LECTURE NOTES

ON

POWER STATION ENGINEERING

PREPARED BY

MR. DEBIPRASAD PATRA

(DEPT. OF MECHANICAL ENGG.)

GOVERNMENT POLYTECHNIC, PURI

UNIT-01 INTRODUCTION

Energy

→ Energy is defined as the ability of doing work.
→ Energy is the capacity of doing work.
→ The unit of energy - Joule (J)
- Kilo Joule (KJ)

→ Energy makes change possible.
→ There are different kinds of energy, those are

- Light energy
- Heat energy
- chemical energy
- Kinetic energy
- Electrical energy

Power

→ The power is defined as the rate of energy delivered per unit time.
→ In other word power is defined as the rate of doing work.
→ Mathematically.

$$P = \frac{W}{\Delta t}$$

→ The unit of power - watt (W)
- Kilowatt (KW)

Note:-
→ 1 watt = 1 Joule/sec
→ 1 KW = 1 KJ/sec
→ 1 KW = 1000 W = 10^3 W

- Source of Energy

There are various source of energy are as follows

1. Fuels
2. Energy stored in water
3. Nuclear energy
4. wind power
5. solar energy
6. Tidal power
7. Geothermal energy
8. Thermoelectric power

- Fuels :-

→ Fuels may be chemical or nuclear.

→ A chemical fuel is a substance which releases heat energy on combustion.

→ The principal combustion elements of each fuel are carbon and hydrogen.

→ The fuels can be classified into following types

(a) solid fuels

(b) Liquid fuels

(c) Gaseous fuels

→ The fuels which occurs in nature are called as primary fuels.

→ The fuels which are derived from the primary fuels are known as prepared or secondary fuels.

pes of fuels

	Primary	Secondary
Solid Fuels	→ wood	→ coke
	→ coal	→ Charcoal
	- Peat	→ Briquetted coal
	- Lignite	
	- Bituminous	
	- Anthracites	

	P.F	S.F
→ Liquid fuels	→ petroleum	→ Gasoline → Diesel → petrol → Kerosene → Alcohol
→ Gaseous Fuels	→ Natural gas	→ petroleum gas → producer gas → Coal Gas → Blast furnance gas etc.

Solid fuels :-

ex- Coal, Coke etc.

- Coal

→ The main constituent of coals are :- carbon, hydrogen, oxygen, nitrogen, sulphur, moisture, ash etc.

→ The different stages of coals are

(i) Peat
(ii) Lignite
(iii) Bituminus
(iv) Anthracites

(i) Peat

→ It is the first stage in the formation of coal from wood.

→ It contains huge amount of moisture and therefore it is dried for 1-2 months before it is put to use.

(ii) Lignite / Brown coal

→ These are the 2nd stage of formation of coal.

→ These are the intermediate stages between peat and Bituminus.

→ They have clay like apperance with high moisture, high ash and low heat containt.

→ These types of coals are difficult to transport because they can brake easily.

→ They burn with smooky flame.

(iii) Bitumirous

→ These are the 3rd stage of formation of coals.

→ After burning this type of coal, it give yellow and smoky flames.

→ It has high percent of volatile matter.

(iv) Anthracites

→ It is the last stage in the formation of coal from the wood.

→ It has very high calorific value.

→ It has a shining black colour.

→ It has a very high percent of carbon contain

Liquid Fuels :-

→ The chief source of liquid fuel is petrolium which is obtained from wells under the earth crust.

→ Liquid fuels have more advantages as compare to solid fuels. in the following aspects.

- It requires less space for storage.
- Higher calorific value.
- Easy control of consumption
- cleanliness
- No ash problems
- Easy to handaling and transportation.

● Petrolium

→ petrolium is probably originated from organic matter like living animals after death by bacterial action.

→ It consists of a mixture of gases, liquids and solid hydrocarbon with small amount of nitrogen and sulphur compound.

→ Important property of liquid
→ specific gravity
→ Flash point
→ Fire point
→ Volatility
→ Pour point
→ Viscosity
→ octane number etc.

Gaseous Fuels :-

ex- Natural Gas
Coal Gas

• Natural Gas
→ The main constituents of natural gases are methane and ethane.
→ It has calorific value of 21000 kJ/m^3.
→ It is used with oil for I.C engine.

• Coal Gas.
→ The main constituents of coal gas are hydrogen, carbon monoxide, hydrocarbon.
→ It is prepared by carbonisation of coal.
→ It is normally used in boiler and sometime used for commercial purpose.

• Energy stored in water :-
→ The energy contained in flowing steam of water is a form of mechanical energy.
→ It may exist as the kinetic energy of a moving steam or potential energy at some elevation or height with respect to the ground level or bottom level.
→ water power is quite cheap and easily available in everywhere.

- **Nuclear Energy :-**

→ Nuclear energy is defined as the energy that is present in the core of atom.

→ It is cheaper than the power generated by conventional source and also available in a very large quantity.

→ One of the outstanding facts about nuclear power is the large amount that can be released from small mass of active material

→ The advantages of Nuclear power
  - practically independent of geographical factor.
  - No combustion products
  - clean source of power
  - fuel transportation and storage facilities not required.

- **Wind power :-**

→ wind power is defined as the power that is obtained from the flowing wind energy

→ wind turbines are used to generate electricity

→ The wind mills are of following types
  (a) The multi-blade turbine wind mill
  (b) The high-speed propeller type
  (c) The rotor

→ The propeller and rotor type are suitable for the generation of electrical energy.

- **Solar Energy :-**

→ It is defined as the energy obtained from the ray of sun.

→ Sun is the prime source of energy.

→ It is the power or heat that comes from the sun.

→ Solar pannels are used for solar energy.

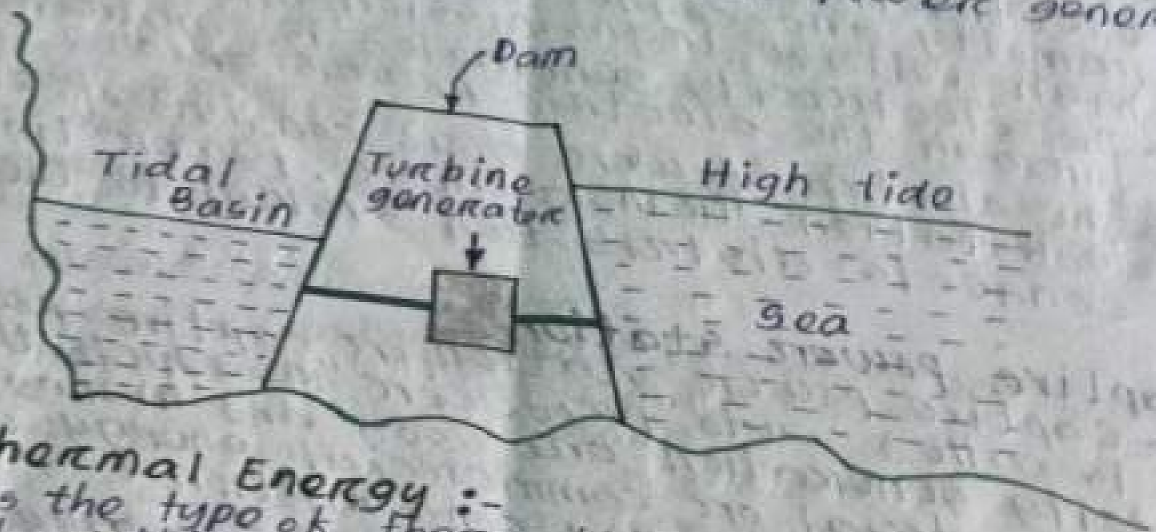
→ The solar energy is non-consumable energy

→ solar energy is easily available in everywhere.

Tidal Energy :-

→ The tidal power or tidal energy is produced by sea or ocean during the rise and fall of the tides.

→ The use of tides for electric power generation.



Geothermal Energy :-

→ It is the type of thermal energy and it is the heat within the earth.

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

- heat energy is transfor to a working fluid which operates the power cycle.
- the hot geothermal water or steam use to operate the turbine directly.

Thermo-electric Power :-

→ It is defined as the rate of change of the thermo electro motive force of a thermocouple with temperature.

- Concept of central and captive power plants

Central power station

→ A central power station is a centralised electricity generation facilities located remotely and connected to a network of high voltage transmission line.

→ The electricity generated is distributed through the electric power grid.

→ The electric power grid consists of electric substation, transformers, power lines that connects distribution system to the consum

Captive power station

→ Captive power station or captive power pla is called auto producer in which the electricity generation are used and managed by their own energy commercial energy used for industrial or commercial consumption

→ captive power plants are generally used by power intensive industries where continuity and quality of energy supply are crucial or important.

→ For example
allumininum smelters
steam and chemical plants etc.

Classification of power plants

The principal types of power plants are

1. steam or thermal power plant
2. IC engine power plants
3. Gas turbine power plants
4. Hydro electric power plants
5. Nuclear power plants.

① Steam Power Plant

→ The steam power plants are powered by coal, oil and nuclear elements.

→ The steam is generated in the boiler of the steam power plants.

→ The steam is utilised to drive the turbines or engine which are couple to a generator to get electricity.

→ In nuclear station the heat is produced in a reactor which replaces the conventional boiler.

② IC engine power plants

→ In these plants spark ignition or compression ignition engines are used as prime mover to drive the electric generators.

→ In SI engine petrol is used.

→ The CI engines using diesel fuels are most commonly used.

③ Gas turbine plants

→ A gas turbine plants works on gas cycle and contains gas turbine, auxilary lubrication, fuel control system, oil cooler, reheater, regenerator etc.

④ Hydro electric power plant

→ This type of plants makes use of the energy of water stored at an elevation or height and allowed to drop to a lower levels.

→ The electric generation is driven by a water turbine, thus producing electricity.

→ A hydroelectric plant includes of turbines governing gear, coolant circulator

Importance of electric power in day to day li[fe]

→ The electricity we used in our day to day li[fe] is a secondary source of energy.

→ The electricity is produced by converting basic and natural energy sources such as coal, natural gas, solar energy, wind energy into electrical energy.

→ The use of electricity has a importance in our day to day life activities such as

- cooking
- heating of water
- Lighting
- Air conditioning
- domestic application
- cleaning
- entertainments etc.

→ In medical ground the electricity is used for the treatment of many disease through the use of electrical therapy devices.

→ In addition to the electricity are used fo[r] scan, x-rays, MRIs that has an huge impac[t] and reduction of death rates.

→ In transport electricity is used in fast trains, metros etc.

→ Electricity plays a major role in industria[l] growth and commercial sectors, in which it operates small machines, lighting for buildings, computer fax machines, elevators (lift) etc.

Overview of method of electric power generation

→ The electric power is generated by various means depending upon the type of energy.

→ The major methods of electric power generations are

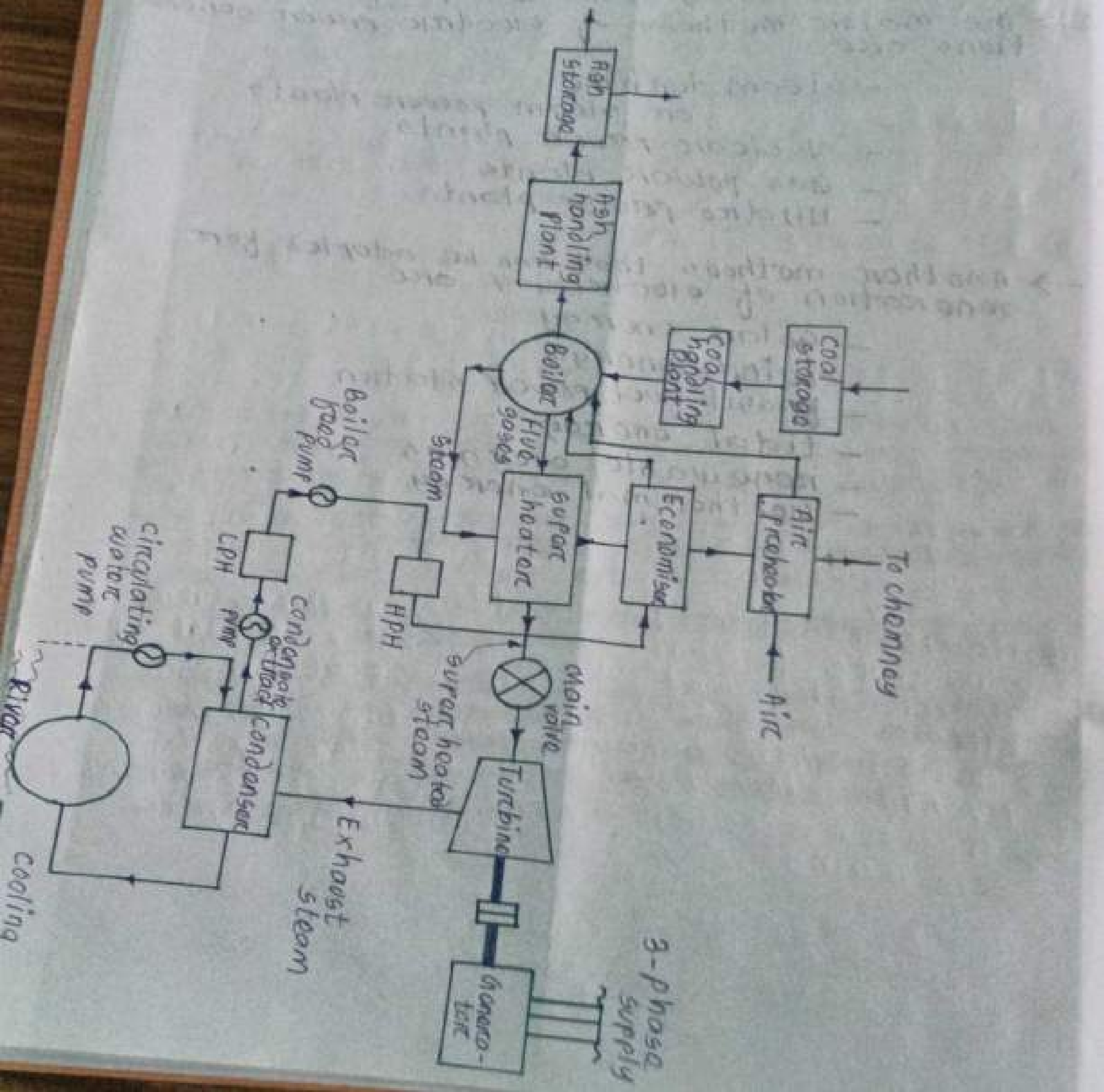
- steam turbine or steam power plants
- Nuclear power plants
- Gas power plants
- Hydro power plants.

→ Another methods that can be adopted for generation of electricity are

- Solar energy
- wind energy
- fossil fuel power station
- tidal energy
- renewable energies
- Geothermal energy

UNIT-02 THERMAL POWER STATIONS

Layout of a modern steam power plant



The layout of a morden steam power plants consists of four circuits.

① Coal and Ash circuits
② Air and Gas circuits
③ Feed water and steam flow circuits
④ Cooling water circuits

① Coal and Ash circuits

→ The coal arrives at the storage yard and after necessary handling passes on to the furnance through the feeding device.

→ Ash resulting from the combustion of coal is collected at the back of the boiler and is more to ash storage yard through the ash handling plant.

② Air and gas circuits

→ The air is taken in from the atmosphere through the action of a forced and powerful fan or induced draught fan and passes on to the furnance through the air preheater, where it has been heated by the heat of flue gases which passes to the chimney through the preheater.

→ The flue gases coming out of the boiler passes through the dust catcher device, through 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 flow circuit condensate leaving the condenser in first heated in a closed low pressure feed water heater through the extracted steam. it then passes through the low pressure heater and then high pressure heater before going into the boiler through the economiser.

→ A part of steam and water is lost while passing through the different components and supplying additional feed water.
→ The feed water should be cleaned and purified before use.

④ Cooling water circuits
→ The cooling water supply to the condenser helps in maintain a low pressure in it.
→ The water may be taken from natural source lake, river, sea) and same water may be cooled and circulated again again.

Steam Power Cycle

In general the thermal power plants may work on vapour power cycle or gas power cycle.

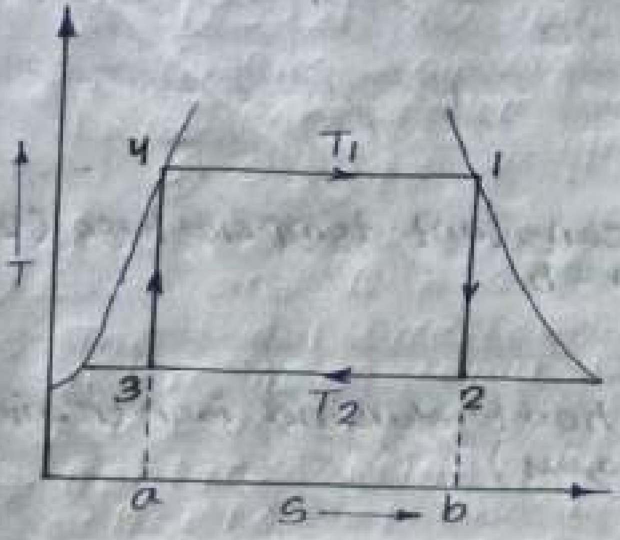
① Vapour Power cycle
  (i) Rankine cycle.
  (ii) Reheat cycle
  (iii) Regenerative cycle.
  (iv) Binary vapour cycle

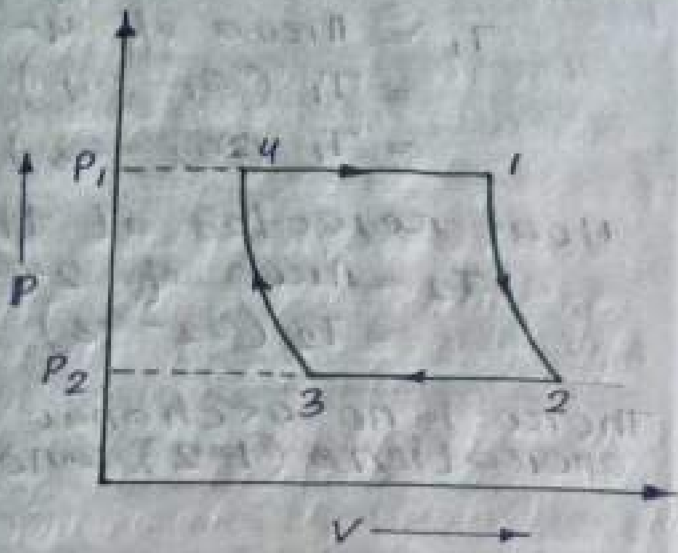
② Gas power cycle.
  (i) otto cycle
  (ii) Diesel cycle
  (iii) Dual combustion cycle.
  (iv) Gas - turbine cycle

  ⓐ open cycle
  ⓑ closed cycle.

Carnot Vapour Power Cycle

→ PV and TS Diagram





① operation (4-1)
In this process 1 kg of boiling water at a temperature of T_1 is heatere from wet steam having dryness fraction of x_4. Thus heat is absorbed at constant temperature T_1 and pressure P_1 during the operation.

② operation (1-2)
During this operation or process the steam is expanded isentropically to temperature T_2 and pressure P_2. The point 2 represents the condition of steam after expansion.

③ operation (2-3)
During this process heat is rejected at constant pressure P_2 and constant temperature t_2. As the steam is oxusted it become watter and cooled from 2 to 3.

④ operation (3-4)
In this operation the wet steam at point 3 compressed isentropically dill the steam regain its original temperature T_1 and pressure P_1. Hence the cycle is completed.

Referring to the T-S diagram

Heat supplied at the constant temperature (4-1)

T_1 = Area of 4-1-b-a

$= T_1 (S_1 - S_4)$

$= T_1 (S_2 - S_3)$

Heat rejected at the constant temperature (2-3)

T_2 = Area of 2-3-a-b

$= T_2 (S_2 - S_3)$

There is no exchange of heat during isentropic operations (1-2) and (3-4)

