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Performance of Solar Flat plate by using Semi- Circular Cross Sectional Tube

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Abstract— Solar flat plate collector is a solar thermal device which is use to raise the temperature of any fluid up to 100^0C. Generally a large number of arrays of circular cross sectional tube are attached to the absorber tube to transfer of heat from absorber tube to working fluid. When using semi circular type tube blow the absorber plate, the area of intimate contact is increases between fluid and absorber plate and also resistance due to adhesive is decreases. Due to this reason performance of solar flat plate collector is increased.

Keywords— Solar flat plate collector, semi-circular tube, absorber plate.

INTRODUCTION

Solar energy is very large, inexhaustible and clean source of energy. Solar energy is the radiation resulted by nuclear fusion reactions in the sun. This energy radiates outwards in all the directions. But, only a tiny fraction 1.4×10^{14}kW, of the total radiation emitted by the sun is intercepted by the earth. The quantity of solar energy striking the Earth's surface averages about 1,000 watts per square meter under clear skies, depending upon weather conditions, location, and orientation of the surface [01]. However, even with this small fraction it is estimated that 30 min of solar radiation falling on earth which is equal to the world energy demand for one year [02].

The solar thermal energy is collected by a device called solar collector. A flat plate collector is such type of solar thermal collector which is using in such place where moderate heat is require. It can increase the temperature of the fluid up to 100^0C above ambient temperature [01]. It is also simple in design, have no moving parts and require little maintenance. They are also relatively cheap and can be used in variety of application. A simple flat plate consists of four components (i) absorber plate (ii) tubes fixed to the absorber plate (iii) the transparent cover (iv) the collector box. The collector plates absorb the maximum possible amount of solar irradiance and transfer this heat to the working fluid which is flowing in absorber tube. The fluid used for heat transfer generally flows through a metallic tube, which is connected to the absorber plate. The absorber is usually made of metallic materials such as copper, steel or aluminum and surface is generally black. The collector box can be made of plastic, metal or wood type insulator to prevent heat loss and the transparent front cover must be sealed so that heat does not escape, and the collector itself is protected from dirt and humidity. The heat transfer fluid may be either water or water with antifreeze liquid. Still the heat losses due to the temperature difference between the absorber and ambient air result in convection and radiation losses. The main advantage of a flat plate collector is that it utilizes both beam and diffuse components of solar radiation [03]. Efficiency of flat plate collector depends on the temperature of the plate, ambient temperature, solar insolation, top loss coefficient, emissivity of plate, transmittance of cover sheet, number of glass cover. Tracking system is also important for improve the efficiency of flat plate collector. Tracking is desirable for orienting a face of solar device towards the sun, therefore collector collecting maximum solar radiation and due to this better performance.

Y.Y. Nandurkar and R.S. Shelke [04] conducted experiments in which reducing area of liquid flat plate collector by increasing tube diameter and reducing riser length. Solar flat plate collector having increasing diameter of copper tube of flat plate collector with integral fins performances is better than the ISI flat plate collector. The present work is an study on the comparative performance analysis of ISI flat plate collector with modified flat plate collector. It is found that the modified flat plate collector with increase in diameter of test section, Nusselt number and Reylonds number is increased with second power of tube diameter.

Thundil Karuppa R. Raj [05] et al investigates a new solar flat plate collector which is of sandwich type. The new type of collector is the water sandwich type collector which is made by bracing two corrugated metal sheets on one another. The absorber is made of 2 sheets of GI (1 mm) with integrated canals, painted silica based black paint. The outer casing which provides mechanical strength to the equipment is insulated to reduce the heat losses from back and sides of the collector. The new collector is differ is the absence of heat carrying metallic tubes. The working fluid is made to pass through the channels that are formed when two corrugated metal sheets are braced one over another. Efficiency of the flat plate conventional is 24.17 and efficiency of the new collector is 20.19%.

