Fundamental of Solar Water Heaters

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Introduction

Solar energy is inexhaustible and available in all the countries of the world, the sunshine hour varying from a few hundred hours per year as in the northern countries and the southern part of South America to about four thousand hours per year as in the Sahara desert and some countries of the Middle East. Greatest amount of solar energy is available in two broad bands [1] encircling the earth between 15^o and 35^o latitude north and south. The next best position is the equatorial belt between 15^o N and 15^o S latitude .

Most of the developing countries, being situated in these regions, are in a favorable position in respect of solar energy. Bangladesh is situated between 20.34^o and 26.38^o latitude north and as such has a good solar energy potential. Bangladesh is a country of enormous sunshine. Average annual solar radiation on a 24^0 inclined surface is estimated as 4.2 $kWh/m^{-2}/day^{-1}$ [2]. But the availability of an energy source does not mean much, if the necessary technology to harness it is not available. During the last decades considerable advances in some of the solar energy technologies have been made and some have already reached the commercial stage.

This lecture presents solar radiation on earth's surface, application of solar thermal, direct solar thermal application, energy balance equations, fundamental of solar water heater, and thermosyphone principle.

Solar Radiation on the Earth's Surface

Solar radiation is received at the earth's surface in an attenuated form because it is subjected to the mechanism of absorption and scattering as it passes through the earth's atmosphere (Figs. 1 and 2). Absorption occurs primarily because of the presence of ozone and water vapor in the atmosphere and to a lesser extend due to other gases (like CO_2, NO_2, CO, O_2 and CH_4) and particulate matter.

It results in an increase in the internal energy of the atmosphere. On the other hand, scattering occurs due to all gaseous molecules as well as particulate matter in the atmosphere. The scattered radiation is redistributed in all directions, some going back into space and some reaching the earth's surface.

