# The Experiment of Heat Absorber from Black Gasket on the Efficiency of Double Slope Solar Still

Nattadon Pannucharoenwong*, Phadungsak Rattanadecho, Snunkhaem Echaroj, Victoria Timchenko, Suwipong Hemathulin, and Kriengkrai Nabudda

***Abstract***— *Solar-based technology is an important strategy against low electricity rural area especially for treatment of water through the distillation method. A tilted double distillation unit with black gasket as heat absorber was constructed to harness solar energy for producing distilled water. The productivity of the distillation unit was found to decrease as the heat absorber area increases due to a reduction in the accessibility of sunlight. Optimum productivity equaled to 1.15 liter per day with efficiency of 24.85% was obtained from distillation over 10% size heat absorber. An increase in the size of heat absorber to 90% was observed to decrease the productivity to 1.01 liter per day with efficiency of 22.53%. The distillation rate in the upper and bottom section of the distillation unit was found to peak at 15:00. Variation in the parameters demonstrated that distillation rate increases with wind speed. However distillation rate decreases with water height and insulator's thermal conductivity. A polynomial model was formed based on experiment data, which can be employed to predict efficiency and productivity by plugging in the size of heat absorber and operating time of the distillation unit.* $R^2$ *calculated from experimental and mathematical model was close to 1 indicating very accurate prediction of productivity and efficiency. Comparison experiment conducted on other type of heat absorber revealed aluminum to have the highest efficiency and productivity.*

***Keywords***— **Distillation rate, solar-base technology, heat absorber, black gasket.**

## 1. INTRODUCTION

Energy source and consumption is an important criterion for the design and development of invention in the 21st century. This is due to the decline in petroleum reservoir and their negative effects on the environment and well-being of residence near the power plant sites. Among different renewable sources of energy, solar thermal energy is one of the most promising source of energy, especially in a tropical country like Thailand [1]. According to satellite data demonstrated via the Solargis model, the daily maximum global horizontal radiation (GHI) was in the range of 5.2 to 5.4 kWh/m$^2$ (average annual sum was in the range of 1899 to 1972 kWh/m$^2$) which was recorded in three different provinces including Nakhon Ratchasimam, Hua Hin and Sing Buri [2]. To take advantage of this high radiation level many solar-based technologies have been developed including photovoltaic panel roof-top and solar farms. In additional to these mega-scale projects, solar radiation can also be useful for the production of clean water through the distillation technology [3], [4]. Clean water is essential for the well-being of communities especially in rural areas where people do not have access to electricity and proper water sanitary system [5], [6]. These rural communities rely on lake water and underground water which may contain heavy metals, salts, undesirable contaminant and pathogen that could threatens the well-being of rural residence. Approximately 30% and 20% of ground water exceed the limits in terms of physical characteristics (color and turbidity) and biological characteristics (total coliform and fecal coliform) [7].

Solar-based water distillation is one of the most effective methods for water disinfection. The technology employed to harness solar energy is especially important in rural area. Solar-based water distillation is appropriate because it does not require skilled worker, very little maintenance is necessary and the technology is easily installed. Currently, there are two type of solar technology including active and passive types. For an active solar system, an external thermal source is required to increase the evaporation rate and hence the productivity of the solar-based distillation system. On the other hand, the passive type employed natural solar radiation which demonstrated lower yield compared with the active type. However, the passive type does not contain any dynamic component so it does not consume power and does not wear easily [8]. In general, a conventional passive solar-based distillation unit composed of a closed basin containing water usually mixed with salt solution and a transparent cover made out of glass. Initially, heat is applied to the salt solution in the form of solar radiation. Water evaporation is promoted by the temperature difference between the glass cover and the fluid inside the basin [9]. In most cases, convection is usually the heat transfer mode that is the driving force behind the increase in the temperature difference [10]. The condensed water rose continuously and is collected on the glass cover at the top, which is then directed to a distillated collection container.

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Distillation of contaminated water has been as interesting and challenging topic for sanitary engineers.

According to many studies, the operating conditions that have significant effect on the productivity of the solar-base distillation unit included the height of water surface in the basin, basin material, wind velocity, solar intensity, and angle of the basin relative to the ground and the location of the device installation. Productivity of clean water is proportional to the temperature different between water in the basin and the incline glass cover. Since the yield of treated water is low for conventional distillation unit, many researches have been developed to modify the system in order to improve the efficiency. Velmurugan and Srithar proposed a brine solution of 80 g per kg of water for an optimum solar-base distillation activity using mini sponge structure inside the basin [11]. Jayaprakash et al. reported high efficiency for a V-type distillation unit using charcoal heat absorber and a boasting mirror. From the performance ratio such as Nusselt number (Nu) and the Grashof number (Gr), the efficiency calculated were 30% for the V-type distillation unit with charcoal heat absorber [12]. Srithar et al. modified the distillation unit by addition of multilevel step in the design, which was found to improve the efficiency of the unit [13]. An improved basin still was developed to provide 30% efficiency with maximum productivity of 1.4 L per square meter per day [14]. Srithar et al. compared the performance of four different heat absorbers including sponges, pebble and sand. Results indicated that sand was the most effective heat absorber giving productivity as high as 5.1 mL per $m^3$ [15]. Phase change material such as lauric acid was added into the distilled basin in order to enhance heat transfer coefficient to improve distillation productivity [16].

