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THE NEOTIA UNIVERSITY

ज्ञानम् आत्म प्रदीपाय

Renewable Energy and Green Technology

PRACTICAL MANUAL

Course Code: CC AGL-428 Credits2 (1+1)
B.Sc. (Hons.) Agriculture

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Familiarization with Biogas Plants

Practical No: 1

Objective: Understanding biogas generation from biomass

What are Biogas and Biogas Plant?

Nature made a unique provision for destroying and disposing off wastes and dead plants and animals. This decay or decomposition is carried out by tiny microorganisms called bacteria. 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 into 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 artificial conditions is known as biogas plant.

What is 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.

How Biogas can be generated?

Biogas generation is a process widely occurring in nature and in which biomass or organic matter, in the absence of oxygen, is converted into 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:

i. **Hydrolysis:** Optimum quantity of dung with water mixture in first stage is hydrolyzed.
ii. **Acid formation:** Hydrolyzed mixture is converted in to acid mixture.
iii. **Methane generation:** The acid mixture is converted in to mechanization stage.

What are the main key features of a Biogas plant?

On the basis of the gas holder the present biogas plants are classified mainly in to two groups:

i. Floating dome type
ii. Fixed drum type.

Both the types of plants have the following functional components.

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.

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.

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

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.

What are the Constitutes 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 1:

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

Table 1: Constituent of Biogas

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).

Practical No: 2.2

Objective: To study about Pragathi Biogas plant

Apparatus:

Digester, Gas holder, Gas pipe, Mixing pit, Outlet, Inlet pipe, Outlet pipe, Partition wall, Cow dung or organic matter, Water.

Some key aspects of Pragathi Biogas Plant:

Pragathi Bio gas plant is also called as floating gas holder type plant. In this, the gas holder floats a digester. In this design the depth of pit is less than K.V.I.C plant. The foundation of this plant is of conical shape. The plant consists of essentially of two parts: (a) Digester and (b) Dome.

What are the Constructional features and Working principle of Pragathi Biogas Plant?

The digester is normally below ground level, and its design starts from the foundation in conical shape for reducing the area and cost of construction. Bottom of the digester provided with two pipe lines, called Inlet and Outlet. The pipe which is at left side is called Inlet and which is at right side is called Outlet. The digester contains animal waste in the form of slurry. Bio mass is fed in to the digester through Inlet. The digested slurry can be collected from the out let.

The dome or gas holder will be sliding on the guide ways provided in the digester. A gas pipe is fixed on the dome. By opening the gas pipe, we can utilize the gas according to our needs.

How Bio gas is being produced in K.V.I.C. Biogas Plant?

Bio gas produces in two phases, i.e.

1. Acid Phase and 2. Methane Phase

When the organic matter is decomposed or fermented in the absence of air, anaerobic group organisms called acid formers produces. This is called as Acid Phase.

The acid former bacteria are then converted in to Methane (CH_4) and carbon-di-oxide (CO_2) after two weeks. The bacteria which are strictly anaerobes are called Methane former bacteria. The combination of Methane and Carbon-di-oxide is known as Bio gas.

The produced bio gas will be stored in the dome. At the bottom of the digester a partition wall is constructed. This wall divides or separates Inlet and Outlet. The digested slurry will be removed from the out let. The digested sludge contains nitrogen, phosphorous and potassium. It can be used as an excellent fertilizer.

The calorific value of Bio gas is 1600 to 2500 KJ/m3. It is an excellent fuel for cooking, lighting, and for running the engines.

Data Required to be noted:

Name of the Bio gas plant: _____

Location : _____

Sl. No.	Date of Feeding Bio Mass	Quantity of Cow Dung	Quantity of Water Mixed	Date of Bio Gas Production	Quantity of Bio Gas Produced

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

Conclusion:

Study of Fixed Drum type Biogas Plants
Experiment No: 3

PRACTICAL NO: 3.1

Objective: To study about Janata Biogas plant.

