Power Plant Engg. Note

INTRODUCTION

Energy:- The capacity of doing work is known as energy.

Sources of energy :-

The various sources of energy are

1. Fuels { Solids - Coal, coke, anthracite etc.
   Liquids - Petroleum and its derivatives
   Gases - Natural gas, blast furnace gas etc.
2. Energy stored in water.
3. Nuclear energy.
4. Wind power
5. Solar energy
6. Tidal power.
7. Geothermal Energy
8. Thermoelectric Power.

① Fuel

Fuels may be chemical or nuclear.

- A chemical fuel is a substance which releases heat energy on combustion.
- The fuel occur in nature called primary fuel and are prepared called secondary fuel.

Solid fuel

Coal - The main constituents are carbon, hydrogen, oxygen, nitrogen, sulphur, moisture and ash.

Peat - It is used as a domestic fuel

It is the first stage in the formation of coal from wood. It contains huge amount of moisture and therefore it is dried for about 1 to 2 months before it is put to use.

Lignite and brown coal

This is the intermediate stage between the peat and coal. Lignites are usually amorphous in character and impose transport difficulties. They burn with a smoky flame.

② **Bituminus coal :-**

It burns with long yellow and smoky flames.

Anthracite coal :-

It is very hard coal and has a shining black lusture. It is very suitable for steam generation.

Coke :- It consists of carbon, mineral matter with about 2% sulphur and small quantities of hydrogen, nitrogen, and phosphorus.

- It is smokeless and clear fuel.
- It is mainly used in blast furnace to produce heat and at the same time to reduce the iron ore.

Liquid Fuel

Petrolium is the main source of liquid fuel.

Imp. properties of liquid fuel :-

i) Specific gravity
ii) Flash point
iii) Fire point.
iv) Viscosity.
v) Carbon residue
vi) Heating value.
vii) Sulphur content. etc.

Advantage :-

- Require less space for storage.
- Higher calorific value.
- Easy control of consumption.
- Staff economy.

Gaseous Fuel

The gaseous fuels are natural gas, coal gas, coke-oven gas, blast furnace gas, producer gas, water or illuminating gas, sewer gas.

Advantage :-

- Better control of combustion.
- Economy in fuel and more efficiency of furnace operation.
- Cleanliness.
- Easy maintenance of oxidizing or reducing atmosphere.

(2) Energy Stored in Water :-

In the flowing stream of water the energy contained is known a form of mechanical energy. It may be exist as the kinetic energy of a moving stream or as potential energy of water at some elevation w.r.t. a lower datum level.

(3) Nuclear Energy

The large amount of energy that can be released from a small mass of active material.

- The nuclear power is not only available in abudance but it is cheaper than the power generated by conventional sources.

Factors of nuclear energy are

- Practically independent of geographycal factors.
- No combustion products.
- Clean source of power which doesn't contribute to air pollution.
- Fuel transportation networks and large storage facilities not required.

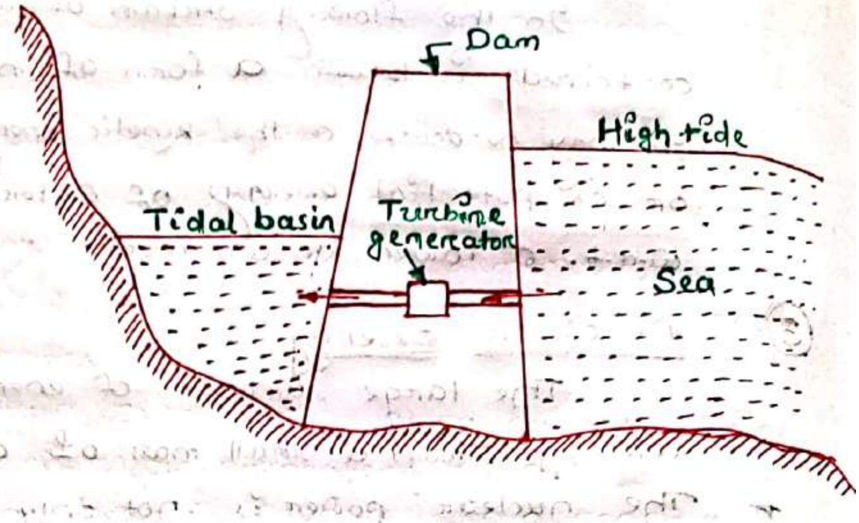
(4) Wind Power

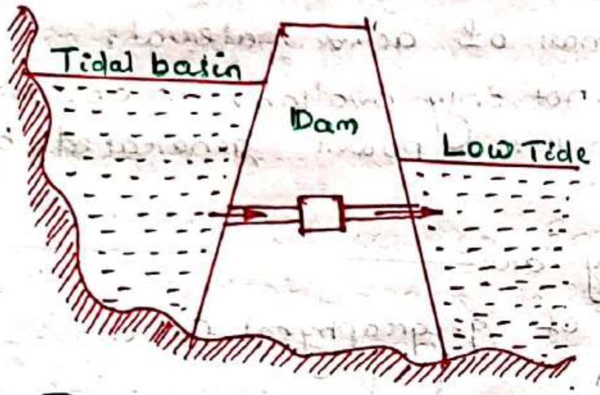
- The wind velocity along coastline has a range 10-16 kmph and a servey of wind power has revealed that wind power is capable of exploitation for pumping water from deep wells or for generating small amounts of electric energy.
- Modern wind mills are capable of working on velocities as low as 3-7 kmph while maximum efficiency is attained at 10-12 kmph.
- The great advantage of this source of energy is that no operator is needed and no maintenance and repairs are necessary for long intervals.
- It is a renewable source of energy and it is nonpolluting.

(5) Solar Energy

- For developing solar energy there are two ways.
- The glass lens and the reflector are the devices which concentrate the solar rays to a focal point which is characterised by a high degree of heat which can be utilised to boil water & generate steam.

④ ⑥ **Tidal Power**





- The use of tides are for electric power generation.
- At the time of high tide the gates are opened and after storing the water in the tidal basin the gates are closed. After the tide has received there is a working hydraulic head between the basin water and open sea/ocean.
- Then the water is allowed to flow back to the sea through water turbines installed in the dam.
- However by using reversible water turbine, the turbine can be run contineously.

⑦ **Geothermal energy**

There are two ways of electric power production from geothermal energy.

- Heat energy is transferred to a working fluid which operates the power cycle. This is useful at the places of fresh volcanic activity where the molten interiore mass of earth vents to the surface through fissures and substantially high temps such as bet^n 450 to 550°c can be found.
- The hot geothermal water or steam is used to operate the turbines directly. From the well-head the steam is transmitted by pipelines upto 1m in dia. over distance up to about 3km to the power station. Water separatores are usualy employed to separate moisture and solid particles from steam.

(8) Thermoelectric Power

When the two ends of a loop of two dissimilar metals are held at different temp, an electromotive force is developed and the current flows in the loop. This method by selecting of suitable materials, can also be used for power generation.

- This method involves low initial cost and negligible operating cost.

Central Powerstation	Captive Powerstation
→ The electrical energy available from these stations is meant for general sale to the customers who wish to purchase it.	→ This type of power station is run by a manufacting company for its own use. Its output is not available for general sale.
→ These stations are condensing type where exhaust steam is discharged into a condenser instead of into the atms.	→ These plants are non-condensing because a large quantity of steam (low press) is required for diff. manufacturing oper?.
→ The steam which has been condensed into water in the condenser, can be recirculated to the boilers with the help of pumps.	→ Here a contineous supply of fresh feed water is required which becomes a problem where there is shortage of pure water.

Classification of Powerplants

The principal types of powerplants are

1. Steam plants using coal, oil or nuclear fission.
2. Internal combustion engine plants
3. Gas turbine plants.
4. Hydro-electric plants.

⑥ ① **Steam plants using Coal, Oil or Nuclear Fission**

- In the boilers/steam generators steam is produced and then utilised to drive the turbines/engines which are coupled to generators to get electricity.
- The steam plants in which coal or oil is used comprise the steam generating equipment and the primemovers.
- Solid fuel, pulverised fuel are used in burners or furnace and oil in oil burners.
- The plant may contain several heat saving devices such as water heater, economisers, air-preheaters etc.
- In nuclear stations heat is produced in a reactor which replaces the conventional boiler.

② **Internal Combustion Engine plants**

- In this plant, spark ignition (S.I.) or compression ignition (C.I) engines are used as primemovers to drive electric generators.
- Diesel fuel is used in C.I. engines which is commonly used to drive small portable electric generators whereas S.I. engines are restricted.

③ **Gas turbineplant**

- This plant working on a modified gas cycle, contain besides the gas turbine, the starting devices, auxiliary lubrication, fuel control system, oil cooler, combustor, reheater, regenerator etc.

④ **Hydro-electric plant**

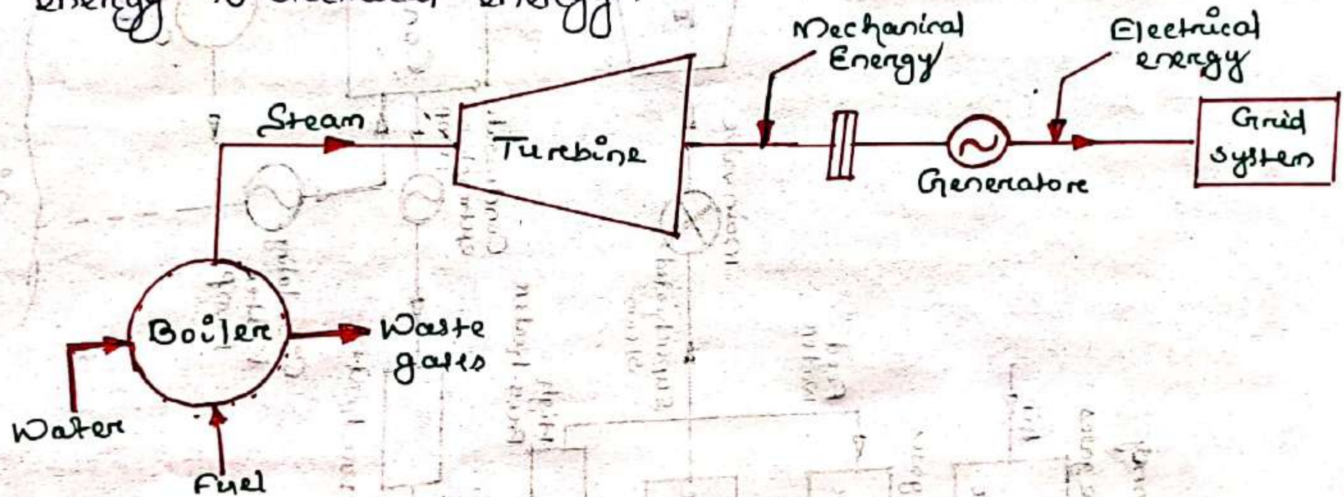
- This plant comprises the turbines, governing gear, coolant circulators etc.
- This type of plant makes use of energy of water stored at an elevation and allowed to drop to a lower level.
- The electric generator is driven by a water turbine through which the water from the pond is made to work.
- The operation of such a plant is usually much simpler than that of a steam, diesel or gas powered plant.

STEAM POWER PLANT

Introduction :-

A steam powerplant converts the chemical energy of the fossil fuels (coal, oil, gas) into mechanical or electrical energy.

- This energy achieved by raising the steam in the boilers, expanding it through the turbines and coupling the turbines to the generators which convert mechanical energy to electrical energy.

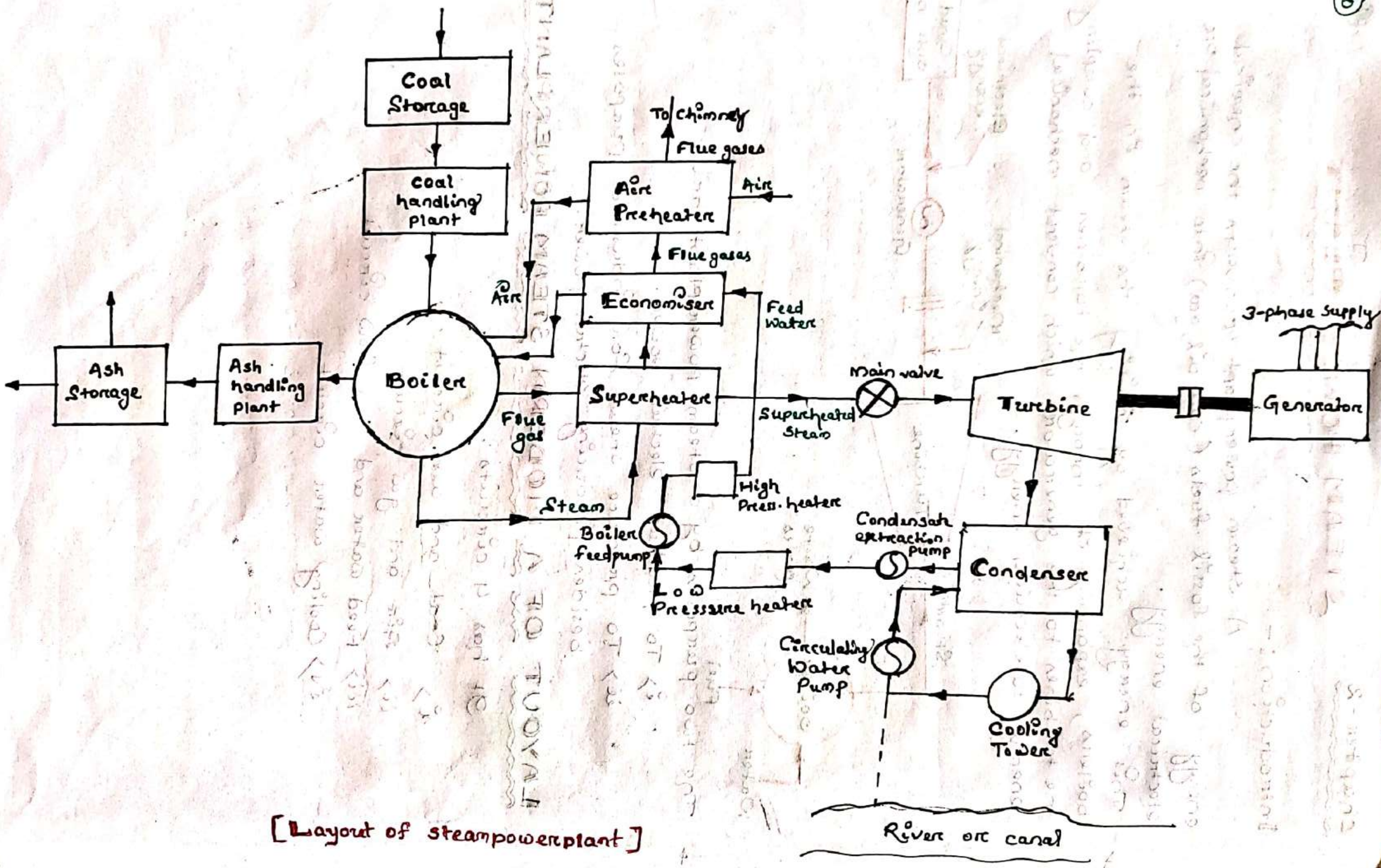


- The two purposes by a steam power plant are
  - i) To produce electric power.
  - ii) To produce steam for industrial purposes besides producing electric power.

LAYOUT OF A MODERN STEAM POWERPLANT

It has 4 circuits.

i) Coal and ash circuit.
ii) Air and gas circuit.
iii) Feed water and steamflow circuit.
iv) Cooling water circuit.



[Layout of steampowerplant]

i) Coal and ash circuit

- The coal arrives from the coal storage and after necessary handling, passes on to the furnace through the fuel feeding device.
- After combustion of coal the ash collects at the back of the boiler and is removed to the ash storage through ash handling equipment.

ii) Air and gas circuit

- Air is sucked from the atmosphere through the 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 gases which pass to the chimney through the preheater.
- The flue gases after passing ~~through~~ around the boiler tubes and superheater tubes in the furnace pass through a dust catching device.
- Then it passes through the economiser finally through the air preheater before being exhausted to the atmosphere.

iii) Feed water and steamflow circuit

- In this circuit the 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.
- Then it passes through the deaerator and some water heater before going into the boiler through economiser.
- In the boiler, water circulates. Wet steam from the drum is further heated up in the superheater before being supplied to the primemover.
- If there is 2 turbines, then after expanding in high press. turbine the steam is taken to the reheat boiler and brought to its original dryness or superheat before being passed on to the low pressure turbine.
- From there it is exhausted through the condenser into the hot well.
- A part of steam and water is lost while passing through different components and this is compensated by suppling additional feed water.

(12) iv) **Cooling Water circuit**

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

Components of a Modern Steam Powerplant

1. Boiler i) Superheater iii) Reheater
   ii) Economiser iv) Air heater
2. Steam turbine
3. Condenser
4. Circulating waterpump
5. Wagon tippler
6. Coal mill
7. Ash precipitators
8. Forced draught fans
9. Control room.
10. Generator
11. Cooling tower
12. Boiler feed pump
13. Crusher house
14. Induced draught fans
15. Boiler chimney.
16. Water treatment plant.
17. Switched yard.

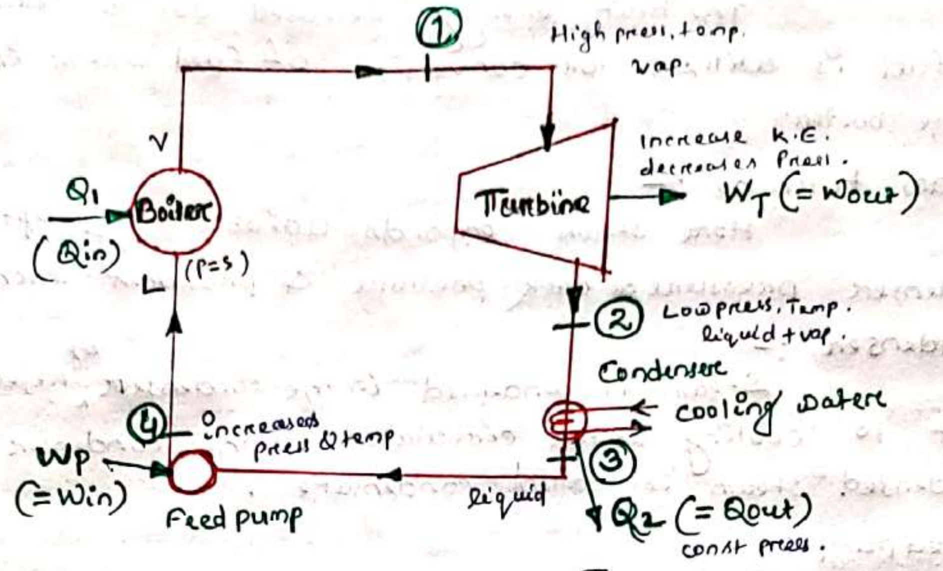
STEAM POWER CYCLE

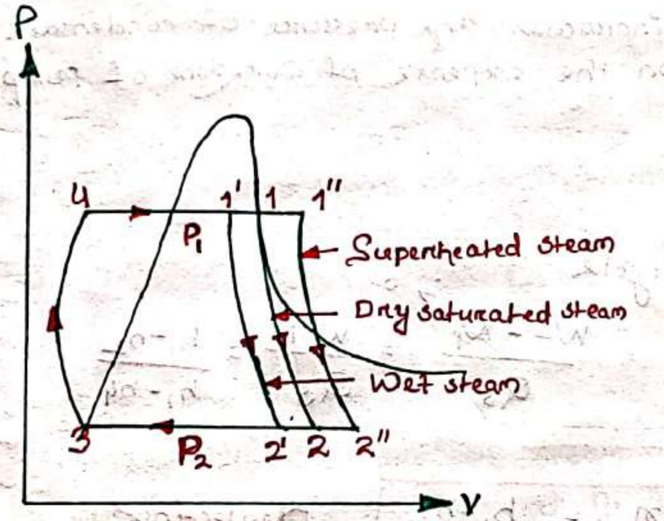
In a steam power station, heat is released by burning fuel, this heat is taken up by water which works as the working fluid. Water is converted into steam as it receives heat in a boiler. The steam then expands in a turbine producing mechanical work which is then converted into electrical energy through a generator. The exhaust steam from the turbine is then condensed in a condenser and condensate thereafter pumped to the boiler where it again receives heat and the cycle is repeated.

