Oxy-Combustion Boiler Development for Tangential Firing

DE-NT0005290

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Alstom Power, Windsor, CT

NETL CO_2 Capture Technology Conference

Pittsburgh, PA

September 14, 2010

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Oxy-Combustion Technology - Why Oxy?

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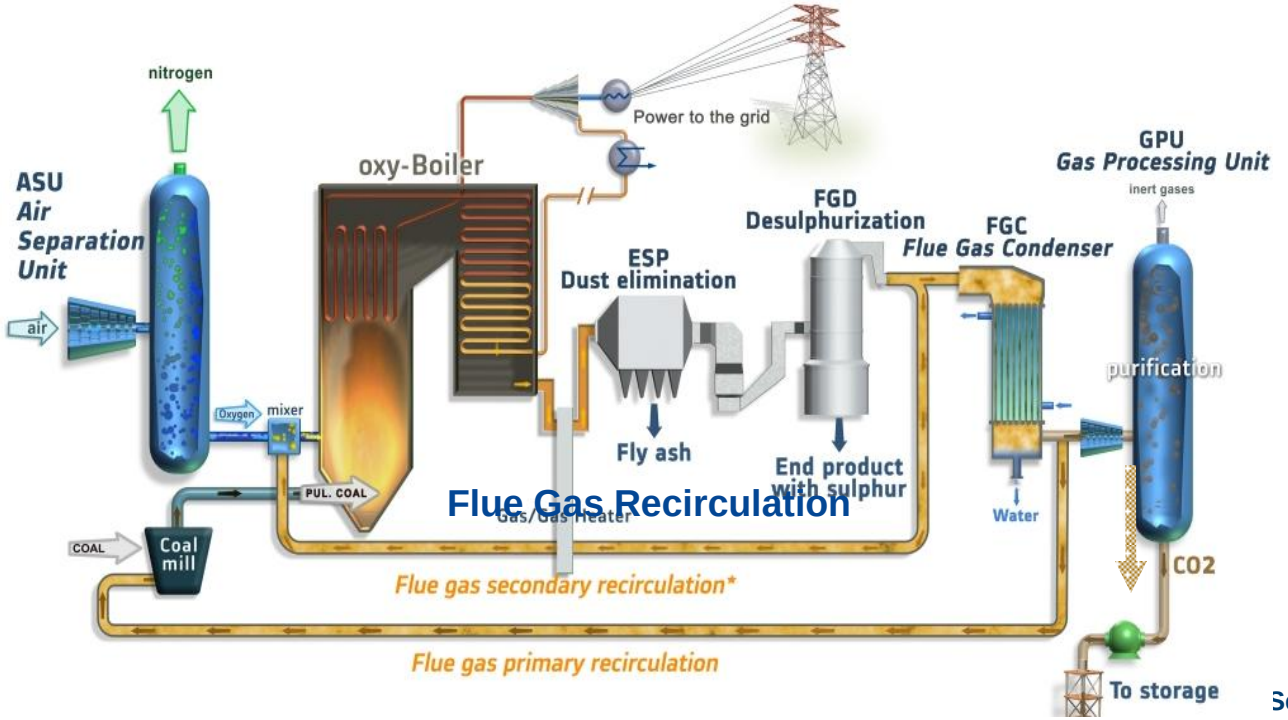
Cost Competitive Near-Term CO_2 Solution

- Low Risk: Adapts Conventional Components
- New and Retrofit Applications
- High CO_2 Capture Rates (>90%)
- Near Zero Emissions
- CO_2 "Ready" Feasible
- Potential for O_2 Generation Cost Reduction



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Main Partnerships & Projects Portfolio

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Advanced Amines	Joint development programme West Virginia Pilot (USA) - Coal		DOW ALSTOM
	Belchatow (Poland) – **Lignite**	>250 MWe	PGE ALSTOM
Chilled Ammonia	Pleasant Prairie (US) – Coal	5 MWt	EPRI we ALSTOM
	Karlshamn (Sweden) – Oil/Gas	5 MWt	e·on ALSTOM
	Mountaineer (US) – Coal	58 MWt	AEP ALSTOM
	Mongstad (Norway) – Gas	40 MWt	TCM Catching our Future ALSTOM
	Commercial Scale Plant – Coal	>200 MWe	AEP ALSTOM
	TransAlta (Canada) – Coal	200 MWe	TransAlta ALSTOM
Oxy-combustion	Schwarze Pumpe (Germany) – **Lignite**	30 MWt	VATTENFALL ALSTOM
	Oxy-Combustion Boiler Development for Tangential Firing (USA)– Coal	15 MW_{th}	NETL ALSTOM
	Jänschwalde (Germany) – **Lignite**	250 MWe (Feasibility study)	VATTENFALL ALSTOM
	Lacq (France) – Gas	30 MWt	TOTAL ALSTOM

5 Pilots in commissioning/operation

Tests completed

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Alstom Oxy PC Technology Development Steps

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Scale – Up

2000

Lab Scale

<1 MWth

2008

Large Pilot Plants

15- 30 MWth

2014-15

Demonstration

150- 300 MWe

< 2020

Full-Scale

600-1100 MWe

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Oxy T-Fired Boiler Development – Project Objectives

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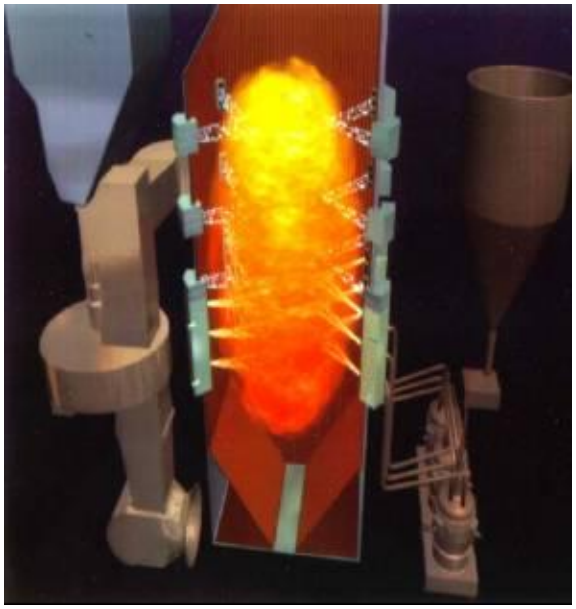
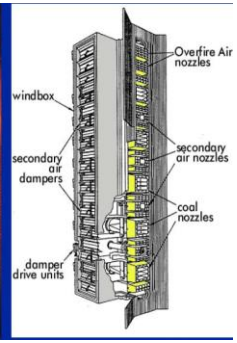
Develop oxyfuel T-fired boiler system for high CO2 content gas. Specifically,

- Design and develop an oxyfuel firing system for T- fired boilers
- Evaluate impacts of oxy process parameters and boiler operating parameters by simulations and 15 MW_{th} combustion testing
- Evaluate the performance in pilot scale tests at 15 MW_{th} testing – including **combustion, heat transfer, pollutant emissions,** ash deposition and corrosion
- Expand the performance database to include a range of coal types
- Evaluate and improve engineering and CFD tools for oxy-combustion by applying detailed test data obtained





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Oxy-PC Boiler Development Areas

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- **Evaluated Under Pilot-Scale Testing**
- **Evaluated Under Design Studies**

