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IMPROVING BOILER RELIABILITY THROUGH NDT

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ABSTRACT

TesTex, Inc. has worked with numerous utilities that experienced Boiler Tube Failures in areas such as water walls, superheaters, reheaters, etc. In this presentation we will discuss specific areas of a given boiler describing what problems (failures) the units were experiencing and what solutions were implemented. We will also discuss various failure mechanisms for boiler tubing, the causes, and various Non-Destructive Testing (NDT) methods used to locate and identify these flaws.

Some specific case studies of boiler tube failures are listed below.

Xcel Energy-Valmont Station, Boulder, CO Boiler: This 166mw Coal Fired Boiler was experiencing water wall tube failures due to corrosion cells and hydrogen damage. This unit has been inspected with Low Frequency Electromagnetic Technique (LFET) four times over the last seven years. This unit has gone from experiencing tube failures every two weeks to only having 1-2 failures per year.

Western, PA Power Plant: This 835 MW Coal Fired Boiler was experiencing reheater tube failures due to oxidation pitting in their horizontal sections. Sections of this reheater were inspected with the Low Frequency Electromagnetic Technique using Low Profile scanners to access the bottom half of the tubes in the horizontal sections. Several flaws were found and repairs were made. Similar inspections were also performed in the plant's other two boilers where no defects were found.

These inspections helped the plant locate and make repairs to flawed regions in the boilers. Their run-time between boilers tube failures has risen significantly.

INTRODUCTION

Boiler reliability is crucial for power plants. Forced outages can cost a plant millions of dollars especially during periods of peak power demand. Non-Destructive Testing inspections during planned outages can prevent many of these forced outages. A good practice is to study the history of the unit and determine where to focus the inspections in the boiler. The goal is to identify potential tube failures and replace the sections during an outage. Another key is determining the cause of the failures in the tubes. The plant can then take corrective actions to prevent the defects from reoccurring. Two specific cases of where Non-Destructive Testing was implemented to help reduce boiler tube failures will be discussed. The first involves the inspection of the water wall tubes where corrosion cells and hydrogen damage were occurring. The second is the inspection of horizontal reheater tubes that were experiencing out of service corrosion. TesTex used the Low Frequency Electromagnetic Technique (LFET) to perform these inspections. The inspections that were provided improved the Time Between Failures for both plants.

NOMENCLATURE

I.D. – Inside Diameter
LFET – Low Frequency Electromagnetic Technique
MW - megawatt
NDT – Non-Destructive Testing
O.D. – Outside Diameter
psi – pounds per square inch

BODY

There are several Non-Destructive Testing technologies and inspections tools that are able to improve boiler reliability. There are (6) critical keys for using NDT to improve boiler reliability.

(1) The first key point is to explain your problems to the NDT Company. Be sure to describe the unit history, any major disruptions to the boiler operation such as the unit overheated, ran without water, or was laid up for an extended amount of time. Inform the company of the failure history including locations, frequency, and suspected root cause of the failures. Any metallurgical reports are also useful.

(2) Provide the NDT Company with any drawings that you may have. Drawings of the unit with the problem areas identified are helpful in analyzing equipment needed and to estimate the amount of time the inspection will take.

(3) Provide the NDT Company with any tube samples that you may have. Samples allow the company a piece for their equipment to inspect. This allows them to fine tune the procedure to the boiler's specific problems. The samples provide the technicians an insight on what the signals will look like for the particular failure mechanism the unit contains. The collected waveforms will help fine-tune the calibration. Be sure to ask the vendor to detail their experience with your particular problem and the results of the past inspections.

(4) During the early part of the actual inspection, the contractor needs to communicate with the plant on their findings. Some suspected defects should be removed to verify the inspection process, improve calibrations, and the accuracy of the calls. These samples will provide an actual comparison for the collected data. This will also provide confidence for the actual inspectors on what they are observing.

(5) Make proper repairs. Try to repair as many of the defects as time and budget allows.

(6) Take corrective actions to prevent and/or reduce future failures. Without taking corrective actions, the failure process may be reduced for a period of time, but the failures will resurface.

Please remember that using NDT should improve your Time Between Failures. It will not eliminate all tube failures.

