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Hydrodynamic study of a circulating fluidized bed used for biomass gasification between 20 °c and 900 °c

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Biomass gasification in a Circulating Fluidized Bed: Hydrodynamic study between 20 °C and 950 °C

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Université de Toulouse

http://lgc.cnrs.fr

GAYA PROJECT OBJECTIVES

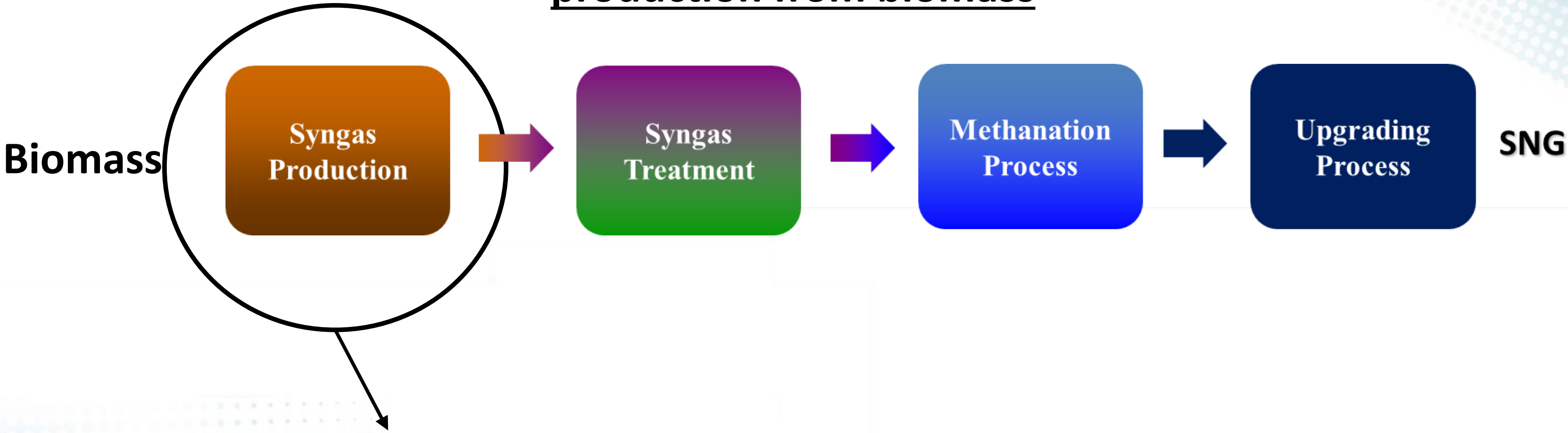
Building of an industrial process for the Synthetic Natural Gas (SNG) production from biomass

Biomass → Syngas Production → Syngas Treatment → Methanation Process → Upgrading Process → SNG

ADEME

GAYA PROJECT OBJECTIVES

Building of an industrial process for the Synthetic Natural Gas (SNG) production from biomass



LGC Objective : Understanding of the **hydrodynamic, thermal and reactive phenomena** occuring in the syngas production pilot plant

Technology : CFB ✓

Employed Technology

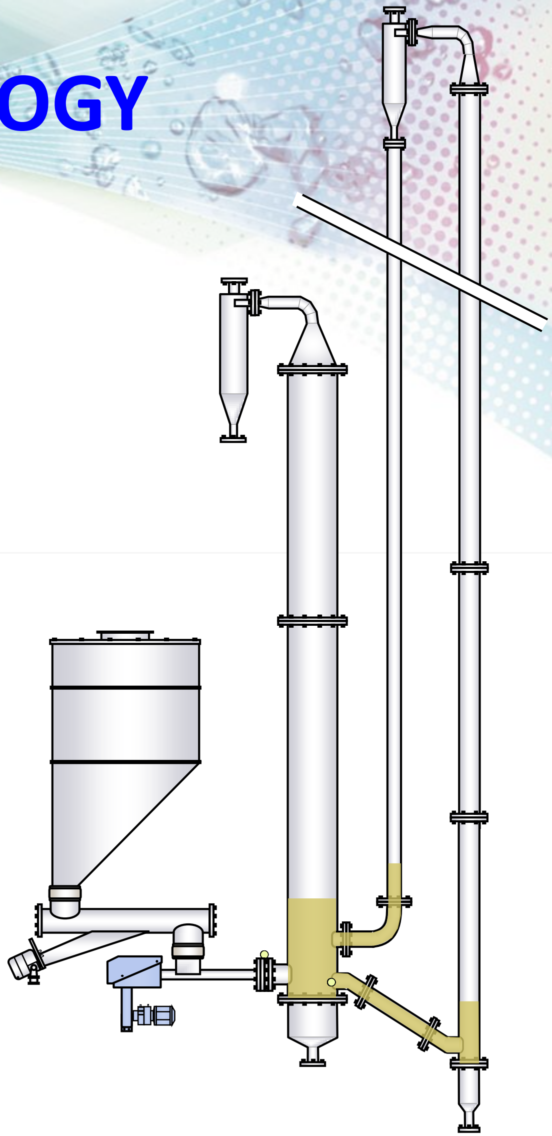
Circulating Fluidized Bed :

Heat Transfer Medium
Olivine

Gasifier (T 800-850 °C)
Globally endothermical biomass conversion
Energy Consumption
Dense Fluidized Bed - Steam

Combustor (T 900-950 °C)
Solid residue from biomass conversion combustion :
Exothermical Reaction
Energy Production
Transported Bed - Air

Heat Transfer Medium
Olivine



EXPERIMENTAL SETUP

- Circulating fluidized bed designed and built-up at the LGC Toulouse

Biomass Feeding

Gasifier / Combustor : Reactive zones

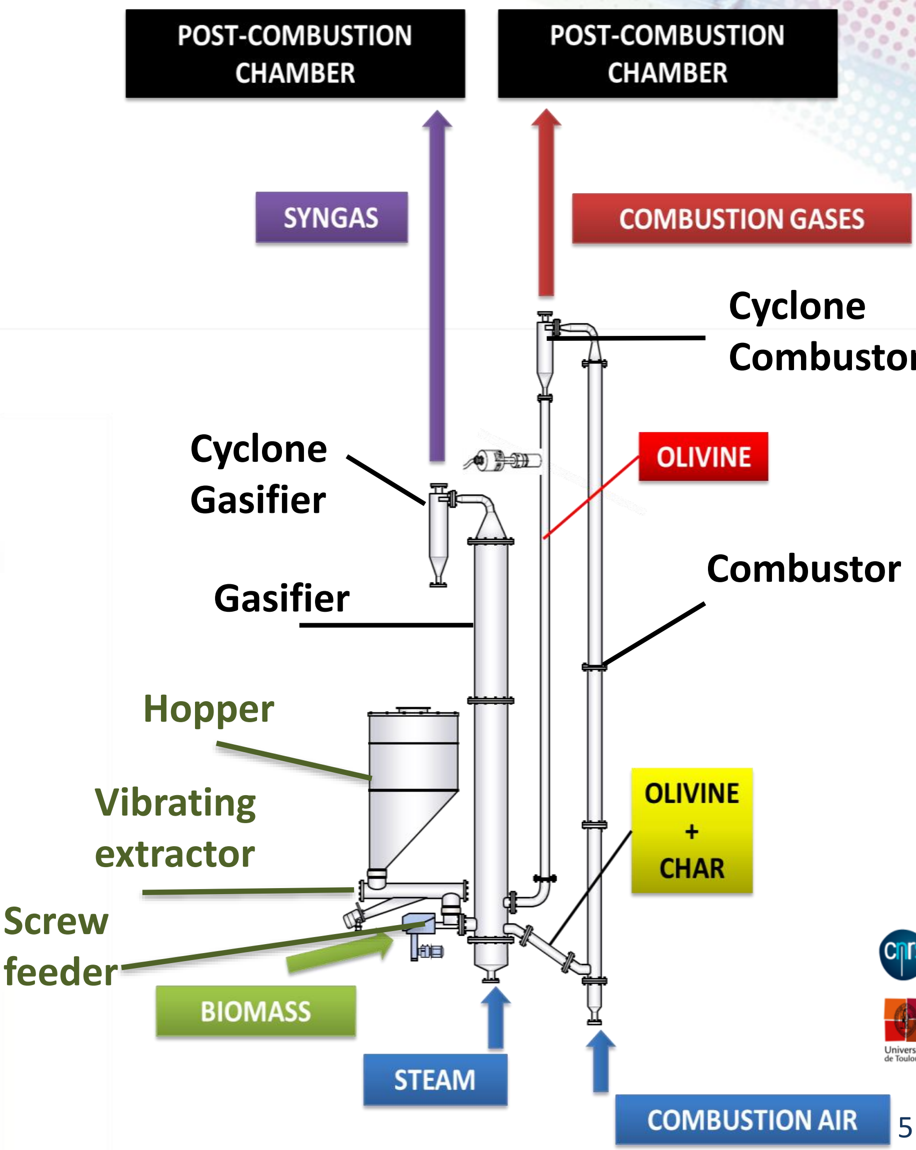
- Electric furnaces 15 and 6 kW :

