No.

* Summary of Rankine ideal and actual cycle *

* Rankine cycle is derived from Carnot Heat cycle but with some few adjustments to make the Carnot cycle more practical for real life.

* almost $\boxed{80\%}$ of the power plants in the world use this cycle. including solar, nuclear powerplants.

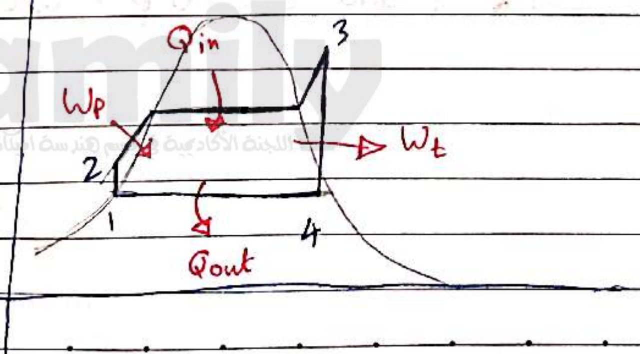
* what's the most important Benifits from it ??

1] solve the problem of the pump inlet. so that it became sat. liquid and that's acceptable for designing
→ $\boxed{h_1 = h_{f_1}}$ always in Rankine

2] the process $\boxed{2 \to 3}$ ((heat addition)) is no more isothermal. it's just isobaric and thats more practical, also $\boxed{4 \to 1}$

3] most of turbines is dealing with a steam with a high moisture $\boxed{> 80\%}$ and that's solved By using the cycle

4] the typical shape of the Rankine cycle is shown on T-s diagram like this :



No.

* Processes

1 → 2 ~~iso thermal expansion~~ intropic compression

2 → 3 iso baric expansion and Heat addition is here

3 → 4 isintropic expansion W_t produced here

4 → 1 iso baric comprission

* effect of $\dot{m}_c$ on work, heat in, heat out :-

→ according to the equation $\boxed{\dot{m}_s q_{out} = \dot{m}_c C_{p_w} \Delta T_c}$

such that :-

* $\dot{m}_c$: is the mass flow rate of the cooling fluid inside the condenser. عادة يكون ماء

* C_{p_c} :- specific heat for the cooling fluid.

* ΔT_c :- Tempreture gained By the cooling fluid.

→ increasing $\dot{m}_c$ will effect on ΔT_c and that will make ΔT_c is smaller, this is good for enviromintal porpuses.

→ increasing $\boxed{\dot{m}_s}$ will effect on $\boxed{X_4}$ so we can't change it too much

* how we can increase η for Rankine cycle???

1- decrease condenser pressure and Tempreture.

→ we can't lower the condensing T under $T = 10°c$ for designing issues, also decreasing the pressure alot will cause leakgge in condenser.

2- increase tempreture of heat addition :- $\boxed{T_H}$

it will increase work But also will increase $\boxed{Q_{in}}$

No.

3- increase P_{Boiler} :-

→ this will improve η in good way But will make x_4 become below $\boxed{80\%}$ so its rejected solution

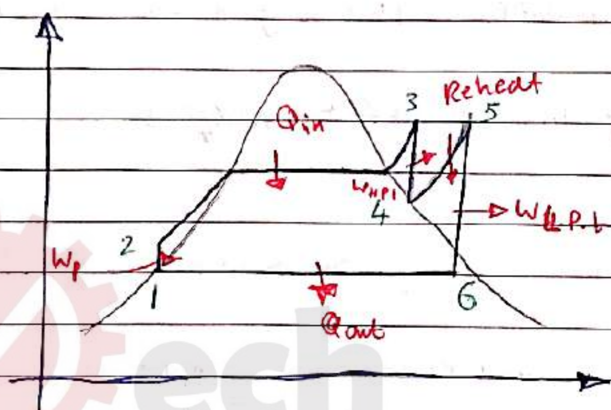
4- Increase P_{Boiler} and T_{max} in the same time :-

→ this solution will give us the best η for the cycle

* لكن مشكلة هذا الحل هو أنه يجعل أنابيب الدورة مضغوطة بشكل كبير وقد تتعرض للكسر عند أي ضربة

→ so the best solution is increase P_B + T_{max} , this is done By a cycle called Rankine Reheat cycle.

