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Effects of heat transfer based water for three square multilayer absorber solar collector

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ABSTRACT. Solar energy is one of the best sources of renewable energy with minimal environmental impact. In this study, the effect of absorber solar collector on the performance of the solar water heating system has been experimentally investigated. This study is aimed to obtain the output of temperature for absorber solar collector based on water moving to the system. In the solar water heating system, volume flow rate with 2, 3 and 4 liters per minute for each solar radiation for 300, 500 and 700 W/ m^2 respectively. The result indicates at higher temperature output at 700 W/ m^2 of solar radiation within 30 minutes during charging and discharging process at volume flow rate 4 l/m is 36.9 °C. A little bit difference for 300 and 500 W/ m^2 which are 36 °C and 36.6 °C respectively. Solar water heating systems, in difference collectors have long distance, have temperature increases based on water medium in the system. Heat transfer performance with different radiation intensities of 300, 500 and 700 W/m^2. The heat transfer performance for radiation of 700 W/m^2 shows the highest followed by 500 W/m^2. The lowest heat transfer performance is seen at 300 W/m^2.

Keywords
Solar radiation, heat transfer, solar water heating system, absorber solar collector

1. Introduction

Renewable energy is the energy that naturally replaced on a human time. Renewable energy sources has three types which are derived directly from the sun (such as thermal, photo-chemical, and photo electric) and indirectly from the sun(such as wind, hydropower, and photosynthetic energy stored in biomass) or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy)[1].

Renewable energy has a great contribution to current technologies which can be considered as clean sources of energy where the optimization in using these resources reduce secondary wastes and have a much lower environmental impact than conventional energy technologies. The development of renewable technologies provide the opportunity for mitigation of greenhouse gas emission and reducing global warming through substituting conventional energy sources[2-8]. It is about two billion people, mostly in rural areas, has no access to modern forms of energy, which depends on this renewable energy [9-15]. Development and implementations of a renewable energy project in rural areas provide job opportunities and thus reduce the migration towards urban areas [16-20]. Renewable energy sources that meet domestic energy requirements promotes to the energy services with zero emissions of both air pollutants and greenhouse gases [2, 21-24]. The other advantage of using renewable energy sources [25-29] are they are distributed over a wide geographical area which makes sure that rural areas have access to the electricity generation at low cost in long term future[30]. Its benefit is not only for the environment in reducing gas emission but also gaining global importance.

The primary forms of solar energy are heat and light from the sun. The sun has special role in ensuring the energy production sustainable where it is the undisputed champion of energy which the terrestrial insolation has presented the resource base was far exceeds that all other renewable energy sources[31]. The sun emits energy at a rate of 3.8×10^{23} kW, of which, approximately 1.8×10^{14} kW is intercepted by the earth [32]. Solar energy can be used directly in various applications such as for heating and lighting homes and other buildings, for generating electricity, and for hot water heating, solar cooling, and variety of commercial and industrial uses. Compared to other forms of energy, the greatest advantage of using solar energy is that it is clean and can be supplied without any environmental pollution.

Solar water heating system is one of the utilization of solar energy collection, which is most simple but has been used in various applications. It is one of the solar thermal systems that contribute to the development of cost-effective renewable energy technologies and has been used widely. Basically solar water heating system consists of a collector, storage tank and connecting pipes which used to supply hot water at a temperature of about 60 °C [33]. There are many methods has been introduced to increase the solar water heater efficiency [34-37]. The development of solar water heating systems is one of sustainable energy utilization, which has great potential in solving ecological problems and energy crisis.

Solar collector has been the major component of any solar thermal system. Solar energy collectors are a special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. There are various type of solar collectors, including flat-plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish, and heliostat field collectors. Thermal solar collectors that have special character can circulate water through the collection unit that collects the sun's thermal energy for heating water purpose [38-47]. Various applications have been implemented with direct absorption solar collectors such as water heating.

One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat [48, 49]. Hence way that the domestic sector can reduce its influence on the environment is by the fixing of absorber solar collector for solar water heating system. While it should be said that some of these collectors have been in facility for the last 40-50 years without any real momentous changes in their design and operational values.

Hence the present study aims to investigate the effect of three square multilayer of solar water heater with water based in the solar water heating system and to prove that the long distance of absorber solar collector results higher temperature and shows that the system has develop for better heat transfer.

