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

Armand Levasseur
Alstom Power, Windsor, CT

NETL CO2 Capture Technology Conference
Pittsburgh, PA
July 11, 2012
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

N°1 in hydro power

N°1 in conventional nuclear power island

Recent acquisition of solar and wind

CO2-Free & Renewables

The Alstom Group:

- N°1 in services for electric utilities
- N°1 in air quality control systems
- N°1 in integrated power plants
- N°1 in hydro power
- N°1 in conventional nuclear power island

Clean Power

Recent acquisition of solar and wind

CO2-Free & Renewables

- N°1 in services for electric utilities
- N°1 in air quality control systems
- N°1 in integrated power plants
- N°1 in hydro power
- N°1 in conventional nuclear power island

Carbon Capture

- Post Combustion
- Oxy Combustion

12 CCS Pilots

5 Large Demo Projects

Tests complete

Operating

Large-scale projects—under development

- NER300
- NER200
- NER300
- NER200
- NER200

Under construction

- NER300
- NER200
- NER200

© ALSTOM 2012. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.
Oxy-Combustion: Benefits and Issues

- **Cost competitive** with other CCS, wind, solar, biomass, nuclear
- **Reliable** - main components only need to be adapted and scaled-up, plant operation demonstrated in large pilots
- **Environmentally friendly** - low emissions, no large chemical feedstocks or new emission sources
- **Retrofit** and “**CCS Ready**” Applications
- **Rapid scale-up** to large commercial (1000 MWe) sizes & high efficiency steam cycles
- **Flexible** operation and power production options
- **High CO2 capture rates (>90%)**
- **Must use the entire boiler island for demonstration requiring substantial funding**

Source: Alstom analysis – 2011 – PC power plants with CCS – transport and storage included
Alstom Oxy-Combustion Technology

Development Steps

Reference Design Studies

2008

Large Pilot Plants

15-30 MWth

2012

Demonstration

150-400 MWe

2017

Full-Scale

600-1100 MWe

Lab Scale

<3 MWth

Modeling & Tool Dev.

© ALSTOM 2012. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.
Oxy T-Fired Boiler Development
Project Objectives

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 MWₜₗ 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

**Total Budget:** $21.5 M  
**Project Start:** Oct 2008  
**Duration:** 5 Yrs

### Project Team:
- Alstom  
- DOE –NETL  
- 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

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>Period 4</th>
<th>Period 5</th>
</tr>
</thead>
</table>
| **Task 1 - Project Management** | ![70% Completed]  
Task 2 - Bench Testing | ![40% Completed]  
Task 3 – Screening Evaluations | ![100% Completed]  
Task 4 - 15 MWth Testing  
4.1 Test Planning  
4.2 Test Preparations  
4.3 Facility Shakedown  
4.4 Campaign 1  
4.5 Campaign 2  
4.6 Campaign 3  
4.7 Campaign 4  
4.8 Campaign 5  
4.9 Campaign 6 | ![85% Completed]  
4.10 Campaign 7 | ![On-Going]  
4.11 Campaign 8  
4.12 Campaign 9  
4.13 Campaign 10  
4.14 Campaign 11  
4.15 Campaign 12  
4.16 Campaign 13  
4.17 Campaign 14  
4.18 Campaign 15  
4.19 Campaign 16  
4.20 Campaign 17  
4.21 Campaign 18  
4.22 Campaign 19  
4.23 Campaign 20  
4.24 Campaign 21  
4.25 Campaign 22  
4.26 Campaign 23  
4.27 Campaign 24  
4.28 Campaign 25  
4.29 Campaign 26  
4.30 Campaign 27  
4.31 Campaign 28  
4.32 Campaign 29  
4.33 Campaign 30  
4.34 Campaign 31  
4.35 Campaign 32  
4.36 Campaign 33  
4.37 Campaign 34  
4.38 Campaign 35  
4.39 Campaign 36  
4.40 Campaign 37  
4.41 Campaign 38  
4.42 Campaign 39  
4.43 Campaign 40  
4.44 Campaign 41  
4.45 Campaign 42  
4.46 Campaign 43  
4.47 Campaign 44  
4.48 Campaign 45  
4.49 Campaign 46  
4.50 Campaign 47  
4.51 Campaign 48  
4.52 Campaign 49  
4.53 Campaign 50  
4.54 Campaign 51  
4.55 Campaign 52  
4.56 Campaign 53  
4.57 Campaign 54  
4.58 Campaign 55  
4.59 Campaign 56  
4.60 Campaign 57  
4.61 Campaign 58  
4.62 Campaign 59  
4.63 Campaign 60  
4.64 Campaign 61  
4.65 Campaign 62  
4.66 Campaign 63  
4.67 Campaign 64  
4.68 Campaign 65  
4.69 Campaign 66  
4.70 Campaign 67  
4.71 Campaign 68  
4.72 Campaign 69  
4.73 Campaign 70  
4.74 Campaign 71  
4.75 Campaign 72  
4.76 Campaign 73  
4.77 Campaign 74  
4.78 Campaign 75  
4.79 Campaign 76  
4.80 Campaign 77  
4.81 Campaign 78  
4.82 Campaign 79  
4.83 Campaign 80  
4.84 Campaign 81  
4.85 Campaign 82  
4.86 Campaign 83  
4.87 Campaign 84  
4.88 Campaign 85  
4.89 Campaign 86  
4.90 Campaign 87  
4.91 Campaign 88  
4.92 Campaign 89  
4.93 Campaign 90  
4.94 Campaign 91  
4.95 Campaign 92  
4.96 Campaign 93  
4.97 Campaign 94  
4.98 Campaign 95  
4.99 Campaign 96  
5.1 Campaign 97 | ![75% Completed]  
Task 5 - Test Data Analysis | ![65% Completed]  
Task 6 – Model Simulations | ![65% Completed]  
Task 7 – Oxy Guidelines | ![25% Completed]  
Task 8 - Oxy Boiler Demo Design | ![65% Completed]  
Task 9 – Commercial Ref. Designs | ![65% Completed]
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
Accomplished