Net workdone

= Heat supplied - Heat rejected

$= T_1 (S_2 - S_3) - T_2 (S_2 - S_3)$

$= (T_1 - T_2)(S_2 - S_3)$

∴ Efficiency of carnot cycle

$$\eta = \frac{\text{workdone}}{\text{Heat supplied}}$$

$$= \frac{(T_1 - T_2)(S_2 - S_3)}{T_1 (S_2 - S_3)}$$

$$= \frac{T_1 (S_2 - S_3) - T_2 (S_2 - S_3)}{T_1 (S_2 - S_3)}$$

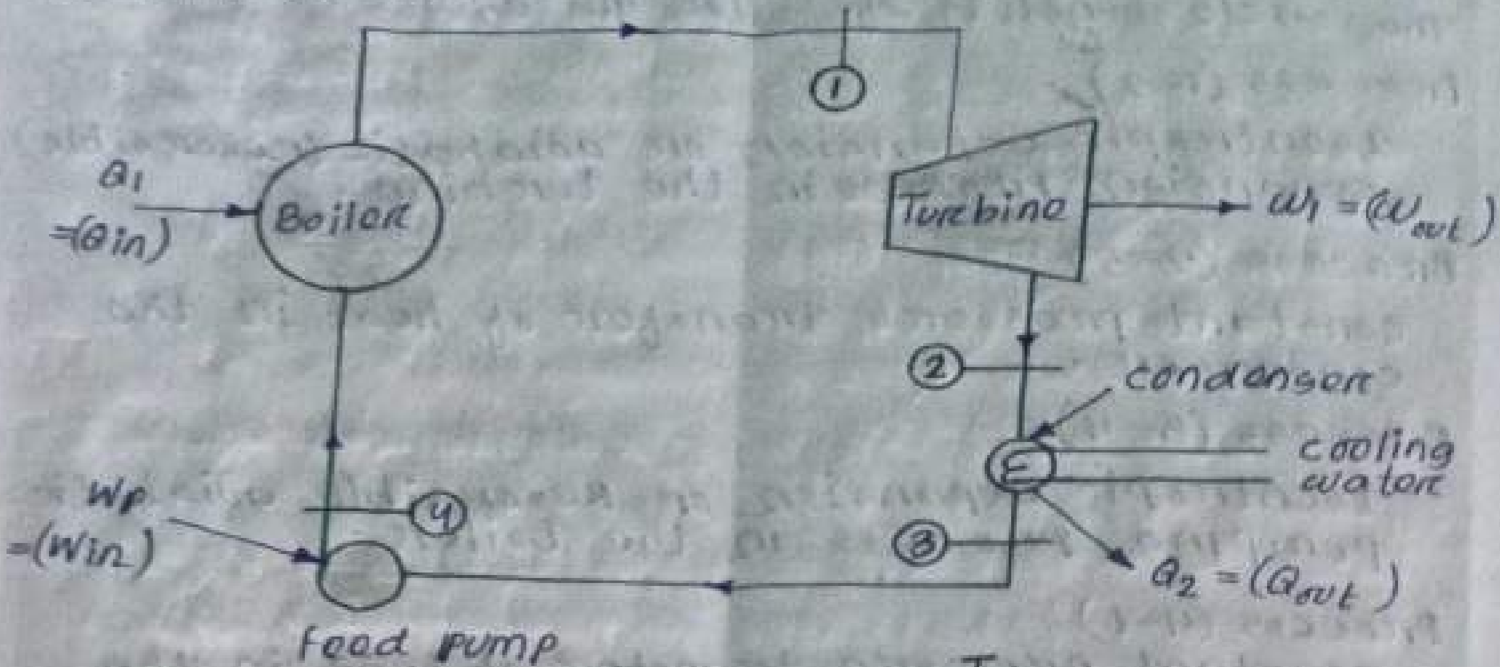
$$= \frac{T_1 - T_2}{T_1}$$

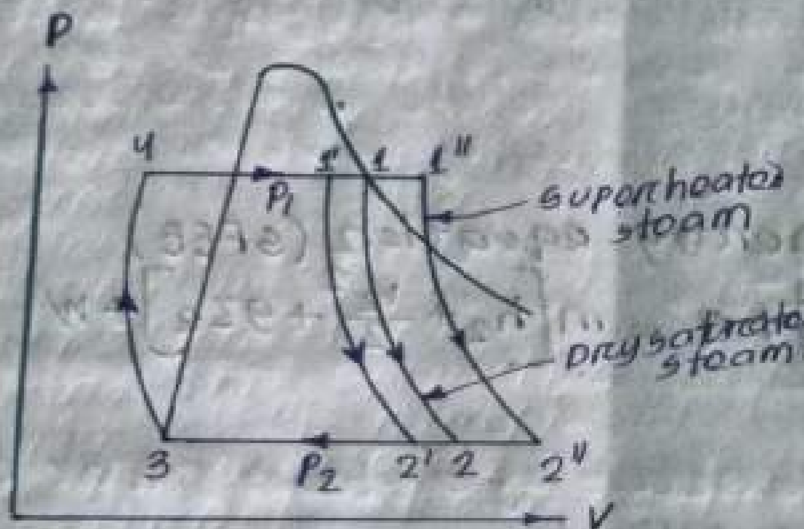
$$= \frac{T_1}{T_1} - \frac{T_2}{T_1}$$

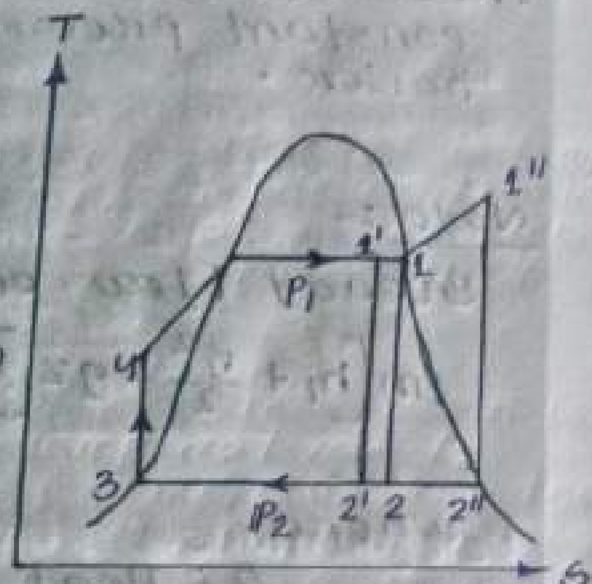
$$= 1 - \frac{T_2}{T_1}$$

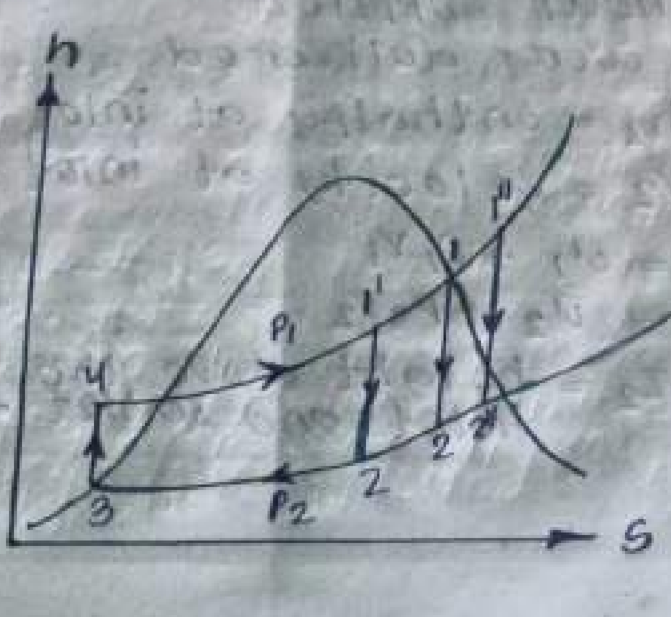
$$\boxed{\eta = 1 - \frac{Q_{out}}{Q_{in}}}$$

Rankine cycle









The above figure represents the Rankine cycle.
The cycle consists of following cycles.

Process (1-2)

Isentropic expansion or adiabatic (reversible) expansion process in the turbine.

Process (2-3)

Constant pressure transfer of heat in the condenser.

Process (3-4)

Isentropic expansion or Reversible adiabatic pumping process in the boiler.

Process (4-1)

constant pressure transfer of heat in the boiler.

Note:-

Steady flow energy equation (SFEE)

$$m\left[h_1 + \frac{v_1^2}{2} + gz_1\right] + Q = m\left[h_2 + \frac{v_2^2}{2} + gz_2\right] + W$$

where

Q = Heat supplied

W = work delivered

h_1, h_2 = enthalpy at inlet and outlet

v_1, v_2 = velocity at inlet and outlet

$h_1 = u_1 + p_1 v_1$

$h_2 = u_2 + p_2 v_2$

z_1, z_2 = height above the datum line at inlet and outlet.

Applying the steady flow energy equation to the boiler, turbine, condenser and pump:

(i) For Boiler (4-1)

$$h_{f4} + Q_1 = h_1$$

$$\Rightarrow Q_1 = h_1 - h_{f4}$$

(ii) For turbine (1-2)

$$h_1 + 0 = h_2 + W_T$$

$$\Rightarrow W_T = h_1 - h_2$$

(iii) For condenser (2-3)

$$h_2 - Q_2 = h_{f3} + 0$$

$$\Rightarrow Q_2 = h_2 - h_{f3}$$

(iv) For the feed pump (3-4)

$$h_{f3} + 0 = h_{f4} + W_P$$

$$\Rightarrow W_P = h_{f4} - h_{f3}$$

The efficiency of Rankine cycle

$$\eta_{Rankine} = \frac{W_{net}}{Q_{in}}$$

Net work = $W_{out} - W_{in}$

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

$$\boxed{\eta_R = \frac{W_T - W_P}{Q_{in}}}$$

where,

W_P = workdone by the pump

W_T = workdone by the turbine

$$\therefore W_T = h_1 - h_2$$
$$W_P = h_{f4} - h_{f3}$$
$$Q_{in} = h_1 - h_{f4}$$

Now the efficiency of Rankine cycle.

$$\eta_R = \frac{(h_1 - h_2) - (h_{f4} - h_{f3})}{h_1 - h_{f4}}$$

The feed pump term $(W_P) = h_{f4} - h_{f3}$ will be usually neglected as it being a small quantity as compared to the turbine work. Therefore the efficiency of Rankine cycle will be

$$\boxed{\eta_R = \frac{h_1 - h_2}{h_1 - h_{f4}}}$$

Performance parameter of a steam power cycle

① Thermal efficiency

The thermal efficiency is defined as the ratio of net workdone to the heat supplied.

Mathematically,

$$\eta = \frac{W_{net}}{Q_{in}} = \frac{W_T - W_P}{Q_{in}}$$

$$\boxed{\eta = \frac{(h_1 - h_2) - (h_{f4} - h_{f3})}{h_1 - h_{f4}}}$$

② Work ratio

It is defined as the ratio of net work output to the turbine work.

Mathematically,

$$W \cdot R = \frac{W_{net}}{W_T}$$

$$= \frac{W_T - W_P}{W_T}$$

$$\Rightarrow \boxed{W \cdot R = 1 - \frac{W_P}{W_T}}$$

③ Back work ratio

It is defined as the ratio of the pump work and the turbine work.

Mathematically,

$$\boxed{B \cdot W \cdot R = \frac{W_P}{W_T}}$$

④ Specific steam consumption

Specific steam consumption is defined as the ratio of mass of the steam in KJ/hour to the power output in KW.

Mathematically,

$$S \cdot S \cdot C = \frac{\text{mass of the steam in KJ/h}}{\text{power output in KW}}$$

Numericals

① A steam turbine receives steam at 15 bar and 350°C, and exhausts to the condenser at 0.06 bar. Determine the thermal efficiency of the ideal Rankine cycle operating between these two limits.

Given data,

$P_1 = 15$ bar (turbine pressure)

$T_1 = 350°C$

$P_2 = 0.06$ bar (condenser pressure)

At pressure $P_1 = 15$ bar and temperature $T_1 =$ from steam table

specific enthalpy (h) = 3148.5 kJ/kg

specific entropy (s) = 7.102 kJ/kg-K

At the pressure $P_2 = 0.06$ bar, from steam table,

$h_{f2} = 151.5$ kJ/kg

$h_{fg2} = 2416.0$ kJ/kg

$s_{f2} = 0.521$ kJ/kg-K

$s_{fg2} = 7.810$ kJ/kg-K

As the steam in the turbine expand isentropically

$\Rightarrow s_1 = s_2$

But, $s_2 = s_{f2} + x_2 s_{fg2}$

$= 0.521 + x_2 \times 7.810$

$s_1 = 7.102$

$s_1 = s_2$

$\Rightarrow 7.102 = 0.521 + x_2 \times 7.810$

$\Rightarrow x_2 = \frac{7.102 - 0.521}{7.810}$

$= 0.84$

$$h_2 = h_{f2} + x_2 h_{fg2}$$
$$= 151.5 + 0.84 \times 2416.0$$
$$= 2180 \text{ KJ/Kg}$$

Now the thermal efficiency

$$\eta = \frac{h_1 - h_2}{h_1 - h_{f4}}$$
$$= \frac{3148.5 - 2180}{3148.5 - 151.5}$$
$$= 0.323$$
$$= 32.3\ \%$$

Note :-

* Enthalpy $(H) = u + PV$
  specific enthalpy $(h) = \frac{H}{m}$
* Entropy (S)
  specific entropy (s)
* volume (V)
  specific volume (v)

→ steam
- → wet steam
- → Dry steam
- → Superheated steam

* $h = h_f + x h_{fg} = h_f + x(h_g - h_f)$
* $s = s_f + x s_{fg} = s_f + x(s_g - s_f)$

② A steam turbine receives steam at a pressure of 16 bar and temperature of 300°C and exhaust to the condenser at 0.08 bar. Determine the thermal efficiency of the ideal rankine cycle.

Soln

Given data,

$P_1 = 16$ bar

$T_1 = 300°C$

$P_2 = 0.08$ bar

From steam table, for pressure $(P_1) = 16$ bar and temperature $(T_1) = 300°C$

the specific enthalpy $(h_1) = 3036.2$ KJ/kg

specific entropy $(s_1) = 6.887$ KJ/kg-K

from steam table for pressure $(P_2) = 0.08$ bar

$h_{f2} = 173.9$ KJ/kg

$h_{fg2} = 2403.2$ KJ/kg

$s_{f2} = 0.593$ KJ/kg-K

$s_{fg2} = 7.637$ KJ/kg-K

$s_1 = 6.887$ KJ/kg-K

$s_2 = s_{f2} + x_2 s_{fg2}$

$= 0.593 + x_2 \times 7.637$

we know,

$s_1 = s_2$

$\Rightarrow 6.887 = 0.593 + x_2 \times 7.637$

$$\Rightarrow x_2 = \frac{6.887 - 0.593}{7.637}$$

$= 0.82$

$h_2 = h_{f2} + x_2 h_{fg2}$

$= 173.9 + 0.82 \times 2403.2$

$= 2144.5$ kJ/kg

$\eta = \frac{h_1 - h_2}{h_1 - h_{f4}}$

$= \frac{3036.2 - 2144.5}{3036.2 - 173.9}$

$= 0.3115$

$= 31.15\%$

③ The following data refers to a steam power plant

SL NO	Location	Pressure	quality/temp	velocity
1	Inlet to turbine	6 mpa = 60 bar	380°C	—
2	Exit from turbine inlet to condenser	10 kpa = 0.1 bar	0.9	200 m/s
3	exit from condenser and inlet to pump	9 kpa = 0.09 bar	saturated liquid	—
4	Exit from pump and inlet to boiler	7 mpa = 70 bar	—	—
5	Exit from boiler Rate of steam flow = 10000 kg/hr	6.5 mpa = 65 bar	400°C	—

calculate:

(i) power output of the turbine

(ii) Heat transfer per hour in the boiler and condenser separately.

Soln

Given data,

$P_1 = 6$ mpa $= 60$ bar

$T_1 = 380°C$

$P_2 = 10$ kpa $= 0.1$ bar

$x_2 = 0.9$

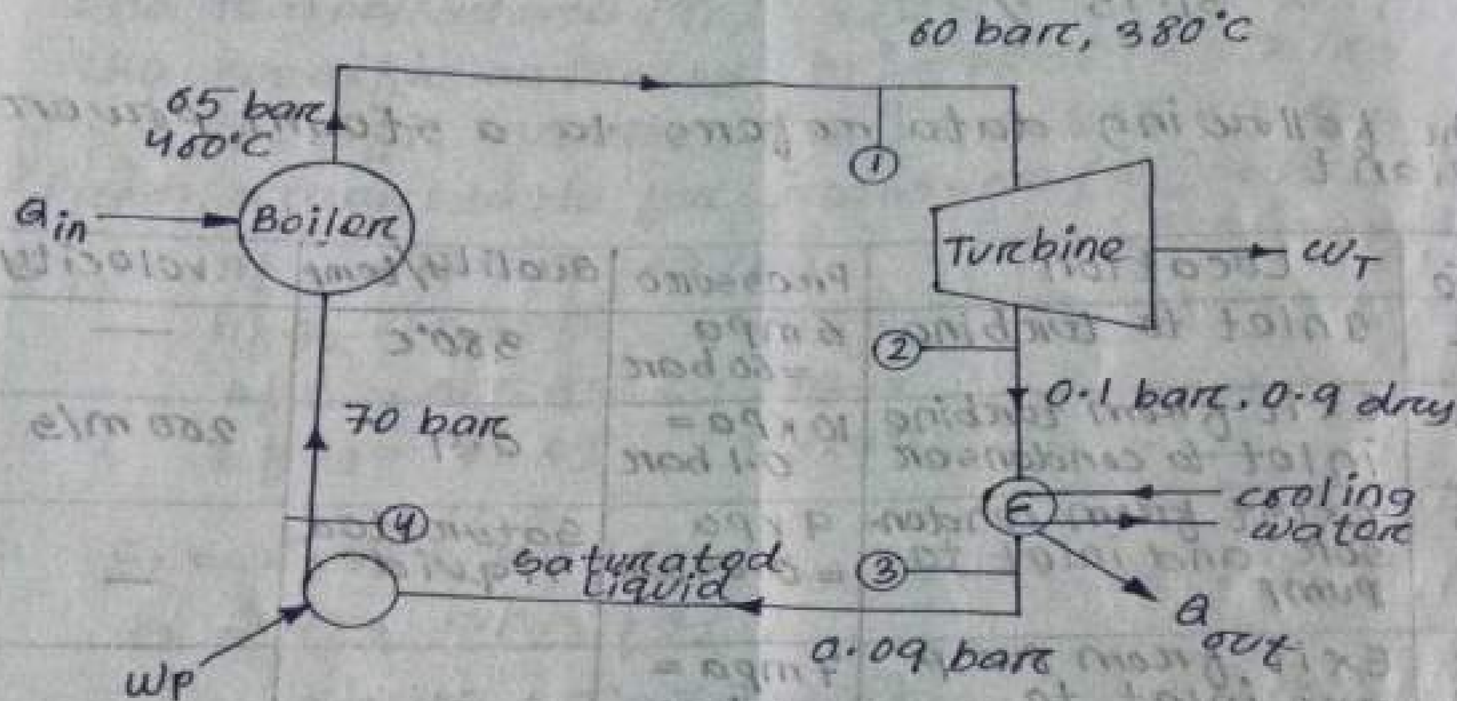
$V_2 = 200$ m/s

$P_3 = 9$ kpa $= 0.09$ bar

$P_4 = 7$ mpa $= 70$ bar

$P_1 = 6.5$ mpa $= 65$ bar

$T_1 = 400°C$



① From steam table at pressure $(P_1) = 60$ bar and temperature $(T_1) = 380°C$

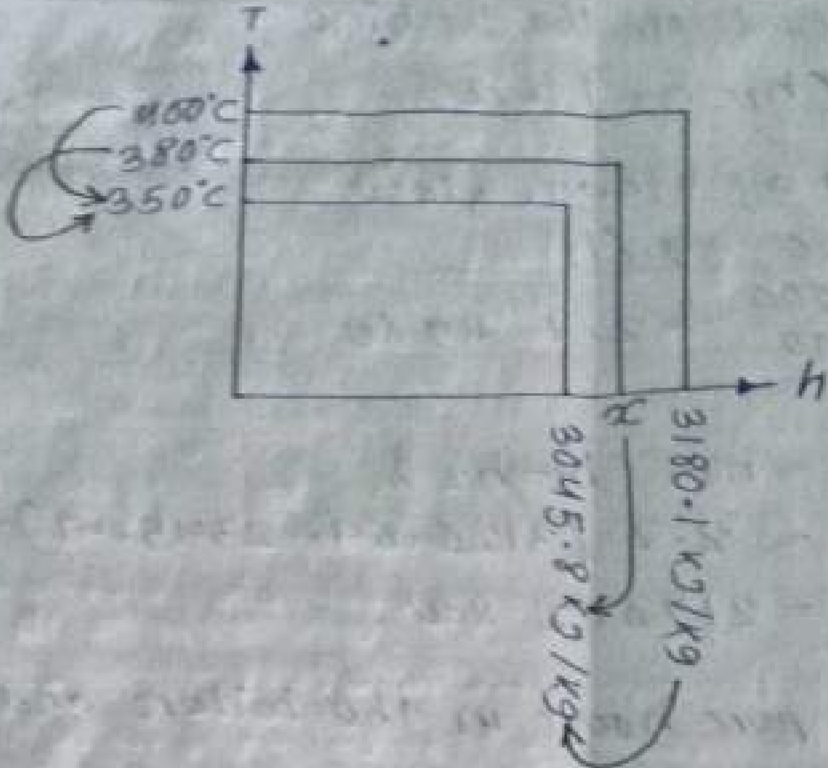
h_1 = specific enthalpy at the inlet of turbine.

At pressure 60 bar, temp 350°C the specific enthalpy

$$h' = 3045.8 \text{ kJ/kg}$$

At 60 bar, 400°C

$$h'' = 3180.1 \text{ kJ/kg}$$



Let x = specific enthalpy at pressure $(P_1) = 60$ bar and, temperature 380°C

$$\frac{400-350}{380-350} = \frac{3180.1-3045.8}{x-3045.8}$$

$$\Rightarrow x = 3126.69 \text{ KJ/Kg} = h_1$$

$$h_2 = h_{f2} + x_2 h_{fg2}$$

From steam table, at pressure $(P_2) = 0.1$ bar

$h_{f2} = 191.8$ KJ/Kg

$h_{fg2} = 2392.9$ KJ/Kg

$x_2 = 0.9$

$$\Rightarrow h_2 = 191.8 + 0.9 \times 2392.9$$

$$= 2345.41 \text{ KJ/Kg}$$

∴ Power output of the turbine

$$m_s (h_1 - h_2) \text{ kW}$$

m_s = rate of steam flow

= 10000 kg/h

$= \frac{10,000}{3600} = 2.7$ kg/s

Power (P) $= m_s (h_1 - h_2)$

$= 2.7 (3126.69 - 2345.41)$

$= 2170.2$ kW

(ii) heat transfer per hour in the boiler and condenser

At pressure (P) = 70 bar, specific enthalpy

$h_{f4} = 1267.4$ kJ/kg

At pressure 65 bar and temp 400°C, specific enthalpy

$h_1 = 3170.8$ kJ/kg

∴ Heat transfer per hour in boiler

$Q_1 = 10000 (h_1 - h_{f4})$

$= 10000 (3170.8 - 1267.4)$

$= 1.9 \times 10^7$ kJ/h

At 0.09 bar, from steam table, specific enthalpy

$h_{f3} = 183.3$ kJ/kg

Heat transfer per hours in the condenser

$Q_1 = (h_2 - h_{f3}) \times 10000$

$= (2345.41 - 183.3) \times 10000$

$= 2.1 \times 10^7$ kJ/h

List of thermal power station in the state with their Capacities

SL No	Name	Location	Capacity
01	Talchar super thermal Power station	Odisha	3000 MW
02.	sterlite Jharsuguda power station	Odisha	2400 MW
03	Mundra Thermal power station	Gujurat	4620 MW
04	Vindhyachal thermal power station	Madhyapradesh	4260 MW
05	Mundra ultra mega power plant	Gujurat	4150 MW
06	KSK Mahanadi power project	CG	3600 MW
07	Jindal Tamnar thermal power station	CG	3400 MW
08	Tiroda Thermal power station	Maharastra	3300 MW
09	Barh super thermal power station	Bihar	3300 MW
10	sipat thermal power Plant	CG	2980 MW
11	NTPC Ramagundam	Telangana	2600 MW
12	Kobra super Thermal power plant	CG	2600 MW
13	Mejia thermal power station	West Bengal	2430 MW
14	Kahalgaon super thermal power station	Bihar	2340 MW
15	Chandrapur super thermal power station	Maharastra	2340 MW
16	Singrauli super thermal power station	UP	2050 MW
17	Rihand thermal power station	Andha pradesh	2000 MW

Boiler Accessories

Boiler accessories are the auxiliary parts required for steam boiler for their proper operation and for their increase in efficiency.

$$Efficiency\ (\eta) = \frac{W_{net}}{Q_{in}}$$

① Air Preheater

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

→ It is generally placed after the economiser therefore the flue gases pass through economiser and then to air preheater.

→ An air preheater consists of plate or tubes with flue gases on one side and air on the other side.

→ The temperature of flue gases transfer to the air so that the air is preheated before it is supply to the boiler.

