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Fluid-dynamic study on a multi-stage fluidized bed column for continuous CO₂ capture via temperature swing adsorption

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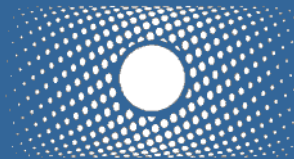
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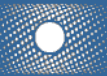
Fluid-dynamic study on a multi-stage fluidized bed column for continuous CO₂ capture via temperature swing adsorption

Design study on internal downcomers

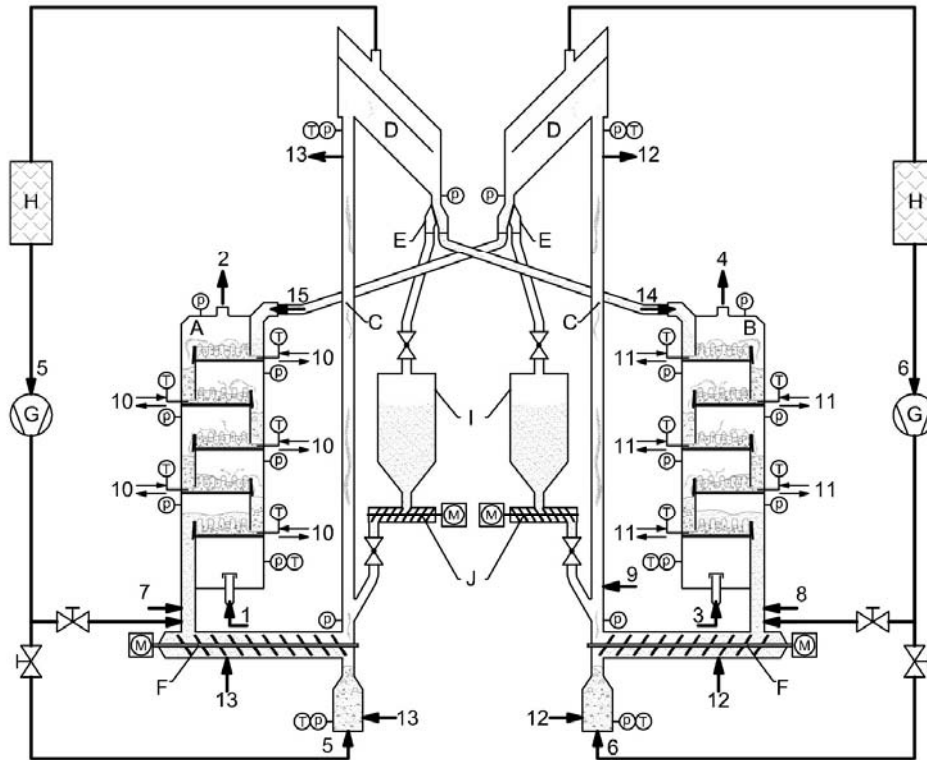
E. Zehetner, G. Schöny, J. Fuchs, T. Pröll, H. Hofbauer

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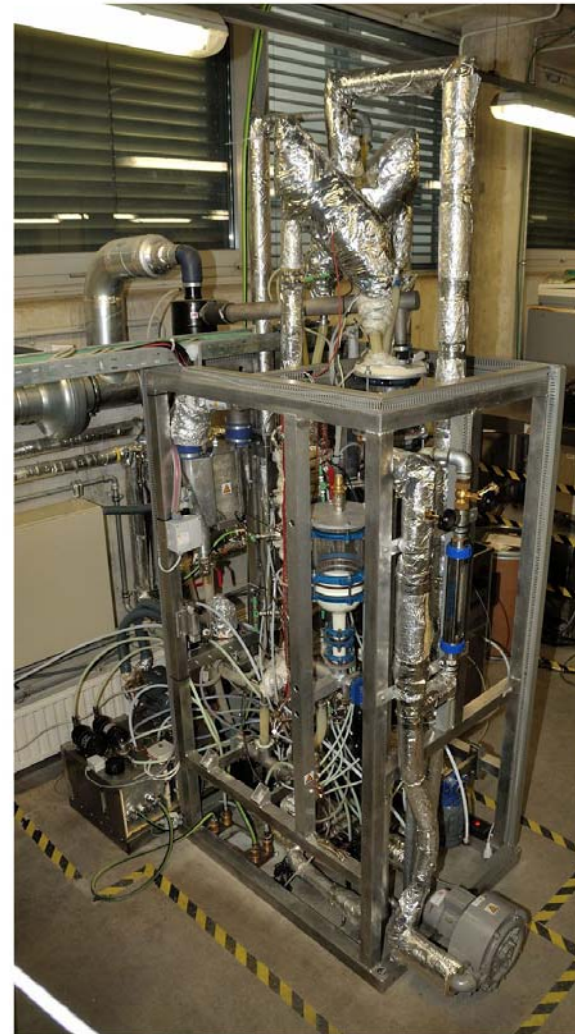


