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THE PERFORMANCE OF HEAT ABSORBER FROM ZINC ON THE EFFICIENCY OF DOUBLE SLOPE SOLAR STILL

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ABSTRACT

The distilled water productivity of the effect of size of the heat absorber from Zinc on the efficiency of double slope solar still. Zinc was chosen to use as heat absorber and was put on the water surface in the second layer of the solar still. The size of Zinc used in the experiment has divided 9 sizes from 10% to 90% of the surface of the water in the second layer of the solar still. The temperature, condensed water and efficiency of solar still were measured and calculated in the experiment. The result was show that using the size of 10% of Zinc absorber has the maximum condensed water at 1.43 liters / day and has the efficiency at 25.99%.The minimum efficiency is 15.02% where size of 90% of Zinc absorber was used the result was also revealed that the efficiency of solar still was decreased according to the increasing of the size at Zinc absorber.

Keywords : Solar still, Efficiency, Absorber, Zinc, Layer

INTRODUCTION

Condenced water is a significant product and has been used in vary uses such as scientific laboratory, medical practices, industries and especially in consumption. Purity of condensed water depends on the usage.Condense water production needs energy for instance electricity, gas, solid coal, boiling water stream, fuel, nuclear energy and solar energy. Water refinery by solar energy still is one way to avoid environmental pollution and let contaminated water to be reused within limited budget and simple maintenance method. Solar energy which is clean energy can be taken throughout the year. The researchers have an idea on efficiency improvement for solar energy water refinery to support the uses of alternative energy instead of expensive fuel which affects on the investment of water refinery. Therefore, an alternative power: solar energy should be taken into consideration to be used in Thailand in water refinery as lower investment. However solar refiner currently hold insufficient efficiency, most researchers have redesigned and developed solar refiner. Solar distillation of saline water has been practised for centuries. Apart from common basin type solar stills, several concepts such as tilted tray, tilted or vertical wick and some other designs have emerged [1–3]. From a practical point of view, it has now been realized that solar distillation cannot compete with other methods of desalination unless a major improvement is achieved.

They can be used in any place, but they have low water-productivities [4]. They are also capital-intensive items [5, 6]. The energy is free, but the area required and the cost of the equipment to intercept and use this low-density, low-grade thermal energy is high. There are several methods of reducing the cost of produced water, one among them is by increasing the output per unit area. Several authors [7, 8] suggested a multiple level, double-basin still. The main advantages of this type is that the latent heat of vapour, condensing over the lower surface of the lower glass cover is utilized in heating the upper layer of water. suggested a multiple level, double-basin still. The main advantages of this type is that the latent heat of vapour, condensing over the lower surface of the lower glass cover is utilized in heating the upper layer of water. Solar distillation of saline water has been practised for centuries. Apart from common basin type solar stills, several concepts such as tilted tray, tilted or vertical wick and some other designs have emerged [9-11]. From a practical point of view, it has now been realized that solar distillation cannot compete with other methods of desalination unless a major improvement is achieved. Basin-type or greenhouse is the most widely studied design of all solar stills. Single and double slope condensing covers are two commonly found basic configurations, where the former has a single flat condensing plate with low inclinations with respect to the horizontal, usually between 4 °C and10 °C meanwhile, the latter uses two condensing plates placed in a triangular fashion with higher inclinations [12] where can be found hourly variations of solar intensity incident on the roofs [13,14], strong thermal asymmetries in temperature and distillate yield for each condensing cover [15], and slight differences in the cumulative volumetric productions for the covers facing a north/south direction [16]. Despite these thermal differences, it is common practice to evaluate the cover performance of a still without regard of its configuration with a single equation, forcing the solution of a double slope still to the case of a single flat condenser equipment [17–21].

Solar energy is clean and has the efficiency in water refinery had designed and evaluated efficiency of 1.5 * 1 meter double solar water refinery, each level height was 20 centimeters, only one side of the glass had slope of 14° and upper level had been designed into steps increasing the surface area. To increase the efficiency of researchers therefore set aims to investigate the effects of relations between the absorbers and the efficiency of solar still water refinery by applying zinc as absorber which conducts much heat on the upper level. Currently the appropriate size is not evaluated.

