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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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Fluid-dynamic study on a multi-stage fluidized bed column for continuous CO_2 capture via temperature swing adsorption

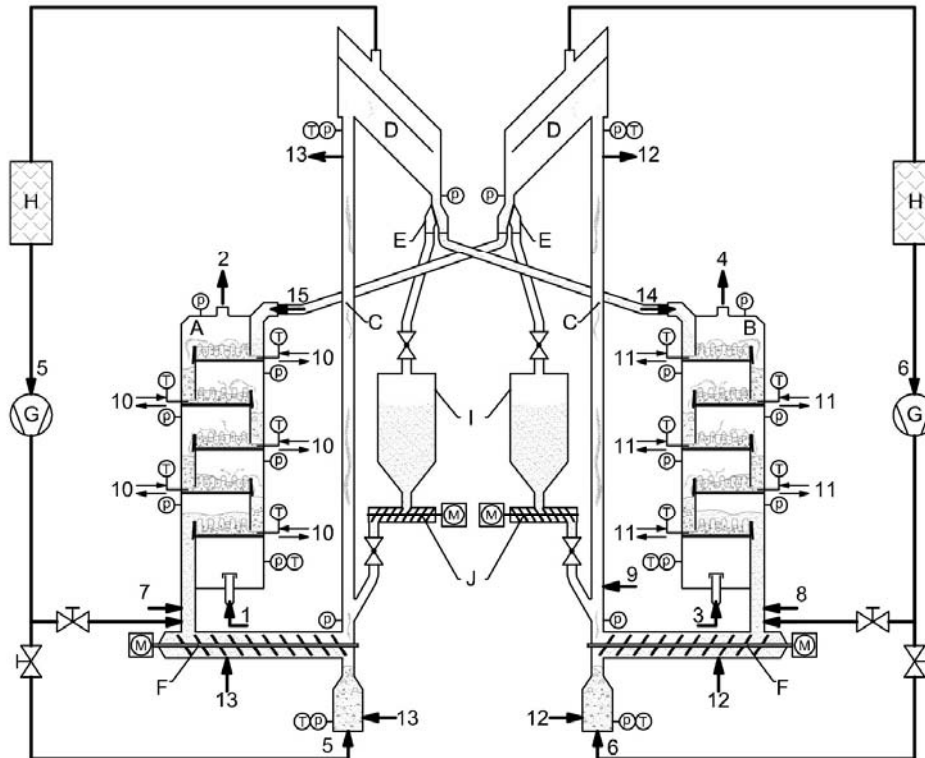## Design study on internal downcomers

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

Fluid-dynamic study on a multi-stage fluidized bed column for continuous CO$_2$ capture via temperature swing adsorption
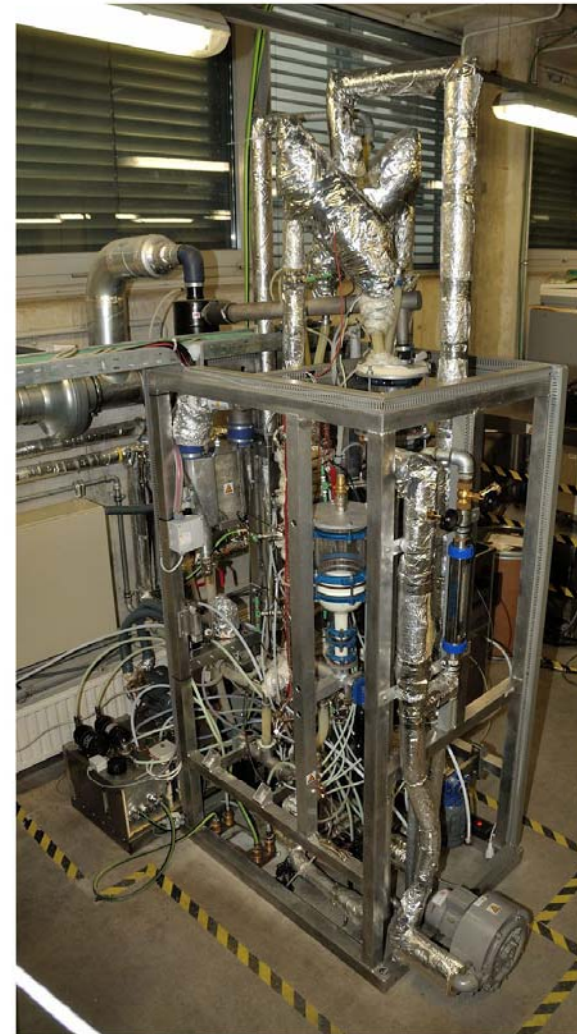
