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 (150-3000C) applications.

❑ Solar Collectors

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 1000C.

❑ 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

(a) **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.

(b) **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 plastics are available at low cost, light in weight and can be used to make tubes, plates and cover but are suitable for low temperature application 70-120 0C with single cover plate or up to 1500C 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.

(c) **Absorber Plate**: It intercepts and absorbs the solar energy. The absorber plate is made of copper, aluminum or steel and is in the thickness of 1 to 2 mm. It is the most important part of collector along with the tubes or ducts 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.

(d) **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 with inhibitors 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:

(a) Incident Solar Radiation: The efficiency of collector is directly related with solar radiation falling on it and increases with rise in temperature.

(b) 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.

(c) 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.

(d) 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 $\phi \pm 150$. The collector is placed with south facing at northern hemisphere to receive maximum radiation throughout the day.

(e) Selective Surface: Some materials like nickel black ($\alpha = 0.89$, $\varepsilon = 0.15$) and black chrome ($\alpha = 0.87$, $\varepsilon = 0.088$), copper oxide ($\alpha = 0.89$, $\varepsilon = 0.17$) etc. are applied chemically on the surface of absorber in a thin layer of thickness 0.1 μ m. These chemicals have high degree of absorption (α) to short wave radiation (< 4 μm) and low emission (ε) of long wave radiations (> 4 μ m). The higher absoption 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 300-4000C, cost less, should not oxidize and be corrosive resistant. The property of material should not change with time.

(f) 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.

(g) **<u>Dust on cover Plate</u>**: 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.

❑ 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 (100-3000C) and high-temperature (above 3000C) 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.

- **FPC with Reflectors**

  The mirrors are placed as reflecting surface to concentrate more radiations on FPC absorber. The fluid temperature is higher by 300C than achieved in FPC. These collections utilize direct and diffuse radiation.

- **Lens Focusing Type**

  The fresnel lenses are used to concentrate the radiation at its focus. The lower side of lenses is grooved so that radiation concentrates on a focus line.

- **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 4000C. 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 20000C. 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.

❑ Center Receiver

Type (Solar Power Tower) These collectors are used to collect the large solar energy at one point. This system uses 100-10000 of flat tracking mirrors called heliostats to reflect the solar energy to central receiver mounted on tower. The energy can be concentrated as much as 1,500 times than that of the energy coming in, from the sun. The losses of energy from the system are minimized as solar energy is being directly transferred by reflection from the heliostats to a single receiver where the sun's rays heat a fluid to produce steam.

❖ Advantages of concentrating collector over flat collector

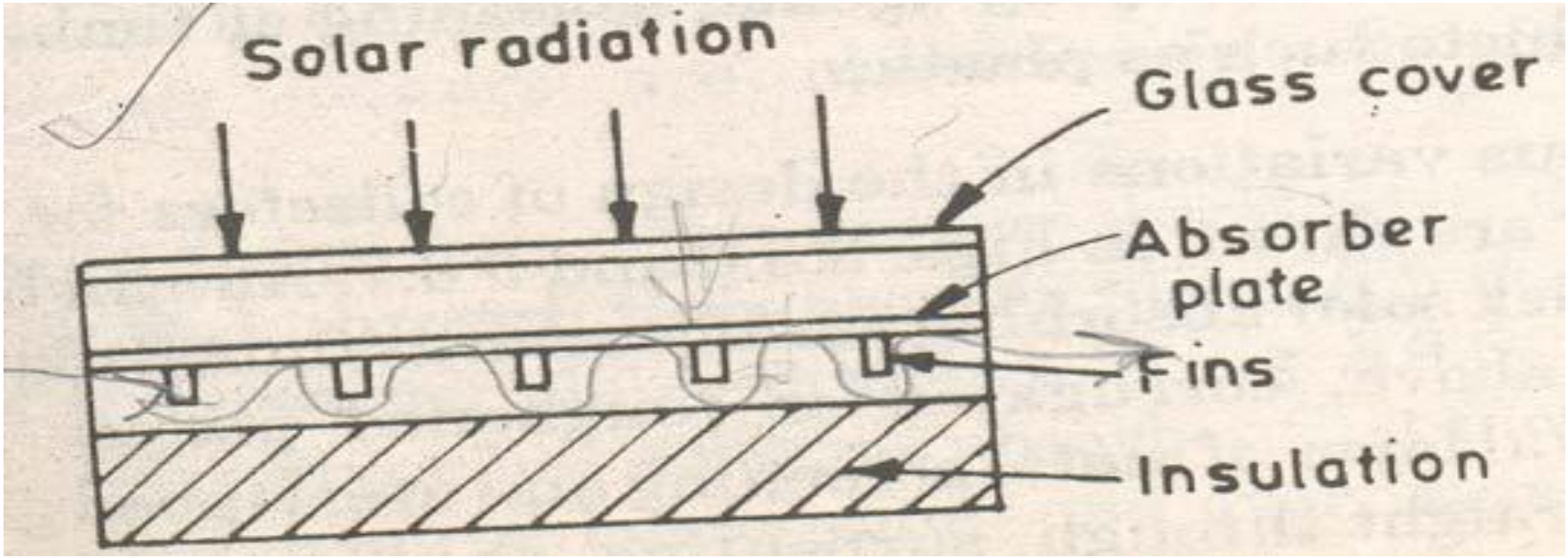
- The size of the absorber can be reduced that gives high concentration ratio.
- Thermal losses are less than FPC. However small losses occur in the concentrating collector because of its optical system as well as by reflection, absorption by mirrors and lenses.
- The efficiency increases at high temperatures.
- In these collectors the area intercepting the solar radiation is greater than the absorber area.
- These collectors are used for high-temperature applications.
- Reflectors can cost less per unit area than flat plate collectors.
- Focusing or concentrating systems can be used for electric power generation when not used for heating or cooling
- Little or no anti freeze is required to protect the absorber in a concentrator system whereas the entire solar energy collection surface requires anti freeze protection in a flat plate collector