This research aimed to evaluate the efficiency of black gasket as a heat absorber for the tilted slope distillation unit. Solar intensity of the installation location was monitored throughout the day. In additional to solar intensity, temperature of five different spot inside the distillation unit was also recorded throughout the day. Other parameters such as wind speed, water height is inside the basin of the distillation unit, thermal conductivity and the size of heat absorber. These data are plugged into an Engineering Equation Solver (EES) in order to determine the efficiency of the distillation unit through numerical algorithm. Mathematical model from experimental data were proposed to predict the treated water productivity and efficiency of the distillation unit [17].

## 2. HEAT TRANSFER GOVERNING AND THEORY

Heat transfer principle inside the distillation unit can be observed as radiation from sunlight penetrated through the transparent glass cover and absorbed by water inside the basin. Heat absorbed by water accumulated until it is higher than the latent heat accelerating cleavage of intermolecular bond. This was found to result in an increase in evaporation activities inside the distillation unit. Water vapor that raise to the glass cover will condense into an outlet gutter which is collected. It is important for the upper distillation unit to be a slope with an appropriate angle in order to improve treated water collected after untreated water inside the basin raise in form of vapor. For this experiment, the slope angle of $14^o$ was used. In addition to the slope, the gutter length was required to be appropriate as well considering the size of the distillation and the amount of water productivity.

### 2.1 Solar Insolation Calculation

Using the formula for sun's location calculated over the year, the maximum degree of radiation that affect the surface of the Earth can be found. Solar insolation per hour ($I_h$) can be calculated from the amount of solar insolation recorded per day ($I_d$) multiply with the total radiation ratio that day $r_{total}$ show in equation (1) and equation (2):

$$I_h = I_d x r_{total} \tag{1}$$

$$r_{total} = \frac{\pi}{24}\left(a + b\cos\omega\right)\left[\frac{\cos\omega - \cos\omega_s}{\sin\omega_s - \left(\frac{2\pi\omega_s}{360}\right)\cos\omega_s}\right] \tag{2}$$

where $a = a_1 + a_2\sin(\omega_s - 60)$ and $b = b_1 + b_2\sin(\omega_s - 60)$, $\omega_s$ is the angle of incidence between the solar ray and the impact area and values of $a_1$, $a_2$, $b_1$, b are governed by many factors. Therefore, they are influenced by the installation location. In the case of this experiment (performed in Ubonratchathani province) the coefficient values of $a_1$ = 0.76, $a_2$ = -0.031, $b_1$ = 0.207 and $b_2$ = 0.238.

### 2.2 Heat transfer in solar-based distillation unit

Energy loss during the heat transfer process usually represents an increase in cost and decrease in the production of distilled water production rate. In addition to conduction and convection heat transfer, radiation also plays a significant role in the distillation process. Radiation can penetrate through the glass screen of the distillation unit and can also be reflected from the glass screen into the water body. Radiation can also accumulate inside the system in the form of heat and also absorbed by the body of untreated water in the unit. Accumulated heat loss from the distillation unit included the following actions: Glass screen absorbed radiation, penetration of radiation through the glass screen, adsorption of radiation by untreated water, heat transfer in radiation mode from glass screen to the atmosphere, heat transfer in convection mode from glass screen to the atmosphere, heat transfer in radiation mode from untreated water to glass screen, heat transfer in convection mode from untreated water to glass screen, heat loss through the bottom/sides of the distillation unit, heat loss during ventilation of the evaporative vapor steam and heat loss along the distilled water outlet.

Heat transfer and the amount of energy throughout the distillation unit can be calculated by energy balance in the distillation container as shown in the equation below.

$$m_{ins}C_{p.ins}\frac{dT_{ins.}}{dt}=I(t)A_{ins}-q_{ins}-q_{loss} \quad (3)$$

Equation (3) is the balance equation for energy input and output along the insulator where $m_{ins}$ is the weight of the insulator which is equaled to 10 kilogram, heat capacity of the insulator is referred to as $C_{p.ins}$, temperature of the insulator is referred to as $T_{ins}$, insulator area is equaled to $A_{ins}$ and the $q_{ins}$ is heat transfer from insulator to the insulator.

$$m_{ws1}C_{p.ws1}\frac{dT_{ws1}}{dt}=I(t)A_{ws1}+q_{ins}-q_{r.ws1}-q_{c.ws1}-q_{ev.ws1} \quad (4)$$

Equation (4) is energy balance for water body at the bottom section of the distillation unit where $m_{ws1}$ is the mass of water in the bottom distillation still, heat capacity of water $C_{p.ws1}$ is 4,178 J/kg° C ,water surface area at the bottom of the distillation unit is refere $A_{ws1}$, radiative heat transfer mode from water to the transparent cover in the bottom section is referred to as $q_{r.ws1}$, heat transfer in convection mode is referred to as .$q_{c.ws1}$ and the evaporation heat transfer mode is $q_{ev.ws1}$

$$m_{gl1}C_{p.gl1}\frac{dT_{gl1}}{dt}=I(t)A_{gl1}+q_{r.gl1}+q_{c.gl1}+q_{ev.gl1}-+q_{c.gl1ws2} \quad (5)$$

