RENEWABLE ENERGY TECHNOLOGIES

Unit 2 : **SOLAR RADIATION**

Module : 2

Solar spectrum, solar thermal collectors, Flat plate and concentrating collectors, Solar thermal Applications.

SOLAR SPECTRUM

The solar spectrum is the range of electromagnetic radiation emitted by the sun, extending from the ultraviolet to the infrared region. It is composed of photons with various wavelengths, which define the spectrum's shape and intensity. It can be defined in terms of solar radiation or solar irradiance. Solar radiation is the direct emission of energy from the sun while solar irradiance is the amount of energy that reaches the Earth's surface.

The solar spectrum can be divided into three main regions: the ultraviolet (UV), visible, and infrared (IR). The UV includes light with a wavelength shorter than 400 nanometers (nm). UV photons have energies ranging from approximately 3 to 5 electron Volts (eV). The visible region extends from 400 to 700 nm. This region contains photons with energies of 1.8 to 3 eV. Finally, the IR region comprises of light of wavelengths longer than 1000 nm, and its photons have energies between approximately 0.35 eV and 1.8 eV.

The intensity of the solar spectrum received on Earth is strongly dependent on the Earth-Sun distance, the angle at which the sun's rays reach the Earth's atmosphere, the weather, and the amount of air pollution. Solar cells, which use photovoltaic technology to convert solar radiation into electricity, are highly sensitive to the shape of the solar spectrum and the intensity of the radiation. Therefore, researchers and engineers working on solar cells must be knowledgeable about the solar spectrum in order to achieve optimal performance and efficiency. Therefore, the solar spectrum is an important phenomenon to consider when designing and working with solar cells.

SOLAR COLLECTORS

Solar thermal energy is the most readily available source of energy. The Solar energy is most important kind of non-conventional source of energy which has been used since ancient times, but in a most primitive manner. The abundant solar energy available is suitable for harnessing for a number of applications. The application of solar thermal energy system ranges from solar cooker of 1 kw to power plant of

200MW. These systems are grouped into low temperature (<150oC), medium temperature (150-300oC) applications.

Solar collectors are used to collect the solar energy and convert the incident radiations into thermal energy by absorbing them. This heat is extracted by flowing fluid (air or water or mixture with antifreeze) in the tube of the collector for further utilization in different applications. The collectors are classified as;

- Non concentrating collectors
- Concentrating (focusing) collectors

Non Concentrating Collectors

In these collectors the area of collector to intercept the solar radiation is equal to the absorber plate and has concentration ratio of 1. Flat Plate Collectors (Glaze Type) Flat plate collector is most important part of any solar thermal energy system. It is simplest in design and both direct and diffuse radiations are absorbed by collector and converted into useful heat. These collectors are suitable for heating to temperature below 100oC. The main advantages of flat plate collectors are:

- It utilizes the both the beam as well as diffuse radiation for heating.
- Requires less maintenance.

Disadvantages:

- Large heat losses by conduction and radiation because of large area.
- No tracking of sun.
- Low water temperature is achieved.

The constructional details of flat plate collector is given below

Insulated Box: The rectangular box is made of thin G.I sheet and is insulated from sides and bottom using glass or mineral wool of thickness 5 to 8 cm to reduce losses from conduction to back and side wall. The box is tilted at due south and a tilt angle depends on the latitude of location. The face area of the collector box is kept between 1 to 2 m2.

Transparent Cover: This allows solar energy to pass through and reduces the convective heat losses from the absorber plate through air space. The transparent tampered glass cover is placed on top of rectangular box to trap the solar energy and sealed by rubber gaskets to prevent the leakage of hot air. It is made of plastic/glass but glass is most favourable because of its transmittance and low surface degradation. However with development of improved quality of plastics, the degradation quality has been improved. The plasticsare available at low cost, light in weight and can be used to make tubes, plates and cover but are suitable for low temperature application 70-120oC with single cover plate or up to 150oC using double cover plate. The thickness of glass cover 3 to 4 mm is commonly used and 1 to 2 covers with spacing 1.5 to 3 cm are generally used between plates. The temperature of glass cover is lower than the absorber plate and is a good absorber of thermal energy and reduces convective and radiative losses of sky.

