ملخص مادة..

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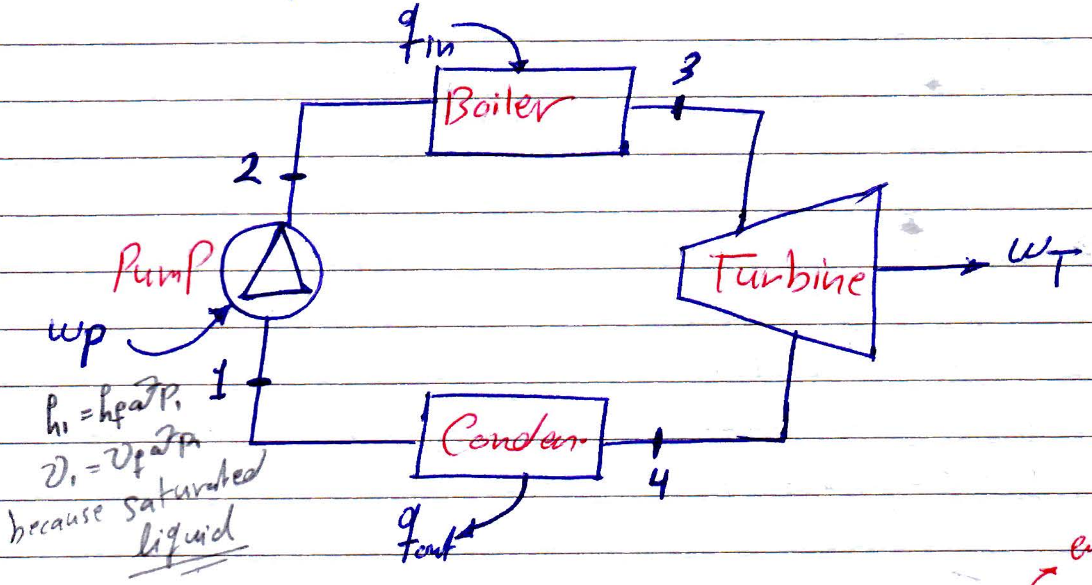
Ch 10 :- Vapor And Combined Power Cycle.

⇒ Simple ideal Rankine cycle.



$h_1 = h_f$ at P_1
$v_1 = v_f$ at P_1
because saturated liquid

entroPy.

1 → 2 isentropec Compression in pump (S constant).
2 → 3 Constant Pressure.
3 → 4 isentropec expantion in Turbine.
4 → 1 Constant Pressure.

⇒ Pump (1 → 2) :-

Work pump.

$$\frac{\cancel{\dot m_1} h_1}{\dot m} + \frac{\boxed{W_P}}{\dot m} = \frac{\cancel{\dot m_2} h_2}{\dot m} \qquad \dot m_1 = \dot m_2 = \dot m$$

Specific work pump ← $w_p = h_2 - h_1 \quad \left(\frac{kJ}{kg}\right)$

$$\frac{W}{\dot m} = \frac{\dot m\, v_1 (P_2 - P_1)}{\dot m} \Rightarrow w = v_1 (P_2 - P_1)$$

Specific Volume at P_1

→ Boiler (2 → 3) :-

$h_2 + q_{in} = h_3$

$\boxed{q_{in} = h_3 - h_2}$

→ Turbine (3 → 4) :-

$h_3 = w_T + h_4$

$\boxed{w_T = h_3 - h_4}$

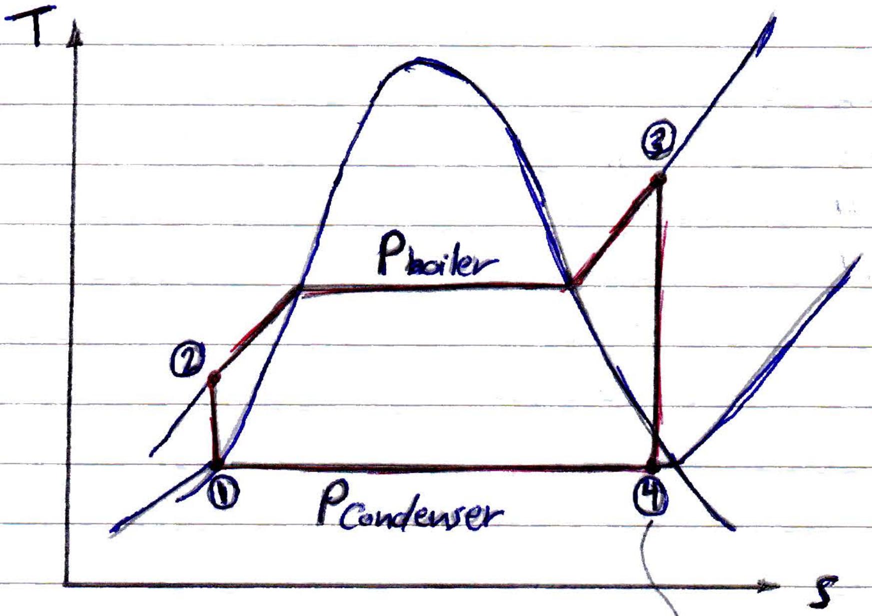
→ Condenser (4 → 1) :-

$h_4 = q_{out} + h_1$

$\boxed{q_{out} = h_4 - h_1}$

* Pressure at
① and ④ constant
② and ③ constant

* Entropy ((S))
constant at ③ and ④.



x (mixture).

$S = S_f + x S_{fg}$.

$h = h_f + x h_{fg}$.

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

$$\eta_{th.car} = 1 - \frac{T_{min}}{T_{max}}$$

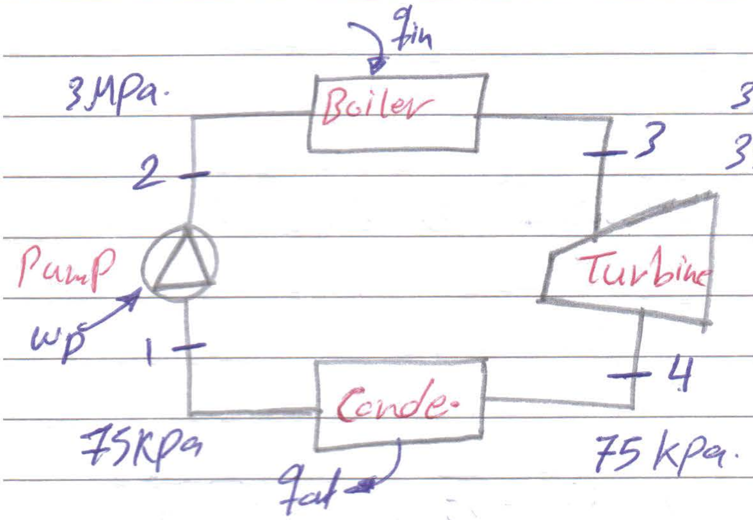
T_{min} → الحراره اللي بتدخل على ال Pump

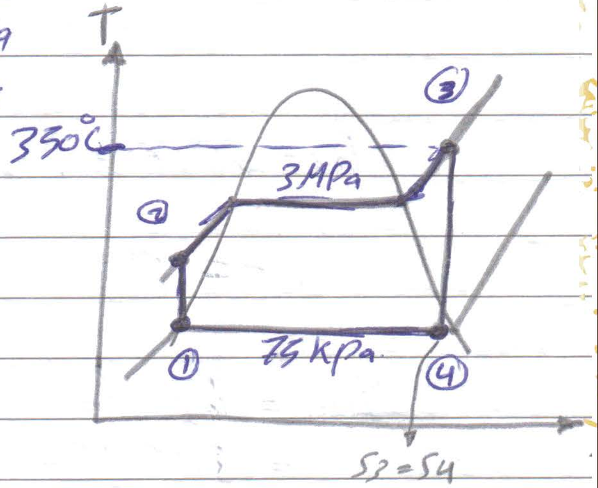
T_{max} → الحراره اللي بتطلع من ال boiler.

Example 10.1

Consider a steam Power Plant operating on the simple ideal Rankine cycle. Steam enters the turbine at 3MPa and 350°C and is condensed in the condenser at pressure of 75 kpa.

Determine the thermal efficiency of this cycle.





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

Solution

① P saturated liquid $\Rightarrow$ $h_1 = h_f$ at $P_1 = 384.36$ kJ/k
$v_1 = v_f$ at $P_1 = 0.001037$ m³/k

$w_p = v_1 (P_2 - P_1)$
$= 0.001037 (3000 - 75) = \boxed{3.03 \text{ kJ/kg}}$

$w_p = h_2 - h_1$
$3.03 = h_2 - 384.36 \Rightarrow h_2 = \boxed{387.39 \text{ kJ/kg}}$

$$\left.\begin{matrix} P_3 \\ T_3 \end{matrix}\right] \Rightarrow \begin{matrix} h_3 = 3115.25 \text{ kJ/kg} \\ S_3 = 6.7427 \text{ kJ/kg-k} \end{matrix}$$

$T_4 = 91.77\ °C$

$$\left.\begin{matrix} P_4 \\ S_4 = S_3 \end{matrix}\right] \Rightarrow \text{Sat. mix}$$

$$X_4 = \frac{S_4 - S_f}{S_{fg}} = \frac{6.7427 - 1.2129}{6.2434}$$

$$= 0.8857$$

$$h_4 = h_f + x\, h_{fg} = 384.36 + 0.8857 * 2278.59$$

$$h_4 = 2402.5 \text{ kJ/kg}.$$

$$q_{in} = h_3 - h_2$$
$$= 3115.25 - 387.39 = \boxed{2727.86 \text{ kJ/kg}}$$

$$q_{out} = h_4 - h_1$$
$$= 2402.5 - 384.36 = \boxed{2018.14 \text{ kJ/kg}}$$

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{2018.14}{2727.86} = \boxed{0.260 = 26\%}$$

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

$$w_{net} = q_{in} - q_{out} = 2727.86 - 2018.14$$
$$= \boxed{709.72 \ kJ/kg}$$

$$\eta_{th} = \frac{w_{net}}{q_{in}} = \frac{709.72}{2727.86} \boxed{= 0.260 = 26\%}$$

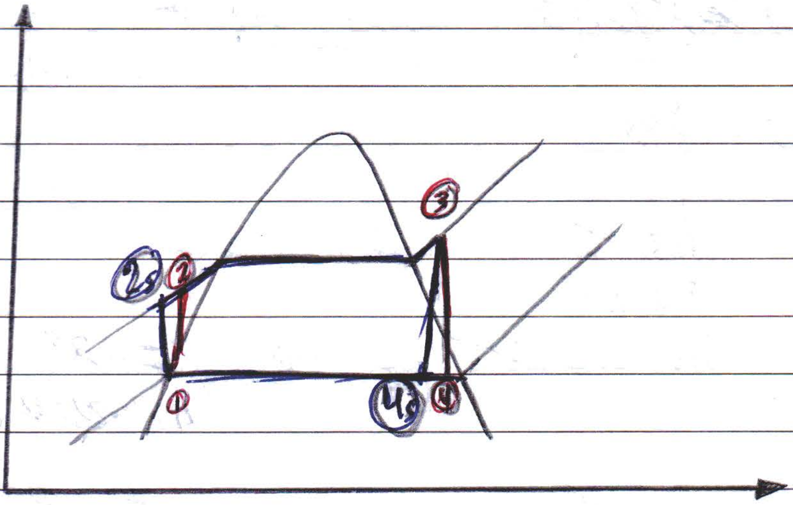
$$\eta_{th.carnot} = 1 - \frac{T_{min}}{T_{max}} = 1 - \left(\frac{91.77 + 273.15}{350 + 273.15}\right)$$
$$= \boxed{0.414 = 41.4\%}$$

Example 10.1 + Deviation

isentropic efficiency of the Turbine $\eta_s = 80\%$

هاد يعني أن السؤال يحل كله بال Deviation .

Pump + Turbine.



اللي بيختلف فقط h2 h4

$w_p = h_{2s} - h_1$

$h_{2s} = w_p + h_1 = 387.39$

$$\eta_{s_p} = \frac{w_s}{w_a} = \frac{\overset{\checkmark}{h_{2s}} - \overset{\checkmark}{h_1}}{\underset{\downarrow ??}{h_{2a}} - h_1 \checkmark}$$

$$\eta_{s.pump} = \frac{h_{2s} - h_1}{h_{2a} - h_1}$$

$$\frac{h_{2s} - h_1}{\eta_{s.pum}} = h_{2a} - h_1$$

$$h_{2a} = \frac{h_{2s} - h_1}{\eta_{s.pump}} + h_1$$

$$= \frac{387.39 - 384.36}{0.8} + 384.36 = 388.1475 \text{ KJ/Kg}$$

~~S_3 h_3 = h_3 S_3~~ $\boxed{S_3 \text{ و } h_3}$ $\Rightarrow$ نفس قيمة السؤال السابق بنجيبهن من الجداول.

$S_3 = S_{4s}$

h_3 ✓
S_3 ✓
$S_{4s} = S_3$ ✓
P_4

$\Rightarrow$ mix $x = 0.88$

$h_{4s} = 2402.5$ KJ/Kg

$$\eta_{s.Tur} = \frac{w_a}{w_s} = \frac{\overset{\checkmark}{h_3} - h_{4a}^{\,\rightarrow ??}}{h_3 - h_{4s}}$$

$h_{4a} = h_3 - \eta_{s.Tur} * (h_3 - h_{4s})$

$= 3115.25 - (0.8 * (3115.25 - 2402.35))$

$= 2545.05$ kJ/kg.

$q_{in} = h_3 - h_{2a} = 2727.1025$ kJ/kg

$q_{out} = h_{4a} - h_1 = 2160.69$ kJ/kg

$$\eta_{Th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{2160.69}{2727.1025}$$

$$= \boxed{0.207 = 20.7\,\%}$$

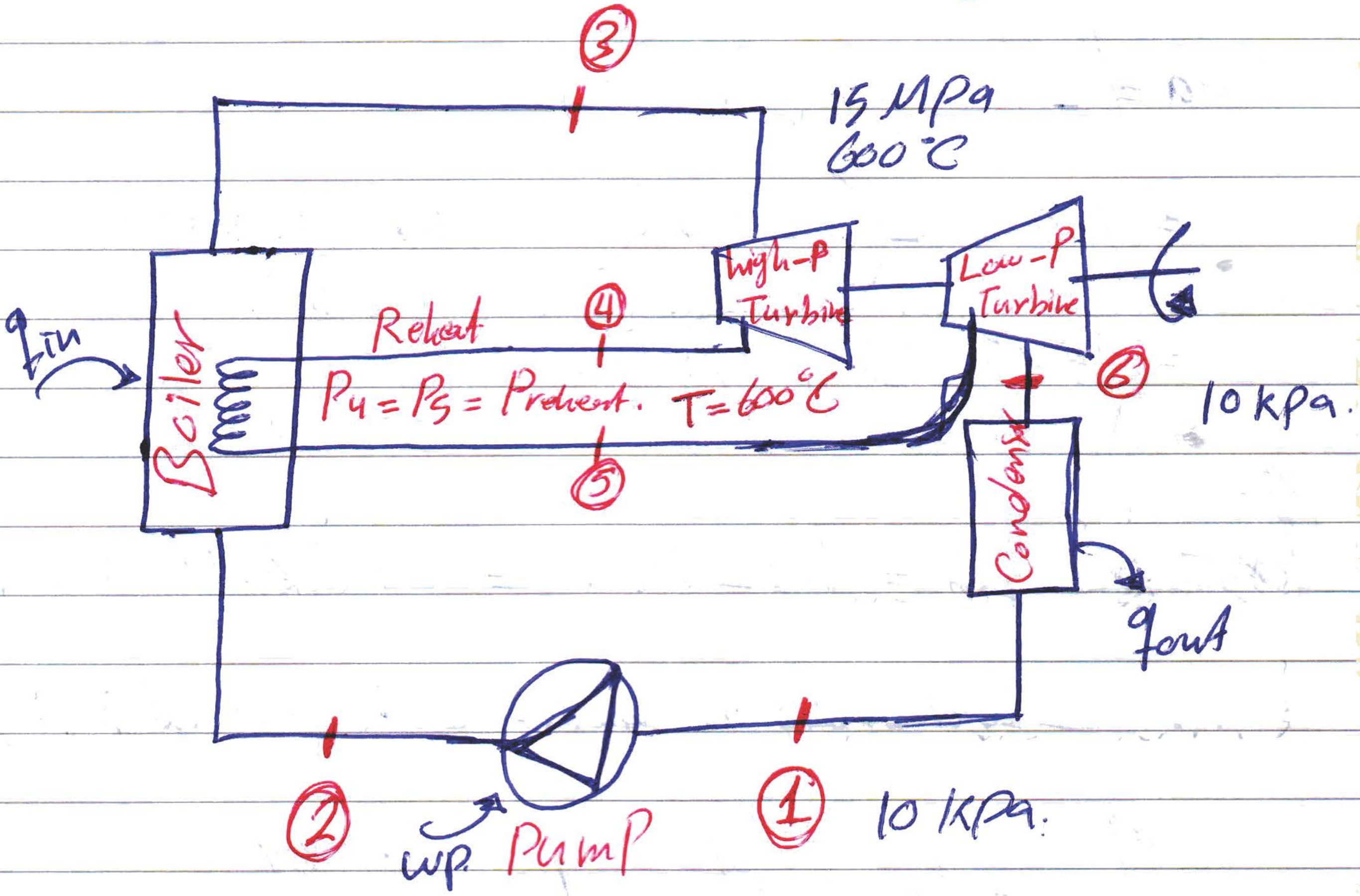
⊛ راجع $\underline{\underline{Sec.4}}$ مهم جداً في زيادة ال efficiency

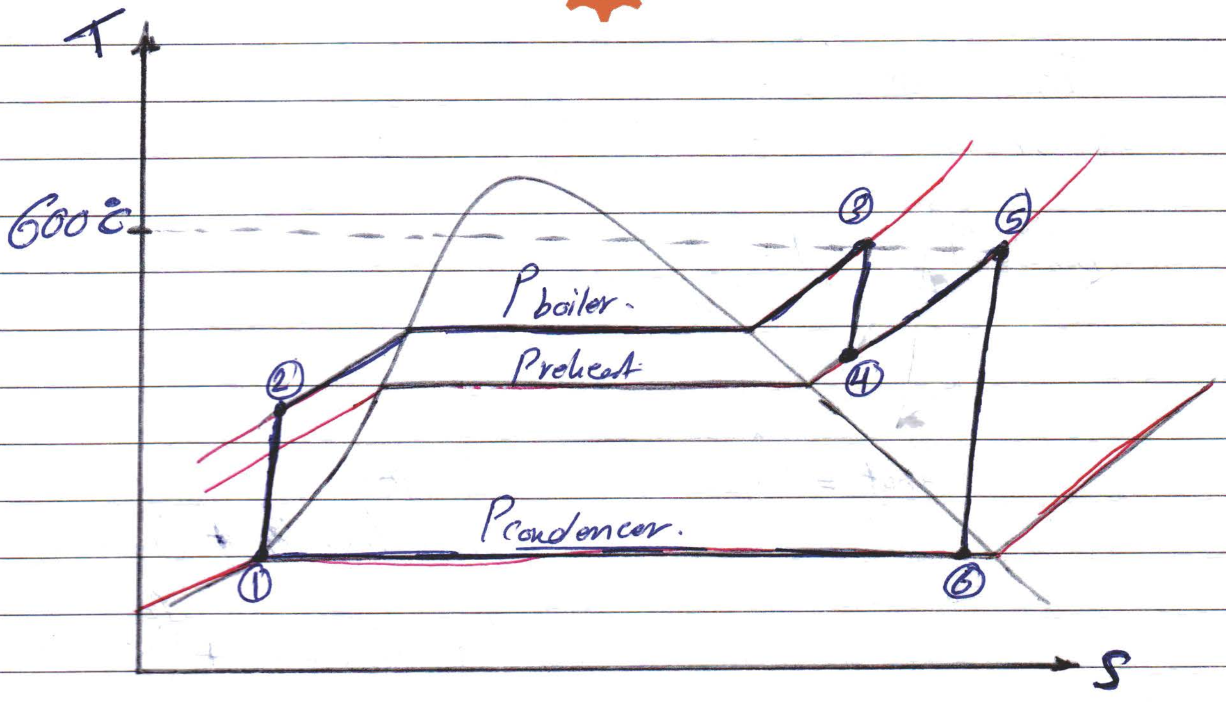
ال Rankine cycle ⊛

$w_{net} = q_{in} - q_{out} = w_T - w_P.$ $w_T = h_3 - h_4$

$W_{net} = \dot{m}_{in}\, w_{net}$ $w_P = h_2 - h_1$

⇛ Ideal Reheat Rankine cycle.





