Combustion for Low Carbon Power Generation
08/04/2014

Integration of CCS with gas turbines:

1. **THE USE OF CO_2 TO IMPROVE STABILITY AND EMISSIONS OF AN IGCC BURNER.**
2. **METHANE OXYCOMBUSTION IN SWIRL STABILISED A GAS TURBINE BURNER.**

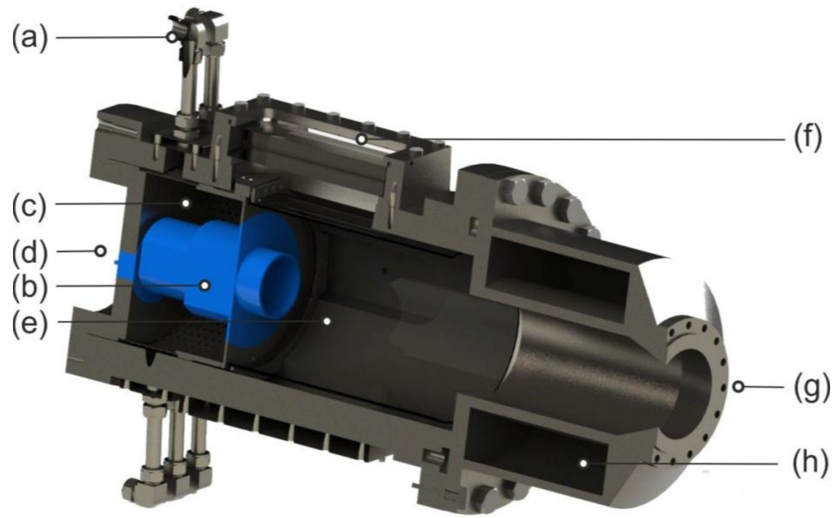
Richard Marsh

Cardiff University – School of Engineering

1. THE USE OF CO_2 TO IMPROVE STABILITY AND EMISSIONS OF AN IGCC BURNER.

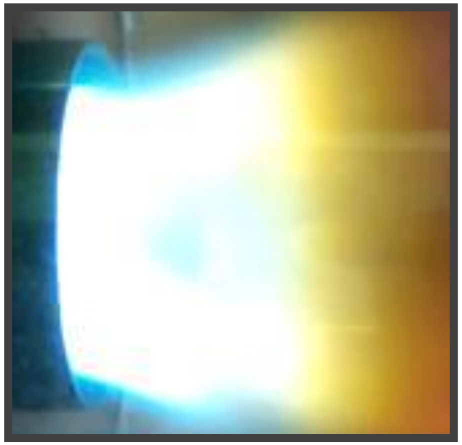
- Fuels with high hydrogen content are resilient to blowoff and prone to flashback, especially in the presence of:
  - High turbulence
  - Elevated pressure
  - Preheat
- Three potential flashback mechanisms are:
  - Boundary layer flame propagation
  - Turbulent flame propagation in the core flow
  - Upstream propagation of coherent structures

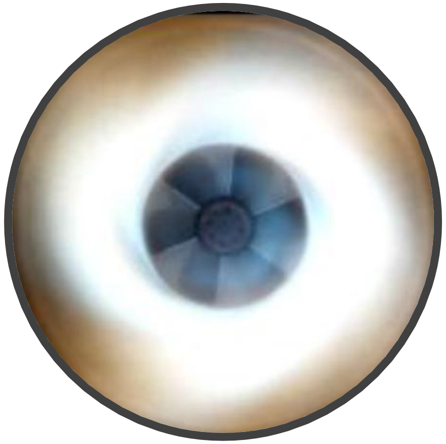
Test Rig



Development Gas Turbine Combustor- Co-swirl design with 110mm exit diameter

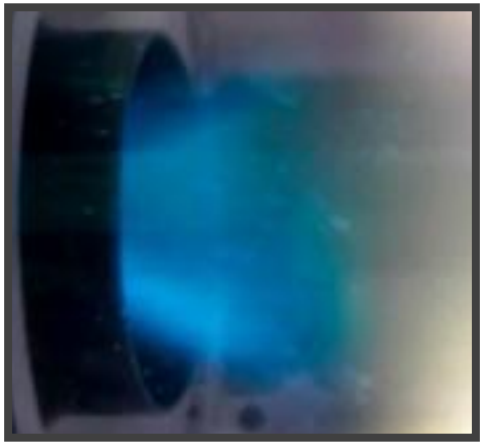
Operated at approximately 500 kW, at atmospheric pressure with 400°C air pre-heat





