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Development of a Fluidized Bed Thermo-Gravimetric Analyzer (FB-TGA)

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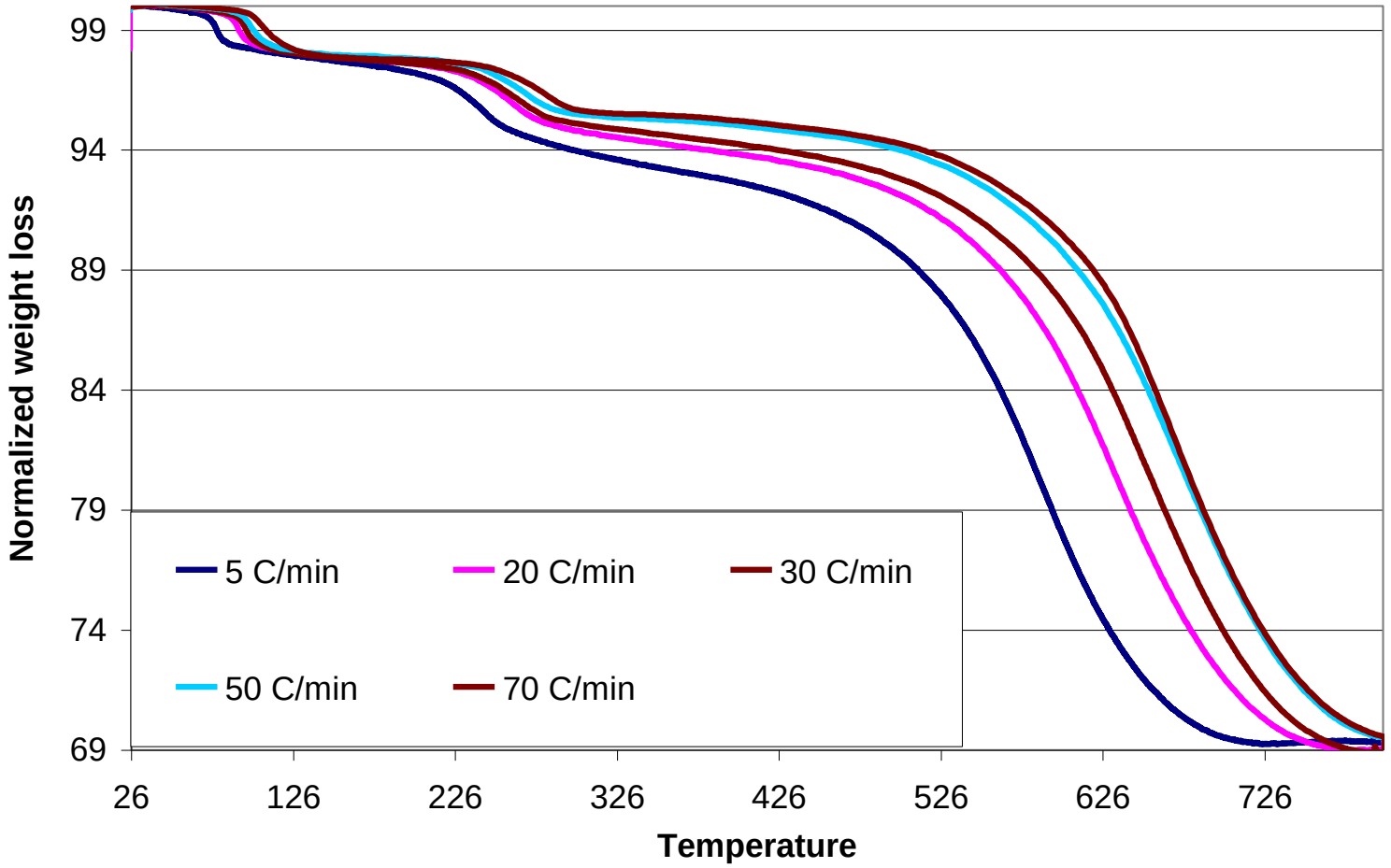
WORLD-CLASS ENGINEERING

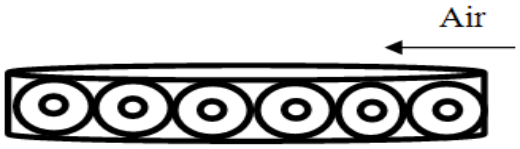
POLYTECHNIQUE MONTRÉAL

CONVENTIONAL TGA LIMITATIONS: EFFECT OF HEATING RATE

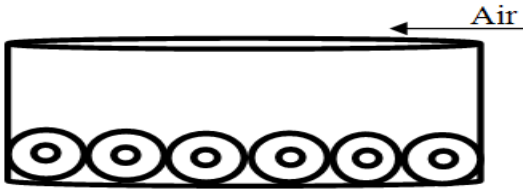
Combustion of Carbon



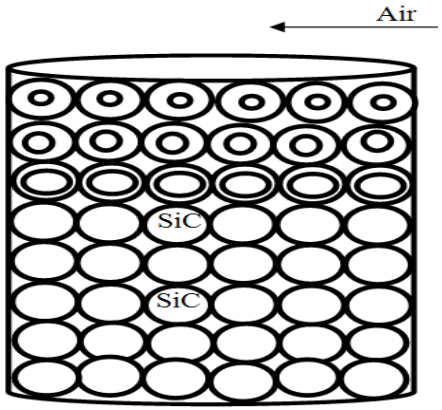
CONVENTIONAL TGA LIMITATIONS: DIFFUSION CONTROL



Type I:
Intra diffusion

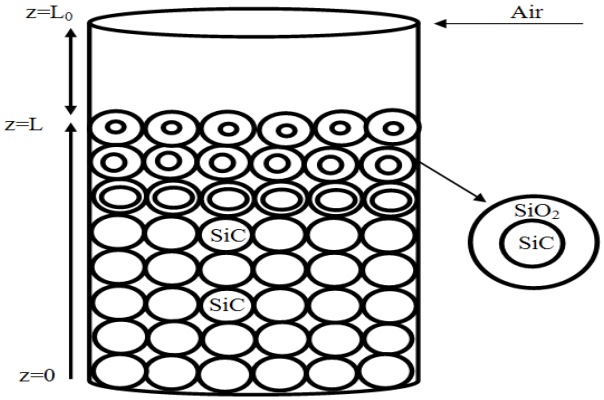


Type II:
Bulk and intra diffusion



Type III:

Inter- and intra diffusion



Type IV:

Bulk, inter- and intra diffusion

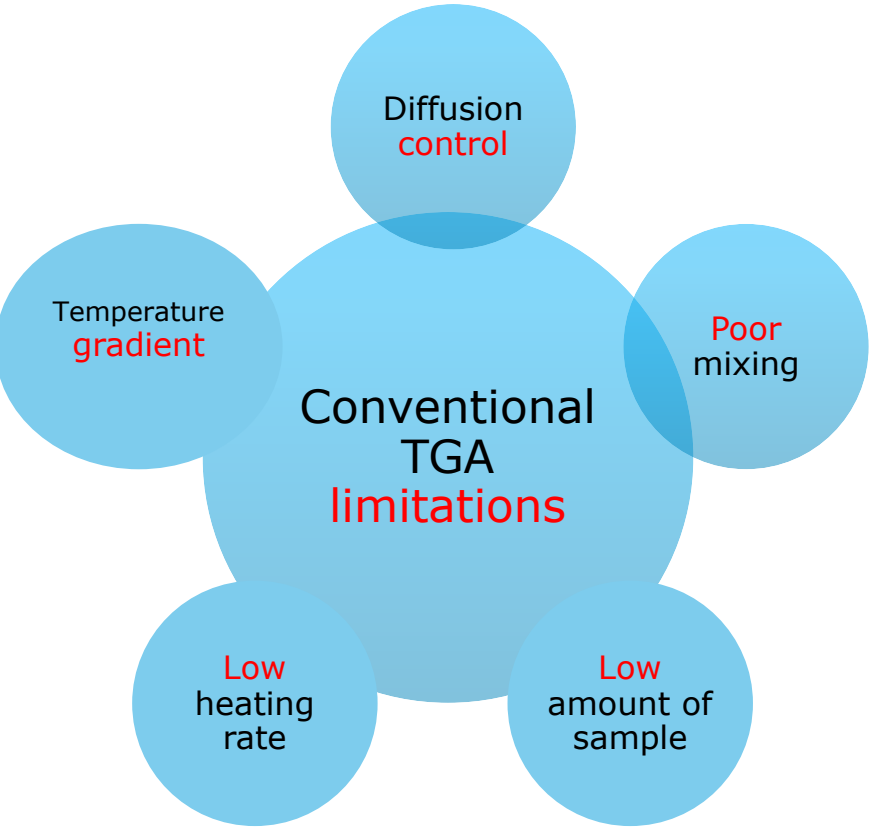
Source: O. Ebrahimpour, et al. « The Oxidation Behavior of Sic Powders and its Kinetics via a Diffusion-Controlled Model in TGA Experiments," J. American Ceramic Society, 2013

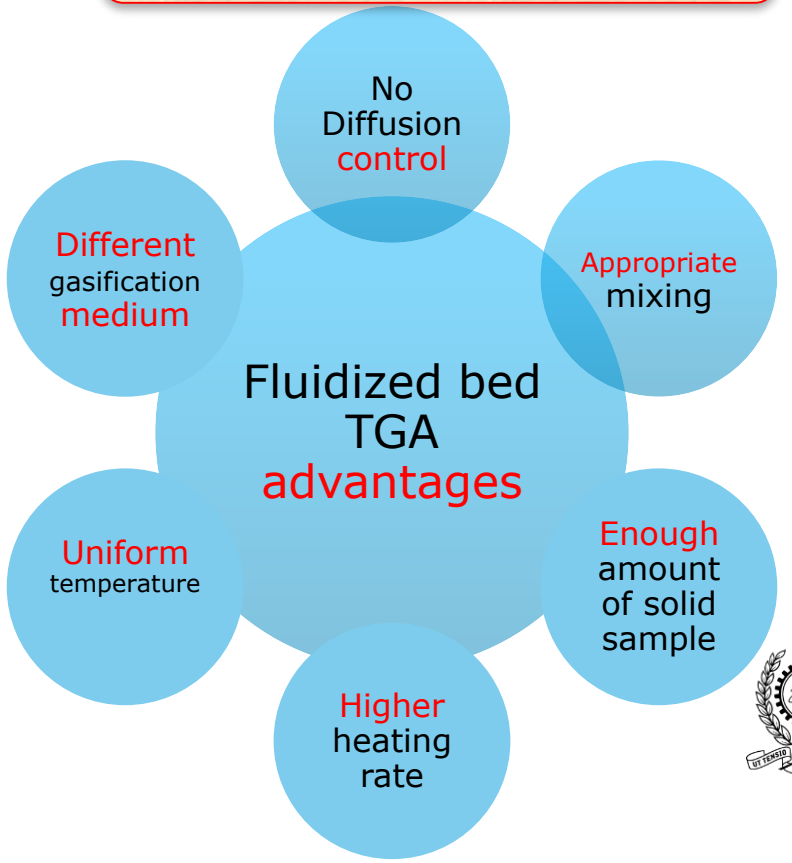
PROBLEMATIC / SOLUTION

Problematic:
Conventional TGA Limitations

?