* T-s diagram for R. Reheat. c



* Processes :-

1) 1→2 , 2→3 are the same as before
2) 3→4 is Work output from High. P. turbine
3) 4→5 is the reheating process
4) 5→6 " work output from Low. P. turbine

No.

* notes :-

1) point $\underline{\underline{4}}$ is not specified, but prefered to be saturated vapor

2) T_5 must be $\leq T_3$ for designing issues

3) we ~~can~~ can add turbines as much as we can. the best no. canbe found in equation wi'll take it in another subject

4) mainly, the best No is $\boxed{3}$ turbines

5) notice that the working fluid passes through 2 turbines and this is good for $\boxed{W_{net}}$.

5) Back work ratio is $\boxed{\frac{W_p}{W_t}}$

Such that W_p is the $\boxed{W_{p_{total}}}$

* Rankine Regenerative Ideal cycle.

→ two types :-

1) open Feed water Heater
2) closed feedwater Heater

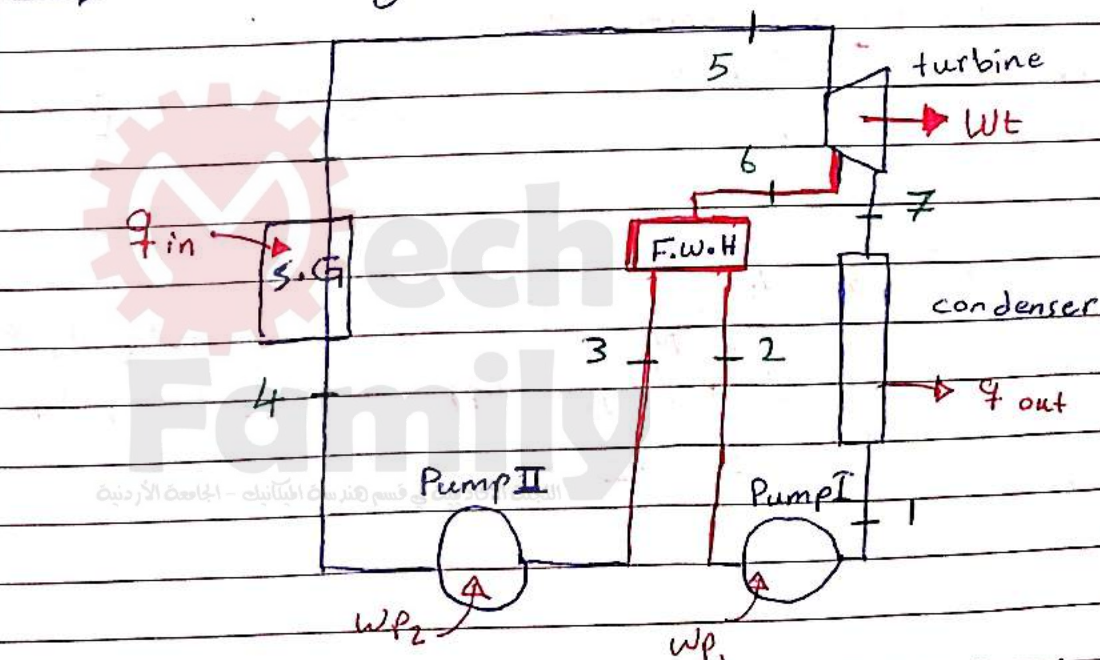
* the Idea is to eleminate some steam fromthe turbine exit and enter it on Heat exchanger . why???

answer:- to reduce the energy needed to raise the temprature of the water from T_1 to T_{sat}

* يعني بالعربي الهدف هو تقليل الطاقة اللازمة لتسخين الماء داخل البويلر.
* كيف؟؟

* how does that happen ??
answer:- as we said, By removing some steam from the turbine, Before entering the condenser and make Heat exchanging with steam after condensing

→ see figure



* as we said , the Feed water Heater (Heat exchanger) has two types:- [1] open [2] closed

Direct mixing ↲ ↳ without mixing

* the heat transfer that happens inside F.W.H is Happens between intersepted steam and the High pressure water and called [Feed water]

*ما الفوائد المكتسبة من هذه العملية ؟؟؟ ((open))

١) غير مكلفة وبسيطة

٢) good Heat transfer

٣) Bring feed water to sat.

