LECTURE NOTES

ON
THERMAL ENGG II

4TH SEMESTER

PREPARED BY
SIDDHANT SINGH BABU
GUEST FACULTY
DEPARTMENT OF MECHANICAL ENGG

GOVERNMENT POLYTECHNIC, NUAPADA
Government of Odisha
ସରକାରୀ ବହୁବୃତି ଅନୁଷ୍ଠାନ, ନୂଆପଡା

THERMAL ENGINEERING - II

INDEX (MECHNICAL)

No.	Topic / chapter names
(1)	Performance of ic engine
(2)	Heat Transfer
(3)	Steam Generator
(4)	Reciprocating Air Compressor
(5)	Properties of steam
(6)	Steam power Cycle

D.t-17/09/23

PERFORMANCE OF IC-ENGINE:-

I.C engine Means It is the type of machine In which the combution of fuel is done Inside the Engine cylinder.

Those engine In which combution of fuel is Done outside the engine is Known as External Combution Engines.

EFFICIENCY:-

Efficiency of any machine can be calculated By using the formula of Ratio between output to Input of a Machine.

$$\eta = \frac{\text{Out Put}}{\text{Input}}$$ It has no unit

η value of any machine can't be 100% beacaus Some amount of Power is lost while performing Any work.

INDICATED POWER:-

It is that Power which is actually developed Inside the engine Cylinder

$$I.P. = \frac{P_{m.e.p} \times L \times A \times n \times 100}{60} \text{ Kw}$$

for multi cylinder $I.p = \frac{P_{m.e.p} \times L \times A \times n \times K \times 100}{60}$

Where K = no. of Cylinder

$P_{m.e.p}$ = Mean effective Pressure

L = Length of the stroke

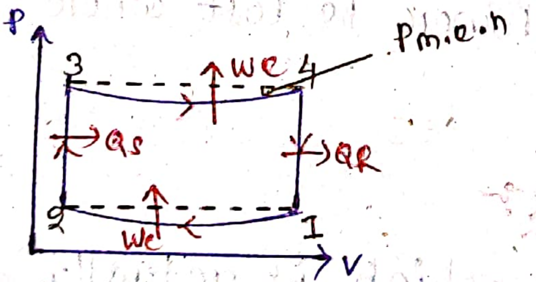
A = Area of the Piston

N = Speed of engine
n = no. of working stroke per minute.
= N = (2 stroke)
= $\frac{N}{2}$ (4 stroke)

Mean effective Pressure :-

It is a hypothetical Pressure that is Considered to be acting on the engine. During The working of an Engine pressure value is changing at every point so to take a Constant Reading of Pressure we Consider it as mean Effective Pressure.

It calculated with the help of the Indicator Diagram. In which (P-V) diagram of the engine cylinder is drawn, then the Area of the Rectangle is considered for Calculations.



Rectangle hight is called P.m.e.n

(Indicator diagram)

BRAKE POWER :-

The Power Available at the Engine crank shaft / fly wheel of an IC Engine is called as BRAKE POWER.

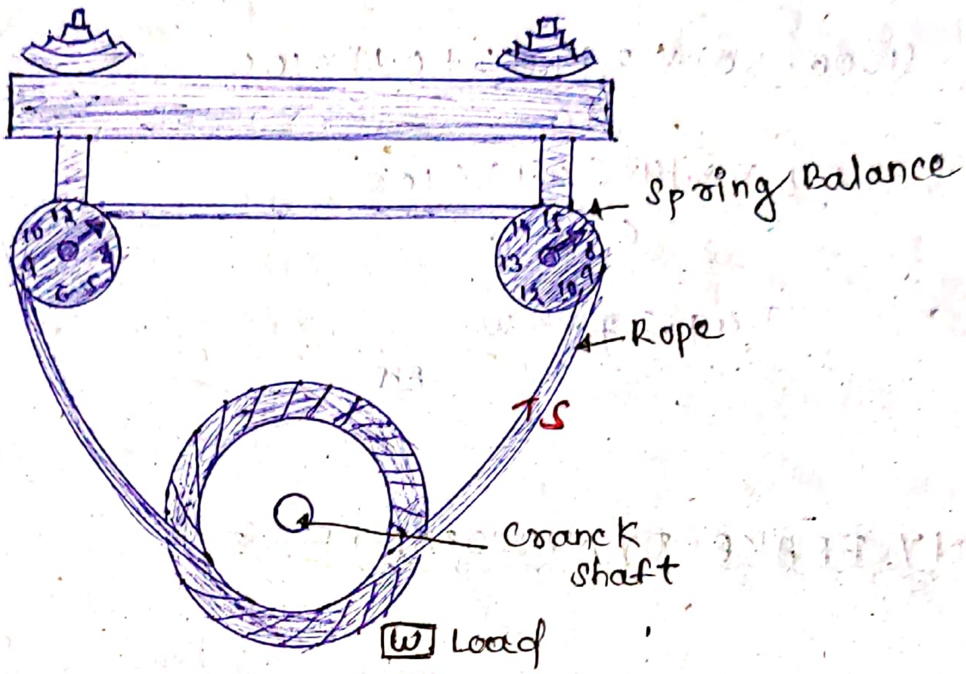
The Brake Power of an Engine is Measured with the Help of Dynamometer.

There are two types of Dynamometer.

(1) :- Rope Dynamometer.

(2) Prony Brake Dynamometer.

(1) ROPE BRAKE DYNAMOMETER:-



Rope Brake furmula:-

$$B.P = \frac{(W-S) \times \pi \cdot (D+d) \times N}{60}$$

$$B.P = \frac{(W-S) \times \pi \cdot (D+d) \times N}{60} \; KW$$

Where

D = crank shaf diameter

d = Rope Diameter.

S = Tension (T) [T = W × r] [T = F × r]

(Q1) In a Rope Breake dynamometer the Diameter of the crank shaft is 2 m and Rope is 100mm Rotating at a speed of 100 R.P.M In which the Load applied on the crank shaft is 100 N and the spring balance Force is 50 N find out the Brake power?

