CONTENTS

CHAPTER – 1
ENERGY SOURCES

1.1. Introduction to energy

The energy of a body is its capacity to do work. It is measured the total amount of work that the body can do.

Energy is the primary and most universal measure of all kinds work by human beings and nature. Every thing what happens the world is the expression of flow of energy in one of its forms.

1.2. Different forms of energy

The different forms of energy are:

1. Mechanical energy (kinetic and potential)
2. Thermal (or) Heat energy
3. Chemical energy
4. Electrical energy
5. Nuclear energy
6. Electromagnetic energy
7. Gravitational energy

The S.I unit of energy is Joule or KJ or Watt.h.

Primary Energy Sources

Primary energy sources can be defined as sources which provide a net supply of energy Coal, Oil, Uranium etc., are examples of this type. The energy required to obtain these fuels is much use than what they can produce by combustion or nuclear reaction. The supply of primary fuels is limited. It becomes very essential to use these fuels sparingly.

Examples

Coal, natural gas, oil and nuclear energy.

Secondary Energy sources

Secondary fuels produce no net energy. Though it may by necessary for the economy, these may not yield net energy.

Secondary sources are like sun, wind, water (tides), etc. Solar energy can by used through plants, solar cells, solar heaters and solar collectors.

1.3. Energy sources and their availability

Introduction

Today every country draws its energy needs from a variety of sources. We can broadly categorize these sources as commercial and non-commercial. The commercial sources include the fossil fuels (coal, oil and natural gas), hydro-electric power and nuclear power, while the non-commercial sources include wood, animal waste and agricultural wastes. In an Industrialized country like U.S.A. most of the energy requirements are met from commercial sources, while in an Industrially less developed country like India, the use of commercial and non-commercial sources are about equal.

1.4. Conventional and non-conventional sources energy

1.4.1. Conventional energy sources

Conventional energy sources are:

(a) Fossil fuel energy

(b) Hydraulic energy

(c) Nuclear energy

(a) Fossil fuel energy

Coal, petroleum, and natural gas are called Fossil fuel as these are formed by the decomposition of the remains of dead plants and animals buried under the earth for a long time. These are non-renewable sources of energy, which, if exhausted, can not be replenished in a short time. Their reserves are limited and are considered very precious. These should be used with care and caution to let them last long. These are also contributing to the global environmental pollution.

(i) Coal

Since the advent of industrialization coal has been most common source of energy. In the last three decades, the world switched over from coal to oil as a Major source of energy because it is simpler and cleaner to obtain useful energy from oil.

Coal is a complex mixture of compounds of carbon, hydrogen and oxygen. Small amounts of nitrogen and Sulphur compounds are also present in coal. It is mainly available in Bihar, West Bengal, Orissa and Madhya Pradesh. The big coal mines in our country are at Jharia and Bokaro in Bihar and at Raniganj in West Bengal. It is considered as the backbone of the energy sector for its use in industry, transportation and electric power generation.

Depending upon the carbon contents of coal, it is classified as follows:

Type of coal	**Carbon content (%)**
1. Peat	60
2. Lignite (soft coal)	70
3. Bituminous (house hold coal)	80
4. Anthracite (hard coal)	90

It is clear that peat is the most inferior quality of coal. Whereas anthracite is the most superior quality of coal. Bituminous is most commonly used in households and industry.

On strong heating, coal breaks up to produce coal gas, ammonia, coaltar and coke. Coke is 98% carbon, obtained after lossing all its volatile constituents during destructive distillation of coal. It can be used as smoke free fuel.

(ii). Petroleum

It is a dark coloured, viscous and foul smelling crude oil. The petroleum means rock oil. It is normally found under the crust of earth trapped in rocks. The crude oil is a complex mixture of several solid liquid gaseous hydrocarbons mixed with water, salt and earth particles. It is a natural product obtained from oil wells.

Some of the crude oil producing locations in our country are:

(i) Ankleshwar and Kalol in Gujarat

(ii) Rudrasagar and Lakwa in Assam; and

(iii) Bombay high (off-shore area)

The oil wells of Bombay high are producing about 22 million tons of crude petroleum oil per year, which is little less than half of the total requirement of the country. The efforts are also being made to search oil well in off-shore deltas to Godavari, Kaveri, and Rajasthan.

The crude petroleum is refined by the process of fractional distillation to obtain more useful petroleum products. The crude petroleum is heated to a temperature of about 400^oC in a furnace and vapors thus formed are passed into a tall fractioning column from near its bottom. As the mixture of hot vapours rises in the column, it starts getting cooled gradually.

The products obtained from crude petroleum as follows:

(i) Petroleum gas (below 40^oC) used as LPG.

(ii) Petrol (40^oC to 170^oC) for light vehicles.

(iii) Kerosene (170 to 250^oC) for household and industrial use.

(iv) Diesel oil (250 to 350^oC) for heavy vehicles.

(v) Residual oil ; (a) Lubrication oils (b) paraffin wax and (c) asphalt

(vi) Fuel oil (350 to 400^oC) for boilers and furnaces.

(iii) Natural gas

It consists about 95% Methane and rest ethane and propane. It occurs deep under the crust of the earth either alone or a long with oil above the petroleum deposits. It is a product of petroleum mining.

The gas is available in Tripura, Jaisalmer, off-shore areas of Bombay High and in the Krishna – Godavari delta. It is used as a domestic and industrial fuel. The natural gas is now also available as CNG (Compressed Natural Gas) a substitution of petrol in automobiles.

(b) Hydraulic energy (or) Water power

Water power is developed by allowing water to fall under the force of gravity. It is used almost exclusively for electric power generation, in fact, the generation of water power on a large scale became possible around the beginning of the twentieth century only with the development of electrical power plants or Hydro electric plants were usually of small capacities usually less than 100 KW.

Potential energy of water is converted into Mechanical energy by using prime moves known as hydraulic turbines. Water power is quite cheap where water is available in abundance. Although capital cost of hydro electric power plants is higher as compared to other types of power plants but their operating Costs are quite low, as no fuel is required in this case. The development rate of hydropower is still low, due to the following problems:

1. In developing a project, it will take about 6-10 years time for planning, investigation and construction.
2. High capital investment is needed, and some parts of the investment have to be designed from foreign sources.
3. There are growing problems on relocation of villages, involved, compensation for damage, selecting the suitable resettlement area and environmental impact.

Because of long transmission line to the villages with low load factor, the electric power will be available to the people in rural areas may not be economical. This leads to the development of Mini or Micro hydroelectric projects to supply the electric power to remote areas. The Importance of Micro hydroelectric projects have been observed in some parts of the country with availability of river flow through out the year.

In order to reduce the cost of development several Measures have been considered as follows:

(a) Development of low cost turbines and generators.
(b) Participation of villages in the development and operation of the project.
(c) Using the appropriate technology and tolerable substandard requirement and project civil work component at the beginning stage.

(c) Nuclear energy

According to modern theories of atomic structure, matter consists of minute particles known as atoms. Heavier unstable atoms such as U^{235}, Th^{239}, liberate large amount of heat energy. The energy released by the complete fission of one Kg of Uranium (U^{235}), is equal to the heat energy obtained by burning 4500 tonnes of coal (or) 220 tons of oil. The heat produced by nuclear fission of the atoms of fissionable material is utilized in special heat exchangers for the production of steam which is then used to drive turbogenerators as in the conventional power plants.

However there are some limitations in the use of nuclear energy namely high capital cost of nuclear power plants, limited availability of raw materials, difficulties associated with disposal of radio active waste and shortage of well trained personnel to handle the nuclear power plants.

The Uranium reserves in the world at present are small. These reserves are recoverable but are expensive. The presently working power plants are:

1. Tarapur atomic power station in Maharashtra
2. Ranapratap sagar atomic power station near Tota, Rajasthan
3. Kalpakkam atomic power station near Madras, Tamilnadu.
4. Narora atomic power station in U.P.

About 3% of the energy produced in India is obtained from nuclear power plants.

1.4.2. Non-Conventional Energy Sources

The sources of energy which are being produced continuously in nature and are in exhaustible are called renewable sources of energy (or) non-conventional energy.

Some of these sources are:

(a) Wind energy

(b) Tidal energy

(c) Solar energy

(a) Wind energy

Winds are caused because of two factors.

1. The absorption of solar energy on the earth's surface and in the atmosphere.
2. The rotation of the earth about its axis and its motion around the Sun.

A wind mill converts the kinetic energy of moving air into Mechanical energy that can be either used directly to run the Machine or to run the generator to produce electricity.

(b) Tidal energy

Tides are generated primarily by the gravitational attraction between the earth and the Moon. They arise twice a day in Mid-Ocean. The tidal range is only a Meter.

Basically in a tidal power station water at high tide is first trapped in a artificial basin and then allowed to escape at low tide. The escaping water is used to drive water turbines, which in turn drive electrical generators.

(c) Solar energy

Brief history of solar energy (or) Importance of solar energy:

Energy from the sun is called solar energy. The Sun's energy comes from nuclear fusion reaction that take place deep in the Sun. Hydrogen nucleus fuse into helium nucleus. The energy from these reactions flow out from the sun and escape into space.

QUESTIONS

Short Questions

1. Define energy?
2. What are the different forms of energy?
3. What are the compounds present in coal?
4. What products can obtain from crude oil?
5. What are the conventional sources of energy?
6. What are non-conventional sources of energy?

Essay Type Questions

1. What are the Conventional sources of energy and explain briefly?
2. What are the non-conventional sources of energy and explain briefly?

CHAPTER – 2
SOLAR ENERGY

2.1. Introduction

Energy from the sun is called solar energy. The Sun's energy comes from nuclear fusion reaction that takes place deep in the sun. Hydrogen nucleus fuse into helium nucleus. The energy from these reactions flow out from the sun and escape into space.

Solar energy is some times called radiant energy. These are different kinds of radiant energy emitted by sun. The most important are light infrared rays. Ultra violet rays, and X- Rays.

The sun is a large sphere of very hot gases. It's diameter is 1.39×10^6KM. While that of the earth is 1.27×10^4 KM. The mean distance between the two is 1.5×10^8KM. The beam radiation received from the sun on the earth is reflected in to space, another 15% is absorbed by the earth atmosphere and the rest is absorbed by the earth's surface. This absorbed radiation consists of light and infrared radiation with out which the earth would be barren.

All life on the earth depends on solar energy. Green plants make food by means of photosynthesis. Light is essential from in this process to take place. This light usually comes from sun. Animal get their food from plants or by eating other animals that feed on plants. Plants and animals also need some heat to stay alive. Thus plants are store houses of solar energy.

The solar energy that falls on India in one minute is enough to supply the energy needs of our country for one day. Man has made very little use of this enormous amount of solar energy that reaches the earth.

2.2 Solar Constant

The sun is a large sphere of very hot gases, the heat being generated by various kinds of fusion reactions. Its diameter is 1.39×10^6 KM. While that of the earth is 1.27×10^4 KM. The mean distance between the two is 1.50×10^8 KM. Although the sun is large, it subtends an angle of only 32 minutes at the earth's surface. This is because it is also a very large distance. Thus the beam radiation received from the sun on the earth is almost parallel. The brightness of the sun varies from its center to its edge. However for engineering calculations, it is customary to assume that the brightness all over the solar disc in uniform. As viewed from the earth, the radiation coming from the sun appears to be essentially equivalent to that coming from a back surface at 5762^{o}k.

"The rate at which solar energy arrives at the top of the atmosphere is called solar constant Isc". This is the amount of energy received in unit time on a unit area perpendicular to the sun's direction at the mean distance of the earth from the sun. Because of the sun's distance and activity vary through out the year, the rate of arrival of solar constant is thus an average from which the actual values vary up to 3 percent in either direction. The National Aeronautics and Space Administration's (NASA) standard value the solar constant, expressed in three common units, is as follows:

(i) 1.353 kilowatts per square meter

(ii) 116.5 Langleys per hour (1 langely being equal to $1 cal/cm^2$ of solar radiation received in one day)

(iii) 429.2 Btu per Sqr.ft. per hour.

The distance between the earth and the sun varies a little through the year. Because of this variation, the extra – terrestrial flux also varies. The earth is closest to the sun in the summer and farthest away in the winter. This variation in the Intensity of solar radiation (I) that reaches the earth. This can be approximated by the equation.

$$\frac{I}{ISC} = 1 + 0.033 \text{ Cos } \frac{360(n-2)}{365}$$

$$= 1 + 0.033. \text{ Cos } \frac{360 \times n}{365}$$

where n is the day of the year.

2.3 Solar Radiation at the Earth's Surface

The solar radiation that penetrates the earth's atmosphere and reaches the surface differs in both amount and character from the radiation at the top of the atmosphere. In the first place. Part of the radiation is reflected back in to the space, especially by clouds. Further more, the radiation entering the atmosphere is partly absorbed by molecules in the air. Oxygen and Ozone (o_3), formed from oxygen, absorb nearly all the Ultraviolet radiation, and water vapour and carbon dioxide absorb some of the energy in the infrared range. In addition, part of the solar radiation is scattered (i.e. its direction has been changed) by droplets in clouds by atmosphere molecules, and by dust particles.

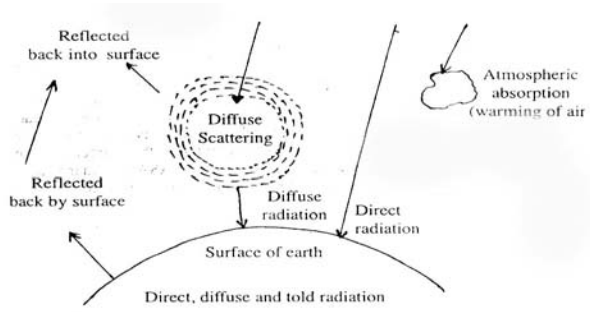


Fig 2.1 Solar Radiation at the Earth's surface

Solar Radiation that has not been absorbed or scattered and reaches the ground directly from the sun is called "Direct Radiation" or Beam Radiation. Diffuse radiation is that Solar Radiation received from the sun after its direction has been changed by reflection and scattering by the atmosphere. Because of the Solar Radiation is cattered in all directions in the atmosphere, diffuses radiation comes to the earth from all parts of the sky. The sum of the beam and diffuse radiation flux is referred to as total or global radiation.

