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Renewable Energy and Green Technology

A Laboratory Manual

Prepared by
Dr. Mahesh Prasad Tripathi

Dr. Khem Singh Gill Akal College of Agriculture
Eternal University, Baru Sahib,
Sirmour-173101, Himachal Pradesh, India
2021

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Dr. Mahesh Prasad Tripathi

Assistant Professor (Agricultural Engineering)

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Dr. Khem Singh Gill Akal College of Agriculture

Eternal University,

Baru Sahib, Rajgarh Himachal Pradesh- 173101

2021

Dr. S.K. Sharma
Dean
Dr. Khem Singh Gill Akal College of Agriculture,
Eternal University, Baru Sahib, District Sirmour (HP) 173101

Foreword

The manual "Renewable Energy and Green Technology" prepared by Dr. Mahesh P. Tripathi is intended primarily as a manual is for B.Sc. (Hons.) Agriculture students of Indian Universities. About 70% of India's energy generation capacity is from fossil fuels, with coal accounting for 40% of India's total energy consumption followed by crude oil and natural gas at 24% and 6% respectively. India is largely dependent on fossil fuel imports to meet its energy demands — by 2030. India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption. In 2009-10, the country imported 159.26 million tons of crude oil which amount to 80% of its domestic crude oil consumption and 31% of the country's total imports are oil imports. The growth of electricity generation in India has been hindered by domestic coal shortages and as a consequence, India's coal imports for electricity generation increased by 18% in 2010. Due to rapid economic expansion, India has one of the world's fastest growing energy markets and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption. Given India's growing energy demands and limited domestic fossil fuel reserves, the country has ambitious plans to expand its renewable and nuclear power industries. India has the world's fifth largest wind power market and plans to add about 20 GW of solar power capacity by 2022. India also envisages increasing the contribution of nuclear power to overall electricity generation capacity from 4.2% to 9% within 25 years. The country has five nuclear reactors under construction (third highest in the world) and plans to construct 18 additional nuclear reactors (second highest in the world) by 2025. This being the first attempt to prepare a manual on "Renewable Energy and Green Technology" for B.Sc. (Hons) Agriculture students will surely be appropriated by the teachers and the students alike and in my opinion will be of great help to them, I appreciate the efforts of Dr. Mahesh P. Tripathi Assistant Professor (Agricultural Engineering) for his keen interest and putting his hard work for bringing this manuscript in presentable form for all interested in Renewable Energy and Green Technology. With these words, I sign off to let the manual speak for itself.

SKSharma
(S.K. Sharma)
Dean

Preface

The present manual is Renewable Energy and Green Technology is for B.Sc. (Hons.) Agriculture students of Indian Universities. The Agriculture sector in our country is now facing serious challenges particularly relating to small and marginal farmers. Low productivity increasing cost of cultivation and unremunerated prices are some of the issues facing the farming sector today so however may be solution of Renewable energy sources derive their energy from existing flows of energy from ongoing natural processes, such as sunshine, wind, flowing water, biological processes, and geothermal heat flows. A general definition of renewable energy sources is that renewable energy is captured from an energy resource that is replaced rapidly by a natural process such as power generated from the sun or from the wind. Currently, the most promising alternative energy sources include wind power, solar power, and hydroelectric power. Other renewable sources include geothermal and ocean energies, as well as biomass and ethanol as renewable fuels.

It is hoped that the present manual will be useful for the students, researchers, extension workers as well as practicing engineers. Author welcome suggestions and comments are welcome for further improvement of this manual.

Eternal University Mahesh P. Tripathi
2021

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EXERCISE -1

Familiarization with Renewable Energy Gadgets

Renewable Energy

Renewable energy sources also called non-conventional energy are sources that are continuously replenished by natural processes. For example, solar energy, wind energy, bio-energy bio-fuels grown sustain ably), hydropower etc., are some of the examples of renewable energy sources A renewable energy system converts the energy found in sunlight, wind, falling-water, sea waves, geothermal heat, or biomass into a form, we can use such as heat or electricity. Most of the renewable energy comes either directly or indirectly from sun and wind and can never be exhausted, and therefore they are called renewable.

Various Forms of Renewable Energy

1. Solar energy
2. Wind energy
3. Bio energy and Biofuel
4. Hydro energy
5. Geothermal energy
6. Wave and tidal energy

1. Solar energy

Solar energy is the most readily available and free source of energy since prehistoric times. India receives solar energy in the region of 5 to 7 kWh/m^2 for 300 to 330 days in a year. This energy is sufficient to set up 20 MW solar power plants per square kilometer land area.

Solar energy can be utilized through two different routes, as solar thermal route and solar electric (solar photovoltaic) routes. Solar thermal route uses the sun's heat to produce hot water or air, cook food, drying materials etc. Solar photovoltaic uses sun's heat to produce electricity for lighting home and building, running motors, pumps, electric appliances, and lighting.

2. Wind energy

Wind energy is basically harnessing of wind power to produce electricity. The kinetic energy of the wind is converted to electrical energy. When solar radiation enters the earth's atmosphere, different regions of the atmosphere are heated to different degrees because of earth curvature. This heating is higher at the equator and lowest at the poles. Since air tends to flow from warmer to cooler regions, this causes what we call winds, and it is these airflows that are harnessed in windmills and wind turbines to produce power.

3. Bio energy

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities. It is derived from numerous sources, including the by-products from the wood industry, agricultural crops, raw material from the forest, household wastes etc.

Biofuel: Unlike other renewable energy sources, biomass can be converted directly into liquid fuels— biofuels— for our transportation needs (cars, trucks, buses, airplanes, and trains). The two most common types of biofuels are ethanol and biodiesel.

Ethanol is an alcohol, similar to that used in beer and wine. It is made by fermenting any biomass high in carbohydrates (starches, sugars, or celluloses) through a process similar to brewing beer. Ethanol is mostly used as a fuel additive to cut down a vehicle's carbon monoxide and other smog-causing emissions. Flexible-fuel vehicles, which run on mixtures of gasoline and up to 85% ethanol, are now available.

Biodiesel, produced by plants such as rapeseed (canola), sunflowers and soybeans, can be extracted and refined into fuel, which can be burned in diesel engines and buses. Biodiesel can also make by combining alcohol with vegetable oil, or recycled cooking greases. It can be used as an additive to reduce vehicle emissions (typically 20%) or in its pure form as a renewable alternative fuel for diesel engines.

4. Hydro energy

The potential energy of falling water, captured and converted to mechanical energy by waterwheels, powered the start of the industrial revolution. Wherever sufficient head, or change in elevation, could be found, rivers and streams were dammed and mills were built. Water under pressure flows through a turbine causing it to spin. The Turbine is connected to a generator, which produces electricity.

5. Geothermal energy

Geothermal energy is heat derived within the sub-surface of the earth. Water and/or steam carry the geothermal energy to the Earth's surface. Depending on its characteristics, geothermal energy can be used for heating and cooling purposes or be harnessed to generate clean electricity. However, for electricity, generation high or medium temperature resources are needed, which are usually located close to tectonically active regions.

6. Tidal and Ocean Energy

Tidal electricity generation involves the construction of a barrage across an estuary to block the incoming and outgoing tide. The head of water is then used to drive turbines to generate electricity from the elevated water in the basin as in hydroelectric dams.

Oceans cover more than 70% of Earth's surface, making them the world's largest solar collectors. Ocean energy draws on the energy of ocean waves, tides, or on the thermal energy (heat) stored in the ocean. The sun warms the surface water a lot more than the deep ocean water, and this temperature difference stores thermal energy.

EXERCISE - 2

To Study Biogas Plants

Bi gas generated through a process of anaerobic digestion of Bio Mass. Bio Mass is organic matter produced by plants, both terrestrial (those grown on land) and aquatic (those grown in water) and their derivatives. It includes forest crops and residues, crops grown especially for their energy content on “energy farms” and animal manure.

Biogas is a clean and efficient fuel. The chief constituent of biogas is methane (65%). It is a mixture of following gases.

