Recovery Act: Oxy-Combustion Technology Development For Industrial-Scale Boiler Applications
DE NT-0005290

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NETL CO_2 Capture Technology Conference
Pittsburgh, PA
August 24, 2011

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- Clean Power

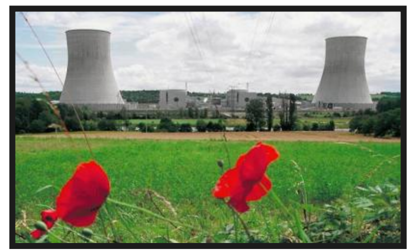
N°1 in integrated power plants

N°1 in air quality control systems

N°1 in services for electric utilities

- CO_2-Free & Renewables

N°1 in hydro power



N°1 in conventional nuclear power island

Recent acquisition of solar and wind

- Carbon Capture
  - Post-Combustion
  - Oxy-Combustion

Full Power Systems Portfolio and Technology Mix

Oxy-Combustion Technology - Why Oxy?

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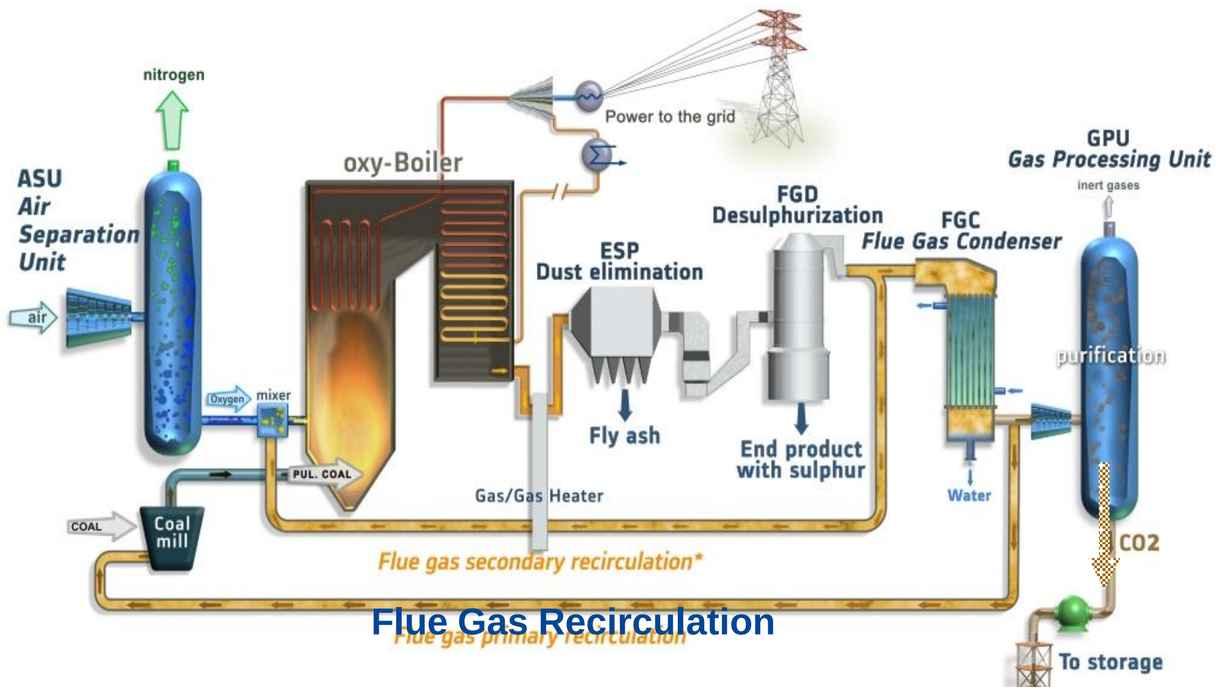
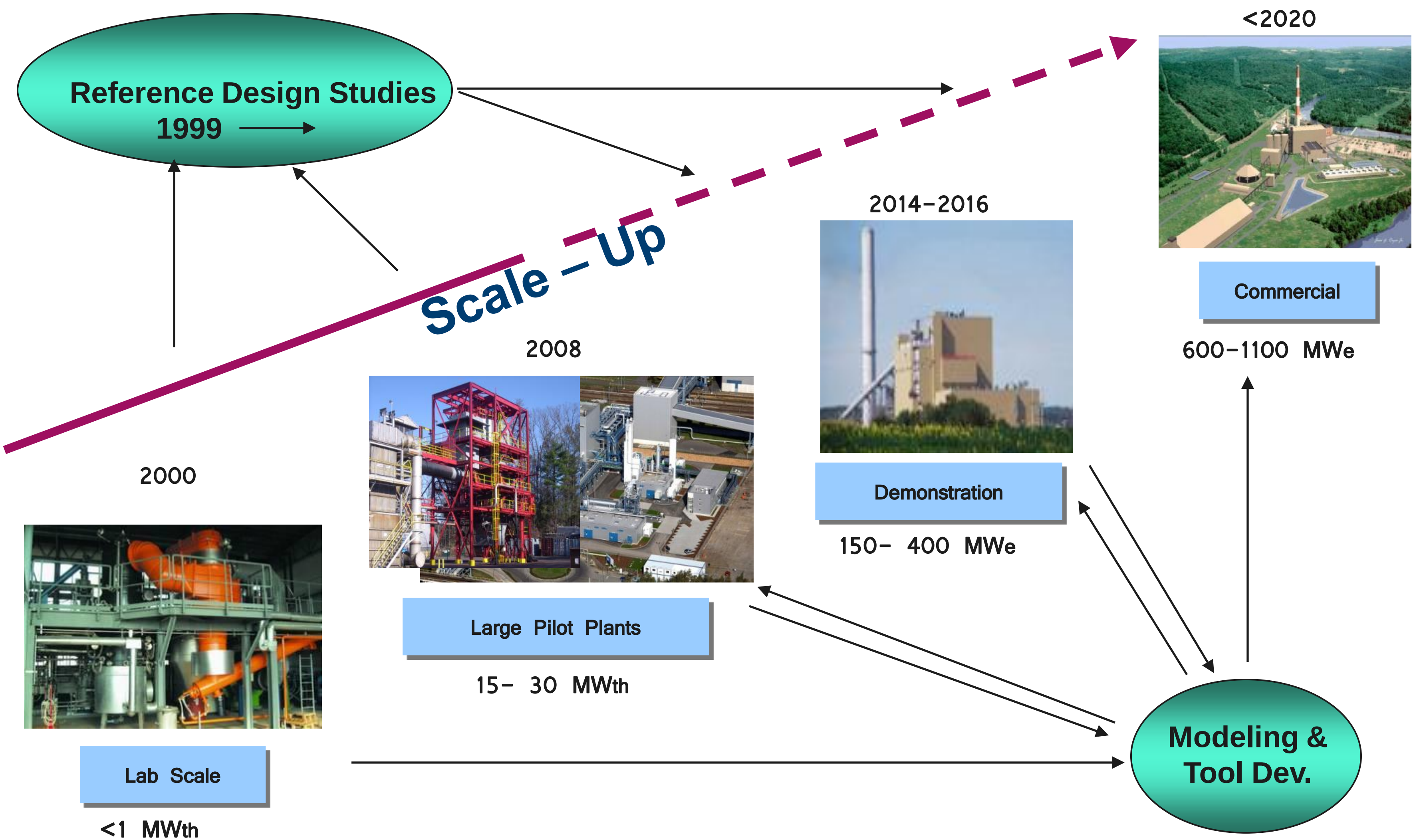
- Cost Competitive (with other CCS, Wind, Solar, Biomass)
- Reliability / Low Risk: Adapts Conventional Components
- New and Retrofit Applications
- High CO_2 Capture Rates (>90%)
- Near Zero Emissions
- CO_2 "Ready" Approach
- Potential for O_2 Production Cost Reduction



Flue Gas Recirculation

Alstom Oxy-PC Combustion Technology Development Steps



DOE – CO2 Capture Technology Meeting August 24, 2011 Pittsburgh, PA

Oxy T-Fired Boiler Development
Project Objectives

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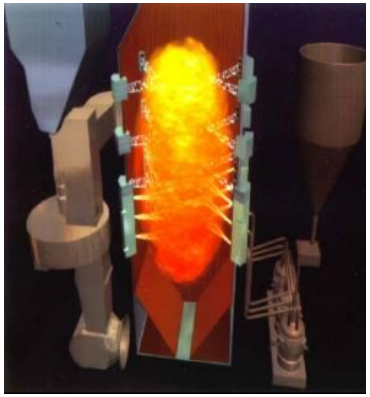
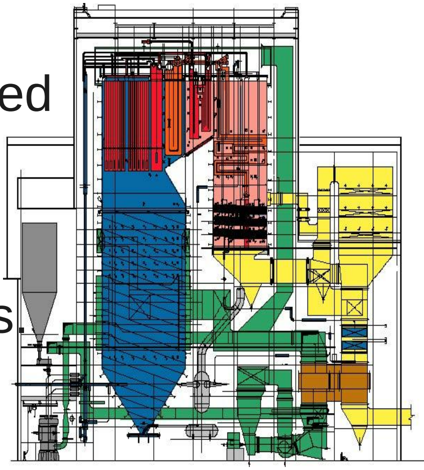
Develop and validate an oxyfuel T-fired boiler system as part of commercially attractive CO_2 capture solutions.