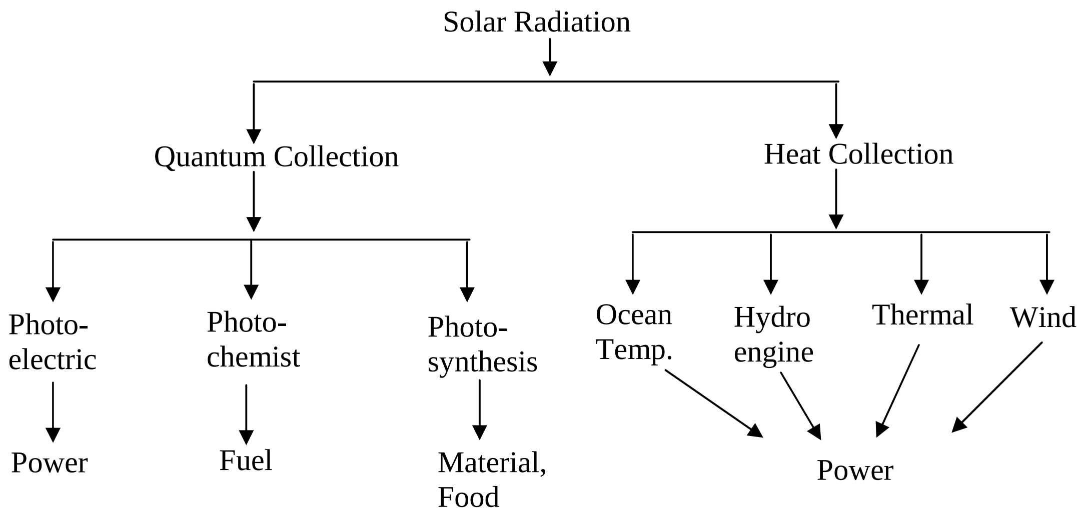


Fig. 1 Different collection processes of solar radiation

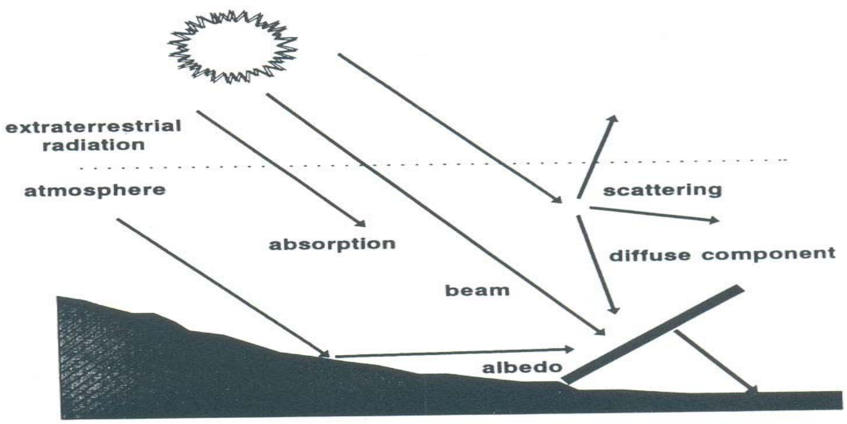


Fig. 2 Schematic representation of the mechanism of absorption and scattering, beam and diffuse radiation received at the earth's surface

Application of Solar Thermal

Most of the solar energy applications are concerned with trapping sunlight as heat. Because of the low energy density of sunlight, the higher the temperature needed, the more complicated and expensive the system will be. Depending on the range of temperature use, solar thermal applications are divided into the three broad categories [3]:

a. Low-temperature applications (below 100^{o}C), such as solar drying, hot water supplies, cooking, etc.
b. Medium-temperature applications (below 150^{o}C), such as refrigeration, industrial process heat, etc.
c. High-temperature (above 150^{o}C) applications, such as electricity generation.

Direct Thermal Applications

Solar space heating and cooling and solar hot water systems may be classified either as passive or active systems. The characteristic of passive systems is that they operate without mechanical devices; the air is circulated past a solar-heated surface (or surfaces) and through the building by natural convection processes.

Active systems use mechanical devices such as fans and pumps to circulate the air and thus may often require a separate heat absorbing fluid in the system.

Energy Balance Equation

$Q_u = A_c[S - U_L (T_{p,m} - T_a)]$
Q_u = Useful Energy Output of Collector
A_c = Area of the collector
S = Solar radiation absorbed by the Collector
U_L= Heat transfer Coefficient
$T_{p,m}$ = Mean absorber plate temperature
T_a = Ambient Temperature

Collector efficiency $\eta = \dfrac{\int Q_u \, d\tau}{A_c \int G\tau \, d\tau}$

$\int Q_u \, d\tau$ = Useful energy gain over some specified time period
$A_c \int G\tau \, d\tau$ = the incident solar energy over the same time period

A number of thermal applications are available, of which solar water heater will be discussed.

Solar Water Heater

In any collection device, the principle usually followed is to expose a dark surface to solar radiation so that the radiation is absorbed. A part of the absorbed radiation is then transferred to a fluid like air or water. When no optical concentration is done, the device in which the collection is achieved is called a flat-plate collector.

The flat-plate collector is the most important type of solar collector because it is simple in design, has no moving parts and requires little maintenance. It can be used for a variety of applications in which temperatures ranging from 40^0 C to about 100^0 C are required.

Thermosyphone

The principle of thermosyphone just like boiling the water. In a flat bed collector in cold water flows to the collector, it gets warm by sunshine and flows upward as it becomes lighter than cold water and stored in the tank which can be used directly.

A collector essentially consists of the following components.

- a coated flat plate which absorbs solar radiation and transforms it into thermal energy
- an insulated storage tank used to reduce thermal losses of heated water glass or plastic
- cover to reduce upward thermal losses of the collector
- bottom insulation to reduce downward thermal losses
- tubes and channels for circulating water to collect thermal energy
- wooden or metallic frame to house the collector assembly

Solar water heater is basically a flat-plate collector in which heat transfer fluid is water. Fig. 3 shows the working principle of solar water heater.

