Assessment of Oxy-Combustion Impacts on Boiler Design and Performance During 15 MW_{th} Pilot-scale Testing

Armand Levasseur, Carl Edberg, James Kenney,
Paul Chapman, David Turek, Shin Kang
Alstom Power Inc
Windsor, CT

Timothy Fout
US DOE, NETL
Morgantown, WV

Ninth Annual Carbon Capture & Sequestration Conference
May 10-13, 2010 Pittsburgh, Pennsylvania

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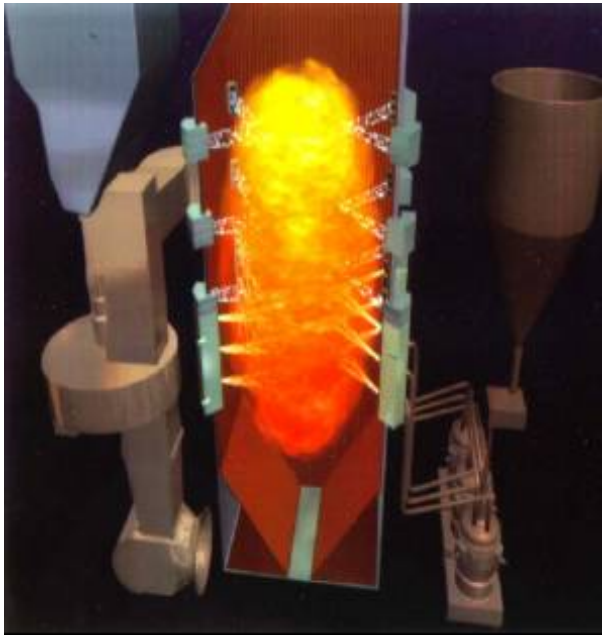
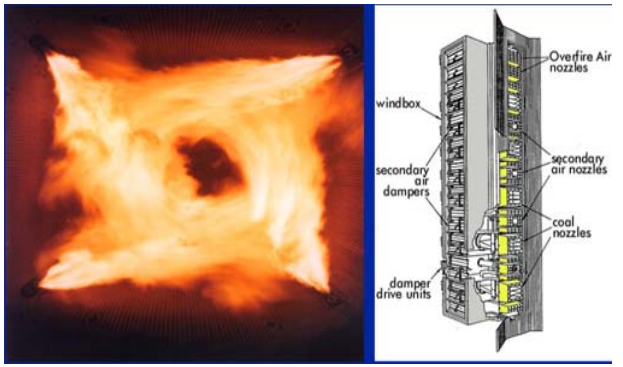
Oxy T-Fired Boiler Development Project

Project Objectives

Develop oxyfuel T-fired boiler system for high CO_2 content gas. Specifically,

- Design and develop an innovative oxyfuel firing system for T- fired boilers
- Evaluate the performance in pilot scale tests at 15 MW_{th} BSF – including **combustion, heat transfer, pollutant emissions,** and deposition and corrosion
- Evaluate and improve engineering and CFD tools for oxy-combustion by applying detailed test data obtained





Oxy T-Fired Boiler Development Project

Project Team:

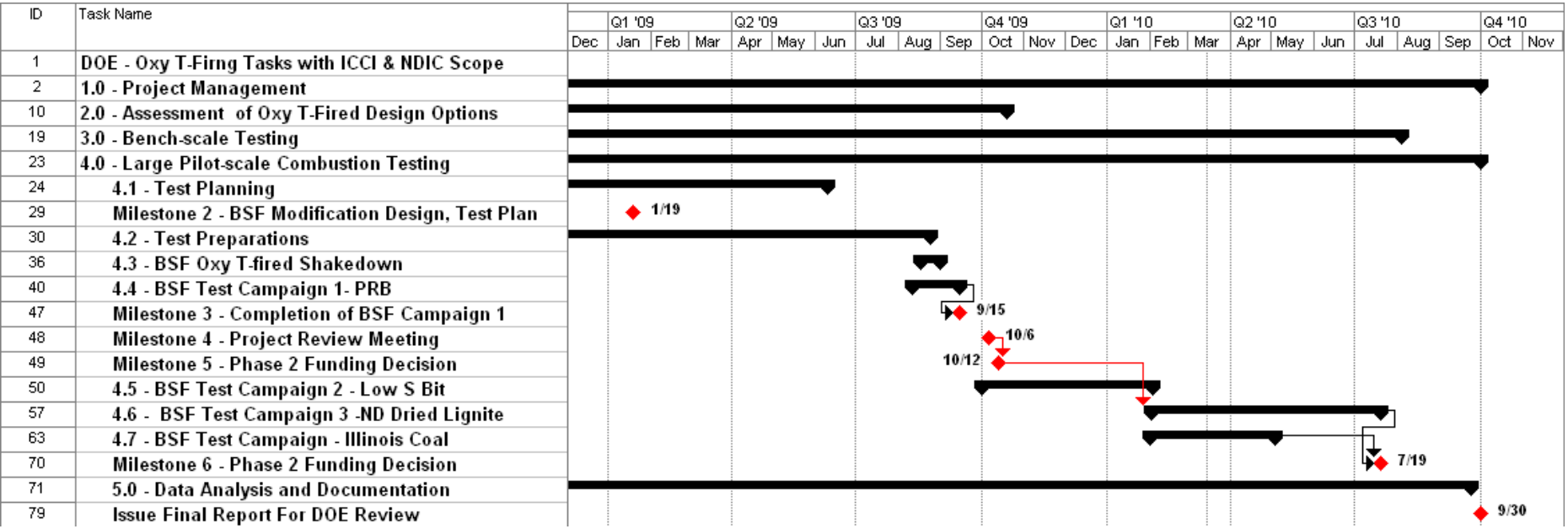
- Alstom –Boiler Laboratories
- Alstom – New & Retrofit Boiler Business
- DOE NETL
- ICCI – Illinois Clean Coal Institute
- NDIC – North Dakota Industrial Commission
- Utility Advisory Group

Ten Utility Members:

Ameren
ATCO
Dominion Energy
Great River Energy
Luminant (TXU)
LCRA and Austin Ene
MidWest Generation
NB Power
OG&E
Vattenfall

Schedule

- Project Budget: $8.8M
- Project Duration: 24 Months
- Start: October 2008
- First Test Campaign: September 2009
- Complete Project:September 2010



Current Status

Scope Accomplished

- Process and CFD Screen Completed
- BSF Modifications For Oxy-Firing Completed
- BSF Commissioning Completed
- BSF Campaign 1 Testing Completed – Subbituminous
- BSF Campaign 2 Completed – Low Sulfur Bituminous
- BSF Campaign 3 Completed – High S Illinois Bituminous

