Electrification of CO_2 capture process with radiofrequency heating

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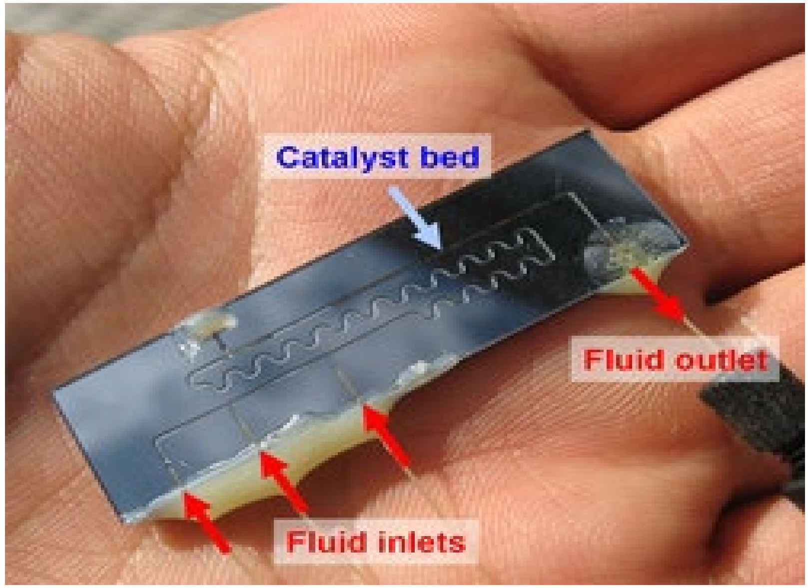
Sustainable Process intensification

Conventional unit

Vs

Intensified unit



- ✓ Significant mass and heat transfer limitations
- ✓ Comparatively low surface to volume ratio
- ✓ Risky and hazardous

- ✓ Good heat and mass transfer rates
- ✓ Very high surface to volume ratio
- ✓ Safe operation
- ✓ Difficult to scale-up

Radiofrequency heating

Induction heating of conductive materials by eddy currents

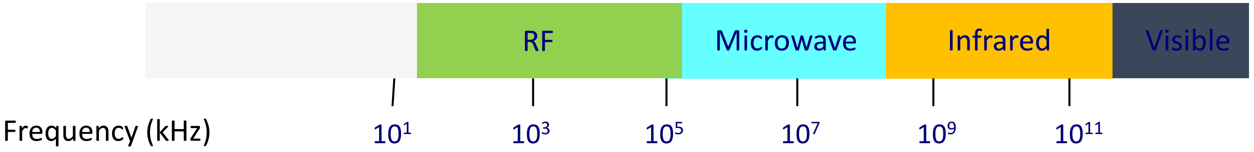
Induction heating

External Magnetic field ⇩ It induces current on conductive material (i.e. steel)

Changing magnetic field with time ⇩ Induction of eddy currents ⇨ Heat

Magnetic materials (Ferrite, magnetite…) ⇨ Heating source

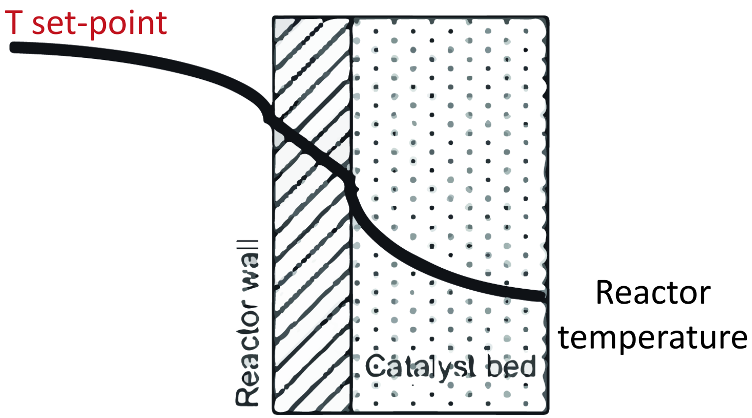
Typical RF heating frequencies: 100-500 kHz