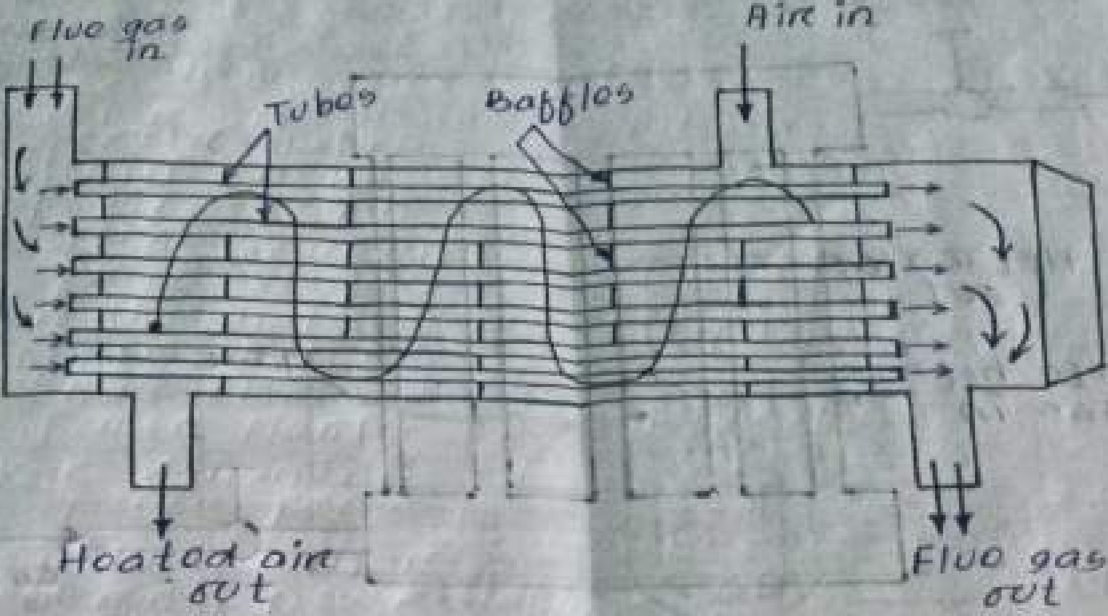
→ The preheated air accelerate the combustion and helps in burning of coal more easily.

→ The air gets initially heated before it is being supplied to the furnace.

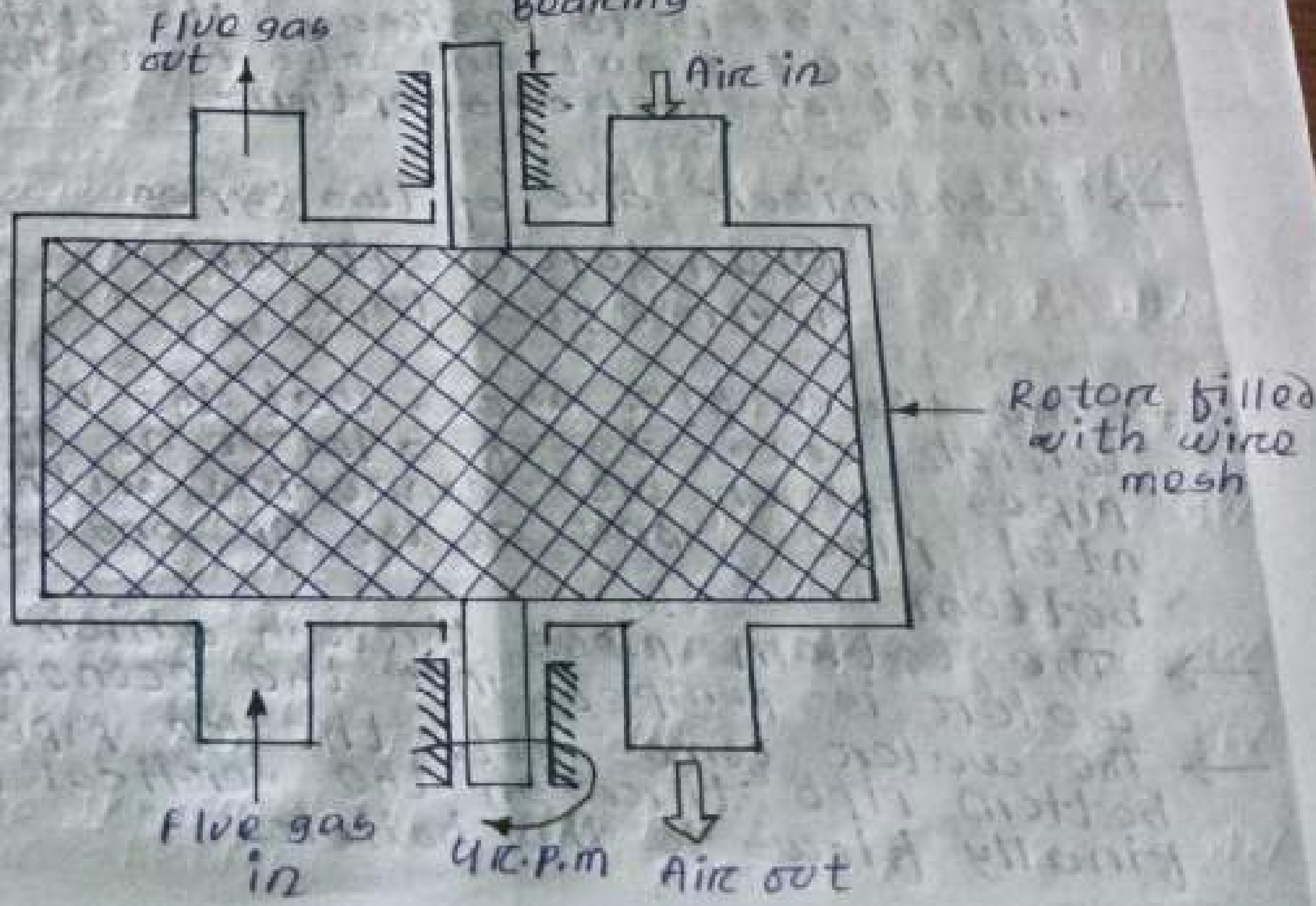
→ There are three types of air preheater.

- Tubular type air preheater
- plate type air preheater
- storage type air preheater

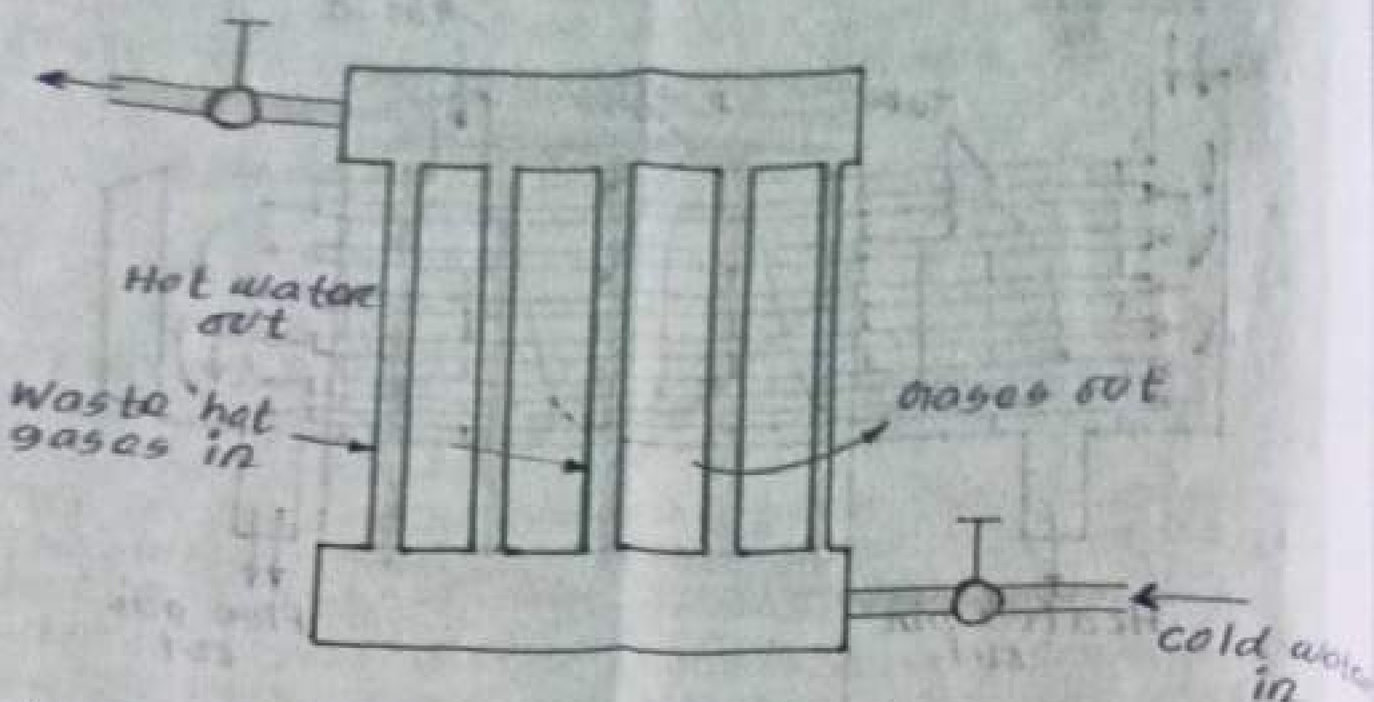
→ Tubular type air preheater



→ Storage type air preheater



② Economizer



→ An economizer is a device in which the waste heat of flue gases is utilized for heating the feed water before it is supply to the boiler, so is to increase the efficiency of the power plant and also to reduce the amount of fuel consumption.

→ Economizer are of two types
- ⓐ Independent type
- ⓑ Integral type.

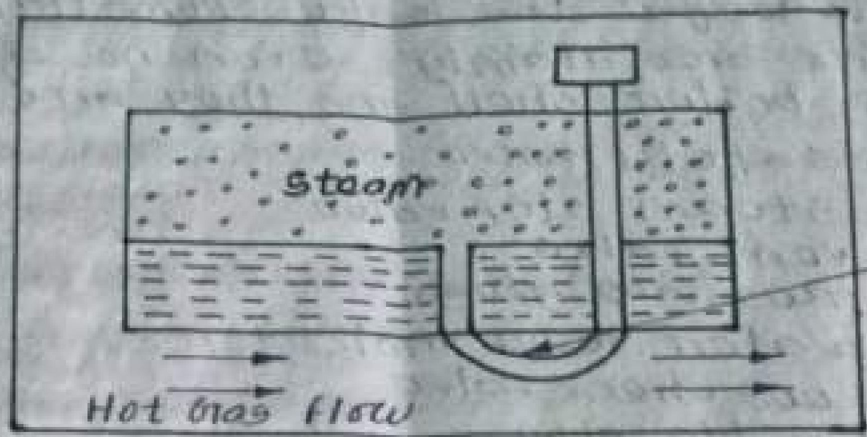
→ The above fig. shows that the economizer which consists of a large no. of vertical pipes which are connected with two horizontal pipes, one at the top and other at the bottom.

→ The bottom pipes through which the feed water is pumped into the economizer.

→ The water comes into the top pipe from the bottom pipe through the vertical pipes and finally flows to the boiler.

→ The flue gases move around the pipes in the direction opposite to the flow of water consequently heat transfer through the surface of the pipe takes place.

③ Super heater



→ The function of a superheater is to increase the temperature of a steam above its saturation temperature.

→ It is a very important accessories of a boiler which can be used both fire tube boiler and water tube boiler.

→ The superheated steam have following advantages.
- Steam consumption of turbine is reduced
- Errosion of turbine blade is eliminated.
- Thermal efficiancy of power plant is increased.

→ There are two types of superheaters
ⓐ Convectional superheater
ⓑ Radiant superheater

→ convectional superheater make use of the heat in flue gases where as radiant superheater is placed in the furnace and wall tubes receives heat from the burning of fuel through radiant process.

④ Boiler Mounting

→ Boiler mounting are a set of safety device instead for the safe operation of boiler.

→ There are mainly seven no. of mounting on a boiler shell and they are

- safety valve
- steam stop valve
- vent valve
- pressure gauge
- water level indicator
- feed check valve
- Fusible plug.

→ These equipments save the boiler from damage due to extreme pressure, steam back flow, shell collapse, low water level, unregulated steam pressure, back flow of feed water etc.

operation of Boiler

A boiler is a closed vassel in which the water is heated. The heated or vapourised water exit the boiler for use in various process and heating application.

➡ Working

→ The boiler is a closed vassel inside which water is stored and heated.

→ The fuel is burnt in furnace and the hot gases are produced.

→ The fuel used is coal.

→ These hot gases come in contact with the water vassel where the heat of these hot gases transfer to the water and steam is produced inside the boiler.

→ This steam is then supplied to the turbine in a thermal power plant.

- **Draught System**

⇒ It is defined as the small pressure difference which causes a flow of gas to takes place.

→ The function of draught in case of boiler is to force the air for complete combustion and also to carry away the gaseous product of combustion.

→ In a boiler proper combustion takes place only when sufficient quantity of air is supplied to the burning fuel.

→ It is classified into two types

(i) Natural Draughts

(ii) Artificial Draughts

- → Forced Draught
- → Induced Draught
- → Balanced Draught

(a) Natural Draught

→ The natural draught is obtained by the use of chimney.

→ The chimney obeys the following functions

① It produces the draught where by the air and gas are forced through furnace and exhausted to atmosphere.

② It carries the product of combustion to such a hight before discharging them such that they are not injurious or pollution to the surroundings.

③ chimney is a vertical tubular structure made of concrete or steel.

(a) The draught produced by the chimney is due to the density difference between the hot gases and the cold gases outside.

(b) Forced Draught
→ In a mechanical draught system, the draught is produced by a fan.
→ In a forced draught system, a blower or fan is installed near or at the base of the boiler to forces the air through various passages like furnace, air preheater, economiser etc.
→ It is a positive pressure draught.

(c) Induced Draught
→ In this system a blower or fan is used near the base of the chimney
→ The pressure over the fuel bed is reduced below that of atmospheric pressure such that a vacum is created and the product of combustion drawn with the help of a blower and then passed through chimney.
→ This draught is used when air preheater and economisor are incorporated in the system.
→ This draught is similar in action with the natural draught.

(d) Balanced Draught
→ It is the combination of both the forced draught and induced draught.
→ In this system the forced draught fan overcomes the resistance in the air preheater and induced draught fan overcomes draught losses through boiler, economisor, air preheater.

Advantages of Draught

→ Reduced chimeney height
→ Increasing evaporating power of a boiler.
→ Improvement in the efficiency of plant.
→ Easy control of combustion and evaporation.
→ Low grade fuel can be used.
→ Preventation of smoke.

Disadvantages of Draught

→ The initial cost of mechanical draught system is high.
→ Maintainance cost is also at higher rate.
→ Noise level of boiler increases due to fan noise and blower noise.
→ Running cost is also high due to the requirement of electricity for running of fan and blower.

Boiler Mounting

① Safety valve

→ The main function of a safety valve is to relieve pressure.
→ It is located on the boiler steam drum and will automatically open when the pressure of inlet side of the valve increases than the saturation pressure.

② Pressure Gauge

→ The main function of pressure gauge is to measure the pressure of steam inside the boiler.
→ It is usually mounted on the front top part of boiler shell so that it should be clearly visible to the operator.

③ steam stop valve

→ The main function of the steam stop valve is to regulate the steam supply from the boiler to the steam line.

→ It is located over the boiler between the steam space and the steam supply line.

④ water level indicator

→ The function of water level indicator is to indicate the level of water in the boiler constantly.

→ It is also called as water gauge.

⑤ vent valve

→ An air vent valve is provided on the top steam drum in a boiler and is used to vent the air when the boiler is initially filled or drained with water.

⑥ Feed check valve

→ It is one of the important component of boiler which control the flow of water from feed pump to the boiler.

→ It also prevent the back flow of water from boiler to the pump when the boiler pressure is more than the pump pressure.

⑦ Fusible plug

→ The main function of fussible plug is to protect the boiler from damage due to over heating of the boiler tubes by low water level.

- Steam Prime movers

→ A steam prime mover is also known as the steam turbine.

→ A steam turbine is a primemover in which the potential energy of steam is converted into kinetic energy and then tranformed into mechanical work which helps to the Rotation of turbine shaft.

→ The turbine shaft connected to the generator shaft which generate the electrical energy.

→ In general a steam turbine consists of the following two parts.

(a) The nozzle in which the heat energy of high pressure steam is converted into kinetic energy so that the steam exit from nozzle with a very high velocity.

(b) The blades which changes the direction of the steam exit from the nozzle and the turbine blades are made in such a way that the steam strikes them without shock and also it reduces the loss of energy.

Classification of steam turbine

① According to the mode of steam action
  (i) Impulse turbine
  (ii) Reaction turbine

② According to the direction of steam flow
  (i) Tangential flow turbine
  (ii) Axial flow turbine
  (iii) Radial flow turbine

③ Accoding to the pressure of steam :
(i) High pressure turbine
(ii) Low pressure turbine
(iii) Medium pressure turbine

④ Accoding to the no of stage
(i) single stage
(ii) multi stage

Advantages of steam turbine

→ The thermal efficiency of the steam turbine is much higher than of steam engine.

→ A steam turbine may develop higher speed as compared to steam engine.

→ A steam turbine there is no loss due to initial condensation of steam.

→ The maintainance cost are generally less as compare to steam engine.

→ with the absence of reciprocating parts the balancing problem is minimized.

→ A steam turbine can be made in various big size and are very suitable for thermal power station where outputs are required.

→ The power generation in a steam turbine at uniform rate, therefore there is no requirement of flywheel are in case of steam engine.

→ No internal lubrication is required as there are no rubbing part in the steam turbine.

Governing of steam Turbine

→ Steam turbine governing is the procedure of controlling the flow rate of steam to the steam turbine so as to maintain its speed of rotation as constant.

→ The variation of load during the operation of steam turbine can have significant impact on its performance.

→ The principal methods of steam turbine governing are

1. Throttle Governing
2. Nozzle Governing
3. By-pass Governing
4. Combination of throttle and nozzle governing
   or
   combination of nozzle and By-pass governing

Nozzle Governing

→ In this method of governing, the nozzles are grouped together and supply of steam to each group is controlled by regulating valves.

→ An alternative and more efficient form of governing is by means of nozzle control.

→ When the load on the turbine becomes more or less than the design value, the supply of steam to a group of nozzles may be varied accordingly so as to restore the original speed.

→ Nozzle control can only be applied to the first stage of a turbine. It is suitable for simple impulse turbine.

Throttle Governing

→ Throttle governing is the most widely used particularly on small turbine, because its initial cost is less and the mechanism is simple.

→ Throttle governing, the pressure of steam is reduced at the turbine entry thereby decreasing the availability of energy.

→ In this method steam is passed through a restricted passage thereby reducing its pressure across the governing valve.

By-Pass Governing

→ By-pass governing of a steam turbine is a method where a by-pass line is provided for the steam.

→ It is used when the turbine is running in overloaded condition.

→ The by-pass line is provided for passing the steam from first stage nozzle box into a later stage where work output increases.

→ The by-pass steam is automatically regulated by lift the valve which is under the control of speed of the governor for all loads within its range.

→ By-pass valve is open to release the fresh steam into the later stage of turbine.

Turbine Efficiency

① Blade efficiency (η_{bl})

It is the ratio of workdone on the blade per second to the energy entering the blade per second.

Mathematically,

$$\eta_{bl} = \frac{2u\,(V_{w1} + V_{w2})}{(V_1)^2}$$

where, V_{w1} = velocity of whirl at inlet

V_{w2} = velocity of whirl at outlet

u_1 = flow velocity at inlet

V_1 = Absolute velocity at inlet

② Stage efficiency (η_{stage})

The stage efficiency covers all the losses in the nozzles, blades, diaphragm and discs that are associated with the stage.

Mathematically,

$$\eta_{stage} = \frac{\text{Net workdone on shaft per stage per kg of steam flowing}}{\text{Adiabatic heat drop per stage}}$$

$$= \frac{\text{Net workdone on blades - Disc friction and windage}}{\text{Adiabatic heat drop per stage}}$$

③ Internal efficiency ($\eta_{internal}$)
This is equivalent to the stage efficiency when applied to the whole turbine.

Mathematically,

$$\eta_{int} = \frac{\text{Heat covered into useful work}}{\text{Total adiabatic heat drop}}$$

④ overall or turbine efficiency ($\eta_{overall}$)
This efficiency covers internal and external losses. for example bearing and steam friction. Leakage. radiation etc.

Mathematically,

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

⑤ Net efficiency or efficiency ratio (η_{net})

$$\eta_{net} = \frac{\text{Brake thermal efficiency}}{\text{Thermal efficiency on the Rankine cycle}}$$

$$\eta_{net} = \frac{\text{Heat converted into useful work}}{\text{Total adiabatic heat drop}}$$

- Steam Condenser

→ A steam condenser is a device or applian in which steam condenser and heat released by water.

→ The absorbed water then supplied to the boiler as hot feed water and for industrial purpose.

or

A steam condenser is a mechanical device which converts the low pressure exhaust steam from the turbine into water.

→ During condensing process some heat of exhaust steam is decipated to the cooling water known as 'circulating water'.

→ In other words, when steam is the working fluid, it may be returned to the boiler and used over again and again.

→ This can be done in a condenser most conviently and economically by first condensing it and then pumping the resulting water into the boiler.

➡ Functions of Condenser

The main function of condenser are

(i) The primary object of condensing exhaust steam in a condenser is to make it possible to remove it economically at a pressure less than that of the atmosphere after it has done its work in the turbine and thus enable the steam to expand to a greater extent and do more work.

(ii) The secondary object of the condenser is to provide hot feed water for the boiler. The condensate is a pure hot water and therefore can be fed into the boiler directly without any treatment. Thus large savings are made and less fuel and time is required to rise the steam.

Classification of condenser

Condenser are broadly classified into two types.

1. Jet condenser
2. surface condenser

➡ Jet condenser

→ In jet condenser the exhaust steam and water come in direct contact with each other.

→ The temperature of cooling water and the condensate is same when leaving the condensers.

→ In this condenser the cooling water is usually sprayed into exhaust steam to cause rapid condensate.

→ The elements of jet condenser are

(i) Nozzle and distributors for the condensing water.
(ii) steam inlet
(iii) mixing chamber
(iv) Hot well.

→ The jet condensers are further classified into following types

(a) parallel flow type
(b) counter-flow type
(c) Ejector type

Parallel flow condenser

The parallel flow condenser are further classified into following two types.

* Lower level type
* Higher level type

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

Counter flow condenser

The counter flow condenser are also further classified into following two types.