Apparatus:

Digester, Gas holder, Gas pipe, Mixing pit, Outlet, Inlet pipe, Outlet pipe, Partition wall, Cow dung or organic matter, Water.

Some key aspects of Janata Biogas 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 KVIC plant.

What are the Constructional features and Working principle of Janata Biogas Plant?

The foundation of Janta or Janata bio gas plant is laid at the base of the underground pit on a levelled ground bear the load of the slurry as well as digester walls. Digester is cylindrical in shape constructed with bricks and cements. It contains animal waste in the form of slurry. The diameter and height ratio for the digester is kept 1.75: 1 ratio.

The gas is stored in the gas portion, which is an integral part of plant, between the dome and digester. The heights of the gas portion is above the inlet and outlet.

Dome or gas holder rests on gas portion. It must be constructed such that no leakage of gas can take place. Gas pipe is fixed on the top of the dome. Inlet and Out let portions are constructed for putting the fresh slurry inside 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 discharge of digested slurry occurs due to the pressure of the gas in the plant. Over the inlet portion an inlet mixing tank is also constructed to mix the dung and water.

How Bio gas is being produced in Janata Biogas Plant?

Bio gas produces in two phases, i.e.

1. Acid Phase and 2. Methane Phase

When the organic matter is decomposed or fermented in the absence of air anaerobic group organisms called acid formers produces. This is called as Acid Phase.

The Acid former bacteria are then converted in to Methane (CH_4) and Carbon-di-oxide (CO_2) after two weeks. The bacteria which are strictly anaerobes are called Methane former bacteria. The combination of Methane and Carbon-di-oxide is known as Bio gas.

The produced Bio gas stored in the gas holder can be utilized by opening the gas pipe according to our needs.

What are the advantages of Janata 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.

What are the disadvantages of Janata Plant?

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

Data required to be noted:

Name of the Bio gas plant: _____

Location : _____

Sl. No.	Date of Feeding Bio Mass	Quantity of Cow Dung	Quantity of Water Mixed	Quantity of BioGas Production	Quantity of BioGas Produced

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

Conclusion:

PRACTICAL NO: 3.2

Objective: To study about Deenabandhu Bio gas plant

Apparatus: Digester, Gas holder, Gas pipe, Mixing pit, Outlet, Inlet pipe, Outlet pipe, Partition wall, Cow dung or organic matter, Water.

Some key aspects of Deenabandhu Biogas 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.

What are the Constructional features and Working principle of Deenabandhu Biogas Plant?

The principle of working of this plant is same as that of Janata model. The foundation of the plant is constructed in the spherical shape. The dome and digester is constructed with same base diameter. Hence the gas holder and digester look as a single unit. The brick masonry and concrete makes it safe, as the plant is always under pressure. Inlet and Outlet portions are constructed for putting the fresh slurry inside the plant and to take the digested slurry out. The Inlet and Out let are of larger sizes, provided on each side of the digester, facing each other. The discharge of digested slurry, due to the pressure of the gas in the plant.

How Bio gas is being produced in Deenabandhu Biogas Plant?

Bio gas produces in two phases

1. Acid phase and 2. Methane phase.

When the organic matter is decomposed or fermented in the absence of air, anaerobic group organisms called acid formers producers. This is called as acid phase.

The acid former bacteria are then converted in to Methane (CH_4) and Carbon-dioxide (CO_2) after two weeks. The bacteria which are strictly anaerobes are called Methane former bacteria. The combination of methane and Carbon-di-oxide is known as Bio gas.

The produced Bio gas stored in the gas holder can be utilized by opening the gas pipe according to our needs.

Data Required to be noted:

Name of the Bio gas plant: _____

Location : _____

Sl. No.	Date of Feeding Bio Mass	Quantity of Cow Dung	Quantity of Water Mixed	Quantity of Bio Gas Production	Quantity of Bio Gas Produced

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

Conclusion:

Study of Different Types of Gasifiers

Practical No: 4

Objective: To study about different types of Gasifiers.

What is Gasification?

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.

What are the types of Gasifiers?