Plan

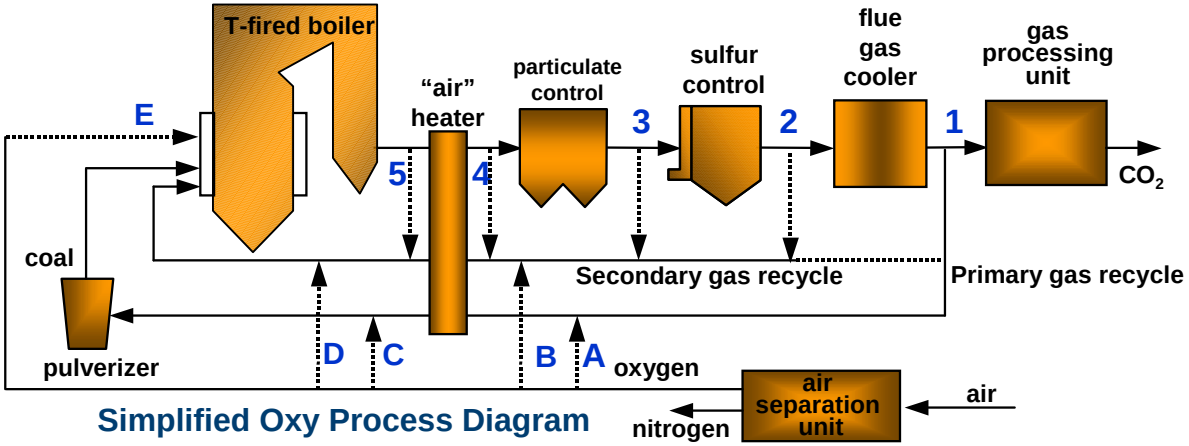
- ND Lignite Testing
- Complete Data Analysis and Tool Validation

Oxy Screening Studies

Process Options: Techno-Economic Evaluation

Major Variables:

- Gas Recycle Take-off Locations
- Oxygen Injection Locations
- Oxygen Heating
- Recycle Rate / Furnace Surfacing



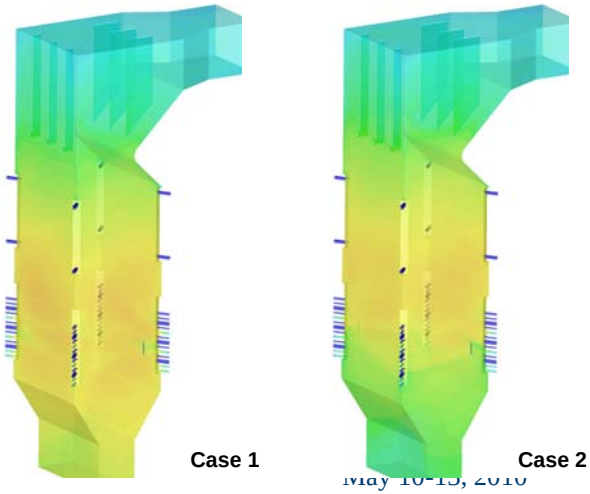
Simplified Oxy Process Diagram

CFD Modeling: Detailed Predictions

Additional Variables:

- Oxygen Injection Method, Conc., Distribution
- Windbox Design (Compartments, Vel.,Angle)
- OFA Design (Location, Vel, Angle)

15 MWt BSF Oxy Simulations



Case 1 Case 2

15 MW_{th} BSF Modifications

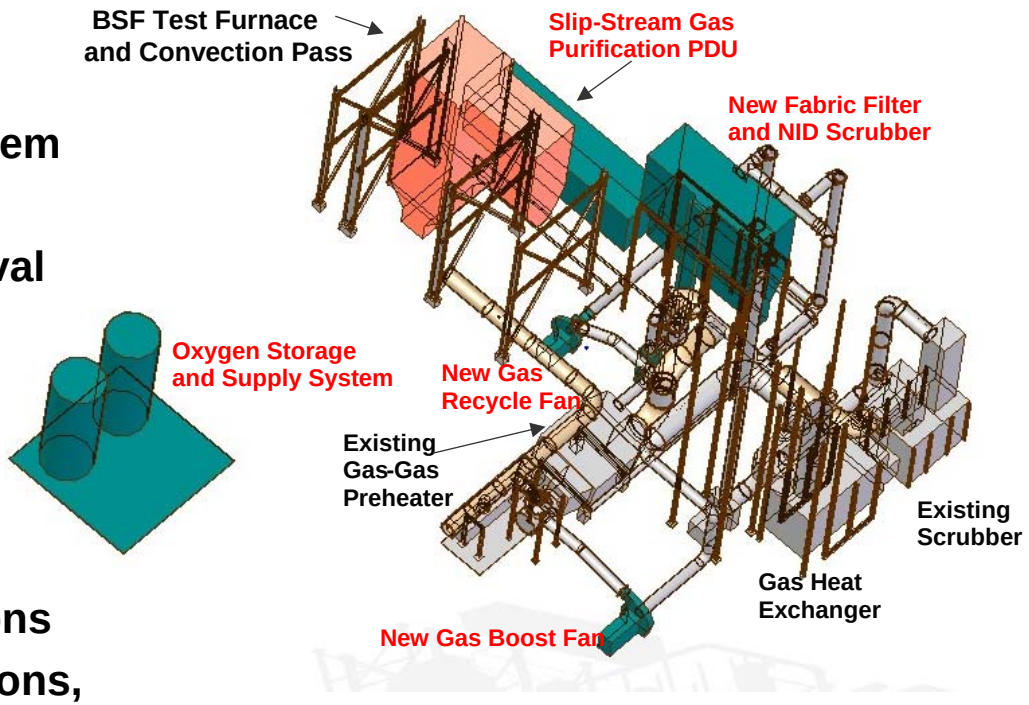
Major New Equipment

- Oxygen Supply and Injection System
- Gas Recirculation Systems
- Fabric Filter for Particulate Removal and NID SO_2 Scrubber
- Instrumentation and Controls