* Lower level type
* Higher level type

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

Ejector Condenser

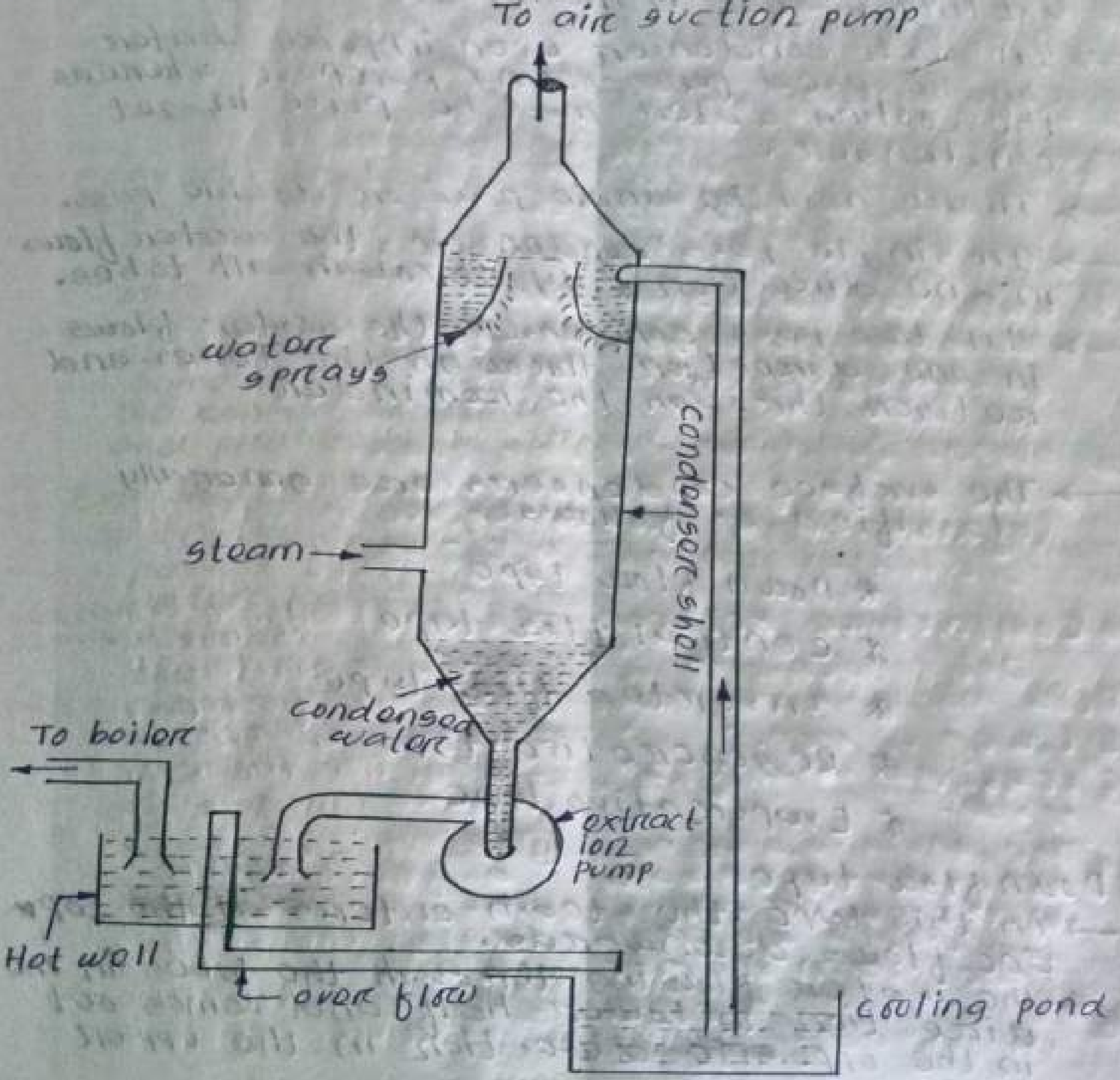
→ In this condenser cold is discharged under a head a head of about 5 to 6 m through a series of convergent nozzles.

→ The steam and air enter the condenser through a non-return valve.

→ steam get condensed by mixing with water.

→ pressure energy is partly converted into kinetic energy at the converging cone.

→ In the diverging cone the kinetic energy is partly converted into pressure energy and a pressure higher than atmospheric pressure is achieved so as to discharge the condensate to the hot well.



➡ Surface condenser

→ In surface condensers there is no direct contact between the steam and cooling water and the condensate can be re-used in the boiler.

→ The steam passes over the outer surface of tubes through which a supply of cooling water is maintained.

→ In such condenser even impure water can be used for cooling purpose whereas the cooling water must be pure in jet condenser.

→ There may be single pass or double pass.

→ In single pass condenser, the water flows in one direction only through all tubes.

→ In two pass condenser the water flows in one direction through the tubes and return through the remainder.

→ The surface condensers are generally classified as follows.

* Down flow type
* central flow type
* Inverted flow type
* Regenerative type
* Evaporative type

Down flow type

→ In this type the steam enters at the top and flows downwards.

→ The water flowing through the tubes in one direction in lower half and comes out in the opposite direction in the upper half.

Elements of condensing plant

① A steam ejector or air pump
→ It is needed to remove air and other non condensible gases from the condenser.
→ The air pumped used to remove gases and air is known as 'Dry air pump'.

② Hot well
→ A hot well is used to collect the condensate

③ Extraction pump
→ It is used to remove the condensate from the condenser and to collect in the hot well and then to feed it into the boiler preheater by means of feed water pump.

④ Circulating water pump
→ It helps to condense the exhaust steam of turbine in the condenser.

⑤ Spray pond or cooling tower
→ It helps for cooling the circulating water of condenser, when there is only a limited quality of cooling water available.

- Comparision Between Jet and surface condenser

Jet condensor	surface condenser
① Low manufacturing cost.	① High manufacturing cost
② Lower up keep.	② Higher up keep
③ Requires small floor space.	③ Requires large floor space.
④ The condensate can not be used as feed water in the boiler unless the cooling water is free from impurities.	④ condensate can be reused as feed water as it does not mix with the cooling water.
⑤ More auxilary power required.	⑤ Less auxilary power needed.

• Cooling Tower

→ In power plants the hot water from condensor is cooled in cooling water, so that it can be reused in condensor 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.

Classification of cooling Tower

According to the material of which those are made, the cooling tower is classified into following types.

ⓐ Timber
ⓑ concrete
ⓒ steel duct type

ⓐ Timber tower.

→ Due to exposure to sun, wind, water etc. timber rosts easily.
→ It has short life.
→ It has high maintainance costs.
→ It has limited cooling capacity.

ⓑ concrete towers

→ Large capacity sometimes of the order of $5 \times 10^3 \ m^3/h$.
→ Improved draft and air circulation.
→ Increased stability under air pressure.
→ It has low maintainance.

© steel duct type

→ Duct type cooling towers are rarely in use of modern power plants owing to their small capacity.

→ The cooling towers may be classified into following types

ⓐ Atmospheric cooling tower

ⓑ Natural draught cooling tower

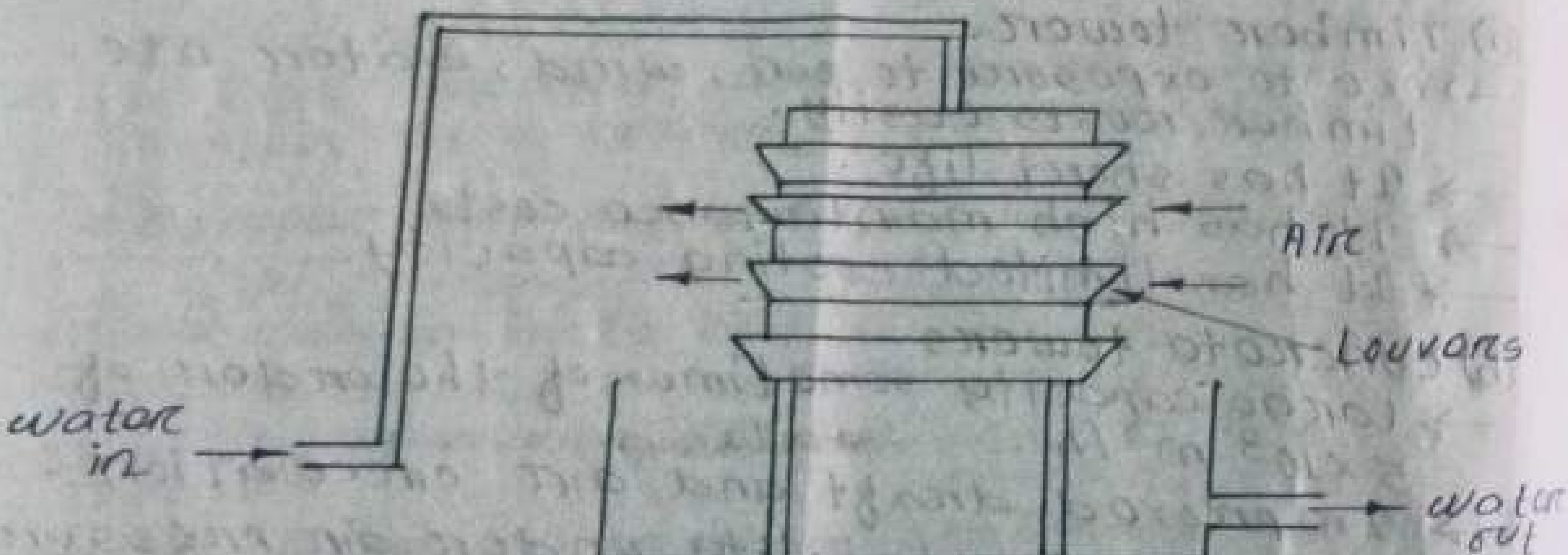
ⓒ Forced or induced draught cooling tower

Atmospheric cooling tower

→ In this cooling tower hot water is allowed to fall louvers.

→ The air flowing across in transverse direction cools the falling water.

→ These towers are used for small capacity power plant such as diesel power plants.



Natural Draught cooling Tower

→ In this type of tower, the hot water from the condenser is pumped to the troughs and nozzles situated near the bottom.

→ Troughs spray the water falls in the form of droplet into a pond situated at the bottom of the tower.

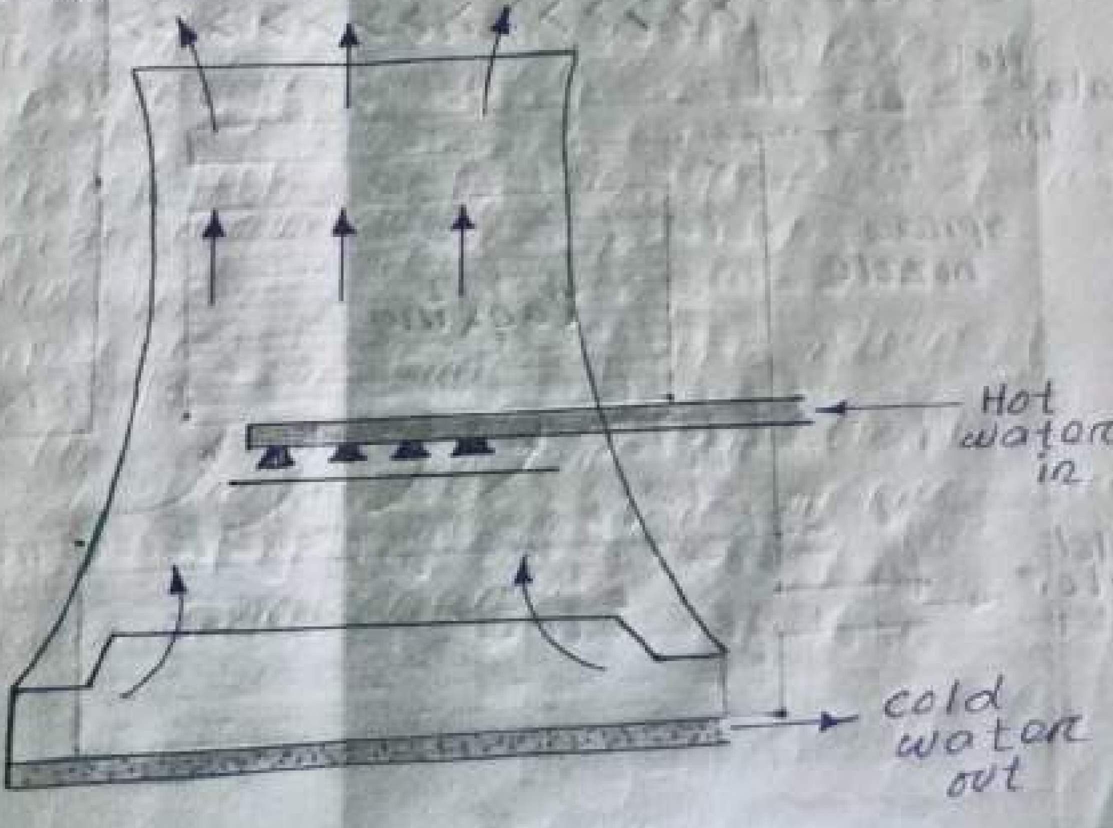
→ The air enter into the cooling tower from air openings provide near the base rises upward and take up the heat of falling water.

→ The advantages of natural draught cooling tower

- Low operating and maintainance cost
- It gives more or less trouble free operation
- Less ground area required.

→ The drawbacks of this type of cooling tower

- High initial cost.
- Its performance varies with the seasonal changes in DBT and RH



Forced Draught cooling tower

→ In this type of cooling tower, the draught air for cooling the tower is produced mechanically by means of propeller fans.

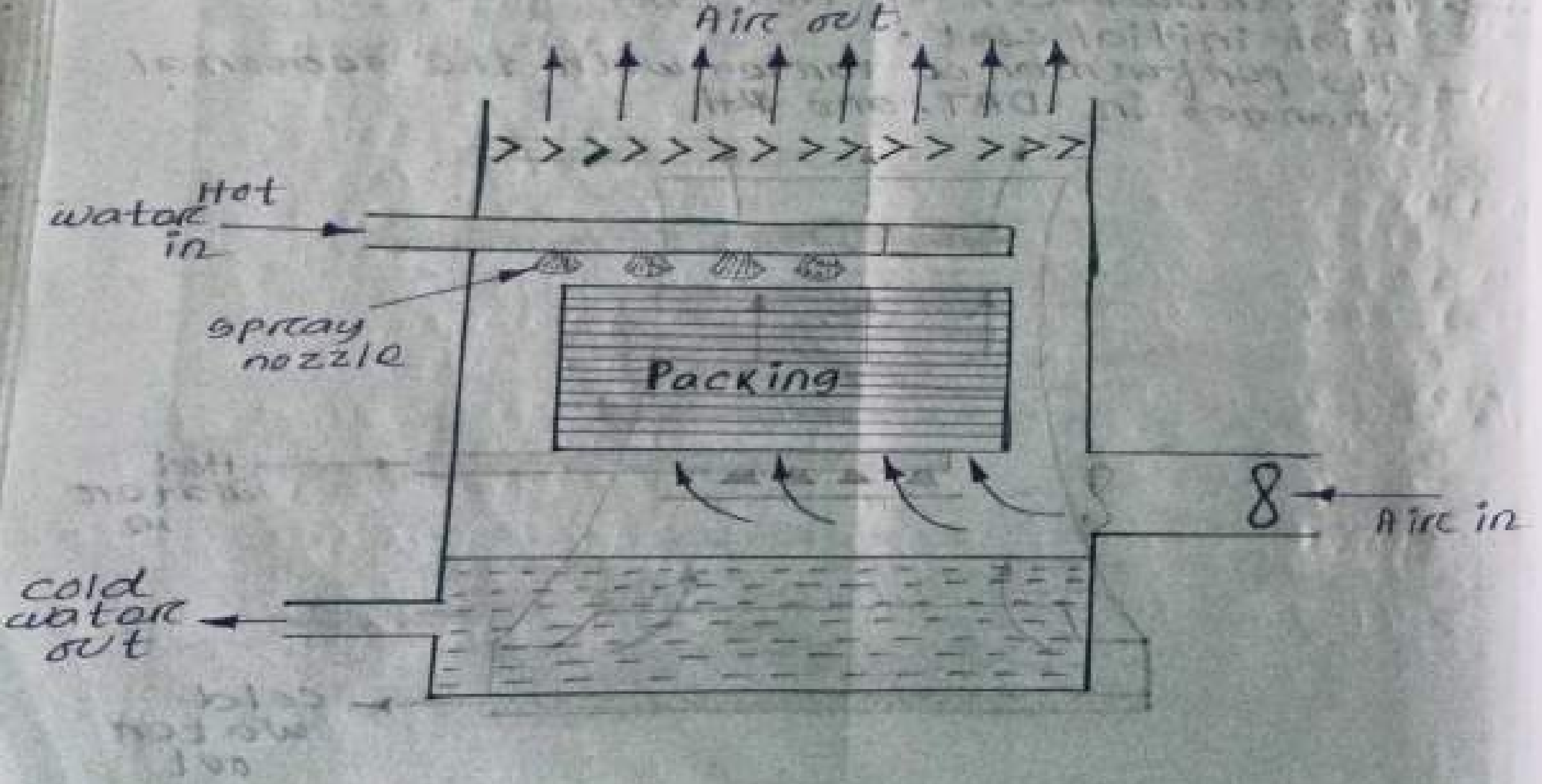
→ These towers are usually built in cells or units, the capacity depending upon the number of cells used.

→ These are also called mechanical draught cooling tower.

→ In this tower draught fan is installed at the bottom of tower.

→ The hot water from the condenser enters the nozzles.

→ The water is sprayed over the tower filling slats and the rising air cools the water.



Function of cooling Tower

→ cooling towers are used to cool down the water being passed through the condenser.

→ A cooling tower serves to dissipate the heat into the atmosphere.

→ A cooling tower is a device that rejects the waste heat to atmosphere through the cooling of a coolant steam.

- **selection of site for Thermal power stations**

The following factors to be considered for selecting a site for thermal power stations.

1. Availability of coal.
2. Availability of raw material
3. Availability of sufficient and cheap land of required quantity.
4. Availability of water
5. Transport facilities
6. Ash disposal facilities
7. Availability of labour.
8. Distance from populated area.
9. size of the plants.
10. Avoidance of obstruction to flying in the vicinity of aerodromes.
11. There should be no adverse effect on fisheries and other species in the river due to cooling water.
12. The direction of flow of wind.

① Availability of coal

→ The major source of energy which is available in India for power plant is coal.

→ Since large quantity of coal is required for a thermal power station is necessary to install the power station near the coal mines.

→ The nearest coal mines helps to the economic transport.

② Availability of raw materials

→ Morden steam power stations using coal or oils as fuel require huge quantity of it per day.

→ A thermal power plants of 400 MW capacity requires 5000 to 6000 tonns of coal per day.

③ Availability of sufficient and cheap lands of required quantity.

→ It should be noticed that sufficient land and cheap rate should be available.

→ The land should include the space required for – coal storage
- ash disposal
- plant building
- machinary
- cooling tower
- switch yard
- office complex
- staff colony
- provision for future expansion

and for other purpose

④ Availability of water

→ A large quantity of water is required for condenser, disposal of ash, as feed water to the boiler for the use by working staff.

→ A 200 MW thermal power station requires about 50 thousand ton/hr of circulating water for condenser and about 1000 ton/hr of make up water.

→ The water required to feed the boiler must be pure as possible to avoid scalling in the boiler tubes.

⑤ Transport facilities

→ Availability of proper transport facilities is another important consideration in locating the thermal power station.

→ It is always necessary to have a railway line available near the power station for bringing in heavy machinary for installation and for bringing the fuel.

⑥ Ash disposal facilities

→ The ash handling problem is more serious than coal handling because it comes out in hot condition and is highly corrosive.

→ Its effect on human body healt concern and atmospheric pollution.

⑦ Availability of Labour

→ During construction of plant enough labour is required.

→ The labour should be available at the proposed site at cheap price.

UNIT-03 NUCLEAR POWER STATIONS

Introduction

Now a days our population as well as industrial sector increases day by day. To fulfil this demand water and coal is of limited edition, so we required searching newly source of energy for production and fulfilment of electrical demands.

To overcome the above mentioned problem, nuclear energy is a best solution to produce huge amount of electrical energy. With the fission process, we have to produce thes energy. This topic is similar to thermal power plant, in thermal power. coal is used to produce heat energy on the other hand in nuclear heat energy is produced with fission process of chromium, thorium and plutonium.

chromium - Cr
Thorium - Th
plutonium - Pu

→ 1 kg. of Uranium(U) can produce by burning of 4500 tonnes of high grade coal.

→ World's first nuclear plant was commisioned in U.S.S.R.

→ In India the list of nuclear power plants are

1. Koiga, Karnatak — 220 × 4 = 880 MW
2. Kakrapur, Gujurat — 220 × 2 = 440 MW
3. Kalpakkam, Tamilnadu — 220 × 2 = 440 MW
4. Narora, UP — 220 × 2 = 440 MW
5. Rawat Bhata, Rajasthan (Kota) — 100 × 1 + 200 × 1 + 220 × 4 = 1180 MW

Classify Nuclear Fuel

→ In the nuclear power plant for the production of heat energy uranium, thorium and plutonium fuels are used.

→ Nuclear fuels are classified into two catagories

(i) fissile fuel material

(ii) fertile fuel material

Fessile material

→ In nuclear engineering, fessile material (nuclide) 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 reactors because they are capable of sustaining a nuclear fission chain reaction.

→ For heavy nuclides with atomic number of higher than 90, most of fissile isotopes meet the fissile rule.

➡ List of fissle materials

* uranium 235, which occurs in natural uranium and inrichand uranium.

* plutonium-239, breed from uranium-238 by neutron capture.

* plutonium-241, breed from plutonium-240 by neutron capture. The 240 Pu comes from 239 pu by same process.

* uranium-233 breed from thorium-232 by neutron capture.

→ P
plutonium-239
plutonium-241

→ U
uranium-233
uranium-235

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 and subsequent nuclei conversions.

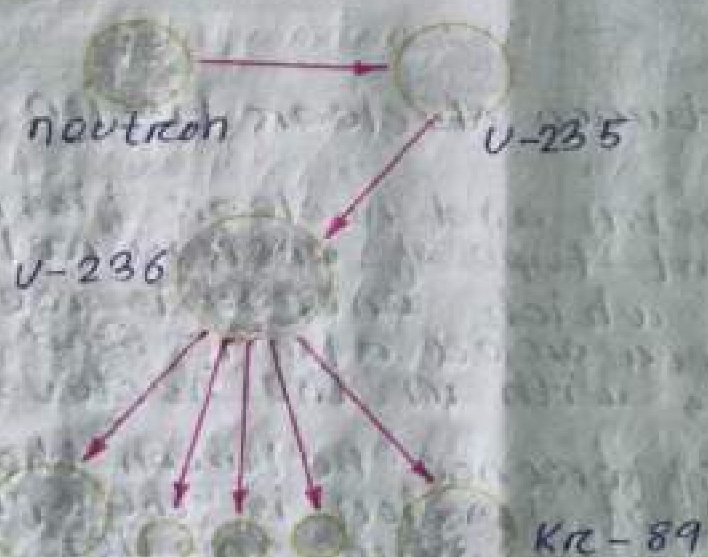
→ In nuclear engineering, fertile material (nuclide) is material that can be converted to fissile material by neutron transmutation and subsequent nuclear decay. The process of the transmutation of fertile materials to fissile material is referred to as fuel breeding.