✓ Startup of the installation

✓ Carrying of hot hydrodynamic tests

- Post-combustion chamber at the outlet

✓ Burning all combustible gas



EXPERIMENTAL SETUP

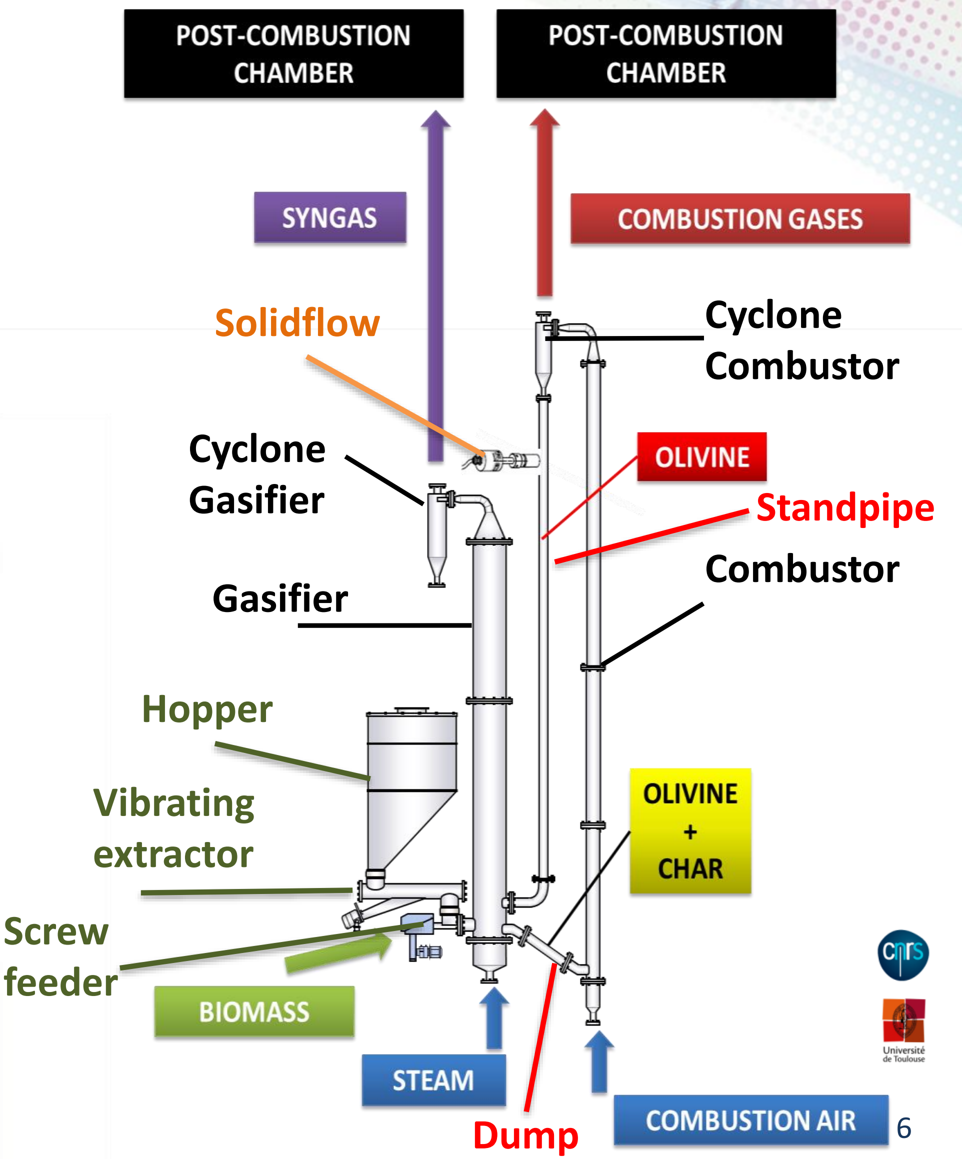
- Circulating fluidized bed designed and built-up at the LGC Toulouse

