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PHASE 1 PROJECT: METHANE OXYCOMBUSTION IN A PRESSURISED SWIRL STABILISED A GAS TURBINE BURNER.

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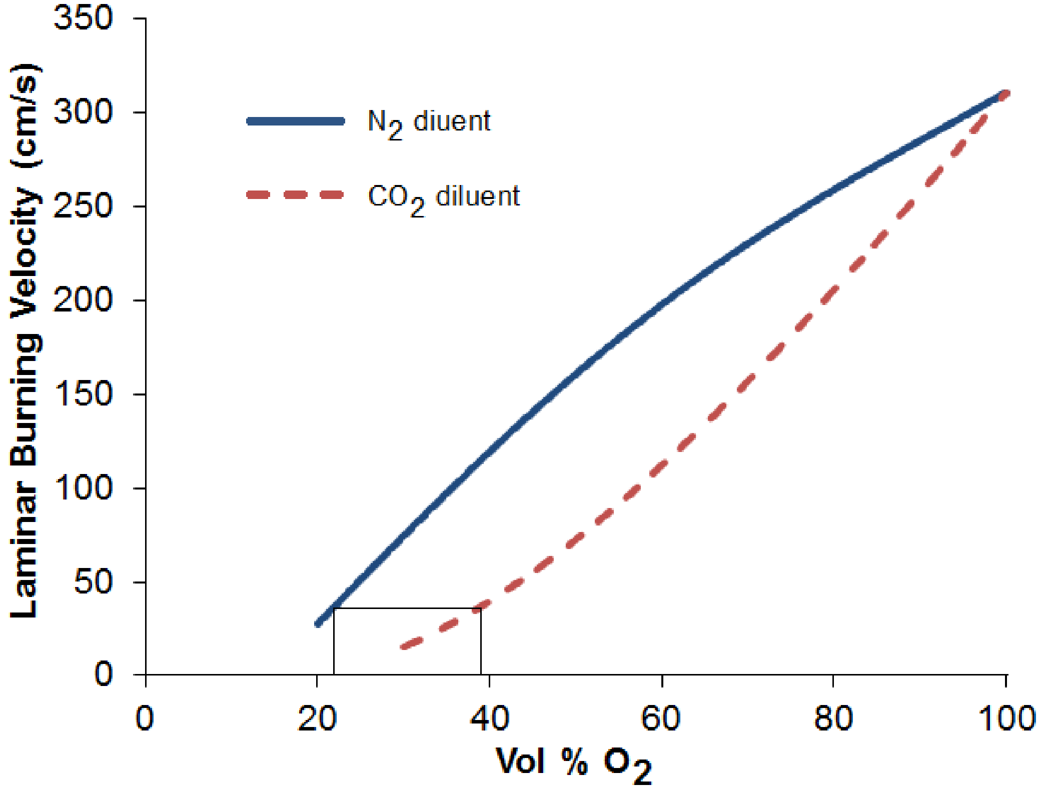
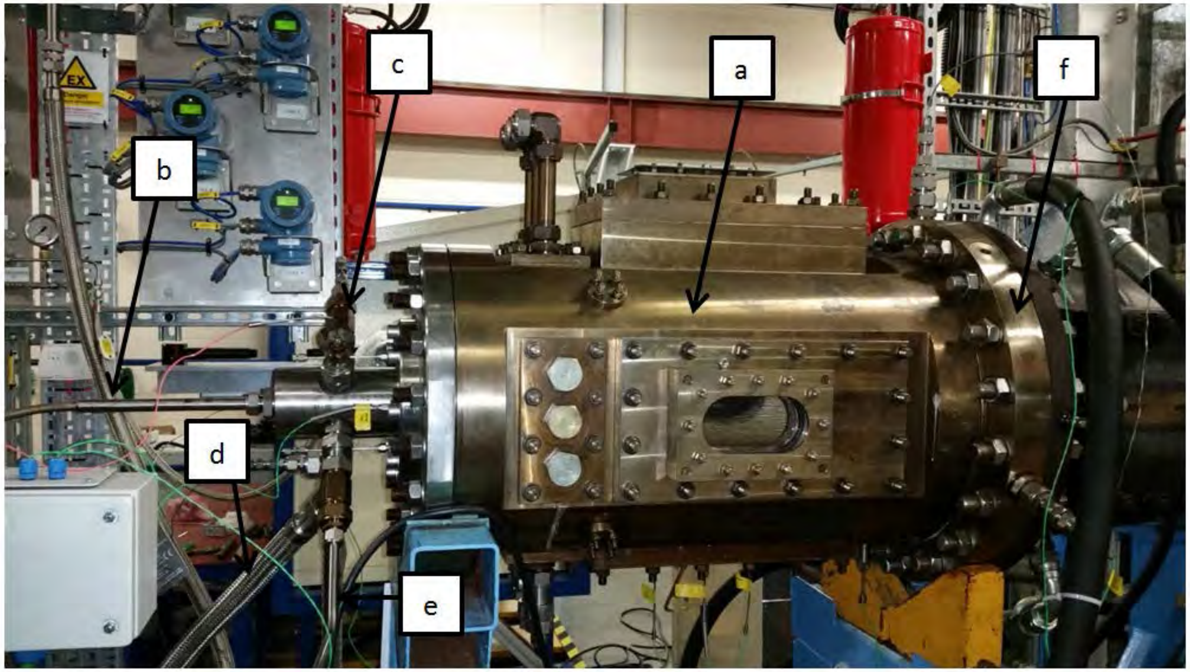
METHANE OXYCOMBUSTION IN SWIRL STABILISED A GAS TURBINE BURNER.