I. INSTRUMENTS AND METHODS

1.1 Instruments

This study is the developing of 1.5 * 1 m^2 and 20 cm. Heights each size - double solar still single side sloped water refiner. Each side of the refiner, there are water release cavity in each level. The bottom area of the refiner is contained with nonconductors, heat absorbers, single side 14° slope glass. The upper level was designed into steps, increasing surface areas by applying more heat absorbers as zinc to transfer heat to the water.

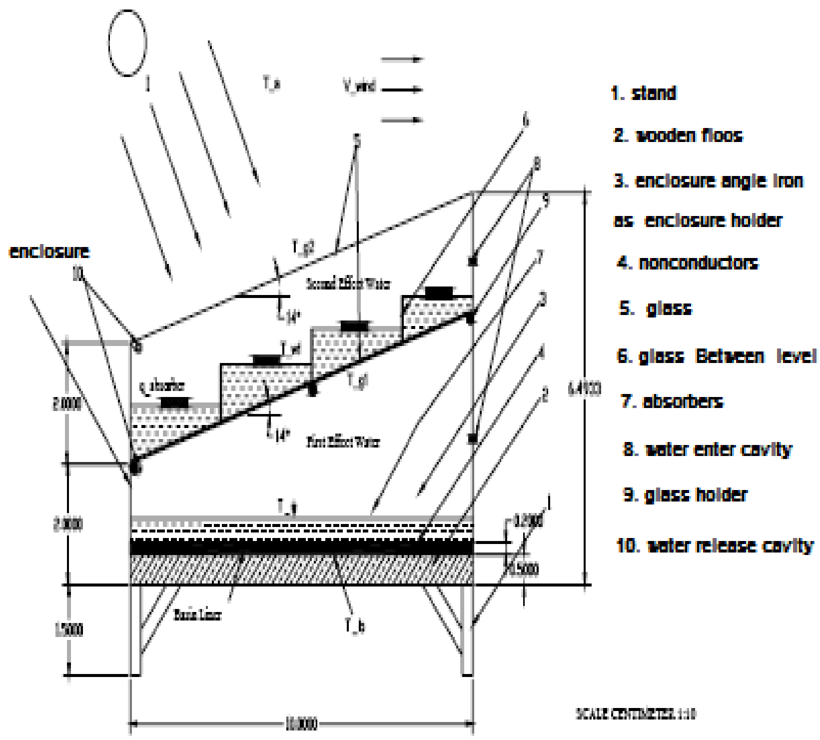

Figure 1 Model of solar still water refiner

1.2 Methods

This research is the study to identify the solar intensity per hour, cumulative water refinery in a day of each layer and temperature change inside the water refiner to analyze the efficiency of the refiner which had applied heat absorbers as zinc. Zinc plates were divided from 10% to 90% the water surface area at the upper level and the experiment is as followings:

1. Apply Thermo Couple Type J at 6 locations: T_b, T_w, T_{g1}, T_{wf}, T_{g2} (shown in figure 1) and connect Thermo Couple with Thermometer Digital to identify each location

temperature, then apply 75 liters ($m_w = 75$) of water at the lower level and 24 liters ($m_{wf} = 24$) for upper level.

2. Apply heat absorber made from zinc with had been divided into 10% to 90% of water surface areas at the top of double slope solar still towards the South direction.

3. Measure condensed water by measuring cup, measure wind speed by Flow meter, use wet and dry Thermometers to measure temperature and relative humidity.

4. Measure all values every hour starting from 1 A.M. to 0 A.M. of the next day.

II. INDENTATIONS AND EQUATIONS

2.1 Water Refinery by Solar Energy

Working Process: Solar radiation will be transferred to translucent cover sheet at upper level which can be glass or plastic. The radiation will be absorbed by raw water and tub. As water heats and steam evaporates to cover sheet in the upper area by heat conducting. Cover sheet needs sufficient degree of the slope to let refined water flow through gutter. The length of gutter needs to comply with the size of the refiner and refined water with be collected at the container.

