PRACTICAL MANUAL

Course Title : Renewable Energy and Green Technology
Credits : 2 (1+1)
Course No. : ENGG - 243
Course : B.Sc. (Hons.) Agriculture
Semester : IV Semester (**New**)

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College of Agriculture,……

CERTIFICATE

This is to certify that Mr./Miss……

Reg.No. …… a student of **IV** Semester **B.Sc.(Hons.)** Agriculture has completed all the exercises successfully of the course: **Renewable Energy and Green Technology**, Course No. **ENGG-243**, during Summer Semester 201 - 201

Place:

Date:

Course Teacher

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Exercise No. 1:

Study of Floating Drum Biogas Plants

Nature made a unique provision for destroying and disposing off wastes and dead plants and animals. Otherwise a severe problem on environment would have developed. This decay or decomposition is carried out by tiny microorganisms called bacteria. Making of Farm Yard Manure (FYM) and compost is also through decomposition of Organic matter (OM). When a heap of vegetable or animal waste and weeds etc., die or decompose at the bottom of back water or shallow lagoons, bubbles can be noticed rising to the surface of water. Sometimes these bubbles burn with dancing flame at dusk. This phenomenon has puzzled man for a long time. It was only during the past hundred years that Scientist unlocked this secret as the decomposition process. The gas thus produced was and is still called **"Marsh Gas"**. The decomposition dung in to combustible gas was first noticed and it was termed as **Gobar gas**. Later on it was observed that all types of biological matter essentially organic in nature can undergo decomposition and produces a combustible gas, which has methane as a chief constituent. The technology of harvesting this gas under artificially created conditions is known as **biogas technology.**

Biogas technology:

Biogas technology has a very significant role to play in integrated agriculture operations, rural sanitation, large scale dairy farms and sewage disposal etc. It is estimated that cattle dung, when passed through a biogas unit, yield 30-40 % more net energy and about 35-45 % more nitrogen in manure as compared with that obtained by burning dung cake and ordinarily prepared compost respectively.

Process description:

Biogas generation is a process widely occurring in nature and in which biomass or organic matter, in the absence of oxygen, is converted in to methane and carbon dioxide. It is characterized by low nutrient requirement, and high degree of waste stabilization process when biogas is one of the two useful products, the other being enriched organic manure in the form of digested slurry. It is essentially a three stage process involving following reaction:

1) Hydrolysis: Optimum quantity of dung with water mixture in first stage is hydrolysised.

2) Acid formation: Hydrolysised mixture is converted in to acid mixture.

3) Methane generation: The acid mixture is converted in to mechanization stage.

For all practical purposes the first two steps are often defined as a single stage i.e. hydrolysis and acid formation stage are grouped as acid formation stage. Micro-organisms are taking part in this phase are termed as acid formers. As a group, these organisms are rapidly growing and are not much dependent upon surroundings. Products of first two stages serve as the raw material for the third stage where organic acids are utilized as carbon source by methane forming microorganisms, which are also known as '**methanogens**'. These methanogens are more susceptible to their surroundings. The tolerated pH range is 6.8 to 7.5 with optimum 7.0. Atmospheric oxygen is extremely toxic for methanogens, as they are strict anaerobes.

Constituent of Biogas:

The gas thus produced by the above process in a biogas plant does not contain pure methane and has several impurities. A typical composition of such gas obtained from the process is as given in Table 4.2.

Table 4.2. : Constituents of Biogas

Methane	60 %
Carbon-di-oxide	38.0 %
Nitrogen	0.8 %
Hydrogen	0.7 %
Carbon monoxide	0.2 %
Oxygen	0.1 %
Hydrogen Sulphide	0.2 %

The calories value of methane is 4800 KCal/m^3 and that of the above mixture is about 4713 Kcal. / m^3. However, the biogas gives a useful heat of 3000 KCal / m^3).

Main feature of the Bio-gas plant:

On the basis of the gas holder the present biogas plants are classified mainly in to two groups (i) Fixed dome type (ii) Floating drum type. Both the types of plants have the following functional components.

(i) Digester:

This is a fermentation tank and is built partially or fully underground. It is generally cylindrical in shape and made up of bricks and cement

mortar. It hold the slurry within it for the period of digestion for which it is designed.

(ii) Gas holder:

This component is meant for holding the gas after it leaves the digester. It may be floating drum or a fixed dome. The gas connection is taken from the top of this holder to the gas burner by suitable pipe line. The floating gas holder is made up of mild steel sheet and angle iron and is required to exert pressure of 10 cm of water in the gas dome masonry and exert a pressure up to 1 m of water column on the gas.

(iii) Slurry mixing tank:

This is tank in which the dung is mixed with water and fed to the digester through an inlet pipe.

(iv) Outlet tank and slurry pit.

An outlet tank is provided in a fixed dome type of plant from where slurry is directly taken to the field or slurry pit for drying. In floating drum plant, the slurry is taken to a pit where it can be dried or taken to the field for direct application.

KVIV Plant:

In 1945 Scientist of Indian Agricultural Research Institute (IARI) New Delhi, worked on semi continuous flow digester and in the year 1961 Khadi and Village Industries Commission (KVIC) patented a design which is being popularized by various agencies in many countries.

This design consist of a deep well shaped underground digester connected with inlet and outlet pipes at its bottom, which are separated by a partition wall dividing the 3/4th of the total height into two parts. A mild steel gas storage drum is inverted over the slurry which goes up and down around the guide pipe with the accumulation and withdrawal of gas.

Advantages of KVIC Plant:

i) Constant gas pressure.
ii) Minimum gas leakage problem
iii) Higher gas production.
iv) Scum problem is minimum
v) Pressure is normally equalizes.
vi) No danger of mixing between biogas and external air. Hence no danger of explosion.

Disadvantages of KVIC Plant:

i) Higher cost
ii) Higher maintenance cost
iii) The outlet pipe should be flexible. It required regular attention.
iv) Heat is lost through gas holder.

Assignment: Draw a Diagram of KVIC Biogas plant and label it properly

Exercise No. 2:

Study of Fixed Drum Biogas Plants

Janata Plant:

The Janata model is fixed dome biogas plant which was developed by PRAD in 1978. This is also a semi continuous flow plant. In this type the digester and gas holder are part of composite unit made of bricks and cement masonry. It has a cylindrical digester with dome shaped roof and large inlet and outlet tanks on two sides. This plant cost about 20-30% less than the KVIV plant.

Advantages of Janta Plant:

i) No moving part therefore no maintenance problem
ii) Longer working life.
iii) No co-erosion problem.
iv) Amount of gas produced is higher than movable drum type.
v) Low operating cost.
vi) Owing to underground construction, heat insulation is better and therefore, rate of
gas production is uniform during night and day.

Disadvantages of Janta plant:

i) Required skilled masons for construction.
ii) Variable gas pressure.
iii) Problem of scum formation.

Deenbandhu Plant:

It is a modification and advance version of Janata fixed dome type biogas plant. Unlike Janata biogas plants for constructing plants of this design no shuttering is required for making the dome shaped roof. This also result in less labour and time required for completing the construction.

Biogas application and appliances:

(i) Cooking and lighting:

The main use of the biogas in rural areas is cooking. The other use is gas lamp which glows like any bright lamp.

(ii) Duel fuel Engine:

This is a recent appliance where certain modification of air intake system helps carburetion of biogas to run the diesel engines. Diesel engines

has wide application in rural areas from irrigation to any stationary operations and these engines can be converted to duel fuel mode. This duel fuel engine is in a position to make use of about 70% biogas and 30 % diesel.

(iii) Refrigeration's, Incubators and Water Boilers:

There are other applications of biogas such as refrigerators, Incubators and Water boilers.

