

Understanding temperature profiles of distillation columns

Lena-Marie Ränger^{1,2}, Ivar Halvorsen², Thomas Grützner¹, Sigurd Skogestad²

¹ Ulm University (Germany), Institute of Chemical Engineering, Laboratory of Thermal Process Engineering

² Norwegian University of Science and Technology (Trondheim), Department of Chemical Engineering, Process Systems Engineering Group

Motivation and Method

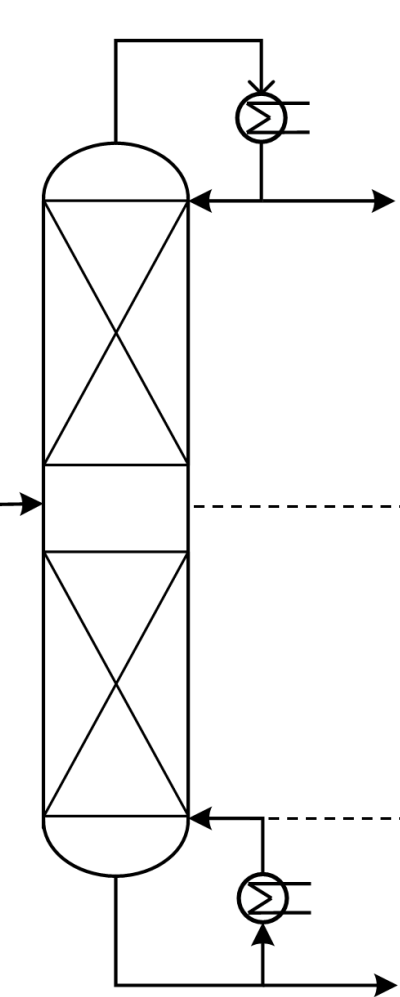
Use temperature profile for troubleshooting!

Literature lacks a comprehensive description on how to read and interpret temperature profiles!

