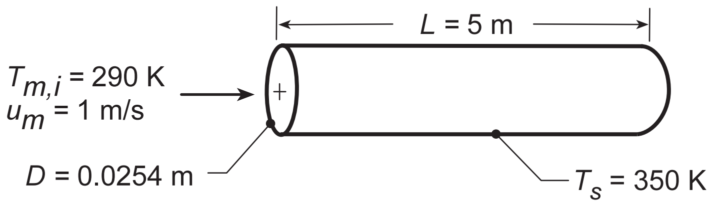
PROBLEM 8.49

KNOWN: Diameter, length and surface temperature of condenser tubes. Water velocity and inlet temperature.

FIND: (a) Water outlet temperature evaluating properties at T_m = 300 K, (b) Repeat calculations using properties evaluated at the appropriate temperature, $\bar{T}_m = (T_{m,i} + T_{m,o})/2$, and (c) Coolant mean velocities for the range $4 \le L \le 7$ m which provide the same $T_{m,o}$ as found in part (b).

SCHEMATIC:



ASSUMPTIONS: (1) Negligible tube wall conduction resistance, (2) Incompressible liquid with negligible viscous dissipation.

PROPERTIES: *Table A.6*, Water ($\bar{T}_m$ = 300 K): ρ = 997 kg/m^3, c_p = 4179 J/kg·K, $\mu = 855 \times 10^{-6}$ kg/s·m, k = 0.613 W/m·K, Pr = 5.83.

ANALYSIS: (a) From Equation 8.41b

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

and evaluating properties at $\bar{T}_m$ = 300 K, find

$$Re_D = \frac{\rho u_m D}{\mu} = \frac{997\,kg/m^3\,(1\,m/s)\,0.0254\,m}{855\times10^{-6}\,kg/s\cdot m} = 29,618$$

The flow is turbulent, and since L/D = 197, it is reasonable to assume fully developed flow throughout the tube. Hence, $\bar{h} \approx h_{fd}$. From the Dittus-Boelter equation,

$$Nu_D = 0.023\,Re_D^{4/5}\,Pr^{0.4} = 0.023(29,618)^{4/5}(5.83)^{0.4} = 176$$

$$\bar{h} = Nu_D\,(k/D) = 176\left(0.613\,W/m\cdot K/0.0254\,m\right) = 4248\,W/m^2\cdot K.$$

With

$$\dot{m} = \rho u_m\left(\pi D^2/4\right) = (\pi/4)997\,kg/m^3\,(1\,m/s)(0.0254\,m)^2 = 0.505\,kg/s.$$

Equation 8.41b yields

$$T_{m,o} = 350\,K - \left(60\,K\right)\exp\left[-\frac{\pi\left(0.0254\,m\right)5\,m\left(4248\,W/m^2\cdot K\right)}{0.505\,kg/s\left(4179\,J/kg\cdot K\right)}\right] = 323\,K = 50^\circ C \qquad <$$

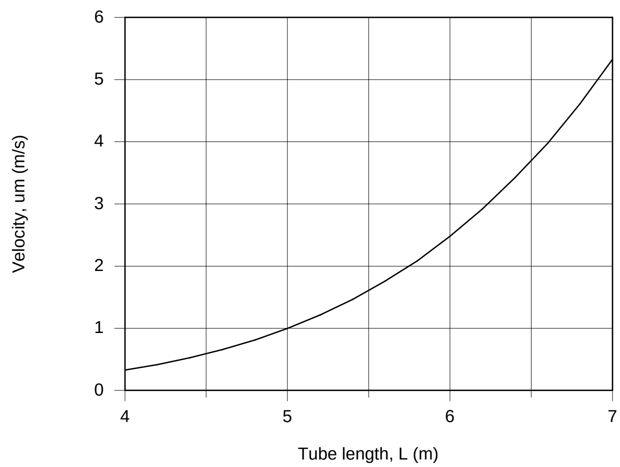
(b) Using the *IHT Correlations Tool*, *Internal Flow*, for fully developed *Turbulent Flow*, along with the energy balance and rate equations above, the calculation of part (a) is repeated with $\bar{T}_m = (T_{m,i} + T_{m,o})/2$ giving these results:

$$\bar{T}_m = 307.3\,K \qquad T_{m,o} = 51.7^\circ C = 324.7\,K \qquad <$$

(c) Using the IHT model developed for the part (b) analysis, the coolant mean velocity, u_m, as a function of tube length L with $T_{m,o}$ = 51.7°C is calculated and the results plotted below.

Continued...

PROBLEM 8.49 (Cont.)



COMMENTS: (1) Using $\overline{T}_m$ = 300 K vs. $\overline{T}_m = (T_{m,i} + T_{m,o})/2$ = 307 K for this application resulted in a difference of $T_{m,o}$ = 50°C vs. $T_{m,o}$ = 51.7°C. While the difference is only 1.7°C, it is good practice to use the proper value for $\overline{T}_m$.

(2) Note that u_m must be increased markedly with increasing length in order that $T_{m,o}$ remain fixed.