Operation/load change: dynamic response

Heat transfer : radiative / convective

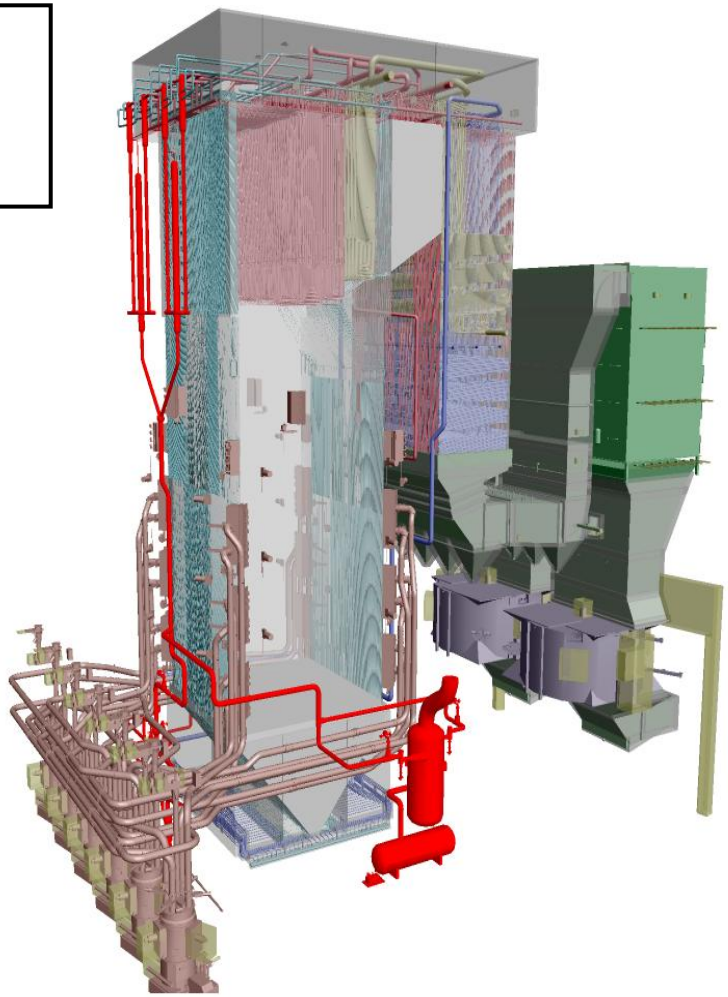
Oxy tangential firing system design

Oxygen Injection

Effect of coal quality

Flue gas recycle

Mill adaptation / integration



Control Logics & Safety

Corrosion
- high temperature
- low temperature

Fouling & Slagging

SCR adaptation

Air in-leakage

Gas pre-heater adaptation

Acid dew point

Excess O2

Emissions

Ash Properties

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Oxy T-Fired Boiler Development

Project Team:

- Alstom – R&D Execution
- 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

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Oxy T-Fired Boiler Development

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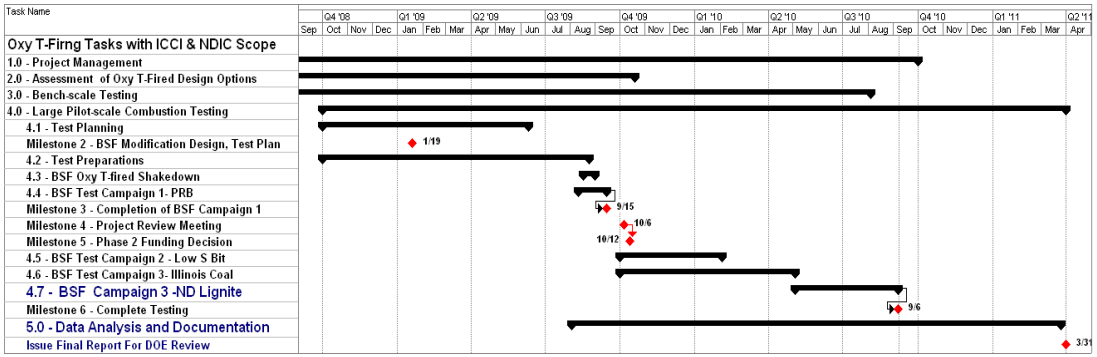
Start: October 2008

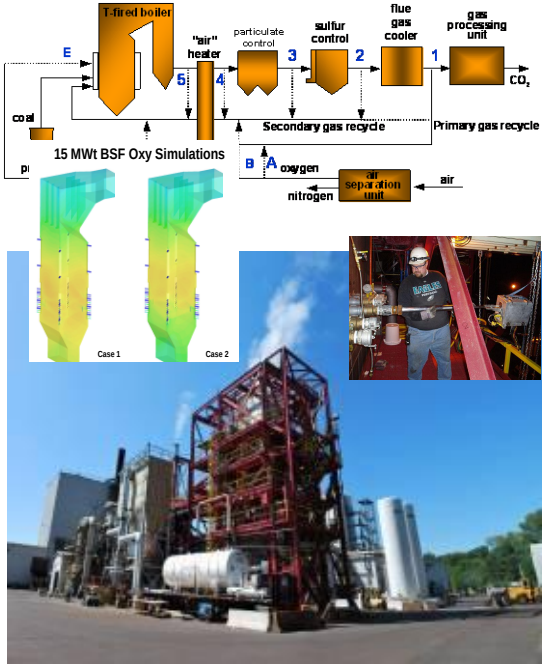
Budget: $8,740,000

DOE Funding: $5,000,000



Status

- Process and CFD Screening Completed
- BSF Modifications For Oxy-Firing Completed
- Campaign 1 Testing Completed Sept. 2009 – Subbituminous
- Campaign 2 Testing Completed Feb. 2010 – Low S Bituminous
- Campaign 3 Testing Completed April 2010 – High S Illinois Bituminous



Next Steps

- Campaign 4 North Dakota Lignite (Scheduled September/October 2010)
- Complete Engineering Tools & CFD Modeling Refinement and Validation

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15 MW_{th} BSF After Oxy Modifications

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Major New Equipment

- Oxygen Supply and Injection System
- Gas Recirculation Systems
- Fabric Filter for Particulate Removal and NID SO2 Scrubber
- Instrumentation and Controls

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15 MW_{th} BSF After Oxy Modifications

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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

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Transitions Between Firing Modes

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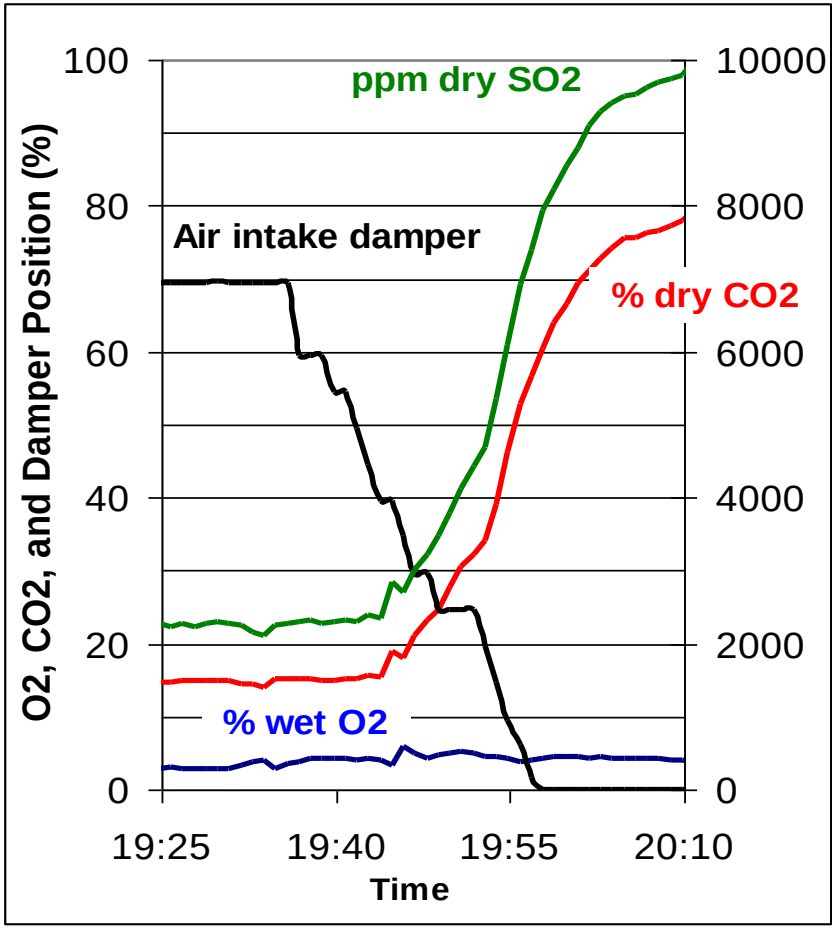
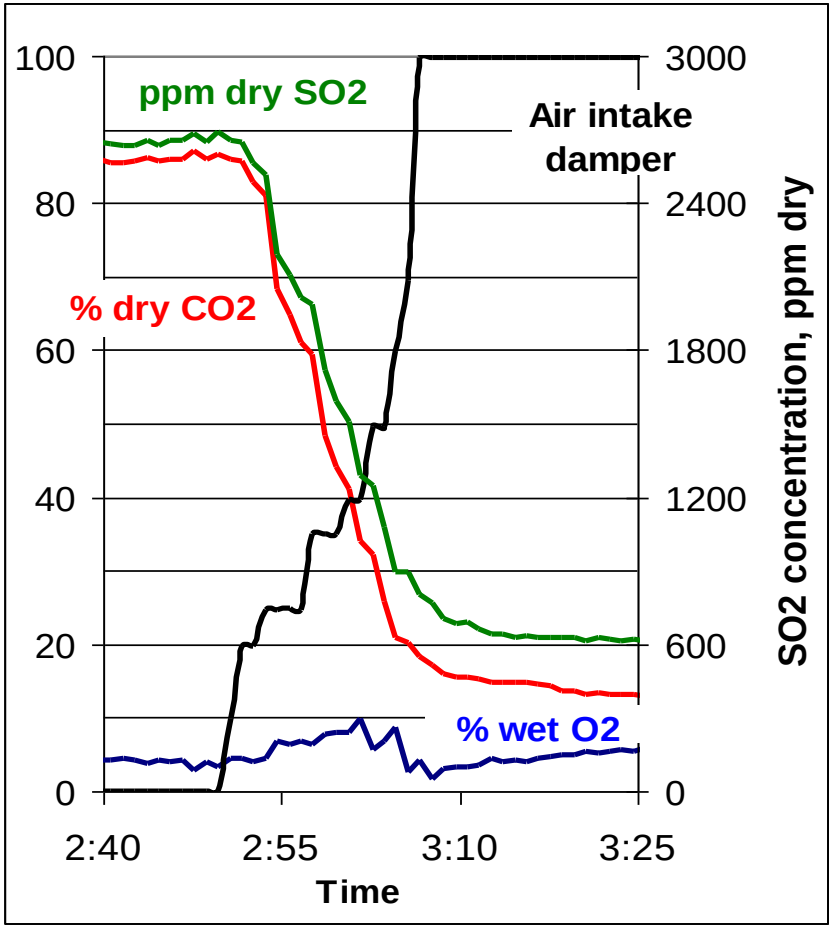
Air to Oxy Transition