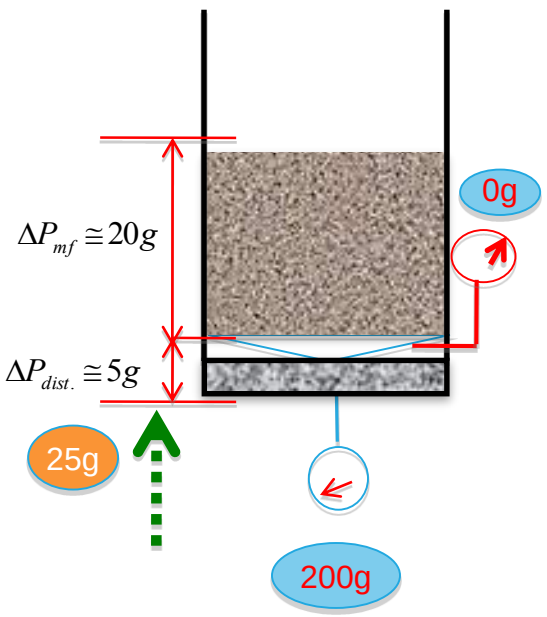
Possible solution:
Fluidized bed TGA



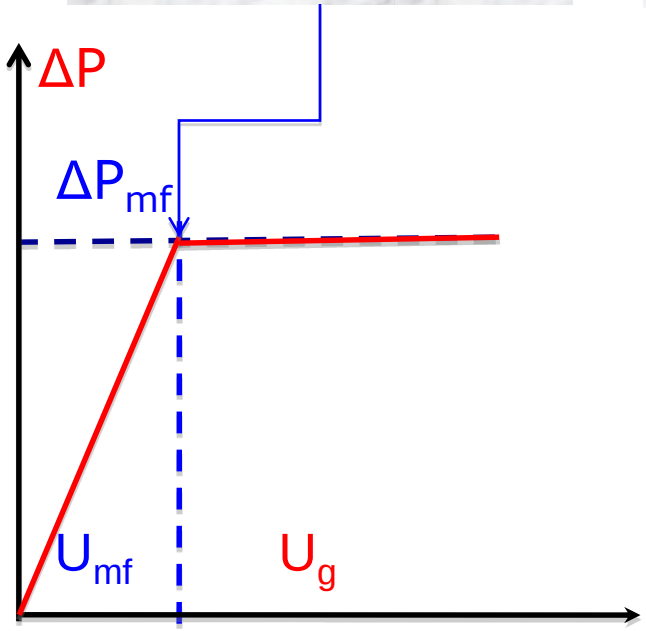


FLUIDIZATION AND WEIGHT MEASUREMENT

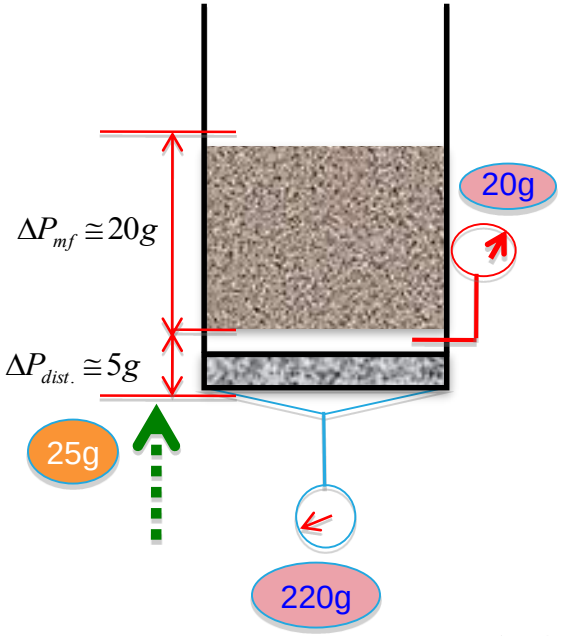
Scenario #1 ($U_g = U_{mf}$)
Bed weight



Minimum fluidization



Scenario #2 ($U_g = U_{mf}$)
Bed and distributor weight



According to the 2nd scenario, the weight of the fluidized bed can be measured by the balance.

FB-TGA DESCRIPTION

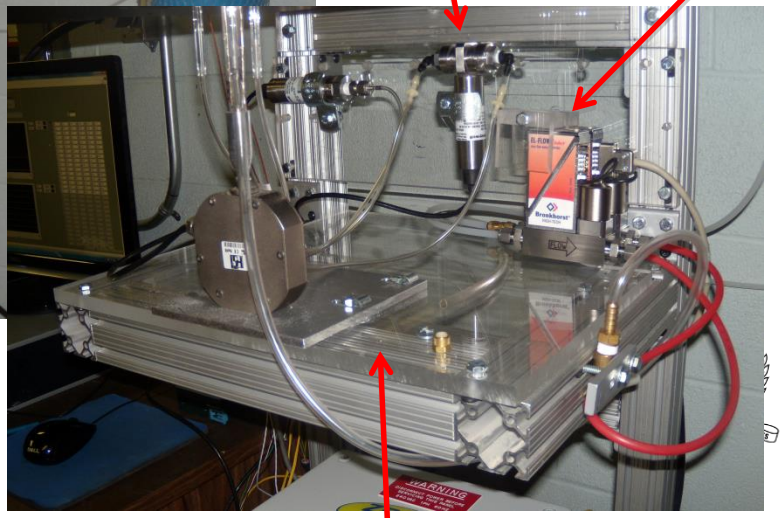
Oven, 2 thermocouples inside

• Fluidized bed (reaction chamber)
• Diameter: 2.5 cm;
• Vessel height: 15 cm;
• Amount of solid sample: up to 5 g

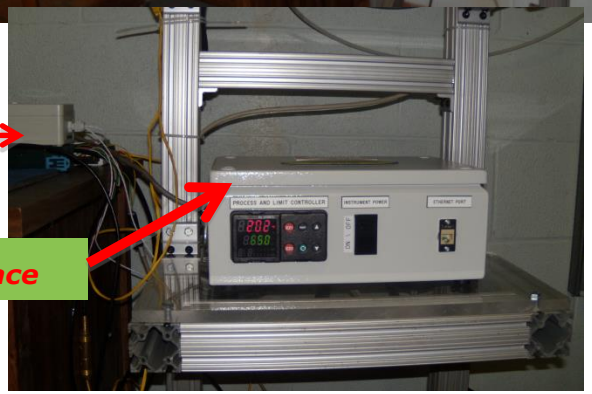
• Thermocouple to data acquisition system
• Gas-outlet pipe to GC-MS

