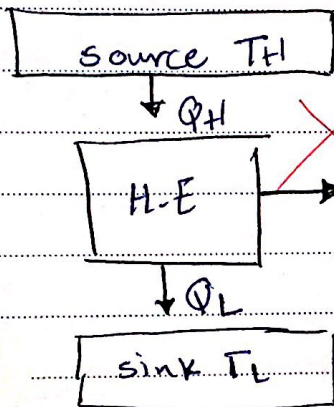


Lecture (1)

ch 10 Vapor Power Cycles

- obj: to develop / Produce Power.
- It follows H.E concept.
- It is supposed to follow kelvin - plank statement.
- work medium $\rightarrow$ liquid, phase change.

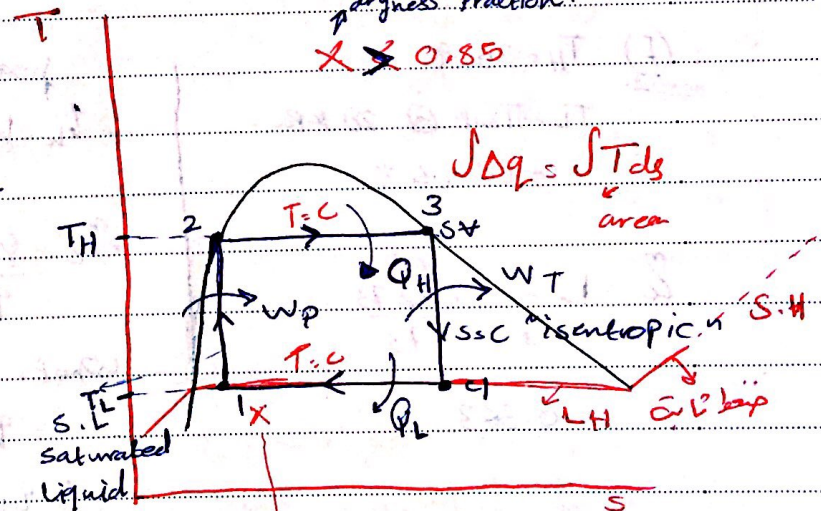
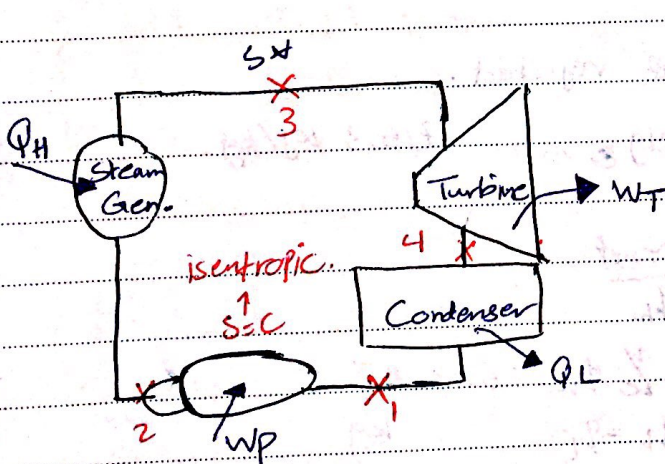


$$W_{net} = Q_H - Q_L$$

$$\eta_{th} = \frac{W_{net}}{Q_H} = \frac{Q_H - Q_L}{Q_H} = 1 - \frac{Q_L}{Q_H} = 1 - \frac{T_L}{T_H}$$

Thermodynamics

* Carnot V.P.C "Vapor power cycle" :



$$Q_H = m T_H (s_3 - s_2) = m (h_3 - h_2) = m h_{fg, 2-3}$$

$$Q_L = m T_L (s_4 - s_1) = m (h_4 - h_1) = m h_{fg, 4-1}$$

dryness fraction. $X \geq 0.85$

wet mix. Pump can't handle 2 Phases.

$$\eta_{\text{carnot}} = \frac{1 - \frac{T_L}{T_H}}{1 - \frac{T_L}{T_H}}$$



$$\eta_c = 1 - \frac{T_L}{T_H}$$

$$w_T = m(h_3 - h_4)$$

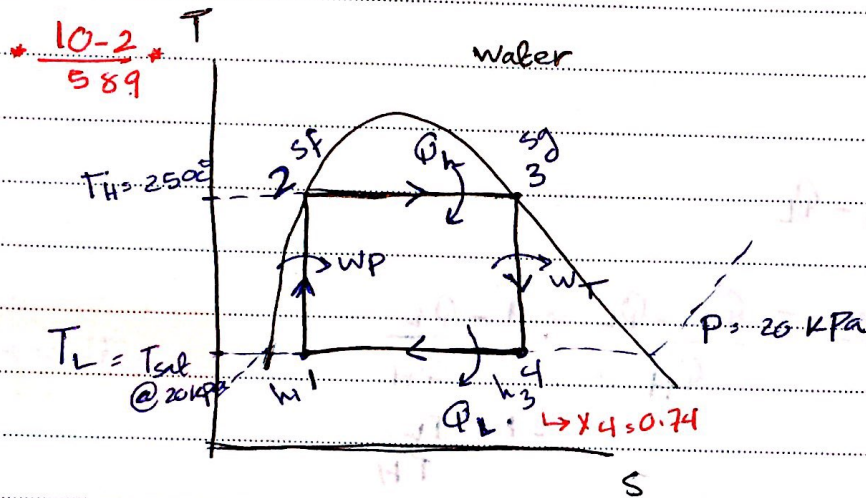
$$w_P = m(h_2 - h_1)$$

∴ Cycle لا الميكانيكي

2 phases 1 - 2

3 - 4

α Isothermal - 3



Solu :-

(I) $T_H = 250^\circ\text{C}$

$T_L = T_{\text{sat}} @ 20 \text{ kPa}$
 $= 60.06^\circ\text{C}$

$\eta_c = 1 - \frac{60.06 + 273}{250 + 273}$
 $= 0.363$

heat rejected.

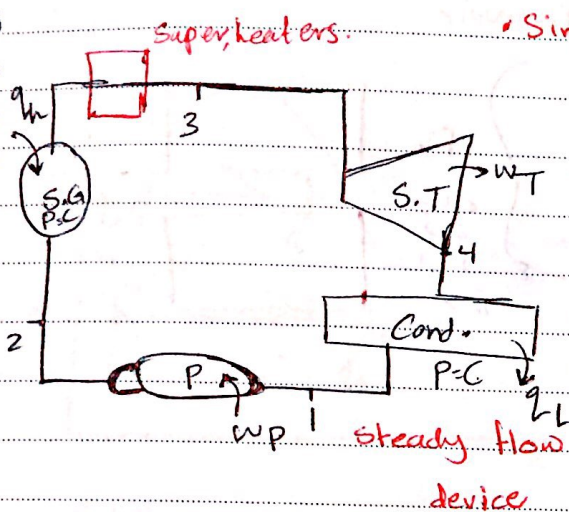
$q_h = h_{fg} @ 250^\circ = 1715.3 \text{ kJ/kg}$

$\eta_c = \frac{w_{\text{net}}}{q_h}$

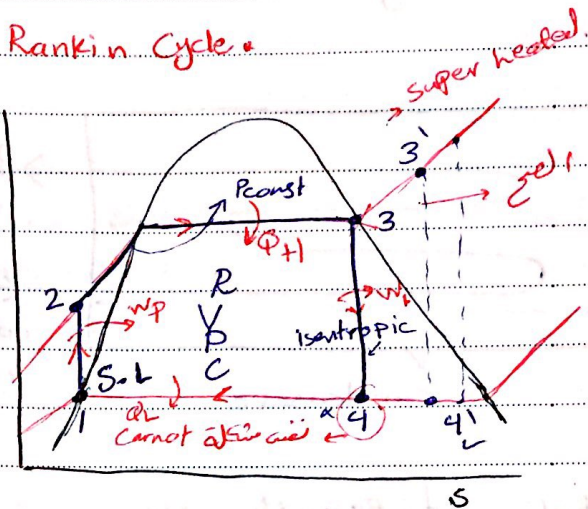
$w_{\text{net}} = \eta_c q_h = 623 \text{ kJ/kg}$
 $= q_h - q_L$

$\therefore q_L = 1092.3 \text{ kJ/kg}$

* Rankine VPC.



* Simple Ideal Rankin Cycle.



super = 3 h₁ h₂
heated

saturated vapor
vapor

جول = turbine لا قبله

* S. Gen steam generator

water-tube fire-tube

الكل لا يأتى
والفان حوله

$$\star (q_{in} - q_{out}) + (w_{out} - w_{in}) = (h_o - h_i) + \frac{1}{2}(V_o^2 - V_i^2) + g(z_o - z_i)$$

for S.G.:

التي لا تاتي
التي لا تاتي

$$q_{in} - q_{out} = h_o - h_i$$

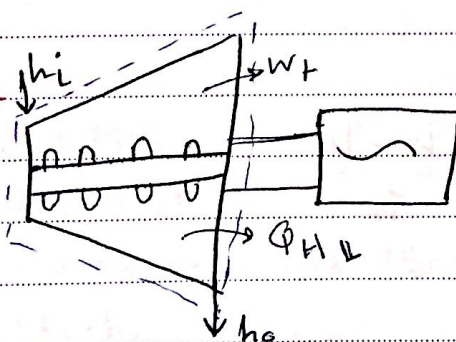
value

$$\dot{Q}_H = \dot{m} (h_o - h_i)$$



* S. turbine

Enthalpy
at high
pressure



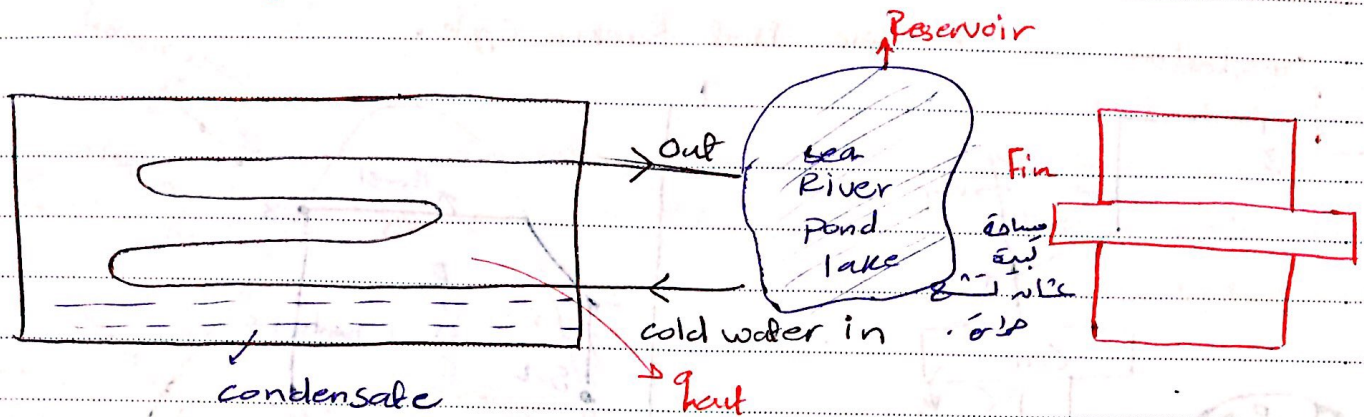
$$-q_{out} + w_{out} = h_o - h_i$$

$$w_{out} = (h_i - h_o) - q_{out}$$

adiabatic turbine

$$q_{out} = 0$$

* Heat Exchanger:-

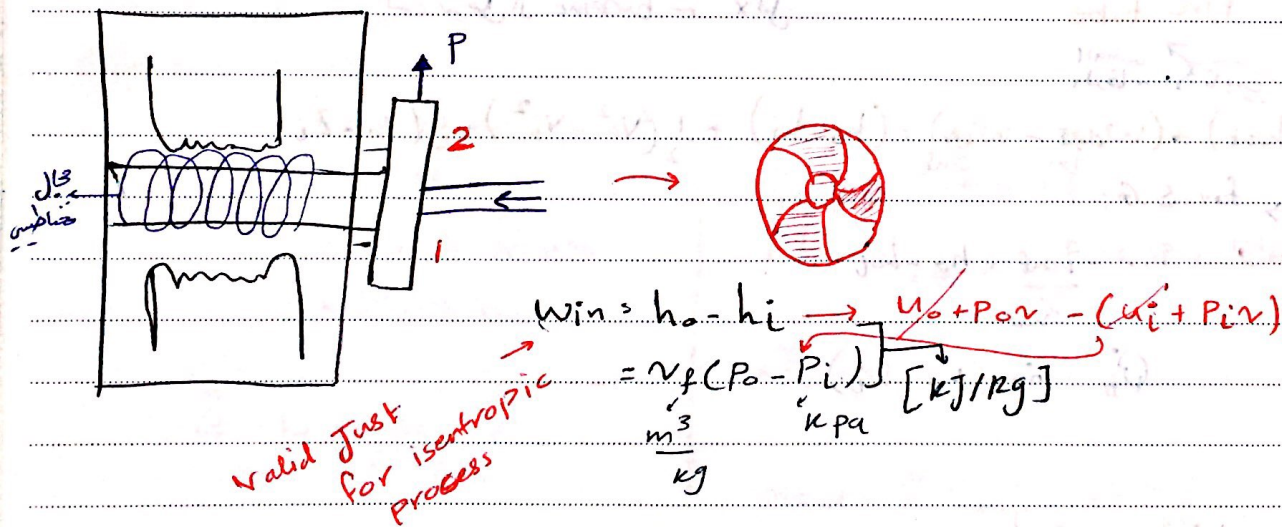


→ Reduction of Elevation:-

$$-q_{out} = h_o - h_i$$

$$q_{out} = h_i - h_o$$

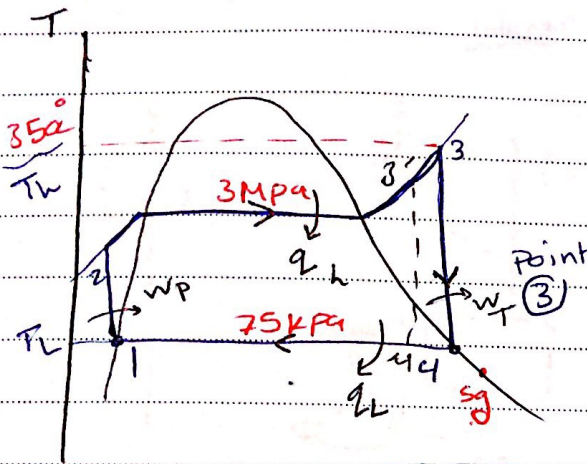
* Water Pump:-



$$\eta_{th} = \frac{w_{net}}{q_{in}} = \frac{w_T - w_P}{q_{in}} = \frac{q_{in} - q_L}{q_{in}}$$

Example :- (1)

$$\begin{matrix} S_2 = S_1 \\ S_3 = S_4 \end{matrix}$$



since $T_3 > T_{sat} @ 3 \text{ MPa}$
 $\therefore$ sup. heated.

$$\begin{matrix} T_3 & \} & h_3 = - \\ P_3 & \} & s_3 = - \end{matrix}$$

Point ②

$$h_2 = h_1 + v_{f,1} (P_2 - P_1)$$

$$h_f, v_f, s_f, s_{fg}, h_{fg}$$

Point ④

sg & sg

sg ? sg

if it's $s_4 > s_g \rightarrow$ super heated $\rightarrow$ tables

if it's $s_4 = s_g \rightarrow$ sat. vapor $\rightarrow h_4 = h_g$

$s_4 < s_g \rightarrow$ mix.

If it's mix. ?

$$s_4 = s_{f,1} + x_4 s_{fg,1}$$

$$h_4 = h_{f,1} + x_4 h_{fg,1}$$

* solution :-

Point 1 :-

$P = 75 \text{ kPa}$, sat. liq.

$$h_1 = h_f = 384.44 \quad s_{f,1} = 1.21332$$

$$h_{fg} = 2278 \quad s_{fg} = 6.2426$$

$$v_{f,1} = 0.001037 \quad s_g = 7.4558$$

$$T_1 = T_{sat} = 91.76^\circ\text{C}$$

Point 2 :-

$$s_2 = s_1, P_2 = 3 \text{ MPa}$$

$$WP = h_2 - h_1 = v_{f,1} (P_2 - P_1)$$

isentropic

$$WP = 0.001037 (3000 - 75) = 3.03 \text{ kJ/kg}$$

$$s_{h_2 - h_1}$$

$$\therefore h_2 = h_1 + WP = 384.44 + 3.03 = 387.47 \text{ kJ/kg}$$

Point 3:

$$P_3 = 3 \text{ MPa}, T_3 = 350^\circ\text{C}$$

$$T_{\text{sat}} @ 3 \text{ MPa} = 233.85^\circ\text{C}$$

Since $T_3 > T_{\text{sat}} @ P_3$: superheat.

$$h_3 = 3116.1, s_3 = 6.745$$

$$\therefore q_L = h_3 - h_2 = 2728.6 \text{ kJ/kg}$$

Point 4:

$$P_4 = 75 \text{ kPa}, s_4 = 6.745$$

Since $s_4 < s_g$: wet mix

$$\therefore x_4 = 0.8861$$

$$h_4 = h_f + x_4 h_{fg} = 2403.03 \text{ kJ/kg}$$

$$w_T = h_3 - h_4 = 713.07 \text{ kJ/kg}$$

$$q_L = h_4 - h_1 = 2018.6$$

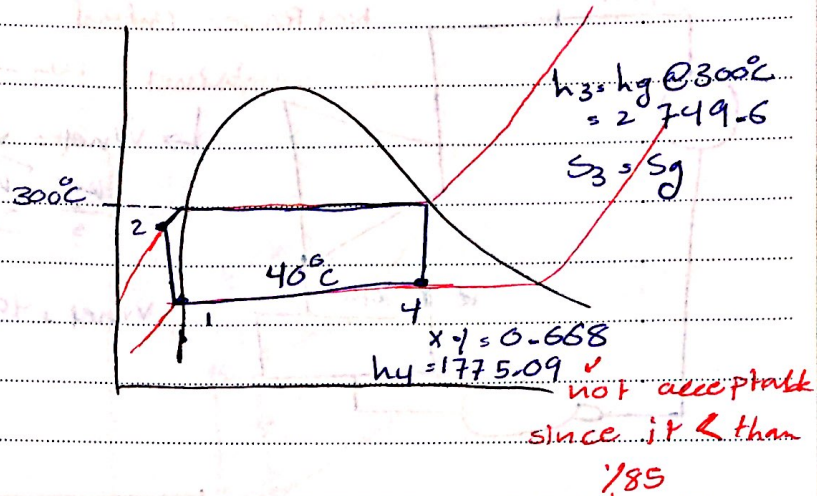
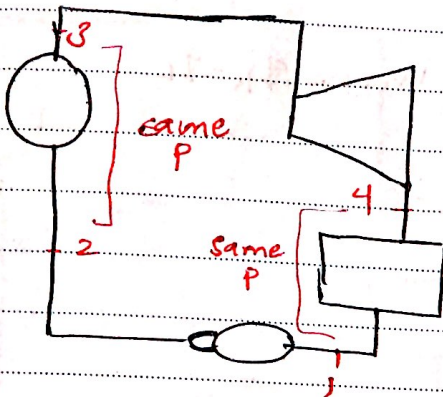
$$\eta_{th} = \frac{w_T - w_P}{q_L} \rightarrow w_{net}$$

$$= 1 - \frac{q_L}{q_H}$$

$$= 26\%$$

$$\eta_{Carnot} = 1 - \frac{91.67 + 273}{350 + 273} = 41.4\%$$

Water



Solu:-

Point 1:-

At 40°C, h_f, s_f, h_{fg}, s_{fg}
 v_f, s_g, P_1

←

$$P_1 = 7.3851$$

$$h_f = 167.53$$

$$v_f = 0.001008$$

$$w_T = 971.86$$

$$w_P = 8.65 \text{ kJ/kg}$$

$$q_h = 2682.42 = h_3 - h_2$$

$$q_L = 1667.2 = h_4 - h_1$$

$$\eta_{th} = 0.375$$

$$\eta_{Carnot} = 1 - \frac{40 + 273}{300 + 273} \left[1 - \frac{T_L}{T_H} \right] \text{ just for Carnot cycle.}$$