- A series of combustion experiments at high pressure yielded very interesting and useful data in demonstrating how oxygen and carbon dioxide affect the flame in a gas turbine swirl burner.
- The large swirl burner has been operated at a number of power and pressure settings, up to 50kW and 3 bar pressure. Ran at oxygen concentrations of almost 60% in some cases.
- Added CO_2 to the flame to study the operational effect of simulated exhaust gas recirculation.
- Made gas analysis and chemiluminescence measurements to quantify what is happening in the flame in terms of heat release, location and products of combustion.

Reminder of oxy / diluent effects



HPOC with burner and oxygen line

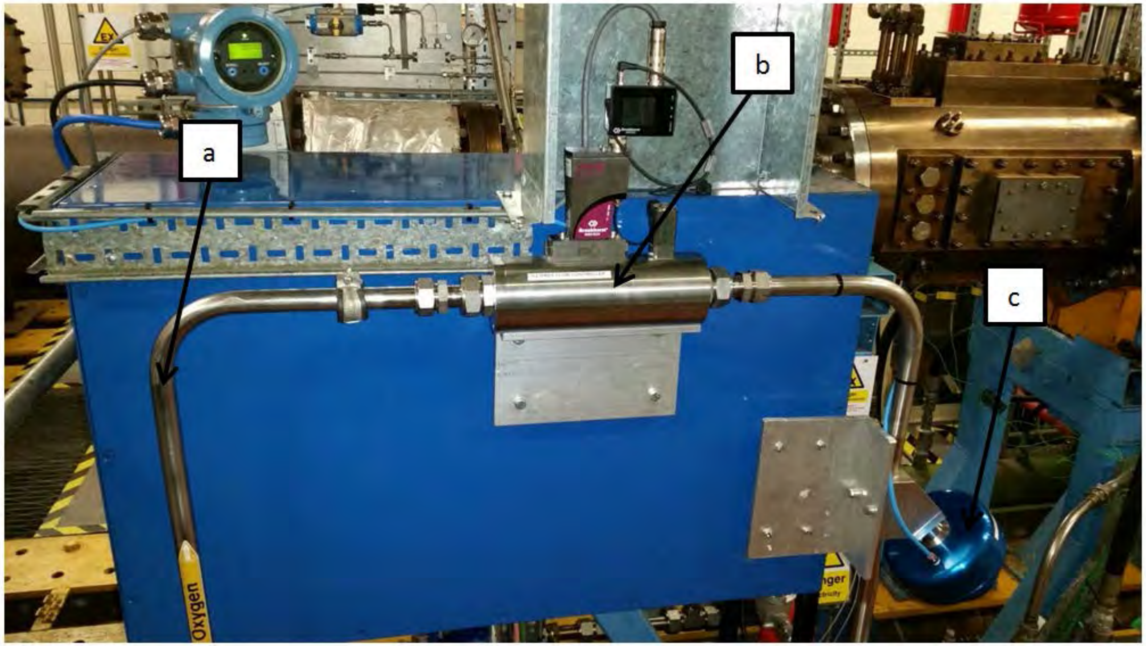


(a) pressure casing (b) spark ignitor (c) fuel line

(b) (d) air line, (e) oxygen line, (f) exhaust section.