2. Experimental setup

In this section, an explanation of the experiment setup will be discussed. Figure 1 shows a simple schematic overview of components of absorber solar collector simulator, which consists of a few important components; storage tank, solar collector, control valve, piping system, and solar collector.

A pump connected to a collecting tank to circulate the working fluid through the system. The collectors consist of the insulated absorber of 8 m long for fluids flow to reduce the rate of heat loss to surrounding. K-type thermocouples were used and fixed at certain location. Three were fixed at the surface of the solar absorber, two were installed to measure inlet and outlet temperature of fluids, and the last one was used to measure the ambient temperature. This sensor was calibrated before running the experiment to provide a good argumentation of results. The details components for this setup shows in figure 2 and table 1.

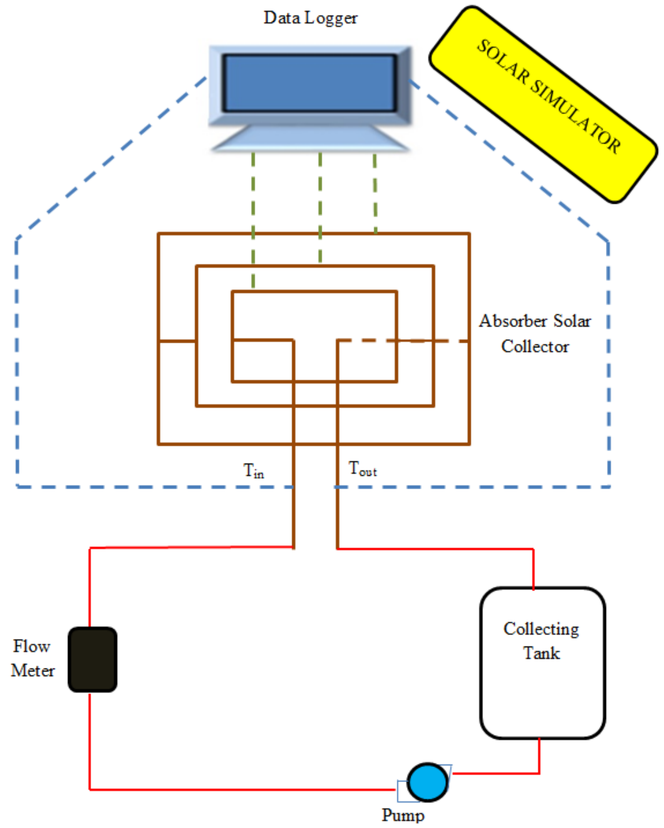

Figure 1. Components of Absorber Solar Collector Simulator

Table 1. Detail description of solar radiation test rig.

No.	Description	Specification
1	Interface Arduino Uno	Coding system
2	Arduino Uno	Reading up flow meter (LPM)
3	Supply tank	5L
4	Controller	Controlling the speed of the pump (by Voltage and Current)
5	Data logger	ADAMView Advantech Data Acquisition
6	Solar submersible pump	Max 7LPM
7	Dimmer	Setting up Intensity Light (300, 500 & 700 W/m^2)
8	Absorber solar collector	Triple square, 3 layer
9	Thermocouple	K-type
10	Pyranometer	Apogcc Logan UT SP-110
11	Spotlight	Halogen 500 W (12 pieces)

