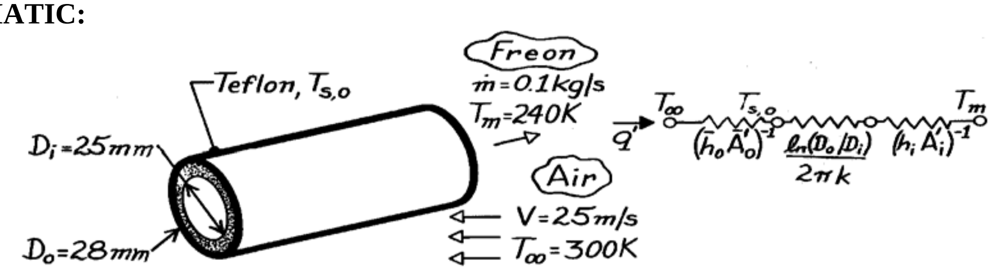
PROBLEM 8.57

KNOWN: Flow rate and temperature of Refrigerant-134a passing through a Teflon tube of prescribed inner and outer diameter. Velocity and temperature of air in cross flow over tube.

FIND: Heat transfer per unit tube length.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) One-dimensional radial conduction, (3) Constant properties, (4) Fully developed flow.

PROPERTIES: *Table A-4*, Air (T = 300 K, 1 atm): $\nu = 15.89 \times 10^{-6}$ m^2/s, k = 0.0263 W/m·K, Pr = 0.707; *Table A-5*, R-134a (T = 240 K): $\mu = 4.202 \times 10^{-4}$ N·s/m^2, k = 0.1073 W/m·K, Pr = 5.0; *Table A-3*, Teflon (T ≈ 300 K): k = 0.35 W/m·K.

ANALYSIS: Considering the thermal circuit shown above, the heat rate is

$$q' = \frac{T_\infty - T_m}{\left(1/\bar{h}_o \pi D_o\right) + \left[\ell n\left(D_o / D_i\right)/2\pi k\right] + \left(1/h_i \pi D_i\right)}.$$

$$Re_{D,i} = \frac{4\dot{m}}{\pi D_i \mu} = \frac{0.4 \text{ kg/s}}{\pi\left(0.025\text{m}\right) 4.202 \times 10^{-4} \text{ N} \cdot \text{s/m}^2} = 12{,}120$$

and the flow is turbulent. Hence, from the Dittus-Boelter correlation

$$h_i = \frac{k}{D_i} 0.023 \, Re_{D,i}^{4/5} Pr^{0.4} = \frac{0.1073 \text{ W/m} \cdot \text{K}}{0.025 \text{ m}} 0.023\left(12{,}120\right)^{4/5}\left(5\right)^{0.4} = 347 \text{ W/m}^2 \cdot \text{K}.$$

With $$Re_{D,o} = \frac{VD_o}{\nu} = \frac{\left(25 \text{ m/s}\right) 0.028 \text{ m}}{15.89 \times 10^{-6} \text{ m}^2/\text{s}} = 4.405 \times 10^4$$

it follows from Eq. 7.45 and Table 7.4 that

$$\bar{h}_o = \frac{k}{D} 0.26 \, Re_{D,o}^{0.6} \, Pr^{0.37} = \frac{0.0263 \text{ W/m} \cdot \text{K}}{0.028 \text{ m}} 0.26\left(4.405 \times 10^4\right)^{0.6}\left(0.707\right)^{0.37} = 131 \text{ W/m}^2 \cdot \text{K}.$$

Hence

$$q' = \frac{T_\infty - T_m}{\left(131 \text{ W/m}^2 \cdot \text{K}\pi 0.028 \text{ m}\right)^{-1} + \ell n\left(28/25\right)/2\pi\left(0.350 \text{ W/m} \cdot \text{K}\right) + \left(347 \text{ W/m}^2 \cdot \text{K}\pi 0.025 \text{ m}\right)^{-1}}$$

$$q' = \frac{\left(300 - 240\right)\text{K}}{\left(0.087 + 0.052 + 0.037\right) \text{ K} \cdot \text{m/W}} = 343 \text{ W/m}.$$ <

COMMENTS: The three thermal resistances are comparable. Note that $T_{s,o} = T_\infty - q'/h_o \pi D_o$ = 300K - 343 W/m/131 W/m^2·K π 0.028 m = 270 K.