2.4 Instruments for measuring solar radiation and sun shine

Solar Radiation flux is usually measured with the help of a pyranometer or a Pyrheliometer, sunshine recorder is used for measuring sunshine.

2.4.1. Pyranometer

A pyranometer is an instrument which measures either global or diffuse Radiation over a hemispherical field of view. A sketch of the Instrument as

Installed for the measurement of global radiation is shown in fig.2.1. Basically the pyranometer consists of a 'black' surface which heats up when exposed to solar radiation. Its temperature increases until its rate of heat gain by solar radiation equals its rate of heat loss by convection, conduction and radiation. The hot Junctions of a thermopile are attached to the black surface. While the cold Junctions are located in such a way that they do not receive the radiation. As a result, an e.m.f. is generated. This emf which is usually in the range of 0 to 10MV can be read, recorded or Integrated over a period of time and is a measure of the global radiation.

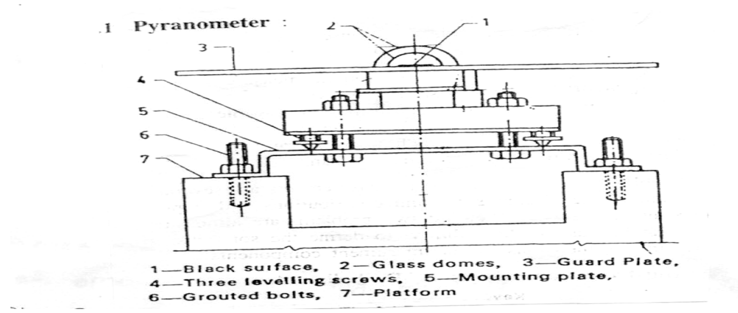


Fig 2.2. Pyranometer

The pyranometer shown in fig 2.2 is used commonly in India it has its hot Junctions arranged in the form of a circular disc of diameter 25MM and is coated with a special black lacquer having a very high absorptivity in the solar wave length region. Two concentric hemispheres, 30 and 50MM in diameter respectively made of optical glass having excellent transmission characteristics are used to protect the disc surface from the weather. An accuracy of about ±2 percent can be obtained with the Instrument.

2.4.2 Sun Shine Recorder

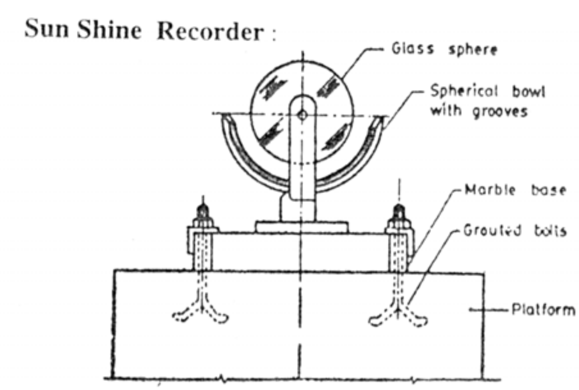


Fig 2.3 Sun Shine Recorder

The duration of bright sun shine in a day is measured by means of a sunshine recorder shown in fig2.3 the sun's Rays are focussed by a glass sphere to a point on a card strip held in a groove in a spherical bowl mounted concentrically with the sphere. Whenever there is bright sunshine, the image formed is intense enough to burn a spot on the cord strip. Though the day as the sun moves across the sky, the image moves alone the strip. Thus, a burnt trace whose length is proportional to the duration of sunshine is obtained on the strip. A photograph of the instrument is shown in plate 3 (bottom).

2.5 Solar Energy Utilization – Basic ideas about the pre-historic way of using solar energy

Energy is a common Man's daily commodity: The world energy consumption in 1975 was 8002 million tons of coal equivalent and is expected to shoot up to 27,400 million tons of coal equivalent in the year 2000. It is becoming scarce day by day even then its demand is on the increase. The increased population has led to depletion of energy. The process of mankind has influenced the subsequent exploitation of new sources of energy from time to time. The utilization of coal, the development of hydro electricity, the discovery of oil and gas and the advents of nuclear energy are significantly mile stones in human history. Each new source brought about a preformed change in the life style of the people. Each new source supplemented the other.

The size of the balance of fossil fuels will be over within a hundred years. Hence it is essential to tap the other sources of energy to supplement the existing energy demands of all non-conventional energy source, solar energy holds the greatest promise as it is abundant, renewable and pollution free. Its collection, storage on conversion is also easy. Hence worldwide attention is now focused on various methods of utilization of solar energy.

All life on the earth depends on solar energy. Green plants make food by means of photosynthesis. Light is essential from in this process to take place. This light usually comes from sun. Animals get their food from plants are store houses of solar energy.

The solar energy that falls on India in one minute, is enough to supply the energy needs of our country for one day. Man has made very little use of this enormous amount of solar energy. That reaches the earth he has used solar energy indirectly, for many thousands of years. Wind mills which are driven by wind that results from infrared solar energy.

2.6 Solar Energy applications

1. Heating and cooling of residential building.
2. Solar water heating.
3. Solar drying of agricultural and animal products.
4. Salt production by evaporation of seawater.
5. Solar cookers.
6. Solar engines for water pumping.
7. Solar Refrigeration.
8. Solar electric power generation.
9. Solar photo voltaic cells, which can be used for electricity.
10. Solar furnaces.

2.6.1 Solar Collectors

A solar collector is a device for collecting solar radiation and transfer the energy to fluid passing in contact with it. Utilization of solar energy requires solar collectors. These are generally of two types.

(i) Non- concentrating (or) flat plate solar collector.

(ii) Concentrating (focusing) type solar collector.

The solar energy collector, with its associated absorber, is the essential component of any system for the conversion of solar radiation in to more usable form (e.g heat or electricity). In the non-concentrating type, the collector area is the same as the absorber area. On the other hand, in concentrating collectors, the area intercepting the solar radiation is greater. By means or concentrating collectors, much higher temperatures can be obtained than with the non-concentrating type. Concentrating collectors may be used to generate medium pressure steam. They use many different arrangements of mirrors and lenses to concentrate the sun's rays on the boiler. This type shows better efficiency than the flat plate type. For best efficiency, collectors should be mounted to face the sun as it moves through the sky.

(i) Flat plate collectors (non-concentrating)

Where temperatures below about 90^{o}C are adequate as they are for space and service water heating flat plate collectors, which are of the non-concentrating type, are particularly convenient. They are made in rectangular panels from about 1.7 to 2.9 sq.m, in area, and are relatively simple to construct and erect. Flat plates can collect and absorb both direct and diffuse solar radiation, they are consequently partially effective even on cloudy days when there is no direct radiation.

Flat plate solar collectors may be divided into two main classifications based on the type of heat transfer fluid used.

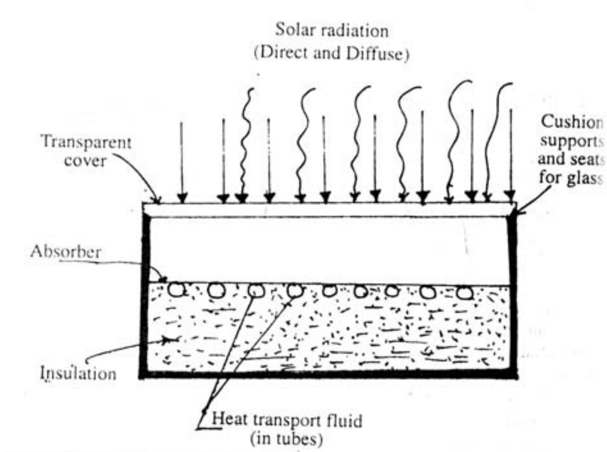


Fig. 2.4. Liquid heating flat plate collector

A. Liquid heating Flat Plate Collector

Liquid heating flat plate collectors are used for heating water and non-freezing aqueous solutions.

There are many flat-plate collector designs, but most are based on the principle shown in fig 2.4. It is the plate and tube type collector. It basically consists of a flat surface with high absorptivity for solar radiation called the absorbing surface. Typically a metal plate, usually of copper, steel or aluminum material with tubing of copper in thermal contact with the plates are the most commonly used materials. The absorber plate is usually made from a metal sheet 1 to 2 mm in thickness, while the tubes, which are also of metal, range in diameter from 1 to 1.5cm. They are soldesed, brazed or clamped to the bottom of the absorber plate with the pitch ranging from 5 to 15 Cm, In some designs, the tubes are also in line and integral with the absorber plate.

The primary function of the absorber is to absorb maximum radiation reaching it through the glazing, to lose maximum heat upward to the atmosphere and down ward through the back of the container and to transfer the retained heat to the working fluid. Black painted absorbers are preferred because they are considerably cheaper and good absorbers of radiation.

Heat is transferred from the absorber plate to a point of use by circulation of fluid (usually water) across the solar heated surface. Thermal insulation of 5 to 10cm. Thickness is usually placed behind the absorber plate to prevent the heat losses from the rear surface. Insulation materials is generally mineral wool or glass wool or fiber glass.

The front covers are generally glass that is transparent to incoming solar radiation and opaque to the infra-red re-radiation from the absorber. The glass covers act as a convection shield to reduce the losses from the absorber plate beneath. The glass thickness of 3 and 4 mm are commonly used. The usual practice is to have 2 covers with specific ranging from 1.5 to 3cm.

Advantages of second glass which is added above the first one are

(i) Losses due to air convection are further reduced. This is important in windy areas.

(ii) Radiation losses in the infra-red spectrum are reduced by a further 25%, because half of the 50% which is emitted out wards from the first glass plate is back radiated.

(ii) Concentrating (focusing) type solar collector

Focusing collector or concentrating type solar collector is a device to collect solar energy with high intensity of solar radiation on the energy absorbing surface. Such collectors generally use optical system in the form of reflectors or refractors. A focusing collector is a special form of flat-plate collector modified by introducing a reflecting or refracting surface between the Solar Radiation and the absorber. In these collectors radiation falling on a relatively large area is focused on to a receiver or absorber of considerably smaller area. As a result of the energy concentration, fluids can be heated to temperatures of 500^0C or more.

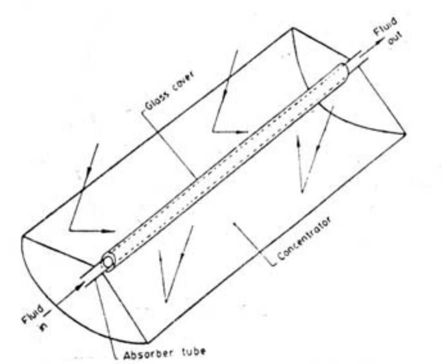


Fig. 2.5 Parabolic concentrating collector

A Schematic diagram of a typical concentrating collector is shown in fig 2.5 the collector consists of a concentrator and a receiver. The concentrator shown is a mirror reflector having the shape of a cylindrical parabola. It focuses the sunlight on to its axis where it is absorbed on the surface of the absorber tube and transferred to the fluid flow through it. A concentric glass cover around the absorber tube helps in reducing the convective and radiative losses to the surroundings. In order that the sun's rays should always be focussed on to the absorber tube, the concentrator has to be rotated. This movement is called tracking in the case of cylindrical parabolic concentrators, rotation about a single axis is generally required. Fluid temperatures up to around 300^oC can be achieved in cylindrical parabolic focussing collector system.

The generation of still higher working temperatures is possible by using parabolic reflectors as shown in fig 2.6 which have a point focus.

A paraboloidal dish collector brings solar radiation to a focus at a point actually a small central volume. A dish 6.6m diameter has been made from about 200 curved mirror segments forming a paraboloidal surface. The absorber, located at the focus, is a cavity made of zirconium-copper alloy with a black chrome selective coating. The heat-transport fluid flows into and out of the absorber cavity through pipes bonded to the interior. The dish can be turned automatically about two axes so that the sun is always kept in a line with the focus and the base of the paraboloidal dish. Thus, the can be fully tracked at essentially all times.

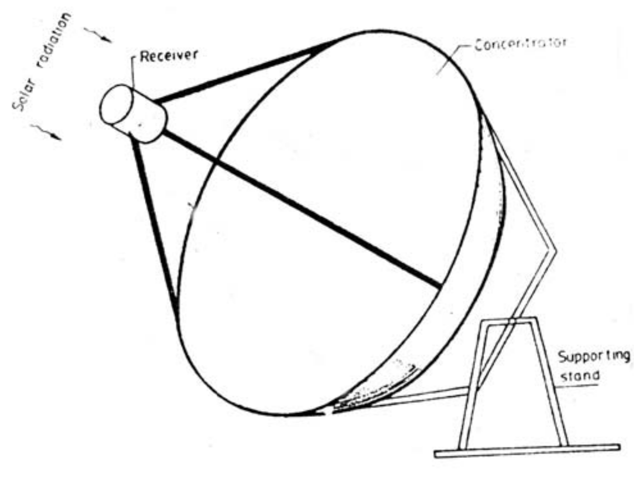


Fig 2.6 Dish Collector (Point Focus)

2.6.3. Solar Cooker

In our country energy consumed for cooking shares a major portion of the total energy consumed in a year. In villages 95% of the consumption goes only to cooking. Verity of fuel like coal, kerosene, cooking gas, firewood, dung cakes and agricultural waste are used the energy crisis is affecting everyone. It is affecting the fuel bills for those who use it for heating the houses and cooking their food. The poor of the developing countries who have been using dry wood, picked up from the fields and forests as domestic fuel, have been affected in their own way, due to scarcity of domestic fuel in the rural areas. At present, fire wood and cow dung too precious to allowed to be used for burning and cooking. It is very useful to improve the fertility of the soil, it should be used in proper way. The supply of wood is also fast depleting because of the indiscriminate felling of trees in the rural areas and the denudation of forests. There is a rapid deterioration in the supply of these fossil fuels like coal, kerosene or cooking gas. The solution for the above problem is the hardnesing of solar energy for cooking purpose.

