

# Design and proof of concept of a continuous pressurized multistage fluidized bed unit for deep removal of sour gas using adsorption

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# Agenda

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Introduction



Background  
and goals



Pilot plant  
design



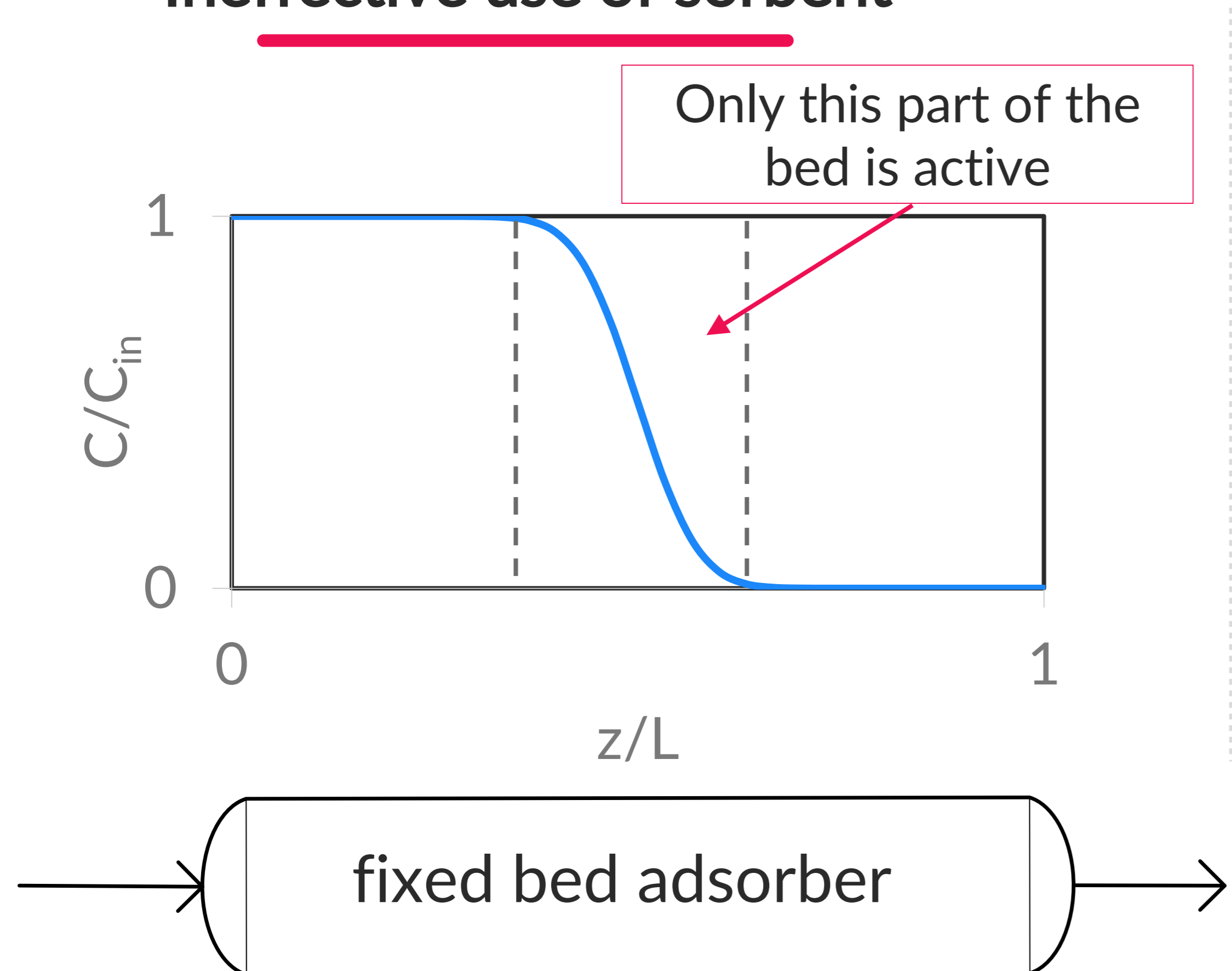
Results and  
proof of concept



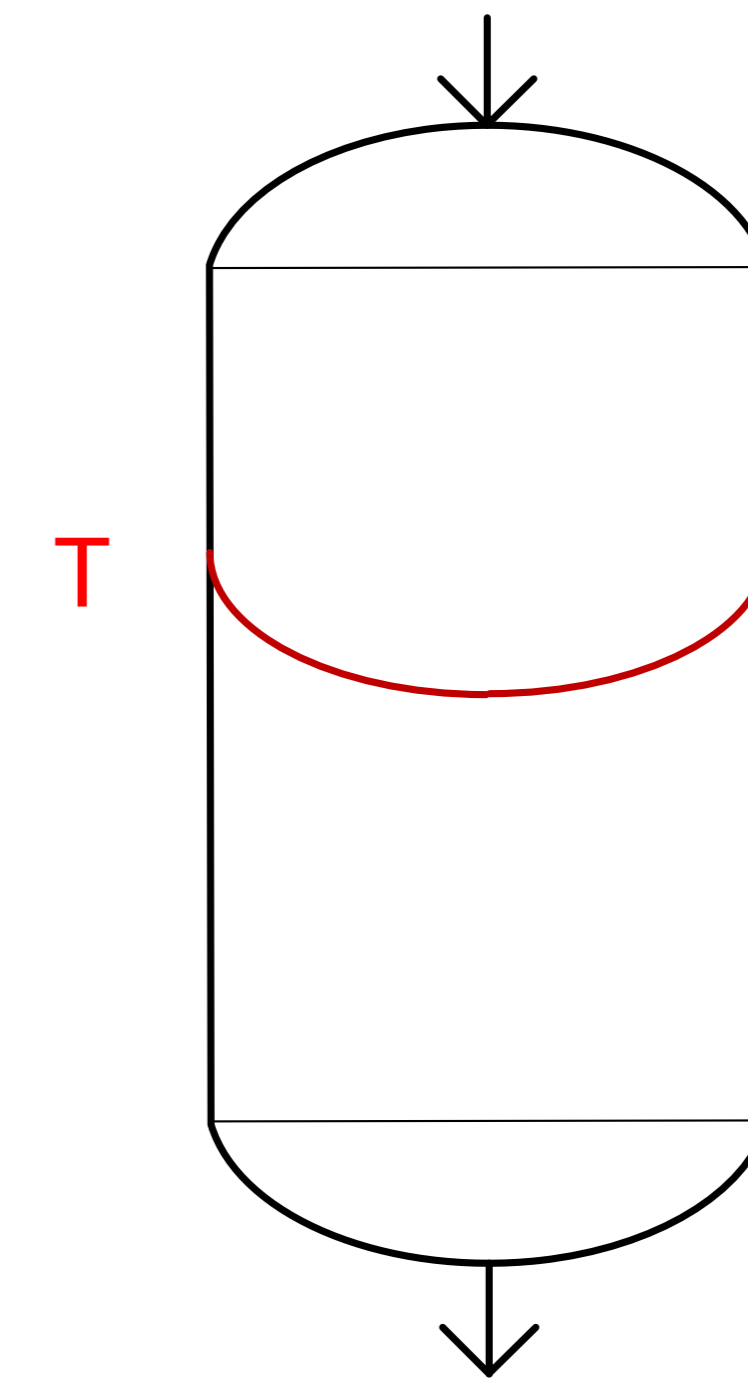
Conclusions

# Disadvantages of fixed bed adsorption

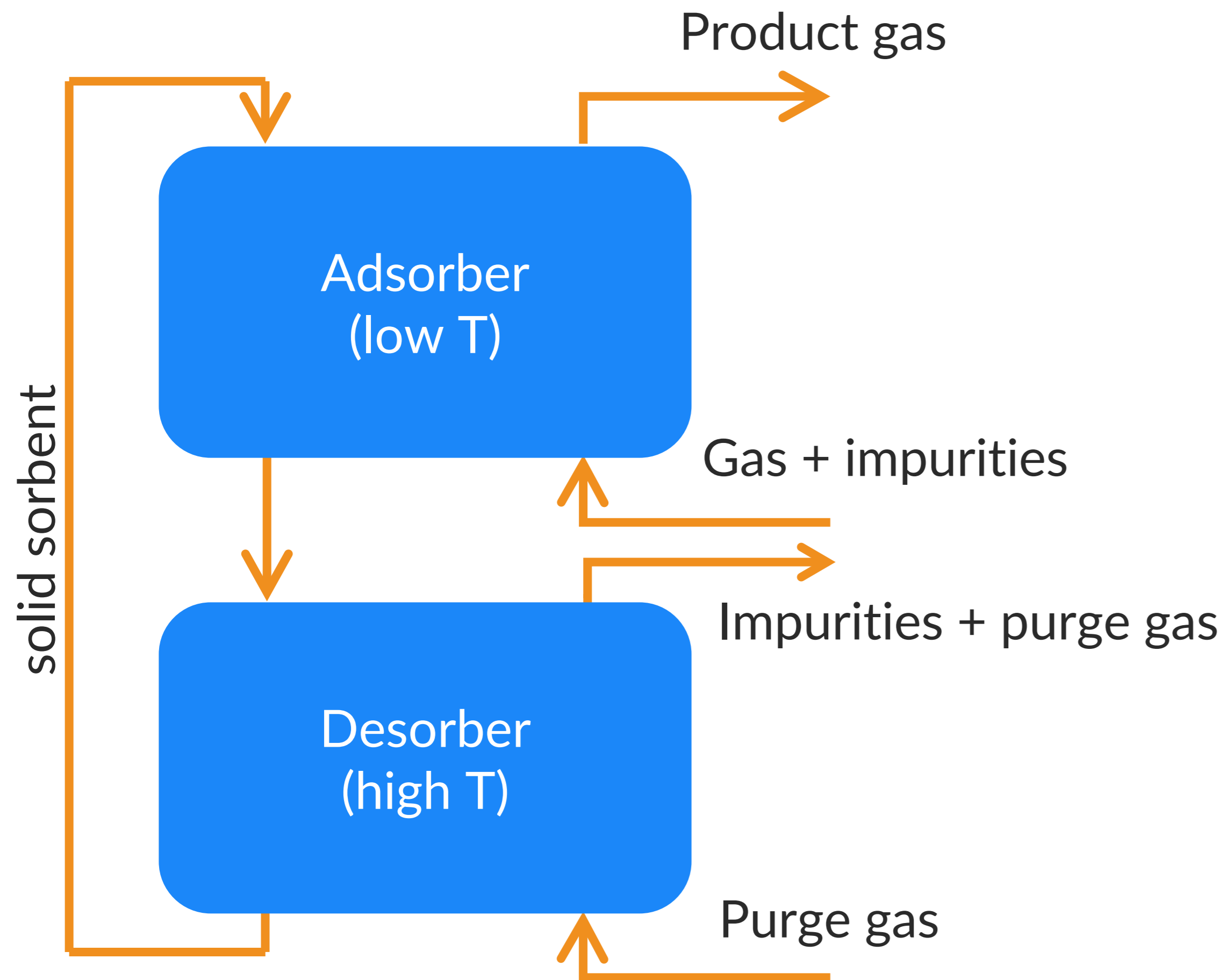
## Ineffective use of sorbent



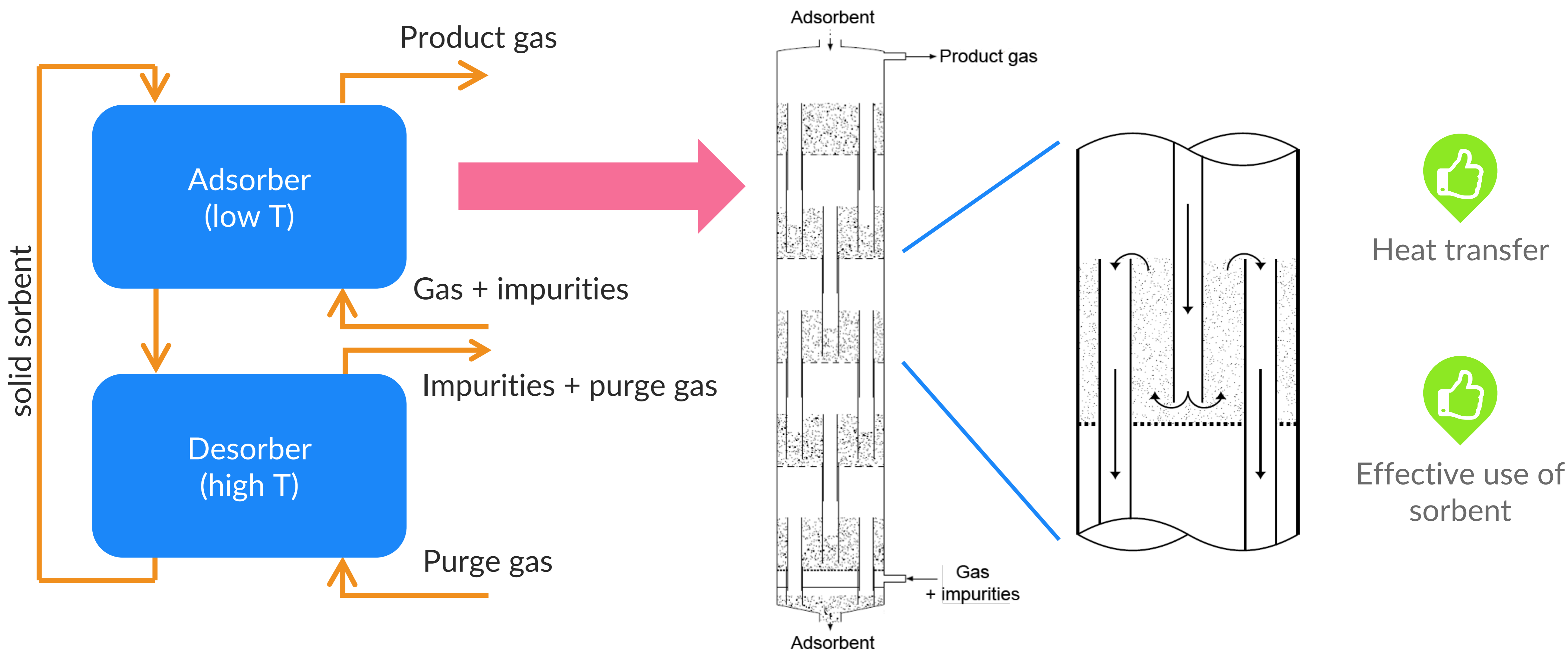
## Slow heat transfer



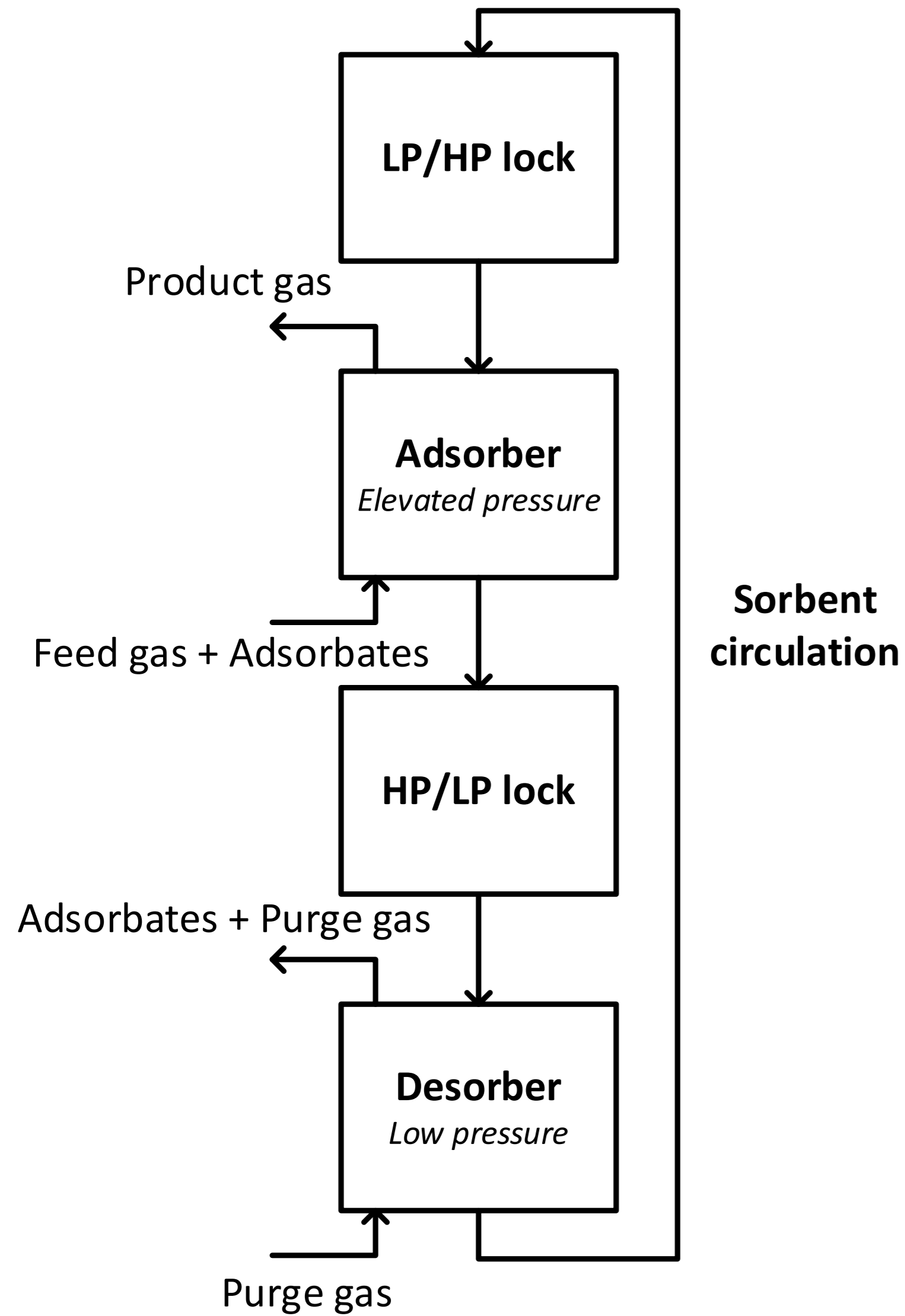
# Continuous adsorption process



# Continuous adsorption process

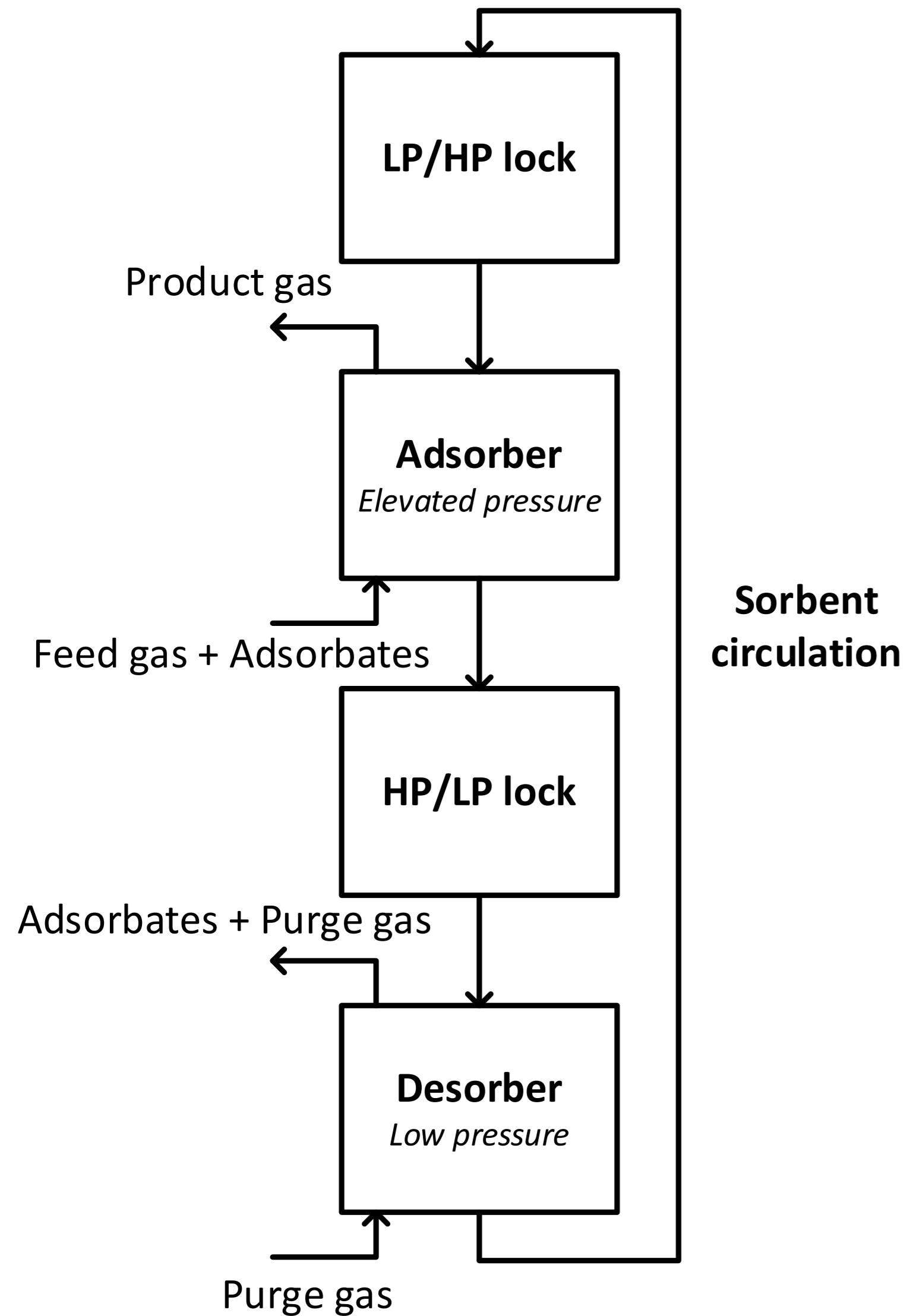


# Continuous pressure swing





# Continuous pressure swing



## Case

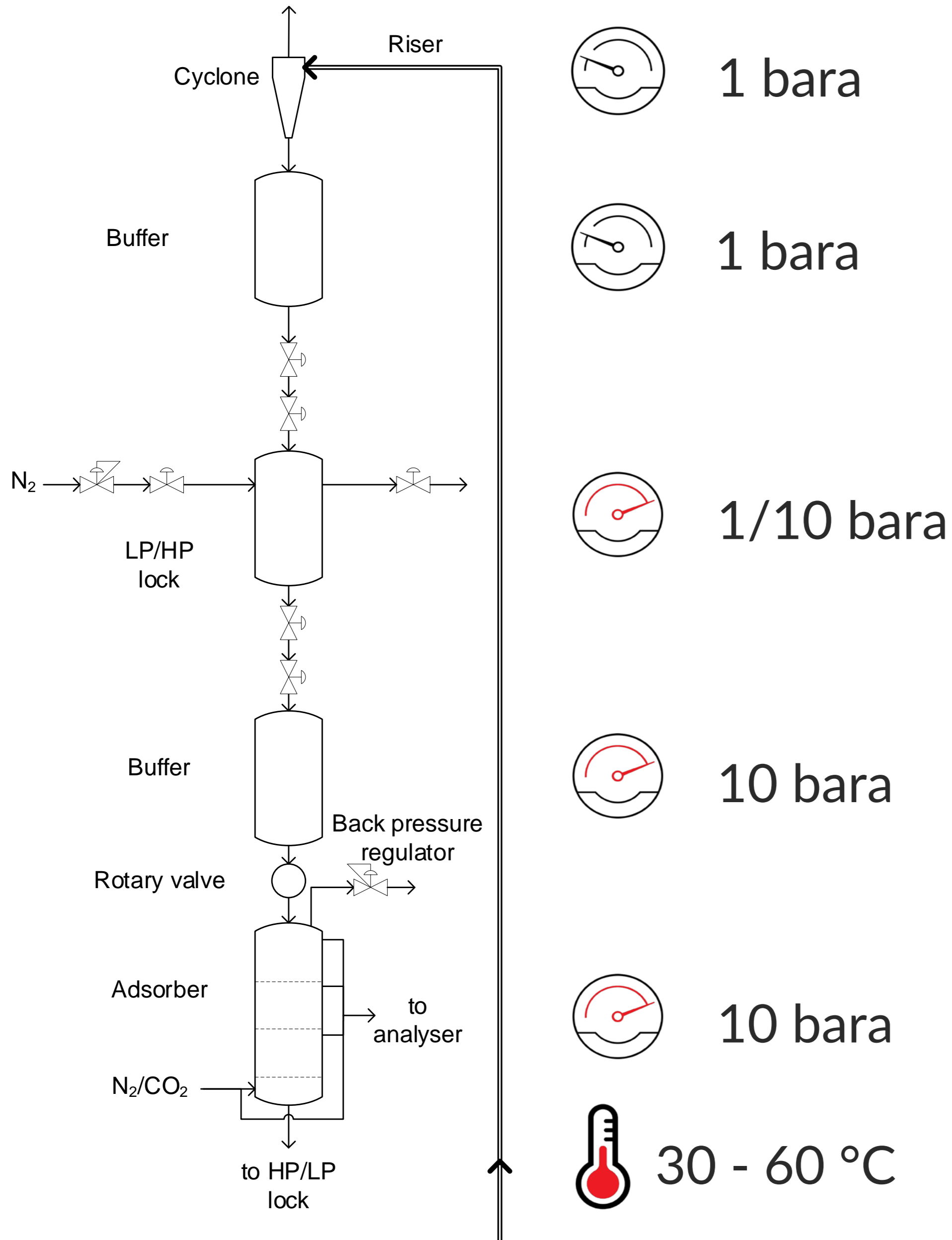
CO<sub>2</sub> and H<sub>2</sub>S removal from natural gas using supported amine sorbents

## Goal

Show that continuous PSA in a MSFB is technically possible for sour gas removal from natural gas.

