Characterization of Oxy-combustion Impacts in Existing Coal-fired Boilers

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For Energy and Environmental Solutions

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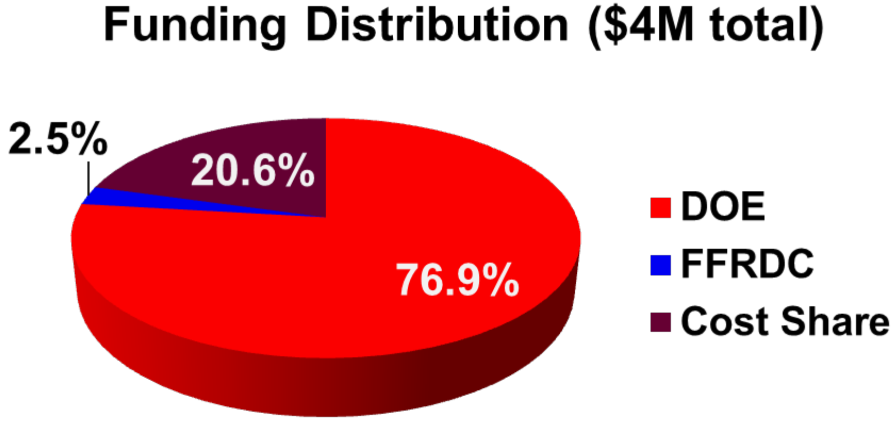
Presentation Outline

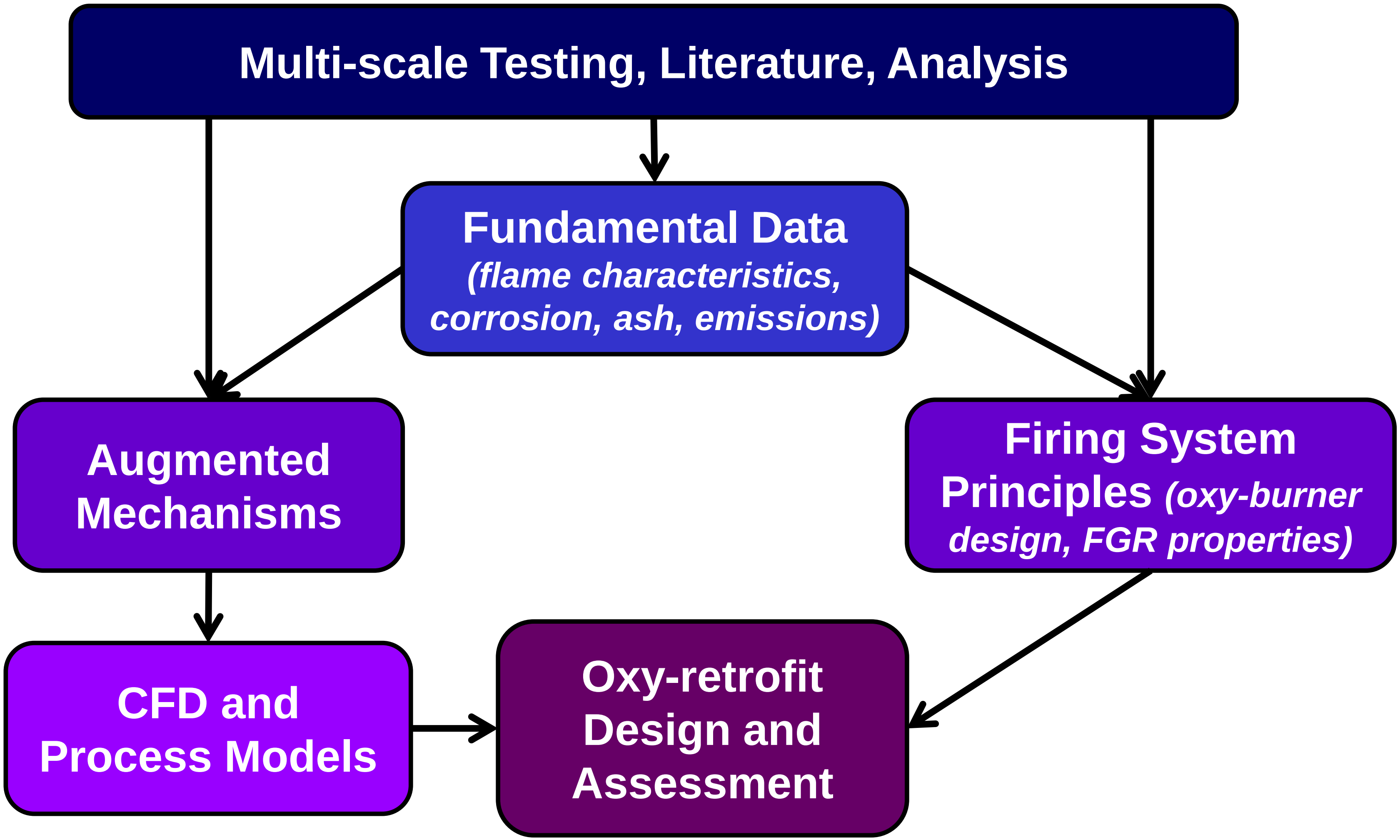
- **Project Overview**
- **Summarize Previous Work**
- **Introduce Current Work**
- **Preliminary Testing Results**
  - **Bench-scale Mercury Measurements**
  - **Pilot-scale Mercury Measurements**
  - **Pilot-scale Corrosion Measurements**
- **Project Status Summary**

Project Overview

- **<u>Objective</u>**: ***Characterize and predict performance and operational impacts of oxy-combustion retrofit designs on existing coal-fired boilers***
- **<u>Schedule</u>: 10/1/08 – 9/30/13 (includes 1-yr extension)**
- **<u>Program Managers</u>: Timothy Fout, Andrew Jones**
- **<u>Budget</u>: $4M total**



