Research Article

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An Experimental

effect. The stratification effect inside the tank will ensure the heat to flow from compartment B to compartment A during collecting period. Meanwhile, during non-collecting period, the heat from the water will lose to the surrounding from compartment B, and eventually the heat will still accumulate at compartment A to provide hot water for usage.

Research Methods

The solar water heater tank is made with a volume of 11.4L of galvanized steel having a thickness of 1mm and were painted black to increase the absorbability of the solar energy. Also, a 4mm thick tempered glass is mounted on the inclined surface of the tank.

The test starts off by filling up the tank with normal tap water knowing that the storage tank has been well insulated with double sided aluminum foil bubble film insulation with a thickness of 9mm. A total of nine calibrated K-type thermocouples (Nickel/Chromium) with an accuracy of ± 1°C are fixed in the positions shown in Figure 2, and then been installed inside the tank. A light projector of 1000W power has been used to represent the solar radiation. It has been set at an initial height of 30cm as shown in Figure 3. It can give an average solar simulated radiation of 1500W/m^2 that measured by a solar power meter TES-1333.

The measurements are taken at 30 minutes intervals for 6 hours of the collection period without any water withdrawal. The steps are then repeated to conduct another test with an average solar simulated radiation of 863W/m^2, 576 W/m^2 and 360 W/m^2, and it's by adjusting the height of the light projector.

Extra experiments have been conducted with a 13mm thickness insulation. The steps are repeated under the solar simulated radiation of 1500W/m^2.

In this test, the tank was kept with the hot water obtained during the shiny period. The system is then left to cool naturally at ambient temperature. The test is conducted under no water withdrawal conditions, for a total cooling period of 18 hours, which represents the time period of no or weak sunshine. The measurements are taken at 30 minutes intervals, and the readings are obtained by connecting the thermocouples to a digital multimeter. The water is then drained out from the tank after 18 hours, for the new experiments to be conducted.

Figure 2 Position of thermocouples in vertical and inclined axis.

Figure 3 Indoor experimental test set up of ICSSWH.

Results and Discussion

The thermal performance of the system has been analyzed based on the experimental data obtained from the indoor solar energy collection and retention test. The heat loss coefficient of the system as well as the efficiency of collection and retention can be determined via calculation proposed by Smyth et al. (2017) and Ronald et al. (2019). The energy supplied over the collection period, $Q_{supplied}$ was determined by equation (1).

$$Q_{supplied} = I_{avg} \times A_{ap} \times \Delta t \quad (1)$$

where I_{avg} is the constant average simulated solar radiation, A_{ap} represents the aperture area of the collector and Δt represents the period of collector illumination by the solar simulator. Meanwhile, $Q_{collected}$ which is the thermal energy collected can be obtained from the equation (2) shown water and $T_{i,w}$ represents the average starting temperature of the water. Hence, with the calculated value of $Q_{collected}$ and $Q_{supplied}$, the

Figure 7 Comparison of heat retention efficiency between current ICSSWH system and the system studied by Ronald et al., 2019.

A comparison of thermal performance between system with 9mm insulation and the system with 13mm insulation is performed. Figure 8 and Table 2 are showing the comparison of thermal performance during the collection and cooling periods. From Figure 8, it can be shown that the system with 13mm thickness insulation is able to achieve a higher normalized water temperature of (50°C), which is 2°C higher than the system with 9mm thick insulation. Also, system with 13mm insulation can retain heat better with a normalized hot water temperature retention of 13°C compared to system with 9mm insulation that just have a normalized hot water temperature retention of 7°C. This is demonstrated in Figure 9 as well, where system with 13mm insulation has a lower temperature loss. Hence, a thicker insulation should be applied to achieve a better retention of heat inside the tank for a long period.

Table 1 Thermal characteristics comparison between current ICSSWH system and the system studied by Ronald et al., 2019.

System	11.4L trapezoidal ICSSWH with extended storage (current project)	16.7L cylindricalthermal diode ICSSWH with aluminium absorber and stainless steel evaporator components (Ronald et al., 2019)	16.7L cylindricalthermal diode ICSSWH with stainless steel absorber and stainless steel evaporator components (Ronald et al., 2019)	27.7L cylindricalthermal diode ICSSWH with stainless steel absorber and stainless steel evaporator components (Ronald et al., 2019)
Heat				

Figure 8 Comparison of performance between the two systems with 9mm and 13mm thermal insulations.

Figure 9 Comparison of temperature loss profile during the 18 hours cooling period between insulation with thickness of 9mm and 13mm.

Table 2 Characteristics of thermal retention during a 12 hours and 18 hours of cooling period.

	Insulation with thickness of 9mm								Insulation with thickness of 9mm	
Distance of light source from the glass cover	30cm		50cm		70cm		90cm		30cm	
Duration of heatreten-tion (hours)	12	18	12	18	12	18	12	18	12	18
Initial water temperature (°C)	74		48		44		41		79	