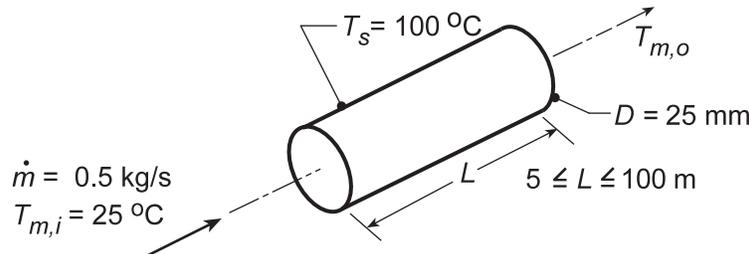


PROBLEM 8.26

KNOWN: Inlet temperature and flowrate of oil moving through a tube of prescribed diameter and surface temperature.

FIND: (a) Oil outlet temperature $T_{m,o}$ for two tube lengths, 5 m and 100 m, and log mean and arithmetic mean temperature differences, (b) Effect of L on $T_{m,o}$ and \overline{Nu}_D .

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Incompressible liquid with negligible viscous dissipation, (3) Constant properties.

PROPERTIES: Table A.4, Oil (330 K): $c_p = 2035 \text{ J/kg}\cdot\text{K}$, $\mu = 0.0836 \text{ N}\cdot\text{s/m}^2$, $k = 0.141 \text{ W/m}\cdot\text{K}$, $Pr = 1205$.

ANALYSIS: (a) Using Eqs. 8.41b and 8.6

$$T_{m,o} = T_s - (T_s - T_{m,i}) \exp\left(-\frac{\pi DL \bar{h}}{\dot{m} c_p}\right)$$

$$Re_D = \frac{4\dot{m}}{\pi D \mu} = \frac{4 \times 0.5 \text{ kg/s}}{\pi \times 0.025 \text{ m} \times 0.0836 \text{ N}\cdot\text{s/m}^2} = 304.6$$

With $x_{fd,h} = 0.05DRe_D = 0.4 \text{ m}$, it is reasonable to assume the flow is hydrodynamically fully developed. However, with $x_{fd,t} = x_{fd,h}Pr = 495 \text{ m}$, the flow is thermally developing. Since thermal entry length effects will be significant and $Pr > 5$, use Eq. 8.57 with Eq. 8.56 for the Graetz number:

$$\bar{h} = \frac{k}{D} \left[3.66 + \frac{0.0688(D/L)Re_D Pr}{1 + 0.04[(D/L)Re_D Pr]^{2/3}} \right] = \frac{0.141 \text{ W/m}\cdot\text{K}}{0.025 \text{ m}} \left[3.66 + \frac{2.45 \times 10^4 D/L}{1 + 205(D/L)^{2/3}} \right]$$

For $L = 5 \text{ m}$, $\bar{h} = 5.64(3.66 + 17.51) = 119 \text{ W/m}^2 \cdot \text{K}$, hence

$$T_{m,o} = 100^\circ\text{C} - (75^\circ\text{C}) \exp\left(-\frac{\pi \times 0.025 \text{ m} \times 5 \text{ m} \times 119 \text{ W/m}^2 \cdot \text{K}}{0.5 \text{ kg/s} \times 2035 \text{ J/kg}\cdot\text{K}}\right) = 28.4^\circ\text{C} \quad <$$

For $L = 100 \text{ m}$, $\bar{h} = 5.64(3.66 + 3.38) = 40 \text{ W/m}^2 \cdot \text{K}$, $T_{m,o} = 44.9^\circ\text{C}$. <

Also, for $L = 5 \text{ m}$,

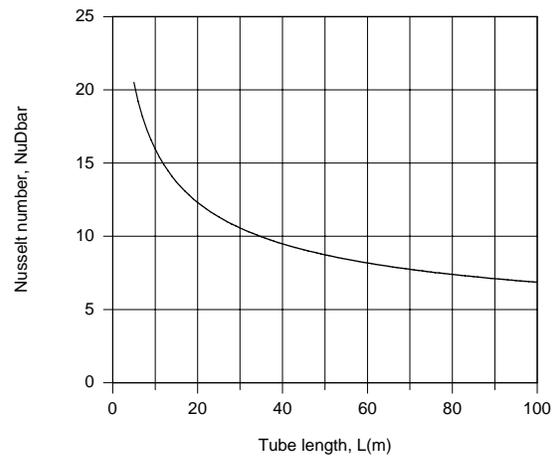
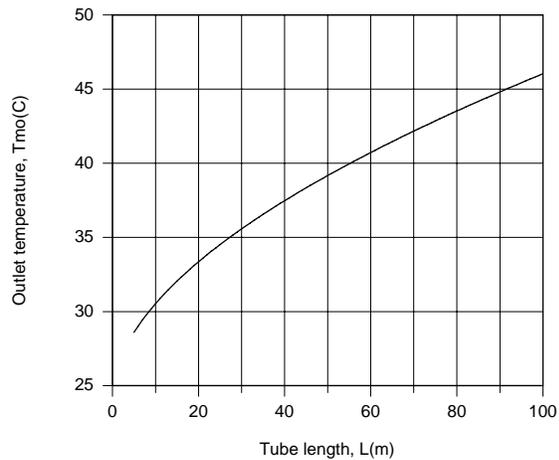
$$\Delta T_{\ell m} = \frac{\Delta T_o - \Delta T_i}{\ln(\Delta T_o / \Delta T_i)} = \frac{71.6 - 75}{\ln(71.6/75)} = 73.3^\circ\text{C} \quad \Delta T_{am} = (\Delta T_o + \Delta T_i)/2 = 73.3^\circ\text{C} \quad <$$

For $L = 100 \text{ m}$, $\Delta T_{\ell m} = 64.5^\circ\text{C}$, $\Delta T_{am} = 65.1^\circ\text{C}$ <

(b) The effect of tube length on the outlet temperature and Nusselt number was determined by using the *Correlations and Properties* Toolpads of IHT.

Continued...

PROBLEM 8.26 (Cont.)



The outlet temperature approaches the surface temperature with increasing L , but even for $L = 100$ m, $T_{m,o}$ is well below T_s . Although \overline{Nu}_D decays with increasing L , it is still well above the fully developed value of $Nu_{D,fd} = 3.66$.

COMMENTS: (1) The average, mean temperature, $\overline{T}_m = 330$ K, was significantly overestimated in part (a). The accuracy may be improved by evaluating the properties at a lower temperature. (2) Use of ΔT_{am} instead of $\Delta T_{\ell m}$ is reasonable for small to moderate values of $(T_{m,i} - T_{m,o})$. For large values of $(T_{m,i} - T_{m,o})$, $\Delta T_{\ell m}$ should be used.