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Characteristics of non-premixed oxygen enriched flames from a swirl burner with a radial fuel injection

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Context

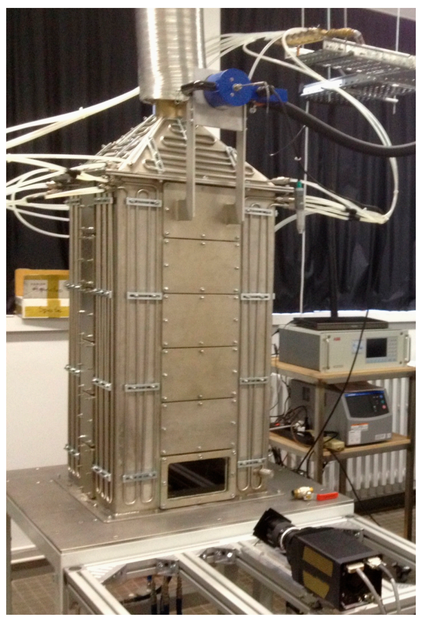
- ✓ The study is motivated by **CO_2 capture applications** further to the increase of CO_2 concentration by the O_2 enrichement.
- ✓ **Support :** French National Research Agency (**ANR**), **CO_2-EnergiCapt** project.

Objective

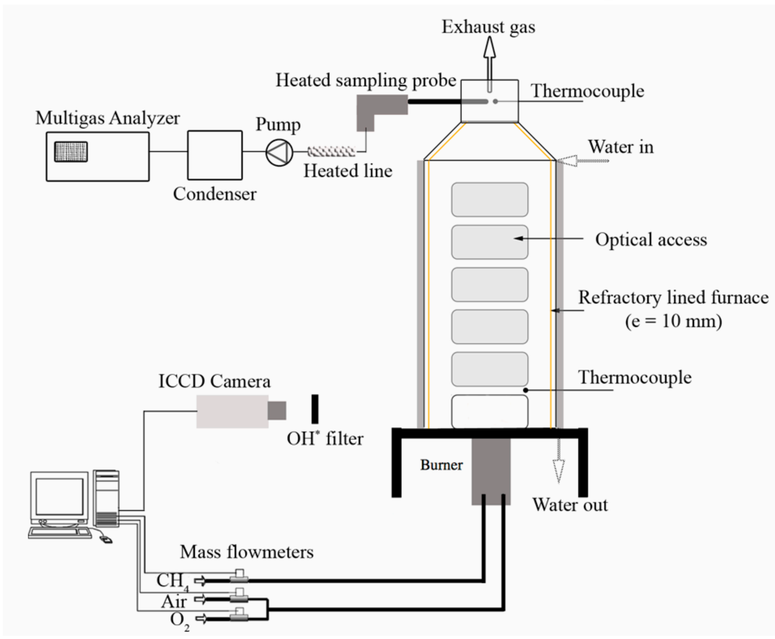
- ✓ Optimization **of industrial boilers** by the combination of combustion air enriched with oxygen and reducing CO_2 by a membrane capture.
- ✓ Study the characteristics of turbulent CH_4-air flames with O_2 enrichment : **Flame stability**, **Pollutant** emissions (CO, NOx, CO_2), **Velocity** fields.

Experimental setup

Combustion chamber

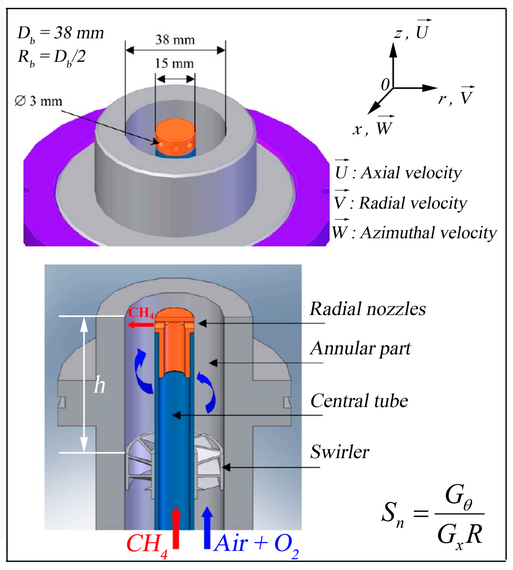


Combustion chamber : 25 kW, dimensions 0.5x0.5x1 m³



Schematic view of the combustion chamber with the OH Chemiluminescence system and the gas analyzer