Burner located in quartz chamber

Oxygen control system

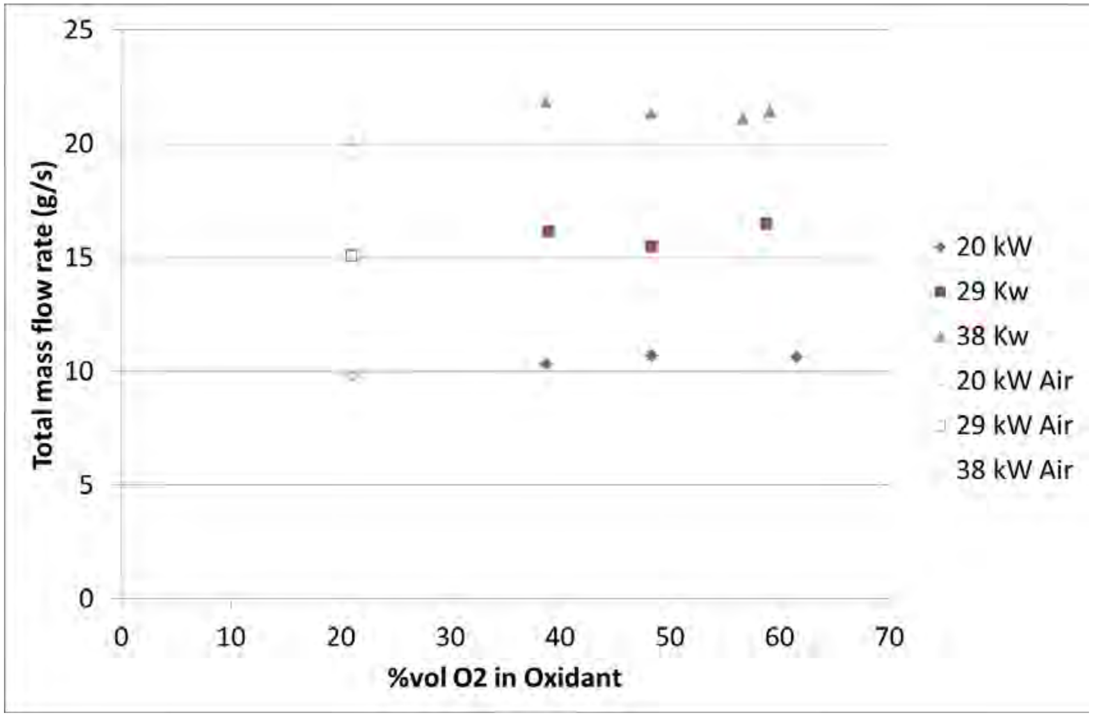


(a) inflow from reservoir
(b) mass flow controller and display
(c) pneumatic cut-off valve.