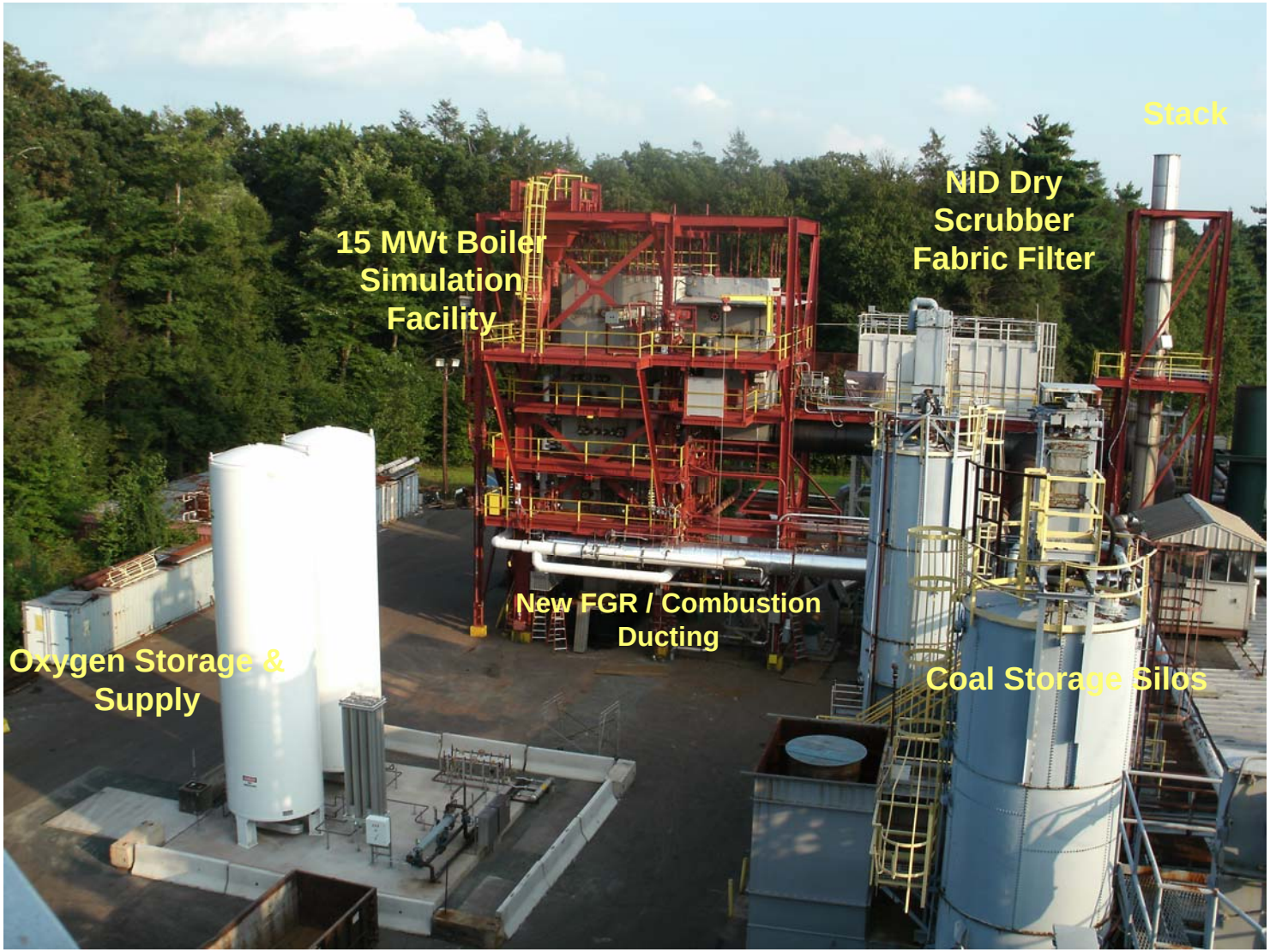
Design for Operating Flexibility

- Operate Both Air- and Oxy-fired
- 5 Different Operating Configurations
- Control of Oxygen Injection locations, concentrations, etc.

Integration of Slip-Stream Gas Purification Unit



15 MW_{th} BSF After Oxy Modifications



BSF Test Campaigns

Primary Test Variables

- **Gas Recycle Take-Off Location**
- **Gas Recycle Flow Rates**
- **Oxygen Injection**
- **Total Excess Oxygen / O2 Conc. at Economizer Outlet**
- **Windbox & OFA Design – Arrangement, Velocity**
- **Operating Load/ Turndown**

BSF Test Campaigns - Measurements

Data Acquisition System (More than 1,000 I/O Points)

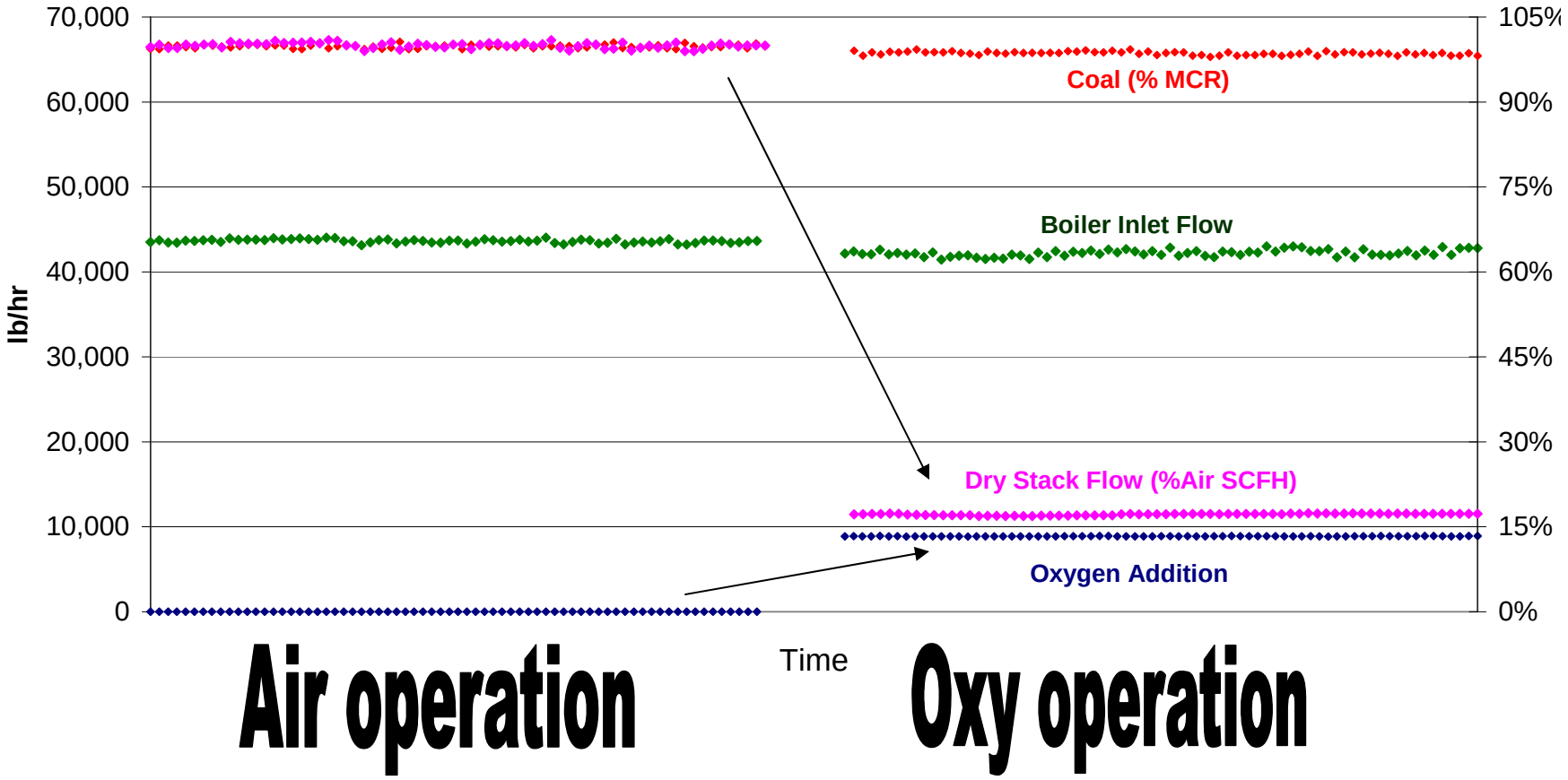
- Continuous Logging of Operating Conditions (System Flow Rates, Gas Compositions,Temperatures, Pressures, Valve Positions, etc.)
- Continuous Heat Transfer Measurements (4 Waterwall Test Panels, 6 Continuous Test Loops Across Furnace Vertical Outlet Plane, 3 Deposition/Corrosion Probes)

