Oxy-Combustion Boiler Development for Tangential Firing

DE-NT0005290

Armand Levasseur Alstom Power, Windsor, CT

CO2 Capture Technology Conference
US DOE/NETL, Pittsburgh
March 25, 2009

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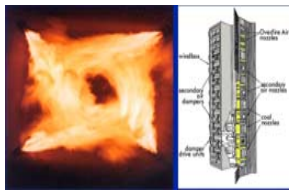
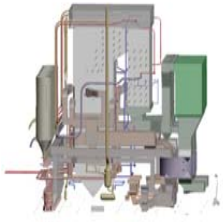
Alstom Tangentially-Fired Boilers Represent:

- More Than 40% of the Installed US Coal-Fired Boilers
- About 20% of the Total US Power Generation



Alstom Is Actively Developing Carbon Capture Technologies Including:

- Post Combustion Scrubbing
- Oxy Combustion - Oxy PC, Oxy CFB, Chemical Looping



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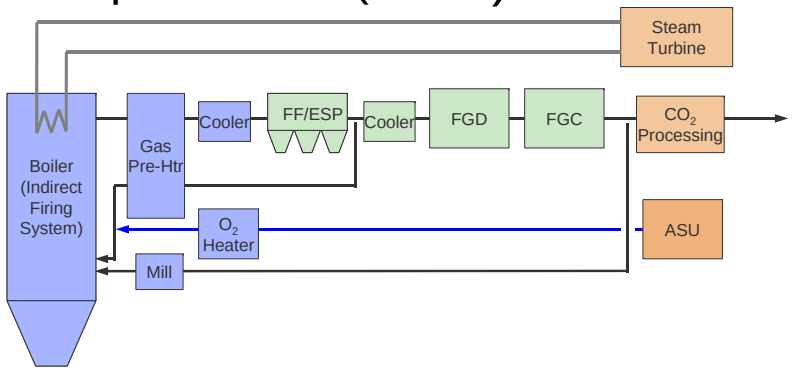
Oxy Combustion Technology

Advantages

- Near Term to Market (Conventional Components)
- High/Known Reliability (Conventional Components)
- Addresses Both New and Installed Base (Retrofit)
- High Efficiency (SC Cycles, Ultra SC Cycles)
- High CO2 Capture Rate (>90%)
- Competitive Cost of Electricity and Cost of CO2 Avoided
- Potential for Further Improvement (e.g. Oxygen Production)

Challenges

- Development of Oxy-Fired Boilers
  - Combustion Characteristics
  - Heat Transfer
  - Pollutant Formation
  - Ash Deposition
  - Fireside Corrosion
  - Air In-Leakage
- Gas Cleanup and Condensers
- Development and Scale-Up Of Large ASU and GPU
- Systems Integration and Optimization (Costs)