Institute of Chemical Engineering
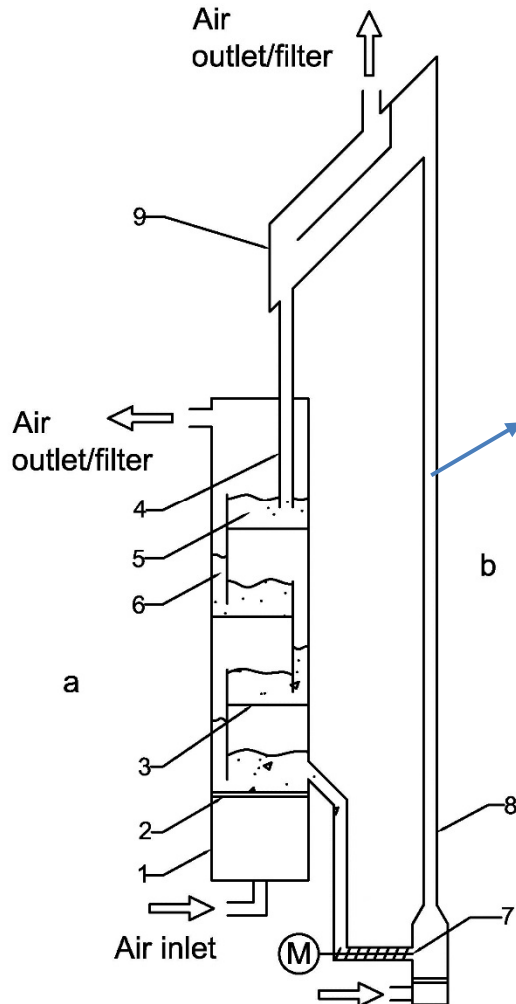Future Energy Technology
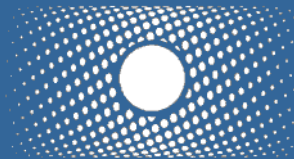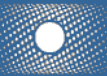
The temperature swing adsorption process

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	

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Multistage fluidized bed cold flow model

Air outlet/filter

9

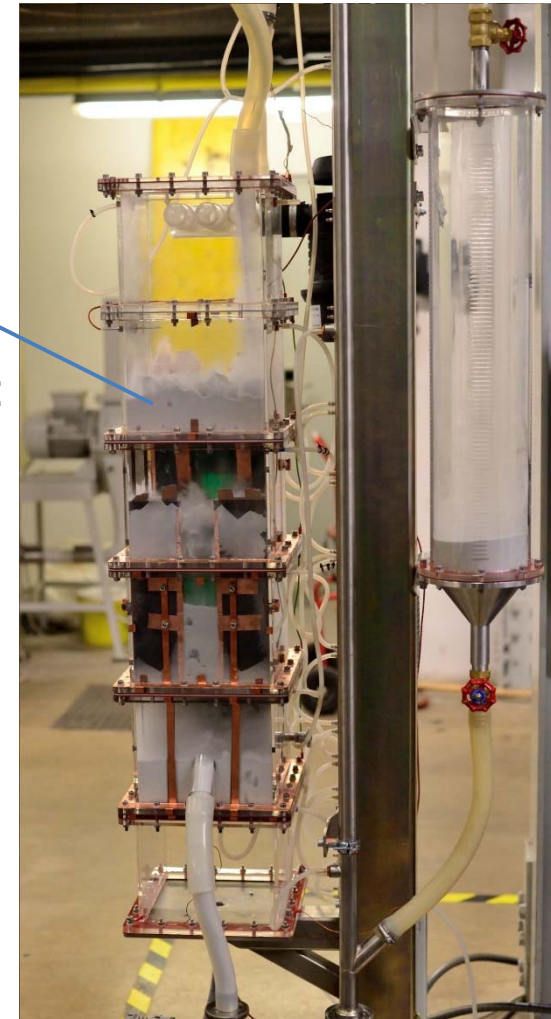Air outlet/filter

4

5

6

a

3

2

1

Air inlet

b

8

7

M

Bed material:
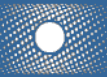- Glas beads (Geldart B)