Aims

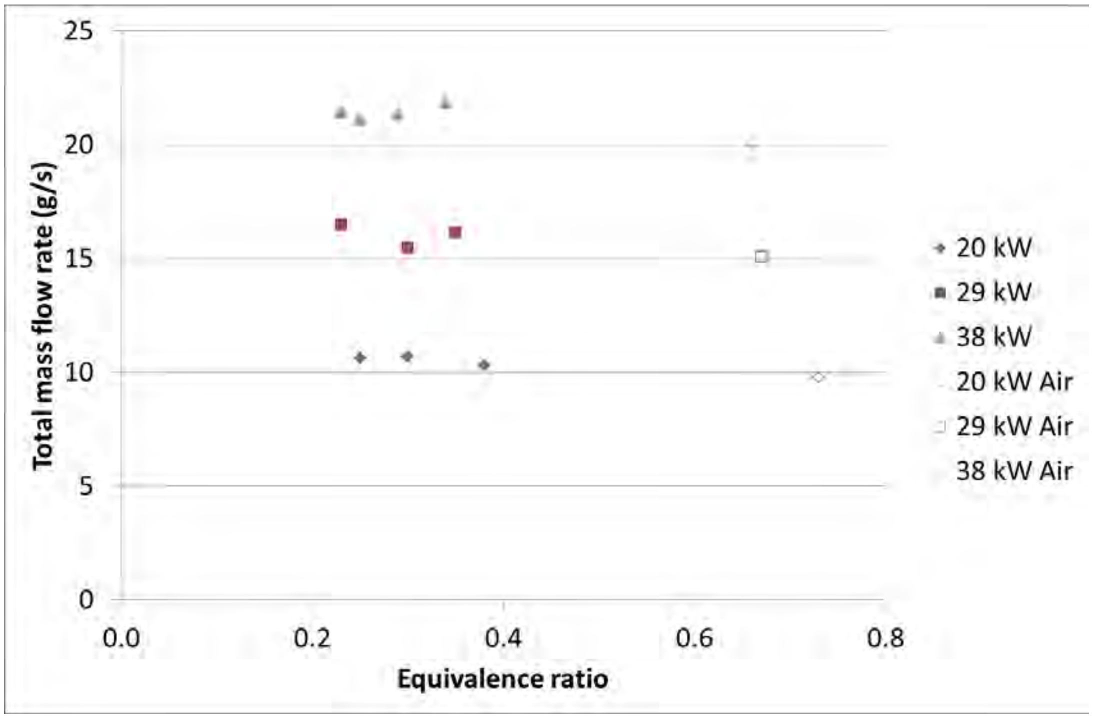
- Testing at small scale atmospheric conditions allowed for the quantification of the stable operating points in a generic burner at variable oxygen and diluent concentrations.
- The larger scale pressurised tests were focussed on showing a smaller number of operating points, to demonstrate the changes in flame shape and emissions.
- Studying O_2 and CO_2 concentrations

Results – Effect of O_2 concentration



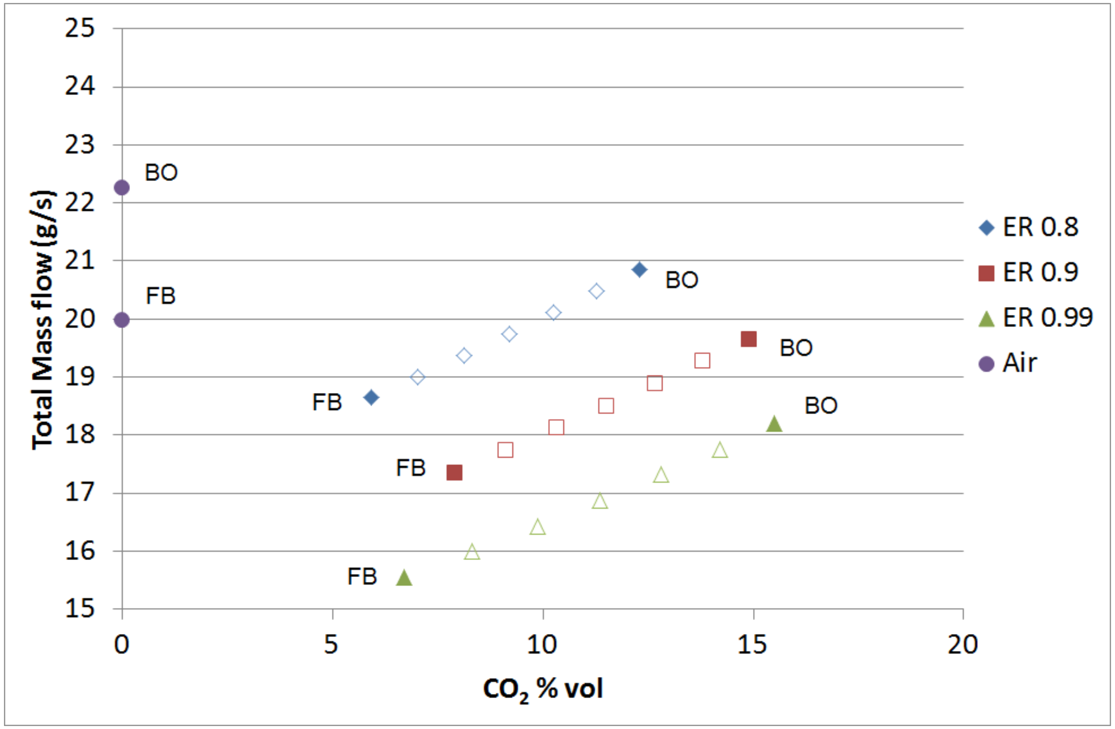
Rich operability limit expressed as total mass flow versus oxygen in oxidant at the 3 power levels examined, plus the equivalent air conditions.

