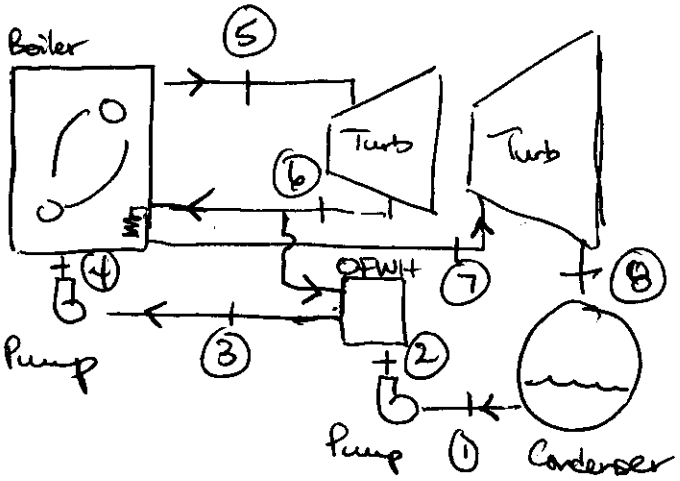
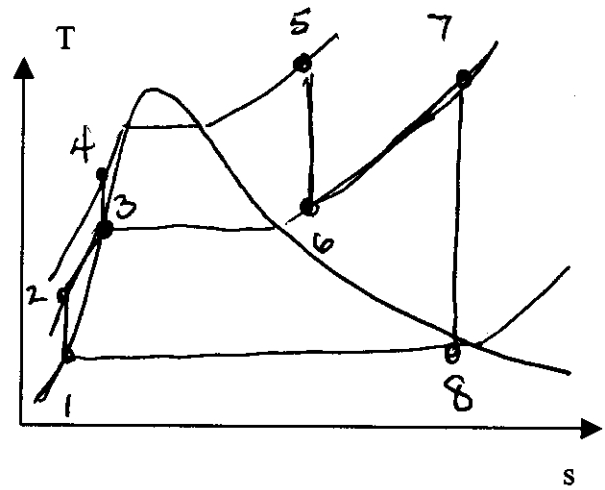
SOLUTIONS

Problem 9.43 A steam power plant operates on an ideal reheat-regenerative Rankine cycle and has a new power output of 80 MW. Steam enters the high-pressure turbine at 10 MPa and 550 C and leaves at 0.8 MPa. Some steam is extracted at this pressure to heat the feedwater in an open feedwater heater. The rest of the steam is reheated to 500 C at is expanded in the low-pressure turbine to the condenser pressure of 10 kPa. Show the cycle on a T-s diagram with respect to the saturation lines.

Draw the physical layout of the cycle and label each component. Sketch the cycle on a T-s Diagram





b) Complete the following table.

State	Pressure	Temperature	h (kJ/kg)	s (kJ/kg*K)	Phase Description
1	10 kPa	45.81	191.83	0.6493	Sat. Liquid
2	0.8 MPa	*****	192.63	0.6493	Comp. Liq
3	0.8 MPa	170.43	721.11	2.0462	Sat. Liquid
4	10 MPa	*****	731.37	2.0462	Comp. Liq
5	10 MPa	550	3500.9	6.7561	Superheated
6	0.8 MPa	****	2811.9	6.7561	Superheated
7	0.8 MPa	500	3480.6	7.8673	Superheated
8	10 kPa	****	2494.4	7.8673	Sat. Mixture

Deterime

(a) the mass flow rate of steam through the boiler

(b) *(b)* the thermal efficiency of the cycle

State 1 ← Sat. Liquid

Table A5 $h_f = 191.83 \frac{kJ}{kg}$ $s_f = 0.6493 \frac{kJ}{kg\,K}$

$P_1 = 10\,kPa$

State 2

$w_{12} = -v_1 [P_2 - P_1] = -0.8\ kJ/kg$

$w_{12} = h_1 - h_2$

$h_2 = 192.63\ kJ/kg$

State 3 ← Sat. Liquid

$P_3 = 0.8\,MPa$ $h_f = 721.11\ kJ/kg$ $s_f = 2.0462 \frac{kJ}{kg\,K}$

State 4

$w_{34} = -v_3 [P_4 - P_3] = -10.26\ kJ/kg$

$h_4 = 731.4\ kJ/kg$

State 5

$\left.\begin{array}{l} P_5 = 10\,MPa \\ T_5 = 550\,°C \end{array}\right\}$ Table A6

$h_5 = 3500.9\ kJ/kg$ $s_5 = 6.7561\ kJ/kg\,K$

State 6

Table A6

$P_6 = 0.8\,MPa$

$s_6 = s_5 = 6.7561\ kJ/kg\,K$

$h_6 = 2811.9\ kJ/kg\,K$

State 7

$P_7 = 0.8$ MPa $\rightarrow$ $h_7 = 3480.6$ kJ/k

$T_7 = 500°C$ $\quad$ $s_7 = 7.8673$ kJ/kg k

State 8

$P_8 = 10$ kPa

$s_8 = s_7 = 7.8673 \frac{kJ}{kg\,k}$

$$x = \frac{s_8 - s_f}{s_{fg}} = 0.9623$$

$h_8 = 2494.4$ kJ/kg

(a) Determine the mass flow rate through the Boiler

$$w_T = (h_5 - h_6) + (1-y)(h_7 - h_8)$$

$$w_P = (1-y)(h_1 - h_2) + h_3 - h_4$$

need to find mass fraction of extracted steam

Energy Balance (OFWH)

$$\dot{m}_6 h_6 + \dot{m}_2 h_2 = \dot{m}_3 h_3$$

$$y h_6 + (1-y) h_2 = h_3$$

$$y = \frac{h_3 - h_2}{h_6 - h_2} = 0.202$$

$$w_T = h_5 - h_6 + (1-y)(h_7 - h_8)$$

$$w_p = (1-y)(h_1 - h_2) + h_3 - h_4$$

$$w_T = 1476 \ \text{kJ/kg}$$

$$w_p = -10.9 \ \text{kJ/kg}$$

$$\dot{m} = \frac{\dot{W}_{net}}{w_{net}} = \frac{80{,}000 \ \text{kW}}{1465 \ \text{kJ/kg}}$$

$$\dot{m} = 54.6 \ \text{kg/s}$$

(b) Thermal Efficiency

$$q_{in} = h_5 - h_4 + (1-y)(h_7 - h_6)$$

$$q_{in} = 3303.1 \ \text{kJ/kg}$$

$$\eta_{th} = \frac{w_{net}}{q_{in}} = 44.3\%$$