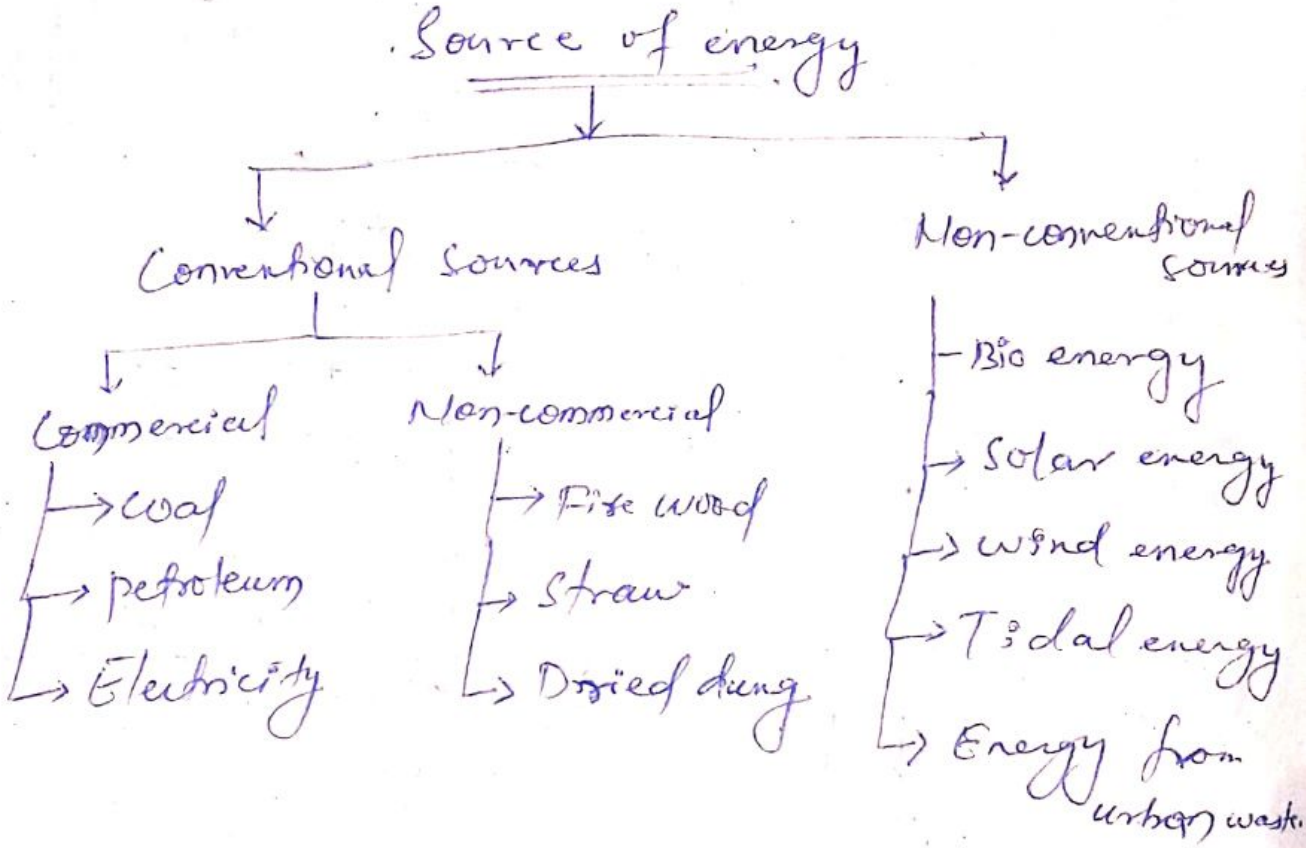
CH-1

Source of energy:-

The two major source of energy can be classified under:-

* Conventional sources.
* Non-conventional sources.



→ CONVENTIONAL SOURCE OF ENERGY:-

The sources of energy are also known as non-renewable source of energy and are available in limited quantity apart from hydro-electric power. Further it can be classified under commercial and non-commercial energy.

⇒ The coal, electricity and petroleum are known as commercial energy.

⇒ Generally the energy sources that are freely available are considered as the

non-commercial energy sources: The example is straw, dried dung, firewood etc.

⇒ "The conventional source of energy is a source of energy that cannot be reuse a source of energy after using it once".

⇒ Non-conventional source of energy:-

These non-conventional sources are also known as renewable source of energy. the natural resources like wind, tides, solar, biomass etc. generate energy.

→ These are pollution free and hence we can use these to produce a clean form of energy without any wastages

Classification of steam power plant :-

The steam power plants may be classified as follows.

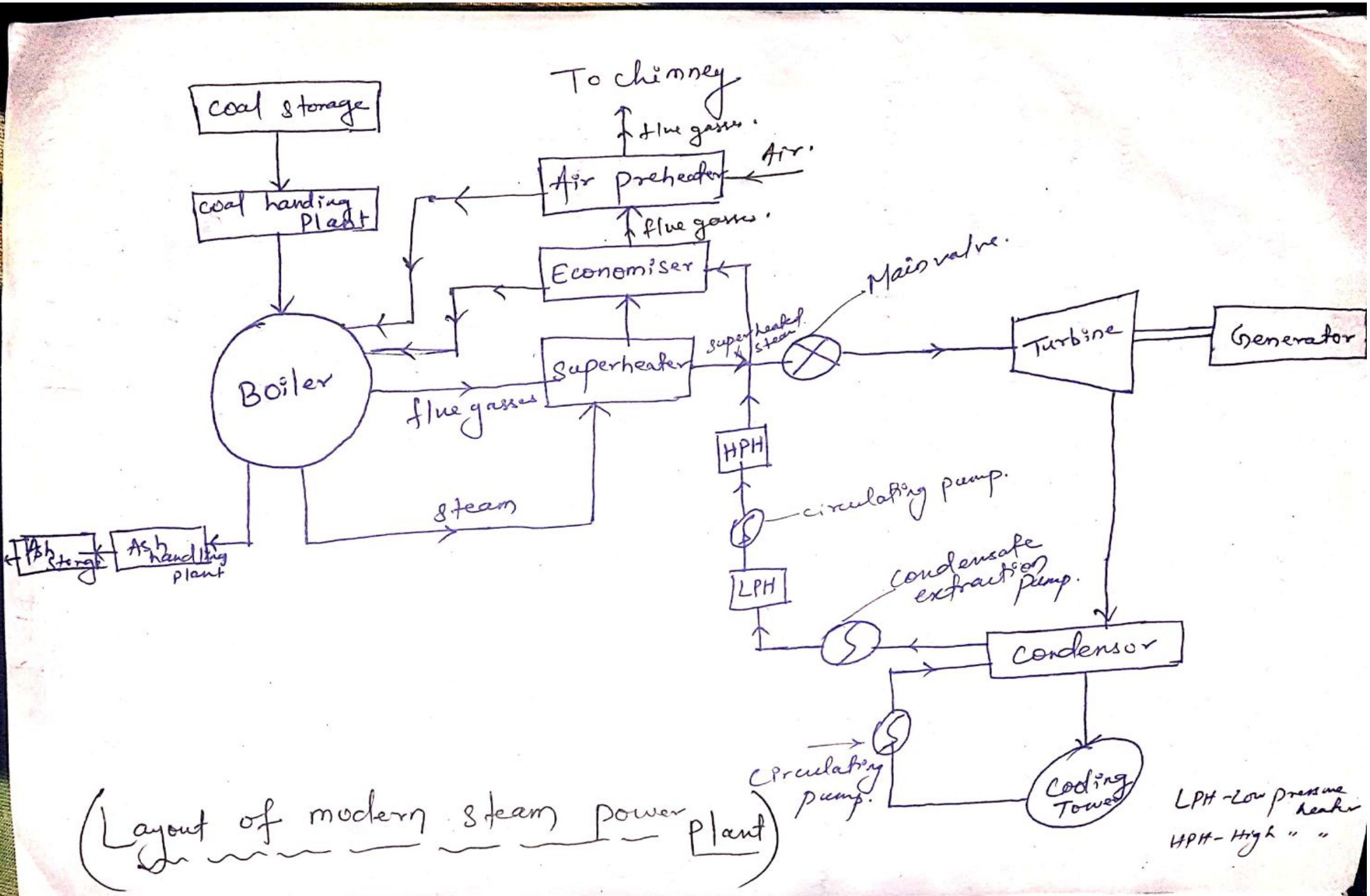
1. Central stations.
2. Industrial Power station or Captive power station.

1. Central station :-

The electrical energy available from these stations is meant for general sale to the customers who wish to purchase it. Generally, these stations are condensing type where the exhaust steam is discharged into a condenser instead of into the atmosphere. In the condenser the pressure is maintained below the atmospheric pressure & the exhaust steam is condensed.

2. Captive power station :-

This type of power station is run by a manufacturing Company for its own use & its output is not available for general sale. Normally these plants are non-condensing because a large quantity of steam is required for different manufacturing operations.



(Layout of modern steam power plant)

Component of model steam power plant :-

1. Boiler :-
   1. Super heater
   2. Reheater
   3. economizer
   4. Air preheater.
2. Turbine :-
3. Generator
4. Condenser.
   - (i) Cooling tower
   - (ii) Circulating water pump.
5. Boiler feed pump.
6. Wagon tripper.
7. Crosser house.
8. Coal mill
9. Induced drought fan.
10. Ash precipretation.
11. Boiler chimney.
12. Forced drought fan
13. water treatment plant.
14. Control room.
15. Switch yard

Selection of site for steam power plant :-

Selection of side for steam power plant :-

* Availability of raw material
* Nature of land
* Cost of land
* Availability of water
* Transport facility
* problem of public
* Ash disposal facilities
* Availability of labour
* size of plant
* Load center
* future extension.

Essential of good steam boiler :-

It should have following features.

* The boiler should produce maximum of weight of steam of required quality at minimum expenses.
* Steam production rate should be as per the requirement.
* It should be absolutely realisible.
* It should be light in weight.
* It should be capable of quick starting
* It should be an easy access to inspect & repair the parts of boiler.
* The boiler component should be easily transport.
* The installation of the boiler should be simple.
* The boiler of the boiler should not accumulated soot or water deposit & should be sufficient strong & allowed wear and corrosion.
* The water & gas circuit should such as to allow of the fluid with less viscosity.

(1) Layout of a modern steam power plant;

Ans:- The layout of a modern steam power plant comprises of the following four circuit.

1. Coal and ash circuit.
2. Air and gas circuit.
3. Feedwater and steam flow circuit.
4. Cooling water circuit.

1. Coal and ash circuit:-

Coal arrives at the storage yard and after necessary handling, passes on to the furnaces through the fuel feeding device. Ash resulting from combustion of coal collects at the back of the boiler and is removed to the ash storage yard through ash handling equipment.

2. Air and gas circuit:-

Air is taken in from atmosphere through the action of a forced or induced draught fan and passes on to the furnace through the air preheater, where it has been heated by the heat of flue gasses which pass to the chimney via the preheater. The flue gases after passing around boiler tubes and superheater tubes in the furnace pass through a dust catching device or precipitator, then through the economiser, and finally through the air preheater before being exhausted to the atmosphere.

3. Feed water and steam flow circuit:-

In the water and steam circuit condensate leaving the condenser is first heated in a closed feed water heater through extracted steam from the lowest pressure extraction point of the turbine. It then passes through the dearator and a few more water heaters before going into the boiler through economiser.

In the boiler drum and tubes, water circulates due

to the difference between the density of water in the lower temperature and the higher temperature sections of the boilers. Wet steam from the drum is further heated up in the Superheater before being supplied to the prime mover. After expanding in high pressure turbine steam is taken to the reheat boiler and brough to its original dryness or superheat before being passed on to the low pressure turbine. From there it is exhausted through the condenser in to the hot well.

4. Cooling water circuit:-

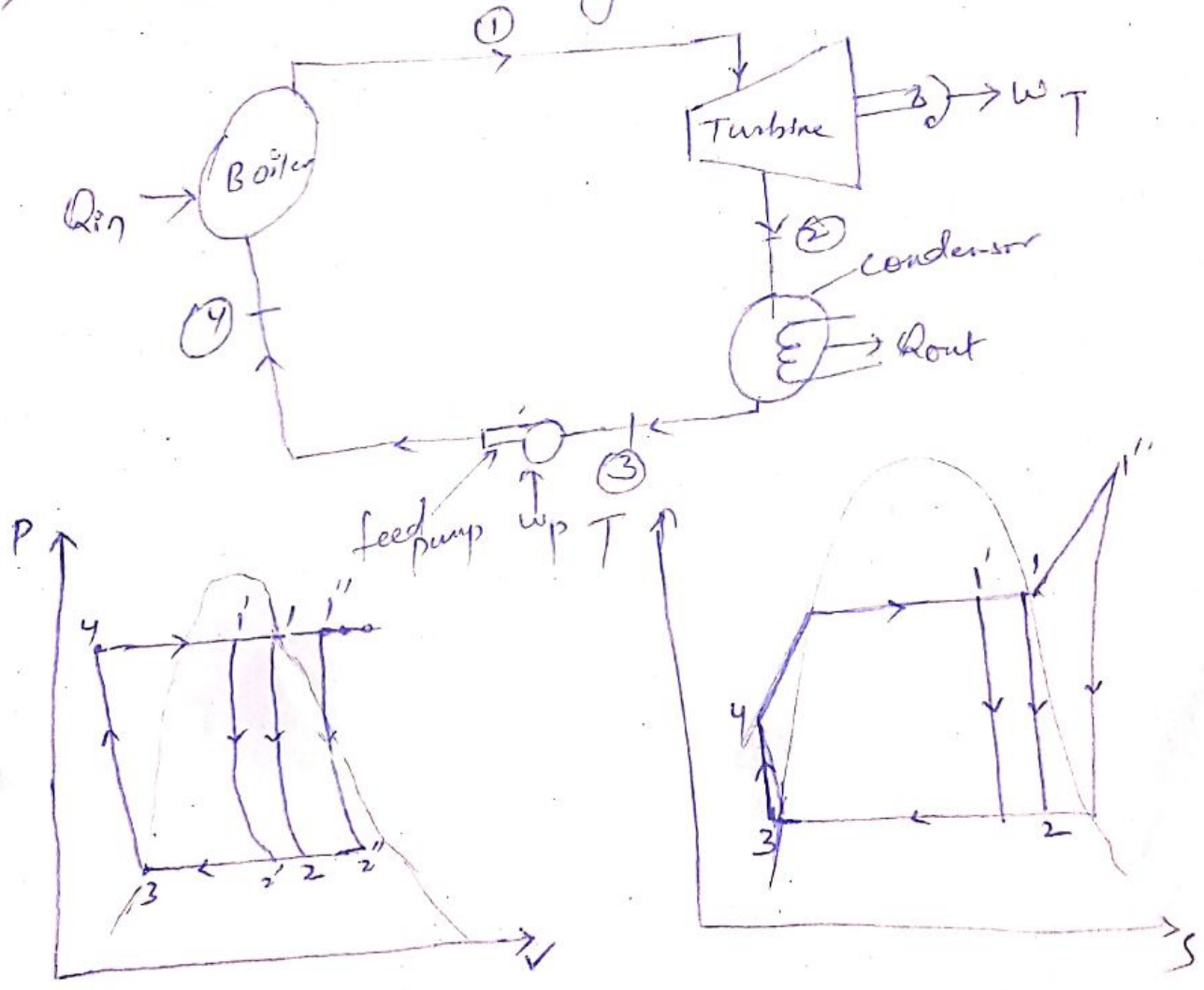
The cooling water supply to condenser helps in maintaining a low pressure in it. The water may be taken from a natural source such as river, lake or sea or the same water may be cooled and circulated over again. In the later case the cooling arrangement is made through spray pond or cooling tower.

Rankine cycle :-

This is a theoritical cycle on which steam turbine or engine works. It is an ideal representation for the vapour power cycle, it consist of two constant pressure process and two constant reversible adiabatic process.

⇒ When all these four process are ideal, the cycle is an ideal cycle called a Rankine cycle.

⇒ This is a reversible cycle.



Process (1-2) :-

Reversible adiabatic expansion of the vapour in turbine.

$$W_T = h_1 - h_2$$

process (2-3) :-

Constant pressure heat rejection at condensor. $Q_{out} = h_2 - h_3 = x_2 h_{fg_2}$

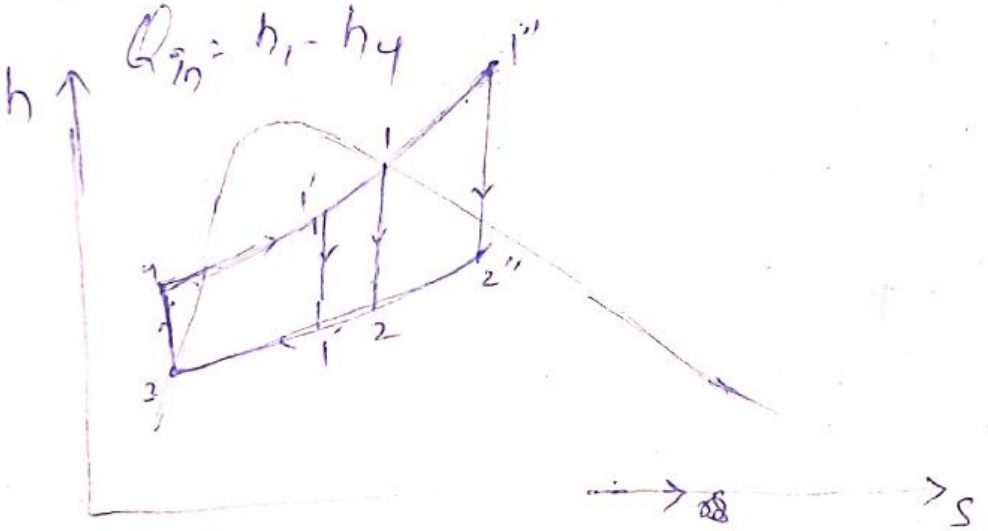
process (3-4) :-

Reversible adiabatic pumping process or compression in feed pump.

$$W_p = h_4 - h_3$$

process (4-1) :-

Constant pressure heat transfer (addition) in boiler.



