GOVERNMENT POLYTECHNIC, GAJAPATI

DEPARTMENT OF MECHANICAL ENGG

STUDY MATERIAL

POWER STATION ENGINEERING (TH-3)

6TH SEMESTER

MECHANICAL ENGG.

BY

SRI BIPIN KUMAR DASH
SENIOR LECTURER,
MECHANICAL ENGG.

CONTENTS:

Course outcomes(CO)

At the end of the course students will be able to:

C323.1	To apply knowledge of basic thermodynamics and its operation in thermal power station and to analyse the performance of thermal power station.
C323.2	To identify nuclear energy sources and compare the nuclear power station with other types of power station.
C323.3	To analyse hydroelectric,diesel and gas turbine power station and their applications as per need of society.

01. SOURCES OF ENERGY

Source of Energy

- Renewable (Water, Solar, wind tidal energy etc.)
- Non-Renew (coal, petrol, Nuclear bu

Renewable source of Energy :-

The source of energy which are essent in exhaustiable such as wind energy solar energy, Thermal energy, Tidal en hydel energy are known as renewable sources of energy.

NON-Renewable source of Energy :-

The sources of energy which are deplete are known as non-renewab energy.

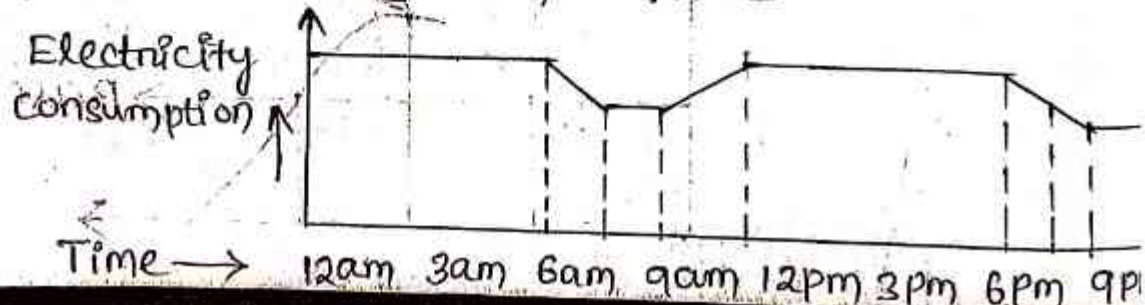
Example :- Coal, diesel, Petrol, nuclea ~~fuel~~ gas, oil, etc

Load Curve :-

Q. What do you mean by load Curve?

Load curve gives an informatic about electricity consumption in a per culare area.

Ex: Load curve an office.



Types of power plant :-

1. According to renewable source of energy
   - → Hydroelectric power plant
   - → Solar power plant
   - → Wind power plant
   - → Tidal power plant
   - → Geothermal power plant.

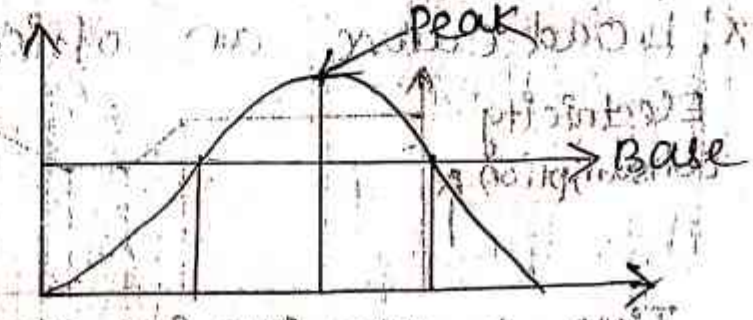
Q. What is Geothermal Energy ?

Heat inside the earth crust is known as Geothermal Energy.

2. According to Non-Renewable Source of Energy.
   - → Thermal power plant
   - → Petrol power plant
   - → Disel power plant
   - → Nuclear power Plant ($_{92}U^{235}$)

3. According to the Load of electricity
   - → Base Load power plant
   - → Peak Load power plant.

4. According to distribution of electricity
   - → Captive power Plant
   - → central power plant



06/01/11

Base Load power plant :-

* The power plant which always run a their fullest capacity to meet the ba Load are called base load power plant
* In Load curve the base load is the min Load.
* In base load power plant the demand never falls below the base load line in Load curve.

Ex: Thermal power plant is the base lo power plant.

Peak Load power plant :-

* The power plant which are operated meet the peak demand are called pea load power plant
* The peak Load in the load curve rep the maximum demand at a particular time.
* This always more than base load.

Ex: Hydroelectric power plant, Diesel p.

Captive power plant :-

If the electricity produced by th power plant is utilized for individual (Organisation) of its own purpose onl then the power plant is known as capt power plant.

Ex:- NALCO, RSP

NALCO - National Aluminium Company

RSP - Rourkela Steel plant.

Central power plant :-

* If the electricity produced by the power plant is utilized for it's own purpose as well as the commercial used then the power plant is known as central power plant.
* It is also uses the outlet of turbine house for irrigation purpose.

Ex :- NTPC, NHPC

Performance parameter

Parameters are

(i) plant load factor
(ii) Specific fuel consumption
(iii) Heat Rate
(iv) Efficiency

1. Plant Load Factor :- PLF =

$$\frac{\text{Actual generation of electricity over a division}}{\text{Generation of electricity at installed capacity}}$$

2. Specific Fuel Consumption :-

* $SFC = \frac{\text{Fuel consumed in a perticular period}}{\text{Energy generated during the same period}}$
* Specific Fuel consumption is defined as the amount of fuel consume to generate 1 Kwh of electrical energy.
* Unit of specific Fuel consumption is Kg/Kwh

Heat Rate:-

*H·R = $\frac{\text{Amount of fuel consumed} \times \text{calorific value of fuel}}{\text{Energy generated by the fuel}}$

* It is defined as the amount of heat required to generate 1 KWh electric energy.
* Unit of Heat Rate is KJ/KWh or Kcal/

Efficiency:-

* Efficiency (η) = $\frac{\text{WORK}}{\left(\frac{\text{Heat supply}}{\text{WORK}}\right)}$
* It is defined as the ratio of work ou to the heat input
* It is the ~~reciprocal~~ reciprocal of heat rate.

$$\eta = \frac{3600}{H \cdot R}$$

Geothermal Energy:-

The heat energy available inside th core of the earth is known as Geotherma energy.

Geothermal power plant:-

The power plant which is run by the heat available inside the core o the earth is known as Geothermal power plant.

2. THERMAL POWER PLANT

08101118

Site selection For Thermal power plant:-

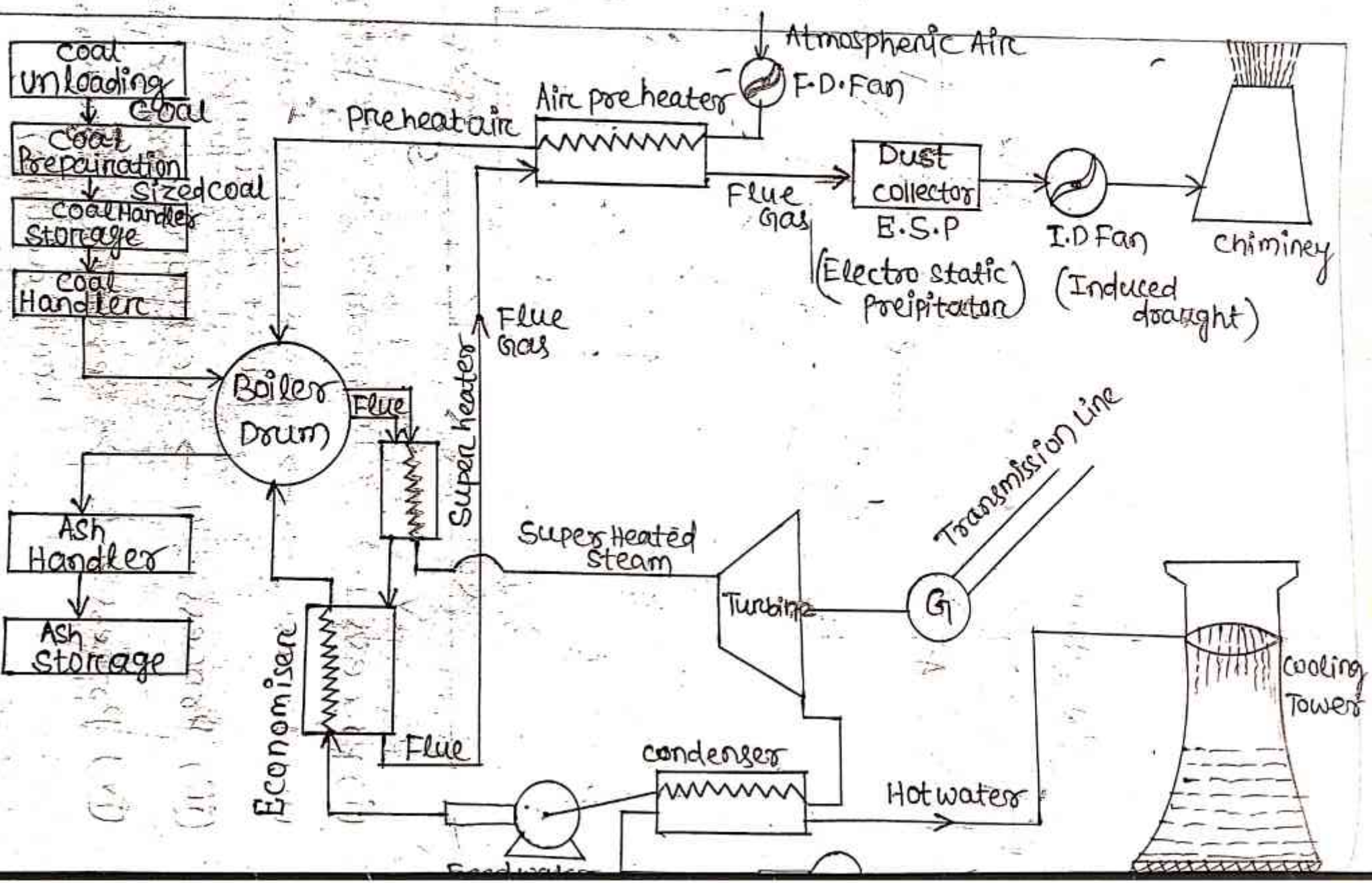
(i) Availability of huge amount of coals.
(ii) Thermal power plant should be closed to coal mines as possible.
(iii) There should be subficients spaee for ash handling.
(iv) A subficiently large water body should be nearer to the plant for the generation of steam cooling etc.
(v) Good transport network.
(vi) Availability of cheap labour in their region.
(vii) So the plant should be away from the dense population.

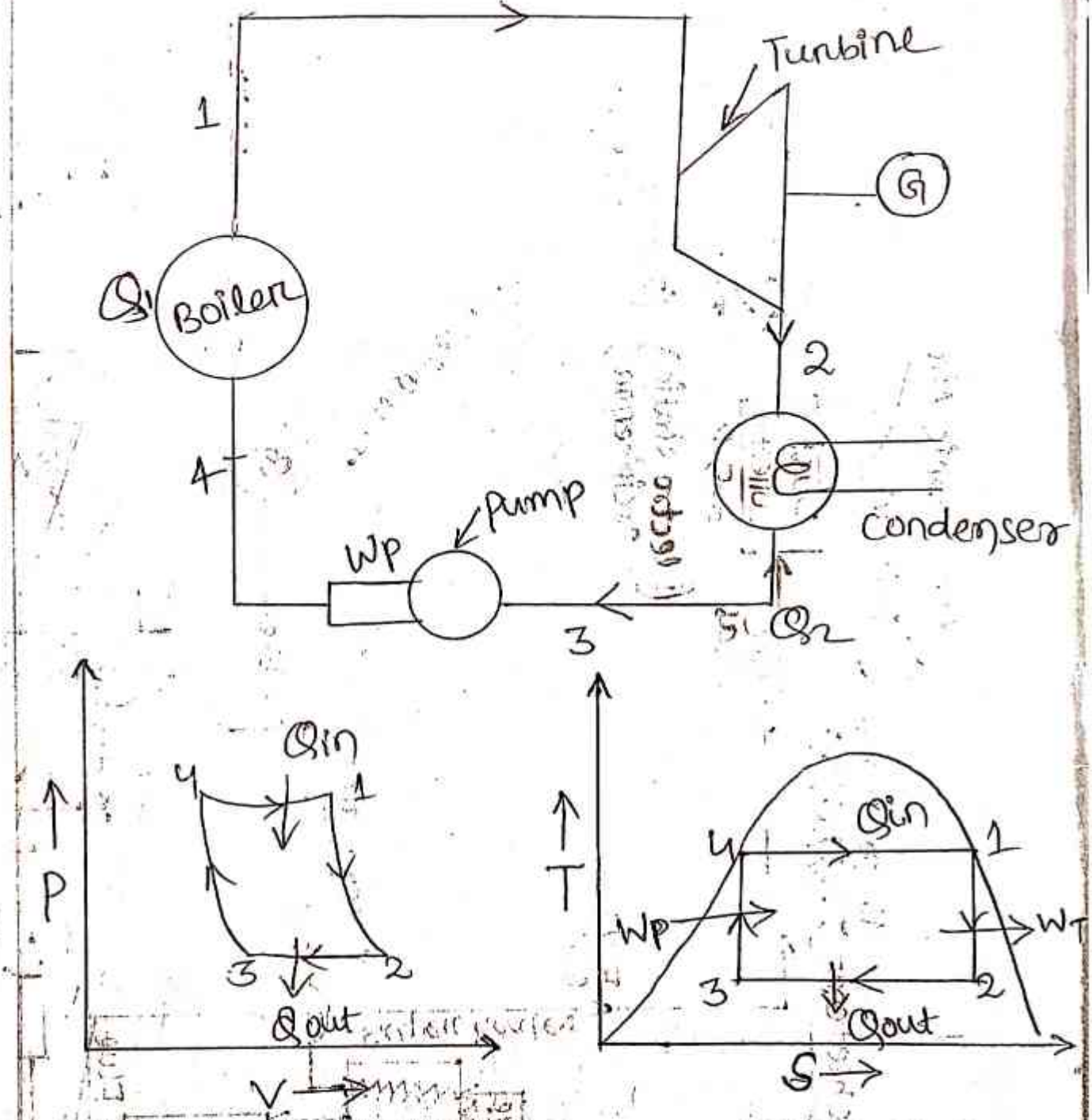
Steam Power cycle:-

Power plant work on the basis of some thermodynamic cycle such as

(i) Carnot Cycle.
(ii) Rankine Cycle.
(iii) Brayton Cycle.

