Experimental investigation on the flat plate solar water heater with glass as absorber material

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Abstract*—In this study the experimental investigation was carried out on identical flat plate solar water heaters with three different absorber materials (i) Absorber Black painted clear toughened glass plate sandwich type (ABPCTG) (ii) Absorber Tinted toughened glass plate sandwich type (ATTG) (iii) Absorber Galvanized Iron plate with pipe (AGI). The efficiencies of the collectors for different absorbers at different flow rates are tested and reported. The experimental results suggest that the first type performs (ABPCTG) better as compared to other two.*

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Keywords — *Solar water heater collector, Scaling, Blockage, Toughened glass as absorber, Sandwich type, Water outlet temperature, Efficiency*.

I. INTRODUCTION

The application of solar energy has increased significantly, due to increase in conventional energy prices and environmental effects viz., air pollution, global heating, depletion of the ozone layer and green house effects. A solar water heater finds extensive application such as domestic water heating, space heating, and industrial processes. Solar collectors, a special type of heat exchanger transforms solar energy to internal energy of the transport medium. Flat plate solar water heater absorbs incoming solar radiation and converts it into heat and transfers to a fluid flowing through the collector. The rate of heat transfer depends on various parameters such as properties of glazing materials, absorbing plate and working fluid. Researchers worldwide attempted various designs to enhance the thermal efficiency of a flat plate solar water heater.

Flat plate solar water heaters are widely used mainly because of their robust design, simple working principle and low maintenance. Due to the stringent compliances of BIS [1], in India the performance deterioration factors such as absorber plate degradation, masking of the glass cover, leakage from deteriorated gaskets etc are eliminated. Scaling in flow system is to be avoided or minimized by taking proper care.

Kalogirou [2] performed an analysis of the environmental problems related to the use of conventional sources of energy and the benefits offered by renewable energy systems. The various types of collectors including flat plate, compound parabolic, evacuated tube, Fresnel lens, parabolic trough, parabolic dish and heliostat field collectors were followed by an optical, thermal and thermodynamic analysis of the collectors and a description of the methods used to evaluate their performance. The thermal performance of the solar collector was determined by obtaining values of instantaneous efficiency for different combination of incident radiation ambient temperature and inlet fluid temperature.

Kostic et al.[3] proposed the concept of advanced solar water heater. According to them, only the upper side of the absorber plate is exposed to the sun because of that the flat plate collectors generally have high heat losses and low efficiency.

Sarath Kumar et al. [4] stated the important function of the absorber plate. It absorbs maximum solar radiation that passes through the transparent cover plate and reflects as less possible radiation reflecting through top and bottom of the collector, and then transfers the absorbed heat to the working fluid.

Arunachala et al. [5] reported that in flat plate solar water heaters performance declines over the years due to system and places related issues. They have cut the risers, header and footer and reported that the scale is formed above 150 mm of length as shown in Fig 1.

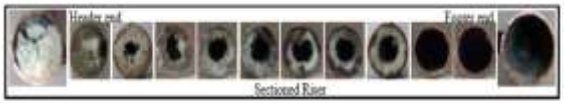

Fig. 1 Scale growth in FPC

Hishikar et al. [6] investigated that in flat plate solar water heater, scale build up can take place in riser tube as shown in Fig. 2.

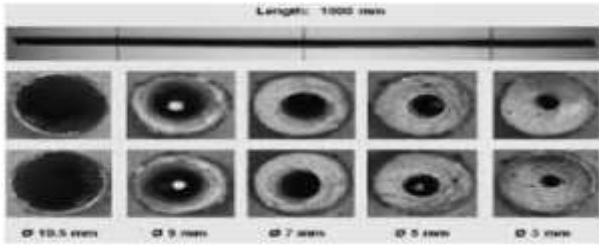

Fig. 2 Scale growth in flat plate collector in sectional Riser

Rommel and Moock [7] investigated and concluded that the efficiency for rectangular duct style collector can have higher thermal efficiency factor than fin and tube.

Matrawy and Farkas [8] carried out a comparison study of two parallel plate collectors with parallel tube collectors and serpentine tube collectors. Their results show that the efficiency of the parallel tube is about 6% more than the serpentine. This is because the temperature distribution over the absorbed plate surface is uniform as well as the uniform distribution of the working fluid between the two plates.

Kulkarni and Deshmukh [9] developed and tested a new design of solar water heater flat plate collector. The collector is made-up of aluminium box in rectangular shape and aluminium pipe. The maximum temperature of water obtained at outlet of collector is about 69 °C.

On review of literature it has been found that no experimental or simulation analysis of these kind of toughened glass sandwich type absorber flat plate solar collectors has been reported.