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) Cross draft gasifier
4) Fluidized bed 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) 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 CO2 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 0C. 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.

4) 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 Diagram of Updraft gasifier, Downdraft gasifier, Cross draft gasifier & label them properly

Biodiesel Production from Vegetable oils

Practical No: 5

Objective: To prepare biodiesel from vegetable oils

Biodiesel and its use

Biodiesel is a renewable, green fuel produced from plant and animal sources. It contains no petroleum but it can be blended at any proportion with petroleum diesel. Biodiesel is made through a transesterification reaction. It is mixable with diesel, stable in mixture, and can be burned in an unmodified diesel engine at any concentration. Using biodiesel as a vehicle fuel improves air quality and the environment, increases energy security, and provides safety benefits.

Transesterification

Transesterification is the chemical process through which one ester (a chemical having the general structure R'COOR'') is changed into another. When the original ester is reacted with an alcohol, the process is called alcoholysis.

Materials required:

- Vegetable oil (200 mL)
- 250 mL graduated cylinder
- Scale or balance
- Weigh boats
- Base (KOH) (≈ 2 g)
- Small spatula
- Methanol (40 mL)
- 50 mL graduated cylinder
- Stop cock jar
- Separatory funnel with ring stand
- Spray bottle with water

Procedure:

Calculating the amounts of reagents and catalysts required

The making of biodiesel from vegetable oil, using base as a catalyst, is simple. For every **1L** of vegetable oil, add **0.2 L** of methanol, and **8.5 g** of KOH.

In this lab, we will be starting with 200 mL of vegetable oil.

1 L oil + 0.2 L methanol + 8.5 g KOH $\rightarrow$ 1 L biodiesel + 0.2 L glycerine + soaps

Have students calculate the amounts of methanol and KOH required:

200 ml vegetable oil_____ml methanol_____g KOH

Making Potassium Methoxide:

1) Using a 50-mL graduated cylinder (located in the fume hood), measure out the correct volume of methanol under the fume hood. Pour the methanol into a volumetric flask or stopper bottle and seal it. If a fume hood is not available, place methanol in a well ventilated area.
2) Put the KOH into the volumetric flask or stopper bottle, secure seal again, and shake the it under pressure.

Making crude biodiesel:

1) Using a graduated cylinder (located near the vegetable oil), measure 200 ml of vegetable oil.
2) Pour the vegetable oil into the volumetric flask or stopper bottle with the potassium methoxide and close it.
3) Carefully and vigorously shake the mixture for at least 10 minutes.
4) Label it with your group name and the jar's contents and let sit.
5) Put it for settle down at least 20-30 minutes.
6) Transfer the separated mixture to a large separating funnel.

You should begin to see a separation in the mixture you have created. The glycerine that was cleaved from the triglyceride is denser than the biodiesel and will settle to the bottom of your container. The biodiesel will float on top as in the image above.

Washing the biodiesel:

At this point the biodiesel you have made is crude because it contains residual base, glycerine, soap, and methanol. To remove these impurities which may negatively impact fuel performance, the crude biodiesel must be washed. Because washing is a time intensive project, we suggest that you do it in several time periods for washing biodiesel.

Using a large separatory funnel pour in crude biodiesel, this will provide a clear visualization of the separation that takes place between the crude biodiesel and crude glycerine. Allow sufficient time to separate (~30 min.). Once there has been a noticeable separation, drain the crude glycerine from the biodiesel.

Using a spray bottle filled with water, gently spray water onto the surface of the biodiesel in the separatory funnel. You should notice an immediate separation as the water moves to the bottom of the funnel. Because of the polarity of water molecules, they will pull the residual catalyst, glycerine,

soap and methanol from your crude biodiesel, and leave you with a purer biodiesel. If the force of the water entering is too great, it may hydrolyze free fatty acids, which will combine with the base to form soap.

