Design and Testing of Basin Type Solar Still With Lid Afloat

Ahmed Walaa, and Amr Mesalem
Military Technical College, Cairo,Egypt, ahmedwalaaomar@gmail.com, amrmesalem@gmail.com,
Supervisor: Ahmed ELWeteedy,Dr, Salman Elshamarka,Dr
Military Technical College, Cairo,Egypt, aelweteedy@gmail.com, selshamrka@mtc.edu.eg

Abstract**– *This paper presents experimental and theoretical work, analyzing the performance of single slope solar still. conducted in Cairo, Egypt. A Comparison of the experimental output yield of the solar still with the theoretical output yield was carried out. Getting the results of different parameters as basin water temperature, glass cover temperature, and the productivity of the still. The experimentations without lid were conducted for 7 consecutive days and the daily output yield ranges from (2.8 liter/day to 3.15 liter/day) with an average output yield of 52% when compared with the theoretical output yield. To improve the output yield of the still, a black fibrous lid was used as our testing material and studied its effect on the output yield. Because of its porosity the evaporation surface area of the still was improved, water depth is considered small above its surface. The experimentations with lid were conducted for 6 consecutive days and the daily output yield ranges from (3.1 liter/day to 3.3 liter/day) with an average output yield of 57.95 % when compared to the theoretical yield.*****

Keywords: single slope, solar still, passive type, floating lid, output yield.

I. INTRODUCTION

The Environment is composed of four main components Air, water, soil, and energy. Without them there won't be an environment, simply there won't be life on earth. Water comes clearly in the second place after air for the existence of life. The water covers a huge area of the earth's surface, more than two-thirds of the earth's surface. About 97.5% of water resources are found in seas and oceans which are not suitable for human consumption as they contain high salty water (3000 part per million to 35000 part per million), and the remaining 2.5% are freshwater present in the lakes, rivers, polar ice, and groundwater. So only a small portion of freshwater is being used in irrigation, industry, and fulfilling the domestic demand.

The world is expected to face the problem of leakage of drinking water due to an increase in population and fast industrial development. Pollution of freshwater resources (rivers, lakes, and underground water) by industrial wastes has heightened the problem as well.

One of the most sustainable solutions to provide fresh water for many communities is water desalination. Desalination is a process in which saline water is separated into two parts using different forms of energy, one that has a low concentration of dissolved salts (freshwater), and the other which has a much higher concentration of dissolved salts than the original feed water (brine concentrate) [1]. Saline water is classified as either seawater or brackish water depending on the salinity and water source.

Large commercial desalination plants that use fossil fuels are in use in most of the countries suffering from water shortages. For instance, several oil-rich areas of the world have neither the financial nor oil resources to allow them to develop similarly. The production of 1000 cubic meter per day of freshwater requires 10,000 tonnes of oil per year [2], which can be considered a highly significant energy consumption, as it involves a recurrent energy expense which few of the water-short areas of the world can afford. The cost of conventional desalination systems operating using fossil fuels keeps increasing due to the increase of world energy prices. Recently, the utilization of renewable energy sources to drive desalination plants appears to be very promising, as it is a sustainable, cheap, and reliable solution for freshwater supply in regions lacking energy supply. Recently, attention has been directed towards improving the coupling of solar energy systems and desalination technologies (which called solar still). Extensive research and activities have been conducted for the sake of reaching this goal.

There are two types of solar still systems which are active solar still and passive solar still. In the active solar still, direct solar radiation and additional thermal energy are fed into the basin. Active distillation systems have been developed to increase the output of distilled water. Raju & Narayana [3]presented experimentally the effect of integrating of flat plate collector (FPC) with solar still. The result found that connecting two FPCs in series with solar still, provides 41% more distilled water when compared with a single FPC. Singh [4] discussed the improvement in the performance of a solar still integrated with evacuated tube collector and showed that the best combination has been found by integrating 10 evacuated tubes with a water depth of 3 centimetre with a maximum daily output yield of 3.8 liter per squared meter. Sampathkumar [5]discussed the performance of various active solar distillation systems.

