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Experimental Investigation of New Innovative Flat Plate Collector for Solar Water Heater

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Abstract*: Paper Water heating is the need for domestic as well as industry. Heating of water by solar water heating system is present but the system takes more time and losses heat fast in a cloud environment. The objective of the paper is to develop a flat plate collector for solar water heater which can heat the water fast i.e. we can get warm water, hot water as per need. The experiment is carried out with two developed model of flat plate collector and comparative results with conventional model are presented.

***Index Terms*: Solar water heater, Concentrator collector, Variable riser tubes, Solar collectors.**

I. INTRODUCTION

There is numerous solar water heating system used so far [2]. As per the literature available on solar water, heater cost is the major factor and therefore different heating element is used for solar water heating, PVC also gives the effective result and it is available at low cost [3]. [4] Gives the experimental studies of the water heating with a humid climate and found there is a need for auxiliary heating. [5] fabricated the solar water heater (SWH) using the locally available material and the performance got was remarkable with 510 C to 550 C. [6-11] experimentally and theoretically analyzed the performance of SWH collector by the effect of spacing between the riser tubes. [12] uses the TRNSYS software to study the effect of thermal conductivity of the steel, aluminum & copper absorber plate in SWH system. [13] Study the effect of sandwich absorber sheet of GI and copper sheet to analyzed the temperature difference using Hottel-Whillier Bliss efficiency curves. [14] Uses the aluminum pocket of size 0.35 m X 0.1 m and aluminum pipe. The absorber is made of the aluminum box and used in flat plate collector. the result obtained with a maximum of 690C. [14] studied the performance of the absorber plate with several profile shapes and optimize for better performance. It studied rectangular, trapezoidal and rectangular profile shape. The trapezoidal profile gives better performance than the other profile.

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[15] study found that the reduction in the heat transfer rate is due to the non-uniform temperature distribution between pipes.[18] design a low-cost type of integrated collector storage solar water heater with a compound parabolic collector (CPC). The design suppresses the thermal losses and increases the optical efficiency with low investment cost. [19 & 20] study the concentration system using asymmetric CPC reflector troughs with an ICS system made up of two storage tanks. Another researcher [21 & 22] used the single and double cylindrical tank in combination with symmetric CPC-type reflectors.[23] uses a solar PV panel with single and double collector flat plate collector in mehsana Gujrat and found the overall increase in efficiency by 12% in double flat plate collector.[24] investigate the performance characteristics of the solar flat plate collector with Solchrome, Matt black and Black chrome coating for riser and header tubes. It is found that black chrome gives better radiant then other. [25] investigate the combined system and SWH model for the incrementally improved performance of the combined system for load, size, and location.

The literature gives the efforts of the researcher for increasing the thermal performance and overall efficiency of the SWH system. The researcher tries many ways by changing the absorber sheet, coating using a PV panel and got the results for their study. The study incorporated in this paper is to replace the absorber sheet with the angular reflector sheet and to use the different diameter of the riser tube for studying the effect on output temperature and overall efficiency of the collector.

II. MATERIAL AND METHODS

For design criteria of the solar collector, one important expects were taken into consideration is more heating with less time involvement. The design is based on thermosyphon principal and the model of the design is built in the CATIA software as shown in Fig. 1. The design used the Indian standard IS 12933 & 12976 for designing the collector. The conventional collector consists of an absorber plate which is a metal plate mostly black in color. It absorbs radiation of the sun and converts it into thermal energy. The absorber plate is attached with the parallel vertical

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tubes known as riser tubes and connected with the header tubes.

The tubes and the plate are placed in the box which is surrounded by insulation from three sides and the top side of the box is covered with the transparent glass (toughen glass). The storage tank is placed at the top of the collector. The water flow from the tank to the riser tubes and the tubes get heated due to sun radiation imparted on the tube and the absorber sheet. The absorber sheet absorbs solar energy as heat. The collector gets heated due to this heat and due to this the water present in the riser tubes get heated and rises up. This rise of the water due to heating is known as the thermosyphon effect.

In this experiment, the flat plate collector is used which is already available in the market. the dimension of the collector is 2000 x 1100 x 100 mm (riser tube of diameter 12 mm, header tube of diameter 25 mm, the distance between the two riser tube is 120mm) [27,28]. This dimension is suitable for heating 125-liter water. Therefore the storage tank used is of 125 liters. The experimental setup is formed by buying the three collectors of the same size and capacity. One collector is kept as it is and another two are developed.