2.2 The Calculation of Solar Radiation

The value of solar radiation per hour (I) can be accumulated by [22, 23] the result from accumulated of solar radiation per day (H) multiplies by the ratio of an hour of solar radiation per accumulated radiation in a day (r_t)

$$I = Hr_t \qquad (1)$$

when

$$r_t = \frac{\pi}{24}(a + b\cos\omega)\frac{\cos\omega - \cos\omega_s}{\sin\omega_s - (\frac{2\pi\omega_s}{360})\cos\omega_s} \qquad (2)$$

since $a = a_1 + a_2 \sin(\omega_s - 60)$ and $b = b_1 + b_2 \sin(\omega_s - 60)$ when ω_s stands for the degree of the sun (Sunset hour angle) as incidence angle between the value of radiation at the area of strike level and the values of a_1, a_2, b_1, b are invariants at vary stations in Thailand. This study has used the coefficient from Ubonratchathani station: $a_1 = 0.76, a_2 =$ -0.031, $b_1 =$ 0.207 and $b_2 =$ 0.238.

2.3 Energy Transferring in Solar Still Water Refiner

Most energy transferring in water refiner costs lost in the system affecting water refinery ratio. When solar radiation transfers to water refiner, some radiation is able to be transferred to the refiner as the reflection of radiation at the bonnet of the water refiner. The transferred radiation in the water refiner will be changed into heat energy accumulatively and some of radiation will be absorbed at the surface. The accumulated heat in water refiner is lost by these conditions:

1. Solar radiation is absorbed into the bonnet. ($Q_{S.AG}$)
2. Energy from solar radiation goes through the bonnet(Q_{TR})
3. Energy from solar radiation goes through the bonnet and absorbed by the water. ($Q_{S.AW}$)
4. Heat transferred from the bonnet to the atmosphere by heat radiation(Q_{RO})
5. Heat transferred from outside surface of the bonnet to the atmosphere by convection (Q_{CO})
6. Heat transfers from water surface to the bonnet by radiation(Q_{RI})
7. Heat transfers from the surface to the bonnet by convection(Q_{CI})
8. Heat lost at the side and bottom parts of water refiner(Q_{L})
9. Heat ventilated from water to the bonnet along with evaporating steam(Q_{E})
10. Heat lost along with the refined water outcome. ($Q_{distill.}$)

The energy at all parts of the refiner can be calculated using energy balance in solar still water refiner as following:

1. Heat energy balance at nonconductors

$$m_b C_{pb} \frac{dT_b}{dt} = I(t) A_b - q_{cbw} - q_{loss} \tag{3}$$

2. Heat energy balance in level 1 water

$$m_w C_{pw} \frac{dT_w}{dt} = I(t) A_w + q_{cbw} - q_{rwg1} - q_{cwg1} - q_{ewg1} \tag{4}$$

3. Heat energy balance at level 1 glass surface

$$m_g C_{pg} \frac{dT_{g1}}{dt} = I(t) A_{g1} + q_{rwg1} + q_{cwg1} + q_{ewg1} - q_{cg1wf} \tag{5}$$

4. Heat energy balance in level 2 water

$$m_{wf} C_{pw} \frac{dT_{wf}}{dt} = I(t) A_{wf} + q_{cg1wf} - q_{cwfg2} - q_{rwfg2} - q_{ewfg2} + q_{absorber} \tag{6}$$

5. Heat energy balance at level 2 glass surface

$$m_g C_{pg} \frac{dT_{g2}}{dt} = I(t) A_{g2} + q_{cwfg2} + q_{rwfg2} + q_{ewfg2} - q_{rg2,sky} - q_{cg2,a} \tag{7}$$

6. Accumulative condensation ratio of both levels

$$\frac{dm_c}{dt} = h_{ewg1}\frac{(T_w - T_{g1})}{h_{fg@T_W}} + h_{ewfg2}\frac{(T_{wf} - T_{g2})}{h_{fg@T_{wf}}} \tag{8}$$

Since T_b, T_w, T_{g1}, T_{wf}, T_{g2} are temperatures at bottom nonconductors, bottom surface water, bottom glass surface, top water surface and top glass surface respectively. The standard room temperature is assigned at 25°C and m_b, m_w, m_g, m_{wf} are the mass of bottom nonconductors, bottom water amount, glass, upper water amount respectively. m_c is the mass of refined water and the variables are assigned as followings:

m_g = 6 kg, m_b = 10 kg, C_{pg} = 800 $J/kg°C$, C_{pb} = 473 $J/kg°C$, C_{pw} = 4,178 $J/kg°C$, ε_g = 0.88, ε_w = 0.96, α = 0.09, α_g = 0.0475, α_w = 0.05, α_b = 0.95, ρ_g = 0.0735, U_b = 14 W/m^2K, h_{bw} = 135 W/m^2K, h_{cg1wf} = 25 W/m^2K

