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Experimental Study on a Water-in-glass Evacuated Tube Solar Water Heater using a Diffused Flat Reflector

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Abstract – **This paper investigates the performance of a water-in-glass evacuated tube solar water heater in terms of effective heat transfer to the working fluid. The experiments were conducted at the Coimbatore during the month of January in 2018. Initially the improvement of temperature of collector tank water has been investigated without any modification. Then the solar water heater is integrated with a diffused flat reflector with improved reflecting surface facing the bottom of the tubes, and the same experiment was repeated to measure the performance. The result showed an appreciable improvement in the tank water temperature in the evening compared to the previous case. This is due to the enhancement of the solar exposure to the bottom of the evacuated tubes with the help of diffused flat reflectors.**

Keywords: **Evacuated tube solar water heater, Diffused flat reflector, Thermal performance.**

I. INTRODUCTION

Solar water heaters have become the promising technological advancements in the recent era to serve the hot water demand for domestic house hold and industrial needs [1–15]. They are the ultimate alternatives for conventional water heaters which basically utilizes the fossil fuels or electricity. The evolution the solar heaters replaced a substantial quantity of nonrenewable energy into the renewable form of solar energy. The solar collector, which is designed to absorb solar radiation and convert it to heat, is an essential part of a solar energy system. From all the type of solar collectors in the market, evacuated-tube solar collectors are having a better thermal performance and economical than conventional flat plate solar collectors [16, 17].

In early days, low-temperature evacuated-tube solar collectors for domestic water heating applications were mainly focused, rather than medium and high-temperature applications [2–6, 15–17]. Also the early studies have proved that providing good vacuum conditions is an effective way to improve the thermal performance of solar collectors [1,6,13].There are many proposed ways to improve the thermal performance of evacuated-tube solar collectors; one is enhancement of heat absorbing capability and the other is reduction of heat loss to the surrounding.

In this type of collectors, the vacuum envelope surrounding the absorber surface helps to curtail heat loss. Different types of heat pipe can be integrated with the tube to enhance the thermal performance of solar collectors [18–21].

Liu et al. [18] fabricated an ETC based on the concept with an external simplified compound parabolic concentrator and unique thermosyphon using a water-based CuO nanofluid as the working fluid. Their experimental results showed that in winter the maximum air outlet temperature exceeded 170°C. Jeong et al. [19,20] experimented the thermal performance of all-glass ETCs with coaxial fluid conduits using a one-dimensional model. An investigation by Glembin and coworkers [21] showed that the flow rate has an important effect on the efficiency of an ETC, as do constructional considerations such as the diameter of the ETC and the material used. In these studies, the evacuated tubes in the ETCs were double-skinned with an external diameter of 58 mm and an internal diameter of 47 mm. An external Compound Parabolic Concentrator may help to improve collector efficiency and the area between the inner tube surface and heat pipe is filled with heat transfer media to reduce heat loss. Nkwetta et al. [13] evaluated the thermal performance of an ETC with an internal low-concentration heat pipe; they also compared the performances of heat-pipe and direct-flow augmented solar collectors.

II. EXPERIMENTAL SETUP

A water-in-glass evacuated tube solar water heater was fabricated for the experimental observations with the technical specifications as mentioned in the Table I. The experiment has been conducted in two different cases. In the first case, the experiment was conducted with solar collector without the diffused reflector, and next case readings have been taken with the integration of the flat reflector at the bottom of the tubes as shown in Fig.1.Each case was conducted on the solar days having similar solar radiation pattern in order to ensure the good comparison of the results for different cases.

TABLE I: TECHNICAL SPECIFICATION OF THE EVACUATED TUBE SOLAR WATER

Item	Required Specification	Quantity
Size of the evacuated tubes	37 mm inner diameter & 47 mm outer diameter	10 Nos.
Area of the collector	2.09 m^2	-
Size of water tank	50 cm diameter & 75 cm length	1 No.
Tank insulation	PUF	-

There are three thermocouples incorporated in the solar collector tank at three different positions to measure the temperature distribution inside the tank. The average of the temperature has been considered for the calculations and analysis for simplifying the investigation as investigation is only based on the temperature enhancement at the end of the day of observation.

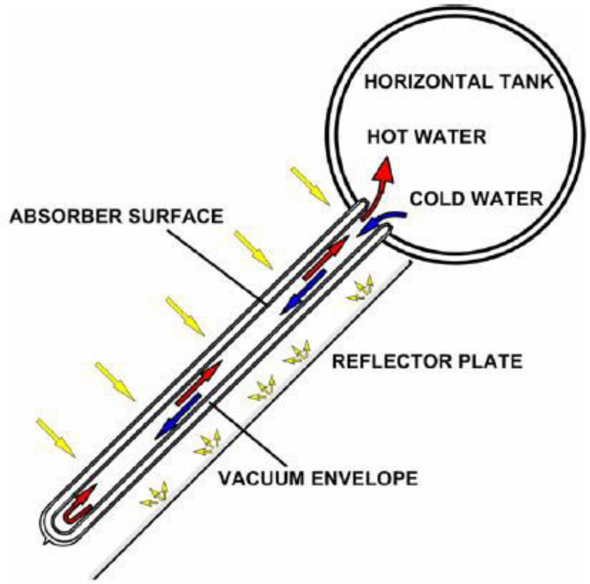

Fig 1. Block diagram of the water-in-glass evacuated tube solar water heater with diffused flat reflector.