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 seperator

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Internal downcomer design
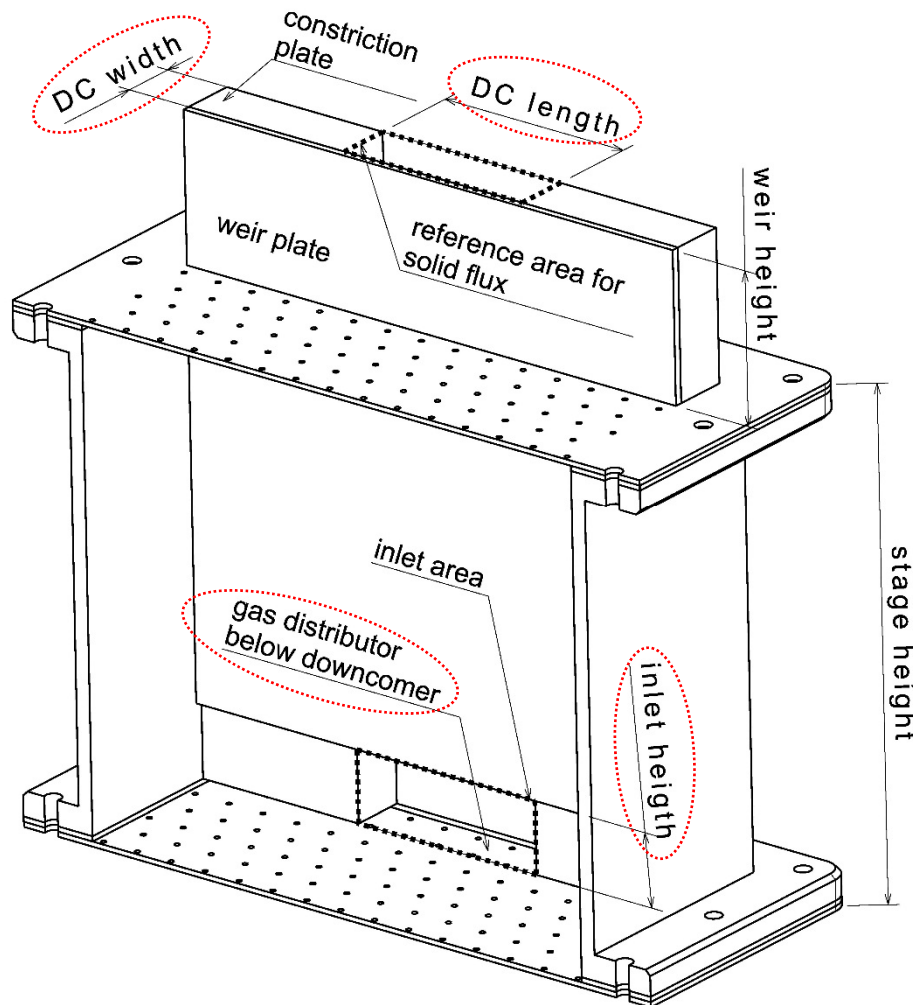
- ➢ Variation of:

- – Downcomer lenght

- – Downcomer width

- – Inlet height

- – Gas distributor design

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

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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/m²s	18 kg/m²s	26 kg/m²s

➢ Reduction of the downcomer lenght
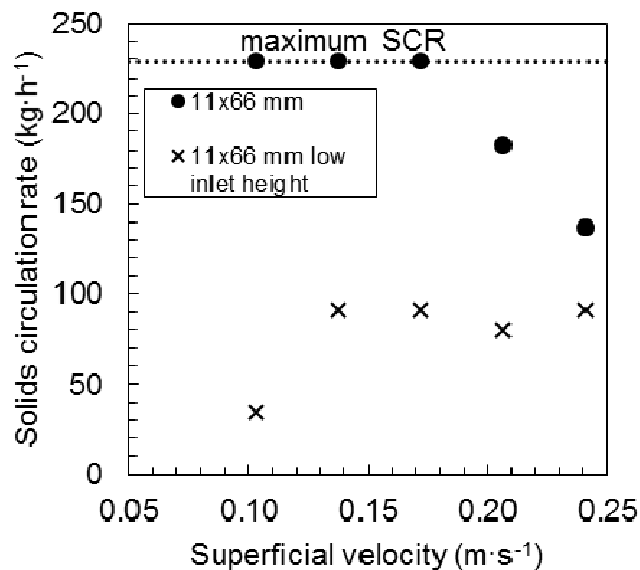
Cross section	**66 x 11 low inlet**	**66 x 11**
Reached solids circulation rate	91 kg/h	230 kg/h
Reached solids flux	35 kg/m²s	88 kg/m²s