Vipin Awasthi [06] et al reported the thermal performance of double glazed flat plate solar collectors with different range of design variable on top heat loss coefficient. The temperature of the absorber surface is above ambient temperature, the surface re-radiates some of the heat and it has go back to the surroundings. Coatings enhance the absorption of sunlight and also enhance the long wavelength radiation loss from the surface. A good coating will produce an absorber surface that is a good absorber of short-wavelength solar irradiance but a poor emitter of long-wavelength radiant Energy. The collector tilt angle is increases then the top heat loss Coefficient and overall transfer coefficient is gradually decreases.

A.T. Fatigun [07] et al conduct experiment in which the effect of tube spacing on the performance of a flat plate collector is compares. Two same aperture area of solar flat plate collector is compare of average adjacent tube spacing of 11 cm (A) and 20 cm (B). Average of 11 cm spacing between adjacent lines yielded 15 turns while 20cm average line spacing yielded 9 turns of tubing per Flat plate. The efficiency of collector (B) was found to be significantly higher than that of collector (A), i.e. 10% and 21% was obtained for collectors (A) and (B) respectively.

Sunil.K.Amrutkar [08] et al evaluates the performance of flat plate collector with different geometric absorber configuration. By varying the collector plate material, glazing material, the efficiency and outlet temperature of flat plate collector is also vary. To reducing the collector area and minimizing the number of tubes, cost of collector is also reduced.

Useful Heat gain by Semi-circular tube

A large number of geometrical parameters influence the performance of a flat plate collector as selective surfaces, numbers of covers, spacing between covers and absorber plate etc. In this study, shape of tube is considered to be semi circular cross-sectional area. The tube attached to the absorber plate is semi circular, so that area of absorbing surface is more than that of a circular tubing system in solar flat plate collector.

The one dimensional flow of heat in the absorber plate in a direction at right angles to the direction of fluid is considered. When considered tube is attached blow of tube, the resistance to heat flow to the tube from the plate may be consisted of three components; (i) the resistance due to the bonding material between the plate and the tube; (ii) the resistance due to the temperature gradient in the fluid at the tube wall; (iii) the resistance due to the wall thickness of the tube. Now, calculating the useful heat gained by fluid per unit length. When cthe volume of fluid contains by circular tube and semi-circular tube assume to be same.

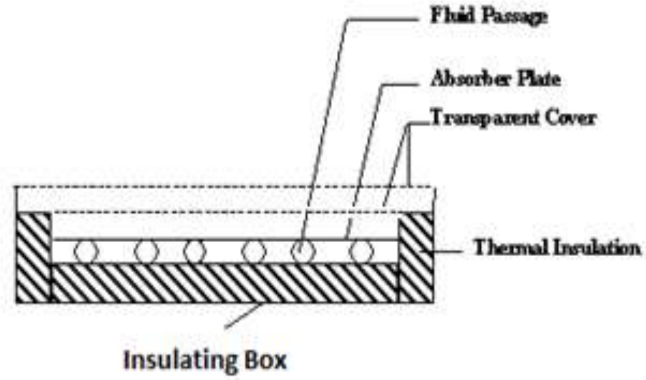


Fig. No.-01 Flat Plate Collector with circular cross-sectional tube

Let, $T_b=100^0C$ and $T_f=60^0C$

Inner diameter of tube (Di) =10mm

$C_w=250W/m^2k$

$C_b=40W/m^2k$

$h_{fi}=100W/m^2k$

Where

T_b=Base temperature above the bond

T_f=Fluid temperature

C_b=Bond conductance

C_w=Conductance of the tube wall

h_{fi}=Film heat transfer co-efficient

$$Q_u = \frac{T_b - T_f}{\frac{1}{C_b}+\frac{1}{\pi D_i h_{fi}}+\frac{1}{C_w}} \quad [09]$$

$=115.174\ W/m^2$

Now when considered that the fluid is flowing through semi circular cross-sectional area, then the resistance due to bonding material and resistance due to wall thickness are eliminated. $Dci=1.414D_i$, is the diameter of semi circular tube. So, the useful heat gain (Q_u) by tube is increases.

