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(RESEARCH ARTICLE)

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Comparative thermal performance investigation of the straight tube and square tube solar water heater

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Abstract

Sustainable energy is a need and demand of time to overcome issues related to greenhouse emissions and climate change and the most easily available and sustainable energy is solar energy which can be used for heating, cooking, and power generation. The most common application of solar energy is water heating and such hot water is used for domestic and industrial purposes for such purposes solar water heater (SWH) is commonly used; in the present work, an attempt has been made by changing the shape of pipe of copper pipe which is commonly used in SWH from a circular cross-section to square and comparing the results of the proposed model with conventional one. The K-type thermocouples measure the temperature at various locations of the experimental setup.

Keywords: Solar Water Heater; K-type thermocouples; Straight Tube; Square Tube

1. Introduction

Solar energy is the most efficient alternative energy source. Due to the increasing demand for energy and the increasing cost of fossil fuels (i.e. gas or oil), solar energy is considered an attractive renewable energy source, which can be used to purify water at home and industry. Hot water accounts for nearly 20% of the total energy consumption of the average home. Solar water heating systems are the cheapest and most affordable clean energy for homeowners who can provide most of the hot water required by their families. SWH systems are usually very simple, using only sunlight to heat the water. A working fluid is exposed to a dark surface exposed to sunlight, causing the temperature of the liquid to rise. This liquid can be directly heated by water. The solar water heater is a device used to heat water and generate steam for domestic and industrial purposes using solar energy. Solar energy is energy that comes from the sun in the form of solar radiation in infinite quantities, when this solar radiation falls on an absorbing surface, it is then converted into heat, and this heat is used to heat water. This type of endothermic loses heat by radiation and convection. These losses increase rapidly as the temperature of the working fluid increases. Soteris A. Kalogirou [1] presented a study on different types of solar collectors and their applications. Samara Sadrin et al [2] focused on a method of replacing solar water heating systems. P. Rhushi Prasad et al. [3] studied the experimental analysis of the flat plate collector and compared the performance with the tracking receiver. Wattana Ratismith et al [4] described a passive collector design in which the outlet temperature is increased by reducing heat loss. Krisztina Uzuneanu et al. [5] described the optimal tilt angle for low-concentration solar collectors. R. Herrero et al. [6] Concentrated enhancement technique for flat plate liquid solar collectors. Mustafa AKTAS et al [7] obtained an experimental analysis of the optimal fin size, which can be used in solar system heat exchangers, was performed. K. Sivakumar et al. [8] designed a flat elliptical heat-pipe solar collector and tested it with a collector tilt angle of 11° from the horizontal.Kalogirou [9] labored on a comparison of the thermal overall performance of the photo voltaic water heater. Madani et al. [10] targeted a lookup titled heating options for residential structures in China: modern-day reputation and future outlook. Souliotis et al. [11] carried out a lookup on the photo voltaic water heating for social housing: power evaluation and existence cycle assessment. Fani et al [12]