Biomass Feeding

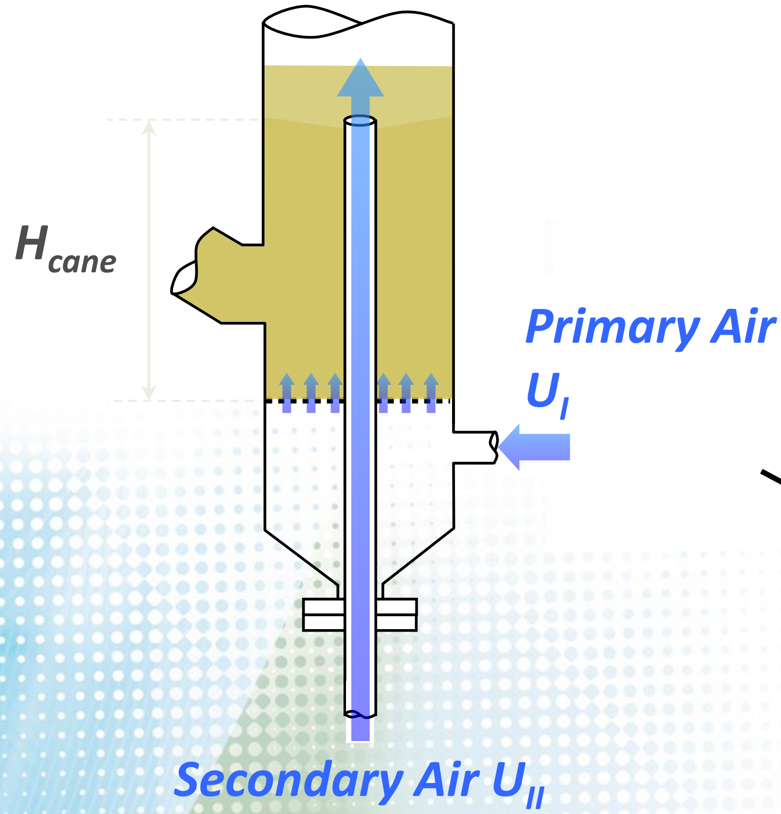
Gasifier / Combustor : Reactive zones

Standpipe / Dump : Solid circulation

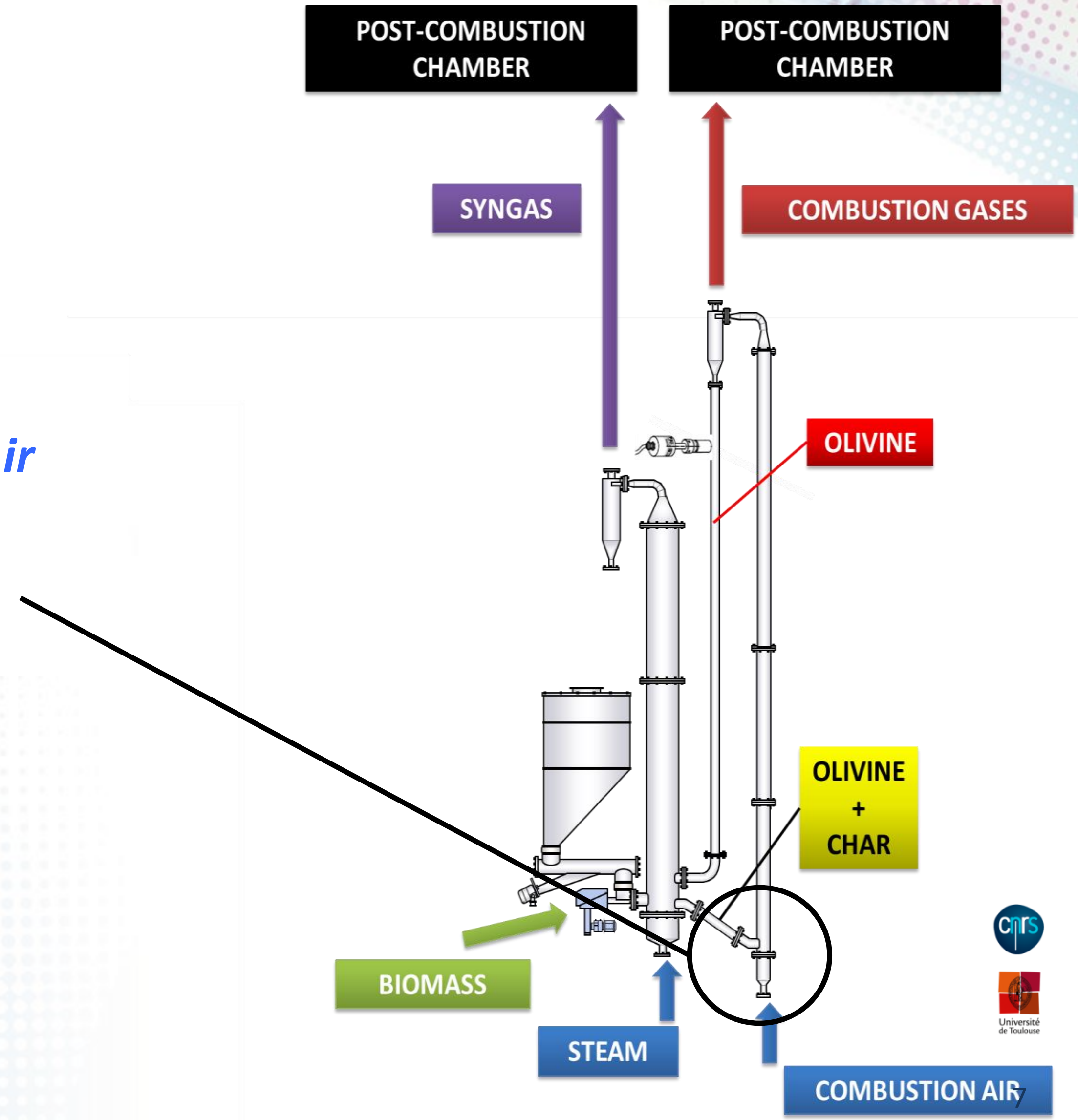
Solidflow : Circulating solid mass flow rate measurement



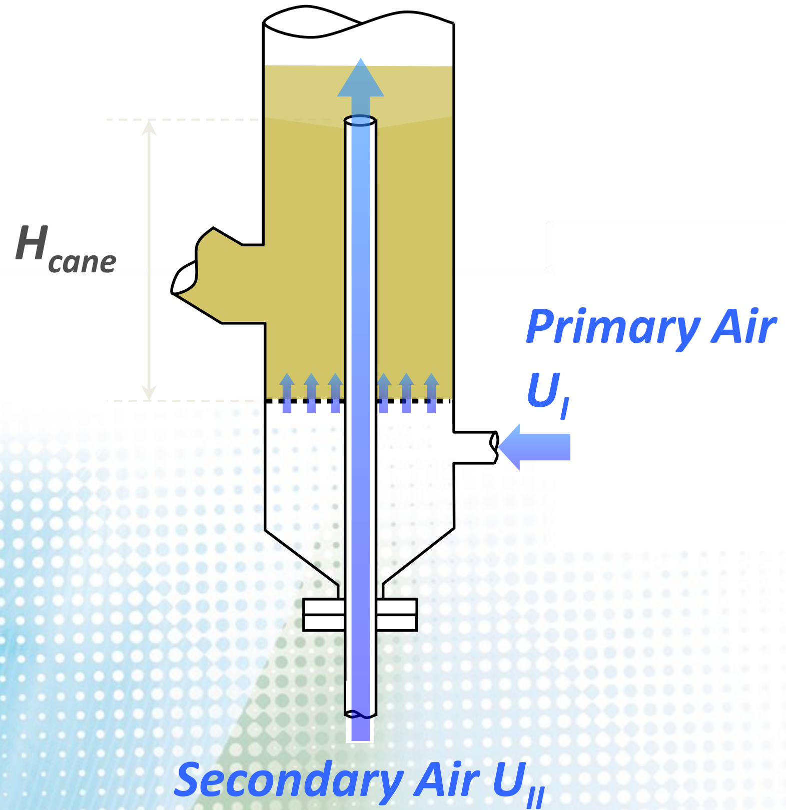
AIR FEEDING IN THE COMBUSTOR



$$U_{comb} = U_I + U_{II}$$



AIR FEEDING IN THE COMBUSTOR



$U_{comb} = U_I + U_{II}$

✓ **Secondary Air injection cane height H_{cane}**
  - Sets the dense fluidized bed height
  - 15 cm

INDUSTRIAL DEVELOPMENT ISSUES

Design/simulation of industrial CFB biomass gasifiers

Dense fluidized bed hydrodyna
properties (U_{mf}, ε_{mf}, ε)

Olivine particle size
[200 – 300 µm] $d_{3/2}$ = 280 µm
[300 – 400 µm] $d_{3/2}$ = 460 µm
[400 – 600 µm] $d_{3/2}$ = 690 µm

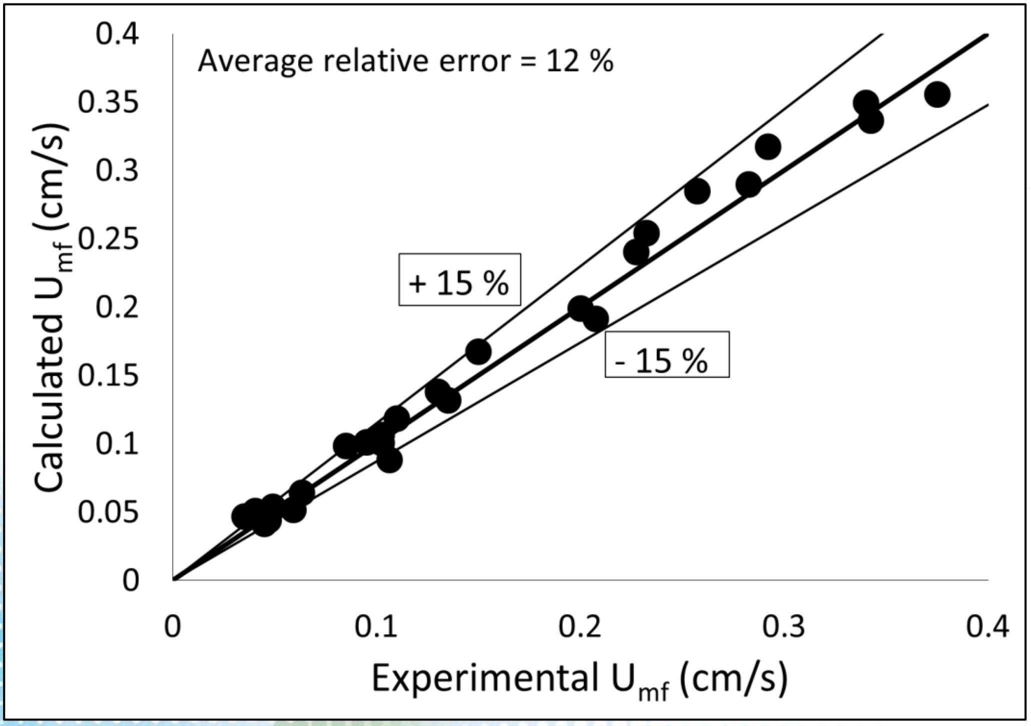
Temperature
[20 – 950°C]