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Blockage of the downcomer

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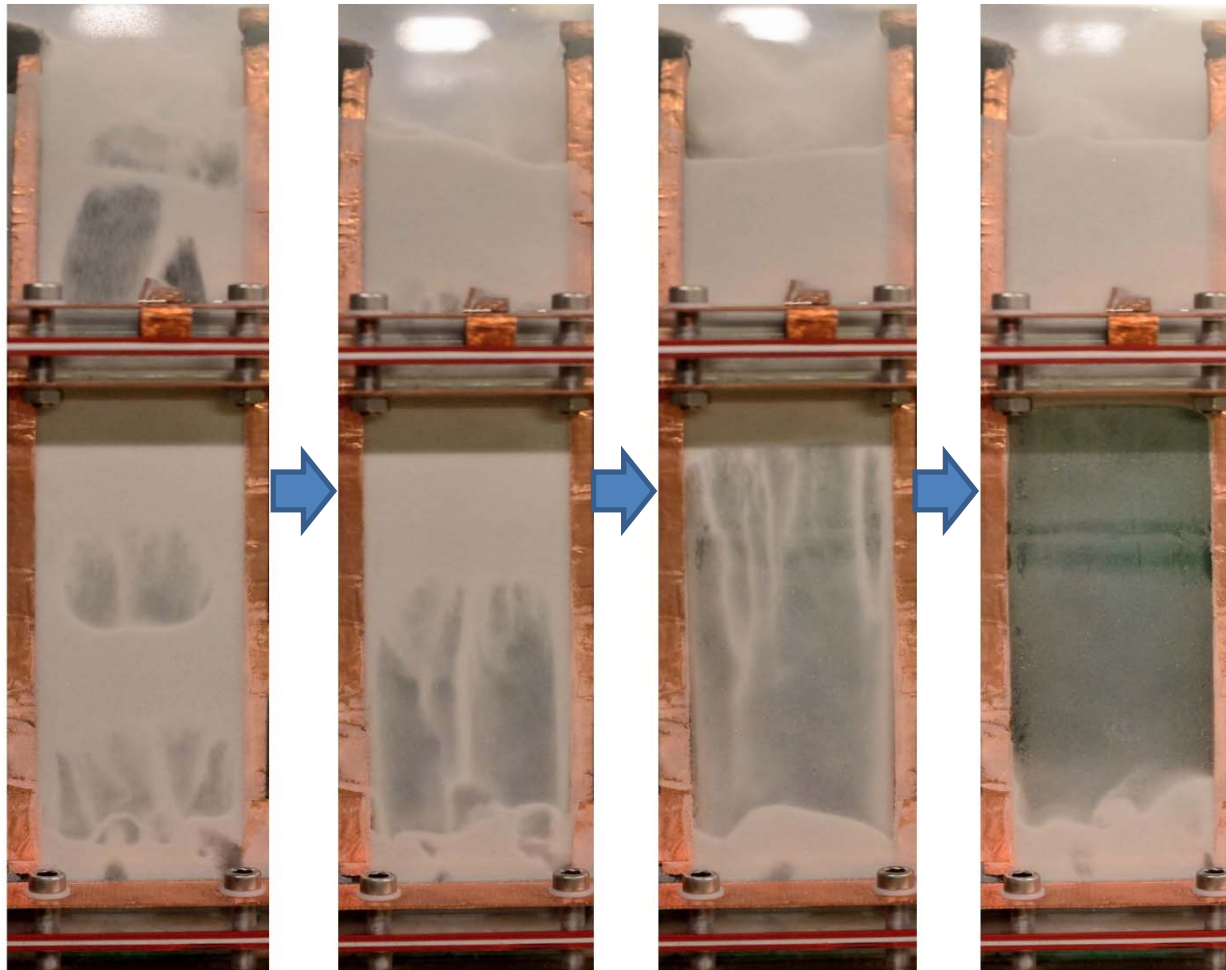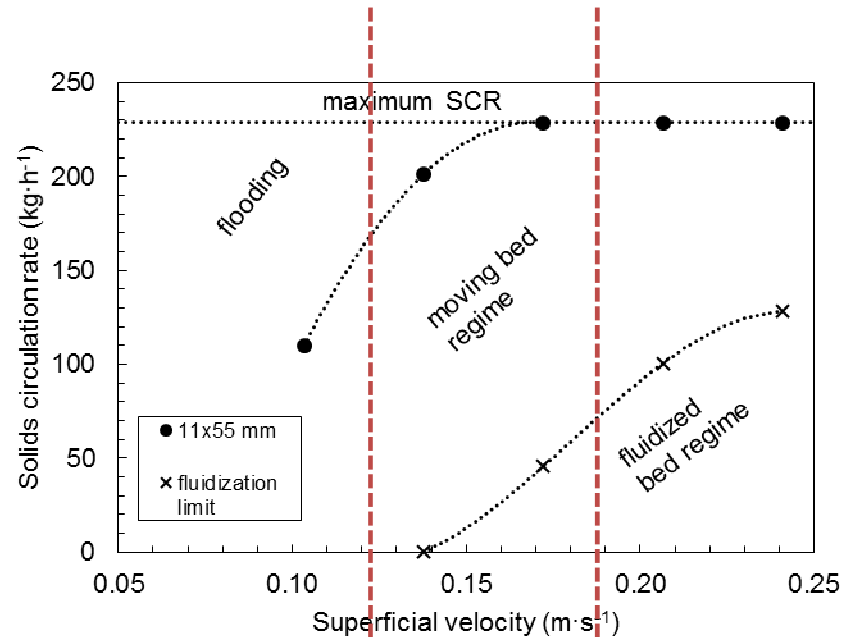
Downcomer variations