Clean Up:

1) Clean all glassware and bench space.
2) Biodiesel can be used in candles or tiki torches (not suitable for use in an engine)
3) Glycerine contains excess methanol. This can be boiled off under a fume hood and the methanol-free glycerine can be used to make soap.
4) Wash water can be sent down the drain

Laboratory safety Caution:

The methanol you will be working with is highly flammable and toxic and the base is caustic. Everyone should put on safety goggles and gloves. Check that you are wearing long pants and closed-toed shoes.

Data to be noted:

Sl. No.	Practical Conducting Time		Duration hrs.	Quantity of Glycerol Collected	Quantity of Biodiesel or methyl esters Collected	Remarks
	Started	Finished				

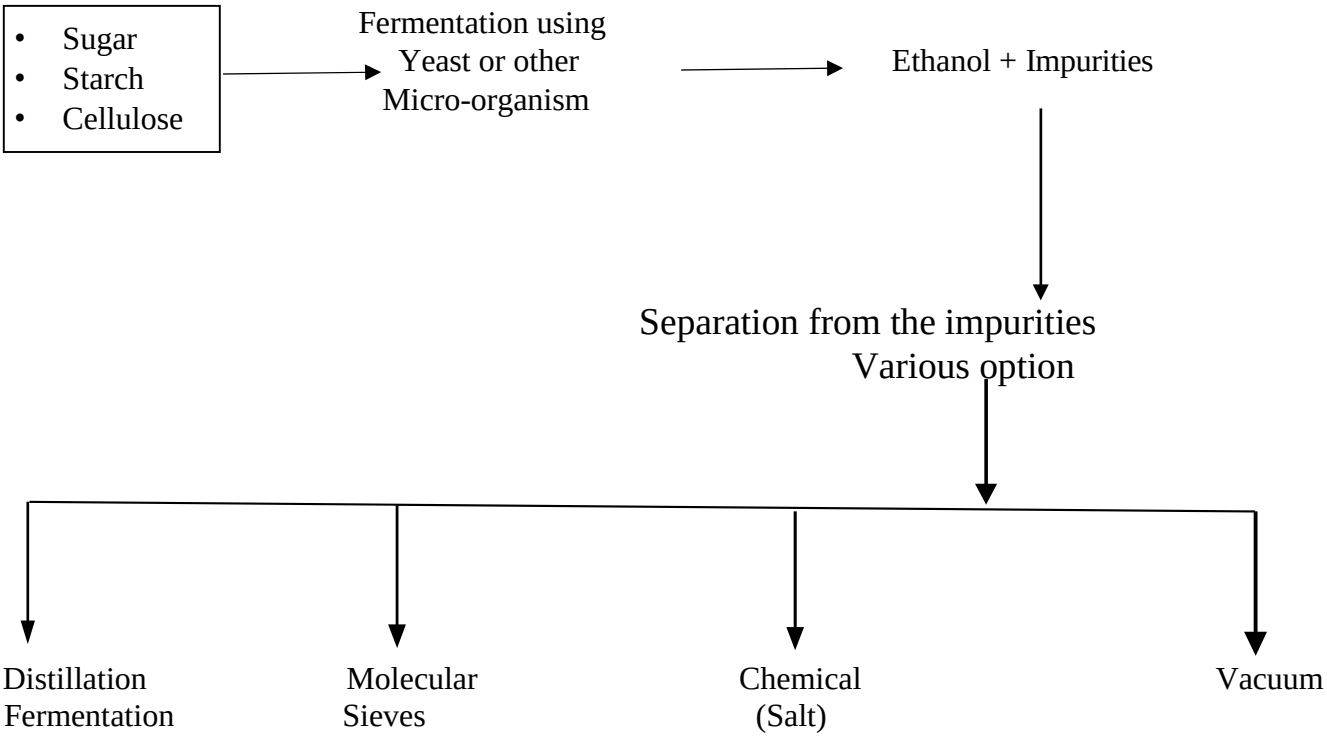
Conclusion:

Study of Production Process of Ethanol
Practical No: 5

Objective: To study about production Process of Ethanol.

Ethanol Production Process:

The process of producing ethanol can be schematized as follows:



What are the methods used to produce ethanol from grain?