→ There are two basic fertile materials

^{239}U

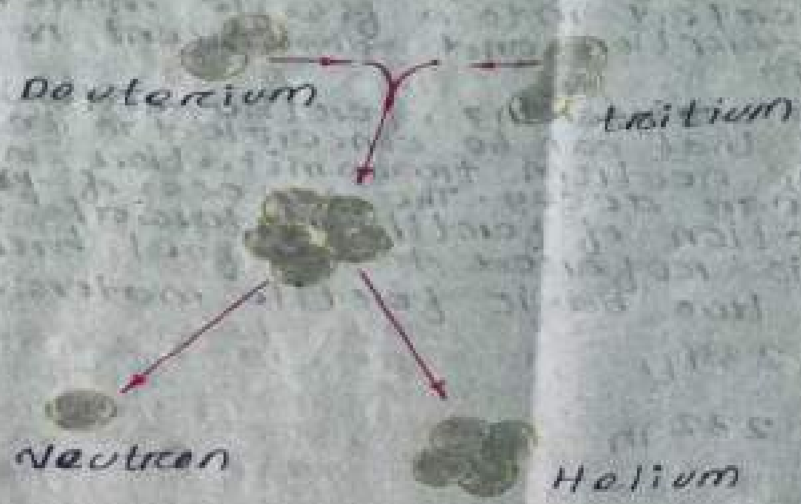
^{232}Th

Nuclear Fission



→ Uranium-235 combine with a neutron to form an unstable intermediate, which quickly split into barium-144 and krypton-89 plus three neutrons in the process of nuclear fission.

Nuclear fussion



→ Deuterium and tritium combine by nuclear fussion to form helium plus a neutron.

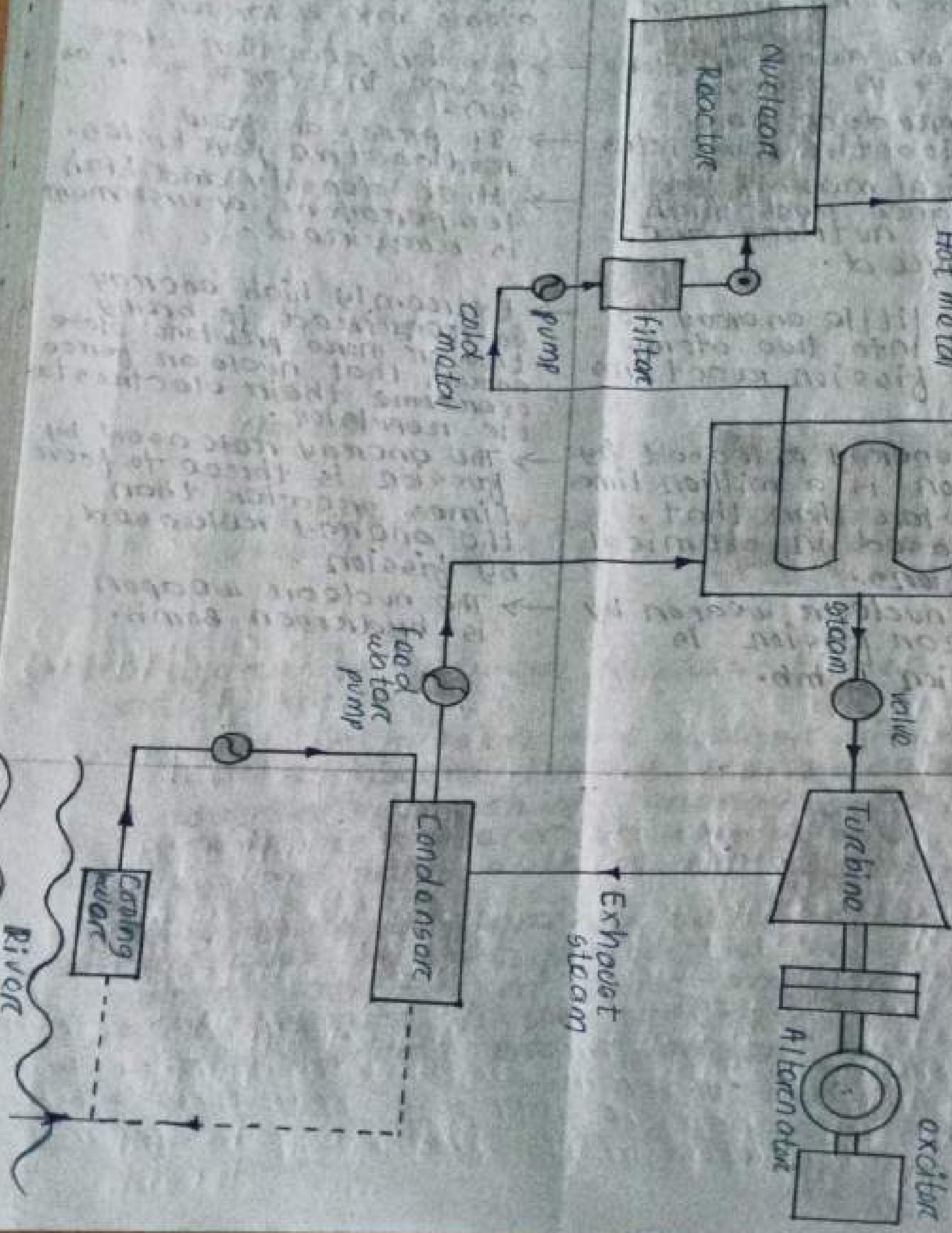
Difference between Nuclear Fission and Nuclear Fussion.

→ Nuclear fussion and nuclear fission are two different type of energy releasing reactions in which energy is released from high powered atomic bond between the particles with in the nucleus.

→ The main difference between those two process is that fission is the spilting of an atom into two or more smaller ones. while fussion is the fussing of two or more smaller atoms into a larger one.

Nuclear Fission	Nuclear Fussion
→ Fussion is the spilting of a large atom into two or more smaller ones.	→ Fussion is the fussing of two or more lighter atoms into a larger one.
→ Fission reaction does occurs in nature.	→ Fussion reaction does occurs in stars, such as sun.
→ It produce many radioactive particles.	→ It produce few radioactive particles.
→ critical mass of the substance and high speed nutrons are required.	→ High density and high temperature environment is required.
→ Takes little energy to spilt into two atoms in a fission reactions.	→ Extremly high energy is required to bring two or more protons close enough that nuclear force overcome their electrostatic repulsion.
→ The energy released by fission is a million times greater than that released in chemical reactions.	→ The energy released by fussion is three to four times greater than the energy released by fission.
→ The nuclear weapon by nuclear fission is fission Bomb.	→ The nuclear weapon is hydrogen Bomb.

Block Diagram of Nucleor power plant



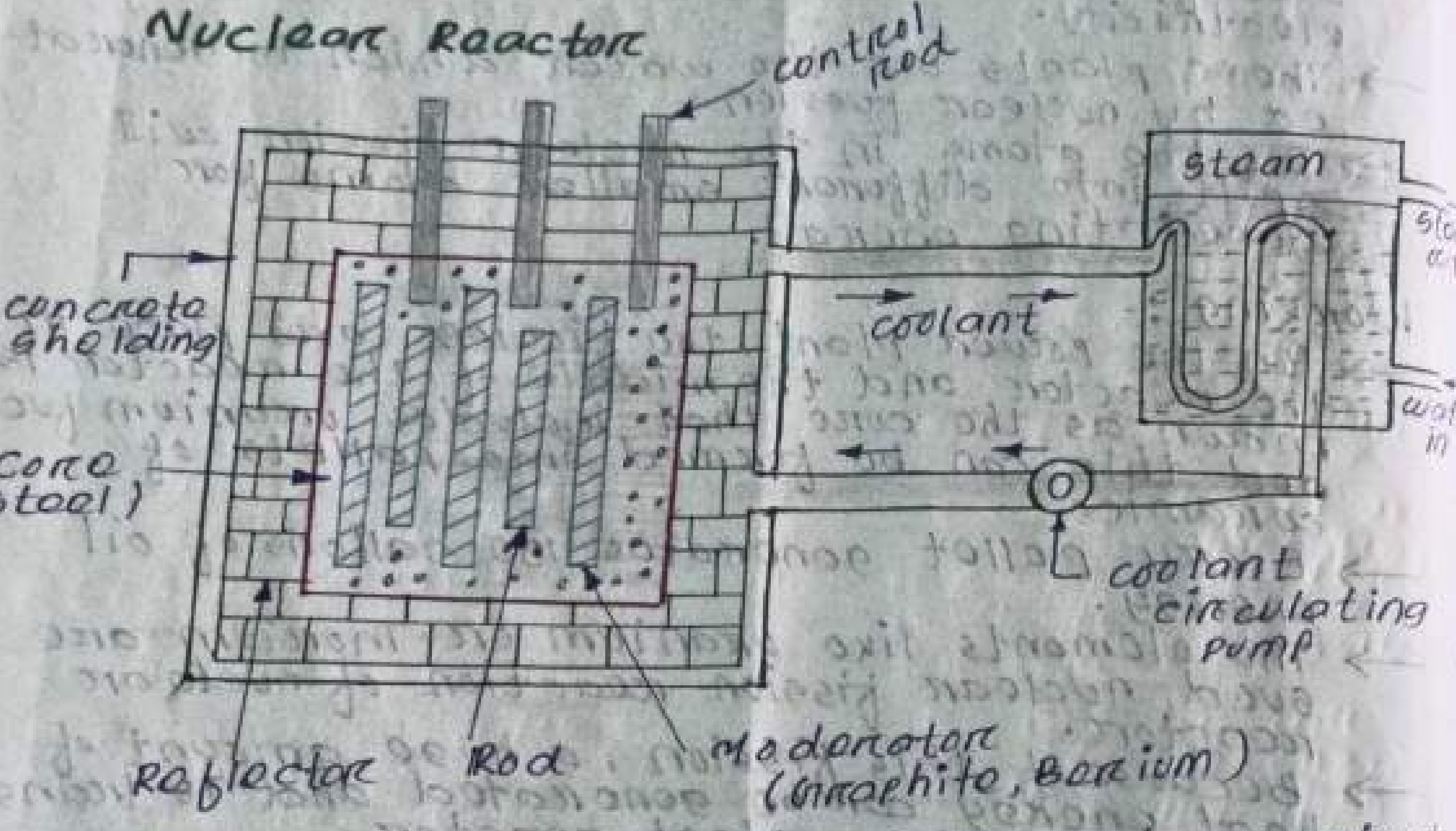
Parts of Nuclear plant
① Nuclear Reactor
② Heat exchanger
③ steam turbine
④ Alternator
⑤ Condenser

Definition
→ The power plant that is used to warm the water to generate steam, than this steam can be used for rotating huge turbines for generating electricity.
→ These plants use the water which is generated by nuclear fission.
→ So the atoms in the nuclear fission will spilt into different smaller atoms for generating energy.

Working :-
→ In the power plant, the fission takes place in the reactor and the middle of the reactor is known as the core that includes uranium fuel. and this can be formed into pallets of ceramics.
→ Every pellet generates 150 gallons of oil energy.
→ The elements like uranium or Thorium are sued nuclear fission reaction of nuclear reactor.
→ Because of this fission, a huge amount of heat energy can be generated and is transmitted to the coolant reactor.
→ Here is the coolant is nothing but water, liquid metal otherwise gas.
→ The water is heated to flow in a heat exchanger so that it changes into high temperature steam.
→ Then water is heated to flow in heat exchanger so that it changes into high temperature steam.

→ Then the steam which produce is permitted to make a steam turbine run.
→ Again the steam can be changed back into the coolant & recyled to use for the heat exchanger.
→ So, the turbine and alternator are connected to produce electricity.
→ By using a transformer, the electricity which is produce can be increased to use in long distance communications.

Nuclear Reactor



→ A nuclear reactor is an apparatus in which heat is produced due to the nuclear fission chain reaction.
→ The nuclear reactor may be used as a substitute for the boiler box of steam plant a combustion chamber of gas turbine plant.
→ The steam on the gas may be used as working fluid in nuclear power plant.

The main parts of nuclear reactor are
- (a) Nuclear fuel
- (b) Moderator
- (c) control rods
- (d) Reflector
- (e) Reactor vessel
- (f) Biological shoilding
- (g) coolant

Nuclear Fuel :-

→ fuel of a nuclear reactor should be fission-able material which can be defined as an element or isotope whose nuclei can be caused to under go nuclear fussion by nuclear bombardment and to produce fission chain reaction.

→ The fuels are U^{233}, U^{235}, Pu^{239}.

→ U^{235} is most unstable and is capable of sustaining chain reaction and has been given the name as primary fuel.

→ U^{233} and Pu^{239} are artificially produced from Th 232 and U238 respectively and called secondary fuels.

→ The fuel should be protected from corrosion and errosion of the coolant and for this it is encased in metal cladding generally stainless steel or alluminium.

→ Another fuel used in nuclear reactor is uranium carbide (UC). It is a black ceramic used in the form of pellets.

Moderator :-

→ In the chain reaction the neutrons produced are fast moving neutrons. These fast moving neutrons are far less effective in causing the fission of U235 and try to escape from the reactors.

→ To improve the utilization of their neutrons their speed is reduced. It is done by colliding them with the nuclei of other material which is lighter, does not the neutrons but scatters them.

→ Each such collision causes loss of energy and the speed of the fast moving neutrons is reduced, such material is called moderator.

→ Graphite, heavy water and beryllium are generally used as moderator.

→ It should have high thermal conductivity, good resistance to corrosion and be stable under high heat and radiations.

Control Rod :-

→ A nuclear reactor contains as much fuel as is sufficient to operate a large power plant for some months. The consumption of this fuel and power level of the reactor depends upon its neutron flux in the reactor core.

→ The energy produced in the reactor core due to fission of nuclear fuel during chain reaction is as much that of it is that it is not controlled properly the entire core and surrounding structure may melt and radioactive fussion products may come out of the reactor.

→ So the power of the reactor may control by some means. This is done by control rod.

→ control rods is the cylindrical or sheet form are made of boron or cadmium. These rod can be moved in and out of the holes in the reactor core.

→ Due to the insertion of control rod, absorb more neutrons and slow down the reaction and their withdrawal absorbs less neutrons.
→ The shifting of control rod is done by automatically and some case mannually.
→ The power of reactor is controlled by shifting control rod.

Reflector :-

→ The neutrons produced during the fission process will be partly absorbed by the fuel rods, moderator, coolant and structural materials etc.
→ Neutrons left unabsorbed will try to leave the reactive core never to return to it and will be lost. Such losses should be minimized.
→ It is done by surrounding the reactive core by a material called reflector which will send the neutrons back into the core.
→ The returned neutrons can then cause more fission and improve the neutrons economy of the reactor.
→ It is made up of Graphite and beryllium.

Reactor Vessel :-

→ It is a strong walled container housing the core of the power reactor.
→ It contains moderator, reflector, thermal shielding and control rods.

Biological shielding

→ shielding is also the important part of a nuclear reactor of a nuclear power plant.
→ During the chain reaction in the nuclear reactor, lots of hazardous rays or radiations are produced which is harmful for man.
→ During fission of nuclear fuel alpha, bita and gama rays are produced and neutrons are produced. A protection must be provided against them.

→ A thick layer of lead or concrete are provided all round the reactor for stopping the gamma rays radiation.
→ Thick layer of metals or plastics are sufficient to stop the alpha and beta-rays.

Coolant
→ It flows through and arround the reactor core.
→ It is used to transfer the large amount of heat produced in the reactor core due to fission of nuclear fuel during chain reaction.
→ The coolant either transfer the heat to another medium or if the water is used as coolant then the water is converted into steam directly.
→ The the steam is sent to the turbine.
→ coolant used should be stable under thermal condition and should have high melting point and the high boiling point.
→ It should not corrode the material and should have high heat transfer coefficient.

- Compare the nuclear and thermal power plant
→ In a nuclear power plant, the heat source is from the nuclear reaction, whereas in a thermal power plant it is from the combustion of coal.
→ There are no fuel transportation, handling and storages and also there is no problem of ash disposal in nuclear power plant as compared to thermal power plant.
→ Nuclear power plant occupies less space in comparision to thermal power plant.
→ The nuclear power plant is more economical as compared to thermal power plant.

→ The number of workman required for the operation of nuclear power plant is much less than a thermal power plant.

→ The capital cost of nuclear power plant is less as compared to thermal power plant (in same size).

- Disposal of Nuclear Waste

→ waste disposal problem is common in every industry.

→ waste from atomic energy installation are radioactive, create radioactive hazard and require strong control to ensure that radioactivity is not released it into the atmosphere to avoid atmospheric pollution.

→ The wastes produced in a nuclear power plant may be in the form of

* Liquid waste
* Gaseous waste
* Solid waste

Liquid waste

The disposal of liquid wastes are done in two ways.

① Dilutation

→ The liquid wastes are diluted with large quantities of water and then released into the ground.

→ This methods suffers from the drawback that there is a chance of contamination of underground water if the dilute factor is not adequate.

(ii) Concentration to small volumes and storage when the dilution of radioactive liquid waste is not desirable due to amount or nature of isotopes, the liquid wastes are concentrated to small volumes and stored in underground tanks. The tanks should be of assured long term strength and leakage of liquid from the tanks should not take place otherwise leakage or contents from the tanks leads to significant underground water contamination.

Gaseous Waste

→ Gaseous wastes can most easily result in atmospheric pollution.

→ Gaseous wastes are generally with air, passed through filters and then released to atmosphere through large chimneys.

Solid Waste

→ Solid waste consists of scrap materials or discarded objects contaminated with radioactive matter.

→ These wastes if combustiable are burnt and the radioactive matter is mixed with concrete, drummed and shipped for burial.

→ Non-combustiable solid wastes are always buried deep in the ground.

- Selection of site for nuclear power station

(1) Availability of water

→ At the power plant site an ample (sufficient) quantity of water should be available for condenser cooling and make up water required for steam generation.

→ The site should be near to river, reservoir or sea.

② Distance from load center
→ The plant should be located near the load center.
→ This will minimize the power losses in transmission line.

③ Distance from populated area
→ The power plant should be located far away from populated area to avoid the radioactive hazard.

④ Accessibility to site
→ The power plant should have rail and road transportation facilities.

⑤ Waste Disposal
→ The wastes of a nuclear power plant are radioactive and there should be sufficient space near the plant site for the disposal of wastes.

⑥ Safeguard against earthquakes.

⑦ Foundation condition

- List of Nuclear power stations

The various nuclear power plants situated in India are as follows.

* Kaiga — Karnataka —— 220 × 4 = 880 MW
* Kakrapur — Gujurat —— 220 × 2 = 440 MW
* Kudankulam — TN —— 1000 MW
* Kalpakkam —— TN —— 220 × 2 = 440 MW
* Narora —— UP —— 220 × 2 = 440 MW
* Rawat Bhata — Rajasthan —— 1180 MW
* Tarapur —— Maharastra —— 1400 MW

UNIT-04 DIESEL ELECTRIC POWER STATIONS

DC = Direct current
AC = Alternative current
DG = Diesel Generator

Introduction

→ In diesel power station, diesel engine is used as the prime mover.

→ The diesel burns inside the engine and the product of this combustion acts as the working fluid to produce mechanical energy.

→ The diesel engine drives alternator which converts mechanical energy into electrical energy.

→ A diesel power station is also known as stand by power station.

→ The diesel power plants are installed where the supply of coal and water is not available in sufficient quantity.

use of Diesel Electric station

- central station
- standby plant
- peak load plant
- Emergency plant
- mobile plant
- Nursery plant
- supply units for cinema

Advantages

→ It is easy to design and install these electric stations.

→ They are easily available in standard capacities.

→ They can respond to load changes without much difficulty.

→ There are less standby losses.
→ They are compact and occupy less space for a given power.
→ They can be started and stopped quickly.
→ They require less cooling water.
→ capital cost is less.
→ High efficiency of energy conversion from fuel to electricity.
→ Efficiency at part load is also higher.

Disadvantages

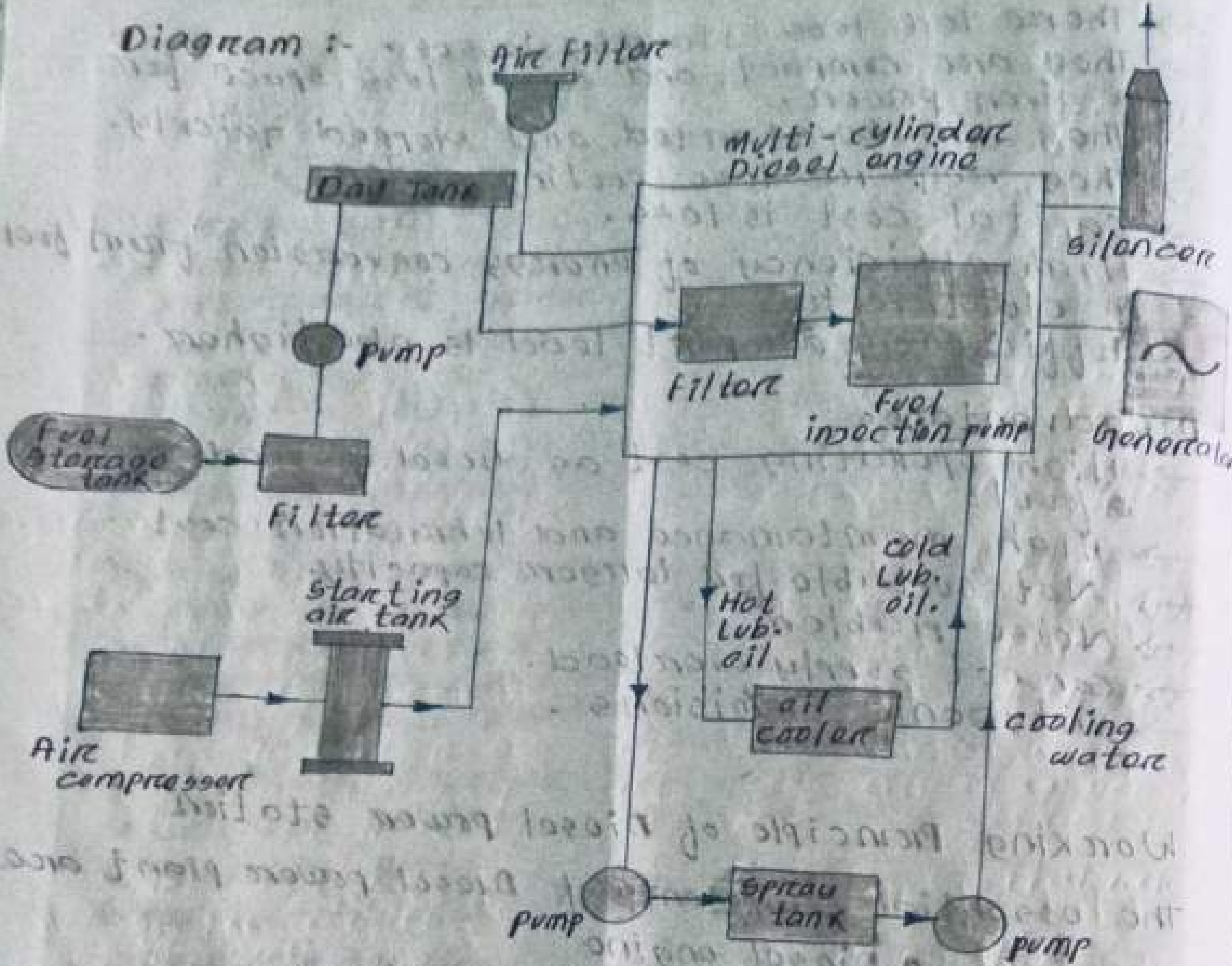
→ High operating cost as diesel is used as a fuel.
→ High maintainance and lubrication costs.
→ Not suitable for larger capacity.
→ Noise problem.
→ can not supply overload.
→ unhygenic emmisions.