Assignment: Draw a Diagrams of Fixed Dome Janata Biogas plant and Deenbandhu Biogas plant & label them properly

Exercise No. 3:

Study of Different Types of Gasifiers

Gasification and types of Gasifiers:

Gasification is a step forward to carbonization where end product of carbonization is finally converted into gaseous mixture of combustible nature. This mixture is known as producer gas which can be used for meeting domestic and motive power requirement. Design of Gasifier depends upon type of fuel used and whether gasifier is portable or stationary.

Gasifiers are classified according to air blast introduction in the fuel column and non-producer gas travels in the reactor before its final use. The most commonly built gasifiers are classified as:

1) Updraft gasifier
2) Downdraft gasifier
3) Twin-fire gasifier
4) Cross draft gasifier
5) Fluidized bed gasifier
6) Other gasifier

1. Updraft gasifier:

An updraft gasifier is clearly defined zones for partial combustion, reduction and pyrolysis. As the name indicates, in this type of gasifier air is introduced at the bottom and act as counter current to fuel flow.

The gas is drawn at higher location. The updraft gasifier achieves the highest efficiency as the hot gas passes through fuel bed and leaves the gasifier at low temperature. The sensible heat given by gas is used to preheat and to dry fuel used.

Disadvantages of updraft gas producer are excessive amount of tar in raw gas and poor loading capability. Hence it is not suitable for running of vehicle. The updraft gasifier is suitable for low tar fuel such as charcoal and coke.

2) Downdraft Gasifier:

The downdraft gasifier convert high volatile fuel (wood, biomass) to low tar gas. This design is very successful for power generation. In this

type of gasifier, air is introduced into downward flowing packed bed or solid fuels and gas is drawn off at the bottom.

A lower overall efficiency and difficulties in handling higher moisture and ash content fuel are common problems in small downdraft gas producers. The time (20-30 minutes) needed to ignite and bring plant to working temperature. It is appropriate design for running vehicle.

3) Twin fire Gasifier:

The advantage of co-current and counter current gasifiers are combined in so called twin fire gasifier. It consists of two defined reaction zones namely Ist reaction zone and IInd reaction zone. In upper zone (Ist zone) drying, low temperature carbonization, and cracking of gases occurs and in lower zone (IInd zone) permanent gasification of charcoal take place. The gas temperature lies between 460 to 520 ^{0}C. Total process takes place with under pressure of 30 mbar. Twin fire gasifier produces fairly clean gas and promising devices for engine application.

4) Cross draft Gasifier:

In this type of gasifier movement of fuel and gas take place. The air is allowed to enter perpendicular to fuel bed, where is producer gas started generated in the same opposite live. Cross draft gas producer have certain advantages over updraft and downdraft gasifiers. The disadvantage of this design include high exit gas temperature poor CO_2 reduction and high gas velocity. Unlike downdraft and updraft gasifiers the ash bin, fire and reduction zone in the cross draft gasifiers are separated. Limitation of this type of design is types of fuel for operation to low ash fuels such as wood, charcoal and coke. The load following ability of cross draft gasifiers is quite good due to concentrated partial zones which operate at temperature up to 2000 ^{0}C. Startup time (5-10 minutes) is much faster than that of downdraft and updraft units. The relatively higher temperature in cross draft gas producer has an obvious effect on gas composition such as high carbon monoxide, and low hydrogen and methane content when dry fuel such as charcoal is used. Cross draft gasifiers operates well on dry air blast and dry fuel.

5) Fluidized bed Gasifiers:

The operation of both up and down draft gasifier is influenced by the morphological, physical and chemical properties of the fuel. Problems

commonly encountered are: Lack of bunker flow, Slagging and extreme pressure drop over the gasifier.

A Fluidized bed gasifier is developed to remove the above difficulties. In this type of gasifier air is blown through a bed of solid particles at a sufficient velocity to keep these in a state of suspension. The bed is originally extremely heated and the feed stock is introduced at the bottom of the reactor, very quickly mixed with the bed material and almost instantaneously heated up to the bed temperature. As a result of this treatment the fuel is pyrolysed very fast, resulting in a component mix with a relatively large amount of gaseous materials. Further, gasification and tar conversion reactions occur in the gas phase.

Assignment: Draw a Diagrams of Updraft gasifier, Downdraft gasifier, Twin-fire gasifier, Cross draft gasifier, and Fluidized bed gasifier & label them properly

Exercise No. 4:

Study of the Production Process of Biodiesel

Biofuel:

Introduction: Biofuel are essentially fuels obtained from biological reaction in the nature and combustible in nature but does not add to the stock of total carbon dioxide in the atoms phase. These are plant forms that, typically, remove carbon dioxide from the atmosphere, and give up the same amount when burnt. Naturally, all the other fossil fuel have done the same.

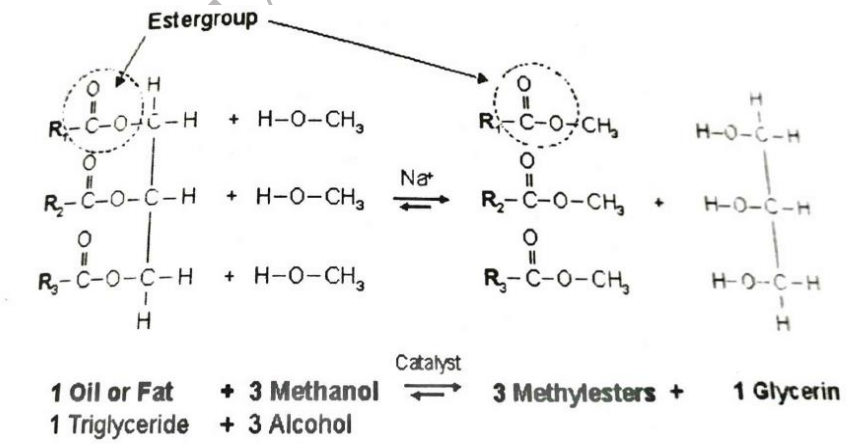
The biofuels are therefore, considered to be **"CO_2 neutral"** not adding to the carbon dioxide level in the atmosphere. The type of biofuel used will depend on a number of factors, chief amongst them being the available feedstock and the energy that can be used locally.

There are two examples of biofuels one Ethanol and Bio-diesel (Renewable diesel).

Ethanol can be made from biomass materials containing sugar, starches, or cellulose.

Bio diesel:

Bio diesel is a mixture of methyl esters of long chain fatty acids like lauric, palmitic, stearic, oleic and so on. It is produced by the transesterification of animal fats and vegetable oils - all of which belong to a group of organic esters called triglycerides. Typical examples are rape / canola oil, soybean oil, sunflower oil, palm oil and its derivatives etc. From vegetable sources, beef and sheep tallow and poultry oil from animal sources and also from used cooking oil. The chemistry is basically the same irrespective of the feed stock. The chemistry of biodiesel is given as:



The abbreviation R_1, R_2 and R_3 are symbolic representation of the fatty acid chains, which can vary in molecular chain length from typically

C_8 to C_{22}, and also their degree of unsaturation. An examples is Oleic acid, which has 18 carbon atoms and one double bond:
$CH_3 - CH_2 - CH_2 - CH_2 - CH2 - CH_2 - CH_2 - CH_2 -CH = CH - CH_2 - CH_2 - CH_2- CH_2- CH_2- CH_2- CH_2- COOH$
Or more simply, $CH_3 (CH_2)_7 CH = CH - (CH_2)_7 COOH$

Bio diesel process: The production of biodiesel involves intensively mixing of methanol (CH_3OH) with oil or fat in the presence of a suitable catalyst, and then allowing the lighter methyl ester phase to separate from the heavier glycerol phase through action of gravity or setting principle. However, as with most organic reaction the degree of conversion depends on the equilibrium reached as well as the influence of other reactions during the course of making and catalystic reaction. Achieving product quality is also very important in this process.

