Doosan Babcock Energy

Current Oxyfuel Combustion Activities at Doosan Babcock Energy Limited

Coal Research Forum 19th Annual Meeting,
University of Nottingham, 10 April 2008

F D Fitzgerald

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Department: Research & Development

Contents

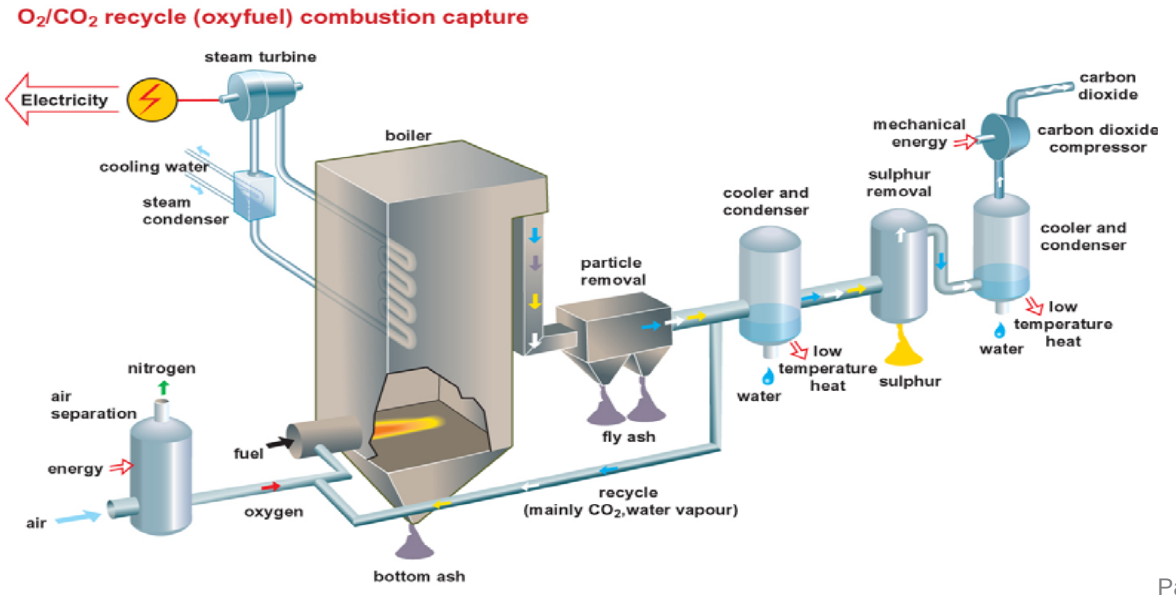
Oxyfuel Technology - Three Stage Development Programme

- 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 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).



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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

OxyCoal-UK: Phase 1 – Work Package 1: Combustion Fundamentals

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

OxyCoal-UK: Phase 1 – Work Package 2: Furnace Design and Operation

Investigation of the performance of the oxyfuel process and its key impacts on utility plant operation and performance.

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

(E.ON-UK)

First coal completed

Characterisation of 1MW_t 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

OxyCoal-UK: Phase 1 – Work Package 3: Flue Gas Clean-Up

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)