S.No.	Gas	Amount (%)
1.	Methane (CH_4)	55–70
2.	Carbon dioxide (CO_2)	30–45
3.	Hydrogen sulphide (H_2S)	1 – 2
4.	Hydrogen (H_2)	
5.	Ammonia (NH_3)	
6.	Carbon monoxide (CO)	trace
7.	Nitrogen (N_2)	trace
8.	Oxygen (O_2)	trace

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

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

COMPARISON OF BIO-GAS WITH OTHER FUELS

S. No.	Name of fuel and Unit	Calorific Value (Kcal)	Mode of burning
1.	Gobar (M^3)	4713	Standard burner
2.	Kerosene (lit)	9122	Pressure stove
3.	Fire wood (Kg)	4700	Open chulha
4.	Cow-dung cake (Kg)	2092	Open chulha
5.	Charcoal (Kg)	6930	Open chulha
6.	Butane (LPG) Kg	10882	Standard burner
7.	Coal gas (M^3)	4004	Standard burner
8.	Electricity (Kwh)	860	Hot plate

SELECTION OF SITE FOR INSTALLATION OF A BIO GAS PLANT Following points to be considered while selecting a biogas plant

1. The distance between the plant and site of gas consumption or kitchen should be less to Minimize cost on gas pipe line and gas leakage.
2. It should be near the cattle-shed to minimize the distance for carrying cattle dung and transportation cost.
3. There should be enough space for storage of digested slurry or construction of compost pit.
4. It should be 10 to 15 meters away from any drinking water well to prevent contamination of water.
5. The area should be free from roots of trees which are likely to creep into the digester and cause damage.
6. It should be open to receive the Sun's rays for most part of the day and to keep the plant in warm. The sunlight should fall on the plant as temperature between 15^oC to 30^oC is essential for gas generation at good rate.
7. It should be on an elevated area so that the plant does not get submerged during normal rains.
8. Sufficient space must be available for day to day operation and maintenance. As a guide line 10 to 12 M2 area is needed per M^3 of the gas.
9. Plenty of water must be available as the Cow dung slurry with a solid concentration of 7% to 9% is used.

CONSTRUCTION MATERIAL FOR BIO GAS PLANT

S. No.	Material	Quality needed
1.	Bricks	Good quality bricks preferably Machine made first class bricks with uniform size and shape.
2.	Cement	Pure port and land with no impurities packed in Polythene bags.
3.	Sand	Fine and Coarse with good quality.
4.	Steel for Bigger size plant	Standard
5.	Concrete	Hard without any impurities
6.	Reinforced concrete for larger tank	Having good quality composition of cement, sand and water
7.	Asbestos - Cement pipes for inlet and out let.	Good qualities with no leakage and should have uniform diameter and length as required.
8.	Ferro – Cement	Having few layers of iron wire Mesh plastered with diameter and length as required.
9.	Bricks Ferro – Cement	Outer wall of brick, inner surface plastered with Ferro-Cement.
10.	Plastic	Fiber-glass Reinforced plastics PVC polythene, etc.

USES OF BIOGAS

1. Domestic fuel
2. For street lighting
3. Generation of electricity
4. If compressed, it can replace compressed natural gas for use in vehicles.

ADVANTAGES OF BIOGAS AS A FUEL

1. High calorific value
2. Clean fuel
3. No residue produced
4. No smoke produced
5. Non polluting
6. Economical
7. Can be supplied through pipe lines
8. Burns readily - has a convenient ignition temperature

PRODUCTION OF BIOGAS - THE BIOGAS PLANTS

There are two types of biogas plants in usage for the production of biogas. These are:

1. The fixed- dome type of biogas plant
2. The floating gas holder type of biogas plant

Principle

Biogas is produced as a result of anaerobic fermentation of biomass in the presence of water.

1. Fixed- Dome Type of Biogas Plant

Construction

The biogas plant is a brick and cement structure having the following five sections:

1. **Mixing tank**: Mixing tank present above the ground level.
2. **Inlet tank**: The mixing tank opens underground into a sloping inlet chamber.
3. **Digester**: The inlet chamber opens from below into the digester which is a huge tank with a dome like ceiling. The ceiling of the digester has an outlet with a valve for the supply of biogas.
4. **Outlet tank**: The digester opens from below into an outlet chamber.
5. **Overflow tank**: The outlet chamber opens from the top into a small over flow tank.

Raw material required

1. Forms of biomass listed below may be used along with water.
2. Animal dung
3. Poultry wastes
4. Plant wastes (Husk, grass, weeds etc.)
5. Human excreta
6. Industrial wastes (Saw dust, wastes from food processing industries)
7. Domestic wastes (Vegetable peels, waste food materials)

Working of fixed dome type biogas plant

The various forms of biomass are mixed with an equal quantity of water in the mixing tank. This forms the slurry. The slurry is fed into the digester through the inlet chamber. When the digester is partially filled with the slurry, the introduction of slurry is stopped and the plant is left unused for about two months. During these two months, anaerobic bacteria present in the slurry decomposes or ferments the biomass in the presence of water. As a result of anaerobic fermentation, biogas is formed, which starts collecting in the dome of the digester. As more and more biogas starts collecting, the pressure exerted by the biogas forces the spent slurry into the outlet chamber. From the outlet chamber, the spent slurry overflows into the overflow tank. The spent slurry is manually removed from the overflow tank and used as manure for plants. The gas valve connected to a system of pipelines is opened when a supply of biogas is required. To obtain a continuous supply of biogas, a functioning plant can be fed continuously with the prepared slurry.

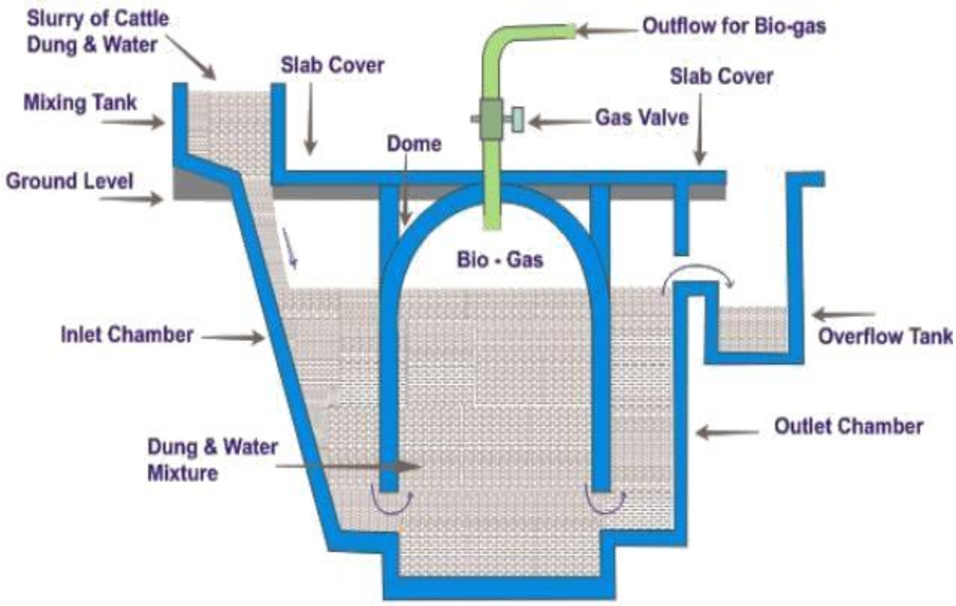


Fig.1 Fixed dome type biogas plant

Advantages of fixed dome type biogas

1. Requires only locally and easily available materials for construction.
2. Inexpensive.
3. Easy to construct.

2. Floating Gas Holder type of Biogas Plant

Construction

The floating gas holder type of biogas plant has the following chambers/ sections:

1. **Mixing Tank** - present above the ground level.
2. **Digester tank -** Deep underground well-like structure. It is divided into two chambers by a partition wall in between. It has two long cement pipes
   - i) Inlet pipe opening into the inlet chamber for introduction of slurry.
   - ii) Outlet pipe opening into the overflow tank for removal of spent slurry.
3. **Gas holder** - an inverted steel drum resting above the digester. The drum can move up and down i.e., float over the digester. The gas holder has an outlet at the top which could be connected to gas stoves.

4. **over flow tank** - Present above the ground level.

Working

Slurry (mixture of equal quantities of biomass and water) is prepared in the mixing tank. The prepared slurry is fed into the inlet chamber of the digester through the inlet pipe. The plant is left unused for about two months and introduction of more slurry is stopped. During this period, anaerobic fermentation of biomass takes place in the presence of water and produces biogas in the digester. Biogas being lighter rises up and starts collecting in the gas holder. The gas holder now starts moving up. The gas holder cannot rise up beyond a certain level. As more and more gas starts collecting, more pressure begins to be exerted on the slurry. The spent slurry is now forced into the outlet chamber from the top of the inlet chamber. When the outlet chamber gets filled with the spent slurry, the excess is forced out through the outlet pipe into the overflow tank. This is later used as manure for plants. The gas valve of the gas outlet is opened to get a supply of biogas. Once the production of biogas begins, a continuous supply of gas can be ensured by regular removal of spent slurry and introduction of fresh slurry.