Project Approach



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Project Team

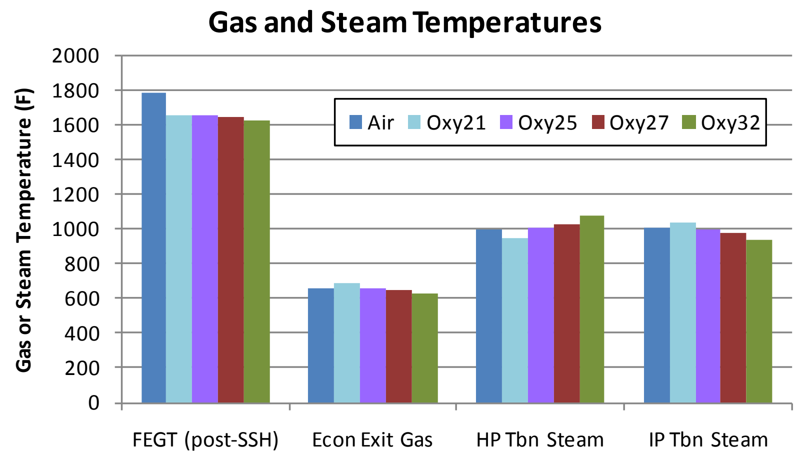
Team Members	Project Role
REI	*program management, testing oversight, mechanism development, simulations*
University of Utah	*laboratory and pilot-scale testing, mechanism development*
Siemens Energy	*burner technology, firing system design*
Praxair	*oxygen and CO_2 supply*
Brigham Young Univ.	*soot measurements*
Corrosion Management	*corrosion tests, mechanism development*
Sandia National Labs	*bench-scale testing, mechanism development*
Vattenfall AB	*mechanism development, validation data*
DTE, PacifiCorp, Praxair, Southern Company, Vattenfall	*Advisory Panel provides industrial perspective on R&D needs, retrofit requirements and constraints, suggested assessment studies*

Previous Work

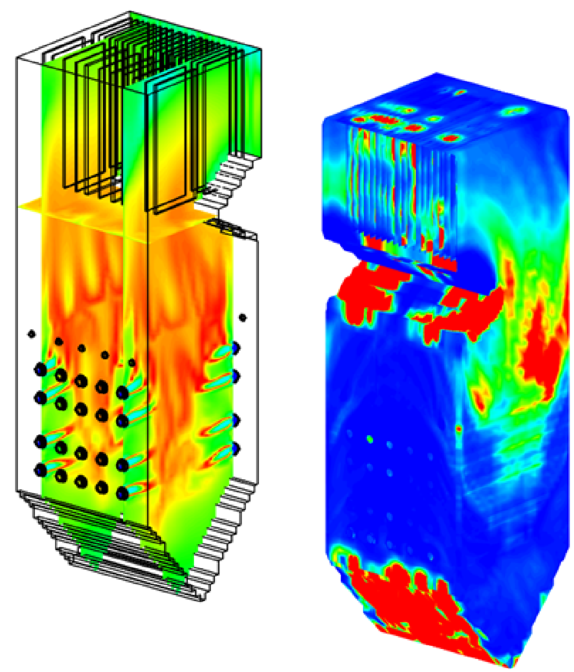
- Testing at bench- and pilot-scales
  - Ignition & flame attachment
  - Char oxidation
  - NOx, SOx, Hg
  - Soot
  - Heat flux profiles
  - Fine particulates / ash aerosols
  - Ash chemistry
  - Waterwall and superheat tube corrosion
- Impacts of oxy-coal burner design and recycle gas properties

Previous Work

- **Mechanism refinement**
  - Slagging / fouling
  - Char oxidation
  - Soot
  - Gas radiation
  - Corrosion



- **Two full-scale oxy-retrofit assessments**
  - Firing-system design
  - CFD & process modeling of combustion, heat transfer, steam properties, deposition, corrosion, emissions
- **Technology Transfer - 45 conference presentations, posters, journal articles and book chapters (to date)**



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Previous Work – Key Results

- **Firing System and Oxy-combustion Burner**
  - Oxy-combustion flame can be designed similar to air-fired flame
  - Oxygen and FGR provide additional degree of freedom
  - ~25-26% oxygen gives reasonable match to air-fired heat transfer
  - FGR properties impact overall heat transfer
  - Reduced flue gas flow may require convective pass adjustments
- **Operational Impacts**
  - Slagging behavior and ash properties similar to air-firing
  - Corrosion similar unless recycle creates high SO_2 and H_2O levels
- **Emissions**
  - Lower NOx, potentially higher SO_2, soot more dependent on burner SR, enhanced char oxidation (lower LOI)
- **No combustion show-stoppers for retrofit**

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Current Work (1-yr extension)

Motivation: Mercury may amalgamate with aluminum surfaces in oxy-combustion flue gas processing units

1) **Determine accuracy of different mercury measurement methods for air and oxy-combustion firing (bench-scale)**
2) **Measure impact of oxy-combustion on performance of mercury control technologies (pilot-scale)**
   - **Bromine boiler additive**
   - **Activated carbon injection**
3) **Measure corrosion impacts of bromine addition under air and oxy-firing conditions (pilot-scale)**
4) **Model mercury emissions and control in oxy-retrofit plants**

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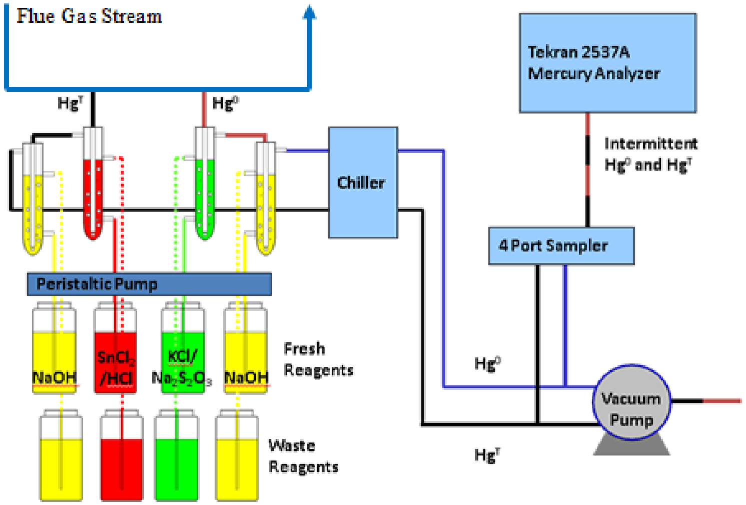
Bench-Scale Measurements

- Objective: Assess potential for mercury measurement bias under different flue gas environment
  - Previous studies have shown possibility for CO_2 absorption in highly concentrated NaOH solution in measurement conditioning systems
- Approach
  - Simulate flue gas with Hg calibration gas generator
  - Assess three Hg measurement techniques
    - Tekran CEM with wet conditioning system (two NaOH solutions)
    - Modified method 30B sorbent traps
    - OL CEM w/ thermo-catalytic conversion
  - Compare elemental and oxidized Hg measurements for different methods



