CENG101B Heat Transfer Fall Quarter 2008

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Quiz IV

This is a 50 minute closed-book exam; no notes. Please put your name on the top sheet. Answer all three questions. Explain your working and state any assumptions you have made.

1 (3 points) Circle the correct answer.

1. The design equation for double-pipe heat exchangers
   - is independent of the area of the heat exchanger.
   - involves the log-mean temperature difference.
   - is used in the (ε,NTU) method.
   - has a correction factor $F = 0.5$.
   - comes from solving the Navier–Stokes equations.
2. The overall heat transfer coefficient U
   - only depends on conduction.
   - is not used in double-pipe heat exchangers.
   - is always determined by experiment.
   - is obtained by adding in series convective and conductive resistances.
   - is independent of Prandtl number.
3. Heat exchanger effectiveness ε
   - is the same as taking $F = 1$.
   - cannot be used to find tube pass lengths.
   - only applies to laminar flows.
   - involves the maximum possible heat transfer in the denominator.
   - is independent of T_h at the hot inlet.

2 (7 points) Water ($C_p = 1$ kJ/kg·K) at 80°C flows through a cross-flow exchanger of area 10 m^2 at a rate of 900 kg/h. Cooling water at 15°C is available. If the water flow rate is 450 kg/h, find the exit temperatures. Take $U = 200$ W/m^2·K.

$$C_H = w \cdot C_p = 900\,(kg/h) \times 1/3600\,(h/sec) \times 1000\,(J/kg \cdot K) = 250\,(J/s \cdot K)$$

$$C_c = w \cdot C_p = 450\,(kg/h) \times 1/3600\,(h/sec) \times 1000\,(J/kg \cdot K) = 125\,(J/s \cdot K) \Rightarrow C_{min}$$

$$NTU = \frac{UA}{C_{min}} = \frac{200 \times 10}{125} = 16 \text{ (off chart)} \Rightarrow \varepsilon_c \simeq 0.9$$

$$\varepsilon_c = \frac{T_{c2} - T_{c1}}{T_{H1} - T_{c1}} = 0.9 \Rightarrow T_{c2} = 0.9(T_{H1} - T_{c1}) + T_{c1}$$
$$= 0.9(80 - 15) + 15 = 73.5\ (°C)$$

$$C_c(T_{c2} - T_{c1}) = C_H(T_{H1} - T_{H2}) \Rightarrow T_{H2} = T_{H1} - \frac{C_c}{C_H}(T_{c2} - T_{c1})$$
$$= 80 - 0.5(73.5 - 15) = 50.75\ (°C)$$

3 (10 points) Show that for a cylindrical pipe of conductivity k with inner and outer radii r_1, r_2, the overall heat transfer coefficient U based on the outer area is

$$U = \left[\frac{1}{h_2} + \frac{r_2}{k}\ln(r_2/r_1) + \frac{r_2}{r_1}\frac{1}{h_1}\right]^{-1},$$

where h_1 and h_2 are the heat transfer coefficients at the inner and outer surfaces.

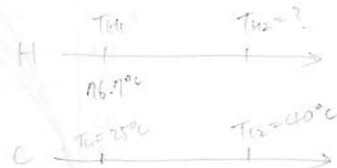
Carbon tetrachloride (boiling point at 1 atm: 76.7°C; heat capacity on a molar basis: $c_p = 131.3$ J/mol·K; atomic weights of carbon and chlorine 12 and 35.45 g/mol respectively) is cooled from its boiling point as it flows through a cocurrent heat double-pipe heat exchanger. The pipe is made of stainless steel ($k = 16$ W/m·K) with inner and outer diameters 1.2 and 1.3 cm respectively. Water ($C_p = 1$ kJ/kg·K) at a flow rate of 200 kg/s enters at 25°C and leaves at 40°C. The heat transfer coefficients of the inner and outer surfaces are both 800 W/m²·K and the length of the pipe is 4 m. Calculate the flow rate of carbon tetrachloride and its outlet temperature.

$$Q = 2\pi L \frac{T_i - T_o}{\frac{1}{r_2 h_2} + \frac{\ln(r_2/r_1)}{k} + \frac{1}{r_1 h_1}} = UA\cdot\Delta T \qquad A = A_2 = 2\pi r_2 L \ (A_{out})$$

$$\frac{2\pi L(T_i - T_o)}{\frac{1}{r_2 h_2} + \frac{\ln(r_2/r_1)}{k} + \frac{1}{r_1 h_1}} = 2\pi r_2 L\, U_o (T_i - T_o)$$

U_o: the overall heat transfer coefficient

$$\Rightarrow U_o = \left[\frac{1}{h_2} + \frac{r_2\ln(r_2/r_1)}{k} + \frac{r_2}{r_1}\frac{1}{h_1}\right]^{-1}$$



$$Q = (\omega \cdot C_p)_C (T_{C2} - T_{C1}) = U_o A_2\, \Delta T_{lm}$$

i) $(\omega\cdot C_p)_c(T_{c2} - T_{c1}) = (200 \times 10^3)(40-25) = 3\times10^6$ (W)

ii) $$U_o A_2 \Delta T_{lm} = \left[\frac{1}{h_2} + \frac{r_2}{k}\ln(r_2/r_1) + \frac{r_2}{r_1}\frac{1}{h_1}\right]^{-1}\cdot(2\pi r_2 L)\cdot \frac{T_{H2} - T_{C2} - (T_{H1} - T_{C1})}{\ln\left(\frac{T_{H2} - T_{C2}}{T_{H1} - T_{C1}}\right)}$$

$$= \left[\frac{1}{800} + \frac{0.0065}{16}\ln\left(\frac{0.0065}{0.006}\right) + \frac{0.0065}{0.006}\cdot\frac{1}{800}\right]^{-1}(2\pi\times0.0065\times4)\cdot\frac{(T_{H2}-40)-(76.7-25)}{\ln\left(\frac{T_{H2}-40}{76.7-25}\right)}$$

$$= 61.95 \cdot \frac{T_{H2} - 91.7}{\ln\left(\frac{T_{H2}-40}{51.7}\right)}$$

$$\frac{T_{H2} - 91.7}{\ln\left(\frac{T_{H2}-40}{51.7}\right)} = \frac{3\times10^6}{61.95} = 48426 \Rightarrow T_{H2}$$

$(\omega C_p)_c (T_{c2} - T_{c1}) = (\omega C_p)_H (T_{H2} - T_{H1}) \rightarrow$ get $(\omega C_p)_H$ $\qquad (C_p)_H = 0.854$ (kJ/kg·K)

$\Rightarrow \omega_H$