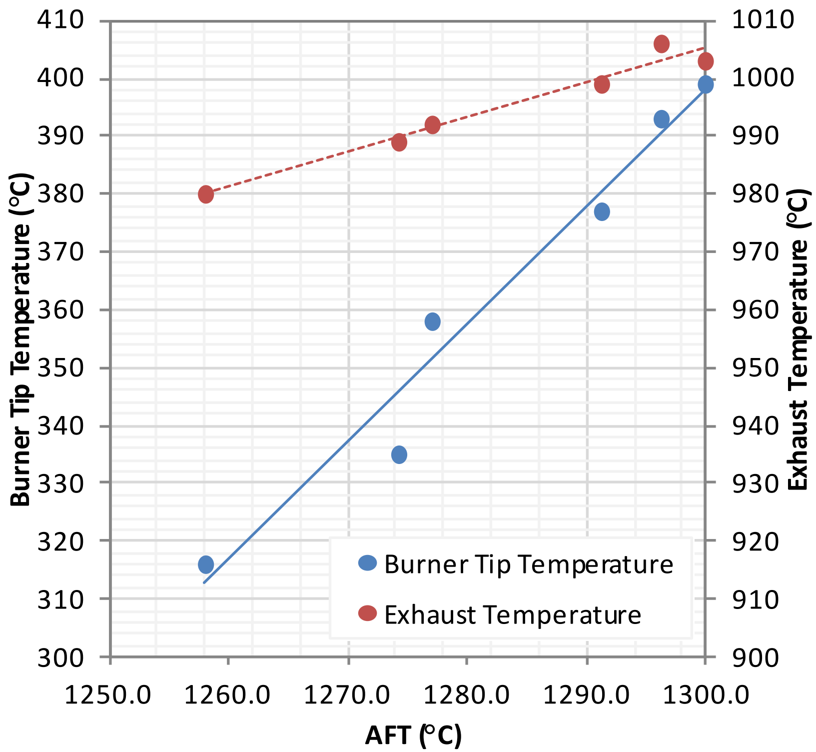
Syngas (vol):
50% Hydrogen
50% Carbon Monoxide