Carnot cycle is an ideal and most efficient cycle. But is not practicaly feasible coal based power plant used Rankine cycle. Where as Brayton cycle used in gas turbine.


Coal unloading
Coal
Coal Preparation
Sized coal
Coal Handler Storage
Coal Handler
Ash Handler
Ash Storage
Boiler Drum
Flue
Super heater
Flue Gas
Preheat air
Air preheater
Atmospheric Air
F.D. Fan
Flue Gas
Dust collector
E.S.P
(Electro static preipitator)
I.D Fan
(Induced draught)
Chiminey
Super Heated Steam
Turbine
G
Transmission Line
Economiser
Flue
condenser
Hot water
Cooling Tower



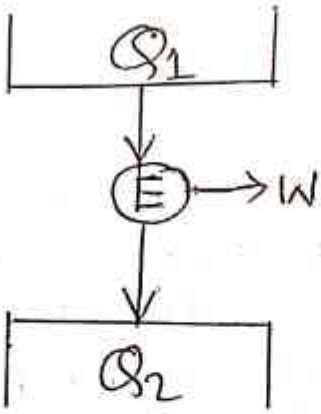
(i) Process 1-2 → Isentropic Expansion

(ii) Process 2-3 → Reversible isothermal (Heat Rejection)

(iii) Process 3-4 → Isentropic compression

(iv) Process 4-1 → Reversible Isothermal heat addition.

It is works like heat engine.



Work done(W) = $Q_1 - Q_2$

According to Kelvin Plank's Statem

Total work Done = $W_T - W_P = Q_1 - Q_2$

$$\eta = \frac{\text{Net W.D}}{\text{Heat supplied}}$$

$$= \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

In reversable Isothermal process

$$(S_1 - S_4) = (S_2 - S_3)$$

$$\Rightarrow \boxed{\eta = 1 - \frac{T_2}{T_1}}$$

Limitation of carnot cycle:-

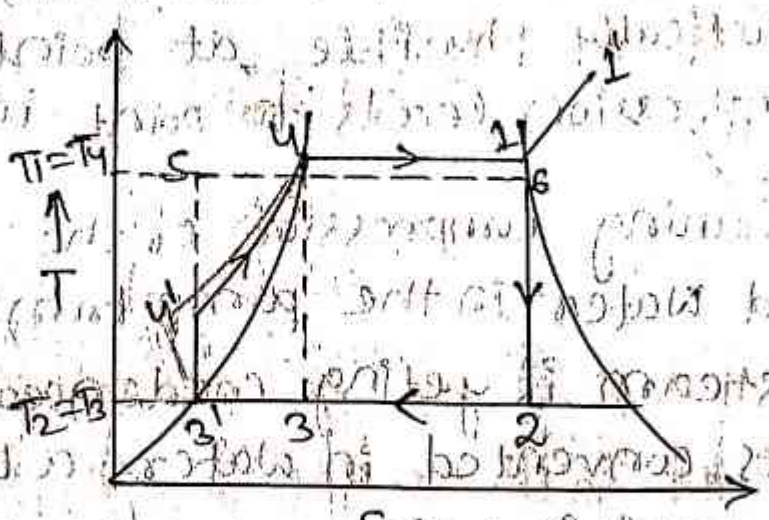
* Termination of condensation process is no Practically physible at point '3' from whe compression leads to point '4' on saturatio line.

* During compression of the mixture of st and water in the pump from point '3' to poi '4' steam is getting condensed. When ste gets converted in water a large differe of specific volume causes cavitation ov the pump impellers damaging in the impell requiring frequent replacement.

* Design of pump or compressor which can handle two phase flow is another difficulty
* If exhaust steam from turbine is completely cooled in condenser then transfer of heat at constant temperature and infinite pressure gradient is not possible. Addition of heat at constant temperature is possible only within the dome. Outside the dome that is either sub-cooled region or super heated region is not possible.

Rankine cycle:-

This limitation can be over-come by completely condensation of vapour up to point 3' as a large amount of water is supplied in the condenser.
* The water thus form is pumped to point 4' and sent to the boiler for addition of sensible and latent heat to get it converted into steam.



Consider area of 2-3'-4-4'-1-2 = Area of 6-2-3'-5 & Tm = Temperature at point 5

$$\eta_C = 1 - \frac{T_2}{T_1}$$

$$\eta_R = 1 - \frac{T_2}{T_m}$$

Here $T_m < T_1$

So Here $\eta_R < \eta_C$

$$\eta_R = \frac{\text{Net work Done}}{\text{Heat Supply}}$$

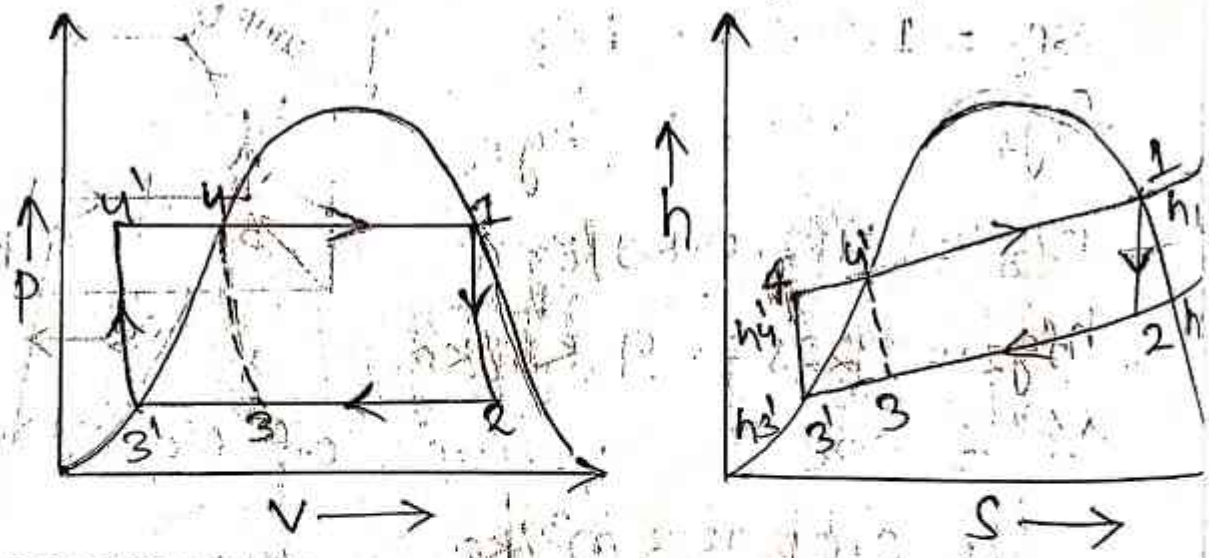
Network Done $= (h_1 - h_2) - (h_{4'} - h_{3'})$

Heat Supplied $= (h_1 - h_{4'})$

$$\eta_R = \frac{(h_1 - h_2) - (h_{4'} - h_{3'})}{(h_1 - h_{4'})}$$

Since workdone by the pump is very sma

So negleted $\eta_R = \frac{(h_1 - h_2)}{(h_1 - h_{4'})}$



PROCESS :-

1-2 = Isentropic Expansion

2-3 = Isothermal heat rejection

3'-4' = Isentropic compression

4-1 = Isothermal heat addition

Problem:-1 Dry Saturated steam at 150 bar enters a steam turbine and comes out at 1 bar calculated the cyclic efficiency.

Solution:- Given: $P_1 = 150$ bar

$P_2 = 1$ bar

From steam table, I find;

Corresponding at point-1;

$h_1 = h_g$ = For Saturated Steam = 2615.1 KJ/Kg

$S_1 = S_g = 5.318$ KJ/Kg

At Point-2

$S_1 = S_2 = 5.318$ KJ/Kg

But $S_2 = S_{f_2} + x S_{fg}$ ——— (1)

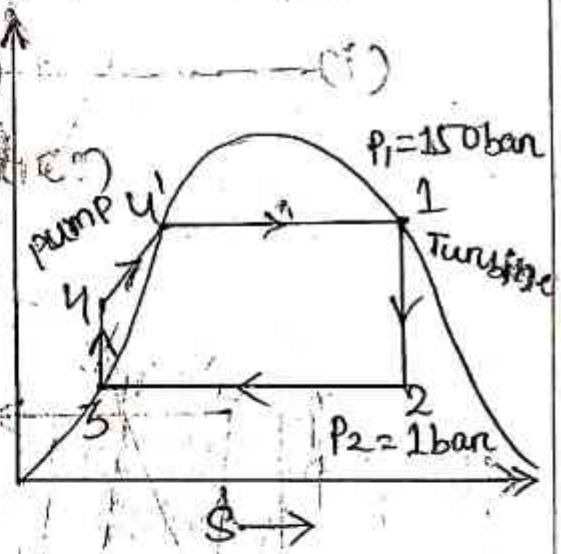
Where x = Dryness fraction

$S_{f_2} = 1.303$ KJ/KgK

$S_{fg_2} = 6.507$ KJ/KgK

$h_{f_2} = 417.5$ KJ/Kg

$h_{fg_2} = 2257.9$ KJ/Kg



V_f = Specific volume of liquid at 1 bar

$= 0.001043 \text{ m}^3/\text{Kg}$

Now Putting the value of S_{f_2} & S_{fg_2} in in eqn (1)

$S_2 = S_{f_2} + x S_{fg_2}$

$\Rightarrow 5.318 = 1.303 + x(6.057)$

$\Rightarrow x = \frac{5.318 - 1.303}{6.057} = 0.662$

$h_2 = h_{f_2} + x h_{fg_2}$

$= 417.5 + 0.662\,(2257.9)$

$= 1912.22$ KJ/kg

W_T = Work done by turbine

$= h_1 - h_2$

$= 2615.1 - 1912.22$

$= 702.88$ KJ/kg

W_P = Work Done on the pump

$= V_f \times dp \times 10^2$

$= 0.001043 \times 149 \times 100$

$= 15.5407$ KJ/kg

1 bar = 10^5 N/

$= 10^2$ KN/

$= 10^2 \frac{\text{KN}}{\text{m}^2}$

$= \frac{10^2 \text{KN}}{\text{Kg}}$

$= 10^2$ KJ/

dP = 150 − 1

= 144 bar

dP = Chang

Press

Net work done = $W_T - W_P$

$= 702.88 - 15.54$

$= 687.34$ KJ/kg

Total heat supply (Q_{in}) = $h_1 - h_4$ [$h_3 = h_{f_2} = 41$

KJ/

$\Rightarrow h_4 = h_3 + W_P$

$\Rightarrow h_4 = 417.5 + 15.54$

$= 433.04$ KJ/kg

$Q_{in} = h_1 - h_4 = 2615.1 - 433.05 = 2182.06$ KJ

∴ Cycle Efficiency (η) = $\frac{\text{Net work Done}}{\text{Total heat supply}}$

$\frac{687.34}{2182.06}$

0.315

0.315×100

$31.5\,\%$

- **Work Ratio :-** It is defined as the ratio between net work output in the cycle to the work done by the turbine.

$$\text{Work Ratio} = \frac{\text{Net work done}}{\text{Turbine to the work done}}$$

$$= \frac{W_{net}}{W_T}$$

$$= \frac{W_T - W_p}{W_T} = 1 - \frac{W_p}{W_T}$$

- **Specific Steam Consumption :-**

It is defined as the steam consumed by the turbine per unit output of power. It is typically measured in Kg/KWh or Kg/KJ

Mathematically

$$\text{Specific steam consumption} = \frac{\text{Amount of steam per hour}}{\text{Power out put in KW}}$$

