LECTURE 4

1. SOLAR ENERGY:

Introduction Solar Radiation.
The sun is the prime souce of all the forms of energy on the earth

Solar power: The Sun provides 1,366 watts/meter² at the distance of the Earth's orbit, but less at ground level.

Solar Constant: I_{sc} is defined as, the rate at which energy is received from the sun on a unit area perpendicular to the rays of the sun at average earth sun distance just out side the earth's atmosphere. Its value is **1353W/m².**

Due to the variation of in the earth sun distance , rate of **Extra-terrestrial incident solar radiation** perpendicular to the rays of the sun I_o varies. The value of I_o on any day can be closely approximated by the equation: $\mathbf{I_o = I_{sc}[1+0.033coss(360n/365)].}$

Solar Radiation measuring instruments
It is necessary to determine the amount of solar radiation received on the surface of the earth. This information is require for

1 Proper utilization of solar energy
2 Energy balance studies.

Principle of solar radiation.

1. **Principle of thermocouple.** When the junction of two dissimilar metal are formed and one of the it is heated , e.m.f. if generated on the ends of open junction. This is known as thermoelectric Phenomenon. This e.m.f. is produced is proportional to the difference of the temp. between two ends.
2. **Photovoltaic Principle:** When the solar radiation fall on the photovoltaic cell the electrons are released in such a way as to set up emf in the circuit. The electrical energy is proportional to intensity of solar radiation. This gives direct measurement of solar radiation.

Measuring Instruments of Solar radiations: Two basic type of instruments are employed for solar radiation measuring.

Pyranometers: These may use a thermopile or a solar cell. most commonly used is the one with thermopiles. In this sensing element, there is a black metal surface. This is placed horizontally as under a single or double glass hemisphere which protects the surface and prevent the loss of heat. Glass is grand transparent to solar radiation. i.e. it permits solar radiation to enter inside. after reacting inside, it gets converted into low temp. radiation. Glass does not permit low temp. radiation to go out. thus it prevent to heat loss. A set of thermocouple is attached to underside of the black surface and working as hot junction. The cold junction of the thermopile are either connected to white surface adjacent to the black

surface or to an electronic cold junction inside the instrument.

Pyrheliometer: This is used to measure only direct beam radiations.
It is consists of cylindrical collimating tube which can be adjusted , and kept in such a way that it remains parallel to in coming solar radiations. Hence, only direct beam radiation are received on sensor plate. Aperture of the collimating tube makes acceptance come of 5.8o. Black surface is mounted behind the collimating tube.

Sun Shine Recorder: The duration of bright sun shine is measured by means of a sun shine recorder. The sun shine recorder is consists of a glass provided with a bowl under it. The bowl of a hemispherical shape and provided with grooves in which specially treated paper is kept. The sun shine recorder is normally fixed on a concrete plat form out.
The sun shine recorder is kept in open where direct sun rays are falling on glass sphere. The solar rays after passing through the glass sphere are concentrated at a point, and fall on the specially treated paper. The concentrated solar rays being power full enough to make burning marks on the paper kept in the groves of bowl When the sun moves east to west , the corresponding burn marks are left on the paper. The length of the mark indicates the period for which there was a clear sunshine.

Various Methods of solar energy utilization
Introduction:
Utilization of solar energy:
Direct Utilization of solar Energy: stated before solar energy converted into useful energy directly. Conversion of solar energy is done by

(1) Thermal energy conversion, and
(2) Photovoltaic conversion.

Thermal Energy conversion: In this method, solar energy is directly absorbed by the absorber or thermal collector, and the working medium is heated. There are many applications of this method:

(a) Solar water heating
(b) Solar Air heating
(c) Solar space heating
(d) Solar cooker
(e) Solar drier
(f) Solar cold storage
(g) Solar pumping
(h) Solar refrigeration
(i) Solar furnace
(j) Wood seasoning
(k) Solar stills for distillation of water, and
(l) Solar power generation.
(m)

Photovoltaic conversion: In this method , solar energy is converted into electrical –DC power, and then it is used for different application. For this purpose, solar cells are used. They are

electronic devices made up of Semi conductor-material. When the sunlight falls on solar cells, they convert it into electricity. This conversion is used for following application:

(a) Solar collectors,
(b) Watches
(c) Solar tube lights
(d) Photovoltaic pump
(e) Battery charging
(f) For radio, tap recorder and TV
(g) For communication
(h) Navigation aid
(i) Railway signals
(j) Domestic electrical appliances
(k) Electricity for space craft, etc.
(l)

Indirect Utilization of solar energy:

(1) wind energy (2) Tidal energy (3) Sea waves energy
(4) Geothermal energy (5) Biomass energy. (6) Hydrolic energy.

