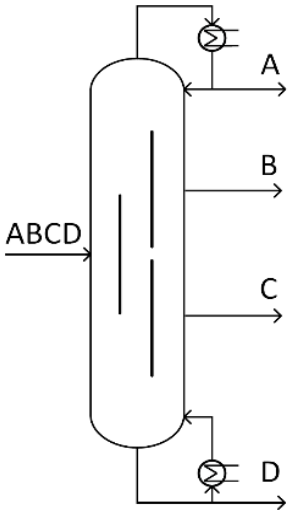
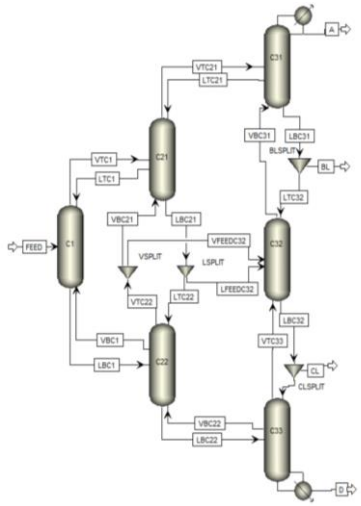
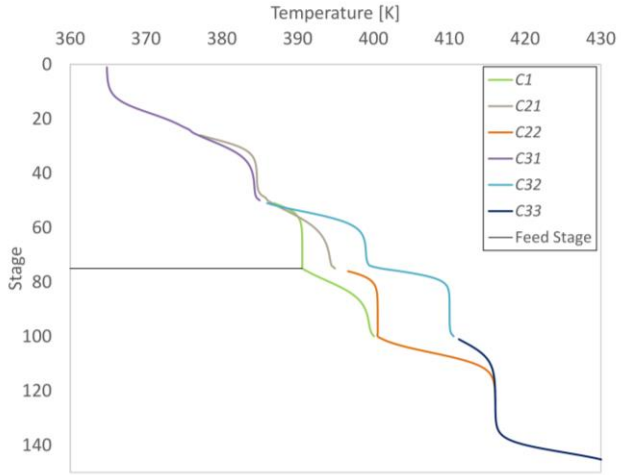
How to Start up Multiple Dividing Wall Columns – A Theoretical and Experimental Study







Yannick Waibel, Lena-Marie Ränger and Thomas Grützner
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Introduction

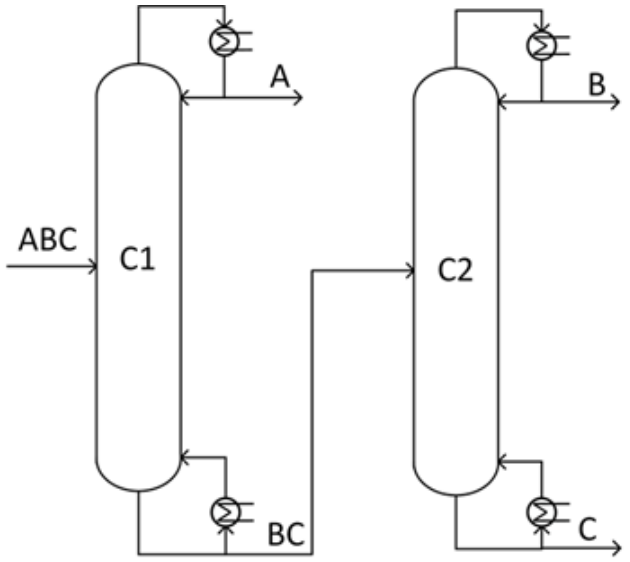
Thermal Process Engineering
Ulm University

Distillation

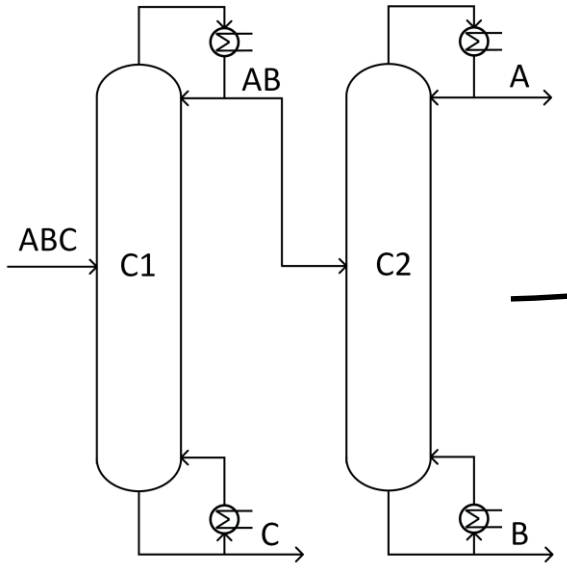
- Biggest share in the energy consumption of the chemical industry
- Low energy efficiency
- High operating costs
  - ➢ Energy savings necessary, especially in the face of a greener economy and rising energy prices!

Multi-component mixtures: separation traditionally in column sequences

Direct split



Indirect split



Introduction

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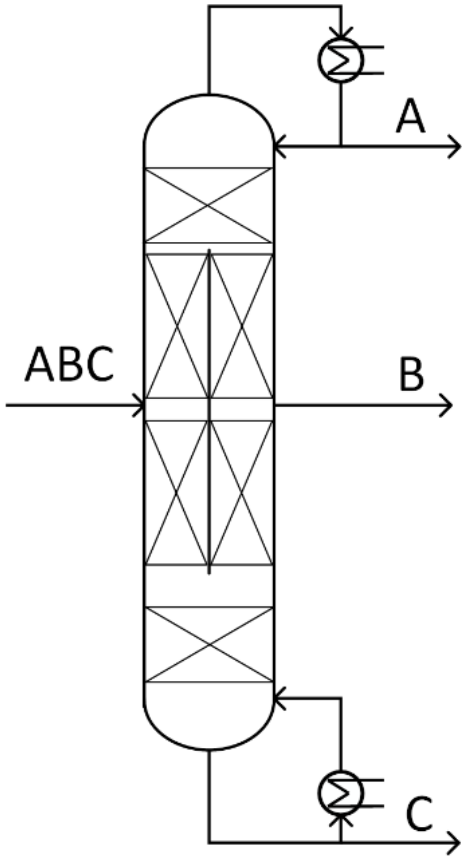
Dividing Wall Column (DWC)



- Separation of ternary mixtures
- Savings of up to 30 % in OPEX and CAPEX[1]
- High complexity of design, operation and control
- First industrial implementation in 1985 by BASF
- Today established technology
- Hundreds of columns already in operation[2]

[1] N. Asprion, G. Kaibel, Dividing wall columns: Fundamentals and recent advances, Chemical Engineering and Processing: Process Intensification 49 (2010) 139–146.
[2] H.-M. Lorenz, D. Staak, T. Grützner, and J.-U. Repke, Divided Wall Columns: Usefulness and Challenges, Chemical Engineering Transactions, vol. 69, pp. 229-234, Oct. 2018.

