ANNAMACHARYA INSTITUTE OF TECHNOLOGY AND SCIENCES::
RAJAMPET
(An Autonomous Institution)

DEPARTMENT OF MECHANICAL ENGINEERING

LECTURE NOTES

NON-CONVENTIONAL SOURCES OF ENERGY

[20A37ET]

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Title of the Course	Non-Conventional Sources of Energy
Category	PEC
Course Code	20A37ET

Year	IV B. Tech
Semester	I Semester
Branch	ME

Lecture Hours	Tutorial Hours	Practice Hours	Credits
3	0	0	3

Course Objectives:

- To grasp the role and potential of new and renewable source
- To recognize the principle, storage and applications of solar energy
- To understand the sources and potentials of wind energy and also to comprehend the Principles of Bio-Conversion of bio-mass and bio-gas uses.
- To explain the principle, working procedure and types of geothermal energy, ocean energy and tidal & wave energy.
- To know the knowledge on direct energy conversion.

Unit 1 Principles Of Solar Radiation 9

Role and potential of new and renewable source, the solar energy option, Environmental impact of solar power, the solar constant, extraterrestrial and terrestrial solar radiation, solar radiation on titled surface, instruments for measuring solar radiation, potential in India

Learning Outcomes: At the end of the unit, the student will be able to:

- Understand types of energy resources. (L2)
- Understand the different types of measuring instruments of solar radiation. (L2)

Unit 2 Solar Energy Collectors 9

Flat plate and concentrating collectors, classification of concentrating collectors, orientation and thermal analysis, advanced collectors. Solar Energy Storage And Applications: Different methods, Sensible, latent heat and tratified storage, solar ponds. Solar Applications solar heating/cooling technique, solar distillation and drying, photovoltaic energy conversion, potential in India.

Learning Outcomes: At the end of the unit, the student will be able to:

- Understand different types of solar collectors. (L2)
- Understand the different types of energy storage systems and applications. (L2)

Unit 3 Wind Energy 8

Sources and potential in India, horizontal and vertical axis wind mills, performance characteristics, Betz criteria. Bio-Mass: Principles of Bio-Conversion, Anaerobic/aerobic digestion, types of Bio-gas digesters, gas yield, combustion characteristics of bio-gas, utilization for cooking, and economic aspects, potential in India

Learning Outcomes: At the end of the unit, the student will be able to:

- Understand the type of winds and windmills components. (L2)
- Understand the types of biomass conversion technologies and biogas digesters. (L2)

Unit 4 Geothermal Energy 10

Resources, types of wells, methods of harnessing the energy, potential in India.

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, potential in India.

Learning Outcomes: At the end of the unit, the student will be able to:

- Classify the Geothermal resources. (L2)
- Understand OTEC, wave and tidal energy extraction methods. (L2)

Unit 5 Direct Energy Conversion 9

Need for DEC, Carnot cycle, limitations, principles of DEC. Thermo-electric generators, Seebeck, Peltier and Joule Thomson effects, materials, applications, MHD generators, principles, dissociation and ionization, hall effect, Magnetic flux, MHD accelerator, MHD Engine, power generation systems, electron gas dynamic conversion, economic aspects. Fuel cells, principles, faraday"s law"s, thermodynamic aspects, selection of fuels and operating Conditions.

Learning Outcomes: At the end of the unit, the student will be able to:

- Classify the Direct energy conversion techniques. (L2)
- Understand the concept and working of MHD generator and Fuel cells. (L2)

Prescribed Text Books:

1. Tiwari and MK.Ghosal, Renewable energy resources: Basic principles and applications, Narosa publications 2005, ISBN 10: 1842651250 ISBN 13: 9781842651254
2. G.D. Rai, Non-Conventional Energy Sources, khanna publications, 2011, ISBN 10: 8174090738, ISBN 13: 9788174090737

Reference Books:

1. Twidell & Weir, Renewable Energy Sources, Routledge , 3rd Ed.2015,ISBN 9780367200756
2. Non Conventional Energy Resources, B.H.Khan, McGrawHIll, 2015, ISBN 1259081397, 9781259081392

Course Outcomes:

A student will be able to	Blooms Level of Learning
1. Summarize the basics of solar radiation and its instruments.	L2
2. Summarize the types of solar collectors, energy storage systems and their applications.	L2
3. Summarize the working of Wind Mills, Bio-Mass energy and their applications.	L2
4. Summarize the concepts of Geothermal resources, Ocean thermal energy conversion plants, wave energy and tidal energy.	L2
5. Summarize different direct energy conversion systems.	L2

CO-PO-PSO Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
20A37ET.1	2	2	1	2	-	-	-	1	-	-	-	1	2	1
20A37ET.2	2	2	1	2	-	-	-	1	-	-	-	1	1	1
20A37ET.3	2	2	1	2	-	-	-	1	-	-	-	1	2	1
20A37ET.4	2	2	1	2	-	-	-	1	-	-	-	1	1	1
20A37ET.5	2	2	1	2	-	-	-	1	-	-	-	1	2	1

Non-conventional Sources of Energy:-

G.D.RAI

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UNIT-1 Principles of Solar Radiation

Syllabus:-

Role and potential of new and renewable source, the solar energy option, Environmental impact of solar power, the solar constant, extraterrestrial and terrestrial solar radiation, solar radiation on tilted surface, instruments for measuring solar radiation, potential in India.

References:-

1. Non-conventional resources "G.D.Rai" Khanna publications.
2. Non-conventional resources "B.H.Khan" Tata Mc. Graw hill.
3. P.B. Kotay, M.V.R. Koteswara rao.

Energy:- Energy is the primary and most universal all Kinds of work by human beings and nature the Renewable Energy resources that divided into two types.

① primary (or) conventional sources of Energy (Non-conventional sources of Energy)

Primary Energy Source:- It can be defined as sources which can provide a net supply of Energy. It can be consumption. Ex:- coal, oil, (uranium/petroleum) etc. This resources are finite and exhaustible, once consumed, these sources cannot be replaced by others.

Coal → Ash → It cannot be reproduced

② Secondary Energy Source (or) Non-conventional sources of Energy (Renewable Sources of Energy):- (not Exhaustible)

→ It can renewed by nature again and again and their supply is not effected by the rate of their consumption are called Renewable sources of Energy.

→ These sources are being continously produced in nature and are not exhaustible.

Examples:- (i) Solar energy (ii) wind Energy (iii) geothermal Energy (iv) ocean Energy such as tidal Energy, wave Energy (v) Biomass energy such as gobar gas.

Q.4 (A) Difference b/w Renewable resources and Non-Renewable resources of Energy:-

Renewable Resources	Non-Renewable Resources
(1) Renewable resources are those resources which can be renewed (or) reproduced.	(1) Non-renewable resources are those resources which cannot be renewed (or) reproduced.
(2) It is inExhaustible.	(2) It is Exhaustible.
(3) Causes Less pollution	(3) causes more pollution.
(4) It can be renewed over a short period of time	(4) It takes millions of years. to occur.
(5) Ex:- Water, wind, soil, forest, solar energy, etc.	(5) Ex:- Minerals, and fossil fuels.
(6) cost of renewable resources is Low.	(6) cost of non-renewable resources is high.
(7) Available in Large amount.	(7) Available in Limited amount.
(8) Infrastructural setup is Expensive. Ex:- wind farms.	(8) Infrastructural setup is Less Expensive.
~~(8) In exhaustible~~	
(9) Large area is required for construction. Ex:- Wind mills, dams, built to harness tidal energy	(9) Less area is required for construction.
(10) Low carbon Emissions.	(10) High carbon Emissions.

→ Global warming & air pollution are the two effects occuring by using conventional sources of energy instead that we can use Non-conventional sources of energy.

~~Role and potential of new and renewable sources:~~

→ Hence there is primary source to use non-conventional energy. Like nuclear energy, solar energy, wind energy, tidal energy, Biomass energy, Geothermal energy etc.

→ These sources of energy are abundant, renewable, pollution free and eco-friendly. This are also called renewable sources of energy.

→ Let us study about the various non-conventional sources of energy.

(1) Nuclear Energy:- These are produced by nuclear energy of Thorium and uranium. It is also known as Nuclear fission

→ Uranium and Thorium which are largely available in Jharkhand and Aravalli Ranges of Rajasthan are used for generate nuclear atomic power, and also available of monazite sand of ~~Kerala~~ Kerala is of rich Thorium

(2) Solar Energy:- India is a tropical country it has rich of solar energy. photovoltaic cells converts Sunlight directly into Electricity.

→ It is used for Solar cooking, generation of power, transparation of energy.

(3) Wind Energy:-

Wind Energy is the 2nd fastest Energy which is growing in the world. India is one of the countries which generates power by wind Energy.

→ In order to make Electricity from wind Energy completely used from Large windmills called wind turbines.

→ The Large wind mills is located from Nagercoil to Madurai in Tamilnadu. other wind farms are Located in Andhrapradesh, Karnataka, Gujarat, Kerala, Maharashtra, Lakshadeep.

(4) Biomass Energy:- Biogas is another Energy which is collected from farm waste, animal waste, human waste.

→ Biogas is produced from decomposition of organic matter.

(5) Ocean Energy (Tidal Energy):- These Energy can be generated from ocean water. when the water is full of Tides.

→ From Tides (Rise & fall) generate power.

(6) Geothermal Energy:-

→ Geothermal Energy that can be collected from super heated fluids from Earth's geothermal resources to generate power.

→ It is located in manikaran in Himachal pradesh other is located Puga Valley in Ladakh

V. Imp (4)

Role and potential of new and renewable source:-

→ World faces many of the environmental problems with usage of fossil fuels (like coal, anthracite, brown coal, oils and gaseous fuels). The burning of fossil fuel produces carbon dioxide (CO_2) everyday. This increased content of carbon dioxide (CO_2) is playing main role for increasing the global atmospheric temperature called as "Global warming Effect".

→ The world's nearly 85% are used only of fossil fuels (coal, natural gas, oil).

→ These problems are under non-Renewable sources:-

① Environmental hazards:-

→ It is one of the major disadvantage of fossil-fuels. It is known fact that CO_2 gas released when fossil fuels are burnt, and it is one the primary gas responsible for global warming.

② Rising prices:-

only few countries have huge reserves of oil and natural gas. Due to heavy usage of fossil fuels, the fuel rates are increased.

③ Acid Rains:- The gases which are emitted by cars, vehicles, and factories are released into the atmosphere. They dissolve in rainwater,

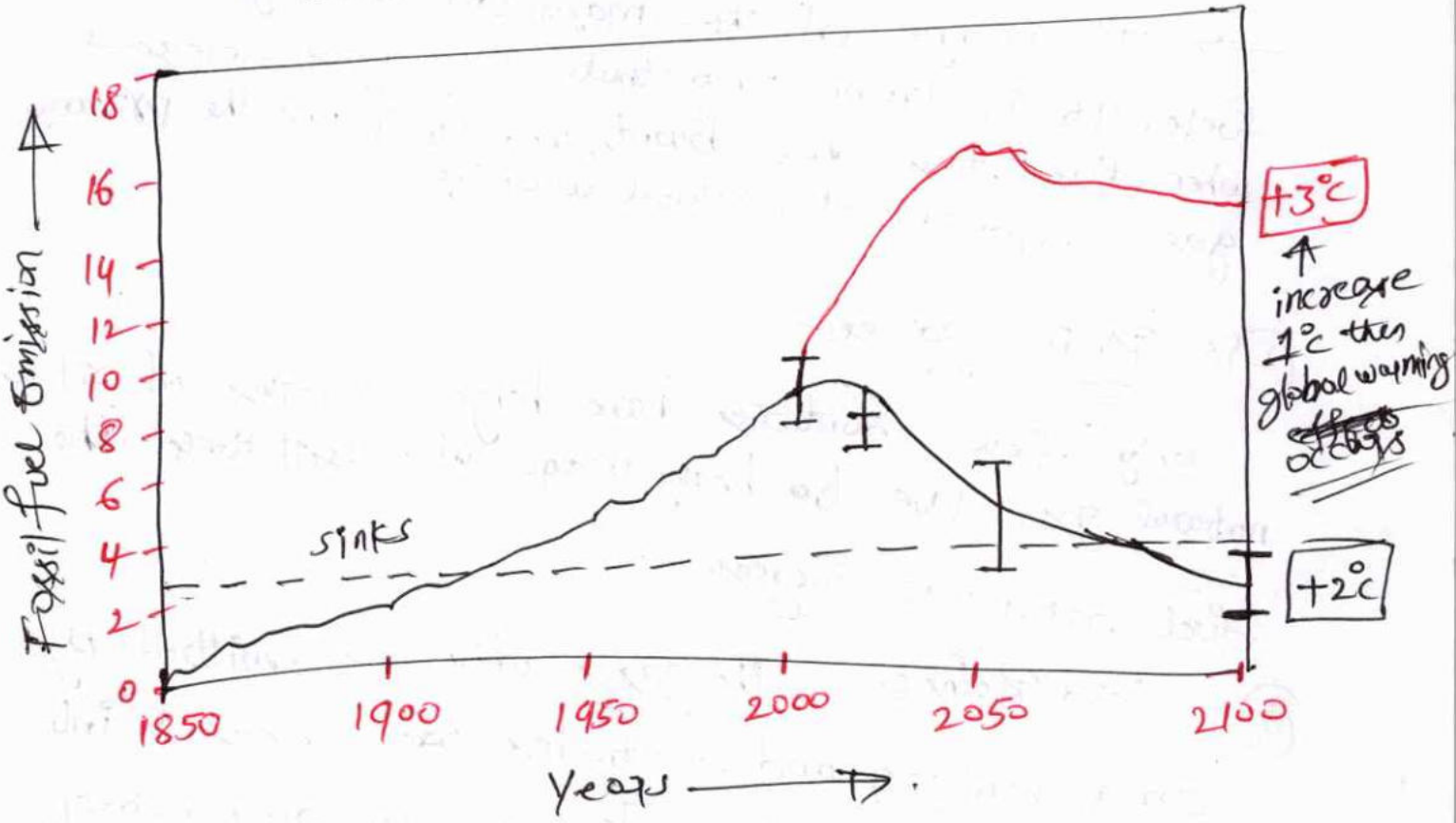
causing acid rains and acid snow. Acid rains will Effect human life to great extent.

(4) Impact on Aquatic Life by oil spill:
↳ It effects acquatic animals. especially in marine areas.

(5) Effect on human health:-
↳ pollution from vehicles it causes health effects of human life which leads to asthma, Lung cancer.

(6) coal mining
↳ It leads to destroys wide areas of Land and results in ecological imbalance.

Result if we prefer fossil fuels:-



By above graph if increase +3°c then increase of global warming.

→ One answer to global warming (for the above problems) is to replace current technologies with alternatives which should have better performance and should not produce carbondioxide. Those alternatives are called as Renewable energy resources which are playing main role instead of non-renewable energy resources for producing Energy.

Use and potential with Role of Renewable source:-

→ Renewable Energy is generally defined as energy which can be used again and again and it is collected from resources which are naturally refilled on human timescale, such as Sunlight, wind, rain, tides, waves, and geothermal heat.

Non conventional Energy:-

→ Energy which is generated by wind, tides, solar, geothermal heat and biomass including farm and animal waste as well as human excreta is called as Non-conventional Energy.

→ All these sources are renewable (or) inExhaustible and do not cause environmental pollution.

Imp point

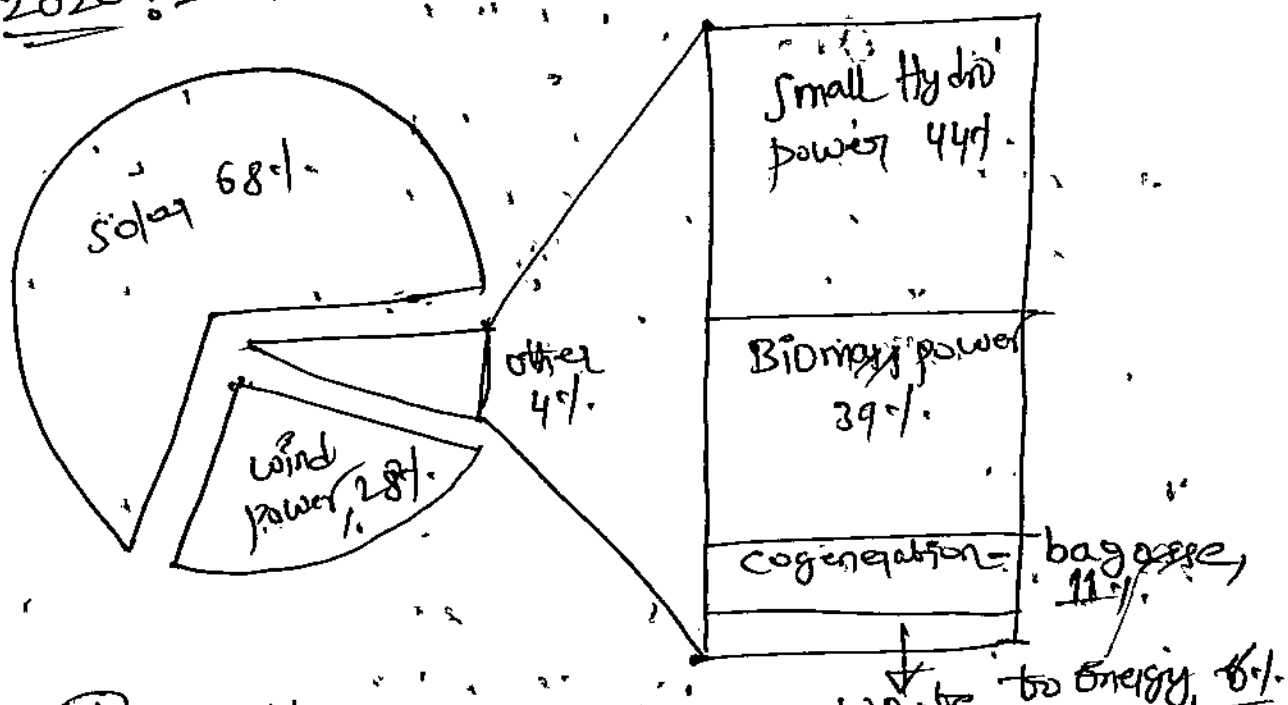
→ Renewable Energy source provide Energy in four important areas. They are electricity generation, air & water heating/cooling, transportation and rural energy services.

Estimated Renewable Energy potential:-

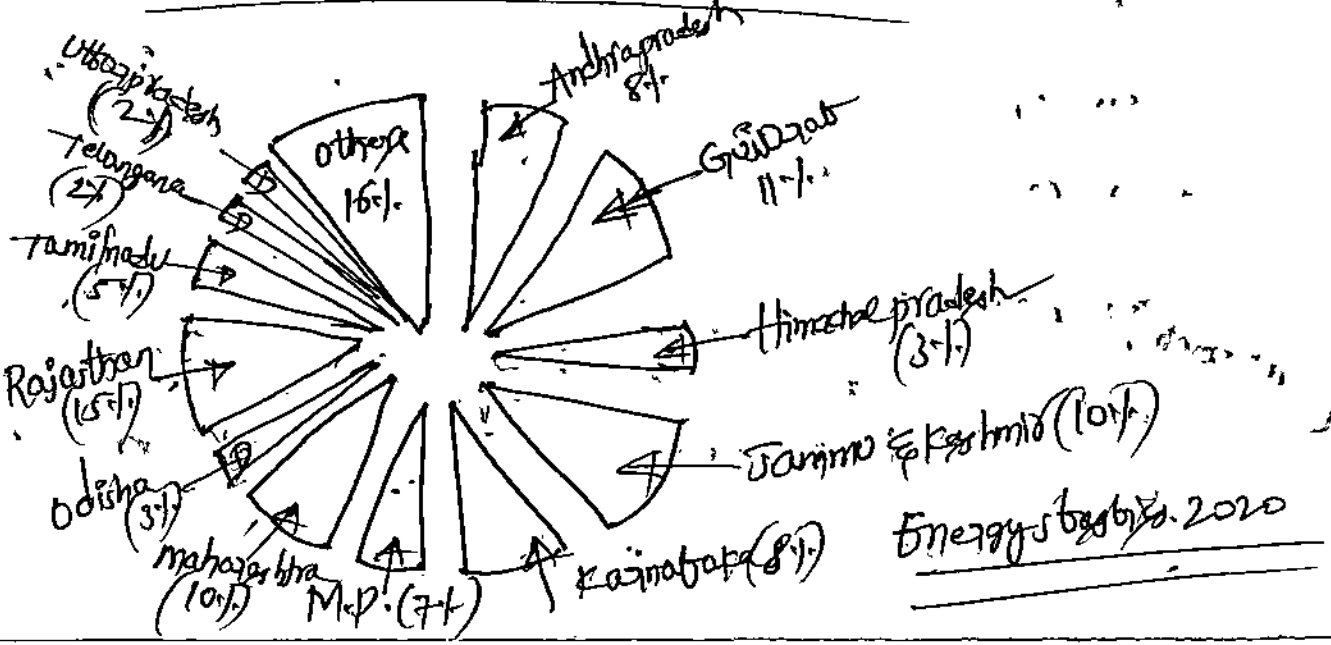
India has an estimated renewable energy potential of about 900 GW.

- Wind - 102 GW.
- Bio-Energy - 25 GW.
- small-Hydro - 20 GW.
- Solar power - 750 GW.

Estimated potential of Renewable power - India 2020:-



Renewable power potential - states:-



Energy sources 2020

(A) Solar Energy option's — Importance

Sun is the source of all energy. The energy obtained from the Sun is called Solar Energy.

The Sun radiates Energy uniformly in all directions in the form of Electromagnetic waves the Solar Energy is utilised into two ways.

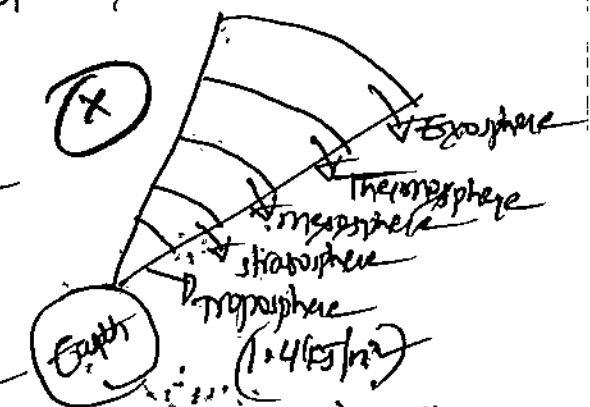
(1) By collecting the radiant energy and using it in thermal system in the form of heat Energy.

(2) By collecting and converting sunlight directly into Electrical Energy using a photovoltaic system.

The Sun emits
① Visible → Light Energy
② Infrared → Heat Energy
③ Small amounts of ultraviolet Radiations

collectively called as Solar Energy.

(X) The upper atmosphere of earth receives around 1.4 kJ/m² only 40% of this reaches on the earth's surface is 0.64 kJ/m².



Advantages of Solar Energy:

- It is free of cost
- It cause no pollution
- It is renewable source of energy.
- It is Ecofriendly.

Solar Energy can be utilized in two ways.

① In direct method → Does not utilize use of direct sunlight.

(a) Solar energy → chemical energy → By converting it to Biomass.

(b) Using wind Energy (unequal warming of sunlight in directly generate wind energy)

Water Energy (water cycle are also effected by the sunlight. And directly it is form of water energy)

Ocean Thermal Energy
Wave Energy
} → depend on Solar Energy

② Direct method: Involves direct use of sunlight to produce Energy.

(a) Solar cookers (By using Infrared rays directly and then cooking of food occurs easily).

(b) Solar cells (These Solar cells convert direct sunlight directly into Electricity).

Applications (or) Uses of Solar Energy:

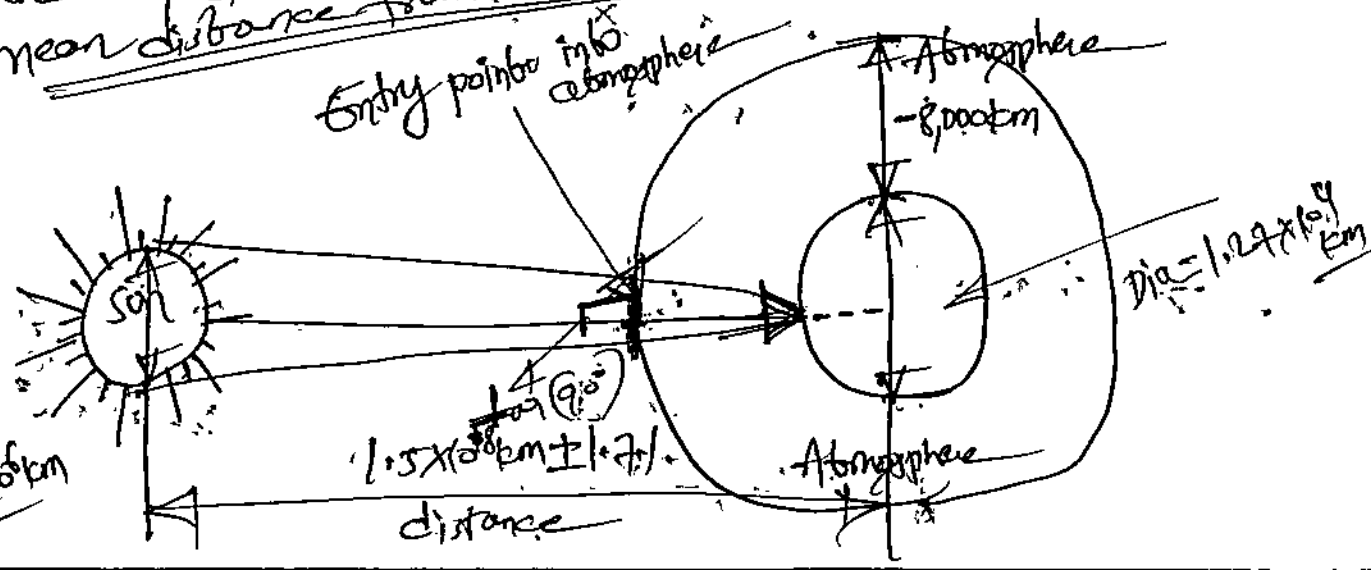
→ plants use Solar Energy to prepare food and this process called photosynthesis. Solar cell converts sunlight into Electricity and used for various purposes.

- Solar energy is a major source of renewable energy.
- Solar cooker, solar water heater, solar vehicle, etc
- Solar energy is inexhaustible, non-polluting, sustainable and non-conventional energy.
- Solar energy systems have low maintenance cost.
- Solar energy systems are expensive, needs more space
- Solar water heating system
- Solar thermal power plants
- Solar space heating systems
- Solar green houses

~~Environmental Impact of Solar power~~

Solar Constants

Definition:- It is total energy received from the sun per unit time on a surface of unit area kept perpendicular to the radiation in space just outside the Earth's atmosphere when the Earth is at mean distance from the sun.



→ Solar constant can be determined by using Angstroms pyrheliometer.

Solar constant (I_{sc}) = Solar Energy received / area x time

The approximate Value of Solar constant is

1.4 KJ per second per square metre

$\Rightarrow 1.4 \text{ KJ} \times \frac{1}{s} \times \frac{1}{m^2}$

$\Rightarrow 1.4 \text{ KW/m}^2$

(X)

The correct value of solar constant can be calculated by above formula.

→ Intensity of radiation (θ_s)

$\theta_s = \sigma T_s^4 = 5.671 \times 10^{-8} \times 5762^4$

(σ = Stefan Boltzmann constant, T_s = temp of sun)

$\theta_s = 5.961 \times 10^7 \text{ W/m}^2$

→ Total radiant power

$P = \theta_s \times A$ (surface of sun / Area of sun)

(θ_s = Intensity of Radiation, $A = 4\pi R^2$, R = Radius)

$= 5.961 \times 10^7 \times 4 \times 3.14 \times (6.96 \times 10^8)^2$ m

$P = 3.630 \times 10^{26} \text{ W}$

→ Radiant flux

$\theta_0 = \frac{P}{4\pi d^2} = \frac{3.630 \times 10^{26}}{4 \times 3.14 \times (1.5 \times 10^{11})^2}$

$\theta_0 = 1362 \text{ W/m}^2$

→ The above value is called solar constant

(A) $I_{sc} = 1367 \text{ W/m}^2$

The change in solar constant can be approximated by the following Equation

$$\frac{I}{I_{sc}} = 1 + 0.033 \cos\frac{360n}{365}$$

Where "I" is solar radiation

'n' is number of days counted from Jan 1st

I_{sc} → solar constant

Extraterrestrial and terrestrial Solar radiation:

Extraterrestrial radiation:

(c) Radiation incident on the outer atmosphere of Earth is known as Extraterrestrial radiation. Nothing in absence of atmosphere.

→ The radiation received by any planet depends on its distance from the sun.

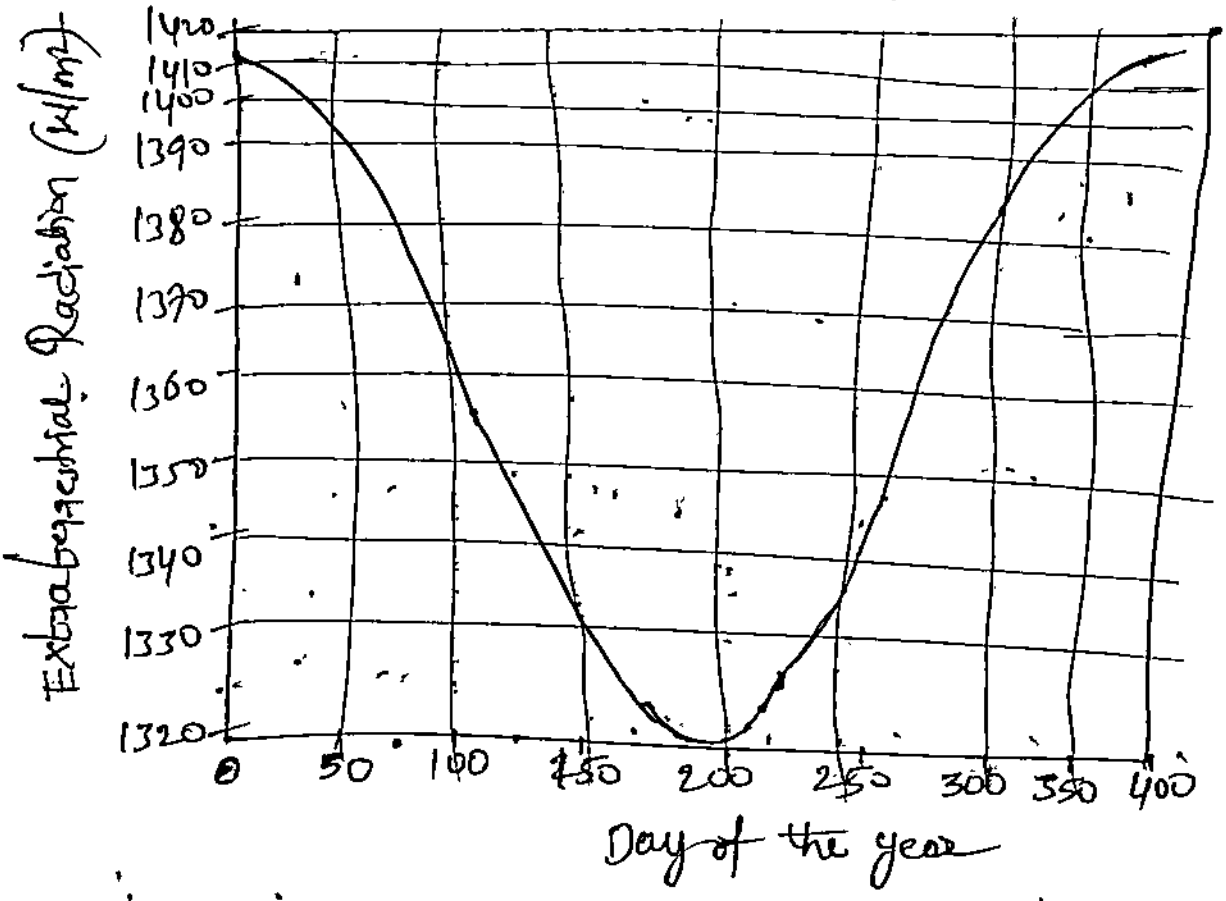
→ The distance of the Earth from the sun is 1.5×10^8 m.

→ Extraterrestrial radiation is the radiation that falls on the outer surface of the Earth's atmosphere.

→ purpose:

(c) This radiation remains almost constant throughout the year as the space (vacuum) b/w the sun and Earth atmosphere does not change with time and the distance b/w the sun and Earth remains almost constant.

Annual Variation in Extraterrestrial Radiation:-



A/c to Extraterrestrial a/g.o varies which can be calculated on anyday by the following Equation.

$$I = I_{sc}\left[1 + 0.33 \cos\frac{360n}{365}\right]$$

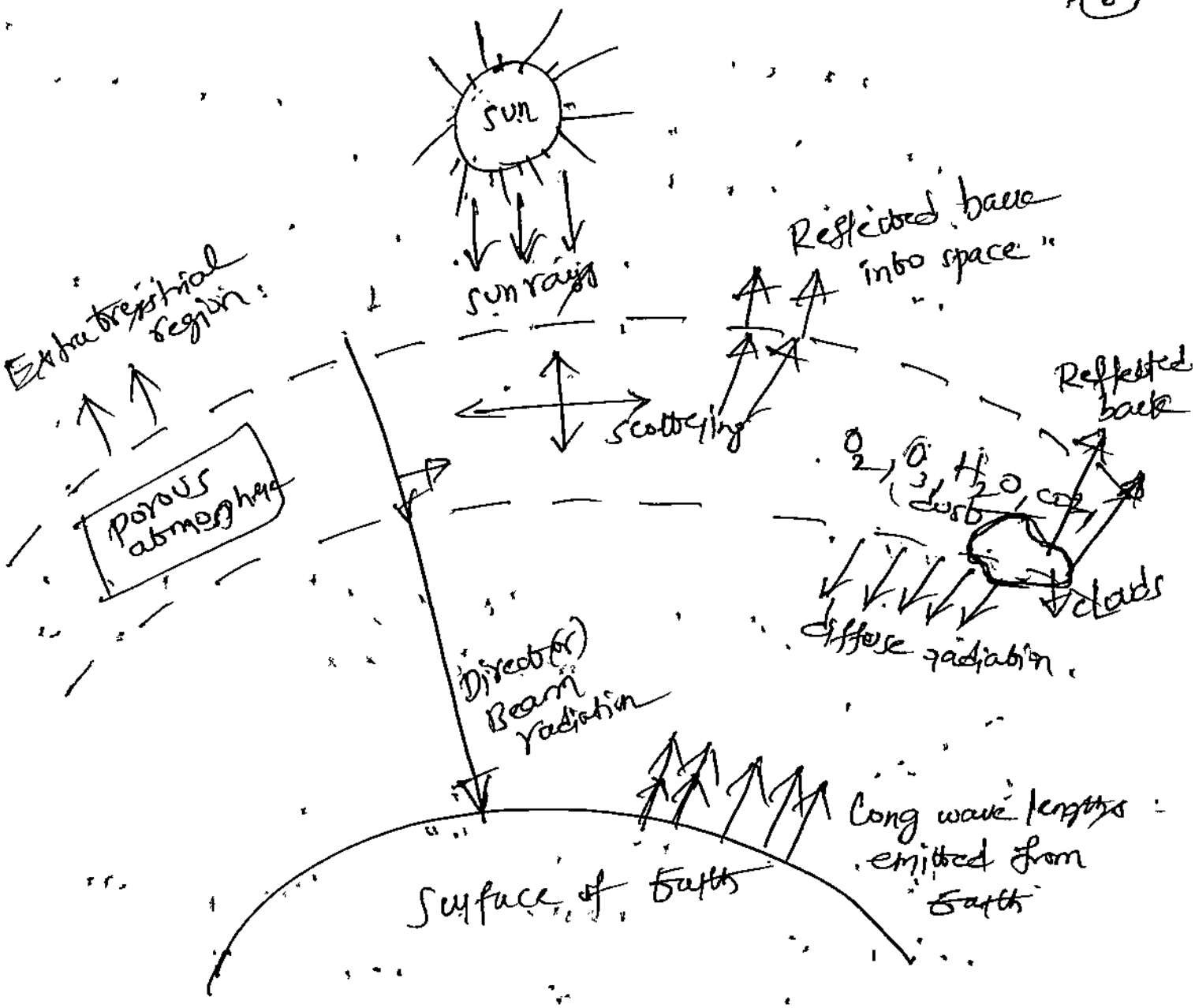
where n = no. of days counted from Jan 1st.

I_{sc} = Solar constant.

I = Solar radiation (or) Solar Irradiance

Terrestrial Solar radiation:-

" Terrestrial radiation is the measure of solar radiation that would be received on the Earth's surface in presence of atmosphere. "



(2) Solar radiation passes through Earth's atmosphere and are subjected to scattering and atmospheric absorption

(3) Scattering:- Scattering is nothing but disorderly obstruction of radiation by air molecules, dust, water droplets that cause

(4) A part of scattered radiation is reflected into space and remaining is directed downwards to the Earth's surface in different directions (i.e.;

diffuse radiation (or) Beam radiation).

In cloudy atmosphere

(1) major part of the incoming solar radiation is reflected back into the space by clouds.

(2) Another part is absorbed by the clouds.

(3) The remaining is transmitted downwards to the Earth surface as diffused radiation.

Absorption:-

→ In absorption process nitrogen, molecular oxygen and other atmospheric gases absorbs X-rays, UV radiations.

→ O_3 absorbs short wave UV radiation.

→ H_2O and CO_2 absorbs along Infrared radiation.

Beam radiation:- (or) direct radiation:-

It solar radiation received on the Earth's surface without change in direction is called Beam radiation (or) direct radiation (I_b).

Diffuse radiation:- The radiation received on the Earth's surface after all parts of the sky dome is called diffuse radiation denoted by (I_d).

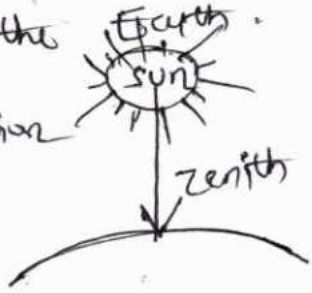
Global (or) total radiation (I_T):-

Sum of both Beam and diffuse radiation called total radiation (I_T) $I_T = I_b + I_d$

Solar insolation:-

"It is defined as solar radiation which is received on flat horizontal surface on the Earth."

Sun at Zenith:- It is the position of the sun directly overhead.



~~Solar radiation on tilted surface:-~~

Instruments for measuring solar radiation:-

The solar radiation data is required for many purposes.

① solar Energy Appliances
② Hydrology ③ weather forecasting.

There are 2 basic types of instruments is used to measure the solar radiation. ① pyraheliometer
② pyranometer.

① pyraheliometer:-

→ "pyraheliometer is one type of instrument, used to measure the direct beam of solar radiation."