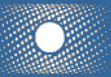


The temperature swing adsorption process

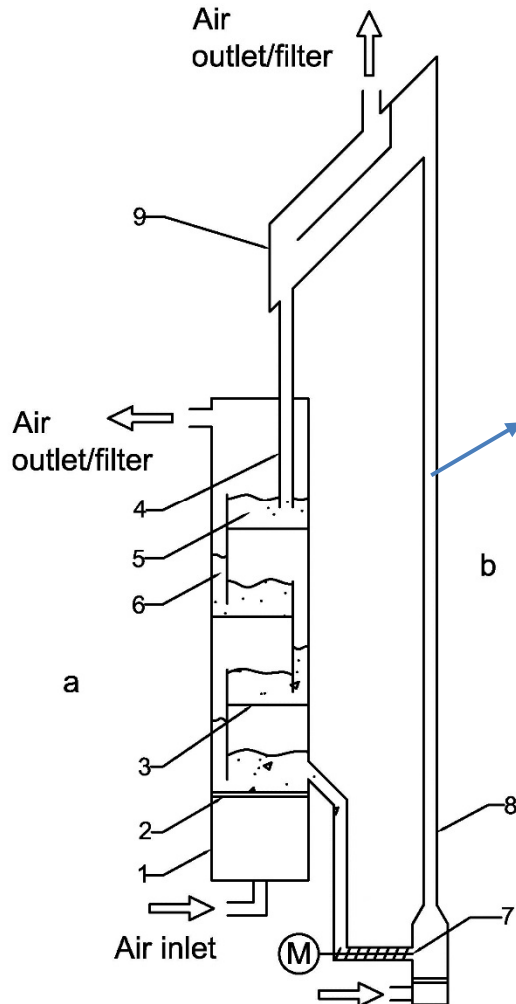


- | | | |
|-------------------------------|---|--|
| A ... adsorber | 1 ... (synthetic) flue gas | 11... desorber stage heating |
| B ... desorber | 2 ... clean flue gas | 12... transport line cooling |
| C ... riser | 3 ... stripping gas (N ₂ , steam) | 13... transport line heating |
| D ... gas-solids separator | 4 ... CO ₂ enriched stripping gas | 14... CO ₂ loaded adsorbent |
| E ... solids directing flap | 5 ... recirculation gas | 15... regenerated adsorbent |
| F ... bottom screw conveyor | 6 ... recirculation gas | |
| G ... recycle-gas blower | 7 ... purge gas (N ₂ , CO ₂) | ⊕ ... pressure sensor |
| H ... particle filter | 8 ... purge gas (N ₂ , steam) | ⊖ ... temperature sensor |
| I ... adsorbent storage | 9 ... dilution stream (N ₂) | Ⓜ ... driving motor |
| J ... adsorbent feeding screw | 10... adsorber stage cooling | |





