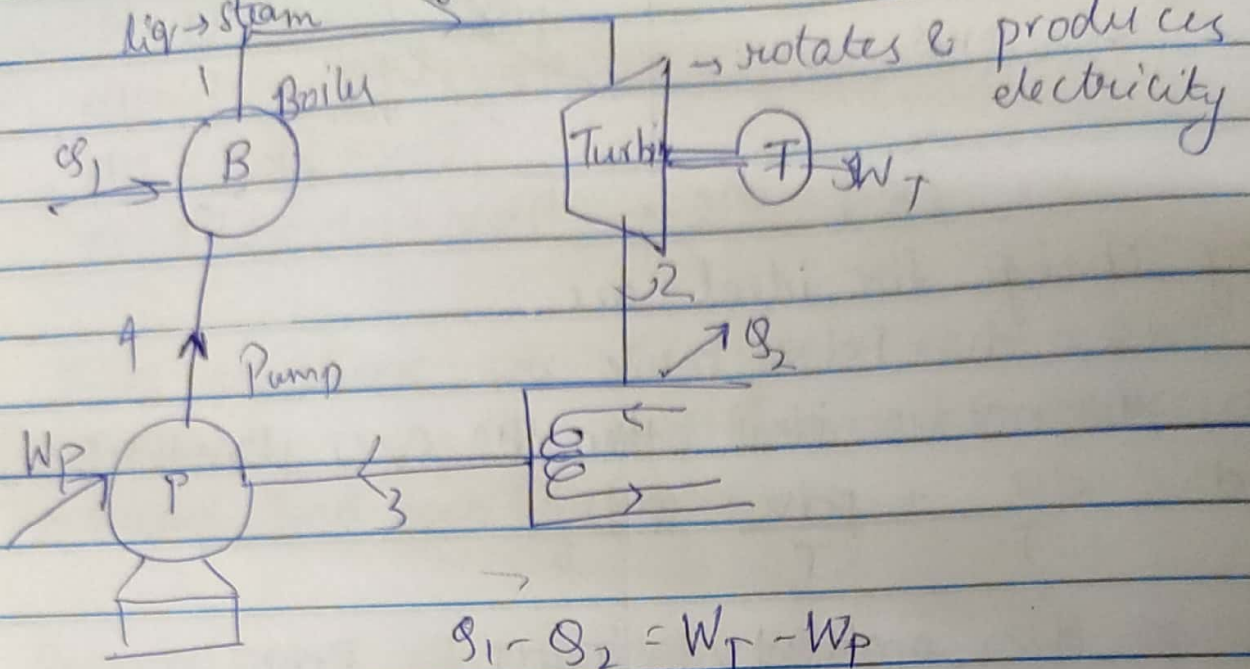
Rankine cycle - Thermal Power Plant



$$Q_1 - Q_2 = W_T - W_P$$

$$\eta_{H.E} = 1 - \frac{Q_2}{Q_1}$$

$$\eta_{HE} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Net mech. Work}}{\text{Heat supplied}}$$

$$= \frac{W_T - W_P}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

For Boiler :-

$$h_4 + \tfrac{1}{2}C_4^2 + gz_4 + Q_{4\to1} = h_1 + \tfrac{1}{2}C_1^2 + gz_1 + W_{4\to1}$$

$$\boxed{Q_1 = Q_{4\to1} = h_1 - h_4}$$

For turbine

$$h_1 + \tfrac{1}{2}C_1^2 + gz_1 + Q_{1\to2} = h_2 + \tfrac{1}{2}C_2^2 + gz_2 + W_{1\to2}$$