Oil, methanol and sodium methylate catalyst are mixed in reactor-1 and allowed to separate in to two phases. The lighter methyl ester/oil phase is then mixed with additional methanol and suitable catalyst in reactor-2 and again allowed to separate. This second reactor stage forces the transesterification process in the direction of the methyl ester and hence maximizes the biodiesel yield and quality. The lighter phase is then washed with water to remove any residual glycerol or methanol dissolved in the ester phase, followed by a vacuum drying to yield biodiesel.

The denser glycerol phase from reactor-2 contains excess methanol and catalyst so this is recycled to the front end of reactor-1. The denser glycerol phase leaving reactor 1 will still contain unreacted excess methanol which is recovered by distillation in the Methanol recovery column and recycled to the front of reactor-1.

The wash water from the water wash column is also fed to the Methanol Recovery Column for methanol recovery. Thus all of the methanol is consumed in the production of methyl ester. The bottom of the Methanol Recovery Column is processed in the Glycerin Water Evaporation column to recover water for recycle to the wash column, leaving a crude Glycerin by product containing 80-85 % glycerin.

The key features of Bio-diesel process are:

(1) Technology applicable to multiple feedstock for biodiesel production.
(2) Continuous process at atmospheric pressure and nominal temperature (60^0C), hence no additional cost on operating conditions.
(3) Duel Reactor System operating with a patented Glycerin Cross flow configuration for maximized conversion and high efficiency.
(4) Reaction using excess methanol but with full methanol recycle to

avoid any losses hence more efficiency.

(5) Closed loop water wash recycle to minimize waste water generation for other productive uses.

(6) Clear phase separation by special gravity process, hence less operation cost.

(7) Based on suitable feed stock, this produces biodiesel of Current World Standard Raw Glycerin to BS 2621.

(8) The crude glycerin can be further upgraded to pharmaceutical glycerin standard EU Pharmacopoeia 99.5 by distillation, bleaching if required and vacuum drying.

Characteristics of Bio diesel:

Biodiesel as an automotive fuel has similar properties to petro diesel and as such can be directly used in existing diesel engines with no or minor modifications. It can be used alone or mixed in any ratio with petro diesel. The most common blend is B20, a mixture of 20% biodiesel with 80% petroleum diesel. Biodiesel has 11 % Oxygen by weight and essentially contain no Sulphur or aromatics.

Some of the physical characteristics of bio diesel are given in Table

Table - Physical properties of bio diesel:

Sr. No.	Properties	Value
1	Specific gravity	0.88
2	Viscosity @ 20 @ (centistokes)	7.5
3	Cetane index	49
4	Cold filter plugging point (^{0}C)	12
5	Net heating value (Kilojoules/lit)	33,300

Environmental benefits:

There are number of environmental benefits through use of biodiesel, which are given as below:

(1) The use of bio-fuel avoids fossil fuel use and hence avoids CO_2 / CO emission in atmosphere. It is one of environmental friendly option

(2) It is a promising alternative fuels source for future especially for automobiles.

(3) Substantial reduction of unburned hydrocarbon, carbon monoxide and particulate matter hence no pollution.

(4) Decrease the solid carbon fraction of particulate matter.

(5) Increase in the green cover as result of plantation would check soil

erosion and retain moisture and soil nutrients.

(6) Positive ecological benefits in terms of lending support to biodiversity, especially since degraded lands are required.

Biofuels also help the environment because the plants grown to make these fuels take greenhouse gases such as carbon dioxide out of the air and fix it in their roots, stem and leaves. Much of this carbon dioxide gets sequestered in the soil, reducing the overall level of carbon dioxide in the atmosphere.

Assignment: Draw a Block Diagram of Biodiesel Process

Exercise No. 5:

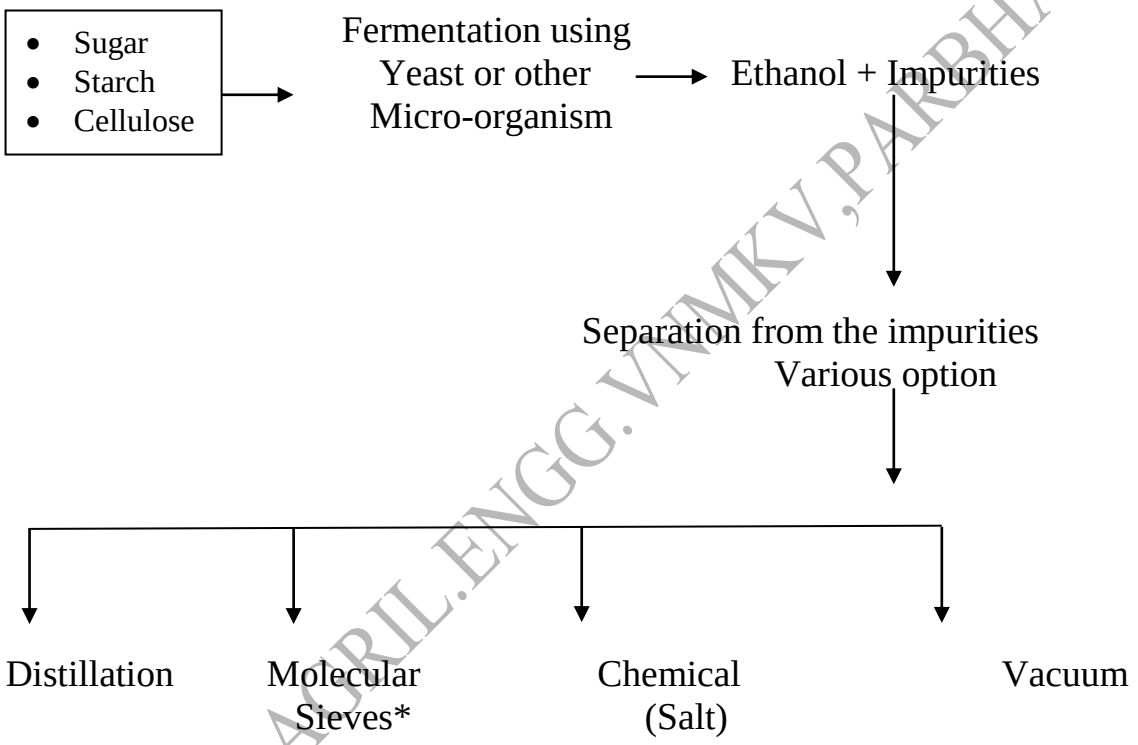
Study of Production Process of Ethanol

Ethanol production process:

The process of producing ethanol can be schematized as follows:

Ethanol Production Process

The process of producing ethanol can be schematized as follows.



*Today, almost all ethanol plants use molecular sieves for dehydration. The technology alone reduces energy use by 10 per cent per liter of ethanol produced.

Two methods are currently used to produce ethanol from grain: **Wet milling and Dry milling.**

Dry mills produce ethanol, distillers', grain and carbon dioxide

The carbon dioxide is a co-product of the fermentation, and the distillers' dried grain with soluble (DDGS) is a non-animal based, high protein livestock feed supplement, produced from the distillation and dehydration process. If distillers' grain are not dried, they are referred to as distillers' wet grain (DWG).

Wet mill facilities are 'bio-refineries' producing a host of high values product.

Wet mill processing plants produce more valuable by product than the dry mill process. For example, in wet mill plant, using corn as feed stock, they produce:

(1) Ethanol
(2) Corn gluten meat (which can be used as natural herbicides)
(3) Corn gluten feed (also used as animal feed).
(4) Corn germ meal
(5) Corn starch
(6) Corn oil and
(7) Corn syrup and high fructose corn syrups.

Assignment: Draw a Block Diagrams of Wet milling and Dry milling for Ethanol production.