- Reduction in methane pilot
- Flame propagation through boundary layer



Syngas (vol):
85% Hydrogen
15% Nitrogen

- Increase in air flow
- Flame propagation through core flow

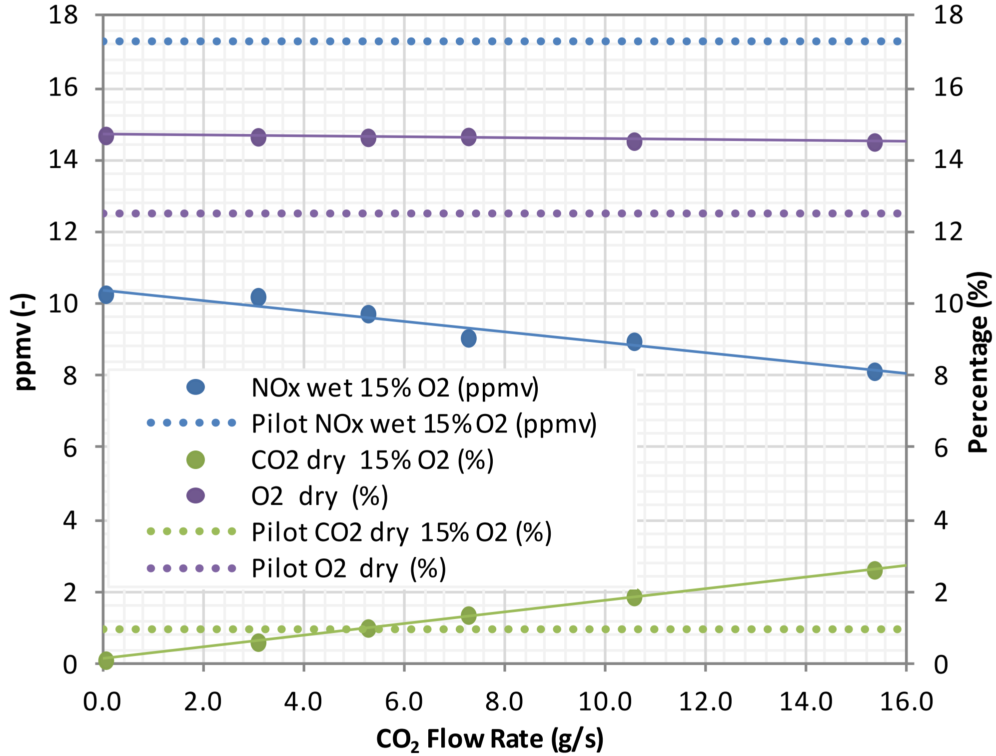


Burner tip temperature decreases 1.67 times greater than AFT

Total 20.8% decrease

Exhaust Temperature decreases 2.01 times less than AFT

Total 2.3% decrease



NO_x decreases by 40.6% with no methane pilot

CO_2 injection causes a 20.9% reduction in NO_x from non-piloted flame

Total 51.0% decrease

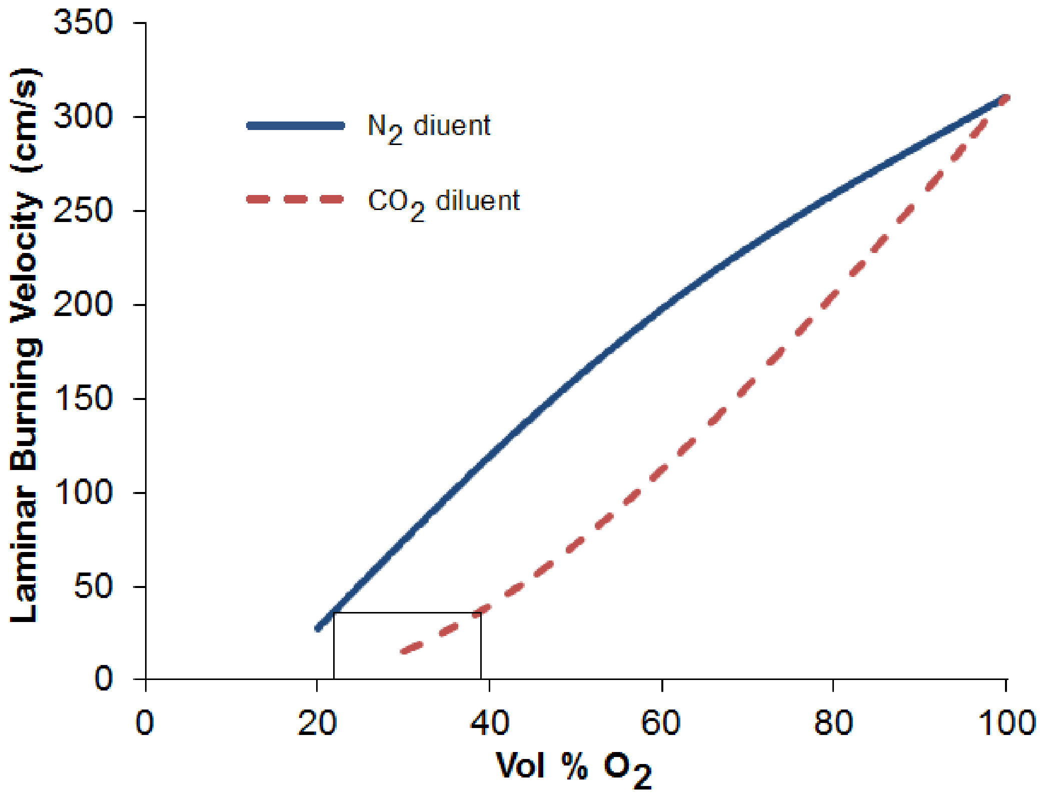
Key Findings

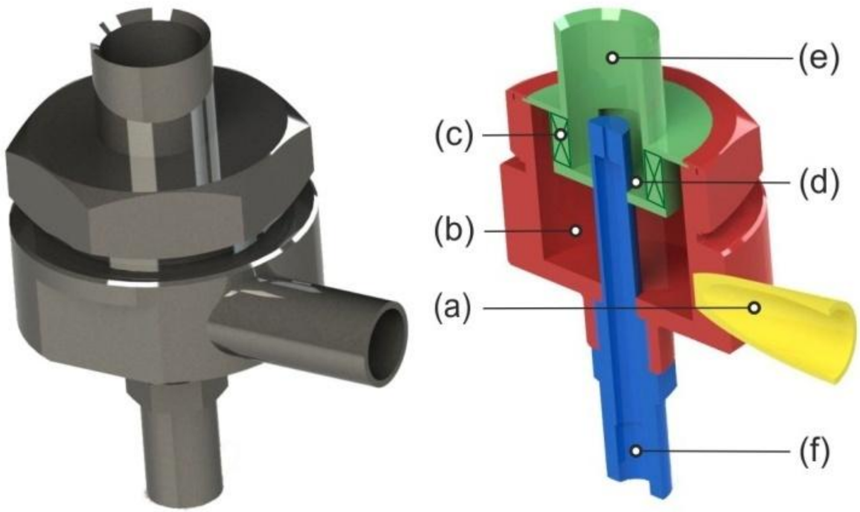
- Lean flashback was observed in a gas turbine combustor due to propagation of coherent structures followed by boundary layer flame propagation or turbulent flame propagation in the core flow
- Diffusive injection of carbon dioxide can prevent structure propagation, whilst reducing burning rates and flame temperature