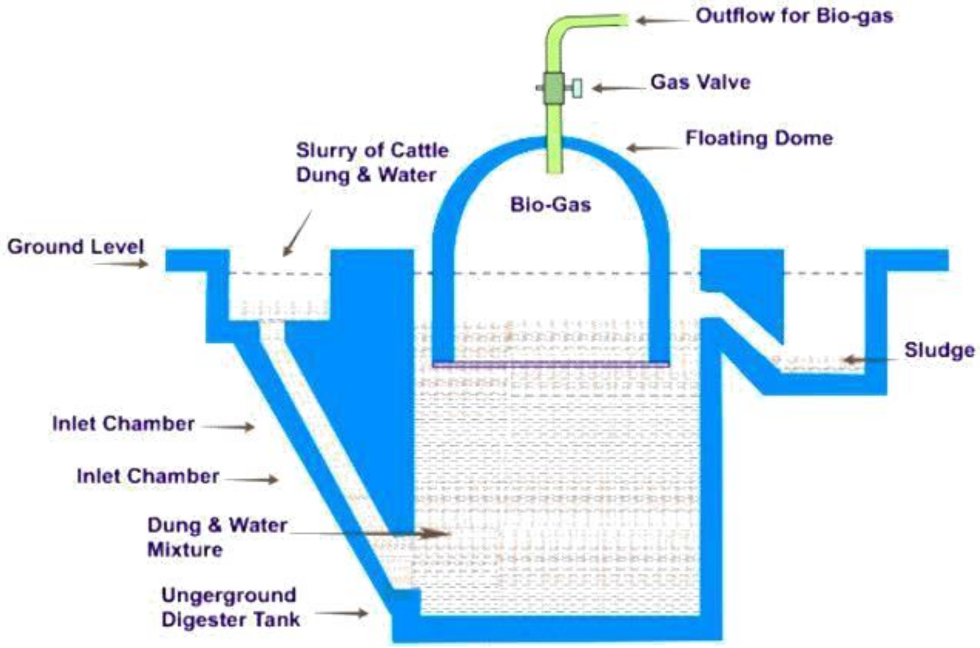


Fig.2 Floating dome type biogas plant

Disadvantages of floating drum biogas plant

1. Expensive
2. Steel drum may rust
3. Requires regular maintenance

EXERCISE - 3

To Study about Gasifiers

Biomass Gasification: Biomass gasification, or producing gas from biomass, involves burning biomass under restricted air supply for the generation of producer gas. Producer gas is a mixture of gases: 18%–22% carbon monoxide (CO), 8%–12% hydrogen (H_2), 8%–12% carbon dioxide (CO_2), 2%–4% methane (CH_4) and 45%–50% nitrogen (N_2) making up the rest.

Gasification reactions

Producing gas from biomass consists of the following main reactions, which occur inside a biomass gasifier.

1. **Drying**: Biomass fuels usually contain 10%–35% moisture. When biomass is heated to about 100 °C, the moisture is converted into steam.
2. **Pyrolysis**: After drying, as heating continues, the biomass undergoes pyrolysis. Pyrolysis involves burning biomass completely without supplying any oxygen. As a result, the biomass is decomposed or separated into solids, liquids, and gases. Charcoal is the solid part, tar is the liquid part, and flue gases make up the gaseous part.
3. **Oxidation**: Air is introduced into the gasifier after the decomposition process. During oxidation, which takes place at about 700–1,400 °C, charcoal, or the solid carbonized fuel, reacts with the oxygen in the air to produce carbon dioxide and heat.

   $$C + O_2 \rightarrow CO_2 + \text{heat}$$

4. **Reduction**: At higher temperatures and under reducing conditions, that is when not enough oxygen is available, the following reactions take place forming carbon dioxide, hydrogen, and methane.

   $$C + CO_2 \rightarrow 2CO$$

   $$C + H_2O \rightarrow CO + H_2$$

   $$CO + H_2O \rightarrow CO_2 + H_2$$

   $$C + 2H_2 \rightarrow CH_4$$

Types of gasifiers

Gasifiers can be classified based on the density factor, which is a ratio of the solid matter (the dense phase) a gasifier can burn to the total volume available. Gasifiers can be (a) dense phase reactors (b) lean phase reactors.

(A) Dense phase reactors: In dense phase reactors, the feedstock fills most of the space in the reactor. They are common, available in different designs depending upon the operating conditions, and are of three types: downdraft, updraft, and cross-draft.

(i) Downdraft or co-current gasifiers

The downdraft (also known as co-current) gasifier is the most common type of gasifier. In downdraft gasifiers, the pyrolysis zone is above the combustion zone and the reduction zone is below the combustion zone. Fuel is fed from the top. The flow of air and gas is downwards (hence the name) through the combustion and reduction zones. The term co-current is used because air moves in the same direction as that of fuel, downwards. A downdraft gasifier is so designed that tar, which is produced in the pyrolysis zone, travels through the combustion zone, where it is broken down or burnt. As a result, the mixture of gases in the exit stream is relatively clean. The position of the combustion zone is thus a critical element in the downdraft gasifier, its main advantage being that it produces gas with low tar content, which is suitable for gas engines.

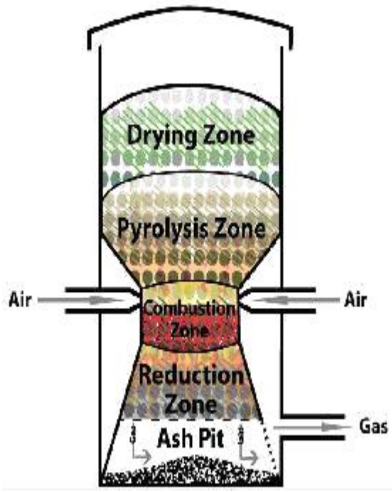


Fig.1 Downdraft gasifier

(ii) Updraft or counter-current gasifier

In updraft gasifiers (also known as counter-current), air enters from below the grate and flows upwards, whereas the fuel flows downwards. An updraft gasifier has distinctly defined zones for partial combustion, reduction, pyrolysis, and drying. The gas produced in the reduction zone leaves the gasifier reactor together with the products of pyrolysis from the pyrolysis zone and steam from the drying zone.

The resulting combustible producer gas is rich in hydrocarbons (tars) and, therefore, has a higher calorific value, which makes updraft gasifiers more suitable where heat is needed, for example in industrial furnaces. The producer gas needs to be thoroughly cleaned if it is to be used for generating electricity.

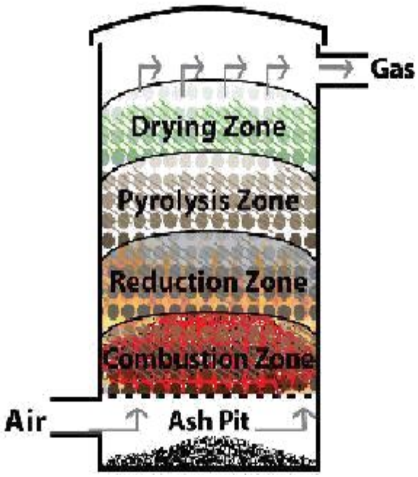


Fig.2 Updraft Gasifier

(iii) Cross-draft gasifier

In a cross-draft gasifier, air enters from one side of the gasifier reactor and leaves from the other. Cross-draft gasifiers have a few distinct advantages such as compact construction and low cleaning requirements. Also, cross-draft gasifiers do not need a grate; the ash falls to the bottom and does not come in the way of normal operation.

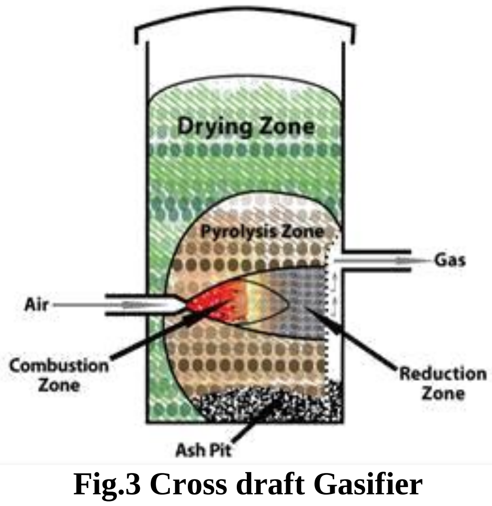


Fig.3 Cross draft Gasifier

(B) Fluidized bed gasifiers

In fluidized bed gasifiers, the biomass is brought into an inert bed of fluidized material (e.g. sand, char, etc.). The fuel is fed into the fluidized system either above-bed or directly into the bed, depending upon the size and density of the fuel and how it is affected by the bed velocities. During normal operation, the bed media is maintained at a temperature between 550 °C and 1000°C. When the fuel is introduced under such temperature conditions, its drying and pyrolyzing reactions proceed rapidly, driving off all gaseous portions of the fuel at relatively low temperatures. The remaining char is oxidized within the bed to provide the heat source for the drying and devolatilizing reactions to continue.

Fluidized bed gasifiers are better than dense phase reactors in that they produce more heat in short time due to the abrasion phenomenon between inert bed material and biomass, giving a uniformly high (800–1000ºC) bed temperature. A fluidized bed gasifier works as a hot bed of sand particles agitated constantly by air. Air is distributed through nozzles located at the bottom of the bed.