The most important is that the solar cooker is a great fuel saver. The department of new conventional energy source has calculated that a family using a solar cooker 275 days a year would save 800kgs of fire wood or 65 liters of kerosene. Similarly an industrial Canteen or a Hostel mess using the larger community solar cooker which can cook for 20 to 25 people could save 400kgs of fire wood or 335 liters of kerosene per year.

Types of Solar Cooker

Basically there are three designs of solar cooker;

(i) Flat plate box type solar cooker with or with out Reflector.

(ii) Multi Reflector type solar cooker.

(iii) Parabolic disc concentrator type solar cooker.

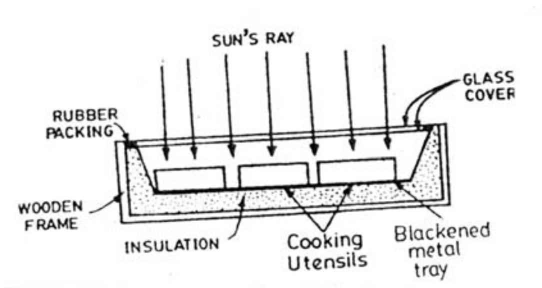


Fig 2.7 Flat Plate box type solar cooker

Flat plate box type design is the simplest of all the designs. This cooker allows. Solar radiation to enter through a double walled glass cover placed inside a blackened box which is well insulated and made airtight. Maximum no load temperature with a single reflector reaches up to 160^{o}C.

In Multi Reflector type, four square or triangular or rectangular reflectors are mounted on the oven body. They all reflect the solar radiation into the cooking zone in which cooking utensils are placed. Temperature obtained is of the order of 200^{o}C. The maximum temperature can reach to 250^{o}C if the compound cone reflector system is used.

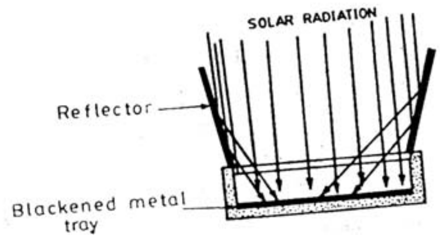


Fig 2.8 (a)

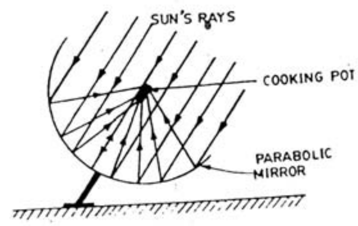


Fig 2.8 (b)

In parabolic type cooker, parallel sun's rays are made to reflect on a parabolic surface and concentrated on a focus on which the Utensils for cooking are placed. The temperature of the order of 450^{o}C can be obtained in which solar radiation are concentrated on to a focal point. Principle of operations of solar cookers is shown in fig 2.8 (b).

Design principle and constructional details of a box type Solar Cooker

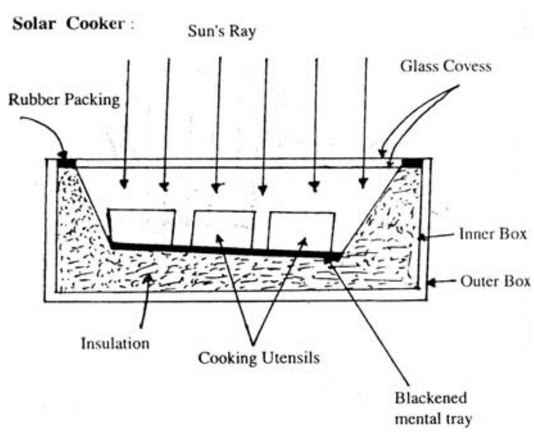
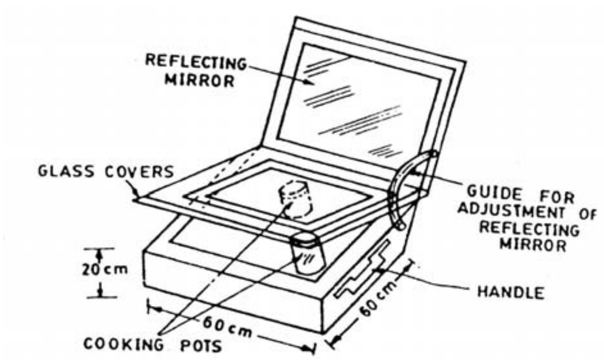


Fig 2.9 Box Type Solar Cooker

The principal of operation of box type solar cooker is illustrated in fig2.9. The solar rays penetrate through the glass covers and absorbed by a blackened metal tray kept inside the solar box. The solar radiation entering the box are of short wave length. Two glass covers are provided to minimize the heat loss. The loss due to convection is minimized by making the box air tight by providing a rubber strip all around between the upper lid and the box. Insulating materials like glass wool, saw dust or any other material is filled in the space between blackened tray and outer cover of the box. This minimize heat loss due to conduction with type of cooker is placed in the sun the blackened surface starts absorbing sun rays and temperature inside the box starts rising. The cooking pots, which are also blackened are placed inside with food material get heat energy and food will be cooked in a certain period of time depending upon the intensity of solar radiation and material of insulation provided. The amount of solar radiation intensity can be increased by provided mirror or mirrors. The solar cooker is made up of inner and outer metal or wooden box with double glass sheet on it. Absorber tray or blackened tray is painted black with suitable black point like black board point. This point is dull in colour and can with stand the maximum temperature attained inside the cooker as well as water vapour coming out of the cooking utensils. The top cover contains 3mm thick two plain glasses fixed on wooden or metal frame, keeping about 25mm distance between the two. The entire top cover can be made tight with padlock hasp. Neoprene rubber sealing is provided around the contact surfaces of the glass cover and hinged on one side of the glass frame. A mechanism (guide for adjusting mirror) is provided to adjust the reflector at different angles with the cooker box when the reflector is adjusted to shine in the cooker box, 115^{o}C to 125^{o}C. Temperature is achieved inside the cooker box. Addition of the reflector is useful in cooking earlier particularly in winter. The solar cooker is able to cook about 1.25kg dry food materials, which is enough for a family of 5 to 7 persons. The total weight of the cooker is about 22kgs. Overall dimensions of a typical model are 60x60x20cm height.



Merits and limitations of a Solar Cooker

Following are the some merits of a solar cooker;

(1) No attention is needed during cooking as in other devices.

(2) No fuel is required.

(3) Negligible maintenance cost.

(4) No pollution.

(5) Vitamins of the food are not destroyed and food cooked is nutrition and delicious with natural taste.

(6) No problem of over flowing of food.

Limitations of a Solar Cooker are

(i) One has to cook according to the sunshine, the menu has to preplanned.

(ii) One cannot cook at short notice and food can not be cooked night or during cloudy days.

(iii) It takes comparatively more time.

(iv) Chapaties are not cooked because high temperature for baking is required.

2.6.4 Solar Water heater

It is a device to heat water using solar energy. Solar water heaters are one of the best options to be adapted in the developing country. Solar water heating systems are commercially produced in the country. Most of the systems available in India are designed to give water temperature from 60 to 90^{o}C. These are suitable for pre heating feed water to boiler and processing industries and hot water application in Hotels, Bakeries, Industries etc.

The term solar water heater includes conventional flat plate collector with either thermosiphon or forced circulation flow system. A solar water heater normally consists of the following components:

(a) A flat plate collector to absorb solar radiation and convert it into thermal energy.

(b) Storage tank to hold water for use and cold water feeding the flat plate collector.

(c) Connecting pipes inlet and out let, for feeding cold water from the storage tank and taking hot water to the storage tank or point of use.

A diagram of a simple, small capacity, natural circulation system suitable for domestic purpose is shown in fig 2.11. The two main components of the storage tank, the tank being located above the level of the collector. As water in the collector is heated by solar energy, it flows automatically to the top of the water tank and its place is taken by colder water from top of the tank. Whenever this is done, cold water automatically enters at the bottom. An auxiliary heating system is provided for use on cloudy or rainy days.

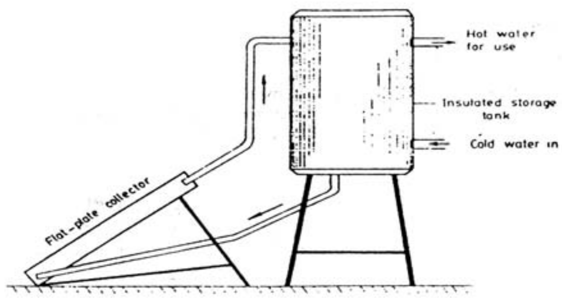


Fig 2.11 Solar Water Heater

Typically, such system have capacities ranging from 100 to 200 liters and adequately supply the needs of a family of four or five persons. The temperature of the hot water delivered ranges from 50 to 70^{o}C. Solar water heating is a good example to illustrate one of the assets of the direct use of solar. This is the possibility of matching the temperature achieved in the heating device with the temperature required for end use. As a result of this matching, the thermodynamic efficiency based on considerations of availability of energy can be shown to be higher in the case of solar water heating system than a water heating system using natural gas or electricity.

Solar water heaters of the natural circulation type were used fairly widely from the beginning of the twentieth century till about 1940 until cheap oil and natural gas became available. Now they are a being installed again. They are in wide spread use in countries like Israel, Australia and Japan.

2.6.5. Solar distillation

Fresh water is a necessity for the sustenance of life and also the key to Man's prosperity. It is generally observed that arid, semi arid and coatal areas which are thinly populated and scattered, one or two family members are always busy in bringing fresh water from a long distance. In these areas solar energy is plentiful and can be used for converting saline water into distilled water. The pure can be obtained by distillation in the simplest solar still, generally known as the “basin type solar still”.

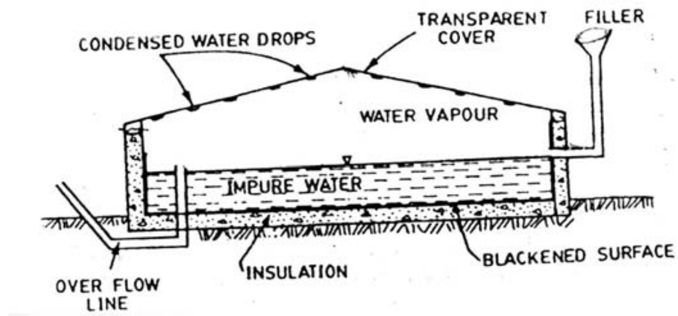


Fig 2.12 Solar Distilluation

Solar water still is shown schematically in fig 3.1, it consists of a blackened basin containing saline water at a shallow depth, over which is a transparent air tight cover that encloses completely the space above the basin. It has a roof-like shape. The cover which is usually glass may be of plastic, is sloped towards a collection through solar radiation passes through the cover and is absorbed and converted into heat in the black surface. Improve water in the basin or tray is heated and the vapor produced is condensed to purified water on the cooler interior of the roof. The transparent roof material transmits nearly all radiation falling on it and absorbs very little; hence it remain cool enough to condense the water vapor. The condensed water flows down the sloping roof and is collected in through at the bottom. Saline water can be replaced in the operation by either continuous operations or by batches.

2.6.6 Solar Pumping

Solar pumping consists in utilizing the power generated by solar energy for water pumping useful for irrigation.

Solar energy offers several features that make its utilization for irrigation pumping quite attractive, first, the greatest need for pumping occurs during the summer months when solar radiation is greatest second, pumping can be intermittent to an extent, during periods of low solar radiation when pumping decreases, evaporation losses from crops are also low. Finally relatively in expensive pumped storage can be provided in the forms of bonds.

A number of recently constructed solar irrigation pump installations are now operational. The major obstacle to increase use of solar irrigation system at this time is their Relatively high capital cost. If the costs of solar pumps can be substantially reduced and assuming that conventional fuel costs continue to rise, solar; irrigation could become economical, and increased use of such system might be anticipated in future.

The basic system consists of the following components:

(1) The solar collector.

(2) The heat transport system.

(3) Boiler or Heat exchanges.

(4) Heat engine.

(5) Condenser.

(6) Pump

The solar pump is not much different from a solar heat engine working in a low temperature cycle. The sources of heat is the solar collector, and sink is the water to be pumped. A typical solar powered water pumping system is shown in fig2.3.

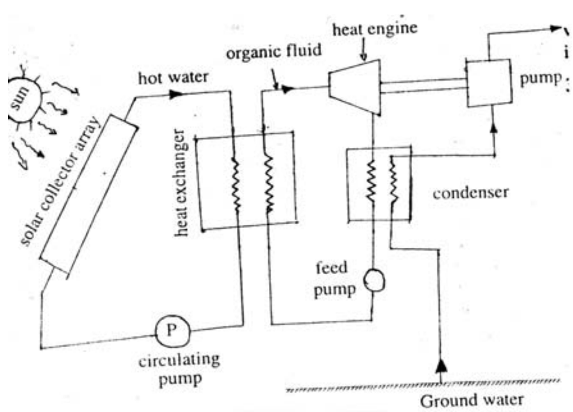


Fig 2.13 Solar Water Pumping

The primary components of the system are an array of flat-plate collectors and an Rankine engine with an organic fluid as the working substance. During operation a heat transfer fluid (Pressurized water) flows through the collector arrays. Depending upon the collector configuration, solar flux and the operating conditions of the engine, the fluid will be heated in the collector to a higher temperature, the solar energy which is thus converted to the thermal energy. The fluid (water) flows into a heat exchanger (boiler), due to temperature, gradient, and comes back to the collector. This water yields its heat to an intermediate fluid in the boiler. This fluid evaporates and expands in the engine before reaching the condenser, where is condenses at low pressure. The condenser is called by the water to be pumped. The fluid is then reinjected in the boiler to close the cycle. The expansion engine or Rankine engine is coupled to the pump and it could of course be coupled to an electric generation.

