

Power Plants

* Rankine Cycle

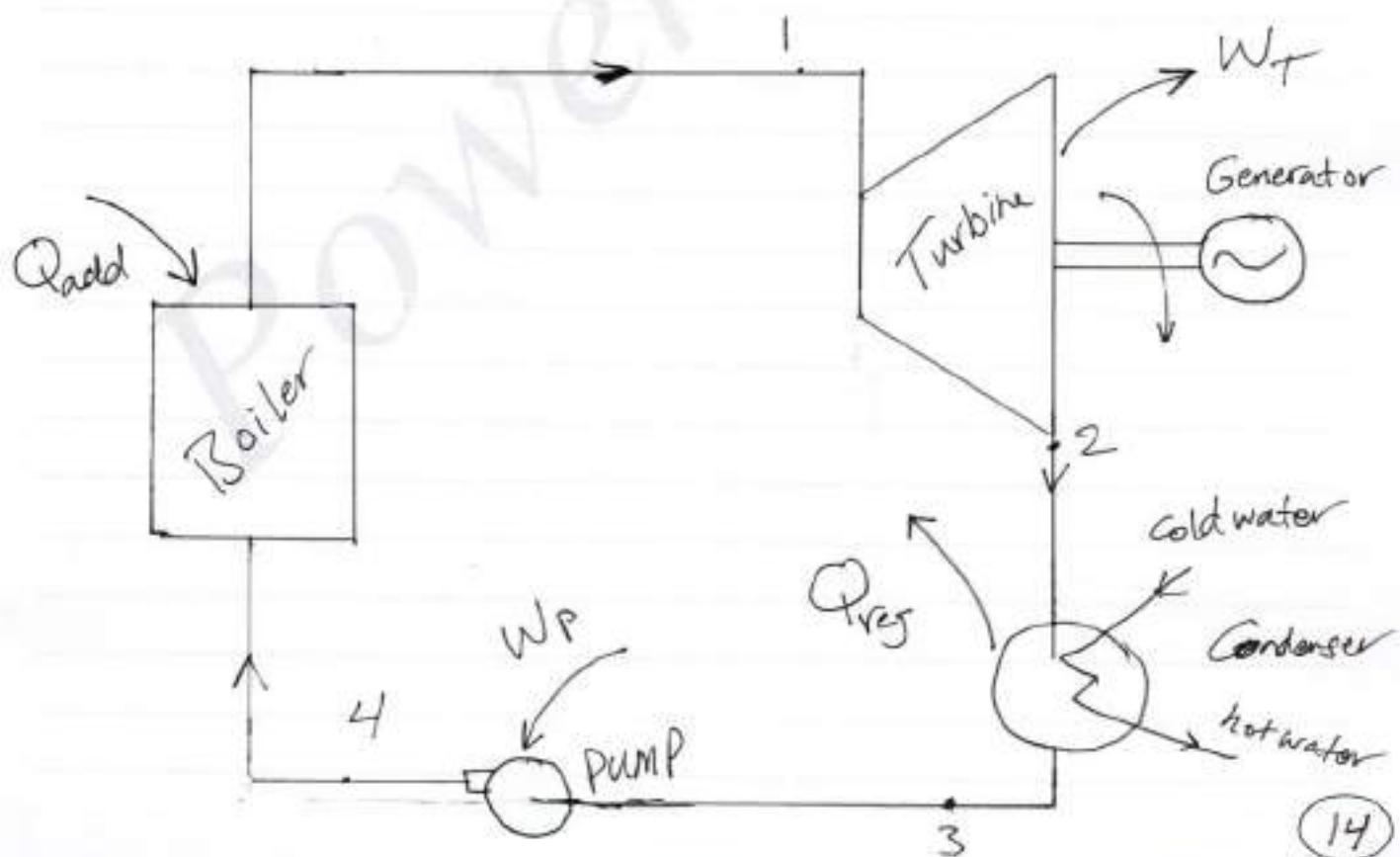
Rankine cycle is a thermodynamic cycle derived from Carnot Vapour Power cycle for overcoming its limitations. Rankine cycle has the following thermodynamic processes :-