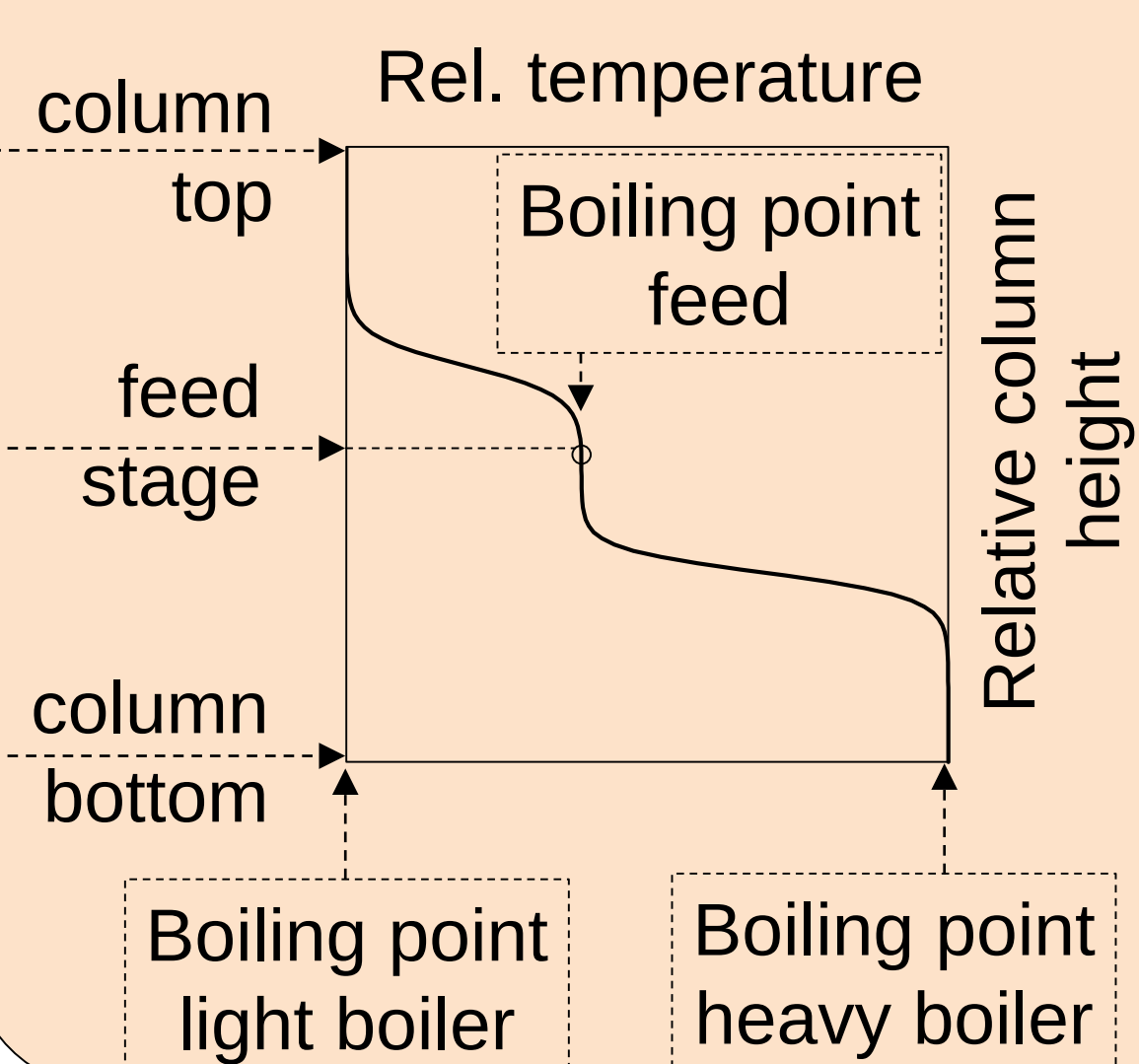


A: Benzene
B: Toluene
(C: *p*-Xylene)
(D: Cumene)