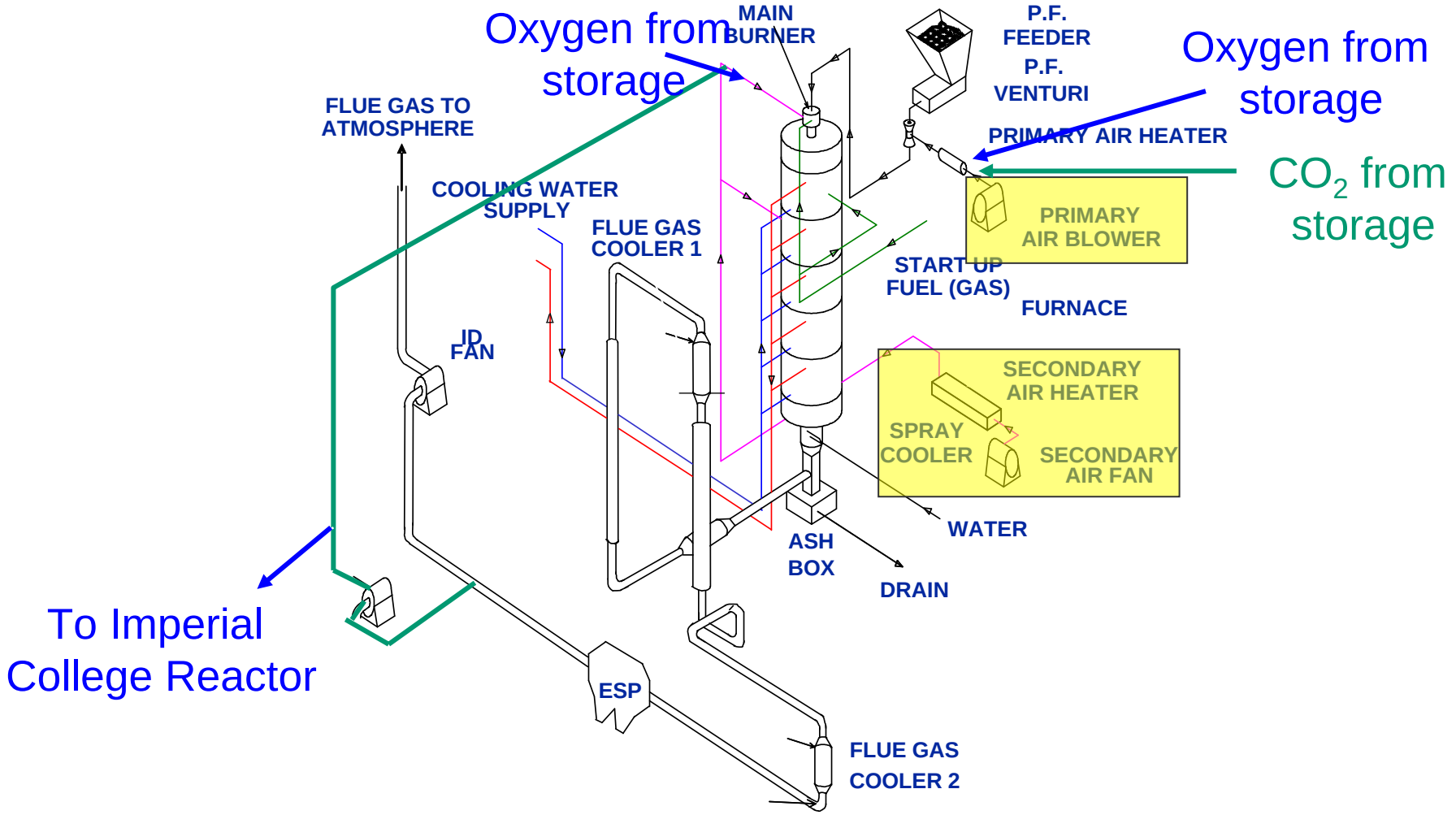
Planned May 2008

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 (CO_2 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



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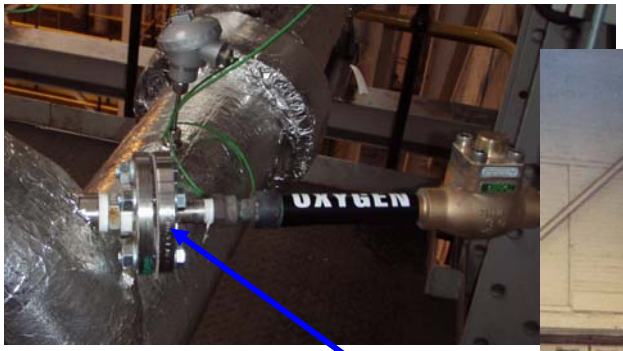
OxyCoal-UK: Phase 1 – NRTF Oxyfuel Installation