1-2 = Reversible adiabatic expansion in the turbine

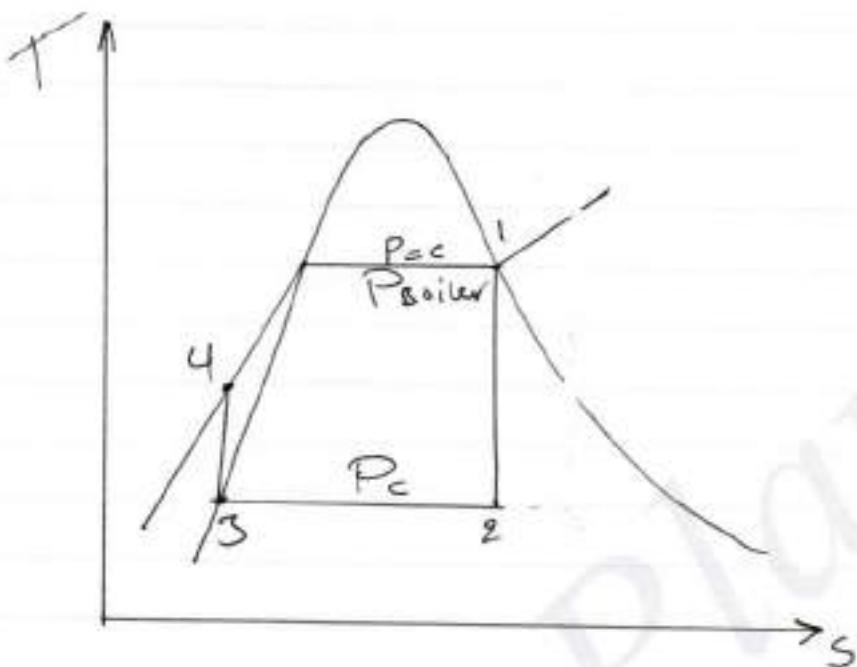
2-3 = Constant-pressure transfer of heat in the Condenser.

3-4 = Reversible adiabatic Pumping Process in the feed Pump

4-1 = Constant-pressure transfer of heat in the boiler.



Power Plants



By applying Steady flow energy equation to boiler, turbine, Condenser and Pump, we get:-

(i) For boiler

$$\frac{dE_{cv}}{dt} = \dot{Q} - \dot{W} + m_i (h_i + \frac{V_i^2}{2} + gZ_i) - m_o (h_o + \frac{V_o^2}{2} + gZ_o)$$

Assumptions :-

- * Steady state ($\frac{dE_{cv}}{dt} = 0$)
- * No change in Velocity ($\frac{V_i^2}{2} - \frac{V_o^2}{2} = 0$)
- * No change in elevation ($gZ_i - gZ_o = 0$)



(15)

Power Plants

o°

$$o = Q - W + m_i h_i - m_o h_o \quad , \quad m_i = m_o$$

$$\boxed{o = q - w + h_i - h_o} \quad \text{eqn ①}$$

In boiler, there is no work added or rejected
 $w = 0$

$$q_{\text{add}} = h_o - h_i$$

or $\boxed{q = h_i - h_u}$ (for boiler Q_{add})

(ii) For turbine

Same steps are applied as we did above.
for turbine, there is heat added or rejected ($Q=0$)
from eqn ①

$$o = -W + h_i - h_o$$

or

$$\boxed{W_{\text{turbine}} = h_1 - h_2} \quad (\text{for turbine } W_+)$$

Power Plants

(iii) For Condenser

In Condenser, there is no work added or rejected ($w=0$)

So, from equation (1)

$$\delta = -q + h_i - h_o \quad (\text{the sign} (-) \text{ is accounted for heat rejection})$$

or $\delta_{\text{Cond.}} = h_2 - h_3$ (for Condenser Q_{rej})

