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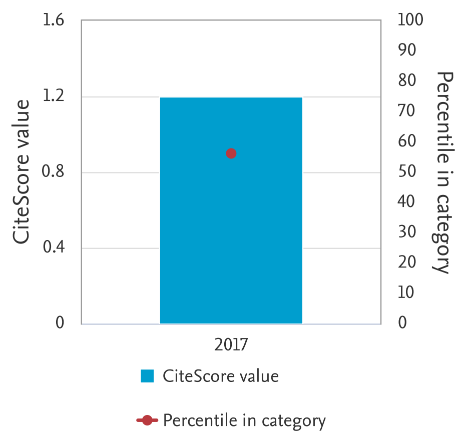

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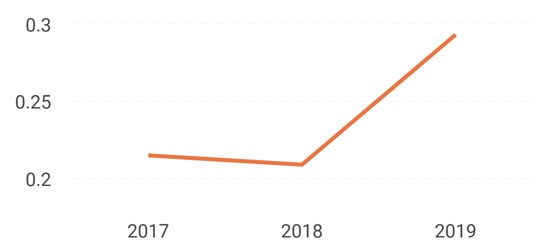

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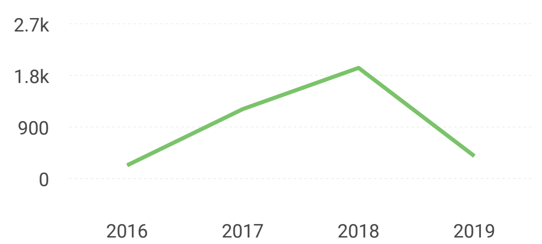

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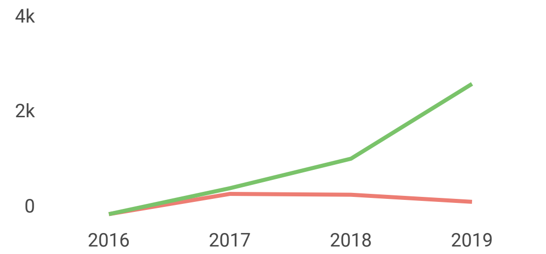

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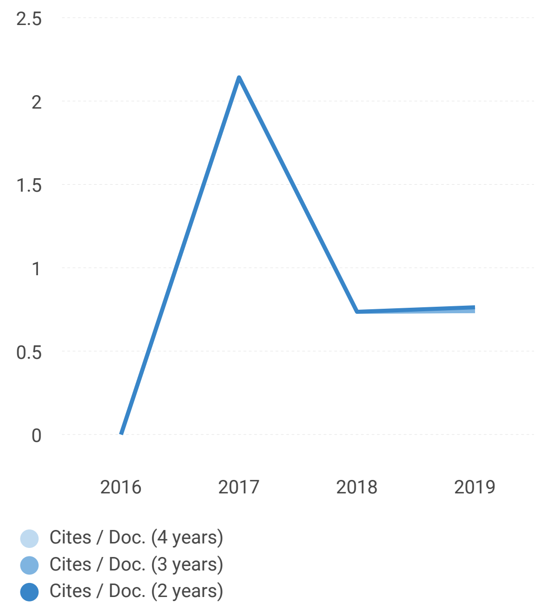

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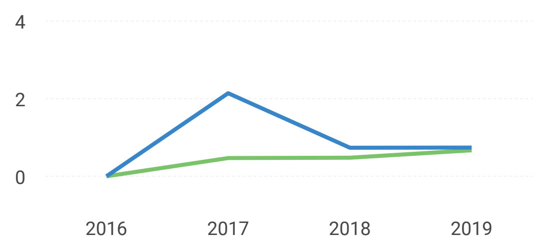

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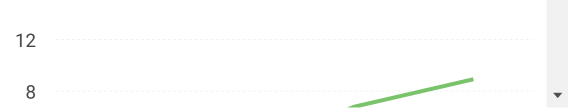