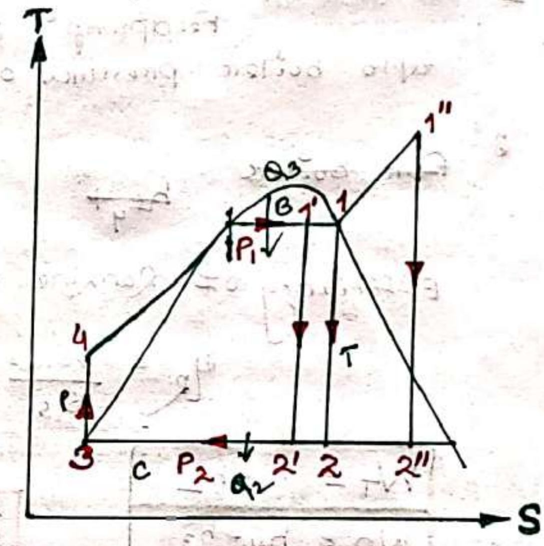
Classification of steam power cycle :-

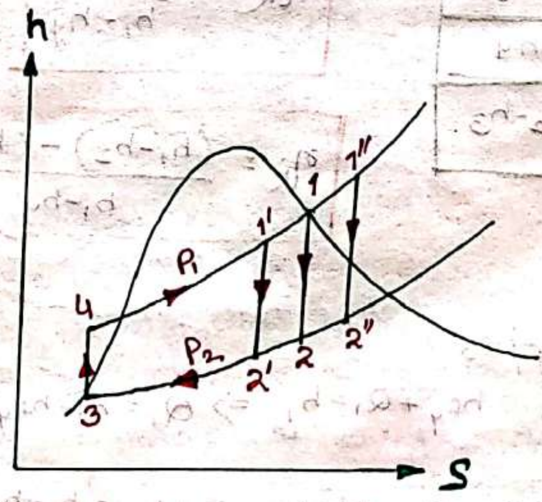
1. Rankine cycle
2. Reheat cycle
3. Regenerative cycle.
4. Binary vapour cycle.

RANKINE CYCLE









Process 1-2 : Reversible adiabatic expansion, in the turbine (steam engine)

Process 2-3 : Constant-pressure, heat rejection transfer of heat in the condenser.

Process 3-4 : Reversible adiabatic pumping process in the feedpump. (isentropic compression)

Process 4-1 : Constant-Pressure transfer of heat in the boiler. heat supplied

(14) **Basic components :-**

1. Steam Boiler :-

The heat energy released due to combustion of fuel is utilized for conversion of feed water into steam in the boiler.

2. Steam turbine :-

Here steam expands adiabatically upto condenser pressure or back pressure & produces mechanical work.

3. Condenser :-

Steam is condensed in the condenser by rejecting heat to cooling water circulated in the condenser and condensed steam is called condensate.

4. Feed pump :-

Feedpump increases the pressure of condensate (liquid) upto boiler pressure on the expense of workdone of pump.

~~For boiler~~

~~h_{f_4} +~~

Efficiency of Rankine cycle

$$\eta_R = \frac{W_{net}}{Q_s} = \frac{W_T - W_P}{Q_s} = \frac{W_T}{Q_s} = \frac{h_1 - h_2}{h_1 - h_4}$$

($W_P \to 0$)

$W_T = h_1 - h_2$
$W_P = h_4 - h_3$
$Q_s = h_1 - h_4$
$Q_R = h_2 - h_3$

$$\eta_R = \frac{h_1 - h_2}{h_1 - h_4}$$ Neglecting pump work

$$\eta_R = \frac{(h_1 - h_2) - (h_4 - h_3)}{h_1 - h_4}$$ considering pump work.

~~$W_P = h_{f_4} - h_{f_3}$~~

→ For boiler $h_{f_4} + Q_1 = h_1 \Rightarrow Q_1 = h_1 - h_{f_4}$

→ For turbine, $h_1 = W_T + h_2 \Rightarrow W_T = h_1 - h_2$

→ For condenser, $h_2 = Q_2 + h_{f_3} \Rightarrow Q_2 = h_2 - h_{f_3}$

For Feed pump, $h_{f_3} + W_P = h_{f_4} \Rightarrow W_P = h_{f_4} - h_{f_3}$

$$\eta_R = \frac{W_{net}}{Q_1} = \frac{W_T - W_P}{Q_1} = \frac{(h_1 - h_2) - (h_{f_4} - h_{f_3})}{(h_1 - h_{f_4})}$$

* When the boiler pressures are low, the feedpump term ($h_{f_4} - h_{f_3}$) being a small quantity in comparison with the turbine work, the pump work will be neglected.

Work Ratio

$$W_{Ratio} = \frac{W_{net}}{W_{turbine}}$$

Specific Steam Consumption

It is defined as the steam consumed by a locomotive's cylinders per unit output of power.

→ It is typically measured in kg/kWh or kg/kJ.

$$\text{Specific steam} = \frac{\text{steam flow}}{\text{power generation}}$$

→ S.S.C is also known as isentropic efficiency.

$$SSC = \frac{3600}{W_{net}}$$

Q A steam turbine receives steam at 15 bar and 350°C and exhaust to the condenser at 0.06 bar. Determine the thermal efficiency of the ideal Rankine cycle operating betn these 2 limits.

Ans. Pressure of steam at the entry to the steam turbine,

$P_1 = 15$ bar, 350°C.

Condenser pressure $P_2 = 0.06$ bar.

From steam table,

At 15 bar, 350°C → $h = 3147.5$ KJ/kg $S = 7.102$ KJ/kgK

At 0.06 bar, $h_f = 151.5$ KJ/kg, $h_{fg} = 2415.9$ KJ/kg

$s_f = 0.521$ KJ/kgK $s_{fg} = 7.809$ KJ/kgK

The steam in the turbine expands isentropically

$$s_1 = s_2 = s_{f_2} + x_2 s_{fg_2}$$

$$\Rightarrow 7.102 = 0.521 + x_2 \times 7.809$$

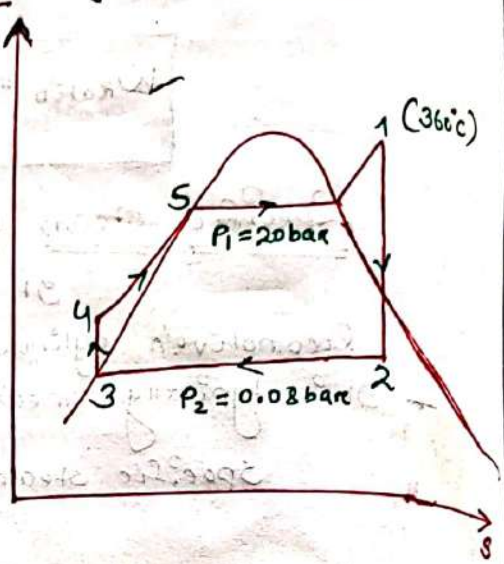
$$\Rightarrow x_2 = 0.843.$$

$$h_1 = 3147.5 \text{ KJ/kg}$$

$$h_2 = h_{f_2} + x_2 h_{fg_2} = 151.5 + 0.843 \times 2415.9 = 2188.1 \text{ KJ/kg}$$

$$\therefore \eta_R = \frac{h_1 - h_2}{h_1 - h_{f_2}} = \frac{3147.5 - 2188.1}{3147.5 - 151.5} = 0.32 \text{ or } 32\%$$

(16) Q In a steam turbine steam at 20 bar, 360°C is expanded to 0.08 bar. It then enters a condenser, where it is condensed to saturated liquid water. The pump feeds back the water into the boiler. Assume ideal processes, find per kg of steam the net workdone and the cycle efficiency.



Sol^n Boiler pressure, $P_1 = 20$ bar.

Condenser pressure, $P_2 = 0.08$ bar.

From steam table,

At 20 bar (P_1) 360°C, $h_1 = 3159.3$ KJ/kg.
$s_1 = 6.9917$ KJ/kg k.

At 0.08 bar (P_2), $h_3 = h_{f(P_2)} = 173.88$ KJ/kg.
$s_3 = s_{f(P_2)} = 0.5926$ KJ/kg k.

$h_{fg}(P_2) = 2403.1$ kJ/kg, $s_g(P_2) = 8.2287$ KJ/kg k.

$v_f(P_2) = 0.001008$ m³/kg. $\therefore s_{fg}(P_2) = 7.6361$ KJ/kg k.

Now $s_1 = s_2$

$6.9917 = s_f + x_2 = 0.5926 + x_2 \times 7.6361$

$\Rightarrow x_2 = \frac{6.9917 - 0.5926}{7.6361} = 0.838.$

$\therefore h_2 = h_f + x_2 h_{fg}$
$= 173.88 + 0.838 \times 2403.1 = 2187.68$ KJ/kg

$W_{net} = W_{turbine} - W_{pump}$

$W_{pump} = h_{f_4} - h_f = v_f (P_1 - P_2)$
$= 0.00108 \times (20 - 0.08) \times 100$
$= 2.008$ kJ/kg

$h_{f_4} = 2.008 + h_f = 2.008 + 173.88 = 175.89$ KJ/kg.

$W_T = h_1 - h_2 = 3153.9 - 2187.68 = 971.62$ KJ/kg.

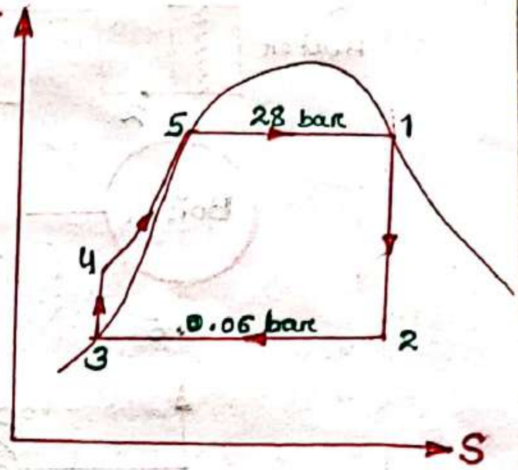
$\therefore W_{net} = 971.62 - 2.008 = 969.61$ KJ/kg

$Q_1 = h_1 - h_{f_4} = 3159.3 - 175.89 = 2983.41$ KJ/kg.

$\therefore \eta_{cycle} = \frac{W_{net}}{Q_1} = \frac{969.61}{2983.41} = 0.325$ or 32.5 % Ans.

Q. A simple Rankine cycle works between pressures 28 bar and 0.06 bar, the initial condition of steam being dry saturated. Calculate the cycle efficiency, work ratio and specific steam consumption. (17)

Sol^n From steam table,



At 28 bar,

$h_1 = 2802 \ kJ/kg$,

$s_1 = 6.2104 \ kJ/kgK$

At 0.06 bar,

$h_{f_2} = h_{f_3} = 151.5 \ kJ/kg$

$h_{fg_2} = 2415.9 \ kJ/kg$

$s_{f_2} = 0.521 \ kJ/kgK$

$s_{fg_2} = 7.809 \ kJ/kgK$

$v_f = 0.001 \ m^3/kg$.

Considering turbine process 1-2, we have

$$s_1 = s_2$$

$$\Rightarrow 6.2104 = s_{f_2} + x_2 s_{fg_2} = 0.521 + x_2 \times 7.809$$

$$\Rightarrow x_2 = \frac{6.2104 - 0.521}{7.809} = 0.728$$

$$\therefore h_2 = h_{f_2} + x_2 h_{fg_2} = 151.5 + 0.728 \times 2415.9 = 1910.27 \ kJ/kg$$

$$\therefore W_T = h_1 - h_2 = 2802 - 1910.27 = 891.73 \ kJ/kg.$$

$$W_P = h_{f_4} - h_{f_3} = v_f (P_1 - P_2)$$

$$= \frac{0.001 (28 - 0.06)}{1000} = 2.79 \ kJ/kg.$$

$[\because h_{f_4} = h_{f_3} + 2.79 = 151.5 + 2.79 = 154.29 \ kJ/kg]$

$$\therefore W_{net} = W_T - W_P$$

$$= 891.73 - 2.79 = 888.94 \ kJ/kg$$

→ Cycle efficiency $= \frac{W_{net}}{Q_1} = \frac{888.94}{h_1 - h_{f_4}}$

$$= \frac{888.94}{2802 - 154.29} = 0.3357 \text{ or } 33.57\%$$

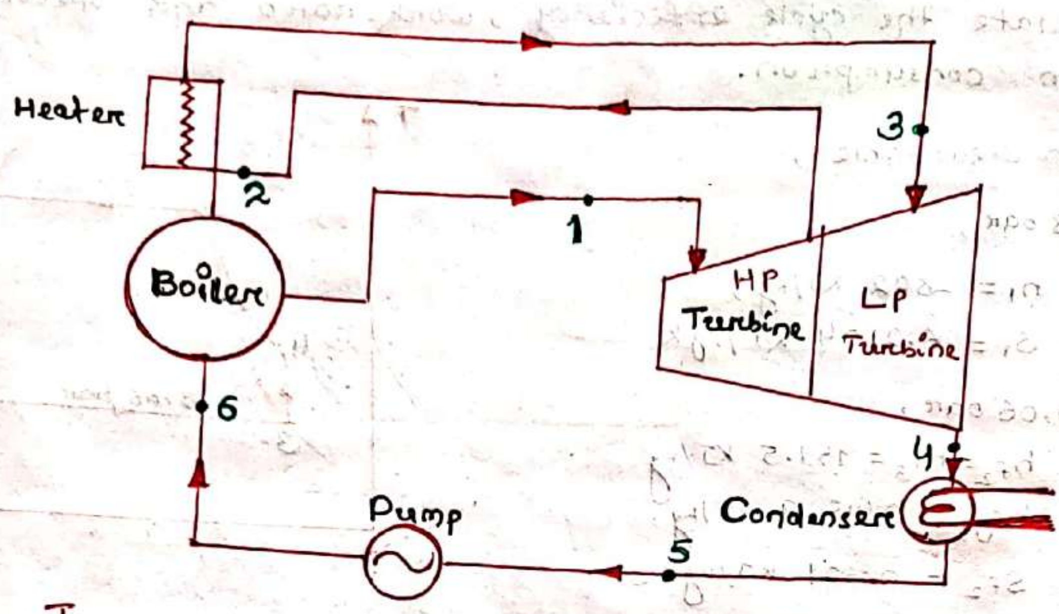
(Ans)

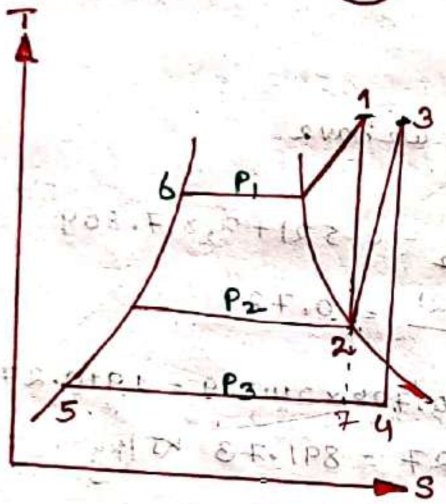
→ Work ratio $= \frac{W_{net}}{W_{turbine}} = \frac{888.94}{891.73} = 0.997$ (Ans)

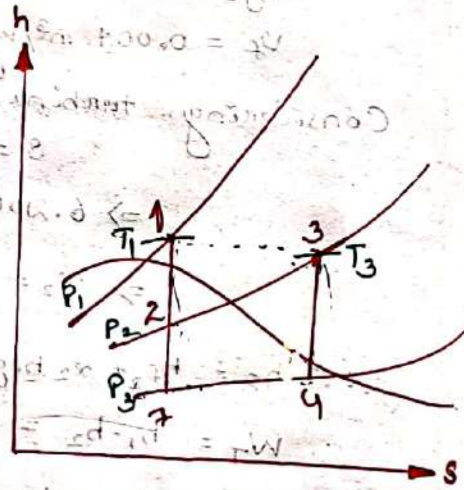
→ Specific steam consumption $= \frac{3600}{W_{net}} = \frac{3600}{888.94} = 4.049 \ kg/kWh$

(Ans)

REHEAT CYCLE







Thermal efficiency with reheating (neglecting pumpwork)

Heat supplied $= (h_1 - h_{f4}) + (h_3 - h_2)$

Heat rejected $= h_4 - h_{f4}$

$W_T = H.S - H.R$

$= (h_1 - h_{f4}) + (h_3 - h_2) - (h_4 - h_{f4})$

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

$$\eta_{thermal} = \frac{(h_1 - h_2) + (h_3 - h_4)}{(h_1 - h_{f4}) + (h_3 - h_2)}$$

extra — Mathematically

$(W_T)_{H.P.} = h_1 - h_2$

$(W_T)_{LP} = h_3 - h_4$

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

$$\eta = \frac{(h_1 - h_2) + (h_3 - h_4)}{(h_1 - h_6) + (h_3 - h_2)}$$

If pump work $W_p = \frac{v_f(P_1 - P_b)}{1000}$ kJ/kg then,

$$\eta_{thermal} = \frac{[(h_1 - h_2) + (h_3 - h_4)] - W_P}{[(h_1 - h_{f4}) + (h_3 - h_2)] - W_P}$$

W_P is usually small and neglected.

Thermal efficiency without reheating is

$$\boxed{\eta_{thermal} = \frac{h_1 - h_7}{h_1 - h_{f4}}} \quad (\because h_{f4} = h_{f7})$$

- The steam as at state point 1 (i.e. pressure P_1 & temp T_1) enters the turbine and expands isentropically to a certain pressure P_2 and temp T_2.
- From state point 2 the whole of steam is drawn out of the turbine and is reheated in a reheater to a temp T_3.
- This reheated steam is then readmitted to the turbine where it is expanded to condenser pressure isentropically.

Advantage of Reheating

- There is an increased output of the turbine.
- Erosion and corrosion problems in the steam turbine are avoided.
- There is an improvement in the thermal-efficiency of the turbine
- Final dryness fraction of steam is improved.
- There is an increase in the nozzle and blade efficiencies.

Disadvantage

- Reheating requires more maintenance.
- The increase in thermal efficiency is not appreciable in comparison to the expenditure incurred in reheating.

Q Steam at a press. of 15 bar abs. and 250°C is expanded through a turbine at first to a press. of 4 bar abs. It is then reheated at const. press. to the initial temp. of 250°C and is finaly expanded to 0.1 bar abs. Using mollier chart, estimate the workdone per kg of steam flowing through the turbine and amount of heat supplied during the process of reheat. Compare the work output when the expansion is direct from 15 bar abs. to 0.1 bar abs without any Reheat. Assume all expansion process to be isentropic.

Sol Given data,

$P_1 = 15$ bar

$P_2 = 4$ bar

$P_4 = 0.1$ bar.

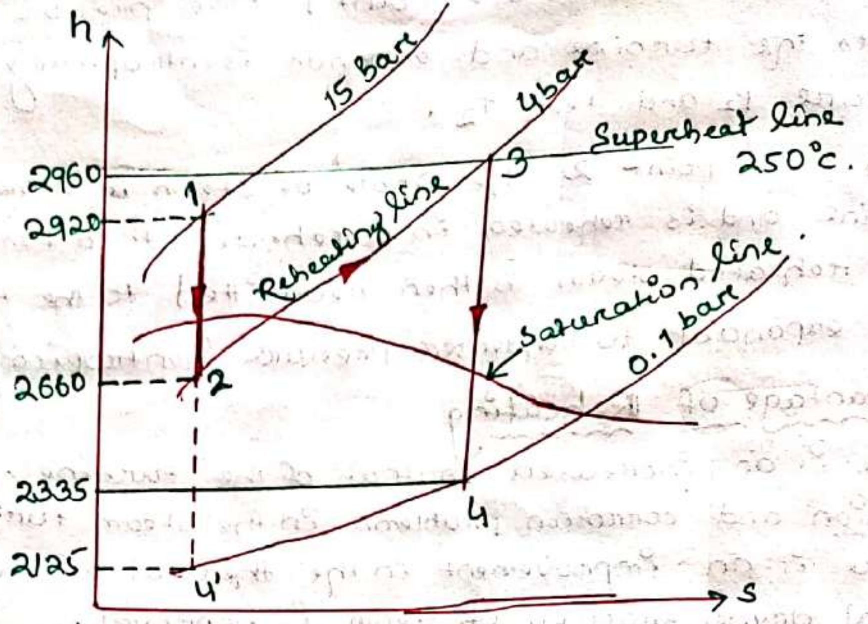
Workdone per kg of steam,

$W =$ Total heat drop.

$= [(h_1 - h_2) + (h_3 - h_4)]$ KJ/kg

Amount of heat supplied during process of reheat,

$h_{reheat} = (h_3 - h_2)$ KJ/kg



From mollier diagram or h-s chart,

$h_1 = 2920$ kJ/kg , $h_2 = 2660$ kJ/kg

$h_3 = 2960$ kJ/kg, $h_4 = 2335$ kJ/kg.

By putting the values in equations

$$W = (2920 - 2660) + (2960 + 2335)$$

$$= 885 \text{ kJ/kg}.$$

Hence Workdone per kg of steam = 885 kJ/kg (Ans).

Amount of heat supplied during reheat,

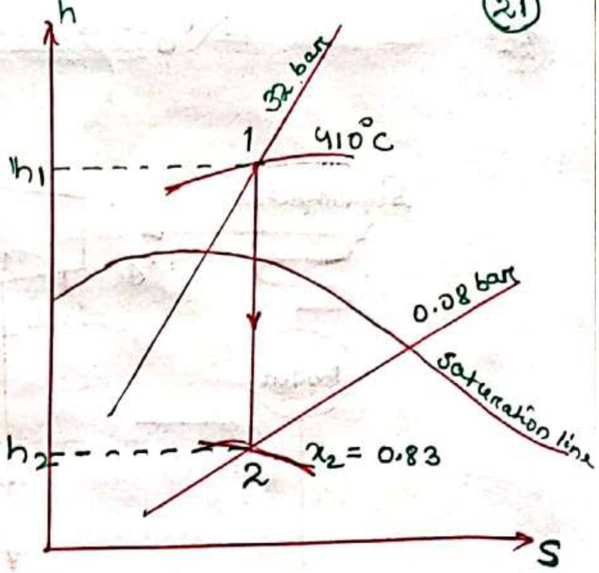
$$h_{reheat} = (2960 - 2660) = 300 \text{ kJ/kg} \quad \text{Ans.}$$

If there is no reheating process, then 1 to 4' is expansion, the work output is $W_1 = h_1 - h_4'$

From molier diagram, $h_4' = 2125$ kJ/kg

$$W_1 = 2920 - 2125 = 795 \text{ kJ/kg}. \quad \text{Ans}$$

Q A turbine is supplied with steam at a pressure of 32 bar and a temp of 410°c. The steam then expands isentropically to a pressure of 0.08 bar. Find the dryness fraction at the end of expansion and thermal efficiency of the cycle. If the steam is reheated at 5.5 bar to a temp of 400°c and then expanded isentropically to a pressure of 0.08 bar, what will be the dryness fraction and thermal efficiency of the cycle.