(iv) For feed pump

In Pump, there is no heat added or rejected ($Q=0$)

so, from eqn. (1)

$$\delta = +w + h_i - h_o$$

the sign $(-)$ was changed to $(+)$ because the pump work is input

So

$$W_{\text{pump}} = h_o - h_i$$

$$W_{\text{pump}} = h_4 - h_3 \quad (\text{for pump } W_p)$$

Power Plants

Now, efficiency of Rankine cycle is given by :-

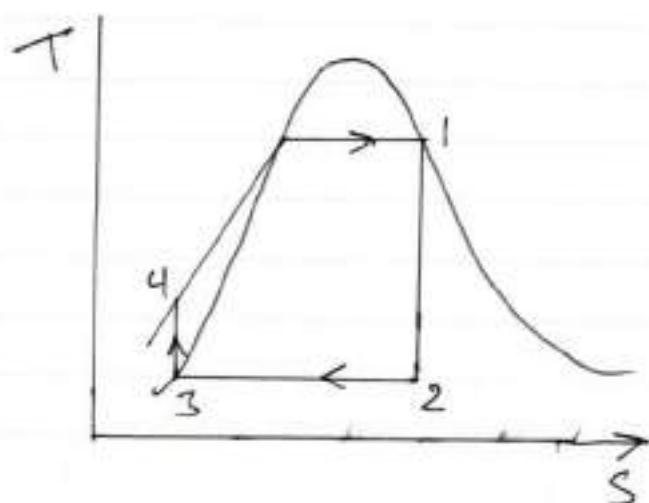
$$\eta_{\text{Rankine}} = \frac{W_{\text{net}}}{Q_{\text{add}}} = \frac{W_T - W_P}{Q_{\text{add}}}$$

$$\eta_{\text{Rankine}} = \frac{(h_1 - h_2) - (h_4 - h_3)}{(h_1 - h_4)}$$

$$W_{\text{pump}} = N(P_{\text{Boiler}} - P_{\text{cond.}}) = h_4 - h_3$$

Ex/ The same example above, calculate
Rankine efficiency Cycle ?

Solutions :-



Power Plants

From Steam table

at 15 bar $h_1 = h_g = 2789.9 \text{ kJ/kg}$
 $s_1 = s_g = 6.4406 \text{ kJ/kg K}$

at 0.4 bar $h_3 = h_f = 317.7 \text{ kJ/kg}$
 $h_{fg} = 2319.2 \text{ kJ/kg}$
 $s_f = 1.0261 \text{ kJ/kg K}$
 $s_{fg} = 6.6448 \text{ kJ/kg K}$
 $\sim = 0.001 \text{ m}^3/\text{kg}$

$s_1 = s_2$ (steam expands isentropically)

$$s_2 = s_f + x_1 s_{fg}$$
$$6.4406 = 1.0261 + x_1 + 6.6448$$

$$x_1 = 0.815$$

$$h_2 = h_f + x_1 h_{fg}$$
$$= 317.7 + 0.815 \times 2319.2$$
$$= 2207.8 \text{ kJ/kg}$$

$$\sim (P_2 - P_1) = h_4 - h_3$$

$$0.001 (1500 - 40) = h_4 - 317.7$$

$$h_4 = 319.16 \text{ kJ/kg}$$

~~Mohamed Afachy~~

1 bar = 100 kPa

$$W_{done} = W_T - W_C = (h_1 - h_2) - (h_4 - h_3)$$

$$= (2789.9 - 2207.8) - (319.16 - 317.7)$$

(19)

Power Plants

$$W_{done} = 580.64 \text{ KJ/kg}$$

$$\begin{aligned}Q_{add} &= h_1 - h_4 \\&= (2789.9 - 319.16) \\&= 2470.74 \text{ KJ/kg}\end{aligned}$$

$$\begin{aligned}\eta_{\text{Rankine}} &= \frac{W_{done}}{Q_{add}} \\&= \frac{580.64}{2470.74} = 23.5\%\end{aligned}$$