2.4 The Calculating of Heat Absorbed by an Object

General formula to calculate energy absorbed by an object is

$$q_{absorber} = \alpha\left(I_b\tau_{wb} + I_d\tau_{wd}\right) \tag{9}$$

When α is the radiation absorption of the object, I_b is the value of solar radiation per hour on plane level. I_d is the value of spread solar radiation per hour on plane level, τ_{wb} is solar radiation transferring of the atmosphere by steam absorption, τ_{wd} is the transferring of solar radiation of the atmosphere as steam scattering.

2.5 Efficiency of Solar Still Water Refiner Calculation

General formula to calculate for efficiency (η) is

$$\eta = \frac{\sum \dot{m}_c h_{fg}}{\sum I} \tag{10}$$

When $\dot{m}_c$ is condensation ratio, h_{fg} is latent heat and I is solar radiation condensation.

2.6 Calculation Methods

Efficiency calculation of solar still water refiner uses EES computer based program. Fixed variables are needed to be assigned as mentioned and solar condensation can be calculated using solar function to get the temperature values of T_b, T_w, T_{g1}, T_{wf}, T_{g2} as 3-8 equation. Then calculate for latent heat (h_{fg}) of both levels to find the ratio of condensation ($\dot{m}_c$) to be able to calculate the efficiency of solar still water refiner as 10 equation.