Results – effect of equivalence ratio



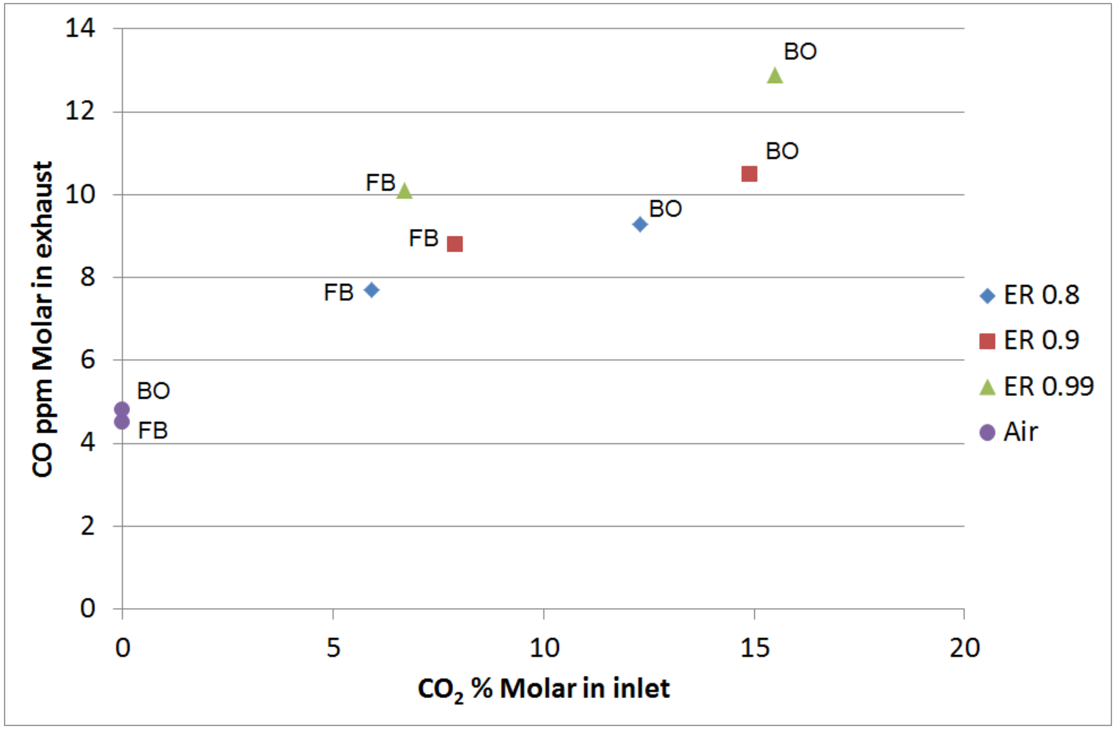
Rich operability limit expressed as total mass flow versus equivalence ratio at the 3 power levels examined showing the **oxygen enhanced conditions**, plus the equivalent air conditions.