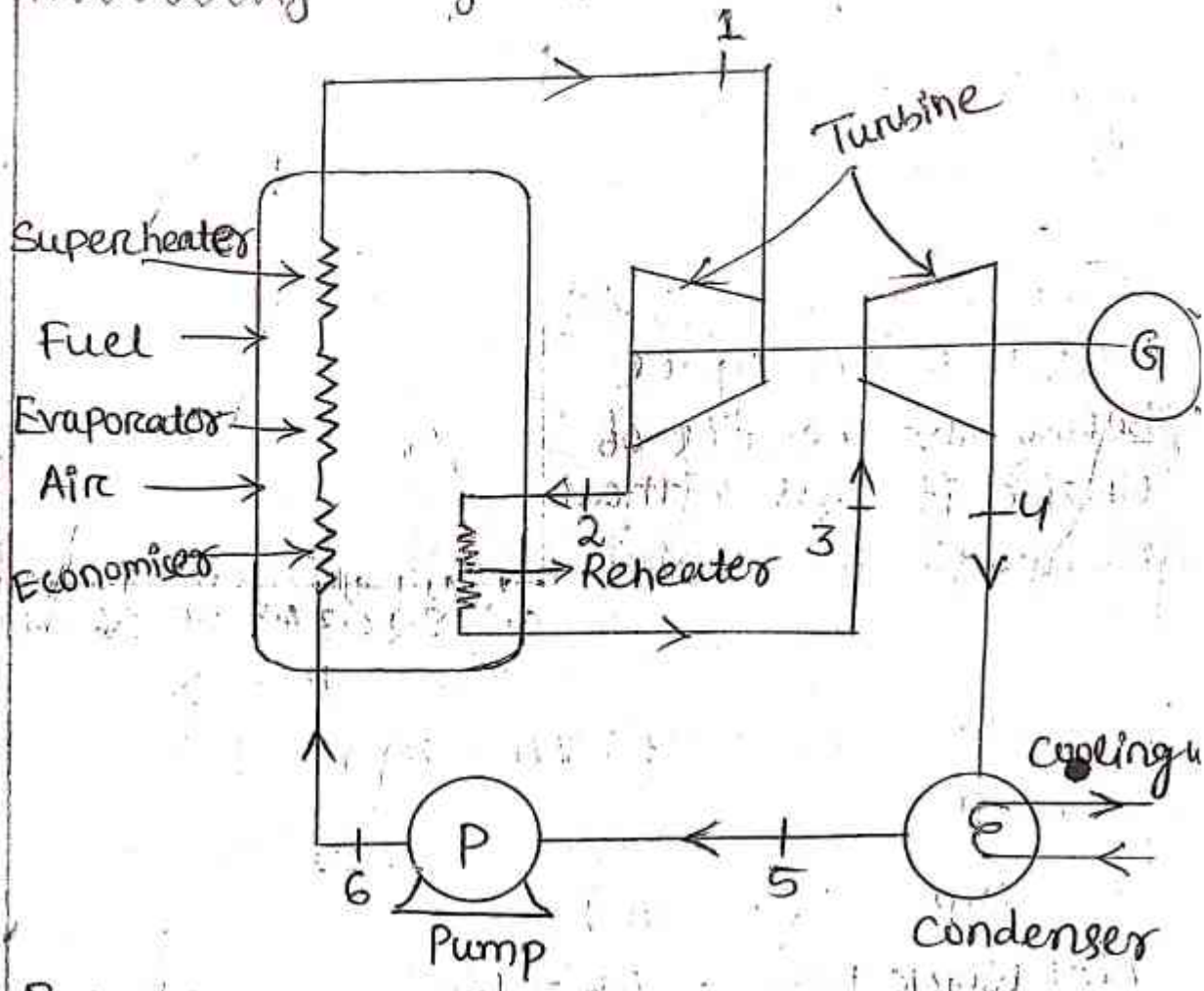
$$= \frac{1 \text{ Kg/h}}{1 \text{ K.W}} = 1 \text{ Kg/KWh}$$

Improvement of Rankine Cycle :-

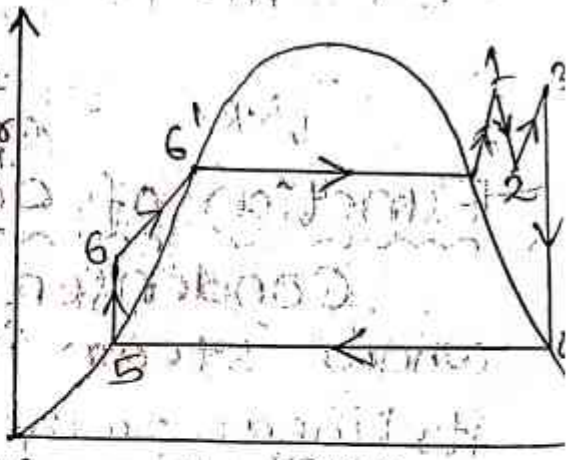
Efficiency of Rankine cycle can be increased by increasing the net work produced with the same heat input or by reducing heat input for the same work out put. The efficiency can be increased by 2 process

(i) Reheating (ii) Regenerating

Reheating: (Layout)



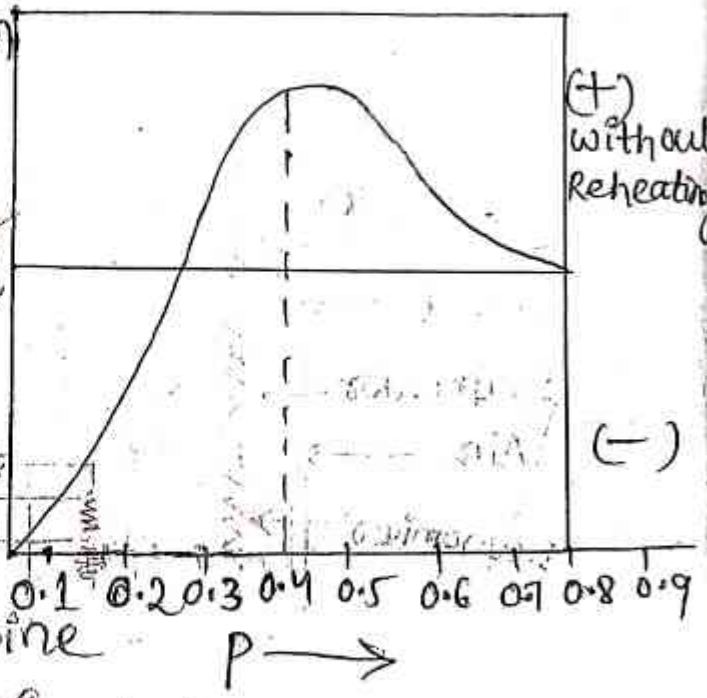
Reheating T-S Diagram:-



In this process after the initial expansion of superheated steam up to a certain pressure the steam is again same to boiler for the heating to maximum temperature and then allow to expand in another tur to get higher work out put. The area enc by the cycle which represents the net wor is improved and hence the efficiency is i proved. It has been seen that reheating im ves performance but this also is limited to certain constant.

* Efficiency Vs Pressure Ratio :-

In this figure efficiency increases up to a certain pressure and then gain in efficiency starts reducing, so $\Delta\eta$ that it even goes below the levels of where it was without reheating. Now,



work done by the turbine

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

work done by the pump

$$W_p = (h_5 - h_6)$$

Net work Done = $W_T - W_p$

Heat input (Q_{in}) $= (h_1 - h_6) + (h_3 - h_2)$

$$\eta_{R.R} = \frac{W_T - W_p}{Q_{in}}$$

Function of condenser :-

Condenser is a heat exchanger where steam is condensed by transfering its heat to the cooling water.

Classification of condenser :-

There are 2 types of condenser

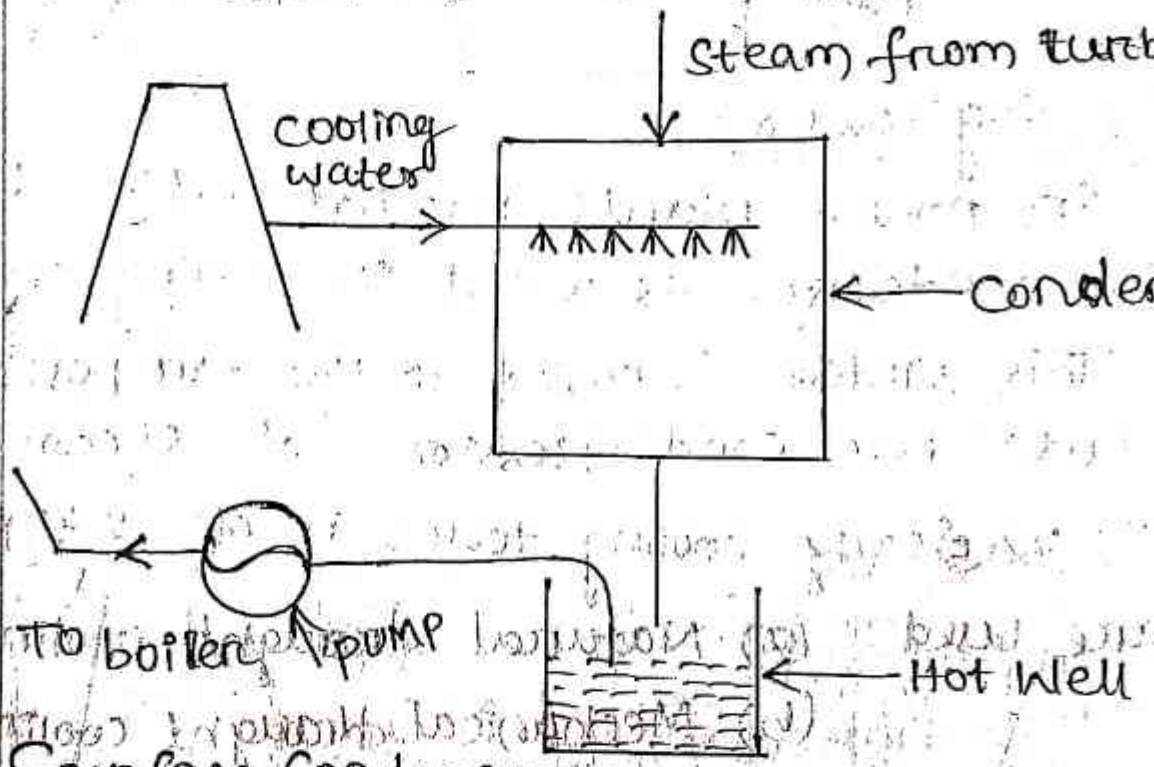
(i) Open type or direct type or jet condenser

(ii) Closed type or indirect type or surface condenser

Explain jet condenser & Surface conden

(i) In jet condenser both the fluid that means steam and water are mixed together.

(ii) Here in jet type of condenser sin both the fluid mixed inside the cond ser openly proper water treatment required before the entry to the condenser which involves extra cost

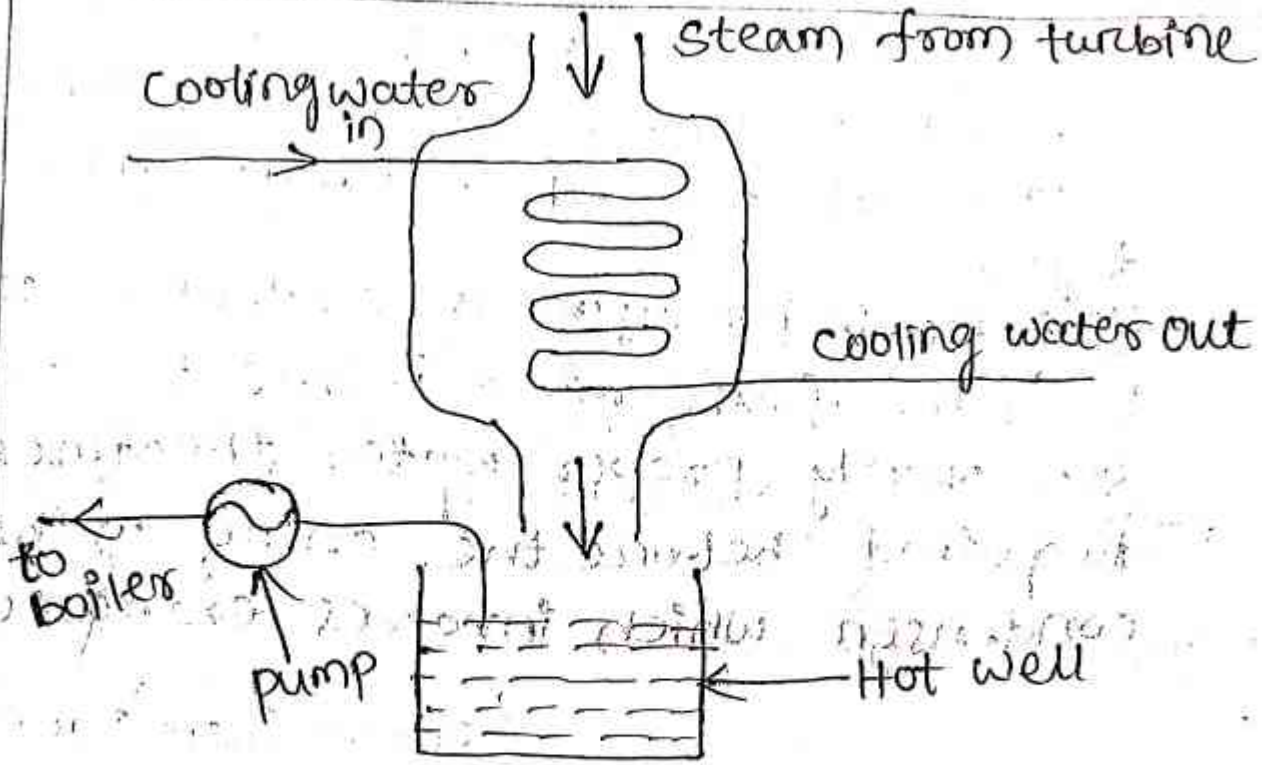


Surface Condenser :-

(i) In Surface condenser both the flu Steam & water are not mixed with eac other.

(ii) The steam from turbine move may fl inside the pipe and cooling water arou it or cooling water flows inside the pip & steam flows around it both the c are possible in surface condenser.

(iii) Since both the fluid are not mixed one use the raw water for cooling purpose.



Cooling Tower:-

(i) In power plants, the hot water from the condenser is cooled in cooling tower.

(ii) This water is cooled for the purpose of reuse for condensation of steam.

