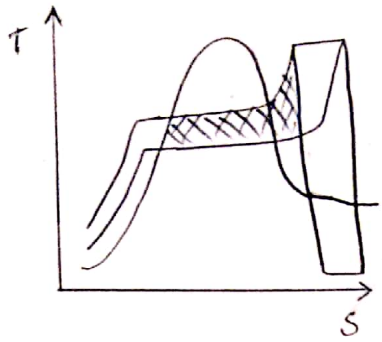
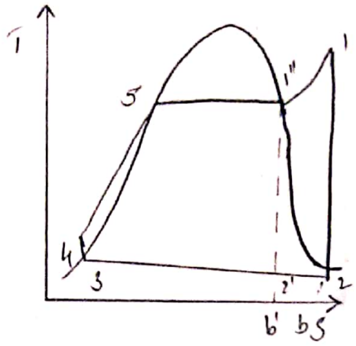
1) a) Effect of Boiler Pressure :-



The effect of increasing the boiler pressure. The rankine cycle efficiency is illustrated on T-S diagram.

In this case, the max temp of the steam as well as exhaust pressure are kept constant. Increase in boiler pressure result in decrease in heat rejection given by the area 2-x-x'-2'-2. Further the network increases by the amount shown by area of double cross hatching. However it decreases by the amount shown by area of single cross hatching. Thus there will not be much change in the network since heat rejected decreases, this results in an increase in rankine efficiency with an increase in max pressure.

Effect of Superheat:-



The above figure shows the effect of super heat on the rankine cycle. It is evident that the work increased by area 1'-1-2-2'-1'. The heat transfered in the boiler increased by area 1'-1-b-b'-1'. The ratio of these two areas is greater than the ratio of net work to heat supply for the rest of the cycle. Hence by the given pressure, superheating the steam increases the rankine cycle efficiency. Further when the steam is super heated the quality of the steam leaving the turbine increases.

1) b) GIVEN DATA :

