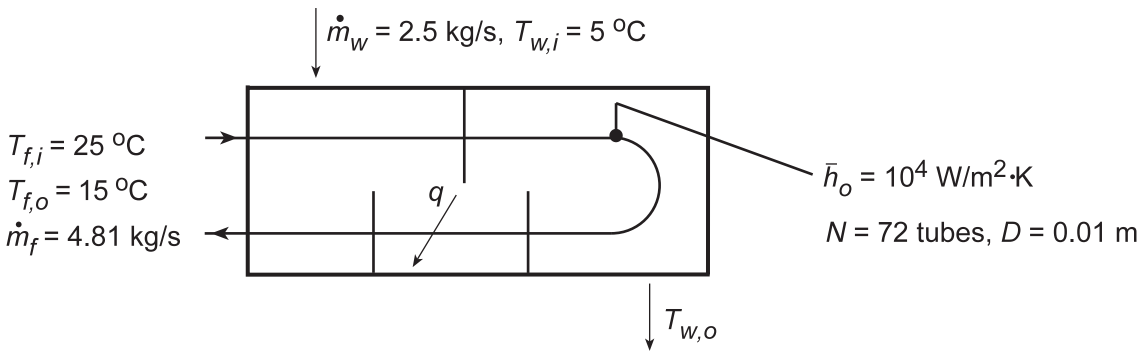
PROBLEM 11.50

KNOWN: Properties and flow rate of computer coolant. Diameter and number of heat exchanger tubes. Heat exchanger transfer rate and inlet temperature of computer coolant. Flow rate, specific heat, inlet temperature, and average convection coefficient of water.

FIND: (a) Tube flow convection coefficient, $\bar{h}_i$, (b) Tube length/pass required to achieve prescribed fluid outlet temperature, (c) Compute and plot the dielectric fluid outlet temperature, $T_{f,o}$, as a function of its flow rate $\dot{m}_f$ for the range $4 \le \dot{m}_f \le 6$ kg/s based upon the length/pass found in part (c), (d) the effect of ±10% change in the water flow rate, $\dot{m}_w$, on $T_{f,o}$ and (e) the effect of ±3°C change in inlet water temperature, $T_{w,i}$, on $T_{f,o}$. For parts (c, d, e), account for any changes in the overall convection coefficient, while all other conditions remain the same.

SCHEMATIC:



ASSUMPTIONS: (1) Negligible heat loss to surroundings, fouling and tube wall resistance; (2) Constant properties; (3) Fully developed flow, (4) Convection coefficient on shell side, $\bar{h}_o$, remains constant for all operating conditions.

PROPERTIES: Coolant (given): c_p = 1040 J/kg·K, $\mu = 7.65 \times 10^{-4}$ kg/s·m, k = 0.058 W/m·K, Pr = 14; Water (given): c_p = 4200 J/kg·K.

ANALYSIS: (a) For flow through a single tube,

$$Re_D = \frac{4\dot{m}_{f,t}}{\pi D \mu} = \frac{4(4.81\,\text{kg/s})/72}{\pi(0.01\text{m})7.65\times10^{-4}\ \text{kg/s}\cdot\text{m}} = 11{,}120$$

and using the Dittus-Boelter correlation, find

$$h_i = (k/D)0.023 Re_D^{4/5} Pr^{0.3} = 0.023\frac{0.058\,\text{W/m}\cdot\text{K}}{0.01\text{m}}(11{,}120)^{4/5}(14)^{0.3} = 508\,\text{W/m}^2\cdot\text{K}\,. <$$

(b) Find the capacity ratio

$$C_f = \dot{m}_f c_{p,f} = 4.81\,\text{kg/s}(1040\ \text{J/kg}\cdot\text{K}) = 5002\,\text{W/K} = C_{min}$$

$$C_w = \dot{m}_w c_{p,w} = 2.5\,\text{kg/s}(4200\,\text{J/kg}\cdot\text{K}) = 10{,}500\,\text{W/K} = C_{max}$$

hence, $C_r = C_{min}/C_{max} = 0.476$ and

$$\varepsilon = \frac{q}{q_{max}} = \frac{C_f(T_{f,i} - T_{f,o})}{C_f(T_{f,i} - T_{w,i})} = \frac{(25-15)^\circ\,\text{C}}{(25-5)^\circ\,\text{C}} = 0.500\,.$$

