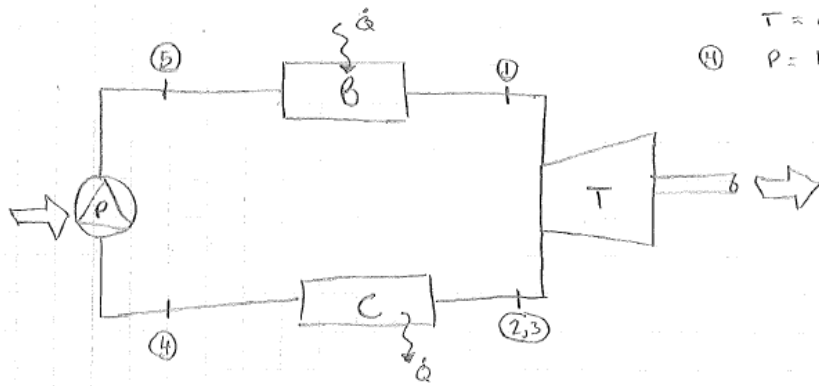
Assignment #3 Solutions

Question 1

GIVEN: $P_{NET} = 100 MW$

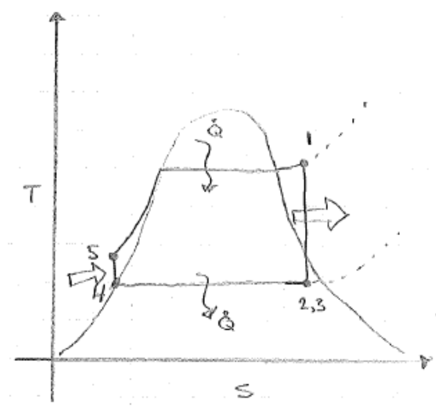
AT ① $P = 15 MPa$, $T = 600°C$

④ $P = 10 kPa$



Version A

STATE	T	P	v	h	S	PHASE
1	600°C *	15 M *		3582.3 kJ/kg	6.6776 kJ/kgK	
2, 3		10 K *		2114.9 kJ/kg	6.6776 kJ/kgK	0.80368
4		10 K *	0.00101 m³/kg	191.83 kJ/kg		SAT. LIQ
5		15 M *		206.97 kJ/kg		$h_5 = h_4 + \Delta P v$



$$h_{23} = h_f + x(h_g - h_f) = 191.83 + 0.80368(2392.8) = 2114.868 \ \frac{kJ}{kg}$$

$$S_{23} = S_f + x(S_g - S_f) \qquad x = \frac{S_{23} - S_f}{S_g - S_f} = \frac{6.6776 - 0.6493}{7.5009} = 0.80368$$

$$h_5 = h_4 + \Delta P_{4-5} v = 191.83 \frac{kJ}{kg} + (15000k - 10k)(0.00101 \frac{m^3}{kg}) = 206.970 \ \frac{kJ}{kg}$$

(a) $$\eta = \frac{W_{ANT}}{COST} = \frac{W_{NET}}{\dot{Q}_{in}} = \frac{W_T - W_P}{\dot{Q}_{in}} = \frac{(h_1 - h_{2,3}) - (h_5 - h_4)}{h_1 - h_5}$$

$$\eta = \frac{(3582.3 - 2114.9) - (206.97 - 191.83)}{(3582.3 - 206.97)} \times 100\% = \boxed{43\%}$$

(b) $P_{NET} = 100\,000 \frac{kJ}{s} = (W_T - W_P)(\dot{m}) = [(3582.3 - 2114.9) - (206.97 - 191.83)]\,\dot{m}$

$$\dot{m} = \frac{100\,000 \frac{kJ}{s}}{1452.26 \frac{kJ}{kg}} = \boxed{68.86 \frac{kg}{s}}$$

(c) BACK WORK RATIO $= \frac{W_P}{W_T} = \frac{(206.97 - 191.83)}{(3582.3 - 2114.9)} = \boxed{0.0103}$

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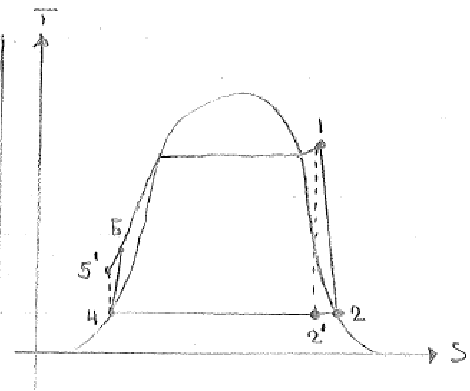
VERSION B

STATE	T	P	ν	h	s	PHASE
1	600°C*	15 M*		3582.3	6.6776	
2′		10 K*		2114.9	6.6776	
2		10 K*		2335.01		
4		10 K*	0.00101	191.83		Sat. liq.*
5′		15.789 M		207.77		
5		15.789 M		210.58		



$\eta_T = \frac{\dot{W}_{T\,Actual}}{\dot{W}_{T\,IDEAL}} = \frac{h_1 - h_2}{h_1 - h_2'} \Rightarrow h_2 = -(0.85(3582.3 - 2114.9) - 3582.3) = 2335.01$

$P_1 = 0.95\, P_5 \Rightarrow P_5 = \frac{15M}{0.95} = 15.789\, M$

$h_5' = h_4 + \nu(P_{5'} - P_4) = 191.83 + 0.00101(15.789 \times 10^3\, K - 10K) =$

$\eta_P = \frac{\dot{W}_{P\,IDEAL}}{\dot{W}_{P\,Actual}} = \frac{h_5' - h_4}{h_5 - h_4}$; $h_5 = \frac{h_5' - h_4}{\eta_P} + h_4 = \frac{(207.77 - 191.83)}{0.85} + 191.83$

