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Quiz 8

Solution

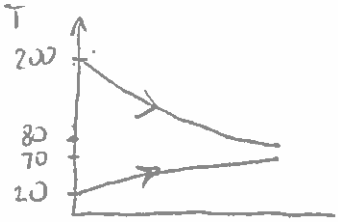
The hot and cold inlet temperatures to a concentric tube heat exchanger are $T_{h,i} = 200°C$ and $T_{c,i} = 20°C$, respectively. The outlet temperatures are $T_{h,o} = 80°C$ and $T_{c,o} = 70°C$. Phase change does not occur in either fluid and there is no heat loss to surroundings.

a) Can this heat exchanger operate in a parallel flow configuration? If so, why? **(2 points)**

Yes, because $T_{h,o} > T_{c,o}$

Assuming the operation in parallel flow configuration is possible:

b) What is the heat capacity ratio (C_r) of the streams in this heat exchanger? **(2 points)**



$$q = C_c \Delta T_c = C_h \Delta T_h \Leftrightarrow C_c(70-20) = C_h(200-80)$$

$$\Rightarrow \frac{C_c}{C_h} = \frac{120}{50} = 2.4 > 1 \text{ hence } C_r = \frac{1}{2.4} = 0.417$$

c) What is the heat exchanger effectiveness? **(3 points)**

$$\varepsilon = \frac{q}{q_{max}} = \frac{C_c \Delta T_c}{C_{min}(T_{h,i} - T_{c,i})} = \frac{C_h \Delta T_h}{C_{min}(T_{h,i} - T_{c,i})} \quad \text{where } C_{min} = C_h$$

$$\text{Thus } \varepsilon = \frac{\Delta T_h}{T_{h,i} - T_{c,i}} = \frac{120}{200-20} = 0.667$$

d) What is the NTU of this heat exchanger effectiveness? **(3 points)**

For parallel flow exchanger

$$NTU = -\frac{\ln[1-\varepsilon(1+C_r)]}{1+C_r} = -\frac{\ln[1-0.667(1+0.417)]}{1+0.417}$$

$$\therefore NTU = 2.04$$

TABLE 11.4 Heat Exchanger NTU Relations

Flow Arrangement	Relation	
Parallel flow	$\text{NTU} = -\dfrac{\ln[1-\varepsilon(1+C_r)]}{1+C_r}$	(11.28b)
Counterflow	$\text{NTU} = \dfrac{1}{C_r-1}\ln\left(\dfrac{\varepsilon-1}{\varepsilon C_r-1}\right)$ $(C_r<1)$	
	$\text{NTU} = \dfrac{\varepsilon}{1-\varepsilon}$ $(C_r=1)$	(11.29b)
Shell-and-tube		
One shell pass (2, 4, . . . tube passes)	$(\text{NTU})_1 = -(1+C_r^2)^{-1/2}\ln\left(\dfrac{E-1}{E+1}\right)$	(11.30b)
	$E = \dfrac{2/\varepsilon_1-(1+C_r)}{(1+C_r^2)^{1/2}}$	(11.30c)
n shell passes ($2n$, $4n$, . . . tube passes)	Use Equations 11.30b and 11.30c with $\varepsilon_1 = \dfrac{F-1}{F-C_r}$ $F = \left(\dfrac{\varepsilon C_r-1}{\varepsilon-1}\right)^{1/n}$ $\text{NTU} = n(\text{NTU})_1$	(11.31b, c, d)
Cross-flow (single pass)		
C_{max} (mixed), C_{min} (unmixed)	$\text{NTU} = -\ln\left[1+\left(\dfrac{1}{C_r}\right)\ln(1-\varepsilon C_r)\right]$	(11.33b)
C_{min} (mixed), C_{max} (unmixed)	$\text{NTU} = -\left(\dfrac{1}{C_r}\right)\ln[C_r\ln(1-\varepsilon)+1]$	(11.34b)
All exchangers ($C_r = 0$)	$\text{NTU} = -\ln(1-\varepsilon)$	(11.35b)