From mollier chart

$h_1 = 3250$ KJ/kg

$h_2 = 2170$ KJ/kg

Heat drop or workdone

$= h_1 - h_2$

$= 3250 - 2170$

$= 1080$ KJ/kg

Heat supplied $= h_1 - h_{f_2}$

$= 3250 - 173.9$

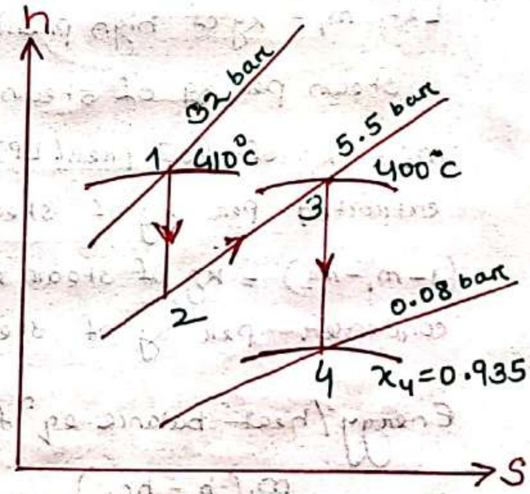
$= 3076.1$ KJ/kg.

[$h_{f_2} = 173.9$ KJ/kg at 0.08 bar]

Thermal efficiency $= \frac{\text{Workdone}}{\text{Heat supplied}}$

$= \frac{1080}{3076.1} = 0.351$ or 35.1 % **Ans**

Exhaust steam conditions, $x_2 = 0.83$ (from Mollier chart)



From mollier chart:

~~$h_1 = 3250$ KJ/kg~~

~~$h_2 = 2807$ KJ/kg~~

$h_3 = 3263$ KJ/kg

$h_4 = 2426$ KJ/kg

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

$= (3250 - 2807) + (3263 - 2426)$

$= 12080$ KJ/kg

Heat supplied $= (h_1 - h_{f_4}) + (h_3 - h_2)$

$= (3250 - 173.9) + (3263 - 2807)$

$= 3532$ KJ/kg

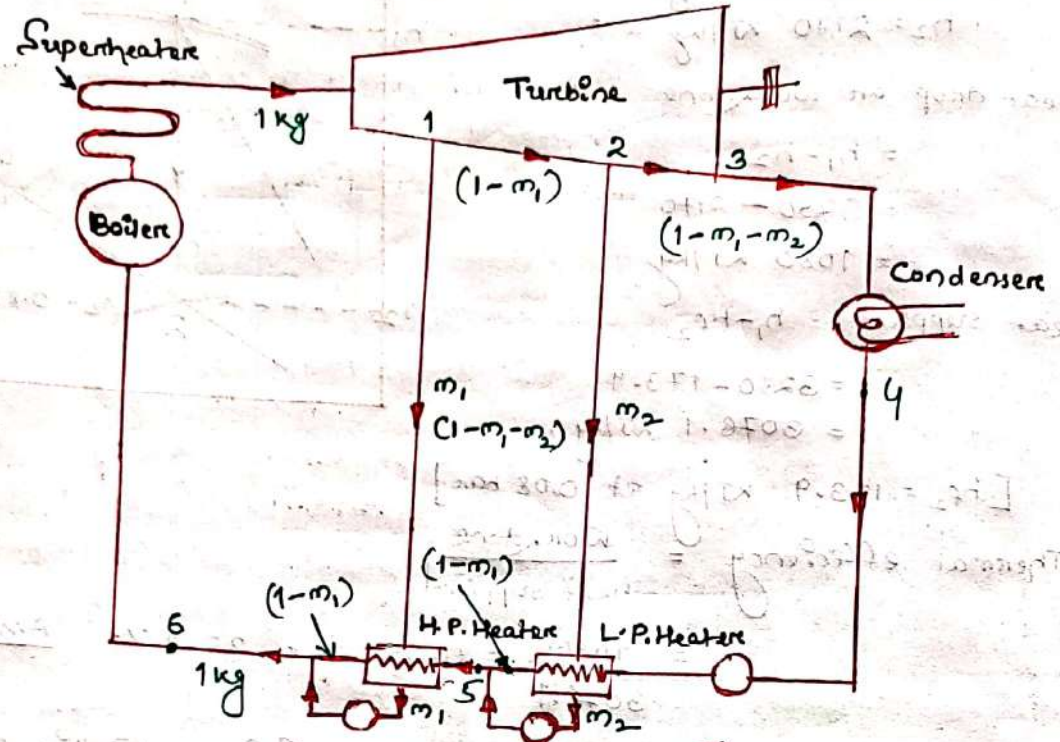
Thermal efficiency $= \frac{\text{Workdone}}{\text{Heat supplied}} = \frac{1280}{3532} = 0.362$ or 36.2%

Condition of steam at the exhaust,

$x_4 = 0.935$ (From mollier chart).

Ans

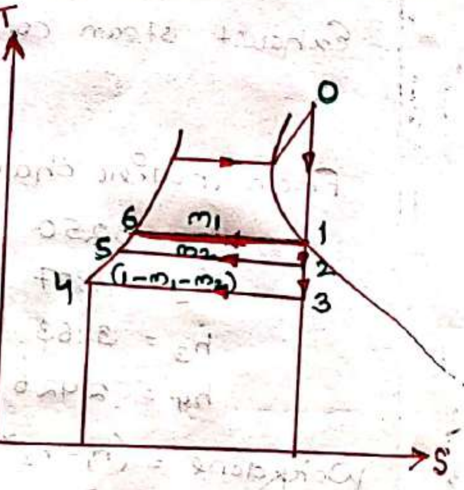
Regenerative Cycle



Let m_1 = kg of high pressure (H.P) steam per kg of steam flow.

m_2 = kg of low press (LP) steam extracted per kg of steam flow.

$(1-m_1-m_2)$ = kg of steam entering condenser per kg of steam flow.



Energy / heat balance eqⁿ for H.P heater

$$m_1(h_1 - h_{f_6}) = (1-m_1)(h_{f_6} - h_{f_5})$$

or $m_1\left[(h_1-h_{f_6}) + (h_{f_6} - h_{f_5})\right] = (h_{f_6} - h_{f_5})$

or $m_1 = \dfrac{h_{f_6} - h_{f_5}}{h_1 - h_{f_5}}$

Energy / heat balance eqⁿ for L.P. heater

$$m_2(h_2 - h_{f_5}) = (1-m_1-m_2)(h_{f_5} - h_{f_3})$$

$\Rightarrow m_2\left[(h_2 - h_{f_5}) + (h_{f_5} - h_{f_3})\right] = (1-m_1)(h_{f_5} - h_{f_3})$

$\Rightarrow m_2 = \dfrac{(1-m_1)(h_{f_5} - h_{f_3})}{(h_2 - h_{f_3})}$

Neglecting pumpwork :

The heat supplied externally in the cycle $= (h_0 - h_{f_6})$

Isentropic workdone $= m_1(h_0 - h_1) + m_2(h_0 - h_2) + (1 - m_1 - m_2)(h_0 - h_3)$

$$\eta_{thermal} = \frac{\text{Workdone}}{\text{Heat supplied}}$$

Advantage

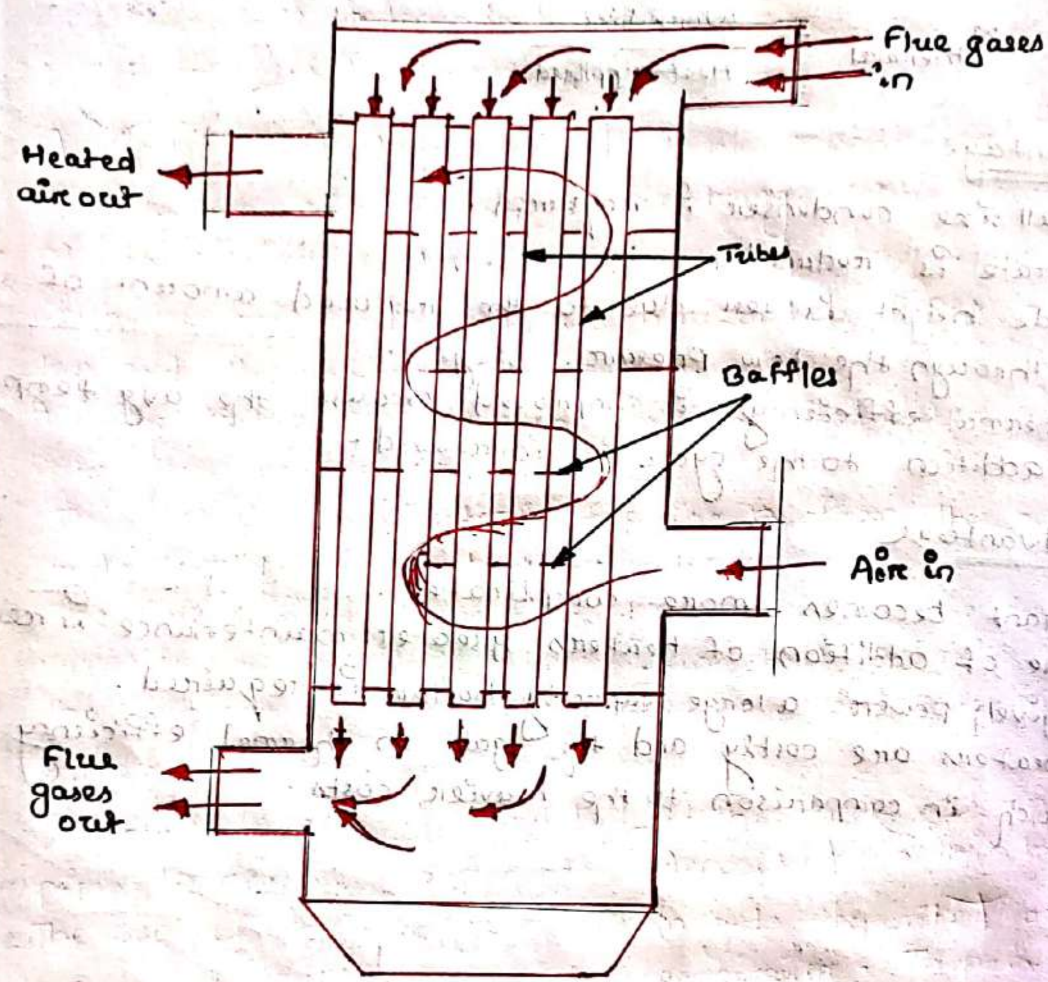
- A small size condenser is required.
- Heat rate is reduced.
- The blade height is less due to the reduced amount of steam passed through the Low Pressure stage.
- The thermal efficiency is improved because the avg temp. of heat addition to the cycle is increased.

Disadvantage

- The plant becomes more complicated.
- Because of addition of heaters greater maintenance is required.
- For given power a large capacity boiler is required.
- The heaters are costly and the gain in thermal efficiency is not much in comparison to the heavier costs.

Boiler Accessories

Air Preheater



[Tubular type of air Preheater]

The function of air preheater is to increase the temp. of air before it enters the furnace.

- It is generally placed after the economiser.
- An air preheater consists of plates or tubes with hot gases on one side and air on the other.
- It preheats the air to be supplied to the furnace.

Degree of preheating depends on

i) Types of fuel.

ii) Types of fuel burning equipment.

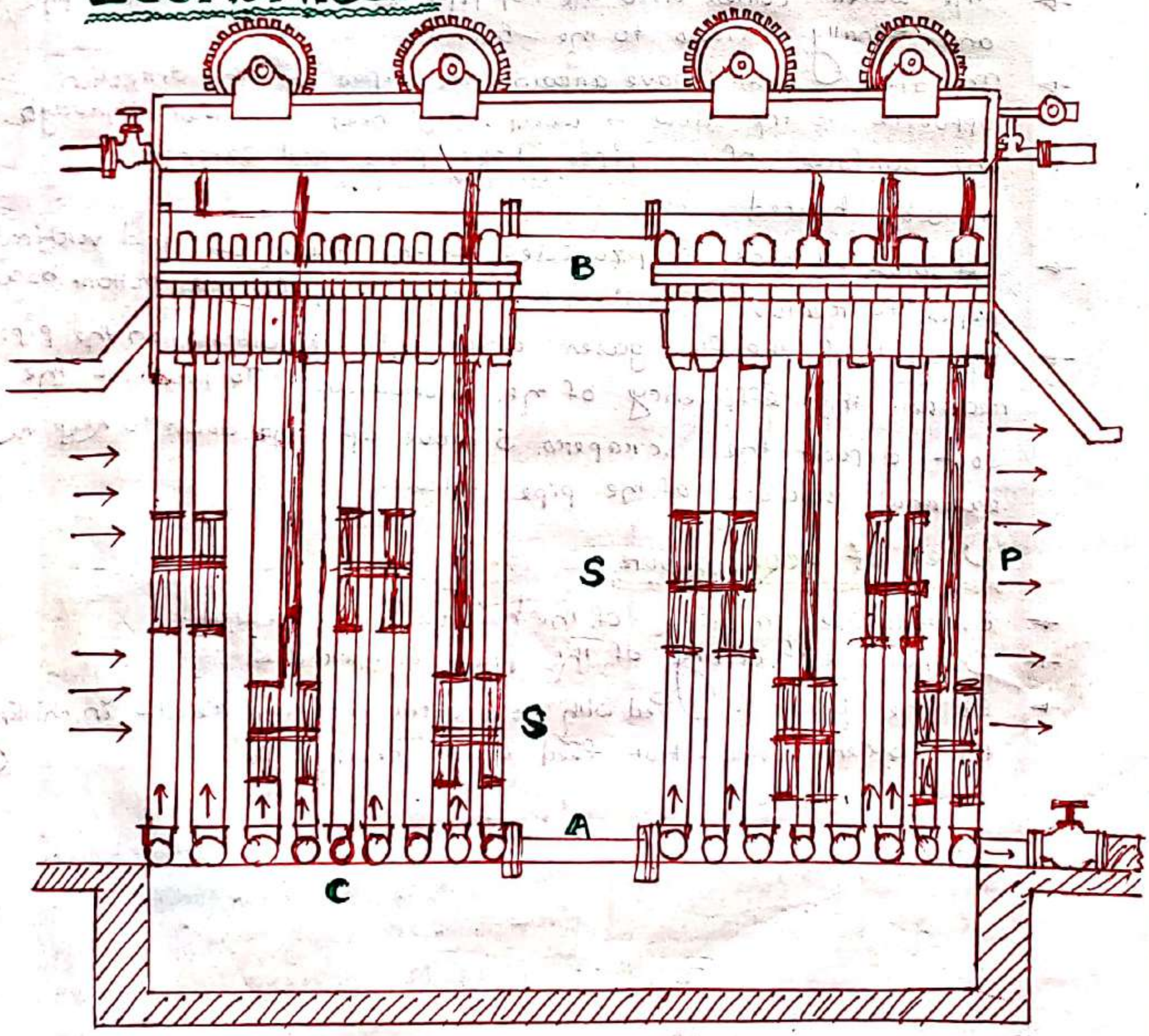
iii) Rating at which the boiler and furnaces are operated.

There are three types of air preheater.

1. Tubular type.
2. Plate type.
3. Storage type.

- After leaving the boiler or economiser the gaseous products of combustion travel through the inside of the tubes of air preheater (Tubular type) in a direction opposite to that of air travell and transfer some of their heat to the air to be supplied to the furnace.
- Thus the air initially heated before being supplied to the furnace.
- The gases reverse their direction near the bottom of airheater and a soot hopper is fitted to the bottom of air heater casing to collect soot.
- In the plate type air preheater the air absorbs heat from the hot gases being swept through the heater at high velocity on the opposite side of a plate.

ECONOMISER



A = Bottom pipe
B = Top pipe
P = Vertical C.I. pipes
S = Scrapers

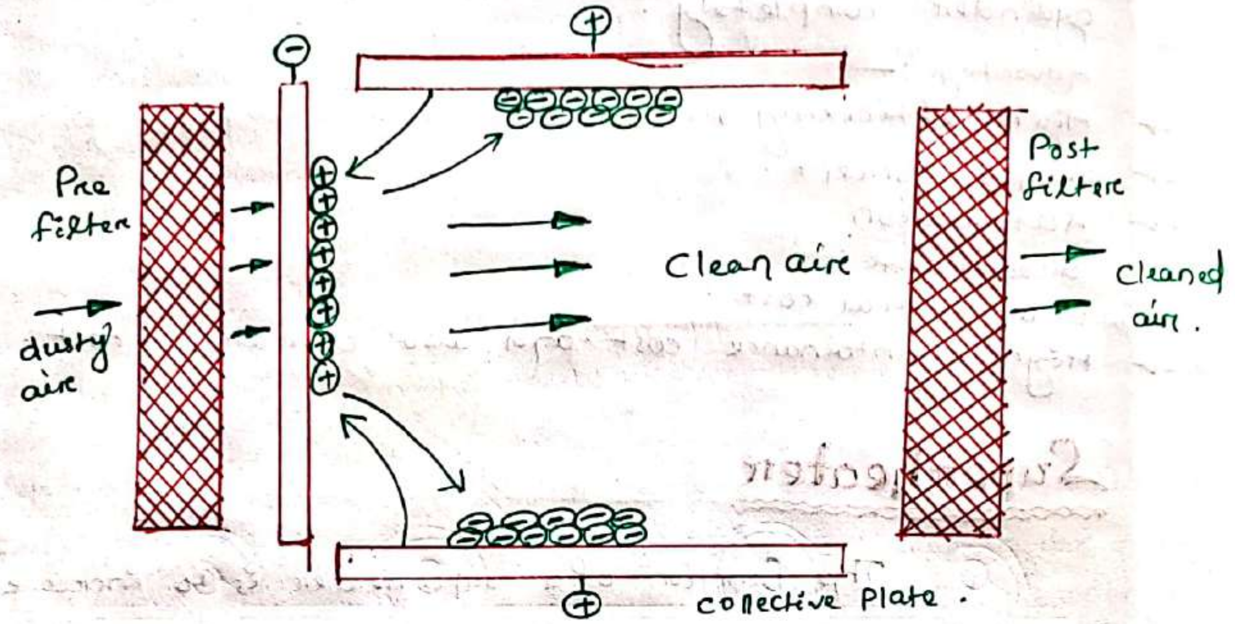
(26)

- An economiser is a device in which the waste heat of flue gases is utilised for heating the feed water.
- Economiser are of two types.
  - i) independent type.
  - ii) Integral type.
- An independent type vertical tube economiser is employed for boilers of medium pressure range upto about 25 bar.
- It consists of a large no. of vertical cast iron pipes P which are connected with two horizontal pipes, one at the top and the other at the bottom.
- A is the bottom pipe through which the feed water is pumped into the economiser.
- The water comes into the top pipe B from the bottom pipe and finally flows to the boiler.
- The flue gases move around the pipes in the direction opposite to the flow of water, and heat transfer through the surfaces of the pipes takes place and water is thereby heated.
- A blow off cock is provided at the back of end vertical pipes to remove sediments deposited in the bottom boxes.
- The soot of the flue gases which gets deposited on the pipes reduces the efficiency of the economiser. To prevent the soot deposit, the scrapers S move up and down to keep the external surface of the pipe clean.

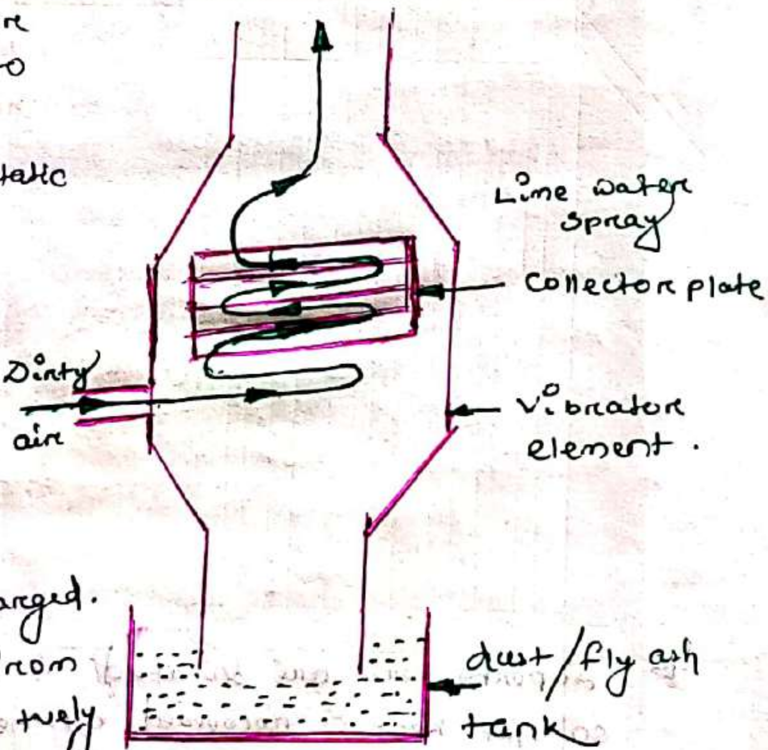
Uses of economiser

- Evaporative capacity of the boiler is increased.
- Overall efficiency of the plant is increased.
- If the boiler is fed with cold water it may result in chilling the boiler metal. Hot feed water checks it.