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

What is Wet 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).

What is Dry milling?

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:

i. Ethanol
ii. Corn gluten meat (which can be used as natural herbicides)
iii. Corn gluten feed (also used as animal feed).
iv. Corn germ meal
v. Corn starch
vi. Corn oil and
vii. Corn syrup and high fructose corn syrups.

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

Conclusion:

Study of Production Process of Briquettes
Practical No: 7

Objective: To study about different types of Briquettes.

What are the steps of 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.

What are the 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.

What are the 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.

What are the 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:

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.

Conclusion:

Study of Solar Photovoltaic System
Practical No: 8

Objective: Study of different types of Gasifiers.

What are the 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).

What are the 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.

How PV Cells work?

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.

How does a PV system Work?

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

Conclusion:

Obtain the Current-voltage characteristics of Solar cell

Practical No: 9

Objective: To obtain the current-voltage characteristics of solar cell with cell temperature at constant light intensities at 515 wb/m^2 and 1000 wb/m^2.

Theory: The current voltage characteristics of crystalline silicon solar cell

$$I = I_0 \left[\exp\left(\frac{q(V - IR_S)}{nKT} \right) - 1 \right] + \left(V - \frac{IR_S}{R_{cn}} \right) - I_L$$

Where I_0 = reverse saturation current

q = electron charge

n = ideality factor of diode

K = Boltzmann constant

T = Temperature

R_S = series resistance

Rsn = Shunt Resistance

I_L = light generated current of a Si cell

The current- voltage characteristics of solar cell with cell temperature at constant light intensity are presented in graph. The observations were under-taken for cell temperature 32º, 42º, 50º and 60º at the constant light intensities 515 and 1000 wb/m^2. Ft is clearly visible in fig that current-voltage characteristics depends on the cell temperature. In current-voltage characteristics, it is observed that the current is maximum as well as almost constant in the lower voltage range and varies with cell temperature in the range 0.065A to 0.049A at constant light intensities 515 wb/m^2. The characteristics estimation follows the order of the cell temperature as the successive higher underestimates the lower one. The trend is reversed about voltage.

The current is found to be decreased rapidly and reduced to minimum in the range with the voltage and the characteristics corresponding to successive lower cell temperature are existed beyond the higher.

Observation:

I. At constant light intensities (515 wb/m^2):

Sl. No.	Temperature (ºC)	Current (A)	Voltage (V)
1	**32**		
2	**32**		
3	**32**		

4	**32**		
5	**32**		
6	**32**		
7	**32**		
8	**32**		
9	**32**		
10	**32**		

II. At constant light intensities (1000 wb/m^2):

Sl. No.	Temperature (ºC)	Current (A)	Voltage (V)
1	**32**		
2	**32**		
3	**32**		
4	**32**		
5	**32**		
6	**32**		
7	**32**		
8	**32**		
9	**32**		
10	**32**		

Conclusion:

Study of Solar Lighting System
Practical No: 10

Objective: To study about Solar Street Lighting System.

Apparatus:

1. Photovoltaic module or solar array
2. Lighting device
3. Inverter
4. Battery

What are the applications of solar lighting?

In our country out of six lack villages, one lack village are still to be electrified. Even in electrified villages, only a quarter of house-holds have proper connection. The bulk of rural house-holds in India, normally use kerosene lanterns for meeting their lighting requirements. These lanterns provided insufficient and poor quality of light. A variety of solar photo-voltaic system have been developed and employed for rural applications such as lighting.

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 Battery 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 overcharge 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.

Conclusion:

Study of Solar Fencing

Practical No: 11

Objective: To study about Solar Fencing System.

What is Solar Fencing System?

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 rating 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

What are the 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 underrated 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.

Conclusion:

Study of Solar Water Pumping
Practical No: 12

Objective: To study about solar water pumping.