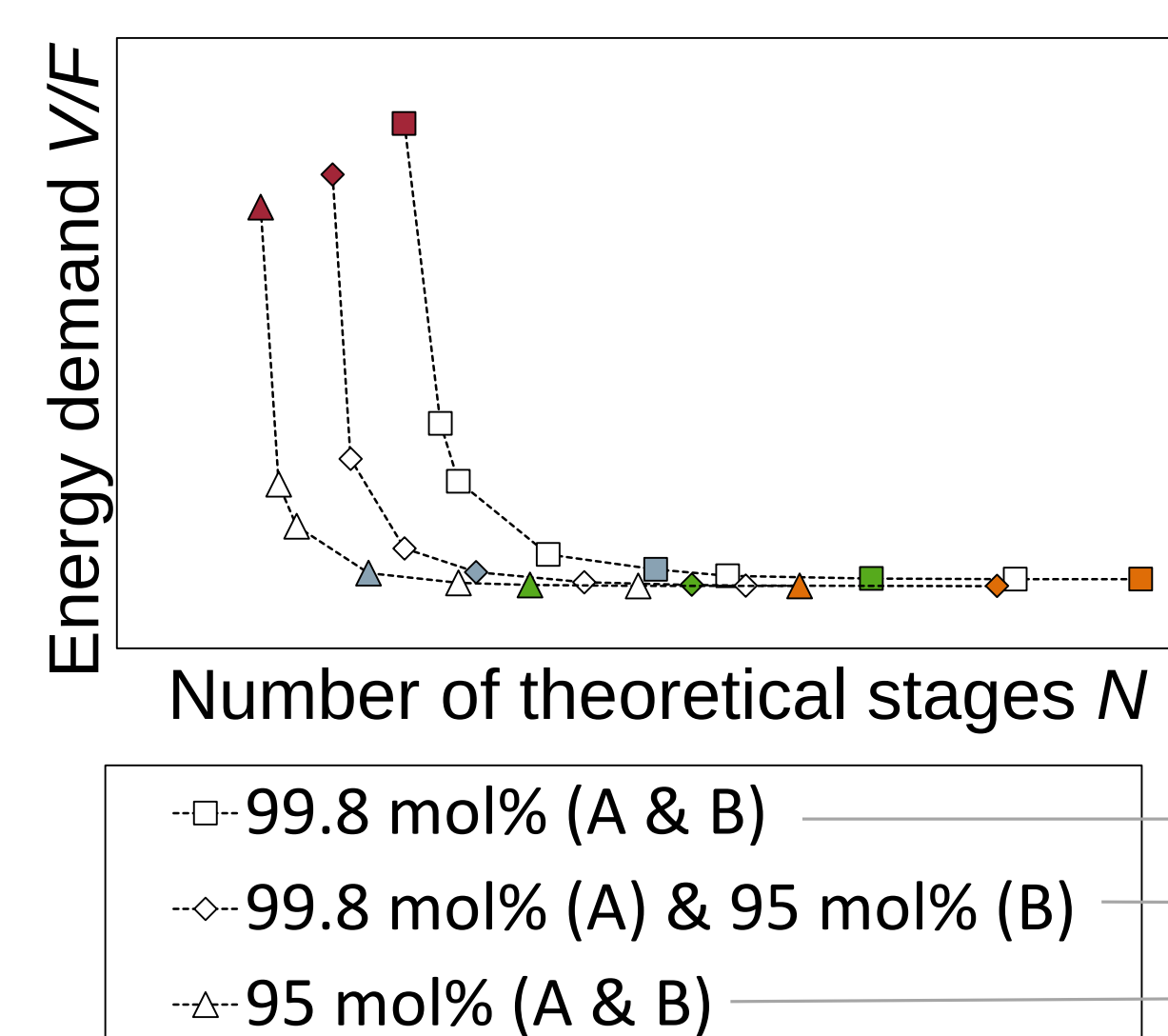
saturated liquid
equimolar



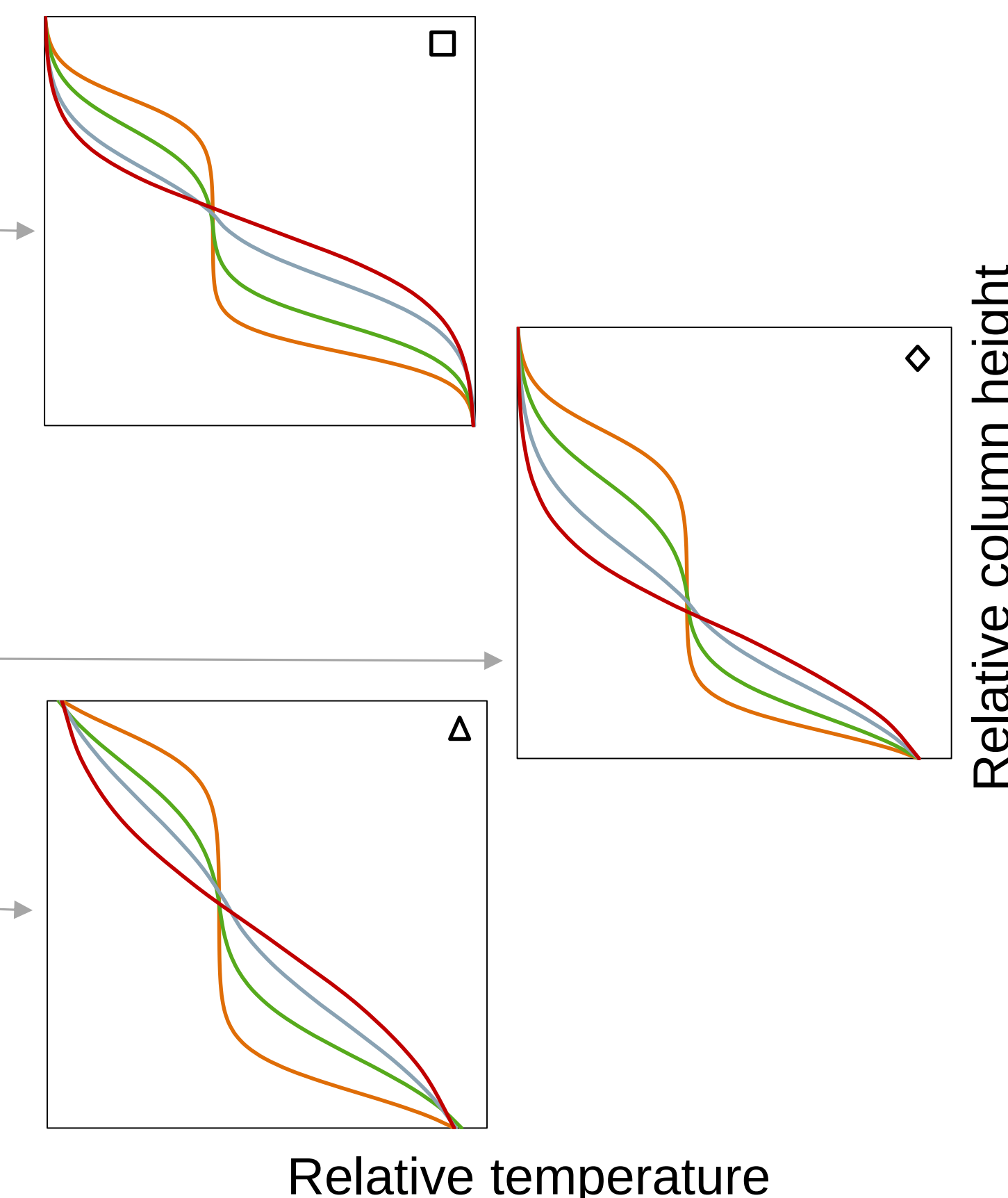
All T-profiles look like this:



Step 1: Impact of number of stages N

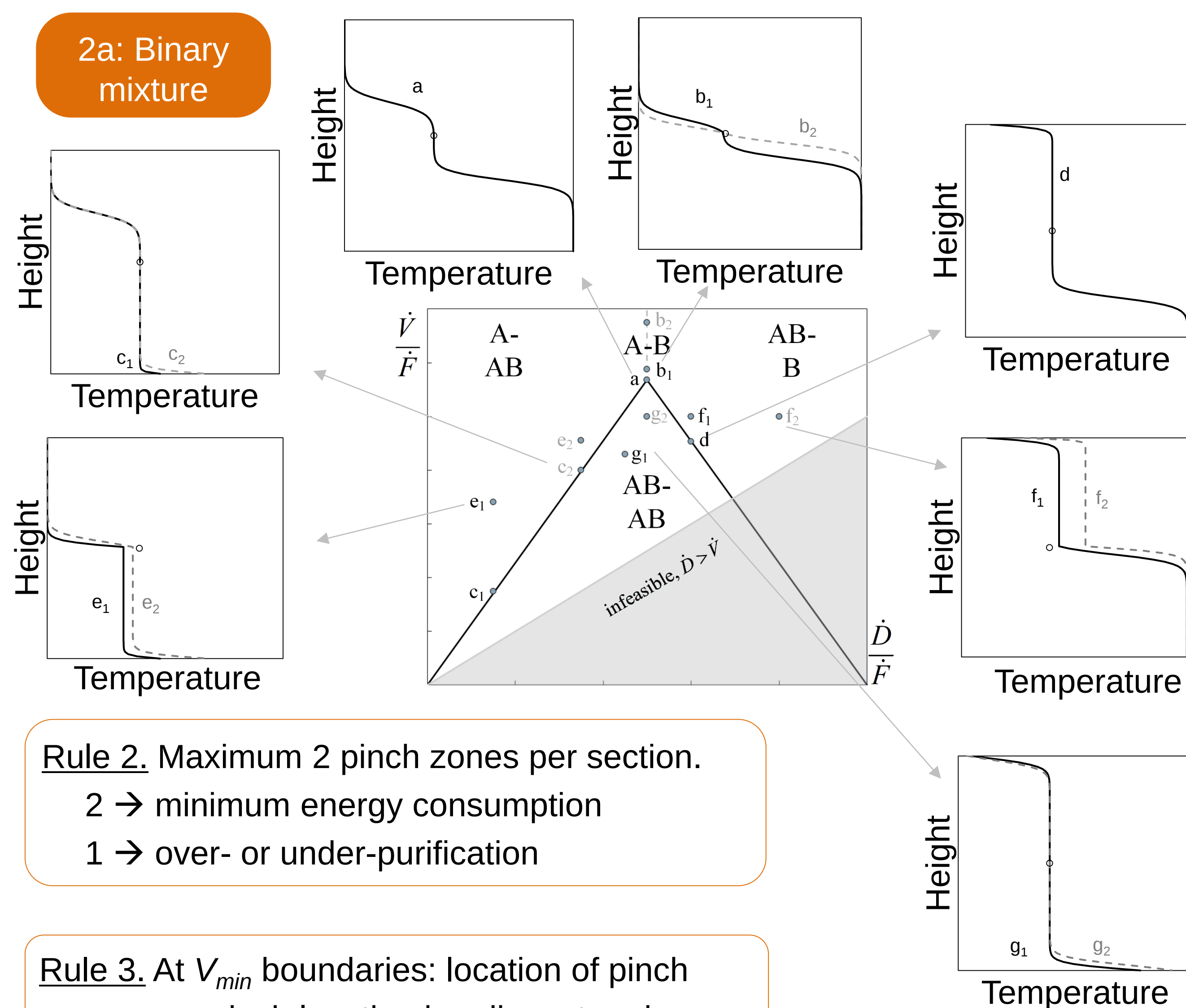


Rule 1. Pinch zone at a column end
→ pure component in product.
Observable independently of total number of stages



Step 2: Impact of operating point (number of stages $N \rightarrow \infty$)

