250 kW Oxy-fuel Combustion Test Facility

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Objectives

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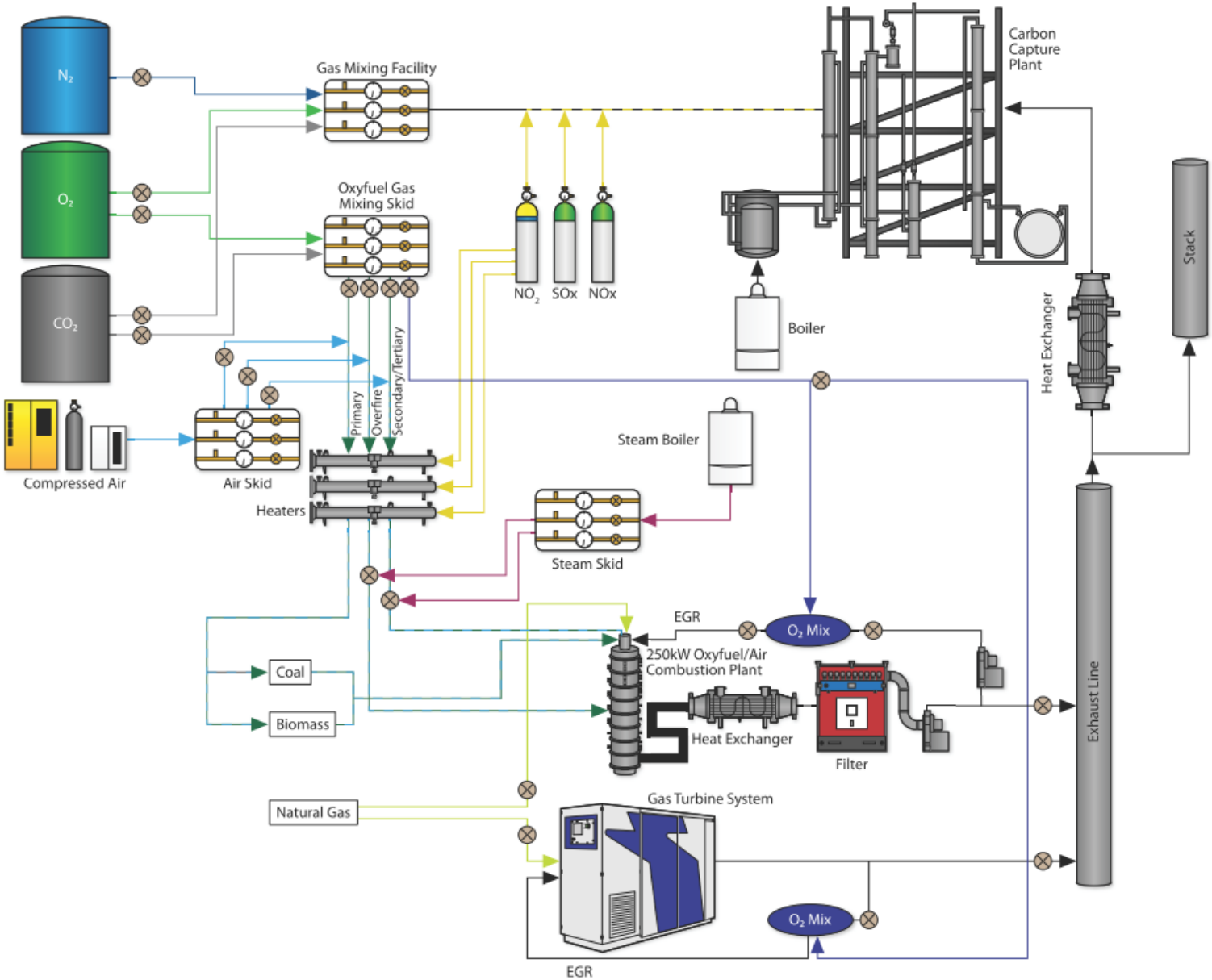
- **Investigate the combustion of pulverised coal and biomass under oxy-fuel conditions in the 250 kW state of the art combustion test facility**

- **Provide a comprehensive and detailed characterisation of pulverised oxy-coal flames, keeping the needs of CFD modellers in mind**

- **Novel 3D flame imaging predicts flame characteristics such as flicker leading to possible LES validation**