# Design of pilot plant

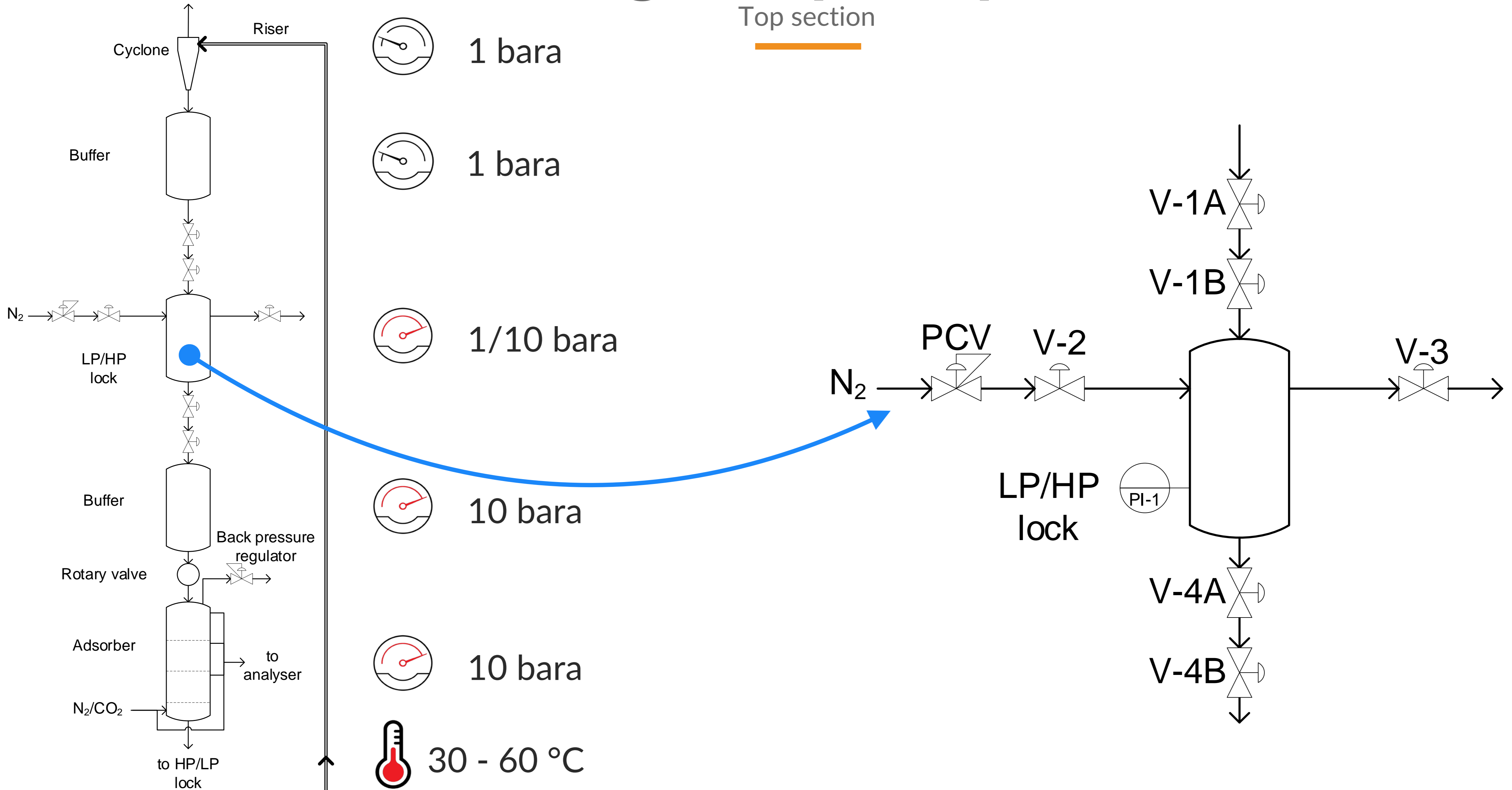
Top section





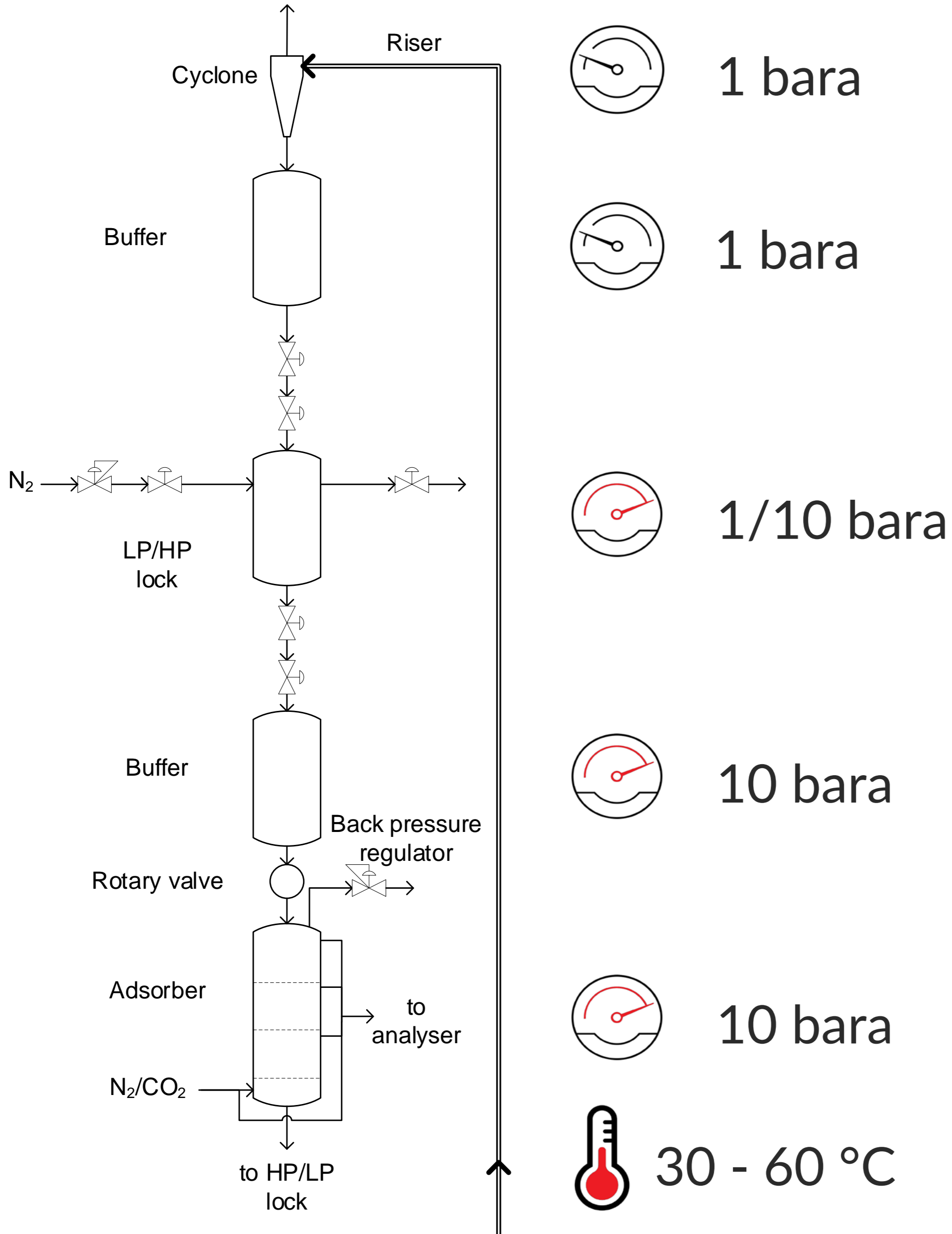
# Design of pilot plant

Top section



# Design of pilot plant

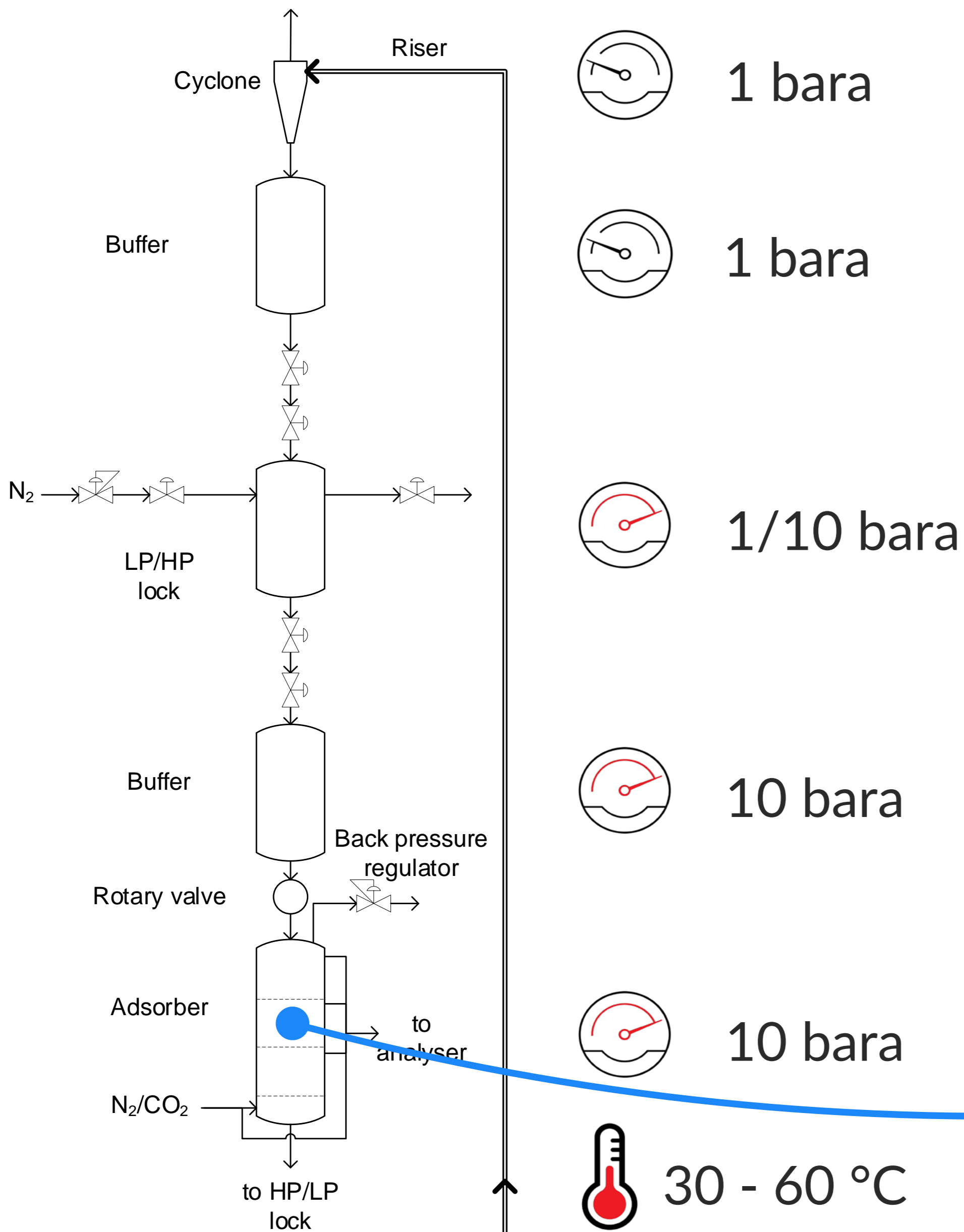
Top section





# Design of pilot plant

Top section

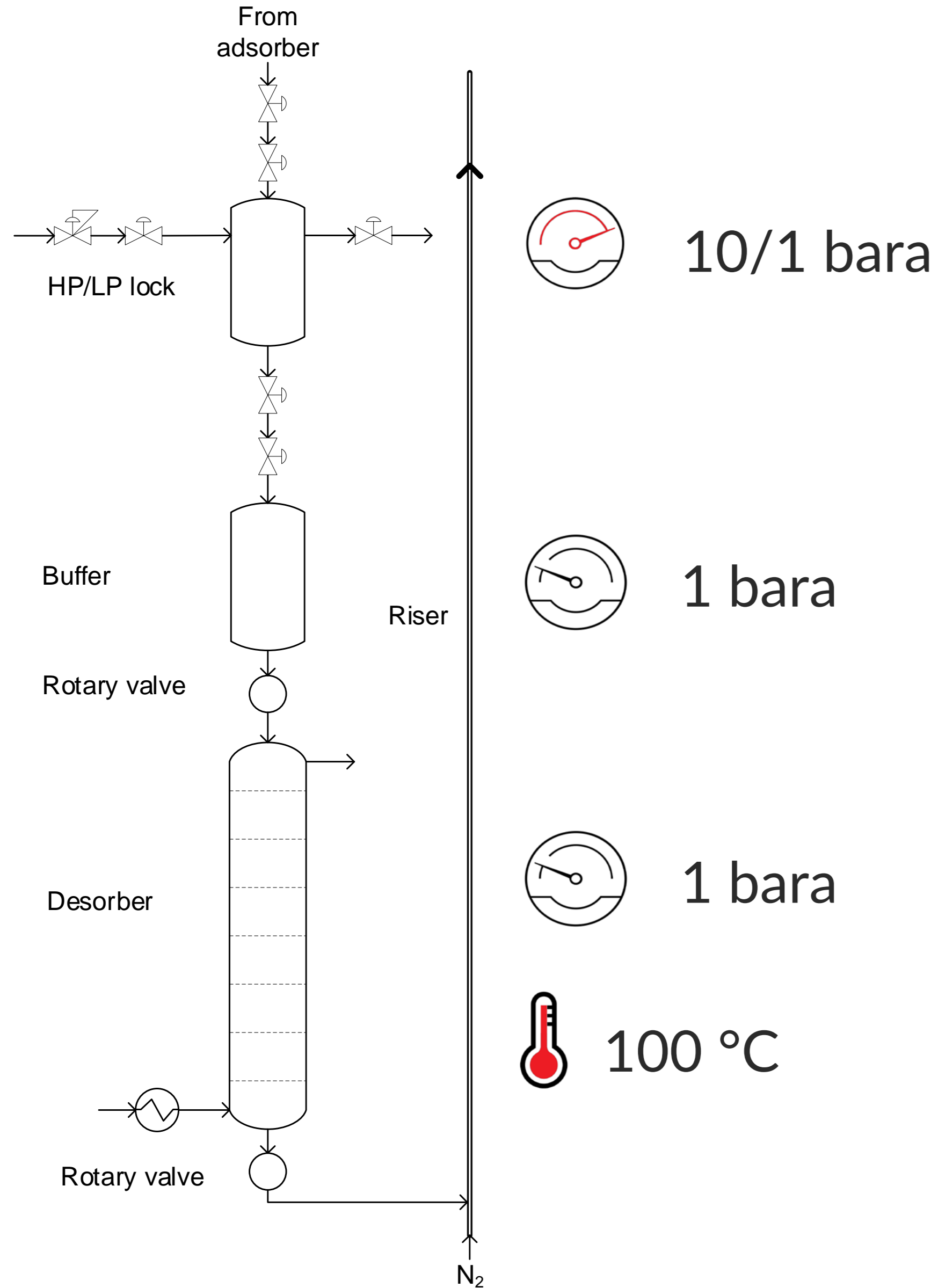


3 stage MSFB  
(50 mm ID)



# Design of pilot plant

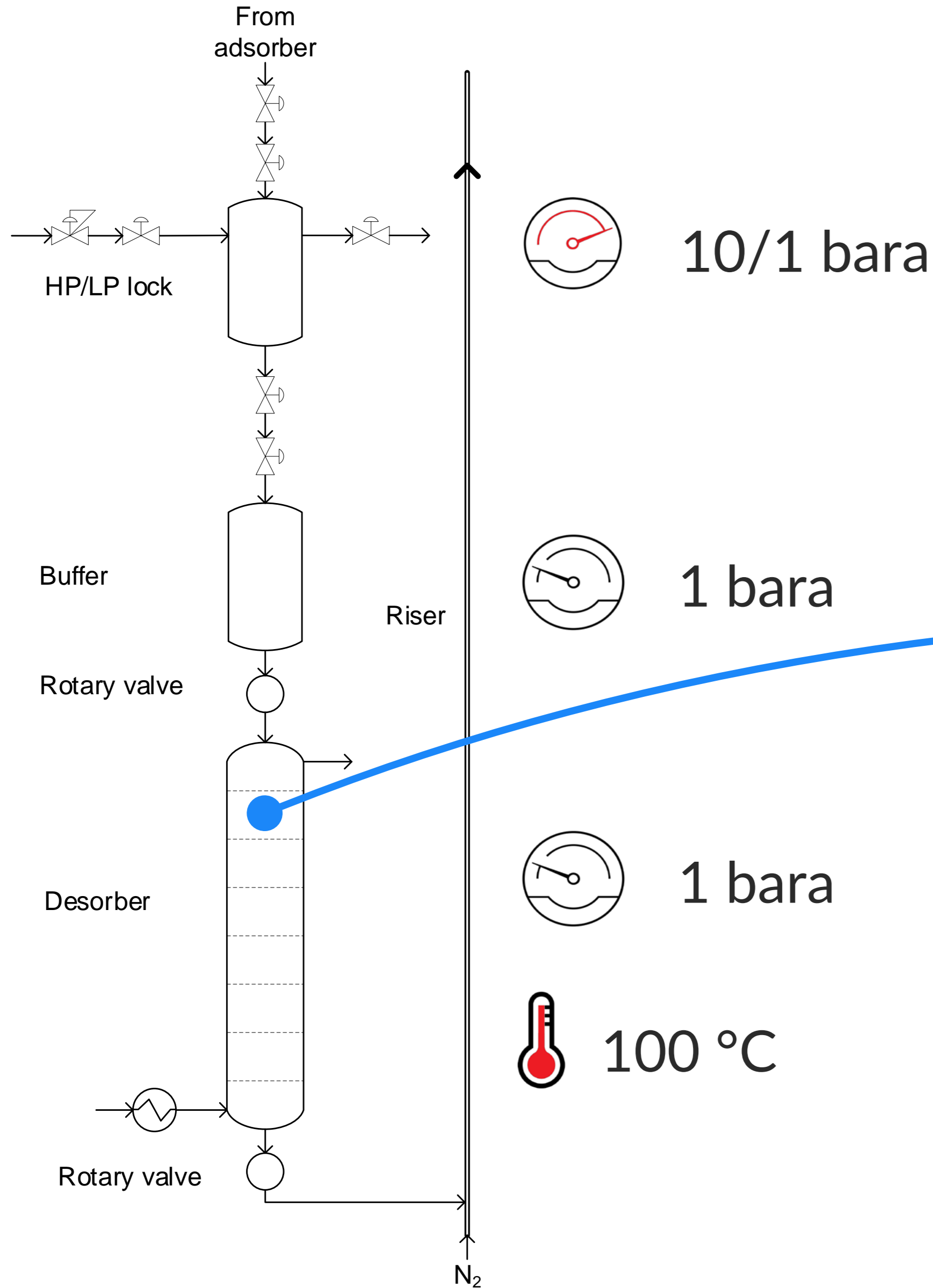
Bottom section



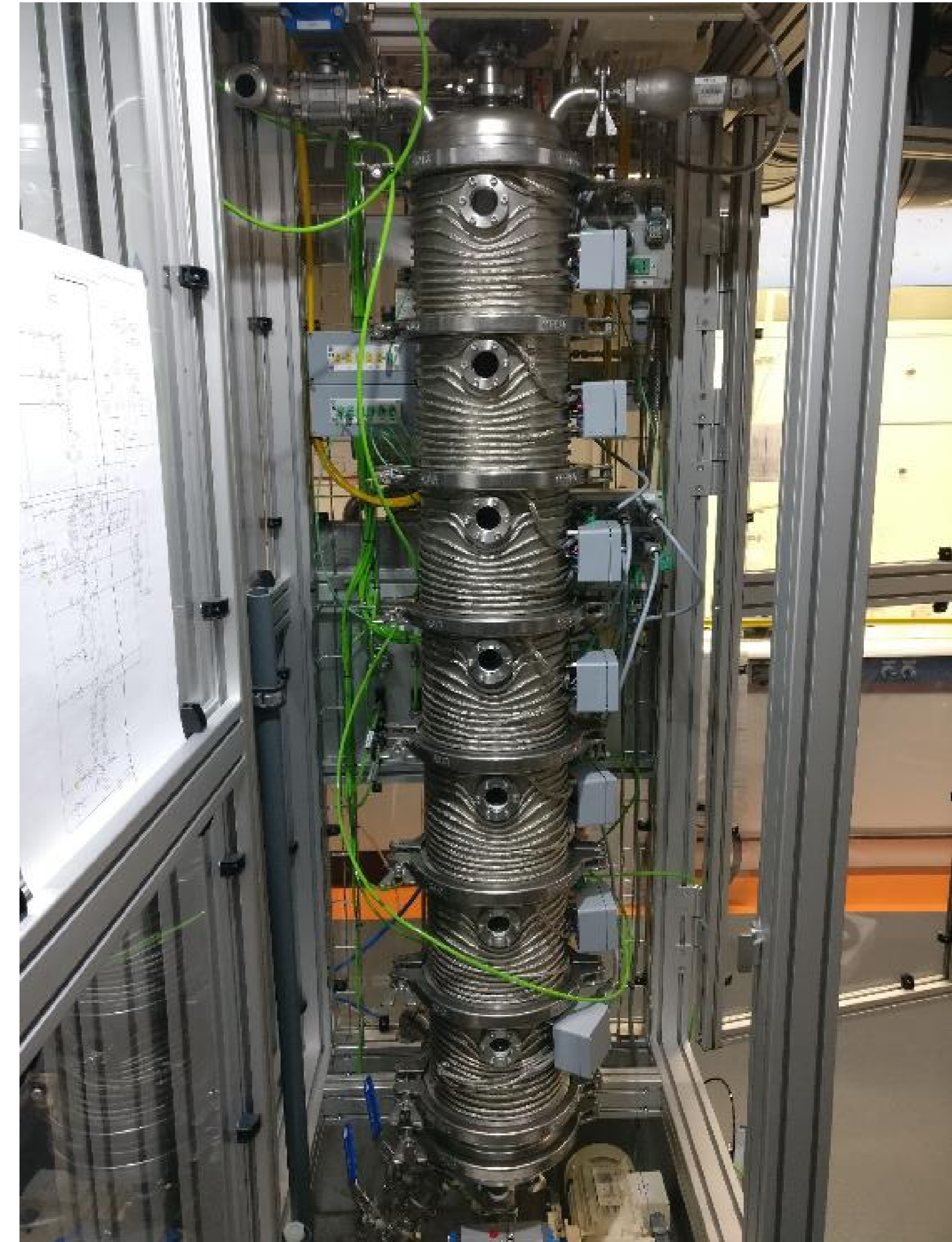


# Design of pilot plant

Bottom section



7 stage MSFB  
(200 mm ID)