$h_5 = 210.579$

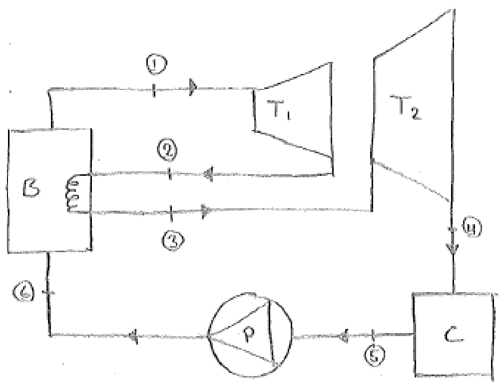
(a) $\eta = \frac{WANT}{COST} = \frac{\dot{W}_T - \dot{W}_P}{\dot{W}_B} = \frac{(h_1 - h_2) - (h_5 - h_4)}{(h_1 - h_5)} = \frac{1228.54}{3371.72} = \boxed{36.4\,\%}$

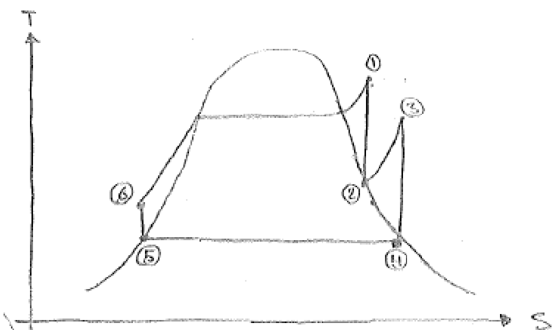
(b) $P_{net} = 100 \times 10^3\, kW = W_{net} \times \dot{m} \Rightarrow \dot{m} = \frac{100 \times 10^3\, kW}{1228.54 \frac{kJ}{kg}} = \boxed{81.4 \frac{kg}{s}}$

(c) Back work ratio $= \frac{W_P}{W_T} = \frac{h_5 - h_4}{h_1 - h_2} = \frac{18.75}{1247.29} = \boxed{0.015}$

QUESTION 2

GIVEN: $P_1 = 9\,MPa$ $T_1 = 600°C$
$x_2 = 1$ $T_3 = 500°C$
$P_4, P_5 = 7.5\,k$ $\dot{m} = 150\,kg/s$





STATE	T (°C)	P (Pa)	v (m³/kg)	h (kJ/kg)	S (kJ/kg·K)	PHASE
1	600	9M		3633.7	6.9589	
2		0.3320M		2729.9	6.9589	X = 1
3	500	0.3320M		3485.6	8.2832	
4		7.5K		2574.8 Approx	8.2832 *Assume Sat Vapour	* S_g 8.2515
5		7.5K	0.001008	168.79		X = 0
6		9M		177.85		

P	h	S
0.3130 M	2727.3	6.9777
P_2	h_2	6.9589
0.3613 M	2733.9	6.9299

$$\frac{6.9777-6.9589}{6.9777-6.9299} = \frac{2727.3-h_2}{2727.3-2733.9} = \frac{0.3130-P_2}{0.3130-0.3613}$$

$P_2 = 0.3320\,M$

$h_2 = 2729.90$

P	h	S
0.3M	3486.0	8.3251
0.3320M	h_3	S_3
0.4M	3484.9	8.1913

$$\frac{0.3-0.3320}{0.3-0.4} = \frac{3486-h_3}{3486.0-3484.9} = \frac{8.3251-S_3}{8.3251-8.1913}$$

$h_3 = 3485.6$

$S_3 = 8.2823$

$h_6 = h_5 + v_5(P_6 - P_5) = 168.79 + 0.001008(9\times10^3 k - 7.5k)$

$h_6 = 177.85\ \frac{kJ}{kg}$

(a) $P_{NET} = W_{T_1} + W_{T_2} - W_P = (h_1-h_2)+(h_3-h_4)-(h_6-h_5)$

$= (3633.7-2729.9)+(3485.6-2574.8)-(177.85-168.79)$

$= 1805.5\ \frac{kJ}{kg} \longrightarrow \left(1805.5\frac{kJ}{kg}\right)\left(150\frac{kg}{s}\right) = \boxed{270.8\,MW}$

(b) $\dot{q}_{RH} = (h_3 - h_2)\dot{m} = (3485.6 - 2729.8)(150) = \boxed{113.4\,MW}$

(c) $\frac{WANT}{COST} = \frac{\dot{W}_{T_1} + \dot{W}_{T_2} - \dot{W}_P}{Q_{B_1} + Q_{B_2}} = \frac{1805.5\ \frac{kJ}{kg}}{(3633.7-177.85)+(3485.6-2729.8)\frac{kJ}{kg}} = \boxed{42.8\%}$

(d)

STATE	T	P	v	h	s	PHASE
3′	550	0.3320 M		3594.3	8.4145	
4′		7.5k		2574.8 * Assumpt.	8.4145	* Assume saturated steam.

T	0.30 MPa		0.3320 MPa		0.40 MPa	
	h	s	h	s	h	s
500	3486.0	8.3251			3484.9	8.1913
550	3594.6	8.4572	3594.3	8.4145	3593.7	8.3236
600	3703.2	8.5892			3702.4	8.4558

$\dot{q}_{RH} = \underbrace{(h_3 - h_2)\,\dot{m}} = (3594.3 - 2729.9)(150) = \boxed{129.7\,MW}$

RATE OF REHEAT ONLY – ok