High Temperature Electrochemical Sensors for In-situ Corrosion Monitoring in Coal-Based Power Generation Boilers

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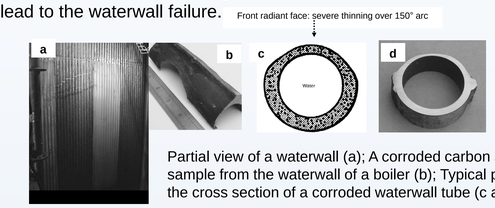
♦ Abstract

Based on our previous work and current industrial techs, a sensor system for high temperature corrosion were designed and tested in the lab. The methods like electrochemical and electrical tests, as well as surface analysis, were involved. Meanwhile, an effort to test this sensor system in actual coal-based boilers were conducted.

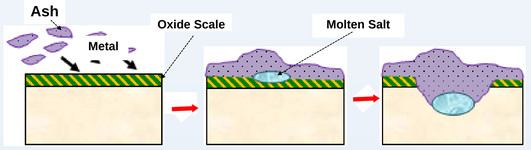
♦ Introduction

1. The corrosion of fireside surface in boiler could cause the loss of tubing materials and mechanic properties; meanwhile the deposit of corrosion product could cause a localized temperature increase. Thus, the tube fatigue and crack initiate and eventually lead to the waterwall failure.



Partial view of a waterwall (a); A corroded carbon steel tube sample from the waterwall of a boiler (b); Typical profile of the cross section of a corroded waterwall tube (c and d). [1]

2. Fly ash and molten salt corrosion



♦Objective

This project aims to develop and test a corrosion sensors system to monitor the high temperature corrosion in coal-based boiler system.

♦Planned tasks & deliverables

ID	Task	Year 1				Year 2				Year 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Project management	♦											
2	Sensor development & optimization												
2.1	Design & construct sensors												
2.2	Sensor packaging												
3	Signal processing & communication instruments												
4	Corrosion sensor testing @ Longview Power's boiler												
4.1	Sensor placement and installation												
4.2	Sensor testing					♦							
4.3	Post-mortem analyses												
5	Corrosion monitoring software & database development												
5.1	Lab-scale sensor optimization												
5.2	Electrochemical and corrosion monitoring validation												
5.3	Post-mortem analysis												
5.4	Database and predictive model development												
5.5	Software development								♦				
6	Tech-transfer & commercialization												
6.1	NPV model & uncertainty analysis							♦					
6.2	NEMS model and economic analysis												♦
6.3	Commercialization pathway development												♦

- Y1-Q1, finish updating PMP
- Y1-Q4, demonstrate the high temperature corrosion sensor can withstand the harsh environment in Longview's A-USC boiler.
- Y2-Q2, complete the NPV model and uncertainty analysis
- Y2-Q4, complete the electrochemical and corrosion database and model construction
- Y3-Q2, complete the NEMS model and economic analysis

♦ Contact information

Welcome to any discussion and further communication

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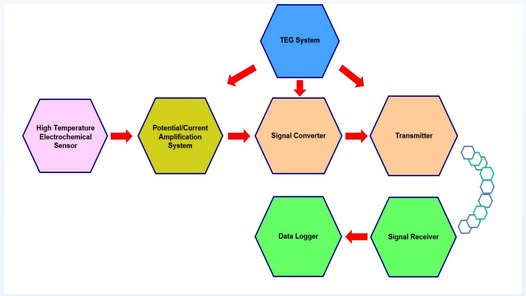
♦ Basics and Approach

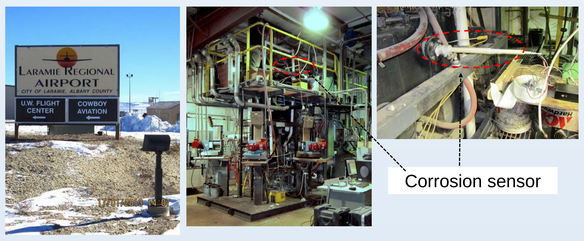
- Methods
  - Electrochemistry
    - ECN: Electrochemical noise; giving the fluctuations of potential and current between same material
    - EIS: Electrochemical impedance spectroscopy; for both mechanism study and estimating corrosion rate
  - Electrics
    - ER: Electrical resistance; based on the fact that the reduction of coupon materials occur with an increase in the electrical resistance;
  - Surface analysis
    - SEM: scanning electron microscope
    - EDS: Energy-dispersive X-ray spec.
    - 3D optical microscope



Conceptual Design of the Self-Powered HT Corrosion Sensor System

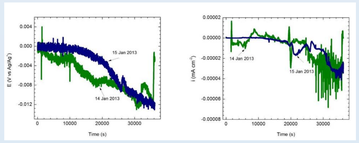
♦ Our previous work

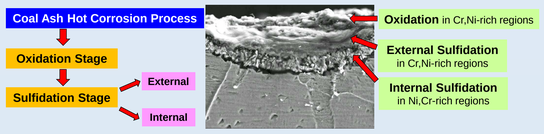
Funded by DoE-Coal Utilization Science Program (2010-2015), we previously developed an electrochemical sensor system for corrosion monitoring in high temperature range (>=750 °C).