ANS Given

D = 2 m

d = 100mm = 0.1 m

N = 100 R.P.M

$W = 100N$, $S = 50N$

we Know that $B.P = \frac{(W-S) \times \pi \cdot (D+d) \times N}{60}$

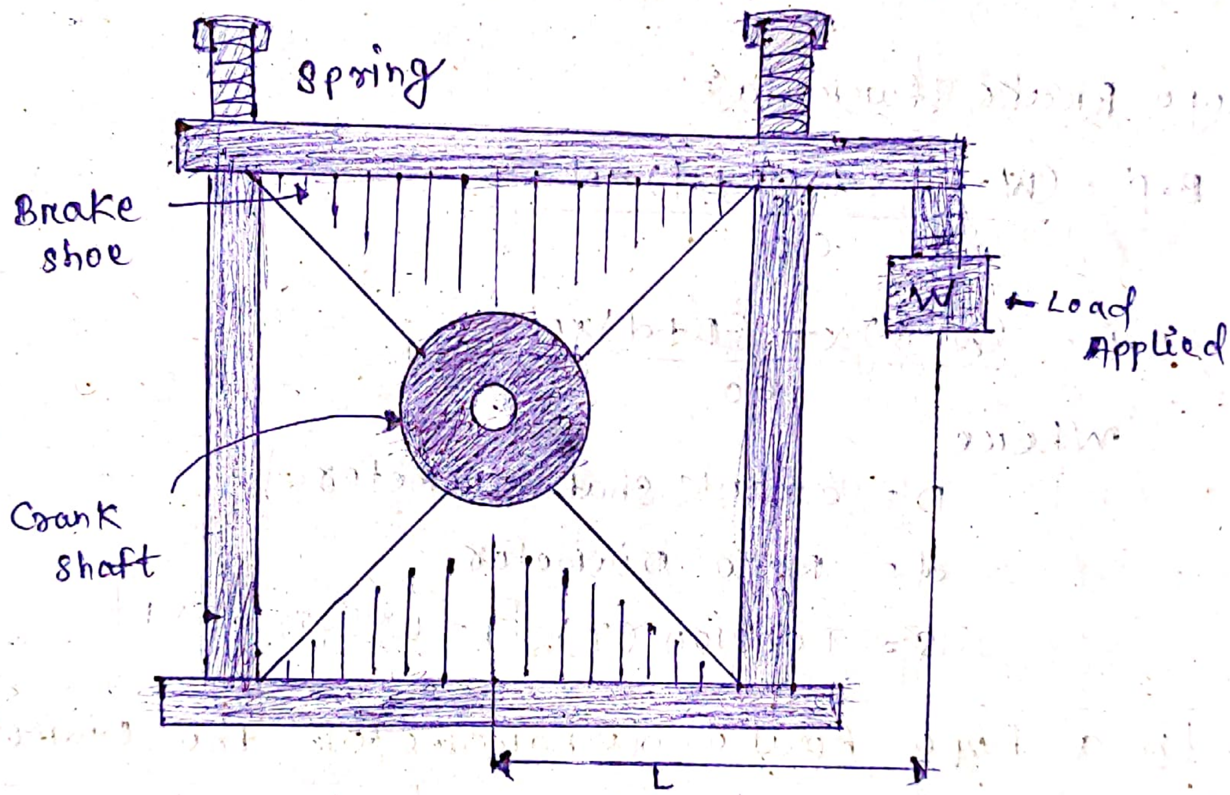
$= \frac{(100-50) \times 3.14 (2+0.1) \times 100}{60}$

$= \frac{50 \times 3.14 \times (2.1) \times 100}{60}$

$= 549.77$ Kw

Ans

(2) PRONY BRAKE DYNAMOMETER :-



Where, L = Arm Length

N = Speed of the Engine

W = Load Applied.

$B.P = \frac{T \times 2\pi N}{60}$

$T = W \times L$ $\quad = B.P = \frac{2\pi N W L}{60}$

$[T = F \times r]$

(Q) In a prony Brake Dynamometer Net load acting on It is 100N and it's Arm Length is 300mm, when the Engine is Running at a speed of 1000 r.p.m find the Brake Power of the Engine?

Ans:-

Given

$W = 100N$

$L = 300mm = \frac{300}{1000} = 0.3m$

$N = 1000$ r.p.m

we know that the B.P. is $\frac{2\pi NWL}{60}$

$$= \frac{2 \times 3.14 \times 1000 \times 100 \times 0.03}{60}$$

$= 314$ kW

Ans

FRICTION POWER:-

The Power lost in overcoming Engine Friction is called Friction Power.

friction Power = I.P − B.P

where, I.P = Indicated Power

(Q) In an Engine the Brake Power and Indicated Power Measured as 9140 kW and 10020 kW, find the friction Power?

Ans:- B.P = 9140 kW

I.P = 10020 kW

we know that F.P = (I.P − B.P)

= (10020 − 9140)

= 880 kW.

MQ:- (Note):- Indicated power is total power of an ic engine. And the Brake Power is power of crank shaft.
Alway Indicated power is greater then Brake power

EFFICIENCY OF I.C ENGINE:-

(1) Mechanical Efficiency:-

$$M.e = \frac{\text{Brake Power}}{\text{Indicated Power}}$$

(2) Breake thermal Efficiency:-

$$\text{Brake thermal efficiency} = \frac{\text{Brake Power}}{m_f \times CV}$$

where, m_f = mass of the fuel
CV = Calorific Value of the fuel.

(3) Indicated thermal efficiency:-

$$I.P\eta = \frac{\text{Indicated Power}}{m_f \times CV}$$

where, I.P = Indicated Power
η = Efficiency

(Q) In an Engine indicated Power is 100 kw And friction Power is 10 kw. find out The Mechanical efficiency of the IC Engine?

Ans :-

Given

$I.P = 200\ kW$

$f.P = (I.P - B.P) = 20\ kW$

$B.P = I.P - F.P$

$B.P = 200 - 10$

$B.P = 90\ kW$

[where, I.P = Indicated Power
B.P = Brake P.
f.P = friction Power]

We known that the Mechanical efficiency

$$= \frac{B.P}{I.P} = \frac{90}{100} = \frac{9}{10} = 0.9 = 9\%$$

Ans

Solved Problems :-

(Q.) In a 2-stroke Engine It is given that the mean Effective Pressure is 5 bar which is a 4-cylinder Engine the speed of the engine is 400 R.P.M and Diameter of the Piston is 200 mm findout The Mechanical efficiency when Brake Power of the Engine is 10 kW and the Length of the stroke is 100 mm

Ans :- Given

$P_{m.e.p} = 5\ bar$

$N = 400\ R.P.M$

$K = 4$

$$D = 200\ mm = \frac{200}{1000} = 0.2\ m$$

$B.P = 10\ kW$

$$L = 100\ mm = \frac{100}{1000} = 0.1\ m$$

We know that

$$I.P = \frac{P_{m.e.p} \times L \times A \times N \times K \times 100}{60}$$

$$= \frac{5 \times 0.1 \times \frac{3.14}{4} \times (0.2)^2 \times 400 \times 4 \times 100}{60}$$

$$= 41.86 \text{ KW}$$

mechanical efficiency

$$\eta_m = \frac{B.P}{I.P} = \frac{10}{41.86} = 0.23 = 23\%$$

Ans

(Q2) A Engine uses 6.5 kg/hr of oil having Calorific value 30,000 KJ/kg If the Brake Power of the engine is 22kg and mechanical Efficiency is 75% find out the

(i) Indicated Thermal efficiency.

(ii) Brake Thermal efficiency.

Ans:-

Given

$m_f = 6.5 \text{ kg/hr}$

$C_V = 30,000 \text{ KJ/kg}$

$B.P = 22 \text{ kg}$

$\eta_m = 75\% = 0.75$

$$\text{mechanical efficiency} = \frac{\text{Brake Power}}{I.P}$$

$$I.P = \frac{B.P}{\eta_m} = \frac{22}{0.75} = 29.3 \text{ KW}$$

∴ Indicated Thermal efficiency

$$= \frac{I.P}{m_f \times C_V} = \frac{29.3 \times 3600}{6.5 \times 30,000} = 0.5 = 54\%$$

∴ Brake thermal efficiency

$$= \frac{B.P}{m_f \times C_V} = \frac{22 \times 3600}{6.5 \times 30,000} = 0.40 = 40\%$$

Ans

MQ:- 1 Hour convert to second - 3600

EFFCIENCY OF I.C ENGINE:-

(4) Air standrad EFFICIENCY:-

(1) $$\eta_{otto} = 1 - \frac{1}{(r_K)^{\gamma-1}}$$ (Petrol engine)

(2)

$$\eta_{diesel} = 1 - \frac{1}{\gamma} \times \frac{1}{(r_K)^{\gamma-1}} \times \frac{r_c^{\gamma-1}}{(r_c - 1)}$$ (Diesel Engine)

(5) Overall Efficiency:-

$$= \frac{\text{Brake Power}}{m_f \times CV}$$

where, m_f = mass of the fuel.
CV = Calorific Value of the fuel.

(6) Relative efficiency:-

$$= \frac{\text{Indicated Thermal Efficiency}}{\text{Air standrad Efficiency}}$$

(7) Specific Fuel Consumption:-

$$= \frac{\text{Mass of the fuel}}{\text{Brake Power}}$$

Solved Problems:-

(1) An Engine working In a otto Cycle Having Compression Ratio 8 and the Engine Indicated Thermal Efficiency Is 60%, find out the Efficiency Ratio?