•Differential pressure transducer for Pressure drop measurement

• 2 Mass flow controllers for gas flowrate adjustment vs T



Data acquisition system



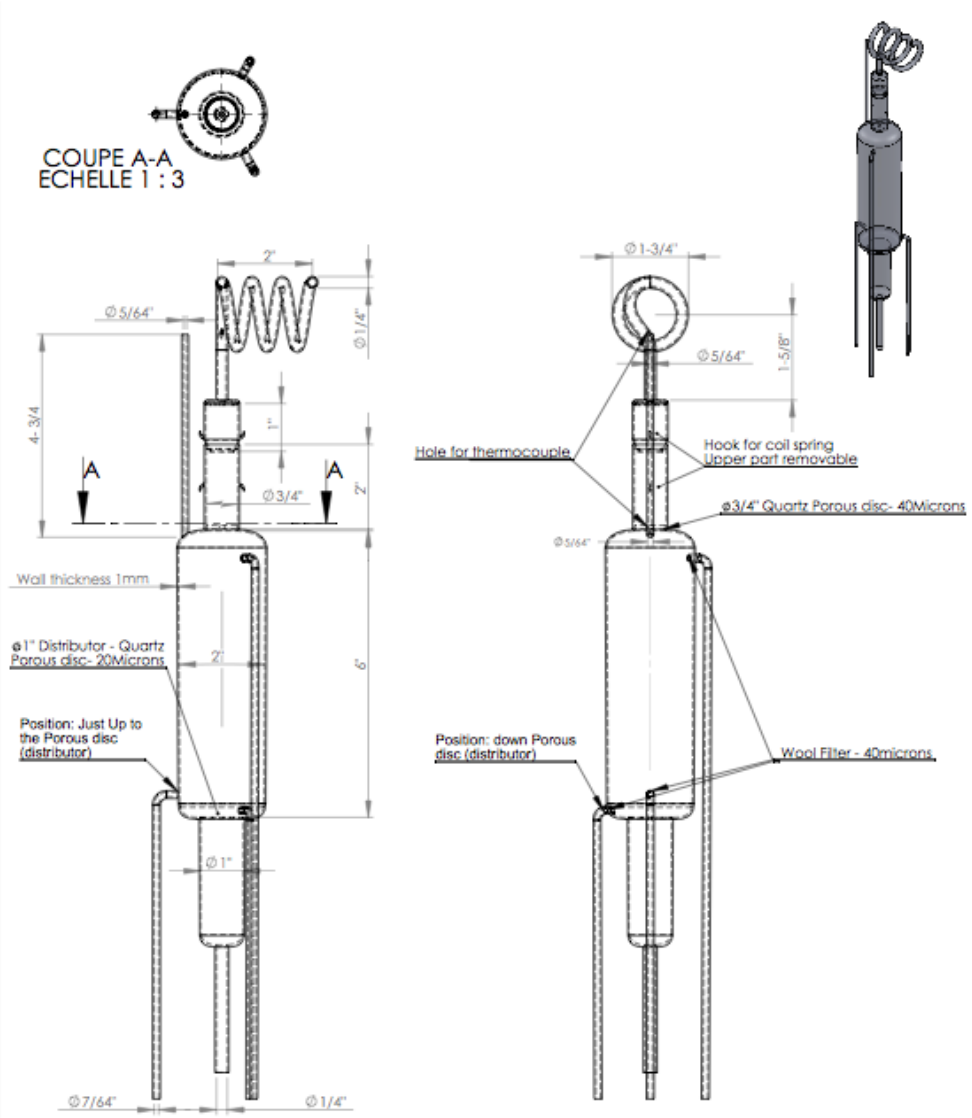
PID Controller for the furnace

• Pipes for air inlet and pressure drop measurement;
• Balance for weight loss measurement;
• Data acquisition system

FB-TGA : THECHNICAL DRAWING

FB- Reactor:

- Material: Quartz
- ID= 1 inch;
- H= 6 inch;
- Solid sample: 5 g



STRATEGIES FOR THE GAS FLOWRATE REGULATION

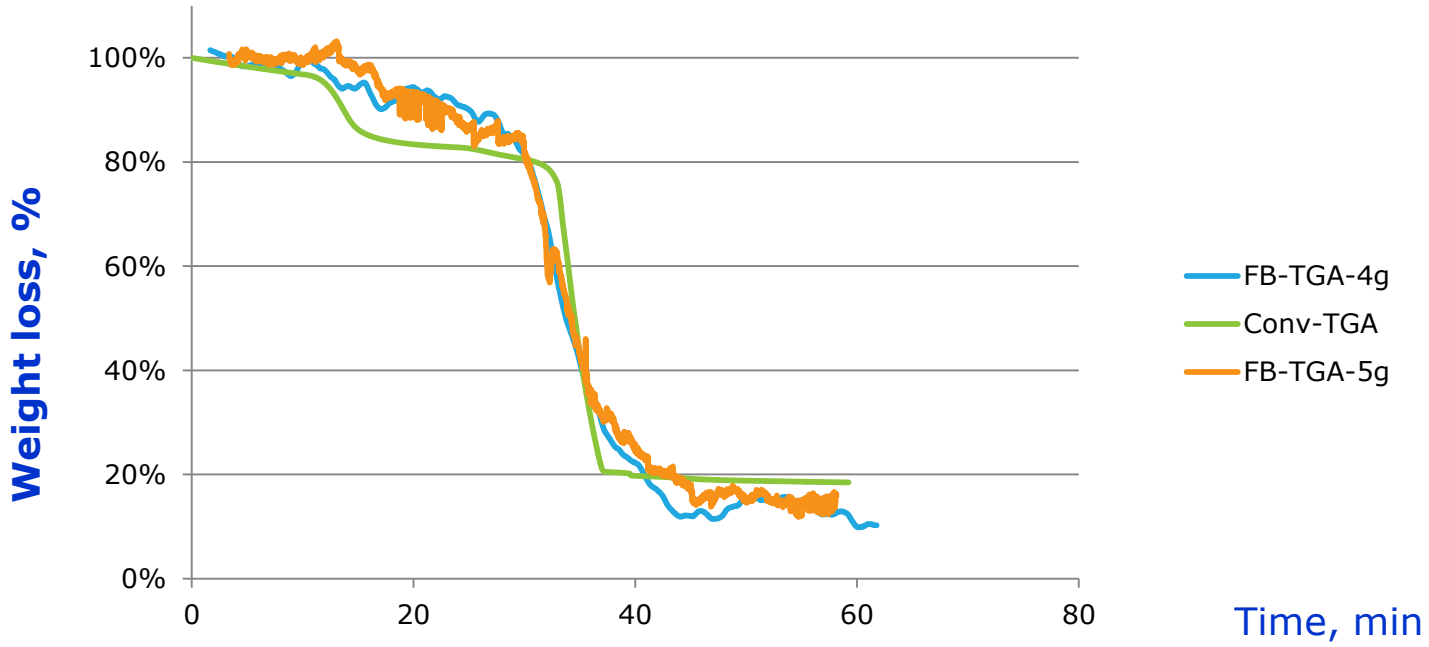
U_{mf} decreases with temperature → Fluidization regime changes: Vibration & Hydrodynamics effect on kinetics.