*ما الخسائر ؟؟؟

← كل Heat exchanger نستخدم تكاليف pump جديدة.

*notes about the cycle :-

1) Pressures of the pipes around the $\boxed{F.W.H}$ are equal

→ $P_6 = P_3 = P_2$. in the ideal state.

called the regeneration Pressure.

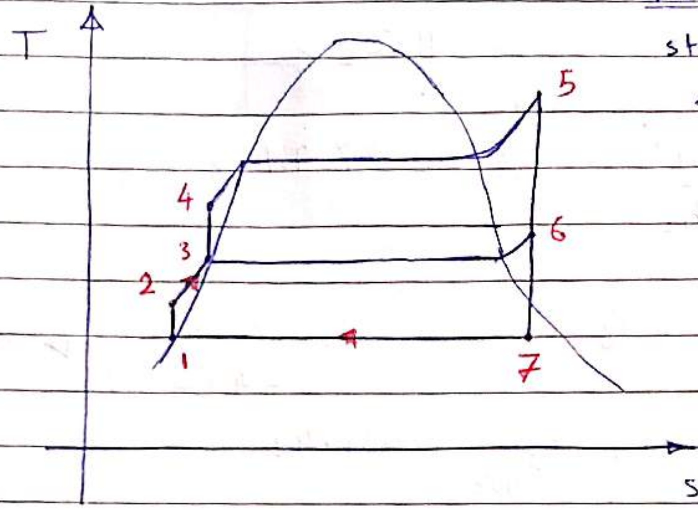
2) the $\boxed{F.W.H}$ exit state is saturated liquid . $\boxed{\text{state } 3}$

3) the equations :-

* $q_{in} = h_5 - h_4$
* $q_{out} = (1-y)(h_7 - h_1) + \cancel{y}$
* $w_t = (h_5 - h_6) + (1-y)(h_6 - h_7)$
* $w_p = (1-y) w_{p_I} + w_{p_{II}}$
* $y = \dot{m}_6 / \dot{m}_5$

* $w_{p_1} = v_1 (P_2 - P_1)$
* $w_{p_2} = v_3 (P_4 - P_3)$

4) T-s diagram



notice that :-

states 1,3 are Sat. liq

" 5,6 " super.hea

5) regenerating has been used in all modern steam power plants around the world Because :-

1) enable the powerplant's supervisor to remove Air from feed water , which if exists can cause leaks or problems in the Boiler

2) helps controlling the large volume flow rate of steam out side the turbine

6) regeneration increase $\boxed{\eta}$, the more $\boxed{F.W.H}$ exist the more $\boxed{\eta}$ increase

7) optimum NO of $\boxed{F.W.H}$ is $\boxed{8}$ Heat exchangers

All the notes above is for Open F.W.H

* Closed feed water Heaters :-

* it have the same purpose as the open but without direct mixing

*نفس هدف المفتوح ، لكن الفروق بسيطة :

*The Differences :-

1) the closed F.W.H has atubing network inside it which make it more complicated and more expensive

"شبكة أنابيب داخلية مكلفة"

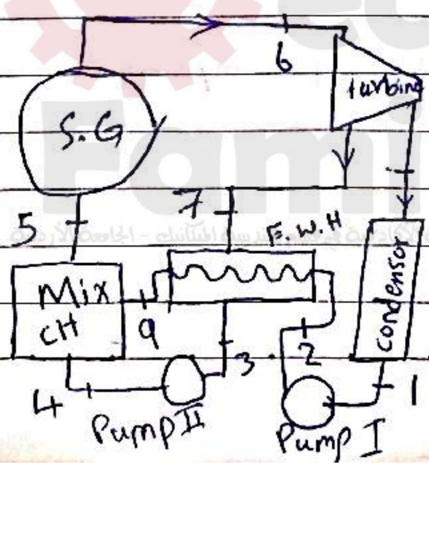
2) No mixing Between the feed water and the steam