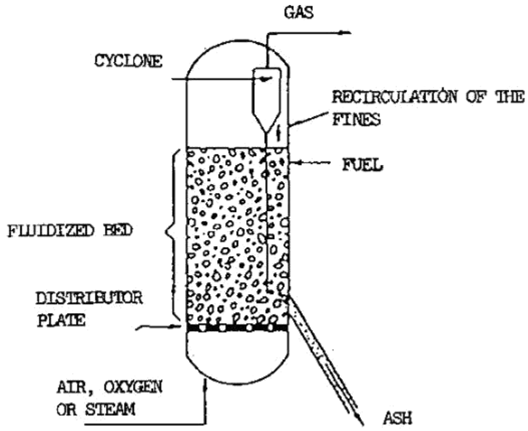


Fig.4 Fluidized bed gasifiers

Entrained-flow gasifiers

In entrained-flow gasifiers, fuel and air are introduced from the top of the reactor, and fuel is carried by the air in the reactor. The operating temperatures are 1200–1600 °C and the pressure is 20–80 bar. Entrained-flow gasifiers can be used for any type of fuel so long as it is dry (low moisture) and has low ash content. Due to the short residence time (0.5–4.0 seconds), high temperatures are required for such gasifiers. The advantage of entrained-flow gasifiers is that the gas contains very little tar.

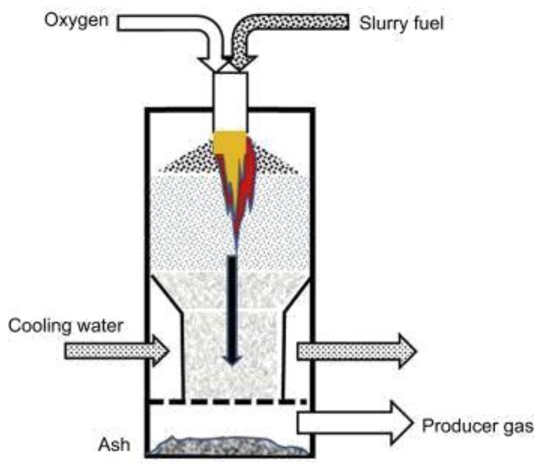


Fig.5 Entrained-flow gasifiers

EXERCISE - 4

To Study the Production Process of Biodiesel

Biodiesel: Biodiesel is a liquid biofuel obtained by chemical processes from vegetable oils or animal fats and an alcohol that can be used in diesel engines, alone or blended with diesel oil. ASTM International (originally known as the American Society for Testing and Materials) defines biodiesel as a mixture of long-chain mono-alkylic esters from fatty acids obtained from renewable resources, to be used in diesel engines.

Blends with diesel fuel are indicated as ‘‘Bx’’, where ‘‘x’’ is the percentage of biodiesel in the blend. For instance, ‘‘B5’’ indicates a blend with 5% biodiesel and 95% diesel fuel; in consequence, B100 indicates pure biodiesel.

Feedstocks Used in Biodiesel Production

The primary raw materials used in the production of biodiesel are vegetable oils, animal fats, and recycled greases. These materials contain triglycerides, free fatty acids, and other contaminants depending on the degree of pre-treatment they have received prior to delivery. Since biodiesel is a mono-alkyl fatty acid ester, the primary alcohol used to form the ester is the other major feedstock. Most processes for making biodiesel use a catalyst to initiate the esterification reaction. The catalyst is required because the alcohol is sparingly soluble in the oil phase. The catalyst promotes an increase in solubility to allow the reaction to proceed at a reasonable rate. The most common catalysts used are strong mineral bases such as sodium hydroxide and potassium hydroxide. After the reaction, the base catalyst must be neutralized with a strong mineral acid.

Typical proportions for the chemicals used to make biodiesel are:

Reactants:	Fat or oil (e.g. 100 kg soybean oil)
	Primary alcohol (e.g. 10 kg methanol)
	Mineral base (e.g. 0.3 kg sodium hydroxide)
Catalyst:	Mineral acid (e.g. 0.25 kg sulfuric acid)
Neutralizer:	

Advantages of the Use of Biodiesel

1. Renewable fuel, obtained from vegetable oils or animal fats.
2. Low toxicity, in comparison with diesel fuel.
3. Degrades more rapidly than diesel fuel, minimizing the environmental consequences of biofuel spills.

4. Lower emissions of contaminants: carbon monoxide, particulate matter, polycyclic aromatic hydrocarbons, aldehydes.
5. Lower health risk, due to reduced emissions of carcinogenic substances.
6. No sulfur dioxide (SO_2) emissions.
7. Higher flash point.
8. May be blended with diesel fuel at any proportion; both fuels may be mixed during the fuel supply to vehicles.
9. Excellent properties as a lubricant.
10. It is the only alternative fuel that can be used in a conventional diesel engine, without modifications.
11. Used cooking oils and fat residues from meat processing may be used as raw materials.

Disadvantages of the Use of Biodiesel

1. Slightly higher fuel consumption due to the lower calorific value of biodiesel.
2. Slightly higher nitrous oxide (NOx) emissions than diesel fuel.
3. Higher freezing point than diesel fuel. This may be inconvenient in cold climates.
4. It is less stable than diesel fuel, and therefore long-term storage (more than six months) of biodiesel is not recommended.
5. May degrade plastic and natural rubber gaskets and hoses when used in pure form, in which case replacement with Teflon components is recommended.
6. It dissolves the deposits of sediments and other contaminants from diesel fuel in storage tanks and fuel lines, which then are flushed away by the biofuel into the engine, where they can cause problems in the valves and injection systems. In consequence, the cleaning of tanks prior to filling with biodiesel is recommended.

It must be noted that these disadvantages are significantly reduced when biodiesel is used in blends with diesel fuel.

EXERCISE - 5

To Study Briquetting Machine

Biomass Briquetting: Fuel derived from compacting the biomass into dense block is known as Briquette. It is cheaper and requires no other raw material and produce heat equivalent to other fuel. Now a day's biomass briquetting is used by the same industries where the low-density biomass is produced. Jute waste, groundnut shell, coffee husk, coir pith and rice husk is used for Briquetting. Biomass briquette plant provides eco fuel briquettes from agriculture waste or biomass feedstock without harming green ambiance. Bio coal briquette machine is the green alternative renewable energy source to fossil fuels like coal, natural gas, diesel etc.

Briquette plant manufacturers are manufacturing biomass briquetting plant and briquetting machine which can make efficient biomass briquettes without spreading pollution in the atmosphere.

Raw material for briquetting

Almost all agro-residues can be briquetted. Agro-residues such as saw dust, rice husk, tapioca waste, groundnut shell, cotton stalks, pigeon pea stalks, soybean stalks, coir pith, mustard stalks, sugar cane bagasse, wood chips, castor husk, coffee husk, dried tapioca stick, coconut shell powder are the commonly used raw materials for briquetting in India. All these residues can be briquetted individually and in combination with or without using binders.

Factors influencing on the selection of raw materials

The factors that mainly influence on the selection of raw materials are moisture content, ash content, flow characteristics, particle size and availability in the locality. Moisture content in the range of 10-15% is preferred because high moisture content will pose problems in grinding and more energy is required for drying. Biomass feedstock having up to 4% of ash content is preferred for briquetting. The granular homogeneous materials which can flow easily in conveyers, bunkers and storage silos are suitable for briquetting.

Briquetting Process

The series of steps involved in the briquetting process are:-

1. Collection of raw materials
2. Preparation of raw materials
3. Drying

4. Size Reduction
5. Raw material mixing
6. Compaction
7. Cooling and storage

1. 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.

Collection of Raw Materials

2. 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.

3. 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.

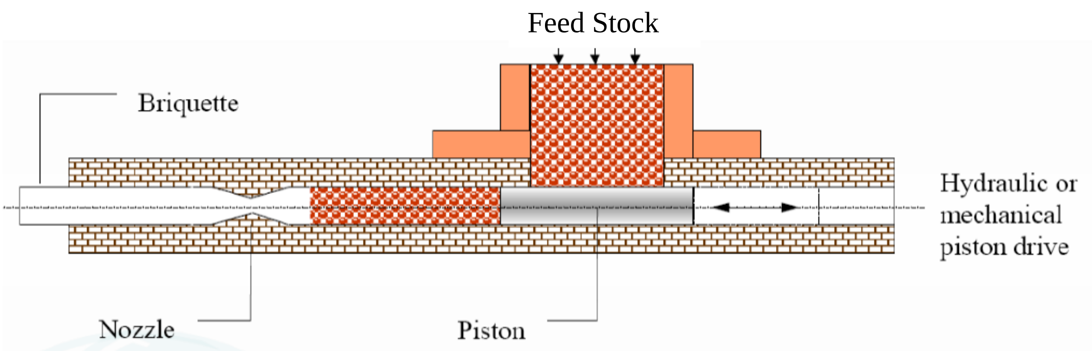
Drying of materials in Polyhouse

4. 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.

Size Reduction by Chopping

5. 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.

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



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

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

1. High pressure or high compaction 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 – 250oC, 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.

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 Tamilnadu all the briquette producing firms' uses hydraulic piston press technology for briquetting.

2. Medium pressure technology: 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.

3. Low pressure technology: 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.

Briquette Production Cycle

Uses of briquettes

1. 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.
2. Tea industries, wine distilleries, textile industries, and farms are the major sectors using briquettes.
3. Briquettes are also used in gasification process for electricity production.

