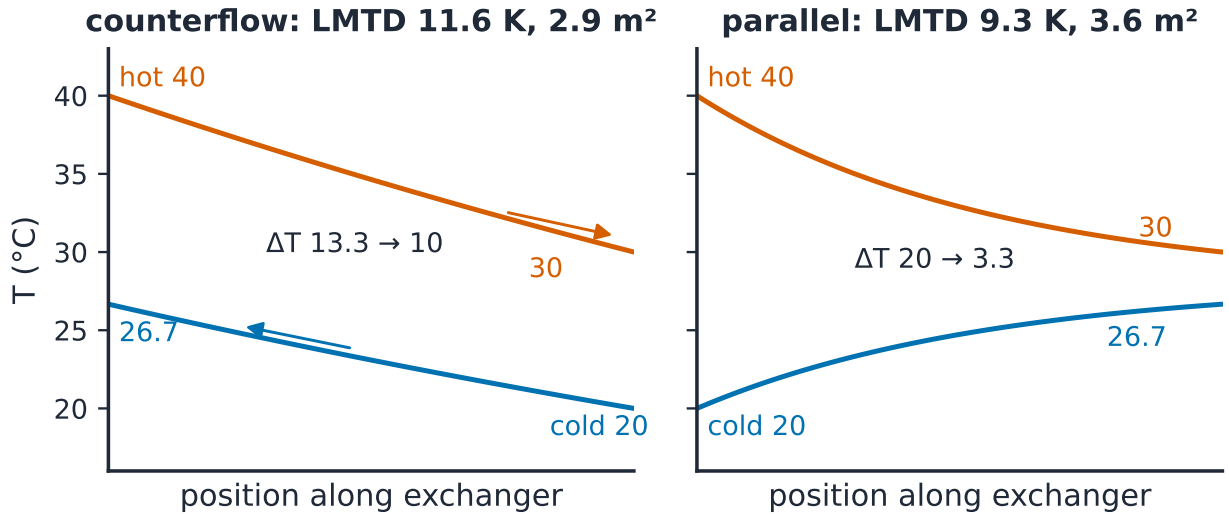
Exercise walk-through

10.5
Heat exchangers

University Mechanical Engineering

Counterflow beats parallel flow



83.6 kW, loop 40 → 30 °C, plant 20 → 26.7 °C: **counterflow** $\Delta T_{lm} = \mathbf{11.6}$ K, $A = \mathbf{2.89}$ m^2; parallel 3.59 m^2.

Rating with fouling

1. **Clean** 3.0 m^2, $NTU = 0.897$, $\varepsilon = \mathbf{0.511}$, $Q = \mathbf{85.5}$ kW - meets 83.6.
2. **Fouled** $R_f = 0.0002 \rightarrow U = 1667$, $\varepsilon = 0.398$, $Q = \mathbf{66.6}$ kW - short.
3. **Resize** Fouled U needs $\mathbf{4.33}$ m^2; more plates also cut velocity, pressure drop and h.

Decision

Buy the area that still works after a year of scale.

Exercises 2.1·2.2

2.1 Oil at 1.5 kg/s is cooled from 90 to 60 °C by water at 2.0 kg/s entering at 20 °C. Find the duty (one decimal, kW) and the water outlet temperature (one decimal, °C). [3]

2.2 For counterflow, find ΔT_{lm} (two decimals, K) and the area at $U = 400$ W/(m^2 · K) (two decimals, m^2). [4]

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2.1

- $Q = \dot{m}_h c_h \Delta T_h = 1.5 \times 2100 \times 30 = \mathbf{94.5}$ kW.
- $T_{c,out} = 20 + Q/(\dot{m}_c c_c) = 20 + 94\,500/8360 = \mathbf{31.3}$ °C.

2.2 For counterflow, find ΔT_{lm} (two decimals, K) and the area at $U = 400$ W/(m^2 · K) (two decimals, m^2). [4]

2.2

- Counterflow ends: $90 - 31.3 = 58.7$ K and $60 - 20 = 40$ K.
- $\Delta T_{lm} = (58.7 - 40)/\ln(58.7/40) = \mathbf{48.75}$ K.
- $A = Q/(U \Delta T_{lm}) = 94\,500/(400 \times 48.75) = \mathbf{4.85}$ m^2.

Exercise 2.3

2.3 Repeat 2.2 for parallel flow and say which arrangement is smaller. [3]

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2.3

- Parallel ends: $90 - 20 = 70$ K and $60 - 31.3 = 28.7$ K; $\Delta T_{lm} = 41.3/\ln(70/28.7) = \mathbf{46.32}$ K.
- $A = 94\,500/(400 \times 46.32) = \mathbf{5.10}$ m^2: counterflow is about 5% smaller.

Exercise 3.1

3.1 The counterflow unit of 2.2 ($A = 4.85\ \text{m}^2$) fouls with $R_f = 0.0005\ \text{m}^2 \cdot \text{K/W}$. Find the new U (one decimal), C_{min}, C_r (four decimals), NTU (three decimals) and ε (three decimals). Find the duty now (one decimal, kW) and the oil outlet temperature (one decimal, °C), and say why LMTD alone cannot answer this directly. [8]

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3.1

- $1/U = 1/U_{clean} + R_f = 1/400 + 0.0005 = 0.003$, so $U = \mathbf{333.3}$ W/(m$^2 \cdot$ K).
- $C_{min} = 1.5 \times 2100 = 3150$ W/K (oil); $C_r = 3150/8360 = \mathbf{0.3768}$.
- $NTU = UA/C_{min} = 333.3 \times 4.85/3150 = \mathbf{0.513}$; counterflow formula gives $\varepsilon = \mathbf{0.377}$.
- $Q = \varepsilon C_{min}(T_{h,in} - T_{c,in}) = 0.377 \times 3150 \times 70 = \mathbf{83.0}$ kW.
- $T_{h,out} = 90 - Q/C_{min} = 90 - 83\,000/3150 = \mathbf{63.6}$ °C.
- Both outlets are unknown, so ΔT_{lm} cannot be found without iterating; ε–NTU needs only the inlets.