Secondary FGR
Oxygen Injection

Flue Gas Recycle Fan

Carbon Dioxide
Storage

Oxygen Storage

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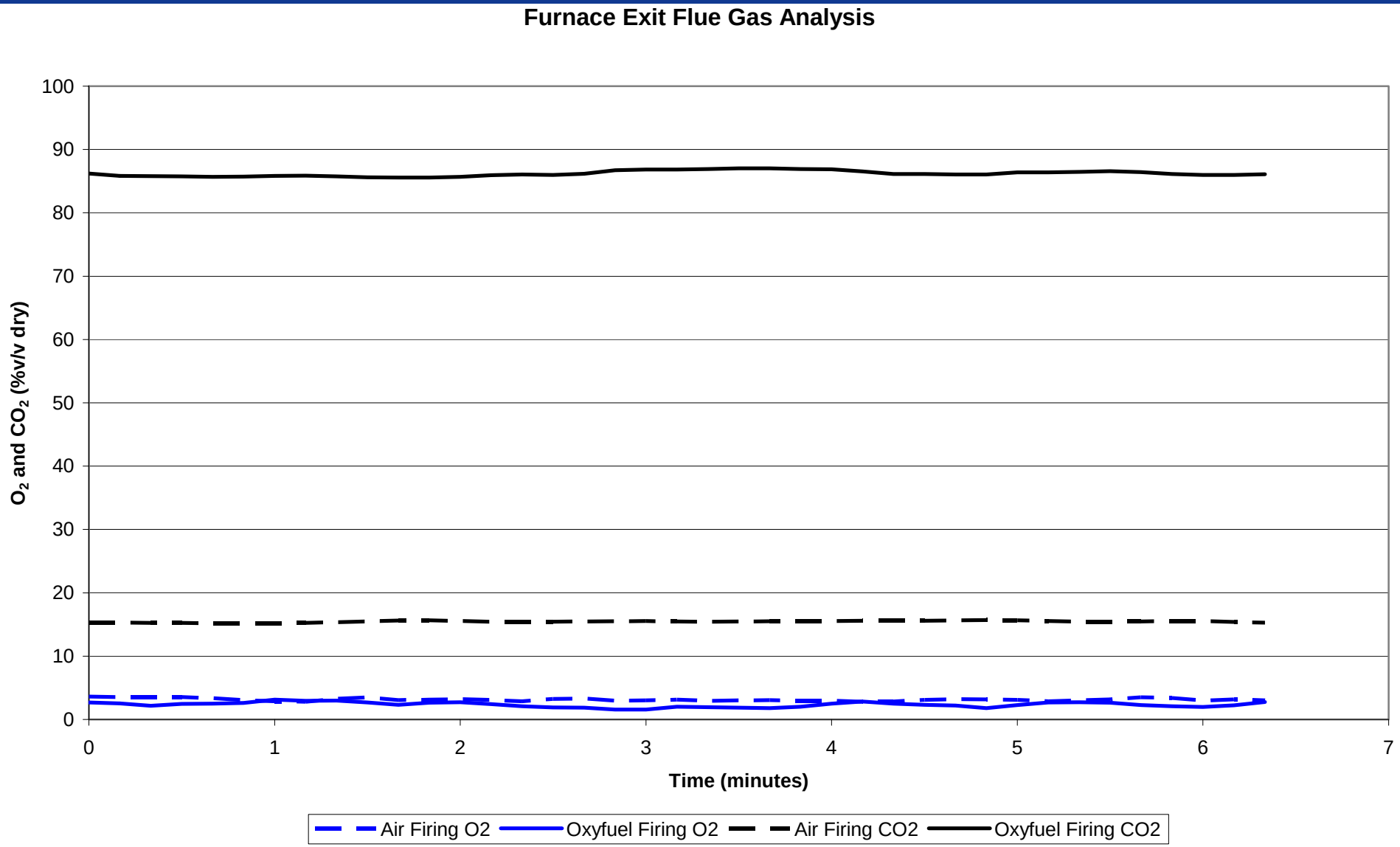
OxyCoal-UK: Phase 1 – NRTF Oxyfuel Commissioning Results



