Problem 11.55a) Recuperator

Cross-Flow Heat Exchanger

$\dot{m}_h = 6.5$ kg/s $\qquad \dot{m}_c = 6.2$ kg/s

$T_{hi} = 700$ K $\qquad T_{ci} = 300$ K

$T_{co} = 500$ K

$U = 100$ W/m²K $\qquad C_p = 1040$ J/kgK

Find the required surface area

$$q = \dot{m}_c C_p \left[T_{co} - T_{ci}\right] = 12.9 \text{ MW}$$

$$q = \dot{m}_h C_p \left[T_{hi} - T_{ho}\right] \Rightarrow T_{ho} = 509 \text{ K}$$

$C_{min} = C_c = 6448$ W/K

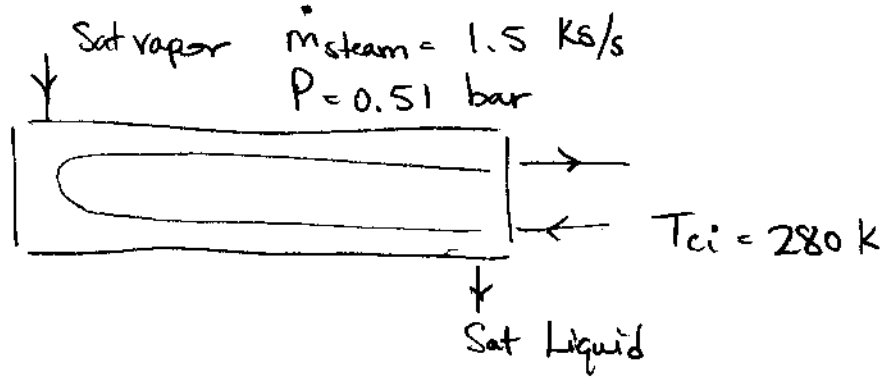
$C_{max} = C_h = 6760$ W/K $\qquad C_r = 0.95$

$$q_{max} = C_{min}\left[T_{hi} - T_{ci}\right] = 25.8 \text{ MW}$$

$$\varepsilon = \frac{q}{q_{max}} = 0.5$$

$$NTU = 1.1 = \frac{UA}{C_{min}} \Rightarrow \boxed{A = 70.9 \text{ m}^2}$$

11.76 a) - c) Rankine Cycle



$N = 100$ Thin-Walled Tubes

$D = 0.01$ m

$\dot{m}_w = 15$ kg/s

$C_{pw} = 4178$ J/kg K $\quad Pr = 4.6$

$\mu = 700 \times 10^{-6}$ N·s/m²

$k = 0.628$ W/mK

Condensation $\quad \bar{h}_o = 5000$ W/m²K

a) Find the water outlet temperature

$h_{fg} = 2304 \frac{kJ}{kg} \quad T_{sat} = 355$ K

$q = \dot{m}_{steam} \cdot h_{fg} = 3456$ kW

$q = \dot{m}_w \cdot C_{pw} \left[T_{co} - T_{ci} \right] = 3456000$ W

$T_{co} = 335.1$ K

b) Required Tube Length

Inside Tubes $\quad \dot{m} = 0.15$ kg/s $\quad D = 0.01$ m

$Re_D = \frac{4\dot{m}}{\pi D \mu} = 27284 \quad \therefore$ Turbulent

$Nu_D = 0.023 \, Re_D^{4/5} \, Pr^{0.4}$ ← Heating

$Nu_D = 149.8 = \frac{hD}{k_f} \Rightarrow h_i = 9408 \frac{W}{m^2 K}$

$$\frac{1}{U} = \frac{1}{h_o} + \frac{1}{h_i} \quad \leftarrow \text{Thin-Walled}$$

$$U = 3265 \ W/m^2K$$

$$C_{min} = \dot{m}_w \cdot C_p = 62670 \ W/K$$

$$q_{max} = C_{min}\left[T_{sat} - T_{ci}\right] = 4700250 \ W$$

$$\varepsilon = \frac{q}{q_{max}} = 0.74 \qquad C_r = 0$$

$$NTU = -\ln(1-\varepsilon) \quad \leftarrow \text{all heat exchangers } C_r = 0$$

$$NTU = 1.33$$

$$NTU = \frac{UA}{C_{min}} \Rightarrow A = \frac{NTU}{U} \cdot C_{min}$$

$$\boxed{A = 25.5 \ m^2}$$

c) Cummulative Fouling Factor, $R_f'' = 0.0003 \ \frac{m^2K}{W}$

$$\frac{1}{U} = \frac{1}{h_o} + \frac{1}{h_i} + R_f'' \Rightarrow U = 1650 \ W/m^2K$$

$$UA = 42060 \ W/K$$

$$NTU = \frac{UA}{C_{min}} = 0.67$$

$$\varepsilon = 1 - \exp\left[-NTU\right] \Rightarrow \varepsilon = 0.488$$

$$q_f = \varepsilon \cdot q_{max} = 2295 \ kW$$

$$m_{f_{\text{steam Condensed}}} = \frac{q_f}{q} = 0.66$$