NUCL 402 HMWK 8

1) BWR One Stage Separation System

$$\eta_{Turbine\ Separation} = 0.90$$
$$\eta_{Pump\ Isentropic} = 0.85$$
$$T_{\infty} = 30^{o}C$$

Point	p (kPa)	x ( )	h (kJ/kg)
1	6890	1.00	1192.4
2s	1380	0.846	1067.09
2	1380	0.861	1079.6
3	1380	1.00	1199.3
4	1380	0.00	355.6
5s	1380	0.800	898.30
5	6.89	0.797	896.95
6	6.89	0.00	69.7
7s	1380	--	70.29
7	1380	--	70.39
8	1380	--	110.5
9s	6890	--	117.06
9	6890	--	118.22

$$\eta_T = \frac{h_1 - h_2}{h_1 - h_{2s}} \rightarrow h_2 = h_1 - \eta_T (h_1 - h_{2s})$$
$$\eta_T = \frac{h_3 - h_5}{h_3 - h_{5s}} \rightarrow h_5 = h_3 - \eta_T (h_3 - h_{5s})$$
$$\eta_p = \frac{h_{7s} - h_6}{h_7 - h_6} \rightarrow h_7 = h_6 - \frac{1}{\eta_p} (h_{7s} - h_6)$$
$$\eta_p = \frac{h_{9s} - h_8}{h_9 - h_8} \rightarrow h_9 = h_8 - \frac{1}{\eta_p} (h_{9s} - h_8)$$
$$m_8 = m_2 = m_1 = m_3 + m_4$$
$$m_4 = m_1 - m_3$$
$$m_8 h_8 = m_2 h_2 = m_1 h_1 = m_3 h_3 + m_4 h_4$$
$$m_7 = m_8 - m_4$$
$$m_7 = m_8 - m_1 + m_3 = m_3$$
$$m_7 h_7 = m_8 h_8 - m_4 h_4$$
$$m_3 h_7 = m_1 h_8 - (m_1 - m_3) h_4$$
$$(m_1 - m_3) h_4 = m_1 h_8 - m_3 h_7$$
$$m_8 h_8 = m_2 h_2 = m_1 h_1 = m_3 h_3 + (m_1 - m_3) h_4$$
$$m_1 h_1 - m_1 h_4 = m_3 h_3 - m_3 h_4$$
$$\frac{h_1 - h_4}{h_3 - h_4} = \frac{m_3}{m_1}$$
$$m_4 = m_1 - m_1 \frac{h_1 - h_4}{h_3 - h_4} = m_1 \left(1 - \frac{h_1 - h_4}{h_3 - h_4}\right)$$
$$m_1 \left(1 - \frac{h_1 - h_4}{h_3 - h_4}\right) h_7 = m_1 h_8 - \left(m_1 - m_1 \left(1 - \frac{h_1 - h_4}{h_3 - h_4}\right)\right) h_4$$
$$h_8 = m_1 \left(1 - \frac{h_1 - h_4}{h_3 - h_4}\right) h_7 + \left(m_1 - m_1 \left(1 - \frac{h_1 - h_4}{h_3 - h_4}\right)\right) h_4$$

a) Cycle Thermal Efficiency

$$\eta_{th} = \frac{\frac{m_2}{m_3}(h_1 - h_2) + \frac{m_3}{m_3}(h_8 - h_5) - \frac{m_3}{m_3}(h_7 - h_6) - \frac{m_7}{m_3}(h_9 - h_8)}{\frac{m_2}{m_3}(h_1 - h_9)} = 0.3419$$

b) Cycle Thermal Efficiency with pumps and turbines having 100% isentropic efficiency

$$\eta_{th} = \frac{\frac{m_2}{m_3}(h_1 - h_{2s}) + \frac{m_3}{m_3}(h_8 - h_{5s}) - \frac{m_3}{m_3}(h_{7s} - h_6) - \frac{m_7}{m_3}(h_{9s} - h_8)}{\frac{m_2}{m_3}(h_1 - h_{9s})} = 0.3790$$

c) Work Lost due to Irreversibility, Conservation of Work

$$W_{in} = 7343.96\,\frac{kJ}{kg}$$

$$W_{umax} = \eta_{th} W_{in} = (0.3419)(7343.96\,\frac{kJ}{kg})$$

$$W_{umax} = 2510.9\,\frac{kJ}{kg}$$

$$W_{NET} = \eta_{th,i} W_{in} = (0.3790)\left(7343.96\,\frac{kJ}{kg}\right)$$

$$I_{TOT} = -\left(\eta_{th,i} W_{in} - \eta_{th} W_{in}\right) = -\left((0.3790)\left(7343.96\,\frac{kJ}{kg}\right) - (0.3419)\left(7343.96\,\frac{kJ}{kg}\right)\right)$$

$$W_{NET} + I_{TOT} = 2510.9\,\frac{kJ}{kg}$$

2) Thermal Efficiency of Brayton Cycle

a) Perfect Gas

$$\gamma = 1.30$$

$$\eta = 1 - \frac{1}{(\gamma_P)^{\frac{\gamma-1}{\gamma}}} = 1 - \frac{1}{\left(\left(\frac{p_c}{p_a}\right)^{\frac{0.30}{1.30}}\right)} = 0.31$$

b) Real Fluid

$$\eta_{th} = \frac{W_{cp} - W_T}{Q} = \frac{(h_a - h_b) - (h_c - h_d)}{h_c - h_b} = 0.255$$

c) Real Fluid, Compressor Turbine have 95% efficiency

$$\eta_{th} = \frac{\frac{1}{\eta_{cp}} W_{cp} - \eta_T W_T}{Q} = \frac{\frac{1}{0.95}(h_a - h_b) - 0.95(h_c - h_d)}{h_c - h_b} = 0.219$$