Electrostatic Precipitator



- Electrostatic precipitator is a dust collector.
- There are +ve plates and -ve plates.
- There are 2 filters. Prefilter and postfilter.
- Electrostatic precepetator is a device which is used to kill impurities from the flue gas by using electrostatic current.



Working

- It consists of a no. of collector plate inside a long cylinder.
- The lower plates are -vely charged and the upper plates are +vely charged.
- The dirty air coming from the inlet, goes to the +vely charged collector plates.
- Now the particles are also -vely charged and goes to the +vely charged collector plates.
- Thus the particles are attracted to the plate and stack with the plate.

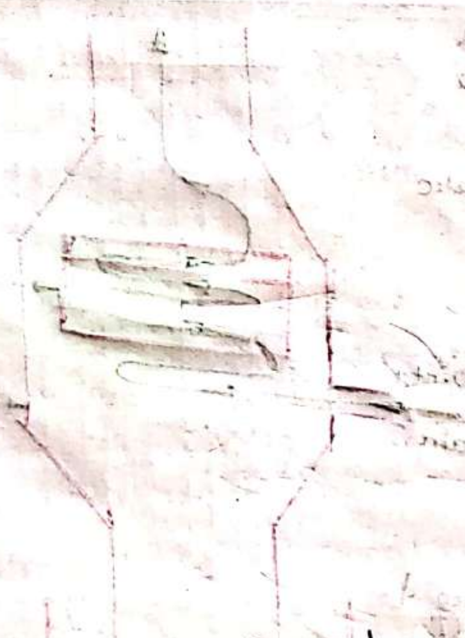
- If any particles left, then water passes out the particles ~~left~~ along with the particles remains in the plate
- All the particles collected in the tank and a vibration element provided to washout the particles stick to the cylinder completely.

Advantage:—
- High efficiency,
- Simple concept.
- Automation

disadvantage:—
- High initial cost.
- High maintainance cost and also operation cost.

Superheater

The function of a superheater is to increase the temp. of the steam above its saturation point.



- Superheaters are located in the path of the furnace gases so that heat is recovered by the superheater from the hot gases.
- There are 2 types of superheaters:
  1. Convective superheater,
  2. Radiant superheater.

- Convective superheater makes use of heat in flue gases where as a **radiant** superheater is placed in the furnace and wall tubes receives heat from the burning fuel through radiant process.
- The radiant type of superheater is generally used where a high amount of superheat temp. is required.

Construction & working principle :-

- Superheater consists of two steel headers to which are attached solid drawn 'U' tubes of steel.
- These tubes are arranged in groups of four and one pair of the headers generally carries 10 of these groups or total of forty tubes.
- The steam from the boiler enters and leaves the headers.
- When the steam is taken from the boiler direct to the main steam pipe, the valve V_1 & V_2 are closed and V_3 is opened. when the steam is passed through the superheater i.e. when the superheater is in action the valve V_3 is closed the valve V_1 & V_2 are opened.
- The path of gases is controlled by the damper which is operated by the hand wheel.

Advantages of superheater :-

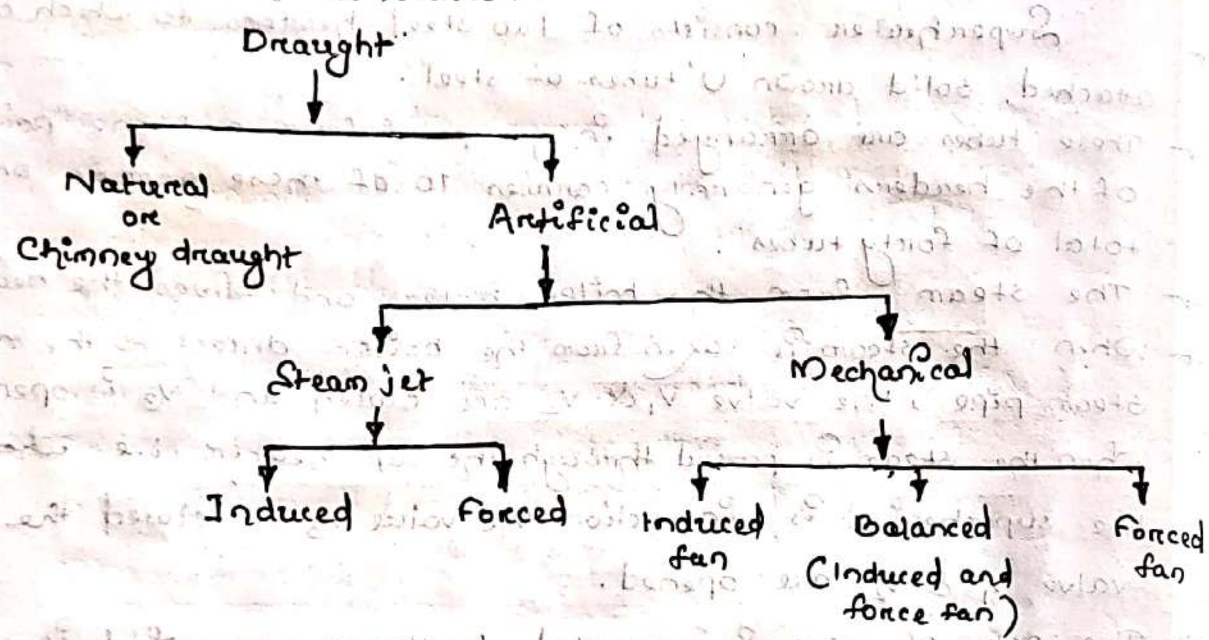
- Steam consumption of the engine or turbine is reduced.
- Losses due to condensation in the cylinders and the steam pipes are reduced.
- Erosion of turbine blade is eliminated.
- Efficiency of steam plant is increased.

Scanned with CamScanner

Draught System

The small pressure difference which causes a flow of a gas to take place is termed as a draught.

- The function of a draught in case of a boiler is to force air to the fire and to carry away the gaseous products of combustion.



- Natural draught
- It is obtained by the use of a chimney.
- The draught produced by the chimney is due to the density difference between the column of hot gases inside the chimney and the cold air outside.
- Artificial draught
- It may be a mechanical or a steam jet draught.
- The former is used for central power stations and many other boiler installation while the latter is employed for small installations and in locomotives.

Forced draught :-

- The draught is produced by a fan.
- Here, a blower or a fan is installed near are at the base of the boiler to force the air through the cool bed and other passages through the furnaces, flues, air preheater, economiser etc.
- It is a positive pressure draught.
- The enclosure for the furnace has to be very highly sealed so that gases from the furnace do not leak out in the boiler house.

Induced draught :-

- In this system a fan or blower is located at or near the base of the chimney.
- The pressure over the fuel bed is reduced below the atms pres.
- This draught is used usually when economisers and air preheaters are incorporated in the system.
- This draught is similar in action to the natural draught.

Balanced draught :-

- It is a combination of the forced and induced draught systems.
- In this system the forced draught fan overcomes the resistance in the air preheater and chain grate stoker while the induced draught fan overcomes draught losses through boiler, economiser, air preheater and connecting flues.

Advantages of Mechanical Draught :-

1. Easy control of combustion and evaporation.
2. Increase in evaporative power of a boiler.
3. Improvement in the efficiency of the plant.
4. Reduced chimney height.
5. Prevention of smoke.
6. Capability of consuming low grade fuel.

Steam Condenser

A steam condenser is a device or an appliance in which steam condenses and heat released by steam is absorbed by water.

Organs of a steam condensing plant :-

- Condenser :- To condense the steam.
- Supply of cooling water.
- Wet air pump :- To remove the condensed steam, the air and uncondensed water vapour and gases from the condenser, separate pumps may be used to deal with air and condensate.
- Hot well :- Where the condensate can be discharged and from which the boiler feed water is taken.
- Arrangement for recooling the cooling water in case surface condenser is employed.

Classification of Condensers

- Jet Condenser
- Surface Condenser

Jet Condenser

- The exhaust steam and water come in direct contact with each other and temp of the condensate is the same as the cooling water leaving the condenser.
- The cooling water is usually sprayed into the exhaust steam to cause rapid condensation.

The condensers may be classified as

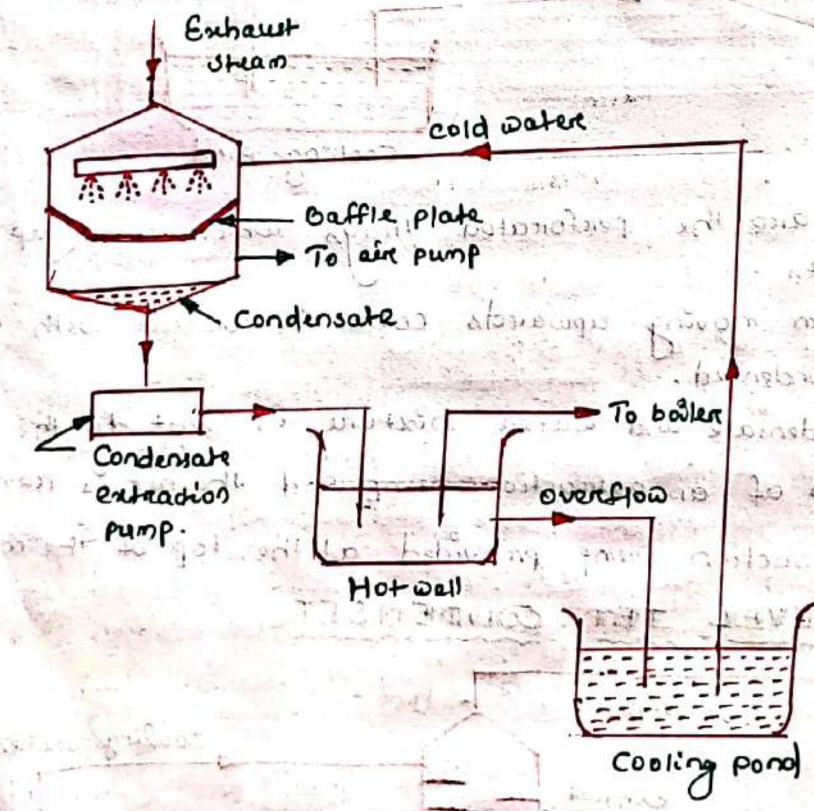
a) parallel flow type.

b) Counter-flow type.

c) Ejector type.

- Parallel flow and counter flow condensers are further sub-divided into two types.
  - i) Low level type.
  - ii) High level type.
- In parallel flow type of condenser, both the exhaust steam and cooling water find their entry at the top of the condenser and then flow downwards and condensate and water are finally collected at the bottom.
- In counter flow type the steam and cooling water enters the condenser from opposite directions. The exhaust steam travels in upward direction and meet the cooling water which flows downwards.

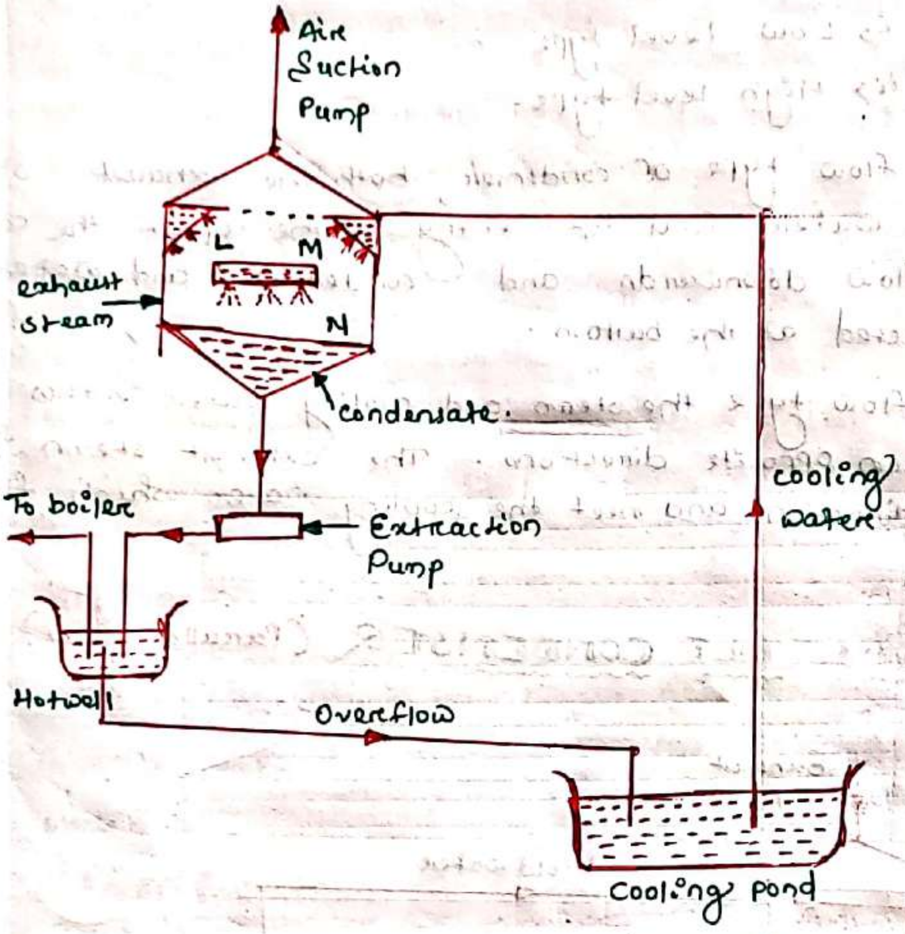
LOW LEVEL JET CONDENSER (Parallel flow)



The exhausting steam is entering the condenser from the top and cold water is being sprayed on its way.

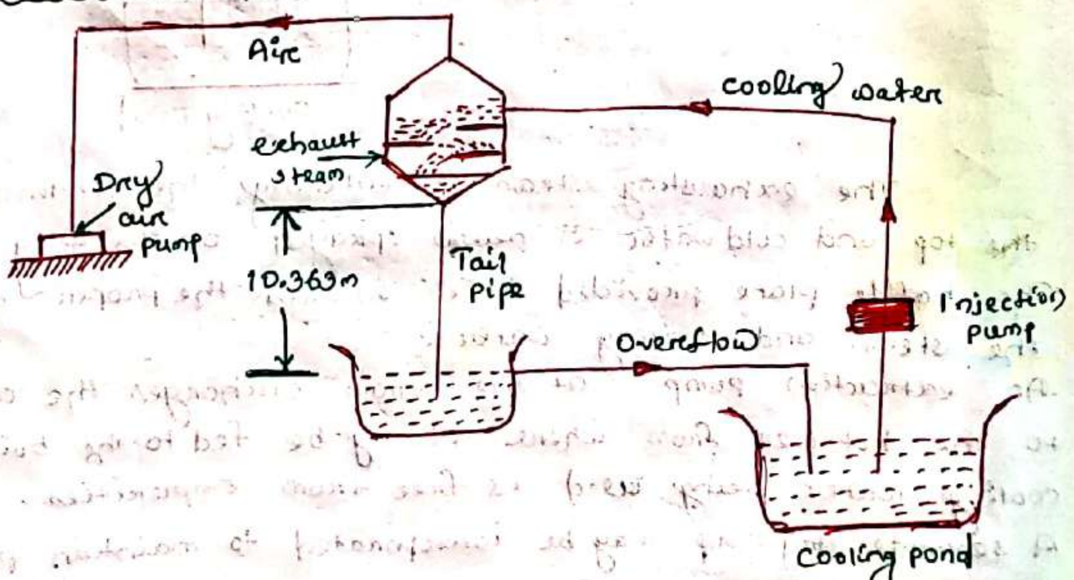
- The baffle plate provided in it ensures the proper mixing of the steam and cooling water.
- An extraction pump at the bottom discharges the condensate to the hot well from where it may be fed to the boiler if the cooling water being used is free from impurities.
- A separate dry pump may be incorporated to maintain proper vacuum.

LOW LEVEL JET CONDENSER (counter-flow)



- L, M, N 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 and the air is removed by an air suction pump provided at the top of the condenser.

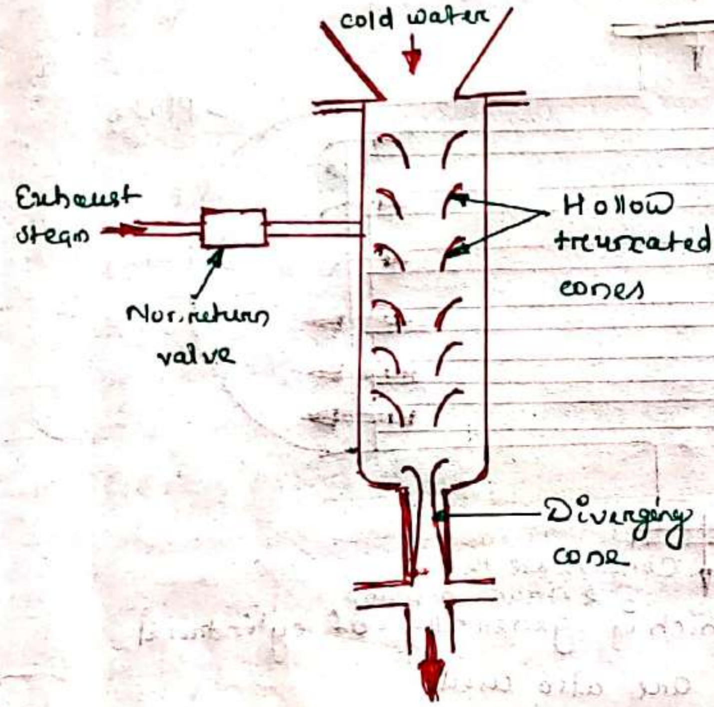
HIGH LEVEL JET CONDENSER



A high level counterflow jet condenser is also called barometric condenser.

- In this case the shell is placed at a hight about 10.363m. above the 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.

Ejector Condenser

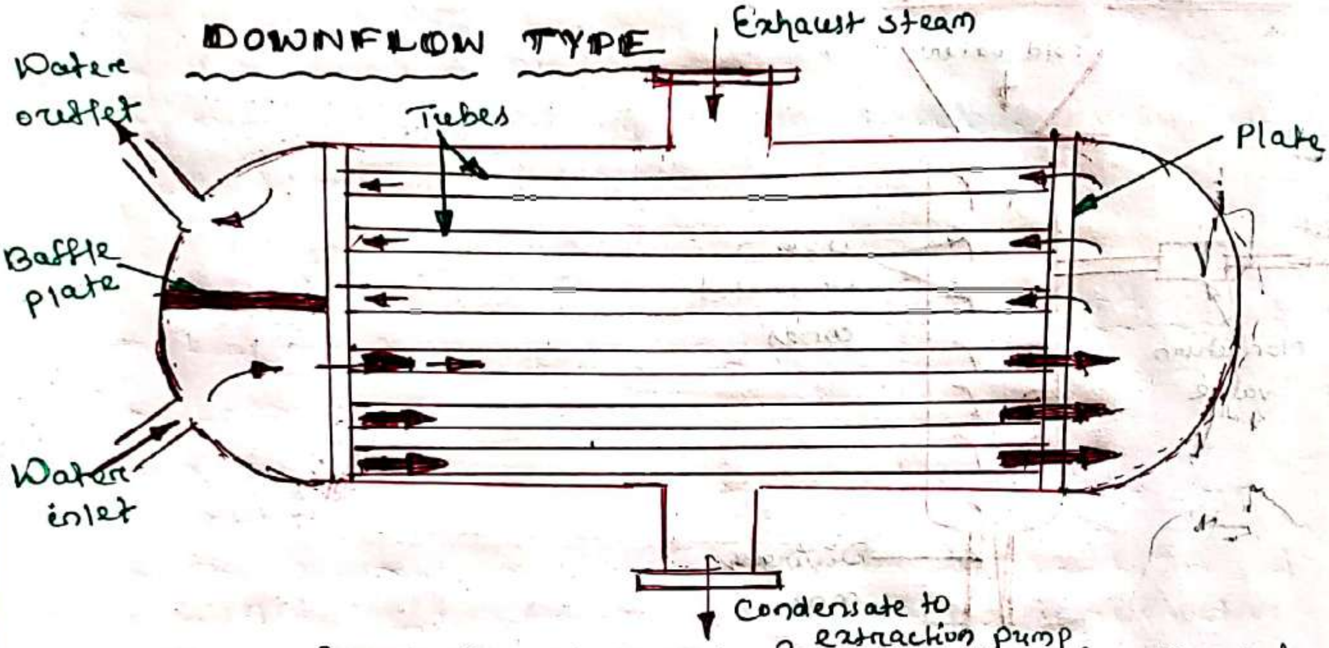


- In this type of condenser the exhaust steam and cooling water mix in hollow truncated cones.
- The cold water having a head of about 6m flow down through the number of cones and as it moves its velocity increases and drop in pressure results.
- Due to this decreased pressure exhaust steam along with associated air is drawn through the truncated cones and finally lead to diverging cones.
- In the diverging cone, a portion of kinetic energy gets converted into pressure energy which is more than the atmospheric so that the condensate consisting of condensed steam, cooling water and air is discharged into the hot well.
- The exhaust steam inlet is provided with a non-return valve which does not allow the water from hot well to rush back to the engine in case a failure of cooling water supply to condenser

SURFACE CONDENSER

i) Downflow type
ii) Central-flow type
iii) Inverted flow type
iv) Regenerative type
v) Evaporative type

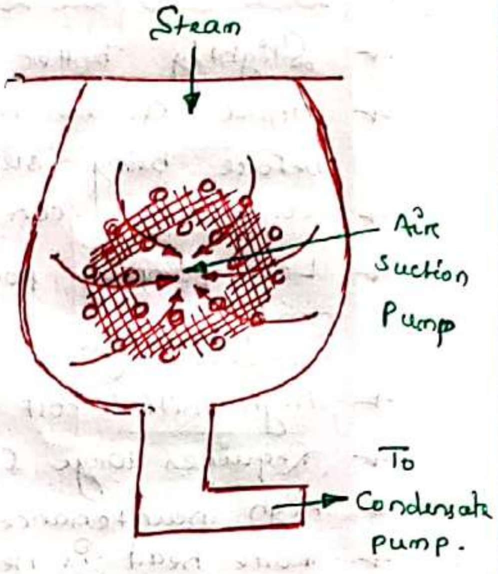
DOWNFLOW TYPE



- It consists of a shell which is generally of cylindrical shape through other types are also used.
- It has coverplates at the ends and 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 flow in a direction right angle to the direction of flow of water, it is also called cross-surface condenser.

