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An investigation into the likely impact of oxy-coal retrofit on fire-side corrosion behavior in utility boilers

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1. Introduction

Real-time electrochemical measurements of corrosion rate were performed to evaluate the respective corrosion rates of one boiler waterwall material (SA210) and three boiler superheater materials (T22, P91 and 347H) while firing Utah Western bituminous, Illinois high-sulfur bituminous and Powder River Basin (PRB) sub-bituminous coals in a 1.5 MW pulverized coal-fired furnace. The raw average measured corrosion rates were very low, between 0.0003 and 0.016 mm/year (0.012 and 0.63 mils/year) for most materials under air- and oxy-fired conditions. For some high-sulfur conditions measured corrosion rates were as high as 0.72 mm/yr (28 mils/year). Waterwall corrosion rates decreased consistently when converting from air- to oxy-firing while superheater corrosion rates generally increased, although they were less than twice the air-fired rate under most conditions. Corrosion rates for the lower alloyed materials (SA210 and T22) increased significantly during transients from reducing to oxidizing conditions. Measured increases in the corrosion rate of 347H material under high sulfur and low temperature conditions, and associated decrease in corrosion rate at higher temperatures on this alloy, were consistent with the formation of trisulphates in the superheater deposits. The increase of corrosion rate with increased metal temperatures was demonstrated, as was the consistently repeatable nature of the observed results.

2. Experimental

In order to obtain a real-time indication of corrosion, a measurement system based on electrochemical noise (EN) sensing was utilized. For this program, one waterwall material and three superheater tube materials were chosen that are typical of those used in US utility boilers. The waterwall and superheater sensors differ in physical construction. The sensor elements of the waterwall probe were constructed from the SA210 material and were located at the tip of the probe on a face orthogonal to the probe axis. When installed in a furnace the probe was positioned so that the

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elements of the probe were in the same plane as the wall of the furnace. This configuration positions the corroding surface of the sensor elements as if they are a waterwall tube. The elements of the superheater probe were rings fabricated from actual boiler tube, i.e. they were fabricated from commercial T22, P91 and 347H tubes. The corrosion surface of these elements retained the tube manufacturers' factory finish. These elements were mounted at the end of a long, cooled stainless steel lance. When inserted into the furnace, the orientation of the sensor elements is that of a tube in cross flow, just like a superheater tube in a utility boiler. The corrosion sensor probe and furnace configuration for these tests is presented in Figure 1.