$T_1 = 400°C \rightarrow P_1 = 60 bar$

$T_3 = 300°C \rightarrow P_3 = 11 bar$

$T_2 = 40°C \rightarrow P_{sat} = 0.07 bar$

$h_f = 167.4 \; KJ/Kg$

$V_f = 0.001$

$x = 100 - 14.67 = 85\% = 0.85$

$H_1 = 3180$

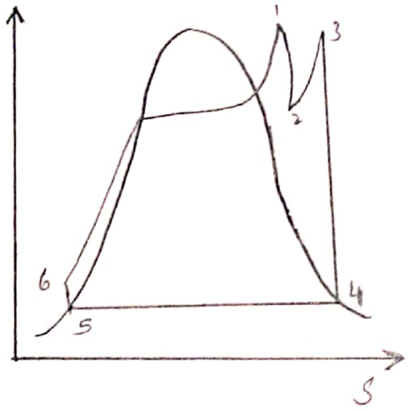
$H_2 = 2780$

$H_3 = 3040$

$H_4 = 2220$

$H_5 = h_f$ at $40°C$

$H_5 = 167.4$



$W_p = V_f (P_1 - P_2) \times 100$

$W_p = 6.39 \; KJ/Kg$

$W_p = h_6 - h_5$

$h_6 = W_p + h_5$

$h_6 = 173.43 \; KJ/Kg$

$W_T = (H_1 - H_2) + (H_3 - H_4)$

$W_T = (3180 - 2780) + (3040 - 2220)$

$W_T = 1220 \; kJ/kg$

$Q_s = H_1 - H_6 = 3180 - 173.43$

$= 3006.57 \; kJ/kg$

$$\eta = \frac{W_T - W_p}{Q_s}$$

$$= \frac{1220 - 6.39}{3006.57}$$

$= 0.4036 \times 100 = 40\%$

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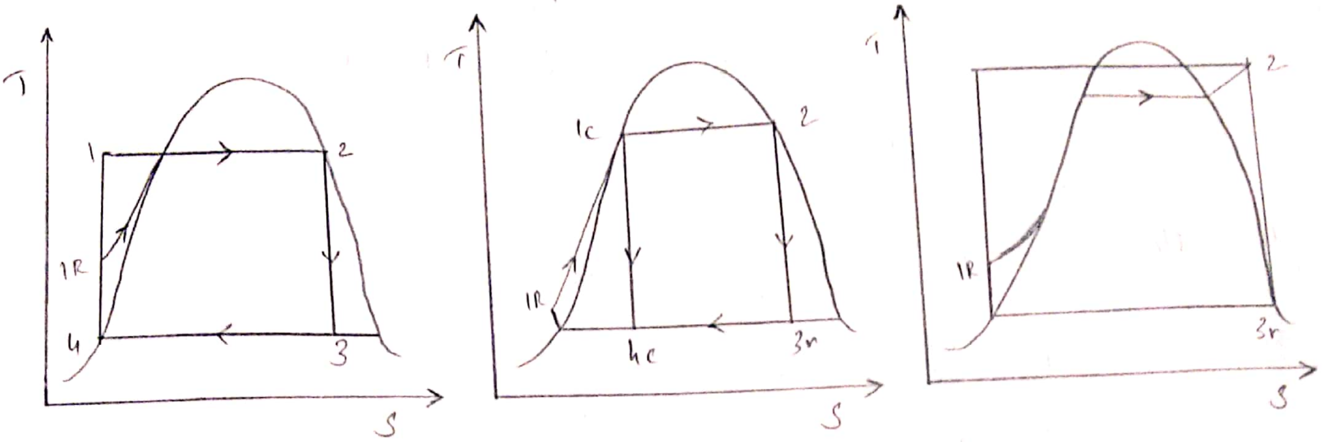
1) c) Rankine and Carnot Cycle



-> In rankine cycle steam undergoes complete condensation

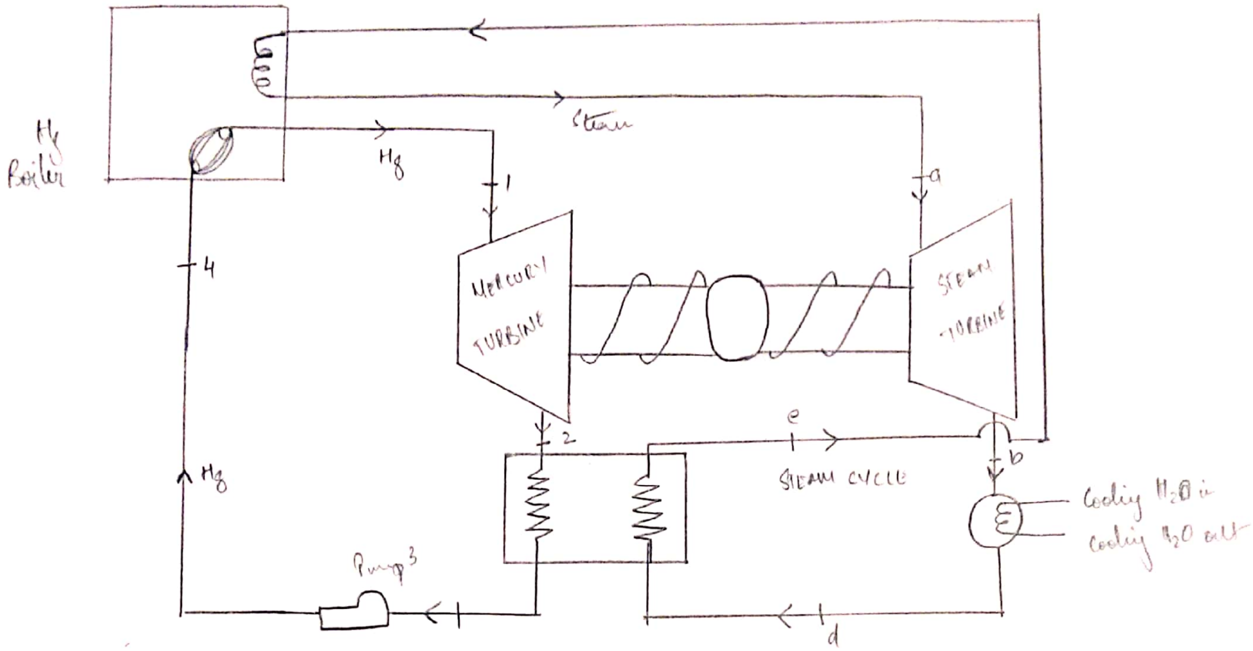
-> In carnot cycle steam undergoes partial condensation.

-> Rankine cycle can be used with any type of steam. where as carnot cycle is used only with wet steam.

-> Carnot cycle gives max. efficiency in practice because of large pump works.

-> Carnot cycle cannot be realized in practice because of large pump work.

2) a) Binary Vapour Cycle :-



The carnot cycle efficiency will increase with an increase in initial supply temperature or with the decrease in exit temperature. It has been already seen that the exit temperature is limited by the length of cooling water. The atmospheric temp when steam is used as working fluid, the rise in temperature is accompanied by rise in pressure. High pressure of the steam creates many difficulties in design, operation an control. It would seem at first sight that, by superheated high steam temperature could be obtained without the necessity of high pressure. It is found that the thermal efficiency of the cycle depends more on the saturation temperature corresponding to supply pressure than on the superheat temperature.