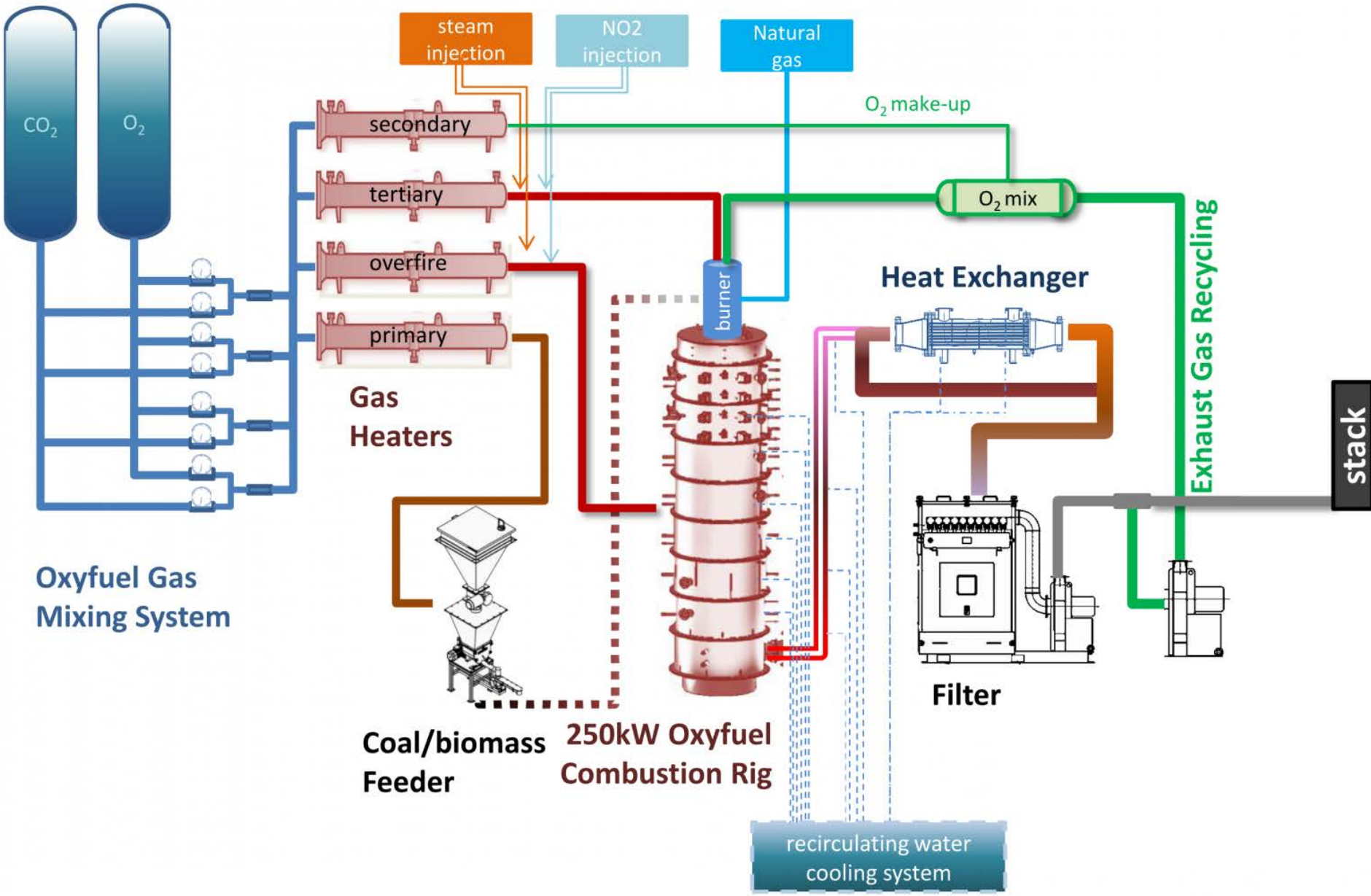
UKCCSRC PACT FACILITIES

PACT Core Facility: Overview



UKCCSRC PACT FACILITIES

250kW Oxyfuel Combustion Plant



250 kW oxy-fuel rig layout

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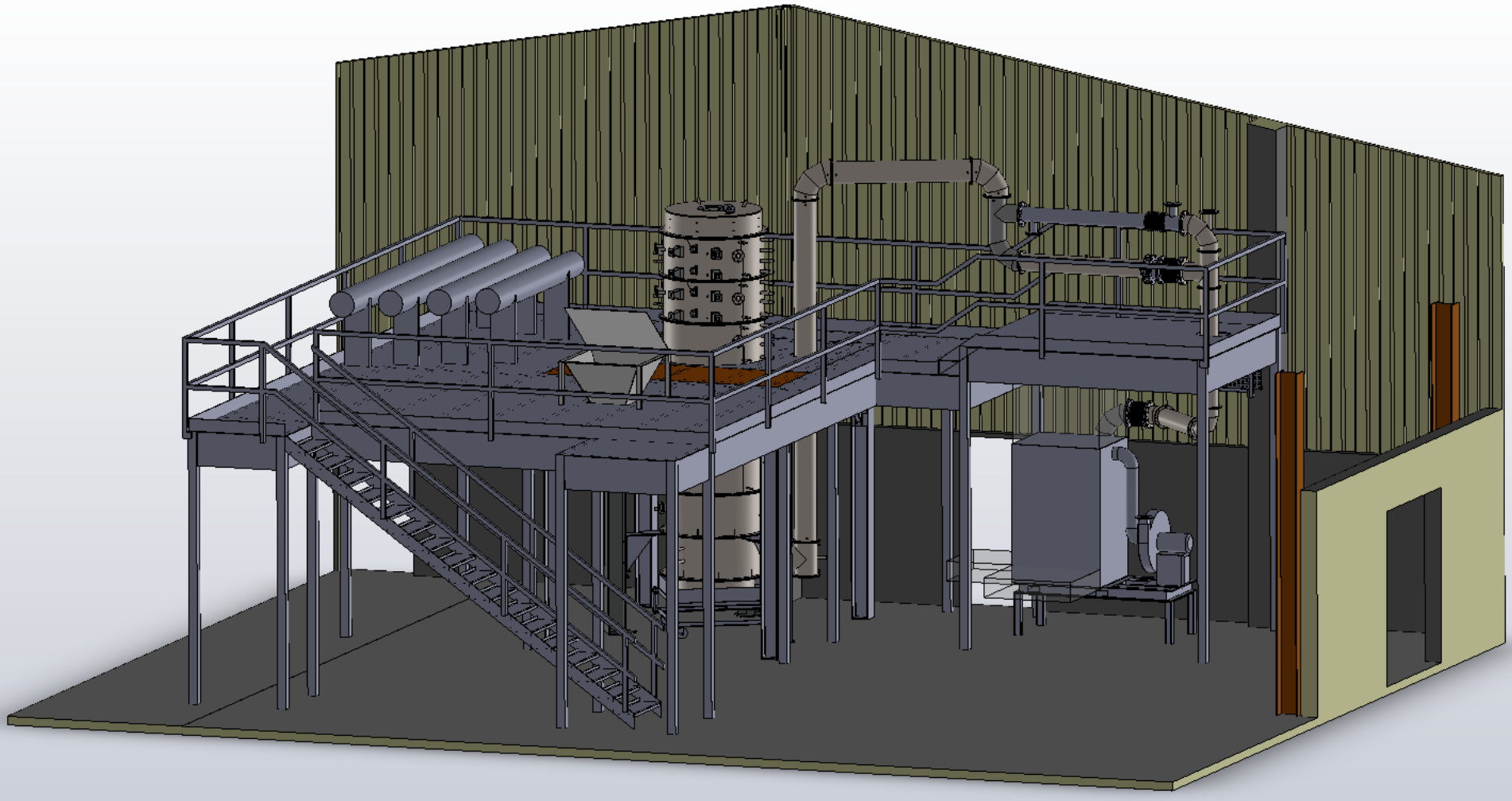