(iii) Basically cooling towers is of 2 types are used (a) Natural draught cooling Tower
(b) Mechanical draught cooling Tower

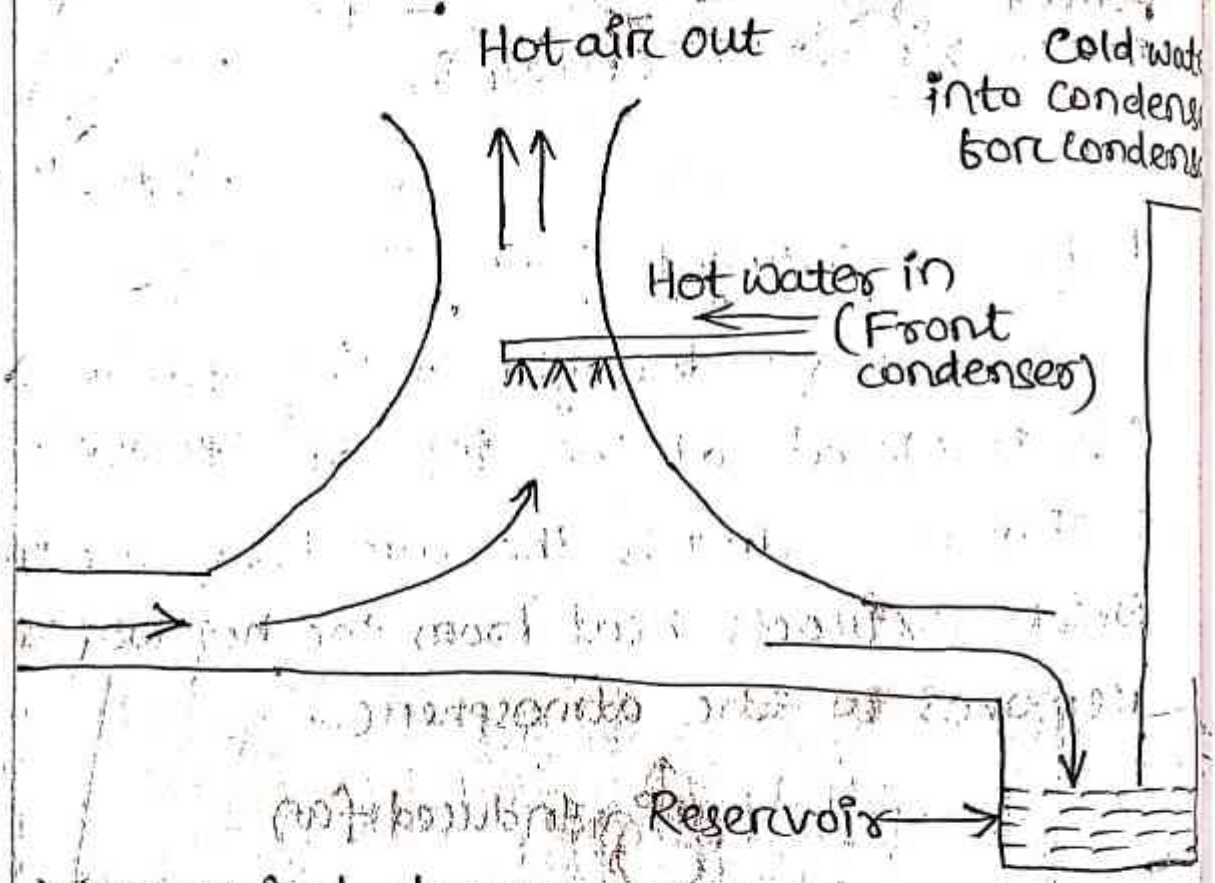
Mechanical draught cooling Tower are 2 types
(a) Forced draught cooling Tower
(b) Induced draught cooling Tower

Natural draught Cooling Tower:-

(i) In this type of cooling Tower the hot water from the condenser is pumped to the nozzle situated near the bottom.

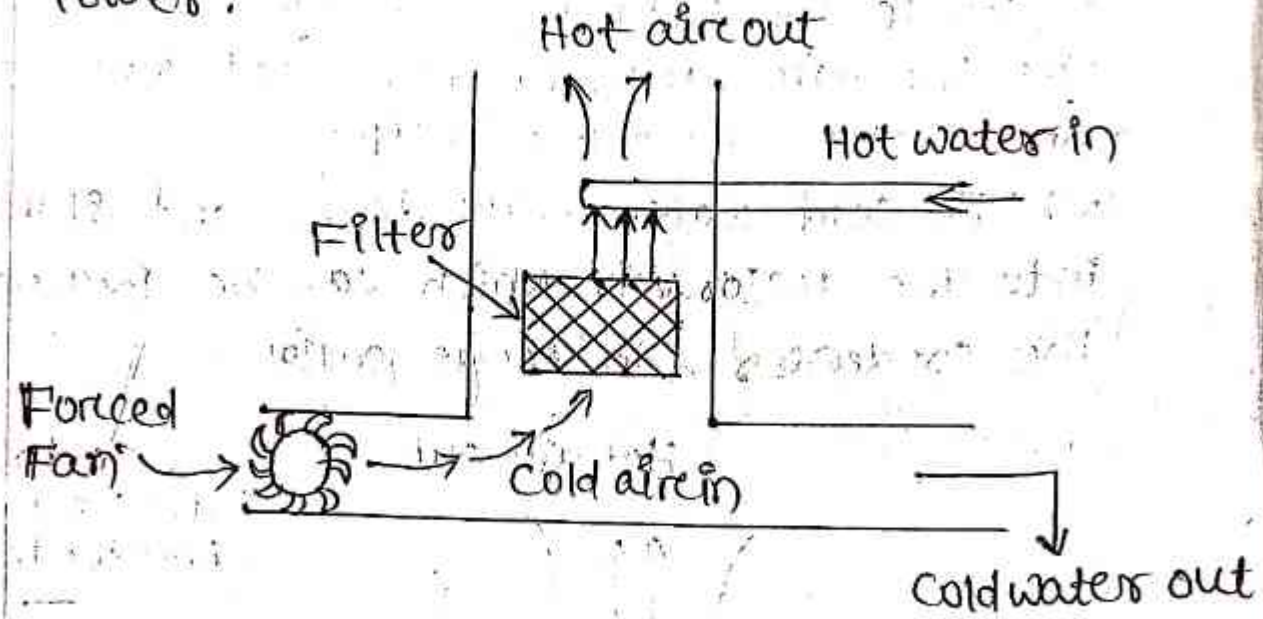
(ii) There are small holes in the pipes through

which water is sprayed.
(iii) The air enters the cooling tower from the opening provided near the base.
(iv) While the hot water sprayed from the pipe the air absorbs the heat from the hot water and moves up.
(v) The cold water falls down and stored into the reservoir which can be pumped the condenser for condensation.



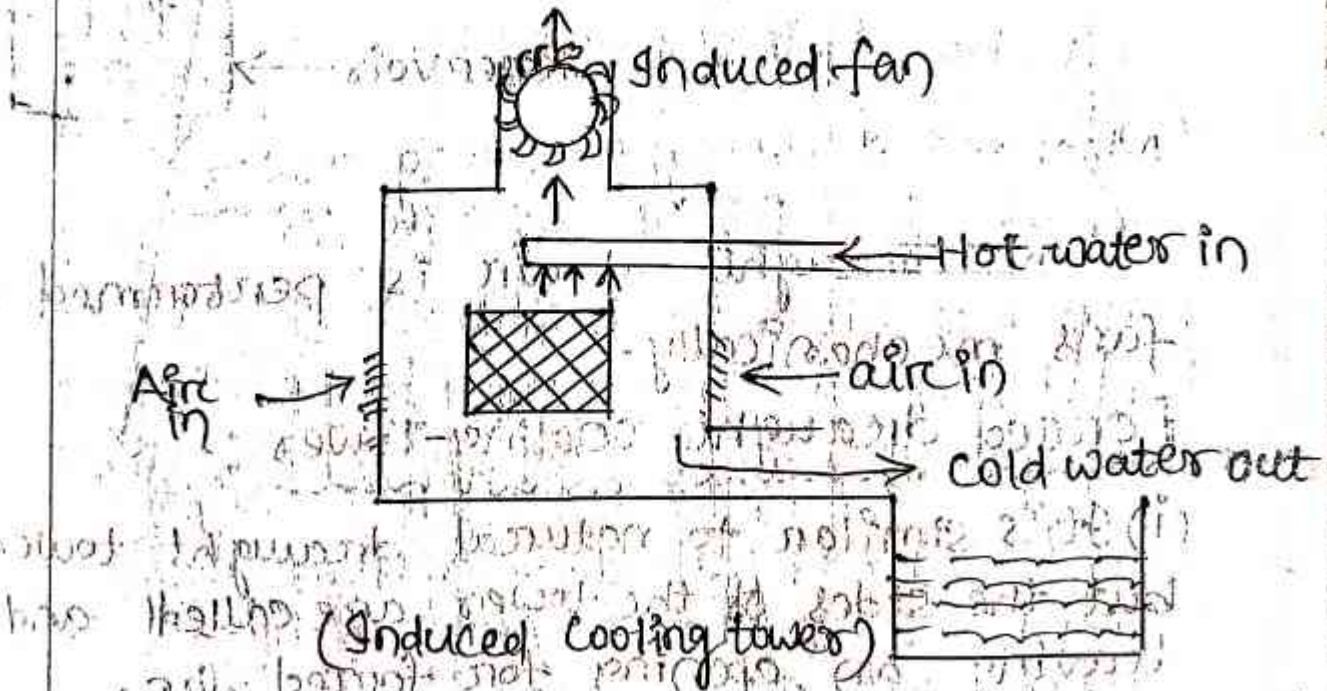
Mechanical draught cooling Tower:-
The draught of air is performed fans mechanically.
Forced draught cooling Tower:-
(i) It is similar to natural draught towe but the sides of the tower are closed and leaving an opening for forced fan.

(ii) This fan causes the cold air to move from the atmosphere to the cooling tower.
(iii) This fan is placed at the buttom of tower.



Induced Draught Cooling Tower :-

(i) In induced draught cooling tower the fan is placed at the top of tower.
(ii) This fan draws the air from the tower which extracts heat from the hot water and removes to the atmosphere.



Boiler Mounting And Accessories :-

(i) Boiler mountings are the part of boiler without which a boiler can not work (Safety)

(ii) The boiler mountings are

(a) steam stop valve
(b) safety valve
(c) Water level Indicator
(d) fusible plug
(e) Blow off cock
(f) pressure gauge
(g) Water level gauge

Boiler Accessories :-

(i) These are the integral part of boiler which increases the efficiency of the boiler.

The boiler Accessories are

(a) Feed pump
(b) Super Heater
(c) Economiser
(d) Air preheater
(e) Steam Separator, etc.

Feed Pump :-

* The feed pump is a pump which is used deliver water to the boiler.
* A feed pump may be of centrifugal ty or reciprocating type. But a double acting reciprocating pump is commonly used as a feed pump these days.

Supercheater:-

(i) Supercheater are used to increase the temperature of steam above saturation point.

(ii) By the result of which turbine work increase which increases the efficiency of the cycle.

(iii) The main advantages of supercheater is erosion is turbine blade eliminated.

Economiser:-

(i) The main function of Economiser is to heat the feed water from the weaste heat of the flue gases.

(ii) Economiser is used to increase the efficiency of the boiler.

(iii) About 4% of total heat gained in the Economiser.

(iv) It is placed just before the boiler.

(v) As Economiser is a closed spaced tube like structure, so there is no change of mixing of water.

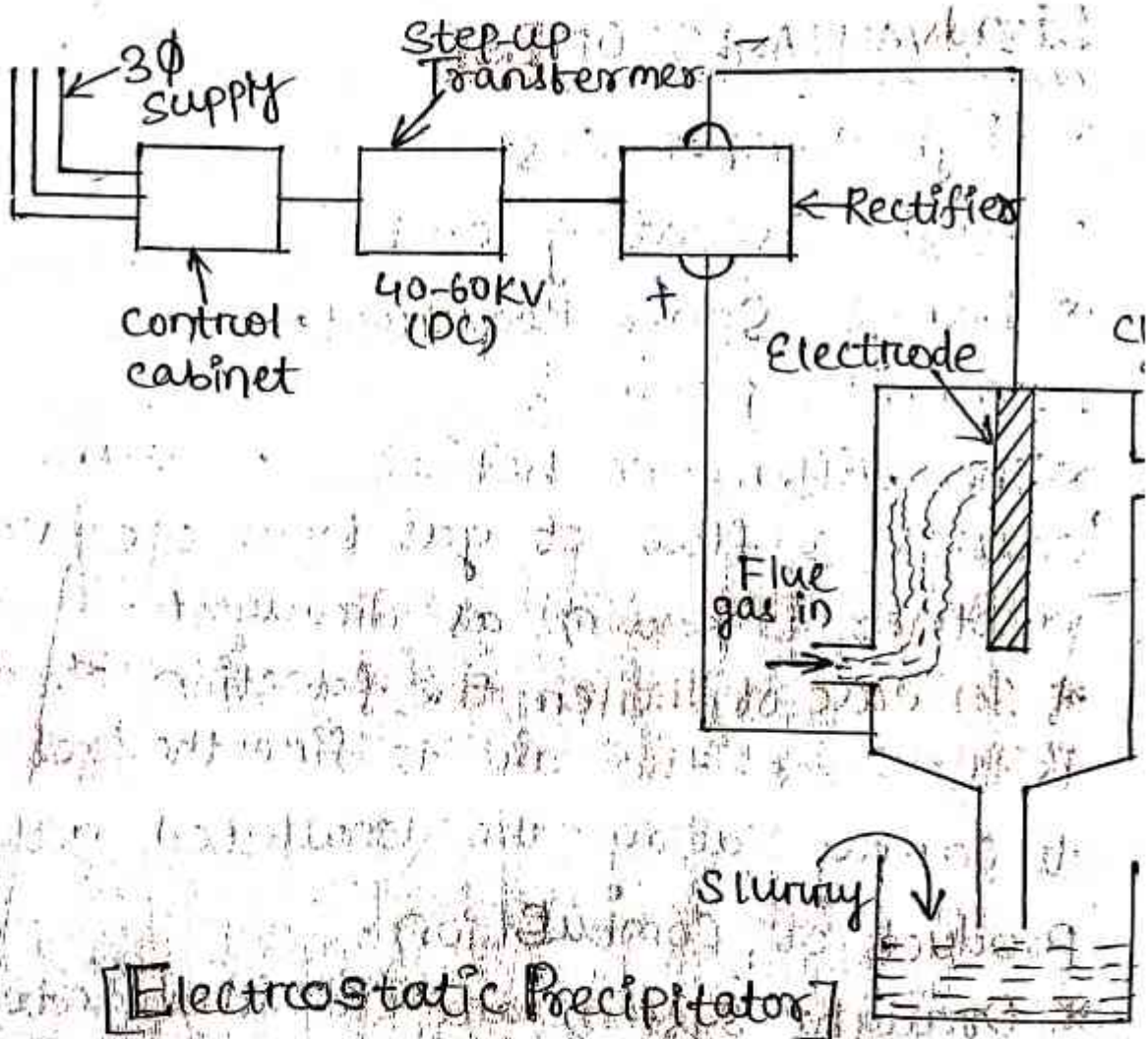
Air preheater:-

(i) The function of air preheater is to increase the temperature of air before entering to the furnace.

