MADE EASY

Mechanical Engineering

Toppers Handwritten Notes

Power Plant Engineering

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POWER PLANT

SAURABH PANDE SIR

whatsapp

→ Gas Turbine
→ Compressor
- Reciprocating
- Centrifugal
- Axial flow

→ Rankine (or) Vapour power cycle
→ Thermal power plant
- Nozzle
- Steam turbine
- Boiler & its components
- Condenser & Cooling tower

→ Jet propulsion

GATE — 4 Marks
ESE
obj :— 10 to 15 Q
Mains :— 100 to 150 Marks

Books

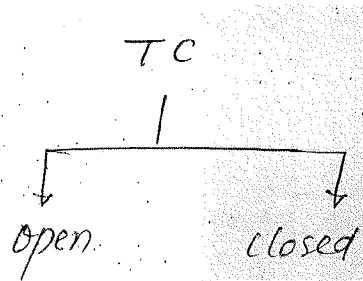
Gas Turbine – V. Ganeshan
+
power plant Engg – P.K Nag

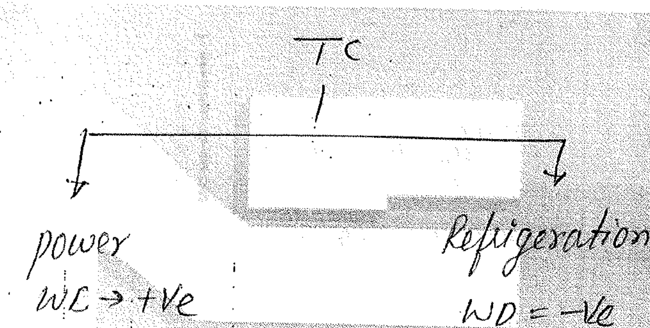
power plant Engg. – R. yadav

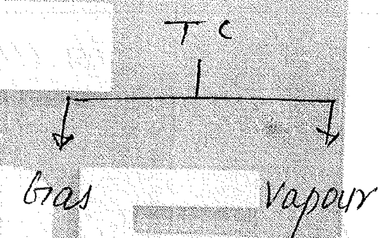
Open cycle - In every cycle fresh working substance is admitted, used and exhausted.

Closed cycle

In every cycle the same working substance is again and again secirculated.







Gas Thermal Cycle (TC)

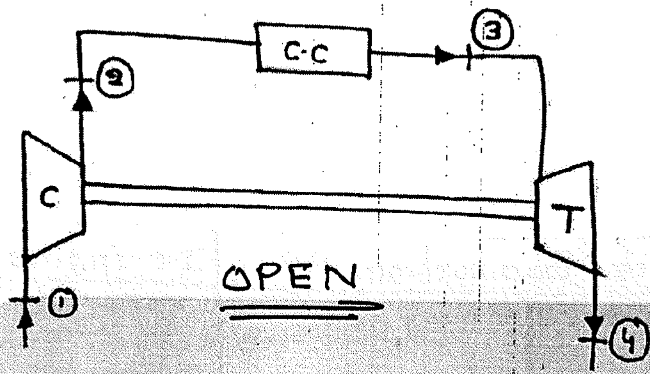
working substance semains in a single gaseous phase through out the cycle.

Vapour cycle

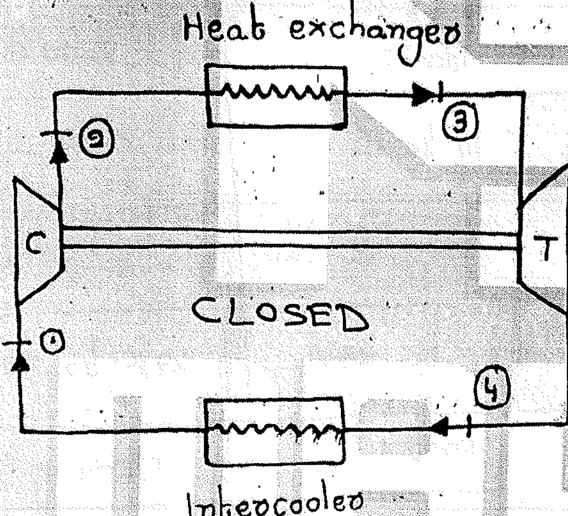
working substance semains in the liquid phase for half the cycle and vapour phase for the next ~~half~~ of cycle.