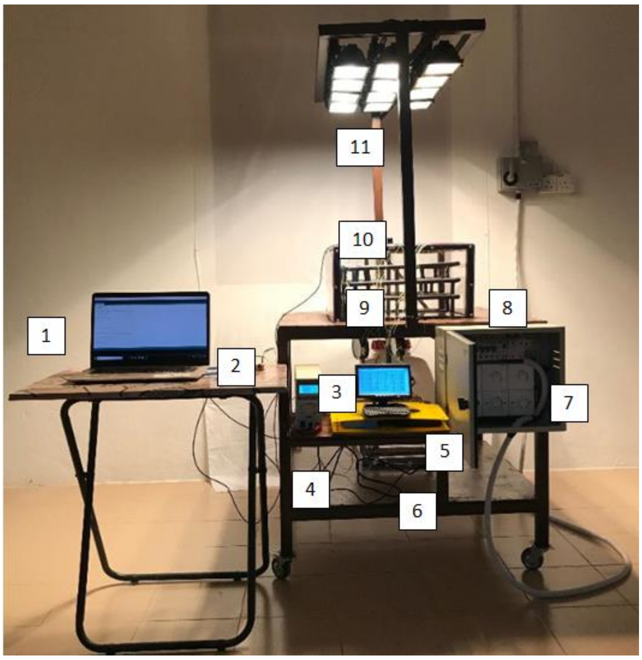

Figure 2. Experimental setup for Absorber Solar Collector Simulator

2.1. Experimental Procedure

The experiment started within 15 minutes of heating/ charging with distilled water is filled into the supply tank. Then, the next 15 minutes is for cooling/discharging. Initial reading is recorded as per below:

- Ambient temperature (T_{at})
- Input temperature (T_{in})
- Absorber temperature (T_2, T_3, T_4)
- Output temperature (T_{out})

3. Results and discussion

The results presented in figure 3, 4, and 5 show the behaviour of output temperature of the absorber based on solar radiation starting with 300, 500, and 700 W/m^2, respectively. Each of the graphs consists of volume flow rate with 2, 3, and 4 litre per minute (LPM). Based on the graph, there is no highest and lowest point on each graph to indicate the end of the charging process and the beginning of the discharging process. Therefore, the results show that after the discharging process, this absorber solar collector store and increase the heat through the system.

Based on the result, the minimum volume flow rate of 2, 3, and 4 LPM are observed to consistently provide higher temperature output at 700 W/m^2 of solar radiation. For solar radiation 300 W/ m^2 the maximum temperature achieved within 30 minutes during charging and discharging process is 36 °C for volume flow rate 4 LPM. However, for solar radiation 500 and 700 W/m^2 the maximum temperature achieved in 30 minutes is almost the same, which are 36.6 and 36.9 °C respectively.

Longer wavelengths in solar absorption higher than ambient air temperature show the difference and high temperature rise when experiments are carried out using solar simulators. It can be seen that temperature changes are higher than mat rays than using solar simulators. This is because the actual situation uses less sunshine than solar simulator operations in infrared waves.

Therefore, it can be concluded that the lower of mass flow rate gives ample time to the copper pipe to transfer the heat to the moving water via convection heat transfer and thus increased its temperature. Similar observation regarding to water based fluid for solar water heating system which improves the heat transfer was also found in previous study by M. Norhafana et al. [50].

Besides, it is clearly shows that the temperature differences for the experiment with the volume flow rate of 4 lpm is the highest at 700 W/m^2 followed by experiment with the volume flow rate of 2 and 3 LPM. From Figure 3-5, the maximum value of temperature difference 36 °C, 36.6 °C and 36.9 °C respectively in opposite to M. Norhafana et al. [50] which is maximum value of intensity light for 700 W/m^2 with temperature 31.8 °C lower than present research.

From the experiment of solar water heating system for three square multilayer absorber solar collector above shows that the increasing volume flow rate and intensity light at angle of sunlight 90° for 30 minutes during charging and discharging process, it can be concluded that the best adapt for volume flow rate and intensity light at 4 LPM and 700 W/ m^2 respectively.