2.6.7 Electricity from Solar Energy

Electricity energy is the most convenient form of energy. It is easy to use, transport, control and transform into other forms of energy.

Modern society has an insatisfiable hunger for energy. This need for energy will continue to increase as the newly developing countries become more industrialized and the mature nations increase their scope of Mechanization. To satisfy this need, vast quantities of coal and petroleum products are required. More recently, the advent of nuclear energy has added vast quantities for future needs.

Although sun is the ultimate source of all the power which man has at his disposal, the conversion of solar radiation directly into electrical power by some cheap and efficient means has been sought for several decades. Many different methods have been tried for this purpose, but none of these could complete with conventional fossil fuel or hydro electric power plants.

2.6.8 Solar Photo Voltaics

The direct conversion of solar energy in to electrical energy by means of the photo voltaic effect, that is the conversion of light (or other electromagnetic radiation) in to electricity. The photo voltaic effect is defined as the generation of the electromotive force as a result of the absorption of ionizing radiation energy conversion devices which are used to convert sun light to electricity by the use of the photo voltaic effects are called solar cells. A single converter cell is called a solar cell or more generally, a photo voltaic cell, and combination of such cells, designed to increase the electric power out put is called a solar module or solar array.

Photo voltaic cells are made of semi conductors that generate electricity when they absorb light. As photons are received, free electrical changes are generated that can be collected on contacts applied to the surface of the semi conductors. Because solar cells are not heat engines, and therefore do not need to operate at high temperatures, they are adopted to the weak energy flux of solar radiation, operating at tome temperature. These devices have theoretical efficiencies of the order of 25 percent. Actual operating efficiencies are less than this value, and decrease fairly rapidly with increasing temperature.

The best known applications of photo voltaic cells for electrical power generation has been is spacecraft, for which the Silicon cell is the most highly developed type. The Silicon cell consists of a single crystal of silicon into which a doping material is diffused to from a semi conductor. Since the early day of solar cell development, many improvement have been manufactured with areas 2x2Cm, efficiencies approaching 10 percent, and operating at 28^{o}C. The efficiency is the power developed per unit area of array divided by the solar energy flux in the free space (1.353 KW/m^2).

For terrestrial applications, silicon solar cells have shown operating efficiencies of about 12 to 15 percent. Though Silicon is one of the earth's most abundant materials, it is expensive to extract (from sand, where it occurs mostly in the from SiO_2) and refine to the purity required for solar cells. The greater barrier to solar cell application lies in the costs of the cells themselves. Reducing the cost of Silicon Cells is difficult because of the cost of making single crystal. One very promising method is being developed to produce continuous thin ribbons of single-crystal Silicon to reduce fabrication costs.

Cells made from the ribbon have so for shown efficiencies of around 8 percent. Several other kinds of photo cells are in the laboratory stage of development. Cadmium Sulfide cells are other possibilities. So far, efficiencies have been in the range of 3 to 8 percent and these cells have been less durable than Silicon cells owing to degradation with exposure to Oxygen, water vapor and sunlight, especially at elevated temperatures. The active part of the Cadmium Sulfide cds cell is a thin polycrystalline layer of cds, about 10μm. Thick on which a layer of Cu_2S compound perhaps 0.1μm thick is grown. These cells can be made by deposition on long sheets of substrates, a process that might be adaptable to expensive mass production.

Photo voltaic cells could be applicable to either small or large power plants, since they function well on a small scale, and may be adaptable to local energy generation on building roof tops. The cost of the energy storage and power conditioning equipment might, however, make generation in large stations the most economical method; solar cells have also been used to operate irrigation pumps, navigational signals high way emergency call system, rail road crossing warnings, automatic meteorological stations, etc; in location where access to utility power lines is difficult.

2.6.9 Applications of Solar Photo-Voltaic System in Rural Areas

A variety of PV system configurations have been developed and deployed for rural applications such as drinking water supply, street lighting irrigation water pumping and for operation of electronic equipment's. Government of India is sponsoring, a program for Popularizing solar lighting, solar water pumping etc; by providing capital subsidies and concessional interest on borrowed capital.

Solar lighting

Electricity for lighting during night is one of the most convenient and preferred form of energy. However in our Country out of 6 Lacks villages, 1 lakh villages are still to be electrified. Even in electrified villages, only a quarter of house-holds have proper connection. Owing to power shortage in many stages, electricity supply situation in villages is precarious and mostly it is not available even in electrified villages for lighting when it is most needed.

The bulk of rural house-holds in India, normally use kerosene lanterns lanterns for meeting their lighting requirements. It is estimated that around 100 million kerosene lanterns are used in India. These lanterns provided insufficient and poor quality of light.

For village lighting, three major system Configuration are available;
(1) Domestic lighting system or solar lantern.
(2) Pole mounted stand alone street lighting system.
(3) Non-grid interactive centralized lighting system.

(i) Solar lantern

Solar photo-voltaic powered lights called lanterns fig 2.14(a) are considered to be alternative solution to village lighting needs. A typical solar lantern consists of small photo-voltaic module, alighting device, a high frequency investor, battery charge controller and appropriate housing. During day time, module is placed under the sunand is connected to lantern through cable for charging a typical lantern uses a 10 watt lamp. The expected life of the lamp is 3 to 5 years.

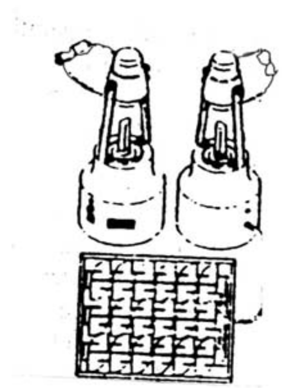


Fig 2.14(a)

Storage battery is one crucial component in lantern, Recombinant maintenance free absorbed electrotype batteries are being used. The battery has a life of 3 to 5 years. Sealed nickel Cadmium battery is a good option considering their deep discharge characteristics.

It is important to have reliable electronics to operate the lamp and provide suitable protection. A high freequency investor is being used to excite compact fluorescent lamp and a charge controller which protect battery from over charing.

(ii) Street lighting system

It is consists of two photo-voltaic modules, mounting frame, 4m long pole, battery box, tubular type lead-acid battery, charge controller, investor and day light senses fig 2.14(b) Time module sensing is used to switch on lights on the evening. It works for one fluorescent tube lights of 20 watts for whole night.

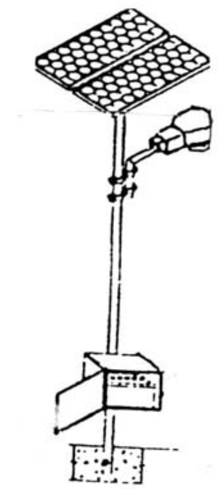


Fig. 2.14(b)

QUESTIONS

Short Answer type questions

(1) Define solar constant?

(2) Define solar energy?

(3) What is diffuse radiation?

(4) What is global radiation?

(5) What are the instruments used for measuring solar radiation and sun-shine?

(6) What are the applications of solar energy?

(7) What are the different types of solar cooker?

(8) Explain the maintenance of a solar cooker?

(9) What are the components of solar water heater?

(10) What are the basic components of solar water pumping?

(11) Define photo voltaic effect?

(12) What are the different applications of solar photo voltaic system in Rural area?

Essay type questions

(1) Explain Pyrometer with the help of neat sketch?

(2) Explain basic ideas about the Pre-historic ways of using solar energy?

(3) Explain any one of the solar collectors with the aid of neat sketch?

(4) What is the importance of solar cooker?

(5) Explain the design principle of constructional details of a box type solar cooker?

(6) Explain briefly about solar water pumping with the help of a heat sketch?

(7) Describe briefly about photo voltaic system?

(8) Explain briefly about the applications of solar photo voltaic system in Rural Areas?

(9) Explain briefly about solar water heates with the help of a neat sketch?

CHAPTER – 3
WIND ENERGY

Wind energy

Winds are caused because of two factors.

(1) The absorption of solar energy on the earth's surface and in the atmosphere.

(2) The rotation of the earth about its axis and its motion around the sun.

Because of these factors, alternate heating and cooling cycles occur, differences in pressure are obtained, and the air is caused to move. The potential of Wind energy as a source of power is large. This can be judged from the fact that energy available in the wind over the earth's surface is estimated to be $1.6x10^7$ K.W Besides the energy available is free and clean.

The problems associated with Utilizing wind energy are that:

(i) The energy is available in dilute form, because of this conversion machines have to be necessarily large.

(ii) The availability of the energy varies considerably over a day and with the seasons.

For this reason some Means of storage have to be devised if a continuous supply of power is required.

A wind mill converts the kinetic energy of moving air into mechanical energy that can be either used directly to run the machine or to run the generator to Produce electricity.

Classification of wind mills

Wind mills

- (a) Horizontal Windmills
  - Single Bladed
  - Double bladed
  - Multi bladed
- (b) Vertical Windmills
  - Darrieus rotor
  - Savonius rotor.

(a) Horizontal Wind mills

i. Horizontal Axis single blade Wind mills

If extremely long blades are mounted on rigid hub. Large blade root bending moments can occur due to tower shadow, gravity and sudden shifts in wind directions on a 200ft long blade. Fatigue load may be enough to cause blade root failure.

To reduce rotor cost, use of single long blade centrifugally balanced by a low cost counter Weight as shown in fig3.1. The relatively simple rotor hub consists of a Universal Joint between the rotor shaft and blade allowing for blade. This type of hub design contains fewer parts and costs less.

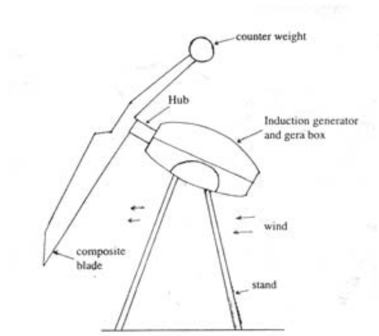


Fig 3.1 Single blade wind mill

(ii) Horizontal axis – two bladed wind mills

In this arrangement rotor drives generator through a step-up gear box. The components are mounted on a bed plate which is mounted on a pinttle at the Top of the tower. The two blade rotor is Usually designed to be oriented down wind of the tower. The arrangement of all the Components used in horizontal axis wind mill is shown in fig3.2.

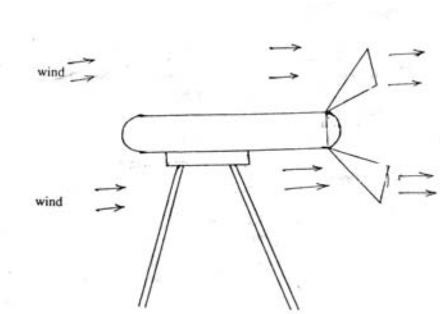


Fig 3.2 Double blade wind mill

When the machine is operating its rotor blades are continuously flexed by Unsteady aerodynamic, gravitational and inertial loads. If the blades are metal, flexing reduces their fatigue life. The tower is also subjected to unsteady load and dynamic interactions between the components of the machine-tower system can cause serious damage.

(iii) Horizontal Axis – Multi bladed Wind Mills

This type of wheel have narrow rims and Wire spokes. The wire spokes support light weight aluminum blades. The rotors of this design have high strength to weight ratios and have been known to survive hours of free wheeling operation in 100kmph winds. They have good power Co-efficient, high starting torque ad added advantage of simplicity and low cost.

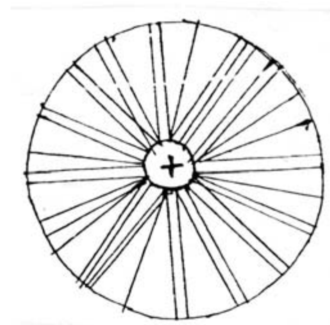


Fig. 3.4 Multi bladed wind mill

(b) Vertical Wind Mills

Wind turbines mounted with the axis of rotation in a vertical Position have advantage that they are omni-directional that is, they need not to be turned to Force the wind. The Vertical mounted Wind Machines eliminates the need for some of the complex mechanical devices and control systems necessary for horizontal mounted wind Machines.

Two types of vertical axis Wind Machines have received attention. The Darrievs rotor consists of two or three convex metal blades with an air foil cross section, mounted on a Central shaft which is supported by bearings at the top and bottom. The rotor assembly is held in position by guy wires running from the top of the rotor to the ground.

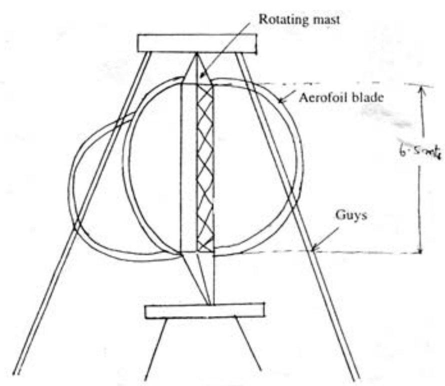


Fig 3.5 Vertical wind mill (Darrieus rotar)

The savonius rotor consists of a long solid's- shaped surface mounted to turn at the center of 's' the savonius rotor is self starting and has an efficiency of about 31% while the Darrievs rotor has a slightly higher efficiency of 35% but is not self starting.

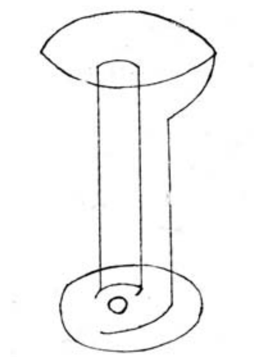


Fig 3.6 (a) Savonius rotor

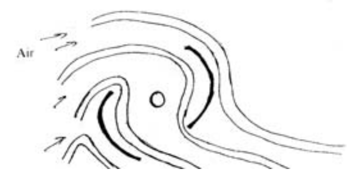


Fig 3.6 (b) Air flow through a savonius rotor

Advantages of Wind energy

(1) The wind energy is free, inexhaustible and does not need transportation.

(2) Wind mills will be highly desirable and economical to the rural areas which are far from existing grids.

(3) Wind power can be used in combination with hydroelectric plants. Such that the water level in the reservoir can be maintained for longer periods.