A. Experimental Setup

The setup is prepared as shown in Fig. 2. The design is prepared with the concept of the concentrator. A study of literature shows the design of the collector with concentrator and without a concentrator. The study found few developments on concentrator techniques in flat plate collector. The new collector with the developed features of concentrator sheet is added instead of the absorber sheet. The construction is simple and the details are explained below.

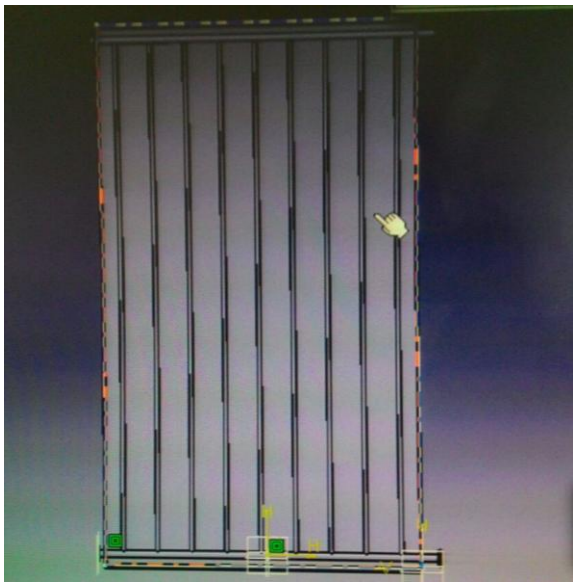
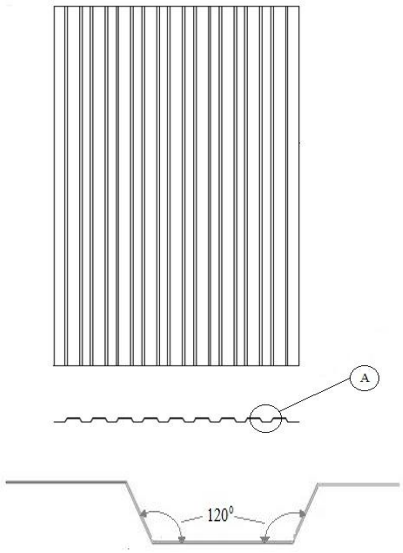


Fig.1. CAD Model of Flat Plate Collector drawn using CATIA software

Fig.2. Photograph view of Design 1 for flat Plate Collector.



(A)

Fig. 3. Angular Reflector sheet view

The developed design of collector consists of a box of the collector with the same dimension as of conventional collector available in the market, riser tubes of different dimensions (having diameter of 12, 15,19 mm), concentrator sheet, insulation, and glazing glass. The tank capacity is same i.e. 125 liters. The sketcher view of the design is shown in Fig.3. which gives the details of angular reflector sheet or concentrator sheet, it shows the front and top view of the reflector sheet with details of the cross section for the angular profile. This sheet is made in such a way that the focal point of all the rays reflected from the sheet is riser tube.

Due to this the riser tube get heated from all side i.e. top surface is heated by the direct sun rays and the bottom part is heated by the reflected rays. This gives quick heating. The angle of the angular sheet is shown in Fig.3 (A). The length of the sheet is 1800 mm and width is 950 mm. The Fig. 2. shows the details of

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riser tubes with a different diameter. There are nine riser tubes out of which 3 tubes are of diameter 12 mm, 3 tubes are of diameter 15 mm and 3 tubes are of diameter 19 mm. The author did so to find the effective tube diameters for concentrating flat plate collector

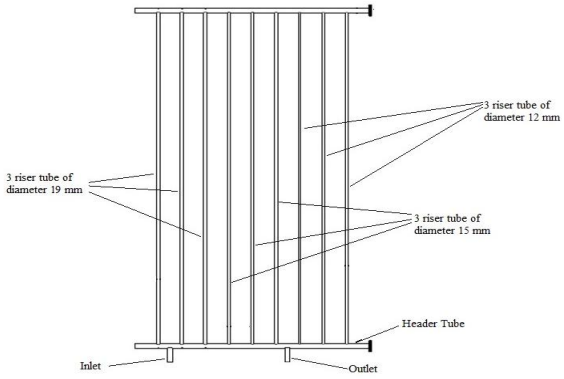

Fig.4. Riser tubes of different diameter.