Net work done $= W_T - W_p$

efficiency $\eta = \dfrac{W_T - W_p}{Q_{in}} = \dfrac{h_1 - h_2 - (h_4 - h_3)}{h_1 - h_4}$

The pump work is usually small compared to the turbine work, and is often neglected.

Note

$\eta = \dfrac{h_1 - h_2}{h_1 - h_{f_2}}$

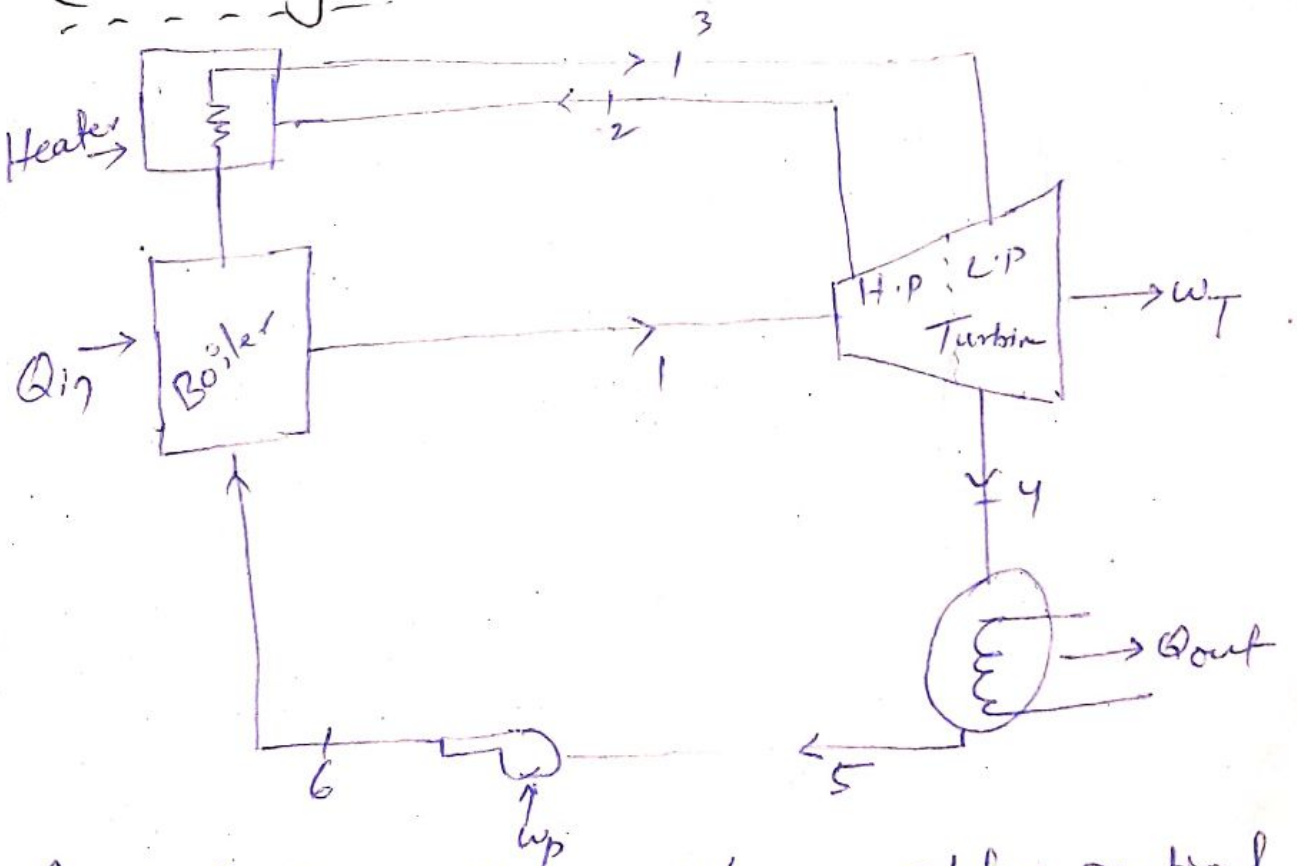
$$\boxed{\eta = \frac{h_1 - h_2}{h_1 - h_4}}$$

→ The capacity of a steam plant is often expressed in term of steam rate or specific steam consumption (S.S.C). It is defined as the rate of steam flow (kg/s) required to produce unit shaft output (1kW).

$$\text{Steam rate} = \frac{1}{W_{net}} \text{ kg/kWs} \quad \text{or} \quad \frac{3600}{W_{net}} \text{ kg/kWh}$$

$$\therefore \text{Heat rate (H.R)} = \frac{Q_1}{W_T - W_p} = \frac{1}{\eta} \text{ kJ/kWs}.$$

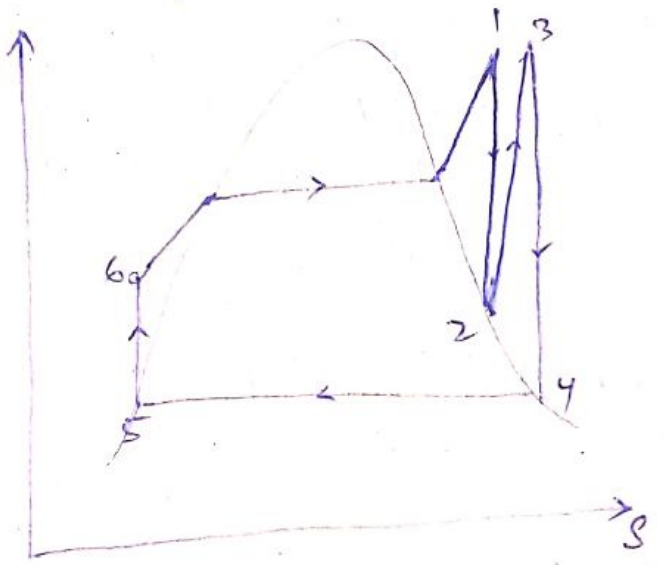
Reheat cycle:-



→ In that case, all the steam after partial expansion in the turbine is brough back to the boiler heater, to reheated by combustion gasses and then feed back to the turbine for further expansion.

For attaining greater thermal efficiency when initial pressure of steam was rise beyond 42 bar it was found that resulting cond^n of steam after, expansion was wetter and exceed the safe limit 12% condensation. It therefore necessary to reheat the steam after expansion was over so that the resulting condition after complete expansion fall within the region of permissible.

Process (1-2)' :-



Process (1-2) :- (HP Turbine)

Here the dry saturated steam from the boiler is allowed to expand in turbine isentropically, $W_T = h_1 - h_2$

Process (2-3) :- (Heater)

The expanded steam is made to attend the require temperature it means reheated in low pressure boiler at constant pressure level.

$$S_1 = S_2 = S_{f_2} + x_2 S_{fg_2}$$

$$h_2 = h_{f_2} + x_2 h_{fg_2}$$

$$S_4 = S_3 = S_{f_3} + x_3 S_{fg_3}$$

$$h_3 = h_{f_3} + x_3 h_{fg_3}.$$

Process (3-4) (L.P Turbine):-

After attaining required temperature steam is passed in to low pressure turbine to carry out the remaining expansion. the enthalpy h_4 & enthropy S_4 are calculated

$$h_4 = h_{f_4} + x_4 h_{fg_4}$$

$$S_4 = S_{f_4} + x_4 S_{fg_4}.$$

Process (4-5) (Condensation):-

After expansion in turbine steam is passed in to the condensor to perform condensation process. The remaining heat of the steam is rejected to the atmosphere.

$$Q_{out} = h_4 - h_5.$$

Process (5-6):-

Water from the condensor is pump feed to boiler using an external pump. During this process pressure increase. P_5 to P_6 Isentropically.

$$W_p = h_6 - h_5$$

Process (6-1) :-

Here the saturated water from the pump is heated by using a constant heat source, the input water saturate is heated till superheated condition. Temperature & enthalpy of saturated water raise up to great extend.

$$Q_{in} = h_1 - h_6 + h_3 - h_2$$

$$\text{Net workdone} = W_T - W_P$$

$$= (h_1 - h_2 + h_3 - h_4) - h_6 + h_5$$

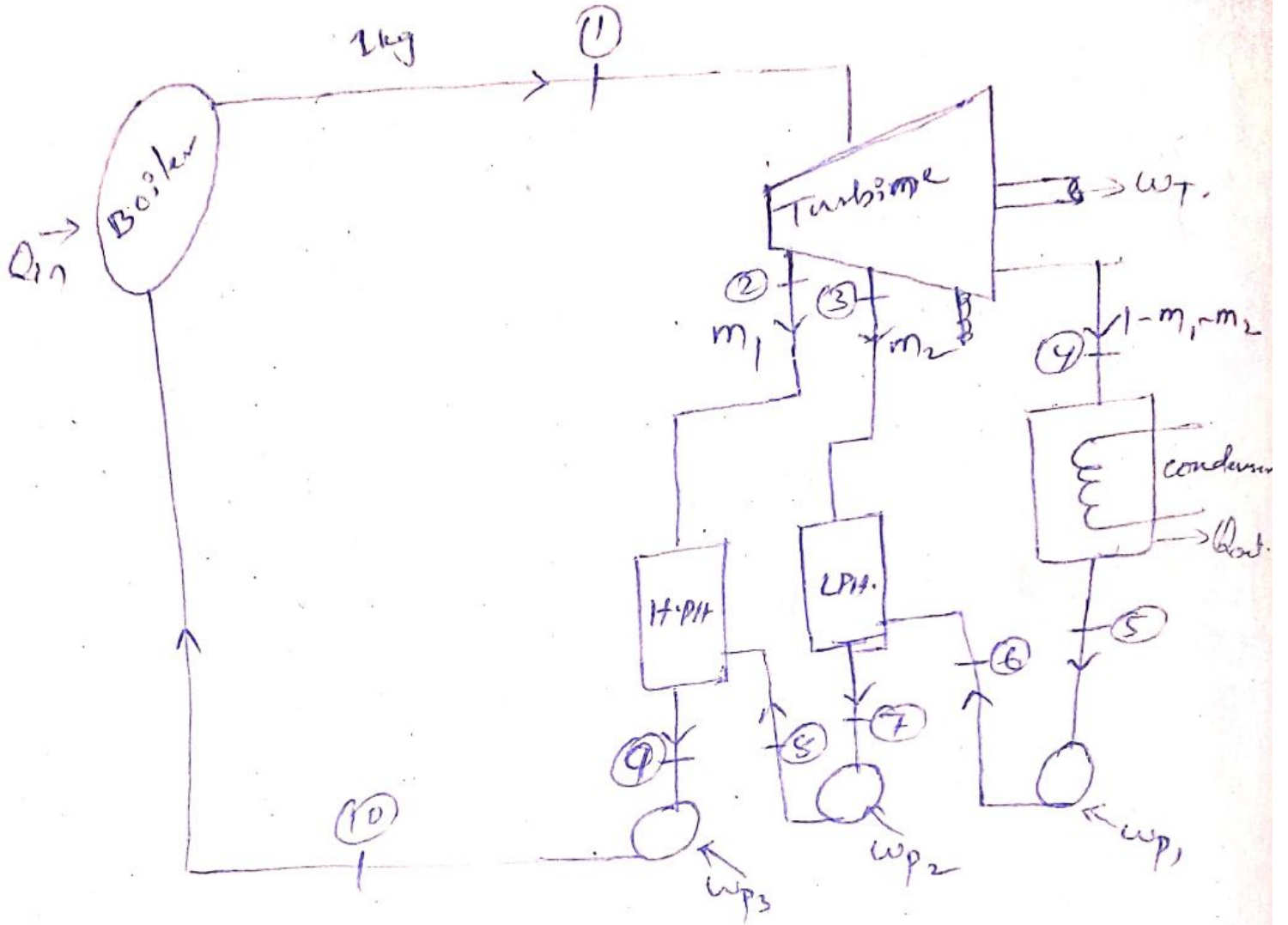
So,

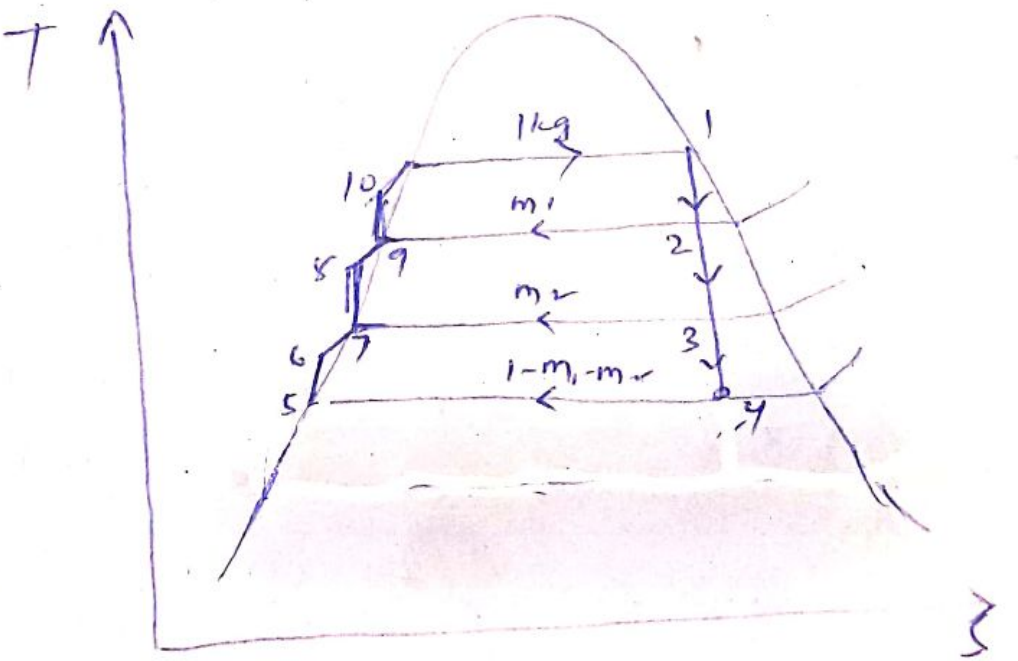
$$\eta = \frac{W}{Q_{in}} = \frac{h_1 - h_2 + h_3 - h_4 - h_6 + h_5}{h_1 - h_6 + h_3 - h_2}$$

Regerative cycle :-

On the rankine cycle it is absorbed that the condensate which is fairly at low temperature has an irreversible mixing with hot ~~boiler~~ water and this result decrease in the thermal efficiency of the cycle.

→ Methods are therefore adopted to heat the feed water from the hot well of condensor irreversibly by the interchange of heat with the steam and the improving the cycle efficiency.





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Boiler terms :-

(ii) Shell :-

A pressure vessels which is riveted or welded.

(i) Grate

(iii) Furnace

(iv) Accessories

(v) Water level

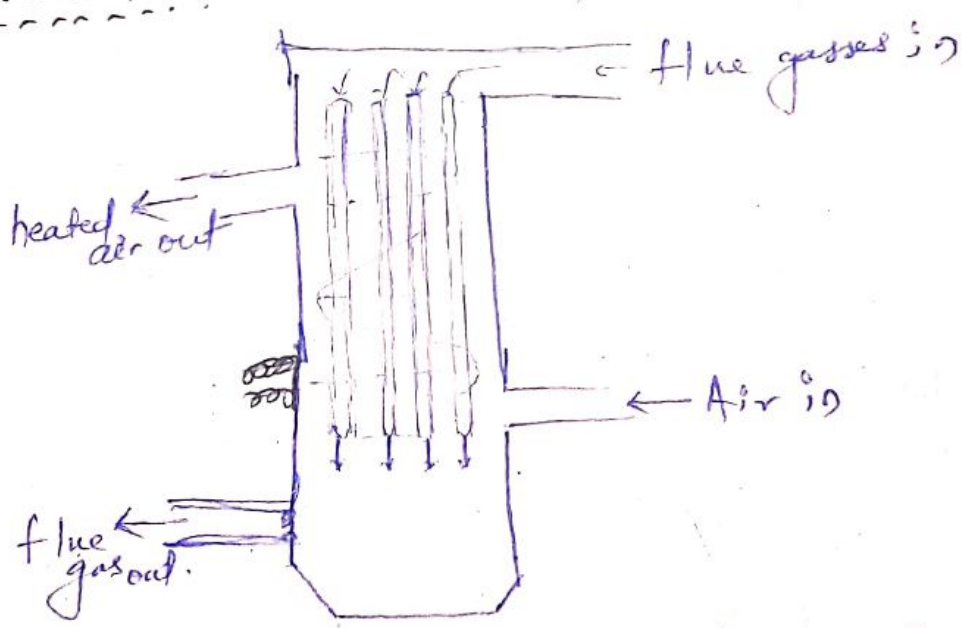
(vi) Foaming

(vii) Blowing

(viii) Refractory

(ix) Boiler mounting.

Air-pre heater :-



The function of air-preheater is increase the temperature of air before it enters the boiler. It placed just after the economiser, so the flue gases passes through the economizer then to the air pre heater. And an air preheater consist of plates or

tube with hot gases on one side and air on the other side. It pre heat the air to be supplied to the furnace. Pre heated air accelerate the combustion. and facilitated the the burning of coal.

The degree of pre heating depends on
* Types of fuel
* type of burning equipment.
* Rating at which the boiler furnace is operated.

Types of air preheater :-
(1) Tubular type
(2) plate type.
(3) Storage type.

function of airpreheater :-
After leaving the boiler and economizer the gaseous product of combustion travel through the inside of tubes of air preheater. in a direction opposite to that of air travel and transfer some there heats to the air to be supplied to furnace. Thus the air get initially heated before being supplied to the furnace.