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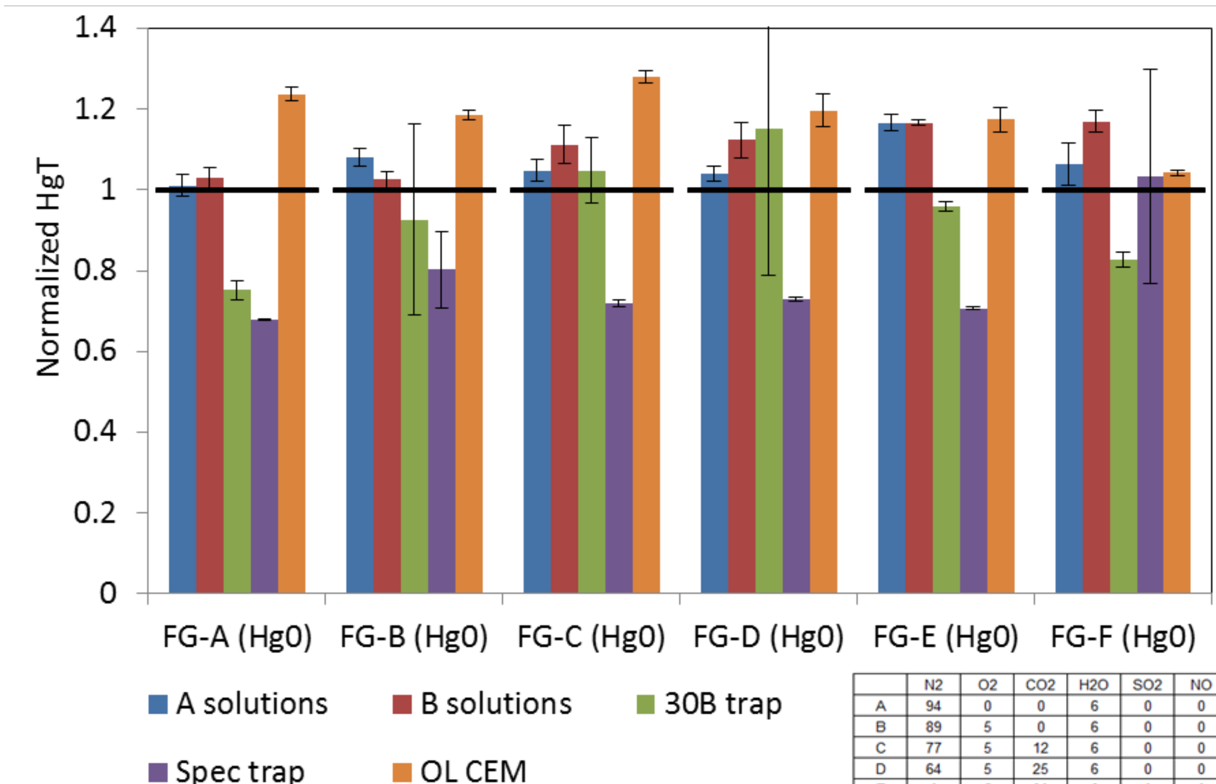
Bench-scale Summary
(PRB coal)

- **Wet conditioning system and OL CEM gave reasonable results**
- **Speciating carbon traps gave low mercury measurements**
- **Results with "B" solutions (highest NaOH concentrations) increased slightly with higher CO_2 concentration, but similar to data scatter**

Overall, no clear Hg measurement bias in high CO_2 environments was noted



	N2	O2	CO2	H2O	SO2	NO
A	94	0	0	6	0	0
B	89	5	0	6	0	0
C	77	5	12	6	0	0
D	64	5	25	6	0	0
E	9	5	80	6	0	0
F	9	5	80	6	420	200

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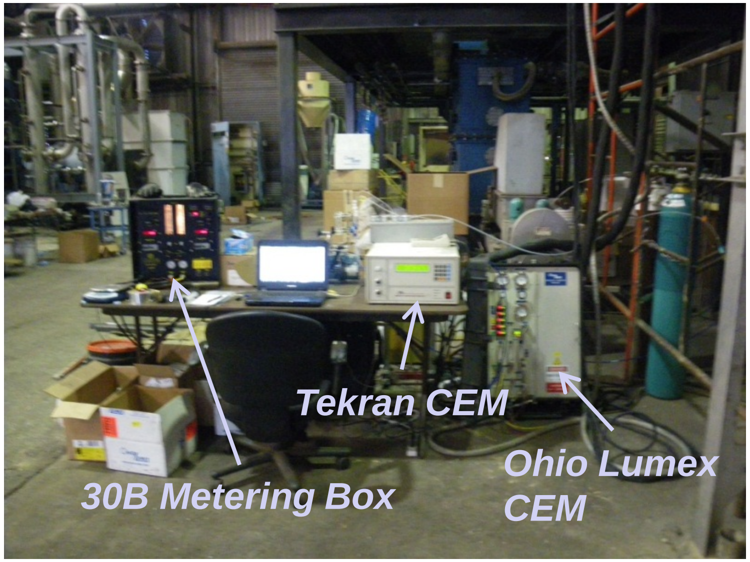
Pilot-Scale Measurements

- **Objective - Measure impact of oxy-combustion on performance of mercury control technologies**
- **Approach**
  - **L1500 pilot-scale furnace**
  - **PRB and bituminous coals**
  - **Air and oxy-firing**
  - **Two Hg control technologies**
    - **Bromine boiler additive ($CaBr_2$)**
    - **Activated carbon injection**
  - **Hg measured before and after baghouse**
  - **Three different Hg measurement techniques**
  - **Testing in May and June 2013**



L1500 Operating Conditions
(PRB coal)