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 results in radial flow of the steam. the better contact betn the outer surface of the tubes and steam is ensured, due to large passage the pressure drop of steam is reduced.



Inverted flow type

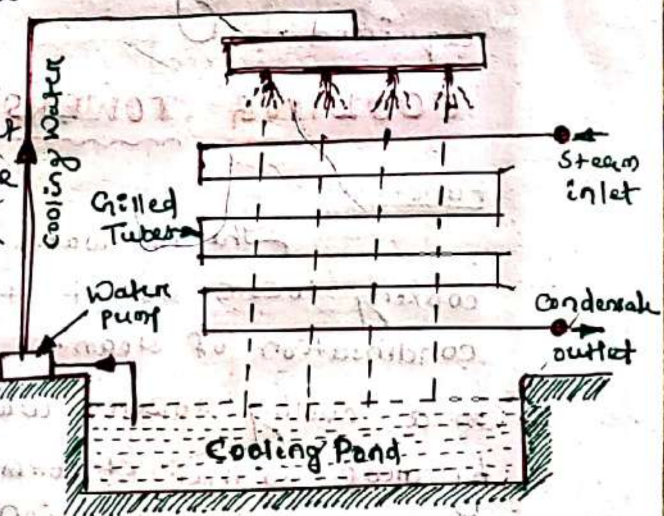
This type of condenser has the air suction at the top, the steam after entering at the bottom, rises up and then again flow down to the bottom of the condenser, by following a path near the outer surface of the condenser. The condensate extraction pump is at the bottom.

Regenerative type

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

Evaporative type

Here 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 finds its application in small size plants.



Advantage of surface condenser

- Slightly better vacuum can be obtained.
- There is no need to treat the condensate chemically before being supplied to the boiler.
- Condensate can be reused for boiler feed water.
- Low pumping power required.

Disadvantage

- High initial cost.
- Requires large floor area.
- High maintenance cost.
- More head is necessary in order to obtain sufficient head on hot well pump.

Jet Condenser	Surface Condenser
Low manufacturing cost.	High manufacturing cost.
Lower up keep.	Higher up keep.
Required small floor space.	Required large floor space.
The condensate can't be used as feed water in boilers unless the cooling water is free from impurities.	Condensate can be reused as feed water as it does not mix with the cooling water.
More auxiliary power required.	Less auxiliary power needed.

COOLING TOWERS

Function

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

- In a cooling tower water is made to trickle down drop by drop so that it comes in contact with the air moving in the opposite direction. As a result of this some water is evaporated and is taken away with air. In evaporation the heat is taken away from the bulk of water which is thus cooled.

According to the material the cooling towers may be classified as

- Timber tower
- Concrete tower.
- Steel duct type.

→ The cooling towers may also be classified as -

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

Natural Draught System

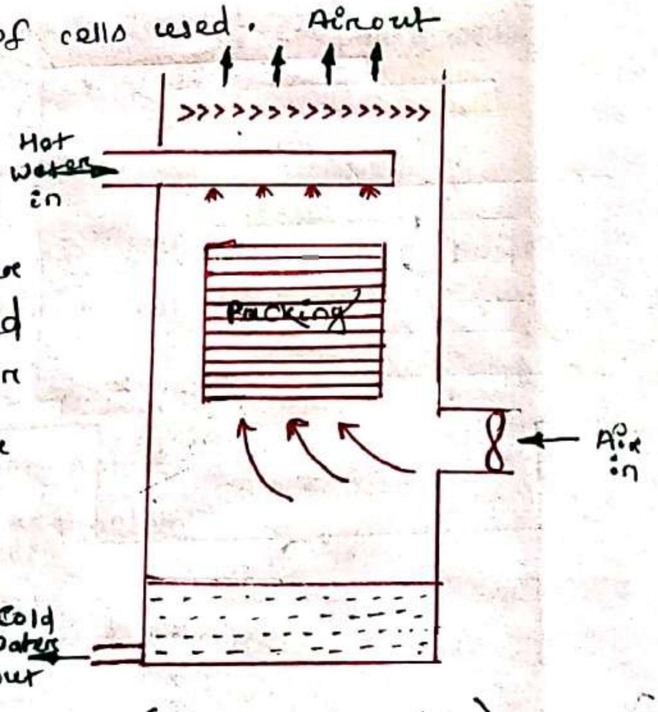
In this type of tower, the hot water from the condenser is pumped to the troughs and nozzles situated near the bottom. Through spray the water falls in the form of droplets into a pond situated at the bottom of the tower. The air enters the cooling tower from air opening provided near the base, rises upward and takes up the heat of falling water.

Mechanical Draught System

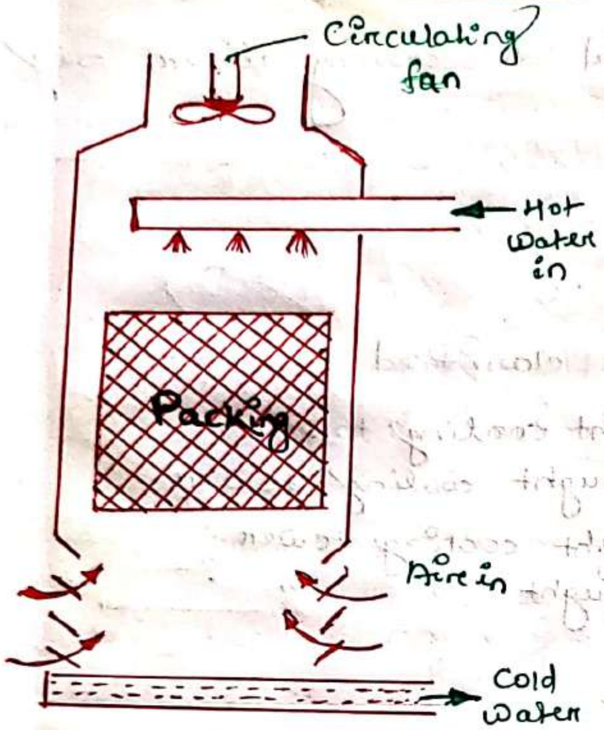
In this type of tower the draught of air for cooling the tower is produced mechanically by means of propeller fans. These towers are usually built in cells or units, the capacity depending upon the no. of cells used.

→ A forced draught cooling tower is similar to natural draught tower, but the sides of the tower are closed and form an air and water tight structure, except for fan openings at the base for the inlet of fresh air, and the outlet at the top for the exit of air and vapour.

There are hoods at the base projecting from the main portion of the tower where the fans are placed for forcing the air into the tower.



(Forced draught cooling tower)



[Induced draught cooling tower.]

Induced draught cooling tower

Here 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.

Steam Prime mover

Advantages of steam turbine

- Since the steam turbine is a rotary heat engine, it is particularly suited to be used to drive an electrical generator.
- Thermal efficiency of a steam turbine is usually higher than that of a reciprocating engine.
- Very high power to weight ratio, compared to reciprocating engines.
- Fewer moving parts than reciprocating engine.
- Steam turbines are suitable for large thermal power plants.
- In general, steam contains high amount of enthalpy. (especially in the form of heat of vapourization). This implies lower mass flow rates compared to gas turbines.
- In general, turbine moves in one direction only, with a far less vibration than a reciprocating engine.
- Steam turbines have greater reliability, particularly in applications where sustained high power output is required.

Disadvantages of steam turbine

- Relatively high overnight cost.
- Steam turbines are less efficient than reciprocating engines at part load operation.
- They have longer startup than gas turbines and surely than reciprocating engines.
- Less responsive to changes in power demand compared with gas turbines and with reciprocating engines.

Elements of steam turbine

The steam turbines are widely used in power generation, refineries and petrochemical industries.

1. Turbine Casing
2. Turbine Rotors.
   i) Disc type rotor
   ii) Drum type rotor.
3. Turbine blades.
4. Stationary blades and nozzles.
5. Shrouds.

6. Turbine Barring device
   i) turbine bearing
   ii) Radial "
   iii) Thrust "
7. Turbine seals.
   i) Shaft seals
   ii) Blade seals.
8. Turbine couplings
9. Governor
10. Lubrication system.

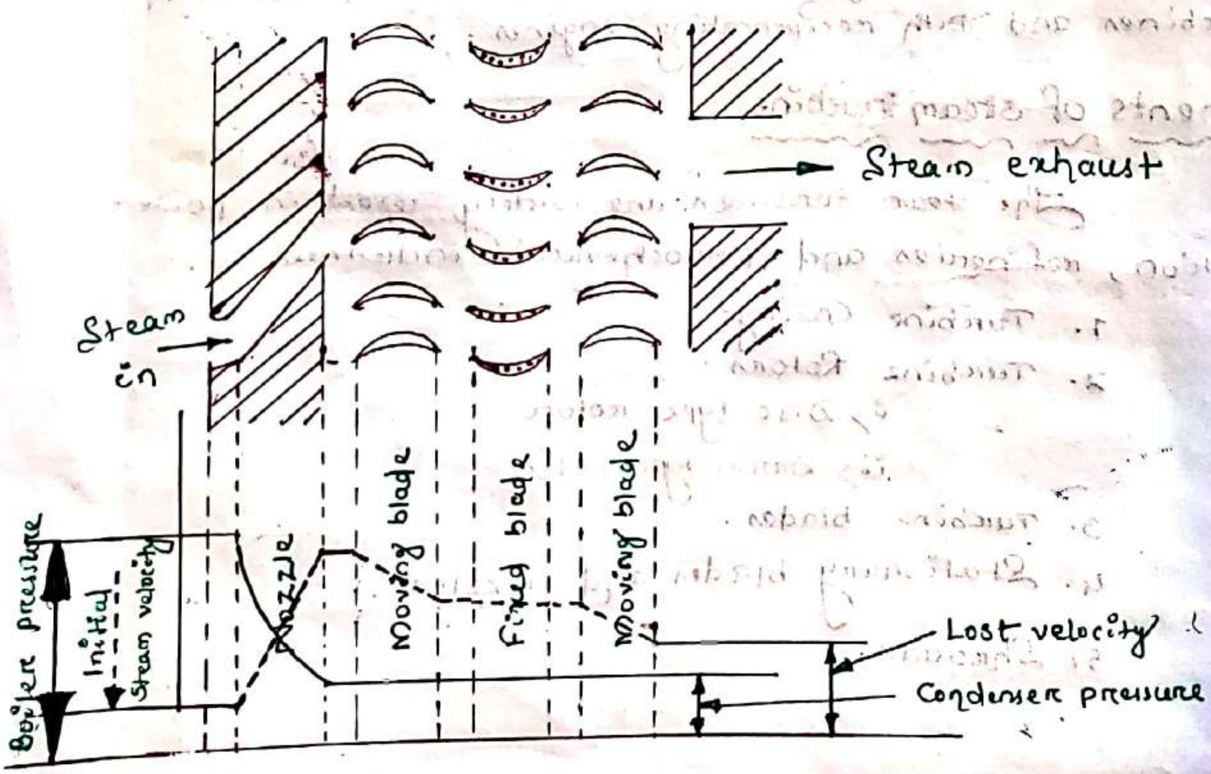
Compounding of steam turbine

- Compounding of steam turbines is the strategy in which energy from the steam is extracted in a number of stages rather than a single stage in a turbine.
- Compounding of steam turbine is used to reduce the rotor speed.

There are different methods of compoundings.

i) Velocity compounding
ii) Pressure compounding
iii) Pressure velocity compounding
iv) Reaction turbine.

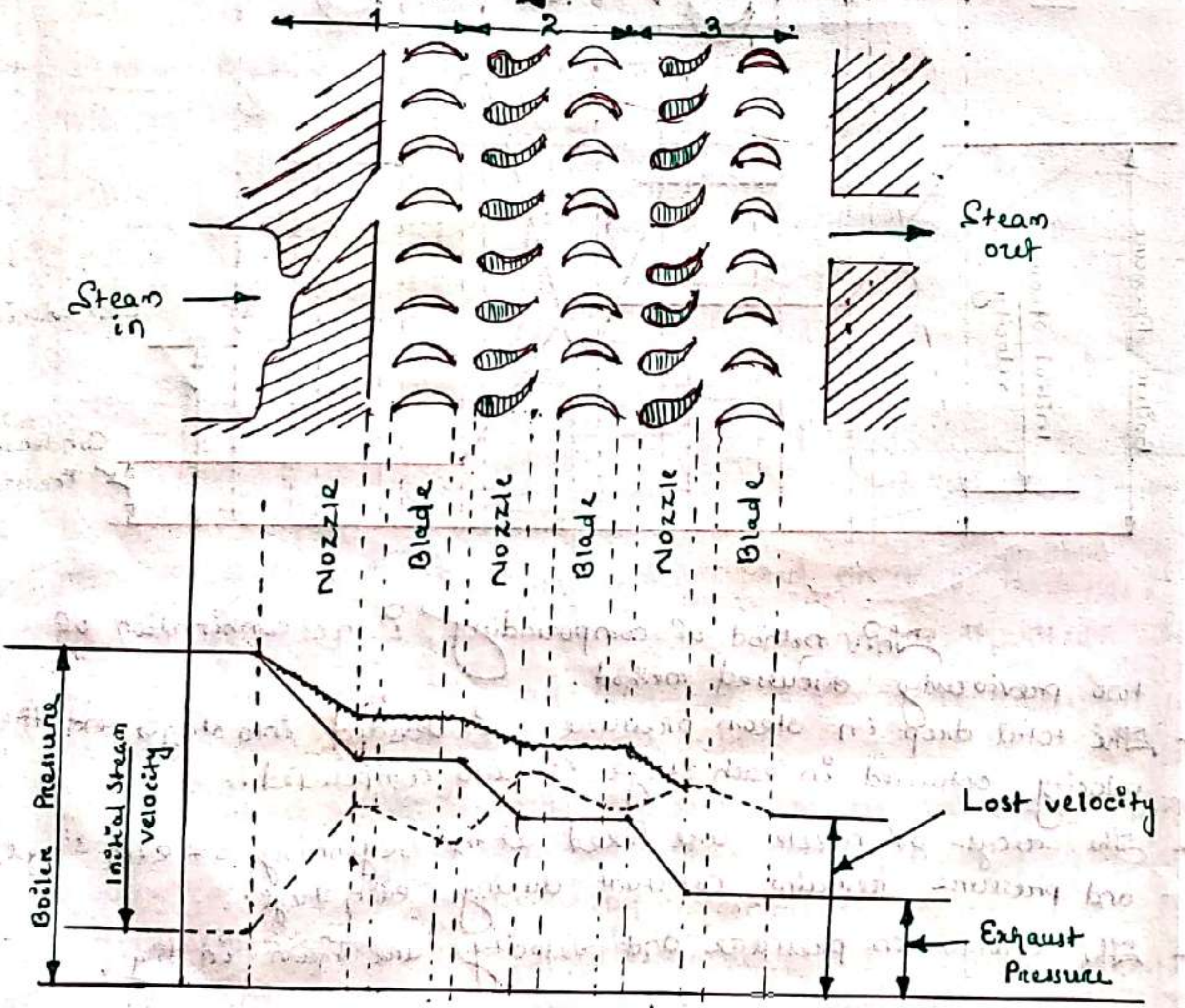
Velocity Compounding



Steam is expanded through a stationary nozzle from the boiler or inlet pressure to condenser pressure.

- So the pressure in the nozzle drops, the K.E. of the steam increases due to increase in velocity.
- A portion of this available energy is absorbed by a row of moving blades. The steam then flows through the 2nd 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 blades where again work is done on them and steam leaves the turbine with a low velocity.
- Through this method has the advantage that the initial cost is low due to lesser number of stages yet its efficiency is low.

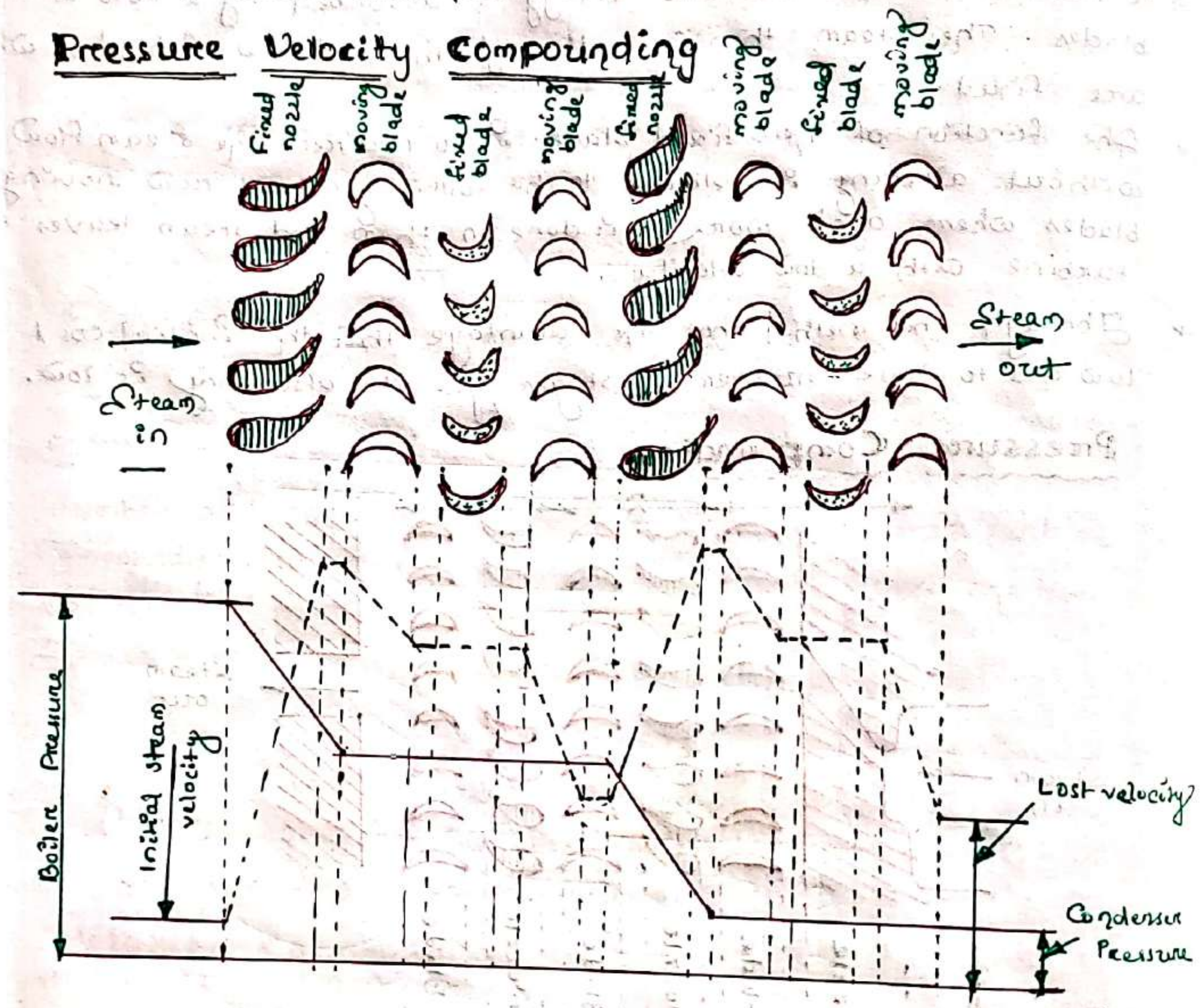
Pressure Compounding



The rings of fixed nozzles incorporated between the rings of moving blades. The steam at boiler pressure enters the first set of nozzle and expands partially. The K.E. of steam thus obtained is absorbed by the moving blade. The steam then expands partially in the 2nd set of nozzles where its pressure again falls and the velocity increases.