Probe Measurements

- Furnace Gas Temperatures and Gas Species Mapping
- In-Furnace Heat Transfer (Total Heat Flux Probes, Ellipsoidal Radiometer Probes)
- Mercury Measurements
- SO_3 Measurements
- Particulate Trace Metals

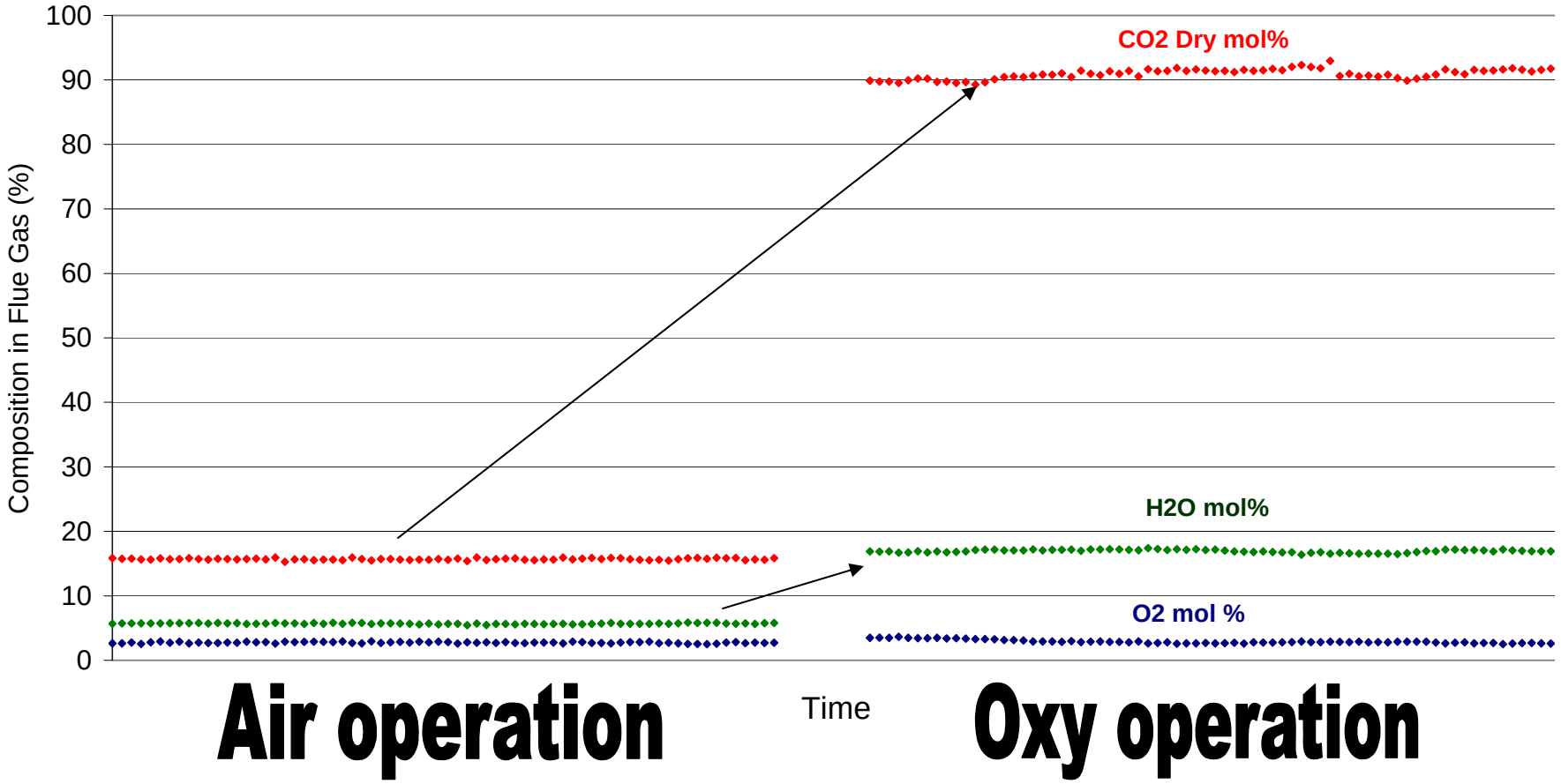
BSF Campaign 2 - Low S Bituminous Steady State Mass Flows

- Dry Stack flow is roughly 20% of Air Fired Volume.



BSF Campaign 2 - Low S Bituminous Steady State Gas Species Compositions

- Able to maintain 90% CO_2 (dry) in flue gas
- Conditions varied from 1.5 to 2.5% Air In Leakage to the facility



15 MW_{th} BSF Furnace Mapping

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Probe Mapping Measurements
Gas Temperatures Heat Flux: -Total Incident - Radiant Gas Species: - O2 - CO - CO2 - SO2 - H2O