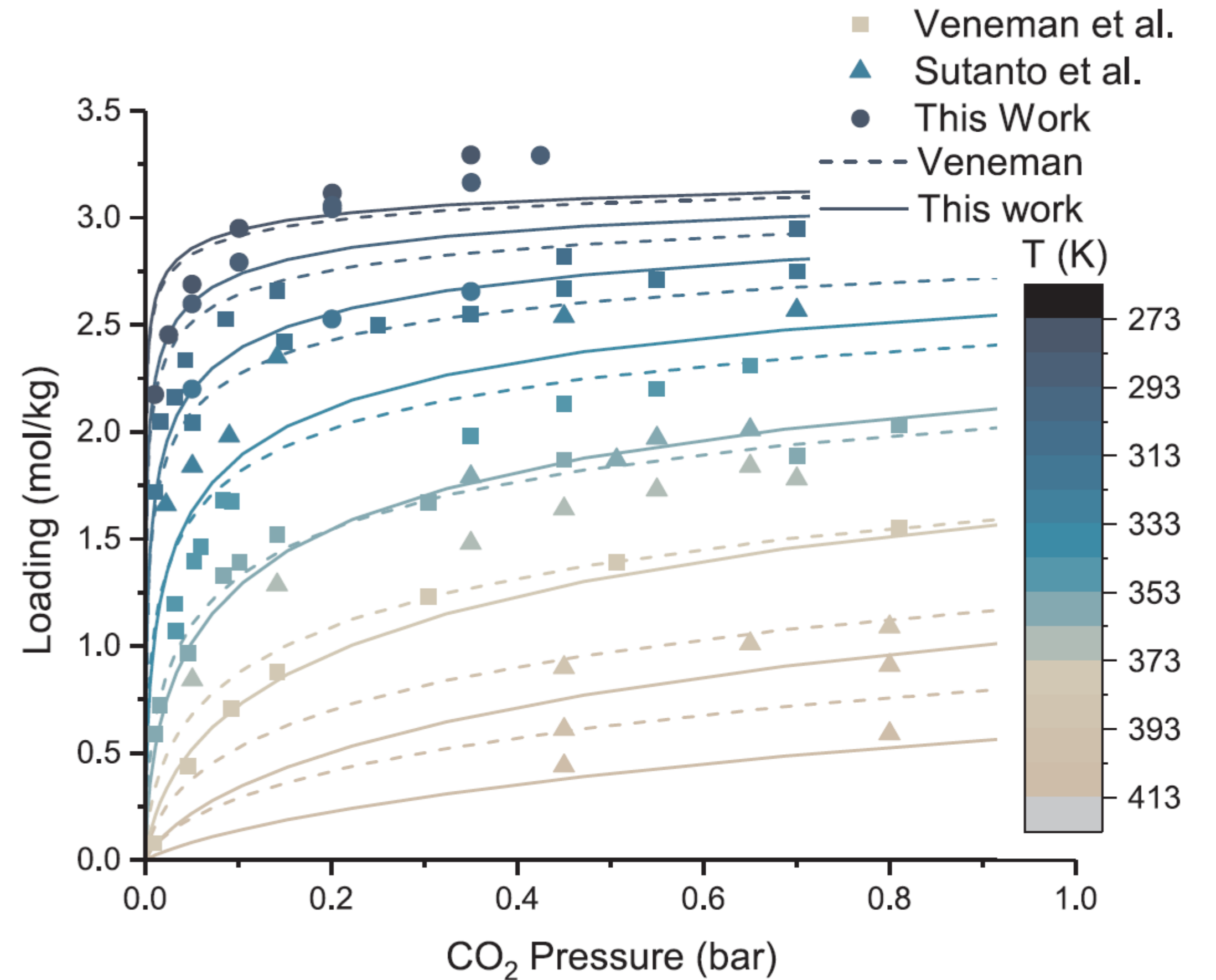


# Results

Definition of tray efficiency

Murphree tray efficiency  
*'Extent to equilibrium'*

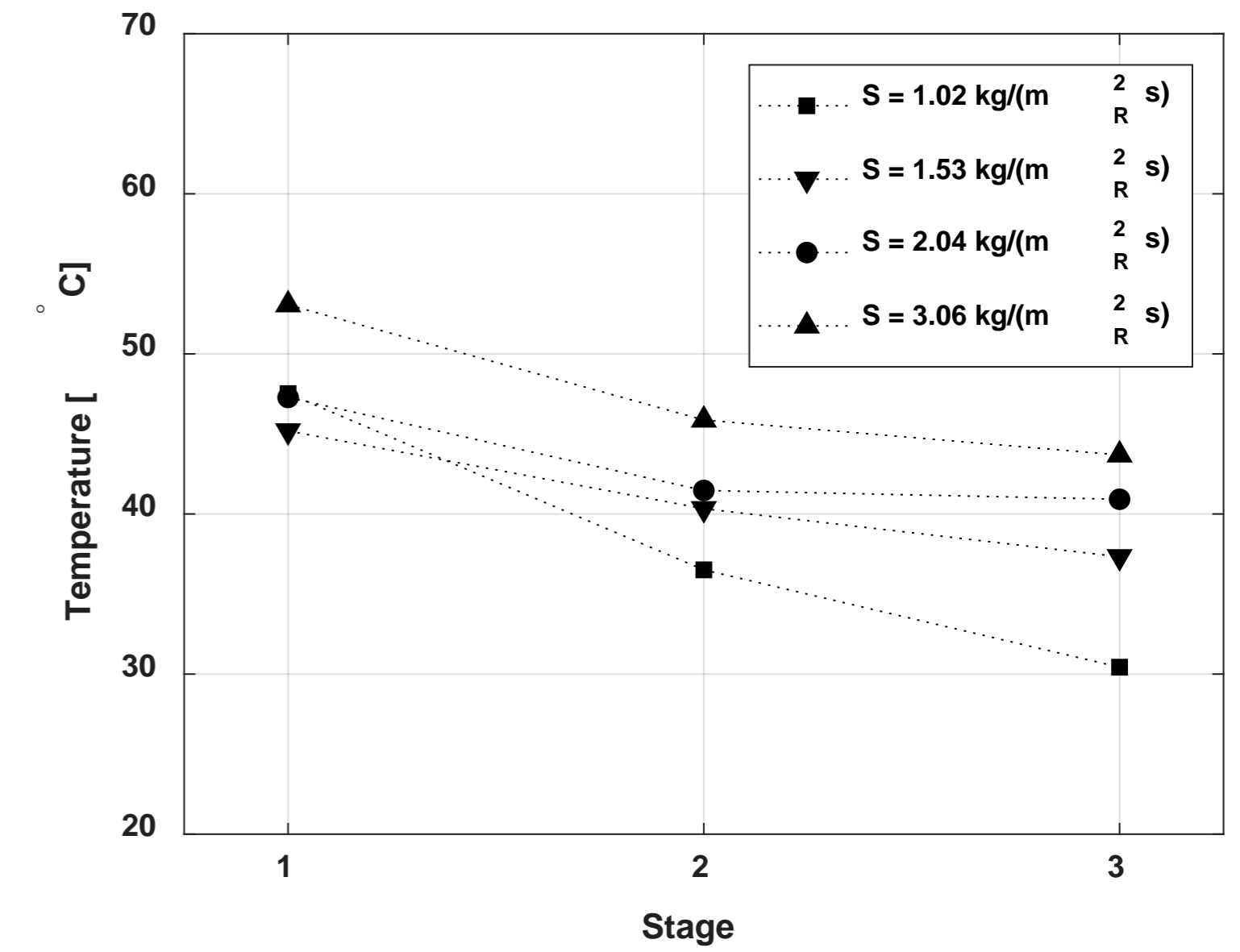
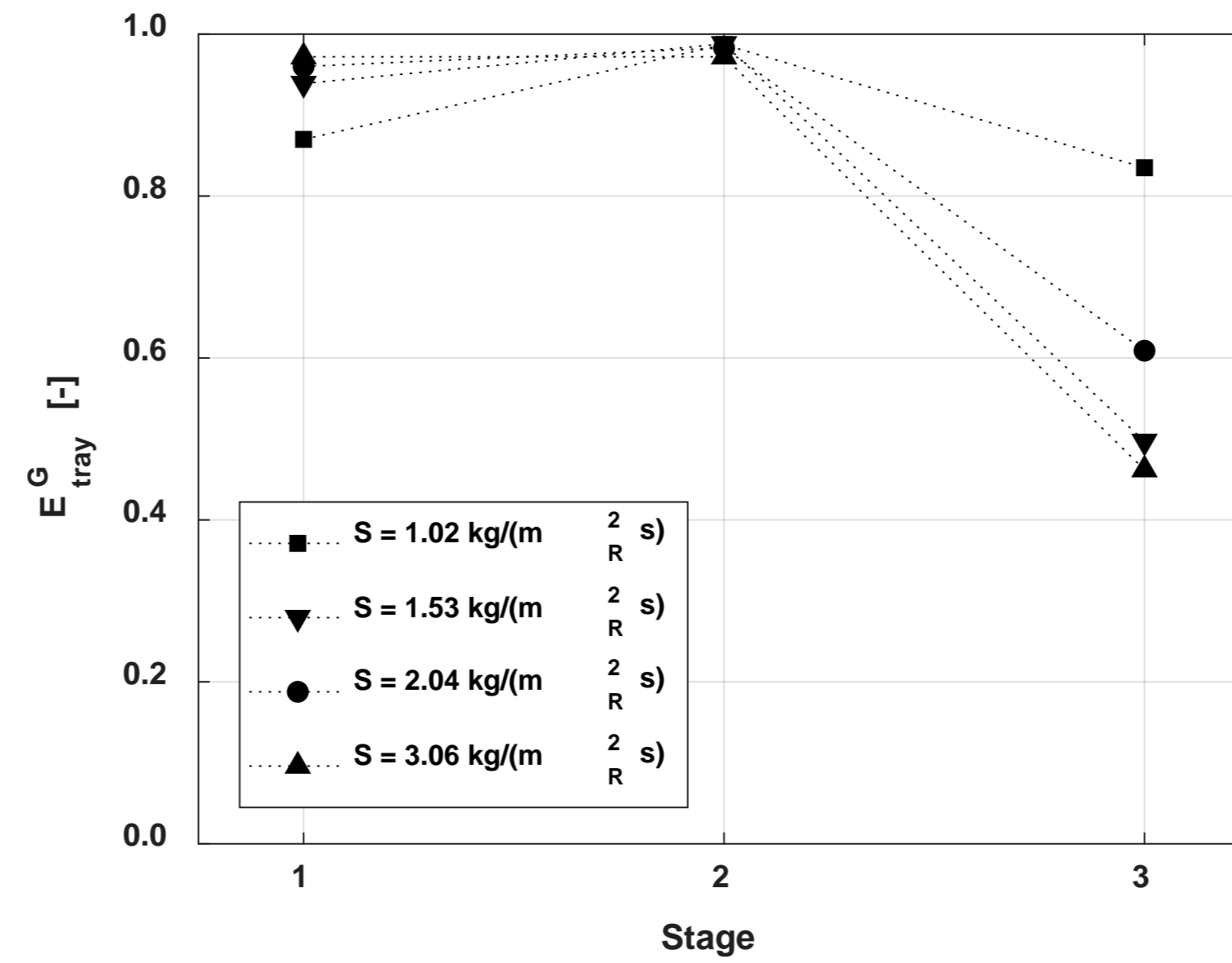
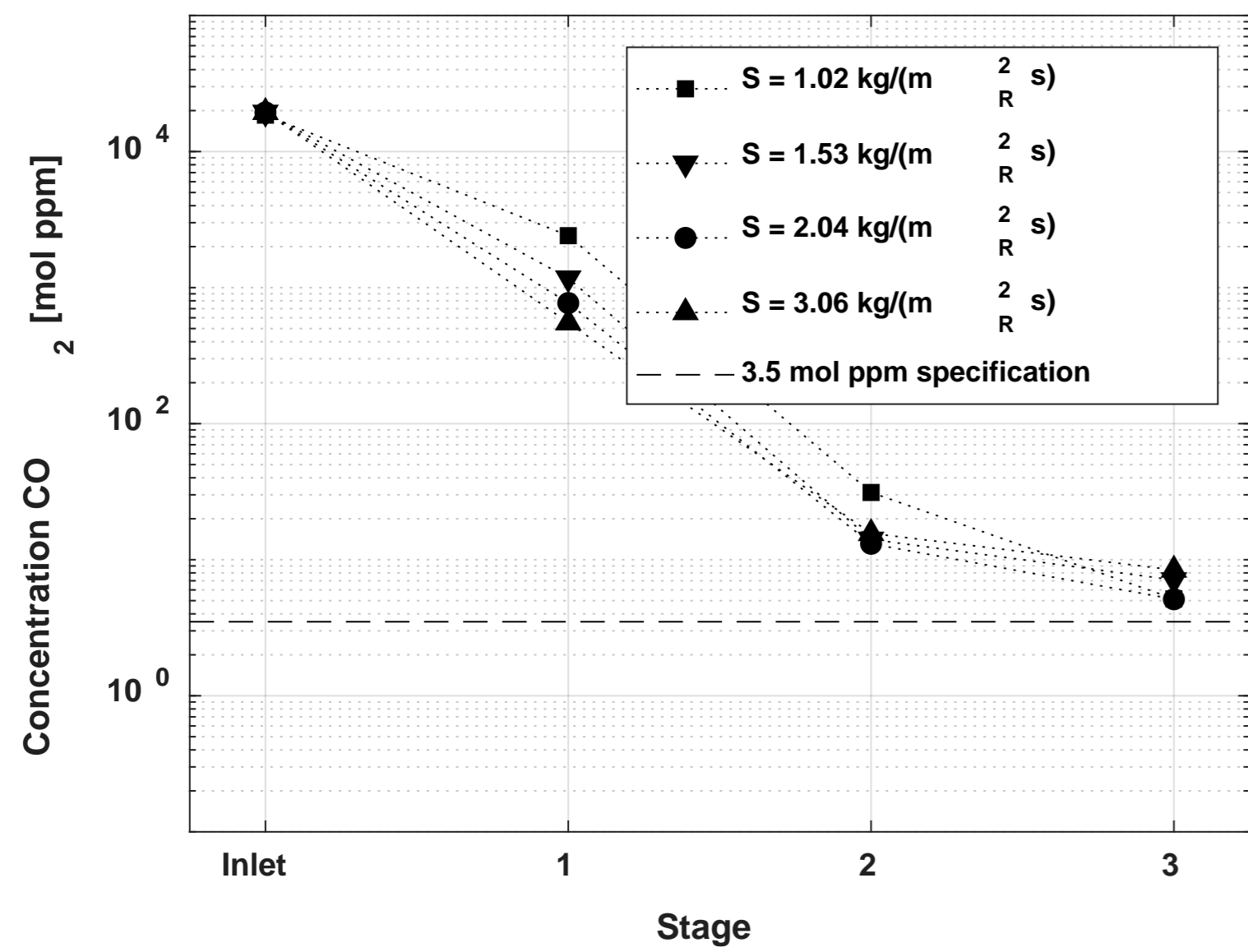
$$E_{\text{tray},n}^G = \frac{c_{n-1} - c_n}{c_{n-1} - c_n^*(q_n, T_n)}$$