Gas nature
Air / Steam

Proposition of correlations

I. Hydrodynamic study of the gasifier

MINIMUM FLUIDIZATION VELOCITY



U_{mf} ⇘ when

- T ⇗
- dp ⇘

U_{mf} (Steam) => U_{mf} (air) :
ρ et μ (Steam) < ρ et μ (Air)

$$Re_{mf} = (20.32^2 + 0.031. Ar)^{0.5} - 20.32$$

I. HYDRODYNAMIC STUDY OF THE GASIFIER

POROSITY / VOIDAGE

Minimum fluidization porosity ε_{mf} :

No effect of bed temperature or particle size => $\varepsilon_{mf} = 0.55$

Average porosity ε :

$\varepsilon \nearrow$ when

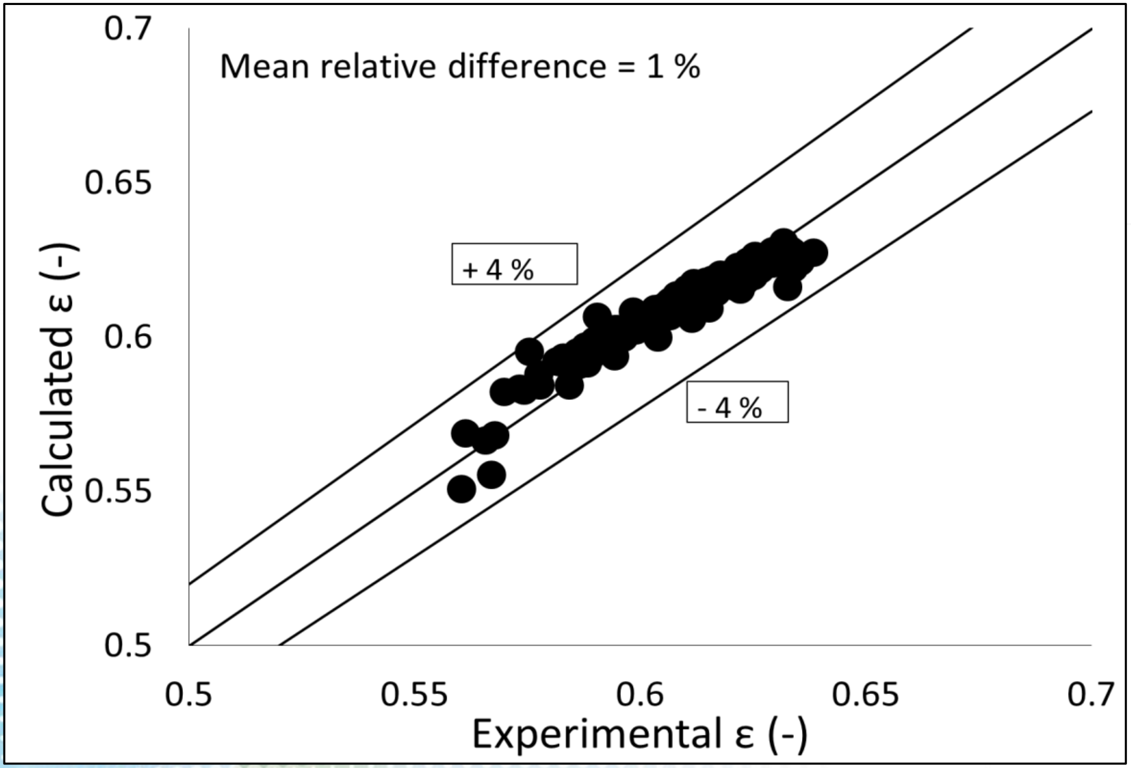
- $U-U_{mf} \nearrow$

But independent of :

- bed temperature
- particle size

I. HYDRODYNAMIC STUDY OF THE GASIFIER

POROSITY / VOIDAGE



$$\frac{\varepsilon}{\varepsilon_{mf}} = 1.0394.\left(\frac{U - U_{mf}}{U_{mf}}\right)^{0.026}.Ar^{0.006}$$

INDUSTRIAL DEVELOPMENT ISSUES

I. Hydrodynamic study of the gasifier

Syngas production efficiency

↓

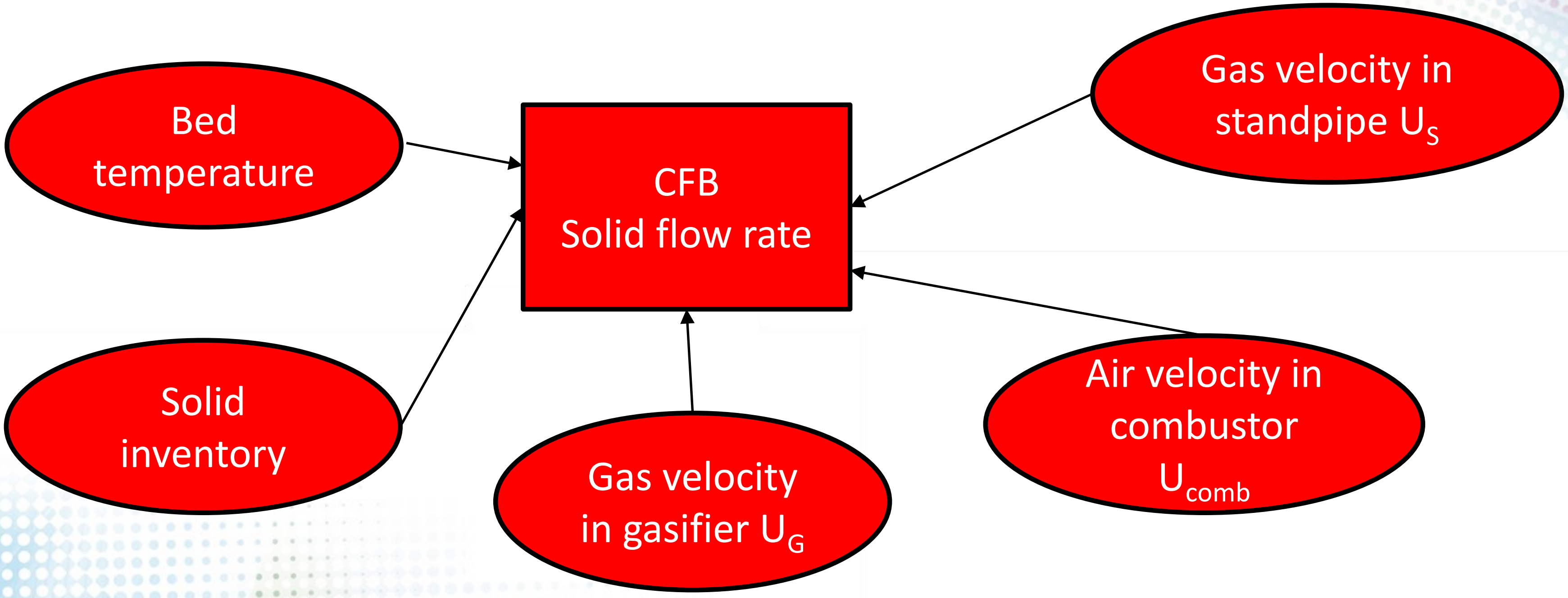
Gasifier / Combustor Relative temperature difference