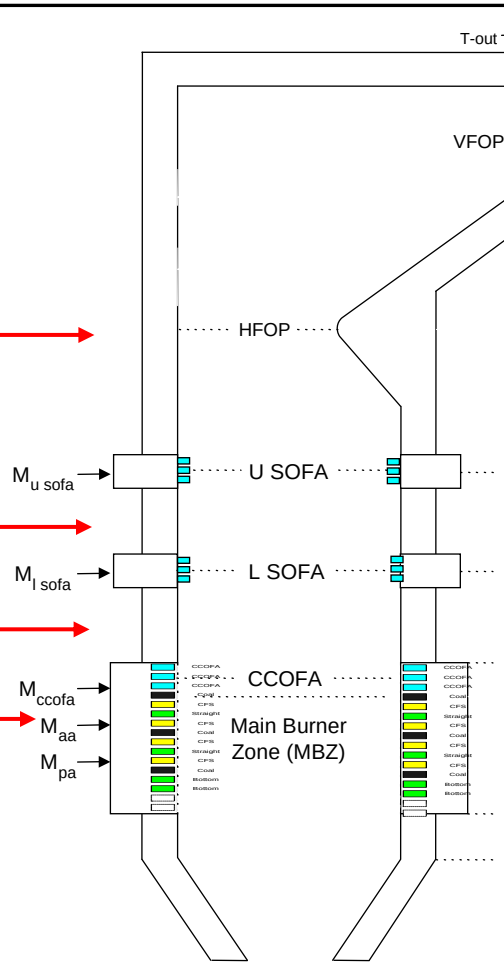
Detailed Mapping Planes

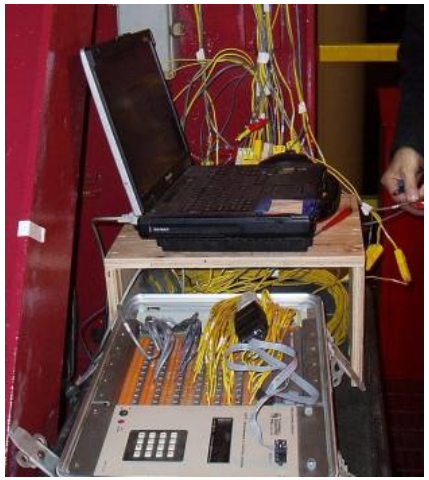
Plane 273

Plane 180

Plane 141

Plane 66

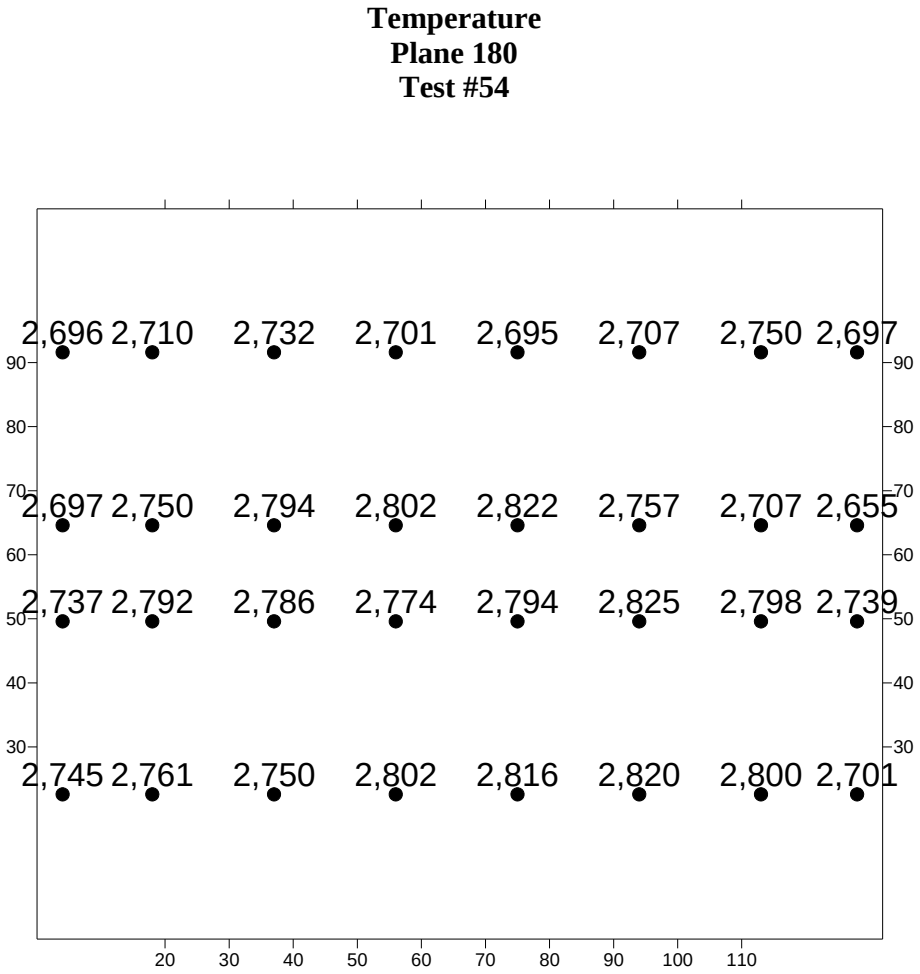




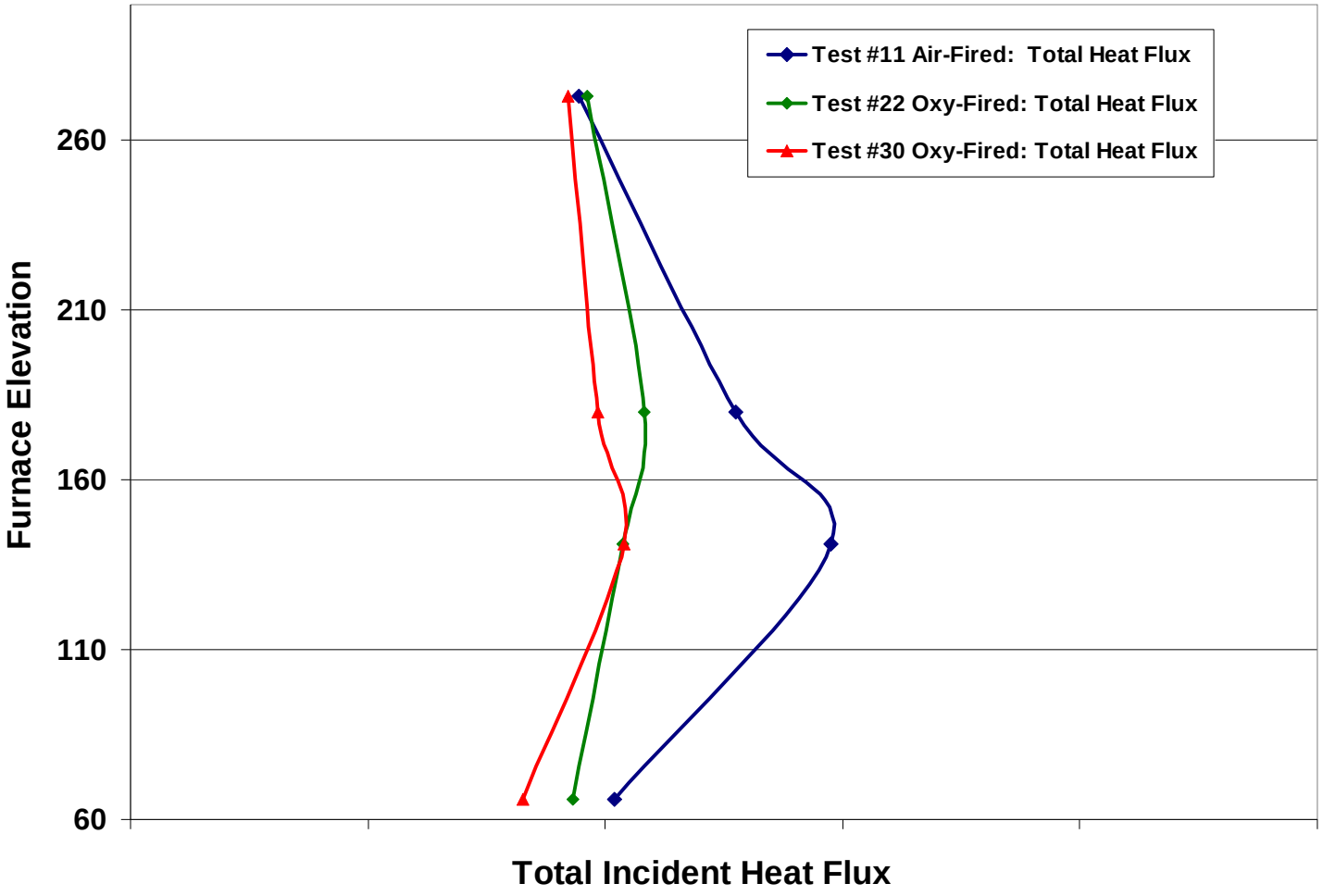
Side View

In-Furnace Temperature – Planar Points