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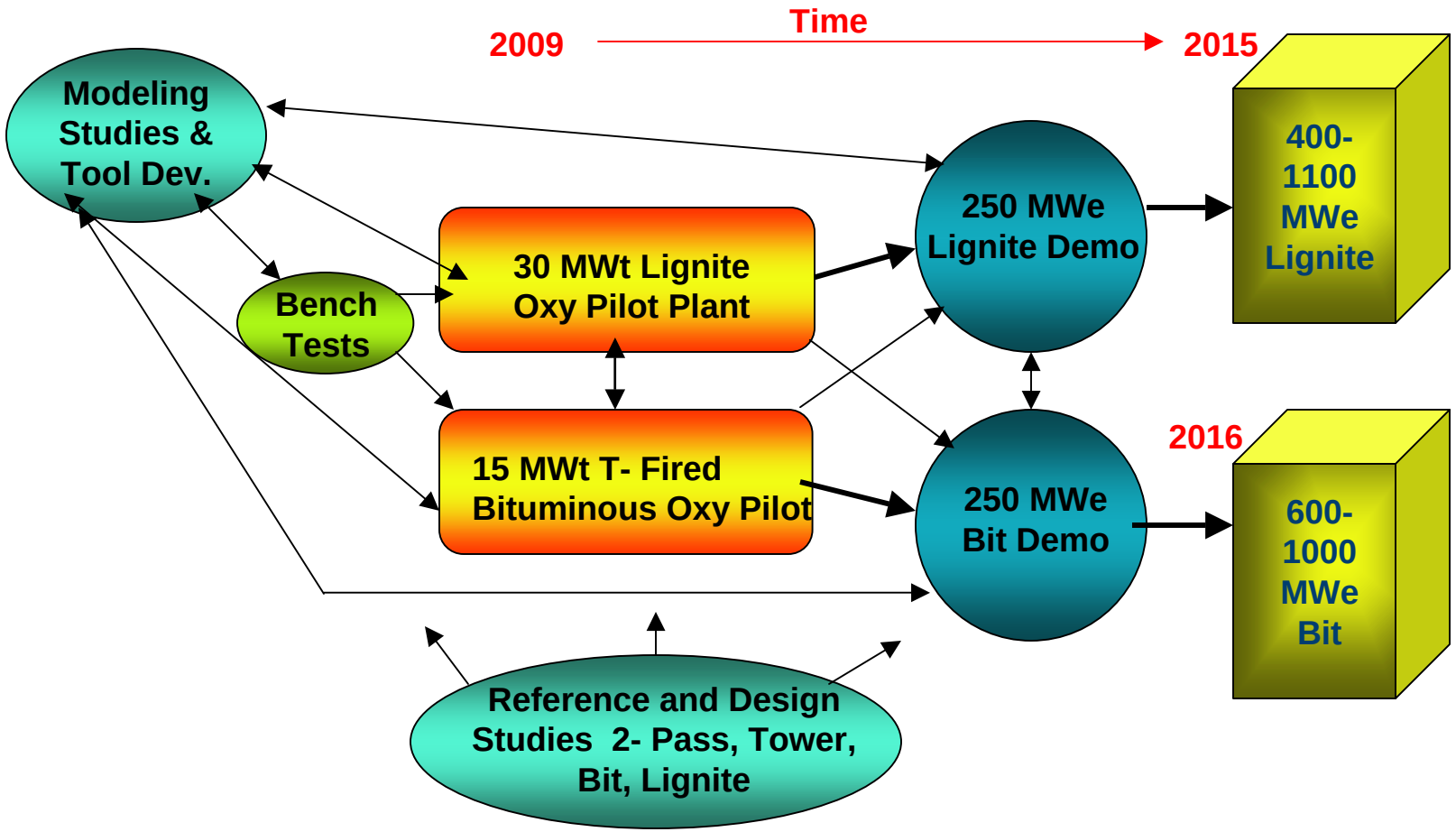
Alstom Oxy PC Development Logic



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30 MWt Oxy Pilot Plant

- Vattenfall's Schwarze Pumpe 30 MWt Oxy Plant - Entire Oxy Train ASU to CO2 Capture.
- Alstom Project Partner with Vattenfall AB – Supplied Oxy Boiler and ESP
- Demonstrated Successful Operation at 30 MWt (more than 900hrs oxy firing and 700hrs of air firing through Feb 2009)
- Comprehensive Test Program - Detailed Performance and Operating Data (Dried Lignite)

Vattenfall AB – 30 MWt Oxy Plant at Schwarze Pumpe Station

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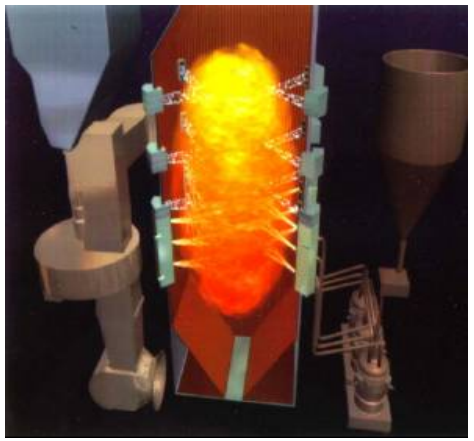
Oxy T-Fired Boiler Development

Develop Competitive CO_2 Solutions – Target of greater than 90% CO_2 capture at less than 35% increase in the cost of electricity.

Project Objectives:

- Design and develop an innovative oxyfuel firing system for T- fired boilers
- Evaluate the performance in pilot scale tests at 15 MWt
- Determine boiler design and performance impacts for oxy- combustion
- Evaluate and improve engineering and CFD tools for oxy-combustion



Address Technical Gaps For Tangentially Fired Oxy Demonstration

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Oxy T-Fired Boiler Development Project

Team

- Alstom – Power Plant Laboratories
- Alstom – New & Retrofit Boiler Business
- Utility Advisory Group

Budget

- Total Budget: $8,012,000
  - Budget Period 1: $4,728,000
  - Budget Period 2: $3,374,000
- DOE Funding: 62%
- Alstom/Industry Cost Share: 32%
- ICCI Funding: 6% (Awarded)