$$= 0.45$$

Point 2:-

$$P_3 = P_{sat} @ 300^\circ\text{C} \quad \text{Point 3}$$

$$= 8587.9 \text{ kPa}$$

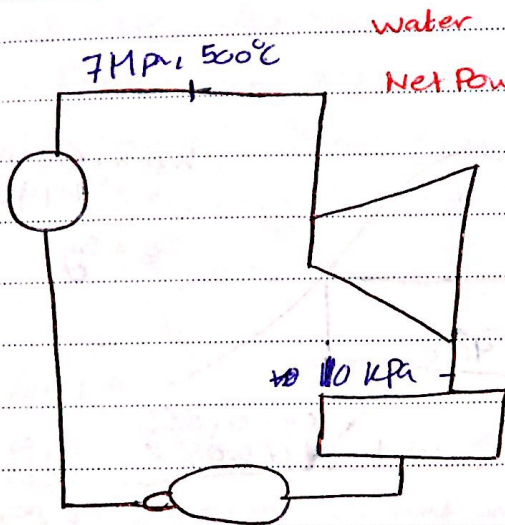
$$P_2 = P_3, s_2 = s_1$$

$$w_P = v_f (P_2 - P_1)$$

$$= h_2 - h_1$$

$$\therefore h_2 = 167.18 \text{ kJ/kg}$$

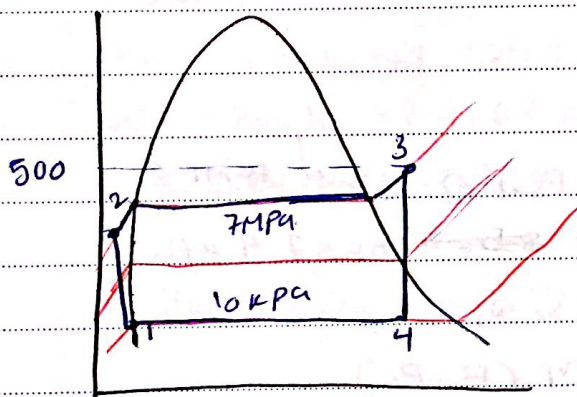
10.18



$$W_{net} = W_T - W_P \quad \text{or} \quad W_{net} = \dot{m} (h_1 - h_2)$$

$$\rightarrow \dot{W}_{net} = \dot{m} \frac{kJ}{kg} = \frac{kg}{s} \frac{kJ}{kg} = \frac{kJ}{s}$$

$$\dot{W}_{net} = 45 \text{ MW}$$



$$h_1 = 141.81$$

$$h_2 = 198.87$$

$$h_3 = 3411.4$$

$$h_4 = 2153.691$$

$$x_4 = 0.8201 \rightarrow \text{Not Practical.}$$

$$x < 0.85$$

$$W_T = h_3 - h_4 = 1257.708 \quad W_P = 7.06 \quad W_{net} = 1250.648 \text{ kJ/kg}$$

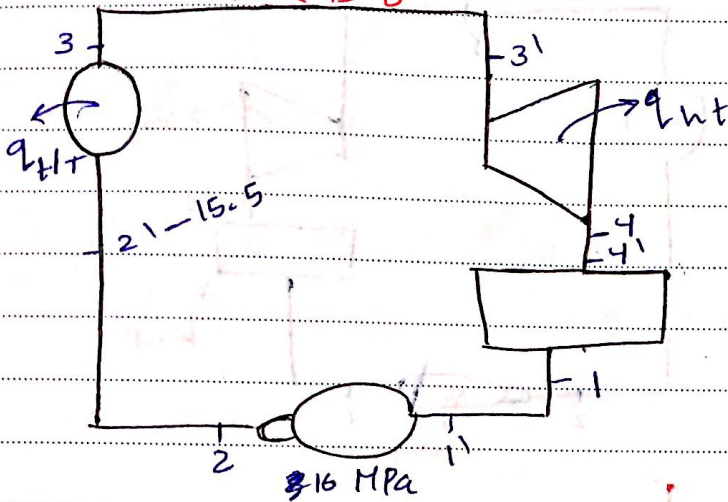
$$\rightarrow \dot{m}_s = \frac{45 \times 10^3}{1250.648} = 36 \text{ kg/s}$$

$$Q = m C_p \Delta T$$

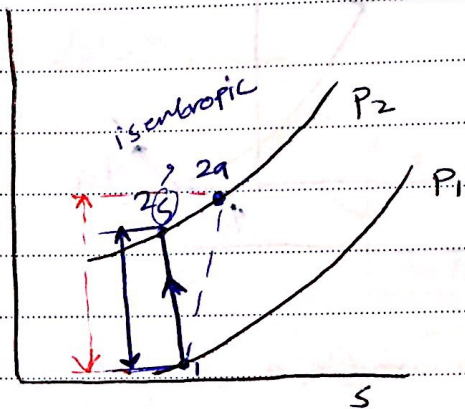
$$\dot{m}_s q_L = \dot{m}_{cw} \times 4.186 \times \Delta T \rightarrow 8.48^\circ\text{C}$$

* Actual Rankin Cycle: → Heat Transfer

$P_3' < P_3$
 $T_3' < T_3$ } $h_3' < h_3$ → Fluid friction } types of loss



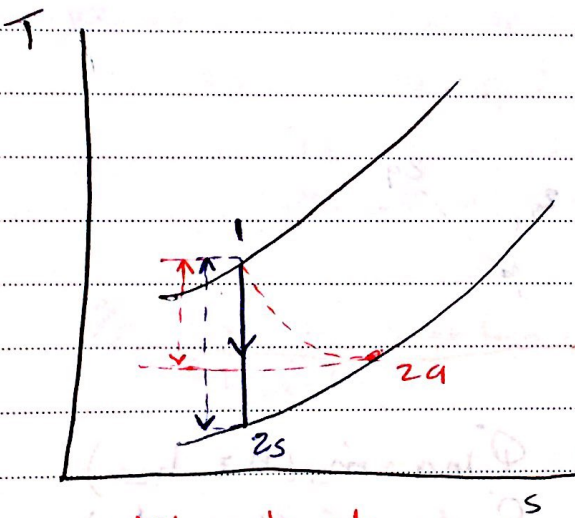
Isentropic ?



$$W_{Ps} = h_{2s} - h_1$$

$$W_{Pa} = h_{2a} - h_1$$

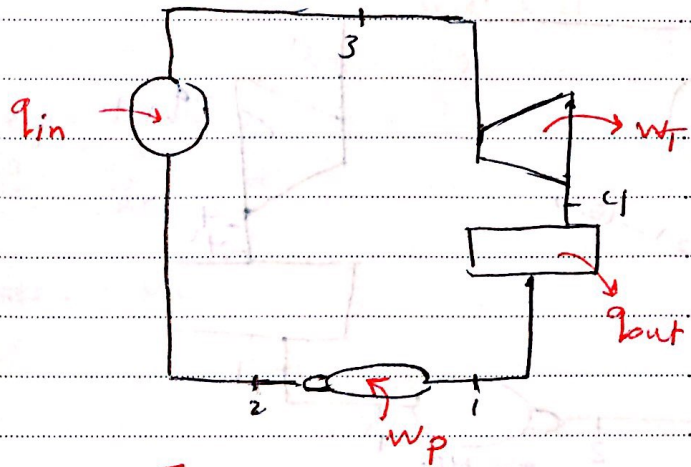
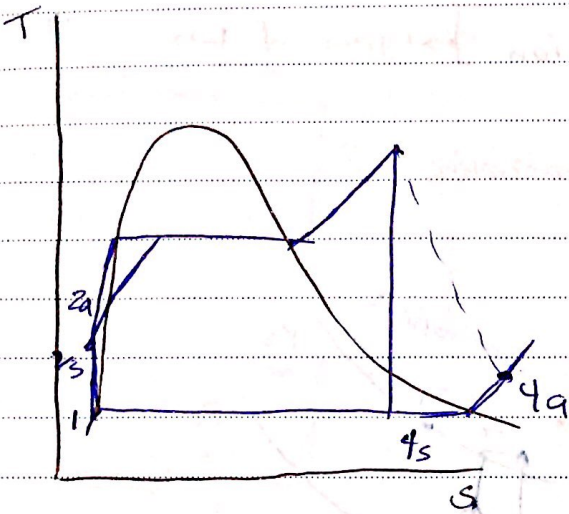
$$\eta_{Ps} = \frac{W_{Ps}}{W_{Pa}}$$



$$W_{Ts} = h_1 - h_{2s}$$

$$W_{Ta} = h_1 - h_{2a}$$

$$\eta_{Ts} = \frac{W_{Ta}}{W_{Ts}}$$



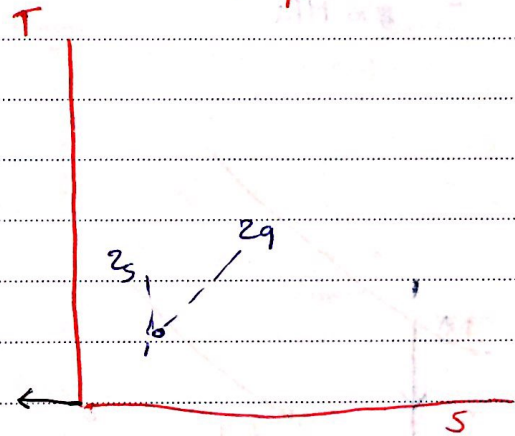
$$\dot{w}_p = \dot{m}_s (h_{2a} - h_1)$$

$$h_{2s} = h_1 + v_{f1} (P_2 - P_1)$$

Just
for
isentropic

$$\eta_{ps} = \frac{h_{2s} - h_1}{h_{2a} - h_1}, \quad h_{2a} > h_{2s}$$

$$\frac{h_{2a} - h_{2s} - h_1 + h_1}{\eta_{ps}}$$

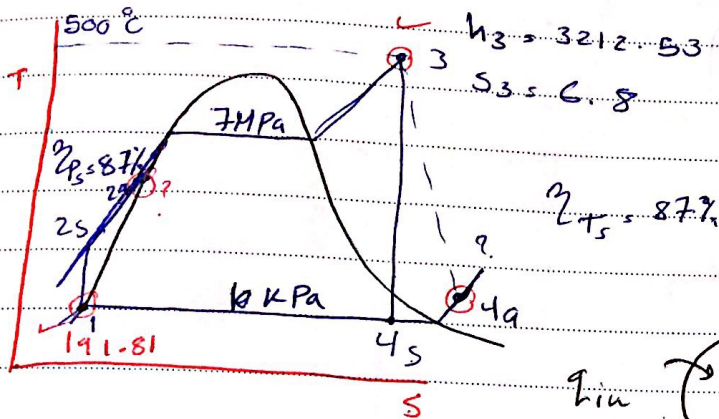


$$\dot{Q}_{in} = \dot{m}_s (h_3 - h_{2a})$$

$$\dot{Q}_{out} = \dot{m}_s (h_{4a} - h_1)$$

$$\dot{w}_{Ta} = \dot{m}_s (h_3 - h_{4a})$$

10.19 / 10.18. ج 5

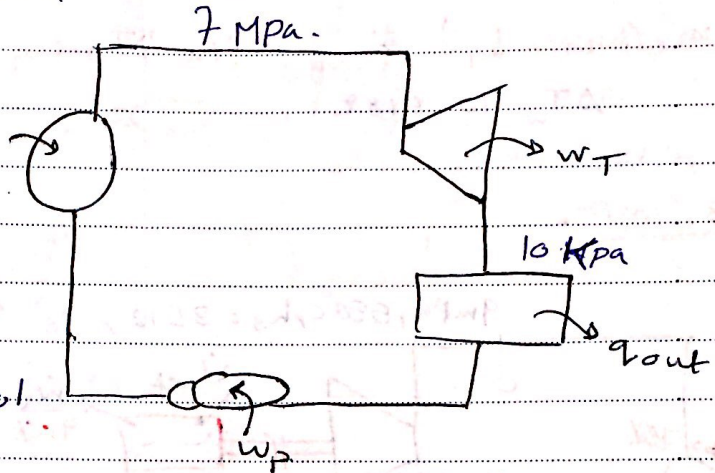


تفاوت بین Ideal و Actual

کلیتاً به هم می افتد Ideal

تفاوتی با سوال تفاوت در turbine

Actual و Ideal or Pump



1) Pump: $h_1 = 191.81$, $v_f = 0.00101$
 $h_{2s} = h_1 + v_f (P_2 - P_1)$
 $= 191.81 + 0.00101 (7005 - 10)$
 $= 198.87 \text{ kJ/kg}$

