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Preliminary Studies on Thermal Performance of Thermosyphon Solar Water Heating System Putu Wijaya Sunu*, I Putu Gede Sopan Rahtika, I Dewa Gede Agus Tri Putra, A. A. Ngurah Bagus Mulawarman, I Made Suarta Mechanical Engineering Department Bali State Polytechnic Badung-Bali, Indonesia *wijayasunu@pnb.ac.id I Wayan Edi Arsawan Business Department Bali State Polytechnic Badung-Bali, Indonesia wayanediarsawan@pnb.ac.id I Nyoman Edi Indrayana Electrical Engineering Department, Bali State Polytechnic Badung-Bali, Indonesia eddyindrayana@pnb.ac.id Ni Made Dwidiani Mechanical Engineering Department Udayana University Badung-Bali, Indonesia dwidiani@gmail.com I Gede Santosa Mechanical Engineering Department Bali State Polytechnic Badung-Bali, Indonesia

Abstract—Experimental investigation for determining the optimal tilt angle of flat-plate solar heater installation in Denpasar city to optimize the thermal energy performance. This preliminary research focused on **2 the performance of a** flat-plate thermosyphon solar water heater system based on temperature difference and total heat absorbed by the water in June until July. The tilt angles were between 15 to 45-degrees with northfacing orientation. The energy-saving in the water provided by solar collectors depends on thermal stratification with in pipe collector. This condition was evaluated by measuring the temperature difference of the header pipe. The results display that the temperature difference inside the collector's 40-degree tilt angle has the best performance. The total heat absorbed between 6 am – 6 pm by the collector at 40-degree higher than the other collector's tilt angle

Keywords—solar water heater, thermosyphon, thermal performance

I. INTRODUCTION In recent decades, energy conservation and sustainability play an important issue in the engineering field. The quantity of energy needed to heat the water for domestic and industrial needs is enormous. The ease of operation and simplicity of solar water heaters to produce hot water in all sectors has proven to be economically viable, so its use is increasingly widespread [1-11]. A solar water heater offers a solution to energy sustainability problems by prioritizing the sustainable use of energy. Solar radiation converts into thermal energy through a working

fluid inside the heater unit. The availability of solar energy, especially in a tropical country is very beneficial for Indonesia. The passive solar water heater system operates on the principle of the thermosyphon with a natural flow. The thermosyphon solar heater has been applied in the domestic sector widely, and the thermal performance has been carried out [12-13]. In this passive system, there is no need for a pump to flow the working fluid into the loop. Cold fluid in the collector becomes hot due to solar radiation, then increases to the top due to differences in density. This process continues as a cycle. The thermal behaviour in a thermosyphon system involves many constraints, such as the intensity of solar radiation conditions, clearness of the sky condition, water volume flow rate through the system, collector orientation, heat exchanger effectiveness, and thermal load. Yuechao et al. [14] examined solar heaters embedded with heat pipes, obtained efficiency reaching 50%. Other researchers investigate solar heaters which include the form of solar collector, the addition of twist tape, the performance of the integrated solar heater with heat pump, and variations in the collector's position were conducted by Li et al [15], Yao et al. [16], Lakshmi et al. [17], Pandya and Behura [18], and Sun et al. [19]. Dehghan and Barzegar [20], Barzegar and Dehghan [21] examined ¹ the vertical storage tank in the domestic application during the consumption period. Hamdan [22] conducted the measurement of air of ² the inlet and outlet temperatures of the collector, the surrounding temperature, and Advances in Engineering Research, volume 208 Proceedings of the International Conference on Innovation in Science and Technology (ICIST 2020) Copyright © 2021 The Authors. Published by Atlantis Press International B.V. This is an open access article distributed under the CC BY-NC 4.0 license -<http://creativecommons.org/licenses/by-nc/4.0/>. 273

the pipe circuits insulation. The performance parameters were completed to find the optimum storage efficiency and the bed tilted angle. Most previous studies on thermosyphons solar water heater were majorly on the performance for domestic application systems. However, a more thermosyphons solar water heater may appear when the system loaded or sufficient hot water consumption is needed. Furthermore, the

consequence of dirt **7** accumulation on the glass cover of the collector has been conducted with various slope by Hegazy [23]. The influence of geographic environments, collector positioning, tilt angle, fabrication, and manufacturing material and configuration of the solar collector system has been investigated by many researchers. In this present experiment, the passive solar water heater configuration and flat-plate thermal collector are used to absorb environmental solar radiation. The thermal performance of the solar water heater was investigated by varying the collector's **4** tilt angle from the horizontal axis. The observation location in the city of Denpasar, Bali-Indonesia.