Schedule

- October 2008 to September 2010
- 24 Months

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Oxy T-Fired Boiler Development Project

Utility Advisory Group

- Provide Comment, Focus and End-User Perspective advise to the Project
- Develop Customer Background for Future Demonstration
- Show Utility Support and Commitment

Ten Utility Members:

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

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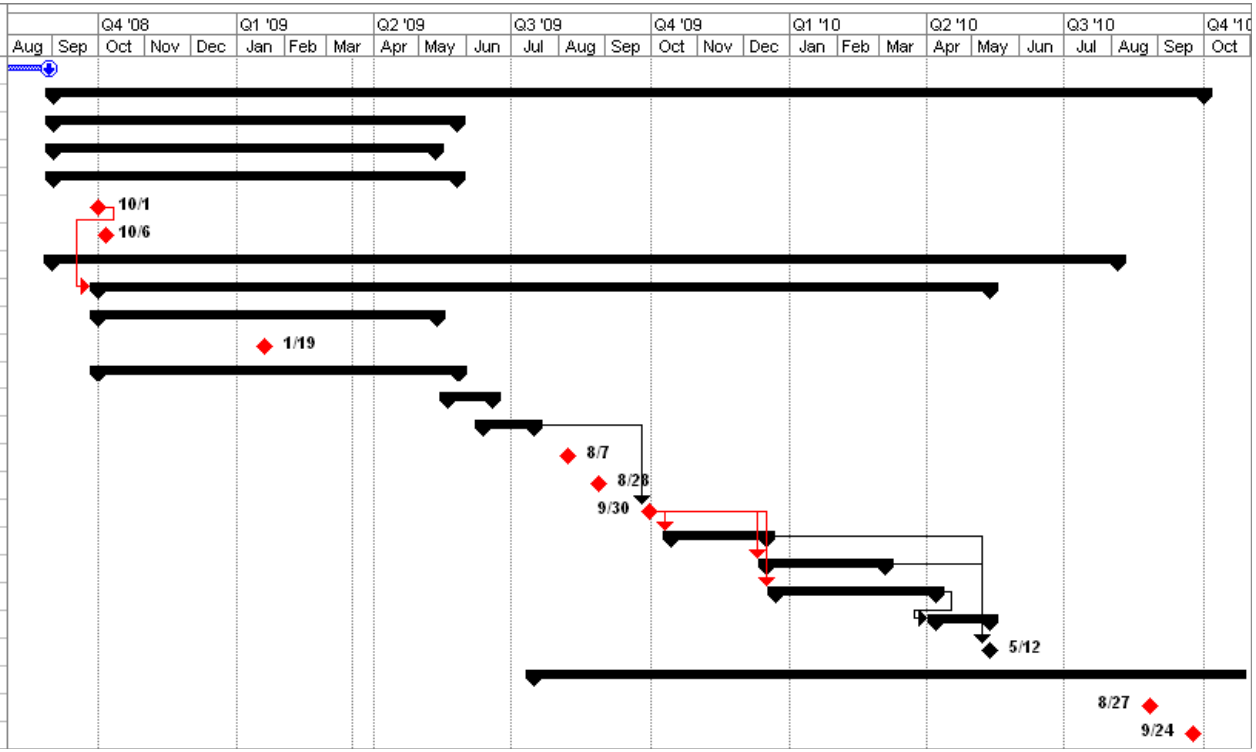
Project Schedule

- Start September 2008
- First BSF Campaign July/Aug 2009
- Complete Testing May 2010
- Final Report Sept 2010

ID	Task Name
1	DOE - Oxy T-Firng Tasks with ICCI Scope
2	1.0 - Project Management
10	2.0 - Assessment of Oxy T-Fired Design Options
11	2.1 - Oxy-Fired Boiler System Process Screening
14	2.2 - Oxy T-Firing System Design Modeling
17	DOE Contract Award
18	Milestone 1 - Project Kickoff Meeting
19	3.0 - Bench-scale Testing
23	4.0 - Large Pilot-scale Combustion Testing
24	4.1 - Test Planning
29	Milestone 2 - BSF Modification Design, Test Plan
30	4.2 - Test Preparations
36	4.3 - BSF Oxy T-fired Shakedown
40	4.4 - BSF Test Campaign 1- PRB
47	Milestone 3 - Completion of BSF Campaign 1
48	Milestone 4 - Project Review Meeting
49	Milestone 5 - Phase 2 Funding Decision
50	4.5 - BSF Test Campaign 2 - Low S Bit
57	4.6 - BSF Test Campaign 3- Dried Lignite
63	4.7 - ISBF Nozzle/Windbox Testing
68	4.8 - BSF Test Campaign 4- Illinois Coal
74	Milestone 6 - Completion of Pilot Scale Testing
75	5.0 - Data Analysis and Documentation
83	Milestone 7 - Final Report
84	Milestone 8 - Project Review Meeting