Exercise No. 6:

Study of Production Process of Briquettes

Briquetting Process:

The series of steps involved in the briquetting process are

1. Collection of raw materials
2. Preparation of raw materials
3. Compaction
4. Cooling and Storage.

Collection of raw materials

In general, any material that will burn, but is not in a convenient shape, size or form to be readily usable as fuel is a good candidate for briquetting.

Preparation of raw materials

The preparation of raw materials includes drying, size reduction, mixing of raw materials in correct proportion, mixing of raw materials with binder etc.

Drying

The raw materials are available in higher moisture contents than what required for briquetting. Drying can be done in open air (sun), in solar driers, with a heater or with hot air.

Size reduction

The raw material is first reduced in size by shredding, chopping, crushing, breaking, rolling, hammering, milling, grinding, cutting etc. until it reaches a suitably small and uniform size (1 to 10 mm). For some materials which are available in the size range of 1 to 10mm need not be size reduced. Since the size reduction process consumes a good deal of energy, this should be as short as possible.

Raw material mixing

It is desirable to make briquettes of more than one raw material. Mixing will be done in proper proportion in such a way that the product should have good compaction and high calorific value.

Compaction

Compaction process takes place inside the briquetting machine. The process depends on the briquetting technology adopted.

Briquetting Technologies

Briquetting technologies used in the briquetting of the agro residues are divided into three categories. They are (i) high pressure or high compaction technology, (ii) Medium pressure technology and (iii) low pressure technology. In high pressure briquetting machines, the pressure reaches the value of 100 MPa. This type is suitable for the residues of high lignin content. At this high pressure the temperature rises to about 200 - 250^{o} C, which is sufficient to fuse the lignin content of the residue, which acts as a binder and so, no need of any additional binding material. In medium pressure type of machines, the pressure developed will be in the range of 5 MPa and 100MPa which results in lower heat generation. This type of machines requires additional heating to melt the lignin content of the agro residues which eliminates the use of an additional binder material. The third type of machine called the low pressure machines works at a pressure less than 5 MPa and room temperature. This type of machines requires addition of binding materials. This type of machines is applicable for the carbonized materials due to the lack of the lignin material.

The high pressure compaction technology for briquetting of agro residues can be differentiated in to two types (i) hydraulic piston press type and (ii) screw press type. Among these two technologies hydraulic piston press type was predominantly used to produce briquettes in India, particularly in Tamil Nadu all the briquette producing firms' uses hydraulic piston press technology for briquetting. Mostly cylindrical shaped briquettes with 30 mm to 90 mm diameter were produced. All the commercial firms involved in briquette making produces 60 mm and 90 mm diameter briquettes.

Cooling and Storage of briquettes

Briquettes extruding out of the machines are hot with temperatures exceeding 100^{o}C. They have to be cooled and stored in dry place.

Uses for Briquettes

The most frequent applications for this type of fuel are of both a domestic and industrial nature; from fireplaces or stoves to boilers generating hot water and steam. Tea industries, wine distilleries, textile industries, and farms are the major sectors using briquettes. Briquettes are also used in gasification process for electricity production.

Advantages of agro residual briquettes:

- The process increase the net calorific value of material per unit volume
- End product is easy to transport and store
- The fuel produced is uniform in size and quality
- Helps solve the problem of residue disposal
- Helps to reduce deforestation by providing a substitute for fuel wood.
- The process reduce/eliminates the possibility of spontaneous combustion waste
- The process reduces biodegradation of residues

Necessary requirements to start a briquette production unit

1. Land requirement:

Land area of minimum 1 acre is required for starting a briquette production unit to store the raw materials for briquetting and produced briquettes.

2. Raw materials:

Continuous availability of raw materials is a major factor for profitable briquette production.

3. Drying facility to dry raw materials:

The raw materials which are commonly available are with higher moisture content. So, any of the drying technologies such as solar driers/ heater/ hot air generator system is required to bring down the moisture content to an desirable level for briquetting.

4. Shredding machine:

A shredding machine with minimum of 5 hp motor is required to powder the agro residues for briquetting.

5. Briquetting machine:

A high pressure hydraulic piston press type briquetting machine powered by minimum of 50 hp motor is required to produce binder less briquettes from agro residues.

Exercise No. 7:

Study of Solar Photovoltaic Fencing

The Solar module generates the DC energy and charges the Battery. The output of the battery is connected to Energizer or Controller or Charger or Fencer. The energizer will produce a short, high voltage pulse at regular rate of one pulse per second. The live wire of the energizer is connected to the fence wire and the earth terminal to the Earth system.

Animal / Intruder touching the live wire creates a path for the current through its body to the ground and back to the energizer via the earth system and completes the circuit. Thus the intruder will receive a shock, the greater the shock the intruder receives the more lasting the memory will be avoided in future.

The Energizer has to be set up with its earth terminal coupled to an adequate earthing or grounding system. The live terminal is coupled to the live insulated wires of the fence. Energizer will send an electric current along an insulated steel wire. An animal or intruder touching the live wire creates a path for the electrical current through its body to the ground and back to the Energizer via the earth or ground system, thus completing the circuit. The greater the shock the animal receives the more lasting the memory will be and the more the fence will be avoided in the future. The shock felt is a combination of fence voltage and pulses time or energy. The higher the *joule r ting of the energizer the greater the shock and the greater the fence performance.

The basic building blocks of a power fence are:

1. Energizer
2. Earthing (Grounding System) and
3. Fence system

Components of solar power fencing system:

Solar panel:

Solar panel acts simply as a battery charger. It converts the sunlight directly in to DC current. The size of the solar panel depends upon the energizer size, power setting, geographical locations, level of usage, full year, and summer or spring autumn.

Battery:
Battery acts as energy storage device (12 V/100AH). It stores the electricity generated by the solar panel, which allows the energizer to operate at night or during cloudy day. While selecting battery points should be considered:
1) It must be sufficient capacity to reliably power the energizer during winter and cloudy day, 2) designed for regular charge and discharge cycles without permanent damage by deep cycle, marine and leisure batteries.

Energizer:
The heart of the Power fence is the Energizer. The energizer is selected depending on the animals to be controls, length of the fence and number of strands. Main function of the energizer is to produce short and sharp pulses of about 8000 volts at regular intervals. The power input is from the DC energy from battery. The energizer should be protected from children, should be enclosed, free from mechanical damage and away from inflammable material.

Earthing system:
The earthing system must be well adjusted in order to complete the pulse circuit and give an effective shock to animals. The earth (ground) system of the energizing device is similar to the radio antenna or aerial as shown in. As a large radio requires a large antenna to effectively collect sound waves and high powered energizer requires large earth (ground) system to collect the large number of electrons from the soil earth (ground) system must be perfect of that the pulse can complete its circuit and give an effective shock to animal.

Fence system: The fence system consist of following components

1) Fence wire: It is used to apply the pulsating power through it. It is smooth one and made up of galvanized iron (G. I.) metal. A 2.5 mm (12.5 gauge) high tensile (H.T.) wire is recommended for electric fence systems.
2) Main post: It is a large diameter (Approximately 3-4 cm) and height 2.6 m galvanized iron pipe. After every 150 m distance it give great support to fence wire. The grouting is done at 60 to 75 cm depth with the help of cement concrete.
3) Supporting post: It is galvanized iron pipe having diameter 1 to 2 cm, used to support the main post from both sides.
4) T-post: The T-post is galvanized iron (G.I.) post of T cross section. It is used in between the two main posts to support or to mount the fence wire on it. It has height 2.6 m including 60-75 cm grouting. The

distance between main post and T-post is six meter and the spacing between two T-post is also six meter.