The Furnace

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Oxidiser feed system

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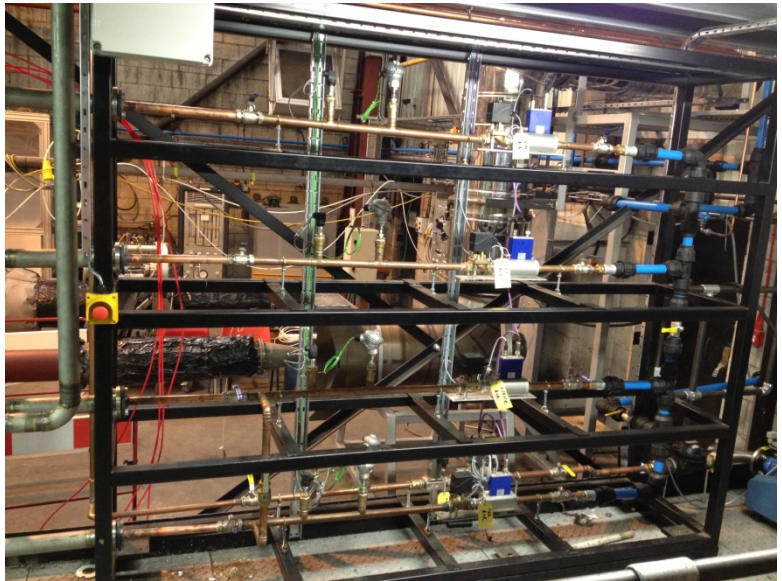

Burners

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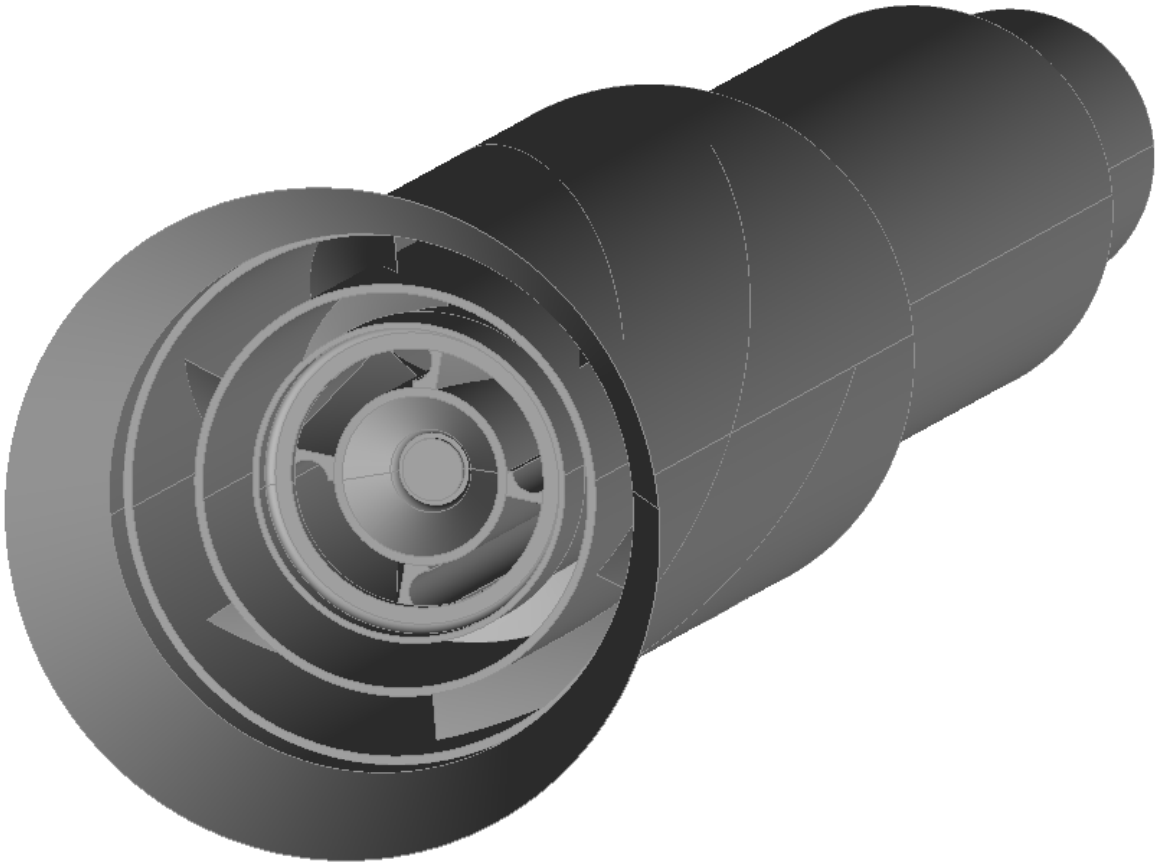
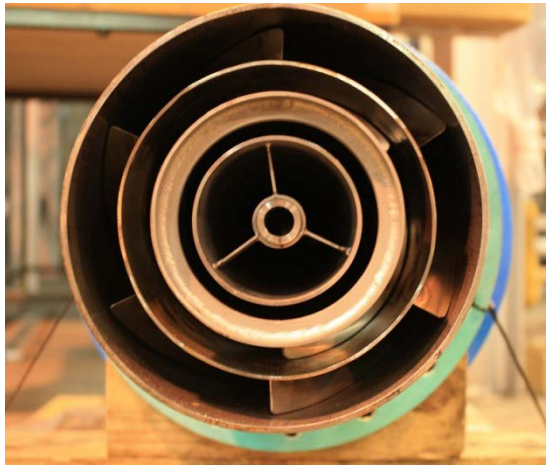