- Design and develop an oxyfuel firing system for T- fired boilers
- Evaluate the performance in pilot scale tests at 15 MW_{th} testing
  - operation, combustion, heat transfer, pollutants, ash deposition and corrosion
- Evaluate and improve engineering and simulation tools for oxy-combustion by applying detailed test data obtained
- Develop design guidelines
- Develop the design, performance and costs for a demonstration-scale oxyfuel boiler and auxiliary systems.
- Develop the design and costs for both industrial and utility commercial-scale reference oxyfuel boilers



Oxy T-Fired Boiler Development
Budget & Schedule

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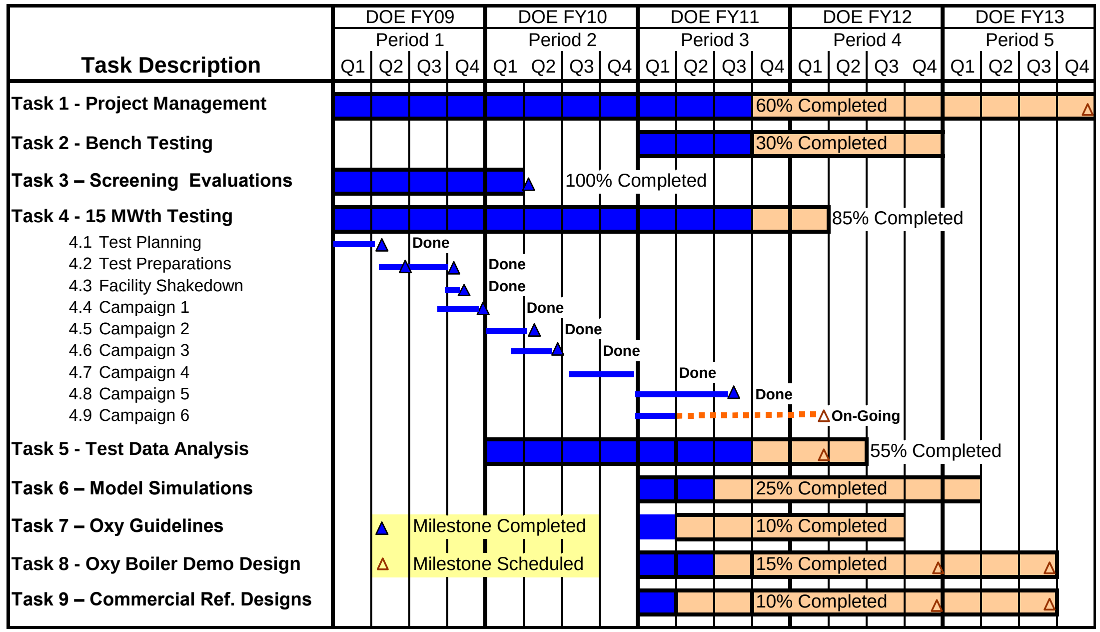
Project Start: Oct 2008 Duration: 5 Yrs

Total Budget: $21.5 M

DOE Funding: $15.0 M

Other Funding: Alstom, ICCI, NDIC, Utilities



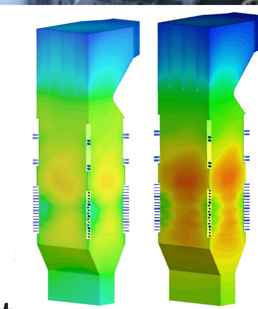
Utility Advisory Group

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

Project Status

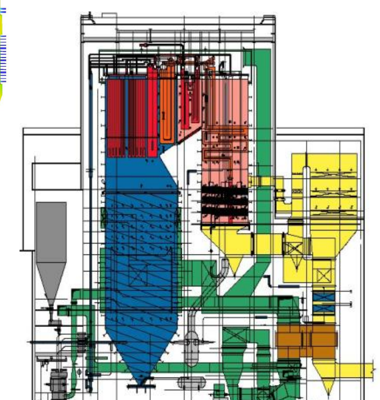
Accomplished

- Process and CFD Screening Completed
- Modifications For Oxy-Firing Completed
- Campaign 1 Testing Completed Sept. 2009 – Subbituminous coal
- Campaign 2 Testing Completed Feb. 2010 - Low S Bituminous coal
- Campaign 3 Testing Completed April 2010 - High S Illinois Bituminous coal
- Campaign 4 Testing Completed Oct. 2010 - North Dakota Lignite
- Campaign 5 Testing Completed August 2011- Schwarze Pumpe Lignite



Next

- Campaign 6 Testing of 2^{nd} Generation Concepts
- Tools & Modeling Refinement and Validation on-going
- Design guidelines On-going
- Reference & Demo designs On-going



15 MWth Oxyfuel Pilot Plant:
Alstom Boiler Laboratories, Windsor, CT

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15 MWth Boiler Simulation Facility -

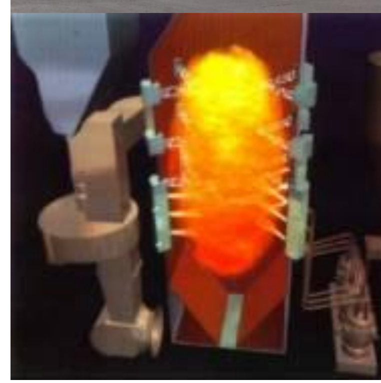
Multi-burner, Tangentially-fired

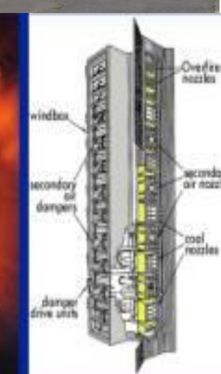
Flexible operating conditions

- air & oxy-firing, gas recycle configuration, oxygen injection, firing system design

Generation of detailed design and performance data

-combustion, emissions, heat transfer, deposition, corrosion





Oxy-PC Boiler
Development areas investigated

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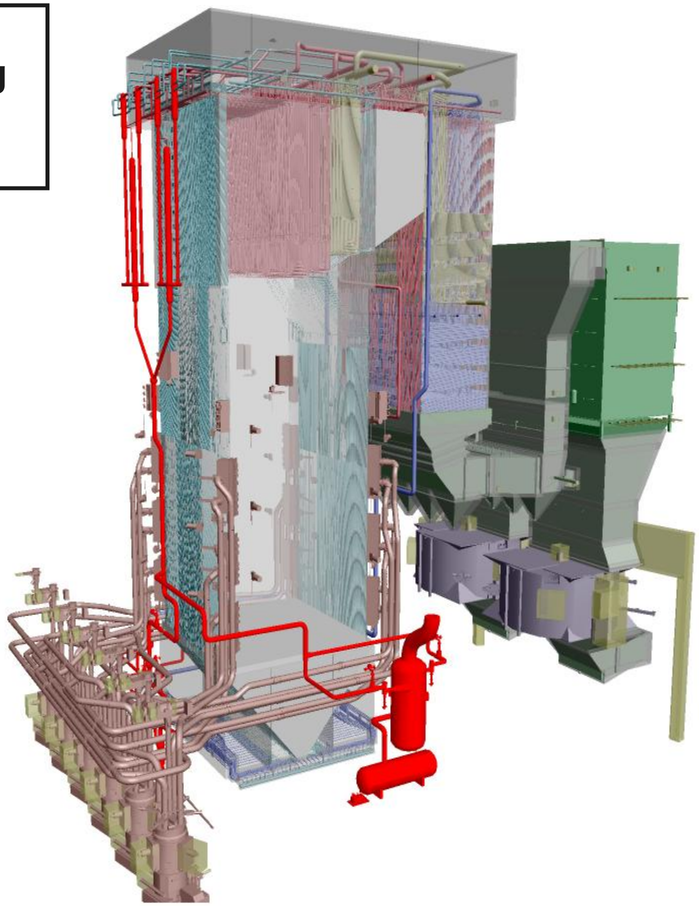
- Evaluated Under Pilot-Scale Testing
- Evaluated Under Design Studies



