealed accumulation of fly ash deposits and some watermark discoloration on the furnace tubes. Heavy scale deposits were also observed on the tubes in some areas. The superheater tubes and penthouse appeared to be in satisfactory condition.
The steam drum showed indications of improper water treatment. The steam filters showed corrosion and appeared full of sediments or deposits. There was no active sign of pitting on the shell, heads, or tubes in the steam drum. All the welds appeared to be satisfactory. Videoscope of selected tubes showed very heavy scale deposits from top to bottom of the tubes.

The mud drum showed very heavy scale deposits in the tubes that appeared to be restricting the tube’s inner diameter. There was an accumulation of loose scale or sediments at the bottom of the mud drum and on the surface of the tubesheet. The mud drum surface showed evidence of improper water treatment. There was no active sign of pitting on the shell, heads, and tubes. The welds in the mud drum appeared to be satisfactory.

The waterwall headers showed moderate scale deposits. There was no active sign of pitting in the internal areas or shell of the waterwall headers.

The valves and gauges appeared to be satisfactory for continued service. The steam and mud drum manways showed signs of gasket leakage. The external casing showed no sign of thermal discoloration, flaking paint, or significant bulging. The springs and structural supports of the boiler appear to be in satisfactory condition.

Ultrasonic thickness (UT) testing of the shell and heads of the steam and mud drum indicated no significant wall loss. UT testing of the waterwall tubes showed no significant wall loss. Magnetic particle testing of the welds in the steam drum showed no relevant indication.

Remote field eddy current (RFEC) testing of all the accessible generating tubes revealed some tubes that needed replacement due to wall thickness loss. The wall thickness loss of the tubes was classified in groups by increments of ten (10) percent of wall thickness loss, for example, 10% and below, 11% - 20%, etc. The project team determined that 156 tubes would need to be replaced based on existing and future wall thickness loss.

TASK 2: Vibration Analysis – The Vibration Analysis was performed on February 10, 2011 by personnel from Riley Power, Inc. and Kinergy Corporation. There was one major point of vibration transmission. It was determined that a cylindrical steel rod directly attached to the grate’s seal was making direct contact with the boiler structure. The rod was transmitting vibrations during the normal operation of the oscillating grate.

In addition, it was observed that handrails adjacent to the boiler oscillated during grate operation. Main steam piping and other plumbing components also oscillated during grate operation. Various flex connections appeared to be ineffective in absorbing the energy of the grate’s oscillation and allowed small transmissions.

Harmonic pressure pulsations were also observed to occur in confined spaces and cavities, such as in the steam tunnel and on the catwalks above the coal bunkers.
CONCLUSIONS AND RECOMMENDATIONS

The Boiler Furnace Tube study and the Vibration Analysis resulted in the following conclusions and recommendations.

TASK 1: Boiler Furnace Tubes – The most critical components of a boiler are the steam and water drums. The shell condition and the presence of defects/conditions are the basis for evaluation. Some of these defects/conditions were observed during the inspection and evaluation of the #2 boiler. The following recommendations should be considered for extending the life of the boiler, improving boiler efficiency, and reducing maintenance costs.

All accessible tubes in the boiler should be mechanically cleaned to remove the scale deposit in the tubes. Cleaning the inner diameter of the tubes will prolong the life of the tubes and will improve boiler efficiency.

The screen tubes and front generating tubes in the firebox should be cleaned of scale deposit. The scale acts as an insulator and contributes to the overheating of the tubes.

The fly ash at the second pass area and at the manway doors should be cleaned. The loose scale/deposits that settled in the mud drum and waterwall header should also be cleaned.

The chemical water treatment of the boiler should be checked and verified for its effectiveness. The deaerator tank should be inspected for proper operation of supplying deaerted feedwater to the boiler. The return condensate should be cleaned before injecting into the deaerator tank.

The sootblowers should be inspected to make sure they are operating properly.

The safety relief valves and pressure/temperature gauges should be calibrated/tested regularly. The low water fuel cut-off device and inspection tees at the water column area should be opened during annual shutdown to make sure no blockage present. The blowdown valve should also be opened and checked at annual shutdown.

The recommendations above require immediate attention before resuming boiler operation and continued during boiler operation. Most of these items are already included in the regular operation and maintenance procedures conducted by the power plant staff. The recommendations emphasize that proper and periodic procedures continue to be performed for safe and efficient operation of the boiler.

TASK 2: Vibration Analysis – There was one major source of transmission of vibrations from the WCOG to the plant and a few minor sources that were identified and isolated. The underlying conclusion that was most positive was the WCOG, as a whole, was well isolated from the plant and was not transmitting unintentional vibrations.
The analysis of the finding determined that the cylindrical steel rod should be reduced/removed in order to not transmit vibrations. In addition, handrails can be stiffened by attaching a brace to a rigid body to detune the oscillation of the handrails. Various flex connections (rubber and accordion) can also be fine tuned to damping oscillations and eliminate outward transmission.

REFERENCES


DISCLAIMER STATEMENT

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