The kinetic energy so obtained is absorbed by the 2nd ring of moving blades. This is repeated in stage 3 and steam finally leaves the turbine at low velocity and pressure. The no. of stages depends on the number of rows of nozzles through which the steam must pass.

Pressure Velocity Compounding :-



This method of compounding is the combination of two previously discussed method.

- The total drop in steam pressure is devided into stages and the velocity obtained in each stage is also compouded.
- The rings of nozzle are fixed at the beginning of each stage and pressure remains constant during each stage.
- The changes in pressure and velocity are shown in fig.

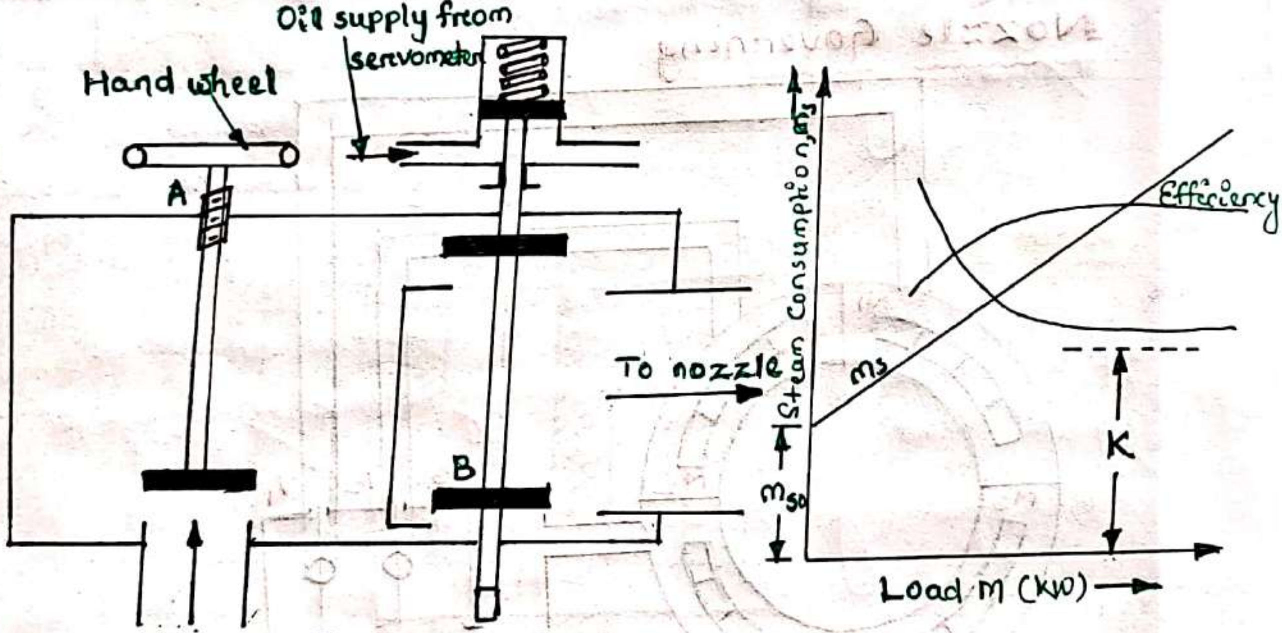
Governing Of Steam turbine

The objective of governing is to keep the turbine speed fairly constant irrespective of load.

The principal methods of steam turbine governing are :

i> Throttle governing
ii> Nozzle governing
iii> By-pass governing
iv> Combination of 1 & 2 and 1 and 3.

Throttle Governing



- This governing is the most widely used on small turbines.
- The object of throttle governing is to throttle the steam, whenever there is a reduction of load compared to economic or design load for maintaining speed and vice versa.
- To start the turbine for full load running valve A is opened.
- The operation of double beat valve B is carried out by an oil servometore which is controlled by a centrifugal governor.
- As the steam turbine gains speed, the valve B closes to throttle the steam and reduces the supply to the nozzle.
- For a turbine governed by throttling the relationship between steam consumption and load is given by the well known line Willan's line.
- This line is straight by several tests.

It is expressed as $m_s = KM + m_{s0}$

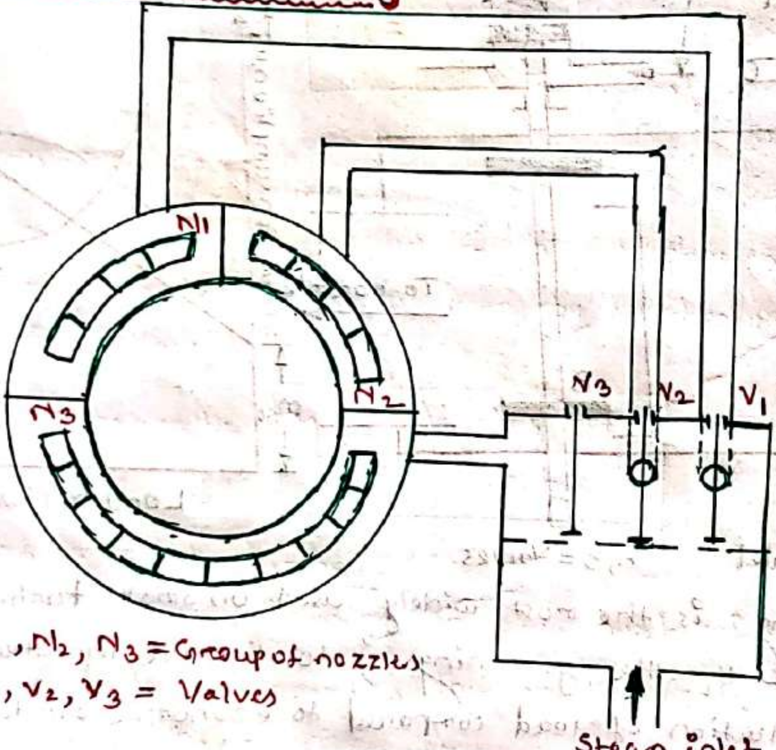
where $\dot{m}_s$ = steam consumption in kg/h at any load M
m_{s0} = steam consumption in kg/h at no load.
m_{s1} = steam consumption in kg/h at full load.
M = Any other load in kW.
M_1 = Full load in kW.
K = constant.

m_{s0} varies from about 0.1 to 0.14 times the full load consumption. The eqⁿ can also be written as

$$\frac{m_s}{M} = K + \frac{m_{s0}}{M}$$

where $\frac{m_s}{M}$ is called the steam consumption per kWh.

Nozzle Governing

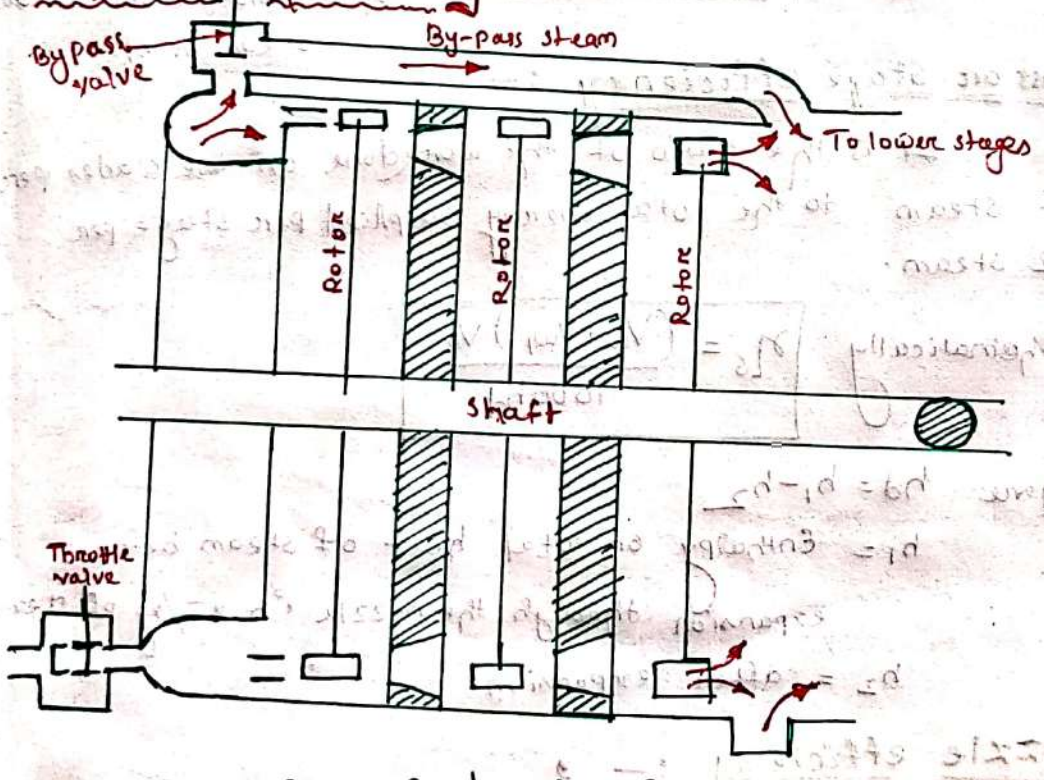


N_1, N_2, N_3 = Group of nozzles
V_1, V_2, V_3 = Valves

- Nozzle control can only be applied to the first stage of a turbine.
- It is suitable for simple impulse turbine and large units which have an impulse stage follow by an impulse-reaction turbine.
- In pressure compounding impulse turbines, there will be some drop in pressure at entry to 2nd stage when some of the 1st stage nozzles are cutout.
- When the load on the turbine becomes more or less than the designed value, the supply of steam to a group of nozzles may be varied accordingly so as to restore the original speed.

Sl. No.	Particulars	Throttle control.	Nozzle Control
1.	Throttling losses	Severe	No throttling losses.
2.	Partial admission losses.	Low	High.
3.	Heat drop available	Lesser	Larger
4.	Use	Used in impulse and reaction turbines both.	Used in impulse and reaction turbine both (if initial stage is impulse).
5.	Suitability	Small turbines.	Medium & larger turbines.

By-pass Governing



- At the maximum load, which is greater than the economic load, the additional steam required couldn't pass through the 1st stage since additional nozzles are not available.
- By-pass regulation allows for this in a turbine which is throttle governed, by means of a 2nd by-pass valve in the 1st stage nozzle.
- This valve opens when throttle valve has opened a definite amount.
- Steam is by passed through the 2nd valve to a ~~throttle valve~~ lower stage in a turbine.
- When by-pass valve operates it is render the control of the turbine governor.

- The secondary and tertiary supplies of steam in the lower stages increase the work output in these stages, but there is a loss of efficiency.
- In Reaction turbines, because of the pressure drop required in the moving blades, nozzles control governing is not possible and throttle governing plus by-pass governing is used.

Performance of steam turbine

1. **Blading or diagram efficiency :-**

It is the ratio of workdone on the blades to the energy supplied to the blade.

Mathematically

$$\eta_b = \frac{V^2 - v_1^2}{V^2}$$

V = Absolute vel. of inlet steam in m/s

v_1 = Absolute vel. of exit steam in m/s.

2. **Gross or stage efficiency :-**

It is the ratio of the workdone on the blades per kg of steam to the total energy supplied per stage per kg of steam.

mathematically

$$\eta_s = \frac{(V_\omega + v_{\omega_1}) V_b}{1000 h_d}$$

where $h_d = h_1 - h_2$

h_1 = Enthalpy or total heat of steam before expansion through the nozzle in kJ/kg of steam.

h_2 = after expansion

3. **Nozzle efficiency :-**

It is the ratio of energy supplied to the blades per kg of steam to total energy supplied per stage per kg of steam

Mathematically

$$\eta_n = \frac{V^2}{2000 h_d}$$

Chapter - 3

Nuclear Power Plant

* What are the materials used in nuclear powerplants ?

Radioactive materials found at nuclear powerplants include enriched uranium, low-level waste and spent nuclear fuel.

* What are fissile and fertile materials ?

Fertile material is a material, which are not itself fissionable by thermal neutrons, can be converted into a fissile material by neutron absorption and subsequent nuclei conversions in nuclear engineering,

Fusion Reaction	Fission Reaction
→ Some light elements fuse together with the release of energy.	→ When heavy unstable nucleon is bombarded with neutrons, the nucleus splits into fragments of equal mass and energy is released.
→ It is possible to have four thousandths of mass converted into energy.	→ About one thousandths of the mass is converted into energy.
→ Residual problem is muchless.	→ Nuclear reaction residual problem is great.
→ A possible advantage is that the total amount of radioactive material in a working fusion reactor is likely to be very much less than that in a fission reactor.	→ Amount of radioactive material in a fission reactor is high.
→ Because of ~~higher~~ lesser radioactive material, health hazards is ~~high in case of acc~~ is much less.	→ Because of higher radioactive material, health hazards is high in case of accidents.
→ It is extremely difficult to construct controlled fusion reactors.	→ It is possible to construct self sustained fission reactor and have positive energy release.
→ Needs unmanageable temp, like 30 million degrees for fusion process to occur.	→ Managable temp are obtained.
→ Reserves of deuterium, the fusion element is available in great quantity.	→ Raw fissionable material is not available in plenty.

Nuclear Reactor

Nuclear Reactor is an apparatus in which nuclear fission is produced in the form of a controlled self-sustaining chain reaction.

→ It is a controlled chain-reacting system supplying nuclear energy.

Classification of Nuclear Reactors

Nuclear Reactors are classified according to the chain reacting system, use, coolants, fuel, material etc.

1. Neutron energies at which the fission occurs.
2. Fuel moderator assembly.
3. Fuel state.
4. Fuel material.
5. Moderator.
6. Principal product.
7. Coolant.
8. Construction of core.

Essential Components of a Nuclear Reactor

1. Reactor core
2. Reflector
3. Control mechanism
4. Moderator
5. Coolants
6. Measuring instruments
7. Shielding.

Reactor Core:

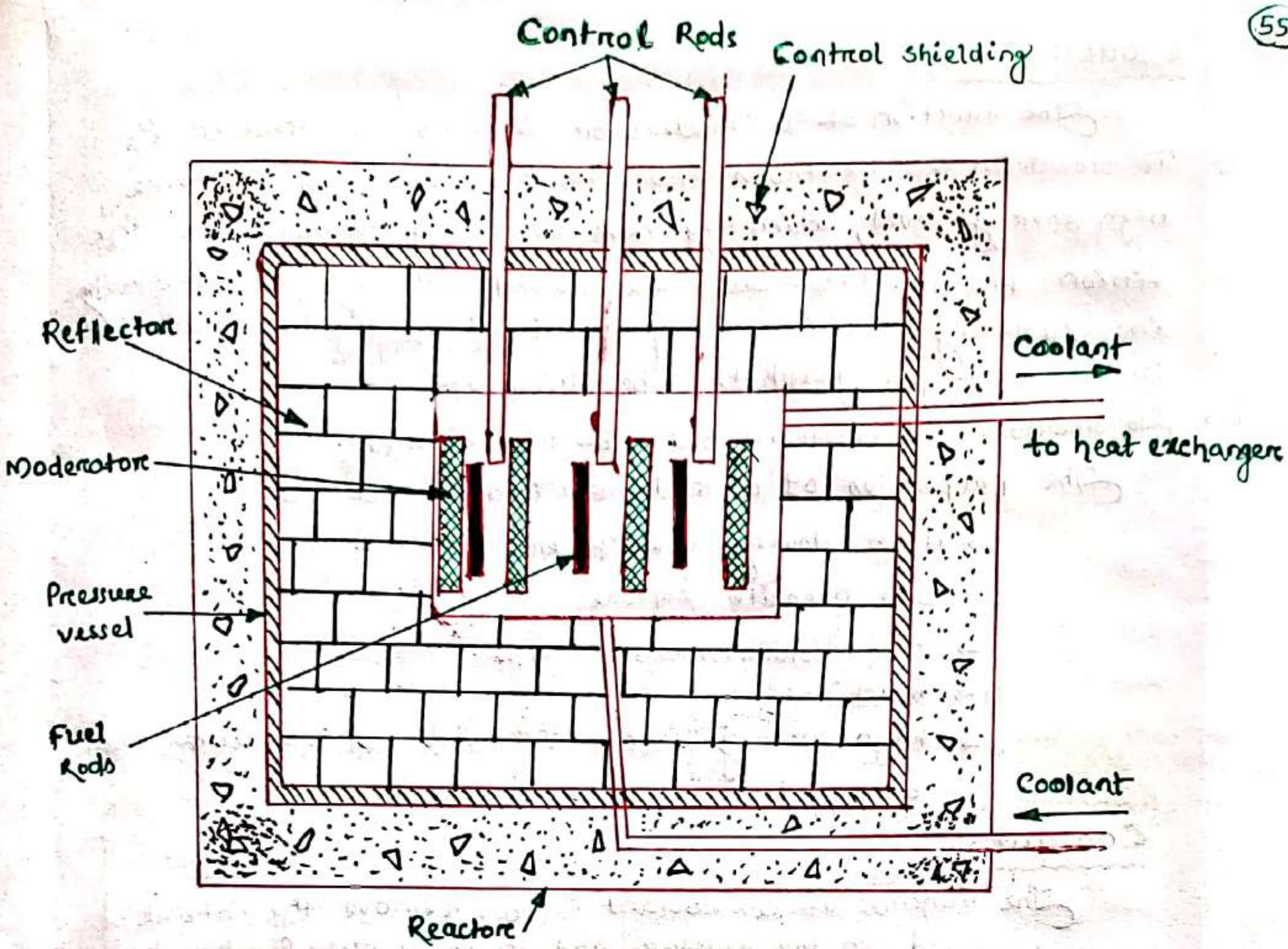
→ It is the part of a nuclear power plant where fission chain reaction is made to occur and where fission energy is liberated in the form of heat for operating power conversion equipment.

→ The core of the reactor consists of an assemblage of fuel elements, control rods, coolant and moderator.

→ Reactor cores generally have a shape approximating to a right circular cylinder with diameters ranging from 0.5 m to 15 m.

→ The pressure vessels which houses the reactor core is also considered a part of the core.

→ The fuel element are made of plates or rods are made of plates or rods of uranium metal.



[Nuclear Reactor]

- These plates or rods are usually clad in a thin sheath of stainless steel, zirconium or aluminium to provide corrosion resistance, retention of radioactivity and in some case, structural support.
- Enough space is provided between individual plates or rods to allow free passage of the coolant.

Reflector:

A reflector is usually placed round the core to reflect back some of the nutrons that leak out from the surface of the core. It is generally made of the same material as the moderator.

Control Mechanism:

It is an essential part of a reactor and serves the following purposes :-

- For starting the reactor i.e. to bring the reactor up to its normal operating level.
- For maintaing at that level i.e. keep power production at a steady state.
- For shutting the reactor down under normal or emergency conditions.

Moderator :

The function of a moderator in a nuclear reactor is

i> To slowdown the neutrons from the high velocities and hence high energy level, which they have on being released from the fission process. Neutrons are slowed down most effectively in scattering collisions with nuclei of the light elements, such as hydrogen, graphite, beryllium etc.

ii> To slowdown the neutrons but not absorb them.

The properties of a moderator in a reactor are:

1→ High slowing down power
2→ Low parasite capture.
3→ Non-corrosiveness.
4→ Machinability.
5→ High melting point for solids and low melting point for liquids.

Coolants :

The function of a coolant is to remove the intense heat produced in the reactor and to bring out for being utilised. The desirable characteristics for a reactor coolant are

1→ Low parasite capture.
2→ Low melting point.
3→ High boiling point.
4→ Low viscosity.
5→ Non-toxicity.

Measuring Instruments :

Main instrument required is for the purpose of measuring thermal neutron flux which determines the power developed by the reactor.

Shielding :-

Shielding is necessary in order to

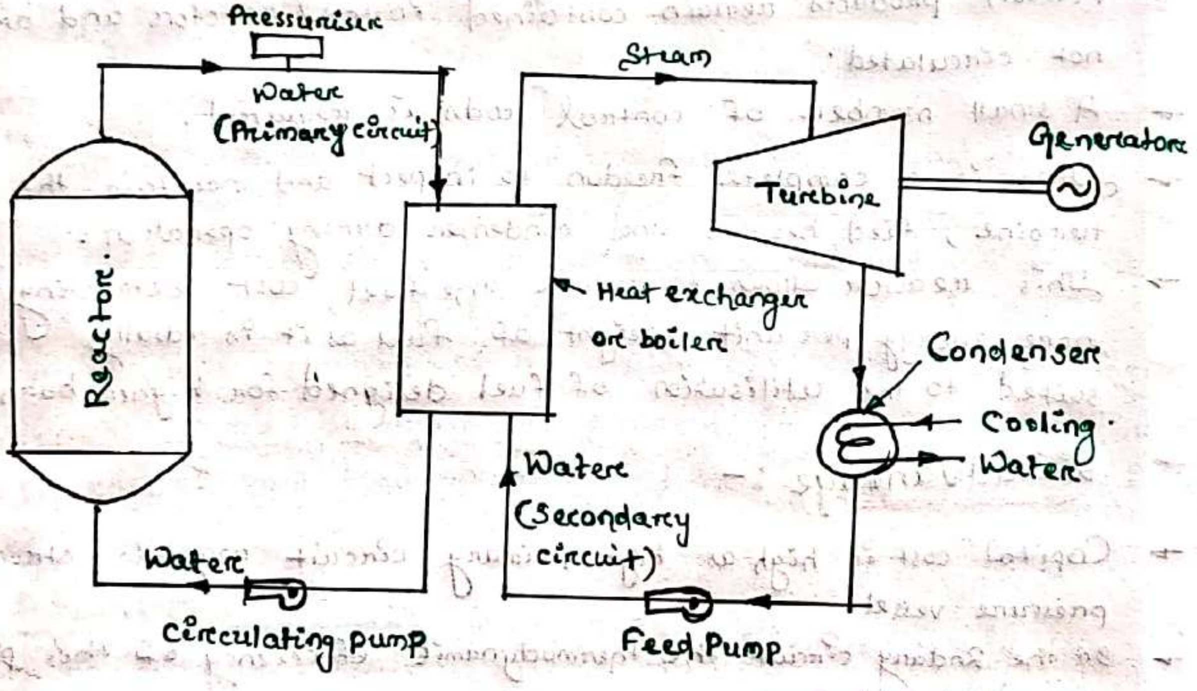
i> Protect the walls of the reactor vessel from radiation damage.

ii> Protect operating personnel from exposure to radiation.