> The gaseous reverse their direction near the bottom of air heater and a hopper is fitted to the bottom of air pre heater. to collect the ash.

Economiser :-

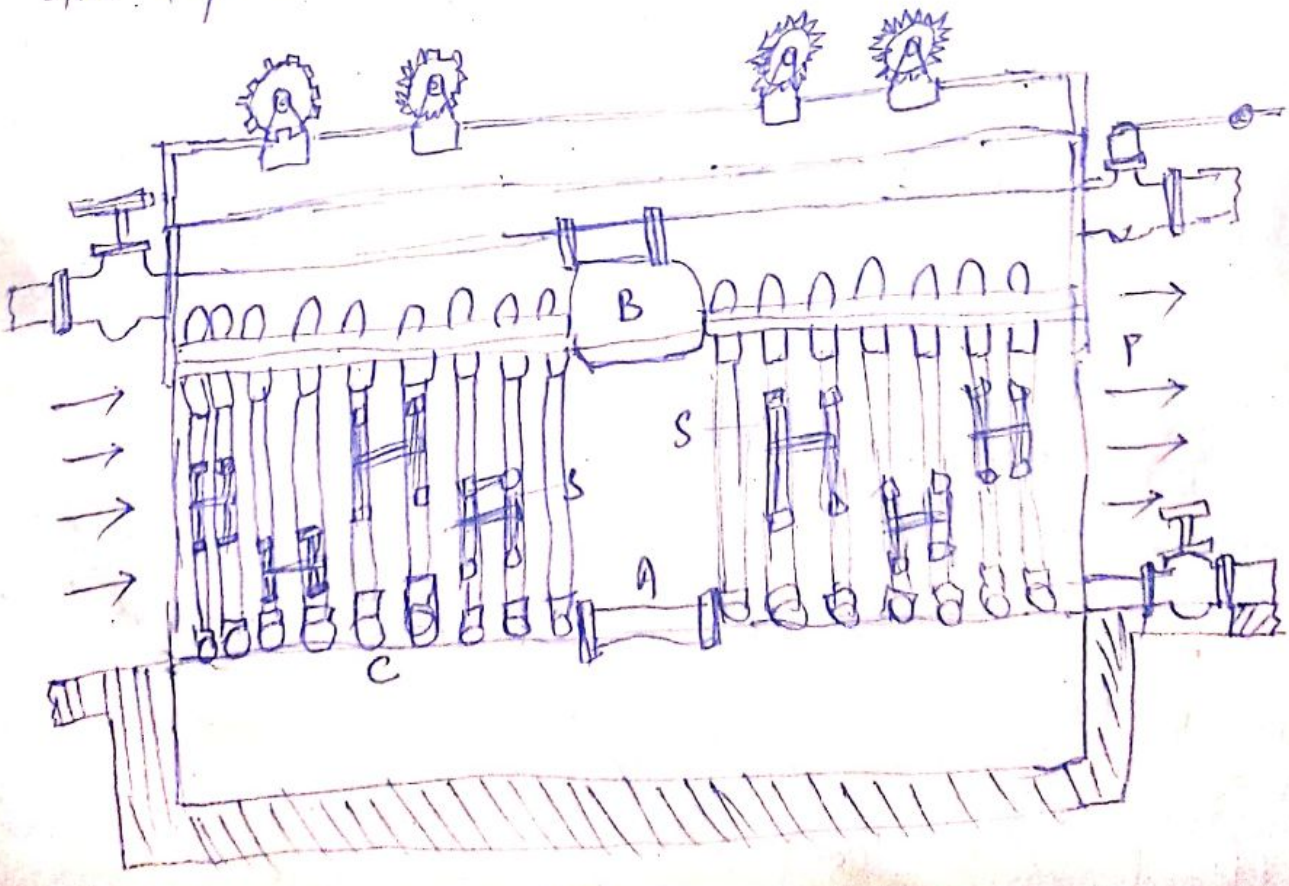
An economiser is a device in which the heat of flue gasses used for heating the feed water.

* There are two types of economiser.
  (i) Integral & independent economiser.

* This is instal in chamber apart from the boiler setting. The chamber is situated on the passage of flow of flue gasses from the boiler to chimney.

Independent type vertical tube economiser (Greens economiser)

It is employed for the boiler for medium pressure upto 25bar. It consist of large number of vertical cast iron pipes, which are connected to two horizontal pipe one at the top another at the bottom.



A = Bottom pipe
B = Top pipe
P = vertical CI pipes
S = Scrapers.

=> The bottom pipe through which feedwater is pumped into the economizer and from the top pipe water enters to the boilers.

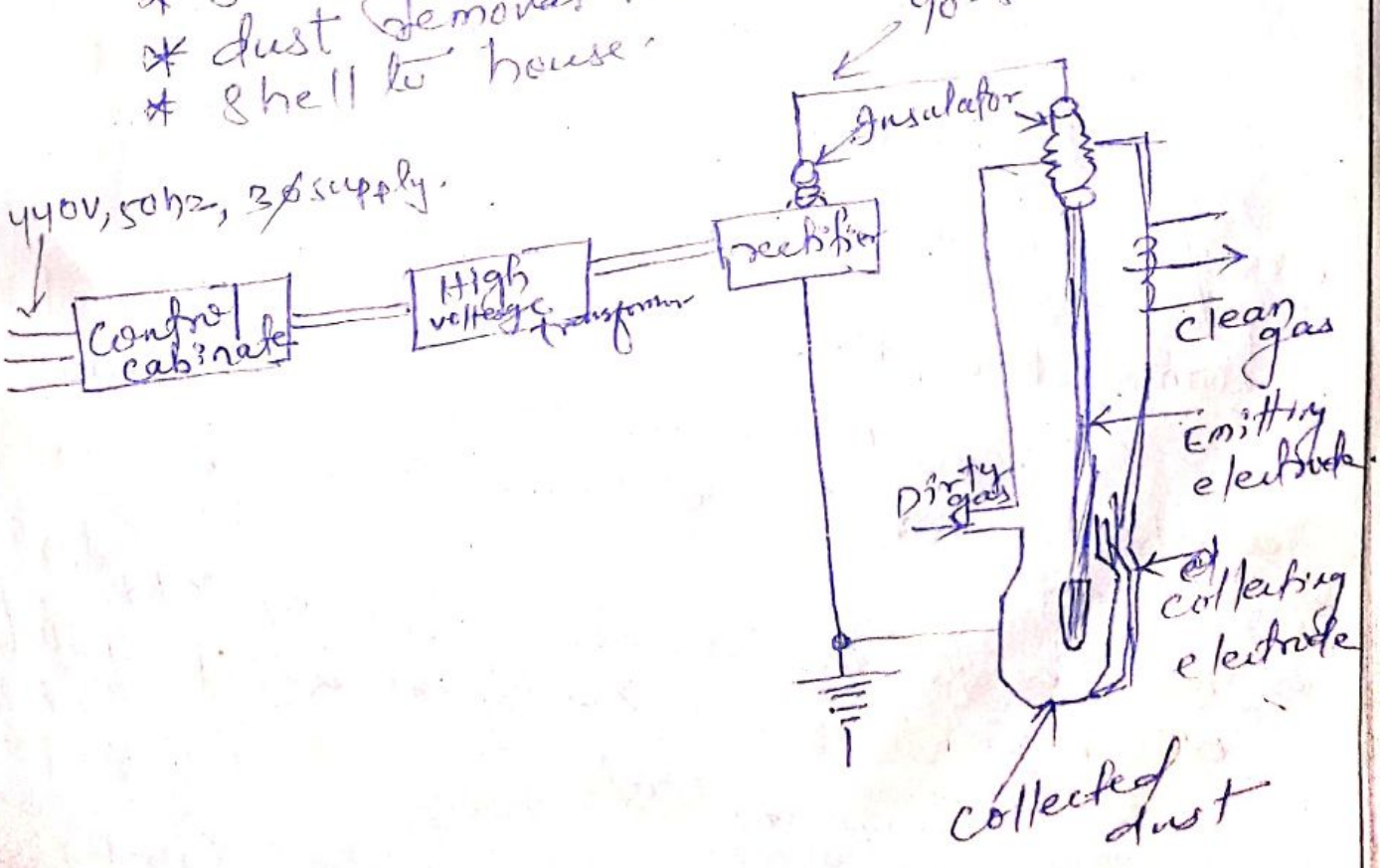
=> The flue gasses moves around the vertical pipe and exchange heat with the feed water to the boiler.

Electrostatic precipetator :-

Electrostatic precipetator also called as coltered precipetator works effectively on finer of flue dust.

Element of precipetator :-

* Source of high voltage
* Ionizing & collecting electrode
* dust removal mechanism
* Shell to house.



⇒ The precipetator has two set of electrode insulated from each other that maintain the electrostatic field.

⇒ The field ionize the dust particle that pass through it, attracting them to the electrode of opposite charge the voltage system maintain a negative potential of 30kv to 60kv with the collecting electrodes grounded. The collecting electrodes has large contact surface.

* A wet type of this unit removes the dust by a water fall following down

Advantage
→ It require less maintanance cost.
→ Increase the ~~#ficiency~~ efficiency.

Disadvantage
→ Cost is high.

Draught system :-

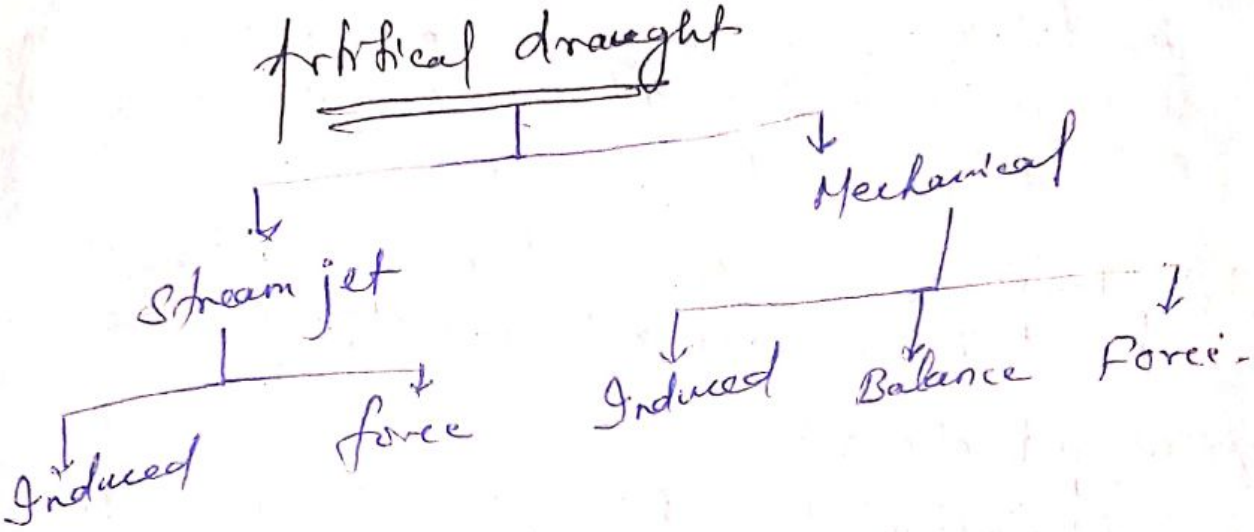
Chimney draught :-

A small pressure difference which cause a flow of gase to take place is term as a draught.

→ In boiler furnace proper combustion take place only when sufficient quality of air is supplied to the burning coal.

→ draught may be classified.

* Artificial draught → stream jet
* Natural draught or chimney draught.



Natural Draught:-

Natural draught is obtain by the use of chimney.

Function of chimney:-

It produces the draught where by the air & the gas are forced through the fuel bed, furnace, boiler passes and shading.

→ It carries the product of combustion to such a height before discharging them to the surrounding.

* The Draught produce by the chimney is due to the density difference between the column of hot gas inside the chimney and the cold air outside.

Artificial Draught :-

In the boiler, it may not be possible to build a chimney high enough to produce the draught of such a large magnitude to meet this requirement artificial draught system should be used. It may be a mechanical draught or a steam jet draught.

=> If the draught is produced by steam jet or fan it is known as artificial draught.

Steam jet draught :-

It employs steam to produce the draught.

Mechanical draught :-

It employs fan or blowers to produce the draught.

Forced Draught :-

In a mechanical draught system draught is produce by a fan. In a forced draught system a blower and a fan is installed near or end the base of the boiler to force the air through the ~~flue~~ bed. and other passage through the furnace flues, air preheater, economizers, It is positive pressure draught.

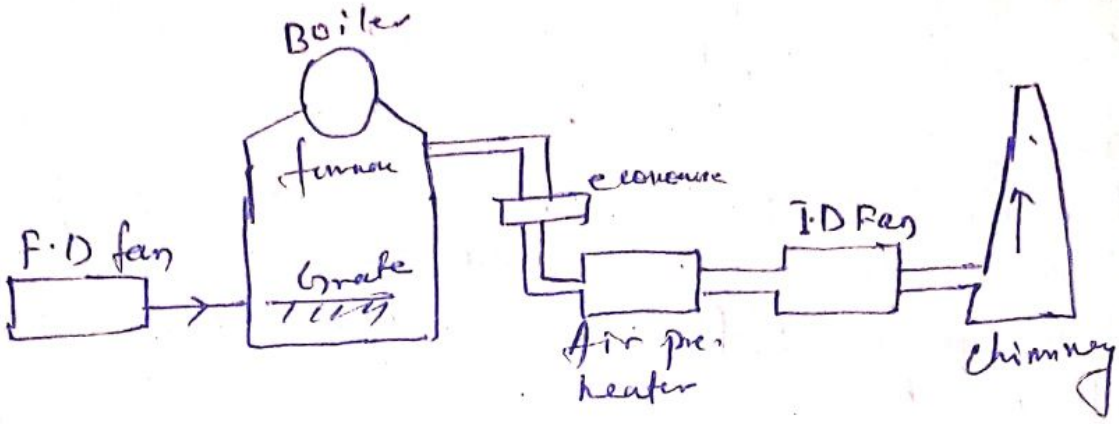
→ The enclosers should be very tightly sealed. So that gasses from the furnace should n't be leak.

Induced draught system:-

In this system, the blower is located near the base of the chimney instead of near the grate. The air is sucked in the system by reducing the pressure through the system below atmospheric. The induced draught fan sucks the burned gases from the furnace and the pressure inside the furnace is reduced below atmosphere & induced the atmospheric air to flow through the furnace. The action of the induced draught is similar to the action of the chimney. This draught is used usually where economizer & air-preheater are incorporated with the system. This is a negative draught system.

Balanced draught system:-

The balanced draught is a combination of forced & induced system. In this system the forced draught overcome the resistance of the fuel bed therefore sufficient air is supplied to the fuel bed for proper and complete combustion. and the induced draught fan removes the gases from the furnace maintaining the pressure in the furnace just below atmosphere. This helps to prevent the blow-off of flame when the doors are opened as the leakage of air is inwards.



Advantage of balanced draught :-

Forced draught system doesn't required water cooled bearing. tendency to early in to the boiler furnace is reduced.

→ No lose due to inrous of cold air through the furnace door. when they are open for fire and cleaning fires.

→ Fan size for the power required for the same draught air 1/5 to 1/2 of that required for an induced draught fan installation. Because forced draught fan handles cold air.

Advantages of mechanical draught :-

(i) Easy control of combustion & evaporation
(ii) increase in evaporative power of boiler.
(iii) Improve the efficiency of plant.
(iv) Reduce chimney height.
(v) Capability of consuming low grade fuel.
(vi) Low grade fuel can be used as the intensity of artificial draught is high.
(vii) The fuel consumption due to artificial draught is 15% less than that for natural draught.

Note

Draught:- Draught is defined as the difference between absolute gas pressure at any point in a gas flow passage and the ambient (same elevation) atmospheric pressure.

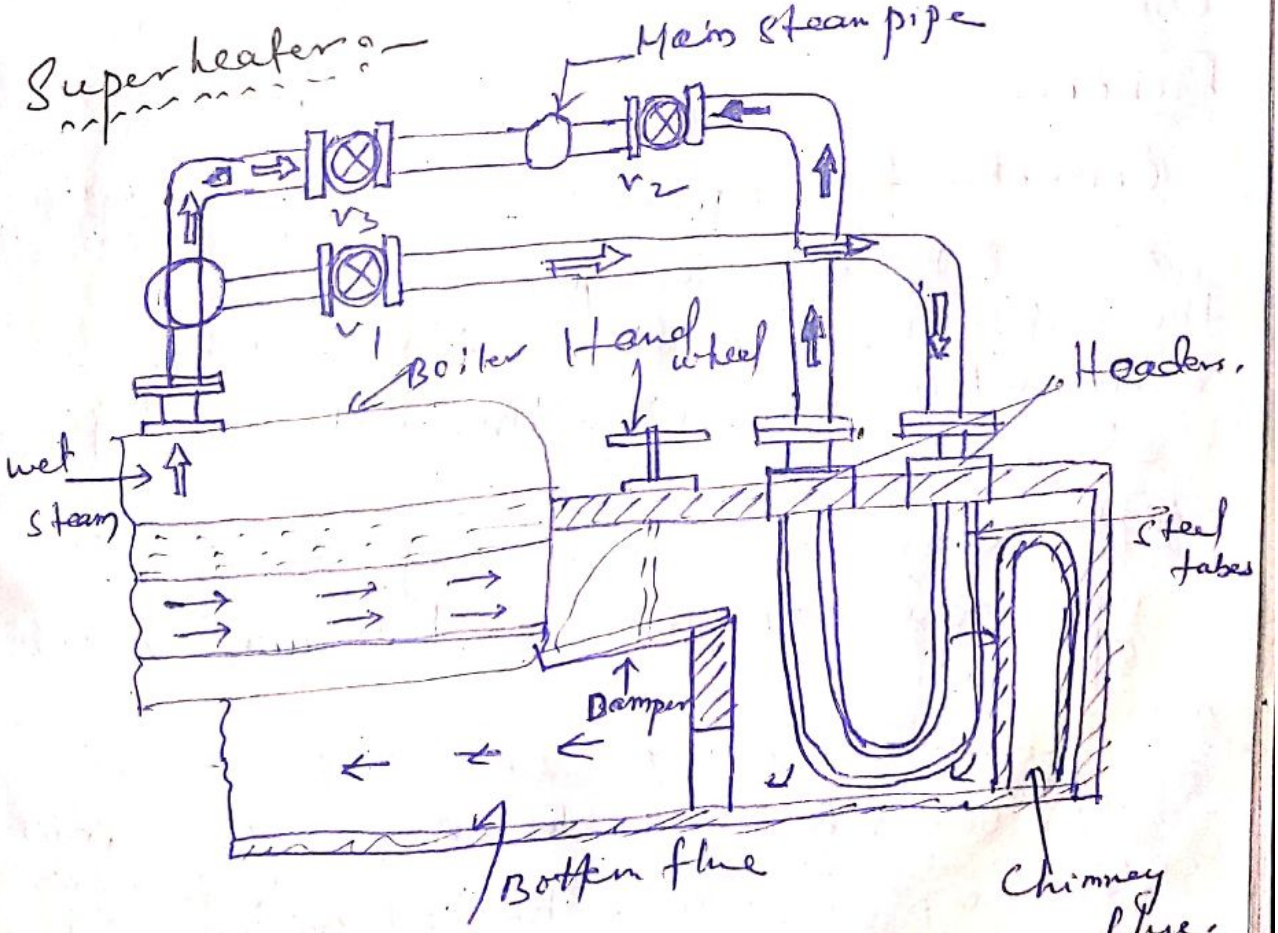
Draught is plus if $P_{atm} < P_{gas}$ and it is minus $P_{atm} > P_{gas}$. It is measured in milimeter (mm) or water.