- Reduction in local flame temperature at point of injection is reduced to a greater extent than global flame temperature
- This reduces NO_x and likelihood of flashback without significantly effecting turbine inlet temperature

2. METHANE OXYCOMBUSTION IN SWIRL STABILISED A GAS TURBINE BURNER.

- The overall design aim would be to develop an oxyfuel GT, using recycled CO_2 as a moderator (rather than N_2 as in air).
- Hence the project objective was to examine the relationship between CO_2 and N_2 diluted swirl flames.
- Given that swirl burners involve a complex interaction between chemical and fluid dynamic timescales, a systematic study of the stability envelope was conducted.

CHEMKIN modelling

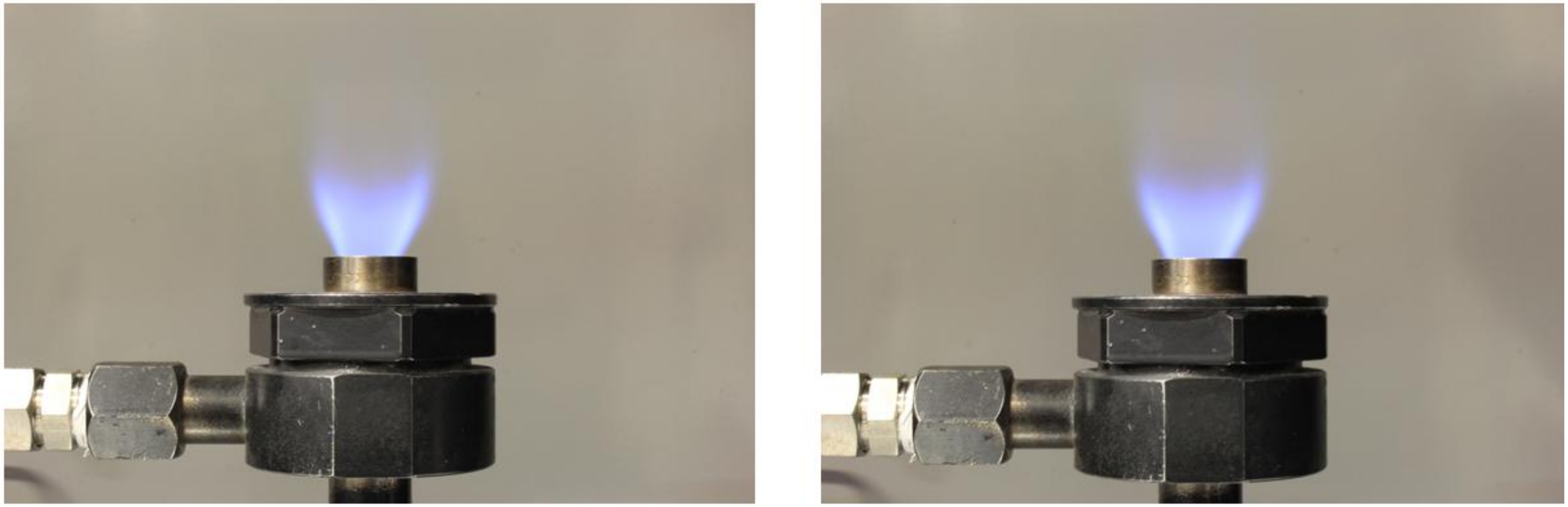




Generic Swirl Burner- Utilises different vane configurations to alter geometric swirl number (28mm exit diameter)