Multistage fluidized bed cold flow model



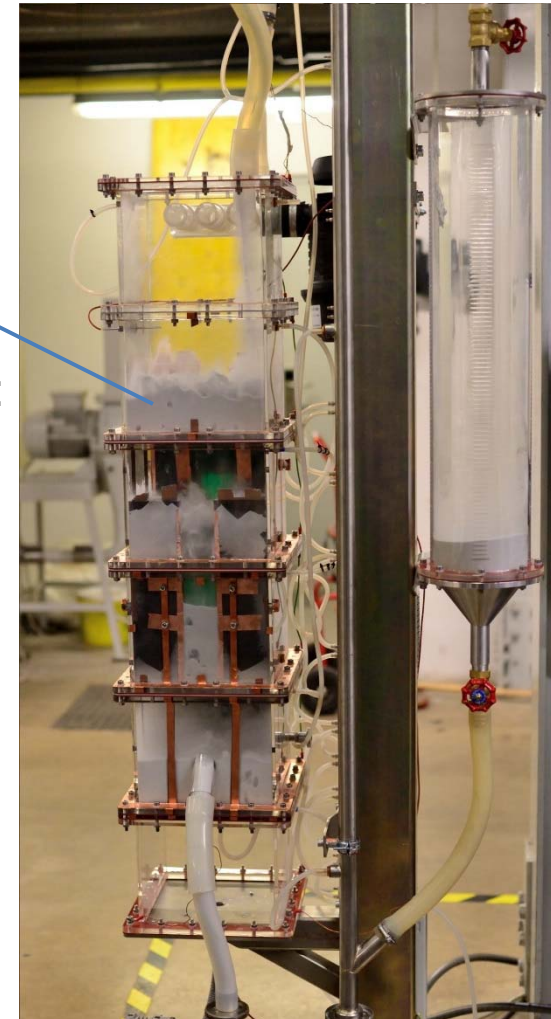
Bed material:

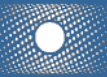
- Glas beads (Geldart B)

Max. solids circulation rate:

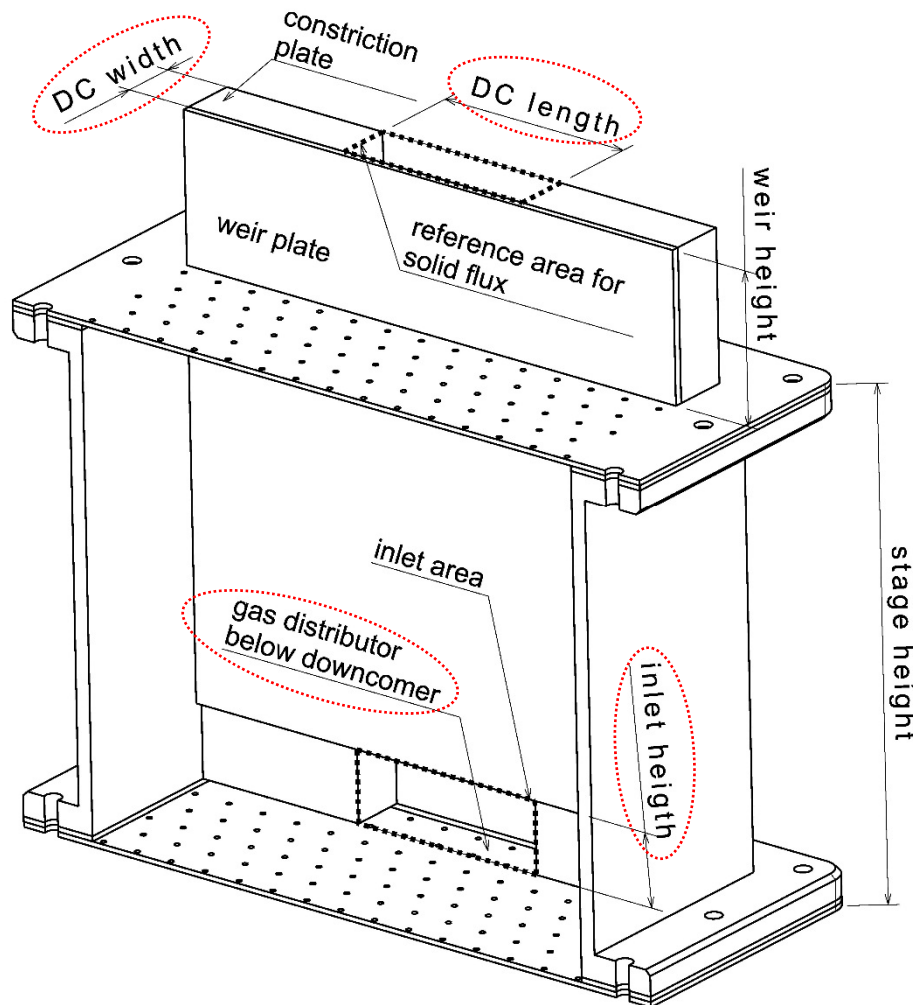
- 230 kg/h

- a... Multistage column
- b... Solids recirculation system
- 1... Windbox
- 2... Bottom gas distributor
- 3... Stage gas distributor
- 4... Solids inlet
- 5... Fluidized bed
- 6... Downcomer
- 7... Screw conveyor
- 8... Pneumatic riser
- 9... Gas-solids separator





Internal downcomer design



- Variation of:
- Downcomer length
 - Downcomer width
 - Inlet height
 - Gas distributor design

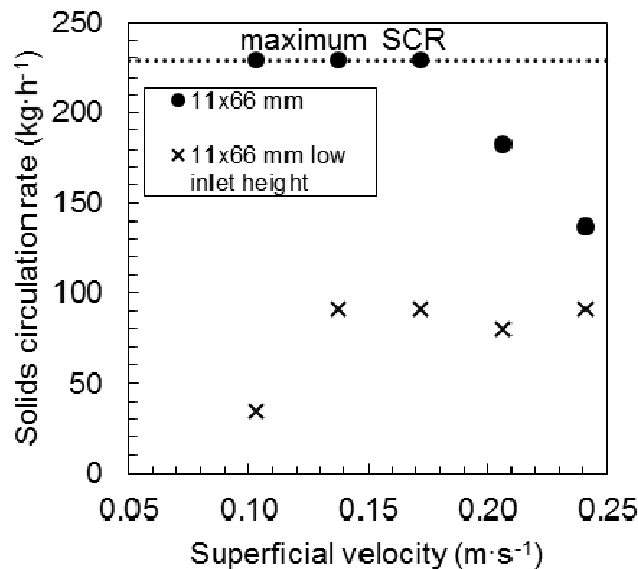
$$\text{Solids flux} = \frac{\text{Solid circulation rate}}{\text{Downcomer cross section}}$$

