PERFORMANCE INVESTIGATION OF DOUBLE GLAZED SOLAR WATER HEATER USING SQUARE PULSE ABSORBER PLATE

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Abstract
An analysis was carried out to assess the performance of Double glazed solar water heater(DGSWH) with square pulse absorber plate was tested experimentally. Mild steel plate of 1.42 x 0.7 m^2 size was in use as an absorber plate. Glass plate of parallel size has been used to guard the absorber plate from heat loss due to atmosphere. Performance of solar water heater for two different mass flow rates (0.0083, 0.0125 kg/s) were investigated and the test results are reported. The Thermal efficiency is found to be higher for Double glazed solar water heater with square pulse absorber plate when compared to the Single glazed solar water heater(SGSWH) with square pulse absorber plate.

Keywords: Double glazed Solar water heater, Solar energy, Square pulse absorber plate, Mild steel plate.

INTRODUCTION

Renewable energy resources of which the sun is a good example are those resources which undergo a faster replenishment rate within a relatively short time than the rate at which they are utilized or depleted. The energy of the sun is generated from the nuclear fusion of its hydrogen into helium, with a resulting mass depletion rate of approximately 4.7×10^6 tons per second. The earth's population currently needs 15 terawatts of power in total, but the solar radiation that reaches the earth on a continuous basis amounts to 120,000 terawatts; hence, just a fraction of the suns energy reaching the earth will cover the bulk of energy requirements [1].Solar Collectors are the key component of active solar-heating system. They gather the sun's energy, transform its radiation into heat, and then transfer that heat to a fluid (usually water or air). The solar thermal energy can be used in solar water-heating systems, solar pool heaters, and solar space-heating systems. There are a large number of solar collector designs, which has shown to be functional. These designs are classified in two general types of solar collectors: Flat-plate collectors – the absorbing surface is approximately as large as the overall collector area that intercepts the sun's rays. Concentrating collectors – large areas of mirrors or lenses focus the sunlight onto a smaller absorber. Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate. These collectors heat liquid or air at temperatures less than 80°C.

Paul Magloire E. Koffi, Blaise K. Koua [2] determined, theoretical and experimental analysis of thermal performance of a solar water heater prototype with an internal exchanger using thermo syphon system. The results focus mainly on the levels of the heat fluxes temperatures recorded, mass flow rate and efficiency of the collector. These tests are performed for a sunny day and cloudy day. Finally the results show that daily efficiency is near to 50%. This reveals that a good compatibility of the system to convert solar energy to heat which can be used for heating water.

In a review of solar water heating systems for domestic and industrial applications carried out by Ogueke et al. [3],water heating systems were grouped into two broad categories (passive and active), each of them operating in either direct or indirect mode. They reported their performances, uses and applications, and factors considered for their selection. The active systems generally have higher efficiencies, their values being 35%–80% higher than those of the passive systems. They are more complex and expensive. Accordingly, they are most suited for industrial applications where the load demand is quite high or in applications where the collector and service water storage tank need not be close to each other or for the applications in which the load requires more than one solar collector. On the other hand, the passive systems of which this work is an example are less expensive and easier to construct and install. They are most suitable for domestic applications and in applications where load demand is low or medium.

Farahat, F. Sarhaddi [4] determined the optimal performance and design parameters of solar flat plate collector. A detailed exergy analysis is carried out for valuating the thermal performance and optical performance, energy flows and losses as well as exergetic efficiency for a typical flat plate solar collector under given operating conditions. In this analysis, the following geometric and operating parameters are considered as variables: the absorber plate area, dimensions of solar collector, pipe's diameter, mass flow rate, fluid inlet and outlet temperature, the overall loss coefficient etc. and also a simulation program is developed for the thermal and exergetic calculations.

Chuawittayawuth and Kumar [5], in their work, presented details of experimental observations of temperature and flow distribution in a natural circulation solar water heating system and its comparison with the theoretical models. The measured profile of the absorber temperature near the riser tubes (near the bottom and top headers) conformed well with the theoretical models. The values at the riser tubes near the collector inlet were found to be generally much higher than those at the other risers on a clear day, while on cloudy days, these temperatures were uniform. The mean absorber plate and mean fluid temperatures during a day were estimated and compared with theoretical models. The temperature of water near the riser outlets was found to be fairly uniform especially in cloudy and partly cloudy days at a given plane during a day. The temperature of water in the riser was also found to depend on its flow rate. Measurements of glass temperature were also carried out in the work.