# Results

Varying solid flux



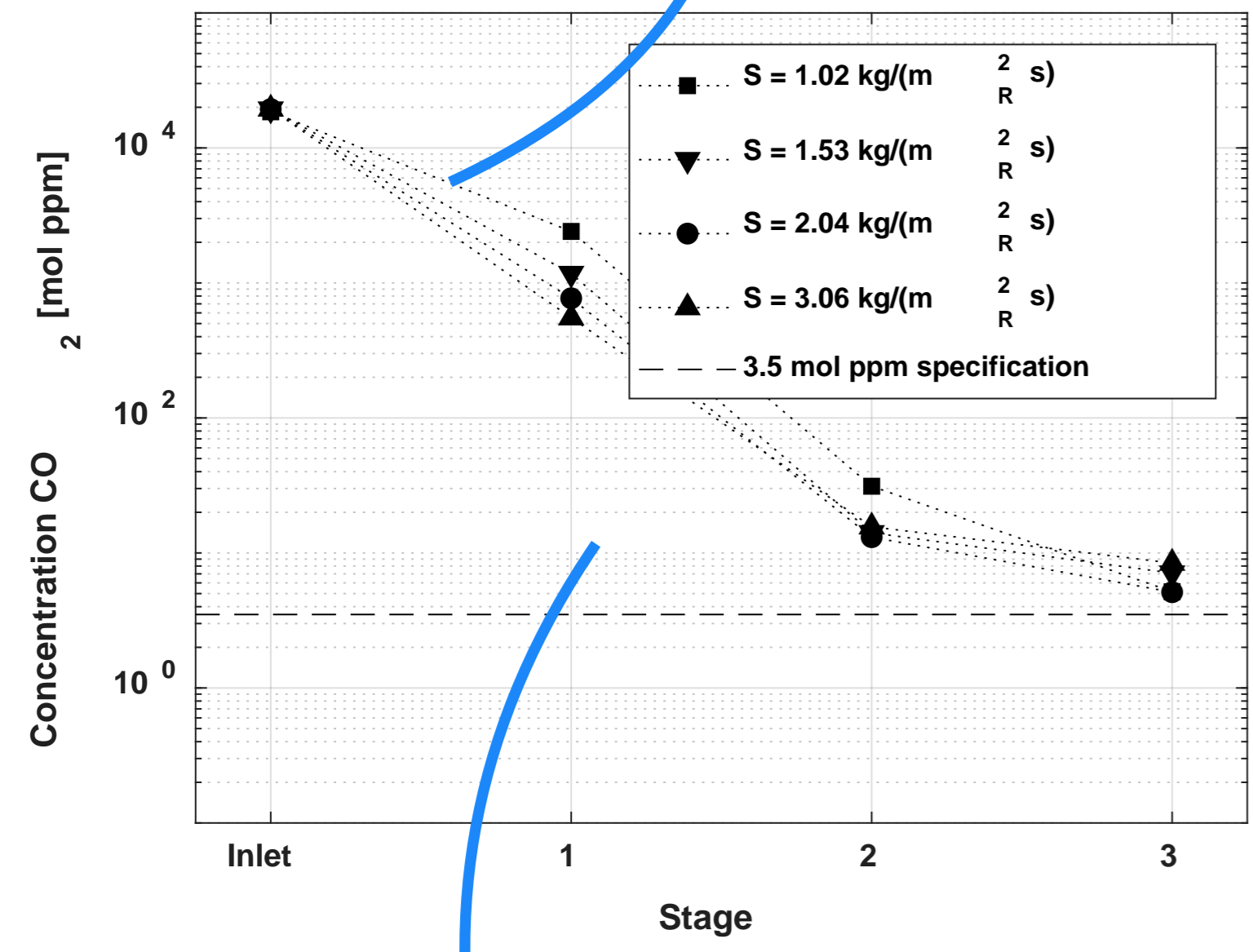
### Parameters

- P = 10 bara
- c<sub>in</sub> = 20 000 mol ppm
- u<sub>0</sub> = 0.084 m/s
- H = 130 mm

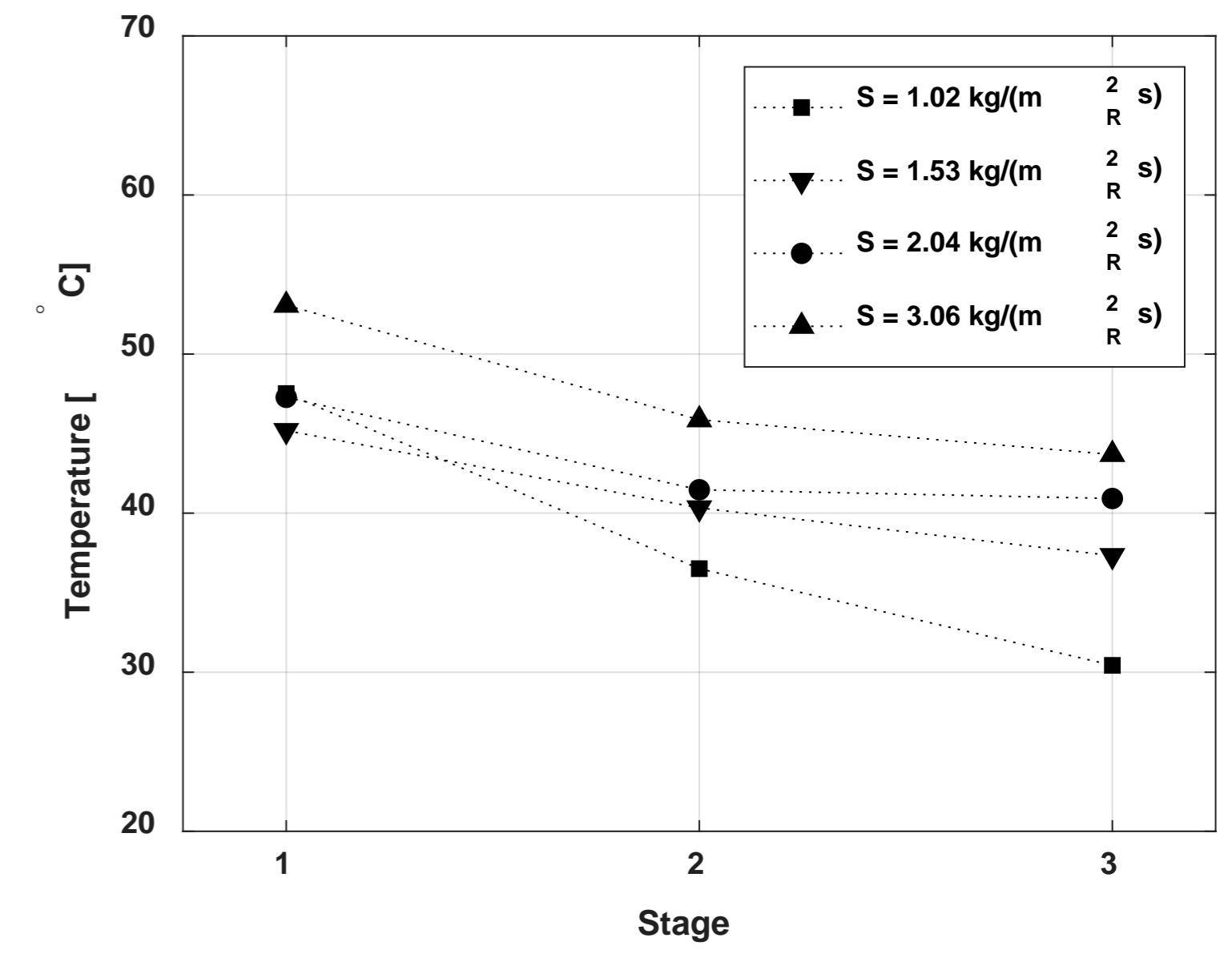
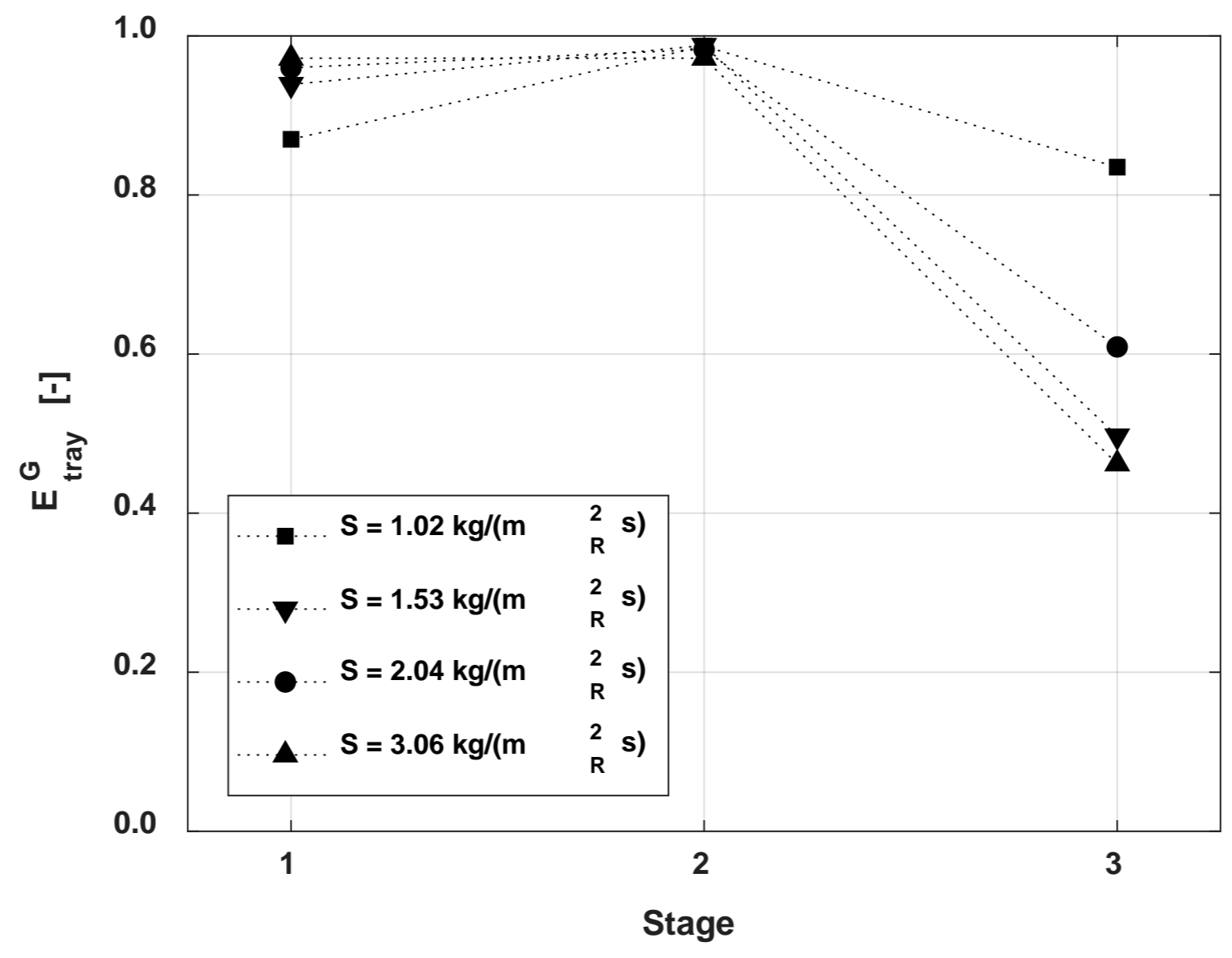
# Results