Purpose

i) To supply required amount of air to the furnace for the combustion of fuel.

ii) To remove the gaseous product of combustion.

Superheater:-



→ flue gases

⇒ wet steam

⇒ superheated steam.

The function of superheater is to increase the temperature of steam above the saturation point.

The superheat is the important accessories of boiler and can be used both for the water tube & fire tube boiler.

Advantages:-

(i) Steam consumption of the steam turbine is reduce.

(ii) Losses due to condensation in the cylinder and steam pipe are reduce.

(iii) Erosion of the turbine can be eliminated.

(iv) Efficiency of the plant is increase.

Function:-

Convective type superheater:-

(i) In convective type superheater the heated flue gasses flow around the tube where the wet saturated steam flows.

(ii) It consist of two steel header to which are attached solid drawn 'U' tube of steel.

(iii) These are arranged in group of four and one pair of header generally carries ten group of pair. The steam enter from the boiler and leave through the header.

(2) type of superheater
Convective type
Radiative type

(iv) Steam pipe may be arranged so as to passed the steam through the superheater. or direct the main steam pipe. when the steam is taken from the boiler direct to the main steam pipe valve V_1 & V_2 are closed and V_3 opens. when steam is passed through the superheater valve V_3 is closed & valve V_1 & V_2 are open for exchange the heat from the flue gasses to the wet saturated steam.

Steam prime mover :-

Turbine is a prime mover in which the potential energy of steam transform into the kinetic energy later on transform into mechanical energy. on rotation shaft.

→ The turbine shaft directly or with the help of reducing gear connect with the generator to produce electrical energy.

→ This is used for diverge field of industry for power generation & transport.

→ the steam turbine uses pressurised steam from a boiler as the working fluid.

→ The superheated steam entering the turbine losses its pressure (enthalpy) moving through the blades of the rotors, and the rotors move the shaft to which they are connected.

→ steam turbines deliver power at a smooth, constant rate, and the thermal efficiency of a steam turbine is higher than that of reciprocating engine but lower than gas turbine engine. due to higher operating temp. of the gas turbine.

Classification of steam turbine :-

1. According to the available of energy.
   (a) Impulse
   (b) Reaction
   (c) Combination of impulse and reaction.

2. According to the number of pressure stage.
   (i) Single stage turbine - with one or more velocity stage usually of small power capacities; these turbines are mostly used for driving centrifugal compressors, blowers & other similar machinery.
   (ii) Multistage turbine - they are made in wide range of power capacities varying from small to large.

3. According to the dir? of steam flow.
   (i) Axial flow - Steam flow parallel to the axis of the turbine
   (ii) Radial flow - Steam flow perpendicular to the axis of the turbine.

4. According to the number of cylinder.
   (i) Single cylinder turbine
   (ii) Double cylinder turbine
   (iii) Three cylinder turbine.
   (iv) Four cylinder turbine.

5. According to the method of governing.
   (i) Turbines with throttle governing
   (ii) Turbine with nozzle governing
   (iii) Turbine with bypass governing.

Advantages of steam turbine over the steam engine

(i) The thermal efficiency of a steam turbine is much higher than that of a steam engine.

(ii) The power generation in a steam turbine is uniform rate. Therefor the use of flywheel (as in the case of steam engine) is not necessary.

(iii) Much higher speeds and greater range of speed is possible in case of steam turbine.

(iv) In large thermal station where we need higher output the steam turbine prove very suitable as this can be made in big size.

(v) With the absence of reciprocating parts the balancing problem is minimize.

(vi) No internal lubrication is required as there are no rubbing parts in the turbine.

(vii) In a steam turbine there is no loss due to initial condensation of steam.

(viii) Considerable overloads can be carried at the expense of slight reduction in overall efficiency.

Steam prime mover :—

Disadvantages :—

(i) High efficiency is ordinarily obtained only at high speed.
(ii) Gas turbine locomotives had similar problems, together with a range of other difficulties.
(iii) These devices are heavy and cumbersome.
(iv) Turbine can rotate in only one direction.

Element of steam turbine :—

(i) Turbine casings
(ii) Turbine rotors.
    * Disc type rotors
    * Drum type rotors.
(iii) Turbine blades.
(iv) Stationary blades (Diaphragms) & nozzles).
    * Nozzle
    * Stationary blades (Diaphragms)
    * Blade fastening
    * Twisted blades.
(v) Turbine bearing device
    * Turbine bearing
    * Radial bearing
    * Thrust bearing.
(vi) Turbine seals.
    * Shaft seals
    * blade seals.
(vii) Turbine couplings
(viii) Governor.
(ix) Lubrication system.

Compounding of turbine :-

Compounding of steam turbines is the strategy in which energy from the steam is extracted in a number of stage rather than a single stage in a turbine. A compounded steam turbine has multiple stage ie. it has more than one set of nozzles and rotors, in series, keyed to the shaft or fixed to the casing, so that either the steam pressure or the jet velocity is absorbed by the turbine in number of stages.

Compounding of steam turbine is used to reduce the rotor speed. It is the process by which rotor speed come to its desired value. A multiple system of rotors are connected in series keyed to a common shafts and the steam pressure or velocity is absorbed in stages as it flows over the blades. The steam produced in the boiler has sufficiently high enthalpy when superheated. In all turbines the blade velocity is directly proportional to the velocity of the steam passing over the blade. Now, if the entire energy of the steam is extracted in one stage, i.e. if the steam is expanded from the boiler pressure to the condenser pressure in a single stage, then its velocity will be very high. Hence the velocity of the rotor (to which the blades are keyed) can reach to about 30,000rpm, which is too high for practical uses because of very high vibration. Moreover at such high speeds the centrifugal forces are immense, which can damage the structure.

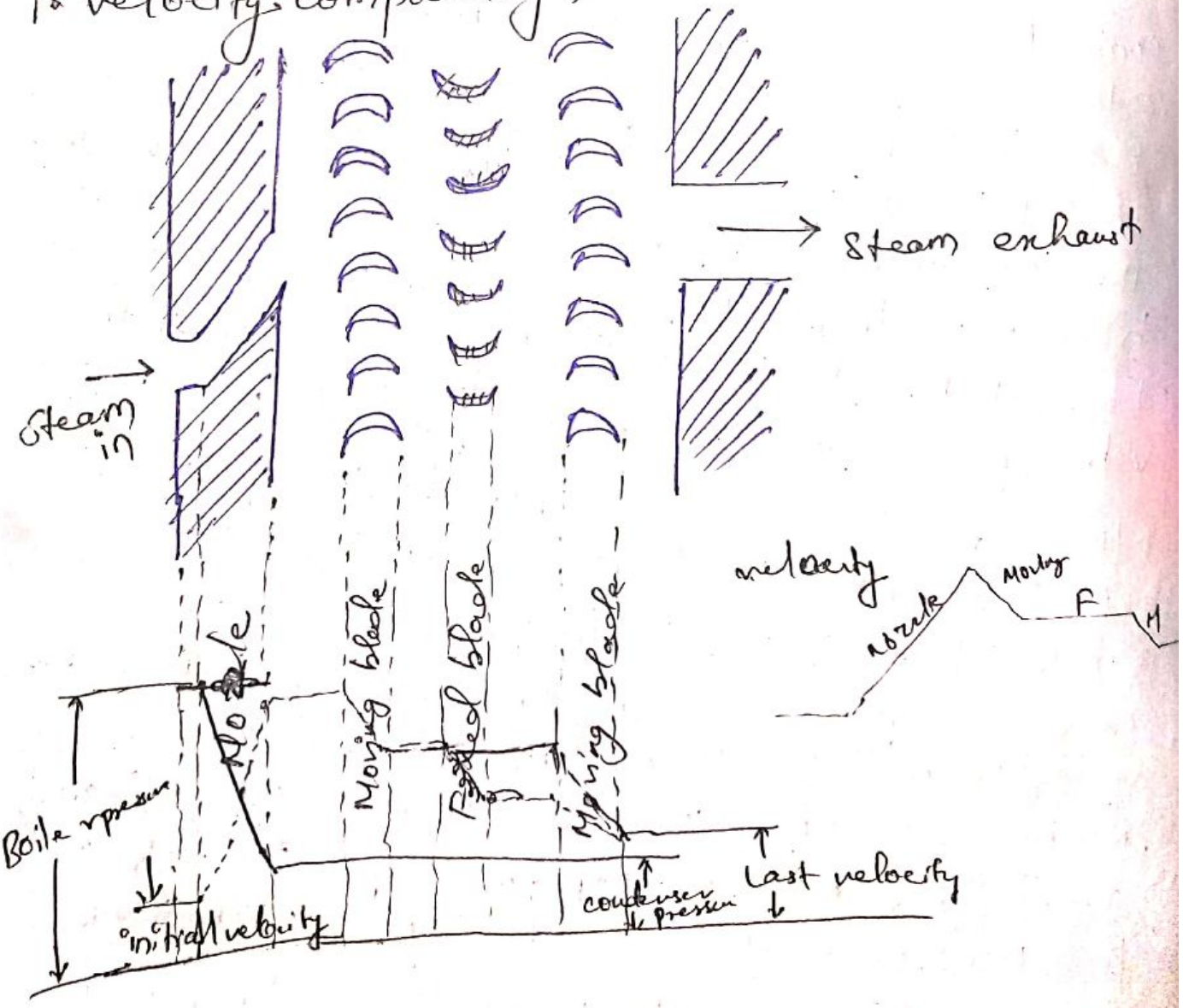
Hence, compounding is needed. The high velocity steam just strike on single ring of rotor that cause wastage of steam ranging 10% to 12%.

To overcome the wastage of steam compound of steam turbine is used.

⇒ The different methods of compoundings are;

1. velocity compounding
2. pressure compounding
3. pressure velocity compounding
4. Reaction turbine.

1. velocity compounding :-

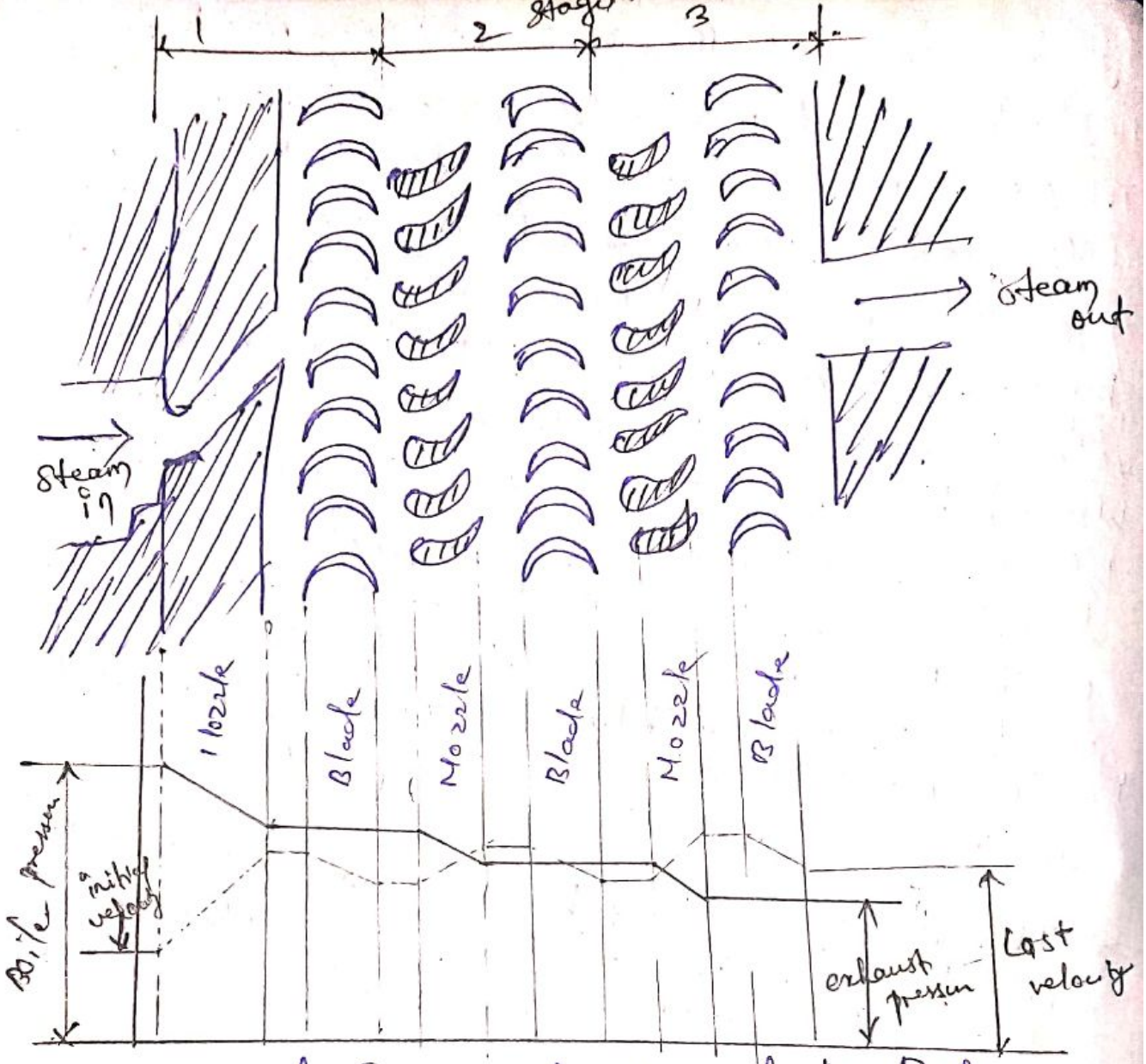


steam is expanded through a stationary nozzle from the boiler or inlet pressure to condenser pressure. So the pressure in the nozzle drops, the kinetic energy of the steam increase due to increase in velocity. A portion of this available energy is absorbed by a row of moving blade. The steam (whose velocity has decrease while moving over the moving blade) then flows through the second row of blades which are fixed. The function of these fixed blades is to redirect the steam flow without altering its velocity to the following next row moving blade where again work is done on them and steam leave the turbine with a low velocity.

→ Though this method has the advantages that the initial cost is low due to lesser number of stages yet its efficiency is low.