Coal burner



Biomass burner

Fuels used

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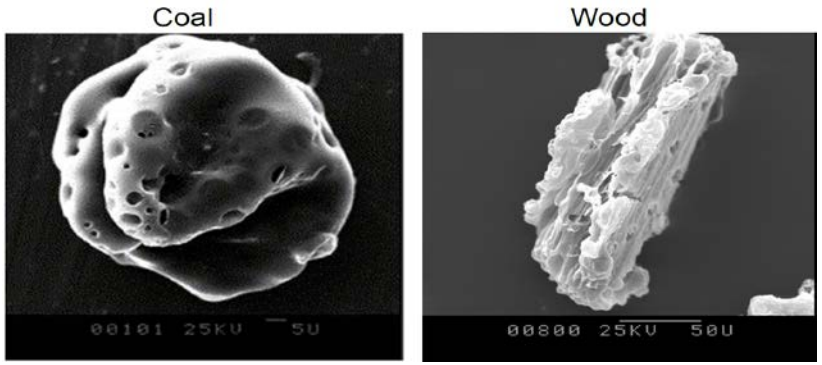
Experimental campaigns:

- 100% coal firing
- Biomass co-firing
- 100% biomass firing



Williams, A. Dr J. M. Jones, Professor M. Pourkashanian. 2007. *Co-firing Coal/Biomass and the Estimation of Burnout and NO_x Formation*. BCURA Agreement Number B 79.

Fuels tested:

- El Cerrejon high volatile bituminous coal
- Biomasses used by power generators
  - milled wood
  - straw
  - torrefied biomass

Jones JM, Williams A, Waldron DJ. An investigation of the grindability of two torrefied energy crops. *Fuel* (89); 3911–18

Experimental Program

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1. Baseline studies

- air-firing
- oxy-firing

2. Parametric studies

- O_2 concentrations (21-35 %),
- recycle ratios,
- optimal O_2 distribution between annuli
- impact of impurities (SO_x, NO_x) – dry/wet synthetic flue gas

Selected cases

are investigated further

Conventional measurements

- temperature (suction pyrometry)
- in furnace heat flux profiles
- species profiles (O_2, CO, CO_2, SO_2, NO_x)
- unburnt carbon
- ash analysis
- deposition studies

Visualisation*

- 2D/3D imaging
  e.g. flame shape, luminosity, non-intrusive flame temperature
- LDV
  non-intrusive velocity measurements
- LIF
  in flame NO and possibly OH

** collaboration with other universities*

Boundary conditions and output

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Fuel Characteristics

- ✓ type, proximate and ultimate analysis
- ✓ size distribution

Boundary conditions

- ✓ oxidiser flow rates, temperature, composition
- ✓ well defined geometry

Output data

- ✓ temperature, heat flux profiles
- ✓ species profiles
- ✓ flame characteristics (flame shape, luminosity, frequency etc.) including direct photographs/videos of the flame
- ✓ burnout
- ✓ ash characterisation
- ✓ laser diagnostics (non-reactive and reactive results)

Flame Characterization via 2D & 3D Imaging

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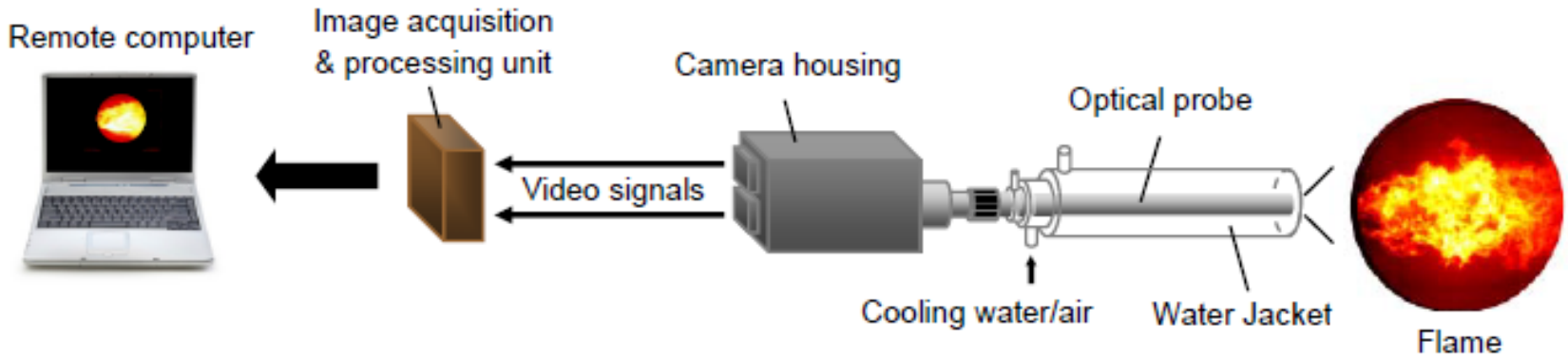