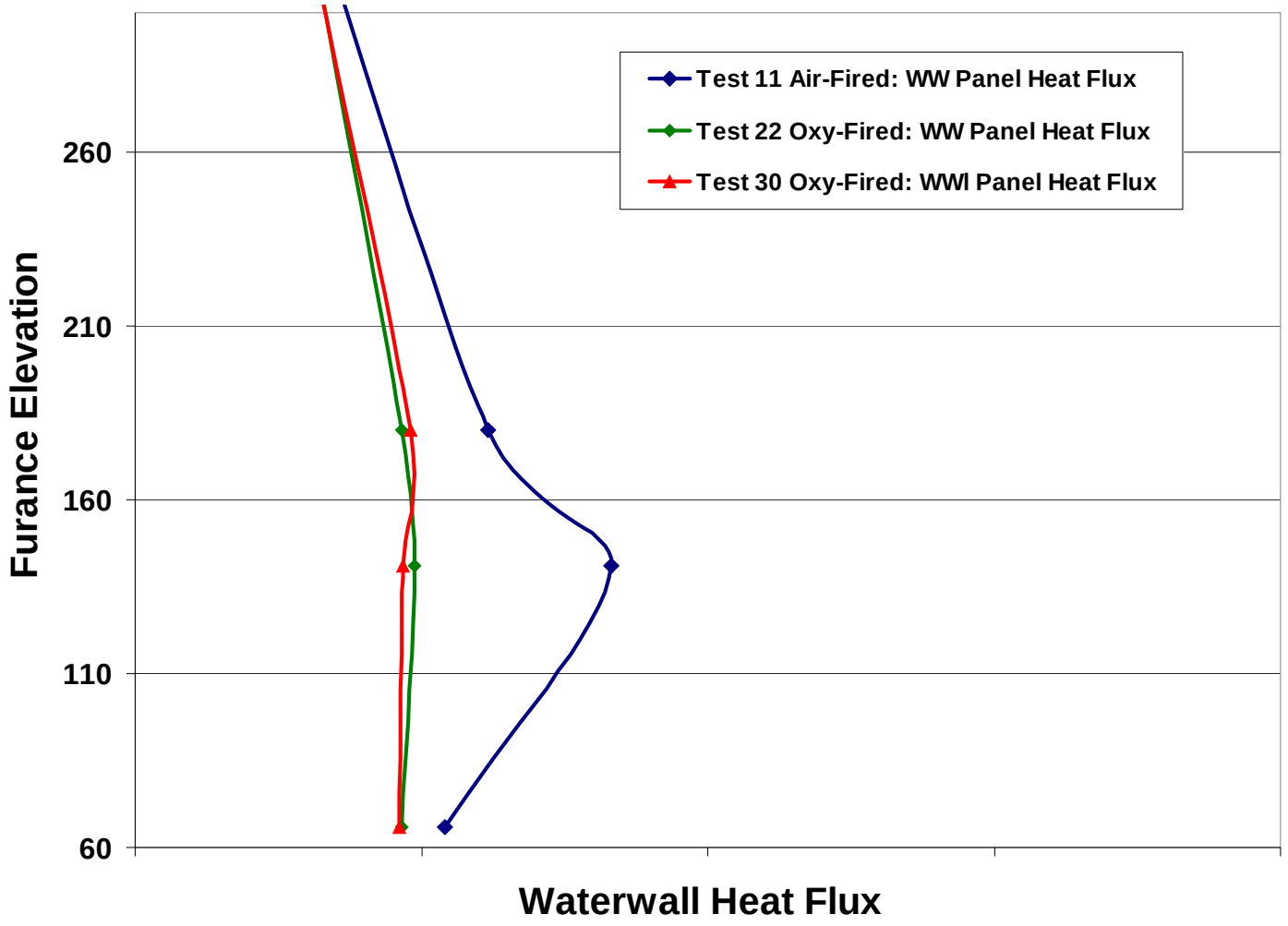
Sample Planar Temperature Profile Between OFAs



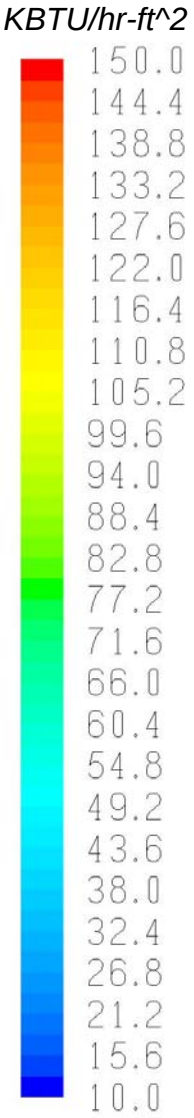
BSF Campaign 1 - PRB
Incident Heat Flux for Air-Firing vs. Oxy-Firing



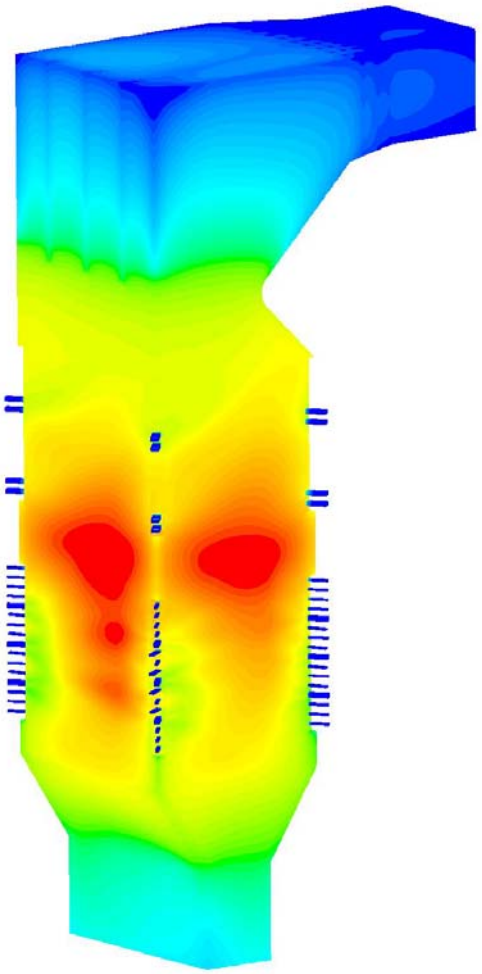
BSF Campaign 1 - PRB
Waterwall Test Panel Heat Flux vs. Elevation



