MOHAMED SATHAK A.J.COLLEGE OF ENGINEERING, SIRUSERI - 603103

OR0551 - RENEWABLE ENERGY SOURCES

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SYLLABUS

UNIT – I

PRINCIPLES OF SOLAR RADIATION : Role and potential of new and renewable source, the solar energy option, Environmental impact of solar power, physics of the sun, the solar constant, extraterrestrial and terrestrial solar radiation, solar radiation on titled surface, instruments for measuring solar radiation and sun shine, solar radiation data.

SOLAR ENERGY COLLECTION : Flat plate and concentrating collectors, classification of concentrating collectors, orientation and thermal analysis, advanced collectors.

UNIT-II

SOLAR ENERGY STORAGE AND APPLICATIONS: Different methods, Sensible, latent heat and stratified storage, solar ponds. Solar Applications- solar heating /cooling technique, solar distillation and drying, photo voltaic energy conversion.

UNIT-III

WIND ENERGY : Sources and potentials, horizontal and vertical axis windmills, performance characteristics, Betz criteria

BIO-MASS : Principles of Bio-Conversion, Anaerobic/aerobic digestion, types of Bio-gas digesters, gasyield, combustion characteristics of bio-gas, utilization for cooking, I.C.Engine operation and economicaspects.

UNIT-IV

GEOTHERMAL ENERGY : Resources, types of wells, methods of harnessing the energy, potential inIndia.

OCEAN ENERGY :OTEC, Principles utilization, setting of OTEC plants, thermodynamic cycles. **Tidal and wave energy:** Potential and conversion techniques, mini-hydel power plants, and their economics.

UNIT-V

DIRECT ENERGY CONVERSION : Need for DEC, Carnot cycle, limitations, principles of DEC.

TEXT BOOKS:

1. Renewable energy resources , Tiwari and Ghosal/ Narosa ,second edition (2008), Mc Graw Hill Company, New Delhi.
2. Non-Conventional Energy Sources ,G.D.Rai, fourth edition(2009), Khanna Publishers, New Delhi.

REFERENCES:

1. Renewable Energy Sources , Twidell& Weir, fourth Edition (2009), Tata McGraw Hill Education Private Limited, New Delhi.
2. Solar Energy, S.P. Sukhatme, Third Edition (2010), Tata McGraw Hill Education Private Limited, New Delhi.

UNIT-I

PRINCIPLES OF SOLAR RADIATION

Role and potential of new and renewable source

India has a vast supply of renewable energy resources, and it has one of the largest programs in the world for deploying renewable energy products and systems. Indeed, it is the only country in the world to have an exclusive ministry for renewable energy development, the Ministry of Non- Conventional Energy Sources (MNES). Since its formation, the Ministry has launched one of the world's largest and most ambitious programs on renewable energy. Based on various promotional efforts put in place by MNES, significant progress is being made in power generation from renewable energy sources. In October, MNES was renamed the Ministry of New and Renewable Energy.

Specifically, 3,700 MW are currently powered by renewable energy sources (3.5 percent of total installed capacity). This is projected to be 10,000 MW from renewable energy by 2012.

The key drivers for renewable energy are the following:

- The demand-supply gap, especially as population increases
- A large untapped potential
- Concern for the environment
- The need to strengthen India's energy security
- Pressure on high-emission industry sectors from their shareholders
- A viable solution for rural electrification

Also, with a commitment to rural electrification, the Ministry of Power has accelerated the Rural Electrification Program with a target of 100,000 villages by 2012.

Introduction In recent years, India has emerged as one of the leading destinations for investors from developed countries. This attraction is partially due to the lower cost of manpower and good quality production. The expansion of investments has brought benefits of employment, development, and growth in the quality of life, but only to the major cities. This sector only represents a small portion of the total population. The remaining population still lives in very poor conditions.

India is now the eleventh largest economy in the world, fourth in terms of purchasing power. It is poised to make tremendous economic strides over the next ten years, with significant development already in the planning stages. This report gives an overview of the renewable energies market in India. We look at the current status of renewable markets in India, the energy needs of the country, forecasts of consumption and production, and we assess whether India can power its growth and its society with renewable resources.

The Ministry of Power has set an agenda of providing Power to All by 2012. It seeks to achieve this objective through a comprehensive and holistic approach to power sector development envisaging a six level intervention strategy at the National, State, SEB, Distribution, Feeder and Consumer levels.

Environmental impacts of solar energy:

Every energy generation and transmission method affects the environment. As it is obvious conventionalgenerating options can damage air, climate, water, land and wildlife, landscape, as well as raise the levels of harmful radiation. Renewable technologies are substantially safer offering a solution to many environmental and social problems associated with fossil and nuclear fuels (EC,1995,1997). Solar energy technologies (SETs) provide obvious environmental advantages in comparison to the conventional energy sources, thus contributing to the sustainable development of human activities

Not counting the depletion of the exhausted natural resources, their main advantage is related to the reduced CO2 emissions, and, normally, absence of any air emissions or waste products during their operation. Concerning the environment, the use of SETs has additional positive implications such as:

* reduction of the emissions of the greenhouse gases (mainly CO2,NO x) and prevention of toxic Gas emissions (SO2,particulates)
* reclamation of degraded land;
* reduction of the required transmission lines of the electricity grids; and
* improvement of the quality of water resources

The basic research in solar energy is being carried in universities and educational and research institutions, public sector institution, BHEL and Central Electronic Limited and carrying out a coordinated program of research of solar energy.

The application of solar energy is

1. Heating and cooling residential buildings
2. Solar water heating
3. Solar drying of agricultural and chemical products.
4. Solar distillation of a small community scale
5. Salt production by evaporation of sea water
6. Solar cookers
7. Solar engines for water pumping
8. Food refrigeration
9. Bio conversion and wind energy and which are indirect source of solar energy
10. Solar furnaces
11. Solar electric power generation by
    - i) Solar ponds
    - ii) Steam generators heated by rotating reflectors
    - iii) reflectors with lenses and pipes for fluid circulation
12. solar photovoltaic cells which can be used for conversion of solar energy directly into electricity (or) for water pumping in rural agriculture purposes.

PRESENT IO:

TPP	-	65.34%
HYDRO	-	21.53%

NUCLEAR - 2.7%
RENEWABLE - 10.42%
WIND CAPACITY - 14550 MW.
20,000 MW solar by 2022.
Installed power generation capacity of India 181.558 GW Per capita energy consumption stood at 704 KW.
1/3 GW of installed capacity by 2017

Solar Radiation

Solar energy, received in the form of radiation, can be converted directly or indirectly in to other forms of energy, such as heat and electricity. The major draw backs of the extensive application of solar energy of

1. the intermittent and variable manner in which it arrives at the earth's surface and
2. the large area require to collect the energy at a useful rate.

Energy is radiated by the sun as electromagnetic waves of which 99% have wave lengths in the range of 0.2 to 4.0 micro meter (1 micro meter = 10^{-6} meter)

Solar energy reaching the top of the earth's atmosphere consists of about

- 8% ultra violet radiation [short wave length >0.39 micrometer]
- 46% visible light [0.39 to 0.78 micrometer]
- 46 % infrared [0.78 micro meter above]

Solar constant

The sun is a large sphere of very hot gases, the heat being generated by various kinds of fusion reactions.Its diameter is 1.39 X 10^6 km while that of earth is 1.27 X 10^4 km. the mean distance between the two is 1.5 X 10^8 km. although the sun is large, its subtends angle of only 32 min. at the earth's surface.

The brightness of the sun varies from its center to its edge. However the calculation purpose the brightness all over the solar disc is uniform.

The total radiation from the sun is 5762 degrees K

The rate at which solar energy arise at the top of the atmosphere is called the solar constant I_{sc}. This is the amount of energy received in unit time on a unit area perpendicular to the sun's direction at the mean distance of the earth from the sun.

The solar constant value varies up to 3 % throughout the year, because the distance between the sun and the earth varies little throughout the year.

The earth is close set of the sun during the summer and farthest during the winter.

This variation in distance produces sinusoidal variation in the intensity of solar radiation I that reaches the earth.

I_{SC} = 1367 watts/m^2

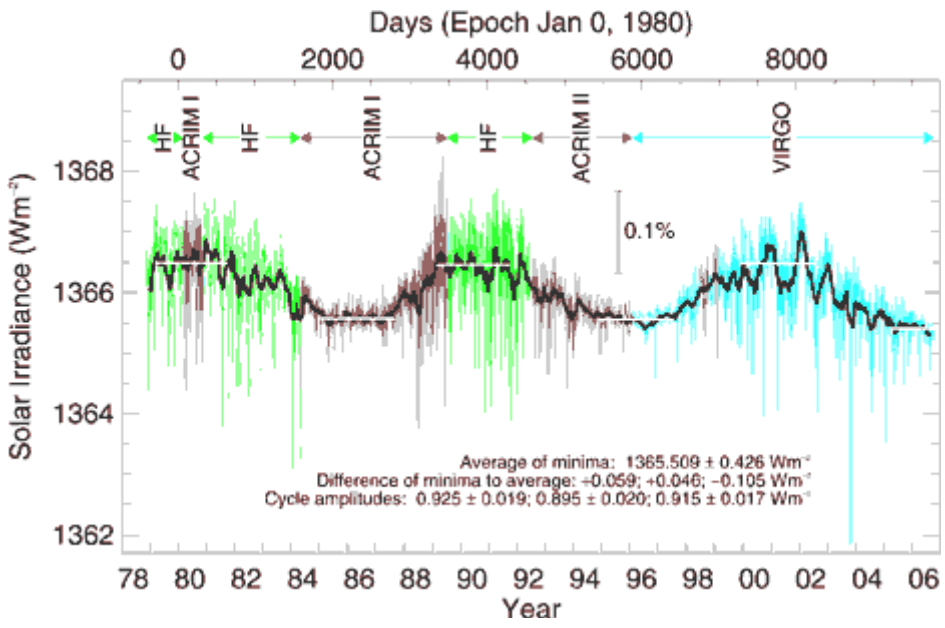
$\frac{I}{I_{SC}} = 1+0.033 \cos\frac{360\ n}{365}$. where n is the day of the year.

Spectral distribution of solar radiation intensity at the outer limit of the atmosphere

The luminosity of the Sun is about 3.86 x 1026 watts. This is the total power radiated out into space by the Sun. Most of this radiation is in the visible and infrared part of the electromagnetic spectrum, with less than 1 % emitted in the radio, UV and X-ray spectral bands. The sun's energy is radiated uniformly in all directions. Because the Sun is about 150 million kilometres from the Earth, and because the Earth is about 6300 km in radius, only 0.000000045% of this power is intercepted by our planet. This still amounts to a massive 1.75 x 1017 watts. For the purposes of solar energy capture, we normally talk about the amount of power in sunlight passing through a single square metre face-on to the sun, at the Earth's distance from the Sun. The power of the sun at the earth, per square metre is called the **solar constant** and is approximately 1370 watts per square metre (W m-2).

The solar constant actually varies by +/- 3% because of the Earth's slightly elliptical orbit around the Sun. The sun-earth distance is smaller when the Earth is at perihelion (first week in January) and larger when the Earth is at aphelion (first week in July). Some people, when talking about the solar constant, correct for this distance variation, and refer to the solar constant as the power per unit area received at the average Earth-solar distance of one "Astronomical Unit" or AU which is 149.59787066 million kilometres. There is also another small variation in the solar constant which is due to a variation in the total luminosity of the Sun itself. This variation has been measured by radiometers aboard several satellites since the late 1970's.

The graph below is a composite graph produced by the World Radiation Centre and shows that our Sun is actually a (slightly) variable star. The variation in the solar constant can be seen to be about 0.1% over a period of 30 years. Some researchers have tried to reconstruct this variation, by correlating it to sunspot numbers, back over the last 400 years, and have suggested that the Sun may have varied in its power output by up to one percent. It has also been suggested that this variation might explain some terrestrial temperature variations. It is interesting to note that the average G-type star (the class of star the Sun falls into) typically shows a much *larger* variation of about 4%.



Solar Radiation Measuring Instruments (Radiometers)

A radiometer absorbs solar radiation at its sensor, transforms it into heat and measures the resulting amount of heat to ascertain the level of solar radiation. Methods of measuring heat include taking out heat flux as a temperature change (using a water flow pyrheliometer, a silver-disk pyrheliometer or a bimetallic pyranograph) or as a thermo electromotive force (using a thermoelectric pyrheliometer or a thermo electric pyranometer). In current operation, types using a thermopile are generally used.

The radiometers used for ordinary observation are pyrheliometers and pyranometers that measure directsolar radiation and global solar radiation, respectively, and these instruments are described in this section.For details of other radiometers such as measuring instruments for diffuse sky radiation and net radiation,refer to ”Guide to Meteorological Instruments and Observation Methods” and “Compendium of Lecture Notes on Meteorological Instruments for Training Class III and Class IV Meteorological Personnel”published by WMO.

Pyrheliometers

Definition:

The pyrheliometer is one type of instrument, used to measure the direct beam of solar radiation at the regular occurrence. This instrument is used with a tracking mechanism to follow the sun continuously. It is responsive to wavelengths bands that range from 280 nm to 3000 nm. The units of irradiance are W/m^2. These instruments are specially used for weather monitoring & climatological research purposes.

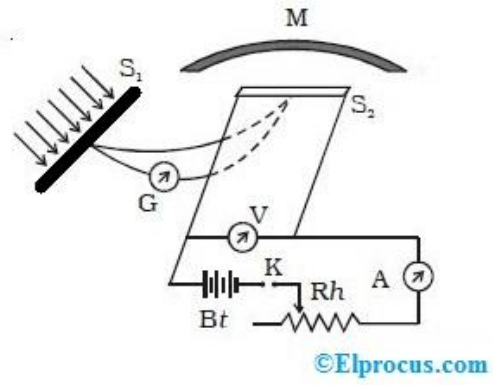
Pyrheliometer Construction & Working Principle

The external structure of the Pyrheliometer instrument looks like a telescope because it is a lengthy tube. By using this tube, we can spot the lens toward the sun to calculate the radiance. The Pyrheliometer basic structure is shown below. Here the lens can be pointed in the direction of the sun & the solar radiation will flow throughout the lens, after that tube & finally at the last part where the last apart includes a black object at the bottom.

The irradiance of solar enters into this device through a crystal quartz window and directly reaches onto a thermopile. So this energy can be changed from heat to an electrical signal that can be recorded.
A calibration factor can be applied once changing the mV signal to a corresponding radiant energy flux, and it is calculated in W/m² (watts per square meter). This kind of information can be used to increase Insolation maps. It a solar energy measurement, that is received on a specified surface region in a specified time to change around the Globe. The isolation factor for a specific area is very useful once setting up solar panels.

Pyrheliometer Circuit Diagram

The circuit diagram of the pyrheliometer is shown below. It includes two equal strips specified with two strips S1 & S2 with area 'A'. Here, a thermocouple is used where its one junction can be connected to S1 whereas the other is connected to S2. A responsive galvanometer can be connected to the thermocouple.
The S2 Strip is connected to an exterior electrical circuit.



Pyrheliometer Circuit

Once both the strips are protected from the radiation of solar, then the galvanometer illustrates there is no deflection because both the junctions are at equal temperature. Now 'S1' strip is exposed to the solar radiation & S2 is protected with a cover like M. When S1 strip gets heat radiations from the sun, then strip temperature will be increased, thus the galvanometer illustrates deflection.

When current is supplied throughout the S2 strip, then it is adjusted and the galvanometer illustrates there is no deflection. Now, again both the strips are at equal temperature.

If the heat radiation amount occurred over the unit area within the unit time on S1 strip is 'Q' & its absorption co-efficient, so the heat radiation amount which is absorbed through the S1 strip S1 within unit time is 'QAa'. In addition, the heat generated in unit time within the S2 strip can be given through VI. Here, 'V' is the potential difference & 'I' is the flow of current through it.

Advantages

The **advantages of the Pyrheliometer** include the following.

- Very low power consumption
- Operates from a wide range of voltage supplies
- Ruggedness
- Stability

Pyrheliometer Applications

The applications of this instrument include the following.

- Scientific meteorological
- Observations of Climate
- Testing research of Material
- Estimation of the solar collector's efficiency
- PV devices

Pyranometers:

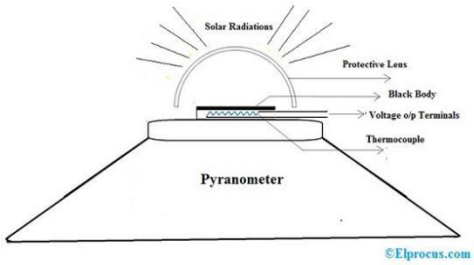
Definition: A type of actinometer used to measure irradiance of solar energy within the preferred location as well as flux density of solar radiation. The range of solar radiation extends between 300 & 2800 nm.

The SI units of irradiance are W/m² (watts /square meter). Usually, these are used in the fields of researches like climatological & weather monitoring, but current attention is showing interest in pyranometers for solar energy worldwide.

pyranometer
The WMO (World Meteorological Organization) was adopted this device which is changed with respect to the standards of ISO 9060. These devices are standardized depending on the WRR (World Radiometric Reference) and it is continued through WRC (World Radiation Center), Davon in Switzerland.

Pyranometer Design/Construction

The pyrometer design or construction can be done using the following three components.



Thermopile

As the name implies, it uses a thermocouple used to notice dissimilarity in temperature between two surfaces. These are hot (labeled active) and cold (reference) accordingly. The labeled active surface is a black surface in flat shape and it is exposed to the atmosphere. The reference surface depends on the difficulty of the pyranometer because it changes from a second control thermopile to the covering of the pyranometer itself.

Glass Dome

Glass dome in the pyrometer limits the response of spectral from 300 nm to 2800 nm from 180 degrees of view. It also protects the thermopile sensor from rain, wind, etc. This construction of the second dome gives extra radiation protection among the inner dome & sensor compared to a single dome because a second dome will reduce the instrument offset.

Occultation Disc

The occultation disc is mainly used to measure the radiation of blocking beam & diffuse radiation from the panel surface.

Pyranometer Working Principle

The working principle of the pyranometer mainly depends on the difference in temperature measurement between two surfaces like dark and clear. The solar radiation can be absorbed by the black surface on the thermopile whereas the clear surface reproduces it, so less heat can be absorbed.

The thermopile plays a key role in measuring the difference in temperature. The potential difference formed within the thermopile is due to the gradient of temperature between the two surfaces. These are used to measure the sum of solar radiation.

But, the voltage which is generated from the thermopile is calculated with the help of a potentiometer. The information of radiation needs to be included through planimetry or an electronic integrator.

Types of Pyranometer

Pyrometers are classified into two types like thermopile pyranometer, photodiode-based pyranometer.

Thermopile Pyranometer

This type of pyranometer is used to measure the flux density of the solar radiation from a 180° angle. Usually, it measures 300nm to 2800 nm with a largely level spectral sensitivity. The first generation of this pyranometer includes the sensor that works as an active part by dividing black & white sectors equally. Irradiation was measured from the two sectors like white & black within the temperature. Here, the black sector is exposed to the sun whereas the white sector doesn't expose to the sun.

These pyranometers are normally used in climatology, meteorology, building engineering physics, photovoltaic systems & climate change research.

Photodiode-based Pyranometer

Photodiode based pyrometer is also known as a silicon pyrometer. This is used to detect the segment of the solar spectrum between 400 nm & 900 nm. This photodiode changes the frequencies of the solar spectrum to current at high speed. This change will be influenced through the temperature with the raise in current, generated by the temperature rise.

These types of pyranometers are executed wherever the amount of irradiation of the noticeable solar spectrum needs to be measured and it can be done by using diodes with exact spectral responses.

These are used in cinema, lighting technique & photography; sometimes these are connected closely to photovoltaic system modules.

Advantages and Disadvantages

The **pyranometer advantages** and disadvantages are

- The temperature coefficient is extremely small
- Standardized to ISO standards
- Measurements of performance ration & performance index are accurate.
- Response time is longer compare to PV cell

The disadvantage of the pyranometer is, its spectral sensitivity is imperfect, so it does not observe the complete spectrum of the sun. So errors in measurements can occur.

Pyranometer Applications

The applications are

- The solar intensity data can be measured.
- Climatological & Meteorological studies
- PV systems design
- Locations of the greenhouse can be established.
- Expecting the requirements of insulation for building structures

Sunshine recorder

A **sunshine recorder** is a device that records the amount of sunshine at a given location or region at any time. The results provide information about the weather and climate as well as the temperature of a geographical area. This information is useful in meteorology, science, agriculture, tourism, and other fields. It has also been called a heliograph.

There are two basic types of sunshine recorders.

JORDAN SUNSHINE RECORDER:

A **Jordan sunshine recorder** is a sunshine recorder in which the movement of the sun provides the occurrence of the event.

(i) MARVIN SUNSHINE RECORDER:

A **Marvin sunshine recorder** is a sunshine recorder which uses a clock type mechanism to record the sun.

Description

A sunshine recorder is a meteorological instrument used for recording the amount of sunlight that a particular location receives throughout a day.

Inside the recorder's adjustable frame are two important pieces: a paper strip, and a glass sphere that can focus the sunlight strongly enough to singe the paper. If the sky is clear, the paper is slowly burned as the sun moves across the sky. If there are clouds, the focused light will not be strong enough to burn the paper. It can be difficult to interpret the output of a sunshine recorder - rain can interfere with the paper's burning, and cloud cover is not an all-or-nothing affair. Furthermore, the paper strip must be manually changed every day.

Solar Radiation Data

Most radiation data is measured for horizontal surfaces. As shown in figure. It is seen a fairly, smooth variations with the maximum occurring around noon is obtained on a clear day.In contrast an irregular variation with many peaks and valleys may be obtained on a cloudy day.

- Peak values are generally measured in April or may with parts of Rajasthan or Gujarat receiving over 600 Langley's per day.
- During the monsoon and winter months, the daily global radiation decreases to about 300- 400 longley per day.
- Annual average daily diffuse radiation received over the whole country is around 175 longlays per day.
- The maximum value is about 300 langleys in Gujarat in July, while the minimum values between 75 and 100 langleys per day, are measured over many parts of the country during November and December as winter sets in.

Solar radiation on tilted surface:

The rate of receipt of solar energy on a given surface on the ground depends on the orientation of the surface with reference to the sun.A fully sun – tracking surface that always faces the sun receives the maximum possible solar energy at the particular location.

A surface of the same area oriented in any other direction will receive a smaller amount of radiation because solar radiation is such a dilute form of energy, it is desirable to capture as much as possible on a ground area.Most of the solar collectors or solar radiation collecting devices are tilted at an angle to horizontal surface with Y=0 facing south for tilted surface.

$\text{Cos}\theta = \text{Sin}\delta\ \text{Sin}\ (\phi - s) + \text{Cos}\ \delta\ \text{Cos}\ \omega\ \text{Cos}\ (\phi - s)$

For horizontal surfaces $\text{Cos}\ \theta_Z = \text{Sin}\ \phi\ \text{Sin}\ \delta + \text{Cos}\ \phi\ \text{Cos}\ \delta$

Cos ω Tilt factor for beam radiation

$$\gamma_b = \frac{\text{Cos}\theta}{\text{Cos}\ \theta Z}$$

$$\gamma_d = \left[\frac{1+\text{Cos}\ s}{2}\right]$$

SOLAR ENERGY COLLECTION:

FLAT PLATE COLLECTORS:

The flat plate collectors forms the heat of any solar energy collection system designed for operation in the low temperature range, from ambient to 60 or the medium temperature, form ambient to 100.

A well engineered flat plate collector is delivers heat at a relatively low cost for a long duration. The flat plat collectors is basically a heat exchanger which transfer the radiant energy of the incident sunlight to the sensible heat of a working fluid-liquid or air. The term 'flat plate' is slightly misleading in the sense that the surface may not be truly flat-it may be combination of flat, grooved or of other shapes as the absorbing surface, with some kind of heat removal device like tubes or channels. Flat plate collectors is used to convert at much solar radiation as possible into heat at the highest attainable temperature with the lowest possible investment in material and labour.

Flat plate collector have the following advantage over other types of solar energy collectors:

(i) Absorb direct, diffuse and reflected components o solar radiation,

(ii) Are fixed in tilt and orientation and thus, there is no needed of tracking the Sun,

(iii) Are easy to make and are low in cost,

(iv) Have comparatively low maintenance cost and Long lie, and

(v) Operate at comparatively high efficiency.

Principle of Flat Plate Collector

The principal behind a flat collector is simple. If a metal sheet is exposed to solar radiation, the temperature will rise until the rate at which energy is received is equal to the rate at which heat is lost from the plate; this temperature is termed as the 'equilibrium' temperature. If the back of the plate is protected by a heat insulting material, and the exposed surface of the plate is painted black and is covered by one or two glass sheets, then the equilibrium temperature will be much higher than that for the simple exposed sheet. This plate may be covered into a heat collector by adding a water circulating system, either by making it hollow or by soldering metal pipes to the surface, and transferring the heated liquid to a tank for storage.

For heat with withdrawal from the system the equilibrium temperature must decrease, since no useful heat can be extracted at he maximum equilibrium temperature at which the collection efficiency is zero.

The other extreme condition is when the flow of liquid is so flat that the temperature rise is very small; in such a case although the losses are small and the efficiency of the heat collection approaches 100 percent, yet no useful heat can be extracted. The optimum is approximately midway between the equilibrium temperature, whereby an output of hot liquid at a useful temperature is obtained.

Components of Liquid flat Plate Collector

A flat collector (Fig 4.14) usually consists of the following components:

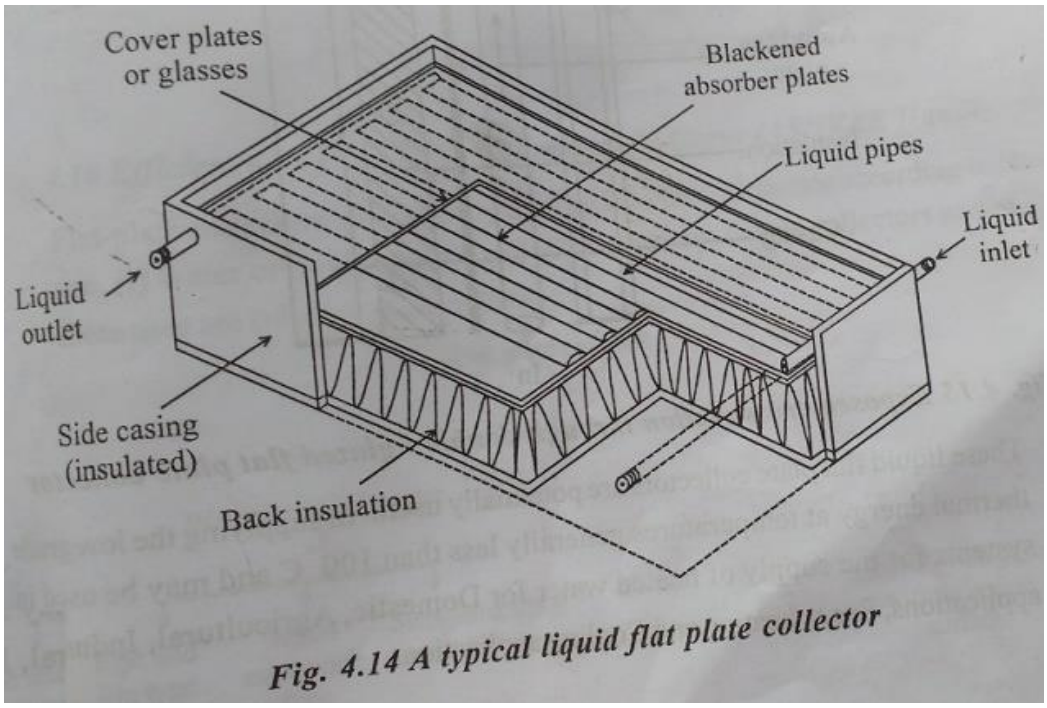


Fig. 4.14 A typical liquid flat plate collector

(i) Glazing, which may be one or more sheets of glass or other diathermanous (radiation transmitting) material(Fig.4.15).

(ii) Tubes, fins or passages for conducting or directing the heat transfer fluid from the inlet to the outlet.

(iii) Observer plate which may be flat, corrugated or grooved with tubes, fins or passages attached to it.

(iv) Header or manifolds, to admit and discharge the fluid.

(v) Insulation which minimizes heat loss from the back and sides of the collector.

(vi) Container or casing which surrounds the various components and protects them from dust, moisture etc.

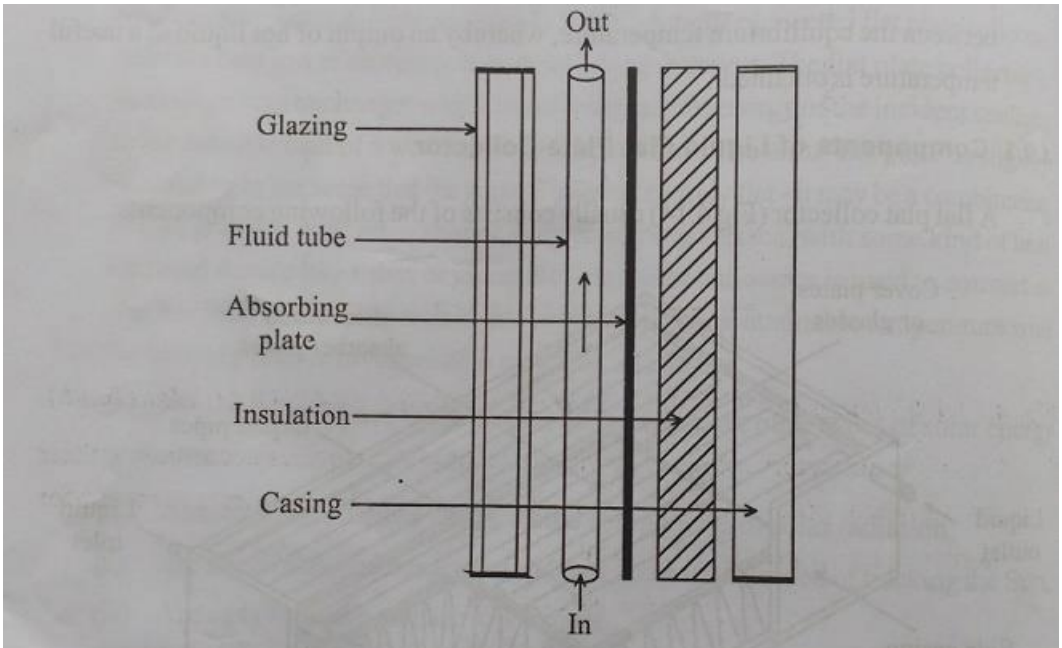


Fig. 4.15 Exposed cross section through double - glazed flat plate collector

These liquid flat plate collectors are potentially useful in supplying the low grade thermal energy at temperature generally less than 100^{o}C and may be used in system for the supply of heated water for Domestic, Agricultural, Industrial applications, Space heating and Cooling application.

Types of flat-Plate collectors

In flat plate collectors, the heat loss by convection is more important in the determination of their performance. The convective heat loss may be decreased by using double glazing, but the radiation reaching the absorber is reduced due to double reflection. Hence, at low temperature where this loss is small, use of single glazing gives a better efficiency than the double one while at higher temperature difference the use of glazing is advisable for better performance. Fig.4.16 Compares the efficiencies of single and double glazing flat plate collector in different temperature ranges.

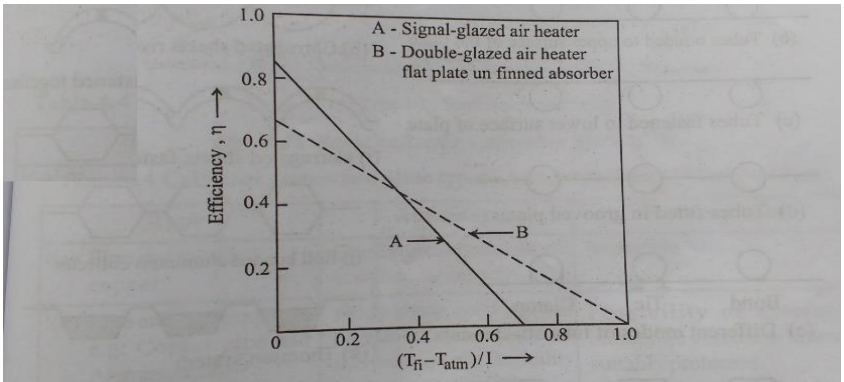
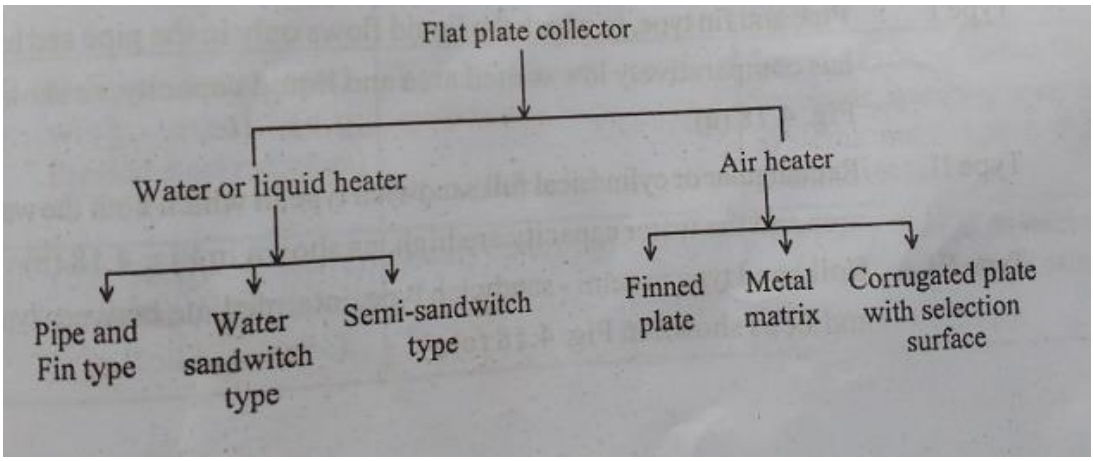
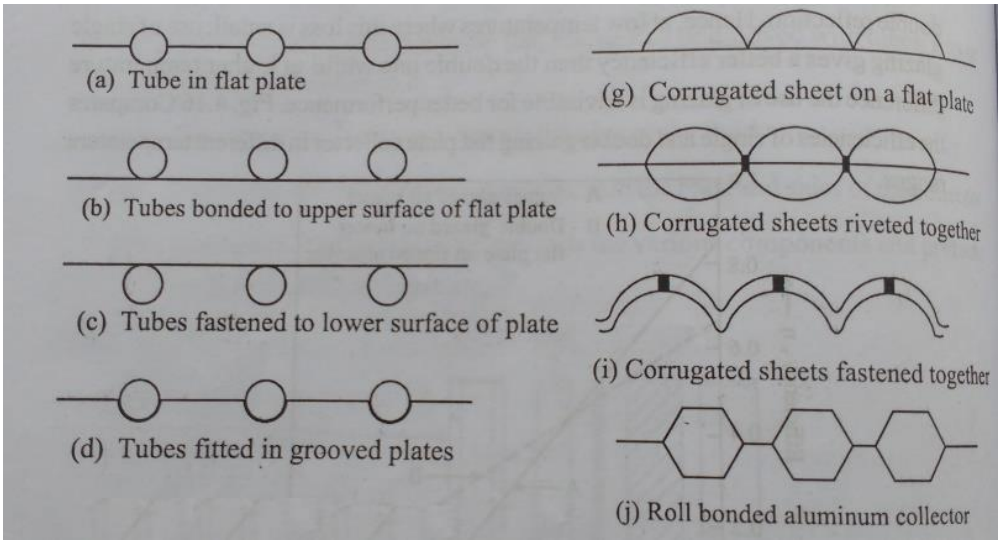


Fig. 4.16 Efficiency Vs (T_{fi} - T_{atm}) Characteristic Curve (ASHRAE Handbook)

Flat-plate collectors are basically divided into two categories according to their use, (i) Water or liquid heaters and (ii) Air heaters. These collectors meant for these uses are sub-divided as follows:



The schematic diagram of all these collectors, with single glazing are shown in Fig. These absorber plates can be broadly classified into three basic types depending on the extent of wetted surface area relative to the absorbing surface area.



