IPESE
Industrial Process and Energy Systems Engineering

École Polytechnique Fédérale de Lausanne

Exercise 03: HEN design Guidelines

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Outline

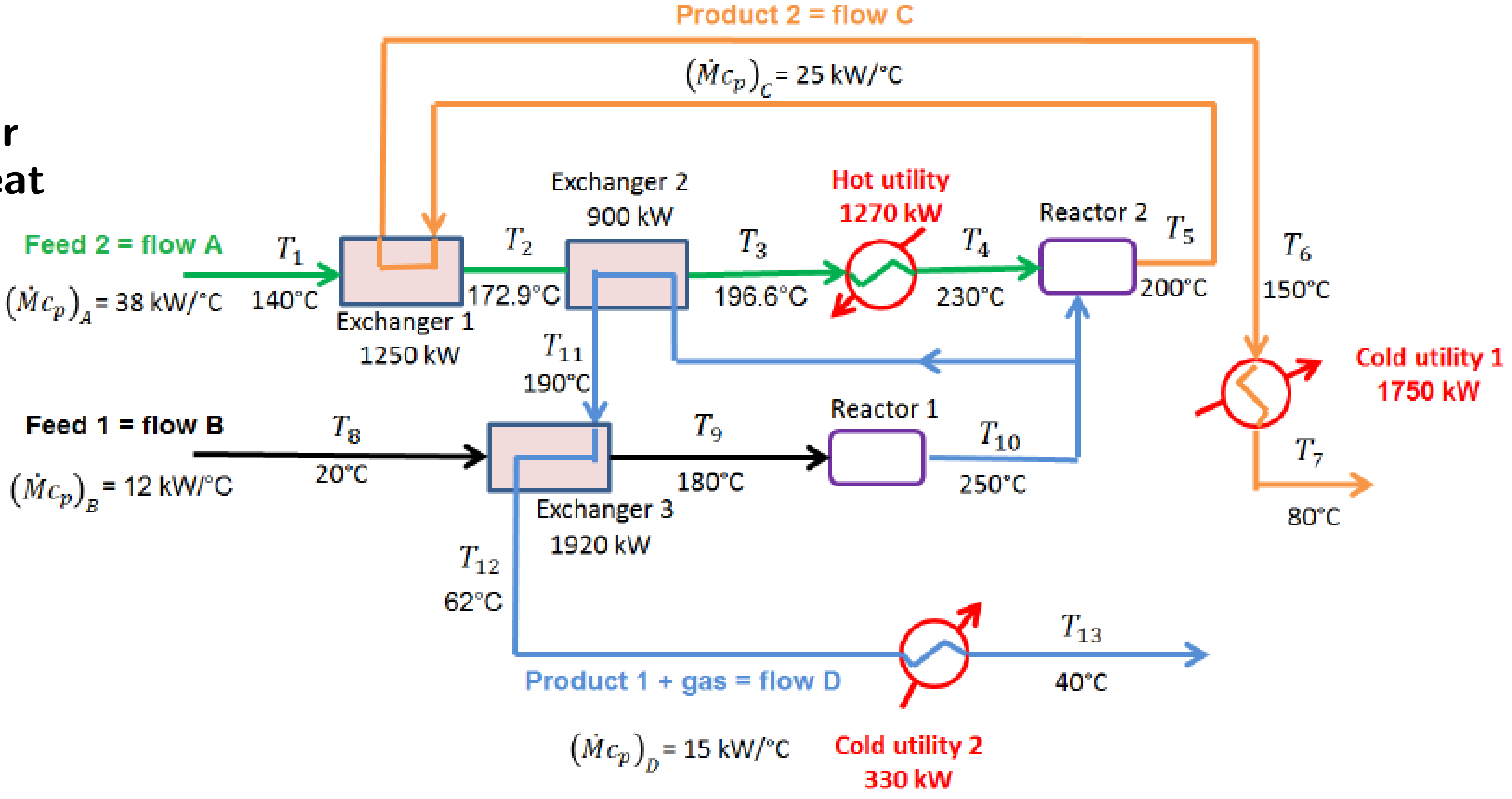
FINAL GOAL

- Compute the HEN (Pinch Design Method):
  - How many HEXs ?
  - Where to place them?
- Estimate the total cost:
  - HEXs investment cost
  - Hot/cold utilities operating cost