Varying solid flux

From 20 000 ppm to <10 ppm  
in 0.5 s



Concentrations lower by orders of magnitude



### Parameters

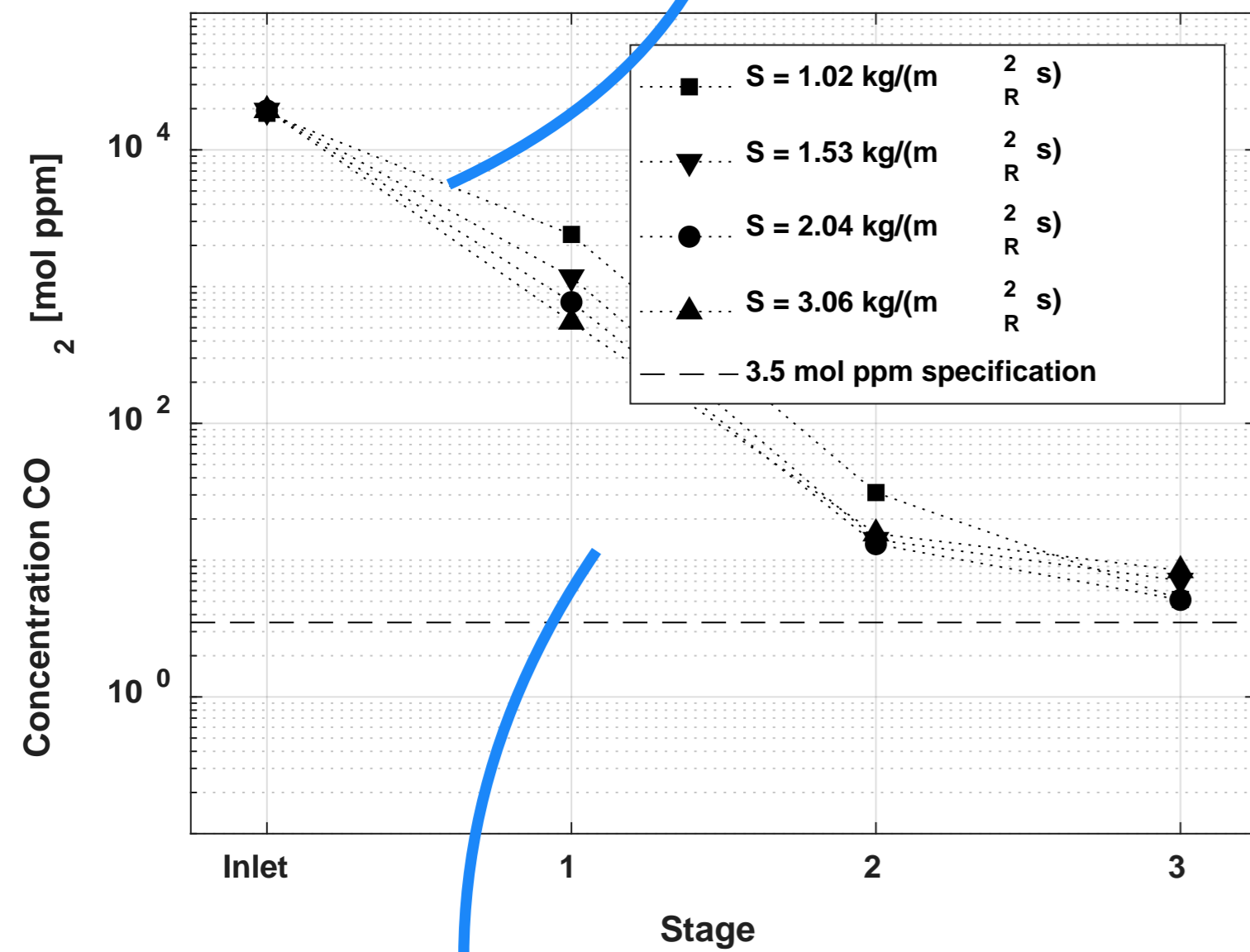
- P = 10 bara
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- u<sub>0</sub> = 0.084 m/s
- H = 130 mm



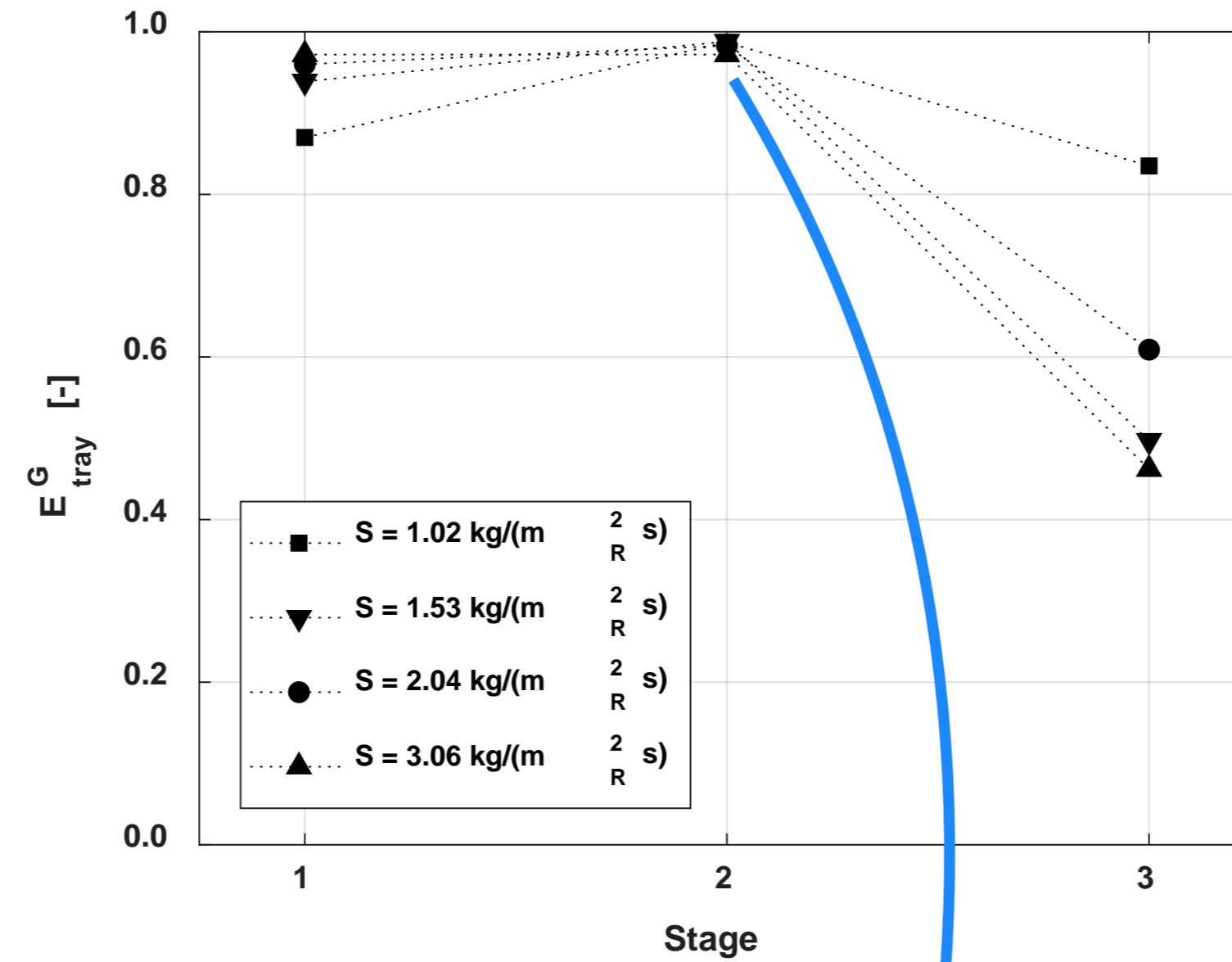
# Results

Varying solid flux

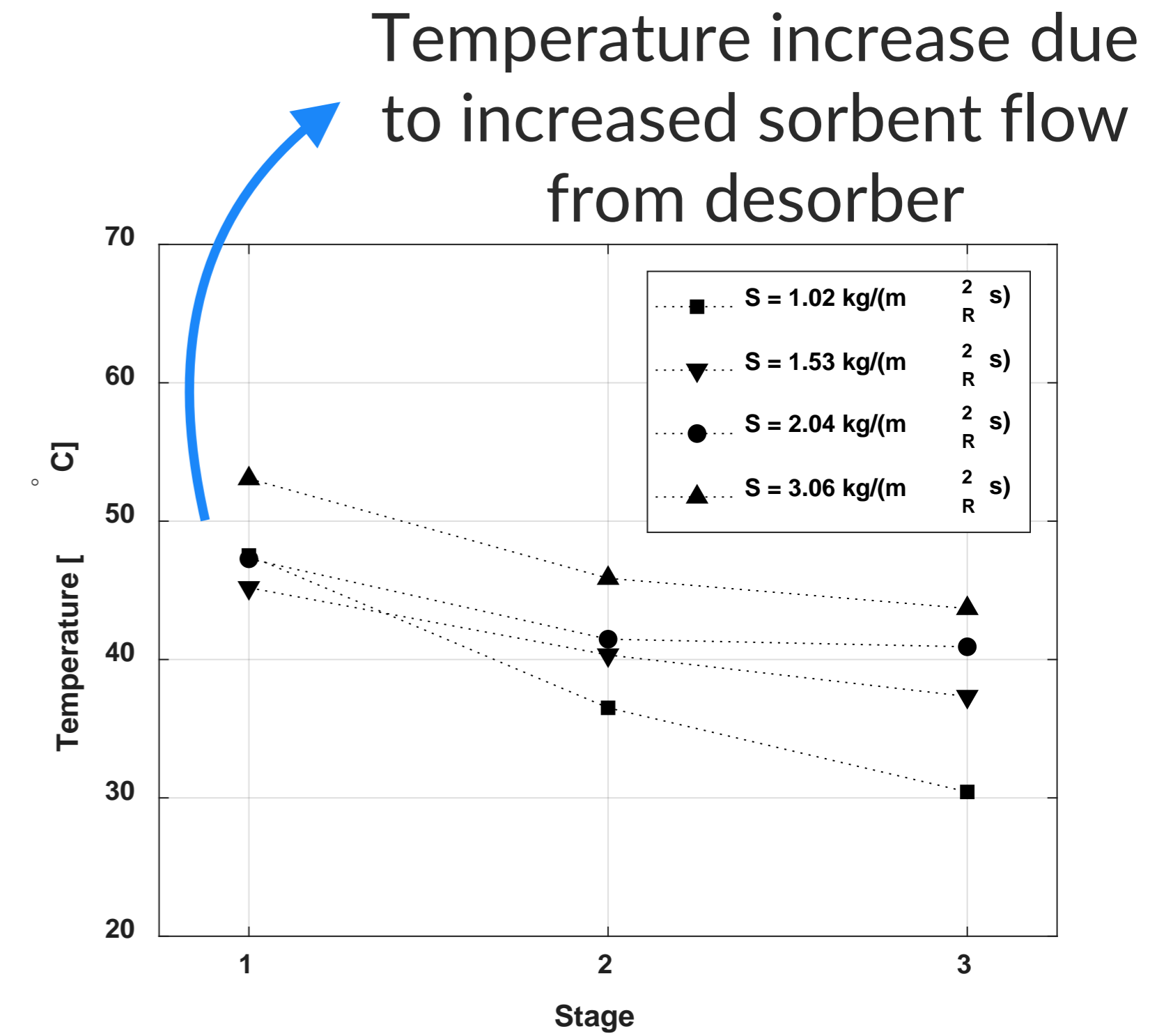
From 20 000 ppm to <10 ppm  
in 0.5 s



Concentrations lower by orders of magnitude



Equilibrium is almost reached



Temperature increase due to increased sorbent flow from desorber

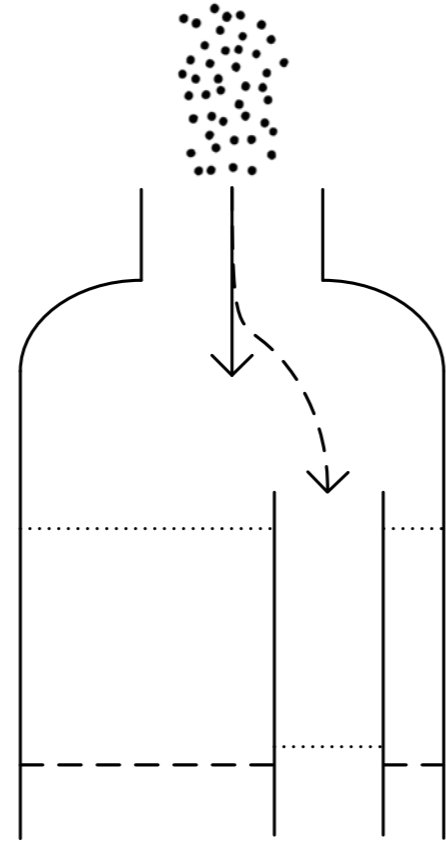
### Parameters

- P = 10 bara
- $c_{in}$  = 20 000 mol ppm
- $u_0$  = 0.084 m/s
- H = 130 mm

# Results

Effect of diverter on top stage

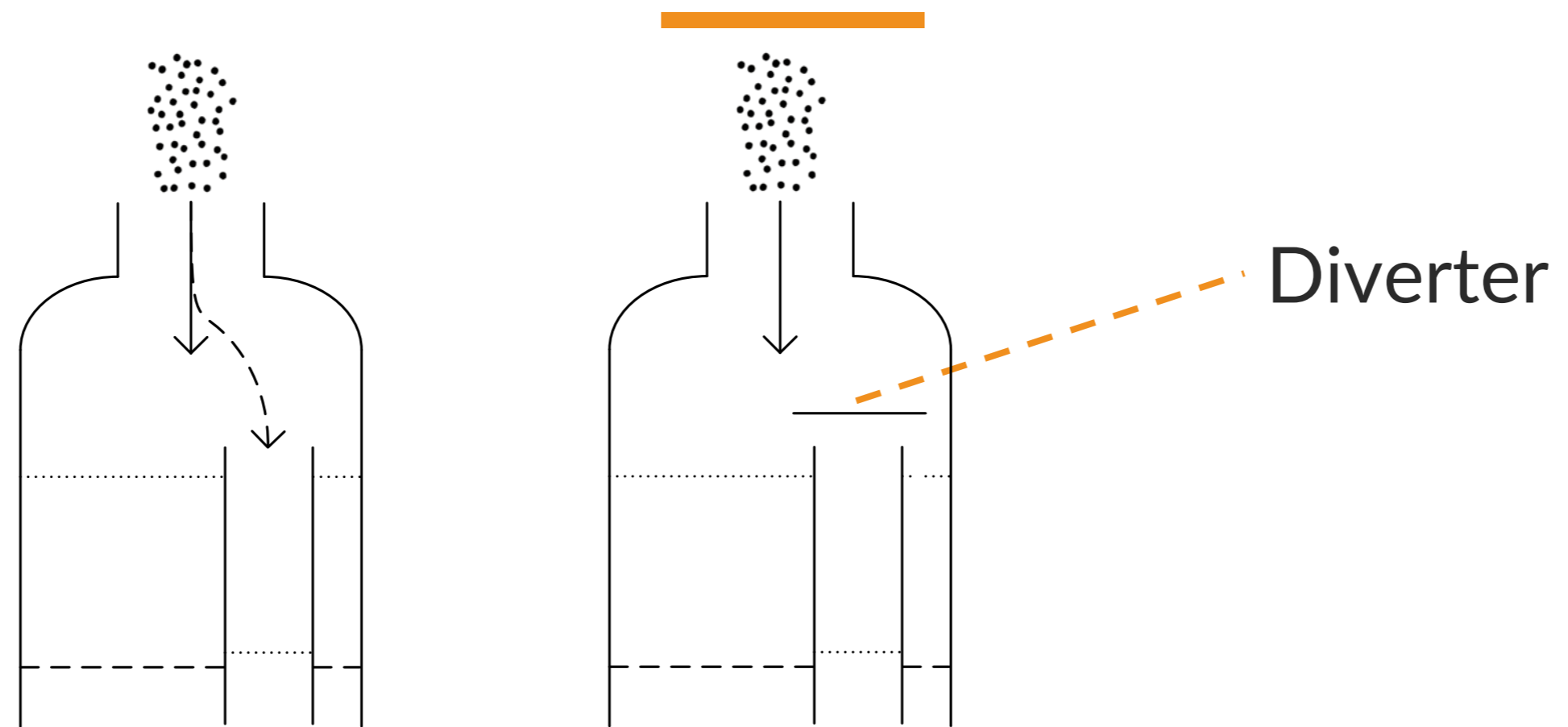
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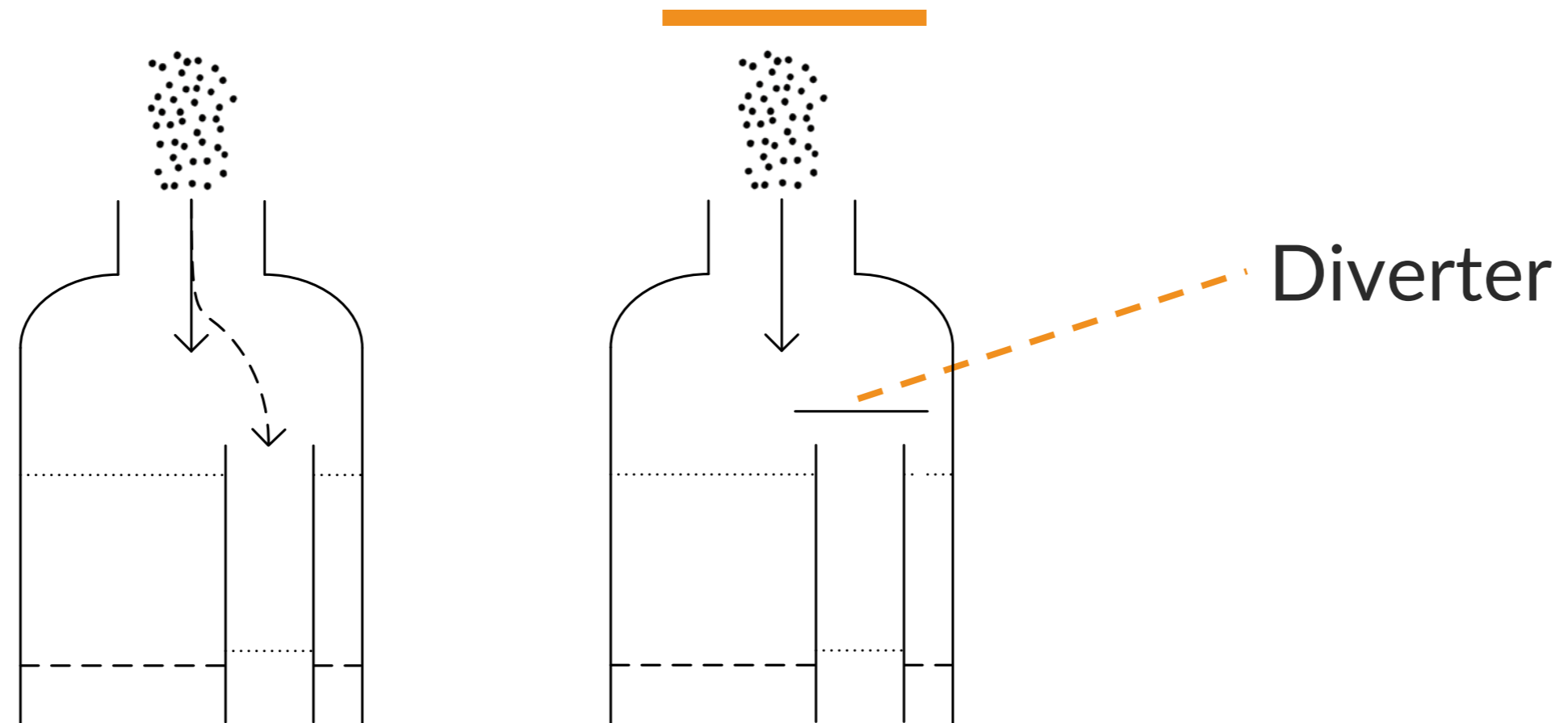
# Results