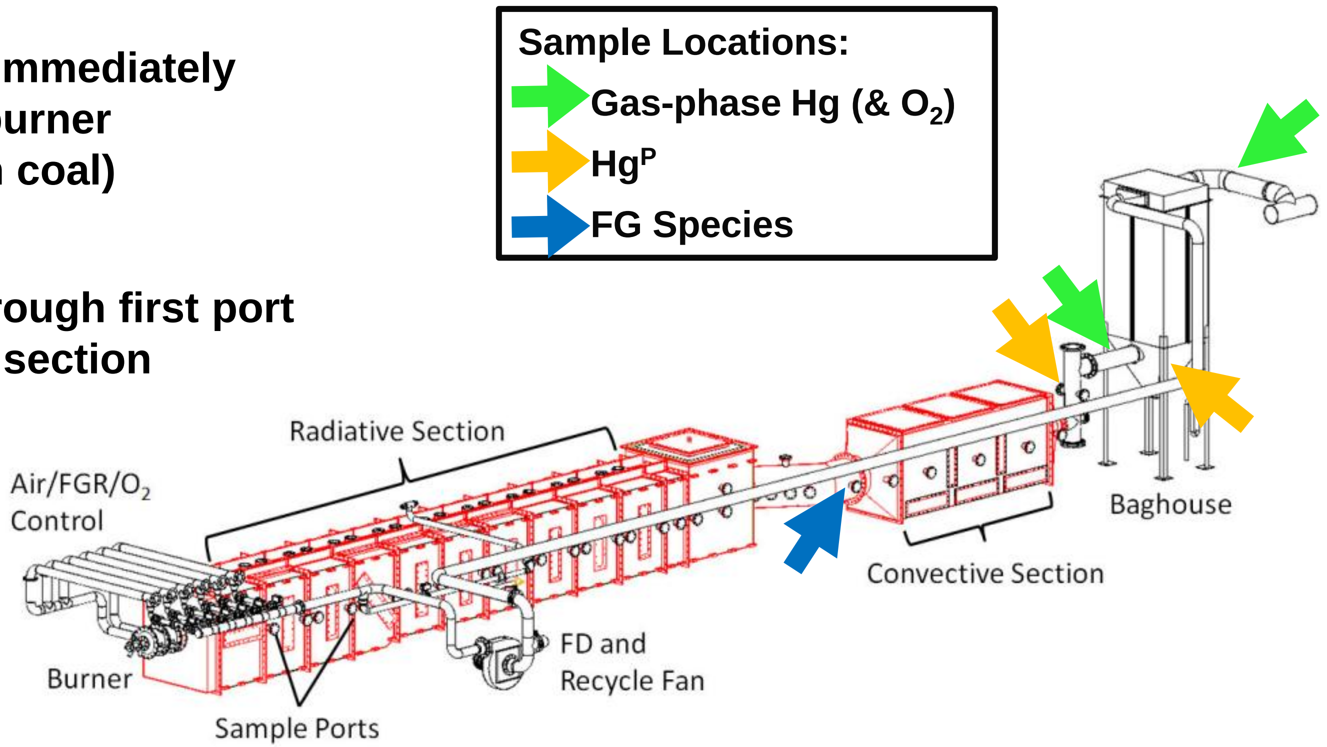
	Firing Rate (kW)	O_2 (%, dry)	CO_2 (%, dry)	BH inlet (F)	BH outlet (F)
Air-Fired	780-860	4.0	14	380	250
Oxy-Fired	780	3.5	83	300	140

Br addition:

Solid $CaBr_2$ injected immediately before coal entered burner (~8-75 ppm Br wet on coal)

ACI:

Darco Hg injected through first port following convective section (~0.5-10 lb/MMacf)



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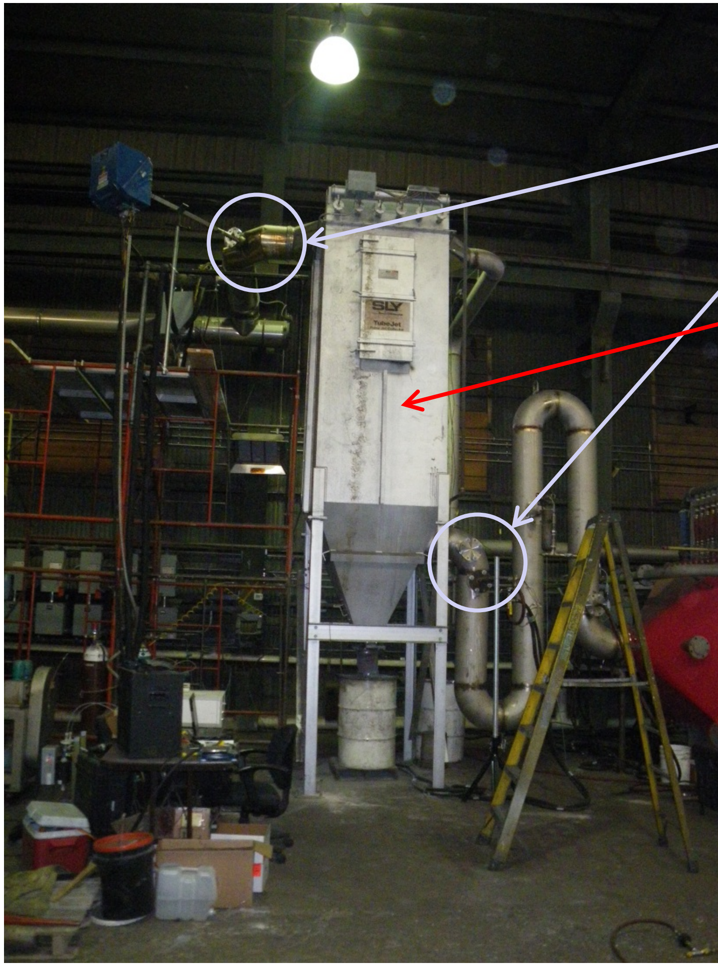
L1500 Mercury Testing Setup