$$\boxed{W_{1\to2} = h_1 - h_2}$$

$\leftarrow T_1$ $\frac{}{T_2}$ $\eta = \eta_x \times \eta_y$

Tmean

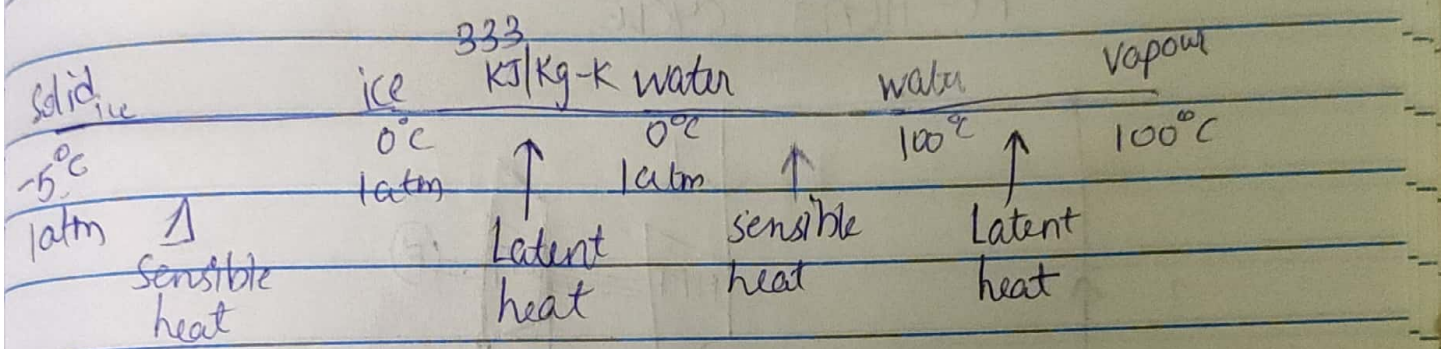
For a condenser

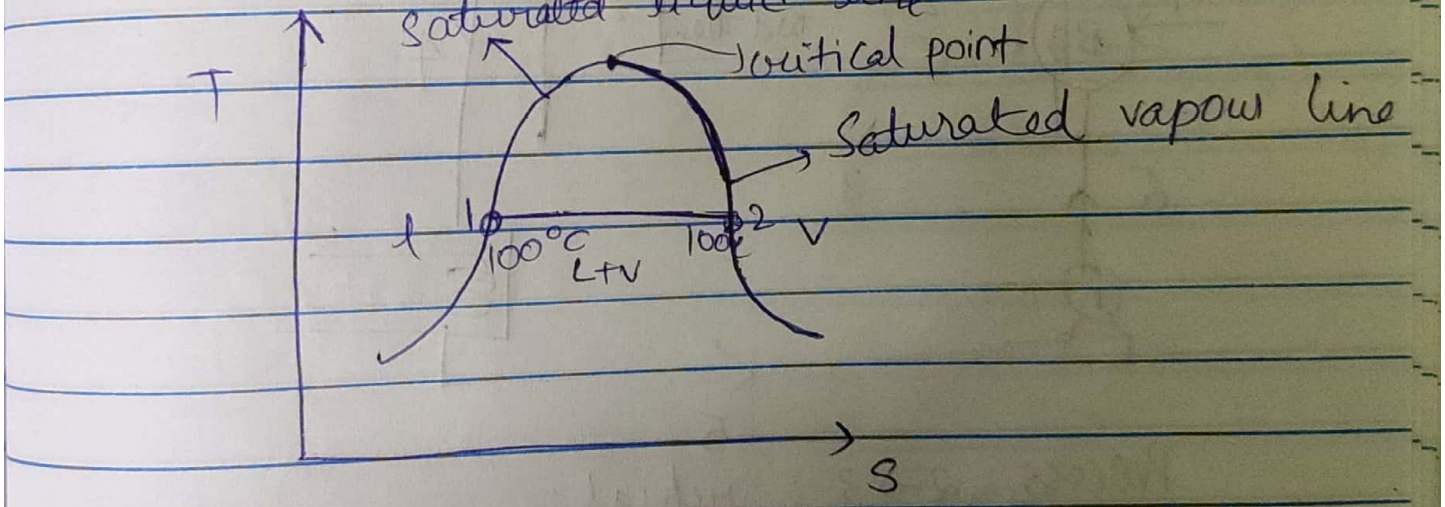
$Q_2 = Q_{2\to3} = h_2 - h_3 \rightarrow$ magnitude