Absorber Plate: It intercepts and absorbs the solar energy. The absorber plate is made of copper, aluminum or steel and is in the thickness of1 to 2 mm. It is the most important part of collector along with the tubes products passing the liquid or air to be heated. The plate absorbs the maximum solar radiation incident on it through glazing (cover plate) and transfers the heat to the tubes in contact with minimum heat losses to atmosphere. The plate is black painted and provided with selective material coating to increase its absorption and reduce the emission. The absorber plate has high absorption (80-95%) and low transmission/reflection.

Tubes: The plate is attached to a series of parallel tubes or one serpentine tube through which water or other liquid passes. The tubes are made of copper, aluminum or steel in the diameter 1 to 1.5 cm and are brazed, soldered on top/bottom of the absorber water equally in all the tubes and collect it back from the other end. The header pipe is made of same material as tube and of larger diameter. Now-a-days the tubes are made of plastic but they have low thermal conductivity and higher coefficient of expansion than metals.

Copper and aluminum are likely to get corroded with saline liquids and steel tubes within hibitors are used at such places.

Removal of Heat: These systems are best suited to applications that require low temperatures. Once the heat is absorbed on the absorber plate it must be removed fast and delivered to the place of storage for further use. As the liquid circulates through the tubes, it absorbs the heat from absorber plate of the collectors. The heated liquid moves slowly and the losses from collector will increase because of rise of high temperature of collector and will lower the efficiency. Flat-plate solar collectors are less efficient in cold weather than in warm weather. Factors affecting the Performance of Flat Plate Collector.

The different factors affecting the performance of system are:

Incident Solar Radiation:

The efficiency of collector is directly related with solar radiation falling onit and increases with rise in temperature.

Number of Cover Plate:

The increase in number of cover plate reduces the internal convective heat losses but also prevents the transmission of radiation inside the collector. More than two cover plate should not be used to optimize the system.

Spacing:

The more space between the absorber and cover plate the less internal heat losses. The collector efficiency will be increased. However on the other hand, increase in space between them provides the shading by side wall in the morning and evening and reduces the absorbed solar flux by 2-3% of system. The spacing between absorber and cover plate is kept 2-3 cm to balance the problem.

Collector Tilt:

The flat plate collectors do not track the sun and should be tilted at angle of latitude of the location for an average better performance. However with changing declination angle with seasons the optimum tilt angle is kept Φ ± 15o.

The collector is placed with south facing at northern hemisphere to receive maximum radiation throughout the day.

Selective Surface:

Some materials like nickel black (α= 0.89, ε= 0.15) and black chrome (α= 0.87, ε= 0.088), copper oxide (α= 0.89, ε= 0.17) etc. are applied chemically on the surface of absorber in a thin layer of thickness 0.1 μm. These chemicals have high degree of absorption (α) to short wave radiation (< 4 μm) and low emission (ε) of long wave radiations (> 4 μm). The higher absorption of solar energy increase the temperature of absorber plate and working fluid. The top losses reduce and the efficiency of the collector increases. The selective surface should be able to withstand high temperature of 300-400oC, cost less, should not oxidize and be corrosive resistant. The property of material should not change with time.

Inlet Temperature:

With increase in inlet temperature of working fluid the losses increase to ambient. The high temperature fluid absorbed the less heat from absorber plate because of low temperature difference and increases the top loss coefficient. Therefore the efficiency of collector get reduced with rise in inlet temperature.

Dust on cover Plate:

The efficiency of collector decreases with dust particles on the cover plate because the transmission radiation decreases by 1%. Frequent cleaning is required to get the maximum efficiency of collector.