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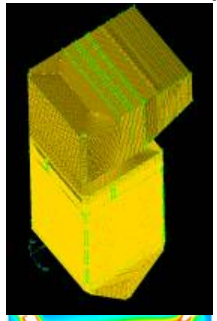
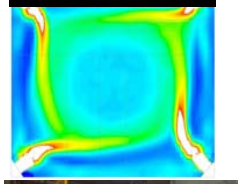
Project General Approach

- Establish technical information needed during Reference and Design Studies and Small Tests
- Use engineering tools and CFD modeling to screen T-fired design concepts (FGR scenarios, O2 Injection)
- Evaluate selected designs under realistic tangentially fired conditions in large pilot (15 MWt) testing - Proven Test Facilities and Methodologies
- Optimize and define performance characteristics of selected T-fired design and burner testing at 15 MWt
- Expand range of database by testing different coal types
- Use detailed performance data (including furnace mapping of temp and gas species) for commercial design and to evaluate and improve model predictions

Boiler Simulation Facility





ISBF

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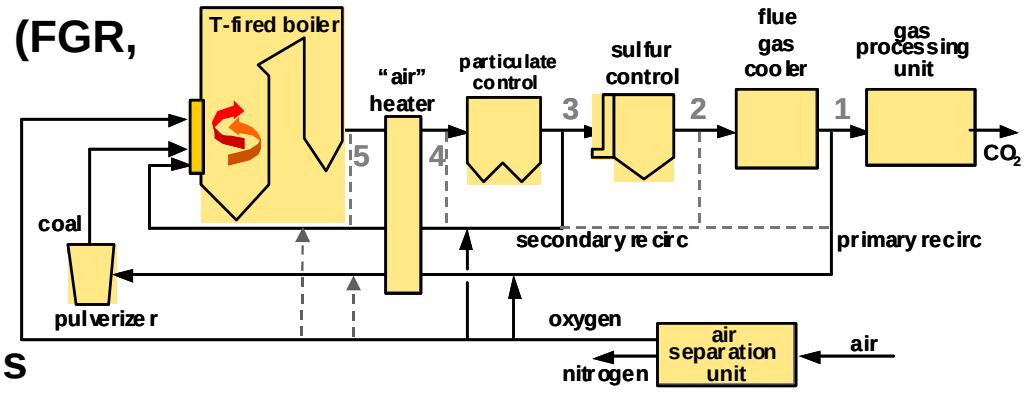
Oxy Process Screening

Approach:

- Use Previous Reference Design Base Case (850 MWe SC Boiler)
- Setup ALPRO for Oxy Process (FGR, FF, FGD, Condenser)
- Compare ALPRO outputs with Reference Case Values

Simplified Oxy Process Diagram



Major Variables:

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

Results:

- Mass & Energy Balances, Performance Impacts
- Economics -Relative CAPEX & OPEX

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CFD Screening for Oxy Firing System