Duffie, J.A and W.A Beckman [6] performed annual simulation to monitor the thermal performance of a direct solar domestic water heating system operated under several controlled strategies. According to authors results higher flow rate leads to higher collector efficiency factor. However, it also leads to higher mixing tank and therefore, a reduction in the overall solar water heating system efficiency.

Hsieh J.S., [7] have concentrated on the development of effective design methods for solar collectors. The cross sectional area of the absorber plate has been constant in the tests conducted by them. However, the collector receives energy from the sun that is absorbed by the plate and is then transferred to the fluid. On this basis, energy transferred increases in the direction of flow energy in a plate. It is a well known fact that for effective design, the profile shape of the absorber plate increases the collector performance

Sae-jung and Krittayanawach [8] have derived the mathematical model and the experimental study for prediction of the temperature of hot water produced from thermo syphon solar water heater. Results are presented of storage temperature, collector temperature and thermal efficiency of the solar water heater.

Ihaddadene and Ihaddadene [9] stated the effect of distance between double glazings on the performance of a solar thermal collector. Experiments were carried out on an active solar energy demonstration system. The results show that the efficiency of double glazing solar collector decreases with increasing the distance separating the two glasses intensity.

Kajavali and Sivaraman [10] have analyzed the single tube and a modified absorber plate in a parabolic trough collector. The solar energy recovery efficiency of the modified absorber plate was found to be higher than the single tube in the form of increased water temperature.

Michaelides et al. [11] presented experimental investigation of the night heat losses of hot water storage tanks in thermosyphon solar water heaters. Utilizing the method suggested by ISO 9459-2:95, they tested three typical thermosyphon solar water heating systems with different storage tank sizes. The results were analyzed to quantify the night heat losses and to investigate the effect that these may have on the system daily performance. Analysis of the results showed that a linear behavior of the heat losses with the night mean ambient temperature exists. The research confirmed that the night loss is one of the most important sources of energy loss in thermosyphonic systems.

Various studies reviewed above have confirmed the importance of performance improvement of the collector in solar water heating system. In this study the different solar water heaters namely, single glazed square pulse absorber plate solar water heater and double glazed square pulse absorber plate solar water heater is designed and constructed with the aim of the cost and to bring out better efficiency.

Objectives

The main objective of this test is to analyze and compare the performance of Double glazed square pulse plate solar water heater with Single glazed square pulse solar water heater at two different mass flow rates.

Materials and methods

A careful study of already existing solar water systems was done; and a choice was made on the type of system to be designed with focus on simplicity, installation, and maintenance cost as well as durability. Use of locally available materials was made a matter of priority. A square pulse plate was used as the absorber. It was integrated with underneath grids or coils of fluid carrying tubes and placed in an insulated casing with a glass or transparent cover. A cold water tank placed above and a hot water tank below incorporated with a thermometer and a carriage are integrated in the system. The water gets heated up and flows into a storage tank through thermosyphon principle. The system was tested on a normal sunny day in between the hours of 10:00 a.m. and 3:30 p.m.; and results collected were tabulated

Experimental Setup

The experimental setup made up of mild steel box and square pulse absorber plates. The line diagram of the experimental setup is shown in Fig.1, and the water heater and square pulse geometry are shown in Fig.2 & 3. Mild steel flat plate of 1.4 x 0.7 m^2 was employed as absorber plate. A glass plate of similar size is used as a protection layer for heat loss from absorber plate to atmosphere and the bottom of the collector was covered with heat resisting material to minimize the heat loss to the surroundings.

