Demonstration of an Oxyfuel Combustion System

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  – Development of a purpose designed oxyfuel demonstration facility
  – Oxyfuel burner design and manufacture
  – Demonstration of an oxyfuel combustion system
Oxyfuel Technology

Oxyfuel combustion is technically viable and economically competitive with alternative technologies.

Air Firing:
Coal + O₂ + 4N₂

Oxy Firing:
Coal + O₂ + xCO₂

Oxy Firing:
ASU

N₂

Air Firing:
CO₂ + 4N₂

Oxy Firing:
CO₂

Air Firing:
Flue

Oxy Firing:
Inerts Removal and CO₂ Compression

Oxy Firing:
CO₂ Recycle
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 1:**
- Fundamentals and Underpinning Technologies (OxyCoal-UK Phase 1, 2007 - 2008)

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

**Phase 3:**
- Reference Designs (2009 - 2010)
OxyCoal-UK: Phase 1 – Project Participants

€2.8 million collaborative project under the BERR Technology Programme.

• Lead company
  
  Doosan Babcock Energy

• Industrial Participants
  
  Air Products  e.on  RWE  bp

• University Participants
  
  Imperial College London  The University of Nottingham

• Sponsors / Sponsor Participants
  
  Scottish and Southern Energy  ScottishPower energy wholesale  EDF Energy  Drax Power Limited  DONG Energy

• UK Government Support
  
  BERR Department for Business Enterprise & Regulatory Reform  EPSRC Engineering and Physical Sciences Research Council
Characterisation of coal ignition, devolatilisation, char burnout and nitrogen partitioning behaviour under oxyfuel firing conditions.

- **Explosion Bomb Characterisation**
  - Coal ignition

- **Drop Tube Furnace (DTF)**
  - Devolatilisation
  - Char burnout
  - Char intrinsic reactivity
  - Nitrogen partitioning

- **Computational Fluid Dynamics (CFD)**
  - Oxyfuel firing conditions

*Drop-Tube Furnace* 2D Temperature Contour CFD model

*Drop-Tube Furnace* (photograph courtesy of University of Nottingham)
Investigation of the performance of the oxyfuel process and its key impacts on utility plant operation and performance.

- Pilot-scale testing on E.ON UK 1 MW₁ Combustion Test Facility (CTF)
  - Behaviour of two coals
  - c. 150 hours oxyfuel combustion operating experience

- Computer Controlled Scanning Electron Microscope (CCSEM)
  - Characterisation of 1MW₁ test deposit samples

- Laboratory-scale corrosion testing

_E.ON UK 1 MW₁ Combustion Test Facility (CTF) (photograph courtesy of E.ON UK plc)_
OxyCoal-UK: Phase 1 – Flue Gas Clean-Up

Development and testing of novel flue gas clean-up system for NO$_x$ and SO$_2$ removal and CO$_2$ purification.

- Theoretical modelling

- Lab-scale testing
  - Simulated flue gas

- Pilot-scale testing
  - Oxyfuel conversion of 160 kW$_t$ NO$_x$ Reduction Test Facility (NRTF)
  - Parametric testing of oxyfuel process
    (c. 70 hours operating experience)
  - Provision of flue gas to gas clean-up test rig

160 kW$_t$ NO$_x$ Reduction Test Facility (NRTF)
Pilot-scale testing of primary and secondary NO\textsubscript{x} reduction technologies and clean coal technologies on the 160 kW\textsubscript{t} NO\textsubscript{x} Reduction Test Facility (NRTF).
OxyCoal-UK: Phase 1 – Flue Gas Clean-Up

20 days pilot-scale flue gas clean-up testing firing El Cerrejon coal on the 160 kW$_t$ NO$_x$ Reduction Test Facility (NRTF).

- Oxyfuel firing vs. Air firing

- Investigate effect of:
  - Burner stoichiometry
  - Flue gas recycle ratio
  - Transport CO$_2$ oxygen content
  - Selective catalytic reduction (SCR)

- Parameters measured:
  - Process conditions
  - Flue gas analyses (NO, O$_2$, CO, SO$_2$, CO$_2$, SO$_3$ and Hg)
  - Carbon in ash
  - Hg in ash
High flue gas CO₂ concentration for oxyfuel combustion (c. 80%v/v dry)
OxyCoal-UK: Phase 1 – Flue Gas Clean-Up

Reduced flue gas NO concentration for oxyfuel combustion by c. 50% on a heat input basis (mg/MJ).

![Graph showing burner stoichiometry and furnace exit NO emissions](image)
Reduced flue gas $\text{SO}_2$ concentration for oxyfuel combustion by c. 25% on a heat input basis (mg/MJ).
OxyCoal-UK: Phase 1 – Generic Process Issues

A desk-top study to investigate the key process issues associated with an oxyfuel installation on a large utility plant.

- Oxyfuel power plant
  - Safety assessment
  - Reliability, availability, maintainability and operability assessment

- Front End Engineering Design (FEED) Study for oxyfuel conversion of 90 MW\textsubscript{t} Multi-fuel Burner Test Facility (MBTF)
OxyCoal-UK: Phase 2 – Project Participants

€9.3 million collaborative project under the BERR Hydrogen Fuel Cells and Carbon Abatement Technologies (HFCCAT) Demonstration Programme.

• Lead Company

Doosan Babcock Energy

• University Participants

Imperial College London
The University of Nottingham

• Prime Sponsor

Scottish and Southern Energy

• Sponsors

Air Products, E.ON, ScottishPower Energy (energy wholesale), EDF Energy, Drax, DONG Energy

• UK Government Support

BERR | Department for Business Enterprise & Regulatory Reform
OxyCoal-UK: Phase 2 – Demonstration of an Oxyfuel Combustion System

Demonstration of an oxyfuel combustion system of a type and size (40 MW_t) applicable to new build and retrofit advanced supercritical oxyfuel plant.

*Doosan Babcock Mk V Burner*

*CFD Modelling*
OxyCoal-UK: Phase 2 – Multi-Fuel Burner Test Facility (MBTF)

Full-scale testing and demonstration of Doosan Babcock, contract or third party burners on the 90 MW_t Multi-fuel Burner Test Facility (MBTF).

- Capability to fire a wide range of fuels
  - Coals, bituminous and low volatiles
    - 8% to 40% volatile matter, dry ash free
    - Up to 35% ash, as fired
    - Up to 20% inherent moisture, as fired

- Facility upgrades
  - Two stage combustion (Summer 2008)
  - Oxyfuel Conversion (Winter 2008)
  - Grit arrestor improvements (Summer 2008)
  - Laser flame mapping (Planned)

CFD Modelling; temperature plot (air-firing)
The three stages of the project are to develop a purpose designed oxyfuel demonstration facility, design and manufacture a burner, and demonstrate of an oxyfuel combustion system.
Concluding Remarks

Doosan Babcock are taking a proactive role in the development and implementation of oxyfuel combustion and carbon capture technologies.

• OxyCoal-UK Phase 1: Fundamentals and Underpinning Technologies
  – Lab- and pilot-scale oxyfuel combustion process performance data being produced and analysed
  – Generic issues identified

• OxyCoal-UK Phase 2: Demonstration of an Oxyfuel Combustion System
  – Planning application approved
  – Revised Scottish Environmental Protection Agency (SEPA) Variation Application submitted
  – Process design complete
  – Mechanical layout design complete
  – HAZOP review complete

• Demonstration of a full-scale (40 MW<sub>i</sub>) oxyfuel burner will form the foundation for an oxyfuel boiler reference design
Contact Details

Thank you for your attention!

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