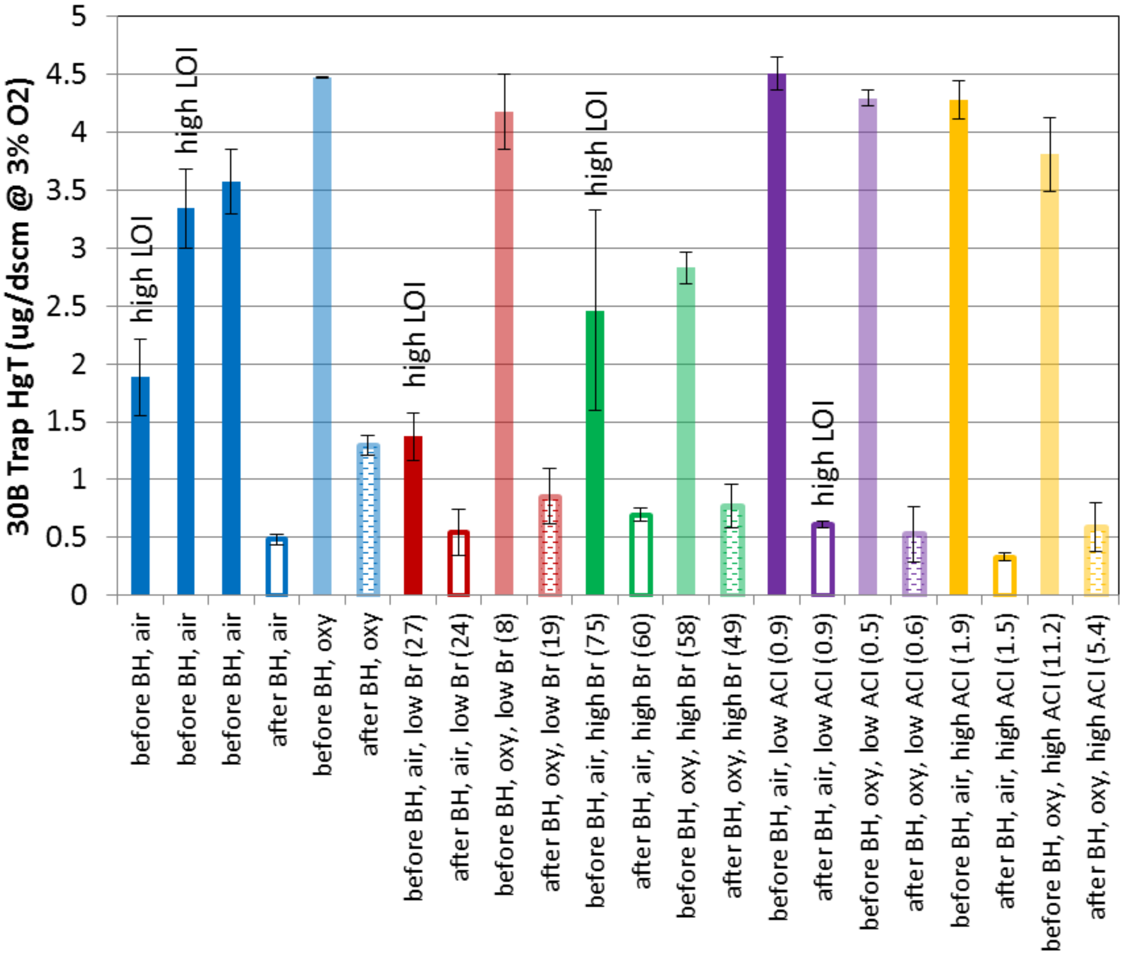


Hg measurement locations

Baghouse

Mercury Emissions
(PRB Coal)

- **Total Hg levels lower after the baghouse**
- **Oxy-firing increased emission levels**
- **Effect of $CaBr_2$ & ACI similar for air vs oxy**



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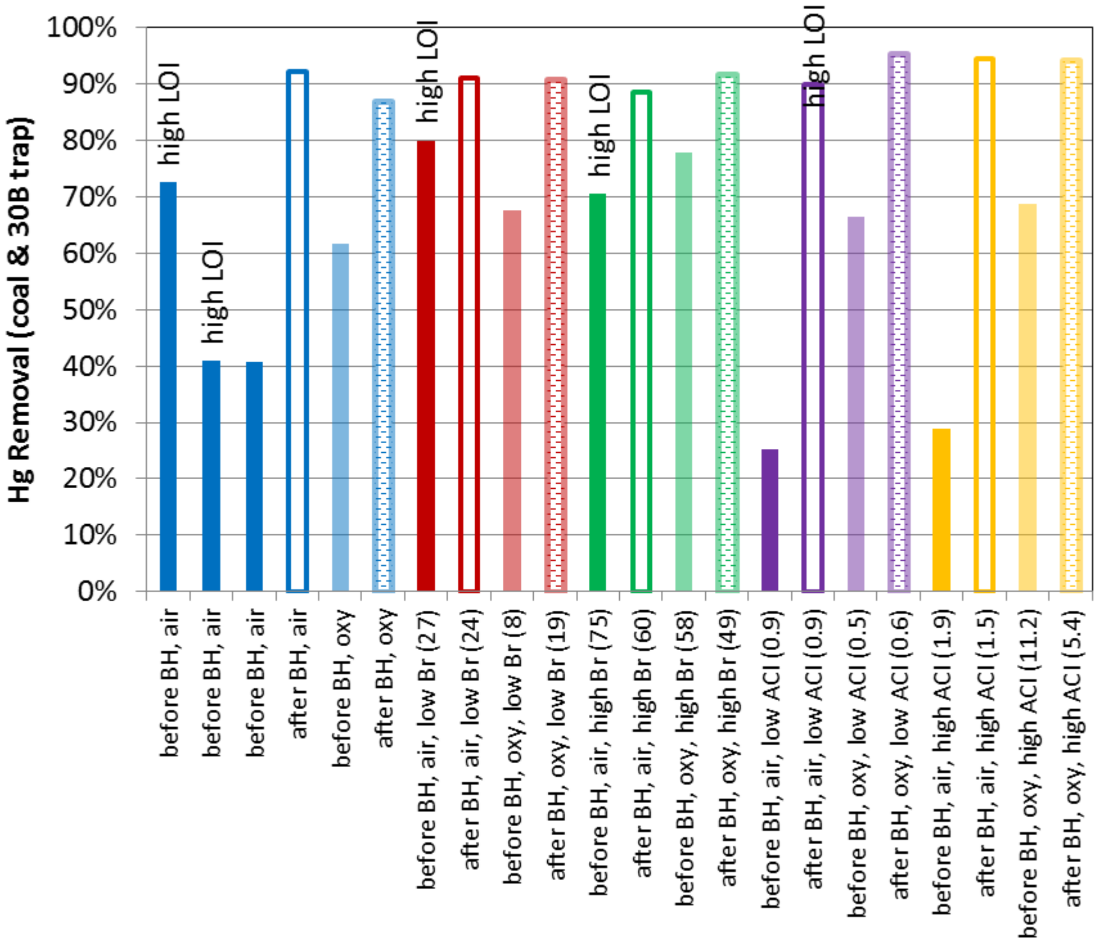
Mercury Removal
(PRB coal)

- **Mercury removal higher after baghouse**
- **After BH, air and oxy removal levels comparable**
- **Addition of $CaBr_2$ or ACI increased removal**
  - **Br addition increased removal before BH**
  - **ACI increased removal across BH**



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Preliminary Mercury Summary
(PRB coal)

- Mercury mass balance poor for many conditions, likely due to unrepresentative ash samples (dropout)
- The three measurement methods generally agreed with the exception of the OL CEM values before the baghouse
  - Uncharacteristically low levels, particles on dilution probe?
- Oxy-firing tended to increase Hg emission and oxidation
  - Flue gas recycle increases Hg and halogen concentrations
- Mercury emissions decreased with addition of $CaBr_2$ or ACI
- No significant difference in additive performance was seen between air- and oxy-firing