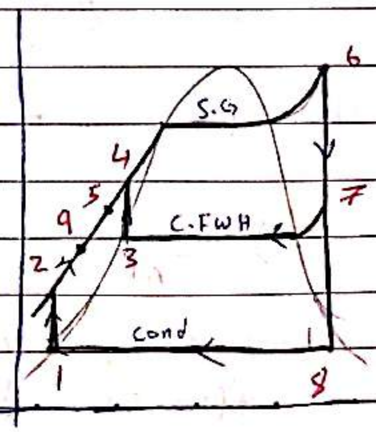
→ this effects on the Heat trans fer effeciency.

3) we don't need apump for every closed F.W.H Because there is no mixing

4) here, we need amixing champer Before the Boiler ((Steam generator)), to make the solution more ((homoguineaus)) to avoid problems inside the Boiler ((S.G))

* the cycle and T-s diagram:-





Notes from the diagram:-

1) Point $\boxed{3}$ $[$F.W.H exit$]$ is a saturated liquid

→ in actual : the tempreture is below the steam (T)
Because of ((Heat transfer Principles)) → not included

2) Points $\boxed{2}$ $\boxed{4}$ $\boxed{5}$ $\boxed{9}$ and $\boxed{6}$ has the same Pressure. which is the mixing champer $\boxed{P}$ and the $\boxed{S.G}$ Pressure

3) Points $\boxed{5}$ $\boxed{9}$ has no more informations can Be extracted from the diagram

← بالعربي: النقطتين محيرات ، و يلزم معلومات من السؤال لتحديد مكانهم بالزبط.

* equations :-

1- $Q_{in} = m(h_6 - h_5)$

2) $W_t = W_{t_1} + W_{t_2} = m(h_6 - h_7) + (m - m_7)(h_7 - h_8)$

3) $Q_{out} = (m - m_7)(h_8 - h_1)$

4) $W_P = W_{P_1} + W_{P_2} = (m - m_7)(h_2 - h_1) + m_7(h_4 - h_3)$

5) $y = \dfrac{m_7}{m}$

* most of power plants around the world uses a combination Between open and closed F.W.H.

** Co generation **

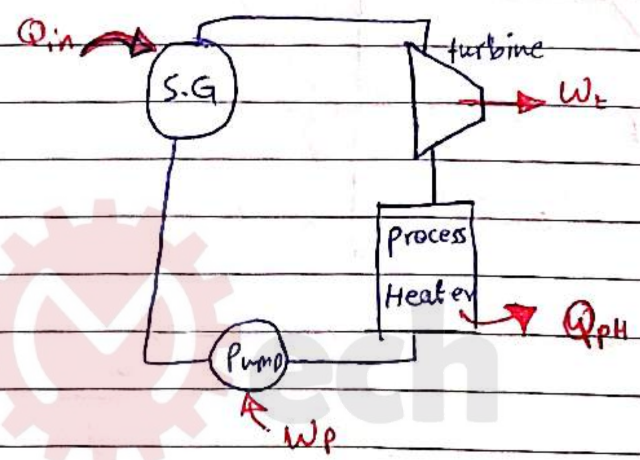
* Definetions :- the production of more than one useful form of energy ((process heat and electric power as example)) from one heat source

الفكرة العامة هي أخذ جزء من البخار المراد تحويله إلى شغل ولكن يكون فائضاً عن الحاجة أو لا يمكن تحويله إلى الشكل المطلوب ومن ثم بيعه لمنشآت بجانب المحطة لأغراض تجارية .

* instead of rejecting water at ~~38°~~ high Temprelure to a river or to an ocean . we can ~~buy~~ sell it !!!

* remember :- it's either useless or more than we need.

