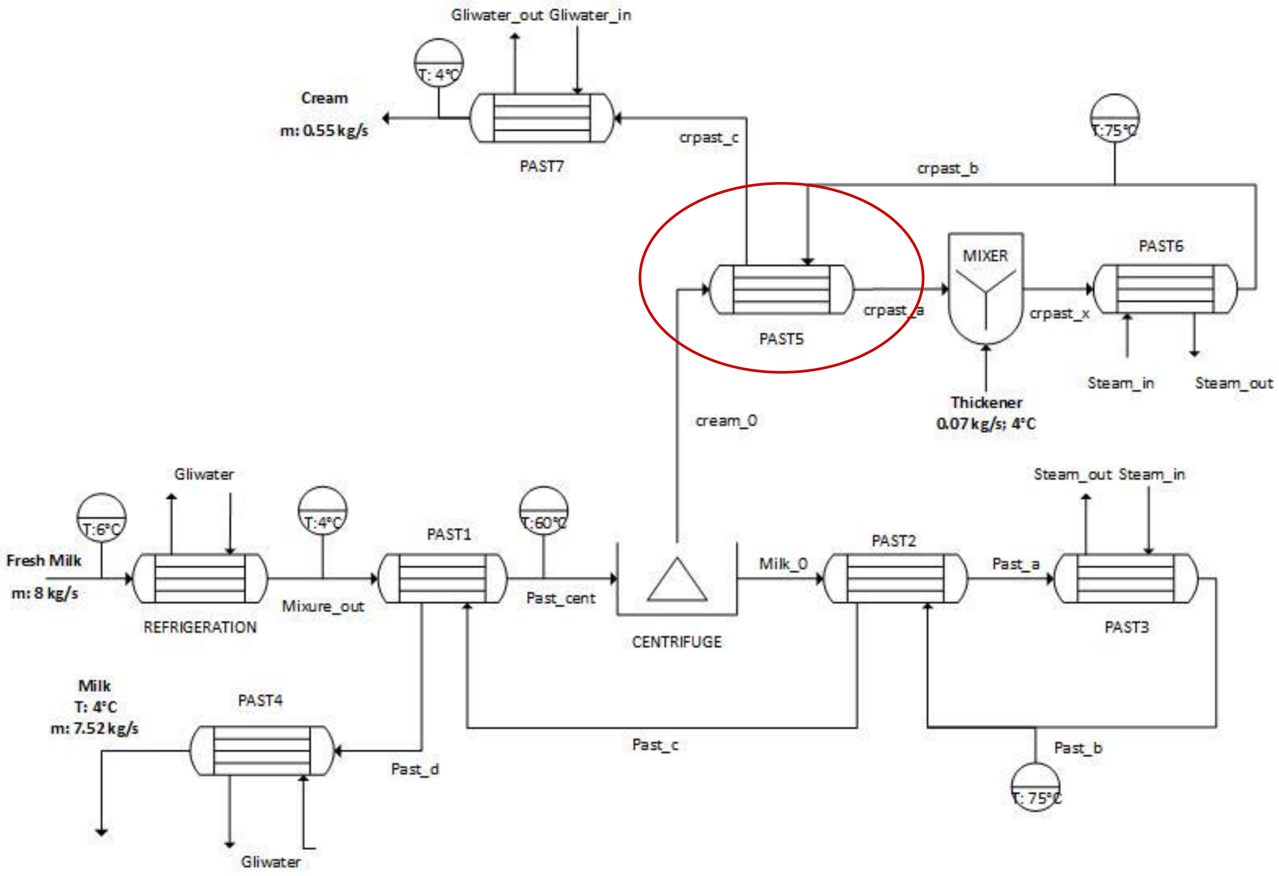
DTmin optimization

Nour Boulos

Advanced Energetics

Pasteurisation Section - Past 5

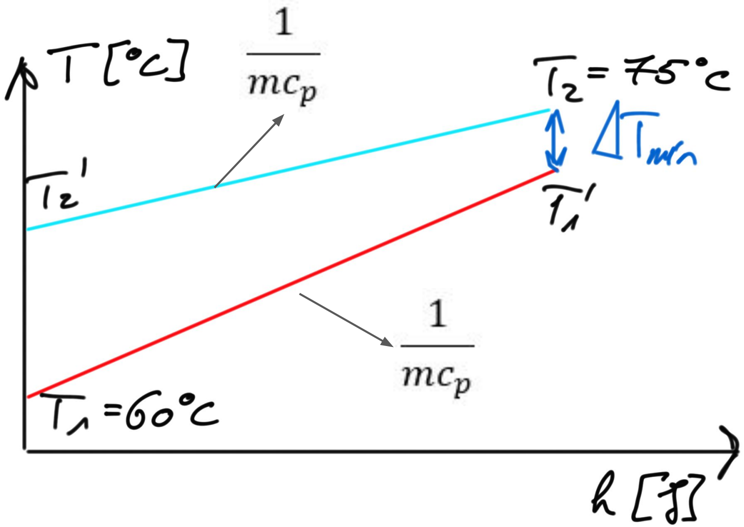


To do

- Initialization: Plot T vs Q and identify DTmin
- Investment costs (CAPEX)
  - HEX area
  - HEX costs
  - HEX annualised costs
- Operating costs (OPEX)
  - Heating costs
  - Cooling costs