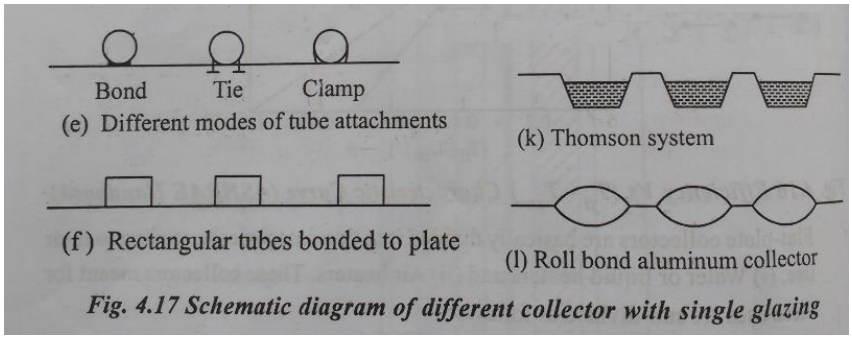


Fig. 4.17 Schematic diagram of different collector with single glazing

Type I : Pipe and in type, in which flows only in the pipe and hence has comparatively low wetted area and liquid capacity, as shown in ig.4.18(a).

Type II : Rectangular or cylindrical full sandwich type in which both the wetted area and the water capacity are high, as shown in Fig.4.18(b).

Type III : Roll bond type or semi-sandwich type, intermediate between types I and II, as shown in Fig.4.18(c).

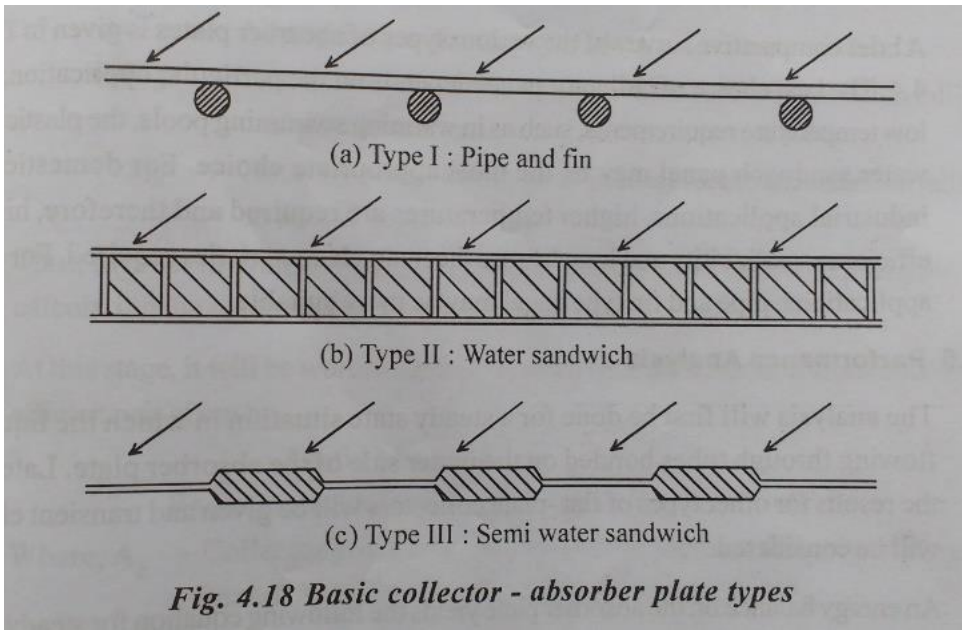


Fig. 4.18 Basic collector - absorber plate types

Type	Advantages	Disadvantages
I(a) Pipe and fin all copper	Good corrosion resistance, low thermal capacity.	Expensive
I(b) Pipe and fin composite e.g: Copper pipe and Aluminium fin	Fairly cheap, good internal corrsoion resistance, low thermal capacity flexibility in choice of materials.	Possibility of external bimetallic corrosion unless suitably protected
II Semi-water sandwich, Plastic.	Cheap and light	Limited of low temperature applications, liable to UV damage, high thermal expansion, high thermal capacity

III (a) Semi-water sandwich, steel (e.g: Pressed steel radiators)	Fairly cheap, readily available	Long-term corrosion problems, suitable for closed systems only, heavy high thermal capacity
III (b) Semi - water sandwich, aluminium (e.g: Roll bond type)	Fairly cheap, light weight.	Very susceptible to internal corrosion specially in mixed metal circuits.

A brie comparative survey o the various types of absorber plates is given in Table 4.4. The best choice of collector panel depends on the particular application. For low temperature requirements, such as in warming swimming pools, the plastic, full water sandwich panel may be the most appropriate choice. For domestic and industrial applications, higher temperatures are required and therefore , higher efficiency, realiability and long life are the main characteristics required. For such applications, pipe and fin type panel may be more suitable.

Concentrating solar collector

A solar collector that uses reflective surfaces to concentrate sunlight onto a small area, where it is absorbed and converted to heat or, in the case of solar photo voltaic (PV) devices, into electricity. Concentrators can increase the power flux of sunlight hundreds of times.

The principal types of concentrating collectors include: compound parabolic, parabolic trough, fixed reflector moving receiver, fixed receiver moving reflector, Fresnel lens, and central receiver.

A PV concentrating module uses optical elements (Fresnel lens) to increase the amount of sunlight incident onto a PV cell. Concentrating PV modules/arrays track the sun and use concentrating devices to reflect direct sunlight onto the solar cell to produce electricity directly. Concentrating solar collectors in Concentrated Solar Power (CSP) facilities concentrate sunlight onto a receiver where it heats a heat transfer fluid that subsequently exchanges its absorbed heat to water to produce steam to power a steam turbine-generator (STG) to produce electricity.

Types of Concentrating Solar Collectors

Primarily there are **four types of concentrating solar collectors**, which are:

- Parabolic trough collector
- Power tower receiver
- Parabolic dish collector
- Fresnel lens collector.

Parabolic Trough Collector

A parabolic trough comprises a linear parabolic reflector that concentrates sunlight on a receiver that is positioned along the focal line of the reflector. The receiver is a tube placed directly over the middle of the parabolic mirror and filled with a working fluid.

The heat absorbed by the working fluid transfers to water for producing steam. The focus of solar radiation changes with the change in the Sun's elevation.

The reflector keeps following the sun during the day by tracking along a single axis. A working fluid (e.g., molten salt is heated between 150 and 350 °C (302–662 °F) as it flows through the receiver and is then used as a source of heat for generating electricity.

Among all the concentrated solar collectors, trough systems are the most developed technology.

Acciona's Nevada Solar One near Boulder City, Nevada, and Andasol were first commercial parabolic trough plants of Europe.

Also, the Solar Energy Generating Systems (SEGS) plants in California and Platforma Solar de Almería's SSPS-DCS test facilities in Spain are other examples of such plants.

Solar Power Tower

A solar power tower comprises an array of dual-axis tracking reflectors or heliostats that concentrate sunlight on a central receiver placed at the top of the tower. The receiver contains a heat-transfer fluid, which contains water-steam or molten salt.

The heliostats are installed around the central tower. Each heliostat rotates into two directions to track the sun. The solar radiation that reflects from heliostats is absorbed by the receiver mounted on a tower of about 500 m height.

Optically a solar power tower is similar to a circular Fresnel reflector. The working fluid in the receiver is heated to 500–1000°C (932–1,832°F or 773-1,273 K). Subsequently, it is used as a heat source for generating electricity or storing energy.

An advantage of the solar tower is that the reflectors can be adjusted instead of the whole tower. The technology of power tower is less advanced than trough systems. However, they provide higher efficiency and better capability of storing energy.

The Ashalim Power Station, Israel, once completed, will be the tallest solar tower in the world. The construction of the tower began in 2014. The tower will have concentrated light from more than 50,000 heliostats.

The Planta Solar 10 (PS10) in Sanlúcar la Mayor, Spain, is the first commercial utility-grade solar power tower in the world.

The Ivanpah Solar Power Facility, located in the Mojave Desert (377 MW capacity), is the largest CSP facility in the world and has three power towers.

Fresnel Reflectors

Fresnel reflectors contain many thin, flat mirror strips to concentrate sunlight on tubes through which working fluid is pumped.

Flat mirrors accommodate more reflective surfaces in the same amount of space than a parabolic reflector. They capture more available sunlight and also much cheaper than parabolic reflectors. Fresnel reflectors can be used in various sizes of CSPs.

Fresnel reflectors are often said to be a technology with the lowest output than other methods.

Some new models of Fresnel reflectors with ray tracing capacity have recently been tested and initially proved to provide higher output than the standard version.

Parabolic Dish Collector

A parabolic dish collector or dish stirling has a stand-alone parabolic reflector that concentrates light on a receiver placed at the focal point of the reflector.

The reflector tracks the Sun along dual axes. The working fluid in the receiver is heated up in the temperature between 250°C and 700°C (482–1, 292 °F) and then used in a stirling engine.

Parabolic-dish systems provide a high level of solar-to-electric efficiency (between 31% and 32%), and their modular nature provides scalability.

SES dishes at the National Solar Thermal Test Facility (NSTTF) in New Mexico set a world record for solar-to-electric efficiency at 31.25% on January 31, 2008.

In 2015, Ripasso Energy, a Swedish firm, the developer of parabolic dish collector, tested the system in the Kalahari Desert in South Africa and recorded 34% efficiency.

Some of the examples of this technology are Stirling Energy Systems (SES), Science Applications International Corporation (SAIC) dishes at UNLV, and

United Sun Systems (USS) and Australian National University's Big Dish in Canberra, Australia.

Because of the limitations of size and the small quantity of fluid, parabolic dish collectors are suitable for small-scale power generation (up to a few kW).

Advantages of Concentrated Solar Collectors

1. **Zero Fuel Cost:** Concentrated solar collectors do not need any fuel like most other renewable energy sources. This is undoubtedly a significant advantage over fossil fuels, the cost of which is going up rapidly every year. Due to this reason, electricity prices are also increasing fast in more parts of the world faster than general inflation.
2. **Can Produce Both Electricity and Heat:** Concentrating solar collectors deliver heat at a much higher temperature. Due to higher temperatures, it is possible for the power generation equipment to generate both electricity and heat.
3. **Round-the-Clock Availability of Electricity:** Concentrated solar collectors make it possible to produce electricity 24-hours a day by storing the energy. Other forms of Renewable energy, like wind energy, are intermittent.
4. **No Carbon Emission:** Concentrated solar collectors do not cause any carbon emission, which is a great advantage.
5. **Job Creation:** Concentrated solar power production can create more permanent jobs and boost the economy as compared to other types of renewable energy resources.
6. **Economy of Scale:** The effects of a significant economy of scale can be observed when shifting to large concentrating systems, which makes the technology cost-effective.

Disadvantages of Concentrated Solar Collectors

1. **High Costs:** The average production cost of concentrated solar thermal energy is much higher than other renewable resources. Though during the past few years, the average cost has dropped to $0.20/kWh. Still, the costs are high as in comparison, the average production cost solar PV is in the range of $0.05 to $0.10/kWh. The average cost of solar PV production will drop even further in the future.
2. **Future Technologies can potentially make CSP obsolete:** Solar energy is witnessing new innovations quite frequently. Companies all over the world are experimenting to find more efficient and cost-effective ways to produce solar energy by making technological breakthroughs. Especially, Chinese solar companies are dominating the solar market by providing low-cost energy using advanced methods. These new innovations may potentially make concentrated solar technology outdated.
3. **May Aggravate Water Shortage:** CSP plants use significant amounts of water, and that may pose a major problem in dry regions. Using non-water cooling increases the cost of CSP projects quite a bit. Though using seawater has been suggested; still, its feasibility remains to be seen.
4. **Environmental Issue:** Using massive arrays of mirrors may negatively impact the wildlife in the dry regions, especially endangering the rare species. For example, there have already been conflicts in California on this issue with project Developers reducing the size of their plants and bearing the additional cost to move wildlife.
5. As concentrated solar collectors can focus only on direct solar radiation, their performance is poor during cloudy days.
6. The cost of building and maintaining concentrated solar collectors is high.

7. Concentrated solar collectors are practical for implementation only in areas with high direct insolation, such as arid and desert regions.

QUESTION BANK

MULTIPLE CHOICE QUESTIONS:

1.The sun rotates with a rotation period of about at the equator
(a) 26 days
(b) 27 days
(c) 28 days
(d) 29 days ANSWER(B)

2. The sun rotates with a rotation period of about at ____ its poles
(a) 27 days
(b) 37 days
(c) 26 days
(d) 36 days ANSWER(B)

3.The equation of solar constant is written as
(a) $S = E(\frac{R}{r})^2$
(b) S=E (R/r)
(c) S=ERr
(d) $S = E(\frac{R}{r})^n$ ANSWER(A)

4.All the energy per unit time that comes out of the sun, must also come out of the sphere at _____

(a) 4 AU
(b) 2 AU
(c) 5 AU
(d) 1AU

ANSWER(d)

5. The power per unit area at 1 AU is _____
(a) $1365\ W/m^2$
(b) $1366\ W/m^2$
(c) $1367\ W/m^2$
(d) $1364\ W/m^2$

ANSWER(b)

6._____ is radiant light & heat from the sun that is harnessed using a range of ever-evolving technologies.
(a) Solar
(b) Geothermal energy
(c) Biomass energy
(d) Wind energy

ANSWER(a)

7.Renewable energy and its technologies are broadly classified into _____

(a) 2
(b) 3
(c) 4
(d) 6

ANSWER(a)

8.The large distance between the sun and the earth , the beam radiation received from the sun of the earth is almost
(a) Parallel
(b) Perpendicular

ANSWER(a)

9.Solar radiation that reaches to the surface of earth without being diffused is called _____

(a) Direct beam
(b) Diffused beam
(c) Global beam

ANSWER(a)

10.As sunlight passes through the atmosphere, some of it is absorbed, scattered & reflected by air molecules, water vapour, cloud etc is called
(a) direct
(b) diffused
(c) global

ANSWER(b)

11.The sun of diffuse & direct solar radiation is called _____
(a) Direct
(b) Diffuse
(c) Global

ANSWER(c)

12.Solar hot water systems use _____ to heat water
(a) Sunlight
(b) Electricity
(c) Heat energy

ANSWER(a)

13. The environmental impact of solar energy is _____ Answer (impact of eco-system)

14.Photo voltaic cells contains _____ materials
(a) Hazardous
(b) Non- hazardous

ANSWER(a)

15.The major impact reported for solar is _____ with spinning rotors
(a) Birds migration
(b) 3F-conflict
(c) HVDC grid

ANSWER(a)

16.The phenomena of the sun is determined by _____
(a) Solar magnetic field
(b) Solar electric field
(c) Electromagnetic field

x

17.The sun is a star compressing about ____ of the total mass of the solar system
(a) 96%
(b) 98%
(c) 99%
(d) 100%

ANSWER(c)

18.A type of acetometer used to measure broadband solar irradiance on a planar surface is called ____
(a) Pyranometer
(b) Pyroheliometer
(c) Sunshine recorder

ANSWER(a)

19.The pyranometer is used to measure _____
(a) Global radiatioin
(b) Direct radiation
(c) Sunshine

ANSWER(a)

20.Pyrheliometer measure the _____ component of solar irradiance which is important when installing concentrating collectors
(a) Global radiation
(b) Direct radiation
(c) Sun shine

ANSWER(b)

21.The _____ solar radiation has two components namely direct & diffuse radiation
(a) global
(b) Direct
(c) Sunshine

ANSWER(a)

22.The device use _____ type of sensors
(a) 3
(b) 4
(c) 2
(d) 5

ANSWER(c)

23.The duration and the intensity of sunlight is measured using a _____
(a) Elector sunshine recorder
(b) Blake-Larsen sunshine recorder
(c) Compbell – stokes sunshine recorder

ANSWER(c)

24.Solar radiation incident outside the earth's atmosphere is called _____
(a) Terrestrial radiation
(b) Extra terrestrial radiation

ANSWER(b)

25._____ is the energy released by the earth itself as opposed to solar radiation that it receives from the sun
(a) Terrestrial radiation
(b) Extra terrestrial radiation

ANSWER(a)

26._____can be converted directly or indirectly into other forms of energy such as heat & electricity.
(a) Solar radiation

(b) Electromagnetic radiation
(c) Infra red radiation

ANSWER(a)

27.The total radiation energy received from the sun per unit of time per unit of area on a theoretical surface perpendicular to the sun rays and at earth means distance from the sun is called _____
(a) Solar radiation
(b) Physics of the sun
(c) Solar constant

ANSWER(c)

28.The focus light from the sun onto a piece of card where it leaves a burnt trace is called _____
(a) Sunshine
(b) Global
(c) Direct

ANSWER(a)

29.Solar radiation is the _____ emitted by the sun, can be captured and converted into useful forms of energy
(a) Ultraviolet energy
(b) Electromagnetic energy
(c) Light energy

ANSWER(b)

30. In flat plate collector the thickness of the metal sheet ranges from _____
(a) 0.4 to 0.8 mm
(b) 0.3 to 0.7 mm
(c) 0.5 to 1.0 mm
(d) 0.6 to 1.0 mm

ANSWER(c)

31. The flat plate collector consist of _____ major plates
(a) 4
(b) 3
(c) 2
(d) 5

ANSWER(d)

32. Which collector having the tracking mechanism
(a) Flat plate collector
(b) Concentrating collector

ANSWER(b)

33. Concentrating collector types _____
(a) 4
(b) 3
(c) 2
(d) 6

ANSWER(a)

34.The throughs concentrate sunlight onto a receiver tube that is positioned along the focal lines of the trough. This type of collector is _____
(a) Parabolic dish
(b) Parabolic trough system
(c) Power tower
(d) Stationary concentrating collectors

ANSWER(b)

35.Which type uses a dual axis sun trackers
(a) Parabolic dish
(b) Parabolic trough system
(c) Power tower
(d) Stationary concentrating collectors

ANSWER(a)

36.A _____uses a field of dual axis sun trackers that direct solar energy to a large absorber located on a tower
Answer: Heliostat

37. Collector that directs radiation on the receiver is called _____
(a) Receiver
(b) Collector
(c) Concentrator

ANSWER(c)

38.The sun itself as a times scale for the sunshine readings _____

(a) Jordon sunshine
(b) Marvin sunshine
(c) Pers sunshine.

ANSWER(a)

39. Some form of dock for the time scale is _____

(a) Jordon sunshine
(b) Marvin sunshine
(c) Pers sunshine.

ANSWER(b)

40. _____ is a device is used to records the amount of sunshine at a given location

(a) Pyranometer
(b) Pyrheliometer
(c) Sunshine recorder

ANSWER(c)

41._____ device is used to study the weather, climate and temperature of a geographical area.

(a) Pyranometer
(b) Pyrheliometer
(c) Sunshine recorder

ANSWER(c)

42._____ have a spectral sensitivity that is as flat as possible

(a) Pyranometer
(b) Pyrheliometer
(c) Sunshine recorder

ANSWER(a)

43._____ is a sensor that is designed to measure a solar radiation flex density from field of view of 180°

(a) Pyranometer
(b) Pyrheliometer
(c) Sunshine recorder

ANSWER(a)

44.The classification of pyranometer is consist of _____ modules
(a) 4
(b) 2
(c) 5

ANSWER(b)

45. _____ collector forms the heat of any solar energy collections systems designed for operating
In the low temperature ranges
(a) Flat plate collector
(b) Parabolic trough collector
(c) Parabolic disc collector

ANSWER(a)

46.In _____ method is made up of directing the heat transfer fluid from the inlet to the outlet
(a) Semi sandwitch method
(b) Full sandwithch method
(c) Fin and tube method

ANSWER(c)

47._____ contain many thin flat mirror strip to concentrate sunlight on tubes
(a) Parabolic trough method
(b) Parabolic disc method
(c) Frenal reflector

ANSWER(c)

48._____ are the main component of the flat plate collector
(a) Glazing
(b) Liquid inlet
(c) Back insulation

ANSWER(a)

49._____ is used to detect the segment of the solar spectrum between 400 nm and 900 nm.
(a) Theromopile pyranometer
(b) Silicon pyranometer
(c) Photo voltaic pyranometer

ANSWER(b)

50. The _____ is mainly used to measure the radiations of blocking beam and diffuse radiation from the panel
surface
(a) Thermopile
(b) Glass dome
(c) Occultation disc

ANSWER(c)

PART-A

1. What is meant by renewable energy?

Is energy generated from natural resources – such as sunlight, wind, rain,tides and geothermal heat.

2. List various energy resources.

Solar energy,

wind energy

Geothermal energy

Hydro energy

Biomass energy

Tidel energy

3. Compose the Environmental impact of Solar Power.

- manufacture processes
  - aesthetic impact
  - use of large areas of land
  - impact on the eco-system

4. Define Solar Constant

The total radiation energy received from the sun per unit of time per unit of area on a theoretical surface perpendicular to the sunrays and at earth means distance from the sun.

5. Summarize the advantage of solar concentrators.

- Zero Fuel Cost
- Can Produce Both Electricity and Heat
- Round-the-Clock Availability of Electricity
- No Carbon Emission
- Economy of Scale

6. Examine briefly the different types of solar energy measuring instruments

Pyranometer

Pyrheliometer

Sunshine recorder

7. Distinguish between diffuse radiation and beam

radiation

Direct Radiation: Solar radiation that reaches to the surface of earth without being diffused is called direct beam radiation.

Diffused Radiation: As sunlight passes through the atmosphere, some of it is absorbed, scattered and reflected by air molecules, water vapour, cloud, dust, and pollutants from power plants, forest fires, and volcanoes. This is called diffused radiation.

Global Solar Radiation: The sum of diffuse and direct solar radiation is called global solar radiation.

8. Compose the extraterrestrial and terrestrial solar radiation

S. NO	Terrestrial Radiation	Extra Terrestrial Radiation
1	The rays of the sun which are reflected back by the earth	The rays of the sun which is incident outside the earth atmosphere
2	In the form of long waves	In the form of short waves

9. List out the advantages of flat plate collectors.

(i) Absorb direct, diffuse and reflected components o solar radiation,

(ii) Are fixed in tilt and orientation and thus, there is no needed of tracking the Sun,

(iii) Are easy to make and are low in cost,

(iv) Have comparatively low maintenance cost and Long lie, and

(v) Operate at comparatively high efficiency.

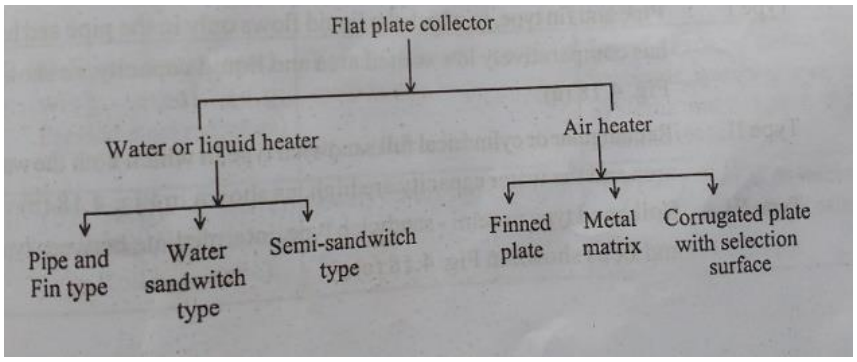
10. **Define Concentrating Collector and classify it.**

A solar collector that uses reflective surfaces to concentrate sunlight onto a small area, where it is absorbed and converted to heat or, in the case of solar photo voltaic (PV) devices, into electricity.

Primarily there are **four types of concentrating solar collectors**, which are:

- Parabolic trough collector
- Power tower receiver
- Parabolic dish collector
- Fresnel lens collector.

11.**List the different types of flat plate collector.**



12.**Discuss about Fresnel type concentrating collectors**

Fresnel reflectors contain many thin, flat mirror strips to concentrate sunlight on tubes through which working fluid is pumped.

13. Outline about central receiver tower.

A solar power tower comprises an array of dual-axis tracking reflectors or heliostats that concentrate sunlight on a central receiver placed at the top of the tower. The receiver contains a heat-transfer fluid, which contains water-steam or molten salt.

14. Define Parabolic trough concentrator.

A parabolic trough comprises a linear parabolic reflector that concentrates sunlight on a receiver that is positioned along the focal line of the reflector. The receiver is a tube placed directly over the middle of the parabolic mirror and filled with a working fluid.

The heat absorbed by the working fluid transfers to water for producing steam. The focus of solar radiation changes with the change in the Sun's elevation.

15. Define Parabolic dish collector.

A parabolic dish collector or dish stirling has a stand-alone parabolic reflector that concentrates light on a receiver placed at the focal point of the reflector.

PART-B

1. Demonstrate the working of a pyrheliometer.
2. Give a short note about sunshine recorder.
3. Interpret the working of a Pyranometer.
4. Explain the difference in the working of Pyrheliometer and pyranometer.
5. What is flat plate collector? Explain its operation.
6. Examine the working principle of various types of concentrating solar collectors with neat sketch.
7. Summarize the advantages and disadvantages of concentrating collectors over a flat plate collector?
8. Analyze different types of Solar collectors based on the way they collect solar radiation.

UNIT - 3 - WIND ENERGY

DEFINITION:

The process by which wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity. Mechanical power can also be utilized directly for specific tasks such as pumping water.

INTRODUCTION

Renewable Energy Sources are those energy sources which are not destroyed when their energy is harnessed. Human use of renewable energy requires technologies that harness natural phenomena, such as sunlight, wind, waves, water flow, and biological processes such as anaerobic digestion, biological hydrogen production and geothermal heat. Amongst the above mentioned sources of energy there has been a lot of development in the technology for harnessing energy from the wind.

Wind is the motion of air masses produced by the irregular heating of the earth's surface by sun. These differences consequently create forces that push air masses around for balancing the global temperature or, on a much smaller scale, the temperature between land and sea or between mountains.

Wind energy is not a constant source of energy. It varies continuously and gives energy in sudden bursts. About 50% of the entire energy is given out in just 15% of the operating time. Wind strengths vary and thus cannot guarantee continuous power. It is best used in the context of a system that has significant reserve capacity such as hydro, or reserve load, such as a desalination plant, to mitigate the economic effects of resource variability.

The power extracted from the wind can be calculated by the given formula:

$$P_W=0.5\rho\pi R^3 Vw^3 C_P(\lambda,\beta)$$

P_w = extracted power from the wind,

ρ= air density, (approximately 1.2 kg/m^3 at 20¤ C at sea

level) R = blade radius (in m), (it varies between 40-60 m)

V_w = wind velocity (m/s) (velocity can be controlled between 3 to 30 m/s)

Cp = the power coefficient which is a function of both tip speed ratio (λ), and blade pitch

angle, (β) (deg.)

Power coefficient (Cp) is defined as the ratio of the output power produced to the power available in the wind.

Betz Limit:

No wind turbine could convert more than **59.3%** of the kinetic energy of the wind into mechanical energy turning a rotor. This is known as the Betz Limit, and is the theoretical maximum coefficient of power for any wind turbine.

The maximum value of $\mathbf{C_P}$ according to Betz limit is 59.3%. For good turbines it is in the range of 35-45%.

The **tip speed ratio** (λ) for wind turbines is the ratio between the rotational speed of the tip of a blade and the actual velocity of the wind. High efficiency 3-blade-turbines have tip speed ratios of 6–7.

The total capacity of wind power on this earth that can be harnessed is about 72 TW. There are now many thousands of wind turbines operating in various parts of the world, with utility companies having a total capacity of 59,322 MW. The power generation by wind energy was about 94.1GW in 2007 which makes up nearly 1% of the total power generated in the world. Globally, the long-term technical potential of wind energy is believed to be 5 times current global energy consumption or 40 times current electricity demand. This would require covering 12.7% of all land area with wind turbines. This land would have to be covered with 6 large wind turbines per square kilometer.

Some 80 percent of the global wind power market is now centered in just four countries—which reflects the failure of most other nations to adopt supportive renewable energy policies. Future market growth will depend in large measure on whether additional countries make way for renewable energy sources as they reform their electricity industries.

A **wind turbine** is a rotating machine which converts the kinetic energy in wind into mechanical energy. If the mechanical energy is then converted to electricity, the machine is called a **wind generator**, **wind turbine**, **wind power unit (WPU)**, **wind energy converter (WEC)**, or **aero- generator**.

Wind turbines can be separated into two types based by the axis in which the turbine rotates. Turbines that rotate around a horizontal axis are more common. Vertical-axis turbines are less frequently used.

HORIZONTAL AXIS WIND TURBINES

Fig.1.1 Horizontal axis wind turbine

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.

Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount.

Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds the

blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since cyclic (that is repetitive) turbulence may lead to fatigue failures most HAWTs are upwind machines.

HAWT advantages

- Variable blade pitch, which gives the turbine blades the optimum angle of attack. Allowing the angle of attack to be remotely adjusted gives greater control, so the turbine collects the maximum amount of wind energy for the time of day and season.
- The tall tower base allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up, the wind speed can increase by 20% and the power output by 34%.
- High efficiency, since the blades always move perpendicularly to the wind, receiving power through the whole rotation. In contrast, all vertical axis wind turbines, and most proposed airborne wind turbine designs, involve various types of reciprocating actions, requiring airfoil surfaces to backtrack against the wind for part of the cycle. Backtracking against the wind leads to inherently lower efficiency.

HAWT disadvantages

- The tall towers and blades up to 90 meters long are difficult to transport. Transportation can now cost 20% of equipment costs.
- Tall HAWTs are difficult to install, needing very tall and expensive cranes and skilled operators.
- Massive tower construction is required to support the heavy blades, gearbox, and generator.
- Reflections from tall HAWTs may affect side lobes of radar installations creating signal clutter, although filtering can suppress it.
- Downwind variants suffer from fatigue and structural failure caused by turbulence when a blade passes through the tower's wind shadow (for this reason, the majority of HAWTs use an upwind design, with the rotor facing the wind in front of the tower).
- HAWTs require an additional yaw control mechanism to turn the blades toward the wind.

Vertical axis Wind Turbines

Fig.1.2 Vertical axis wind turbine

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. Key advantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective. This is an advantage on sites where the wind direction is highly variable. VAWTs can utilize winds from varying directions.

With a vertical axis, the generator and gearbox can be placed near the ground, so the tower doesn't need to support it, and it is more accessible for maintenance. Drawbacks are that some designs produce pulsating torque. Drag may be created when the blade rotates into the wind.

VAWT advantages

- A massive tower structure is less frequently used, as VAWTs are more frequently mounted with the lower bearing mounted near the ground.
- Designs without yaw mechanisms are possible with fixed pitch rotor designs.
- A VAWT can be located nearer the ground, making it easier to maintain the moving parts.
- VAWTs have lower wind startup speeds than HAWTs. Typically, they start creating electricity at 6 M.P.H. (10 km/h).
- VAWTs may have a lower noise signature.

VAWT disadvantages

- Most VAWTs produce energy at only 50% of the efficiency of HAWTs in large part

because of the additional drag that they have as their blades rotate into the wind.

- While VAWTs' parts are located on the ground, they are also located under the weight of the structure above it, which can make changing out parts nearly impossible without dismantling the structure if not designed properly.
- Having rotors located close to the ground where wind speeds are lower due to wind shear, VAWTs may not produce as much energy at a given site as a HAWT with the same footprint or height.
- Because VAWTs are not commonly deployed due mainly to the serious disadvantages mentioned above, they appear novel to those not familiar with the wind industry. This has often made them the subject of wild claims and investment scams over the last 50 years.

Wind Turbine Glossary

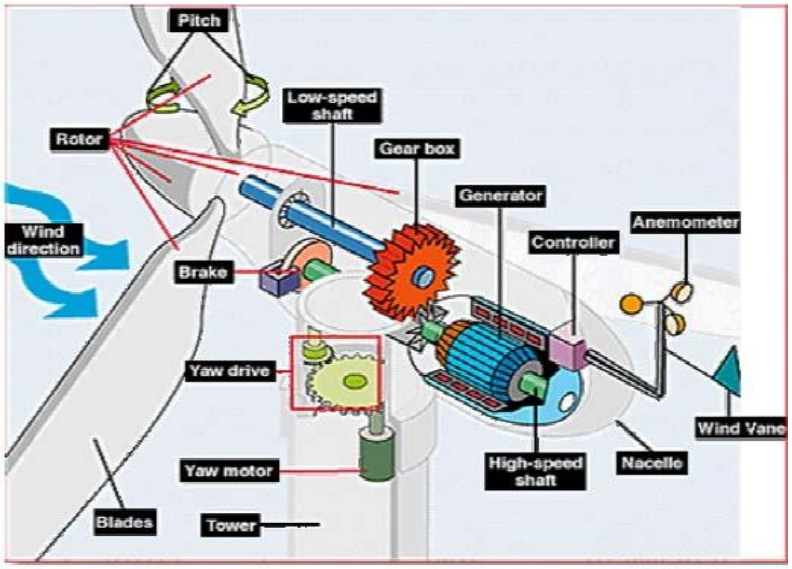


Fig.1.3 Parts of a wind turbine

Anemometer: Measures the wind speed and transmits wind speed data to the controller.

Blades: Most turbines have either two or three blades. Wind blowing over the blades causes the blades to "lift" and rotate.

Brake: A disc brake which can be applied mechanically, electrically, or hydraulically to stop the rotor in emergencies.

Controller: The controller starts up the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 65 mph. Turbines cannot operate at wind speeds above about 65 mph because their generators could overheat.

Gear box: Gears connect the low-speed shaft to the high-speed shaft and increase the rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1200 to 1500 rpm, the rotational speed required by most generators to produce electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gear boxes.

Generator: Usually an off-the-shelf induction generator that produces 60-cycle AC electricity.

High-speed shaft: Drives the generator. Low-speed shaft: The rotor turns the low-speed shaft at about 30 to 60 rotations per minute.

Nacelle: The rotor attaches to the nacelle, which sits atop the tower and includes the gear box, low- and high-speed shafts, generator, controller, and brake. A cover protects the components inside the nacelle. Some nacelles are large enough for a technician to stand inside while working.

Pitch: Blades are turned, or pitched, out of the wind to keep the rotor from turning in winds that are too high or too low to produce electricity.

Rotor: The blades and the hub together are called the rotor.

Tower: Towers are made from tubular steel (shown here) or steel lattice. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity.

Wind direction: This is an "upwind" turbine, so-called because it operates facing into the wind. Other turbines are designed to run "downwind", facing away from the wind.

Wind vane: Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind.

Yaw drive: Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. Downwind turbines don't require a yaw drive, the wind blows the rotor downwind.

Yaw motor: Powers the yaw drive.

The following is a graph between Power Coefficient (C_P) vs Tip Speed Ratio (λ)

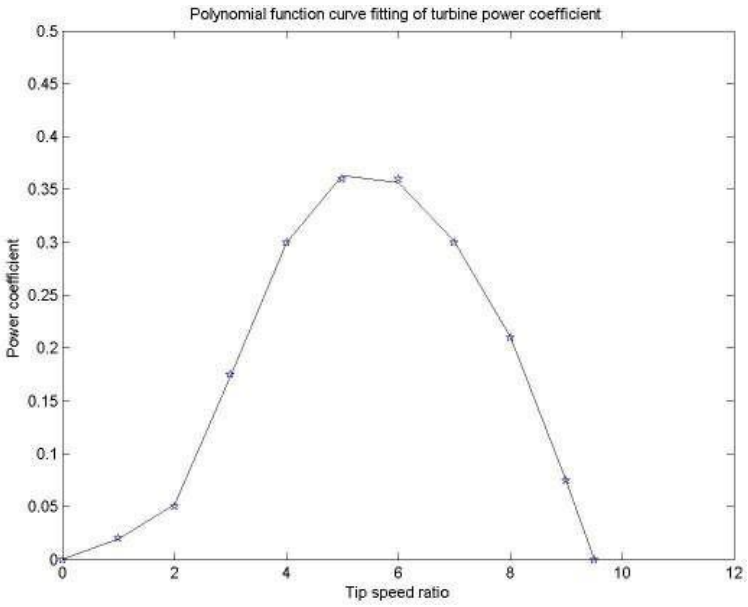


Fig.1.4 Power coefficient vs tip speed ratio

Wind turbines typically have two degrees of freedom to optimize power generation.

1. ***The ability to change their yaw or compass orientation*** by turning (using motors) the entire nacelle unit so the rotor is pointed directly into the wind. This process is controlled by wind direction information from nearby wind vanes which are located to minimize the effect due to wake turbulence from the wind turbines.
2. ***The pitch of the blades*** which can be changed to keep a near-constant rotation rate under varying wind speeds, where the rotation rate is chosen to optimize the power-generation efficiency of the turbine. Another purpose of both the blade pitch control and yaw Mechanisms is to act as a brake under extremely strong wind condition.

Cut- in speed: The lowest wind speed at which a wind turbine begins producing usable power is called cut-in speed. It is about **3m/s**.

Cut-out speed: The highest wind speed at which a wind turbine stops producing power is called cut-out speed. It is about **30m/s**.

ADVANTAGES:

- Unlimited, free, renewable resource (the wind itself), economic value, maintenance cost, and placement of wind harvesting facilities.

