Current Oxyfuel Combustion Activities at Doosan Babcock Energy Limited

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Contents

• Three Stage Development Programme
• OxyCoal-UK Phase 1
  – Project Participants
  – Structure
  – Aims and Progress
    • Work Package 1
    • Work Package 2
    • Work Package 3
    • Work Package 4
• OxyCoal-UK Phase 2
  – Project Participants
  – Aim
  – Task 1
  – Task 2
  – Task 3
  – Progress
• Concluding Remarks
Oxyfuel Technology - Three Stage Development Programme

• To Develop a competitive Oxyfuel firing technology suitable for full plant application post-2010.

• A phased approach to the development and demonstration of oxyfuel technology:


  Phase 2: Demonstration of an Oxyfuel Combustion System (OxyCoal-UK Phase 2, 2007 – 2009).

OxyCoal-UK: Phase 1 – Project Participants

Lead company
Doosan Babcock Energy Limited

Industrial Participants
Air Products plc
BP Alternative Energy International Limited
E.ON UK plc
RWE npower plc

University Participants
Imperial College London
University of Nottingham

Sponsors / Sponsor Participants
Scottish and Southern Energy plc
ScottishPower Energy Wholesale
EDF Energy plc
Drax Power Limited
DONG Energy Generation A/S

Government Support
Department of Business, Enterprise and Regulatory Reform
Technology Strategy Board
Engineering and Physical Sciences Research Council
OxyCoal-UK: Phase 1 – Structure

- Work Package 1: Combustion Fundamentals
- Work Package 2: Furnace Design and Operation
- Work Package 3: Flue Gas Clean-Up
- Work Package 4: Generic Process Issues
Characterisation of coal ignition, devolatilisation, char burnout and nitrogen partitioning behaviour under oxyfuel firing conditions. Development of oxyfuel firing CFD predictive capability.

Drop tube furnace (DTF) characterisation of devolatilization, char burnout and nitrogen partitioning behaviour of six UK and world-trade coals under oxyfuel firing conditions. (University of Nottingham)
First two coals completed

Development of devolatilization and char burnout kinetic parameters from DTF data and application in CFD models of oxyfuel burner and oxyfuel boiler. (Doosan Babcock)
In progress

Explosion bomb characterisation of coal ignition behaviour under oxyfuel firing conditions (same coals as DTF tests). (Imperial College London (Mechanical Engineering))
In progress
Investigation of the performance of the oxyfuel process and its key impacts on utility plant operation and performance.

Pilot scale testing (1MWt) of oxyfuel firing behaviour of two coals (parametric testing, deposition and corrosion behaviour).

(E.ON-UK)
*First coal completed*

Characterisation of 1MWt test deposit samples by Computer Controlled Scanning Electron Microscope (CCSEM).

(Imperial College (Materials))
*In progress*

Laboratory-scale corrosion testing of candidate materials for final superheater and reheater sections of boiler under simulated oxyfuel flue gas.

(Doosan Babcock)
*First test completed and analysis in progress*
Development and testing of novel flue gas clean-up system using simulated and real oxyfuel flue gas.
(Imperial College London (Chemical Engineering) and Air Products)

Theoretical modelling and lab-scale testing in progress
Pilot-scale testing planned May 2008

Conversion of 160kW$_t$ NO$_x$ Reduction Test Facility (NRTF) to oxyfuel firing configuration.
(Doosan Babcock)
Completed. Commissioning in progress

Parametric testing of Oxyfuel Process.
(Doosan Babcock)
Planned May 2008
NRTF Oxyfuel Conversion – Scope

• Retain air firing capability.

• Additional Equipment:
  – Flue Gas Recycle (FGR) Fan.
  – FGR Heater.
  – Oxygen Storage, Supply and Injection System.
  – Carbon Dioxide Storage and Supply System
    (CO₂ used in place of primary FGR to minimise PF system blockage problems).
  – Ductwork.
  – Isolating and Control Dampers.
  – E, C & I, including Burner Management System, Modifications.
  – Data Logging Modifications.
  – Connections in Flue Gas Ductwork for installation of Imperial College/Air Products flue
gas clean-up test rig.
OxyCoal-UK: Phase 1 – NRTF Schematic Diagram

Oxygen from storage

To Imperial College Reactor

CO₂ from storage
OxyCoal-UK: Phase 1 – NRTF Oxyfuel Installation

Secondary FGR
Oxygen Injection

Flue Gas Recycle Fan

Carbon Dioxide Storage
Oxygen Storage
OxyCoal-UK: Phase 1 – NRTF Oxyfuel Commissioning Results

Furnace Exit Flue Gas Analysis

Time (minutes)

O$_2$ and CO$_2$ (%v/v dry)

Air Firing O$_2$

Air Firing CO$_2$

Oxyfuel Firing O$_2$

Oxyfuel Firing CO$_2$
A desk-top study, supplemented by test results from the other project activities, is being undertaken to investigate the key process issues associated with an oxyfuel installation on a large utility plant.

Assessment of oxyfuel power plant reliability, availability, maintainability, operability and safety.
(RWE npower, Air Products, BP Alternative Energy International, Imperial College London (Mechanical Engineering))  
*In progress*

Front End Engineering Design (FEED) Study, including preliminary HAZOP study, for oxyfuel conversion of 90MWt Multi-fuel Burner Test Facility (MBTF)  
(Doosan Babcock)  
*Completed*
HAZOP Study Key Concerns

• Material compatibility in oxygen enriched atmospheres.
• Effect of fly ash on oxygen safety.
• Leaks of CO₂ rich flue gas from flue gas recycle (FGR) ducts.
• FGR spray cooler effluent disposal.