5) Lightning diverter (lightning strikes) and choke kit: Lightning strikes can damage energizers. The damage can be minimized by disconnecting the energizer from the fence line and unplugging it from the power supply during electrical storms. An IG684K lightning diverter kit is recommended to minimize energizer damage. Lightning always finds the easiest way to earth. Therefore earth (ground) system of the lightning diverters must better than the energizer earth (ground).
6) Super earth kit: It consists of earthing rods of stainless steel (122 cm length) along with the earthing material bag. There are seven earthing rods at central farm for two units.
7) Super strain insulator: They are high insulators used to join the fence wire to the main post, while running along its lengths. The strain insulator is specially designed plastic insulator. Its main function is to avoid direct contact between live fence wire and main post.
8) Permanent wire tightener and chain wire strainer: Wires can be tensioned by using a chain wire strainer with a built-in tension indicator or by using a permanent wire tightener.
9) Tension springs: It is used in fence line to release the tension on fence line and protect them the breaking down. When animals are forced through electric fences bush fire or by dogs, in such situation the springs gets released which releases load or pressure on fence line and thus avoid the breaking down of fence line.
10) Double insulted lead out cable: This is one of the insulated cable used to give connections from battery to energizer, energizer to fence live line, energizer to earthing system; where.
11) Joint clamps: It is specially designed iron clamps used join one fence wire to another fence wire. In this fencing system, it is used to join the four live wire and four-earth wire.
12) Cut-out switches: It is used to help find faults by isolating sections of the fencing system. Use two screws to attach a cut out switch to the inside a post from loop in tails from second wire and fasten securely to base of cut out switch.
13) Fence voltage alarm: Alarm on earth output and fence voltage alert you if any animal control is at risk. When voltage in live fence wire drops 3.6 KV due to any unusual fault, the fence voltage alarm get ON and siren gives a high frequency sound which alert you

Precautions:

1) Never use household electrical cable
2) Never use copper wire undergate cable because electrolysis problems occur where it is joined to the galvanized fencing wire.
3) Never electrify barbed wire. It is dangerous, has the potential to cause faults and is illegal in some countries.

Assignment: Draw a Block Diagrams of solar power fencing system.

Exercise No. 8:

Study of Solar Cookers

Solar cooking: Solar cooker works on solar energy and need no fuel, no smoke, no soot's spoil cooking utensils and keeps the environment clean.

The principle methods of cooking food are boiling, frying, roasting and baking. For preparation of pulse, vegetables and rice, the process temperature of food being cooked is about 100 ^{0}C. For frying and boiling heat is supplied from all the sides of the material being cooked. In most of food water is already present in raw material. Further some water is also added to get homogenous mixture of food for cooking. In such cases once the boiling temperature close to 100 ^{0}C is reached, not much heat is required except the thermal loss from the vessel. The thermal losses are evaporation loss from the food, radiation and convection losses from vessel.

In the design of solar cooker attention is given to following points:

(1) It should provide sufficient heat for quick boiling of water.

(2) Heat loss is minimized by incorporating insulation on the sides of vessel and keeping vessel covered with a lid.

(3) The temperature for cooking food by boiling is about 100 ^{0}C, but to have high heat transfer rates, the temperature of the heat source should be high. Therefore a solar collection of sufficient size be adopted.

Classification of solar cooker:

(A) Direct or focusing type:

(i) Point focusing type
(ii) Conical reflector type
(iii) Paraboloidal reflector type
(iv) Step reflector
(v) Spherical reflection (umbrella) type.
(vi) Multi faced spherical reflector type
(vii) Cylindro-parabolic reflector type
(viii) Spherical parabolic type

(B) Indirect or box type solar cooker:

(i) Single reflector type (Box type)
(ii) Multi reflection type (Solar oven)
(iii) Flat plate collector with plane side reflector
(iv) Flat plate collector with compound side reflector.

(C) Advanced type or Separate collector and cooking chamber type solar cooker:

(i) Heat transfer system type solar cooker.
(ii) Energy storage type solar cooker
(iii) Combination of heat transfer and energy storage.

Indirect or Box type solar cooker:

It is a good reflector, absorber and transmitter. In this type of solar cooker there is direct interception of solar radiation through glazing. There is indirect interception through reflection from plane mirror is made on the black body where raw material is placed for cooking. The insulated hot box may be square, rectangular or cylindrical in shape, which is painted black from inside with double glazing for direct interception of solar radiation. The indirect entry of solar radiation through reflection is provided by single or multiple reflectors. It is slow cooker and take long time for cooking. Roasting and baking cannot be prepared with this cooker.

Parts of Box type Solar cooker:

(A) The Outer box:

The outer box of a solar cooker may be made of wood, iron sheet or fiber reinforced plastic having suitable dimensions, which accommodate black body inner box and insulating pads.

(B) The inner box:

The inner box may be made from G.T. sheet or alluminum sheet. All the four sides and the bottom are coated with black board paint for absorbing maximum amount of solar radiations.

(C) Insulator:

The hot box must be thermally insulated so that heat gained through solar radiation be effectively used for cooking purpose. Therefore, the space between outer box and inner box must be filled with a quality insulating material such as glass wool, thermocole etc.

(D) Double glazing:

A double glass cover is provided on the top of the inner box. These covers have length and breadth slightly greater than the inner box. Covers are fixed in a wooden frame maintaining a small space between the two glasses. This air cavity between glazing act as a insulator, which prevent heat loses from the inside box.

(E) Plane mirror:

A plane mirror is attached to the cooker, so that it enhances the entry of solar radiation by about 50 per cent in the inner box. In fact plane mirror acts as reflector and it increases the radiation input on the absorbing surface.

(F) Cooking container:

These containers with covers are made of alluminum or stainless steel and having dull black paint on their outer surface so that maximum amount of radiation can be directly absorbed.

Assignment: Draw a neat Diagram of Box type solar cooker and label it properly.

Exercise No. 9:

Study of Solar Water Heater

Water heating is one of the simplest applications of solar energy. Hot water is required for domestic activities as well as industrial activities. For house hold requirement hot water is used for taking bath, cleaning, utensils, washing cloths and floors etc. It has been observed that 100 litres solar water heater can save about 2000 units of electricity annually.

Advantages of Solar Water Heater:

(1) Simple in construction and installation.
(2) Almost no maintenance and operating cost.
(3) It saves time and energy for heating water.
(4) Easily retro-fittable to existing houses as per requirement.
(5) Economically viable as compared to electric water heater.
(6) Moderate temperature required, domestic affairs could easily achieved.

Types of Solar Water Heater:

(A) Collector coupled to storage tank
(B) Collector cum storage system.

(A) Collector coupled to storage tank:

This type of solar water heater can extract heat from solar collectors in two ways as (i) Natural convection (thermosiphon effect) and (ii) forced flow of water using an electrically operated pump. Collector coupled to storage tank type of water heater is used as domestic water heater where the maximum temperature required is not more than 70 ^{0}C. A typical system consists of solar collector (front glazing), metallic absorber, back insulation and collector box, insulated storage tank, piping, controls and pump.

Heating is accomplished by collection of solar radiation with flat plate collector on south facing roof or walls. The collector is usually placed below the storage tank. Cold water from the storage tank flows down to the inlet of the collector, gets heated on the collector and rises to the tank by thermosyphonic effect. A density difference created by the temperature gradient causes the fluid to flow up in the collector.

The collectors are usually oriented towards south with an inclination angle equal to latitude of the place. However, for winter use, it is preferable to keep angle of inclination at latitude + 15^0. **The required collector area for 100 liter hot water demand at 50 ^{0}C is about 2 m^2.**

In the cold climates, it is essential to mix anti freeze materials in the heat extracting fluid. In this case a heat exchanger may also be used and which prevent antifreeze fluid to flow directly through the collector. It is known as indirect natural circulation type solar water heater.