	Steam Power Plant	Gas turbine P.P	I.C Engine P.P
	60%	[10% – 12%]	[1% – 2%]
Cycle	Rankine	Brayton	Diessel or otto
Fuel	Coal, H_2O, oil etc	Natural gas, Methane	Diesel, Petrol, Kerosene
Max-temp	620°C	1300°C	2500°C
pressure ratio	180 to 300	10 to 12	15 to 25
weight/power	55kg/KW	20kg/KW ← Air craft	115kg/KW
Thermal 'η'	32 to 37%	22% to 27%	27% to 32%
pollution	Highest	Least	Medium
Installation	3 to 4 Yrs/200MW	2 to 3 Yrs/200MW	1-2 month/1-2MW
Mechanical 'η'	Highest [lower rpm]	Medium [Higher rpm]	lowest
Same Power Turbine	Smaller Turbine	Bigger turbine	
ω_{net} [KJ/kg]	Higher [1200 KJ/kg of steam]	lower [300 KJ/kg of air]	
Power Plant	More power and Bigger in size	less power & Smaller in size	

GAS TURBINE



OPEN

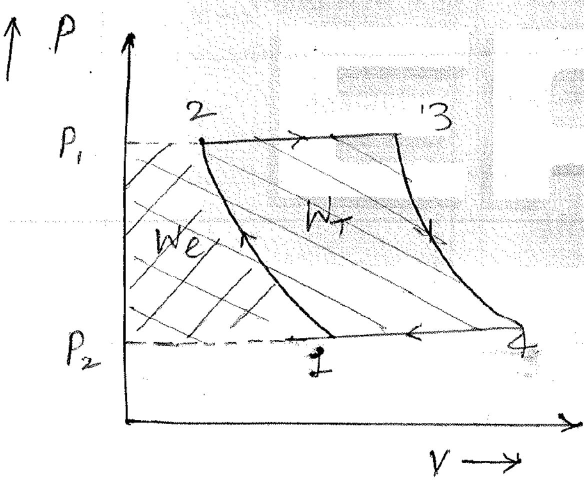


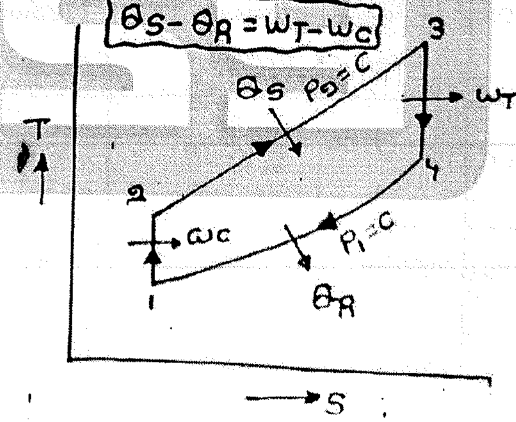
CLOSED

$E_{in} = E_{out}$

$Q_S + W_C = W_T + Q_R$

$\boxed{Q_S - Q_R = W_T - W_C}$





Compression work $[W_C]$:- 1-a-b-2-1

Turbine work $[W_T]$:- 4-a-b-3-4

W_{net} :- $W_T - W_C$

W_{net} :- Area → 1-2-3-4-1

$W_{net} = W_T - W_C$

= Area 1-2-3-4-1

Brayton cycle is a practical working cycle for Gas turbine p.p & Consist of (4) process.

1-2 :- Reversible adiabatic compression of air or gas from lower press to higher press in a compressor

2-3 :- Constant press heat addition process either directly in the "C.C" or indirectly in a H.E.

3-4 :- Reversible adiabatic expansion from higher to lower pressure in Gas Turbine.

4-1 :- Constant press heat rejection process either directly to atmosphere or indirectly in an intercooler.

* Advantages of closed cycle:-

- More efficient & compact b/w the same Max & Min temperature.
- Any lower grade fuel can be used as the working substance is not mixed with fuel.
- Any better properties working substance like Helium, argon gas can be used.
- It can work at low atmospheric pressure.
- There is no problem of Turbine blade erosion.

* Disadvantages of closed cycle:-

- Cycle becomes complicated, costly, Bulky.
- leak proofing of Below atmospheric cycle is very difficult.
- Bcz of being bulky cannot be used for aircraft application.