↓

Heat transfer medium circulation flow rate

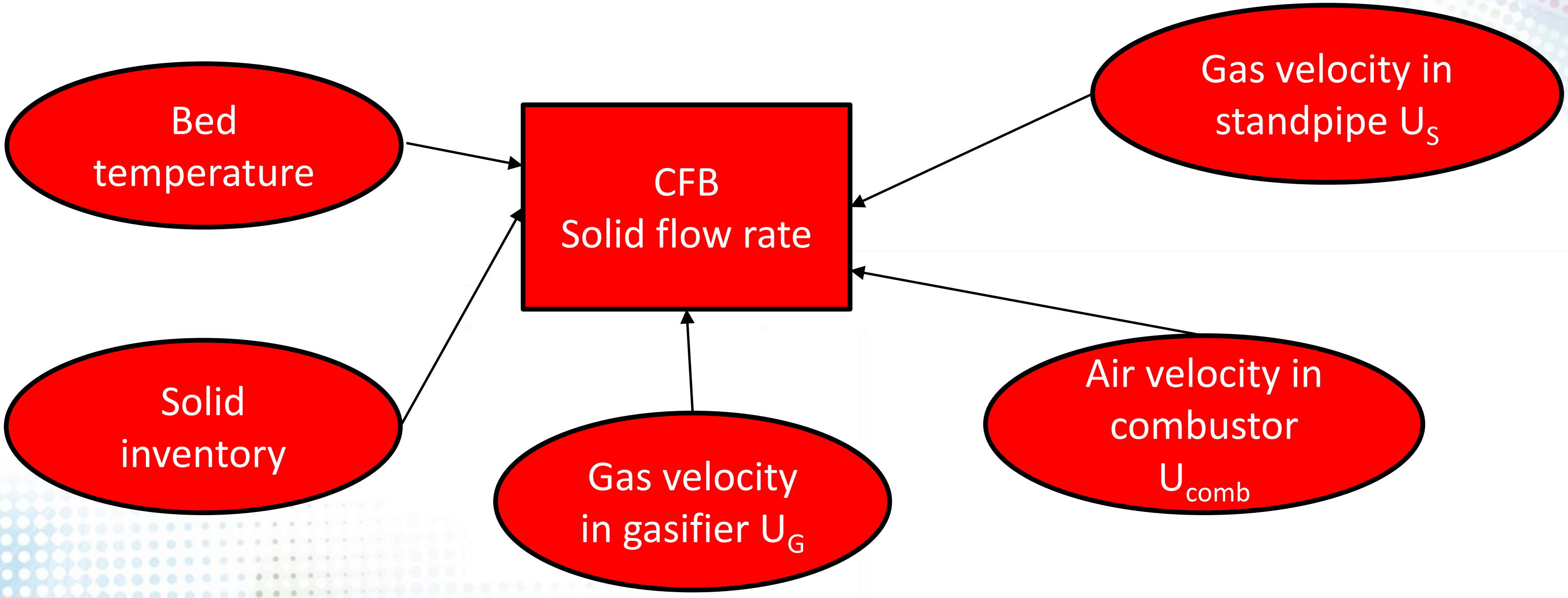
Solid flow rate control parameters ?

II. Hydrodynamic study of the CFB



	T (°C)	m_p (kg)	U_G (U/U_{mf})	U_{comb} (U/U_t)	U_S (U/U_{mf})
Reference	500	35	4	2.4	8
Range	[20 – 850]	[35 – 60]	[1 – 8]	[0.4 – 3]	[1 – 8]

II. Hydrodynamic study of the CFB



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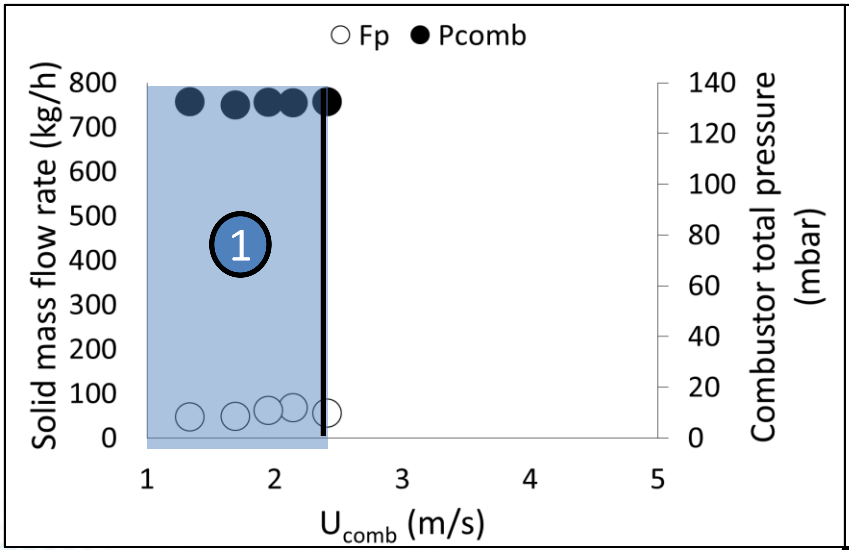
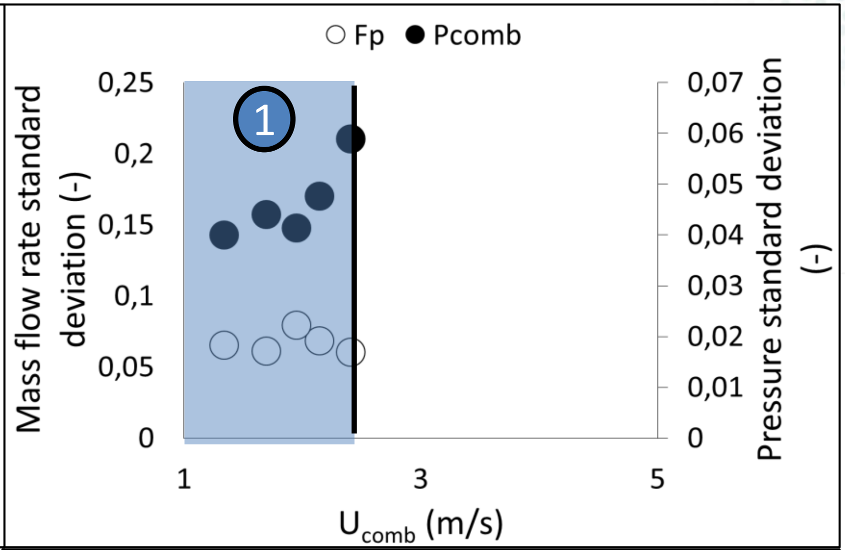
Reference	500	35	4	2.4	8
Range	[20 – 850]	[35 – 60]	[1 – 8]	[0.4 – 3]	[1 – 8]

II. Hydrodynamic study of the CFB

EFFECT OF THE GAS VELOCITY U_{comb} :

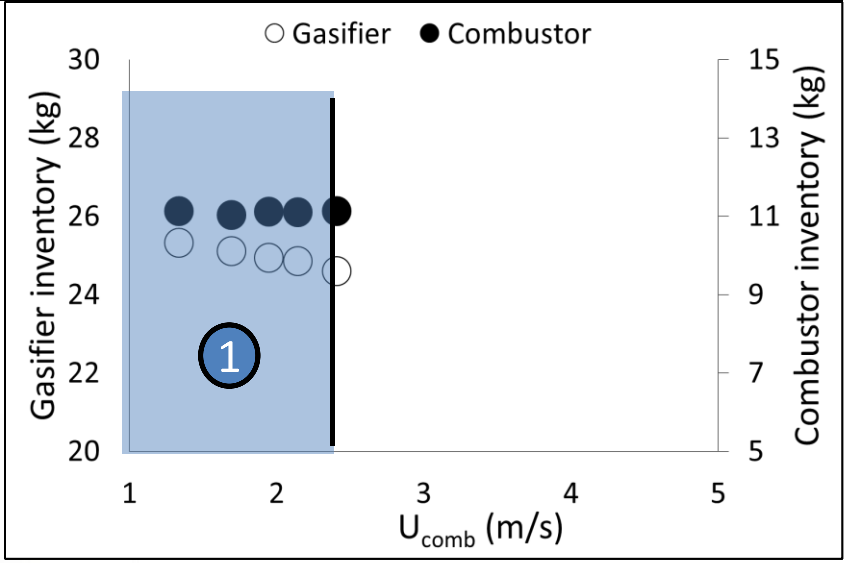
1 Dense fluidized bed





Three hydrodynamic regimes identified in the combustor :

