International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 02, Issue – 11, November – 2017, PP – 81-85

Design of a Solar Flat Plate Collector

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Abstract: Solar water heaters (SWH), in comparison to conventional hot-water heating systems, represents an alternative with moderate costs in countries with high energy costs and sufficient irradiation. While having significance for the supply of energy in these countries, the introduction of this new but simple techniques also opens up possibilities for sustainable socio-economic development.

A typical flat plate collector is a type of solar water heater which is a metal box or a wooden box with a glass or plastic cover called glazing on top and a darken colored absorber plate on the bottom..

Keywords: Flat, heater, plate, solar, thermosiphon

1. Introduction

The whole assembly of the solar collector, the fluid carrying pipes and the reservoir tank are mounted on iron stands. At first, the cold water enters through a separate inlet provided at the reservoir tank. Proper capping will be provided at the inlet to prevent any leakage or heat loss. When the water level will reach the other end of the inlet, it will flow down to the absorber plate. The functioning of the absorber plate will be discussed later. After the operation of heating of the fluid in the absorber plate, the hot fluid being less dense, will flow up through the outlet pipe due to thermosyphon effect and back to the reservoir tank. Now the hot water will fill the upper portion of the reservoir and the cooler water at the bottom of the tank is then pushed down to re-enter the solar collector where it is heated further. The outlet will be in the form of a tap from where the hot water can be collected. [1]

2. Construction

The construction of the solar flat plate collector has been carried out in the following manner. [1]

2.1 Framework

While constructing , iron rods of thickness 3cm and length 108 cm and 90 cm have been used for the front and rear end respectively and being arranged using the process of electric welding (MS electrodes, 34 mm thickness) with several other equipments.

2.2 Casing work

The casing is then constructed with Bosom wood where the proper dimensions were considered according to the base of plywood using the following carpentry tools-

- Rip Saw
- Round file
- Half round file
- Smooth file
- Sand papers
- Blow hammer

The bottom surface plate is constructed from plywood with dimensions (106 x 64 cm).

2.3 Insulation

Thermal insulation with the help of glass wool and thermocole is placed on the inner sides of the frame and on above the plywood surface on the bottom of the frame to minimize heat loss.

2.4 Absorber plate

The tubes or ducts (7 in number) are made with soft copper to appropriate length and diameter of 12.5 mm with the help of duct cutter and then arranged with the header which again is made of copper of 25.4 mm diameter using gas welding process (copper filler rod). All parts of the copper riser and the header are painted black. The aluminium sheet is flattened using hammer and the tubes are then wrapped with this sheet for an increased surface area for better heat absorption. The sheet too, is spray painted black.

2.5 Glazing

For the cover of this flat plate ordinary glass which is fixed on top of the casing with the support of thin wooden pieces on all the four sides and putty.

2.6 Reservoir tank

A reservoir tank of 20 liter capacity is being constructed with one provision for the immersion of cold inlet water, one for the entry of hot outlet water and the other for the tap which is for the collection of the hot water for use. The tank is being placed properly on the iron clamps which are being arc welded on the main framework. The tank is placed in such a way that the thermosiphon principle holds good.

Fig1: Flat plate collector 1

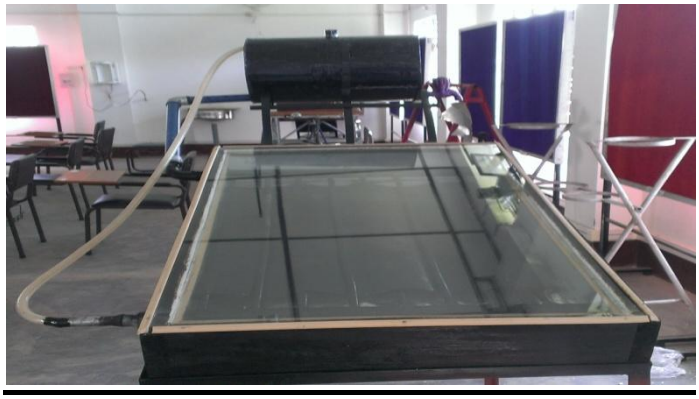

Fig2: Flat Plate Collector 2

3. Methodology

There are two basic principles behind the operation of a solar flat plate collector, namely

- Thermosiphon principle
- Difference in densities of the hot and cold fluid.

Thermosiphon is a property or a method of passive heat exchange, which circulates a substance without the necessity of a mechanical pump. Thermo siphoning is used for circulation of liquids and volatile gases in heating and cooling applications, such as heat pumps, water heaters, boilers and furnaces. In our model of solar flat plate, the cold water first enters the absorber plate through the reservoir tank. There is a separate inlet to fill up the tank initially with cold water. Absorber plates are made of aluminum and copper as they have very high thermal conductivity. Solar radiations fall on the topmost double glazing surface and it transmits the heat to the absorber plate. As the absorber plate progressively is being heated up, the fluid acts here as the heat carrier and it carry the heat flowing through the copper tubes. All these copper tubes are connected with a common header, which again is made of copper. As the water is heated, it expands and being less dense it rises up through the pipe to the reservoir tank

As the hot water fills up the upper portion of the reservoir, the bottom part is occupied by cold water coming in from the main supply. Now the circulation of the energy transporting fluid is effected by the difference in density between the hotter fluid in the collector and the colder fluid in the tank situated above the collector. Cooler water at the bottom of the tank is then pushed down to re-enter the bottom of the solar collector where it is heated further. This cycle continues throughout the day with the water stored in the tank getting hotter. [1]

Table1: Observation Table 1

Serial no	Time	Temperature(°C)
1	11:00 am	21
2	11:30 am	21.3
3	12:00 pm	21.8
4	12:30 pm	23.1
5	1:00 pm	22.4
6	1:30 pm	23.5
7	2:00 pm	23.9
8	2:30 pm	24.8
9	3:00 pm	25.02
10	3:30 pm	26.6
11	4:00 pm	27.8

Experimental tests conducted on 19th June, 2017.
Dibrugarh temperature = 29°C
The values were taken under very cloudy conditions.