provides $0.8 \leq Sg \leq 1.5$ for thermal output up to 50 kW

Swirl stabilised oxyfuel flames diluted with: (a) N_2 and (b) CO_2 at comparable equivalence ratios.

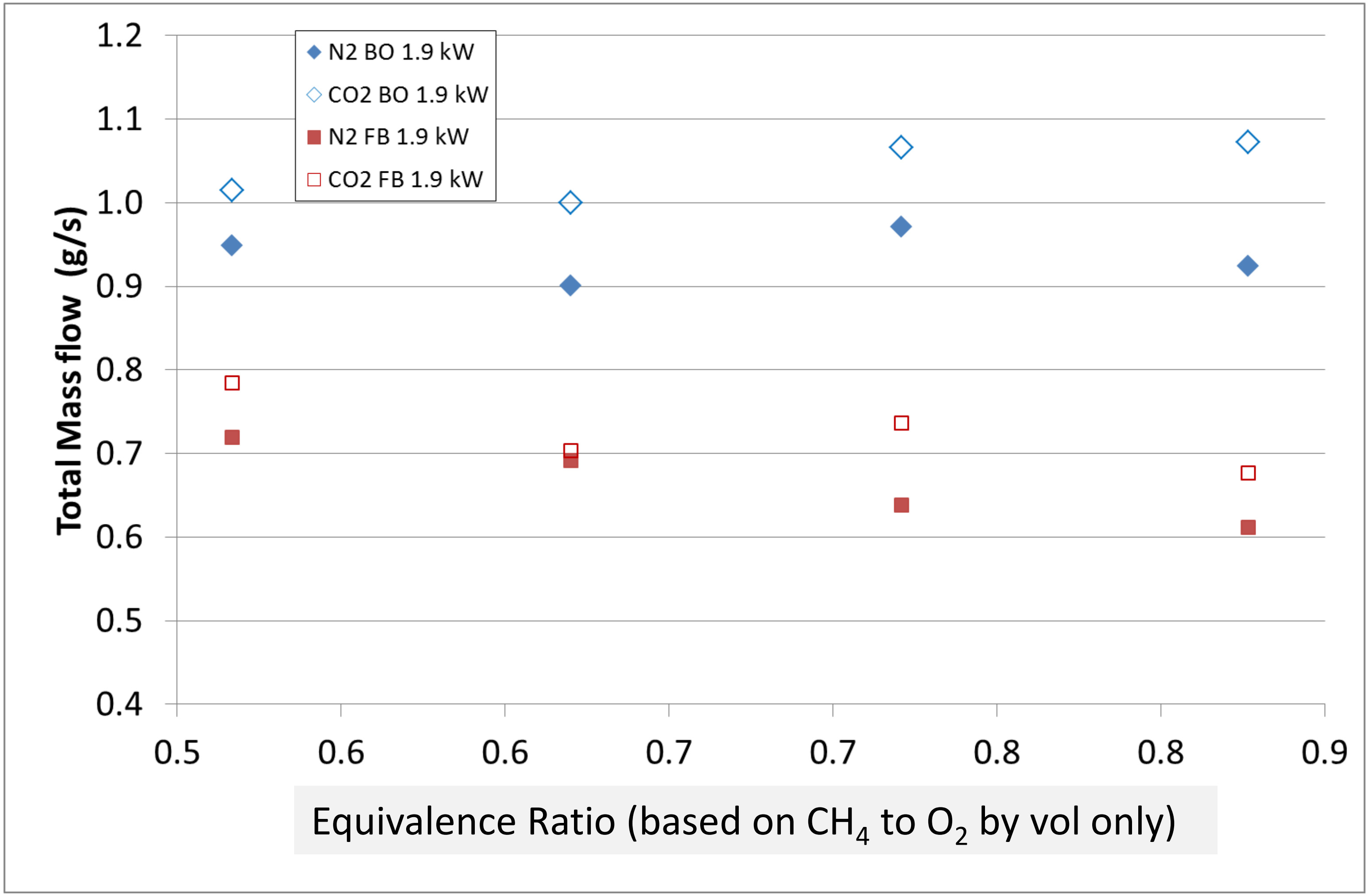


(a) (b)

