RENEWABLE ENERGY SOURCES.

UNIT - 5 :- Miscellaneous Energy Technologies

Ocean - 1 :- Energy from Tides :

Tidal Energy :

Defination : Tide is a periodic rise and fall of the water level of sea which are carried by the action of the sun and moon on the water of the earth.

Basic Principal of Tidal Energy :-

→ Tides are produced mainly by the gravitational attraction of the moon and the sun of the water of solid earth and the oceans. About 70% of the tide producing force is due to the moon and 30% to the sun. The Moon is thus the major factor in the tide formation.

→ Surface water is pulled away from the earth on the side facing the moon, and at the same time the solid earth is pulled away from the water on the opposite side.

→ Thus, high tides over occur in these two areas with low tides at intermediate points.

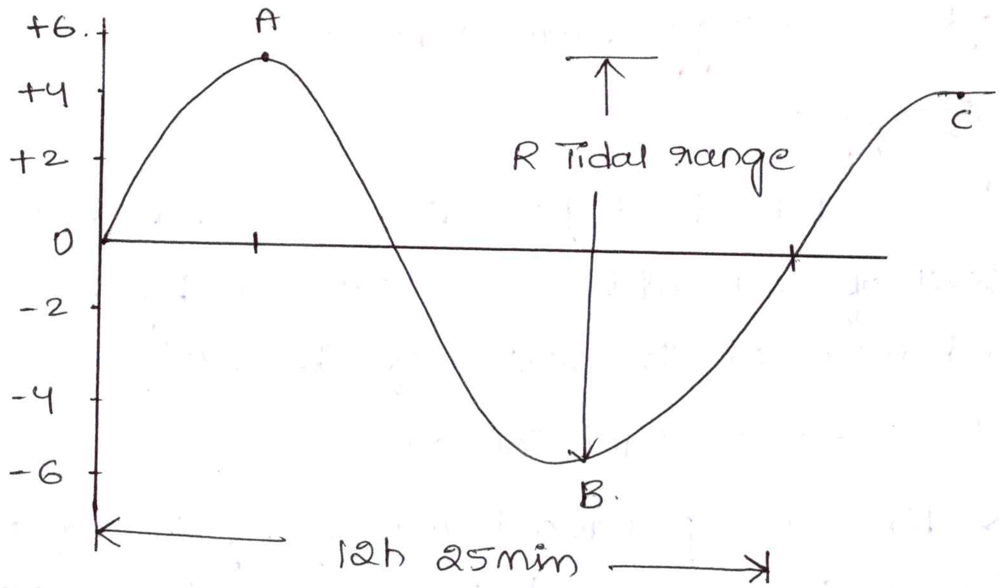
→ As the earth rotates, the point of position of a given area relative to the moon changes, and so also do the tides. There are thus a periodic succession of high and low tides.

→ A high tide will be experienced at a point which is directly under the moon.

→ Thus a full moon as well as a no moon produce a high tide.

→ In a period of 24 hrs 50 minutes, there are therefore, two high tides and two low tides.

→ The rise and fall of the water level follows a sinusoidal curve, shown with point A indicating the high tide point and point B indicating the low tide point.



→ The Difference between high and low water levels is called the range of the tide.

The tidal range R is defined as :

R = water elevation at high tide − water elevation at ~~hi~~ low tide

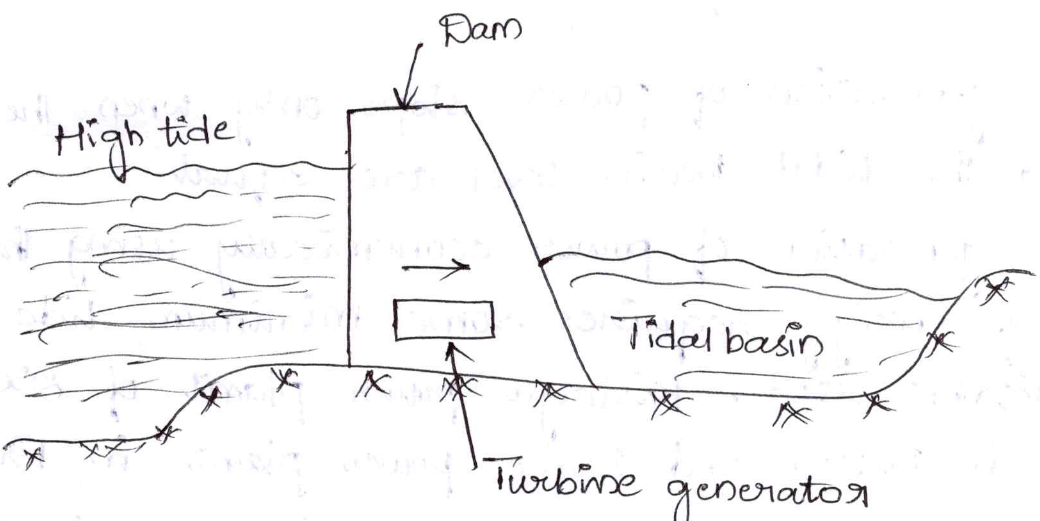
Working principle of Tidal power plants :-

Tide or wave is periodic rise and fall of water level of the sea. Tides occur due to the attraction of sea water by the moon. Tides contain large amount of potential energy which is used for power generation. when the water is above the mean sea level, it is called "flood tide". when the water level is below the mean level it is called ebb tide.

Working :-

The arrangement of this system is shown in fig. The ocean tides rise and fall and water can be stored during the rise period and it can be discharged during fall.

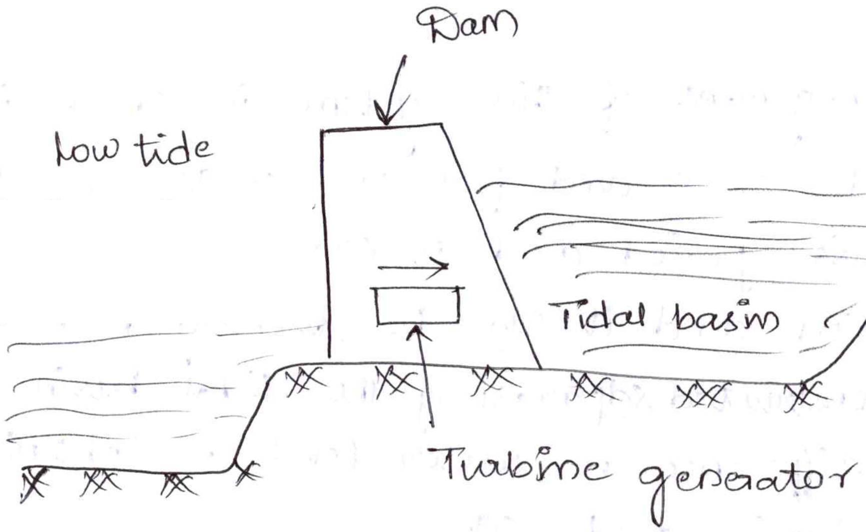
A dam is constructed separating the tidal basin from the sea and a difference in water level is obtained between the basin and sea.



(a) High tide

During high tide period, water flows from the sea into the tidal basin through the water turbine. The height of tide is above that of tidal basin.
Hence the turbine unit operates and generates power, as it is directly coupled to a generator

During low tide period, water flows from tidal basin to sea, as the water level in the basin is more than that of the tide in the sea. During this period, also, the flowing water rotates the turbine and generator power



(b) low tide.

The generation of power stops only when the sea level and the tidal basin level are equal.
For the generation of power economically using this source of energy requires some minimum tide height and suitable site. Kislaya power plant of 250 MW capacity in Russia and Rance power plant in France are the only examples of this type of power plant

Advantages of Tidal power plants :-

(1) It is free from pollution as it does not use any fuel.

(2) It is superior to hydro power plant as it is totally independent of rain.

(3) It improves the possibility of fish farming in the tidal basins and it can provide recreation to visitors and holiday makers.

(4) Peak power demand can be effectively met when it works in combination with thermal or hydro electric system..

DisAdvantages of Tidal power plant :-

(1) Tidal power plants can be developed only if natural sites are available

(2) As The sites are available on The bays which are always far away from load centres, The power generated has to be transmitted to long distances. This increases the Transmission cost and transmission losses.

(3) variability in output, caused by The variations in The tidal range.

(4) Sea water is corrosive and it was feared That machinery may get corroded

(5) Construction in sea is found difficult

(6) Cost is not favourable compared To other sources of energy.

Ocean - 2 : WAVE ENERGY :

wave Energy :-

wave Energy is a form of renewable energy that can be utilized from the motion of waves. As waves are formed in the ocean, they create kinetic energy or movement.

→ It is used to run turbines and create energy that can be converted into electricity.

Energy and power from the waves.

A two-dimensional progressive wave as shown in fig is represented by the sinusoidal simple harmonic wave shown at time.

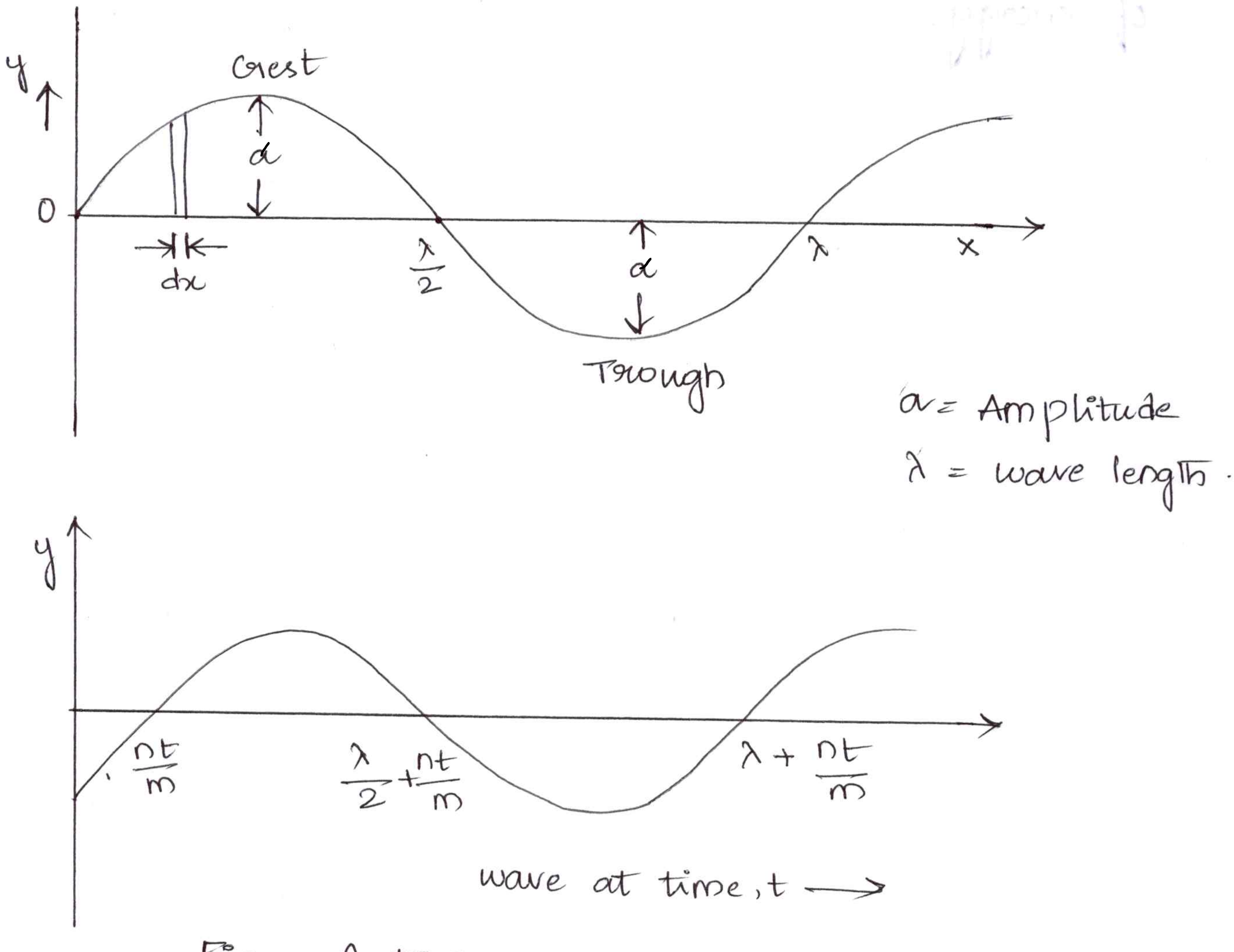


Fig - A typical progressive wave.

shown at time $t=0$, and at time t.