Ans:-
Given

$r_K = 8$

Thermal Efficiency of I.P = 60% = 0.60

We Know that

Relative efficiency

$$= \frac{\text{Indicated Thermal efficiency}}{\text{Air standrad efficiency}}$$

$$= \frac{0.60}{1 - \frac{1}{(8)^{0.4}}} = 1.062$$

Ans

(2) In a Prony Brake Dynamometer measures the Load acting on It is 100N and the Ratio of Brake drum is 1000mm when 65 kg/hr of the fuel is used, engine seed is 1000R.P.M Determine the

(1) Find Brake Power

(2) Specific fuel Comsumption.

Ans:-

Given

$W = 100N$, $m_f = 65$ kg/hr

$R = 1000mm = \frac{1000}{1000} = 1m$

$N = 1000R.P.M$

$T = F \times r = 100 \times 1 = 100N-m$

we know that

$$B.P = \frac{2 \times \pi \times N T}{60}$$

$$= \frac{2 \times 3.14 \times 1000 \times 100}{60}$$

$= 10466$ watt

Specific fuel comsumption

$$= \frac{\text{mass of the fuel}}{\text{Brake Power}}$$

$$= \frac{65}{10466 \times 3600}$$

$$= 0.000000172$$

Ans

(3) In a 2-stroke engine the Indicated Power is given as 65 Kw and speed of the engine is 100 R.p.m, Length of the stroke and piston diameter is 100mm and 300mm find the mean effective Pressure ?

Ans:- Given

$n = N = 100$ r.p.m

$I.P = 65 Kw$, $K = 1$

$L = 100mm = 0.1m$

$d = 300mm = 0.3m$

we know that

$$I.P = \frac{Pm.e.p \times L \times A \times N \times K \times 100}{60}$$

$$Pm.e.p = \frac{I.P \times 60}{L \times A \times N \times K \times 100}$$

$$= \frac{65 \times 60}{0.1 \times \frac{\pi}{4} \times (0.3)^2 \times 100 \times 1 \times 100}$$

$$= 55.173$$

Ans

(4) A Rope Brake has brake wheel diameter of 600mm and the Diameter of Rope is 5mm the Dead Load on the Brake is 210 N and Spring Balance reads 30N. If the engine makes

450 r.p.m find the Brake Power Developed ?

Ans :-

Given

$D = 600\ mm = 0.6 m$

$d = 5 mm = 0.005 m$

$W = 210 N$

$S = 30 N$

$N = 450 r.p.m$

we know that the B.P

$$= \frac{(W-S) \times \pi \times (D+d) \times N}{60}$$

$$= \frac{(210-30) \times 3.14 \times (0.6+0.005) \times 450}{60}$$

$= 2570$ watt $= 2.57$ KW

Ans

(4) A gas engine has piston diameter of 150 mm, Length of stroke is 400 mm and mean effective Pressure 5.5 bar. The engine makes 120 explosions per minute. Determine the mechanical efficiency of the engine, if it's B.P = 5 KW ?

Ans :-

Given

$d = 150 mm = 0.15 m$

$L = 400 mm = 0.4 m$

$P_{m.e.p} = 5.5$ bar

$n = 120$

$B.P = 5 KW$

we know that

$$I.P = \frac{P_{m.e.p} \times L \times A \times n \times K \times 100}{60}$$

$$= \frac{5.5 \times 0.4 \times \frac{\pi}{4} \times (0.25)^2 \times 220 \times 2 \times 100}{60}$$

$$= 7.77 \text{ Kw}$$

Mechanical efficiency

$$\eta_m = \frac{B.P}{I.P} = \frac{5}{7.77} = 0.64 = 65\%$$

Ans

(5) A four cylinder two stroke cycle petrol Engine Developed 23.5 Kw Brake Power at 2500 r.p.m the Mean effective pressure on each piston is 8.5 bar & The Mechanical Efficiency is 85%. Calculate the Diameter and stroke of each cylinder, assuming the length of stroke equal to 1.5 times the diameter of the cylinder.

Ans:-

Given

$K = 4$

$B.P = 23.5 \text{ KW}$

$N = 2500 \text{ r.p.m}$

$P_{m.e.p} = 8.5 \text{ bar}$

$\eta_m = 85\% = 0.85$

$L = 1.5 . D.C$

we know that

$$A = \frac{\pi}{4} \times Dc^2$$

$$A = \frac{3.14}{4} \times Dc^2$$

$$= 0.785 \, Dc^2$$

$$\eta_m = \frac{B.P}{I.P}$$

$$I.P = \frac{B.P}{\eta_m} = \frac{23.5}{0.85} = 27.64\ KW$$

$$I.P = \frac{P_{m.e.p} \times L \times A \times N \times K \times 100}{60}$$

$$27.64 = \frac{8.5 \times 1.5D_C \times 0.785 D_C^2 \times 2500 \times 4 \times 100}{60}$$

$$27.64 = 165750 D_C^3$$

$$D_C^3 = \frac{27.64}{165750} = 0.000166$$

$$D_C = 0.054 = 54\,mm$$

$$L = 1.5 D_C = 0.08243\ m$$

$$L = 82.43\ mm$$

Ans

(6). A single cylinder Two stroke Petrol engine Developes 4 KW Indicated Power, find the Average Speed of the Piston If the m.e.p is 6.5 Bar and Piston diametere is 100mm ?

Ans :-
Given

$I.P = 4W$

$P_{m.e.p} = 6.5$ bar

$d = 100\ mm = 0.1\ m$

we Know that

$$I.P = \frac{P_{m.e.p} \times L \times A \times N \times K \times 100}{60}$$

$$4 = \frac{6.5 \times L \times \frac{\pi}{4} \times (0.1)^2 \times N \times 1 \times 100}{60}$$

$$4 = 0.85084\ L \times N$$

$$L \times N = \frac{4}{0.85084} = 4.7$$

Avarage Speed $= 2 \times L \times N = 2 \times 4.7 = 9.4\ m/s$

Ans

(7) A Rope brake has brake wheel diameter 600mm and Diameter of Rope is 5mm. Dead Load on the Brake is 120 N and Spring balance Reads 30N If engine makes 450 r.p.m find the Brake Power Developed?

Ans:-

Given

$D = 600mm = 0.6m$

$d = 5mm = 0.005m$

$W = 120 N$

$S = 30N$

$N = 450$ r.p.m

we know that

$$B.P = \frac{(W-S) \times \pi \times (D+d) \times N}{60}$$

$$= \frac{(120-30) \times 3.14 \times (0.6+0.005) \times 450}{60}$$

$= 1282$ watt $= 1.282$ kw

Ans.

Calorific value of fuels:-

It is also called as Heating value of the fuel which is defined as the energy liberated by The complete oxidation of a unit mass or volume of a fuel, It is expressed In kJ/kg for solid and liquied fuel kg/m³ for liquid fuel.

Air-fuel Ratio (A/F):-

Air fuel Ratio is the mass ratio of air to a Solid, liquid or gaseous fuel Present in a Combusition Process, the Combustion takes Place In a controlled manner In an I.C engine The (A/F) Ratio is a significat Indicator and very

Important measure for Petrol engines: Performance: In a perfect condition the

$$\frac{A}{F} = \frac{14.7 \text{ parts of air}}{1 \text{ part of fuel.}} \quad \text{(For best fuel economy)}$$

→ A/F Ratio is the most important parameter in Petrol engine

→ it is parts of carbuerator.

Solved Probems:-

(1) An engine uses 6.5 kg of oil per hour of Cv 30,000 kJ/kg. If the Brake Power of the engine is 22 kw and mechanical efficiency is 85%. find the I. thermal efficiency, Brake thermal efficiency and specific fuel consumption?

