Automated Condition Assessment of Boiler Water Wall Tubes, Using Remote Field Technology. A Revolution Over Traditional and Existing Techniques

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Abstract

Electromagnetic inspection techniques have gained popularity for inspection of boiler and heat exchanger tubes from inside the tube. A new robotic "wall crawler" makes use of EM Techniques to inspect boiler water walls from the outside of the tube. The deployment of the technique is described, plus a case history.

Key Words

Tube Cat, Vertiscan, Electromagnetic Technique, Remote Field Technique, Boiler Water Wall Tubes, Vertiscan, Wall Crawler, Probe, Scaffold, Phase, Amplitude

Introduction

Boiler tube failures continue to be the leading cause of forced outages in boilers. To get your boiler back on line and reduce or eliminate future forced outages due to tube failure, it is extremely important to determine and correct the root cause. Detecting flaws before they cause failures is of critical importance in boiler maintenance. Localized wall thinning due to corrosion in boiler water-wall tubing is a significant inspection concern for boiler operators.

There are at least (4) other methods used for the inspection of Boiler Water walls. These methods are Spot Check UT, A-Scan UT, EMAT, and Scanning Thermograpy. Spot Check UT only gives thickness readings and gets very minimal coverage of the total surface area of the furnace water walls; the chances of finding I.D. flaw mechanisms using Spot Check UT are minimal at best. If Boiler Water walls have been sandblasted, A-Scan UT may be used to inspected larger areas of the furnace walls; in these cases, a steady flow of water is most often used as the couplant. The EMAT technique requires that any Boiler Water wall surfaces be sandblasted. The EMAT technique does not inherently get good surface area coverage unless the inspection team does multiple passes using the EMAT probe. Scanning Thermography is the most recent development for the inspection of Boiler Water walls; however, it is not yet commercially available in enough capacity.

This paper will present a discussion on the deployment of robotic wall crawler using electromagnetic technique to inspect boiler water walls from outside of the tube coupled with the theoretical background of the technique which explains the quantitative nature of the inspection.

Further, a case study will be presented for the technique that allows the extraction of thickness information from the inspection data.

Background of Remote Field Technology

A branch of Electromagnetic Technique known as Remote Field Technique of Non Destructive Testing was pioneered in 1950's by the Shell Development Company. It was first used to inspect well casings for corrosion and wall thinning, and for a number of years was used primarily petroleum and pipeline industries. In mid 1980's this technology became a subject of sophisticated research and the combination of basic research and industrial innovation has resulted in elegant theoretical models eventually developed into strong analytical methods which enable a greater variety of anomalies to be detected and quantified. RFT is now a well established inspection method for the condition assessment of ferromagnetic tubes.

Principle of Remote Field Testing (RFT)

RFT is based on a through-transmission principle. The field passes from the exciter coil through the tube wall, along the outside of the tube, and back in through the tube wall at the location of the detector coil (Figure 1). Metal loss causes the field to arrive at the detector coil with less travel time and less attenuation, resulting in a change in signal phase and amplitude. The signal values of phase (time of flight) and log-amplitude (signal strength) are directly related to wall thickness in the area of the detector coil(s).

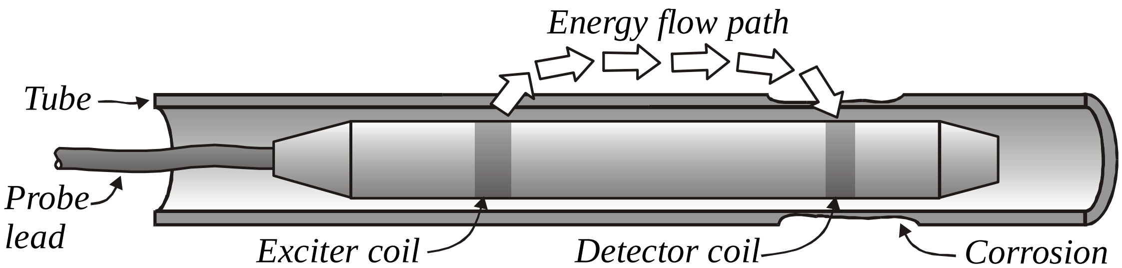

Figure 1: *A typical RFT probe. In comparison with conventional eddy current, RFT coils are widely spaced in order to measure the through-transmission field.*

RFT can be used for all conventional carbon steel material specifications, diameters and wall thicknesses. It is therefore used in many different types of heat exchangers, including fossil fuel boilers (especially in water wall and generator bank tubes), black liquor recovery boilers, shell and tube exchangers and air fin coolers. Remote field testing operates at relatively low frequencies. Remote field testing is a non contact technique, so the probes have minimal friction with the pipe wall and require no couplant.