Conventional vs RF heating

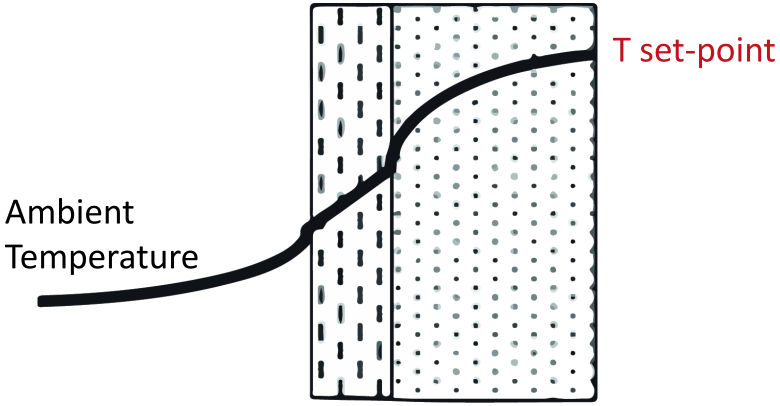
Conventional heating

Inside the reactor



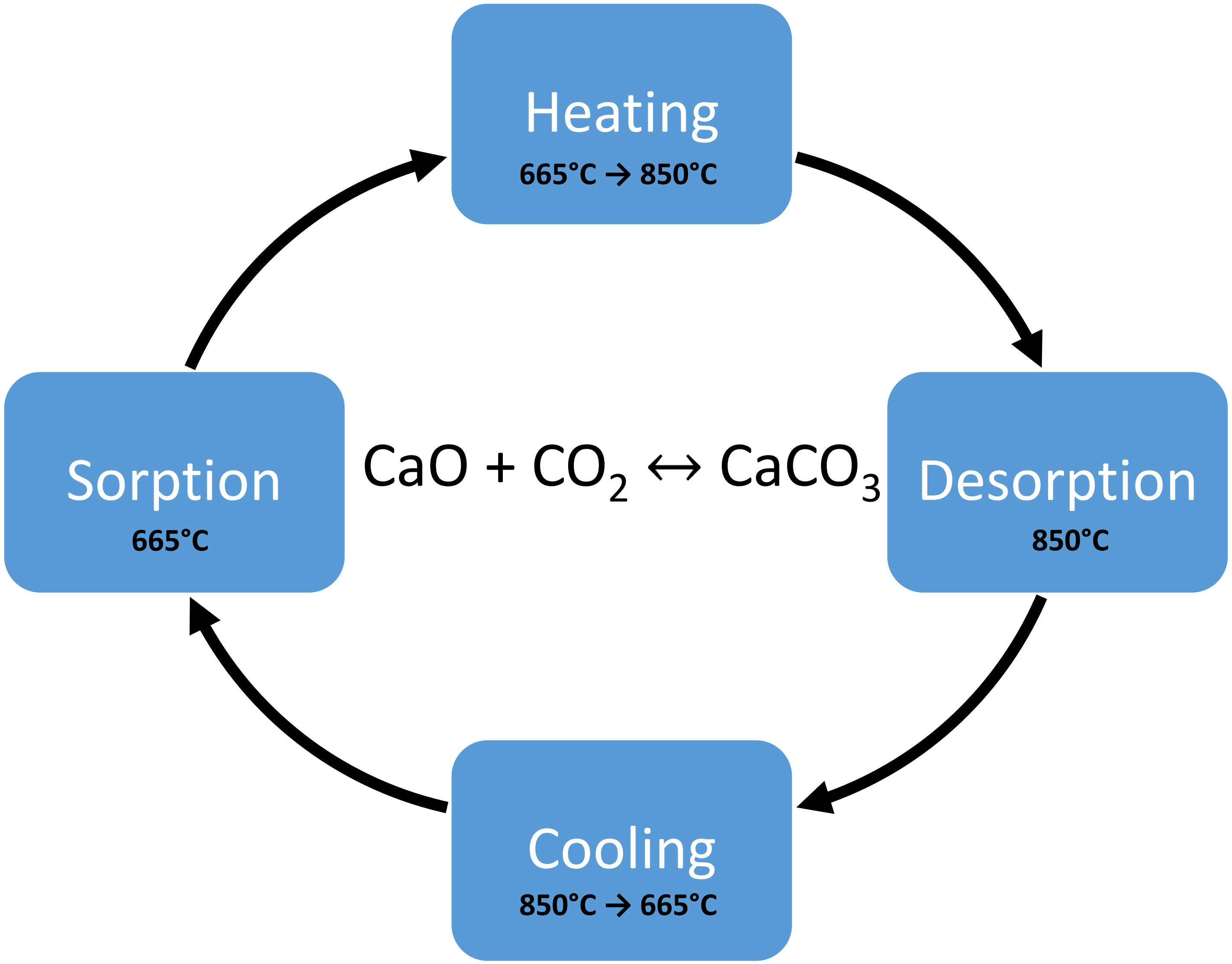
- Heat is supplied from outside to inside (conductive heating through external heat source)
- Inefficient heat transfer - the thermal conductivity of the reactor materials
- Slow heat transfer