2. Pressure compounding:

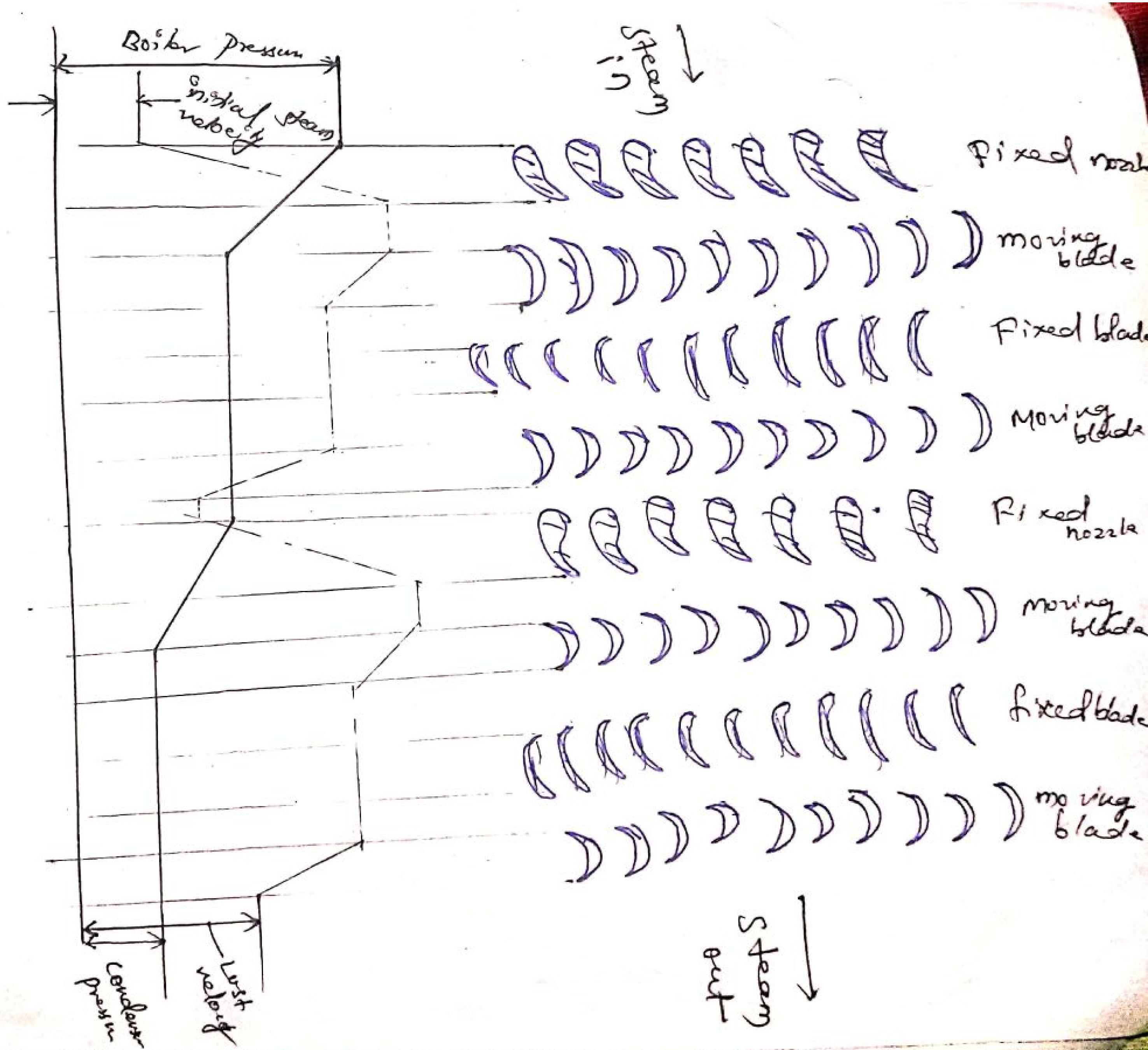
The steam at boiler pressure enters the first set of nozzles and expand partially. The kinetic energy of the steam thus obtain is absorbed by the moving blade (stage 1). The steam then expands partially in the second set of nozzles where its pressure again falls & the velocity increases; the kinetic energy so obtained is absorbed by the second ring of moving blades (stage 2). This is repeated in stage 3 and steam finally leaves the turbine at low velocity & pressure. The number of stages (or pressure reduction) depends on the number of rows of nozzles through which the steam must pass.



This method of compounding is used in Rateau and Zoelly turbine. This is most efficient turbine since the speed ratio remains constant but it is expensive owing to a large number of stages.

Pressure velocity compounding :—

This method of compounding is the combination of two previously discussed method. The total drop in steam pressure is divided into stages and the velocity obtained in each stage is also compounded. The rings of nozzle are fixed at the beginning of each stage and pressure remains constant during each stage.



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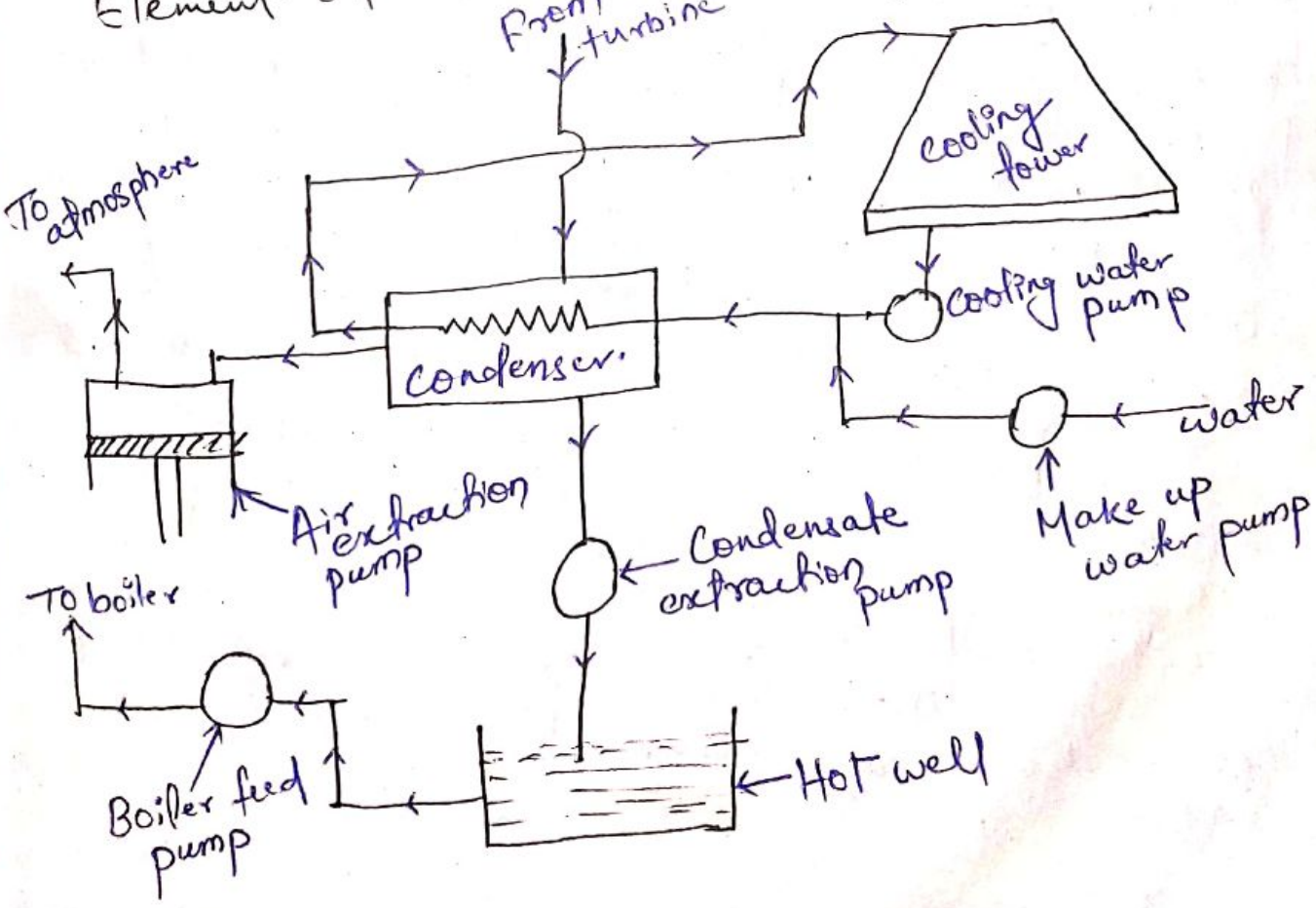
Steam Condensers :-

A steam condenser is a device or an appliances in which steam condenses and heat released by steam is absorbed by water. It serves the following purposes:

1. To maintain low pressure (below atmospheric press) at the outlet of the steam turbine so as to obtain the maximum possible energy.
2. It supplies to the boiler pure & hot feed water as the condensed steam which is discharged from the condenser and collected in a hot well, can be used as feed water for the boiler.

Function of condenser auxiliaries :-

Element of steam condensing plant :-



(i) Condenser :- It is a closed vessel used to condense the steam. The low pressure steam gives off its heat to the coolant (here water from cooling tower) and get converted in to water during the process of condensation.

(ii) Condensate extraction pump :-
It is a pump which is installed in between the condenser and hotwell. It transfers the condensate from the condenser to the hot well.

(iii) Hot well :-
It is a sump that lies in between the condenser and boiler. It receives the condensate from the Condenser by condensate pump. The feed water is transfered from the hot well to the boiler.

(iv) Boiler feed pump :-
It is a pump installed in between the hot well and boiler. It pumps the feed water from the hot well to the boiler. And this is done by increasing the pressure of condensate above boiler pressure.

(v) Air extraction pump :-
It is a pump used to extracts or removes the air from the steam Condenser.

(vi) Cooling tower :- It is a tower which contains the cold water and this water is made to circulate within the condenser for cooling of steam.

(vii) Cooling water pump :-
It is a pump lies in between the cooling tower & condenser. It circulates the cooling water through the Condenser.

WORKING :—

The steam Condenser receives the exhaust steam from one end and come in contact with the cooling water circulated within it from the cooling tower. As the low pressure steam comes in contact with the cooling water, it condenses and converts in to water. It is connected to the air extraction pump and condensate extraction pump. After the condensation of steam, the condensate is pump to the hot well with the help of condensate extraction pump. The air extraction pump extracts the air from the condenser and creates the vacuum inside it. The vacuum created helps in the circulation of cooling water and flow of Condensate downward.

Classification of Condenser :—

(1) Jet Condensors or mixing type condenser.
(2) Surface Condenser or non mixing type Condenser.

(1) Jet Condensor :—

In jet condensers, the exhaust steam & water come in direct contact with each other. and temperature of the condensate is the same as that of cooling water leaving the condenser. The cooling water is usually sprayed into the exhaust steam to cause rapid condensation.

These condenser may be classified as :—
(a) parallel flow type
(b) Counter flow type
(c) Ejector type.

Parallel flow and counter flow condenser are further sub-divided into two type
(i) Low level type (ii) High level type.

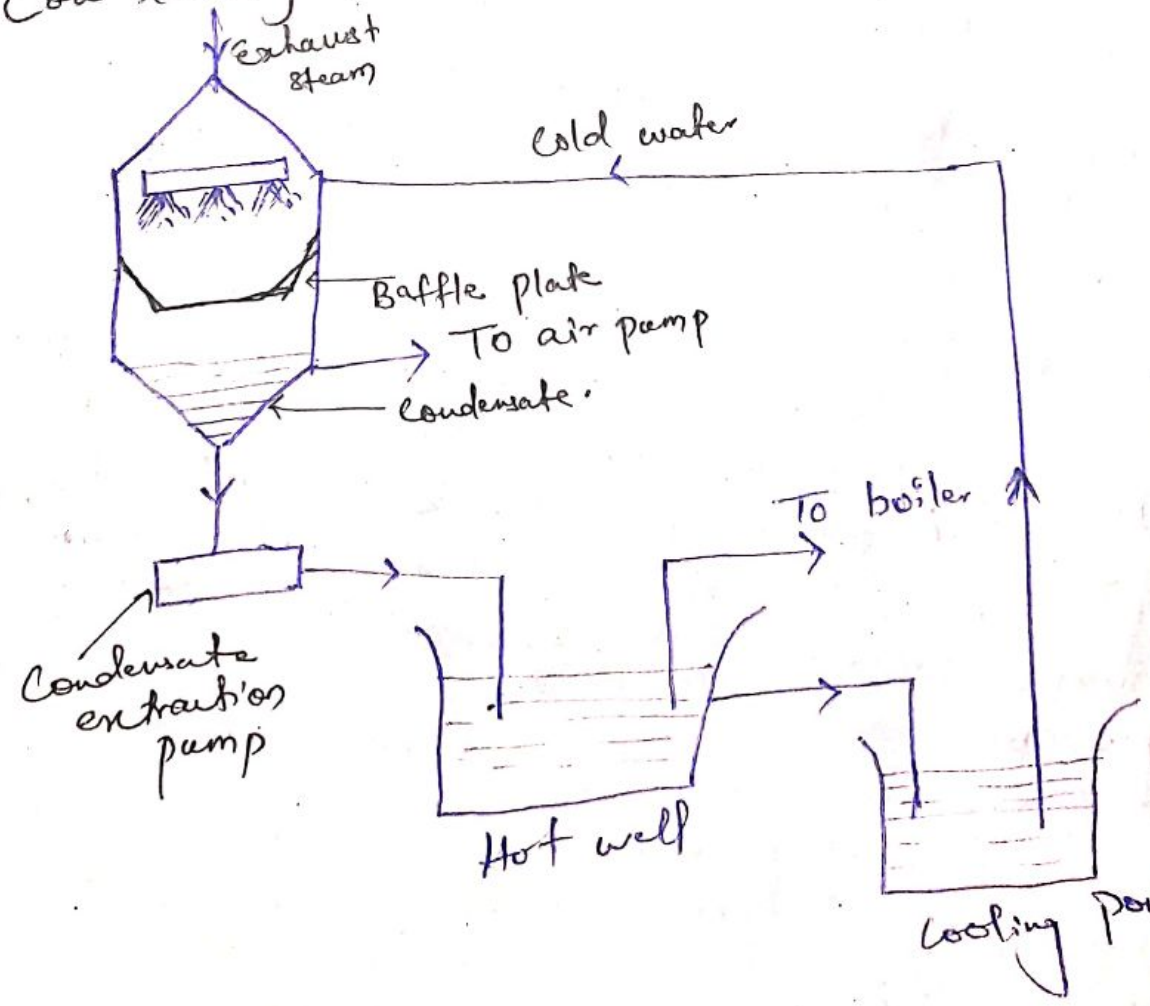
(a) Parallel flow :-

In parallel flow type of condenser, both the exhaust steam & cooling water find their entry at the top of the condenser and they flow downward and condensate and water are finally collected at the bottom.

(b) Counter flow :-

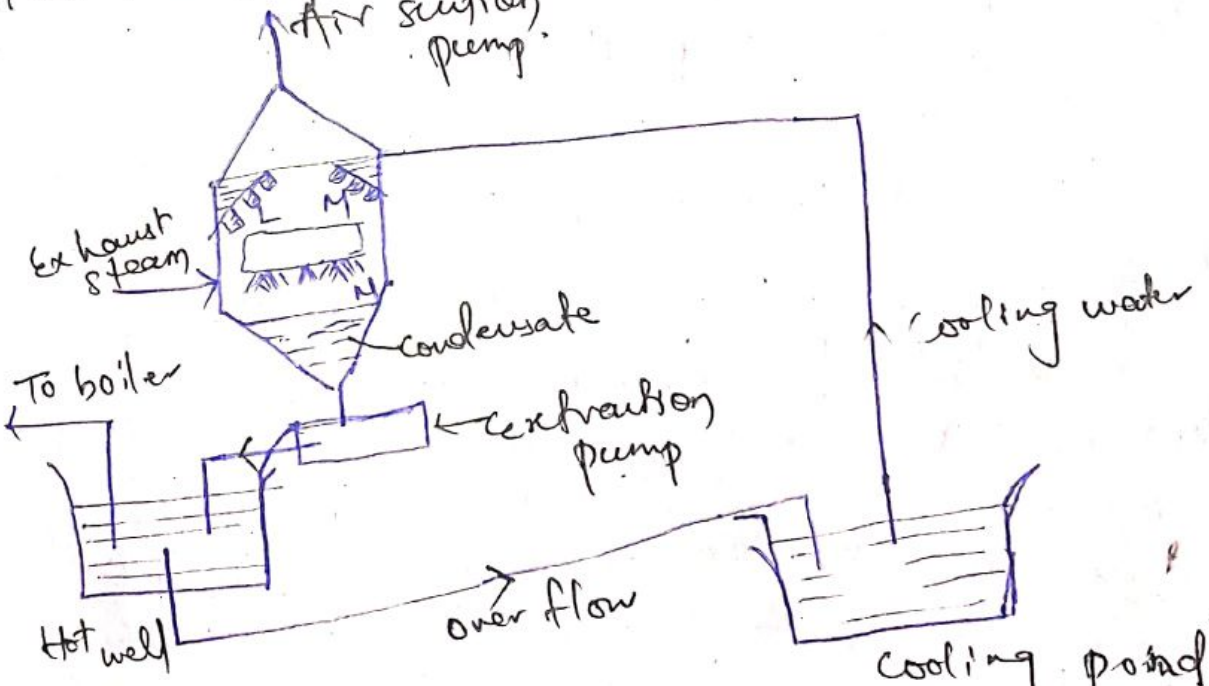
In counter flow type, the steam & cooling water enter the condenser from opposite directions. Generally the exhaust steam travels in upward direction and meet the cooling water which flows downwards.

