Parabolic trough collector’s heat transfer analysis with changes of variation on the pipe absorber system

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Abstract. Solar energy is one of the most important sources of renewable energy. One of the technologies used for converting solar energy is Parabolic Trough Collector (PTC). The PTC is used to focus the heat of solar radiation. This study discusses the analysis of the PTC heat transfer with an alteration of the pipe absorber system. The goal of the research is to know the design of efficiency absorber pipe system for PTC. The research method used is an experimental research by testing the system in sunny weather conditions. The pipe absorber system is designed with two variations: PTC\textsuperscript{1} and PTC\textsuperscript{2}. PTC\textsuperscript{1} uses an open loop system while PTC\textsuperscript{2} uses a closed loop system. When the experiment was conducted, the pool water temperature, the intensity of the sun, and the temperature of the fluid in the pipe absorber were measured. The results obtained showed that the highest pool water’s temperature from PTC\textsuperscript{1} is 39.3°C at an intensity of 806.59W/m\textsuperscript{2}. Meanwhile, at PTC\textsuperscript{2} the highest pool water’s temperature is 36.2°C at an intensity of 828.71W/m\textsuperscript{2}. Based on the findings, PTC\textsuperscript{1} with an open loop pipe system has a better efficiency than the PTC\textsuperscript{2} with a closed loop pipe system.

1. Introduction
Solar energy is one of the most important sources of renewable energy. Solar energy as renewable energy is an interesting thing to develop. Nearly 4.000.000 EJ of solar energy reaches the earth [1]. Utilization of solar energy globally is predicted to increase by 8.9% in the period between 2012 and 2040 [2]. Solar energy can be utilized to generate thermal energy through the use of a water heater and propulsion. There are two ways of converting solar radiation into other energies, namely through solar cells and collectors. One method of utilizing solar energy is the use of parabolic trough collector technology. Parabolic trough collector is a heat collecting system that uses a parabolic reflector. The working principle focuses the heat from the radiation of the sunlight that comes to the metallic absorber tube [3]. Parabolic trough collector is generally used in desalination [4], cooling installation [5], CPVT [6], cooking [7], water pasteurization [8], an absorption refrigeration system integrated to cool the ice-cream mixture, ice cream factory [9]. The thermal performance of the solar collector for power plants and industrial processes was studied [10]. The researchers are still attempting to determine the optimal design of the collector/receiver that increases the efficiency and reduces the costs of the system [11].
2. Experimental Methods

2.1 Experimental Set-Up
This study was conducted to determine the effect of altering the absorber pipe system to the efficiency generated by parabolic trough collector (PTC). The research was tested from 11:00 to 14:00 pm. Parabolic trough collector is designed in two system variations. The PTC has the following parabolic specifications:

| Specification | Value |
|---------------|-------|
| Length of parabolic | 150 cm |
| Aperture | 50 cm |
| Angle of the rim | 90° |
| Focus distance | 12.5 cm |
| Comparison of concentration, Cr | 12.54 |
| Depth collector | 12.5 cm |
| Reflector Material | Aluminum |

The variations of absorber pipe system used are the open loop and closed loop system. The complete specification of the absorber pipe system of the parabolic trough collector is shown in Table 2. and Table 3.

| Specification | Value |
|---------------|-------|
| Material absorber pipe | Copper (1.27 cm) |
| Total length of absorber pipe | 604 cm |
| High buffer | 70 cm |
| Discharge of water pump | 0.67 kg/s |
| Pool water volume | 7600 cc |

| Specification | Value |
|---------------|-------|
| Material absorber pipe | Copper (1.27 cm) |
| Total length of absorber pipe | 728 cm |
| High buffer | 70 cm |
| Discharge of water pump | 0.67 kg/s |
| Pool water volume | 7600 cc |

2.2 Experimental Design
The research on the efficiency of the PTC absorber pipe system was tested by changing the system design. The absorber pipe is designed with an open loop and closed loop system. In the open loop system, the pool water is pumped directly through the system and redirected to the pool. Whereas in a closed loop system, heat transfer occurs through water that is circulated in a closed fashion in the absorber pipe. The research was examined by measuring the temperature of the pool water. Two models of the pool were made. Pool 1 is pool with PTC treatment and pool 2 is pool without PTC treatment. Pool water temperatures were measured using a digital thermometer with a 15-minute interval.
Figure 1. shows the two models of the absorber pipe system. There are open loop system (Figure 1.a) and closed loop system (Figure 1.b).

3. Results and Discussion
The results showed the relationship between the intensity of sunlight and pool water temperature. The pool water temperature measured is pool water without treatment PTC (T1) and pool water with treatment PTC (T2).

Figure 2. The Influence of Sunlight Intensity on Water Temperature on Open Loop System
Figure 2. shows that the higher the intensity of sunlight, the higher increase in temperature of the pool water with PTC treatment and contrariwise. The highest temperature obtained was 39.3°C with an intensity of 806.59 W/m². The temperature of the water in the pool without PTC treatment continue to increase until the end of the test. The highest temperature obtained was 29.8°C
The results showed the relationship between the intensity of sunlight and the temperature of the pool water in the closed loop system. The pool water temperature measured is the pool water without treatment PTC (T1) and pool water with treatment PTC (T2).
Figure 3. The Influence of sunlight intensity on water temperature on the closed loop system

Figure 3 shows that the higher the intensity of sunlight, the higher increase in the temperature of pool water with PTC treatment and contrariwise. The highest temperature obtained is 36.2°C with a solar light intensity of 828.71 W/m². The water temperature of the pool without PTC treatment continues to increase until the end of the test. The highest temperature obtained was 29.1°C. The efficiency data of the open loop system and closed loop system are then obtained from the results of research from the data retrieval and efficiency calculation.

Figure 4. Efficiency of the open loop system and the closed loop system

Figure 4 shows that the open loop system has a higher efficiency than the closed loop system. The efficiency continues to increase from the start of the test time till when the highest efficiency obtained for each absorber pipe system. For the open loop system, the highest efficiency was obtained at 13:15 pm with an efficiency of 45.59%. As for the closed loop system, the highest efficiency was obtained at 13:30 pm which is an efficiency of 33.96%. There is a decrease in efficiency for each absorber pipe system after passing the highest point of acquisition. At the end of the test time, the open loop system has an efficiency of 43.40%. As for the closed loop system, it has an efficiency of 32.93%. 
4. Conclusion
In conclusion, the use of the parabolic trough collector increases the temperature of the pool water. The higher the intensity of sunlight, the higher the temperature of the pool water generated in the parabolic trough collector (PTC). The design of the parabolic trough collector (PTC) with the open loop system has a better efficiency than the closed loop system. The highest pool water temperature of the open loop system is 39.3°C with an efficiency of 45.59%. While the highest temperature of pool water in the closed loop system is 36.2°C with the efficiency of 33.96%. The water temperatures of the pools without PTC treatment continue to increase with the increase in time of testing.

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