Radiofrequency heating

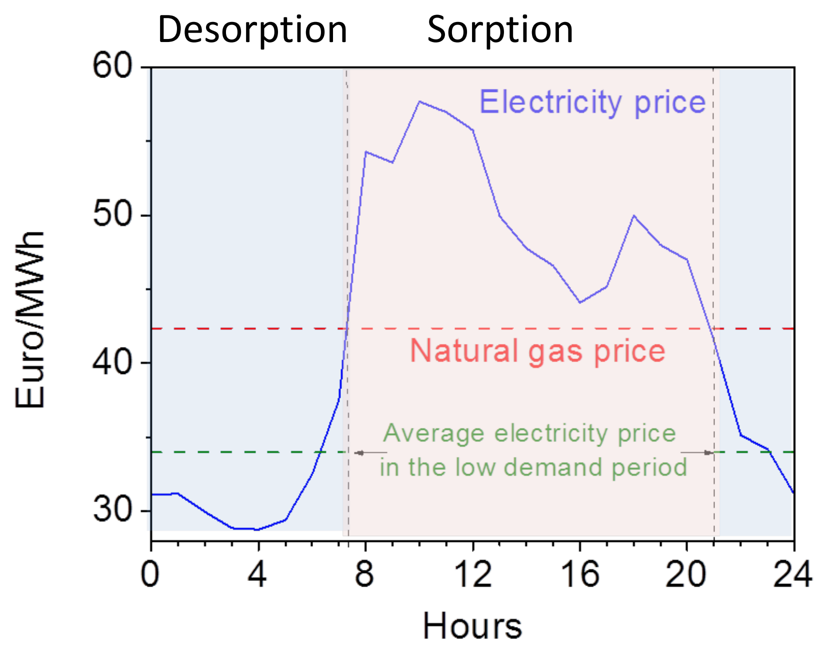


- Heat is transferred inside out
- Avoiding hot spots
- Very high heat transfer
- Separation & transfer of catalysts in continuous operation by external magnet

CO_2 sorption-desorption cycles



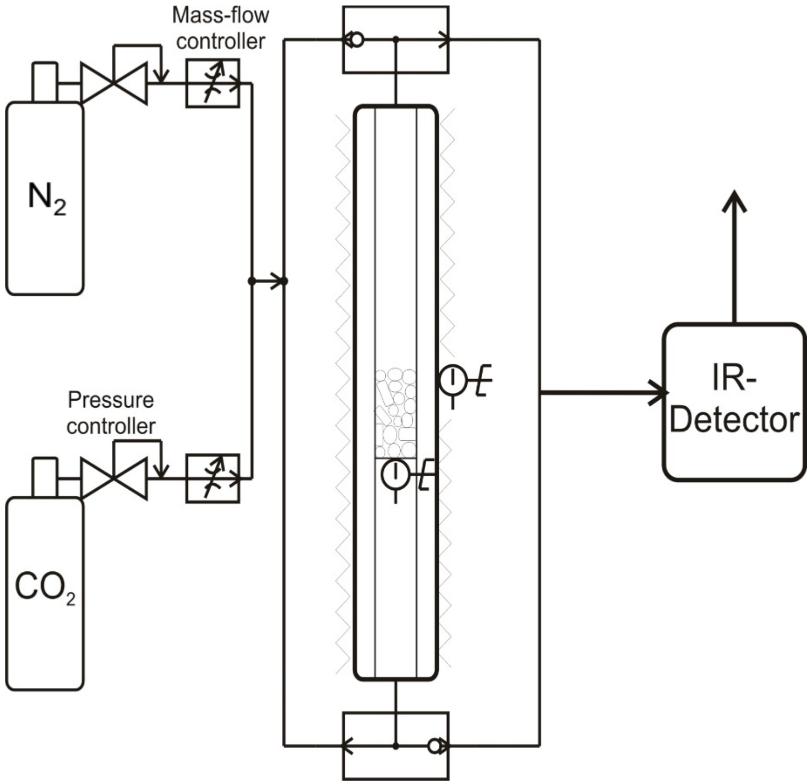
$$CH_4 + H_2O \Leftrightarrow CO + 3H_2$$
$$CO + H_2O \Leftrightarrow CO_2 + H_2$$
$$CH_4 + 2H_2O \Leftrightarrow CO_2 + 4H_2$$