Ans:-

Given

$m_f = 6.5$ kg/hr, B.P = 22 kw

$C_V = 30,000$ kJ/kg, $\eta_m = 0.85$.

we know that

$$\eta_m = \frac{B.P}{I.P} \Rightarrow I.P = \frac{22}{0.85} = 25.88 \text{ kw}$$

$$\eta_I = \frac{I.P \times 3600}{m_f \times C_F} = \frac{25 \times 3600}{6.5 \times 30,000} = 0.48 = 48\%$$

$$\eta_B = \frac{B.P \times 3600}{m_f \times C_P} = \frac{22 \times 3600}{6.5 \times 30,000} = 0.406 = 40.6\%$$

Specific fuel

$$\frac{m_f}{B.P} = \frac{6.5}{22} = 0.295 \text{ kg/B.P/hr.}$$

Ans

✱ ✱ ✱ ✱ ✱

HEAT TRANSFER:- (2nd chapter)

Heat transfer always occours at a body which Is at higher temperature to a body at a lower Temperature. means

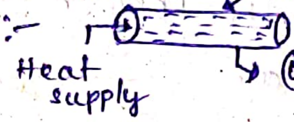
Heat Is always flows from higher Temperature to Lower temp.

Ex:- 

Is to possible some external force

Mode of Heat Transfer:-

(1) Conduction:- It is the transfer of heat from one part of the subtance to another part, having physical contact Between them. Heat is transfer by the moleccules of the object. (solid).

Ex:- 

↳ Only in solid object

(2) Convection:-

Here it is the heat transfer process occours In fluids (Liquid and gas) here the Real Process of Heat transfer occours by Conduction.

These are two types

(1) Natural convection.

(2) forced convection.

Natural convection:-

The heat transfer occours due to the Difference In densities of hot and cold fluid No external Source Is Responsible for heat transfer.

forced Convection:-

Heat transfer occours In fluid when an External force Is applied to the fluid (By Means of Pump or blower).

(3) Radiation:-

It does not Reaquired any medium to Transfer Heat It can be solid, Liquid or gas. Heat is transfer from hot body to cold body.

(1) Laws used In Conduction:-

FORIER'S LAW OF HEAT CONDUCTION:-

It state that the Rate of flow of Heat Through a single homogeneous solid is Directly Proportional to the Temperature gradient and Inversly to change In length. Also Directly proportional to it's Area.

Mathemathically we can write

(1) $Q \propto dT$ . . . . (i)

(2). $Q \propto \frac{1}{dx}$ . . . . (ii)

(3) $Q \propto A$ . . . . . (iii)

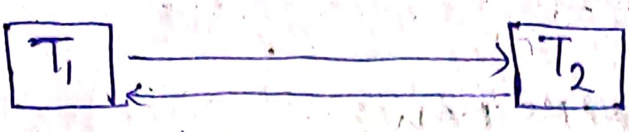
Equating all equation we get

$$Q \propto A \frac{dT}{dx}$$

$$\Rightarrow Q = -K \cdot A \frac{dT}{dx}$$

where, K = Thermal Conductivity

Thermal conductivity:- The high heat Absorb Ability In a metal or a body is called Thermal Conductivity.



$(dT = T_2 - T_1)$

If the value of T_1 is greater then T_2 . then we are using (-ve) sign.

$$q = -K \cdot A \frac{dT}{dx}$$

(2) using law in Convection :-

NEWTON'S LAW OF COOLING :-

The heat transfer from a hot body to Cold body is Directly proportional to the surface Area and the Temperature. Difference betn them.

Mathemathically we write

$Q \propto$ Surface Area

$Q \propto dT$

Equating Above equation we get

$Q \propto A \cdot dT$ $\boxed{T_1 < T_2}$

$Q \propto A\ (T_1 - T_2)$

$Q = h \times A \times (T_1 - T_2)$

where,

h = Heat transfer co-efficient

It is only measure In Fluid (liquid or gas).

RADIATION'S LAW:-

(1) STEFAN'S BOLTZMAN'S LAW:-

The emmissive Power of a black body is Directly propertional to the fourth power of Absolute temperature.

$$E \propto T^4$$

$$E = \sigma T^4$$

where;

σ = Boltzman Constant

$= 5.67 \times 10^{-8} \, W/m^2 . K^2$

(2) Kirchoff's Law:-

The Ratio of Emmissive Power to the Absorbity Power of all the bodies are same.

$$\frac{E_1}{\alpha_1} = \frac{E_2}{\alpha_2}$$

where,

E = Emissive Power

α = Absorbity Power.

(3) Wein's Displacement Law:-

The Product of wave length corresponding to maximum Power and the absolute temperature of a black body is constant.

(Lambda) → $\lambda_{max} \times T$ = Constant

= 2.88 mm - kelvin.

* * * * *

:STEAM GENERATOR:

Boiler:-

Boil - hot, ler - function.

Process of Steam:-

water → Boiler → Steam → turbine → power Generate.

(i) Boiler is the most Important in thermal power plant or Steam power plant.

(ii) Boiler is also known as Steam Generator.

(iii) we are suppling water to Boiler and Boiler Converts the water into steam.

(iv) Boiler is only Generate Seam.

TYEPS OF BOILER:-

(1) Fire tube Boiler.

(2) water tube Boiler.

CLASSIFICATION OF BOILER:-

(1) Based upon the flow of (hotgas / Fluegas):-

- Fire tube boiler.
- water tube boiler.

(2) Based upon the no. of Tubes:-

- single-tube
- multi-tube.

(3) Based on the axis of Boiler:-

- Horizontal.
- Vertical.

(4) Based upon the (fluid/water) circulation:-

- Natural circulation.
- Forced circulation.

(5) Based upon the Burning process:-

- Internally fired.
- Externally fired.

(6) Based on the pressure Range:-

- high Pressure (more than 25 bar)
- Medium pressure (10 to 15 bar)
- low pressure (3.5 to 10 bar)

(7) Based upon the loading condition:-

- stationary.
- Portable.

IMPORTANT TERMS USED IN BOILER:-

(1) Boiler shell.

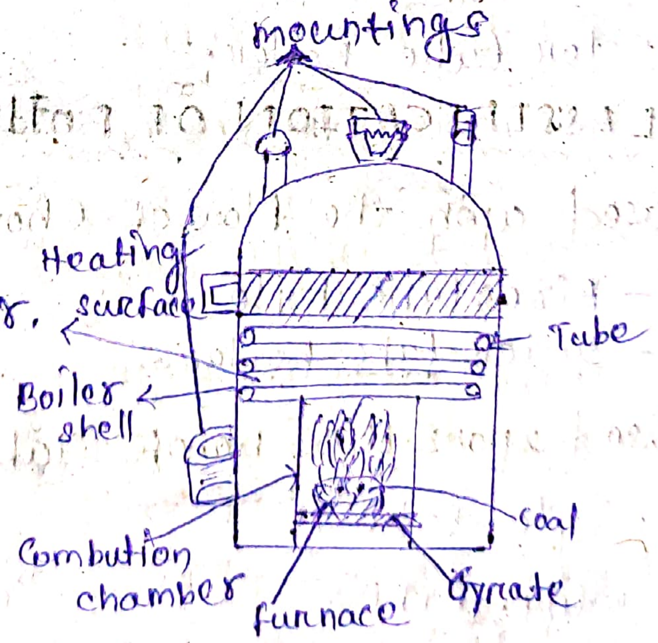
(2) Grate.

(3) Furnace.

(4) combution chamber.