Pilot-scale Corrosion Measurements

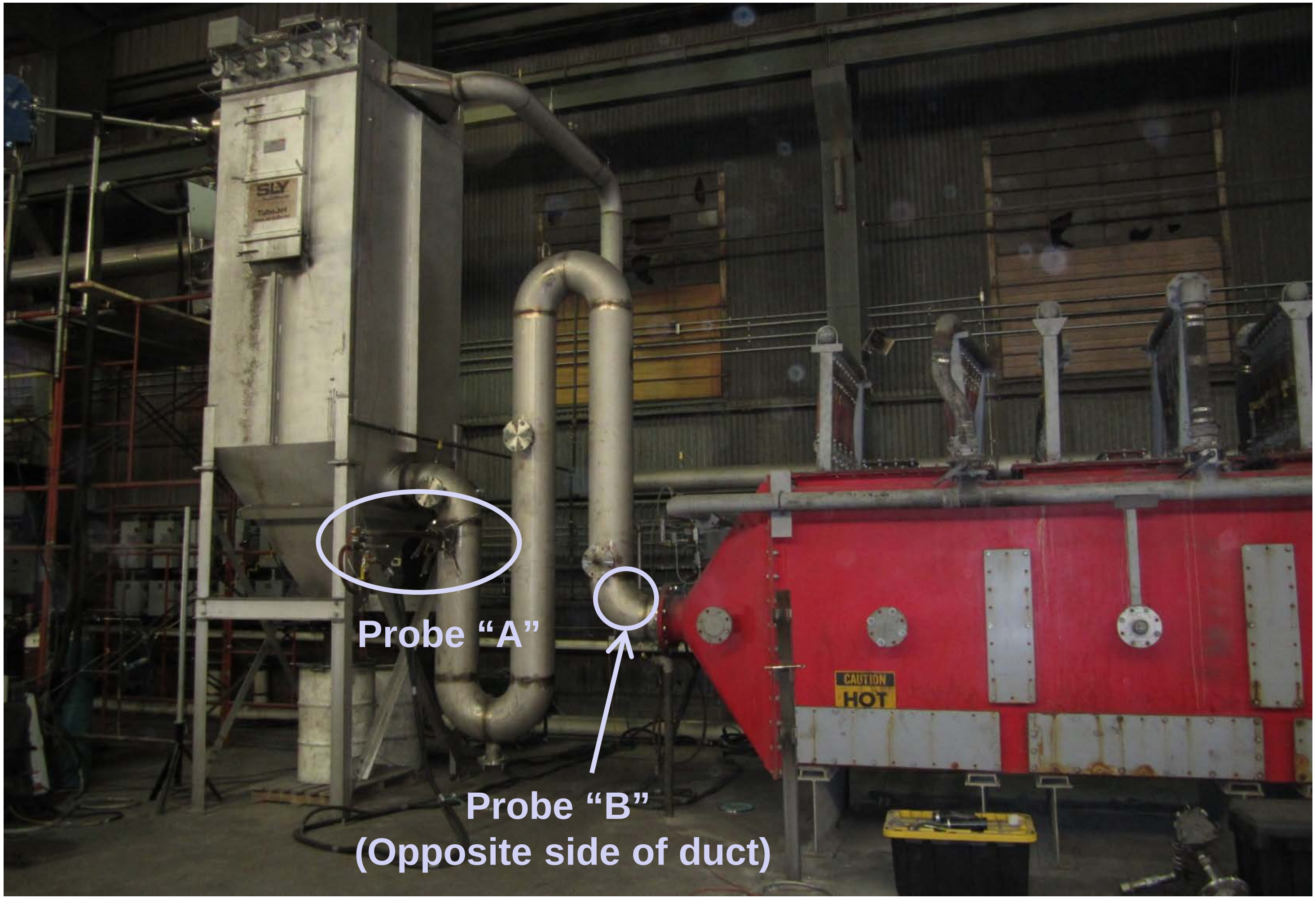
Objective:

- **Measure changes in corrosion rates at temperatures representative of an air heater,**
- **In the presence of various mercury control additives (baseline, bromine, activated carbon),**
- **Under both air-fired and oxy-fired conditions**

Method:

- **Use air cooled corrosion probes positioned in the flue gas just upstream of the baghouse**
- **Vary probe cooling to alter element surface temperature to be representative of air heater temperatures**
- **Only bituminous coal results shown**

Corrosion Probe Placement



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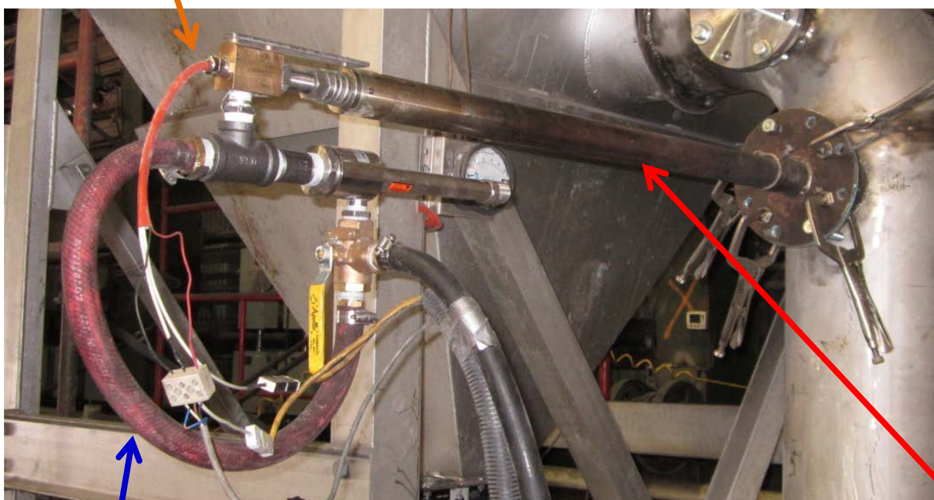
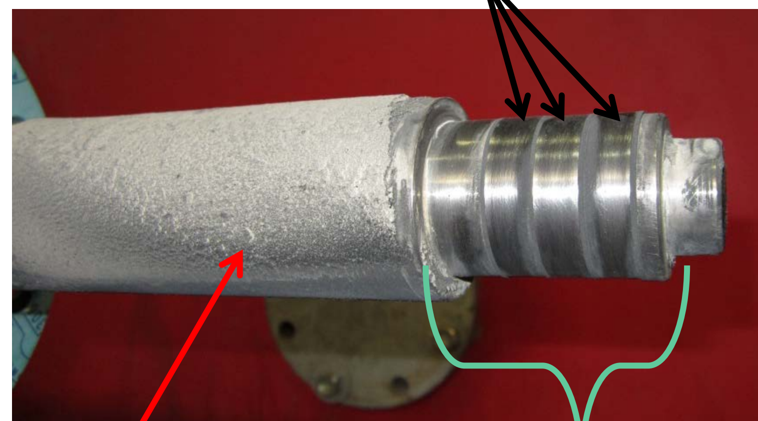
ECN Corrosion Probes

