Automated Condition Assessment of Boiler Water Wall Tubes

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Abstract

Boiler tube failures continues to be the primary cause for forced outages in boilers. To get the boiler back on line and reduce (eliminate) future forced outages due to tube failure, it is extremely important to determine and correct the failure root cause. Detecting and sizing flaws before they cause failures is of critical importance in boiler maintenance. Localized and general wall thinning due to corrosion & erosion in boiler water-wall tubing is a significant inspection concern for boiler operators. There are at least four (4) other methods used for the inspection of Boiler Water walls. These methods are Spot Check UT, A-Scan UT, EMAT, and Scanning Thermography. 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. 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 together with the theoretical background of the technique which explains the quantitative nature of the inspection. Further, case studies will be presented for the technique that allows the extraction of tube wall thickness information from the inspection data.

Key Words: Electromagnetic Technique, Remote Field Technique, Robotic system for Boiler water wall tubes inspection, Vertiscan, Probe, Wall thinning.

Background of Remote Field Technology (RFT)

A branch of Electromagnetic Technique known as Remote Field Technique (RFT) 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 by 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).

![Diagram of Remote Field Testing](image)

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.

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).

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 5% of wall thickness for general wall loss. The accuracy is generally less 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.

**Figure 2:** 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: Inspection of Boiler tubes.](image)

**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 “60 m” height and tube sizes from “35 mm” to “100 mm”. Inspection speed is 3 meters/minute so an entire wall, “45 m” 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 “9 mm” of each web, using 12 detection coils for high precision (figure 4). Pits, as small as “3 mm” diameter, can be detected.

![Figure 3: Without Scaffolding](image)
Case Study 1-Deployment of VertiScan at the Power Generation Station, (this uses Orimulsion as fuel)

Figure 4: Heavy Scaling the Unit # 1 of Power Generation that uses 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 5): note that the crown is often scale free but the spaces between the tubes always have heavy scale.

![Figure 4: Heavy Scaling](image)

**Figure 5: Vertiscan System**

The VertiScan™ System was used to inspect water wall tubes of Unit #1. The system comprised of:

**TubeCAT™**
Magnetic crawler with odometer

**VertiScan™** probe for inspection of 5 tubes simultaneously

**E-PIT™** hand-scan probe for inspections of individual tubes
- **Ferroscope™** 308, 16 channel RFT instrument
- **Remote** vision system
- **“60 m”** umbilical
- **Industrial** Laptop

![Figure 5: Vertiscan](image)
Case Study 2 - Deployment of VertiScan at the Power Generation Station, (this uses Coal as fuel)

VertiScan system in Unit #2 of Power Generation that uses Coal as fuel. Followed high pressure water jet cleaning the scale deposition on the tubes and web in such boilers is better than Orimulsion fired boilers. Example on figure 6.

![VertiScan System in a coal fired boiler](image)

Figure 6: VertiScan System in a coal fired boiler

**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 (case study 1), the thinned area of tubes on one of the walls at the burner elevation was used to produce the following calibration curve (figure 7).

![Calibration Graph at F1](image)

Figure 7: Calibration Graph at F1

**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 8).
Confirmations

The Vertiscan inspection results were backed up using visual and ultrasonic inspection methods.  
Case Study 1: figure 9 and 10.  
Case Study 2: figure 11 and 12.

Summary

- The VertiScan System proved effective in identifying general wall loss and local thinning. Thinning was confirmed by ultrasonic thickness readings. Thermal Fatigue cracking was confirmed visually and MPI inspections.  
- The scaffold gap must be a minimum of “0.25 m” from the crown of the tubes for the VertiScan system to pass by  
- 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  
- Internal and External Pitting.

Figure 8: Showing the water wall of boiler #1 (zoomed out)
Figure 9: Butt Weld with possible loss below (east wall 62-66)  

Figure 10: U.T. results of same tubes above (Wall loss detected)

Figure 11: Thermal Fatigue cracking on tubes #  

Figure 12: Flame Side Erosion
References