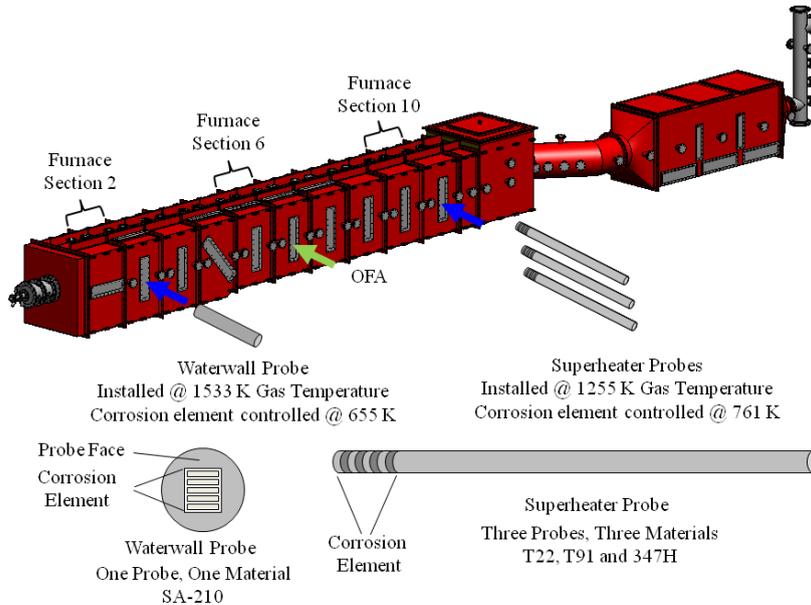


Figure 1. Corrosion sensor probe configuration

The sensor elements of the waterwall probe typically were maintained at 655 K and the probe was installed in section 2 of the L1500 with gas temperatures about 1533 K. The sensor elements on the superheater probes typically were controlled at 761 K and were installed in a location where the gas temperature was approximately 1255 K. To target this gas temperature the superheater probes were installed in section 10 of the L1500. For all fire-side corrosion tests, the firing rate was 1.03 MW. For the majority of these tests, the burner was staged with a stoichiometric ratio of 0.9. The overall stoichiometric ratio was sufficient to produce 3.0% O₂ (dry) in the flue gas, dependent on air or oxy-fired conditions. The overfire air was introduced in section 6 of the furnace. These operating conditions are referred to as the baseline conditions for this study.

3. Key Results

Over a period of six weeks of furnace operation, extensive measurements of the corrosion rates for each of the materials were performed at baseline conditions. These data were evaluated during windows of time where the furnace and probes were operating stably at the desired conditions. All of the data from these windows of operation were reduced to an average corrosion rate for every combination of material, coal and firing condition. The average corrosion rates measured for the baseline conditions are presented in Figure 2. The raw average measured corrosion rates were very low, between 0.0003 and 0.016 mm/year (0.012 and 0.63 mils/year) for most conditions. The

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corrosion rates were higher for the T22 material while air- and oxy-firing Utah and Illinois coals and for the 347H material when oxy-firing Illinois coal; and were in the range of 0.21 to 0.72 mm/yr (8.3 to 28.3 mils/year). These corrosion rates assume that the loss of material had occurred evenly over the entire sensor element. Actual peak corrosion rates would be expected to be on the order of 3 times higher.

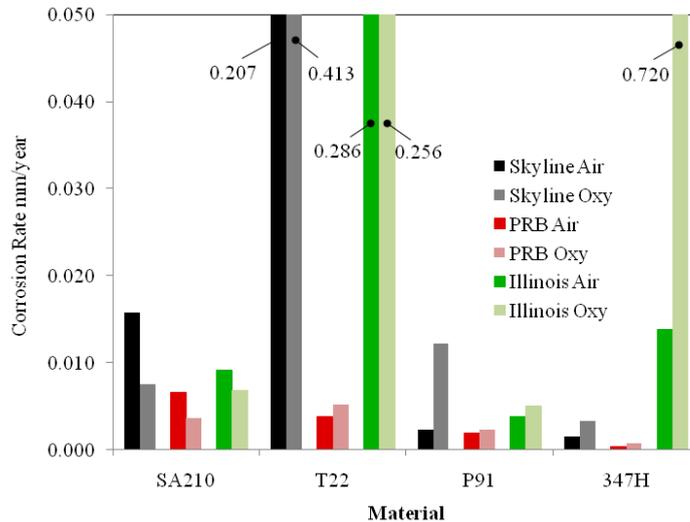


Figure 2. Summary of average corrosion rates for the baseline conditions

Waterwall (SA210) corrosion rates consistently decreased when converting from air- to oxy-firing for all coals. An expected decrease in the rate of corrosion attack on these heat transfer surfaces when retrofitting for oxy-combustion could be a facilitating result for the technology. Superheater corrosion rates increased when converting from air- to oxy-firing for all conditions with the exception of the T22 material when firing Illinois coal. During these tests, the flue gas environment was sub-stoichiometric for the waterwall probes and super-stoichiometric for the superheater probes. The increase in superheater corrosion rate when comparing the oxy-fired condition with the air-fired condition was generally very small (double or less) with the exception of the P91 material with Utah coal (5.2 times higher) and 347H material with Illinois coal (52.2 times higher).

Corrosion rates for the lower alloyed materials (SA210 and T22) were shown to increase significantly during transients from reducing to oxidizing conditions when air-firing, and from oxidizing to reducing conditions when oxy-firing. Such transients are likely to contribute greatly to practical in-plant corrosion rates in the near-burner and near-OFA port regions. These effects cannot be resolved using coupon tests.

Measured increases in the corrosion rate of 347H material under high sulfur and low temperature conditions was consistent with the presence of trisulphate deposits on the superheater probes. The increase in corrosion rates with increased probe material temperatures was demonstrated as was the consistently repeatable nature of the results.

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