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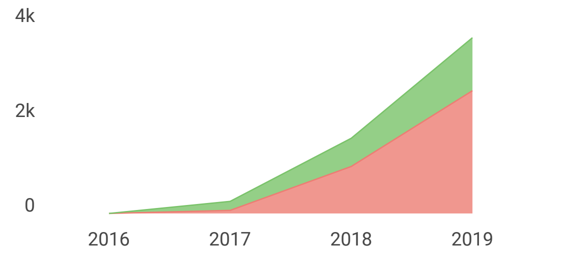

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ENHANCEMENT OF GRANITE STONE FLAT PLATE COLLECTOR EFFICIENCY USING MULTIPLE COVERS

M. Wirawan, M. Mirmanto, IG. B. Susana, R. Sutanto, M. Wijana and IM. Suartika
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ABSTRACT

Solar energy in Indonesia has high potential to be developed because Indonesia is a region that has sunlight all the year with a radiation intensity of 900kW/m². This study uses flat plate collectors with granite stone absorber and multiple covers. The aim of this study is to know the effect of multiple covers on the collector performance. The covers employed were 1, 2 and 3 made of transparent glass. To test the collector, several volumetric flow rates of water were run, i.e. 300cc/min, 400cc/min, and 500cc/min. The pipes as the duct buried in the absorber were arranged in parallel comprising 7 copper pipes with a nominal diameter of 1/2 inch. The overall size of the collector was 100 cm x 80 cm x 10 cm. The results show that at the volumetric flow rates of 300 and 400 cc/min, increasing the cover number decreasing the performance and efficiency of the collector, while at the higher volumetric flow rate of 500 cc/min the effect is not significant or deteriorated.

Keywords: Granite stone, absorber, volumetric flow rate, collector.

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1. INTRODUCTION

The need of energy in the world increases with the increase in the population. Most people use fossil energy such as liquid and gas fuel, and coal. Fossil energy cannot be renewed and it has been depleting. Therefore, it is necessary to find alternative energies. Nevertheless, to use alternative energy should consider some factors such as economic, environment, and safety, Kalogirou [1].

Solar energy is one of the renewable energies that have high potency in Indonesia. Indonesia gets the sunlight all the year with an intensity of 900kW/m². To convert this energy, a flat plate collector can be used. Nevertheless, the collector should have some criteria, e.g. ecology, efficiency and economic, Stefanovic and Bojic [2].

Common collector absorbers are made of metal such as aluminum and copper because metal can transfer heat very well. However, in this research, the absorber was made of granite stone. The reasons for this are (i) not corrosion, (ii) local material, (iii) saving the heat. Furthermore, till now there is no research that uses granite stone as an absorber of flat plate collector. However, a preliminary research of granite stone absorber has been performed, e.g. Wirawan et al. [3, 4]. They stated that using granite stone, the working water flowing through the absorber could get heat logger, even until at around 6 pm. The pipe arrangement used in their research was parallel and serpentine. Then they concluded that the parallel arrangement was better because of the low-pressure drop. The parallel arrangement was also used by several researchers although their studies were different, e.g. Mirmanto et al. [5, 6]. Mirmanto et al. [5] used the parallel arrangement for their heat exchanger for turning down the room temperature, while Mirmanto et al. [6] used a heat exchanger arranged in parallel to dry agriculture products. They also explained that parallel was better from the viewpoint of pressure drops. Recently, Susana et al. [7] also used a parallel heat exchanger for their dryer. They used the parallel heat exchanger because of low-pressure drop requirement.

The use of granite stone for an absorber is a new and advanced step for absorber material in the field. Some studies prior to this study, some nature absorbers have been investigated such as the black sand absorber, gravel absorber. Those materials showed characters that can be used for substituting the metal absorber. Those are also useful for collectors that are installed in the remote areas where metal is difficult to be obtained. Even, Wirawan and Sutanto [8] stated that using black sand absorber could reduce the heat loss from the collector to the ambient.