PRESSURISED WATER REACTOR (P.W.R)

It is a light water cooled and moderated thermal reactor having an unusual core design, using both natural and highly enriched fuel. The principal parts of the reactors are :—

i) Pressure vessel.
ii) Reactor thermal shield
iii) Fuel elements
iv) Control rods.
v) Reactor containment
vi) Reactor pressuriser.



In PWR, there are two circuits 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 consists of heat exchanger or the boiler and the turbine.
- As such the steam in the turbine is not radioactive and need not be shielded.
- The pressure in the primary circuit should be high so that the boiling of water takes place at high pressure.
- A pressuring tank keeps the water at about 100 kgf/cm^2 so that it will not boil.
- Electric heating coils in the pressuriser boil some of the water to form steam that collects in the dome.

- As more steam is forced into the dome by boiling, its pressure rises and pressurises the entire circuit.
- The pressure may be reduced by providing cooling coils or spraying water on the steam.
- Water acts both as coolant as well as moderator. Either heavy water or the light water may be used for the above purpose.

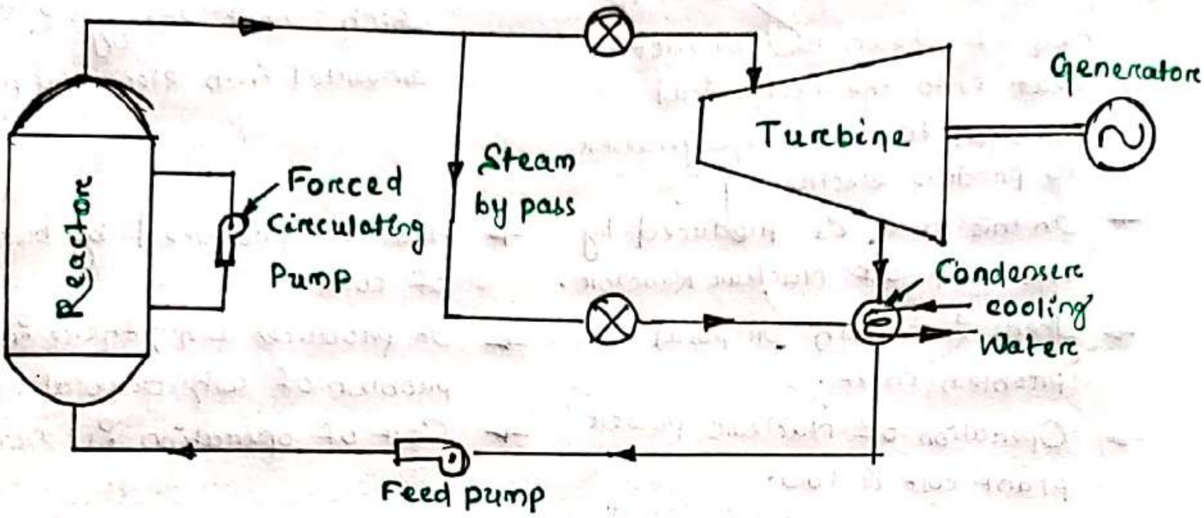
Advantage :-

- Water used in reactor (as coolant, moderator and reflector) is cheap and easily available.
- The reactor is compact and power density is high.
- Fission products remain contained in the reactor and are not circulated.
- A small number of control rods is required.
- There is a complete freedom to inspect and maintain the turbine, feed heaters and condenser during operation.
- This reactor allows to reduce the fuel cost extracting more energy per unit weight of fuel as it is ideally suited to the utilisation of fuel designed for higher burn-ups.

Disadvantage :-

- Capital cost is high as high primary circuit requires strong pressure vessel.
- In the 2ndary circuit the thermodynamic efficiency of this plant is quite low.
- Fuel suffers radiation damage and therefore its reprocessing is difficult.
- Severe corrosion problems.
- Fuel element fabrication is expensive.

BOILING WATER REACTOR (BWR)



- In a boiling water reactor enriched fuel is used.
- 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 of BWR

- Heat exchanger circuit is eliminated and consequently there is gain in thermal efficiency and gain is cost.
- There is use of a lower pressure vessel for the reactor which further reduces cost and simplifies containment problems.
- The metal temp. remains low for given output conditions.
- It is more efficient than PWR.

Disadvantages

- Possibility of radioactive contamination in the turbine mechanism should there be any failure of fuel element.
- More elaborate safety precautions needed which are costly.
- Wastage of steam resulting in lowering of thermal efficiency on part load operation.
- Boiling limits power density; only 3 to 5% by mass can be converted to steam per pass through the boiler.

Nuclear Plant	Thermal Plant
The nuclear power plant will generate electricity with the help of steam to convert heat into the mechanical rotation to rotate the generator to produce electricity	The thermal power plant in which heat energy is converted into electrical power.
In this heat is produced by the help of Nuclear Reactor.	Heat is produced by burning of coal.
There is no ash disposal problem in it.	It produces ash, there is a problem of ash disposal.
Operation of Nuclear power plant cost is low.	Cost of operation is more.
This is more economical than thermal power plant.	This is not as economical as nuclear plant.
The required space for constructing the nuclear plant is less.	Space required is more.
This doesn't affect any weather conditions.	This gets affected by adverse weather condition.
Cost of nuclear power plant construction is high.	Cost of construction is less.

The nuclear waste also known as spent fuel is kept underwater for a few years until the radiation decays and it can safely disposed off.

- Nuclear waste or radioactive waste, is what is left over of the nuclear substances that were being used.
- The harm from improperly disposed material
  - a) Affecting human population.
  - b) Affecting wildlife.
  - c) Affecting local flora.
  - d) Affecting Nuclear workers.

Various Nuclear Waste Disposal Method

* **Incineration** – Burning radioactive waste is largly done through commercially-operated incinerators developed for this purpose. Although certain large companies have the means to do this on their own.
* **Storage** – Overtime, the radioactivity of nuclear material does decay, so storing this material until it is no longer radioactive is another way to deal with proper nuclear waste disposal. This process called radioactive decay depends on the amount of materials and the radioactivity level. Therefore, storage is typically only done with radioactive waste that has a shorter half life.
* **In Water** – At nuclear sites, a common way of storing material is in water. Nearly all of these sites have a special pond or have a special pool constructed which is a place that they can store fuel that has already been used for the process of generating power.
* **Recycling** – For some radioactive material, such as previously used fuel, certain radioactive elements can be processed or extracted for reuse. Uranium and plutonium elements have long lives, so they can be separated and recycled.
* **The Ocean** – A very small amount of liquid waste that is common when waste is reprocessed to extract usable elements is released into the ocean.
* **Space Disposal** – The expense related to this is far too prohibitive when compared with the positive effects.
* **Seabed** – Another proposal was to embed waste deep with in the seabed. However, international powers decided that the risk was far greater than the benifits.

Diesel Engine Powerplant

Where supply of coal and water is not available in sufficient quantity or where power is to be generated in small quantity, Diesel engine power plants are installed.

Advantages :

- Design and installation are very simple.
- Can respond to varying loads without any difficulty.
- The standby losses are less.
- Occupy less space.
- Can be started and put on load quickly.
- Require less quantity of water for cooling purpose.
- No problem of ash handling.
- The lubrication system is more economical.
- The diesel power plants are more efficient than steam powerplants

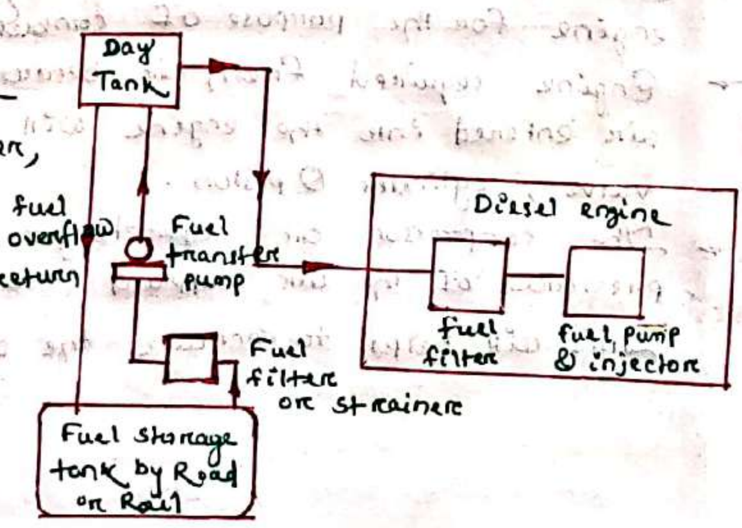
Disadvantages :

- High operating cost.
- High maintenance and lubrication cost.
- Here noise is serious problem.
- These are not economical where fuel has to be improved.
- These plants can't supply overloads contineously.
- The life of a diesel power plant is quite small (2 to 5 yrs or less) as compared to that of a steam power plant. (25 to 30 yrs)

Different systems of diesel powerplant

* Fuel Supply System :-

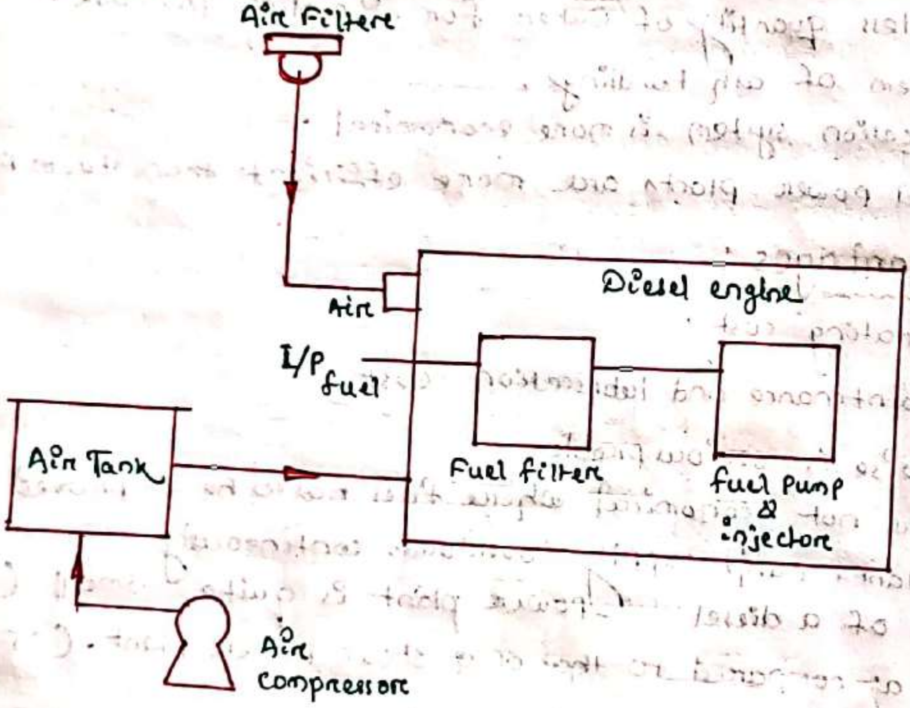
It consists of fuel storage tank, fuel filter or strainer, Fuel transfer Pump, Day tank, Heaters & connecting pipes.



First of all with the help of transportation facility available (road, rail etc) the diesel fuel stored in storage tank.

- Then this diesel fuel transfer to day tank, the function of day tank is how much quantity of diesel required for 24 hrs is store.
- If the day tank is full or overflow occurs, then excessive diesel returned to storage tank.
- The filter or strainer is used to purify diesel.
- With the help of fuel transfer pump the diesel is transfer to day tank.

* Air Intake system



This system includes air filters, air tank, compressors & connecting pipes.

- The air filters are used to supply the fresh air to diesel engine for the purpose of combustion.
- Engine required fresh air because if dust particles in the air entered into the engine will cause disastrous effect to valve, cylinder & piston.
- The compressor or supercharger is used to increase the pressure of the air supplied to the engine. This will helps to increase the output power.

* Fuel Injection System

The mechanical heart of the Diesel engine is the fuel injection system.

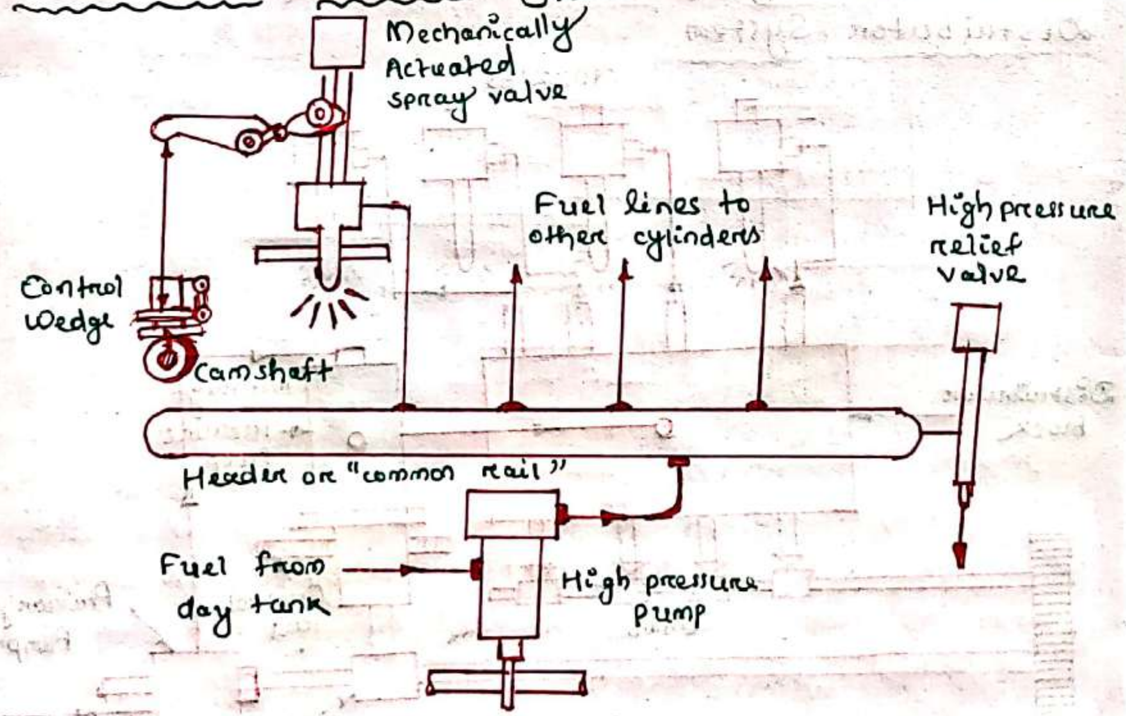
Functions of a fuel injection System

- Filter the fuel.
- Meter or measure the correct-quantity of fuel to be injected.
- Time the fuel injection
- Control the rate of fuel injection.
- Automise or breakup the fuel to fine particles.
- Properly distribute the fuel in the combustion chamber.

Types of fuel injection system

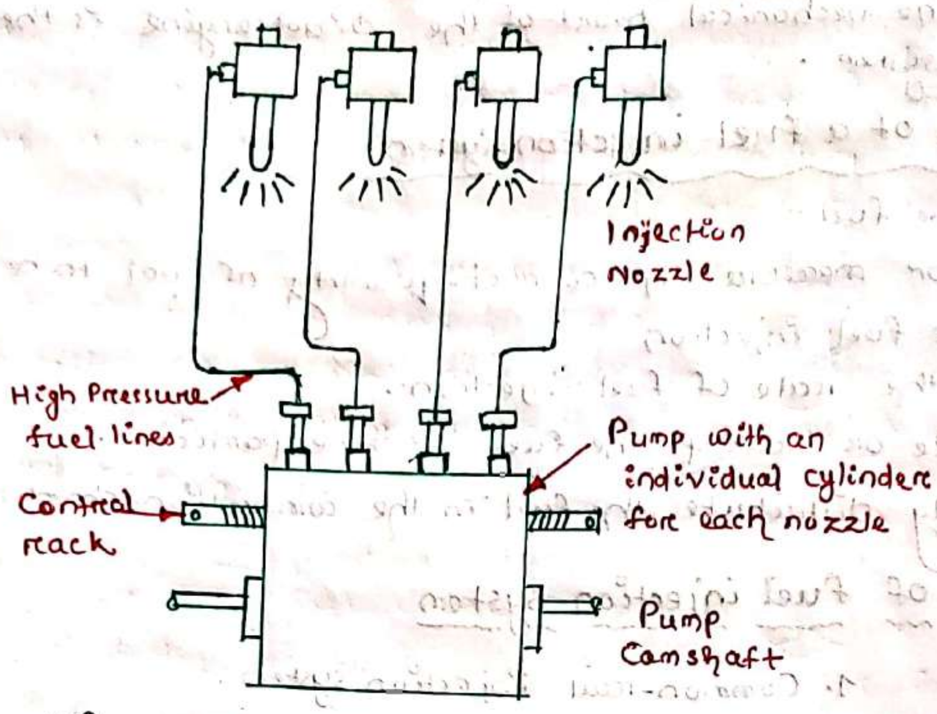
1. Common-rail injection system.
2. Individual pump injection system.
3. Distributor

1. Common-rail injection system



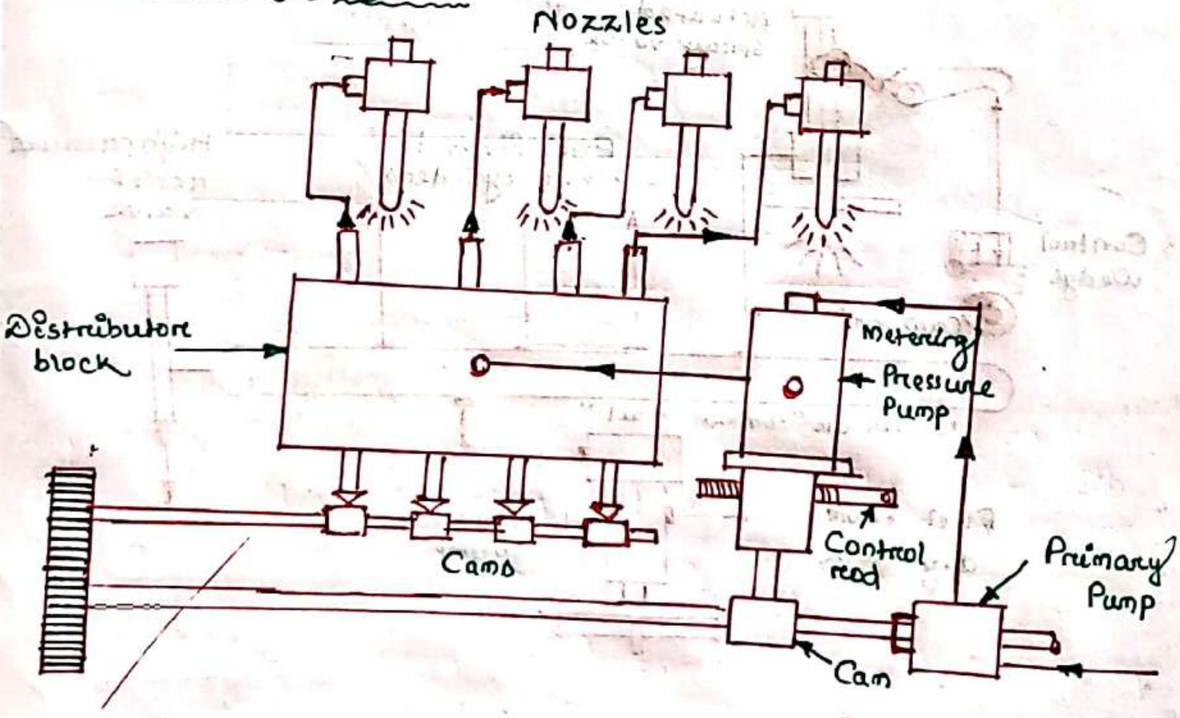
A single pump supplies high-pressure fuel to header, a relief valve holds pressure constant. The control wedge adjust the lift of mechanical operated valve to set amount and time of injection.