Example 10.4 moisture 10.4%

$x = 100 - 10.4 = 89.6\% = \boxed{0.896}$

determine ⇒ ⓐ $P_{reheat} = P_4 = P_5$.

ⓑ η_{th}.

Assume the steam is reheated to the inlet temperature of the high Pressure turbine. Turb. يعني سخن لعند درجة حرارة الـ

مرة أخرى يعني النقطة ⑤ $T_5 = 600\ °C$ # معلومة مهمة جداً جداً جداً #

Solution @P_6, x_6 ⇒ $h_6 = h_f + x h_{fg} = 191.81 + (0.896 * 2392.82)$

$= 2335.77\ kJ/kg$

$S_6 = S_f + x S_{fg} = 0.6492 + (0.896 * 7.5010)$

$= 7.3688\ kJ/kg \cdot K$

احنا بلشنا من النقطة ⑥ لأنه هذه النقطة على استقامة عامودية

مع ⑤ وبالتالي $\boxed{S_6 = S_5}$ مهم جداً.

$T_5 = 600°$, $S_5 = S_6$] ⇒ $P_5 = 4\,MPa$
$h_5 = 3674.9\ kJ/kg.$

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

$q_{out} = h_6 - h_1$

$q_{in} \Rightarrow$

$h_2 + h_4 + \cancel{h_5} + q_{in} = h_3 + h_5$

$q_{in} = (h_3 - h_2) + (h_5 - h_4)$

⊛ $P_1 = 10\,kPa$, sat. liquid] → $h_1 = h_f\ @\ P_1 = 191.81\ kJ/kg.$
$v_1 = v_f\ @\ P_1 = 0.001010\ m^3/kg.$

$w_{pump.in} = v(P_2 - P_1)$

$= 0.001010(15000 - 10) = 15.14\ kJ/kg.$

⊛ $w_{pump} = h_2 - h_1$
$h_2 = w_{pum} + h_1 = 15.14 + 191.81 = 206.95\ kJ/kg$

⊛ $P_3 = 15\,MPa$, $T_3 = 600°C$ } $h_3 = 3582.3\ kJ/kg$
$S_3 = 6.6775\ kJ/kg \cdot K.$

⊛ $P_4 = P_5 = 4\,MPa$, $S_4 = S_3 = 6.6775$ } $h_4 \Rightarrow$

6.5843	3093.3
6.6796	h_4
6.7714	3214.5

$$\frac{6.5843 - 6.6796}{6.5843 - 6.7714} = \frac{3093.3 - h_4}{3093.3 - 3214.5}$$

$$\boxed{h_4 = 3155.0\ kJ/kg}$$

$T_4 \Rightarrow$

6.5843	350
6.6796	T_4
6.7714	400

$$\frac{6.5843-6.6796}{6.5843-6.7714} = \frac{350-T_4}{350-400}$$

$$\boxed{T_4 = 375.5°C}$$

$$q_{in} = (h_3-h_2)+(h_5-h_4)$$

$$= (3582.3-206.95)+(3674.9-3155.0)$$

$$= 3895.25 \text{ kJ/kg}.$$

$$q_{out} = h_6 - h_1$$

$$= 2335.77-191.81 = 2143.96 \text{ kJ/kg}.$$

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{2143.96}{3895.25} = 0.449 = 44.9\%$$

$$\approx 45\%$$

→ The Ideal Regenerative Rankine cycle

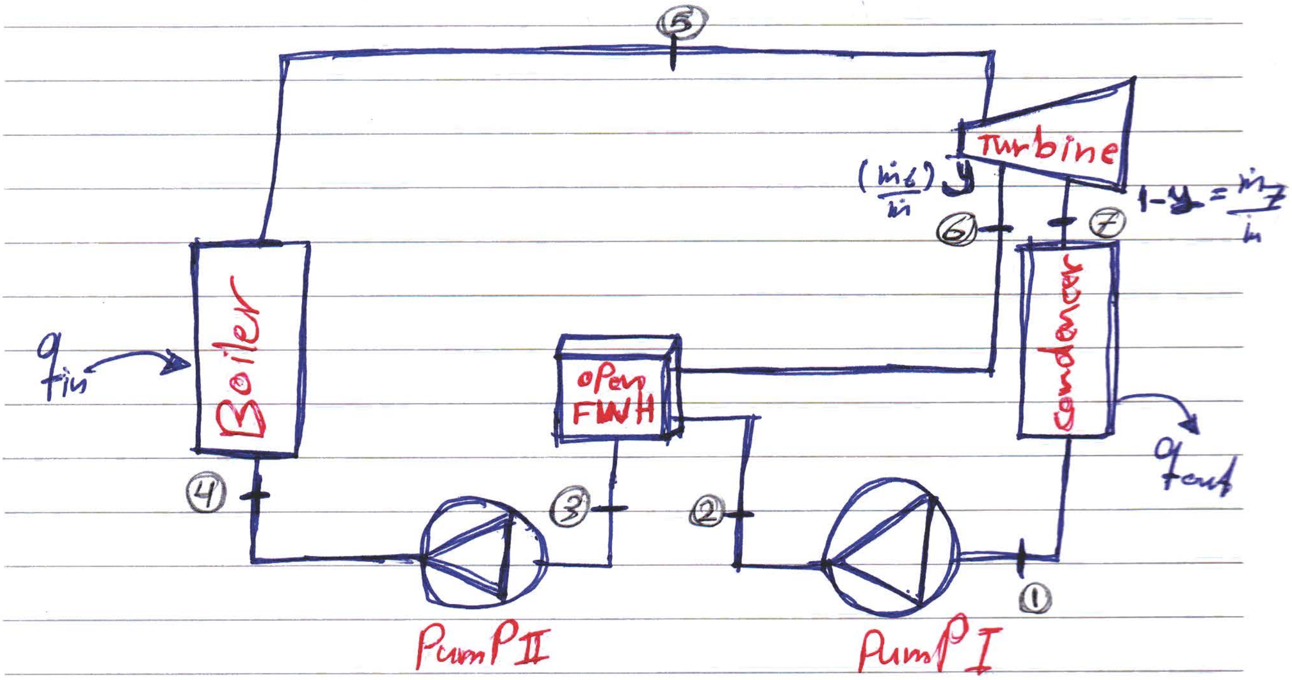
⊛ Open feedwater heaters

هي عملية خلط الـ water الخارجة من الـ Turbine مع الـ water الخارجة
من الـ Pump (ماء مضغوطة) ممكن تكون يكون heat exchanger مع بعض
يعني mixing وممكن يكون heat exchanger من دون عملية خلط.

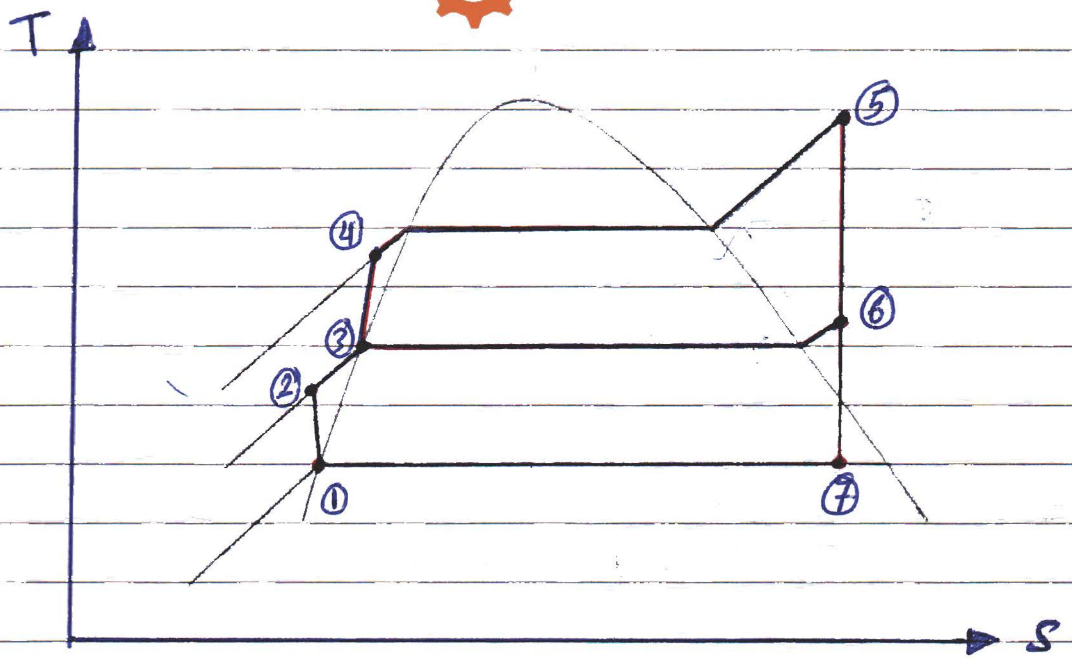
الـ Advantages :- ① حتى نزيد الـ efficiency للـ cycle.
② تقليل الـ Air lekage يعني منع الصدأ الممكن
أن يكون في الـ cycle داخل الـ Boiler

FWH :- هو عبارة Heat exchanger سواءً كان mix أو
without mix (عند نفس الضغط).

⊛ الخلط يتم حسب الـ system المطلوب وبقيم معينة حسب
الظروف المطلوبة.



-- ②⑥③ must be the same Pressure.
①⑦ the same Pressure.
④⑤ the same Pressure.



1,3 saturated liquid.
2,4 liquid.
5,6 Superheated Vapor.
7 mixing.

$S_6 = S_5 = S_7$ $T_5 = T_{max}.$

$y \Rightarrow$ fraction of steam extracted from the Turbine.

$\circledast$ $\boxed{q_{in} = h_5 - h_4}$

$$\frac{\dot{Q}_{out}}{\dot{m}} = \frac{\dot{m}_7}{\dot{m}}(h_7 - h_1)$$

$\circledast$ $\boxed{q_{out} = (1-y)(h_7 - h_1)}$

$\circledast$ $\frac{\dot{m}_6 h_6}{\dot{m}} + \frac{\dot{m}_2 h_2}{\dot{m}} = \frac{\dot{m}_3 h_3}{\dot{m}}$ $\frac{\dot{m}_2}{\dot{m}} = \frac{\dot{m}_1}{\dot{m}} = \frac{\dot{m}_7}{\dot{m}}$

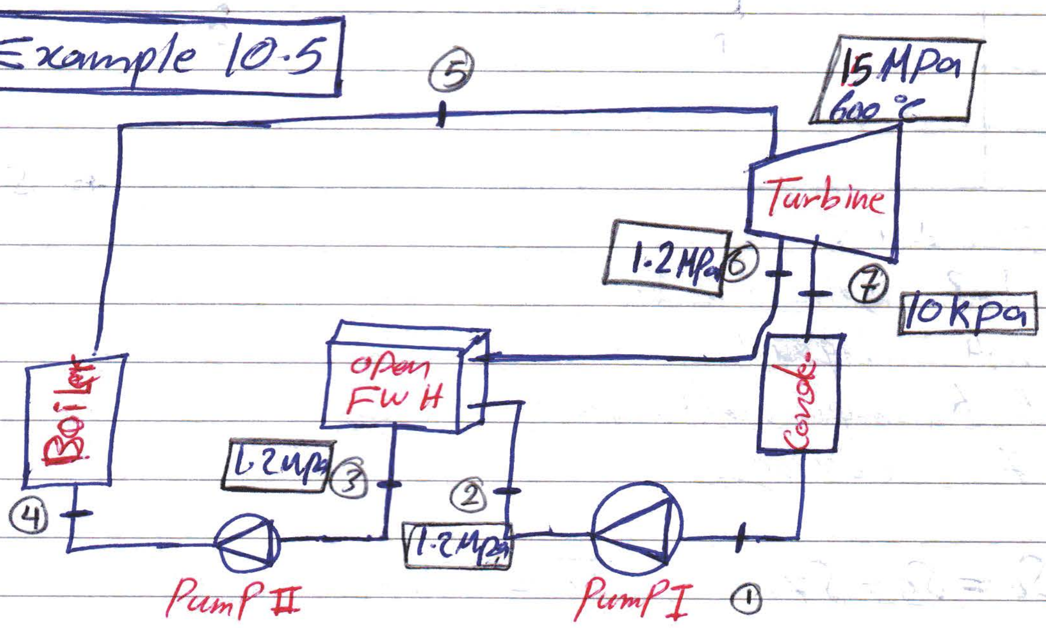
$\boxed{y h_6 + (1-y) h_2 = h_3}$

$w_{PI} = (1-y)(h_2-h_1)$ $\quad w_{PI} = v_1(P_2-P_1)$

$w_{PII} = (h_4-h_3).$ $\quad w_{PII} = v_3(P_4-P_3)$

$w_{T_{out}} = (h_5-h_6) + (1-y)(h_6-h_7)$

Example 10.5



Find :- ① y ② η_{th}

Solution $\quad y\,h_6 + (1-y)h_2 = h_3$

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

$q_{out} = (1-y)(h_7-h_1)$

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

$h_1 = 191.81$ kJ/kg.
$h_2 = 193.0119$ kJ/kg.
$h_3 = 798.33$ kJ/kg.
$h_4 = 814.0344$ kJ/kg.
$h_5 = 3583.1$ kJ/kg.
$h_6 = 2860.19$ kJ/kg.
$h_7 = 2115.3$ kJ/kg.

$P_1 = 10 kpa$, Sat. liquid $\} \Rightarrow h_1 = 191.81 \ kJ/kg$, $v_1 = 0.001010 \ m^3/kg$

$$wp_I = v_1 (P_2 - P_1) = 0.001010 (1200 - 10) = 1.2019 kJ/kg$$

$$wp_I = h_2 - h_1 \Rightarrow h_2 = wp_I + h_1 = 1.2019 + 191.81$$

$$h_2 = 193.0119 \ kJ/kg$$

$P_3 = 1200 \ kPa.$ satu. liquid $\} \Rightarrow h_3 = 798.33 \ kJ/kg.$, $v_3 = 0.001138 \ m^3/kg.$

دائماً داخل كل المضخة sat. liqui

$$wp_{II} = v_3 (P_4 - P_3) = 0.001138 (15000 - 1200)$$

$$= 15.7044 \ kJ/kg.$$

$$wp_{II} = h_4 - h_3$$

$$h_4 = wp_{II} + h_3 = 15.7044 + 798.33$$

$$= 814.0344 \ kJ/kg.$$

$P_5 = 15000 kPa$, $T_5 = 600 °C$ $\} \; h_5 = 3583.1 \ kJ/kg.$, $S_5 = 6.6796 \ kJ/kg.K.$

$P_6 = 1200 kPa$, $S_6 = 6.6796 \ kJ/kg.K$ $\} \; h_6 \Rightarrow$ Interpolation.

6.5909	2816.1
6.6796	h_6
6.8313	2935.6

$h_6 = 2860.19 \ kJ/kg$

$P_7 = 10 \ kPa$, $S_7 = 6.6796 kJ/kg.K$ $\} \Rightarrow$ mix

$$X_7 = \frac{S_7 - S_f}{S_{fg}}$$

$$= \frac{6.6796 - 0.6492}{7.4996} = 0.8041$$

$$h_7 = h_f + x h_{fg} = 191.81 + (0.8041 * 2392.1) = 2115.3 kJ/kg.$$

$$W_{PI} = (1-y)(h_2-h_1)$$

$$y = 1 - \frac{W_{PI}}{h_2-h_1} = 1 - \frac{1.2019}{193.0119-191.81} = 0$$

هاض الحل غلط راح يعطيك
صفر (مهم جداً جداً) .

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

$$y(2860.19) + (1-y)(193.0119) = 798.33$$

← على الآلة الحاسبة

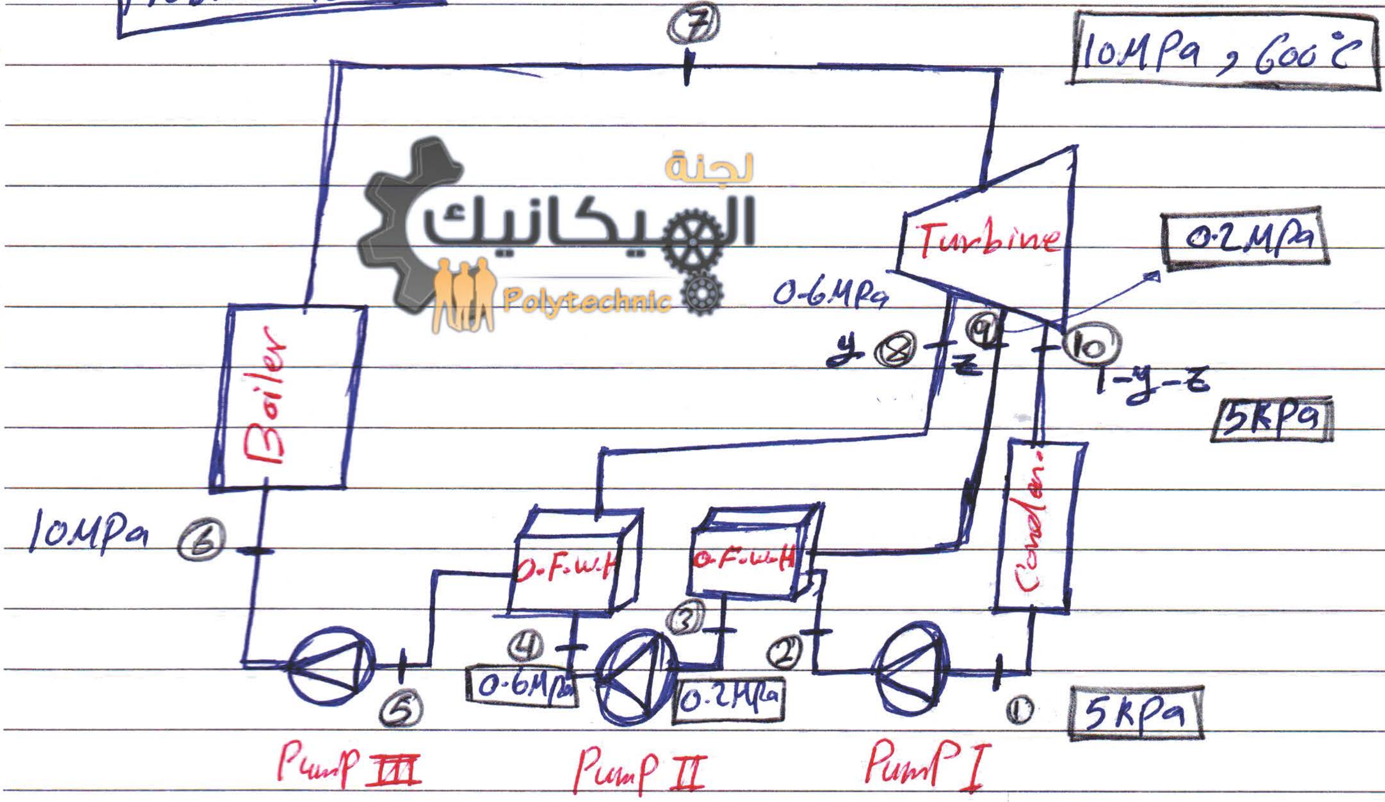
$y = 0.227$ دائماً قيمة الـ y قليلة
بـ الـ Range هاضا عادة.