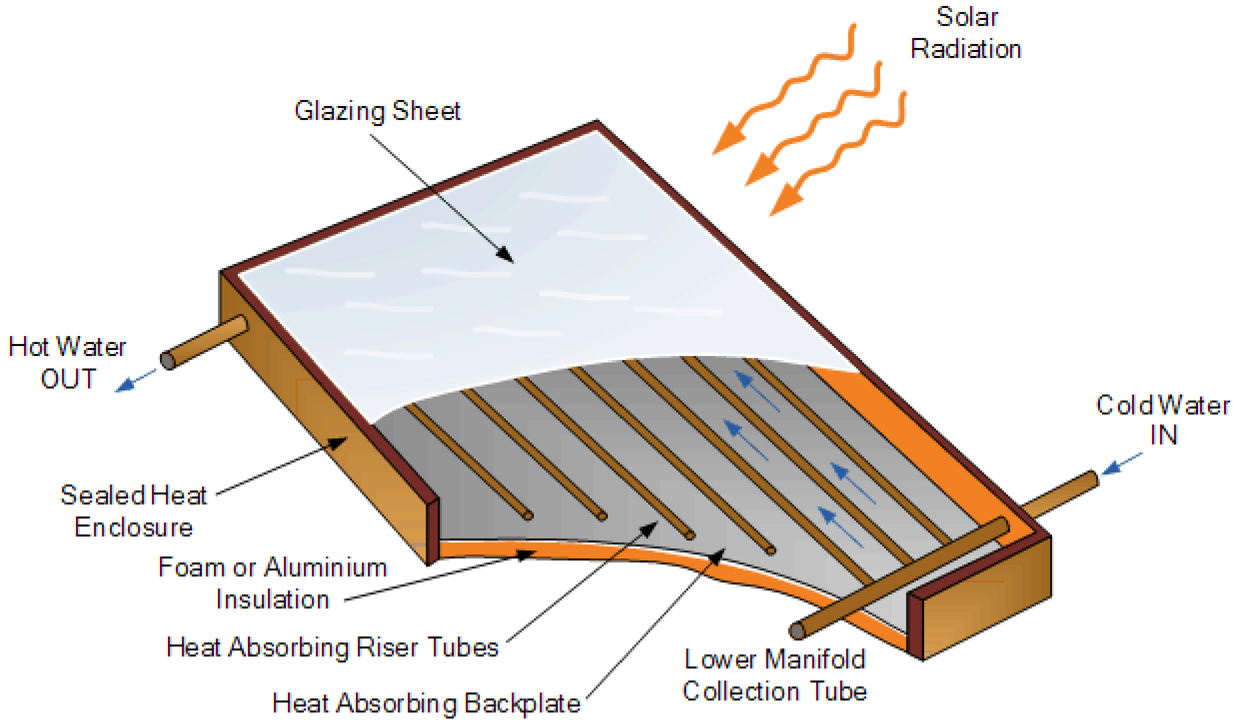


Fig. Flat plate collector

Concentrating Collectors

Concentrating collector is a device to collect solar energy with high intensity of solar radiation on the energy absorbing surface. Such collectors use optical system in the form of reflectors or refractors.

These collectors are used for medium (100-300o C) and high-temperature (above 300oC) applications such as steam production for the generation of electricity. The high temperature is achieved at absorber because of reflecting arrangement provided for concentrating the radiation at required location using mirrors and lenses.

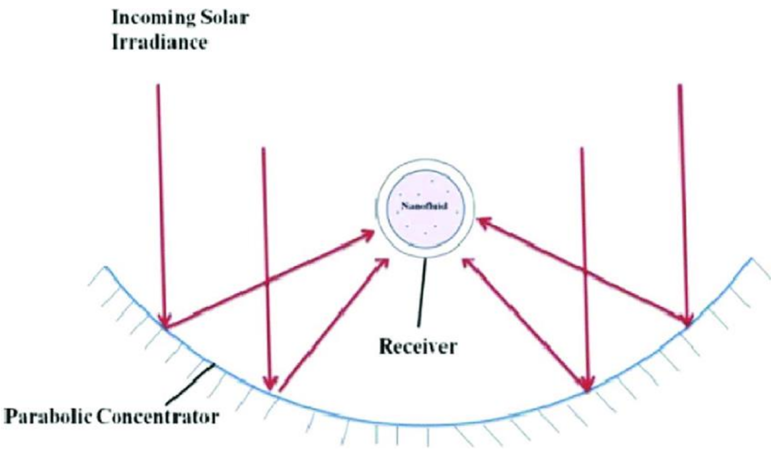
These collectors are best suited to places having more number of clear days in a year.