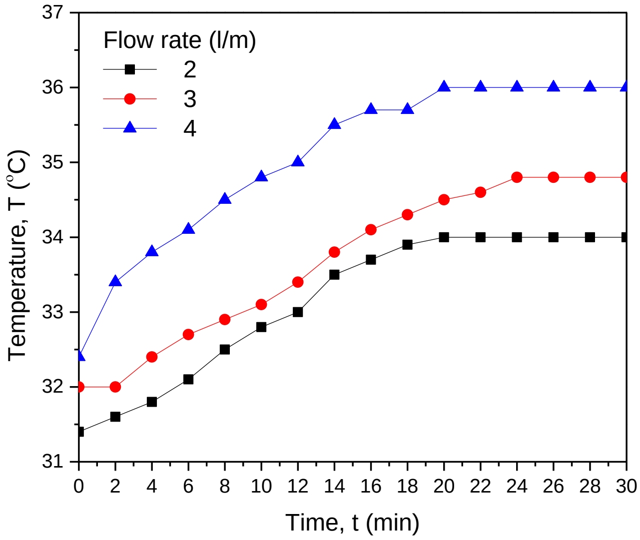

Figure 3. Temperature output of the absorber with solar radiation 300 W/ m^2

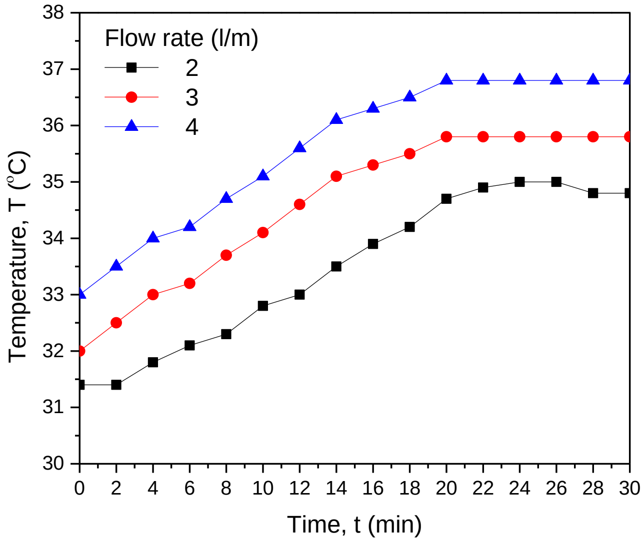

Figure 4. Temperature output of the absorber with solar radiation 500 W/ m^2

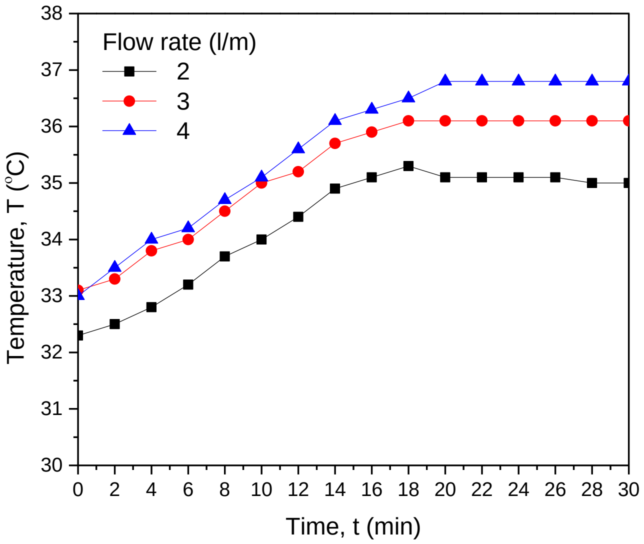

Figure 5. Temperature output of the absorber with solar radiation 700 W/ m^2

The Absorber Solar Collector Simulator setup was validated at a working temperature inlet of 30 °C with constant radiation of 700 W/m^2. The experimental data of water are compared with the estimated values of the Dittus-Boelter [55] for different Reynolds number (*Re*). Figure 6 presented the Nusselt number (*Nu*) use water for experimental data at an inlet temperature of 30 °C. Data observed in good agreement compared to Dittus-Boelter [55] with deviations of less than 9%.

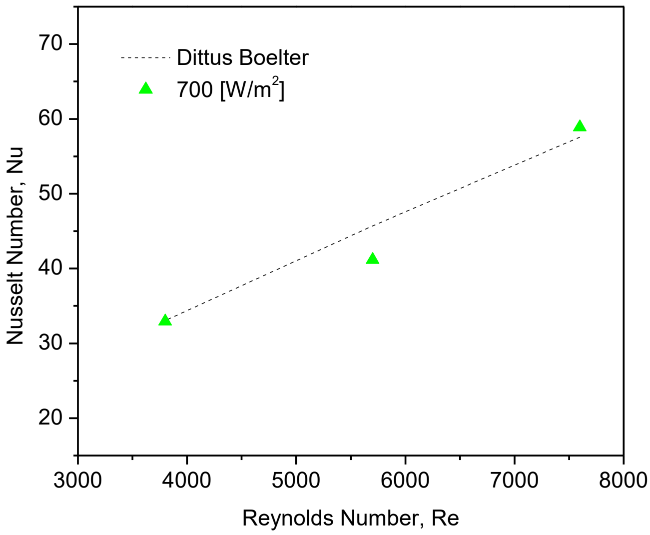

Figure 6. Validation of Nusselt number (*Nu*) for temperature 30 °C and constant heat flux 700 W/ m^2

Figure 7 illustrated the heat transfer coefficient for the experimental data using water. Heat transfer coefficients with different radiation intensities of 300, 500 and 700 W/m^2. The heat transfer coefficient for radiation of 700 W/m^2 shows the highest followed by 500 W/m^2. The lowest heat transfer performance is seen at 300 W/m^2.