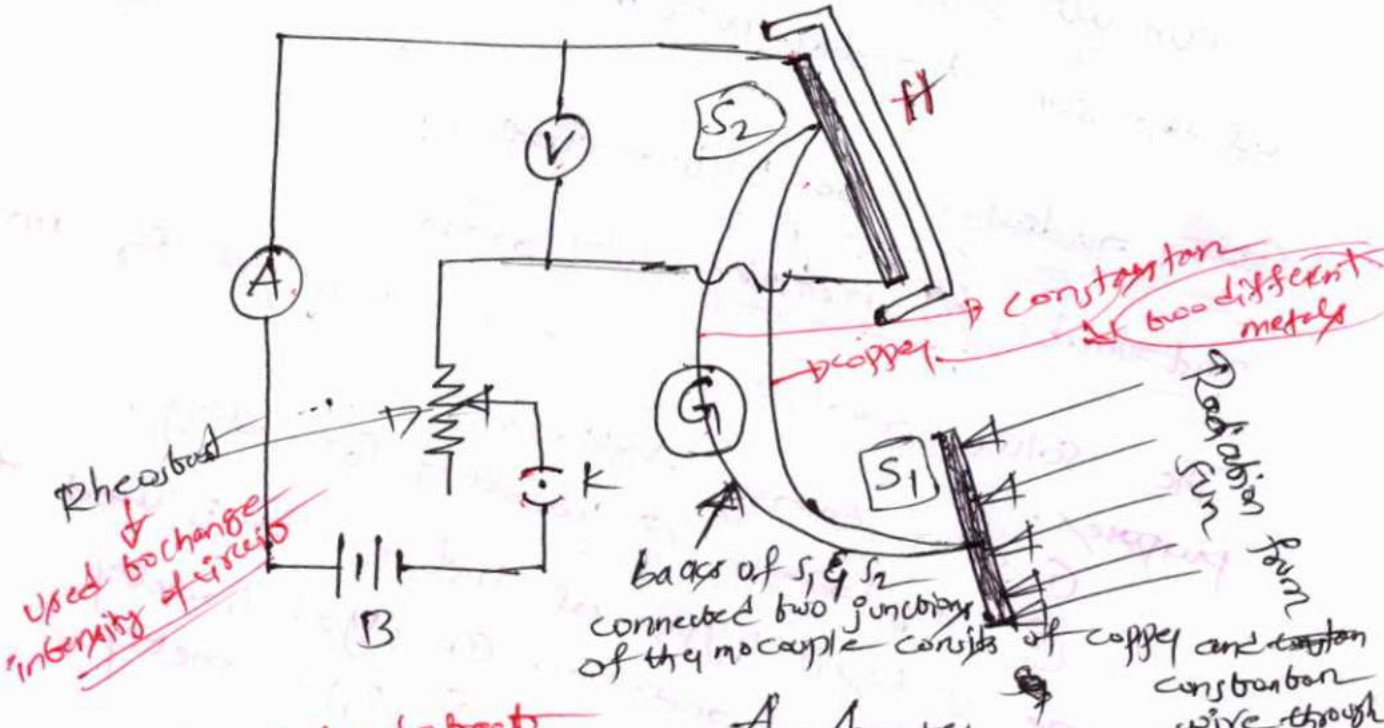
→ This instrument is used with a tracking mechanism to follow the sun continously.

↓
to track the sun continously then get direct beam radiation.

→ The units of irradiance (or) solar radiation are kJ/m². This instruments are specially used for weather monitoring & climatological research purposes.

→ The instrument used for the determination of solar constant are called pyraheliometer. i.e; nothing but Angstroms pyraheliometer.

Angstrom's pyrheliometer



"Galvanometer is used to detect the current 'I' in the circuit"

Thermocouples are prepared by two different metals one is copper and another is constantan.

A - Ammeter
V - Voltmeter
B - Battery
K - plug key
G - Galvanometer
S_1, S_2 - strips.

Construction:

→ It consists of two thin exactly similar blackened strips of platinum (~~and~~) constantan S_1 & S_2.
(metal + alloy) (combination of copper and nickel)

→ The two strips are arranged such that one is open to receive the radiation from the sun normally while the other is protected by a double walled shield "H".

→ The backs of S_1 & S_2 are connected to two junctions of a thermocouple consisting of copper and constantan wire through galvanometer "G".

→ The strip S_2 is heated electrically with the help of electric circuit → Ammeter is used to measure the current and voltmeter is used to measure the voltage, Battery is used to supply the power and finally rheostat is used to change intensity of current in circuit.

Working:-

→ when the temperatures of strips S_1 and S_2 are same then the galvanometer shows no deflection (or) null deflection.

→ But the strip "S_1" is irradiated (or) receives the solar radiation from the Sun. then temp of strip S_1 is rises then galvanometer shows deflection.

→ For that to make null deflection the temp of strip "S_2" is raised by electric heating method. to heat the temp of S_2 by Battery is connected by adjusting the current in the circuit such that galvanometer shows null deflection. At this point the strips S_1 & S_2 are at same temp.

→ But how much of heat energy is supplied to "S_2" by know the current (I) and voltage (V).

→ If "A" be the area of cross section of the strip and "a" be the absorption coefficient, then solar radiation received per minute per square centimetre

is given by.

$$S = \frac{(I \times V \times 60)}{(A \times a \times 4.2)}$$

Solar constant

Units:- $\frac{cal}{cm^2 \times min}$ (or) $\frac{W}{m^2}$

1 cal = 4.2 J

→ The Experiment is to be repeated several times on the same day under constant sky conditions with different elevations of the sun

→ To find out the average value of solar constant is then calculated by performing the experiments throughout the year.

→ The observed value of solar constant S and true value of solar constant S_0 are connected by the relation $S = S_0 \tau^{\sec Z}$ where "τ" is the transmission coefficient of atmosphere, "Z" is the Zenith distance of the sun.

Where τ → Transmission coefficient of the atmosphere
Z → Zenith distance of the sun (angular altitude)

Advantages:-

(1) very low power consumption (2) stability
(3) operates from a wide range of voltage supplies.

Applications:-

(1) scientific meteorological
(2) Observations of climate.
(3) Testing research of material.

Pyranometer:-

→ A type of actinometer used to measure irradiance of solar energy within the preferred location as well as flux density of solar radiation extends b/w 300 to 2800nm.

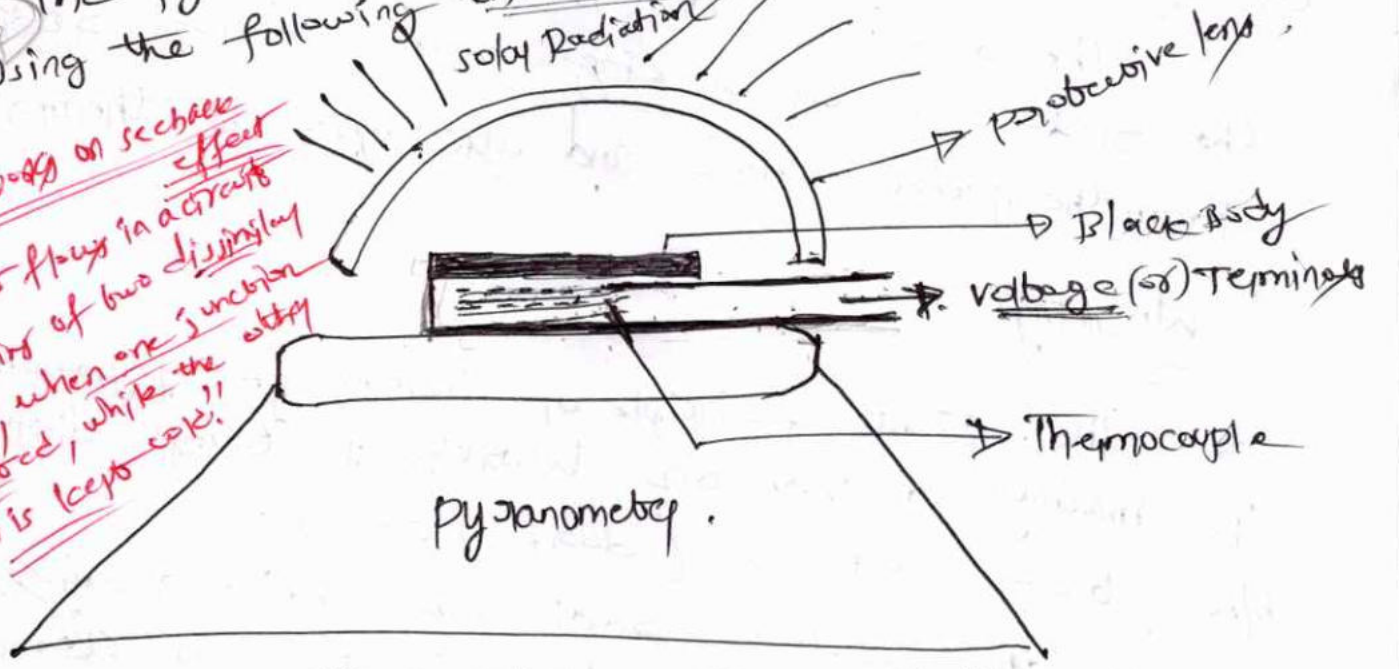
→ It is the combination of magnitude and direction of the flow of substance.

→ The SI units of irradiance are W/m^2.

→ usually, these are used in the fields of researches like climatological & weather monitoring.

construction:-

Using the following three components. the pyranometer design (or) construction can be done



* It works on seebeck effect
* A current flows in a circuit consisting of two dissimilar metals, when one junction is heated, while the other junction is kept cold.

① Thermopile ② Glass dome ③ occulbation.

① Thermopile:-

→ As the name implies, it uses a thermocouple used to notice dissimilarity in temp. b/w two surfaces. These are hot & cold accordingly.

→ The Labelled active surface is a black surface in photoshape and it is exposed to atmosphere.

② Glass dome:-

→ Glass dome in the pyranometer limits the response of spectral from 300nm to 2800nm from 180 degree 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 second dome will reduce the instrument offset.

③ occultation:-

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

Working:-

→ The first principle of working of pyranometer is mainly depends on working of temp. difference b/w two surfaces (dark & clear).

→ If the solar radiation which receive the from black surface to thermopile but in clear surface which is reproduce the heat then only at the condition Less heat is generated.

→ The main role of thermopile is used to measure the difference b/w the temp. of dark and clear surfaces.

→ finally to create potential difference (V) from the temp. gradients of two surfaces dark and clear

↓ hot body - cold body.
(or) dark surface - clear surface

→ pyranometer is used to measure sum of solar radiation but the voltage which generated from thermopile with the help of potentiometer to calculate it.

Types of pyranometer:-

1. Thermopile pyranometer
2. photodiode based "

Adv & Disadv:-

→ The temp. coefficient is extremely small.
→ standardized to ISO standards.
→ Response time is longer compare to PV cell
→ Measurements of performance ratio & performance index are accurate.
→ 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.

Applications:-

→ PV systems design
→ the solar intensity data can be measured.
→ climatological & meteorological studies,
→ Locations of the green house can be established.

UNIT-2

680 (1)

SOLAR ENERGY COLLECTORS

Flat plate and concentrating collectors, classification of concentrating collectors, orientation and thermal analysis, advanced collectors. 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, photovoltaic Energy conversion, potential in India.

~~Solar thermal Energy collectors (or) collector :-~~

Actually Solar Energy is used into two ways.

1. solar thermal Energy
2. solar photovoltaic cells.

collector (or) solar thermal Energy collectors :-

A solar thermal Energy collector (or) solar collector is an Equipment in which the solar Energy is collected by observing a radiation in an observed and then transferring to a fluid. these are two types of collectors.

1. flat plate collectors (or) non-concentrating type collector (or) ~~Focusing type of collector~~
2. concentrating type collectors (or) focusing type of collectors.

A solar thermal collector (or) collector is a device which used to collecting solar radation from the sun and transfers the Energy for heating to fluid.

1

Solar collectors

Non-concentrating type
(Flat-plate collector)

(a) Liquid flat-plate collector
(b) flat-plate air-heating collector.

concentrating type

Focus type

Line Focus (one axis tracking)

(a) cylindrical parabolic concentrator
(b) Fixed mirror solar concentrator
(c) Linear Fresnel lens collector

Point Focus (two-axis tracking)

(a) paraboloidal dish collector
(b) Hemispherical bowl mirror concentrator
(c) circular fresnel lens etc.
(d) central tower receiver.

Non-focus type

(a) modified flat-plate collector.
(b) compound-parabolic concentrating (CPC) type

Any two explain in Exams

2

Comparison of concentrating and Non-concentrating types (Flat-plate Type) of solar collectors:-

The solar energy collector, with its associated absorber, is the essential component of any system for the conversion of solar radiation Energy into more useful form (i.e; heat (or) Electricity).

Flat plate (or) non-concentrating type solar collector	concentrating type (or) Focusing type solar collector
(1) It has no optical concentrator the collector area is Equal to the absorber area. The Efficiency is Low and the working fluid temp can raise upto 100c.	(1) Here is the area (i.e, concentrator) receiving the solar radiation is several times greater than the absorber area and efficiency is high. Mirrors and Lenses are used to concentrate the sunrays on collector and working fluid temp raise upto 500c.
(2) Here the temp. concentration is Low. and efficiency is Low	(2) Here the temp concentration is high. and it shows better efficiency than the flatplate type.

Flat plate collectors (or) Non-concentrating type collectors :-

(1m) Defination:-

" Flat plate collector is a heat exchanger device which convert the solar Energy into Heat Energy "

(or)

" It is a device which is used to collect the heat from solar radiation "

→ The main function of collector is to collect the heat from sun radiation.

→ We use the heat Energy for domestic purpose.

→ Flat plate collector is used for below 90°c.

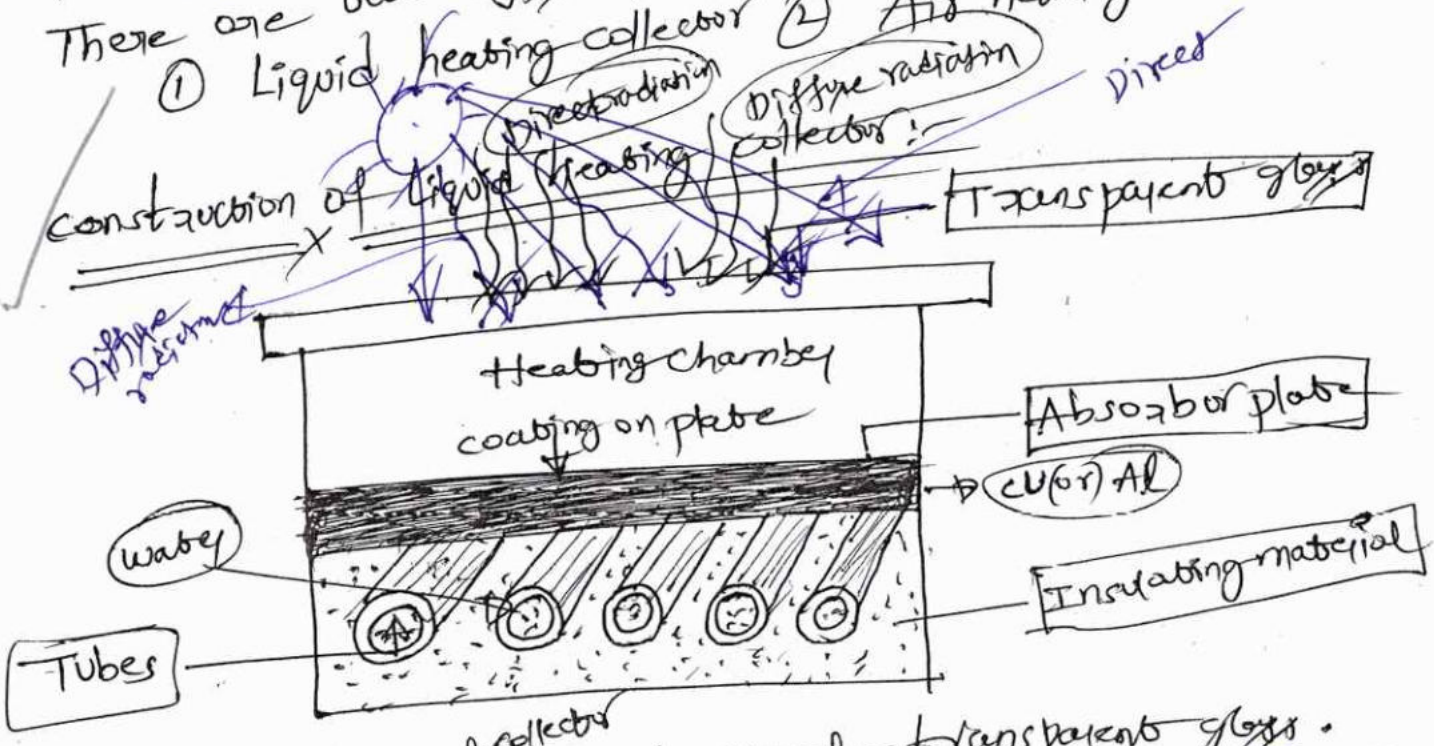
→ It has rectangular in shape
→ It absorbs both, direct and diffuse radiation.

Direct radiation:- when radiation of sun directly reaches to Earth known as direct radiation.

Diffuse radiation:- when radiation reaches to Earth i.e, scattered some part of its reflect back and some part of it transmits known as diffuse radiation.

There are two types of flat plate collector.
① Liquid heating collector ② Air heating collector.

construction of Liquid heating collector:-



→ outer surface of collector is made up of transparent glass.
It consists absorber plate is made up of copper (or) aluminum. (Cu (or) Al), and it is coated with Black color.
→ The main function of absorber plate is used to absorb the heat from sun radiation.
→ Tubes are attached with absorber plate consists of diameter 2cm. and these tubes are insulated by insulating material of foam, glass wool are used as insulating material.
→ The main function of insulation is to maintain the temp. around tubes.

Insulation is maintained at thickness of 5 to 10 cm. All components are arranged in rectangular container.

Working:-

→ From Sun the solar radiation receives the absorber plate which contains direct and diffuse radiation.

→ Temp. of absorber plate increases by absorbing the heat from radiation.

→ Since, absorber plate covered by transparent glass, that's why heat stored in heating chamber do not get heat outside.

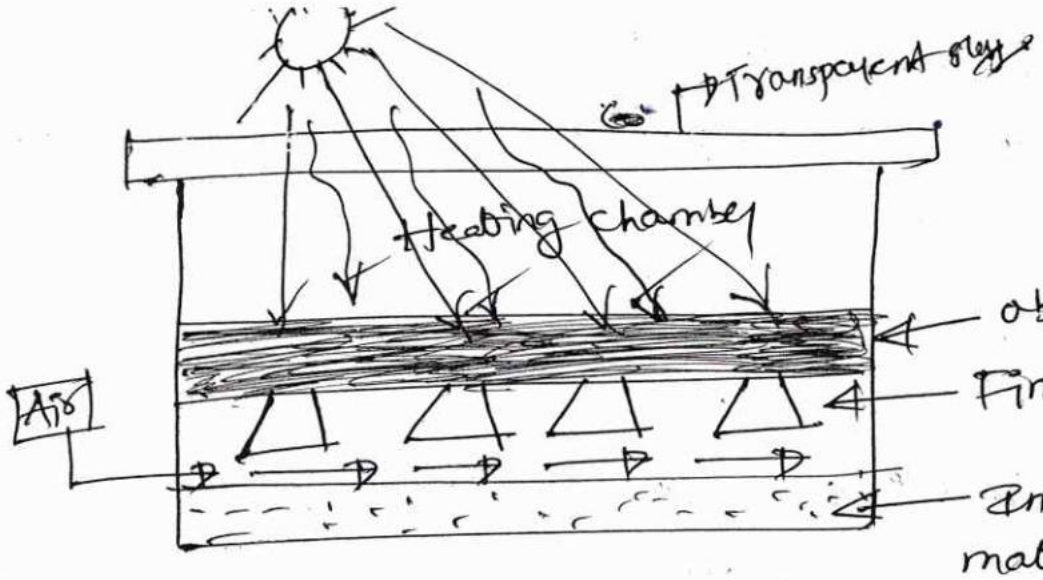
→ Insulation is also maintains the heat which does not desipiate outside

→ Tube is attached with absorb plate so tube will also heat. Liquid is stored to heat inside the hot tube and temp increases.

→ After that hot water is used for domestic purpose.

(2) Air heating collector:-

Almost working and construction is similar to the liquid heating collector. The main difference is that tubes are not attached with absorber plate instead of that Fins are used.



→ It is used to increase the contact area

→ As a insulation mineral wool is used which main to the heat and does not desipate outside.

Working:-

→ when direct and diffuse radiation directly incident on the absorbey plate. Then absorber plate absorb the radiation for that Fins is also attached then fins temp increases.

→ when air flow along fins air is heated due to high temp and we uses that hot air for general purpose.

There are two type of Air heating collector

① porous type ② non-porous type.

→ It has Absorbey plate
→ Air heated by flowing with porous absorbey plate

→ It has non-porous Absorbey plate
→ Air will not flow with absorbey plate

Applications of solar air heater:-

(1) Heating buildings (2) Drying agricultural produce and Lumber (3) Heating green house (4) Air conditioning buildings. (5) solar cooking (6) solar drying (7) Solar heating

Advantages of Flat plate collectors:-

(1) Flat plat collectors use both beam (or) direct and diffuse radiation
(2) They do not require orientation towards the Sun.
(3) They require Little maintenance.
(4) They are simple than the concentrating reflectors, absorbing surfaces and orientation devices of focusing collectors.

Concentrating collectors:-

(A) → Concave reflecting surface (shaped mirrors (or) Lenses)
→ Here collector area is receives highy radiation and it is several times greater than the absorber area.
→ Concentrating collectors are preferred when high temperatures around 150°C to 300°C are required. and working fluid can be raise upto 500°C.
→ Higher temperatures can be achieved by collecting more amount of solar Energy on a smaller area.
→ This can be achieved by using reflecting mirrors (or) a refracting arrangements of Lenses.
→ The purpose of using concentrating collectors are given below → To increase Energy delivery temp
→ To reduce the cost.

→ provides a high temp than flat plate collectors.

→ concentrating Energy

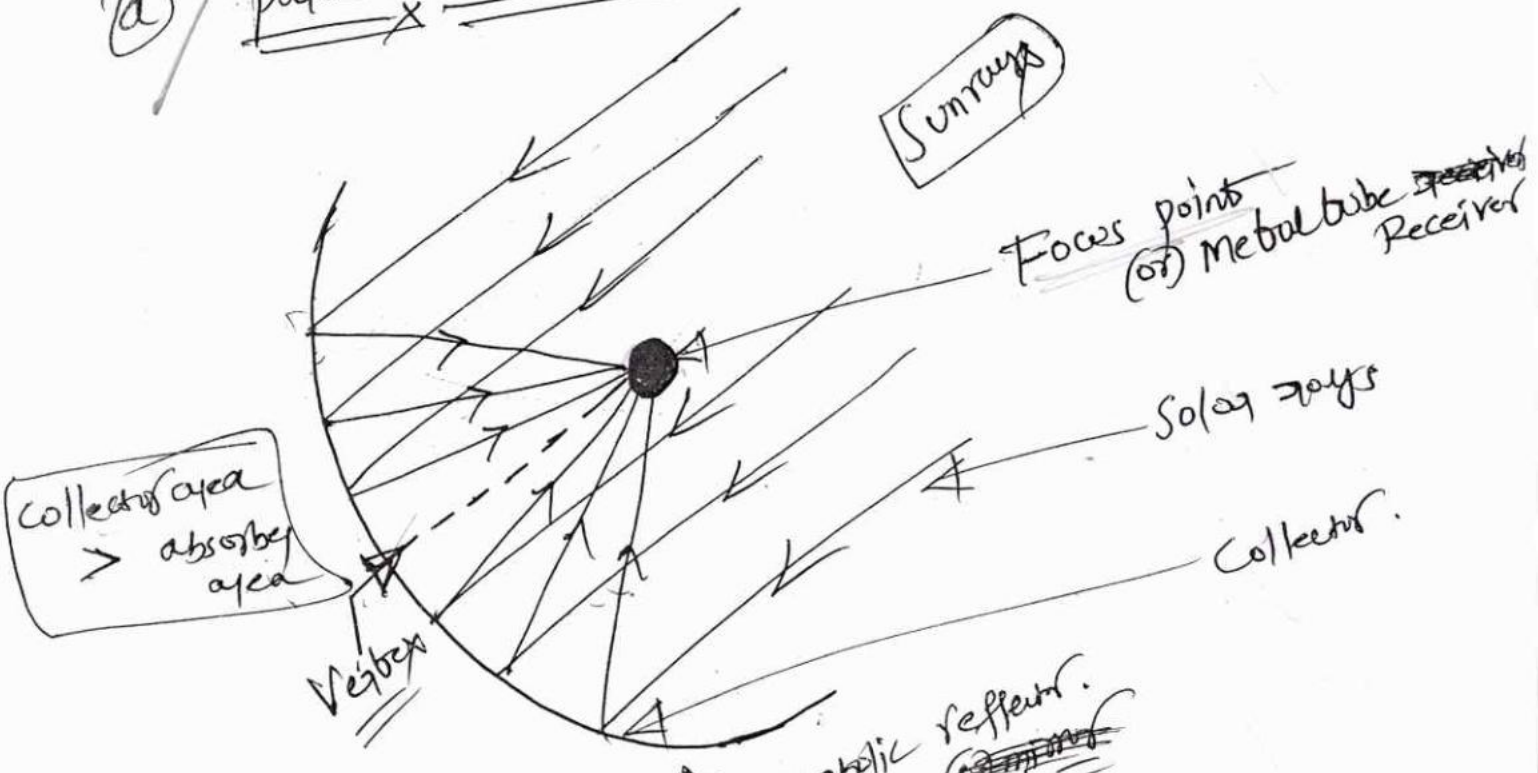
focus type
* on a point focus high to very high temp
* on a Line focus moderate to high temp
* Non focusing - Low to moderate temp

concentrating collectors are classified into two types ① Focus type ② Non-Focus type

① Focus type
   (i) Line focus (ii) point focus.

(i) Line focus:- (one axis tracking).

(a) parabolic trough concentrator (or) parabolic reflector.



construction and working:-

It consists of cylindrical parabolic trough reflector (or) collector and a metal tube receiver at its

focal line.

→ The receiver tube is Blackend at the outside surface to increase the absorption and it is rotated about one axis. tracking.

→ The collector may be oriented any of 3 directions E-W, N-S, and polar.

→ The concentration ratio (C.R) is 5 to 30.

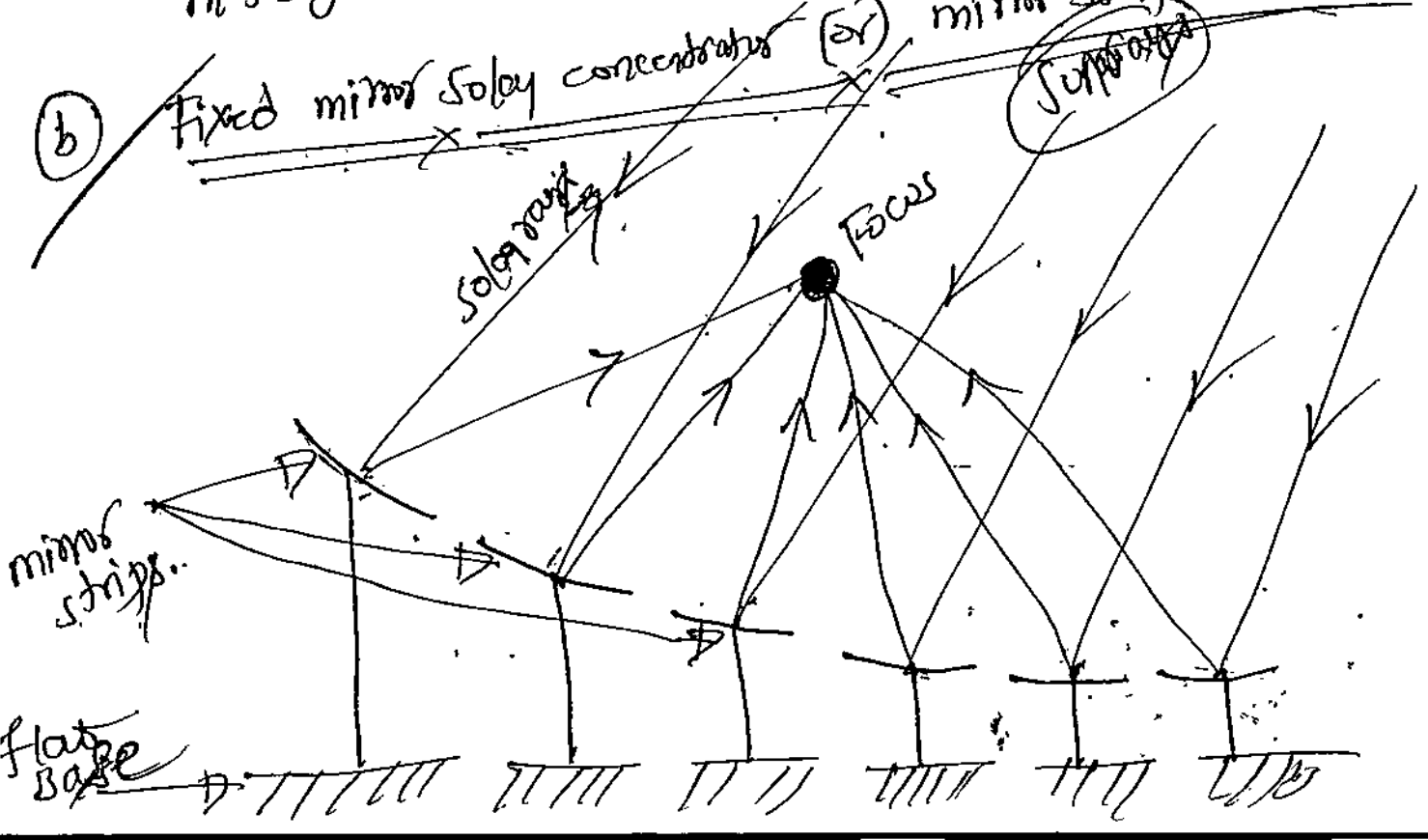
→ Its temp is very high. Its having high Intensity → It requires Less material as compared to flat plate collector.

→ Absorbey area is small compared to flat plate collector.

→ It is also Economical feasible.

→ It is used for Electric power generation. mostly used in Desert area.

(b) Fixed mirror Solay concentrator (or) mirror strip reflector:

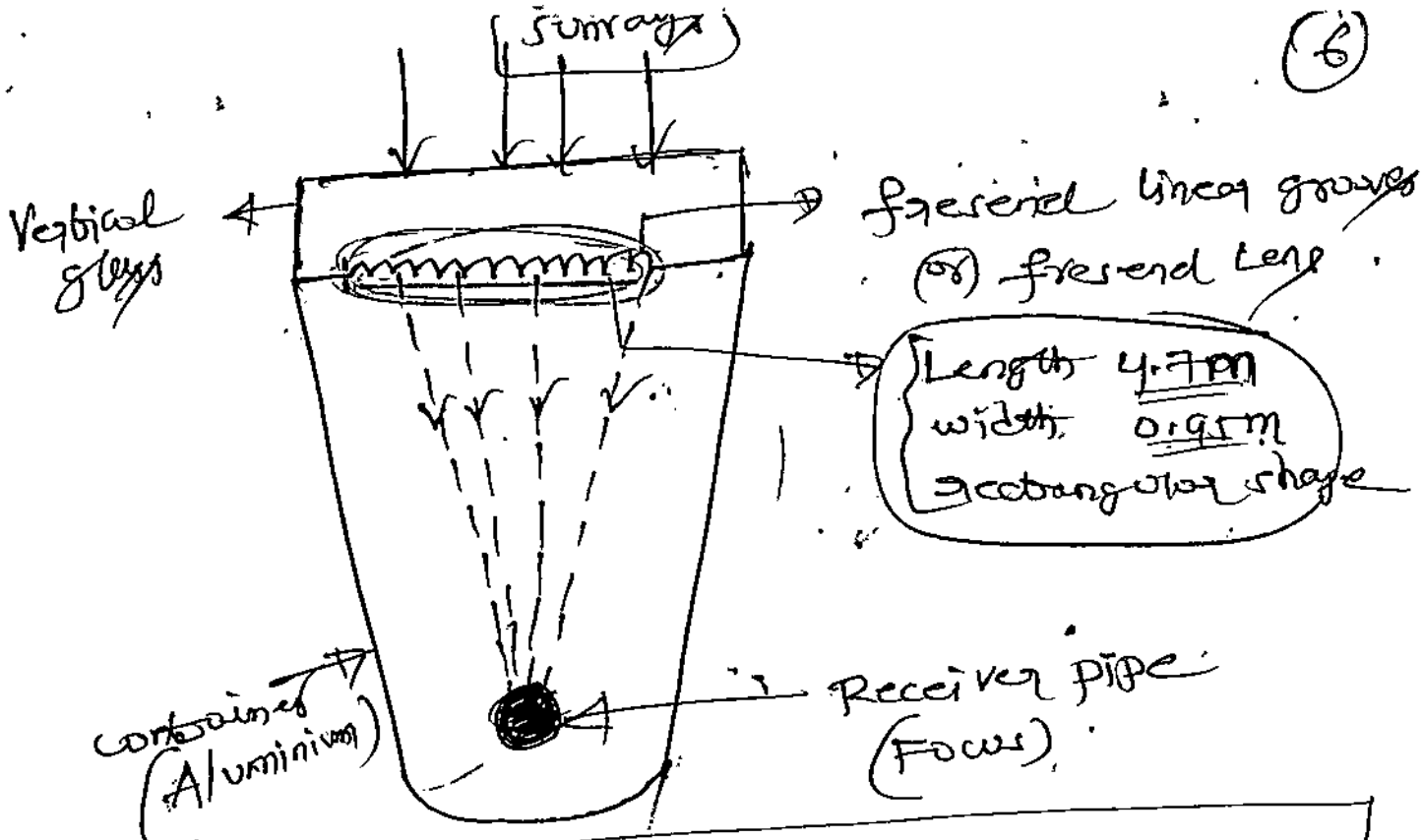


→ It is of similar type of parabolic reflector.
→ Here the solar rays which is Incident on the mirror strips separately which is in the concave shape.
→ This mirror strips are supported by the flat Base.
→ Whenever the solar rays is incident on the mirror strips. they are in a separate position they generate more reflection and absorbs more heat by focus point. It is to be of Black coated type
→ It is to be of one axis tracking.
Here the concentration ratio (CR) is increased when compared to parabolic reflector because of attached with mirror strips

Uses:-
(1) It is used to generate Electric power generation by using heat energy.

(c) Fresnel Lens collector:-

Construction and Working:-
→ when the Sun rays falls on to the Vertical gl
than heat is stored in it and sent to
the Fresnel Lens grooves which is in the shape
of rectangular shape.



C.R → 10 to 30
Temp working fluid → 150 to 400°C

→ This fresenel are in ~~the shape of~~ made up of Aluminium consists of Length 4.7m and width 0.95m.

→ This whole thing should be kept with made up of container designed with Aluminium material

→ container is to be helps to maintains the temp in constant manner.

→ from fresenel Lens finally the ~~rays~~ heat is to be collected by Receiver pipe (or) focus point.

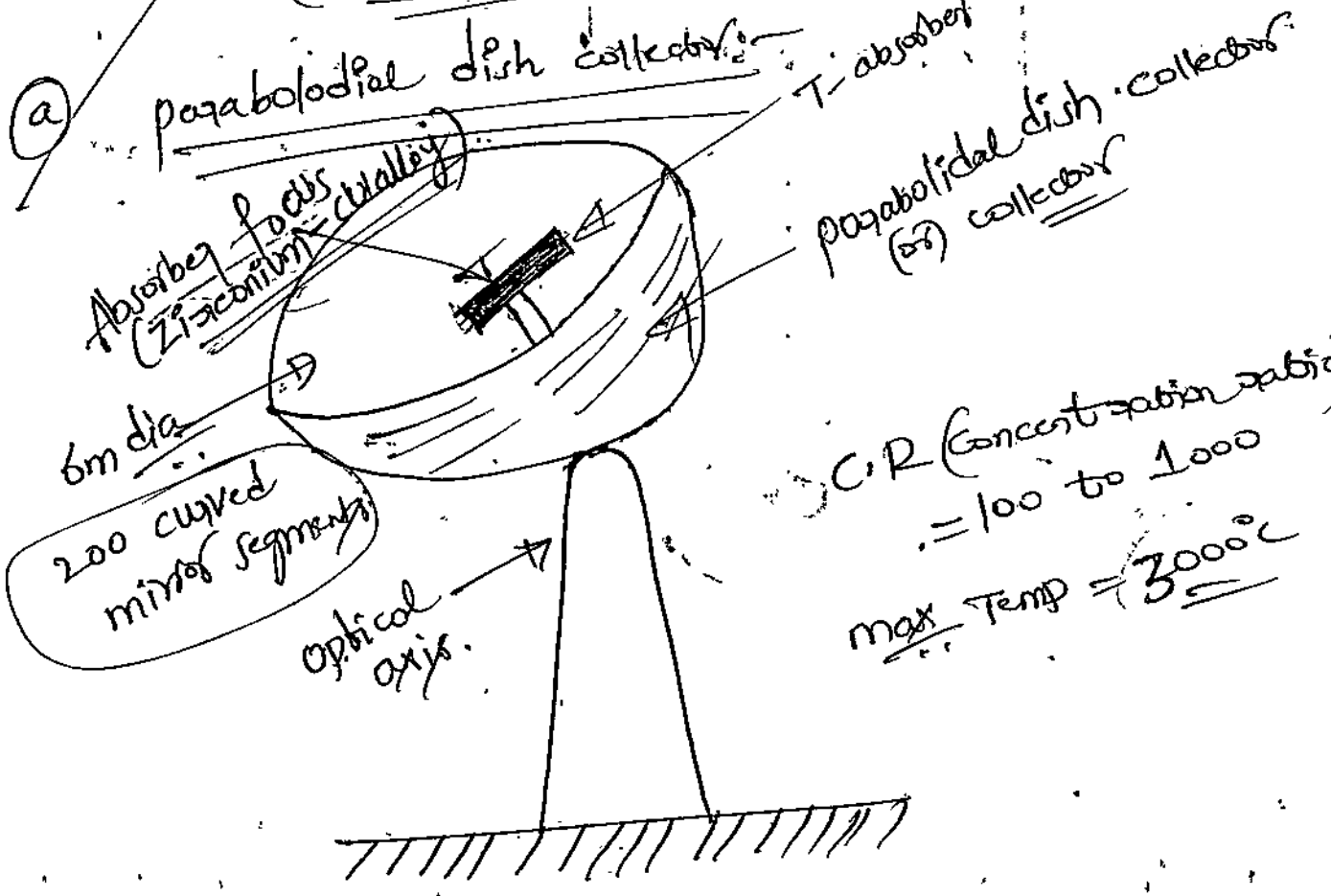
Advantages:-

→ ~~when~~ when compared to parabolic reflector and mirror strip reflector Here the concentration ratio (C.R) will be high i.e; 10-30.

→ Temp working fluid will be range in temp of 150c to 400c. → It is used to generate heat energy and finally converted to Electric power

(ii) point Focus:- (Two axis tracking).
(maximum high temp maximum working fluid)

(a) paraboloidal dish collector:



Construction and working:-

→ when a parabola is rotated about its optical axis, a paraboloidal surface is generated.

→ The combination of both (direct + Beam) radiations is focussed at a point in the paraboloidal surface

→ The concentration ratio (CR) range is from 100 to 1000 with a temp of 3000°C.

→ Here the collector requires two-axes tracking. Hence it requires more heat. The diameter of the collector is 6m to 7m → The dish can be turned automatically about two-axes i.e) up-down and Left-right.