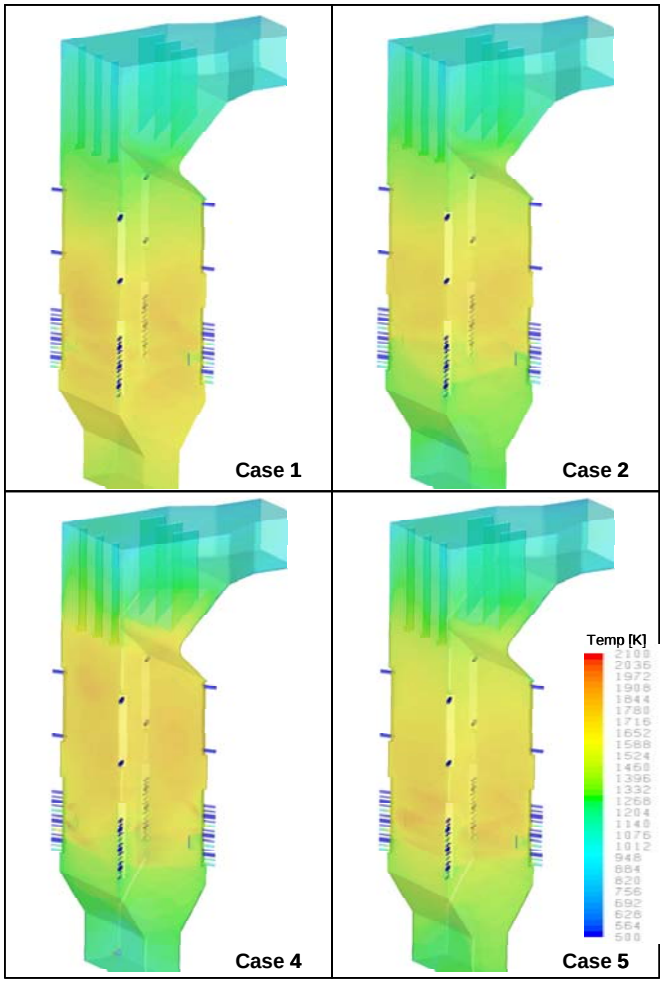
Approach:

- Incorporate Oxy Improvements Into Fluent™
- Use BSF Model for Screening
  - Grid Size, Submodels (radiation, gasification, reaction set), and runtimes
  - Calibrate With Available BSF Test Data for Air-firing
- Compare BSF Simulations with Commercial (850 MWe) Air- and Oxy-fired Simulations

Design Variables:

- Gas Recycle Ratio (Gas Flow Rates)
- Gas Recycle Composition
- Oxygen Injection Method/Distribution
- Windbox Design (Compartments, Vel., Angle)
- OFA Design (Location, Vel, Angle)

15 MWt BSF Oxy Simulations



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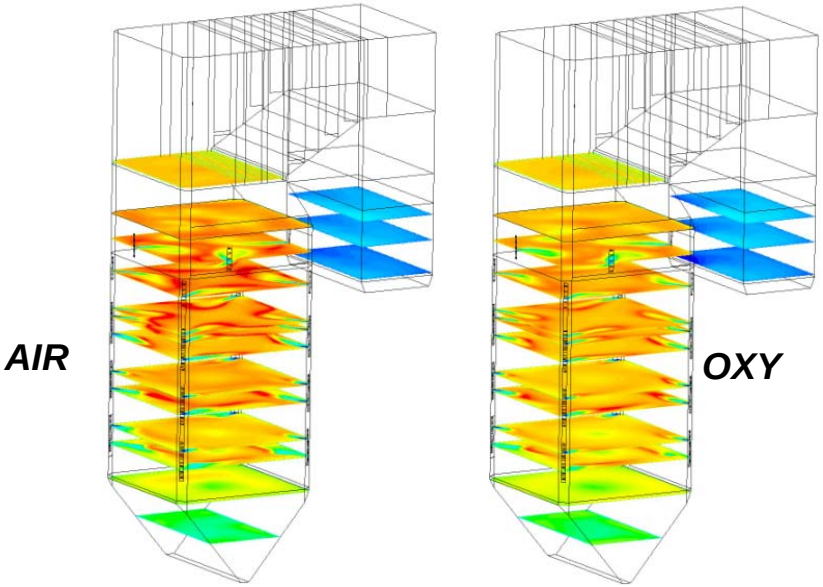
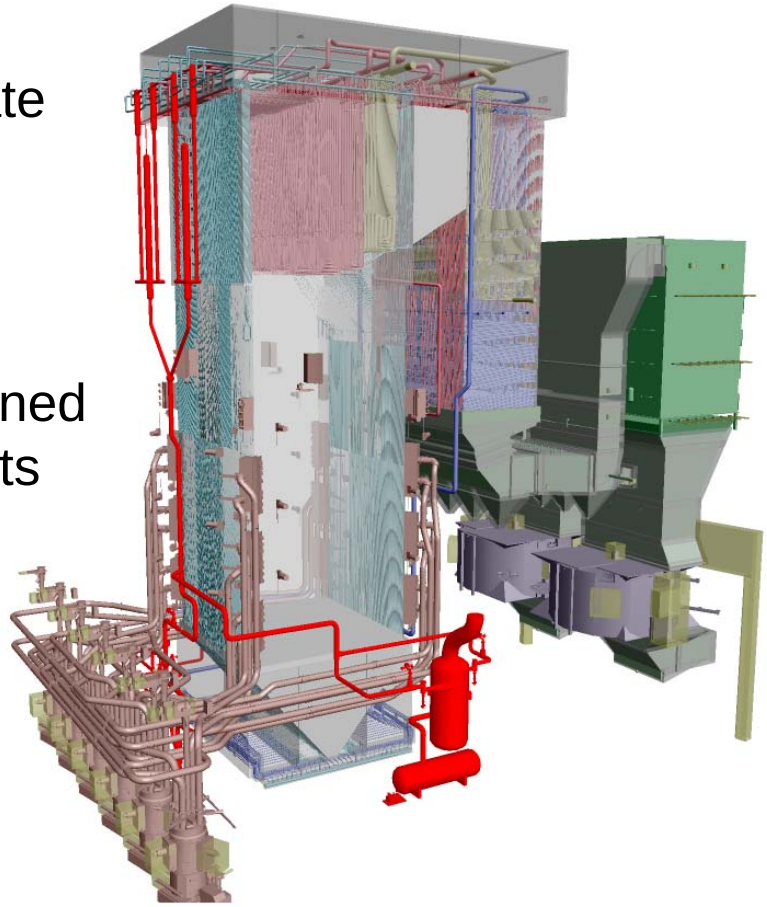
850 MWe CFD Modeling