Equation (5) is energy balance for glass cover at the bottom stage where $m_{gl1}$ is the weight of glass cover in the bottom section which is equaled to 6 kilograms, the heat capacity of glass in the bottom stage is referred to as $C_{p.gl1}$ or 800 J/kg° C temperatureof glass cover in the bottom section is referred to as $T_{ws1}$, the area of glass cover in the bottom section is $A_{gl1}$ and heat transfer in the upper section between water surface and glass cover is $q_{c.gl1ws2}$.

$$m_{ws2}C_{p.ws2}\frac{dT_{ws2}}{dt}=I(t)A_{ws2}+q_{c.g1ws2}-q_{c.ws2gl2}-q_{r.ws2gl2}-q_{r.ws2gl2}+q_{HA} \quad (6)$$

Equation (6) represented the energy balance water in the upper section of the distillation unit where $m_{ws2}$ is the weight of water surface in the upper section, heat capacity is referred to as $C_{p.ws2}$, temperature of water in the bottom section is $T_{ws2}$, area occupied by water in the bottom section is referred to as $A_{ws2}$, heat transfer between glass in the bottom section and water in the upper stage is referred to as $q_{c.gl1ws2}$, and heat transfer between water and glass in the upper section of the distillation unit are referred to as $q_{c.ws2gl2}/q_{r.ws2gl2}/q_{r.ws2gl2}$, and heat transfer in the area of heat absorber is $q_{HA}$.

$$m_{gl2}C_{p.gl2}\frac{dT_{gl2}}{dt}=I(t)A_{gl2}+q_{c.ws2gl2}+q_{r.ws2gl2}+q_{ev.ws2gl2}-q_{r.gl2atm}-q_{c.gl2atm} \quad (7)$$

Equation (7) demonstrated energy balance of glass in the upper section of the distillation unit where $m_{gl2}$ is the weight of glass in the upper section of the unit, heat capacity of glass $C_{p.gl2}$, temperature of glass in the bottom section is referred to $T_{gl2}$, area of the bottom section is referred to as $A_{gl2}$, heat transfer between water and glass in the upper section is referred to as $q_{c.ws2gl2}/q_{r.ws2gl2}/q_{ev.ws2gl2}$, radiation from transparent glass $q_{r.gl2atm}$ is the heat transfer in radiation mode from glass screen in the upper stage to the atmosphere, and heat transfer in convective mode from glass screen in the upper section to the atmosphere.

$$\frac{dm_d}{dt}=h_{e.ws1gl1}\left[\frac{T_{ws1}-T_{gl1}}{h_{fg@T_{ws1}}}\right]+h_{e.ws2gl2}\left[\frac{T_{ws2}-T_{gl2}}{h_{fg@T_{ws2}}}\right] \quad (8)$$

Equation (8) illustrated the accumulation of distillation rate between both the upper and bottom section of the distillation unit where $m_d$ is the amount of accumulated distilled water produced over time, and the heat transfer coefficients are $h_{e.ws1gl1}/h_{fg@T_{ws1}}/h_{fg@T_{ws2}}$.

### *2.3 Transfer of heat inside the distillation unit*

Energy loss during the heat transfer process usually represents an increase in cost and decrease in the production of distilled water production rate .In addition to conduction and convection heat transfer, radiation also plays a significant role in the distillation process .. Radiation can penetrate the glass screen of the distillation unit and can also be reflected from the glass screen into the water body .Radiation can also accumulate inside the system in the form of heat and also absorbed by the body of untreated water in the unit . Accumulated heat loss from the distillation unit included the following actions :Glass screen absorbed radiation, penetration of radiation through the glass screen, adsorption of radiation by untreated water, heat transfer in radiation mode from glass screen to the atmosphere, heat transfer in convection mode from glass screen to the atmosphere, heat transfer in radiation mode from untreated water to glass screen, heat transfer in convection mode from untreated water to glass screen, heat loss through the bottom/sides of the distillation unit, heat loss during ventilation of the evaporative vapor steam and heat loss along the distilled water outlet.

### *2.4 Calculation heat transfer of the heat absorber object*

The equation for finding the energy absorbed by heat absorber is shown in equation (9).

$$q_{HA} = \alpha\left(I_a \tau_{sa} + I_s \tau_{ss}\right) \quad (9)$$

where $\alpha$ represent the absorption in radiation mode by the material, $I_a$ represents the hourly solar radiation impact on plane level, $I_s$ represents the hourly distribution of solar radiation impacted on plane level, $\tau_{sa}$ represents the transfer of solar radiation transferring via steam absorption, $\tau_{ss}$ represents the transfer of solar radiation via steam scattering.

**Table 1. Parameters for operating the double slanted-glass distillation unit [18]**

| Operating conditions | Abrev. | Value | Unit |
|---|---|---|---|
| Glass emissivity | $\varepsilon_g$ | 0.88 | - |
| Water emissivity | $\varepsilon_w$ | 0.96 | - |
| Radiation absorption of glass | $\alpha_g$ | 0.0475 | - |
| Radiation absorption of water | $\alpha_w$ | 0.05 | - |
| Reflectivity of glass | $\rho_g$ | 0.0735 | kg/(cm$^3$) |
| Overall heat transfer coefficient | $U_b$ | 14 | W/(m$^2$K) |
| Heat coefficient insulator | $h_{ins}$ | 135 | W/(m$^2$K) |
| Convection coefficient | $h_{c.gl1ws2}$ | 25 | W/(m$^2$K) |
| Wind velocity | $Vwind$ | 3 | m/s |
| Thermal conductivity coefficient | $k$ | 0.04 | W/(mK) |

### *2.5 Calculating the efficiency of solar distillation unit*

The equation for calculating the efficiency (η)of the distillation unit is shown in equation (10).

$$\eta = \frac{\sum \dot{m}_d h_{fg}}{\sum I} \quad (10)$$

where $\dot{m}_d$ is distillation rate, $h_{fg}$ is latent heat and $I$ is solar radiation condensation.