Exercise 03 – HEN design

Previous results and idea

- Energy bill of an industrial process
- MER with problem table method
- Energy bill under MER
- HEN design: **use the minimum number of HEXs to achieve the maximum heat recovery**



ABOVE PP: cool down hot streams to the pinch temperature without cold utilities

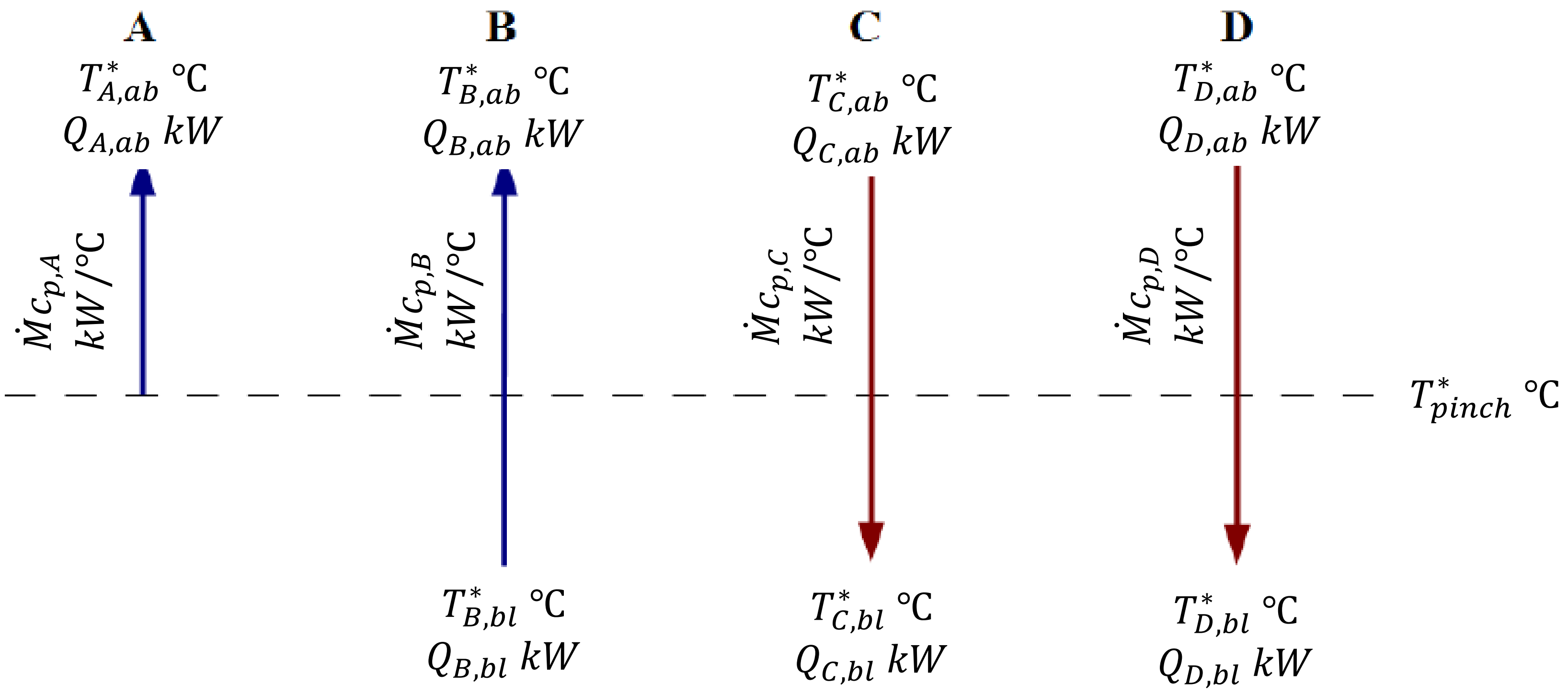
BELOW PP: heat up cold streams to the pinch temperature without hot utilities