Effect of diverter on top stage



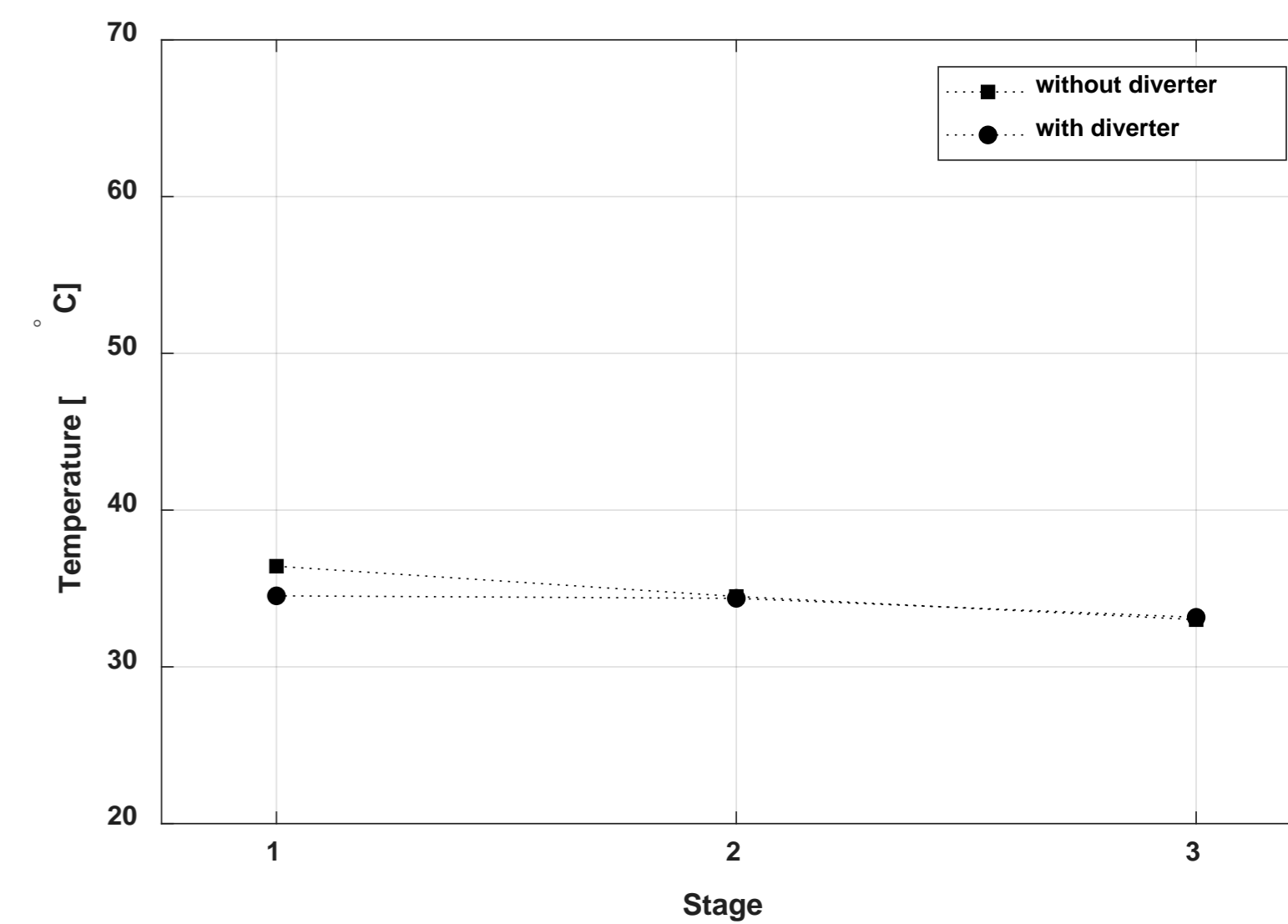
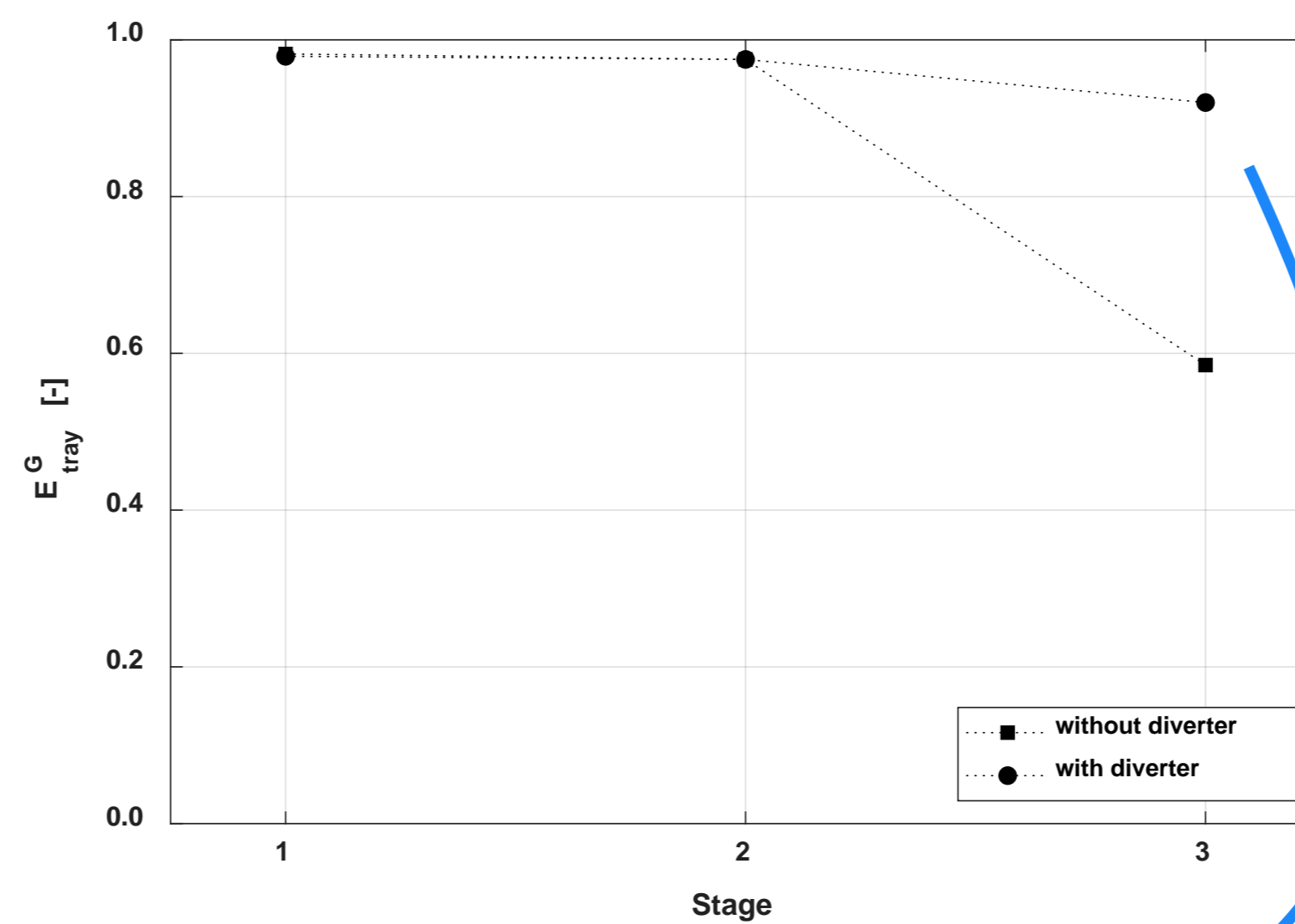
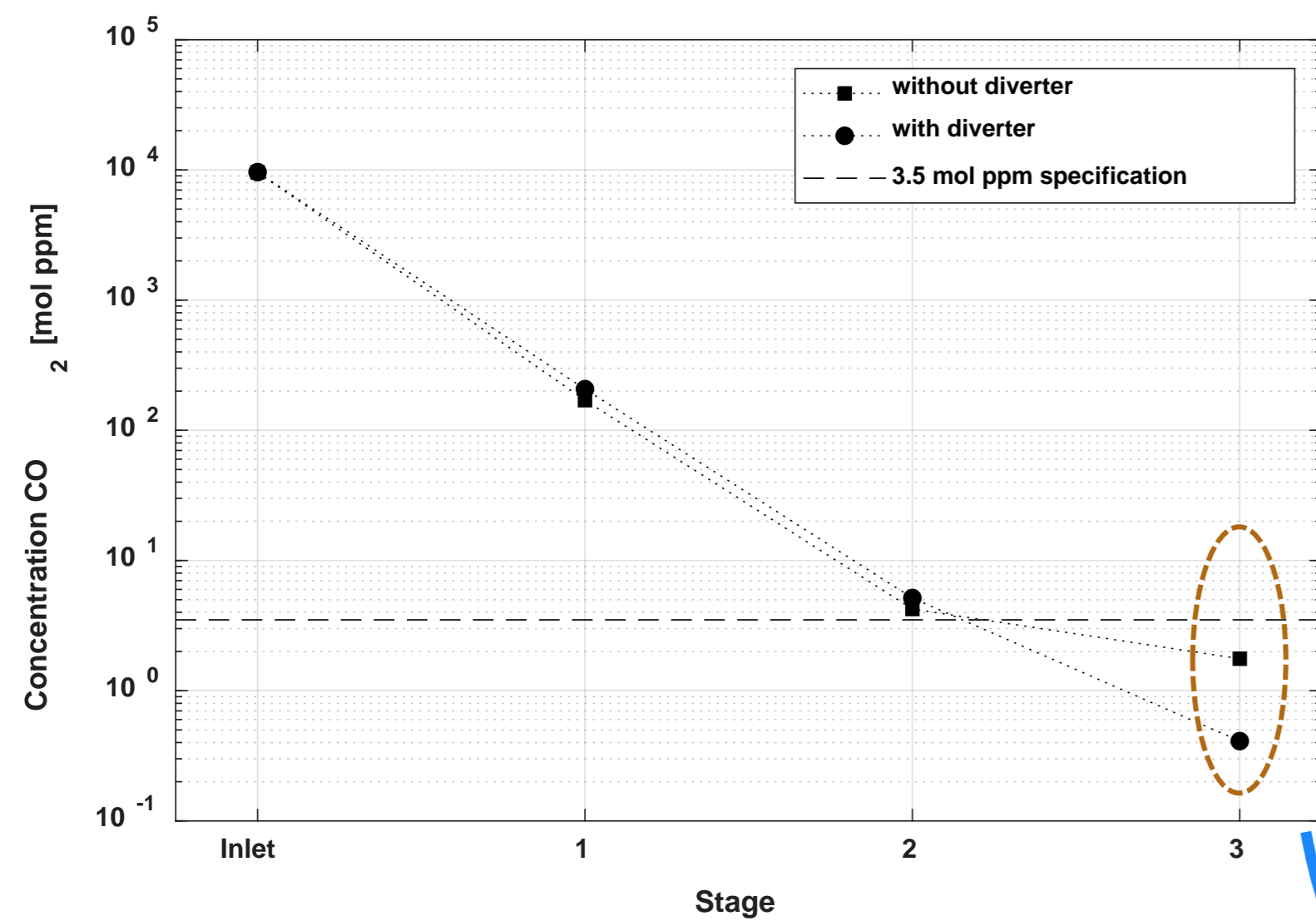
# Results

Effect of diverter on top stage



## Parameters

- $P = 10$  bara
- $c_{in} = 20\ 000$  mol ppm
- $u_0 = 0.084$  m/s
- $H = 130$  mm