Working Principle of Diesel power station

The essential components of Diesel power plant are

- Diesel engine
- Air filter and supercharger
- Engine starting system
- Fuel system
- Lubrication system
- cooling system
- Governing system
- Exhaust system.

Diagram :-



- Diesel Engine
  - → This is the main component of a diesel power plant.
  - → The engines are classified into two catagories
    - two stroke engine
    - four stroke engine
  - → Engines are generally directly coupled to the generator for developing power.
  - → In diesel engines, air admited into the cylinder is compressed.
  - → At the end of compression stroke, fuel is injected.

→ The fuel is burned and burning gases expand and do work on the piston.

→ The shaft of the engine is directly coupled to the generator.

→ After the combustion, the burned gases are exhausted to the atmosphere.

• Air filter and supercharger

→ The air filter is used to remove the dust from the air which is taken by the engine.

→ Air filters may be of dry type, which is made up of felt, wool or cloth.

→ In oil bath type of filters, the air is swept over a bath of oil so that dust particles get coated.

→ The function of the supercharger is to increase the pressure of the air supplied to the engine and thereby the power of the engine is increased.

• Engine starting system

→ Diesel engine used in diesel power plant is not self starting.

→ Engine starting system includes air compressor and starting air tank.

→ This is used to start the engine in cold conditions by supplying the air.

→ The following are the commonly used starting systems in large and medium size engines.

- starting by an auxillary engine
- use of electric motor or self starters.
- compressed air system.

- fuel storage
  - → The fuel is store in the storage tank.
  - → The fuel storage tank is connected with filter and by pump the fuel is supplied to the Day tank.
- fuel supply system
  - → It includes the storage tank, fuel pump, fuel transfer pump, strainers and heaters.
  - → pump draws fuels (diesel) from storage tank and supply it to the small day tank through the filter.
  - → Day tank supplies the daily fuel need for the engine.
  - → The day tank is usually placed at high so that diesel flows to engine under gravity.
  - → Diesel is again filtered before being injected into the engine by the fuel injection pump.
- Fuel injection system
  - → The mechanical heart of the diesel engine is the fuel injection system.
  - → The fuel injection system plays a vital role in the diesel engine.
  - → A very small quantity of fuel must be measured out, injected, atomised and mixed with combustion air.
  - → The mixing problem becomes more difficult - the larger the cylinder and faster the rotative speed.
  - → The fuel injection system performs the following functions.
    - Filter the fuel
    - meter the correct quantity of the fuel to be injected.
    - Time the injection process
    - Regulate the fuel supply.

- secure the fine atomization of fuel oil
- Distribute the atomized fuel properly in the combustion chamber.

- Air intake system

→ The air intake system conveys fresh air through pipes or ducts to
  - Air intake mainfold or four stroke engine
  - The scavening pump inlet of a two stroke engine.
  - The supercharger inlet of a supercharged engine.

→ The air system begins with an intake located outside the buildings provide with a filter to catch dirt which would otherwise cause excessive wear in engine.

→ The filters may be of dry or oil bath.

→ Electrostatic precipitator filter can also be used.

→ Light weight steel pipe is the material for intake ducts.

→ In some cases, the engine noise may be transmitted back through the air intake system to the outside air.

- Exhausting system

→ The purpose of the exhaust system to discharge the engine exhaust to the atmosphere outside the buildings.

→ Every engine should be provided with its independent exhaust system.

→ The exhaust gases coming out of the engine is very noisy.

→ In order to reduce the noise a silencer (muffler) is used.

- Fuel storage
  → The fuel is store in the storage tanks.
  → The fuel storage tank is connected with filter and by pump the fuel is supplied to the Day tank.
- Fuel supply system
  → It includes the storage tank, fuel pump, fuel transfer pump, strainers and heaters.
  → pump draws fuels (diesel) from storage tank and supply it to the small day tank through the filter.
  → Day tank supplies the daily fuel need for the engine.
  → The day tank is usually placed at high so that diesel flows to engine under gravity.
  → Diesel is again filtered before being injected into the engine by the fuel injection pump.
- Fuel injection system
  → The mechanical heart of the diesel engine is the fuel injection system.
  → The fuel injection system plays a vital role in the diesel engine.
  → A very small quantity of fuel must be measured out, injected, atomised and mixed with combustion air.
  → The mixing problem becomes more difficult - the larger the cylinder and faster the rotative speed.
  → The fuel injection system performs the following functions.
    - Filter the fuel
    - meter the correct quantity of the fuel to be injected.
    - Time the injection process
    - Regulate the fuel supply.

→ The hot oil after cooling the moving parts return to the lubricating oil tank.

• Governing system
→ It is used to regulate the speed of the engine.
→ This is done by varying the fuel supply according to the engine load.

Selection of site for diesel electric power plants

① Distance from the load center
→ The site should be as near to the load center as possible in order to avoid transmission costs and loses.

② Availability of land
→ The land should be available at cheap rate to keep the capital cost of the plant to the reasonable one.

③ Availability of fuel
→ The fuel should be easily available and at reasonable rate.

④ Availability of transportation facilities
→ The transportation facilities should be available.

⑤ Availability of water
→ water should be available in sufficient quantity for cooling purpose.

⑥ Distance from populated area
→ The site should be away from thickly populated area because of noise and nuisance caused from exhaust.

⑦ Type of land
→ The land should be of high bearing capacity to withstand the load of the plant and also vibrations transmitted to the foundations from compressors and diesel engine.

- Cooling system

→ The temperature of the burning fuel inside the engine cylinder is the order of 15000°C to 20000°C.

→ In order to lower this temperature, water is circulated around the engine.

→ The water envelopes (water jacket) the engine the heat from the cylinder, piston, combustion chamber etc. is carried by the circulating water.

→ The hot water leaving the jacket is passed through the exchanger.

→ The heat from the heat exchanger is carried away by the raw water circulated through the heat exchanger and is cooled in the cooling water.

→ Almost 25 to 35 percentage of total heat supplied in the fuel is removed by the cooling medium.

→ Heat carried away by lubricating oil and heat lost by radiation amounts 3 to 5 % of total heat supplied.

→ There are mainly two methods of cooling.

- Air cooling
- Liquid cooling

- Lubricating system

→ It includes oil pumps, oil tanks, coolers and pipes.

→ It is used to reduce the friction of moving parts and reduce wear and tear of the engine parts such as cylinder walls and pistons.

→ Lubrication oil which gets heated due to the friction of the moving part is cooled before re-circulation.

→ In the lubrication system the oil is pumped from the lubricating oil tank through the oil cooler where the oil cooled by the cooled water entering the engine.

→ The hot oil after cooling the moving parts return to the lubricating oil tank.

• Governing system
→ It is used to regulate the speed of the engine.
→ This is done by varying the fuel supply accoding to the engine load.

Selection of site for diesel electric power plants

① Distance from the load center
→ The site should be as near to the load center as possible in order to avoid transmission costs and loses.

② Availability of land
→ The land should be available at cheap rate to keep the capital cost of the plant to the reasonable one.

③ Availability of fuel
→ The fuel should be easily available and at reasonable rate.

④ Availability of transportation facilities
→ The transportation facilities should be available.

⑤ Availability of water
→ water should be available in sufficient quantity for cooling purpose.

⑥ Distance from populated area
→ The site should be away from thickly populated area because of noise and nuisance caused from exhaust.

⑦ Type of land
→ The land should be of high bearing capacity to withstand the load of the plant and also vibrations transmitted to the foundations from compressors and diesel engine.

Application of Diesel power station

→ Central power stations
→ standby power stations
→ peak load plants
→ Emergency plants
→ private power plant for small industries.
→ hospitals
→ radio stations
→ cinema halls
→ Nursery stations
→ Emergency plant
→ Mobile plant

performance and thermal efficiency of Diesel electric power station.

① Indicated mean effective Pressure (IMEP)

In order to determine the power developed by the engine, the indicator diagram of engine should be available. from the area of indicated diagram it is possible to find an average gas pressure which while acting on the piston throughout one stroke would account for the net workdone. the pressure is known as indicated mean effective pressure.

② Indicated Horse power (IHP)

It is the total power developed by combustion of fuel in the combustion chamber is called indicated horse power or indicated power.

$$I.H.P = \frac{P_m \, L A N . n}{4500 \times K} \text{ kW}$$

where, P_m = IMEP in kg/cm^2

L = length of stroke in meter

A = piston area in cm^2.

N = speed in R.P.M
n = number of cylinder
K = 1 for two-stroke engine
  2 for four-stroke engine

③ Brake Horse power (B.H.P)

Brake horse power is defined as the net power available at the crankshaft. It is found by measuring the output torque with a dynamometer.

$$B.H.P = \frac{2\pi N T}{4500}$$

where,
T = torque in kg.m.
N = speed in R.P.M

④ Frictional Horse power (F.H.P)

The difference of I.H.P and B.H.P is called F.H.P.

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

⑤ Indicated thermal efficiency (η_i)

It is defined as the ratio of indicated work to the thermal input.

$$\eta_i = \frac{I.H.P \times 4500}{W \times C_v \times J}$$

where, W = weight of fuel supplied in kg per min.
C_v = calorific value of fuel oil in kcal/kg.
J = Joules equivalent = 427

⑥ Brake thermal efficiency (η_b)
It is defined as the ratio of brake output to thermal input:

$$\eta_b = \frac{B.H.P \times 4500}{W \times C_V \times J}$$

⑦ Mechanical efficiency (η_m)
It is defined as the ratio of BHP to IHP.

$$\eta_m = \frac{BHP}{IHP}$$

Numericals

① In a gas engine the mean effective pressure (m.e.p) is 4.8 kg/cm² and the ratio of diameter of piston to stroke is 2/3. Calculate the size of four stroke cycle gas engine if it runs at 250 R.P.M and its BHP is 16. The mechanical efficiency of the engine is 80 %.

Soln

Given data

$P_m = 4.8 \ kg/cm^2$

$\eta_m = 80\,\% = 0.8$

$N = 250$ rpm

$n = 1$

$K = 2$

$BHP = 16$

$\frac{D}{L} = \frac{2}{3}$

we know,

$$\eta_m = \frac{BHP}{IHP}$$

$\Rightarrow 0.8 = \frac{16}{IHP}$

$\Rightarrow IHP = \frac{16}{0.8} = 20$

we know,

$$IP = \frac{P_m LAN \times n}{4500 \times K}$$

$$20 = \frac{4.8 \times L \times A \times 250 \times 1}{4500 \times 2}$$

$$\Rightarrow LA = \frac{20 \times 4500 \times 2}{4.8 \times 250 \times 1}$$

$$L \cdot A = 150$$

$\frac{D}{L} = \frac{2}{3}$

$\Rightarrow D = \frac{2}{3} L$

$\Rightarrow L = \frac{3}{2} D = \frac{3}{2} \times \frac{1}{100} D \text{ m.}$

$$L \cdot A = 150$$

$$\Rightarrow \frac{3}{2} \times \frac{1}{100} D \times \frac{\pi}{4} D^2 = 150$$

$$\Rightarrow D^3 = 150 \times \frac{4}{\pi} \times \frac{100}{1} \times \frac{2}{3}$$

$$= 12732.39$$

$$\Rightarrow D = \sqrt{12732.39} = 23.35 \text{ cm}$$

$$L = \frac{3}{2} \times D = \frac{3}{2} \times 23.35$$

$$= 35 \text{ cm.}$$

② The following observations refers to trial on a four-stroke cycle gas engine:

Mean effective pressure = 7 kg/cm^2
Fuel gas supplied = 0.24 m^3/min
Calorific value of gas = 4500 kcal/m^3
Stroke = 50 cm
Bore = 20 cm
Brake load = 70 kg
Speed = 300 R.P.M
Radius of Brake drum = 0.8 meters

Determine the following
ⓐ I.H.P
ⓑ B.H.P
ⓒ Mechanical efficiency
ⓓ Thermal efficiency

Soln

Given data.

ⓐ $IHP = \frac{P_m L A N \times n}{4500 \times K}$

$= \frac{7 \times 50 \times \frac{1}{100} \times \frac{\pi}{4}(20)^2 \times 300 \times 1}{4500 \times 2}$

$= 36.65$ KW

ⓑ $BHP = \frac{2\pi N T}{4500}$

$= \frac{2 \times \pi \times 300 \times 7 \times 0.8}{4500}$

$= 23.45$ KW

(c) $$\eta_m = \frac{BHP}{IHP}$$

$$= \frac{23.45}{36.65} = 63.9\ \%$$

(d) $$\eta_b = \frac{BHP \times 4500}{W \times CV \times J}$$

$$= \frac{23.45 \times 4500}{0.24 \times 4500 \times 427}$$

$$= 22.8\ \%$$

UNIT-05 HYDEL POWER STATIONS

Introduction

→ A hydro electric power station consists of turbi the rely on gravity flow of water from the to turn a turbine to generate electricity.

→ A generating station which utilizes the pote- tial energy of water at a high level for the generation of electrical energy is known as hydro-electric power station.

→ Hydro-electric power stations are gener located in hilly area where dams can be buil conveniently and large water reservoir can be obtained.

→ In a hydro-electric power station water head is created by constructing a dam across a river or lake.

→ From the dam, water is led to a water turbine.

→ The water turbine capture the energy in the falling water and changes the hydraulic energy into mechanical energy at the turbine shaft.

→ The turbine drives the alternator which converts the mechanical energy into electrical energy.

→ In a hydro-electric power plant, the water can be stored with potential energy by the dam on the lake or river. The dam creates a high water head and it flows the water with kinetic energy and the water then strikes on the turbine blade and rotate the blade and it rotates the shaft, here the kinetic energy converted into mechanical energy. The turbine shaft connected with generator shaft. It converts the mechanical energy into electrical energy.

Advantages of Hydel power plant

→ No fuel is required, hence operating cost is less.
→ More reliable and low maintainance.
→ started and synchronized in few minitues.
→ No standby losses.
→ Long life.
→ Accurate governing is possible.
→ The efficiency is high and fall with age.
→ Required few skilled persons.
→ No pollution.
→ The cheapest energy source.

Disadvantages

→ They depend on monsoons - hence power output is not constant.
→ Low transmision lines are required.
→ capital cost is more.
→ submerges huge areas.
→ uproots large parulation.
→ Depend on whether
→ Aquatic life is effected.
→ can only be used in mountainous areas.

Classification

The hydro-electric power plants are mainly classified into several types depanding upon the following factors:

① Based on the availability of head

ⓐ Low head plant
ⓑ medium head plant
ⓒ High head plant.

② Based on plant capacity
ⓐ Micro hydel plants
ⓑ Medium capacity plants
ⓒ High capacity plants
ⓓ super plants

③ Based on nature of load / duty
ⓐ Base load plants
ⓑ peak load plants

④ Based on type of location
ⓐ out-door type
ⓑ Indoor type
ⓒ semi-outdoor station
ⓓ under ground station.

⑤ Based on capacity of flow regulation
ⓐ Run off river plants
ⓑ storage plant
ⓒ pumped storage plant

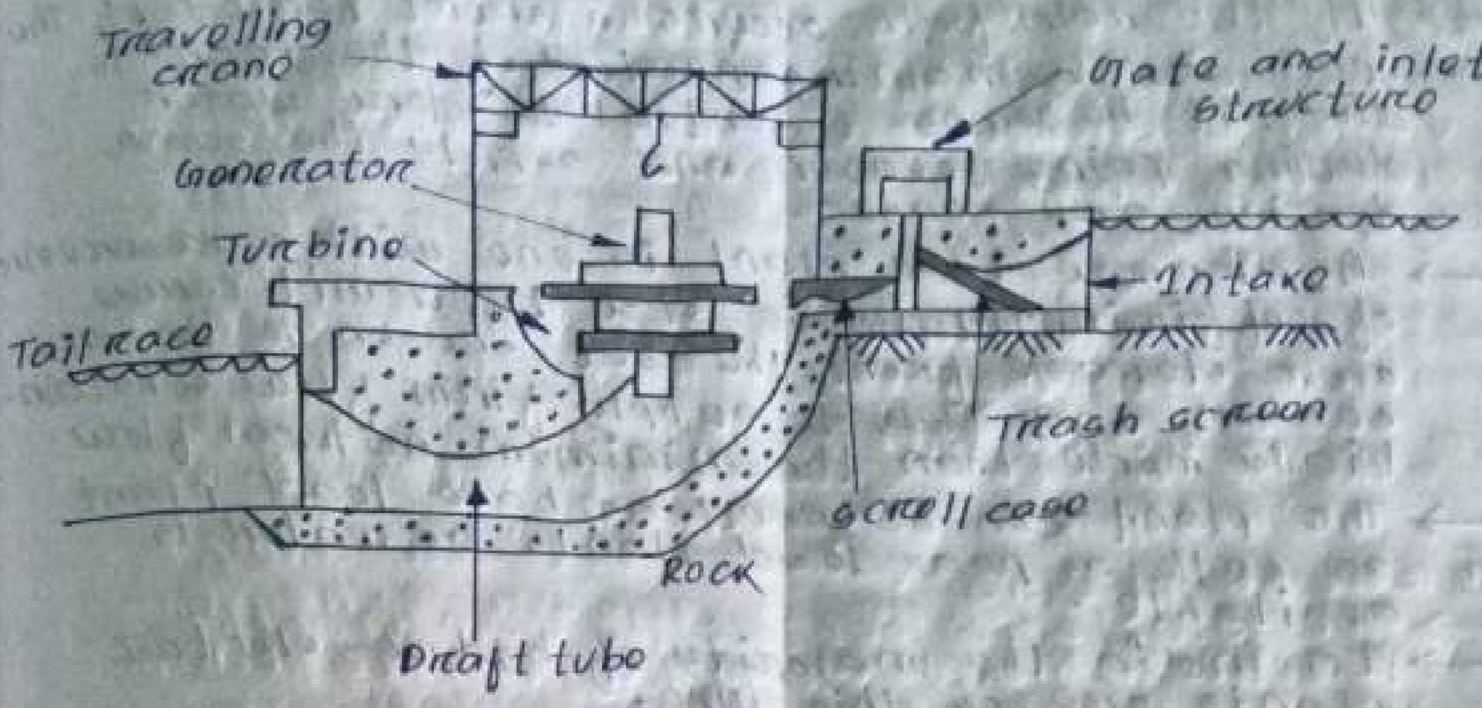
⑥ Based on specific speed.
ⓐ High specific speed
ⓑ medium specific speed
ⓒ Low specific speed.

ⓐ Run of River Plant

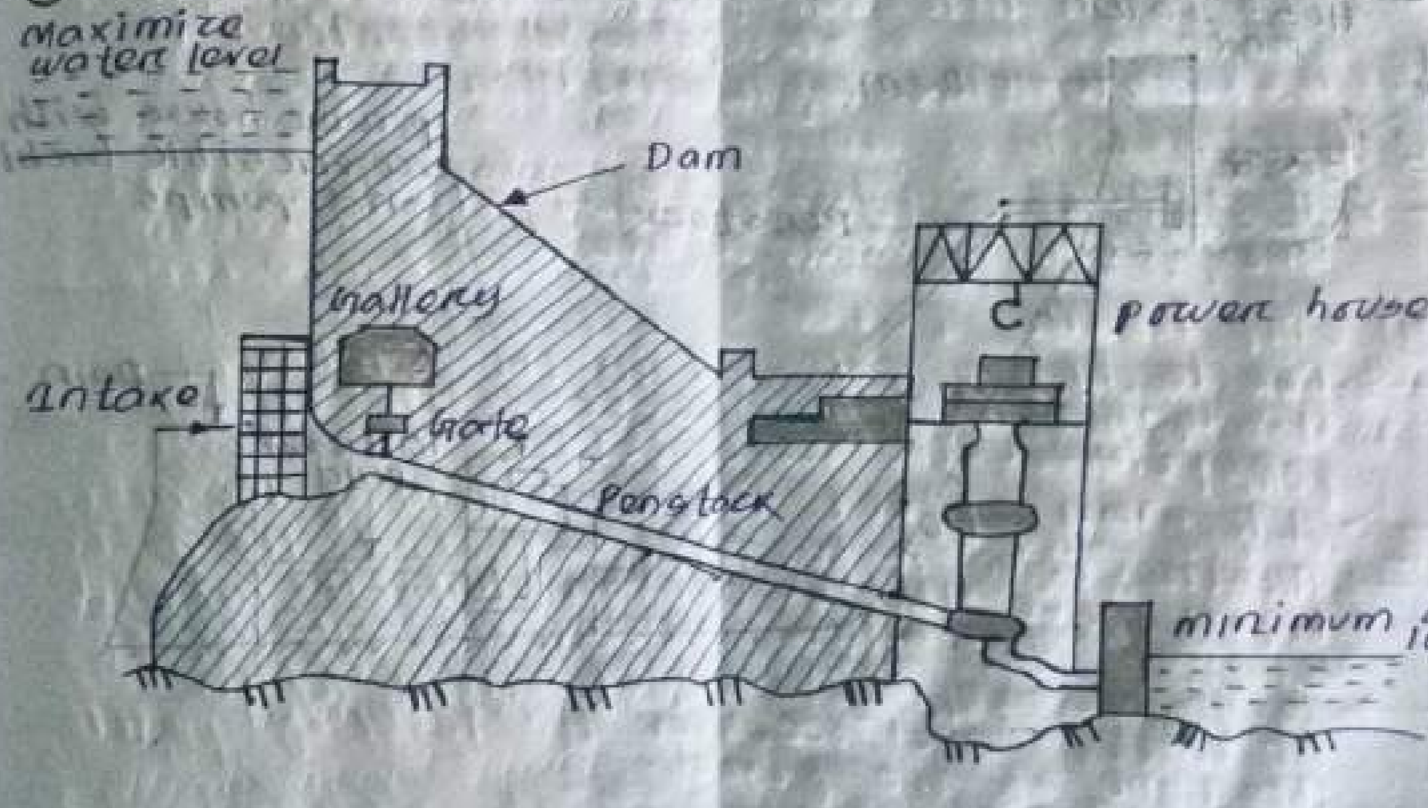
→ This type of power plant has no control over the river flow and uses the water as it comes.

→ During the rainy season high water flow is available and if is available and if the power plant is not able to use this large flow of water some quantity of water is allowed to flow over dam spilways as waste

→ whereas during dry season, due to low rate of water, the power produced by such plant will be low.