❑ Disadvantages

- Out of the beam and diffuse solar radiation components, only beam component is collected in case of focusing collectors because diffuse component cannot be reflected and is thus lost.
- In some stationary reflecting systems it is necessary to have a small absorber to track the sun image; in others the reflector may have to be adjustable more than one position if year round operation is desired; in other words costly orienting systems have to be used to track the sun.
- Additional requirements of maintenance particular to retain the quality of reflecting surface against dirt, weather, oxidation etc.
- Non –uniform flux on the absorber whereas flux in flat-plate collectors in uniform.
- Additional optical losses such as reflectance loss and the intercept loss, so they introduce additional factors in energy balances.
- High initial cost.

❑Solar Air Heaters

Air stream is heated by the back side of the collector plate in flat plate collector. Fins attached to the plate increase the contact surface. The back side of the collector is heavily insulated with mineral wool or some other material. If the size of collector is large, a blower is used to draw air into the collector and transmit the hot air to dryer.



The most favourable orientation of a collector for heating only is facing due south at an inclination angle to the horizontal equal to the latitude plus 150. The use of air as the heat transport fluid eliminates both freezing and corrosion problems and small air leaks are of less concern than water leaks

Disadvantages:

1. Need of handling larger volumes of air than liquids due to low density of air as working substance.
2. Thermal capacity of the air is low.
3. They have relatively high fluid circulation costs (especially if the rock heat- storage unit is not carefully designed)
4. They have relatively large volumes of storage (roughly three times as much volume as for water heat-storage)
5. They have a higher noise level.
6. The system has difficulty of adding conventional absorption air-conditioners to air systems
7. The space is required for ducting.

❑ Types of Air Heaters

1. Non porous absorber in which air stream does not flow through the absorber plate
2. Porous absorber that includes slit and expanded material, transpired honey comb and over lapped glass plate

1. Non-porous absorber plate type collectors:

A non-porous absorber may be cooled by the air stream flowing over both sides of the plate. In most of the designs, the air flows behind the absorbing surface. Air flow above the upper surface increases the convection losses from the cover plate and therefore is not recommended if the air inlet temperature rise at the collector are large. Transmission of the solar radiation through the transparent cover system and its absorption is identical to that of a liquid type flat-plate collector. To improve collection efficiency selective coating may be applied provided there is no much cost. Due to low heat transfer rates, efficiencies are lower than liquid solar heaters under the same radiation intensity and temperature conditions. Performance of air heaters is improved by:

(a) Roughening the rear of the plate to promote turbulence and improve the convective heat transfer coefficient

(b) Adding fins to increase heat transfer surface. Usually turbulence is also increased which enhances the convective heat transfer. Absorption of solar radiation is improved due to surface radioactive characteristics and the geometry of the corrugations, which help in trapping the reflected radiation.

2. <u>Collectors with porous absorbers</u>: The main drawback of the non-porous absorber plate is the necessity of absorbing all incoming radiation over the projected area from a thin layer over the surface, which is in the order of a few microns. Unless selective coatings are used, radiative losses from the absorber plate are excessive, therefore, the collection efficiency cannot be improved. Too many surfaces and too much restriction to air flow will require a larger fan and a larger amount of energy to push the air through. The energy required for this cancels out saving from using solar energy, particularly if fan is electrical and if the amount of energy which is burned at the power plant to produce the electrical energy is included.

The solar air heating utilizing a transpired honey comb is also favourable since the flow cross section is much higher. Crushed glass layers can be used to absorb solar radiation and heat the air. A porous bed with layers of broken bottles can be readily used for agricultural drying purposes with minimum expenditure. The overlapped glass plate air heater can be considered as a form of porous matrix, although overall flow direction is along the absorber plates instead of being across the matrix.