(c) Low level jet condenser (parallel-flow) :-



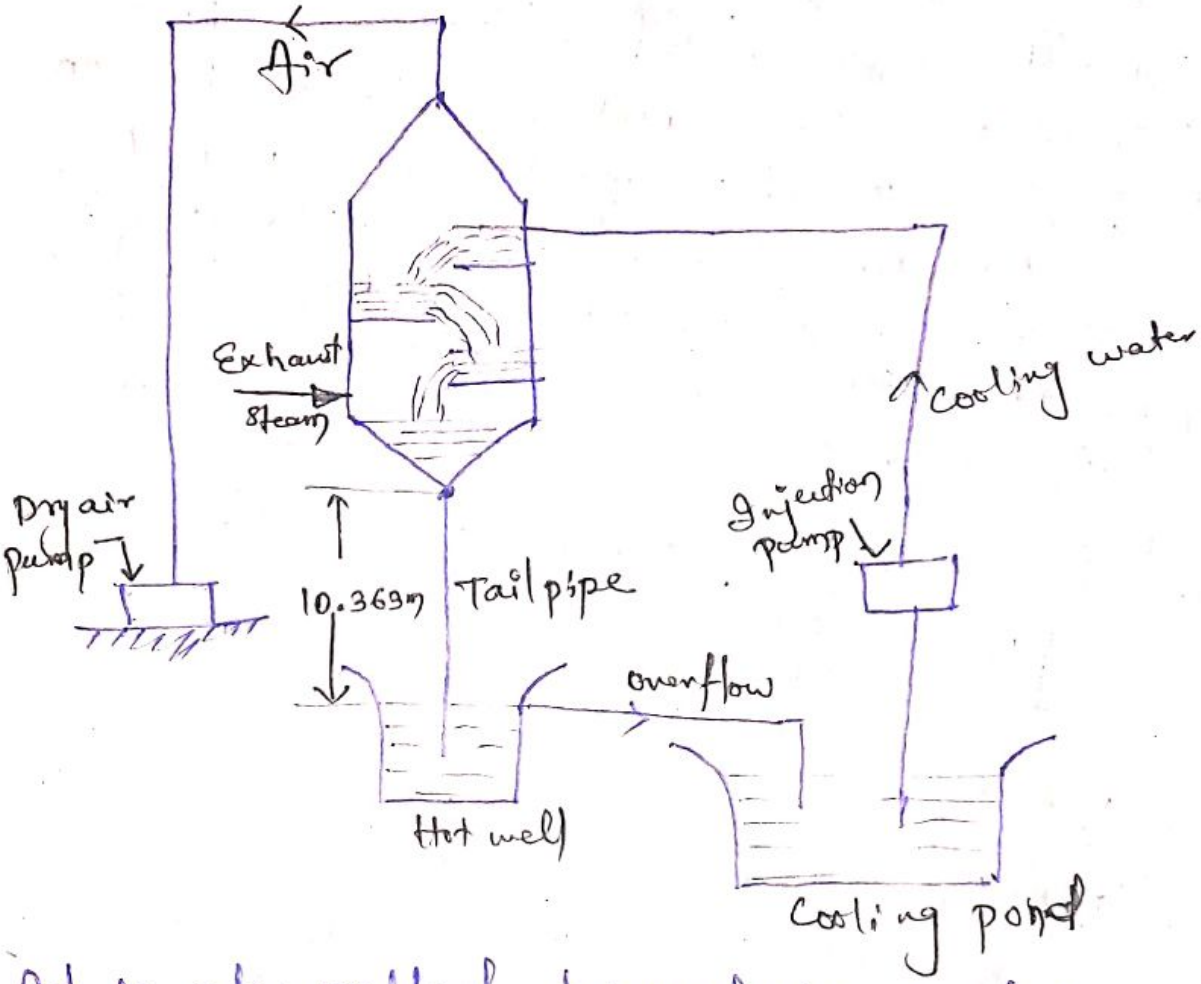
⇒ The exhaust steam is entering the condenser from the top and cold water is being sprayed on its way. The baffle plate provided in it ensures the proper mixing of the steam & cooling water. An extraction pump at the bottom discharges the condensate to the hot well from where it may be feed to the boiler if the cooling water being used is free from impurities. A separate dry pump may be incorporated to maintain proper vacuum.

Low level jet condenser (counter flow) :-



Refer figure L, M & M are the perforated trays which break up water into jets. The steam moving upwards comes in contact with water and gets condensed. The condensate and water mixture is sent to the hot well by means of an extraction pump & the air is removed by an air suction pump provided at the top of the condenser.

(c) High level jet Condenser :— (Counter flow type)



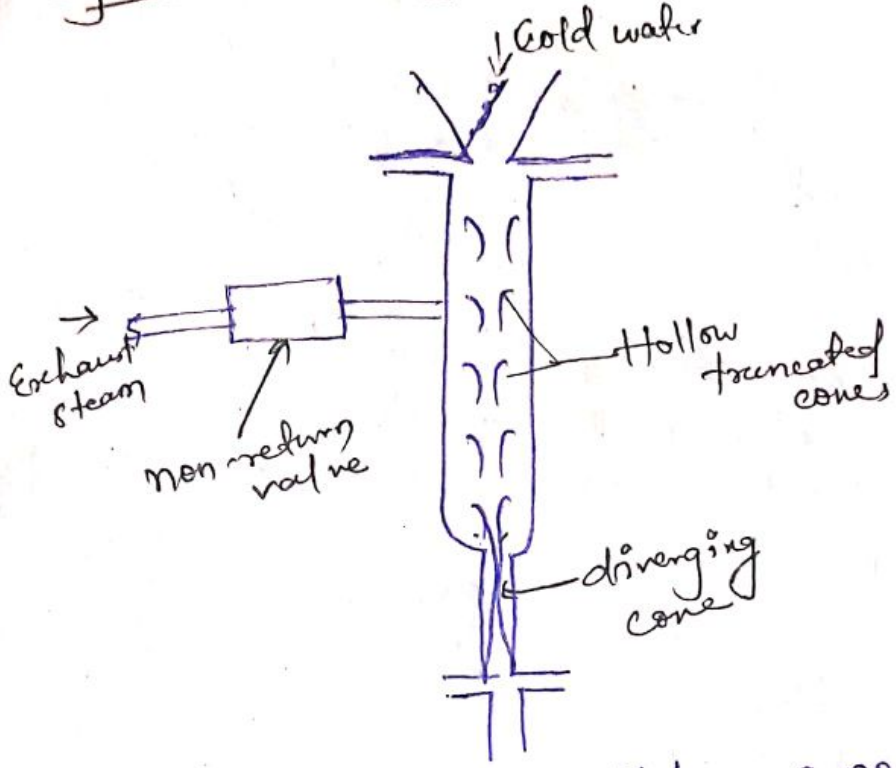
It is also called barometeric condenser.
In this case the shell is placed at a height about 10.369 m above hot well and thus the necessity of providing an extraction pump can be obviated. However provision of own injection pump has to be made if water under pressure is not available.

→ The condensate and cooling water flows in the hot well because of the gravity.

→ An injector pump is used to flow cooling water at the top of the condenser.

→ In this condenser, the steam enters at the bottom and flows in upward direction & meets with the down coming cooling water.

Ejector Condensor :-



In ejector condensers, it has a non return valve through which exhaust steam enters, hollow truncated cones, and diverging cone.

In these condensers, the cooling water is injected at the top. The steam enters in the condenser through a non-return valve. The steam and water mixes with each other while passing through series of hollow truncated metal cones and steam changes in to water. At the end of the metal cones a diverging cone is present when the condensate passes through diverging cone, its kinetic energy is partly transformed in to pressure energy.

The condensate and cooling water is then discharge to the hot well.

(2) Surface Condenser :-

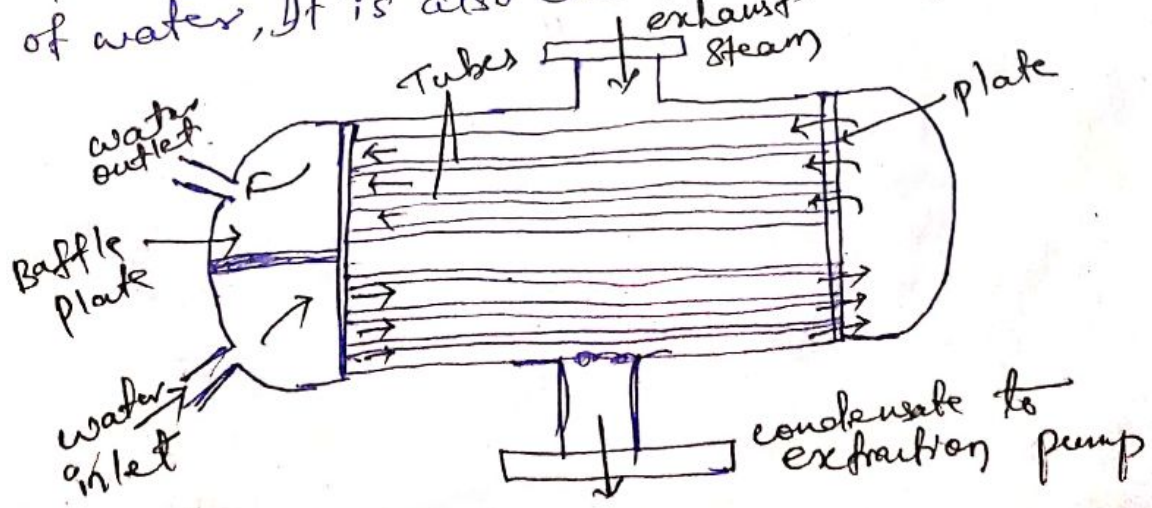
In Surface Condenser, the exhaust steam and water do not come in to direct contact. The steam passes over the outer surface of tubes through which a supply of cooling water is maintained.

-> Most condensers are generally classified on the direction of flow of condensate, the arrangement of the tubing and the position of the condensate extraction pump.

(i) Down flow type
(ii) Central flow type
(iii) Inverted flow type
(iv) Regenerative type
(v) Evaporative type.

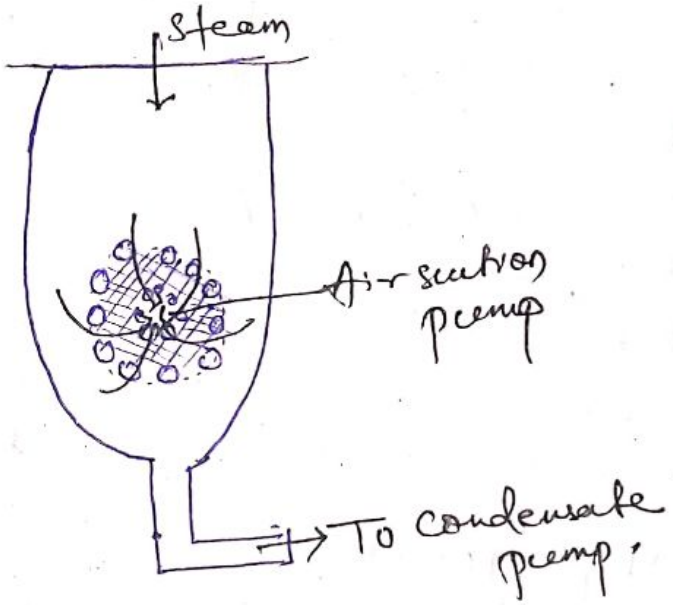
(i) Down flow type :-

It consists of a shell which is generally of cylindrical shape; though other types are also used. It has cover plates at the ends & furnished with number of parallel brass tubes. A baffle plate partitions the water box into two sections. The cooling water enters the shell at the lower half section and after travelling through the upper half section comes out through the outlet. The exhaust steam entering shell from the top flows down over the tubes and gets condensed and is finally removed by an extraction pump. Due to the fact that steam flows in a direction right angle to the direction of flow of water, It is also called cross surface condenser.



(iv) Central flow type :-

In this type of condenser, the suction pipe of the air extraction pump is located in the centre of the tubes which result in radial flow of the steam. The better contact between the outer surface of the tubes & steam is ensured, due to large passages the pressure drop of steam is reduced.



(v) Inverted flow type :-

This types of condenser has the air suction at the top, the steam after entering at the bottom rises up and then again flows down to the bottom of the condenser, by following a path near the outer surface of the condenser. The condensate extraction pump is at the bottom.

(vi) Regenerative type :-

This type is applied to condensate adopting a regenerative method of heating of the condensate. After leaving the tube nest, the condensate is passed through the feeding exhaust steam from the steam engine or turbine thus raising the temperature of the condensate, for use as feed water for the boiler.

(v) Evaporative type :-

The underlying principle of this condenser is that when a limited quantity of water is available, its quantity needed to condense the steam can be reduced by causing the circulating water to evaporate under a small partial pressure.

→ The exhaust steam enters at the top through gilled pipes. The water pump sprays water on the pipes and descending water condenses the steam. The water which is not evaporated falls into the open tank (cooling pond) under the condenser from which it can be drawn by circulating water pump and used over again. The evaporative condenser is placed in open air and find its application is small size plants.

COOLING TOWER :-

In power plants the hot water from condenser is cooled in cooling tower, so that it can be reused in condenser for condensation of steam.

→ A cooling tower is a specialized heat exchanger in which air and water are brought into direct contact with each other in order to reduce the water's temperature. As this occurs, a small volume of water is evaporated, reducing the temperature of the water being circulated through the tower.

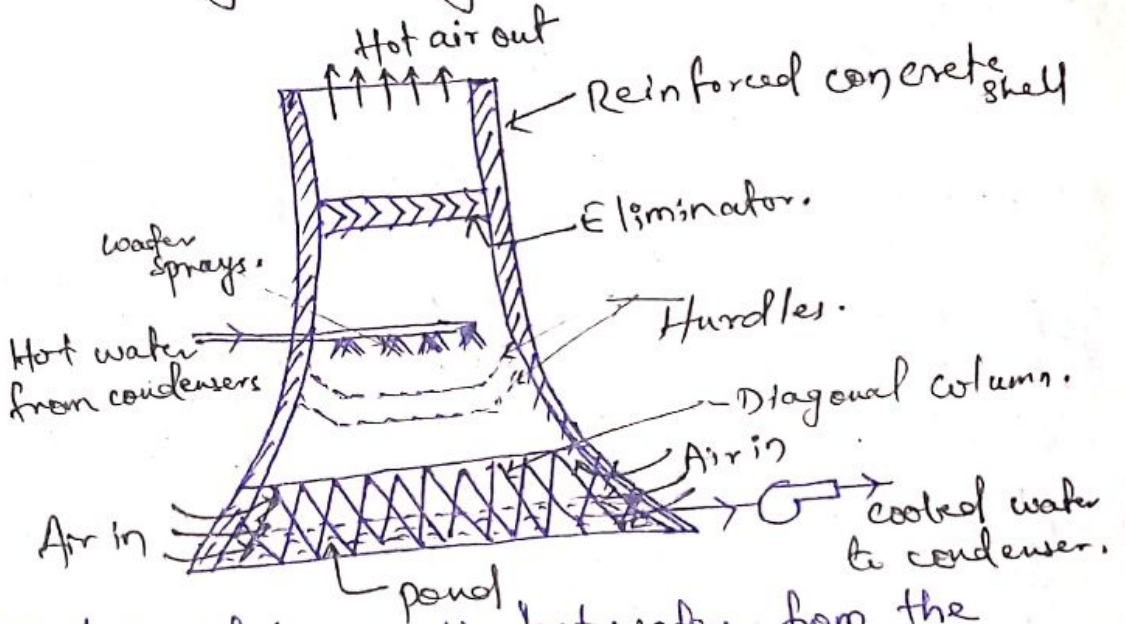
→ Factor affecting cooling of water in a cooling tower are

1. Temperature of air.
2. Temperature of hot air.
3. Humidity of air.
4. Size & height of tower.
5. velocity of air entering tower.
6. Accessibility of air to all parts of tower.
7. Arrangement of plates in tower
8. Degree of uniformity in descending water.

The cooling towers may also be classified as follows:-

1. Natural draught cooling towers.
2. Mechanical draught cooling towers.
   (i) Forced draught cooling towers.
   (ii) Induced draught cooling tower.

1. Natural draught cooling towers:-



In this type of tower, the hot water from the condenser is pumped to the troughs and nozzle situated near the bottom. Troughs sprays the water falls in the from of droplets in to a pond situated at the bottom of the tower. The air enters the Cooling tower from air openings provided near the bases, rises upward and takes up the heat of falling water. A concrete hyperbolic cooling tower shown in fig.

Advantages of Natural ~~co~~ natural over mechanical:-

(i) Low operating and maintenance cost.
(ii) It gives more or less trouble free operation.
(iii) Considerable less ground area required.
(iv) Large capacity.

Disadvantages:-

(i) High initial cost.
(ii) Its performance varies with the seasonal changes in DBT and Relative humidity of air.

(2) Mechanical draught cooling towers :-

In these towers the draught of air for cooling the tower is produced mechanically by means of propeller fans. These towers are usually built in cells or units, the capacity depending upon the number of cells used.

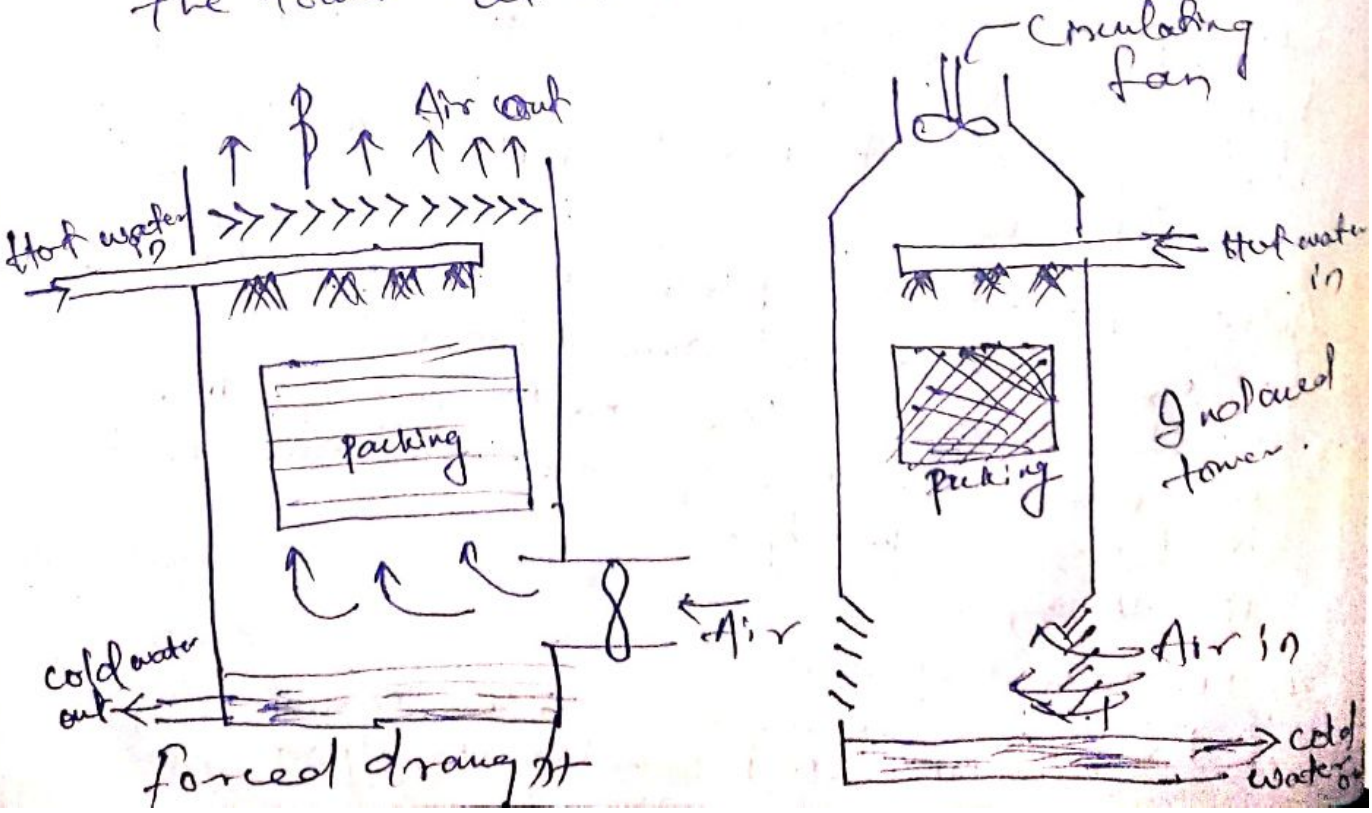
→ In this type of cooling tower, fan is used to circulate the air.