The wave length may be expressed by the following relation involving some parameters:

$$y = \alpha \sin\left(\frac{2\pi}{\lambda} x - \frac{2\pi}{\tau} t\right) \rightarrow \text{Eq } ①$$

where,

y = height above its mean level in m
α = amplitude in m
λ = wavelength in m
t = time in seconds
τ = period in seconds

$$2\pi = \left(\frac{x}{\lambda} - \frac{t}{\tau}\right) = \text{phase angle (dimension less)}$$

The relationship between wavelength and period is approximately

$$\lambda = 1.56\,\tau^2 \longrightarrow \text{Eq } ②$$

The expression can be expressed as Eq ②

$$y = \alpha \sin(mx - nt) \longrightarrow \text{Eq } ④$$

where $m = \frac{2\pi}{\lambda}$ and $n = \frac{2\pi}{\tau}$ = phase rate.

2α = height (from crest to trough).

Potential Energy :- The potential energy arises from the elevation of water above mean level (i.e $y=0$) considering a differential volume $y.dx$, it will have a mean height $\lambda/2$. Thus its potential energy is.

$$dPE = mg\,y/2 = (\rho y\,dx\,L)\,g\,\frac{y}{2}$$

$$= \frac{g\rho y^2 L\,dx}{2} \rightarrow Eq\ (5)$$

where

m = mass of the liquid in y, dx, kg

g = gravitational constant.

ρ = water density, kg/m^3,

L = arbitary width of two dimensional wave, perpendicular combining (4) and (5) we obtain:

$$PE = \frac{\rho L a^2 g}{2}\int_0^{\lambda} \sin^2(mx - nt)\,dx.$$

$$= \frac{\rho L a^2 g}{2}\left(\frac{1}{2}mx - \frac{1}{4}\sin 2mx\right)_0^{\lambda}$$

$$= \frac{1}{4} g\rho a^2 \lambda L \longrightarrow Eq\ (6)$$

The potential energy density per unit area is $\frac{PE}{A}$, where $A = \lambda L$, in J/m^2.

$$\frac{PE}{A} = \frac{1}{4} g\rho a^2 \longrightarrow Eq\ (7)$$

Kinetic Energy :-

The derivation of the KE is rather complex and beyond the scope of the book. From hydrodynamic theory this can be expressed as

$$K.E = \frac{1}{4} g.\rho a^2 \lambda L \longrightarrow Eq\ (8)$$

and the KE density is

$$\frac{KE}{A} = \frac{1}{4} g \rho a^2 \longrightarrow Eq\ (9)$$

Total Energy and power density can be written as

$$\frac{E}{A} = \frac{1}{2} g \rho a^2, \longrightarrow Eq\ (10)$$

$$\frac{P}{A} = \frac{1}{2} g \rho a^2 . f \longrightarrow Eq\ (11)$$

where f is the frequency.

(The power P = energy × frequency).

Working of wave Energy :-

Some of the main concepts for converting wave energy into mechanical energy or electrical are described briefly as follows :-

(1) Wave Energy conversion by Floats :-

wave motion is primarily horizontal, but the motion of the water is previously primarily vertical

→ Mechanical power is obtained by floats making use of the motion of water

→ The concept visualizes a large floats that is driven up and down by the water within relatively stationary guides

→ This reciprocating motion is converted to mechanical and then electrical power is generated

→ A system based on this principle as shown in fig which a square float moves up and down with the water

It is guided by four vertical manifolds That are part of a platform.

→ There are four large under water floatation tanks which stabilizes the platform. Platform is supported by buoyancy forces and no vertical or horizontal displacement occurs due to wave action. Thus the platform is made stationary in space

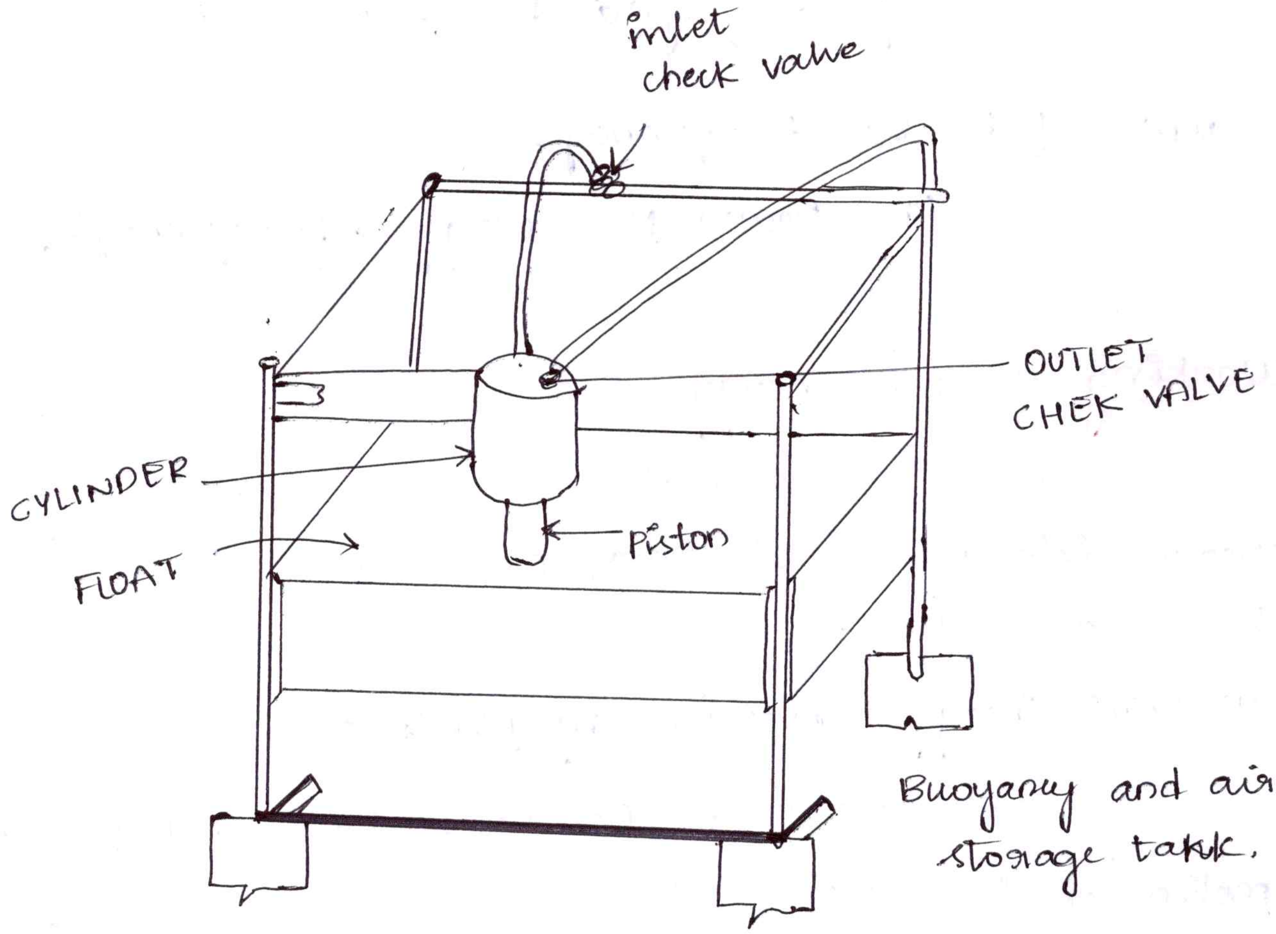


Fig - Schematic of a float wave power conversion devi

→ A piston which is attached to float as shown in fig moves up and down inside a cylinder.

→ A piston and cylinder arrangement is used as a reciprocating compressor

→ The downward motion of The piston drawn air into The cylinder via an inlet check valve. This air is compressed by upward motion of The piston and is supplied to four under water bloation tanks, through an outlet check valve via The four manifolds.

(2) High level Reservoir wave Machine.

The concept of this device is illustrated with reference to fig in which a magnification piston is used. The pressurized water is elevated to a natural reservoir above the wave generator, which would have to be near a shore line, or to an artificial water reservoir. The water in the reservoir is made to flow through a turbine coupled to an electric generator, and then back to sea level.

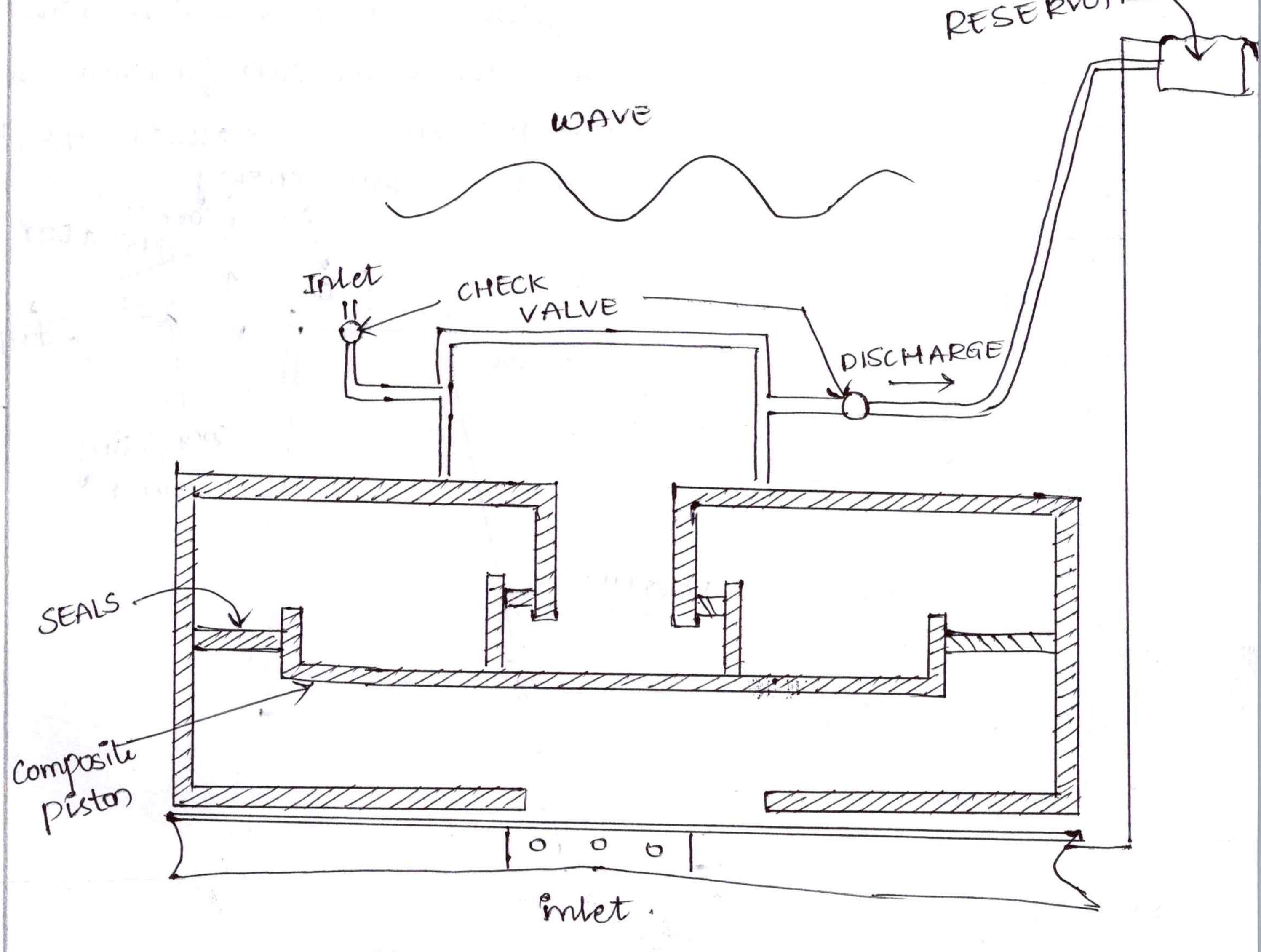


fig: Schematic of a high level reservoir wave length.

3) The Dolphin - Type Wave-Power Machine.

This type of wave-generator which is designed by Tsu Research Laboratories in Japan is shown in Fig. The system consists of following major components :

(i) a dolphin
(ii) a float
(iii) a connecting rod
(iv) two electrical generators

→ This device uses the float which has two motions. The first is a rolling motion about its own fulcrum with the connecting rod. Revolving moments are caused b/w the float and the connecting rod.

→ The other is a nearly vertical or heaving motion about the connecting rod fulcrum.