Disadvantage of Wind energy

(1) Wind power is not consistent and steady, which makes the complications in designing the whole plant.

(2) The wind is a very hazard one. Special and costly designs and controls are always required.

(3) The cost factor, which has restricted the development of wind power in large scale for feeding to the existing grid .

(4) It has low power coefficient.

(5) Careful survey is necessary for plant location.

Wind Energy

Questions

(a) Short Answer Questions

(1) How the Wind mills are classified?

(2) What are the advantages of Wind Power?

(3) What are the disadvantages of Wind Power?

(b) Essay type Questions

(1) Explain briefly about the horizontal Wind mills with neat sketches?

(2) Explain briefly about Vertical Wind mills with neat sketches?

CHAPTER – 4
BIO ENERGY

4.1 Introduction

Bio gas is generated through a process of anerobic digestion of Bio Mass. Bio Mass is organic matter produced by plants, both terrestrial (those grown on land) and aquatic (those grown in water) and their derivatives. It includes forest crops and residues, crops grown especially for their energy content on "energy farms" and animal manure. Unlike coal, oil and natural gas, which takes Millions of years to form, bio mass can be considered as a renewable energy source because plant life renews and adds to it self energy year. It can also be considered a from of solar energy as the latter is used indirectly to grow these plants by photosynthesis.

Bio Mass means organic matter and Photo Chemical approach to harness solar energy means harnessing of solar energy by photo synthesis. Solar energy is stored in the from of chemical energy. Hence solar energy –> Photosynthesis –> Bio Mass->energy generation.

Out of several sources of renewable energy like solar, wind, tidal, wave energy, Geothermal energy, nuclear energy, energy through bio mass are important features in our Country. Biogas Production Technology contributes in following ways.

Advantages of Bio Gas technology

(1) It provides a better and cheaper fuel cooking, lighting and for power generation.

(2) It produces good quality, enriched manure to improve soil fertility.

(3) It proves an effective and convenient way for sanitary disposal of human excreta, improving the hygienic conditions.

(4) It generates social benefits such as reducing burden on forest for meeting cooking fuel by cutting of tree for fuel wood, reduction in the drudgery of women and children etc.

(5) As a smokeless domestic fuel, it reduces the incidence of eye and lung diseases.

(6) It also helps in generation of productive employment

Bio Gas and its Compositions

Bio gas contains 55-70% methane and 30-45% carbon dioxide as well as small quantities of(N_2, H_2, H_2S) some gases. It is lighter than the air and has an ignition temperature of approximately 700^oC. The temperature of the flame is 870^oC. its calorific value is approximately 4713kcal/m^3. The methane content of bio gas produced from different feed stock is given in Table .1.

Content of Methane in Bio-gas produced from different feed stocks

S.No.	Feed Stock	Content of Methane in Bio gas in Percentage
1.	Cattle Manure	54-56
2.	Pig Manure	57
3.	Poultry Manure	55
4.	Farm yard Manure	55
5.	Straw	55
6.	Grass	60
7.	Leaves	58
8.	Kitchen Waste	50-52
9.	Human excreta	60

The bio gas system is most suitable technology to solve the energy problems in rural areas, as it Produces Manure, clean fuel and improves rural sanitation. It's thermal energy Per Unit volume is sufficient to meet domestic energy needs the comparison of bio gas with other fuels is given in table II.

Comparison of Bio-gas with other fuels

S.No.	Name of fuel and Unit	Calorific value (K Cal)	Mode of Burning
1.	Gobar (M^3)	4713	Standard burner
2.	Kerosene (lit)	9122	Pressure stove
3.	Fire wood (Kg)	4700	Open chulla
4.	Cow-dung cake (Kg)	2092	Open chulla
5.	Charcoal (Kg)	6930	Open chulla
6.	Soft cake (Kg)	6292	Open chulla

S.No.	Name of fuel and Unit	Calorific value (K Cal)	Mode of Burning
7.	Butane (LPG) Kg	10882	Standard burner
8.	Coal gas (M^3)	4004	Standard burner
9.	Electricity (Kwn)	860	Hot plate

4.2.2 History of Bio-gas

In the field of an aerobic digestion of waste Material India and China are recognized world leaders. This practice is based upon an age-old tradition of composting human, animal and plant wastes to produce and organic fertilizer. In fact bio gas programme has been recognized for making available a clean and efficient fuel for cooking, lighting, engine and the liquid slurry as a fertilizer and soil conditioner all over the World. Since the 1920's there have been sporadic attempts made to recover bio gas from sewage wastes and animal dung. A few bio gas plants for sewage disposal and bio gas recovery were installed in Europe and the U.S.A. in 1920's and 1930's respectively.

Although the Chinese have been experimenting with bio gas since the 1950's and China had its first bio gas Plant in 1936, yet it was reported only in the 70's in Sichvan. Mainly, there was a movement to extend the practice and reproduce the digester in a large way throughout the country side.

The history of bio gas from cattle dung in India goes back to 1939 when Indian Agricultural Research Institute (ARI) New Delhi, was able to ferment cattle dung to produce Methane.

Subsequently Proof N.V.Joshi; at Poona patented a model of bio gas plant in 1945. Later on Jashbhai, J.Patel evolved a simple model called "Gramalaxmi" and patented it in the year 1951. Mean while, J.J.Patel continued his efforts to simplify his eariler patented. Model, which resulted in the development of two chamber digester with central guide for free up and down movement of steel gas holder. This design was accepted by the Khadi and Villages Industries Commission (KVIC) Bombay, in India during 1962. Subsequently, many Scientists, Engineers, Government, Semi-Government and different social organisations contributed to the development of bio-gas technology.

The Planning Research and Action Division (PRAD) of State Planning Institute, Government of Uttar Pradesh, Lucknow developed a cheap and convenient model of bio gas in 1957, and called it Janata bio gas plant. After independence the Ministry of Agriculture, Government of India, was looking the bio-gas programme, related development and extension activities. K.V.I.C and state Government's continued the programme in 1970-1980. The national Project on Bio-gas development was launched in 1980-81 under Ministry of Agriculture. Currently Department of non-conventional energy source(DNES), the Ministry of Power and Non-Conventional energy is also actively involved in supporting research and diffusion of bio gas technology and many institutions and State Agricultural Universities are supporting research programme on bio gas technology.

4.2 Process of Bio gas, generation – Wet Process, dry Process

(i) Wet process

(a) Anaerobic digestion

Bio gas is produced by the bacterial decomposition of wet sewage sludge, animal dung or green plants in the absence of oxygen. Feed stocks like – wood shavings, straw, and refuse maybe used, but digestion takes much longer. The natural decay process 'anaerobic decomposition' can be speeded up by using a thermally insulated, air-tight tank with a stirrer Unit and heating system. The gas collect in the digester tank above the slurry and can be piped off continuously. At the optimum temperature (35^{o}C) complete decomposition of animal or human farces takes around 10 days. Gas yields depend critically on the nature of the waste-Pig manure, for example, is better than cow dung or house hold refuse. The residue left after digestion is valuable fertilizer. It is also rich in protein and could be dried and used as animal feed-supplement.

(b) Fermentation

As stated, ethanol or ethyl alcohol is produced by the Fermentation of sugar solution by natural yeast's. After 30 hours of fermentation the brew or 'beer' contains 6-10% alcohol and this can readily by removed by distillation. Traditionally, the fibrous residues from plant crops like sugar cane bagasse have been burnt to provide the heat. Suitable feed stocks include crushed sugar came and beet, fruit etc sugar can also be manufactured from vegetable starches and Cellulose, Maize, Wheat grain, or Potatoes. For they must be ground or pulped and then cooked with enzymes to release the starch and convert it to fermentable sugars. Cellulose materials like wood, paper waste or straw, require harsher pre-treatment typically milling and hydrolysis with hot acid. One tonne of sugar will produce up to 520 liters of Alcohol, a tonne of grain, 350 liters and a tonne of wood, an estimated 260 to 540 liters. After fermentation, the residue from grains and other feed syffs contains high protein content and is a useful cattle-feed supplement.

The hydrolysis and distillation step require a high energy input; for woody feed stocks direct combustion or pyrolysis is probably more productive at present, although stem treatment and new low-energy enzymatic hydrolysis techniques are under development. The energy requirement for distillation is also likely to be cut drastically. Alcohol can be separated from the beer by many methods which are now under intensive development. These include solvent extraction, reverse osmosis, molecular sieves and use of new desiccants for alcohol drying. It may soon be possible to have the energy required for alcohol production to produce a greater net energy gain.

(iii) Dry Process

Pyrolysis

A wide range of energy-rich fuels can be produced by roasting dry woody matter like straw and wood-chips. The material is fed into a reactor vessel or retort in a pulverized or shredded form and heated in the absence of air. As the temperature rises the cellulose and lignin break down to simpler substances which are driven off leaving a char residue behind. This process has been used for conturies to produce charcoal.

The end products of the reaction depend critically on the conditions employed, at lower temperatures around 500^{o}C, organic liquid predominate, whilst at temperatures nearer 1000^{o}C combustible mixture of gases results.

4.3 Raw Materials available for Bio gas Fermentation

(i) Manure: This kind of Material is available from animal waste and poultry waste. Their compositions vary with the feeding stuff. In chines rural areas, the fresh manure is used to be fermented with shorter retention time (about two months). The manure from human, cattle, chicken and pigs are subject to inhabitation when fermented without other Carbon source. Manures can be used as Bio mass.

(ii) Plants: Most of the Plants of the grass family can be used for fermentation. Both aqnolic and terrestrial plants can be used as Bio mass. As such they are difficult to be biodegraded. In order to ferment them more easily, pretreatment and a longer retention time are generally needed. Adequate amount of nitrogen rich elements urea etc; should be added for the fermentation.

(iii) Industrial Organic Waste Water: Industrial effluents from food processing, biochemical pharmacy, paper making etc; can be treated by anaerobic fermentation. Most organic matters of these liquid are soluble and their composition are more stable than that of agricultural wastes, while the water quantities may fluctuate. Some effluents may be nutrient deficient or even toxic. Thus pretreatment, such as the elimination of toxicity, adding nutritional additives and so on, or necessary for anaerobic digestion. In food processing Industries planty of organic waste will availble. By utilizing two organic waste we can produce Bio gas by anaerobic digestion.

(iv) Organic Matter in Municipal Wastes: They are in solid and inorganic contents need separation. Organic matter is availble in Muncipal wastes. By utilizing this organic matter. Bio-gas can be produced.

4.4 Selection of site for Installation of a Bio gas plant

Careful selection of the best site for installation of a bio gas unit should be done for every beneficiary. The following points should be taken into consideration.

(1) The distance between the plant and site of gas consumption or kitchen should be less to Minimize cost on gas pipe line and gas leakage. For a plant of capacity $2m^3$, the optimum distance is 10 Cm.

(2) It should be near the cattle-shed to minimize the distance for carrying cattle dung and transportation cost.

(3) There should be enough space for storage of digested slurry or construction of compost pit.

(4) It is should be 10 to 15 meters away from any drinking water well to prevent contamination of water.

(5) The area should be free from roots of trees which are likely to creep into the digester and cause damage.

(6) It should be open to receive the Sun's rays for most part of the day and to keep the plant in warm. The sunlight should fall on the plant as temperature between 15^oC to 30^oC is essential for gas generation at good rate.

(7) It should be on an elevated area so that the plant does not get submerged during normal rains.

(8) Sufficient space must be available for day to day Operation and Maintenance. As a guide line 10 to 12 M^2 area is needed per M^3 of the gas.

(9) Plenty of water must be available as the Cow dung slurry with a solid concentration of 7% to 9% is used.

4.5 Materials required for the Construction of bio gas plant

The Materials required for the construction of bio gas plant are listed in table1, however, the quantity of material will depended on type and size of the bio gas plant. The quality of the construction material should be ensured before use.

Construction material for bio gas plant

S.No.	Material	Quality needed
1.	Bricks	Good quality bricks preferably Machine made first class bricks with uniform size and shape.
2.	Cement	Pure port and land with no impurities packed in Polythene bags.
3.	Sand	Fine and Coarse with good quality.

S.No.	Material	Quality needed
4.	Steel for Bigger size plant.	Standard
5.	Concrete	Hard with out any impurities
6.	Reinforced concrete for larger tank	Having good quality composition of cement, sand and water
7.	Asbestos - Cement pipes for inlet and out let.	Good qualities with no leakage and should have uniform diameter and length as required.
8.	Ferro – Cement	Having few layers of iron wire Mesh plastered with diameter and length as required.
9.	Bricks Ferro – Cement.	Outer wall of brick, inner surface plastered with Ferro-Cement.
10.	Plastic	Fiber-glass reinforced plastics PVC polythene, etc.

4.6 Constructional Details of Biogas Plant

Floating gas holder type

The construction techniques used in Bio gas plant should be simple with low demand of Materials, low in Cost and it should be easily known to Mason. The standard requirement for bio gas plant Construction is specially trained skilled Mason to make it leak proof and air tight. Otherwise, the chances of failure of the plant would be more.

1. Layout

The first step is to Mark the lay out of the plant on selected and leveled site by marking the out – line of the plan on the ground according to required dimensions using accord stretched from the center.

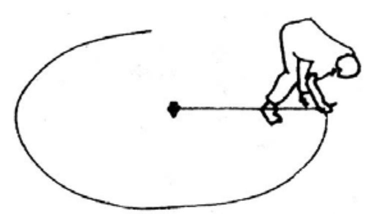


Fig 4.1 Marking the out line of the plant

2. Excavation

Excavate with care so that the sides do not collapse. The deeper the Pit, the more dangerous the excavation work becomes. Especially in sandy soil walls, the pit should be supported with a frame of bamboo poles. The excavated soil should be thrown at least half a meter away from the site so that it does not fall in when the construction work is in progress. The diameter of the Pit to be excavated, should be equal to the base diameter.