Results – CO_2 diluted tests at 38 kW



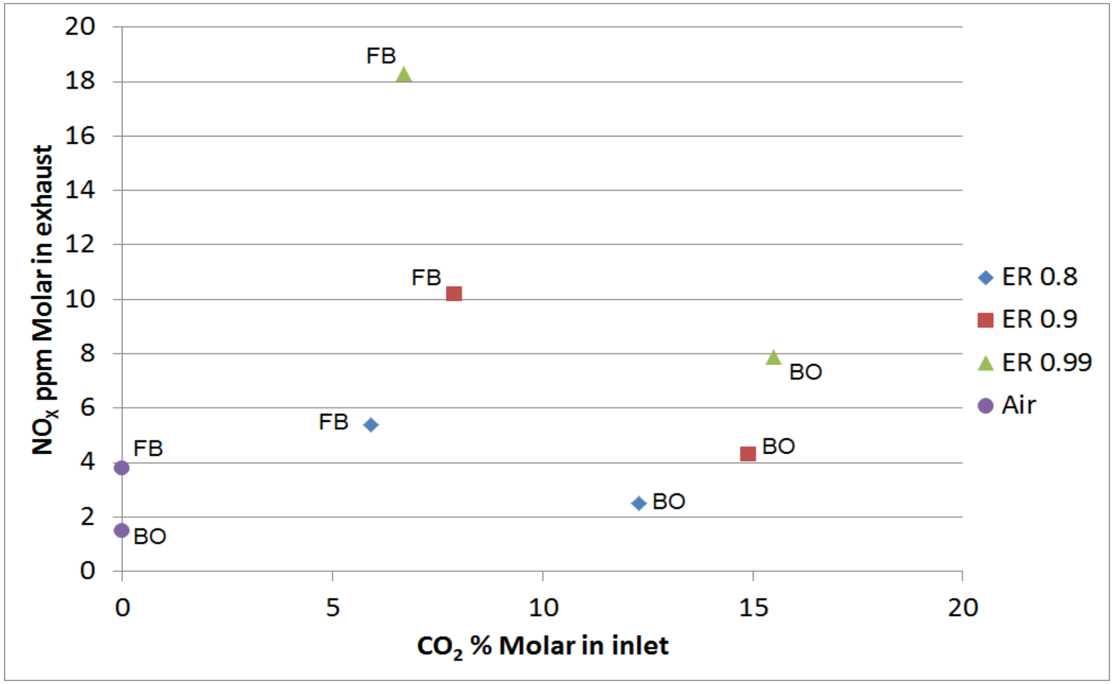
Operation points and limits expressed as total mass flow versus inlet CO_2 concentration at the 3 equivalence ratios, plus the equivalent air conditions.

Results – CO production during CO_2 diluted operation at 38 kW



Carbon monoxide exhaust concentrations (dry) versus inlet CO_2 concentration at the 3 equivalence ratios, plus equivalent air conditions.