(5) Heating surface

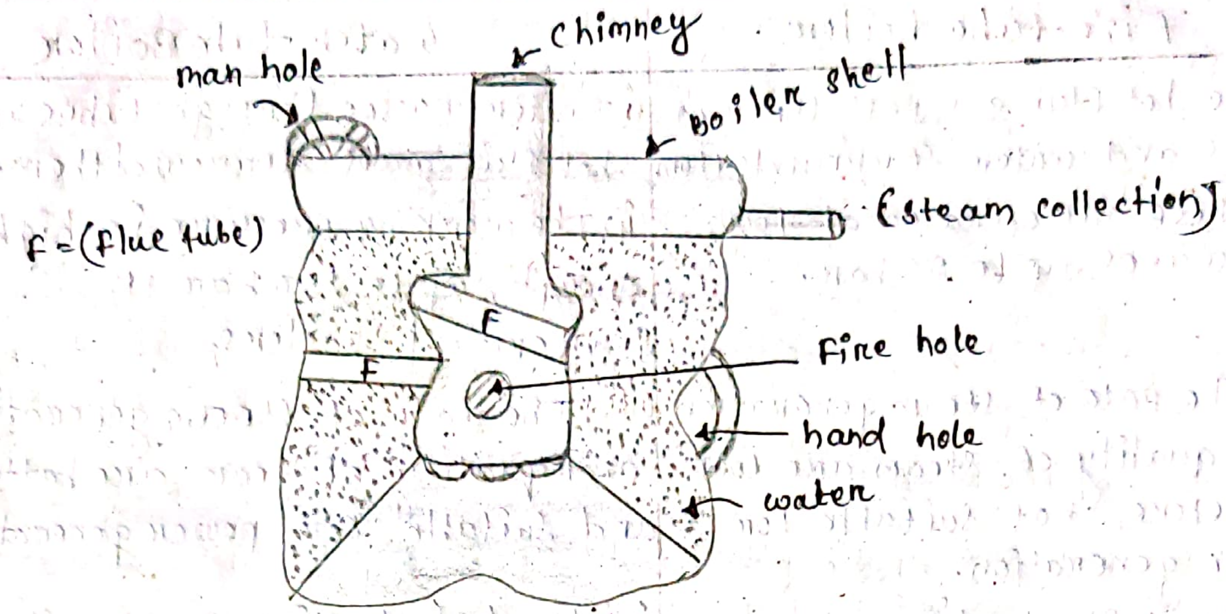
(6) Mountings.



TYEPS OF BOILER:-

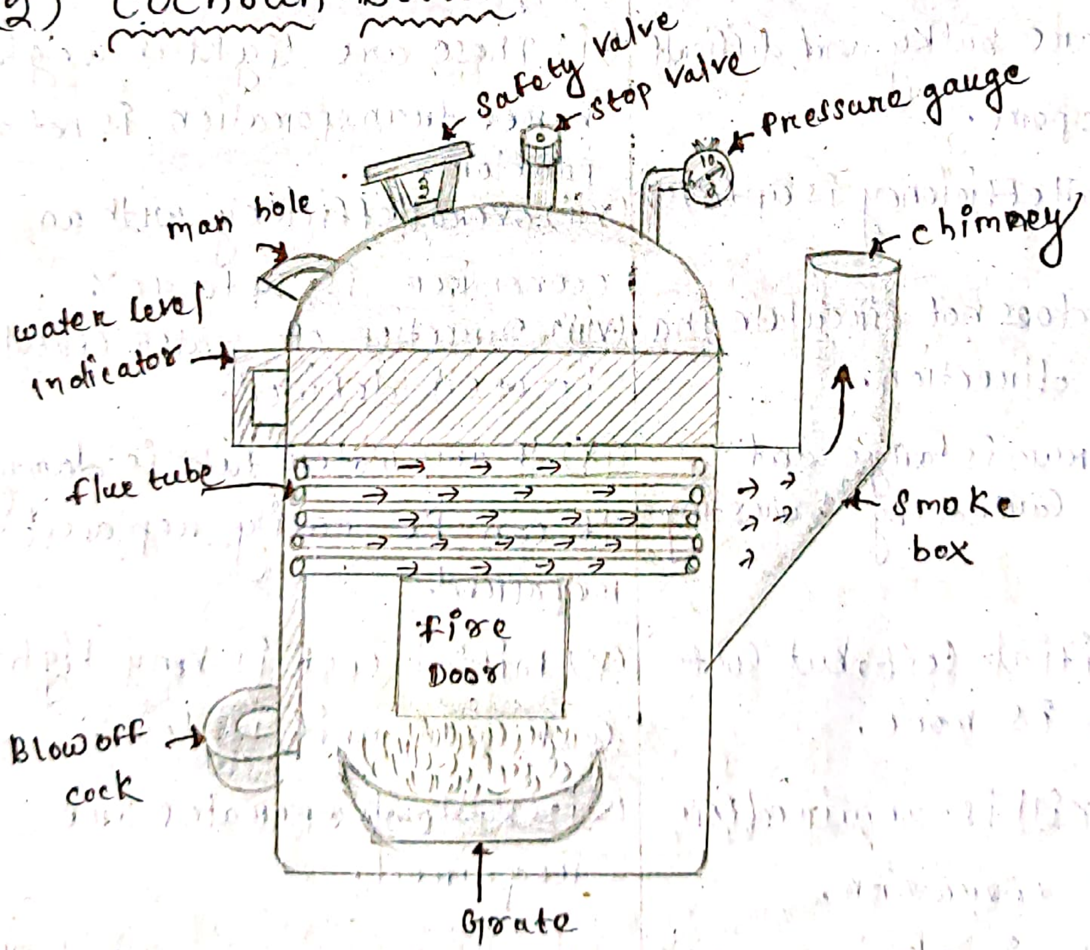
FIRE TUBE BOILER:-

(1) simple vertical boiler:-



(i) Low steam generation.
(ii) low pressure Range.

(2) Cochran Boiler :-



Difference betn fire-tub & water tube boiler:

Fire-tube boiler	water-tube Boiler
(i) The hot flue gas pass through tubes and water surrounds them	(i) water passes through tubes and hot flue gases surround them.
(ii) These are operated at low pressures up to 20 bar.	(ii) The working pressure is high enough, up to 250 bar in supercritical boilers.
(iii) The rate of steam generation and quality of steam are low, therefore, not suitable for power generation.	(iii) The rate of steam generation and quality of steam are batter and suitable for power generation.
(iv) Load fluctuations cannot be handled.	(iv) Load fluctuations are easily handled.
(v) It requires more floor area for a given out put.	(v) It requires less floor area for a given output.
(vi) They are bulky and difficult to transport.	(vi) These are light in weight, hence transporation is not a problem.
(vii) overall efficiency is upto 75%	(vii) overall efficiency with an economiser is upto 90%
(viii) water does not circulate in a Definite direction.	(viii) Direction of water circulation is well defined.
(ix) The drum is large and Damage caused by bursting is large.	(ix) If any water tube is damaged, It can be easily replaced or repaired.
(x) less initial cost, but cost per unit is more.	(x) Initial cost is very high, but cost per unit is low.
(xi) less skill is required for efficient operation.	(xi) skilled operatos are required.
(xii) simple in design, easy to erect and low maintenace cost.	(xii) complex design, difficult to erect and high maintenance cost.
xiii) used in process Industry.	(xiii) use In large power plants.

(XIV) The treatment of feed water is not very essential, as overheating due to scale formation can not burst the thick shell.	(XIV) Treatment of feed water is very essential as small scale deposite inside the tubes can cause overheating and bursting.

STEAM GENERATOR:-

The steam boiler or steam generator is a closed vessel in which water is heated, vaporised and converted into steam at a pressure higher than the atmospheric pressure.

Fire-tube & water-tube Boiler:-

In a water-tube boiler, the water flows through a number of small tubes, which are surrounded by hot combustion gases, while in a fire-tube boiler, the hot combustion gases pass through the boiler tubes, and water surrounds them.

Boiler:-

The steam boiler is a closed vessel in which water is heated, vaporised and converted into steam.

LANCASHIRE BOILER:-

(i) Fire tube Boiler.

(ii) Horizontal Boiler.