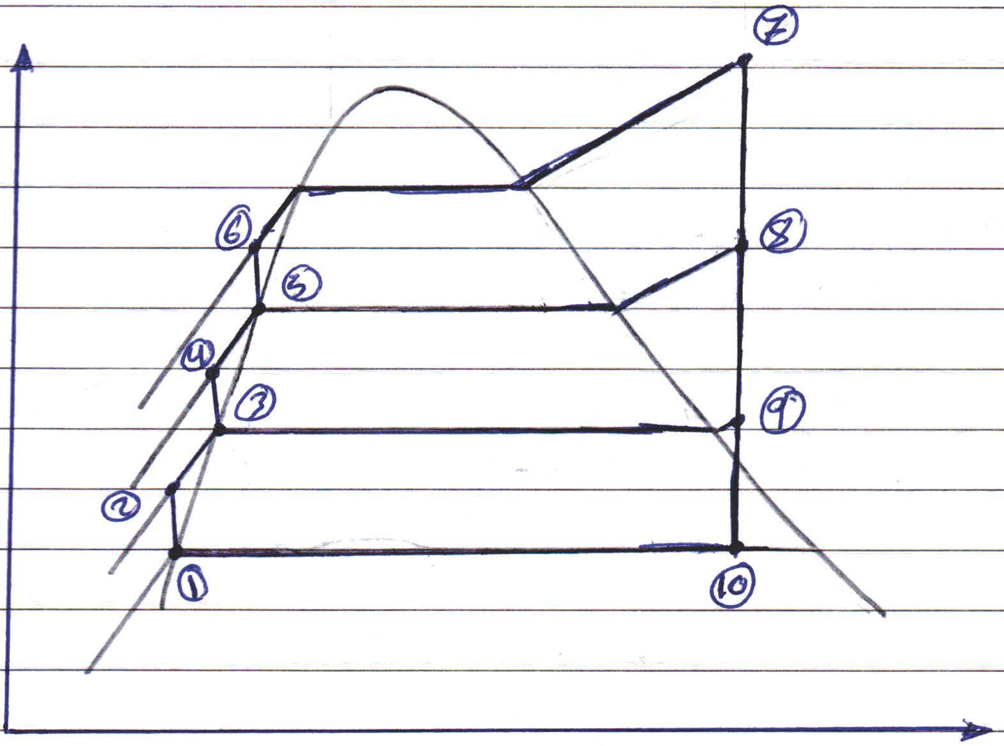
$$q_{in} = h_5 - h_4 = (3583.1 - 814.0344) = 2769.1 \text{ kJ/kg}.$$

$$q_{out} = (1-y)(h_2-h_1) = (1-0.227)(2115.3-191.81)$$
$$= 1486.9 \text{ kJ/kg}.$$

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{1486.9}{2769.1} = \boxed{0.463 = 46.3\%}$$

Problem 10.46





Find :- ① T-S ② W_{net} ③ η_{th}

$z h_9 + (1-y-z) h_2 = (1-y) h_3$

$y h_8 + (1-y) h_4 = h_5$

$q_{in} = h_7 - h_6$

$q_{out} = (1-y-z)(h_{10} - h_1)$

(specific) $w_{net} = q_{in} - q_{out}$

$W_{net} = w_{net} \times \dot{m}$

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

$h_1 = 137.75$ kJ/kg.
$h_2 = 138$ kJ/kg.
$h_3 = 504.71$ kJ/kg.
$h_4 = 505.1344$ kJ/kg.
$h_5 = 670.38$ kJ/kg.
$h_6 = 680.73$ kJ/kg.
$h_7 = 3625.8$ kJ/kg.
$h_8 = 2821.783$ kJ/kg.
$h_9 = 2618.246$ kJ/kg.
$h_{10} = 2105.226$ kJ/kg.

① $P_1 = 5$ kPa
sat. liquid $\Big\} \Rightarrow h_1 = 137.75$ kJ/kg
$v_1 = 0.001005$ m³/kg.

$w_{pI} = v_1 (P_2 - P_1) = 0.001005(200-5) = 0.196$ kJ/kg.

$w_{pI} = h_2 - h_1 \Rightarrow h_2 = w_{pI} + h_1 = 0.196 + 137.75$

$h_2 = 138$ kJ/kg.

③ $P_3 = 200$ kPa
sat. liquid $\Big\} \Rightarrow h_3 = 504.71$ kJ/kg
$v_3 = 0.001061$ m³/kg.

$w_{pII} = v_3 (P_4 - P_3) = 0.001061(600-200) = 0.4244$ kJ/kg

$h_4 = w_{pII} + h_3 = 0.4244 + 504.71$

$= 505.1344$ kJ/kg.

⑤ $P_5 = 600\ kPa$, Sat. Liquid } $h_5 = 670.38\ kJ/kg$, $v_5 = 0.001101\ m^3/kg$.

$$wp_{III} = v_5(P_6 - P_5) = 0.001101(10000 - 600) = 10.35\ kJ/kg$$

$$h_6 = wp_{III} + h_5 = 10.35 + 670.38 = 680.73\ kJ/kg.$$

⑦ $P_7 = 10000\ kPa$, $T_7 = 600\ °C$ } $h_7 = 3625.8\ kJ/kg$, $S_7 = 6.9045\ kJ/kg.K$

⑧ $P_8 = 600\ kPa$, $S_8 = 6.9045$ } h_8 = Interpolleation.

6.7593	2756.2	
6.9045	h_8	$\Rightarrow h_8 = 2821.783\ kJ/kg$
6.9683	2850.6	

⑨ $P_9 = 200\ kPa$, $S_9 = 6.9045$ }

$\boxed{\text{mixture}}$ حل السعة

$$x_9 = \frac{S_9 - S_f}{S_{fg}} = \frac{6.9045 - 1.5302}{5.5968} = 0.96$$

$$h_9 = h_f + x_9 h_{fg} = 504.71 + (0.96 * 2201.6)$$
$$= 2618.246\ kJ/kg.$$

⑩ $P_{10} = 5\ kpa$, $S_{10} = 6.9045$ } $\boxed{\text{mixture}}$

$$x_{10} = \frac{S_{10} - S_f}{S_{fg}} = \frac{6.9045 - 0.4762}{7.9176} = 0.812$$

$$h_{10} = h_f + x_{10} h_{fg} = 137.75 + (0.812 * 2423.0) = 2105.226\ kJ/kg$$

⊛ $y h_8 + (1-y) h_4 = h_5$

$y(2821.783) + (1-y)(505.1344) = 670.38$

$y = 0.07133$

⊛ $z h_9 + (1-y-z) h_2 = (1-y) h_3$

$z(2618.246) + (1-0.07133-z)(138) = (1-0.07133) \times 504.71$

$z = 0.1373$

⊛ $q_{in} = h_7 - h_6 = 3625.8 - 680.73 = \boxed{2945.07\ kJ/kg}$

⊛ $q_{out} = (1-y-z)(h_{10} - h_1)$

$= (1-0.07133-0.1373)(2105.226-137.75)$

$\boxed{q_{out} = 1557\ kJ\ kg}$

$w_{net} = q_{in} - q_{out} = 2945.07 - 1557 = 1388.07\ kJ/kg$

⊛ $W_{net} = w_{net} \times \dot{m} = 1388.07 \times 22 = 30537\ kW$

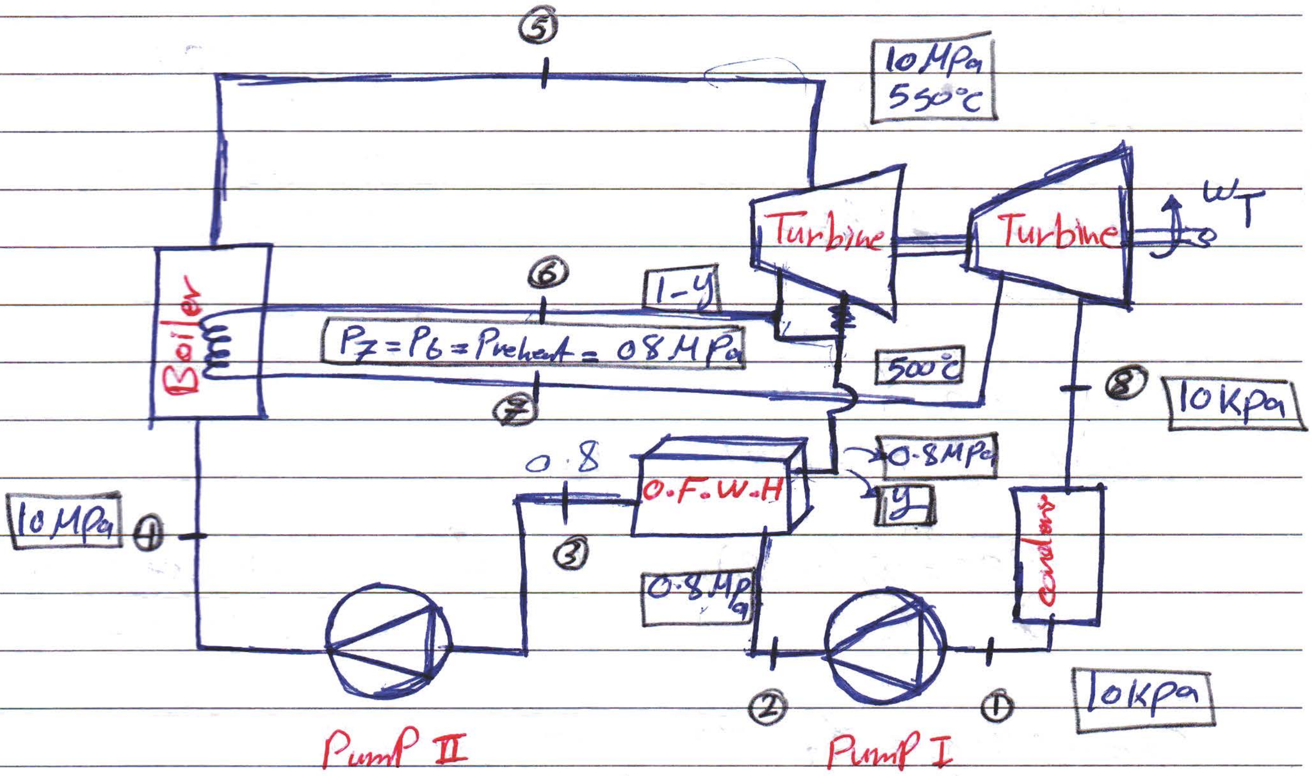
$= \boxed{30.537\ MW}$

⊛ $\eta_{th} = \left(1 - \frac{q_{out}}{q_{in}}\right) \times 100\% = \left(1 - \frac{1557}{2945.07}\right) \times 100\%$

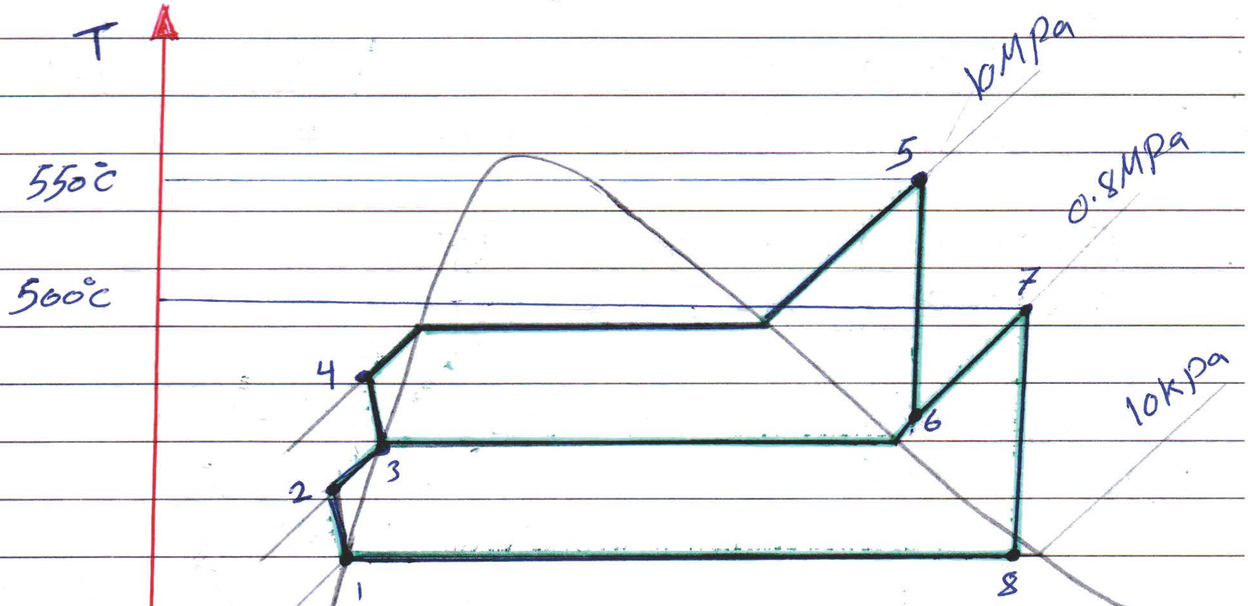
$\boxed{\eta_{th} = 47.1\%}$

Problem 10.49 exist in 5th edition

$W_{net} = 80 MW$



Find: ① T-S ② $\dot{m}$ ③ η_{th}



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

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

$$q_{out} = (1-y)(h_8 - h_1)$$

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

$h_1 = 191.81$ kJ/kg.
$h_2 = 192.61$ kJ/kg
$h_3 = 720.87$ kJ/kg.
$h_4 = 731.128$ kJ/kg
$h_5 = 3502.0$ kJ/kg
$h_6 = 2812.884$ kJ/kg
$h_7 = 3481.3$ kJ/kg
$h_8 = 2494.68$ kJ/kg.

$P_1 = 10 kPa$ } $h_1 = 191.81$ kJ/kg
sat. liquid } $v_1 = 0.001010$ m³/kg.

$$w_{pI} = v_1 (P_2 - P_1) = 0.001010(800 - 10) = 0.80 \text{ kJ/kg}$$

$$w_{pI} = h_2 - h_1 \Rightarrow h_2 = w_{pI} + h_1 = 0.80 + 191.81 = 192.61 \frac{kJ}{kg}$$

$P_3 = 0.8 MPa$ } $h_3 = 720.87$ kJ/kg.
sat. liquid } $v_3 = 0.001115$ m³/kg.

$$w_{pII} = v_3 (P_4 - P_3) = 0.001115(10000 - 800) = 10.258 \frac{kJ}{kg}$$

$$h_4 = w_{pII} + h_3 = 10.258 + 720.87 = 731.128 \text{ kJ/kg}$$

$P_5 = 10 MPa$ } $h_5 = 3502.0$ kJ/kg
$T_5 = 550°C$ } $S_5 = 6.7585$ kJ/kg.k

$P_6 = 0.8 MPa$ } ⇒ $h_6 =$ Interpolation.
$S_6 = 6.7585$ kJ/kg.k }

6.6616	2768.3
6.7585	h_6
6.8177	~~[illegible]~~ 2839.8

$h_6 = 2812.884$ kJ/kg.

$$\left.\begin{array}{l} P_7 = 0.8\,MPa \\ T_7 = 500C \end{array}\right\} \begin{array}{l} h_7 = 3481.3\ kJ/kg. \\ S_7 = 7.8692\ kJ/kg.k. \end{array}$$

$$\left.\begin{array}{l} P_8 = 10\,kPa \\ S_8 = 7.8692\,kJ/kg.k \end{array}\right\} \text{mixture.}$$

$$x_8 = \frac{S_8 - S_f}{S_{fg}} = \frac{7.8692 - 0.6492}{7.4996} = 0.9627$$

$$h_8 = h_f + x h_{fg} = 191.81 + (0.9627 * 2392.1)$$
$$= 2494.68\ kJ/kg$$

$$\Rightarrow y\,(2812.884) + (1-y)(192.61) = 720.87$$

$$y = 0.2016$$

$$q_{out} = (1-y)(h_8 - h_1) = (1-0.2016)(2494.68 - 191.81)$$
$$= 1838.61\ kJ/kg.$$

$$q_{in} = (h_5 - h_4) + (h_7 - h_6)(1-y)$$
$$= (3502.0 - 731.128) + (3481.3 - 2812.884)(1-0.2016)$$
$$= 3304.53\ kJ/kg.$$