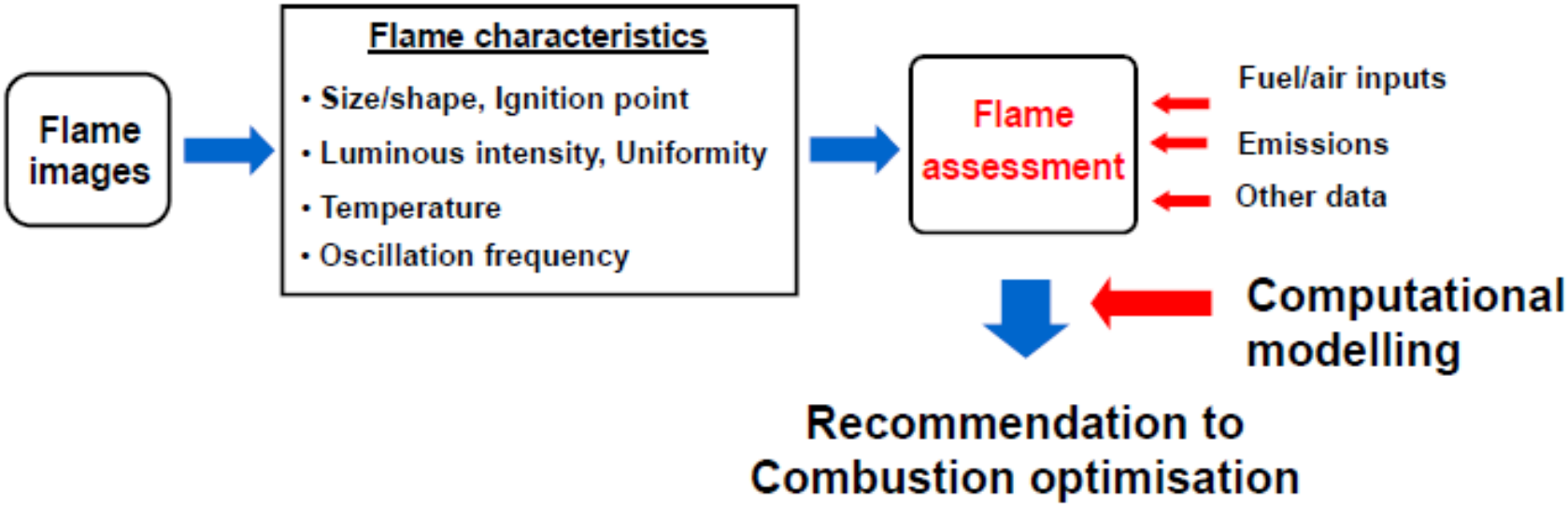

3D imaging system

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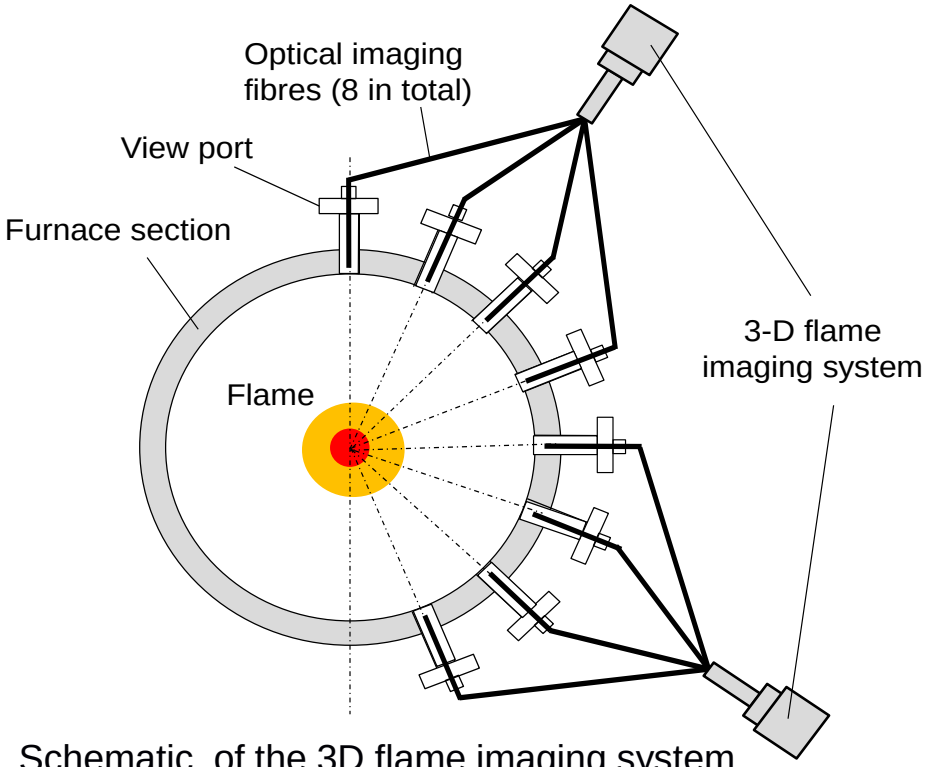
- The 3D flame imaging system consists of eight optical image fibre bundles protected by water jackets, two CCD cameras and a PC with associated application software, capable of acquiring eight 2D flame images simultaneously from eight equiangular directions.

Specifications of each fibre bundle:

- **30k fibres;**
- **650-700mm length;**
- **92° angle of view;**
- **operating temp: 70°C (max);**
- **mini band radius: 50mm**



Schematic of the 3D flame imaging system

Ref. : M. Hossain, G. Lu, Y. Yan, "Optical fiber imaging based tomographic reconstruction of burner flames", *IEEE Transaction on Instrumentation and Measurement*, vol. 61, no. 5, pp. 1417-1425, May 2012.