The accuracy for remote field testing in the straight part of the tubes is about 10% of wall thickness for general wall loss. The accuracy is generally less (20 percent of wall) for highly localized discontinuities and near external conducting objects because of the changes in magnetic properties of the tube in that area and because of shielding effects of external objects. Remote field testing is also equally sensitive to inside and outside surface discontinuities but usually cannot discriminate between them without the help of near field coils. Remote field testing is relatively insensitive to scale and magnetic debris.

Deployment of Robotic Wall Crawler using Remote Field Technique

For Boiler tubes, it is very difficult to obtain access to the inside of boiler tubes so that an inspection tool can be inserted. Therefore all inspection must be performed from the outside of the tubes, inside the boiler. In this case, it is desirable to have an external tool that can detect corrosion or wall thinning without exhaustive cleaning of the surface, or removal of coatings.

The traditional method of inspecting boiler water wall tubes for loss of wall thickness is by taking many thousands of ultrasonic thickness readings spaced several feet apart in elevation (figure 2). In order to do this the boiler must be scaffolded and the tubes must be cleaned to bare metal where the ultrasonic thickness readings are to be taken.

Scaffolding and cleaning costs often exceed $100,000, and the ultrasonic inspection can cost the same amount again.

Figure 2:

If the boiler will be scaffolded anyway, the tubes can be inspected rapidly with a hand-held scanning tool that delivers the equivalent of up to 2000 thickness readings per foot, at a scanning speed of up to 10 feet/minute (figure 3).

Figure 3:

For boilers that are not scaffolded, a magnetic "wall-crawler" can be used to carry the "E- PIT" RFT probe up the water wall. The crawler can handle water walls up to 200' height and tube sizes from 1.5" to 3.5". Inspection speed is 10'/minute so an entire wall, 100' high and 100 tubes wide, can be inspected in less than 3 shifts (12 hour shift). The E-PIT probe inspects the flame side of the tube to within 3/8" of each web, using 12 detection coils for high precision (figure 4).
Pits, as small as 1/8" diameter, can be detected.

Figure 4:

Case Study - Deployment of Vertiscan at the Power Generation Station, (which uses Orimulsion as fuel)

The Unit # 1 of Power Generation uses that Orimulsion as fuel. Orimulsion is bitumen-in-water emulsion produced from the vast reserves of the Orinoco belt in Venezuela. The emulsion contains 70% natural bitumen and 30% water. This liquid fuel, resembling a black latex paint, has a relatively high energy content on a weight basis (i.e., about 110%that of coal, and 70% that of heavy fuel oil). The scale deposition on the tubes and web in such boilers is worse than coal fired boilers. Example of scale (figure 6): note that the crown is often scale free but the spaces between the tubes always have heavy scale.

Figure 6: Heavy Scaling

Figure 5: Vertiscan System

The Vertiscan™ System was used to inspect water wall tubes of Boiler #1 in 2006.
The system comprised of :
- **TubeCAT™** magnetic crawler with odometer
- **E-PIT™** tool for the inspection of 5 tubes simultaneously
- **E-PIT™** hand-scan tool for inspections of individual tubes
- **Ferroscope™** 308, 16 channel RFT instrument
- **Remote** vision system
- **200'** umbilical
- **Industrial** Laptop

Calibration

The equipment was calibrated on-site by taking ultrasonic thickness readings on at least two separate elevations of the same tube having both nominal thickness and known wall loss. In this instance, the thinned area of tubes on one of the walls at the burner elevation was used to produce the following **calibration curves (fig. 7 and 8)**.