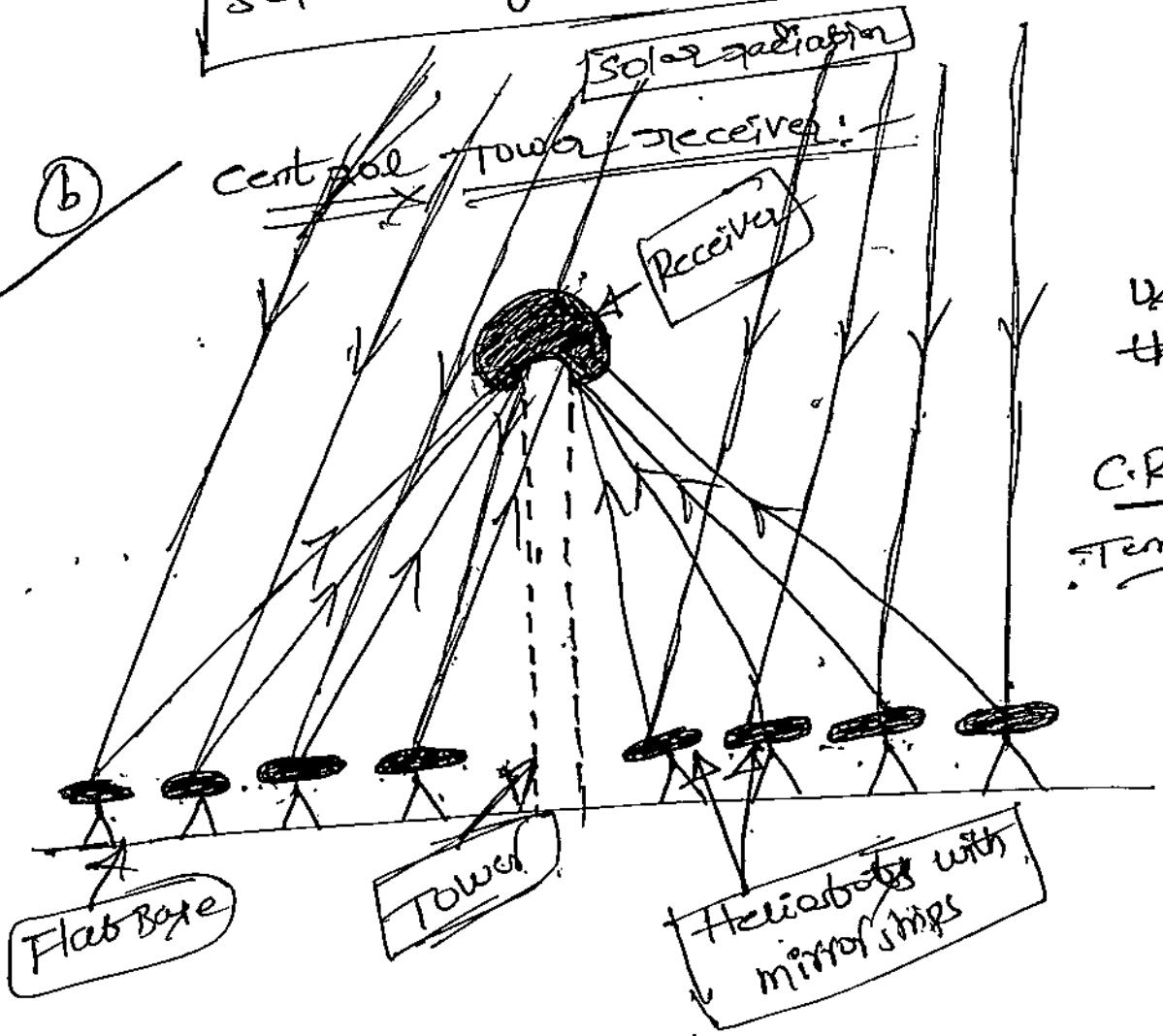
→ The sun is fully tracked at essentially all times.

→ The absorber located at the focus is made (7)
of a Zirconium-Cu alloy with a black chrome selec
coating.

→ The heat is transport and absorbed by th
absorber (or) focus point and this heat energ
is used and convert it into finally Electricity.

Solar Energy → Heat Energy → Electrical Energy

(b) Central Tower receiver:



Used in S
thermal pow

C.R. = 3000

Temp = 500°

Construction and working:-

→ In a central tower receiver the receiver (
Focus point is located at the top of the tower
→ Beam radiation is reflected on it from a large
number of independently controlled, almost flat mirrors,
known as heliostats, spread over a large area
on the ground surrounding the tower.

→ Thousands of such type of heliostats receives the solar radiation and finally the receiver receives

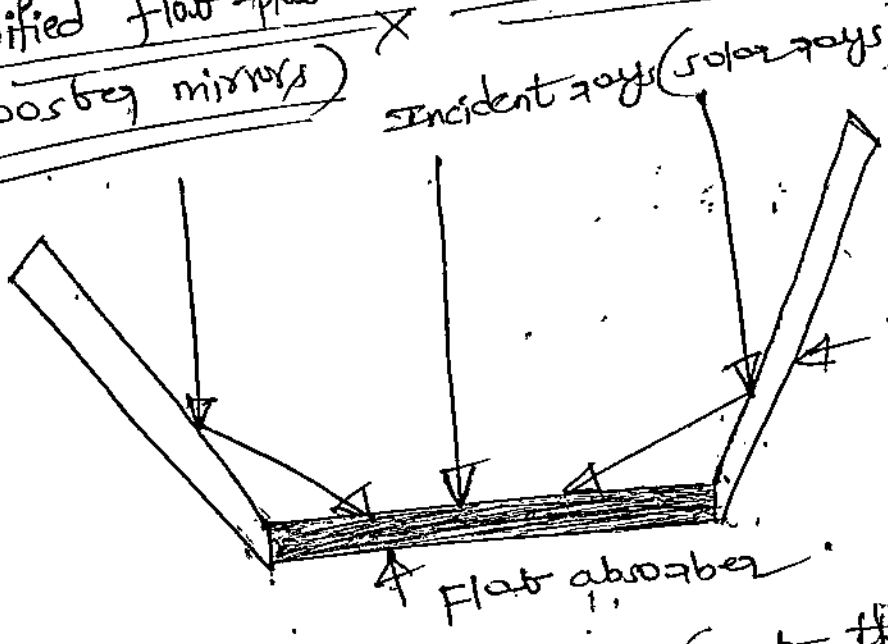
→ The CR is 3000 and temp can be raise up to 500°C.

→ The heat energy whatever we can absorbed and these can be delivered to generate power generation

→ It is used in thermal power plants.

(X) Non-focussing type collectors:

Modified flat-plate collector (flat-plate collector with Boosted mirrors)



CR → 4 (very low)
temp → very less

→ By providing plane reflectors at the edges of a flat-plate collector to reflect additional radiation into the receiver, the concentration of solar radiation can be increased. → These mirrors are also called booster mirrors.

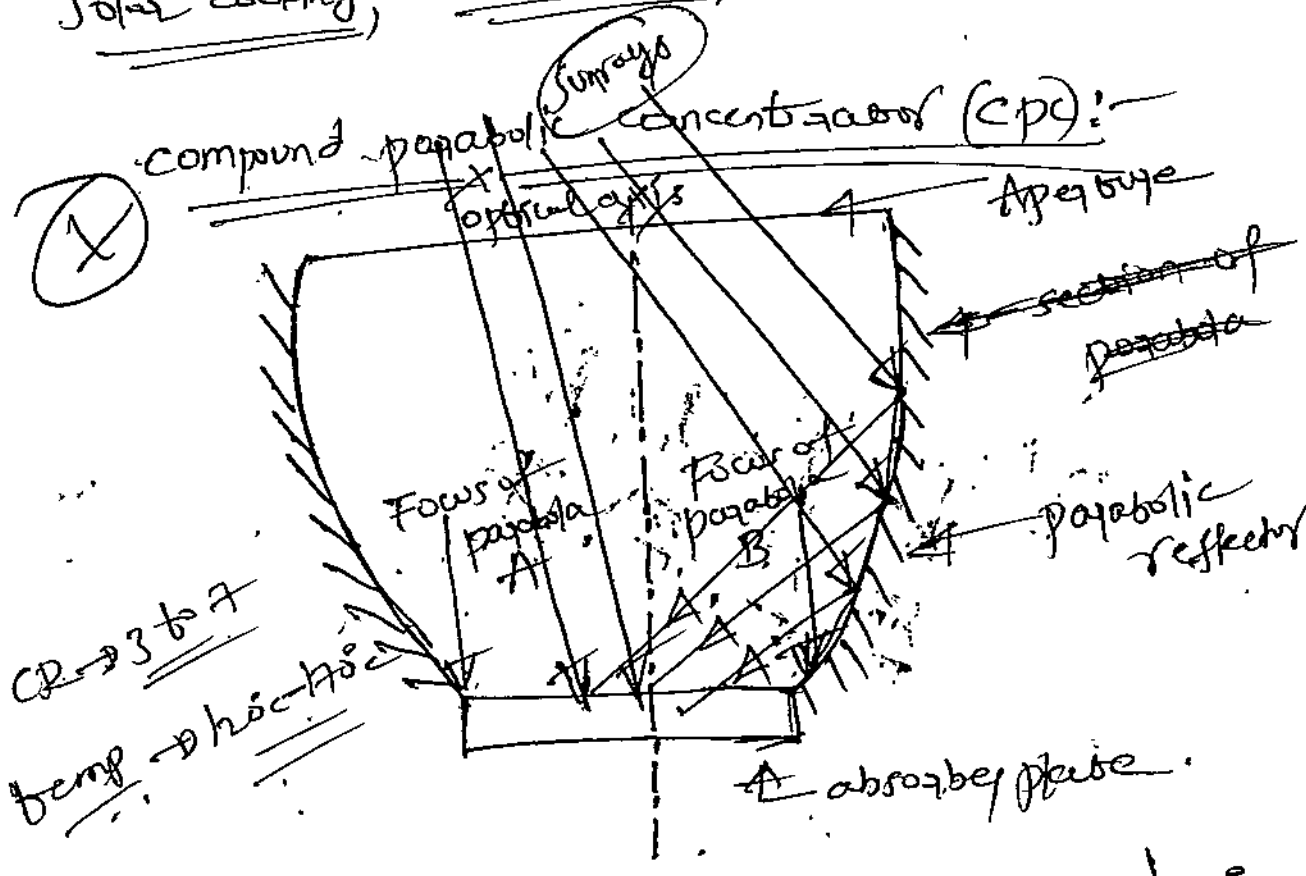
→ The concentration ratio (CR) of these concentrators has a maximum value of 4.

→ This can be arranged in the East-West direction to provide and get Beam radiation

→ This type are not much used.

→ These are used in for domestic purpose such as Solar cooking, solar drying, solar heating etc.

(1) Compound parabolic concentrator (CPC):-



→ A compound parabolic concentrator is having two mirror segments (or) two parabolic reflectors which is attached to a flat receiver (or) absorber plate.

→ The Sunrays (or) Beam radiation fall on to the two mirror segments and oriented and finally the receiver

→ Here the it having large acceptance angle and need to adjust Easily.

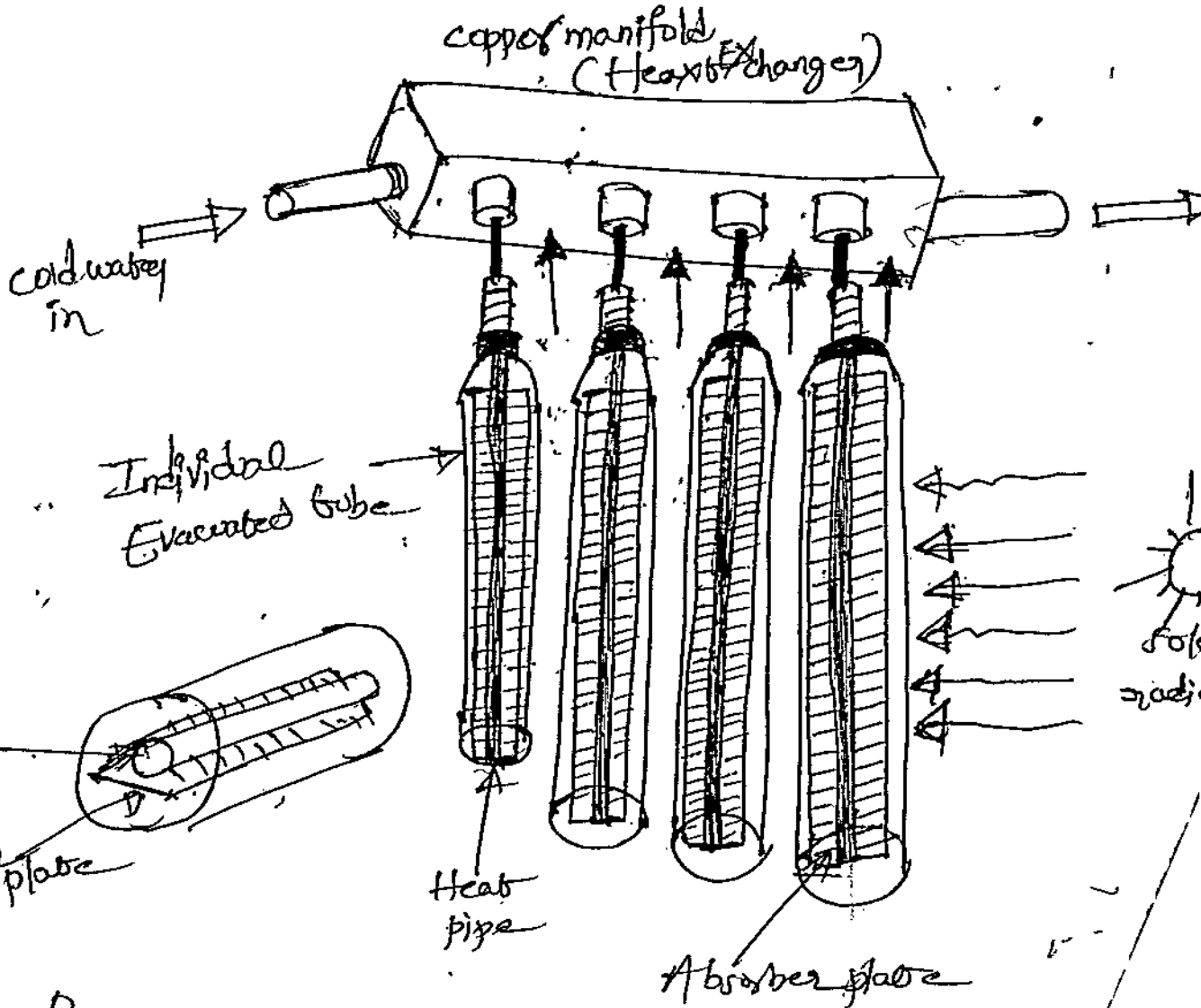
→ Here the CR (Concentration ratio) is range 3-7. Here the working temp is 120°-170°C.

Uses:-

→ It also used for domestic purposes. i.e.) Solar cooking, Solar heating, Solar drying, Heating buildings, ~~etc~~ green house buildings.

Advanced Solar Collectors:-

Evacuated Tubular collectors :-



In previous type of solar collectors or having some of the losses and some of the problems those to rectify losses some of the development and to improve the efficiency. to use advanced solar collectors.

n that one is Evacuated solar collec
e Evacuated means Insulat

Construction:-

→ In Evacuated solar collector Evacuated means Vaccum which acts as an Insulator.

→ copper manifold (Heat Exchanger) it is the function that water fluid flows, from inlet to outlets. From inlet cold water flows. and in outlet Hot water EXIT.

→ In Bottom Evacuated tubular collector consists of no. of rows of parallel transparent glass connected with Header pipe used in place of Blackend heat type of absorber plate.

→ The glass tubes which is made up of Borosilicate glass are in cylindrical shape therefore the solar rays which are Incident in each other Even the heat is stored at Late Evening and forenoon also.

→ when solar radiation Incident on Evacuated tube which acts as an Insulator then heatpipe with Absorber plate absorbs the heat and directly passes to Heat Exchanger

→ Here the cold water Exchanges finally to collect Hot water out.

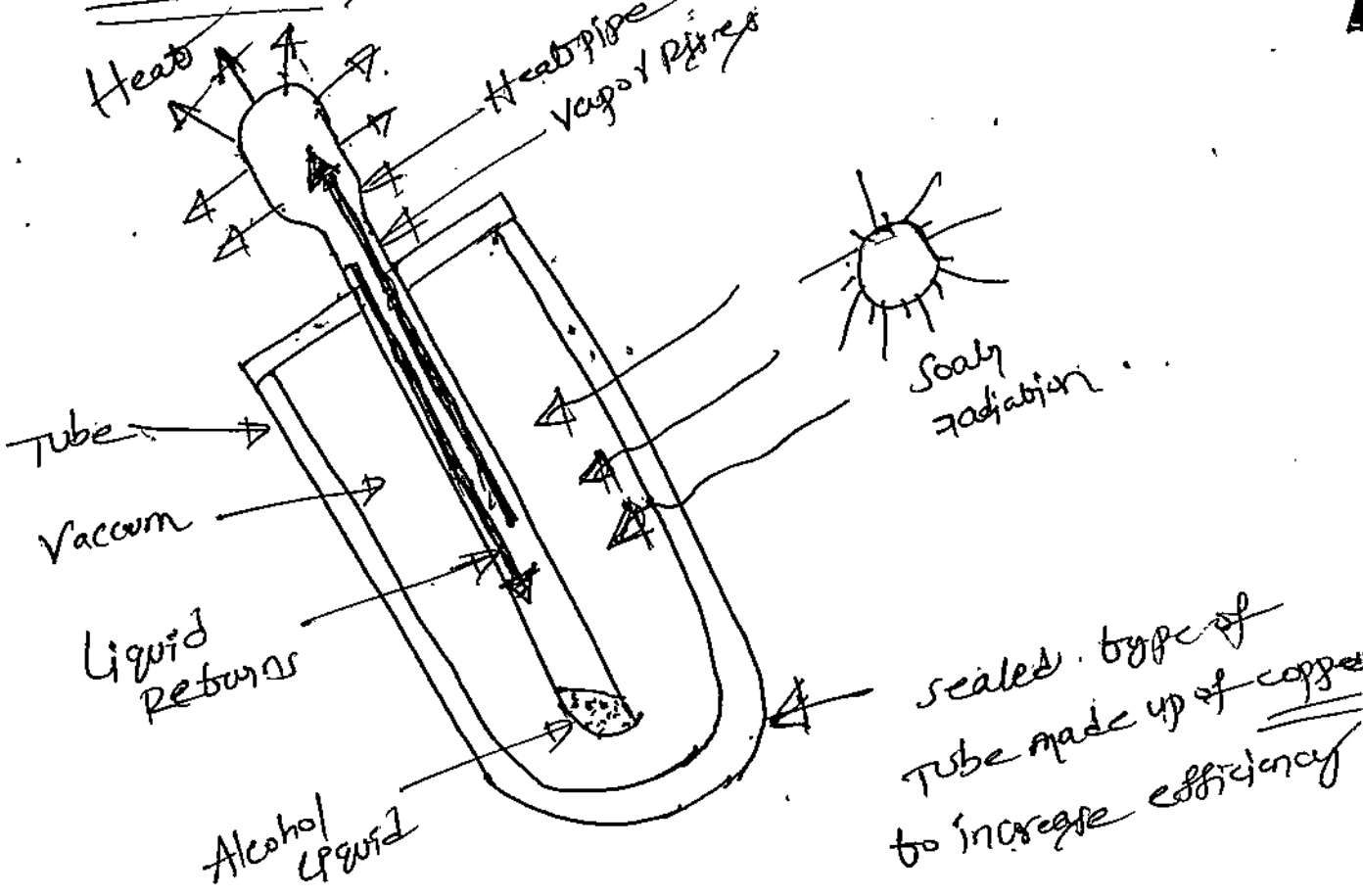
→ when compared to flat plate collector it produce high temperatures of 150°C

There are two types of Evacuated tubular collector

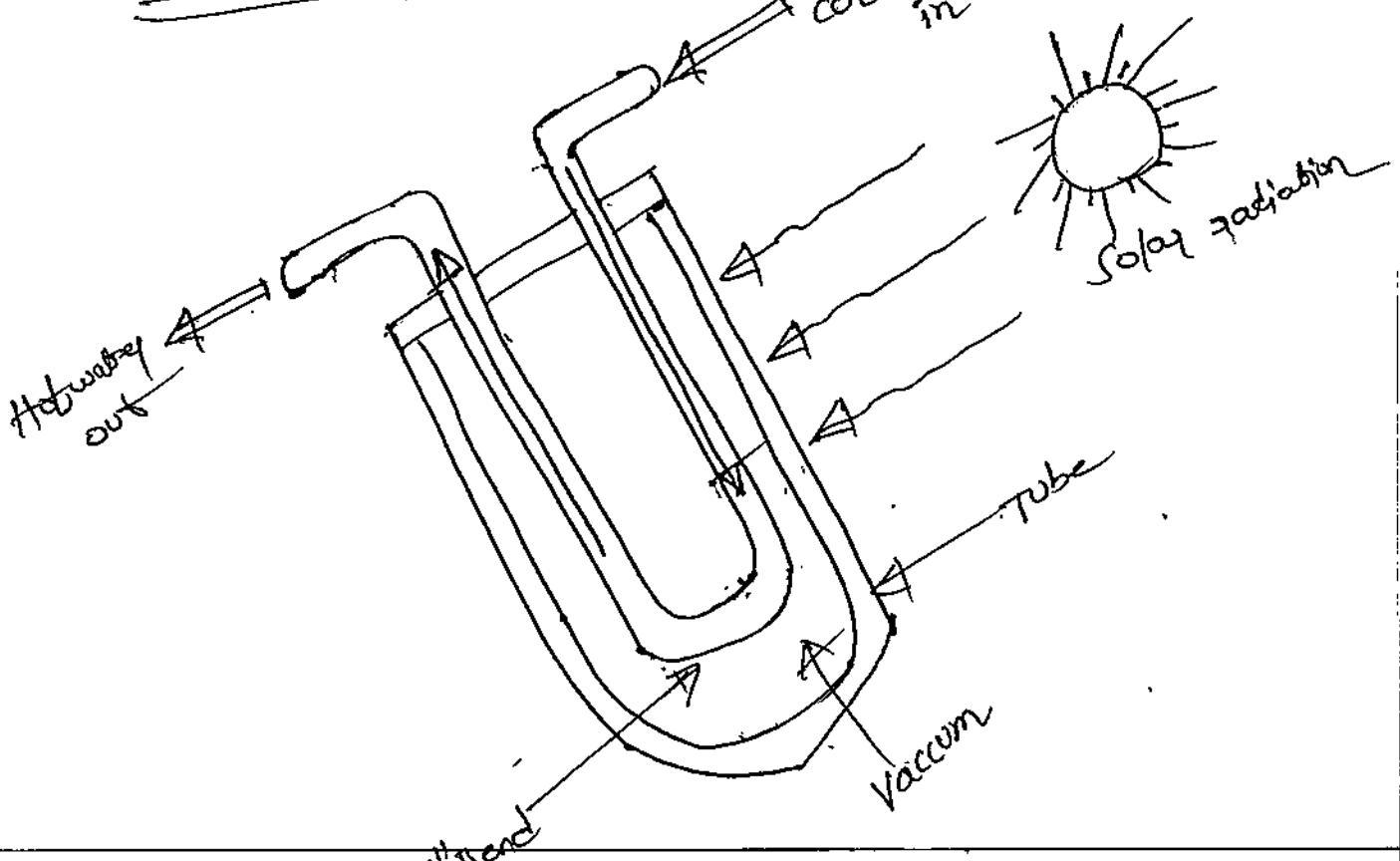
(1) Heat pipe Evacuated

(2) Direct flow Evacuated.

Heat pipe Evacuated Tube collectors:-



Direct Flow Evacuated Tube collectors:-



Advantages and Disadvantages of Evacuated Tube collectors:-

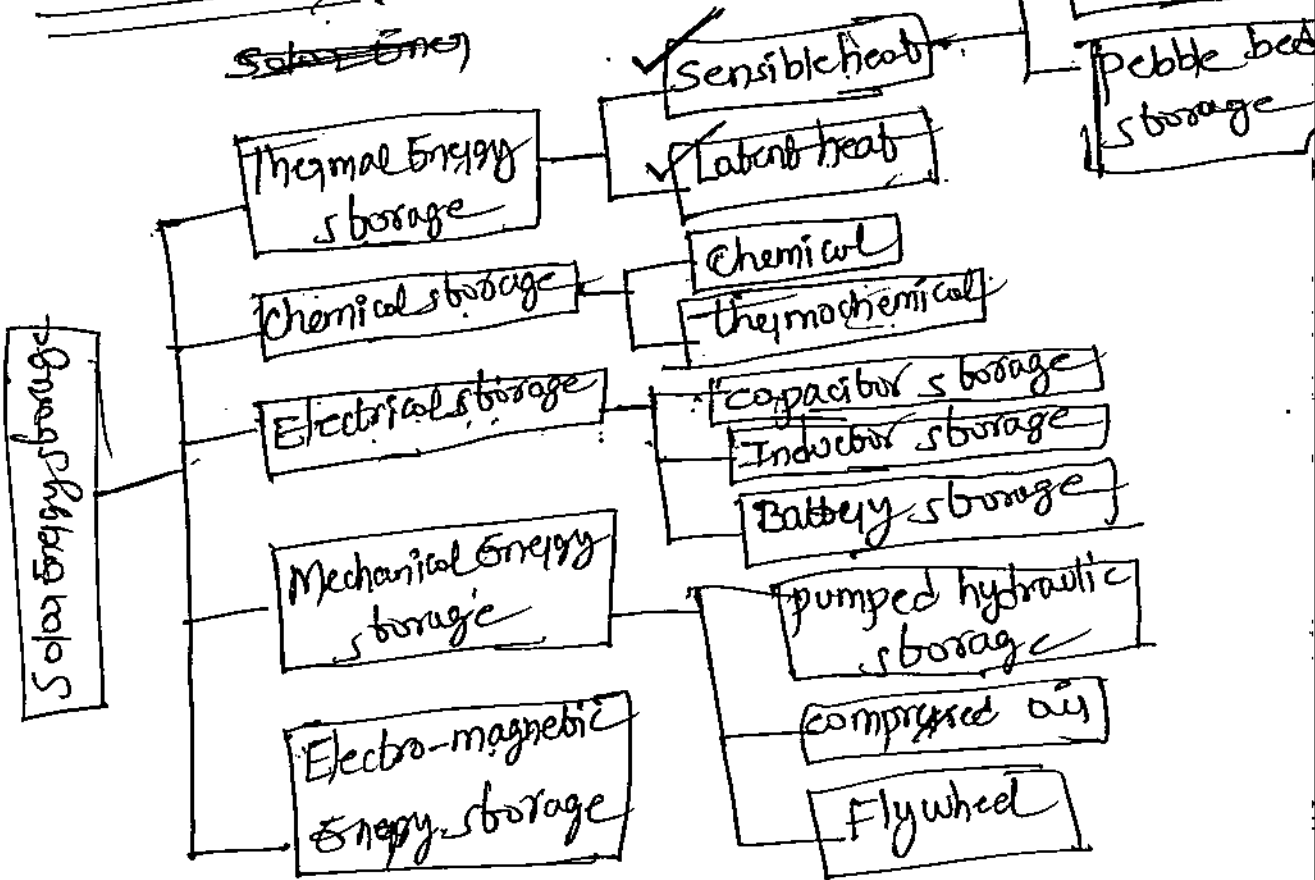
Advantages:-

- Achieves a high efficiency with Large temperatures.
- Supports space heating
- Achieves higher temp.
- Low weight system.

Disadvantages:-

- more Expensive system.
- more susceptible to breaking in domestic use
- Cannot be mounted horizontally, must have a slope of 25°C.

Solar Energy storage ~~and Applications~~



Diff b/w sensible and latent heat:-

Sensible heat:-

"It is the amount of heat which Required for increasing the temperature of the Body without change in phase"

(or)

Simply sense the heat

Ex:-

(Here heat can be (A))

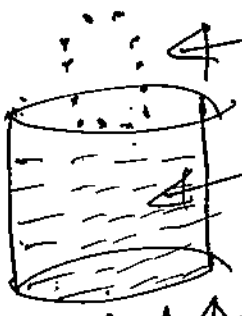
↑↑↑↑ By applying heat

Latent heat:-

"It is the amount of heat which required for changing phase of the body without change in temperature"

Ex:- Like solid into liquid (or) Liquid into Vapour

Ex:-



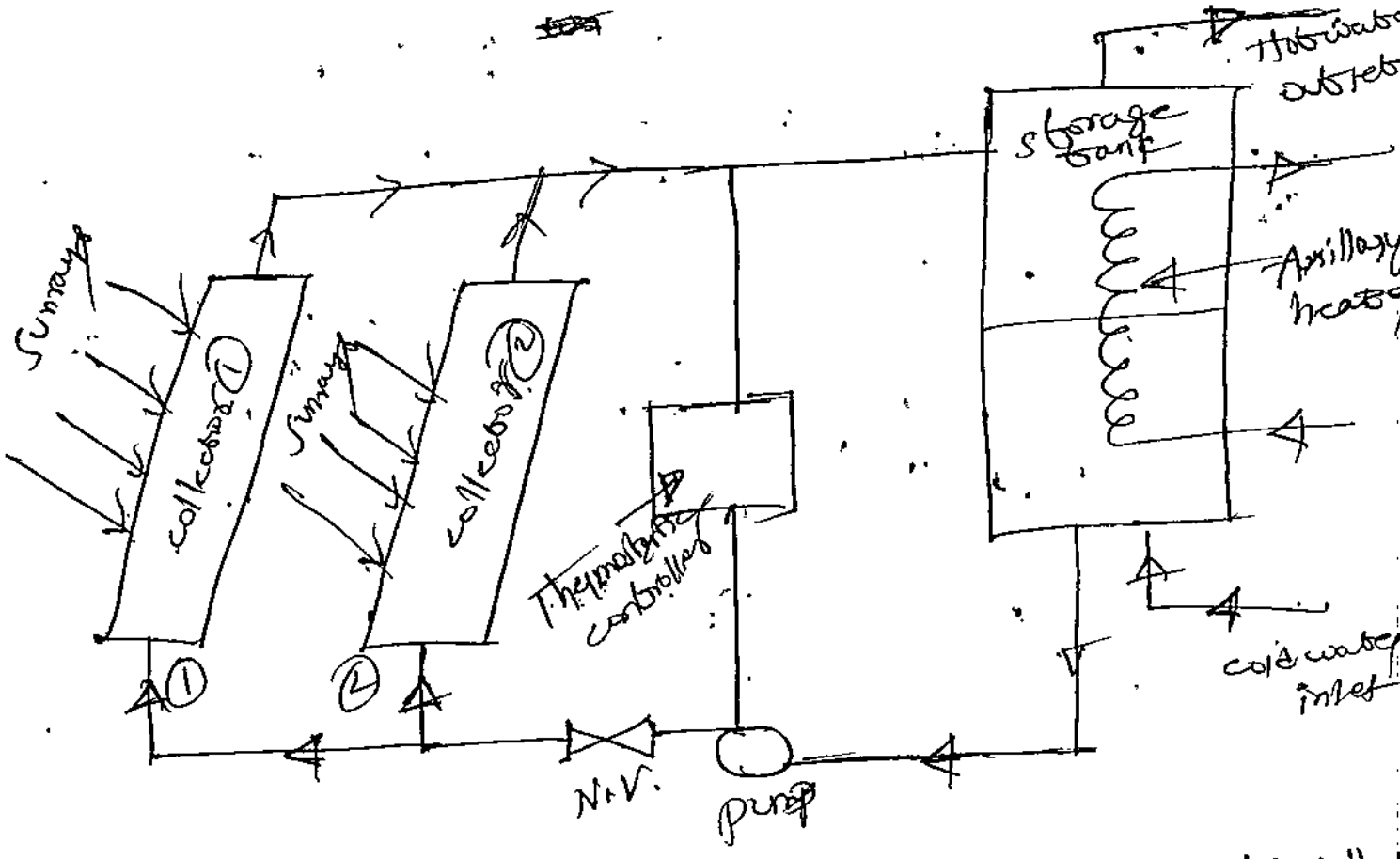
↑↑↑↑ By applying heat

→ 1500 units of Electricity saves every year

Applications:-

① Used in House purposes.

② Forced circulation solar water heater:-



→ The solar energy collector from solar water collected with water then at the time thermostatic controller will exceeds temp more and finally send to storage bank

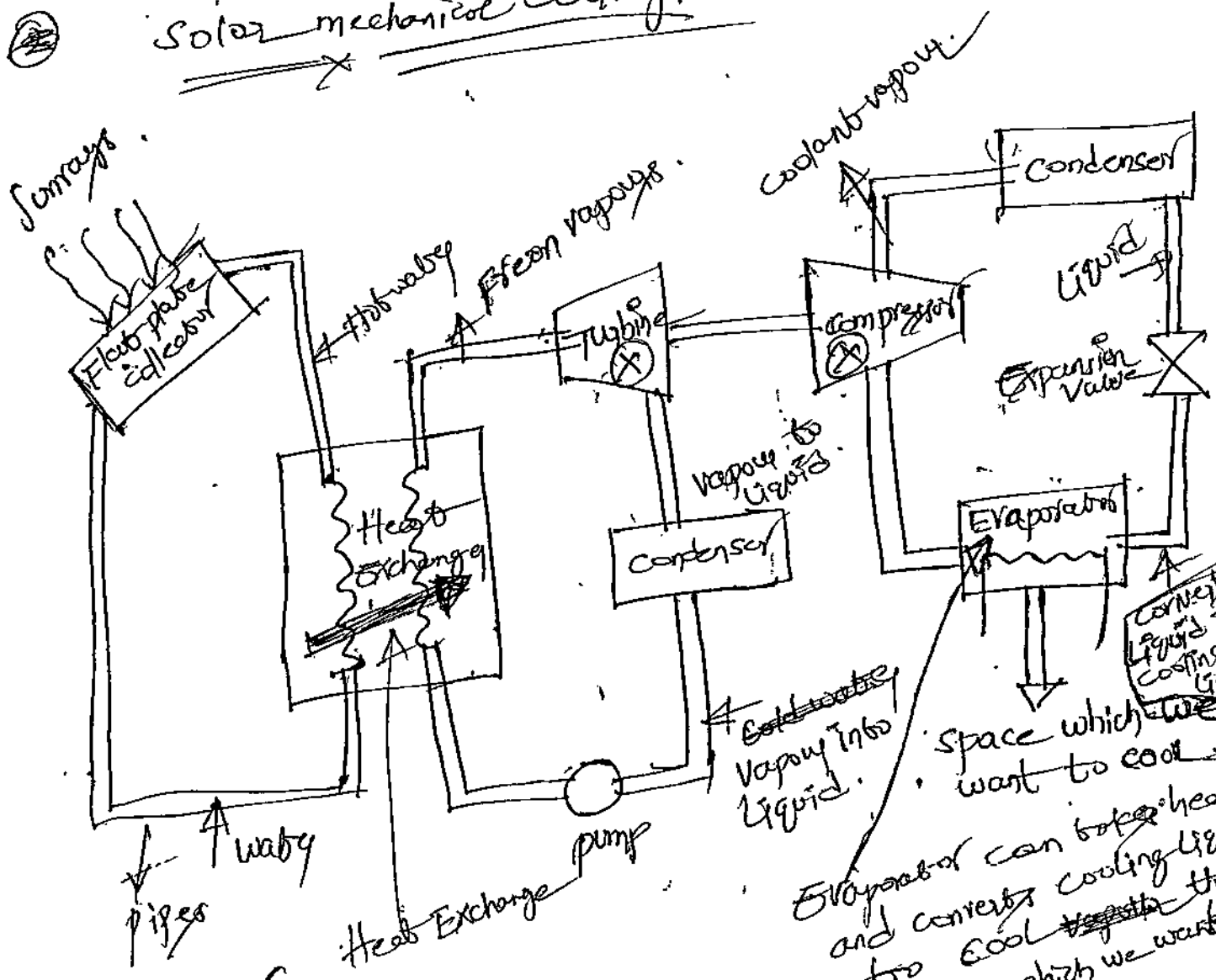
→ pay back period is 3-4 years and Life time is 15-20 years.

→ capacity is 10,000 Litres and saves the 30,000 units of Electricity per year.

Applications:-

① Used in Industries, Hospitals etc.

(2) Solar mechanical cooling:-



(3) Solar distillation (or) Solar still:-

→ Portable (or) fresh water is one of the fundamental necessities of life for a man. Industries and agriculture also require fresh water without which they cannot survive.

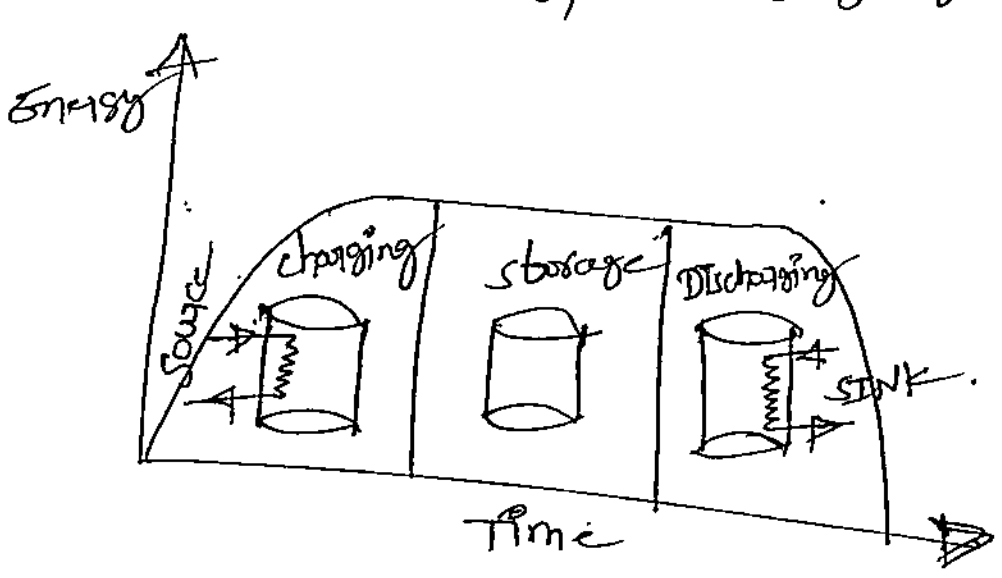
→ man has been dependent on rivers, lakes and underground water resources to fulfill this need of fresh water.

Thermal Energy storage:-

→ Thermal Energy is charged while the Energy source is available. After a short or long term storage the Energy is discharged when the source is not available.

→ In a thermal Energy storage (TES) unit, the charging, storage, and discharging processes repeat consecutively in a cyclic manner.

→ A typical charging/discharging cycle of a TES unit



→ If the charging is happens because of Electrical Energy is called Electrical storage. If the charging is happens because of solar Energy is called solar storage.

Solar Thermal Energy storage:-

→ It is nothing but collecting and storing the solar Energy in the form of heat and it is uses for Later use.

The various thermal Energy storage technologies are:

1. (1) sensible Thermal Energy storage
   (2) Latent thermal Energy storage.