### 2.6 *Calculation system*

EES computer-based program is employed to find the efficiency of the distillation unit as shown in Fig. 1. Some input parameters must be given in order to calculate the solar radiation equations from equation (3) to equation (8) to obtain temperature value at each location inside the distillation unit $T_{atmosphere}$, $T_{insulator}$, $T_{glass2}$, $T_{water\ surface2}$, $T_{glass1}$ and $T_{water\ surface1}$. Variable demonstrated in the logical path for EES are required in order to calculated efficiency of the solar-base distillation and the temperature function to get the temperature values $T_{atmosphere}$ , $T_{insulator}$, $T_{glass2}$, $T_{water\ surface2}$, $T_{glass1}$ and $T_{water\ surface1}$ as shown in equation (3)-(8) . Additionally, latent heat ($h_{fg}$) demonstrated in the upper and bottom stage was employed to calculate for the distillation rate productivity; $m_d$ and eventual figured out the efficiency of solar-based distillation system according to equation (10). Other input parameters are shown in Table 1**.**

## 3. EXPERIMENTAL SET UP

### *3.1 Distillation unit design*

A double-slope basin type distillation unit was designed for water distillation. As shown in Fig. 1, the dimension of the distillation under was generally 150 x 100 cm. and the water level was 20 cm. A water channel was installed in each level of the unit .Each section of the upper stage contained varied surface area zinc heat absorber .The bottom stage of unit contained a panel of insulator and the glass slope made a 14$^o$ slope with the base of the unit.

Experiments on the distillation unit were conducted to monitor the solar intensity per hour, amount of distillation per day performed by each section of the unit and temperature variations inside the distillation unit. These quantities are then employed to determine the efficiency of the distillation unit using different size heat absorber from 10% to 90% of the size of water surface in the bottom section of the unit. Temperature were measured at each location including temperature of the insulator ($T_{ins}$) temperature of water surface in the bottom section ($T_{ws1}$) temperature of glass in the bottom , section ($T_{gl1}$)tempeatuer of water surface in the upper , section ($T_{ws2}$)and temperature of glass in the upper section ($T_{gl2}$). The basin in the bottom level is filled with 75 liters of water and the upper level is filled with 24 liters of water. A measuring volumetric flask was employed to measure volume of the collected distillate water, the wind speed was measured by a digital flow meter, and temperature was measured by a digital thermometer.

## 4. RESULTS AND DISCUSSION

### *4.1 Solar-based distillation unit*

In this experiment black gasket was modified to be used as heat absorber with varied size as a percentage of the area of water surface in the bottom section of the distillation from 10% to 90%. The amount of distillated water produced as measured which was then use to find the efficiency of the distillation unit. Solar flux was monitored for the 10% heat absorber on March 5$^{th}$ 2019 which can be regarded as one of hottest month of the year. The average solar flux was equaled to 542.21 W/m$^2$. The maximum total solar flux measured exactly at noon was 873.8 W/m$^2$