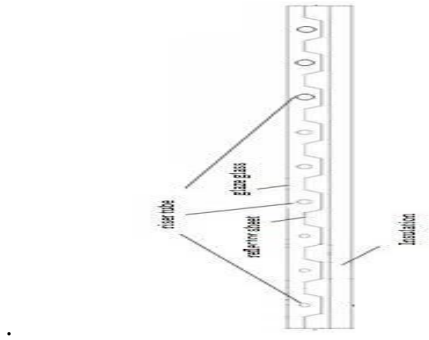

Fig. 5. Assembly View of the collector

This arrangement also helps to maintain the temperature of the water in the tank at a moderate level for a long time. The assembly view of the collector explains the position and placement of the riser tubes and concentrator sheet in the collector. It can be understood from Fig. 5. The area of the collector is 2.06 m^2 for each collector. For proper experimentation work, two units of solar water heater were bought with the same capacity of 125 liters.

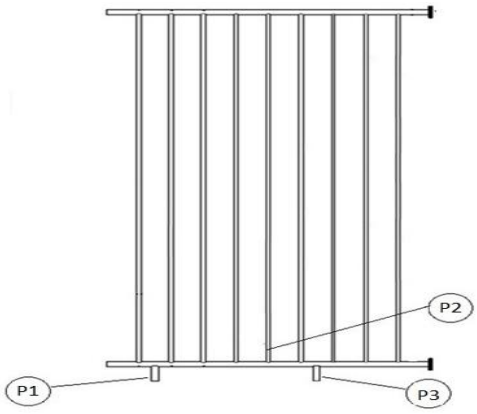

Fig. 6. Shows the sensor location for the conventional collector

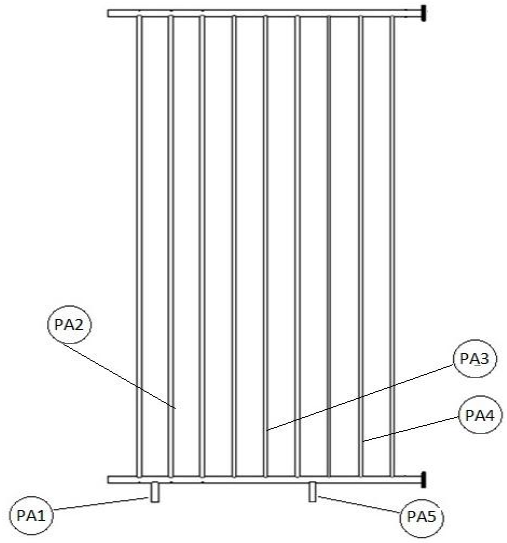

Fig. 7. The sensor's location for model A

One unit is kept as it is and named as a conventional collector. Another collector is modified and named as Model A. In model A the area is kept the same as compared to the conventional collector. The insulation is kept as it is and the absorber sheet is replaced by the concentrator sheet. The concentrator sheet is shown in fig 3. Which is made up of SS304 (3mm thickness).The concentrator sheet is placed just below the riser tube and the distance between the riser tube and the concentrator sheet is kept as 20 mm. This distance gives the proper concentration of rays on the riser tube.

The setup is placed on the rooftop and the sensor PT 100 is attached to the required position for proper readings. The Fig. 6shows sensor location for the conventional collector the sensor used for sensing the temperature is PT100, three sensors implanted on the collector on input P1, Tube temperature P2 for output temperature and P3 is for the lateral copper tube temperature. In the same manner, a sensorimplanted on the modify collector of model A. Total Five sensor implant on the collector named PA1 implant on the input, PA2 on riser tube of 19mm diameter, PA3 on riser tube of 15mm diameter, PA4 on riser tube of 12mm diameter &PA5 on output.

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Fig.8. Conventional solar water heater system and modified collector model A.

In the meanwhile, the second model B is developed with the same features as of model A but with only 12 mm diameter riser tubes. To study the phenomena of change in temperature with different diameter tube and same diameter tube is experimented and being studied. The sensor position for model B is similar to the conventional collector which can be seen in Fig.6.

B. Experimental Description

The experimental system shown below is kept on the rooftop with facing towards the south and inclination angle of the collector is 37^0. Below fig.8 gives the view of the experimental setup. Firstly, the storage tank is filled with normal water. Then due to gravity, the water from the tank flows through the riser tubes. The sun rays coming on the collector surface get imparted on riser tube directly but only on the half circumferential area of the tube. The rays which distract from the tube impregnated on concentrator sheet and being reflected back to tube lower circumferential area. This gives a 360-degree heating of tube. The sensor inserted in the tube senses the temperature of the water and recorded in the data logger. The sensor position and its name are shown in fig. 6 & 7. The temperature reading for both the system i.e. Model A & B with the conventional collector is recorded.