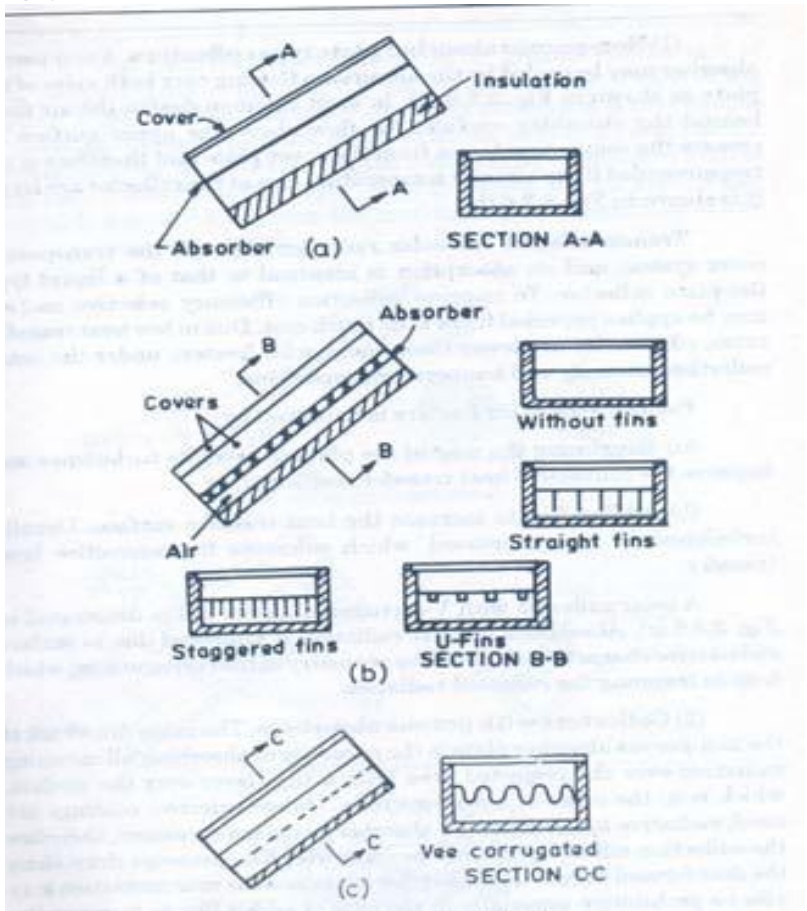


Fig. 3.3.6. Non-porous type air heaters.

Basically air heaters are classified in the following two categories.

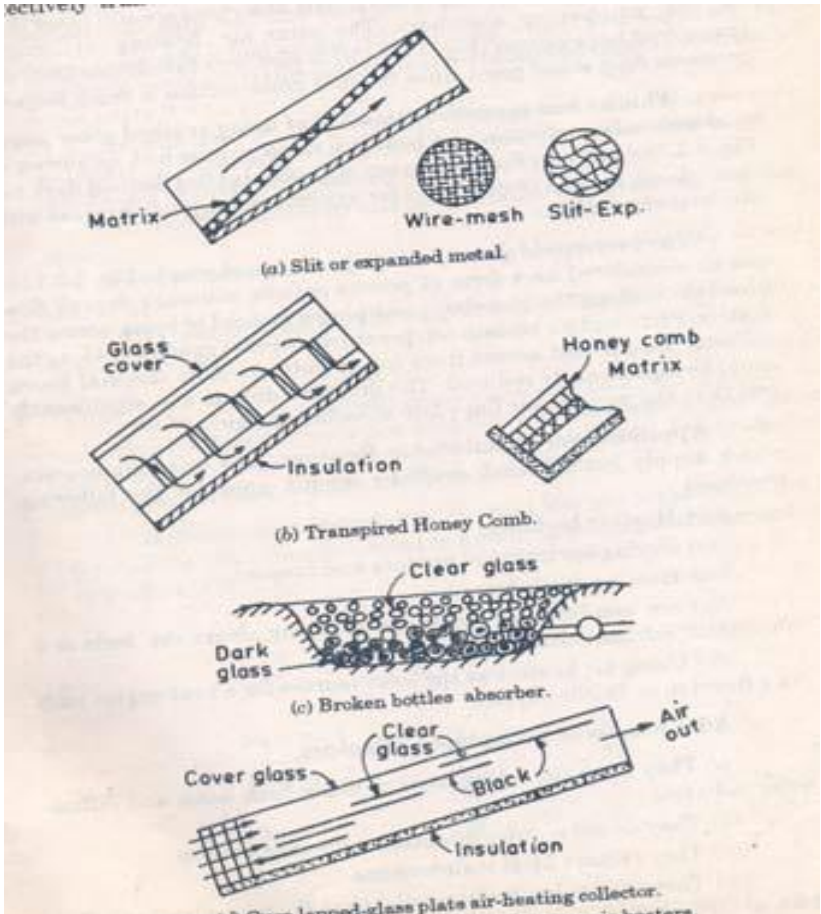


Fig. 3.3.7. Sketches of porous absorber-type air heaters.

- Applications of Solar air heaters
- Heating buildings
- Drying agricultural produce and lumber
- Heating green houses
- Air conditioning buildings utilizing desiccant beds or a absorption refrigeration process
- Heat sources for a heat engine such as a Brayton or Stirling cycle