

Alex Hobbs

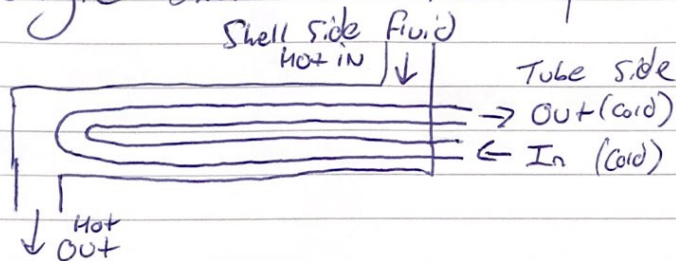
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Question 1

a) $\dot{Q} = UAF \Delta T_{LM}$ Denotes maximum heat transfer.

$\dot{Q} = \epsilon \times \dot{Q}_{max}$ Denotes actual heat transfer using heat exchanger efficiency

b) i) Single Shell two tube pass



ii) $\dot{Q} = \dot{m} C_p (T_{out} - T_{in})$

$\dot{Q} = 0.95 \times 2350 \times (135 - 165)$

$\dot{Q} = -66975 \text{ W}$ (Heat given up)

iii) $\dot{Q} = \dot{m} C_p (T_{out} - T_{in})$

$\dot{Q} = \dot{m} \times 4180 (60 - 15)$

$\frac{66975}{45 \times 4180} = \dot{m}$

$\dot{m} = 0.3561 \text{ kg/s}$

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$$iv) \dot{Q} = UAF \Delta T_{LM}$$

$$\Delta T_{LM} = \frac{\Delta T_o - \Delta T_i}{\ln\left(\frac{\Delta T_o}{\Delta T_i}\right)}$$

For Counter flow

$$T_i = T_{H,in} - T_{C,out} = 165 - 60 = 105^\circ\text{C}$$

$$T_o = T_{H,out} - T_{C,in} = 135 - 15 = 120^\circ\text{C}$$

$$\Delta T_{LM} = \frac{\Delta T_o - \Delta T_i}{\ln\left(\frac{\Delta T_o}{\Delta T_i}\right)} = \frac{120 - 105}{\ln\left(\frac{120}{105}\right)}$$

$$\Delta T_{LM} = 112.33^\circ\text{C}$$

$$\dot{Q} = UAF \Delta T_{LM}$$

$$A = \frac{\dot{Q}}{U F \Delta T_{LM}} = \frac{66975}{350 \times 0.97 \times 112.33}$$

$$A = 1.756 \text{ m}^2$$

c)

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Question 2

- a) It is possible to neglect the conduction resistance because the value is often so small its impact is negligible. Where

$$R = \frac{1}{h_{HA}A} + \left(\frac{x}{kA} \right) + \frac{1}{h_{CA}A}$$

↑
Conduction resistance
value very small

- b) Hot Stream

$$125 \text{ l/min} = \frac{125}{60 \times 1000} = 0.0021 \text{ m}^3/\text{s}$$

Cold Stream

$$500 \text{ l/min} = \frac{500}{60 \times 1000} = 0.00833 \text{ m}^3/\text{s}$$

Surface area of hot and cold interface

$$\begin{aligned} \text{Area} &= \pi \times \phi \times l \\ &= \pi \times 0.05 \times 10 = 1.571 \text{ m}^2 \text{ or } \frac{1}{2}\pi \end{aligned}$$

Overall heat transfer coefficient (U)

$$U = \frac{1}{RA} \quad \text{where } R = \frac{1}{h_{HA}A} + \frac{1}{h_{CA}A}$$

$$R = \frac{1}{2619 \times 1.571} + \frac{1}{8.5 \times 1.571} = 0.075$$

$$U = \frac{1}{0.075 \times 1.571} = 8.49 \text{ W/m}^2\text{K}$$

Capacity rates and Ratio

$$C_H = \dot{m} \times C_{pH} = (\dot{V}_H \times \rho_H) \times C_{pH}$$

$$= 0.0021 \times 972 \times 4180$$

$$C_H = 8532.216 \text{ W/K} \quad \leftarrow \text{Max}$$

$$C_C = \dot{m} \times C_{pC} = (\dot{V} \times \rho_C) \times C_{pC}$$

$$= 0.00833 \times 1.2041 \times 1005$$

$$C_C = 10.1 \text{ W/K} \quad \leftarrow \text{min}$$

Capacity Ratio

$$\frac{C_{\min}}{C_{\max}} = \frac{10.1}{8532.216} = 1.18 \times 10^{-3}$$

Number of Transfer Units

$$NTU = \frac{U \cdot A}{C_{\min}} = \frac{8.49 \times 1.571}{10.1}$$

$$NTU = 1.321 \text{ Units}$$

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The Effectiveness (Counterflow)