- Used existing design and air-fired performance data to setup and calibrate
- Generated very detailed model of the furnace (Grid >8 million cells)
- Setup for Boiler MCR conditions
- Oxy case same geometry, but maintained velocity ratios for recycle gas flow inputs





850 MWe T- Fired SC Unit

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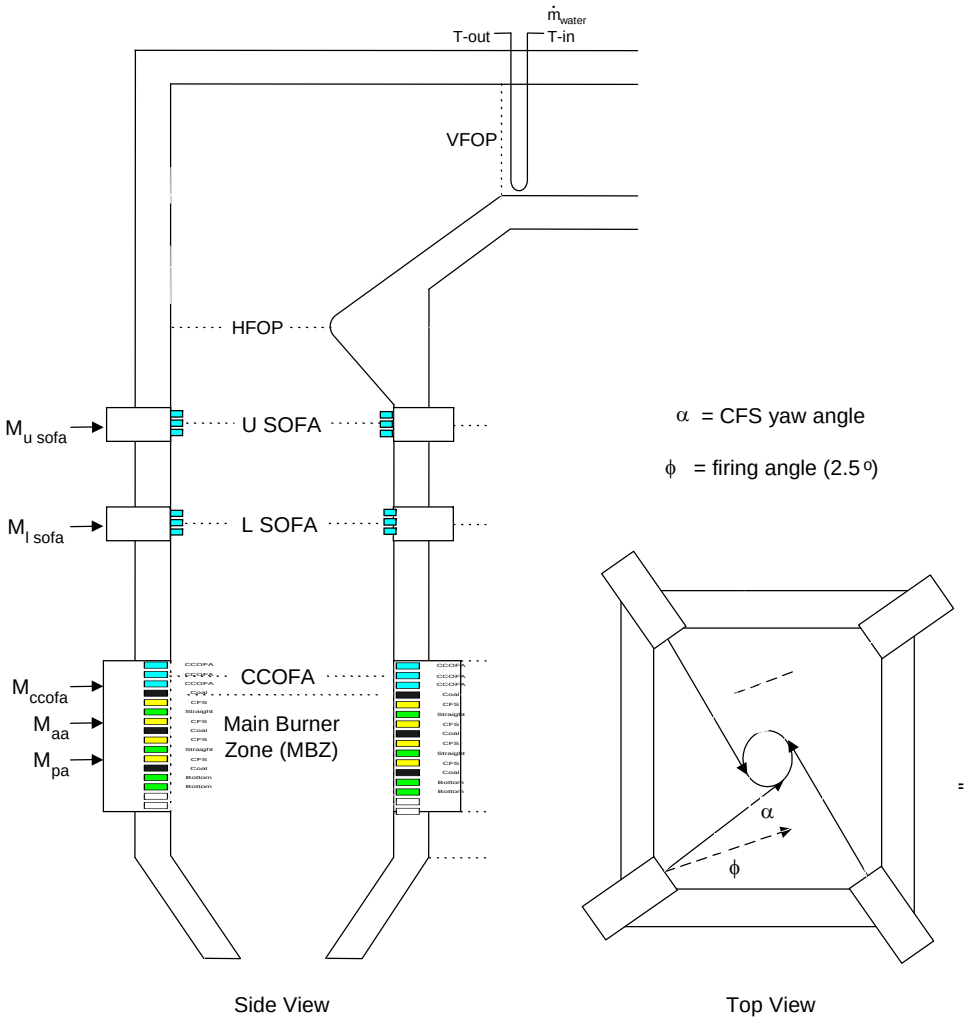
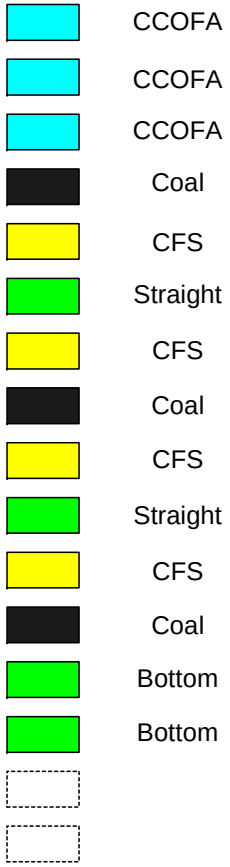
15 MWt BSF Firing System