(ii) It is placed after the Economiser i.e flue gases first passed through the Economiser and then air preheater.

Electrostatic precipitator :- (ESP)

* The Esp chamber is connected to positi terminal and electrode (plates) are conne to negative terminal.
* Initially the flue gases are neutral it ~~gates~~ gets ionized when a potential d ence of 40 to 60 KV DC is created supply this process is known as changin process.



[Electrostatic Precipitator]

* About 80% of the dust particles ionis are positively charged.
* This positive charged dust particles mo towards the electrode and it is collected o the plates this process is known as collection proc

*When the electric supply is cut-off again the dust particles becomes neutrals and falls down from the electrode. This known as discharging process.

*This dust particle are collected at the bottom of ESP chamber and converted to ash slurry according to nature of dust.

ADVANTAGES OF ESP

* Efficient collection of fine ash particle.
* Dry ash is available for utilization.

DISADVANTAGES OF ESP

* High capital cost.
* High Operating cost
* Large Space Required.

Draught Systems :-

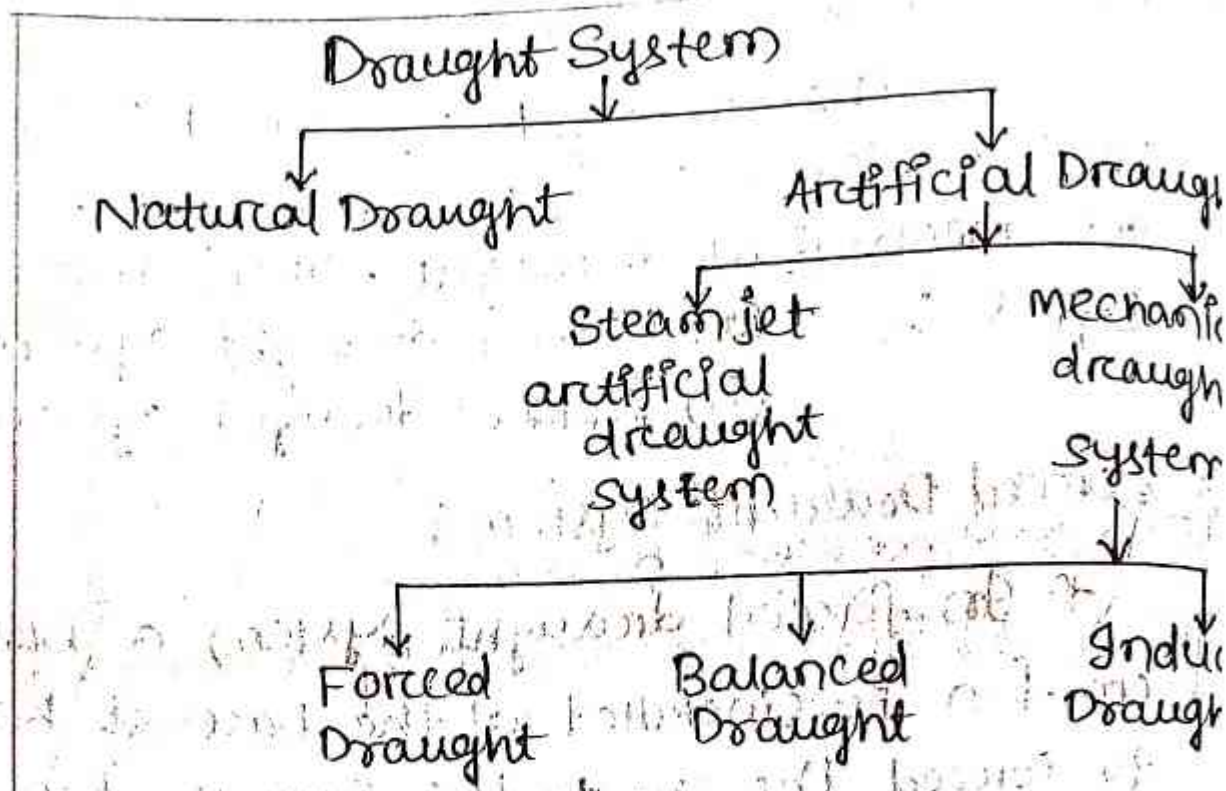
*The difference between pressure which causes a flow of gas from one point to another is known as draught.

* In case of boiler the function of draught is to force the air to fire the fuel and to carry away the unwanted gaseous product of combustion.

* Draught system are classified into 2 types

(a) Natural Draught system

(b) Artificial draught system



Natural Draught :-

* Natural draught is obtained by the u
of a chimney
* It performs :
(a) It produces the draught where the
and gas are forced to the fuel bed, fu
& other settings.
(b) It carried away the gaseous combusti
product to a such height which will not
affect the human society.
* The draught produced from the chimn
is due to decreasing Crossection area
the height increases.

Artificial Draught :-

According to the requirement if the drau
is created forced fully by the human b
then the draught is known as Artificial
draught.

Mechanical Draught :-

If the draught produced by the help of fans then the draught is known as mechanical draught. There are 2 types : (a) Forced draught system
(b) Induced draught system

Forced Draught system :-

* In forced draught system a blower or fan is installed at the base of boiler to forced the air to the furnace for the burning of fuel.
* It is also called a positive pressure draught.

Balanced Draught system :-

It is a combination of forced and induced draught system.

Induced draught system :-

* In induced draught system a blower or a fan is located at the base of chimney or at the top of the chimney.
* It carries the unwanted flue gases from the furnace and send to the at a height of atmosphere.

ADVANTAGES OF MECHANICAL DRAUGHT :

* Easy control of combustion & Evaporation.
* It can reduce the chimney height.

* It can capable of consuming low grad fuel.
* It improves efficiency of plant.
* The burning capacity of fuel can b increased.

Steam Turbine (ST) :- / Prime mover

Steam turbine is a prime mover in whi the potential energy of the steam is transferm into kinetic energy and a this kinetic energy of steam is converte mechanical energy. I.C. engine example of prime mo. EX: steam turbine, steamen

Classification of Steam turbine :-

Steam turbine is classified as following method:

(i) Impulse Steam
(ii) Reaction turbine
(iii) combination of impulse & Reac

Advantages of Steam Turbine :-

* Thermal efficiency of steam turbine is mo than the thermal efficiency of steam en
* Uniform rate of power generation.
* No internal lubrication is required.
* Balancing problem is minimize.
* Much higher speed than steam engine.
* No loss due to condensation.
* It can utilize the optimum steam.

Compounding Steam Turbine:

* If the steam is expanded from the boiler pressure to condenser pressure in one st

the speed of the rotor becomes very high, which results practical complicated.

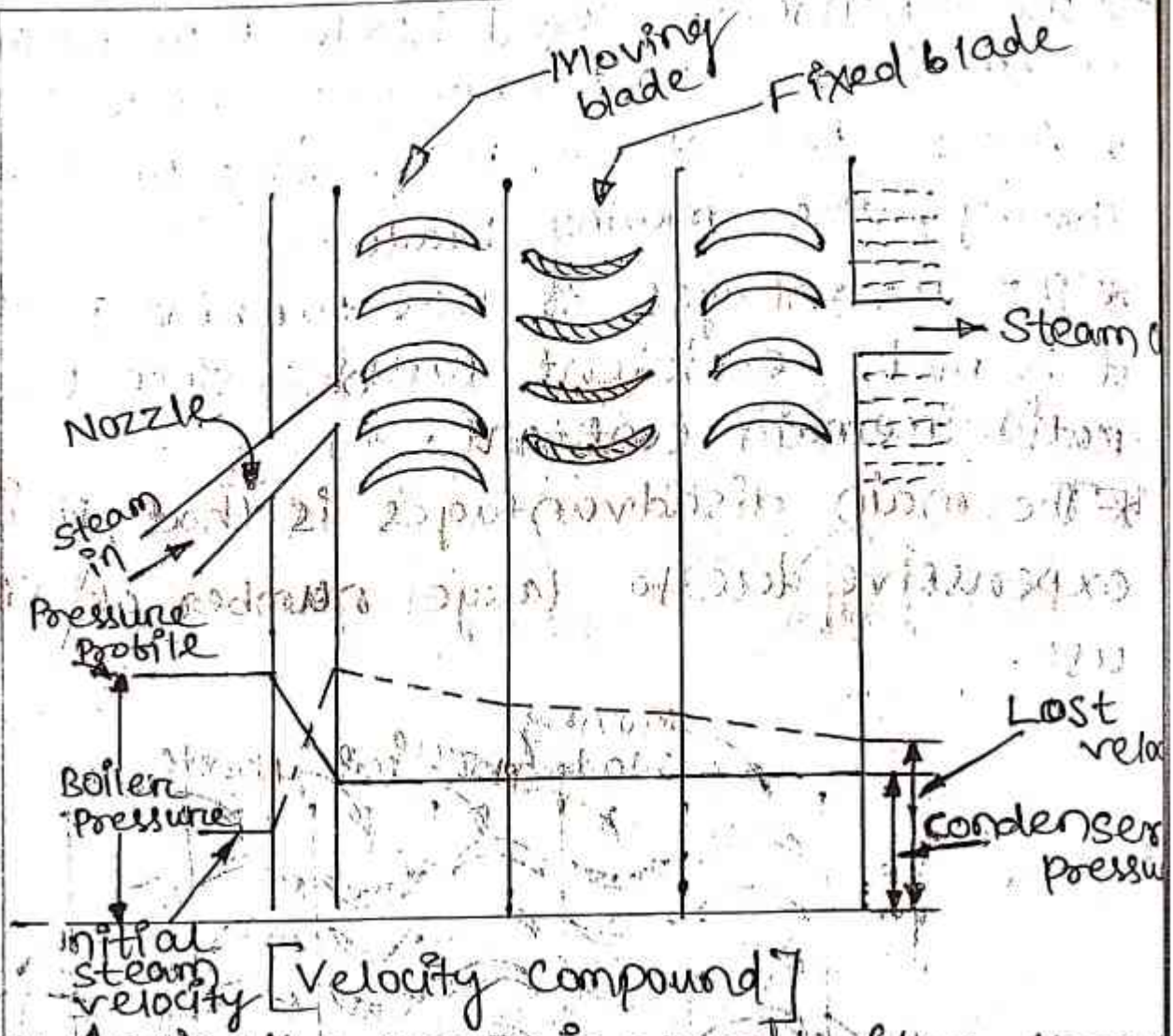
* There is a method to reduce the speed of the rotor by utilizing multiple system in series keyed on a common shaft & the steam pressure of jet velocity is absorved in different stages. This is known as compounding steam turbine

* There are different types of method are used in

(a) Velocity compounding
(b) Pressure compounding
(c) Pressure-velocity compounding

Velocity Compounding :-

* Steam is expanded through a stationeary nozzle from the boiler pressure to condenser pressure.
* The pressure drops in nozzle and hence the kinetic energy increases due to increasing velocity.
* A portion of this energy is absorbed by a row of moving blade.
* Then the steam flows through the second row of blades which are fixed.
* The function of fixed blade is to redirect steam flow without changing the velocity -



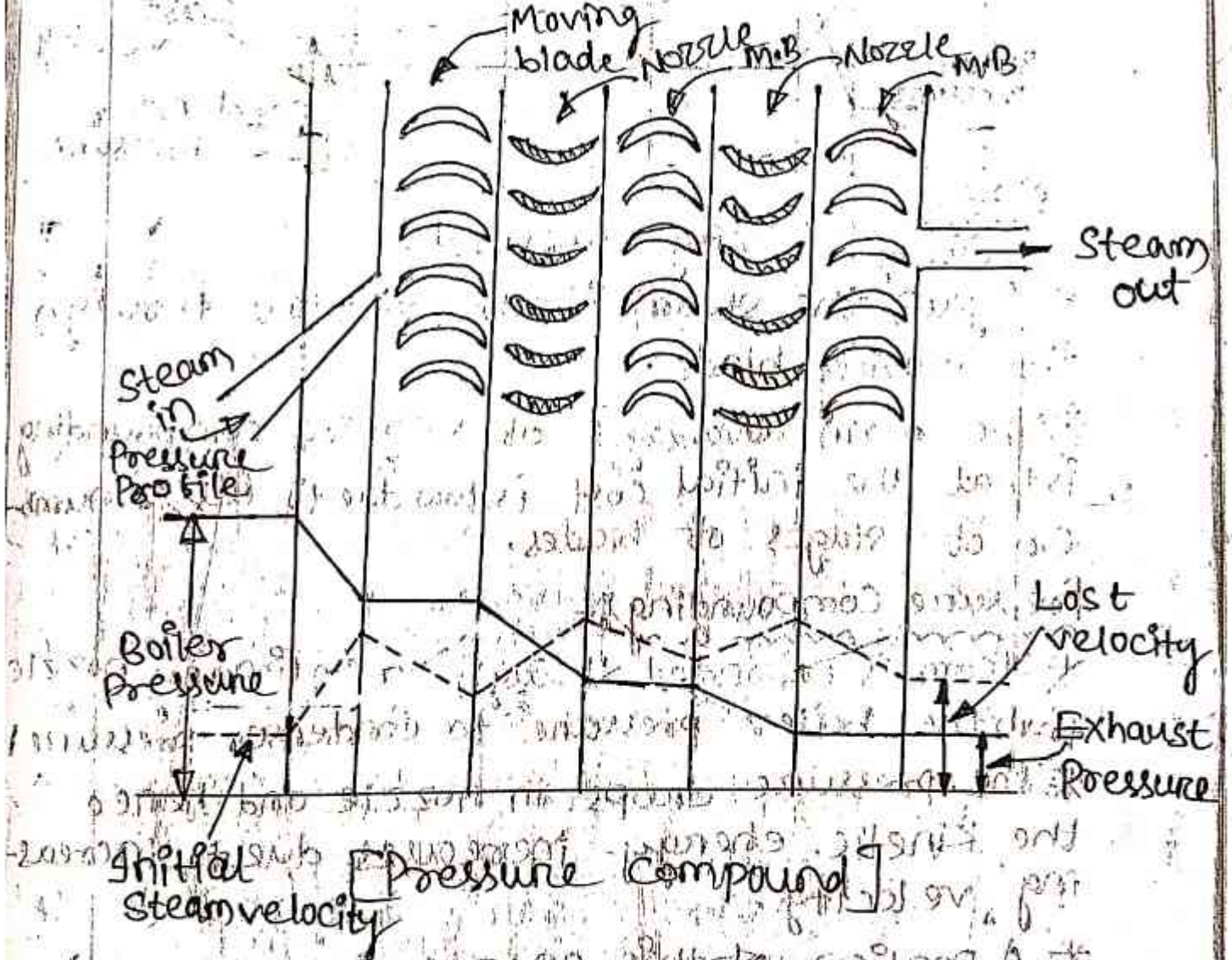
[Velocity compound]

* Again the steam is allowed to flow throu the moving blade.
* The main advantages of velocity compoun is that the initial cost is low due to lesser n er of stages of blades.