(B) Collector cum storage system type of Solar Water Heater:

In case of collector cum storage type solar water heater, all three functions i.e. solar energy collection, storage and control are combined into a single unit. A typical collector cum storage water heating system consists of three main components, front glazing (solar flat type collector), absorber sheet and insulated storage tank. Solar radiation passes through the front glazing and gets absorbed by the absorber which further heats the water. The storage tank acts as a collector cum storage for hot water.

To find out optimum size of the solar water heater, the load requirements on daily and on seasonal basis need to be known. This will help in deciding the collector area and also the storage capacity. The effectiveness of solar water heater depends on proper matching of solar collection with hot water demand.

Normally the solar water heaters are either installed on the roof top or on the ground. For system to be installed on the roof top roof construction and load bearing capacity, orientation of building, avoiding shadow due to nearby structures and trees and availability of cold water at a required height must be ensured. Similar care is taken for the systems to be installed on the ground.

The solar collectors could be either be made a part of the south facing wall of the building or could be installed on the window / door overhangs.

Normally four types of collectors are being used in solar water heaters for different temperature requirements:

(1) Unglazed polymer collector for heating of swimming pool water.
(2) Metallic collector with black painted absorbers (copper tube / copper sheet and copper tube aluminum sheet etc.) for temperature application up to 60 ^{0}C.
(3) Collector with selectively coated metallic absorber for temperature up to 80-85 ^{0}C and
(4) Evacuated tubular collector for temperature above 80 ^{0}C.

In thermosiphon type of solar water heater, the flow of water from bottom of the tank through the collector to the top of the tank takes place because of the temperature gradient created in the collector under the

sunlight. Since there is no moving part in such a system, the chances of failure are very rare.

In the forced flow type of solar water heater pumps with controls are added at appropriate place in the system to ensure the flow of water through all the collectors. This type of system can either be a single pass system where the water enters the collector array at one end and leaves at the other end or a recirculation type system. Where water is taken from the storage tank circulated through collector array and returns back to the tank repeatedly. Since in a single pass system the collector operates at comparatively lower temperature than in recirculation type. The system efficiency is better in single pass system.

Assignment: Draw a Diagrams of Thermosiphon type Solar Water Heater, Indirect Natural Circulation Solar Water Heater and Collector-Cum storage type Solar Water Heater & label them properly.

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Exercise No. 10:

Study of Solar Dryer

Drying is a method for preserving the food and helps in storage and easy transportation, because food becomes lighter due to moisture removal. Dried product not only increases shelf life but also reduces cost of transportation and storage. Traditionally food products are dried by spreading in open Sun in thin layers, called as **natural or open Sun drying**. It is economical and simple method of drying. However it is having following **disadvantages**:

(i) There is no control on the rate of drying. Product may be over dried or under dried during open sun drying.
(ii) There is no uniform drying. It results poor quality of product.
(iii) There are chances of deterioration of food in both slow and fast drying.
(iv) There is no protection of products against rain and dust storm etc.
(v) There may be considerable damage due to bird, rodents, insects and pests in open sun drying.
(vi) There may be chances of loss of germination power and nutritional in the seeds.

Therefore in order to have product quality wise and quantity wise and to prolong storage capabilities and improve transportability, controlled mechanism of solar drying system is required. Solar drying is one of the direct use of solar heat, which involves removal of moisture from the substance through the application of solar energy. The removal of moisture requires only low temperature heating, which can be met easily by absorbing solar energy by the surface. This increases the temperature of the air inside the dryer. The moisture produced from the drying product is carried out along with the exhaust air. The characteristic of solar energy is good for the drying at low temperature. The intermittent nature of solar radiation cannot affect the drying performance at low temperature. Solar energy is available at the site of use and saves transportation cost.

Natural convection type solar dryer essentially consists of an enclosure for keeping the products to be dry with a transparent cover placed over the enclosure. The internal surfaces of the enclosure are painted black. The evaporation of moisture from the product takes place due to direct absorption of solar radiation by the product as well as transfer of heat by the

internal surface. Removal of moisture takes place through naturally created draft.

In forced circulation type solar dryer, air is heated through collectors and is forced on to the drying material. Such dryers are comparatively efficient, faster and can be used for drying large agricultural products.

Dryers are also classified as direct as well as indirect type of solar dryer. In the direct type solar dryer, the material to be dry is put on trays in the dryer and direct entry of Sun through a suitable transparent cover is made and finally moisture after getting evaporated goes out. Whereas in the indirect solar dryer air heater are used through which air gets heated and passes over to drying material. Similarly direct cum indirect type of solar dryer, directly sun radiations are allowed inside the tray and also heated air from outside air collectors is used for boosting output of the dryer.

Different types of solar dryers:

(1) Natural Convection type
(2) Forced circulation type.

(1) Natural Convection type:

(a) Direct Solar dryer
(b) Indirect Solar dryer
(c) Direct cum indirect type dryer

(a) Direct Solar dryers:

(i) Rack type solar dryer
(ii) Solar cabinet type
(iii) Green house type solar tunnel dryer

(b) Indirect solar dryers:

(i) Chimney type
(ii) Fruit and vegetable dryer
(iii) Wing ventilated type

(c) Direct cum Indirect type dryer:

(i) Chimney type having both provision.

(2) Forced circulation type dryer:

(a) Bin type grain dryer
(b) Tunnel or Belt dryer
(c) Solar assisted or hybrid type
(d) Solar Timber dryer or Solar Kiln.

(a) Bin type grain dryer:

(i) Recirculating type bin dryer
(ii) Non recirculating type bin dryer
(iii) Continues cross flow dryer
(iv) Continues parallel flow bin dryer.

Assignment: Draw a Diagrams of Indirect Forced Convection Solar Dryer , Green House Solar Dryer, Natural Convection Direct cum Indirect Solar Dryer and Forced Convection Direct cum Indirect Solar Dryer & label them properly

Exercise No. 11:

Study of Solar Water Pumping System

Small capacity (360 W) surface mounted photovoltaic invertors pumping systems are available in India. These pumps are capable of yielding 20-30 cu. m. of water on a clear sunny day, from a depth of 3-5 meters. For small land holdings and cash crops where the canal irrigation system with lift is used, the 360 W pumps are reasonably effective and economical.

A variety of higher capacity and deep well water pumping units operated on solar energy, both DC and AC operated are also available. Submersible pumps suitable for photovoltaic operation and installed in 100 m diameter is also available. A simple PV water pumping system consists of a PV array, a motor/pump set, a manual tracking type metallic structure, delivery pipe network and wires. When a DC motor /Pump set is used power conditioning is not required. For an AC motor, an inverter is needed. The design of a system and choice of components are determined as a function of water demand and the characteristics of the solar and water resources. In general the well depth and solar resources determine array size and power conditioning requirements.

For static heads up to about 10 meters, a single stage centrifugal pump directly to a DC motor can be used.

For higher head pumping positive displacement pumps can be used but they do not have characteristics that can be well matched directly to a PV array. It is therefore necessary to introduce a small battery or maximum power point tracer to overcome the impedance mismatch to some extent.

The selection of the motor for the PV water pumping system is dependent on the size, requirement, need for the motor to be submerged. There are three basic types of motors as:

1. Permanent magnet DC motors
2. Wound-field motors
3. AC motors

Solar Photovoltaic Deep well Pump:

The solar photovoltaic water pumping system commonly used for deep well pumping is comprised of:

1. A solar photovoltaic array having 42 panels
2. A Dc with AC inverter

3. A submersible pump
4. Electrical cables

Each panel of SPV array is having 36 multi-crystalline solar cells interconnected in series with 1.8 kW peak capacity. The size of one panel is 1.0 m x 0.41 m. The array is having area of 17.22 m^2 of seven sub array of 6 panels, each connected in series and these sub arrays are further connected in parallel to get a maximum of 150 V open circuit voltage and 10 A at short circuit current. The power produced during sunshine hours is transmitted through electric cables to a submersible pump (5 cm. Diameter) via DC to Ac inverter. The life of the array is around 20-25 years. The array has south facing orientation to get maximum absorption of sunlight by the solar cells.