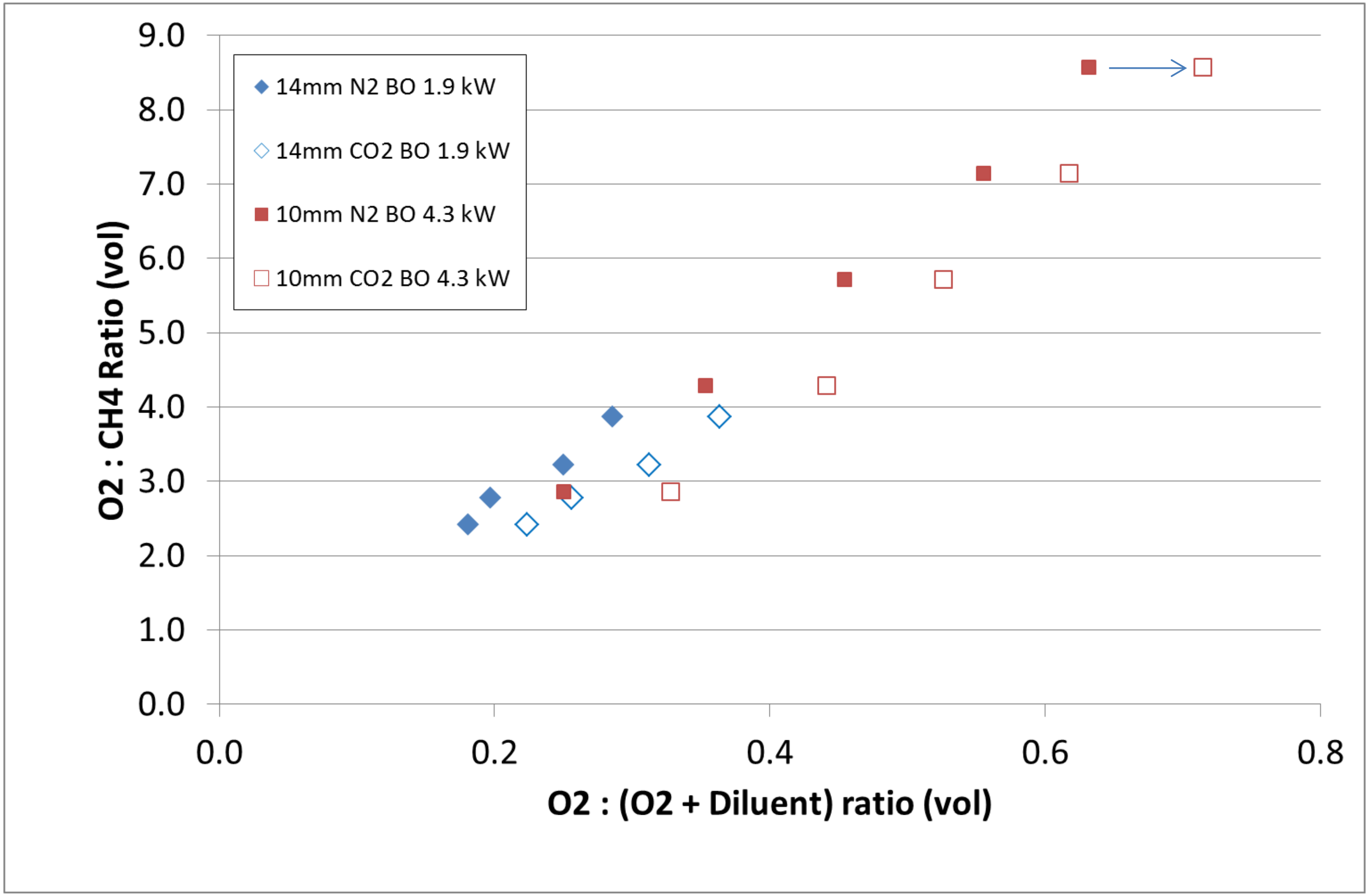
N_2 and CO_2 diluted flames at a thermal power of 4.3 kW and an equivalence ratio of close to 0.5. On visual inspection the flame shapes are similar, but the CO_2 diluted flame appears to be wider which is supported by subsequent PIV analysis.

