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.

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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
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\textsubscript{x} decreases by 40.6% with no methane pilot

CO\textsubscript{2} injection causes a 20.9% reduction in NO\textsubscript{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\textsubscript{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\textsubscript{2} as a moderator (rather than N\textsubscript{2} as in air).
- Hence the project objective was to examine the relationship between CO\textsubscript{2} and N\textsubscript{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

![Graph showing laminar burning velocity (cm/s) vs. volume percent of oxygen (Vol % O₂) for N₂ diluent and CO₂ diluent.](image-url)
Generic Swirl Burner- Utilises different vane configurations to alter geometric swirl number (28mm exit diameter)

provides $0.8 \leq S_g \leq 1.5$ for thermal output up to 50 kW
Swirl stabilised oxyfuel flames diluted with: (a) \( N_2 \) and (b) \( CO_2 \) at comparable equivalence ratios.

\( N_2 \) 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

Equivalence Ratio (based on CH$_4$ to O$_2$ by vol only)
Effect of oxygen concentration at Blowoff

- E.R. = 0.5
- E.R. = 1.0

Diagram showing the effect of oxygen concentration at Blowoff with different conditions:
- 14mm N2 BO 1.9 kW
- 14mm CO2 BO 1.9 kW
- 10mm N2 BO 4.3 kW
- 10mm CO2 BO 4.3 kW

O2 : CH4 Ratio (vol)
O2 : (O2 + Diluent) ratio (vol)
20mm diameter burner

No diluent
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\textsubscript{2} with CO\textsubscript{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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2. Methane oxycombustion in swirl stabilised a gas turbine burner.

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