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Diluted Combustion of Low Calorific, Alternative Fuels on a 30 kW furnace

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Diluted Combustion

Why

- High combustion efficiencies
- **Low NOx & CO** emissions
- **No flame front** formation

How

- **High recirculation rates**
- Flue gases temperature higher than **self-ignition** fuel one

Framework

Increasing request from industry for new combustion techniques which can be safely used to burn **biogas**, **gasified waste** or **by-product gases**.

Diluted combustion can be a very interesting solution. **No flame front** is present, thus fuel with **highly variable calorific values** can be burned with no or after simple injection system modifications.

Research at UMONS

Main Objectives

- Creation of an **experimental database** for a furnace working in diluted combustion with different **alternative fuels**. Successfully tested

	N2	CO2	CH4	H2	CO	LHV (kJ/Nm³)
CH4			100%			35806
COG	2%	1,5%	28,5%	62%	6%	17652
B50	28%	12%	14,25%	32,5%	13,25%	10282
Biogas		40%	60%			21484
Syngas	45,5%	12%	1,5%	20%	21%	5346

- Understanding of **main phenomena** and the influence of **changes in main parameters setting** for the different fuels. Main investigated effects:
  - *Air preheating temperature*
  - *Immersion of the water cooled tubes*
  - *Diameter of the fuel injectors*
  - *Reduced fuel power*

Test campaign 2014

Biogas
CH4
Syngas*

- **30kW** Fuel power **(*15kW)**
- Excess Air **15%**
- Air preheating **800°C**
- Fuel injectors **Ø 2,8 & 4,5* mm**
- Window: **Opened*** (& **Closed** for **Biogas**)
- Immersion **10* – 20 – 30 cm**