Apparatus:

1. Solar collector array
2. Heat exchanger
3. Organic fluid
4. Heat engine
5. Condenser
6. Pump

Overview of components of Solar water pumping:

1. **Solar collector array:** It consists of solar collector and water tubes. The inner surface of the collector and the water tubes are coated with black paint.
2. **Heat Exchanger:** It consists of two pipes, one is for carrying hot water and other is for circulating organic fluid.
3. **Organic fluid:** The organic fluid changes its phase from liquid to vapor when it is hot and vapor to liquid when it gets cool.
4. **Heat engine :** It consists of a turbine
5. **Condenser:** It consists of two pipes one is for carrying organic fluid and other is for pumping the ground water.
6. **Pump:** Pump shaft is coupled with heat engine shaft. It is used to pump the water.

What is the working principle of Solar water pumping?

When the sun rays falls on the solar collector, black body absorbs the sun rays and water in the tubes gets heated up and circulates in the heat exchanger. Through the heat exchanger, hot water is again pumped back in the solar collector with the help of a pump.

The organic fluid in the other tube senses the heat produced in the heat exchanger and converts its phase in to vapor. The vapor runs the turbine provided in the heat engine and losses its heat, and again converted in to liquid. This organic fluid again pumped back in to the heat exchanger with the help of a feed pump.

Ground water is pumped with the help of a pump, which is coupled with heat engine.

Data Required to be noted

Name of the instrument : _____

Sl. No.	Practical Conducting Time	Duration hrs	Amount of Water Collected	Remarks

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

Conclusion:

Study of Concentrating Disc Type Solar Cooker Practical No: 13

Objective: To calculate the variation in light intensity with respect to the distance from the collector surface of a concentrating disc type solar cooker.

Theory:

This concentrating type Solar Cookers are capable of generating much higher temperatures and suitable for faster cooking application.

This concentrator solar cookers are the concentrating devices with a dish umbrella type reflector to focus the incident solar radiation on the cooking pot, and have a precise turning and fitting mechanism to adjust the parabolic reflector facing to the sun, with the cooking pot.

It has an aperture of 1.4 m diameter and has focal length of 0.28 m. The cooking utensil is supported at its focal point, where the bottom temperature of the utensil could be around 250 - 350° C and that temperature is suitable for boiling, roasting and frying of foods. The design of utensil supporter such that the major part of the concentrate reflected radiation is directly focused on the bottom of the cooking utensil.

The cooker requires some orientation adjustment towards the sun axis to get the optimum heat output, generally it takes about 10-15 minutes of interval. This type of cooker can meet the cooking needs of 10-15 people sunny days.

Benefits:

- No naked flame.
- No risk of burning the food.
- No smoke and inhalation problem.
- No soot accumulation of on cooking food.
- Minimal requirement of water

Specification:

- Diameter of Disc: 1.4m
- Material used in Reflector: 3mm Aluminum Sheet
- Reflectivity: More than 90%
- Focal length: 4.6 inch
- Tracking mechanism: Manual

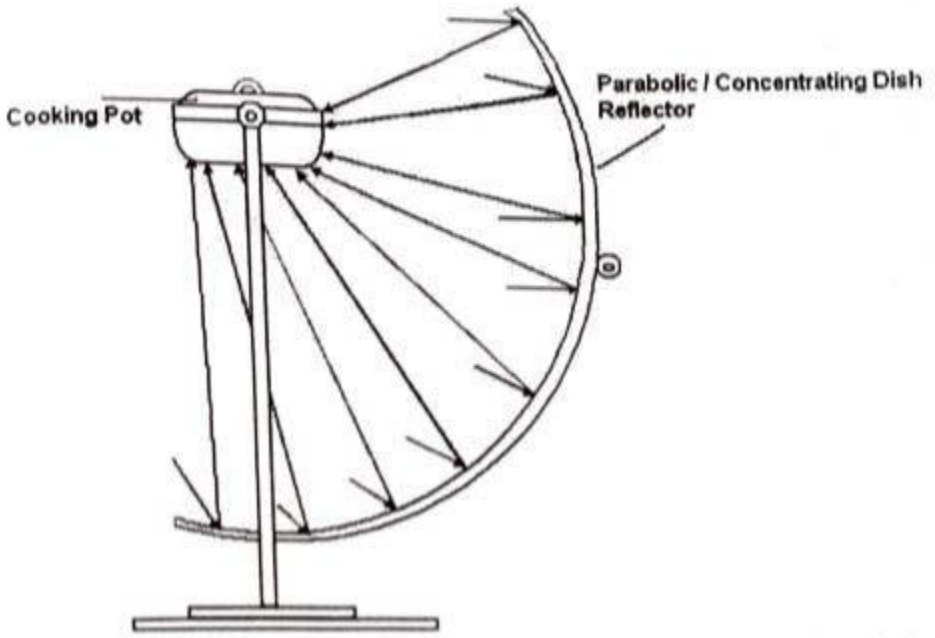
Materials required:

1. Concentrating Disc Type Solar Cooker
2. Lux meter
3. Wrench set
4. Meter Scale

Procedure:

- Cleaning of the disc before starting the Practical.
- Join two threads from one point pf the disc to the other point and locate the center point.
- Place the meter scale on the disc through the center point.
- Record the intensity at various distance from the disc of the concentrating disc cooker
- Note the maximum solar intensity available

Schematic diagram of a concentrating disc type solar cooker



Data Required to be noted:

Name of the instrument : _____

Name of the manufacturer / supplier: _____

Sl. No.	Practical Conducting Time	Distance from surface	Solar light intensity	Remarks

Conclusion:

Study of Solar Water Heater

Practical No: 14

Practical No: 14.1

Objective: To study about Thermosiphon solar water heating system.

Apparatus:

1. Flat plate collector
2. Insulated storage tank
3. Connecting pipes

Procedure:

A flat plate collector is used to collect solar radiation and converts it into thermal energy. Insulated storage tank is used to hold the hot water for use and cold water for feeding the flat plate collector.

Connecting pipes inlet and outlet is used for feeding cold water from the storage tank and taking hot water from the storage tank.

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 the bottom of the tank. Hot water for use is withdrawn from the top of the tank. An auxiliary heating system is provided for use on cloudy or rainy days.

Data Required to be noted

Name of the instrument : _____

Name of the manufacturer / supplier: _____

Sl. No.	Practical conducting Time	Quantity of Water	Initial Temperature	Final Temperature	Duration hrs.

Assignment: Draw a Diagrams of Thermosiphon type Solar Water Heater & label them properly.

Conclusion:

PRACTICAL NO: 14.2

Objective: To study about Forced circulation solar water heating system

Apparatus:

1. Arrays of flat plate collector
2. Insulated storage tank
3. Pump
4. Connecting pipes
5. Auxiliary heating system

Procedure:

Water is fed by some mechanical device like pump is known as forced circulation system. This type of water heater is used for industrial purposes where large quantity of water required to heat. The main components are:

(i) Arrays of Flat plate collector:

It is used to absorb solar radiation and convert it in to thermal energy.

(ii) Insulated storage tank:

It is used to hold the hot water for use and cold water for feeding the arrays of collector.

(iii) Pump: It is used to feed cold water into arrays of flat plate collector

(iv) Connecting pipes:

Inlet and outlet pipes are used for feeding cold water from the storage tank and taking hot water from the storage tank.

(v) Auxiliary heating system:

It is provided for use on cloudy or rainy days and during nights.

Systems of this type are well suited for places like hospitals, hotels, milk dairies, industries etc.

Data Required to be noted:

Name of the instrument : _____

Name of the manufacturer / supplier: _____

Sl. No.	Practical Conducting Time	Quantity of Water	Initial Temperature	Final Temperature	Duration hrs.	Remarks

Assignment: Draw a Diagrams of Thermosiphon type Solar Water Heater & label them properly.

Conclusion:

Questions for Evaluation:

After performing the practical task the students are required to answer the following questions:

Q1. What are the apparatus required for solar water heating system?

Ans.

Q2. What is the use of flat plate collector?

Ans.

Q3. What are the different types of solar water heating systems?

Ans.