→ It causes relative revolving movements b/w the connecting rod and the stationary dolphin

→ In both the cases, the movements are amplified and converted by gears into continuous rotary motions that drive the two electrical generators.

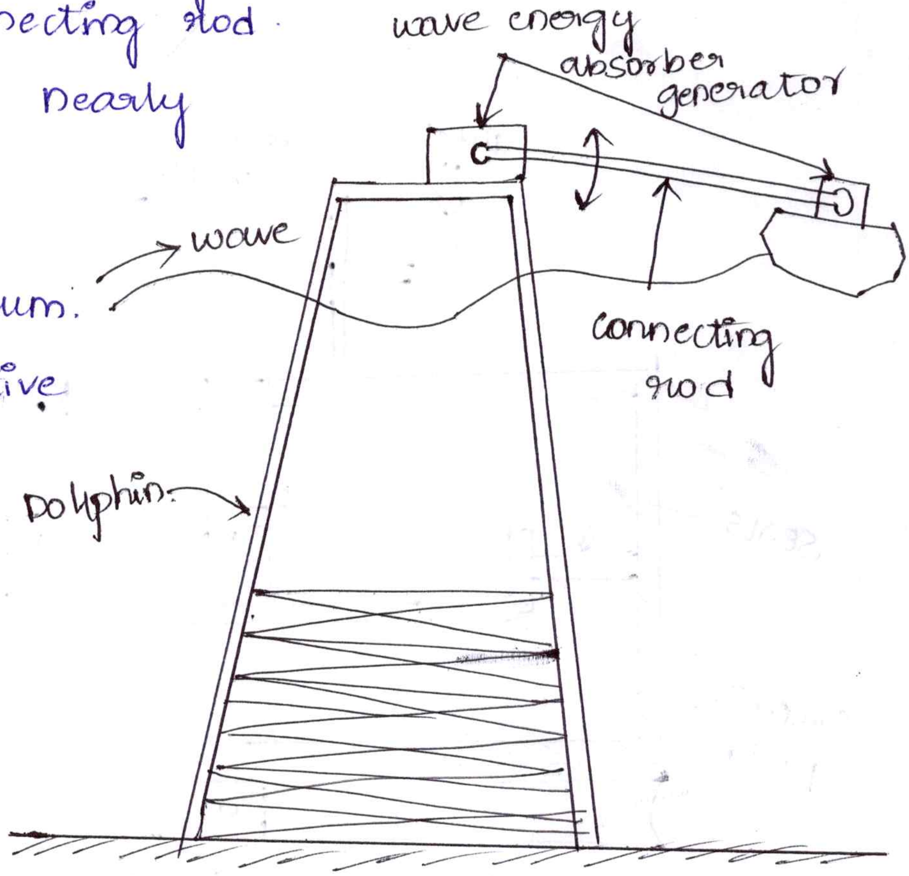


fig:- Schematic of the Dolphin-type wave power generator.

Advantages and DisAdvantages of wave Energy

The Advantages are as follows:

(1) It is a free and renewable energy source

(2) It is pollution free

(3) It is highly suitable to develop power in remote islands, on drilling platforms and on ship where other alternatives are impossible

(4) wave Energy conversion devices help in reducing The erosion of costal region.

(5) Waves are continuosly formed and power can be extracted continuosly. No storage of power is required

The DisAdvantages are as follows:

(1) Sea water is Corrosive and life of equipment used in Conversion devices is limited

(2) Marine growth such as algae adversely affects The working of wave energy conversion devices.

(3) Wave energy conversion devices obstruct shipping traffic

(4) strong waves during storms can damage The wave energy conversion devices.

(5) Installation of conversion devices is costly.

(6) Repair, replacement and maintenance are difficult To perform

Biomass

→ BioMass :-

→ BioMass is Organic matter produced by plants, both terrestrial and aquatic and their derivatives. It includes forest crops and residues, crops grown especially for their energy content on "energy farms" and animal manure

→ Biomass can be considered a renewable energy source because plant life renews and adds to itself every year.

→ It can also be considered a form a solar energy as the latter is used indirectly to grow these plants by photosynthesis.

→ Solar energy → photosynthesis → Biomass → Energy generation.

→ BioMass Resources :-

1) Forests :-

→ Forests are source of fuel wood, charcoal and producer gas.

2) Agriculture residues :-

→ straw, rice husk, groundnut shell, coconut shell and sugarcane bagasse are crop residues which are the main biomass resources.

3) Energy crops :-

→ Energy crops are those cultivations which provide raw materials for biofuels. These include

(i) sugar plants to provide bioethanol

(ii) starch plants to produce bioethanol

(iii) Oil producing Plants (sunflower, palm oil) to produce biodisel

4) Urban waste :-

→ Urban waste can be garbage or municipal solid waste and sewage or liquid waste.

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5) Aquatic Plants :-

→ The Fast growing water plants include water hyacinth, seaweed, algae and kelp.

→ BioGas :-

→ Biogas is the gaseous fuel which is obtained from biomass by means of an anaerobic digestion or fermentation of wet organic matters.

→ The biogas is a flammeable of wet organic gas.

→ The composition of biogas includes 50-60% methane gas, 35-40% carbon dioxide 5% hydrogen and a small amount of hydrogen sulphide and other gases.

→ Aerobic and Anaerobic Processes :-

→ Aerobic is any process taking place in the presence of air, while anaerobic means any process taking place in the absence of air or oxygen.

→ It is the anaerobic process or digestion in biomass slurry which helps in converting biomass into biogas.

→ BioMass Conversion Technologies :-

→ There are basic technologies or procedures to convert the biomass into (i) Direct energy
(ii) More valuable products

→ These technologies or procedures are incineration, thermochemical and biochemical.

(1) Incineration :-

→ It is the buring or combustion of the biomass to obtain useful heat.

→ The heat can be used for space heating and cooking or it can be used to generate steam in boiler to run turbine with electric generater, thereby producing electricity.

→ Furnances and boilers have been designed to burn various types of biomass such as wood waste wood, agricultural waste products, food industry waste, Urban waste and forest industry waste.

(2) Thermochemical :-

The biomass can be converted into more valuable and convinient fuels by the use of the thermochemical process called pyrolyis.

→ Pyrolysis can process all forms of biomass, including rubber and plastic which cannot be converted by any other methods.

→ Three types of biofuels are obtained by pyrolysis depending upon feed stock, temperature and pressure.

(i) A gaseous mixture of gases such as H_2, CO, CO_2, CH_4, N_2.
(ii) A liquid in the form of oil such as acetic acid, acetone, methanol, oil and tar.
(iii) A pure carbon char.

→ Liquid product from biomass is obtained by catalytic liquefaction process at low temperature (250 - 450°c) and high pressure (270 atm).

(3) Biochemical :-

The conversion of biomass is carried out using metapolic action of microorganism or bacteria

→ The process produces liquid and gaseous fuel

→ The Major biochemical processes for the conversion of biomass are as follows

(i) Anaerobic digestion or fermcation
(ii) Ethanol fermeantation.

(i) Anaerobic digestion or fermentation :-

The biomass in the presence of water is converted into biogas by the action of anaerobic bacteria

→ The Methane and carbon dioxide are the two main components of biogas.

$$\text{Biomass} + \text{water} \xrightarrow[\text{anaerobic digestion}]{25-75^\circ C} \text{Biogas } (CH_4\ 50-60\% + CO_2\ 35-40\%)$$

→ The biomass used includes animal manure, algae, kelp, hyacinth, urban waste (garbage + sewage) and industrial waste.

(ii) Ethanol fermentation :-

→ It is formed due to the alcoholic fermentation of simple hexose sugars (six carbon atoms per molecule such as $C_6H_{12}O_6$) in aqueous solution by the action of a enzyme present in yeast in the acidic condition

→ The chemical reaction can be given as :

$$C_{16}H_{12}O_6 \xrightarrow[\text{fermentation}]{32^\circ C} \underset{\text{(ethanol)}}{2C_2H_5OH} + \underset{\text{(carbon dioxide)}}{2CO_2}$$

Bio gas Generation Plant :-

→ Biogas is produced from biomass slurry having 90-95% water content by the bacterial action of microorganism called anaerobe.

→ The carbon part of biomass is oxidized and the remaining is reduced to produce mainly methane gas (65-75%) and CO_2 (25-35%)

→ These bacteria are found to live and grow without atmospheric oxygen as they produce oxygen.

→ The Digestion of fermentation process of wet biomass by these bacteria is favoured by the factors such as wetness, warmness and darkness conditions

→ The general eq for Anaerobic digestion as follows:

$$C_xH_yO_z + \left(x - \frac{y}{4} - \frac{z}{2}\right)H_2O \longrightarrow \left(\frac{x}{2} + \frac{y}{8} + \frac{z}{4}\right)CO_2 + \left(\frac{x}{2} + \frac{y}{8} - \frac{z}{4}\right)CH_4$$

→ In case of cellulose the equation is given by:

$$(C_6H_{10}O_5)_n + nH_2O \longrightarrow 3n\,CO_2 + 3m\,CH_4.$$

→ The airtight equipment used to convert the wet biomass into biogas by digestion or fermentation process is called biogas digester or plant which is properly constructed and controlled to favour biogas or methane production

→ The conversion process is called biodigestion or anaerobic fermentation and the output is methane

→ The residuals or nutrients such as soluble nitrogen compounds remaining in the wet biomass slurry provide or produce excellent natural fertilizes & humans

→ The biogas can provide 60-75% of the energy of the dry converted biomass during combustion

→ The biochemical process of converse in from biomass to biogas takes place in the following 3 stages

(i) Hydrolysis of organic matter.

(ii) Anaerobic and facultative microorganisms

(iii) Digestion.

(i) Hydrolysis of organic matter :-

The biomass (complex compounds of carbohydrate, protein and fats) is broken due to the action of water (hydrolys into simple soluble compounds.

→ Similarly, Large malecules (polymers) are reduced to basic molecules (monomeres)

→ This process is completed in a day at a temperature of about 25°c.

(ii) Anaerobic and Faculative microorganisms :-

→ These bacteria start growing to produce acetic and propionic acids. This process is completed in a day at the temperature of 25°c.

→ The output of the process is the production of CO_2.

(iii) Digestion :-

→ Anaerobic bacteria slowly digest the biomass slurry to produce biogas.

→ The process is completed in 2 weeks at the temperature of about 25°c

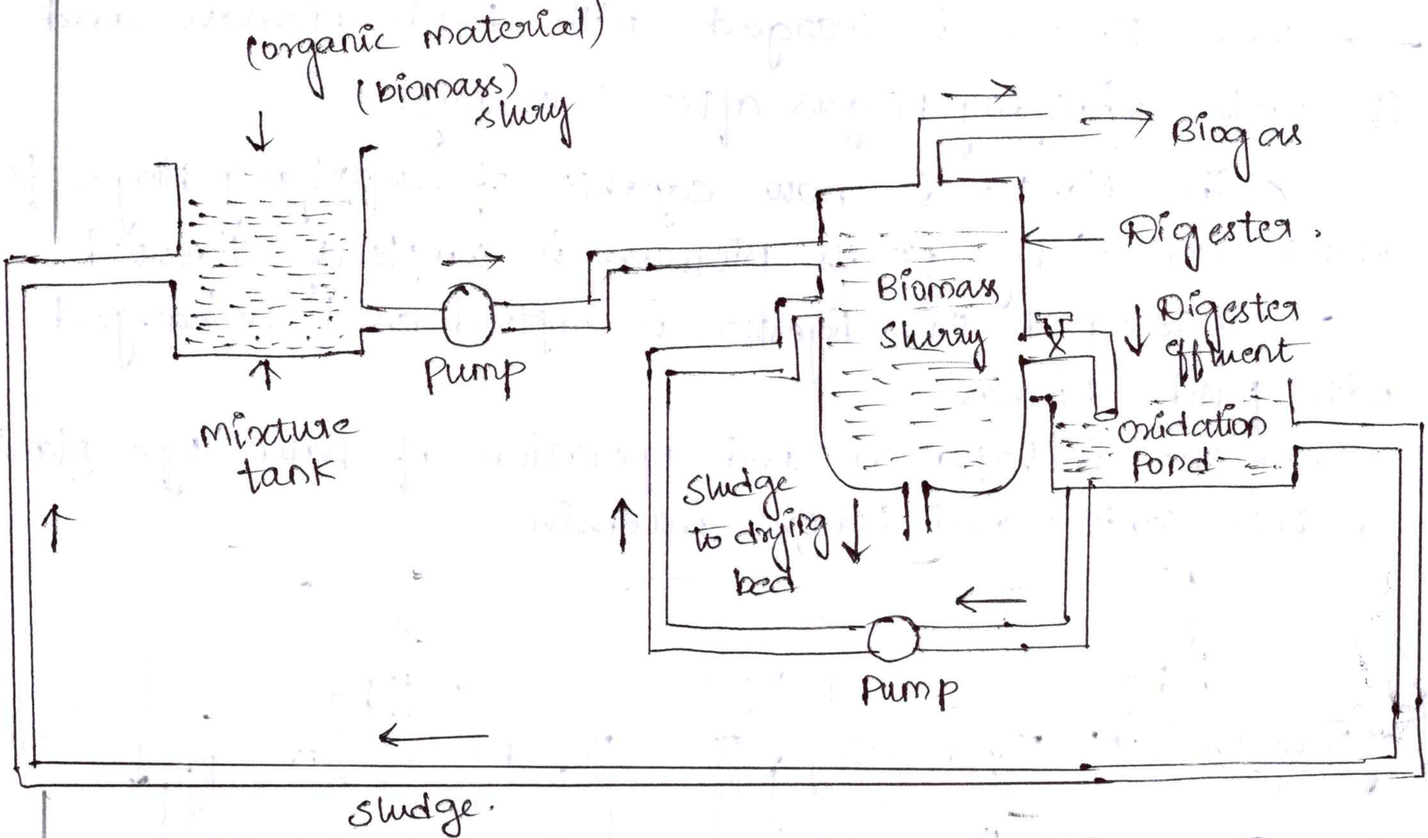
Digester :-

The anaerobic digester or plant is shown in fig. Feed consists of organic material slurry prepared in mixing tank. Feed supply per day to the digester is calle the loading rate.