Advantages of Agro-residual Briquettes

1. The processes increase the net calorific value of material per unit volume.
2. End product is easy to transport and store.
3. The fuel produced is uniform in size and quality.
4. Helps solve the problem of residue disposal.
5. Helps to reduce deforestation by providing a substitute for fuel wood.
6. 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 - 6

To Study the Production Process of Bio-Fuels

Biofuel: Unlike other renewable energy sources, biomass can be converted directly into liquid fuels— biofuels— for our transportation needs (cars, trucks, buses, airplanes, and trains). The two most common types of biofuels are ethanol and biodiesel.

Ethanol is an alcohol, similar to that used in beer and wine. It is made by fermenting any biomass high in carbohydrates (starches, sugars, or celluloses) through a process similar to brewing beer. Ethanol is mostly used as a fuel additive to cut down a vehicle's carbon monoxide and other smog-causing emissions. Flexible-fuel vehicles, which run on mixtures of gasoline and up to 85% ethanol, are now available.

Biodiesel, produced by plants such as rapeseed (canola), sunflowers and soybeans, can be extracted and refined into fuel, which can be burned in diesel engines and buses. Biodiesel can also make by combining alcohol with vegetable oil, or recycled cooking greases. It can be used as an additive to reduce vehicle emissions (typically 20%) or in its pure form as a renewable alternative fuel for diesel engines.

Production of Ethanol

Ethanol can be produced from biomass by the hydrolysis and sugar fermentation processes. Biomass wastes contain a complex mixture of carbohydrate polymers from the plant cell walls known as cellulose, hemi cellulose and lignin. In order to produce sugars from the biomass, the biomass is pre-treated with acids or enzymes in order to reduce the size of the feedstock and to open up the plant structure. The cellulose and the hemi cellulose portions are broken down (hydrolysed) by enzymes or dilute acids into sucrose sugar that is then fermented into ethanol. The lignin which is also present in the biomass is normally used as a fuel for the ethanol production plants boilers. There are three principle methods of extracting sugars from biomass. These are concentrated acid hydrolysis, dilute acid hydrolysis and enzymatic hydrolysis.

(i) Concentrated Acid Hydrolysis Process

The Arkanol process works by adding 70-77% sulphuric acid to the biomass that has been dried to 10% moisture content. The acid is added in the ratio of 1.25 acids to 1 biomass and the temperature is controlled to $50^{O}C$. Water is then added to dilute the acid to 20-30% and the mixture is again heated to $100^{O}C$ for 1 hour. The gel produced from this mixture is then pressed to release an acid sugar mixture and a chromatographic column is used to separate the acid and sugar mixture.

(ii) Dilute Acid Hydrolysis

The dilute acid hydrolysis process is one of the oldest, simplest and most efficient methods of producing ethanol from biomass. Dilute acid is used to hydrolyse the biomass to sucrose. The first stage uses 0.7% sulphuric acid at $190^{O}C$ to hydrolyse the hemi cellulose present in the biomass. The second stage is optimised to yield the more resistant cellulose fraction. This is achieved by using 0.4% sulphuric acid at $215^{O}C$.The liquid hydrolats are then neutralised and recovered from the process.

(iii) Enzymatic Hydrolysis

Instead of using acid to hydrolyse the biomass into sucrose, we can use enzymes to break down the biomass in a similar way. However, this process is very expensive and is still in its early stages of development.

(iv) Wet Milling Processes

Corn can be processed into ethanol by either the dry milling or the wet milling process. In the wet milling process, the corn kernel is steeped in warm water, this helps to break down the proteins and release the starch present in the corn and helps to soften the kernel for the milling process. The corn is then milled to produce germ, fibre and starch products. The germ is extracted to produce corn oil and the starch fraction undergoes centrifugation and scarification to produce gluten wet cake. The ethanol is then extracted by the distillation process. The wet milling process is normally used in factories producing several hundred million gallons of ethanol every Year.

(v) Dry Milling Process

The dry milling process involves cleaning and breaking down the corn kernel into fine particles using a hammer mill process. This creates a powder with a course flour type consistency. The powder contains the corn germ, starch and fiber. In order to produce a sugar solution, the mixture is then hydrolyzed or broken down into sucrose sugars using enzymes or a dilute acid. The mixture is then cooled and yeast is added in order to ferment the mixture into ethanol. The dry milling process is normally used in factories producing less than 50 million gallons of ethanol every Year.

(vi) Sugar Fermentation Process

The hydrolysis process breaks down the cellulosic part of the biomass or corn into sugar solutions that can then be fermented into ethanol. Yeast is added to the solution, which is then heated. The yeast contains an enzyme called invertase, which acts as a catalyst and helps to convert the sucrose sugars into glucose and fructose (both $C_6H_{12}O_6$).

The chemical reaction is shown below:

$$\underset{\textbf{Sucrose}}{C12H22O11} \quad + \quad \underset{\textbf{Water}}{H2O} \quad \underset{\textbf{Catalyst}}{\xrightarrow{\textbf{Invertase}}} \quad \underset{\textbf{Fructose}}{C6H12O6} \quad + \quad \underset{\textbf{Glucose}}{C6H12O6}$$

The fructose and glucose sugars then react with another enzyme called zymase, which is also contained in the yeast to produce ethanol and carbon dioxide.

The chemical reaction is shown below:

$$\underset{\textbf{Fructose / Glucose}}{C6H12O6} \quad \underset{\textbf{Catalyst}}{\xrightarrow{\textbf{Zymase}}} \quad \underset{\textbf{Ethanol}}{2C2H5OH} \quad + \quad 2CO2$$

The fermentation process takes around three days to complete and is carried out at a temperature of between 250^{o}C and 300^{o}C.

Fractional Distillation Process

The ethanol, which is produced from the fermentation process, still contains a significant quantity of water, which must be removed. This is achieved by using the fractional distillation process. The distillation process works by boiling the water and ethanol mixture. Since ethanol has a lower boiling point (78.3^{o}C) compared to that of water (100^{o}C), the ethanol turns into the vapor state before the water and can be condensed and separated.

EXERCISE - 7

Familiarization with Different Solar Energy Gadgets

Solar Energy

Solar energy is the most readily available and free source of energy since prehistoric times. It is estimated that solar energy equivalent to over 15,000 times the world's annual commercial energy consumption reaches the earth every year.

India receives solar energy in the region of 5 to 7 kWh/m^2 for 300 to 330 days in a year. This energy is sufficient to set up 20 MW solar power plants per square kilometer land area.

Solar energy can be utilized through two different routes, as solar thermal route and solar electric (solar photovoltaic) routes. Solar thermal route uses the sun's heat to produce hot water or air, cook food, drying materials etc. Solar photovoltaic uses sun's heat to produce electricity for lighting home and building, running motors, pumps, electric appliances, and lighting.

Solar Energy Gadgets

1. Solar Cooler : To cook food
2. Solar Water Heater : To heat water
3. Solar Dryer : For drying of agricultural produce
4. Solar Pond
5. Solar Distillation
6. Solar Photovoltaic System : To generate electricity
    a. Solar Light
    b. Solar Fencing
    c. Solar Pumping

Solar Cooker

Solar cooker is a device, which uses solar energy for cooking, and thus saving fossil fuels, fuel wood and electrical energy to a large extent. However, it can only supplement the cooking fuel, and not replace it totally. It is a simple cooking unit, ideal for domestic cooking during most of the year except during the monsoon season, cloudy days and winter months. Basically there are three designs of solar cooker:

a. Flat plate box type solar cooker with or without reflector.

b. Multi-reflector type solar oven and,
c. Parabolic disc concentrator type solar cooker.

Solar Water Heater

Solar water heaters most solar water heating systems have two main parts: a solar collector and a storage tank. The most common collector is called a flat-plate collector. It consists of a thin, flat, rectangular box with a transparent cover that faces the sun, mounted on the roof of building or home. Small tubes run through the box and carry the fluid - either water or other fluid, such as an antifreeze solution – to be heated. The tubes are attached to an absorber plate, which is painted with special coatings to absorb the heat. The heat builds up in the collector, which is passed to the fluid passing through the tubes. An insulated storage tank holds the hot water. It is similar to water heater, but larger is size. In case of systems that use fluids, heat is passed from hot fluid to the water stored in the tank through a coil of tubes.

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.

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

Solar Distillation

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.

SOLAR ELECTRICITY GENERATION

Solar Photovoltaic (PV): Photovoltaic is the technical term for solar electric. Photo means "light" and voltaic means "electric". PV cells are usually made of silicon, an element that naturally releases electrons when exposed to light. Amount of electrons released from silicon cells depend upon intensity of light incident on it. The silicon cell is covered with a grid of metal that directs the electrons to flow in a path to create an electric current. This current is guided into a wire that is connected to a battery or DC appliance. Typically, one cell produces about 1.5 watts of power.

Some applications for PV systems are lighting for commercial buildings, outdoor (street) lighting, rural and village lighting etc. Solar electric power systems can offer independence from the utility grid and offer protection during extended power failures. Solar PV systems are found to be economical especially in the hilly and far flung areas where conventional grid power supply will be expensive to reach.