Introduction

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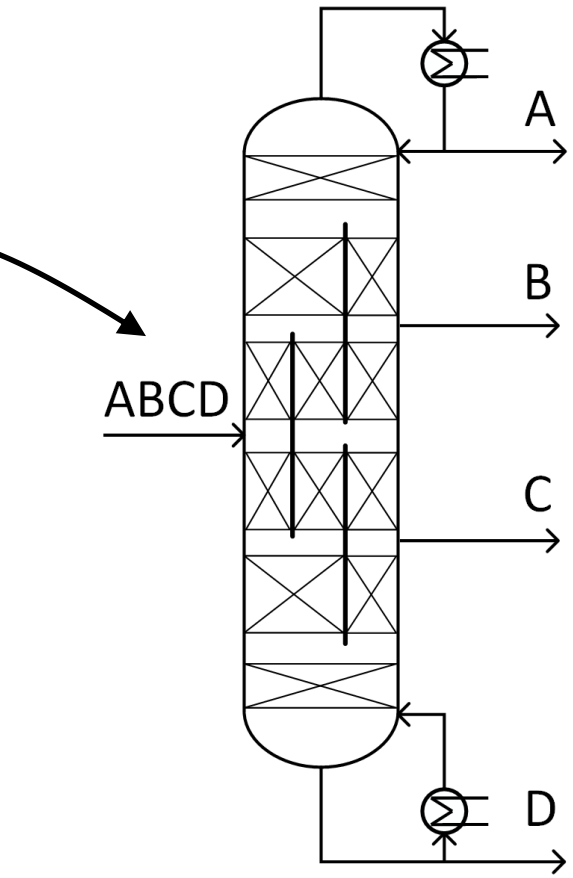
Multiple Dividing Wall Column (mDWC)



- Separation of mixtures with four or more components
- Savings of up to 55 % in OPEX[3] and lower CAPEX
- Very high complexity of design, operation and control
- No previous practical implementations of mDWCs
  - ➢ World‘s first mDWC comissioned in fall 2021 at Ulm University
  - ➢ Research on the whole development cycle of mDWCs
- Meanwhile: world’s first commercial application of a mDWC in 2023 at BPCL in Mumbai, India[4]

⇒
- Increasing relevance of mDWCs
- Need for better understanding on operation including the start-up process

[3] I. Dejanović et al., Designing four-product dividing wall columns for separation of a multicomponent aromatics mixture, Chemical Engineering Research and Design 89 (2011) 1155–1167.
[4] DWC Innovations, Successful Commissioning of World's First Commercial Application of Dual Dividing Wall Column at BPCL, Mumbai, Press Release (2023), https://www.dwcinnovations.com/press-release/successful-commissioning-of-dual-dividing-wall-column-at-bpcl-mumbai/

Start-up of distillation columns

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Why is the start-up of distillation columns relevant?

- Start-up generally a non-productive process
- Growing importance of minimizing production costs and generated waste
  - ➢ Achieved by shortening the start-up time
- Intensively discussed topic in research:
  - Several studies on the time-optimal start-up of distillation columns
  - Start-up of dividing wall columns discussed in some works
    - ➢ Start-up time strongly dependent on selected start-up strategy
  - Start-up of mDWCs:
    - ➢ Neither been studied in theory, nor in practice yet, to the best of the author’s knowledge

Pilot column

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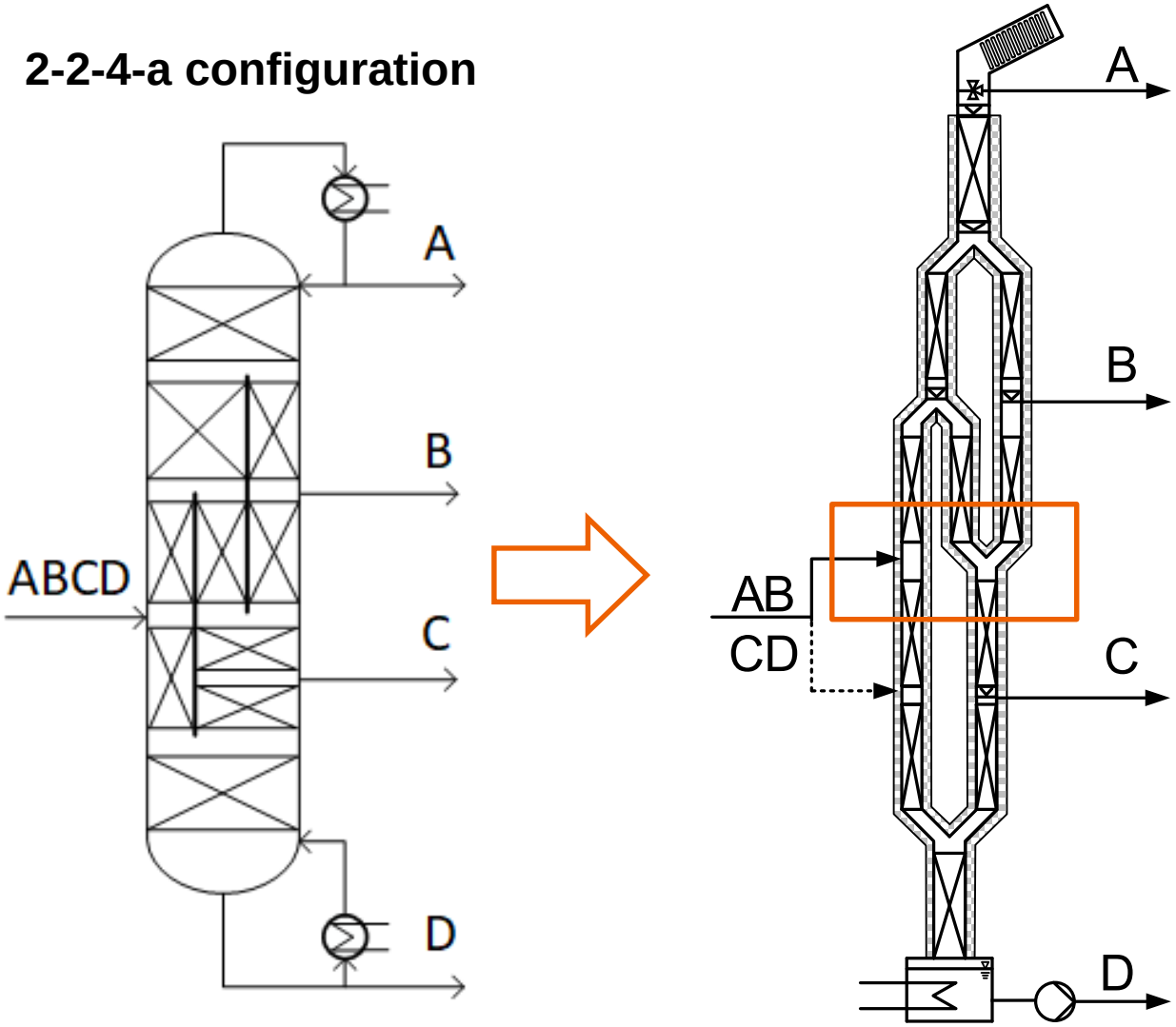
2-2-4-a configuration