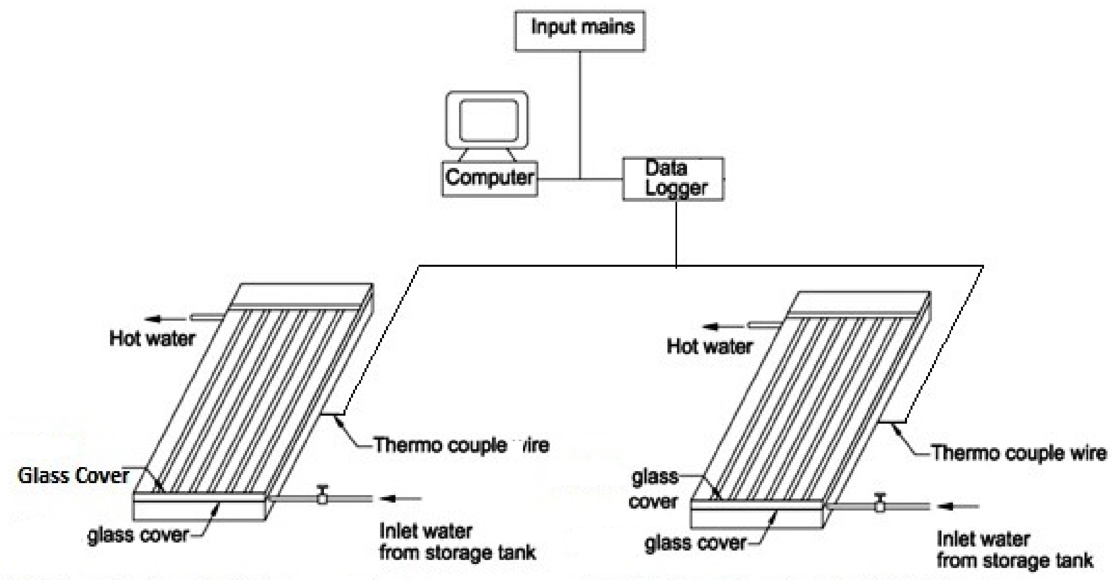

Figure-1. Line diagram of experimental setup.

Figure 2: Square Pulse Absorber Plate Solar Water Heater

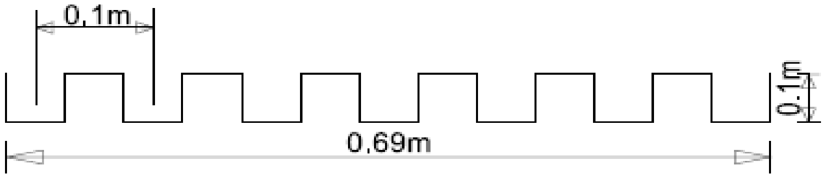

Figure 3: Square pulse absorber plate geometry

Figure 4: Agilent Data Logger

Table-1. Specification of the experimental setup.

square pulse absorber plate solar water heater

Length of the collector	1.42m
Width of the collector	0.7m
Area of the collector	$1m^2$
Diameter of the tube	0.0127m
Tube centre to centre distance	0.1m
Length of the absorber plate	0.69m
Material of the absorber plate	G.I
Glass cover emissivity	0.85
Refractive index	1.5
Diameter of the header pipe	0.019m
Insulating material	Glass wool
Density of the insulating material	200kg/m3

Measuring Equipment

Agilant Data logger has been used to acquire all the data. T-type copper constantan thermocouples have been used. Inlet, outlet and glass plate temperatures were measured.

Experimental Procedure

The performance of solar water heater is studied with single and Double glass solar water heater of square pulse absorber plates. solar water heater and square pulse absorber plate geometry shown in Figs 2 and 3. The single and double glass solar water heater with square pulse absorber plate were fabricated and tested. At the starting the data logger is switched ON 10 minutes before the commencement of experiment. Readings are recorded at a uniform interval of 10 min from 10.00 a.m. to 3.30 p.m. Experiments were conducted on single and Double glazed solar water heater with uniform solar intensity and the data were collected on the data logger. The thermal efficiency and heat gained by the water were calculated and the results are discussed`

Results and Discussion

Different solar water heaters with square pulse absorber plate absorber plate selected for experimentation . Graphs were plotted between Time VS efficiency (%), Heat gained by the water (W) and solar intensity (w/m^2) respectively as illustrated in Fig 5 to 9 for the mass flow rate of 0.0083 kg/s and 0.0125kg/s.