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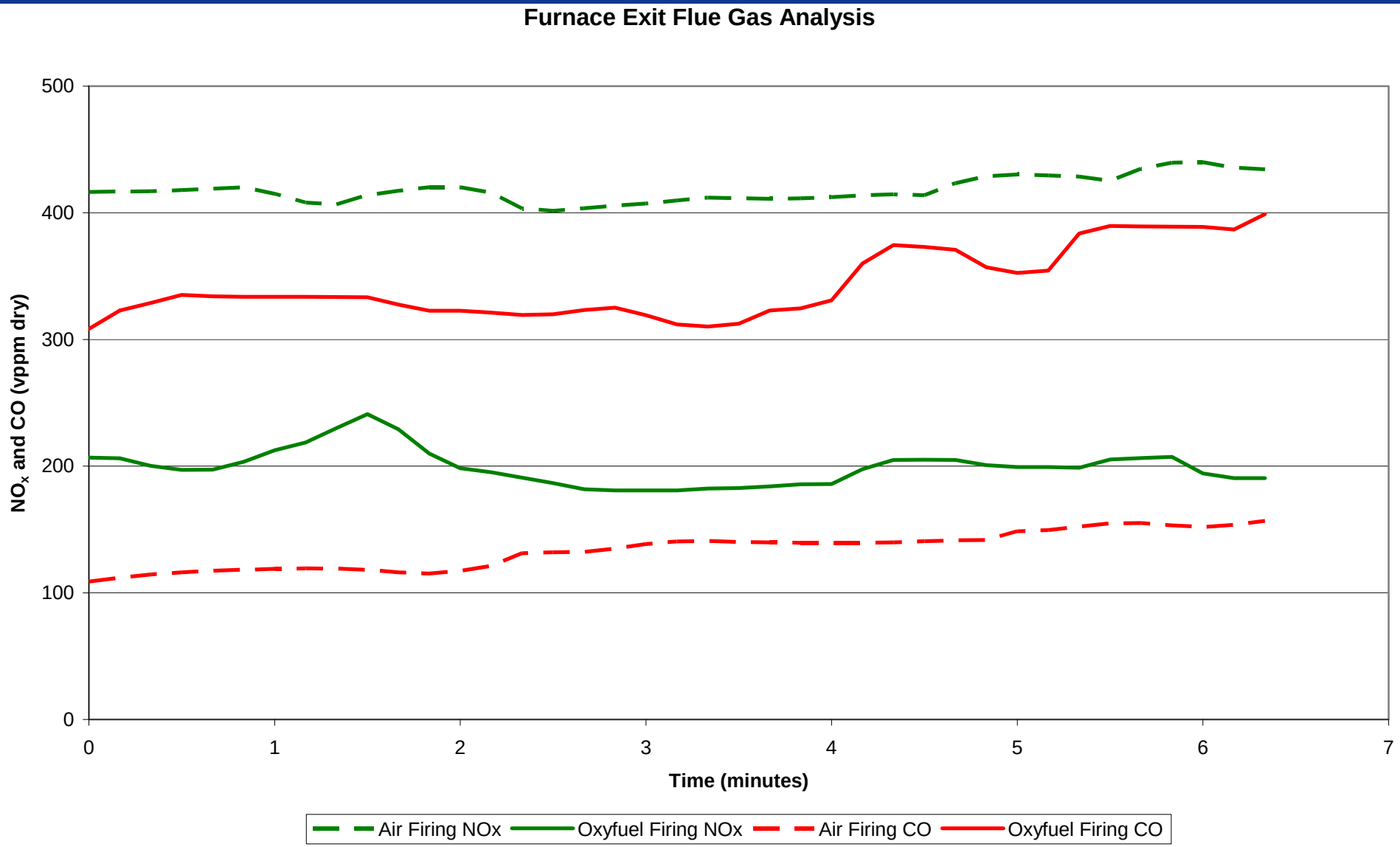
OxyCoal-UK: Phase 1 – NRTF Oxyfuel Commissioning Results



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OxyCoal-UK: Phase 1 – Work Package 4: Generic Process Issues

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

OxyCoal-UK: Phase 1 – MBTF FEED Study Results

HAZOP Study Key Concerns

- Material compatibility in oxygen enriched atmospheres.
- Effect of fly ash on oxygen safety.
- Leaks of CO_2 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

OxyCoal-UK: Phase 2 – Demonstration of an Oxyfuel Combustion System

Project Aim:

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

- The specific objectives are:

  – Demonstrate successful performance of a full-scale ($40MW_t$) 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, NOx, 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

OxyCoal-UK: Phase 2 – Task 1

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

OxyCoal-UK: Phase 2 – MBTF Oxyfuel Conversion Scope

- 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.

OxyCoal-UK: Phase 2 – Tasks 2 and 3

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

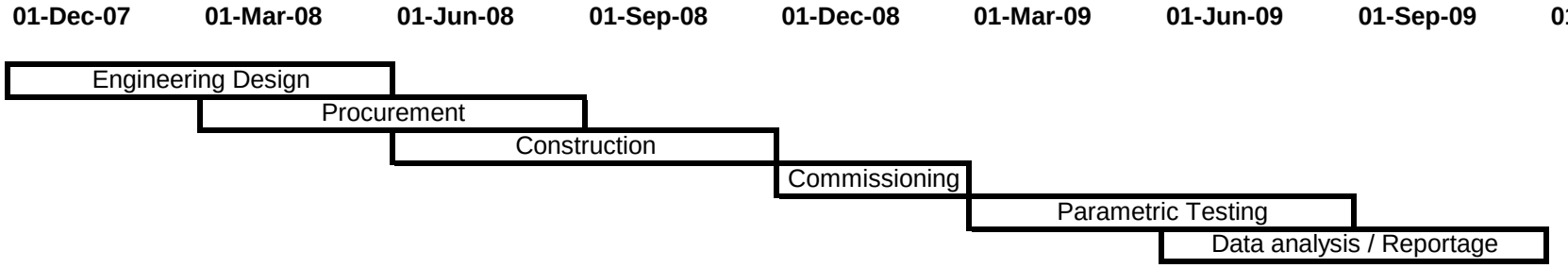
- Cold commissioning
- Hot commissioning