$$\begin{aligned} \epsilon &= \frac{1 - \exp(-NTU \times (1 - Cr))}{1 - Cr \times \exp(-NTU \times (1 - Cr))} \\ &= \frac{1 - \exp(-1.321 \times (1 - 1.18 \times 10^{-3}))}{1 - 1.18 \times 10^{-3} \times \exp(-1.321 \times (1 - 1.18 \times 10^{-3}))} \end{aligned}$$

$$\epsilon = 0.73 \quad \text{or} \quad 73\%$$

Amount of heat transferred from
hot to cold (Q_{act})

$$Q_{act} = \epsilon \times Q_{max}$$

$$Q_{act} = \epsilon \times (C_{min} \times T_{H,in} - T_{C,in})$$

$$Q_{act} = \epsilon \times (10.1 \times (80 - 20))$$

$$Q_{act} = 442.38 \text{ W}$$

Outlet temperatures

$$Q_{act} = C \times (T_{H,in} - T_{H,out})$$

For Hot outlet

$$\frac{Q_{act}}{C_H} = 80 - T_{H,out}$$

$$0.052 = 80 - T_{H,out}$$

$$T_{H,out} = 80 - 0.052 = 79.948^\circ\text{C}$$

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For Cold outlet $Q_{act} = C_c \times (T_{c,out} - T_{c,in})$

$$Q_{act} = 10.1 \times (T_{c,out} - 20)$$

$$\frac{442.38}{10.1} + 20 = T_{c,out}$$

$$T_{c,out} = 63.8^{\circ}\text{C}$$

Design improvement to increase effectiveness
of the heat exchanger

A design improvement would be to increase
the surface area

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Question 3

$$a) \quad \dot{Q}_M = \dot{m}_M \times c_{pH} \times (T_{Mout} - T_{Min})$$

$$\dot{Q}_M = 0.001 \times 4209 \times (30 - 70)$$

$$\dot{Q}_M = -168.36 \text{ W (heat given up)}$$

$$\dot{Q}_H = 0.16836 \text{ kW}$$

$$b) \quad \dot{m}_c = \frac{1}{60} \times 1.2041 = 0.02 \text{ kg/s}$$

$$\frac{\dot{Q}_c}{\dot{m}_c c_{pc}} = T_{out} - T_{in} = 8.376^\circ\text{C}$$

$$T_{out} = 8.376 + 20$$

$$T_{out} = 28.376^\circ\text{C}$$

$$\Delta T_{LM} = \frac{\Delta T_o - \Delta T_i}{\ln\left(\frac{\Delta T_o}{\Delta T_i}\right)}$$

$$\Delta T_i = T_{in,h} - T_{c,out}$$

$$= 70 - 28.376$$

$$\Delta T_i = 41.624^\circ\text{C}$$

$$\Delta T_o = \frac{10 - 41.624}{\ln\left(\frac{10}{41.624}\right)}$$

$$\Delta T_o = T_{h,out} - T_{c,in}$$

$$= 30 - 20$$

$$\Delta T_o = 10^\circ\text{C}$$

$$\Delta T_{LM} = 22.175^\circ\text{C}$$

$$\dot{Q} = U A F \Delta T_{LM}$$

$$A = \frac{\dot{Q}}{U F \Delta T_{LM}} = \frac{168.36}{250 \times 0.94 \times 22.175} = 0.032 \text{ m}^2$$

c)

Capacity rates and ratio

$$C_m = \dot{m} \times C_{pH} = 4.209 \text{ W/K} \quad - \text{Min}$$

$$C_c = \dot{m} \times C_{pC} = 0.02 \times 1005 = 20.1 \text{ W/K} - \text{Max}$$

Capacity ratio

$$\frac{C_{min}}{C_{max}} = 0.2094$$

$$NTU = \frac{U \times A}{C_{min}} = \frac{250 \times 0.032}{4.209} = 1.9 \text{ units}$$

The effectiveness (counter flow)

$$E = \frac{1 - \exp(-NTU(1-Cr))}{1 - Cr \times \exp(-NTU(1-Cr))}$$

$$E = 0.815 \quad \text{or} \quad 81.5\%$$

Amount of heat transferred from hot to cold

$$Q_{act} = E \times Q_{max}$$

$$= 0.815 \times 168.36$$

$$= 137.21 \text{ W}$$

$$d) \quad Q_{\text{theoretical}} = Q_{\text{max}} \times 0.65$$

$$Q_{\text{th}} = 109.434 \text{ W}$$

For Cold Stream

$$Q_{\text{th}} = C_{\text{min}} \times (T_{\text{hot}} - T_{\text{cin}})$$

$$\frac{Q_{\text{th}}}{C} = (T_{\text{c out}} - T_{\text{cin}})$$

$$\frac{109.434}{20.1} = 5.4717 + T_{\text{cin}}$$

$$T_{\text{c out}} = 25.4717^{\circ}\text{C}$$