Evaluated Under Pilot-Scale Testing:
- Operation/load change: dynamic response
- Heat transfer : radiative / convective
- Oxy tangential firing system design
- Oxygen Injection
- Effect of coal quality
- Flue gas recycle
- Control Logics & Safety
- Corrosion
  - high temperature
  - low temperature
- Fouling & Slagging
- Air in-leakage
- Gas pre-heater adaptation
- Acid dew point
- Excess O2
- Emissions
- Ash Properties

Evaluated Under Design Studies:
- Mill adaptation / integration
- SCR adaptation

Comprehensive Test Program Addresses Several Areas

15 MWth Oxyfuel Pilot Plant:
Switch from air to oxy firing demonstrated

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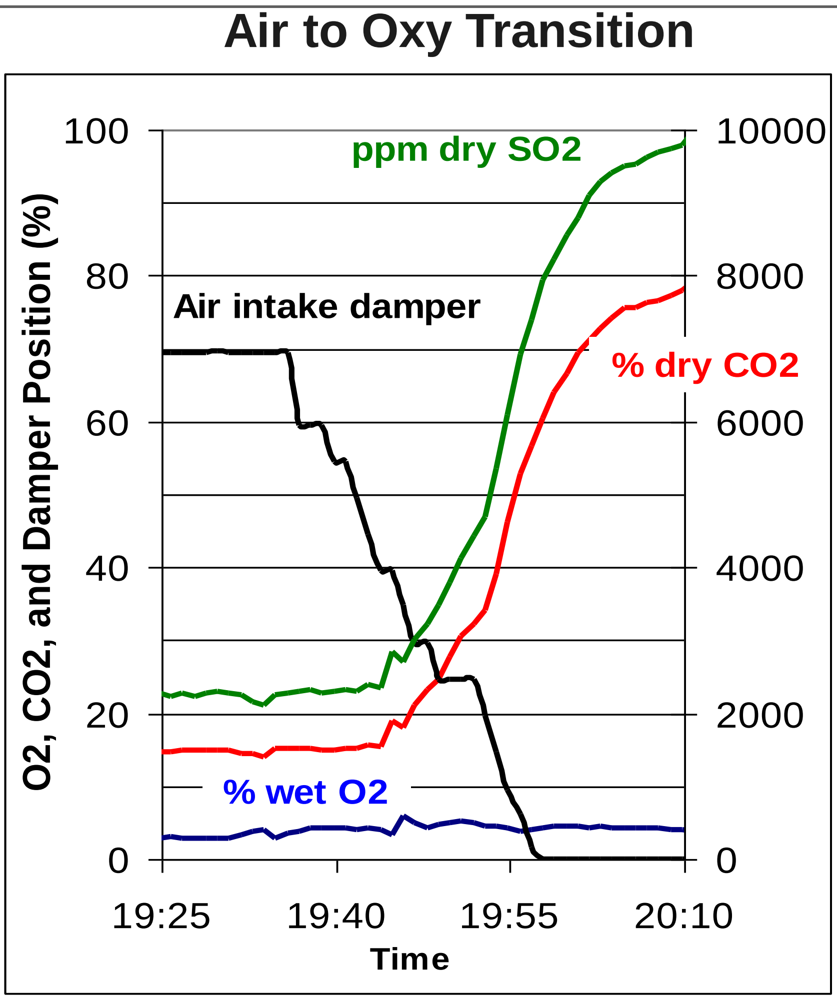