Signal wires and thermocouple leads

Carbon steel corrosion sensor elements





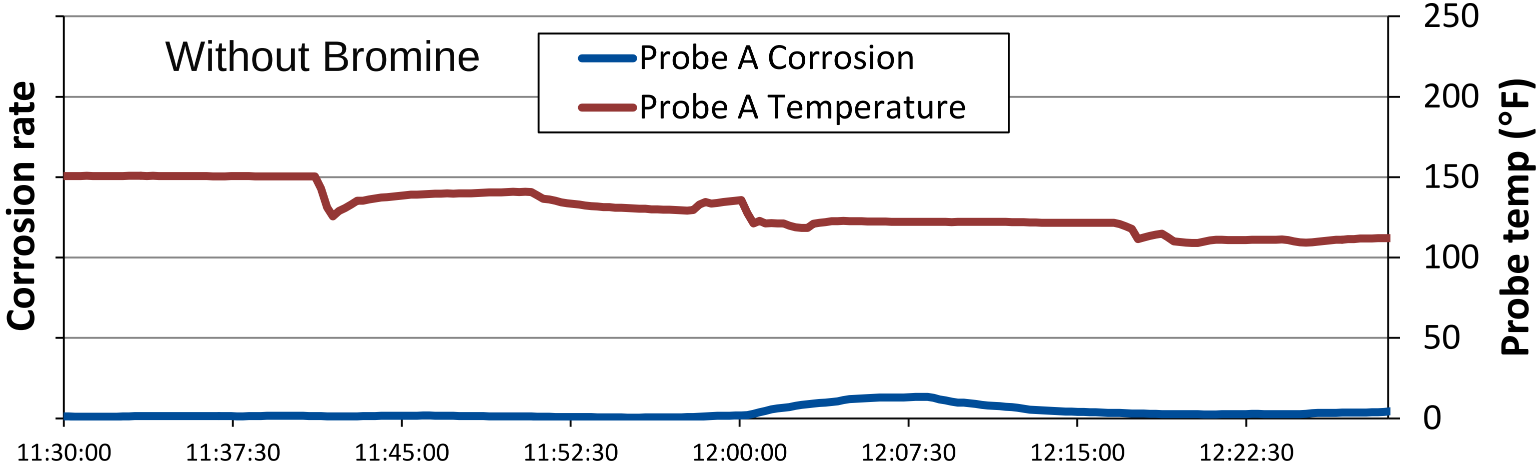
Cooling air into probe

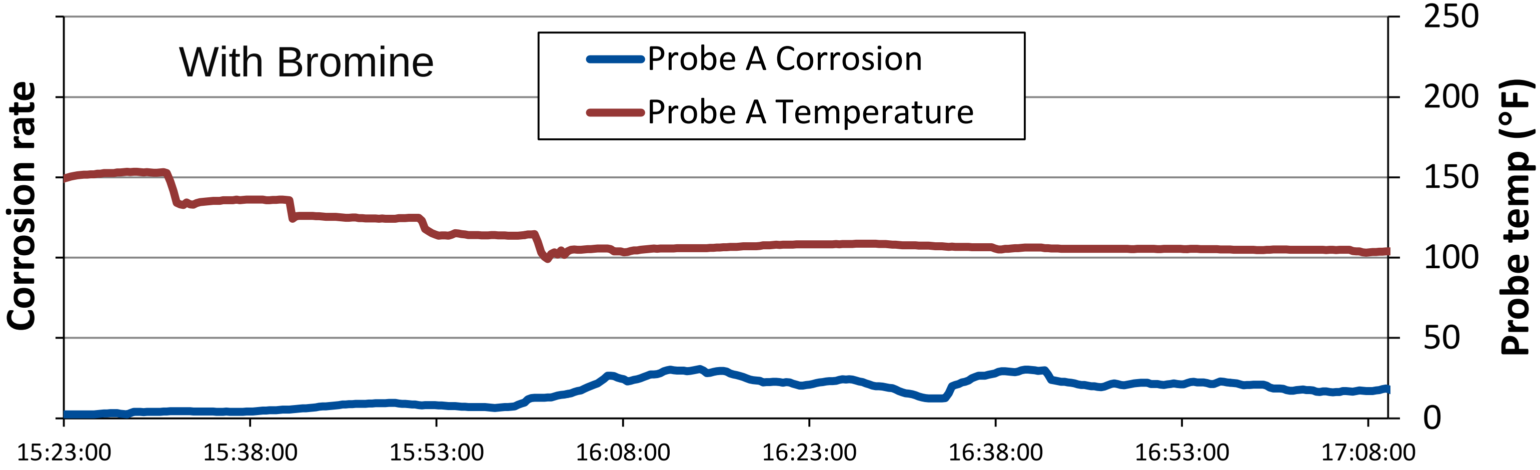
Stainless Steal Probe Body

Sensor array (centered in flue gas duct)

Sensor surface temperatures were varied between ~350 °F and ~100 °F

Smoothed Corrosion Rates (air-fired)
(bituminous coal)





