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Assignment # 6 - Thermodynamics II

1. H_2O $T_{avg} = 110°C$, $V_{avg} = 3.5\ m/s$, $L = 5m$ stainless steel tube
$k = 14.2\ W/m°C$ $D_i = 1.0\ cm$, $D_o = 1.4\ cm$

$h_o = 8400\ W/m^2 \cdot °C$

Find i) h_i, U_i, U_i [$R_{f,i} = 0.0005\ m^2 \cdot °C/W$]

$\rho = 950.6$

$h_i = \frac{k}{D_i} \times Nu$ $\quad Re = \frac{VD_i}{\nu} \rightarrow \frac{3.5\ m/s \times 0.01m \times 950.6}{0.255 \times 10^{-3}}$

$\hookrightarrow 130'474$

$Pr = 1.58$

$k = 0.682$

$Nu = 0.0155\ Pr^{0.5} Re^{0.83}$

$Nu = 0.0155 (1.58)^{0.5} (130474)^{0.83}$

$Nu = 343.2$

$h_i = (343.2) \times \frac{(0.682\ W/m°C)}{(0.01\ m)}$

$h_i = 23'406\ W/m^2°C$ ✓

U_i

$R_{total} = \frac{1}{h_i A_i} + \frac{\ln(D_o/D_i)}{2\pi k L} + \frac{1}{h_o A_o}$

$A_i = 0.1570796\ m^2$

$A_o = 0.219911\ m^2$

$= [0.000272 + 0.00075424 + 0.00054134]$

$R_{total} = 0.0015676\ °C/W$

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$R_{total} = 1/U_i A_i \rightarrow U_i = 4'061\ W \cdot m^2/°C$ ✓

U_i w/ $R_{f,i}$ ✓

$R_{total} = R + \frac{R_{f,i}}{A_i} \rightarrow 0.0015676 + \frac{0.0005\ m^2 \cdot °C/W}{A_i} \rightarrow R_{total} = 0.018859\ °C/W$

$\hookrightarrow U_i = 1340\ W \cdot m^2/°C$

(2.) - Double Pipe Counter Flow

- ethylene glycol
  - $C_p = 2560$ J/kg°C
  - $\dot{m} = 3.5$ kg/s
  - $\Delta T = 80°C \rightarrow 40°C$
- water
  - $C_p = 4180$ J/kg°C
  - $\Delta T = 20°C \rightarrow 55°C$

Overall $U = 250$ W/m²·°C

a. $\dot{Q} = \dot{m} C_p (40°C - 80°C)$

$\dot{Q} = +358'400$ J/s ✓

b. $\dot{m}_{water} = \dot{Q} / C_p \Delta T$ (cp of water)

↳ $= 358400 / (4180 \times 35°C)$

$\dot{m}_{water} = 2.45$ kg/s ✓

c. $\Delta T_{lm} = \dfrac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)}$

$\Delta T_1 = T_{hin} - T_{cout} \rightarrow 80 - 55 = 25$

$\Delta T_2 = T_{hout} - T_{cIN} \rightarrow 40 - 20 = 20$

$\Delta T_{lm} = \dfrac{(25 - 20)°C}{\ln(25/20)}$

$\Delta T_{lm} = 22.407$

$A_s = \dot{Q} / (U \times \Delta T_{lm})$

$A_s = 358400 / (250 \times 22.407) \rightarrow A_s = 63.98$ m² ✓

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(3)

- Shell and Tube
- 2 shell passes
- ethyl alcohol ... $C_p = 2670$ J/kg·°C
  $\dot{m} = 2.1$ kg
  $\Delta T = 25°C \rightarrow 70°C \rightarrow [\Delta] = 45°C$
- water ... $C_p = 4190$ J/kg·°C
  $\Delta T = 95°C \rightarrow 45°C \rightarrow [\Delta] = 50°C$

$U = 950$ W/m²·°C

Heat Transfer $\dot{Q}$

$\dot{Q} = U A_s F \Delta T_{lmCF}$

$\dot{Q} = mC_p\Delta T \longrightarrow 2.1\frac{kg}{s} \times 2670 J/kg{\cdot}°C (45°C)$

$\dot{Q} = 252\,315$ J/s ✓

$A_s = \dot{Q} / F \times U \times \Delta T_{lmCF}$

$F = 2$ $\quad R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{95°C - 45°C}{70°C - 25}$

$R = 1.1$

$\Delta T_{lmCF} = \frac{(45-25)°C - (95-70)°C}{\ln(20/25)}$

$P = \frac{45°C}{95-25} \rightarrow P = 0.6420$

$\Delta T_{lmCF} = 22.407$ °C

$\therefore F = 0.84$ ✓ 5/5

$A_s = \frac{252\,315 J/s}{0.84 \times 22.4 \times 950}$

$A_s = 14.11$ m² ✓