BSF Campaign 1 - PRB
CFD Predictions of Wall Radiation

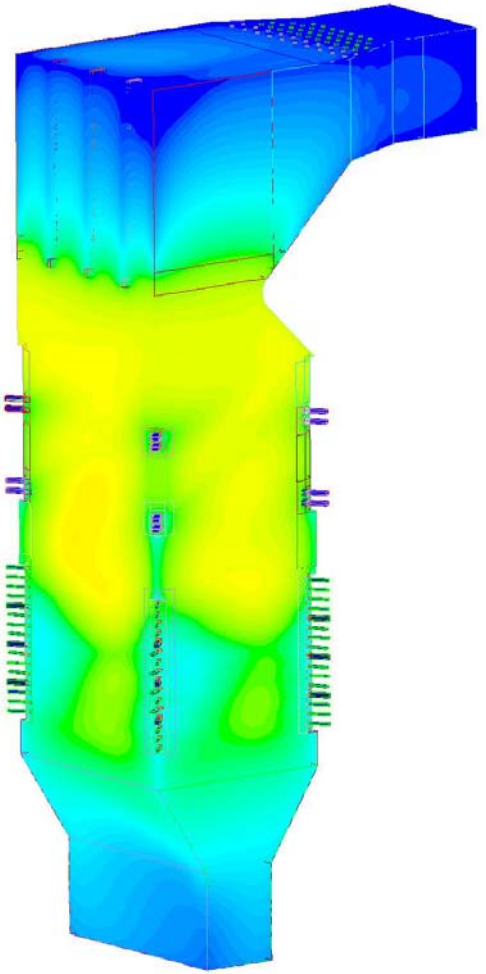


AIR Test 11



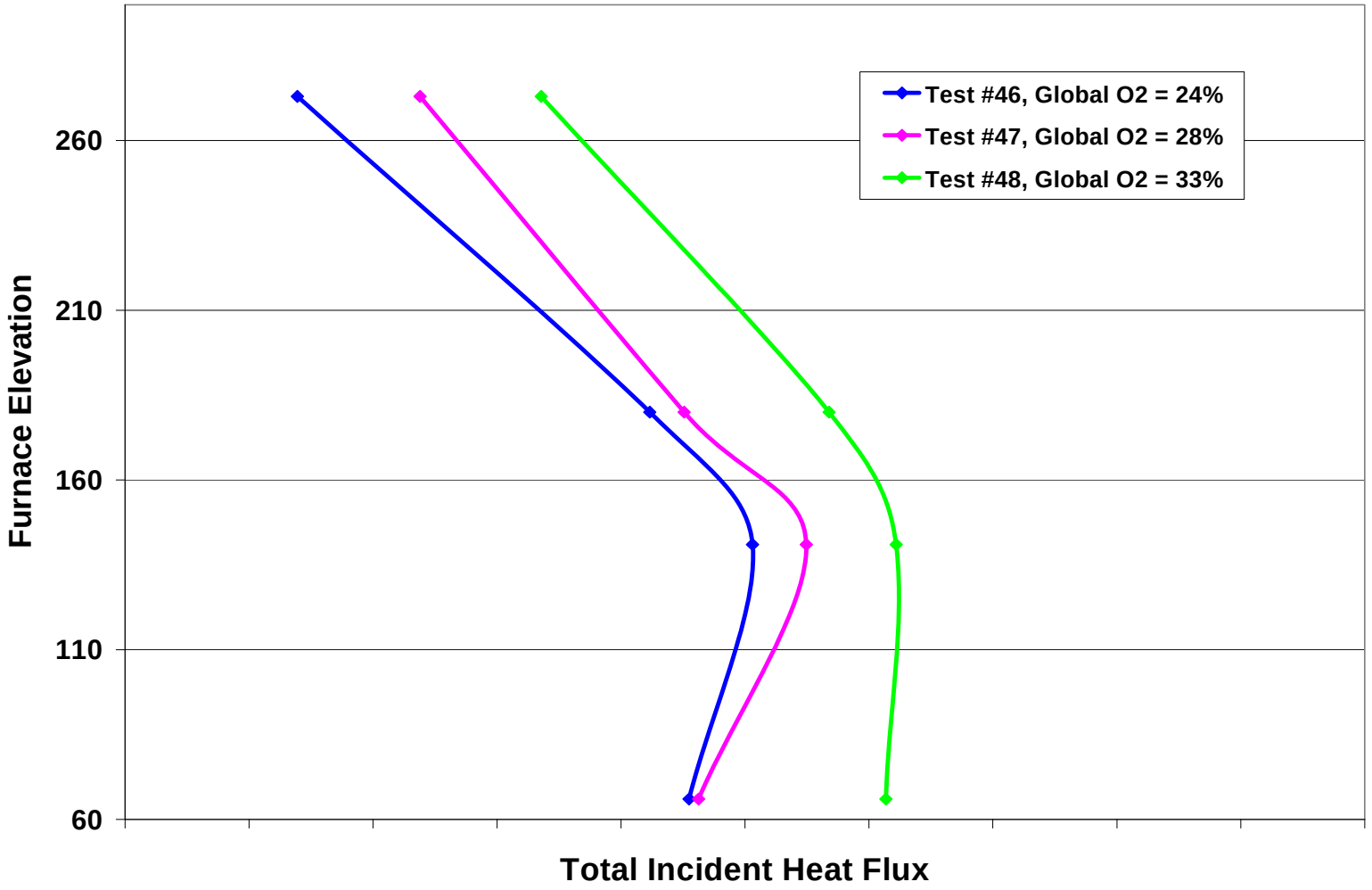
AIR

OXY Test 22

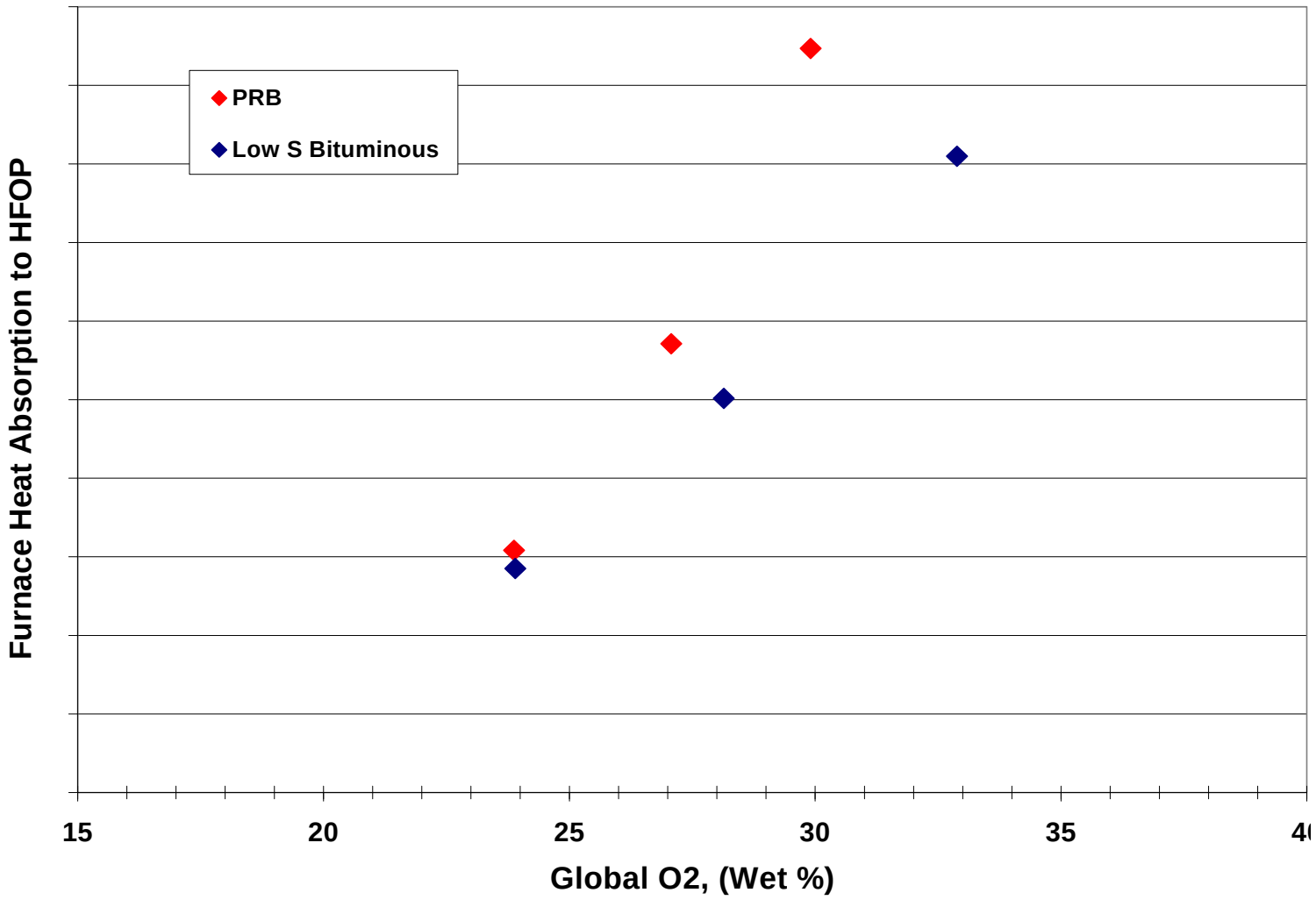


OXY

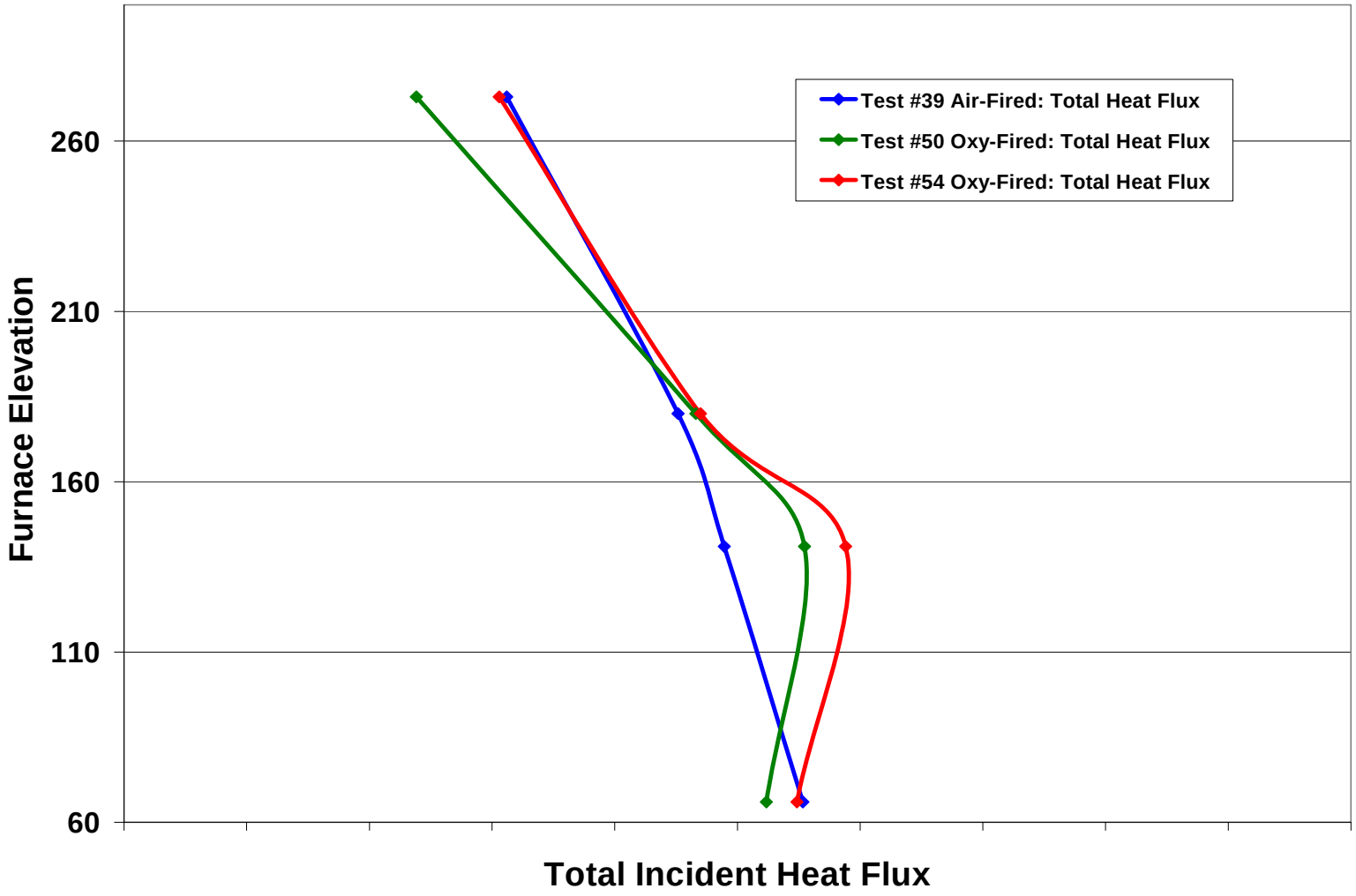
BSF Campaign 2 - Low S Bituminous Recycle Variations - Vertical Heat Transfer Profile



Impact of Gas Recycle – Lower Furnace Heat Absorption



BSF Campaign 2 - Low S Bituminous
Incident Heat Flux for Air-Firing vs. Oxy-Firing



BSF Campaign 1 & 2 - General Observations

- **General Facility Operation**
  - Stable operation over broad range of test conditions
  - Able to produce high (>90%) CO2 Flue Gas
- **Combustion**
  - Very good performance during both air and oxy testing with both PRB Sub and WV Bit Coals
    - Able to operate at low excess oxygen (Less than 2% O2 at Economizer Outlet)
    - Low CO Emissions (near Zero)
    - Low Carbon in Fly ash
- **NOx Emissions**
  - Lower NOx Emissions with Oxy-firing with both PRB Subbituminous and WV Bituminous)
    - Roughly 50% Reduction from Air-Firing on lb NOx / MMBtu Fired

BSF Campaign 1 & 2 - General Observations

- **Heat Transfer**
  - Generally similar range of heat flux and temperature
  - Able to change profile by adjusting operating conditions
- **SO_3 Formation**
  - SO_2 to SO_3 conversion appears to be similar
  - SO3 concentrations about 3 times high for oxy-firing
- **Ash Deposition**
  - Appeared generally similar
  - Fly ash and lower furnace deposits had similar composition, upper furnace had higher sulfur content
- **Waterwall Corrosion**
  - Appeared generally similar

Conclusions

- Major large oxy pilot projects are underway providing key technical information on
  - oxy firing impacts on boiler performance and operation
  - overall oxy plant integration and control.
- Pilot programs are providing design guidelines, performance data and validated tools.
- Pilot results along with other Alstom oxy projects, provide a strong foundation for the next step of demonstration (~250 MWe).
- Alstom is ready to take the next step of commercial scale demonstration

Thank You For Your Attention !

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Acknowledgements

This research was made possible with support, in part, by

- US Department of Energy Through the National Energy Technology Laboratories
- Illinois Department of Commerce and Economic Opportunity Through the Office of Coal Development and the Illinois Clean Coal Institute Illinois Clean Coal Institute
- Vattenfall AB
- Utility Advisory Members

  Vattenfall, ATCO, Dominion Energy, Ameren, Luminant (TXU), LCRA, OG&E, MidWest Generation, Great River Energy, NB Power

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