$\eta_{ps} = \frac{h_{2s} - h_1}{h_{2a} - h_1} \Rightarrow h_{2a} = \frac{198.87 - 191.81}{0.87} + 191.81$
 $= 199.925$

$W_{Pa} = h_{2a} - h_1 = 8.115 \text{ kJ/kg}$

$q_{in} = h_3 - h_{2a} = 3211.475$

$h_{4s} = 2153.691$, $x_{4s} = 0.8201$

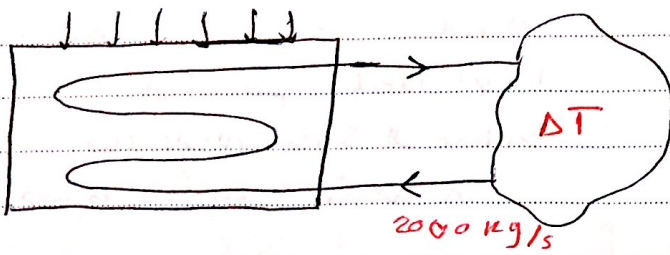
$\eta_{th} = \frac{w_{net}}{q_{in}}$

$\eta_{Ts} = \frac{h_3 - h_{4a}}{h_3 - h_{4s}} \Rightarrow h_{4a} = \frac{3212.53 - 2153.69}{0.87} + 2153.69$
 $= 2317.193 \text{ kJ/kg}$

$w_{Ta} = h_3 - h_{4a} = 1094.206$

$w_{net} = w_{Ta} - w_{Pa} = 1086.091$

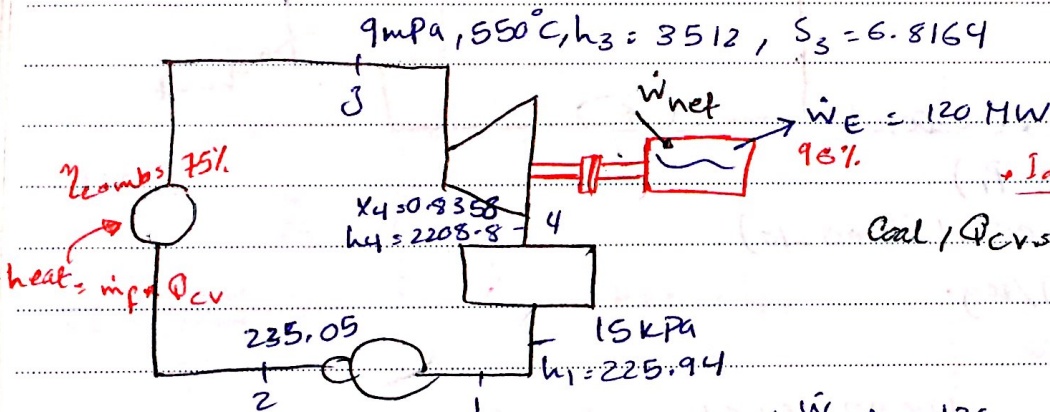
$\therefore \dot{m} = \frac{45000}{1086.091} = 41.4 \text{ kg/s}$



$$\dot{m}_s (h_{4a} - h_1) = \dot{m}_{cooling} * c_{p,w} \Delta T_{cooling}$$

$$\Delta T_w = 10 - 518^\circ\text{C}$$

10.23 / impo.



* Ideal كفاءة بالموال معيها

$$Coal / Q_{cv} = 29300 \text{ kJ/kg}$$

$$\dot{W}_{net} = \frac{120}{0.96} = 125 \text{ MW}$$

Assuming 75% — to the steam.

↓ impo. sent.
electric generator has —

$$\dot{W}_{comb} * \dot{m}_{fuel} * Q_{cv} = \dot{m}_s (h_3 - h_2)$$

$$\dot{W}_{net} = \dot{m}_s [(h_3 - h_4) - (h_2 - h_1)]$$

$$\therefore \dot{m}_s = 96.6 \text{ kg/s}$$

$$\dot{m}_{fuel} = 14.405 \text{ kg/s}$$

$$\eta_{overall} = \eta_{th} \eta_{gen} \eta_{comb}$$

ques 26 مع الكا نيوال الكالم منظم الـ

29/25/26]

/ /

* another soln. &

التي ان في كذا ان صلا على اس

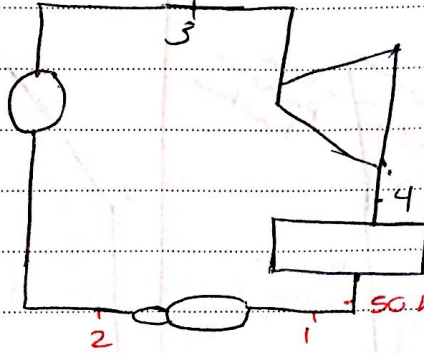
- Heat

$$Q_{in} = W_{net}$$

طريقة المثل

12.20

6 MPa, 450°C



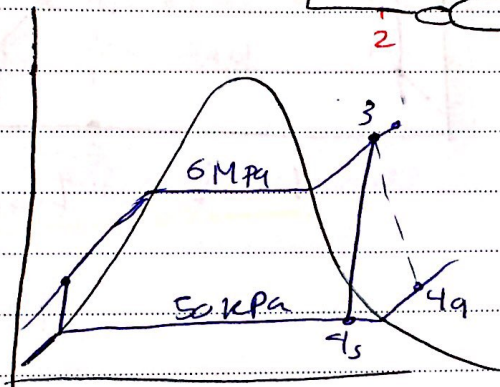
Subcooled by 6.3

$$T_1 = 81.3 - 6.3$$

$$= 75^\circ\text{C}$$

$$h_1 = h_f @ 75^\circ\text{C}$$

$T_{sat} = 81.3^\circ\text{C}$



Manual Ques. 23

The water leaving the condenser (1)

--- 6.3°C

* How to improve η_{th} ?

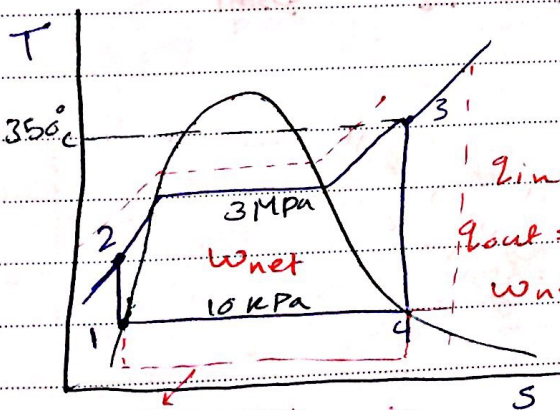
التي ان في كذا ان صلا على اس

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}}$$

Fuel

التي ان في كذا ان صلا على اس

التي ان في كذا ان صلا على اس



q_{in} is area under 3-2

q_{out} is area under 4-1

$$W_{net} = q_{in} - q_{out}$$

3-concept.

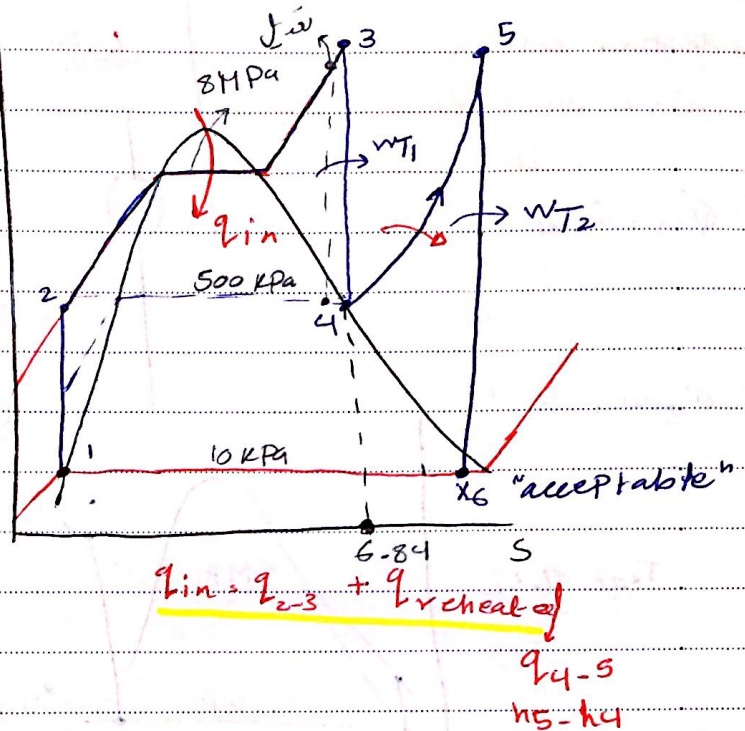
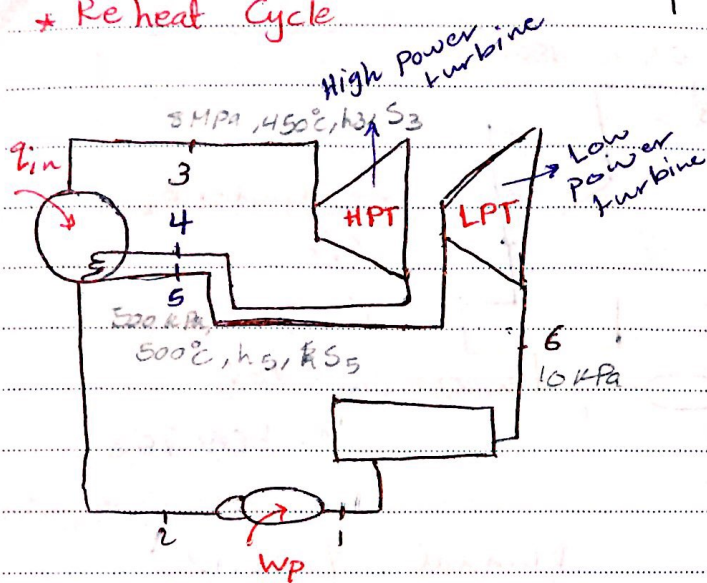
$$\eta_{th} = \frac{W_{net}}{q_{in}}$$

$$\eta_{th} = \frac{W_T - W_P}{q_{in}}$$

$$\eta_{th} = \frac{W_{net}}{q_{in}}$$

$$\eta_{th} = \frac{q_{in} - q_{out}}{q_{in}}$$

* Reheat Cycle



10-30

Point ① $h_1 = h_f @ 10 \text{ kPa} = 191.81$
 $v_f = 0.00101 \text{ m}^3/\text{kg}$