(Udomsirichakorn and Salam, 2014, Sánchez-Biezma et al., 2011, Yancheshmeh et al., 2016, Felice, 2013, Derevschikov et al., 2011, Lysikov et al., 2008)

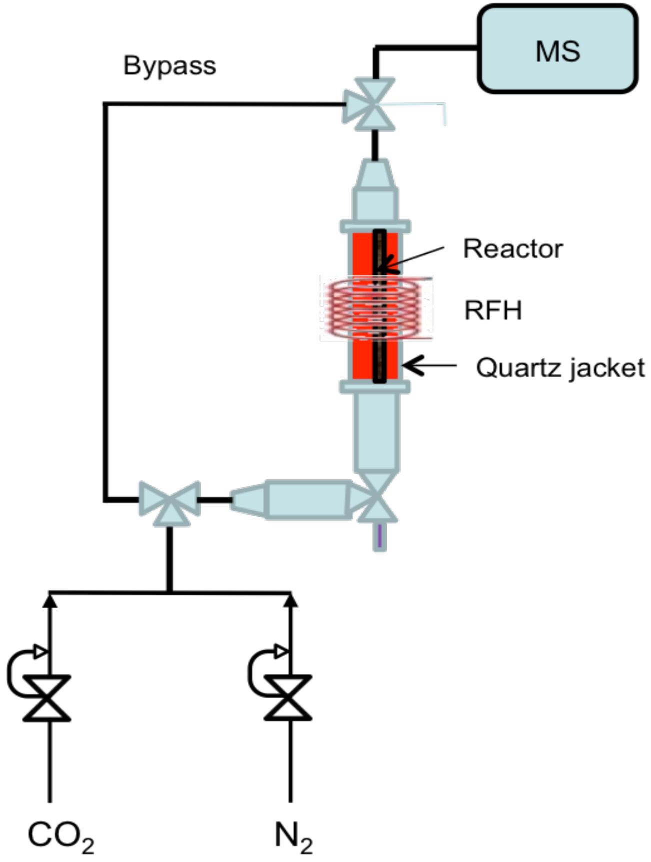
