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EXPERIMENTAL DEVELOPMENT TO DETERMINE TIME CONSTANT FOR POLYMER COLLECTOR

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ABSTRACT

The presents study presents an experimental development to determine the time constant for the polymer collector under hot and humid climate in Malaysia. The experimental setup has been conducted at the Taman Inovasi Teknologi Hijau, Universiti Kebangsaan Malaysia (UKM). It used water as a working fluid and conducted according the ASHRAE Standard 93-2010 (Methods of testing to determine the thermal performance of solar collectors). The closed system of experiment rig was equipped with heat exchanger and auxiliary heater to control the water inlet temperature from the polymer collector to ensure it close with the ambient temperature ($T_i \approx T_a$) during an experiment. The available polymer collector in the market was used with minor modification was developed by inserting an insulator underneath the collector. This able to reduce the heat losses on the bottom part of collector to the environment. It shows the time constant of modified polymer collector was 90 seconds during the test day. The information of the time constant of polymer collector is vital to conduct an experiment of quasi steady state thermal performance of the polymer collector. It also provides the information of the collector behavior under transient condition during outdoor experiment. For example, the effect of the water and surface temperature once the irradiance change abruptly.

Keywords: polymer collector, ASHRAE standard 93-2010, time constant, hot and humid climate.

INTRODUCTION

The Malaysia located at the equator blessed by the abundant solar energy throughout a year. The application of solar energy : just name a few, solar drying, water heating for domestic hot water, pool heating, food processing for industry, air or space heating for domestic, producing electric by photovoltaic, producing heat and electric simultaneously by using photovoltaic thermal (PVT) 1, 2. One of the most common applications of solar energy is a solar collector. Solar collector is devices that use the solar use the solar energy. It convert the heat gain from the sun ray or irradiance to the useful heat. All the application can be divided by useful heat category in term of low, medium and high thermal applications 3, 4. The type of working fluid which water or air. Thus, determining the thermal performance of the solar collector is important to ensure the collector is suitable for application thermal range and the output of the system5. The thermal performance of the collector can be obtained by indoor or outdoor experiment 6, 7. To determine the thermal performance of the thermal performance of collector, data of the time constant must to be obtain8. The temperature changes of the collector during the fluctuating of irradiance. Time constant is the value to determine the transient effect time for the collector. The information is vital because it gives the interval time for predicting the thermal performance of collector test for each collector under quasi steady state conditions. Thus, before the experimental of thermal performance collector conducted, the experiment of time constant test need to be perform. It will gives the fluctuation of irradiance especially during the abruptly information of time response of the collector during the changes on the irradiance. The information refer to the water temperature and surface of collector temperature. There is some work done on determining the time constant of collector. One of the methods was using mathematical modelling regardless considering the temperate water inlet to be equal to temperature ambient which recommended in the ASHRAE Standard 9. In this project the ASHRAE Standard 93-2010 has been used for the guidelines. The main criteria need to be full fill during the test were irradiance need to be greater than 800 W/m2 and the wind velocity in the range of 2-4 m/s[10].

METHODOLOGY

EXPERIMENTAL DESIGN

The collector experiment rig equipped with the data logger has been developing according the ASHRAE Standard. The close loop system for the collector rig was developing facing South with 10° tilting from horizontal. A commercial polymer collector was selected and was install on the experimental rig. The minor modification was done on the polymer collector by inserting an insulator underneath the polymer collector to avoid the heat losses to the environment. The fiber wool type of insulator was selected due to avoid the heat losses to the environment. Figure-1, Figure-2, Figure-3 and Figure-4 shows the polymer collector, the cross section of the polymer collector, schematic diagram of experiment setup and water direction flow in polymer collector respectively.

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Figure-1. Polymer collector mounted of the experiment rig.