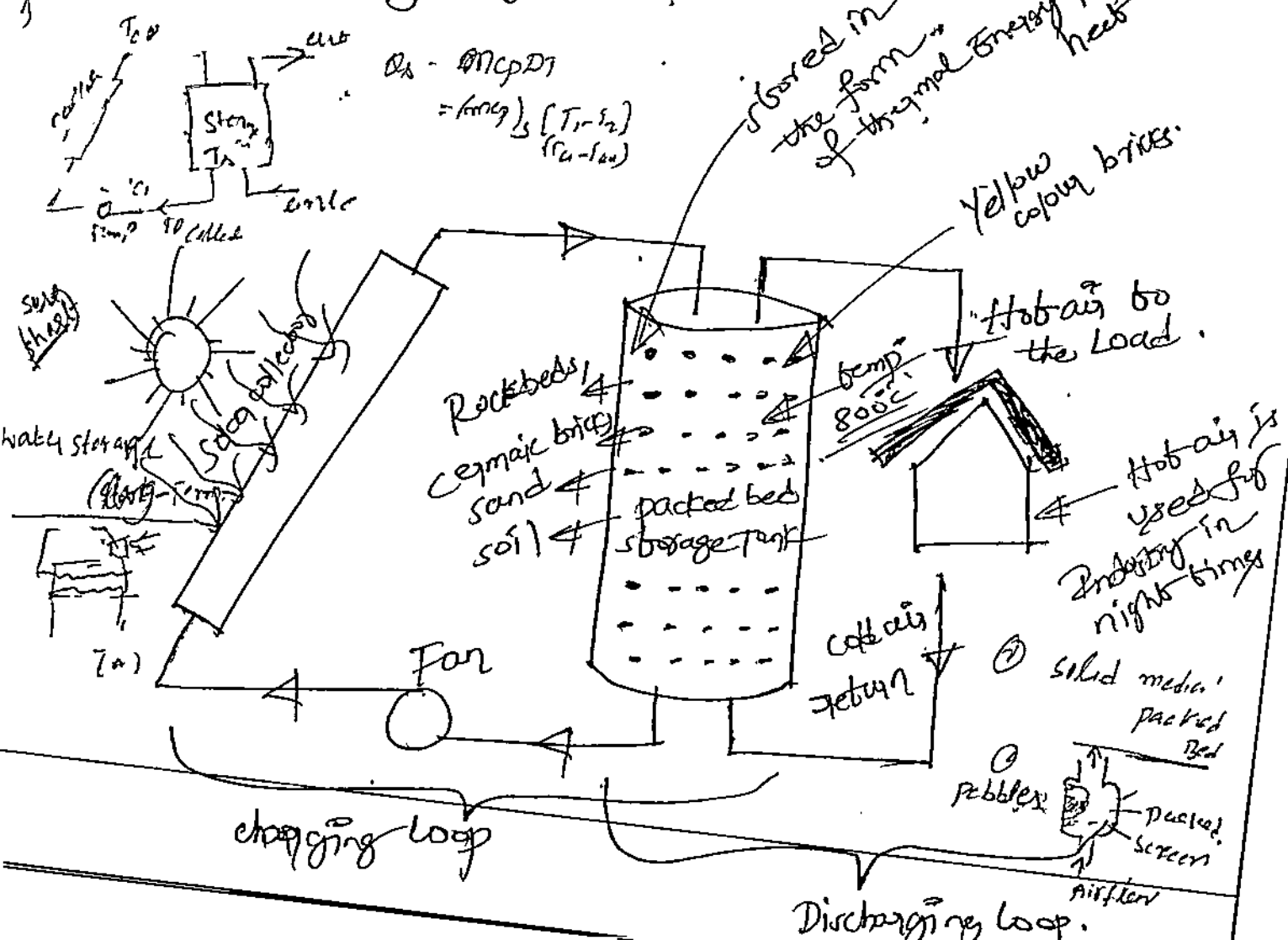
① Sensible heat thermal Energy storage: (SHTES)

→ sensible heat storage means shifting the temp. of a storage medium without phase change.

→ Rock beds, ceramic bricks, sand and soil are the solid storage mediums mostly used in SHTES systems.

→ The temp of the solid storage medium can reach up to 800°C.

→ In this system, the hot air from the collector passes through the narrow gaps b/w the solid particles (e.g., rock (or) sand), and the temp of the solid medium increases during daytime.

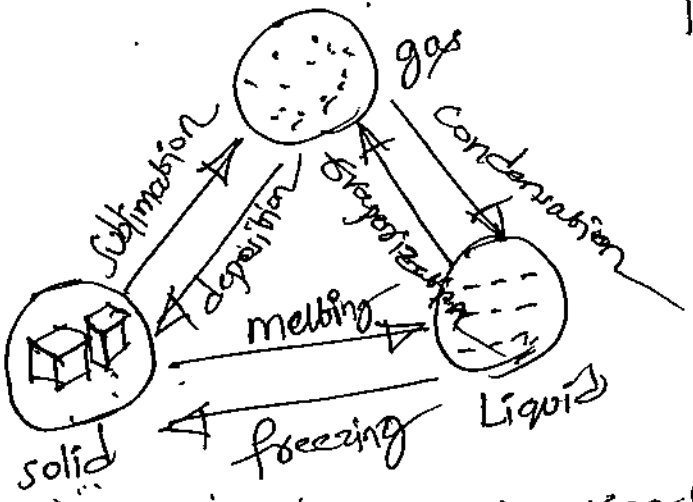


→ the stored sensible energy inside the tank is circulating the discharge loop during night time.

(2) Latent Heat Thermal Energy storage: (LHTES)

↳ Here temp not changed phase changed.

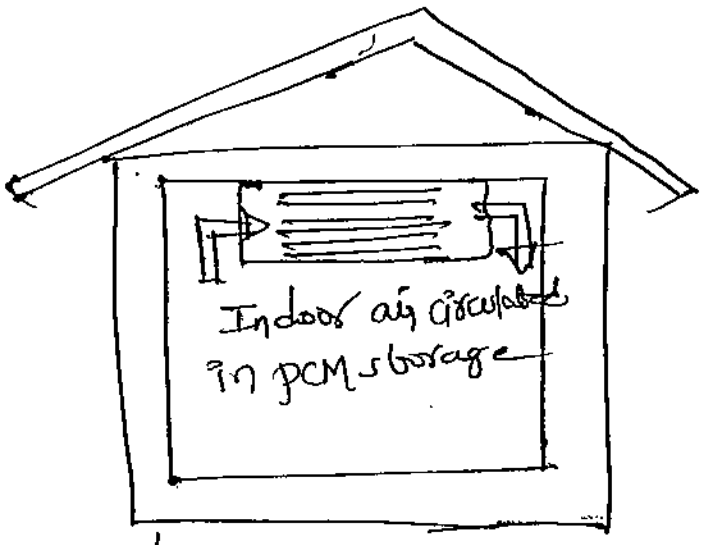
(Na2SO4, 10H2O)
1) Sodium sulphate decahydrate
2) Calcium chloride hexahydrate ($CaCl_2 6H_2O$)



→ In LHTES units, during heating (or) cooling process, the storage medium undergoes a phase change (solidification (or) melting), therefore the storage medium of an LHTES unit is also known as phase change Material (PCM)

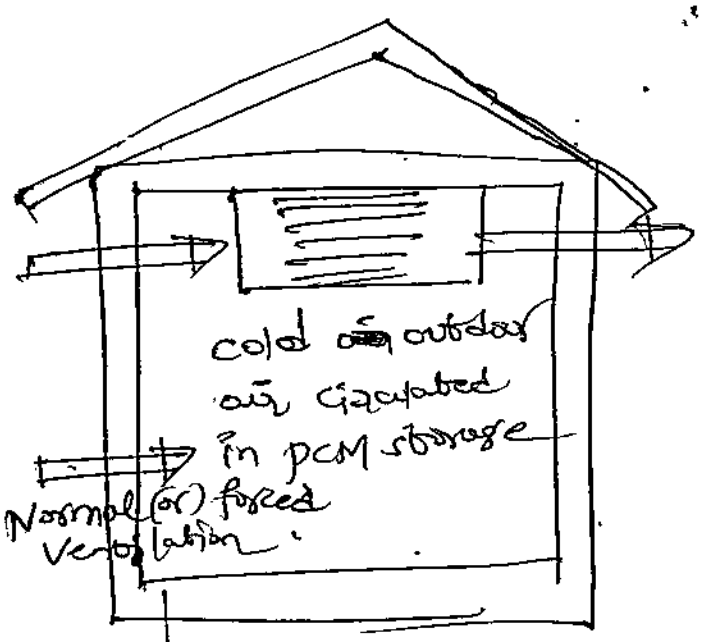
→ PCMs are used as potential latent heat thermal Energy storage (LHTES) technology because of its high Energy storage and isothermal storage process.

→ changing the phase of the material from a solid to liquid absorbs thermal Energy, and reverse process releases thermal Energy.



(a) Discharging process

Hot → cold
solid → liquid



(b) Charging process

cold → hot
liquid → solid.

Discharging process: (solid to liquid) (heat absorbs)
(hot absorbs to cold)
indoor air

→ This occurs during the day when the solid PCM absorbs the hot indoor air.

→ The temp of the indoor air is reduced as it conveys to the cold air.

→ This cooled air is circulated to the interior of the building.

Charging process: (Liquid to solid) (heat release)

→ This occurs during the night when the outdoor air temp is lower than room temp.

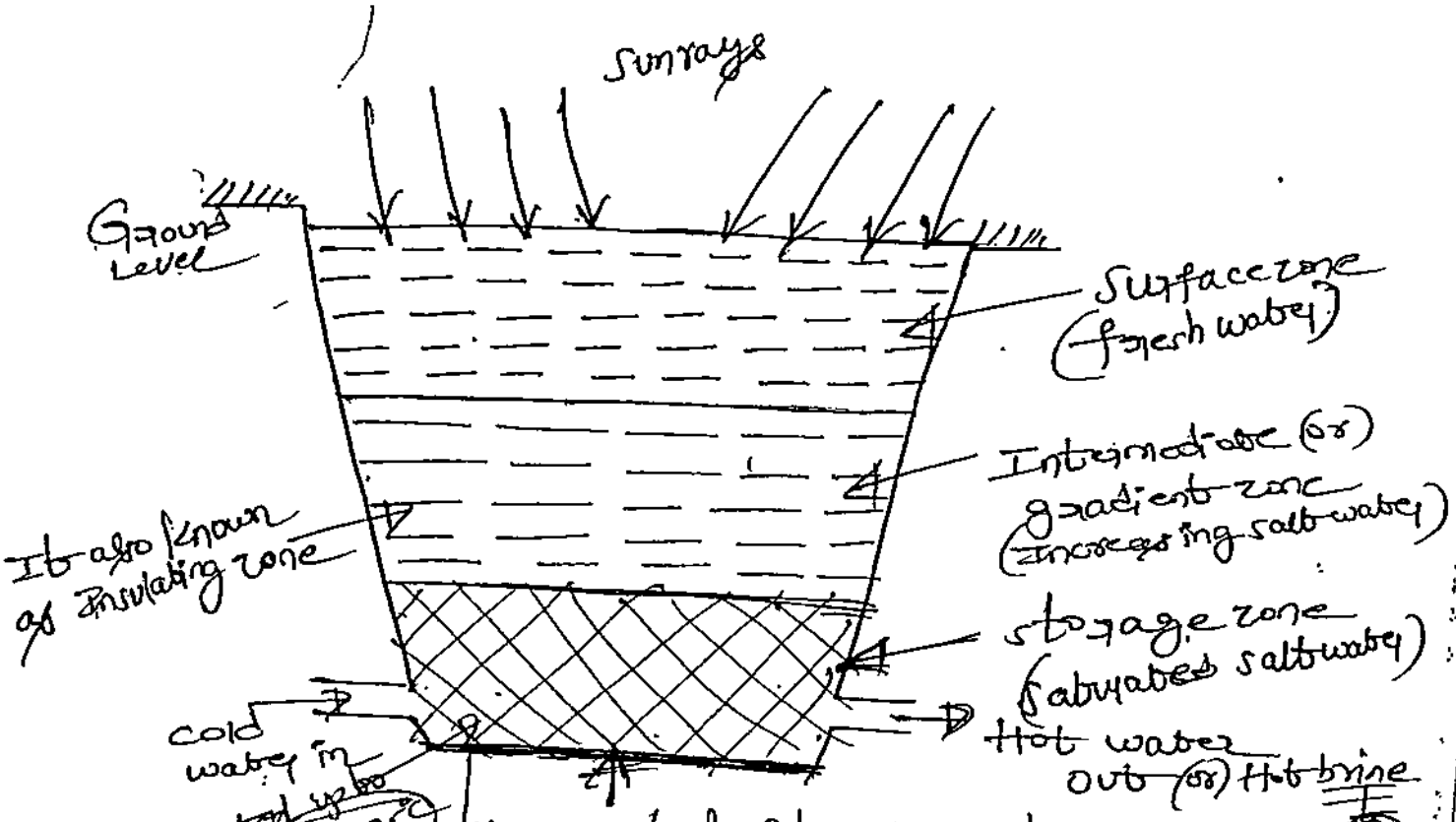
→ Here the cold air has to be changed and finally it changes to hot air.

V. Imp

Solar ponds:- Imp

Definition:-

(A) "It is a pool of salt water that is used to collect & store solar energy. This heat energy can be used for various applications like heating, refrigeration and solar power generation."



Introduction:-

→ Formally known as a salinity gradient solar pond, solar ponds are an alternative source of harnessing the suns energy to heat water that can be converted to electricity. This technology is very basic and easy to use with adequate land space and proper design.

→ A solar pond is simply a pool of saltwater which collects and stores solar thermal energy.

→ ~~Whenever the solar energy is passed~~. The saltwater naturally forms a vertical salinity gradient also

known as a halocline in which the density increases on top of high salinity water.

→ The layers of such solutions increase in concentration (and therefore density) with depth.

Construction:

→ A pond of 2m-2.5m depth is dug and filled with water.

→ The bottom of the pond is generally lined with a durable plastic liner made from material such as black polythene and hypalon reinforced with nylon mesh.

→ Salts like magnesium chloride, sodium chloride (or) sodium nitrate are dissolved in the water.

→ Typically, a salt gradient solar pond consists of three zone:

① surface zone ② Insulation (or) gradient zone ③ storage zone.

Working principle:

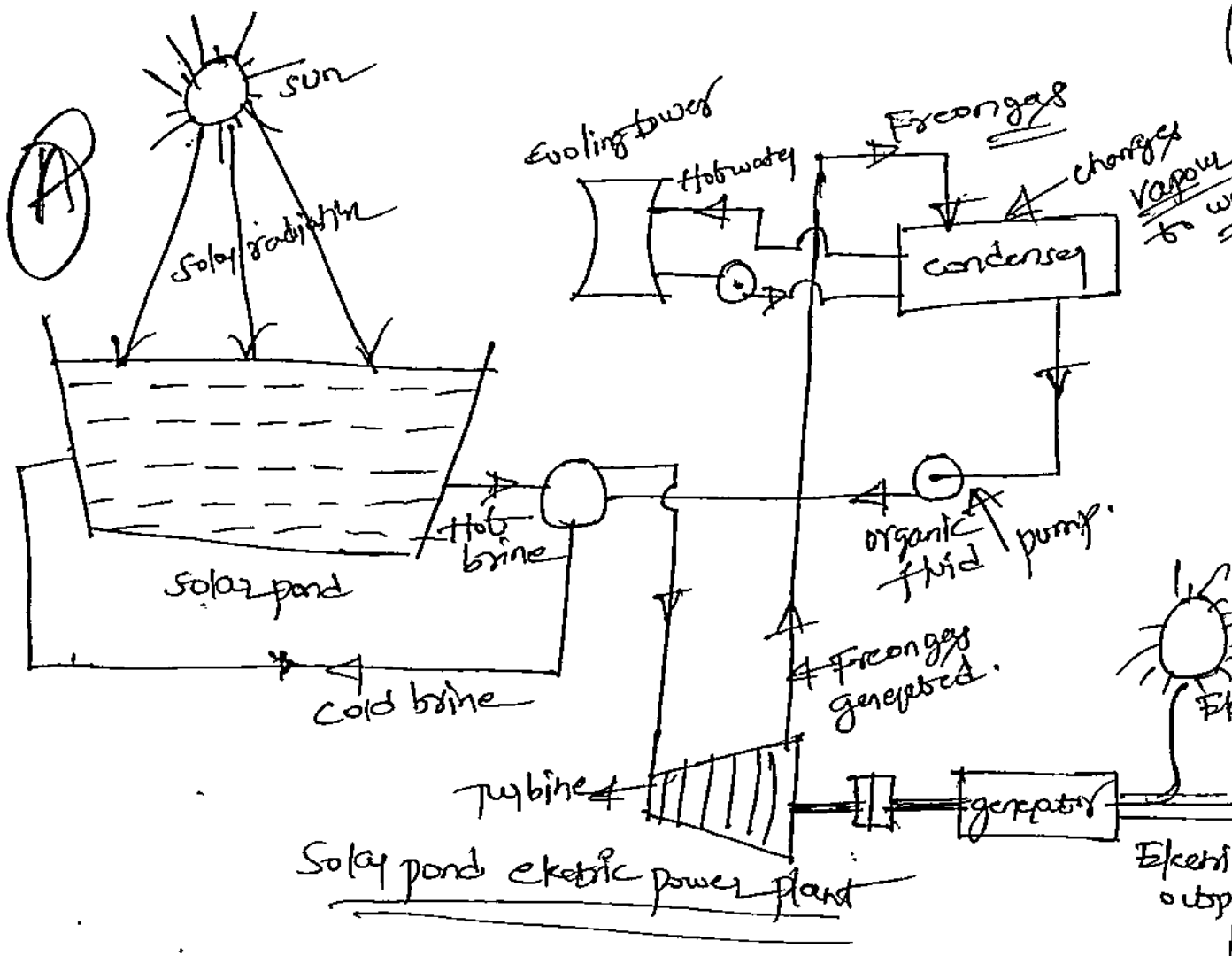
→ When the solar radiation strikes the pond, most of it is absorbed by the surface of the bottom of the pond. The temp. of the dense salt layer therefore increases.

→ The temp. of the lower layer may rise to as much as 95°C.

→ Hot water is removed continously from the bottom, passed through a heat exchanger and then returned to bottom through hot water outlet.

→ To generate electricity, heat stored in hot water is piped to an evaporator.

→ Liquid freon in the Evaporator (or) turbine is heated and converted into gas.



Solar pond electric power plant

→ The pressure generated by the gas rotates a turbine and electricity is produced by the generator.

→ Freon gas is then cooled and recycled and used again.

Applications:-

(1) Generation of Electricity (2) Heating applications Industries (3) Desalination.

Advantages:-

(1) Very reliable (2) Less construction and maintenance cost (3) simplest technique for conversion of solar energy to thermal energy

Disadv:-

(1) Requires lot of land area (2) Land must be very low cost

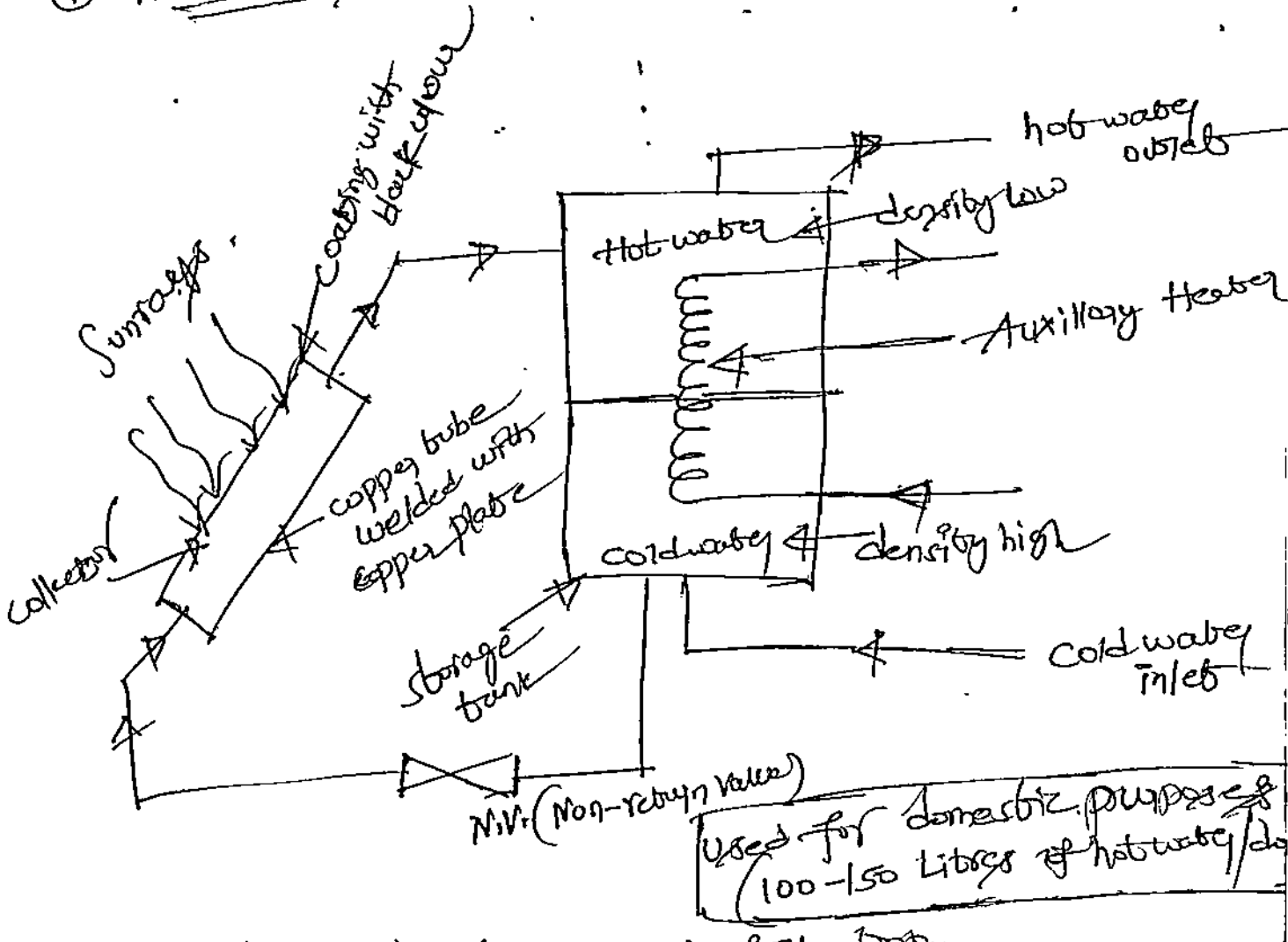
(3) once a solar pond is built, the productivity of a solar pond cannot be increased.

Solar Applications:

Solar heating / cooling Techniques:

(1) Natural circulation Solar water heater → used in house purpose
(2) forced circulation " " " → applicable in industries, hospitals

(1) Natural circulation Solar water heater:



→ It is placed at roof of the bldg.
→ Due to density difference the hot water from collector and cold water in the storage tu
→ This Auxillary heating system is used in Rainy and cloudy days.

UNIT-3

WIND ENERGY.

(1)

Sources and potential in India, horizontal and vertical axi wind mills, performance characteristics, Betz criteria, Biomass:- principles of Bio-conversion, Anaerobic/aerobic digestion, types of Bio-gas digesters, gas yield, combustion characteristics of bio-gas, utilization for cooking and econor aspects, potential in India.

(seminar) (seminar) (seminar)

Sources and potential in India:-

Wind Energy:-

(A)

→ Wind energy is a form of solar energy. Wind energy (or wind power) describes 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.

(or) Wind turbines → kinetic energy → mechanical power → generator → electricity

Wind Energy:-

(2)

→ The motion of air along that is parallel to the surface of the Earth is called wind.

→ moving air is called wind.

→ Air moves from the regions of high pressure to the region low pressure.

→ Solar Energy is one of the main factors responsible for the air movement in atmosphere.

→ The Kinetic Energy possessed by air due to its velocity is called wind Energy.

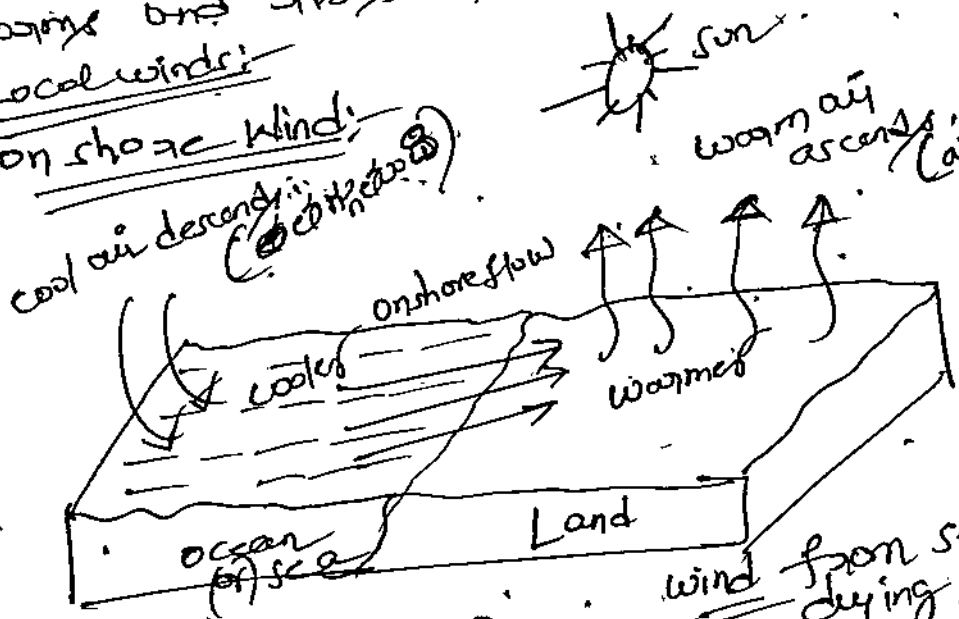
Source of wind Energy:-

Planetary winds:

(1) The sun is the ultimate source of wind energy. As the sun heats the surface of the Earth, the air above it warms and rises upwards into the atmosphere.

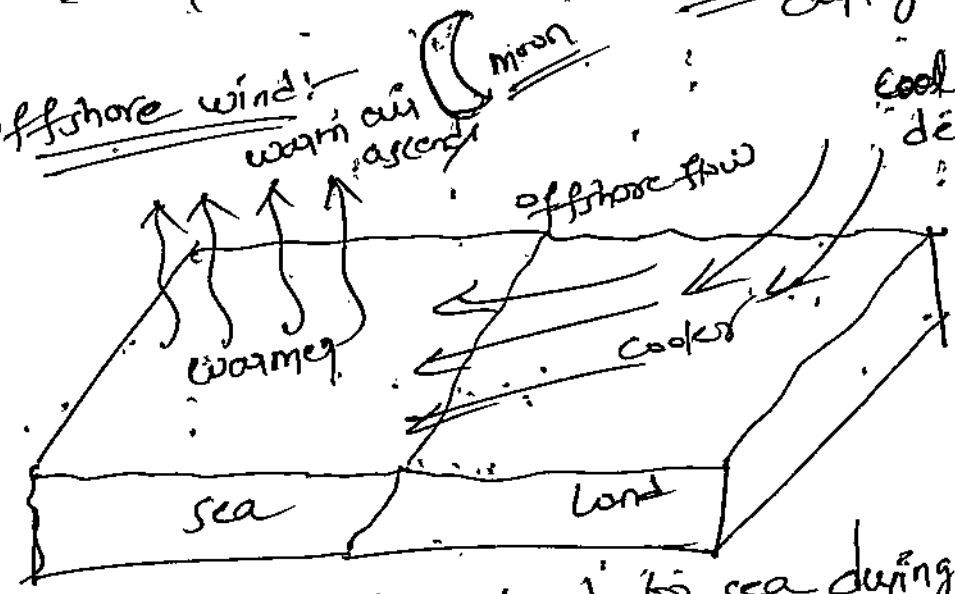
Local winds:

(2) onshore wind:



wind from sea to land during day time

(3) offshore wind:



wind from land to sea during night time

Local winds are formed due to uneven heating of the Earth surface, local winds are produced into two ways. (1) onshore wind
(2) offshore wind.

(1) onshore wind:-

During the day solar energy is converted to sensible thermal energy on the land surface which increases the temp.

→ on watey bodies, solar Energy is partly consumed in evaporating watey and partly absorbed to cause an increase in temp.

→ The Land mass becomes hottey than watter, which cause differential heating of air above them. As a result cool heavier air flows from the watey towards the Land.

② offshore wind:

At night, the direction of wind is reversed as the Land mass cools to stey more rapidly than watey.

④ The second mechanism of local winds is differential heating of slopes on the hillsides and that of Low Lands.

Potential of wind Energy in India:

→ India ranks 4th in Global wind power installed capacity with 35.6 GW. However, India has a wide Variety of wind regimes (wind sites)

→ The best wind regimes are found in coastal areas, and on the top of hills to get more wind Energy

→ most of this potential is spread over nine windy states of India

→ India has a potential of more than 695GW of wind energy at 120 metres hub height and 302GW at 100 metres height.

→ modern turbines are designed to harness energy even in low and medium wind regimes.

→ over 50 different turbine models operate in India

→ Suzlon has a comprehensive and superior range of products to harness energy in all of India's wind regimes and across all Indian windy states.

→ The states which can generate wind energy more Tamilnadu, Gujarat, Maharashtra, Karnataka, Rajasthan, Madhya pradesh, Andhra pradesh, Kerala are generated Estimated potential in MW a/c to the year 2024 is 102,788 MW and Installed capacity is 19,052 MW.

Classification of Wind Turbines:-

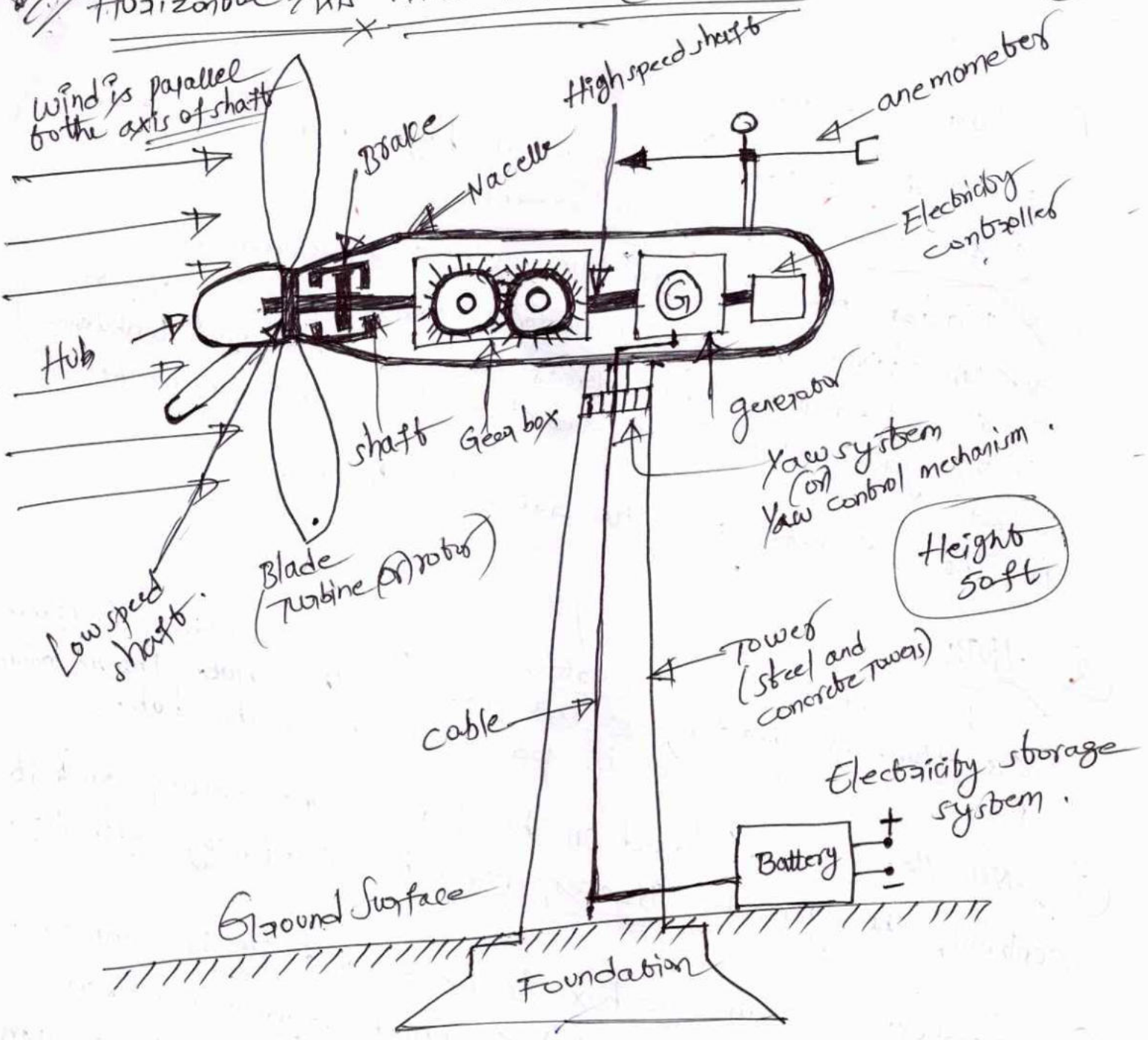
→ Wind turbines are classified into two categories.

→ When the axis of rotation is parallel to the air stream (i.e; horizontal), the turbine is said to be a Horizontal Axis wind Turbine (HAWT) and when it is perpendicular to the air stream (i.e; vertical), it is said to be a Vertical Axis Wind turbine (VAWT).

→ The size of the rotor and its speed depends on rating of the turbine.

Turbine (or) Blades

2nd / Horizontal Axis Wind Turbine (HAWT):-



→ HAWT is a unique technology
→ It is produce the electricity with the help of some mechanism from the wind.
→ It has three turbine blade. The mechanism system are set Horizontal.

→ Uses:-
→ generate the Electricity for save the electricity for future
→ It mostly used in Urban areas.

Construction:-

(1) Turbine Blades:-

→ Turbine blades are made of high density wood (or) glass fibre and epoxy composites.

→ Blades have an airfoil type of cross section.

→ In addition to centrifugal force and fatigue due to continous vibrations, many forces arising from wind turbulence gust, gravitational forces and directional changes in the wind.

→ The diameter of the rotor is 100m.

(2) HUB:-

The central solid portion of the rotor wheel is known as HUB. All blades are attached to the hub. The mechanism for pitch angle control is provided inside the hub.

(3) Nacelle:- It placed on the top of the tower and it contains, the generator, Brakes, Gear box, Electricity controller.

(4) Gearbox:- spur gear box is used and it is connected to the step planetary gear box which rotates from Low speed box to high speed box. from 50 to 80 rpm to produce Electricity.

(5) High speed shaft:- It drives the generator.

(6) Low speed shaft:- The rotor turns the Low speed shaft at speed of 30 to 60 rpm.

(7) Brakes:- A disc type of brake is applied Electrically, mechanically to stop the rotors in Emergency.

(8) Rotors:- The Blades and hubs together is called the rotor. The rotor having longer blades captures higher velocity of wind.

(9) Towers:- It is made up of steel & concrete to support all the parts.

(10) Anemometer:- To measure the wind speed (rpm) in certain direction.

(11) Yaw control mechanism-

→ The mechanism to adjust the nacelle around the vertical axis to keep it facing the wind is provided at the base of the nacelle.

→ The Yaw control mechanism continously orients the rotor in the direction of wind.

Working:-

→ When the blades (or) turbine rotors are rotated when then wind is passes over the rotors in parallel direction with axis of shaft. The rotors rotate with the help of Hub.

→ The Hub rotates by Low speed shaft at a speed of 30 to 60rpm. Gear box which is connected to the generator. Highspeed shaft which drives the generator.

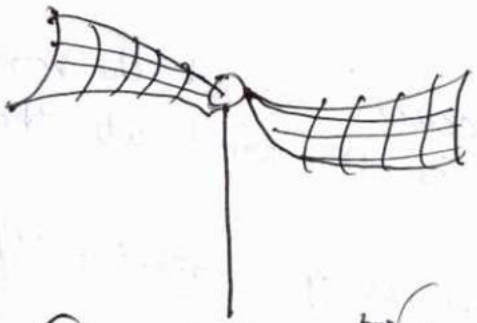
→ The cable which is connected finally to the battery to generate the Electrical power. Finally convert wind Energy into Electrical Energy.

~~Vertical axis w~~

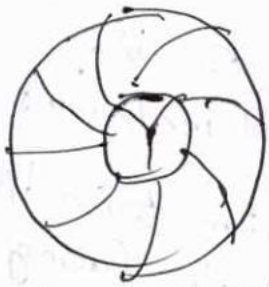
Types of rotors in HAWT:-

Type of wind machine

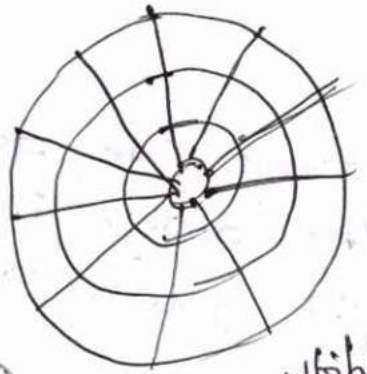
(a) single blade rotor (b) two blades (c) Three blades.



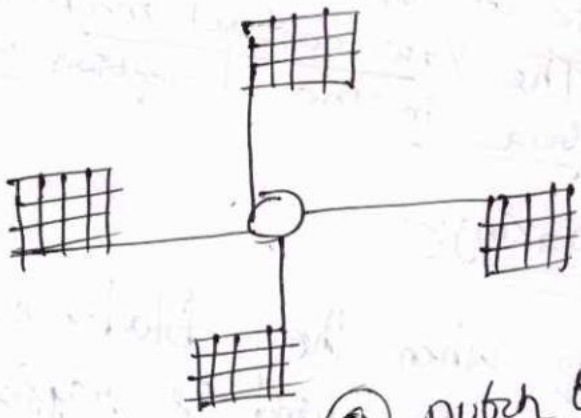
(d) Sailwing rotor.



(e) chalk multi blade



(f) American multiblade



(g) Dutch type blade.

Ans Vertical Axis wind Turbine (VAWT):-

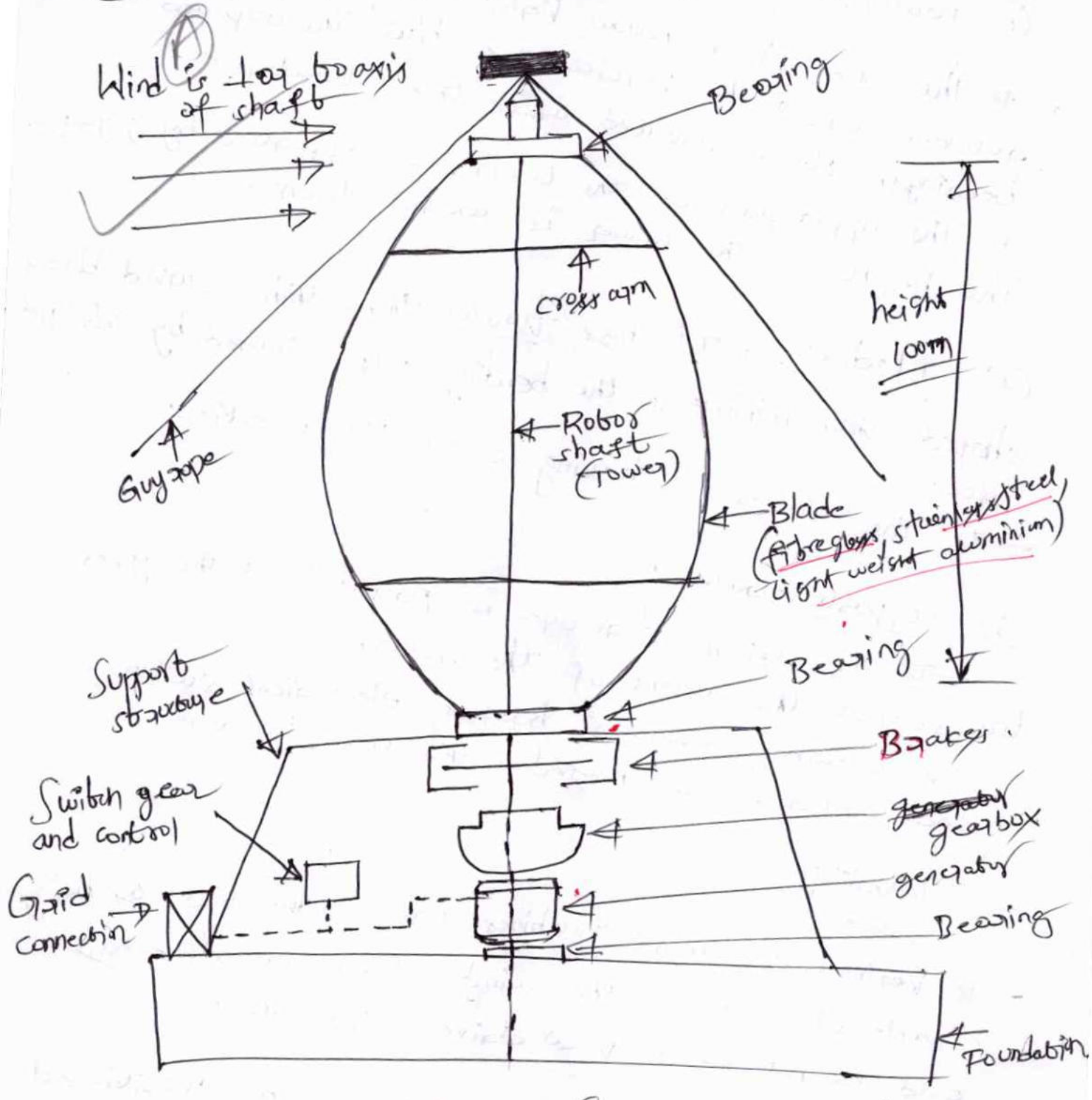
VAWT's are in the development stage and many models are undergoing field trial. The main attractions of a VAWT are

(i) it can accept wind from any direction, eliminating the need of Yaw control,

(ii) the gearbox, generator etc. are located at the ground, thus eliminating the heavy nacelle at the top of the tower, thus simplifying the design and installation of the whole structure, including the tower,

(iii) the inspection and maintenance also gets easier and

(iv) it also reduces the overall cost.