- Thermally coupled packed column
- Every separation section as separate column
  - ➢ Easier construction
  - ➢ No heat transfer across dividing walls
- Total height of 9.6 m
- Column diameter DN80 and DN50 for parallel sections
- Controllable liquid splits
- More than 80 sensors for temperature, pressure (difference) and flow rate

Pilot column

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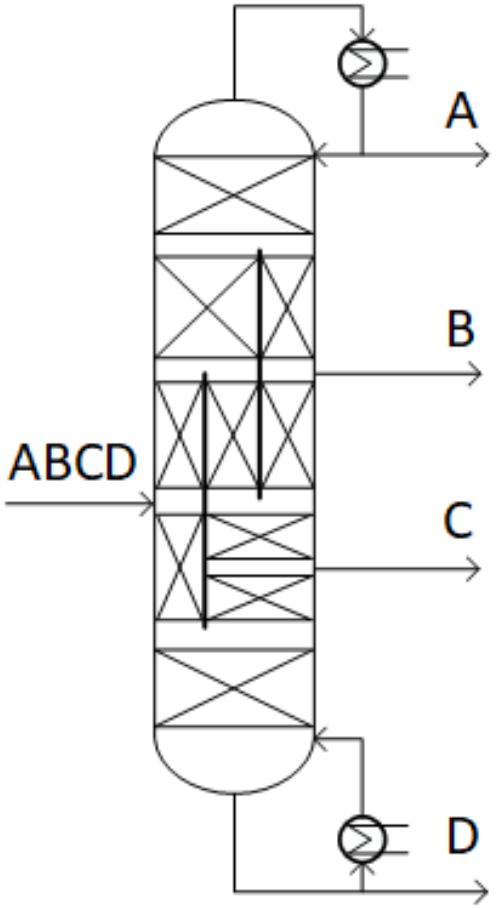
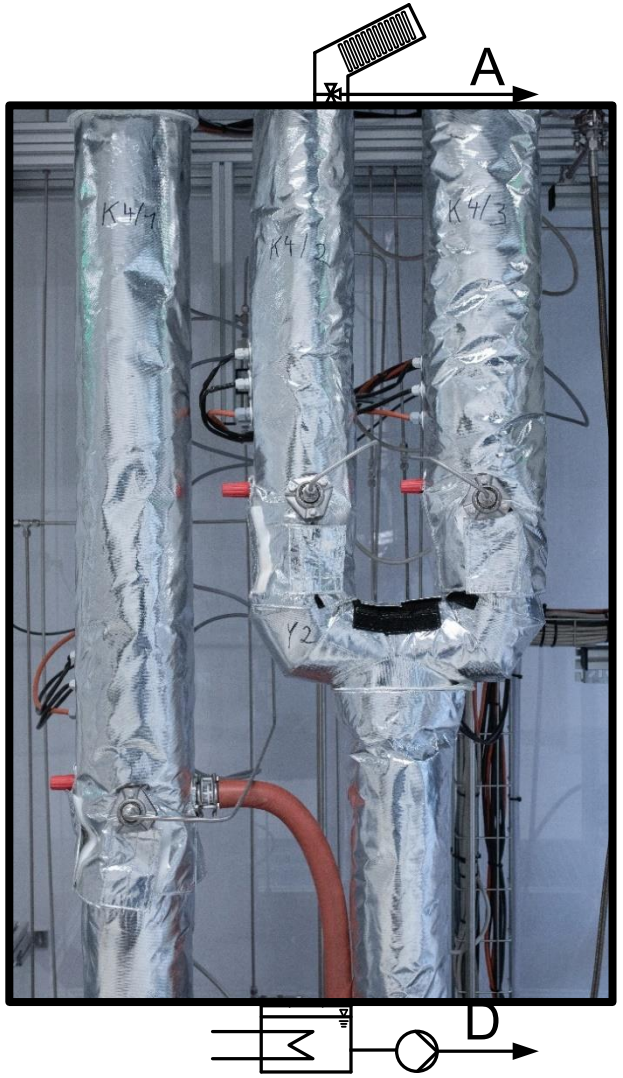
2-2-4-a configuration





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Column Start-up

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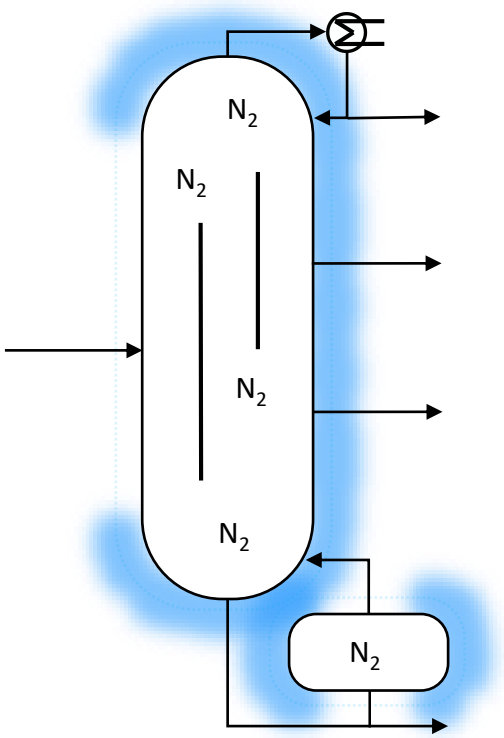