In order to keep the system at around minimum fluidization regime, 03 scenarios were used:

- 1st scenario: $U_g(T) = U_{mf}(T)$;
- 2nd Scenario: $U_g(T)$= Cste/ segment ΔT;
- 3rd Scenario: ρU_g^2 = Cste/ segment of ΔT.

PRIMARY RESULTS - COAL COMBUSTION: Conventional vs Fluidized Bed TGA

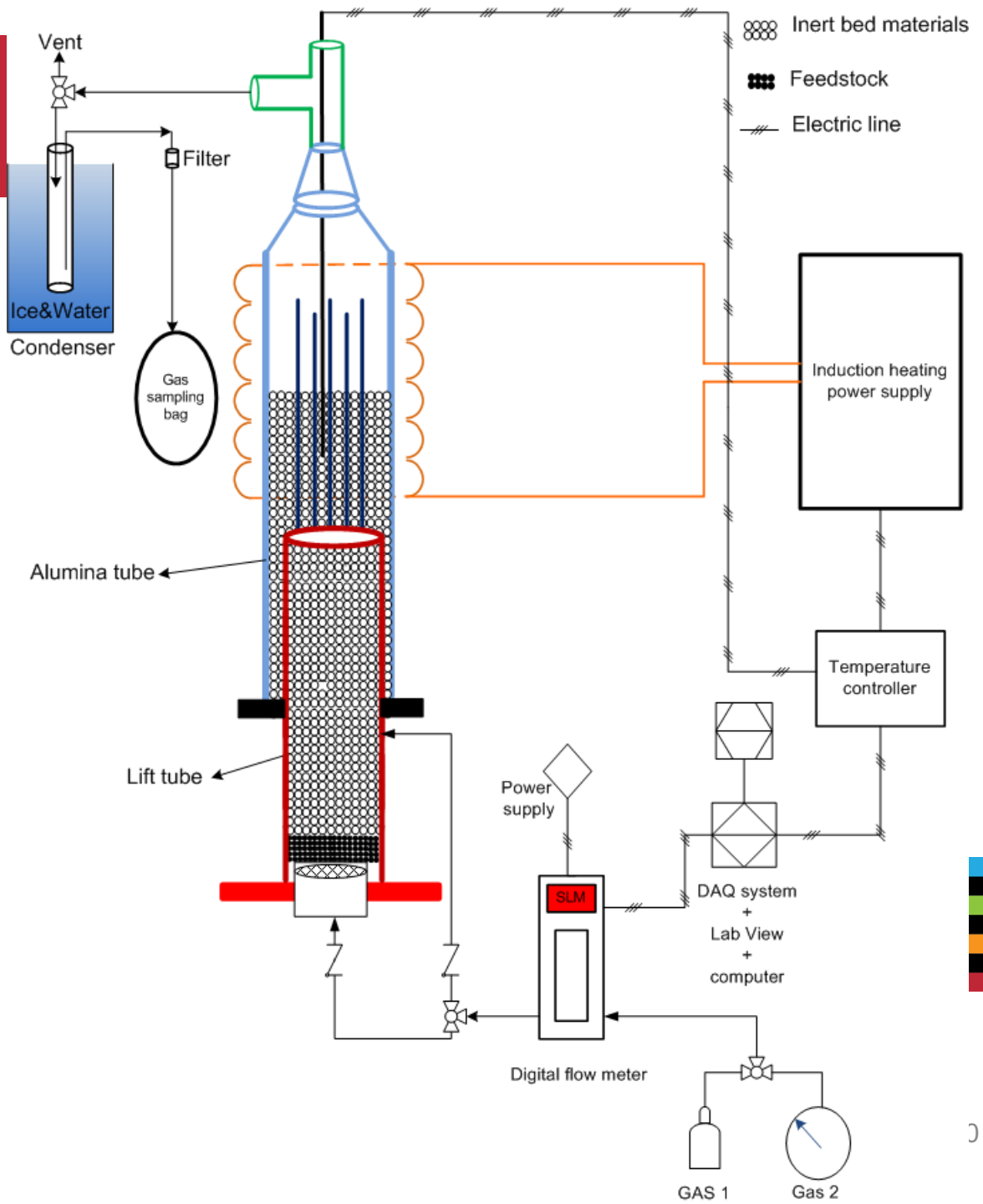
Heating rate: 20C/min; mcoal: **20 mg (Conv. TGA)** & **4-5 g (FB-TGA)**



- Coal combustion has been tested on the new fluidized bed TGA;
- Kinetics of coal and biomass gasification will be studied in the new FB-TGA.