DISADVANTAGES:

- **Aesthetic impact:** Many people are concerned with the visual effects that wind turbines have on the beautiful scenery of nature. They believe that giant wind turbines distract viewers from the beautiful surroundings. Fig. 2 shows just how big wind turbines can be.
- **Wildlife:** Wind turbines may be dangerous to flying animals. Many birds and bats have been killed by flying into the rotors. Experts are now conducting research to learn more about the effects that wind turbines have on marine habitats.
- **Remoteness of location:** Although this may be an advantage (placing wind turbines in desolate areas, far away from people), it may also be a disadvantage. The cost of travel and maintenance on the turbines increases and is time consuming. Offshore wind turbines require boats and can be dangerous to manage.
- **Noise:** Some wind turbines tend to generate a lot of noise which can be unpleasant
- **Safety at Sea:** In the darkness/at night it may be difficult for incoming boats to see wind turbines thus leading to collisions.
-

Comparison Chart

HORIZONTAL AXIS WIND TURBINE	VERTICAL AXIS WIND TURBINE
Axis of rotation is parallel to the air stream	**Axis of rotation is perpendicular to the air stream.**
Yaw control mechanism is required to adjust the rotor around a vertical axis to keep it facing the wind.	**No orientation of rotor is required; these turbines can generate power with the wind coming from any direction.**
The heavy nacelle containing the gearbox, generator, etc. is mounted at the top of the tower, thus the design and installation is complex.	**The nacelle is not required because the gearbox, generator, etc., are located at the ground, thus the design and installation are simple.**
The power coefficient and tip speed ratio are high.	**The power coefficient and tip speed ratio are considerably low.**

MCQ IMPORTANT QUESTION

1. Wind energy is harnessed as _____ energy with the help of windmill or turbine.
(A) Mechanical

(B) Solar

(C) Electrical

(D) Heat ANS: A

2. **Winds having following speed are suitable to operate wind turbines.**
(A) 5 – 25m/s

(B) 10 – 35m/s

(C) 20 – 45m/s

(D) 30 – 55m/s **ANS: A**

3. The following factor(s) affects the distribution of wind energy

(A) Mountain chains

(B) The hills, trees and buildings

(C) Frictional effect of the surface

(D) All of the above **ANS: D**

4. How many blades does a modern wind turbine have?

(A) 3

(B) 2

(C) 4

(D) There is no standard number of blades **ANS: A**

5. Which of these is NOT a part of a modern wind turbine?

(A) Gearbox

(B) Yaw Drive

(C) Compressor

(D) Nacelle **ANS: C**

6. What is the diameter of wind turbine blades?

(A) 320 feet

(B) 220 feet

(C) 80 feet

(D) 500 feet **ANS: B**

7. What are used to turn wind energy into electrical energy?

(A) Turbine

(B) Generators

(C) Yaw motor

(D) Blades **ANS: A**

8. The following is(are) the classification of winds

(A) Global wind

(B) Local Wind

(C) Both (A) and (B)

(D) None of the above **ANS: C**

9. What is not applicable for wind power?

(A) It releases no greenhouse gases or acid-forming emissions.

(B) It provides a constant, uninterruptible source of energy

(C) It has been used for hundreds of years

(D) It can be used to produce electricity **ANS: B**

10. Yaw control is the part of

(A) solar concentration collector

(B) OTEC devices

(C) biomass energy generator

(D) wind energy conversion system **ANS: D**

2 MARKS

1. **Define gusts.**

   Rapid fluctuations in the wind velocity over a wide range of frequencies and amplitudes, due to turbulence caused by mechanical mixing of lower layers of atmosphere by surface roughness, are commonly known as gusts.

2. **Define wind turbines.**

   A Wind turbine which converts wind power into rotary mechanical power. A wind turbine has aerofoil blades mounted on the rotor. The wind drives the rotor and produces rotary mechanical energy.

3. **Define power coefficient.**

   The fraction of the free flow wind power that can be extracted by a rotor is called the power – coefficient.

   Power coefficient = power of wind turbine/ power available in the wind

4. **Define Cut-in speed and Cut- out speed .**

   Cut- in speed: The lowest wind speed at which a wind turbine begins producing usable power is called cut-in speed. It is about **3m/s**.

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5. Write the types of Wind Turbines.
   A) Horizontal Axis Wind turbines
   B) Vertical Axis Wind Turbines.

6. Write Betz Limit

No wind turbine could convert more than **59.3%** of the kinetic energy of the wind into mechanical energy turning a rotor. This is known as the Betz Limit, and is the theoretical maximum coefficient of power for any wind turbine.

PART B:

1. Describe Briefly about the HAWT and give the advantages and disadvantages.

2. Describe Briefly about the VAWT and give the advantages and disadvantages.

3. Compare horizontal and vertical wind turbine.

4. Explain the parts of wind turbines.

BIOMASS ENERGY

INTRODUCTION:

Biomass as a renewable resource

- Biomass is biological organic matter derived from living or recently-living organisms
- Bioenergy is the energy contained (stored) in biomass
- Biomass is an extremely important energy source, available nearly everywhere
- Biomass encompasses a large variety of materials, including wood from various sources, agricultural and industrial residues, and animal and human waste
- Two forms of biomass

Raw: forestry products, grasses, crops, animal manure, and aquatic products (seaweed)

Secondary: materials that undergone significant changes from raw biomass. Paper, cardboard, cotton, natural rubber products, and used cooking oils.

Biomass energy is the use of organic material to generate energy. Biomass is just organic matter – think, stuff that's made in nature – like wood pellets, grass clippings and even dung.

Biomass energy is **energy** generated or produced by living or once-living organisms. The most common **biomass** materials used for **energy** are plants, such as corn and soy, above. The **energy** from these organisms can be burned to create heat or converted into electricity.

BIOCONVERSION:

Change of waste into a source of energy by the action of microorganisms, such as in conversion of biomass into ethanol, methanol, or methane.

Anaerobic digestion is a **process** through which bacteria break down organic matter—such as manure—without oxygen. As the bacteria "work," they generate biogas. Codigestion occurs when **anaerobic digestion** is used to break down multiple types of organic waste in one **anaerobic digester**.

Aerobic digestion is a process in sewage treatment designed to reduce the volume of sewage sludge and make it suitable for subsequent use. More recently, technology has been developed that allows the treatment and reduction of other organic waste, such as food, cardboard and horticultural waste.

Types of Biogas Digesters and Plants

- Fixed Dome Biogas **Plants**.
- Floating Drum **Plants**.
- Low-Cost Polyethylene Tube Digester.
- Balloon **Plants**.
- Horizontal **Plants**.
- Earth-pit **Plants**.
- Ferro-cement **Plants**.

GASYIELD:

Gas content is the total content of **gas** and the **gas yield** is the **gas** evolved at any temperature. Naturally once the **gas** is evolved the **gas** content will reduce. **Gas** content and **gas yield** can be correlated.

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Direct Combustion for Heat

Direct combustion for heat is the oldest method of biomass conversion to energy since the earliest civilizations. Thermochemical conversion (combustion) could be achieved in a number of ways using varied feedstock.

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Biomass based generators use diesel derived from vegetable oils to fuel diesel generators. The generators burn the organic diesel to produce energy to produce electricity.

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Apart from stand-alone combustion, biomass could be blended with other fossil fuels and burnt to generate energy. This is called co-firing.

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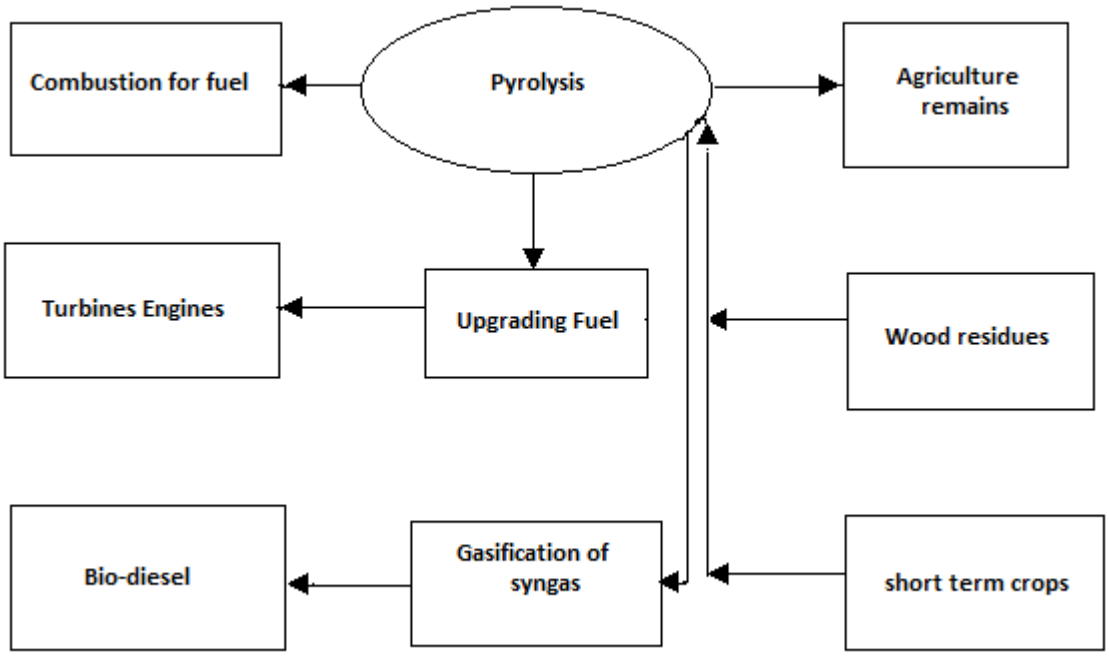


Alcoholic Fermentation

Alcoholic fermentation is the process that converts sugars into cellulose. The process results in ethanol and carbon dioxide as the by-products. This process is considered anaerobic since it takes place in the absence of oxygen. Apart from bread baking and manufacturing alcoholic beverages, this process produces alcoholic fuel. The chemical formula for alcoholic fermentation is given by −

$C_{6}H_{12}O_{6}+yeast\longrightarrow\:2C_{2}H_{5}OH+2CO_{2}$

Sugarcane is the main feedstock for this process especially in dry environments. Corn or sugar bits are used in temperate areas.

Application of Products

The products have the following applications −

- **Acetone** is a product used for production of food additives, dissolving glue, thinning of paint, grease removers and in cosmetic products.
- **Hydrogen** is used as a cooling agent in power industry. It is also used in hydrogen cells for energy production.
- **Butanol** provides better fuel than ethanol. It is also used as an ingredient in paint, cosmetic products, resins, dyes, polymer extractions and in the manufacture of synthetic fiber.
- **Ethanol** is used as fuel, paint component, and an additive in antiseptics. It is also used in alcoholic beverages.

Anaerobic Digestion of Biogas

Anaerobic digestion is the biological process by which organic matter is broken down to produce biogas in the absence of Oxygen. Microorganisms such as Acidogenetic bacteria and

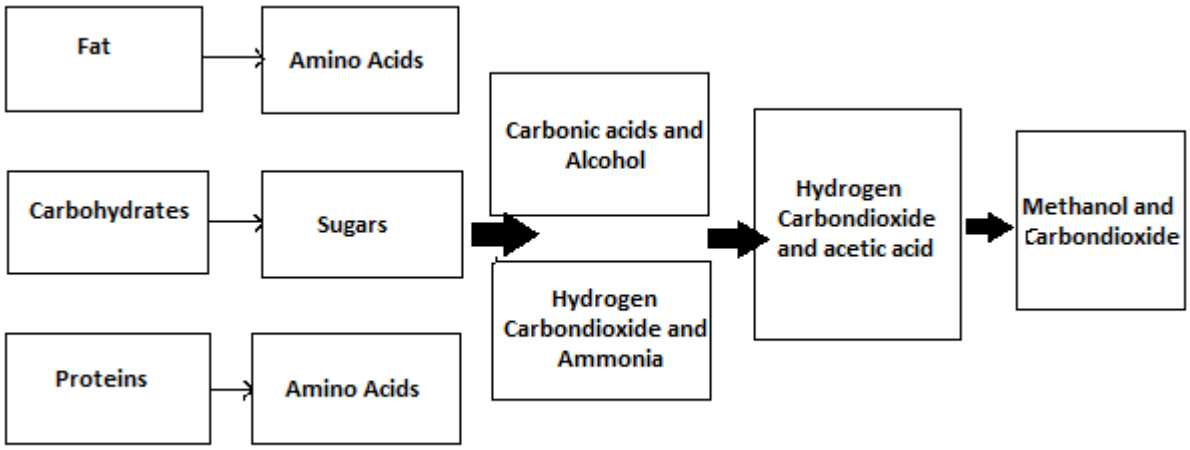
acetogens convert the biodegradable matter to biogas. Apart from being a source of energy, it is also a waste deposition method and environmental conservation technique.

The main equation for this conversion that yields carbon dioxide and methane is as follows −

$C_{6}H_{12}O_{6}\longrightarrow\:3CO_{2}+3CH_{4}$

The step-by-step process is explained below −

- **Step 1** − Breakdown of organic matter to sizable molecules for conversion. This process is known as hydrolysis.
- **Step 2** − Acidogens act on the decomposed matter converting them into volatile fatty acids (VFAs) alongside ammonia, CO2 and hydrogen sulfide. The process is called acidogenesis.
- **Step 3** − The VFAs are further broken down into acetic acid, carbon dioxide and hydrogen.
- **Step 4** − The final stage is the combination of emissions above to produce methanol, carbon dioxide, and water.



COMBUSTION CHARACTERISTICS OF BIOGAS:

The molar fraction of carbon dioxide (CO_2) is high, which ranges from 40% to 60% depending on the source of **biogas**, so **biogas** is a low-calorific-value fuel. Due to the high content of diluting gas CO_2, the **combustion characteristics of biogas** are inferior to natural gas.

HOW DOES AN INTERNAL COMBUSTION ENGINE WORK?

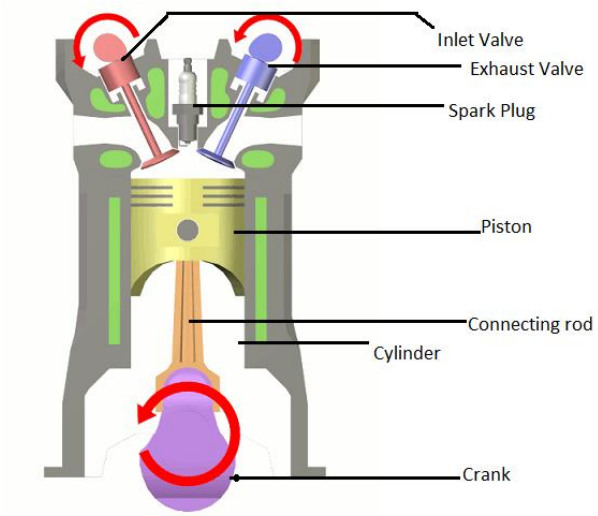
Combustion, also known as burning, is the basic chemical process of releasing energy from a fuel and air mixture. In an internal combustion engine (ICE), the ignition and combustion of the fuel occurs within the engine itself. The engine then partially converts the energy from the combustion to work. The engine consists of a fixed cylinder and a moving piston. The expanding combustion gases push the piston, which in turn rotates the crankshaft. Ultimately, through a system of gears in the powertrain, this motion drives the vehicle's wheels.

There are two kinds of internal combustion engines currently in production:

1) the spark ignition gasoline engine and
2) the compression ignition diesel engine.

Most of these are four-stroke cycle engines, meaning four piston strokes are needed to complete a cycle. The cycle includes four distinct processes: intake, compression, combustion and power stroke, and exhaust.

Spark ignition gasoline and compression ignition diesel engines differ in how they supply and ignite the fuel. In a spark ignition engine, the fuel is mixed with air and then inducted into the cylinder during the intake process. After the piston compresses the fuel-air mixture, the spark ignites it, causing combustion. The expansion of the combustion gases pushes the piston during the power stroke. In a diesel engine, only air is inducted into the engine and then compressed. Diesel engines then spray the fuel into the hot compressed air at a suitable, measured rate, causing it to ignite.



An **Automobile engine** is called an **Internal combustion engine(IC Engine)** because the combustion process takes place internally.

Before entering into the working let us understand some important parts of an **IC Engine** (**Automobile engine**) so that we can understand its working very easily.

1. Cylinder

A cylinder is a path that guides the piston to move in a to and fro motion i.e up and down movement.

(Reciprocating motion) which carries the gas under pressure while an Automobile is moving.

2. Piston

The piston moves in to and fro motion (Reciprocating motion) thus transfers the motion to connecting rod.

Connecting rod further connects crank which converts to and fro motion to rotary motion.

3. Connecting rod

The connecting rod is linked to the piston on one end and crank on another end. Its main function is to convert the to and fro motion of the piston to rotary motion with a crank.

4. Crank

As we discussed that Crank will have a rotary motion which is required for the wheels to turn. This rotary motion of crank is transmitted to wheels. Thus an automobile moves.

5. Inlet Valve

in the inlet valve the fuel enters inside the engine thus combustion takes place.

6. Exhaust valve

Though exhaust valve the hot flue gases are removed out of the engine.

7. Spark plug

Spark plug generates sparks to lit the fuel so that the combustion takes place. Oly petrol engines have spark plugs.

Note - Diesel engines do not have Spark plugs.

How does an Automobile engine work?

1. Suction stroke

In this stroke, through the inlet valve, the air-fuel mixture with a correct proportion is entered inside the cylinder.

The piston moves from Top dead center(TDC) to bottom dead center(BDC). Which creates a suction effect.

2. Compression stroke

In this stroke, both inlet and exhaust valves remain closed the piston moves from Bottom to Top now the fuel is compressed at a high temperature and pressure.

3. Expansion stroke

In this stroke, the piston moves from top to bottom and the spark plug lits fire thus high temperature is produced.

4. Exhaust stroke

In this stroke, the piston moves from bottom to top and removes the flue gases to the atmosphere through the exhaust valve.

APPLICATION:

Internal Combustion (IC) Engine	
Type	**Application**
Gasoline Engines	Automotive, Marine, Aircraft
Gas Engines	Industrial Power
Diesel Engines	Automotive, Railways, Power, Marine
Gas Turbines	Power, Aircraft, Industrial, Marine

MCQ IMPORTANT QUESTIONS

1. The term biomass most often refers to _____
a) Inorganic matter
b) Organic matter
c) Chemicals
d) Ammonium compounds ANS: (B)

3. Dead organisms also come under the biomass.
    a) True
    b) False ANS: A
4. Biomass is useful to produce _____
    a) Chemicals
    b) Fibres
    c) Biochemicals
    d) Transportation fuels ANS: D
5.

BIOGAS INTRODUCTION

Biomass energy is the use of organic material to generate energy. Biomass is just organic matter – think, stuff that's made in nature – like wood pellets, grass clippings and even dung.

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BIOCONVERSION:

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What is Anaerobic Digestion?

Anaerobic digestion is the process by which organic matter such as animal or food waste is broken down to produce biogas and biofertiliser. This process happens in the absence of oxygen in a sealed, oxygen-free tank called an anaerobic digester.

Difference between Aerobic and Anaerobic Digestion:

s.no	*Aerobic Digestion*	*Anaerobic Digestion*
1		

In both aerobic and anaerobic systems the growing and reproducing microorganisms within them require a source of elemental oxygen to survive.

In an anaerobic system there is an absence of gaseous oxygen. In an anaerobic digester, gaseous oxygen is prevented from entering the system through physical containment in sealed tanks. Anaerobes access oxygen from sources other than the surrounding air. The oxygen source for these microorganisms can be the organic material itself or alternatively may be supplied by inorganic oxides from within the input material. When the oxygen source in an anaerobic system is derived from the organic material itself, then the 'intermediate' end products are primarily alcohols, aldehydes, and organic acids plus carbon dioxide. In the presence of specialised methanogens, the intermediates are converted to the 'final' end products of methane, carbon dioxide with trace levels of hydrogen sulfide. In an anaerobic system the majority of the chemical energy contained within the starting material is released by methanogenic bacteria as methane.[3]

In an aerobic system, such as composting, the microorganisms access free, gaseous oxygen directly from the surrounding atmosphere. The end products of an aerobic process are primarily carbon dioxide and water which are the stable, oxidised forms of carbon and hydrogen. If the biodegradable starting material contains nitrogen, phosphorus and sulfur, then the end products may also include their oxidised forms- nitrate, phosphate and sulfate In an aerobic system the majority of the energy in the starting material is released as heat by their oxidisation into carbon dioxide and water. Composting systems typically include organisms such as fungi that are able to

break down lignin and celluloses to a greater extent than anaerobic bacteria. Due to this fact it is possible, following anaerobic digestion, to compost the anaerobic digestate allowing further volume reduction and stabilisation

Types of Biogas Digesters and Plants

Fixed Dome Biogas **Plants**.

Floating Drum **Plants**.

Low-Cost Polyethylene Tube Digester.

Balloon **Plants**.

Horizontal **Plants**.

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What is biomass?

https://youtu.be/dQ-cIVJuDks

How biomass works?

https://youtu.be/-jln6yi7LF0

Biomass | Biomass Energy | What is Biomass? What is Biomass Energy? How does Biomass Energy Work?

https://youtu.be/Cux0Xwvy0cU

https://youtu.be/9Ifl-Ms_Vz4

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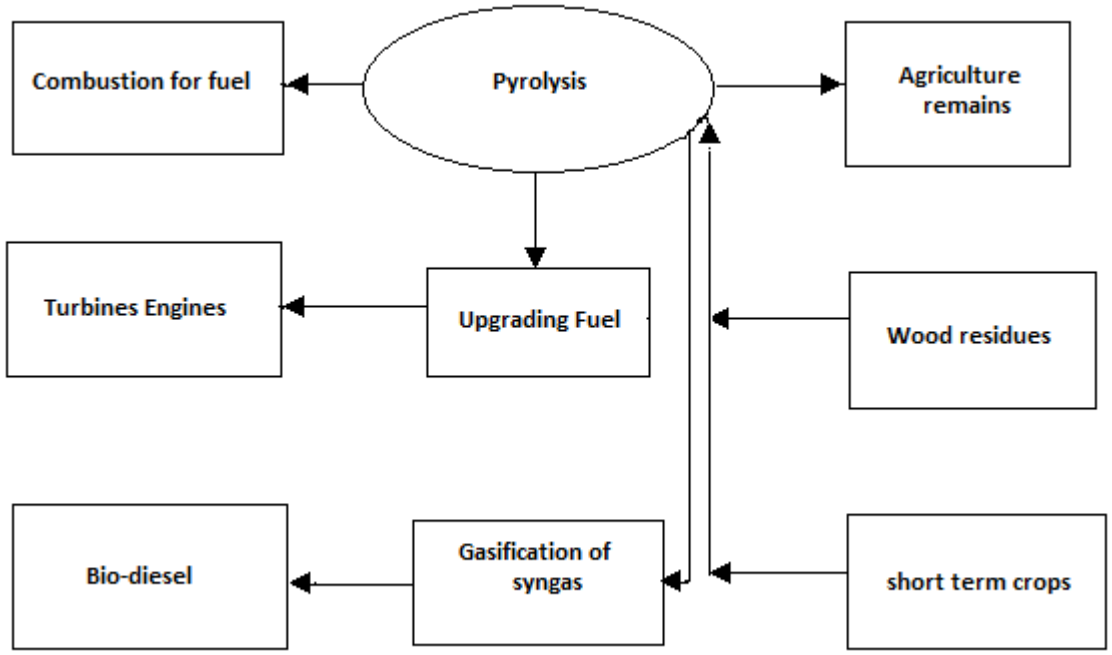
Bio-oil has a number of advantages. It is easier to transport, burn, and store. Many kinds of feedstock can be processed through pyrolysis to produce bio-oil.

The diagram given below explains the process in converting energy in to a usable form from bio-fuels through Pyrolysis.



Alcoholic Fermentation

Alcoholic fermentation is the process that converts sugars into cellulose. The process results in ethanol and carbon dioxide as the by-products. This process is considered anaerobic since it takes place in the absence of oxygen. Apart from bread baking and manufacturing alcoholic beverages, this process produces alcoholic fuel. The chemical formula for alcoholic fermentation is given by −

$C_{6}H_{12}O_{6}+yeast\longrightarrow\:2C_{2}H_{5}OH+2CO_{2}$

Sugarcane is the main feedstock for this process especially in dry environments. Corn or sugar bits are used in temperate areas.

Application of Products

The products have the following applications −

- **Acetone** is a product used for production of food additives, dissolving glue, thinning of paint, grease removers and in cosmetic products.
- **Hydrogen** is used as a cooling agent in power industry. It is also used in hydrogen cells for energy production.

- **Butanol** provides better fuel than ethanol. It is also used as an ingredient in paint, cosmetic products, resins, dyes, polymer extractions and in the manufacture of synthetic fiber.
- **Ethanol** is used as fuel, paint component, and an additive in antiseptics. It is also used in alcoholic beverages.

Anaerobic Digestion of Biogas

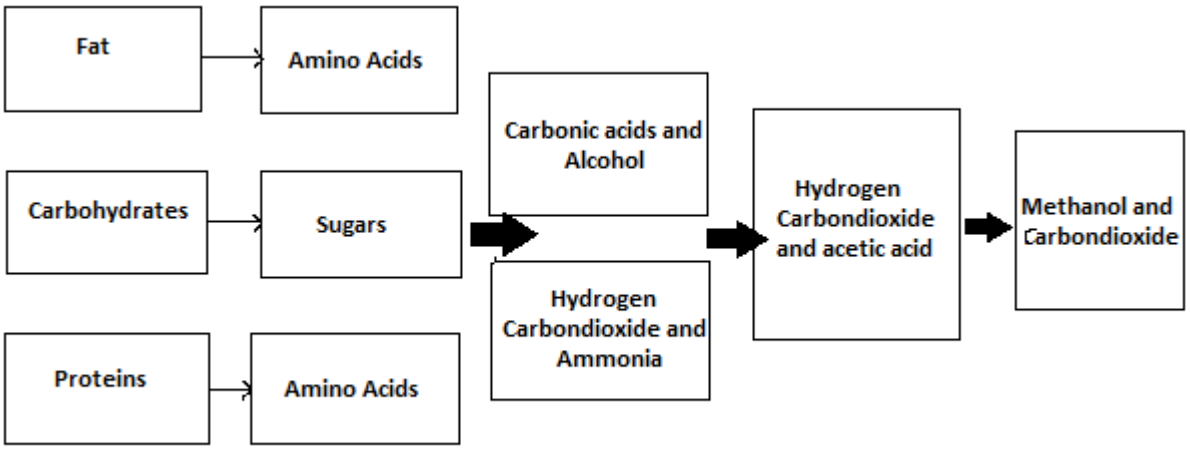
Anaerobic digestion is the biological process by which organic matter is broken down to produce biogas in the absence of Oxygen. Microorganisms such as Acidogenetic bacteria and acetogens convert the biodegradable matter to biogas. Apart from being a source of energy, it is also a waste deposition method and environmental conservation technique.

The main equation for this conversion that yields carbon dioxide and methane is as follows −

$C_{6}H_{12}O_{6}\longrightarrow\:3CO_{2}+3CH_{4}$

The step-by-step process is explained below −

- **Step 1** − Breakdown of organic matter to sizable molecules for conversion. This process is known as hydrolysis.
- **Step 2** − Acidogens act on the decomposed matter converting them into volatile fatty acids (VFAs) alongside ammonia, CO2 and hydrogen sulfide. The process is called acidogenesis.
- **Step 3** − The VFAs are further broken down into acetic acid, carbon dioxide and hydrogen.
- **Step 4** − The final stage is the combination of emissions above to produce methanol, carbon dioxide, and water.



MCQ QUESTIONS

1. **The aerobic digestion of sewage is utilized in the production of**

(a) metal articles

(b) biofuels

(c) biomass

(d) synthetic fuels ANS: B

2. **Biomass is used in the production of**
(a) fibers
(b) chemicals
(c) transportation fuels
(d) biochemicals ANS: C

3. **This forestry material is used as biomass**
(a) fish oil
(b) logging residues
(c) manure
(d) tallow ANS: B

4. Dead organisms also come under the biomass.
a) True
b) False ANS: A

5. The _____ is used as the agricultural fertilizer.
a) Bio ethanol
b) Bio ethane
c) Bio methanol
d) Digestrate ANS: D

6. The term biomass most often refers to _____
a) Inorganic matter
b) Organic matter
c) Chemicals
d) Ammonium compounds ANS: B

7. Which of the following statements about traditional biomass cooking are true?
Please select all that apply.

A) Improved cooking stoves eliminate the damaging effects of air pollution
b) Charcoal production can be sustainably produced and cleanly burnt in stoves
c) Adding a chimney is a cheap, versatile and effective solution to air pollution from stoves
d) Reducing air pollution significantly requires insulating the combustion region and providing sufficient air. ANS: B

8. Which of the following statements about biomass are true?
Please select all that apply.

a) Water supply is not a concern for large scale biomass production.
b) Food production can be in competition with biomass production.

c) Electricity from biomass does not require energy storage.
d) Biomass is a carbon-neutral fuel. ANS: C

9. _____ digestion is the decomposition of organic matter in the absence of air by bacteria.

A) Anerobic
B) Anearobic ANS: B

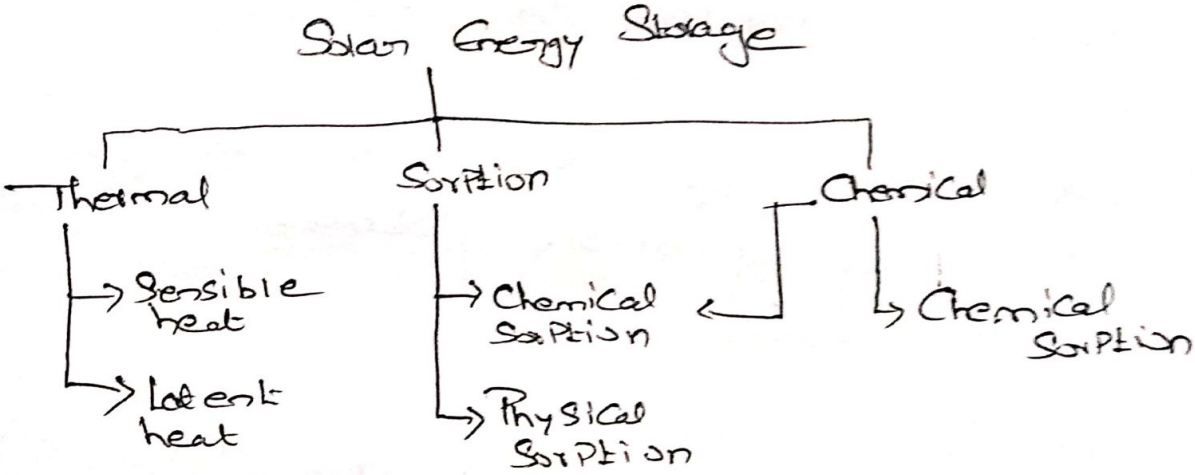
10. Which of the following biochemical conversion process is performed by microorganisms?
A) Anaerobic digestion
B) Fermentation
C) Composting
D) All of the above ANS: D

Unit-2 Solar Energy Storage & Applications

1. Explain the need & Methods of Solar Energy Storage

[N-D-19]

The need of energy Storage arises because of mismatch between availability of Solar Energy Capturing to Cover energy needs of the applications. Depend on the application the Solar Energy Storage will be decided.



Thermal energy Storage:

*) It can be directly Stored

* In Sensible heat Storage, Such as Steam or hot water by changing the temperature of materials (liquid (or) Solid) during Peak hour energy, energy is stored in the form on Sensible heat.

$$E = m C_p \Delta T$$

*) In latent heat Storage, Such as Phase change materials by changing the Phase of materials (liquid or Solid) during Peak hour energy, the energy is stored in the form of latent heat.

$$E = m \cdot \lambda \qquad \lambda \rightarrow \text{latent heat of fusion.}$$

Sorption Energy

*) Two Chemicals are bonded together under Standard Condition. which are seperated using Peak hour energy. Energy is released when the two Chemicals exposed to Standard Conditions.

Chemical energy storage:

Heat generated from Concentrated Solar Power is used to carry out the endothermic Chemical transformation & Produces Storable & transportable fuel.

Ex:- Solar hydrogen, Solar metal & Solar Chemical heat Pipe.

Some of the Conderations which determine the Selection method of Storage and design are as follows.

* temperature range of Storage
* Capacity of the Storage System especially the Collector.
* Heat losses from the Storage have to be kept to a minimum. this more important in long-term Storage
* Cost of the Storage unit. it includes initial, Containers & insulation, Operating Cost
* Suitability of materials used for the Container.

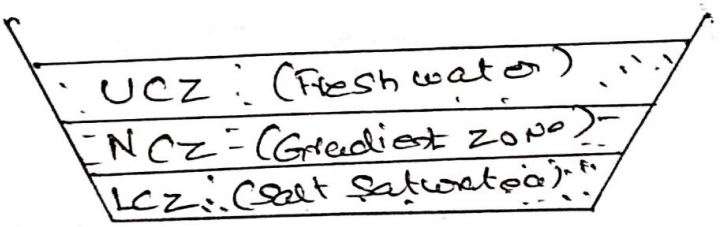
2. Solar Ponds with neat Sketch & its application merits & demerits. [N-D-19]

Solar Pond is a body of water that collects & stores solar energy.

We have to use some methods to trap the heat from a warm water otherwise it losses the heat due to convection or evaporation process.

Solar Pond also called Solar Salt Pond, is an artificially designed Pond with salty water maintaining a definite concentration gradient.

There are three layers in the Solar Pond



Upper Convective Zone (UCZ)

*) it acts as a buffer zone b/w environment fluctuations
*) it is nearly fresh water
*) about 10cm to 20cm thick with a low uniform concentration at nearly to the ambient air temperature.

Non Convective Zone (NCZ)

*) Zone keeps the two convective zones (CSZ & LCZ) apart & gives the Solar Pond its unique thermal performance.
*) excellent insulation for the storage layers.

*) amount of Salt is transported by molecular diffusion from LCZ to SCZ.

*) SCZ (or) UCZ Salt was removed by using desalination method using Solar energy. to remain the SCZ keeps fresh water.

*) UCZ remains at ambient temperature. while LCZ at steady state temp about 60°C to 85°C

Optical transmission properties & related Collation efficiency vary & depend on the factors :

*) Salt Concentration *) Quantity of dust (or) other particles

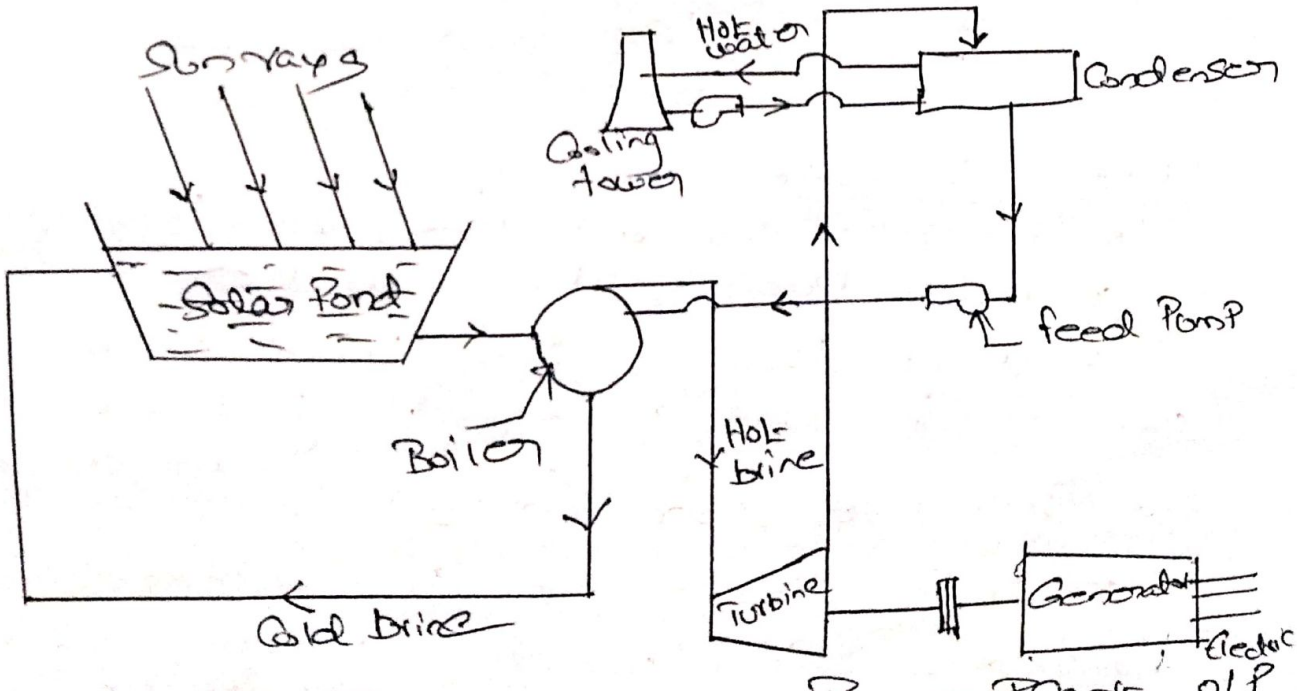
*) Surface impurities (leaves, algae etc)

*) Type of Salt.