Point ② $s_2 = s_1$, $h_2 = h_1 + v_f (P_2 - P_1) = 199.88 \rightarrow$ Ideal
 Ideal compression process
 $P_2 = 5 \text{ MPa}$

Point ③ $h_3 = 3273.3$, $s_3 = 6.5579$
 $q_{2-3} = h_3 - h_2 = 3073.42 \text{ kJ/kg}$

Point ④ $s_4 = s_3 = 6.5579$ (wet mix)
 $x_4 = 0.947$, $h_4 = 2636.4$

طريقة 4 نفس
 Ideal compression
 ليس 0 - T

Point ⑤ $h_5 = 3454.5$
 $s_5 = 8.0893$

Point ⑥ $s_6 = s_5$ at 10 kPa, $s_6 = 8.1501$

$$x_6 = 0.9921$$

$$h_6 = 2564.9$$

$$\left. \begin{array}{l} q_{in total} = 3921.5 \\ q_{out} = 2373.1 \end{array} \right\} \eta_{th} = 0.395$$

$$w_{BP} = \frac{w_P}{w_T} = 0.00518$$

$$\dot{W}_{net} = 5000 \text{ kW}$$

$$= \dot{m}_s [(h_3 - h_4) + (h_5 - h_6) + (h_2 - h_1)]$$

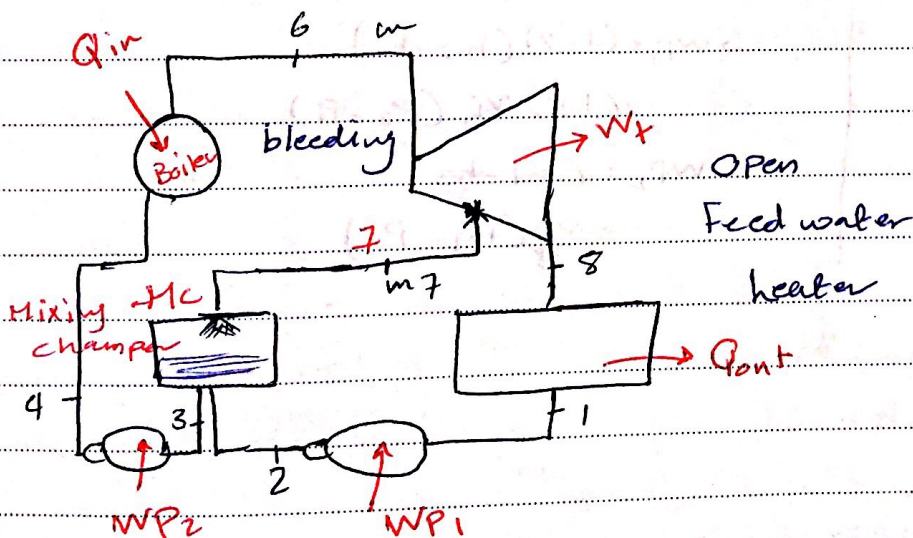
$$\therefore \dot{m}_s = 3.23 \text{ kg/s}$$

$$\eta_{Carnot} = 1 - \frac{45.81 + 273}{520 + 273} = 0.587$$

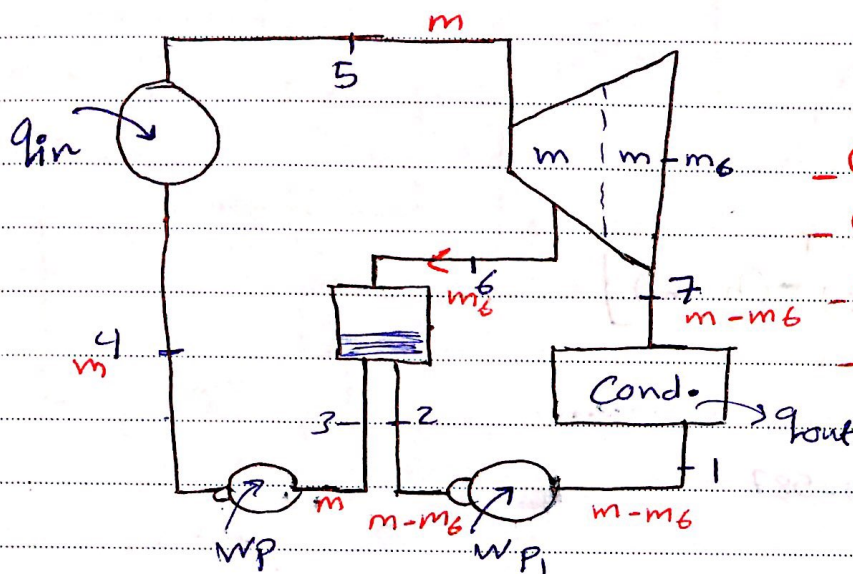
* Regeneration process :

Heating feed water before it enters the S-G

steam generator



open
* FWH (Regeneration)
feed water heater



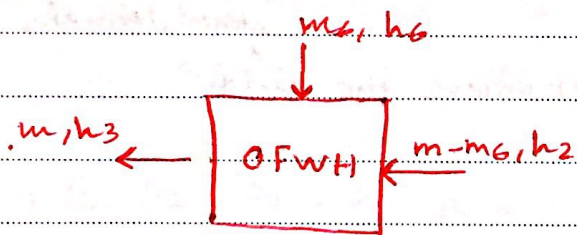
$$- Q_{in} = m(h_5 - h_4)$$

$$- Q_{out} = (m - m_6)(h_7 - h_1)$$

$$- W_T = m(h_5 - h_6) + (m - m_6)(h_6 - h_7)$$

$$- W_{P1} = (m - m_6)(h_2 - h_1) \\ = (m - m_6) v_{f1} (P_2 - P_1) \rightarrow s_2 = s_1$$

$$- W_{P2} = m(h_4 - h_3) \\ = m v_{f3} (P_4 - P_3) \rightarrow s_3 = s_4$$



$$(m - m_6)h_2 + m_6 h_6 = m h_3$$

Divide all by m

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

$$Y(h_6 - h_2) = h_3 - h_2$$

$$\therefore Y = \frac{h_3 - h_2}{h_6 - h_2}$$

* mass fraction $Y = \frac{m_6}{m}$

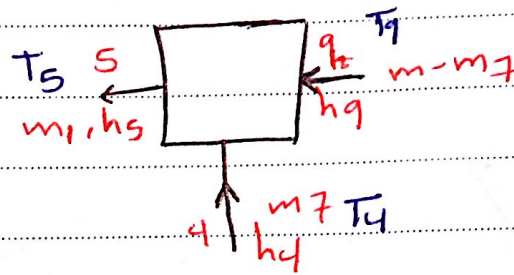
$$\rightarrow q_{in} = (h_5 - h_4)$$

$$\rightarrow q_{out} = (1 - Y)(h_7 - h_1)$$

$$\rightarrow W_T = (h_5 - h_6) + (1 - Y)(h_6 - h_7)$$

$$\rightarrow W_{P1} = (1 - Y)(h_2 - h_1) \\ = (1 - Y) v_{f1} (P_2 - P_1)$$

$$\rightarrow W_{P2} = (h_4 - h_3) \\ = v_{f3} (P_4 - P_3)$$

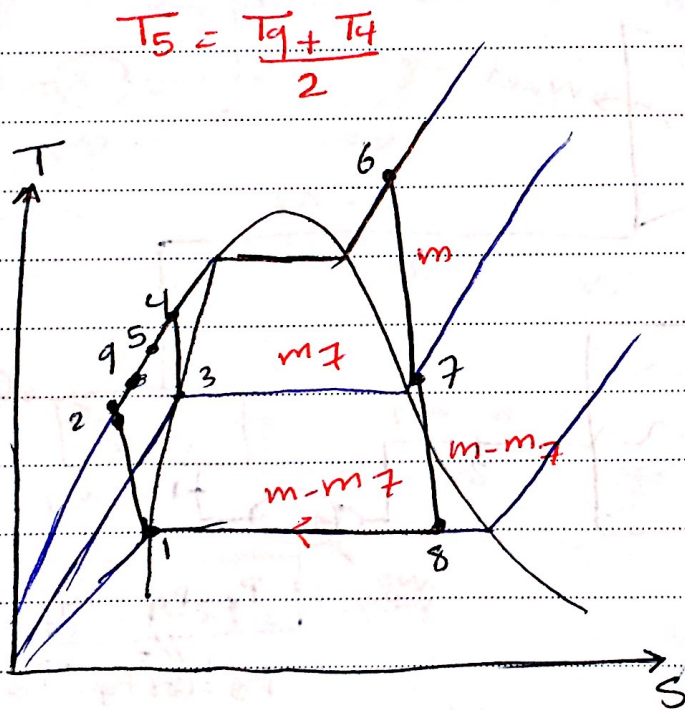


$$(m-m_7)h_9 + m_7h_4 = m h_5$$

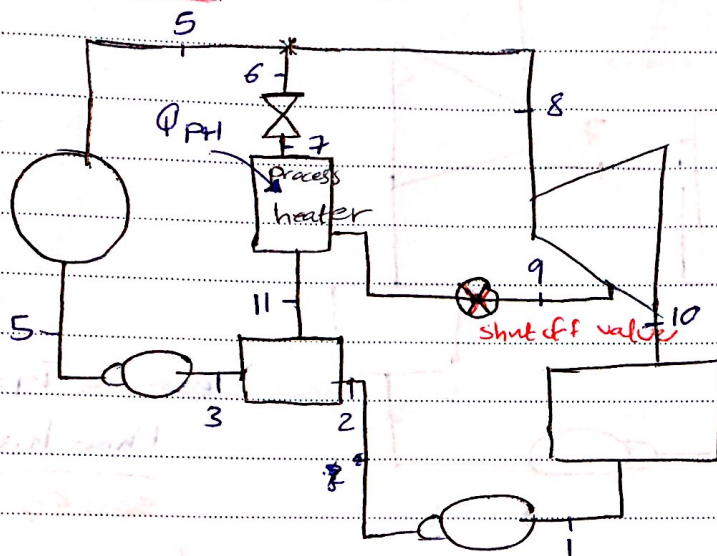
$$\rightarrow (1-y)h_9 + y h_4 = h_5 \quad \text{--- (2)}$$