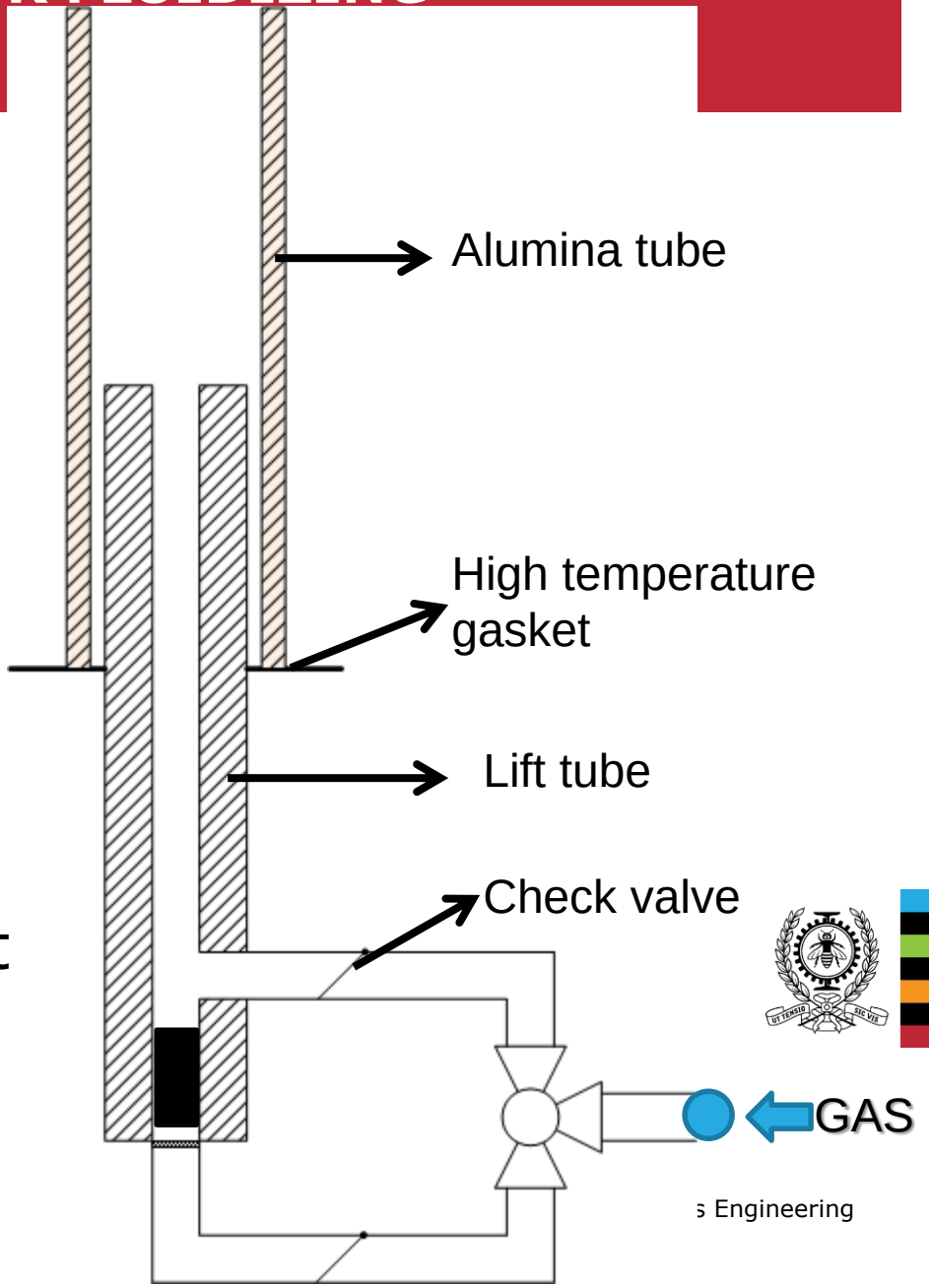
REACTOR SETUP

- Currently, reactor operates as a semi batch reactor
- Setup has potential to be used as a TGA
- Inlet gases and feed can be flexible depending on the reaction
- Condensable products are collected in a condenser
- Outlet of condenser is filtered
- Collected gas mixture in a bag is analyzed by GC and FTIR

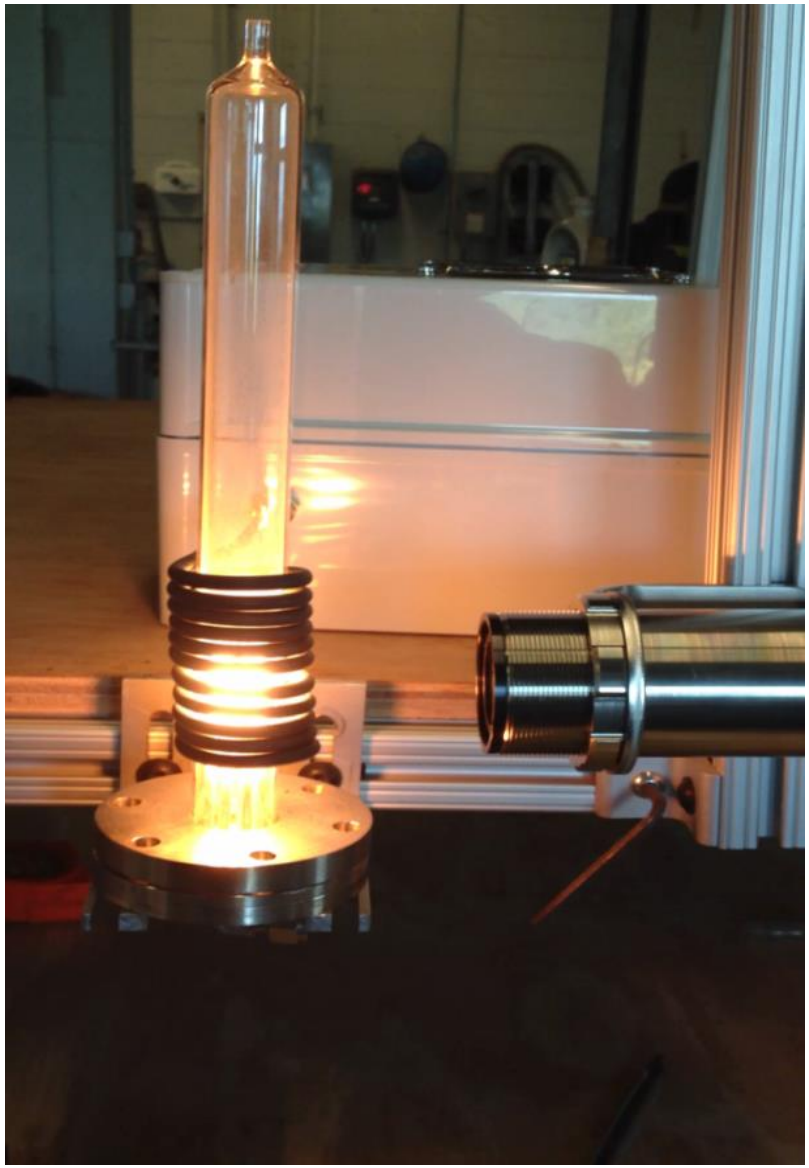


LIFT TUBE: TO KEEP REACTOR FLUIDIZING

- Sand particles are fluidized during heat-up
  - To keep uniform temperature in bed
  - To prevent particles agglomeration
  - Flow rate of inlet gas is adjusted versus temperature to keep bubbling regime in bed
- Once setpoint temperature is reached, direction of inlet gas is switched towards bottom of the lift tube
  - Feed is carried upward