Pressure Compounding:-

* Steam is expanded through a stationary no from the boiler pressure to condenser pressu
* The pressure drops in nozzle and hence the kinetic energy increases due to incr ing velocity.
* A portion of this energy is absorbed a row of moving blade.
* Then the steam flows through the sec row of blades which are fixed.

* The function of fixed blade is to redirect steam flow without changing the velocity.
* Again the steam is allow to flow through the moving blade.
* The advantages of this turbine is that it is most efficient turbine since the speed ratio remain constant.
* The main disadvantages is that it is expenssive due to large number of stages use.



Governing of steam turbine:-

The governing of steam turbine is to keep the speed of turbine fairly constan irrespective of load. This is achieved by controlling the steam supply to the turb and this can be achieved one of the follo methods:

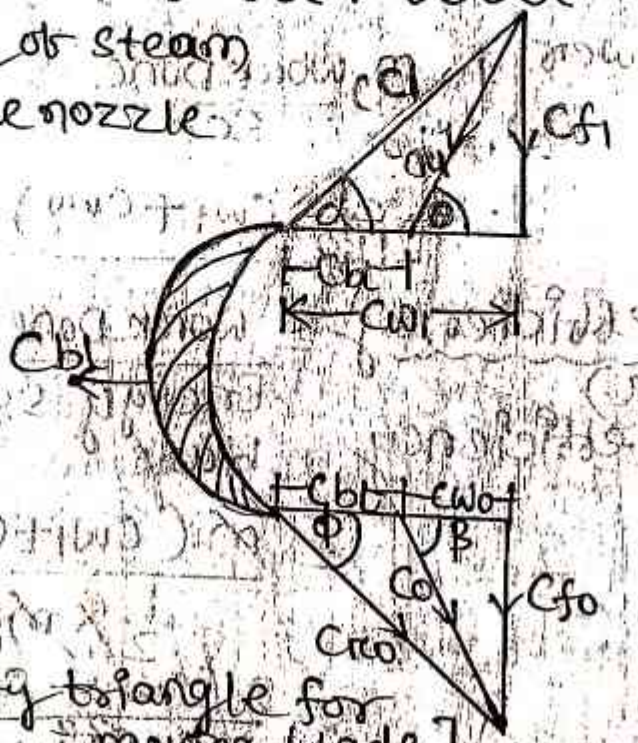
- Throttle governing
- Nozzle governing
- Bypass governing
- Combination of 1&2 or 1&3

Disadvantages of steam turbine:-

* It is very costly.
* Design of blade is complicated.
* If damage occure then turbine should completely replaced without any repair.

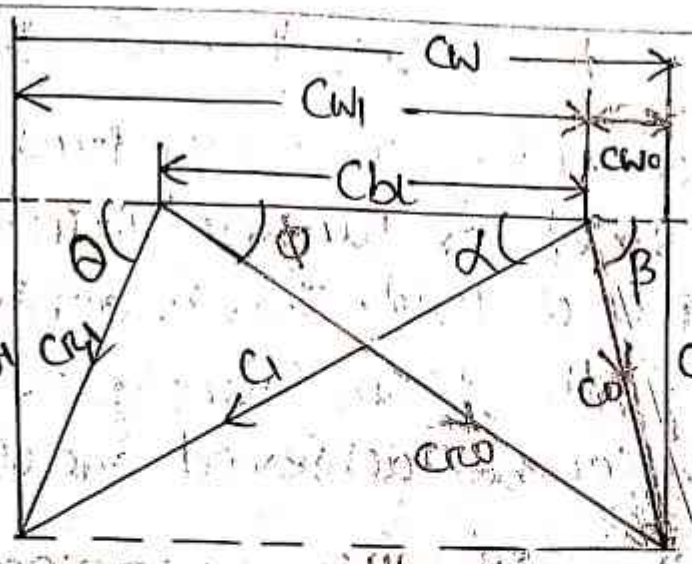
Performance of steam turbine:-

C_1 = velocity of steam leaving the nozzle



Velocity triangle for moving blade

velocity diagr
full describe
Page No-3



(i) Force on wheel = mass × acceleration)

$$= \text{mass} \times \frac{V}{t}$$

$$= \frac{\text{mass}}{\text{sec}} \times (\text{change of velocity})$$

$$= \boxed{m(C_{w1} - C_{wo})}$$

(ii) Work Done on blade/sec

= Force × displacement

$$= \frac{m}{\text{sec}} \times C_w \times C_{bl}$$

$$= m(C_{w1} + C_{wo}) \times C_{bl}$$

∴ Power = $\frac{\text{Work Done}}{\text{sec}}$

$$= \boxed{m(C_{w1} + C_{wo}) \times C_{bl} \text{ watt}}$$

(iii) Blade efficiency (or) diagram efficiency = $\frac{\text{Work Done on blade}}{\text{Energy supplied to the blade}}$

$$= \frac{m(C_{w1} + C_{wo}) C_{bl}}{\frac{1}{2} \times m C_1^2}$$

$$= \frac{2(C_{w1} + C_{wo}) C_{bl}}{C_1^2}$$

(iv) Stage efficiency :

$$= \frac{\text{Work Done on blade per kg of steam}}{\text{Total energy supplied per kg of st}}$$

$$= \frac{\dot{m}\,(C_{w1} + C_{wo})\,C_{bl}}{\dot{m}\,(h_1 - h_2)}$$

$$= \frac{(C_{w1} + C_{wo})\,C_{bl}}{h_1 - h_2}$$

or

$$\text{Nozzle efficiency} = \frac{C_1^2}{2\,(h_1 - h_2)}$$

$$\eta_{stage} = \eta_{nozzle} \times \eta_{blade} = \frac{(C_{w1} + C_{wo})}{h_1 - h_2}$$

(v) Axial force on wheel

= mass of steam x axial acceleratio

$$= \dot{m}\,(C_{f1} - C_{fo})$$

(vi) Energy converted to heat by blade friction = Loss of kinetic energy duri flow over blades

$$= \frac{1}{2}\dot{m}\,(C_{r1}^2 - C_{ro}^2)$$

NOTE : Blade velocity coefficient :-

It is defined as the ratio of relative velocity of outlet to the relative velo of inlet. It is represented by 'K'

$$K = \frac{C_{ro}}{C_{ri}}$$

Thermal Efficiency :-

$$= \frac{\text{Heat converted into useful work per Kg of steam}}{\text{Total heat in steam at stop valve} - \text{water heat in exhaust}}$$

Gross Efficiency :-

$$= \frac{\text{Work delivered at the turbine coupling in heat units per kg of steam}}{\text{Total adiabatic heat drop}}$$

Blade Speed Ratio :-

It is defined as the ratio of blade speed to steam speed. It is denoted as 'ρ'

$$\rho = \frac{C_{b1}}{C_1}$$

Internal efficiency :-

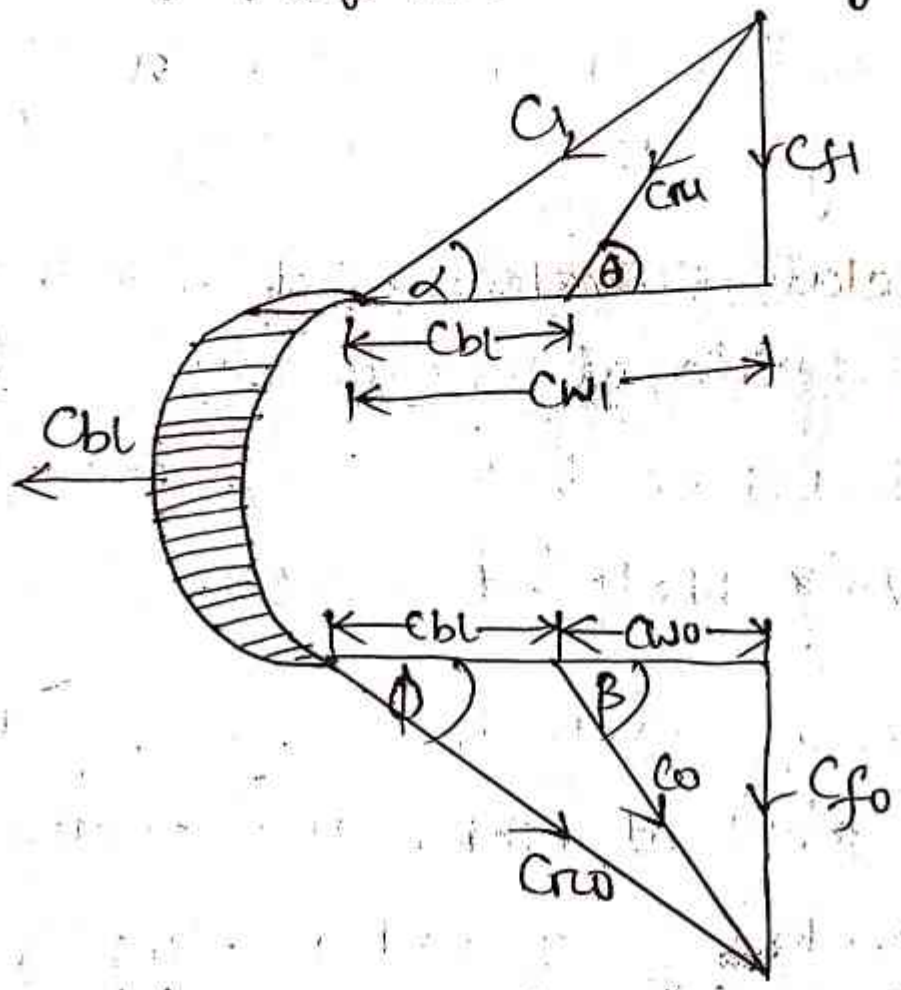
This is equivalent to the stage efficiency when applied to the whole turbine, as and is defined as:

$$= \frac{\text{Heat converted into useful work}}{\text{Total adiabatic heat pump}}$$

$$\frac{\text{out}}{\text{in}} = 1$$

Impulse Turbines :=

velocity diagram for moving blade :-



C_{bl} = Linear velocity of moving blade(

C_1 = Absolute velocity of steam enteri
moving blade (m/s)

C_o = Absolute velocity of steam leav
moving blade (m/s)

C_{w1} = Velocity of whirl at the entranc
of moving blade = tangential compone
of C_1

C_{w0} = Velocity of whirl at exit of t
moving blade = tangential component of

C_{f1} = velocity of flow at entrance of the moving blade = axial component of C_1

C_{fo} = velocity of flow at exit of the moving blade = axial component of C_o

C_{r1} = Relative velocity of steam to moving blade at entrance

C_{ro} = Relative velocity of steam to moving blade at exit

α = Angle with the tangent of the wheel at which the steam with velocity C_1 enters. This is also called nozzle angle.

β = Angle which the discharge steam makes with the tangent of the wheel at the exist of moving blade.

θ = Entrance angle of moving blade

ϕ = Exit angle of moving blade.

Reheat Factor:-

* It is defined as the ratio of commulative heat (enthalpy) drop in the isoentropic heat (enthapy) drop in a steam turbine.

* RF = $\frac{\text{Cummulative enthalpy drop}}{\text{Isoentropic enthalpy drop}}$

$= \frac{(h_1 - h_2') + (h_2 - h_3')}{(h_1 - h_3')}$

* Reheat factor depends on the stage efficiency, initial pressure and temperature and the exit pressure

Terrestrial heat:-(or) Surface heat

* Terrestrial or Surface heat flow relates to an area of land or sea from which heat transferred occure across Earth's surface at that place per unit area per unit time.
* It is determined as the product of the thermal conductivity and the vertical gradient of temperature.
* It's units of watt/m^2.

