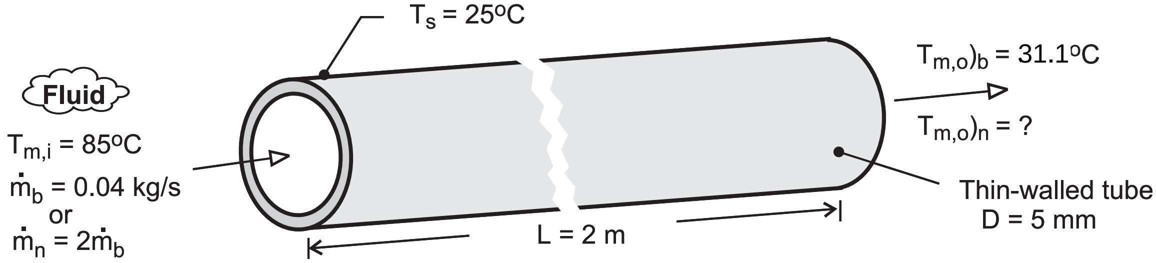
PROBLEM 8.79

KNOWN: Fluid enters a thin-walled tube of 5-mm diameter and 2-m length with a flow rate of 0.04 kg/s and temperature of $T_{m,i}$ = 85°C; tube surface temperature is maintained at T_s = 25°C; and, for this *base* operating condition, the outlet temperature is $T_{m,o}$ = 31.1°C.

FIND: The outlet temperature if the flow rate is doubled?

SCHEMATIC:



ASSUMPTIONS: (1) Flow is fully developed and turbulent, (2) Fluid properties are independent of temperature, (3) Constant surface temperature cooling conditions, (4) Applicability of Eq. 8.34.

ANALYSIS: For the *base* operating condition (b), the rate equation, Eq. 8.41b, with $C = \dot{m}c_p$, the capacity rate, is

$$\frac{T_s - T_{m,o})_b}{T_s - T_{m,i}} = \exp\left(-\frac{PL\,\bar{h}_b}{C_b}\right) \tag{1}$$

Substituting numerical values, with P = πD, find the ratio, $\bar{h}_b / C_b$,

$$\frac{25-31.1}{25-85} = \exp\left[-\pi \times 0.005\text{ m} \times 2\text{ m}\left(\bar{h}_b / C_b\right)\right]$$

$$\bar{h}_b / C_b = 72.77\text{ m}^{-2}$$

For the *new* operating condition (n), the flow rate is doubled, $C_n = 2C_b$, and the convection coefficient scales according to the Dittus-Boelter relation, Eq. 8.60,

$$\bar{h} \sim Re_D^{0.8} \sim \dot{m}^{0.8}$$

$$\bar{h}_n = 2^{0.8}\bar{h}_b \text{ and } \left(\bar{h}_n / C_n\right) = \left(2^{0.8}/2\right)\left(\bar{h}_b / C_b\right) \tag{2}$$

Using the rate equation for the new operating condition, find

$$\frac{T_s - T_{m,o})_n}{T_s - T_{m,i}} = \exp\left(-\frac{PL\,\bar{h}_n}{C_n}\right) = \exp\left[-PL \times 0.871\left(\bar{h}_b / C_b\right)\right] \tag{3}$$

$$\frac{25 - T_{m,o})_n}{25-85} = \exp\left[-\pi \times 0.005\text{ m} \times 2\text{ m} \times 0.871 \times 72.77\text{ m}^{-2}\right]$$

$$T_{m,o})_n = 33.2°\text{C}$$ <