(b) Storage Plant



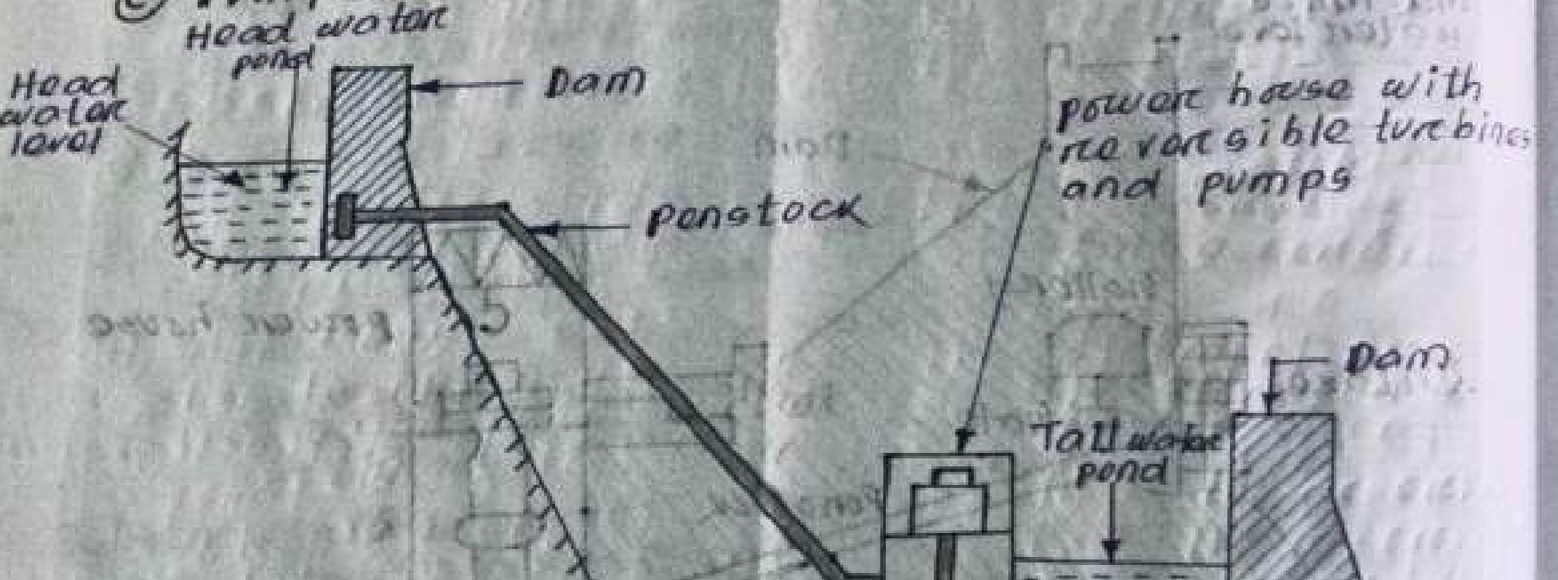
→ If the rain fall occurs a short period of the year and remaining period of the year is dry, it becomes essential to store water during rainy season and supply the same during dry season.

→ A storage type plant is one with a reservoir of sufficiently large size to permit carry over storage from the wet season to the dry season and thus to supply firm flow substantially more than the minimum natural flow.

→ The plant can be used as base load plant as well as peak load plants as water is available.

→ In india the majority of hydro-electric plants are of this type.

Ⓒ Pumped storage plant



→ pumped storage plant in combination with hydro electric power plant is used for supplying the sudden peak load of short duration.

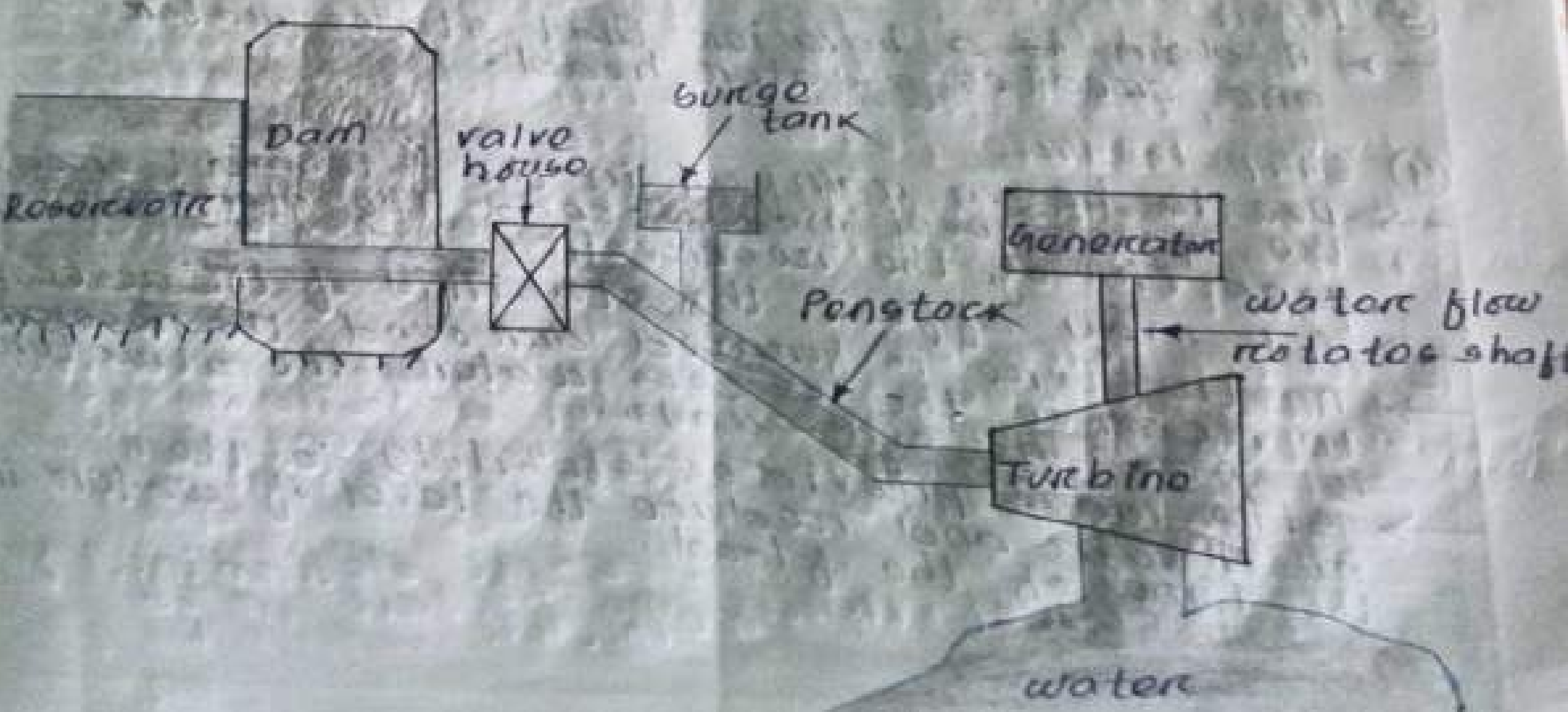
→ The water leaving the turbines of hydro electric power plant is stored in tail-race pond.

→ This water is pumped back to the head race reservoir by means of reversible pump turbines sets and is used for power generation at the peak load time.

→ pumped storage plants are generally inter connected with other plants such as steam power plant.

→ The off peak capacity of steam power station can be used for pumping water in the head reservoir.

Working Principle of Hydro-electric Plant



Components of Hydro-electric power plant
① catchment area
② Reservoir
③ Dam
④ slip-way
⑤ surge-tank
⑥ penstock
⑦ water turbine

① Catchment area
→ The total area behind the dam in which water is collected and steamflow is obtained is known as catchment area.

② Reservoir
→ It is an integral part of the power plant, where water is stored and supplied to a water turbine continously.

③ Dam
→ A dam is a barrier that stores water and creates a water head.

④ slip-way
→ Due to heavy rainfall in the catchment area, the water level may exceed the storage capacity of the reservoir.
→ It may affect the stability of the reservoir.
→ A structure is formed arround the reservoir to remove the excess water, the structure is known as slip-ways.
→ slip ways provides stability to the reservoir and reduce the level of water in the time of the flood.

⑤ Surge tank

→ It is a small tank (open at top).

→ It is provided to reduce the pressure surge in the conduit.

→ It is located near the begining of penstock.

⑥ Penstock

→ penstocks are open or closed conduits that carry water to the turbine.

→ The conduit is also known as penstock.

→ The penstock are generally made of RCC or steel.

→ The RCC penstocks are suitable for low water head (< 30 m.)

→ The steel penstocks are ideal for any head, as they can be designed according to water head or working pressure.

⑦ Water turbines

→ It works as an energy conversion device.

→ It is a machine through which the potential energy of water is converted into the mechanical energy of shaft.

→ The main types of water turbines are

* Impulse turbine
* Reaction turbine

Working :-

→ The water turbine changes the kinetic energy of the falling water into mechanical energy at the turbine shaft.

→ In simple words, falling water spins the water turbine.

→ The turbine drives the alternator coupled with it and converts mechanical energy to electrical energy.

→ This is the basic 'working principle of hydroelectric power plant'.

→ Hydroelectric power plants are very populer because the stores of fuels are exhausting day by day.

→ They are also benifical for irrigation and flood control purposes.

Selection of site of Hydel power plant

① Availability of water

→ In hydro-electric power stations potential energy of waterfall or kinetic energy of flowing stream is utilized for generation of electric power.

→ The water available at good head or huge quantity of water flowing across a given point.

② water storage

→ The storage of water in suitable reservoir at a higher at a height or building of dam across the river is essential in order to have continuous and perennial supply during the dry season.

→ The storage capacity can be determined from the hydrograph or mass curve or by using analytical methods.

③ water head

→ Availability of head of water has considerable effect on the cost and economy of the power generation.

→ An increase in effective head reduces the quantity of water to be stored and handled penstocks, screens and turbines.

→ Therefore the capital cost of the plant is also reduced.

④ Distance from load center

→ The hydro-electric power plant is usually located away from the load center.

→ For economical transmission of electric power the routes and the distances need active considerations.

⑤ Accessibility of the site

→ Adequate transportation facilities must be available or there should be a possibility of providing the

⑥ water pollution

→ polluted water may causes excessive corrosion and damage to the metalic structures.

⑦ Large catchment area

→ The reservoir must have a large catchment area so that level of water in the reservoir may not fall below the minimum required in dry season.

⑧ Availability of land

→ The land available should be cheap in cost and rocky in order to withstand the weight of the large building and heavy machinary.

List of Hydro-power station

SL NO	Hydroelectric power plant	State	Capacity (MW)
01	Srisailam Hydel project	Andhra pradesh	1670
02	Upper Sileru hydro electric project	Andhra pradesh	120
03	Pambikai	Kerala	360
04	Hirakud project	Orissa	427
05	Ukra project	Tapi, Gujurat	160
06	Chonani Hydel project	Tawi, J & K	37
07	Salal Hydel project	Chenab, Kashmir	690
08	Idduki Hydel project	Idduki, Kerla	780
09	Kodayar Hydro electric project	Tamilnadu	100
10	Kundah Basin development project	Tamil nadu	425
11	Tungabhadra project	Karnataka	126
12	Balimela hydro-electric project	Orissa	480
13	Bhakra Nagal project	Punjab - HP	1325
14	Beas Dam at pong	Punjab-Himachal	360
15	Kotoshwar	Uttarakhand	400
16	Tehri Dam	Uttarakhand	1000
17	Teesta	Sikkim	510
18	Loktak	Manipur	105
19	Indira sagar	Maharastra	1000
20	Kalinadi	Karnataka	1225
21	Uri	J & K	480
22	Dulhasti	J & K	390
23	Baira	HP	180
24	Pong	HP	396

Types of Turbines and Generation used

The hydraulic turbines are classified according to type of following factors.

1. Accoding to the energy available at the inlet of turbine.
   - Impulse turbine
   - Reaction turbine
2. Accoding to the direction of flow through runner
   - tangential flow turbine
   - Radial flow turbine
   - Axial flow turbine
   - mixed flow turbine
3. Accoding to the head at inlet of turbine
   - Higher head turbine
   - Lower head turbine
   - Medium head turbine
4. Accoding to the specific speed of turbine
   - Lower specific speed turbine
   - medium specific speed turbine
   - Higher specific speed turbine

Impulse Turbine

→ Impulse turbine works on the basic principle of impulse.

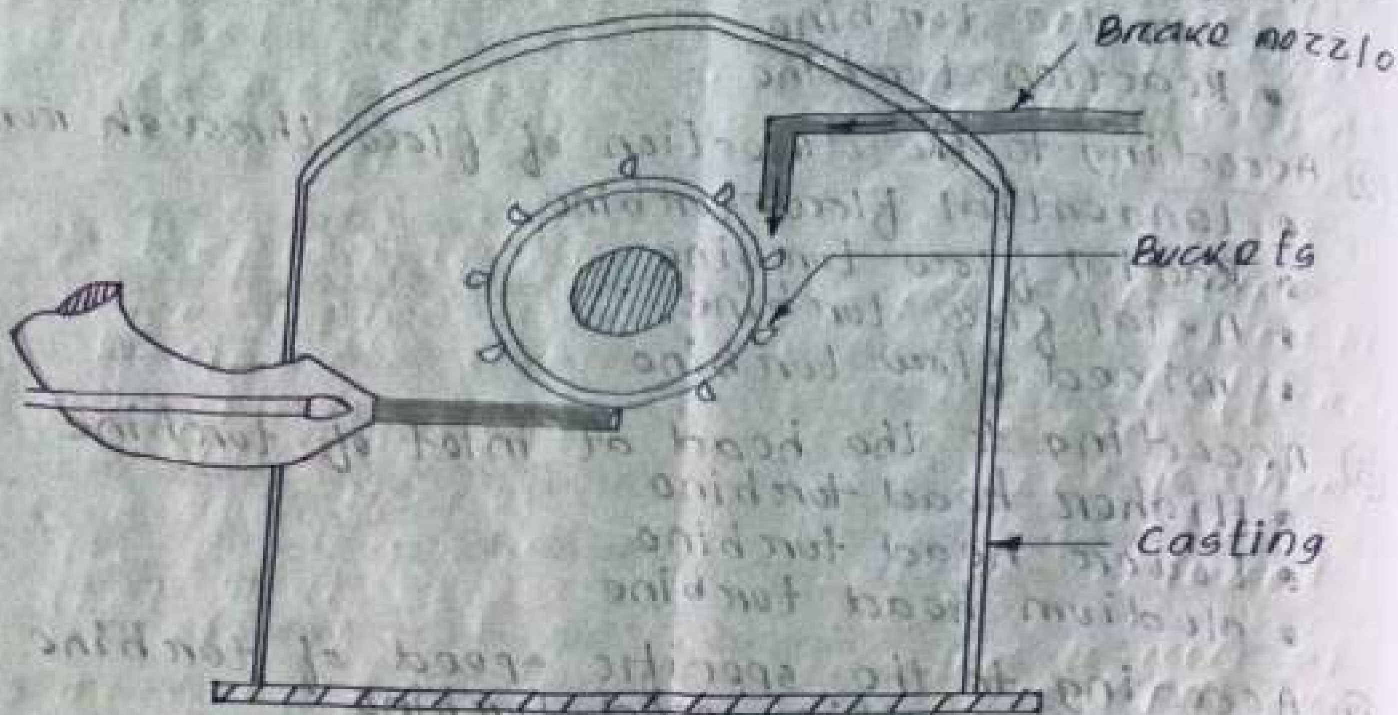
→ Impulse turbine is a power generating device in hydro power plant in which the potential energy first converted into kinetic energy and the water strikes to the turbine blade at high velocity through nozzle.

→ Then the kinetic energy is converted into mechanical energy.

→ The mechanical energy is converted into electrical energy by the generator.

→ The entire pressure of water is converted into kinetic energy in a nozzle and the velocity of the jet drives the wheel.

ex- pelton wheel



→ This is a special type of axial flow impulse turbine generally mounted on horizontal shaft.

→ A number of buckets are mounted round the periphery of the wheel.

→ The water is directed towards the wheel through a nozzle or nozzles. The flow of water through the nozzle is generally controlled by special regulating system.

→ The water jet after impinging on the buckets is directed through an angle of 160° and flows axially in both direction thus avoiding the axial thrust on the wheel.

→ The hydraulic efficiency of pelton wheel lies between 85 to 90 %.

→ pelton wheels are used for very high head upto 2000 m.

Reaction Turbine

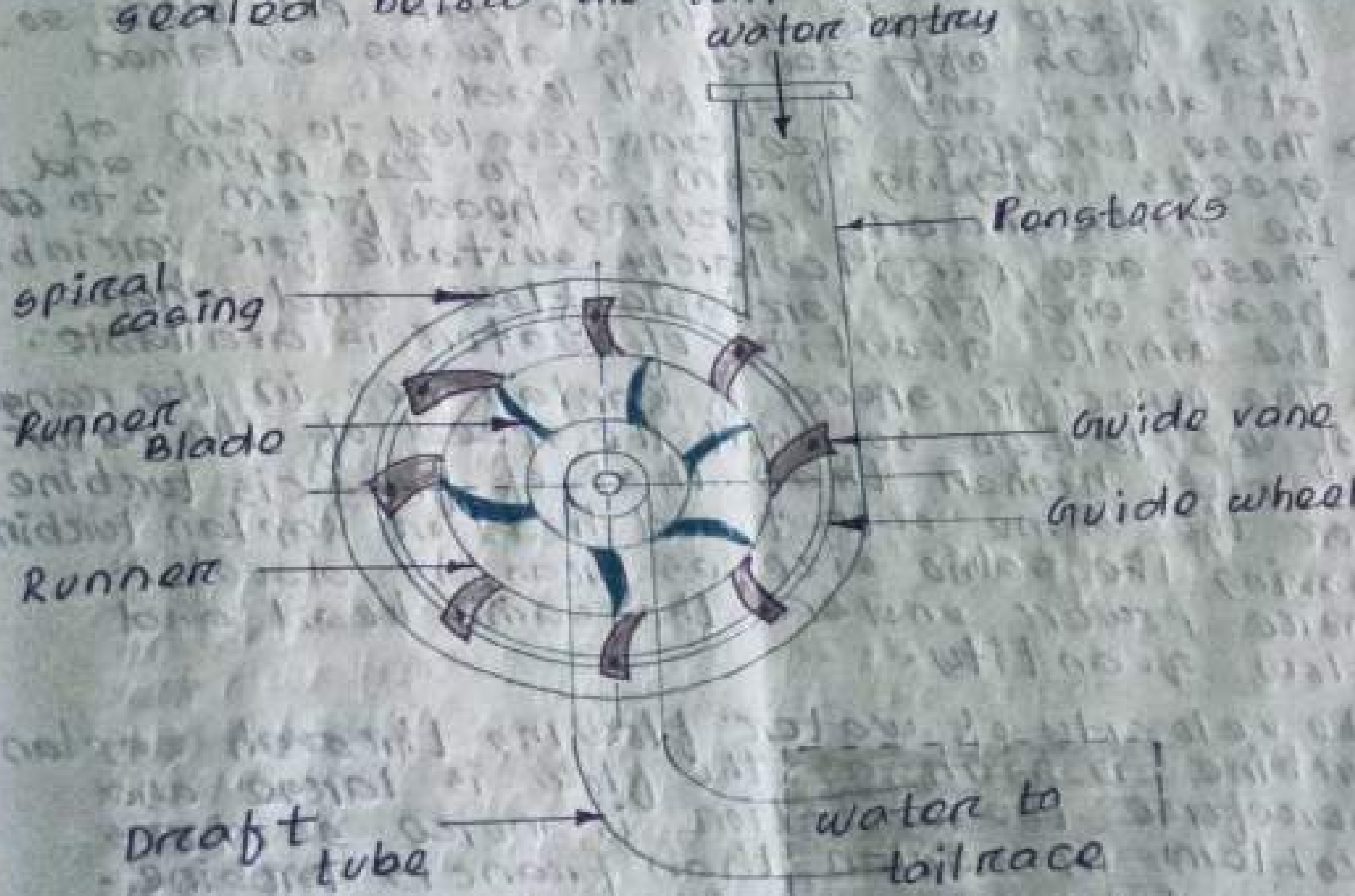
→ Reaction turbines are used for low and medium heads.

→ The water enters the runner partly with pressure energy and partly with velocity heads.

→ The important type of reaction turbines are
- Francis turbine
- keplan turbine

→ Francis Turbine

→ In francis turbine, the water enters into a casting with a relatively low velocity, passes through guide vanes located around the circuference and flows through the runner and finally discharges into a draft tube sealed below the tail water level.



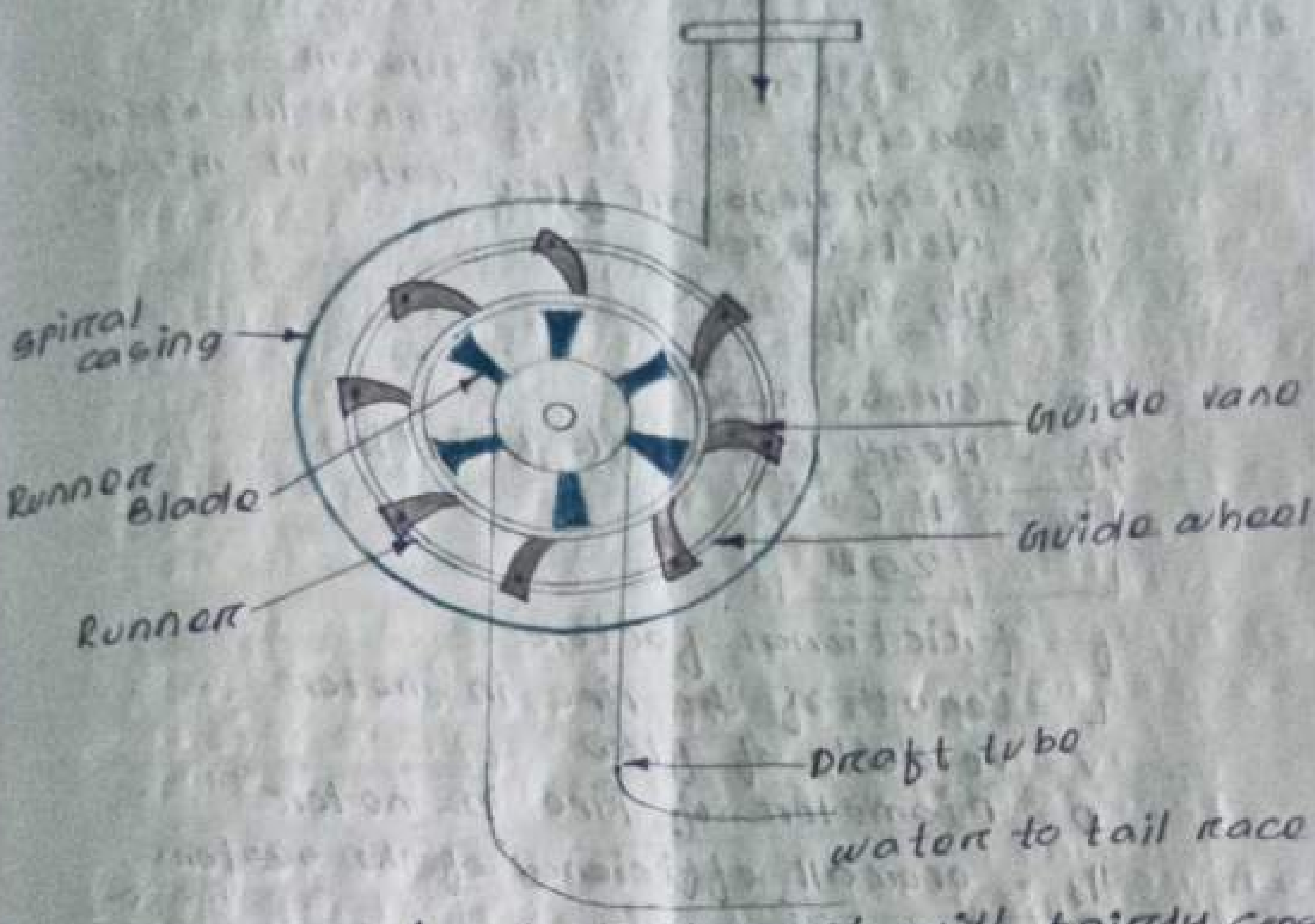
- → The water passage from the headrace to tail race is completely filled with water which acts upon the whole circumference of the runner.
- → A large part of the power is obtained from the difference in pressure acting on the front and back of the runner buckets, and only a part of total power is derived from the dynamic action of the water.