TesTex, Inc. has a proprietary technology called "Low Frequency Electromagnetic Technique (LFET) to inspect boiler tubes from the O.D. of the tube. LFET injects an electromagnetic signal into the test piece. The electromagnetic signal is measured. Any changes in the signal are noted and the distorted signals are compared to calibrations to determine the amount of wall loss. It detects and quantifies I.D. and O.D. defects in ferrous and non-ferrous materials. LFET is a dry non-contact method based on the principles of electromagnetics. It is forgiving to uniform surface scale. This means the scanning requires the surface to be smooth but does not need to be sandblasted down to bare metal. A high-pressure water blast is usually sufficient in coal burning plants. The technology is adaptable to different applications, which allows the inspection of different diameters of tubing, the inspection of bends, and the inspection of tubes in space-constricted areas. A standard LFET water wall scanner has (8) pickup sensors and is able to inspect most of the hot side of the tube in one scan. The system is lightweight, modular, and uses digital signal processing electronics while being operated with a laptop computer. The results are displayed in real-time with high-resolution color graphics 3D display.

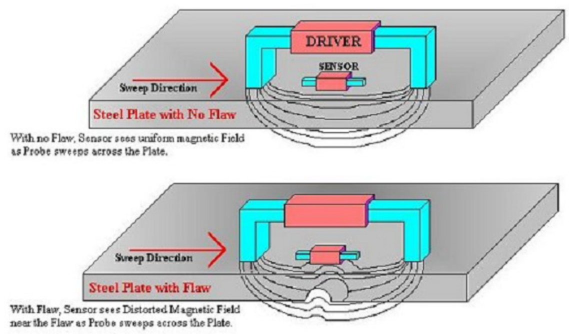

Figure 1 shows a schematic of how LFET functions.

LFET boiler inspections are able to find caustic and phosphate gouging, corrosion cells, hydrogen damage, oxygen pitting, cracking, erosions, and manufacturing defects. Ultrasonic Thickness testing is used to prove up indications found when access allows.

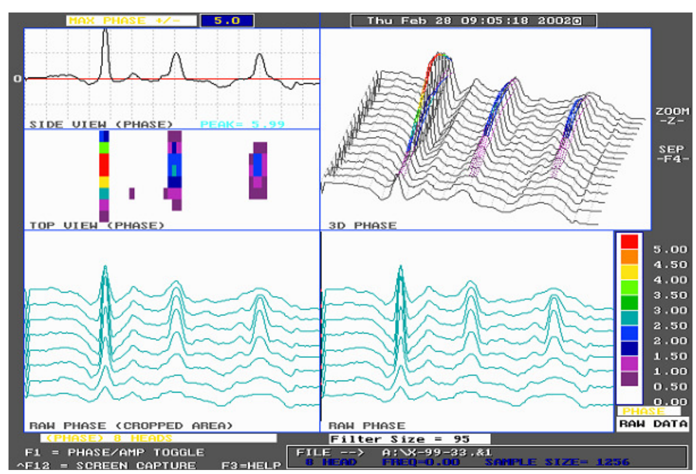

Figure 2 is a LFET calibration waveform showing .375" diameter pits with 60%, 40%, and 20% wall loss on a 2.5" O.D. carbon steel tube with a wall thickness of 0.203".

Water Wall Tube Failures due to Corrosion Cells/ Hydrogen Damage

The #5 Boiler at the Xcel Energy – Valmont Station was experiencing water wall tube failures at a high rate due to corrosion cells and hydrogen damage. The #5 Boiler was installed in 1964. It is a Combustion Engineering 166 MW Coal-Fired, Tangential-Fired, 1,925 psi Natural Circulation Boiler. The furnace wall tubes are 2.5" O.D., 0.203" wall, carbon steel. The bullnose tubes are 3" O.D., 0.240" wall, carbon steel.

Figure 3 shows a LFET Inspection being performed on a water wall

There were 10 boiler tube failures in 1999 due to hydrogen damage. During one of these forced outages, TesTex was called to the sight to perform a LFET inspection in a small area that was accessible from floating scaffolding. Approximately 1800 linear feet[1] was inspected with LFET on the North Wall. The LFET inspection found 11 existing defects.