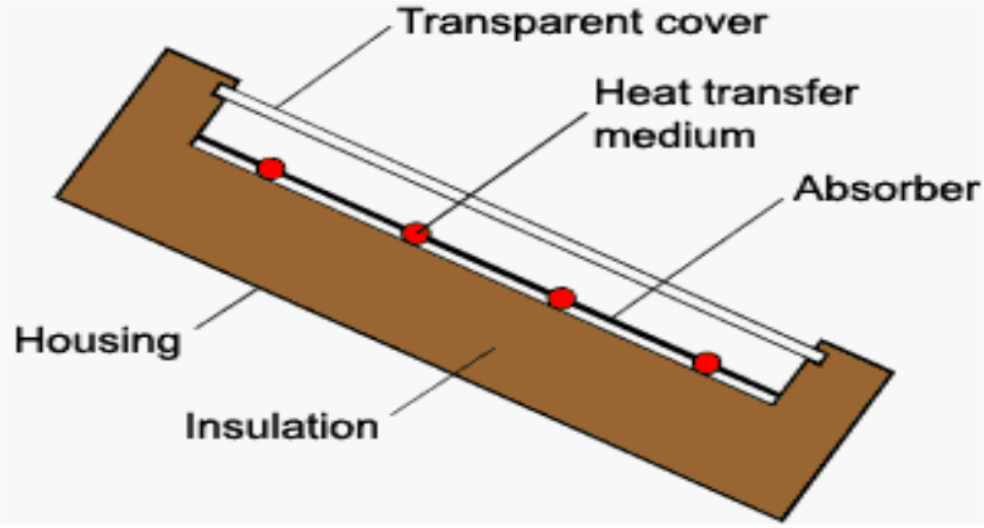
Solar Thermal Collector.

Introduction: Solar thermal collector is the direct method of solar energy utilization.
There are two type :

1 Liquid flat plate collector.
2 Solar air heater.

Flat-plate Collectors: A flat-plate collector consists of an absorber, a transparent cover, a frame, and insulation. Usually an iron-poor solar safety glass is used as a transparent cover, as it transmits a great amount of the short-wave light spectrum.

Construction and working of solar liquid flat plate collector:

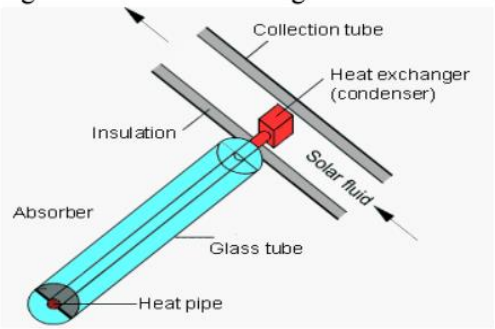


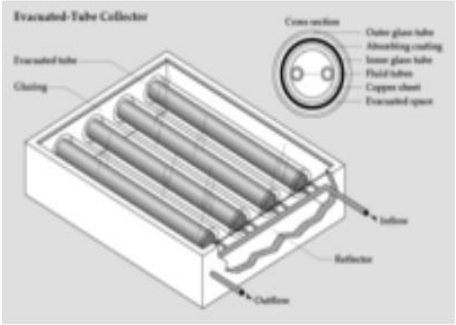
Advantages and Disadvantages of LFPC:

Uses of flat plate collector:

Types of Absorber Plate:

1. Tubes bound on the surface of the absorber plate.
2. Tubes fitted in grooved absorber plate.
3. Tubes in absorber plate.
4. Roll Bend aluminum absorber plate.
5. Corrugated sheets fastened together.





Evacuated (or vacuum) tubes panel.

Evacuated tube collectors are made of a series of modular tubes, mounted in parallel, whose number can be added to or reduced as hot water delivery needs change. This type of collector consists of rows of parallel transparent glass tubes, each of which contains an absorber tube.

Solar Air heater:

Introduction: We have discussed in the previous lesson that flat plate liquid collectors are used fro heating water. Solar air heater are used for heating air. Heated air is used for many purposes such as space heating, air drying etc.