The number of the cover is also suspected of having effects on the collector performance. A study on the effect of the cover number was performed by Kalidasan and Srinivas [9]. They concluded that the efficiency of the collector increased and then decreased after the optimum number of cover. They used cover numbers of 1, 2 and 3 covers. They found that the highest efficiency was obtained using 2 covers. Due to this finding, this study also uses 1, 2 and 3 covers to check which number of the cover is optimum; the absorber employed in this study is different with that used by Kalidasan and Srinivas [9] though.

2. MATERIALS & EXPERIMENTAL PROCEDURES

The material used in this study is water that is used for taking heat from the absorber, while the device used in this study is a flat plate collector with an absorber made of granite stone. The test facility is shown in figure 1, comprising a reservoir and three identical flat plate collectors. All collectors use granite stone as their absorbers. To remove heat from each absorber, 7 parallel pipes were installed on the absorber and connected to the inlet and outlet of the collector. The water volumetric flow rate was measured using a volume meter and a stopwatch. The volumetric flow rates employed were 300, 400 and 500cc/min.

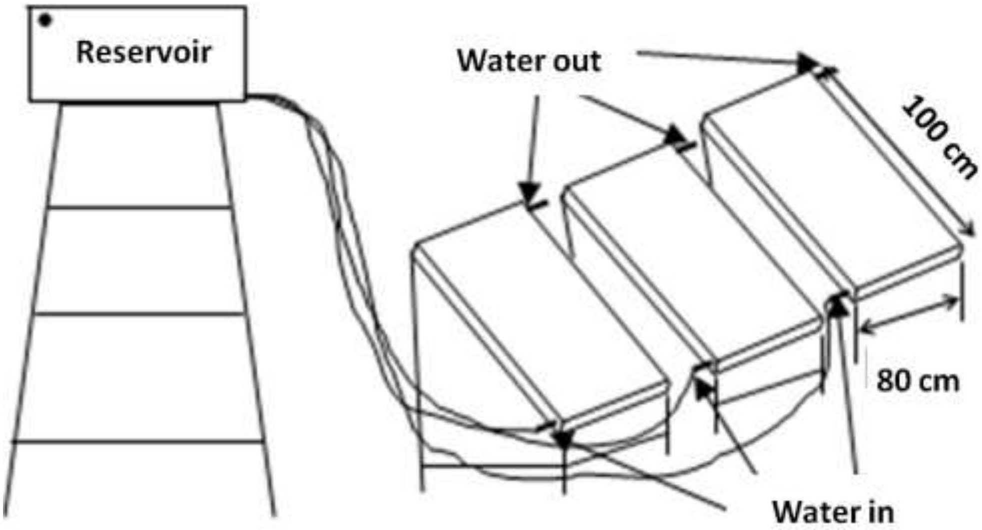

Figure 1 Schematic diagram of the experimental apparatus

All temperatures were measured using calibrated K-type thermocouples, which were connected to the NIDAQ 9714 data logger. The temperature uncertainty was found to be of approximately ± 0.5°C. Then all temperatures were recorded in the PC interfaced using LabView program at every second. The ambient wind velocity was measured using a digital anemometer with an uncertainty of ± 3% reading. The radiation intensity was measured using a solar power meter SP-2016 with a maximum range measurement of 10000 W/m² and an uncertainty of ± 5% reading.

The collectors were made of aluminum, styrofoam, and triplex. The size of the collector was 80 cm x 100 cm x 10 cm. The collectors were installed facing North at 15°C to get maximum radiation intensity. The collector with 1 cover is symbolized as k1, and the collector with 2 covers is noted as k2, while the collector with 3 covers is denoted with k3.