Defects were classified three ways. The first classification was a tube showing less than 0.180" wall remaining out of 0.203" nominal wall. The second was a tube showing attenuation when inspected with A-scan Ultrasonic thickness testing. Attenuation is when the echo of the ultrasound is lost. This is usually due to the material having a rough ID surface or micro cracking within the grain structure. The third classification was a tube with hydrogen damage. This was confirmed using the Ultrasonic Tangential L-Wave Velocity Shift method. Most defects found showing major wall loss and/or hydrogen damage were removed. Defects that only showed minor wall losses with >0.150" wall remaining with no signs of hydrogen damage were left in place.

The Valmont Station had a planned outage in May 2000. Hard scaffolding was erected in the furnace and the tubes were cleaned with a high-pressure water blast. This method of cleaning removed the ash deposits and left the tubes with a uniform surface scale that allowed the LFET scanner to travel across smoothly. Please note the tubes were not sandblasted down to white metal. This saved time and money since LFET only requires the tubes to be smooth. As stated previously, LFET does not require any couplant nor a bare metal surface for a quality inspection. A total of 32,500 linear feet was inspected with LFET on four walls including the bullnose. Forty-five defects were found. Xcel Energy personnel inspected these defects with the Ultrasonic Ultrasonic Tangential L-Wave Velocity Shift method. This method confirmed hydrogen damage was present in several tubes. The tubes with hydrogen damage were removed. This inspection took a crew of eight men four days to complete.

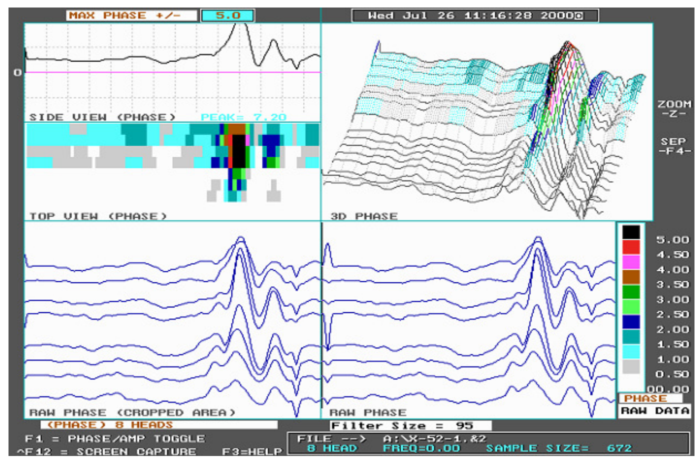

Figure 4 shows a waveform of a tube with confirmed hydrogen damage that was in inspected during the May 2000 outage. The carbon steel tube dimensions are 2.5" O.D. with a wall thickness of 0.203".

The Xcel Energy – Valmont Station had an outage in March 2002 and hard scaffolding was erected in the boiler again. Approximately 30,000 linear feet was inspected with LFET. The inspection identified 209 defects with ten of these defects containing hydrogen damage that were confirmed using the Ultrasonic Tangential L-Wave Velocity Shift method. The LFET Inspection took eight men four days to complete. Please note that Figure 5 shows a waveform of a tube that contained hydrogen damage with no wall loss present. The micro cracking from the hydrogen damage causes the electromagnetic signal to distort.

Structural Integrity used the "Time of Flight Diffraction" (TOFD) technique to inspect the butt welds. Thirty-seven of the butt welds showed hydrogen damage. The tubes with hydrogen damage were replaced along with some tubes that showed severe wall thinning. After this inspection, the unit ran

[1] Linear footage is calculated by multiplying the numbers of tubes tested by the length. For example 50 tubes tested at a length of 20' per tube is 1000 linear feet.

until the next planned outage in October of 2004 with only one tube failure due to hydrogen damage.