Exercise 03 – HEN design

Pinch design method

- T^*_{pinch} pinch point temperature in the corrected temperature domain
- $T^*_{I,ab}$ = corrected temperature above the pinch point (outlet for cold streams and inlet for hot)
- $T^*_{I,bl}$ = corrected temperature below the pinch point (inlet for cold streams and outlet for hot)
- $\dot{M}c_{p,I}$ = stream heat capacity
- $Q_{I,ab} = \dot{M}c_{p,I} \cdot \left(T^*_{I,ab} - T^*_{pinch}\right)$
- $Q_{I,bl} = \dot{M}c_{p,I} \cdot \left(T^*_{pinch} - T^*_{I,bl}\right)$

GRID REPRESENTATION



Exercise 03 – HEN design

Pinch design method

1. Divide above and below the pinch point
2. Start from the pinch point and go to further temperature
3. Apply feasibility rules: **THEY MUST BE SATISFIED**

Rule	Above PP	Below PP
# of streams	$N_{pinch_{cold}} \geq N_{pinch_{hot}}$	$N_{pinch_{hot}} \geq N_{pinch_{cold}}$
c_p	$\dot{M}c_{p,hot} \leq \dot{M}c_{p,cold}$	$\dot{M}c_{p,cold} \leq \dot{M}c_{p,hot}$
	$\sum_{remaining} \dot{M}c_{p,hot} \leq \sum_{remaining} \dot{M}c_{p,cold}$	$\sum_{remaining} \dot{M}c_{p,cold} \leq \sum_{remaining} \dot{M}c_{p,hot}$

4. Exploit heuristic rules to minimize the number of HEX:
   - **Tick-off rule:** first choose the heat load so that all the heat requirement of one of the two streams is completely satisfied
   - **Splitting:** when splitting choose the splitting factor so that isothermal mixing is achieved after the heat exchanger
   - **First choice:** try to start with the biggest heat capacity streams
   - **Utilities:** place the utilities at the end of the temperature range
5. After placing one heat exchanger check that the MER hasn't changed

Exercise 03 – HEN design

Example: above the pinch point

$\Delta T_{min} = 10\ °C$

Stream	T^*_{in} [°C]	T^*_{out} [°C]	$(\dot{M}c_p)$ [$kW/°C$]	$\dot{Q}$ [kW]
stream A	**145**	235	38	-3420
stream B	**145**	185	12	-480
stream C	195	**145**	25	1250
stream D	245	**145**	15	1500
Imbalance				-1150

1. **# of streams rule:**
   $N_{pinch_{cold}} \geq N_{pinch_{hot}}$?

   $2 \geq 2$? **YES**
2. **Start with the highest heat capacity:**
   Stream A among the cold and C among the hot
3. **Cp rule 1:**
   $\dot{M}c_{p,hot} \leq \dot{M}c_{p,cold}$?
   $(\dot{M}c_p)_C = 25 \leq (\dot{M}c_p)_A = 38$? **YES**
4. **Cp rule 2:**
   $\sum_{remaining} \dot{M}c_{p,hot} = 15 \leq \sum_{remaining} \dot{M}c_{p,cold} = 12$? **NO** → Stream C (highest heat capacity) has to be split in C1 and C2 so that an heat exchanger can be placed between B and C1
5. **Tick-off rule:**
   Satisfy all the heat requirement of one stream → $\dot{Q}_{E1} = \dot{Q}_B = 480\ kW$

Exercise 03 – HEN design

Example: above the pinch point

$\Delta T_{min} = 10$ °C

Stream	T^*_{in} [°C]	T^*_{out} [°C]	$(\dot{M}c_p)$ [kW/°C]	$\dot{Q}$ [kW]
stream A	**145**	235	38	-3420
stream B	**145**	185	12	-480
stream C	195	**145**	25	1250
stream D	245	**145**	15	1500
Imbalance				-1150

