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An Experimental Study of Different Thermal Boxes Heated by Solar Thermal Radiation for Hot Water System at Daytime

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Abstract. This research is related to thermal efficient water heating system, specifically to improve the water heating system that exists nowadays. The goal of this research is to improve the current water heating system by using solar heat as the energy source to heat the water. The focus is to improve the thermal efficiency by adding different thermal boxes as the absorber bed. By implementing the black body and radiation concept, the air trapped in the box is heated. The trapped air then increases the collisions between the molecules and directly increases the temperature inside the box, higher than the outside environment. Based on a daytime experimental result revealed steel thermal box is better to be used for tropical weather like Malaysia.

Introduction

A solar collector is commonly used for water heating system. There are many inventors that came up with their design to improve the efficiency of the thermal water heater [1,2,3]. This is because the opportunities of this technology to grow are wide open. The source for this technology is the sun, which is a utopian fuel, limitless, ubiquitous and clean. These are the main causes that attracted many researchers to investigate and develop this technology wider. There are many researchers tried to optimize the usage of solar energy such as Lindblad [4], Hammer [5], Reim [6] and Trillat-Berdal [7]. As known, the source of the sunlight is limitless and clean but in order to use this kind of source, there are many optimizations needed to be done on the system to make it more efficient. The theory on transferring the heat from the sun light is well known and is usually a famous topic to be discussed about. This is clearly proven when researchers such as Velraj [8], Mettawee and Assassa [9] and Jaisankar [10] attempted to improve the efficiency of the solar water heating system. The less energy usage for the water heater becomes the main reason for many researchers to keep improving the system in order to replace conventional water heater [11,12,13]. This is because the energy that is required to heat the water is higher than cooling the water. Therefore, by using solar as an energy source for heating the water, the use of electricity for the heating process can be replaced. Thus, the thermal hot water system needs to be redesigned in order to improve the efficiency of the thermal conductivity to produce heat that is equal to the heat generated by the electrical energy. In this research, a thermal box material is proposed to improve the thermal hot water system efficiency by considering Malaysia weather conditions.

Materials, Method & Procedures

Materials used to produce the collector is determined and selected by CES Edu Pack (2010) software system. This software was used to select the material based on the attribute that is needed for the product. In this case, the thermal attribute of the material is the most important part to be determined and then followed by the cost of the material. Based on CES, steel and the galvanized iron are the materials that have the highest solar radiation absorption. Therefore, the materials are selected as the main material for the thermal box. For heat pipe characteristic, copper is chosen due to its high thermal conductivity. Table 1shows the component of the product and the material that has been chosen.

Table 1: List of Material for hot water system.

Component of the product	Material
Heat pipe	Copper
Thermal box (body)	Steel
	Galvanize Iron
Thermal box (top)	Steel
	Galvanize Iron
Transparent top cover	Glass
Connector slot	Copper
Tank	PVC
Pipe	PVC

The materials were selected depending on their function and cost of the raw material. Material for the component such as pipe, connector, lip boundaries and etc are selected by the thermal insulator characteristic. This product is related to the heat; therefore the thermal expansion of the material characteristic is usually an issue. In order to overcome the problem, the selected materials are required to resist high temperature to avoid the deformation from happening.

In this experimental research, selected material efficiency was tested to fabricate the thermal box. There are a few things that need to be controlled to make sure the experiment goes smoothly. The variables in this research are time of the testing, material of the component, dimension of the product, design of the product, and flow rate of the water. In order to differentiate the efficiency of the thermal box, the experiment was conducted by evaluating both conditions. First is evaluated without the thermal box and the other evaluated with the thermal box. By comparing the result, the more efficient system can be determined.

