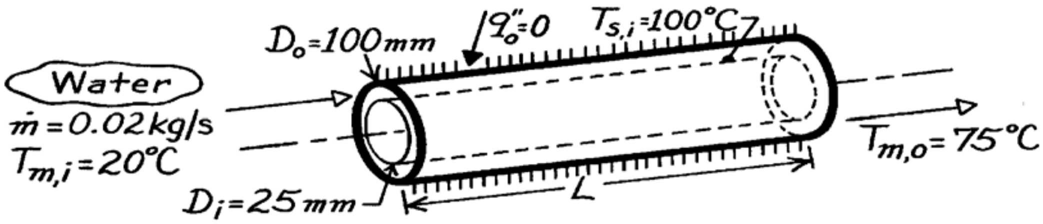
PROBLEM 8.93

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

FIND: (a) Length required to achieve desired outlet temperature, (b) Heat flux from inner tube at outlet.

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) Water is incompressible liquid with negligible viscous dissipation.

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

ANALYSIS: (a) From Eq. 8.41a,

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

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

$$Re_D = \frac{4 \times 0.02 \text{ kg/s}}{\pi\left(0.125\text{m}\right)577 \times 10^{-6}\,\text{N}\cdot\text{s/m}^2} = 353$$

the flow is laminar. Hence, from Eq. 8.69 and Table 8.2,

$$\bar{h} = h_i = \frac{k}{D_h} Nu_i = \frac{0.64 \text{ W/m}\cdot\text{K}}{\left(0.100 - 0.025\right)\text{ m}} 7.37 = 63 \text{ W/m}^2\cdot\text{K}$$

and $$L = -\frac{0.02 \text{ kg/s}\,\left(4180 \text{ J/kg}\cdot\text{K}\right)}{\pi\left(0.025\text{m}\right)63 \text{ W/m}^2\cdot\text{K}} \ell n \frac{\left(100-75\right)^\circ\text{C}}{\left(100-20\right)^\circ\text{C}} = 19.7 \text{ m.}$$ <

(b) From Eq. 8.67

$$q_i''\left(L\right) = h_i\left(T_{s,i} - T_{m,o}\right) = 63\frac{\text{W}}{\text{m}^2.\text{K}}\left(100-75\right)^\circ\text{C} = 1575 \text{ W/m}^2.$$ <

COMMENTS: The total heat rate to the water is

$$q = \dot{m}\, c_p\,\left(T_{m,o} - T_{m,i}\right) = 0.02 \text{ kg/s} \times 4180 \text{ J/kg}\cdot\text{K}\left(55^\circ\text{C}\right) = 4598 \text{ W.}$$