$$T_3 = T_9 \quad \text{ideally}$$

مردود 3 و 9 مساوی است
 $h_9 = h_3$ زیرا



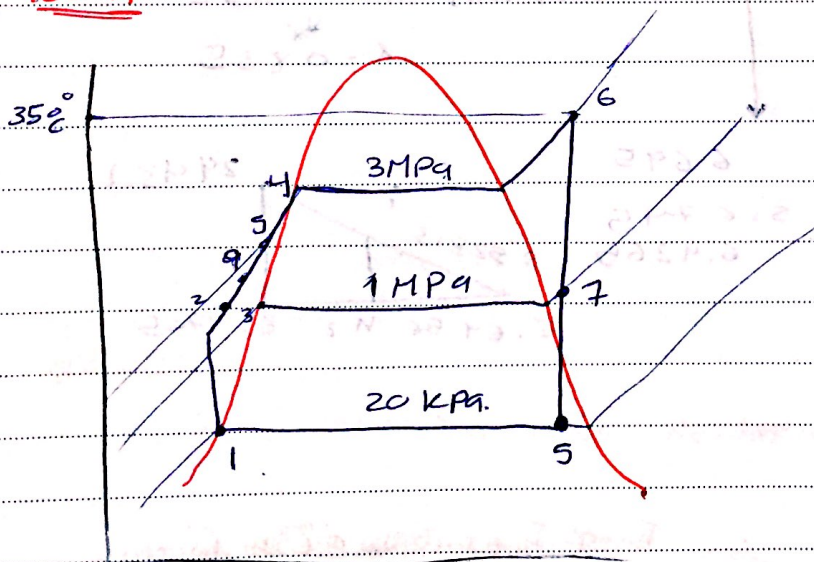
* Cogeneration



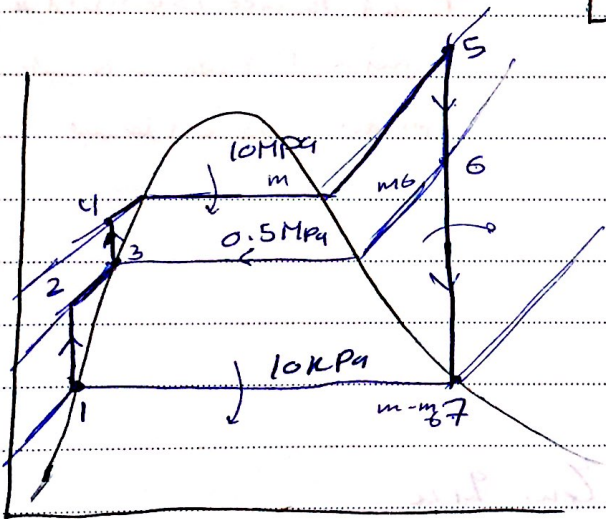
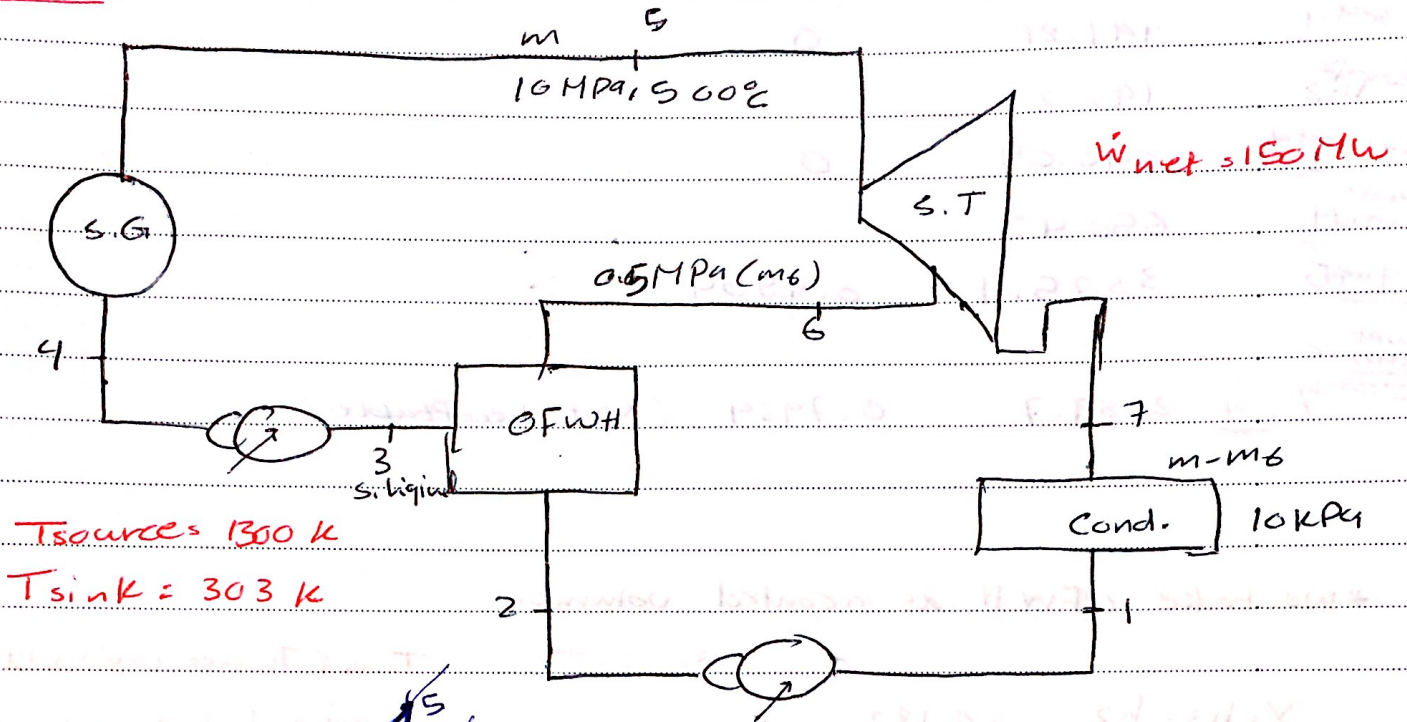
$$\text{utilization factor} = \frac{Q_{PH} + W_T}{Q_{in}}$$

* closed feed water heater

10-47



10-92



$$P_2 = P_3 = P_6$$

0.5 MP is $S_5 \rightarrow S_6$ نفاذ

* Point(1): $\frac{hf}{10kPa}$

$$\star \text{Point}(2) \therefore h_2 = h_1 + V_{F1}(P_2 - P_1)$$

• Point (3): Saturated.

* Poin (4) : $h_4 \leq h_3 + v f_3 (p_4 - p_3)$

53554

→ If 6 wet mix

7 is the same

	<u>h</u>	<u>x</u>
sat. 1	191.81	0
comp. li. 2	192.3	
saturated 3	640.09	0
comp. liquid	650.47	
s. Hot 5	3375.1	0.9554
wet mix 6		
7 wet	2089.7	0.7934 (Not acceptable)

* We take OFWH as a control volume.

$$y = \frac{h_3 - h_2}{h_6 - h_2} = 0.182$$

* 2nd law to find $\dot{m}$:-

$$\dot{q}_{in} = h_5 - h_4 = 2724.6$$

$$\dot{q}_{out} = (1-y)(h_7 - h_1) = 1552.7$$

$$W_{net} = 1172$$

$$\eta_{thermal} = 0.43$$

$$\dot{m}_s = 128 \text{ kg/s}$$

$$W_{net} = \eta_{th} \cdot \dot{q}_{in}$$

$$\eta_{th} = \frac{\dot{q}_{in} - \dot{q}_{out}}{\dot{q}_{in}}$$

* Efficiency for Carnot :-

$$\eta_{Carnot} = 1 - \frac{T_{sink}}{T_{source}}$$

$$= 1 - \frac{303}{1300} = 0.767$$

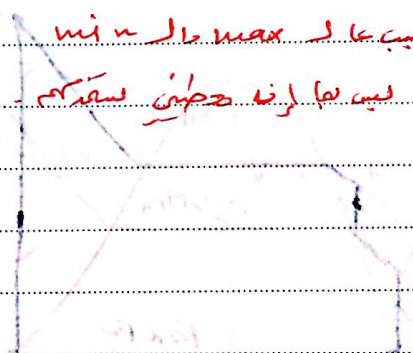
Second law

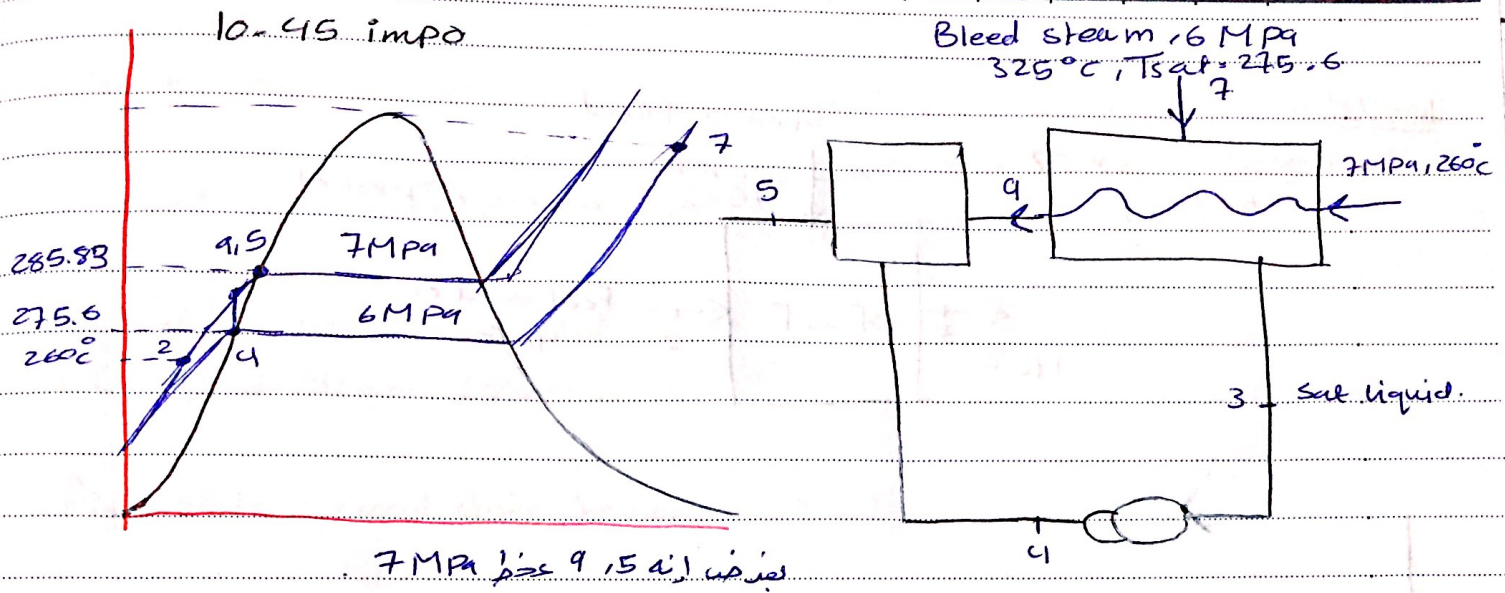
eff.