3. RESULTS AND DISCUSION

Testing the three collectors were performed to obtain data including water inlet temperature, water outlet temperature, absorber temperature, cover temperature, wall temperatures, and ambient temperature. The measurements were conducted in July and August 2017. The recorded temperature differences, which is equal to T_o - T_i, are shown in figure 2. The measurements were conducted at 10 am to 5 pm. From figure 2, the different results are not significant because all lines touch each other. The lines of ΔT for k1, k2, and k3 are overlapping. Hence, from ΔT viewpoint, there is no difference between k1, k2, and k3. However, the instantaneous maximum ΔT was achieved using single cover or k1 at the volumetric flow rate of 300 cc/min. Increasing the volumetric flow rate decreases ΔT. This is due to the velocity of flow. Higher volumetric flow rate, of course, lower ΔT, because at the higher volumetric flow rate, the velocity of flow is high, therefore, there is no time for water to remove heat from the pipe walls. This phenomenon was also found by Wirawan et al. [3, 4]. They elucidated that decreasing the flow increased ΔT. Furthermore, they found that increasing ΔT corresponded to the increase in solar radiation. The power of the solar radiation that enters the collector is denoted by Q_{in} as shown in figure 3. Q_{in} fluctuates because of the weather. From figure 3, Q_{in} reaches the peat between 11.00 to 13.00. After that it decreases fairly until of around 100 W. However, Q_u is the useful heat that is removed from the absorber by the water increases with the time and then it decreases after its peak heat at around 11.00 to