In passive solar still, the water in the basin is heated by solar radiation directly so the productivity is very low compared to active solar still. The daily output yield of passive solar still can be increased by changing the design of conventional still (single slope) or by making modifications in the conventional design. Prasad and Sathyamurthy [6]made a comparison between the output yield of triangular basin solar still (TBSS) and conventional basin solar still (CBSS), the experiment revealed that The daily output yield obtained from

CBSS and TBSS was found to be 2.7 and 3.2 kg/m, respectively. Also, the daily efficiency of the TBSS was improved by 11.36% than the CBSS.

VembathuRajesh & Sundaram [7]designed and fabricated a concave type solar still with four glass cover surface (Pyramid shape) and studied it experimentally. The results show that the average productivity during the daytime is 4L/m^2 with a system efficiency of 0.38, higher than the conventional type solar still. T. Arunkumar & R. Jayaprakash [8] made an experimental study on hemispherical solar still which has a higher efficiency than conventional solar still and compared the daily distillate output with and without flowing water over the cover The efficiency was 34% and increased to 42% with the top cover cooling effect (flowing water). Laxmikant [9] investigated experimentally a concave-type solar still with different temperature and solar intensity and it was noted that The highest daily productivity (3.7 l/m^2. day) was achieved during march 2020 This may be attributable to the highest average intensity of the radiation (1005 W/m^2) and the most top average temperature difference of 10.5 °C. H.E. Gad & Sh. Shams El-Din [10]manufactured and compared the experimental results of conical solar still with conventional type solar still with the same area. The results showed that the daily productivity for conical and conventional solar stills were 3.38 and 1.93 L/m^2/day. Many researchers made modifications to designs other than conventional solar still, to increase the output yield even more. Also, many researches were made about modifications in conventional solar still concerning the different parameters and their effects on the yield.

Table 1 shows the recent modifications in conventional solar still.

Table 1 Modifications on conventional solar still

Researcher	**Modification**	**Results**
K.K. Matrawy [11]	Formed the evaporative surface as a corrugated shape. Decreased the heat capacity by using porous material.	Improvement of about 34% in the productivity.
Abdallah& Abu-Khader [12]	Discussed the effect of various absorbing materials on the thermal performance of solar stills. materials: black coated and uncoated metallic wiry sponges, and black rocks.	Distilled water collections were 28%, 43%, and 60% for coated and uncoated metallic wiry sponges and black rocks respectively.
Srivastava & Agrawal [13]	Modification is made by incorporating multiple low thermal inertia porous absorbers, floated adjacent to each other	Increase in the evaporation surface area. On clear days 68% more distillate output was obtained. 35% more on cloudy days
Agrawal & R. S. Rana [14]	multiple V-shaped floating wicks are used to enhance heat absorption and thereby increase productivity.	The evaporative surface area of modified solar still is 26% larger than that of conventional solar still. The maximum daily productivity in one of the clear days is found to be approximately 6.20 kg/m2 in summer and 3.23 kg/m2 in winter with daily efficiencies of 56.62% and 47.75%.
Gawande & Bhuyar [15]	Discussed the Effect of Shape of the Absorber Surface on the Performance of Stepped Type Solar Still. The shape of the absorber surface provided in the basins of solar stills was flat, convex, and concave.	When the convex and concave type, the average daily water production has been found to be 56.60% and 29.24% higher than that of flat type.
Ana Johnson & Lei Mu & Valles[16]	Performed a theoretical and experimental study on single-basin solar still when an external solar enhancement is used (Fresnel lens)	Parametric study by varying the water depth showed the Fresnel lens was more effective for larger water depths. The Fresnel lens can aid in improving the overall efficiency of the solar still.