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targeted photo voltaic assisted CCHP system, energetic, economic, and environmental analysis, case study: academic workplace buildings. Altoé et al. [13] labored on lookup of titled an evaluation of the monetary viability and greenhouse gasoline emissions savings ensuing from the use of solar water heaters in a standard Brazilian dwelling. Hossain et al. [14] furnished a lookup titled Thermal and financial evaluation of less expensive modified flat-plate photo voltaic water heater with parallel two-side serpentine flow. Şerban et al. [15] focused on a lookup titled Monetary and environmental evaluation of investing in photo voltaic water heating systems. Bouhal et al. [16] studied on lookup titled graph and thermal overall performance optimization of a pressured collective solar warm water manufacturing gadget in Morocco for strength saving in residential buildings. Ayadi et al [17] got outcomes from a lookup titled Contrast of photo voltaic thermal and photo voltaic electric powered house heating and cooling structures for structures in exceptional climatic regions. Alayi et al. [18] carried out a lookup titled thermal evaluation of parabolic trough attention photovoltaic/thermal machine for use in buildings. Jignesh A. Patel at. el [19] developed a spiral image voltaic water heater to reflect on the consideration of thermal normal overall performance utilizing bettering turbulence in the waft and consider the outcomes with a straight tube image voltaic water heater. Hardik A. Parmar et al [20] based on the thermal universal overall performance of serpentine photograph voltaic water and sold the variant in effectivity rate with understanding to time. P.P.Patil et al [21] offer graph consideration of the photo voltaic water heaters to reap warm water for home and industrial applications. S. Jaisankar et. al [22] studied a range of strategies to beautify the thermal effectivity in a photo voltaic water heater. In addition to this, a distinctive dialogue on the barriers of current research, lookup hole, and advised viable adjustments are made. Runsheng Tang et al [23] centered on inspecting outcomes of water temperature in the storage tank and peak distinction between collector loop connections at the tank on freeze safety of flat-plate collectors. Selmi et al. [24] performed a validated CFD mannequin for a flat plate photo voltaic water heater. M.Z.H. Khan [25] additionally performed experiments in photo voltaic heating gadgets for effectivity closer to sustainable development. H.I. Abu-Mulaweh [26] defined designing and improvement of photo voltaic water heating device experimental apparatus. A standardized checking-out technique is required for evaluating the effectiveness of extraordinary kinds of collectors and designing and determination of proper equipment. Sushil Tiwari et al [27] reviewed the variety of strategies recommended by a range of researchers to decorate the overall performance of photo voltaic water heaters. Ho et al. [28] carried out an experimental and theoretical evaluation of a recycling flat-plate photo voltaic water heater outfitted with rectangle conduits. D Prakash et. al. [29] focused on the environment-friendly use of photo voltaic electricity via a new solar water heating scheme and the float of warmness in the indoor development is detained utilizing sufficient ceiling insulation material. S. Sadhishkumar et. al. [30] initiated to find out about the opportunity of the usage of Phase Change Materials (PCMs) to keep photo voltaic electricity and to use this electricity in the course of the nighttime to warmness water for home purposes. Ankit S. Gujrathi et. al. [31] tried to use Ansys 15.0 Workbench software program to mannequin a Parabolic Trough Collector and the PTC has been meant for an awareness ratio of 25. TR Bajracharya et al. [32] fabricated two panels collector with every having a fine vicinity of 1.55 m2 and a hundred liters ability storage tank. Zhand and Malla [33] designed and developed a photo voltaic water heater (SWH) to generate and shop warm water beneath intense prerequisites such as ambient temperatures, as low as −20°C. Helwa et al. [34] studied a one-of-a-kind photo voltaic monitoring structures layout: a constant gadget going through south and tilted 40°, a vertical-axis tracker, a 6° tilted-axis tracker, and a two-axis tracker. Malla et al. [35] developed herbal thermosiphon SWHS at an excessive altitude lookup station with consequences validated with the TRNSYS model. Hematian et al. [36] targeted an estimation of experimental analyzed flat plate photo voltaic collector efficiency. [37-40] Patel Anand et al. [41] HD Chaudhary et al. [42-49] Patel Anand et al. evaluate various geometrical variations of absorber plate to enhance heat transfer efficiency in the solar heater. These studies are directly utilized in this research as well. The heat transfer enhancement phenomenon is performed in various applications such as [50, 51] Anand Patel et al. heat transfer devices [52, 53] Nikul Patel et al biofuels. The practical feasibility of solar heater are conceptualized using [54] S. Jaisankar et al. [55] N. V. Ogueke et al. [56] Ruchi Shukla et al. [57] Patel et al. The thermal performance enhancement for solar heaters is studied in [58] Hussain Al-Madani et al. Cylindrical Solar Water Heater [59] S. Vasanthaseelan et al. Different types of turbulators in a solar ware heater [60] S. Sadhishkumar et al. historical solar water heating system work review paper. [61] Tengyue Wang et al. [62] Li et al. [63] Kime and Seo et al. [64] Pakdaman et al. document a thermal performance comparison between a solar air heater, a conventional tube collector, and a transparent tube collector which is helpful to perform the in the current study in comparison of Straight Tube and Square Tube Solar Water Heater.