13.00. The effect of cover number seems unclear in figure 3 for the graphs are overlapping each other.

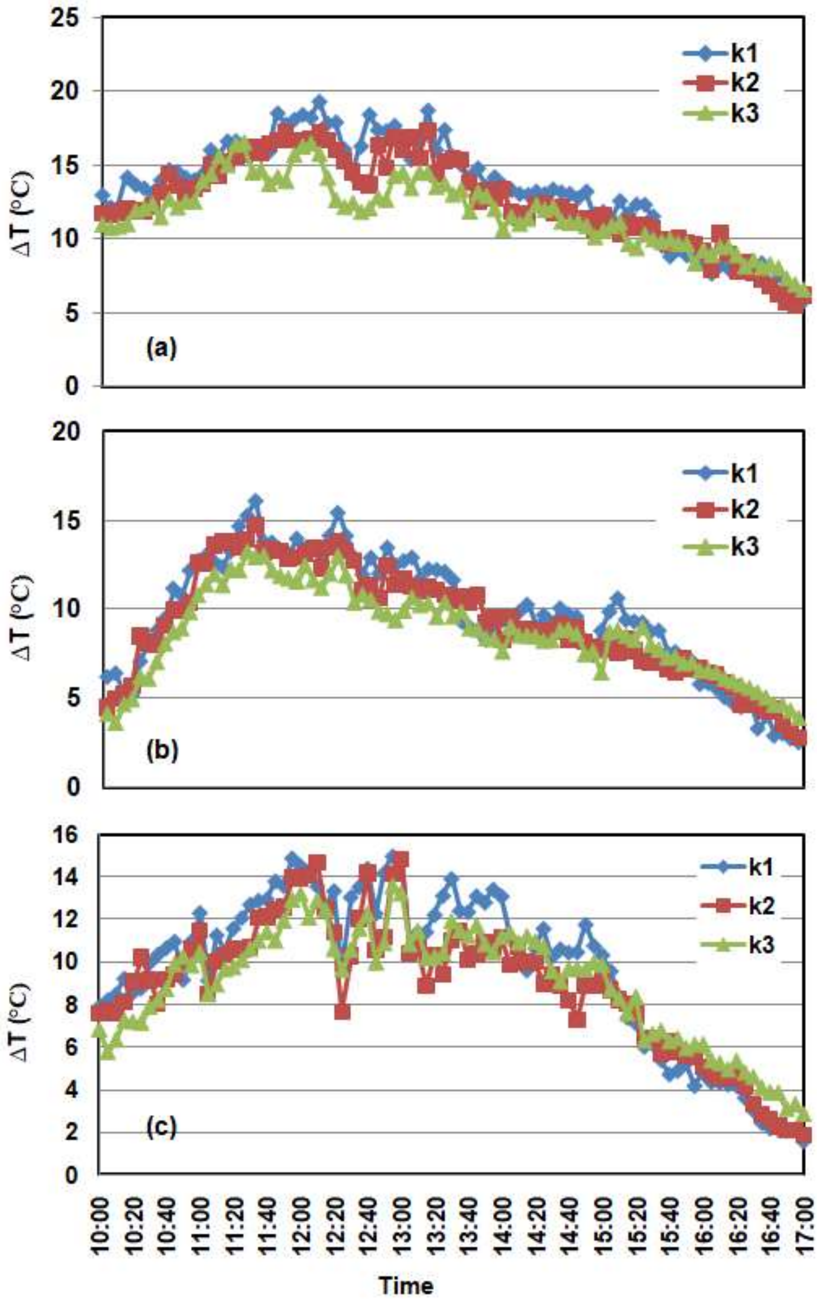

Figure 2 ΔT versus observation time for volumetric flow rates; (a) 300 cc/min, (b) 400 cc/min, (c) 500 cc/min. k1 is single cover, k2 is double covers and k3 is three covers.