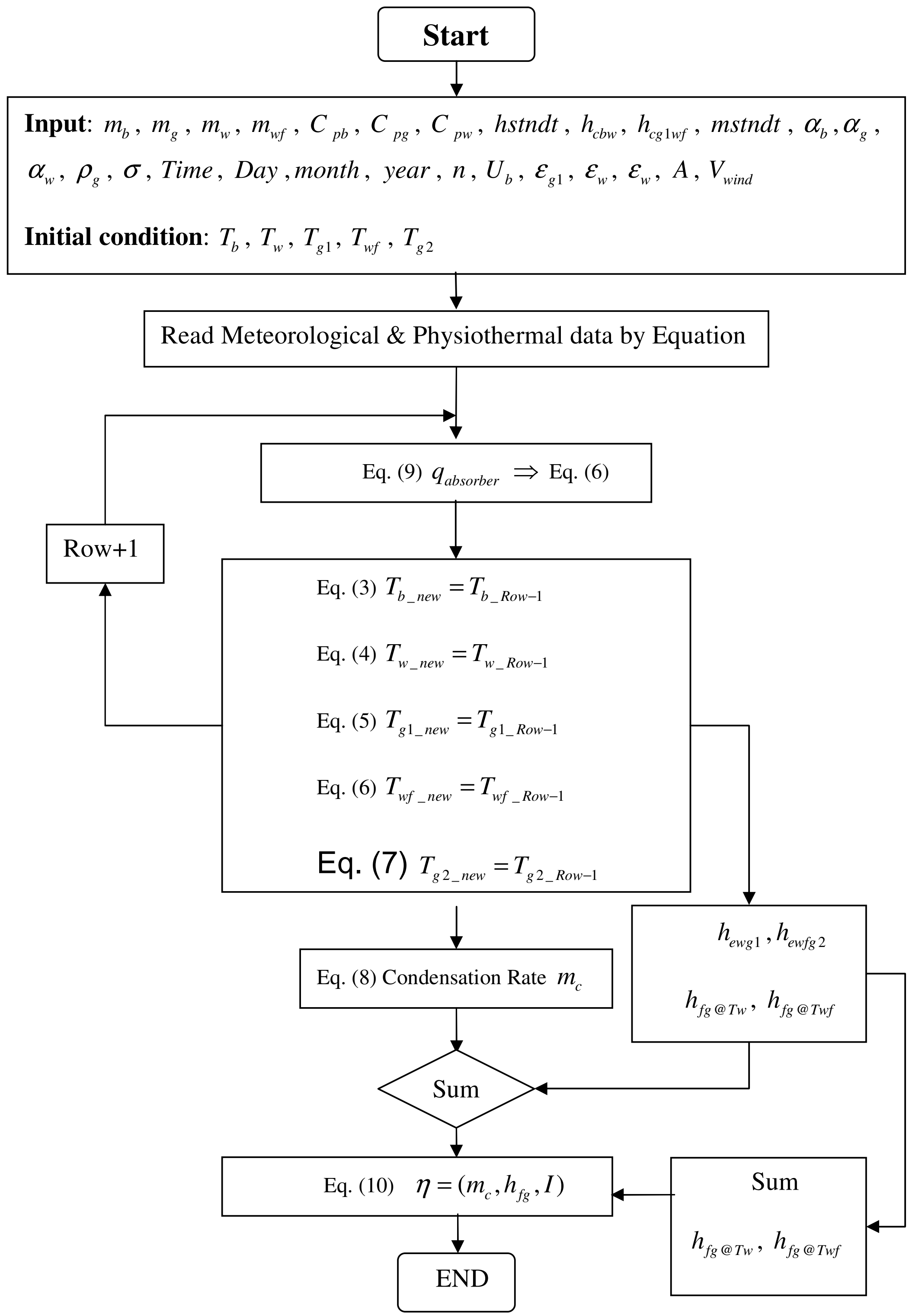

Figure 2 The calculation using the Engineering Equation Solver (EES)

III. RESEARCH RESULTS AND DISCUSSION

3.1 Solar Radiation Condensation

The experiment of applying zinc as absorbers covering 10% to 90% of 2nd level of water surface area was tested for data of temperature variation in water refiner, amount of refined water and calculated for the efficiency of refined water. In case of using heat absorber sheet size 10% that was conducted on December 4th, 2008 with day average solar condensation of 393.80 W/m^2, 13.00 P.M. maximum of 708.33 W/m^2 the sunlight can be notified from 7.00 A.M. until 18.00 P.M. accumulated as 11 hours.