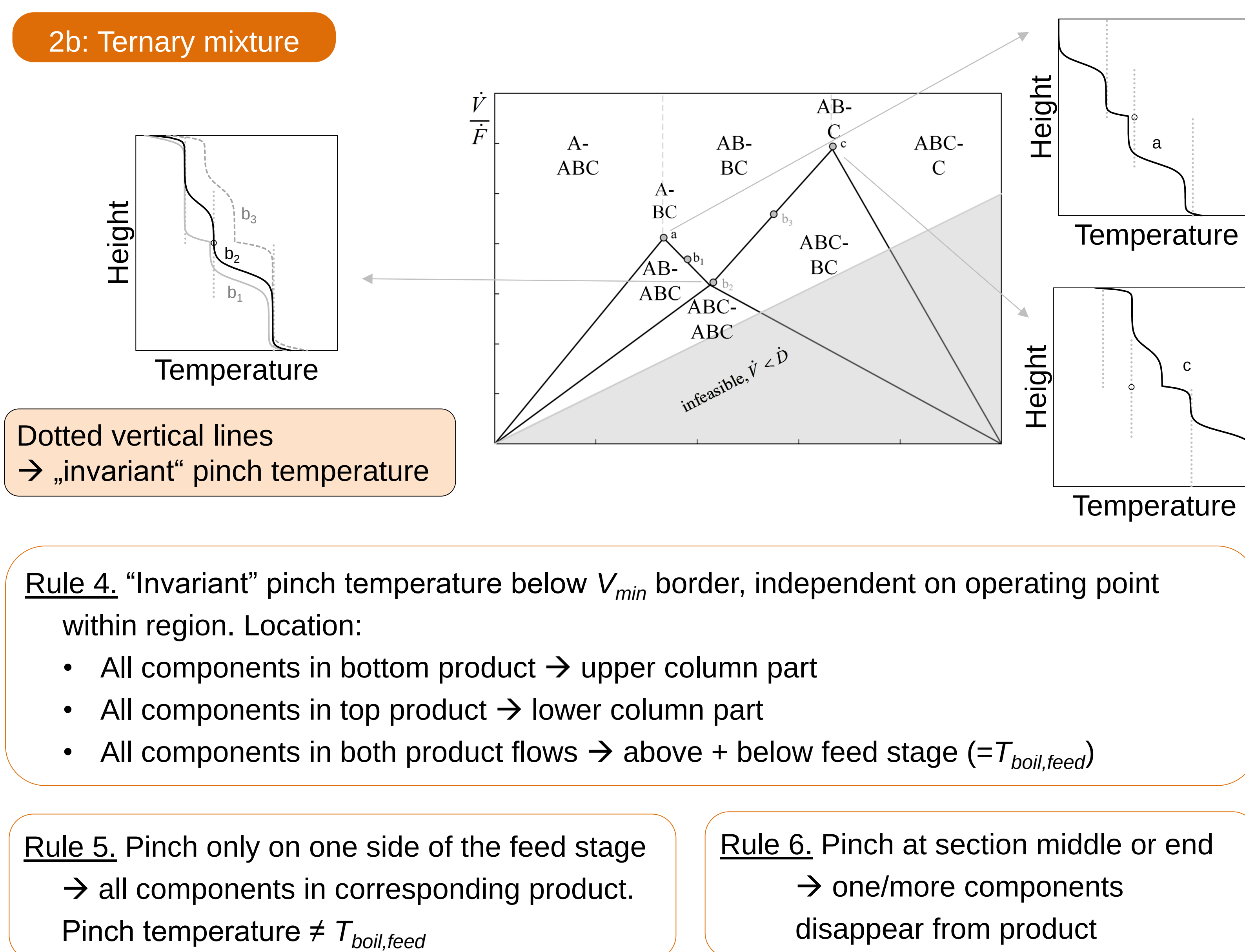
2a: Binary mixture



Rule 2. Maximum 2 pinch zones per section.
2 → minimum energy consumption
1 → over- or under-purification

Rule 3. At V_{min} boundaries: location of pinch zones = pinch location in adjacent regions