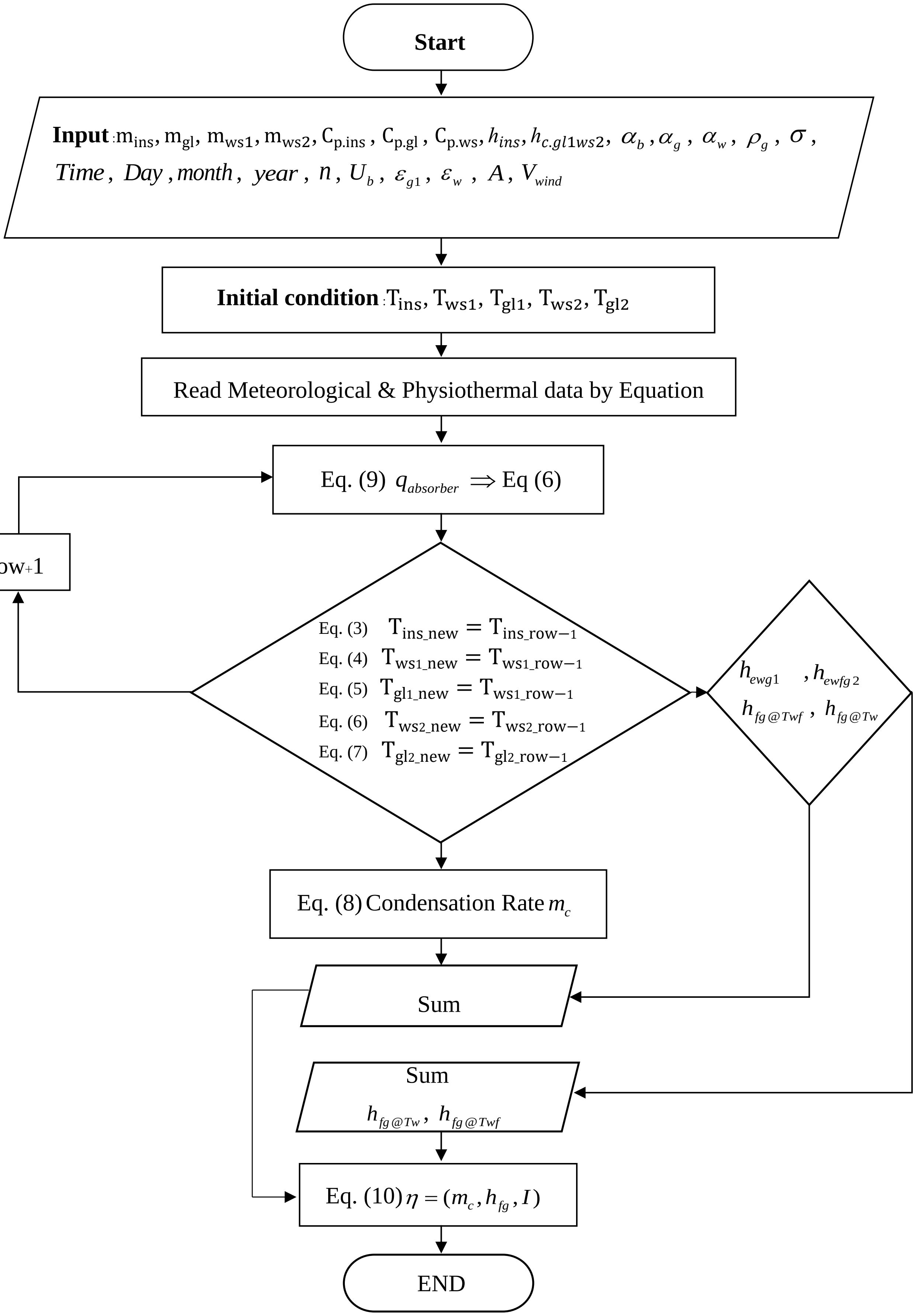



**Fig. 1.** **Using Engineering Equation Solver (EES) to find efficiency of the distillation unit use in the experiment.**

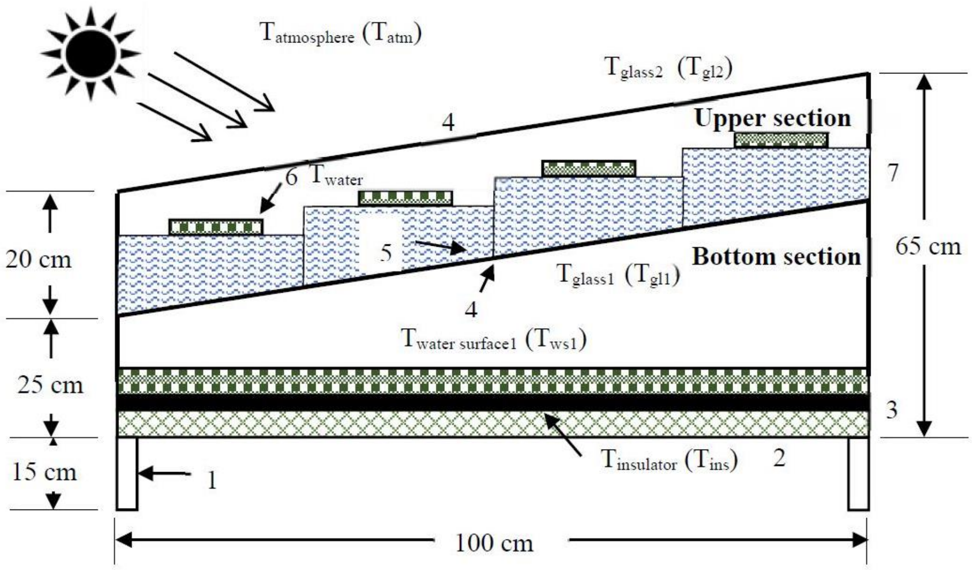



**Fig. 2. Model of solar still water distillation. 1. Distillation leg stand, 2. Bottom wall, 3. Insulator, 4. Glass cover, 5. Upper gutter, 6. Heat absorber and 7. Inlet water.**

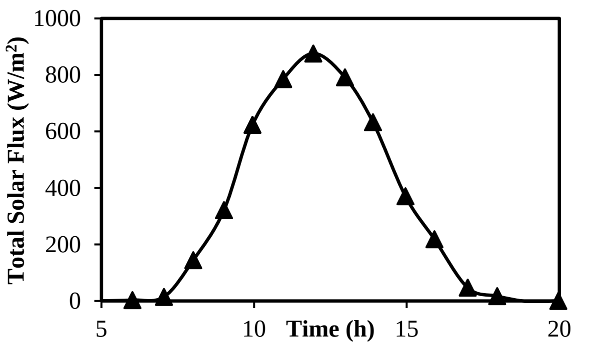



**Fig. 3. Monitoring solar flux from 7:00 A.M. to 19:00 P.M for black gasket with 10% heat absorber.**

### *4.2 Distribution of temperature inside the distillation unit*

Fig. 4 demonstrated temperature measured at five points inside the distillation unit. Maximum temperature was measured at 15:00 for all points inside the distillation unit. Temperature of the insulator located at the bottom section of the distillation unit was found to be the highest compared with other location (53.4 °C). Component of the distillation unit that demonstrated the lowest temperature was the glass screen located at the upper section (also peaked at 15:00 at 45 °C). Temperature measured for water surface in the upper and bottom section of the distillation unit was quite different. It was also observed that the temperature different between water and glass screen in the bottom section was significantly lower than that of the upper section of the distillation unit. The different in temperature was clearly noticeable when data was recorded after 13:00. This temperature difference created a gradient for heat transfer to take place from low to higher temperature difference. The highest difference in temperature recorded in the bottom section was 1.23 °C. For the upper section the temperature difference was 1.67 °C.