Lower Convective Zone (LCZ)

it is at the bottom layer with highest Salt Concentration where higher temperatures can be built up.

Stores the Solar energy for further use.



Solar Pond electric Power Plant

Types of Solar Ponds

*) Convective → Fresh water is covered with bag sheet to avoid evaporation.

*) Non-Convective → Salt Solar Pond used artificially.

Application of Solar Ponds

* Power generation
* Space heating & Cooling
* Crop drying
* desalination
* Process heat

Advantage

*) low investment cost
*) Diffuse radiation is fully used
*) Large scale energy generation is Possible
*) it is attractive for rural areas.
*) Seperate Collector is not needed

Limitations

*) Efficiency is 17% when operated b/w 80°C to 20°C
*) Need of large land area.
*) accumulated Crystal salts have to removed Periodically. & its add maintenance expenses.
*) it can be operated only in sunny days
*) algae & dusts are reduce the thermal efficiency of a Solar Pond.
*) Due to evaporation, non-saline water is constantly required to maintain salinity gradients.

3. Solar heating technologies & applications

Direct thermal application involve the direct use of heat thereby resulting the absorption of solar radiation for space heating & cooling of residences, other buildings. etc. at moderate temperatures

Various solar direct thermal application systems are there.

*) Solar water heater
*) Solar cooker
*) Solar space heating
*) Solar furnace

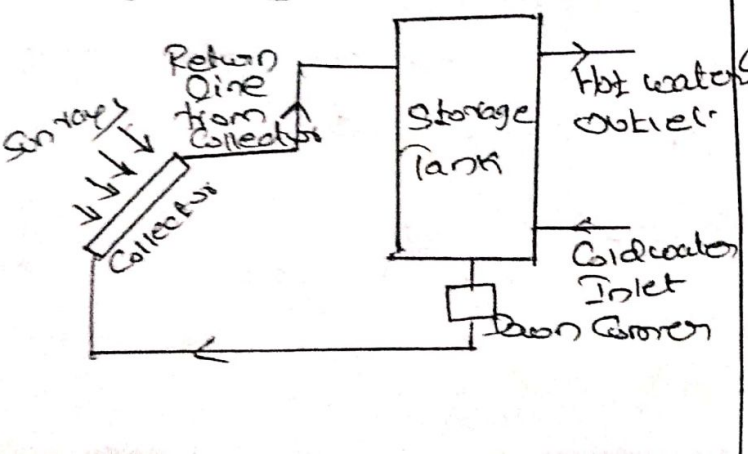
Solar water Heater:

*) Solar water heater are one of the best options to be adapted in the developing country.
*) It is operated at 60°C to 90°C.
*) Suitable for Pre-heating the feed water of boiler.

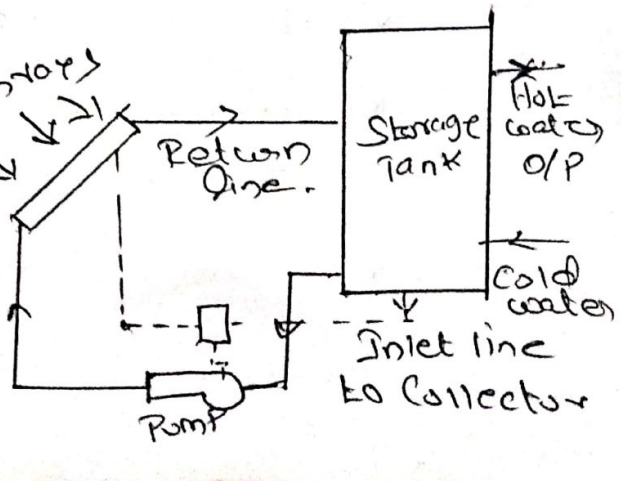
Components *) flat Plate Collector
*) Storage tank
*) Connecting Pipe

Two types of Solar water heaters

i) Thermo Syphon (or) natural Circulation



ii) forced Circulation System



Thermo Syphon:

* Operating temp are 80°C to 100°C
*) Capacities 100 litres to 200 litres
*) Storage tanks & Pipes are insulated
*) heat gains from Solar Collector & transferred to storage tanks. then heat is transfer to the Pipe line again it goes circulated to Solar collector.

Forced Circulation System:

*) here they using Pumps for forced circulation and for auxiliary units.

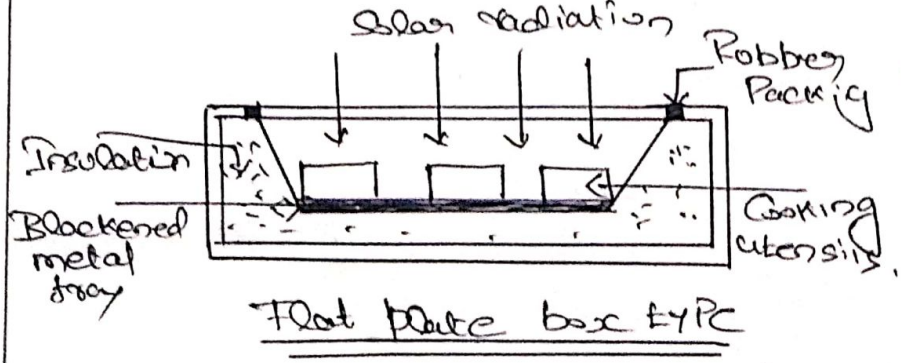
Solar Cooker:

Solar Energy used for Cooking Purpose with the design of Solar heating technique. is a Solar Cooker.

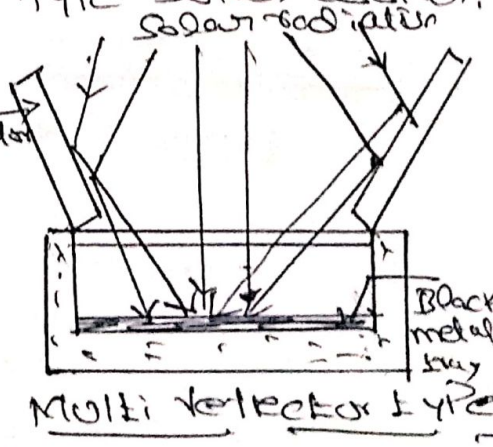
Solar Cooker can use 275 days a year could save 800 kgs of fire wood or 65 litres of Kerosene. for a family.

Types of Solar Cooker.

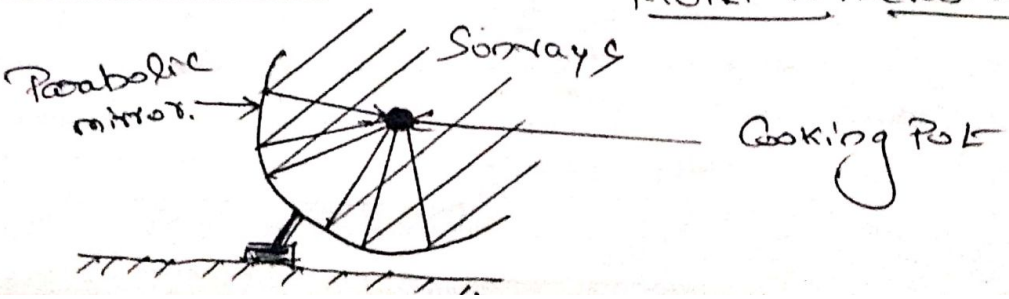
*) Flat box type Solar Cooker (90°C to 110°C)
*) Multi reflector type Solar Cooker (250°C)
*) Parabolic disc Concentrator type Solar Cooker. (450°C)



Flat plate box type



Multi reflector type



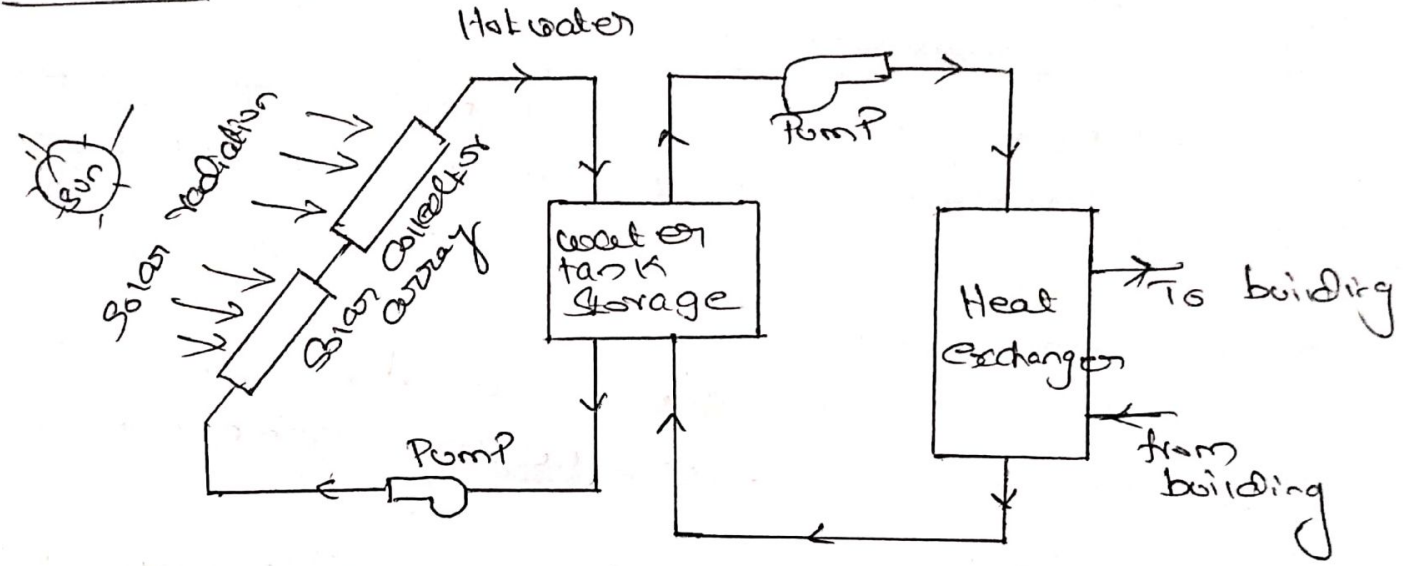
Solar Space heating :

This system used to heat the space of buildings with the help of Solar Collectors.

Direct Circulation (Open loop)

* Water is circulated directly through Solar Collectors
* System cannot be used in areas temperatures below freezing

Indirect Circulation (closed loop)



Solar space heating system

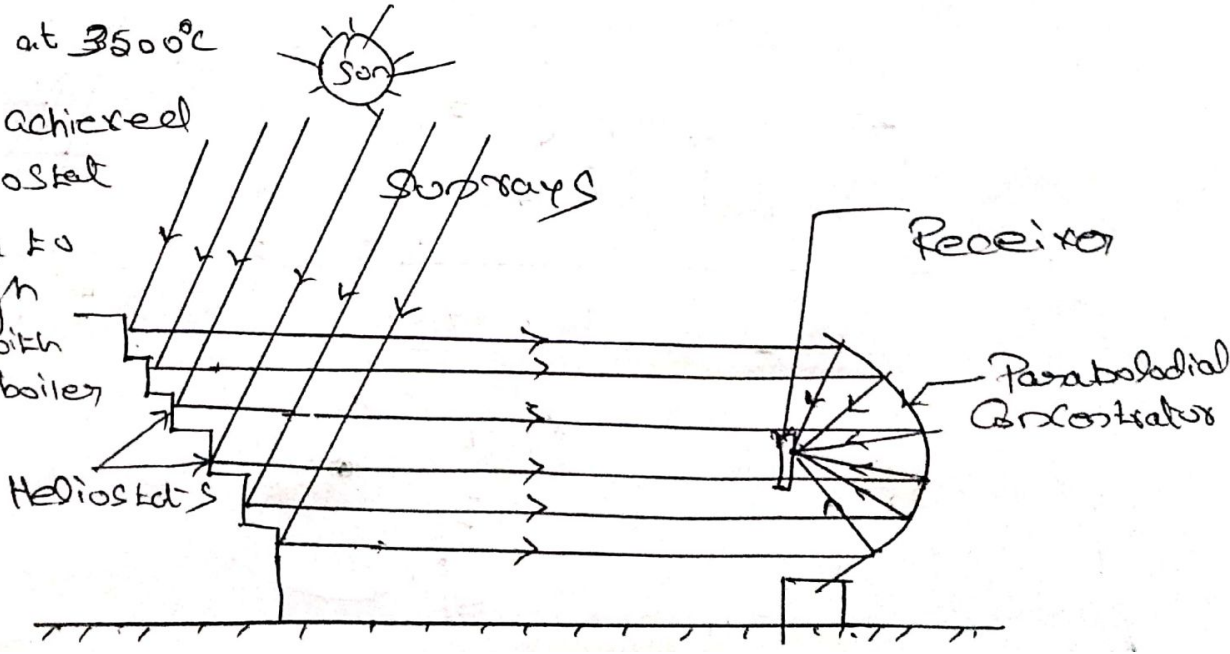
* Operates at 55°C to 80°C.
* It is a closed loop & recirculated circuit
* Two circuits one is connected with Solar Collector & other circuit is used to exchange heat to buildings through heat exchanger.

Solar Furnace :

Operates at 3500°C

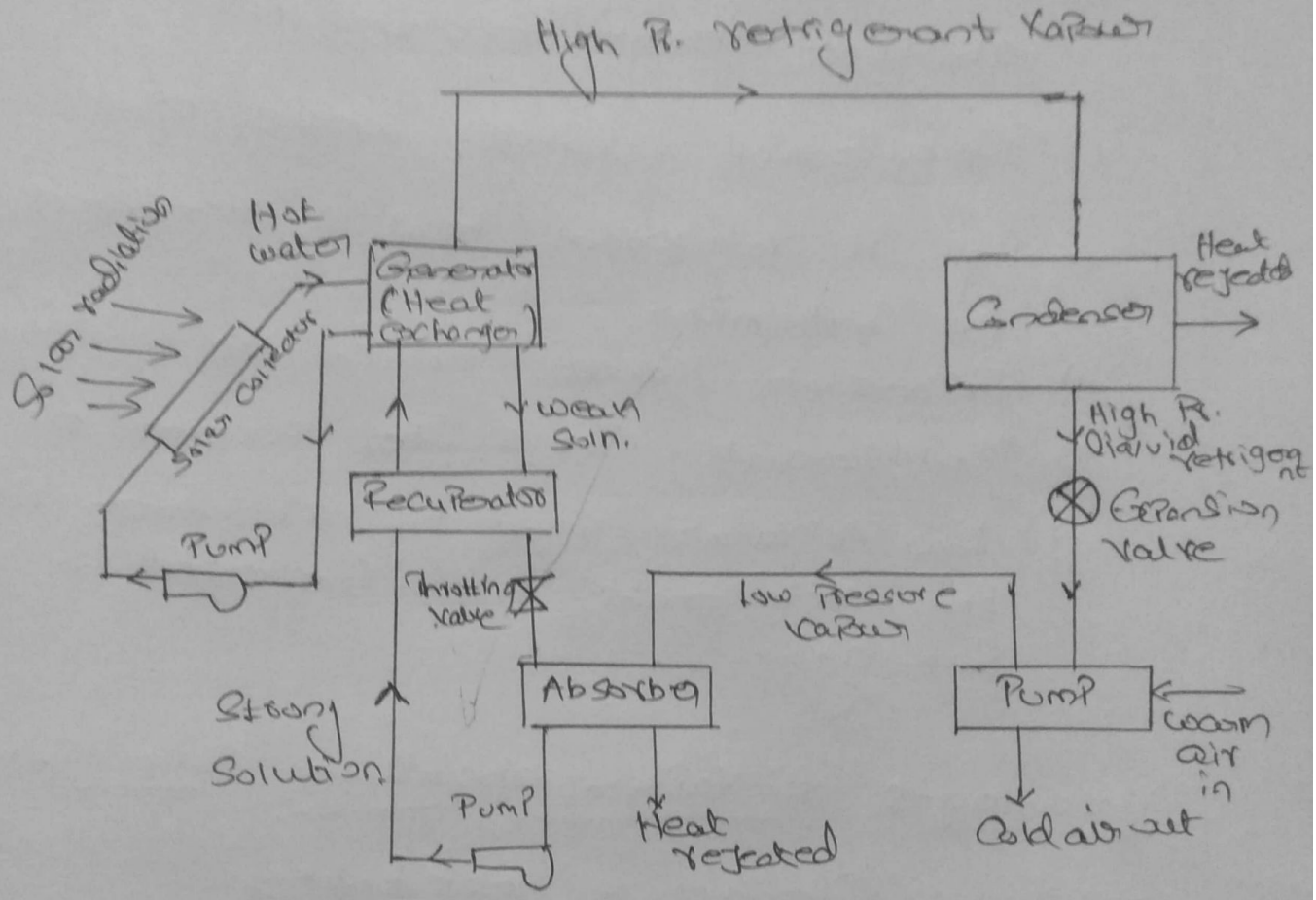
530°C is achieved with heliostat

It is used to Produce high Pr. Steam with the help of boiler setup.



Solar Cooling Technique & its merits

Solar Cooling is a technology which converts the heat collected from the sun into useful cooling for delivery to application such as building air conditioning.



Vapour Absorption Solar Cooling System

Solar heat is collected by a thermal driven process which generates chilled water (or) cooling conditioned air for use in the building.

For solar space cooling, either vapour absorption refrigeration cycle (or) vapour compression refrigeration cycle may be used.

Vapour absorption system commonly used are lithium bromide-water & ammonia-water. These absorbent absorbs heat during evaporation and hence it produces a cooling effect.

The fig shows the layout of vapour absorption system.

*) From Solar Collector heat is transferred to generator

*) Generator supply the heat to the strong soln. then the ammonia is converted in to High Pr refrigerant vapour and passed to condenser.

*) the weak soln is again send to the absorber through Recuperator.

*) Recuperator absorbs waste heat

*) High Pr. refrigerant heat is removed by the condenser

*) Expansion valve reduce the Pr. of refrigerant

*) Refrigerant cools the room air

*) low Pr vapour send to absorber it cools the refrigerant it is converted to strong soln. again.

Advantages of vapour absorption Solar Cooling System

*) it is compact & less bulky

*) it has no moving part except the motor driven pump & hence, it reduces less wear

*) It is quiet in operation & it has less moving parts

*) less maintenance is required.

25

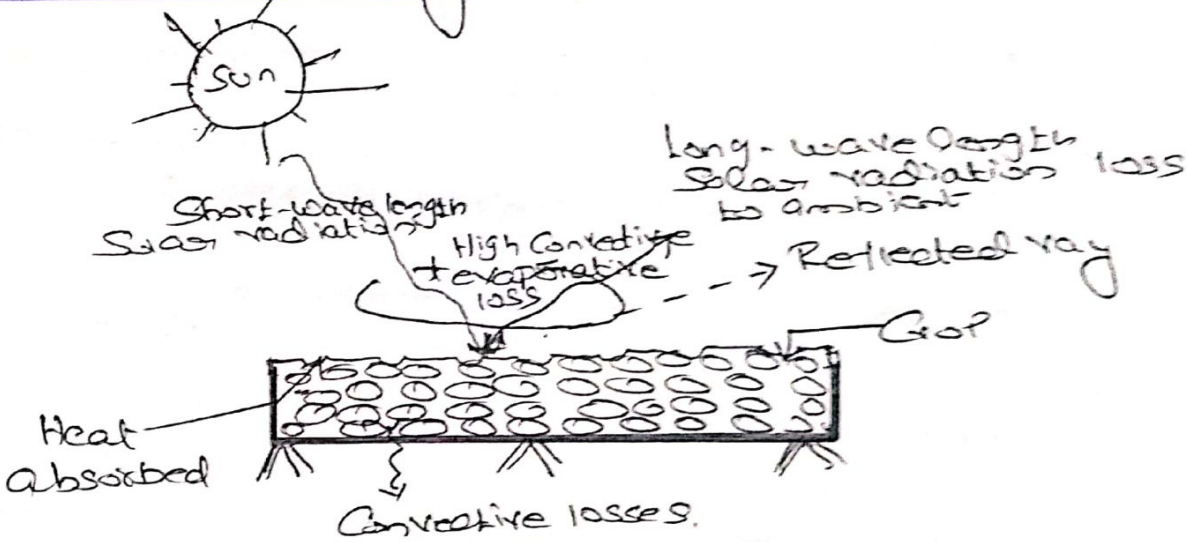
Solar drying & its methods

The drying of food is necessary to store it for long time between harvesting and consumption.

High moisture content in the food spoils it due to fungus formation during the storage time of harvesting.

Methods are used for solar drying.

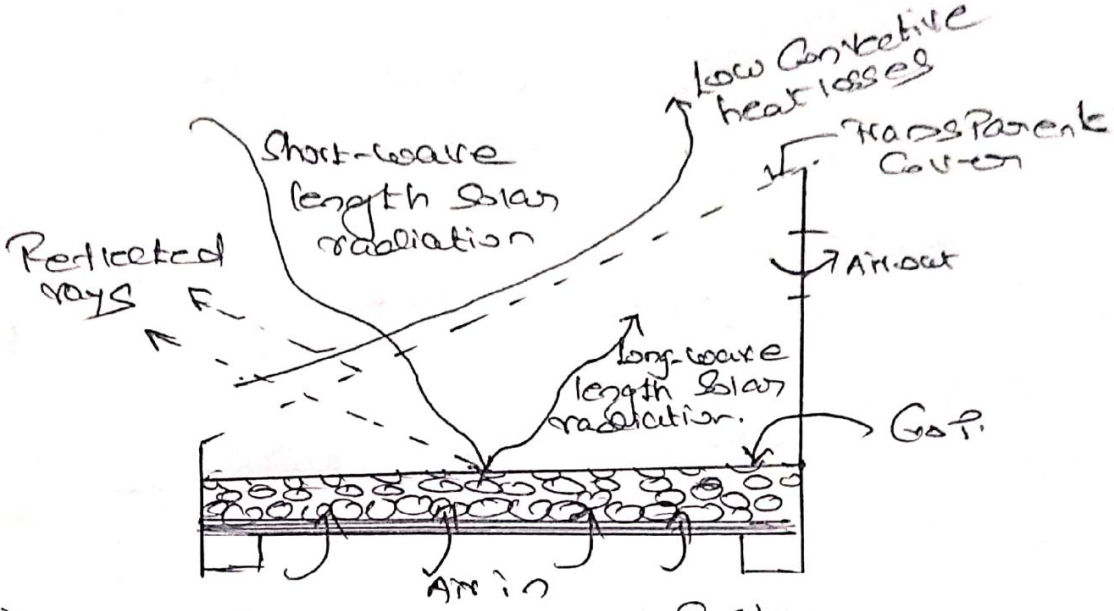
i) Open Sun drying



Open Sun Crop drying

* it is simple & widely used in rural area.
*) Crops are spread over the open surface area where there is direct sun light.
*) Short wave length solar radiation falls on the uneven Crop surface.
*) A part of solar radiation is reflected remaining is absorbed by crops. depending on the colour.
*) The Crop is dried due to evaporation of moisture taking place in the form of evaporative losses.

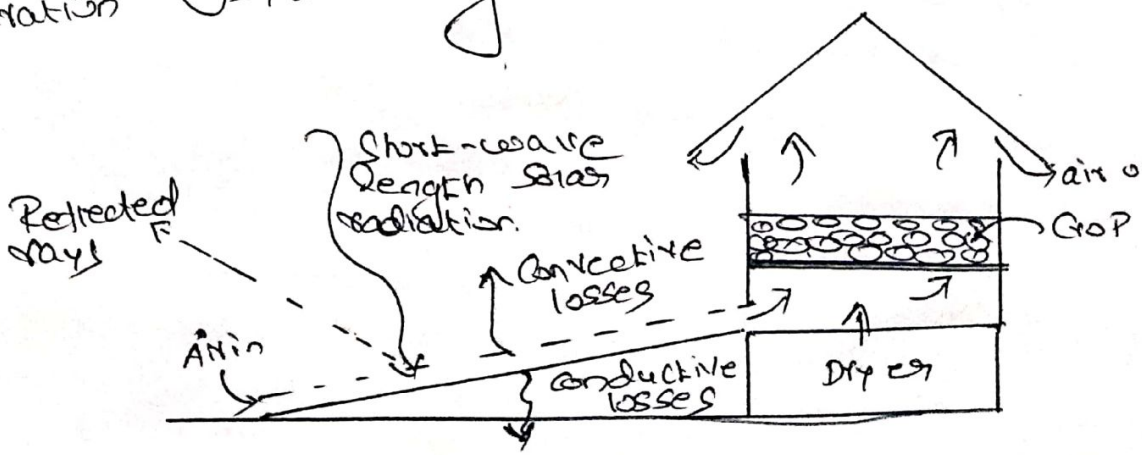
ii) Direct - Solar drying



* it is a Cabinet dryer System
*) Reflection due to transparent Cover and Crops surface glacier.
*) long wave length is arrested inside the box by transparent Cover so Convective loss is reduced.
*) The temperature above the Crop inside Chamber becomes high.

iii) Indirect Solar drying

* To minimize the discolouration & Cracking on the surface of the Crop using Indirect Solar radiation.
*) Separate unit a Solar air heater is used for Crop drying by allowing hot air in to Chamber.
*) The hot air is allowed to flow through the wet Crop.
*) drying is achieved by difference in moisture Concentration b/w drying air & air at Crop surface.



6. ## Solar Distillation (or) Solar Still

Solar still is a device used to convert saline water in to pure drinkable water by using solar energy. it is called distillation process.

The conventional distillation process are thin-film distillation, reverse osmosis & electrodialysis are energy intensive technique.

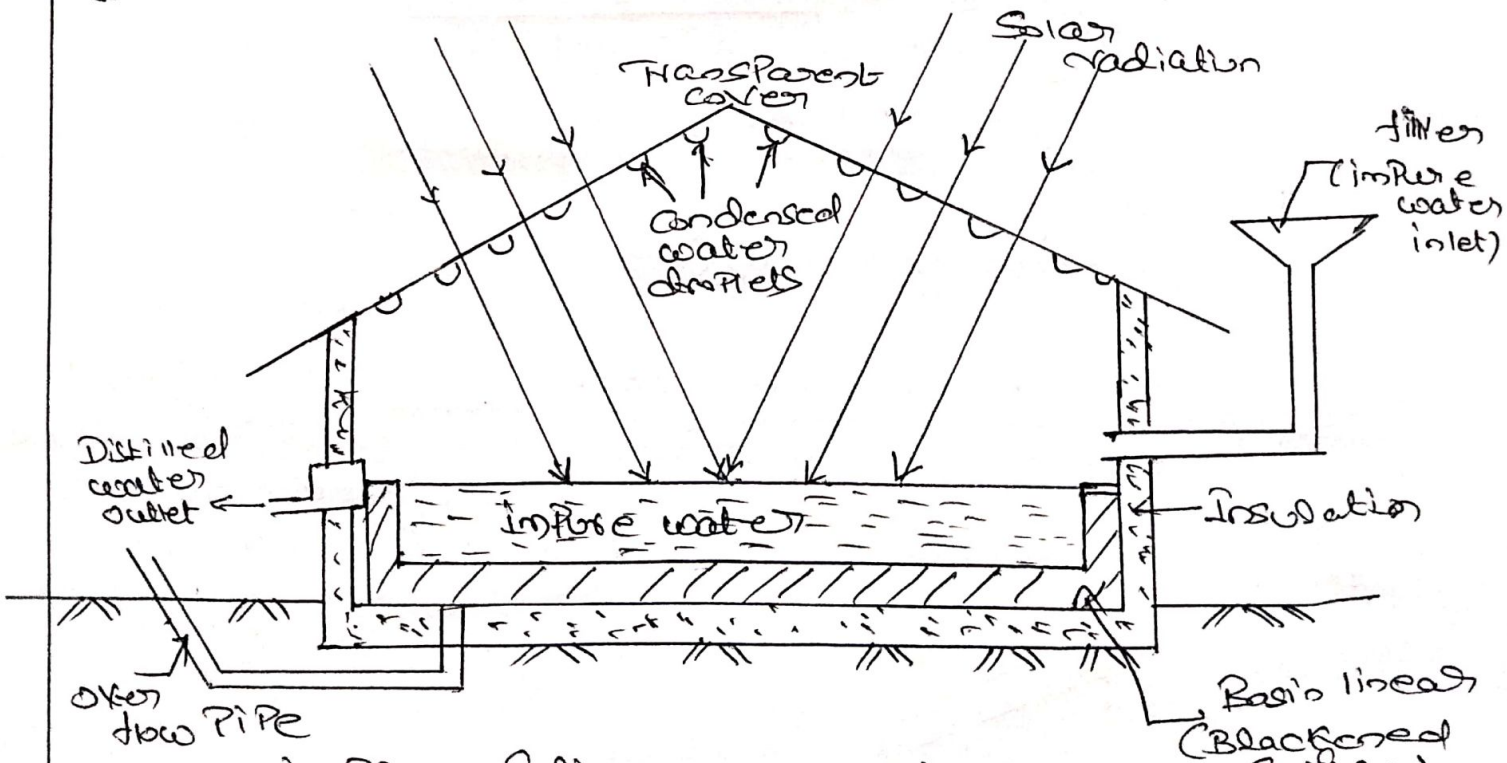
*) Passive Solar Still (Conventional type Solar Still) low temperature operating

*) Active Solar Still (extra auxillary thermal energy used for high Productivity)

Basin (or) Box type Solar Still: (Passive Solar Still)

Passive Solar still. A transparent light air cross encloses the space above basin completely

The cover which is glass (or) Plastic is sloped towards a collection trough.



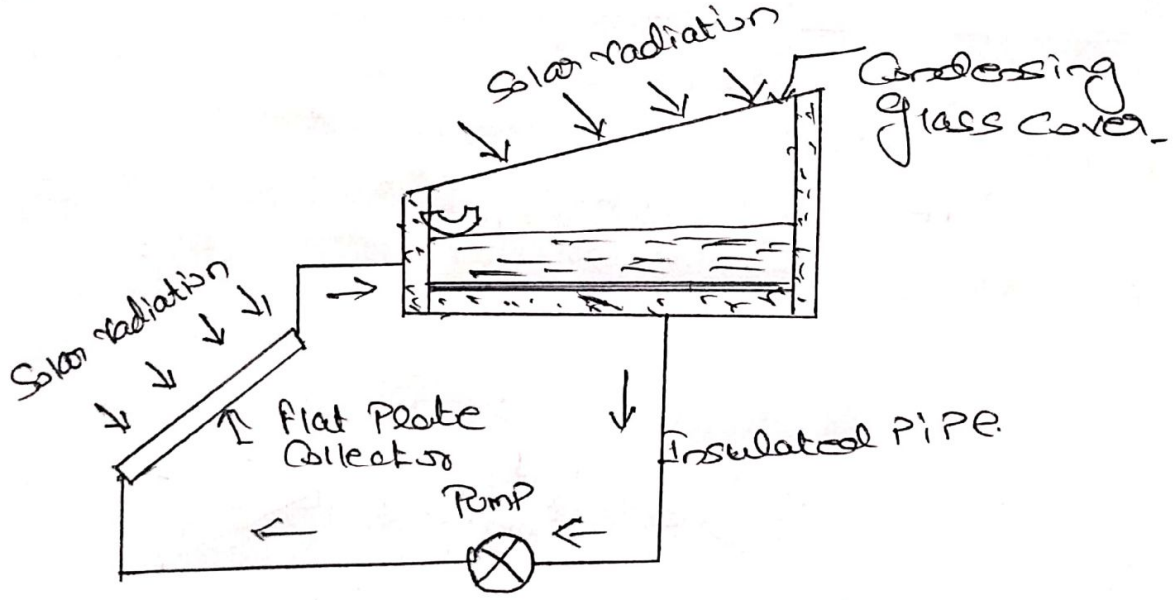
* impure saline water in the basin is vaporized due to the solar radiation the fresh water is arrested by the transparent cover

The Condensed water flows down the sloping roof & there is a Provision to Collect the distillate at lower end of the glass cover.

Solar Still may Provide about 15 to 50 litres/day/10m2.

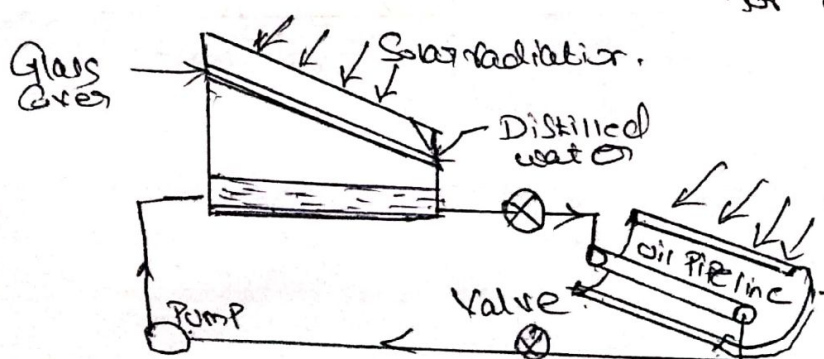
SOLAR STILL COUPLED WITH FLAT PLATE COLLECTOR

Active Solar Still. It is similar to basin type except the that an additional flat Plate Solar Collector is used to increase evaporation rate



Solar Still Coupled with Parabolic Solar Collector.

Parabolic trough Collector is used to increase evaporator rate. It achieves high efficiency than the flat Plate Collector. it needs Sun tracking system for Concentrating Collector.



Advantages of Solar distillation

*) low energy Consumption
*) No fuel is reqvired
*) No Pollution
*) Simple design
*) Less skilled labour may be sufficient

Disadvantages

*) Impractical as a Primary drinking wato
*) Very slow treatment rate
*) Solar distillers do not kill bacteria
*) The large area tilted glass cover might be an attraction to bugs & insects.

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7. Solar PV Power generation System:

Basic Photovoltaic System integrated with the utility grid. It consists of the following elements.

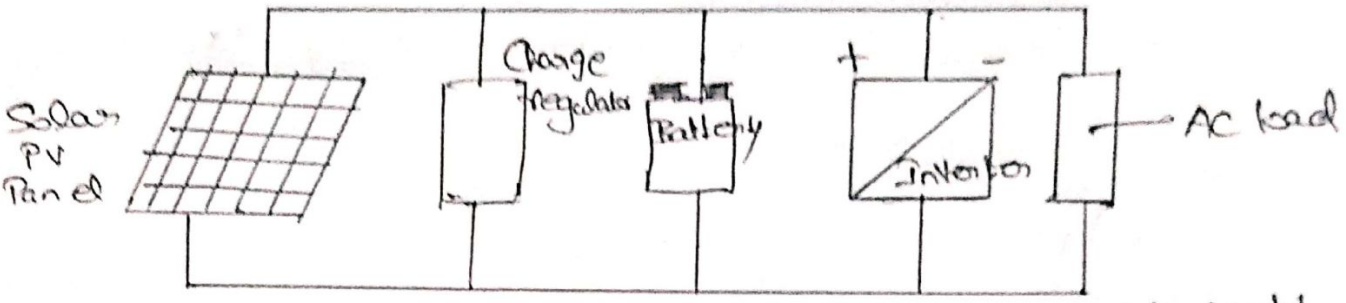
1. Solar array (Solar insolation Convert to DC electrical)
2. Blocking diode
3. Battery Storage
4. Inverter/Converter (DC to AC Converter)
5. Switches/Circuit breakers

Solar PV Systems are broadly Classified in to three Categories.

1. Standalone Power Systems
2. Central Power System
3. Hybrid System.

Stand alone Power System:

It is located at the load Centre. it is more relevant & successful System in remote & rural areas which have no access to grid supply



Indicative Capacity of System is 10W to 100W

Energy Storage to meet the demand at the low Solar irradiation & night time.

