Increase the heating capacity of solar water heaters through two conditions of placing paraffin in copper tubes

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Increase the heating capacity of solar water heaters through two conditions of placing paraffin in copper tubes

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Abstract. Nowadays, Energy is an essential requirement for daily activities. Indonesians use solar energy for various activities such as electricity, water heaters, and dryers. Solar collectors are devices that absorb solar energy and convert it into heat energy. Solar energy heats copper pipes and water passes through heat tubes induces an increase in water temperature. The increase in heating capacity in this experiment was carried out by adding paraffin (as thermal storage material) into a tube in a solar collector. Solar water heaters equipped with solar collectors (called cylindrical trough collectors) have been developed in this experiment. Paraffin placed in the copper tube with two conditions. They are called Collector A and Collector B. The effect of two conditions of placing paraffin in copper tubes on the water-out temperature has been studied in this experiment. The result shows that the highest water temperature found with 56^{o}C in collector A. It is due to the highest solar radiation intensity also record at 1,289 W/m^2 (1:00 PM). While Collector B only produces the water-out temperature of 52^{o}C at 1:00 PM. The conclusion shows that the position of paraffin in tubes with Collector A can increase the water-out temperature in the solar water heating system if compared with the collector.

1. Introduction

Population growth is a primary cause of the increasing gap between current world energy demand and energy supply. Renewable energy such as solar energy is one solution to the energy crisis. Solar energy is potential energy to be managed and developed as a source of further energy reserves, especially for Indonesia as a tropical country whose sun shines throughout the year. Several studies have been observed in the utilization of solar energy for water heaters.

The efficiency of solar collectors with nanofluid-based nanoparticles has been studied from the economics side. The results show that nanoparticles for nanofluid-based solar collectors have economic value if compared to conventional solar collectors. [1]. The potential for solar energy for water heater applications in Inland Norway has been investigated [2]. Solar energy application for water heat systems forced by natural convective flow have been observed using working fluids; it utilized supercritical CO2 [3]. The optimization of integrated solar collectors that integrated with parabolic concentrator (CPC) reflectors to produce hot water has been done by characterizing the geometry of the heater system [4]. The thermal performance of the evacuated-tube solar water heater has been systematically evaluated by placing two collectors side by side, i.e., the water-in-glass and

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heat-pipes [5]. The highest temperature and sun ray intensity were recorded at 01:00 pm, it observed in an experiment in Aceh-Indonesia after the tsunami. It can affect the results of water heating [6-7].

Thermal storage materials as phase-change materials (PCMs) have been applied to solar heating and cooling systems [8]. The shot peening process can increase the material properties of AISI 304 stainless steel [9]. Solar water heating systems with practical collectors have been optimized through its design [10]. Two water heater designs are built-in storage water heater-plain, and newly designed finned type have been compared for both performances [11]. The use of polymeric materials for glass components and heat exchanger have been reviewed for domestic and industrial applications of solar water heating systems [12-13]. The solar water heating system with a slab has been applied [14]. The relationship between the Nusselt number and friction factor for a solar air heater has been developed [15] and a turbine ventilator application [16]. An Integrated Collector Storage (ICS) to improve the performance of solar water heater has been designed with an emphasis on optics [17]. This experiment aims to investigate the water-out temperature with two conditions of placing paraffin as heat storage material in copper tubes by using solar collectors with cylindrical trough collectors of solar water heater systems.

2. Material and Method

Solar water heaters equipped with cylindrical trough collectors have been successfully built in our laboratory as shown in Figure 1. Copper tubes placed on the top of the solar collector plate with parabolic shaped so that the radiation energy is focused (sun ray in the form of a line) along the copper tube. Solar energy heats copper tubes, and water passes through the heat tube, then the temperature of the water out from those tubes can increase. Furthermore, heat capacity can continue to increase by adding thermal storage material to the copper tube. The material used in this experiment is paraffin for latent heat storage, which applied to solar water heater systems. Paraffin used in this experiment is the standard paraffin available on the Banda Aceh-Indonesia market.

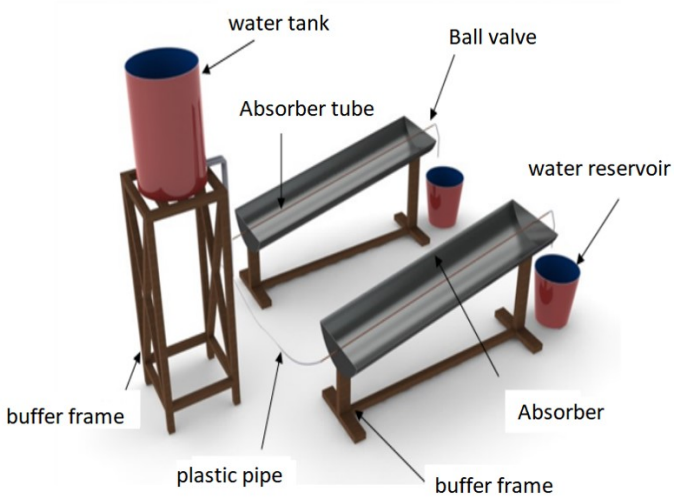

Figure 1. Apparatus of solar water heater developed in this experiment.

