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On-line corrosion mapping of industrial plant using advanced electrical resistance techniques

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Abstract

Rowan Technologies Ltd, a UK based company, has recently developed a range of scanner systems for monitoring corrosion/erosion and thermal behaviour over small or large areas of plant. Data can be presented in the form of multi-dimensional plots. The systems are non-intrusive, using electrodes connected externally to the plant, and are maintenance-free at the monitoring location, allowing lifetime monitoring in potentially inaccessible areas.

The corrosion/erosion aspect of the system has evolved from the well-established electrical resistance technique for monitoring corrosion where thinning of a metal increases its measured electrical resistance. However, this measured resistance is also temperature dependent and the system has the ability to simultaneously measure temperatures and resistances to a high degree of accuracy, allowing this temperature dependency to be effectively nulled out (1). Corrosion, remaining thickness and time-to-replacement maps can be produced at intervals of a few weeks, depending upon the application.

The scanner has a range of applications, for example: boilers, incinerators, furnaces, storage tanks, pipelines and other industrial plant. This paper presents data from two corrosion and thermal scanner systems installed at AES Drax power station, UK, followed by an overview of a range of applications to which the scanner technology can be applied.

1. Introduction

Typical scanner systems use an array (or arrays) of simple and robust electrodes which are typically welded to the external surface of the item being monitored. These are maintenance free and so can be installed in areas which are normally inaccessible during normal operating conditions.

To monitor corrosion/erosion, electrical resistance measurements are made between pairs of adjacent measurements points using a four-wire measurement technique (2). These measurements are performed in sequence throughout the node array on a periodic basis together with associated temperature measurements. Having compensated for temperature variations, increases in measured resistance reflect the amount of corrosion taking place.

Relating changes in wall thickness with changes in resistance can be readily established experimentally and theoretically, enabling corrosion rates or remaining wall thickness to be quantified [3].

A dedicated computer-controlled logging system controls the scanning process and can be interfaced with plant control and information systems if desired. The systems are flexible and adaptable in nature - the design is such that single pairs of electrode connections can be monitored at different locations, or large arrays can be used containing anything up to 500 points.

2. AES Drax Power Station: A Case Study

AES Drax Power Station is the largest coal-fired station in Western Europe with six 660MW units. The boiler membrane walls are constructed from welded carbon steel tubes through which the heated water/steam passes. The tube walls directly exposed to the internal boiler conditions can, under certain conditions, be subject to considerable fireside corrosion. Furnace wall corrosion is known to result from reducing conditions with low oxygen, high carbon monoxide and hydrogen sulphide levels at the furnace tube walls. The attack is exacerbated by the presence of high chloride concentrations and elevated temperatures [4].

The first scanner system was installed on the Unit 4 boiler in 1999, Figure 1. This has been monitoring the condition of one of the sidewalls over the last three years. A second, much larger system, has recently been commissioned on the Unit 1 boiler and covers areas of both sidewalls which are susceptible to corrosion.

2.1 Unit 4 Corrosion/ Erosion Data

Unit 4 boiler was shut down for scheduled maintenance in July 2002. Ultrasonic/EMAT wall thickness measurements taken within the monitored area have now confirmed the wall thickness data acquired by the scanner system over the last three years. Typical corrosion rates, derived from scanner data, and remaining wall thickness maps are shown in Figures 2 and 3 respectively.

The area of the wall bounded by a dashed line (see maps) is weld overlayed with Inconel 625 alloy with the intention of reducing previously high corrosion rates. Corrosion rates in the weld overlay area were much lower than the adjacent exposed carbon steel which shows rates in excess of 60nm/hr (approx. 0.5 mm per year). The data gave confidence to AES staff over the materials performance of the Inconel 625 weld overlay installed on new carbon steel tubes; weld overlay has subsequently been installed on tubing in Unit 3.