Downcomer variations

➤ Initial experiments

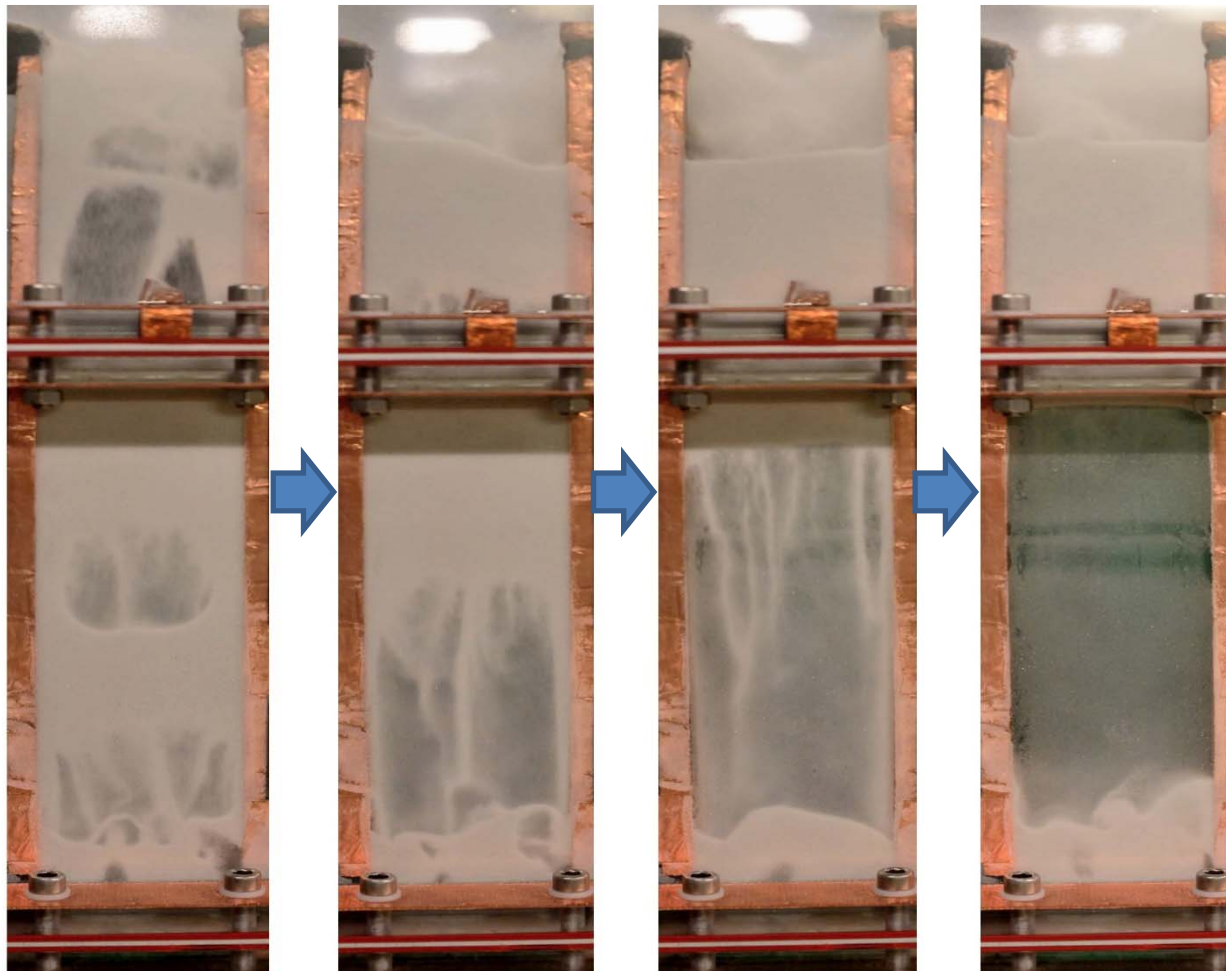
| Cross section | 220 x 22 | ➔ | 220 x 16.5 | ➔ | 220 x 11 |
|---------------------------------|------------------------|---|------------------------|---|------------------------|
| Reached solids circulation rate | 230 kg/h | | 230 kg/h | | 230 kg/h |
| Reached solids flux | 13 kg/m ² s | | 18 kg/m ² s | | 26 kg/m ² s |

➤ Reduction of the downcomer length



| Cross section | 66 x 11 low inlet | ➔ | 66 x 11 |
|---------------------------------|--------------------------|---|------------------------|
| Reached solids circulation rate | 91 kg/h | | 230 kg/h |
| Reached solids flux | 35 kg/m ² s | | 88 kg/m ² s |