The area of the absorber is kept less than the aperture through which the radiation passes, to concentrate the solar flux. These collectors require tracking to follow the sun because of optical system. The tracking rate depends on the degree of concentration ratio and needs frequent adjustment for system having high concentration ratio. The efficiency of these collectors lies between 50-70%. The collectors need more maintenance than FPC because of its optical system. The concentrating collectors are classified on the basis of reflector used; concentration ratio and tracking method adopted.

Types of Concentrating Collectors:

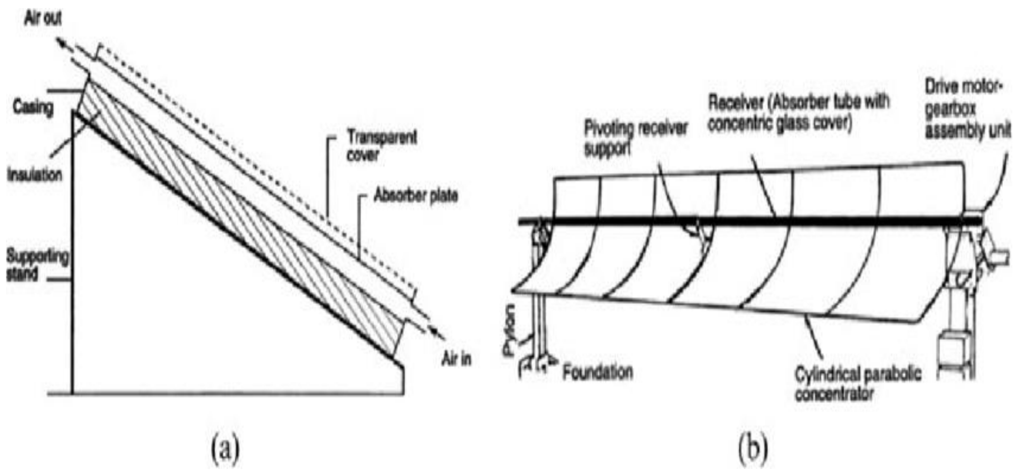
Compound Parabolic Collectors

These collectors are line focusing type. The compound parabolic collectors have two parabolic surfaces to concentrate the solar radiation to the absorber placed at bottom. These collectors have high concentration ratio and concentrator is moving to track the sun.