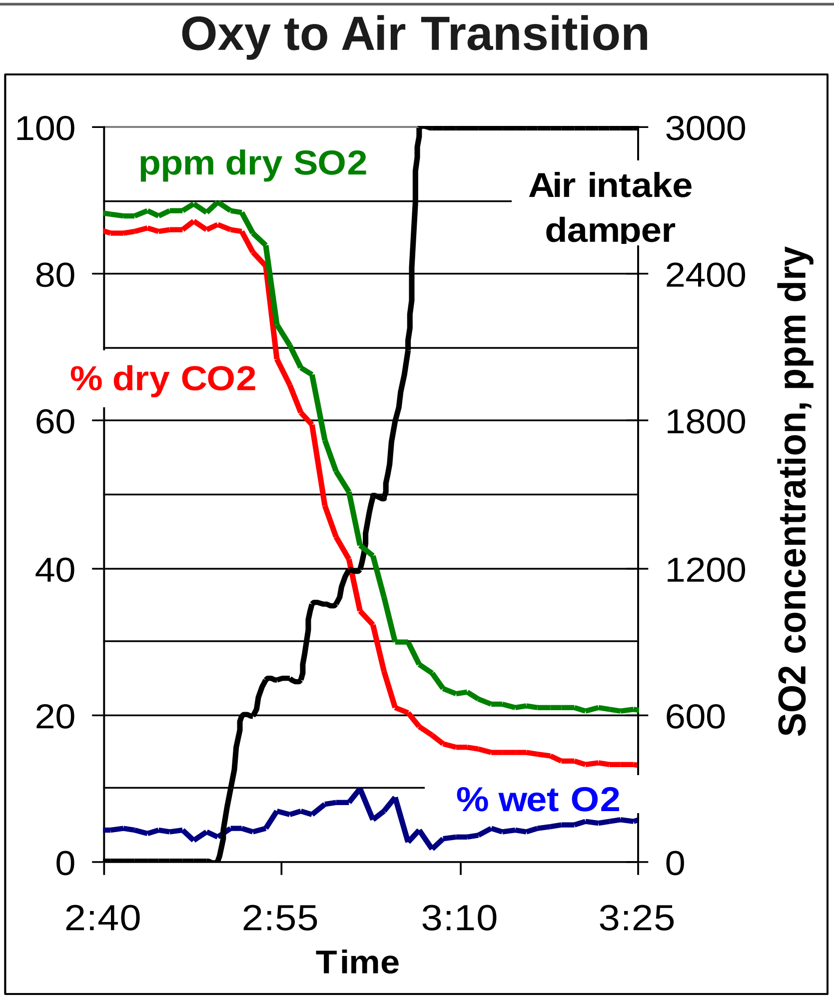

Transitions Air-to-Oxy or Oxy-to-Air about 30 mins

Changes in Oxy-Firing Gas Compositions – Illinois High Sulfur Coal

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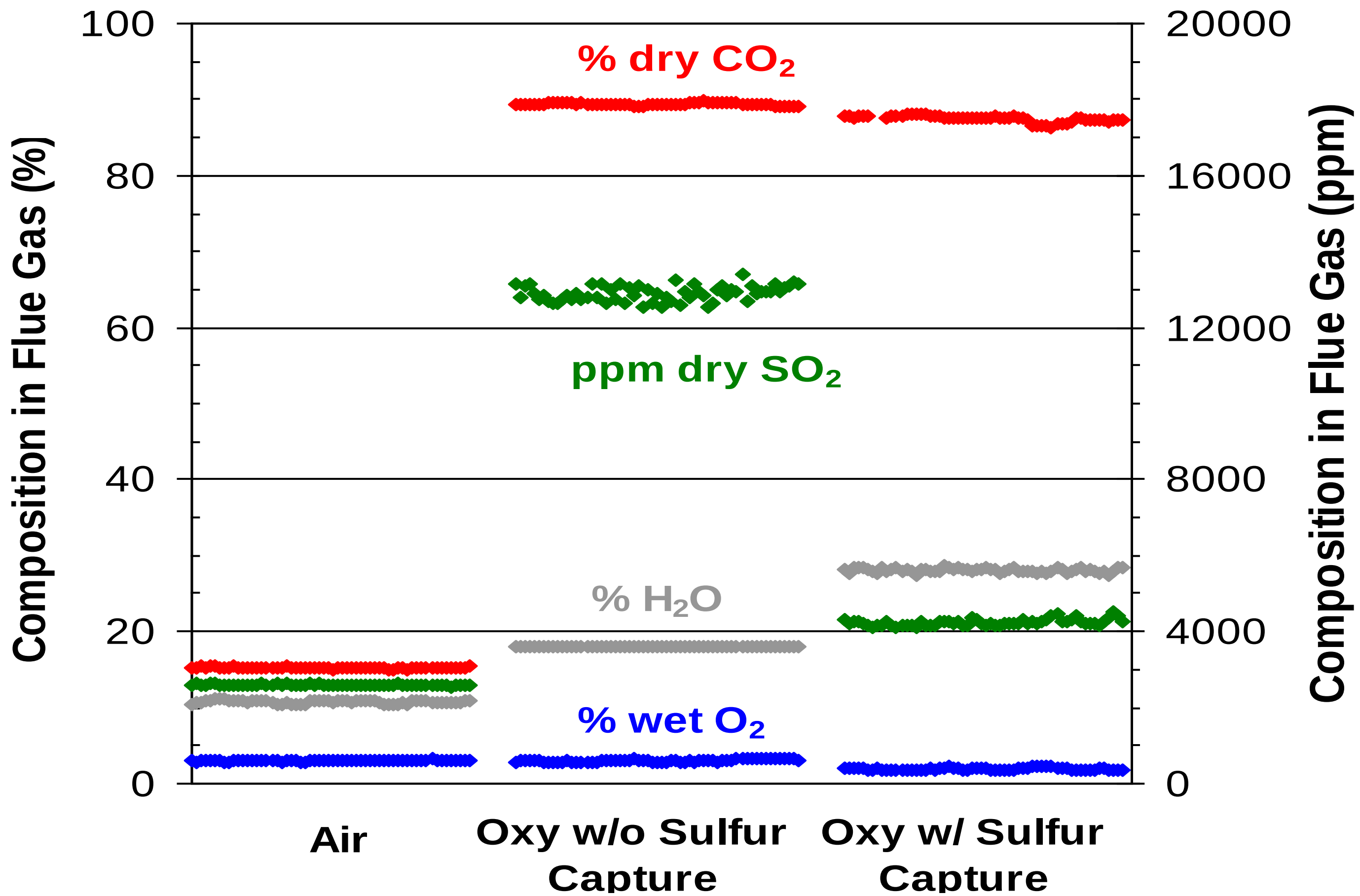

Significant Increase in SO_2 even with sulfur capture

Similar SO_3 Conversion Rate As Air Firing - Economizer Outlet Measurements in BSF

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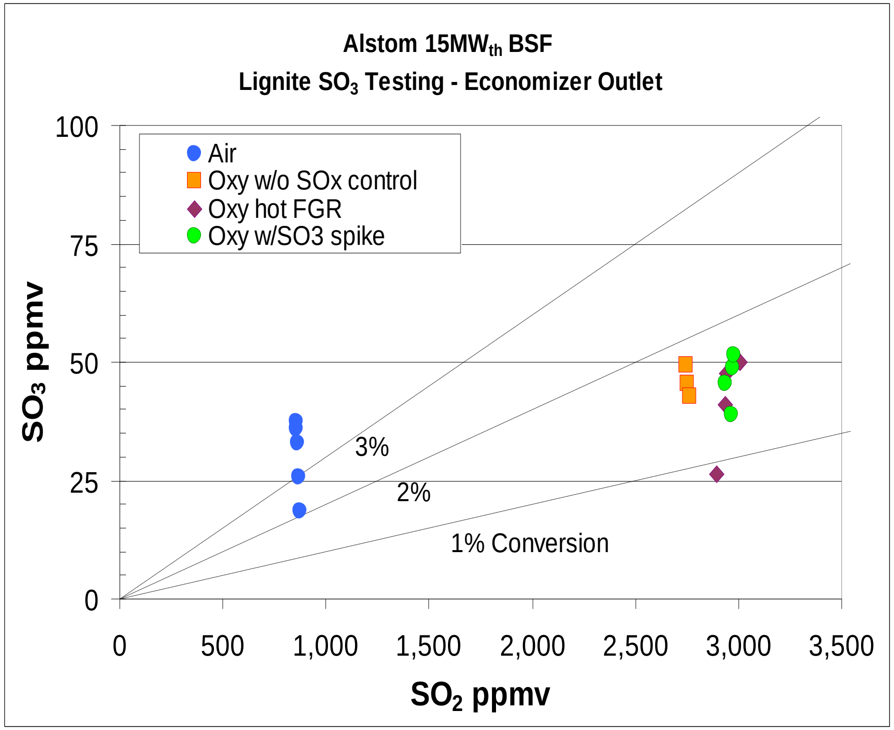
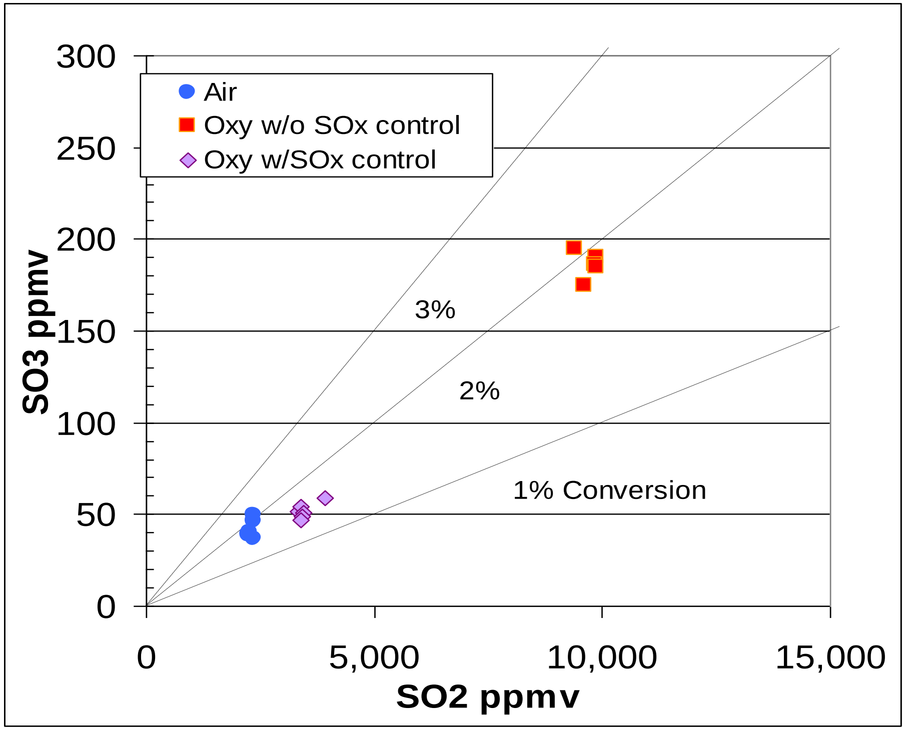
North Dakota
Economizer Outlet SO_3 results



Illinois Bituminous
Economizer Outlet SO_3 results



Similar SO2 to SO3 conversion rates

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Conversion Checked By SO_3 Addition: SO_3 Measurements Along System Path