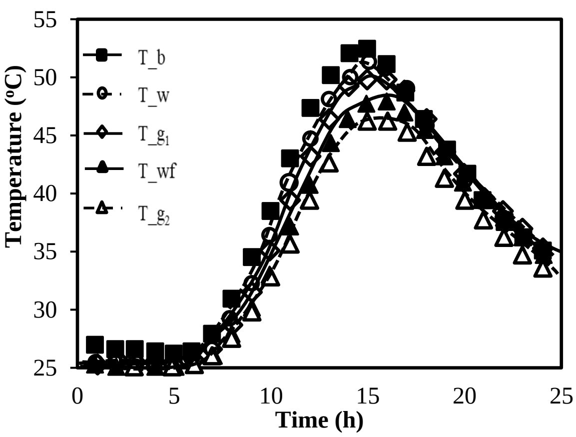



**Fig. 4. Temperature distribution profile recorded in water distillation unit with10% black gasket plate heat absorbers.**

### *4.3 Temperature different between water and glass surface*

Fig. 5 demonstrated difference in temperature measured between the glass and water surface in the bottom and upper section of the distillation unit. These measurements were recorded between 7:00 in the morning to 24:00 at night. Up until 10:00 in the morning, the temperature difference between water and glass in upper and bottom section are very close together. An increase in temperature difference between the upper and bottom section incline significantly after 11:00 in the morning. It is observed that after the initial period the temperature difference in the upper section is significantly higher than the temperature difference in the bottom section. The maximum temperature different recorded in the bottom section and upper section of the distillation unit was 6.2 °C and 7.9 °C.

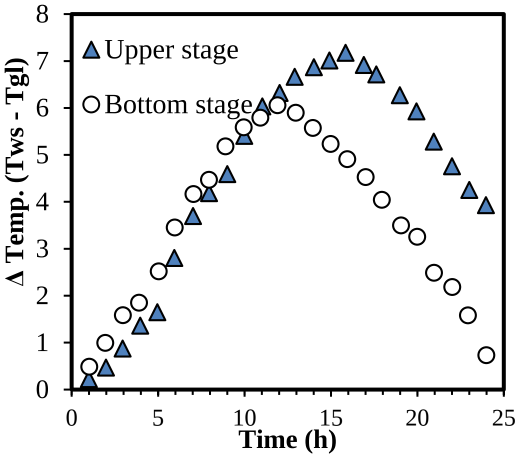



**Fig. 5. Temperature difference between glass and water body in the upper and bottom section.**

### *4.4 Productivity of treated water and distillation rate*

Fig. 6 illustrated the collection of distilled water content over time from 10:00 in the morning to mid-night. The total collection of treated distilled water reached 1.4 litres over the period of the experiment. Productivity increased at an accelerated rate from 10:00 in the morning to 16:00 in the eveningUnlike the bottom section, the accumulation of distilled water continued after 17:00 in the evening According to Fig. 7,the distillationrate in the upper section was significantly higher than that of the bottom section. This is because of the formation of temperature gradient between water body and glass in th upper section. The maximum rate of water distllation recorded at 15:00 was 0.26 g/s·m$^2$ from the upper section a0.007 g/s·m$^2$from the bottom section. Distillation activity was not detected before 8:30 because the energy accumulated is not yet higher than latent heat.

Formation of the mathematical equations to predict productivity based on the period of time was also conducted. Among different mathematical models, polynomial model was found to sufficiently predict the outcome of the experiment. As shown in equation (11), productivity can be calculated as a function of operating time through the sixth order polynomial equation. Calculated value from equation (11) give very close productivity compared with the experimental data. Statistical analysis was revealed $R^2$ very closer to 1.

$$y = 4x10^{-7}t_o^6 - 3x10^{-5}t_o^5 + 0.0008t_o^4 - 0.0096t_o^3 + 0.0528t_o^2 - 0.1245t_o + 0.1111 \quad (11)$$

where $t_o$ is the operating time of the distillation unit.

### *4.5 Effect of operating conditions on rate of distillation*

Fig. 8 showedthe influence of operatin conditions such as insulator's thermal conductivity, heat absorber's conductivity and water height on the rate of water distllation. The rate of distillation increased as the wind speed inclined from 1 m/s to 10 m/s. However, in the upper section an increase in water height resulted in reduction in the rate of distillation. This is because water shield the heat absorber from being directly exposed to sunlight causing a significant reduction in energy input. Similarly, an increase in insulator's thermal conductivity also caused a decline in distillation rate. In contrary, the rate of distillation increases with heat absorber conductivity. The effect of heat absorber size on distillation efficiency is shown in Fig. 8f.