3. NUCLEAR POWER PLANT

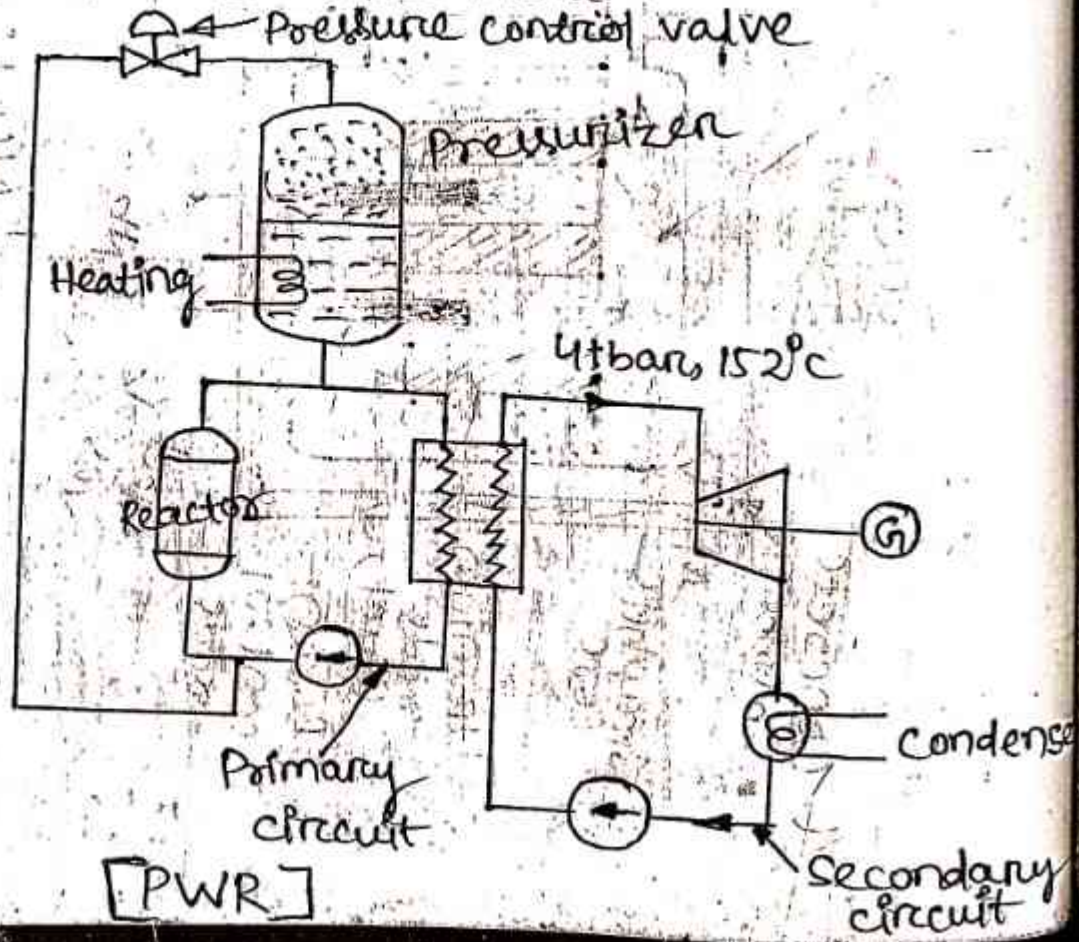
06/03/18

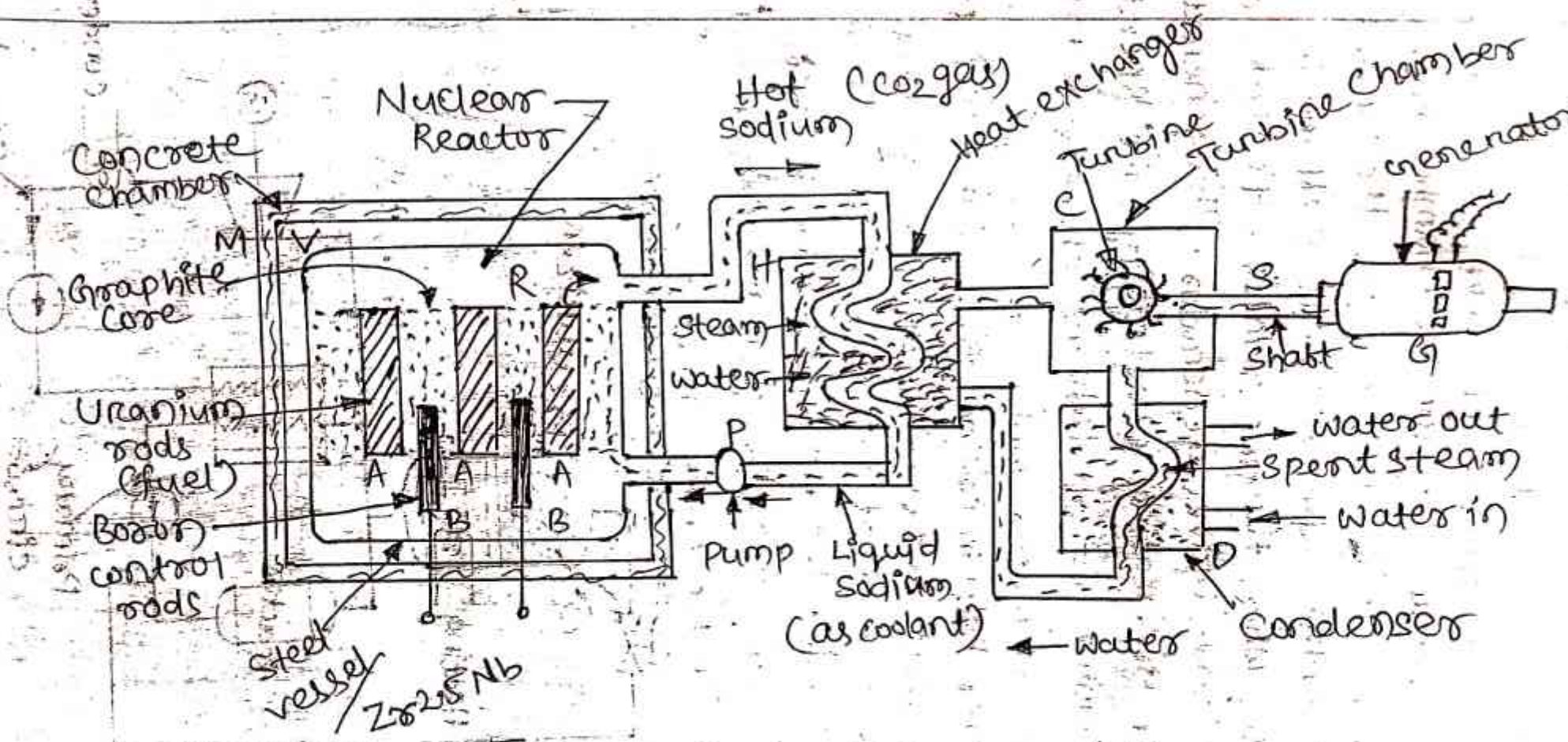
Nuclear Power plant use nuclear fission reaction to generate electricity and the fuel used for this purpose is Uranium-235.

In a nuclear power plant fission reaction is carried out in a steel pressure vessel & inside a nuclear reactor. In a nuclear reactor Uranium-235 rods are inserted in graphite core. Graphite is called the moderator as it helps in slowing down the speed of nutrons so that a proper fission reaction takes place. In between the Uranium-235 rods are place boron rods as they help in absorbing excess neutrons and prevent nuclear fission reaction to of out of control. Boron rods are called control rods. The nuclear rods can be raised inside or pulled outside the reactor as the demand is. The nuclear reactor is enclosed in a concrete chamber which has thick wall so that it can absorb the nuclear radiations.

Now the heat produced due to fission reaction in the reactor in the reactor is cooled by using liquid sodium or carbon dioxide gas which also helps it transfer to heat exchanger. Here with the help of a coolant water is converted into steam. The steam produced is used to turn the turbines and run generator. Then amount of heat energy is produced. When controlled fission reaction takes place in nuclear reactor. That is why liquid sodium is pumped continously through the pipes attached to the reactor. Sodium helps in absorbing the heat produced

in the reactor. Then through pipes extremely hot sodium is passed through water in the heat exchanger. Water absorbs heat from hot sodium and boils to form steam. This steam is then passed at high pressure into turbine chamber having turbine. This steam then rotates the turbine which is further attached to its shaft and the generator. So, when turbine rotates, it's shaft also rotates and drives generator. This generator helps in generating electricity. The spent steam coming out of turbine chamber is passed through condenser which contains water and this water helps in cooling the steam. This steam then converts into water and through pipes is again sent to heat exchanger. The waste material produced in the nuclear fission reaction of Uranium-235 is radio active and extremily harmful for the environment.





[NUCLEAR POWER PLANT]

[BWR]

Differentiate between, Nuclear Fission and Nuclear Fusion.

ON THE BASIS	NUCLEAR FISSION	NUCLEAR FUSIO
Defination	Fission is the splitting of a large atom into 2 or more smaller atoms with the production of energy.	Nuclear fussion is the fusing of 2 or more lighter atom into a larger one atoms with the evolution of energy
Condition	Critical mass of substance and high speed neutron are required.	High temp., Pressur and density are required for fussi
Energy Requirement	Energy requirement is less than the fussion reaction.	Energy requirem is more than the fission reaction.
Energy Released	Nuclear fission liberate an Enormous (large) amount of energy during reaction.	The energy releas in fusion Reaction i 3 to 4 times greate than the energy released by fissio
Nuclear Weapon	Fission bomb it is also known as atomic bomb or atom bomb.	Hydrogen bomb i produced by Nuclear fusion reaction.
Fuel	Uranium is the basic type of fuel in use in fission reaction.	Uranium is the basic type of fuel in use in fusion Reaction other fuels are thorium, plutonium.

Example of Reaction	$^{2}_{1}$Deuterium + $^{3}_{1}$Tritium $\rightarrow$ $^{4}_{2}He + ^{1}_{0}n$ + 17.6 MeV	(i) $^{235}_{92}U + ^{1}_{0}n = ^{236}_{92}U$ (ii) $^{236}_{92}U = ^{144}_{56}Ba + ^{89}_{36}Kr$ + 3n + 177 meV * Nuclear fussion occurs naturaly in sun hydrogen atoms combines to form helium gas and the production of large amount of heat energy.

Difference between PWR & BWR :-

PWR	BWR
(i) PWR stands for Pressurize water Reactor	(i) BWR stands for Boilling Water Reactor
(ii) In PWR heat from the reactor is passed through a boiler to generate steam.	(ii) In BWR steam is generated in Reactor core.
(iii) This is known as indirect cycle through the reactor and the steam generating unit are different.	(iii) The steam is directly sent to the turbine without use of intermediate boiler so it is also known as direct cycle reactor.
(iv) In PWR the pressure maintained near about 2250 pound/inch^2	(iv) BWR operates the pressure lower than the PWR.
(v) There is an extra unit called Pressurized which is used to control the pressure in Reactor.	(v) There is no pressurized to control pressure in Reactor.

Give a comparission between Nuclear P.P & Thermal power plant.

Thermal Power Plant	Nuclear Power Plant
(i) The fuel is use T.P.P to coal produce heat energy.	(i) In N.P.P the fuel used as Uranium.
(ii) The steam condition at the enterance turbine is Super heated steam.	(ii) The steam condition at the inlet turbine is wet steam or saturated steam.
(iii) Generally the pressure of steam is 170 bar or higher.	(iii) In NPP the steam pressure is maintained 78 bar.
(iv) Temp. maintaines 550°C, to 600°C at Super heated steam.	(iv) The steam temp. in N.PP 290°C.
(v) Thermal efficiency of T.P.P is more than the N.P.P.	(v) Less Thermal efficien
(vi) Unit cost of fuel is less than the fuel used in the NPP.	(vi) Unit cost of fuel is more than the fuel us in T.P.P.
(vii) No radio active rays are produced in TPP thats while it is safer than NPP.	(vii) It may produced Hazardous effect on people though it produc radio active rays.
(viii) Space Requirment in thermal power plant is more as it needs sufficient space for storage of fuel, storage of ash etc	(viii) It requires less space to run NPP.
(IX) Thermal Power station is acts as peak Load Power plant.	(IX) NPP is used as base load power plant.

Explain the disposal of nuclear waste.

(i) In all power plants where electricity produce waste are produce what ever the fuel used.

(ii) Compare to thermal power plant the waste produced in Nuclear power plant is very less but it is radioactive waste.

(iii) For Radioactive waste, it is isolating or diluting in such a way that the rate of concentration of any radio nucli return to the atmosphere is harmless.

(iv) To achive this practically all radio active waste needs deep and permanent durial.

(v) There are 3 types of radio active waste produce

(i) Lower level waste.

(ii) Intermediate level waste.

(iii) High level waste.

(vi) Lower level waste, are generated from hospitals and industry (It paper, tools, filters, clothing etc)

(vii) It comparison resin, chemicals, sludge, metals fuel cladding etc.

(viii) This waste are put inside them Concrete seal deep in ground.

(ix) High level waste are produced in Nuclear power plant. It contains the fission product (Uranium, Thorium and other gases produce in fission Reaction) (x) This waste are disposed in the deep of sea under the ground.

4. Diesel Engine Power Plant

What is a Diesel Power plant?

(1) In diesel power plant a diesel Engine is acting as prime mover.

(2) The combustion product generated by the burning of diesel inside the cylinder.

(3) Diesel acts as working medium.

(4) The crankshaft converts the reciprocating motion of piston into rotary motion.

(5) This rotary motion drives alternator and hence electricity produced.

Advantages and Disadvantages of Diesel P. Plan

Advantages:-

(i) This is simple in design.

(ii) Diesel are easily available.

(iii) It occupie less space.

(iv) It can be installed at any place.

(v) It takes less starting time.

(vi) It requires less quantity of water for cooling.

(vii) Overal cost of this plant is less than the other power plant.

(viii) Thermal efficiency of diesel power plant is higher than the other power plant.

(IX) It requires less operating staffs.

Disadvantages:-

(i) It is having high running cost.

(ii) The running cost is more due to Diesel fuel is Cost layer.

(iii) Performance of this plant is at high load condition.

(iv) It's capacity is low.

(v) It is having high lubrication cost.
(vi) Maintenance cost is high.

Working of Diesel power plant :-

(i) In Suction stroke the air is directed to enter combustion chamber through air filter.
(ii) This air is then compressed at the end of compression. Here the temperature 500°C near about.
(iii) The compression ratio is mainten between 15 to 22 and pressure maintains 40 bars.
(iv) Diesel fuel is loaded to the storage tank from the truck, railway etc.
(v) The storage tank is designed in such a way that, it can supply the fuel up to 8 hours.
(vi) From the fuel tank the oil is sent to the fuel filter which removes unwanted particles.
(vii) The fuel injection pump Atomizes, vaporizes an pumps the fuel at a high pressure to the combustion chamber.
(viii) The fuel injector ensures that the fuel is broken down into small droplets that means atomizes properly and distributed evenly in the cylinder.
(IX) The heat of the compressed air vaporise the fuel from the surface of the droplet.
(x) The vapours are them ignited by the heat from the compressed air in the combustion chamber.