$Q_{2\to3} = h_3 - h_2 \rightarrow$ direction

For a pump

$W_{3\to4} = h_4 - h_3$



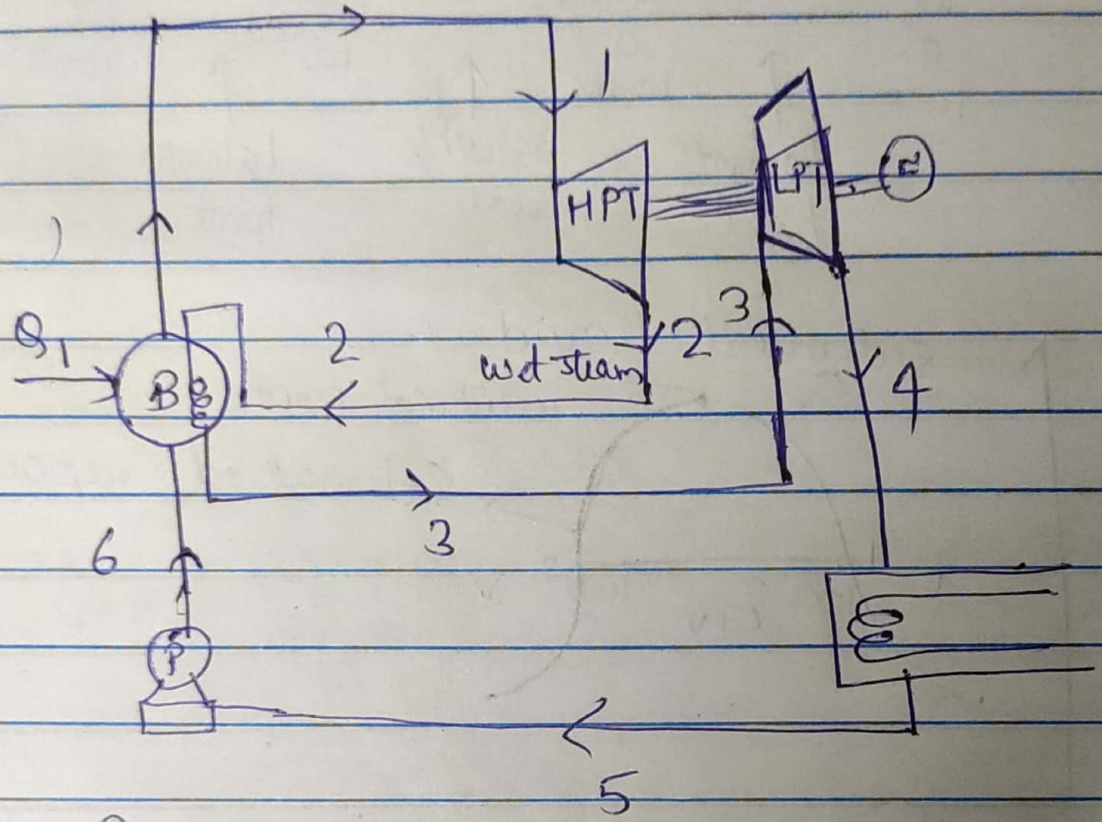


A phase change will take place at cons. temp & cons. pressure.

Dryness fraction $x = \frac{m_v}{m_l + m_v}$

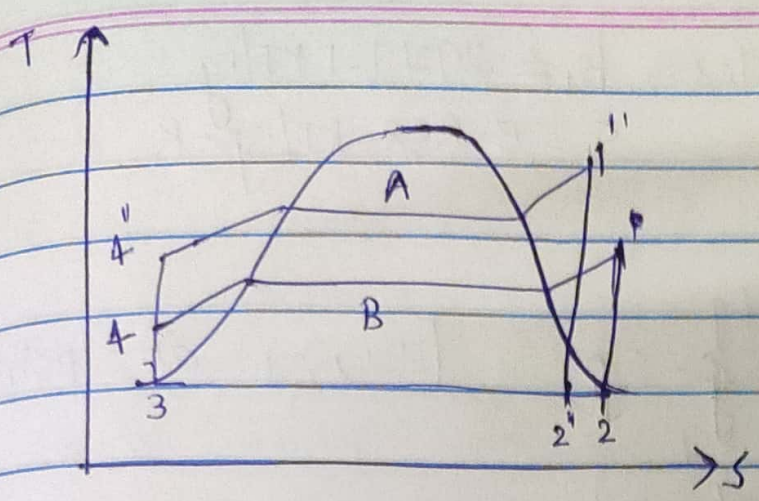
$T_{mean}(S_1 - S_4) = h_1 - h_4$

RE-HEAT CYCLE



Process 2→3 ; reheat

Two turbines are used so as to prevent formation of moisture in turbine.