Oxy to Air Transition



Transitions Air to Oxy or Oxy to Air in 15-20 mins

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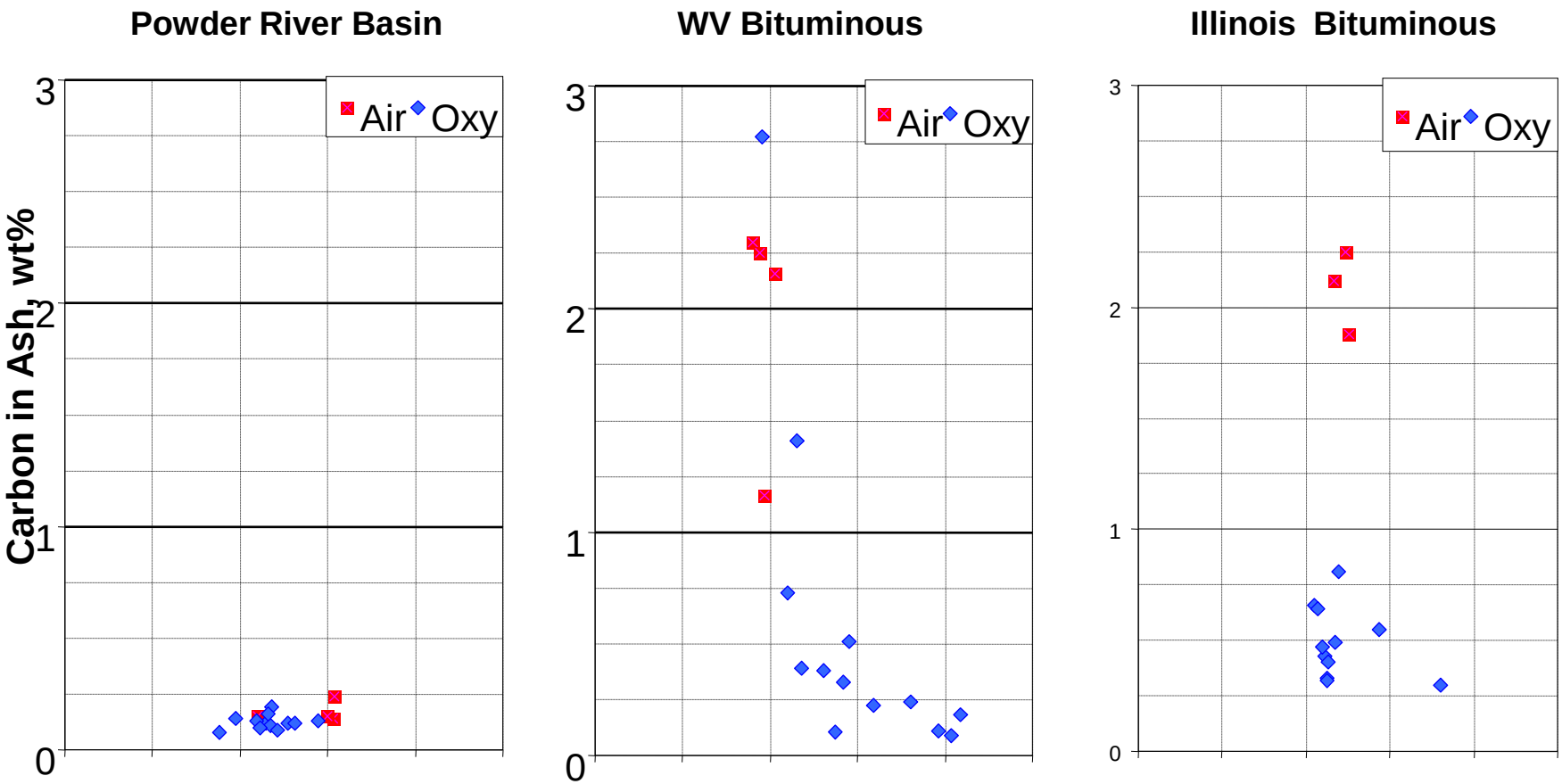
Carbon Burnout During BSF 15MWt Testing