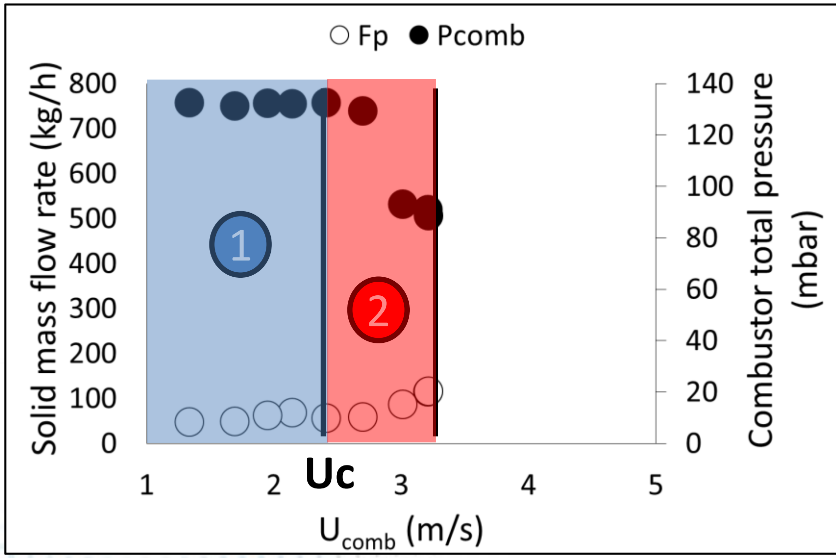
- 1) Dense fluidized bed regime

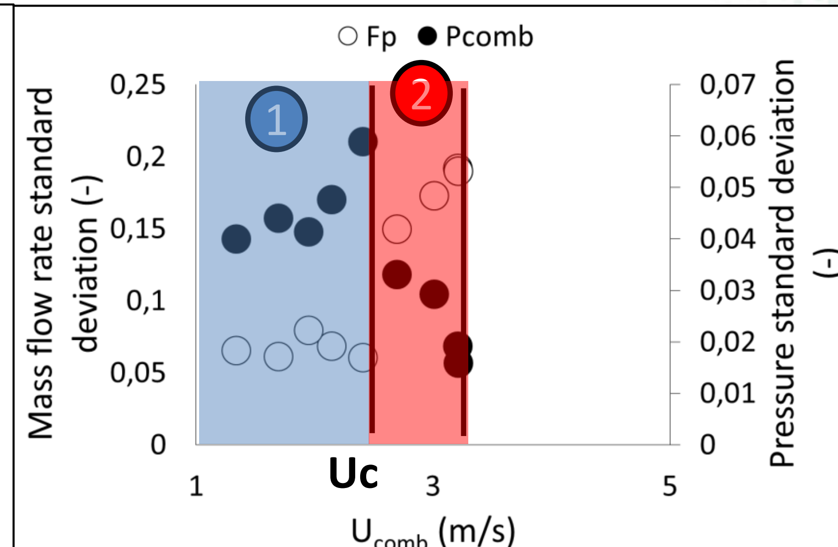


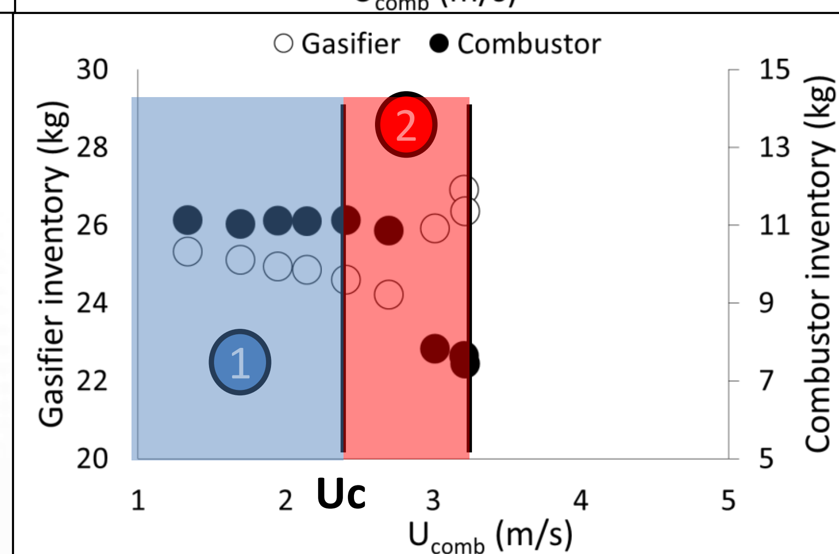
II. HYDRODYNAMIC STUDY OF THE CFB

EFFECT OF THE GAS VELOCITY U_{comb} :

2 Turbulent bed







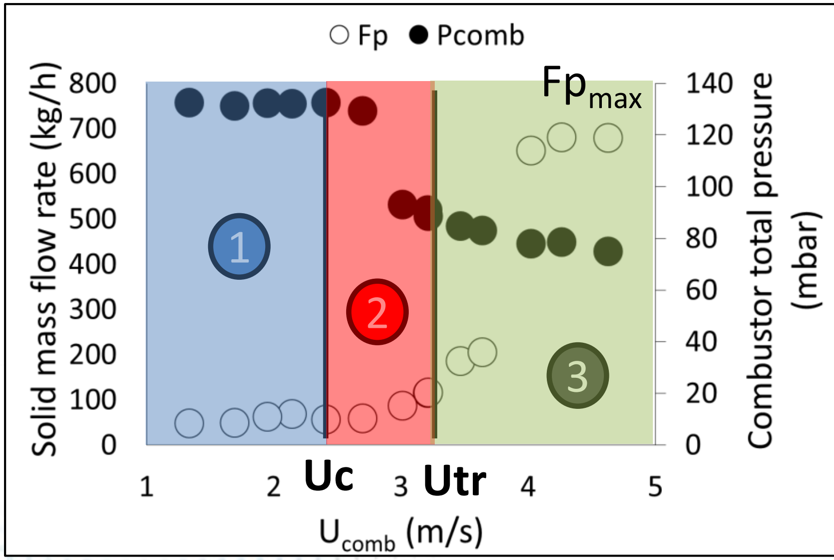
Three hydrodynamic regimes identified in the combustor :

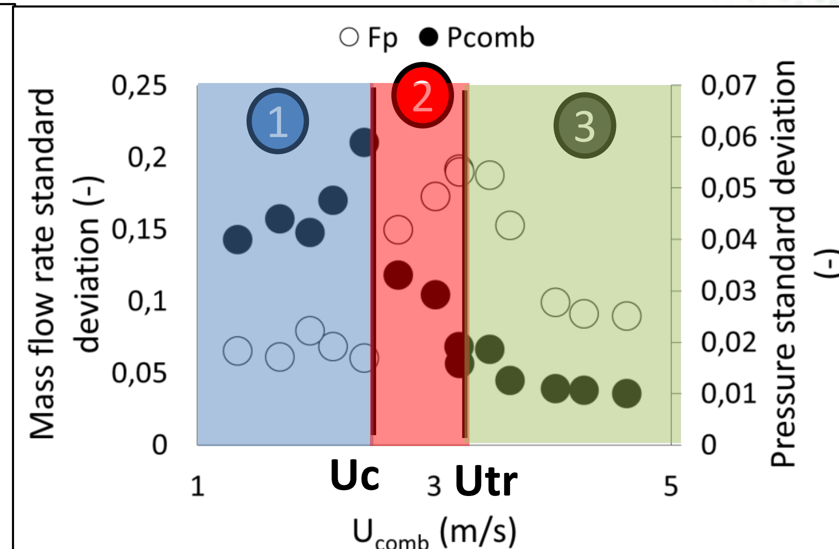
- **1) Dense fluidized bed regime**
- **2) Turbulent (transition) bed regime**