II. OBJECTIVE

Flat plate solar water heater is common because of its simple design and reduced maintenance. But it performance declines over the years because of system and the places related issue. Especially the problem of scaling is important as it is based on quality of water used. In fin and tube flat plate collector, scale increases the pressure drop with ultimately resulting in reduced water flow rate. The other defect of scale formation is reduced transfer of heat from fins to the circulating fluid. The scale in the absorber tube surface can act as an insulation layer and thus increases the heat transfer resistance. The Significant scaling in FPC will result in rise in absorber plate temperatures and hence poor system performance. Overcome this problem a new type of toughned glass absorber is investigated.

III. EXPERIMENTAL SETUP

The line diagram of the fin and tube absorber plate and toughened glass sandwich type absorber are shown in Figs. 3 & 4. ABPCTG absorber made of two toughened glass, top one is clear glass plate and bottom one frosted on one side for painting purpose has been used for the investigated. A gap is provided between two glass plates using 2 mm glass strip for flow passage. ATTG absorber is also made of two toughened glass, top one is clear glass plate and bottom one is tinted glass. Fig. 5 shows the photographic view of the experimental setup. The three identical solar water heaters with different absorber material viz., G.I Absorber plate, clear toughened glass, tinted toughened glass, with collector area of 1 m^2 is fabricated and are placed in the north south direction to obtain the maximum solar intensity throughout the day for the comparative analysis.

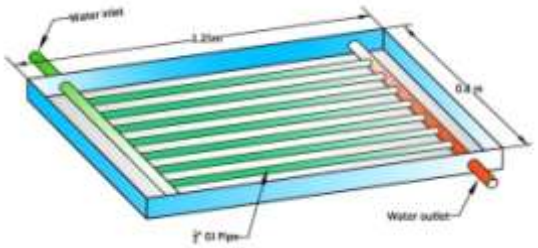

Fig. 3 Line diagram of G I fin and tube absorber

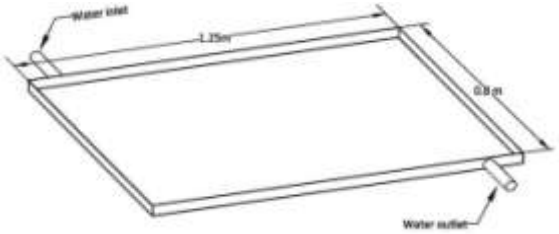

Fig. 4 Line diagram of sandwich type toughened glass absorber

IV. EXPERIMENTAL PROCEDURE

Photographic view of Experimental setup is shown in Fig. 5. During the test, water to be heated is allowed at uniform mass flow rate to pass through the three types of absorber. T-type copper constantan thermocouple has been used to measure the temperature of water inlet, outlet absorber plate and glass plate temperature. The solar irradiation has been measured by means of an Eppley Pyranometer.