3. Floor

The bottom should be consolidated and levelled. If the bottom is muddy or soft and sandy, a layer of broken bricks or stones must be pounded in until the ground is firm. Bricks for the floor, including wall foundations are set on their edge. This method gives sufficient strength. Where the ground condition is very bad concert or reinforced concrete should be used.

4.Side Wall

A circular well should be constructed. It is essential to back fill between the wall and the sides after every 30Cm height has been added to the walls. Back filling should be done thoroughly with a piece of wood and water added to help compact the soil shown in fig4.2 failure to properly ram the back fill will cause cracking in the walls.

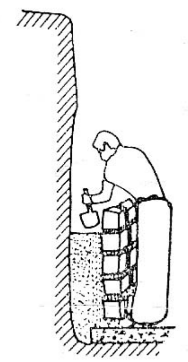


Fig 4.2 Back filling

5. Partition Wall

A Partition wall is constructed to divide the circular well into two equal halves in floating gas holder plants of $3M^3$. It controls the flow of slurry. A half brick wall is enough. It is built up to the level of the top surface of the central guide frame or ledge.

6. Inlet and Outlet Pipes

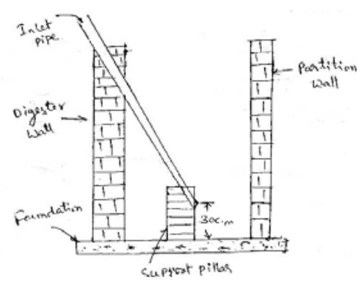


Fig 4.3 Inlet and outlet Pipes

These should be fixed slanting and inserted at an appropriate height in the walls. There should not be any bends in the pipe as these cause blockage. The lower end of the inlet is placed in about the center of the compartment. This position is not vital, but what is important bottom and dead patches of unmoving slurry are not above to form the mouth of the pipe is about 30-35Cm above the floor of the digester. This prevents any blockage of the inlet pipe and also provides some volume in case stones, sand etc; get inside the plant and collect over a period of time. The lower end of the out let pipe is constructed in a similar way. The only difference is that the mouth of the pipe is set about 25-30Cm above the floor as it is less likely that stones, sand etc; will come down this pipe.

The difference in the top level of the inlet and out let pipe should be at least 0.45M to allow digested slurry to come out automatically when fresh slurry is added.

7. Plastering

The digester should be plastered from inside with 1:3 Mortar of cement sand and cured properly.

8. Slurry Mixing Tank

In order to mix dung water throughly before feeding into the digester, a Masonry Tank is provided in the bio gas plant.

It may be provided with a Mechanical or hand operated stirrer for preparation of homogenous Mixture. The bottom of the tank is given a slope opposite to the direction of inlet chamber in order to prevent entry of sand or in-organic materials in to the digester.

9. Compost Pit

These can be dug in the ground or limed with Masonry. The volume should be sufficient to receive the amount of Slurry Put in per day Multiplied by the number of days required for emptying the pits.

10.Placing of the gas holder

The guide frame is greased generally and then the gas holder is mounted carefully without causing any tilting of the guide pipe and damage to the digester wall.

11. Testing and Operation

The digester Portion should also be tested for water leaks. When the plant is found leak proof, it is ready to fed with dung slurry and for the production of gas.

4.7 Utilization and benefits of Biogas Technology

(i) It provides simultaneous dual benefits in terms of fuel for cooking and lighting as well as fertilizer.

(ii) Bio gas burns efficiently without smoke or smell and eleminates the possibility of eye and lung diseases caused by smoke.

(iii) It reduces the drudgery of women and children in terms of providing relief from the collection of fire wood and preparation of dung cakes.

(iv) The gas can also be used in dual-fuel engines, where up to 80% of the diesel can be replaced with biogas.

(v) Besides gas, the digested slurry can be used as natural fertilizer which improves the soil fertility.

(vi) Utilization of waste materials in the plant not only improves the sanitary condition of your village but also prevents deforestation and assures e-ecollegial and environmental balance.

Bio gas is a cheep and clean fuel. It burns with a blue flame. Which is smoke-free. When it is burnt in silk mantle lamps, it illuminates better than kerosene in petromax lanterns. Bio gas can replace Petrol and diesel in engines.

4.8 Common Operational Problems

The common problems encountered with bio gas units and their remedial measures are given in table 4.1.

Defect	Cause	Remedy
1.Installation		
(i) Cracking of digester wall.	(i) Sinking of foundation or improper back filling.	(i) Repair and do proper back-filling.
(ii) Falling of partition wall.	(ii) Unequal Pressure of slurry in the inlet and out let chambers.	(ii) Fill the slurry initally from both inlet and out let sides. If the wall has fallen, then empty the digester and rebuild it.
(iii) Gas leakage.	(iii) Improper welding of iron gas holder or improper construction of dome.	(iii) Check and repair

(iv) Accumulation of water in pipe line.	(iv) Improper installation of water trap.	(iv) Check levels and set the water trap at correct position,
2.Operation		
(i) No gas after first filling of plant	(i) Lack of time	(i) It may take 3-4 weeks.
(ii) Gas holder does not rise or slurry level does not rise in inlet and out let chambers, even though gas is being produced.	(ii)(a) Insufficient addition of slurry (b)Leak in gas holder and pipe (c) Hard scum	(ii)(a) Add More slurry (b)Check and Correct (c) Rotate drum or agitate slurry bamboo pole in fixed dome type plant.
(iii) No gas at stove but plenty in the plant.	(iii)(a) Gas pipe blocked by (b)Insufficient pressure (c) Gas out let blocked by scum.	(iii) (a) Remove water condensate from Moisture trap. (b)Increase weight on gas holder. (c) Disconnect the out let valve from the hose pipe and clean it by pouring water.
(iv) Gas does not burn	(iv) Wrong kind of gas	(iv) Add properly mixed slurry
(v) Flame far from burner.	(v) Pressure to high or deposition of Carbon on the nozzle.	(v) Adjust gas out let value and clean nozzle.
(vi) Flame dies quickly.	(vi) Insufficient pressure.	(vi) Check quantity of gas. Increase pressure by putting weight on gas holder and break the scum by rotating the holder.
(vii) Corrosion of Iron gas holder and pipe line.	(vii) Improper Maintenance.	(vii) Paint periodically and replace corroded material.
(viii) Clogging of inlet and out let pipes.	(viii) Addition of materials other than cleaning dung.	(viii) Use cattle dung only and clean pipes by pushing a bamboo pole in and out of them.
(ix) Insanitary condition around bio gas plant.	(ix) (a) Improper digestion. (b) Improper disposal of slurry.	(ix)(a) Add correct quantity of slurry (b) Use slurry for composting of crop residue.

4.9. Economical, social environmental and health benefits of bio gas utilization

Economical benefits of bio gas utilization

From the national economic point of view the bio gas yields following economic benefits:

(1) Bio gas technology, which is based on recycling of readily available resources in rural areas, gives comparatively cheaper and better fuel for cooking lighting and power generation.

(2) An individual can reduce the consumption of commercial energy sources such as fire wood, coal, kerosene, etc. by adopting waste recycling technology which vigorously help in reducing the family fuel budget.

(3) The problem of uncertainly of availability of commercial energy can be resolved by use of bio gas technology.

(4) The rural population of the country uses fire wood for meeting their cooking requirements. This reduces the national forest wealth. Our forest area can be conserved by using bio gas.

(5) The dependency on chemical fertilizer for better-agricultural production has increased to a great extent after independence in India. Bio gas slurry can be proved a best organic fertilizer which helps in improving soil fertility and crop production.

(6) Presently country is facing the problem of foreign exchange and balance of payment. Bio gas technology reduces the import of chemical fertilizers by using home made organic fertilizer and also petroproducts.

(7) Bio gas technology utilizes effectively, the man power and resources, resulting in self-sufficiency and self reliance in the society.

Social Benefits

Bio gas is one of the best options in rural areas, which provides self-sufficiency in energy and helps in increasing standard of living of rural people. The social benefits from bio gas utilization are as follows:

(1) Bio gas burns giving shootless flame and smokeless cooking, as such it provides cleanliness in the houses.

(2) The cooking on bio gas is faster and also women is not required to waste their time to collect fuel from forest, as such it reduces the drudgery of women who can use her free time for other developmental activities.

(3) The bio gas provides lighting in the rural areas, which are far away from electrical supply lines. Thus it helps the children to use their time in study of employment.

(4) It helps in generation of employment opportunities to village artisans. This also stops the Migration of people from rural to urban areas in search of employment.

(5) Generally, rural women and children spend their energy and time for collection of fuel, chopping wood, collecting wood and crop stalks or buying coal or kerosene for cooking from distant places, energy and time saved due to sue of bio gas can be used for constructive work or going to school for education.

Environmental and Health Benefits

Bio gas system contributes to maintain clean and healthier environment by processing human growth. More transportation means have increased the pressure on environment. The scientists are worried about environmental protection and looking for appropriate means for the same, which are locally available. In present circumstances bio gas utilization would be a solution for environmental protection for healthy and prosperous society. Environmental benefits from bio gas are enormous. Some of them are as under:

(1) lungs and eye diseases are very common among village women and children due to smoky kitchen. Bio gas utilization reduces the disease spread. Thus reducing health problem rush in hospitals and waste of national wealth.

(2) Sanitation problems in villages through systematic collection and through proper processing of animal dung and human excreta will be solved.

(3) It helps to prevent deforestation. consequently it controls soil erosion, and floods.

4.10. KVIC Bio gas Plant

The Floating gas holder digester developed in India is of Masonry construction with gas holder made of M.S. Plates. The drum in the KVIC Model is the costliest component and its life is comparatively less.

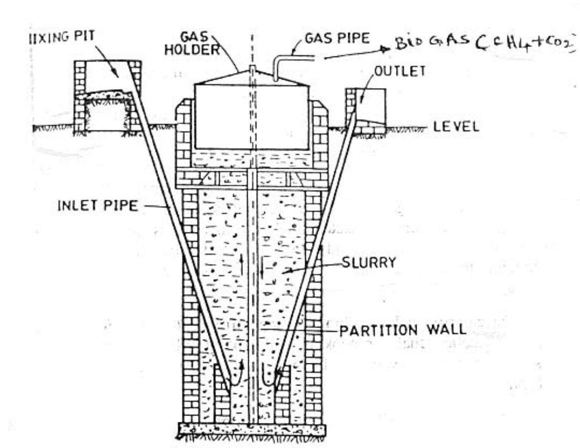


Fig. 4.4 KVIC Bio-gas plant

The design of KVIC plant was developed and perfected in India in the year 1945. This was taken up propagation in the villages in the year 1962, by Khadi and village industries commission, Bombay. Therefore, it is known as KVIC design. The design is available in sizes of 1 cum to 140 cum gas per day. In KVIC plant the gas is stored in mild steel drum of storage capacity of 30-40 percent of plant size at a pressure of about 10cm of water column. Which is sufficient to carry it up to a length of 20 meters to 100 meters, depending on the size of the plant.

The plant consists of two parts. The digester, which is well containing the animal waste in the form of a slurry, and the dome which floats on the slurry and serves as the gas holder.

The digester is normally below ground level and two pipe lines lead to its bottom. One for feeding the animal waste slurry and the other for spent slurry called sludge to come out after it has under gone fermentation. It is worth noting that the sludge to come out retains all the nitrogen, phosphorous and potassium and in an excellent fertilizer. A vertical partition wall divides it into two equal parts and serves to direct the flow of the slurry.

The gas generation process occurs in two stages. In the first stage, the complex organic substance contained in the waste are acted upon by a certain kind of bacteria called acid formers and are broken up into small chain simple acids. In the second stage, these acids are acted upon by another kind of bacteria which produces Methane and Carbon dioxide.

The calorific value of bio gas ranges from 1600 to 2500 KJ/m^3. It is an excellent fuel for cooking and lighting. When compared with diesel it is also be a very good fuel for compression, ignition engines and can save 70 to 80 percent of diesel.

4.10.1 Pragathi Design Bio gas Plant

The design has been developed by United Socio-Economic Development and Research Programme (UNDARP) Pune, in order to have a cheaper floating drum bio gas plant. In this design the depth of pit is less than K.V.I.C plant so that it can be constructed in hilly and high water tabel areas. The cost of Pragathi plant is 20% less than KVIC plant.

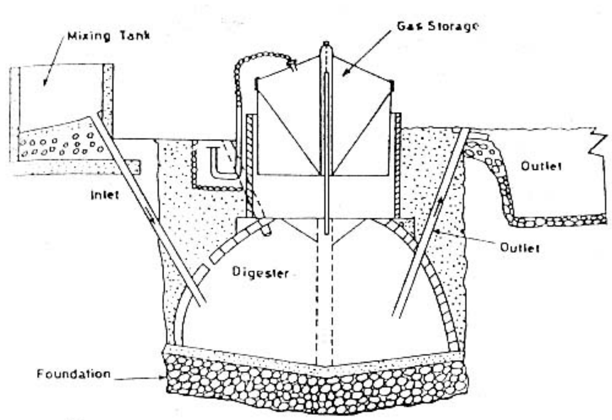


Fig 4.5 Pragathi Design Bio gas Plant

The design shown in fig 4.5, indicates its different parts. The foundation of this plant is of conical shape, with difference of one feet between outer periphery and its center so as to reduce the earth and digester wall work. It is constructed at the base of the pit with cement, sand and concrete, keeping the site conditions in view so it can bear the load due to weight of slurry in the digester.

The digester of Pragathi design plant start from the foundation in dome shape there by reducing the constructional area, for same digester volume, thus reducing the cost of construction of the plant. The wall thickness of digester is kept 75mm only. Dome shape construction takes place up to a collar base, where a central guide frame is provided. the digester wall above guide-frame is constructed in cylindrical shape, Partition wall is constructed in the digester for 4cum.and bigger sizes so as to control the flow of slurry in side the digester It divides digester in two parts separating inlet and outlet.

The inlet is through pipe, placed while construction digester wall. It is used for feeding daily slurry in to the digester and is generally of 100mm diameter. The out let pipe is also 100mm in diameter, and fixed while constructing digester wall. The asbestos cement pipe can be used for inlet and out let.