Mini Induction Heating FB Reactor

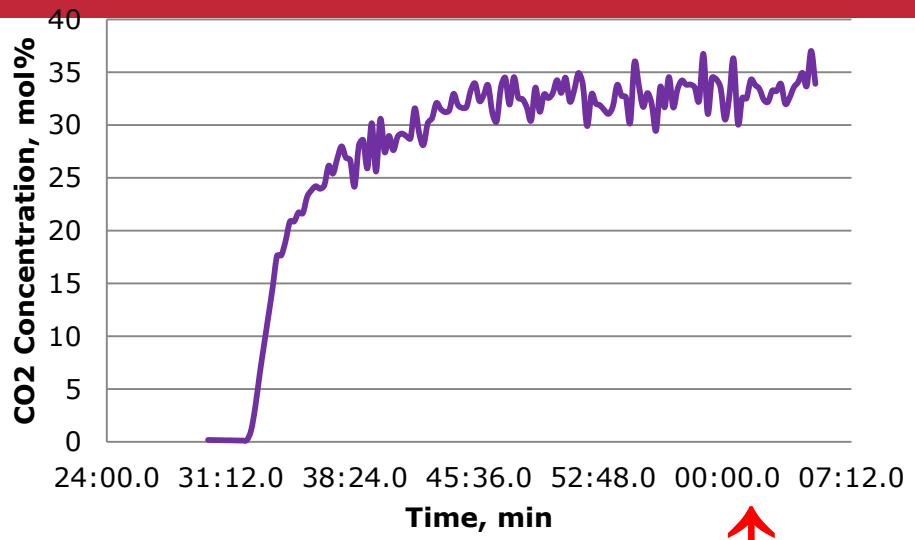


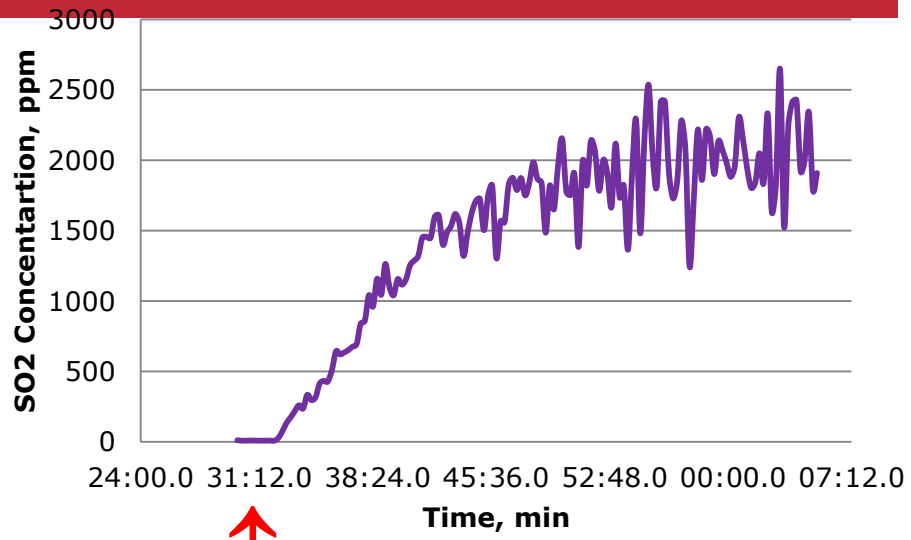
EXPERIMENTAL DATA:
REDUCTION OF EMISSIONS FROM XXX COMBUSTION

EXPERIMENTAL METHODOLOGY

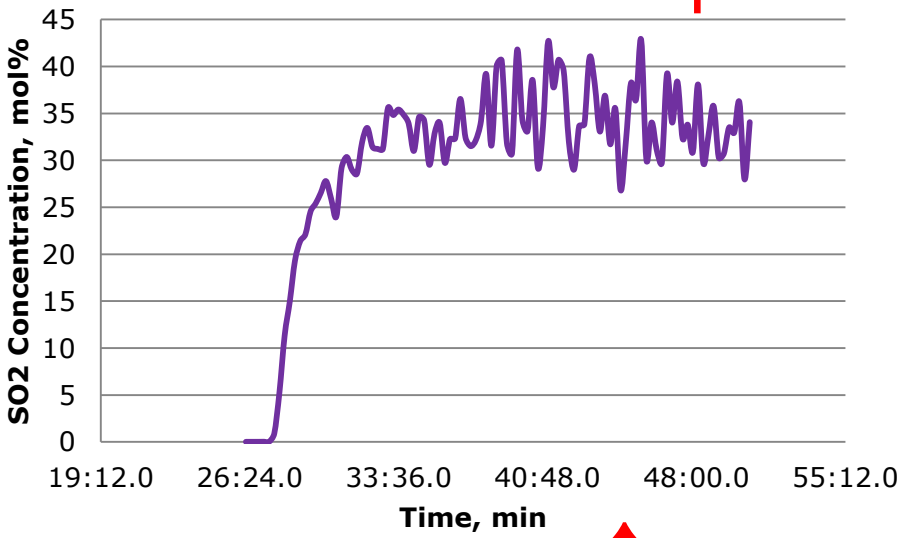
- Temperature: 900° C
- Mass of feed (XXX & XXX+additive): 750 mg
- Sand particles size: 200 to 250 micron
- Coal particles size: 200 to 250 micron
- Inlet reactive gas: Oxygen 99.9%
- Fluidization regime: bubbling bed (inlet flow rate varied versus temperature)

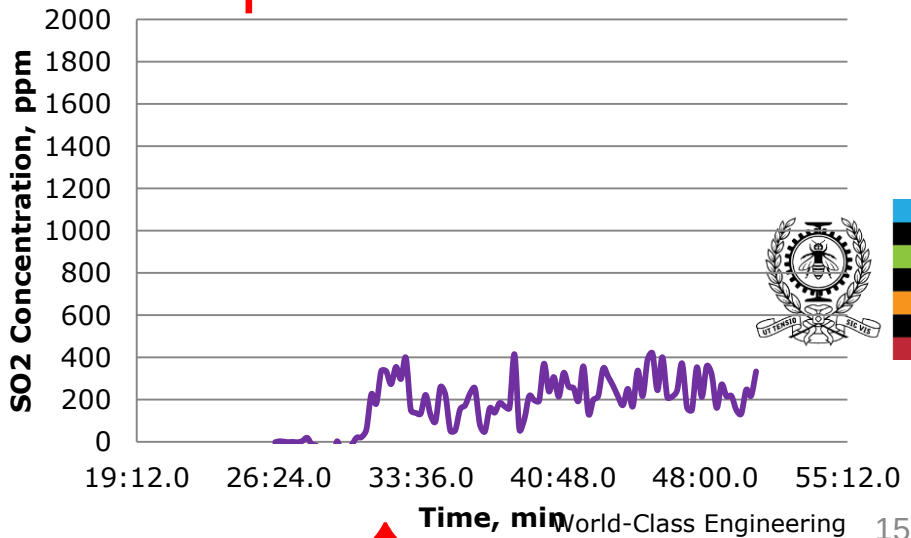
FTIR RAW ANALYTICAL DATA:





XXX combustion



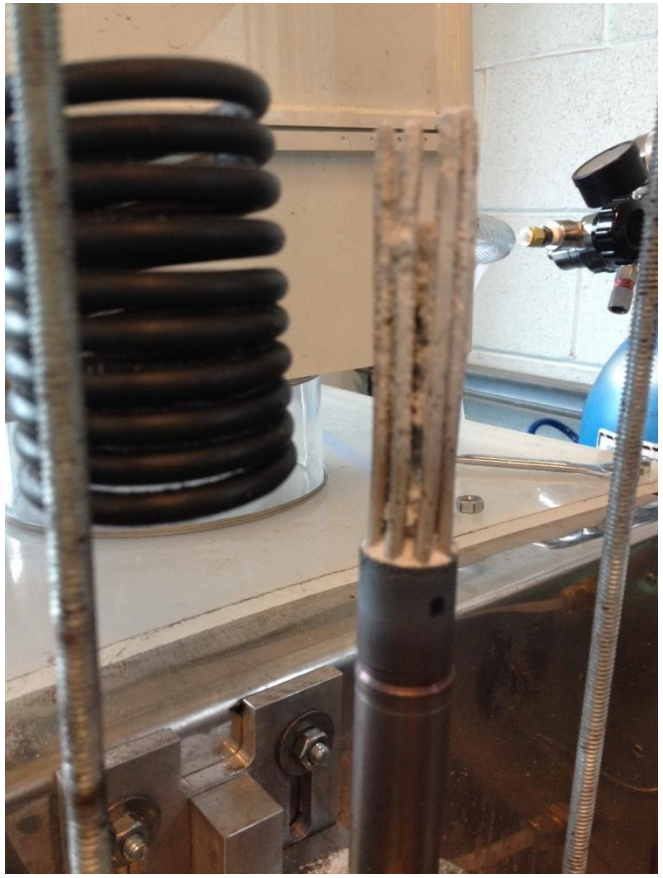


XXX+additive combustion

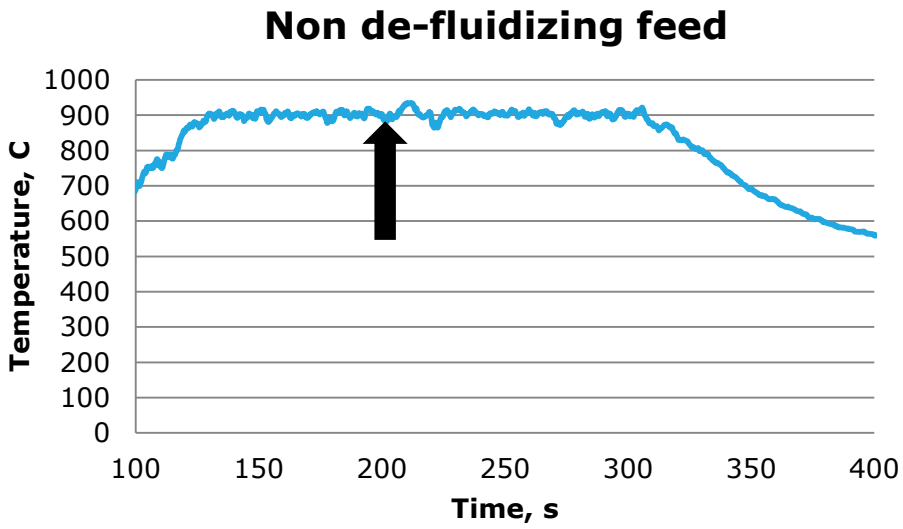
EXPERIMENTAL DATA:

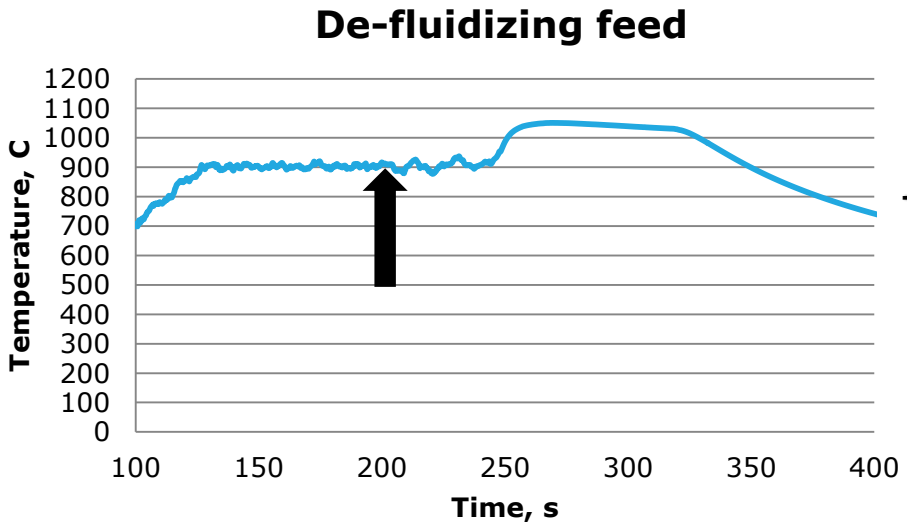
DETECTION OF DE-FLUIDIZATION OF SAND PARTICLES

EFFECT OF FEED COMPOSITION ON DE-FLUIDIZATION



TEMPERATURE VARIATION IN THE FLUIDIZED BED: FEED COMPOSITION





The arrow shows the moment when feed is injected to the fluidized bed zone

CONCLUSION

- FB-TGA;
- Mini Induction Heating FB Reactor;
- Other new mini reactors