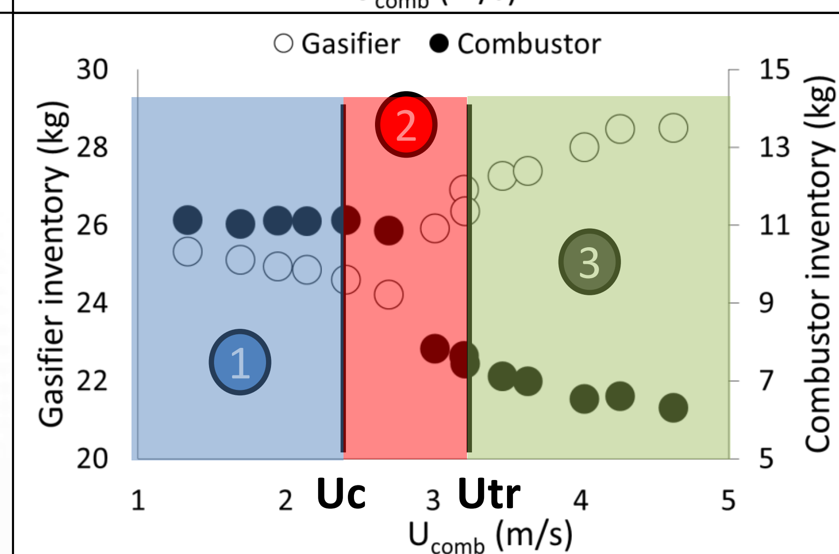
II. Hydrodynamic study of the CFB

EFFECT OF THE GAS VELOCITY U_{comb} :

3 Transported bed







Three hydrodynamic regimes identified in the combustor :

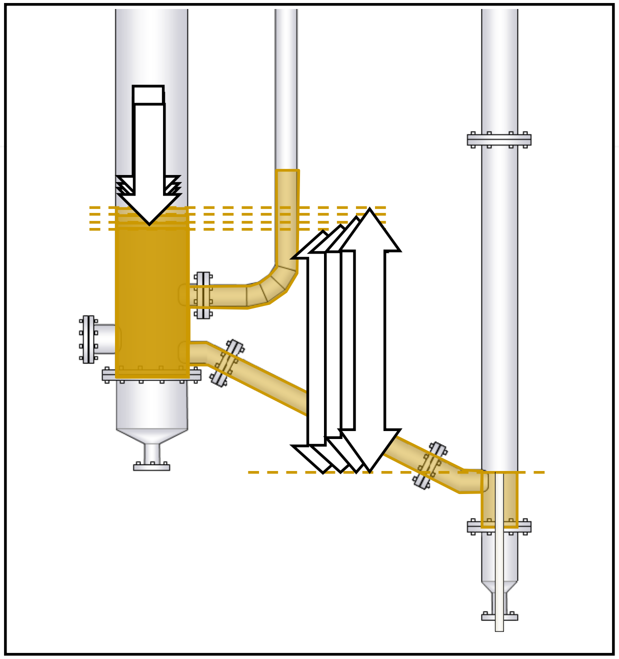
- **1) Dense fluidized bed regime**
- **2) Turbulent (transition) bed regime**
- **3) Transported (circulating) bed regime**

II. HYDRODYNAMIC STUDY OF THE CFB

EFFECT OF THE SOLID INVENTORY :

$H_{cane} = 15\ cm = H_{comb}$

- When m_p ↗ $H_{Gasifier}$ ↗

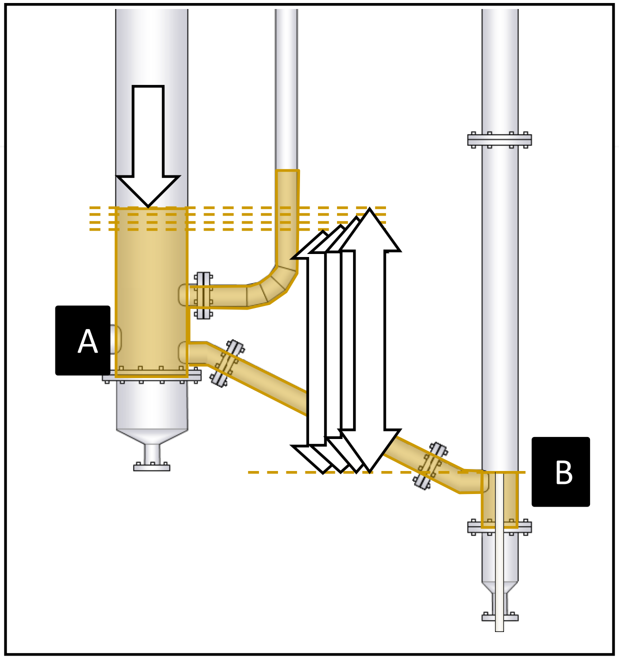


II. HYDRODYNAMIC STUDY OF THE CFB

EFFECT OF THE SOLID INVENTORY :

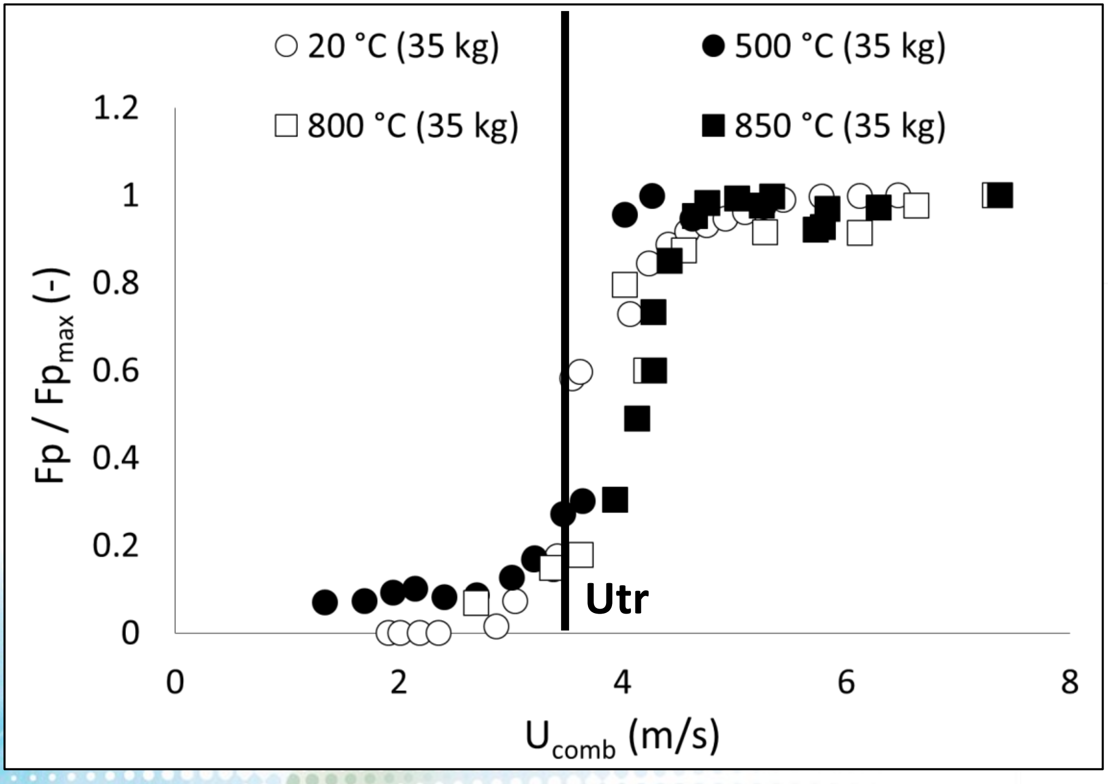
H_{cane} = 15 cm = H_{comb}

- When m_p ↗ $H_{Gasifier}$ ↗
- ΔP between A and B (driving force of the circulation) ↗
- Fp_{max} ↗



