An implementation of aluminum as a heat absorber in double slope solar still

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Abstract

The distilled water productivity of the effect of size of the heat absorber from aluminum on the efficiency of double slope solar still. Aluminum 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 aluminum 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 condensed temperature water and efficiency of solar still were measured and calculated in the experiment. The result was showed that 10% of using the size in aluminum absorber has the maximum volume of condensed water is 1.6 liters / day and the efficiency is 26.34%. While the minimum efficiency is 17.29% with 90% of aluminum absorber sizing. The result was also revealed that the efficiency of solar still was decreased according to the increasing of the size at aluminum absorber.

Keywords: *solar still, efficiency, absorber, aluminum, layer*

1. Introduction

Water is a significant product such as scientific laboratory, medical practices, industries and especially in consumption while 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 affected on the investment of water refinery. These communities obtain fresh water from other places by transportation. However, the cost and reliability of transportation are limiting factors. Thus, producing fresh water by a solar still with its simplicity would be a suitable solution of the water shortage problem [1]. Delyannis reported that although the advantage of cost free energy is partly offset by increased amortization cost, solar distillation was considered, for a long time, as the most favorable process for small capacity of water desalting [2]. However, the amount of distilled water is somewhat small which makes the basin solar still unacceptable in some instances. Therefore, many researches were directed towards improving the efficiency and reducing the construction cost through appropriate design. Many configurations of solar still have been constructed and experimentally tested [3,4]. They are simple from the maintenance view and low construction cost. Other sophisticated solar stills have been constructed, but the gain of increasing the productivity is canceled by the complexity of the unit. Far away from the sophistication and complexity in the configuration of the solar still, found that fresh water productivity by a solar still can be increased by the presence of some absorbing materials, such as rubber [5].

Solar energy is clean and has the efficiency in water refinery had designed and evaluated efficiency of 1.5 x 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. The results showed that the efficiency was 27.43%. 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 black rubber as absorber which conducts much heat on the upper level. Currently the appropriate size is not evaluated.

2. Instruments and Methods

2.1 Instruments

This study is the developing of 1.5 * 1 m^2 and 20 cms. 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 aluminum to transfer heat to the water.

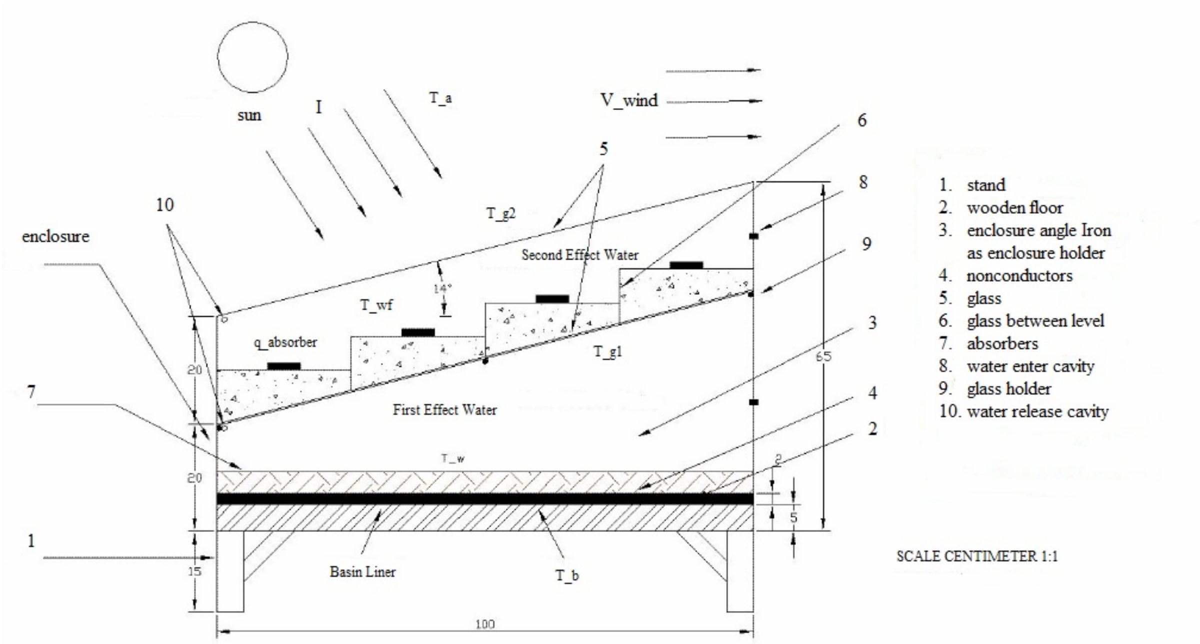

Fig. 1 Model of solar still water refiner

2.2 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 aluminum. Aluminum 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 aluminum 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.

