PowerPlant Chemistry® **The Journal of All Power Plant Chemistry Areas**

International Edition **ISSN 1438-5325** **December** **Volume 6 (2004), No. 12**

Abstracts

R. Barry Dooley and Richard Tilley
Tube Failures in Conventional Fossil Fired Boilers and in Combined Cycle/HRSGs

Boiler tube failures (BTFs) in conventional fossil plants can be beaten by a comprehensive management-supported Boiler Tube Failure Reduction Program/Cycle Chemistry Improvement Program. Case study results are included to illustrate the superb results that have emanated from six organizations. HRSG tube failures (HTFs) are also the leading cause of availability loss in combined cycle units. The primary failure mechanisms are thermal- and creep-fatigue, and flow-accelerated corrosion (FAC). In the HRSG there is an opportunity to avoid these HTFs by incorporating the known avoidance factors in the design, and by conducting thermal and chemical monitoring early in the life of the HRSG. For both BTF and HTF, the optimum approaches to alleviation are included.

International Conference
Boiler Tube and HRSG Tube Failures and Inspections

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Digby D. Macdonald
Stress Corrosion Cracking in Reactor Coolant Circuits – An Electrochemist's Viewpoint

Extensive work over the past hundred years has shown that the stress corrosion cracking of metals and alloys in aqueous environments is primarily an electrochemical phenomenon falling within the realm of the differential aeration hypothesis. An important feature of the differential aeration hypothesis is that the local anode and the local cathode are spatially separated, with the former existing within the crack enclave (on the crack flanks and at the crack tip) and the latter existing on the bold, external surfaces. Because of the need to compensate the positive charge being deposited into the crack enclave from metal dissolution, anions (e.g., Cl^-) are transported into the crack, a process that is manifest as a positive current flowing from the crack to the external surfaces, where it is consumed by hydrogen ion, water, and/or oxygen reduction. Thus, strong electrochemical coupling exists between the crack internal and external surfaces and this coupling has been observed in stress corrosion cracking in a variety of

systems, including intergranular stress corrosion cracking (IGSCC) in sensitized Type 304 SS in simulated boiling water reactor coolant environments at 288 °C, IGSCC in the same sensitized alloy in thiosulfate solutions at ambient temperature, and caustic cracking in AISI 4340 high strength steel at 70 °C. Examination of this "coupling current," which is easily measured experimentally using a sensitive zero resistance ammeter, shows that it contains "structured" noise superimposed upon a mean. In the case of the sensitized stainless steel in the high temperature aqueous environment, the mean current is found to be linearly related to the crack propagation rate and, indeed, the measurement of the coupling current may provide a sensitive method of measuring crack growth rate. Furthermore, the noise in the current is found to yield a wealth of information on the fracture events that occur at the crack tip, including their frequency, temporal relationship with other events, and size. This information has provided a clearer view of the fracture mechanisms, which in all three cases (IGSCC in sensitized stainless steel in BWR environments and in thiosulfate solution and caustic cracking in AISI 4340) appear to involve brittle microfracture events of a few micrometers to a few tens of micrometers in size. These data are more consistent with hydrogen-induced fracture than they are with a slip/dissolution mechanism, even when the external environment is oxidizing in nature. Finally, this improved understanding of IGSCC in high temperature aqueous systems has led to a more complete assessment of the viability of various electrochemical methods for controlling and mitigating IGSCC in sensitized Type 304 SS in the primary coolant circuits of boiling water reactors.

Stefan Ritter and Hans-Peter Seifert

The Effect of Chloride and Sulfate Transients on the Stress Corrosion Cracking Behavior of Low-Alloy Reactor Pressure Vessel Steels under Simulated BWR Environment

The adequacy and conservative character of the Boiling Water Reactor (BWR) Vessel and Internals Project (BWRVIP-60) stress corrosion cracking (SCC) Disposition Lines during and after water chemistry transients were evaluated and assessed in the context of the current Electric Power Research Institute (EPRI) BWR water chemistry guidelines. For this purpose, the SCC behavior of three nuclear grade low-alloy reactor pressure vessel steels during and after sulfate and chloride transients was investigated under simulated BWR power operation conditions by tests with periodical partial unloading (PPU) and experiments under constant load. Modern high-temperature water loops, on-line crack growth monitoring with direct current electrical potential drop measurement and fractographical analysis by scanning electron microscope were used to quantify the cracking response.

In oxygenated, high-temperature water (T = 288 °C, 8 mg · kg^{-1} dissolved oxygen), the addition of 370 µg · kg^{-1} sulfate (> EPRI Action Level 3) did not result in acceleration of crack growth under PPU and constant load in all materials, and the SCC crack growth rates (CGRs) under constant load during sulfate transients were conservatively covered by the BWRVIP-60 Disposition Line 2. The addition of 10 µg · kg^{-1} (≥ EPRI Action Level 1) to 50 µg · kg^{-1} chloride (≥ EPRI Action Level 2) resulted in acceleration of the SCC CGRs in all investigated materials by at least one order of magnitude and in fast, stationary SCC under constant load in the investigated stress intensity factor range K_I from 32 to 62 MPa · $m^{1/2}$ with CGRs significantly above the BWRVIP-60 Disposition Line 2. In some cases stable, stationary SCC with CGRs above the BWRVIP-60 Disposition Line 2 could be sustained after severe (≥ EPRI Action Level 2) and prolonged chloride transients for much longer periods (> 1 000 h) than the 100 h interval suggested by BWRVIP-60.

Matthias Meierer and Norbert Eimer

Corrosion Damage on the Stack of Unit 4/Boiler 15 of Grosskraftwerk Mannheim AG

The subject matter of this report is unexpected corrosion damage which was detected on the double-shell steel stack of Unit 4 of the Grosskraftwerk Mannheim AG power plant. Unit 4 is a hard-coal-fired supercritical cogeneration unit with an output of 220 MW. The flue-gas cleaning system consists of an electrostatic precipitator, a wet flue-gas desulfurization system (limestone/gypsum process), and an SCR DeNOx system in a tail-end arrangement. Unit 4 went online in 1970. The FGD and DeNOx systems were retrofitted in 1988.

The unexpected corrosion damage and its causes are described in detail. The basic options for rehabilitating the stack are presented, compared, and evaluated. The rehabilitation measures performed on the facility are described. The aspects of time frame, operational conditions, rehabilitation work on the inner and outer tubes, statics and construction, installation and quality control are explained in detail.

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