* the ideal cogeneration plant



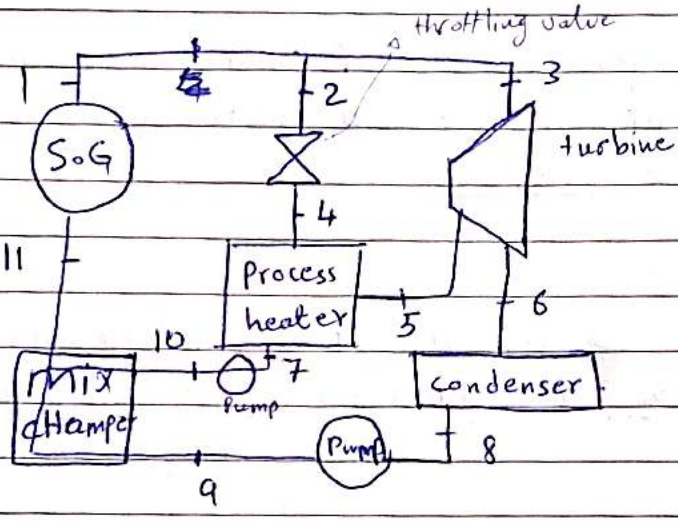
* notice that we have no more condensers in the cycle

→ this means, no more heat rejection in the plant .

* Utilization factor of cogenerative plant

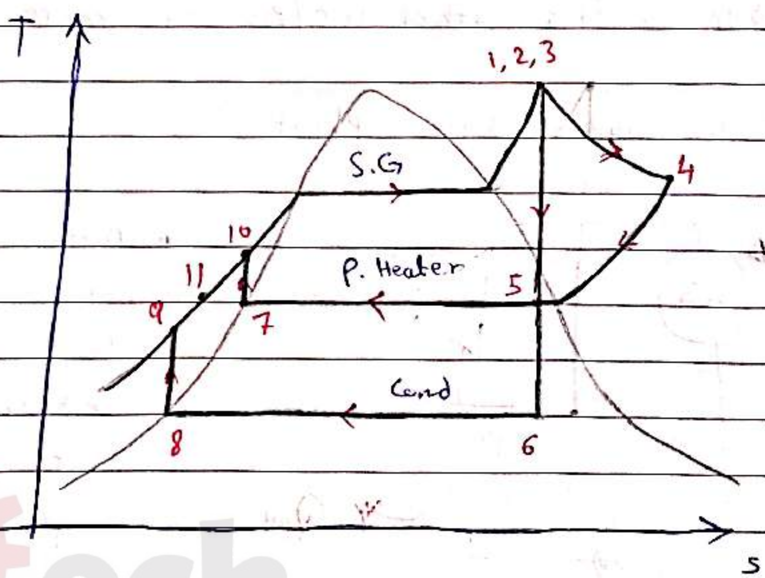
$$E_u = \frac{\dot{W}_{net} + \dot{Q}_{PH}}{\dot{Q}_{in}}$$

* normal cogeneration plant :-



* Process Heat :- the part that we give it to the P. Heater

T-s diagram :-



Notice that :-

1) Process Heater exit is saturated liquid [Point $\boxed{7}$]

2) Points 1, 2, 3 are the same point

* important notes:-

1) when the demand on Process Heat is at the max demand → all Q_{in} from the S.G is converted to the p.Heater

→ thus; $\dot{m}$ inside the turbine and the condenser $= 0$

$\dot{m}$ in the P. Heat $= \dot{m}_{total}$

2) when there is no demand $\boxed{\dot{m}_{P.H} = 0}$, $\boxed{\dot{m}_t = \dot{m}_{total}}$

Q) * why throttling Value ??!!!!!