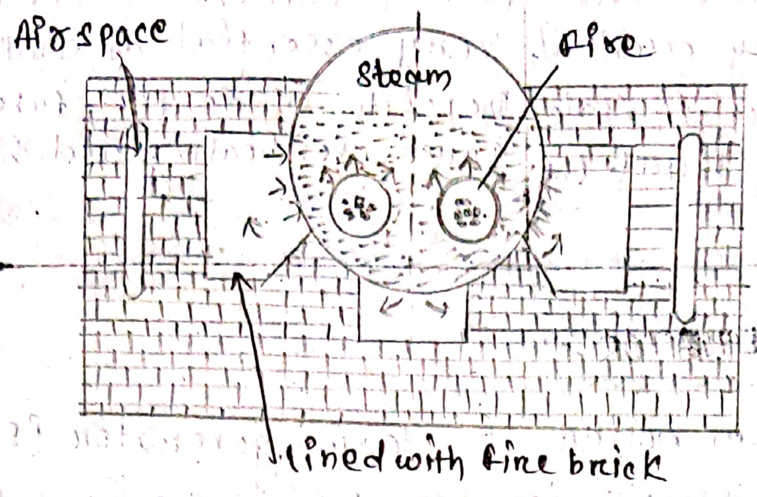
(iii) Internally fired Boiler.

(iv) Stationary Boiler.

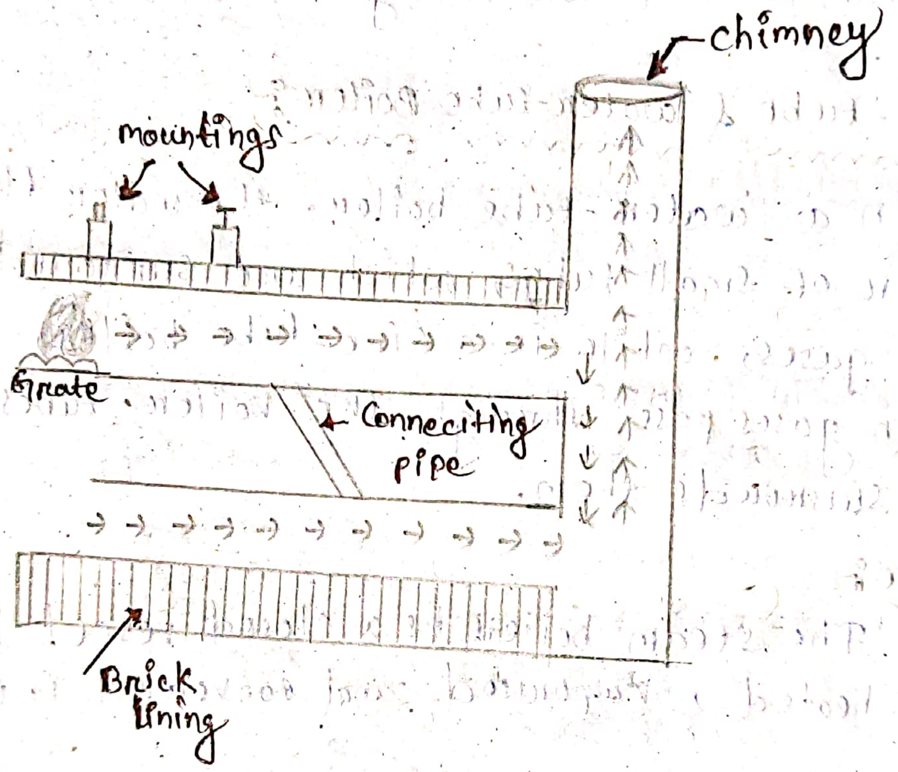
(v) Natural ~~Bo~~ Circulation Boiler.

(vi) Multi-tube Boiler.

(vii) Medium Pressure Boiler.



side view



(INTERNAL VIEW)

Special features:-

(i) Its heating surface area per unit volume is considerably large.

(ii) It maintenance is easy.

(iii) This boiler can easily handle the load fluctuation to large steam capacity.

(iv) It is highly suitable for process industries.

WATER TUBE BOILER:-

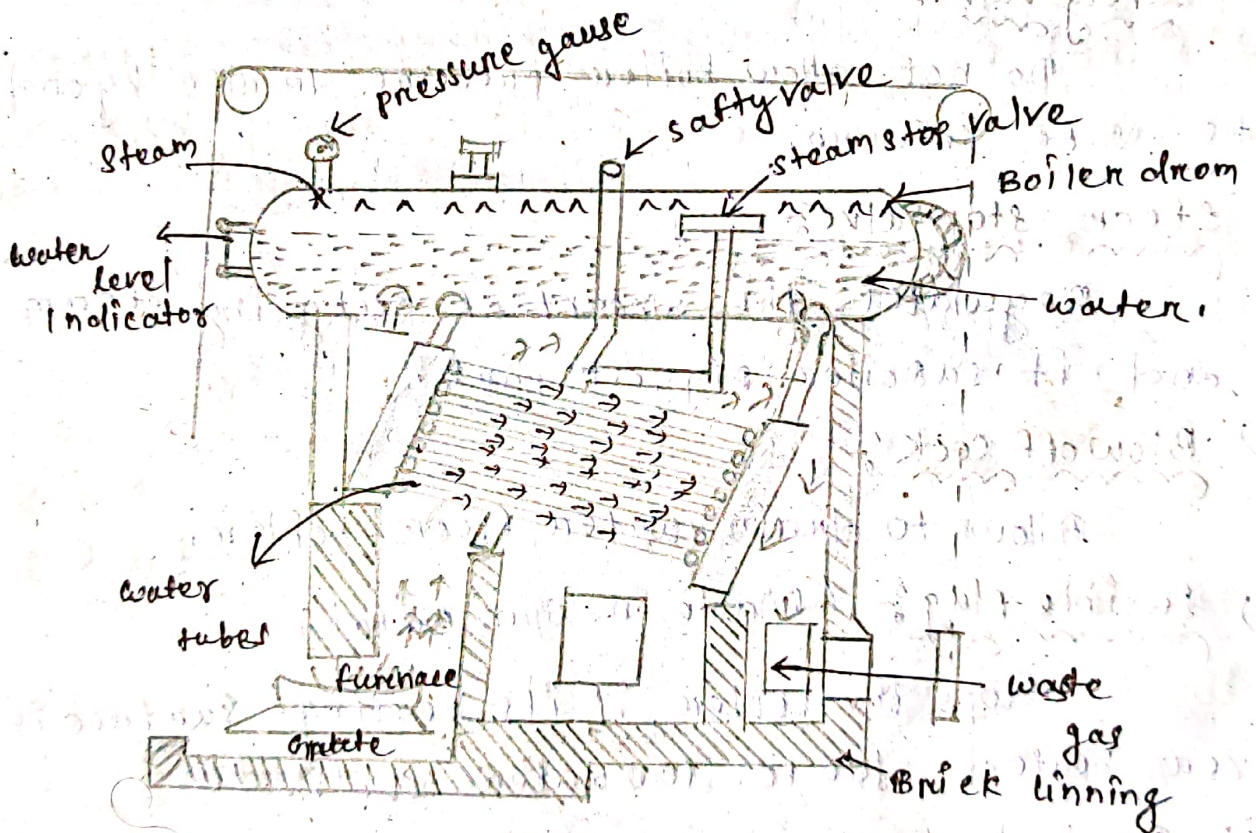
Here the water flows inside the tubes And the hot gases are present surrounding to it.

Ex:- Babcock & wilcox Boiler.

These can produce more steam as compared to fire tube Boilers.

BABCOCK & WILCOX BOILER:-

The babcock & wilcox boiler is probably the first water tube boiler designed and widely used.



Special features:-

(i) The draught losses are minimum

(ii) It evaporating capacity is quite high compared with other boilers (20,000 to 40,000 kg/h). The operating pressure lies between 11.5 to 17.5 bar.