SPW Service public de Wallonie

iea Energy Technology Network

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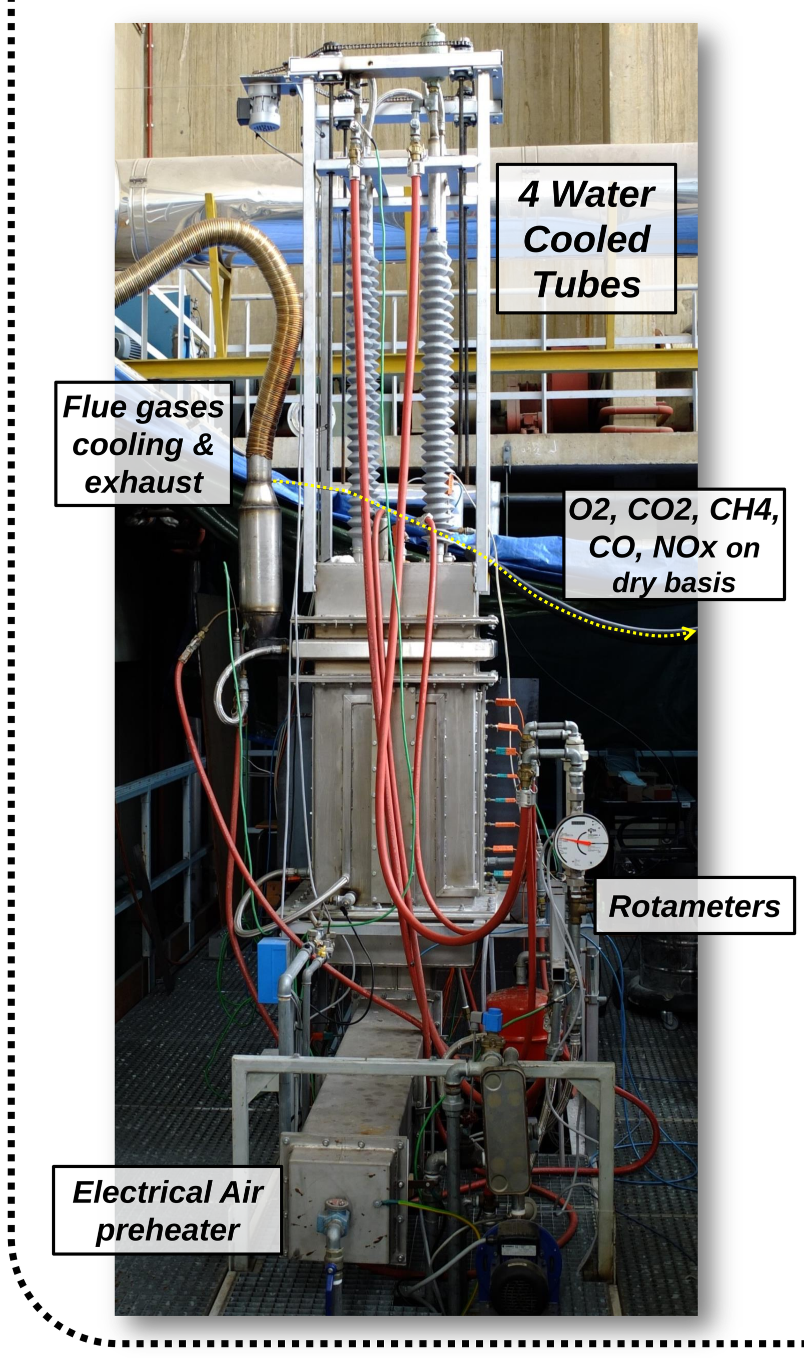
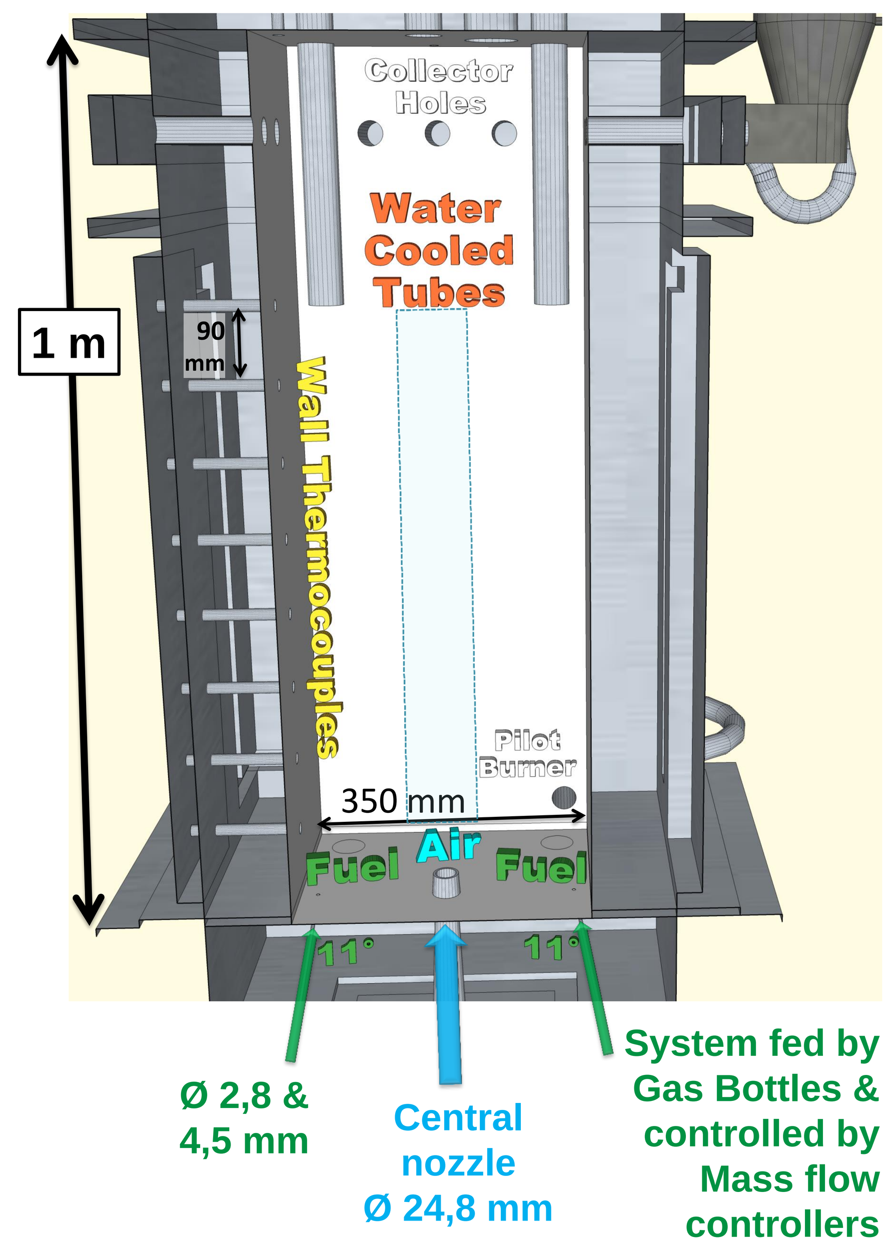
30 kW Test facility