→ Neither overloading nor ~~overload~~ underloading of the digester is desirable as it reduces biogas production.

→ The acid forming bacteria grows rapidly, whereas methane forming bacteria grows slows

→ To obtain maximum biogas generation rate, seeding of digestion slurry with methane forming bacteria is done.



→ This is achieved by adding certain portion of digested slurry to the fresh slurry.

→ It is also possible to add nutrients containing nitrogen, hydrogen, oxygen, phosphorous, sulphur and carbon, which can also increase the anaerobic digestion rate.

→ The recommended PH value for the digestion of biomass slurry is about to 7-8

classification of Biogas plants :-

Biogas plants can be classified as batch type and continuous type. The continuous type biogas plants can be further classified as

(i) floating drum or constant pressure type plant and

(ii) Fixed dome or constant volume type plant.

(1) Batch type plant :-

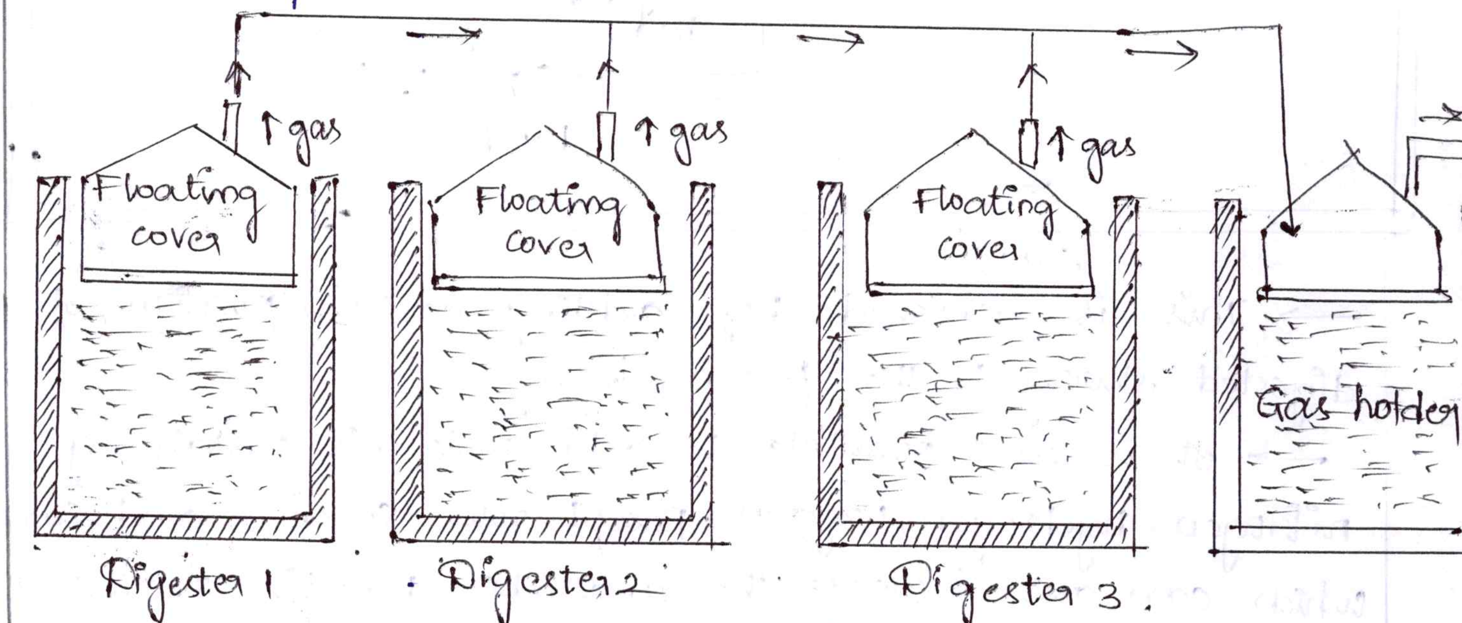
→ A Batch type plant consists of a number of digesters. which are charged, used and emptied one by one in a synchronous manner.

→ Each digester is charged with fresh biomass and it starts supplying biogas after 8-10 days

→ The digester is now capable of supplying biogas for about 40-50 days till its biomass is completely digested.

→ Afterwards, this digester is emptied and recharged with fresh biomass.

→ The installation and operation of batch type plant is both capital and labour intensive.



(2) Continuous type biogas plant :-

→ In continuous type biogas plant, a certain quantity of biomass slurry is fed daily into the digester.

→ This is made possible by the removal of digested slurry through an outlet so that the digester can have space to intake fresh biomass slurry.

→ The biogas produced is either stored in the digester or removed to be stored in a gas holder.

→ The plant operates continuosly and it is stopped only the removal of sludge.

→ The layer of scum at the top of the biomass slurry is periodically broken with the help of the stirrer as shown in fig

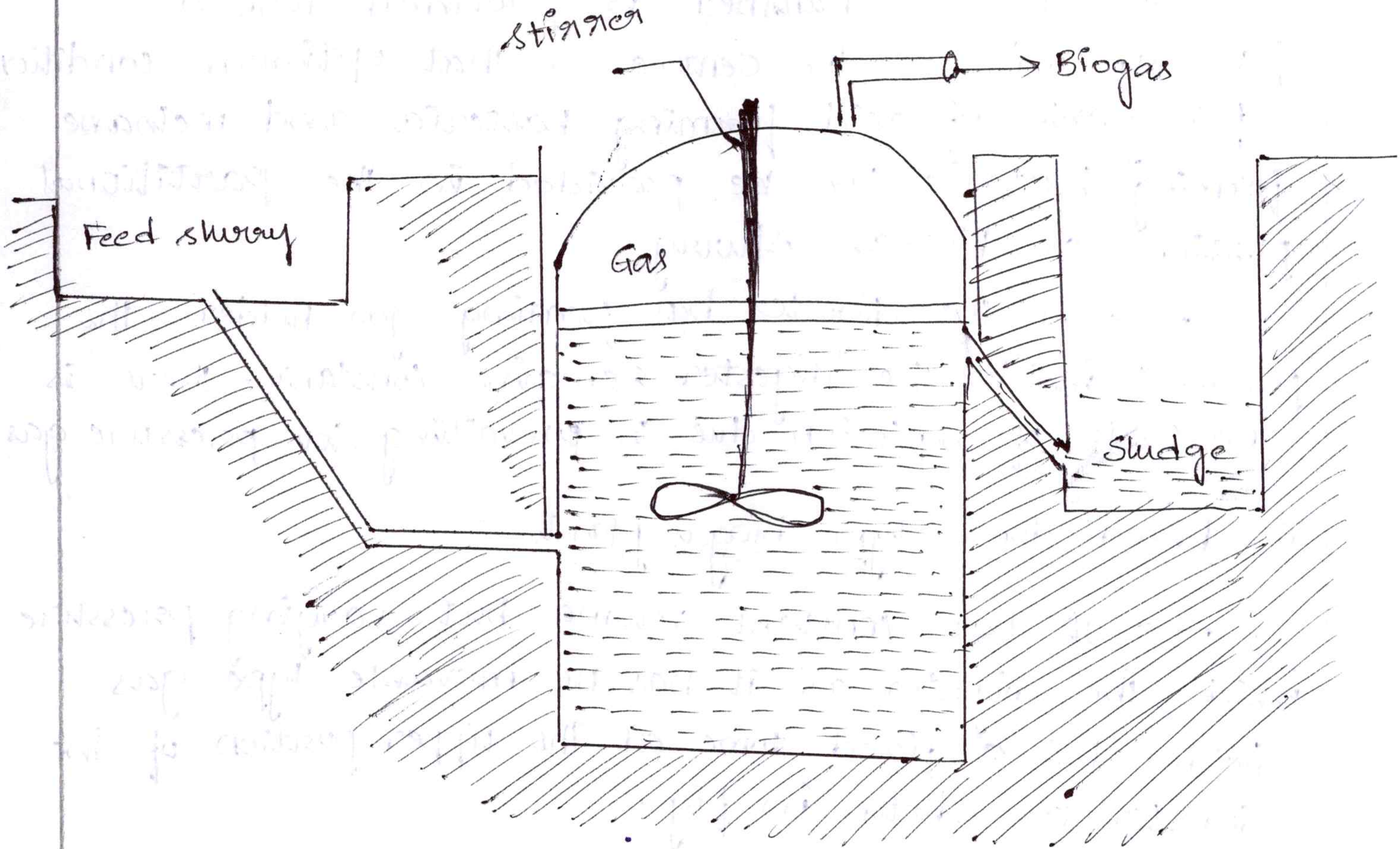


fig :- Continuous type Biogas plant

(i) Floating drum type biogas plant :-

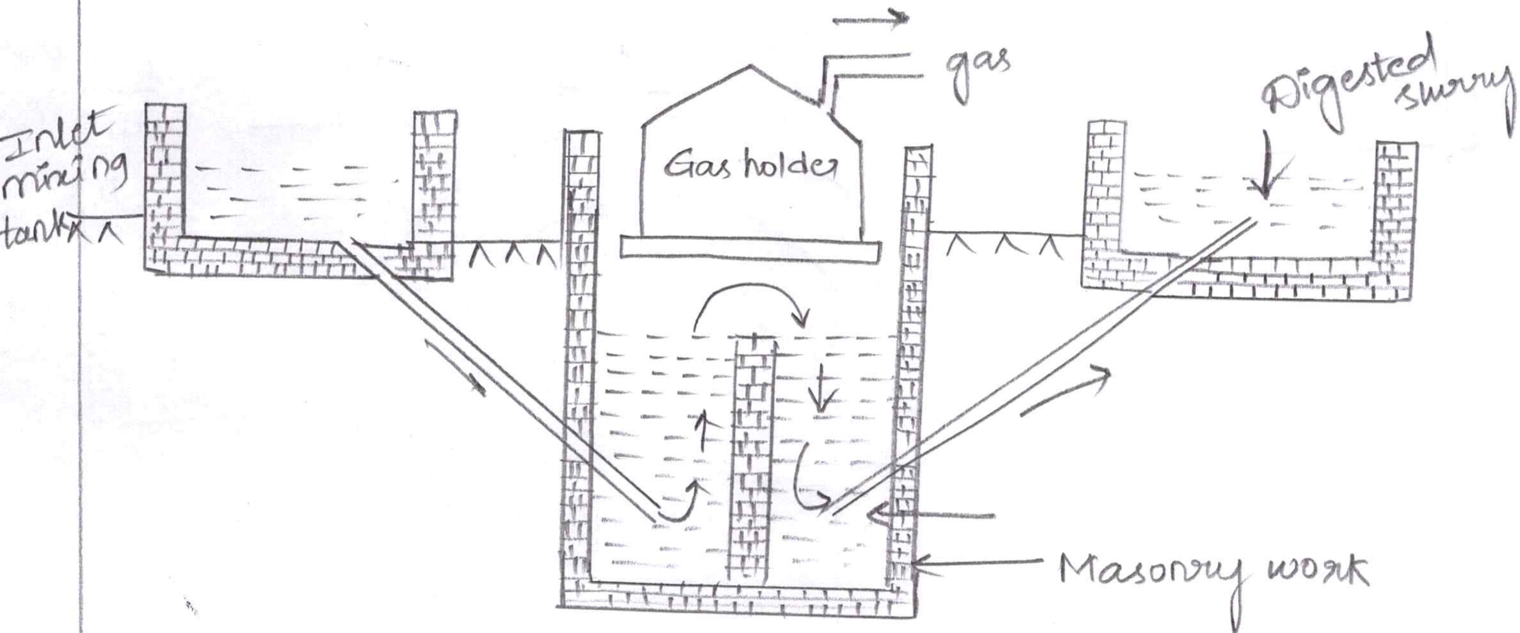


Fig: Floating drum type Biogas plant

→ The digester chamber is provided with a partition wall at the centre so that optimum condition for growth of acid forming bacteria and methane forming bacteria can be provided in the partitional portions as biomass slurry.