Imaging probes hardware

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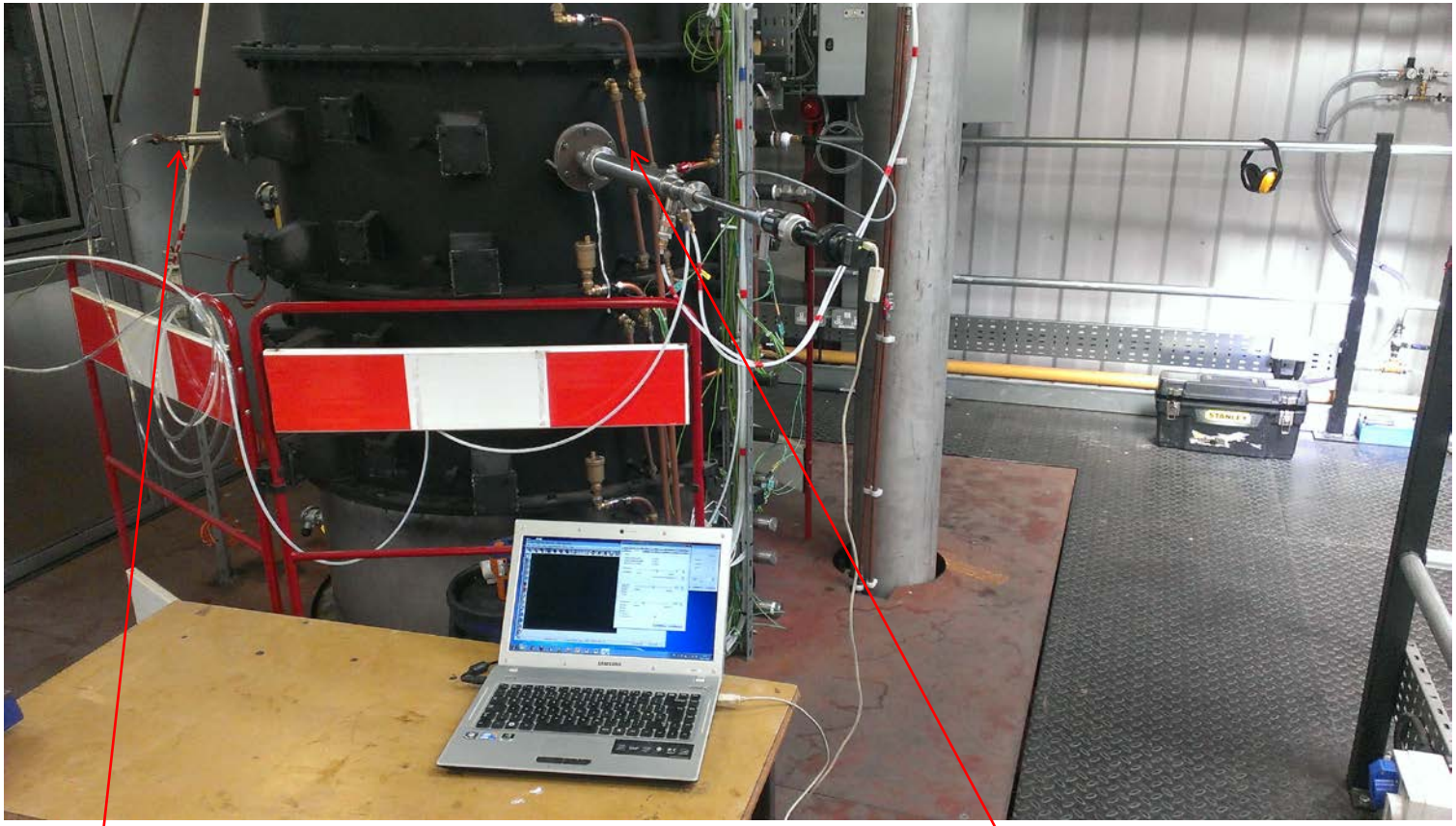

3-D imaging probe

2-D imaging probe

Video of 225kW PF flame

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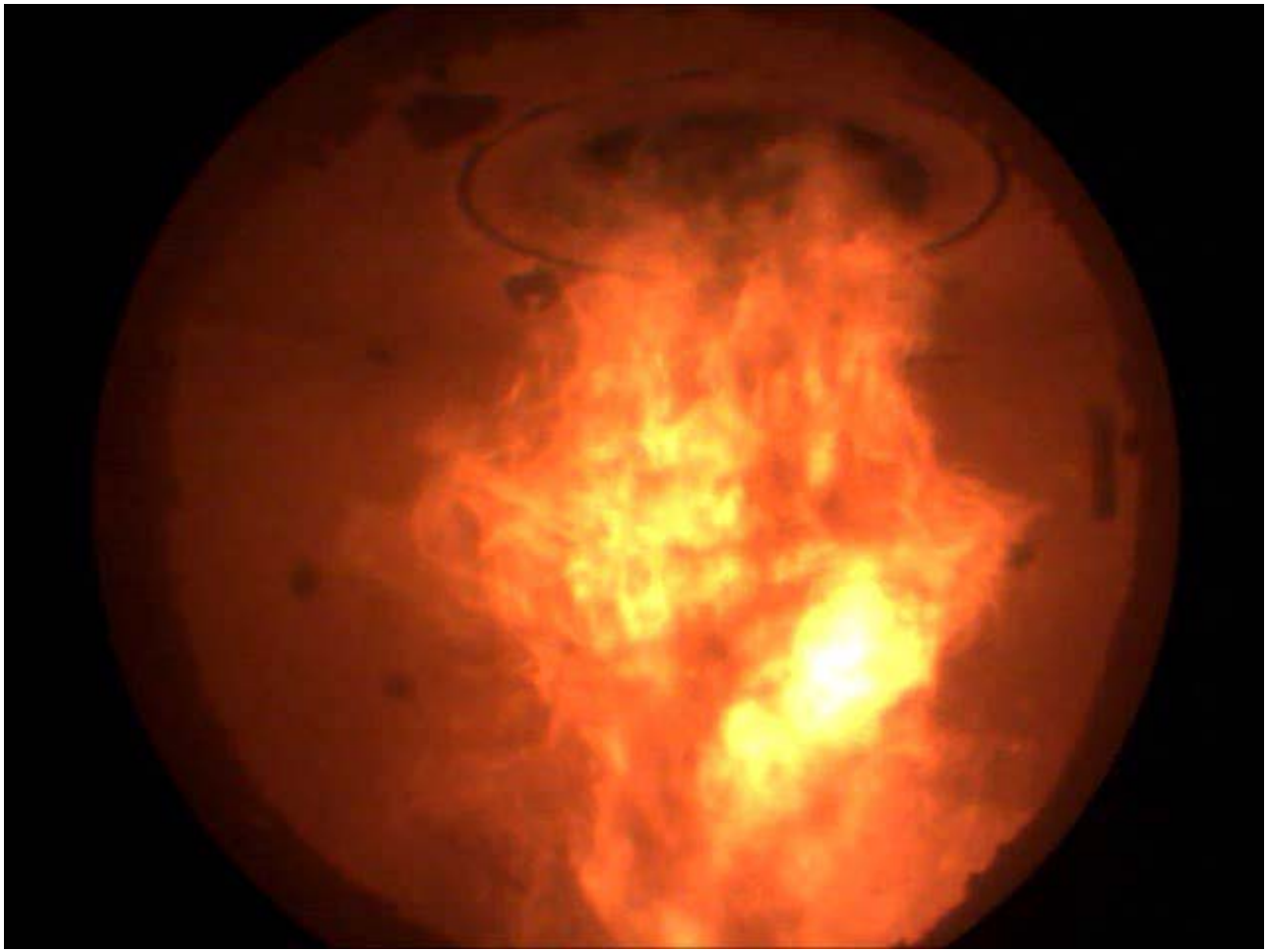