Initialisation

- $T_{cream0} = T_1 = 60°C$ (cold stream)
- $T_{crpastb} = T_2 = 75°C$ (hot stream)
- $(m \cdot c_p)_{\text{cold}} \leq (m \cdot c_p)_{\text{hot}}$
- T_1' and T_2' must be optimized



- Thanks to $\frac{1}{mc_p}$ slopes, one can see that the ΔT_{min} occurs between T_2 and T_1' !
- $T_1' = T_2 - \Delta T_{min}$
- Energy balance is required to find T_2'

Investment costs (CAPEX) – HEX area

- $A_{ex} = \frac{\dot{Q}_{ex}}{U \cdot LMTD}$
  - $\frac{1}{U} = \frac{1}{\alpha_{cold}} + \frac{e}{\lambda} + \frac{1}{\alpha_{hot}}$
    - e : thickness [m]
    - λ : thermal conductivity $\left[\frac{kW}{m \cdot K}\right]$
    - α : heat transfer coefficient $\left[\frac{kW}{m^2 \cdot K}\right]$
    - Assumptions : $e \ll 1$; $\alpha_{cold} \approx \alpha_{hot} \rightarrow U = \frac{\alpha}{2}$
  - $LMTD = \frac{(T_{h,in} - T_{c,out}) - (T_{c,in} - T_{h,out})}{ln\left(\frac{T_{h,in} - T_{c,out}}{T_{c,in} - T_{h,out}}\right)}$

Investment costs (CAPEX) – purchased costs

- $C_p = \frac{I_t}{I_{t,ref}} \cdot 10^{k_1 + k_2(\log(A_{ex}))}$, for k_1 and k_2 see Turton p.913 [$]
- $C_{BM} = F_{BM} \cdot C_p \cdot e$ e : currency exchange rate $\left[{}^{CHF}/_{\$}\right]$

Investment costs (CAPEX) – annualisation

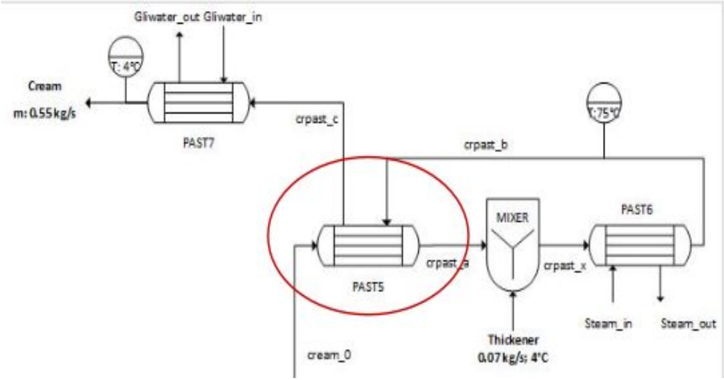
- Annualization factor : $a_n = \frac{i(1+i)^n}{(1+i)^n - 1}$
  - i : investment rate [-]
  - n : number of years [-]

- $IC_{ex} = C_{BM} \cdot a_n$

Operating costs (OPEX) – heating costs

1. Calculate the outlet temperature of the mixer
2. Calculate the new heat load of HEX past6
3. Calculate the heating costs linked to this heat load using price of natural gas and boiler efficiency

$$OC_{heating} = c_{ng} \cdot \dot{Q}_{ng} \cdot t_{op} = c_{ng} \cdot \frac{\dot{Q}_{past6}}{\eta_{boiler}} \cdot t_{op}$$



Units

- c_{ng} $[{}^{CHF}/_{KWh}]$

Operating costs (OPEX) – cooling costs

1. Calculate the new heat load in cr_{past7}
2. Calculate the electric work required by the refrigerant cycle

$$\dot{W}_{elec} = \frac{\dot{Q}_{past7}}{COP}$$

3. Calculate the required mass of cooling water

$$\dot{Q}_{water} = \dot{Q}_{past7} + \dot{W}_{elec}$$

$$\dot{m}_{water} = \frac{\dot{Q}_{water}}{c_{p,water}}$$

4. The resulting operating costs are :

$$OC_{elec} = \dot{W}_{elec} \cdot c_{elec} \cdot t_{op}$$

$$OC_{water} = \dot{m}_{water} \cdot c_{water} \cdot t_{op}$$

5. $OPEX = OC_{water} + OC_{elec}$

Units

- c_{elec} $[{}^{CHF}/_{KWh}]$
- c_{water} $[{}^{CHF}/_{kg}]$

Conclusion

- $TOTEX = OPEX + CAPEX$
- Final goal : find the value of ΔT_{min} which minimize the total costs !