III. RESULTS AND DISCUSSION

The observations have been made on the days having similar solar radiation pattern to ensure the correctness in the comparison of the results in two different cases of investigation.

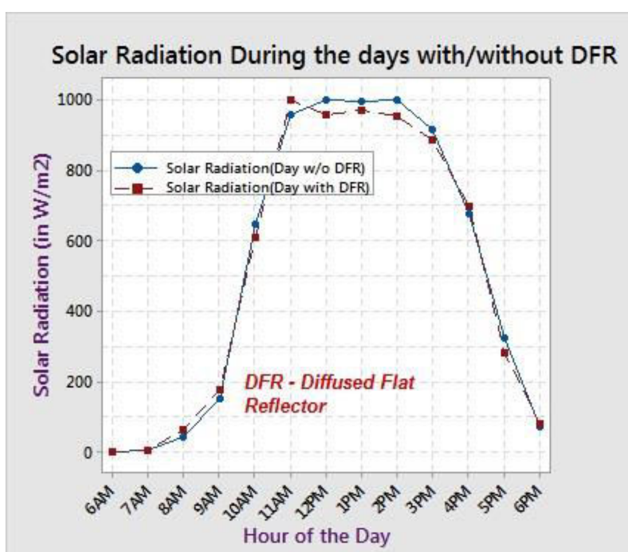

Fig 2. The average solar radiation during the days of experiment

A solarimeter is used to measure the solar radiation during experimentation days. The radiation was recorded every one hour time interval. The Fig.2 shows the variation of the solar radiation during the days of experiment viz., with diffused flat reflector and without diffused flat reflector. The average solar radiation recorded on experimental the days was 25.22 kJ/Day.

The variation of the averaged atmospheric temperature and averaged water temperature of the collector tank (both the cases, with and without diffused flat reflector) have been recorded using the K type thermocouple for further analysis. The variations were drawn over the graph and presented in the Fig. 3.

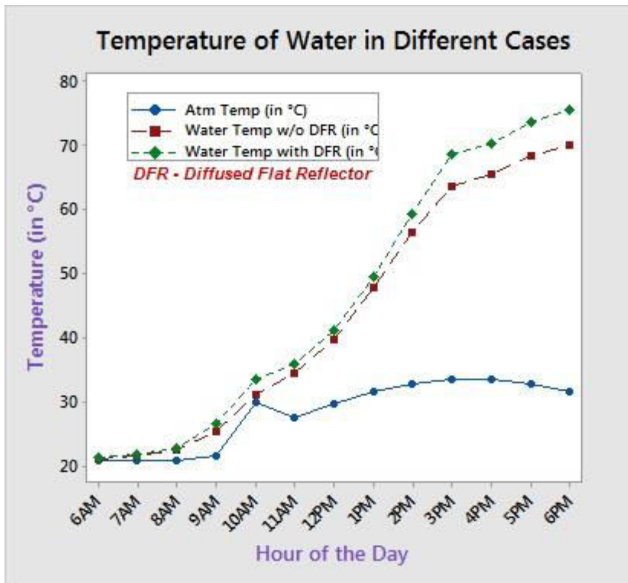

Fig 3. Variation of atmospheric temperature and tank water temperature in two cases.

The plot vividly shows the gradual increase of tank water temperature during the day time in two cases. The readings were noted down between 6 AM and 6 PM during the day of experiment. This experiment was only focused on the temperature variation in the tank and tank final temperature during end of the day of the experiment. It was noted that the tank temperature gradually enhances right from the morning and temperature increment was rapid during noon and the afternoon as solar radiation hit the maximum value during this time period.

The pattern of variation of the tank temperature in both the cases such that with diffused flat reflector and without diffused flat reflector were looking similar. Still, when comparing the rate of increase in tank temperature, the diffused reflector's contribution is substantial. The diffused reflector contributes around 5.6°C more temperature of water than the case without diffused flat reflector. The reason behind this improvement is that the diffused reflector increases the net solar energy input to the collector by reflecting additional quantity of solar radiation at the bottom of the tubes, which was shadow region in the absence of reflectors.

IV. Conclusions

An experimental test rig was fabricated with a water-in-glass evacuated tube solar water heater with the suitable instrumentation. The performance of the solar water heater has been studied without any additional modification and the temperature variation pattern was recorded. Then a highly reflective diffused flat reflector was integrated with the evacuated tubes such that the reflector was facing the bottom of the tubes. Again the performance of the solar water heater was measured in terms of heat transfer characteristics. The incorporation of the diffused reflector improved average tank water temperature of the solar collector to 5.6°C by means of diffused reflection. The result concretely proved that the integration of diffused reflector substantially improve the thermal performance of the water-in-glass evacuated tube solar water heater.

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