The unused drum with 55.5 cm in diameter split in vertically into two parts. Two split drums welded and obtained 170 cm in total length, then its used as a cylindrical collector. Stainless steel plates as reflectors with thickness, length and width are respectively 0.06, 170, and 85 cm, placed on the surface of the drum (parabolic-shaped). Two diameters of copper tubes used as heat absorber are Ø 1.3 cm (1/2 in) and Ø 0.95 cm (3/8 in) with length 190 cm, respectively. Black Styrofoam sheets with 0.9 cm thick are used as a heat insulator. Other instrument used in this experiment consisted of measuring glass, stopwatch, K type thermocouple, thermometer, Solar Power meter, main water tank, valve, PVC pipe, and plastic pipe, storage tanks for water-out. The temperature of water out is measured by two test conditions specified by placing two positions of paraffin in copper tubes. The

first is called Collector A where paraffin placed in tube 2. The second is called Collector B where paraffin inserted between tubes 1 and 2 (inside tube 1 and outside tube 2) as shown in Figure 2. Two copper tubes arranged as parallel with diameter outer ½ in and diameter inner 3/8 in, paraffin placed in a different position at both collectors, that are collector A (paraffin in tube 2) and collector B (paraffin in tube 1 outside tube 2).

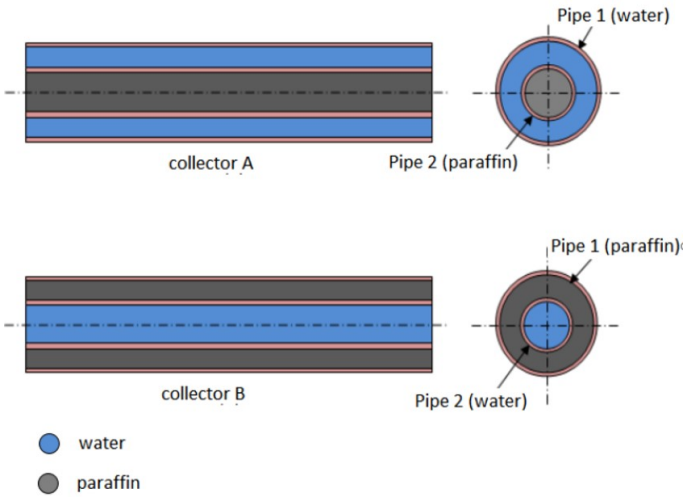

Figure 2. Paraffin placed in different positions.

Temperature recorded at several points in this experiment as shown in Figure 3. There are TA1 and TA2 as thermocouple placed in the surface of copper tubes outside of cylindrical collectors (before water passed solar collector). TB1 and TB2 as thermocouple placed in the surface of copper tubes inside of cylindrical collectors. TC1 and TC2 as thermocouple placed in the surface of copper tubes outside of cylindrical collectors (after water passed solar collector). TP1 and TP2 as thermocouple placed on the surface of the collector plate. TR1 and TR2 as collectors room temperature are recorded. Tf1 as the temperature of water-in, Tf2 as the temperature of water-out, T∞ as ambient temperature.