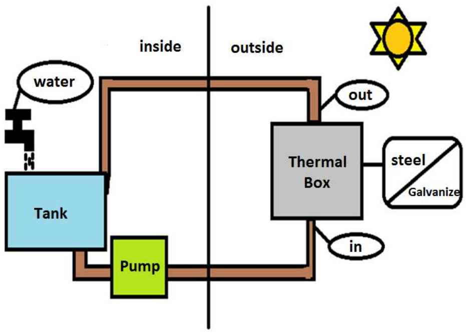


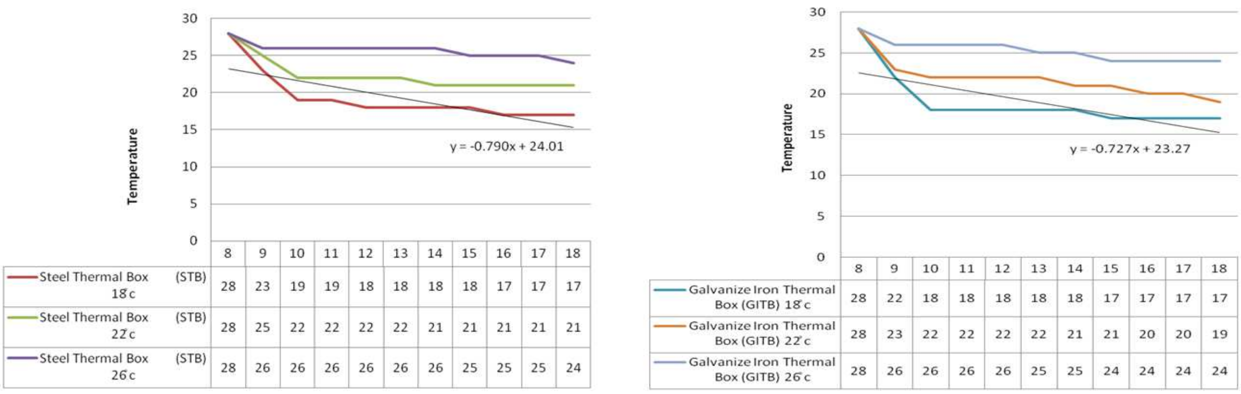
Figure 1: Schematic experiment setup.

The control experiment is conducted as reference for the other experiment that is held. This experiment is held at a room temperature. The room temperature remains constant 18 °C, 22 °C, and 26 °C. The purpose of this experiment is to evaluate the temperature changes in a controlled environment. The experiment was held at Universiti Teknikal Malaysia Melaka. The testing duration started from 8.00 am till 6.00 pm. The materials used in the experiment are steel and galvanize iron. Fig.1 depicted the schematic experiment setup.

Results and Discussion

The experiments were held in an air-conditioned room. This is because the ambient temperature is controlled to get the reading for the efficiency of the steel thermal box. The duration of the control experiment is 10 hours (a daytime only). It started from 8 am to 6.00 pm. There are three different surrounding temperatures that were tested. There are two types of thermal box tested. The material used is steel for the thermal box 1 and galvanized iron for the thermal box 2.

By using steel as the material for the thermal box, control experiments are made to determine the relationship between the material and temperature ambient. Based from the reading measured by using a thermometer, the initial temperature drops and starts to maintain following the ambient temperature. The slope for the graph is y = -0.790x + 24.01 as shown in Fig. 2(a). The galvanize Iron as the material for the thermal box show that the gradient is higher. The initial temperature of the water source is 28 °C for both boxes. The temperature drops according to the surrounding temperature. This shows that the thermal box is sensitive to the temperature changes of the surrounding. The Fig. 2(b) shows slope for the graph is y = -0.727x + 23.27. The gradient of STB is higher than GITB because the temperature drop in STB is high.

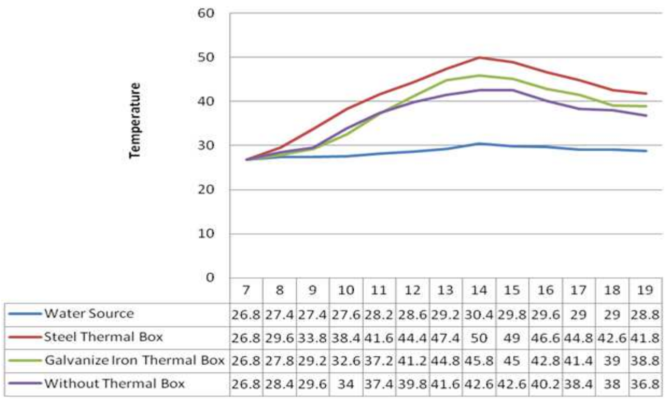


	8	9	10	11	12	13	14	15	16	17	18
Steel Thermal Box (STB) 18˚c	28	23	19	19	18	18	18	18	17	17	17
Steel Thermal Box (STB) 22˚c	28	25	22	22	22	22	21	21	21	21	21
Steel Thermal Box (STB) 26˚c	28	26	26	26	26	26	26	25	25	25	24

	8	9	10	11	12	13	14	15	16	17	18
Galvanize Iron Thermal Box (GITB) 18˚c	28	22	18	18	18	18	18	17	17	17	17
Galvanize Iron Thermal Box (GITB) 22˚c	28	23	22	22	22	22	21	21	20	20	19
Galvanize Iron Thermal Box (GITB) 26˚c	28	26	26	26	26	25	25	24	24	24	24

(a) (b)

Figure 2: Daytime temperature for (a) steel thermal box, and (b) galvanize thermal box.