Corrosion rates near the boiler corners were low, increasing towards the centre where wall temperatures were higher. The maximum rates were found to be associated with reducing conditions where carbon monoxide levels increased to levels greater than 7000 ppm. The unit had been fitted with low NO_x burners which effectively produce long thinner flames by the careful control of primary and secondary air. This results in reduced maximum

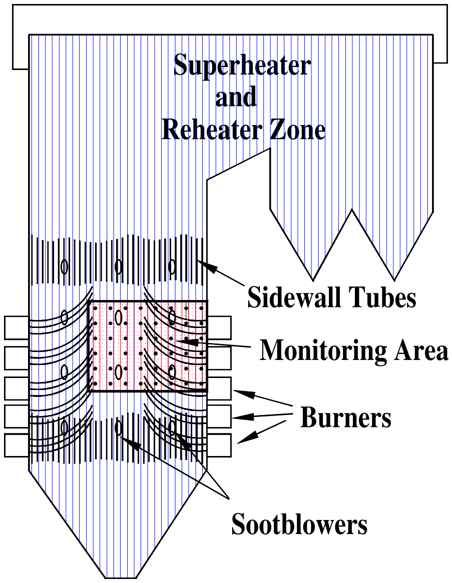
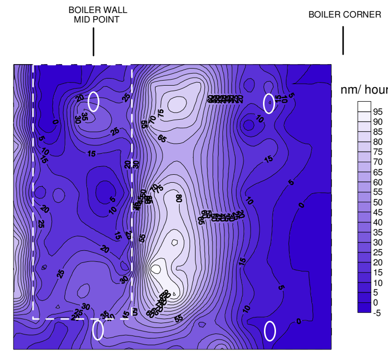
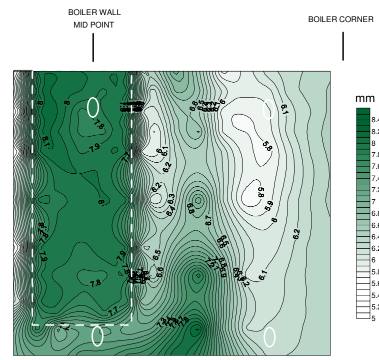


Figure 1: Schematic of the Electrode Array on Unit 4





Figures 2 and 3: Typical Corrosion Map (Top) and Remaining Thickness Map (Bottom)

temperatures for the flames, which minimises the production of nitrogen oxides. However, this also leads to areas of incomplete combustion and reducing conditions on the walls.

Information provided by these maps has previously only been obtainable during major boiler outages when ultrasonic/EMAT measurements of remaining wall thickness are made from within the boiler. The scanner system, however, provides this information (on-line) within a matter of weeks rather than years. The scanner has shown that high periods of corrosion are frequently transient, lasting a matter of only a few weeks before moving to another location. This justifies the use of a 2-dimensional scanner technique over the use of individual corrosion probes installed at fixed locations. These transient effects may be associated with flame chemistry where the proximity of the flame results in reducing conditions on the walls. Further work is underway to help understand the variations in corrosion activity.

Changes in remaining thickness over time in an area of high corrosion are shown in Figure 4. This trace is one of over 100 traces obtained throughout the array (these are combined to produce the 2-dimensional maps) and identifies periods when the corrosion rate has accelerated and subsided in this region. The scatter in the data, as seen on the trace, is principally due to spatial variations in temperature over the area where resistance measurements are being made - the resistance measurements encompass the whole area between adjacent nodes (typically 1.5 metres apart) whereas temperatures are measured at two individual points. Data is also logged during shutdown periods; this off-line isothermal data (where no heat flux is present) helps to verify the observed on-line corrosion trends.

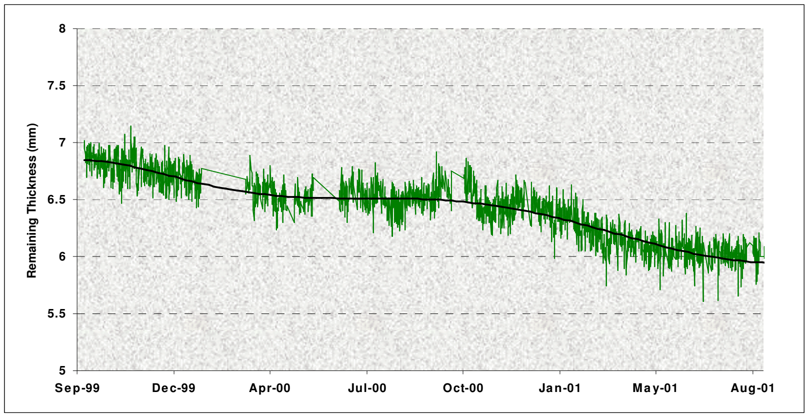


Figure 4: Typical Tube Wall Remaining Thickness Trace as a Function of Time (Area of Higher Corrosion)