2b: Ternary mixture



Dotted vertical lines
→ „invariant“ pinch temperature

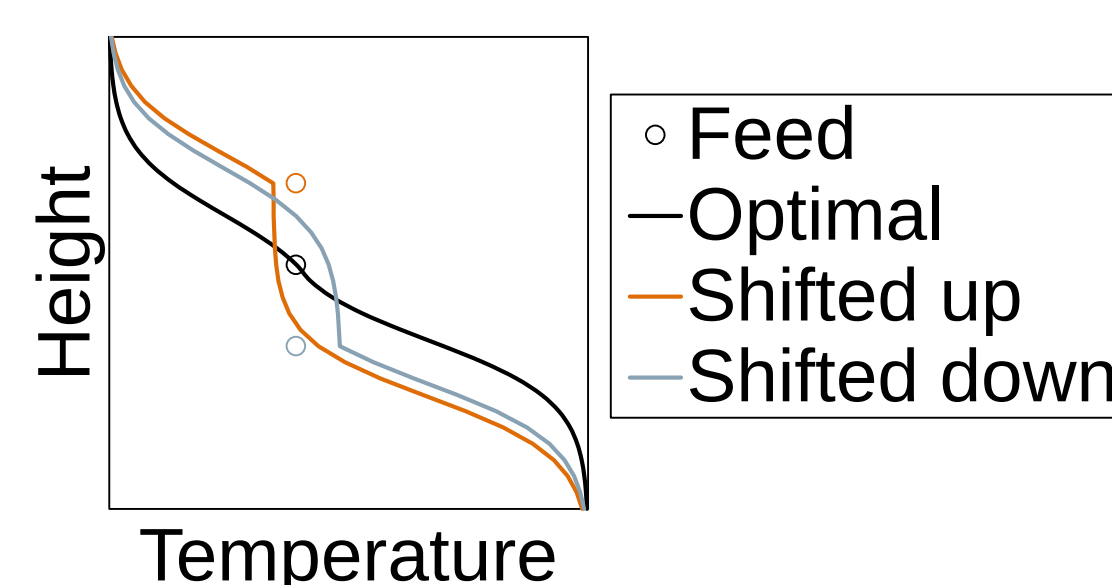
Rule 4. „Invariant“ pinch temperature below V_{min} border, independent on operating point within region. Location:
• All components in bottom product → upper column part
• All components in top product → lower column part
• All components in both product flows → above + below feed stage ($=T_{boil,feed}$)

Rule 5. Pinch only on one side of the feed stage
→ all components in corresponding product.
Pinch temperature $\neq T_{boil,feed}$

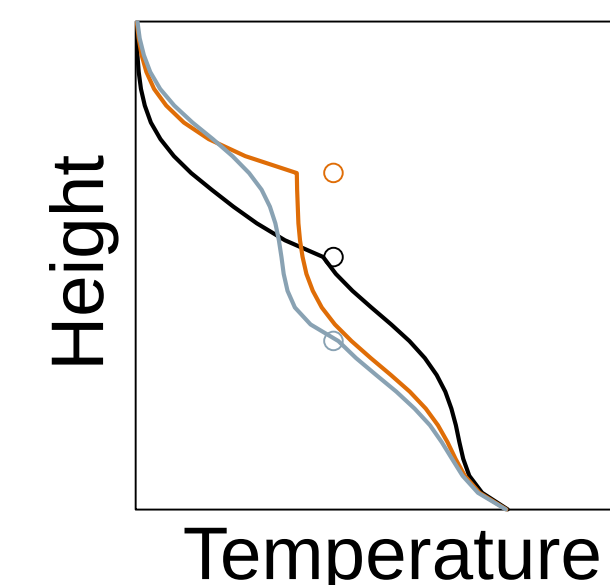
Rule 6. Pinch at section middle or end
→ one/more components disappear from product