→ As the digester has floating gas holder, the pressure inside the digester remains constant. There is no risk of explosion due to prevailing low pressure gas.

(iii) Fixed dome type biogas plant :-

→ It has constant volume but varying pressure inside the digester as it has no movable type gas holder but a fixed dome at the upper portion of the digester as shown in fig.

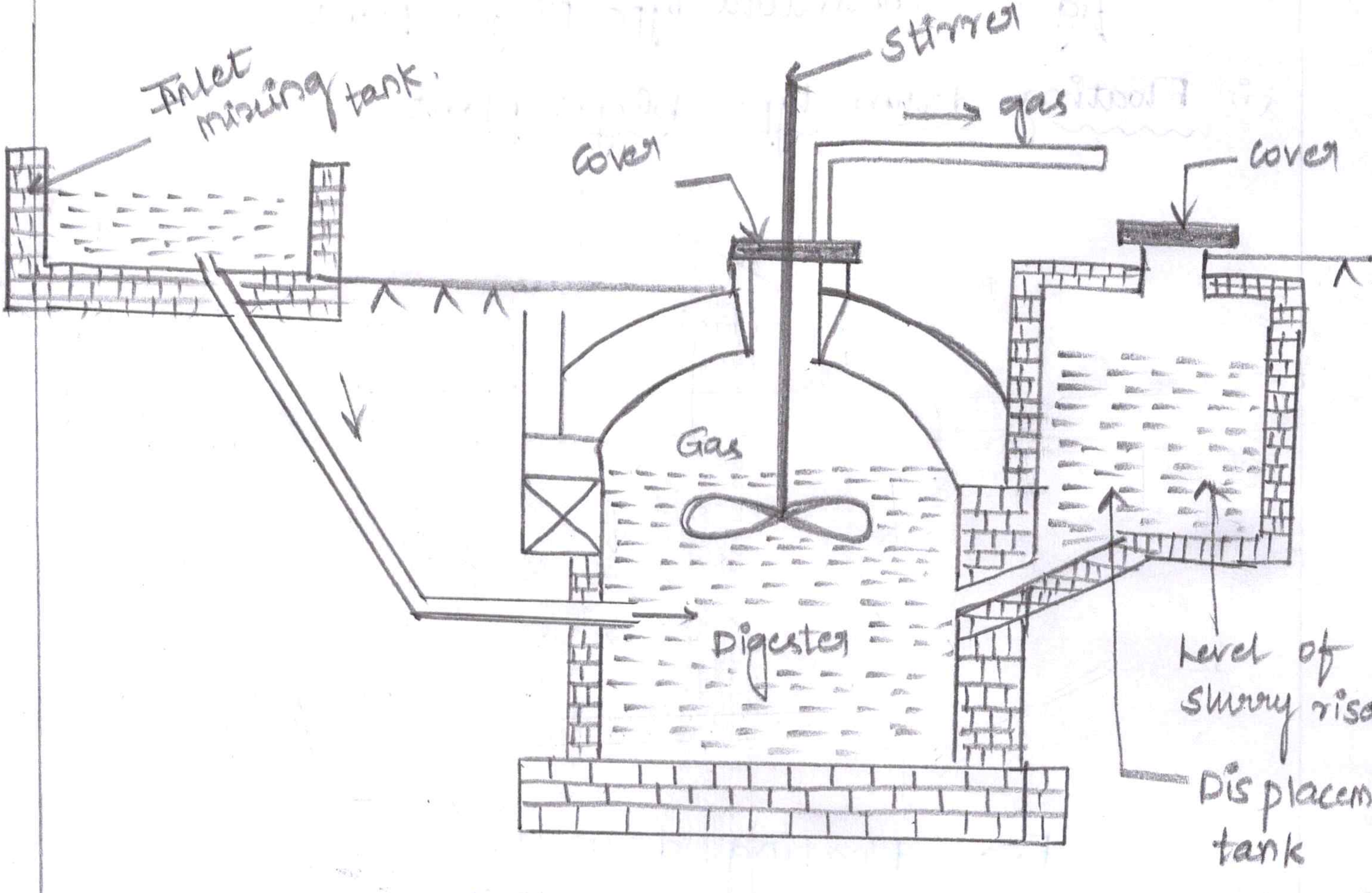


Fig. Fixed dome type biogas plant

→ A stirrer is provided in the digester tank, which is fed into the digester mixing of scum floating on the slurry.

→ In the modified fixed dome type biogas plant, a displacement tank is also provided which is connected to the digester.

→ This arrangement helps in maintaing a constant pressure inside the digester about 1m of water column and the removal of digested slurry from displacement tank.

Comparison of floating drum and fixed dome types of plants :-

Floating Drum.	Fixed Dome.
(1) It has constant pressure in the digester	(1) It has constant volume in the digester.
(2) The Pressure in the digester in slightly more than the atmosphere pressure	(2) The Pressure inside the digester can be as high as 1m of water column
(3) No danger of explosion of gas as pressure in the digester is low	(3) Danger of explosion exists as pressure in high
(4) No danger of leakage of gas	(4) Due to high pressure there is danger of leakage of gas.
(5) Cost is more due to floating steel drum	(5) Less costly
(6) Gas production is high due to lower pressure in the digester	(6) Low production of gas
(7) Installation is simple	(7) Installation is difficult

Advantages and DisAdvantages of fixed drum type biogas plant :-

The Advantages are as follows :.

(i) It has lower cost
(ii) It has no corrosion problem
(iii) It has better heat insulation
(iv) It requires no maintenance.

The Disadvantages are as follows.

(i) Gas production per cubic meter of the digester is les
(ii) It has variable pressure of biogas.
(iii) It has more risk of leakage due to higher pressure of gas.
(iv) It has more risk of explosion.
(v) It involves complex installations.

Advantages and Disadvantages of floating drum type biogas plant :-

(i) Higher gas production per cubic meter of digester volun
(ii) No gas leakage problem
(iii) Constant gas pressure
(iv) No danger of gas explosion.
(v) Simple installation

DisAdvantages are as follows:

(i) It has higher cost due to movable metallic drum
(ii) It has corrosion problem in the metallic movable drum provided
(iii) It requires more maintenance.

Constructional Details of Some Main Digesters :-

(1) KVIC Digester of Gobar Gas Generator :-

Construction of the gas plant can be understood broadly from fig. It mainly consists of two main parts.

(1) Digester or pit
(2) The gas holder or the gas collector.

Digester :-

Also called the fermentation plant, it is a sort of well of masonry work, dug and built below the ground level

→ The depth of this well varies from 3.5mts to 6mts, and diameter from 1.35mts to 6 mts, depending upon the gas generating capacity and the quantity of raw material fed each day

→ The digested well is divided vertically into two semi-cylindrical compartments by means of a partition wall in the centre

→ Two slanting cement pipes reach the bottom of the well on either side of the partition wall

→ One pipe serves as the inlet and the other as outlet

→ An inlet chamber near the digester at surface level serves for mixing dung and water which is done mechanically or manully. The mixture of dung and water in proportion of 4:5 by volume, called slurry, flows down the inlet pipe to the bottom of the primary compartment of the digester.

→ The outlet chamber is again at surface level, just a few cms below the level of the inlet chamber.

Gas holder :-

→ It is a drum constructed of mild steel sheets, cylindrical in shape with a conical top and radial supports at the bottom. It fits into the digester like a stopper.

→ It sinks into the slurry due to its own weight and rests upon the ring constructed for this purpose

→ As the gas is generated the holder rises and floats freely on the surface of the slurry

→ As pipe is provided at the holder for flow of gas for usage.

→ The holder also acts as a seal for the gas.

Maintenance of the Plant :-

→ The only maintenance required in the painting of the gas collector at regular intervals.

(2) Chinese Digester (Janta Biogas plants).

→ chinese have mainly gone into biogas technology for the sake of fertilizer with biogas as by product.

→ The chinese design is quite different from that of KVIC. The chinese design contains a fixed dome for the collection of the gas and hence the gas availability is at variable pressures. This type of design is shown schematically in Fig.

→ The cost of the design is very much low and the construction is easier.

→ The Fixed dome is made of masonry and this aeroplaces the floating drum of KVIC digester.

→ Planning, Research and Action Division (PRAD) lucknow has designed Janta plants modifying the design of chinese plants.

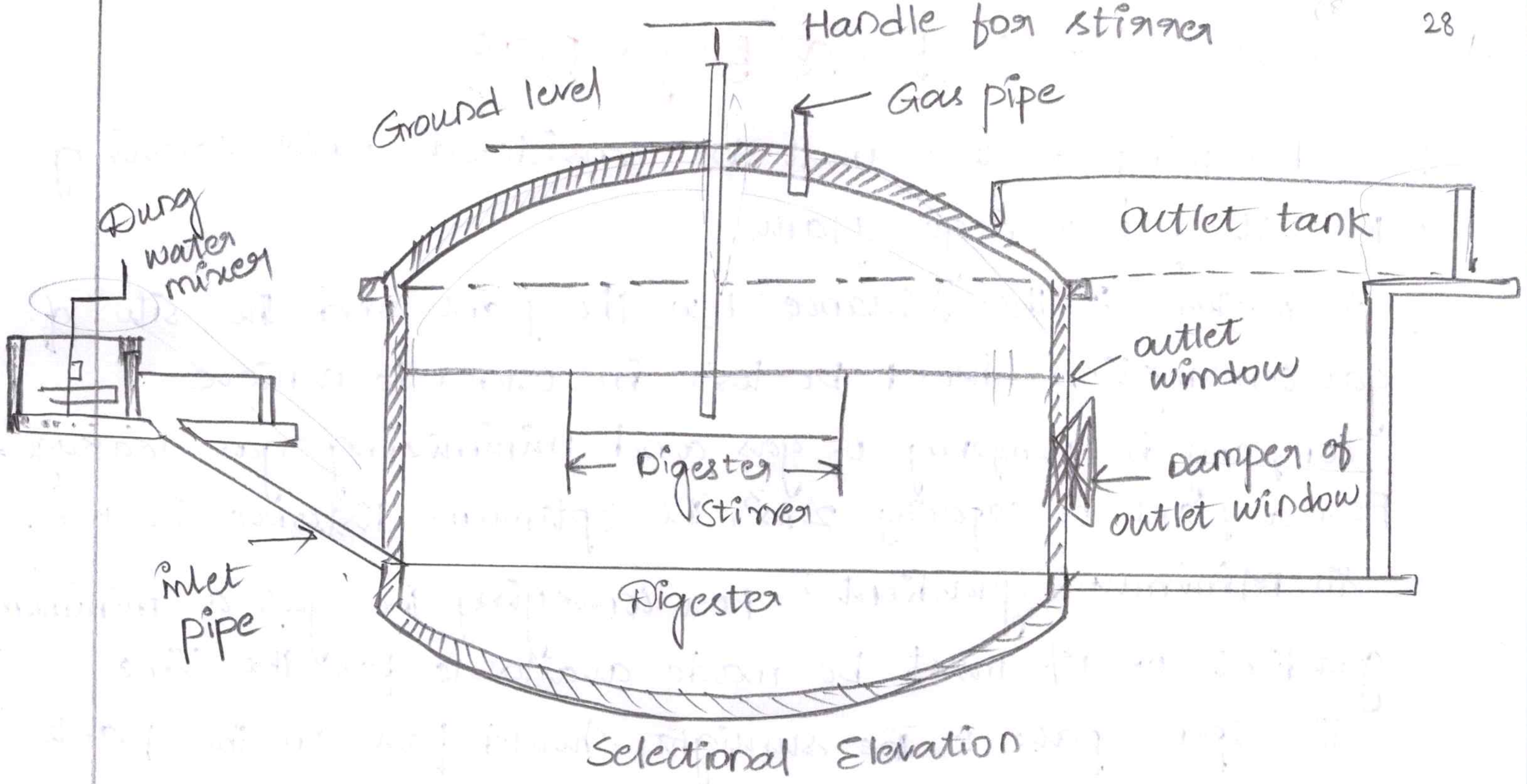


Fig :- Precast RCC Biogas Manure Plant

→ Therefore, at least three layers of extra careful plasters are a must to prevent any leakage.