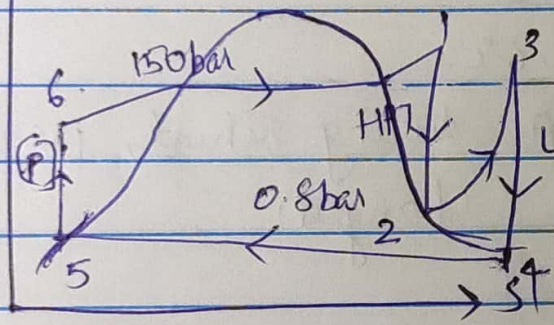


1, 1'' → Tsup

$x = 2'' = 0.75$

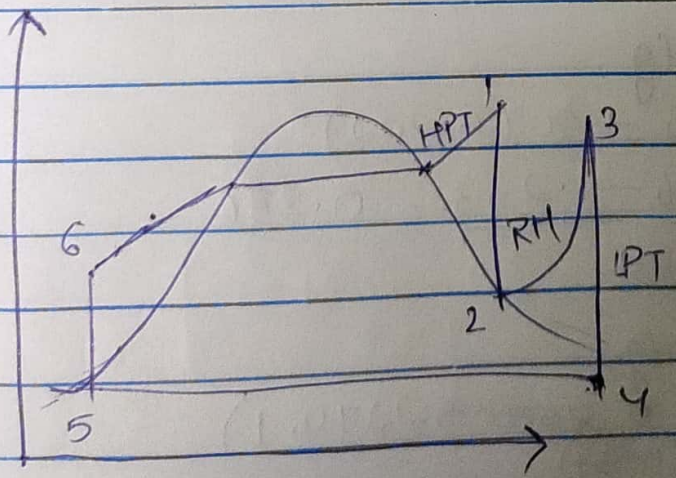
$x = 2 = 0.95$

Working under 3 pressures



$$\eta_{RH} = \frac{(h_1 - h_2) + (h_3 - h_4) - (h_6 - h_5)}{(h_1 - h_6) + (h_3 - h_2)}$$

Numerical



$T_{inlet} = 400^\circ C$

$P_{in} = 150$ bar (P_1)

Reheat

$P_{out} = 0.8$ bar (P_4)

From Pg-14 of steam table.

Corresponding temp ~~of~~ at 150bar is 342.1°C

∴ the given condition is in superheated region.

From steam tables, $h_1 = 2979.1$ KJ/kg

$S_1 = 5.888$ KJ/kg-K

$S_1 = S_2$

$S_2 = S_f + x S_{fg}$

$5.888 = S_f + x(S_g - S_f)$ [$\because x = 1$ at point 2]

$5.888 = S_f + S_g - S_f$

$S_2 = S_g$ $\boxed{S_g = 5.888 \text{ KJ/kg K}}$

$h_2 = h_g = 2785$ KJ/kg

$P_2 = 60$ bar

$T_2 = 275.6°C$

$P_2 = P_3 = 60$ bar (As during reheat, pressure isn't changed)

$T_1 = T_3 = 400°C$

From steam tables, $h_3 = 3180.1$ KJ/kg

$S_3 = 6.546$ KJ/kg-K

$S_3 = S_4$

$S_4 = S_f + x S_{fg}$

$6.546 = 1.233 + x(6.202)$

$x = \frac{6.546 - 1.233}{6.202} = 0.856$

$h_4 = h_f + x h_{fg}$

$= 391.7 + (0.856)(2274.1)$

$= 2338.3296$ KJ/kg

$h_6 - h_5 = \int v dP$

$= v_5(P_6 - P_5)$

$h_6 - 391.7 \times 10^3 = 0.001(150 \times 10^5 - 0.8 \times 10^5)$

$h_6 = 15311.7$ KJ/kg

$h_1 - h_6$ → Heat supplied to the boiler

$h_1 - h_2$ → W.D by HPT

$h_5 - h_4$ → Heat removed in the condenser

$h_3 - h_4$ → W.D by LPT

$h_3 - h_2$ → reheat supplied to

$h_6 - h_5$ → Work done by pump.

$$\eta_{RH} = \frac{(h_1 - h_2) + (h_3 - h_4) - (h_6 - h_5)}{(h_1 - h_6) + (h_3 - h_2)}$$