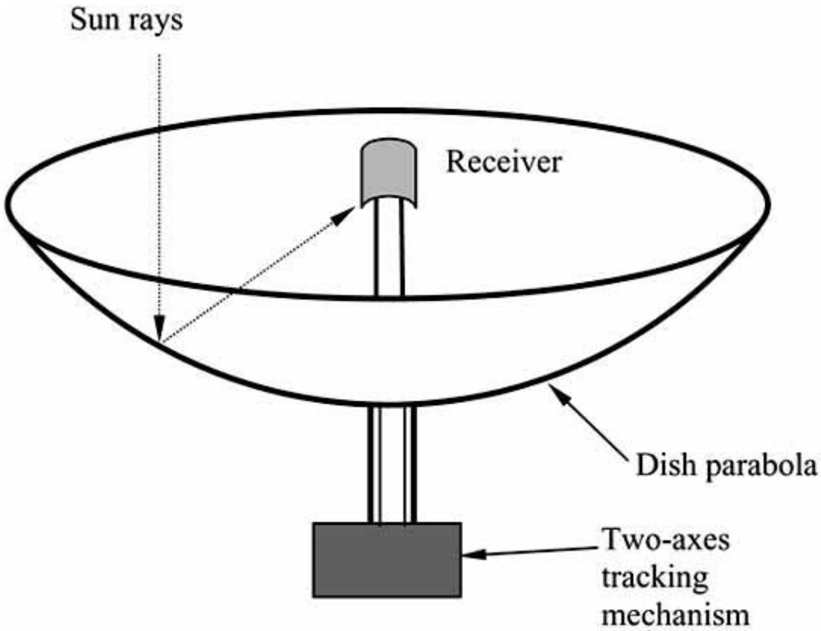
Cylindrical Parabolic Collectors

The troughs concentrate sunlight onto a receiver tube, placed along the focal line of the trough. The temperature at the absorber tube is obtained at nearly 400o C. The absorber in these collectors is moving to receive the reflected radiations by reflector, while the concentrators (trough) remains fixed. Because of its parabolic shape, it can focus the sun at 30 to 100 times its normal intensity (concentration ratio) on a receiver. The heat transfer medium carries the heat at one central place for further utilization.



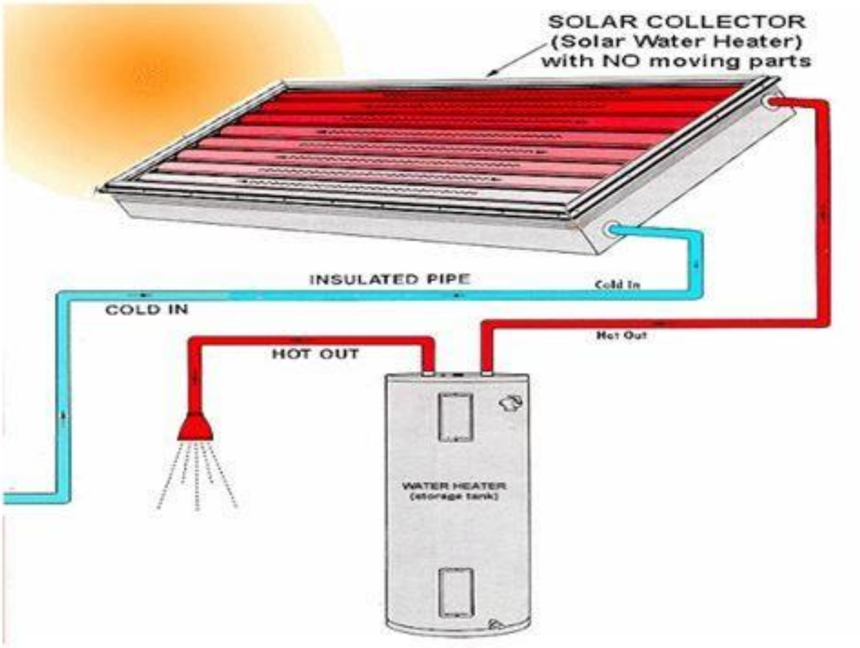
Parabolic Dish Collector

The collectors have mirror-like reflectors and an absorber at the focal point. These collectors are point focusing type. The concentrating ratio of these collectors is 100 and temperature of the receiver can reach up to 2000o C. These collectors have higher efficiency for converting solar energy to electricity in the small-power plant. In some systems, a heat engine, such as a Stirling engine, is connected to the receiver to generate electricity.