Vertical axis wind (Darrieus turbine)

Construction (or) components:

The constructional details of a vertical axis wind turbine (Darrieus-type rotor) are shown in fig. The details of the main components are as follows:

(1) Tower (or) Rotor shaft:

→ The tower is a hollow vertical rotor shaft, which rotates about the vertical axis b/w the top and bottom bearings. It is installed above the structure.

→ The upper part of the tower is supported by guy ropes. The height of the tower is around 100m.

(2) Blades:

→ It has two (or) three thin, curved blades shaped that minimizes the bending stresses caused by centrifugal force.

→ The blades is having airfoil cross section.

(3) Support structure:

→ The support structure is provided at the ground to support the weight of the rotor.

→ Gearbox, generator, brakes, electrical switchgear and controls are housed within this structure.

Working:

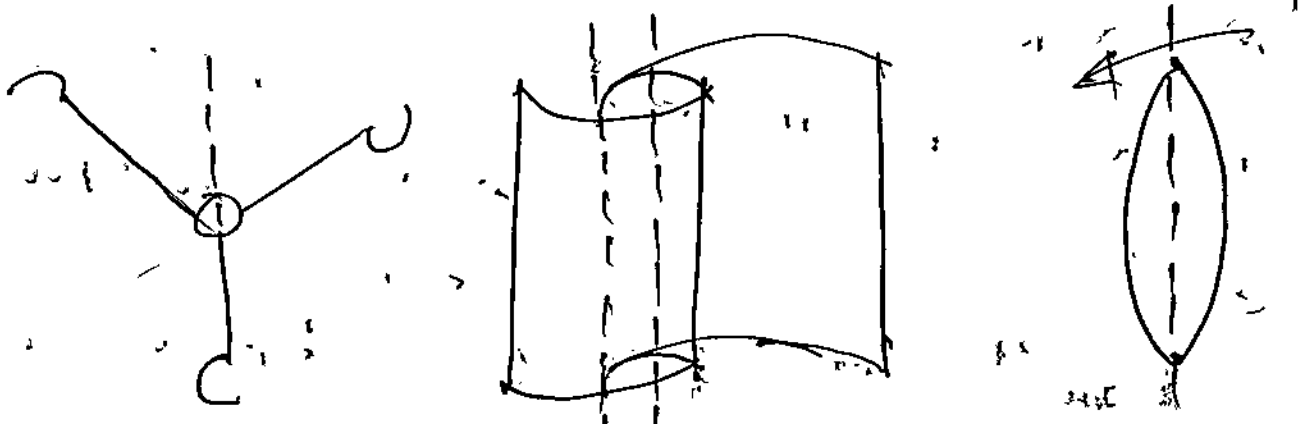
→ Vertical axis wind turbines are advocated as being capable of catching the wind from all directions and do not need Yaw drive, Nacelle.

→ Their electrical generators can be positioned close to the ground for convenient way.

→ Actually in VAWT the wind is to the blade.
→ Its maintainence cost is low and occupy the largespace.
→ The most commonly used in VAWT is Darrieous type and savonious type of rotor height 94m and diameter 65m and produce 3.8MW.
→ Here in VAWT the tower is reinforced with guy wires for supporting purposes.
→ Here the blades made from composite fibre glass, stainless steel and light weight aluminium are Extremely strong and flexible.
→ The main working of VAWT is from Guy wires it should be rotated then rotorshaft rotates then the set of Electrical generator (Gearing, gearbox, brakes) works then through grid connection then power generated.

VAWT Types:

① cup type blade ② Savonious rotor ③ Darrieous rotor



Advantages and Disadvantages of wind energy:

① It is Renewable, and available free of cost.
② Helpful for supplying the Energy in Rural areas.
③ wind does not require any transportation it operates low cost.

④ Economically competetive.

Disadvantages:-

① Available in low power density mainly variable with power and time.
② It used only in remote areas.
③ The transmission Loss are more
④ It produce noise pollution.
⑤ wind cannot be stored as a conventional source.

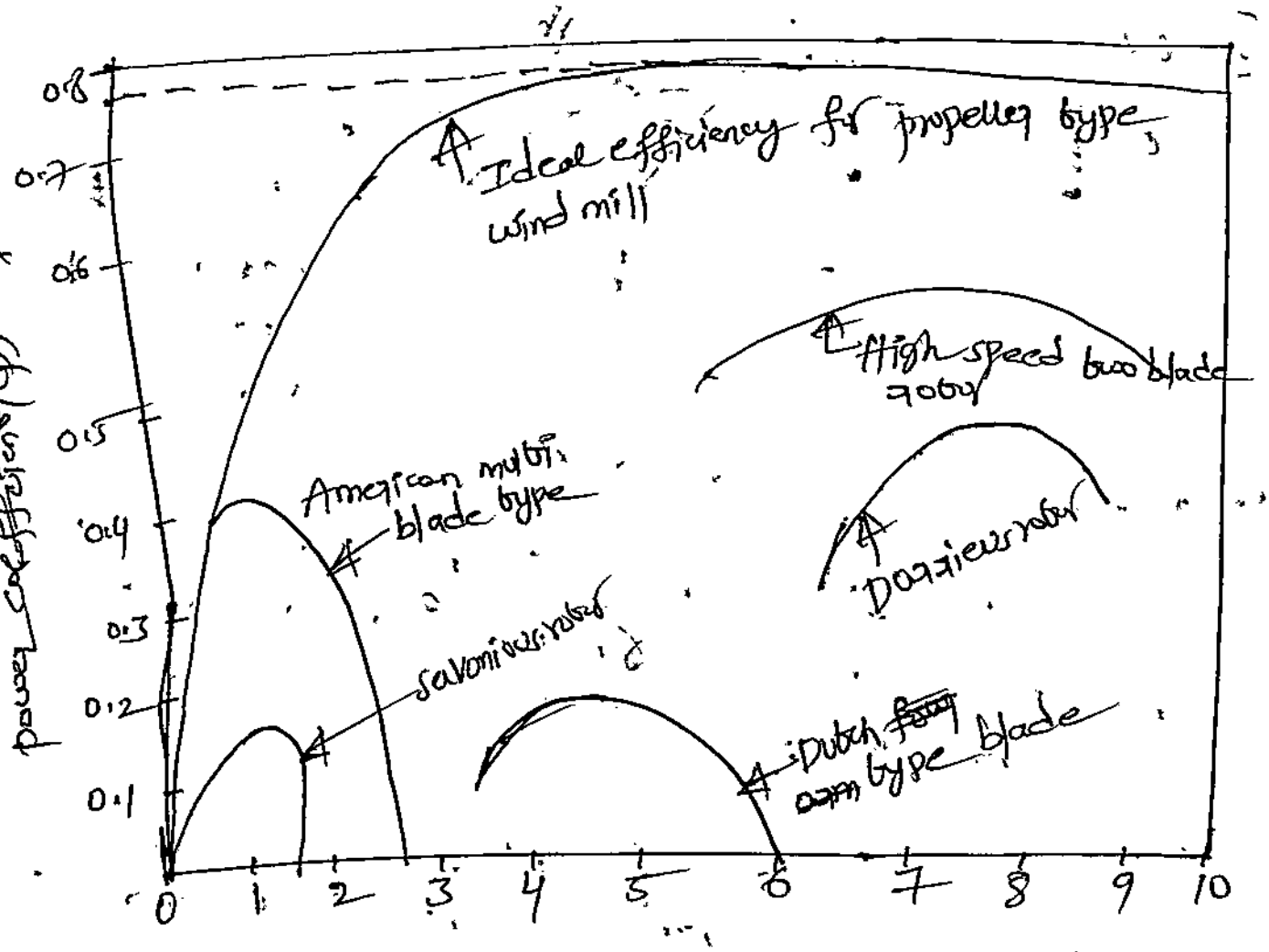
Differences b/w HAWT & VAWT:-

HAWT	VAWT
① Tower Required	① No Tower
② More speed	② Low speed
③ More cost	③ Less cost
④ Need more maintence	④ Less maintence
⑤ Require Yaw control.	⑤ Yaw control not required.
⑥ ~~More~~ Less power generation possible	⑥ More power generation possible
⑦ Cp (power coefficient) is high and tooth speed ratio (TSR) is high.	⑦ Cp & TSR is low

Performance characteristics of wind turbines:-

→ Performance characteristics is mainly depend upon the graph b/w power coefficient (C_p) and turbine tip speed ratio (TSR).

→ C_p and TSR is high in HAWT (Horizontal axis wind turbine). But the C_p and TSR is Low in VAWT (Vertical axis wind turbine).

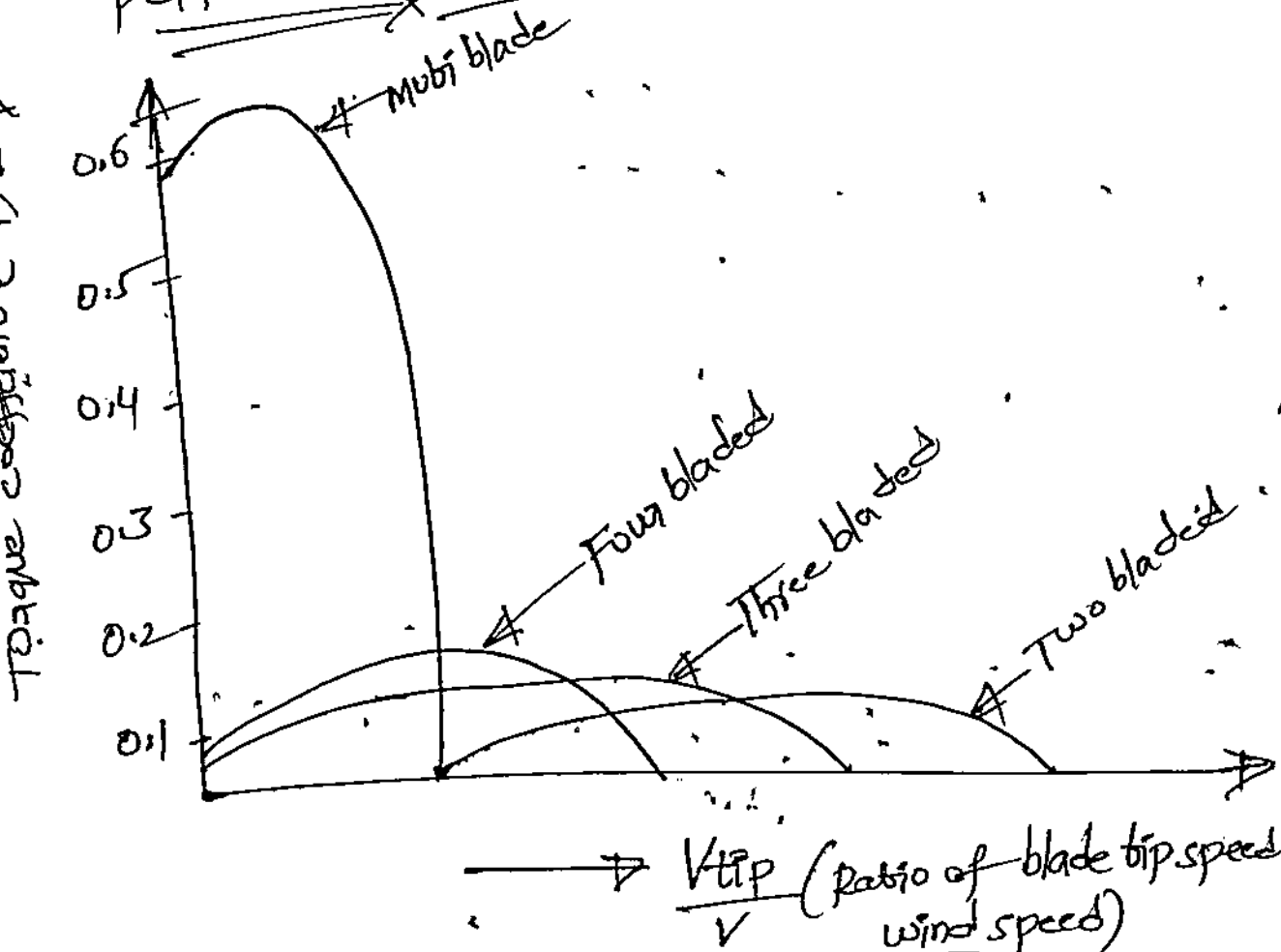


Power coefficient (C_p):- "C_p" is defined as the ratio of power extracted by the wind turbine

Tip speed ratio (TSR):- TSR refers to the ratio b/w the ~~wind speed~~ blade tip speed (V_{tip}) to wind speed (V)

$$TSR = \frac{V_{tip}}{V}$$

Performance of wind machines:



Imp **Betz Criteria:** (Albert Betz scientist)

→ All the kinetic energy in the wind cannot be converted to shaft power, the air must able to flow away from the rotor area.

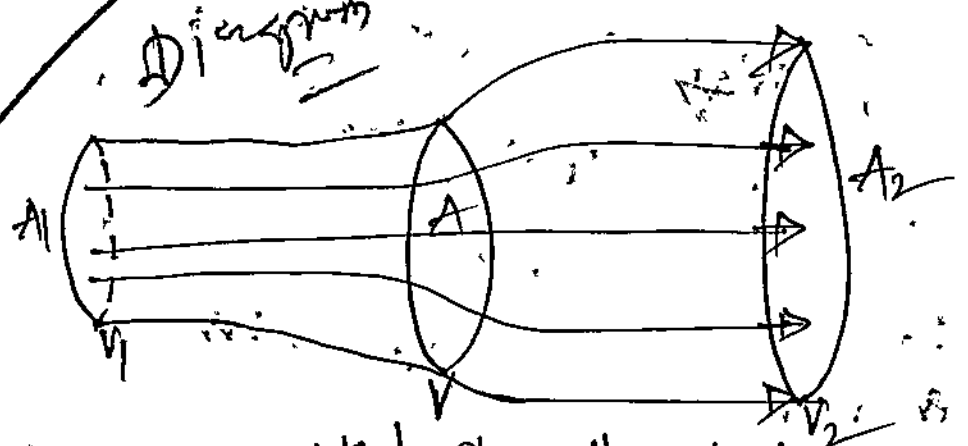
∴ A/c to Betz criteria, no turbine can capture more than 16/27 (59.3%) of the kinetic energy in wind. The factor 16/27 (0.593) is known as Betz's coefficient (or) Betz limit.

→ Betz concluded that this value is 59.3% of the kinetic energy from wind can be used to spin the turbine and generate electricity.

→ Betz criteria is derived using the principles of conservation of momentum and conservation of energy which gives a max possible turbine η (59%).

Wind Energy Extraction from the turbine:-

(8) Diagram



Wind flow through turbine.

The wind turbine Extraction Energy from wind streams from converting the K.E. of motion to rotational motion required to operate the Electric generator.

p = atmospheric wind pressure
p_u = pressure on upstream of the wind turbine
p_d = pressure on downstream of the " "
V = atmospheric wind velocity.
V_u = velocity of wind upstream of wind turbine
V_d = " " " downstream " " "
V_b = velocity of wind at blades.
A = Area of blades.
m = mass flow rate of wind
ρ = air density.

∴ The K.E. of wind stream passing is, $K.E. = \frac{1}{2} m V_b^2$
and $\dot{m} = \rho A V_b$.

then. $K.E = \frac{1}{2}\rho A V_b^3$ ——— (1)

Force on the disc of rotor can be expressed as

$F = (P_u - P_d)A$ ——— (2)

Force on rotor can be expressed as change of momentum per unit time from upstream to the downstream of wind.

$F = m(V_u - V_d)$ ——— (3)

Applying the Bernoulli's Equation to upstream and downstream

formula

$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$

$P + \frac{1}{2}\rho V_u^2 = P_u + \frac{1}{2}\rho V_b^2$ ——— (4)

~~$P_d + \frac{1}{2}\rho V_b^2 = P + \frac{1}{2}\rho V_d^2$~~ ——— (5)

$P + \frac{1}{2}\rho V_d^2 = P_d + \frac{1}{2}\rho V_b^2$ ——— (5)

Solving the Eq (4) and (5) we get

$P_u - P_d = \frac{1}{2}\rho(V_u^2 - V_d^2)$ ——— (6)

Equating the equations (2) & (3).

$(P_u - P_d)A = m(V_u - V_d)$ ——— (7)

$(P_u - P_d)A = \rho A V_b (V_u - V_d)$

$(P_u - P_d) = \rho V_b (V_u - V_d)$ ——— (7)

Solving (6) & (7)

$\frac{1}{2}\rho(V_u^2 - V_d^2) = \rho V_b (V_u - V_d)$

$V_b = \frac{V_u + V_d}{2}$ ——— (8)

In a wind turbine system the steady flow work W is equal to the difference b/w the K.E. b/w upstream and downstream of turbine for unit mass flow rate.

$$W = (KE)_u - (KE)_d$$

$$W = \frac{1}{2}(V_u^2 - V_d^2) \quad \text{——— (9)}$$

power output of pressure (P)

$$P = m\left(\frac{V_u^2 - V_d^2}{2}\right)$$

$$= \rho A\left(\frac{V_u + V_d}{2}\right)\left(\frac{V_u^2 - V_d^2}{2}\right)$$

$$P = \frac{1}{4}\rho A(V_u + V_d)(V_u^2 - V_d^2) \quad \text{——— (10)}$$

for max turbine power o/p differentiate the eq (10) w.r.t "V_d" equate to zero obtain.

$$\frac{dp}{dV_d} = 3V_d^2 + 2V_uV_d - V_u^2 = 0$$

i.e; $V_d = \frac{1}{3}V_u$

and $V_d = V_u$.

for generation of power $V_d < V_u$.

$$V_d = \frac{1}{3}V_u \quad \text{——— (11)}$$

$$= \frac{\rho A}{4}\left(V_u + \frac{V_u}{3}\right)\left(V_u^2 - \frac{V_u^2}{3}\right)$$

$$= \frac{\rho A}{4} \times \frac{4V_d}{3} \times \frac{8V_u^2}{9}$$

$$\boxed{P_{max} = \frac{8}{27}\rho A V_u^3} \quad \text{——— (12)}$$

$$= \frac{16}{27}\left(\frac{1}{2}\rho A V_u^3\right)$$

The total power of wind stream

$$\boxed{P_{total} = \frac{1}{2}\rho A V_u^3}$$

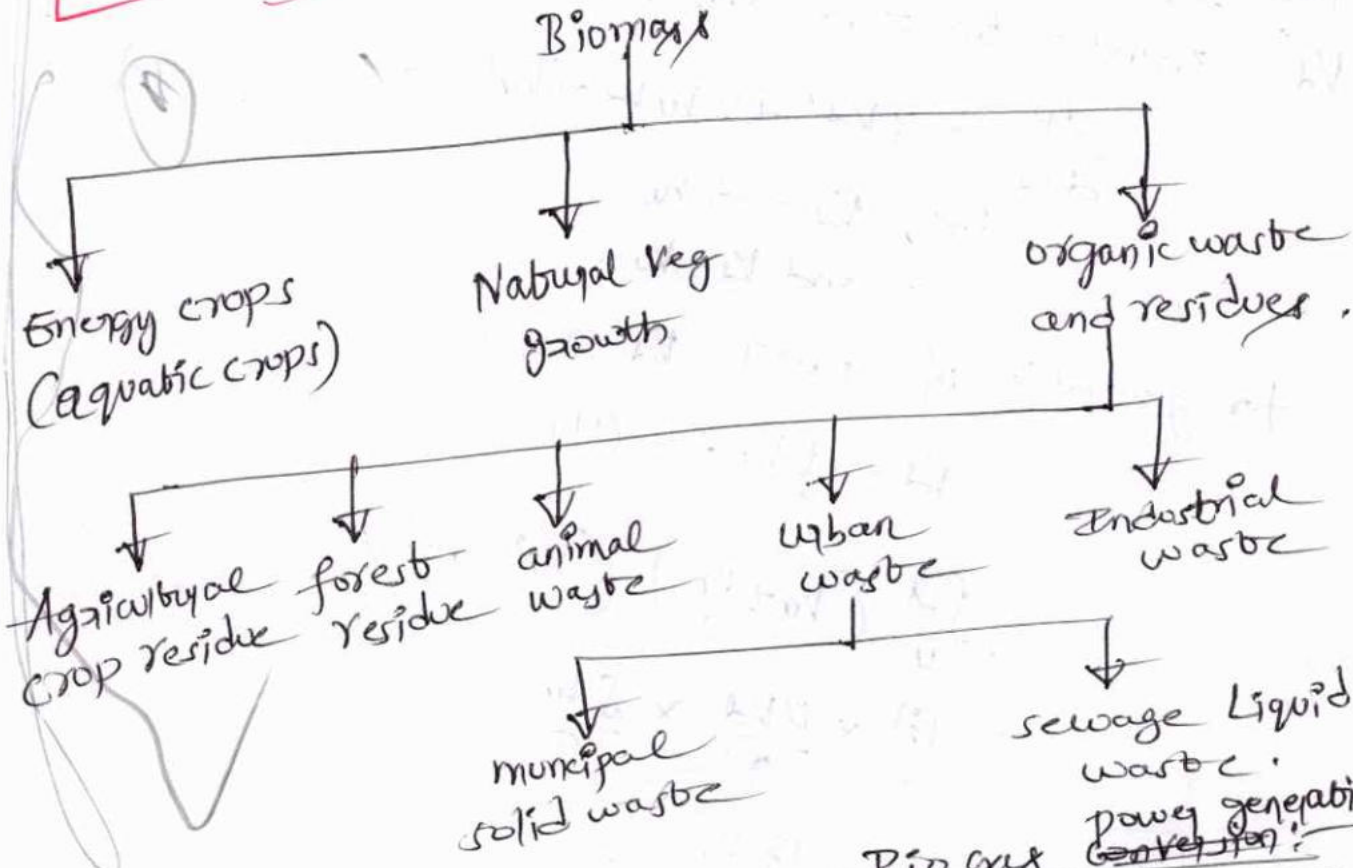
$$\boxed{P_{max} = 0.593 \times P_{total}}$$

$$\boxed{\eta = 59\%}$$

Biomass:-

Biomass Energy:- → "The term Biomass generally refers to the renewable organic matter generated by plants in the process of photosynthesis the Bio is a greek word it means Life".

→ The Biomass refers to the residue of agricultural wastes, and forestry, animal waste and discarded materials from the food processing plants.



Principles of Bio-conversion:- Biogas Power generation:

Introduction:-

→ (1) The main source for biogas is a Wet cattle dung

Biogas:-

→ Biogas is a clean and efficient fuel.

→ It is a mixture of
(1) methane (2) carbondioxide (3) Hydrogen and
(4) Hydrogen sulphide. (5) watery vapour.

→ It is clean but slow burning gas and usually has a heating value about 18 MJ/m3.
→ It can be used directly in cooking, reducing the demand for firewood.

(2) Methane:-

→ Methane is a gas that can be collected and burned as a fuel.
→ This gas is produced by animal waste as it decays.
→ Some farms collect animal waste and store it in tanks, processing the collected gas.
→ The resulting methane gas is then compressed in tanks / containers. and distributed to customers.
Applications:
→ It can be used to heat cookers, houses and even to power car engines.

(1) The cycle starts with animals on a farm, grazing and producing waste.
(2) The waste is collected on a regular basic. It is transferred to decomposing tanks and the methane gas is collected and stored.
(3) Gases are stored in tanks and transferred to tankers. It is transported to customers (or) compressed and transferred to small cylinder tanks.

Applications:-

→ The methane gas can be used for household applicances such as cookers.

→ It is also used as the fuel for cars specially adopted to burn methane gas rather than petrol.

→ These vehicles are less polluting their speed and acceleration are reduced.

Advantages of Biogas:-

(1) Gas production is cheap.
(2) Less pollution
(3) waste material can be used as fertilizer.
(4) Gas is used for cooking, lighting, as fuel etc.

Disadvantages of Biogas:-

(1) Not efficient enough on a Large scale
(2) contains impurities.
(3) When methane gas is used it reacts with oxygen than highly inflammable CO_2 gas is formed it Leads to effect in Environment. and ozone layer.

(1) Principles of Bio conversion:-

Bio conversion:-

** ((Bio conversion, also known as biotransformation is the conversion of organic materials, such as plants (or) animal waste into usable

"Products" Involving ~~&~~ carbon microorganisms. (11)

Three different processes for bio conversion:-

1. Enzymatic hydrolysis
2. synthesis gas fermentation
3. C.O.R.S. and Grub composting.

① Enzymatic hydrolysis:-

In this process a single source of feed (animal waste) stock (- waste material [illegible]) is mixed with strong enzymes which convert a portion of cellulosic material into sugars which can be then fermented (or) conversion into Ethanol.

feed stock + Enzymes → cellulose → sugars → Ethanol → Bio-Ethanol (or) Bio Diesel

② synthesis gas fermentation:-

→ In this process a blend of feed stock (animal waste) not Exceeding 30% water is to be gasified in a closed Environment is finally produced as a syngas containing mostly carbon monoxide and hydrogen.

→ This syngas is further cooled Expose to bacteria or other catalysts and finally converted to usable products.

animal waste → gasified → produce syngas (gobar gas) (carbon monoxide (CO) + H_2) → usable product → heat & power.

(3) C.O.R.S (conversion of organic Refuse by Saprophages) and Grub composting:

one type of insects

→ This type of Saprophages has to take organic matter and it reduce to convert organic waste into a high quality feedstock and oil. This is used in biodiesel Industry.

Saprophages (one type of insects) → organic matter → organic waste of high quality feedstock oil → used in Bio diesel industry

Anaerobic digestion:

(IV) "Anaerobic digestion is another method of converting biomass into Energy. In this process the bacteria break down organic matter such as animal manure, waste water biosolids, and food wastes in the absence of oxygen to create methane rich bio gas. This can then be burned to generate heat and Electricity".

They are Four basic phases of anaerobic digestion which is convert finally biomass into biogas. by using anaerobic micro organisms

(1) Hydrolysis

(2) acidogenesis

(3) acetogenesis

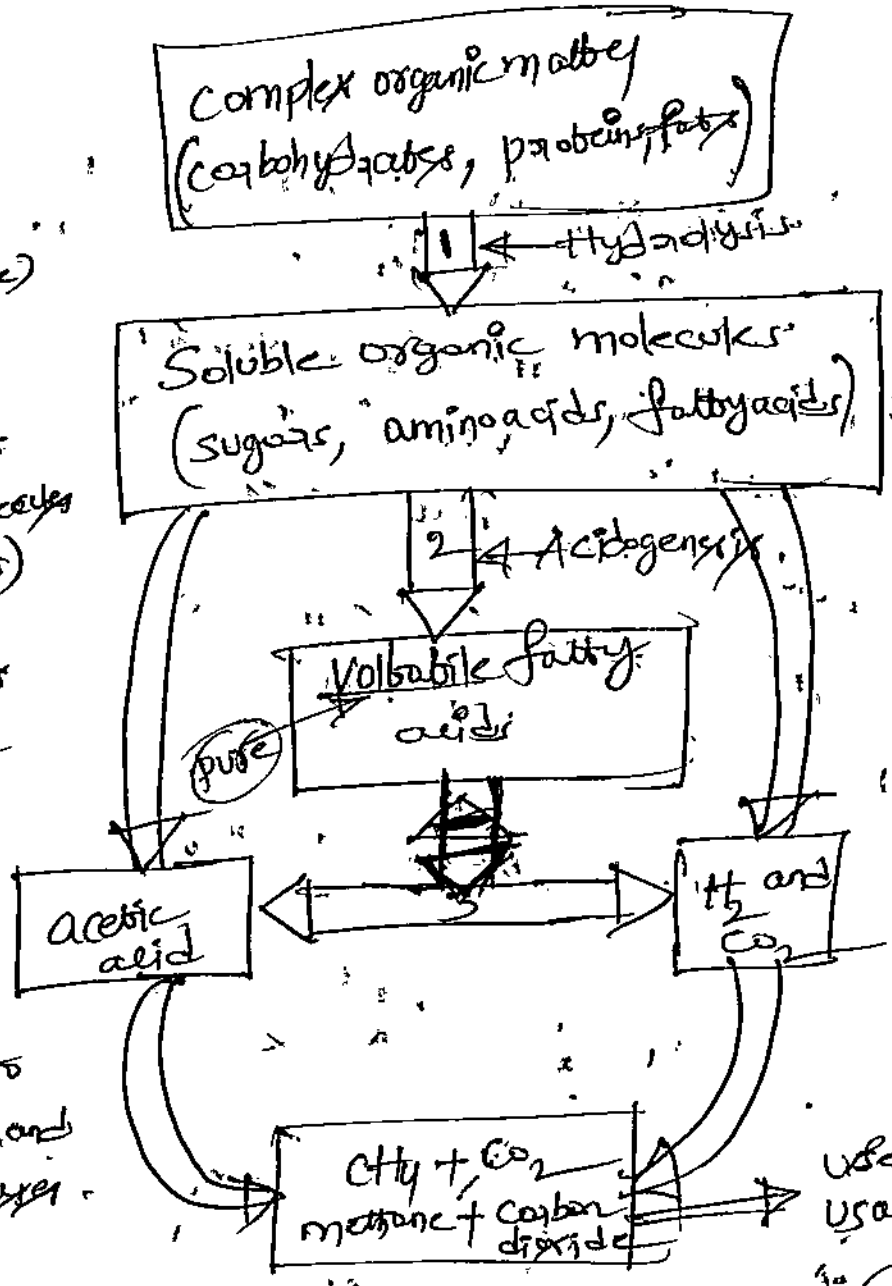
(4) methanogenesis

① Hydrolysis (Complex organic molecules to soluble)

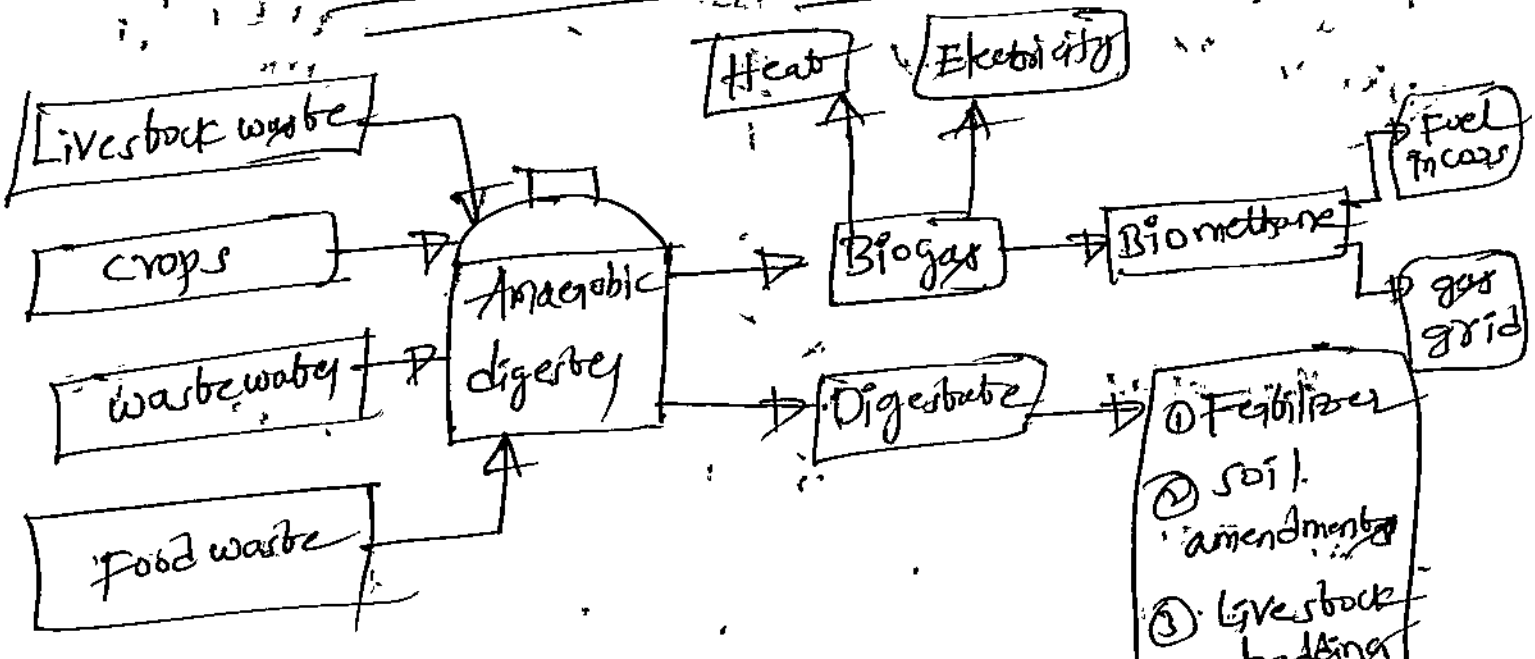
② Acidogenesis (Soluble organic molecules to fatty acids)

③ Acetogenesis (Conversion to acetic acid and CO_2 and H_2)

④ Methanogenesis final Conversion to methane (CH_4) and CO_2 and other gases



Converting of Biomass into Energy (Biogas)

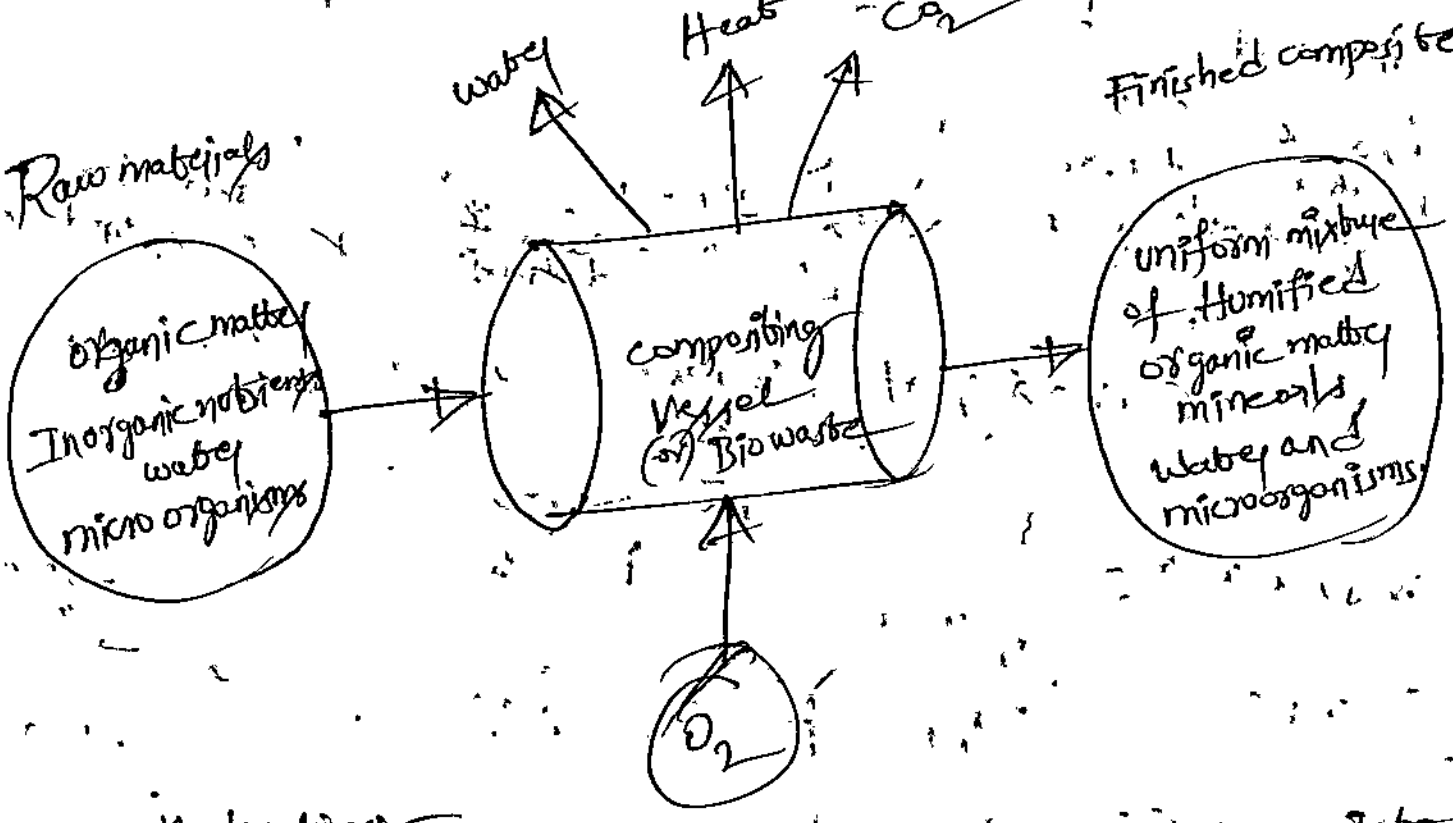


Q) Aerobic digestion:

→ Aerobic digestion system is the combination of composting (or) Bio waste (or) sewage sludge of wastewater with micro organisms from atmosphere Especially called fungi which is survived in the presence of oxygen and breakdown into small pieces.

→ This process is compared to anerobic digestion is to be fast manner.

Aerobic composting



Applications:

→ It is used to promote organic mixture into bio diesel.