→ The above limitations are considered in the development of the fixed dome biogas plant at ATRC Bardoli (Gujarat) and suggested to cast precast RCC digester into three main elements.

The purposes of precasting the digester are:

(i) to achieve better technical results in controlled conditions;

(ii) to relieve the farmers facing lot of troubles in producing procuring raw materials of the plant and getting skilled mason and labouries;

(iii) to facilitate use of vibrator for compact and impermeable construction.

Selection of site for a Biogas plant :-

Following factors must be considered while selecting the site for a biogas plant.

(i) Distance :- The Distance b/w the plant and the site of gas consumption should be less in order to achieve company in pumping of gas and minimizing gas leakage. For a plant of capacity $2 m^3$, the optimum distance is 10m.

(ii) Minimum gradient : For conveying the gas a minimum gradient of 1% must be made available for the line

(iii) Open Space :- The sunlight should fall on the plants as temperature b/w 15°c to 30°c is essential for gas generation at good rate.

(iv) Water Table :- The plant is normally constructed underground care should be taken to prevent the seepage of water and plant should not be constructed if the water table is more than 10ft (3m)

(v) seasonal run off :- proper care has to be taken to prevent interference of run off water during monsoon.

(vi) Distance from wells :- The seepage of fermented slurry may pollute the well water. Hence a minimum of 15m should be maintained from the wells.

(vii) Space requirements :- Sufficient space must be available for day to day operation and maintenance.

(viii) Availability of water :- plenty of water must be available as the cowdung slurry with a solid concentration of 7% to 9% is used.

(ix) Source of cowdung / materials for biogas generation. This distance b/w the material for biogas generation & the gas plant site.

Digester Design considerations :-

Digestion tanks may be of any convenient shape and provided with a cover to retain the gas. The Cover may be a fixed one or floating. A number of factors are to be taken into account to arrive an optimum size of a biogas plants.

These are :

(1) period of digestion,
(2) The volume of waste to be digested daily.
(3) Methods of stirring, The contents if any,
(4) Methods of adding the raw waste and removing digested slurry.
(5) The type and amount of waste available for digestion consistenly
(6) Effeciency of The collection of the raw waste,
(7) The climate condition of the region,
(8) Type of the cover
(9) Information about sub-soil condition and water table,
(10) The availability of other cellulosic fermentable waste in That area

→ The capacity of the digestion tank may be formulated approximately as

$$\text{Capacity} = \frac{V_1 + V_2}{2} \, t$$

where V_1 = The volume of raw waste added daily
V_2 = volume of the waste after digestion
t = period of digestion in days

Advantages and Disadvantages of Biomass Energy :-

(i) It is a renewable source
(ii) It can be stored and used as per the requirement
(iii) It helps in waste management
(iv) It is an indigenous source of energy
(v) It helps in economic development of rural areas
(vi) It helps in improving sanitation in rural areas and towns.
vii) It helps in providing fertilisers.
viii) It provides economical use of various types of wastes and residues.

Dis-Advantages :-

(i) It has low energy density.
(ii) It is a labour intensive energy source
(iii) Its production requires large land areas.

— x —

ELECTROCHEMICAL EFFECTS AND FUEL CELLS.

Fuel cell :-

Fuel cells operate on the principle of Electrochemistry

→ The fuel cell uses fuel and oxidant. It directly converts fuel and oxidant into electrical energy without any combustion.

→ The Efficiency of fuel cells is generally about 60% with the voltage output of about 0.7V

Oxidation and Reduction :-

Oxidation and Reduction are two electrochemical reactions. Oxidation is a reaction in which electrons are liberated from a fuel and reduction of a reaction in which electrons are consumed.

List the fuels used in fuel cells:-

The various combinations of the fuel and oxidant are shown in Table 7.1

S.NO	Fuel	Oxidant.
1.	Hydrogen	Oxygen
2.	Hydrogen - rich gas	Air
3.	Ammonia	Air
4.	Hydrocarbon	Air
5.	synthesis gas	Air
6.	Hydrocarbon	Air.

- Explain the working principle of fuel cell with the help of a neat sketch.? (or)
- Working of a hydrogen-oxygen fuel cell. (or)
- Explain the basic principle of fuel cell with reference to hydrogen-oxygen fuel cell.

Principle of fuel cell :-

→ A fuel cell converts chemical energy of a fuel directly into electrical energy.

→ The Fuel cell consists of two electrochemically conducting electrodes separated by an electrolyte. The arrangement of fuel cell components is shown in fig-1.

→ The Electrodes are made of porous nickel material to collect charges and concentrated phosphoric acid is filled b/w the electrodes, which acts as the electrolyte

→ The fuel (hydrogen) is fed into the anode side of cell

→ The fuel (hydrogen) is oxidised and liberated electrons move to the external circuit.

→ The Oxidant (oxygen) is fed into the cathode side, where it is reduced by the electrons coming from anode through external circuit. The remaining negative oxygen ions enter the electrolyte from the porous wall of cathode

→ The Negative oxygen ions and positive hydrogen ions combine to form water.

→ The electrochemical reactions are as follows.

(i) Anode

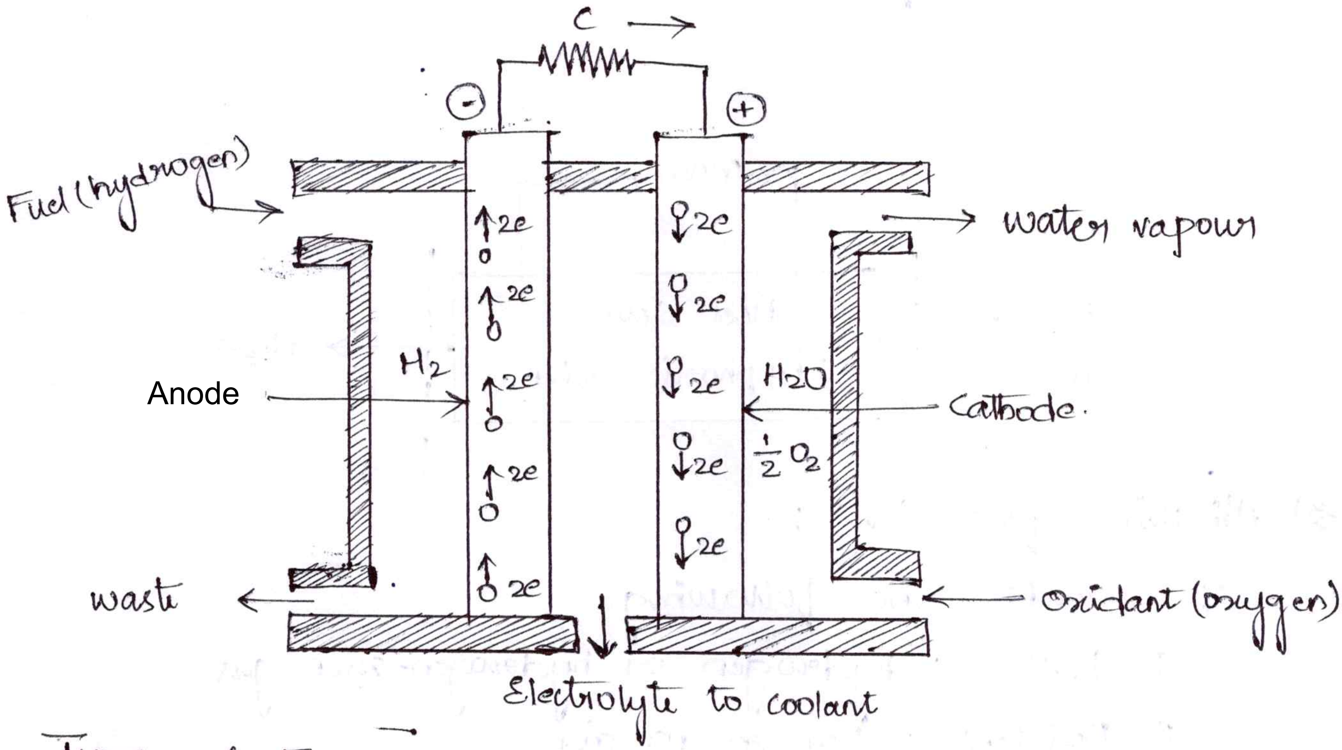
$$2H_2 \longrightarrow 4H^+ + 4e$$

(ii) Cathode

$$O_2 + 4e \longrightarrow 2O^{2-}$$

(iii) Electrolyte

$$4H^+ + 2O^{2-} \longrightarrow 2H_2O.$$



Types of Fuel Cells :-

According to the type of electrolyte, the fuel cells can be phosphoric acid fuel cell (PAFC), alkaline fuel cell (AFC), polymer electrolyte membrane fuel cell (PEMFC), molten carbonate fuel cell (MCFC) and solid oxide fuel cell (SOFC)

(1) Phosphoric acid and hydrogen - Oxygen fuel cell.

It includes the following.

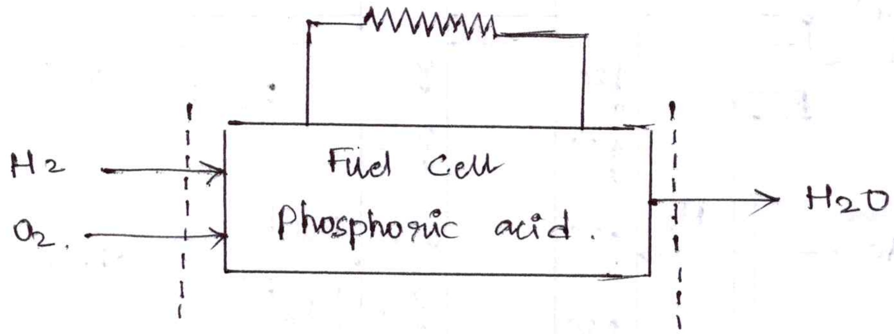
(i) Fuel : hydrogen
(ii) Oxidant : Oxygen.
(iii) Electrolyte : phosphoric acid.
(iv) Electrodes : porous nickel
(v) Reactions.

$$H_2 \longrightarrow 2H^+ + 2e^- \text{ (anode)}$$

$$2H^+ + \frac{1}{2} O_2 + 2e^- \longrightarrow H_2O \text{ (cathode)}$$

(vi) Output : 1.23 V at 25%

(vii) Efficiency : 83%



2) Alkaline fuel cell :

It includes the following.

(i) Fuel : hydrogen or hydrogen-rich gas

(ii) Oxidant : Oxygen or air.

(iii) Electrodes : porous nickel

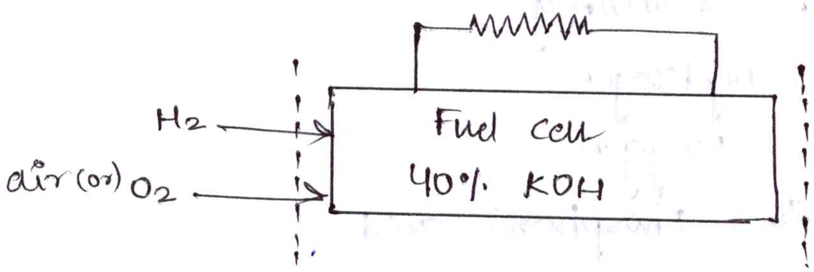
(iv) Electrolyte : KOH (40%)

(v) Reactions.

$$\frac{1}{2} O_2 + H_2O + 2e \longrightarrow 2OH^- \text{ (cathode)}$$

$$H_2 + 2OH^- \longrightarrow 2H_2O + 2e \text{ (anode)}$$

(vi) Output : 1.23 V at 90°c.



3) polymer electrolyte or proton exchange membrane fuel cell.

It is also called solid polymer fuel cell (SPFC).

It includes the following.

(i) Fuel : hydrogen

(ii) Oxidant : Oxygen.

(iii) Electrodes : deposited plantinum layers.