PACT :
Pulverised Fuel Rig - 250kW

DPS PF burner

2-D imaging

Video of 225kW PF flame

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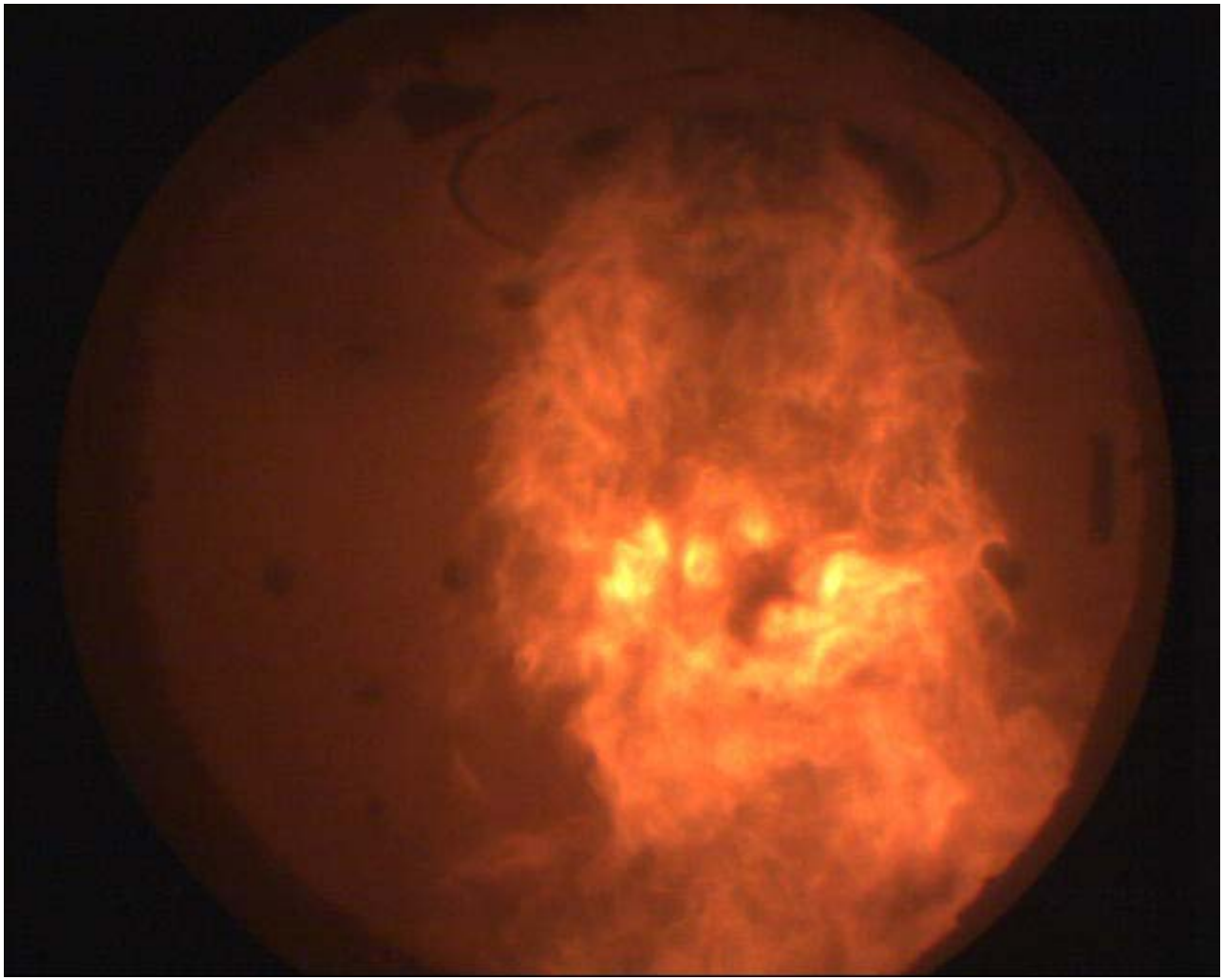