Main Burner Zone Stoichiometry

All Tests with between 1.5% and 3% O2 (wet) at furnace outlet

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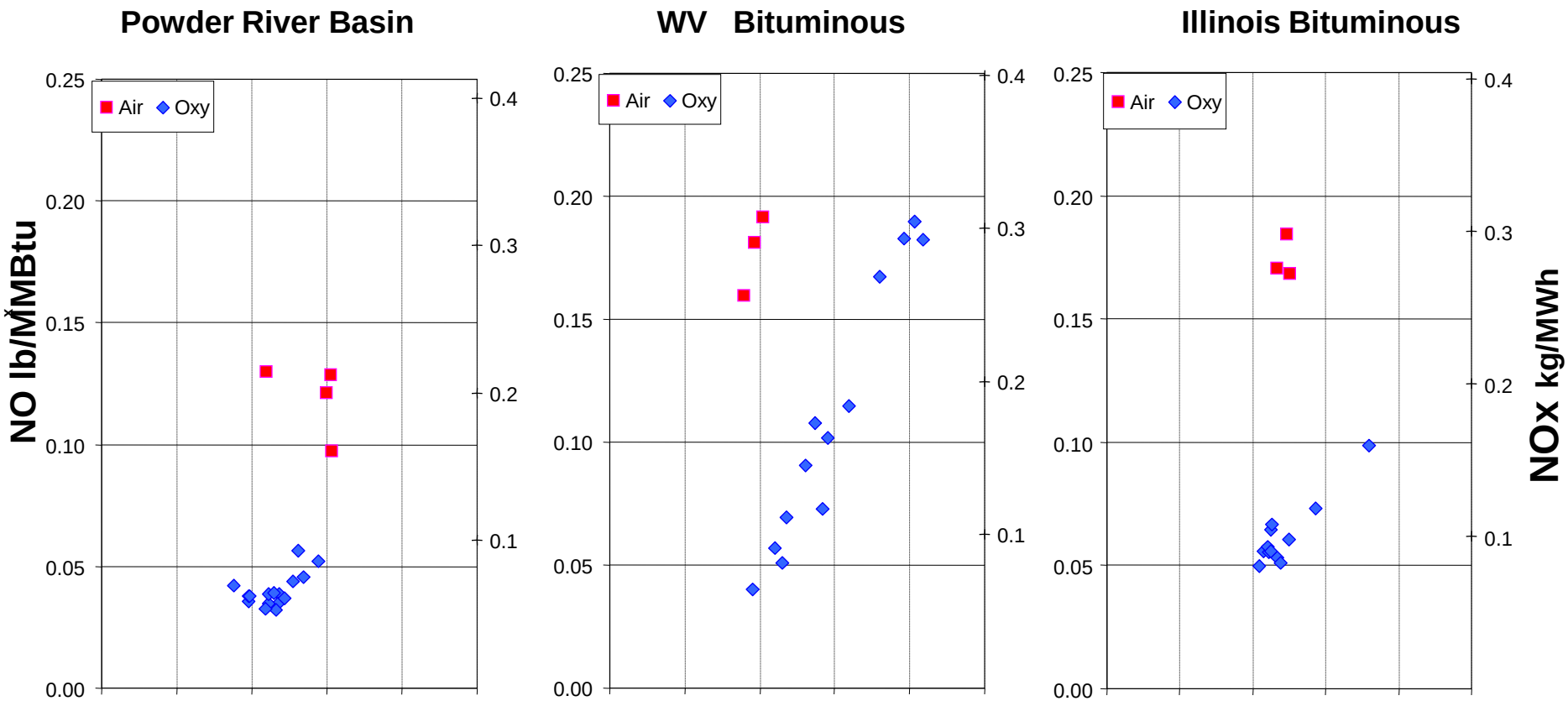
NOx Emissions During BSF 15MWt Testing



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All Tests with between 1.5% and 3% O2 (wet) at furnace outlet

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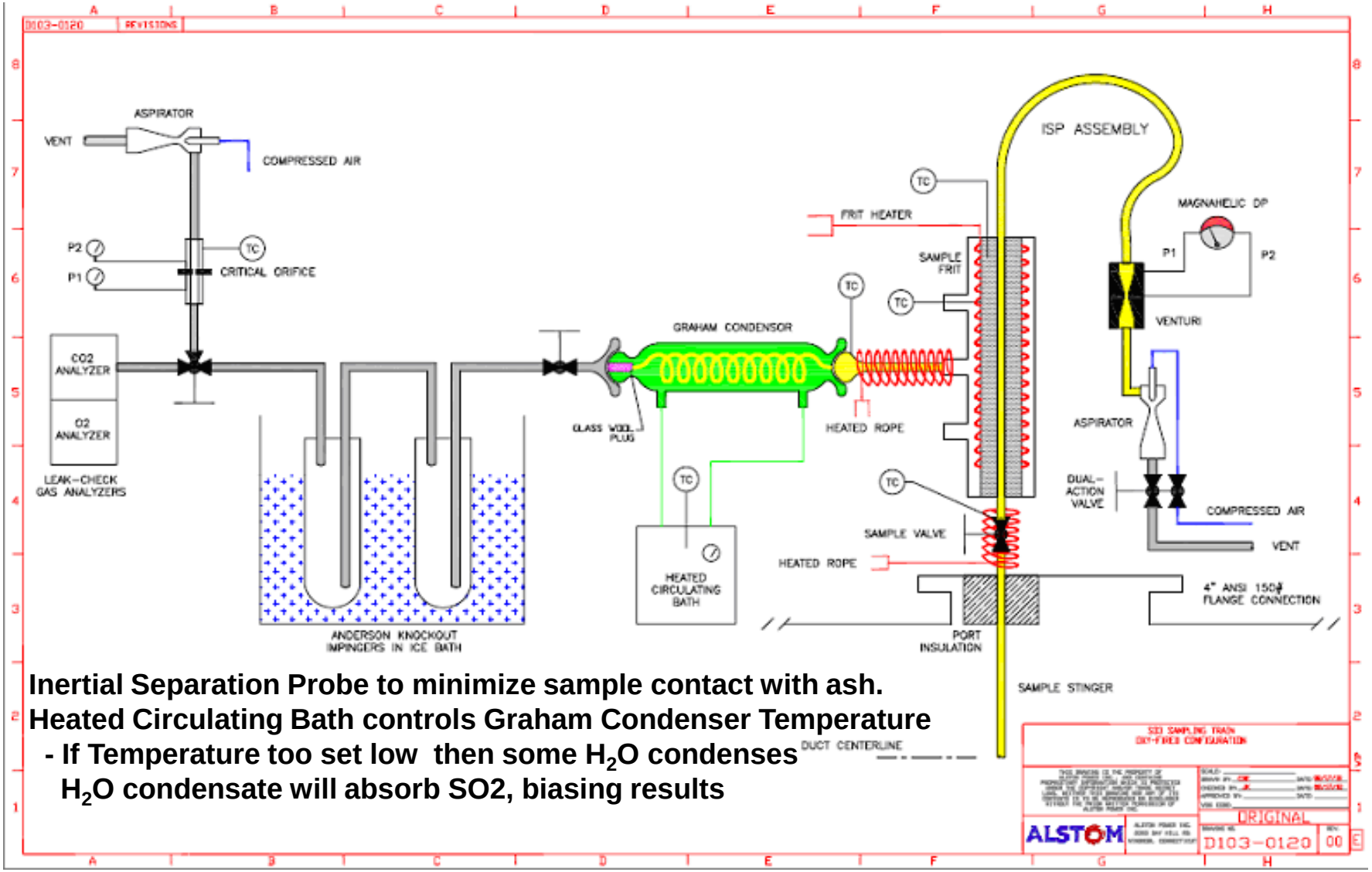
SO3 Testing – Alstom Modified Condensation Method



Inertial Separation Probe to minimize sample contact with ash.

Heated Circulating Bath controls Graham Condenser Temperature

- **If Temperature too set low then some H_2O condenses**
  H_2O condensate will absorb SO2, biasing results

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SO3 - Economizer Outlet Measurements and Conversion