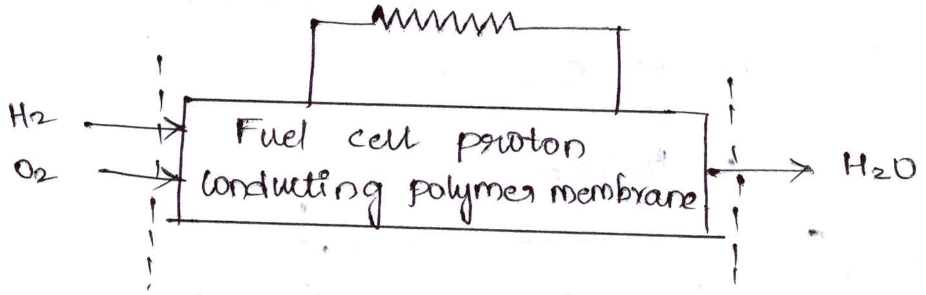
(iv) Electrolyte : proton conducting polymer membrane

(v) Reaction

$$H_2 \longrightarrow 2H^+ + 2e^- \text{ (anode)}$$

$$\frac{1}{2} O_2 + 2H^+ + 2e^- \longrightarrow H_2O \text{ (cathode)}$$

(vi) Output : 1.23 V at 25°c.



(4) Molten carbonate fuel cell.

The cell includes the following

(i) Fuel : synthesic gas ($H_2 + CO$)

(ii) Oxidant : air

(iii) Electrodes : nickel and silver

(iv) Electrolyte : Molten carbonate.

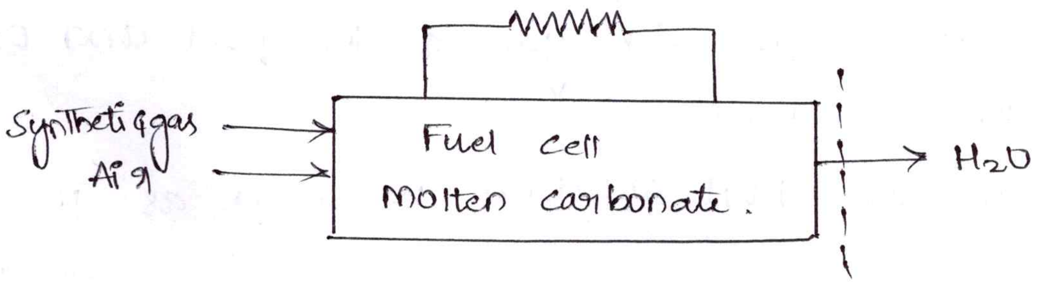
(v) Reaction :

$$H_2 + CO_3^{2-} \longrightarrow H_2O + CO_2 + 2e^- \text{ (anode)}$$

$$CO + CO_3^{2-} \longrightarrow 2CO_2 + 2e^- \text{ (anode)}$$

$$O_2 + 2CO_2 + 4e^- \longrightarrow 2CO_2 \text{ (cathode)}$$

(vi) Output : 1 V at 700°c



5) Solid oxide fuel cell.

It includes the following

(i) Fuel : synthetic gas ($H_2 + CO$)

(ii) Oxidant : air.

(iii) Electrodes : Porous Plantinum ceramic

(iv) Electrolyte : ceramic conducting oxygen ions

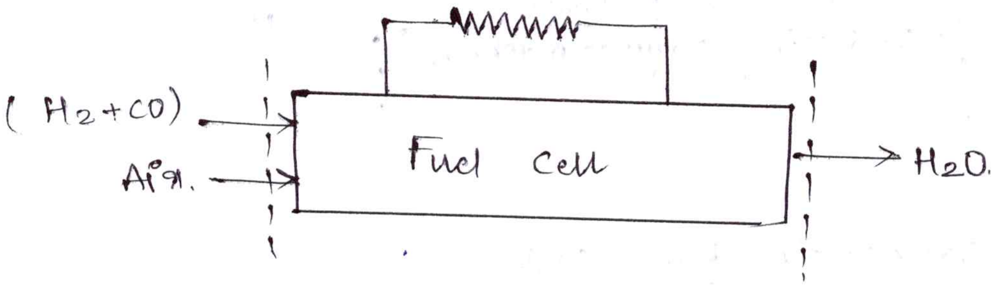
(v) Reaction

$$H_2 + O^{2-} \longrightarrow H_2O + 2e^- \text{ (anode)}$$

$$CO + O^{2-} \longrightarrow CO_2 + 2e^- \text{ (anode)}$$

$$O_2 + 4e \longrightarrow 2O^{2-} \text{ (cathode)}$$

(vi) Output : 1V at 800 - 1000°c



6) Regenerative cell :

In a regenerative fuel cell, the reactants are regenerated from the products and the regenerated reactants are recycled into fuel cell. The regenerative fuel cell has efficiency of 5 - 20%.

Alkaline Fuel Cell :-

The Principle of working of alkaline fuel cell is the same as that of a phosphoric acid or hydrogen-Oxygen cell.

→ It uses H_2 or H_2 rich gas as the fuel and oxygen or air as the oxidant

→ 40% aqueous KOH solution is used as the electrolyte.

→ The Hydrogen gas at anode is oxidised, resulting in the liberation of electrons.

→ Electrons are forced through external circuit to cathode. At cathode, oxygen gas water and electrons combine to produce OH^- ions.

The reactions given as follows

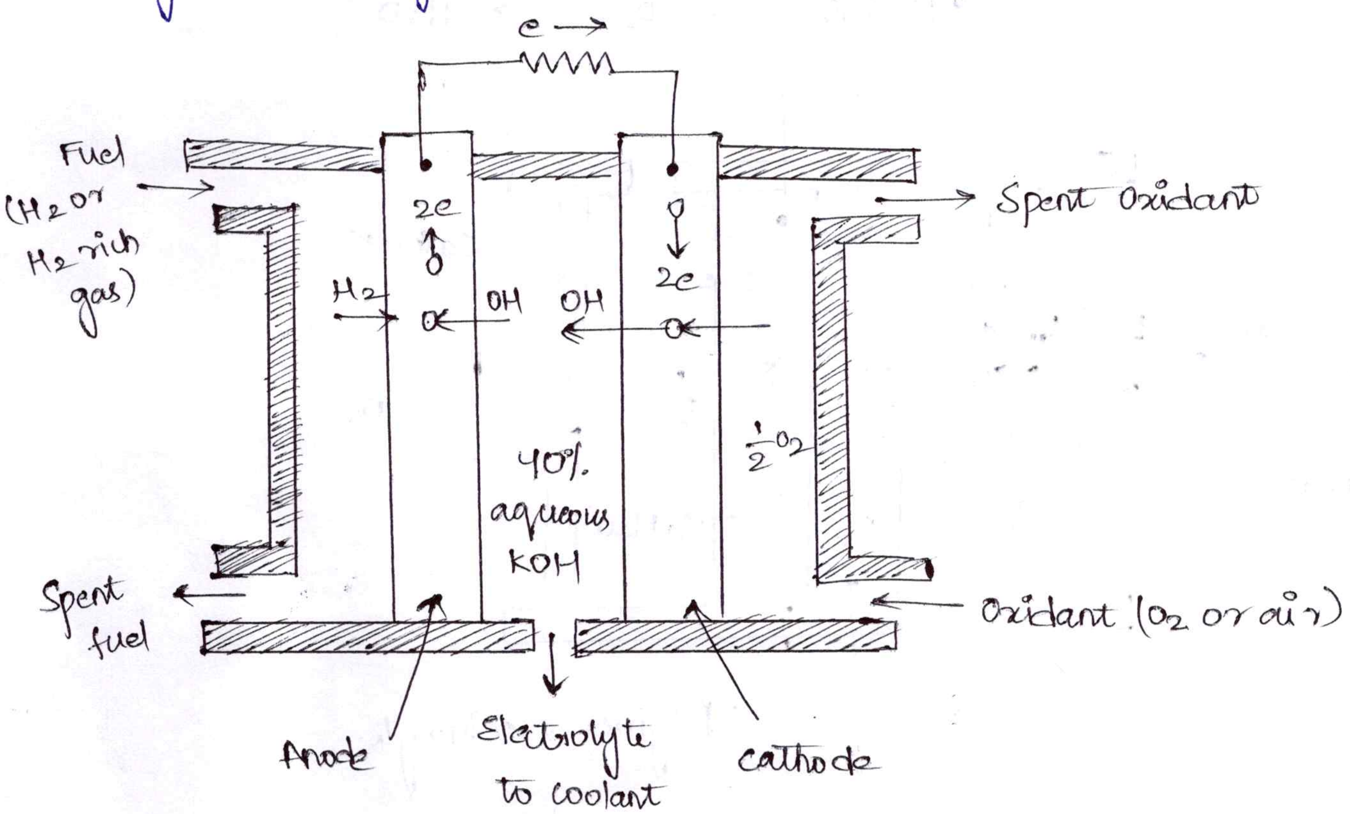
$$\frac{1}{2} O_2 + H_2O + 2e^- \longrightarrow 2OH^-$$

These OH^- ions move from cathode to anode through the electrolyte, where these combine with hydrogen gas to produce water.

The reaction is as follows.

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

The alkaline fuel cell is shown in Fig. It has porous electrodes of nickel separated by the electrolyte consisting of a solution of KOH (40% which also helps in preventing the reactants (hydrogen and oxygen) from directly interacting with each other.



39 ' ## Polymer Electrolyte Membrane Fuel Cell :

The Fuel cell uses a membrane of organic materials such as polystrene sulphoric acid as electrolyte. sulphoric acid as electrolyte.

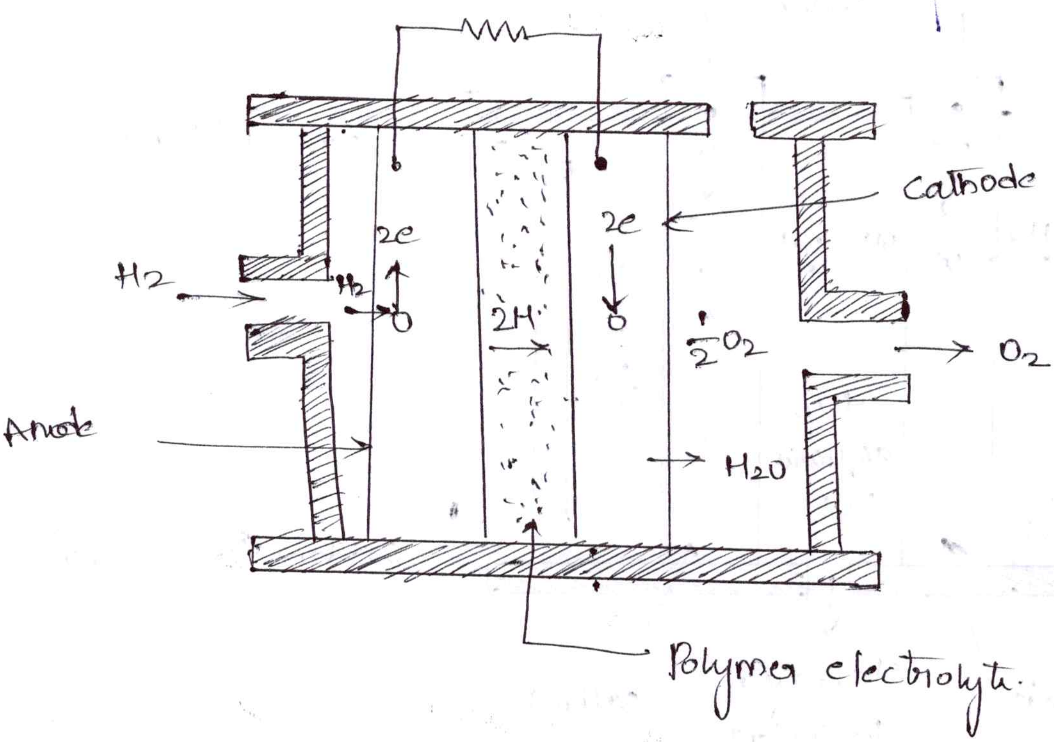
→ The Membrane has property To allow H^+ ions to pass Through it.

→ The Fuel cell consists of a thin layer of electrolyte membrane which has plantinum deposited on its each surface to act as electrodes (anode and cathode). H_2 enters and interact with anode. The gas is converted into H^- ions and electrons and liberated. The reaction is given by

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

→ Hydrogen ions formed at anode are transpored to cathode Through photon exchange membrane and electrons are forced Through The outer circuit to cathode. At cathode, ions, electrons and oxygen gas interact to produce water.

$$2H + 2e^- + \frac{1}{2}O_2 \longrightarrow H_2O$$



Molten Carbonate Fuel cell:

→ The Molten carbonate fuel cell has a high operating temperature with molten carbonate mixture as electrolyte.