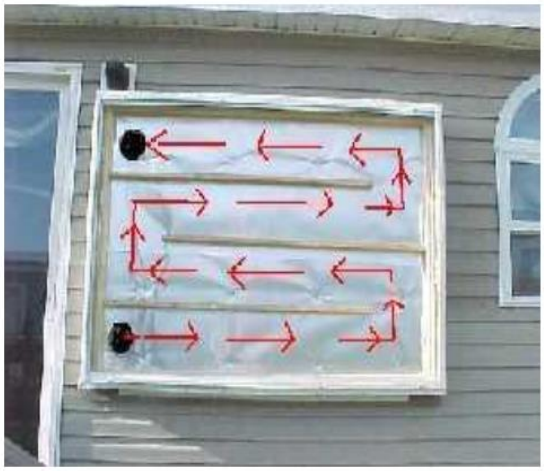
Construction and working of solar air heater:

The air heater are similar to liquid flat plate collector

(a) Principle: When the solar radiation fall on the black surface, they are absorbed by the absorber plate. The air passing close to it , is heated up.

(b) Construction: the air heater has following important parts():

1. Absorber Plate:
2. Air passage:



3. Transparent cover:
4. Insulation:
5. Casing:

Working:

Non-porous absorber collector

Porous absorber

Types of solar Air heater

a. Simple Flat plate collector:
b. Finned Plate Absorber air Heater:
c. Corrugated Plate air heater :
d. Overlapped Glass Plate Air Heater:

Porous air heaters

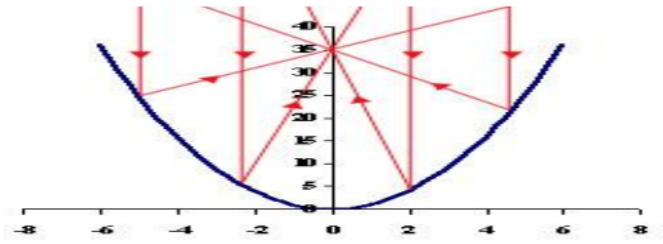
1 Matrix Air heater:
2 Honey Comb porous Air Heater:

Comparison between Liquid flat plate collector and Air heater:

Liquid collector	Air Heater
• Water to be heated up is passing through the water tubes. • Leakage of water stops the functioning of collector. • Absorber plates and cooling water tubes are integral to each other. No fins are provided. • There is a problem of corrosion. • Due to smaller dia. of cooling water tubes there is large increase in temp. • In cold countries water in the collector may get frozen and damage the tubes. • Heat transfer value for a surface and liquid is much higher than for air. This results in higher collector efficiency.	• There are no tubes . Usually air passages through space between absorber plate and insulation. • Leakage of air does not stop the working of collector. It reduces the its efficiency. • Usually an air passage around matrix of honey comb or fins are provided to increase heat transfer. • There is usually no problem of corrosion. • The space through which the air is circulated is large hence it is difficult to obtain higher temp. • No such problem in this type of collector. • Heat transfer rate for a surface and air is much lower than for liquid. This results in lower collector efficiency. Special arrangements to increase heat transfer coefficient are required.

Solar Concentrating type collector

Working principles of solar concentration: Two types of optical principle are used in solar concentrators:



1. **Reflection principle:** The incident solar radiation is reflected from the concave surface of mirrors and collected at its focus. The working fluid or any material to be heated is kept at focus, it can be heated to very high temp.

2. **Refraction Principle:** The incident solar radiation is directed by an arrangement of lenses at the focus after refraction. This also gives very high temp. of working fluids.

Tracking and Non tracking Collectors:

Types of Concentrating collectors:

1 **Fresnel lens collector:**
2 **Flat Plate collector augmented with mirrors:**
3 **Compound parabolic collector(CPC) or Wiston Collector:**
4 **Parabolic Collector:**
5. **Cylindrical Parabolic Collector:**
6. **Heliostat Collector:**

Energy can be stored in mechanical or electrical devices, or in containers of chemicals called eutectic or phase changing salts.

Utilization of solar energy is of great importance to India since sunlight is abundanty for a major part of the year.

The applications of solar energy are:
1) Heating and cooling of residential buildings.
2) Solar water heating.
3) Solar distillation.
4) Solar cooking.
5) Solar engines for pumping water.
6) Solar furnaces.
7) Solar drying of agricultural and animal products.
8) Solar electric power generation is by

(a) Solar ponds
(b) Reflectors with lenses and pipes for fluid circulation.
(c) Steam generators heated by rotating reflectors(heliostat mirrors).