3. Related Theories in Calculation

3.1 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.

3.2 The Calculation of Solar Radiation

The value of solar radiation per hour (I) can be accumulated by 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)

$$I = Hr_t \tag{1}$$

when

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

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.

Fig. 2 The solar radiation incident on a planar surface and an inclined plane

Thermal energy incident on the object. Total thermal energy of the radiation transmitted in all directions. From sources of heat. When the total thermal energy of the radiation incident on the part of the energy is reflected, absorptivity and transmissivity.

3.3 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

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

2. Heat energy balance in level 1 water

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

3. Heat energy balance at level 1 glass surface

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

4. Heat energy balance in level 2 water

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

5. Heat energy balance at level 2 glass surface

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

6. Accumulative condensation ratio of both levels

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

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

4. The Calculating of Heat Absorbed by an Object

General formula to calculate energy absorbed by an object is

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

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.

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.

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.

7. Research Results and Discussion

The experiment of applying aluminum 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 November 23th, 2009 with day average solar condensation of 434.391W/m^2, 12.00 P.M. maximum of 781.39 W/m^2 the sunlight can be notified from 7.00 A.M. until 18.00 P.M. accumulated as 11 hours.

Temperature at Surfaces

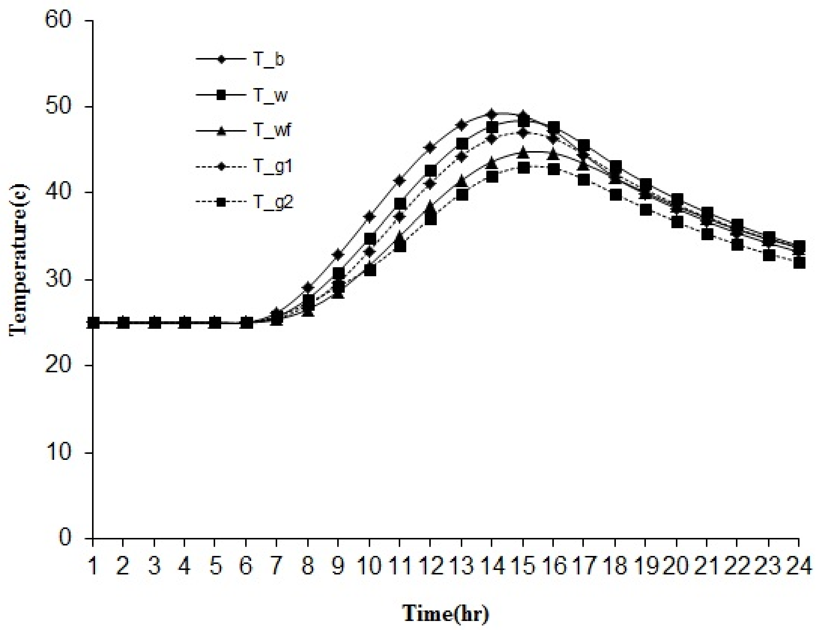

Fig. 3 Temperature variation in water refiner applied 10% aluminum plate heat absorbers

According to figure3, 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 2 P.M. the highest temperature moment: 49.2 °C between glass surface and water surface of both levels. Both levels had the differences of temperature between glass surface and water surface of 1.6°C indicating that level 2 had more condensation than level 1 (as shown in Figure4) 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.

Single day Accumulative Water Refinery Ratio

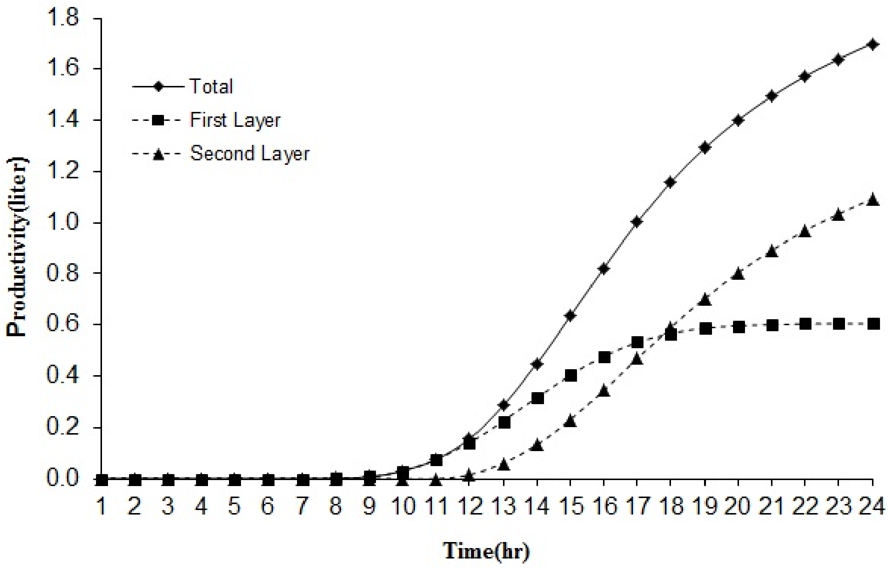

Fig. 4 Single day accumulative water refinery ratio from the experiment of applying size 10% of aluminum as heat absorber