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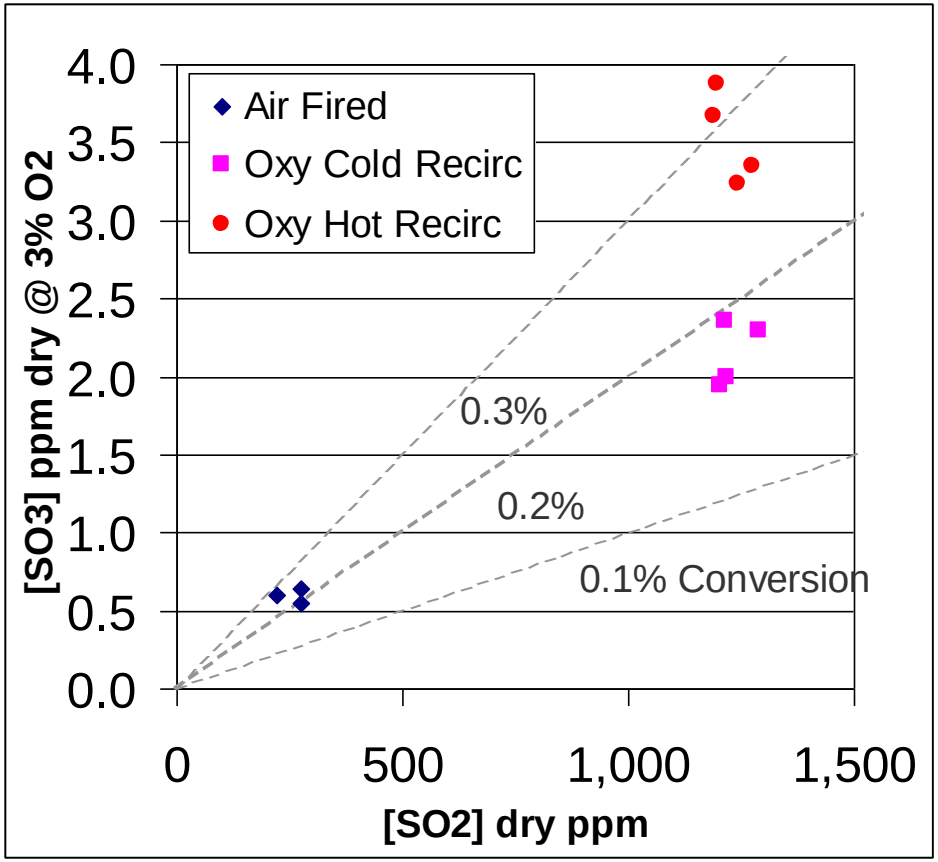
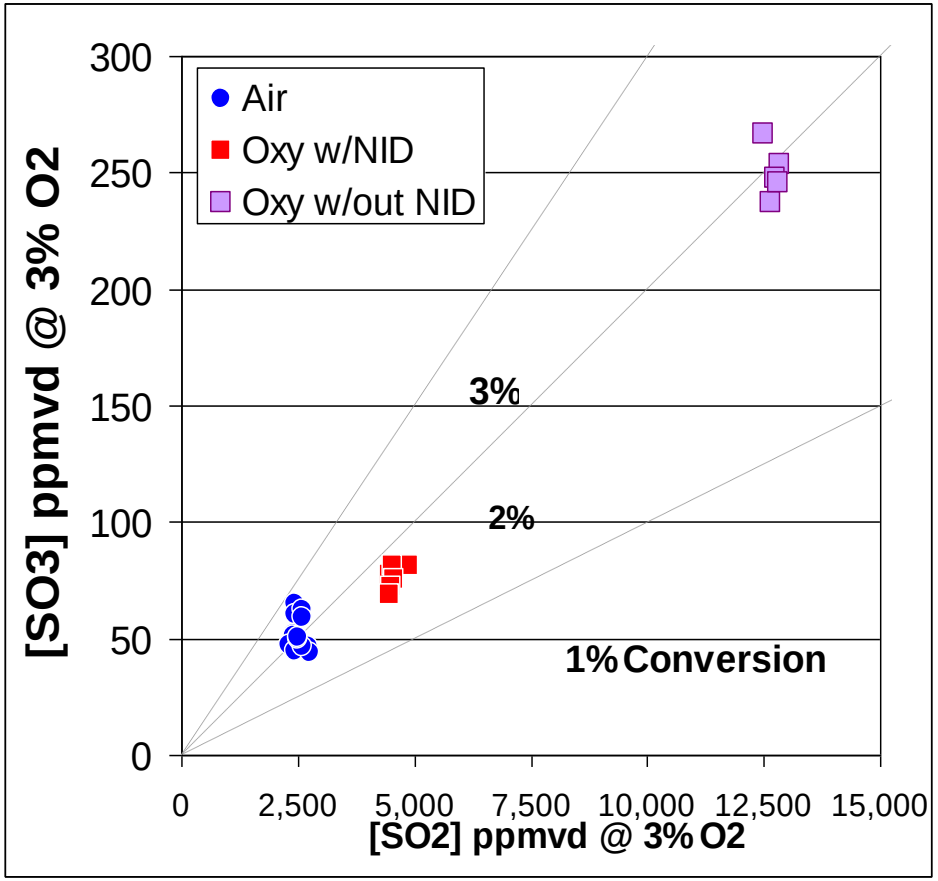
PRB Sub-Bit Economizer Outlet SO_3 Results



Illinois Bit Economizer Outlet SO_3 Results



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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
- TCH