2.2 The Newly - Commissioned Unit 1 System

A much larger scanner system has now been commissioned on the Unit 1 boiler at Drax. A schematic of the overall system layout is given in Figure 5. This latest system has 2 arrays each of 120 nodes to cover both sidewalls of the boiler. The system is controlled from a central location within the station, remote from the boiler. This boiler was recently fitted with low NO_x burners and the scanner system is monitoring the tube wall corrosion with these burner modifications in mind. Resistance measurements over the last few months have so far indicated that little corrosion has taken place throughout the monitored region. This boiler recently has been running with excess oxygen levels and this would almost certainly account for the lack of corrosion activity

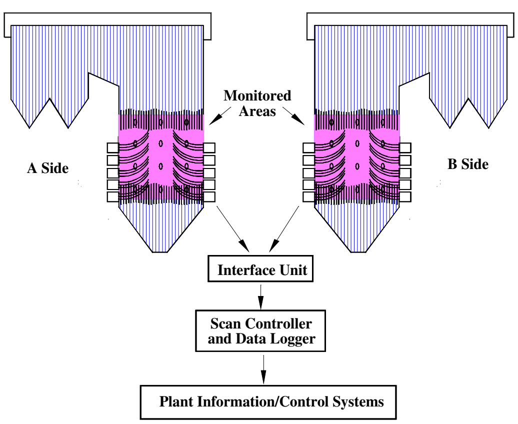


Figure 5: Schematic of the Unit 1 System

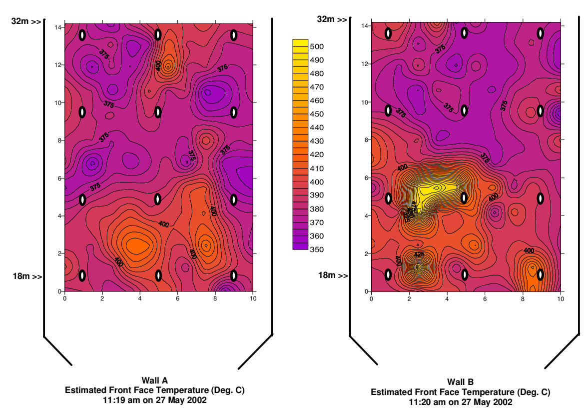


Figure 6: Examples of Unit 1 Sidewall Thermal Maps

Typical thermal maps from both sidewalls of Unit 1 are presented in Figure 6 and, although being of similar boiler type to Unit 4, exhibits different thermal behaviour. Note on Wall B the presence of a localised hot-spot resulting from possible flame impingement under a particular burner configuration. Such information is useful in helping to prevent tube integrity problems at a later date as a consequence of overheating of the tube material.

Thermal monitoring, as performed using these scanners, may soon be used to automate the tube wall cleaning processes on these boilers. Clear pictorial information, as given by these maps, is available in real time. This enables the boiler operators to see the immediate effect of changes in boiler operation on the wall's thermal performance, information valuable both for boiler efficiency and materials performance reasons.