9) Solar photovoltaic cells for directly converting solar energy nito electricity or for water pumping.
10) Salt production by evaporation of sea water.
11) Food refrigeration.
12) Bioconversion and wind energy, which are indirect sources of solar energy.

The heat from solar collectors is directly used for warming the living spaces of a building through radiators and hot air registers. When the building does not require heat, the warmed air from the collector is moved to a heat storage container with a pile of rocks or some

heat-holding material. In the case of hot liquid, the storage is usually a large insulated tank of water which has considerable heat capacity. Heat is also stored in containers of chemicals called eutectic or phase changing salts, which melt when they are heated and release heat later as they cool and crystallize. When the building needs heat, the air or water from its heating system passes through the storage is warmed and fed through conventional heaters to warm the living spaces of the building.

The heat from solar energy can also be used to cool buildings by employing the absorption cooling principle used in gas-fired refrigerators. This requires extremely high operating temperatures.

Solar water heaters are used for domestic purpose in Australia, Israel, Japan etc. It composes of a blackened flat plate metal collector with an associated metal tubing, facing the general direction of the sun. The collector is provided with a transparent glass cover and a layer of thermal insulation beneath the plate. The collector tubing is connected by a pipe to an insulated tank that stores hot water during non-summer periods. The collector absorbs solar radiation and by transfer of resulting heat to the water circulating through the tubing by gravity or by pump, hot water is supplied to the storage tank.

For insulated applications, solar water heaters meet the low and medium temp. process heat requirements using hot water upto 90^0 C, hot air upto 110^0 C and low pressure steam upto 140^0 C. These are specially useful in engineering, textile, chemicals, pharmaceuticals, food processing, sugar industries.

Solar distillation involves admitting solar radiation through a transparent cover to a shallow covered brine basin. Water evaporates from the brine and the vapour condenses on the covers which are so arranged that the condensate flows into the collection troughs and into product-water storage tank. In arid, semi arid or coastal areas, there is abundant sun light that can be used to convert brackish water into potable distilled water.

Solar energy is used for drying agricultural products such as soft fruits, gram, paddy, maize, ginger, cashew, pepper etc., spray drying of milk, timber, fish etc.

Solar refrigeration can be used for preserving food or storing biological and medical materials. There are two methods of solar refrigeration: (a) Vapour absorption refrigeration system which uses low grade thermal energy obtained from flat plate collectors with minor modification. (b) Concentrating collectors (by focusing) to supply heat at a higher temp. to a heat engine which then drives the compressor of a conventional refrigerator.

Solar refrigeration with an absorption system is a better way of direct utilization of energy. The vapour absorption system replacing the compressor by a generator absorber assembly can work with wide range of absorbents and refrigerants.

Electricity from Solar Energy :-

Electricity can be produced from the solar energy by photo voltaic solar cells, which convert the solar energy directly to electricity. The most significant applications of photo voltaic cell in India, are the energisation of pump sets for irrigation, drinking water supply and rural electrification covering street lights and small power loads. When photons from the sun are absorbed in a semi-conductor, they create free electrons with high energy. Then there must be an electric field to induce these free higher energy electrons to flow out of the semiconductor to do useful work. The photovoltaic effect can be described easily for p-n

junction in semi-conductor materials of solar cells which are Silicon Cadmium Sulphide/Copper Sulphide, Gallium, Arsenite,etc.

In a solar thermal power production system, the energy is first collected by using a solar pond, a flat plate collector, focusing collector or heliostats. This energy is used to increase the temperature of a fluid which may be directly used in Rankine cycles or through a heat exchanger to heat a secondary fluid used in the cycle to produce mechanical power from which electrical power can be produced easily.

Solar thermal power cycles can be classified as low, medium and high temperature cycles. Low temp. cycles generally use flat plate collectors or solar pond, with a max. temp. of about 90 to 100^0 C. Medium temp. cycles work at max. temps. ranging from 150 to 300^0 C, using concentrating collectors. High temp. cycles work at max. temp. of about 300^0 C.

In solar tower conc. System(tower power concept), the incoming solar radiation is focussed to a central receiver of plane reflectors called heliostats.

Solar energy will be quite competitive with other energy sources if the solar tower plant size is 100-200 MW with 3-6 hours thermal storage. Experimental power plants have been built in USA, France, Italy and Japan.