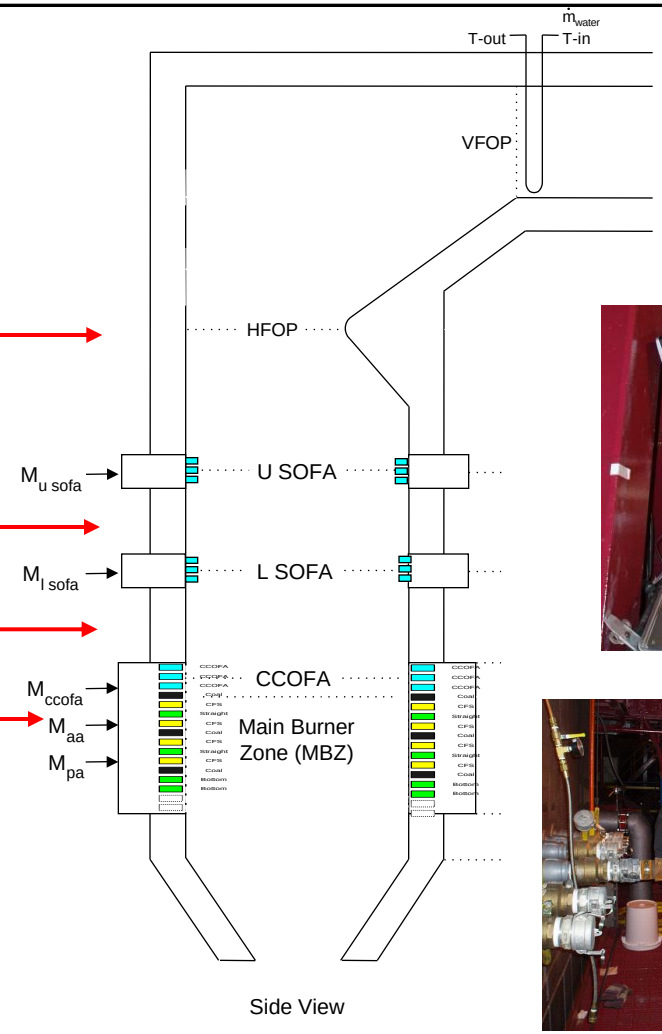
Detailed Mapping Planes

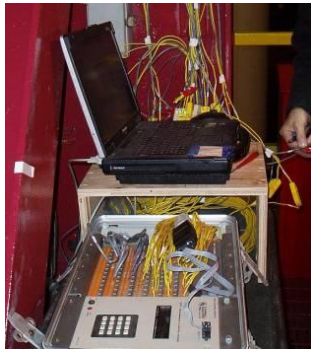
Plane 273

Plane 180

Plane 141

Plane 66





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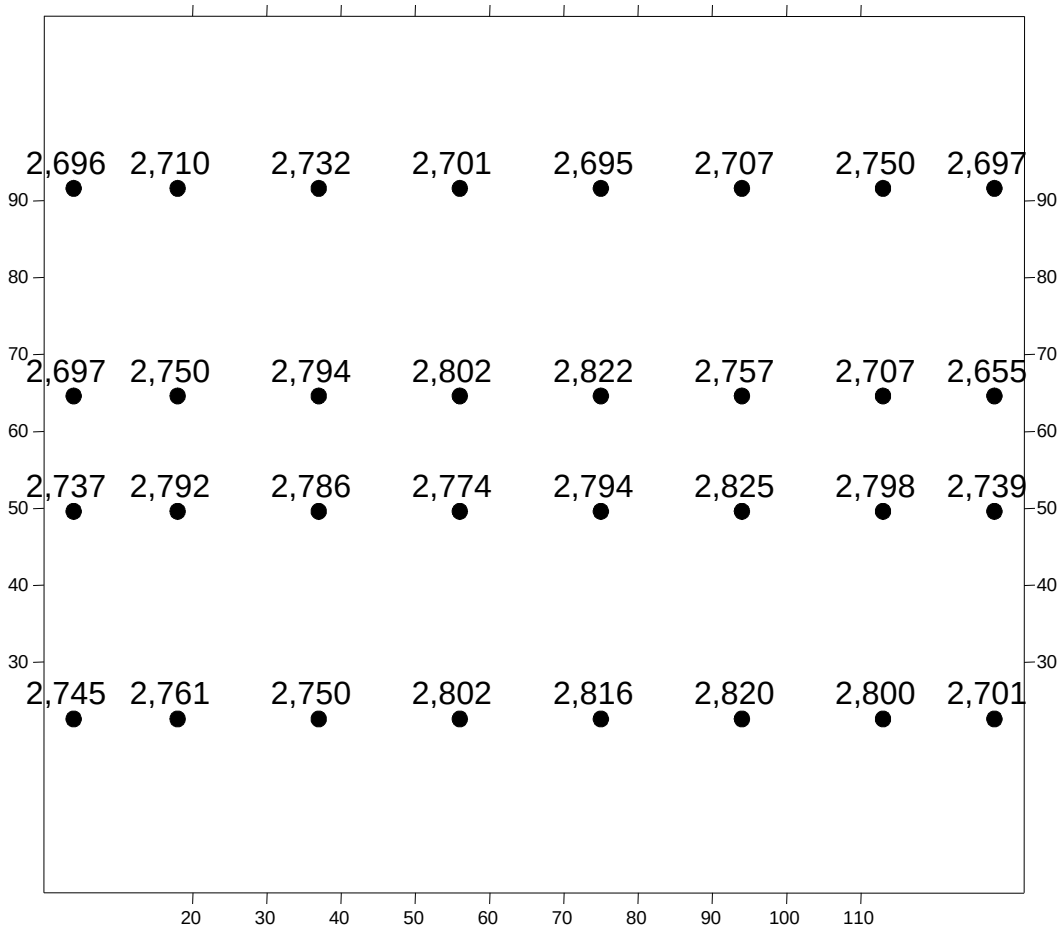
In-Furnace Temperature – Planar Points

Sample Planar Temperature Profile Between OFAs



Front

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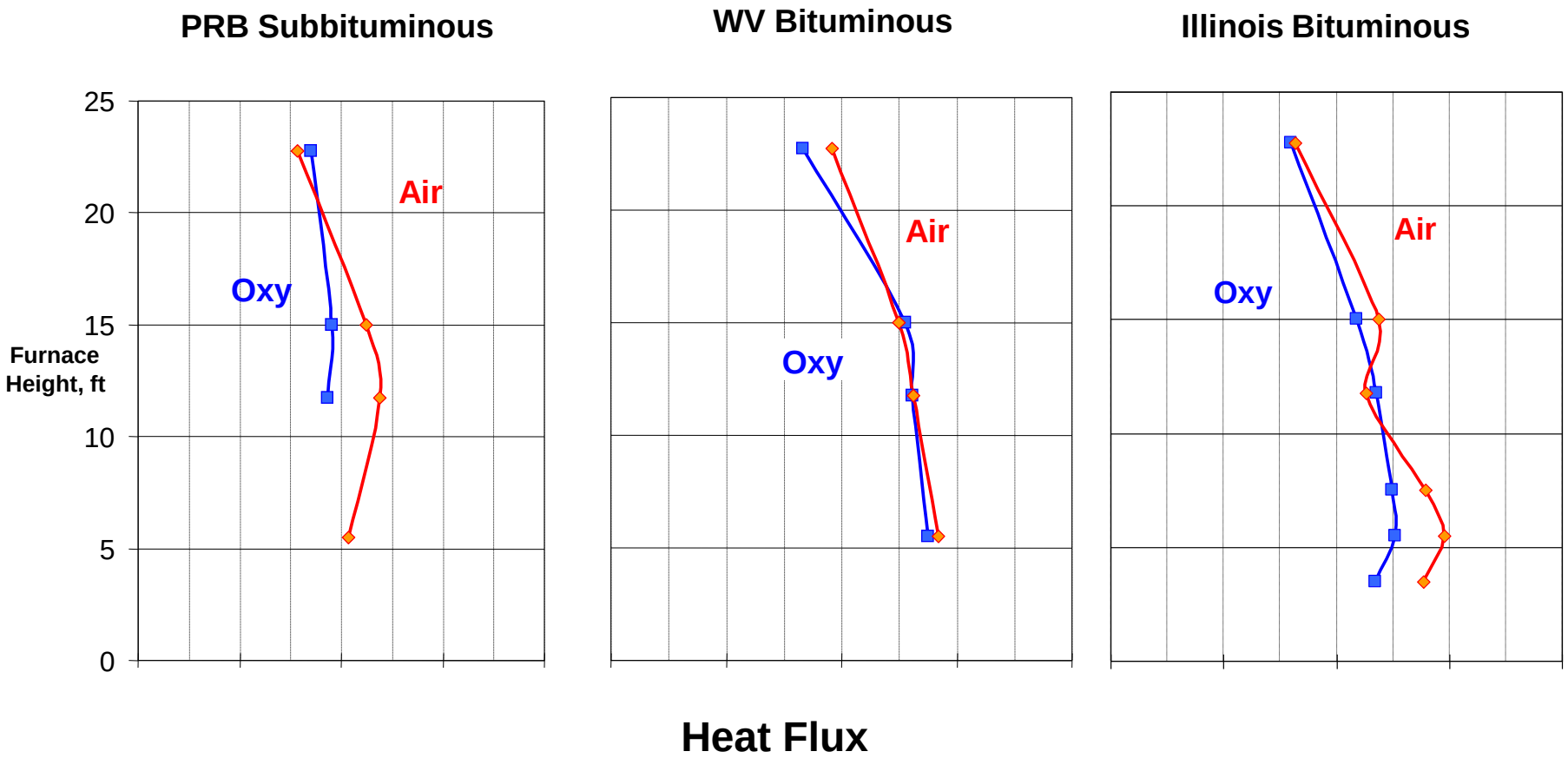
Incident Heat Flux – Air vs Oxy Long Term Tests



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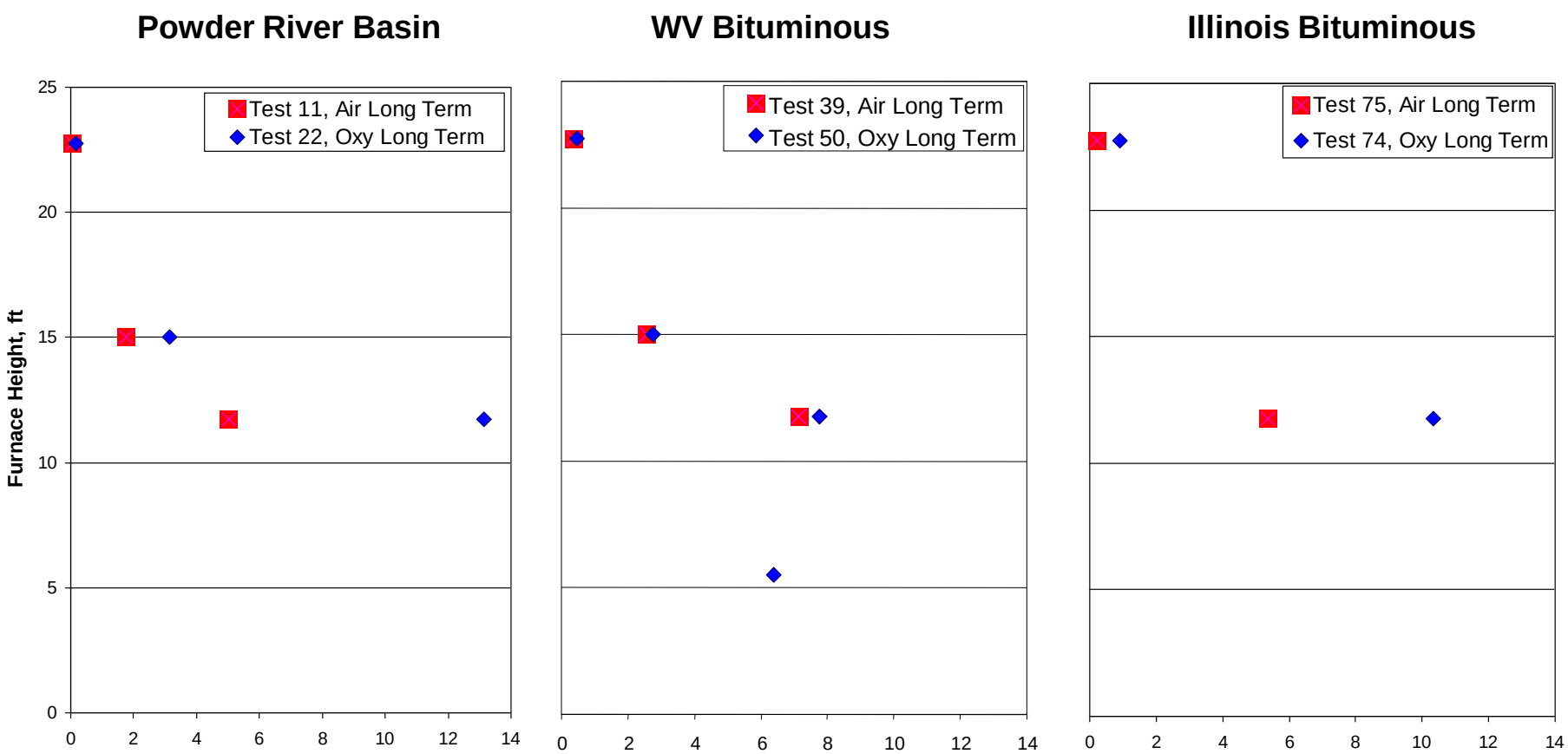
Gas Probe Measurements – CO Profile