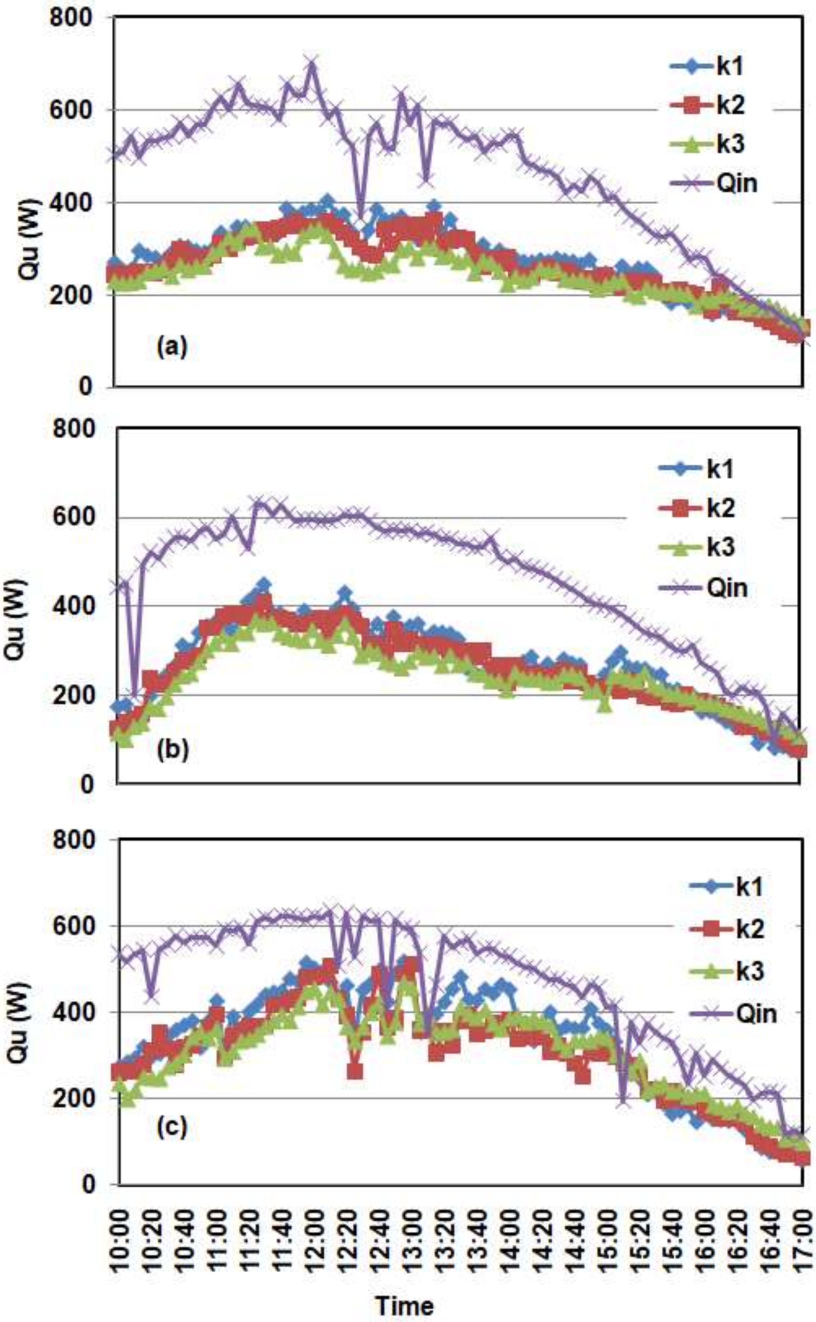

Figure 3 Useful heat (Q_u) versus observation time at several volumetric flow rates; (a) 300 cc/min, (b) 400 cc/min, (c) 500 cc/min for the three collectors.

Q_{in} is the input heat attained from the solar radiation coming through the glass cover and reaching the granite stone absorber. Q_{in} can be obtained using equation (1).

$$Q_{in} = IA\tau\alpha \quad (1)$$

Where I is the radiation intensity (W/m²), A is the area of the absorber (m²), while τα is the transmission-absorption of the glass cover, which is called glass efficiency. Meanwhile, the useful heat, Q_u can be predicted as:

$$Q_u = \dot{m}c_p\Delta T = \dot{m}c_p\left(T_o - T_i\right) \quad (2)$$

Where $\dot{m}$ is the mass flow rate (kg/s), which is equal to $\rho\dot{\forall}$, ρ is the fluid density (water in this study), which has a unit of kg/m³, c_p is the specific heat (J/kg°C), and $\dot{\forall}$ is the volumetric flow rate (m³/s). The fluid density is determined from the water property table based on the bulk temperature, $\left(T_i + T_o\right)/2$. T_i and T_o are the water inlet and outlet temperatures (°C).