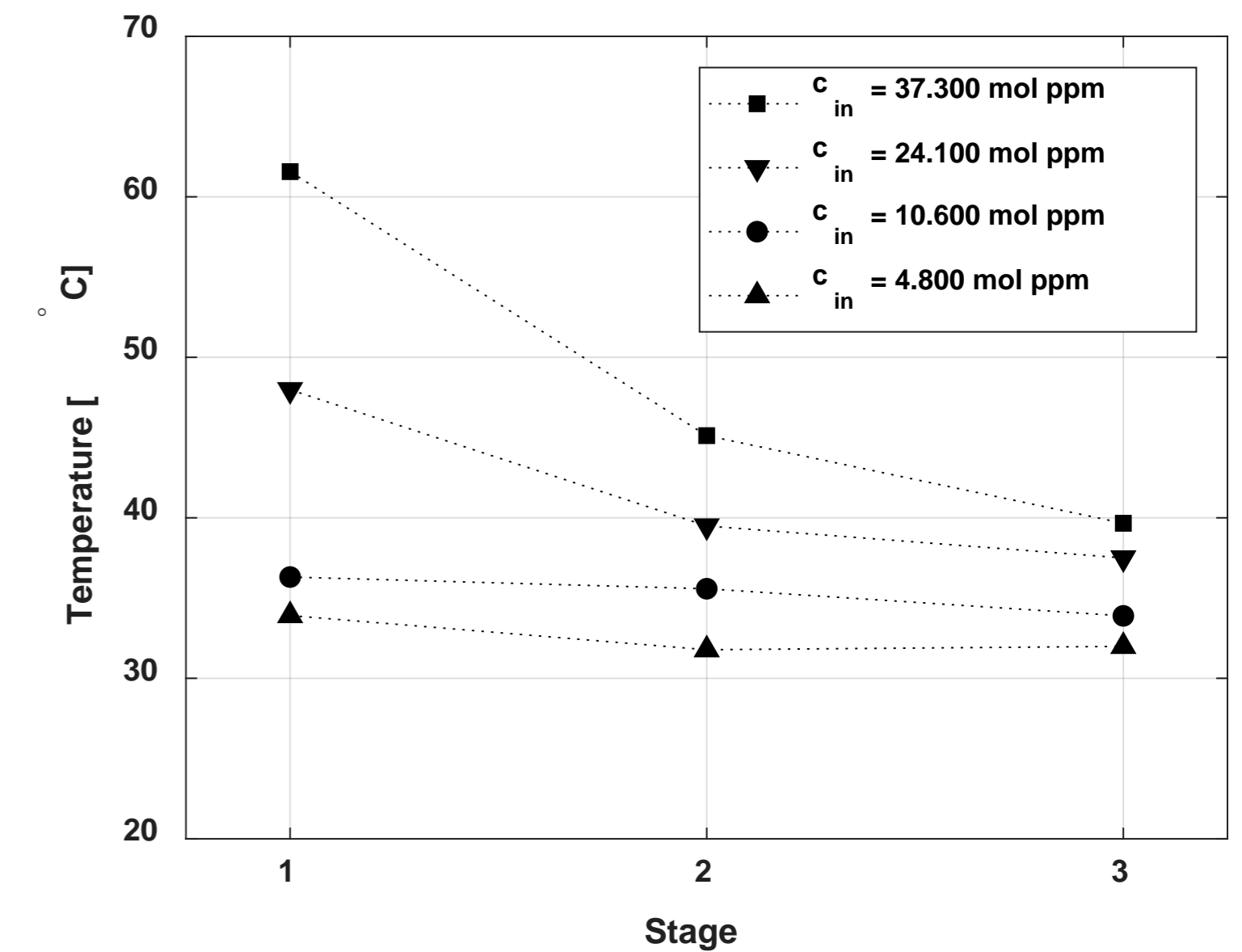
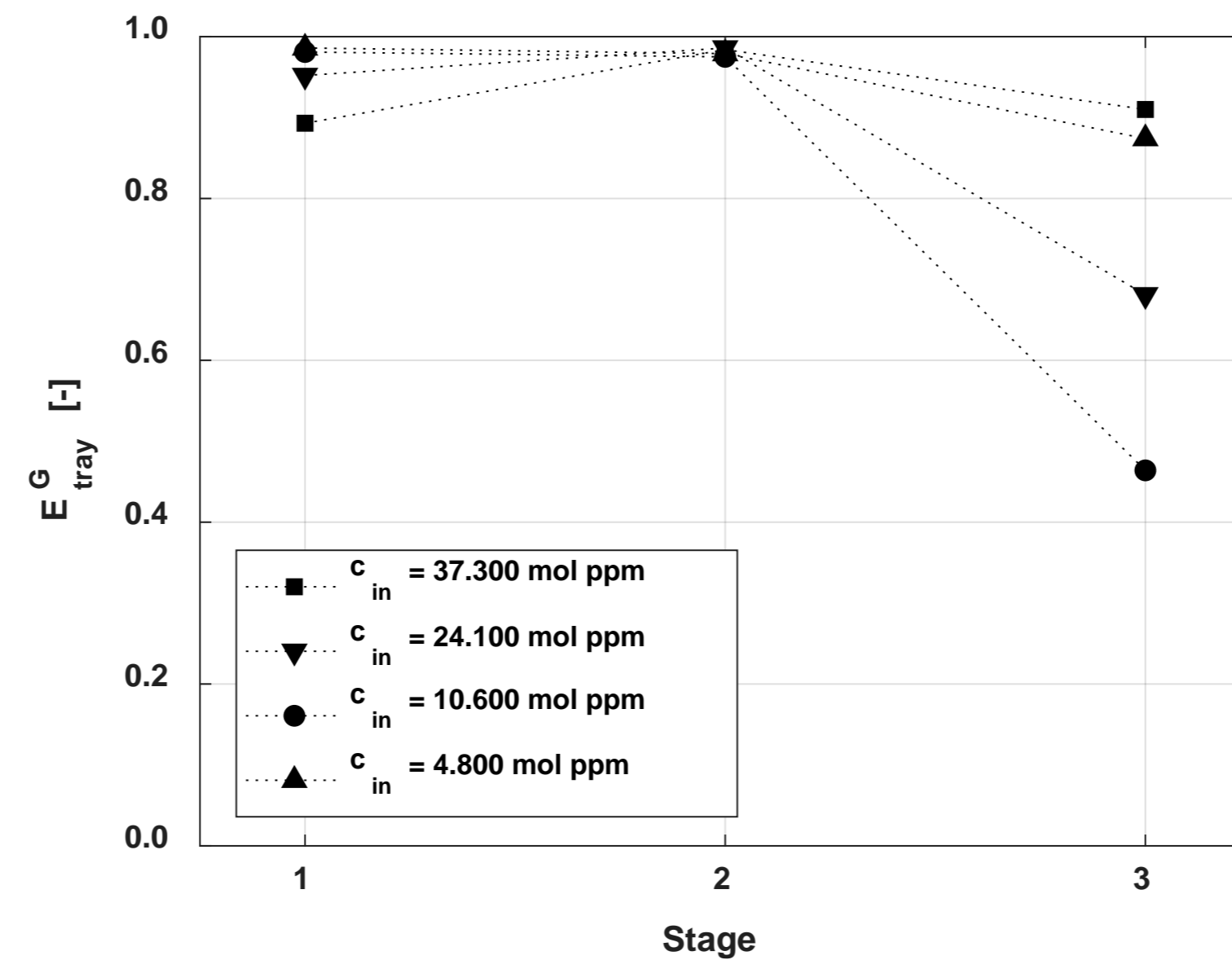
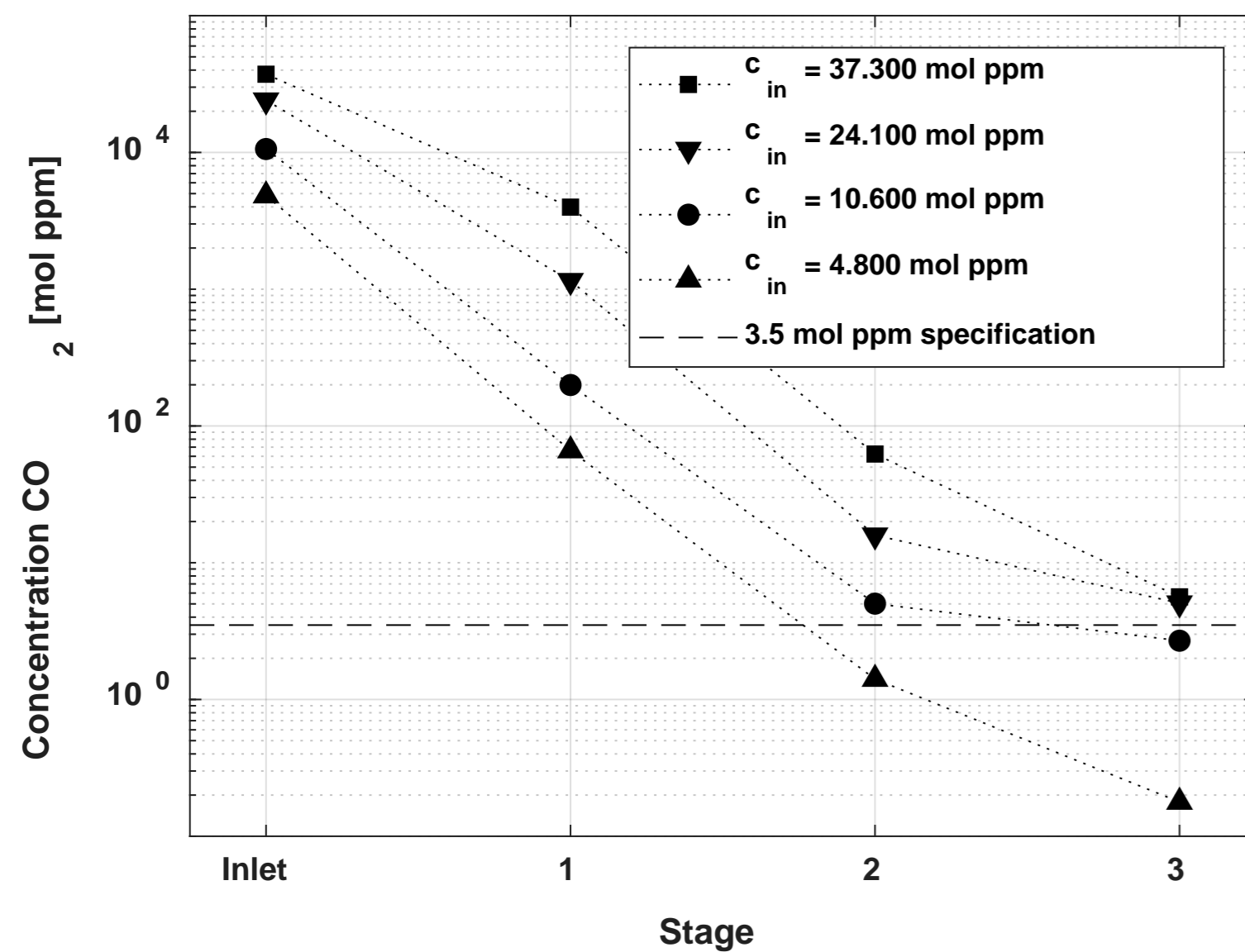


Sorbent bypassing without diverter is significant



# Results

Varying inlet concentration



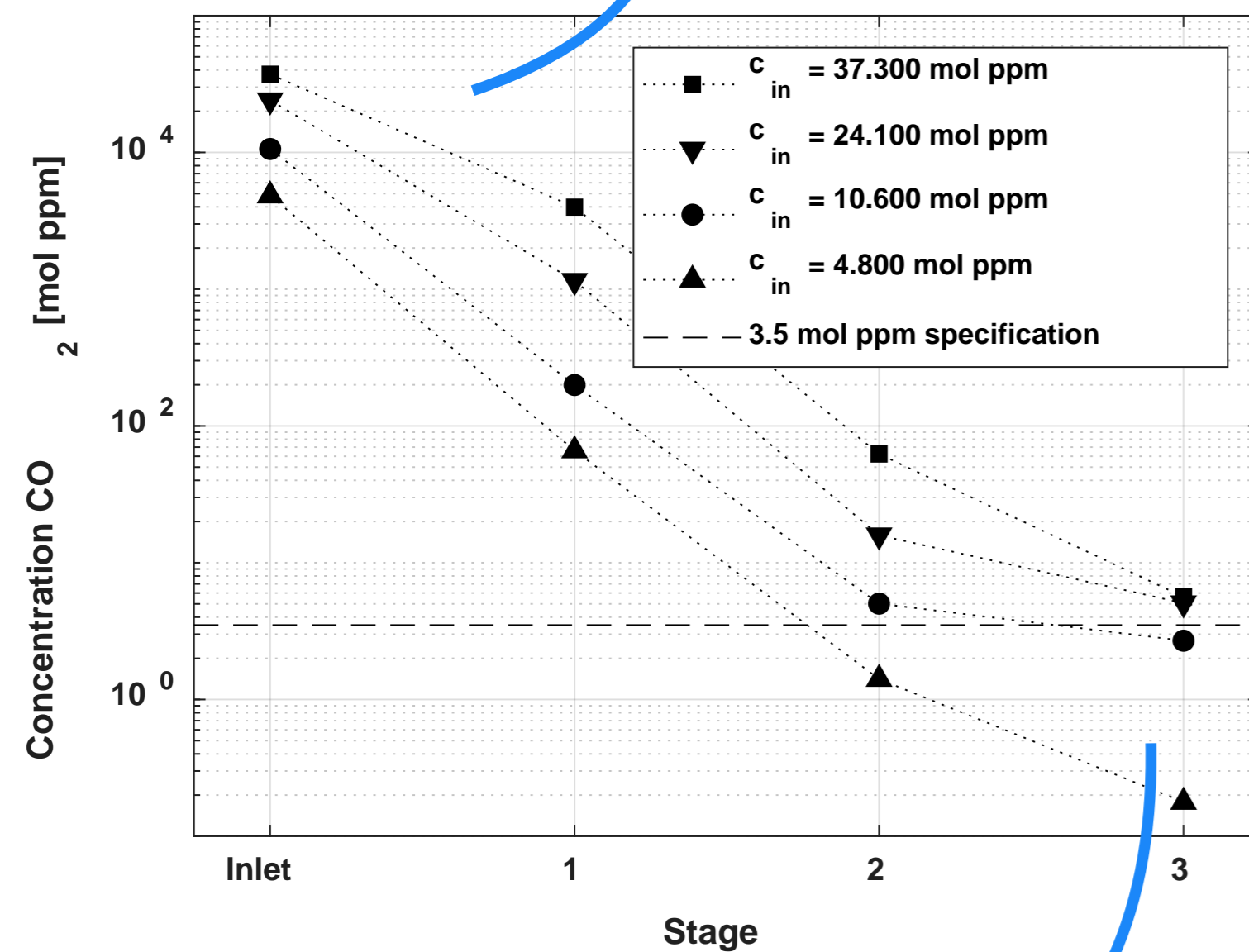
## Parameters

- $P = 10$  bara
- $u_0 = 0.084$  m/s
- $S = 2.04$  kg/( $m_R^2$  s)
- $H = 130$  mm

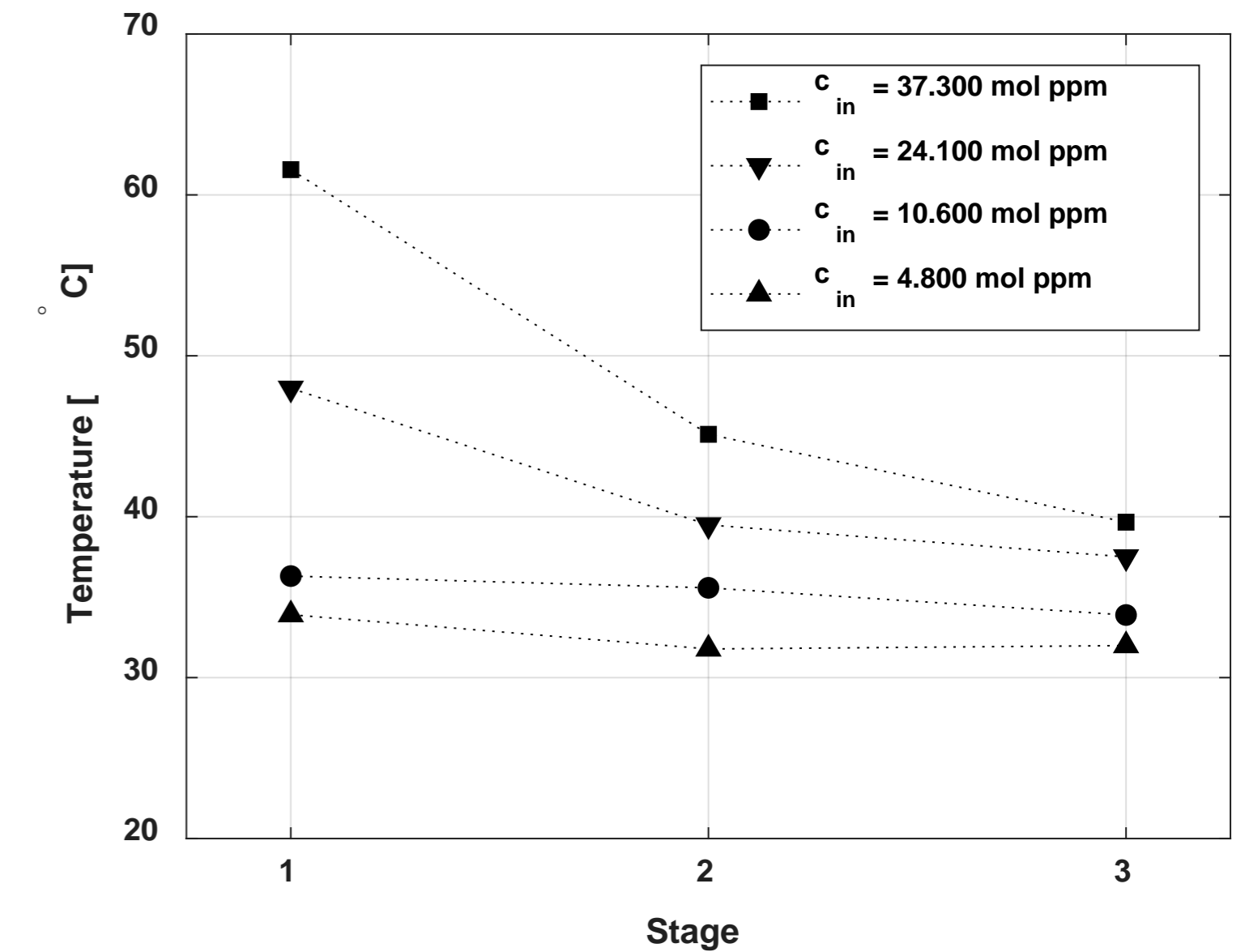
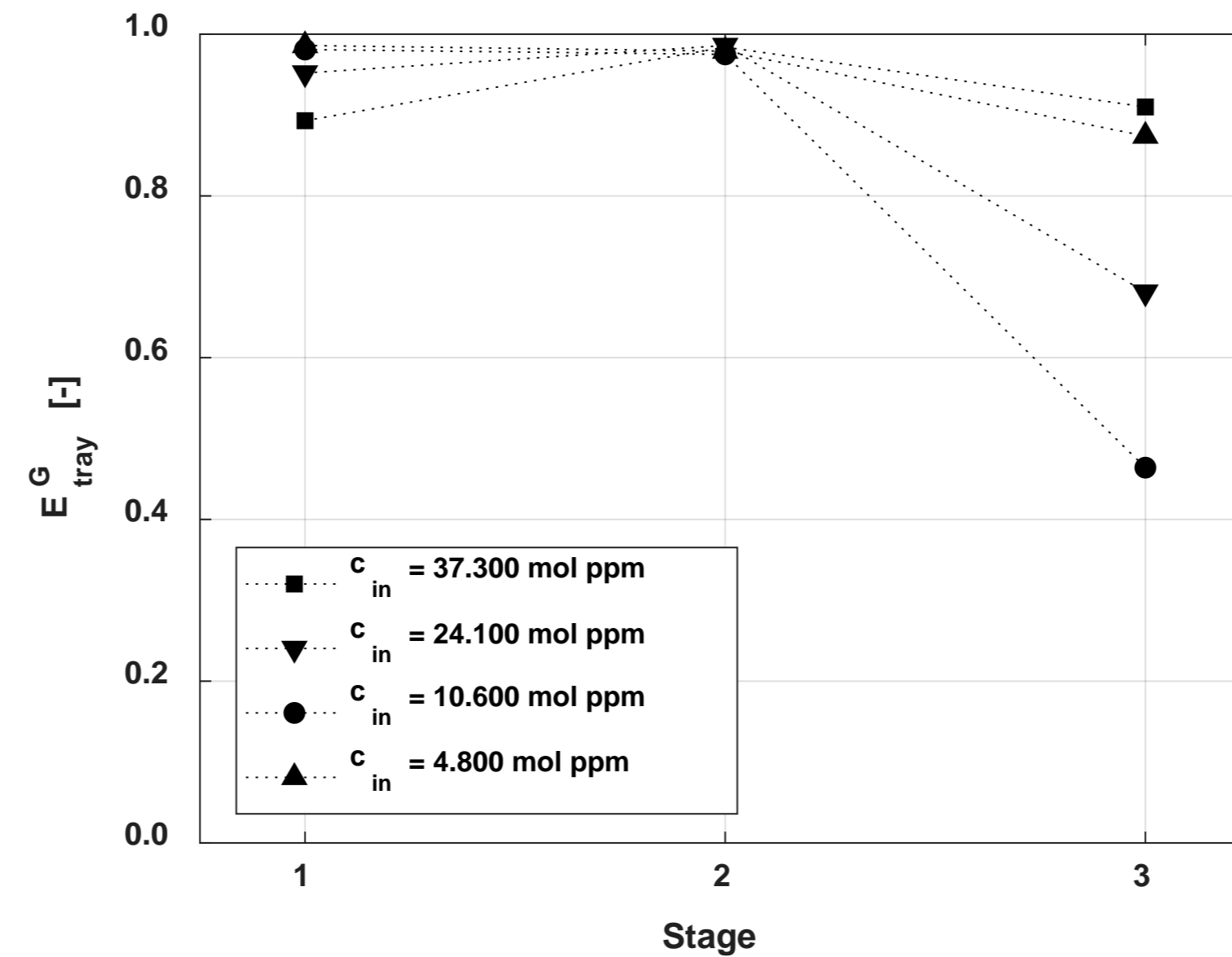
# Results