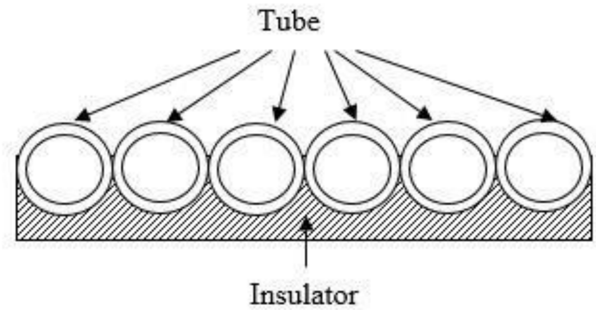

Figure-2. Cross section of polymer collector.

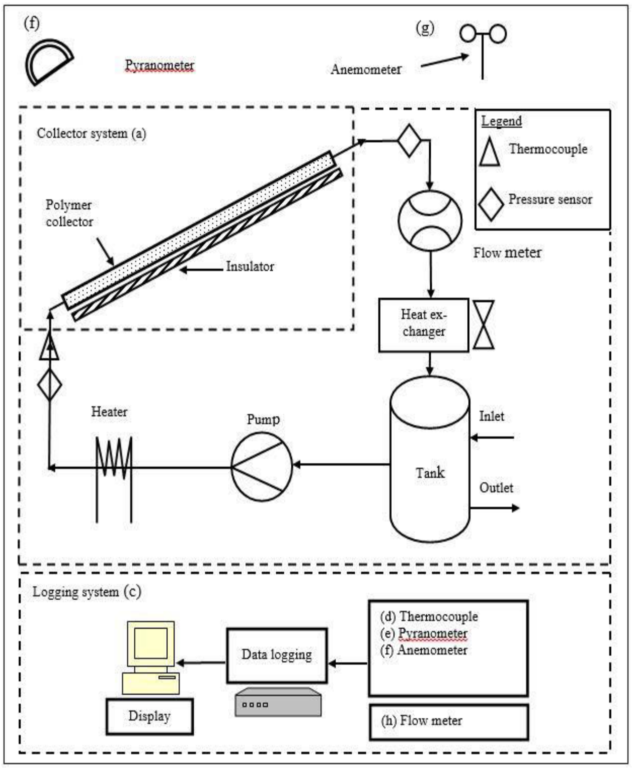

Figure-3. Schematic diagram of the experimental setup.

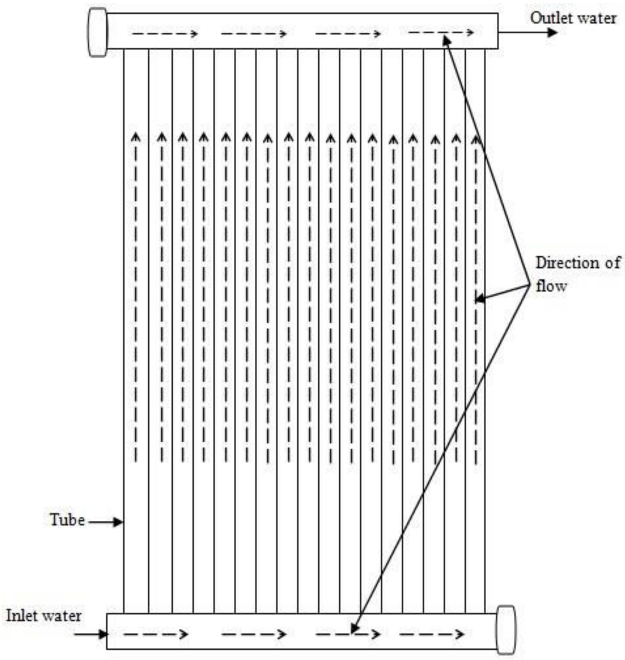

Figure-4. The flow of the water in the polymer collector.

Meanwhile, Table-1, Table-2 and Table-3 and Figure-5 shows the accuracies of all test instruments, polymer collector parameter, breakdown of the module data logging system used for the experiment setup and display unit of experiment data respectively.

