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Performance of a Pillow Plate Thermosiphon Reboiler for Hexanol, Pentanol, and their Mixtures

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Pillow Plate Heat Exchangers (PPHEs)

- more compact than shell and tube HEs & more temperature- and pressure-resistant than plate HEs
- advantageous usage as thermosiphon reboiler (TR): stabilized natural circulation & enhanced operating ranges towards low pressures, low submergences, and small driving temperature differences [1]
- lack of experimental data and model for PPHEs, especially for mixtures

Aim: determining the performance of a PPTR for pure substances and mixtures

Experimental Result

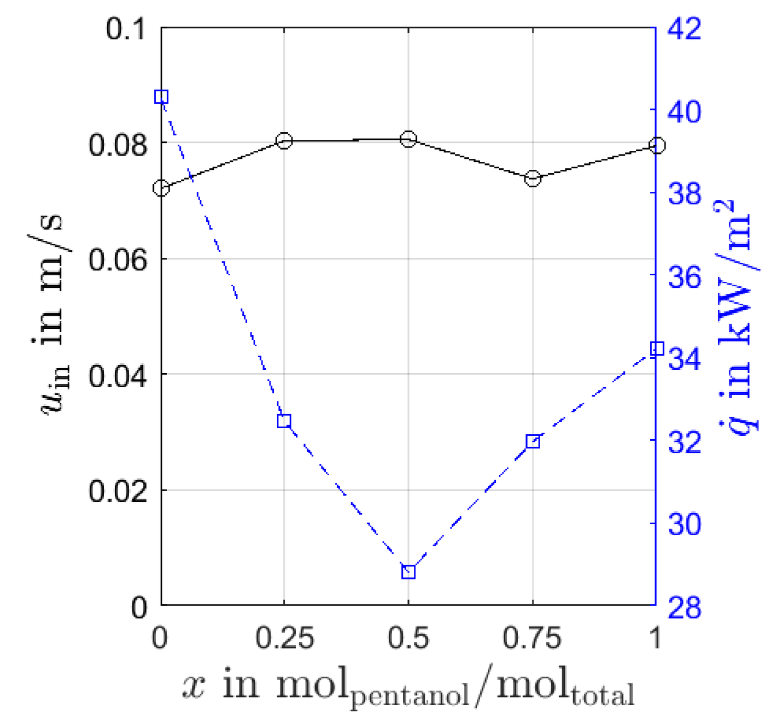
Fluid dynamics: Inlet velocity

- barely influenced by varying pentanol fractions
- main cause: similar density

Thermal performance: Heat flow density

- hexanol > pentanol > mixture
- minimum at x = 0.5 $mol_{pentanol}/mol_{total}$
- main cause: the enrichment of the lower boiling component in the vapor phase is highest for intermediate compositions of the mixtures [2]

Operating conditions: ΔT = 20 K, p = 800 mbar, submergence 90%



Heat transfer modeling

- using equivalent tube bundle geometry
- $1/\alpha_{(PS)} = 1/k - 1/\alpha_{HS} - s/\lambda_{wall}$

  with $k = \frac{\dot{Q}}{A\cdot\Delta T}$, $\Delta T = T_{HS} - \bar{T}_{PP}$,

  and α_{HS} according to [2]
- Bennet&Chen's model [3]

  $\alpha_{Bennet\&Chen} = S\cdot\alpha_{nb} + F\cdot\alpha_{fc}$

  nb: nucleate boiling [2]