→ The carbonate of alkali metals (Na, K, and Li) in molten state is used as the electrolyte. This necessity makes the cell to operate at a temperature above the melting point of carbonate (range of 600 - 700°c)

→ The porous nickel and silver are used as the oxidant cathode electrode respectively with are separated by electrolyte held by a sponge-like ceramic matrix.

→ The synthetic gas ($H_2 + CO$) is used as the fuel and air is used as the oxidant.

→ The synthetic gas is passed through the anode, where the hydrogen and carbon monoxide are oxidised with CO_3^{2-} ions, thereby liberating electrons

→ The Electrons move to cathode from the external circuit

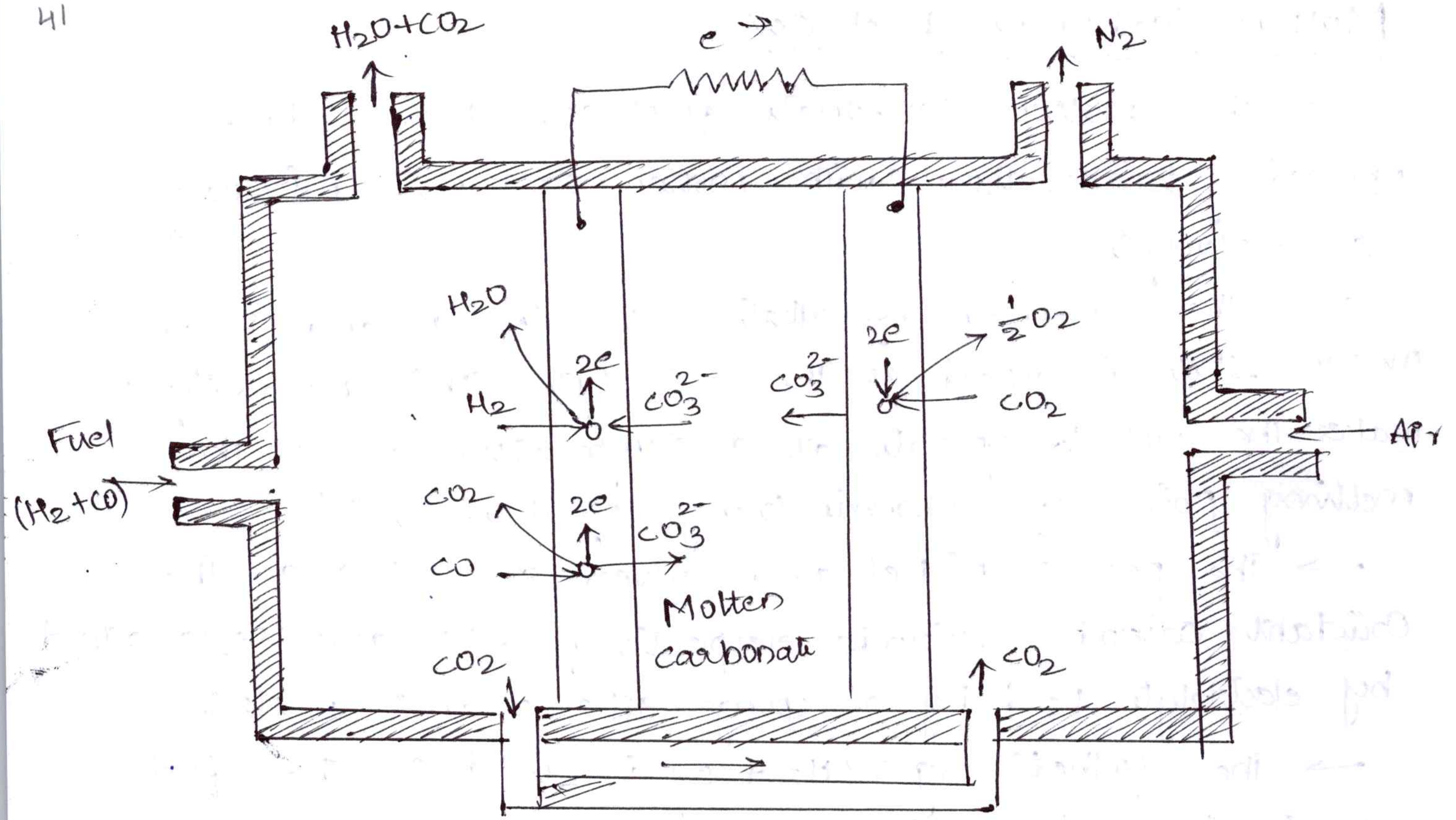
→ At the cathode, oxygen gets reduced in the presence in the pressure of carbon dioxide and electrons, thereby forming CO_3^{2-} ions. The reactions are as follows.

$$H_2 + CO_3^{2-} \longrightarrow H_2O + CO_2 + 2e^- \quad \text{(anode)}$$

$$CO + CO_3^{2-} \longrightarrow 2CO_2 + 2e^- \quad \text{(anode)}$$

$$O_2 + CO_2 + 4e^- \longrightarrow 2CO_3^{2-} \quad \text{(cathode)}$$

→ The Emf generated by the cell is about 1 V at 700°c.



Solid Oxide or Ceramics Fuel cell :-

→ It has been found that certain solid oxides or ceramics can be used as an electrolyte and these ceramics can conduct oxygen ions at a high temperature. Zirconium oxide is one such ceramic.

→ The fuel cell has porous nickel as anode electrode and indium oxide as cathode electrode.

→ The operating temperature of the cell ranges from 600 to 1000°c.

→ The Fuel is a synthetic gas, that is, a mixture of hydrogen and carbon monoxide

→ At the anode, hydrogen and carbon monoxide react with oxygen ions present in the electrolyte to produce carbon dioxide and water

→ Hydrogen and carbon monoxide liberate electrons on oxidation

→ The liberated electrons flow through external circuit to cathode.

→ At the cathode, oxygen is reduced by electrons to oxygen ions (Fig)

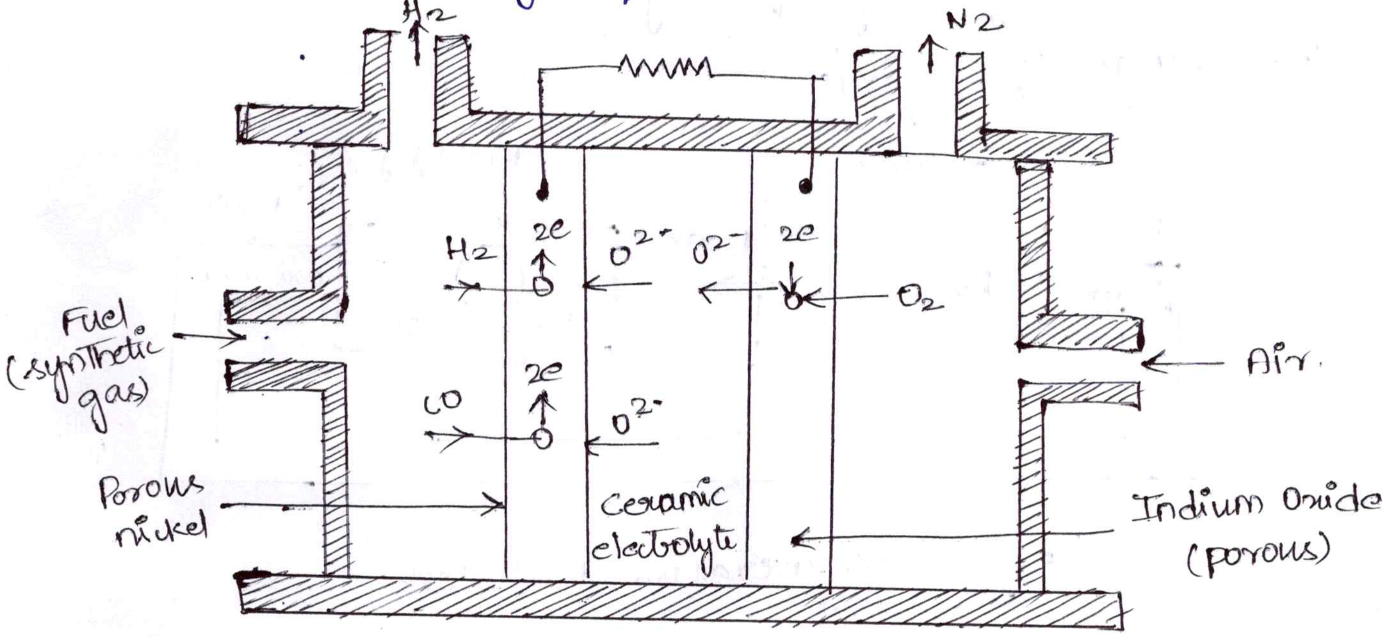
The reaction is as follow:

$$CO + O^{2-} \longrightarrow CO_2 + 2e^-$$

$$\frac{1}{2} O_2 + 2e^- \longrightarrow O^{2-}.$$

The heat of discharge (spent fuel and oxidant) can be utilized as process heat or power generation.

The output voltage of full load is about 0.63 V.



Regenerative Fuel cell:

→ Regenerative or reversible fuel cell is a cell in which the reactants (fuel and oxidant) are generated from the products formed from the oxidation and reduction of fuel and oxidant respectively

→ It implies that are reactants are generated from its products so that these can be recycled into the fuel cell.

→ The regeneration can be applied out using chemical, electrical, thermal, radioactive and photochemical method.

→ In a regenerative fuel cell, reactants are converted into products with the removal of electrical work (w) and the products are converted into reactants in a regenerator at a higher temperature (T_H). (Fig)

→ Hence, products can be considered as working fluid and fuel cell with regenerator forms a heat engine cycle, that is heat heat engine performing cycle to give work output using heat supplied.

→ The efficiency of regenerative fuel cell is in the range of 5-20%.

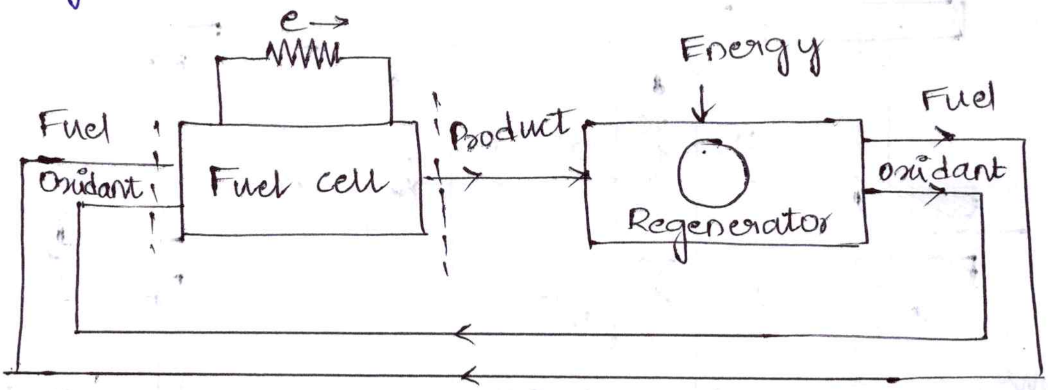


Fig Regenerative Fuel cell

Advantages and limitations of a fuel cell.

The advantages of a fuel cell are as follows

(i) It has a very high conversion efficency.

(ii) It can be installed near the load point, therby reducing the requirement of transmission lines.

(iii) It is noiseless and can operate quietly because of the absence of moving parts.

(iv) Fuel cells are non-polluting.

(v) No cooling required to condense the discharge

(vi) Fuel cells require lesser time for installation and operation.

(vii) Fuel cells need a lesser area for installation and operation.

(viii) As fuel cells are noiseless, they can be installed in residential areas.

(ix) Fuel cells can easily meet the varying load of customers.

Limitations of the fuel cell are as follows:

(i) Capital cost of fuel cell is high

(ii) Heavy corrosion of electrodes causes low lifespan of a fuel cell.

(iii) Degradation of electrodes and electrolyte reduces the performance of a fuel cell.

Applications of a fuel cell:

The Applications of a fuel cells are as follows.

(i) Fuel cells can be employed for levelling of load in power plants.

(ii) Fuel cells can use synthetic gas (a mixture of hydrogen and carbon monoxide) for conversion into electric power with high efficiency (about 70%)

(iii) Fuel cells can also suitable to be used for dispersed generation. The transmission and distribution cost can be reduced by operating fuel cells at different load centers

(iv) Fuel cells can provide power at remote and inaccessible areas

(v) Fuel cells can replace batteries as an alternative power source

(vi) Emergency and critical supply such as to hospital can be met by fuel cells.