The guide frame is made of angle iron and steel pipe, is embedded in the digester wall at top of spherical portion of digester. The central guide pipe holds gas holder which is also made of M.S sheet and angle iron. It floats up and down along pipe depending on the quantity of gas in the drum.

4.10.2 Janata Bio gas Plant

This was first developed by the planning, Research and Action division, Lucknow, in 1978. It is an improved version of the Chinese fixed-dome bio gas plant. The plant is shown in fig4.6 with different parts. The foundation of Janata Bio gas plant is laid at the base of the under ground pit on a leveled ground bear the load of the slurry as well as digester walls.

Digester is cylindrical in shape constructed with bricks and cements the dung slurry for a retention. Time, so that the bio gas is produced from the slurry in the digester. It should be noted that the diameter and height ratio of the digester is kept 1.75:1.

The gas is stored in gas portion which is an integral part of plant, between dome and digester. Where the usable gas is stored, the heights of the gas portion is above the inlet and out let openings to the beginning of dome, and is equal to maximum volume of the gas to be stored(30-40) (Percent of plant Capacity) and equal to volume of slurry to be displaced in inlet and outlet.

Dome is constructed over the gas portion, with volume of 60 percent of the plant capacity. It must be constructed very carefully integrated it with digester and gas portion so that no leakage of gas can take place. The gas out let pipe is fixed at the top of dome for laying the line.

Inlet and outlet portions are constructed for putting the fresh slurry in side the plant and to take the digested slurry out. The inlet and outlet are of larger sizes. Provided on each side of the digester, facing each other. The opening to the digester for feeding the waste material and effluent out let from it are also of large sizes. The discharge of slurry out of the plant is due to pressure of the gas in the plant. Over the inlet portion an inlet Mixing tank is also constructed to mix the dung and water.

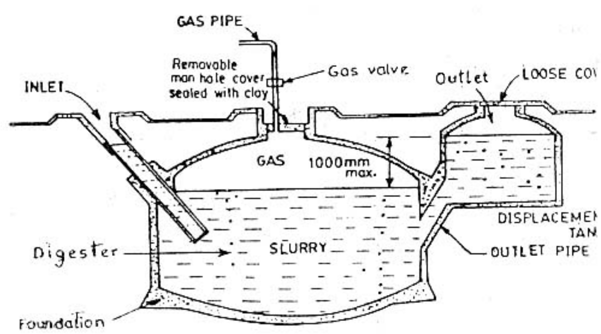


Fig 4.6 Jnanatha Bio gas Plant

4.10.3 Deenbandhu Bio Gas Plant

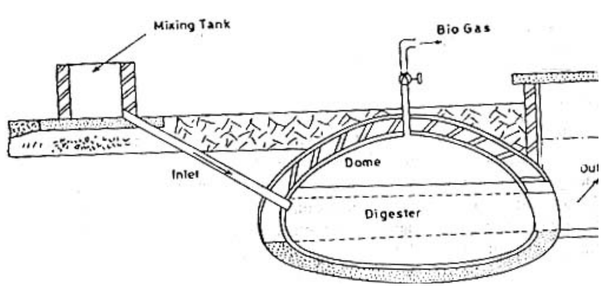


Fig 4.7 Deenbandhu Bio gas Plant

This is also a fixed dome plant development by action for food production, New Delhi, which is a allow cost bio gas plant. The principle of working of this plant is same as that of Janata model, except configuration of inlet entrance and digester.

The foundation of the plant is constructed in the segment of spherical shape as shown fig4.7 on the outer periphery of this foundations the dome shaped digester is constructed with same base diameter. In this way the digester, gas portion and dome look as a single unit. The surface area of bio gas plant is reduced with same digester volume, reducing the earth work and cost of construction with out sacrificing the efficiency. Th e higher compressive strength of the brick masonary and concreate makes it a safe structure as the plant is always under compression. A spherical, Structure loaded from the convex side will be under compression and therefore, the internal load will not have any residual effect on the structure.

At the top of the foundation a window opening is kept (outlet portion) for the out ward movement of the digested slurry. The asbestos cement pipe of 15Cm diameter is used for inlet instead of separate opening. The pipe is embedded in the digester wall at a fixed position ,just opposite to out let opening, to avoid short circuiting of fresh material and digested slurry.

The volume of the out let is increased to produce requisite gas pressure through the weight of the displaced slurry. At the top of the dome a gas outlet pipe is fixed as incase of Janata plant.

Bio gas energy – Questions

Short Answer Questions

1. Define Biogas energy?
2. What are the raw materials required for fermentation?
3. What are the benefits of Bio gas technology?
4. What is Bio Mass?
5. Write the Percentage compositions of Bio gas?
6. What is aerobic and anaerobic?

Essay type Questions

1. Write the brief History of Bio gas?
2. Explain briefly about the process of Bio gas?
3. Explain briefly about the selection site for installation of a Bio gas plant?

4. Explain briefly about the material requirement for construction of Bio gas plant?
5. Explain briefly about the construction techniques of bio gas plant?
6. Explain briefly about the common problems with bio gas units and their remedies?
7. What are the economic benefits of Bio gas Utilization?
8. What are the social benefits of Bio gas Utilization?
9. What are the environmental and Health Benefits of bio gas Utilization?
10. Explain KVIC Bio gas plant with the help of neat sketch?
11. Explain Pragathi design Bio gas plant with the help of neat sketch?
12. Explain Janata Bio gas plant with the help of neat sketch?
13. Explain Deenbhandu Bio gas plant with the help of neat sketch?

CHAPTER – 5
TIDAL POWER PLANTS

5.0 Introduction to Tidal Power Plants

The development of a nation is estimated from the total amount of energy it produces and consumes in relation to its size and Population. Human-Progress has been judged from the ways in which man has been able to develop and harness energy.

The present shortage of the energy production sources due to deplitable nature of fossil flues has awakened the world human community to search for new unconventional and replenishable energy sources. According to the energy experts, exhaustible resources extracted from the ground (coal, oil, gas, and uranium), in the face increasing demand, results into a cycle. This cycle starts at zero production increases exponentially than decreases exponentially and finally comes to zero. It is estimated that Petroleum reserves of the world will be nearly exhausted by 2020. Under such circumstances, man has to find out some source of energy for his survival. In this context, three sources of energy, tidal, wind and solar have been brought to be most promising.

What is tidal power? Tide is periodic rise and fall of the water level of the sea. Tides occur due to the attraction of seawater by the moon. These tides can be used to produce electrical power which is known as tidal power.

When the water is above the mean sea level, it is called flood tide and when the level is below the mean level, it is called ebb tide. A dam is constructed in such a away that a basin gets separated from the sea and a difference in the water level is obtained between the basin and sea. The constructed basin is filled during high tide and emptied during low tide passing through sluices and turbine respectively. The Potential energy of the water stored in the basin is used to drive the turbine which in turn generates electricity as it is directly coupled to an alternator.

Though the idea of utilizing tides for human service relates to eleventh century when tidal mills were used in England but the use of tidal power for electric power generation is hardly a decade old as the world's first Rance tidal power plant of 240 MW capacity in France was commissioned by President be Gaulle in 1965 who described it a magnificent achievement in the human life.

Tidal power has been a dream for engineers for many years and it remained dream because of large capital cost involved in its development. But after the inauguration of Rance Tidal Project, a new chapter in the history is now opened.

5.1 Factors affecting the suitability of the site for tidal power plant

The feasibility and economic vulnerability of a tidal power depends upon the following factors.

1. The power produced by a tidal plant depends mainly on the range of tide and the cubature of the tidal flow occurring in the estuary during a tidal cycle which can be stored and utilized for power generation. The cubature of the tidal flow not only depends on the tidal range but on the width of estuary mouth.
2. The minimum average tide range required for economical power production is more.
3. The site should be such that with a minimum cost of barrage it should be possible to create maximum storage volume. In addition to this, the site selected should be well protected from waves action.
4. The site should not create interruption to the shipping traffic running through the estuary other wise the cost of the plant will increase as locks are to be provided.
5. Silt index of the water of the estuary should be as small as possible to avoid the siltation troubles. The siltation leads to reduction of the range of tides and reduces the power potential of the plant.
6. The fresh water prism that falls into the reservoir of the tidal plant (due to the surface flows in the streams having out fall in the estuary) eats away the valuable storage created for storing the tidal prism. Therefore, the

ratio of fresh water prism to tidal water prism becomes an important index in determining the economic feasibility of a tidal scheme. The effective and cheaper will be the power production with decreasing the ratio mentioned above.

5.2 Classification of tidal Power Plants

The tidal power plants are generally classified on the basis of the number of basins used for the power generation. They are further subdivided as one-way or two-way system as per the cycle of operation for power generation.

The classification is represented with the help of a line diagram as given below

Classification

- Single basin systems
  - One-way system
  - Two-way system
  - Two-way with pump storage
- Double basin systems
  - Simple double basic
  - Double basin with pumping

5.3 Working of Different Tidal Power Plants

5.3.1 Single basin-One-way cycle

This is the simplest form of tidal power plant. In this system, a basin is allowed to get filled during flood tide and during the ebb tide. The water flows from the basin to the sea passing through the turbine and generates power. The power is available for a short duration during ebb tide.

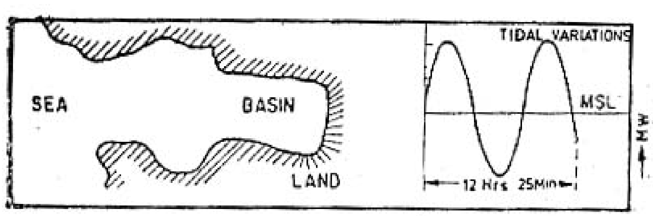
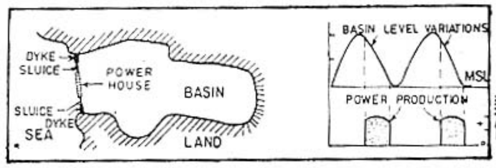


Fig 5.1 Single basin Tidal Power Plant

Fig 5.1 shows a single tide basin before the construction of dam and Fig5.2 shows the diagrammatic representation of a dam at the mouth of the basin and power generation during the falling tide.

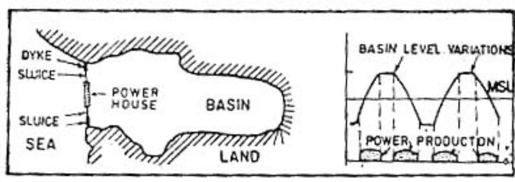


(*b*) Single basin, one-way tidal power plant.

Fig 5.2

5.3.2 Single-basin two-way cycle

In this arrangement power is generated both during flood tide as well as ebb tide also. The power generation is also intermittent but generation period is increased compared with one-way cycle. However the peak power obtained is less than the one-way cycle. The arrangement of the basin and the power cycle is shown in Fig 5.3.



Single-basin two-way tidal power plant.

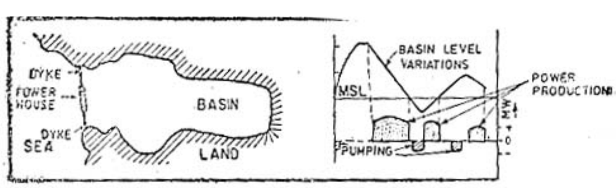
Fig 5.3

The main difficulty with this arrangement, the same turbine must be used as Prime mover as ebb and tide flows pass through the turbine in opposite directions. Variable pitch turbine and dual rotation generator are used for such schemes.

5.3.3. Single-basin two-way cycle with pump storage

The Rance tidal power plant in France uses this type of arrangement. In this system, power is generated both during flood and ebb tides. Complex machines capable of generation Power and Pumping the water in either directions are used. A part of the energy produced is used for introducing the difference in the water levels between the basin and the sea at any time of the tide and this is done by pumping water into the basin up or down. The period of power production with this system is much longer than the other two described earlier. The cycle of operation is shown in Fig 5.4.

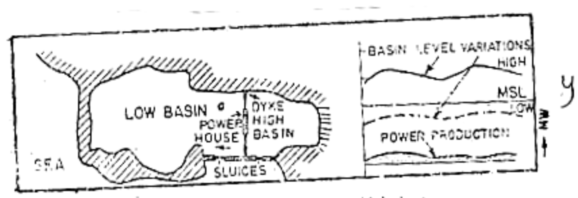
Fig 5.4



Single-basin, two-way tidal plant coupled with pump storage system.

5.3.4 Double basin type

In this arrangement, the turbine is set up between the two basins as shown in Fig 5.5. one basin is intermittently filled by the flood tide and other is intermittently drained by the ebb tide. Therefore a small capacity but continuos power is made available with this system as shown in Fig5.5. The main disadvantage of this system is that 50% of the Potential energy is sacrificed in introducing the variation in the water levels of the two basins.



Double basin, one-way tidal plant.

Fig 5.5

5.3.5 Double basin with Pumping

In this case, off peak power from the base load plant in a interconnected transmission system is used either to pump the water up the high basin. Net energy gain is possible with such a system if the pumping head is lower than the basin-to-basin turbine generating head.

5.4 Advantages and disadvantages of Tidal Power Plants

Advantages

1. Exploitation of tidal energy will in no case make demand for large area of valuable land because they are on bays.
2. It is free from pollution as it does not use any fuel.
3. It is much superior to hydro-power plant as it is totally independent of rain which always fluctuates year to year. Therefore, there is certainty of power supply a the tide cycle is very definite.
4. As in every form of water power, this will also not produce any unhealthy waste like gases, ash, atomic refuse which entails heavy removal costs.
5. Tidal Power is superior to conventional hydro power as the hydro plants are know for their large seasonal and yearly fluctuations in the output of energy because they are entirely dependent upon the nature’s cycle of rainfall, which is not the case with tidal as monthly certain power is assured. The tides are totally independent on nature’s cycle of rainfall.