PACT :
Pulverised Fuel Rig - 250kW

DPS PF burner

2-D imaging

Flame Temperature Distribution

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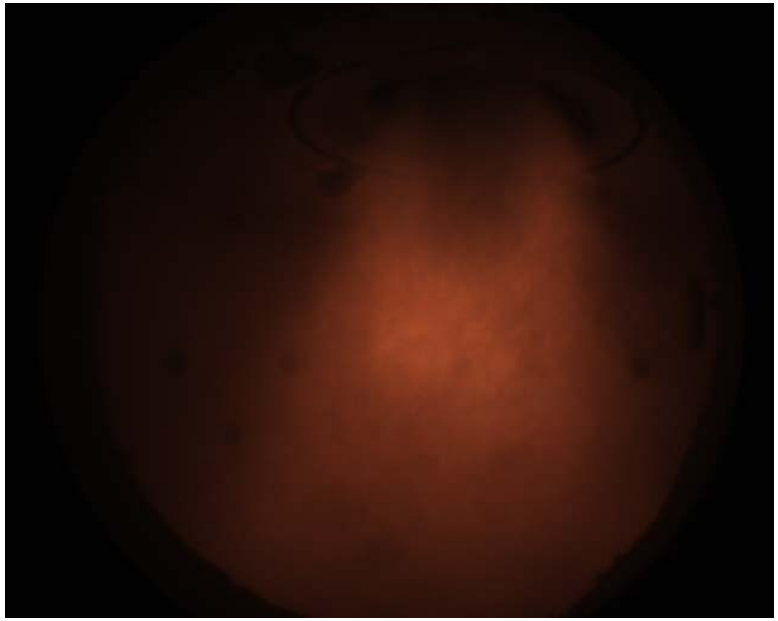
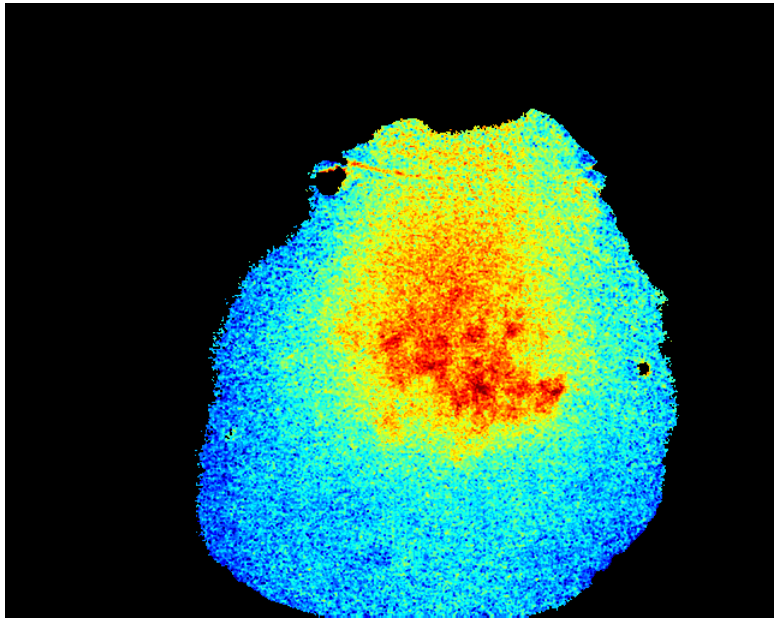


Averaged flame image
(from 46 instantaneous images captured during 26/07/2013 14:52~14:53)



Temperature distribution

3D gray-level reconstruction

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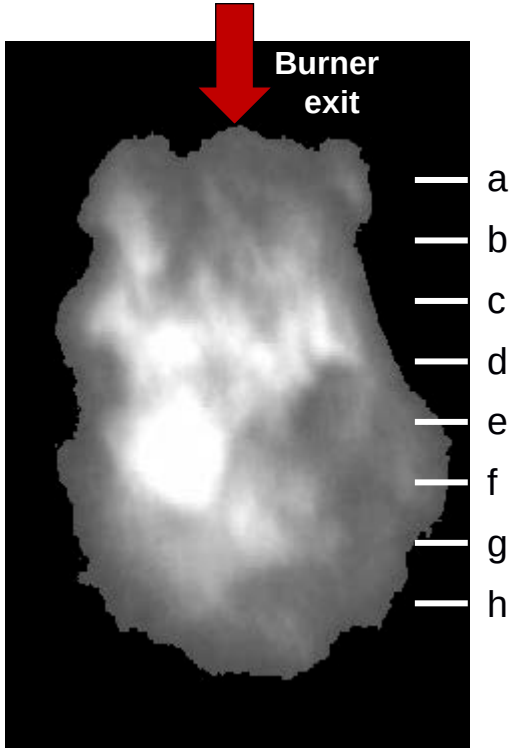
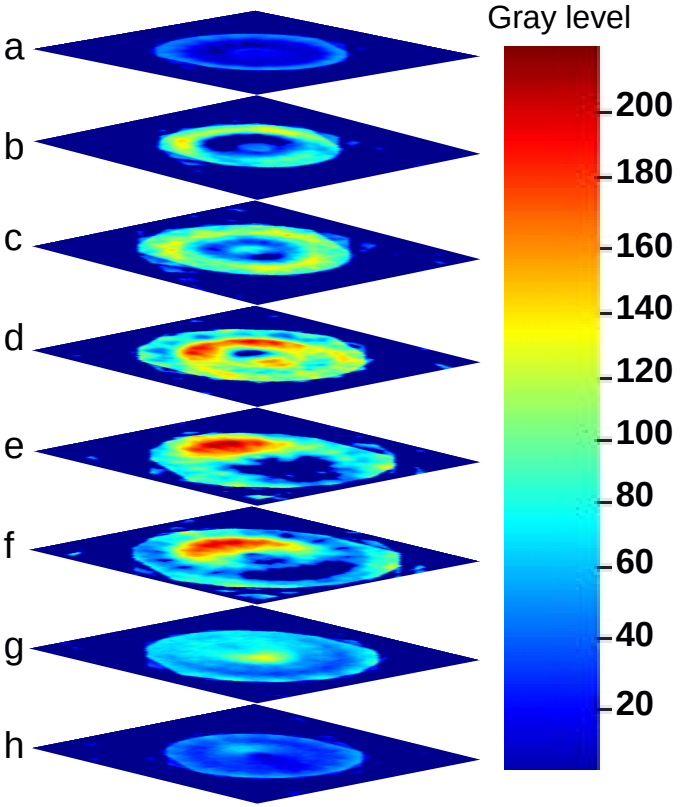
- A new tomographic algorithm that combines the logical filtered back-projection (LFBP) and the simultaneous algebraic reconstruction technique (SART) is used to reconstruct the flame sections.

- Eight image projections assumed here as symmetric.



2D gray-level image captured at load 160kW



Typical example of cross-sectional reconstruction

Summary
Flame Flickering Studies

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- **Digital imaging provides a viable approach to online monitoring and characterization of coal flames**
- **Flame flickering frequencies from digital imaging and Large Eddy Simulations (LES) can be calculated**
- **The work presented demonstrates the potential importance of using measured data for validation of LES turbulence models for coal combustion.**

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Thank you

Questions?

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