Solar Fencing

Solar fences can be used to protect farmhouses, farmlands, forest bungalows, etc from animals. These control the animals by giving them a short, sharp but safe shock that teaches them to stay away from the fence. Solar fencing is safe, as its output is discrete (not continuous).

Solar Water Pumps

In solar water pumping system, the pump is driven by motor run by solar electricity instead of conventional electricity drawn from utility grid. A SPV water pumping system consists of a photovoltaic array mounted on a stand and a motor-pump set compatible with the photovoltaic array. It converts the solar energy into electricity, which is used for running the motor pump set. The pumping system draws water from the open well, bore well, stream, pond, canal etc.

EXERCISE - 8

To Study Solar Photovoltaic System

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

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

The best known applications of photo voltaic cells for electrical power generation have been is spacecraft, for which the Silicon cell is the most highly developed type. The Silicon cell consists of a single crystal of silicon into which a doping material is diffused to from a semi-conductor. Since the early day of solar cell development, many improvements have been manufactured with areas 2x2 cm, efficiencies approaching 10 percent, and operating at 28oC. The efficiency is the power developed per unit area of array divided by the solar energy flux in the free space (1.353 KW/m^2).

For terrestrial applications, silicon solar cells have shown operating efficiencies of about 12 to 15 percent. Though Silicon is one of the earth's most abundant materials, it is expensive to extract (from sand, where it occurs mostly in the from SiO2) and refine to the purity required for solar cells. The greater barrier to solar cell application lies in the costs of the cells themselves. Reducing the cost of Silicon Cells is difficult because of the cost of making single crystal. One very promising method is being developed to produce continuous thin ribbons of single-crystal Silicon to reduce fabrication costs.

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

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

EXERCISE - 9

To Study the Solar Lighting

Solar Lantern

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

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

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

Solar Street Light

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

EXERCISE - 10

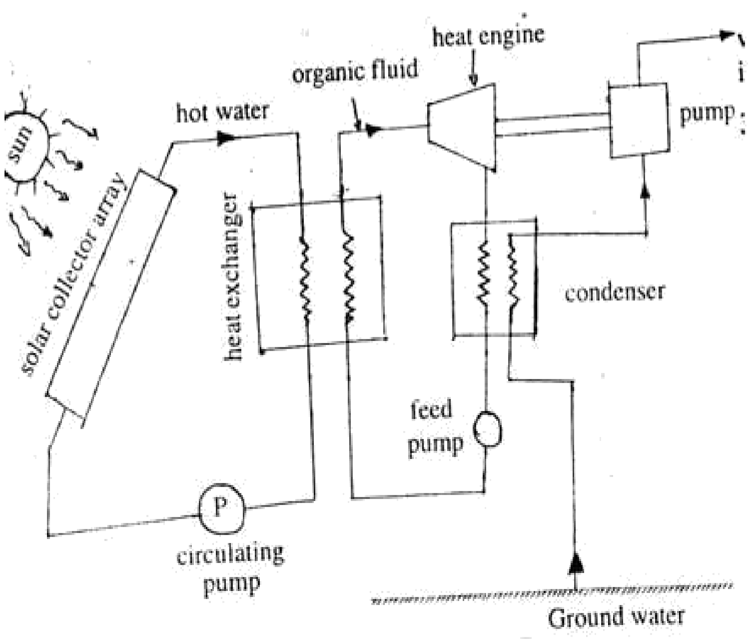
TO STUDY THE SOLAR PUMPING

Solar water pump: A solar-powered pump is a pump running on electricity generated by photovoltaic panels or the radiated thermal energy available from collected sunlight as opposed to grid electricity or diesel run water pumps. The operation of solar powered pumps is more economical mainly due to the lower operation and maintenance costs and has less environmental impact than pumps powered by an internal combustion engine (ICE). Solar pumps are useful where grid electricity is unavailable and alternative sources (in particular wind) do not provide sufficient energy.

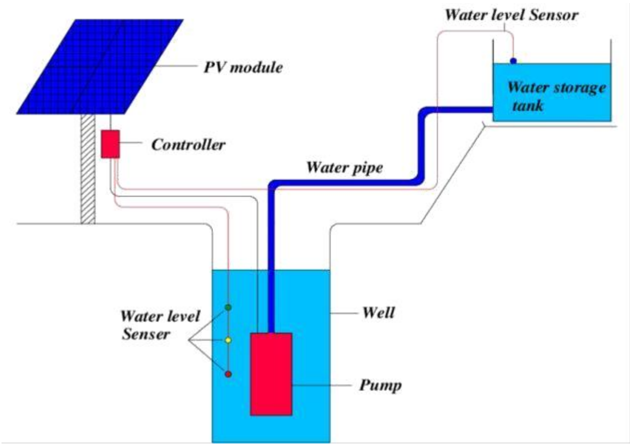
The basic system consists of the following components:

1. The solar collector
2. The heat transport system
3. Heat exchanges
4. Heat engine
5. Condenser
6. Pump

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



When the solar energy drops sun rays on the PV panels then the solar panel converts the rays into electrical energy with the help of Si wafers fixed within the PV panels. Then the solar energy supplies to the electrical motor to operate the pumping system using cables. By the revolution of the shaft which is fixed to the pump, then the pump begins to pick up the soil water and supplies to the fields.



Schematic Diagram of solar pump

Solar Pump Advantages

The solar pump advantages include the following

1. The installations of solar pumps are flexible & applicable to different applications.
2. It allows people to handle their water supply for drinking, farm animals watering, irrigation, & other housing applications.
3. Generally, the usage of water in summer is utmost. During this season, the PV panels can generate the most power so that more water can be pumped into the water tank.
4. Because of the ease of PV power-driven water pumps, solar technology is consistent, as well as needs small protection.

Solar Pump Disadvantages

The solar pump disadvantages include the following

1. It is expensive.
2. The output of the panel will depend on the weather.
3. It requires a water storage tank as well as a battery.

EXERCISE – 11

To Study the Solar Fencing

Working Principle of 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 earthling 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.

*JOULE: Unit of energy. One joule is one watt for one second. It is an important measure of the power of an Energizer.

The basic building blocks of a power fence are:

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

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 earth or ground system of the Energizer is like the antenna or aerial of a radio. A large radio requires a large antenna to effectively collect sound waves and a high powered Energizer requires a large number of electrons from the soil.

The earth or ground system must be perfect to enable the pulse to complete its circuit and give the animal an effective shock. Soil is not a good conductor so the electrons spread out and travel over a wide area, inclining towards moist mineral soils. If possible, select an area for the energizer earth site which is damp all the year.

FENCE WIRE SYSTEMS:

They are of two types:

A. All live Wire System and B. Earth or ground Wire Return System.

A. All Live Wire System:

The all live wire system should be used where there is relatively even rainfall and where there is some green vegetation most of the year, or in areas with highly conductive soils.

The all live wire system should be used as much as possible.

B. Earth or ground Wire Return System:

The earth or ground wires return system should be used where there is low rainfall stony and dry soil condition most of the year. The system overcomes the problem of dry, nonconductive, or frozen soils not allowing sufficient current to flow through the animal's feet back to the energizer. The fence should have both live and ground wires. By touching the live and ground wires on the fence, the animal gets the full shock.

Fence wire:

1. 2.5 mm (12.5 gauge) High tensile (H.T) wire is recommended for electric fence systems because of its advantages:
    a. It retains its tension far longer than soft wire.
    b. It conducts sufficient current for most applications.
    c. It is reasonable visible.

2. High Conductive Aluminum Coated Wire is best used for long leadouts i.e. several kilometers.
3. Double insulated Leadout Cable is used in building, under gateways and where the soil could corrode exposed galvanized wire.

Precautions:

1. Never use household electrical cable.
2. Never use copper wire under gate 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.

EXERCISE – 12

To Study Solar Cooker

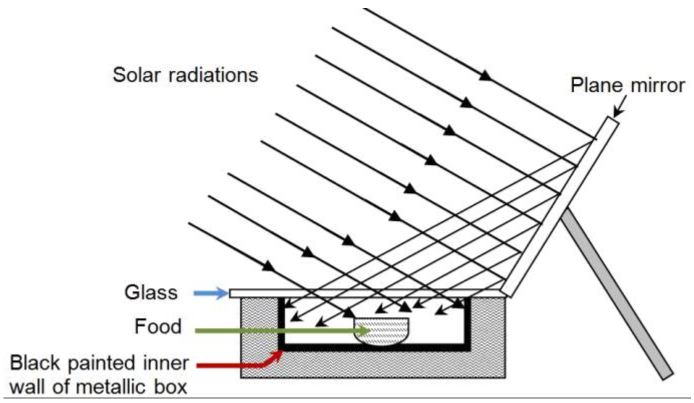
Basically there are three designs of solar cooker:

i) Flat plate box type solar cooker with or without reflector.