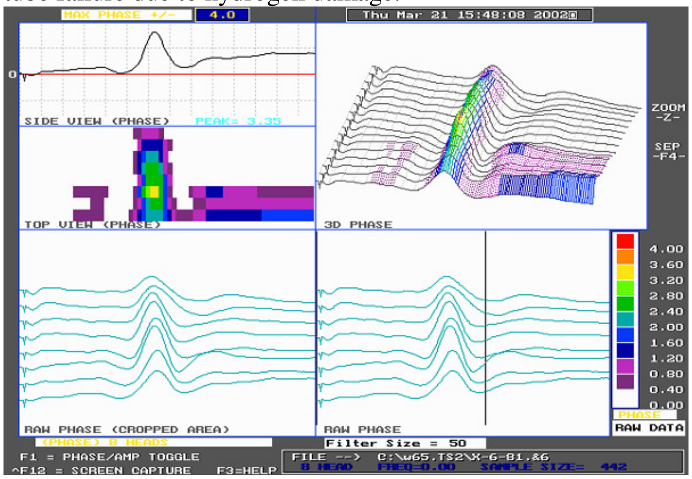

Figure 5 shows a waveform of a tube with nominal wall but with hydrogen damage. This waveform was collected during the March 2002 inspection. The carbon steel tube dimensions are 2.5" O.D. with a wall thickness of 0.203".

In October of 2004, the Valmont Station had an outage and hard scaffolding was erected in the furnace. TesTex inspected approximately 13,740 linear feet with LFET with the inspection focusing on the rear wall including the bullnose and all four corners of the boiler. The inspection detected 87 defects. Eleven of these defects showed hydrogen damage that was verified by Ultrasonic Tangential L-Wave Velocity Shift.

This inspection scope was repeated in April 2007. The LFET inspection, found 104 defects. The Ultrasonic Tangential L-Wave Velocity Inspection identified eighteen of the defects to have hydrogen damage.

The plant took the following steps to reduce boiler tube failures:

1) Coated the Condenser Tubesheets
2) Performed Eddy Current on the Condenser
3) Chemical Cleaned the Boiler
4) Chemistry Control
5) Paid close attention to burner/fireball alignment.
6) Conducted Periodic Inspections.

The steps listed above significantly reduced the boiler tube failures. The coating of the condenser tubesheet cut down on the amount of deposits that formed in the tubes. The eddy current inspection of the condenser tubes and subsequent plugging of damaged tubes reduced contaminants in the boiler water. The chemical clean removed ID deposits in the tubes. The plant carefully observed the water chemistry. The plant also paid special attention to burners and fireball alignment to reduce hotspots on the furnace walls.

Horizontal Reheater Failures due to Oxidation Pitting

A power plant in western Pennsylvania experienced boiler tube failures in the horizontal reheater section in one of their boilers. The plant has three identically designed 835 MW coal-fired Foster Wheeler Units. Tube samples near the failures showed I.D. pitting approximately 3/16" in diameter on the bottom side of the tubes. Due to the design of the reheater, access to the bottom of the tubes was very limited. The tubes were 2.5" O.D., 0.180" wall thickness, with the material being SA-213T22.

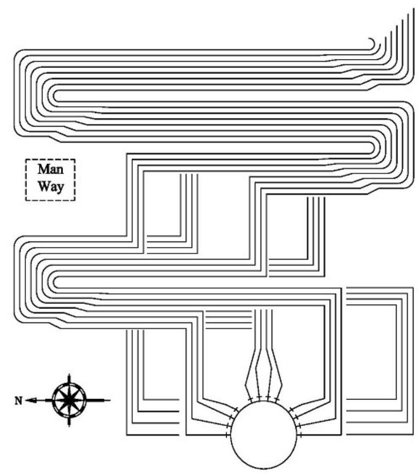

Figure 6 shows a side view of the horizontal reheater.

Plant personnel notified TesTex and described the situation. The unit had recently experienced a few tube failures in the horizontal reheater. The unit had been repaired and returned to operation. The plant needed a method to assess the condition on the horizontal reheater. TesTex went out to site and looked at some drawings and tube samples. There was less than 1" of vertical space between the tubes to place a scanner. Side to side access between the pendants was also limited. The tube samples showed I.D. pitting with an approximate pit diameter of 3/16". Some of the samples contained clusters of pits while other samples contained an isolated pit.

The inspection required a scanner that could fit between the tubes and be able to see pits as small as 3/16" in diameter. TesTex already had a Low Profile Scanner but the current design for the detection of a very small single pit was limited. A new LFET scanner with a double driver coil design was manufactured. The new scanner was able to see these small pits and through the use of calibrations was able to size the defects. Several scanners were manufactured for the upcoming outage.