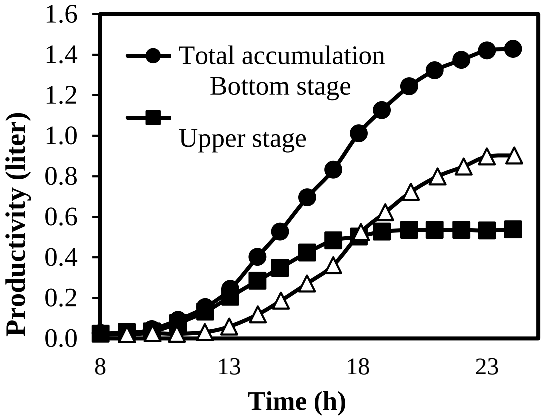



**Fig. 6. Accumulated sampling of distilled water product from 8:00 to 24:00 at night using distillation unit with 10% black gasket heat absorber.**

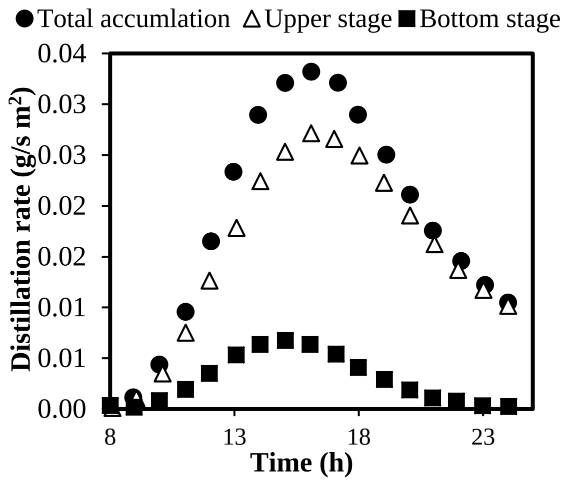
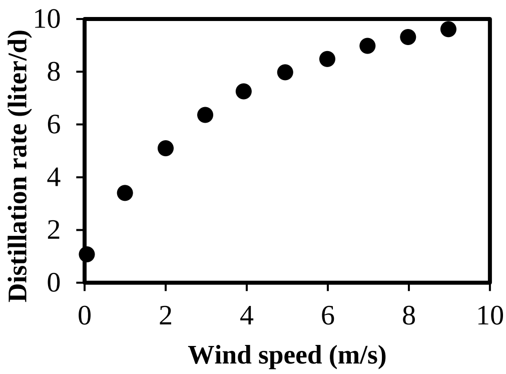


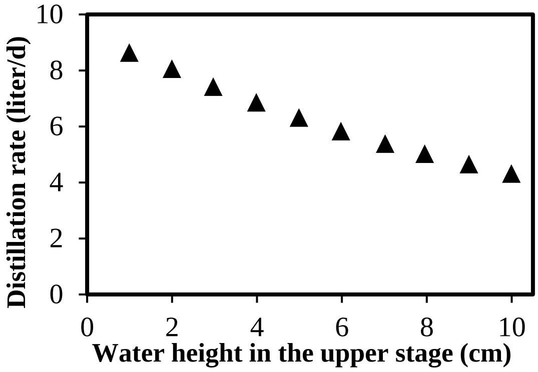

**Fig. 7. Distillation rate calculated based on the period of time from 8:00 to 24:00.**

A mathematical model employed for the prediction of efficiency as a function of the size of heat absorber was a polynomial equation of the fourth order, as shown in equation (12). The $R^2$ of 0.9973 suggested that the equation for predicting efficiency as a function of the size of heat absorber ($S_o$) is accurate compared with the experimental data.

$$\text{Efficiency (\%)} = 9x10^{-7}(S_o)^4 - 0.0002(S_o)^3 + 0.0106(S_o)^2 - 0.3492(S_o) + 28.359 \quad (12)$$




(a)

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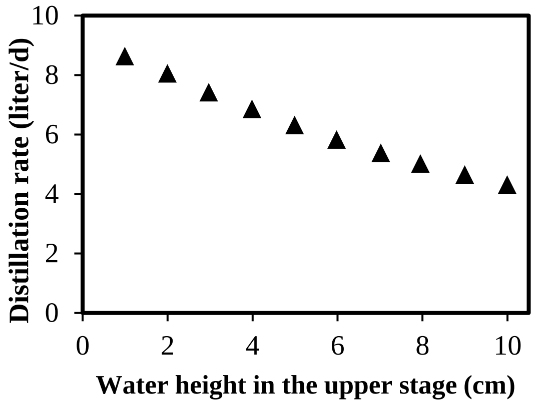


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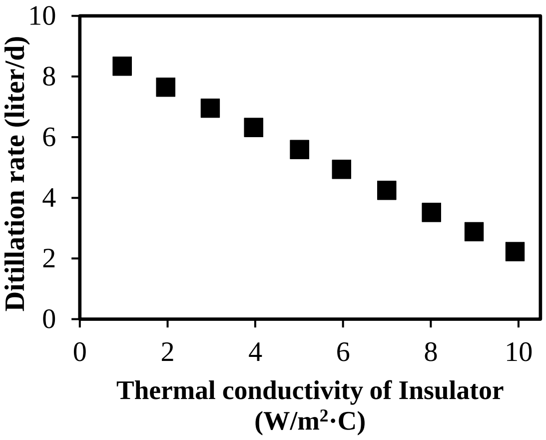