Operation and Maintenance:

Operation and maintenance requirements for a solar photovoltaic water pumping system are minimal. Maintenance is required only of the motor/pump set such as the lubrication of parts and replacement of brushes. The cleaning of the top glass surface of the photovoltaic modules with a duster is required regularly. Cleaning of the glass surface with water may be done. Batteries can be considered only in the case of motors requiring high starting current. If the batteries are of stationary, tubular type not much maintenance is needed and only addition of distilled water is required.

Assignment: Draw a Block Diagram of Solar Photovoltaic Deep Well Pump & label it properly.

Exercise No. 12:

Study of Solar Lighting System

The electricity generated by Solar Photovoltaic system can be utilized for the following applications:

1. Telecommunication
2. Railway signaling
3. Navigation aids
4. Traffic warning light
5. Remote instrumentation
6. Crop spraying and
7. Water pumping

Following are the application of electricity generated by Solar Photovoltaic system for lighting purpose:

1. Solar Lantern:

A typical solar lantern consist of a small photovoltaic module, a light source, a high frequency inverter, battery, charge controller and appropriate unit. During the day hours the module facing south is placed in the sun and it converts the solar radiations into electricity and charges the battery, which is connected to the lantern through a cable. In the evening, the lantern with the charged battery is dis-connected from the module and is available for indoor or outdoor use. A single charge can operate the lamp for about 4-5 hours.

2. Solar Street Light System:

This system is designed for outdoor application in un-electrified remote rural areas. This system is an ideal application for campus and village street lighting. This system is provided with battery storage backup sufficient to operate the light for 10-11 hours daily. The system is provided with automatic ON/OFF time switch for dusk to down operation and overcharge/ deep discharge prevention cut-off with LED indicators.

The solar street light system comprises of:

- 74 W Solar PV module
- 12 V, 75Ah Tubular plate battery with Battary box
- Charge Controller cum inverter (20-35 kHz)

- 11 W CFL lamp with fixtures
- 4 meter mild steel post above ground level with weather proof paint and mounting hardware.

The SPV module are reported to have a service life of 15-20 years. Tubular batteries provided with the solar street lighting system requires lower maintenance, longer life and gives better performance. The system electronics provide for over-charge and over-discharge cut-off essential for preventing battery and luminaries damages.

3. **Domestic Lighting System:**

The following types of domestic lighting systems are available in our country:

a) Fixed domestic lighting units (one module, 2 CFL and 7 W each with sealed battery and controls)
b) Portable lighting units-lanterns (10 W module, 5-7 Watt CFL and sealed battery)
c) Service connections from photovoltaic plants.

4. **Community PV Lighting System and PV Power Plants:**

For village level use, two types of systems are available:

a) A 300 W PV installation for the community centers in villages, largely comprising lights
b) Village based PV power plants of 2 to 10 KW capacity or even higher capacity plants.

Assignment: Draw a Diagrams of Solar Lantern and Solar Street Lighting System & label them properly.

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Exercise No. 13:

Study of Solar Photovoltaic System

Photovoltaic fundamentals:

Photovoltaic (PV) or solar cells are often referred to semiconductor devices that convert sunlight into direct current (DC) electricity. Groups to PV cells are electrically configured into modules and arrays, which can be used to charge batteries, operate motors and to power any number of electrical loads. With the appropriate power conversion equipment, PV system can produce alternating current (AC).

Merits of PV System:

(i) PV system can be designed for a variety of applications and operational requirements.
(ii) PV system have no moving parts, are modular, easily expandable and even transportable in some cases.
(iii) Energy independence and environmental compatibility.
(iv) The fuel (sunlight) is free.
(v) No noise or pollution is created from operating PV system.
(vi) It requires minimal maintenance and have long service life.

At present the high cost of PV Modules and equipment's (as compared to conventional energy sources) is the primary limiting factor. In some cases, the surface area requirements for PV arrays may be a limiting factor. Due to the diffuse nature of sunlight and the existing sunlight, surface area requirements for PV array installations are on the order of 8 to 12 m^2 per kilo watt of array capacity.

Working of PV Cells:

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus -doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load.

A typical silicon PV cell produces about 0.5 - 0.6 Volt DC under open circuit, no load conditions. The current and power output of a PV cell depends on its efficiency and size and is proportional to the intensity of sunlight striking the surface of the cell.

Under peak sunlight conditions a typical commercial PV cell with a surface area of 160 cm^2 will produce about 2 watt peak power. If the

sunlight intensity were 40 per cent of peak, this cell would produce about 0.8 watt.

PV Cells, Modules and Arrays:

Photovoltaic cells are connected electrically in series and or parallel circuits to produce higher voltages, currents and power levels. Photovoltaic modules consists of PV cell. Circuits sealed in an environmentally protective laminate, and are the fundamental building block of PV systems.

Photovoltaic panels include one or more PV modules assembled as a pre-wired, field installable unit. A photovoltaic array is the complete power generating unit, consisting of any number of PV modules and panels.

The performance of PV modules and arrays are generally rated according to their maximum DC power output, under standard test conditions. Which include module (cell) operating temperature of 25 ^{0}C, and incident solar irradiance level of 1000 W/m^{2} and under Air mass 1.5 spectral distribution. Actual performance is usually 85 to 90 per cent of STC rating.

Working of PV system:

Although a PV array produces power when exposed to sunlight, a number of other components are required to properly conduct, control, convert, distribute and store the energy produced by the array.

The specific components are a DC-AC power inverter, battery bank, and system and battery controller, auxiliary energy sources and specified electrical load appliances. In addition an assortment of balance of system (BOS) hard ware, including wiring, over current, surge protection and disconnect devices.

Batteries are often used in PV systems for the purpose of storing energy produced by the PV array during the day, and to supply it to electrical loads, as needed during the night and periods of cloudy weather. Other reasons batteries are used in PV systems are to operate the PV array near its maximum power point to power electrical loads at stable voltage. In most cases, a battery charge controller is used in these systems to protect the battery from overcharge and over discharge.

Assignment: Draw a Diagrams of Photovoltaic Cell, Photovoltaic Cells, Modules, Panels and Arrays, and Major Photovoltaic System Components & label them properly

Exercise No. 14:

Study of Solar Distillation System

There is an important need for clean, pure drinking water in many developing countries. Often water sources are brackish (i.e. contains dissolved salts) and / or contain harmful bacteria and therefore, cannot be used for drinking. In addition, there are many coastal locations where sea water is abundant but potable water is not available. Pure water is also useful for batteries, hospitals or schools.

Distillation is one of process that can be used for water purification. This requires an energy input. Solar radiations can be used as a source of energy for this process. In distillation water is evaporated, thus separating water vapour from dissolved matter and then evaporated water is condensed as pure water.

An early large scale solar still was built in 1872 to supply drinking water to a mining community in Chile.

Energy requirements for Water Distillation:

The energy required to evaporate water is equivalent to the latent heat of vaporization of water. It is 2260 KJ/kg. To produce 1 litre (1kg) of pure water by distillation brackish water requires a heat input of 2260 KJ. It should be noted that although 2260 KJ/kg is required to evaporate water, to pump a kg of water through 20 m head requires only 0.2 KJ/kg. Therefore, distillation is normally considered only where there is no local source of fresh water than can be easily pumped or lifted.

Operation of Simple Solar Still:

In the solar still the incident solar radiation is transmitted through the glass cover and is absorbed as heat by a black surface in contact with the water to be distilled.