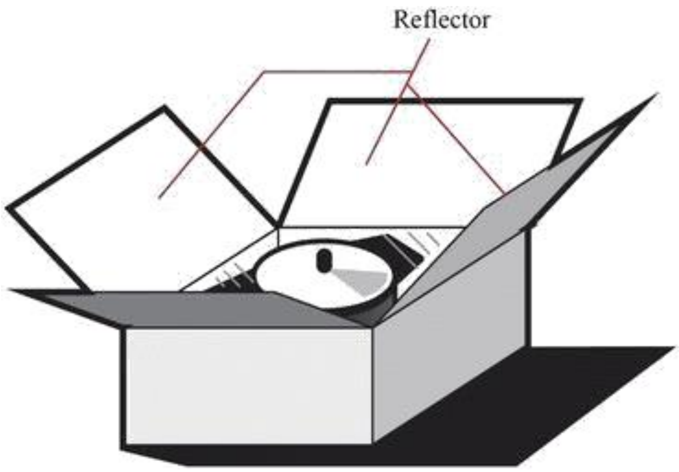
ii) Multi-reflector type solar oven and,

iii) Parabolic disc concentrator type solar cooker.

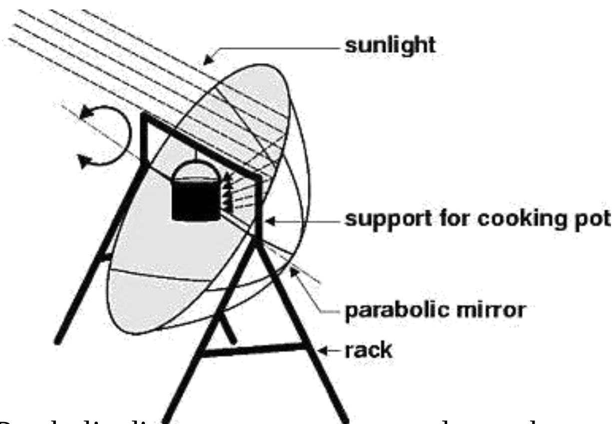
Flat plate box type design is the simplest of all the designs. Maximum no load temperature with a single reflector reaches up to $160^{o}C$. In multi reflector oven four square or triangular or rectangular reflectors are mounted on the oven body. They all reflect the solar radiations into the cooking zone in which cooking utensils are placed. Temperature obtained is of the order of $200^{o}C$. The maximum temperature can reach up to $250^{o}C$, if the compound cone reflector system is used. With parabolic disc concentrator type solar cooker, temperatures of the order of $450^{o}C$ can be obtained in which solar radiations are concentrated onto a focal point. Principle of operation of solar cookers is shown in Fig. (a-c).



(a) Principle of box type solar cooker



(b) Multi reflector type solar cooker



(c) Parabolic disc concentrator type solar cooker

Principle and constructional details of a box type solar cooker

The solar rays penetrate through the glass covers and absorbed by a blackened metal tray kept inside the solar box. The solar radiations entering the box are of short wavelength. The higher wavelength radiation is not able to pass through the glass cover i. e. re-radiation from absorber plate to outside the box is minimized by providing the glass cover. Two glass covers are provided to again minimize the heat loss. The loss due to convection is minimized by making the box air tight by providing a rubber strip all rounds between the upper lid and the box. Insulating material like glass wool, paddy husk, saw dust or any other material is filled in the space between blackened tray and outer cover of the box. This minimizes heat loss due to conduction. When this type of cooker is placed in the sun, the blackened surface starts absorbing sun rays and temperature inside the box starts rising. The cooking pots, which are also blackened, are placed inside with food material, get heat energy and food will be cooked in a certain period of time depending upon the actual temperature attained inside. The temperature attained depends upon the intensity of solar radiation and material of insulation provided. The amount of solar radiation intensity can be increased by providing mirror or mirrors.

The solar cooker is made up of inner and outer metal or wooden boxed with double glass sheet on it. Absorber tray (blackened tray) is painted black with suitable black paint. This paint should be dull in colour so that it can withstand the maximum temperature attained inside the cooker as well as water vapour coming out of the cooking utensils. The top cover contains two plain glasses each 3 mm thick fixed in the wooden frame with about 20 mm distance between them. The entire top over can be made tight with padlock hasp. Neoprene rubber sealing is provided around the contact surfaces of the glass cover and the cooker box. A small vent for vapour escape is providing in the sealing. Collector area of the solar cooker is increased by providing a plane reflecting mirror equal to the size of the box, and hinged on one side of the glass frame. A mechanism (guide for adjusting mirror) is provided to adjust the reflector at different angles with the cooker box. A 15 to 25^{O}C rise in temperature achieved inside the box when reflector is adjusted to reflect the sun rays into the box. In winter, when sun rays are much inclined to horizontal surface, reflector is a most useful addition.

Overall dimensions of the latest model are 60 X 60 X 20 cm height. This type of cooker is termed as family solar cooker as it cooks sufficient dry food materials for a family of 5 to 7 people. The temperature inside the solar cooker with a single reflector is maintained from 70 to 110^{O}C above the ambient temperature. This temperature is enough to cook food slowly, steadily and surely with delicious taste and preservation of nutrients. Maximum air temperature obtained inside the cooker box (without load) is 1400C in winter and 1600C in summer. Depending upon the factors such season and time of the day, type of the food and depth of the food layer, time of the cooking with this cooker ranges from 1 to 4 h. Meat should be allowed to stay for 3-4 hours. Vegetables take from ½ to 2½ hours. All types of Dals can be cooked between 1½ to 2 hours. Rice is cooked between 30 minutes and 2 hours. The best time of the day for cooking is between 11 am and 2 pm. Cooking is faster in summer than in winter due to high ambient temperature.

Merits of a solar cooker are:

i) No attention is needed during cooking as in other devices.
ii) No fuel is required.
iii) Negligible maintenance cost.
iv) No pollution.
v) Vitamins of the food are not destroyed and food cooked nutritive and delicious with natural taste.
vi) No problem of charring of food and no over flowing.

Limitations of a solar cooker are:

i) One has to cook according to the sun shine; the menu has to be preplanned.
ii) One cannot cook at short notice and food cannot be cooked in the night or during cloudy days.
iii) It takes comparatively more time.

EXERCISE – 13

To Study Solar Drying System

Conventional method of drying: Conventional method of drying is to spread the material in a thin layer on ground and let it exposed to the sun. Such a method has various disadvantages like,

- Accumulation of dust and harms due to insects
- Wastage of material due to birds
- Non uniform drying due to varying intensity of sun
- Larger area required for drying

All these difficulties are removed by using solar drier. There are two types of solar driers.

1. Natural convection solar drier
2. Forced convection solar dryer

Natural convection solar drier:

Natural air-drying is an in bin drying system with the following typical characteristics:

- Drying process is slow, generally requiring 4 to 8weeks.
- Initial moisture content is normally limited to 22 to 24%.
- Drying results from forcing unheated air through grain at airflow rates of 1 to 2 cfm/bu.
- Drying and storage occur in the same bin, minimizing grain handling.

- Bin is equipped with a full-perforated floor, one or more high capacity fans, a grain distributor and stairs
- Cleaning equipment is used to remove broken kernels and fines.

Cabinet Drier

It can be of fixed type and also of portable type. Generally, it has an area of about 3 x 5 m^2 glass sheet fixed at the top at an angle of about 0 to 300. Holes are provided at the bottom and at the topsides for airflow by natural convection. Wire meshed black tray is provided to the material to be dried.

Forced convection solar dryer (Hot air system):

In these, the collectors are provided with duct. Generally, a duct of 2.5 cm depth is provided. It is made out of two plates welded together lengthwise. Cold air is blown through a blower into the collectors, which gets heated during the passage through it. The hot air thus available is then used for drying the products kept on the shelves of driers. This hot air takes away the moisture of the products and is let out through a properly located outlet.

1. Absorber with ducting
2. Blower with motor and
3. Drying bin

Description

This drier has three main components viz., flat plate collector, blower and drying bin. The area of the collector is $8m^2$. It is divided into 4 bays each having 2m x 1 m absorber area. The absorber is made out of 20 g. corrugated G.I. sheet and is painted with dull black colour. Another plain G.I. sheet placed 5 cm below the absorber plate creates air space for heating.

This sheet is insulated at the bottom with glass wool and is supported at the bottom with another plain G.I. sheet. The absorber is covered at the top with two layers of 3 mm thick plain glass. The unit is supported on all sides with wooden scantling and is placed at 110 to the horizontal facing south. Baffle plates are provided in the air space. The air space is open at the bottom to suck atmospheric air and at the top it is connected to a duct leading to suction side of the blower. The blower is of 80 m3 / min, capacity run by 3HP electric motor. The delivery side of the blower is connected to the plenum chamber of a circular grain holding bin.

Forced Convection Solar Drier for Drying of Grains

For drying high moisture paddy, the solar drier can be used. The different components of the drier are air heater, air ducts and blower and grain drying chamber. The flat plate collector used for heating the air has an efficiency of 60% and rise in ambient air temperature is 13^{O}C. Freshly harvested paddy can be dried and it may take about 7-8 hours to bring the moisture content from 30% to 16% (d.b.). After drying the grains, the milling quality can be tested. The use of solar air heater for drying of grains indicates that 10-15^{O}C rise in the temperature of the air is enough to reduce the relative humidity of the air to 60% or less which is quite useful for drying of cereal grains.

