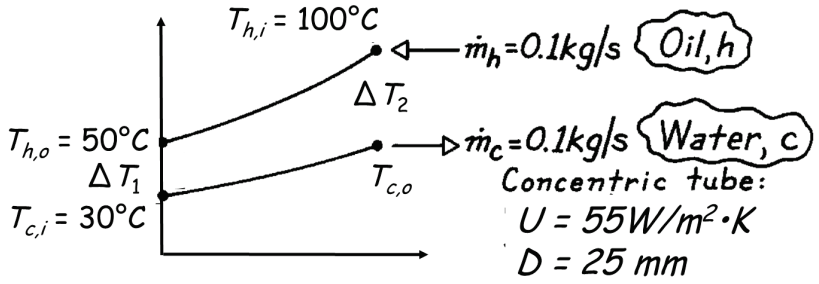
PROBLEM 11.20

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, $T_{c,o} = 50°C$, from an overall energy balance on the hot (oil) fluid, find

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

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

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

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

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

where

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

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

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

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

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

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

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