→ It is used to generate heat and CO_2 but not methane gas

Diff. Difference b/w Anaerobic and Aerobic digestion:

Anaerobic digestion	Aerobic digestion
(1) It is digestive	(1) It is composing
(2) It contains and finally produce CO_2	(2) It contains and finally produce CO_2
(3) Here finally used gas is methane	(3) Here finally and used one is Heat.
(4) microorganisms breakdown organic material in the absence of oxygen	(4) microorganisms breakdown organic material in the presence of oxygen
(5) It is slow manner	(5) It is fast manner

Types of Biogas digesters:

Useful:
1. Fixed dome type plant
2. Floating drum " "

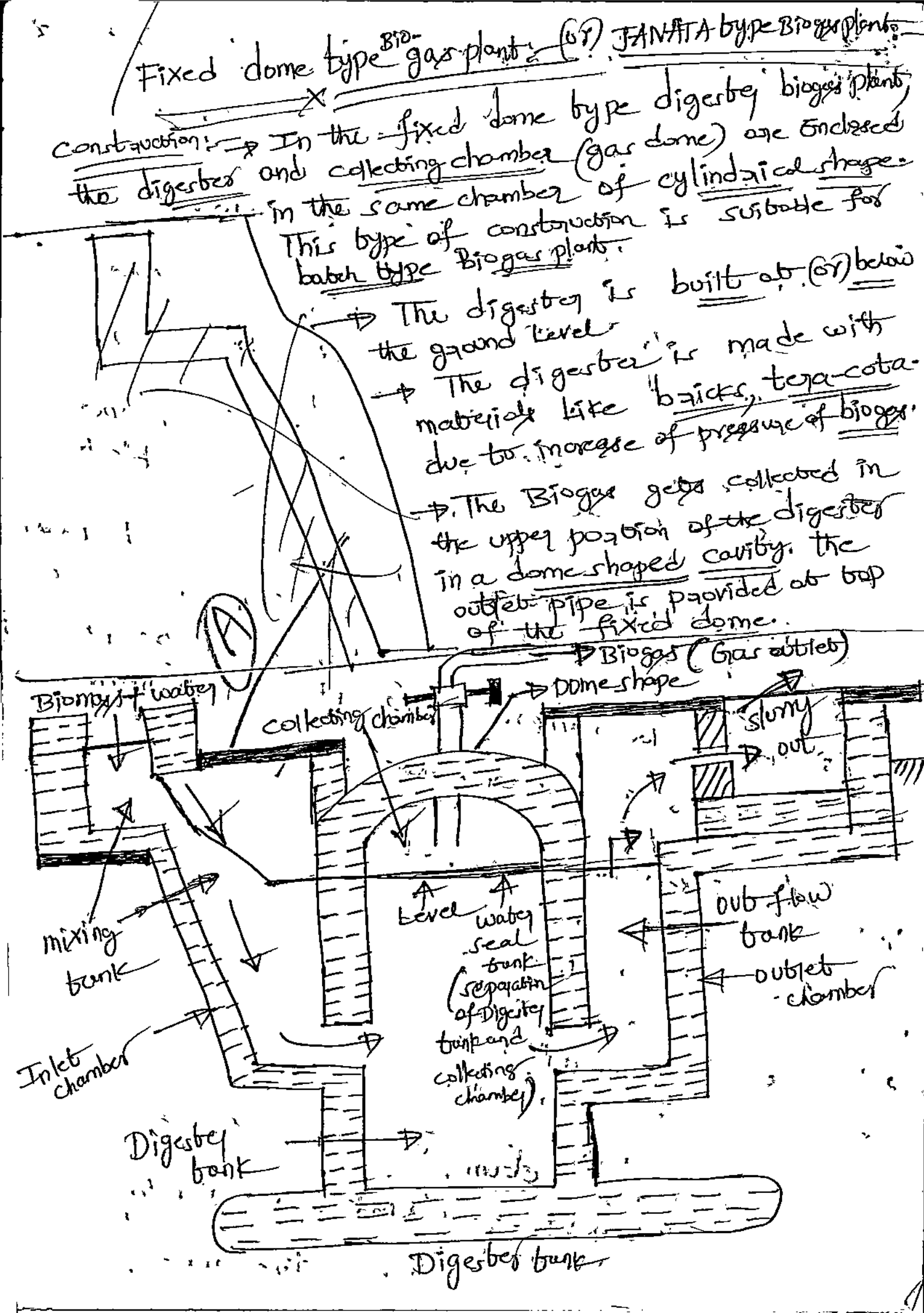
Due to heavy cost not used:
3. Balloon type plant
4. Horizontal " "
5. Earth pit " "
6. Ferro cement " "

But commonly used type of biogas plants are:-
1. Floating drum type
   Eg:- KVIC-type (Khadi village Industries commission)
2. Fixed dome type
   Eg:- Janata type (chinese model).

Fixed dome type Bio-gas plant (or) JANATA type Biogas plant:

Construction:- In the fixed dome type digester biogas plant the digester and collecting chamber (gas dome) are enclosed in the same chamber of cylindrical shape. This type of construction is suitable for batch type Biogas plant.

- The digester is built at (or) below the ground level.
- The digester is made with materials like bricks, tera-cota due to increase of pressure of biogas.
- The Biogas gets collected in the upper portion of the digester in a dome shaped cavity. the outlet pipe is provided at top of the fixed dome.



→ The digester tank and gas collector (collecting chamber chambers are seperated by watery sealed tank.

Working:-

→ Here in fixed dome type mainly they are three parts ① Inlet ② gas chamber ③ outlet for slurry (for Biomass and water).

→ The proper mixing of organic matter (animal waste, human waste, plant waste etc) is said to be a Biomass with proper mixing with water is sent to Inlet tank (or) mixing tank.

→ Through mixing tank sent to the digester tank upto the level of watery seal tank

→ After some duration twice 24 hrs time the mixed one is get to decomposed.

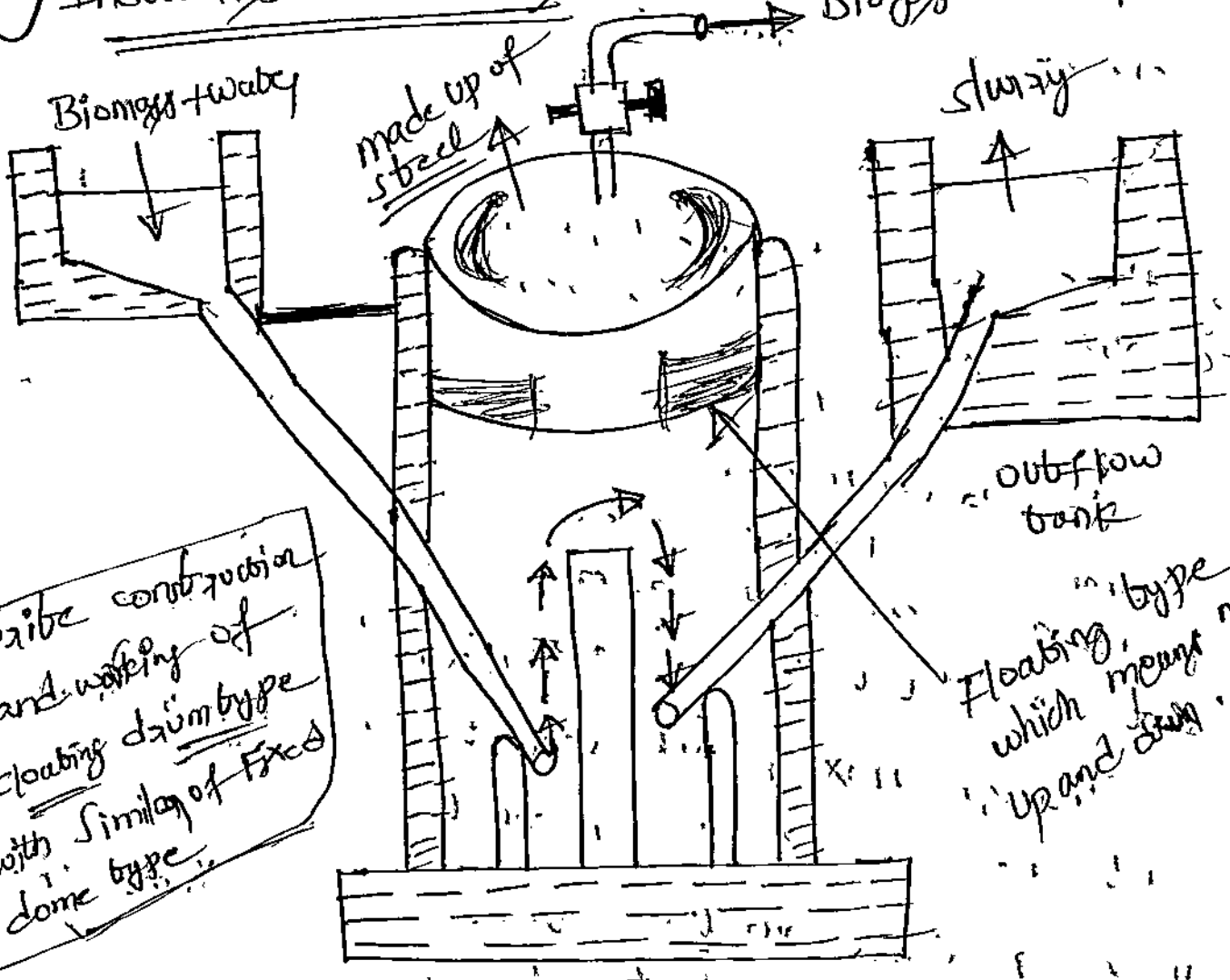
→ Then release the gas and collect in collecting chamber.

→ Finally the Bio-gas is collected at out through proper valve in close (or) open type.

→ This bio-gas is used for cooking and in houses.

→ Finally the wastage of slurry is collected in outlet tank.

(ii) Floating drum type Biogas plant (or) KVIC-type (Khadi village Industries commission):-



Write construction and working of Floating drum type with similar of Fixed dome type

Floating type which means move upand down.

Advantages of Biogas plants:-

1. "Biogas" is Ecofriendly
2. Biogas generation Reduces soil & water pollution.
3. It is simple and low cost technology.
4. Biogas generation produces organic fertilizers.
5. Reliable
6. produces enriched of organic manure.
7. Economically viable
8. utilization of waste
9. generation of organic fertilizer.

Disadvantages of Biogas plants:-

- It contains impurities.
- Biogas generation is also affected by weather.
- The technology is not completely efficient and developed.
- Not economically Viable
- It cannot work in all Locations.
- Requires Large areas.
- Less suitable for Metropolitan areas
- Flammability.

UNIT-4 (NCSE)

Geothermal Energy:

Resources, types of wells, methods of harnessing the energy, potential in India, A seminar

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, potential in India.

Geothermal Energy:

"Geothermal Energy is heat within the Earth. The Word geothermal comes from the Greek words geo (Earth) and therme (heat). Geothermal Energy is a renewable energy source because heat is continously produced inside the Earth. people use geothermal heat for bathing, to heat buildings, and to generate Electricity"

Types of Geothermal Resources:

→ There are four types of geothermal resources.
① Hydrothermal ② Geopressured ③ hot dry rock (HDR) and ④ Magma.

→ At present the technology for economic recovery of Energy is available for hydrothermal resources only.

→ Thus, this is the only commercially used resource at present. other resources are going through a development

phase and have not become commercial so far.

Geothermal Energy:

Definition:

"The Entire heat content of Earth's crust upto depth of 10km about 15°c is defined as geothermal resources i.e; Inner Energy of the Earth is called Geothermal Energy".

(or)

"The analanous amount of Energy is available inside the Earth is known as Geothermal Energy".

→ Low grade heat about 50°c to 70°c of geothermal resources can be directly used for thermal applications.

→ High grade heat about 90°c can be used for Electrical power generation.

→ Extraction of heat can be done by conventional method by natural (or) forced circulation of water which brings out heat in the form of hot springs.

Geothermal Resources:

→ Geothermal resources are of five types:

(1) Hydrothermal convective systems.
These are subdivided into
(a) Vapour-dominated (or) dry steam fields.
(b) Liquid-dominated (or) wet steam fields.
(c) Hot water field ~~(or) Hybrid system~~.

(2) Geo pressure resources.
(3) petro thermal (or) Hot dry Rocks (HDR)
(4) Magma Resources. (5) Volcanoes.

(1) Hydro thermal systems:

Hydro thermal systems are those in which water is heated by contact with the hot rock.

These are again subdivided into

crust
mantle
hot rocks
core (magma)

(a) Vapour dominated (or) dry steam field: (200°C - 450°C)

→ In this water is vapourised into steam that reaches the surface in respectively dry condition of about 200°C to 450°C. water $\xrightarrow{200°C}$ steam

→ These steam (200°C) is used in hydro Electric power plants.

→ These type of geothermal systems have problems like in the presence of corrosive gases, erosive material and Environmental problems.

→ These are used in Less number.

→ The power plants of this type used Matsukawa in Japan, Geysers in California.

(b) Liquid dominated systems (or) Wet steam field: (175°C to 315°C)

→ In these systems the hot water circulating and trapped underground at a temp range of 175°C to 315°C.

→ When trapped by drilled wells, the water flows naturally to the surface (or) is pumped upto it.

→ It contains relatively large concentration of dissolved salts. solids particles.

→ Wet steam fluid used to generate power but power production is effected because of

by these solids to enter in pipes and heat Exchanger surfaces thus reducing the flow and heat transfer.

→ The power plants of this type are at puna (USA), Latera (Italy), Agores (portugal).

(c) Hot water field:- (80°c - 90°c)

→ The Hot water reservoir can be tapped by drilling and get the hot water at temp. 80°c to 90°c.

→ This hot water can be used either for heating purposes and small power generation using Low boiling refrigerant.

→ This water contains sulphur which is used in the medicines for cure of skin diseases.

→ Such hot springs are available at Tabapani (near shimla), Sahastra Dhara (near Dehradun), Sacred kund (at Badrinath) etc.

(2) Geo pressurised Resources:- (90° to 200°c)

→ these resources occur in Large, deep sedimentary basins (present in crust part).

→ These reservoirs are hot water aquifers containing dissolved methane (CH_4) trapped under high pressure in sedimentary formations at a depth of approximately 3-6 km. and at a depth 900 to 2400m.

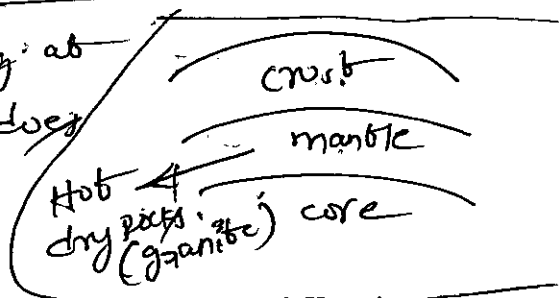
→ Temp range from 90°c to 200°c

→ Dissolved methane (CH_4) gas is used for heating, generation of power in power plants, and also used as fuel in cars.

(3). Hot Rock field:- (150°c to 290°c)

→ This system is also called as petro thermal system.

→ These are very hot solid rocks occuring at moderate depths but to which water does not have access, either because of the absence of ground water (or) the Low permeability of the rock and made up of granite. It does not contain much of water only air gaps



→ for to break the rocks and get the hot water use at the surface.

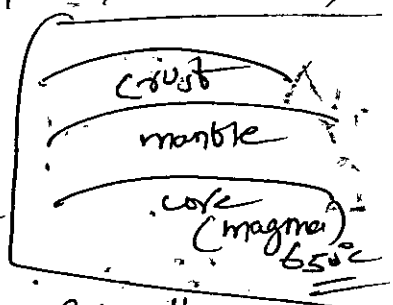
→ Hot dry rock very the heat and produce at temp of 150°c to 290°c. This energy is called petro thermal energy.

→ Used in the application of to produce Electricity.

(4) Magma system: (>650°c)

→ Magma is a molten rock with temperatures in excess of 650°c. at moderate depths.

→ A Heat Exchanger will be dipped in the molten Liquid & then water is passed from one side from the Earth surface at a higher pressure & steam will be taken out from the other side of heat Exchanger.



→ Used in the applications of thermal power plants.

(5) Volcanoes: (Old Volcanoes) (Lavas)

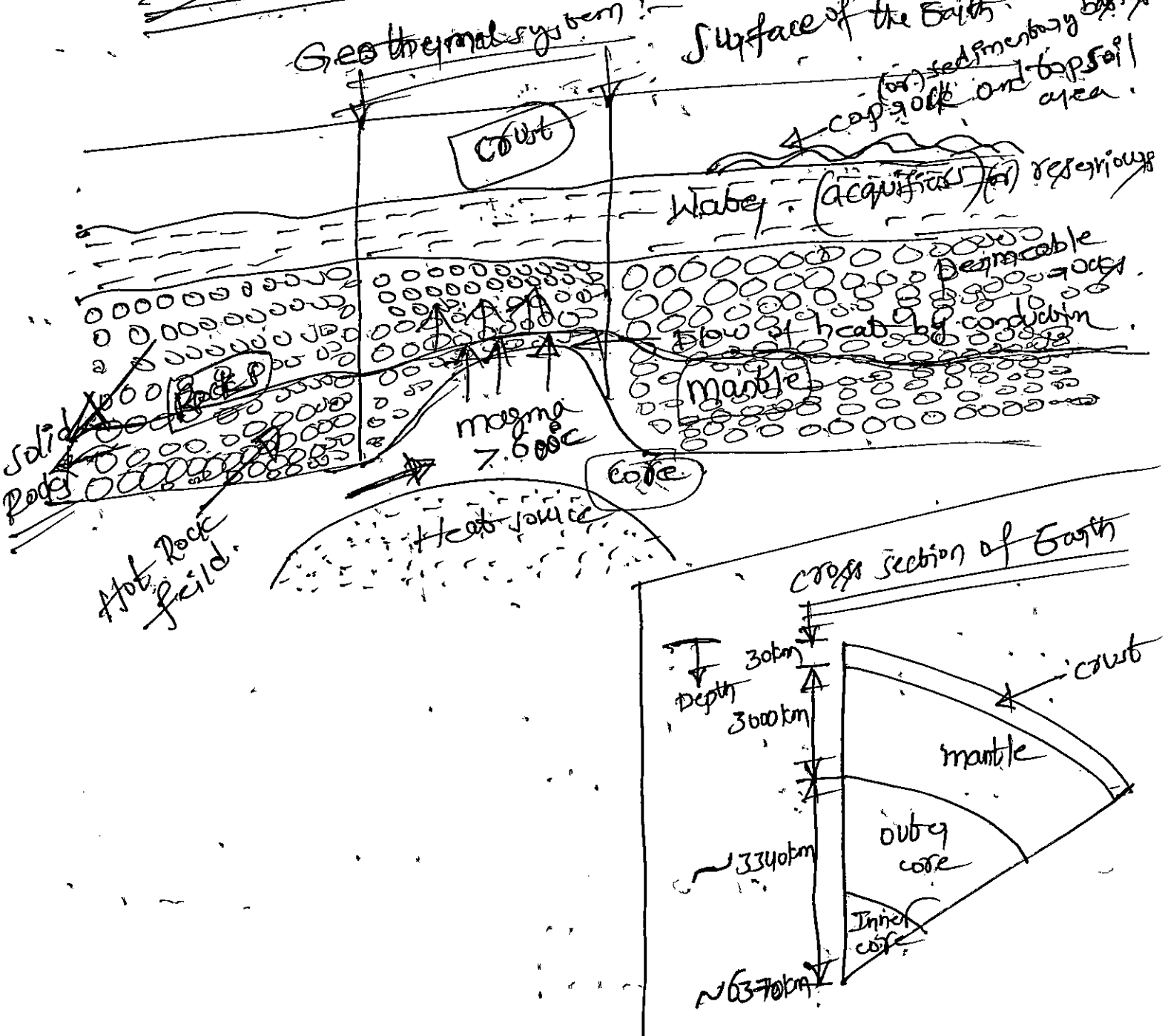
"The molten rock (magma) in the Earth's core that drives volcanic eruptions can also provide heat for Electricity generation".

Methods of harnessing the Energy:-

There are three main types of methods of harnessing the Energy:

1. Direct Use and district heating systems.
2. Geothermal power plants
3. Geothermal heat pumps (By heating and Cooling of Buildings).

Geothermal power plants:



Imp Geothermal power generation plants:

~~Hydro~~

Imp (1) Liquid dominated Resources (or) wet steam

(a) (i) Flashed steam system (or): Liquid dominated high temp system,
(i) single flashed steam system
(ii) Double flashed steam system

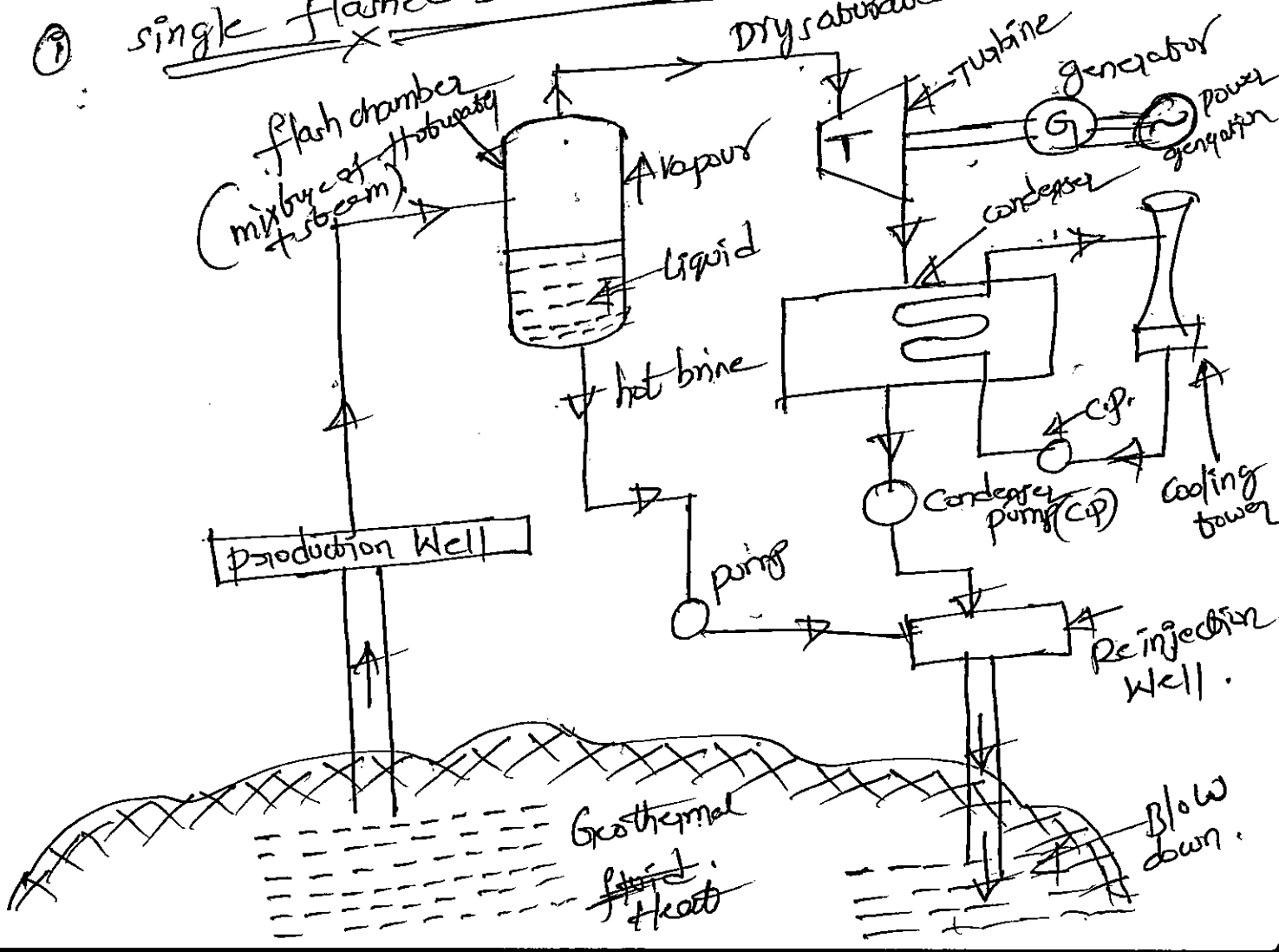
(b) Binary cycle system (or) Liquid dominated - Low temp system

Imp (2) Vapour dominated resources (or) dry steam.

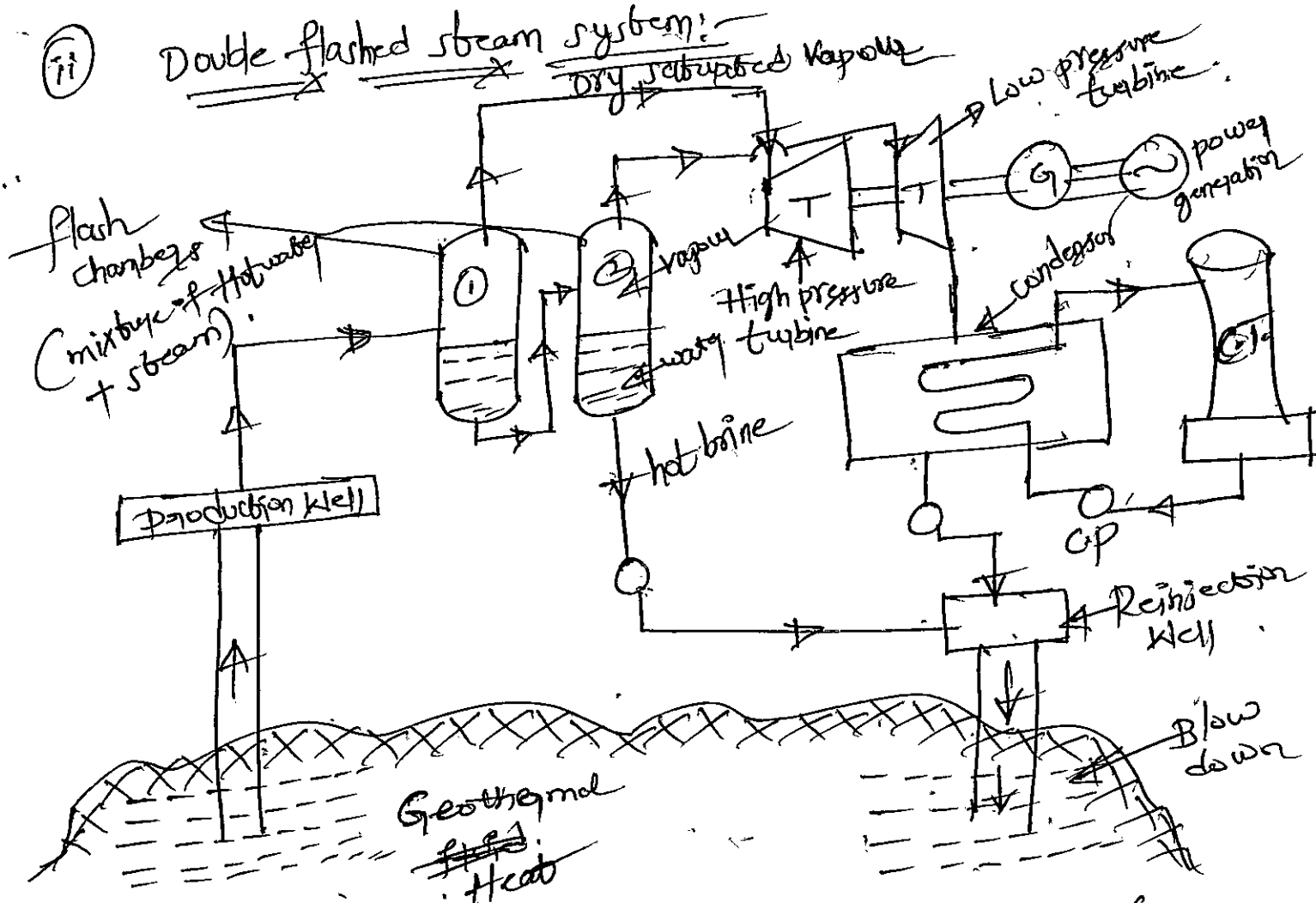
Imp (1) Liquid dominated (or) Wet steam Resources:

(a) Flashed steam system (or) Liquid dominated - high temp system (temp > 175°C):

(i) single flashed steam system:



(ii) Double flashed steam system:



→ In Liquid dominated reservoir, the water temp is above the normal boiling point temp (100°C).

→ The water in the reservoir is under pressure, it does not boil but remains in the liquid state.

→ when the water comes to the surface the pressure is reduced, rapid boiling increases the water flashes into mixture of hot water and steam.

→ The steam can be seperated and is used to generate Electric power and the remaining hot water is used as a distilled water. (or) reinject into the ground.

→ These are subdivided into
(1) Liquid dominated high temp system.
(2) Liquid dominated low temp system.

In (a) Liquid dominated, high temp system, the water temp is above 175°C.

→ It remains in Liquid state under high pressure.

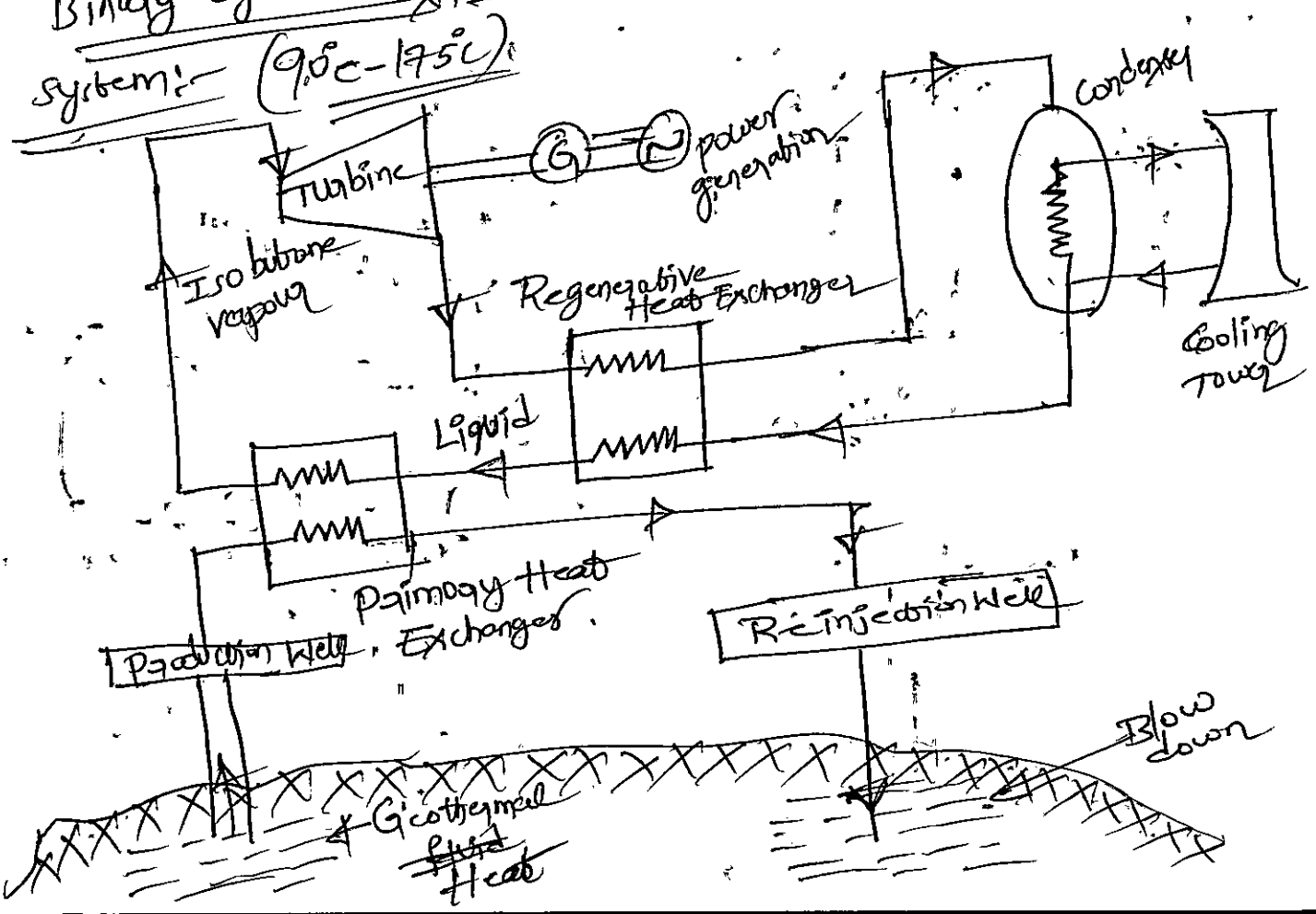
→ In such systems, the reservoir temp and pressures are 230°C and 40 atm and depths are 600m to 1400m.

→ when water is brought to the surface and pressure is reduced, rapid boiling occurs and it flashes into steam and Hot water.

→ steam is used for power generation & hot water (brine) can be used for direct heat and reinjected into the ground.

→ But in dual flash systems flash chamber and turbine are again used to get more power and more heat water.

(b) Binary cycle system (or) Liquid dominated - Low temp system:- (90°C - 175°C)



→ These are available at moderate temp range of 95c to 175c.

→ This temp. is not enough for flash steam production.

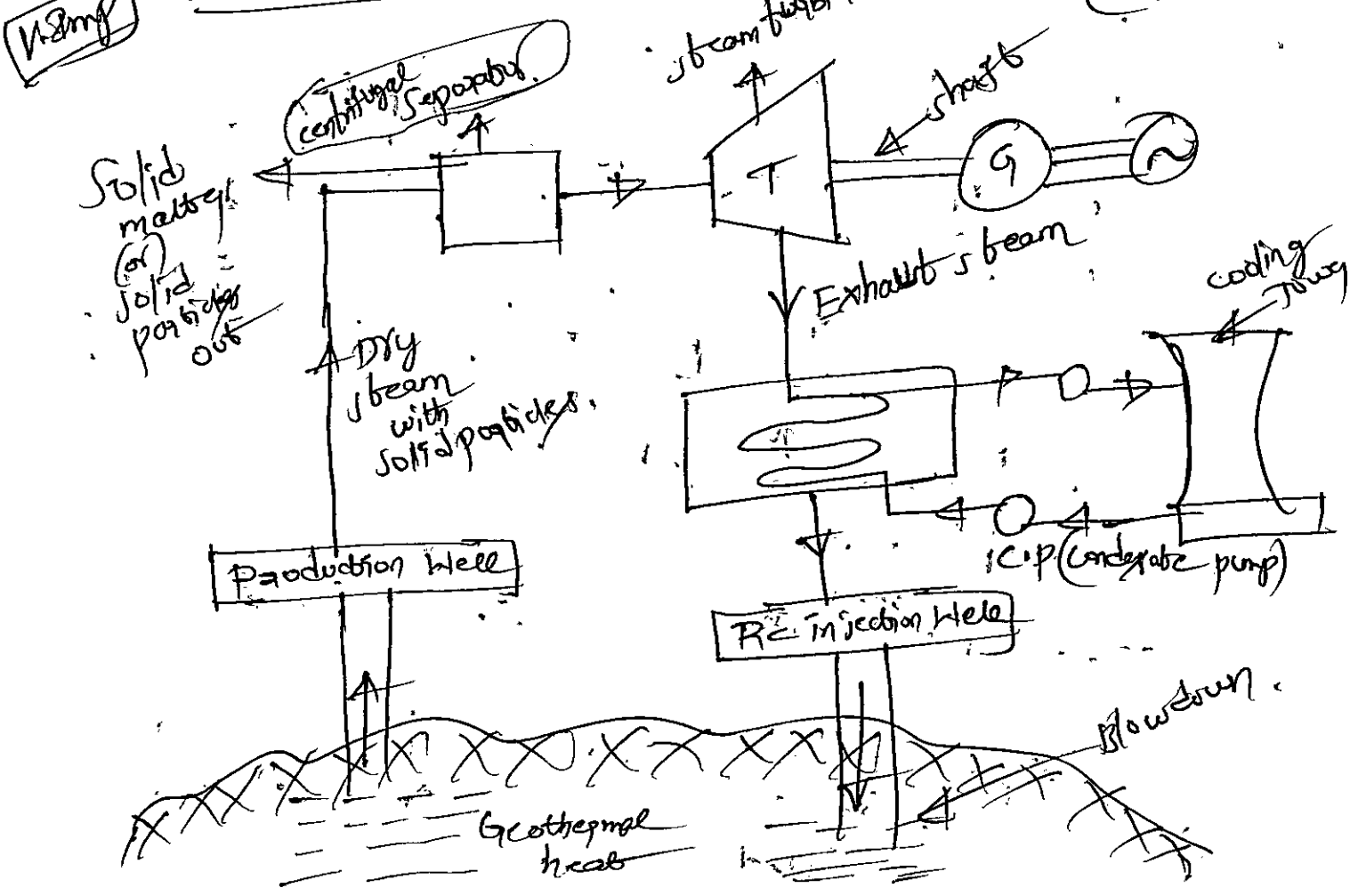
→ A binary fluid system is employed, where the heat of geothermal fluid is used to vaporize a volatile organic fluid, such as isobutane vapour.

→ By using Isobutane vapour to run the turbine and finally Electricity produced.

→ The Recover steam is send to the Regenerative Heat Exchanger sent to condenser and Cooling tower and Libegated water sent to primary Heat Exchanger and wastage has to be sent to Reinjection well.

(2) Vapour dominated Resource (or) Dry steam Resource:-

(240c - 455c)



Working:-

→ Such system delivers steam with little (or) no water of high pressure and temp upto (205c - 450c).

→ This steam is used to generate electrical Energy by Electro mechanical Energy conversion.

→ The steam extracted from the Earth may contain some amount of water and solid particles those are removed in centrifugal separator

→ This pure dry steam is then directly supplied to steam turbine which is coupled to generator.

→ By the use of condensor the steam is converted to hot water which is used for distilled water. (or) reinject back to the Earth.

Applications of Geothermal Energy:-

(1) Generation of Electric power.
(2) Industrial process heat and space heating for the various process of buildings.
(3) The green house heating.
(4) Used in Refrigeration.
(5) Used in geothermal heat pumps.
(6) More than half of the heat is used for space heating, and another third for heated pools.

Advantages:-

(1) It is a Reliable
(2) It is a Renewable Source of Energy
(3) It is a cheap source of Energy.
(4) It is available 24 hours per day

(5) It is almost pollution free
(6) Geothermal plants Little land area.
(7) The Emission of CO_2 and SO_2 by the geothermal power plant is far less compare with the conventional fossil fuel plants.

Disadvantages:

(1) The life of the plant reduce
(2) The available thermal energy distributed the over huge distance.
(3) Vapour dominated resources have some problems by corrosive gases, Environmental problems.
(4) By using Liquid dominated resource it dissolved solid particles which leads to directly reduce of heat transfer.

TYPES of WELLS

The geothermal power plant companies drill two separate wells to the extremely hot water reservoir Under the Earth Surface (1) The production well (2) Injection well.

(1) Production Well:

→ Source of steam
→ Depth 1 km to 10km
→ It is used to transmit fluids (or) heat derived from a geothermal resource to the surface.
→ Where the heat is used for Industrial, commercial and domestic purposes.

(2) Injection Well:

→ The Excess condensate and the hot brine (or) hot water from the separator (or) from condenser returns back to the underground thermal reservoir.
→ Reinjection wells are Located in appropriate places.
→ Some reservoirs can give outputs for years without reinjection.

Ocean Energy:-

Ocean thermal Energy conversion system (OTEC):-

Defination:-

OTEC (ocean thermal Energy conversion) is a process that can produce Electricity by using the temp. difference b/w deep cold ocean water (5-7°C) and warm tropical surface water (23-29°C). Energy from the Sun heats the surface water of the ocean.

→ OTEC plants pump large quantities of deep cold sea water and surface seawater to run a power cycle and produce Electricity.

status of OTEC system in India:-

→ A vertical tremendous ocean thermal Energy conversion in India is Tamilnadu. they started in Kulasekharapatnam in 1980.

→ By using the plant produce 1MW in 1984. by the method of closed cycle. The plant was prepared by IIT chennai.