To the level consists of safe moisture content for storage 500 kg of paddy could be dried from 30 to 40 % moisture content in a period of 6 hours on bright sunny day by using air flow rate of 4 m3/min with temperature rise 8-10^{O}C.

Solar drier consists of air heater, blower drying chamber, air distribution system and thermal storage system. The heated air is blown to drying chamber by blowers of the centrifugal type to handle large quantity of air. Batch type or continuous flow type drying chamber artificially creates the necessary radiation to reduce moisture. Hot air from the collector is sucked by a blower through the inlet pipe and is being forced into the drying chamber. An auxiliary heating system to supplement heat requirement may be arranged. This type of auxiliary systems and thermal storage systems for collecting extra energy during daytime, take care of the night operations.

The heat required Q in kcal/hr

$$Q = VC_P T \qquad (1)$$

Where V = air flow rate, m^3/hr

= density of air, kg/ m^3

C_P = the specific heat of air, and

T = temperature rise.

Moisture content assessed per tonne of paddy (m) for drying pre-boiled paddy, yield the volume of air to be handled V from

Moisture content assessed per tonne of paddy (m) for drying pre-boiled paddy, yield the volume of air to be handled V from

$$m \; latent \; heat = VC_p T \; efficiency \quad (2)$$

The volume of rock pile required V' for thermal storage of heat energy Q is

$$V' = \frac{Q}{'C'_p T'} \quad (3)$$

Where '
Q = density of rock

C'_p = specific heat of rock

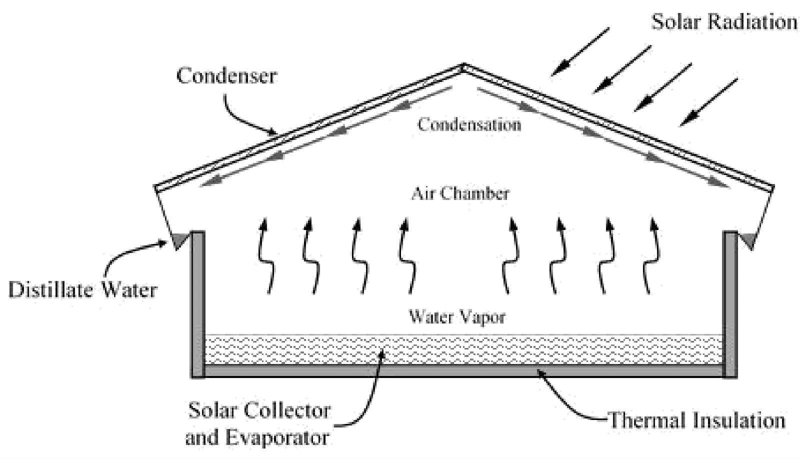
T = temperature increase in rock.

EXERCISE – 14

To Study Solar Distillation and Solar Pond

SOLAR DISTILLATION

Fresh water is a necessity for the sustenance of life and also the key to man's prosperity. It is generally observed that in some arid, semi-arid and coastal areas which are thinly populated and scattered, one or two family members are always busy in bringing fresh water from a long distance. In these areas solar energy plentiful and can used for converting saline water into distilled water. The pure water can be obtained by distillation in the simplest solar still, generally known as the "basin type solar still". It consists of a blackened basin containing saline water at a shallow depth, over which is a transparent air tight cover that encloses completely the space above the basin. It has a roof-like shape. The cover, which is usually glass may be of plastic, is sloped towards a collection trough. Solar radiation passes through the cover and is absorbed and converted into heat in the black surface. Impure water in the basin or tray is heated and the vapour produced is condensed to purified water on the cooler interior of the roof. The transparent roof material, (mainly glass) transmits nearly all radiation falling on it and absorbs very little; hence it remains cool enough to condense the water vapour. The condensed water flows down the sloping roof and is collected in troughs at the bottom. Saline water can be replaced in the operation by either continuous operation or by batches. Although there are numerous configurations of basin type units, their basic theory is identical. The basin type solar still has produced distilled water at a cost per unit of product lower than other types of solar equipment and is the only type in operation. Operating efficiencies of 35 to 50% for basin type still have been achieved in practical units, as compared with a theoretical maximum of slightly more than 60%.



Basin type solar still

EXERCISE – 15

To Study Solar Pond

Principle of operation of solar ponds

A solar pond is a solar energy collector, generally fairly large in size that looks like a pond. This type of solar energy collector uses a large, salty lake as a kind of a flat plate collector that absorbs and stores energy from the Sun in the warm, lower layers of the pond. These ponds can be natural or man-made, but generally speaking the solar ponds that are in operation today are artificial.

How they Work

The key characteristic of solar ponds that allow them to function effectively as a solar energy collector is a salt-concentration gradient of the water. This gradient results in water that is heavily salinated collecting at the bottom of the pond, with concentration decreasing towards the surface resulting in cool, fresh water on top of the pond. This collection of salty water at the bottom of the lake is known as the "storage zone", while the freshwater top layer is known as the "surface zone". The overall pond is several meters deep, with the "storage zone" being one or two meters thick.

These ponds must be clear for them to operate properly, as sunlight cannot penetrate to the bottom of the pond if the water is murky. When sunlight is incident on these ponds, most of the incoming sunlight reaches the bottom and thus the "storage zone" heats up. However, this newly heated water cannot rise and thus heat loss upwards is prevented. The salty water cannot rise because it is heavier than the fresh water that is on top of the pond, and thus the upper layer prevents convection currents from forming. Because of this, the top layer of the pond acts as a type of insulating blanket, and the main heat loss process from the storage zone is stopped. Without a loss of heat, the bottom of the pond is warmed to extremely high temperatures - it can reach about 90°C. If the pond is being used to generate electricity this temperature is high enough to initiate and run an organic Rankine cycle engine.

It is vital that the salt concentrations and cool temperature of the top layer are maintained in order for these ponds to work. The surface zone is mixed and kept cool by winds and heat loss by evaporation. This top zone must also be flushed continuously with fresh water to ensure that there is no accumulation of salt in the top layer, since the salt from the bottom layer diffuses through the saline gradient over time. Additionally, a solid salt or brine mixture must be added to the pond frequently to make up for any upwards salt loses.

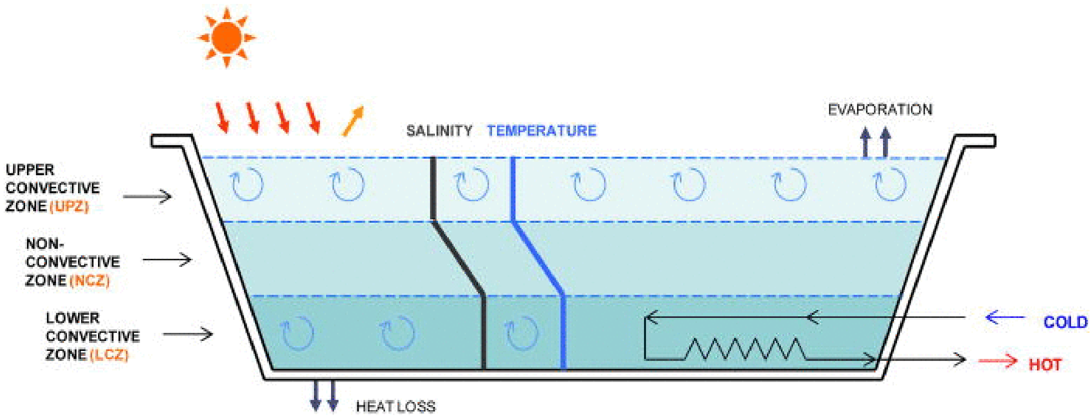
Applications

The heat from solar ponds can be used in a variety of different ways. First, since the heat storing abilities of solar ponds are so great they are ideal for use in heating and cooling buildings as they can maintain a fairly stable temperature. These ponds can also be used to generate electricity either by driving a thermo-electric device or some organic Rankine engine cycle - simply a turbine powered by evaporating a fluid (in this case a fluid with a lower boiling point). Finally, solar ponds can be used for desalination purposes as the low cost of this thermal energy can be used to remove the salt from water for drinking or irrigation purposes.

Benefits and Drawbacks

One benefit of using these ponds is that they have an extremely large thermal mass. Since these ponds can store heat energy very well, they can generate electricity during the day when the Sun is shining as well as at night.

Despite being a source of energy, there are numerous thermodynamic limitations as a result of the relatively low temperatures achieved in these ponds. Because of this, the solar-to-electricity conversion is fairly inefficient - generally less than 2%. As well, large amounts of fresh water are necessary to maintain the right salt concentrations all through the pond. This is an issue in places where fresh water is hard to come by, especially in desert environments. These ponds also do not work well at high latitudes as the collection surface is horizontal and cannot be tilted to collect more sunlight.



Solar Pond