2. Individual pump injection system :



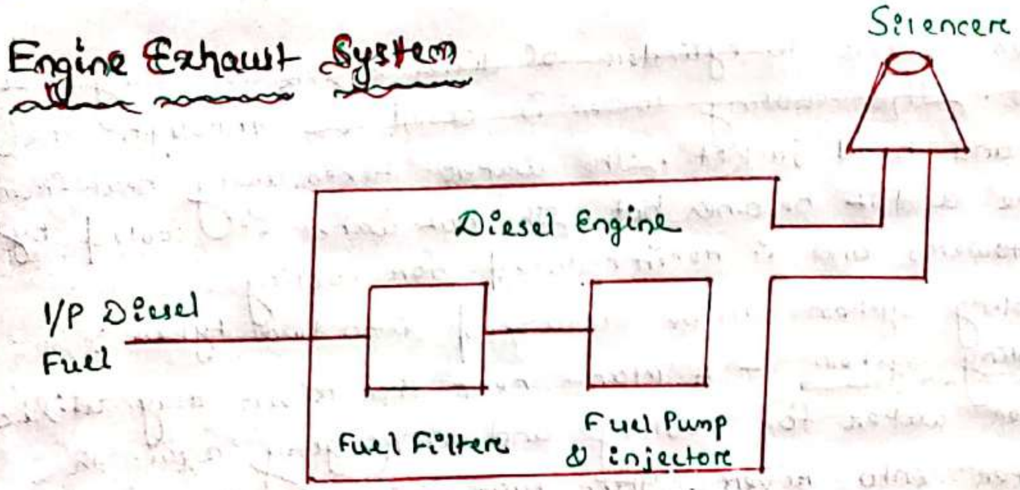
In this system an individual pump or pump cylinder connects directly to each fuel nozzle. Pump meters charge and control injection timing. Nozzle contains a delivery valve actuated by the fuel-oil pressure.

3. Distributor System



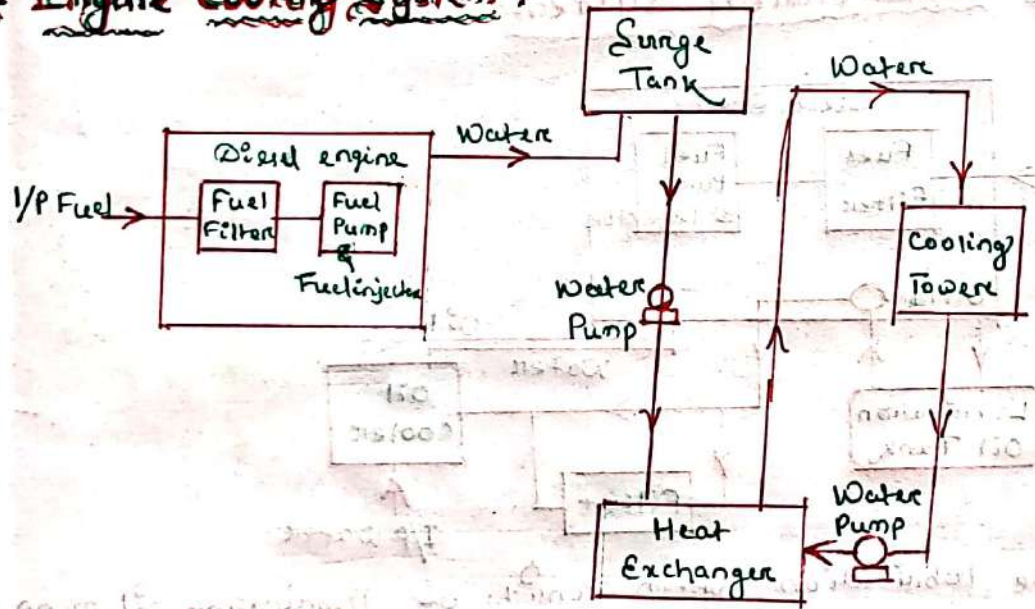
In this system, the fuel is metered at a central point ; a pump pressurises, meters the fuel and times the injection. From here, the fuel is distributed to cylinders in correct firing order by cam operated poppet valves which open to admit fuel to the nozzles.

* Engine Exhaust System



These system consists of silenceres & connecting ducts. As the temp of the exhaust gases is sufficiently high, it is used for heating the fuel oil or air supplied to the diesel engine. The exhaust gas is removed from engine, to the atmosphere by means of an exhaust system. A silencer is normally used in this system to reduce noise level of the engine.

* Engine Cooling System :



The diesel engine cooling system consists of coolant pumps, water cooling towers or spray pond, water treatment or filtration plant & connecting pipe works.

The heat produced due to internal combustion drives the engine. But some parts of this heat raise the temp. of different parts of the engine. High temp. may cause permanent damage to the m/c. Hence it is essential to maintain the overall temp of the engine to a tolerable level. Cooling system of diesel power station does exactly so.

The cooling system is required to carry heat from diesel engine to keep its temp within safe limit. The water pump circulates water ~~to cylinder of diesel engine to carry away the heat. The cooling tower is used for~~ through the cylinder and head jacket. The water takes away heat from the engine and it becomes hot. The hot water is cooled by cooling towers and is recirculated for cooling.

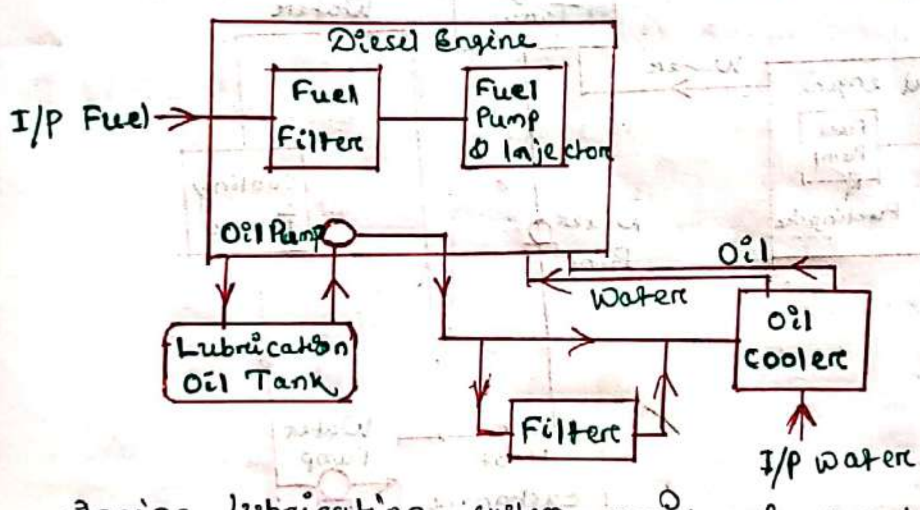
→ The cooling system can be classified into two types :

1. **Open Cooling system** – A plant near the river may utilize the river water for cooling and discharging again the hot water into river. This type of cooling system is known as open cooling system.

2. **Closed cooling system**

The cooling water is circulated again and again and only water lost due to leakage, evaporation etc. is made up by taking make up water from supply source.

* Engine Lubrication System



Engine lubrication system consists of lubricating oil pump, oil tanks, coolers, purifiers & connecting pipes. This system provides lubricating oil to moving parts of the system to reduce the friction between them wear & tear of the engine parts.

This system minimizes the water 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 coolere is provided in the system to keep the temp of the lubricating oil as low as possible.

It is then cooled through heat exchanger by means of cold water and then it is fed to the engine.

* Engine Starting System :-

The engine function of starting system is to start the engine form stand still or cold conditions by supplying compressed air.

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 shaft is provided by handles but for large diesel power station. Compressed aire is made for starting.

This system includes storage compressed air tank, self starter, auxiliary engines & electrical motors (battery) etc.

→ Starting of Small Engine :-

Small sets or small capacity of diesel engines are started manually.

→ Starting with the help of Auxiliary Engine :-

When it is started by auxiliary engine, the engine is disengaged by the main engine & started by hand. When it's warmed up, it is geared with the main engine so that it will start to rotate. After that within few seconds auxiliary engine disengaging.

→ Starting with the help of batteries :-

To start the electrical motor batteries are used, the motor is geared with diesel engine, it will start rotating with the motor and will start ~~with~~ in few seconds & as it picks up the speed the motor gets disengaged automatically. In some cases the motor works as a generator, this will further helps to charge the batteries.

→ Starting with the help of compressed air :-

A large capacity (above 75 KW) diesel engines are started with the help of compressed air. Diesel engines are started with the help of compressed air following procedure adopted.

1. First open the compressed air valve, then starting lever operated.
2. Air should be cut off in first combustion. Then open ventilating valve. Starting the engine after two or three revolutions.

Governing System

The function of the governing system is to maintain the speed of the engine constant, irrespective of load on the plant.

- The principal control devices on any engine is the governor. It governor or controls the engine speed at some fixed value while power output changes to meet demand. This is achived by the governor automatically adjusting the engine fuel pump setting to meet the desired load at the set speed.

Governing System is described in chapter 2.

CHAPTER - 5

HYDEL POWER PLANT

⇒ Hydropower or hydroelectricity refers to the conversion of energy from moving water into electricity. It is known as traditional renewable energy source.

⇒ principle of Hydro-electric power plant

The water stored in dam contains potential energy, when this water flows through penstock it has kinetic energy and when it strikes the turbine it gets converted into mechanical energy. The turbine is mechanically coupled with generator. And this generator converts mechanical energy to electrical energy

⇒ Advantages of Hydel power plant

(i) No fuel charges

(ii) Maintenance and operation charges are low

(iii) Running cost of plant is low

(iv) The plant efficiency doesn't change with age

(v) It takes few minutes to run and synchronise the plant.

(vi) No ash problem and atmosphere is not polluted

(vii) Such plant have a long life

(viii) The no. of operation required is very less.

Disadvantage :

(1) The intial cost of plant is very high

(2) It takes long time for erection of such plants

(3) The cost of transmission lines and losses will be more.

(4) The power generation is dependent on quantity of water.

classification of hydel power plant

It is classified into 3 categories

(A) According to Availability of head

(i) High head power plant

(ii) Medium head power plant

(iii) Low head power plant

(B) According to the nature of load

(i) Base load plants

(ii) peak Load plants

(C) According to quantity of water available

(i) Run off of river plant without pondage

(ii) Run - of river plant with pondage

(iii) Storage type plant

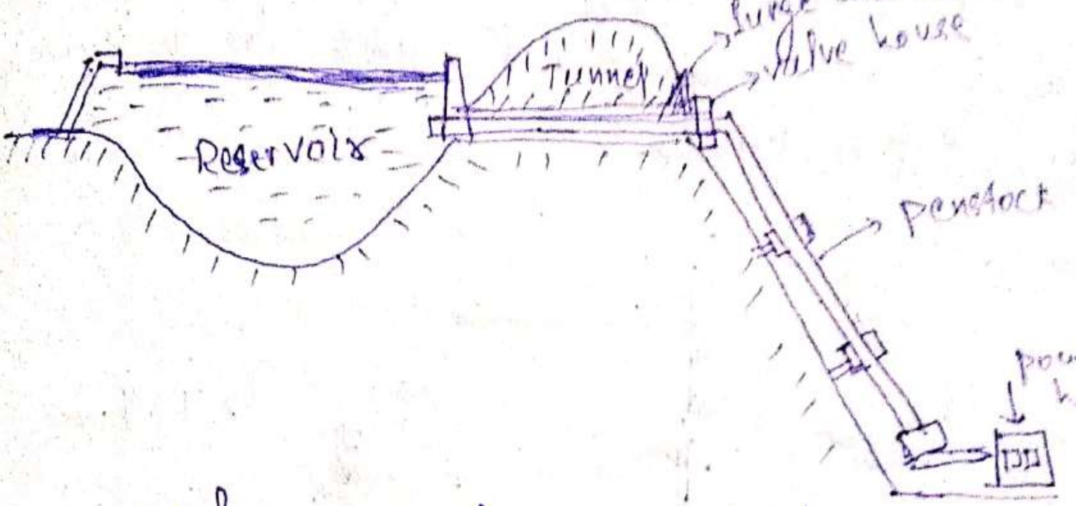
(iv) pump storage plant

(v) Mini & Micro hydel plant

Scanned with CamScanner

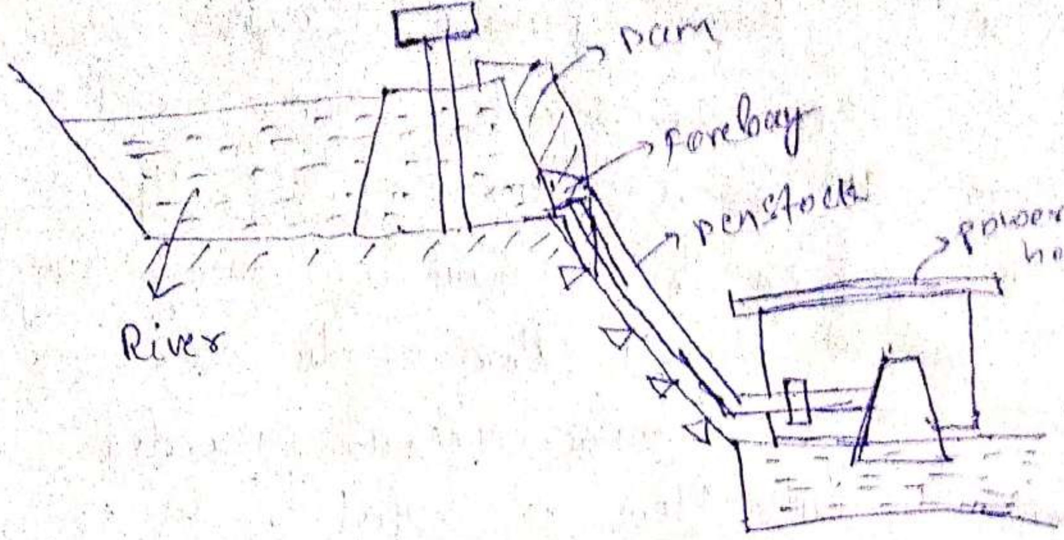
(A)(i) High head power plants

These types of plants works under 100m and above water is stored up in lakes ~~and~~ on high mountains during rainy season; the tunnel through the mountain has a surge chamber ~~excavet~~ excavated near the exit. Flow is control by valves. The pelton wheel is the common prime ~~mover~~ mover used in high power plant

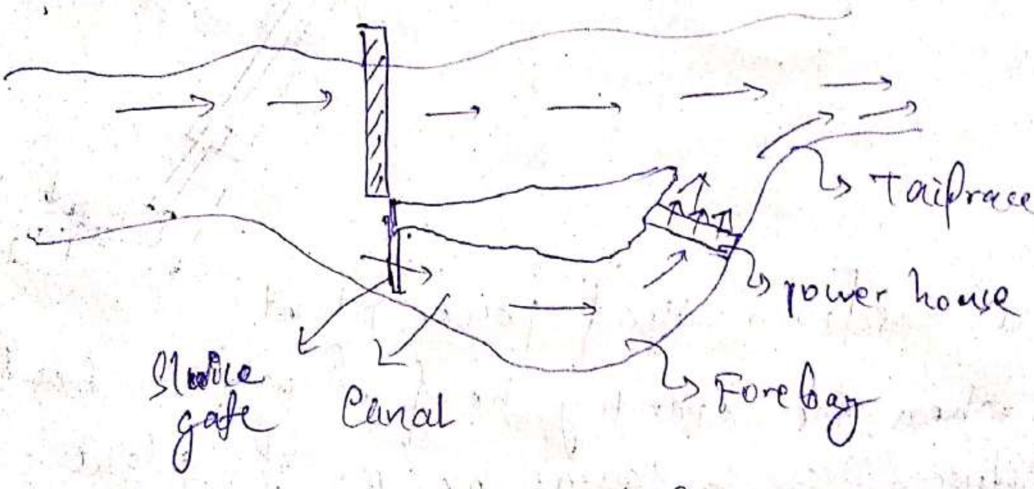


(ii) Medium Head power plant

when the operating head of water ~~lies~~ lies between 30 to 100m. This type of plant commonly uses Francis turbine. The foreboay provided at the begining of the penstock serves as water reservour. The water is generally carried in open canals from main reservour to the forebay and then to the power house through penstock.



(iii) Low head power plant
These plants usually consist of a dam across a river. This power plant uses francis turbine or Kaplan turbine



B) According to nature of load

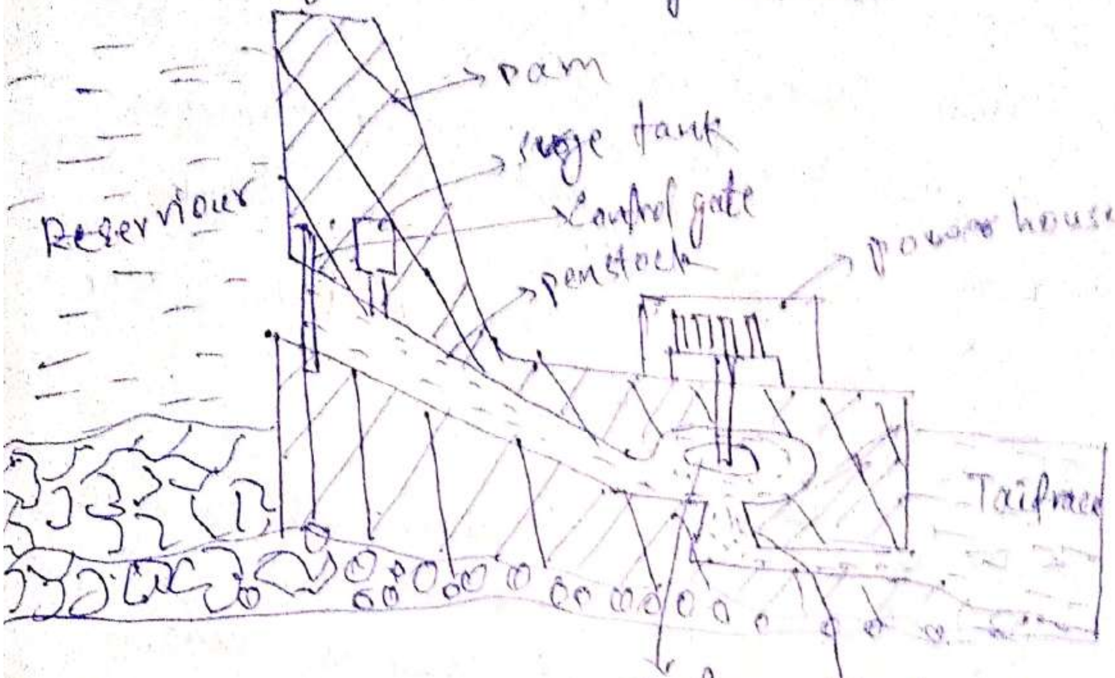
(i) Base Load plants - These plants are required to supply a constant power when connected to the grid.

(ii) peak Load plants ; The plants which can supply the power during peak loads.

c) According to quantity of water available

Storage type power plant

These are usually base load plants. It has a large reservoir which stores the excess water during the flood days to use it during summer.



Dam

· A dam is constructed across a river which acts as an artificial storage reservoir

Spillway - The excess water from dam is discharges through spillway at a permissible level

penstock - It is a device which is used in hydroelectric power plant for the purpose of flow of water. The water flows from dam towards turbine with help of penstock. It converts the potential energy to kinetic energy

Surge tank - It is a device Connected Between dam and power house. when the load on power plant decreases then the valve reduces the discharge of water. Due to sudden reduction in water discharge causes increase in pressure of water in penstock. Due to high pressure penstock may damage ; therefore a surge tank helps by storing this rejected water immediately.

valve house - It is installed near power house its function is to ~~Strat o~~ Start or stop the flow of water towards turbine

Power house - It's main function is to produce electrical power. For that purpose the turbine is mechanically coupled with generator. The mechanical energy is converted into electrical energy through generator.

prime mover (turbine) - It converts kinetic energy of water into mechanical energy

Draft tube - It is used in hydroelectric power plant near the turbine. Its main function is to ~~press the water and its pressure.~~ ~~increases~~ reduce the velocity of discharged water to minimize the loss of kinetic

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energy ite of the outlet.

Tail Race - After generation the remaining water discharge to river or lake through tailrace. From ground level to the turbine some height is maintained to discharge the water

SAMPLE QUESTIONS
Short question

1) Define captive power station?
2) write the various sources of energy?
3) Draw P-V & T-S diagram of Rankine cycle?
4) Define Specific Steam Consumption?
5) write the function of Economiser?
6) write the function of Superheater?
7) write the function of Draught system?
8) what do you mean by Compounding of turbine?
9) Define thermal efficiency & stage efficiency?
10) write the function of steam Condenser?
11) write the function of Cooling Tower?
12) write the various components of Nuclear reactor?
13) what do you mean by fissile ~~and~~ material
14) write the various Component of diesel power plant?

Long question

1) Explain Central and Captive Power plant
2) Explain Rainkine cycle with P-V and T-S diagram?
3) Explain Reheat Cycle?
4) Explain Combination of Reheat and Regenerative cycle.
5) Explain various Sources of energy?
6) write down various draught System used in power plant?
7) why Compounding of Steam turbine is necessary? Mention various types of Compounding describing one of them in details?
8) write down the function and classification of condensers. Draw the Sketch of a Surface Condenser.
9) Explain with neat Sketch about an artifical cooling tower.
10) Compare between nuclear plant and thermal power plant.
11) Explain how nuclear waste is disposed of?
12) with neat Sketch explain throttle governing of steam turbine?

13) With neat sketch explain the working of boiling water reactor plant?

14) Explain the fuel storage and supply system of diesel power plant?

15) State the advantages and disadvantages of hydroelectric power plant?

16) Explain the requirement of good condensing system?

17) Draw the layout of a thermal powerplant and discuss its component in detail?

18) Draw and explain the hydel power plants.