6. Another notable advantage of tidal power is that it has a unique capacity to meet the peak power demand effectively when it works in combinatiion with thermal or hydroelectric system.
7. It can provide better recreational facilities to visitors and holiday makers, in addition to the possibility of fish forming in the tidal basins.

Disadvantages

1. These Power plants can be developed only if natural sites are available.
2. As the sites are available on the bay which will be always far away from the load centers. The power generated must be transported to long distances. This increases the transportation cost.
3. The supply of power is not continuous as it depends upon the timing of tides. Therefore some arrangements (double basin or double basin with pump storage) must be made to supply the continuous power. This also further increases the capital cost of the plant.
4. The capital cost of the plant (Rs.5000/kw) is considerably large compared with conventional-power plants (hydro, thermal)
5. Sedimentation and siltration of the basins are some of the added problems with tidal power plants.
6. The navigation is obstructed.
7. It is interesting to note that the output of power from tidal power plant varies with lunar cycle, because the moon largely influences the tidal rhythm, where as our daily power requirement is directly related to solar cycle.

In addition to all the above mentioned (imitations of tidal power, the utilization of tidal energy on small scale has not yet proved economical.

Components of Tidal Power plants

There are three main Components of a tidal Power plant. i.e,

(i) The Power house

(ii) The dam or barrage

(iii) Sluice-ways from the basins to the sea and vice versa.

The turbines, electric generators and other auxiliary equipment's are the main equipments of a power house. The function of dam to form a barrier between the sea and the basin or between one basin and the other in case of multiple basins.

The sluice ways are used either to fill the basin during the high tide or empty the basin during the low tide, as per operational requirement. These are gate controlled devices.

It is generally convenient to have the power house as well as the sluice-ways in alignment with the dam.

The design cycle may also provide for pumping between the basin and the sea in either direction. If reversible pump turbines are provided, the pumping operation can be taken over at any time by the same machine. The modern tubular turbines are so versatile that they can be used either as turbines or as pumps in either direction of flow. In addition, the tubular passages can also be used as sluice-ways by locking the machine in to a stand still. As compared to conventional plants, this, however, imposes a great number of operations in tidal power plants. For instance, the periodic opening and closing of the sluice-way of a tidal plant are about 730 times in a year.

Dam (Barrage)

Dam and barrage are synonymous terms. Barrage has been suggested as a more accurate term for tidal power scheme, because it has only to with stand heads a fraction of the structure's height, and stability problems are far more modest. However, the literature does not always make the distinction, even though heads are small with tidal power cutoffs.

Tidal power barrages have to resist waves whose shock can be severe and where pressure changes sides continuously.

The barrage needs to provide channels for the turbines in reinforced concrete. To build these channels a temporary coffer dam in necessary, but it is now possible to built them on land, float them to the site, and sink them into place.

Tidal barrages require sites where there is a sufficiently high tidal range to give a good head of water – the minimum useful range is around three meters. The best sites are bays and estuaries, but water, can also be impounded behind bounded reservoir built between two points on the same shore line.

The location of the barrage is important, because the energy available is related to the size of trapped basin and to the square of the tidal range. The nearer it is built to the mouth of bay, the larger the basin, but the smaller the tidal range. A balance must also be struck between increased out put and increased material requirements and construction costs.

Gates and Locks

Tidal power basins have to be filled and emptied. Gates are opened regularly and frequently but heads very in height and on the side where they occur, which is not the case with conventional river projects. The gates must be opened and closed rapidly and this operation should use a minimum of power. Leakage, is tolerable for gates and barrages. Since we are dealing with seawater, corrosion problems are actuate, they have been very successfully solved by the catholic protection and where not possible by paint. Gate structures can be floated as modular units into place.

Though, in existing plants, vertical lift gates have been used. The technology is about ready to substitute a series of flap gates that operates by water pressure. Flap gates are gates that are positioned so as to allow water in to the holding basin and require no mechanical means of operation. The flap gates allow only in the direction of the sea to basin. Hence, the basin level rises well above to sea level as ebb flow area is far less than flood flow area.

Power house

Because small heads only are available, large size turbines are needed; hence, the power house is also a large structure. Both the French and Soviet operating plants use the bulb type of turbine of the propeller type, with revisable blades, bulbs have horizontal shafts coupled to a single generator. The cost per installed kilowatt drops with turbine size, and perhaps larger turbines might be installed in a future major tidal power plant.

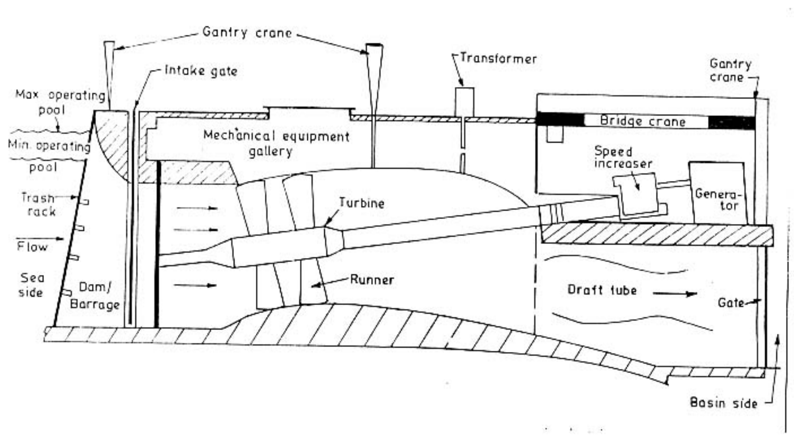


Fig 5.6 Schematic Lay out of Tidal Power House

Questions

Short answer Questions

1) What are the components of Tidal Power plant?
2) What are the advantages and disadvantages of Tidal Power plant?
3) Define Tidal energy?

Essay type Question

1) Explain briefly about Tidal Power plant and Mention the advantages and disadvantages of tidal power plant?

CHAPTER – 6
FUEL CELLS

6.0 Introduction

Fuel Cells are efficient and quiet, operate on a veriety of hydrocarbon fuels, and produces almost no objectionable emissions. The concept has been proven in numerous small scale applications. The recent infusion of power cost from fossil fuels may convert this promising device into a major source of electric power generation.

The electric Power Research Institute and United Technologies Corporation recently agreed to construct a 4.8MW capacity plant, with an investment of 25 million dollars. It is predicted that if the fuel cell clears a number of technical hurdles and proves financially viable, it could contribute 20,000MW power to the US grid, by the end of 1985. This would save $1 billion in power generating costs and 100 million barrels of fuel oil annually.

6.1 Working of Fuel Cell

The fuel cell represents one of the successful ways by passing the heat cycle and converting the chemical energy of fuels directly into electricity. It may be defined as an electrochemical device for the continuous conversion of the portion of the free energy change in a chemical reaction to electrical energy. It is distinguished from a battery in that it operates with continuous replenishment of the fuel and oxidant at active electrode areas and does not require recharging.

The arrangement of fuel cell components in shown in fig 6.1

The working of the fuel cell is explained here with reference to the Hydrogen-Oxygen fuel cell using aqueous electrolyte. The fuelcell consists of an anode, a cathode and an electrolyte Hydrogen fuel is fed into the anode side of the cell. Positive H_2 ions move from the anode-side and enter the electrolyte through porous cell walls. The anode is left with a negative charge. Air is fed into the cathode side. O_2 ions enter the electrolyte leaving the cathode side with a positive charge. Excess anode electrons flow to the cathode creating a current flow H_2 and O_2 ions combine in the electrolyte to from water which leaves the cell as steam.

The reaction taking place at the electrodes are given below

(1) Hydrogen electrode (anode)

$2H_2 \rightarrow 4H$

$4H + 4OH \rightarrow 4H_2O + 4e$

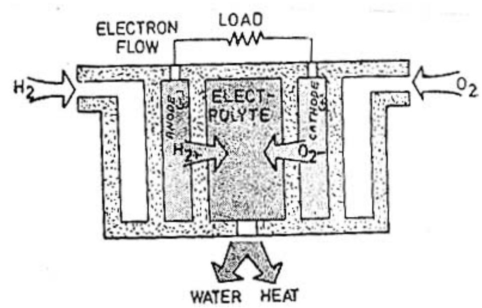


Fig 6.2 Fuel Cell

(2) Oxygen electrode (cathode)

$O_2 \rightarrow 20$

$2 O + 2H_2O + 4e \rightarrow 4 OH$

(3) Overall cell reaction

$2H_2 + O_2 \rightarrow 2H_2O$

The above reactions indicate H_2 molecules break up into H Atoms at the anode and they combine with OH ion to form water and free electron at anode. The formed free electrons travel to the cathode through the external circuit as shown in fig. At the cathode, O_2 molecules break up into two O_2 atoms and these atoms combine with the four electrons arriving by the external circuit and two molecules of water (out of 4 molecules produced at the anode to from 4OH oins. The OH ions migrate towards the anode and are consumed there. The electrolyte remains invariant. It is prime requirement that the composition of electrolyte should not change as the cell operates. The major difficulty experienced in the design of fuel cell is to obtain sufficient fuel-electrode-electrolyte reaction sites in a given volume. There are many other types of cells as ion exchange membrane cell, direct and indirect oxidation fuel cells, molten carbonate fuel cells and many others.

The present research work done in this area is to increase the efficiencies or modify the design of the three major components of fuel cell power plant to increase the overall efficiency of the system. The arrangement of the fuel cell power plant which will be used in future is shown in fig6.3.

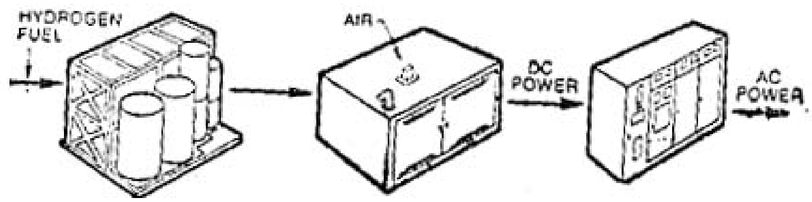


Fig 6.3

(a) Processor

It converts a hydrocarbon fuel into a hydrogen rich gas that can be accepted by the cell. One of the main problems regarding fuel-cell development is finding away to convert low grade fuel into H_2 rich gas that has a minimum of impurities. Material such as sulpher in fuel can adversely affect the fuel processor. Presently the research is directed to find a cell electrolyte that is more tolerant of fuel impurities. It is predicted that the developments in both processor and electrolyte will allow the use of standard fuel oil as fuel in the 1990s and ultimately residual oil and coal gas.

Hydrogen generation processes from the petrochemical industry are being adopted to the fuel cell's needs steam reforming is an other successful fuel processing technique now commonly used with phosphoric-acid electrolyte fuel cells. The life of such a processor is presently limited to about 15,000 hrs.

(b) Electrolyte

Initial work has been done chiefly with phosphoric acid which has an operating temperature of 160^{o}C to 200^{o}C. This electrolyte can give fuel cells efficiency of 50%.

Next generation of fuel cells will use molten carbonate electrolyte. Operating at a temperature of 500 to 750^{o}C, this material is more tolerant of fuel impurities and gives a fuel cell efficiency of 40 to 50%. Life for existing molten carbonate fuel cells is about 10,000 hrs. A 50,000hr, life is expected to be achieved by 1990.

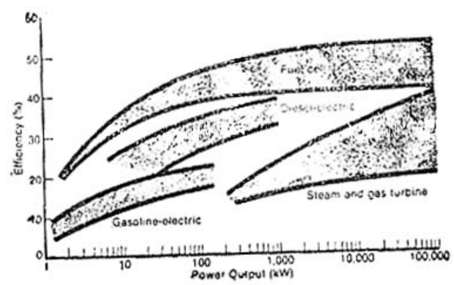
Solid oxide may be electrolyte of the third generation of fuel cells, which are probably 20 years away. This electrolyte will give a fuel efficiency of 60% or better and will be compatiable with many of the coal gasification processes.

(c) Inverter

The last element in the fuel cell power generation system which converts DC to AC does not yet exist commercially in the sizes needed for large scale power conversion. To date inverters with a capacity of 20 to 40KW are in limited use and some capable of 1.8MW have been tested. Major research work is presently directed to develop the inverters of high capacity.

The predicted performance of fuel cell power plant is shown in fig relative to three other power generation methods.

6.2 Advantages of Fuel Cells



1) The fuel cell converts its fuel directly to electric power. Pollutant levels range from 1/10 to 1/50,000 of those produced by a fossil fuel power plant as there it no combustion
2) No cooling water is needed so it can be located at any desired place.
3) As it does not make noise. It can be readily accepted in residential areas.
4) The fuel cell takes little time to go into operation.
5) It would be an ideal reserve power source with in large conventional power plants to handle peak or emergency loads.
6) There is no efficiency penalty for part load operation. Efficiency remains constant from 100% to 25 % of rated load.
7) There is no maximum or minimum size for a fuel cell power plant. Individual fuel cells are joined to from stacks. The stacks are joined to

form power modules. The number of modules can be tailored to power plant requirements.

8) The land requirement is considerably less compared with conventional power plants.
9) Possibly the greatest advantage of the fuel cell is its high operating efficiency. Present-day fuel cell efficiency is 38% and it is expected to reach to 60% before the end of this century.
10) Fuel cell power plants may further cut generation costs by eliminating or reducing line losses. Fuel cell power plant in rural areas or highly congested residential areas would eliminate the need for long lines to bring in power from remote generating stations.
11) A wide variety of fuels can be used with the fuel cell. Although presently limited to using substances that produce pure H_2 rich gas, the cell may one day be able to operate on fuels derived from low grade shale oils or highly sulfur coals.
12) The maintenance charges are low as there are no moving parts and outages are also less.
13) Fuel cells have an overload capacity of 50 to 100% for a short duration.
14) The weight and volume of the fuel cell is considerably low compared to other energy sources.
15) In H_2-O_2 cell, the reaction product is water which is portable.

QUESTIONS

Essay type Questions

1. Explain briefly about the working of Fuel Cell?
2. What are the advantages of Fuel Cells?