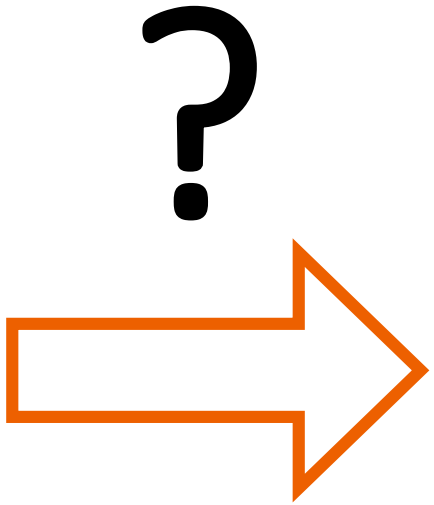

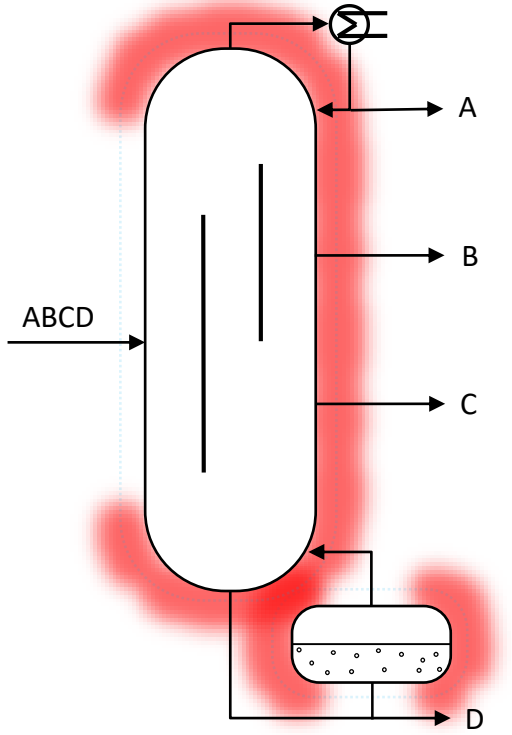

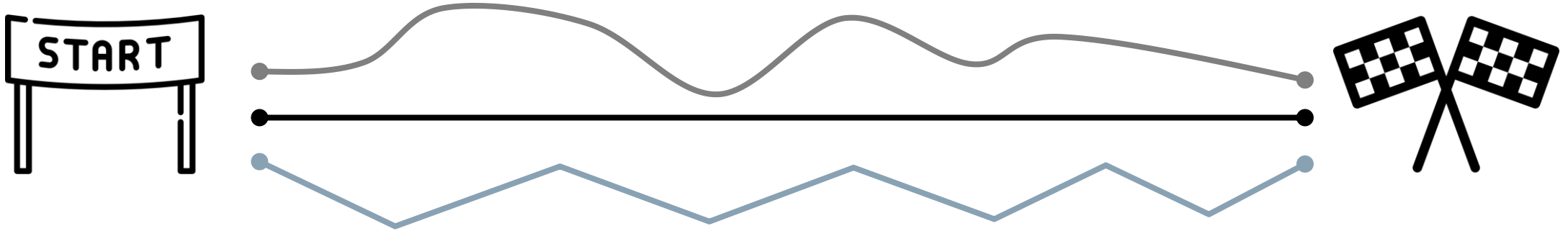

New start-up strategy

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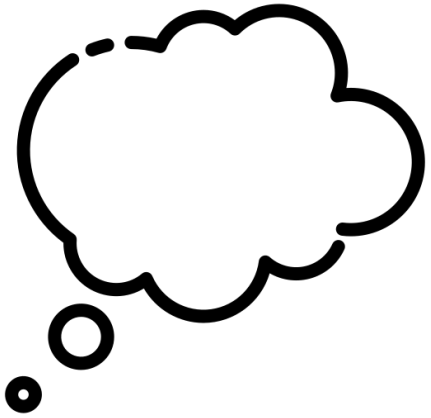

What makes a start-up strategy a good start-up strategy?

- Meet operating point
- Short start-up time
- No complex process control
- Reliable start-up process

➢ **Development of a start-up strategy using a dynamic simulation in Aspen HYSYS V11**

- Equilibrium stage model
- Pressure and gravity driven
- Start-up from dry and cold state
- Test system: Ethanol / n-propanol / i-butanol / n-butanol
- NRTL as thermodynamic model
- Heat capacity of the column and the packing can not be considered

New start-up strategy

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- No strategies for the start-up of mDWCs available
  - ➢ Adaptation of existing start-up strategies for DWCs[5,6]

Continuous start-up strategy

- Developed by Niggemann, Hiller and Fieg[5]
- Continuous feed stream
- Start of heating as reboiler filled to desired level
- All process parameters set to their steady state values when reflux stream sufficient

Discontinuous start-up strategy

- Developed by Wu, Shen and Ling[6]
- Discontinuous feed stream
- Product withdrawal in intervals
- Constant introduction of feed as steady state temperature profile obtained
- All process parameters set to their steady state values

[5] G. Niggemann, C. Hiller, G. Fieg, Modeling and in-depth analysis of the start-up of dividing-wall columns, Chemical Engineering Science 66 (2011) 5268–5283.
[6] H. Wu, B. Shen, H. Ling, Startup of divided wall column for high purity separation of aromatic reformate, Can. J. Chem. Eng. 96 (2018) 2627–2637.

Simulation of the start-up process

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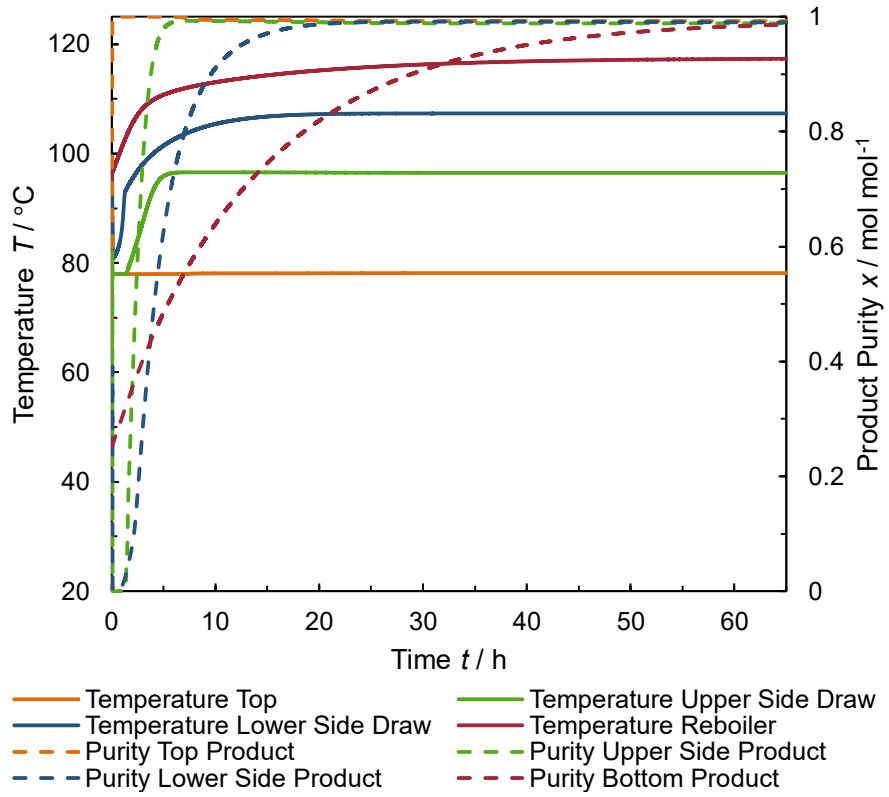
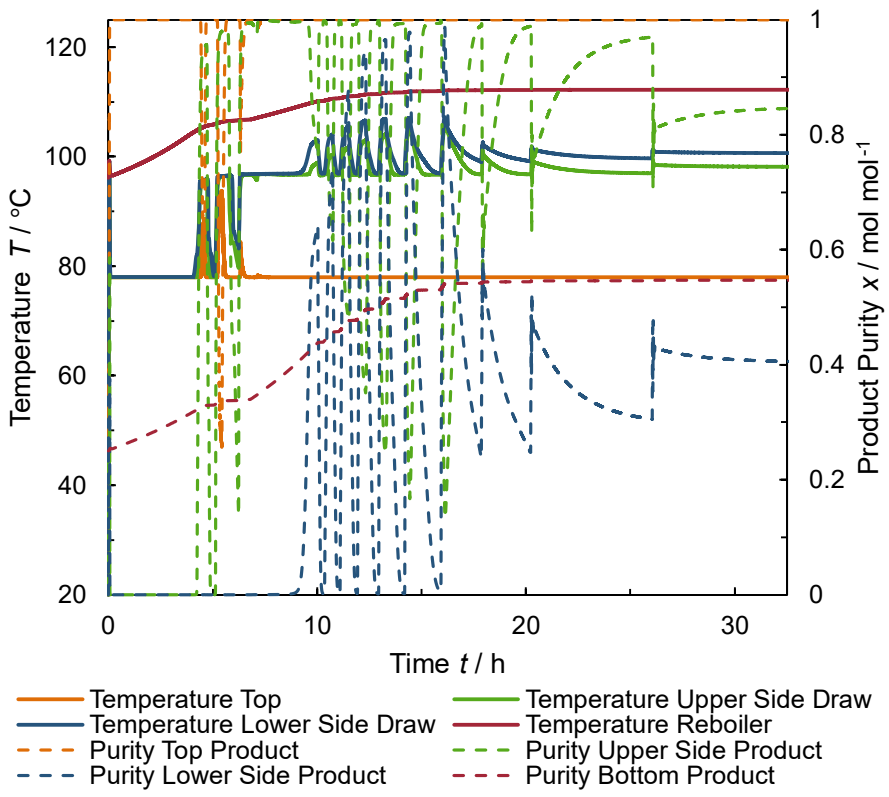
Continuous start-up strategy