- Process and CFD Screening **Completed**
- Modifications For Oxy-Firing **Completed**
- Campaign 1 **Completed**
  Sept. 2009 – PRB subbituminous coal
- Campaign 2 **Completed**
  Feb. 2010 - Low S bituminous coal
- Campaign 3 **Completed**
- April 2010 - High S Illinois Bit coal
- Campaign 4 **Completed**
  2010 - North Dakota lignite
- Campaign 5 **Completed**
  Aug. 2011- Schwarze Pumpe lignite
- Campaign 6 – Test 1 **Completed**
  Dec. 2011 – Advanced Concepts

On-Going

- Tools & Modeling Refinement and Validation
- Design Guidelines
- Reference & Demo designs
Comparsion of 15 and 30 MWth Schwarze Pumpe Lignite Results

Tested over conditions overlapping both 30 MW and previous 15 MW tests

Established link between 15 and 30 MWth Test Programs

Similar NOx Behavior in Both Pilots
Demonstrated Close-Coupled (High Temp) gas recycle for low S coal

Savings in downstream equipment CAPEX (SCR, gas-gas heater, ESP) and fan power – Overall economics evaluated in FY13

Able to achieve 100% secondary gas recycle with single eductor and O2 motive gas (Replaces FD fan in oxy mode)
15 MWth Oxy-Combustion Pilot Plant: Detailed Mapping Data For CFD Validations

Probe Measurements
- Gas Temperatures
- Gas Composition
- Heat Flux

Oxyfired heat flux profile can be controlled to match air fired
Furnace Waterwall Heat Flux – Can Be Control During Oxy-Firing

Ability to control heat flux magnitude with recycle rate

Able to closely match air firing heat flux

Reduced recycle rate shifts heat duty to furnace
CFD Model Development
Oxy-PC Boiler Model Refinement and Validation

- ANSY FLUENT code: Submodel improvements for radiation, soot, NOx
- Detail comparisons with 15 MW BSF tests, 30 MW OxPP, and 0.5 MW IFK oxy combustor
  - refinement
  - validation
- Joint effort with ICSE at U of Utah
  - Systematic evaluation of experimental data and simulations
  - Uncertainty analysis
  - Large Eddy Simulations
Dynamic Model Development
Oxy-PC Boiler Island Model

Aspen Dynamics Platform
- Detailed boiler model
- Overall oxy capture plant model

Dynamic Simulation
- Assess transient response
  - Operating modes
  - Load changes
  - Failure behavior
- Design advanced controls
Oxy T-Fired Boiler Designs

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 – 900 MWe gross USC bit coal
- Development of oxy-fired boiler designs for demonstration opportunities – 400 MWe Dual Air/Oxy optimized design
- Optimization, detailed design, performance assessment and costing
Large Commercial Reference Boiler Design

**Boiler Specifications**

- 900 MWe Gross
- Supercritical, sliding pressure with spiral wall evaporator
- USC – 279/52 bar, 600/620 C
- Direct pulverized coal firing, Tilting-tangential firing system

**Design Fuel**

- Range of Bituminous Coals

**Operation**

- Optimized for Oxy
- Base load operation
- Min. Load 40%

**Boiler Design Optimized for Overall Plant Performance and Cost**
Oxy-firing Integrated Approach: For entire capture plant

- 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)
- Optimize pollutant removal
- Power plant operation and control
- Optimize arrangement and minimize footprint

An integrated approach minimizes the cost of electricity
Demonstration Unit Design

**Boiler Specifications**
- 400 MWe Gross
- Supercritical, sliding pressure with spiral wall evaporator
- USC – 279/52 bar, 600/620 C
- Direct pulverized coal firing, Tilting-tangential firing system

**Design Fuel**
- Range of Bituminous Coals

**Operation**
- Dual 100% Air / 100% Oxy
- Cycling load operation
- Min. Load 25%

**Boiler Design Optimized for Overall Plant Performance and Cost**
The White Rose CCS Project in the UK

Project: New 426 MWe Plant
Ultra Supercritical Steam
Entire Gas Stream Processed
Pipeline Transport & Offshore Storage
Applied for UK & EU Funding
Pre-FEED Nearly Completed

Location: Drax Power Station, North Yorkshire, UK

Project Promoters

- Oxy-fuel Power Plant
  - ALSTOM
- CO₂ Transportation & Storage
  - BOC-Linde
- DRAX
- NATIONAL GRID

© ALSTOM 2012. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.
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 or better as air firing
  – Oxy boiler design concepts to improve overall plant performance and cost are being investigated

• 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
Acknowledgements and Disclaimer

**Acknowledgement**

The work presented was supported by the US Department of Energy through the National Energy Technology Laboratories under Agreement DE-NT-0005290. The guidance and direction of NETL Project Manager Tim Fout is acknowledged and appreciated.

**Disclaimer**

Parts of this presentation were prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Information disclosed herein is furnished to the recipient solely for the use thereof as has been agreed upon with ALSTOM and all rights to such information are reserved by ALSTOM. The recipient of the information disclosed herein agrees, as a condition of its receipt of such information, that ALSTOM shall have no liability for any direct or indirect damages including special, punitive, incidental, or consequential damages caused by, or arising from, the recipient’s use or non-use of the information.