Boiler mountings :-

The boiler mountings are the different fittings And devices which are mounted on a boiler shell for proper functioning and safety. These form an Integral part of the boiler.

(i) Water level indicator :-

Shows working level of water in the boiler.

(ii) Pressure gauge :-

Indicates working pressure of Boiler.

(iii) Man hole :-

Allows a person to go inside the boiler dram for repairs, etc.

(iv) Safety valve :-

Do not allow boiler pressure to rise byond its safe pressure.

(v) Steam stop valve :-

Regulates the amount of outgoing steam and its a Boiler Biggest part.

(vi) Blow off cock :-

Allow to drain water from boiler.

(vii) fusible plug :- (Made in Gun metal)

Stops the boiler if its heating surface is over heated due to low water level.

(viii) Feed check valve :-

checks the amount of feed water going to the boiler and does not allows it return.

(ix) feed pipe :-

load the feed water to the Inside of the boiler.

BOILER ACCESSORIES:-

The accessories are mounted on the Boiler to Increase its efficiency. These units are optional on an efficient boiler. The important accessories of Boiler are :-

(1) Super heater.

(2) Air - pre heater.

(3) Economiser.

(1) SUPER HEATER:-

It converts the Dry saturated steam to Super heated steam so that we can get more Efficiency from the turbine.

Increase the temperature of steam at constant Pressure beyond saturation.

(2) AIR-PRE HEATER:-

The Rate of burning of fuel is dependent on oxygen supply when atmospheric air passes Through air-preheater. The Temperature of the Air Increases and dissolved gases can also be Romoved

Pre heat the fresh air by using the Heat of waste flue gases.

(3) ECONOMISER:-

It uses the heat from the hot flue gas And use it to heat the feed water. It helps to Maintain the Economy of the power plant.

Preheating the feed water by utilising the Heat of waste flue gases.

BOILER DRAUGHT:-

For better combustion of the fuel we need To supply proper amount of oxygen to the Greate. This process is called Boiler Draught.

· To Exhaust the extra hot gas from the combution chamber; we use boiler draught.

TYPES OF BOILER DRAUGHT:-

(1) NATURAL DRAUGHT:-

It is also called chimney Draught.

- Due to density of hot air and cold air are Defferent defferent the hot air flows out and the cold air is flws in of the Boiler.
- Natural Draught is produce due to the difference Between Density of hot air and density of cold air.

(2) FORCED DRAUGHT:-

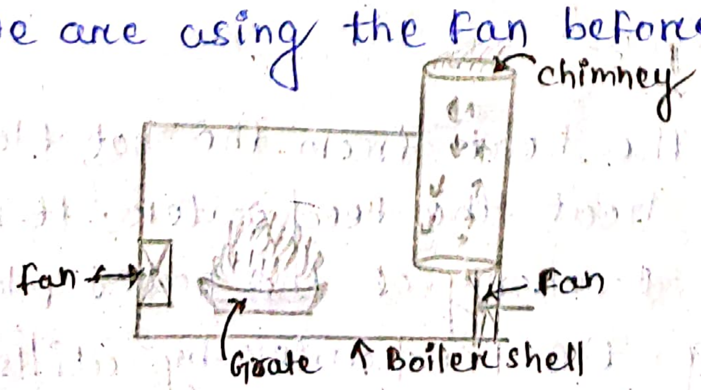
- It is also called artificial Draught.

(i) Mechanical Draught:-

we are using the fan at the base of the chimney.

(ii) Induced Draught:-

we are using the fan before Grate.



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RECIPROCATING AIR COMPRESSOR:-

AIR COMPRESSOR:- It is a mechanical device which Takes the air from the atmosphere and discharge It at a very high Pressure.

USE:- (Reverting, pneumatic, Automobailes industry)

Types:-

(1) **Based upon it's stage:-**

(1) single stage (2) multi stage.

(2) **Based upon the force acting on the piston:-**

(1) Single acting - One direction.

(2) Double acting - Both direction.

(3) **Based upon it's working:-**

(1) Reciprocating (2) Rotary

(1). **single stage:-**

A Compressor in which the compression of Gas to Final delivery pressure is carried out in One cylinder only.

Multi stage Compressor:-

A Compressore which compresses the gas to the Final pressure in more than one cylinder in series.

(2). **single acting compressore:-**

A Compressor in which all actions take place only one side of the piston during a cycle.

Double-acting Compressore:-

A Compressare in which suction, compression and delivery of gas take place on bothe side of the piston.

(3) Reciprocating Compressor :-

A reciprocating machine, used to compress the air during each stroke of piston.

Rotary compressor :-

A machine which compressor the air by Dynamic action.

IMPORTANT TERMS USED IN COMPRESSOR :-

(1) PRESSURE RATIO :- (Compression ratio) :-

The ratio of absolute discharge pressure to absolute suction pressure.

$$\text{Compression Ratio} = \frac{P_2}{P_1} = \frac{\text{discharge Pressure}}{\text{Inlet pressure}} = \gamma_p$$

→ Compression ratio is always grater than 1.

(2) Compressor capacity :-

Quanitity of air delivered per unit time at Atmospheric conditions.

→ It is measured in mm^3/min (How much volume of Air Discharged).

(3) Free air delivery :-

Discharge volume of compressor corresponding to ambient conditions.

→ (Normal operating Condition - discharge of air)

(4) Mean effective pressure :-

At avery time pressure is change then we take constant value of pressure we use mean effective pressure.

$$m.e.p = \frac{\text{workdone}}{\text{stroke Volume or swept volume}}$$

(5) Volumetric efficiency :-

$$\eta_v = \frac{\text{Actual Volume of air during suction}}{\text{Stroke volume}}$$

(6) Stroke volume or swept volume :-

$$V_{stroke} = \frac{\pi}{4} \times D^2 \times L \quad (A \times L)$$

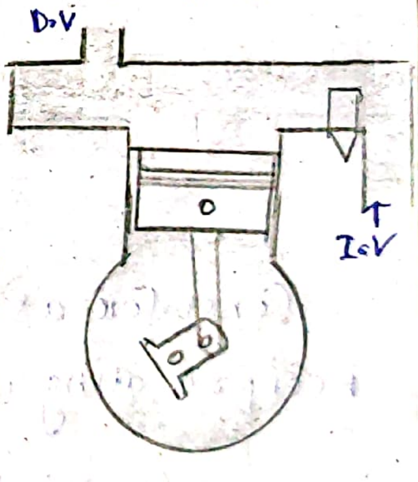
D = diameter of the piston.

L = length of the stroke.

(7) Inlet pressure (P_1), (8) Discharge pressure (P_2).

WORKING PRINCIPAL OF SINGLE STAGE RECIPOCATING AIR COMPRESSOR

It Consists of cylinder, piston Inlet valve And discharge valve and when the Piston moves down ward (suction stroke) the pressure inside the cylinder falls below the atmospheric Pressure. due to the Pressure difference the Inlet valve Gets opened and Fresh air is entered Into the engine cylinder. when the Piston moves upward (Delivery stroke) The pressure Inside the cylinder goes On Increasing until It Reaches the Delivery pressure during the delivery stroke small quantity of air, is at High pressure Is left in the clearance space. Here The three Process suction, Compression and Delivery of air Takes place in two stroke of the Piston or single Revolution of the crank shaft.



WORK DONE BY SINGLE STAGE RECIPROCATING AIR COMPRESSOR:-

(1). work is done on the piston during suction.

(2). work is done on the piston during compression.