III. RESULT AND DISCUSSION

The setup of the solar water heater with a tank is placed on a rooftop. The conventional collector with model A and B is placed beside each other. The entire solar water heater unit is facing towards the south. The sensors implanted on the required position on all three units. The sensor P1, P2 and P3 shows the temperature T1, T2 and T3 in graph 1. The sensor PA1, PA2, PA3, PA4 & PA5 shows the temperature T1, T2, T3, T4 and T5 in graph 2. Whereas the sensor position and temperature notation of model B is same like conventional collector. The reading of collectors is recorded for two months from 7:00 am to 7:00 pm with an interval of an hour. For simplicity of the presentation, the reading of a single day is plotted and shown in graph 1 to 3. The data recorded shows that the temperature gain is more in model B as compared to conventional and model A.

The temperature reading was taken under consideration is the output water temperature. Model A and model B shows fewer drops in temperature as compared to a conventional collector for the low light environment. Model A and B show better performance even for the cloudy region than a conventional collector. The graph plotted for a single day chart explains the result more clearly. Model A gives an increase in temperature of the output water by 2-3 degree. The benefits of the model A are it gives the warm water which is more needed for the domestic purpose. The hot water is mostly got in model B with an increase in temperature of water by 4-5 degree. If the model B is redefined with more performance parameters, then more hot water can get which is more essential for industrial purpose. Graph 1 to 3 gives the day chart analysis of three collectors (conventional, model A and model B).

IV. CONCLUSION

Solar water heater (SWH) is one of the important and essential devices in saving fossil fuel. The collector is redesign and two models named model A and B. Experimental investigation confirmed our prediction as the use of concentrator in the flat plate collector is possible and heating can be achieved from this.

The average gain in temperature recorded for the two models is 3-4 degree for mode A and 4-6 degree in model B. The investigation found that the system can be redefined with and without insulation. Overall the new model of collector gives better performance even if the climate is cloudy. This feature makes the collector more different from the conventional collector.