(a) Forced draught cooling tower :-

It is similar to natural draught tower as far as interior construction is concerned, but the sides of the tower are closed and form an air & water tight structure, except for fan opening at the base for the inlet of fresh air; & the outlet at the top for the exit of air & vapour.

(b) Induce cooling tower :-

In these towers, the fans are placed at the top of the tower and they draw the air in through louvers extending all around the tower at its base.



Forced draught cooling Tower

Advantages

1. More efficient (than induce)
2. No problem of fan blade erosion (as it handle dry air only)
3. More safe.
4. The vibration & noise are minimum.

Disadvantages.

1. The fan size is limited to 4 mt.
2. power requirement high.

Induce draught Tower :-

Advantages :-

1. The coldest water comes in contact with the driest air and warmest water comes in contacts with the most humid air.
2. In this tower, the recirculation is seldom a problem.
3. Lower first cost. (due to the reduce pump capacity and smaller length of water pipes)
4. Less Space required.
5. This tower is capable of cooling through a wide range.

Disadvantages :-

1. The air velocities through the packing are unevenly distributed and it has very little movement near the walls & centre of the tower.
2. High H.P motor is required to drive the fan.

NUCLEAR POWER PLANT

Introduction :—

Nuclear fission works by splitting the atoms apart to produce smaller atoms, and as a result energy is released. Nuclear fission is used in nuclear power plants to generate electricity through the splitting of the nuclei of uranium atoms.

On the other hand, when atoms are joined together to form a larger atom is commonly referred to as nuclear fusion. The sun produces energy through nuclear fusion where the nuclei of hydrogen atoms are fused into helium atoms.

Uranium – The nuclear fuel

Uranium is the most common fuel used today by nuclear power plants. Uranium is a common metal discovered in rocks all over the world and it is considered as non-renewable. A certain type of uranium known as U-235 is used in nuclear power plants because its atoms are easily split apart.

Using Nuclear energy to generate electricity power plants burn fuel to produce heat to generate electricity, however, nuclear power plants use the heat given off during fission as fuel to turn water in to steam. Steam is then used to turn huge turbine blades that drive generator to make electricity.

Nuclear chain Reaction :-

A chain reaction refers to a process in which Neutrons released in fission produce an additional fission in at least one further nucleus. This nucleus in turn produces neutrons, and the process repeats. The process may be controlled (nuclear power) or uncontrolled (Nuclear weapon)

Nuclear fission :-

Nuclear fission, subdivision of a heavy atomic nucleus, such as that of uranium & plutonium, into two fragments of roughly equal mass. The process is accompanied by the release of a large amount of energy.

Classify Nuclear fuel :-

① Fissile material :-

In nuclear engineering, fissile material is material that is capable of undergoing fission reaction after absorbing thermal (slow or low energy) neutron. These materials are used to fuel thermal nuclear reactor, because they are capable of sustaining a nuclear fission chain reaction.

Fissile nuclides in nuclear fuel include:
Uranium-235 which occurs in natural uranium and enriched uranium.

Uranium-233

plutonium-239
plutonium-241

② Fertile material :—
Fertile material is a material that, although not itself fissionable by thermal neutrons, can be converted into a fissile material by neutron absorption & subsequent nuclear conversions.

⇒ There are two basic fertile materials ^{238}U and ^{232}Th.

Nuclear power station :—

The basic principle of a nuclear power station is the same as a conventional thermal power station. The only difference is that, instead of using heat generated due to coal combustion, here in a nuclear power plant, the heat generated due to nuclear fission is used to produce steam from water. This steam is used to drive a steam turbine.

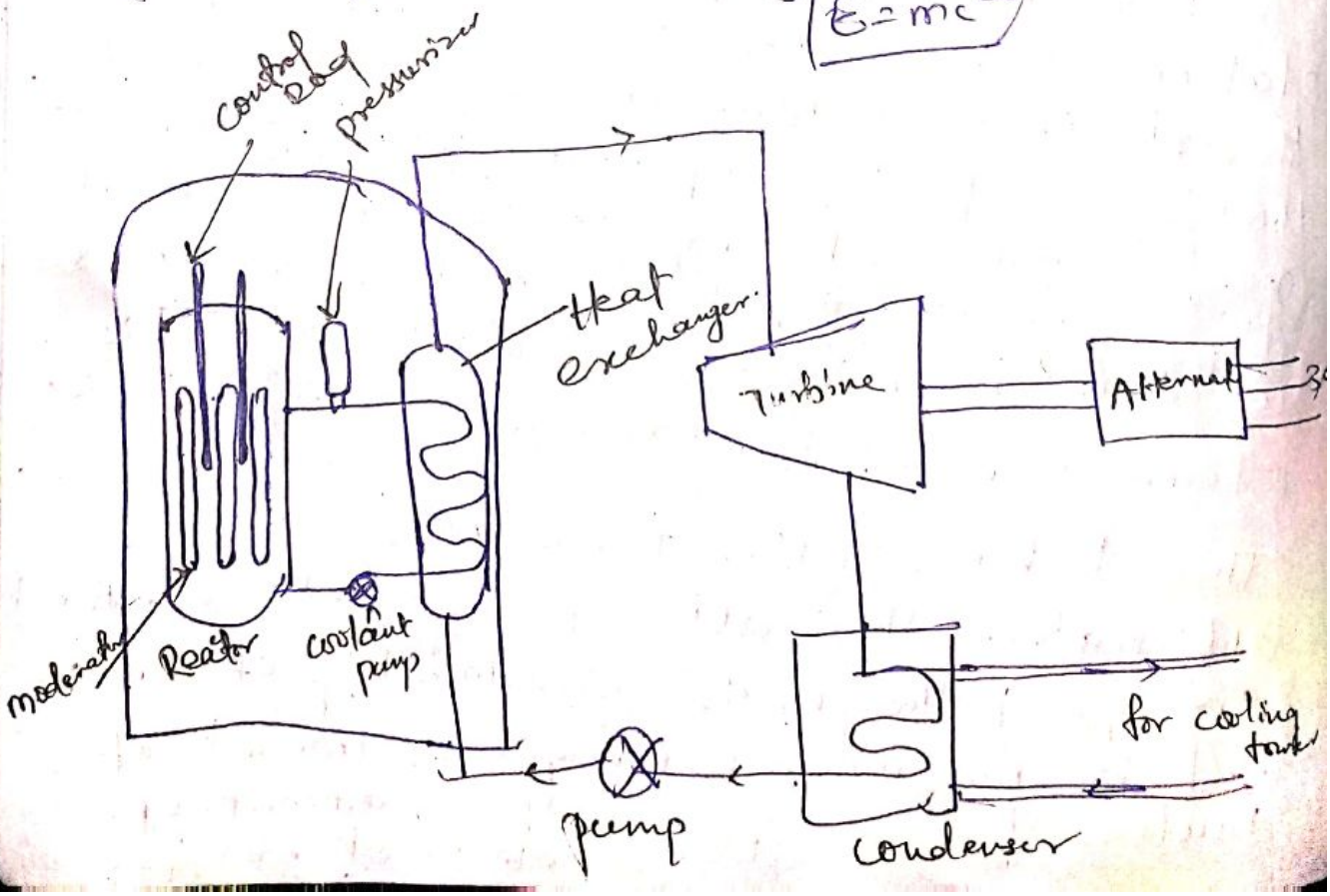
This turbine is the prime mover of the alternator. This alternator generate electrical energy. Although, the availability of nuclear fuel is not much but very less amount of nuclear fuel can generate huge amount of electrical energy.

This is the unique feature of a nuclear power plant. One kg of uranium is equivalent to 4500 metric tons of high grade coal. That means complete fission of 1 kg uranium can produce as much heat as can be produced by complete combustion of 4500 metric tons high grade coal.

Nuclear fission :-

In the fission process, the nuclei of heavy radioactive atoms are broken into two nearly equal parts. During this breaking of nuclei, a huge quantity of energy is released. This release of energy is due to a mass defect. That means the total mass of the initial product would be reduced during fission. This loss of mass during fission is converted into heat energy as per the famous equ established by Albert Einstein

$$E = mc^2$$



Working principle:-

Heavy element such as Uranium (U^{235}) or Thorium (Th^{232}) are subjected to nuclear fission reaction in a nuclear reactor. Due to fission, a large amount of heat energy is produced which is transferred to the reactor coolant. The coolant may be water, gas or a liquid metal. The heated coolant is made to flow through a heat exchanger where water is converted into high temperature steam. The generated steam is then allow to drive a steam turbine. The steam after doing its work, is converted back in to the water & recycled to the heat exchanger. The steam turbine is coupled to an alternator which generates electricity

Basic Component of a nuclear power plant:-

The main components are:

1. Nuclear reactor.
2. Heat exchanger (steam generator)
3. Steam turbine.
4. Condenser.

(1) Nuclear reactor :-

A nuclear reactor is a cylindrical shape stent pressure vessel. The fuel rods are made of nuclear fuel i.e. Uranium moderates, which is generally made of graphite cover the fuel rods. The moderates slow down the neutrons before the collision with uranium nuclei. The control rods are made of cadmium because cadmium is a strong absorber of neutrons.

The control rods are inserted in the fission chamber. These cadmium control rods can be pushed down and pull up as per requirement. when these rods are pushed down enough, most of the fission neutrons are absorbed by these rod, hence the chain reaction stops. Again while the control rods are pulled up, the availability of fission neutrons becomes more which increase the rate of chain reaction.

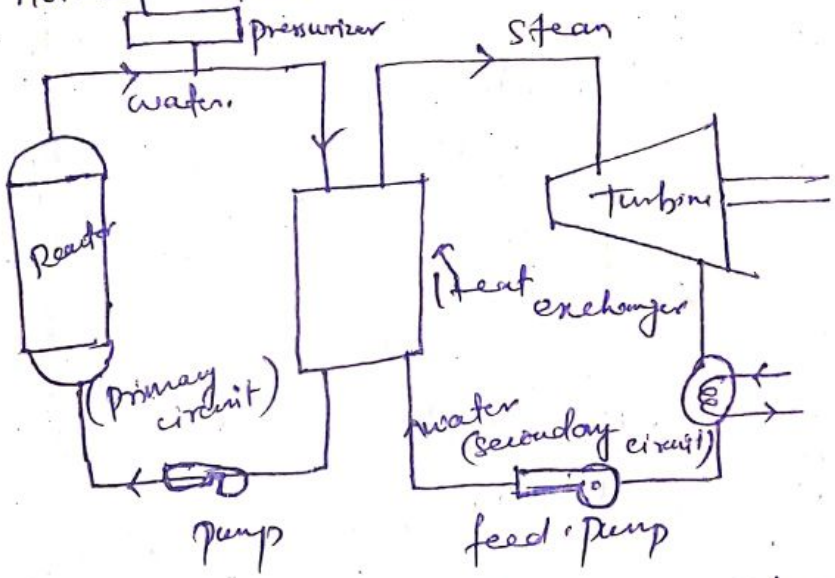
Hence, it is clear that by adjusting the portion of the control rods, the rate of nuclear reaction can be controlled & consequently the generation of electrical power can be controlled.

Pressurised water Reactor (PWR) :-

A pressurised water reactor, in its simplest form, is a light water cooled and moderate thermal reactor having an unusual core design. using both natural and highly enriched fuel. The principal parts of the reactor are :-

1. Pressure vessel.
2. Reactor thermal shield
3. Fuel elements.
4. Control rod.
5. Reactor containment
6. Reactor pressuriser.

The component of the secondary system of pressurised water plant are similar to those in a normal steam station.



In PWR, there are two circuit of water., one primary circuit which passes through the fuel core and is radioactive. This primary circuit then produces steam in a secondary circuit which consist of heat exchanger or the boiler & the turbine. As such steam in the turbine is not radioactive & need not be sheilded.

→ Water acts both as coolant as well as moderator. Either heavy water or the light water may be used for the above purpose.

Advantages :-

1. Water used in reactor (as coolant, moderator and reflector) is cheap and easily available.
2. The reactor is compact and power density is high.
3. Fission products remain contained in the reactor and are not circulated.
4. A small number of control rod is required.
5. There is complete freedom to inspect and maintain the turbine, feed heaters, and condenser during operation.

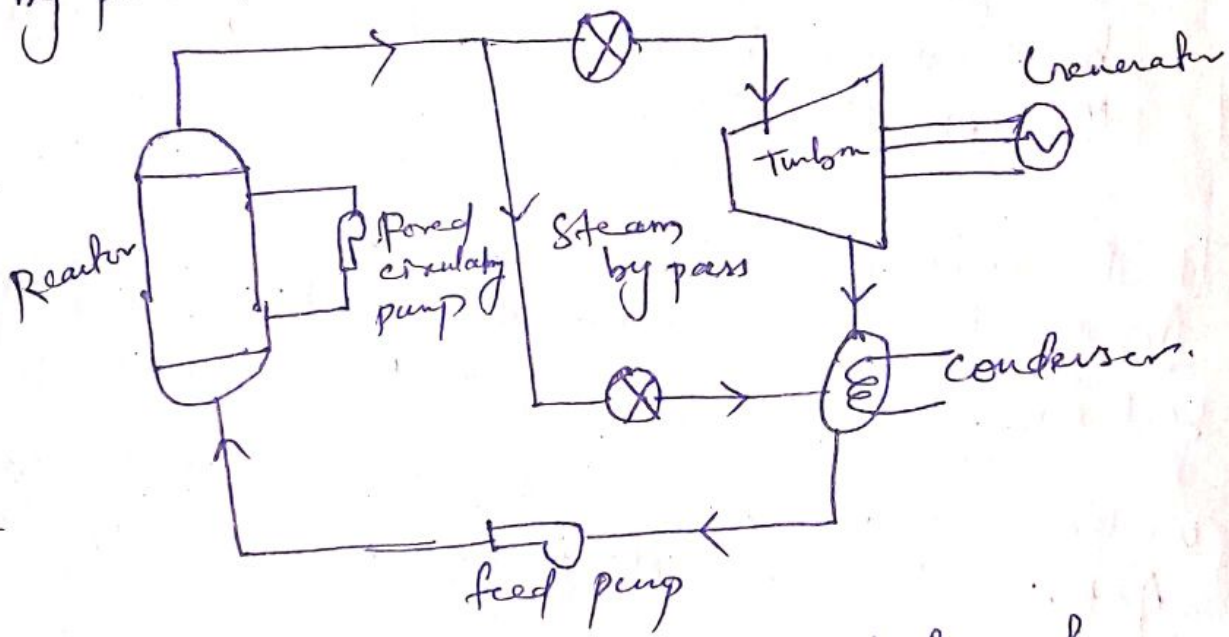
6.

Disadvantages :-

1. Capital cost is high as high primary circuit requires strong pressure vessel.
2. In the secondary circuit the thermodynamics efficiency of this plant is quite low.
3. Severe corrosion problem.
4. Fuel suffers radiation damage & therefore its reprocessing is difficult.
5. low volume ratio of moderator to fuel makes fuel element design and insertion of control rods difficult.
6. fuel element fabrication is expensive.

Boiling water Reactor (BWR):→

In BWR enriched fuel is used. As compared to PWR, the arrangement of BWR plant is simple. The plant can be safely operated using natural convection within the core or forced circulation. For the safe operation of the reactor the pressure in the forced circulation must be maintained constant irrespective of the load. In case of part load operation of the turbine some steam is by passed.



Advantages:→

(1) Heat exchanger circuit is eliminated and consequently there is gain in thermal efficiency and gain in cost.

(2) There is use of a lower pressure vessel for the reactor which further reduces cost & simplifies containment problems.

(3) The metal temperature remains low for given output cond".

(4) The cycle of BWR is more efficient than PWR for given containment pressure.

(5) The pressure inside the pressure vessel is not high

So a thicker vessel is not required.

1) Disadvantages:-

(1) Possibility of radioactive contamination in the turbine mechanism should there be any failure of fuel elements.

(2) More elaborate safety precautions needed which are costly.

(3) Wastage of steam resulting in lowering of thermal efficiency on part load operation.

(4) Boiling limits power density, only 3 to 5% by mass can be converted to steam per pass through the boiler.

2) Heat exchanger:-

In a heat exchanger, the heat carried by sodium metal (coolant) is dissipated in water & water is converted to high pressure steam here. After releasing heat in water the coolant comback to the reactor by means of a coolant circulating pump.

Diesel engine Power Plant

CH-04

Advantages :-

⇒ portable
⇒ Less cost.
⇒ Low fuel cost.
⇒ ~~Less~~ maintanance.
⇒ More efficient
⇒ Less space.
⇒ Sustainable for varying load cond^n (2 to 100 MW)
⇒ Overall efficiency is very high.
⇒ Low transmission cost.
⇒ Stand by loss is very less
⇒ Easy start, run kutt.
⇒ Less operating staff required.
⇒ No ash handling problem.
⇒ ~~Low~~ fuel cost / coolant.
⇒ Civil construction very low.
⇒ Design & installation are very simple.