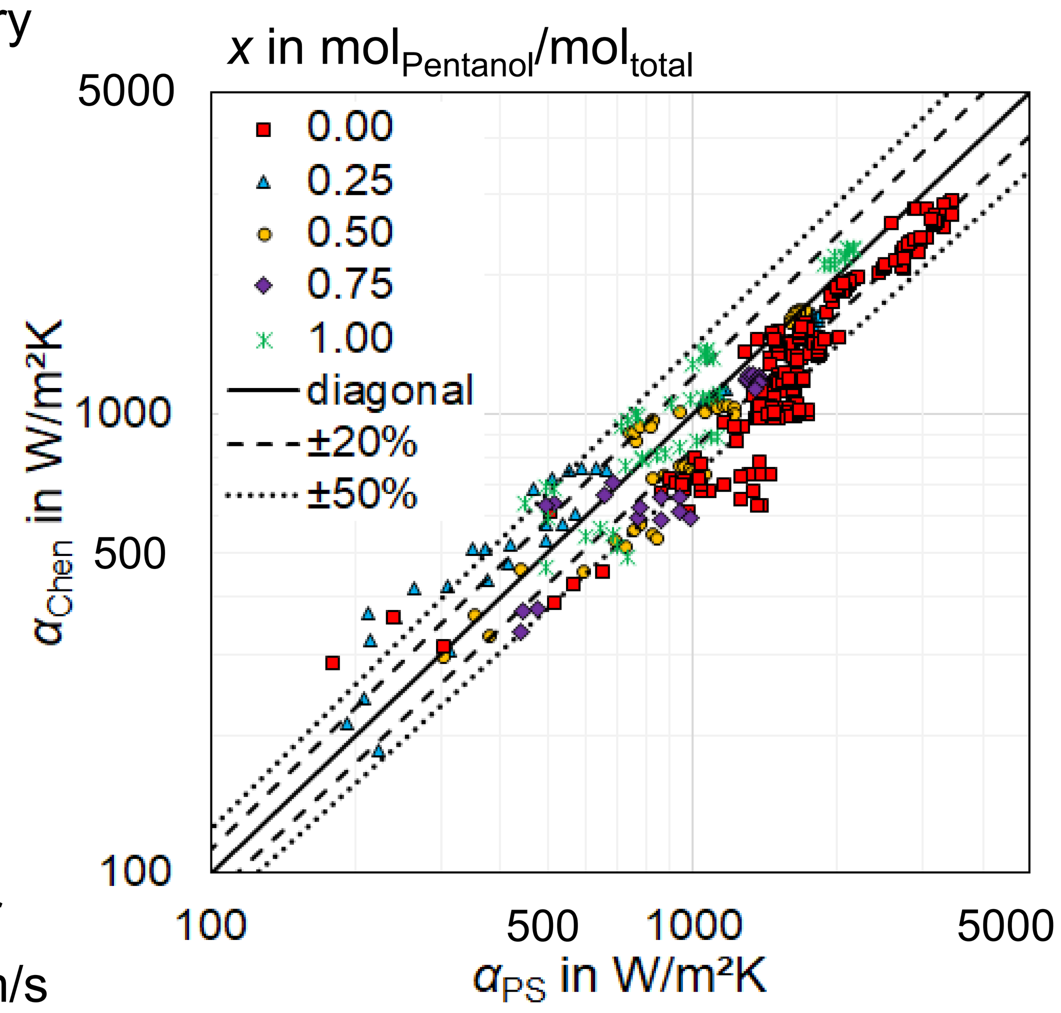
  fc: forced convection [3]
- mean absolute percentage deviation

  $= \frac{100\%}{n}\cdot\sum\left|\frac{\alpha_{Bennet\&Chen}-\alpha_{PS}}{\alpha_{PS}}\right|$ = 17%

  validity range:

  7 K ≤ ΔT < 21 K, 0.1 bar ≤ p ≤ 1.0 bar

  $\dot q$ ≤ 47 kW/m², 0.02 m/s ≤ u_{in} < 0.12 m/s



Bennet&Chen's model is capable for PP TRs → Why? → The single-phase zone is negligible small due to low height and low pressure loss of PPs

Experimental Setup

pillow plate (PP):