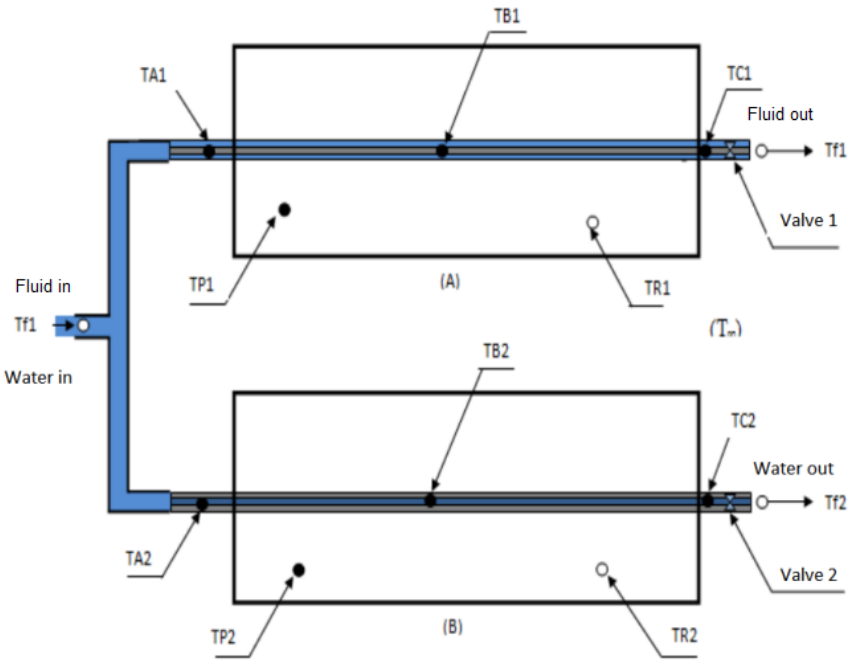

Figure 3. Measurement positions (A) Collector A and (B) Collector B.

3. Result and Discussion

The effect of the water-out temperature by two conditions of placing paraffin as heat storage material in copper tubes by using solar collectors with cylindrical trough collectors of solar water heater systems has been studied in this experiment. The velocity of the flow rate for both collectors is kept constant at 25 ml/minute.

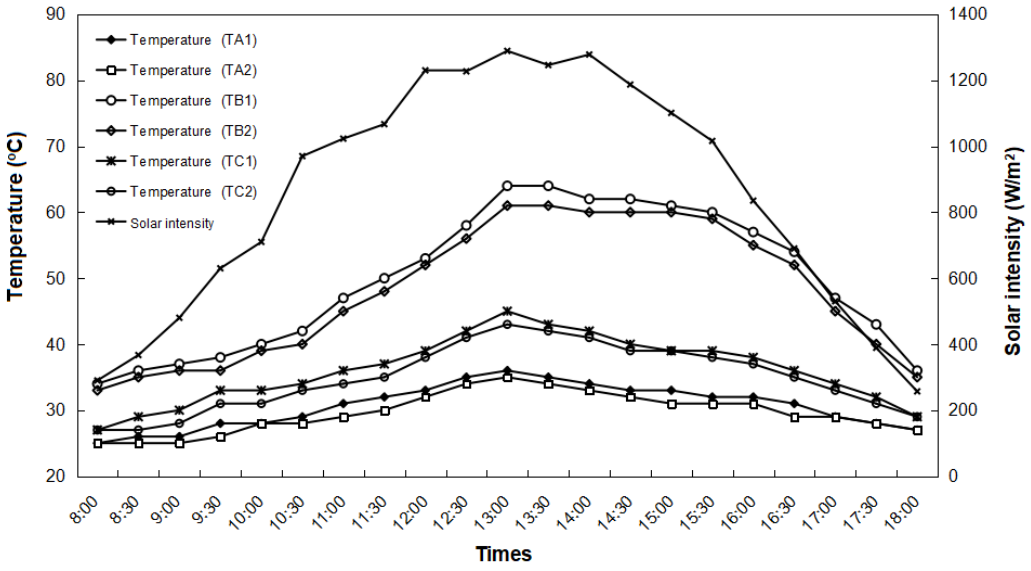

Figure 4. The temperature distribution water-in, water at room collector, and water-out foe Collector A and Collector B against time.

Temperatures recorded on apparatus by variation between collector A (paraffin inside) and collector B (paraffin outside) as shown in Figure 4. The temperature of water-in (before collectors) for both Collector is 25°C; temperature does not affect by heat from solar collectors. The highest temperature of water-out (water after passed solar collector) reaches 64°C. The maximum of solar intensity obtained 1,289 W/m^2 at 13:00 WIB (1:00 p.m.) (Indonesia Western Standard Time). However, the highest temperature of water-out at Collector B found 63°C.

Figure 5 shows the plate temperature, and room temperature for both Collectors (Collectors A and B) have the same temperature is 28°C at 08:00 WIB with a sun intensity 290 W/m^2. It is an initial experimental condition. Starting at 08:30 WIB (8:30 a.m.), plate temperature, and room temperature continued to increase as increased the solar intensity and reached a peak at 13:00 WIB (1:00 p.m.). The plate temperature reaches a maximum that is 77°C while the room temperature is 69°C the difference between the two is 8°C. The water-out temperature in Collector A began to rise started with 32°C, and 31°C for Collector B. The highest temperature reached 56°C at 13.00 WIB for Collector A and 52°C for collector B, the intensity of solar radiation was 1,289 W/m^2. Plate temperature and room temperature at 13:00 - 15:30 WIB are still up and down, while at 16.30 WIB - 18.00 WIB the difference between the plate temperature and the room temperature is not significant, it caused by the solar intensity begun to decline to 257 W/m^2. The temperature increase is not only caused by exposure to sun ray but also due to the heat energy absorb and release by paraffin that placed in the copper tube during the experiment process.