Experimental setup

Conventional heating



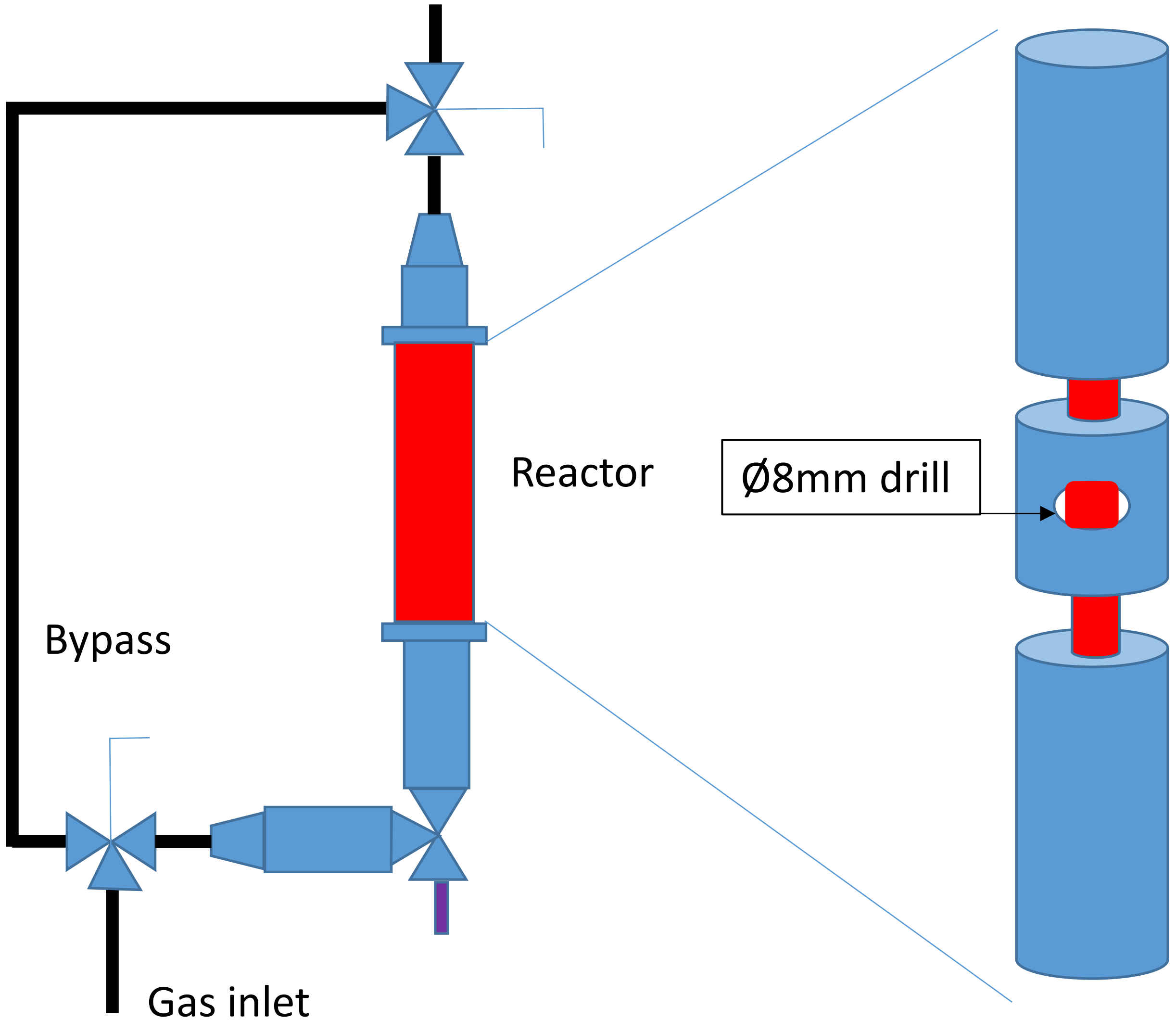
Tubular reactor: CaO looping under conventional heating by nickel-chrome heating element.

