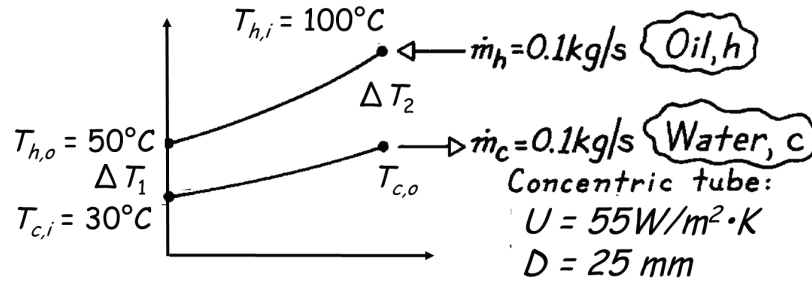


PROBLEM 09

KNOWN: Counterflow concentric tube heat exchanger.

FIND: (a) Total heat transfer rate and outlet temperature of the water and (b) Required length.

SCHEMATIC:



ASSUMPTIONS: (1) Negligible heat loss to surroundings, (2) Negligible thermal resistance due to tube wall thickness.

PROPERTIES: (given):

	ρ (kg/m ³)	c_p (J/kg·K)	ν (m ² /s)	k (W/m·K)	Pr
Water	1000	4200	7×10^{-7}	0.64	4.7
Oil	800	1900	1×10^{-5}	0.134	140

ANALYSIS: (a) With the outlet temperature, $T_{c,o} = 50^\circ\text{C}$, from an overall energy balance on the hot (oil) fluid, find

$$q = \dot{m}_h c_h (T_{h,i} - T_{h,o}) = 0.1 \text{ kg/s} \times 1900 \text{ J/kg} \cdot \text{K} (100 - 50)^\circ\text{C} = 9500 \text{ W.} \quad <$$

From an energy balance on the cold (water) fluid, find

$$T_{c,o} = T_{c,i} + q / \dot{m}_c c_c = 30^\circ\text{C} + 9500 \text{ W} / 0.1 \text{ kg/s} \times 4200 \text{ J/kg} \cdot \text{K} = 52.6^\circ\text{C.} \quad <$$

(b) Using the LMTD method, the length of the CF heat exchanger follows from

$$q = UA\Delta T_{lm,CF} = U(\pi DL)\Delta T_{lm,CF} \quad L = q / U(\pi D)\Delta T_{lm,CF}$$

where

$$\Delta T_{lm,CF} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)} = \frac{(50 - 30)^\circ\text{C} - (100 - 52.6)^\circ\text{C}}{\ln(20 / 47.4)} = 31.8^\circ\text{C}$$

$$L = 9500 \text{ W} / 55 \text{ W/m}^2 \cdot \text{K} (\pi \times 0.025 \text{ m}) \times 31.8^\circ\text{C} = 69.3 \text{ m.} \quad <$$

COMMENTS: Using the ϵ -NTU method, find $C_{\min} = C_h = 190 \text{ W/K}$ and $C_{\max} = C_c = 420 \text{ W/K}$. Hence

$$q_{\max} = C_{\min} (T_{h,i} - T_{c,i}) = 190 \text{ W/K} (100 - 30) \text{ K} = 13,300 \text{ W}$$

and $\epsilon = q/q_{\max} = 0.714$. With $C_r = C_{\min}/C_{\max} = 0.452$ and using Eq. 11.29b,

$$NTU = \frac{UA}{C_{\min}} = \frac{1}{C_r - 1} \ln \left(\frac{\epsilon - 1}{\epsilon C_r - 1} \right) = \frac{1}{0.452 - 1} \ln \left(\frac{0.714 - 1}{0.714 \times 0.452 - 1} \right) = 1.574$$

so that with $A = 5.437 \text{ m}^2 = \pi DL$, find $L = 69.3 \text{ m}$.