α = CFS yaw angle

ϕ = firing angle (2.5 º)



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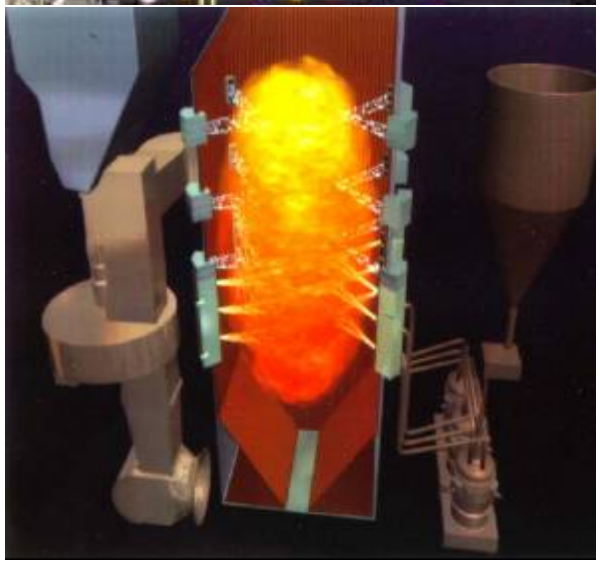
Oxy T-Fired 15 MWt Pilot Testing

Test Campaigns:

- BSF Campaign 1 -
  - Subbituminous Coal (PRB)
  - Baseline Air-firing and Oxy-firing
  - Evaluate Broad Range of Oxy Process and Firing System Design Options
- BSF Campaign 2
  - Bituminous Coal
  - Optimize Selected Design
- BSF Campaign 3
  - Lignite – Vattenfall 30 MWt Fuel
  - Establish Link With Schwarze Pumpe
- BSF Campaign 4 (with ICCI Support)
  - High Sulfur Illinois Coal
  - Gas Recycle Before and After FGD

Alstom Boiler Simulation Facility



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Oxy T-Fired 15 MWt Pilot Testing

Key Measurements

- Operating Conditions- Online Data Acquisition System (Flows, Temperatures, Pressures)
- Heat Transfer – Test Panels, Heat Flux Meters, Heat Flux Probe Measurements
- Gas Composition At Various Locations (CO_2, O_2, H_2O, NOx, SO_2, Total Hydrocarbons)
- Furnace and Convection Pass Gas Temperatures – Suction Pyrometer
- Mercury, Trace Metals, and SO_3 Measurements at Selected Stable Conditions
- Deposition and Corrosion Probes - Analyze the Probes and Collect Deposits for Further Evaluation
- Detailed Furnace Mapping – Temperature, Gas Composition, Particulate Sampling

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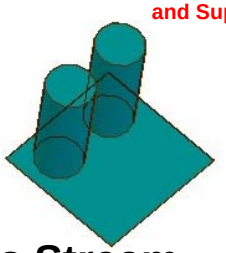
Oxy T-Fired 15 MWt Pilot Testing