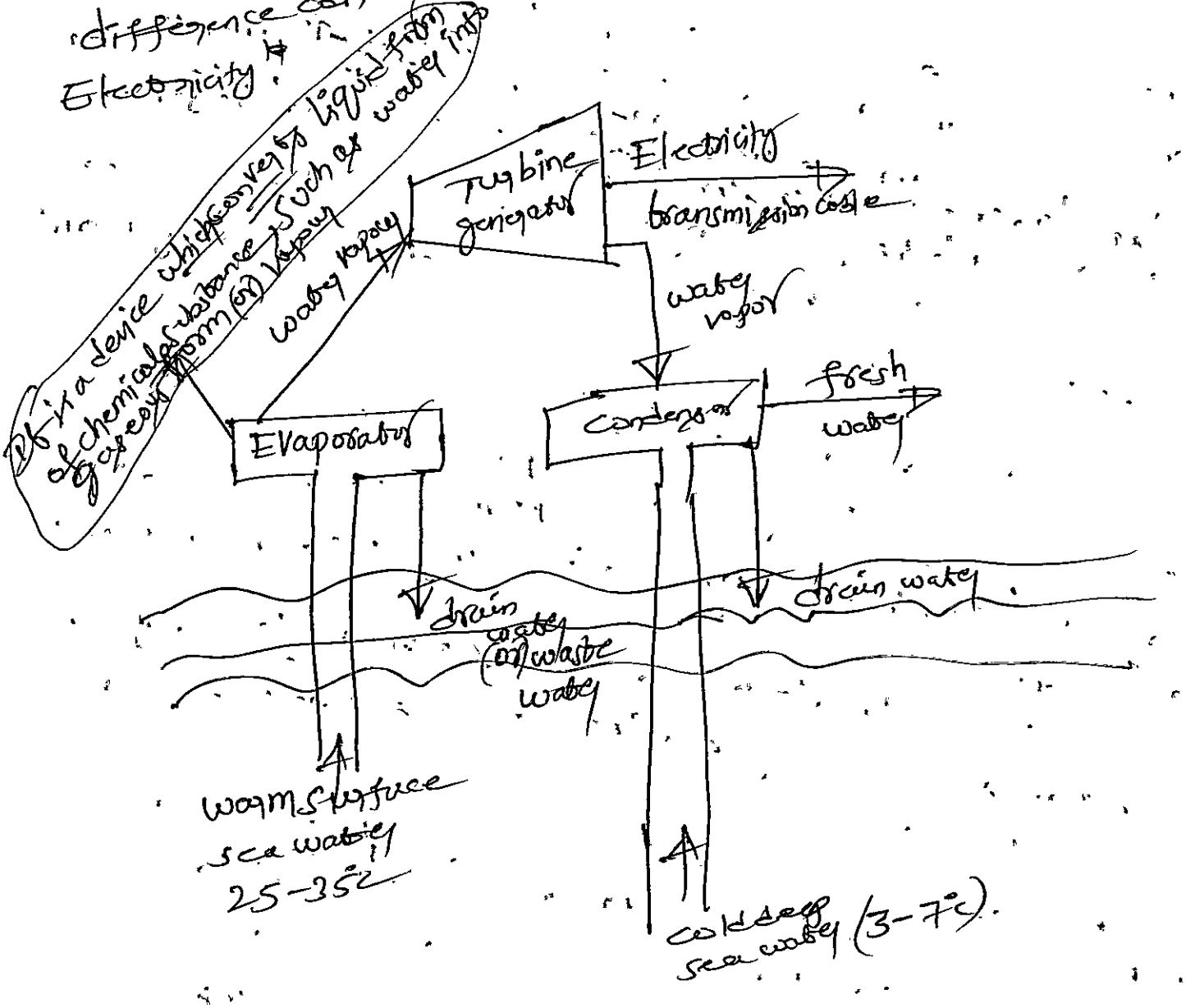
→ The national Institute of ocean technology is implementing in the world first floating, closed cycle plant in Tuticorin (or) Toothukudi (Tamilnadu). It produce 10-25MW and in future it produce 100MW.

→ After 1 year the floating plant that was shifted to Andaman & Nicobar islands.

→ For 1 year per Annum around the coastal line generate the power: 1,80,000MW.

Working principle of OTEC:-

((The water at the surface of the ocean is warmer than the water at deeper depths". This temp difference can be used by OTEC systems to generate Electricity.



Setting of OTEC plants:-

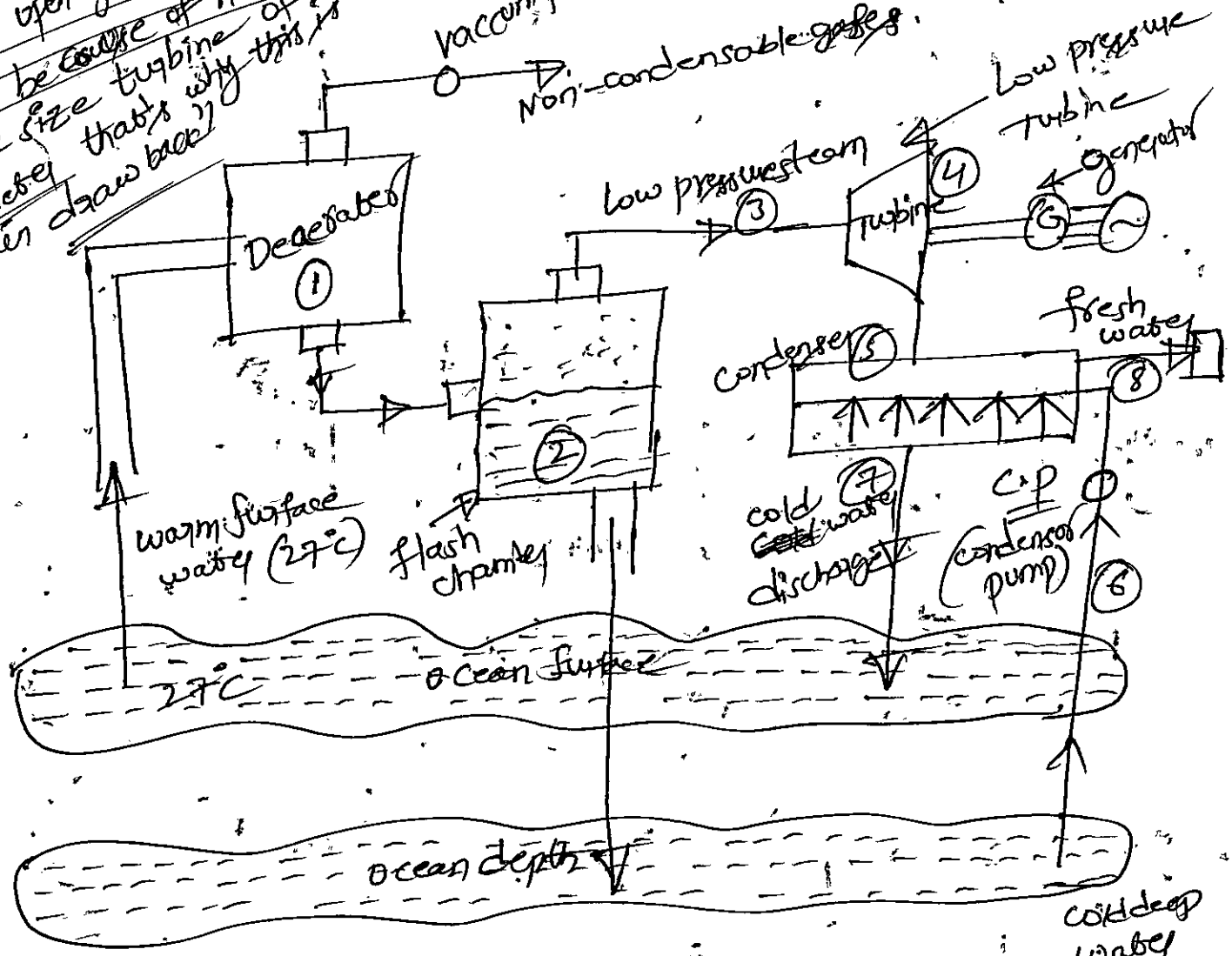
They are three cycles:-

1. open cycle (or) claude cycle ocean thermal energy conversion (OTEC)
2. closed cycle (or) Anderson cycle OTEC system
3. Hybrid cycle (or) (combination of both open cycle + closed cycle for obtaining max theoretical efficiency).

(1) open cycle (or) cloude cycle OTEC system:

→ Implemented in (1932).

cc
* Mostly open cycle are not used because of needed Large size turbine of diameter that's why this is main drawback)



Working:

→ The warm surface water is collected in Deaerator which is contained of Non-condensable gases can be removed by using vaccum pump.

→ Then steam + water has passes to flash chamber

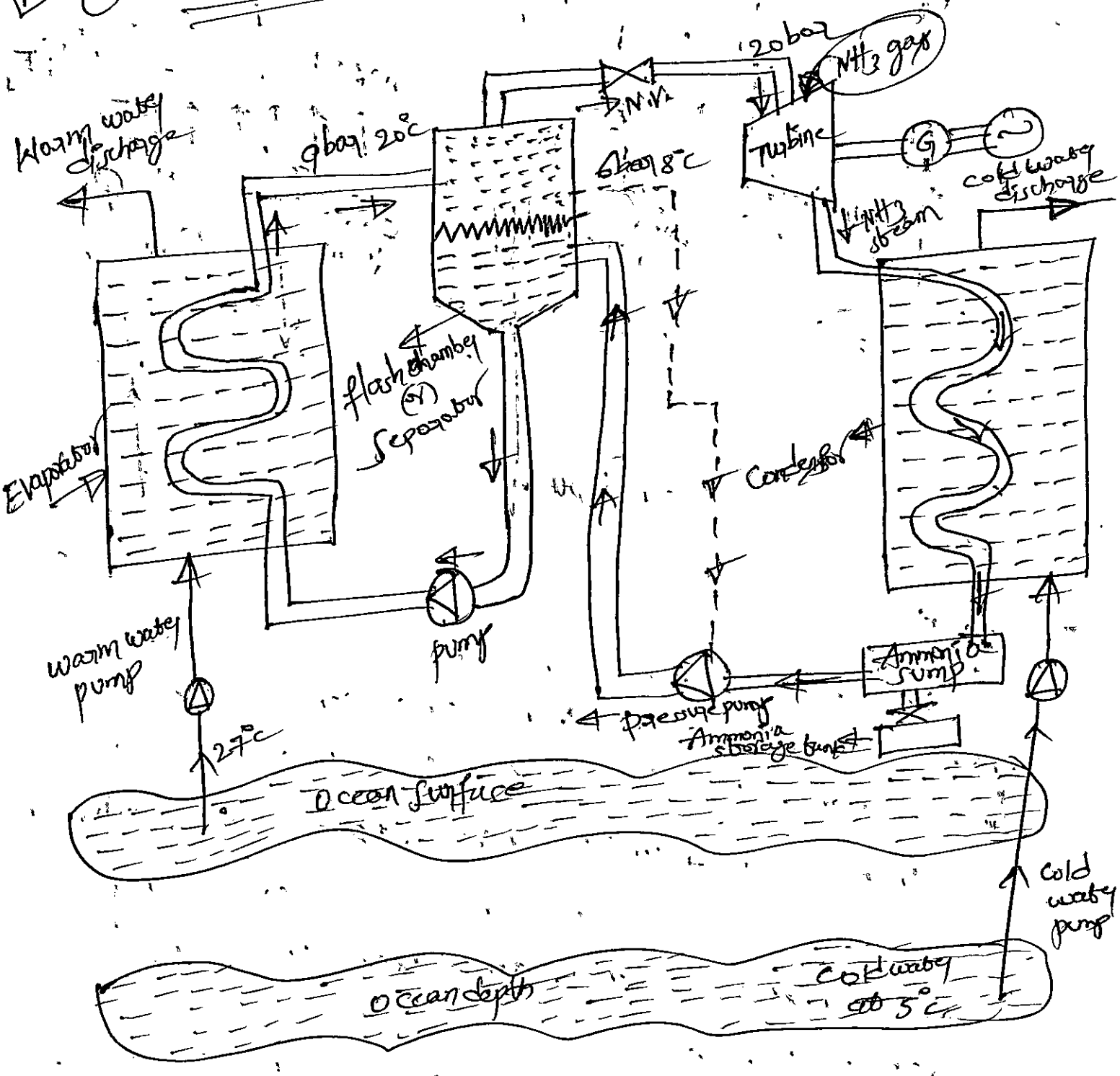
→ Here to separate the vapour (steam by Low pressure steam) passes through low pressure Turbine.

→ Finally Electricity produced by generator.

→ The separated water vapour is discharged into ocean surface by using condenser.

→ from cold deep seawater (5°c) passes through condenser and finally separated fresh water and also discharge cold water back to the surface.

Mistamp (2) closed cycle (or) Anderson closed cycle OTEC systems



→ The warm water from the surface with at a temp of 27°c is brought in one pipe and cold water at 5°c is brought another pipe at a depth of about 1000m in OTEC plant. Two water pipes are used in conjunction with a working fluid to generate the Electric power. In closed cycle Low working fluids are NH_3 (or) Propane is used.

→ The different operational activity in the plant.

① The warm sea water Evaporates the liquid ammonia into Vapour in a unit called Evaporator. This can be done because the NH_3 Exist in the form of gas at the surface of sea water.

② The liquid NH_3 which is not Evaporised collects in its again. Recirculated to the Evaporator. It is in the form of high pressure it pass to the turbine and generate Electricity.

③ The NH_3 Vapour is coming out the turbine which is at the pressure lower than the when Entry to the turbine when it is condensed back to the liquid ammonia by cooling it with cold sea water.

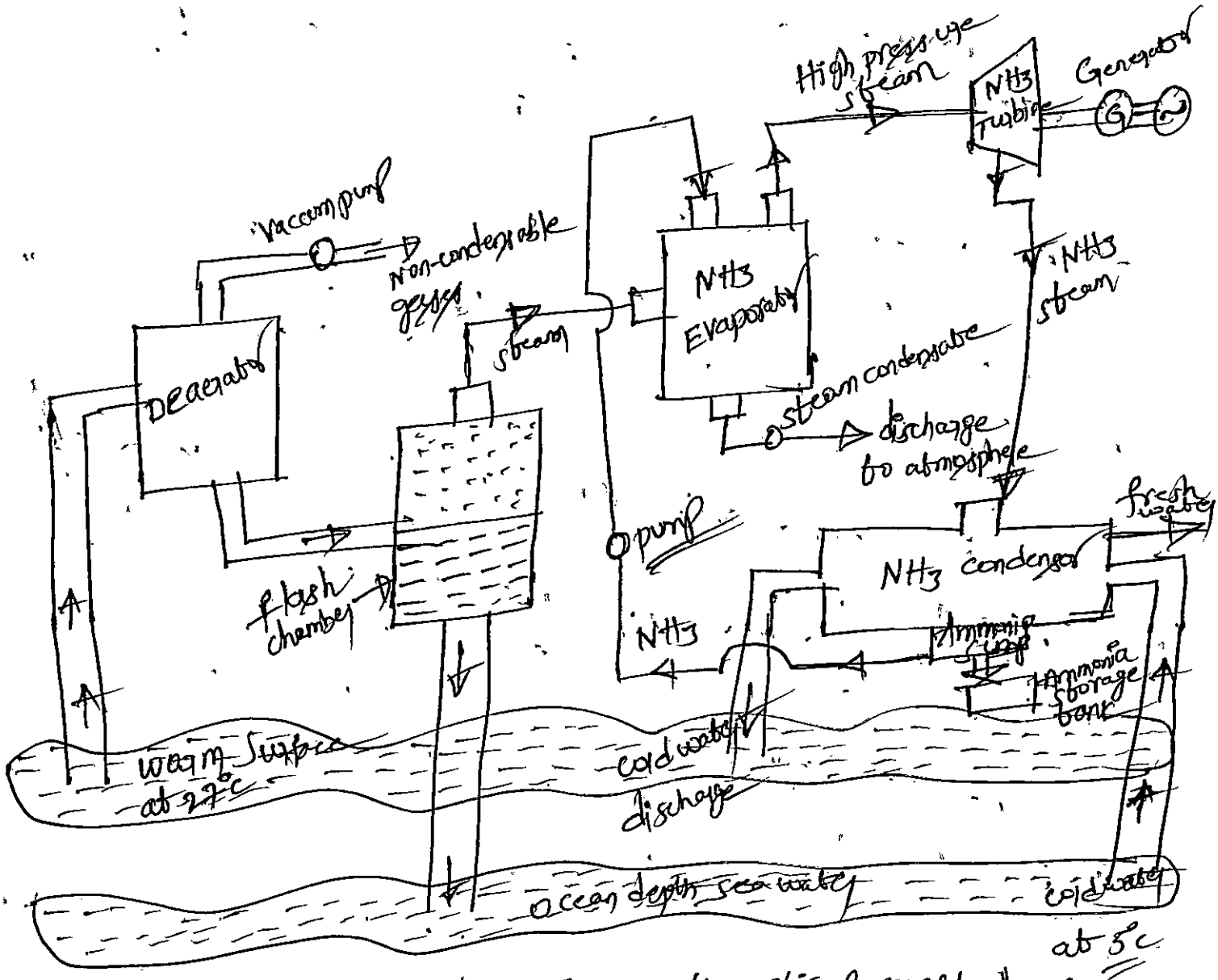
④ The liquid NH_3 collected in Ammonia sump after few hours of time, The liquid NH_3 is pumped back to the Evaporator thus completing the cycle.

⑤ Hence this process is happens in closed cycle it repeats the process again and again.

Advantage:-

when compare to open cycle the turbine size is reduces 1/10th size of closed cycle. But maintainence cost is more.

③ Hybrid cycle (or) combination of both open and closed cycle:-



→ The Hybrid OTEC is a theoritical method of maximisation the uses of ocean thermal energy.

① The cycle is a combination of both open and closed cycle.
② The η_{th} (overall thermal efficiency) of hybrid system is higher than the other two system.
③ It produces Electricity and fresh water to drink.

There are two concepts of hybrid system:

① To produce non-condensable gases whereas steam produced from that to produce Electricity:
② NH_3 ammonia is available and circulated through NH_3 Evaporator, and produce finally Electricity.

Advantages of OTEC:-

(1) It is Environmental friendly
(2) The additional products of the food, portable water, air conditioning system etc which is readily can be provided.
(3) The cold sea water is rich in nutrients and can be utilised for water plants (or) for the aqua culture used to increase the production.
(4) The thermal resources of the ocean enables that the power sources is available day (or) night.
(5) It can produced Electricity at any time.

Disadvantages:-

(1) The plants get effected with natural climatic conditions.
(2) The power cost is more.
(3) The construction and pipe length affects the marine Ecosystem.
(4) The closed cycle OTEC can causes the pollution if Intermediate chemical leakages into the oceans.
(5) The Heat Exchangers (Evaporators & Condensers) must be made (or) highly conductive materials which increase their capital cost.
(6) Difficult to maintainance
(7) The construction of the floating plant is difficult.

Applications of OTEC:-

(1) The desalinated water used for irrigation and human consumption.

Ex:- A small 1MW plant it can be capable of producing the 4500m³/day for freshwater per day. It is Enough for suppling the 20,000 population

(2) The closed cycle OTEC plant can also acts as a chemical treatment plant.

(3) The cold chilled water is used for cooling the green houses and air conditioning systems and creating the cold storage facilities for preserving the food.

(4) The Enclosing area can be used for aquaculture and mariculture.

(5) The deep sea cold water is rich in nutrients and used for various applications.

Unit-5

Direct Energy conversion:-

Need for DEC, cannot cycle, Limitations, principles of DEC, Thermo Electric generators, Seebeck and Peltier, and Joule Thomson Effects, materials, applications, MHD generators, principles, dissociation and ionization, Hall effect, magnetic flux, MHD accelerator, MHD Engine, power generation systems, Electron gas dynamic conversion, economic aspects.

Fuel cells, principles, Faraday's Laws, thermodynamic aspects, selection of fuels and operating conditions.

Direct Energy conversion:-

"A direct Energy conversion device converts one form of energy to another through a single process".

Ex:- Solar cell is a direct Energy conversion device that converts Electro magnetic radiation into Electricity".

(or)

"Transformation one type of Energy (such as Sunlight) to another (such as Electricity) without passing through a intermediate stage (such as water → steam → Turbine → Electricity).

↳ Indirect energy conversion

Examples:-

1. Fuelcell is an Electro chemical producer of Electricity was developed by william Robert grove.
2. Thermo Electric generators are devices which converts heat directly into Electricity.

~~Tidal Energy:~~ ③ Solar cells has to convert direct Electromagnetic radiation into Electricity.

NEED FOR DEC:-

① No conversion of energy into mechanical and to Electricity.
② Less Losses in conversion process.
③ More Efficient process
④ cost also reduced.

Imp Carnot cycle:-

→ carnot cycle has the greatest efficiency possible of an engine based on the assumption of the absence of incidental wasteful processes such as friction and no conduction of heat b/w different parts of the engine

Definition:-

"An ideal reversible closed thermodynamic cycle in which the working substance goes through the four successive operations of isothermal Expansion and ~~isothermal~~ adiabatic Expansion to a desired point, isothermal compression, and adiabatic compression back to its initial state."

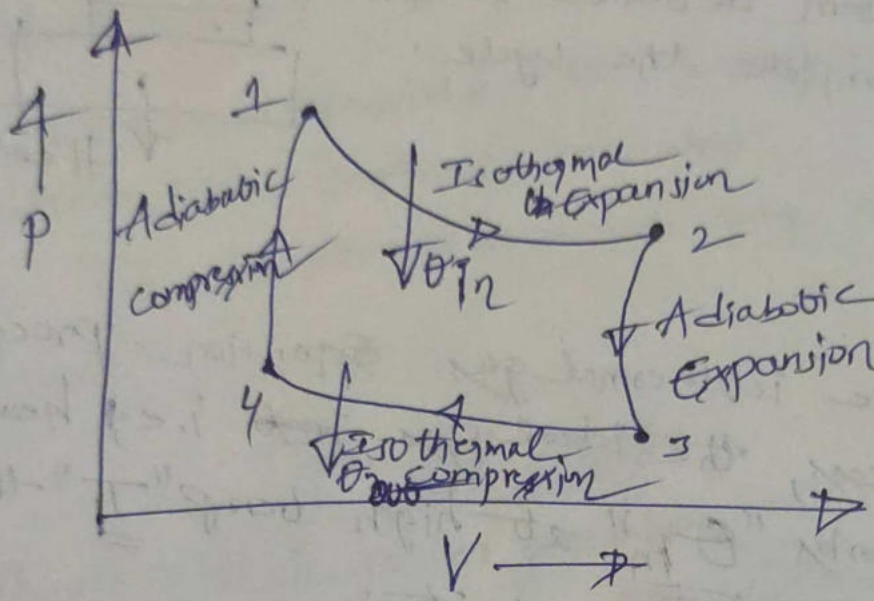
~~Working~~ Introduction of carnot cycle:-

→ carnot cycle is an ideal cycle of reversible process.

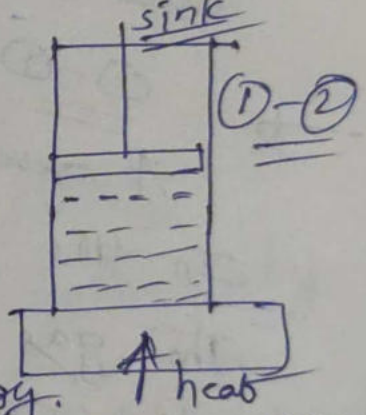
→ carnot cycle is a theoritical thermodynamic cycle proposed by Nicolas Leonard Sadi carnot in

Process of carnot cycle:-

Take the P-V diagram



Process ①-②:- Heat is supplied from source at high temperature T_1. (Isothermal Expansion).

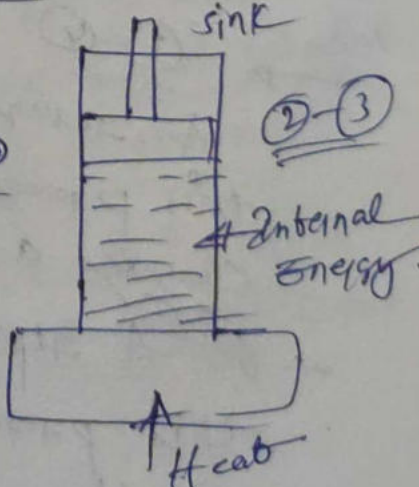


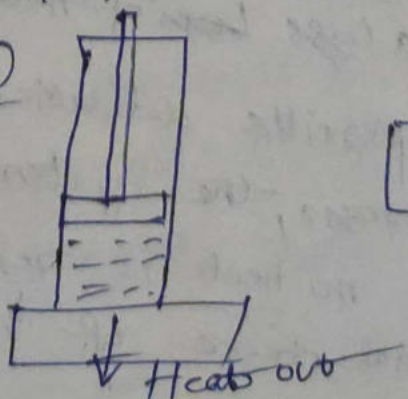
Process ②-③:- (Adiabatic Expansion)

No Heat is supplied however the workdone by the expense of internal Energy. As a result temp falls from T_1 to T_2.

Process ③-④:- (Isothermal compression)

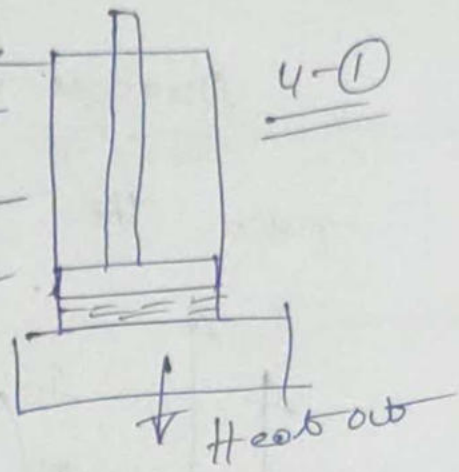
Heat is rejected from sink at low temperature T_2.





Process 4-① (Adiabatic Compression)

No Heat is rejected. Workdone on the system. As a result the temp. increase from T_2 to T_1 and the system returned to initial state to complete the cycle.



Working:-

① - ②

→ A reversible isothermal gas Expansion process. In this process, the ideal gas i.e; heat is supplied (or) absorbs "Q" at high temp "T_1" through heat source and Expand it.

② - ③

→ A reversible adiabatic gas Expansion process. In this process the system is thermally insulated. The gas continues to Expand and do work which causes the system to cool and lower the temp. from T_1 to T_2.

③ - ④

→ A reversible isothermal gas compression process. In this process work is done at the gas T_1 and causes a loss of heat, Q.

④ - ① A reversible adiabatic gas compression process. In this process, the system is thermally insulated. Here no heat is rejected and back to the initial stage of increase temp.

Limitations of carnot cycle:-

→ The carnot cycle is Hypothetical (something that doesn't really exist)

→ practically it is not possible to neglect friction b/w piston & cylinder.

→ It is impossible to construct cylinder walls which are perfect insulators

→ The output obtained per cycle is very small.

TYPES OF DEC:-

① Thermo Electric power generation.
② Thermo ionic power generation ③ Magneto hydro dynamic systems ④ photo voltaic power systems ⑤ Fuel cells.
⑥ Thermo nuclear fusion power generation.

principle of Thermo Electric power generation:- (TEG) (or) DEC:-

→ The pioneer in thermoElectric ways defined by a german scientist (or) team thomas Johann seebeck (1770-1831).

(principle of TEG:- (or) DEC.

→ ThermoElectricity refers to a class of phenomenon in which a temp difference creates an Electric potential (or) an Electric potential creates a temp difference.

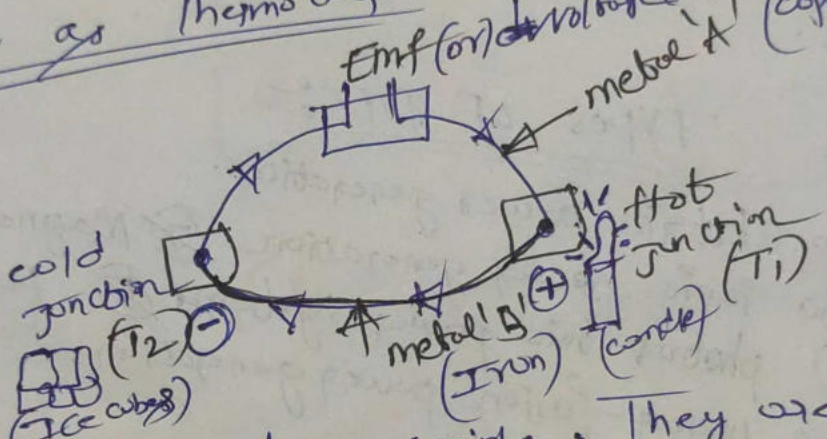
(temp point)

→ Thermo Electric power generator is a device that converts the heat energy into Electrical energy based on the principle of seebeck effect.

→ Later, in 1834 French scientist called peltier define peltier effect and in 1851 Thomson define called Joule Thomson effect. Both effects works on thermal effects on conductors of thermo electric conversion.

Thermocouple:-

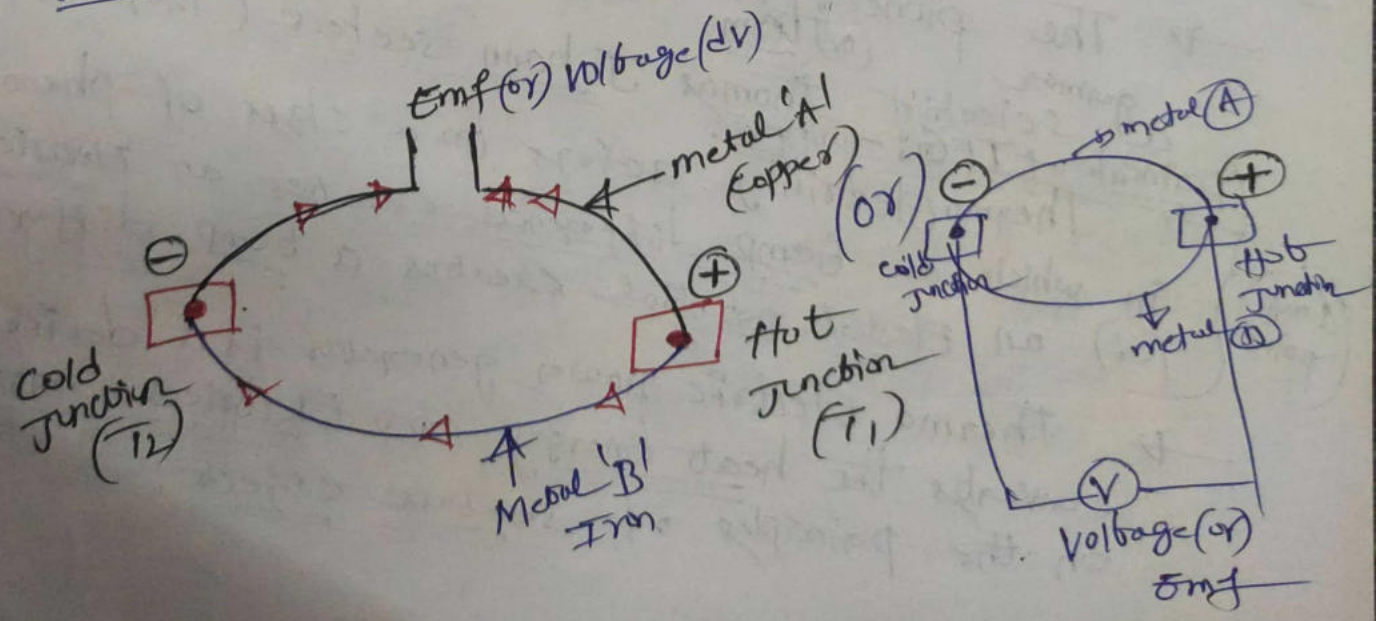
" when two dissimilar metals are connected to each other to form two junctions & these are subjected to different temperatures, an electric current flows through it. This combination of two dissimilar metal is called as thermo couple



Based on thermocouple principle. They are
① seeback Effect ② peltire Effect ③ Thomson Effect.

① seeback Effect:-

Imp



"Seeback Effect states that whenever two dissimilar metals are connected together to form two junctions. out of which one junction is subjected to high temp and another junction is subjected to low temp then emf induced is proportional to temp difference b/w two junctions!!

Voltage (or) Emf $\propto \Delta T$

$$\text{Emf (or) } dV = \alpha \Delta T$$

$$dV = \alpha \Delta T$$

$$\alpha = \frac{\Delta T}{dV}$$

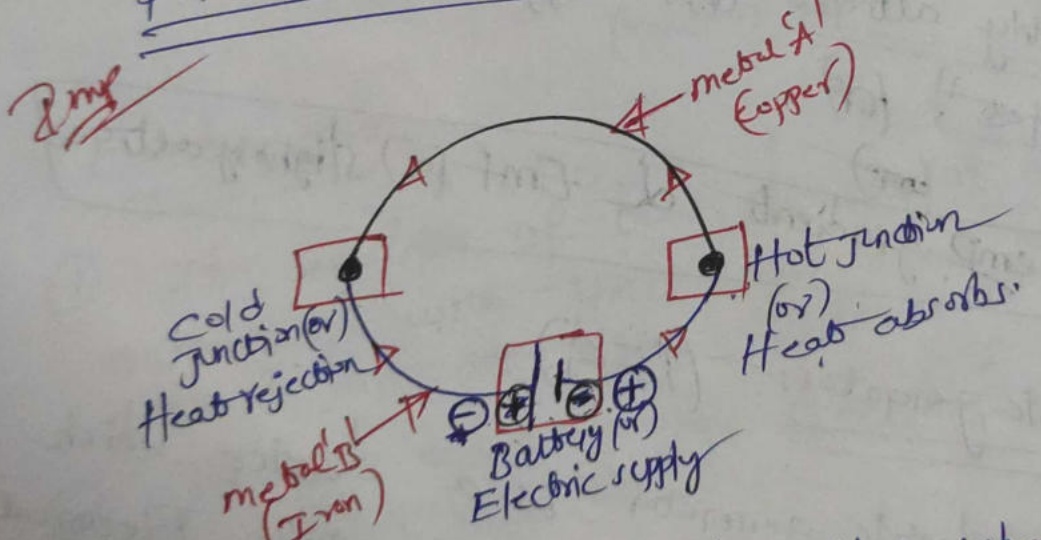
where

'α' = seeback coefficient

ΔT = temp difference

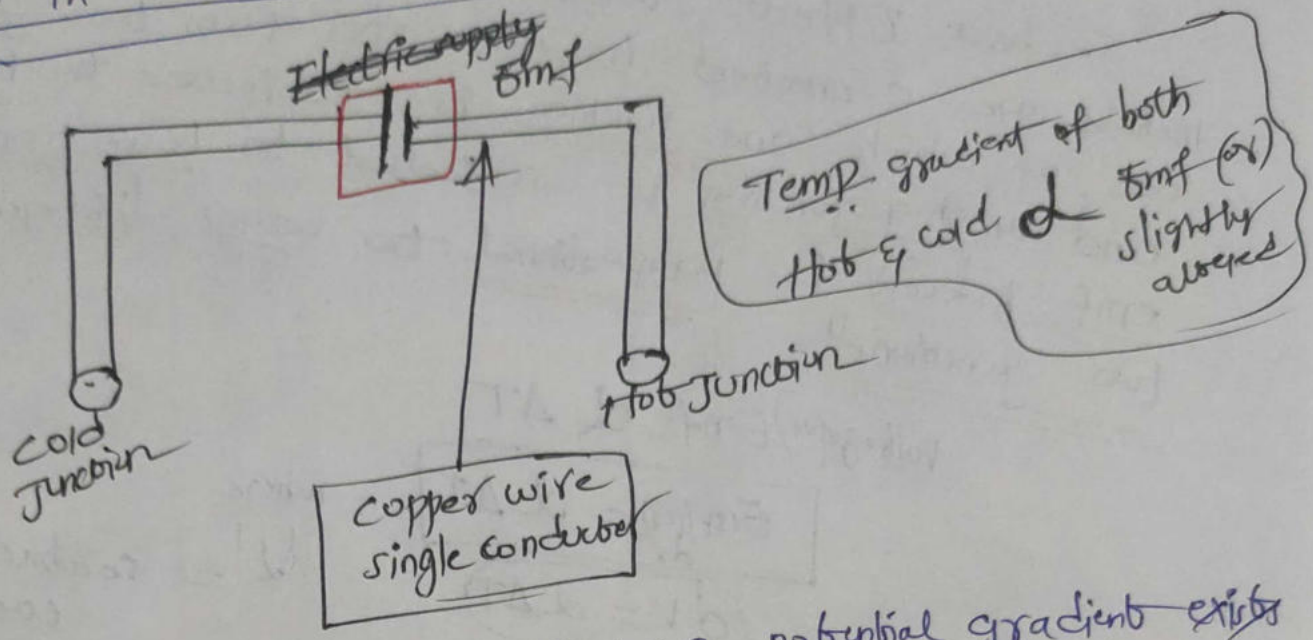
dV = voltage.

Peltire Effect:- (Reverse of seeback Effect)



"peltier Effect states that when two dissimilar metals form a closed loop if Externally current forced to flow through closed loop, then one junction will get heated (or) Heat absorbs & other will become cool. (or) Heat rejection. "

Ans Joule Thomson Effect:-



→ " Thomson Effect states that a potential gradient exists Even in a single conductor having temp gradient."

→ " If a temp gradient exist along any one metal (or) both the metal of thermo couple then Junction EMF may be slightly alloyed this Effect is called as Thomson Effect."

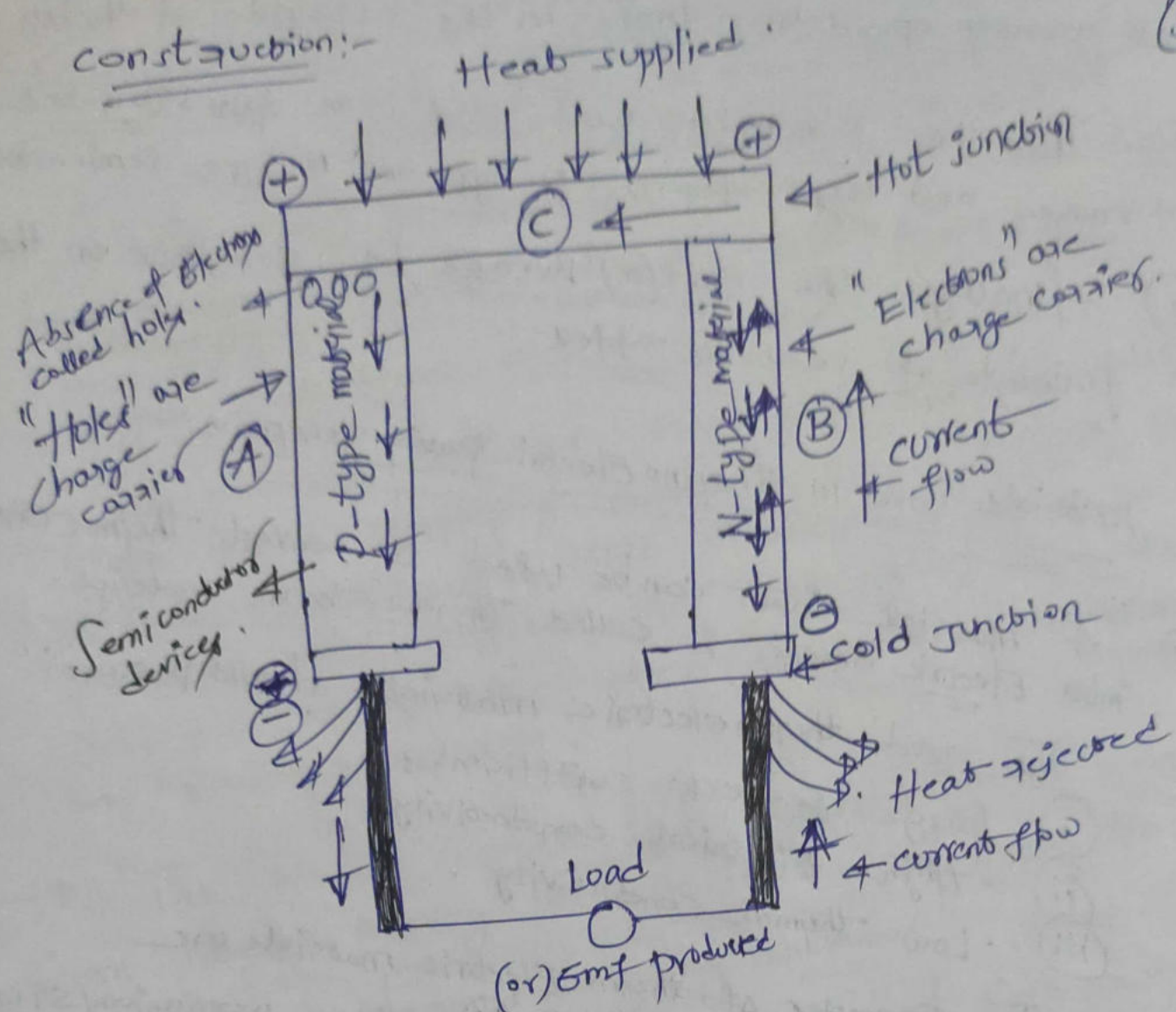
Temp. gradient ∝ Emf (or) slightly alloyed

Ans Thermo Electric generator:- (TEG)

Def:- " Thermo Electric generator is a device which converts heat Energy (or) heat flux into Electrical Energy based on the principles of seebeck Effect."