According to Figure. 4, The graphs indicate both levels accumulative water refinery ratio. Level 1 outcome refined water was 1.00 l/m^2 and level 2 outcome refined water was 0.60 l/m^2 and accumulative refined water was 1.60 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.

Average Accumulative Efficiency During the day

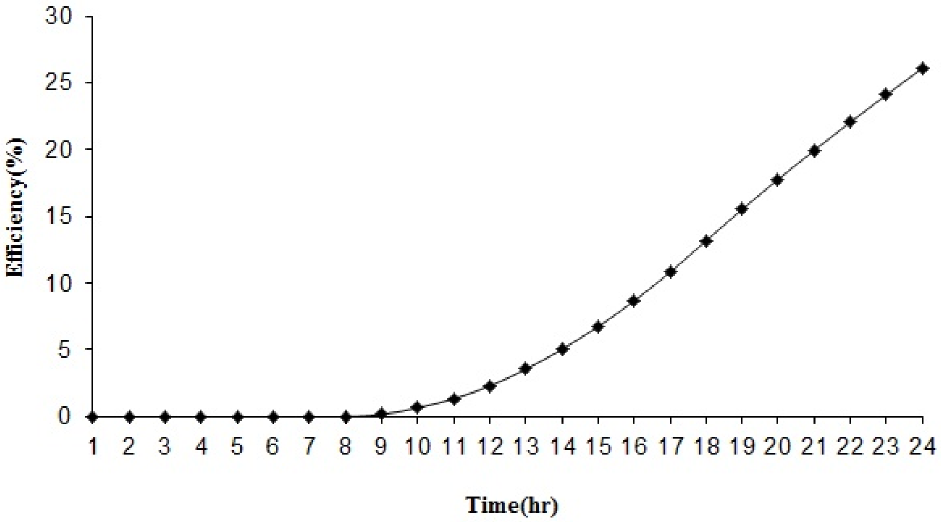

Fig. 5 Single day average accumulative efficiency, applied with aluminum heat absorber of 10%

According to Figure. 5, Single day average accumulative efficiency, applied with aluminum size 10% and the use of equation 10 showed that the refiner had single day average accumulative efficiency of 26.34%

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

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

Date	Sizes of Aluminum	Average Solar intensity	Amount of refined water	Efficiency
	(%)	(W/m^2)	$(liter)$	(%)
23/11/2008	10%	434.91	1.60	26.34
5/12/2008	20%	411.69	1.44	24.94
7/12/2008	30%	416.62	1.42	24.36
15/12/2008	40%	405.42	1.37	24.07
17/12/2008	50%	406.16	1.32	23.24
1/02/2009	60%	393.96	1.19	21.59
5/02/2009	70%	398.45	1.13	20.22
8/02/2009	80%	380.04	1.08	18.73
11/02/2009	90%	373.01	0.98	17.29

According to Table1, The efficiency decreased when aluminum heat absorber's size increased. The highest efficiency (26.34%) is at size 10% and the lowest (17.29%) is at size 90% . The size of 10% aluminum indicated the highest refined water at 1.60 l/day and single day accumulative efficiency of 26.34%. Aluminum size of 90% produced the lowest amount of refined water at 0.98 l/day and single day accumulative efficiency of 17.29%. 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.

8. Conclusions

The results indicated that aluminum can act as heat absorbers and the size of aluminum plate affected on the efficiency of single side sloped-double solar still water refiner. The area increased reduced the efficiency. 10% size of aluminum indicated the highest refined water at 1.60 l/day and single day accumulative efficiency of 26.34%. Aluminum size of 90% produced the lowest amount of refined water at 0.98 l/day and single day accumulative efficiency of 17.29%. The experiment without aluminum as heat absorber showed 27.11% of efficiency which was more than ones with heat absorbers. Therefore the efficiency of double solar still water refiner decreased the size of aluminum increased as aluminum covered the surface which solar radiation needed for heat transferring to level 1 of the refiner.

9. Recommendations

The study should have an experiment on other kinds of heat absorber to compare temperature variation in water refiner, the amount of refined water and the efficiency of solar still water refiner.

10. Acknowledgements

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