Varying inlet concentration

Pressurized MSFB technology  
is also suitable for high  
concentrations



H<sub>2</sub>S specification (<3.5 ppm)  
can be reached



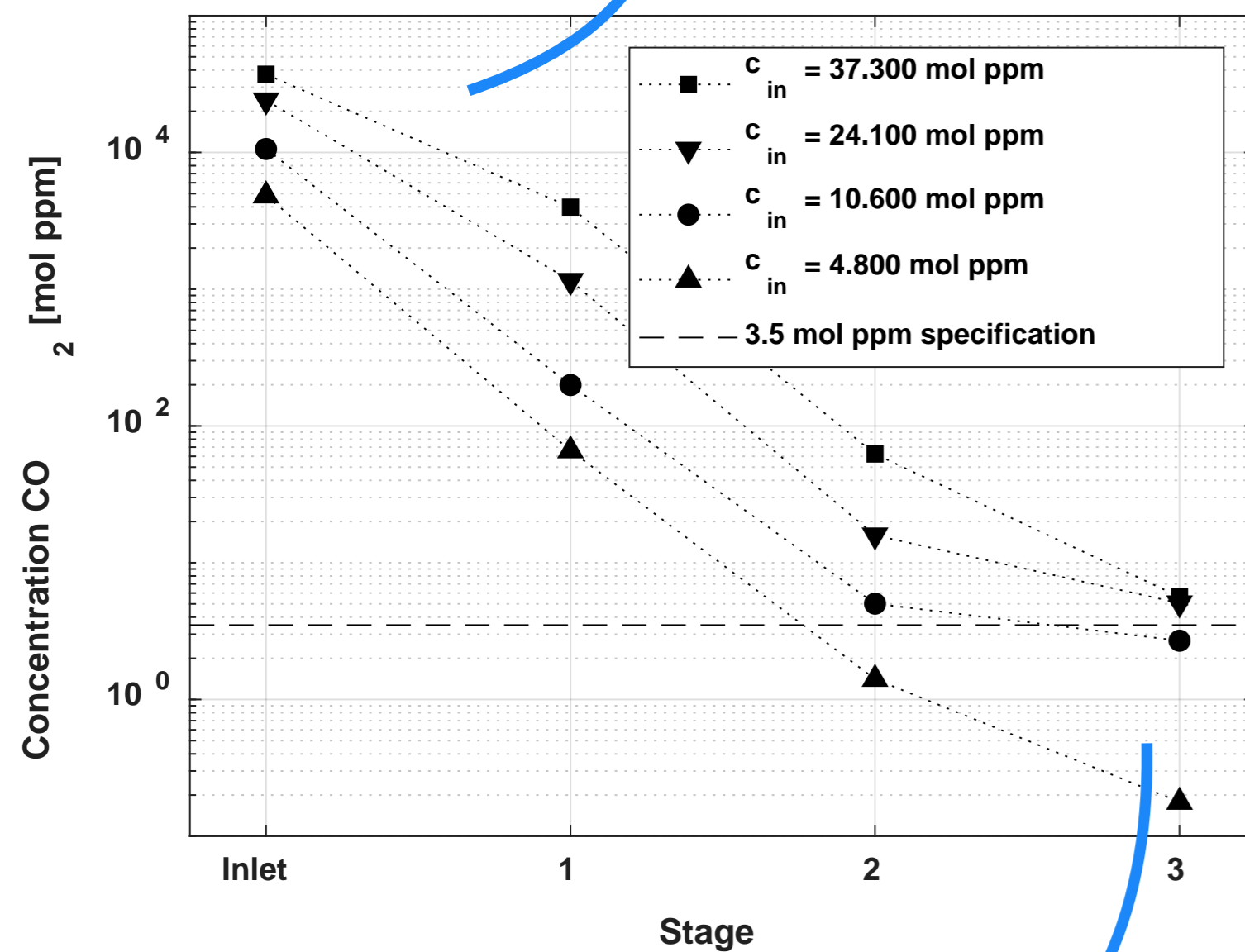
## Parameters

- $P = 10$  bara
- $u_0 = 0.084$  m/s
- $S = 2.04$  kg/(m<sub>R</sub><sup>2</sup> s)
- $H = 130$  mm

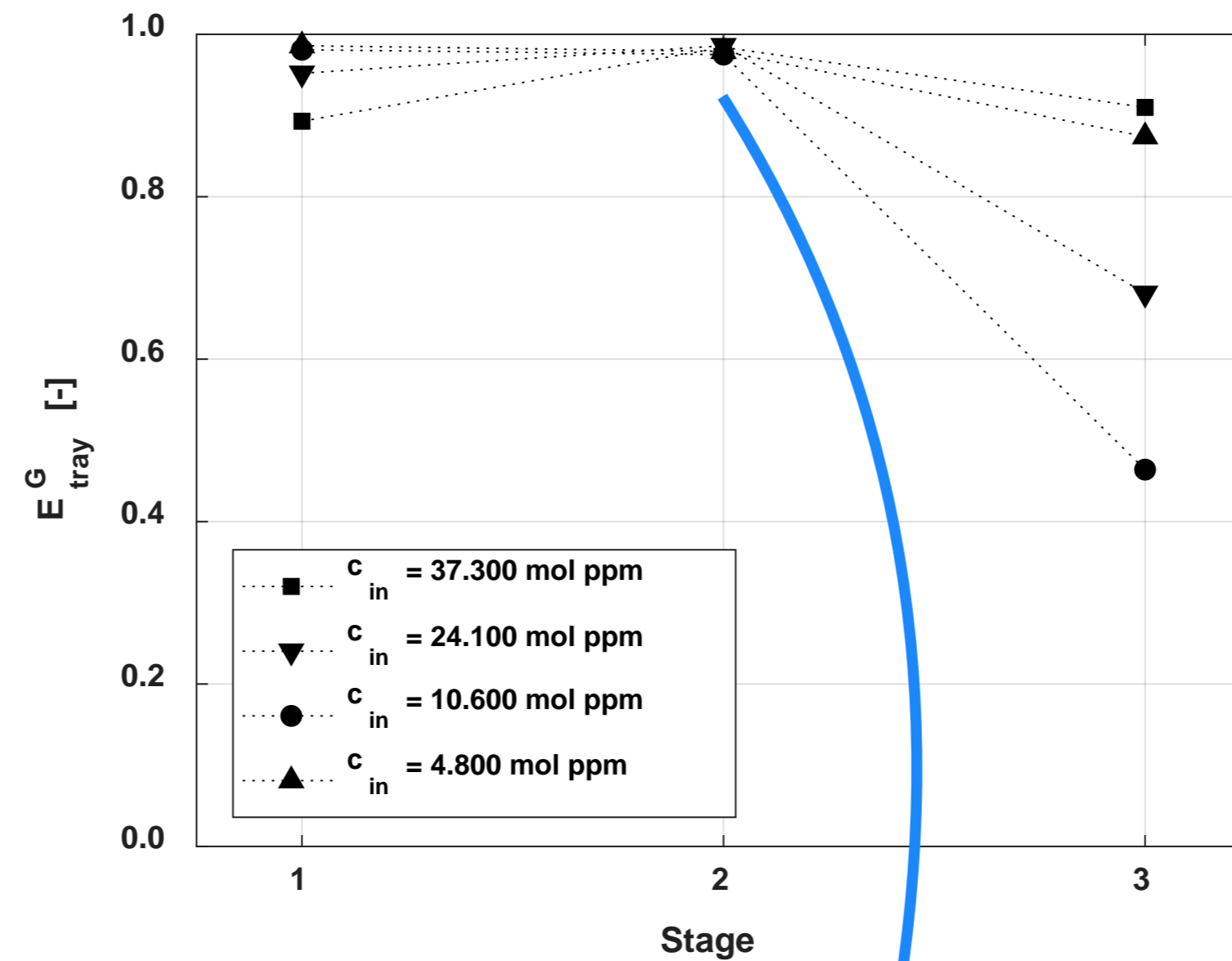
# Results

Varying inlet concentration

Pressurized MSFB technology is also suitable for high concentrations

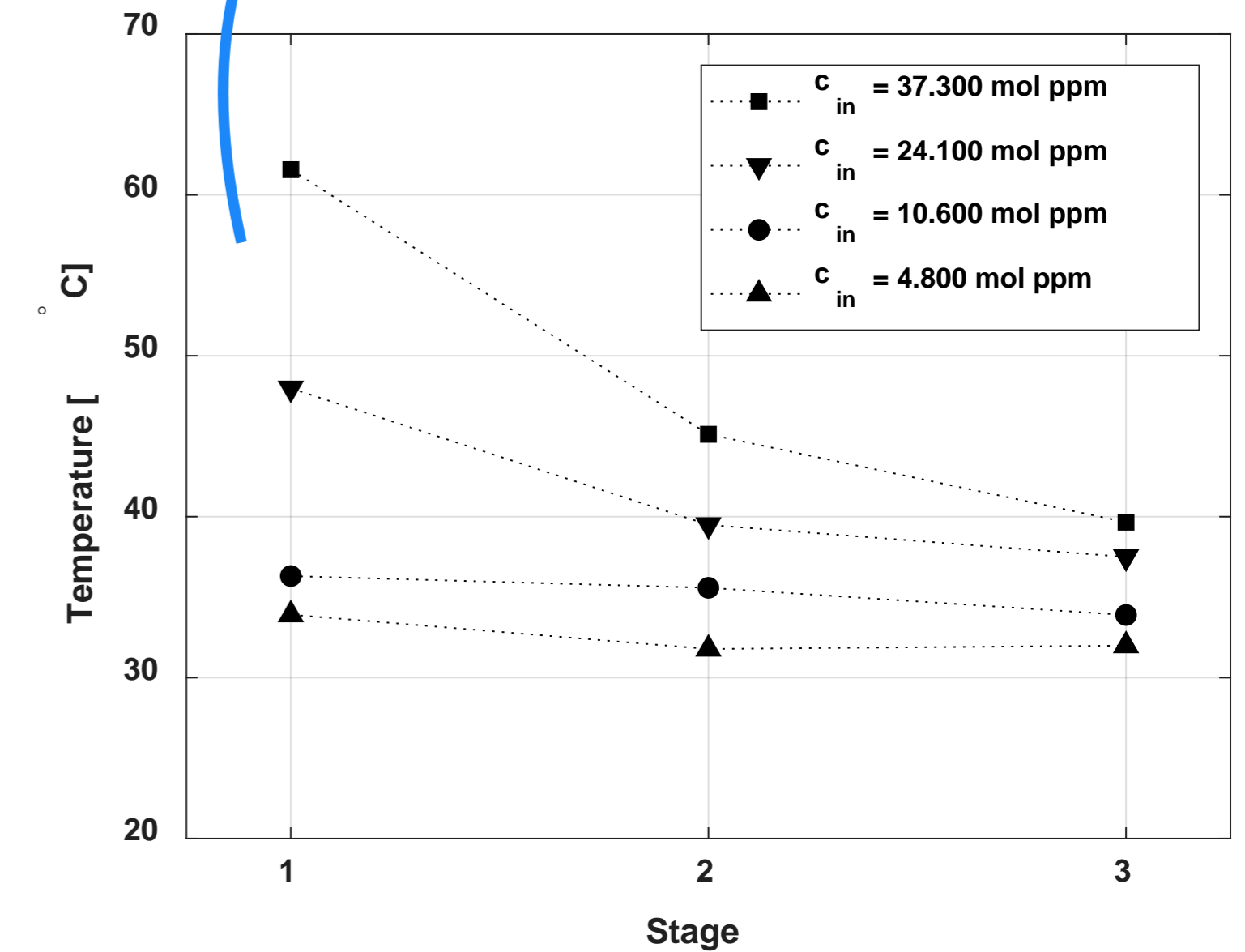


$\text{H}_2\text{S}$  specification (<3.5 ppm) can be reached



Tray efficiencies remain high: >90%

Temperature increase due to exothermic adsorption



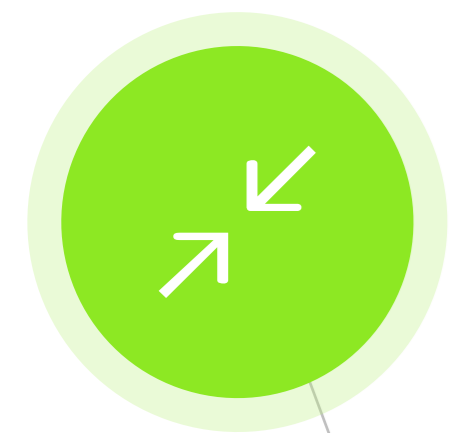
## Parameters

- $P = 10$  bara
- $u_0 = 0.084$  m/s
- $S = 2.04$  kg/( $m_R^2$  s)
- $H = 130$  mm



# Conclusions

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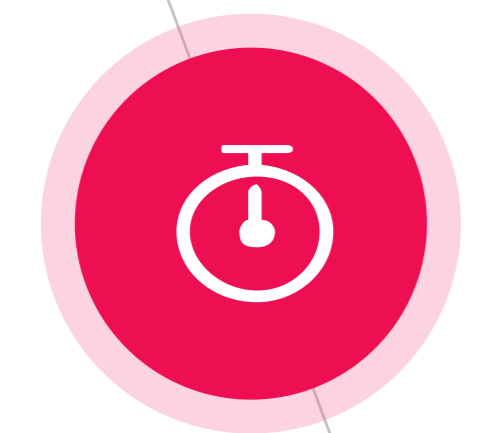
## Compact

A pressurized MSFB provides small adsorption equipment.



## Possible

Continuous PSA is technically possible and demonstrated.



## Fast

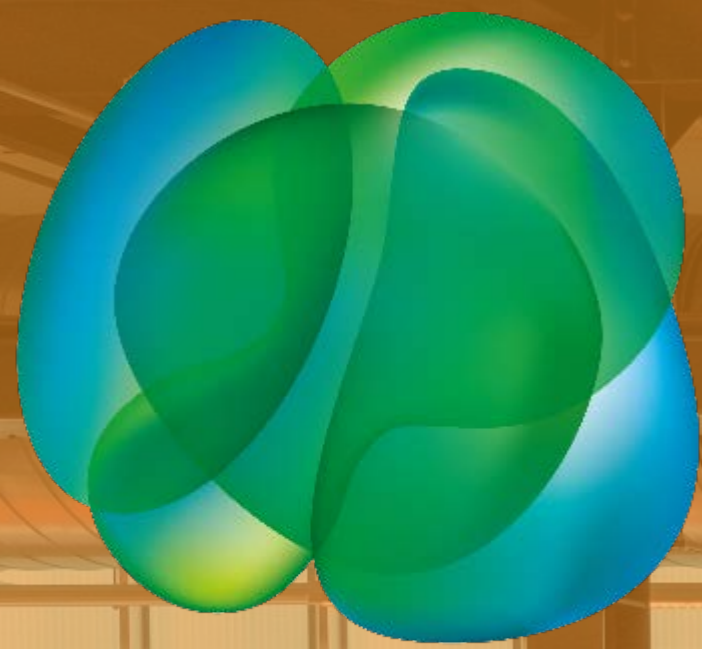
Deep removal is possible: 40 000 ppm to <10 ppm in <2 s.



## Efficient

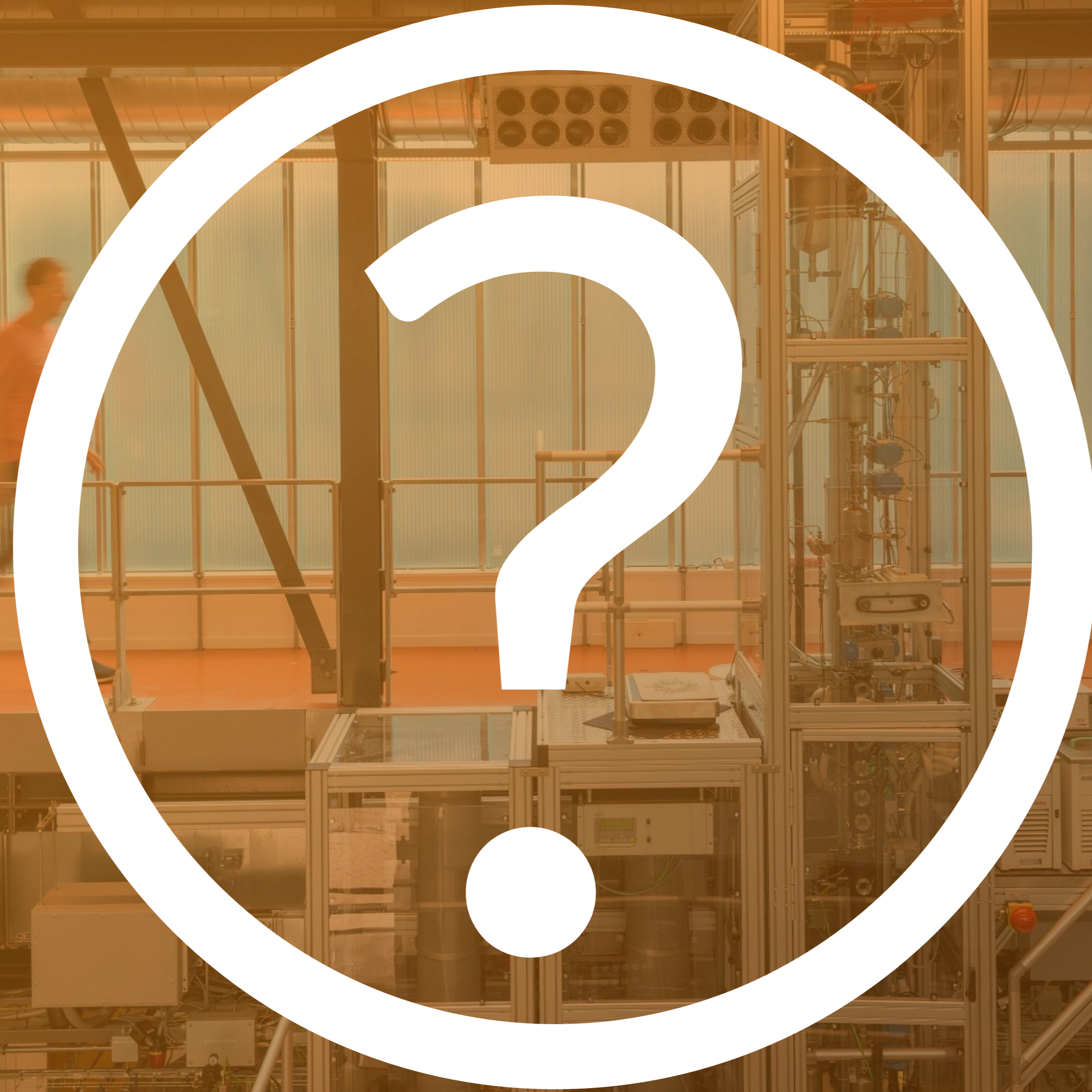
Equilibrium is almost reached at every stage.





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