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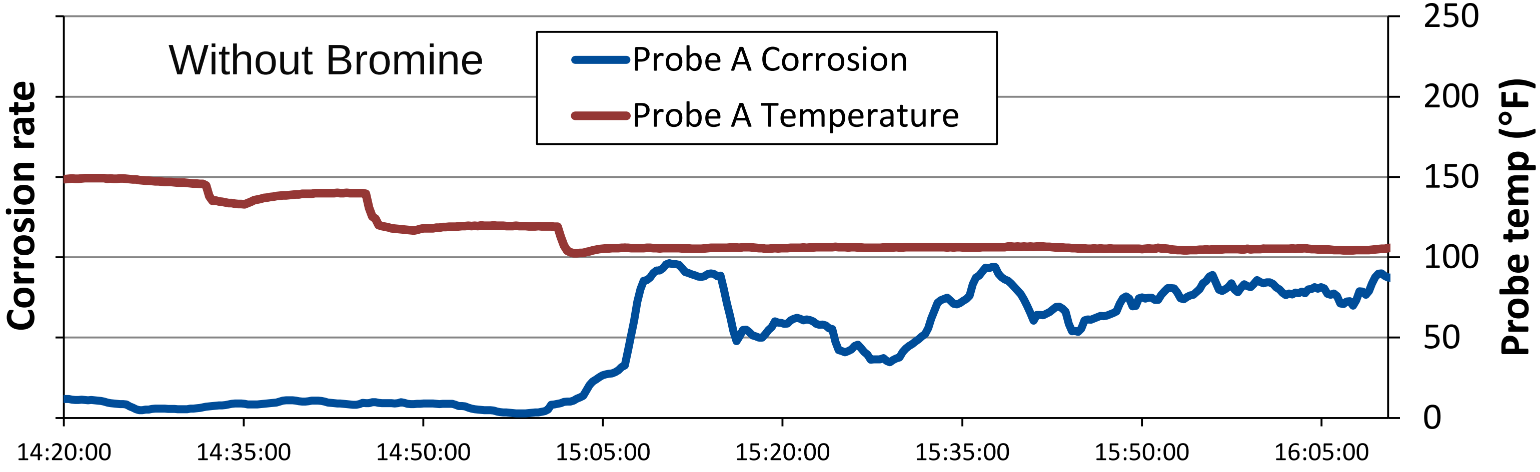
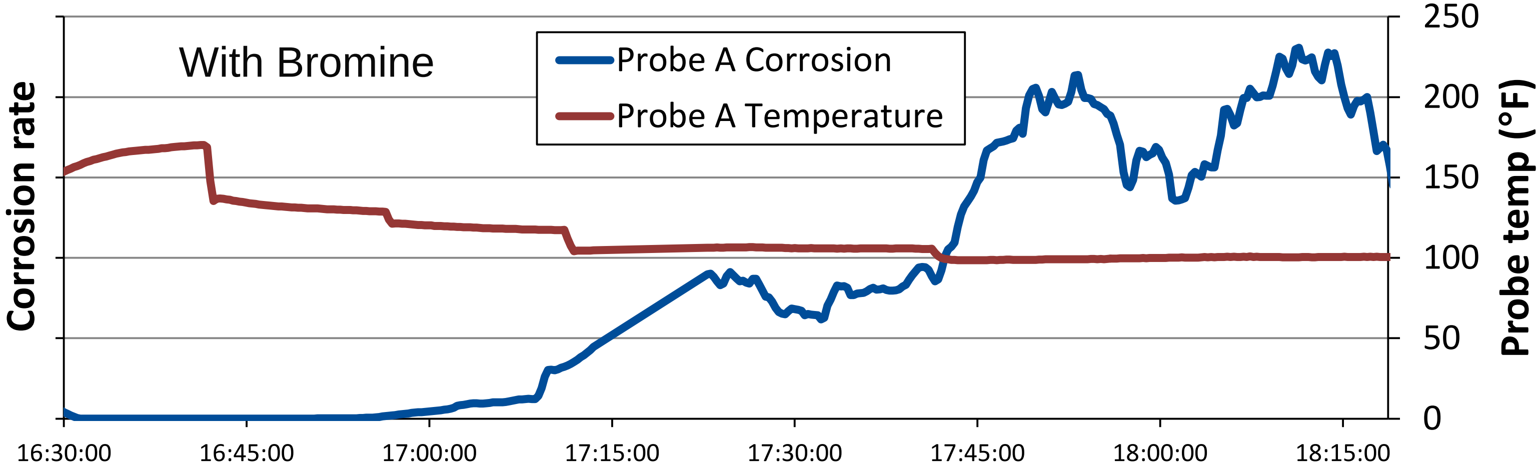
Smoothed Corrosion Rates (oxy-fired)
(bituminous coal)





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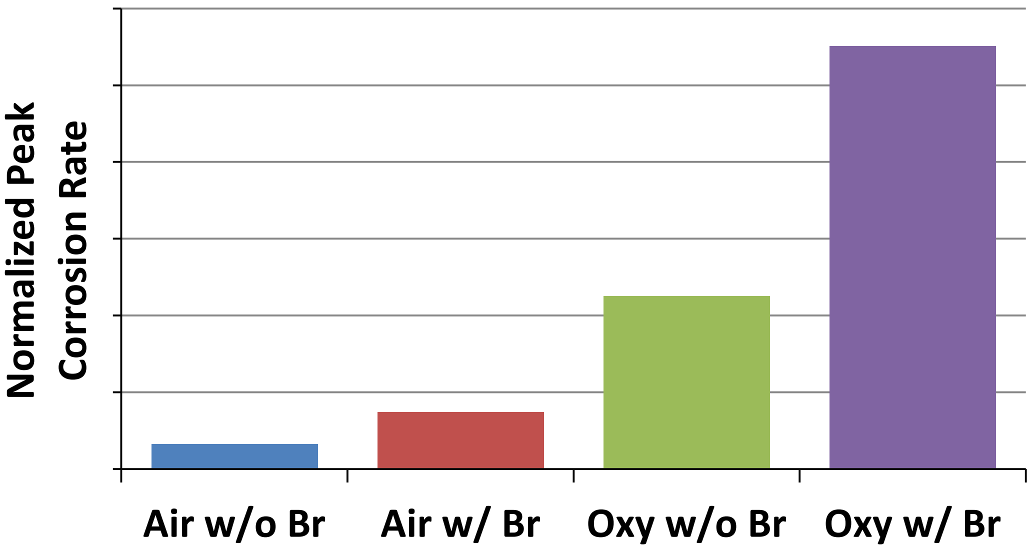
Preliminary Corrosion Summary
(bituminous coal)

- **Corrosion rates increased with bromine addition**
- **Corrosion rates increased with oxy-combustion**
- **Suspect dew point corrosion for sulfur (SO_3) and bromine**
  - **Rates dependent on flue gas concentrations and moisture level (both higher with oxy-combustion)**
  - **Different mechanism than high-temperature corrosion**



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Project Status

- Previously completed testing and modeling work on oxy-combustion flame characteristics, operational impacts, firing system design and full-scale retrofit evaluations
- Completed bench-scale Hg measurement evaluation
- Completed pilot-scale air and oxy-firing tests:
  - Hg emissions and control technologies
  - Low-temperature corrosion
- Next tasks:
  - Hg modeling of full-scale oxy-retrofit unit (9/30/13)
  - Complete final report and project close-out

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