The water is thus heated and gives off water vapour. The vapour condenses on the glass cover, which is at a lower temperature because it is in contact with the ambient air and runs down into a gutter from where it is fed to a storage tank. Here condensation is not drop wise, whereas it is film wise, therefore, condensed water along the glass cover is allowed to trap in a channel fixed at its bottom.

For high efficiency the solar still should maintain:

(a) A high feed (un-distilled) water temperature.
(b) A large temperature difference between feed water and condensing

surface.

(c) Low vapour leakage.

(a) A high feed water temperature can be achieved if:

(i) a high proportion of incoming radiation is absorbed by the feed water as heat. Hence low absorption glazing and a good radiation absorbing surface are required.

(ii) heat loss from the floor and walls are kept low.

(iii) the feed water should be shallow so there is no much heat required for evaporation.

(b) A large temperature difference can be achieved if:

(i) the condensing surface absorbs little or none of the incoming radiation.

(ii) condensing water dissipates heat which must be removed rapidly from the condensing surface by, second flow of water or air, or by condensing at night.

Design types and their performance:

(a) Single effect basin stills:

It includes only one side for trapping solar energy for the purpose of evaporation and then condensation. Single effect basin stills are having efficiencies in the range of 20-25 % are typical. Daily output of pure water is greatest in the early evening when the feed water is still hot but when outside temperatures are falling. The cover can be either glass or plastic. Glass is considered to be best for most long term applications, whereas plastic can be used for short term use. Sand concrete or water proof concrete are considered best for the basin of a long life still. For factory manufactured stills, prefabricated Ferro-concrete is a suitable material.

(b) Multiple effect basin stills:

These stills have two or more compartments. The condensing surface of the lower compartment is the floor of the upper compartment. The heat given off by the condensing vapour provides energy to vaporize the feed water of the upper compartment. Efficiency is therefore, greater than a single basin still. The efficiency of multiple-effect basin still typically being 35 % or more.

(c) Wick stills:

In wick still, the feed water flows slowly through a porous, radiation absorbing pad called the wick. The wick can be tilted so that the feed water presents a better angle to the sun. Less feed water is in the still at any time and so the water heated more quickly and to a high temperature.

Simple wick stills are more efficient than basin still and less cost as compared to still basin for the same output.

(d) Emergency still:

To provide emergency drinking water on land, a very simple still can be made. It makes use of the moisture in the earth. All that is required is a plastic cover, a bowl or bucket and a pebble.

Assignment: Draw a Diagram of Simple Solar Still & label it properly.

Exercise No. 15:

Study of Solar Pond

Solar Pond: A natural or artificial body of water for collecting and absorbing solar radiation energy and storing it as heat. Thus a solar pond combines solar energy collection and sensible heat storage.

The simplest type of solar pond is very shallow, about 5 to 10 cm deep, with a radiation absorbing (black plastic) at bottom. A bed of insulating material under the pond minimizes loss of heat to the ground. A curved cover, made of transparent fiber glass, over the pond permits entry of solar radiation but reduces losses by radiation and convection. In a suitable climate, all the pond water can become hot enough for use in space heating and agricultural and other processes. In shallow solar pond the water soon acquires a fairly uniform temperature.

In a deeper pond also temperature variations generally exist. Loss of heat from the surface at night, results in circulation of water by convection. This situation is changed if the pond contains salt water at the bottom with a layer of fresh water above it. Because of its salt content, the solar pond bottom water is more dense than the cooler fresh water at the top and hence it does not tend to rise. A relatively stable layer of heated salt water is thus produced at the bottom of the pond. A cooler fresh water acts as a heat insulator above it. This type of solar ponds are called as **Salt gradient solar pond** or **non convecting solar pond**. The energy is stored in low grade (60 to 100 ^{0}C) thermal form which might be suitable for a variety of applications such as space heating, industrial process heat and to obtain mechanical and or electrical energy.

Principle of operation and description of non-convective Solar Pond:

A solar pond is a mass of shallow water about 1 m or 2 m deep with a large collection area, which acts as a heat trap. It contains dissolved salts to generate a stable density gradient. Part of the incident solar radiation entering the pond surface is absorbed throughout the depth and the remainder which penetrates the pond is absorbed at the black bottom. If the pond were initially filled with fresh water, the lower layers would heat up, expand and rise to the surface. Because of the convective mixing and heat loss at the surface, only a small temperature rise in the pond could realized. On the other hand convection can be eliminated by initially creating a

sufficiently strong salt concentration gradient. In this case, thermal expansion in the hotter lower layers is insufficient to destabilize the pond

With convection suppressed, the heat is lost from the lower layers only by conduction. Because of the relatively low conductivity, the water acts as an insulator and permits high temperature (over 90 ^{0}C) to develop in the bottom layers.

At the bottom of the pond, a thick durable plastic liner is laid. Materials used for the liner include butyl rubber, black polyethylene and hypalon reinforced with nylon mesh. Salts like magnesium chloride, sodium chloride or sodium nitrate are dissolved in the water, the concentration varying from 20 to 30 per cent at the bottom to almost zero at the top.

In the salt-gradient solar ponds, dissolved salt is used to create layer of water with different densities- the more salt, the dense water. The concentration of the salt at the surface is low usually less than 5 per cent by weight and thus the water is relatively light. The salt concentration steadily increases with depth until at the bottom where it is very high around 20 per cent. Thus a solar pond has three zones with following salinity with depth.

(i) Surface convective zone or upper convective zone:
(0.3 - 0.5 m), Salinity < 5 %

(ii) Non convective zone 1 to 1.5 m, salinity increases with depth

(iii) Storage zone or lower convective zone: 1.5 m to 2.0 m, Salinity-20 %.

At the bottom is the **storage zone**, which is typically 1 or 2 m deep but can be as little as half a metre, or as much as several metres deep. The **surface convective zone** usually has a small thickness, around 10 to 20 cm. It has a low, uniform concentration which is close to zero and temperature uniformly close to ambient air temperature.

The **non-convective zone** is much thicker and occupies more than half depth of the pond. Both concentration and temperature increases with depth in it. This layer mainly as an insulating layer and reduces heat loss in the upward direction. This part acts as a thermal storage as some of the heat collection also takes place in this zone.

In **lower convective zone** or **storage zone**, both the concentration and temperature are nearly constant. It serves as the main heat collection as well as thermal storage medium. The deeper the zone, the more heat is stored. The lowest zone traps heats for the long periods. The main advantages of salt gradient solar ponds are:

(i) they can be tapped for energy at night as well as during the day.

(ii) even during long periods of cloud cover or even ice cover the stored energy is still available.

(iii) the solar pond is non-convecting, the warmed water stays tapped below.

Some heat is still lost by conduction to the surface, but this process is much weaker than convection. Lower waters may even warm up-to and above the boiling point of pure water. The highest temperature even recorded in solar pond is 108 ^{0}C.

Depending on location, water clarity and temperature, the solar pond can capture 10 to 20 per cent of the solar energy. Hence, each sq. m. of pond surface area can supply one half to two Giga joules of thermal energy per year at temperature from 40 ^{0}C to 80 ^{0}C.

Assignment: Draw a Diagram of Non convective type of Solar Pond & label it properly.

Exercise No. 16:

Visit to Renewable Energy Integrated Plant
Visit Report

1. Place of Visit:
2. Name of the Institute:

3. Identifying and Listing of Biogas Plants:
   (a)
   (b)
   (c)
   (d)
   (e)
4. Identifying and Listing of Gasifiers:
   (a)
   (b)
   (c)
5. Identifying and Listing of Solar equipment's:
   (a)
   (b)
   (c)
   (d)
   (e)
   (f)
   (g)

6. Identifying and Listing of Wind Energy Equipment's:
   a)
   b)
   c)
   d)
   e)
   f)