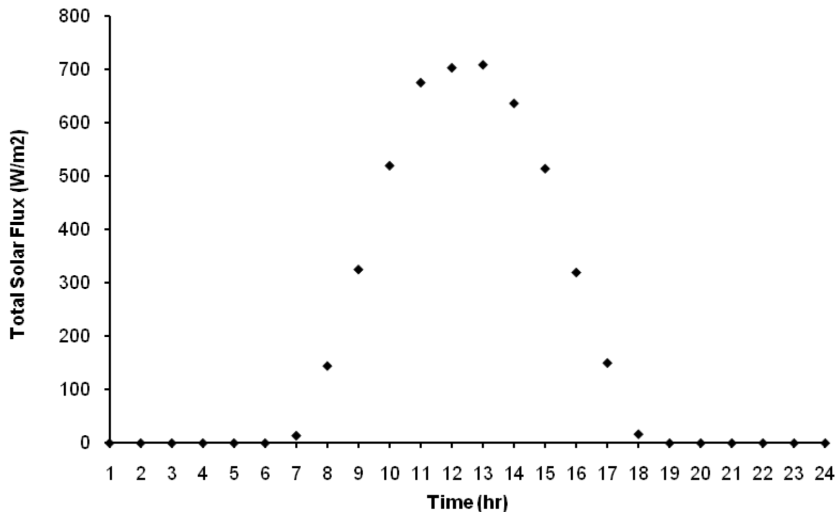

Figure 3 Solar radiation condensation graphs

5.2 Temperature at Surfaces

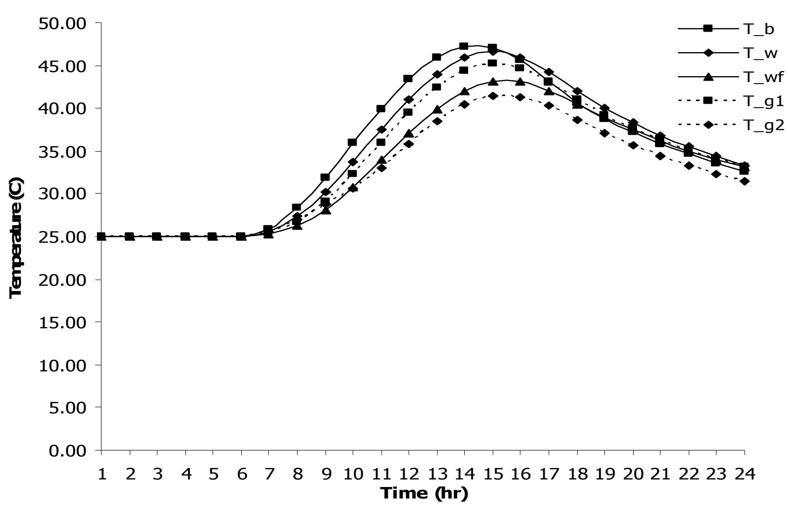

Figure 4 Temperature variation in water refiner applied 10% zinc plate heat absorbers

According to figure 4, the graphs indicate temperature calculated from locations in solar still water refiner and the results showed that the difference of temperature between the surface of glass at level 1 (T_{g1}) and water surface level 1(T_w) was more than the difference between glass surface level 2 (T_{g2}) and water surface level 2 (T_{wf}) At level 2 the difference between water and glass is more than the difference of level 1. At 3 P.M. the highest temperature moment: 47.22 °C between glass surface and water surface of both levels. Both levels 2 had the differences of temperature between glass surface and water surface of 1.67°C and levels 1 had the differences of temperature between glass surface and water surface of 1.37°C indicating that level 2 had more condensation than level 1 (as shown in Figure3) and condensation remained when there was no sunlight as the difference of temperature between glass surface and water surface still remained however the condensation without sunlight was lower.

5.3 Difference of temperature between the surface of glass

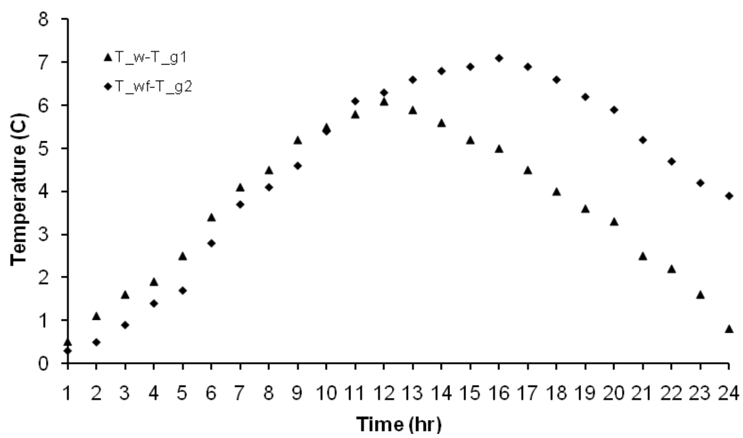

Figure 5 Difference of temperature between the surface of glass

According to figure 5, the results showed that the difference of temperature between the surface of glass at level 1 (T_{g1}) and water surface level 1(T_w) was and the difference between glass surface level 2 (T_{g2}) the sunlight can be notified from 7.00 A.M. until 12.00 A.M. at level 1 the difference between water and glass is more than the difference of level 2. At 3 P.M. At 3.00 P.M. at level 2 the difference between water and glass is more than the difference of level 1. Indicating that level 2 had more condensation than level 1 (as shown in Figure 5). Both levels 2 had the differences of temperature between glass surface and water surface of 7.10°C. Both levels 1 had the differences of temperature between glass surface and water surface of 6.10°C

5.4 Single day Accumulative Water Refinery Ratio

According to Figure 6, The graphs indicate both levels accumulative water refinery ratio. Level 1 outcome refined water was 0.51 l/m^2 and level 2 outcome refined water was 0.92 l/m^2 and accumulative refined water was 1.43 l/m^2. At 9.00 A.M. From 1 P.M. to 6 P.M.

the refinery ratio was highest as the graphs shows most incline during the day: Between 7.00 A.M. to 9.00 A.M. there was no condensation as the refiner needed accumulative heat to reach latent heat value of evaporation. Than the heat later evaporated to glass surface and condense.