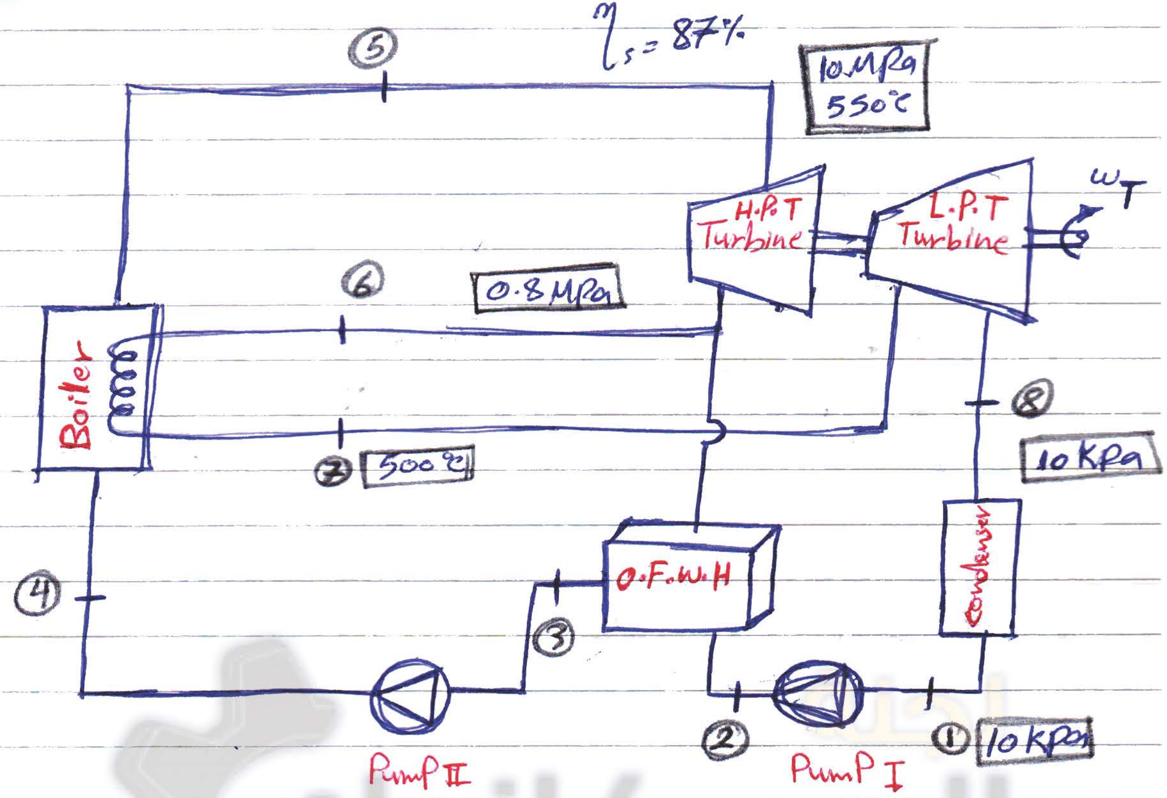
$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{1838.61}{3304.53} * 100\% = 44.36\%$$

$$w_{net} = \frac{\dot{W}_{net}}{\dot{m}} \Rightarrow \dot{m} = \frac{\dot{W}_{net}}{w_{net}}$$

$$w_{net} = q_{in} - q_{out} = 3304.53 - 1838.61 = 1465.92\ kJ/kg$$

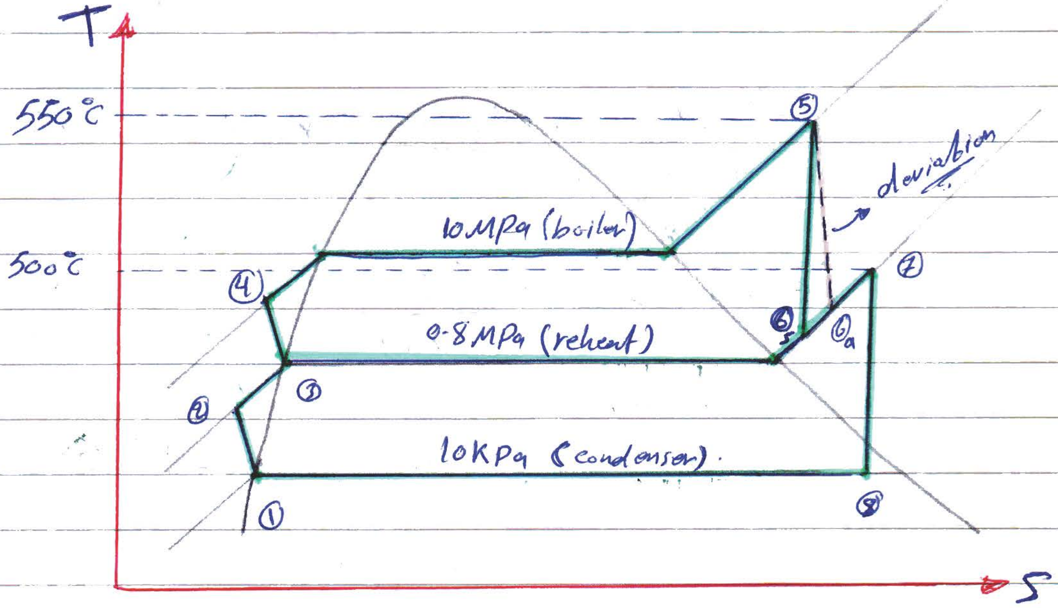
$$\dot{m} = \frac{80000}{1465.92} = 54.57\ kg/s$$

Example $W_{net} = 80\ MW$



Knowing that isentropic efficiency for high Pressure turbine is 87% $\eta_{s_{H.P}} = 87\%$

Find :- ① T-S ② $\dot{m}$ ③ Power for each Pump
④ η_{th}.



$\boxed{\text{Solution}}$

$$\left.\begin{array}{l} P_1 = 10\ \text{kPa} \\ \text{sat. liquid} \end{array}\right\} \begin{array}{l} h_1 = 191.81\ \text{kJ/kg.} \\ v_1 = 0.001010\ \text{m}^3/\text{kg.} \end{array}$$

$$w_{pI} = v_1 (P_2 - P_1) = 0.001010(800 - 10) = 0.80\ \text{kJ/kg}$$

$$h_2 = w_{pI} + h_1 = 0.80 + 191.81 = 192.61\ \text{kJ/kg.}$$

$$\left.\begin{array}{l} P_3 = 0.8\ \text{MPa} \\ \text{sat. liquid} \end{array}\right\} \begin{array}{l} h_3 = 720.87\ \text{kJ/kg} \\ v_3 = 0.001115\ \text{m}^3/\text{kg} \end{array}$$

$$w_{pII} = v_3 (P_4 - P_3) = 0.001115\ (10000 - 800) = 10.258\ \text{kJ/kg}$$

$$h_4 = w_{pII} + h_3 = 10.258 + 720.87 = 731.128\ \text{kJ/kg.}$$

$$\left.\begin{array}{l} P_5 = \cancel{3}10\ \text{MPa} \\ T_5 = 550^\circ\text{C} \end{array}\right\} \begin{array}{l} h_5 = 3502.0\ \text{kJ/kg.} \\ s_5 = 6.7585\ \text{kJ/kg.K .} \end{array}$$

$$\left.\begin{array}{l} P_{6s} = 0.8\ \text{MPa} \\ s_5 = s_{6s} = 6.7585 \end{array}\right\} h_{6s} = \text{Interpolleation}$$

$$h_{6s} = 2812.884\ \text{kJ/kg.}$$

$$\eta_s = \frac{w_a}{w_s} = \frac{h_5 - h_{6a}}{h_5 - h_{6s}}$$

$$0.87 = \frac{3502.0 - h_{6a}}{3502.0 - 2812.884} \Rightarrow h_{6a} = 2902.47\ \text{kJ/kg}$$

$$\left.\begin{array}{l} P_7 = 0.8\ \text{MPa} \\ T_7 = 500^\circ\text{C} \end{array}\right\} \begin{array}{l} h_7 = 3481.3\ \text{kJ/kg.} \\ s_7 = 7.8692\ \text{kJ/kg.K.} \end{array}$$

$$\left.\begin{array}{l} P_8 = 10\text{kPa.} \\ s_8 = s_7 = 7.8692\ \text{kJ/kg.K} \end{array}\right\} \text{mixture.}$$

$$x_8 = \frac{s_8 - s_f}{s_{fg}} = \frac{7.8692 - 0.6492}{7.4669} = 0.9827$$

$$h_8 = h_f + x h_{fg} = 2494.68 \text{ kJ/kg}.$$

$$y = 0.2016$$

$$q_{out} = (1-y)(h_8 - h_1) = 1838.61 \text{ kJ/kg},$$

$$q_{in} = (h_5 - h_4) + (h_7 - h_6)(1-y)$$
$$= 3233 \text{ kJ/kg}.$$

$$\eta_{th} = \left(1 - \frac{q_{out}}{q_{in}}\right) \times 100\% = \left(1 - \frac{1838.61}{3233}\right) \times 100\%,$$

$$= \cancel{43}\ 43.13\%$$

$$w_{net} = q_{in} - q_{out} = 1394.4 \text{ kJ/kg}.$$

$$\dot m = \frac{W_{net}}{w_{net}} = \frac{80000}{1394.4} = 57.37 \text{ kg/s}$$

$$w_{PI} = 0.8 \text{ kJ/kg}.$$
$$w_{PII} = 10.258 \text{ kJ/kg}$$

$$W_{PI} = \dot m_I\, w_{PI}$$

$$W_{PI} = 45.8 \times 0.8 = 36.64 \text{ k}\overset{W}{\cancel{J}}$$

$$W_{PII} = \dot m\, w_{PII} = 57.37 \times 10.258$$
الكلية
$$= 588.5 \text{ kW}$$

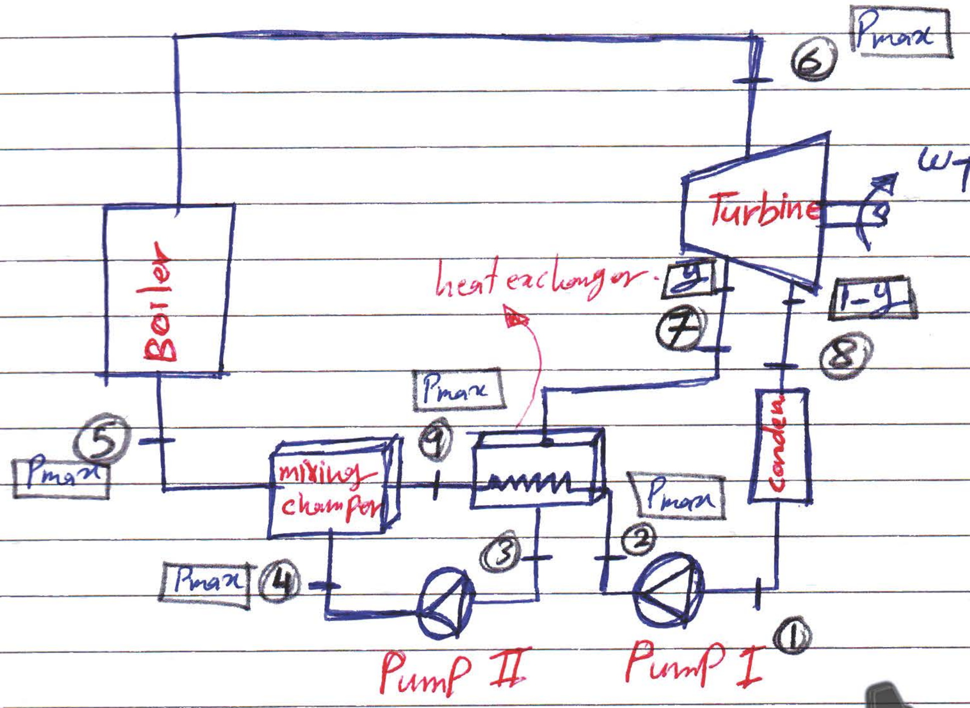
$$1 - y = \frac{\dot m_1}{\dot m}$$
$\dot m \rightarrow \dot m$ الكلية

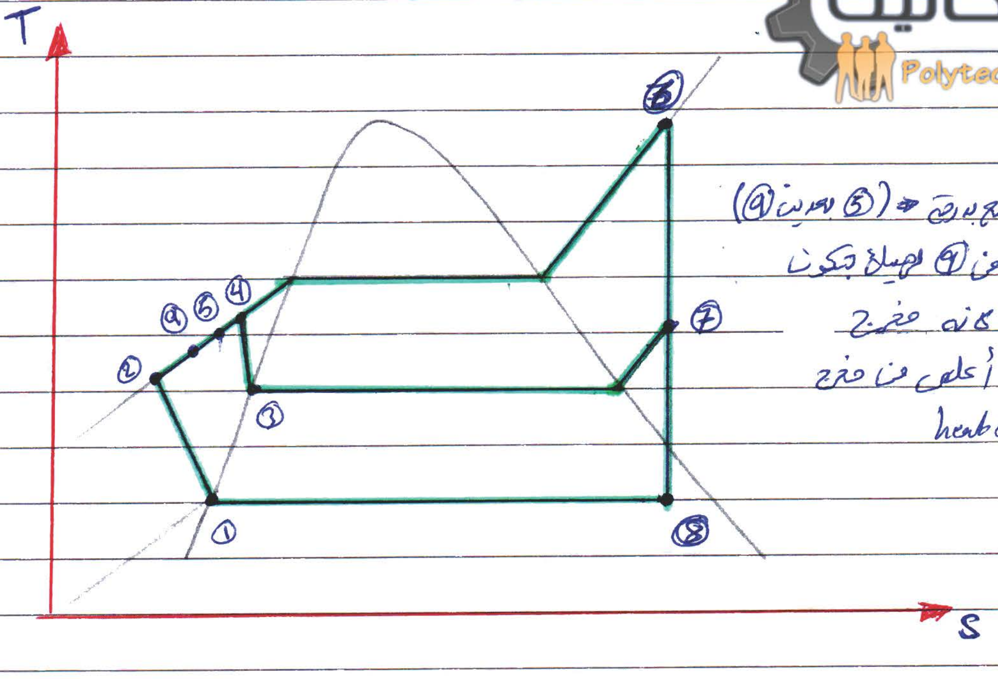
$$1 - 0.2016 = \frac{\dot m_I}{57.37}$$

$$\dot m_I = 45.8 \text{ kg/s}.$$

⊛ Closed Feedwater heater.

⊗ ما بيصير فيه خلط مباشر بل يصير فيه انتقال حرارة عن طريق
heat exchanger له مدخلين ومخرجين .





جـ نوع ⑤ تطلع بدرجة ⇐ (⑤ بعدين ⑨)
حرارة أعلى من ⑨ الهيلة بتكون
أكبر . لأنه مخرج
الـ mixing أعلى من مخرج
الـ heat excha.

$P_2 = P_6 = P_5 = P_9 = P_4 \Rightarrow$ mixing [illegible] and ~~P~~ ∴ P_2 الداخل على نفس خط
heat exch. على

$$y h_7 + (1-y) h_2 = y h_3 + (1-y) h_9$$

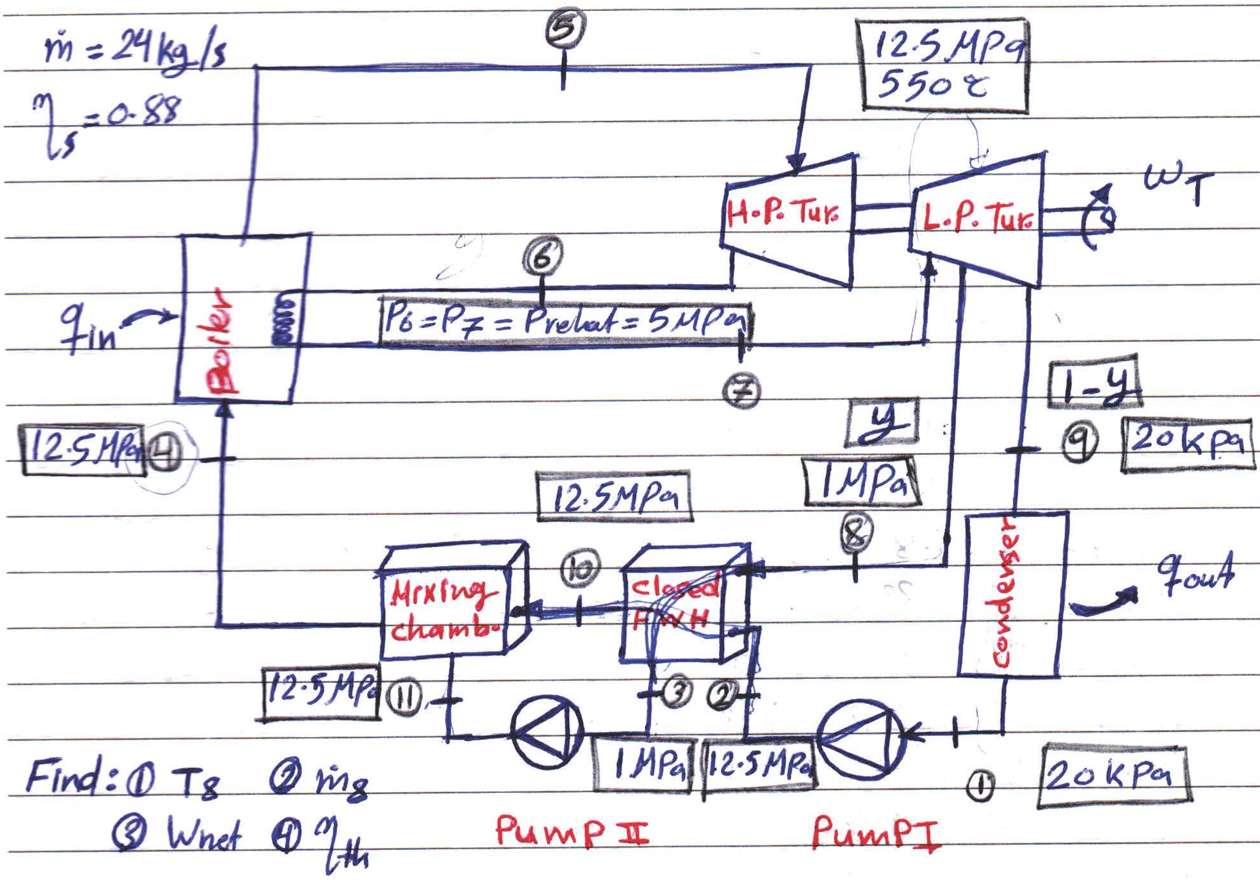
$$(1-y) h_9 + y h_4 = h_5$$

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

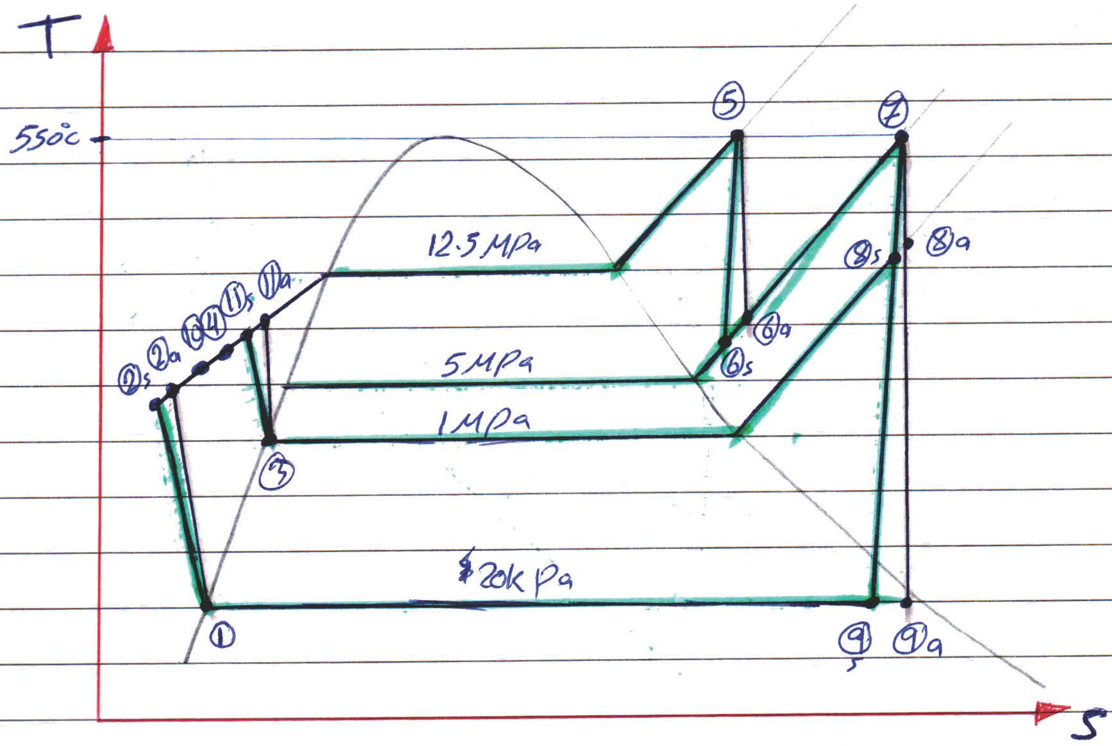
$$w_{P_I} = (1-y)(h_2 - h_1) \qquad w_{P_{II}} = y(h_4 - h_3)$$

$$q_{in} = h_6 - h_5 \qquad q_{out} = (1-y)(h_8 - h_1)$$

Problem 10.52 Exist in 5th edition



Find: ① T_8 ② $\dot m_8$
③ W_{net} ④ η_{th}



$y h_8 + (1-y) h_2 = y h_3 + (1-y) h_{10}$

$y h_{10} + (1-y) h_{11} = \cancel{y}\, h_4$

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

$q_{out} = (1-y)(h_9 - h_1)$

$h_1 = 251.42$ kJ/Kg.