Figure 7 shows the Low Profile LFET scanner in a reheater bank.

Once the unit was offline, the reheater section was blown down with air to remove the ash. The inspection focused on five different areas that were accessible where the past failures had occurred. The scanners were able to inspect three tubes deep into the bank without having to spread the tubes.

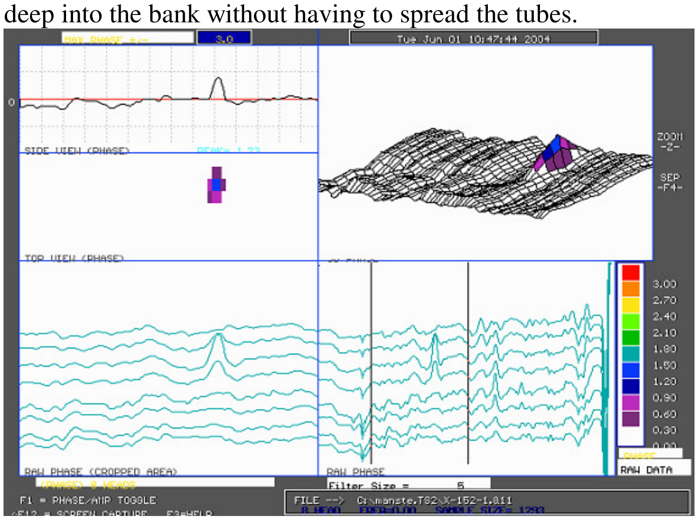

Figure 8 shows a waveform of a tube with a pit that has 25% wall loss. The tube dimensions are 2.5" O.D. SA-213T22 tube with a wall thickness of 0.180".

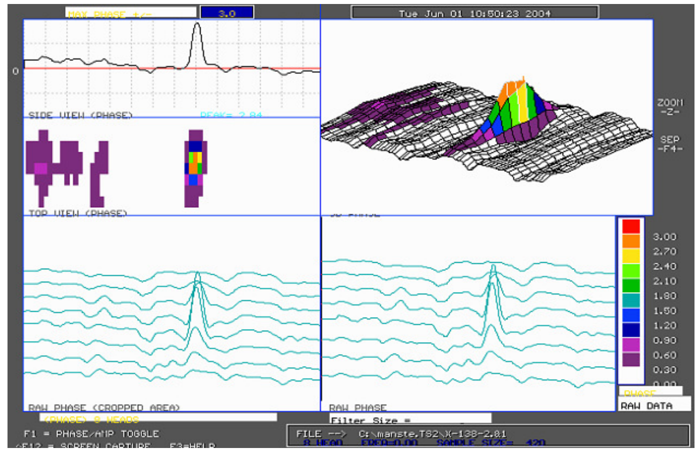

Figure 9 shows a waveform of a tube with a pit that has greater than 70% wall loss. The tube dimensions are 2.5" O.D. SA-213T22 tube with a wall thickness of 0.180".

A total of 44 defects was found. The defects were marked. The areas with the most severe flaws were removed. Minor defects were pad welded. The low profile LFET scanners were able to identify pitting as shallow as 20% wall loss or a wall remaining of 0.144" out of 0.180". Some tubes had several pits over a 4' area while other tubes only showed a single pit. The repairs the plant made saved them from several forced outages.

The other two boilers were not experiencing failures in the horizontal reheater sections. The plant decided to go ahead and perform similar inspections on these units because they were of the same design. The same areas were inspected. No defects were found in either boiler.

Conclusions

Through the use of NDT, both of these plants were able to reduce costly forced outages. The plants identified their issues and worked with a vendor to improve the boiler run time. The end results are less plant down time due to equipment failure, less unscheduled maintenance, and less safety issues. The NDT inspections provided a more efficient boiler operation. The LFET inspections provided a fast, accurate, cost effective method to test the boilers.

The keys to success in both of these cases were due to the plant accurately explaining the problem to the NDT Company. Tube samples and drawings of the unit were provided. Tubes were cut out during the inspection to verify results, improve accuracy, and provide confidence. The plants made the proper repairs. Collective actions were taken to prevent and or reduce future failures.