➢ Start-up time of over 60 h

Discontinuous start-up strategy



➢ Not feasible for the given operating conditions

Simulation - Adjustment of the start-up process

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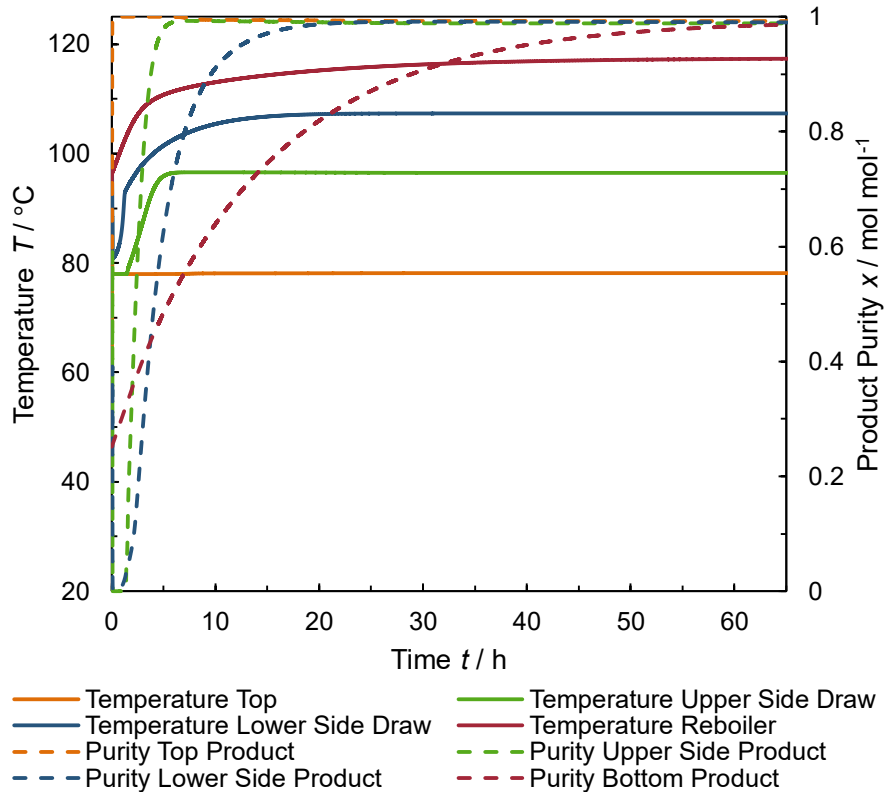
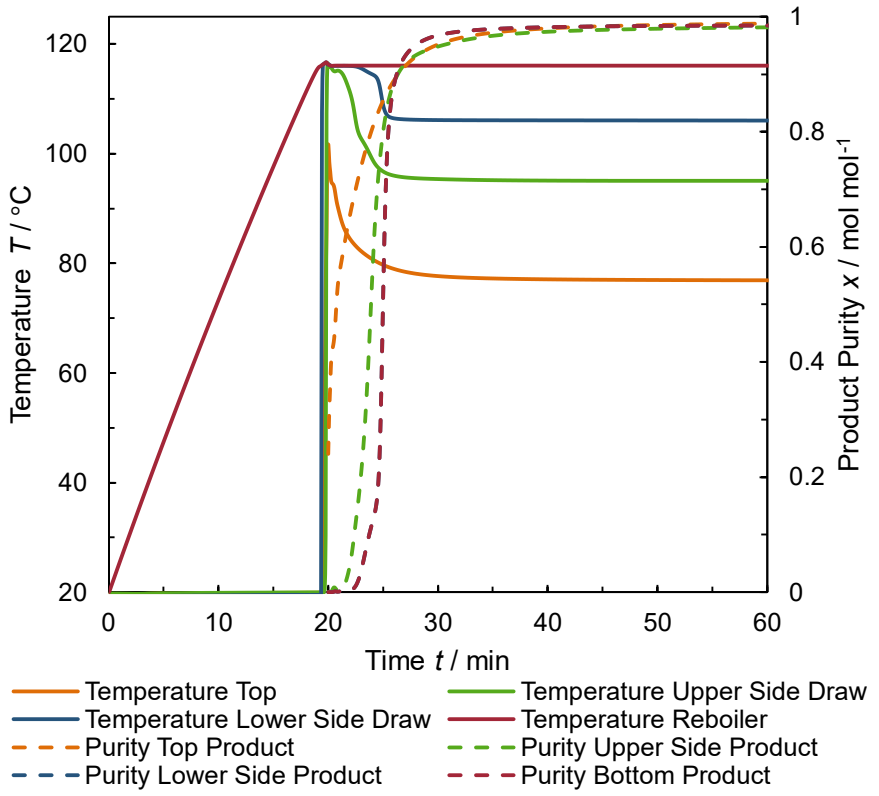
Continuous start-up strategy



Initially filling the reboiler with heavy boiler

Introduction of feed when reboiler is at boiling temperature

Modified continuous start-up strategy



➢ Reduction of the start-up time from over 60 h to considerably shorter time

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Simulation - Influence of the time of feed introduction