II. DESCRIPTION AND MODELLING **3** OF SOLAR WATER HEATER

For this experimental investigation, a typical laboratory scale of flat plate solar water heater manufactured in Denpasar **as shown in Fig. 1**. The location of Denpasar city is 8°39'50" south latitude dan 115°11'40" east longitude. The principles of the solar water heater in general, solar radiation traverse's energy to working fluid inside the tube collector. A density stratification is formed by **12** the temperature difference between the copper tube and makes a natural flow of water called the effect of thermosyphon. In this condition the warm water flowing up and the cold water flowing down. Fig. 1. Schematic installation. The major physical specification for the flat-plate solar water heater is shown in Table 1. It involves an effective area of 1.0 m² of a flat-plate collector, orientating north, tilted angles ranged from 15° - 45° from horizontal level, and an insulated 60 L thermal storage tank. The water enters at the top section and exits at the bottom section of the tank. All pipe circuits are insulated well to prevent heat loss. A single solar water heater was tested at an outdoor test at 3 m elevation.

TABLE

I. COMPONENT DESCRIPTION

No	Component	Specification
1	Collector aperture area	1.0 m ²
2	Collector protection material	Single glass, 5 mm thickness
3	Collector channel	Copper tube, 0.25 inch
4	Collector slope	15° – 45°
5	Thermal storage tank	Horizontal orientation, 60L

A. Instrumentation The test conditions at daily solar radiation and environment temperatures were measured digitally. The solar radiation was measured by solar power meter with sampling time 10 seconds, solar power accuracy 5%, and angular accuracy with a cosine corrected <5%. The water initial temperature, ambient air

temperature, and the water temperature at each collector point were measured by K-type thermocouples. Data temperature from all sensing temperature were collected every 10 seconds for 12 hours in a day by acquisition equipment with the accuracy data 0.1°C. B. Data Processing This research aim is to calculate the total heat absorbed by the collector. The temperature observed from the solar heater model. The measured the temperature in the collector system was used to indicate the system performance. The stratification of the temperature of the collector tube affects **2 the thermal performance of a solar** water heater. The temperature distributions inside the collector during the day indicate the heat distribution to **1 the thermal storage tank** through the working fluid. The mean initial temperature of water (T1) in °C, the end of the heating temperature (T2) in °C, heat capacity on constant pressure (Cp) in kJ/kg°C were used to calculate the heat (Q) collected by **2 the thermal storage tank** at the end of the experimental period. The total heat absorbed by the working fluid determined below, (1) III. RESULTS AND

DISCUSSION The solar water heater was connected with thermal storage tanks on a horizontal frame (about 3 m above the ground), and it oriented north at the Denpasar city in Bali. All of the data were collected from June to July 2020 on a sunny day. They were connected with the solar collector with insulated flexible pipes. Advances in Engineering Research, volume 208 274

Fig. 2. Time series of the average solar radiation. Fig. 2 shows the average variation of solar radiation measured by a solar power meter on typical days. Generally, the maximum solar radiation was recorded around 13:00 to 14:00 h on bright days. **1 It is seen that** the solar radiation of a 25-degree solar collector reached the maximum value compared to others. Fig. 3. Average ambient temperature. The ambient temperature Fig. 3 observed similar trends with solar radiation. This ambient temperature has a strong correlation with meteorological circumstances. The data was taking from June to July 2020. The climate in Denpasar city is tropical, dry season. The clearness of the sky is high. The temperature ambient in this experiment periods was the lowest throughout the year. Fig. 4. Average inlet collector temperature. Fig. 5. Average outlet collector temperature. Fig. 6. Average

delta t solar collector. Advances in Engineering Research, volume 208 275

Fig. 4 to 6 shows the water temperature on inlet, outlet, and its difference measured by thermocouples. The inlet water temperature started slowly until 13.00 h and reached a maximum of around 16.00 h. It is shown that the water temperature inlet reached the maximum value at around 16.00 h. From Fig. 5 see the maximum outlet temperature reached by 400 solar collectors. The same trend is seen in Fig. 6. For a flatplate-thermosyphon solar heater, the value of temperature and its difference inside a collector, glass cover temperature, **1 thermal storage tank, and** solar radiation intensity has a correlation on the thermal performance. The 40° tilted solar collectors have the lowest inlet water temperature **4 as shown in Fig. 5.** In the other hand, it has the highest outlet water temperature as proved in Fig. 6. So that **2 the temperature difference between** outlet and inlet collector for 40° tilted have the highest value. Fig. 7. Average glass cover temperature. Fig. 8. Average thermal storage temperature. For glass cover temperature, the 40° tilted solar collectors have modest value **1 as shown in Fig. 7. The thermal performance of** thermosyphon solar heater may indicated by outlet and inlet water temperature difference. This phenomenon proved in Fig. 8, as shown the maximum thermal storage tank temperature reached by 40° tilted solar collectors. IV. CONCLUSION A flat-plate-thermosyphon solar water heater equipped with **a horizontal storage tank** has been investigated in five different tilted angles. Water temperature was digitalized during solar collection on the day period. For the optimum tilted angle 40°, gave the best result (22°C) in temperature difference between outlet and inlet solar collector in this experiment. The total **2 heat absorbed by the** 40° solar collectors was about 5520 kJ.

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