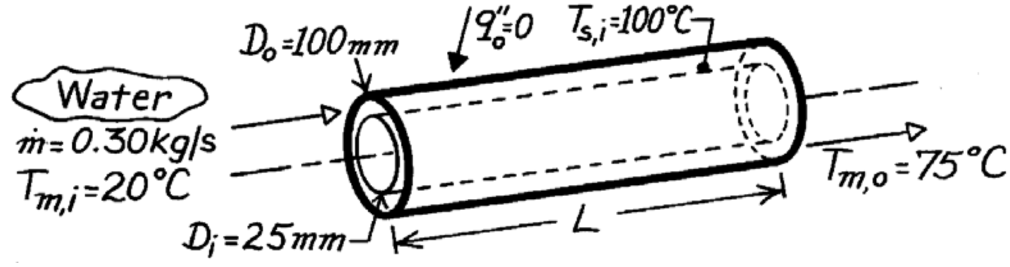
PROBLEM 8.94

KNOWN: Surface thermal conditions and diameters associated with a concentric tube annulus. Water flow rate and inlet temperature.

FIND: Length required to achieve desired outlet temperature.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Fully developed conditions throughout, (3) Adiabatic outer surface, (4) Uniform temperature at inner surface, (5) Constant properties, (6) Incompressible liquid with negligible viscous dissipation.

PROPERTIES: *Table A-6*, Water $\left(\overline{T}_m = 320\text{K}\right)$: c_p = 4180 J/kg·K, $\mu = 577 \times 10^{-6}$ N·s/m^2, k = 0.640 W/m·K, Pr = 3.77.

ANALYSIS: From Eq. 8.41a,

$$L = -\frac{\dot{m}\, c_p}{P\,\overline{h}} \ell n \frac{\Delta T_o}{\Delta T_i} = -\frac{\dot{m}\, c_p}{\pi\, D_i \overline{h}} \ell n \frac{T_s - T_{m,o}}{T_s - T_{m,i}}.$$

With

$$Re_D = \frac{\rho\, u_m D_h}{\mu} = \frac{\dot{m}\left(D_o - D_i\right)}{(\pi/4)\left(D_o^2 - D_i^2\right)\mu} = \frac{4\,\dot{m}}{\pi\left(D_o + D_i\right)\mu}$$

$$Re_D = \frac{4 \times 0.30\ \text{kg/s}}{\pi\left(0.125\text{m}\right)577 \times 10^{-6}\ \text{N}\cdot\text{s/m}^2} = 5296$$

and the flow is turbulent. Hence, from Eq. 8.60,

$$\overline{h} = \frac{k}{D_h} Nu_D = 0.023 \frac{k}{D_h} Re_D^{4/5}\, Pr^{0.4}$$

$$\overline{h} = 0.023 \frac{0.640\ \text{W/m}\cdot\text{K}}{0.075\ \text{m}} \left(5296\right)^{4/5} \left(3.77\right)^{0.4} = 318\ \text{W/m}^2\cdot\text{K}$$

and hence the required length is

$$L = -\frac{0.30\ \text{kg/s}\left(4180\ \text{J/kg}\cdot\text{K}\right)}{\pi\left(0.025\text{m}\right)\ 318\ \text{W/m}^2\cdot\text{K}} \ell n \frac{\left(100-75\right)^\circ \text{C}}{\left(100-20\right)^\circ \text{C}} = 58.4\ \text{m}.$$ <

COMMENTS: (1) Increasing $\dot{m}$ by a factor of 15 increases Re_D accordingly, and the flow is turbulent. However, $\overline{h}$ increases by a factor of only 5 from the result of Problem 8.93, in which case the tube length must be a factor of 3 larger than that of Problem 8.93. (2) The Gnielinski correlation would be more accurate than the Dittus-Boelter correlation for the low (but turbulent) conditions suggested by the value of the Reynolds number.