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# Heat transfer challenge and design evaluation for a multi-stage temperature swing adsorption (TSA) process

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# Introduction | Continuous $CO_2$ adsorption, TSA

- Adsorption kinetics fast
  → TSA limitation: Heat exchange (HEX)
- Contactors may be designed as fixed / moving bed
  → poor HEX rates!
- Solution: **Multi-stage bubbling fluidized bed** (BFB) columns with counter-current flow of gas & solids
- Considered particles: Geldart Type B

# Introduction | Continuous $CO_2$ adsorption, TSA

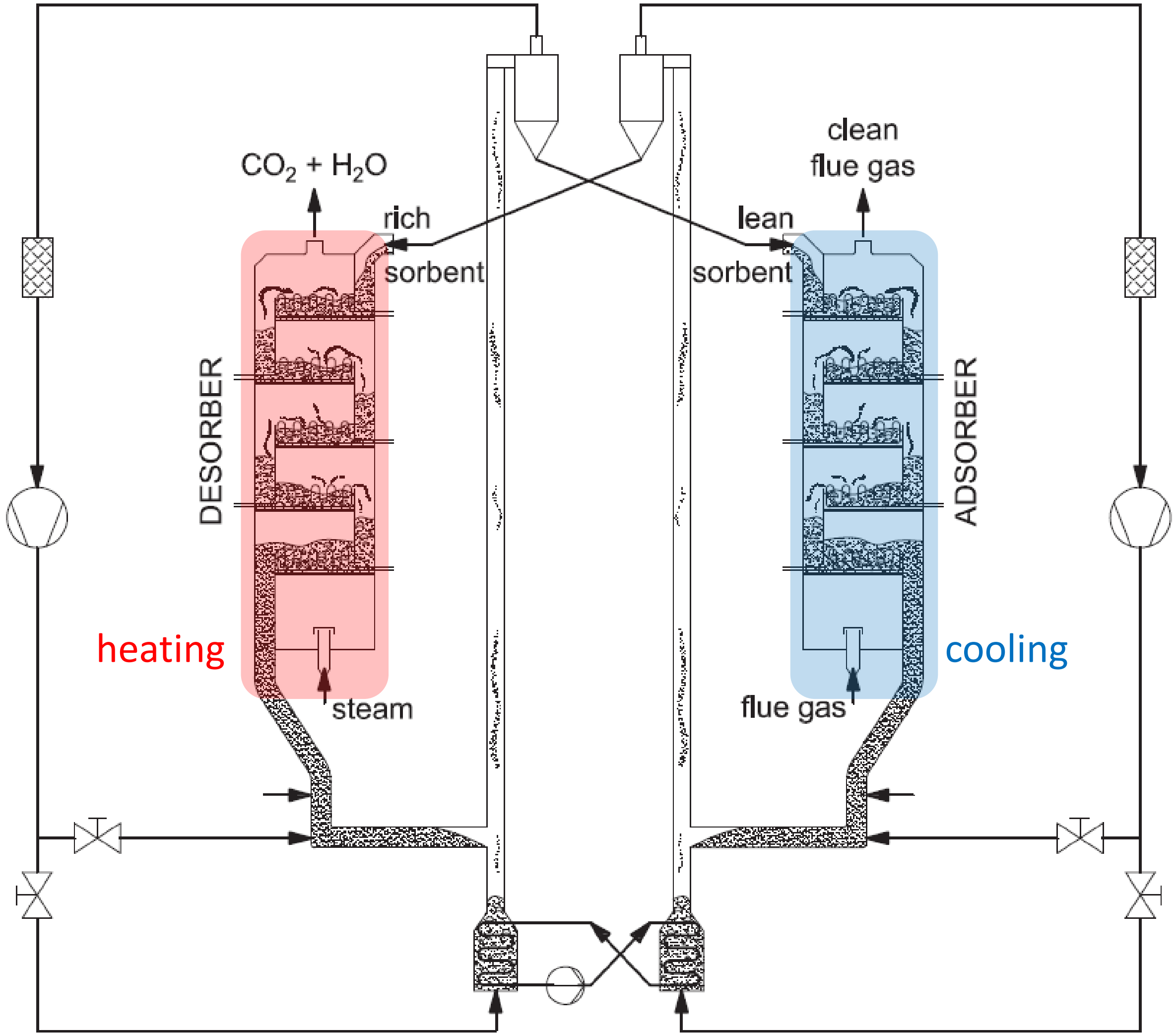


*Fig. 1. Principle of continuous TSA*

# Introduction | Continuous $CO_2$ adsorption, TSA

- Heat exchanger design: **tube bundles**
- Design parameters