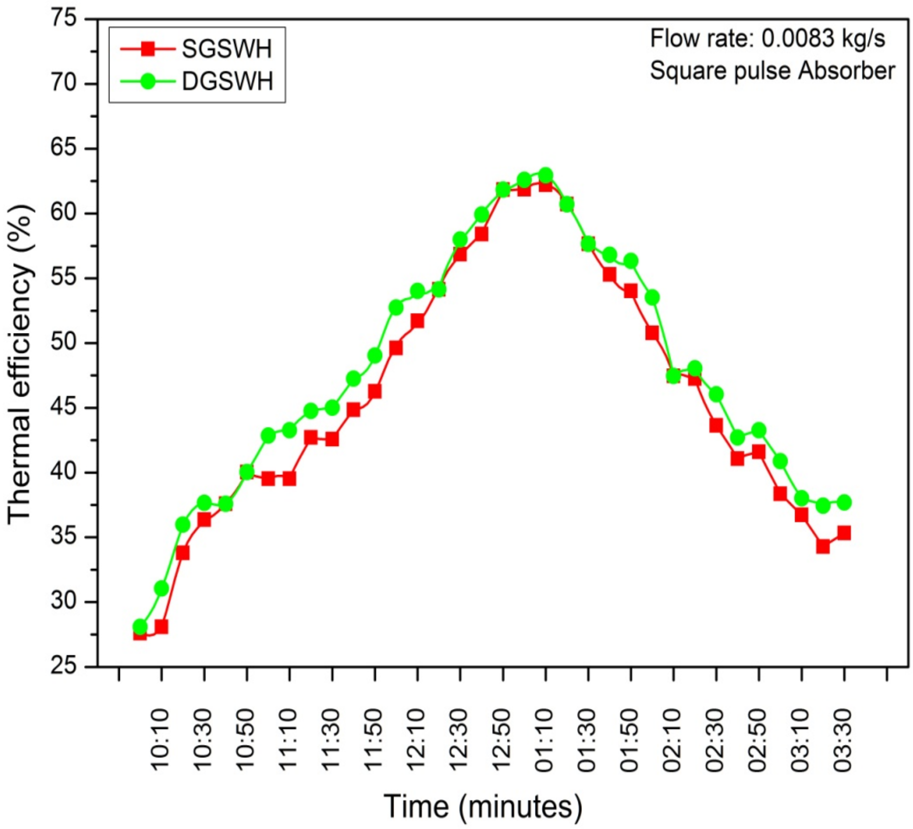

Figure-5. Thermal Efficiency versus time (Flow rate 0.0083 kg/s).

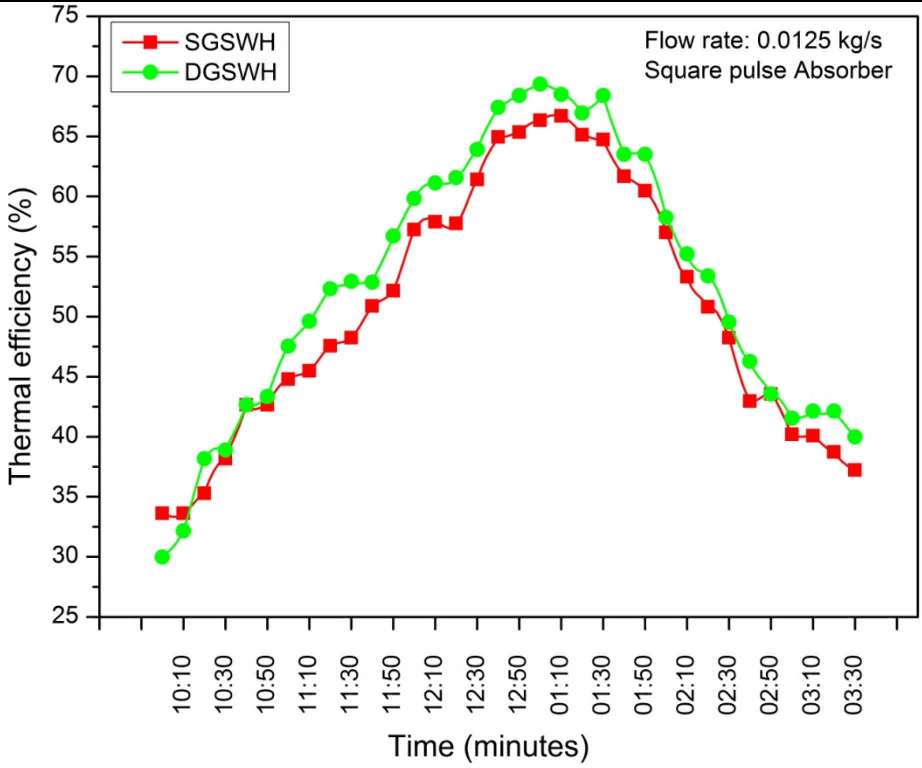

Figure-6. Thermal efficiency versus time (flow rate 0.0125kg/s).