HAZOP Study Actions

• Discussions regarding material compatibility concluded.
• FGR off-take located downstream of grit arrester rather than downstream of economiser to reduce FGR fly ash concentration.
• Primary FGR and Secondary FGR fans located as close to burner front as possible to minimise length of pressurised FGR duct.
• Primary FGR / Transport FGR spray cooler design to minimise effluent acidity and discussions regarding appropriate disposal route.
OxyCoal-UK: Phase 2 – Project Participants

**Lead company**
Doosan Babcock Energy Limited

**University Participants**
Imperial College London
University of Nottingham

**Prime Sponsor**
Scottish and Southern Energy plc

**Sponsors**
Air Products plc
DONG Energy Generation A/S
Drax Power Limited
EDF Energy plc
E.ON UK plc
ScottishPower Energy Wholesale

**Government Support**
Department of Business, Enterprise and Regulatory Reform
HFCCAT Demonstration Programme
Project Aim:
• Demonstration of an oxyfuel combustion system of a type and size (40MW\textsubscript{t}) applicable to new build and retrofit advanced supercritical oxyfuel plant.

• The specific objectives are:
  – Demonstrate successful performance of a full-scale (40MW\textsubscript{t}) oxyfuel burner firing at conditions pertinent to the application of an oxyfuel combustion process in a utility power generating plant.
  – Demonstrate performance of an oxyfuel burner with respect to flame stability, NO\textsubscript{x}, flame shape and heat transfer characteristics.
  – Demonstrate operational envelope of an oxyfuel burner with respect to flame stability, turndown, start-up shutdown and the transition between air- and oxyfuel-firing.
  – Demonstrate safe operation of an oxyfuel combustion process under realistic operating conditions.
  – Generate sufficient oxyfuel combustion process performance data to inform future investment decisions.
  – Demonstrate level of technology readiness of the oxyfuel combustion process.
OxyCoal-UK: Phase 2 – Multi-Fuel Burner Test Facility (MBTF)

• 90 MW Thermal Input

• Capability to Fire a Wide Range of Fuels
  – Coal
    • 8% to 40% Volatiles, Dry Ash Free
    • Up to 35% Ash, As Fired
    • Up to 20% Inherent Moisture, As Fired
  – Heavy Fuel Oil
  – Natural Gas
  – Orimulsion

• Facility usage:
  – New burner development
  – Contract burner testing
  – Third party burner testing
Task 1: Development of a Purpose-Designed Oxyfuel Demonstration Facility

Task 1.1: MBTF Oxyfuel Conversion Design
   – Planning Approval
   – Design (Process, Mechanical, Civil and EC&I)
   – Safety
     • HAZOP Study
     • Risk Assessments
     • Work Instructions
     • Operating Procedures
     • Method Statements
     • COSHH Assessments
   – Coal Characterisation by University of Nottingham

Task 1.2: MBTF Oxyfuel Conversion Installation
   – Procurement
   – Fabrication
   – Installation
• Retain air firing capability.

• Additional Equipment:
  – Flue Gas Recycle (FGR) Fans.
    • Transport FGR.
    • Primary FGR.
    • Secondary FGR.
  – Transport FGR Cooler.
  – Primary FGR Cooler.
  – Primary FGR Heater.
  – Oxygen Storage, Supply and Injection Systems for Primary and Secondary FGR.
  – Ductwork.
  – Isolating and Control Dampers.
  – E, C & I, including Burner Management and SCADA System, Modifications.
Task 2: Burner Design and Manufacture
Task 2.1: Oxyfuel Burner Design and Fabrication
   – First generation oxyfuel burner design based on Doosan Babcock’s expertise and experience in air firing technology for coal

Task 2.2: MBTF Oxyfuel Conversion Commissioning
   – Cold commissioning
   – Hot commissioning

Task 3: Demonstration of an Oxyfuel Combustion System
   • Establish operational envelope of the burner and performance characteristics of the combustion process. Key parameters to be investigated include:
     – Change-over from air to oxyfuel firing at various loads.
     – Turndown.
     – Flame stability.
     – Heat release and heat flux to furnace walls.
     – Pollutant emissions.
     – Flame visualisation and modelling by Imperial College London
**OxyCoal-UK: Phase 2 – Progress**

- **Project Start:** 1 December 2007

  - 01-Dec-07 01-Mar-08 01-Jun-08 01-Sep-08 01-Dec-08 01-Mar-09 01-Jun-09 01-Sep-09 01-Dec-09

  - Engineering Design
  - Procurement
  - Construction
  - Commissioning
  - Parametric Testing
  - Data analysis / Reportage

- **Planning application submitted**

- **Initiated Scottish Environmental Protection Agency (SEPA) Variation application**

- **Design in progress – all disciplines**
  - Site Layout
  - PFD
  - Duct and fan sizing
  - Oxygen plant
  - Civils
  - Power supply requirements
  - P&ID
Concluding Remarks

Phase 1
• Investigation of combustion fundamentals, furnace design and operation, flue gas clean-up and generic issues associated with oxyfuel process is well advanced.
  – Lab- and pilot-scale test data being produced and analysed.
  – Safety, reliability, availability, maintainability and operability issues associated with oxyfuel process identified.

Phase 2
• MBTF oxyfuel conversion in progress and full-scale oxyfuel burner test scheduled for 2009.

The current tasks will complete the foundation for the development of an oxyfuel boiler reference design.
Thank you for your attention

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