➡ Kaplan Turbine

- → The kaplan turbine is a propeller type having a moveable blade instead of fixed blade
- → The blades are rotated to the most efficient angle by a hydraulic servo-motor.
- → A cam on the governor is used to change the blade angle with the gate positions so that high efficiency is always obtained at almost any % of full load.
- → These turbines are constructed to run at speeds varying from 60 to 220 rpm and the work under varying head from 2 to 60m
- → These are particularly suitable for variable heads and for variable flows and where the ample quantity of water is available.
- → The specific speed of kaplan lies in the range of 400 to 1500 so that the speed of the rotor is much higher than that of francis turbine for the same output and head or kaplan turbine having the same size as francis develops more power under the same head and flow quantity.
- → The velocity of water flowing through kaplan turbine is high as the flow is large and therefore the cavitation is more serious problem in kaplan than francis turbine.
- → The propeller type turbines having an outstanding advantages of higher speed which results in lower cost of runner, generator and similar

power house substructure and superstructure.

→ The capital and maintainance cost of kaplan turbine is much higher than fixed blade propeller type units operated at a point of maximum efficiency.



→ For a low head development with fairly constant head and requiring a number of units, it is always advisable to install fixed blade propeller type runner for most of them and kaplan type for only one or two units.

→ with this combination, the fixed blade units could be operated at point of maximum efficiency and kaplan units could take the required variation in loads.

Numericals

$$\text{Power } (P) = \frac{\eta w Q H}{75}$$

where,

η_0 = the efficiency of the system
w = specific weight of water in kg/m^3
Q = Discharge or flow rate in m^3/sec
H = Net head
$= H_g - h_f$

H_g = Gross head
h_f = Head loss due to friction.

$$h_f = \frac{4 f L v^2}{2 g D}$$

f = frictional factor
L = Length of the pipe in meter
v = velocity of flow
D = Diameter of pipe in meter
η_0 = overall efficiency of the system

$$Q = V \times A$$

$$A = \frac{\pi}{4} d^2$$

① Calculate the power that can be developed from a hydro electric power station having following data.

catchment area = 100 sq km

Average rainfall = 120 cm/annum

yeild factor = 80 %

Available head = 300 m

overall efficiency = 75 %

soln:

Quality of water available/year

= catchment area × annual rainfall × yeild factor

$$= \frac{100 \times 10^4 \times 1.2 \times 0.8}{365 \times 24 \times 60 \times 60}$$

$Q = 3.044 \ m^3/sec$

$H = 300 m$

$$power (P) = \frac{W \times Q \times H \times \eta}{10^2}$$

$$= \frac{1000 \times 3.044 \times 300 \times 0.75}{10^2}$$

= 6714.7 kW

= 6.7147 MW.

② Determine the firm capacity of a run-of-river hydro power plant to be used as a 9 hours peaking plant assuming daily flow in a river to be constant at 16 m³/sec. Also calculate pondage factor and pondage if the head of the plant is 12m and overall efficiency is 80%.

Soln

Given data,

$w = 1000\ kg/m^3$

$Q = 16\ m^3/s$

$H = 12\ m$

$\eta_o = 0.8$

$$P = \frac{w \times Q \times H}{75} \times \eta_o$$

$$= \frac{1000 \times 16 \times 12 \times 0.8}{75}$$

$$= 2048\ H.P$$

pondage factor $(P.F) = \frac{t_1}{t_2}$

where, t_1 = total hours in one day = 24

t_2 = No. of hours of plant running = 9

$$P.F = \frac{24}{9} = 2.67$$

$$Q_1 = 9 \text{ hours flow} = Q \times \frac{24}{9} = \frac{16 \times 24}{9}$$

$$= 42.67\ m^3/s$$

P_1 = firm power with pondage

= power × pondage factor

= 2048 × 2.67

= 5468 H.P

S = magnitude of pondage
= 24 - 9 = 15 hours of flow
= 15 × 60 × 60 × 16
= 864 × 10³ m³.

③ A pump storage plant has a gross head of 300 m. The head race tunnel is 3.8 m diameter and 650 m long. The flow velocity is 7 m/sec and frictional factor is 0.017. If the overall efficiency of pumping and generating are 84% and 89% respectively Determine the plant efficiency. The power plant discharge directly in the lower reservoir.

given data,

$H = 300\,m$
$D = 3.8\,m$
$L = 650\,m$
$V = 7\,m/s$
$f = 0.017$
$\eta_p = 84\% = 0.84$
$\eta_g = 89\% = 0.89$

we know,
h_f = frictional head loss

$$= \frac{4 f L V^2}{2 g D}$$

$$= \frac{4 \times 0.017 \times 650 \times (7)^2}{2 \times 9.81 \times 3.8}$$

$$= 29.04$$

Now $h_f = KH$

$$\Rightarrow K = \frac{h_f}{H} = \frac{29.04}{300} = 0.096$$

∴ plant efficiency is given by

$$\eta = \frac{1-K}{1+K} \times \eta_p \times \eta_g$$

$$= \frac{1-0.096}{1+0.096} \times 0.84 \times 0.89$$

$$= 0.6166$$

$$= 61.66\,\%$$

UNIT-06 GAS TURBINE POWER STATIONS

Selection of site for gas turbine station

① Distance from load center
→ The site should be as near to the load center as possible so that transmission costs and losses are minimized.

② Availability of Land
→ The land should be available at cheap rate in order to keep the capital costs of the plant low.

③ Availability of fuel
→ The fuel should be easily available and at reasonable rate.

④ Availability of transportation facilities
→ The transportation facilities should be available.

⑤ Distance from populated area
→ The site should be away from thickly populated area because of noisy operations.

⑥ Type of Land
→ The land should be of high bearing capacity to withstand the load of the plant and also the vibrations transmitted to the foundations from compressors and turbines.

⑦ Population
→ The station is populated by gas outlets. noise . so that station should be away from populated area.

Fuels for gas turbine

The various fuels used in gas turbine are as follows.

- Gaseous fuels
- Liquid fuels
- solid Fuels

Gaseous Fuels

→ Natural gas is the ideal fuel for gas turbine
but this is not available everywhere.
→ Blast furnace gas and producer gas may
also be used for gas turbine power plants.

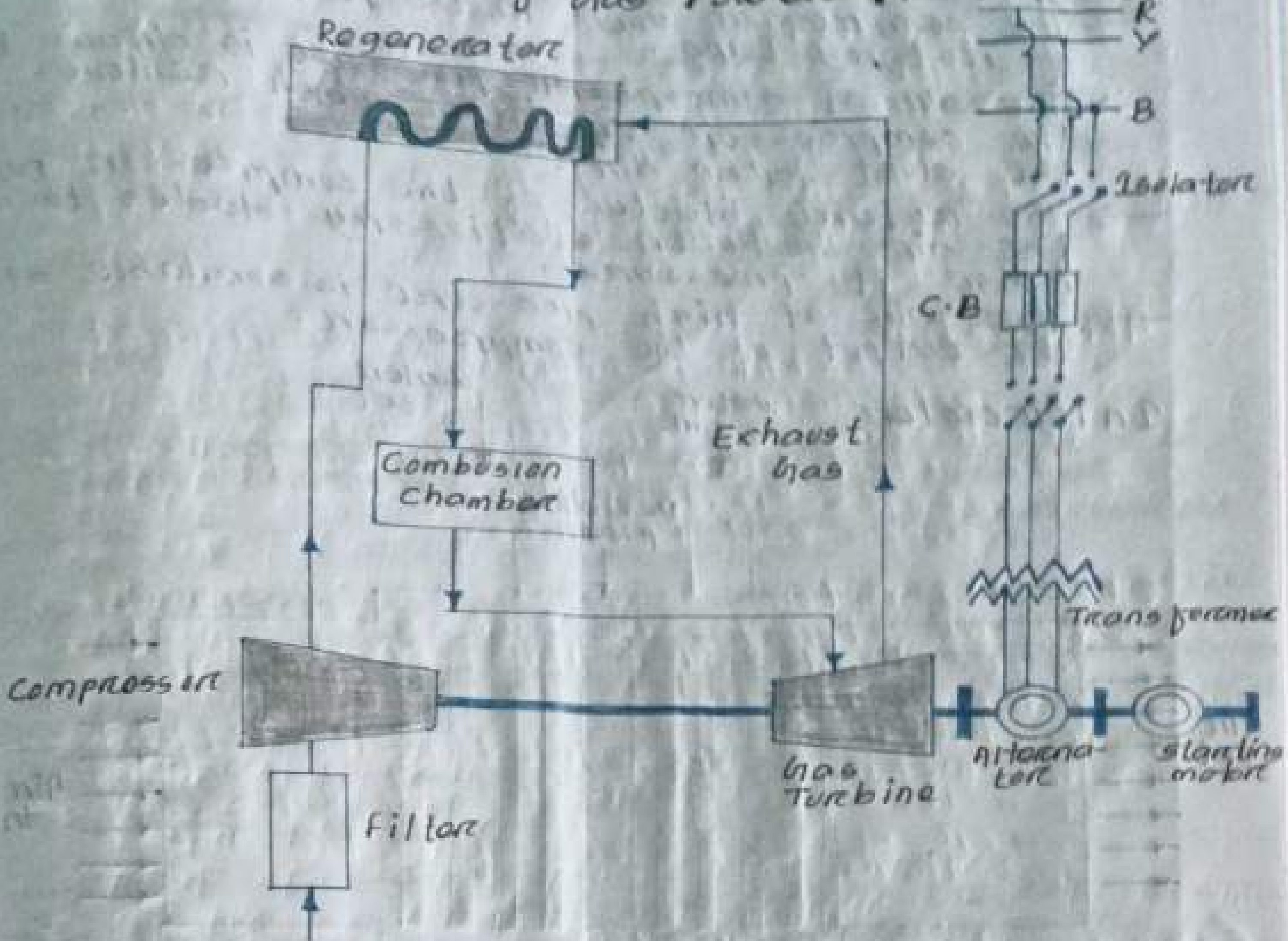
Liquid Fuels

→ Liquid fuels of petroleum origin such as distillate
or residual oils are most commonly used for
gas turbine plants.
→ The essential quantities of these fuels include
proper volatility, viscosity and calorific value.
→ At the same time it should be free from
any content of moisture and and suspended
impurities that would clog the small passages
of the nozzles and damage valves and plungers
of the fuel pump.
→ Minerals like sodium, vanadium and calcium
prove very harmful for the turbine blading
as these build deposits or corrode the
blades.
→ The sodium ash should be less than 30% of the
vanadium contents as otherwise the ratio tends to be critical.
→ The actual sodium content may be between
5 ppm to 10 ppm.
→ PPM stands for parts per million.
→ If the vanadium is over 2 ppm than the magnesium in ash tends to become critical.
→ It is necessary that the magnesium in ash
is least three times the quantity of vanadium.
→ The content of calcium and lead should not be
over 10 ppm and 5 ppm respectively.
→ sodium is removed from residual oils by
mixing with 5% of water and then double
centrifuging when sodium leaves with water.
→ Magnesium is added to the washed oil by
mixing the form of epsom salts before the
oil sent into the carburator.

→ This checks the corrosive action of vanadium.
→ Residual oil burns with less than distillate oils and the latter are often used to start the unit from cold, after which the residual oils are fed in the combustor.
→ In cold conditions residual oil needs to be preheated.

Solid Fuels
→ The use of solid fuels such as coal in pulverised from in gas turbines present several difficulties must of which have been only partially over come yet.
→ The pulverising plants for coal in gas turbine application is much larger and smaller than its counter part in steam generator.
→ Introduction of fuels in the combustion chamber of a gas turbine is require to be done against a high pressure whereas the pressure in the furnace of a steam plant is atmospheric.
→ Furthermore, the degree of completeness of combustion in gas turbine application has to be very high as otherwise soot and dust in gas would deposite on the turbine blading.
→ some practical applications of solid fuel burning in turbine combustors have been commercially made available in recent years.
→ In one such design finely crushed coal is used instead of pulverized fuel.
→ The fuel is carried in steam of air tangentially into one end of a cylinder furnace while gas comes out at the center of opposite end.
→ The advantages of the fuel is that only clean air is handled by the turbine.

Working Principle of Gas Power Plant



Components :-
The main components of the gas turbine power plant are as follows.

① compressor
② Regenerator
③ combustion chamber
④ Gas turbine
⑤ Alternator
⑥ starting motor.

Compressor

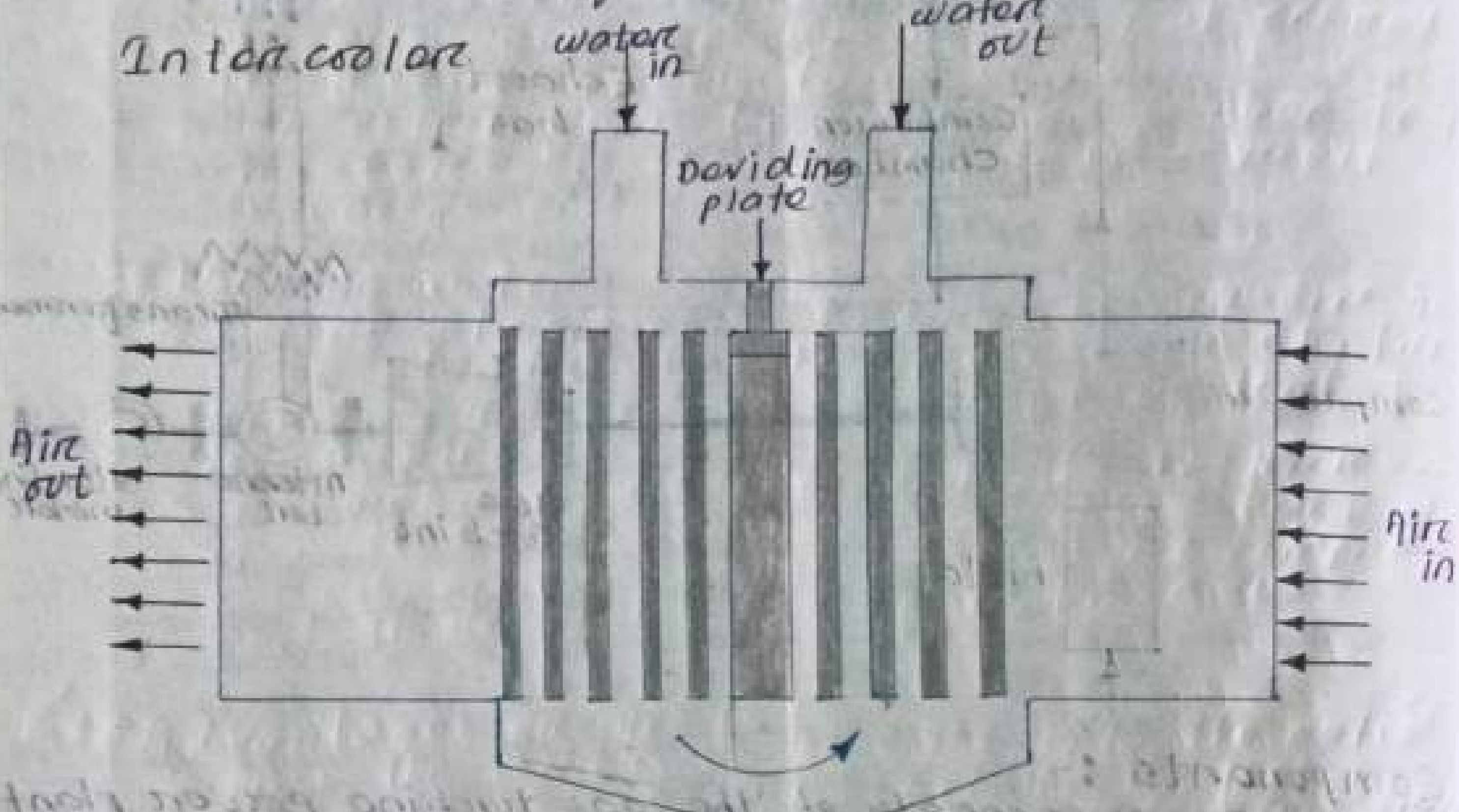
→ The compressor used in the plant is generally of rotary type.

→ The air at atmospheric pressure is drawn by the compressor via filter which removes the dust from air.

→ The rotary blades of the compressor push the air between stationary blades to raise its pressure.

→ Thus air at high pressure is available at the output of the compressor.

Intercooler



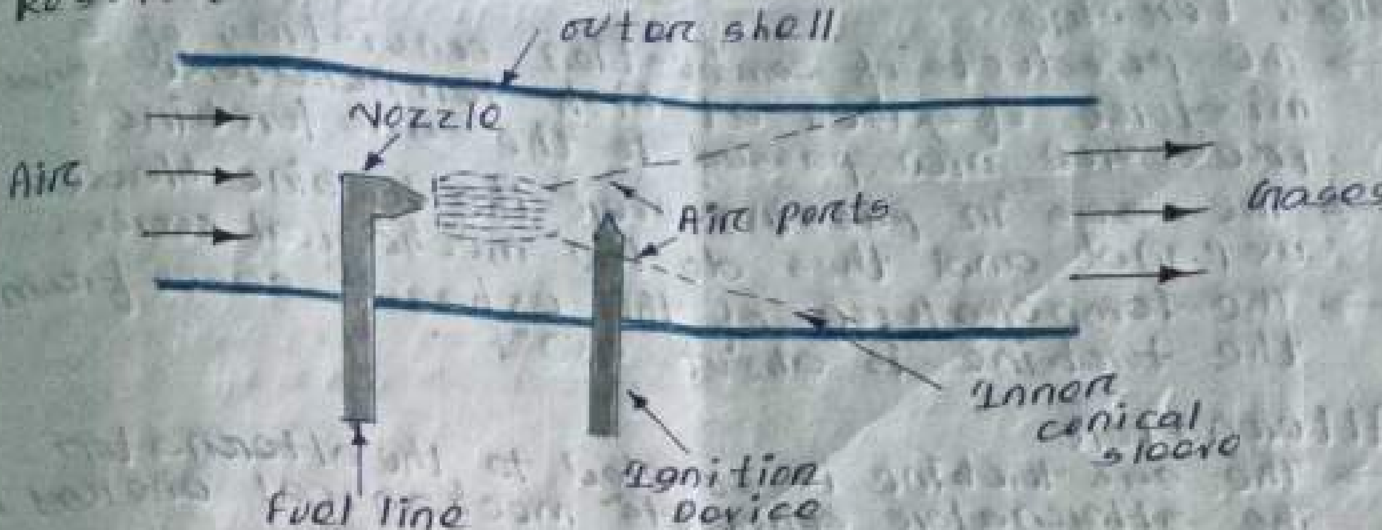
Intercooler

→ In a gas turbine plant the intercooler is generally used when the pressure ratio used is sufficiently large and the composition is completed with two or more stages.

→ The cooling of compressed air is generally done with the use of cooling water.

→ A cross-flow type intercooler is generally preferred for effective heat transfer.

Regulator



→ A regenerator is a device which recovers heat from the exhaust gases of the turbine.

→ The exhaust is passed through the regenerator before wasting to atmosphere.

→ A regenerator consists of a nest of tubes contained in shell.

→ The compressed air from the compressor passes through the tubes on its way to the combustion chamber.

→ In this way compressed air is heated by the hot exhaust gases.

Combustion chamber

→ The air at high pressure from the compressor is led to the combustion chamber via the regenerator.

→ In the combustion chamber, heat is aided to the air by burning oil.

→ The oil is injected through the burner into the chamber at high pressure to ensure atomisation of oil and its through mixing with air.

→ The result is that the chamber attains a very high temperature (about 3000°F)

→ The combustion gases are suitably cooled to 1300°F to 1500°F and then delivered to the gas turbine.

Gas turbine

→ The products of combustion consisting of a mixture of gases at high temperature and pressure are passed to the gas turbine.

→ The gas in passing over the turbine blades expand and thus do the mechanical work.

→ The temperature of the exhaust gases from the turbine is about 900°F.

Alternator

→ The gas turbine is coupled to the alternator. The alternator converts mechanical energy of the turbine into electrical energy.

→ The output from the alternator is given to the bus-bars through transformer circuit breakers and isolators.

Starting motor

→ Before starting the turbine, compressor has to be started. For this purpose, an electric motor is mounted on the shaft as that of the turbine.

→ The motor is energiesed by the batteries. Once the unit starts, a part of mechanical power of the turbine drives the compressor and there is no need of motor now.

→ Advantages or merits

→ Once the turbine is brought upto the rated speed by the starting motor and the fuel is ignited, the gas turbine is accelerated from cold start to full load without warm-up time.

→ Low weight and size the weight in kg per kW developed is less.

There is no standby losses.

→ It does not require large amount of water for cooling.

→ The plant is smaller size in than steam power plant for the steam capacity.

→ The plant can be started quickly and can be put on load in a very short time.
→ The maintainance of the plant is easy.
→ Maintainance cost is low.
→ The lubrication of the plant is easy.
→ The plant does not require heavy foundation and buildings.
→ It is very reliable.
→ A wide variety of fuels can be used.
→ It has fewer auxilaries.
→ No coal handling and ash handling is required.

↳ Disadvantages
→ part load efficiency is low.
→ It require very big heat exchanger as compared other power plant.
→ Air and gas filter have to be of very high quality
→ Net work output is low.
→ Temp. of combustion chamber is too high thus resulting in lower life.

Applications :-
- For electric power generation.
- For jet propulsion engine.
- supercharging
- Marine field
- Railway
- Road transport
- Industry.