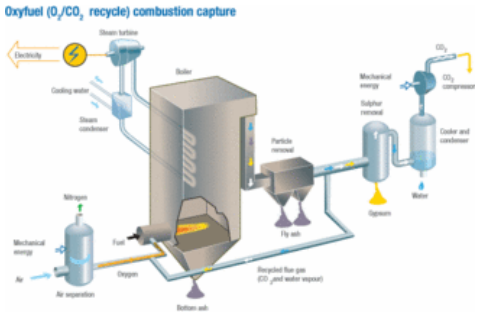
Capturing the moment: an underground revolution

Carbon capture units could be the next big thing. Relatively low cost, suitable for retrofitting and using commercially available components, Doosan Babcock's Oxycoal units could become standard kit for coal fired power plants – as common as flue gas desulphurization units in fact. Doosan Babcock Energy's CEO Iain Miller explains.

Iain Miller, Doosan Babock Energy, UK

Clean coal is now recognized as an important part of an ongoing, balanced, global energy portfolio, reinforced by international bodies such as the International Energy Agency and the European Commission (EC), as well as publications such as the Stern Review.

Coal is being used in increasing quantities for power generation, particularly in parts of the world such as the United States, China, India and Europe, which have large resources. Increased energy efficiency and renewable energy sources are important long-term solutions to reaching emission targets. However, we cannot reduce UK, Europe or worldwide carbon dioxide (CO_2) emissions by 50 per cent in 2050 if we do not also plan to capture CO_2 from industrial installations and store it in geological formations.



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Doosan Babock's Oxycoal carbon capture unit features an air separation unit which removes nitrogen so that the coal is burned in pure oxygen. The CO_2 emitted is then compressed for piping away.

In the European Union (EU) alone, reductions of CO_2 by carbon capture and storage from the power sector could reach 161 Mtonnes in 2030 and 800-850 Mtonnes (20 per cent) in 2050. The industry welcomes the EC's Energy and Environment package because it finally recognizes the vital role of clean power from fossil fuels in the future global energy mix.

The Kyoto Protocol includes a commitment to working with industry and with national and international research programmes and partnerships to explore the potential of carbon capture and storage (CCS) technologies. In accordance with these terms, the UK government has committed to a Carbon Abatement Technology Strategy in which it recognizes that fossil fuels will be used for many years to come.

As a result, there is a need to develop technologies to reduce CO_2 emissions from fossil fuel fired power plant, in addition to the technologies currently employed to control NOx, SO_2 and particulate emissions.

If Britain builds power plants (coal and gas) designed for CCS and demonstrates the technologies at full scale, it will set an important example to the world and, just as importantly, will be at a competitive advantage.

The development of Oxycoal

Oxyfuel firing is one of several carbon abatement technologies that are currently under development worldwide. It involves the combustion of fuel in a medium that comprises injected oxygen plus recycled flue gas and offers a means of generating CO_2-rich flue gas that requires minimal treatment before sequestration or beneficial use.

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Doosan Babcock's test rig in Renfrew, Scotland, will host the Oxycoal development

Doosan Babcock made a preliminary investigation of oxyfuel combustion in 1992 and has carried out several paper studies investigating the application of oxyfuel combustion technology to new power plants and retrofitting to existing power plants. The studies have included technical and economic comparisons of oxyfuel combustion technology and alternative carbon abatement technologies.

Doosan Babcock is currently engaged in a three-phase development programme aimed at developing and demonstrating a competitive oxyfuel firing technology suitable for full plant application post-2010.

The phases are:

- Phase One: Fundamentals and Underpinning Technologies (2007-2008)
- Phase Two: Demonstration of Oxyfuel Combustion System (2007-2009)
- Phase three: Development of Reference Designs (2009-2010)

Doosan Babcock is leading two collaborative projects funded by the UK government that address Phase One and the Phase One development programme objectives.

Oxycoal-UK Phase ONE

The Oxycoal-UK Phase One: Fundamentals and Underpinning Technologies Project is partly funded by the Department of Business, Enterprise and Regulatory Reform (BERR) under the Technology Programme, Low Carbon Energy Technologies scheme and the Engineering and Physical Sciences Research Council (EPSRC).

The project consortium comprises Doosan Babcock Energy (lead), Air Products, E.ON UK, RWE npower, BP Alternative Energy International, the University of Nottingham and Imperial College London. Scottish and Southern Energy, ScottishPower Energy Wholesale, EDF Energy, Drax Power and DONG Energy A/S are sponsor participants. The objectives of the project are:

- Investigation of coal ignition, devolatilization, char burnout and nitrogen partitioning behaviour under oxyfuel firing conditions through explosion bomb testing by Imperial College London's Department of Mechanical Engineering, and drop tube furnace testing by the University of Nottingham.
- Development of corresponding coal devolatilization and char burnout kinetics parameters for CFD modelling and subsequent CFD simulation of a single oxyfuel burner and an oxyfuel-fired furnace by Doosan Babcock.
- Conversion of the Doosan Babcock 160 kWt NOx Reduction Test Facility (NRTF) to oxyfuel firing.
- Doosan Babcock and E.ON UK, respectively, will carry out parametric testing of the oxyfuel combustion process on 160 kWt and 1 MWt combustion test facilities.
- Investigation of slagging, fouling and corrosion characteristics, including deposit analysis, at lab- and pilot-scale by E.ON UK, Imperial College London's Department of Materials and Doosan Babcock.
- Development and laboratory-scale testing of a novel CO_2 clean-up process that uses simulated flue gas and real flue gas supplied from the 160 kWt combustion test facility by Air Products and the Department of Chemical Engineering at Imperial College London.
- Investigation of oxyfuel power plant reliability, availability, maintainability and operability (RAMO) and safety concerns, led by RWE npower, with contributions from all project participants.
- Front-End Engineering Design by Doosan Babcock for the conversion of their 90MWt Multi-Fuel Burner Test Facility (MBTF) to oxyfuel firing, including a preliminary Hazard and Operability (HAZOP) study.

progress update

The Oxycoal-UK Phase One project is well advanced. The Drop Tube Furnace characterization of the first two of the planned six coals has been completed and preparations for the explosion bomb tests of the same six coals are in progress.