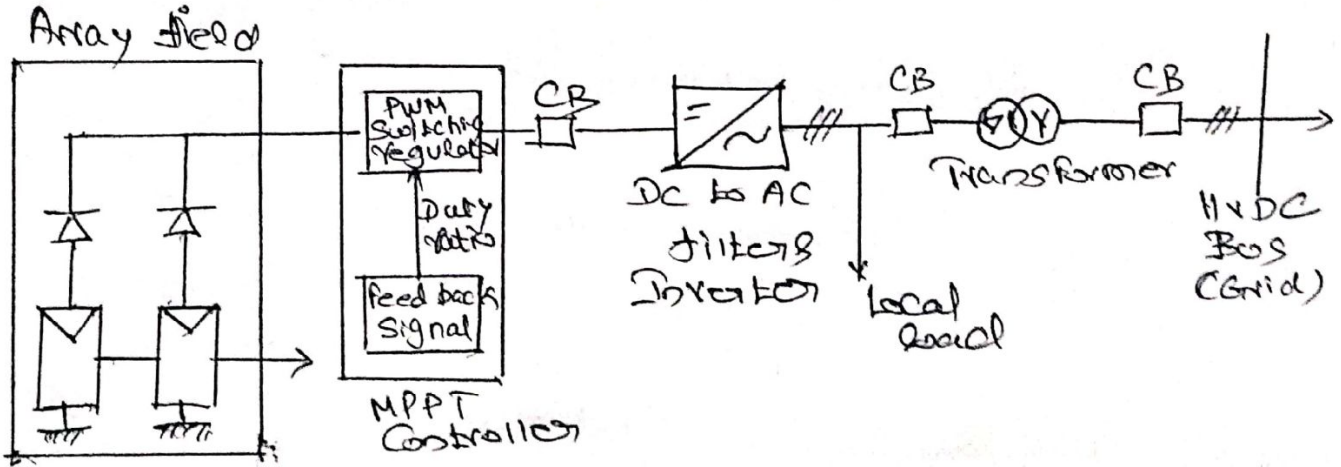
Charge Controllers are used to regulate the Charge transfer & Prevent the battery from being excessively Charged & discharged.

Central Power System (or) grid Connected System

This System is also known as grid interactive system.

In this System, PV Panels are Connected to a grid through inverters without battery Storage & all excess Power is fed in to grid.

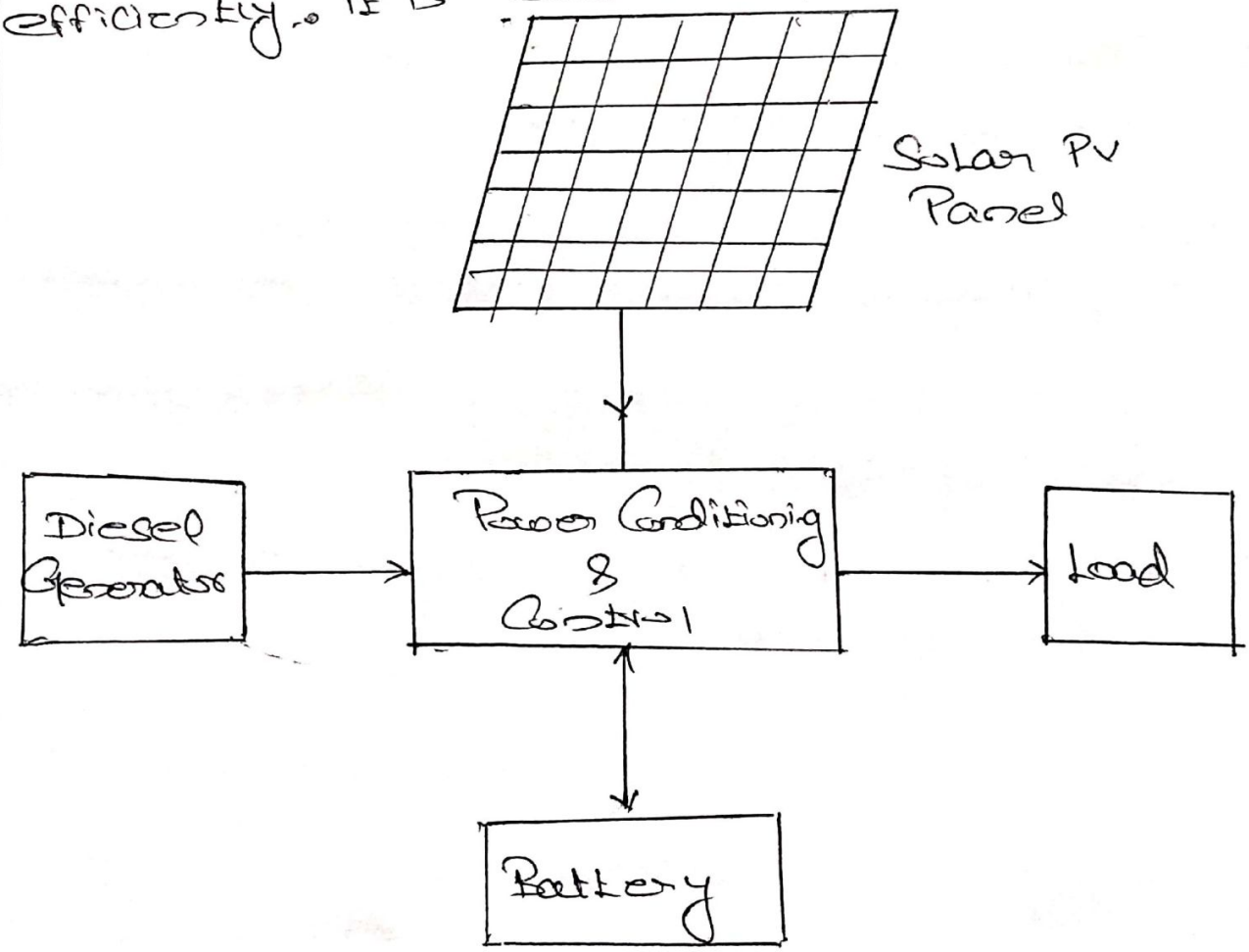
They are Proposed in few MW range to meet day time Peak load only.



Hybrid System:

Conventional Power system used in remote areas often based on manually controlled diesel generators operating continuously or a few hours.

Renewable energy sources such as PV can be added to remote area Power system using diesel & other fossil fuel Power generators to Provide 24-hr Power economically and efficiently. it is called hybrid system



Advantages

*) It has no moving parts & hence no wear
*) it Produced no Pollution
*) it has a wide Power handling capacity.

*) It has long effective life
*) it is highly reliable
*) Power to weight ratio is high
*) it can be used with (or) without sunlight

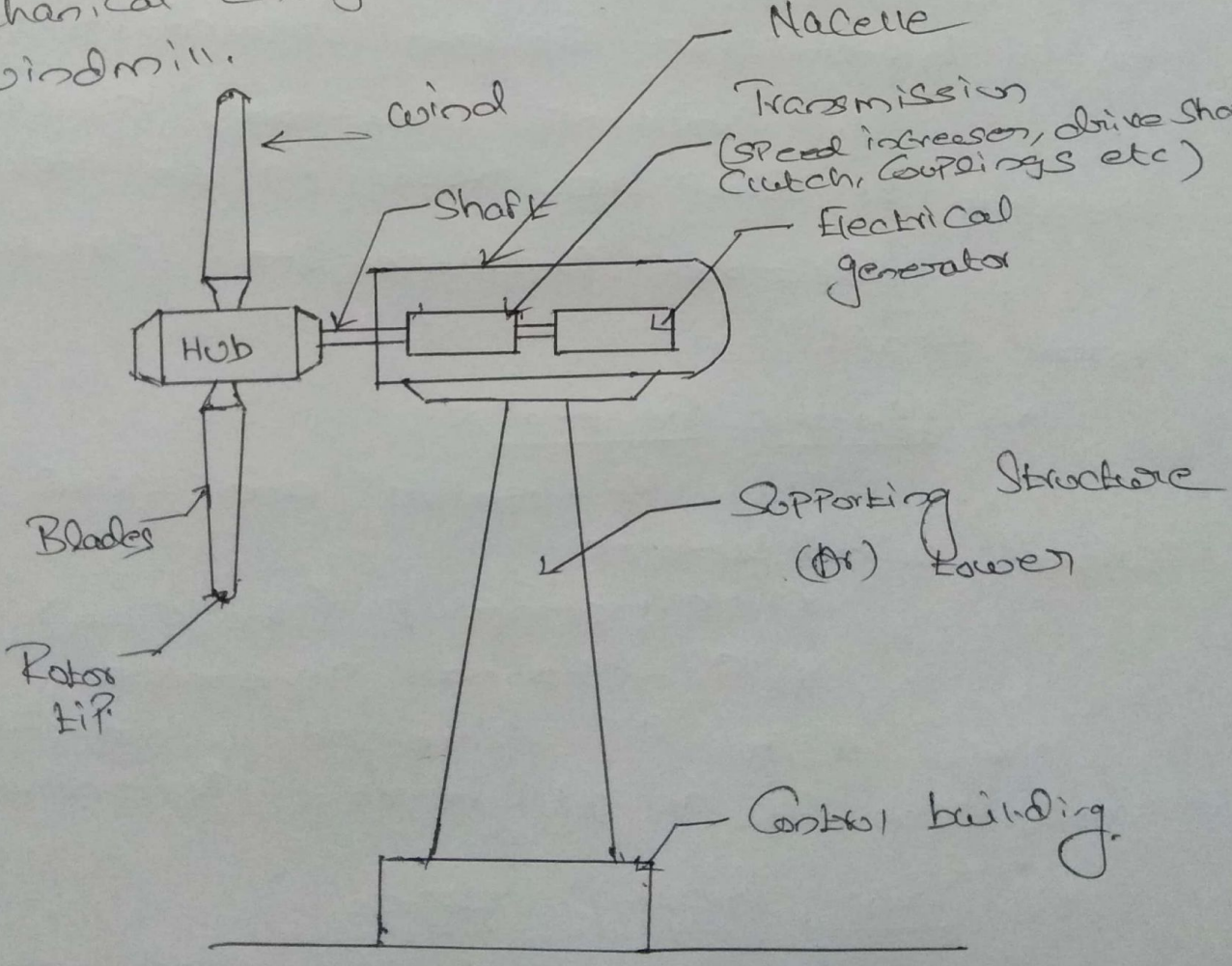
Disadvantages

*) Solar energy is somewhat more expensive
*) Solar Power is a variable energy source with energy Production dependent on the sun.
*) Energy storage is required because of no insolation at night.
*) In case of land-mounted PV Panel installations they require relatively large area for deployment
*) Solar Panels efficiency levels are relatively low (1H-25%)
*) They are ~~big~~ fragile & can be damaged relatively easily.

1. Explain the components of wind energy conversion system and illustrate about Horizontal axis windmills with a neat sketch. [N-D-19]

Wind Power is the conversion of wind energy in to a useful form of energy such as using wind turbine to make electricity or windmills for mechanical Power, wind pumps for water pumping (or) drainage (or) sails to Propel ships.

wind turbine is a rotating machine which converts the kinetic energy of wind in to mechanical energy. the machine is usually called a windmill.



Components of wind turbine

Main Components of a wind energy Conversion System are as follows

*) Wind turbine
   *) Na Celle [Housing with Transmission, Generator]
   *) Rotor [Horizontal mill have Two or three blades]
   *) Hub & Shaft [Rotors of the wind turbine are attached with the Shaft & hub assembly]
   *) Anemometer [to measure wind speed]

*) Transmission System

Mechanical Power generated by the wind turbine is transmitted to the electric generator by a transmission system located in nacelle.

It contains Gearbox, Clutch & braking system to stop the rotor in an emergency.

Gearbox increase the speed of the rotor shaft.

*) Electric Generator

Two generators are used in Constant speed wind turbine
   *) asynchronous (Induction)
   *) Synchronous generators.

Most of the grid connected wind turbines installed so far as induction generators.

*) Yaw- Control System:

The horizontal axis wind turbine has a yaw control system that turns the nacelle according to the actual wind direction using a rotary actuator to the gear ring at top of tower.

*) Storage

* excess Power is stored in the lead -acid battery

* Energy Converters

wind turbine Produce DC, so it should be Converted in to AC using a alternator before supplying in to the transmission grid for industrial & household appliances.

*) towers

Types of wind mills

*) Horizontal axis wind machines
*) Vertical axis wind machines

Applications

*) Power generation Connected with electrical grid System.
*) wind turbine for remote homes generate DC Current for battery Charging
*) Pumping Purpose
*) Suitable for residential (or) village Scale wind Power ranges from 500 w to 50 kw

Advantages

*) No green house gases
*) free of cost (wind)
*) Electricity to remote areas
*) Potential of wind Power is enormous
*) wind turbines are incredible space-efficien-

2. Explain Vertical Axis wind mills & its types

In Vertical axis wind turbines, the main rotor shaft arranged vertically & the axis of rotation is vertical with respect to the ground.

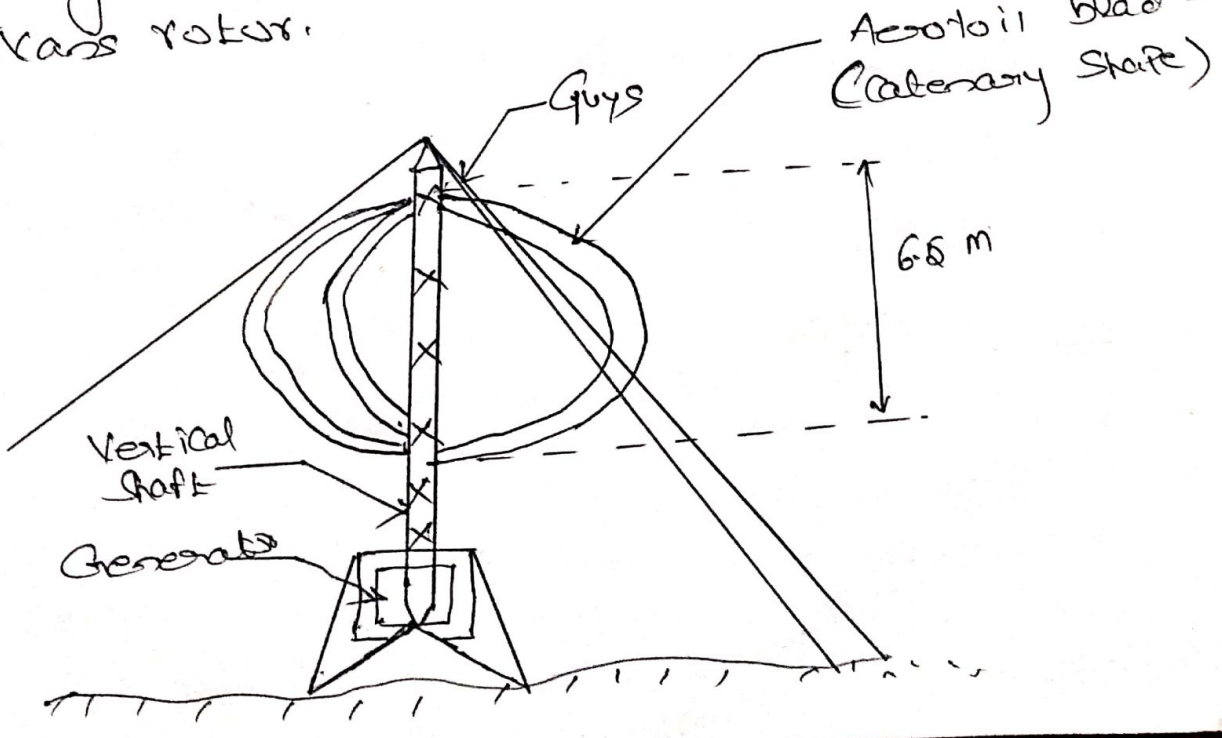
It is an advantage on sites where the wind direction is highly variable. With a vertical axis turbine, the generator & gearbox can be placed near the ground.

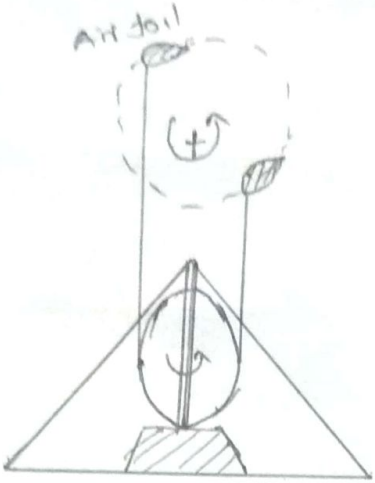
Drawbacks are that some design produce pulsating torque.

It cant be fixed in towers, it should be fixed in roofs & buiding tops. the wind speed is slow at lower altitude.

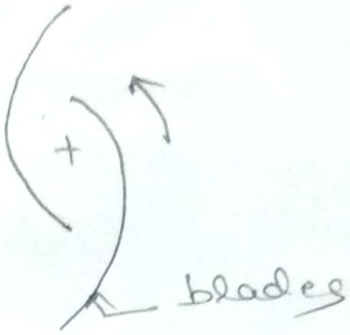
Various Types of vertical axis wind turbine:

1. Darrieus rotor
2. Savonious rotor
3. Multiple blade rotor
4. Musgrove rotor
5. Evans rotor.

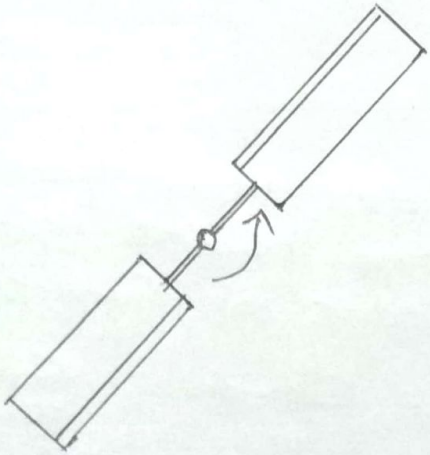




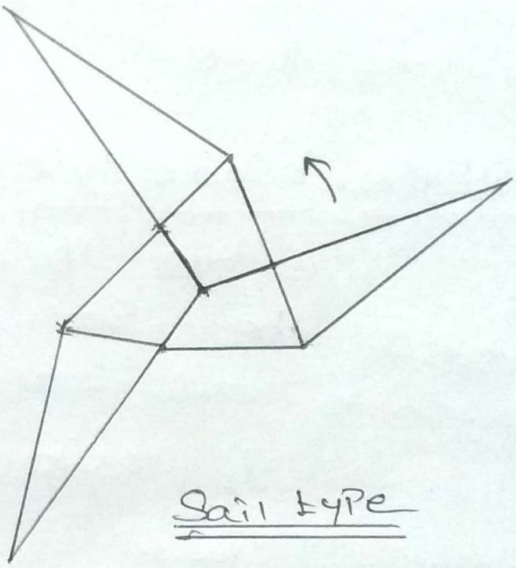
Darrieus type



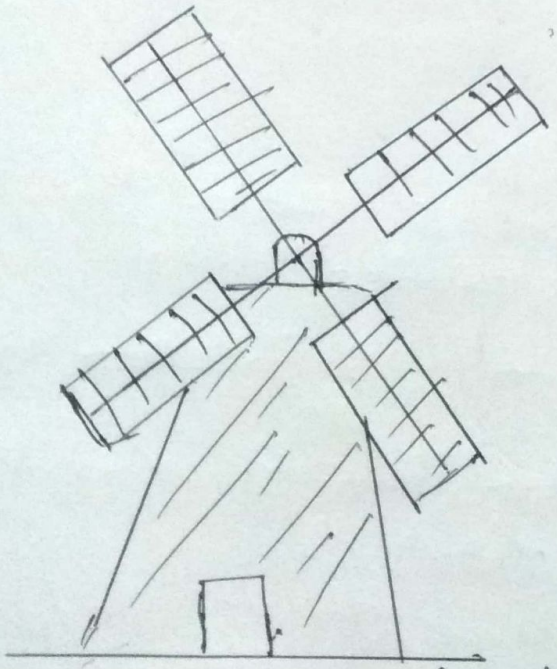
Savonius type



Propeller type



Sail type



four-blade dutch wind mill

Darrieus rotor :

Its like egg beater shape. The driving forces are lifting forces. It needs less surface area

Initial movement generated with motor.

Savonius rotor :

Complicated motion of wind through & around the two curved sheet aerofoils rotates by drag force.

Multiple blade type :

it has 12 to 24 blades made from metal sheets. The sail type three blades made by stitching out triangular pieces of canvas cloth

It runs at slow speed of 60rpm 80rpm

Musgroxe rotor :

Blades are vertical for normal power generation. the rotal has fail-safe shut down in strong winds

Evan's rotor :

Vertical axis for control and a fail-safe Shut down the vertical blades are twist.

four-blade clutch mill & Propeller type

application : for water Pumping and small battery operation,
Electricity generation.

3 Explain the types of wind Power Plants & Site Selection for wind Energy System

Wind Power Plants are varies depend on the areas & application. Such as

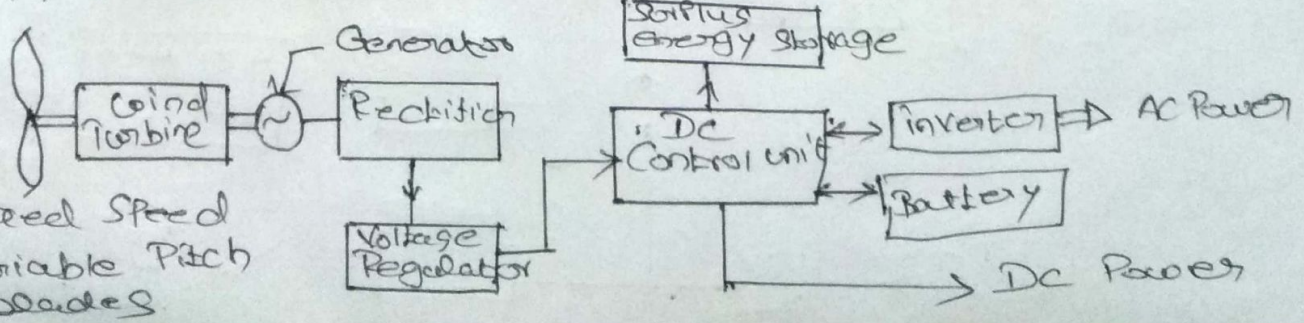
*) Remote (or) off grid wind Power Plants
*) Small Scale (or) Stand alone wind turbine Plants
*) Medium Scale wind turbine Plants
    a) Single - mode electricity supply
    b) Multiple - mode distribution
*) Hybrid wind Power Plants
*) Grid Connected wind Power Plants
*) wind farms.

i) Off-grid wind Power Plants:

wind turbine used in rural areas at high wind speed. maintenance free.
ex: to keep Vaccine cold, rural Clinic lights
Communication equipment running Continuously.

ii) Small Scale (or) Stand alone wind turbine Plant:

Mechanical Control & Pitch Power Control of wind turbines are generally used for Constant frequency generation
Relatively Small Power 240V/50Hz obtained from batteries to 110V/60Hz. Can be by inverters.



iii) Medium scale wind turbine Plants

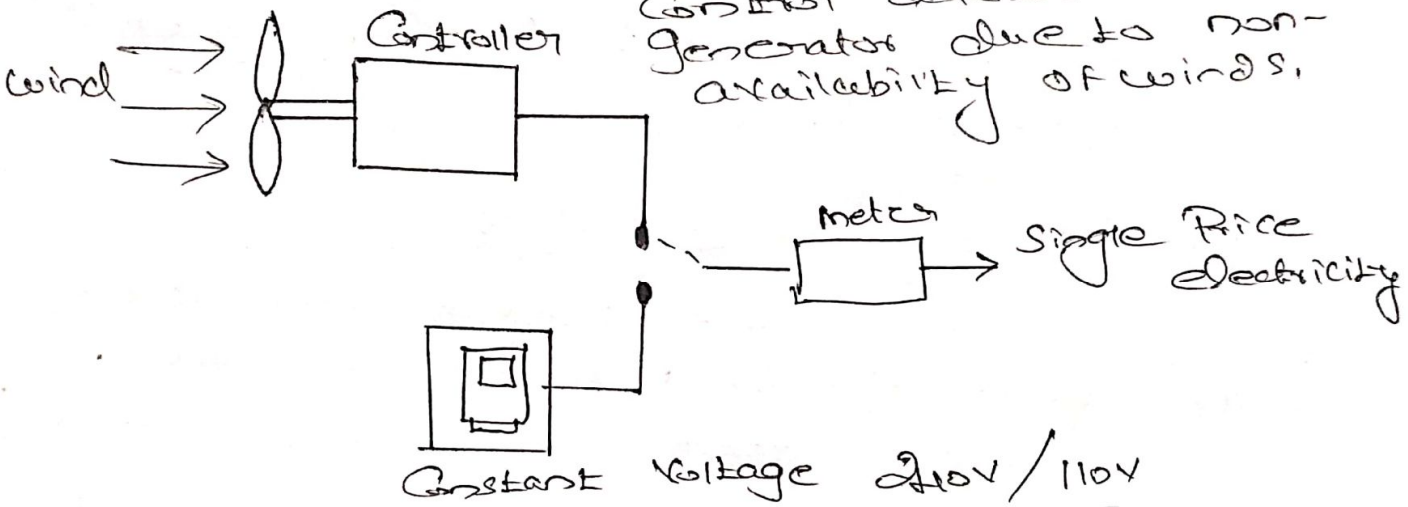
Medium scale wind Power Plants are used in variety of Places such as Community Center, health Clinic (or) School.

The basic aim of the wind turbine is to be a diesel Saver.

a) Single-mode electricity supply distribution:

Single Phase to domestic dwellings with a single set of distribution Cable & System operates at a single mode at fixed voltage.

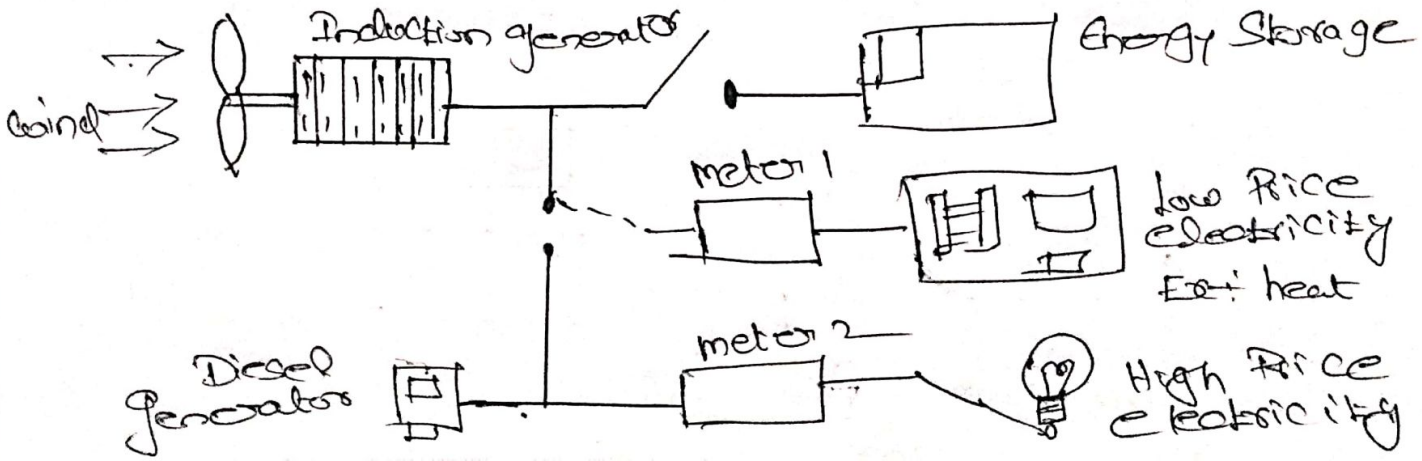
* without load-management control depends on diesel generator due to non-availability of winds.



b) Multiple mode distribution

Economic electricity for many applications in windy conditions is offered.

The economic adv. of multiple mode operation is used at all times.



iv) Hybrid wind Power Plants:-

wind is not fully reliable so we cannot depend on wind alone for generating wind Power.

So Solar and wind energy is Combined to generate Continuous Power is called hybrid wind Power Plants.

*) Grid Connected with wind Power Plants

like a hybrid system the wind Power Plant in Conjunction with a grid which supplies the most of the Power.

Site Selection for wind Energy Systems

Few sites are selected to install the wind mills for the extract of wind energy.

*) Plane site
*) Hill top site
*) Sea-Shore site
*) Off-Shore Shallow water site

main Considerations for selecting a site

*) wind farms are away from main cities
*) selection site should Provide good dry wind velocity through out the year
*) site should be at high altitude
*) stable ground is selected
*) the selection site should be easily accesible to Provide a transport facility for the erection
*) site should be near to Consumer for reducing the Cost & transmission losses.
*) wind direction is also considered for the site selection.

4. Explain Bio-mass Gasification & its types of gasifier with neat sketch. (or) Updraft & down draft gasifier.

The word gasification implies the conversion of solid fuel in to a gaseous fuel by thermo-chemical method without leaving any Carbonaceous residue.

Gasifier is equipment which converts biomass in to Producer gas.

Raw materials are

1. Wood chips
2. Coconut shells
3. Straw
4. Rice husk.

Gasifier reactions

$C + O_2 \rightarrow CO_2 + 393800$ kJ/kgmol (Combustion)

$C + H_2O \rightarrow CO + H_2 - 131400$ " (water gas)

$CO + H_2O \rightarrow CO_2 + H_2 + 41200$ " (water shift reaction)

$C + 2H_2 \rightarrow CH_4 + 75000$ kJ/kgmol (methane reaction)

Chemistry of the gasification Process:

1. Oxidation Zone
2. Reduction Zone
3. Distillation Zone

Oxidation Zone - O_2 in the air stream blast reacts with the Carbon in the fuel to reduce Carbon to form hydrogen & Carbon monoxide

CO_2 is reduced in the reduction zone. the final gas composition relies on the water gas - Shift reaction.

$$CO + H_2O \longrightarrow CO_2 + H_2$$

Distilation Zone, The raw fuel is Preheated & Carbonized by giving of Condensable & non-Condensable gas

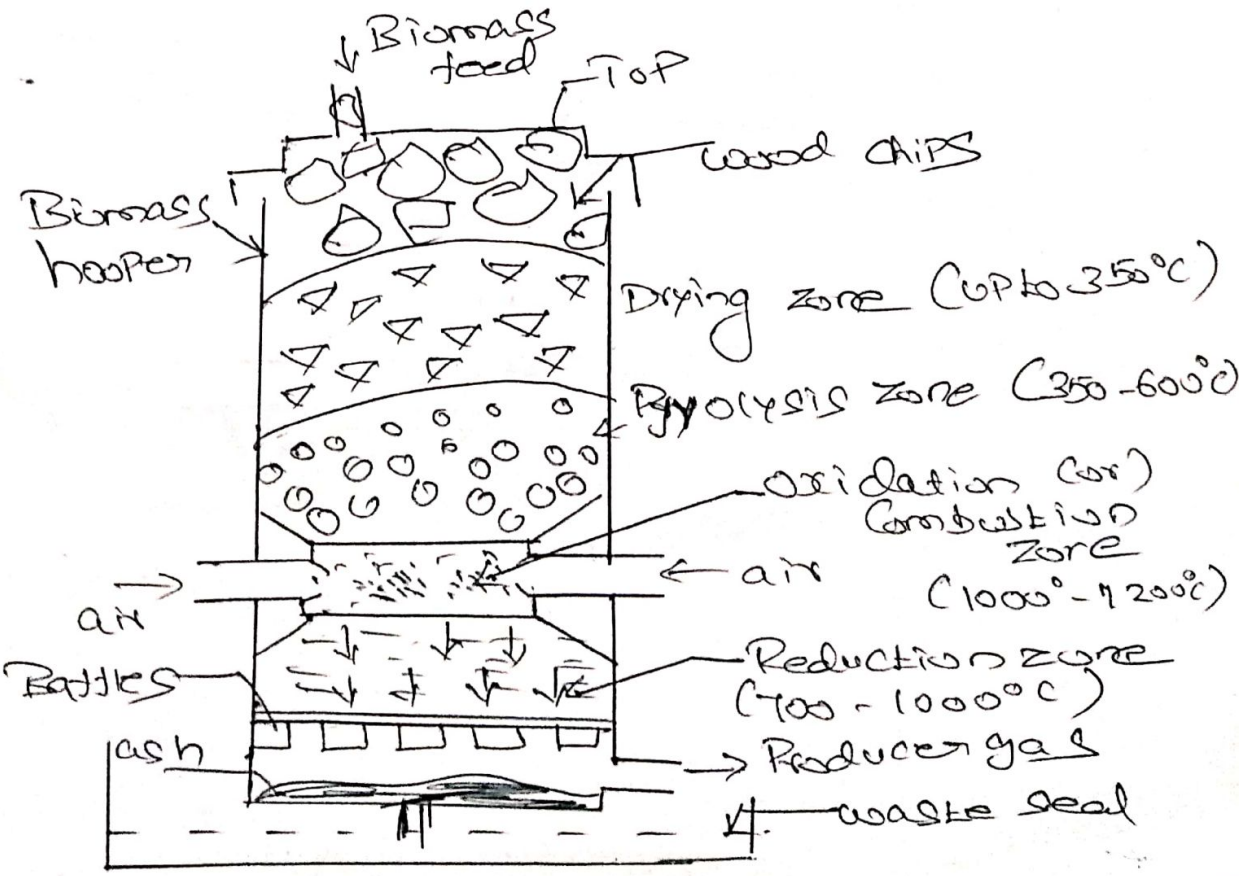
Classification of Biomass gasifier.

1. According to direction of the gas flow, the gasifiers are classified into
   i) Down draft (or) Co-current gasifiers
   ii) up draft (or) Counter-current "
   iii) Cross draft gasifier

2. According to output Power
   i) Small size gasifier
   ii) medium size "
   iii) Large size "
   iv) Very large size "

3. According to type of bed
   i) fixed bed
   ii) Fluidised bed

Downdraft (or) Co-current gasifier.



fixed type downdraft gasifier gas leaves bottom of the gasifier.

* Power generation up to 150 KW
*) 70-80% of weight losse in Pyrolysis zone (350-600°C)
*) Pyrolysed gas burn with air (1000-1200°C)
* about 40-70% air is drawn through orifice depending on the Pr. drop conditions due to size of wood chips & gas flowrate.

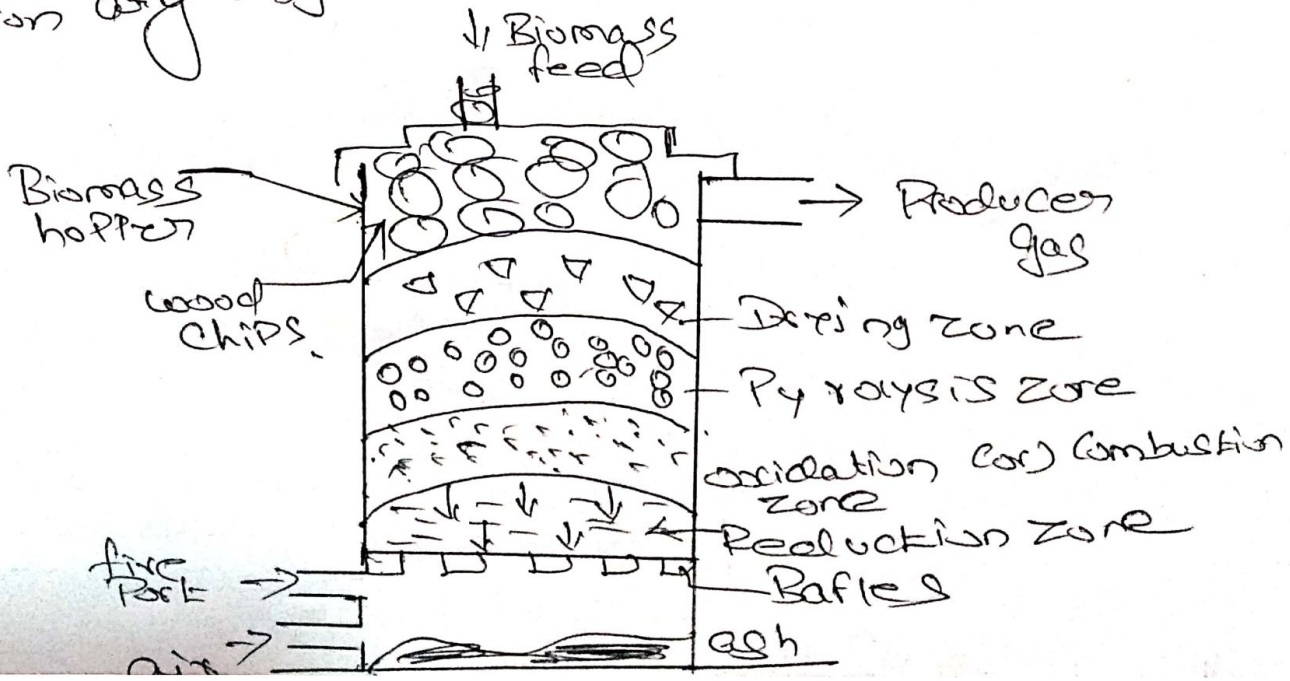
A typical composition of gas obtained from wood gasification on the volumetric basis is
Co = 18 to 22%. H_2 = 13 to 19%. CH_4 = 1 to 5%. HC = 0.2%.
N_2 = 45 to 55% & water vapour = 4%.