$$\eta_{II} = \frac{\eta_{th}}{\eta_{Carnot}} = 0.56$$

T_{sink} & T_{source} (در دما)

min & max (حدا کم و حدا کث)





S.I.

$$h_2 \Rightarrow h_f @ 260^\circ = 1134.8$$

$$h_7 \Rightarrow h_7 = 2964.75$$

$$h_3 \Rightarrow h_3 = 1213.8$$

$$h_9 \Rightarrow h_9 = 1267$$

$$h(5), \text{ around } 1240^\circ$$

FW is a control volume
as a control volume

* Note:

closed $\Rightarrow$ مغلقة

1) cycle كدورة

2) FWH فوه

* EXERGY:

how much the max. Performance.

max. output
or

min. input

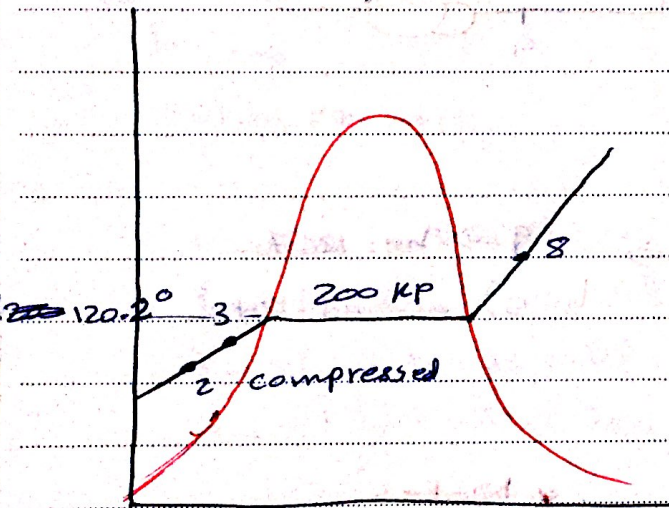
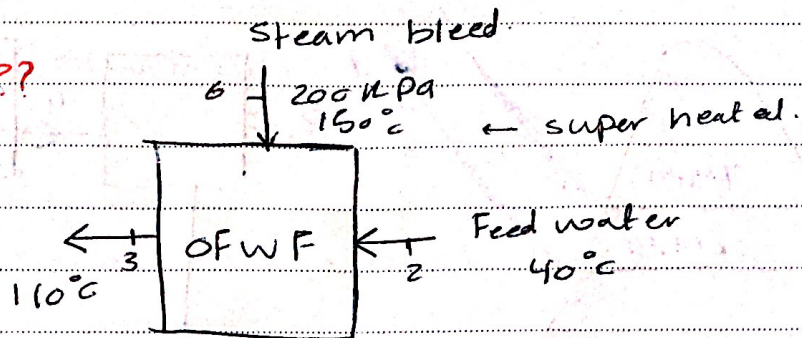
* around reference $\Rightarrow$ Patm

* dead no more interact with surrounding, T_{atm}

Reference state: $\rightarrow$ system
Dead state: $\rightarrow$ system

10-94

Find $\frac{m_b}{m_{total}} = Y??$



* start with point 6

$$h_6 = 2769.1 \text{ kJ/kg}$$

$$h_2 = h_f @ 40^\circ\text{C} = 167.53$$

$$h_3 = h_f @ 110^\circ = \text{---}$$

$$Y = \frac{h_3 - h_2}{h_6 - h_6}$$

*check T_{sat} @ 200 kPa.

* Exergy analysis of vapor power cycle ?

Sink hole
google it

- work Pot., Exergy, availability $\rightarrow$ max. energy, Work
 $\downarrow$
min. W_{in}
- actual work $W_u \rightarrow$ useful work
- $\rightarrow$ Exergy destroyed, Irreversibility (I)

final state = dead state h_o, s_o, u_o, p_o, T_o

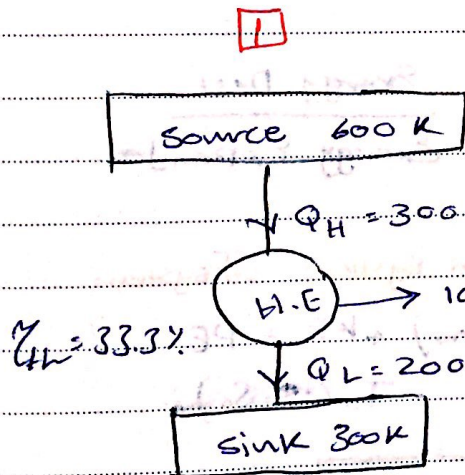
$$p_o = p_{atm}$$

$$T_o = T_{atm}$$

$$* W_{rev, out} = \dot{Q}_{th} * \eta_{th}$$

$$= \left(1 - \frac{T_L}{T_H}\right) \dot{Q}_H$$

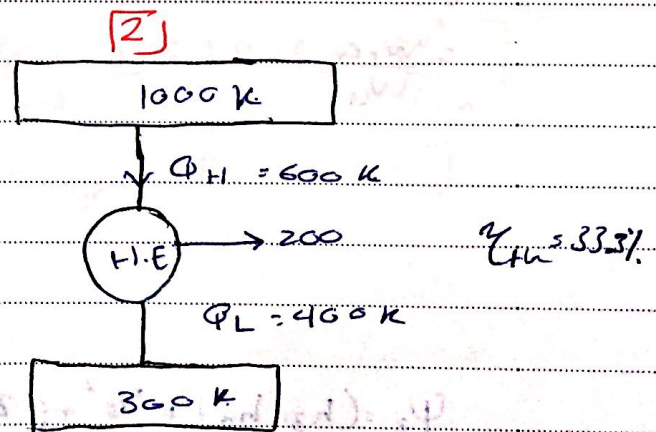
$$\eta_{th} = \frac{W_{net}}{\dot{Q}_H} \rightarrow \frac{\dot{E}_{o, max}}{\dot{Q}_H} \rightarrow \eta_{Carnot} \sim \eta_{max}$$



$$\eta_{th} = 33.3\%$$

$$\eta_{rev} = 1 - \frac{T_L}{T_H} = 1 - \frac{300}{600} = 50\%$$

$$\eta_{II} = \frac{\eta_{th}}{\eta_{rev}} = 66.6\%$$



$$\eta_{th} = 33.3\%$$

$$\eta_{rev} = 1 - \frac{300}{1000}$$

$$\eta_{II} = 47.5\%$$

[1] better than
2, $\eta_{II,1} > \eta_{II,2}$

cycle I) $W_{rev} = \left(1 - \frac{T_L}{T_H}\right) * Q_H$
 $= \left(1 - \frac{300}{600}\right) * 500$

$= 150 \text{ kJ}$

$W_u = 100 \text{ kJ}$

$I = 150 - 100 = 50 \text{ kJ}$

$\eta_{II} = \frac{100}{150} =$

* $\eta_{II} = \frac{\eta_{th}}{\eta_{carnot}}$

$= \frac{W_u}{W_{rev}}$

out $\rightarrow W_{rev} > W_u$

$\eta_{II} = \frac{COP_u}{COP_{rev}}$

* for Heat Exchanger:

$= \frac{W_{rev}}{W_u}$

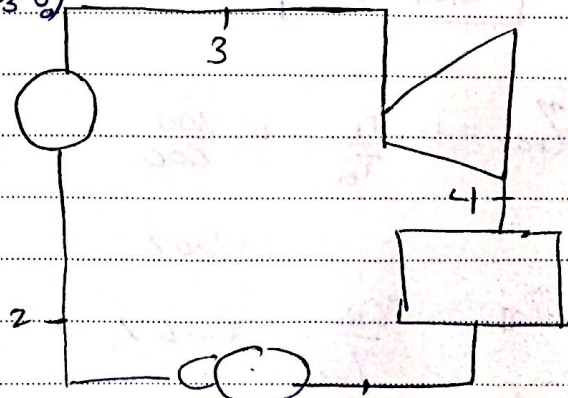
in

$\eta_{II} = 1 - \frac{\text{Exergy Dest.}}{\text{Exergy Expended}}$

* for open system SFsystem

$\psi = (h - h_0) + KE + PE - T_0(S - S_0)$

$\psi_3 = (h_3 - h_0) + \frac{V_3^2}{2} + g z_3 - T_0(S_3 - S_0)$

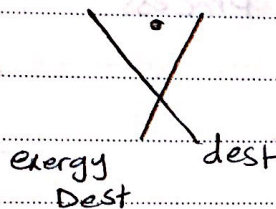


Simple ideal Rankin Cycle

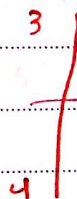
* Exergy change during process $\Delta\psi = \psi_f - \psi_i$
 $= \psi_3 - \psi_4 = (h_3 - h_4) + \Delta KE + \Delta PE - T_0(s_4 - s_3)$
 $w_u = (h_3 - h_4)$

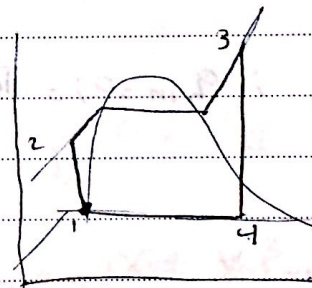
T_0 s_{gen}
 $\downarrow$
 if isentropic $s_4 = s_3$
 $\Delta\psi = \Delta h$

* Exergy Destroyed:-


 $= T_0 \left[s_f - s_i + \frac{q_{out}}{T_{out, sink}} - \frac{q_{in}}{T_{in, source}} \right]$

if isentropic $\rightarrow \dot{x}_{dest} = 0, \eta_{II} = 100\%$

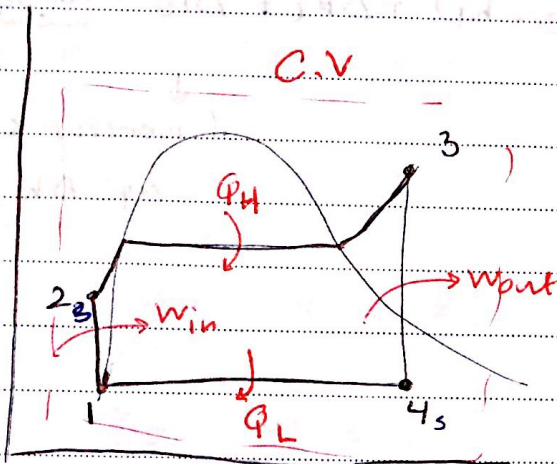

 $\rightarrow$ No heat or q_{inv}
 $s_f = s_i$ & .