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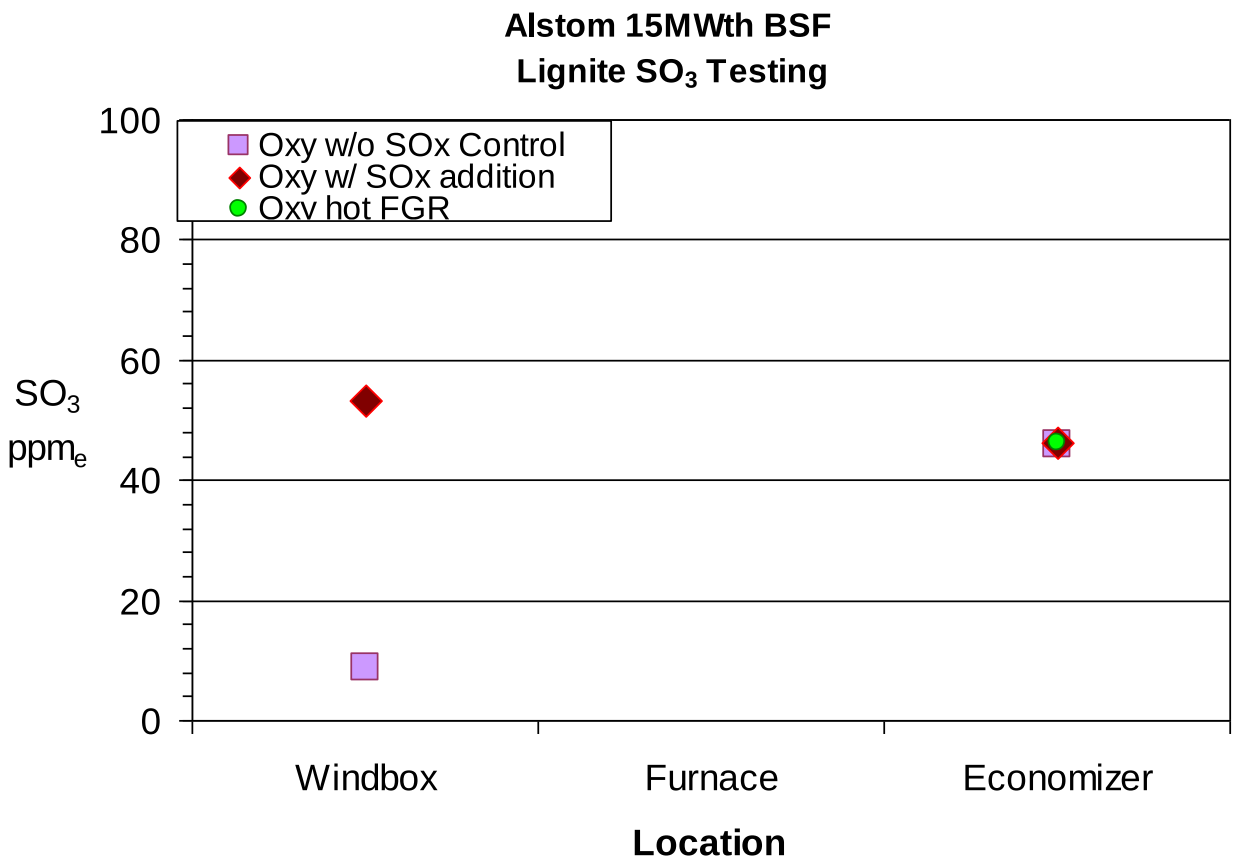

For windbox ppm$_e$ is the equivalent ppm impact @ the economize outlet

$$ppm_e \equiv ppm \bullet \frac{\dot{n}_{SecondaryFGR}}{\dot{n}_{FurnaceOut}}$$

Recycled SO_3 does not impact outlet emissions

Mercury Measurements -15 MWt North Dakota Lignite Testing

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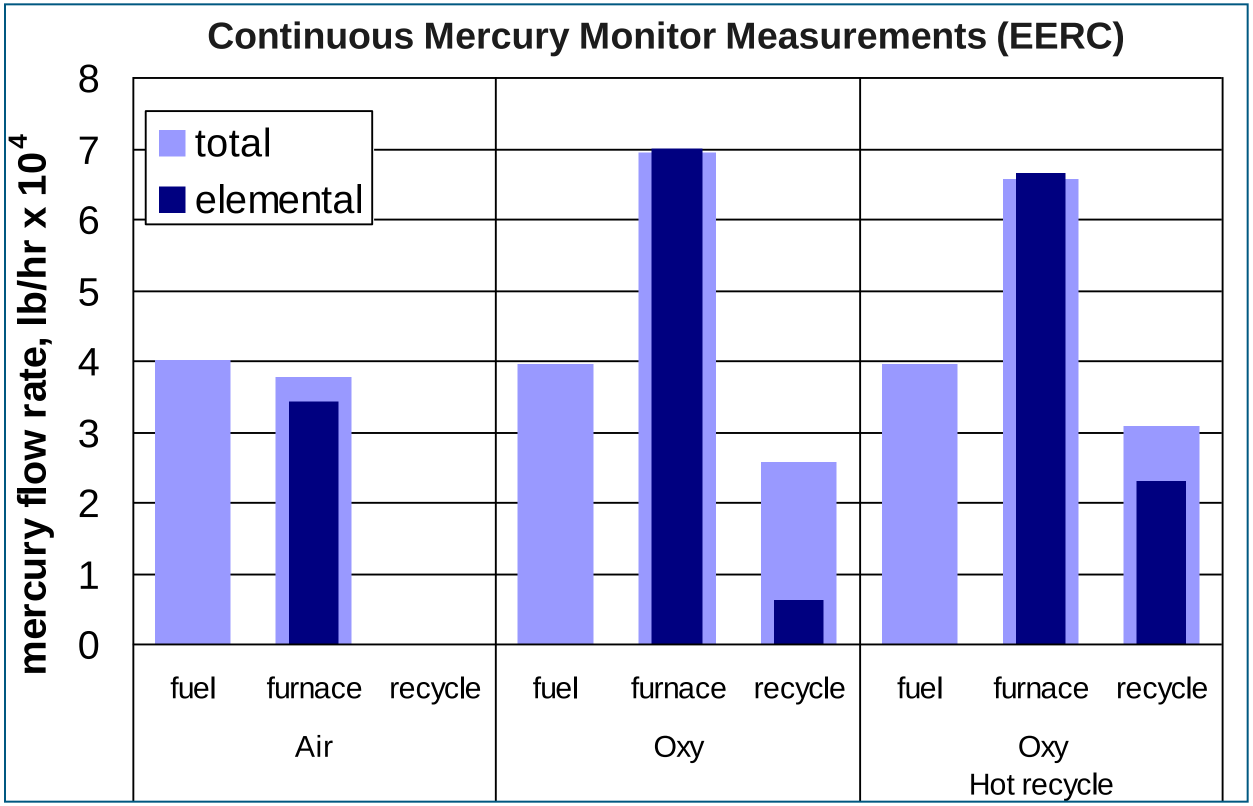
Mercury Measurements (Total and Speciation)

- Continuous Mercury Monitors (Tekran)
- Sorbent Traps
- Ontario Hydro



Mercury levels increase during oxy-firing at economizer outlet
Net mercury loadings leaving the boiler system similar to air

15 MWth BSF furnace mapping

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Probe Mapping Measurements

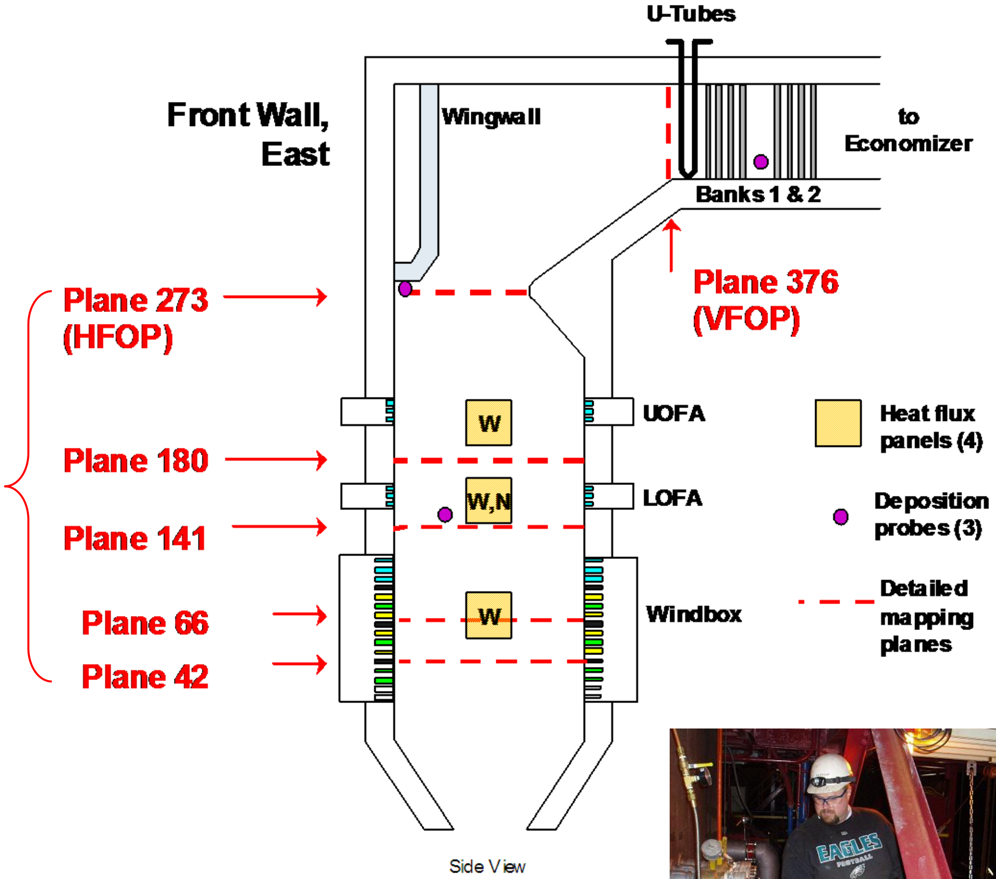
Gas Temperatures

Heat Flux:

- **-Total Incident**
- **- Radiant**

Gas Species:

- **- O_2**
- **- CO**
- **- CO_2**
- **- SO_2**
- **- H_2O**
- **- TCH**



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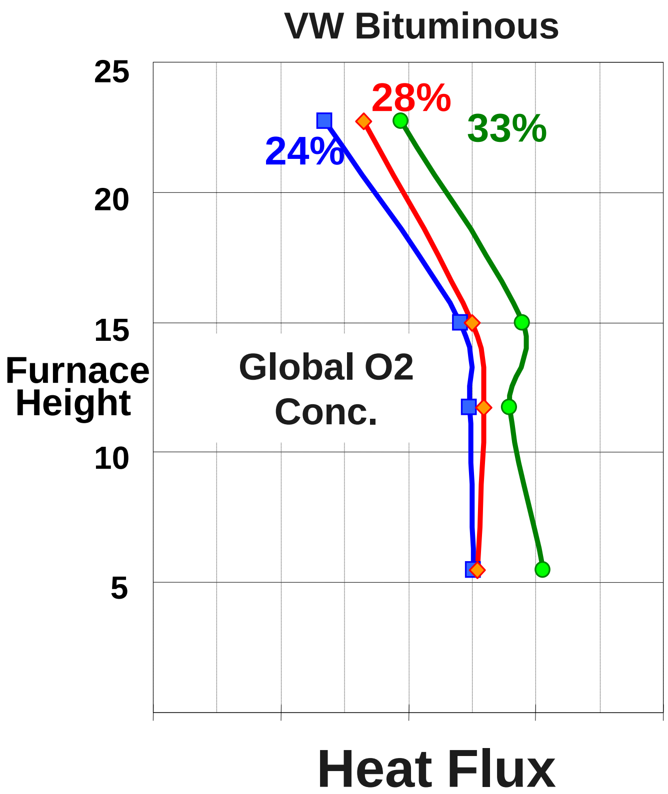
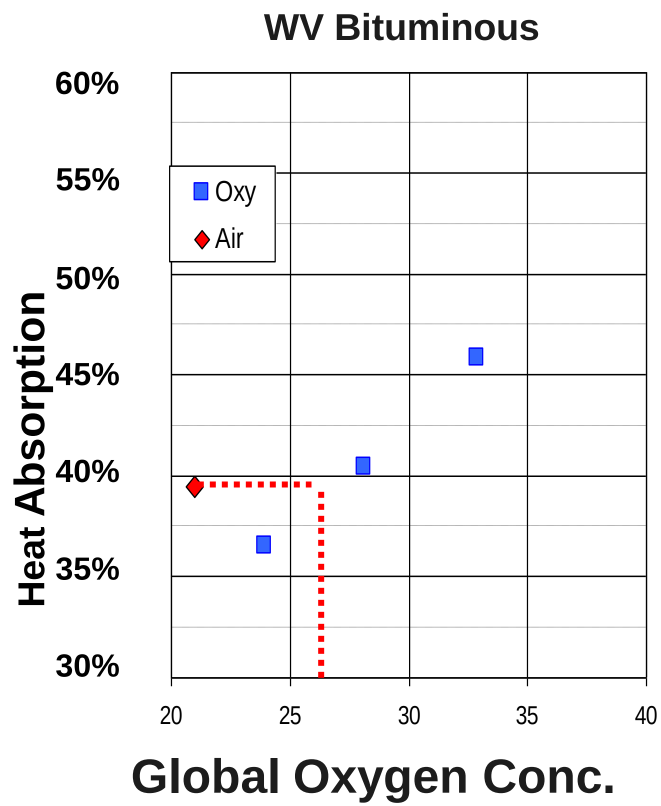
Furnace WW heat flux – gas recycle rate impacts

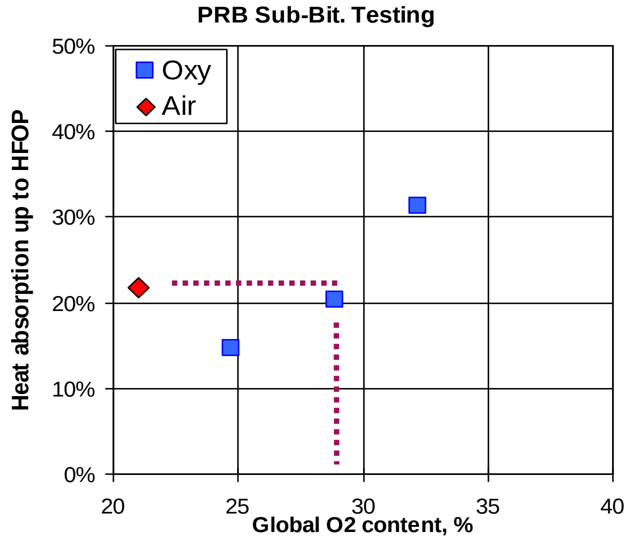


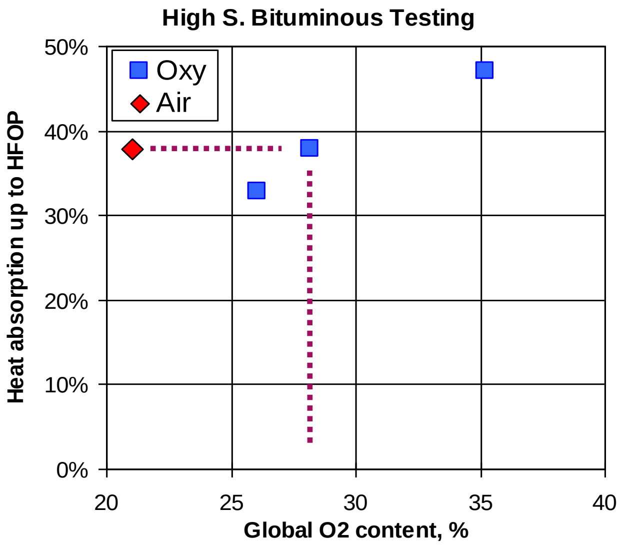


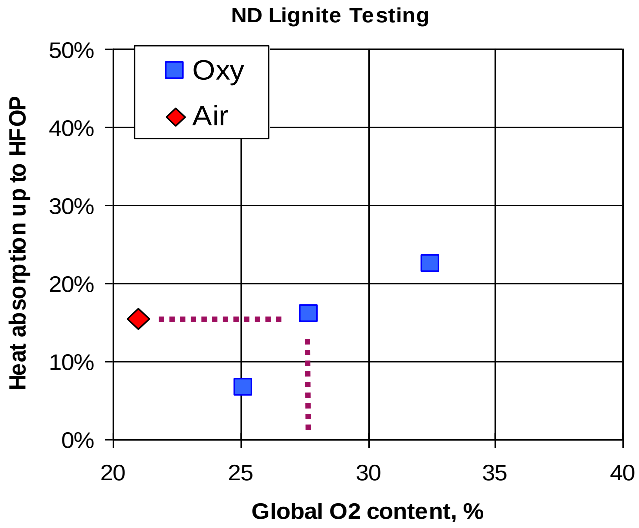
Ability to control heat flux magnitude with recycle rate

Reduced recycle rate shifts heat duty to furnace

A reduced recycle rate shifts more heat absorption to the furnace







In each case, a global O_2 of ~26 - 28% gives the same furnace absorption as air firing in the BSF

