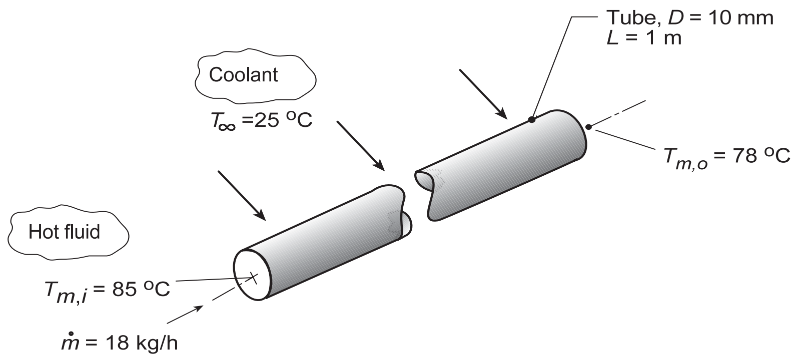
PROBLEM 8.60

KNOWN: Hot fluid passing through a thin-walled tube with coolant in cross flow over the tube. Fluid flow rate and inlet and outlet temperatures.

FIND: Outlet temperature, $T_{m,o}$, if the flow rate is increased by a factor of 2 with all other conditions the same.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2)Hot fluid is incompressible with negligible viscous dissipation, (3) Constant properties, (4) Fully developed flow and thermal conditions, (5) Convection coefficients, $\bar{h}_o$ and $\bar{h}_i$, independent of temperature, and (6) Negligible wall thermal resistance.

PROPERTIES: Hot fluid (Given): ρ = 1079 kg/m^3, c_p = 2637 J/kg·K, μ = 0.0034 N·s/m^2, k = 0.261 W/m·K.

ANALYSIS: For conditions prescribed in the Schematic, Eq 8.45a can be used to evaluate the overall convection coefficient with P = πD,

$$\frac{T_\infty - T_{m,o}}{T_\infty - T_{m,i}} = \exp\left(-\frac{PL}{\dot{m}_o cp}\bar{U}\right) \tag{1}$$

$$\frac{(25-78)^\circ C}{(25-85)^\circ C} = \exp\left(-\frac{\pi \times 0.010\,m \times 1m}{(18/3600)\,kg/s \times 2637\,J/kg \cdot K}\bar{U}\right)$$

$$U = 52.1\,W/m^2 \cdot K$$

The overall coefficient can be expressed in terms of the inside and outside coefficients,

$$U = \left(1/\bar{h}_i + 1/\bar{h}_o\right)^{-1} \tag{2}$$

Characterize the internal flow with the Reynolds number, Eq. 8.6,

$$Re_D = \frac{4\dot{m}_o}{\pi D \mu} = \frac{4 \times (18/3600)\,kg/s}{\pi \times 0.010m \times 0.0034\,N \cdot s/m^2} = 187$$

and since the flow is laminar, and assumed to be fully developed, $\bar{h}_i$ will not change when the flow rate is doubled. That is, U = 52.1 W/m^2·K when $\dot{m}$ = 2m$_o$. Using Eq. (1) again, but with $T_{m,o}$ unknown,

$$\frac{(25-T_{m,o})^\circ C}{(25-85)^\circ C} = \exp\left(-\frac{\pi \times 0.010\,m \times 1m}{2(18/3600)\,kg/s \times 2637\,J/kg \cdot K} \times 52.1 W/m^2 \cdot K\right)$$

$$T_{m,o} = 81.4^\circ C$$ <

COMMENTS: Examine the assumptions and explain why they were necessary in order to affect the solution.