RF heating

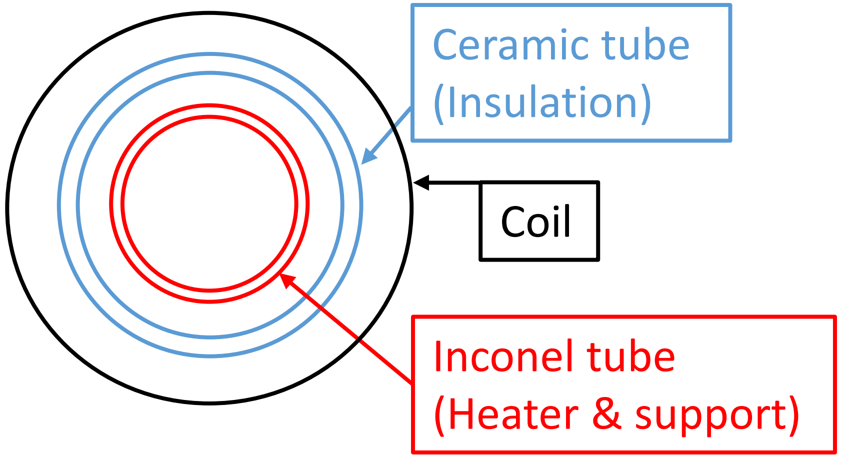


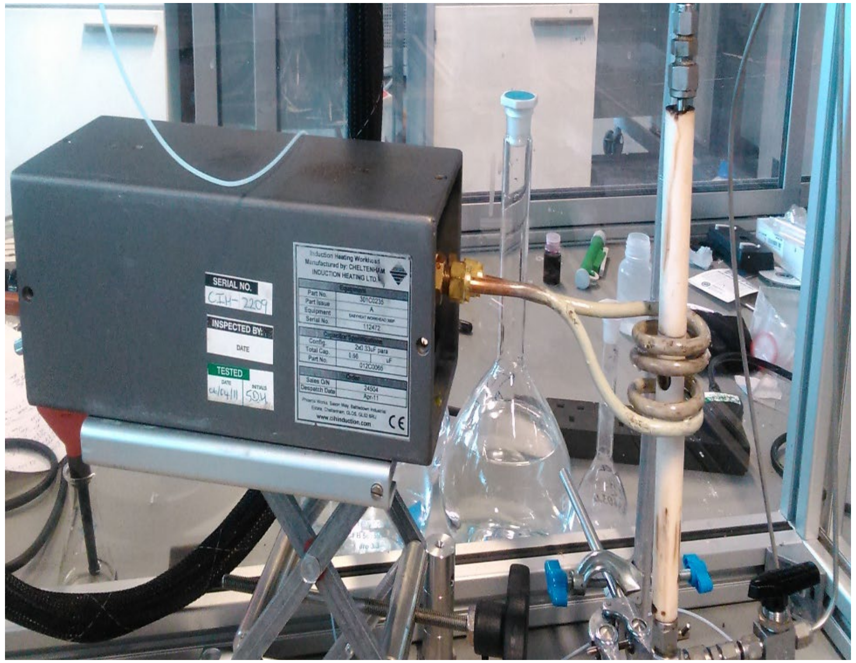
Tubular reactor: CaO looping assisted with RF heating.

Experimental setup



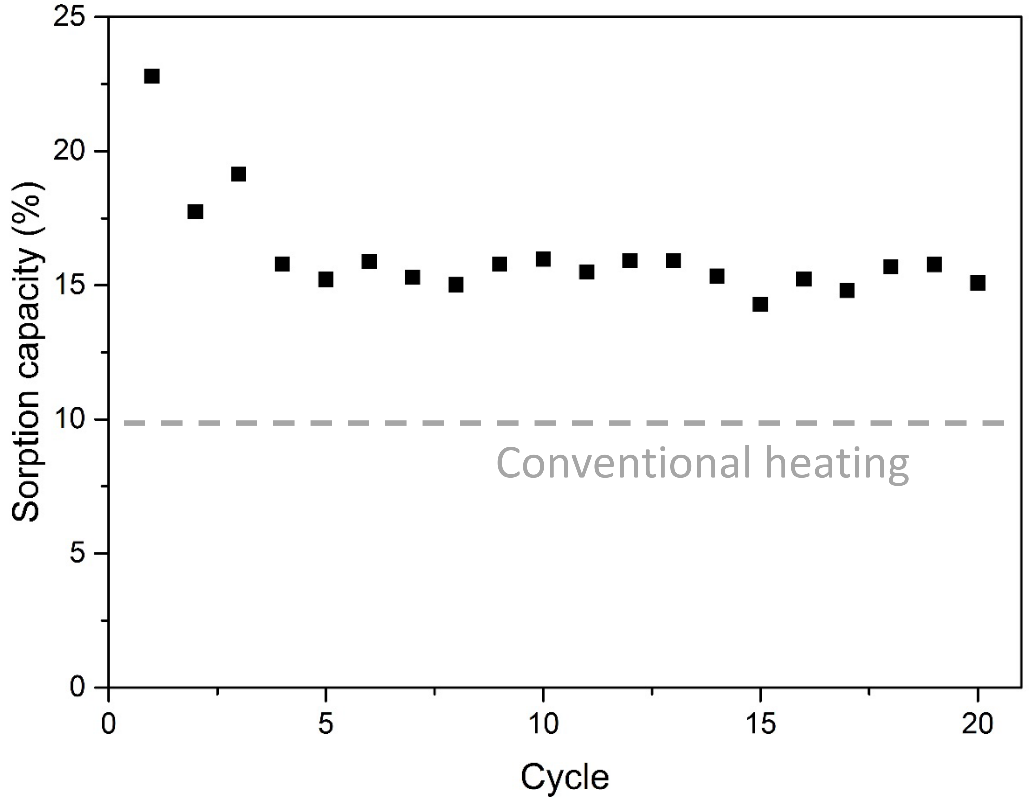
$$Inlet\ Q = 10\ mL/\min; x_{CO_2}=0.30$$