UP-draft (or) Counter Current gasifiers.

In this type air enters below the combustion zone & Producer gas leave near the top of the gasifier.

*) highest efficiency as the hot gasses pass through the fuel bed & leaves the gasifier at low temperature.

*) These types of gasifiers are suitable for tar free fuels such as Char-Coal especially in station ary engines.



5 Explain Bio-gass Digesters & Classification of Digestion Process.

Biogas digester is a large tank where inside biogas is Produced through the decomposition/ breakdown of organic matter through a Process called anaerobic digestion.

It is called a digester because organic material is eaten & digested by bacteria to Produce biogas.

Bio gas digestor delivers CH_4, CO_2, and other impurities.

Capacity varies 0.5 m^3/day to 650 m^3/day

Bio gas raw materials

1. Animal waste (Cattle dung, fish wastes)
2. Human waste
3. Agricultural waste (Sugarcane, bagasse, Cotton etc)
4. Industrial waste (Tannery, Paper etc)

Classification of Digestion Processes;

1. Beneficial Bacteria (biogas compost, Vinegar)
2. Harmful Bacterial (cholera, typhoid, etc)

Based on oxygen requirements

1. Aerobic (oxygen Presence)
2. Anaerobic (absence of oxygen)

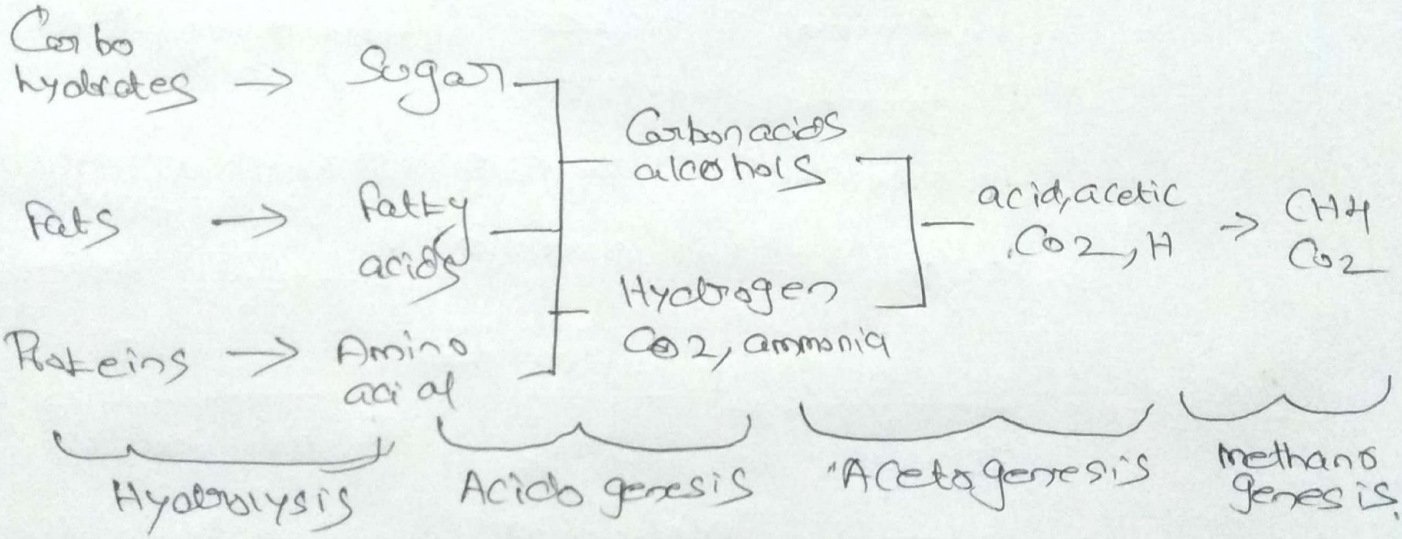
Anaerobic Digestion Process:

A digestor is a sealed tank or container in which the biological requirements of digestion are controlled to achieve fermentation to produce gas.

Anerobic digestion process under absence of oxygen condition and in the presence of methanogenic bacteria. as a result produces a methane rich biogas.

Anerobic digestion occurs in the following four steps

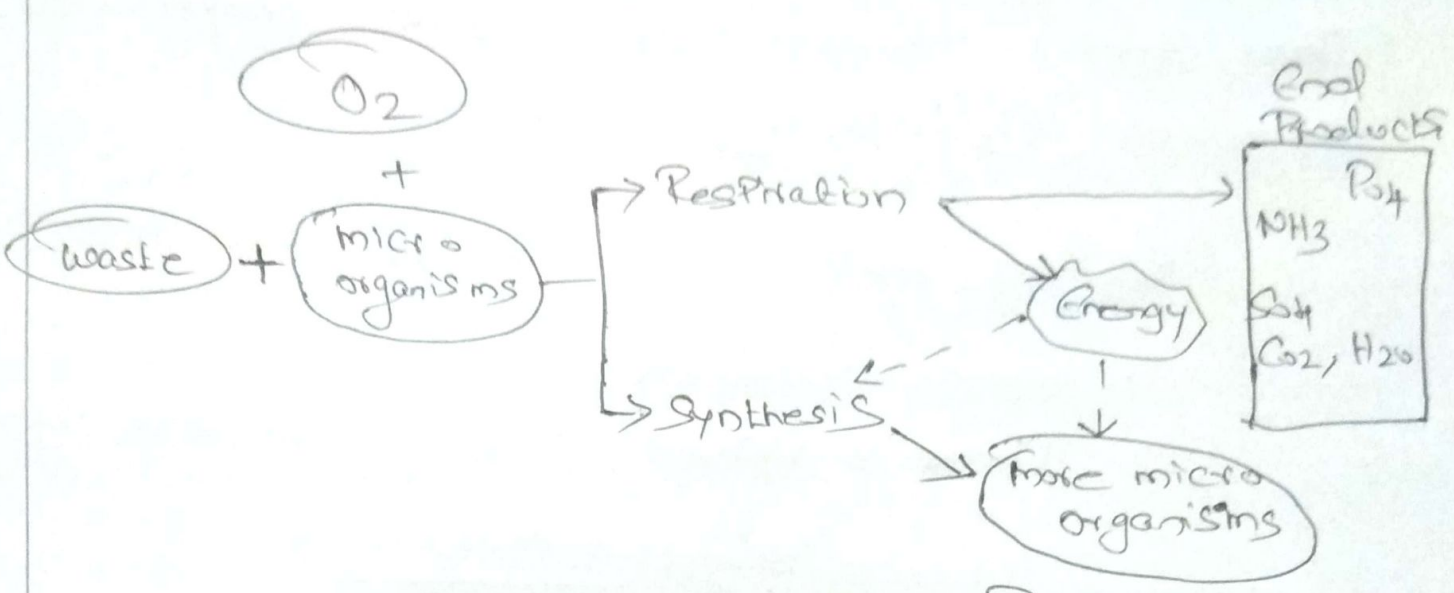
1. Hydrolysis 2, fermentation 3, Acetogenesis 4, methanogenesis.



Aerobic Digestion Process

Aerobic digestion process involves the decomposition of organic wastes in the presence of oxygen.

This process involves the oxidation of biodegradable & microbial cellular matter by aerobic micro-organisms resulting in over all reduction in the mass of sludge & generate stabilized cell mass.



Aerobic Digestion Process

The factors affecting the performance of aerobic digestion are Solid retention time, temperature, PH, mixing, Solid type & bio gas configurations.

Aerobic digestion method is the most widespread process which is used throughout the world.

The capital costs for aerobic digestion are lower bcoz of the fact the aerobic digestion occurs much faster than anerobic digestion.

disadvantage is CH_4 is not recovered, it produces more sludge for disposal.

6 Explain the types of Bio Gas DIGESTERS & ~~Brei~~ Briefly explain the fixed Dome type Digester [N-D-19]

Biogas digestors mainly classified into

1. Continuous & batch types (according to Process)
2. Dome & drum types (according to Construction)

Continuous Process Biogas digestor

* It requires small digestion Chambers
* It will Continuously Produce gas
* It has fewer Problems Compared to a batch type
* It needs lesser Period of digestion.

** Two Types are there

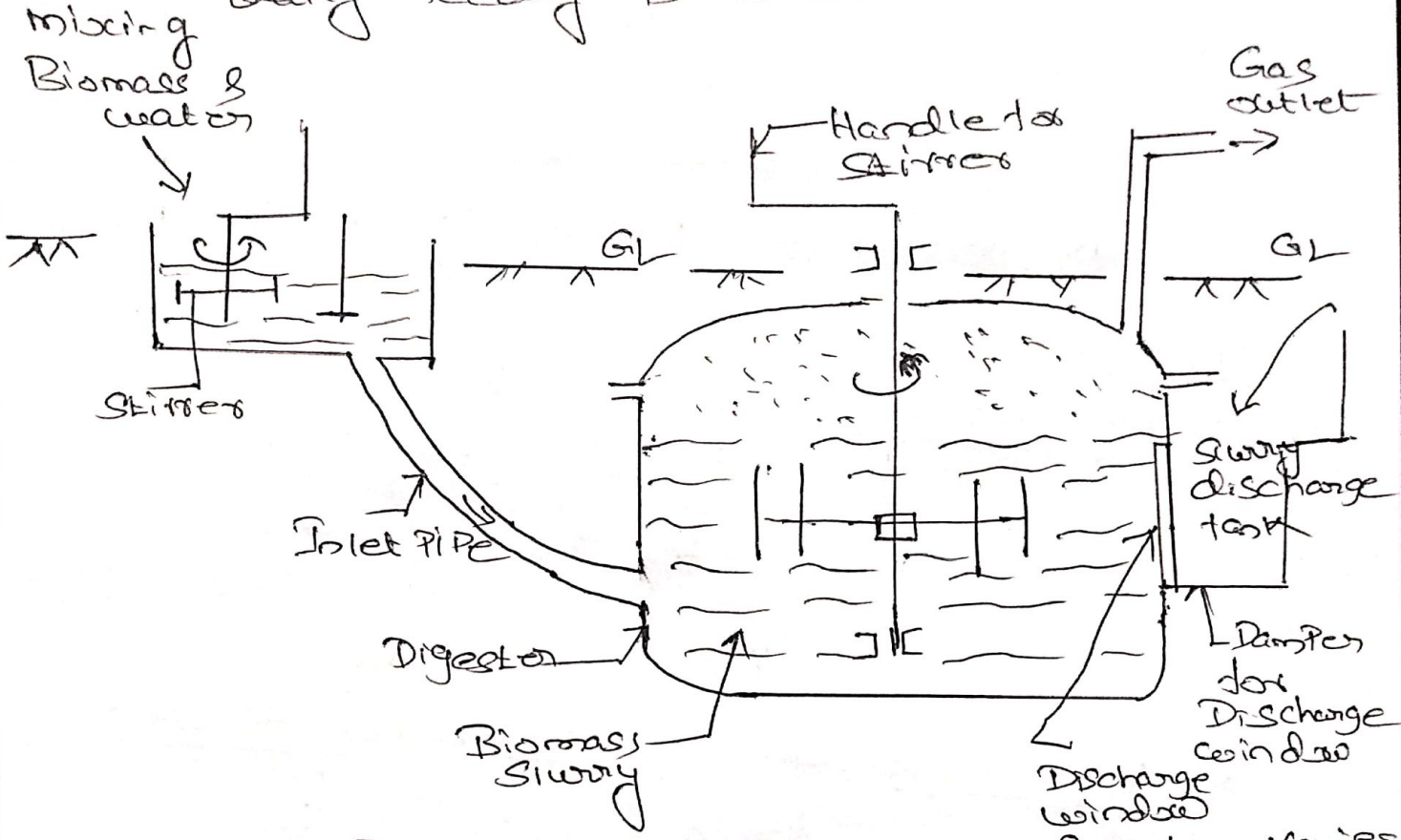
i) Single Stage Process
ii) Double Stage Process

Batch Process Biogas Digestor:

*) Batch type Plants deliver gas intermittently
*) It needs several digestors or Chambers for Continuous gas Production.
*) It needs initial seeding to start the anerobic fermentation
*) Its operation & maintenance are relatively more Complex.
*) It has longer digestion time.

fixed - Dome Type digester.

The digester & gas holder are combined it is also called Chinese Plant. it is best suited for batch Processes especially when daily feeding is adopted in small quantities



The Pressure inside the digester varies as the gas is liberated.

Advantages of fixed dome digester;

1. It has no Corrosion trouble
2. it requires less cost compared to a floating drum type
3. It does not need maintenance
4. Heat insulation is better temp will Cost.

Dis advantages

1. It Produces a variable gas Pressure
2. It required skilled masons
3. Scum formation is a Problem.

7. Given data: [N-D-19]

for a horizontal shaft, Propeller type wind turbine

wind velocity $(V_1) = 10$ m/s

$P = 1$ atm;

$T = 15°C$

Turbine speed $(N) = 40$ rpm

at maximum efficiency $(\eta) = 42\%$.

Soln

a) Air density $(\rho) = P/RT$

$P = 1.01325 \times 10^5$ N/mm²

$R = 287$ J/kg K

$T = 288.15$ K

$= 15 + 273.15$

$\rho = 1.225$ kg/m³

b) Total Power density in wind stream

$P_E/A = (\rho \cdot V_1^3)/2$

$= (1.225 \times 10^3)/2$

$P_E/A = 612.5$ W/m²

c) Max. Possible Power density

$P_{max}/A = (8 \cdot \rho V_1^3)/27$

$= (8 \times 1.225 \times 10^3)/27$

$P_{max}/A = 363$ W/m²

d) Actual obtainable Power density

$P/A = \eta \cdot P_E/A$

$P/A = 0.42 \times 612.5$

$P/A = 257.25$ W/m²

e) Total Power from the wind turbine of 120m dia:

$$P = 0.25725 \times (\pi \times 120^2) / 4$$

$$\boxed{P = 2908 \text{ kw}}$$

f) Torque & axial thrust on the wind turbine

$$T_{max} = (2/27)(\rho \cdot D \, V_i^3)/N_s$$

$$= (2/27)(1.225 \times 120 \times 103) / 40/60$$

$$\boxed{T_{max} = 16,333 \text{ Nm}}$$

Axial thrust $(F_x) = (\pi/9) \cdot (\rho \cdot D^2 V_i^2)$

$$= (\pi/9)(1.225 \times 120^2 \times 10^2)$$

$$\boxed{F_x = 615.44 \text{ KN}}$$

Result

$P = 2908$ kw

$T_{max} = 16,333$ Nm

$F_x = 615.44$ KN

$\rho = 1.225$ kg/m3

UNIT-5 GEOTHERMAL ENERGY

1. Explain the working & Construction of liquid-dominated Systems with neat Sketch.

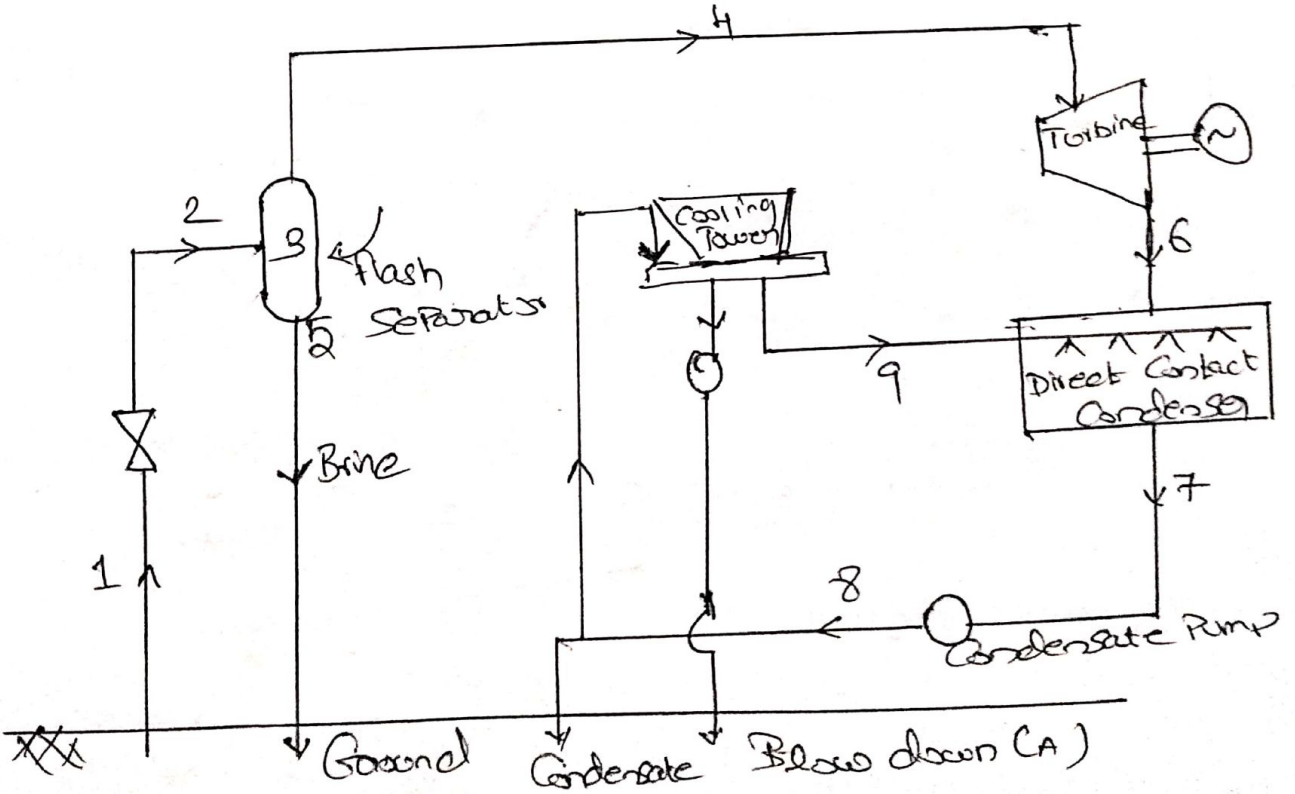
In the liquid dominated reservoir, the water temperature is above the normal boiling point 100°C However, it does not boil but it remains in liquid state because the water in the reservoir is under Pressure.

The steam can be separated & used to generate electric Power (or) to Provide space & Process heat or it may be distilled to yield the Purified water.

Three methods which will be covered are follows:

a) Flashed - Steam System
b) Binary - Cycle System
c) Total flow System.

a) Flashed - Steam System:-

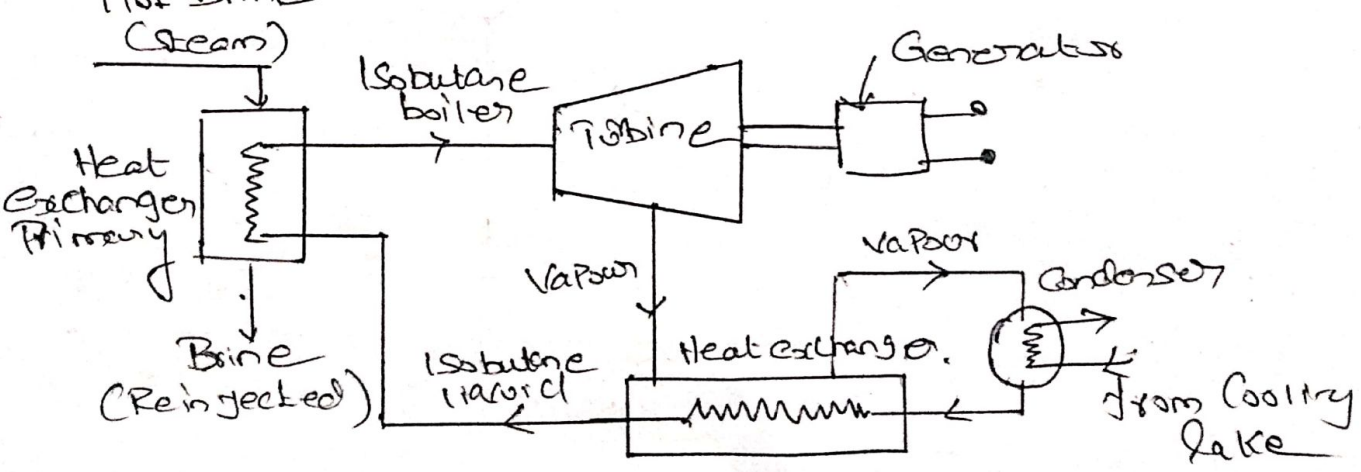


1 -> reaches the wellhead at point
2 -> at a low Pressure
3 -> flash separator
4 -> mixture is now separated in to dry saturated steam
5 -> Saturated brine
6 -> dry steam expand in turbine
7 -> Condensation

The Power generation from such system can be made more economical by associating a chemical industry with the Power Plant to make use of the brine & gaseous effluents

b) Liquid-Dominated - Binary Cycle

* It works with Rankine cycle with organic working fluid
*) One Circuit have a brine water & in binary Circuit freon-12 low boiling point fluid
*) it operates the turbine by freon-12
*) The exhaust vapour from turbine is cooled in the regenerative heat exchanger & then it is condensed using an air-cooled Condenser.
*) In the binary cycle, there are no problems of corrosion or scaling in the working cycle components such as turbines & condensers.



2. Explain the geopressured Resources & describe about Hybrid (Geothermal fossil fuel) systems

Drilling for oil & gas has revealed the existence of reservoirs containing salt water at moderately high temp & high pressure in a belt for 1200m in length. Because of abnormally high pressure of water up to 1350 atm in the deepest layers, the reservoirs are referred as geopressured.

Hot Dry Rock systems.

HDR is a heated geological formation formed in the same way as hydrothermal resources but containing no water as the cavities or fractures required to conduct water to the surface are not present.

Magma Resources (molten-Rockchamber) systems

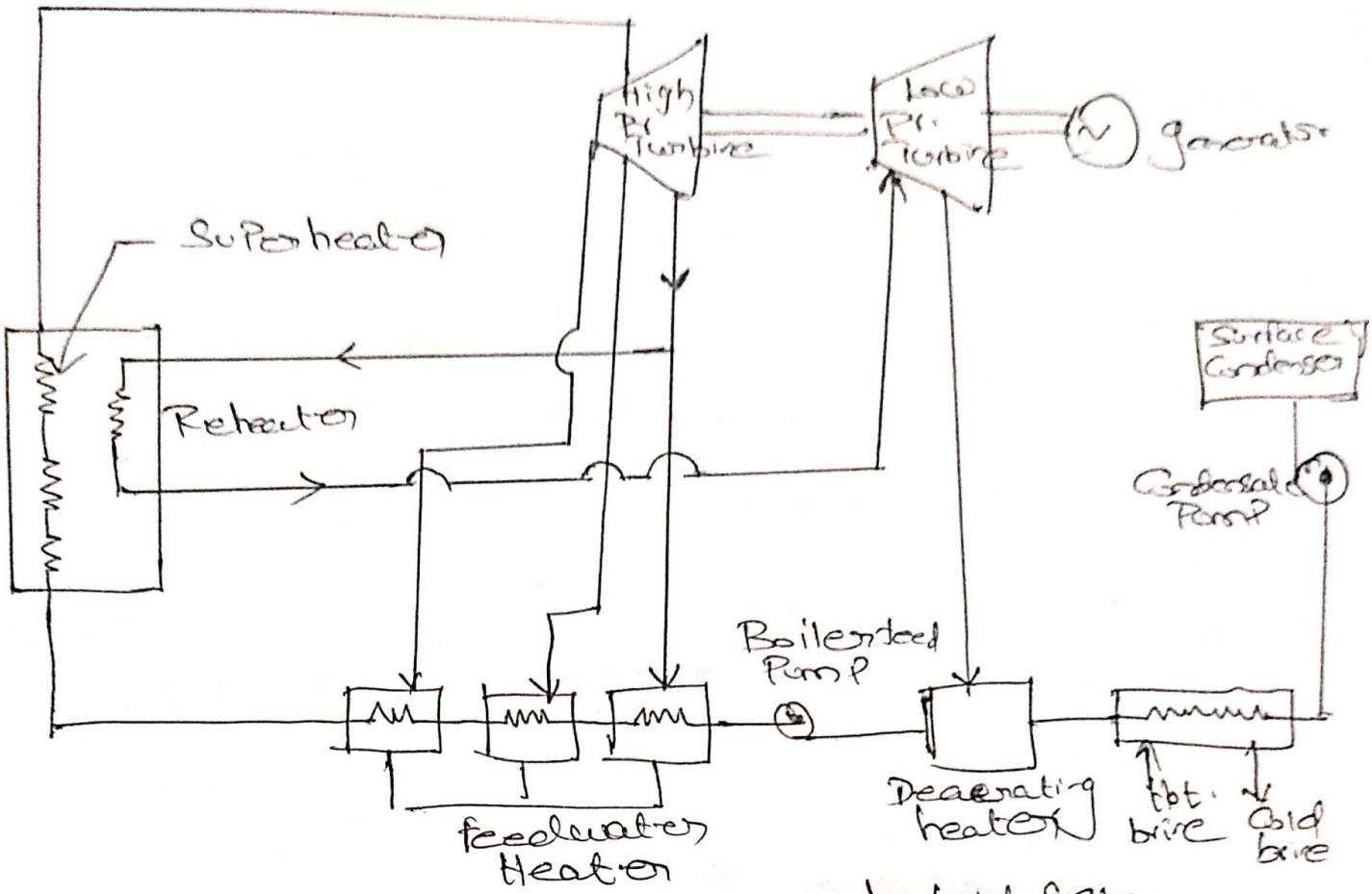
* Very large temperature above 650°C
* it is not feasible
* The concept of using heat exchange within magma is studied by Sandia National lab.

Hybrid (Geothermal fossil fuel) systems

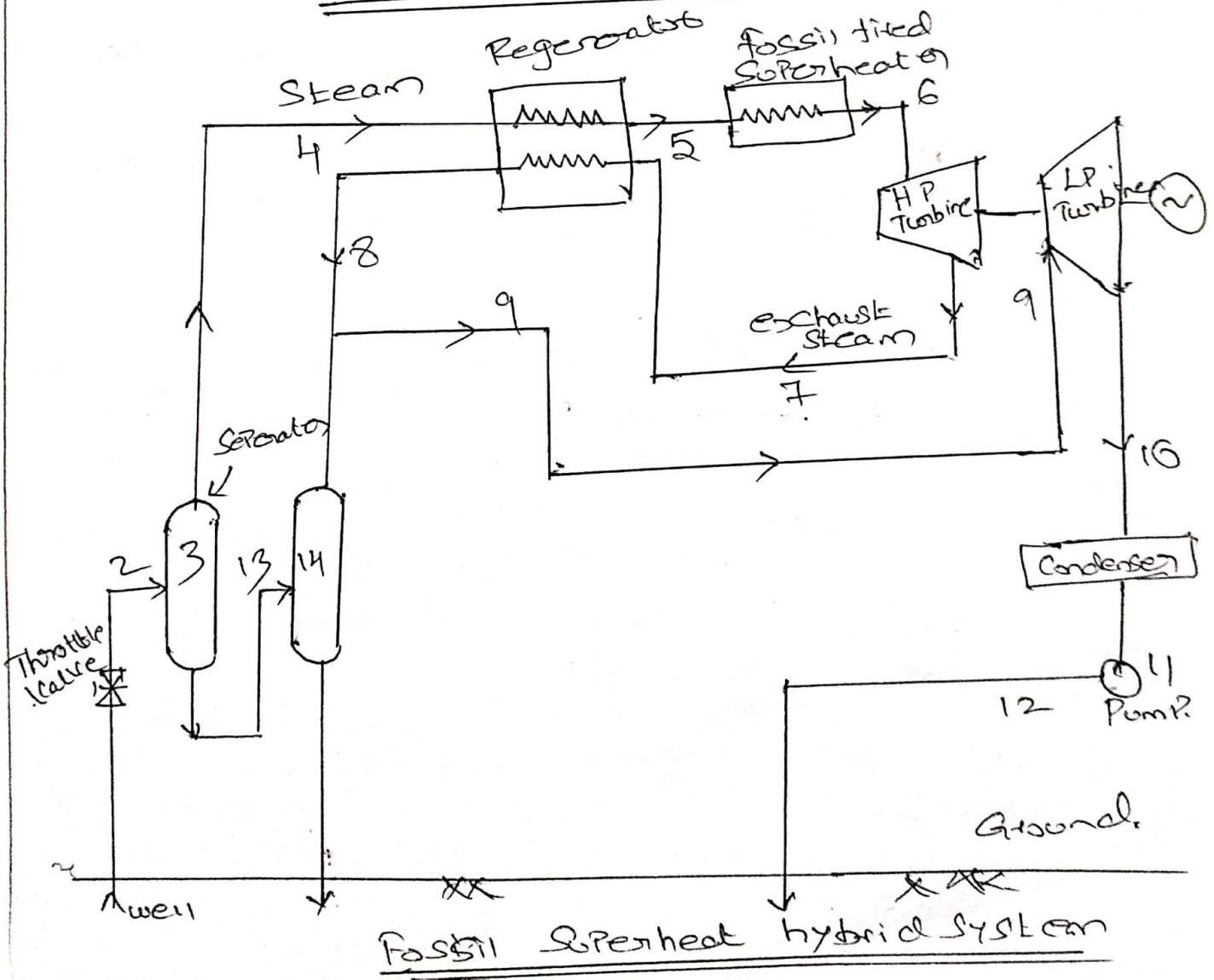
The concept of hybrid geothermal fossil fuel system utilizes relatively low temperature heat of geothermal sources in low temp. end of a conventional cycle & high temp heat from fossil fuel combustion to the high-temperature end of the same cycle.

The arrangements of hybrid plants are as follows.

1. Geothermal Reheat and
2. Fossil superheat



Geothermal - Reheat hybrid system



Fossil Superheat hybrid system

(4)

(3) Explain the OTEC & its types. (Open & closed OTEC) with neat sketch.

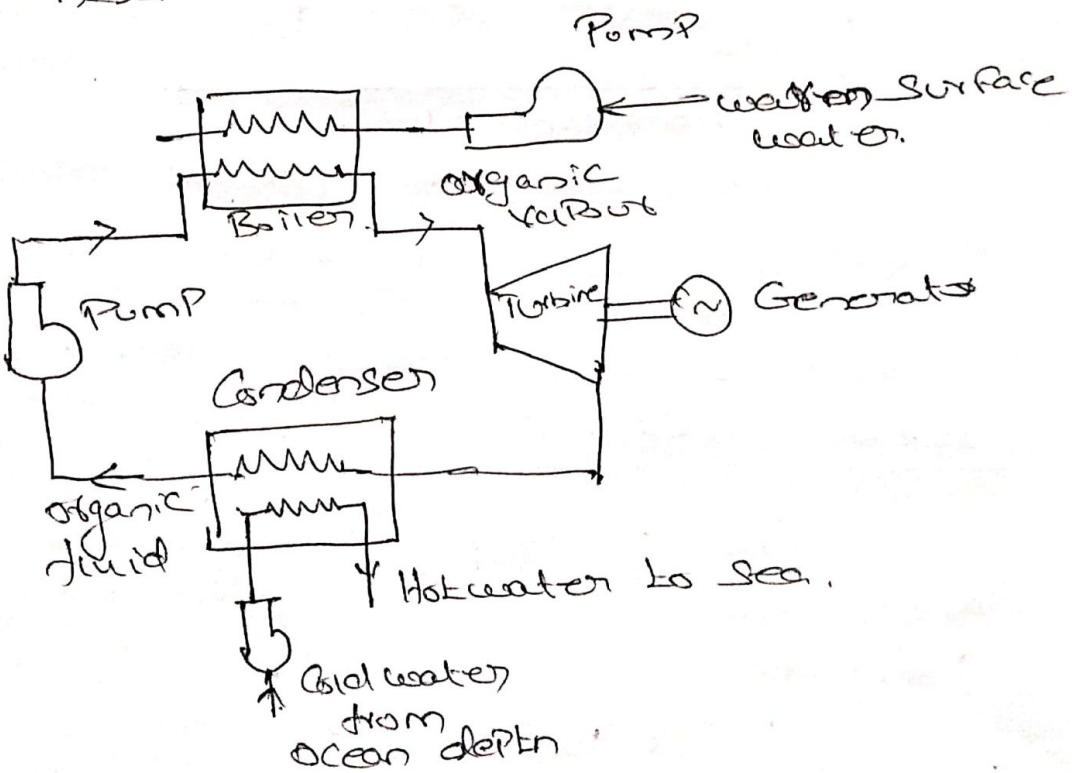
Ocean Thermal Energy Conversion Plants are operated with sea & lake temperature deviation in the top surface & bottom surface of the water.

Top surface is warm water due to solar radiation

bottom surface is cool water due to absence of solar rays in deep water.

Using warm water temperature the heat is transferred to low boiling liquid and run the turbine & generator.

using cold deep water temperature the heat is rejected from the low boiling liquid with the help of condenser.

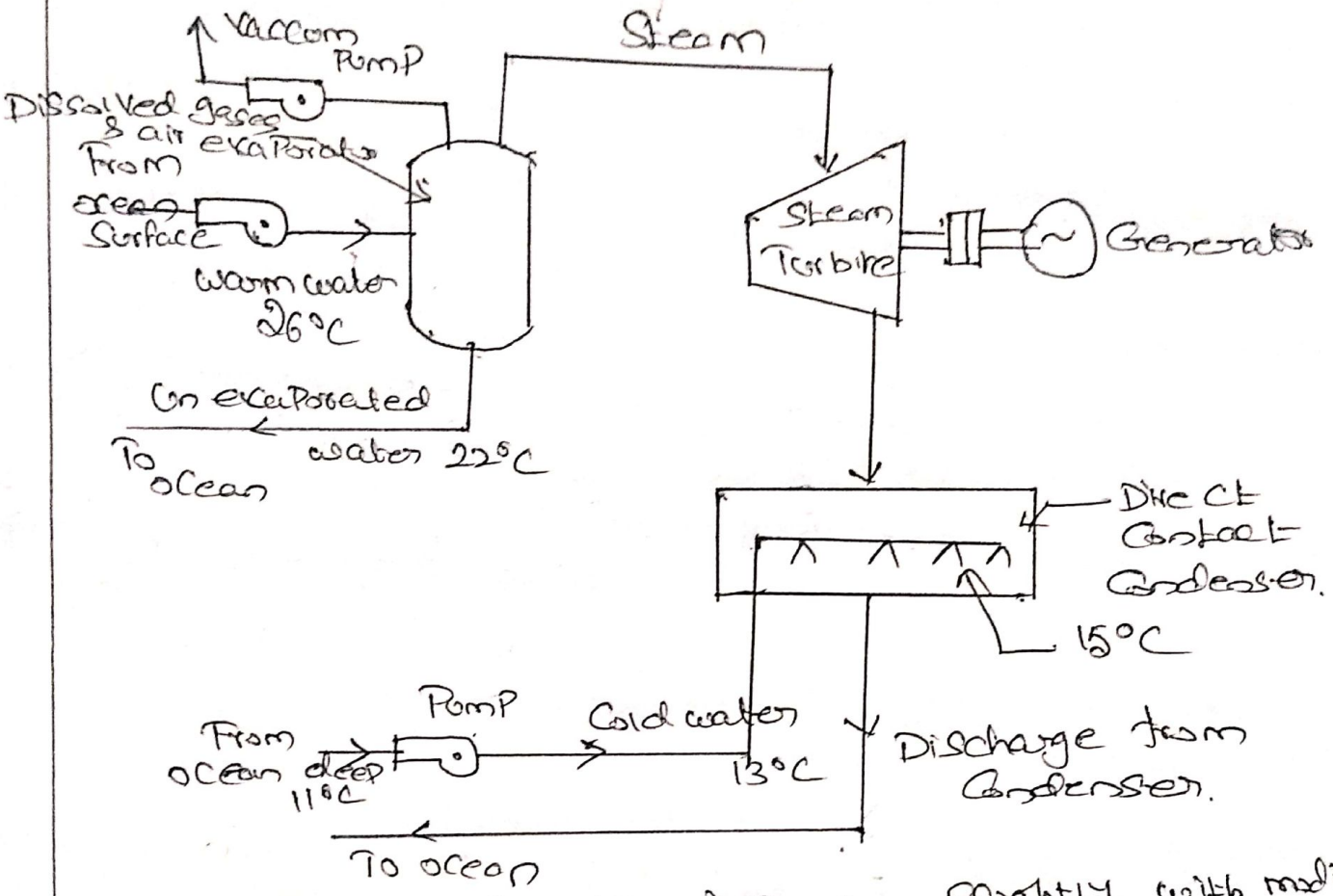


Thermodynamic Cycle in OTEC

1. Open Cycle (Claude cycle, Steam Cycle)
2. Closed Cycle (Anderson Cycle, Vapour Cycle)

Open Cycle OTEC System

Warm water temp at 80°F. Steam drives steam turbine generator to deliver electrical energy



Efficiency can be increase slightly with modified OTEC.