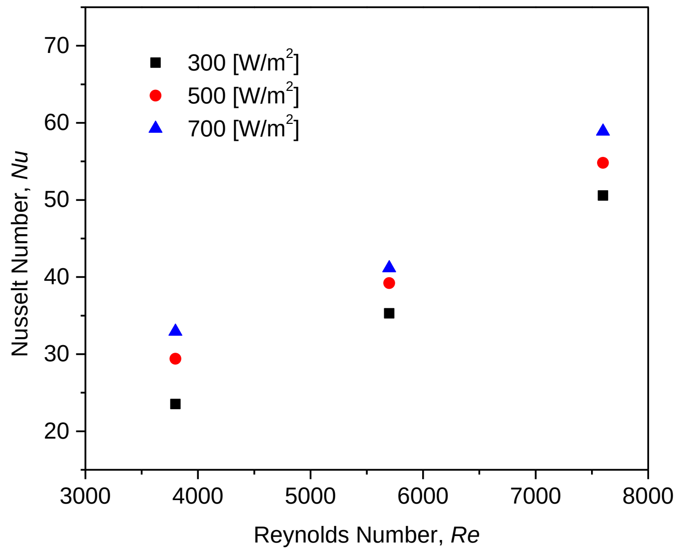

Figure 7. Heat transfer coefficient of water at different intensity radiation.

The Nusselt number of water with various intensity radiation of 300, 500 and 700 W/m^2 was shown in Figure 8. The Nusselt number (*Nu*) with different radiation intensities of 300, 500 and 700 W/m^2. The heat transfer coefficient for radiation of 700 W/m^2 shows the highest followed by 500 W/m^2. The lowest heat transfer performance is seen at 300 W/m^2.

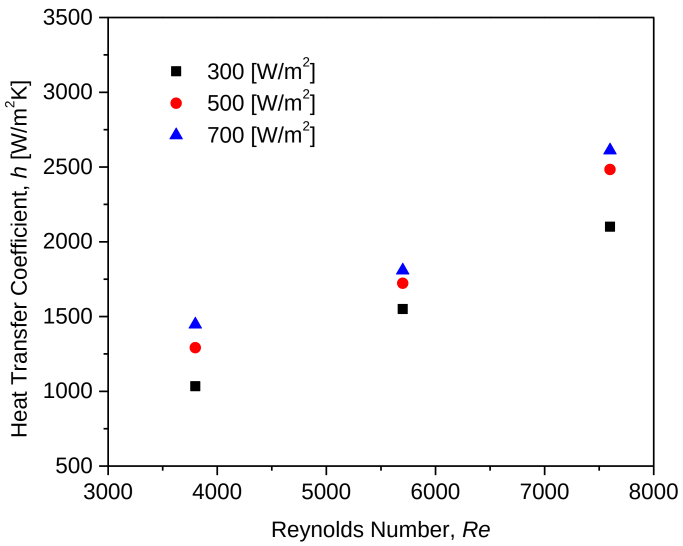

Figure 8. Nusselt number (*Nu*) of water at different intensity radiation.

4. Conclusion

The presented work deals with the study of three square multilayer absorber solar collectors. Solar water heating experimental models consists of storage tank, three square multilayer collector and pump. There are several methods introduced to increase the performance of the solar water heating system. But the novel approach is to introduce the different of absorber solar collector in solar water heater instead of conventional solar collector in the market. Effects of the solar water heating system can be improved by the use of nanofluids as a medium of water flow [51-54] and other design of absorber solar collector to enhance the heat transfer. As a conclusion, the three square multilayer absorber solar collector of solar water heating system is proven to play its main role when it can adapt in multidirectional solar radiation with different intensity of solar simulator. Heat transfer performance with different radiation intensities of 300, 500 and 700 W/m^2. The heat transfer performance for radiation of 700 W/m^2 shows the highest followed by 500 W/m^2. The lowest heat transfer performance is seen at 300 W/m^2.

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