Flashback video

28mm Diameter burner Flashback and Blowoff limits



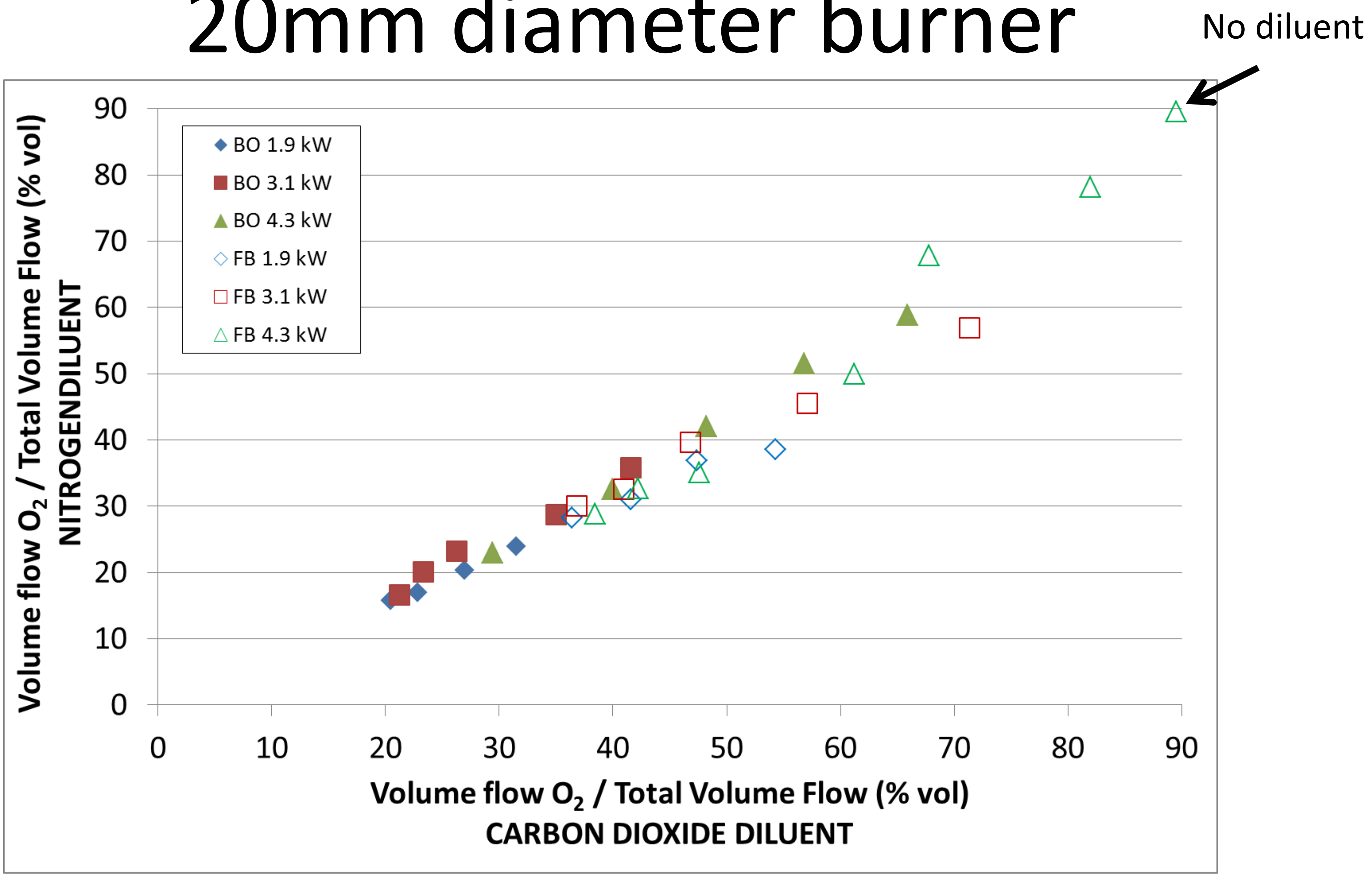
Effect of oxygen concentration at Blowoff