3.1 Efficiency Calculation

Average solar energy received by earth in terms of energy $R = 392 w/m^2/Hr$

Solar radiation received by earth in 5hours in terms of energy $R = 392 * 5\, W/m^2/day$

$= 1960 Wh/m^2$

$= 7056000 W\, Sec/m^2$

Let,
A = Area of flat plate collector in m^2
T_1= Temperature of water at inlet in °C
T_2 = Temperature of water at outlet in °C
C_p = Specific heat of the heat transfer fluid (water)
Mass of water taken in the storage tank = 20kg
Specific heat of water = 4.182 KJ/Kg K

Area of the flat plate collector $A = L * W\, m^2$

$= 1.02 * 0.64\, m^2$

$= 0.652\, m^2$

Radiation received by collector, $R_1 = R * A$

$= 7056000 * 0.652 J$

$= 4600512\, J$

Output of the stationary collector, $Q = M * C_p * (T_2 - T_1)$

$= 20 * 4.187 * 1000 * (27.8 - 21)$

$= 569296\, J$

Efficiency of fixed flat plate collector,

Efficiency, η = Output of the collector/Input radiation

$\eta = M * C_p * (T_2 - T_1) / R * A$

= 569296 / 4600512

= 12.3 %

Table2: Observation Table2

Serial No	Time	Temperature(°C)
1	11:30 am	24.5
2	12:00 pm	25.1
3	12:30 pm	26.8
4	1:00 pm	26.2
5	1:30 pm	28.03
6	2:00 pm	30.03

7	2:30 pm	29.5
8	3:00 pm	31.4
9	3:30 pm	32.7

Experimental tests conducted on 23rd June, 2017.
Dibrugarh temperature = 33°C

3.2 Efficiency Calculation

Average solar energy received by earth in terms of energy $R = 392 w/m^2/Hr$
Solar radiation received by earth in 5hours in terms of energy $R = 392 * 4\, W/m^2/day$
$= 1568 Wh/m^2$
$= 5644800 W\, Sec/m^2$
Mass of water taken in the storage tank = 20kg
Specific heat of water = 4.182 KJ/Kg K
Area of the flat plate collector, $A = L * W\, m^2$
$= 1.02 * 0.64\, m^2$
$= 0.652\, m^2$
Radiation received by collector, $R_1 = R * A$
$= 5644800 * 0.652 J$
$= 3680409.6\, J$
Output of the stationary collector, $Q = M * C_p * (T_2 - T_1)$
$= 20 * 4.187 * 1000 * (32.7 - 24.5)$
$= 686504\, J$
Efficiency of fixed flat plate collector,
Efficiency, ɳ = Output of the collector/Input radiation
$ɳ = M * C_p * (T_2 - T_1) / R * A$
$= 686504 / 3680409.6$
$= 18.6\ \%$

Table: Observation table 3

Serial no.	Time	Temperature(°C)
1	10:30 am	19
2	11:00 am	20
3	11:30 am	21.2
4	12:00 pm	23.3
5 `	12:30 pm	25.07
6	1:00 pm	28.22
7	1:30 pm	30.21
9	2:00 pm	29.11
10	2:30 pm	29.5
11	3:00 pm	30
12	3:30 pm	30.03

Experimental tests conducted on 26th June, 2017.
Dibrugarh temperature = 35°C

3.3 Efficiency Calculation

Average solar energy received by earth in terms of energy $R = 392 w/m^2/Hr$
Solar radiation received by earth in 5hours in terms of energy $R = 392 * 5\, W/m^2/day$
$= 1960 Wh/m^2$
$= 7056000 W\, Sec/m^2$
Mass of water taken in the storage tank = 20kg
Specific heat of water = 4.182 KJ/Kg K
Area of the flat plate collector, $A = L * W\, m^2$
$= 1.02 * 0.64\, m^2$
$= 0.652\, m^2$
Radiation received by collector, $R_1 = R * A$
$= 7056000 * 0.652 J$

$$= 4600512\,J$$

Output of the stationary collector, $Q = M * C_p * (T_2 - T_1)$

$$= 20 * 4.187 * 1000 * (30.03 - 19)$$

$$= 946036\,J$$

Efficiency of fixed flat plate collector,

Efficiency, □ = Output of the collector/Input radiation

$$\eta = M * C_p * (T2 - T1) / R * A$$

$$= 946036 / 4600512$$

$$= 20.5\ \%$$

The value of average radiation received by earth in terms of energy in Dibrugarh is 3.92 KWh/m^2 . The efficiency calculation doesn't include the loss factors which are irrelevant for small flat plate collectors. Sophisticated solar flat plate collectors using selective coating, proper high absorbtivity glazings will have a better efficiency.

All the temperatures were calculated using a laboratory thermometer. [1] [2]

4. Conclusion

With the current price rise in fuel and increase in pollutants using non-conventional sources is a boon to human society. Solar energy being abundant in nature can be utilized efficiently for power generation.

Flat plate collectors which are commercially available is costlier and it is really hard for people from rural areas to purchase one, so our main objective of this paper is to make it cost efficient by using recycling scrap materials and to achieve efficiency which would be beneficial for small scale operation.

References

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[2]. www.geda.gov.in (Gujarat Energy Development Agency)