The heat flux profile can also be controlled by adjusting the O_2 injection

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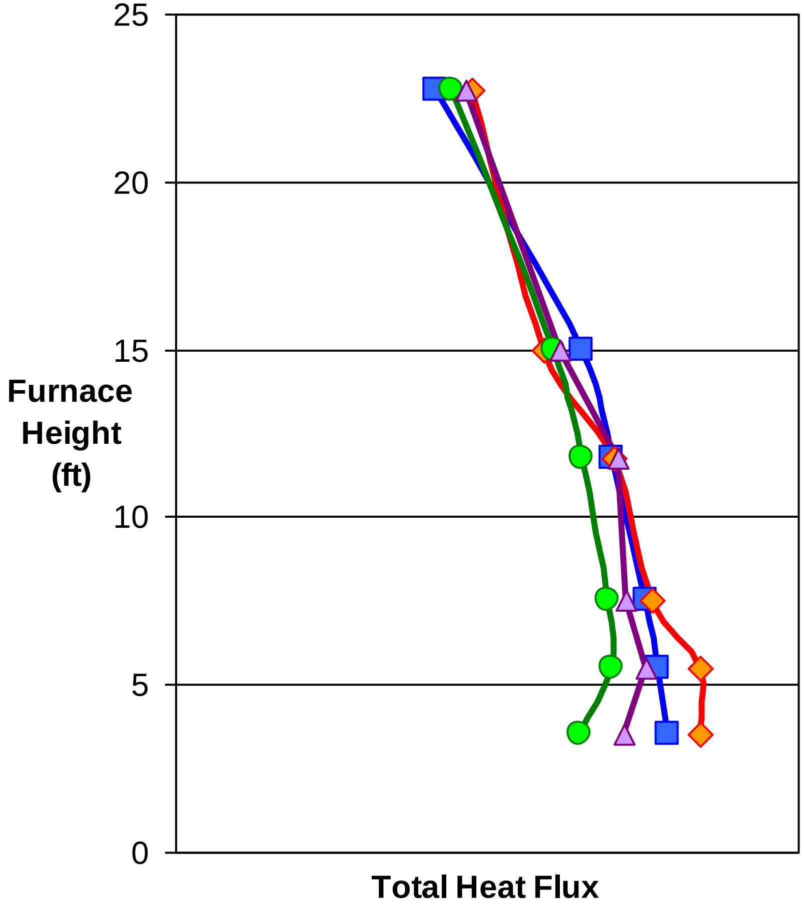
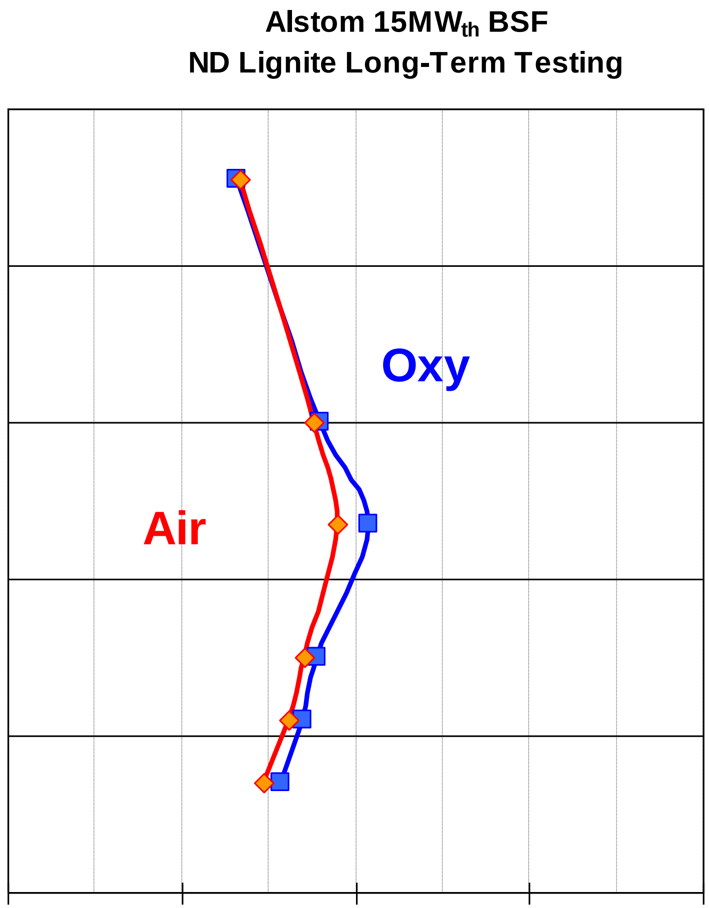


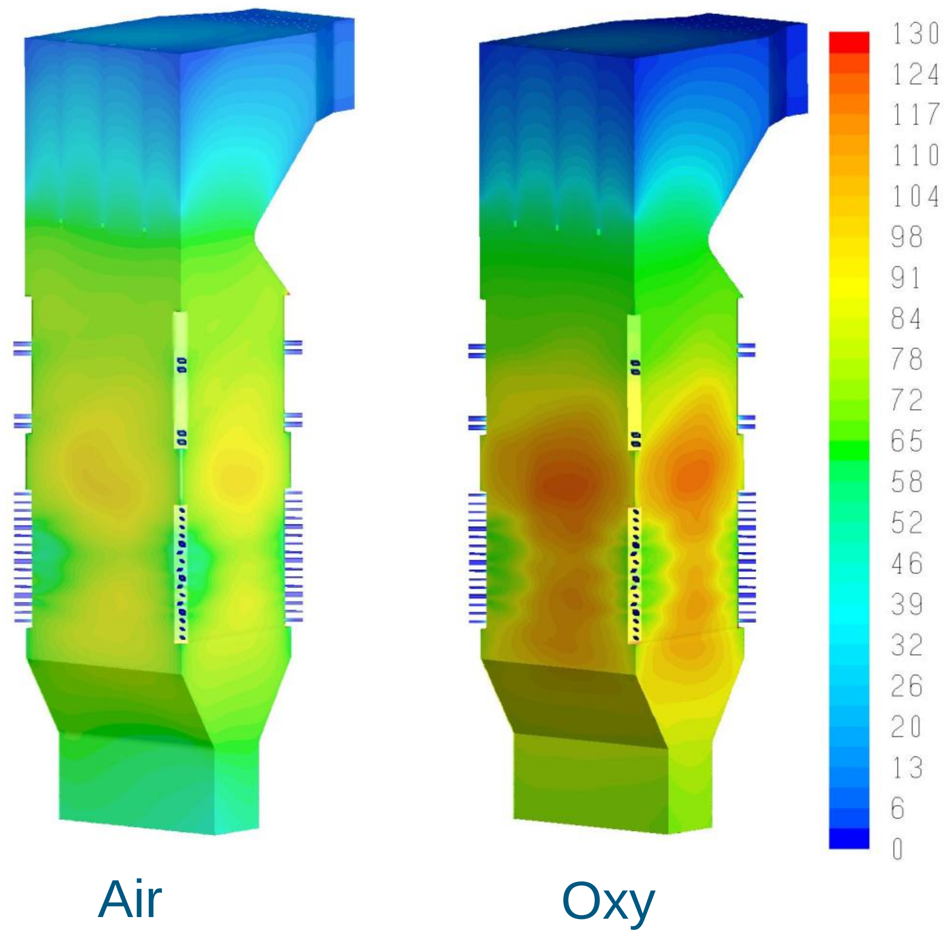
High-S bituminous

Furnace heat flux changed with oxygen flow rate and concentration

- Oxygen was varied between the overfire and windbox locations
- Oxygen was varied among the different windbox compartments