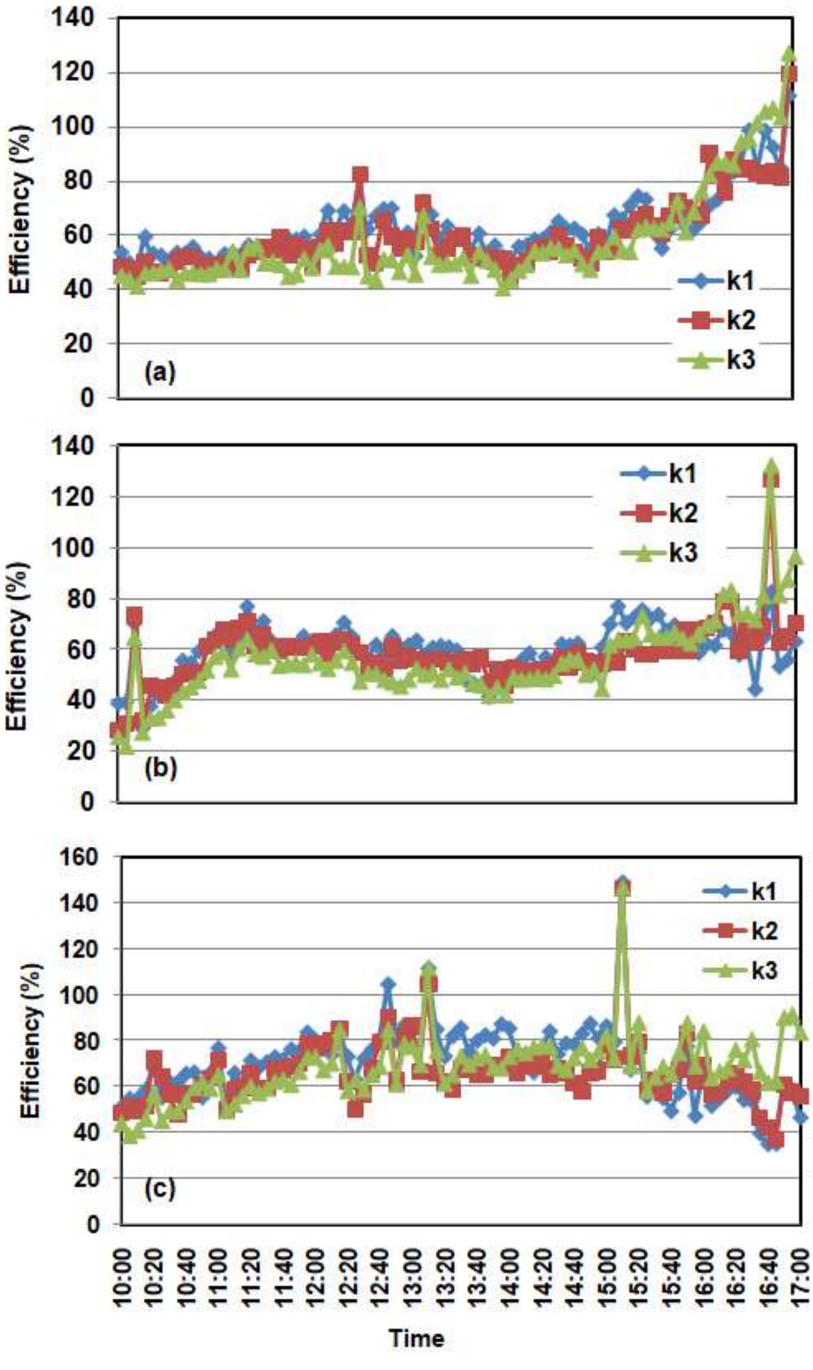

Figure 4 Collector efficiency versus observation time for three collectors; (a) 300 cc/min, (b) 400 cc/min, and (c) 500 cc/min.

At the flow rate of 300 cc/min, Q_u obtained using the single cover collector is of approximately 402.35 W at 0.30 pm, and at the flow rate of 400 cc/min, the useful heat attained is around 448.07 W at 11.30 am, while at the flow rate of 500 cc/min, the useful heat gained using the collector with three covers is 516.64 W at 11.55 am. Hence, based on Q_u, the effect of flow rate seems to be significant, but at the different time though. Meanwhile, the collectors that use more than 1 covers, results in lower useful heat. Therefore, from this viewpoint, the collector with the single cover is better. Nevertheless, from figure 3, at the time above 02.20 pm, all collectors indicate similar performance, because all lines of the useful heat are touching each other or overlapping each other. Then, here, it can be inferred that the effect of cover number is deteriorated or not clear.