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Table-1. The accuracies of measuring instruments.

No	Instruments	Measurements	Accuracies
1	Pyranometer - KIPP ZONEN serial number 113002	Irradiance	± 9.01 x 10^{-6} V/Wm^{-2}
2	Temperature Type T	Ambient Water inlet Water outlet	± 1.0 °C ± 0.5 °C ± 0.5 °C
3	Anemometer cup	Wind velocity	±0.5 m/s
4	Pressure transducer	Pressure inlet Pressure outlet	±3.5 kPa ±3.5 kPa
5	Flow meter	Mass flow rate	±4.0%

Table-2. Parameter of polymer collector.

No.	Parameter	Data
1	Dimensions (Width x Length)	1.22 x 2.44 m
2	Effective area (A)	2.853 m^2
3	Material	Polyolefin
4	Color	Black
5	Conductivity (k)	0.018–0.209 $W/m^2.K$
6	Absorptivity (α)	0.96
7	Emissivity (ε)	0.9
8	Type of flow	Parallel tube
9	Number of tubes (N)	96
10	Diameter of tube (D_o)	5 mm
11	Thickness of tube (t)	1 mm
12	Gap between tube (W)	0.5 mm

Table-3. Data logging system.

No	Sensor	Module	Quantity
1	Temperature	KV-NC4TP	3
2	Pump regulator	KV-NC2DA	1
3	Pressure, velocity, pyranometer	KV-NC4AD	1
4	Current and voltage	KV-NC4AD	1
5	Processing unit	KV-NC32T	1

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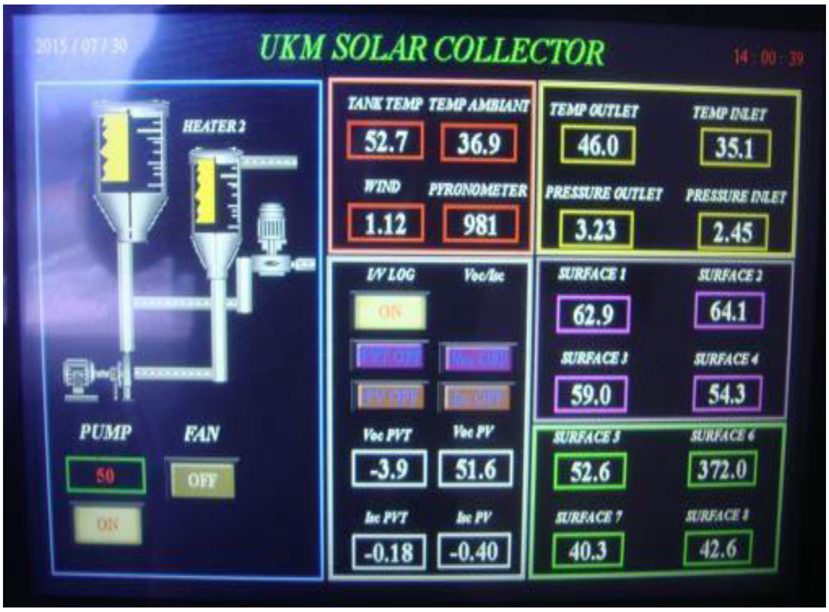

Figure-5. Display unit of experiment data.

The data logging system were used KEYENCE module. It has four channel and have the specific input and output depends on the type of sensor. In this project, five module were used to obtain the desire data. From sensor, it convert to the module signal before entering the processing unit.