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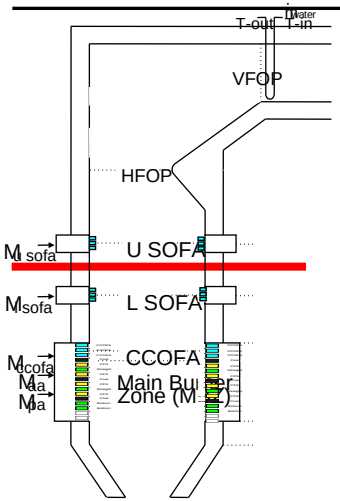
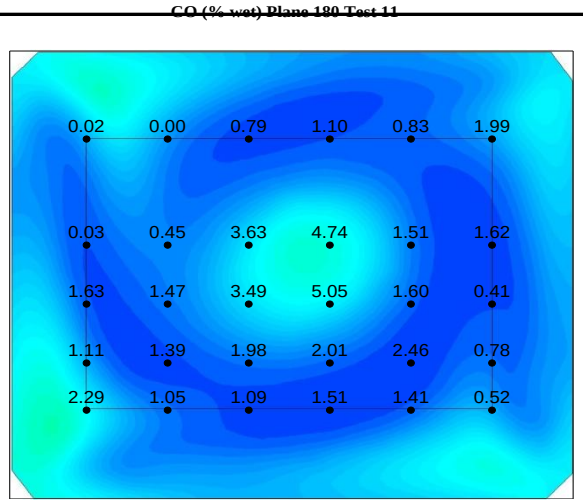
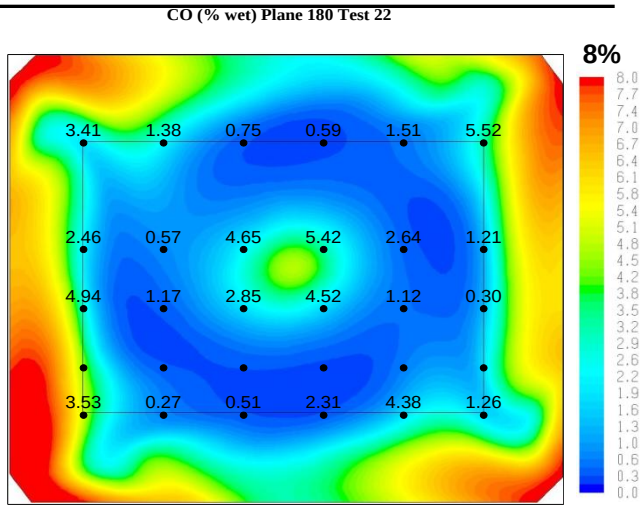
In-Furnace CO Concentrations: Air-Fired Vs. Oxy-Fired



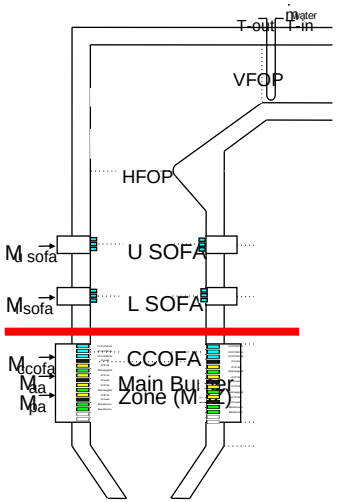
Side View



Air-Fired



Oxy-Fired



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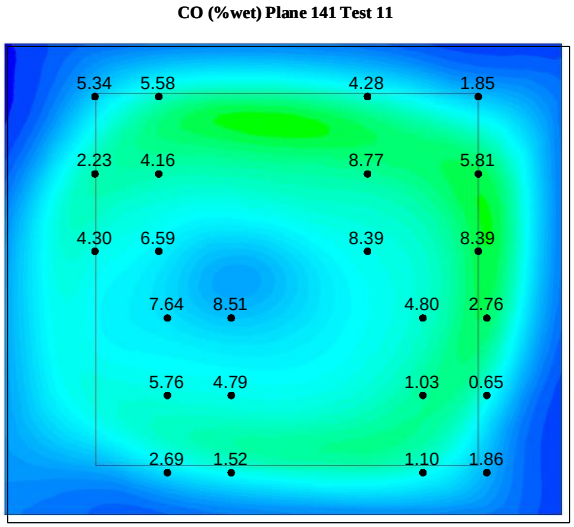