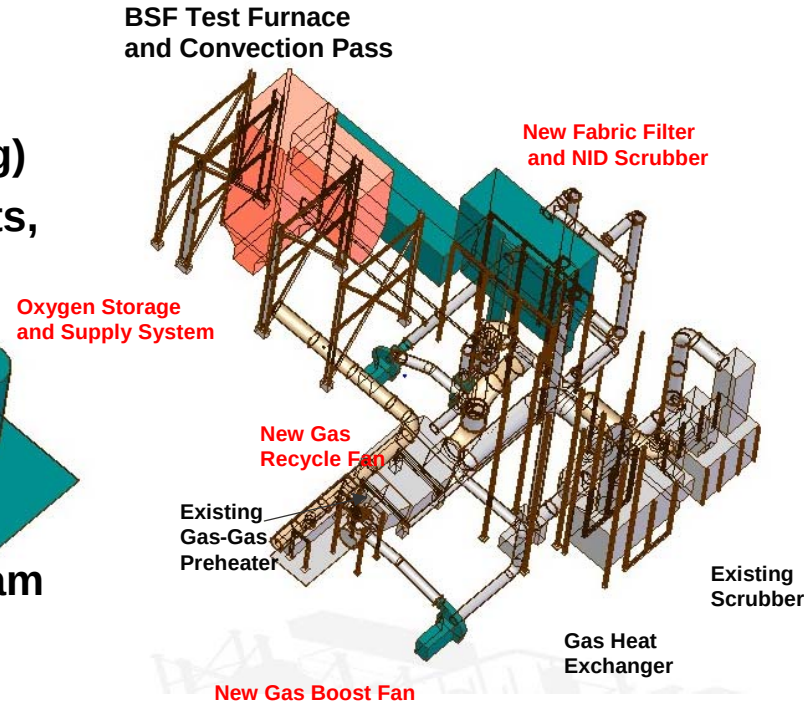
Major New Equipment

- Oxygen Supply and Injection System (Multiply locations, O2 Diffusers, Lances)
- Gas Recycle Systems (FGR Fan and Ducting)
- Air In-Leakage (Boost Fan, Sootblower, Ports, Welded Duct Construction)
- Fabric Filter for Particulate Removal and NID Scrubber



General Design

- Operate Both Air- and Oxy-fired
- Flexibility to Operating 5 Different Gas Stream Configurations
- Oxygen Injection Control – Premixed and Lance, Various Locations and Concentration
- Instrumentation and Controls, Sampling Access, Safety/Hazard Control



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T-Fired 15 MWt Boiler Simulation Facility

North View of BSF- Excavation For Fabric Filter Foundation

South View of BSF - Excavation For Oxygen Supply Foundation

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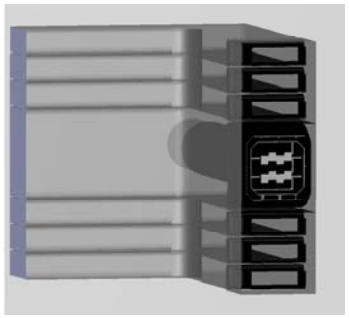
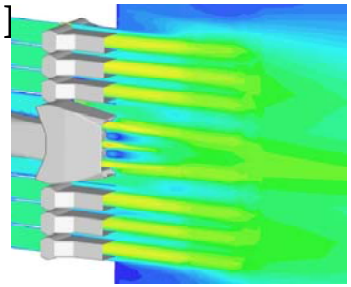
Alstom Industrial Burner Test Facility

ISBF Test Campaign

- Focus on Hardware Requirements
  - Detailed Firing System Component Design (Nozzles, Lances, etc)
  - Materials and Overheating
- Near Field Behavior
  - Flame Stability and Scanner Performance
  - Combustion and Pollutant Formation
- Various Recycle Schemes





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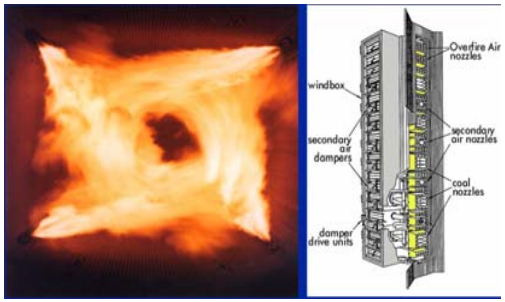
Oxy T-Fired Boiler Development Project

Summary

- This project provides a comprehensive evaluation of key oxy process and boiler design parameters under large scale pilot testing.
- An innovative oxy tangential firing system will be developed and optimized.
- Key technical data will be obtained defining oxy firing impacts on boiler performance and operation.
- Engineering and CFD modeling tools will be refined and validated with test results.
- Project results will provide design guidelines and performance data that, along with results of other Alstom oxy projects, provide a strong foundation for the next step of demonstration of an oxy tangentially fired boiler (~250 MWe).



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