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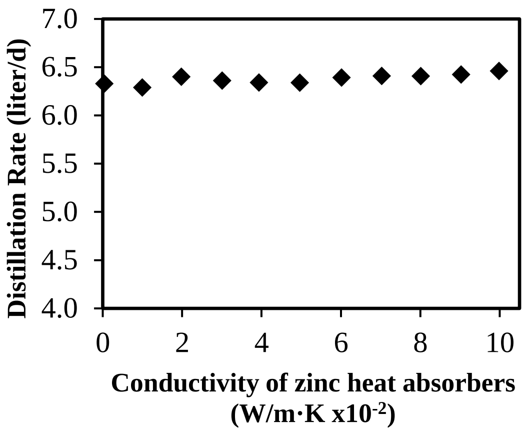


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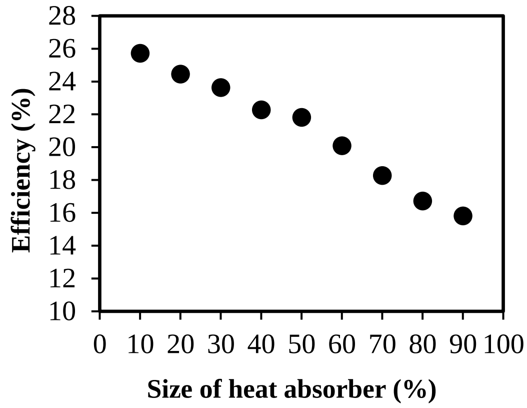


(f)

**Fig. 8. Effect of operating conditions including wind speed water height, insulator thermal conductivity and heat absorber conductivity on the distillation rate.**

A comparison between efficiency and productivity of different materials for heat absorber is shown in Fig. 9. It is clearly demonstrated that heat transfer capability of aluminum heat absorber is the highest followed by Zinc. Black rubber and black gasket have similar efficiency and productivity.

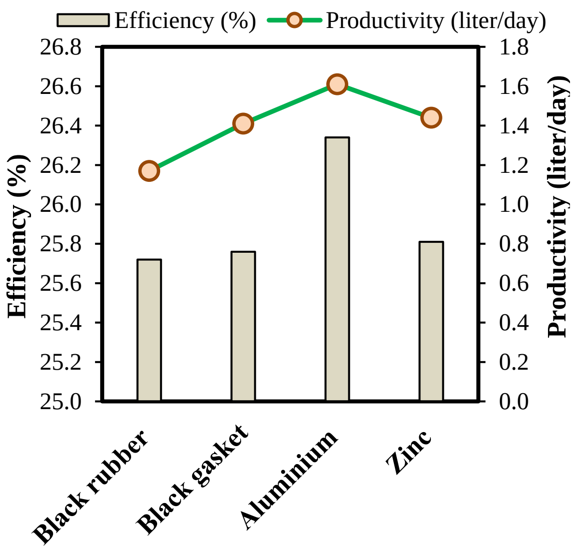


**Fig. 9. Comparison between efficiency and productivity of distillation unit with different type of heat absorbers.**

## 5. CONCLUSION

In this study, the effect of using black gasket as a heat absorber for the solar-based distillation unit has been investigated. An increase in area of the heat absorber was found to cause a reduction in the efficiency of the distillation unit. The highest productivity of distilled water was 1.15 liter per day collected from the distillation unit which was equaled to 24.85% efficiency using 10% heat absorber. The lowest amount of distilled water of 1.01 liter per day (efficiency of was obtained of 22.53%) was obtained from a 90% area black gasket. The highest distillation rate of 26 $g/s{\cdot}m^2$ was recorded at 15:00 in the upper section and 0.007 $g/s{\cdot}m^2$ in the bottom section. An increase in wind speed has a positive effect on the distillation rate. Water height and insulator's thermal conductivity have a negative impact on the distillation rate. Two mathematical models were obtained for predicting the productivity of distillation as a function or operating time throughout the day and efficiency based on the size of the black gasket heat absorber. Both polynomial equations gave $R^2$ value very close to 1 which suggested that the models can be used to predict productivity and efficiency. Performance testing of other materials as heat absorber indicates that aluminum has the highest efficiency and productivity.

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## NOMENCLATURE

| | |
|---|---|
| $m_g$ | Glass screen weight, kg |
| $m_b$ | Insulator weight, kg |
| $C_{pg}$ | Heat capacity for glass material, J/kg°C |
| $C_{pw}$ | Heat capacity for water, J/kg°C |
| $\varepsilon_g$ | Glass emissivity |
| $\varepsilon_w$ | Water emissivity |
| $\alpha_g$ | Radiation absorbed by the glass screen |
| $\alpha_w$ | Radiation absorbed |
| $\rho_g$ | Glass reflectivity, kg/cm$^3$ |
| $U_b$ | Overall heat transfer coefficient, W/m$^2$K |
| $T_b$ | Temperature for the insulator, °C |
| $T_{g1}$ | Temperature for the glass screen in the bottom layer, °C |
| $T_{g2}$ | Temperature for the glass screen in the upper layer, °C |
| $T_w$ | Temperature for water surface in the bottom layer, °C |
| $T_{wf}$ | Temperature for water surface in the upper layer, °C |

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