Q4. What is the use of an auxiliary heating system?

Ans.

Q5. What is the use of insulating material?

Ans.

Q6. What are the main apparatus used in forced circulation solar water heating system?

Ans.

Study of Solar Dryer

Practical No: 15

Objective: Study of Solar Dryer.

Introduction:

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**:

a. There is no control on the rate of drying. Product may be over dried or under dried during open sun drying.
b. There is no uniform drying. It results poor quality of product.
c. There are chances of deterioration of food in both slow and fast drying.
d. (There is no protection of products against rain and dust storm etc.
e. There may be considerable damage due to bird, rodents, insects and pests in open sun drying.
f. 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

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

(b) Indirect Solar dryer

(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
  (i) Recirculating type bin dryer
  (ii) Non recirculating type bin dryer
  (iii) Continues cross flow dryer
  (iv) Continues parallel flow bin dryer
(b) Tunnel or Belt dryer
(c) Solar assisted or hybrid type
(d) Solar Timber dryer or Solar Kiln.

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

Conclusion:

Study of Solar Distillation System
Practical No: 16

Objective: Study of Solar Distillation or Solar Still.

Apparatus:

1. Transparent Covers
2. Filler
3. Over flow line
4. Insulation
5. Blackened surface Basin

Objective:

Fresh water is a necessity for the sustenance of life and also the key to man's prosperity. It is observed that arid and coastal areas which are thinly populated, the 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 by using solar still.

Procedure: It consists of an insulated blackened basin containing saline water. A transparent cover is enclosed on the top of the basin. It has a roof like shape. The cover, which is usually glass or plastic sheet. . Solar radiation passes through the cover and is absorbed and converted into heat in the black surface. Impure water in the basin is heated and the vapor produced is condensed as water drops on the interior of the roof. The condensed water can be collected through the pipes provided in the solar still.

Data Required to be noted

Name of the instrument : _____

Name of the manufacturer / supplier: _____

Sl. No.	Practical Conducting Time	Duration hrs.	Quantity of Saline or Impure Water	Quantity of Pure Water Collected	Remarks

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

Conclusion:

Questions for evaluation:

After performing the practical task the students are required to answer the following questions:

Q1. What are the main parts of Solar Distillation or Solar Still?

Ans.

Q2. What is the use of Transparent?

Ans.

Q3. What acts as an absorber?

Ans.

Q4. What is the use of Solar Distillation?

Ans.

Solar Pond
Practical No:

Objective: Study of Solar Pond.

Introduction:

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 denser 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 be 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.

Study of Horizontal Axis Wind Mill
Practical No: 18

Objective: Study of Horizontal Axis Wind Mill

Apparatus:

1. Induction generator and gear box
2. Blade (Single or Double or Multi-blade)
3. Rotor
4. Transmission
5. Tower

Description:

In this, the axis of rotation of wind mill is horizontal. Horizontal axis wind mills are further classified as single bladed, double bladed and multi-bladed.

Main components of the wind mill are:

a) **Rotor:** It consists of blades. Rotor is mounted on the horizontal shaft and connected to the generator through transmission with the help of bearings.

b) **Transmission:** It consists of gears, belts, chains, clutches etc., It controls the wind speed or rotor speed according to the generator speed. When the wind speed is low, the transmission system increases rotor sped. Similarly when the wind speed high, it decreases the rotor speed.

c) **Generator:** It generates Electricity

d) **Tower:** Tower is a supporting device. It holds all the parts of wind mill. It is made of reinforced concrete or Iron poles. The height of the tower depends on the capacity of the plant.

Assignment: Draw a Diagram of Simple Horizontal Axis Wind Mill & label it properly.

Conclusion:

Question for Evaluation:

After performing the practical task the students are required to answer the following questions:

Q1. What are the main parts of Horizontal wind mill?

Ans.

Q2. How do you classify wind mills?

Ans.

Q3. What are caused because of two factors?

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

(ii) The rotation of the earth about its axis and its motion around the sun Q4. How wind mill works?

Ans.