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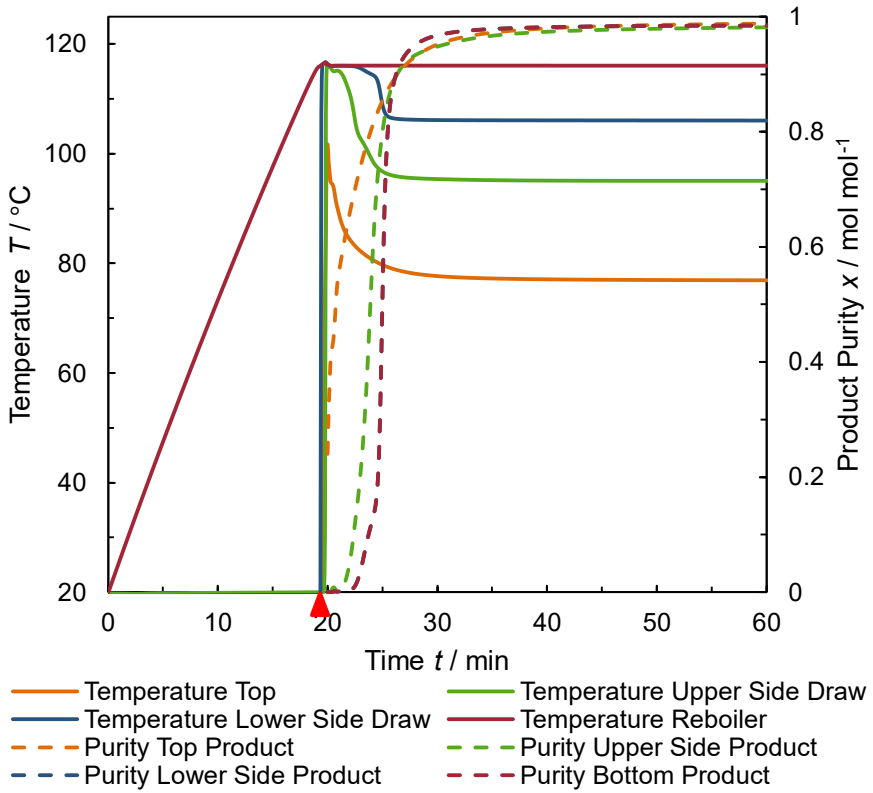
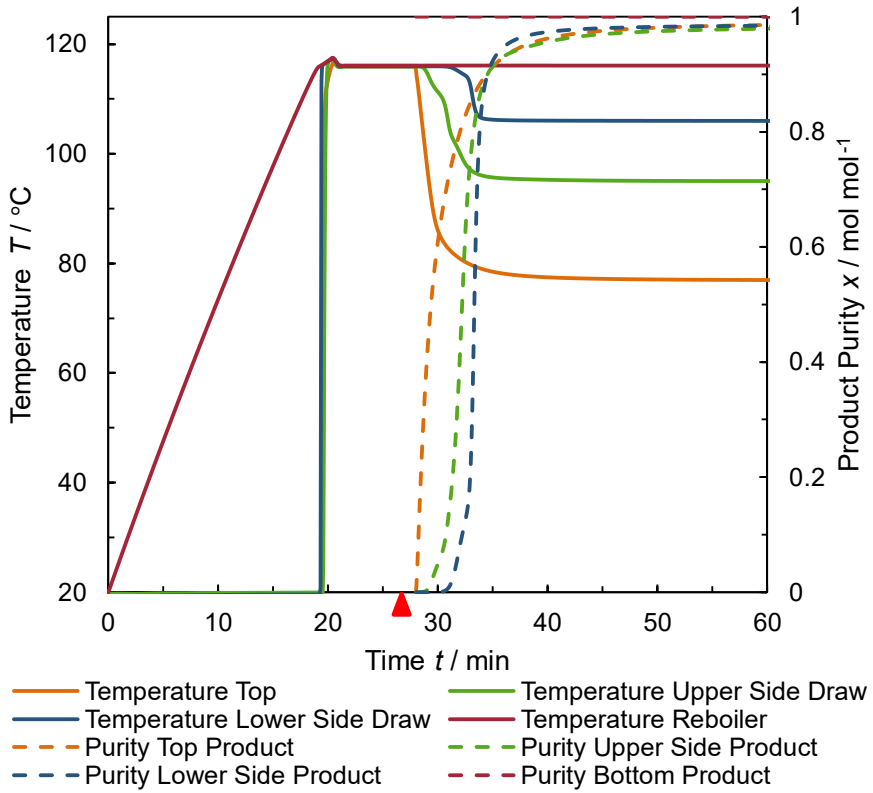
When reboiler at boiling temperature



When top temperature stable



➢ Delay of the start-up process for later feed introduction

Simulation - Influence of the time of product valve opening

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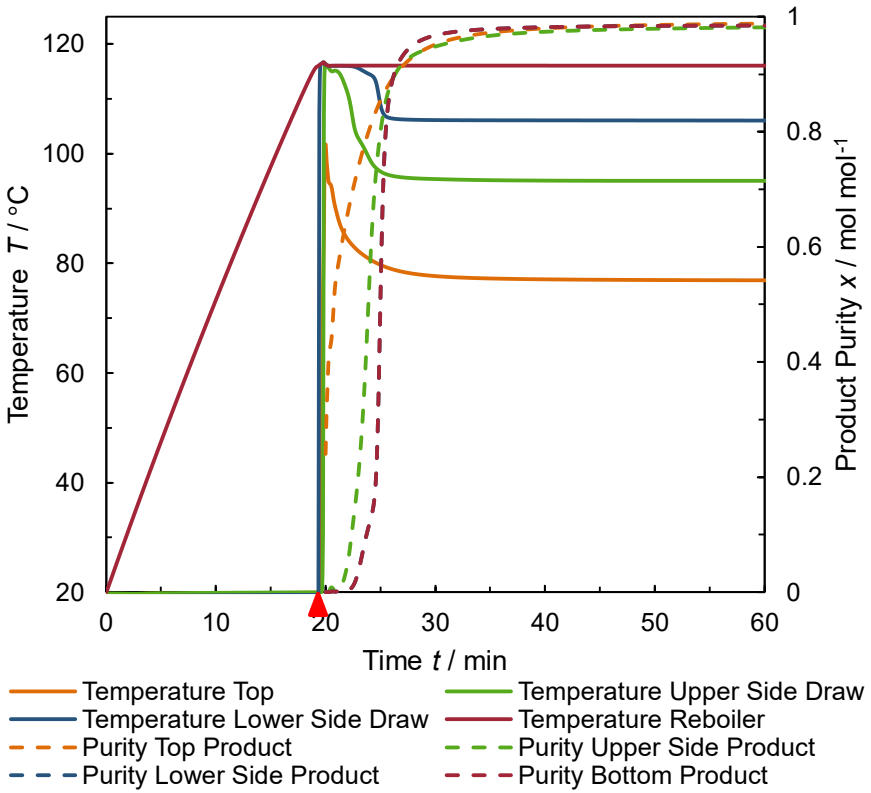
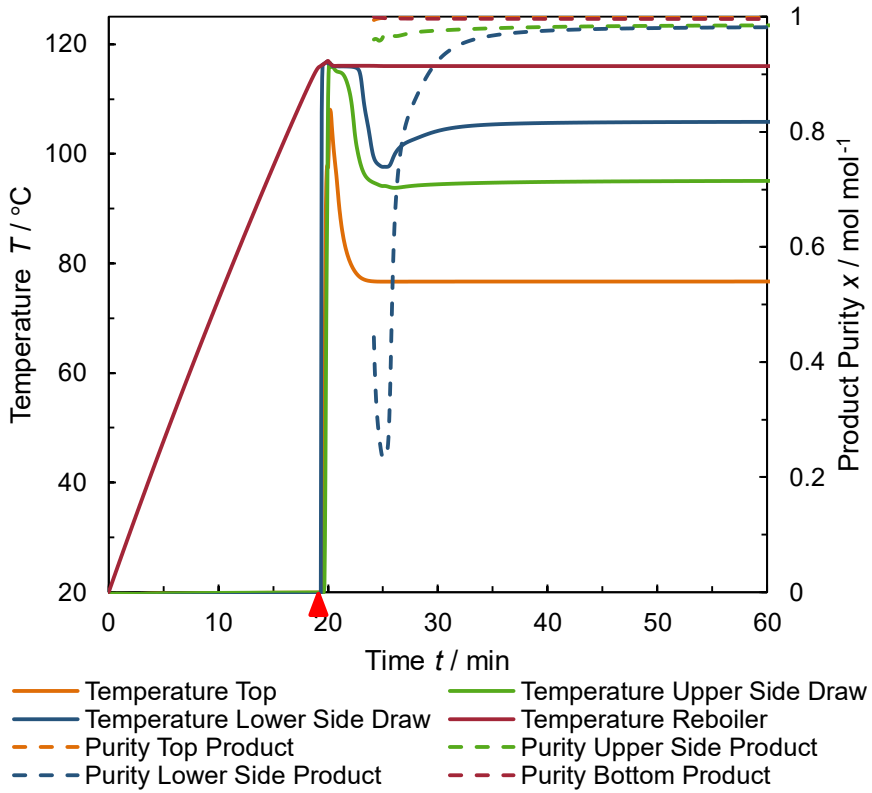
When reflux sufficient