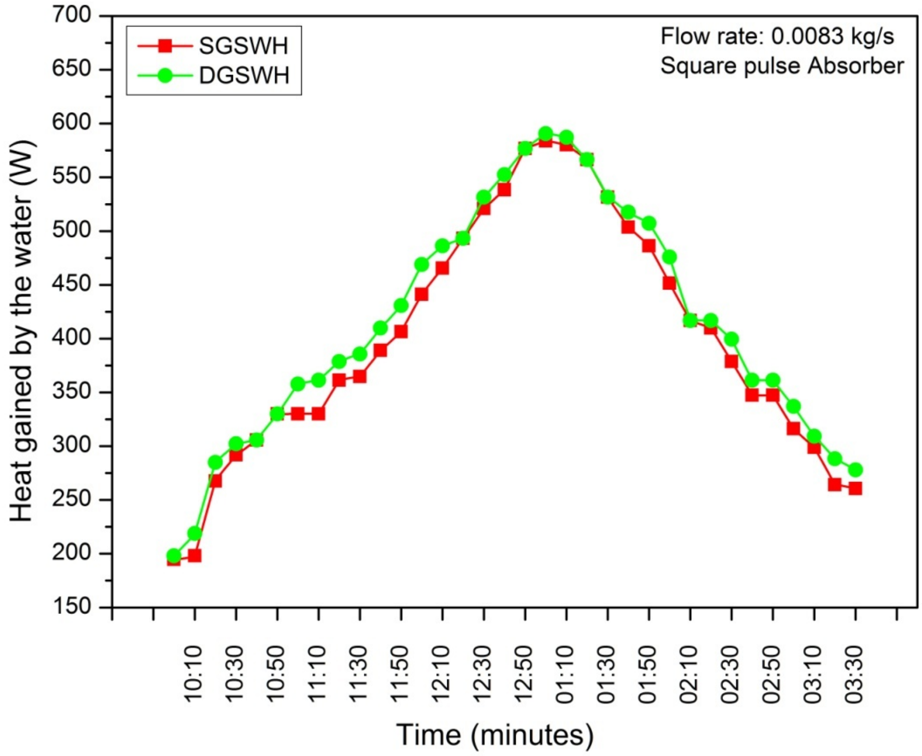

Figure. 7. Heat gained by the water versus Time **(**flow rate 0.0083 kg/s**).**

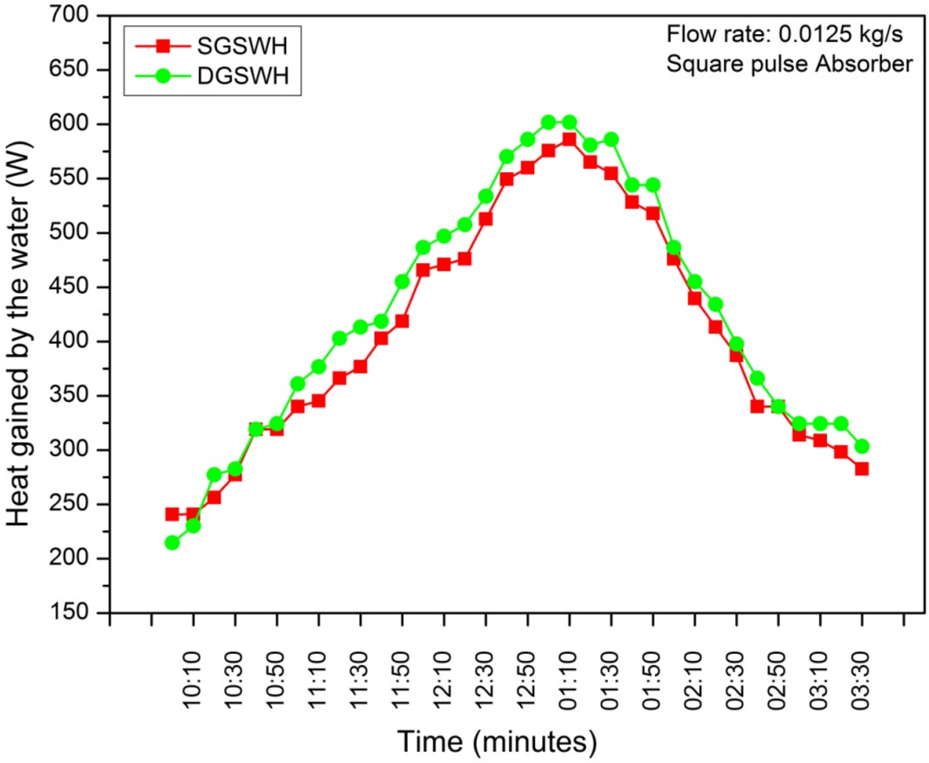

Figure. 8. Heat gained by the water versus Time **(**flow rate 0.0125 kg/s**).**

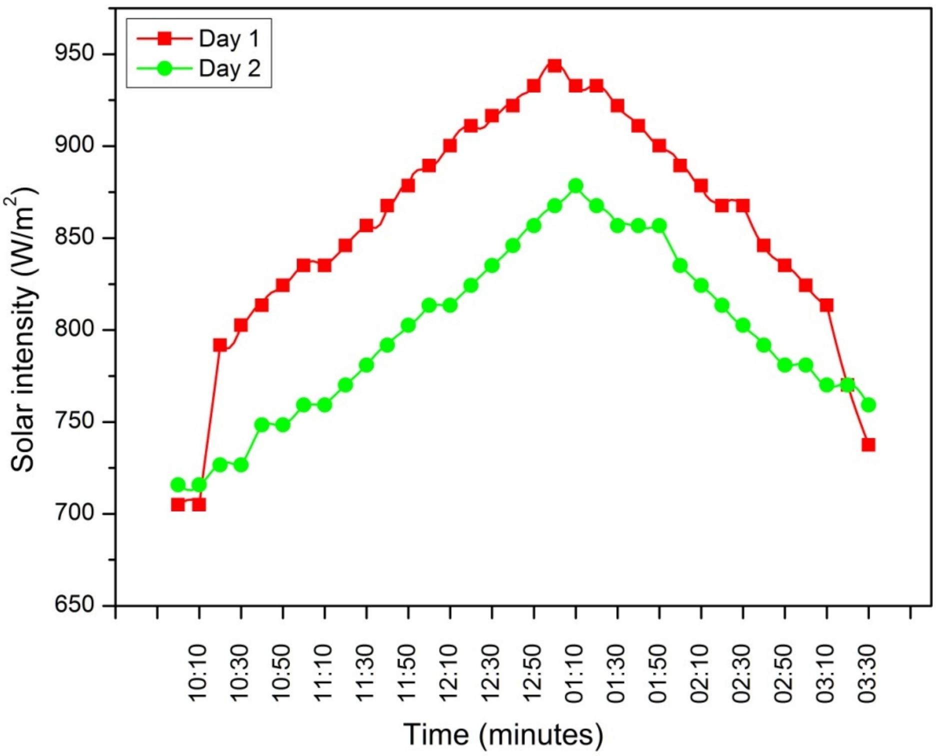

Figure. 9. Solar intensity versus time.

CONCLUSION

A Double glazed solar water heater is a long-term investment that can help us save money and energy for many years. Like other renewable energy systems, solar water heaters minimize the environmental effects of enjoying a comfortable, modern lifestyle at reduced costs because they do not have the hazards introduced by fossil fuels but are environmentally friendly and almost completely running cost free. The system designed in this work requires little or no maintenance because of the thermosyphon principle involved. It was made basically from locally available raw materials.

Experiments were conducted with Single and Double glazed solar water heater for the square pulse absorber plates subjected to uniform mass flow rate to find the performance of the set-up. The following conclusions were obtained from this study.

1. The Double glazed square pulse absorber plate temperature is higher than the Single glazed Square pulse absorber plate water heater during experimentation.
2. The Double glazed square pulse absorber plate water heater Thermal efficiency is higher than the single glazed square pulse absorber plate water heater.
3. Heat gained by the water in Double glazed square pulse absorber plate water heater is comparatively higher than single glazed square pulse absorber plate solar water heater.
4. Thermal efficiency and heat gained by the water increases with increase in mass flow rate.

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