10.5 Heat exchangers

Name: _____ Class: _____ Date: _____ **Total: 18 marks**

KEY WORDS log mean temperature difference • overall heat transfer coefficient • effectiveness–NTU method • counterflow • parallel flow • fouling resistance

Objective

Size a heat exchanger by the log mean temperature difference, compare counterflow with parallel flow, and rate a fouled unit by the effectiveness–NTU method.

1 Key knowledge and worked examples

■ Two methods

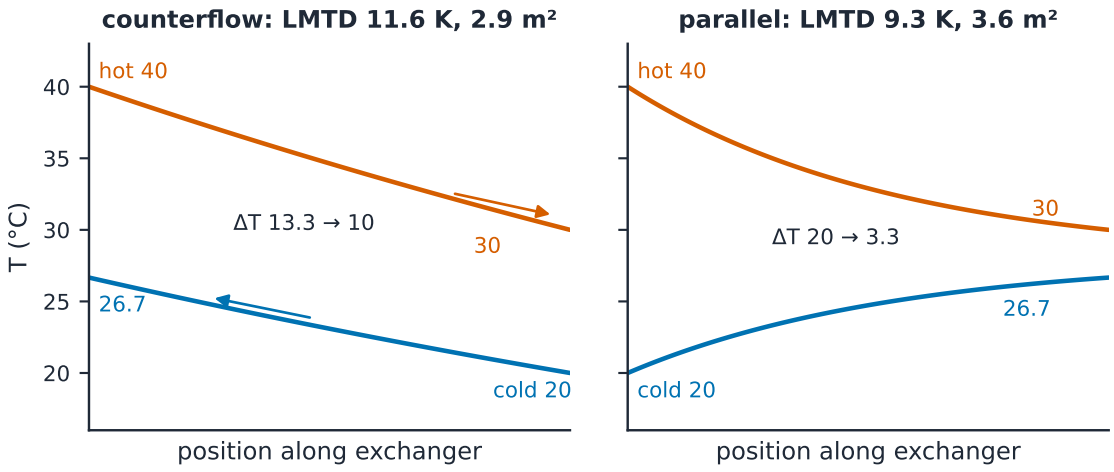
- Energy balance: $Q = \dot{m}_h c_h \Delta T_h = \dot{m}_c c_c \Delta T_c$.
- **Log mean temperature difference**: $\Delta T_{lm} = (\Delta T_1 - \Delta T_2)/\ln(\Delta T_1/\Delta T_2)$ over the two ends; $Q = U A \, \Delta T_{lm}$, with the **overall heat transfer coefficient** U.
- **Effectiveness–NTU method** – (outlets unknown): $NTU = UA/C_{min}$, $C_r = C_{min}/C_{max}$; for **counterflow** $\varepsilon = \dfrac{1 - e^{-NTU(1-C_r)}}{1 - C_r e^{-NTU(1-C_r)}}$, and $Q = \varepsilon C_{min}(T_{h,in} - T_{c,in})$.
- **Fouling resistance**: $1/U = 1/U_{clean} + R_f$.

■ Worked example. Sizing by LMTD

Loop water 2.0 kg/s, 40 → 30 °C; plant water 3.0 kg/s in at 20 °C.

- $Q = \dot{m} c \Delta T = 2.0 \times 4180 \times 10 =$ **83.6** kW; plant water leaves at 26.7 °C.
- Counterflow ends 13.3 and 10 K: $\Delta T_{lm} =$ **11.6** K.
- $A = Q/(U \Delta T_{lm}) = 83\,600/(2500 \times 11.6) =$ **2.89** m^2; **parallel flow** needs 3.59 m^2.

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2 Practice

Oil $c = 2100$ J/(kg · K); water $c = 4180$ J/(kg · K).

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]

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

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3 Exam-style questions

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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