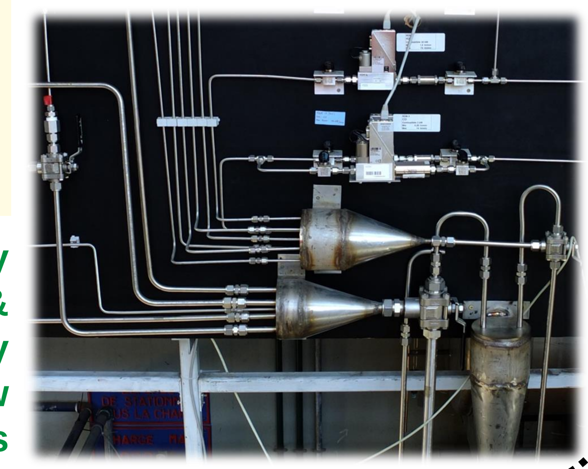
Front main view



Section (Rear view)



Rear wall: Optical Access



Test Campaign 2014: Results with Opened Window

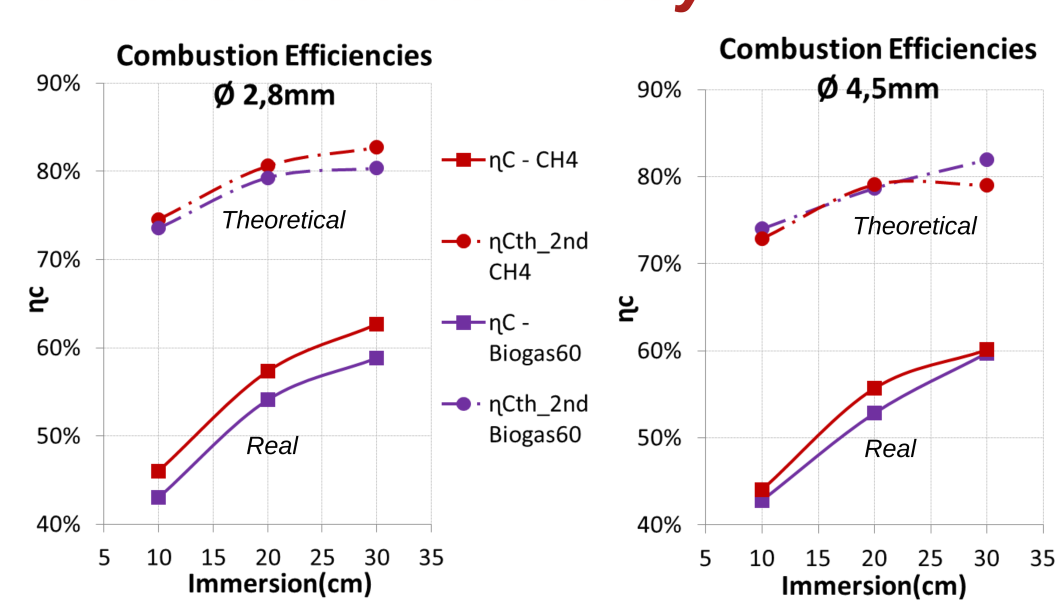
Heat balance

$$P_{comb} + S_{hFuel} + P_{Air} = P_{Flue} + P_{Load} + P_{Wall} + \Delta P$$

P_{comb} → 30 kW; S_{hFuel} → negligible; ΔP → P_{Losses}

	Biogas60			CH4			
Imm (cm)	**10**	**20**	**30**	**10**	**20**	**30**	
Pflue (kW)	20,3	18,7	17,6	19,6	18,0	17,1	Fuel Injectors Ø 2,8 mm
Pload (kW)	9,1	12,9	14,9	10,1	14,0	16,3	
Pload+Pwall(kW)	12,9	16,2	17,6	13,8	17,2	18,8	
ΔP (kW)	6,7	5,0	4,7	6,5	4,7	4,1	
Pflue (kW)	20,5	18,9	17,8	19,7	18,1	16,8	Fuel Injectors Ø 4,5 mm
Pload (kW)	9,4	13,0	15,5	9,9	13,8	16,0	
Pload+Pwall(kW)	12,8	15,8	17,9	13,2	16,7	18,0	
ΔP (kW)	6,5	5,1	4,2	7,0	5,1	5,1	