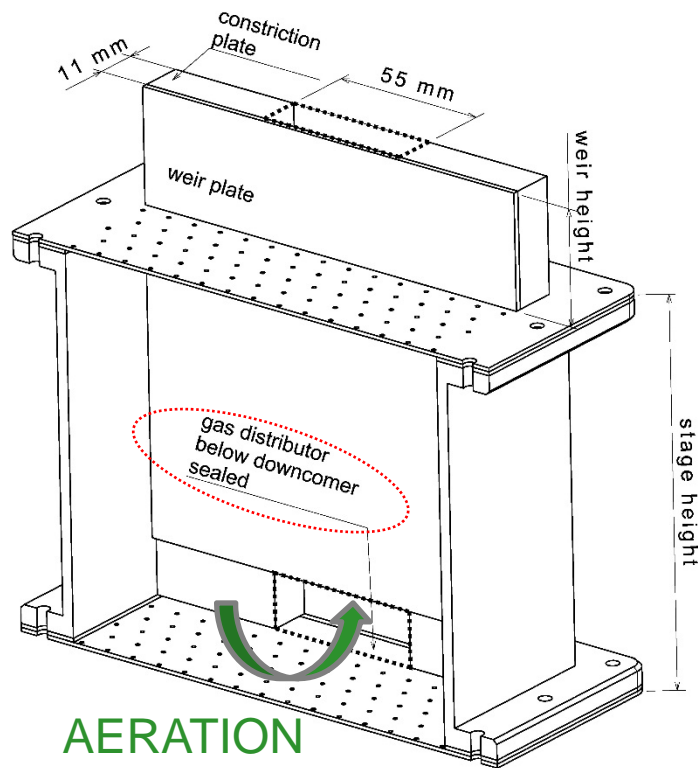
Blockage of the downcomer



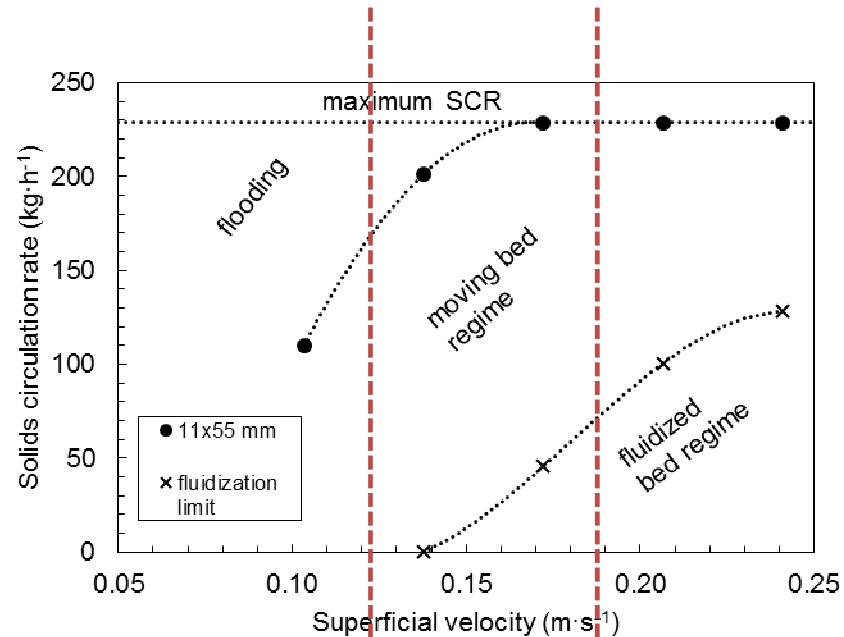


Downcomer variations

➤ Sealing of the orifices below the downcomer section



AERATION
GAS



Cross section

11 x 55

Reached solids
circulation rate

230 kg/h

Reached solids flux

105 kg/m²s





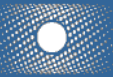
Downcomer variations

- Summary of all investigated downcomer designs

| Superficial velocity (m·s ⁻¹) | 22x220x30_o | 16.5x220x30_o | 11x220x30_o | 11x66_30_o | 11x66_15_o | 11x55_30_o | 11x55_30_p | 11x55_30_s | 11x27.5_30_s | 22x27.5_30_o |
|--|---|---------------|-------------|------------|------------|------------|------------|------------|--------------|--------------|
| | Solid flux (kg·m ⁻² ·s ⁻¹) | | | | | | | | | |
| 0.10 | 13* | 18* | 26* | 88* | 13 | 44 | 74 | 50 | 21 | 37 |
| 0.14 | 13* | 18* | 26* | 88* | 35 | 0 | 36 | 92 | 42 | 41 |
| 0.17 | 13* | 18* | 26* | 88* | 35 | 0 | 32 | 105* | 63 | 37 |
| 0.21 | 13* | 18* | 26* | 70 | 31 | 0 | 21 | 105* | 69 | 32 |
| 0.24 | 13* | 18* | 26* | 53 | 35 | 0 | 16 | 105* | 76 | 28 |

* Maximum circulation rate of transport system reached

Downcomer in moving bed regime at maximum flux



Conclusions

- Reduction of the solids flux for lower inlet height
- Highest solids fluxes measured for downcomers in the moving bed regime
- Limitation for moving bed downcomers by stage height
- Also high fluxes for downcomers in the fluidized bed regime
- Limitation for fluidized downcomers by slugging and blockage
- Slugging can be avoided by downcomer size or gas distributor design

Any Questions?