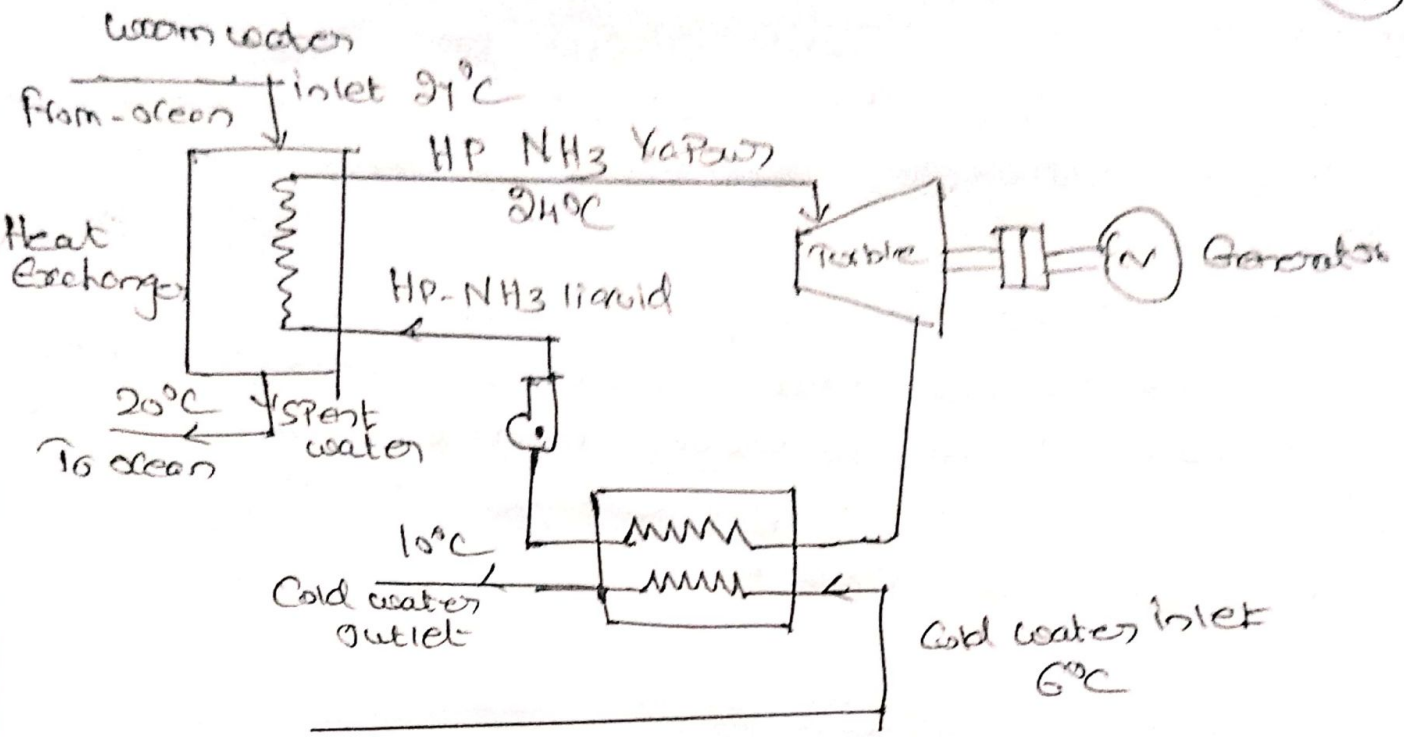
*) Controlled flash-steam evaporator is used instead of a conventional type of evaporator

*) Contact Condenser is replaced by a surface Condenser.

Closed - Cycle OTEC System

The working fluid (Ammonia, NH_3) is circulated through the closed cycle consisting of the following components

1. Evaporator
2. Vapour Turbine
3. Vapour Condenser
4. Liquid Pressurizer



Closed cycle OTEC Plant

Site selection for OTEC Plant

*) Equatorial water defined as lying between 10°N & 10°S are adequate except for the west coasts of South america & Africa

*) Tropical water defined as extending from the equatorial region boundry to 20°N & 20°S are adequate except for the west coast of South america & Africa.

*) The Preservation of environment in the area of the selected site.

4. Briefly Explain the Tidal barrage Power Plants & its modes of operation & generation of tidal barrage Power with neat sketch [MJD-19].

Tidal barrage Power Plants involve the Creation of huge Concrete dams with Sluices. Tidal barrage make use of the Potential energy difference in height between high & low tides.

Components of tidal Power Plant

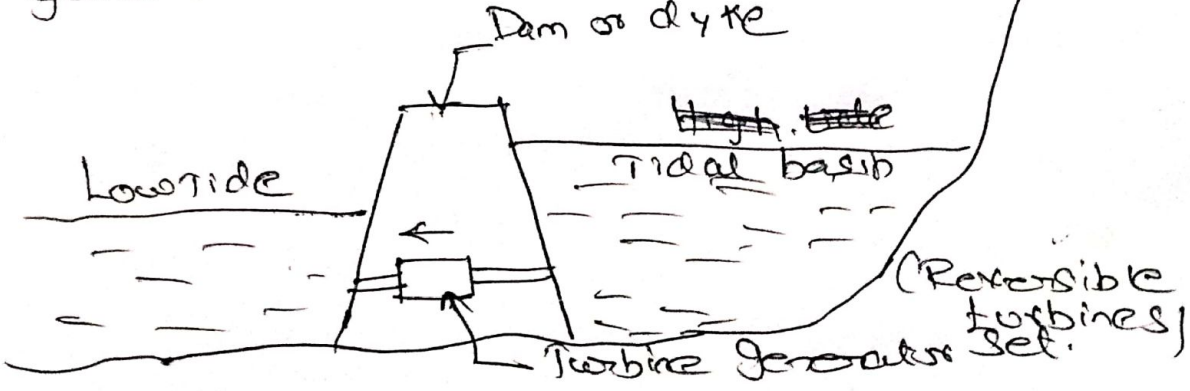
*) Barrage (or) Dyke (or) Dam
*) Sluice ways [gate Controlled devices]
*) Embankments [to Prevent water from flowing at Certain Parts of barrage]
*) Power house [turbines, generators, other auxillary equipment]

Modes of operation of Tidal barrage Power Plants

i) Ebb generation

Simplest & most Common form of barrage Power generation.

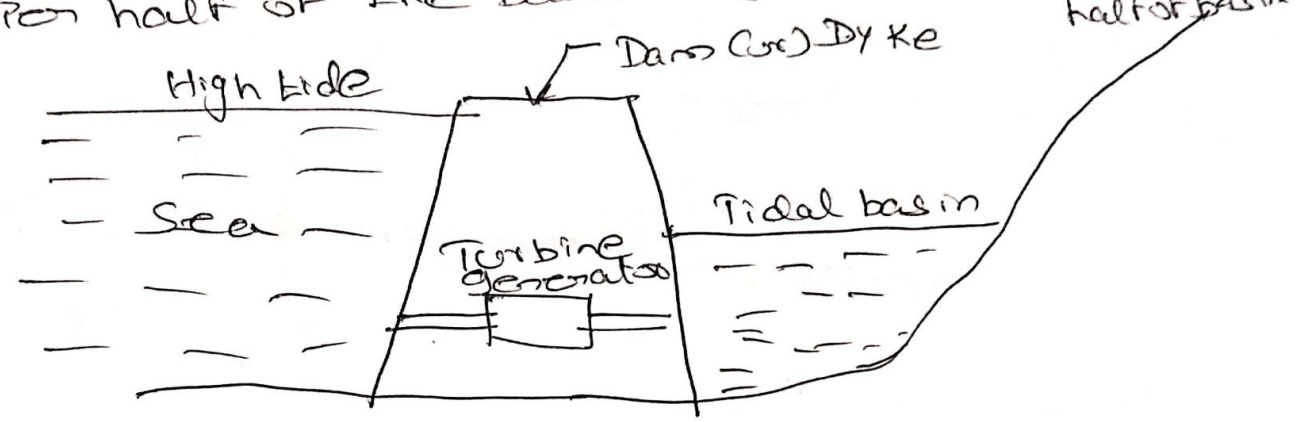
Tidal basin is filled through sluices during high tide. Then sluices gates are closed the stored water is then made to flow through turbines to sea when it gate is open to generate Power until the head is low.



ii) Flood generation

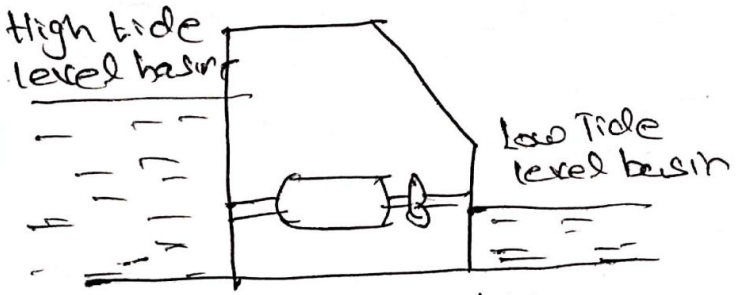
here the Power is generated from high tide sea to Tidal basin through the turbine generator.

less efficient than ebb generation because the volume obtained in the upper half of the basin is greater than lower half of basin.

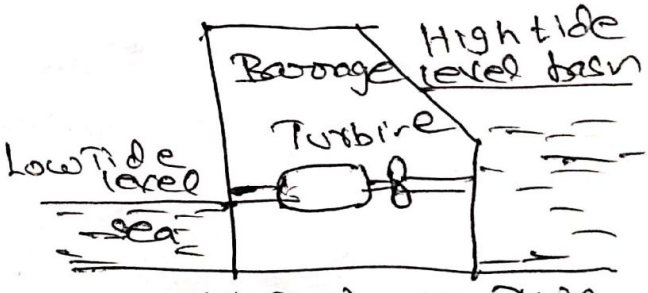


iii) Two-way generation

Power generation both during high tides from basin from sea and during low tides from basin to sea.



a) During filling



b) During emptying

iv) Pumping & turbining

reservoir is filling using

*) rise of sea water during high tides

*) Pumps to pump sea water in to the reservoir.

5. Explain Briefly wave energy & wave energy Conversion devices with neat sketch.

wave energy is energy of interchanging Potential & Kinetic energy in the wave.

It Can be either Converted into mechanical energy or electrical energy through wave energy Conversion Plants.

Energy range of 10 kw/m to 70 kw/m with respect to amplitude & wave length.

Wave retain energy differently depending on water depth:

*) lose energy slowly in deep water.
*) lose energy quickly as water becomes shallower because of friction between moving water particles & sea bed.

Location for wave energy Conversion device

*) At the shore line
*) Near the shore line
*) off-shore

The most generally & successfully used wave energy Conversion system at each of these locations is oscillating water column.

maximum wave energy between latitudes of 40° & 60°.

The annual energy exploration from wave energy is above 5 kw to 15 kw.

Wave Energy Conversion devices

hydro kinetic energy Conversion devices are generally Categorized as either wave energy Convertors (WEC)

The different type of WEC devices are

*) Wave Profile device [oscillating height of ocean's surface into mechanical energy]

*) oscillating water Columns [waves into air Pressure]

*) wave Capture devices [waves into P.E]

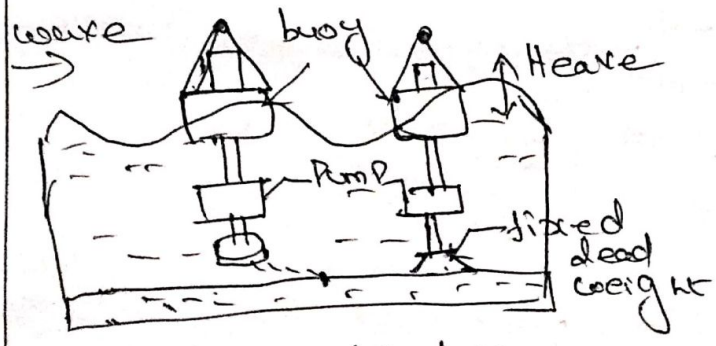
*) Rotating wave devices

Rotating wave devices Capture the K.E of a flow of water such as a tidal stream, ocean Current as it Passes across a rotor.

Wave Profile devices

a) Point absorber

energy absorption can be achieved by a floating body Called buoy.



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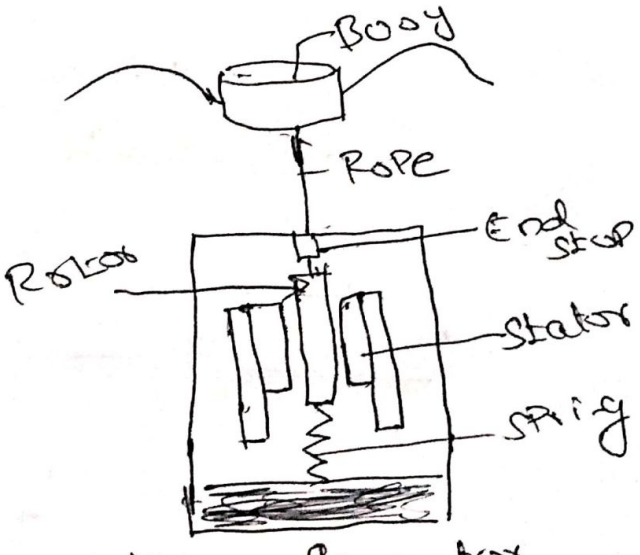
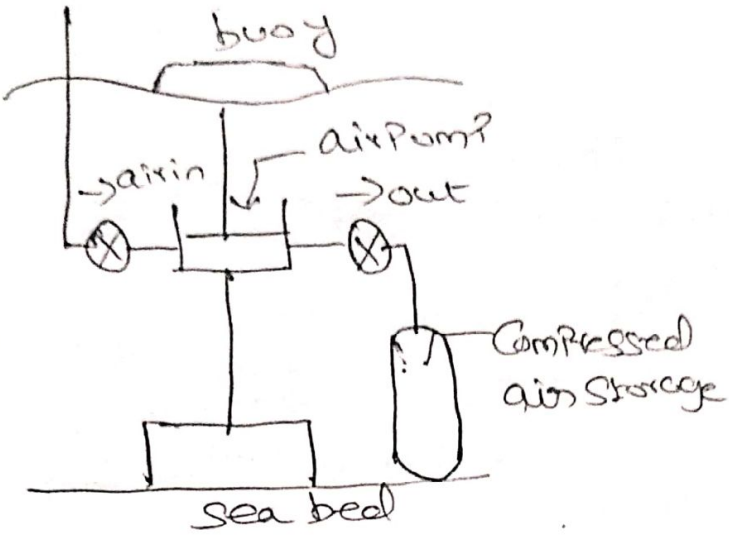
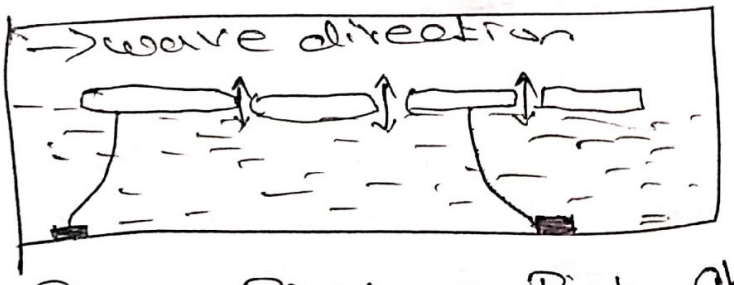


Linear generator
Point absorber



Float with Air Pump

ii) Linear absorbes



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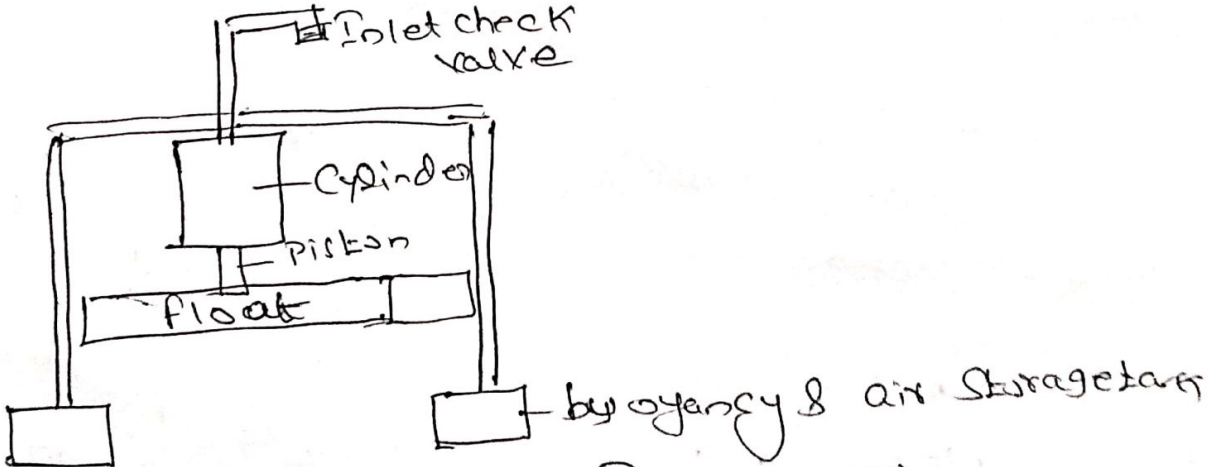

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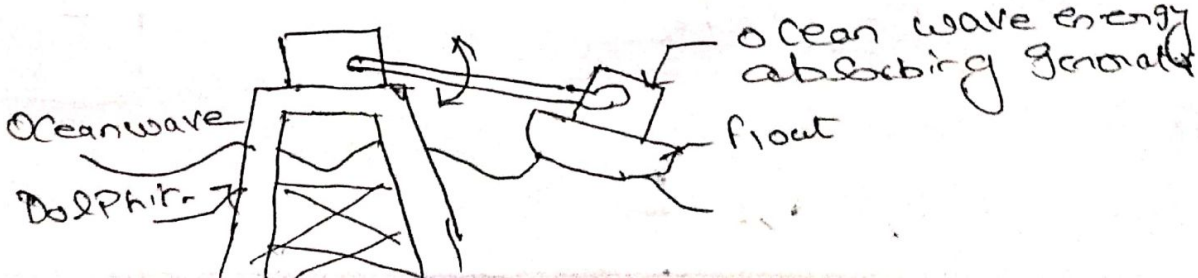

6. Write a note on DEC & Types of DEC

Direct Energy Conversion (DEC) is also called simply direct conversion which converts one form of energy to another without passing through an intermediate stage.

It also implies the elimination of the mechanical rotary machinery (turbines) used in conventional Power generation devices.

Ex:- Solar cell, batteries, tachometer, Pressure sensors.

Need for DEC:

*) There is need to use energy conversion device such as generators or turbines to generate & convert mechanical energy in to electricity

*) less losses occur in conversion Process.

*) it is more efficient Process.

*) The energy conversion cost is drastically reduced.

Principle of DEC

DEC Systems follow any of the following effects

i) Seebeck effect

ii) Peltier effect

iii) Joule effect

Irreversible conversion of electrical energy in to heat when a current I flows through a resistance 'R'

$$Q_j = I^2 R$$

Types of DEC

1) Magneto hydro dynamic Systems
2) Thermionic Power generation
3) Thermoelectric Power generation
4) Solar Photovoltaic Power Systems
5) fuel Cells
6) Thermo nuclear direct Energy Conversion

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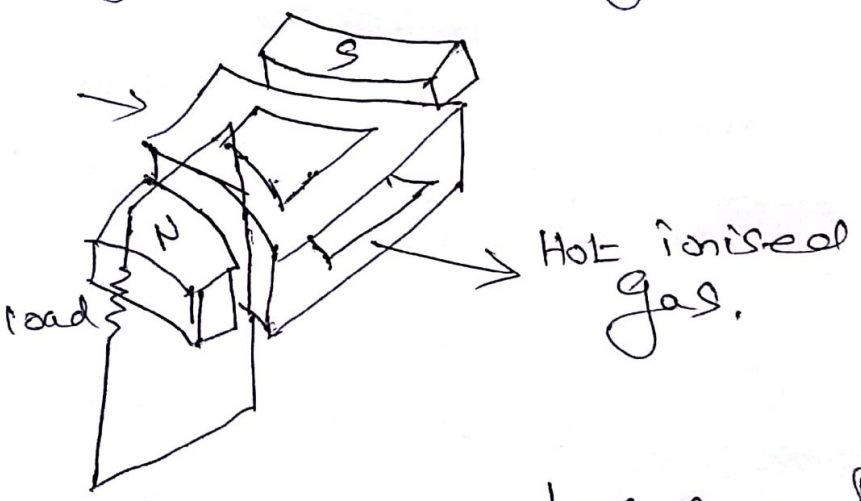
7 Magneto Hydro dynamic (MHD) Systems

MHD is a highly efficient heat engine which directly converts thermal energy is to electricity the Conventional Power Station are having the efficiency of only 45%.



MHD generator based on Faradays law of electromagnetic induction.

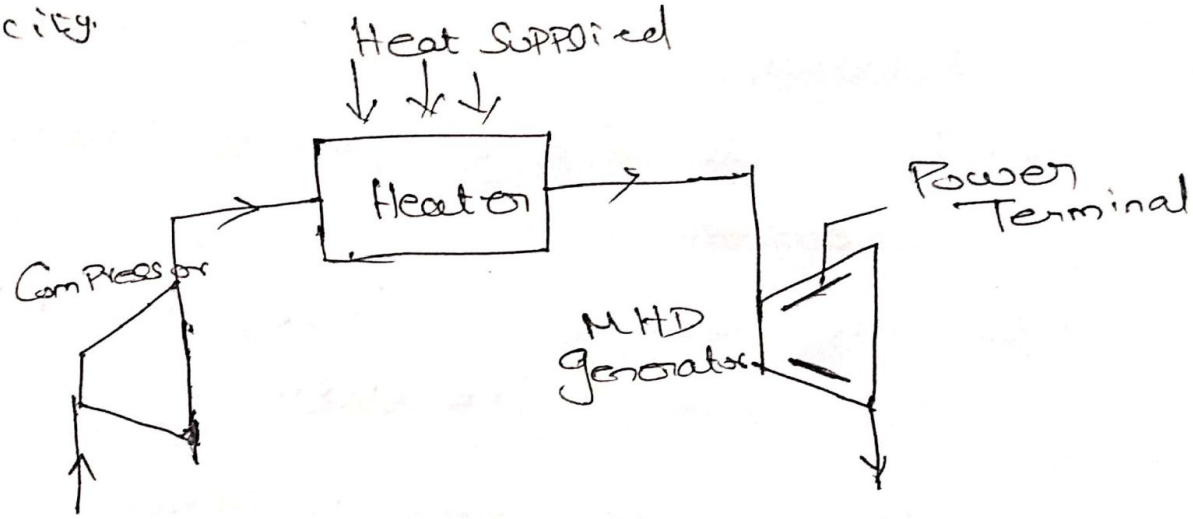
Changing magnetic field induces an electric field in any Conductor located init. it may be Solid, liquid (or) gas

The working fluid is Partialy ionized gas when an ionized gas flows across the lines of magnetic field, a voltage is induced.

Types of MHD Cycles

1. Open Cycle MHD

the Products of Combustion with Preheated air are seeded with 1% Potassium & it is entered in the MHD duct at about 2500-3000 K where some part of Internal energy is converted to electricity.



2) Closed Cycle MHD

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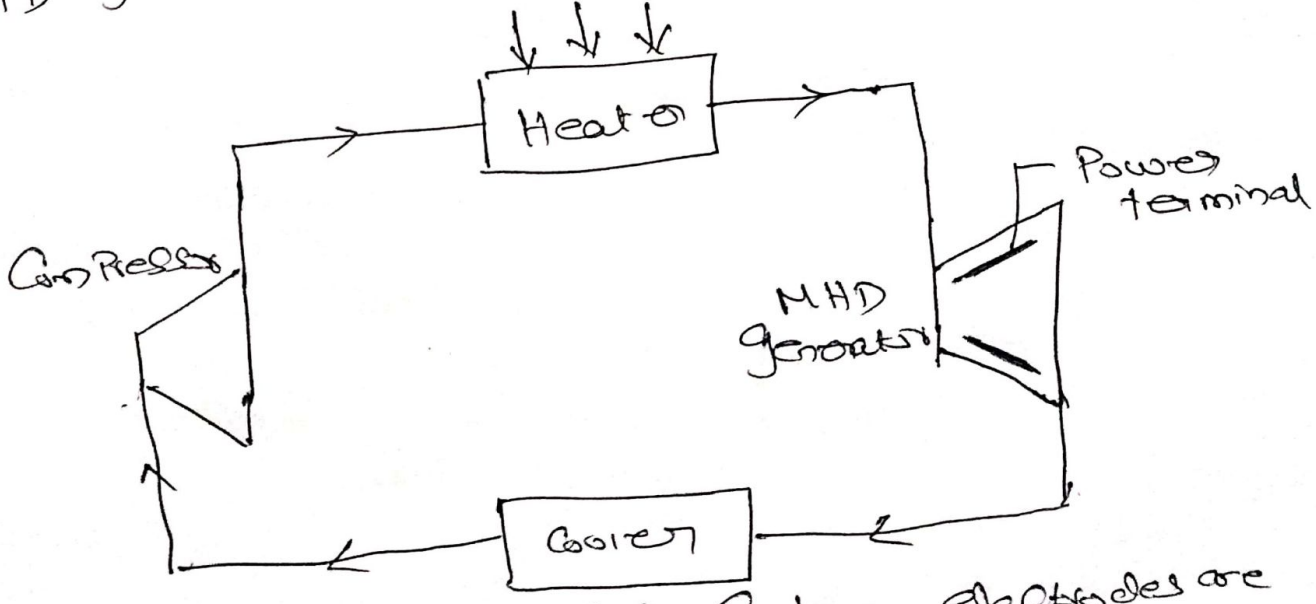


The Tungsten (or) Carbon electrodes are used.

Advantages of MHD generator

1. High efficiency when compared to other Power Plants
2. Fuel economy
3. Eliminating the lost Process of Producing mechanical energy via steam
4. Power & Steam can be Combinedly Produced.
5. The exhaust from the MHD is used to Preheat the air.
6. There is no need of feed water heaters & reheaters in the steam cycle

UNIT-5 GEOTHERMAL ENERGY

1. Explain the working & Construction of liquid-dominated Systems with neat Sketch.

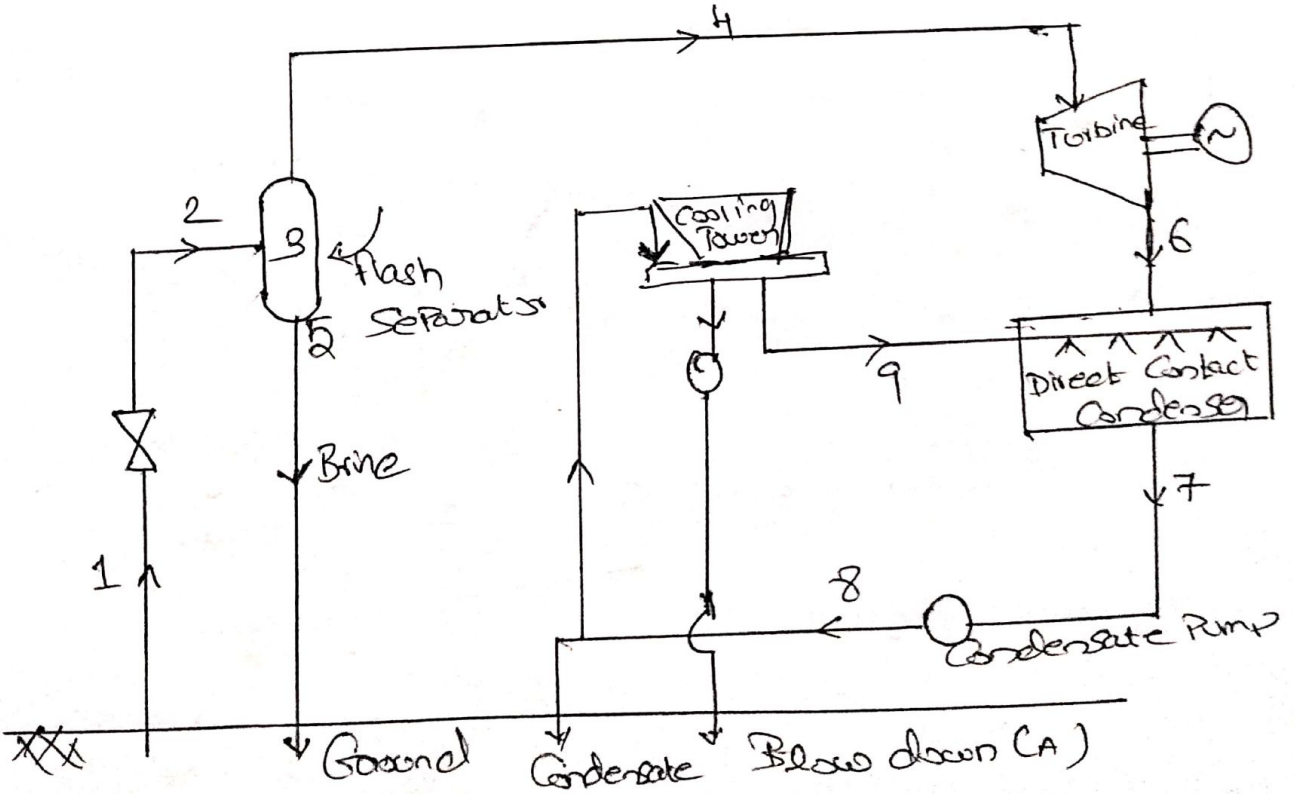
In the liquid dominated reservoir, the water temperature is above the normal boiling point 100°C However, it does not boil but it remains in liquid state because the water in the reservoir is under Pressure.

The steam can be separated & used to generate electric Power (or) to Provide space & Process heat or it may be distilled to yield the Purified water.

Three methods which will be covered are follows:

a) Flashed - Steam System
b) Binary - Cycle System
c) Total flow System.

a) Flashed - Steam System:-

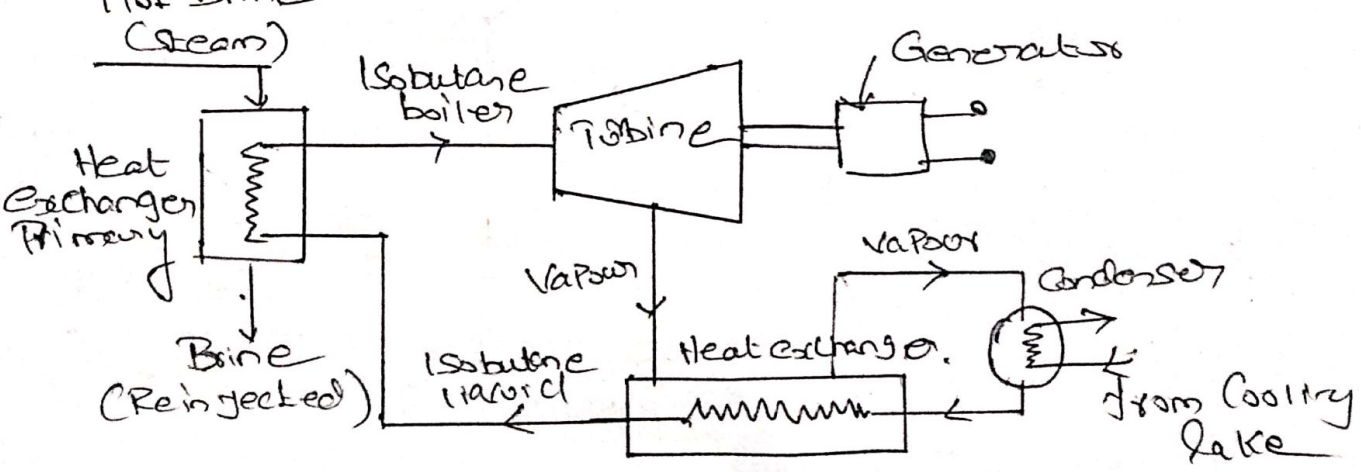


1 -> reaches the wellhead at point
2 -> at a low Pressure
3 -> flash separator
4 -> mixture is now separated in to dry saturated steam
5 -> Saturated brine
6 -> dry steam expand in turbine
7 -> Condensation

The Power generation from such system can be made more economical by associating a chemical industry with the Power Plant to make use of the brine & gaseous effluents

b) Liquid-Dominated - Binary Cycle

* It works with Rankine cycle with organic working fluid
*) One Circuit have a brine water & in binary Circuit freon-12 low boiling point fluid
*) it operates the turbine by freon-12
*) The exhaust vapour from turbine is cooled in the regenerative heat exchanger & then it is condensed using an air-cooled Condenser.
*) In the binary cycle, there are no problems of corrosion or scaling in the working cycle components such as turbines & condensers.



2. Explain the geopressured Resources & describe about Hybrid (Geothermal fossil fuel) systems

Drilling for oil & gas has revealed the existence of reservoirs containing salt water at moderately high temp & high pressure in a belt for 1200m in length. Because of abnormally high pressure of water up to 1350 atm in the deepest layers, the reservoirs are referred as geopressured.

Hot Dry Rock systems.

HDR is a heated geological formation formed in the same way as hydrothermal resources but containing no water as the cavities or fractures required to conduct water to the surface are not present.

Magma Resources (molten-Rockchamber) systems

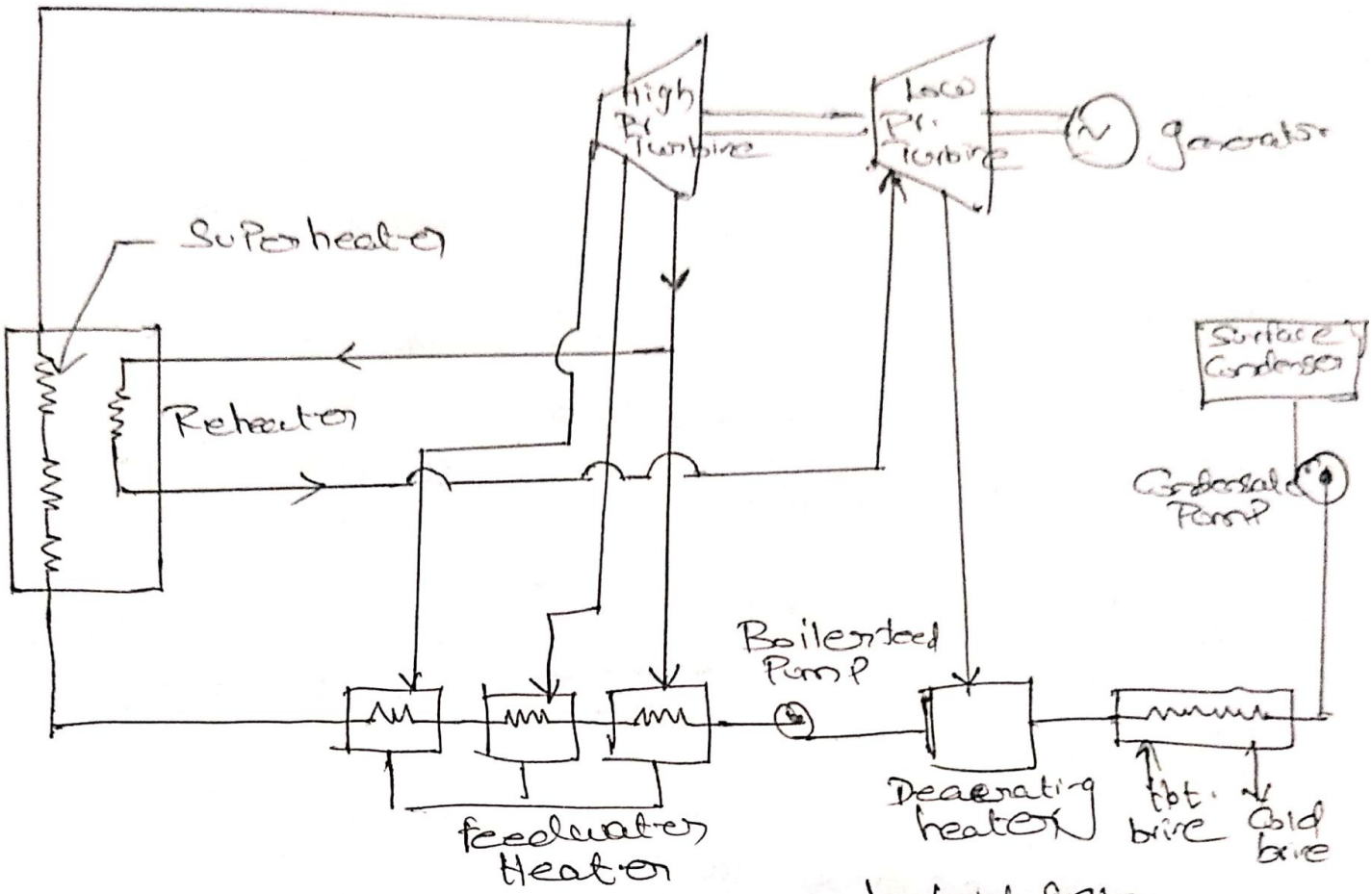
* Very large temperature above 650°C
* it is not feasible
* The concept of using heat exchange within magma is studied by Sandia National lab.

