VTER Corrosion Probes – Overview and Applications

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Introduction

Rowan Technologies originally developed Variable Temperature Electrical Resistance (VTER) corrosion probes in the 1990s for use in on-line monitoring of furnace wall and superheater corrosion in power generation boilers. These probes are inserted through entry ports into the furnace void, they are air-cooled and have a corrosion element mounted at the probe end.

The corrosion element is typically made of the same material as the furnace tubes themselves, but may be fabricated from an alternative material that is being assessed for corrosion performance. A thermocouple, embedded within the element, is used as part of a feedback control system that uses cooling air to maintain the element at a pre-set temperature. Set-point temperatures are chosen either to simulate the real-world conditions of the tubes themselves or to examine the effect of different metal temperatures on corrosion rates.

A well-known four-wire electrical resistance technique is used to monitor thinning of the corrosion elements: as the element thins as a consequence of corrosion or erosion the measured resistance will increase. However, this resistance is also temperature-dependant and so thermocouples, embedded with the element, closely monitor the mean element temperature and this information is used to compensate the measured resistance for any small temperature fluctuations.

In this paper we explore some of the different probe designs and hardware configurations that have been developed and also some recent applications of this technology.

Design Overview

VTER probes are available that use either 'flush-fitting' or tubular corrosion elements. 'Flush-fitting' elements are usually used to simulate furnace wall tubing and are made from discs of the material under investigation. These are typically positioned flush, or in line with, the furnace wall.

Tubular elements, on the other hand, are typically used when simulation of superheater or reheater tubing is required. These protrude out from the tube wall and into the void of the furnace.

Flush-Fitting Element

Tubular Corrosion Element

The probe’s sensitivity to corrosion is principally determined by the thickness of the corrosion elements. Thin elements are more sensitive than thicker elements because the percentage loss in thickness (and hence change in measured resistance) is greater: for example, a 0.1mm metal loss from a 2mm element equates to a 5% change in thickness; the same metal loss from 1mm element equates to a 10% change, twice as much. Usually there is a trade-off between element thickness and probe life: a thicker element will last longer before requiring replacement, but may be less sensitive to short-term corrosion behaviour than a thinner element. Thus each installation is considered in a case-by-case basis to determine an optimum element thickness.

If the inner, or rear, face of the element is also likely to be susceptible to corrosion then a protective coating is applied to the back of flush-fitting elements, whilst tubular elements are fitted with a thin stainless steel liner.

To control the element temperature, a PID (proportional/integral/derivative) temperature controller is used together with a proportional (i.e. smoothly-varying) solenoid valve to precisely control cooling air flow to the element. By this method, the controlling thermocouple, embedded within the element, can be maintained to within very narrow temperature band (typically less than 1^0C).

Applications

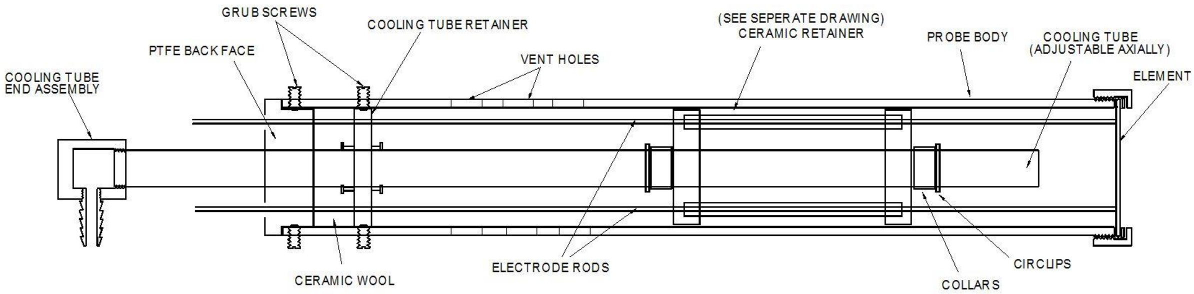
Combustion Trials – Alabama, USA

This research project was sponsored by EPRI (the US Electrical Power Research Institute): Rowan Technologies supplied a VTER monitoring system with flush fitting probes for trials within a combustion chamber at the Southern Research Institute (SRI), Birmingham, Alabama. The probes had 0.5mm thick corrosion elements to help maximise the probes sensitivity, and hence speed of response, to corrosion.

One of the aims of the project was to establish how quickly the probes could quantify rates of corrosion and to compare results with totally novel ideas that were being trialled at the institute.

Probe and Monitoring Instrumentation – SRI Combustion Trials

The 0.5mm elements were the thinnest that RTL has ever supplied. Fine thermocouples were attached to the rear of the elements and then a plasma coating was applied to prevent rear-side corrosion, so leaving only the front face exposed. A schematic of the probe's cross section is shown below:

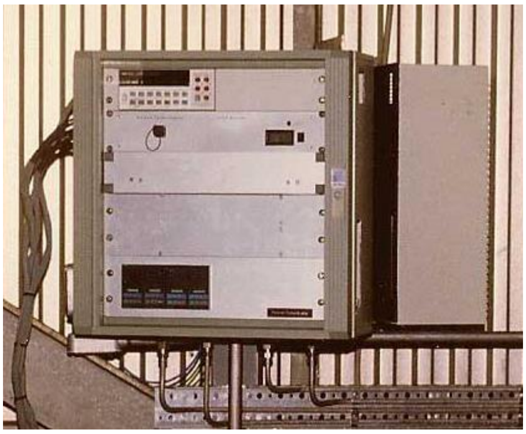


Within the probe bodies a central cooling tube is installed that directs air on to the rear face of the corrosion elements. Measurement electrodes and thermocouples run the entire length of the probe body and emerge at the rear.