$h_{2s} = 264.11$ KJ/kg.

$h_{2a} = 265.84$ KJ/Kg. $h_3 = 762.51$ KJ/kg.

$h_4 = 774.32$ kJ/kg

$h_5 = 3476.5$ kJ/kg.

$h_{6s} = 3185.948$ kJ/kg.

$h_{6a} = 3220.814$ kJ/kg.

$h_7 = 3550.8$ kJ/kg.

$h_{8s} = 3048.7$ kJ/kg.

$h_{8a} = 3108.952$ kJ/Kg.

$h_{9s} = 2083.978$ kJ/kg.

$h_{9a} = 2260$ kJ/kg.

$h_{10} = 769$ kJ/kg.

$h_{11s} = 775.47$ kJ/kg.

$h_{11a} = 777.237$ kJ/kg.

$P_1 = 20\,kpa$, sat. liquid $\Big\}$ $h_1 = 251.42\ kJ/kg$. $v_1 = 0.001017\ m^3/kg$.

$$w_{PI} = v_1 (P_2 - P_1) = 0.001017 (12500 - 20) = 12.692\ kJ/kg.$$

$$h_{2s} = w_{PI} + h_1 = 12.692 + 251.42 = 264.11\ kJ/kg.$$

$$\eta_{sP} = \frac{w_s}{w_a} = \frac{h_1 - h_{2s}}{h_1 - h_{2a}} \Rightarrow 0.88 = \frac{251.42 - 264.11}{251.42 - h_{2a}}$$

$$h_{2a} = 265.84\ kJ/kg.$$

$P_3 = 1000\,kPa$, sat. liquid $\Big\}$ $h_3 = 762.51\ kJ/kg$. $v_3 = 0.001127\ m^3/kg$.

$$w_{PII} = v_3 (P_{11} - P_3) = 0.001127 (12500 - 1000) = 12.9605\ kJ/kg$$

$$h_{11s} = w_{PII} + h_3 = 12.9605 + 762.51 = 775.47\ kJ/kg.$$

$$0.88 = \frac{762.51 - 775.47}{762.51 - h_{11a}} \Rightarrow h_{11a} = 777.237\ kJ/kg.$$

X Also $h_4 = h_{10} = h_{11} = 777.237\ kJ/kg$ since the two fluid streams which are being mixed have the samenthalpy.

هذا الفرض لا تعتبره ↑ واح نعتقد فرض ثاني تابعونا

$P_3 = 1000\,kpa$, sat. liquid $\Big\}$ $T_3 = T_s = T_{10} = 179.88\,°C$

$\rightarrow T < T_s \quad P > P_s$

$P_{10} = 12500\,kPa$, $T_{10} = 179.88\,°C$ $\Big\}$ …… Phase $\Rightarrow$ Compressed liquid water.

10000 kpa 767.68

12500 kpa h_{10} $\Rightarrow h_{10} = 769\ kJ/kg$

15000 kpa 770.32

$T_s @ P_{10} = 327.84\,K$

$T_s > T \Rightarrow$ compressed liquid.

$P_5 = 12500\,kPa$, $T_5 = 550°c$ $\Big\}$ $h_5 = 3476.5\ kJ/kg$, $S_5 = 6.6317\ kJ/kg.s$

$P_{6s} = 5000\,kPa$, $S_5 = S_{6s} = 6.6317$ $\Big\}$ h_{6s} = Interpollcation

6.4516	3069.3	
6.6317	h_{6s}	$\Rightarrow h_{6s} = 3185.948\ kJ/kg$
6.6483	3196.7	

$$\eta_{ST} = \frac{W_a}{W_s} = \frac{h_5 - h_{6a}}{h_5 - h_{6s}}$$

$$0.88 = \frac{3476.5 - h_{6a}}{3476.5 - 3185.948} \Rightarrow h_{6a} = 3220.814\ kJ/kg$$

$P_7 = 5000\,kPa$, $T_7 = 550\,C$ $\Big\}$ h_7 = Interpollcation, S_7 = Interpollcation

500	3434.7	
550	h_7	$\Rightarrow h_7 = 3550.8\ kJ/kg$
600	3666.9	

500	6.9781	
550	S_7	$\Rightarrow S_7 = 7.1193\ kJ/kg.K$
600	7.2605	

$P_8 = 1000\,kPa$, $S_{8s} = S_7 = 7.1193\ kJ/kg.K$ $\Big\}$ h_{8s} = Interpollcation $= 3048.7\ kJ/kg$

$$0.88 = \frac{3550.8 - h_{8a}}{3550.8 - 3048.7} \Rightarrow h_{8a} = 3108.952\ kJ/kg$$

$P_9 = 20$ kpa. } mixture.

$S_{9_s} = S_7 = 7.1193$ kJ/kg.k

$$x_{9s} = \frac{S_{9s} - S_f}{S_{fg}} = \frac{7.1193 - 0.2965}{8.3696} = 0.815188$$

$$h_{9s} = h_f + x_{9s} * h_{fg} = 83.915 + (0.815188 * 2453.5)$$

$= 2083.978$ kJ/kg.

$$0.88 = \frac{3550.8 - h_{9a}}{3550.8 - 2083.978}$$ $h_{9a} =$ ~~2259~~ 2260 kJ/kg

$$y h_8 + (1-y) h_2 = y h_3 + (1-y) h_{10}$$

$y = 0.177$

$h_4 = y h_{10} + (1-y) h_{11} \Rightarrow h_4 = 774.32$ kJ/kg.

$\frac{\dot{m}_8}{\dot{m}} = y$ $\quad \dot{m}_8 = y \dot{m} = 0.177 * 24 = 4.248$ kg/s.

$q_{in} = 3032.166$ kJ/kg $\quad q_{out} = 1653.06$ kJ/kg.

$w_{net} = q_{in} - q_{out} = 1379.106$ kJ/kg

$W_{net} = \dot{m}\, w_{net} = 24 * 1379.106 = 33.09$ MW.

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 0.453 = \boxed{45.3\%}$$

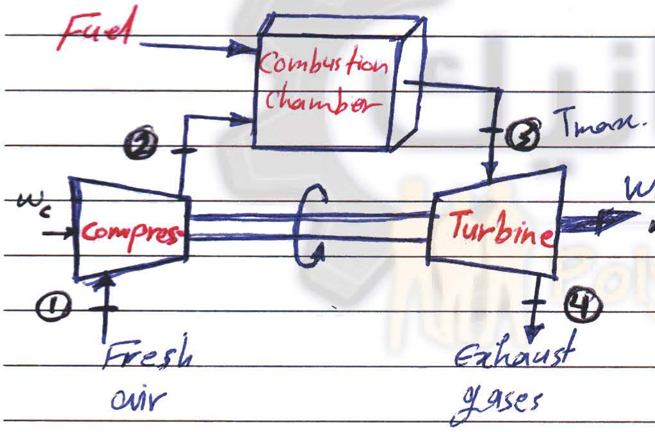
Ch 9: Gas Turbine Power Plant.

- هو عبارة عن دورة هواء (مثل محطة السمراء في الزرقاء).
- الكفاءة بتصل من 50% إلى 56%.
- راح نتكلم في هذه المحطة عن Brayton cycle.

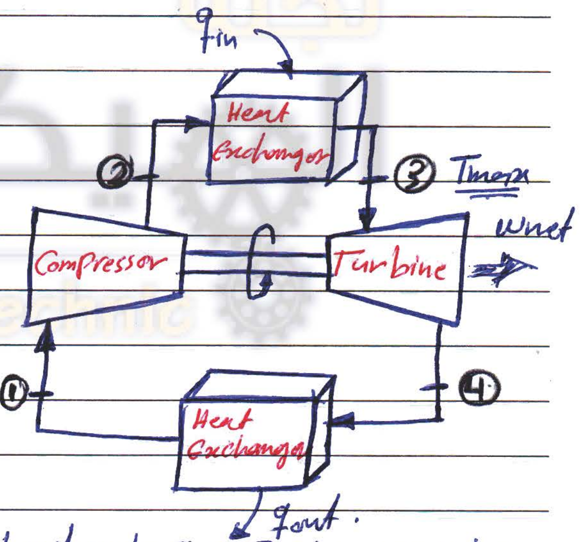
Brayton cycle :- The ideal cycle for gas-Turbine Engines. used in :-

① reciprocating oil-burning engine.

~~Today~~ ② Gas Turbines only where both the Compression and expansion Processes take place in rotating machinery.



An open cycle gas turbine engine.



A closed cycle gas Turbine engine.

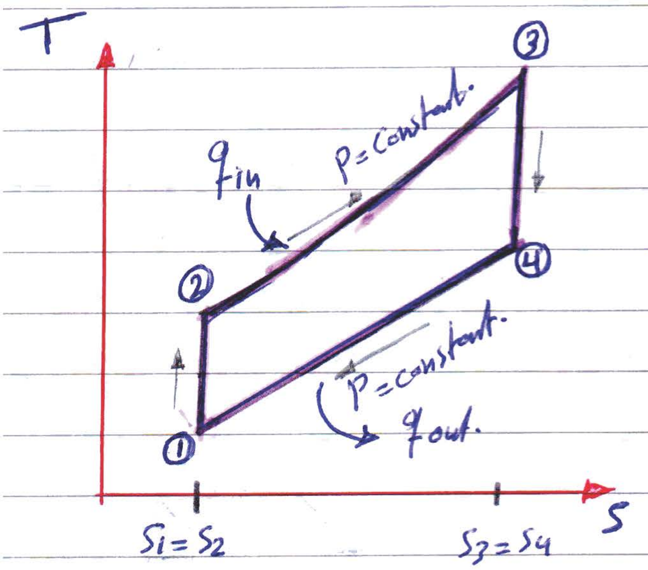
يدخل الـ Fresh air للـ Compresser وهذا الـ Comp. يضغط الهواء للـ Combu.chamb ويدخل مع الـ Fuel حتى يحرق ويسخن هذا الهواء ويرفع حرارته ليصل الى درجة حرارة ③ ((Tmax)) ثم يدخل في الـ Turbine ليدور الـ shaft حتى يولد طاقة حسب الحث الكهربائي ومن يخرج الغاز أو الهواء الساخن من الـ Exhaust.

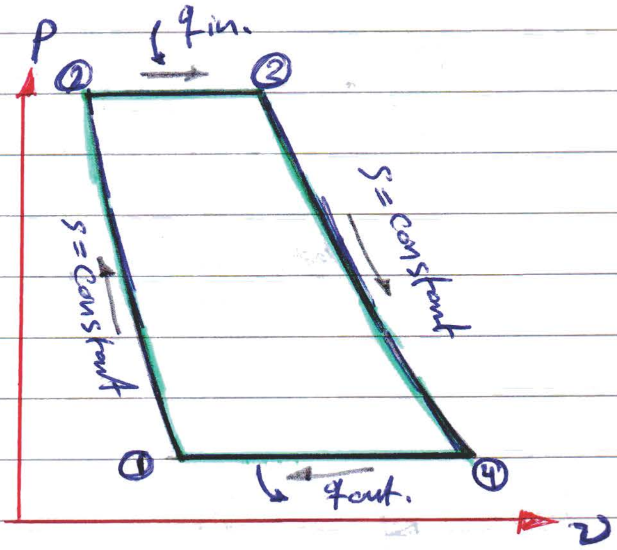
$W_{net} = W_T - W_C$

الـ Closed نفس الـ open لكن الفرق الوحيد هو بدل من خسران الهواء الخارج من الـ Exhust فإننا نستفيد منه وننقله heat exchangers ونعيده إلى الـ Compre. حتى يعود في دورة جديدة.

⊛ Closed - cycle gas- Turbine engine:-

1 → 2 Isentropic Compression (in a compressor).
2 → 3 Constant Pressure heat addition.
3 → 4 Isentropic expansion (in a turbine).
4 → 1 Constant Pressure heat rejection.





$q = (h_2 - h_1) = C_p(T_2 - T_1)$ · ① assume constant specific
$Q = \dot{m}(h_2 - h_1) = \dot{m} c_p (T_2 - T_1)$ · heat @ room Temperature.

$\boxed{1 \to 2}$ Compressor

$$\frac{T_2}{T_1} = \left[\boxed{\frac{P_2}{P_1}}\right]^{\frac{k-1}{k}} = \boxed{r_p}^{\frac{k-1}{k}}$$ Pressure ratio.

$W_c = C_p(T_2 - T_1) = h_2 - h_1$
↳ Specific heat @ constant Pressure = 1.004 kJ/kg·K
↳ k for air = 1.4

$\boxed{2 \to 3}$ heat exchanger

$$q_{in} = h_3 - h_2 = Cp(T_3 - T_2).$$

$\boxed{3 \to 4}$ Turbine.

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{k-1}{k}} = (rp)^{\frac{k-1}{k}}$$

$$w_T = h_3 - h_4 = Cp(T_3 - T_4).$$

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} = \left(\frac{1}{rp}\right)^{\frac{k-1}{k}}$$

$\boxed{4 \to 1}$ heat exchanger.

Specific heat ← $q_{out} = h_4 - h_1 = Cp(T_4 - T_1).$

$$\frac{T_3}{T_1} = rp$$

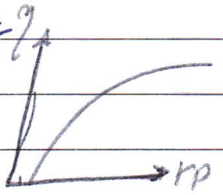
$$\dot{Q}[kw] = q\,[kJ/kg] \times \dot{m}\,[kg/s]$$

Prove important

$$\eta_{th} = \frac{W_{net}}{q_{in}} = \frac{w_T - w_c}{q_{in}} = \frac{q_{in} - q_{out}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}}$$

$$= 1 - \frac{\cancel{Cp}(T_4 - T_1)}{\cancel{Cp}(T_3 - T_2)} = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}$$

$$= 1 - \frac{T_1\left(\frac{T_4}{T_1} - 1\right)}{T_2\left(\frac{T_3}{T_2} - 1\right)}$$



$$\frac{T_2}{T_1} = rp^{\frac{k-1}{k}} = \frac{T_3}{T_4} = rp^{\frac{k-1}{k}}$$

$$\frac{T_2}{T_1} = \frac{T_3}{T_4} \therefore \frac{T_4}{T_1} = \frac{T_3}{T_2} = A$$

$$= 1 - \frac{T_1\,\cancel{(A-1)}}{T_2\,\cancel{(A-1)}}$$

$$\eta_{th} = 1 - \frac{T_1}{T_2} = \boxed{1 - \frac{1}{rp^{\frac{k-1}{k}}}}$$

\# كلما زاد rp زادت η_{th}

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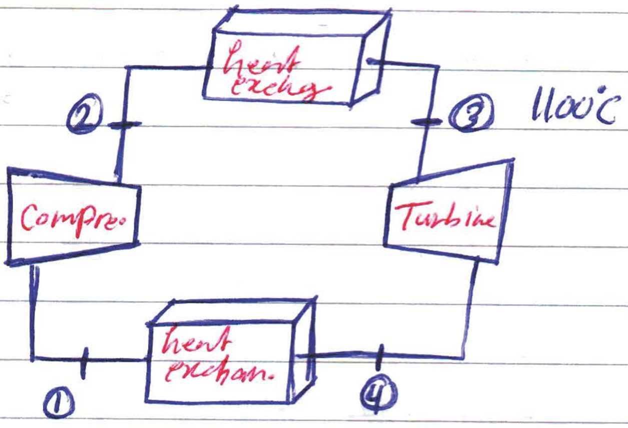
④ Back work ratio :- (w_b)