When top temperature stable



➢ Significant disturbances in the temperature profile for later opening of the product valves

Experimental validation of the simulation results

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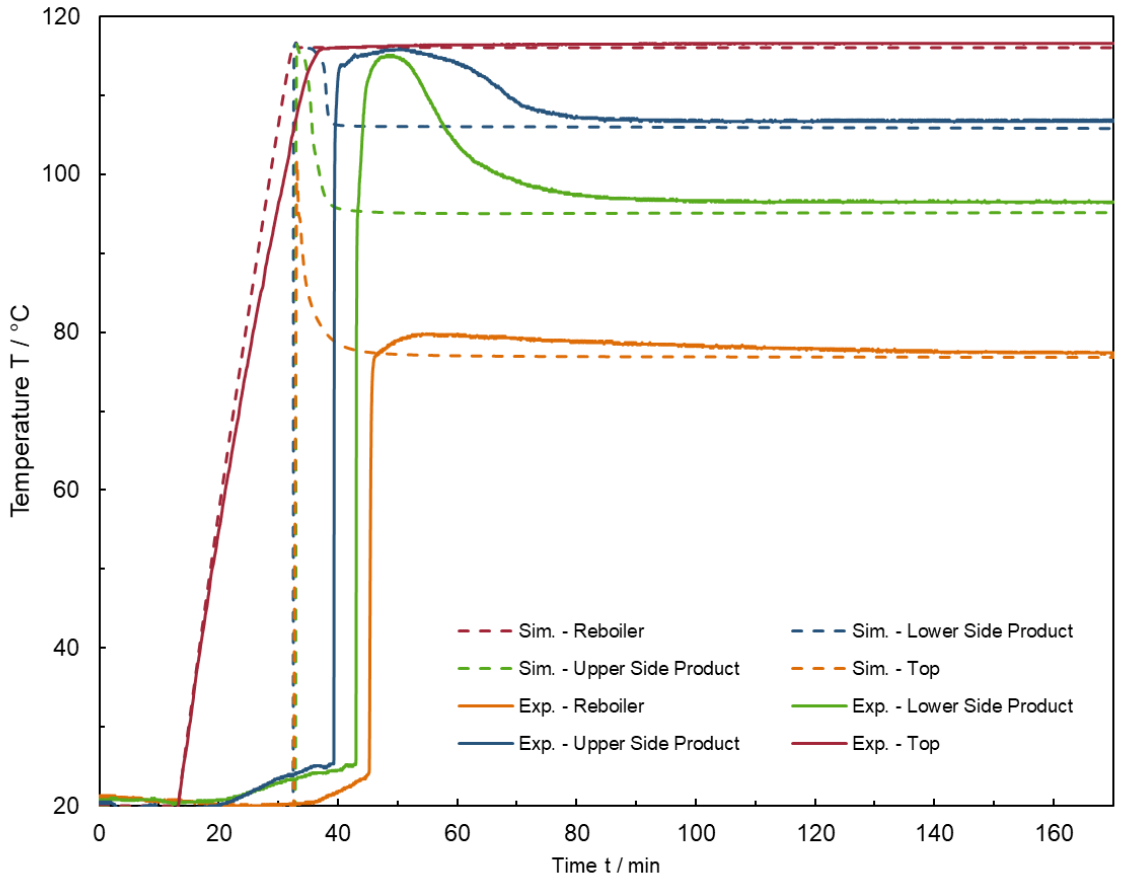
Start-up process of the column with the modified continuous start-up strategy:



- Developed start-up strategy is applicable to the real pilot plant
- Start-up within few hours

- Good agreement with simulation results

Experiment - Influence of the time of feed introduction

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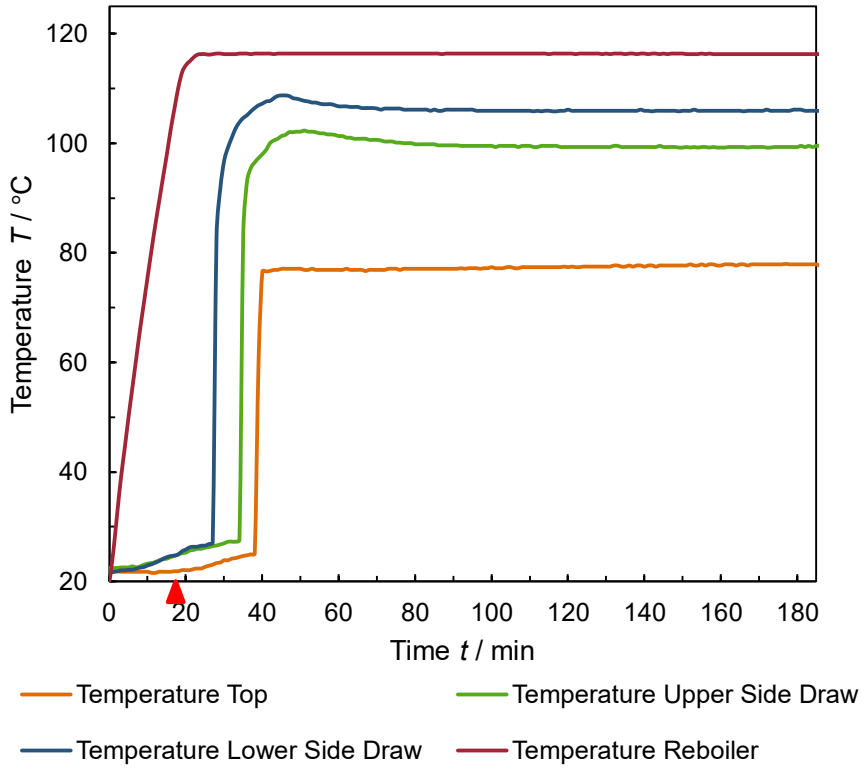
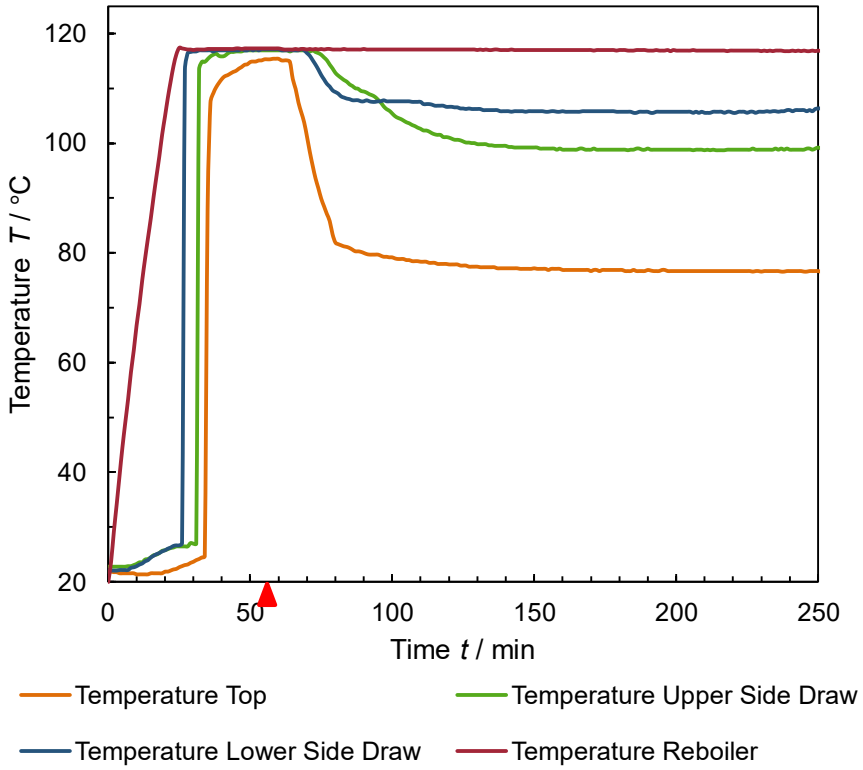
When reboiler close to boiling temperature