Step 3: Impact of feed stage

3a: Binary mixture

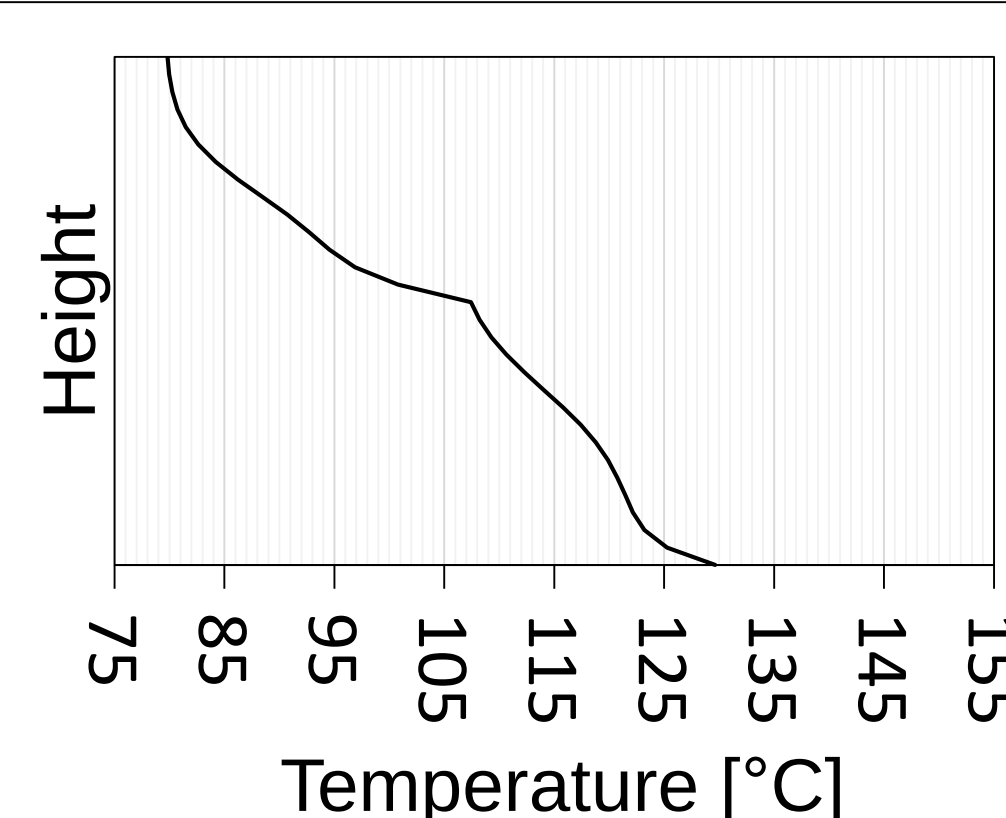
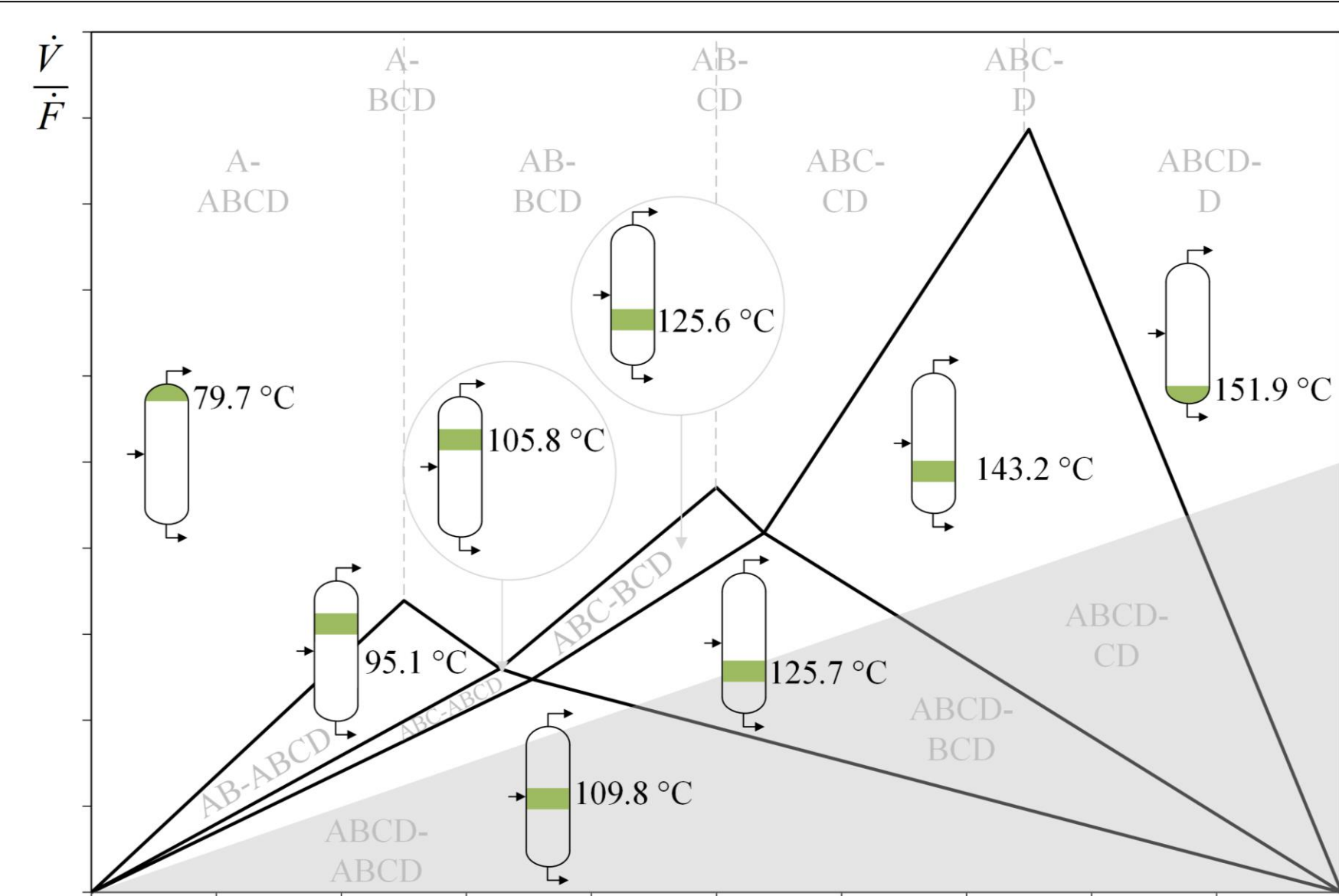