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

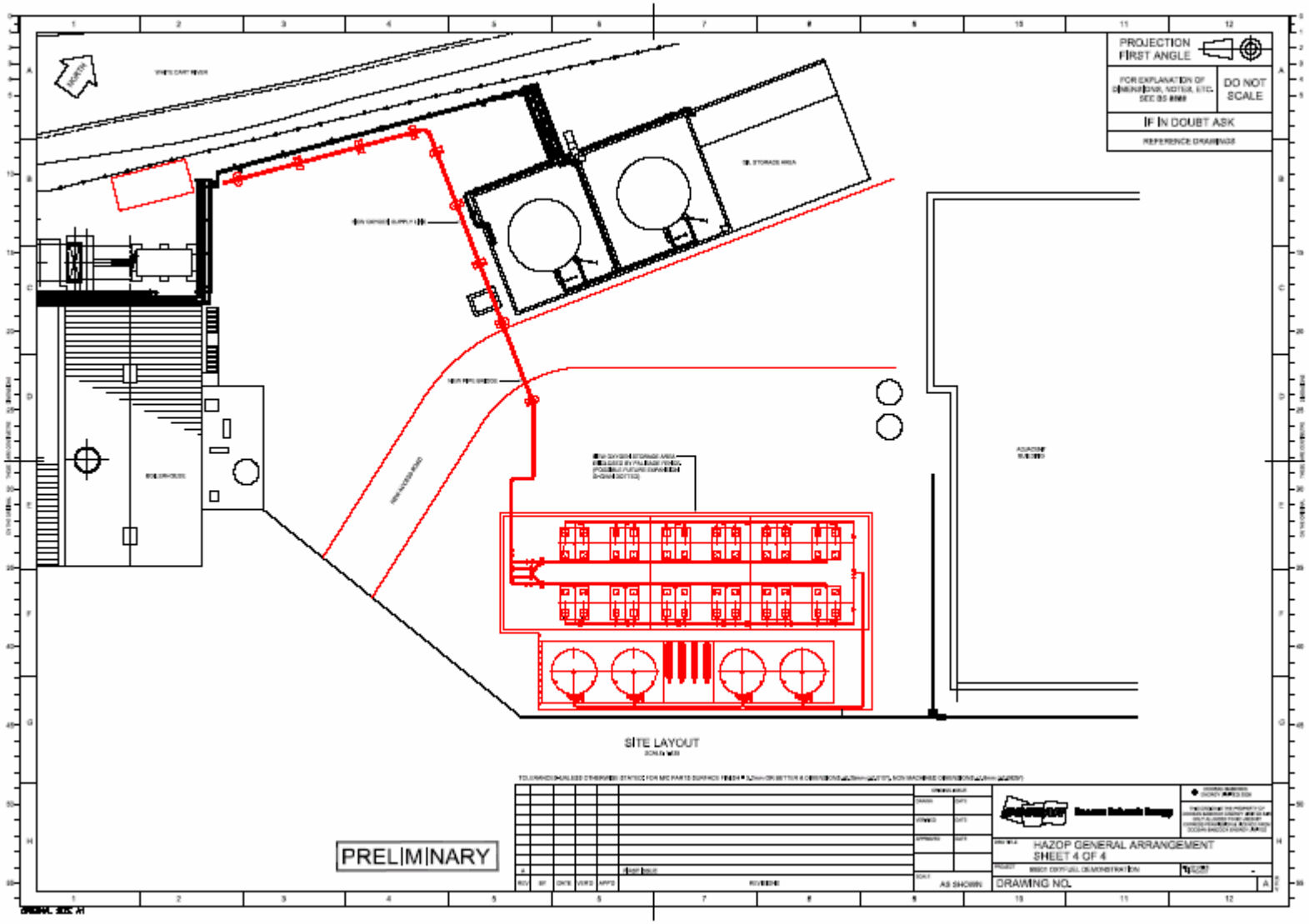
OxyCoal-UK: Phase 2 – Progress

- Project Start: 1 December 2007



- 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

OxyCoal-UK: Phase 2 – Planned Layout 1: Oxygen Storage