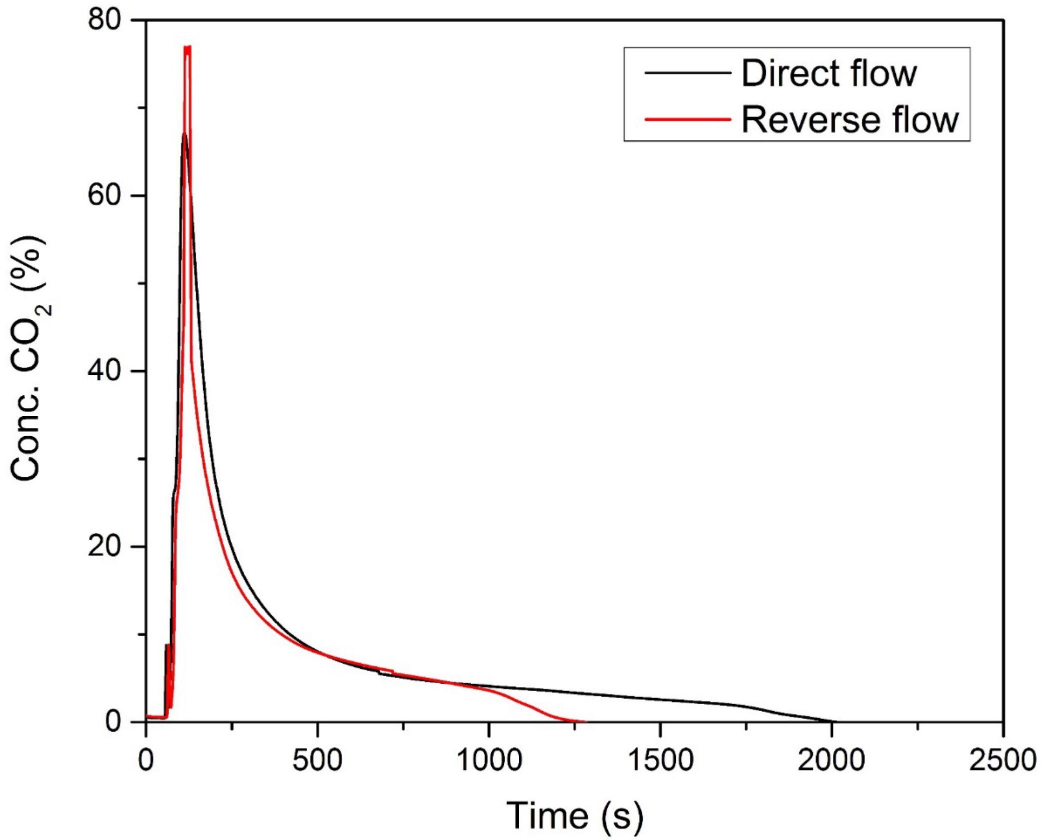


CO_2 sorption-desorption cycles

Sorption capacity



Desorption

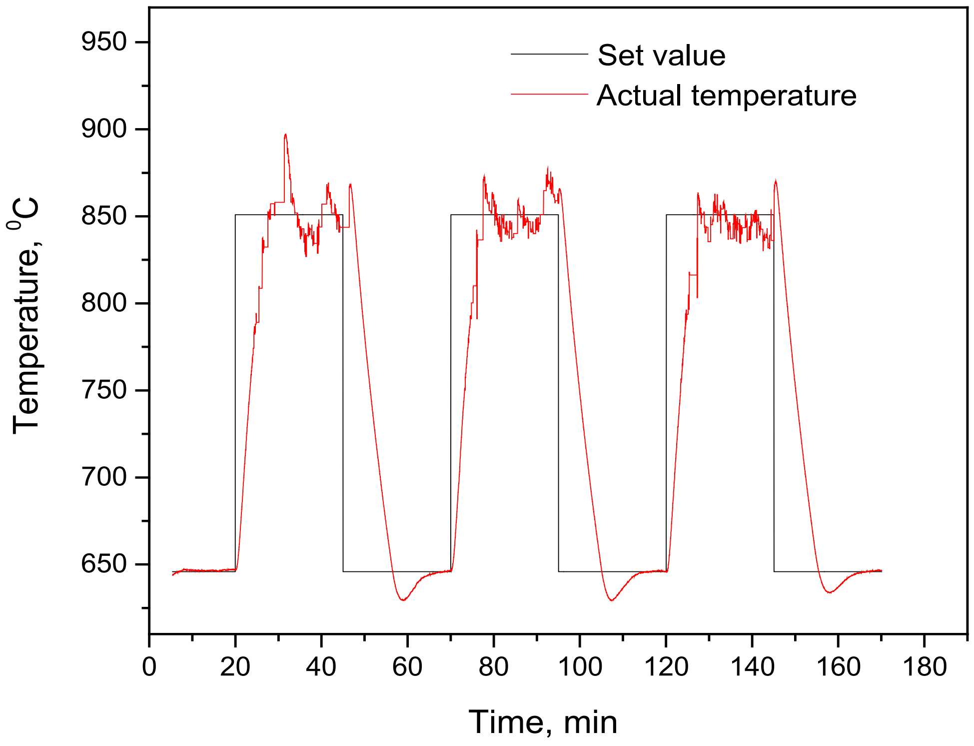


Sotenko et al., Chemical Engineering and Processing 122 (2017) 487–492

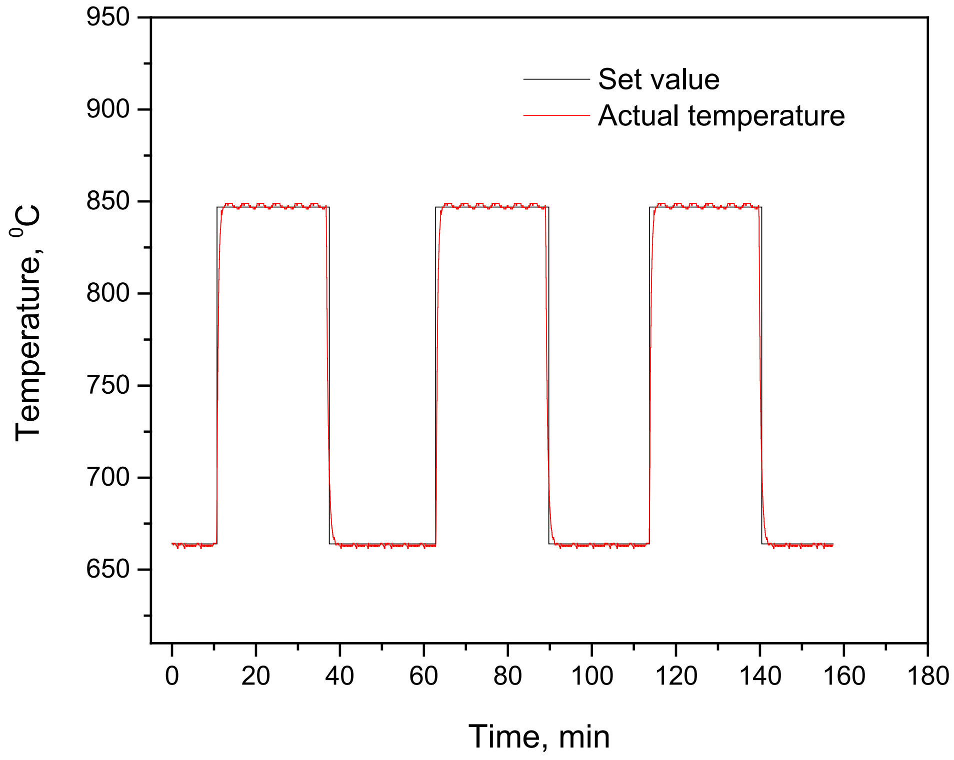
CO_2 sorption-desorption cycles

Type	Conv.	RF
Time (min)	5	1
Energy input (kJ)	11.9	1.6
Heat loss (kJ)	19.7	5.5

Conventional heating



RF heating



Conclusions

- Feasibility of radiofrequency heating for the enhancement of CO_2 capture industrial application.
- Calcium looping cycle time is reduced 21 % using this approach.
- RF heating resulted in 9 times lower heat losses during the heating step.
- The transition time between the CO_2 calcium looping modes was reduced by a factor of three using RF heating.
- The application of RF heating provided substantial energy savings as it drastically reduces the reactor idle time at high temperatures.

Networking

- To develop functional composites combining magnetic materials with CO_2 sorbents to be tested with RF.
- To discuss new sectors with heating needs which could be replaced & enhanced through RF.

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Thanks for your attention