EXPERIMENTAL PROCEDURE

The polymer collector was mounted on the experiment rig by ensuring the top header is upward to allow water fill up the tube. The inlet temperature of the transfer fluid need to be close as possible of ambient temperature. It recommended within ± 1°C. The control of the inlet temperature used a heat exchanger to cool the transfer fluid during the closed loop circulation. To set the increment of the temperature for inlet water, the adjustable in line electric resistance heater was conducted while circulating the transfer fluid through the collector. The flow rate of the collector was 0.02 kg/sm² specified in the standard. In this case the mass flow rate apply was 0.06 kg/s. At the same time, the minimum incident solar energy is 800 W/m² at all time during the experiment. In Malaysia, the high irradiance particularly can be obtain in the range of 11.30 am until 2.30 pm. The collector was shaded by opaque cover appropriately. When all the condition was satisfy (irradiance greater then 800 W/m² and water temperature inlet almost same as temperature ambient), the opaque cover was shaded on the top surface of polymer collector abruptly. The opaque cover must be suspended or hanging from the collector to allow the ambient air to pass over the collector as prior of the beginning of the test. The temperature of inlet water temperature (T_i) and outlet water temperature (T_o) were continuously monitor as function of time until a steady state condition is achieved, when

$$\Delta t_\tau = T_{o,\tau} - T_i \qquad (1)$$

T_τ = Temperature water steady state
$T_{o,\tau}$ = Temperature water outlet steady state
T_i = Temperature water inlet

The actual time constant is the time T required for the quantity

$$(T_{o,\tau} - T_i) / (T_{o,init} - T_i) = 0.368 \qquad (2)$$

where $T_{o,\ init}$ is temperature fluid outlet during initial condition. The detail of the information can be depicted on the Figure-6.

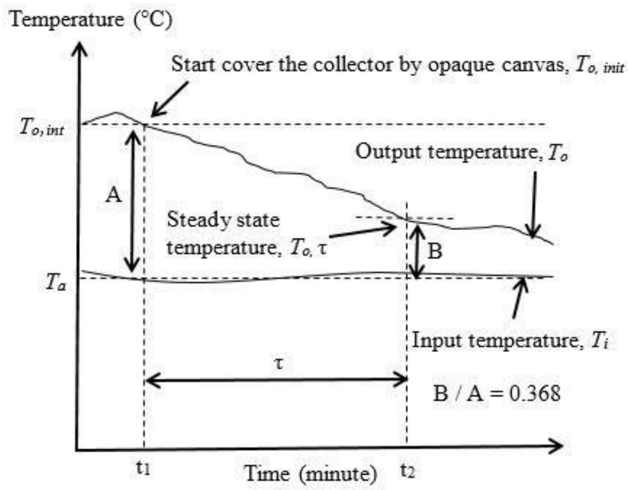

Figure-6. Time constant graph for typical collector.

DISCUSSIONS

The development of the experiment rig was successfully developed to obtain the time constant for the polymer collector under hot and humid climate in Malaysia. Using the close loop system for the water circulation, it gives a better control and avoids the wastage water to the drainage. Based on the calculation using the equation (1) and (2), the time constant of the polymer collector was 90 seconds. The detail data can be refer in Table-4.

Table-4. Parameter for polymer collector - time constant.

Parameter	Data
T_i	36.0 (°C)
$T_{o, init}$	48.8 (°C)
$T_{o, \tau}$	37.76 (°C)
t_1	12:42:48
t_2	12:44:18
$\tau = t_1 - t_2$	90 second
A	4.8 (°C)
B	1.76 (°C)
A/B	0.368

These results may be vary by time to time due to the ranging of wind speed, ambient temperature and irradiance during the test day. The control of the temperature water input is very crucial to obtain more accurate results. Thus, the result of time constant also vary if the test conducted in opposite way by placing the shaded first and open the cover once meet the satisfying equation of time constant.

SUMMARY

This paper has successfully demonstrated the development of polymer collector experimental rig to determine the time constant for the polymer collector. The test referring the ASHRAE Standard 93-2010 quasi steady state condition on outdoor test using the close system setup. It shows the time constant for polymer collector with insulator was 90 seconds. This information is useful to proceed the next step of project which to determine the thermal efficiency of polymer collector under quasi steady state conditions and give a clear picture the effect for the transient analysis.

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