  - Tube diameter ($d_t$)
  - Tube spacing ($p_h$, $p_v$)
  - Tube arrangement
  - Tube alignment
  - Tube surface

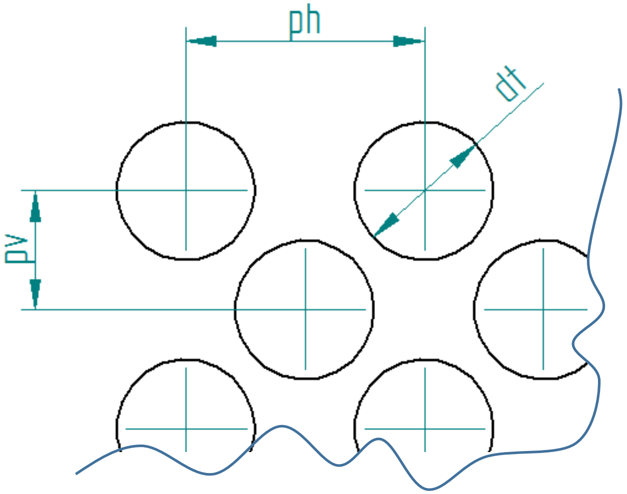


*Fig. 2. Characteristical tube bundle design parameters*

# Problem definition | Pt.1

- Restricted BFB pressure drop $\Delta p_{fb}$ | sf.gas velocity $U$
  → Limitation of installable HEX surface ($A_{HEX} \sim \Delta p_{fb} \sim 1/h$)
- Trade-off 1: $U$ | $h$
- Trade-off 2: Heat exchanger design | $h$

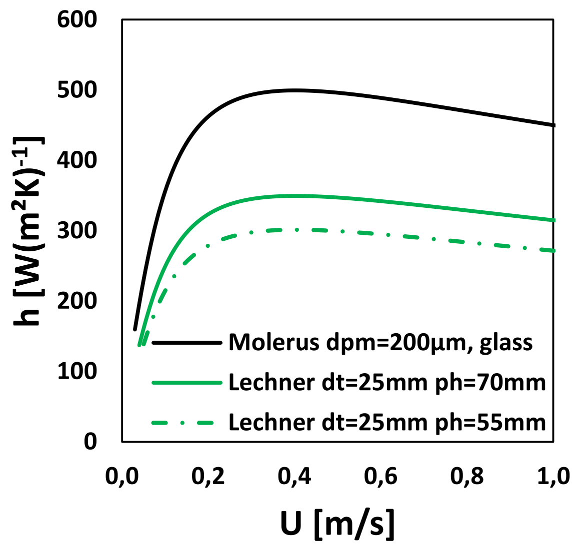


*Fig. 3. Calculated HEX rates for single tube (Molerus et al., 1995) and selected tube bundles (Lechner et al., 2013)*

# Problem definition | Pt.2

- Resistance to particle flow
  - →Tube alignment
  - →Residence time dist. (RTD)
- Scale-up
  - →Forces to tubes
  - →Durability
- Maintainability