$$w_b = \frac{w_c}{w_T}$$

④ $r_p = \frac{P_2}{P_1} = \frac{P_3}{P_4}$

Example



Find :- ① W_c

② w_T

③ η_{th}

100 kPa

20°C

$r_p = 12$ $\dot{m} = 10\ kg/s$

Solution

$\boxed{1\to2}$ $\frac{T_2}{T_1} = (r_p)^{\frac{k-1}{k}}$

$$\frac{T_2}{20+273.15} = (12)^{\left(\frac{1.4-1}{1.4}\right)}$$

$T_2 = 596.24\ K$

$T_2 = 323.09\ °C$

$$w_c = C_p(T_2 - T_1)$$
$$= 1.004(596.24 - 293.15) = 304.3\ kJ/kg$$

$$W_c = \dot{m}\, w_c = 3043\ kW$$

$\boxed{3 \to 4}$ $\frac{T_3}{T_4} = rp^{\frac{k-1}{k}}$

$\frac{1100+273.15}{T_4} = 12^{\frac{1.4-1}{1.4}}$ $T_4 = 675.12\ °k$

$T_4 = 401.97\ °C$

$w_T = cp(T_3 - T_4) = 1.004(1373.15 - 675.12)$

$= 700.82\ kJ/kg$

$W_T = \dot{m} w_T = 7008.2\ Kw.$

⊗ لازم يكون w_T أكبر من w_c ⊗

$q_{in} = Cp(T_3 - T_2) = 780.017\ KJ/kg.$

$Q_{in} = \dot{m}\, q_{in} = 7800.17\ Kw.$

$q_{out} = cp(T_4 - T_1) = 1.004 * (675.12 - 293.15)$

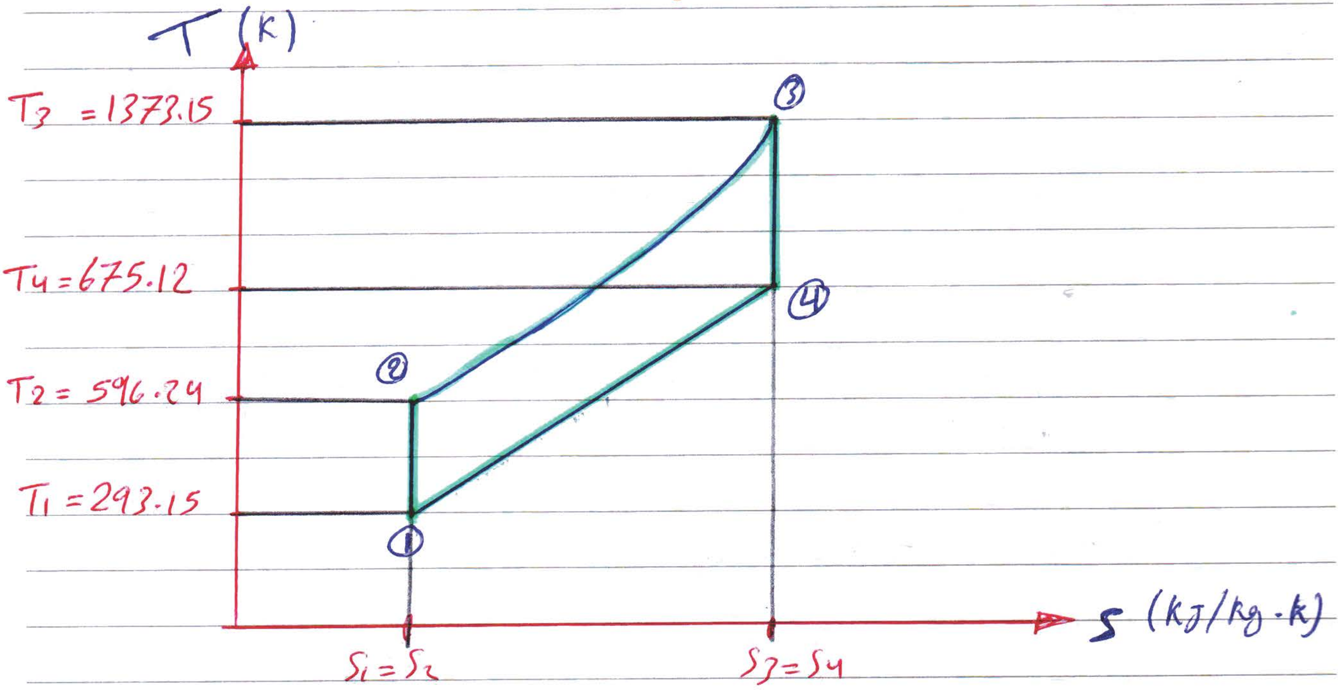
$= 383.5\ KJ/kg$

$Q_{out} = \dot{m}\, q_{out} = 3835\ Kw.$

$\eta_{th} = \frac{W_{net}}{Q_{in}} = \frac{W_T - W_c}{Q_{in}}$

$= \frac{7008.2 - 3043}{7800.17} * 100\% = 50.83\%$

$wb = \frac{w_c}{w_T} = \frac{3043}{7008.2} = 0.43$

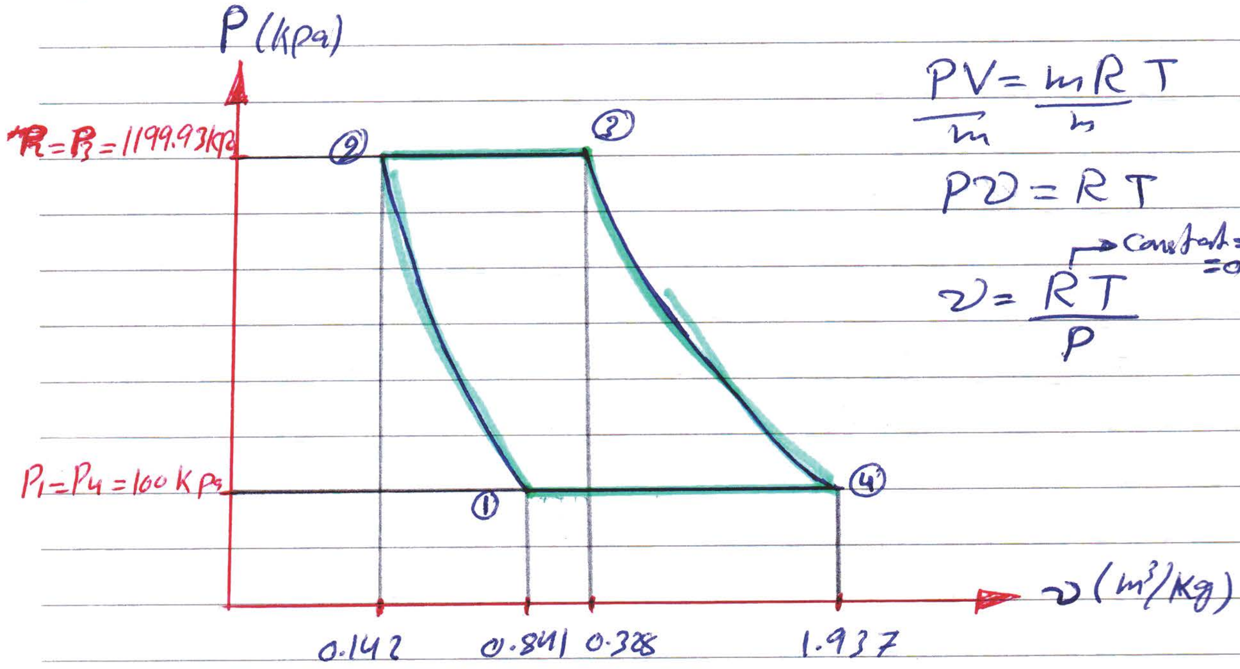


$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \qquad \frac{596.24}{293.15} = \left(\frac{P_2}{100}\right)^{\frac{1.4-1}{1.4}}$$

$P_2 = 1199.93$ kPa.

$P_1 = P_4 = 100$ kPa

$P_2 = P_3 = 1199.93$ kPa.



$$\frac{PV}{m} = \frac{mRT}{m}$$

$$P\upsilon = RT$$

$$\upsilon = \frac{\overset{\xrightarrow{\text{Constant} = 0.287 \text{ kJ/kg.k}}}{R}T}{P}$$

① $v_1 = \frac{RT_1}{P_1} = \frac{0.287 * 293.15}{100} = 0.841\ m^3/Kg$

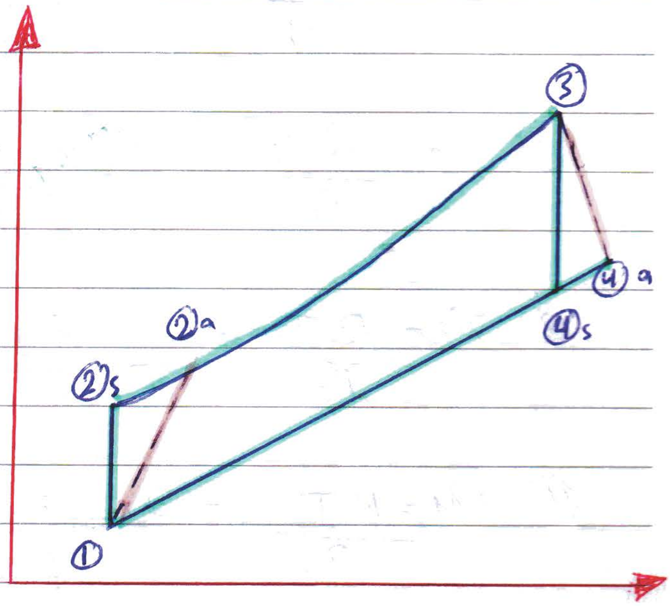
② $v_2 = \frac{RT_2}{P_2} = \frac{0.287 * 596.24}{1199.93} = 0.142\ m^3/kg$

③ $v_3 = \frac{RT_3}{P_3} = \frac{0.287 * 1373.15}{1199.93} = 0.328\ m^3/kg.$

④ $v_4 = \frac{RT_4}{P_4} = \frac{0.287 * 675.12}{100} = 1.937\ m^3/kg.$

$\eta_{th.Brytan} = 1 - \frac{1}{rp^{\frac{k-1}{k}}} = 1 - \frac{1}{(12)^{\frac{1.4-1}{1.4}}} = 0.5083$

$= 50.83\%$



⊛ Deviation :-

⊛ $\frac{T_{2s}}{T_1} = (r_p)^{\frac{k-1}{K}}$

$W_{sc} = C_p(T_{2s} - T_1)$

$\eta_{sc} = \frac{W_{sc}}{W_{ac}} \Rightarrow W_{ac}$

$W_{ac} = C_p(T_{2a} - T_1)$

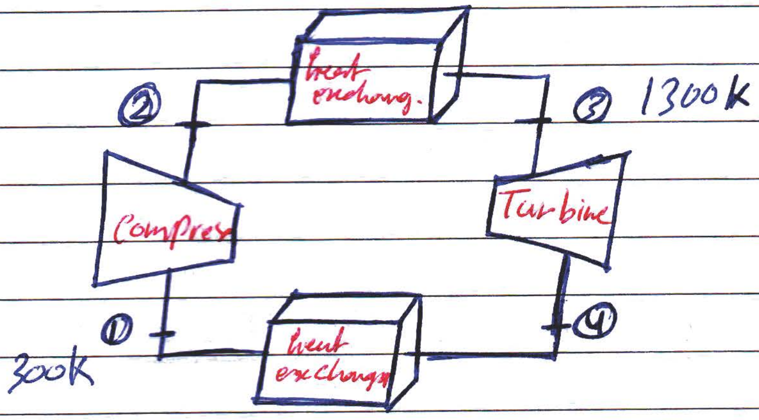
$$\eta_{sc} = \frac{W_{sc}}{W_{ac}} = \frac{\cancel{C_p}(\boxed{T_{2s}} - T_1)}{\cancel{C_p}(T_{2a} - T_1)}$$

⊛ $\frac{T_3}{T_{4s}} = r_p^{\frac{k-1}{K}}$

$W_{sT} = C_p(T_3 - T_{4s})$ $\eta_{sT} = \frac{W_{aT}}{W_{sT}} \Rightarrow W_{aT} = C_p(T_{4a} - T_3)$.

$$\eta_{sT} = \frac{W_{aT}}{W_{sT}} = \frac{\cancel{C_p}(T_{4a} - T_3)}{\cancel{C_p}(T_{4s} - T_3)}$$

$\boxed{\text{Example}}$ $\eta_{sc} = 80\%$ $\eta_{sT} = 85\%$ $rp = 8$



Find :- W_b

η_{th}

T_{4a}

$T_1 = 300$ K.

$T_{2s} = 543.43$ K.

$T_{2a} = 604.28$ K.

$T_3 = 1300$ K.

$T_{4s} = 717.658$ K.

$T_{4a} = 805$ K

$\boxed{\text{Solution}}$

$$\frac{T_{2s}}{T_1} = rp^{\frac{k-1}{k}} \Rightarrow T_{2s} = 543.43K$$

$$w_{sc} = CP(T_{2s} - T_1)$$
$$= 1.004(543.43 - 300) = 244.4 \text{ kJ/kg}.$$

$$\eta_{sc} = \frac{W_{sc}}{W_{ac}} \Rightarrow w_{ac} = \frac{w_{sc}}{\eta_{sc}} = \frac{244.4}{0.80} = 305.5 \text{ kJ/kg}.$$

$$w_{ac} = CP(T_{2a} - T_1) \Rightarrow T_{2a} = 604.28 \text{ K}.$$

$$\frac{T_3}{T_{4s}} = rp^{\frac{k-1}{k}} \Rightarrow T_{4s} = 717.658 \text{ K}$$

$$W_{sT} = CP(T_3 - T_{4s}) = 584.67 \text{ kJ/kg}.$$

$$W_{aT} = W_{sT} * \eta_{sT} = 584.67 * 0.85 = 496.97 \text{ kJ/kg}.$$

$$W_{aT} = CP(T_3 - T_{4a}) \Rightarrow T_{4a} = 805k$$

$$w_b = \frac{W_{ac}}{W_{aT}} = \frac{604.28}{805} = 0.75$$

$$q_{in} = c_p(T_3 - T_{2a}) = 698.3 \text{ kJ/kg.}$$

$$q_{out} = c_p(T_{4a} - T_1) = 507.02 \text{ kJ/kg}$$

$$\eta_{th} = \frac{w_{net}}{q_{in}} = \frac{W_T - W_C}{q_{in}} = \frac{496.97 - 303.5}{698.3} \times 100\%$$

$$= 27.41\%$$

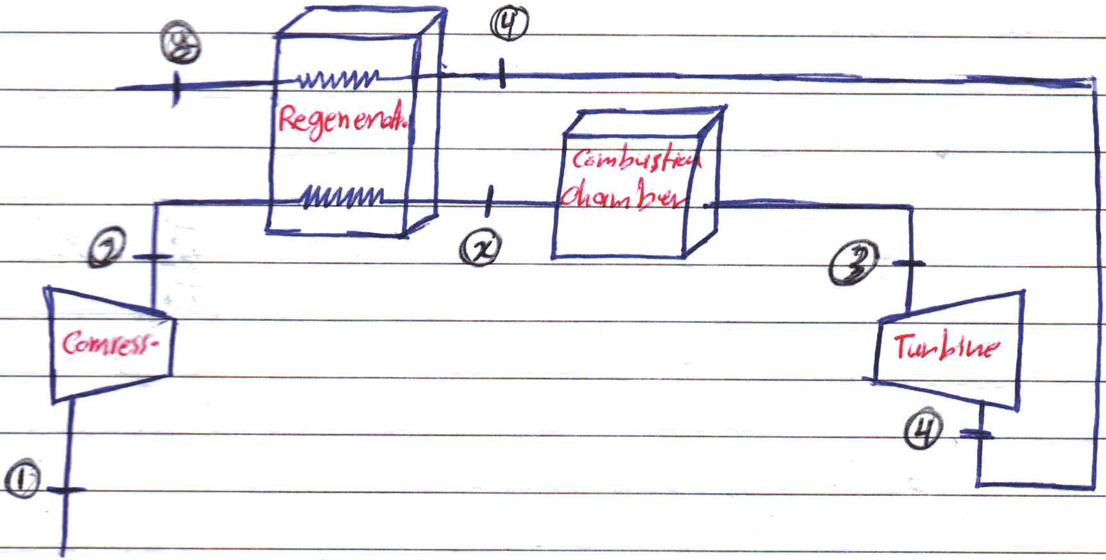
$$\eta_{th.Bray} = \left(1 - \frac{1}{r_p^{\frac{k-1}{k}}}\right) \times 100\% = 44.8\%$$

إذا بدك تحل كله ال $\underline{\underline{h}}$

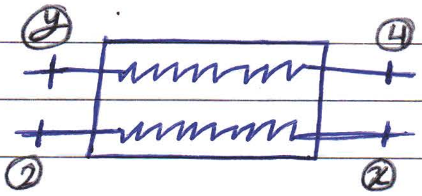
Table A7 from book thermo.

Table A17 from book approach.

The Ideal Brayton Cycle with regenerative.



يتم أخذ الهواء الخارج من الـ Turbine وثم عمل خلط له في الـ mixing، الهواء الخارج من الـ Turbine حرارته عالية وعند أخذه إلى عملية الـ Mix فإنه يعمل تبادل حراري من الهواء الخارج من الـ Compress. مما يعمل على رفع درجة حرارة هذا الهواء قبل دخوله إلى الـ Compustion chamber، هذا النظام يعمل على رفع كفاءة المحطة وأيضاً تقليل استهلاك الوقود عند الحرق.



Ideal :-

Regenerativell ← Effectiveness ($\varepsilon = 1$)

$$T_x = T_4$$
$$T_y = T_2$$

$q_{in} = C_P\ (T_3 - T_x) = C_P(T_3 - T_4)$

$w_T = C_P\ (T_3 - T_4)$ for ideal $w_T = q_{in}$.

$q_{out} = C_P\ (T_y - T_1) = C_P\ (T_2 - T_1)$

$w_c = C_P(T_2 - T_1)$ for ideal $w_c = q_{out}$.

Prove :- for ideal regenerative $\eta_{th} = 1 - \frac{T_1}{T_3}(r_p)^{\frac{k-1}{k}}$.

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{\cancel{C_p}(T_2-T_1)}{\cancel{C_p}(T_3-T_4)}$$

$$= 1 - \frac{T_1\left(\frac{T_2}{T_1}-1\right)}{T_3\left(1-\frac{T_4}{T_3}\right)} \qquad \because \frac{T_2}{T_1} = \frac{T_3}{T_4} = r_p^{\frac{k-1}{k}}$$

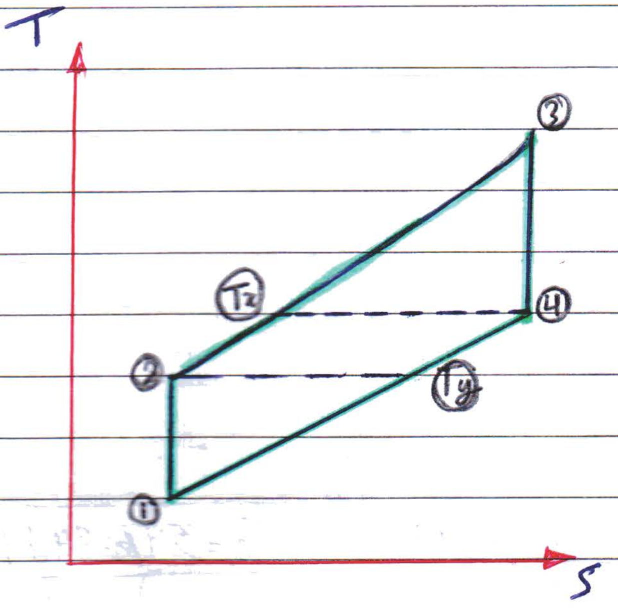
$$\eta_{th} = 1 - \frac{T_1}{T_3}\,\frac{\left(r_p^{\frac{k-1}{k}}-1\right)}{\left(1-\frac{1}{r_p^{\frac{k-1}{k}}}\right)}$$

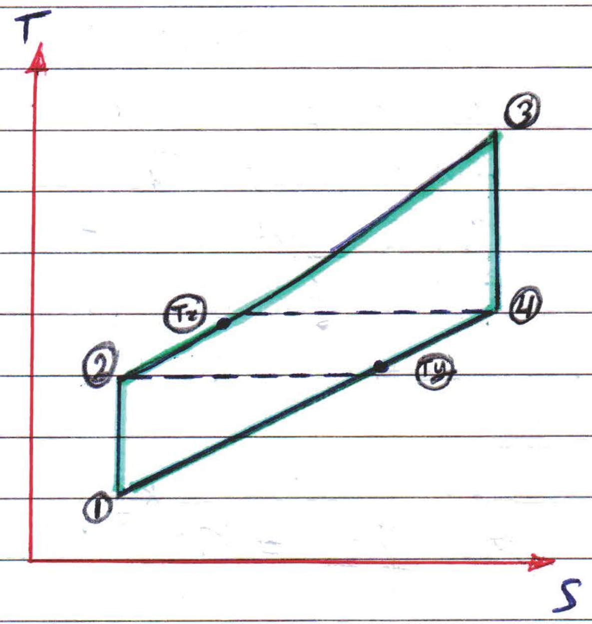
$$= 1 - \frac{T_1}{T_3}\, r_p^{\frac{k-1}{k}}\, \frac{\cancel{\left(1-\frac{1}{r_p^{\frac{k-1}{k}}}\right)}}{\cancel{\left(1-\frac{1}{r_p^{\frac{k-1}{k}}}\right)}}$$

$$\boxed{\eta_{th} = 1 - \frac{T_1}{T_3}\, r_p^{\frac{k-1}{k}}} \qquad \#$$

⇒ **Non Ideal :-** (Deviation)

$$\varepsilon = \frac{q_{act}}{q_{max}} = \frac{\cancel{C_p}(T_x-T_2)}{\cancel{C_p}(T_4-T_2)} \qquad \# \; q_{in} = C_p(T_3-T_x)$$