Disadvantages :-

(i) Noise problem / Air problem.
(ii) Power generation should be limited, because large size of diesel engine power plant cannot be established.
(iii) Life time of diesel engine powerplant is 2-3 year where as steam power plant 25-30 year.
(iv) The power plant cannot be suitable where no fuel supply is there.
(v) Lubrication & maintanance cost is very high.
(vi) High maintanance & lubrication cost.

Application Diesel engine PP :-

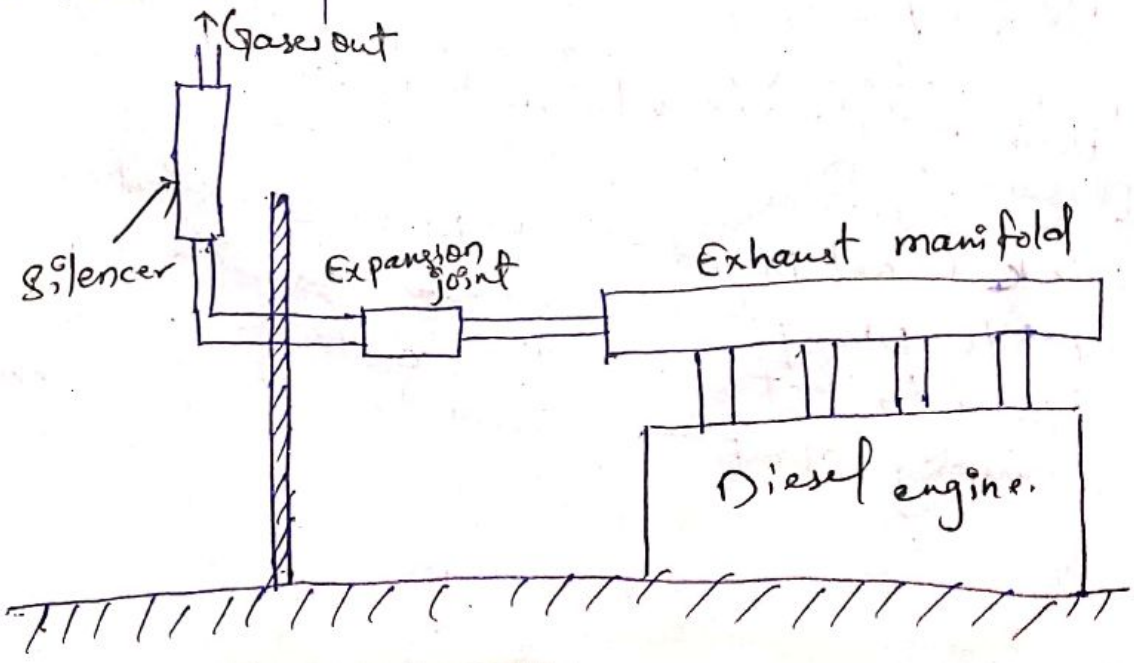
(i) Peak load plant
(ii) Mobile plant
(iii) Stand by unit
(iv) Emergency plant
(v) Nerssery station
(vi) Starting station
(vii) Central station.
(viii) Industrial corners.

Different system of Diesel power plant :-

1. Engine :-
It is the main component of the plant & is directly coupled to the generator.

2. Air intake system :-
It is used to remove the dust particles from the atmospheric air to supply fresh air to the engine for combustion, it may be dry bath filter or oil immersed filter, and it consist of pipes to supply the fresh air and filters to remove dust particle from the air.

3. Exhaust system :-
The exhaust gas is removed from engine, to the atmosphere by means of an exhaust system. The exhaust manifold connects the engine cylinder exhaust outlets to the exhaust pipe which is provided with a silencer to reduce pressure on the exhaust line and eliminate most of the noise which may result if gases are discharged directly to the atmosphere.

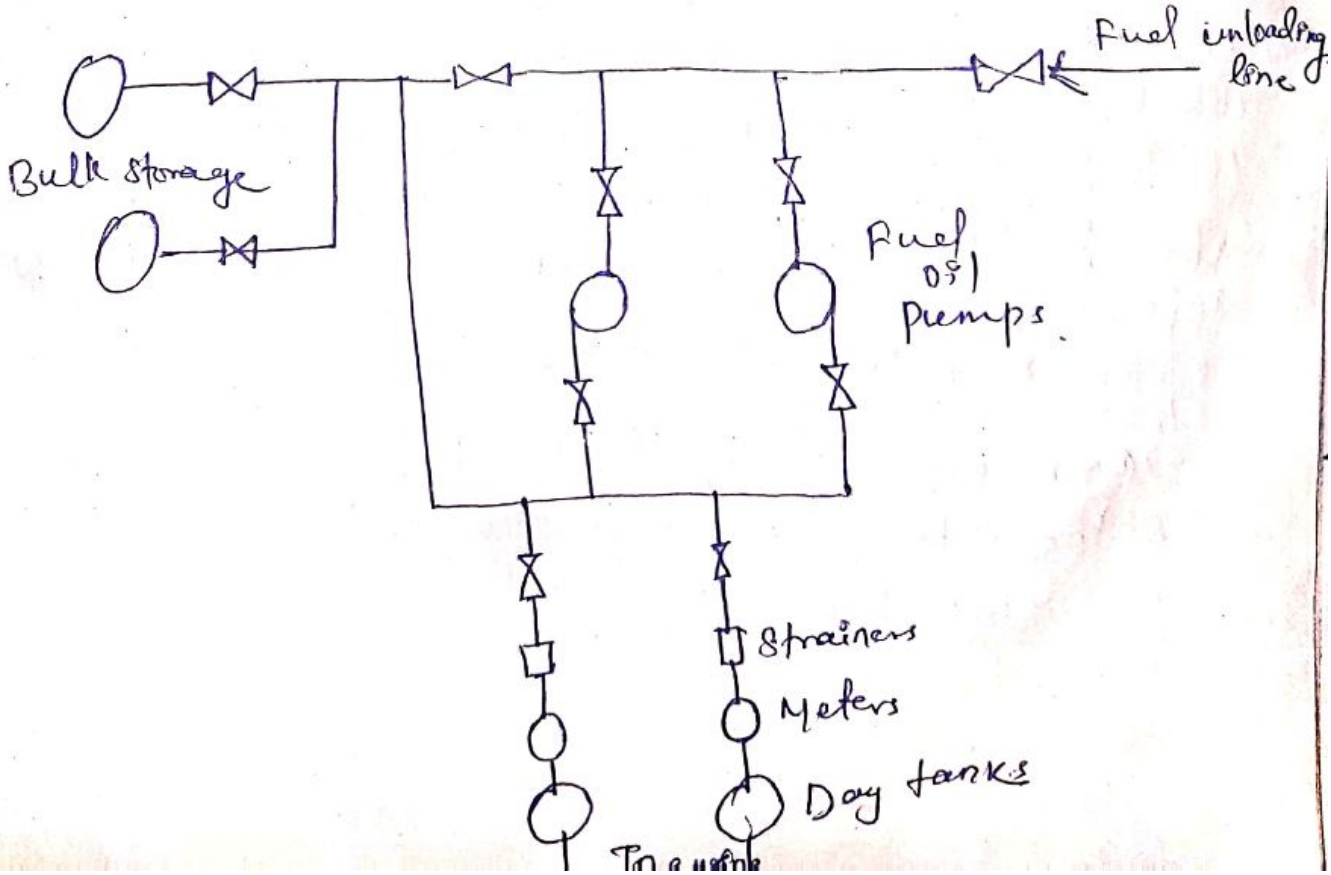


4. Fuel System :-

It consist of a storage tank where store the oil supplied to the plant, all day fuel tank where the oil pump for usage, The main flow is made workable and practical by arranging the piping equipment with the necessary heaters, by pass, shut-offs, drain lines, relief valves, strainers and filters, flow meters and temperature indicators.

→ ~~strainer~~ During transfering from main tank to smaller day tank, the oil passes through strainer to remove solid impurities. From day tank to main tank, there is another pipe connection. This is overflow pipe. This pipe connection is used to return the oil from day tank to main tank in the event of overflowing.

→ From day tank the oil is injected in the diesel engine by means of fuel injection pump.



5. Fuel injection system:-

The fuel injection system is the heart of a diesel engine. A very small quantity of fuel must be measured out, injected, atomised, and mixed with the combustion air. Engine driving electric generators have lower speeds and simple combustion chambers that promote good mixing of fuel and air. The fuel injection perform the following functions.

(a) Filter the fuel
(b) Meter the correct quantity of fuel to be injected
(c) Time the injection process
(d) Regulate the fuel supply.
(e) Ensure fine atomization of fuel oil.
(f) Distribute the atomized fuel properly in the combustion chamber.

Oil is atomized either by air blast or pressure jet. Early diesel engines used air blast fuel atomization where compressed air at about 70 bar was used to atomize as well as to inject the fuel oil. For this an air compressor and a storage tank are needed which becomes expensive. In pressure jet atomization the fuel oil is forced to flow through spray nozzles at a pressure above 100 bar. It is known as solid injection, which are more common. Solid injection system may be classified as follows.

(a) Common rail injection system.
(b) Individual pump injection system.
(c) Distributor system.

(b) Cooling System :-

It is very important in the diesel Power Station to have cooling system to maintain the overall temperature of the engine at an agreeable level. The cooling of the engine is necessary for the following reasons:-

(a) The lubricating oil used determines the max^m engine temp. that can be used. This temp. varies from 160°c to 200°C. Above these temp. the lubricating oil deteriorates very rapidly and may evaporate and burn damaging the piston and cylinder surfaces. piston ~~sie~~ seizure due to overheating may also occur.

(b) Increase in temperature cause thermal stresses due to which uneven expansion of various parts often resulting in cracking.

(c) Due to high cylinder head temp., the volumetric efficiency & hence power o/p of the engine are reduced.

Following are the two methods of cooling the engine.

(i) Air cooling
(ii) Water cooling.

→ Air cooling is used in small engines, where fins are provided to increase heat transfer surface area.

→ Big diesel engine are always water cooled. The cylinder and ~~it~~ its head are enclosed in a water jacket which is connected to a radiator. water flowing in the jacket carries away the heat from the engine and becomes heated. The hot water then flow in to the radiator and get cooled

by rejecting heat to air from the radiator walls. Cooled water is again circulated in the water jacket.

(7) Lubricating System :-

This system minimises the wear of rubbing surface of the engine. Here lubricating oil is stored in main lubricating oil tank. This lubricating oil is drawn from the tank by means of oil pump. Then the oil is passed through the oil filter for removing impurities. From the filtering point, this clean lubricating oil is delivered to the different points of the m/c where lubrication is required, the oil-cooler is provided in the system to keep the temperature of the lubricating oil as low as possible.

(8) Starting System :-

For starting a diesel engine, initial rotation of the engine shaft is required. Until the firing start and the unit runs with its own power.

For small DG set, the initial rotation of the shafters is provided by handles but for large diesel power station. compressed air is used for starting.

The starting method may be :-

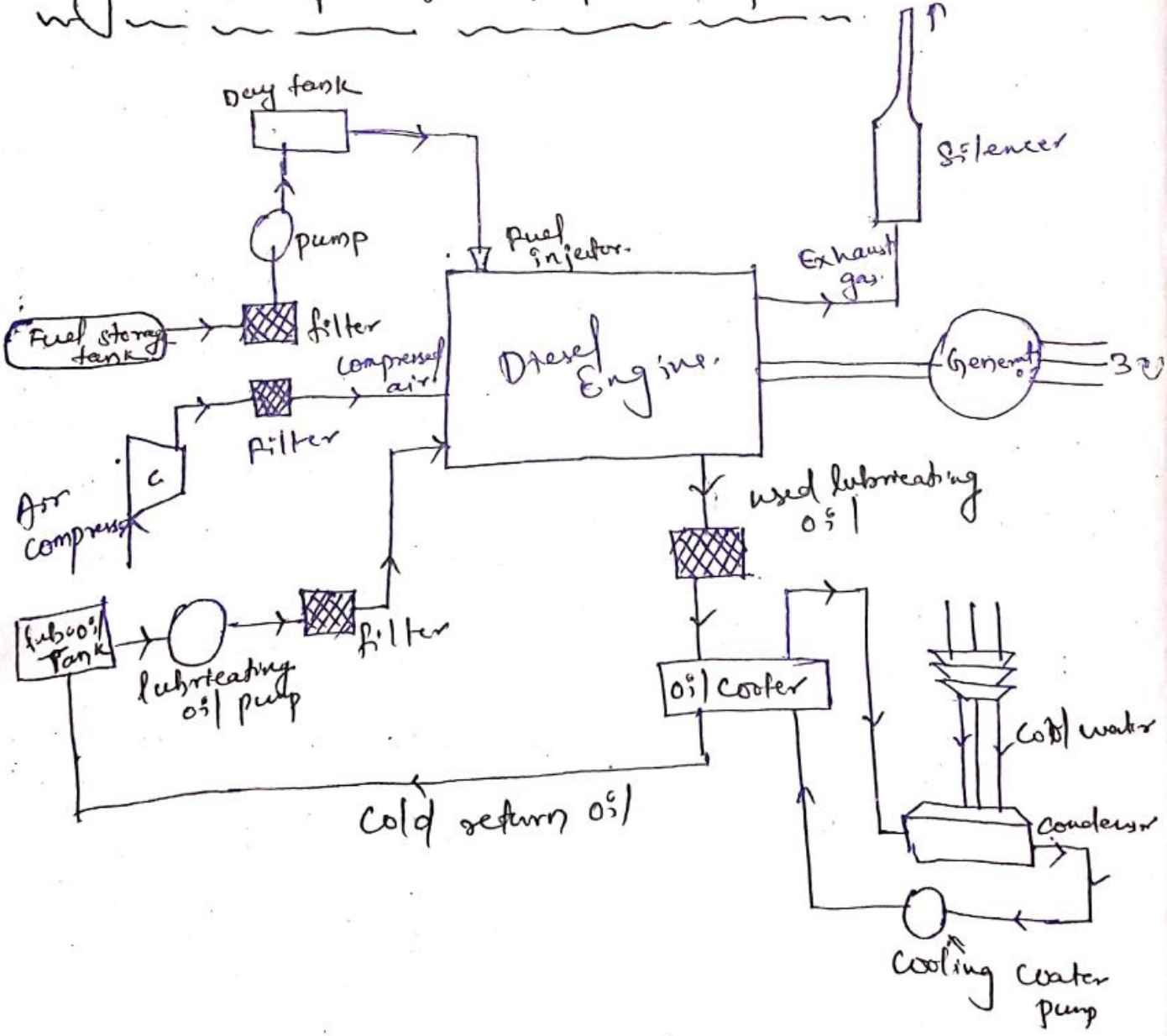
(a) Self starters :- which used in small diesel engine where motors draws heavy current and designed to work for continuously 30 sec after its cooled.

(b) Auxiliary engine :- They are located closed to the main engine and driven through a clutch and gears as the clutch disengaged to start the engine.

(c) Compressed air system :- which used in large engine and its supplied from an air tank.

(d) Governing system :-
It is used to control the speed of the engine by changing the fuel provide according to engine load.

Lay Out of Diesel power plant :—



The layout of Diesel power plant shown in fig.

Air from the atmosphere is drawn into the compressor and it is compressed. The compressed air is sent to the diesel engine through the air filter. In the air filter, dust, dirt, from the air is filtered and only air is sent to the diesel engine.

→ The fuel from the fuel storage tank pass through a filter and pump to a Day tank. and then clean oil from the Day tank inject to the Diesel engine through the fuel injector.

→ The mixture of the compressed air & spray of fuel oil are ignited in the engine & combustion takes place.
After the combustion exhaust gasses deliver to atmosphere by using silenser.

→ The released heat energy is utilised for driving the generator which produces power.

→ The cooling water is continously supplied to cool the engine & lubricating oil is supplied to lubricate the engine parts.

HYDROLLIC POWER PLANT CH-05

Hydroelectric power plant :-

In hydro-electric plant energy of water utilize to move the turbine which in turn run the electric generator. The energy of water utilize for power generation may be kinetic or potential energy. The kinetic energy of water is its energy in motion & the function of mass & velocity, while the potential energy is the function of the different in head, both the point.

→ However it has been observed that only a small part of the rainfall can actually be utilised for power generation. A significant part is accounted for by direct evaporation, while another similar quantity seeps into the soil and forms the underground stage. Some water is also absorbed by the vegetation. Thus only a small part of rainfall is being utilized for power generation.

Major obstrucle :-

→ Large investment
→ Long gestation period
→ Increase cost of transmission.

Application of Hydro power plant :-

→ Power Generation
→ Irrigation project
→ Ground water level recharge
→ Obstrucle of wastage rain water.

Advantages :-

→ No fuel requirement
→ It is highly reliable.
→ Maintenance & operation cost are very low.
→ The plant has no stand by loss.
→ The plant efficiency doesn't changes with age.
→ It takes a few minutes to run & synchronize of plant.
→ Less supervising required.
→ No fuel transportation required.
→ No ash & air pollution problem.
→ This plant is also used for irrigation & flood control.
→ Such a plant is comparitively long life. (200-250 years).
→ The no. of operation required is comparatively low as compare to steam power plant.
→ Since hydro power plant runs at 300 to 400 rpm Then is no mechanical problem.

Disadvantages :-

→ High initial cost.
→ It required long time for the erection Manufacture of the plant.
→ Since the plant are situated at hill area transportation & transmission problem are there.

→ It only depends on the quantity of rain water.

Site section:-

1. Availability of water.
2. water storage.
3. water head.
4. Accessibility to site.
5. distance from load centre.
6. Types of land of site.

Essential features of the hydroelectric power plant

* Catchment Area.
* Reservoir
* Dam
* Sp'l way
* Condict
* storage tank
* prime mover
* Draft tube
* Power house & equipment.