(xi) This process continue when the pressure is sufficient to move the piston downward.
(xii) The crank shaft is connected to the piston by the result of which the shaft rotates.
(xiii) The generator converts the shaft power into electrical power.

Main components of a diesel engine power Plan

(a) Fuel supply system.
(b) Fuel injecting system.
(c) Air intake system. (h) Governing system
(d) Exhaust system.
(e) cooling system.
(f) Lubricating system.
(g) Engine starting system.

Fuel supply system:-

It consists of a storage tank, strainers and injectors. The fuel is passed through strainers to remove suspended impurities t avoid blockage of the injector. Clean oil is injected into the engine by fuel injecti pump.

Fuel injecting system:-

In order to atomize diesel, it has t be pumped into the cylinders at a high pressure. The fuel pump is operated by a cam driven by the engine. The fuel is pumped into an injector, which gives a fine spray of fuel required in the cylin fore combustion.

Air intake system :-

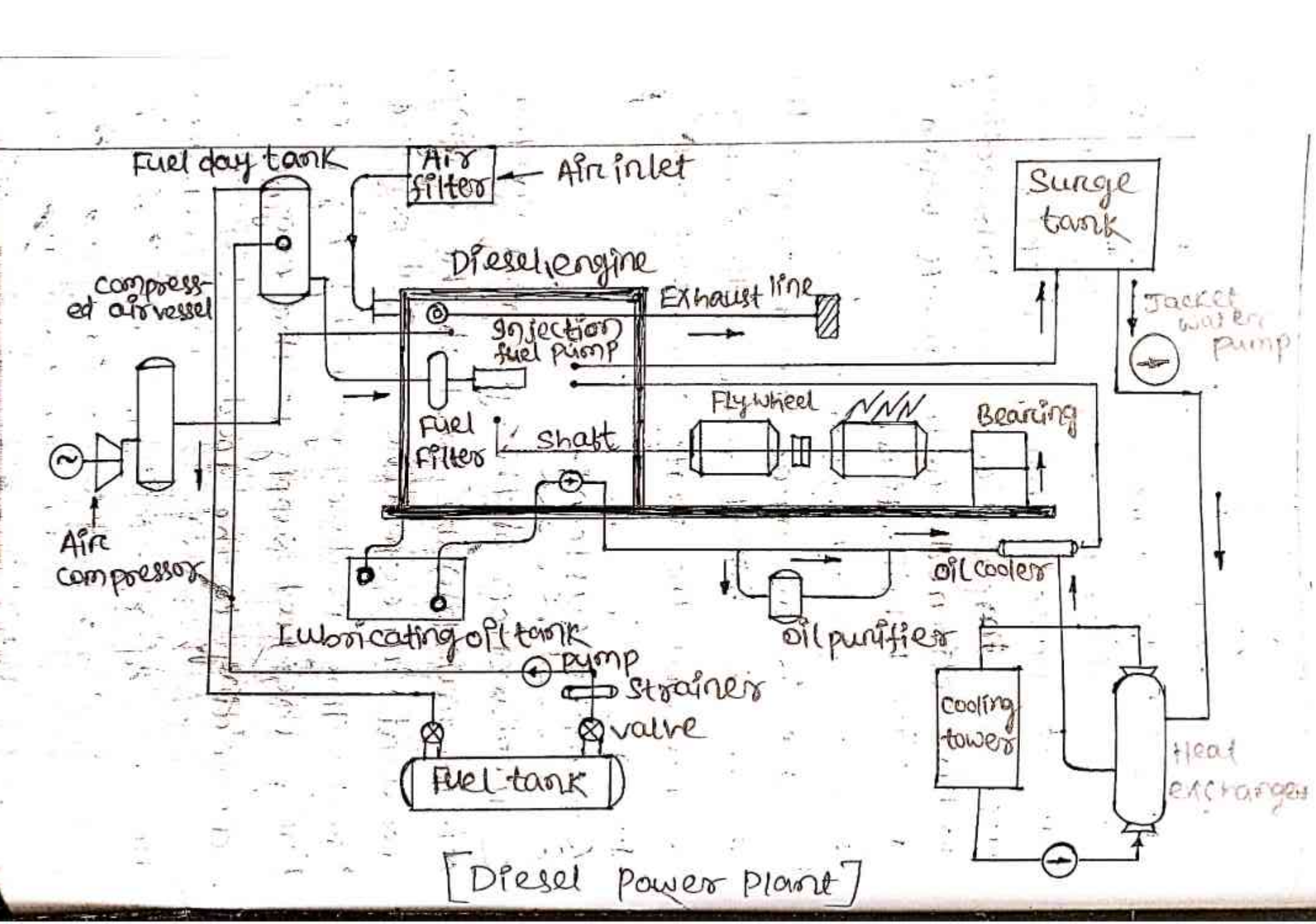
The air necessary for the combustion of fuel is supplied by the air intake system. Filters are provided to remove dust particles from the air which may act as abrasive in the engine cylinder.

Exhaust system :-

This system leads the engine exhaust gases out of the building and discharge into the atmosphere. A silencer is usually incorporated in the system to reduce the noise level.

Cooling system :-

Only a part of the heat released by the burning of fuel in the cylinder is converted into work and the rest is passed through the cylinder wall, Piston rings etc and may cause damage to the system. In order to keep the temperature of the engine parts within the safe operating limits, cooling is provided. Thus, cold water is circulated through the cylinder and head jacket. The water takes away heat from the engine and becomes hot. To re circulated the same water again for cooling, it is sent to the cooling towers or radiator.



[Diesel Power Plant]

Lubricating System:-

The lubricating system minimizes the wear and tear of the rubbing surface of the engine. The lubricating oil is drawn from the oil tank by the pump and is passed through a filter to remove impurities. Clean lubricating oil is delivered to the points which require lubrication.

Engine starting System :-

This is an arrangement to give the engine an initial start, until firing starts and the units runs with own power.

Governing system:-

The function of the governing system is to maintain the speed of the engine constant irrespective of load on the plat. This is done generally by varying the fuel supply to the engine according to the load.

5. Hydro Electric Power Plant

What is a hydro-electric power plant?

The power plant which utilizes the energy of water in order to drying to run the turbine to produce electricity is known as hydroelectric power plant

Principle of hydro-power plant:-

Explain hydro electric power plant with it's components through needs sketch?

(i) The potential head of water is converted to kinetic head.

(ii) This kinetic energy of water strikes on the turbine blade which causes the rotation of turbine shaft.

(iii) The turbine shaft is coupled with the generator shaft.

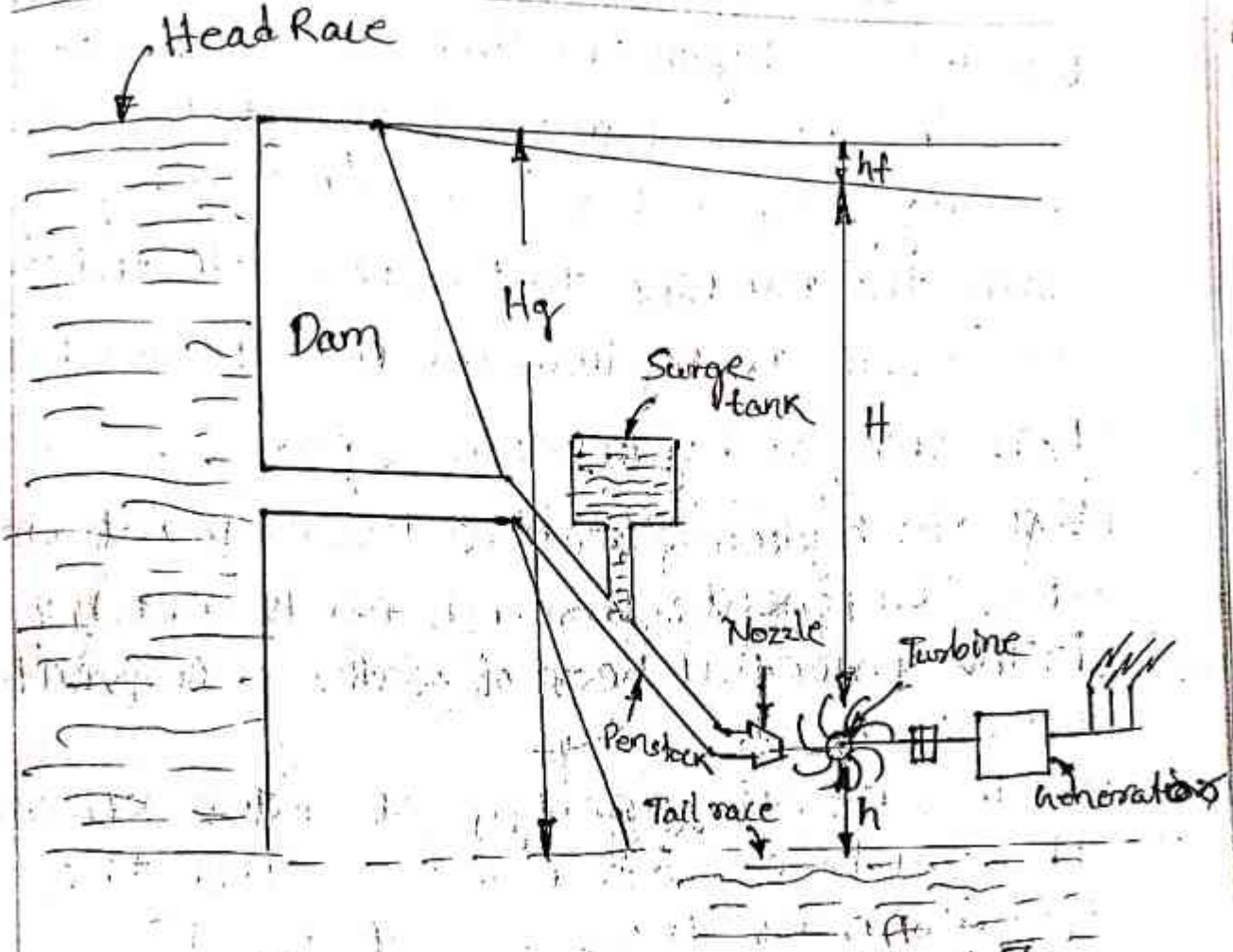
(iv) As the turbine shaft rotate, generator shaft rotates and hence electricity produced

Gross Head:- It is defined as the distance between head race and tail race. It is represented as "Hg".

If h = height of nozzle above tail race

h_f = Frictional head loss in penstock

$$H = Hg - h - h_f$$



[Hydro-electric Power Plant]

Different components of hydro electric power plant:

The main components of hydro electric power plant are

(a) Head Race
(b) Tail Race
(c) Reservoir
(d) Spillway
(e) penstock
(f) surge tank
(g) Turbine
(h) power lines
(i) Draft tube
(j) Catchment area

Head Race & Tail Race:- The water level at the dam is known as head race and the water level at the down stream is called tail race.

Reservoir:- Water from the different sources (Rain water, River water, stream water) is stored in a place known as reservoir.

Dam:- The dam is constructed to restrict to water flow from the reservoir and creats a water head.

Spillway:- It is the path for removing (spilling) of water from the dam if the water level rises above the determined limit.

Penstock:- This is the path through which water flow from dam to turbine house it converts the potential head to kinetic head.

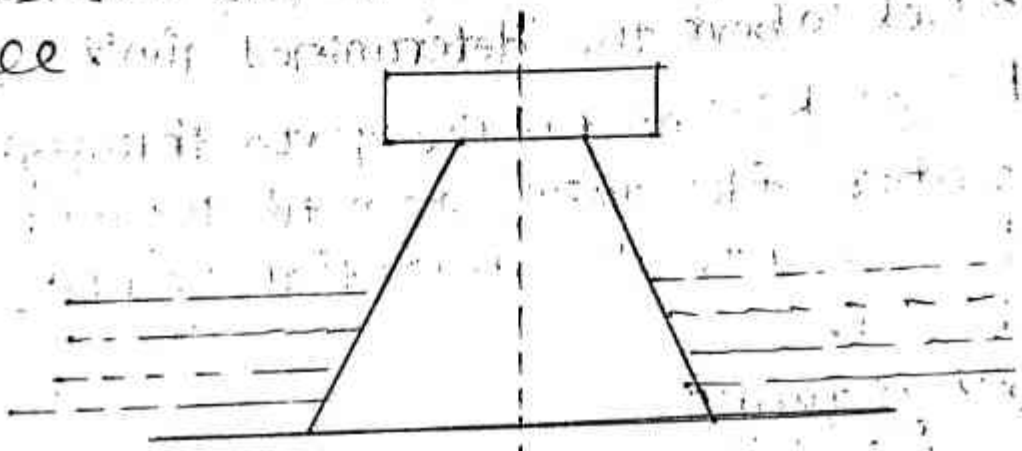
Surge tank:-

* It is connected to the penstock before the turbine.
* It surge the water when the water requirement reduces suddenly.
* It also supplied additional water according to the sudden increasing in demand.
* It surge the purpose of reducing water hammering in pipes.

Power line:- *As the turbine shaft and generator shaft are coupled with each other, if the turbine shaft rotates the generator shaft rotate which produce electricity.

*The power produced in the generator it is send to various power destribution station through power lines.

Draft Tube :- The function of the draft tube is to increase or recover a major portions of kinetic energy at the outlet of turbine so that water flows from the turbine house to tail race.



Catchment area :-
It is the area behind the dam.

Advantages of Hydro electric power plant :-
(i) It is renewable & it produces no gas emission
(ii) It does not produces any ~~waist~~ waste
(iii) It is more reliable than solar P.P, wind power plant.
(iv) Operation cost is less
(v) The water after use can be reused for irrigation purpose.

Disadvantages:-

(i) Large space requirement
(ii) Initial cost is high.
(iii) plant life can affected by the change of water quality.
(iv) No society can be form behind the dam.