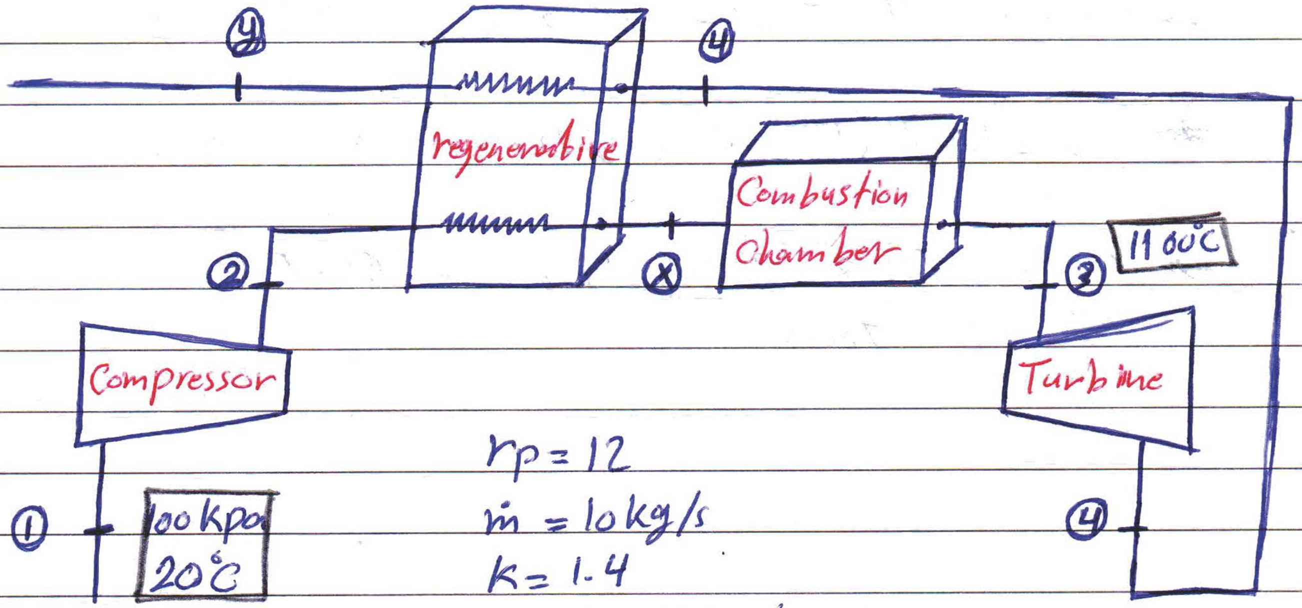
Ideal $\varepsilon = 1$

ملاحظة هذا هو الوضع الطبيعي

non Ideal $\varepsilon < 1$

$T_x < T_4 \quad T_y > T_2$

Example



$r_p = 12$

$\dot{m} = 10 \, kg/s$

$k = 1.4$

$c_p = 1.004 \, kJ/kg.k$

Ideal regenerative $\Rightarrow \varepsilon = 1$

$w_c = C_p(T_2 - T_1)$

$w_T = C_p(T_3 - T_4)$

$q_{in} = C_p(T_3 - T_4)$

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

Solution

⇛ $\frac{T_2}{T_1} = r_p^{\frac{k-1}{k}}$ $\frac{T_2}{293.15} = 12^{\frac{1.4-1}{1.4}}$ $\boxed{T_2 = 596.24\ K}$

⇛ $\frac{T_3}{T_4} = r_p^{\frac{k-1}{k}}$ $\frac{\cancel{T}1373.15}{T_4} = 12^{\frac{1.4-1}{1.4}}$ $\boxed{T_4 = 675.12\ K}$

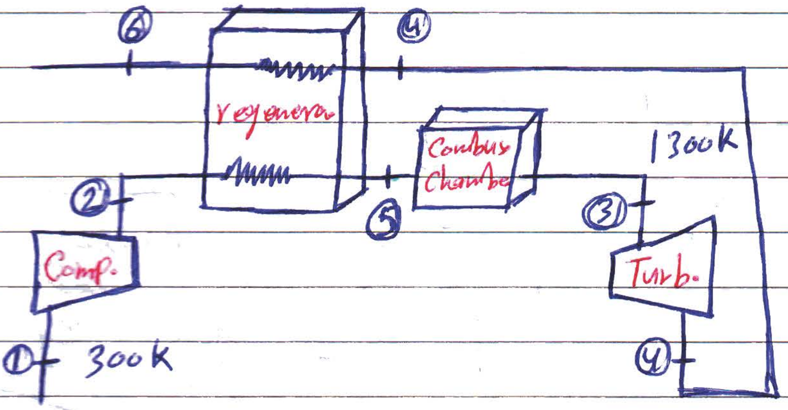
⇛ $w_c = 1.004(596.24 - 293.15) = 304.3$ KJ/kg.

⇛ $w_T = 1.004(1373.15 - 675.12) = 700.8$ KJ/kg

⇛ $q_{in} = 1.004(1373.15 - 675.12) = 700.8$ KJ/kg.

⇛ $\eta_{th} = \left(\frac{700.8 - 304.3}{700.8}\right) * 100\% = \boxed{56.57\%}$

Example



$rp = 8$

$\eta_{sc} = 0.8$

$\eta_{sT} = 0.85$

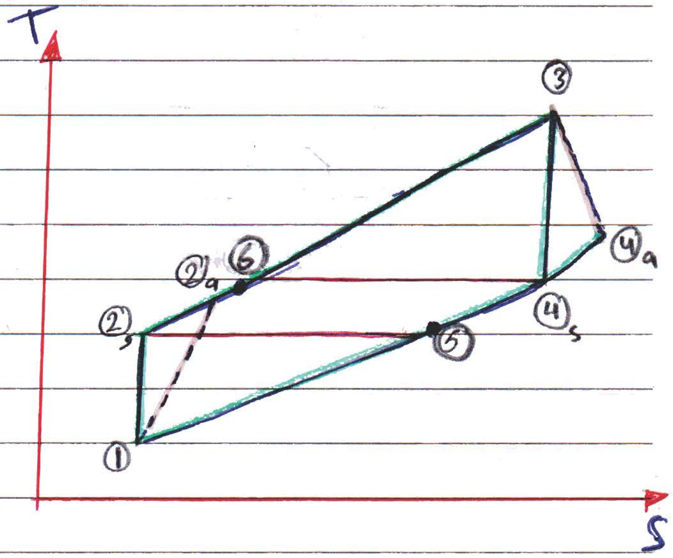
$\varepsilon = 0.8$

Solutio

$$\Rightarrow \frac{T_{2s}}{T_1} = rp^{\frac{k-1}{k}} \qquad \boxed{T_{2s} = 543.8\,k}$$

$$\eta_{sc} = \frac{w_s}{w_a} = \frac{\cancel{C}p(T_{2s} - T_1)}{\cancel{C}p(\underset{?}{T_{2a}} - T_1)}$$

$$\boxed{T_{2a} = 604.75\,k}$$



$$\Rightarrow \frac{T_3}{T_{4s}} = rp^{\frac{k-1}{k}} \qquad \boxed{T_{4s} = 717\,k}$$

$$\eta_{sT} = \frac{w_a}{w_s} = \frac{\cancel{C}p(T_3 - \overset{?}{T_{4a}})}{\cancel{C}p(T_3 - T_{4s})} \qquad \boxed{T_{4a} = 804\,K}$$

$$\Rightarrow \varepsilon = \frac{q_{act}}{q_{max}} = \frac{\overset{?}{T_5} - T_{2a}}{T_{4a} - T_{2a}} \qquad \boxed{T_5 = 764.6\,K}$$

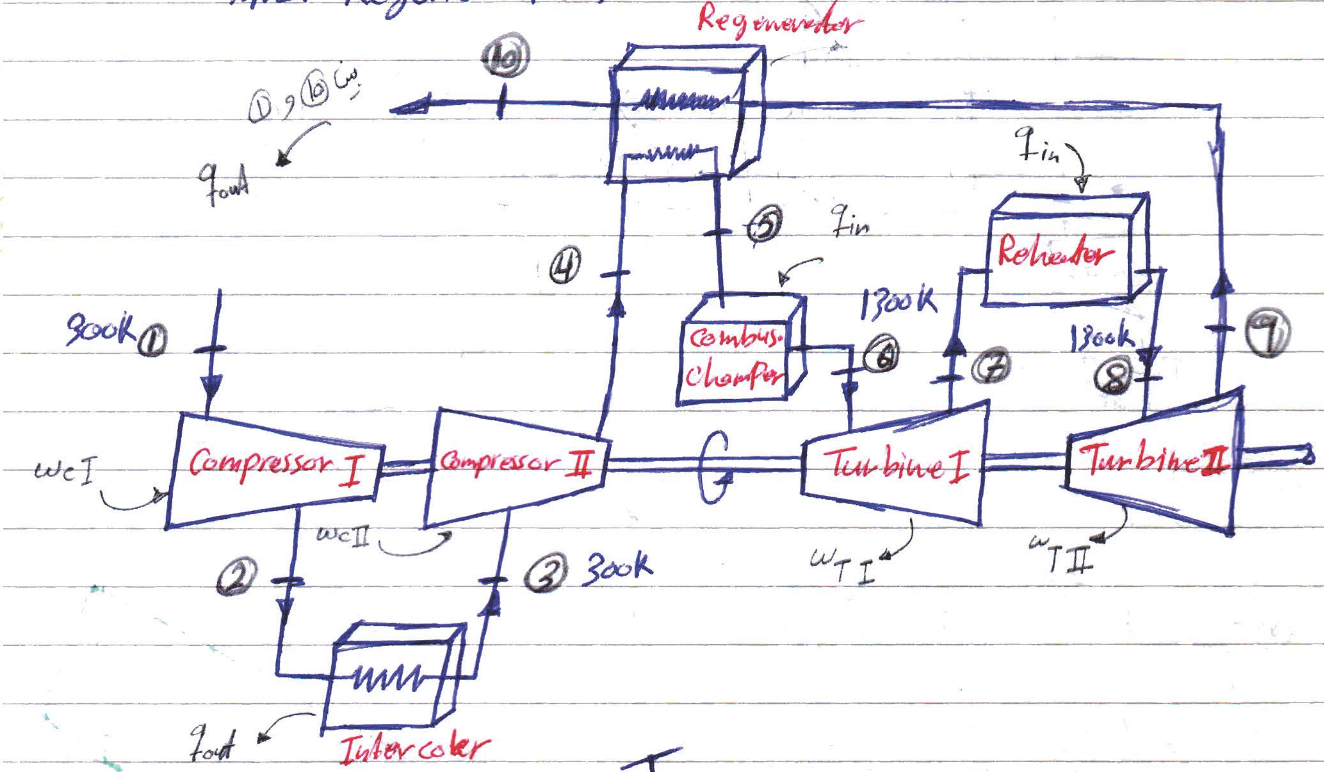
$\Rightarrow w_{Ca} = Cp(T_{2a} - T_1) = 305.969\ kJ/kg.$

$\Rightarrow w_{Ta} = Cp(T_3 - T_{4a}) = 497.984\ kJ/kg.$

$\Rightarrow q_{in} = Cp(T_3 - T_5) = 537.54\ kg/kg.$

$$\eta_{th} = \frac{497.984 - 305.969}{537.54} = 0.357 = \boxed{35.7\%}$$

⊛ The brayton cycle with intercooling, Reheating, And Regeneration.



Ideal :-

$T_1 = 3$

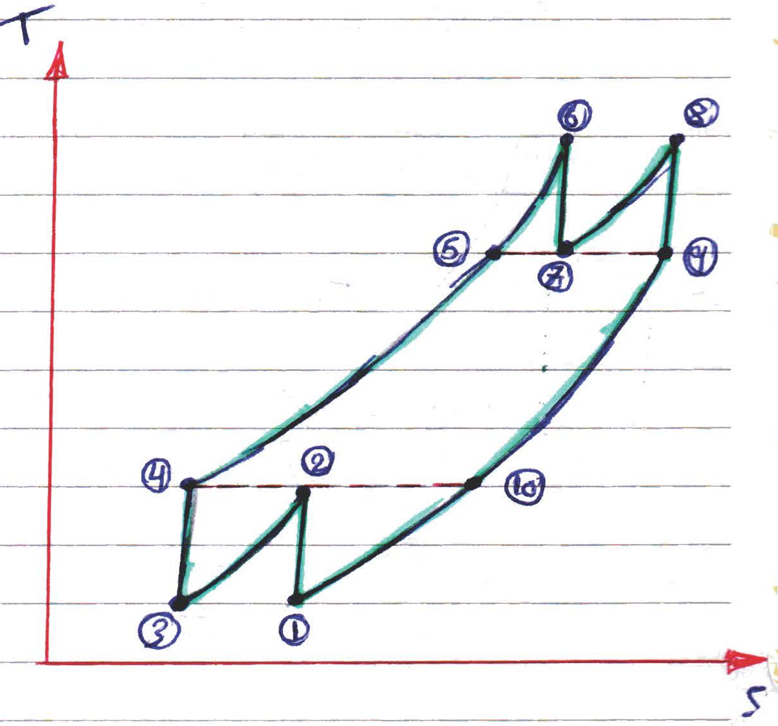
$T_6 = 8$

$T_4 = T_2 = T_{10}$

$T_5 = T_7 = T_9$

$$rp = \frac{P_2}{P_1} = \frac{P_4}{P_3}$$

$$rp = \frac{P_6}{P_7} = \frac{P_8}{P_9}$$



⊛ بالنسبة لل rp فهي لل Compressor الخارج على الداخل .
أما في ال Turbine الداخل على الخارج .

⊛ rp = 17

Comp I = $\sqrt{17}$

Comp II = $\sqrt{17}$

Comp III = $\sqrt{17}$

⊛ one stage Turbine rp = 15

Comp I = $\sqrt{15}$

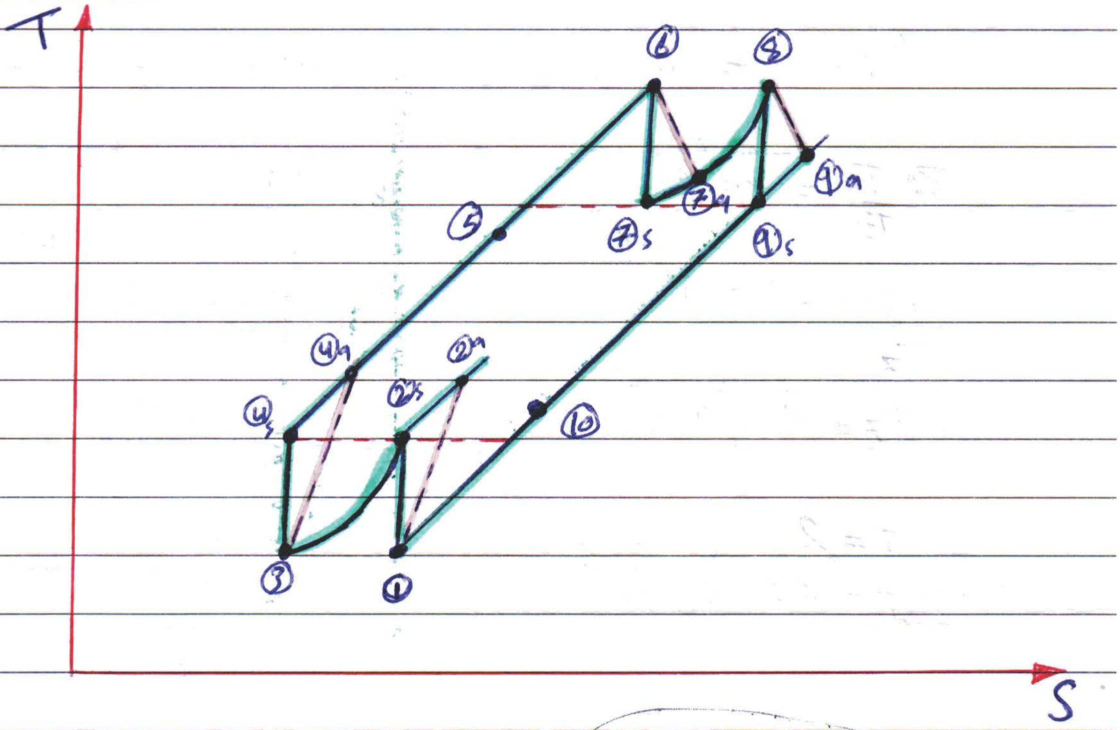
Comp II = $\sqrt{15}$

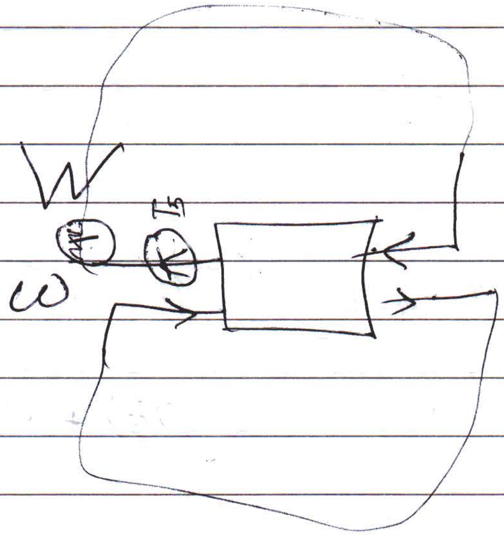
⊛ one stage compresser rp = 16

Turb I = $\sqrt{16}$

Turb II = $\sqrt{16}$

⊛ Deviation:-





CP (

Example 9.8

Ⓑ المعلومات على الرسمة السابقة Ⓑ

$rp = 8$

Solution:

$T_1 = T_3 = 300\,K$

$T_6 = T_8 = 1300\,K$

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

$w_T = w_{TI} + w_{TII}$

$w_C = w_{CI} + w_{CII}$

~~T_7~~ $\frac{T_6}{T_7} = rp^{\frac{k-1}{k}}$

$\frac{1300}{T_7} = (\sqrt{8})^{\frac{1.4-1}{1.4}}$

$\boxed{T_7 = 965.9\,K}$

$\frac{T_2}{T_1} = rp^{\frac{k-1}{k}}$

$\frac{T_2}{300} = (\sqrt{8})^{\frac{1.4-1}{1.4}}$ $\boxed{T_2 = 403\,K}$

$T_2 = T_4$

$w_T = 2\,C_p(T_6 - T_7)$

$\boxed{w_T = 671\,KJ/kg}$

$w_C = 2\,C_p(T_2 - T_1)$

$\boxed{w_C = 208.5\,KJ/kg}$

اذا ضربنا في 2 لأنه معطى في السؤال أن كل stage يساوي الـ stage الآخر للـ Compressor و Turbine لكن لو ما ذكر إنهن متساويات ومعي كل stage له درجة حرارة مختلفة فيجب حساب الـ work لكل stage على حدا ثم يتم جمعهم وذلك للـ Turbine والـ Compressor.