Black Liquor Boiler – South Carolina, USA

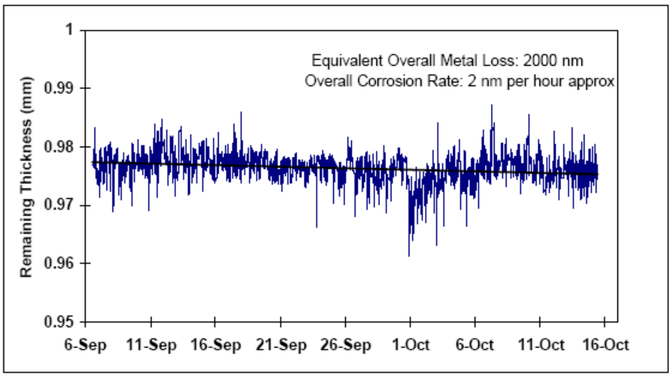
For these boiler trials, two tubular VTER probes were supplied to a customer in South Carolina to help assess the corrosion performance of the tube alloy T11, used in boiler construction, under different operating temperatures and under differing boiler operating regimes.

The T11 corrosion elements, manufactured directly from boiler tubing, were supplied 1mm in thickness and had a 0.5mm stainless steel liner that was welded to the element ends to prevent internal corrosion. Data from the probes was stored locally using a small data logger installed within the instrument cabinet and this data was retrieved at regular intervals for analysis.

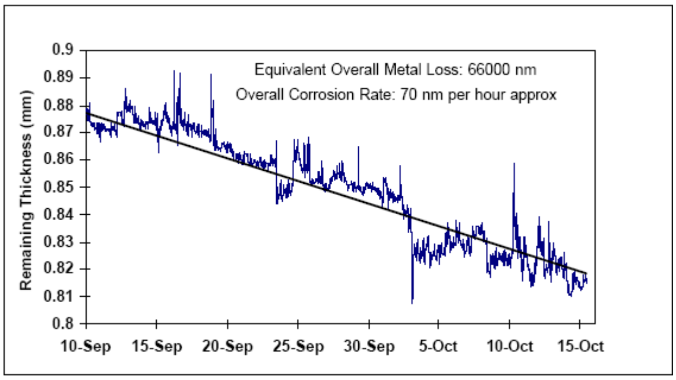


VTER Instrument Cabinet and Probe – Black Liquor Boiler Trials

To assess the effect of metal temperature on corrosion rates, the two probes were set at differing set point temperatures. Examples of the resulting corrosion data is shown below:



580°C Set Point Temperature



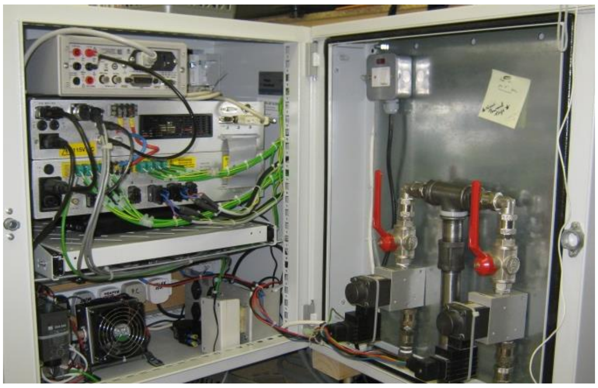
650°C Set Point Temperature

This data was acquired over an approximate 40-day period and graphs show the very obvious effect of increased metal temperature on measured corrosion rate. Note that small deviations (mostly small spikes) in the data are due to exfoliation of deposits from the probes – exfoliation temporarily exposes small areas of the corrosion element to higher temperatures until deposits reform once more and sometimes these localized events cannot be fully compensated for during data processing.

Biomass Trials – Europe

Drax power station, UK, has six 660MW sub-critical boilers. The plant is in the process of converting some of these units from coal-fired operation to biomass. At the start of this conversion process two tubular VTER probes, with 1mm thick elements, together with associated electronics, were supplied to the plant to help investigate the effects of burning different types of biofuel on corrosion of superheater tubing.

The results of these trials are confidential, however we are able to report that variations in corrosion rates with differing biomass fuels were significant and were readily quantified using the VTER probes.



VTER Instrument Cabinet and Probes used for the Biomass Trials

Drax has now installed more than ten tubular VTER probes in three of its boilers for continuous on-line monitoring. These probes have 2mm thick elements, some with stainless steel liners where required. The probes are designed to monitor corrosion of the superheater and reheater tubing at the top of each boiler.

These particular probes have been interfaced with RTL's scanner systems installed on the same units. Data from the VTER probes is fed back to the same data loggers that store the scanner's information. RTL has a remote internet connection to these loggers, allowing close, continuous monitoring of these systems.

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