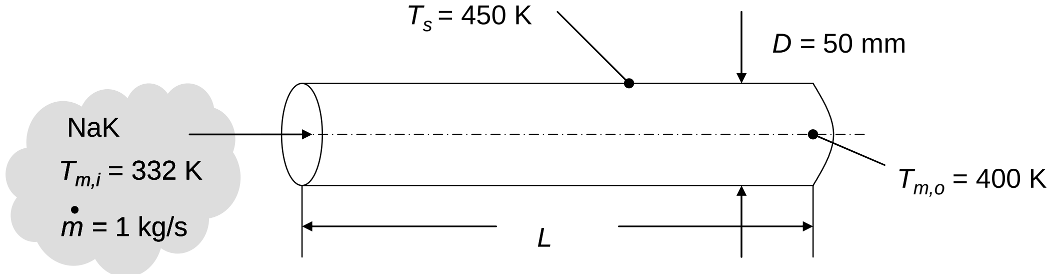
PROBLEM 8.43

KNOWN: Flow rate of NaK, NaK inlet and outlet temperatures, tube wall temperature, tube diameter.

FIND: Tube length, and local convective flux at the tube exit.

SCHEMATIC:



ASSUMPTIONS: (1) Constant properties, (2) Negligible viscous dissipation, (3) Fully developed flow.

PROPERTIES: *Table A.7* NaK (45%/55%; $\overline{T}_m = (332\text{K} + 400\text{K})/2 = 366\text{K}$): ρ = 887 kg/m^3, k = 25.6 W/m·K, $\nu = 6.52 \times 10^{-7}$ m^2/s, Pr = 0.026, c_p = 1130 J/kg·K.

ANALYSIS: The Reynolds number is

$$Re_D = 4\dot{m} / \pi D\nu\rho = 4 \times 1 \text{ kg/s} / \left[\pi \times 0.05 \text{ m} \times 6.52 \times 10^{-7} \text{m}^2/\text{s} \times 887 \text{ kg/m}^3\right] = 44{,}000$$

and the flow is turbulent. The Peclet number is $Pe_D = Re_D Pr = 44{,}000 \times 0.026 = 1145$. Therefore, we may use Eq. 8.65 if the flow is fully developed. Hence,

$$h = \frac{k}{D}\left(5.0 + 0.025 Pe_D^{0.8}\right) = \frac{25.6\text{W/m} \cdot \text{K}}{0.05\text{m}} \times \left(5.0 + 0.025 \times 1145^{0.8}\right) = 6140\text{W/m}^2 \cdot \text{K}$$

The required tube length is, from Eq. 8.41a,

$$L = -\frac{\dot{m}c_p}{\pi D h} \ln\frac{\Delta T_o}{\Delta T_i} = -\frac{1 \text{ kg/s} \times 1130 \text{ J/kg} \cdot \text{K}}{\pi \times 0.05\text{m} \times 6140\text{W/m}^2 \cdot \text{K}} \ln\left(\frac{50}{118}\right) = 1 \text{ m}$$ <

The local convective heat flux at $x = L = 1$ m is

$$q'' = h(T_s - T_{m,o}) = 6140\text{W/m}^2 \cdot \text{K} \times (450 - 400) \text{ K} = 30{,}700 \text{ W/m}^2$$ <

COMMENTS: The dimensionless tube length is L/D = 1m/0.05m = 20. The flow is therefore fully developed, and use of Eq. 8.65 is appropriate.