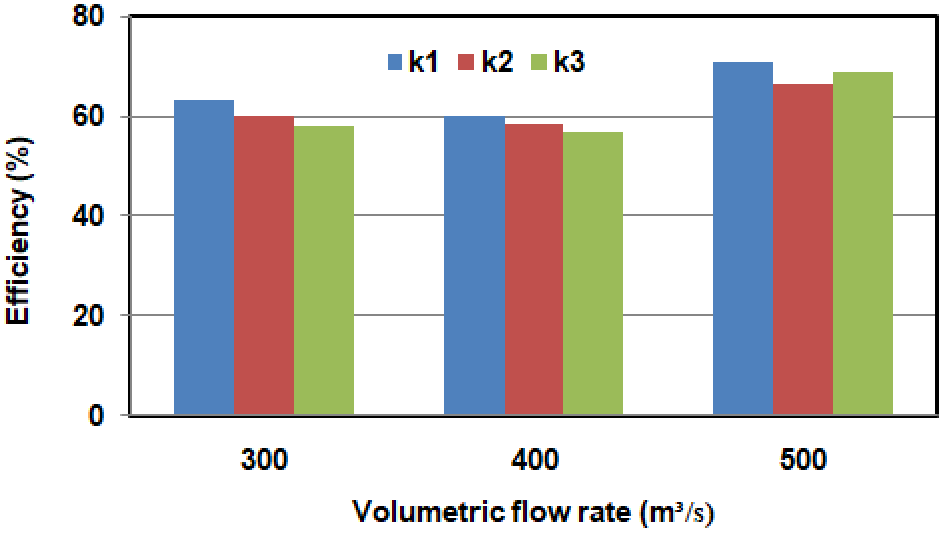

Figure 5 Daily efficiency for the three collectors

Figure 4 can be obtained using the equation of collector efficiency that can be found in Lunde [10], which is expressed as:

$$\eta = \frac{Q_u}{Q_{in}} = \frac{\dot{m}c_p(T_o - T_i)}{IA\tau\alpha} \tag{3}$$

Where η is the collector efficiency. As shown in figure 4, the efficiency increases with the time, especially between 10.00 to 13.00. After that, it is nearly constant or just decreases fairly. However, the efficiency fluctuates due to the weather. In figure 4a, after 14.50 the efficiency increases, this is due to the sun covered by the cloud, or Q_{in} is low, but the absorber is still hot so that Q_u is still high. The effect of the flow rate is significant. Increasing the flow rate increases the efficiency. This agrees with equation (3), and this phenomenon was also found by Wirawan et al. [3, 4], Wirawan and Sutanto [8]. From figure 4, it can be concluded that the effect of the cover number seems not significant. Nevertheless, from figure 5, it can be seen that the daily efficiency for the collector that uses single cover is always higher than that uses more than 1 covers. Figure 4 can be obtained using the equation of collector efficiency that can be found in Lunde [10], which is expressed as:

$$\eta = \frac{Q_u}{Q_{in}} = \frac{\dot{m}c_p(T_o - T_i)}{IA\tau\alpha} \tag{3}$$

4. CONCLUSION

Experimental investigation on the effect of cover number has been performed with volumetric flow rates ranging from 300cc/min to 500cc/min. Some conclusion can be drawn as follows:

1. The water outlet temperature increases with the observation time and the peak of the water outlet temperature is achieved at around 11.30 – 13.30.
2. The number of the cover influences the performance of the collectors; however, in this study, the effect of the cover number is not significant.

3. The parameters obtained in this study are temperatures, useful heat, and efficiency.
4. At the flow rates of 300cc/min, 400cc/min, and 500cc/min, the maximum temperature difference is attained using the single cover collector.
5. The collector efficiency is affected by the useful heat and the input heat.
6. The maximum efficiency is obtained using the single cover collector for all flow rates.
7. Similarly, the maximum daily efficiency is achieved by the single cover collector.

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NOMENCLATURE

A = Aperture collector area (m^2)
C_p = Specific heat (J/kgK)
I = Solar radiation intensity (W/m^2)
$\dot{m}$ = Mass flow rate (kg/s)
Q_{in} = Solar radiation reaching the absorber (W)
Q_u = Useful heat (W)
T_i = Water inlet temperature (°C)
T_o = Water outlet temperature (°C)

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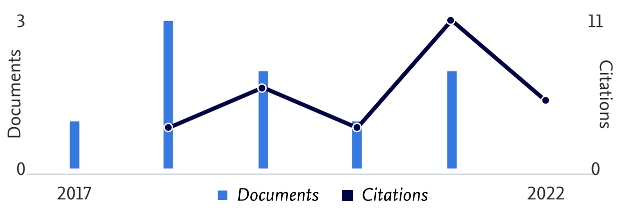

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