Fig. 5 Photographic view of experimental setup

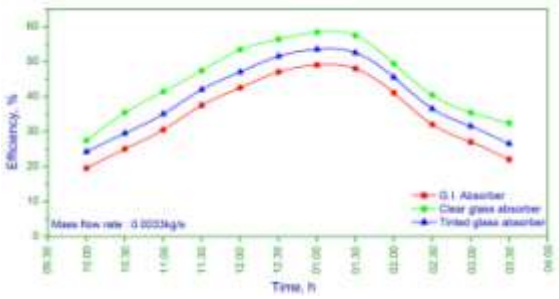

Fig. 6 Variation of thermal efficiency for flow rate of 0.0033 kg/s

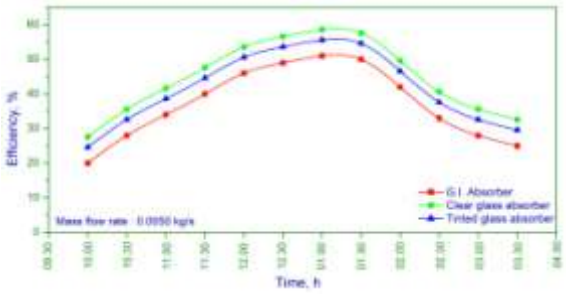

Fig. 7 Variation of thermal efficiency for flow rate of 0.0050 kg/s

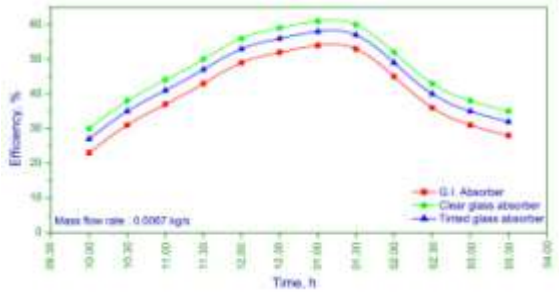

Fig. 8 Variation of thermal efficiency for flow rate of 0.0067 kg/s

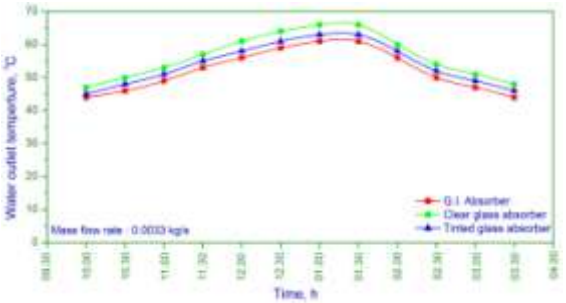

Fig. 9 Variation of outlet temperature for flow rate of 0.0033kg/s

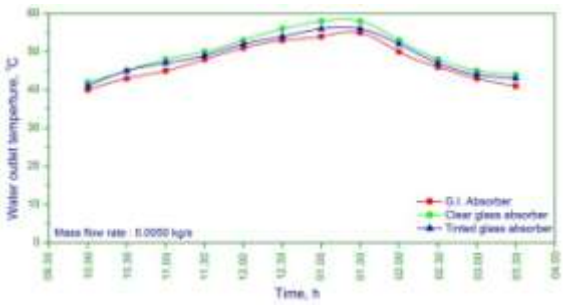

Fig. 10 Variation of outlet temperature for flow rate of 0.0050 kg/s

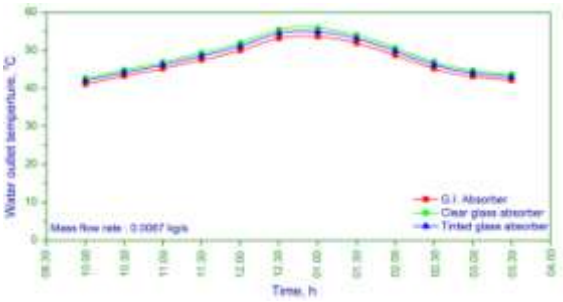

Fig. 11 Variation of outlet temperature for flow rate of 0.0067 kg/s

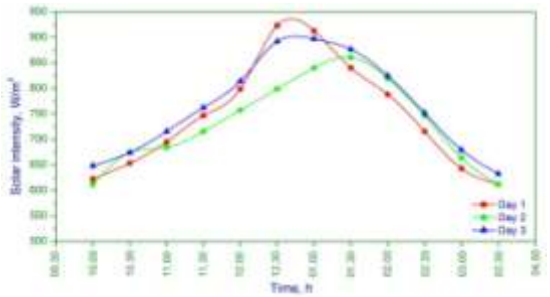

Fig. 12 Variation of solar intensity for the experimental days

V. Result and Discussion

The performance analysis of flat plate solar water heater with three types of absorber plate materials done experimentally in Energy Laboratory, Department of Mechanical Engineering, Annamalai University, Annamalai Nagar, Tamil Nadu, India (11.3921° N latitude and 79.7147° E longitude). Graphs were plotted between Time Vs efficiency, water inlet and outlet temperature and solar intensity as shown in Figs. 6 to 12.

Figs. 6, 7 and 8 shows the variation of efficiency of three types of absorber material at different mass flow rate of water 0.0033, 0.0050 and 0.0067 kg/s. The thermal efficiency of ABPCTG for a flow rate of 0.0067 kg/s was found to range between 30% and 59%. The thermal efficiency is higher for absorber black painted clear toughened glass sandwich type (ABPCTG) than other two types. As the mass flow rate of water increases the efficiency also increases. Comparing the three

absorbers tested, the ABPCTG was found to show highest thermal efficiency throughout the day, followed by ATTG. The conventional AGI was found to show the lowest value for all the day.

Figs. 9, 10 and 11 shows the outlet water temperature. It was higher in absorber black painted clear toughened glass sandwich type (ABPCTG) than other two types for different mass flow rate of water (0.0033, 0.0050 and 0.0067 kg/s). Comparing the three absorbers tested, the ABPCTG obtained maximum water outlet temperature of 54°C for the flow rate of 0.0067 kg/s.

Fig. 12 shows the variation of solar intensity for the experimental days when the mass flow rate of water taken as 0.0033, 0.0050 and 0.0067 kg/s. The intensity increases and reaches maximum at mid day and then decreases.

The new design of the sandwich type toughened glass absorbers is in direct contact with the entire flowing fluid which increases the heat gained by the water than the fin and tube type.

With this type of new sandwich glass absorber plate, degradation of absorber material and scaling on the absorber material are eliminated.

From the above it has been found that the ABPCTG is performing satisfactorily than other two types with respect to efficiency of solar water heater.

VI. CONCLUSION

The following conclusions were drawn from the investigation and Experiment conducted on flat plate solar water heater with three types of absorber plate material.

- Selection of absorber material has influence on the performance of flat plate collectors.
- Maximum temperature of hot water is obtained for absorber black painted clear toughened glass sandwich type (ABPCTG) when compared to other two types which are used in this work.
- The thermal efficiency of collector is highest for absorber black painted toughened glass sandwich type ABPCTG

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