2. Experimental Setup

In this article, a ½ inch copper pipe is made from two ½ inch L-shaped sections of 1 m in length, and these three pipes are made by brazing as shown in Plate 7 and Plate 8 with pipe length of 0.5 m square pipe top and bottom of these three pipes using brazing, and these two top and bottom pipes are connected by ½ inch round copper pipe which can be connected with PVC pipe. The PVC pipe is connected to the water tank. To absorb more heat, the pipes are painted black.

All the tubes are housed in a wooden box covered with an absorbing plate made of a 0.1mm thick galvanized steel sheet painted black, the upper part of which is covered with 2 mm thick transparent glass.

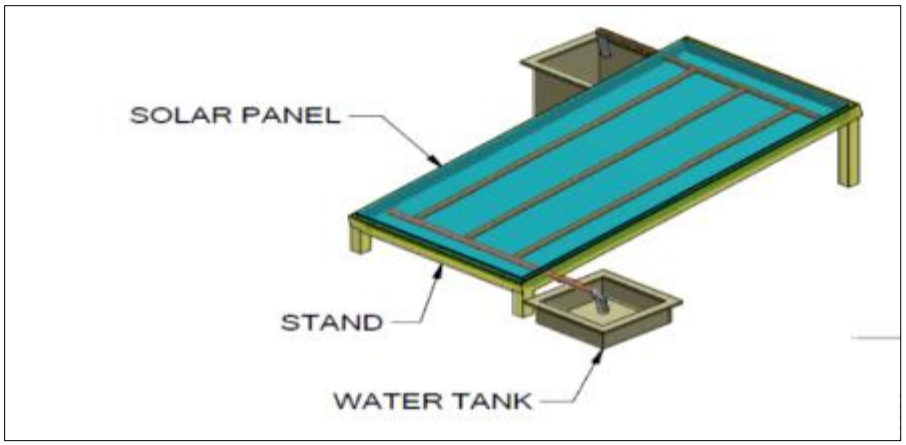

Figure 1 CAD Model of Experimental Setup

Figure 2 L shape copper sheet

Figure 3 Square Tube

Figure 4 Assembly of Solar Water Heater Pipe

Figure 5 End Connection of Solar Water Heater

Figure 6 Copper Pipes

Figure 7 Pipe Assembly of Solar water

Figure 8 Square Tube Solar Water Heater Experimental Setup

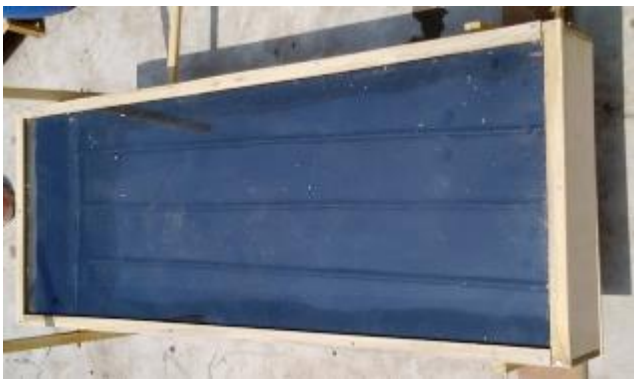

Figure 9 Straight Tube Solar Water Heater Experimental Setup

Similarly, with the same frame dimensions solar water heater is fabricated using three round copper pipes of ½" diameter at connect with ½" diameter copper pipe of 0.5 m length at the top and bottom. The K-type thermocouples are used to measure water inlet, outlet, and body temperature too in both experimental setups and using a 1 lt measuring flask with a stopwatch for flow measurement purposes.