The 1 MWt oxyfuel parametric and corrosion tests for the first of the planned two coals have been completed. The second coal is to be tested during May. Analysis of the collected deposits is in progress and the first laboratory-scale corrosion experiment has been completed.

Theoretical modelling and laboratory testing (using simulated flue gas) of the novel CO_2 clean-up process is in progress, and testing using real flue gas is scheduled to start this month.

Conversion of the NRTF has been completed and commissioning is nearing completion.

The RAMO and safety work are in progress and the MBTF oxyfuel conversion FEED study was completed in December 2007. The FEED study provided the foundation for the detail design of the MBTF oxyfuel conversion, which is included in the second UK government-funded collaborative project.

Oxycoal-UK Phase Two

The Oxycoal-UK Phase Two: Development of an Oxyfuel Combustion System Project is partly funded by BERR under the Hydrogen, Fuel Cell and Carbon Abatement Technology (HFCCAT) Demonstration Programme.

The project consortium comprises Doosan Babcock Energy (lead), Imperial College London and the University of Nottingham. Air Products, Scottish and Southern Energy, ScottishPower Energy Wholesale, E.ON UK, EDF Energy, Drax Power and DONG Energy A/S are sponsor participants, with Scottish and Southern Energy being the prime sponsor.

The project is broken down into three main tasks, with an option of additional testing as a fourth task.

Task 1 – Purpose-Designed Oxyfuel Test Facility

The oxyfuel combustion system will be demonstrated by modifying the existing 90 MW MBTF located at Doosan Babcock's Research and Development Centre in Renfrew, Scotland. The main test facility components, including the furnace, boiler and coal and ash handling plant, will be retained.

During the first year of the project, new equipment, including an oxygen storage, vaporization and supply system, flue gas recycle fans (coal transport, primary and secondary), transport/primary flue gas cooler (to facilitate moisture removal) and ancillary equipment, primary flue gas heater, control and isolation dampers, ducts and pipework, process control instrumentation, and gas analysis systems, will be installed.

Additional control functions will be incorporated into the existing control system, along with a number of safety-specific systems that will be added to the modified test facility building: forced ventilation fans to prevent a build-up of CO_2, CO_2 detection/alarms, and a positive-pressure system for the control room.

The converted test facility will retain its air-firing capability to permit continued development and testing of air-firing burners and to facilitate rig start-up prior to switching to oxyfuel firing.

The design, construction and commissioning is being carried out almost entirely within Doosan Babcock's diverse business groups.

Task 2 – Burner Design and Manufacture

A 40 MW, first generation oxyfuel burner will be designed and manufactured during the first year of the project and installed for testing following completion of the test facility modifications. The 40 MW burner size has been selected, since it is a standard size installed at many coal fired power plants worldwide and will be available for oxyfuel retrofit applications.

Task 3 – Demonstration of an Oxyfuel Combustion System

The demonstration programme will gather data on the operation and performance of the burner across a range of oxyfuel firing conditions. Key parameters to be investigated include the change over from air to oxyfuel firing at various loads, turndown, flame stability, heat release, heat flux to furnace walls and pollutant emissions.

Flame visualization and modelling will be provided by Imperial College London's Department of Chemical Engineering. Testing will take place during 2009 and will be carried out by Doosan Babcock Research and Development Centre.

Task 4 – Further Oxyfuel Combustion System Testing

Following the oxyfuel system demonstration testing of Task 3, there will be the option of further oxyfuel testing in years 3 and year 4. A review will consider the outcome of the testing completed within the project and the results arising from other work being conducted elsewhere.

The scope of the additional testing will be defined and may, for example, include the testing of an improved oxyfuel burner design, the testing of the oxyfuel burner at different operating conditions or the collection of more detailed (for example in-flame) data.

The test rig is being modified via investment from the UK government and several major European utilities

The two projects complete the foundation for the development of an oxyfuel boiler reference design, demonstration plant installation and operation. Investing in demonstration projects is a fundamental part of developing the technology that will provide a technically viable solution for CO_2 capture, combining well-proven commercially available components with minimal controlled risk.

Dr Mike Farley, Doosan's director of technology policy, said: "We believe retrofitting coal fired plants with carbon capture is technically and economically viable. This project forms part of a commercial demonstration."

Farley added that the loss of efficiency caused by operating the Oxycoal system's air separation unit and CO_2 compressor – as much as ten per cent – would eventually be reduced through research and development, perhaps to around seven per cent.

The Oxycoal projects will enable Doosan Babcock to gain the knowledge necessary to accelerate the implementation of clean coal technology projects in the UK and around the world.

Clean coal is vital to achieving the global objectives of preventing an energy gap, reducing emissions and ensuring security of supply. It is extremely important that the UK government, in parallel with its other actions on energy and climate change, sets an example of adopting capture-ready, best available technology for coal fired power plants (as well as gas). It should demonstrate continued commitment to clean coal as a vital part of a balanced ongoing energy portfolio both in the UK and globally.

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