Increasing the temperature of the water out after flowing through the copper tube in the solar collector is caused by several things. First, the parabolic reflector (cylindrical solar concentrator) reflects sun ray focused along the copper tube (focus line) causing an increase in the copper tube temperature. Second, the solar collector chamber which is completely covered with glass at the top causes increasing room temperature, where the heat from room temperature will induce copper tube.

Third, paraffin in the copper tube act as material to store heat. Copper tubes exposed by sun ray and the heat of room collector absorbed and stored heat into paraffin, subsequent water that passes through copper tubes will accumulate all heat and increase the water-out temperature.

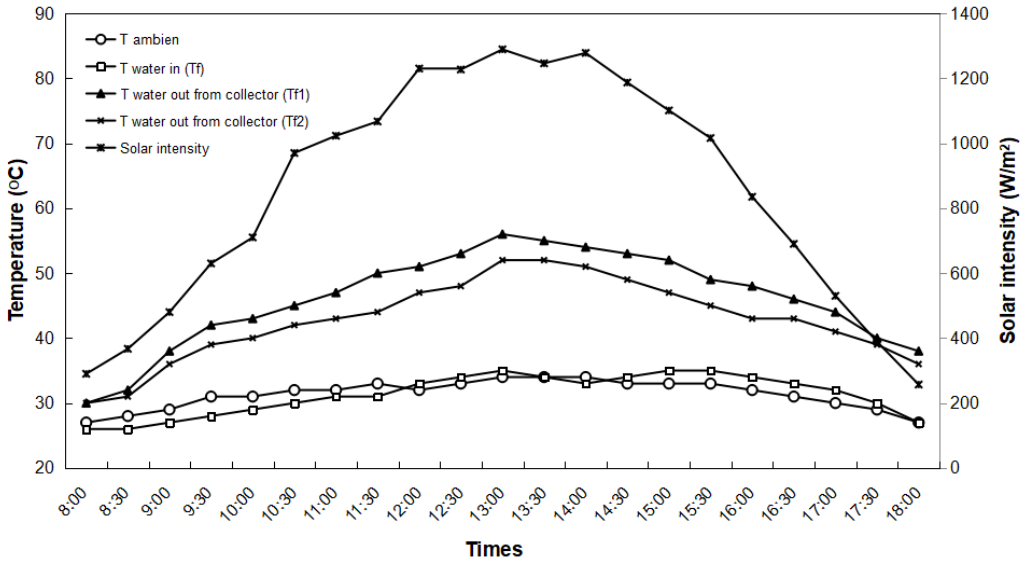

Figure 5. The temperature distribution of water-in and water-out for both conditions (collector A and B).

Comparison of the two positions of paraffin in copper tube affects the water-out temperature are discussed — collector A where paraffin placed at the core of copper tubes appears better compared to Collector B (paraffin covers the water-out channel). The highest water-out temperature obtains in Collector A; this causes by water passing through copper tubes exposed by heat from the sun ray reflector and the heat of the collector space. Heat from water passing will absorb by paraffin which is stored and released in slowly and can affect to the water passing through it. Copper tubes exposed to heat from the sun's reflector and collector room do not directly affect to water passing. The position of paraffin restrains the heat flow that affects the water-out temperature (case of heat transfer).

Parabolic mirror collector that the mirror design allows the collector to focus and collect radiation directly and spread without tracking the sun ray [18]. Absorbent tubes covered with evacuated tubes for reduction of heat losses. There are several types of collectors with high efficiency and can produce high temperatures [19-22]. Classification of solar water heaters is generally divided into two types, and most solar water heaters need a well-insulated storage tank. Solar energy preheats water before entering water heaters with two tank system. However, the backup heater combined with solar storage in one tank system [23,24].

4. Conclusion

The influence of the water-out temperature by two conditions of placing paraffin as heat storage material in copper tubes by using solar collectors called cylindrical trough collectors of solar water heater systems had been intensively investigated. It can be concluded:

- Heat focus line through parabolic reflector as cylindrical solar concentrator is successfully increasing water-out temperature; it developed in this experiment.
- Solar collector chamber with covered by plate glass also induced copper tube and affected to water-out temperature.

- Effect of adding paraffin as the thermal storage material does not significant increasing water-out temperature.
- The position of paraffin has affected to water-out temperature.
- The water out temperature inside the collector for the solar water heater depending on the solar intensity during the experiment.
- The highest temperature of water output obtain at collector A (paraffin in pipe 2) at 56^{o}C, and the solar intensity maximum recorded at 1,289 W/m^2. It is due to paraffin placement in pipe 2 (collector A) can increase the efficiency of the solar water heating system.

5. Acknowledgment

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