3. Results and discussion

Table 1 shows the result of both experimental setups and Fig 10 represents temperature variation for time in both solar water heaters. Here square pipe of ½" square hole and a copper pipe of ½" through which water flows the interesting part is the cross-section area of the square pipe is more than 21 % circular pipe and so the time required for water is less than circular pipe and as the surface area on which radiation is incident is more in case of square tube solar water

heater and so better temperature results can be obtained in case of square tube solar water heater and so thermal performance is also better in case of square tube solar water heater.

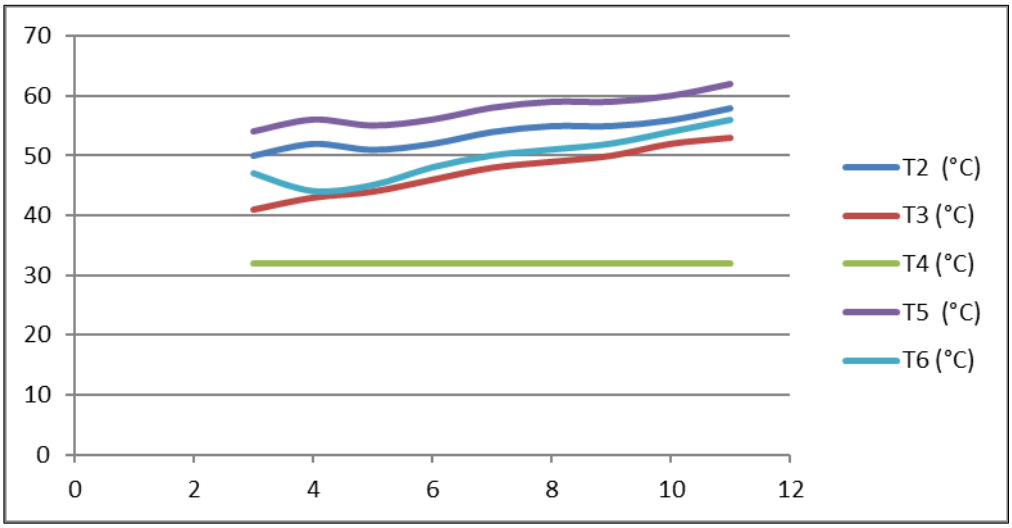

Figure 10 Temperature Variation w.r.t Time

Table 1 Result Table

Time required to fill 1000 ml tank		**Mass Flow Rate (Kg/s)**		**Heat Gain Qo kW**		**Heat Input Qi kW**		**Efficiency η**	
Square	Straight	Square	Straight	Square	Straight	Square Tube	Straight	Square Tube	Straight
292	353	0.003	0.003	0.130	0.142	0.681	0.681	19.17	20.92
292	353	0.003	0.003	0.142	0.154	0.681	0.681	20.92	22.66
292	353	0.003	0.003	0.166	0.190	0.681	0.681	24.40	27.89
292	353	0.003	0.003	0.190	0.214	0.681	0.681	27.89	31.37
292	353	0.003	0.003	0.202	0.225	0.681	0.681	29.63	33.12
292	354	0.003	0.003	0.213	0.237	0.681	0.681	31.29	34.76
292	355	0.003	0.003	0.236	0.259	0.681	0.681	34.66	38.13
292	356	0.003	0.003	0.247	0.282	0.681	0.681	36.29	41.48
292	357	0.003	0.003	0.301	0.281	0.681	0.681	44.25	41.36

Nomenclature

T1 = inlet water Temperature in Straight Tube, T2 = Body Temperature in Straight Tube, T3 = water outlet Temperature in Straight Tube, T4= inlet water Temperature in Square Tube, T5= Body Temperature in Square Tube, T6= water outlet Temperature in Square Tube Qo = Heat gain Qi = Heat input

4. Conclusion

Thermal performance point of view this solar water heater is a better option but economically it is not viable due difficult to manufacture and the high cost of fabrication.

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