3. Applications and Performance Criteria

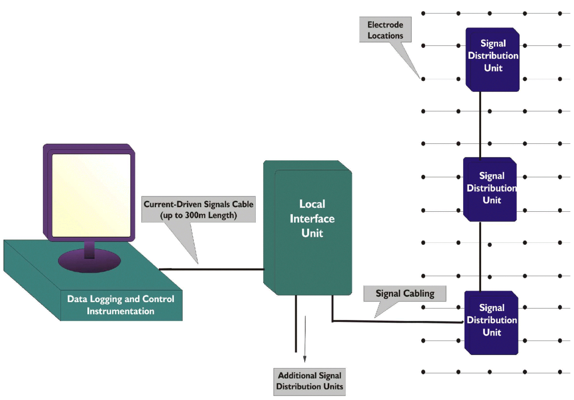


Figure 7: Typical Arrangement for a Large Permanent Installation

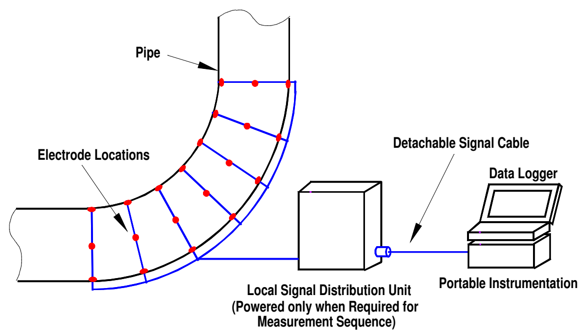


Figure 8: Example Application of a Portable System

The scanner systems are readily adaptable to suit individual requirements. Permanently installed systems are appropriate for large scale monitoring at frequent measurement intervals (e.g. at Drax). A typical layout for larger systems is shown in Figure 7.

The arrangement becomes simpler as the size of the monitoring task is reduced. For certain applications a portable system could be used e.g. on a pipeline in a hazardous area, Figure 8. In this application, the measurement electronics are connected and powered up when conditions are safe.

Rowan Technologies develops electrical resistance measurement systems that can resolve up to 50 ppm. However, the amount of corrosion these systems can detect depends on several factors. One of these factors is the percentage change in metal thickness: very small changes can be much more easily detected on, for example, thin membranes than for objects which are tens of millimetres thick.

Another important factor is the dependence of measured electrical resistance is temperature, and for perfect temperature compensation of resistance values, the mean metal temperature needs to be established. For thermally dynamic conditions (e.g. boiler walls) there will be a small degree of uncertainty in this mean temperature at any one point in time - statistical averaging then becomes important. For relatively isothermal conditions, temperature compensation becomes a simple process and averaging may not be necessary.

Using off-the-shelf scanner electronics, systems can detect roughly10 microns metal loss on a 3mm plate under laboratory conditions. Under the hostile and thermally dynamic conditions of a power station boiler about 50 micron metal loss on a 6mm tube wall can typically be detected once uncertainties in mean wall temperatures have averaged out.

Systems are usually adapted to suit the demands of the application. High precision electronic components are used; where ambient temperature variations are significant, more thermally-sensitive components are housed in a temperature controlled environment and, where required, comparative techniques are employed using suitable references.

4. Conclusions

Scanner systems are now available for use in the power generation, refinery, chemical and incineration industries. They are adaptable in size and measurement capability to suit the requirements of particular applications. They may be used in conjunction with large arrays, as may be required on boiler or reaction vessel walls, or smaller arrays for use on sections of pipe, weld junctions or other areas where localised corrosion may be prevalent. The systems allow corrosion/erosion activity to be closely monitored and on a continuous basis.

The scanners avoid the use of insert probes and associated entry ports and instead use the actual electrical conductivity of the plant as an in-situ sensor. This approach enables the integrity of plant components be readily evaluated, thereby enhancing reliability, availability and maintainability.

The scanner electrodes are simple and extremely robust, potentially allowing remote monitoring of a structure over its lifetime, without any requirement for maintenance or replacement at the monitoring location.

References

1. B. Robbins and D. Farrell, UK Patent App. No. 99200263.

2. D M Farrell and M J B Lee, 'Inspection and Monitoring of Fireside Corrosion in Coal Fired Boilers', UK Corr. 93 London, October 1993.

3. C J Davis, P J James and L W Pinder, 'Combustion Rig Studies of Fireside Corrosion in Coal Fired Boilers', Corrosion 97, New Orleans, Louisiana, USA, March 1997.

4. D M Farrell and B J Robbins, 'On-line Monitoring of Furnace Wall and Superheater Corrosion', CSS 98, 39th Corrosion Science Symp. Univ. of Northumbria, September 1998.