OxyCAP UK: Oxyfuel Combustion - Academic Programme for the UK

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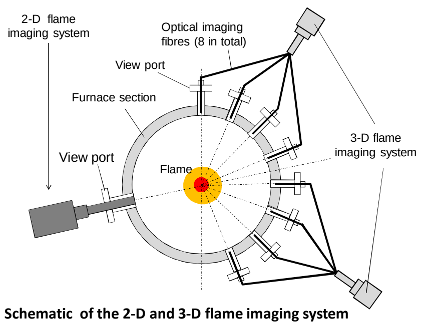
250 kW Solid Fuel Combustion Test Facility

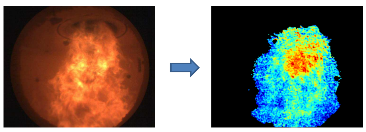
The 250 kW CTF is part of the UK CCS Research Centre PACT facilities and is designed to generate a comprehensive database for oxy combustion under various test conditions and provide much needed validation data for CFD submodel development.
The facility can use gas, coal, or coal/biomass blends as fuel. The oxidising medium can be either air, a synthetic mixture of CO_2/O_2 with or without steam injection, or a mixture of wet recycle gas and O_2. The facility can also supply flue gas to the connected post combustion carbon capture plant for solvent testing and development.
Measurements include:

- in-flame temperature profiles using suction pyrometry;
- heat flux profiles using an ellipsoidal radiometer and total heat flux probes;
- in-flame and exhaust species profiles;
- flame characterisation, including shape, luminosity, temperature, and oscillation frequency, using 2-D and 3-D flame imaging systems. These techniques will provide direct photographs and videos of the flame, as well as computer tomographic reconstruction of the flame in 3-D; and
- velocity profiles within the top section of the furnace (for both non-reactive and reactive cases) using laser diagnostics (Particle Image Velocimetry);
- coal burnout and ash characterisation.

Panoramic photos of the 250 kW Combustion Test Facility



Schematic of the 2-D and 3-D flame imaging system



Flame image and temperature distribution

100 kW Coal/Biomass Rig

Work has also been undertaken using a 100kWth coal/biomass rig at Cranfield University that is also part of the UKCCSRC PACT facilities. The two main activities are experimental trials in a 100kW retrofitted oxy-combustor, and the development of a kinetic model using Aspen Plus that predicts gas composition and temperatures of the process when varying the main operational parameters.

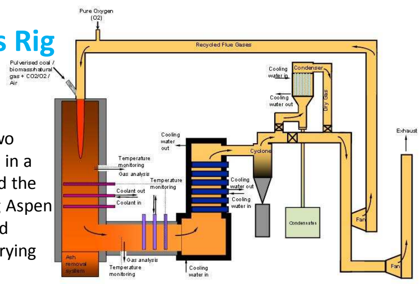
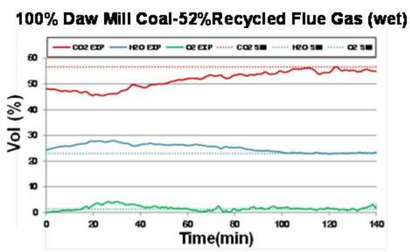


Diagram of 100kWth Oxy-Combustor with Condenser

For the experimental part of the project, primary parameters such as type of fuel (coal/biomass/coal-biomass blends), percentage of recycle flue gas, and type of recycle flue gas (dry/wet) were varied to analyse their effects on the outputs of the process (gas composition, temperatures reached, and composition of ash generated). Additional aspects like sulphur trioxide levels inside the combustor, heat transfer, and study of the process using a dry recycle flue gas, have started to be studied in the last stage of experiments. In parallel, a kinetic simulation model has been designed to study the oxy-combustion process through the co-firing of coal and biomass blends.