	7	8	9	10	11	12	13	14	15	16	17	18	19
Water Source	26.8	27.4	27.4	27.6	28.2	28.6	29.2	30.4	29.8	29.6	29	29	28.8
Steel Thermal Box	26.8	29.6	33.8	38.4	41.6	44.4	47.4	50	49	46.6	44.8	42.6	41.8
Galvanize Iron Thermal Box	26.8	27.8	29.2	32.6	37.2	41.2	44.8	45.8	45	42.8	41.4	39	38.8
Without Thermal Box	26.8	28.4	29.6	34	37.4	39.8	41.6	42.6	42.6	40.2	38.4	38	36.8

Figure 3: The average of water temperature at daytime.

Figure 3 shows the average temperature of the water source increased at 7.00am until 2.00pm, so, the average temperature of the water also increased. At 2.00 pm until 7.00 pm, the average temperature of water source started to decrease, therefore the average temperature of water also decreased. The temperature drop is caused by the decreasing environment temperature. It showed that the average temperature of water at 2.00 pm is high.

The steel thermal box has a higher average temperature than galvanized iron thermal box. Based on the graph, the temperature started at a same point which is 26.8 °C average. The steel absorbs more energy to heat the water due to the high temperature reach on it. Thus, when the temperature starts to drop, the temperature is still higher than the galvanized iron thermal box.

The peak hour is determined based on the highest point of the temperature in a whole day. Based on the reading from the graph, the peak hour is at a range of 2.00 pm until 4.00 pm. The temperatures are measured during the day based on situations which are Steel Thermal Box, Galvanized Iron Thermal Box and without Thermal Box as shown in Table 2.

Table 2: Average temperature of water at peak hours.

Time	Average Temperature From Three Thermal Boxes at Peak Hours					
	Steel Thermal		Galvanized Iron Thermal		Without Thermal	
	in	out	in	out	in	out
2.00	50.0	50.2	45.8	45.6	42.6	42.6
2.15	50.0	50.4	45.6	45.4	42.6	42.6
2.30	50.4	50.2	45.8	45.2	42.8	42.4
2.45	49.6	49.2	45.0	45.0	42.6	42.6
3.00	49.0	48.4	45.0	44.4	42.6	42.2
3.15	48.6	48.6	44.8	44.2	41.6	41.4
3.30	48.4	47.0	44.2	43.8	41.4	41.0
3.45	47.6	46.8	43.6	43.2	40.8	40.8
4.00	46.6	46.6	42.8	42.8	40.2	40.6

The percentage of temperature difference is more during the day because there is the presence of the sun. However, as the sun goes down, so does the temperature because the temperature could not be contained since the surrounding temperature during night time is cold. There are the temperature changes in the percentage of readings for each experiment which is done by using steel thermal box, galvanized iron thermal box and without thermal box. The thermal box temperature changes percentage is very high at the extreme temperature especially for steel and galvanized iron thermal box. The highest temperature changes percentage that was achieved for the thermal box is 64.47 % at 2.00 pm which is represented by steel thermal box. It is followed by the galvanized iron thermal box that has a difference in temperature percentage which is 53.42 % at 1.00 pm. However, the average temperature without using the thermal box is higher than the average temperature of its water source. This is because the surrounding temperature is very low, which results in the high percentage of average temperature drop. Based on the calculation, zero is also found as the value of temperature changes. This is because the environment temperature has achieved the equilibrium. This clearly shows that the temperature of the water source is the same as the water that was tested in the experiment. Therefore, when the surrounding temperature is cold, it releases the temperature and drops it until the equilibrium temperature is achieved.

The efficiency of the thermal water heater is calculated based on the peak hour data. This is because; the efficiency of the water heater is more suitable to be calculated during the highest performance of the thermal water heater. From calculation show the efficiency of the thermal box achieved 70 % above. Therefore, the thermal box is efficient and shows the mechanism of preheating the water by using the concept is efficient and can be utilized. The data used for calculating the efficiency is in the range of 2 pm until 4 pm. The time range is chosen based on the peak hours. The peak hours of the temperature follow the highest performance that the thermal box can achieve. This is because the water is preheated by using the surrounding temperature and the radiation from the solar.

Conclusion

Based on the experiment carried out, the steel thermal is better compared to the other due to several reasons. The steel thermal works in term of its high efficiency and also the temperature. This refers to it having a different efficiency in which it is efficient and retains the warm temperature even though there is an absence of the thermal box. When the sun is at its peak, the steel thermal produces a higher temperature compared to the galvanized iron box. When the sun sets and night falls, the surrounding temperature becomes cold and the water temperature drops. However, the steel thermal's water temperature is still warmer than the other materials. Thus, it basically refers back to the materials that are used in carrying out the experiment.

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