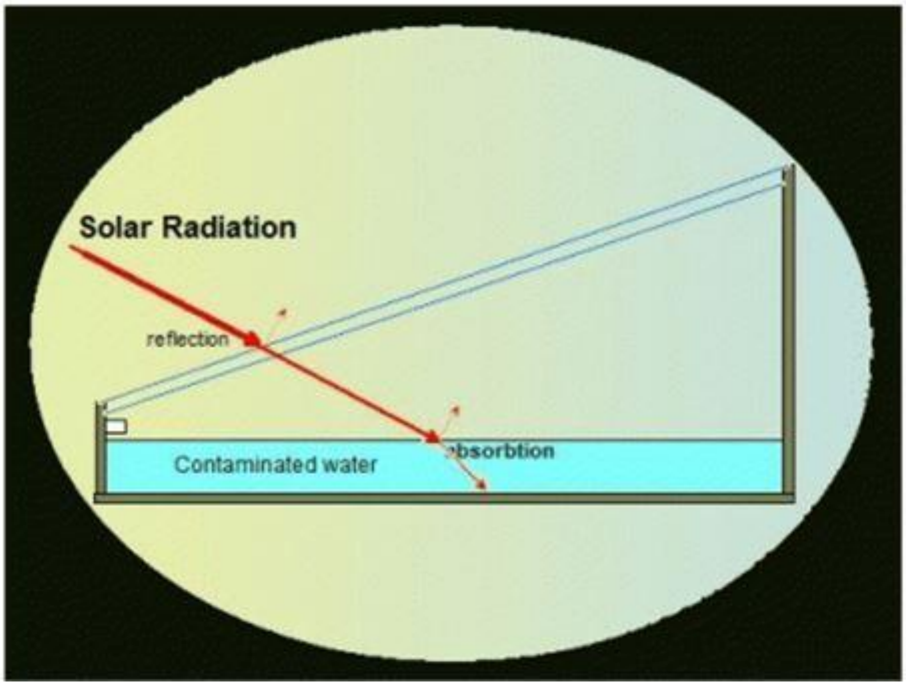


Applications of Solar Thermal Energy

1] Water Heating: Now since the basics of solar thermal systems have been introduced, it is time to delve into some of their applications. One of their major applications is water heating. They use thermosiphon and integrated water and storage (ICS) systems to heat the water inside the pipe. Thermosiphons and ICS systems are passive heating systems which use natural convection to aid fluid circulation. They work on the principle that as the water/fluid gets hotter, the better it circulates because of lesser density. The hot fluid flows towards the top and the colder, denser water flows to the bottom to replace the fluid in the collector. If there is no radiation or low radiation, then the water stagnates in the collector and no convection takes place. These passive systems are a good alternative to active systems by helping in reducing costs. They are suitable for milder climates which don't experience wild fluctuations in the temperature of the surroundings.



2] Solar Distillation and Desalination: Another application for solar thermal systems is for water purification through solar distillation and desalination. Distillation is one of the oldest methods that are commonly used to purify a substance by filtering out the components based on their volatilities. It involves evaporating a solvent in one location and condensing the solvent vapour in another location. This purifies the solvent and when the energy supplied to facilitate this process is provided by solar radiation, it is termed as solar distillation. Conventionally, distillation occurs in constant conditions of temperature, pressure and flow rate but solar distillation is dependent on the solar insolation available with the highest performance shown during maximum irradiance. It also varies throughout the year with it showing better performance during the warmer months as compared to the colder months. The major advantages of opting for solar distillation are because the need for regular operation and maintenance is minimized due to the absence of moving parts. The use of solar radiation also completely avoids burning of fossil fuels and hence has zero greenhouse gas semissions. The versatility in being able to install these systems in remote locations also provides an added advantage. Water desalination using solar thermal energy is a classification of solar distillation which uses passive systems to minimize dependency on construction, operation and maintenance. Using a solar collector significantly reduced thermal losses and increased efficiency because of the small surface area of the absorber and because of the lack of need for extra components.



3]Food Drying: The final application of solar thermal systems is food drying using an indirect passive system. Drying food crops is one of the highly practised methods to remove moisture from food items. Moisture often provides a medium for bacteria and fungi to grow which consequently leads to the food being spoiled. This greatly affects the farmers who harvest these crops and at the same time affect the nation's economy if not managed effectually. Preventing moisture from seeping into the food helps to retain the flavour and nutritional value of the food. The major factors that affect food drying are airflow, humidity and temperature. The use of passive solar systems uses the process of convection to keep the foods dry by using solar radiation. It is more economical and helps in managing the temperature, humidity and airflow conditions during the different stages of drying