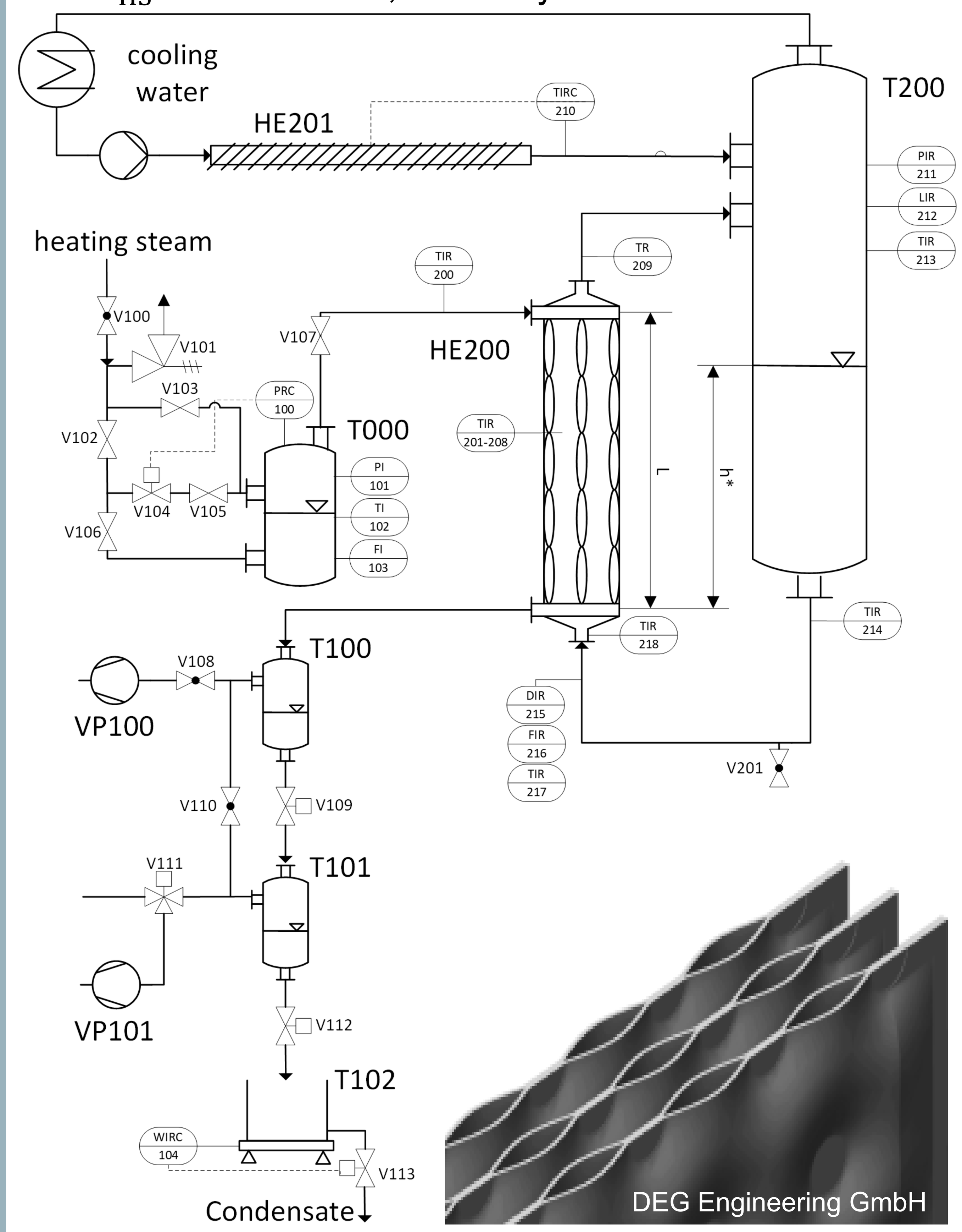
- one double-sided + two single-sided expanded plates
- material SS 1.4571, L x B = 800 x 220 mm²,
- d_h = 17.51 mm, A_{ht} = 0.704 m² [1]

product side (PS):

- self-circulation through the gaps between PPs
- pressure 100 - 1000 mbar, submergence 30% - 130%

heating side (HS):

- heating steam inside PP
- T_{HS} : 65 … 180 °C, heat duty: 5 … 30 kW



Literature

[1] R. Goedecke, S. Scholl, *Heat MassTransf.* 2019, 55(1), 95–104.

[2] P. Stephan, S. Kabelac, M. Kind, D. Mewes, K. Schaber, T. Wetzel (Eds.), 12. ed., Springer Vieweg, Berli, Heidelberg, 2019.

[3] D.L. Bennet,J.C. Chen, Correlation for Boiling Heat Transfer to Saturated Fluids in Convective Flow, *Ind. Eng. Chem. Eng. J.* 26, 454-462, 1980.

Conclusions and Outlook

- Fluid dynamics and thermal performance of PPTRs are differently influenced by varying pentanol fractions.
- The heat transfer in the gaps between PPs can be calculated using equivalent tube bundle geometry and Bennet&Chen's model of flow boiling.
- Investigation of further mixtures e.g. water - ethylene glycol

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