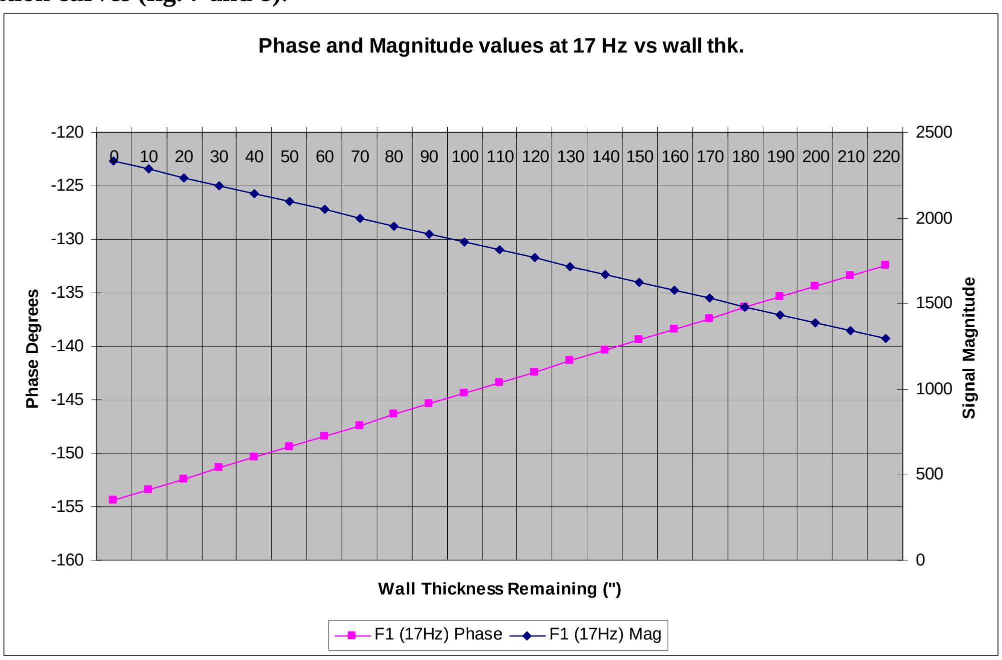

Figure 7: Calibration Graph at F1

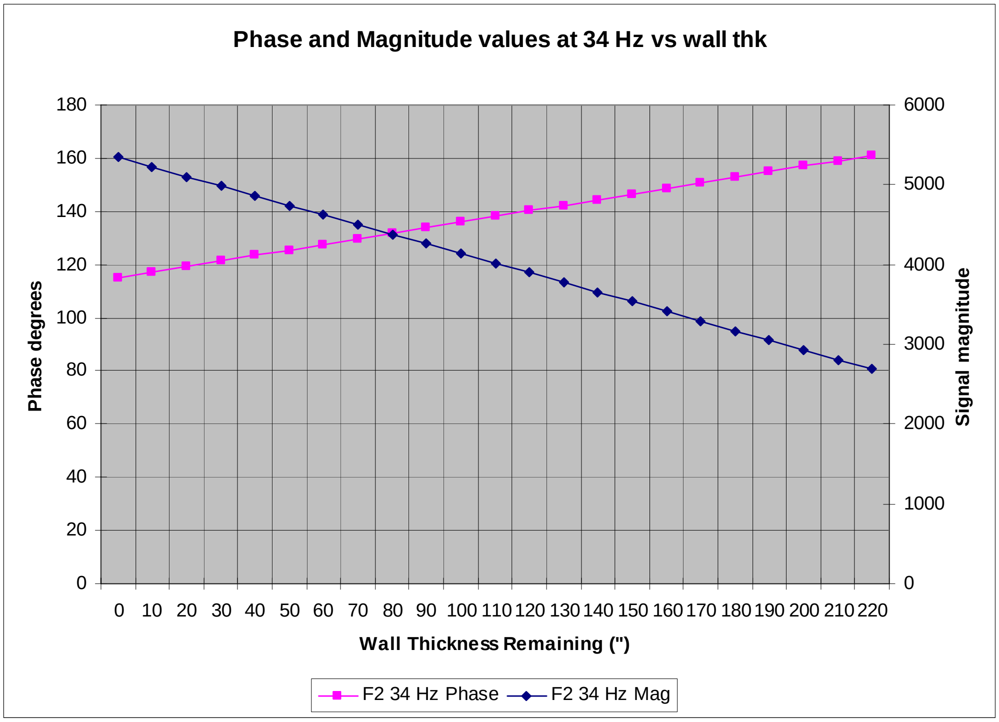

Figure 8: Calibration Graph at F2

Procedure

A datum line is marked on the wall from which all measurements are taken. In this instance the datum line was approximately at the 99'6" elevation. The E-PIT tool detectors were aligned with this datum for each of the scans performed.
From the datum line, the VertiScan system descended the wall at a speed of approximately 10'/minute while gathering data from the crowns of 5 tubes simultaneously. Depending on the frequency and sample rate, this can equate to (up to) 2000 thickness readings per foot.
Once reaching target height, the crawler was stopped and the direction reversed. Data was also gathered on the way up and was used to confirm any indications of wall loss detected.