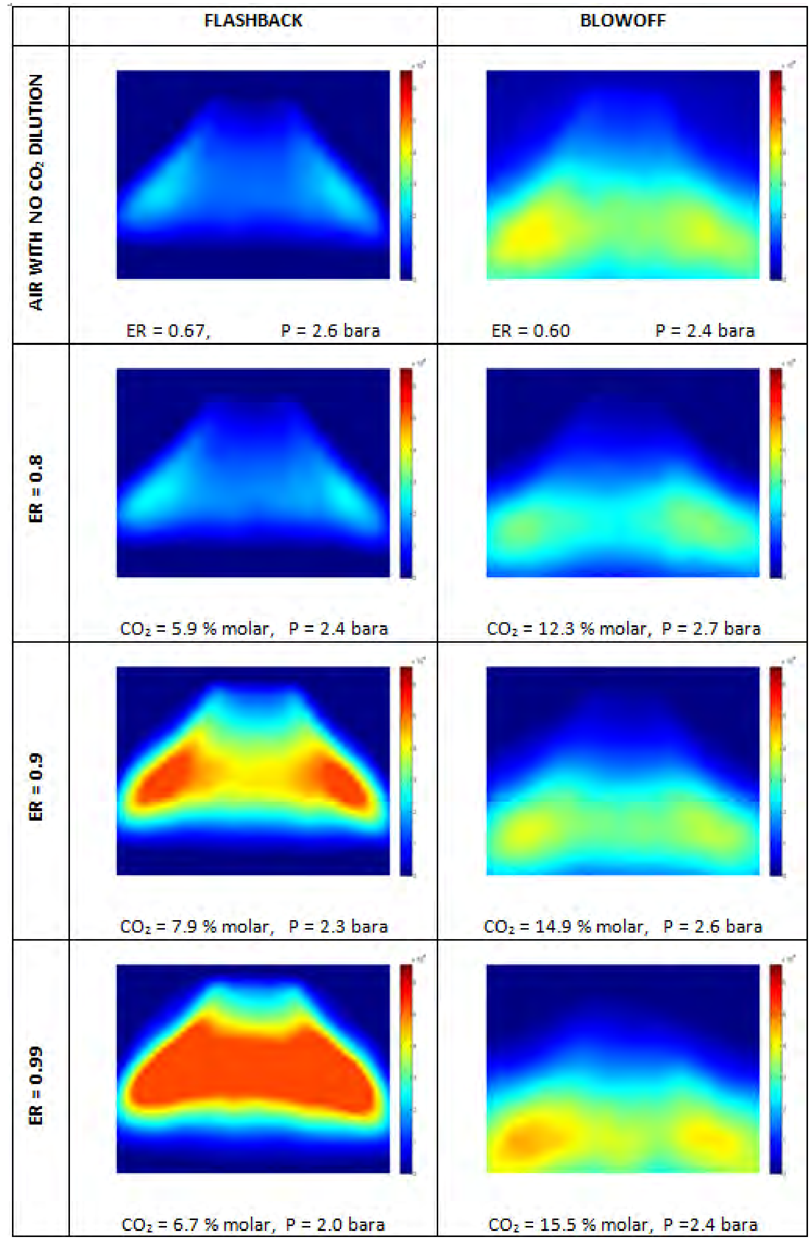
Results - NO_X production during CO_2 diluted operation at 38 kW



NO_X exhaust concentrations (dry) versus inlet CO_2 concentration at the 3 equivalence ratios, plus the equivalent air conditions.

Single false colour chemiluminescence images of 37.5 kW flame at 3 equivalence ratios with varying CO_2 levels to provide flashback and blowoff conditions.

When the CO_2 concentration is increased, with reducing air towards the stoichiometric condition, it can be seen that the OH* emission becomes more concentrated over the flame zone, which is consistent with the observed increase in NO_X shown in previous slide



- The presence of high concentrations of oxygen does not significantly affect the operational envelope of the burner in terms of mass flow rate. This is explained by the dilution effect of the excess O_2, effectively replacing the role of N_2 in the flame as a diluent and combustion moderator. Since O_2 and N_2 have very similar physical properties, the flame appears unchanged.
- It has been possible to operate the swirl burner with high O_2 concentrations at elevated pressure. This is not favourable in terms of the operation of a carbon capture plant, thus EGR to enhance CO_2 concentrations is an important consideration.
- Testing to simulate potential operation of a pressurised swirl burner with EGR has been successful.
- The presence of CO_2 in the reactants causes a reduction in the burning velocity of the mixture and acts as a greater heat sink than atmospheric N_2. Subsequently stable operation at elevated pressure was achieved at lower mass flows than air operation.

- It was possible to run the burner at stoichiometric levels of air and methane when CO_2 was used as a diluent. This meant that the dry exhaust gas concentration comprised mostly of CO_2 and N_2 only.
- The highest molar CO_2 inlet concentration achieved during this test was 15.5%, which provided a (dry) molar exhaust gas CO_2 concentration of 29%, with the remainder N_2.
- There is strong evidence to suggest that (diluent) CO_2 will dissociate in the flame, leading to the production of CO in the exhaust, although in this campaign only comparatively small levels were observed.
- There is some evidence to suggest that high levels of CO_2 diluent will more readily transport heat to the root of the flame and this could be the reason for slightly elevated NO_X production.

Impact

- The data shows that despite very different physical properties between the diluents, under the conditions tested, stability is still largely governed by velocity distributions in the central recirculation zone.
- Thus for CO_2 moderated flames, existing swirl burner design rules can be modified.