6. **Splitting:**
   Split C so that isothermal mixing is achieved

   $$(\dot{M}c_p)_{C1} = \frac{\dot{Q}_{E1}}{T^*_{in,\mathrm{C}} - T^*_{\mathrm{pinch}}} = 9.6\ kW/°\mathrm{C}$$

   $$(\dot{M}c_p)_{C2} = (\dot{M}c_p)_C - (\dot{M}c_p)_{C1} = 15.4 kW/°\mathrm{C}$$

7. **Cp rule 1:**
   $\dot{M}c_{p,hot} \leq \dot{M}c_{p,cold}$?
   $(\dot{M}c_p)_{C1} = 9.6 \leq (\dot{M}c_p)_B = 12$? **YES**

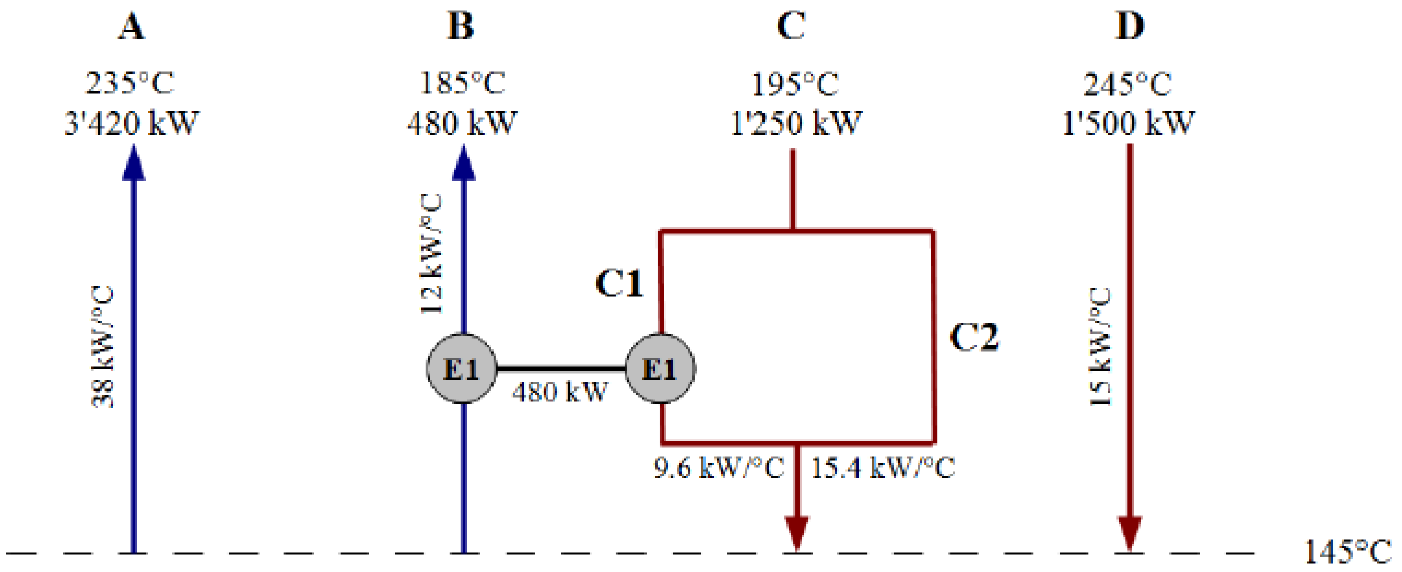
8. **Cp rule 2:**
   $\sum_{remaining} \dot{M}c_{p,hot} = 30.4 \leq \sum_{remaining} \dot{M}c_{p,cold} = 38$? **YES**

Place the heat exchanger E1

Exercise 03 – HEN design

Example: above the pinch point

9. **Place the heat exchanger**
10. **Check that MER didn't change**
11. **Continue with the remaining streams: A, C2, D from step 1**



- **Compute the investment cost of all heat exchangers**
- **Compute the operating cost of hot/cold utilities**

Conclusions

- The Pinch Design Method is based on feasibility and heuristic rules
- Apply the Pinch Design Method to design the HEN achieving the MER
- The solution is **NOT UNIQUE**!

Questions?

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