➢ Sealing of the orifices below the downcomer section
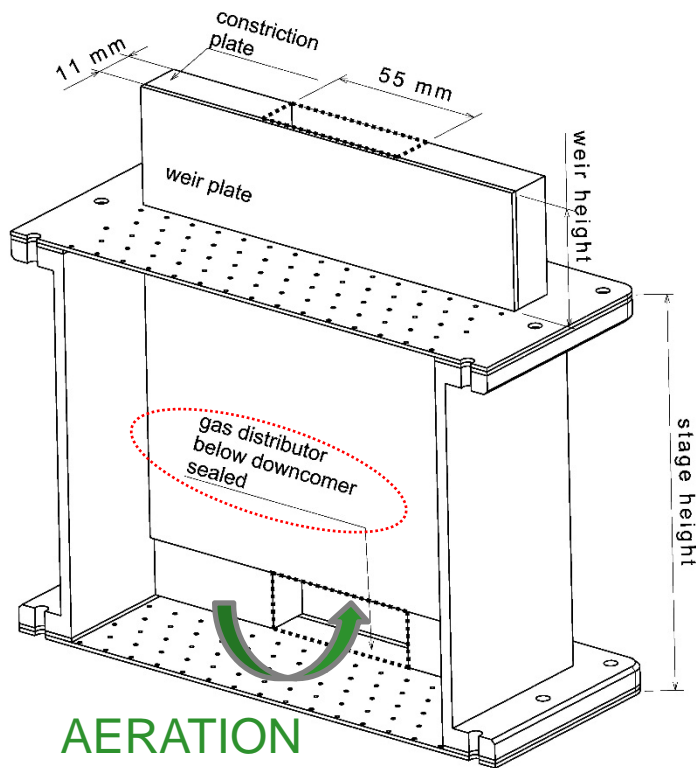
Cross section	11 x 55
Reached solids circulation rate	230 kg/h
Reached solids flux	105 kg/m²s

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Downcomer variations

> Summary of all investigated downcomer designs

Superficial velocity ($m \cdot s^{-1}$)	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 ($kg \cdot m^{-2} s^{-1}$)				
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

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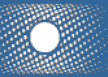
Conclusions

➢ 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?