Combustion efficiency



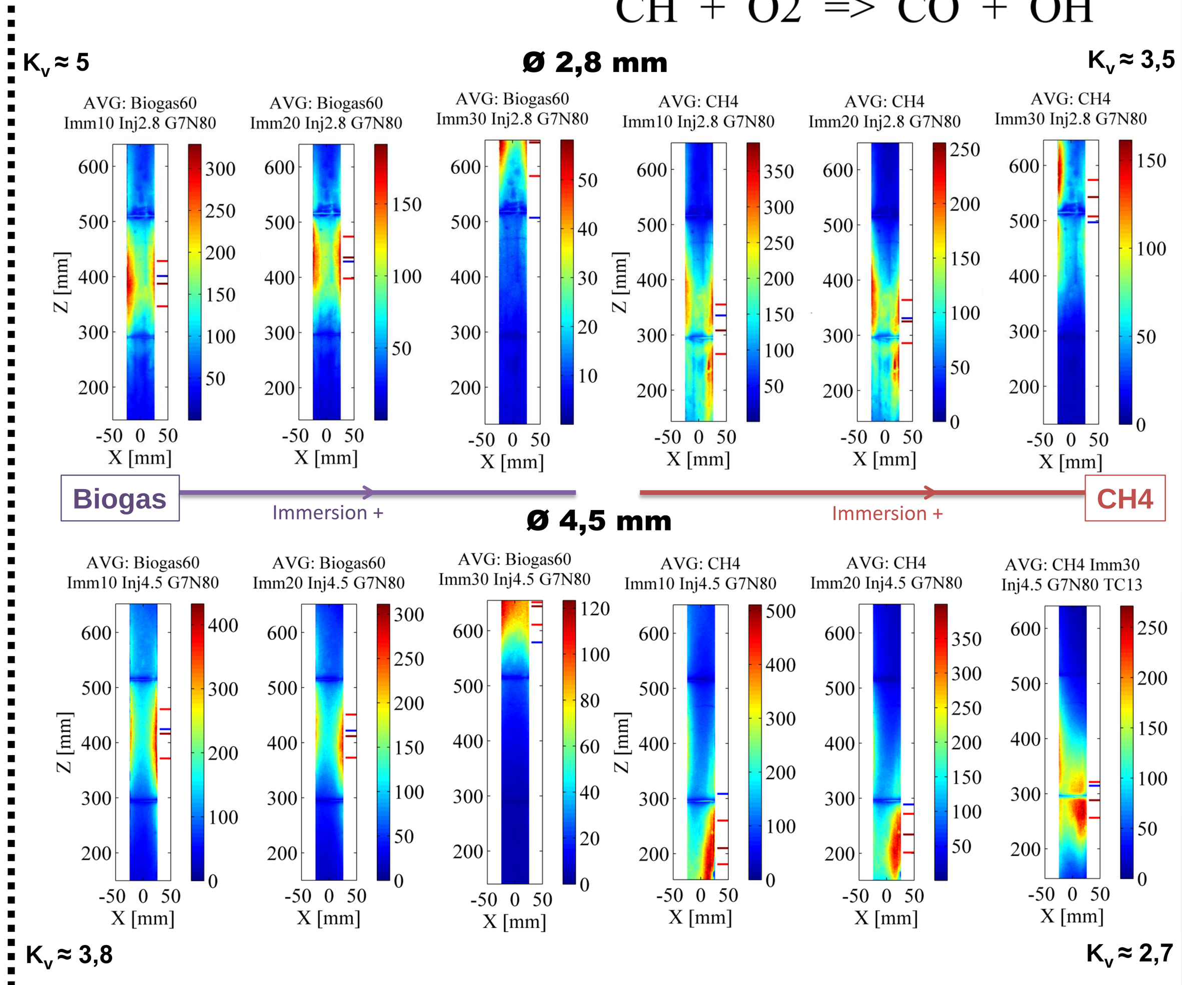
$$\eta_{C_{th}} = \frac{P_{Load} + P_{wall} + P_{Load2}}{P_{comb}}$$

$$\eta_C = \frac{P_{Load} + P_{wall}}{P_{comb}}$$

From P_{flue}, considering the useful power still available after the Air preheating (Used **ε-NTU** method)