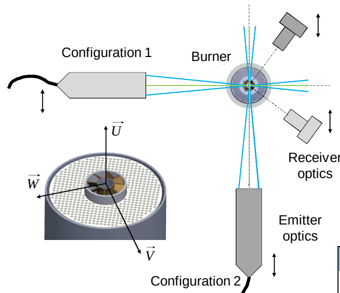


Selected Related Papers at OCC3

- T. Farrow, C-G. Sun, C. Snape, Impact of CO_2 on Biomass Devolatilisation, Nitrogen Partitioning and Char Combustion - A Drop Tube Furnace Analysis
- B.M. Franchetti, F. Cavallo Marincola, S. Navarro-Martinez, S. Black, M. Pourkashanian, A.M. Kempf, Large Eddy Simulation of a 100 kWth Oxy-coal Swirl Burner
- N. Jurado, H. Darabkhani, E.J.B. Anthony, J. Oakey, Co-firing Performance of a Retrofitted Oxy-Combustor Burning Coal/Biomass Blends: Experimental and Simulation Study
- J. Szuhánszki, W. Nimmo, M. Pourkashanian, S. Li, G. Lu, Y. Yan, Experimental Investigation of Oxy-coal Combustion at a 250 kW Combustion Test Facility
- I. Trabadela, J. Gibbins, H. Chalmers, Coal Dust Ignition Experiments for Oxyfuel Safety

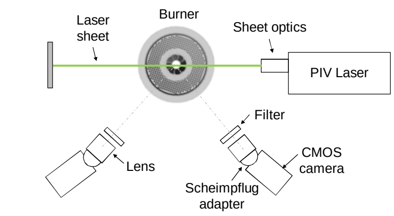
2-D and 3-D Flame Imaging Systems

Two-dimensional (2-D) and three-dimensional (3-D) flame imaging systems have been developed to quantify the fundamental physical characteristics of oxyfuel flames. The systems are capable of measuring a range of flame characteristics, including length, volume, surface area, temperature distribution, soot concentration and emissivity. Photodiodes are incorporated in the 2-D imaging system to measure the oscillation frequency and stability of the flame. Experimental work is being undertaken on the 250 kW solid fuel combustion test facility (see left) to assess the performance and operability of the systems. In addition, a novel instrumentation system for measuring the velocity, concentration and particle size distribution of a pulverised coal flow has also been developed. The system operates on electrostatic and piezoelectric sensors and signal processing algorithms. It has been evaluated on a coal/biomass flow test rig at Kent and on a biomass flow pipeline at Tilbury Power Station. The project has also developed improved capability to use laser diagnostic techniques to make flow field measurements under oxyfuel conditions building on previous experience at the University of Cambridge.



Seeding particle	Median size (μm)
Aluminium oxide	1.0
Pulverized coal	75

Laser Doppler velocimetry



LDV	PIV
System: Dantec Dynamics	System: LaVision
Probe volume: 0.91 X 0.14 X 0.14 mm³	Imaging area: 60.5 X 52.4 mm²
Data rate: ~10,000 Hz	Data rate: 3,000 Hz
Samples: 10,000	Samples: 4,096

High-speed stereo particle image velocimetry

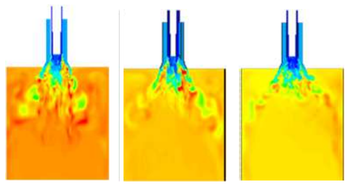
Coal Property Measurements and Ash Characterisation

The impact of CO_2 and steam on devolatilisation and char burn-out in relation to normal air firing is being assessed by a comprehensive drop tube furnace (DTF) programme at the University of Nottingham.
The DTF operates up to 1450ºC which is high enough to achieve the maximum volatile matter yields for coals with relatively short residence times. The results have indicated the enhanced volatile matter yields and char burn-out rates that can be achieved in CO_2. This has been complemented by dust ignition tests in oxyfuel atmospheres carried out at the University of Edinburgh (see right). Ash transformation and deposition in oxyfuel environments is being explored in a programme of work led by Imperial College London.

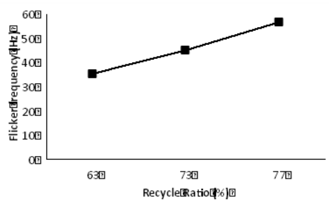
Ignition test chamber

Computational Fluid Dynamics

CFD simulations have been performed in ANSYS FLUENT using RANS and LES in the 250 kW solid fuel combustion test facility under air firing and a variety of oxy-fuel conditions. New CFD submodels including radiation and char gasification reactions are important for oxy-coal combustion as well as other techniques such as flicker analysis. Validation and improvements to new and existing models are a core focus for air and oxy-coal conditions. Model development includes incorporating the full spectrum correlated k-method (FSCK) and Mie theory for spectral radiation in CFD.



Instantaneous LES snapshots of temperature for different recycle ratios



Flicker frequencies predicted by LES at the centre of the quarl exit

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