2) b) Psychometric Properties :-

-> Dry Air : The mixture of nitrogen and oxygen neglecting the water vapour and other gases is known as dry air.

-> Moist Air : Mixture of dry air and water vapour is known as moist air / saturated air.

-> Dry Bulb Temperature : The temperature of air is measured by an ordinary thermometer is known as dry bulb temperature.

-> Wet Bulb Temperature : The temperature of air measured by a thermometer where its bulb is covered to the wet cloth and is exposed to the air.

-> Dew Point Temperature : It is the temp at which water vapour mixture present in the air begins to condense when the air is cooled.

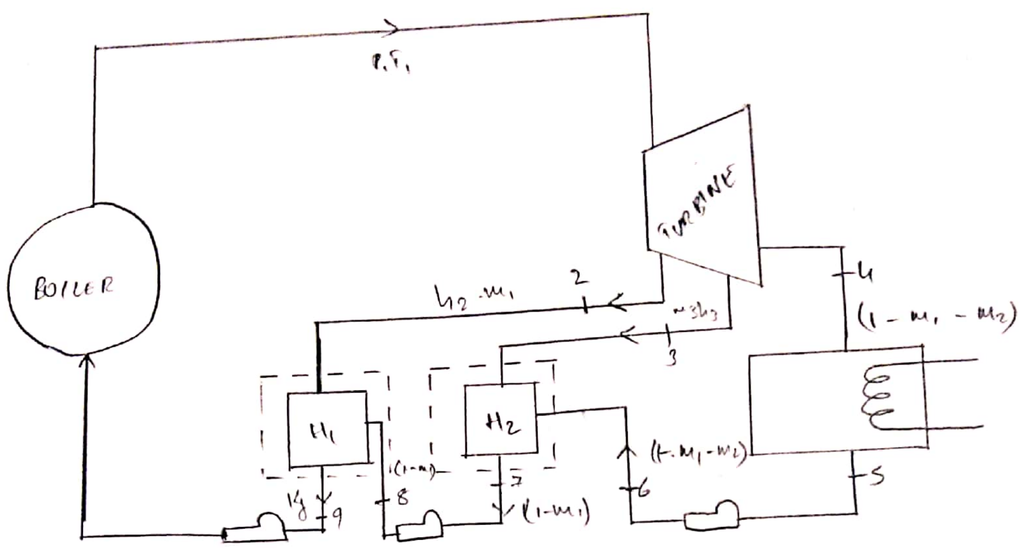
Specific Humidity : It is the mass of water vapour present in 1 Kg of dry air.

→ Absolute Humidity: The mass of water vapour present in the unit volume of dry air is known as absolute humidity.

→ Relative Humidity: It is the ratio of actual mass of water vapour in a given volume of dry air to the mass of water vapour.

→ Degree of saturation: It is defined as the mass of water vapour in unit mass of dry air to the mass of water vapour where air is saturated at same temperature.

2) c) Open Feed Water Heater :-



The feed water enters the boiler at a temperature between 10 or 1, and it is heated by steam extracted from intermediate stages of the turbine.

For every kg of steam entering the turbine, let m_1 kg of steam extracted from an intermediate stage of the turbine where the pressure is P_2 and it is used to heat up feed water ($1-m_1$ kg at state 1) by mixing in heater 1. The remaining $1-m_1$ kg of steam expands in the turbine from pressure P_2 (state 2) to pressure P_3 (state 3). When m_2 kg of steam is extracted for heating feed water in heater 2.

→ Cycle Efficiency $\eta_F = \frac{Q_S - Q_R}{Q_S} = \frac{W_T - W_P}{W_T}$

3) ii) Ideal Regeneration ...