(3). work is done on the piston during Delivery.

work done CONDIONS :- PROCESSES:-

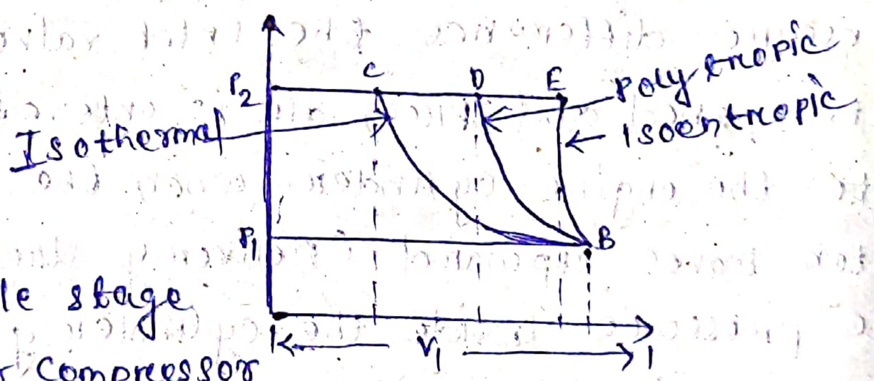
(1) Isothermal - $T = C$ (Least work done.

(2). Isoentropic - Adiabatic ($PV^{\gamma} = \text{constant}$) $dq = 0$.

(3) Polytropic Process. ($PV^{n} = \text{constant}$)

where n = adiabatic index.

work done by Compressure without clearance volume



Consider a single stage Reciprocating air Compressor

P_1 = initial pressure → P_2 = Final pressure

V_1 = initial Volume → V_2 = Final Volume

T_1 = initial Temperature → T_2 = Final Temperature

(r_p) Compression ratio = $\frac{P_2}{P_1}$

(P~V) diagram for single acting Compressor is shown above without clearance volume air is compressed here at constant Temperature. Compression Continue till it -

Reaches to the pressure (P_2). Here As a matter of Fact the compression may be isothermal, Isoentropic or polytropic Compression.

(1). workdone during Isothermal Compression ($T = C$).

$$W = 2.3 P_1 V_1 \log\left(\frac{V_1}{V_2}\right)$$

$$= 2.3 P_1 V_1 \log\left(\frac{P_2}{P_1}\right)$$

$$= 2.3 mRT_1 \log\left(\frac{P_2}{P_1}\right)$$

$$= 2.3 mRT_1 \log\left(\frac{V_1}{V_2}\right)$$

we know that Ideal gas equation $PV = mRT$, $P_1V_1 = P_2V_2$.

(2). work done during Polytropic compression ($PV^n = C$).

$$W = \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \frac{n}{n-1} mRT_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \frac{n}{n-1} P_1 V_1 \left[\left(\frac{V_1}{V_2}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \frac{n}{n-1} mRT_1 \left[\left(\frac{V_1}{V_2}\right)^{\frac{n-1}{n}} - 1\right]$$

(3). work done during isoentropic compression (Reversible Adiabatic)

$$W = \frac{\gamma}{\gamma-1} P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

$$= \frac{\gamma}{\gamma-1} mRT_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

$$= \frac{\gamma}{\gamma-1} P_1 V_1 \left[\left(\frac{V_1}{V_2}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

$$= \frac{\gamma}{\gamma-1} mRT_1 \left[\left(\frac{V_1}{V_2}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

SOLVED PROBLEMS:-

(Qn) In a single stage Reciprocating air Compressor follow $PV^{1.25}$ = constant process the Initial pressure is 1 bar and delivery Pressure is 8 bar the Compressor compresses the volume 60 m^3 of air find The work done ?

Ans:- Given

$n = 1.25$

$P_1 = 1$ bar $= 1 \times 10^5$ pascal

$P_2 = 8$ bar $= 8 \times 10^5$ pascal

$V = 60\ m^3$

we Know that w

$$W = \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

$$= \frac{1.25}{1.25-1} \times 1 \times 10^5 \times 60 \times \left[\left(\frac{8 \times 10^5}{1 \times 10^5} \right)^{\frac{1.25-1}{1.25}} - 1 \right]$$

$$= \frac{1.25}{0.25} \times 60 \times 10^5 \times \left[8^{\frac{0.25}{1.25}} - 1 \right]$$

$= 15471.49$ KJ

$= 1547149$ J

Ans

(Qn) find the work done in isothermal Process when to compress 1 m^3 of air at a temperature of 15°c the initial pressure is 1 bar and final Pressure is 7 bar take $R = 0.287$ KJ/kg.K?

Ans:- Given

$V_1 = 1\ m^3$

$T_1 = 15°c = 15 + 273 = 288$ K

$P_1 = 1$ bar $= 1 \times 10^5$ pascal

$P_2 = 7$ bar $= 7 \times 10^5$ pascal

$R = 0.287$ KJ/Kg.K

We Know that

$w = 2.3 P_1 V_1 \log\left(\frac{P_1}{P_2}\right)$

$= 2.3 \times 1 \times 10^5 \times 1 \log\left(\frac{1 \times 10^5}{7 \times 10^5}\right)$

$= 230000 \log\left(\frac{1}{7}\right)$

$= -(-193200)$ (We Know that the work done on the system is taken as Nagative)

$= 193200$ Joule

$= 193.200$ KJ

Ans

or

We know that

$P_1 V_1 = mRT_1$

$= 1 \times 10^5 \times 1 = m \times 0.287 \times 300$

$= m = \frac{1 \times 10^5 \times 1}{0.287 \times 300}$

$= 1161$ g

$= 1.161$ kg

$w = 2.3 \times 1.161 \times 0.287 \times 300 \log\left(\frac{P_1}{P_2}\right)$

$= 193.20$ KJ

Ans

(3) Find the work done in all three process when to Compress air at a temp. of 15°C. The initial pressure Is 1 bare and final pressure is 7 bar take $R = 0.287$ KJ/Kg.K when the initial volume is 30 m^3.

(1) Isothermal, (2) Adiabatic $pv^{1.26} = c$ (3) polytropic $pv^{1.25} = c$.

Ans:-

Given

$T_1 = 15°C = 15+273 = 288$ K

$P_1 = 1$ bar $= 1 \times 10^5$ Pascal

$P_2 = 7$ bar $= 7 \times 10^5$ pascal

$V_1 = 30\ m^3$

$R = 0.287$ KJ/Kg.K

$n = 1.25$

$\gamma = 1.26$

(1) Isothermal Process

$$W_{iso} = 2.3\ P_1 V_1 \log\left(\frac{P_2}{P_1}\right)$$

$$= 2.3 \times (1 \times 10^5) \times 30 \log\left(\frac{7}{1}\right)$$

$$= (6900000) \times (-0.84509804)$$

$$= 5831176.476 \text{ J}$$

$$= 5831.176 \text{ kJ}$$

Ans

(2) Adiabatic process

$$W_{adi} = \frac{\gamma}{\gamma - 1} \times P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\left(\frac{\gamma-1}{\gamma}\right)} - 1\right]$$

$$= \left(\frac{1.26}{1.26-1}\right) \times (1 \times 10^5) \times (30) \left[\left(\frac{7}{1}\right)^{\left(\frac{1.26-1}{1.26}\right)} - 1 \right]$$

$$= (14538461.54) \times (0.494119 4175)$$

$$= 7183736.147 \text{ J}$$

$$= 71837.36147 \text{ kJ}$$

Ans

(3) Polytropic process

$$W_{poly} = \frac{n}{n-1} \times P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\left(\frac{n-1}{n}\right)} - 1 \right]$$

$$= \frac{1.25}{1.25-1} \times (1 \times 10^5) \times (30) \left[\left(\frac{7}{1}\right)^{\left(\frac{1.25-1}{1.25}\right)} - 1 \right]$$

$$= \frac{1.25}{0.25} \times (1 \times 10^5) \times (30) \left[\left(\frac{7}{1}\right)^{\left(\frac{0.25}{1.25}\right)} - 1 \right]$$

$$= (15000000) \times (0.4757731616)$$

$$= 7136597.494 \text{ J}$$

$$= 71365.97424 \text{ kJ}$$

Ans