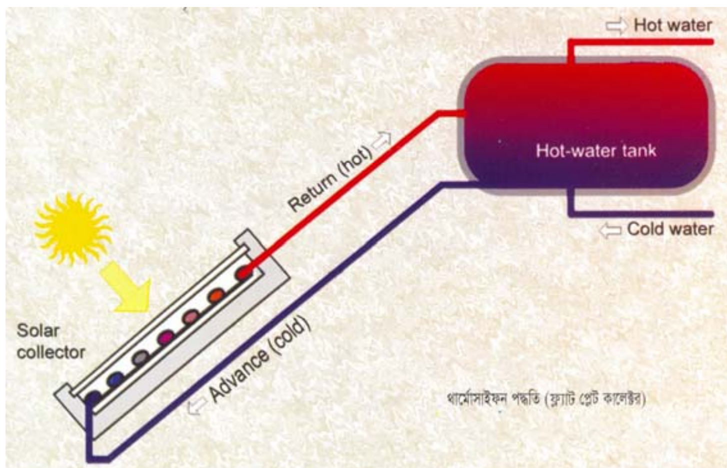


Fig. 3 Thermosyphone Principle-Solar Heater [4]

The coated plate absorbs solar radiation, converts it into heat and transfers the resulting heat to circulating water. Hot water is then supplied to the storage tank for domestic or space heating use. These collectors are useful for supplying low-grade thermal energy at temperatures below 90^{o}C.

The important parts of a typical liquid heating flat-plate solar collector, as shown in Fig. 4, are the" black" solar energy-absorbing surface, which means for transferring the absorbed energy to a fluid; envelopes transparent to solar radiation over the solar absorber surface that reduce convection and radiation losses to the atmosphere; and back insulation to reduce conduction losses as the geometry of the system permits.

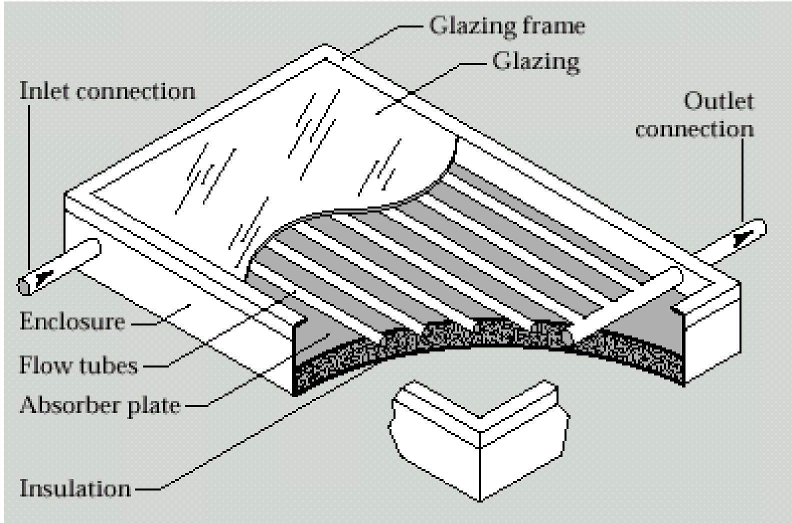


Fig. 4 Important parts of a typical liquid heating flat-plate solar collector

Recently the Centre for Energy Studies of BUET installed two solar water heaters at the roof of Old Academic Building (Fig. 5).

Fig. 5 Solar water heaters at the roof of Old Academic Building

A special type of solar water heater arrangement is presented in Fig. 6 for domestic use. In that arrangement, to keep the hot water storage tank and the solar collector always full (necessary for thermosyphone flow to operate) a cold water storage tank has been provided at a higher level. If the capacity of the tank is too low, hot water will be exhausted quickly and if large capacity tank it will take longer time to heat. Hence as a compromise is needed.