Burner

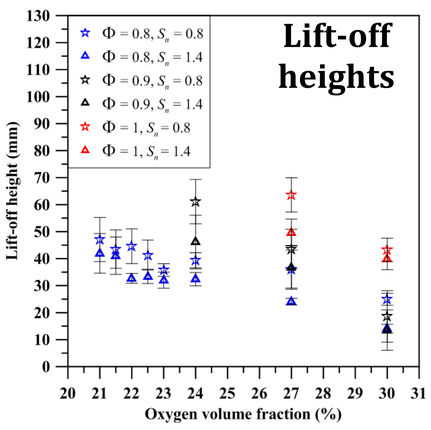


Burner : two concentric tubes with a **swirler** in the annular part

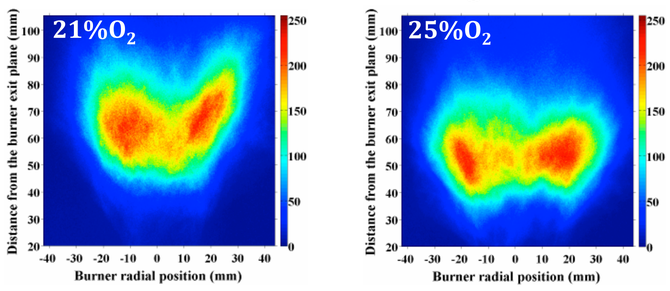
Details of measurement techniques

- ✓ **Multi-gas analyzer** : NO_x, CO, CO_2, O_2, SO_2
- ✓ **OH chemiluminescence**: ICCD camera, a 105 mm UV lens, a 306 nm filter.
- ✓ **Stereo-PIV system** : a double-pulsed Nd:YAG laser (25 mJ/pulse) at 532 nm, 10 Hz. 2 TSI Powerview Plus 4MP, 2048 x 2048 px², Scheimpflug adaptaters. Seeding : Al_2O_3 0.5-1 µm.
- ✓ **V3V system of TSI:** V3V-9000-TS probe, 3 cameras 4MP-HS, 2 Evergreen 200 mJ PIV lasers.

Flame behavior



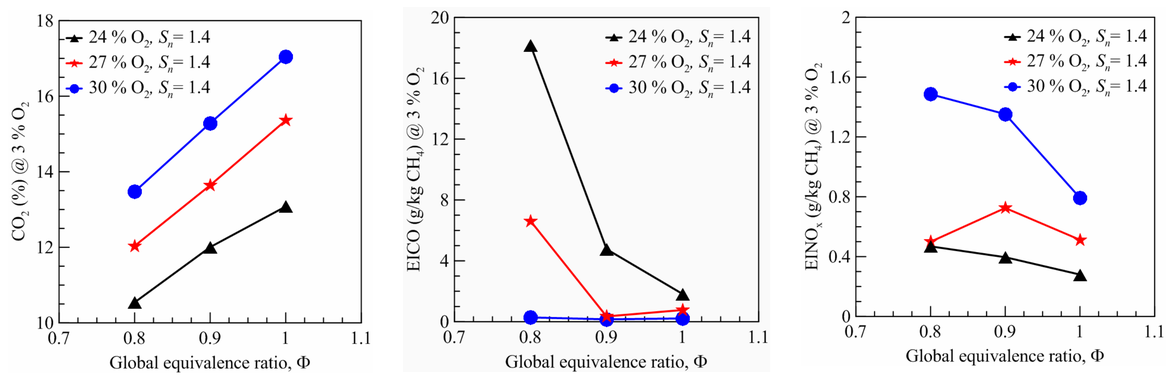
Instantaneous OH* images



➲ **Flame stability** is **enhanced** with oxygen addition even for **low oxygen enrichment** rates.

- ✓ Lift-off heights ⇲ with O_2 addition.
- ✓ Fluctuations of lift-off heights ⇲ with O_2 addition.
- ✓ Lift-off heights ⇲ with swirl number (S_n).
- ✓ Lift-off heights ⇲ when equivalence ratio (Φ) ⇲.