3b: Ternary mixture



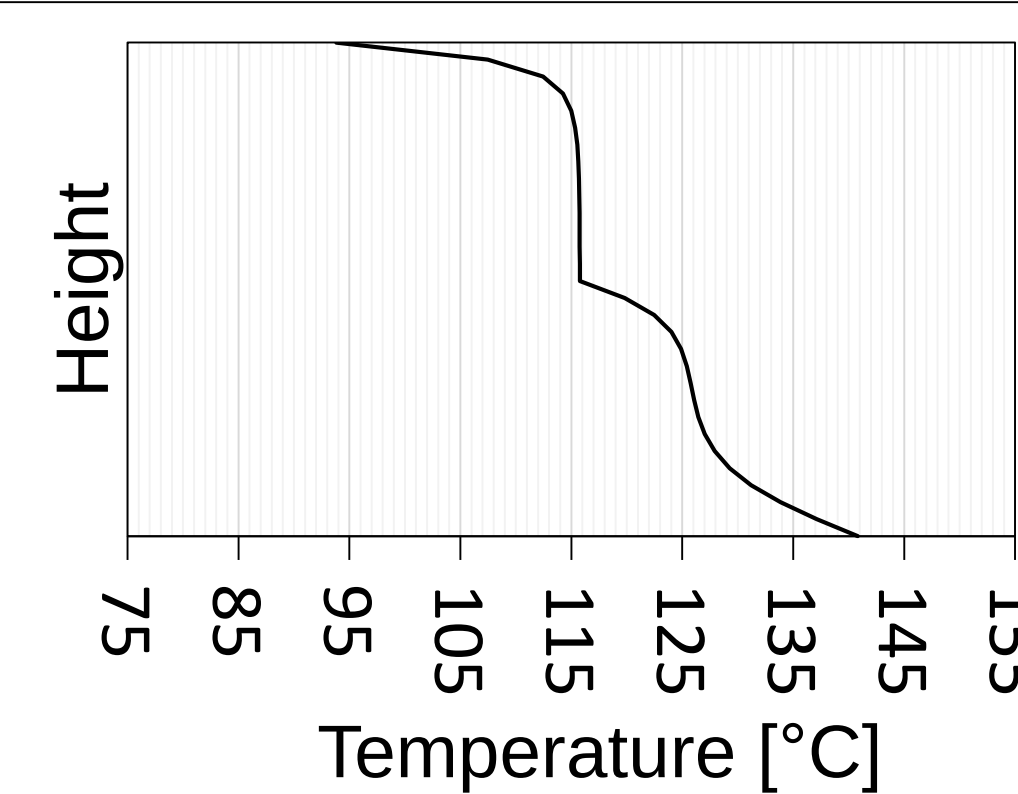
Rule 7. Clearly visible pinch in one section
+ poorly visible in the other section
→ non-optimal feed stage

Quiz



Try to apply the rules and determine the operating point!

- Pinch at top → **Rule 1:** pure A
- 2nd pinch (95 °C) in upper section
→ **Rule 2, 3:** min. energy, adjacent to AB-ABCD
- 2 pinches in lower section
→ **Rule 2:** min. energy
→ **A-BCD**



- Pinch in lower section (ca. 125 °C)
→ **Rule 4:** invariant in 2 regions
- Pinch above feed
→ **Rule 5:** ABCD in top
→ **ABCD-BCD**