Images: OH

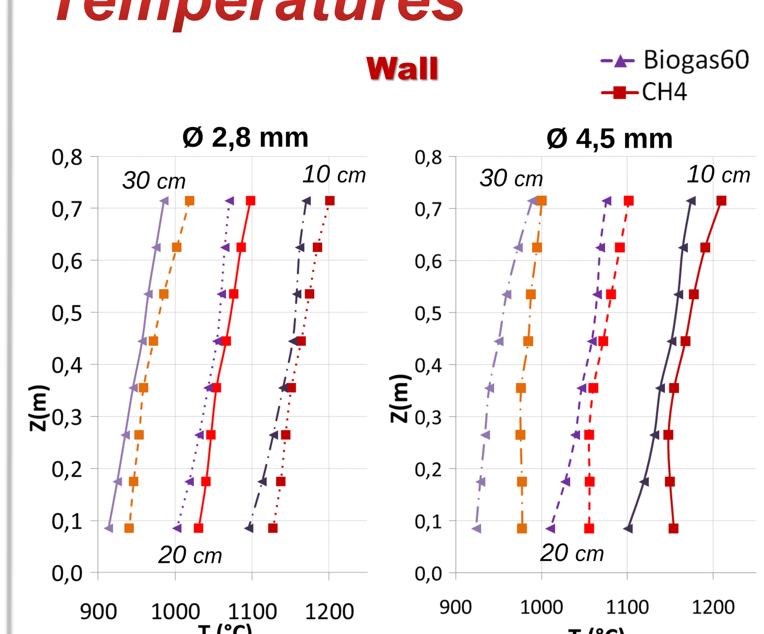
Mainly formed by the reaction CH + O2 => CO + OH



- Extraction of OH profiles
- Comparison to Wall Temp.
- Calculation of speeds from experimental data

	Biogas60	CH4	
Imm (cm)	**10-20-30**	**10-20-30**	
Vair (m/s)	75	75	
Vfuel (m/s)	119	72	Ø 2,8 mm
Vfuel (m/s)	47	28	Ø 4,5 mm

Temperatures

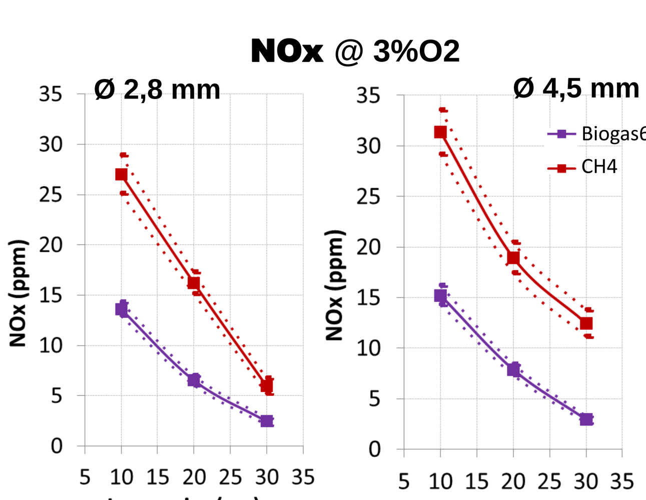


Flue Gases & Recirculation zone

		Biogas60			
		10cm	20cm	30cm	
Ø 2,8	Tflue(°C)	**1226**	**1141**	**1083**	
	Trec (°C)	*1137*	*1040*	*949*	
Ø 4,5	Tflue(°C)	**1237**	**1153**	**1094**	
	Trec (°C)	*1140*	*1046*	*950*	
		CH4			
Ø 2,8	Tflue(°C)	**1272**	**1183**	**1128**	
	Trec (°C)	*1162*	*1062*	*972*	
Ø 4,5	Tflue(°C)	**1282**	**1188**	**1113**	
	Trec (°C)	*1174*	*1075*	*963*	

Emissions

- Flue gases sample taken at the **exhaust**
- **O2, CO2, CH4, CO, NOx** measured on **dry basis**
- Detected **CO** levels always **lower than 100 ppm**



Main conclusions

- **Similar behavior** between Biogas and CH4
- **No strong differences** in terms of efficiencies
- **Reduced wall temperatures & NOx levels for Biogas** (cooling effect of CO2 higher content)
- Higher losses when main reaction zone is placed at the bottom of the chamber
- **Biogas more sensitive** to the increase of the Load immersion, so to the decrease of flue gases temperature.
- Effects of **decreasing fuel injectors diameter**:
  - main reaction zones are more **stable** and do not show asymmetries;
  - the reaction zones are **more extended** along the chamber height due to the high momentum rate of fuel jets.