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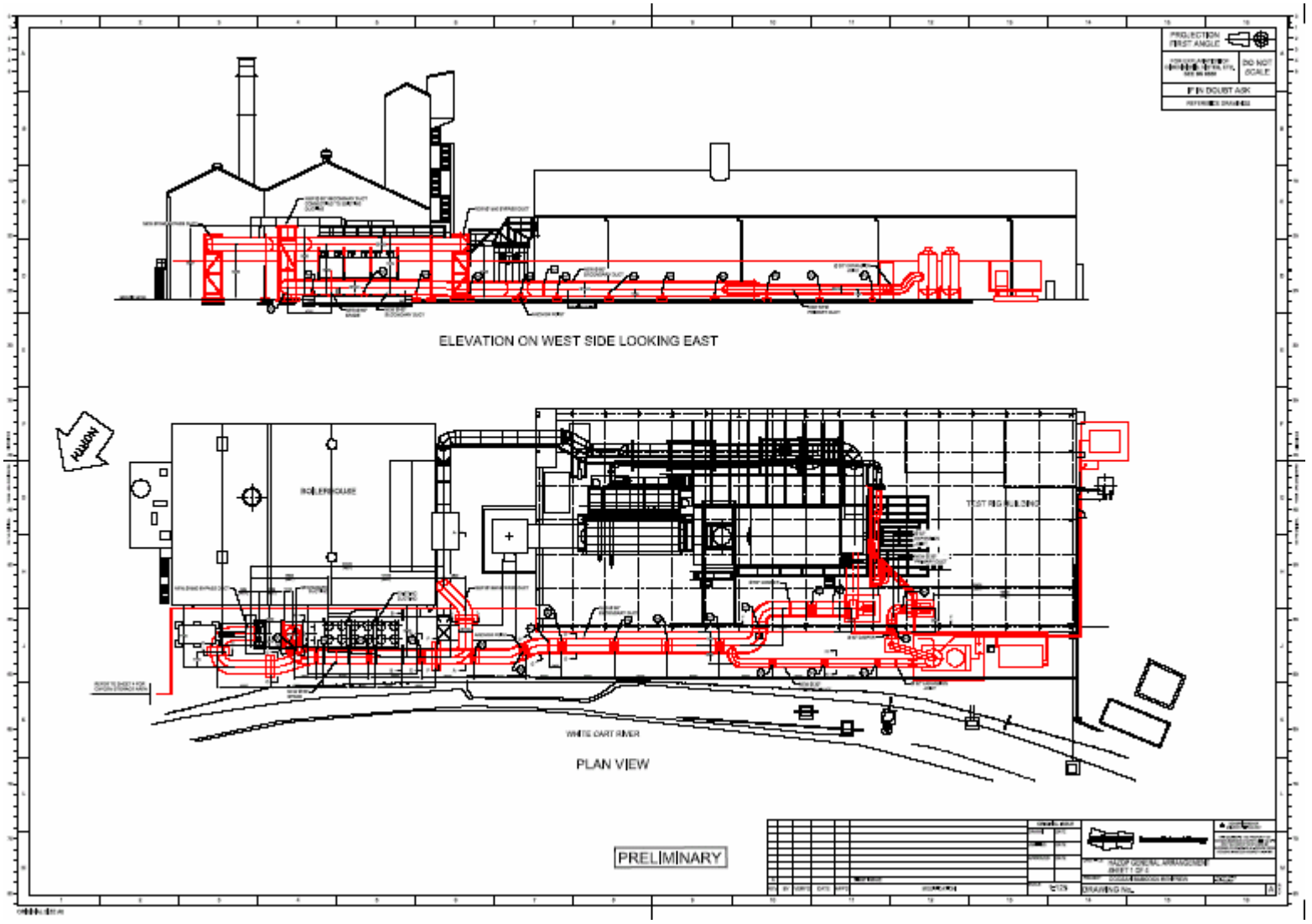
OxyCoal-UK: Phase 2 – Planned Layout 2: FGR Ducts



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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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