* Air Standard Assumptions:- *Otto / diesel*

- Air is the working substance throughout & its chemical composition doesn't change.
- C_p, C_v, γ value is remaining constant throughout [Cold air assumption]
  → *But in actual it changes with time.*

- changes in K.E & P.E are neligable.
- Compression & Expansion process are adiabatic.
- There is no loss of pressure while flow takes place through various components.

→ ① process 1-2 (W_c)

By SFEE ① and ②

$$h_1 + \frac{V_1^2}{2} + z_1 g + q_{1-2} = h_2 + \frac{V_2^2}{2} + z_2 g + W_{1-2}$$

$V_1 = V_2$ $z_1 = z_2$ $q_{1-2} = 0$ $W_{1-2} = -W_c$

$$\Rightarrow W_c = h_2 - h_1 = C_p (T_2 - T_1)$$

② process 2-3 (Q_s)

By SFEE ② and ③

$$h_2 + \frac{V_2^2}{2} + z_2 g + q_{2-3} = h_3 + \frac{V_3^2}{2} + z_3 g + W_{2-3}$$

$V_3 = V_2$ $z_2 = z_3$ $W_{2-3} = 0$

$q_{2-3} = Q_s$

$h_2 + Q_s = h_3 \Rightarrow Q_s = h_3 - h_2$

$Q_s = C_p (T_3 - T_2)$

③ process 3-4 (W_T)

$h_3 = h_4 + W_T$

$$\Rightarrow W_T = h_3 - h_4 = C_p (T_3 - T_4)$$

④ process 4-1 (Q_R)

$$h_4 - Q_R = h_1$$

$$\Rightarrow Q_R = h_4 - h_1 = C_p(T_4 - T_1)$$

$$W_{net} = W_T - W_c$$

$$= (h_3 - h_4) - (h_2 - h_1)$$

$$= (h_3 - h_2) - (h_4 - h_1)$$

$$W_{net} = Q_S - Q_R = W_T - W_c$$

→ process 1-2 (Isentropic)

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{P_2}{P_1} = \text{pressure Ratio} = r_p$$

$$\frac{T_2}{T_1} = (r_p)^{\frac{\gamma-1}{\gamma}} \quad \text{—ⓐ}$$

process 3-4 (Isentropic)

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

$$P_2 = P_3 \quad \& \quad P_1 = P_4$$

$$\frac{T_3}{T_4} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = (r_p)^{\frac{\gamma-1}{\gamma}} \quad \text{—ⓑ}$$

by ⓐ and ⓑ

$$* \boxed{\frac{T_2}{T_1} = \frac{T_3}{T_4}} *$$

$\rightarrow \eta = \dfrac{W_{net}}{\dot{Q}_s}$

$= \dfrac{Q_S - Q_R}{Q_S}$

$\eta = 1 - \dfrac{Q_R}{Q_S}$

$= 1 - \dfrac{(T_4 - T_1)}{(T_3 - T_2)}$

$\eta = 1 - \dfrac{T_1}{T_2} \dfrac{(T_4/T_1 - 1)}{(T_3/T_2 - 1)}$

$\eta = 1 - \dfrac{T_1}{T_2} = 1 - \dfrac{1}{(T_2/T_1)}$

$\eta = 1 - \dfrac{1}{(r_p)^{\frac{\gamma - 1}{\gamma}}}$

* $\eta_{\text{Simple Brayton}} = 1 - \dfrac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}}$ *

Backward Ratio [r_{bw}]:-

$r_{bw} = \dfrac{-\text{ve work in a Cycle}}{+\text{ve work in a Cycle}}$

$\boxed{r_{bw} = \dfrac{W_C}{W_T}}$

Gas Turbine :- 40% to 60%

Steam Turbine :- 1% to 2%

Work Ratio [r_w]:-

$r_w = \dfrac{\text{Net work in a cycle}}{+\text{ve work in a cycle}}$

$\boxed{r_w = \dfrac{W_{net}}{W_T}} \Rightarrow r_w = \dfrac{W_T - W_C}{W_T} = 1 - \dfrac{W_C}{W_T}$

$\boxed{r_w = 1 - r_{bw}}$

Gas Turbine :- 40% to 60%

Steam Turbine :- 98% to 99%

* for Simple Brayton cycle η increases with Increase in pressure Ratio and γ Value