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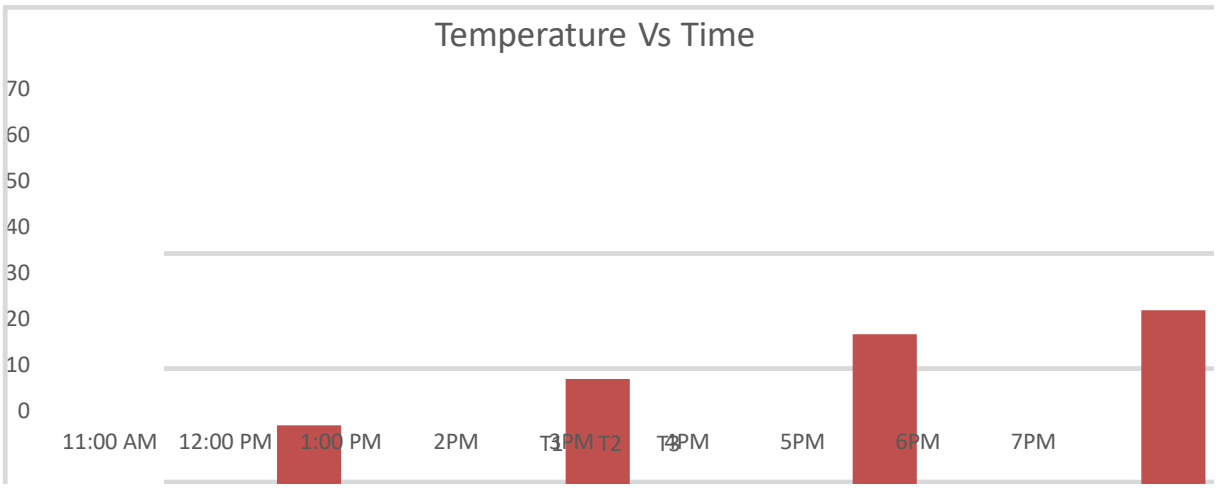
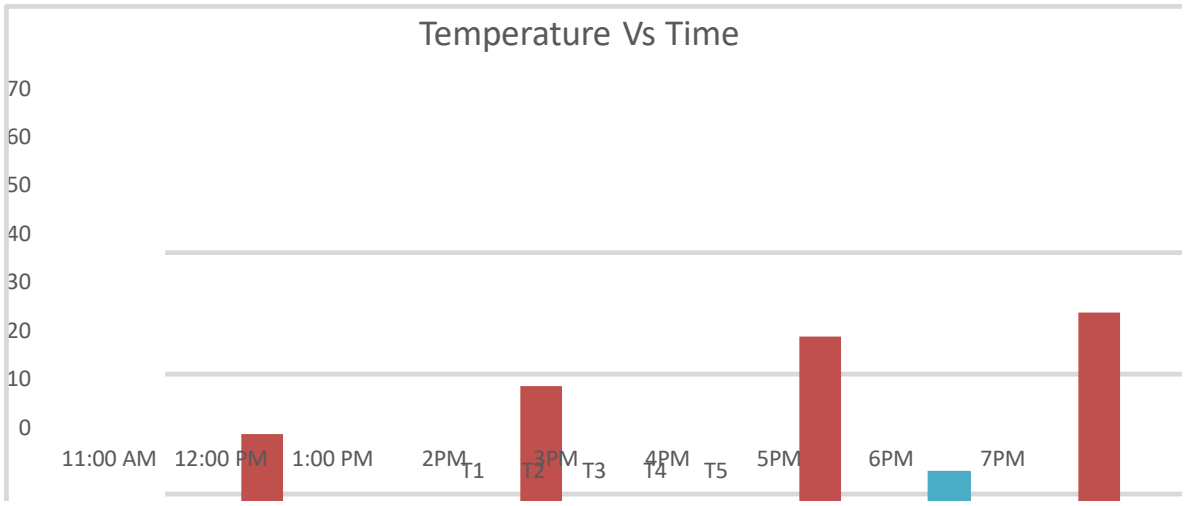
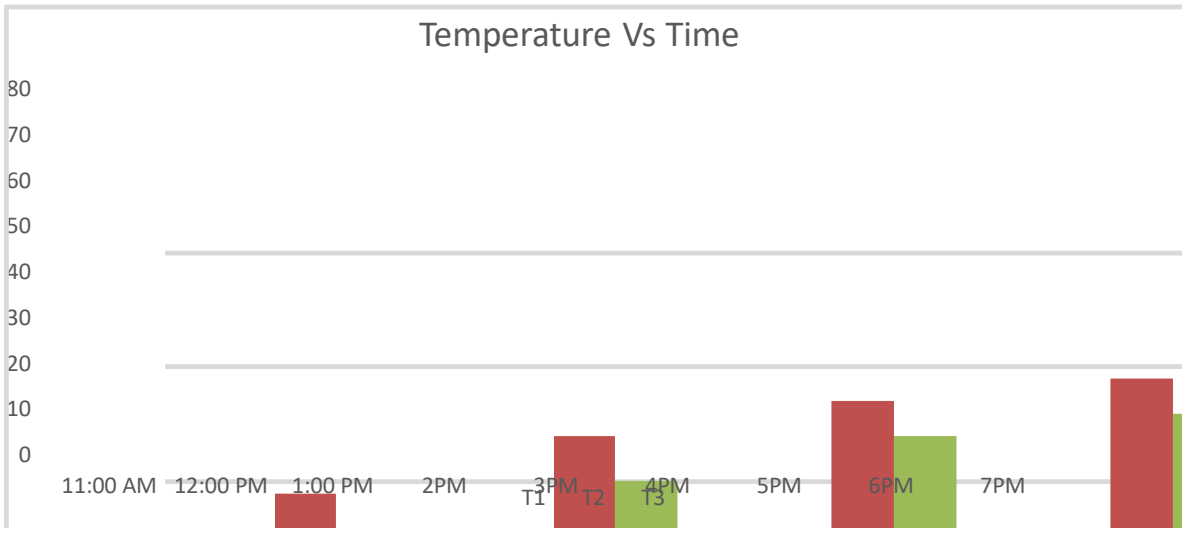


Graph.1. Graph of temperature vs time of date 07/02/2018 for the conventional collector.



Graph.2. Graph of temperature vs time of date 07/02/2018 for model A.



Graph.3. Graph of temperature vs time of date 10/04/2018 for model B.

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