E.R. = 0.5

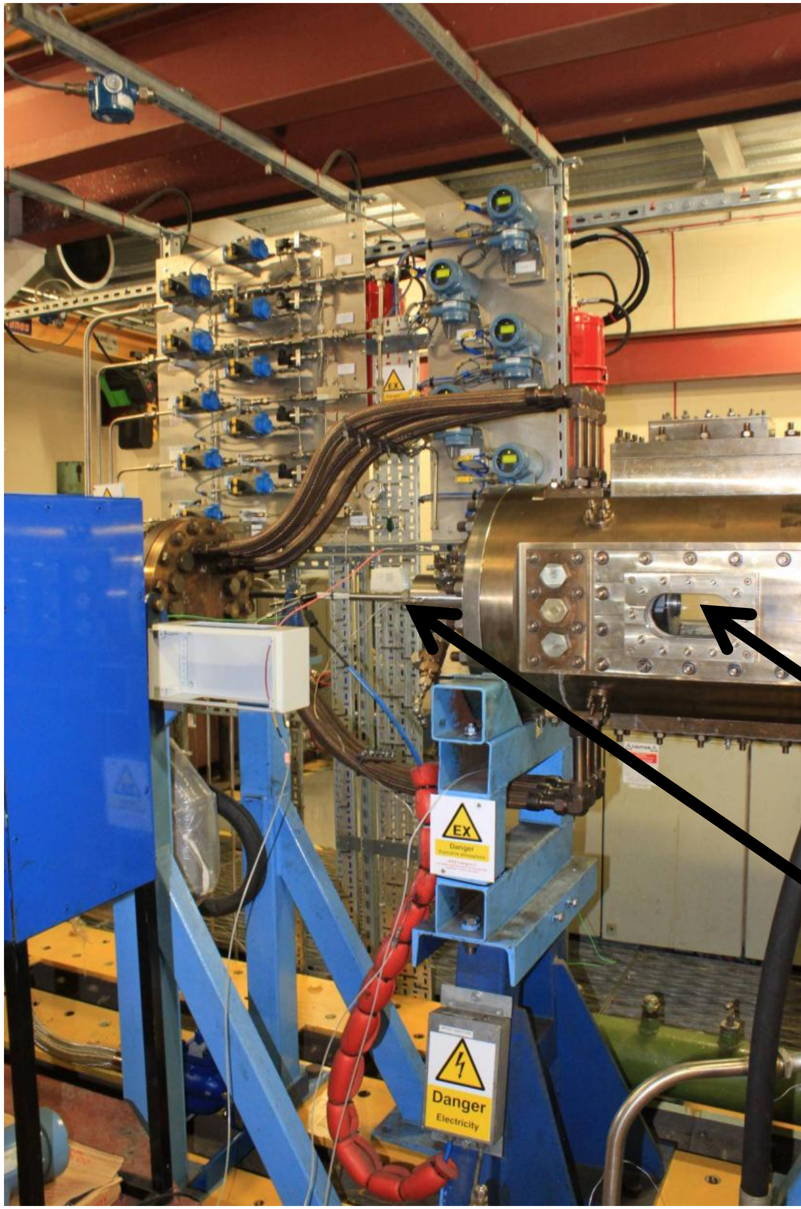
E.R. = 1.0

20mm diameter burner



Key Findings

- Achieving a stoichiometric methane oxyflame wasn't possible with a traditional swirl burner (not without the redesigned burner looking like a rocket motor anyway!)
- It is possible to operate without a diluent, but the momentum required to sustain the recirculation zone is only possible at very dilute (oxygen) conditions.
- Replacing N_2 with CO_2 as a combustion diluent appears to widen the stability range of the swirl flame.
- Initial results are encouraging and subsequent tests will evaluate the effects of pressure.



Next Steps:

Larger scale burner installation into High Pressure Optical Combustor (up to 500 kW)

Fuel and oxy lines

Burner head in optical chamber

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