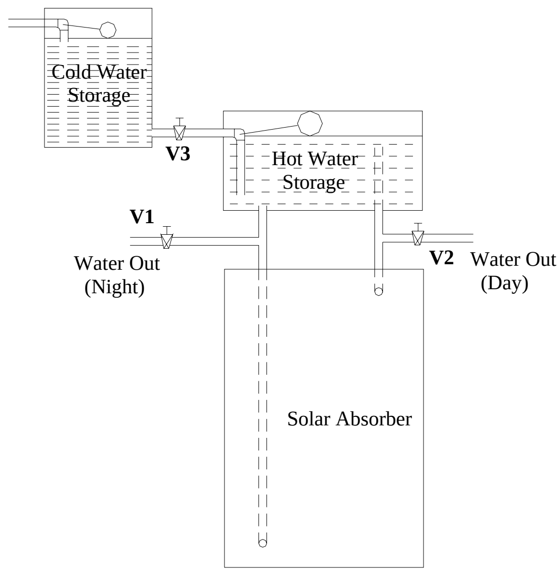


Fig. 6 Arrangement of solar absorber, cold-hot water storage tanks

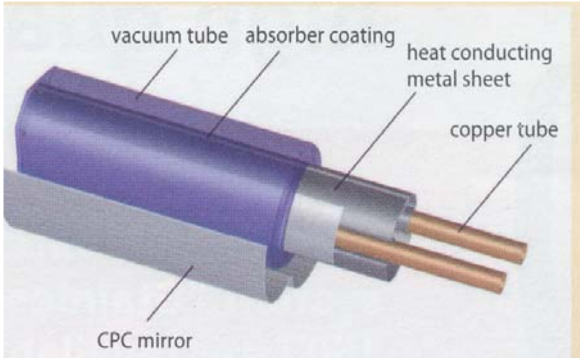
If no warmer water is used over a longer period, the thermosiphon system can heat up considerably. As soon as water evaporates, the pressure increases. To be able to guarantee the safety of the system also in such cases the manufacturers incorporate either pressure relief valves or additional expansion tanks.

Tubes of Solar Water Heater

Conventionally copper tubes shown in Fig. 7 are used to carry heat transfer fluid. Recently vacuum tubes collectors are used. It is said to more efficient them the copper tube.

Fig. 7 View of the Copper Tube Collector in a Water Heater

The construction and working principle of thermos flask tube [5] or so-called Sydney tube and Lenz tubes are shown Figs. 8 and 9.



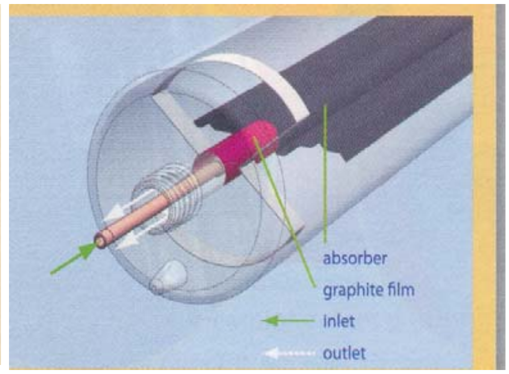


Fig. 8 Construction of Sydney Tube

Fig. 9 Diagram of The Lenz Tube

The thermos flask tube or so-called Sydney tube consists of two glass tubes melted into each other, with an evacuated clearance in between. The aluminium nitride absorber is sputtered onto the inner tube. In order to lead the heat away, there is a heat-conducting metal sheet in the thermos flask, curved in a circular way. Into this sheet, the direct flow U-shaped pipe register is inserted. Due to the round shape of the absorber, the light from the back of the collector can also be harvested by means of a mirror. The Lenz tube is also a thermos flask that does not need any metal-glass transition and works on the same principle.

Nepal is using this solar water heaters (Fig. 10) for house hold hot water for over 25 years. Convention copper tube heaters are very common and recently vacuum technology is getting popularity. The price is affordable. China is by far the largest solar thermal market in the world and a lot of tubes have been exported from China.

Fig. 10 Solar water heater in rural village in Nepal

Conclusion

This lecture has presented briefly of solar radiation on earth's surface, application of solar thermal, direct solar thermal application, energy balance equations, fundamental of solar water heater, and thermosyphone principle. It is hoped that the solar water heater as a source of renewable energy will have positive impact in reducing electrical energy consumption.

References

[1] Charles E. Brown, "World Energy Resources", Springer, USA, 2002.

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