→ well, most of industrial and home using needs a saturated water not a super Heated. so we pass from point $\boxed{5}$ not from the valve

* second purpose is to reduce pressure without miss in $\boxed{h}$ here we pass from the value

* equations

1- $\dot{Q}_{out} = (\dot{m} - \dot{m}_2 - \dot{m}_5)(h_6 - h_8)$

2- $\dot{Q}_{in} = \dot{m}(h_1 - h_{11})$

3- $\dot{W}_t = (\dot{m} - \dot{m}_2)(h_3 - h_5) + (\dot{m} - \dot{m}_2 - \dot{m}_5)(h_5 - h_6)$

4- $W_p = (\dot{m} - \dot{m}_2 - \dot{m}_5)(h_9 - h_8) + (\dot{m}_2 + \dot{m}_5)(h_{10} - h_7)$

$$\dot{Q}_{pH} = \dot{m}_2 h_4 + \dot{m}_5 h_5 - (\dot{m}_2 + \dot{m}_5)(h_7)$$

Notes:-

1) $\dot{Q}_{pH}$ equation is from energy Balance principle

2) We have 3 ways to deliver the Process heat

a) Passing the throttle value ((for minimizied pressure usings))

b) Passing Point 5 ((for home uses))

c) Passing them both ((need's calibration))

3) the co generative plant is frendly for the inviroment.

4) its more economic than the others.

** second law efficiency of Rankine cycle **

* But first we will define **Exergy** :

Def. exergy :- The maximum useful work possible during process.

⟹ exergy is known as a "state function"

* يعني بيعتمد على المراحل وليس على ((paths)).

→ exergy represents the upper limit on the amount of work a device can deliver without violating any thermodynamics law.

* reversible work has the same meaning like exergy

and W_{rev} = exergy only when the second state is the dead state

* what's the ((dead state)) ?????

→ the place where no energy left in the system

we can reach the dead state only when the process is $\boxed{\text{reversible}}$ → $P = 1\ atm$, $T = 25^\circ C$

* Irreversibility or exergy destroyed :-

→ the irreversibility can be viewed as awaste work or the lost work that we couldn't make use from it

* يعني عبارة عن طاقة (شغل) ضائع لم يتم الاستفادة منه بسبب (الاحتكاك، انتقال الحرارة، الخ ...)

* any thing that make's intropy change make exergy destruct

← أي شيء يكون فيه تغيير للانتروبي يجب أن يكون فيه ex.dest .

$$\boxed{X_{dest} = T_o\, S_{gen}} \qquad \boxed{\text{Joule}}$$

→ exergy for $\boxed{\text{one}}$ state

$$\psi = (h - h_o) + \frac{U^2}{2} + gz - T_o(s - s_o)$$

→ * exergy destruction is always positive quantity

* over all $\quad X_{dest} = |W_{rev} - W_u|$

No.

second law efficiency :-

* it can make us compare between the maximum work and the useful work

→ for power producing ($\dot{W}_{out}$) :-

$$\eta_{II} = \frac{W_u}{W_{rev}} = \frac{\eta_{th}}{\eta_{rev}}$$

$\dot{X}_{dest}$: max output

→ for power consuming ($\dot{W}_{in}$) :-

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

X_{dest} :- minimum input

over all :-

$$\eta_{II} = \frac{\text{exergy recovered}}{\text{exergy available}}$$

also ex. recovered = ex. available − ex. destroyed

$$\boxed{\eta_{II} = 1 - \frac{\text{ex. destroyed}}{\text{ex available}}}$$

For a turbine

$$\eta_{II} = 1 - \frac{T_0 S_{gen}}{\psi_1 - \psi_2}$$

No.

→ for compressor, pump, fan, Blower

$$\boxed{\eta_{II} = \frac{w_{rev}}{w_u} = 1 - \frac{T_0 S_{gen}}{h_2 - h_1}}$$

→ for Heat transfer parts :-

$$\boxed{X_{dest} = \left(1 - \frac{T_0}{T}\right) Q}$$

over all

$$\boxed{\dot{X}_{dest} = T_0 \left[\dot{m}(s_f - s_i) + \frac{q_{out}}{T_{out}} - \frac{q_{in}}{T_{in}} \right] \frac{kJ}{kg}}$$

last :- exergy destroyed for cycle is the summation of ex. dest for every process

$$\boxed{\dot{X}_{dest,\,cycle} = \sum^{i} \dot{X}_{process}}$$

note :- T_L هي نفسها T_0 ما لم يفرض السؤال عكس ذلك

Questions :- 10 - 2, 23, 18, 19, 30, 37, 38, 44, 41, 45, 58 and example 7