The oxy-fired heat flux profile can be controlled to match the air fired





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Oxy T-Fired Boiler Design

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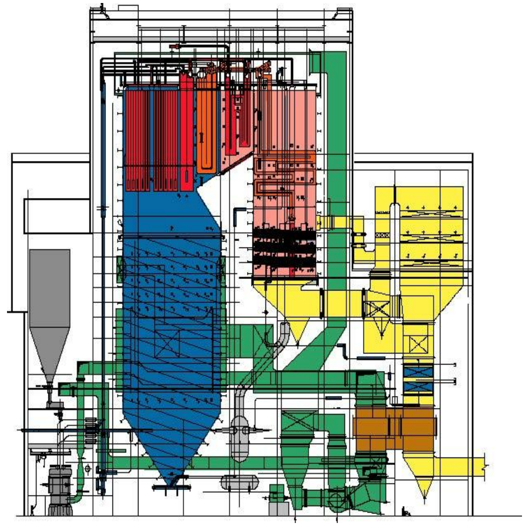
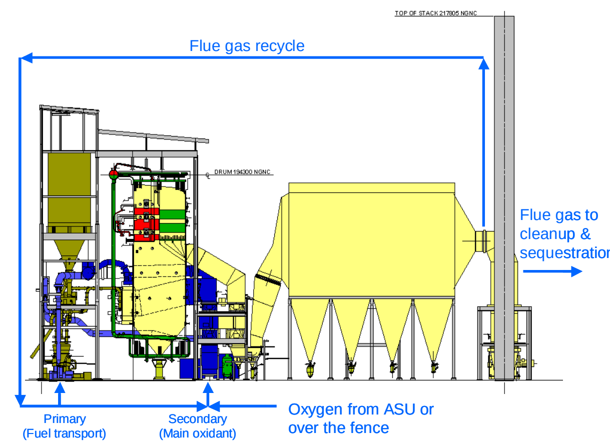
Oxy Demonstration and Reference Boiler Design Packages

- Application of test results and design tools
- Development of a full-scale oxy-fired boiler design for demonstration
- Development of reference oxy-fired utility boiler design for future market
- Development of reference oxy-fired boiler design for industrial application
- Detailed design, performance assessment and costing for entire boiler island to the level needed for firm bid sale





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Oxy-fired Boiler Demonstration Design

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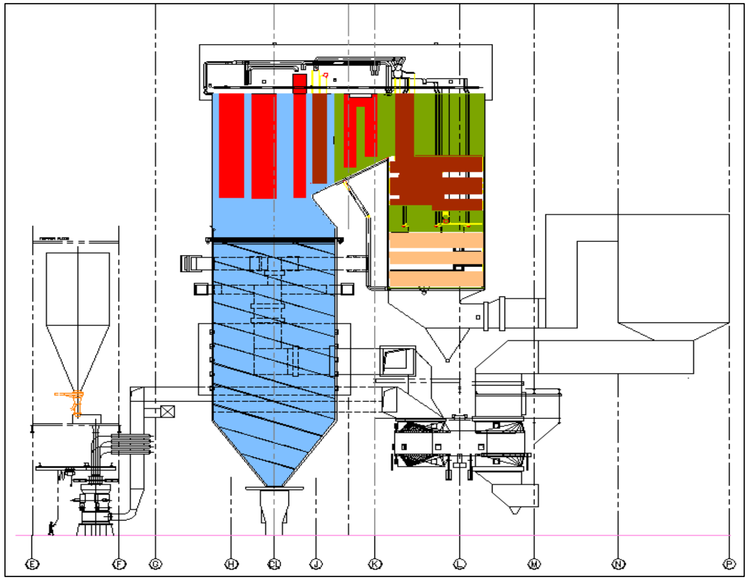
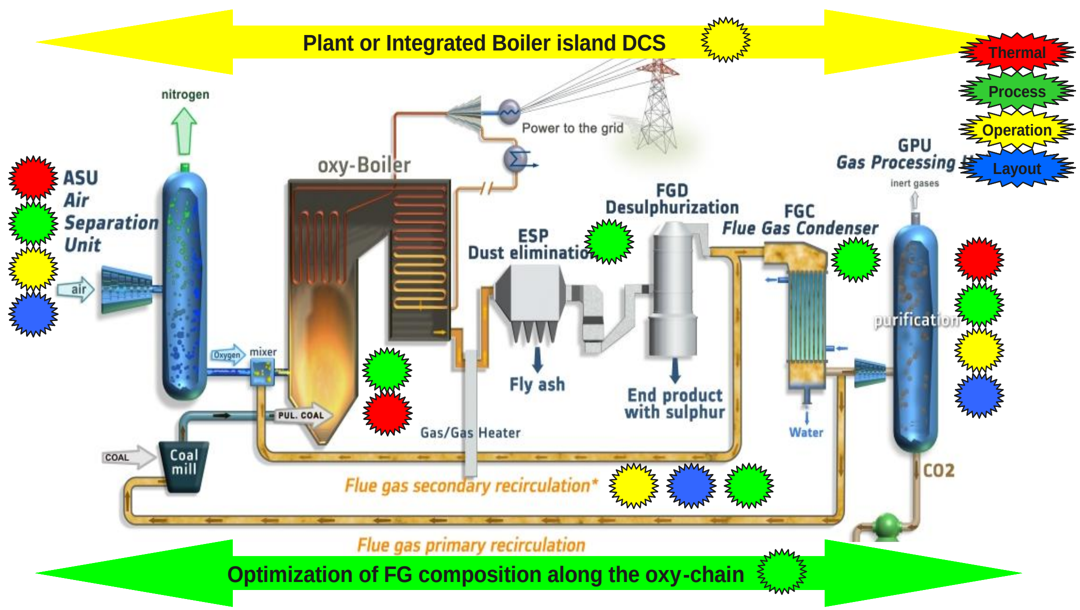
- Developed specifications for 400 MWe supercritical design (low sulfur bituminous design coal)
- Phase 1 develops oxy-fired design that retains air-firing capability. (Addresses retrofit case).
- Phase 2 develops oxy-fired design with advanced supercritical steam cycle optimized for oxy-firing. Including assessment of trade-offs
  - materials
  - pressure part arrangement
  - recycle configuration
  - overall plant cost & performance



Oxy-fired Reference Designs

- Developed specifications for 900 MWe advanced supercritical design (low sulfur bituminous coal)
- Preliminary specifications for reference industrial design for co-generation unit firing coal and biomass (equivalent steam generation ~150 MWe)
- Oxy-fired design optimized globally for plant performance and cost of electricity
  - Integration (process, heat, arrangement, operation)
  - Balance trade-offs between main subsystems (performance and costs)

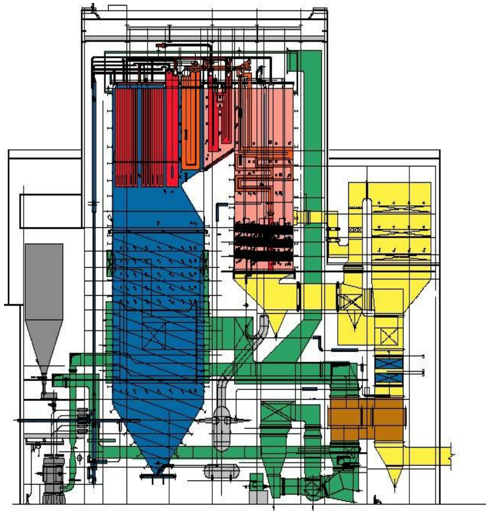


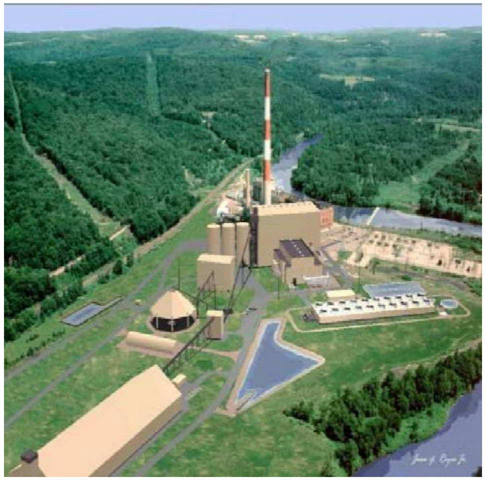
Concluding Remarks

- No technical barriers that would restrict the continued development and commercialization of oxy-combustion
- Combustion performance, emissions, and thermal behavior (temperature, heat flux intensity, heat flux profile) can be controlled to similar levels as air firing.
- An oxy tangentially-fired boiler does not require major changes to current boiler design.
  - For oxy-combustion retrofit, boiler size and pressure part surfaces should only require minor design modifications.
  - For new applications, additional control under oxy-firing may be used to an advantage with innovative design concepts to improve oxy-fired boiler performance and costs.

Concluding Remarks

- Detailed test data from this project and other Alstom R&D programs is being applied to
  - refine and validate design tools and design procedures.
  - support overall oxy plant integration and optimization efforts
  - develop and optimize designs for demonstration opportunities and future commercial plants





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