Oxy-Fired Tangential Boiler Development and Large-Scale (15 MWth) Validation

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Alstom Power

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Yeppoon, Queensland, Australia
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The Alstom Group: A Worldwide Leader in Power Generation

• Clean Power
  - N°1 in integrated power plants
  - N°1 in air quality control systems
  - N°1 in services for electric utilities

• CO₂-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?

- Cost Competitive (with other CCS, Wind, Solar, Biomass)
- Reliability / Low Development Risk: Adapts Conventional Components
- New and Retrofit Applications
- High CO₂ Capture Rates (>90%)
- Near Zero Emissions
- CO₂ “Ready” Approach
- Potential for O₂ Production Cost Reduction
- Scale-up to Large Commercial Sizes (1000 MWₑ)
Alstom Oxy-PC Combustion Technology Development Steps

**Reference Design Studies** 1999

**Lab Scale** <1 MWth

**Large Pilot Plants** 15-30 MWth

**Demonstration** 150-400 MWe

**Commercial** 600-1100 MWe

**Scale-Up** 2008

2014-2016

<2020
15 MWth Oxyfuel Pilot Plant: Alstom Boiler Laboratories, Windsor, CT

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 T-Fired Boiler Development Project

## Project Team:
- Alstom Power
- DOE NETL
- ICCI
- NDIC
- Advisory Group

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

## Project Start: Oct 2008  Duration: 5 Yrs

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- DOE FY09 Period 1: Q1, Q2, Q3, Q4
- DOE FY09 Period 2: Q1, Q2
- DOE FY09 Period 3: Q1, Q2, Q3, Q4
- DOE FY09 Period 4: Q1, Q2, Q3
- DOE FY09 Period 5: Q1

- 60% Completed
- 30% Completed
- 100% Completed
- 85% Completed
- 55% Completed
- 25% Completed
- 15% Completed
Develop and validate an oxyfuel T-fired boiler system as part of commercially attractive CO₂ capture solutions.

- Design and develop an oxyfuel firing system for T-fired boilers
- Evaluate the performance in pilot scale tests at 15 MWth 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
- 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
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 2nd Generation Concepts
- Tools & Modeling Refinement and Validation on-going
- Design guidelines On-going
- Reference & Demo designs On-going
Oxy-PC Boiler
Development areas investigated

- Heat transfer: radiative / convective
- Oxy tangential firing system design
- Oxygen Injection
- Effect of coal quality
- Flue gas recycle
- Mill adaptation / integration
- Operation/load change: dynamic response

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

Comprehensive Test Program Addresses Several Areas
15 MWth Oxyfuel Pilot Plant: Switch from air to oxy firing demonstrated

Transitions Air-to-Oxy or Oxy-to-Air about 30 mins
Changes in Oxy-Firing Gas Compositions – Illinois High Sulfur Coal

Significant Increase in SO2 even with sulfur capture from recycle
Similar $\text{SO}_3$ Conversion Rate As Air Firing - Economizer Outlet Measurements in BSF

**Illinois Bituminous Economizer Outlet $\text{SO}_3$ results**

![Graph showing SO2 vs SO3 conversion rates for Illinois Bituminous fuel. The graph includes data points for Air, Oxy w/o SOx control, and Oxy w/SOx control. The y-axis represents SO3 ppmv, and the x-axis represents SO2 ppmv. The graphs show conversion rates at 1%, 2%, and 3%.](image)

**North Dakota Economizer Outlet $\text{SO}_3$ results**

![Graph showing SO2 vs SO3 conversion rates for North Dakota fuel. The graph includes data points for Air, Oxy w/o SOx control, Oxy hot FGR, and Oxy w/SO3 spike. The y-axis represents SO3 ppmv, and the x-axis represents SO2 ppmv. The graphs show conversion rates at 1%, 2%, and 3%.](image)

**Similar $\text{SO}_2$ to $\text{SO}_3$ conversion rates**

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Recycled SO$_3$ does not impact outlet emissions
NOx Emissions During BSF 15MWt Testing

Main Burner Zone Stoichiometry

Air firing NOx consistent with field; NOx during Oxy firing more than 50% less
### 15 MWth BSF furnace mapping

#### Probe Mapping Measurements

**Gas Temperatures**
- Total Incident
- Radiant

**Heat Flux:**
- Total Incident
- Radiant

**Gas Species:**
- O₂
- CO
- CO₂
- SO₂
- H₂O
- Tₐ₁₉

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**Diagram:**

- Front Wall, East
- Wingwall
- U-Tubes
- Banks 1 & 2
- to Economizer

- Plane 273 (HFOP)
- Plane 180
- Plane 141
- Plane 66
- Plane 42

- Side View
- UOFA
- LOFA
- W, N
- W
- Detailed mapping planes
- Deposition probes (3)

- Heat flux panels (4)
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 O₂ 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.

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

15 MW t BSF – High S bituminous
The oxy-fired heat flux profile can be controlled to match the air fired
Oxy Reference Plant and Demonstration Boiler Designs

- Application of test results and design tools
- Development of reference oxy-fired utility boiler design for future market
- Development of a full-scale oxy-fired boiler design for demonstration opportunities
- Optimization, detailed design, performance assessment and costing
Oxy-firing integrated approach: Reference plant design

- Numerous parameters impacting performance and cost – Integration is key (process, thermal, operation, arrangement)
- Globally optimize cost of electricity
- Balance trade-offs between main subsystems (performance and costs)
- Determine specification for the new subsystems
- Power plant operation and control
- Optimize arrangement and minimize footprint

An integrated approach minimizes the cost of electricity
UK Oxy CCS Demo Project

- A new modern 426 MW Gross Oxyfuel Power Plant
- PC Boiler; ultra-supercritical conditions
- Clean power generation with the entire flue gas treated to capture 2 MTA CO$_2$
- Biomass co-firing leading to zero CO$_2$ emission
- Located at the existing Drax Power Station Site at Selby, North Yorkshire
- A part of Yorkshire/Humber cluster for transport and offshore storage of CO$_2$
- FEED under way
- NER funding application under evaluation

Project Promoters

ALSTOM  DRAX  ASU  NATIONAL GRID

Oxyfuel Power Plant  CO$_2$ Transportation & Storage

Largest Oxyfuel CCS Demo
Concluding Remarks

• No technical barriers - Combustion, emissions, and thermal performance can be controlled to similar levels as air firing.

• An oxy boiler design does not require major changes.
  - For oxy-combustion retrofit, only minor pressure part changes
  - For new applications, additional control under oxy-firing may be used 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
Clean Power Today!™

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Production Efficiency
Carbon Capture & Storage

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