When top temperature stable



➢ Delay of the start-up process for later feed introduction

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Experiment - Influence of the time of product valve opening

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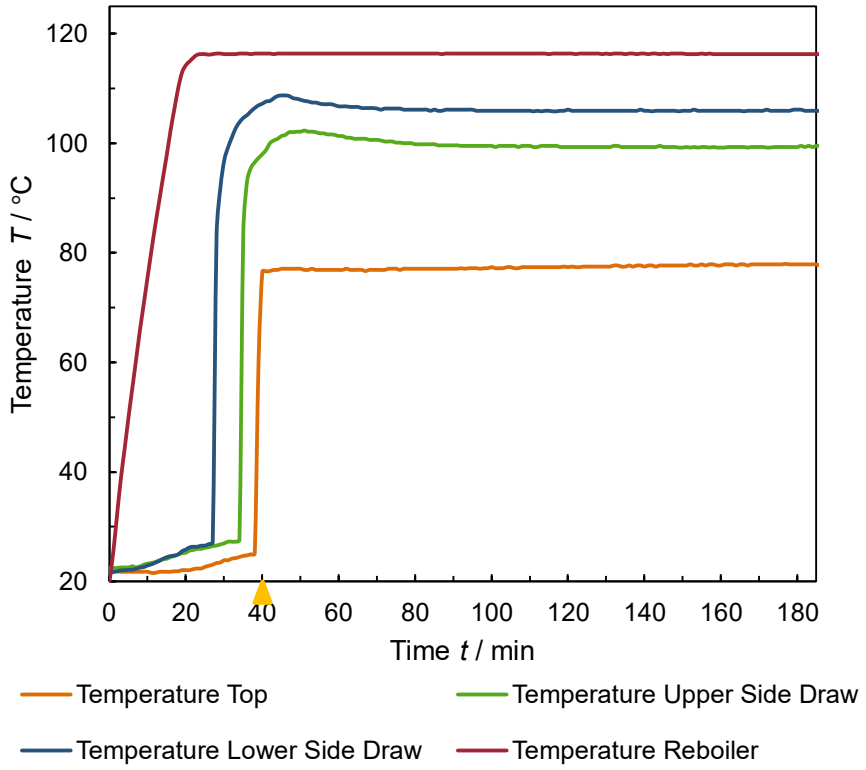
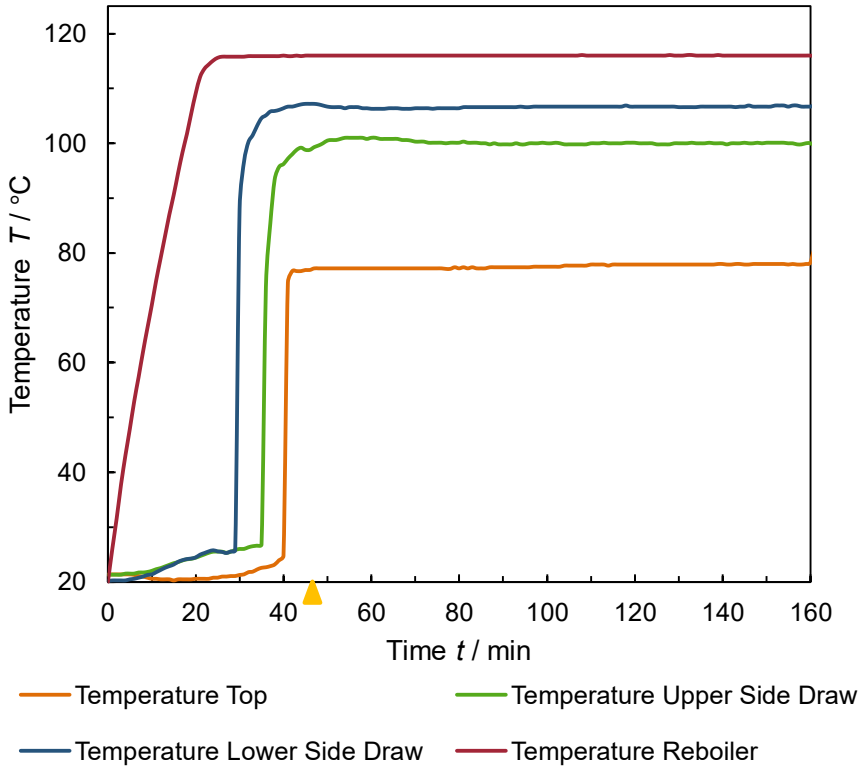
When reflux sufficient



When top temperature stable



➢ No large influence of the time of product valve opening, in contrast to the simulation

Summary

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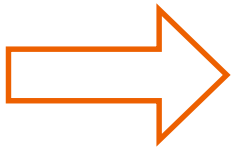
- World‘s first multiple dividing wall column comissioned in fall 2021 at Ulm University
- Implementation as thermally coupled 2-2-4-a configuration
- Testing of new start-up strategies for multiple dividing wall columns in a dynamic simulation model
- Development of start-up strategies is heavily based on empirics
- Experimental validation of the simulation model
  - ➢ Start-up process in the range of few hours
  - ➢ Good agreement with simulation results



Developed start-up strategy allows for a quick and reliable start-up

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Thank you for your attention!

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