$w_{net} = 462.5\,KJ/kg.$

$q_{in} = C_p(T_6 - T_5) + C_p(T_8 - T_7) = 670.87\,KJ/kg.$

$q_{out} = C_p(T_{10} - T_1) + C_p(T_2 - T_3) = 208.48\,KJ/kg.$

$$\eta_{th} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}} = 69\,\%$$

$$\eta_{th.cond} = 1 - \frac{T_{\overset{min}{\cancel{max}}}}{T_{\underset{max}{\cancel{min}}}} = 1 - \frac{300}{1300} = 76.9\,\%$$

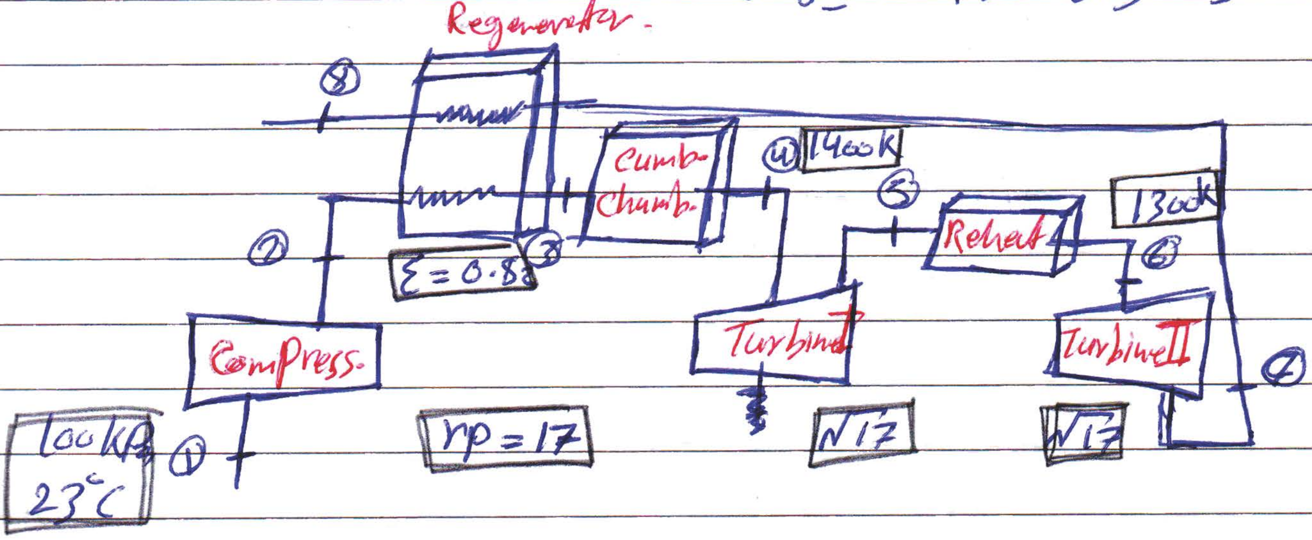
⊛ في حال ما كان في generator :-

فقط بيختلف عندي قيمة الـ q_{in} :-

$$q_{in} = CP(T_6 - T_4) + CP(T_8 - T_7)$$

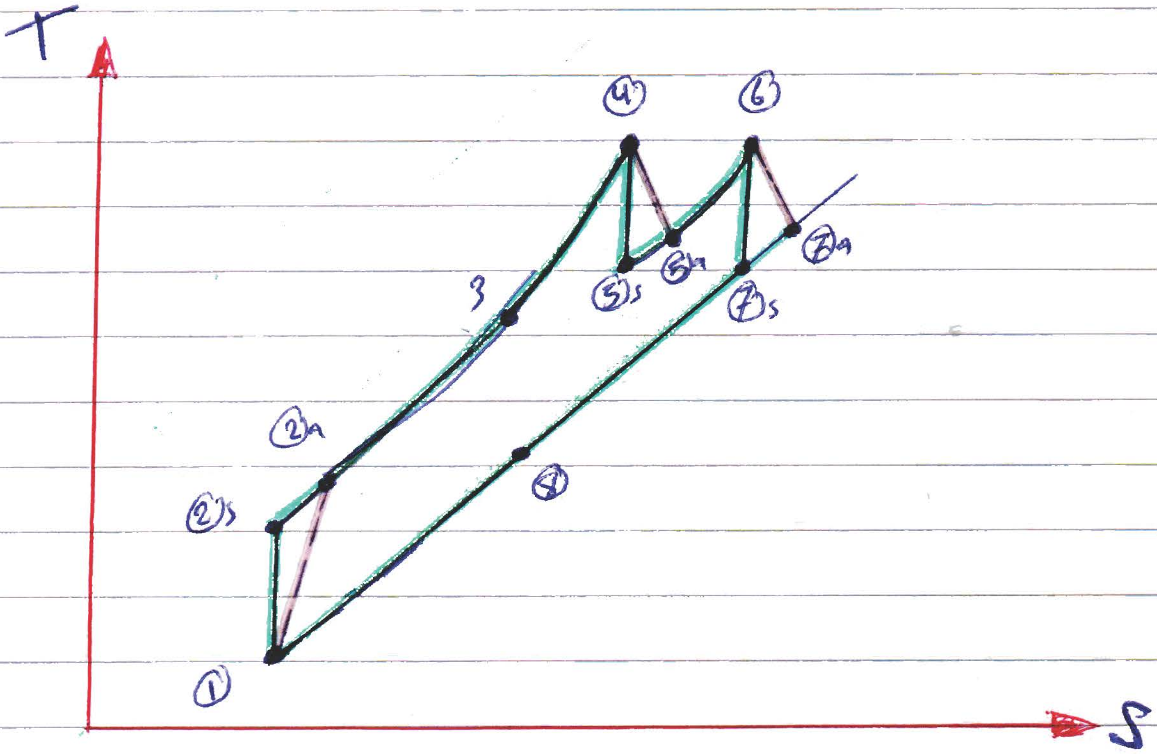
$$\eta_{th} = 37.4\,\%$$

⊛ فكرة سؤال لازم تحل عليها ⊛



endehave Turbine isontropic efficiency = 90%

Compressor isontropic efficiency = 82 %



$$W_c = cp(T_{2a} - T_1)$$

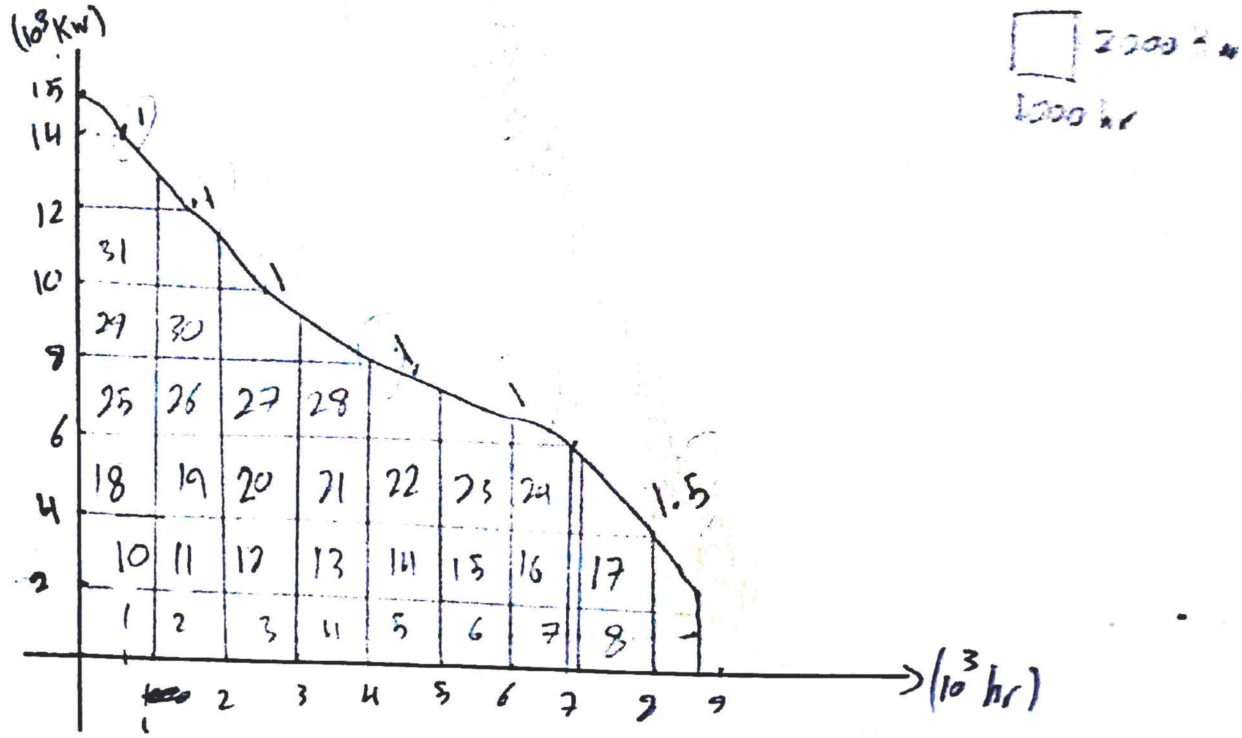
$$w_T = Cp(T_4 - T_{5a}) + Cp(T_6 - T_{7a})$$

$$q_{in} = Cp(T_4 - T_3) + cp(T_6 - T_{5a})$$

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

اقتصاديات

EX 1



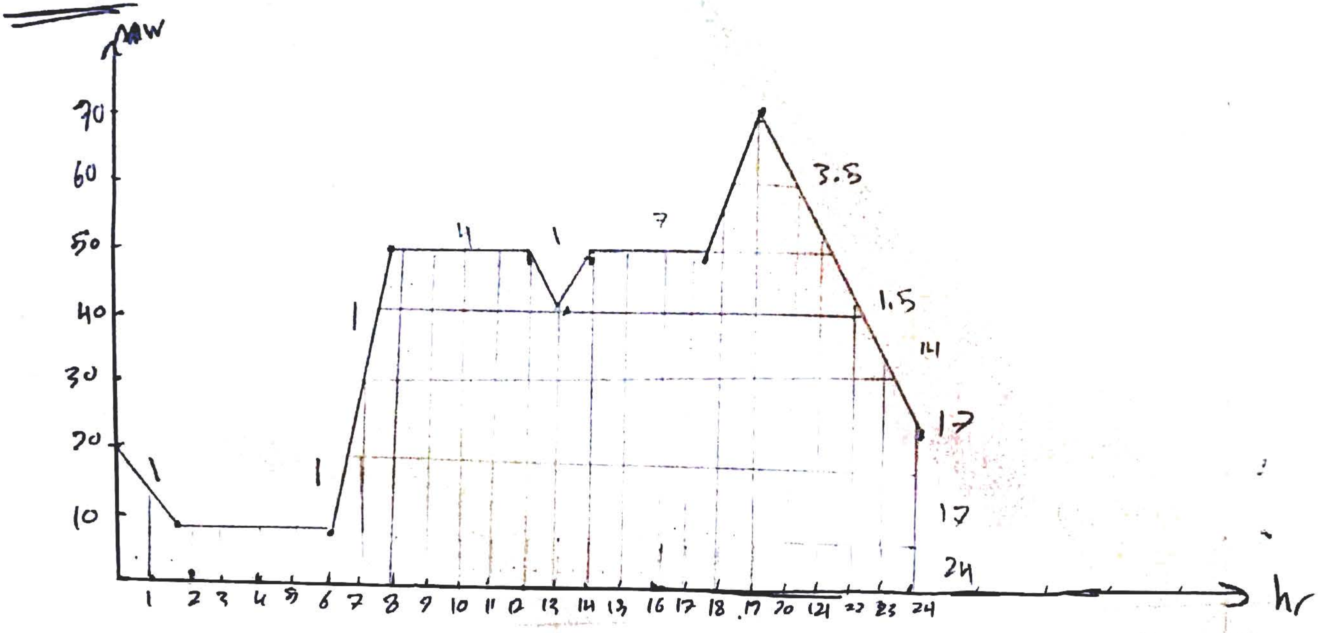
$$NO.\ Box = 31 + 6.5 = 37.5$$

$$Area = 37.5 \times 2000\ MWh = 75000\ MWh = \text{Total Energy}$$

$$L_{avg} = \frac{E.T}{No.\ hour} = \frac{75000}{8760} = 8.56\ MW$$

$$L.F = \frac{L_{avg}}{L_{max}} = \frac{8.56\ MW}{15\ MW} = 0.57$$

EX 2



NO . Box = 92

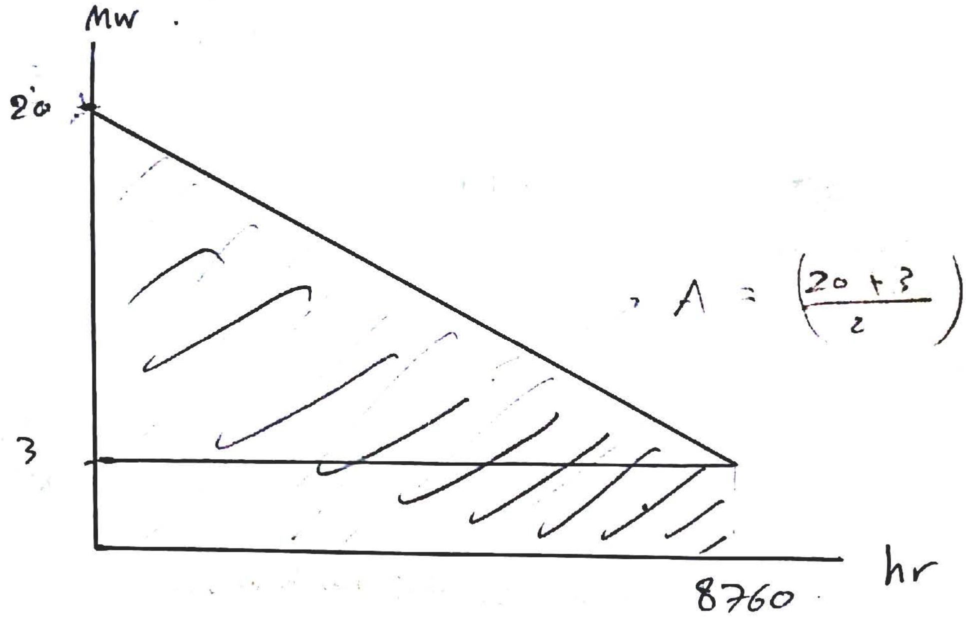
area = 92 * 10 MWh = 920 MWh

$$L_{avg} = \frac{area}{NO. hour} = \frac{920}{24} = 38.3 \text{ MW}$$

$$L.F = \frac{L_{avg}}{L_{max}} = \frac{38.3}{70} = 0.55$$

$$U.F = \frac{L_{max}}{capacity} = \frac{70 \text{ MW}}{100 \text{ MW}} = 0.7$$

EX 3



$A = \left(\frac{20+3}{2}\right) \times 8760$

Tow Torbin $<$ 10 mw, 10 mW

one = → 5 mW

① Installed capacity = 10+10+5 = 25 MW

② Max load = 20 MW

③ Utilization factor = $\frac{20}{25}$ = 0.8

④ Plant Factor = $\frac{L_{avg}}{\text{capacity}} = \frac{11.5}{25} = 0.46$

⑤ $L_{avg} = \frac{11.5 \times 8760 \xrightarrow{} \text{Energy}}{8760 \xrightarrow{} \text{hours}} = 11.5$ MW

⑥ Load Factor = $\frac{L_{avg}}{L_{max}} = \frac{11.5}{20} = 57.5\%$

EX (4)

① $D.F = \frac{\Sigma L_{max}}{L_{max}} = \frac{1000 + 2000 + 5000}{L_{max}} = 1.4$

$\Rightarrow L_{max} = \frac{8000}{1.4} = 5714 \text{ KW}$

② Energy of each type:

$R.S \Rightarrow L.F = \frac{E/24}{L_{max}}$. $\Rightarrow E = L.F * L_{max} * 24$

$R.S = 1000 * 0.2 * 24 = 4800 \text{ KW.h}$

$C.S = 2000 * 0.3 * 24 = 14400 \text{ Kw .h}$

$I.S = 5000 * 0.8 * 24 = 96000 \text{ KW.h}$

Total E. = 115200 KW.h

③ $L_{avg} = \frac{115200}{24} = 4800$

$L.F = \frac{4800}{5714} = 84\%$

Ex (5)

✱ Fixed cost

① Boiler

A → $11.8 \ \frac{lb}{kWh} * 16.32 \ \frac{\$}{lb\text{-}hr} * 10000 \ KW = 1925760 \ \$$

B → $10.5 * 18.8 * 10000 = 1974000 \ \$$

C → $8.5 * 26 * 10000 = 2210000 \ \$$

② Turbine

A → $114 \ \frac{\$}{Kw} * 10000 \ KW = 1140000 \ \$$

B → $126 * 10000 = 1260000 \ \$$

C → $153 * 10000 = 1530000 \ \$$

Fixed cost	A	B	C
① Boiler	1,925,760	1,974,000	2,210,000
② Turbine	1,140,000	1,260,000	1,530,000
③ electrical equipment	500,000	500,000	500,000
④ structur	〃	〃	〃
⑤ Total	4,065,760	4,234,000	4,740,000
⑥ Total + 10% or Total *(1.10)	4,472,336	4,657,400	5,214,000

$\boxed{*}$ Fixed cost (P) change to annual payment (A)

① Total cost $\overset{\text{interest}}{(i)}$ = $\underset{\text{cost}}{\text{initial}}$ $\overset{\text{interest}}{(i)}$ + insuranse + depreciation (d) + taxes

$$d = \frac{i}{(1+i)^n - 1} = \frac{0.06}{(1.06)^{15} - 1} = 0.0429$$

$$i = 0.06 + 0.002 + 0.04 + 0.0429 = 0.1449$$

② For (A) to change Annual :-

$$A = P \left[\frac{i}{1 - (i+1)^{-n}} \right]$$

$$= 4{,}472{,}336 * \left[\frac{0.1449}{1 - (1.1449)^{-15}} \right] = 591{,}586 \ \$$$

For (B) ⇒ $A = 4{,}657{,}400 \left[\quad 〃 \quad \right] = 616066 \ \$$

For (C) ⇒ $A = 4{,}214{,}000 \left[\quad 〃 \quad \right] = 557414 \ \$$

☒ Annual payment:

① Fuel & repair cost:

* حساب ثمن الوقود و الصيانة
في خطوة واحدة

$25\ \$ + 0.9\ \$ = 25.9\ \$$

$$A \Rightarrow \frac{25.9\ \$}{\cancel{\text{short ton}}} * \frac{\cancel{\text{short ton}}}{2000\ \cancel{\text{lb}}} * \frac{\cancel{\text{lb}}}{14\,2000\ \cancel{\text{Btu}}} * \frac{16\,000\ \cancel{\text{Btu}}}{\cancel{\text{Kwh}}} * 50\ \text{GWh}$$

A → 729577 $

B → 615580 $

C → 547183 $

② Salary cost:

① $\frac{24\text{ h}}{8\text{ h}} * 7\text{ day} = 21\ \frac{\text{shift}}{\text{week}}$ for one position

② Each position need $\frac{21}{5} = 4.2$ man

عدد العمال لموقع واحد

③ for all position $4.2 * 4 = 16.8 \approx 17$ man

④ salary $= 17 * 15000 = 255\,000\ \$$

☒ Annual payment :

① Fuel & repair cost :

* حساب ثمن الوقود و الصيانة
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~~A~~ → ~~704225~~ $ A → 729577 $

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