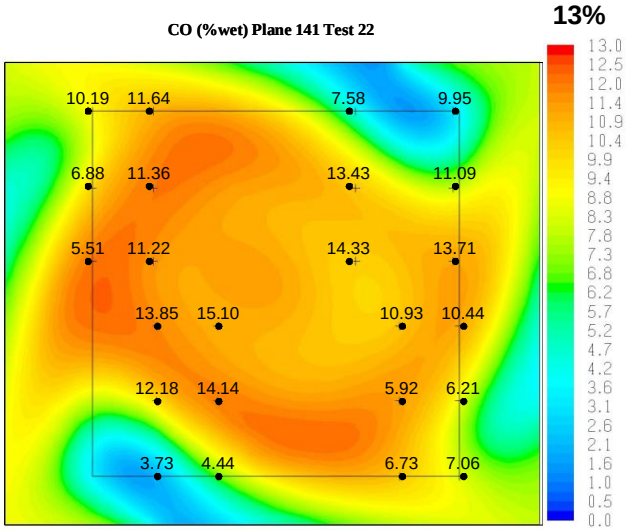

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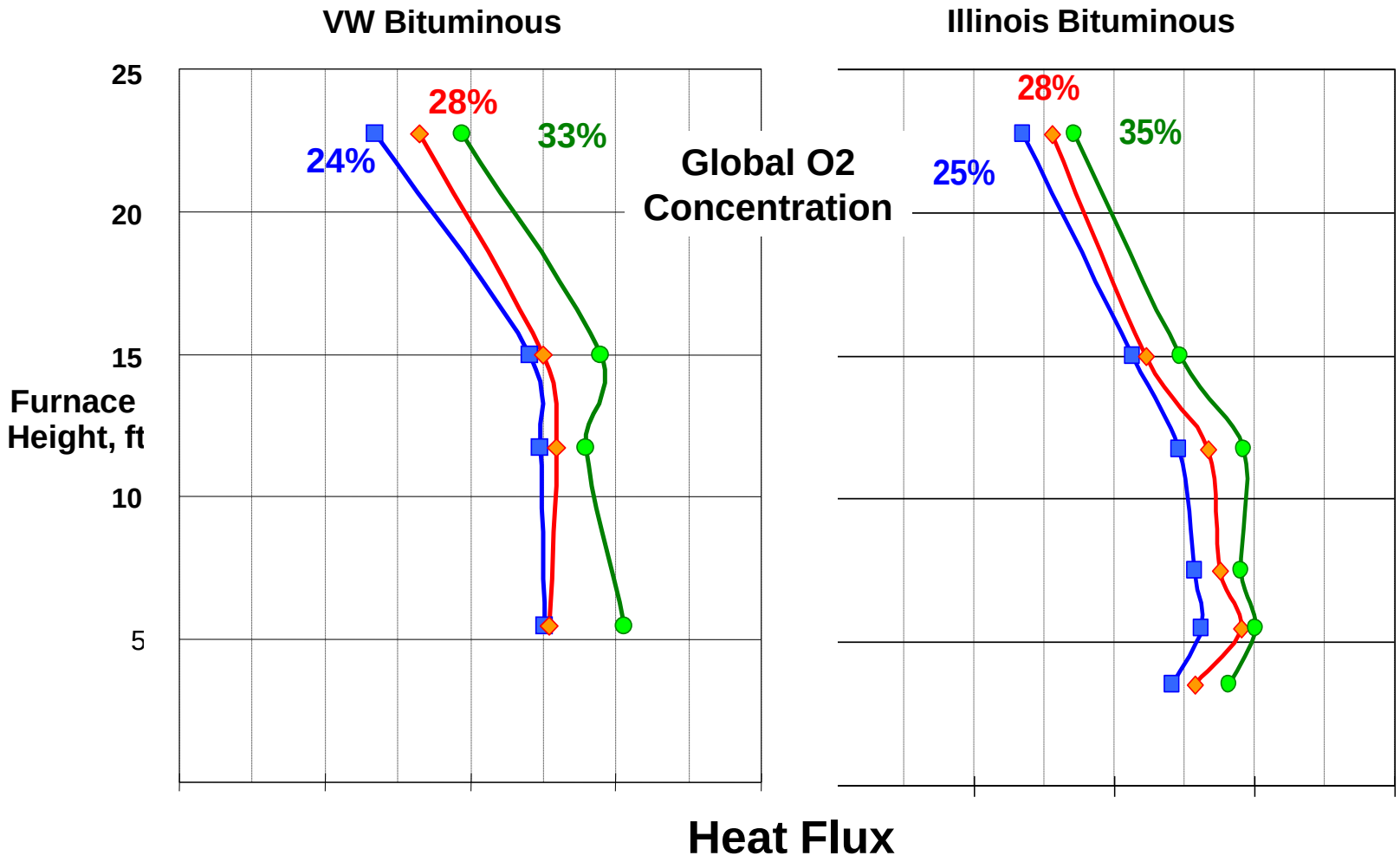
WW Heat Flux – Recycle Rate Impacts



Ability to control heat flux magnitude with recycle rate

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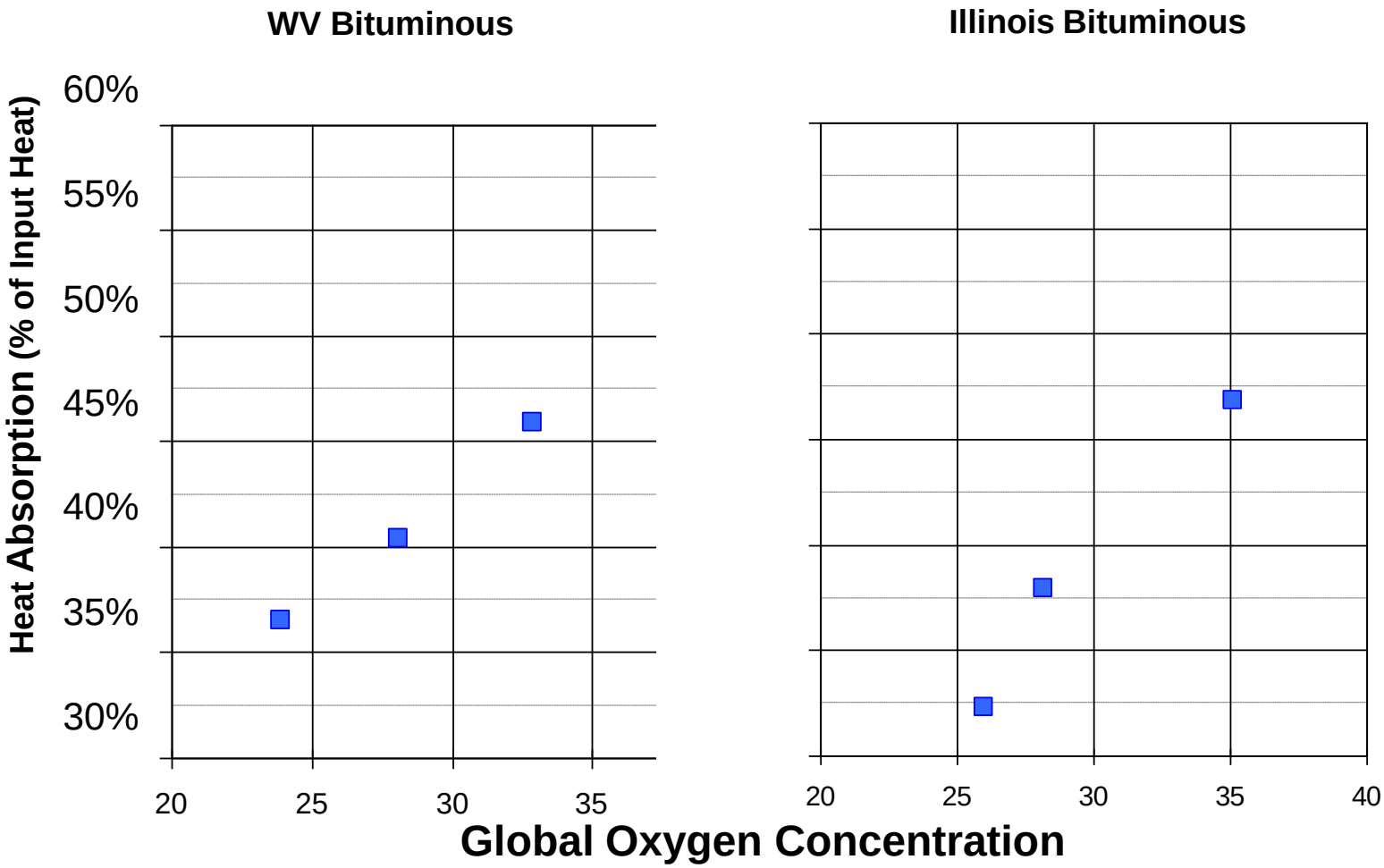
Furnace Energy Absorption – Recycle Rate Impacts



Energy Absorption to HFOP based on average of Suction Pyrometer measurements

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BSF Testing - General Results

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- **Heat Transfer**
  - Generally similar range of heat flux and temperature
  - Able to change profile by adjusting operating conditions
- **SO3 Formation**
  - SO2 to SO3 conversion appears to be similar
  - SO3 concentrations could be much higher for oxy-firing depending on recycle scheme
- **Ash Deposition**
  - Appeared generally similar
  - Fly ash and lower furnace deposits had similar composition, upper furnace deposits had higher sulfur content for PRB
- **Waterwall Corrosion**
  - Appeared generally similar

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BSF Testing – General Results

ALSTOM

- **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 Bituminous 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 than Air firing (PRB Subbituminous, WV Bituminous, Illinois Bituminous)
    - Roughly 50% Reduction from Air-Firing on lb NOx / MMBtu Fired

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Conclusions

- **The project is providing evaluation of important oxy-combustion process and boiler design parameters.**
- **Key technical data is being obtained defining oxy firing impacts on boiler performance and operation.**
- **Engineering and CFD modeling tools are being refined and validated with test results.**
- **Pilot results are providing design guidelines and performance data that provide a strong foundation for the <u>next step of commercial - scale demonstration</u> of an oxy-combustion PC boiler.**

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- Illinois Department of Commerce and Economic Opportunity Through the Office of Coal Development and the Illinois Clean Coal Institute Illinois Clean Coal Institute
- North Dakota Industrial Commission and Lignite Council
- 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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