Bailer $\rightarrow \dot{x}_{dest, 2-3} = T_0 \left[s_3 - s_2 - \frac{q_{in}}{T_{in}} \right]$

pump $\rightarrow \dot{x}_{dest} = T_0 [s_{2a} - s_1]$

* Ideal Rankin Cycle



$$\dot{X}_{dest} = 0, \quad \eta_{II} = 100\%$$

3-4s
1-2s

$$\left[\begin{array}{l} \Delta s = 0 \\ \Delta s = 0 \end{array} \right]$$

because isentropic Process.

input is isentropic

$$\dot{X}_{dest} : q_{out} = 0; = T_0 \left[s_3 - s_2 - \frac{q_{in}}{T_{in, source}} \right]$$

2-3

$$\dot{X}_{dest} : q_{in} = 0; = T_0 \left[s_1 - s_4 + \frac{q_{out}}{T_{sink}} \right]$$

4-1

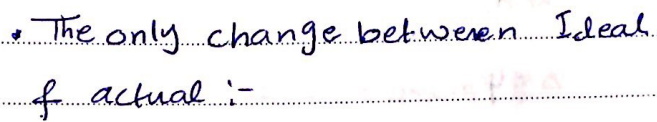
$$X_{expended} = X_{heat, in} + X_{pump}$$

input

$$= \left(1 - \frac{T_0}{T_{source}} \right) q_{in} + w_p$$

$$X_{recovered} = X_{wout} = w_T$$

/ /



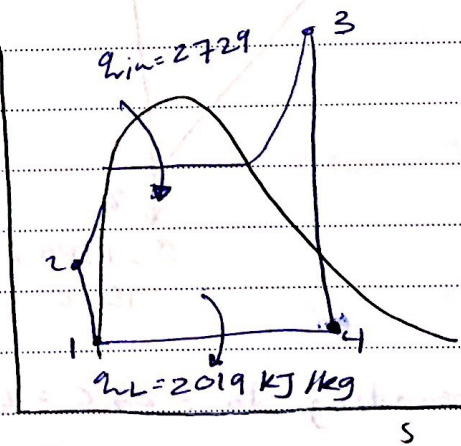
11/20/2019

ارجع ص 7-10 بح

Diagram illustrating a Carnot heat engine cycle (Ideal) operating between two reservoirs:

- Heat Source: $T_{\text{source}} = 800 \text{ K}$ (Furness)
- Heat Sink: $T_{\text{sink}} = 300 \text{ K}$
- Process 1-2: Isothermal compression at T_{sink} .
- Process 2-3: Isochoric heating.
- Process 3-4: Isothermal expansion at T_{source} .
- Process 4-1: Isochoric cooling.
- Work Output: $W_T = 713$
- Pressure at state 4: 75 kPa
- Heat input: Q_H
- Heat output: Q_{out}
- Labels: 1, 2, 3, 4, Ideal

$$X_{\text{dest}} = 0, \quad \gamma_{II} = 100\%$$



$S_0 = SF @ 300k =$

$$\rightarrow \dot{X}_{\text{dest}} = T_0 \left[(S_f - S_i) + \frac{q_{\text{out}}}{T_{\text{sink}}} - \frac{q_{\text{in}}}{T_{\text{source}}} \right] \quad \text{3-4} \quad \dot{X}_{\text{dest}} = 0$$

$$= \frac{1}{41} \left[1.2132 - 6.745 \right] + \frac{2019}{300}$$

→ $x_{dest} = 0$
1-2

$$X_{\text{dest } 2-3} = 300 \left[\overset{1.2132}{\underset{6.745}{(s_3 - s_2)}} - \frac{2729}{800} \right] = 636 \text{ kJ/kg} \quad \boxed{X_{\text{total}} = 996 \text{ kJ/kg}}$$

$$X_{\text{total}} = 996 \text{ kg}$$

* Exergy Analysis of vapor power cycles:

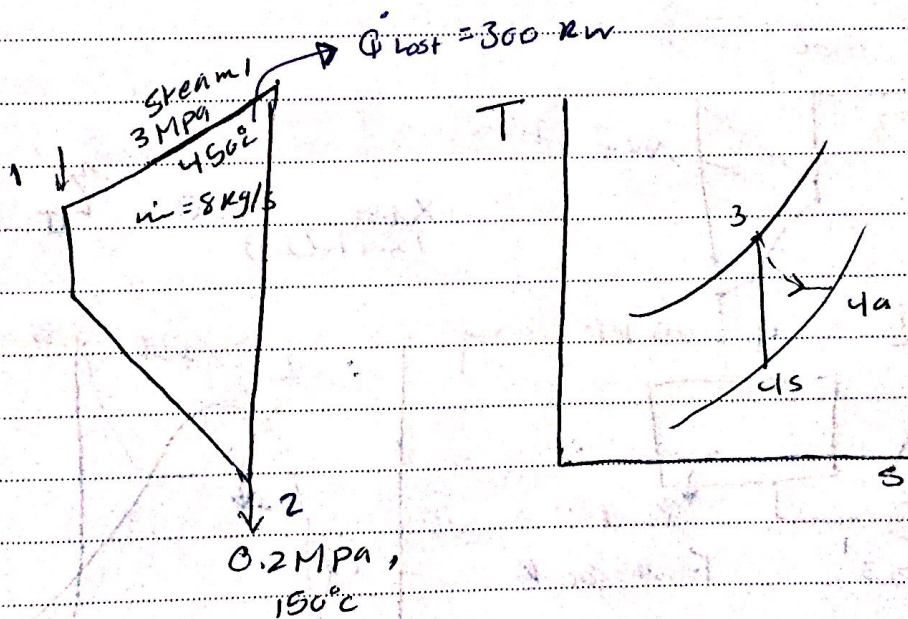
W_{useful} ; Exergy.

$$\rightarrow \text{flow } \psi_{\text{at pt.}} = (h - h_0) + KE + PE - T_0(S - S_0)$$

$$\Delta \psi_{\text{process}} = \dots$$

$$\dot{X}_{\text{dest}} = T_0 \left[(\dot{S}_f - \dot{S}_i) + \frac{\dot{Q}_{\text{out}}}{T_{\text{sink}}} - \frac{\dot{Q}_{\text{in}}}{T_{\text{source}}} \right]$$

Exp. 8.15
page 456



* Surrounding $T_0 = 25^\circ\text{C} = 298\text{ K}$
 $P_0 = 100\text{ kPa}$

Point (1): $h_1 = 3344.9\text{ kJ/kg}$
 $S_1 = 7.0856$

2) $h_2 = 2769.1$
 $S_2 = 7.281$

interpolation

3) $h_0 = h_f @ 298\text{ K} = 104.83$
 $S_0 = S_f @ 298\text{ K} = 0.3762$

$$\begin{aligned}\psi_1 &= (h_1 - h_0) + \cancel{KE_1} + \cancel{PE_1} - T_0(S_1 - S_0) \\ &= (3344.9 - 104.83) - 298(7.0856 - 0.3672) \\ &= 1238 \text{ kJ/kg}\end{aligned}$$

$$\dot{\psi}_1 = \dot{m} \psi_1 = 9904 \text{ kW}$$

القدرة
التي
تتدفق

$$\begin{aligned}\psi_2 &= (h_2 - h_1) + KE_2 + PE_2 - T_0(S_2 - S_0) \\ &= 604 \text{ kJ/kg}\end{aligned}$$

$$\dot{\psi}_2 = 483.2 \text{ kW}$$

$$\begin{aligned}\rightarrow \dot{w}_{rev} &= \dot{m}(\psi_1 - \psi_2) \\ &= 5072 \text{ kW}\end{aligned}$$

$$\dot{m}h_1 = \dot{Q}_L + \dot{w}_u + \dot{m}h_2$$

$$\rightarrow \dot{w}_u = \dot{m}(h_1 - h_2) - \dot{Q}_L$$

$$\begin{aligned}\rightarrow \dot{w}_{useful} &= \dot{m}(h_1 - h_0) - \dot{Q}_L \\ &= 4306 \text{ kW}\end{aligned}$$

$$\eta_{II} = \frac{\dot{w}_{useful \text{ out}}}{\dot{w}_{rev \text{ out}}} = 0.849$$

$$* \dot{w} = \dot{w}_{rev} \text{ if } \dot{x}_{dest} = 0$$

$$\begin{aligned}I &= \dot{w}_{rev \text{ out}} - \dot{w}_{useful} \\ &= 766 \text{ kW}\end{aligned}$$

Game example "Doctor Method"

$$\dot{W}_u = \dot{m}_s (h_1 - h_2) - \dot{Q}_L = 4306 \text{ kW}$$

$$\dot{X}_{\text{dest}} = \dot{m}_s \left[(s_f - s_i) + \frac{q_{\text{out}}}{T_{\text{sink}}} - \frac{q_{\text{in}}}{T_{\text{source}}} \right]$$

s_f is at T_{sink}

T_{sink}

$$T_{\text{sink}} = T_{\text{atm}} = 300 \text{ K}$$

$$= \dot{m}_s T_0 (s_2 - s_1) + 300$$

$$= 765.85 \text{ kW}$$

$$\star \dot{W}_{\text{rev, out}} = 4306 + 765.85 \approx 5072 \text{ kW}$$

Exp. 10-7 :-

$$\eta_{\text{Carnot}} = 1 - \frac{300}{800} = \text{0.625}$$

$$\eta_{\text{th}} = 26\%$$

$$\eta_{\text{II}} = \frac{0.26}{0.625}$$

$$= 41.6\%$$

$$\rightarrow W_{\text{rev, cycle max}} = \eta_{\text{Carnot}} Q_H \quad \left. \vphantom{W_{\text{rev, cycle max}}} \right\} \text{لا تفوت}$$