Sensor tests conducted in Industrial USC Boiler in Western Research Institute, Laramie WY

Corrosion potential and current signals based on in-situ corrosion sensor testing @ WRI.

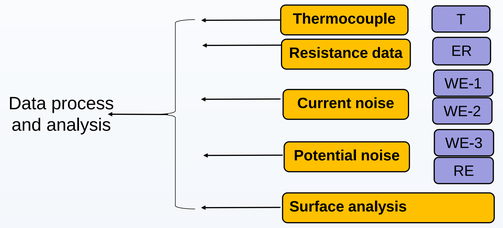


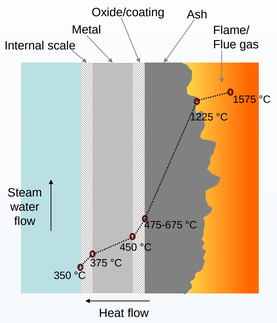


The sensors were based on our patented technology [2], and has been successfully tested in Western Research Institute's Combustion Testing Facility. More detail could be seen in our technical report and peer-reviewed papers [3–7].

♦ Research progress

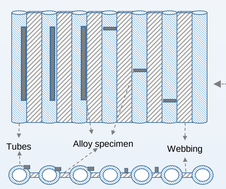
Schematic diagram of WVU high temperature corrosion sensor

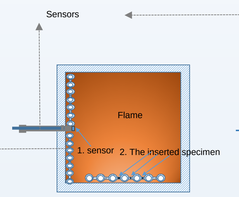




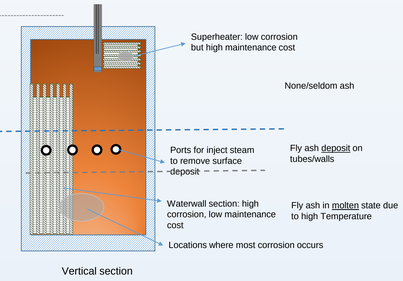
Temperature gradients through the waterwall tube[1]

a. Modules of the sensor system : sensor probe, cooling system, signal saving/transfer, etc.
b. Two key techs: ECN provide info on corrosion type, while ER changes could reflect the direct materials lose.

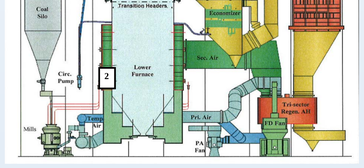




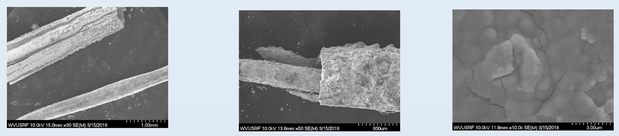
Cross section of boilers



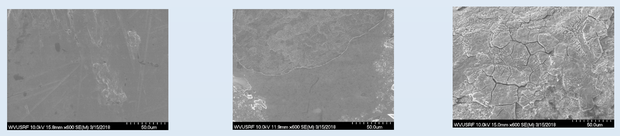
Vertical section



Sketch of Longview Power Boiler showing proposed sensor placement: (1) Superheater (SH) Tubes; and (2) Water Wall



ER steel wire in fly ash with $ZnCl_2$ at 450 °C



Metal coupon in air at 450 °C

Metal coupon in fly ash air at 450 °C

Metal coupon in fly ash with $ZnCl_2$ at 450 °C

♦ Summary

Our previous work and the scientifically feasible principle allow us to develop the insitu sensor for intermedium temperature corrosion. Our work plan mainly includes serval key stages: sensor designing and lab testing, packaging and onsite testing.

♦ References

[1]. High-Temperature Corrosion And Materials Applications. George Y. Lai, editor, p259-320, DOI: 10.1361/hcma2007p259
[2] J. Xu, X. Liu, Y. Jiang, F. Goodwin, 2012, US patent: US8173007B2.
[3] N.N. Aung, X. Liu, Corros. Sci. 65 (2012) 1–4.
[4] N.N. Aung, X. Liu, Corros. Sci. 76 (2013) 390–402.
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[7] X. Liu, Technical Report, 2015. doi:10.2172/1312516.

♦ Acknowledgements

DoE Award No. DE-FE5717
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Bob Romanosky, Susan Maley, Chuck Miller etc.
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Cross-cutting Program: Briggs White, Sidni CJessica Mullen
Current Team: WVU (Debangsu Bhattacharyya, Trina Wafle), Aspinity (Brandon Rumberg), Longview (Chad Hufnagel)