Pollutant emissions



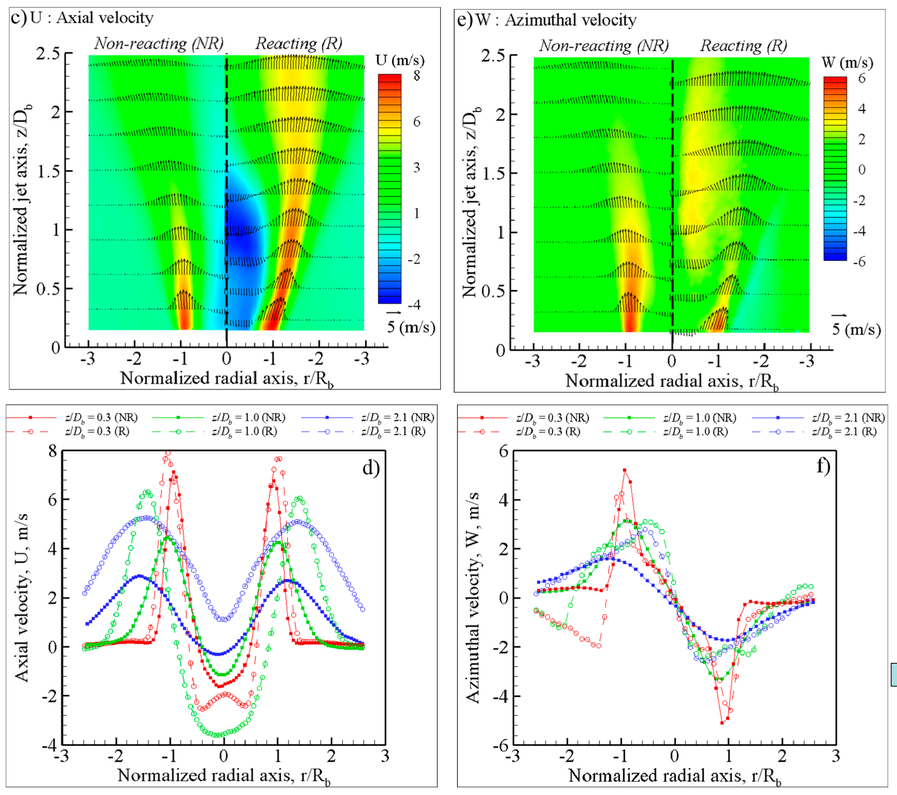
- ✓ CO_2 concentrations increase with O_2 addition and global equivalence ratio (a).
- ✓ CO emissions largely decrease with O_2 addition and global equivalence ratio (b).
- ✓ NO_x emissions increase with oxygen addition, and decrease with equivalence ratio (c).

Flow analysis by stereo-PIV and V3V* system

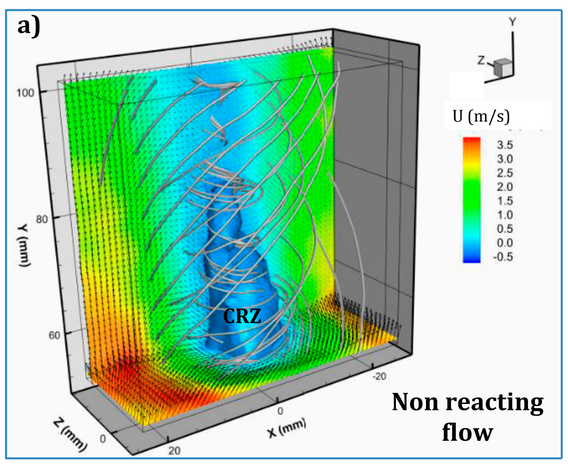
Stereo-PIV results of non reacting and reacting flow

Case : Swirl number S_n=0.8, equivalence ration Φ=0.8

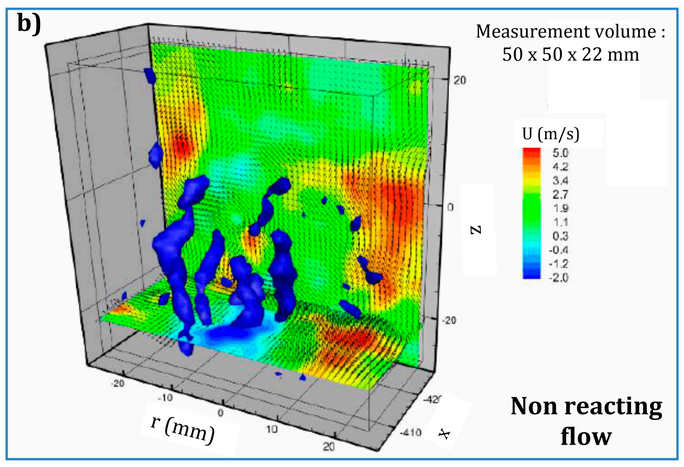
U : axial velocity (m/s) **W : tangential velocity (m/s)**



First results of V3V measurements _ Collaboration with TSI® on 2014



Swirling flow demonstrated by the streamlines



Plot of Q-criteria showing counter-rotating vortices extending from the center of the burner

- ✓ The presence of flame increases the central recirculation zone (CRZ) (c, d) compared to non reactive cases
- ✓ Strong axial expansion is induced by combustion (c, d)
- ✓ In the reacting the azimuthal velocity field tends to show that the intensity of the swirling motion is lower than the motion originally imposed to the flow (e, f)
- ✓ Increasing S_n ⇨Increasing reverse flow velocities

*Volumetric 3-Component Velocimetry System