Using Fig. 11.12 with NTU = $(UA/C_{min}) = (UN\pi D2L/C_{min}) \approx 0.85$,

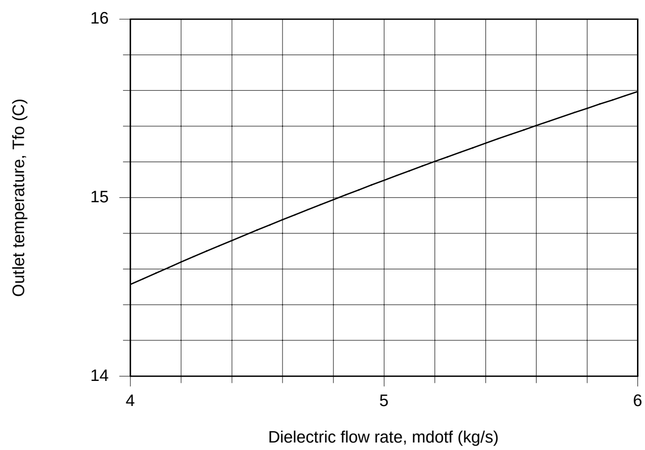
Continued...

PROBLEM 11.50 (Cont.)

$$U = \left(h_i^{-1} + h_o^{-1}\right)^{-1} = \left[(508)^{-1} + \left(10^4\right)^{-1}\right]^{-1} \mathrm{W/m^2 \cdot K} = 483\,\mathrm{W/m^2 \cdot K}$$

$$L = 0.85\left(5002\ \mathrm{W/K}\right) \Big/ 144\pi\left(483\,\mathrm{W/m^2 \cdot K}\right)0.01\mathrm{m} = 1.95\mathrm{m}\,.$$ <

(c) Using the *IHT Heat Exchanger Tool*, *Shell and Tube*, *One-shell pass and N-tube passes*, and the *Correlation Tool*, *Forced Convection*, *Internal Flow* for *Turbulent*, *fully developed conditions*, a model was developed using the effectiveness-NTU method employed above to compute and plot $T_{f,o}$ as a function of $\dot{m}_f$.



A change in the dielectric fluid flow rate of ±1 kg/s causes approximately ±0.5°C change in its outlet temperature.

(d) Using the above IHT model with the base conditions for part (c), the effect of a ±10% change in the water flow rate from its design value, $\dot{m}_w$ = 2.5 kg/s (2.25 ≤ $\dot{m}_w$ ≤ 2.75 kg/s) causes the dielectric fluid outlet temperature to change as

$$T_{f,o} = 15 \pm 0.14^\circ\mathrm{C}$$ <

(e) Using the IHT model of part (c) with the base case conditions for part (c), the effect of a ±3°C in the water inlet temperature from its design value, $T_{c,i}$ = 5°C (2 ≤ $T_{c,i}$ ≤ 8°C) cause the dielectric fluid outlet temperature to change as

$$T_{f,o} = 15 \pm 1.5^\circ\mathrm{C}$$ <

COMMENTS: (1) For the analyses of part (a), Eq. 11.30b,c yields NTU = 0.85 and q = 50 kW and $T_{w,o}$ = 9.76°C.

(2) The results of the analyses provide operating performance information on the effect of changes due to dielectric fluid flow rate (±1 kg/s of $\dot{m}_f$), water fluid flow rate (≤ 10% of $\dot{m}_w$) and water inlet temperature (±3°C of $T_{w,i}$) on the dielectric fluid outlet temperature, $T_{f,o}$, supplied to the computer. The greatest effect on $T_{f,o}$, is that by the input water temperature.