Results

A detailed report (spreadsheet) for each wall was generated by the software semi automatically along with the field notes and a collage of "color map" for the full-scan data from each wall was made (figure 9).

Confirmations

The Vertiscan inspection results were backed up using ultrasonic (figure 10 and 11).

Summary

- The VertiScan System proved effective in identifying general thinning and local thinning near the welds at elevation 90.5'. Thinning was confirmed by ultrasonic thickness readings.
- The scaffold gap must be a minimum of 10" from the crown of the tubes for the VertiScan system to pass by
- For future inspections, it would help to have a fourth man doing on-site data analysis only. The operation of the VertiScan System when scaffolds are present is a three man job (two men if no scaffolds are present).
- The VertiScan System provides best value when there is no scaffold in the boiler.
  Generally one full water wall can be scanned per shift if just one system is in use.

Capabilities

The technique is sensitive to all types of wall thinning, including:

- Hydrogen Damage,
- Under scale Pitting and Graphitization,
- Flame and Soot Blower Erosion,
- Blister and Local Overheating,
- Creep damage (thermal fatigue),
- Elephant Skin, Rhino Hide,
- Dents and Gouges and
- Internal Pitting.

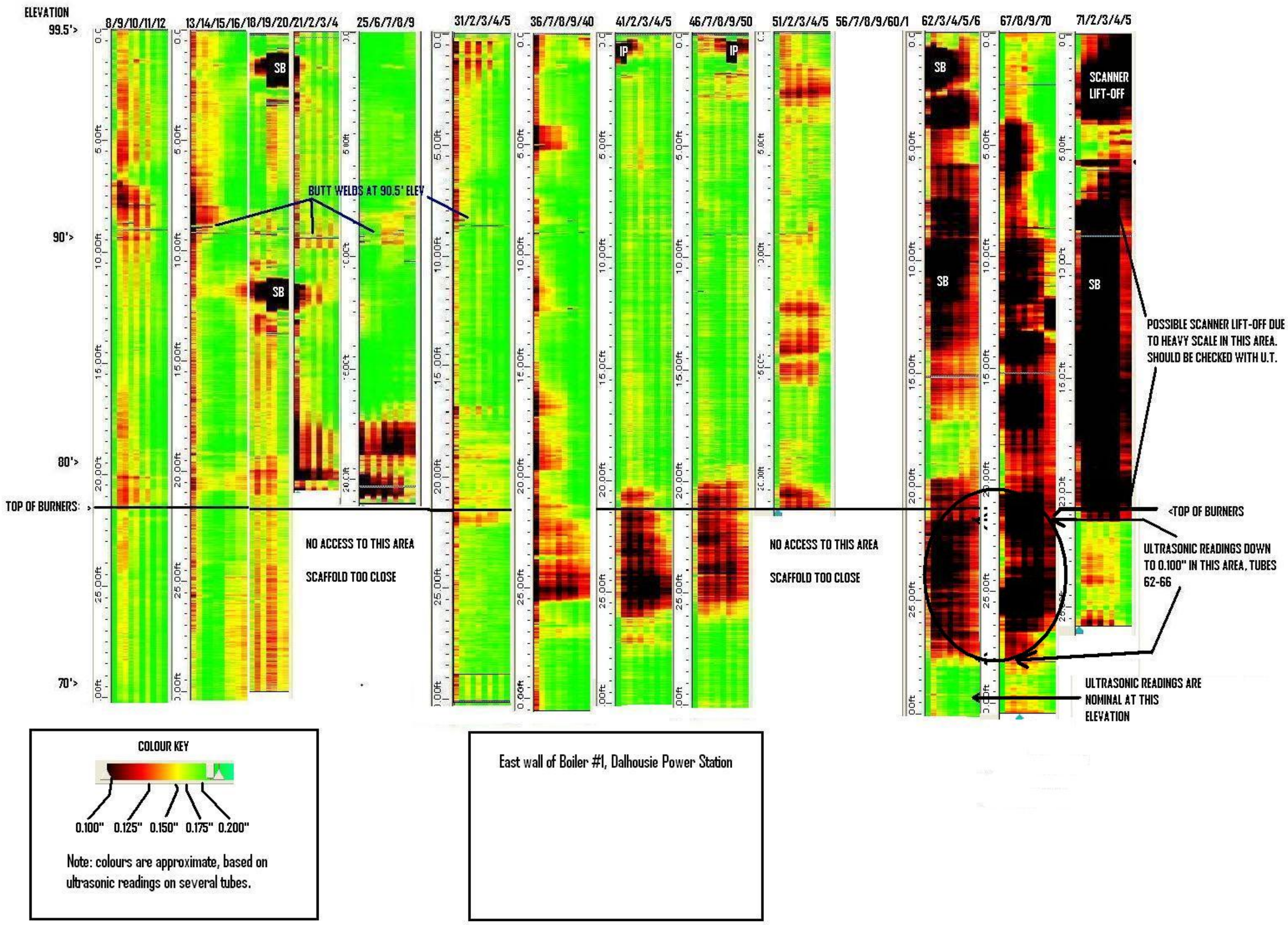

Figure 9: showing the water wall of boiler #1 (zoomed out). The area shown includes from elevation 70' (below burners) to elevation 99.5' (just below superheater tubes).
The dark area below the line showing the top of the burners was confirmed by ultrasonic readings to be 0.098" to 0.150" (black to yellow colours resp.). The dark area to the right (South corner) is due to heavy scale which lifted the scanner away from the wall. Individual tube numbers are shown at the top, and the distance scale and elevation is shown to the left.

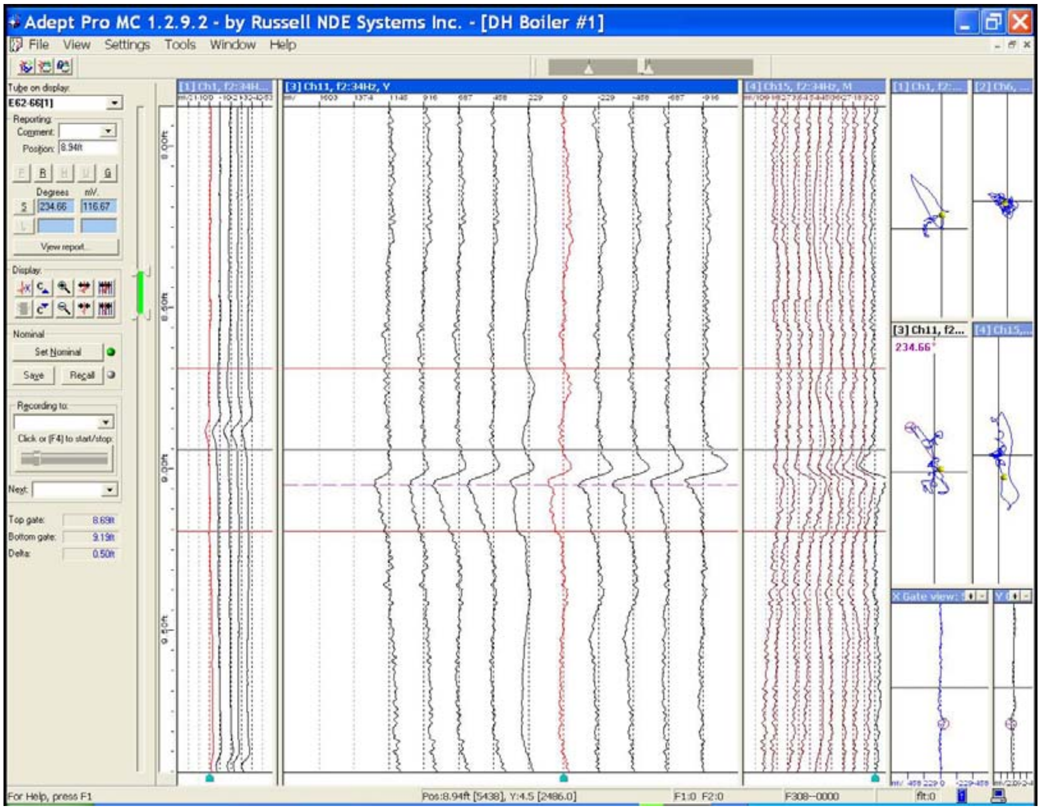

Figure 10: Butt Weld with possible loss below (east wall 62-66)

Figure 11: U.T. results of same tubes above (wall loss detected)

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