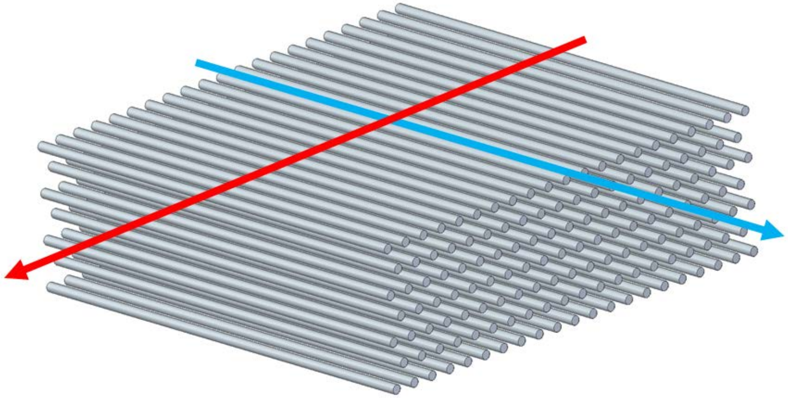

*Fig. 4. Horizontal tubes and particle flow possibilities (red = transversal, blue = longitudinal)*

# Practical work

- TSA needs most accurate heat exchanger design for efficient operation

- Evolved calculation models for **single tube** heat transfer rate available → **significant quantity-differences**
  (e.g. Martin, Molerus et al., …)

→ HEX measurements

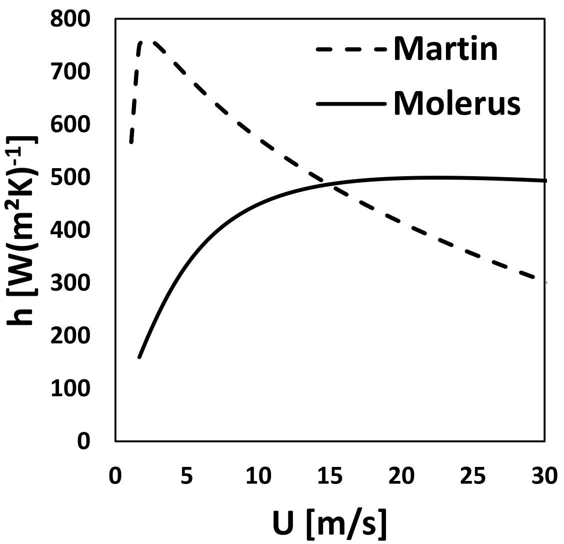


*Fig. 5. HEX-rate comparison*

# HTMT | Heat transfer measurement test device

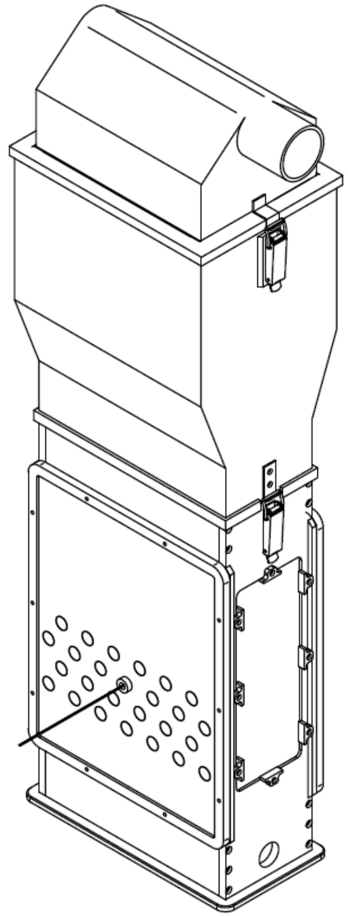

*Fig. 6. HTMT construction assembly*

*Fig. 7. HTMT lab unit*

# Conclusion

- Adsorption kinetics fast → HEX limits TSA efficiency
- TSA heat exchanger design highly dependent on:
  - Restricted fluidized bed pressure drop
  - Intended superficial gas velocity
  - Scalability
  - Durability
  - Maintainability
- Heat transfer measurement test device successfully put into operation

# Outlook

- HEX measurements with various
  - Bulk materials
  - Heat exchanger designs
- Investigate effect of tube bundles to residence time distribution (RTD) of particles
- Determine optimal tube bundle design for TSA

# Questions & suggestions are appreciated!

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