→ "When the Junctions of two different metals are maintained at different temperature, then emf is produced in the circuit."

Construction:-



Construction:-

(1) It consists of two dissimilar metals. "A and B" respectively with their ends joined together at point 'C' which is kept at higher temp.

(2) The other end of metals A and B is kept at low temp and induced voltage (or) Emf.

(3) The simplest thermoelectric generator consists of a thermocouple comprising of p-type and n-type material.

Working:-

(1) consider a metal bar whose one side is kept at a higher temp than the other.

(2) If the free Electrons in the metal are considered to behave a gas of higher kinetic energy will moving

at greater speed than those in the cold side of the bar.

(3) Then the Electrons and holes are vibrated more and pass from p-type and N-type semiconductors.

(4) finally the Emf(or) voltage is generated on the principle of seebeck effect.

materials used in thermo Electric power generation:-

(1) "A material that can be used to convert thermal Energy into Electric Energy is called thermo Electric material.

(2) The good thermo electric materials should possess.
   (i) Large seebeck coefficients
   (ii) High Electrical conductivity
   (iii) Low thermal conductivity.

(3) The Examples of thermo Electric materials are
   (i) Lead telluride (PbTe) (ii) silicon germanium (SiGe)
   (iii) Bismuth antimony (BiSb) (iv) Bismuth telluride (Bi_2Te_3).

Applications of thermo Electric materials:-

(1) Used in Biothermal batteries
(2) used in Electronic devices. (3) Automotive power generation
(4) used in Electricity generation (5) Used in Refrigeration and air conditioning (6) used in heating/cooling devices.
(7) used in Biomedical devices.

V.V.V. Prof

MHD generators: "MHD (magneto Hydro dynamics) concerned with flow of a conducting fluid in the presence of magnetic and electric field. fluids include plasmas, liquid metals and salt water"!

"An MHD generator is a device for converting heat energy of a fuel directly into Electrical Energy (or) thermal energy without conventional electric generator"!

→ In advanced countries MHD generators are widely used but in developing countries like INDIA, it still under construction, this construction work in progress at TRICHI in TAMILNADU, under the join efforts of BARC, ACC (Associated cement corporation) and Russian technologists.

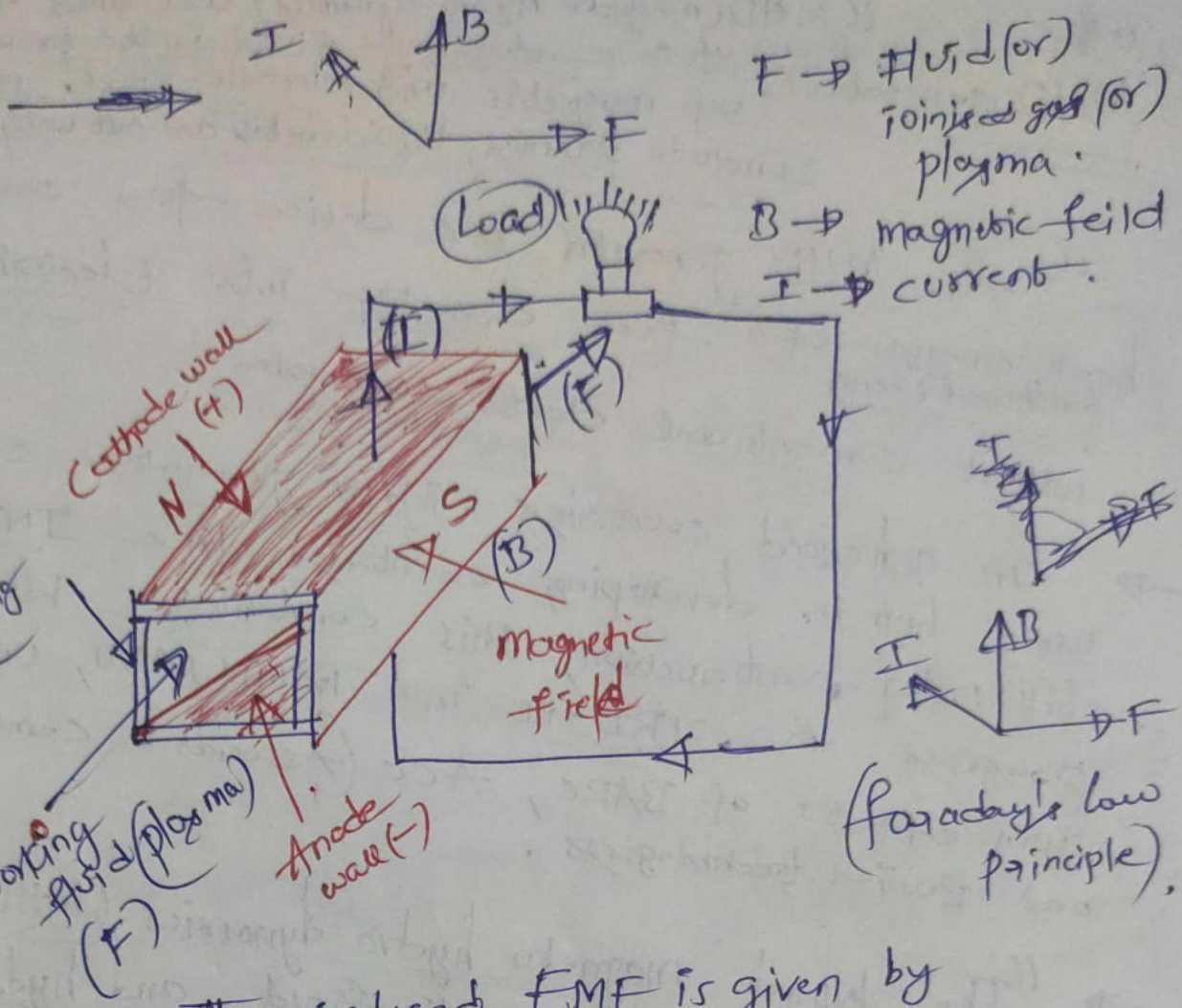
→ "The word magneto hydro dynamics (MHD) is derived from magneto meaning magnetic field and hydro meaning Liquid, and dynamics meaning movement" Here fluids include pure plasmas, Liquid metals and Salt water.

→ The field of MHD was initiated by "Hannes Alfven" for which he received the Nobel prize in physics in 1970

Principle of MHD generators:- (Faraday's Laws principle)

→ MHD generator works on the principle of "FARADAYS LAWS" of Electro magnetic Induction"!

→ If taken principle:- "when the conductor (or) ionized plasma moves through a magnetic field, it generates an Electric field perpendicular to the magnetic field & direction of conductor"!



The induced EMF is given by

$$E_{ind} = u \times B$$

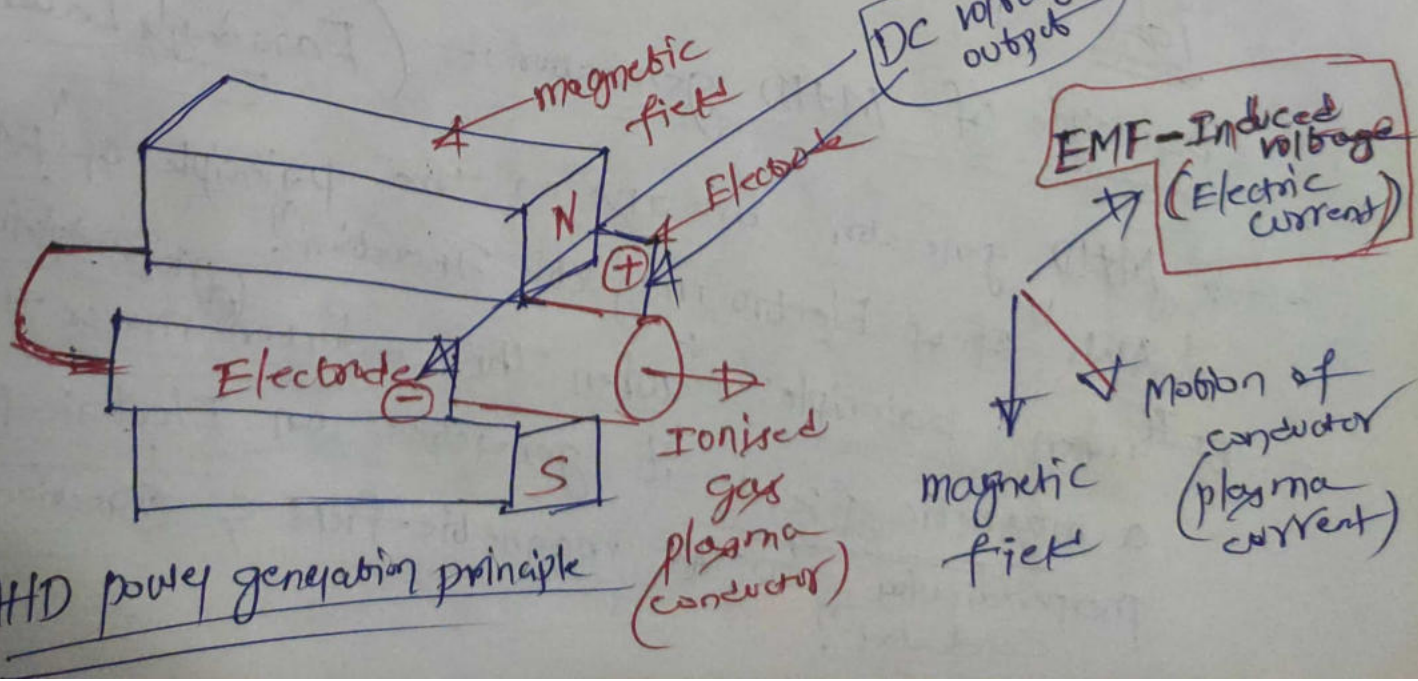
where u = velocity of the conductor

B = magnetic field intensity.

The induced current is given by

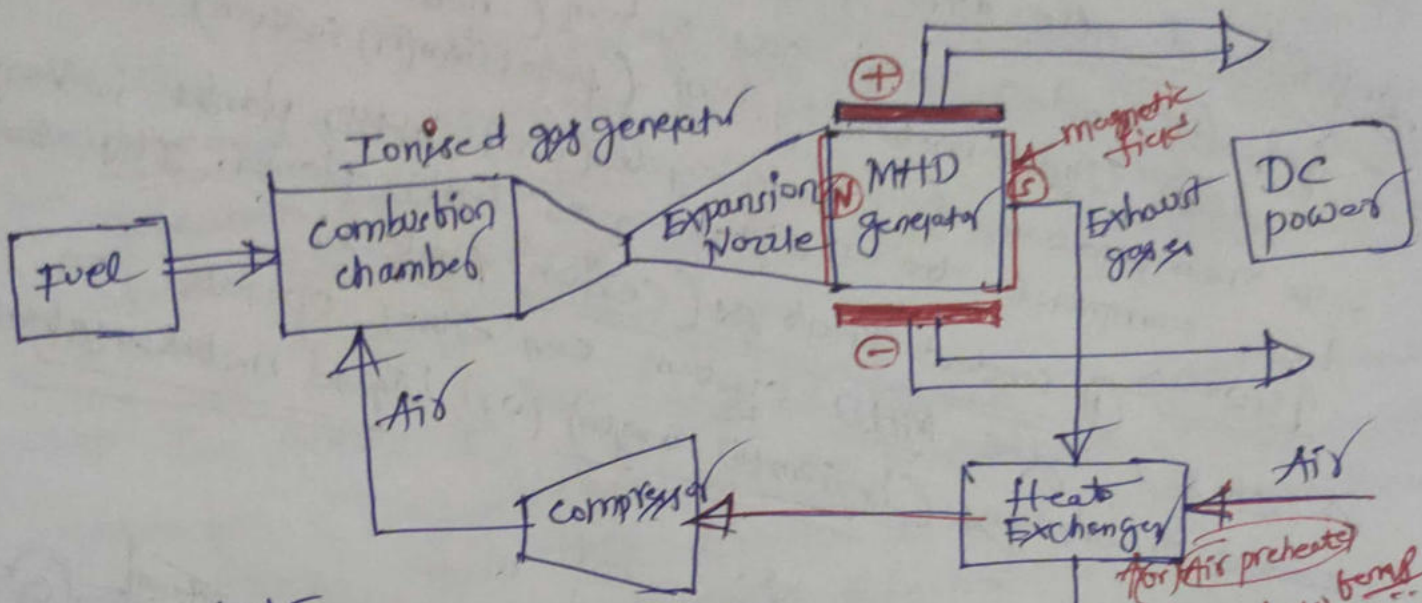
$$I_{ind} = C \times E_{ind}$$

where C = electric conductivity.



MHD power generation principle

MHD Electricity generation:- (primary working) (7)



Note:-

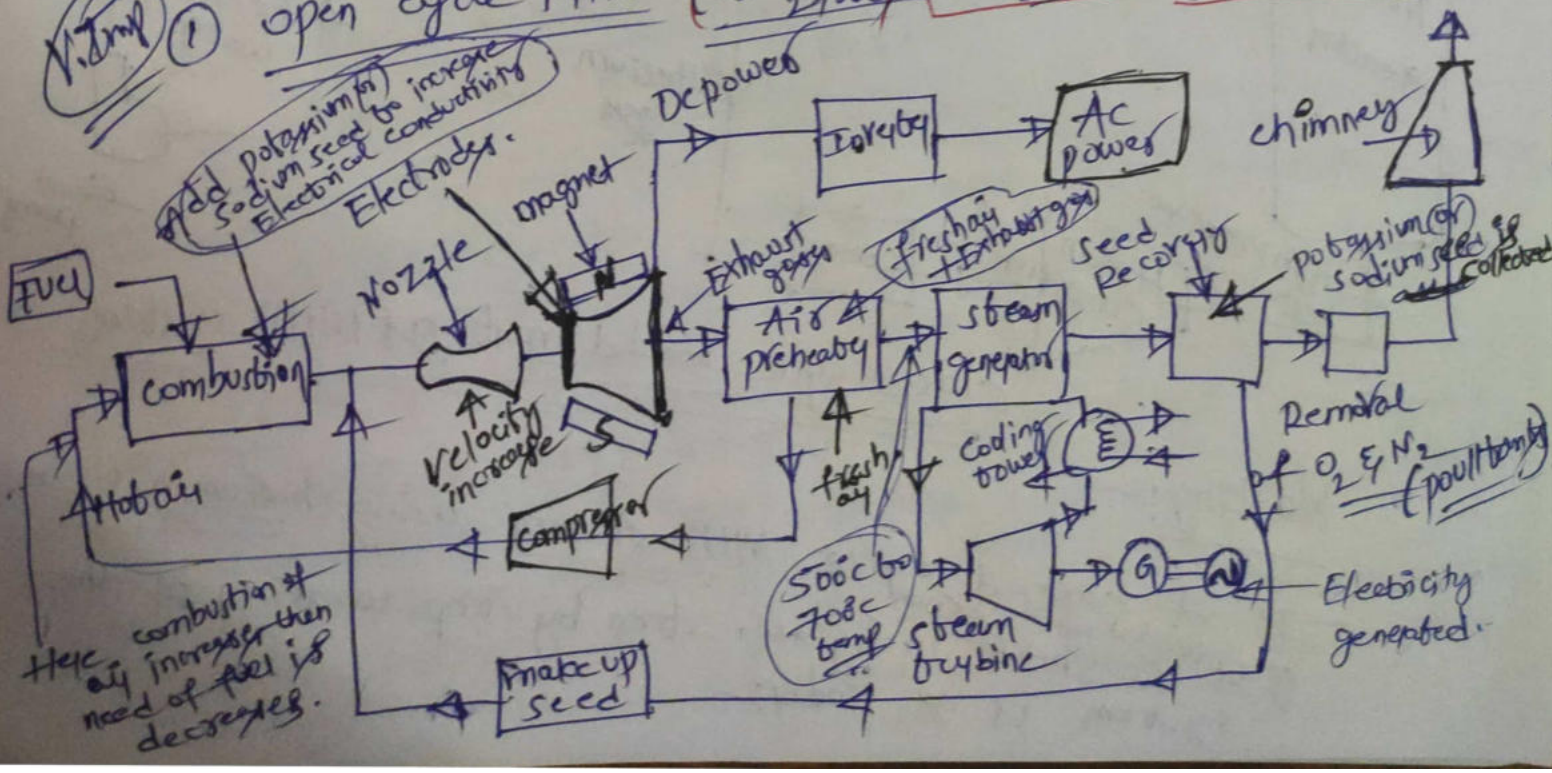
write working of your own manner

Types of MHD generator:-

Imp (1) open cycle MHD generator (2) closed cycle MHD generator.

(2) It generates 1400°C temp when compare open cycle and it is low compare to open cycle

(1) open cycle MHD:- (2300°C to 2700°C)



Note:- write working of your manner

V. Imp Closed cycle MHD generator:- (1400°C)

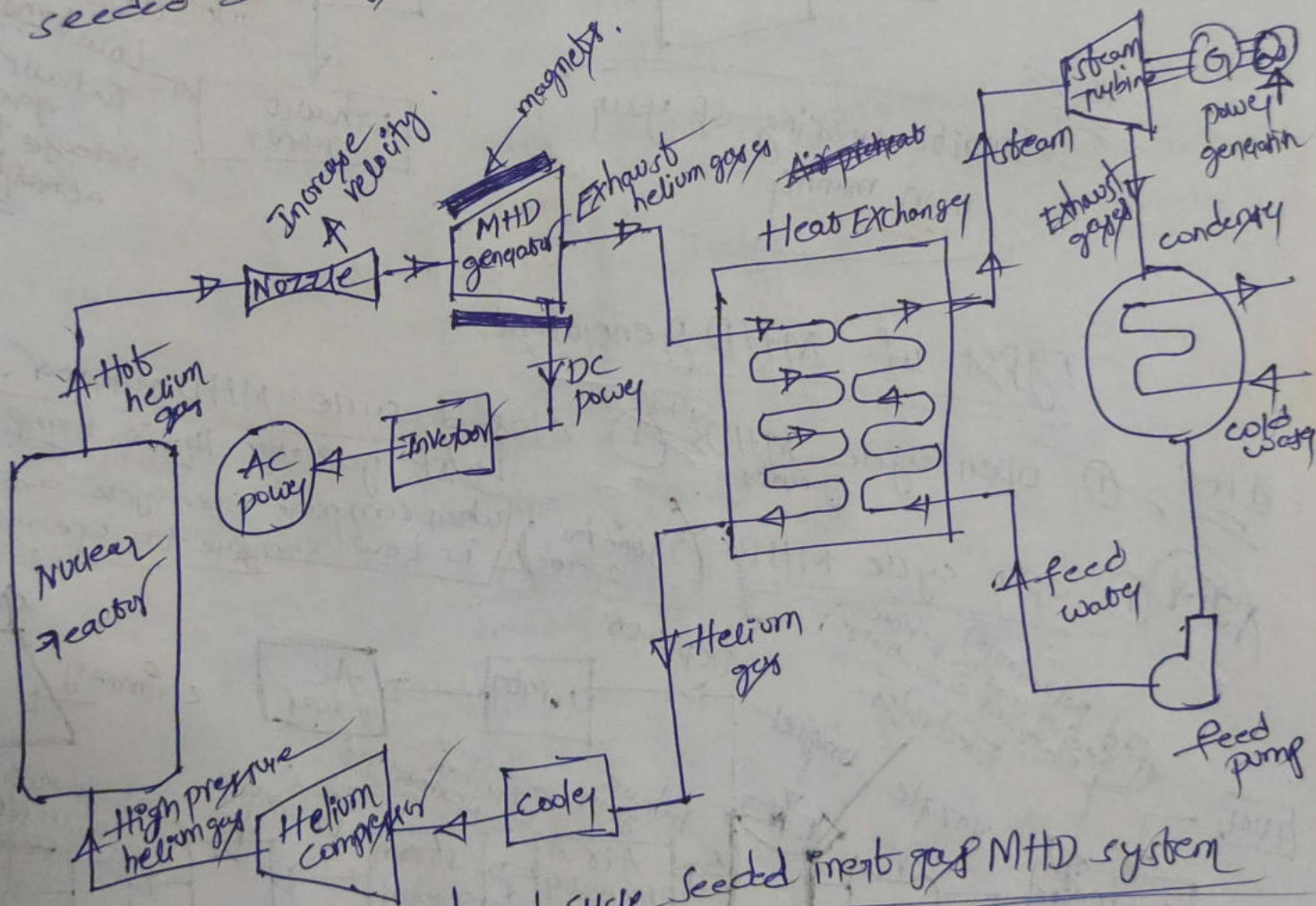
1st ① seeded Inert gas system (helium (or) argon)

2nd ② Liquid metal system (potassium (or) sodium)

→ Temperature of closed cycle (CC) MHD plants is very Less compared to OC (open cycle) MHD plants. It is about 1400°C.

① seeded Inert gas (Cesium) system:-

A closed cycle MHD system can either operate on seeded Inert gas (helium (or) argon) (or) Liquid metal system



closed cycle seeded inert gas MHD system

Working:-

→ A closed cycle MHD system using helium (or) argon gas seeded with cesium is shown in figure. step by step working of the system is as under:-

→ In this system, helium gas seeded with cesium is heated to a very high temperature in a nuclear reactor.

→ The hot helium gas is passed through a nozzle to increase its velocity and then supplied to MHD generator to produce DC power. Here some part of the internal energy of the gas is directly converted into DC power.

→ In next step, the gas is passed through the heat exchanger (i.e; steam generator) to convert feed water into steam. Now this steam is used in a conventional steam power plant to generate electricity.

→ The Exhausted helium gas from steam generator is cooled in the cooler and compressed in the compressor. Thereafter, it is supplied back to the nuclear reactor and complete cycle is repeated again.

Rmf ② Liquid metal closed cycle MHD system:-

same as inert gas system except that it uses liquid metal (potassium) in the place of helium (or) argon gas as the working fluid.

Rmf Differences b/w open cycle and closed cycle MHD systems:-

open cycle system	closed cycle system
① working fluid after generating electrical energy is discharged to the atmosphere through a stack (or) chimney.	① working fluid is recycled to the heat source and thus is used again.
	② Helium (or) argon (with cesium seeding) is used as the working fluid.

(2) operation of MHD generator is done directly on combustion products.	(3) Temperature requirement 1400°C.
(3) Temperature requirement 2300°C to 2700°C.	(4) Less developed.
(4) More developed.	

2nd Applications of MHD systems:-

(1) Large power MHD generator (2) plasma physics applications.
(3) power generation in space crafts (4) Defence applications.
(5) Electrical power production for domestic applications.
(6) They can be used as power plants in industry.
(7) MHD generators are used in submarines and aircrafts.

2nd Advantages of MHD systems:-

(1) No moving parts, so no mechanical losses.
(2) overall efficiency is about 50%.
(3) Large amount of pollution free power is generated (closed cycle system using).
(4) size of the plant is small compared to other fossil fuel plants (5) Less overall generation cost.

2nd Disadvantages of MHD systems:-

(1) Very Large Magnets are needed, this is the major Expense (2) High friction and heat transfer losses.
(3) High operating temperature
(4) DC to AC converters increase the cost of plant
(5) MHD Equipments have shorter life due to high temperature stresses.

V.V.V.vamp

Fuel cells:-

" Fuel cell is a Electro chemical device that converts chemical energy into Electrical energy".

→ The fuelcell is similar to other electric cells in the respect that it consists of positive and negative electrodes with electrolyte in b/w them.

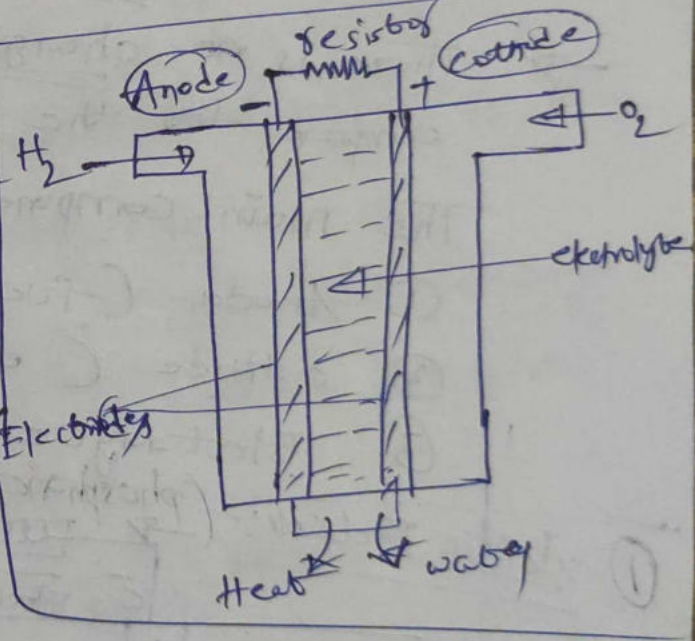
chemical Energy → Electrical Energy

Note:-

But Battery will convert chemical to Electrical (or) Electrical to chemical Energy. This is the main difference b/w Battery and fuel cell.

Construction of Fuel cell:-

→ Fuel in a suitable form is supplied to the negative Electrode and O_2 which is supplied to the positive Electrode at the time cell operates, then fuel is oxidized then converts chemical energy into Electrical energy.



→ Here Electrodes are made up of Graphite, (or) platinum, (or) Teflon

→ Here Anode Electrode is coated with platinum because it absorbs Hydrogen gas easily.

→ Instead of Hydrogen gas use Hydrogen (or) Methane (or) CO_2 (or) CH_3OH (methanol) gases as a fuel. (CH_4)

→ Instead of oxygen gas as oxidants use O_2 (or) Air (or) H_2O_2 (Hydrogen peroxide) (or) O_3 etc.

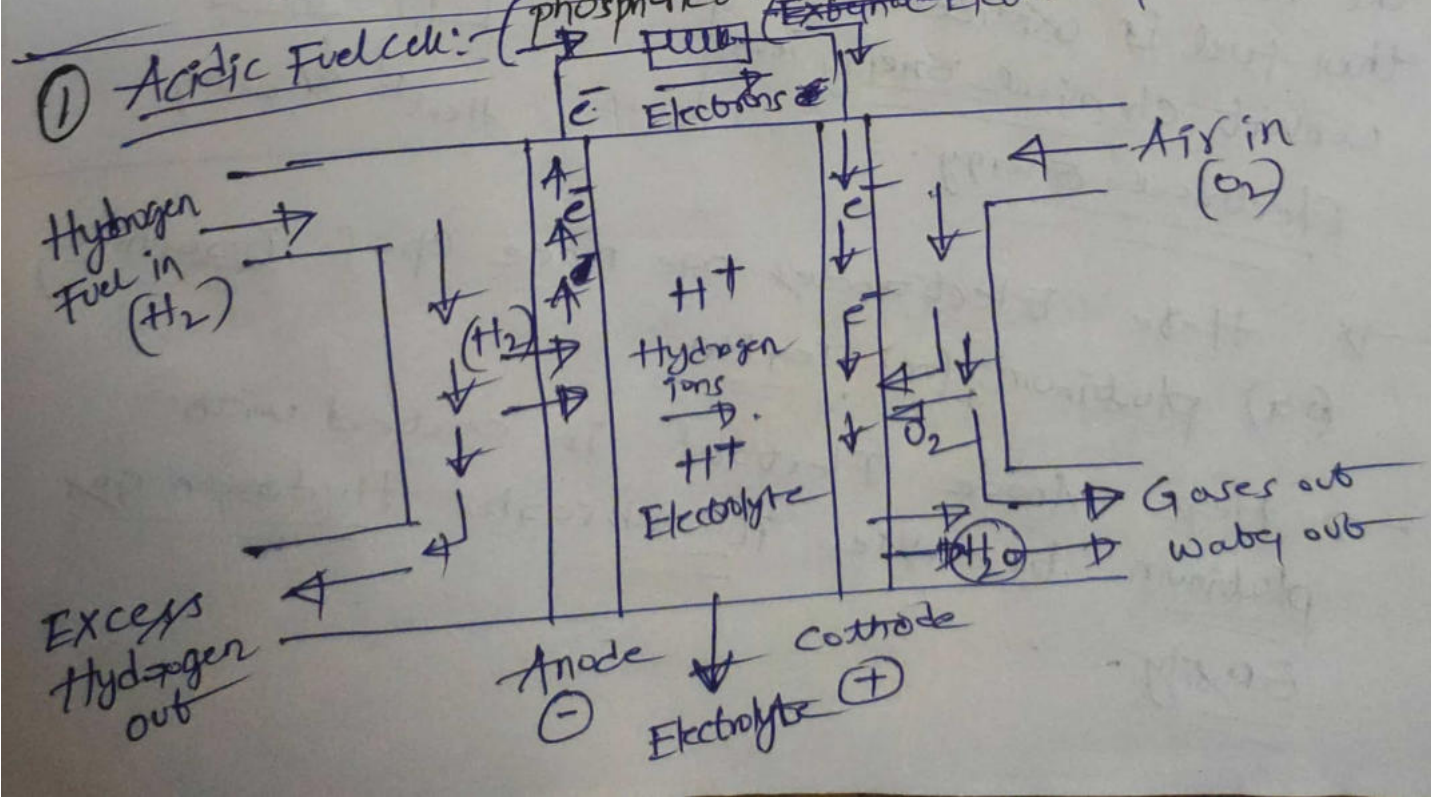
Principle and Working of a fuel cell:-

→ Fuel cell is a storage battery but with regular supply of fuel and oxidant.
fuel → H_2
oxidant → O_2.

→ There is no charging and discharging with fuel cell compare to the Battery.

The main components of fuel cells are.
① Anode (fuel electrode (or) negative electrode)
② cathode (oxidant (or) positive electrode).
③ Electrolyte (acidic or alkaline).

① Acidic Fuelcell: (phosphoric acid fuel cell)



→ And other components are fuel supplier, oxidant supplies, containers and separators etc

→ when two permeable (meaning small holes) nickel Electrodes are immersed in a well conducting Electrolyte.

→ If the electrolyte solution is H_2SO_4 acid then the cell is acidic fuel cell. (or) H_3PO_4 (phosphoric acid)

→ If the electrolyte solution is KOH alkaline (or) NaOH then the cell is alkaline fuel cell.

① In acidic fuel cell :- H_3PO_4 (phosphoric acid fuel cell)

The electrolyte is ~~H_2SO_4~~ (or) H_2SO_4 (sulphuric acid fuel cell) (H_2SO_4 sulphuric acid)

At anode :- The hydrogen gas is ionized, producing free Electrons ($4e^-$) and H^+ ions ($4H^+$)

$$2H_2 \longrightarrow 4H^+ + 4e^-$$

At cathode :- The oxygen reacts with coming Electrons and H^+ ions from anode to give water molecule.

$$O_2 + 4e^- + 4H^+ \longrightarrow 2H_2O$$

Overall Net Reaction :-

$$2H_2 \longrightarrow 4H^+ + 4e^-$$

$$O_2 + 4e^- + 4H^+ \longrightarrow 2H_2O$$

$$2H_2 + O_2 \longrightarrow 2H_2O + \text{Energy (Electrical Energy)}$$

② In Alkaline fuel cell:- (K^+OH^- (or) Na^+OH^-)

The Electrolyte is potassium hydroxide (KOH) (or) NaOH (sodium hydroxide). The important feature is that there is an Excess of OH^- ions and these are play a key role in the reactions.

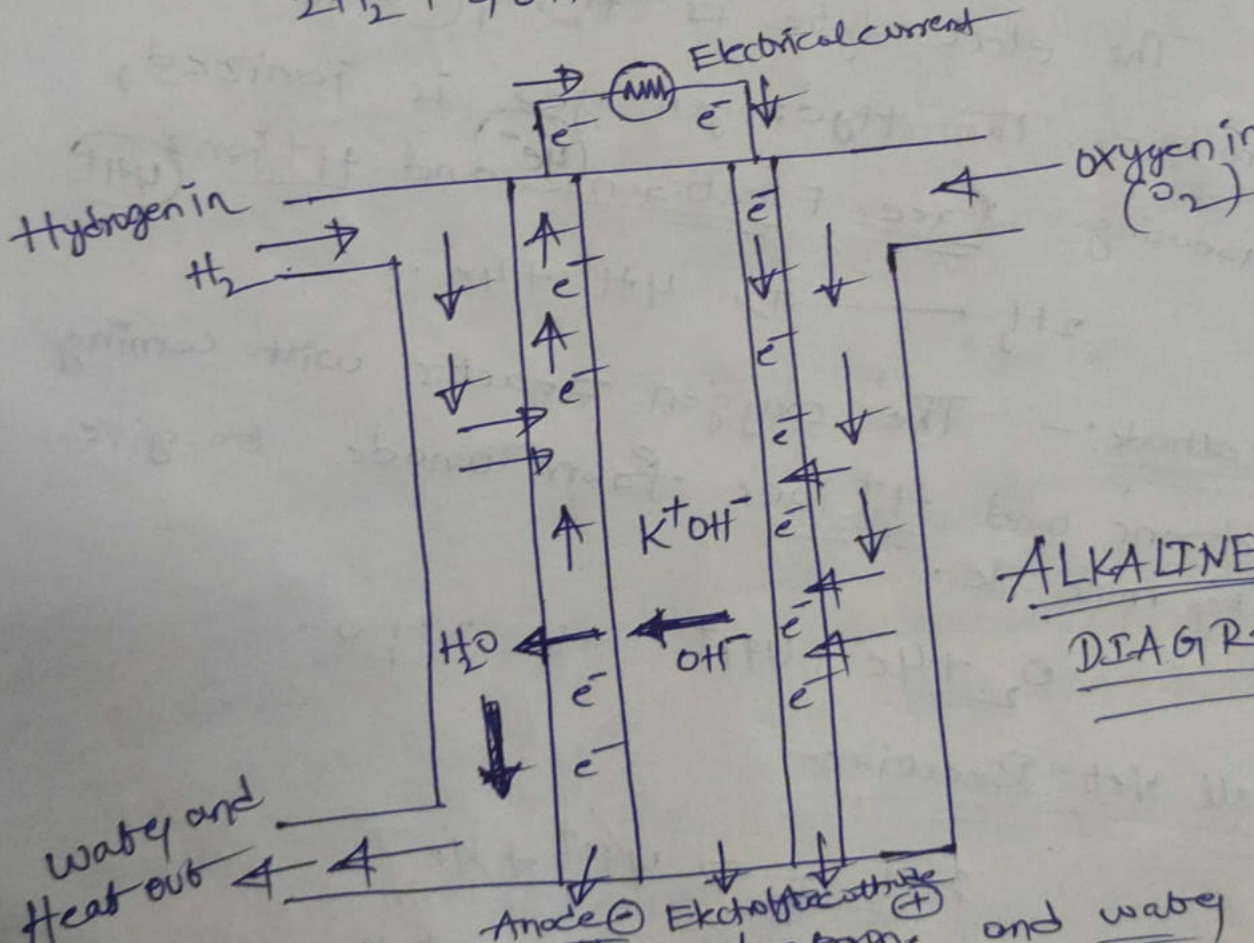
K^+OH^- (or) Na^+OH^-

At Anode:-

Hydrogen gas reacts with OH^- ions producing water and releasing electrons.

↑ Excess amount

$$2H_2 + 4OH^- \longrightarrow 4H_2O + 4e^-$$



ALKALINE FUEL CELL DIAGRAM

At cathode:- The electrons produced at anode is reacts with oxygen and water to form excess of OH^- ions.

$$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$$

→ The OH^- ions move through the Electrolyte and Electrons move around the circuit.

→ The water produced at the anode is used at cathode.

Over all net Reaction:-

$$2H_2 + 4OH^- \longrightarrow 4H_2O + 4e^-$$

$$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$$

$$2H_2 + O_2 \longrightarrow 2H_2O + \text{Energy}$$

(3) Molten carbonate fuel cell

(4) solid oxide fuel cell

not amp.

→ The Hydrogen and oxygen supplied to the fuelcell produce Electrical Energy, water and heat.

→ Here water and heat are waste products.

Diff Difference b/w Battery and fuel cell

Battery	fuel cell
(1) Battery makes Electricity from the Energy it has stored inside the Battery.	(1) A fuelcell makes its Electricity from fuel in an External fuel tank.
(2) Its Life time is Less than fuel cell.	(2) Its Life time is Longer
(3) It stores energy by the Electricity.	(3) It stores Energy by converting available fuel.
(4) Battery runs down the electrodes dissolve.	(4) fuelcell operates for as long as oxygen and hydrogen flow.

(5) It has high efficiency than fuel cell.	(5) It has less efficiency.
(6) Here no need of fuel supply.	(6) fuel supply is continously.
(7) There is charging and discharging cycle.	(7) There is no charging and discharging cycle.
(8) Used in clocks, Lamps, phones etc	(8) Used in automobiles, Inverters etc

2nd Applications of Fuel cells:

→ This fuel cells providing power for Base station (or) cell sides.
→ These are used in distributed power generation.
→ These are used in scientific Laboratories data centers, telecommunications Equipments.
→ These are used in UPS.
→ These are used in hybrid vehicles Like buses, the overall world 100 fuel buses are developed.
→ These are used in submarines, toys, aircrafts, buses and high power generators.

2nd Advantages of Fuel cells:

(1) Fuel cells system are environmentally.
(2) High conversion efficiency.
(3) Extremely Low Emission.
(4) Has no moving parts.
(5) Availability to use at any Location. So Less transmission & distribution Losses.
(6) No requirement of cooling power as conventional plants.
(7) Less space require as compared to conventional plants.

2nd Disadvantages of Fuel cell:

(1) The main disadvantage of fuel cell are their high initial costs and Low service life
(2) Initial cost of installation is higher. (3) Energy produced by one fuel cell is around 0.7 volts.
(4) High initial cost. (5) Lifetimes of the cells are not accurately known. (6) High cost of pure Hydrogen. (7) Lack of Infrastructure for distributing hydrogen.