Hybrid (Geothermal fossil fuel) systems

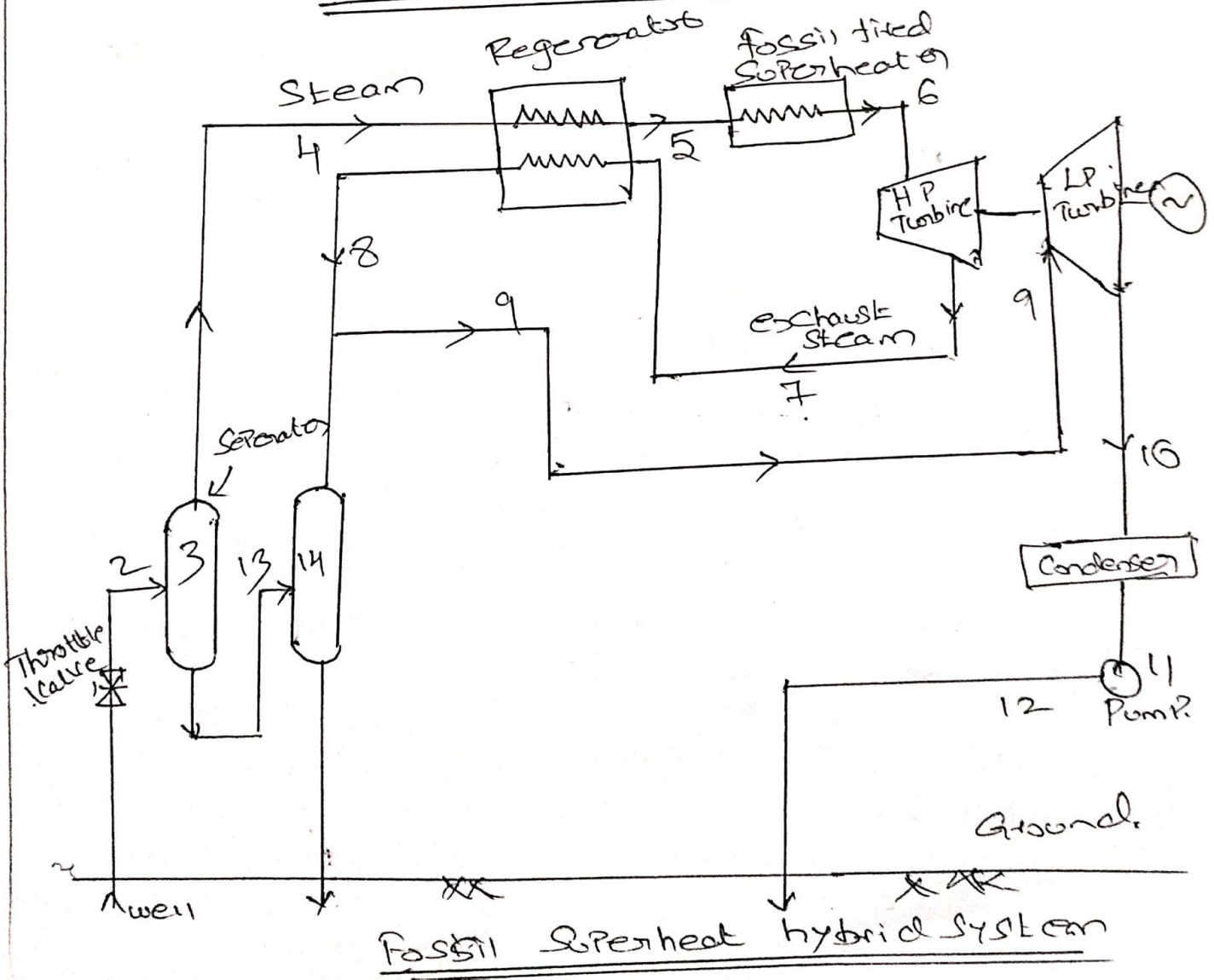
The concept of hybrid geothermal fossil fuel system utilizes relatively low temperature heat of geothermal sources in low temp. end of a conventional cycle & high temp heat from fossil fuel combustion to the high-temperature end of the same cycle.

The arrangements of hybrid plants are as follows.

1. Geothermal Reheat and
2. Fossil superheat



Geothermal - Reheat hybrid system



Fossil Superheat hybrid system

(4)

(3) Explain the OTEC & its types. (Open & closed OTEC) with neat sketch.

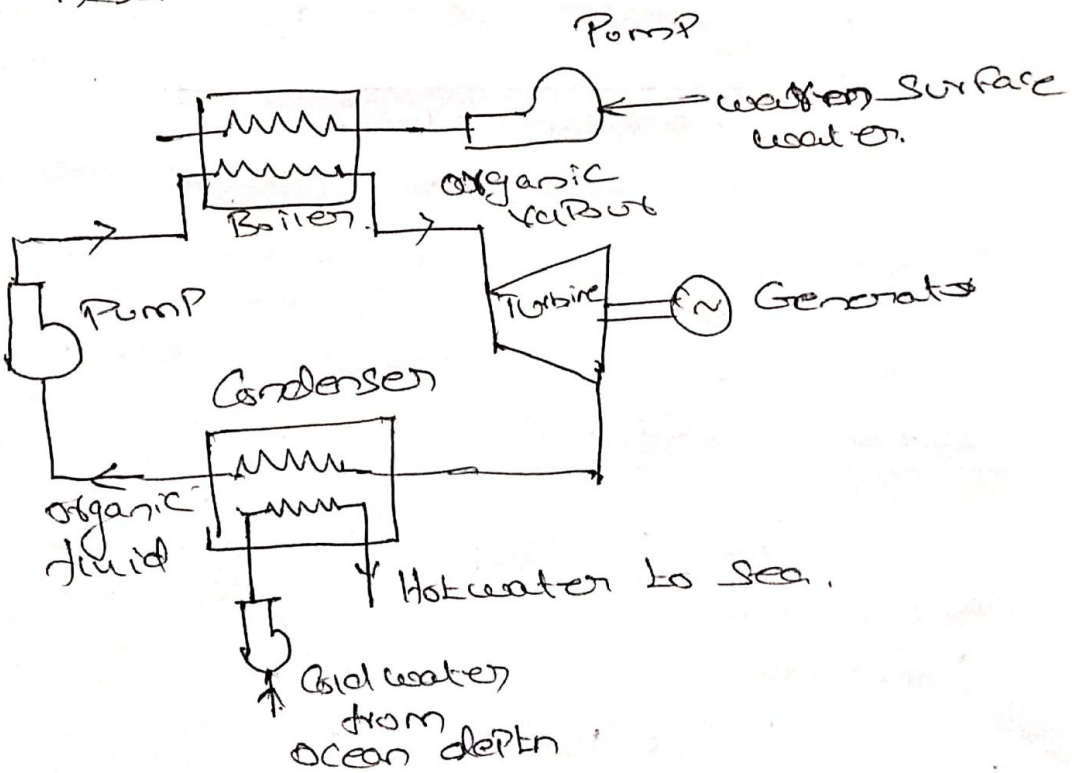
Ocean Thermal Energy Conversion Plants are operated with sea & lake temperature deviation in the top surface & bottom surface of the water.

Top surface is warm water due to solar radiation

bottom surface is cool water due to absence of solar rays in deep water.

Using warm water temperature the heat is transferred to low boiling liquid and run the turbine & generator.

using cold deep water temperature the heat is rejected from the low boiling liquid with the help of condenser.

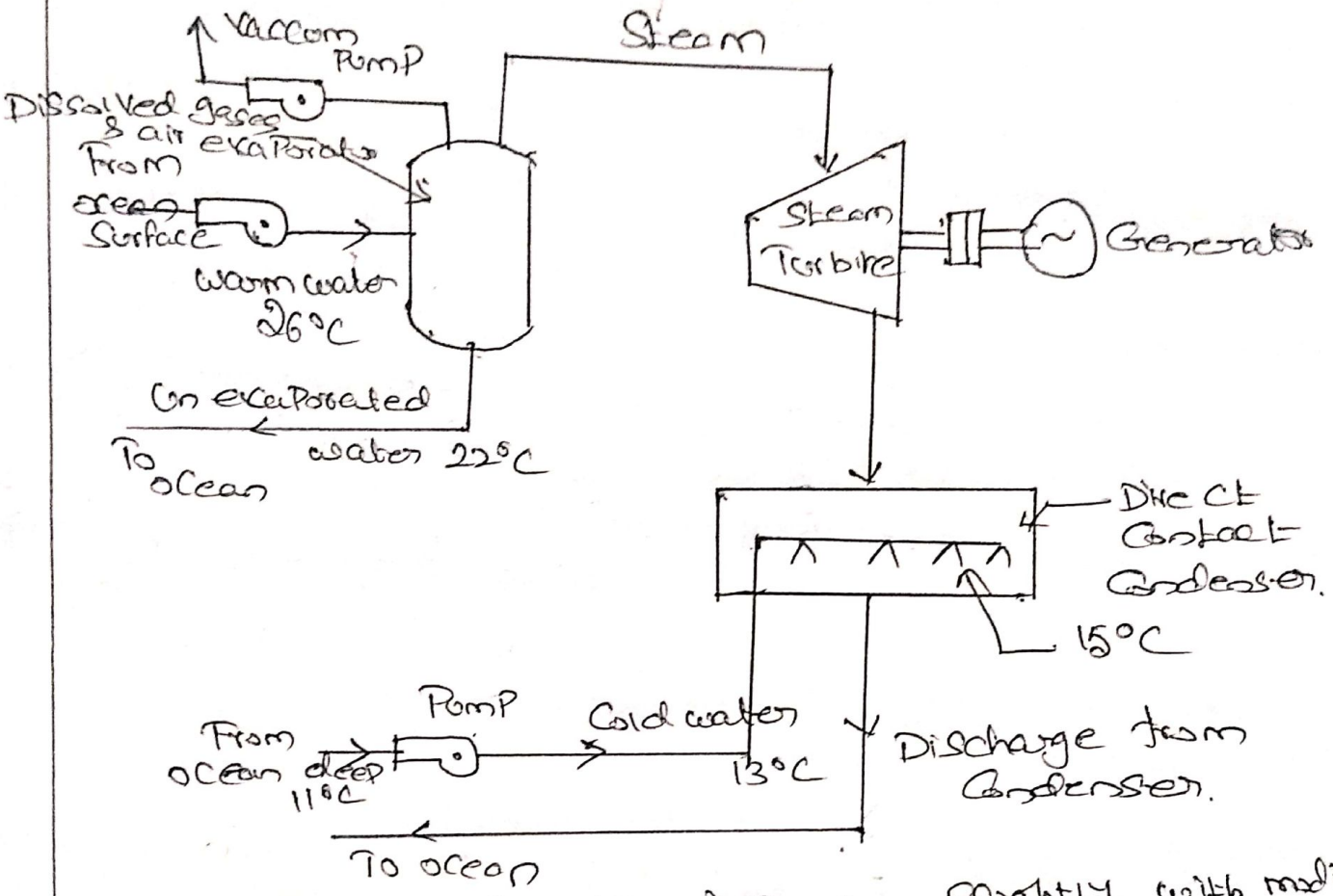


Thermodynamic Cycle in OTEC

1. Open Cycle (Claude cycle, Steam Cycle)
2. Closed Cycle (Anderson Cycle, Vapour Cycle)

Open Cycle OTEC System

Warm water temp at 80°F. Steam drives steam turbine generator to deliver electrical energy



Efficiency can be increase slightly with modified OTEC.

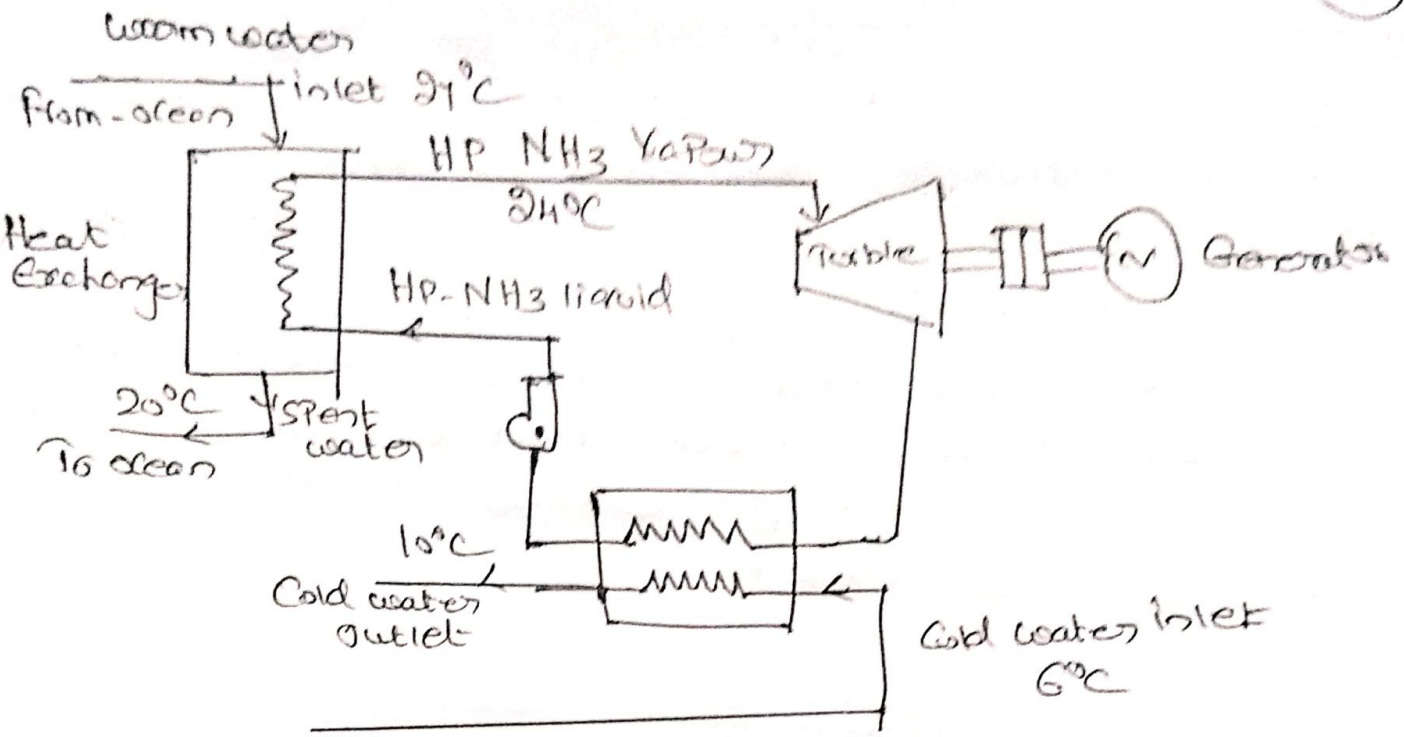
*) Controlled flash-steam evaporator is used instead of a conventional type of evaporator

*) Contact Condenser is replaced by a surface Condenser.

Closed - Cycle OTEC System

The working fluid (Ammonia, NH_3) is circulated through the closed cycle consisting of the following components

1. Evaporator
2. Vapour Turbine
3. Vapour Condenser
4. Liquid Pressurizer



Closed cycle OTEC Plant

Site selection for OTEC Plant

*) Equatorial water defined as lying between 10°N & 10°S are adequate except for the west coasts of South america & Africa

*) Tropical water defined as extending from the equatorial region boundry to 20°N & 20°S are adequate except for the west coast of South america & Africa.

*) The Preservation of environment in the area of the selected site.

4. Briefly Explain the Tidal barrage Power Plants & its modes of operation & generation of tidal barrage Power with neat sketch [MJD-19].

Tidal barrage Power Plants involve the Creation of huge Concrete dams with Sluices. Tidal barrage make use of the Potential energy difference in height between high & low tides.

Components of tidal Power Plant

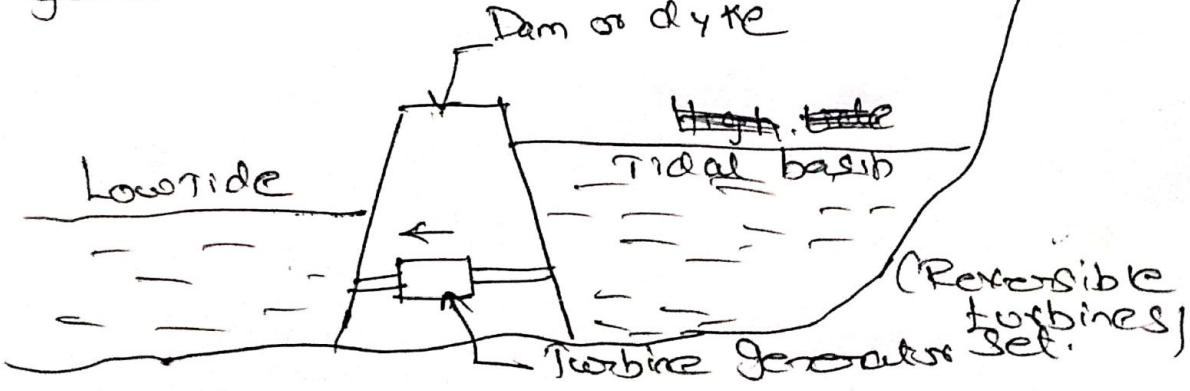
*) Barrage (or) Dyke (or) Dam
*) Sluice ways [gate Controlled devices]
*) Embankments [to Prevent water from flowing at Certain Parts of barrage]
*) Power house [turbines, generators, other auxillary equipment]

Modes of operation of Tidal barrage Power Plants

i) Ebb generation

Simplest & most Common form of barrage Power generation.

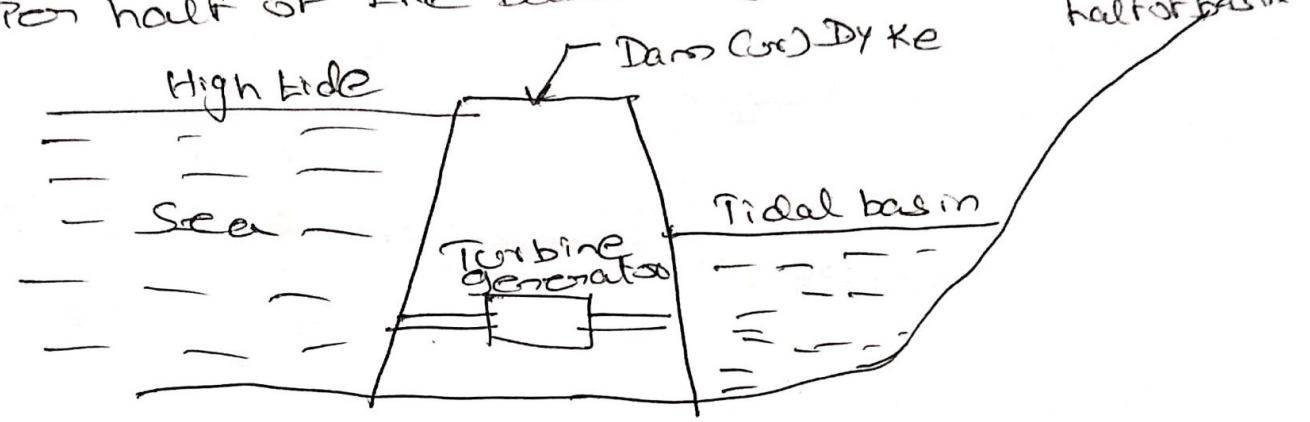
Tidal basin is filled through sluices during high tide. Then sluices gates are closed the stored water is then made to flow through turbines to sea when it gate is open to generate Power until the head is low.



ii) Flood generation

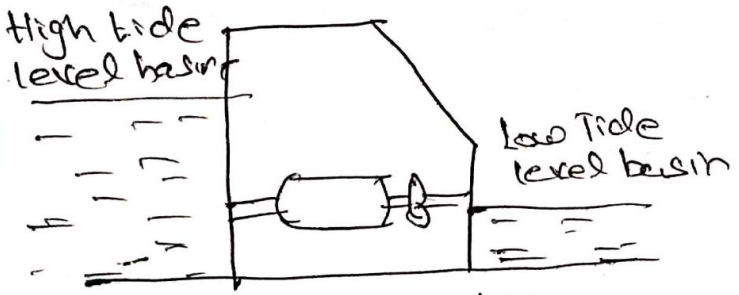
here the Power is generated from high tide sea to Tidal basin through the turbine generator.

less efficient than ebb generation because the volume obtained in the upper half of the basin is greater than lower half of basin.

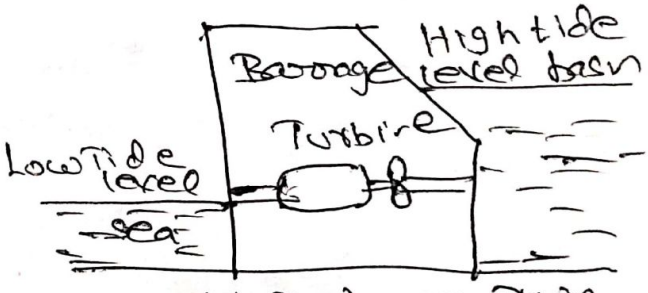


iii) Two-way generation

Power generation both during high tides from basin from sea and during low tides from basin to sea.



a) During filling



b) During emptying

iv) Pumping & turbining

reservoir is filling using

*) rise of sea water during high tides

*) Pumps to pump sea water in to the reservoir.

5. Explain Briefly wave energy & wave energy Conversion devices with neat sketch.

wave energy is energy of interchanging Potential & Kinetic energy in the wave.

It Can be either Converted into mechanical energy or electrical energy through wave energy Conversion Plants.

Energy range of 10 kw/m to 70 kw/m with respect to amplitude & wave length.

Wave retain energy differently depending on water depth:

*) lose energy slowly in deep water.
*) lose energy quickly as water becomes shallower because of friction between moving water particles & sea bed.

Location for wave energy Conversion device

*) At the shore line
*) Near the shore line
*) off-shore

The most generally & successfully used wave energy Conversion system at each of these locations is oscillating water column.

maximum wave energy between latitudes of 40° & 60°.

The annual energy exploration from wave energy is above 5 kw to 15 kw.

Wave Energy Conversion devices

hydro kinetic energy Conversion devices are generally Categorized as either wave energy Convertors (WEC)

The different type of WEC devices are

*) Wave Profile device [oscillating height of ocean's surface into mechanical energy]

*) oscillating water Columns [waves into air Pressure]

*) wave Capture devices [waves into P.E]

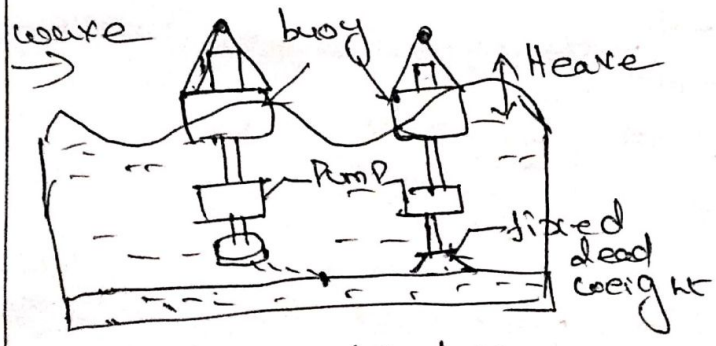
*) Rotating wave devices

Rotating wave devices Capture the K.E of a flow of water such as a tidal stream, ocean Current as it Passes across a rotor.

Wave Profile devices

a) Point absorber

energy absorption can be achieved by a floating body Called buoy.



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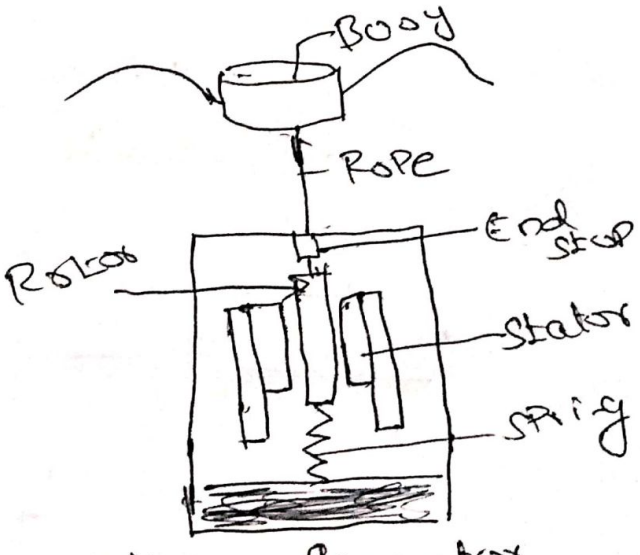

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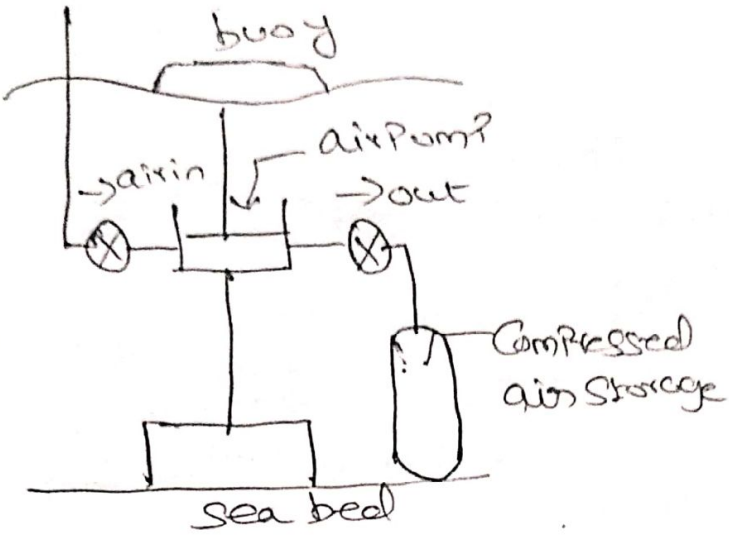

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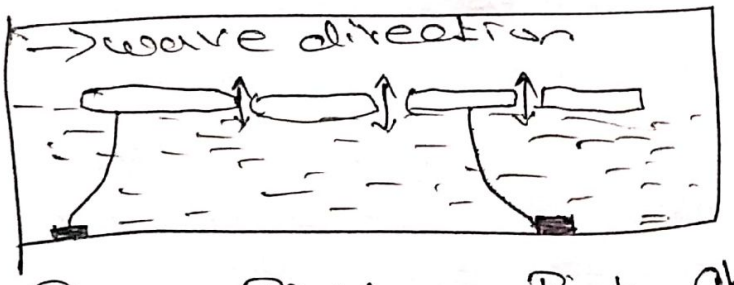

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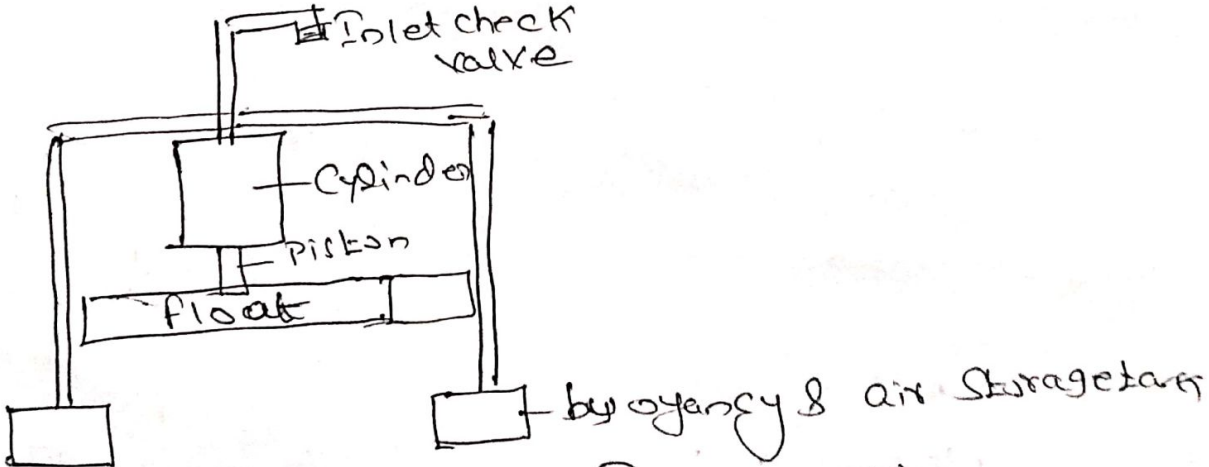

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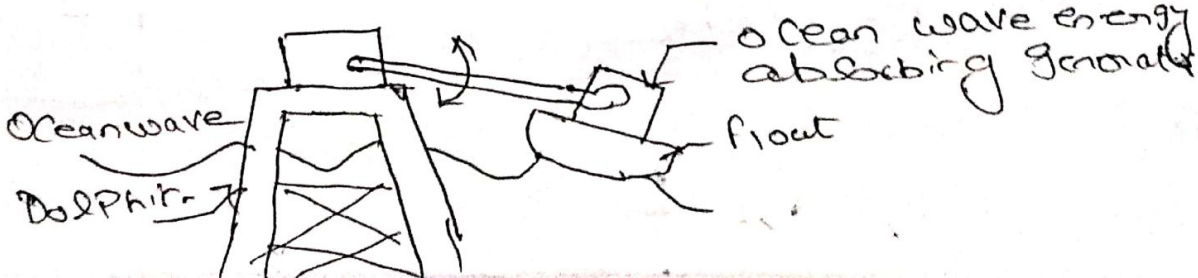

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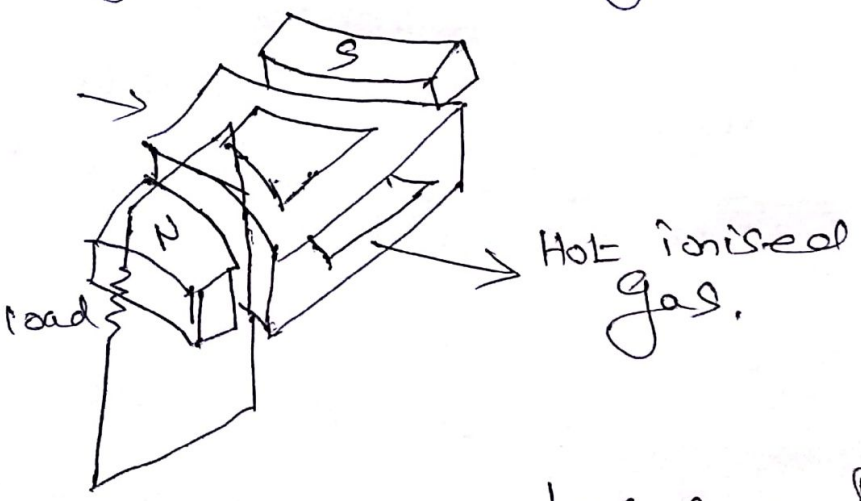

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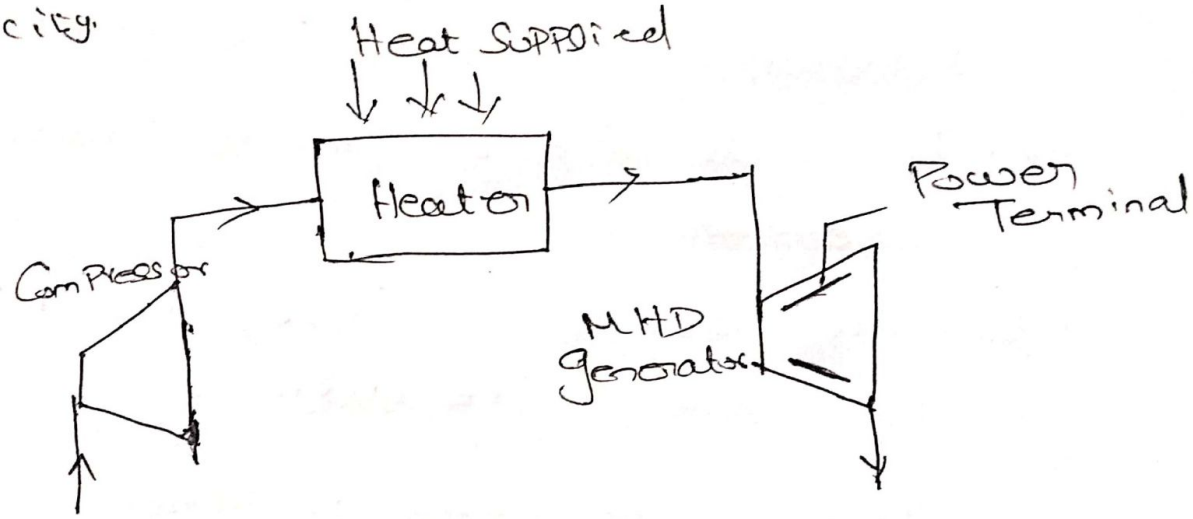

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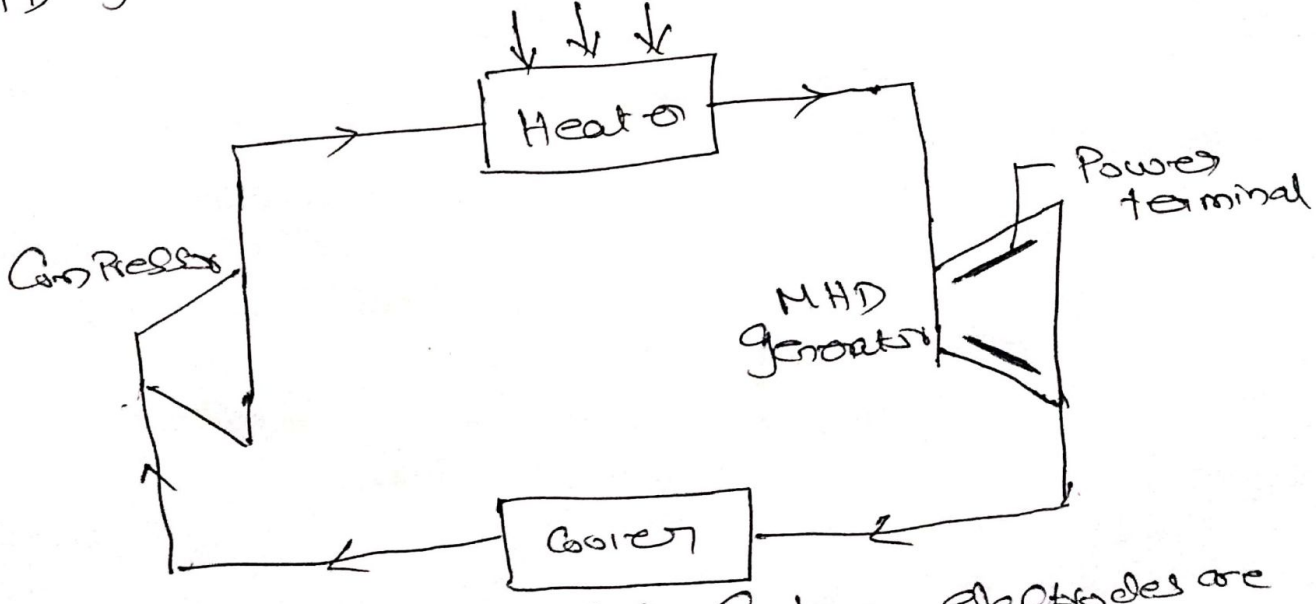

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