II. Hydrodynamic study of the CFB

EFFECT OF THE BED TEMPERATURE : 20-850 °C

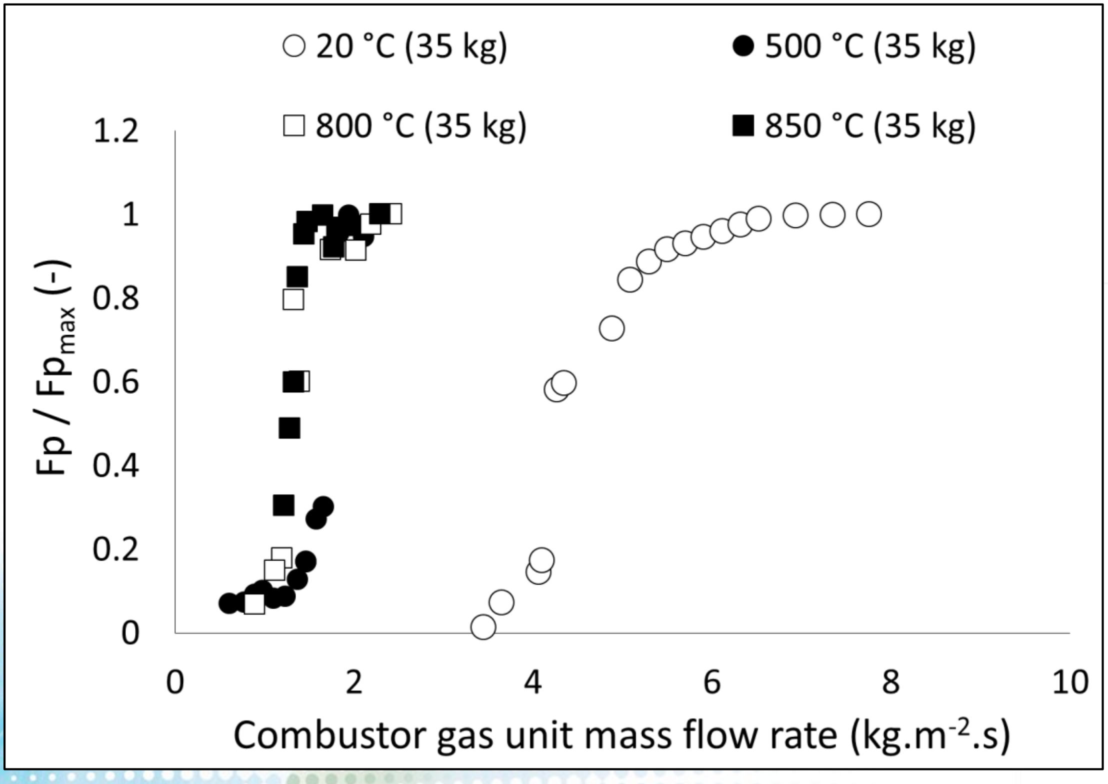


When bed temperature ↗

=> Low effect on Utr

II. Hydrodynamic study of the CFB

EFFECT OF THE BED TEMPERATURE : 20-850 °C

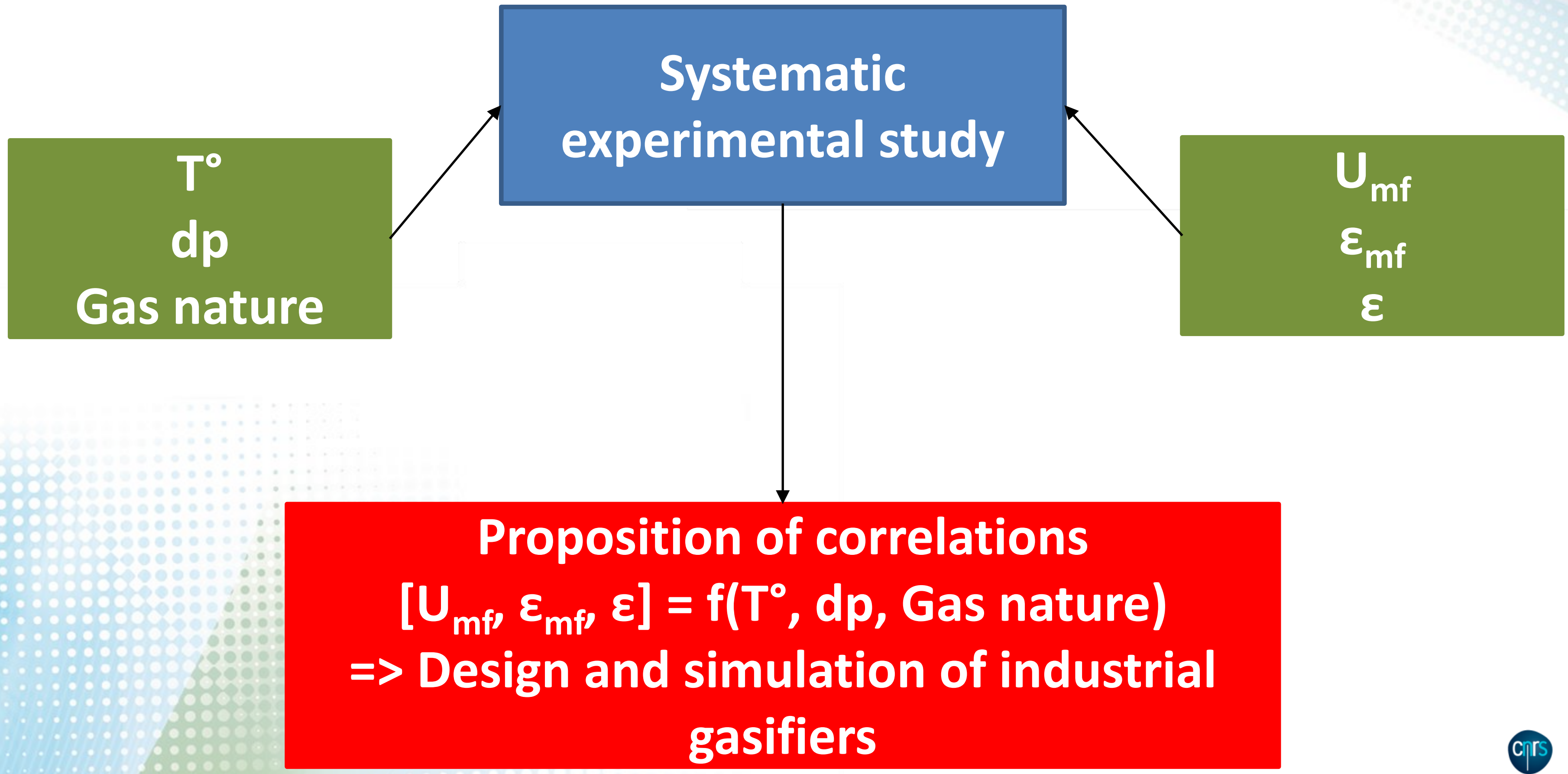


When bed temperature ↗

=> Air consumption ↘

CONCLUSION

- **Dense fluidized bed tests (20 – 950 °C)**



Conclusion

- **Circulating fluidized bed tests (20 – 850 °C)**

→ **Hydrodynamic regimes in the combustor :**
3 between dense fluidized bed and transported bed

→ **3 key parameters : gas velocity U_{comb}, solid inventory and bed temperature**

For U_{comb} and solid inventory ↗

Circulating solid flow rate ↗

For bed temperature ↗

Air consumption ↘

Thank you for your attention