→ Steam flow rate $S.F.R. = \frac{3600}{W_T - W_P}$ Kg/KW.h

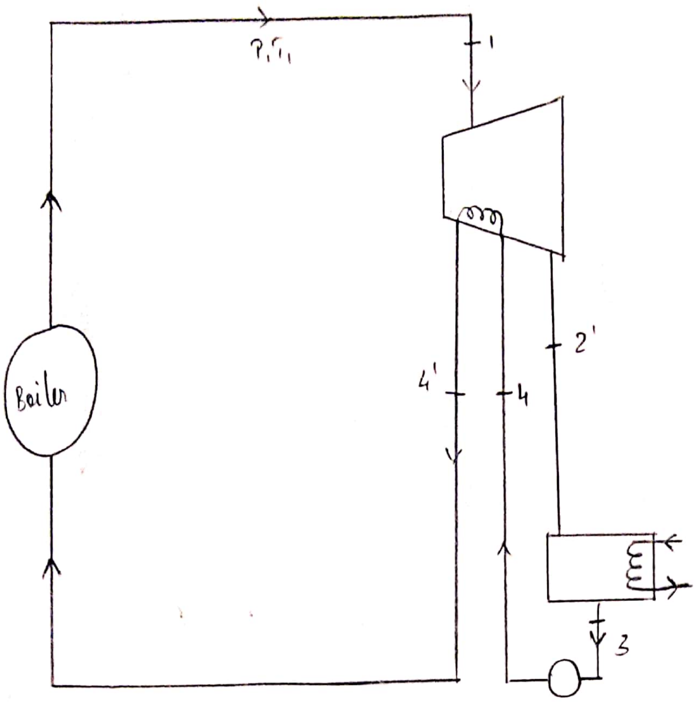
→ Energy Balance for heater 1

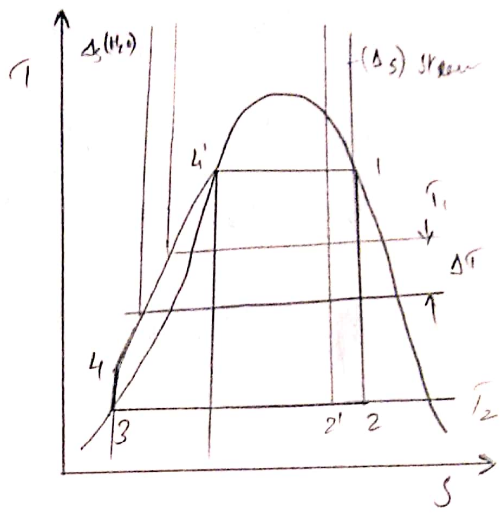
$$m_1 = \frac{h_9 - h_8}{h_2 - h_8}$$

→ Energy Balance for heater 2

$$m_2 = \frac{(h_7 - h_6)(1 - m_1)}{(h_3 - h_6)}$$

3) a) Ideal Regenerative Cycle :-





-> For maximum efficiency all heat should be supplied at T_1 and feed water should enter the boiler at ~~state~~ 4'.

-> This may be accomplished in what is known as ideal regenerative cycle.

-> The feature of the ideal ~~regen~~ regenerative cycle is that the condensate after leaving the pump circulates around the turbine casing in counter flow to the direction.

-> Δs of water is $\Delta s\,(H_2O) = -\Delta s$ (steam). Then the slopes of line (1-2') & (4'3) will be identical at every temperature and lines will be identical in contour.

-> The areas 4-4'-b-a-4 & 2'-1-d-c-2'' are equal. Therefore all the heat added from an external source is at constant Temperature T_1 ~~and~~ all heat rejected is at constant temperature.

$$Q_S = h_1 - h_4' \ , \quad Q_R = h_2' - h_3$$

$$\therefore \eta_R = \frac{Q_S - Q_R}{Q_S}$$

$$Q_S = h_1 - h_4' = T_1 (S_1 - S_4)$$

$$Q_R = h_2' - h_3 = T_2 (S_2' - S_3)$$

$$\eta_R = \frac{Q_S - Q_R}{Q_S} = \frac{T_1 (S_1 - S_4') - T_2 (S_2 - S_3')}{T_1 (S_1 - S_4')}$$

b) <u>Limitations of Carnot Cycle</u> :-

-> Carnot cycle is the most efficient one but it is not practically possible.

-> Isothermal heat addition in boiler takes place only in wet region, but super heating of steam cannot be taken inside the boiler as it produces steam

-> During isothermal condensation process the condensation is stopped

-> The higher power requirement for compression reduces the plant efficiency.

-> The plant size for the specified power output is large as the specific steam consumption is higher.

c) GIVEN DATA :-

$P_1 = 25$ bar

$P_2 = 0.2$ bar

$x = 80\%$

$T_{sup} = 76.18°C$

$H_1 = 2640$

$H_2 = 2180$

$t_s = 60.09°C$

$V_f = 0.0010172 \ m^3/Kg$

$h_f = 251.5 \ KJ/Kg$

$H_3 = h_f = 251.5 \ KJ/Kg$

$W_p = V_f (P_1 - P_2) \times 100$

$= 0.0010172 (25 - 0.2) \times 100$

$= 2.52$

$H_4 = W_p + H_3$

$= 2.52 + 25.5$

$= 254.02$

$Q_S = (H_1 - H_4)$

$= (2640 - 254.02)$

$= 2385.98 \ KJ/Kg$

$W_T = (H_1 - H_2)$

$= 2640 - 2180$

$= 460 \ KJ/Kg$

$W_{net} = W_T - W_p$

$= 460 - 2.52$

$= 457.48 \ KJ/Kg$

$$\eta_R = \frac{W_{net}}{Q_S} = \frac{457.48}{2385.78} \times 100 = 19.17\%$$