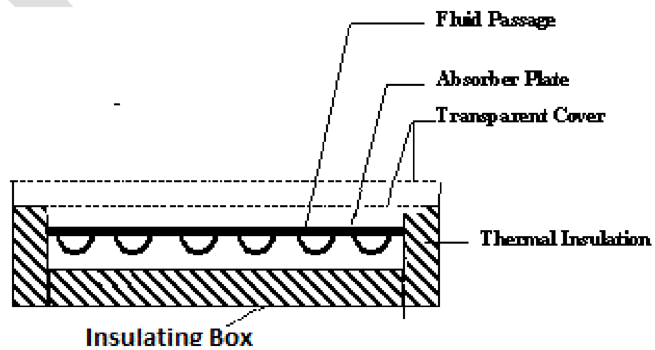
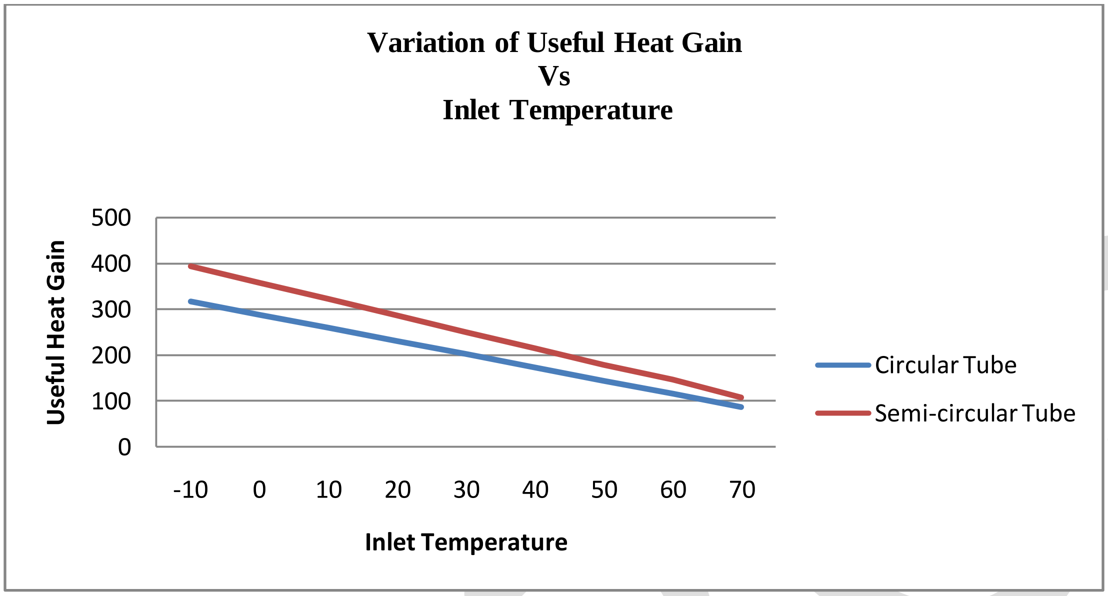


Fig. No.-02 Flat Plate Collector with semi-circular cross-sectional tube

And the useful heat gain is given as

$$Q_u = \frac{T_b - T_f}{\frac{1}{\pi D_{ci} h_{fi}}}$$

$$=177.69 \text{ W/m}^2$$



Result and discussion: By using the semi-circular tube below the absorber plate, the useful heat gain is increase. The graph shows that when using the fluid at low temperature, the semi-circular type tube absorbed more heat than circular tube. This result also indicates that when using the fluid having low melting point the useful heat gain by the fluid is more.

Conclusion: The flat plate collector with semi circular cross sectional tube has absorbed more heat than that of circular cross-sectional area tube, due to increasing absorbing area of tube, reducing the resistance due to the bonding material between the plate and the tube and the resistance due to the wall thickness of the tube. So, this method improves the efficiency of flat plate collector.

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