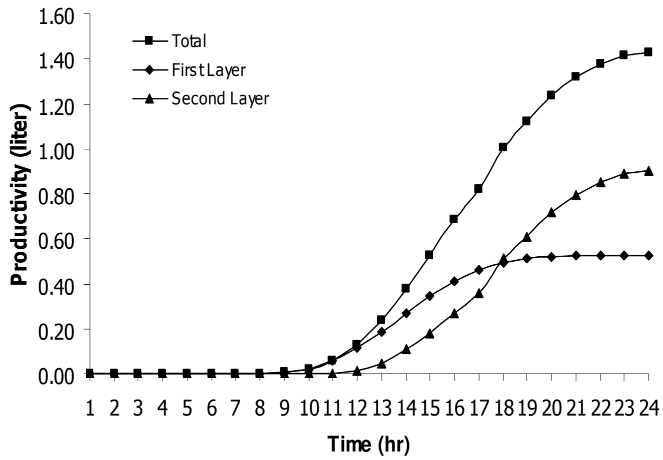

Figure 6 Single day accumulative water refinery ratio from the experiment of applying size 10% of zinc as heat absorber

According to Figure 7, Single day average accumulative efficiency, applied with zinc size 10% and the use of equation 10 showed that the refiner had single day average accumulative efficiency of 25.99%

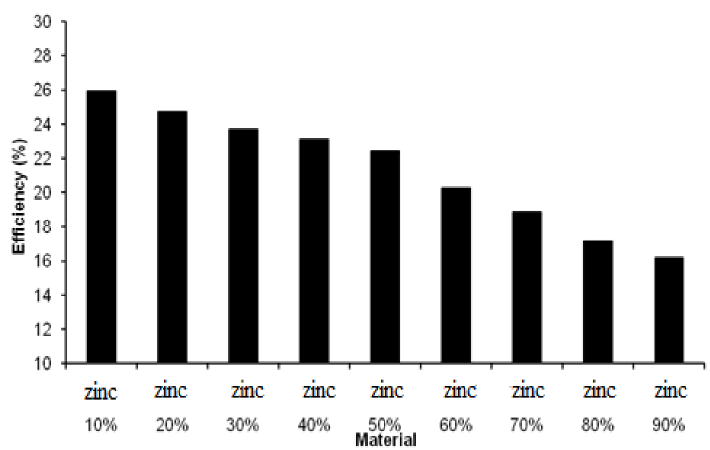

Figure 7 Single day average accumulative efficiency, applied with zinc heat absorber of 10%-90%

The experiment of water refinery then was conducted by original refiner but replaced with all sized of zinc as heat absorbers from 10% to 90%. The results and the calculations are indicted in Table1.

Table 1 Results of experiments on zinc as heat absorber at sizes

Date	Sizes of Zinc	Average Solar intensity	Amount of refined water	Efficiency
	(%)	(W/m^2)	$(liter)$	(%)
04/12/2012	10%	393.80	1.43	25.99
09/12/2012	20%	395.39	1.31	23.71
11/12/2012	30%	393.87	1.23	22.35
13/12/2012	40%	390.53	1.19	21.80
20/12/2012	50%	377.89	1.14	21.56
09/02/2012	60%	391.94	1.08	19.72
10/02/2012	70%	404.10	1.02	18.07
13/02/2012	80%	432.22	0.97	16.07
16/02/2012	90%	438.03	0.92	15.02

According to Table1, The efficiency decreased when zinc heat absorber's size increased. The highest efficiency (25.99%) is at size 10% and the lowest (15.02%) is at size 90% the graphs of temperature variation at different surfaces of the refiner, accumulate amount of refined water when applied heat absorber from size 20% to 90% resulted very close outcome compared to sized 10% experiment.

IV. CONCLUSION

The results indicated that zinc can act as heat absorbers and the size of zinc plate affected on the efficiency of single side sloped-double solar still water refiner. The area increased reduced the efficiency. 10% size of zinc indicated the highest refined water at 1.43 l/day and single day accumulative efficiency of 25.99%. Zinc size of 90% produced the lowest amount of refined water at 0.92 l/day and single day accumulative efficiency of 15.02%. The experiment without zinc as heat absorber showed 25.99% of efficiency which was more than ones with heat absorbers. Therefore the efficiency of double solar still water refiner decreased the size of zinc increased as zinc covered the surface which solar radiation needed for heat transferring to level 1 of the refiner.

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