Gupta& Sharma& Baredar [17]	-Studied the performance of modified solar still using water sprinkler. Attachment of water sprinkler with constant water flow rate of 0.0001kg/s on the glass cover.	The distilled water output was recorded 2940 ml and 3541ml from conventional and modified solar stills respectively. Water productivity (output yield) of single slope solar still is increased by 20%. The overall efficiency is increased by 21% over the conventional solar still.

Nomenclatures

A_b	Basin liner surface area of still (m^2)
A_s	Basin sidewall area of still (m^2)
C_w	Specific heat of water in solar still(J/kg °C)
C_i	Specific heat of insulation in still(J/kg °C)
d_w	Water depth in basin(m)
h_{cwg}	Convective heat transfer coefficient from basin water to glass cover (W/ m^2 °C)
h_{ewg}	Evaporative heat transfer coefficient from basin water to glass cover (W/ m^2°C)
h_{rwg}	Radiative heat transfer coefficient from basin water to glass cover(W/ m^2°C)
h_{twg}	Radiative heat transfer coefficient from basin water to glass cover(W/ m^2°C)
h_{cga}	Convective heat transfer coefficient from glass cover to ambient (W/ m^2 °C)
h_{rga}	Convective heat transfer coefficient from glass cover to ambient (W/ m^2°C)
h_{tga}	Total heat transfer coefficient from glass cover to ambient (W/ m^2 °C)
h_{cbw}	Convective heat transfer coefficient from basin liner to water(W/ m^2 °C)
h_{tba}	Total heat transfer coefficient from basin liner to ambient(W/ m^2°C)
h_{ba}	Total heat transfer coefficient from bottom of basin to ambient (W/ m^2°C)
h_{cba}	Convective heat transfer coefficient from bottom of basin to ambient (W/ m^2 °C)
h_{rba}	Radiative heat transfer coefficient from bottom of basin to ambient (W/ m^2 °C)
I(t)	Solar Intensity (W/ m^2)
K_i	Thermal conductivity of insulation(W/m °C)
L_{ev}	Latent heat of vaporization of water(J/kg)
$t_g L_i$	Thickness of insulation(m)
m_w	Mass of water in basin(Kg)
M_w	Hourly distillate output per unit basin area (Kg/ m^2 /h)
M'_w	Daily distillate output per unit basin area (Kg/ m^2/d)
P_w	Partial saturated vapor pressure at a basin water temperature (N/ m^2)
P_g	Partial saturated vapor pressures at glass cover temperature(N/ m^2)
q_{cwg}	Convective heat transfer from basin water to glass cover (W/ m^2)
q_{ewg}	Evaporative heat transfer from basin water to glass cover (W/ m^2)
q_{rwg}	Radiative heat transfer from basin water to glass cover(W/ m^2)
q_{twg}	Total heat transfer from basin water to glass cover (W/ m^2)
q_{cga}	Convective heat transfer from glass cover to ambient (W/ m^2)
q_{cba}	Convective heat transfer from the bottom of the basin to ambient (W/ m^2)
q_{rba}	Radiative heat transfer from the bottom of the basin to ambient (W/ m^2)
R_g	Reflectivity of glass cover
R_w	Reflectivity of basin water
R_b	Reflectivity of basin liner
t	Time interval(s)
t_g	Glass cover thickness(m)
T_g	Glass cover temperature(°C)
T_w	Basin water temperature(°C)
T_b	Basin liner temperature (°C)
T_a	Ambient temperature (°C)
T_{sky}	Sky temperature(°C)
U_b	Overall bottom heat transfer coefficient from bottom to ambient (W/ m^2 °C)
U_t	Overall top heat transfer coefficient from basin water to ambient(W/ m^2 °C)
U_L	Overall heat transfer coefficient for still (W/ m^2°C)
V_w	Velocity of Wind(m/s)

Greek symbols

α_g	Absorptivity of glass cover
α_w	Absorptivity of basin water
α_b	Absorptivity of basin liner
α'_g	Fraction of solar flux absorbed by a glass cover
α'_w	Fraction of solar flux absorbed by basin water
α'_b	Fraction of solar flux absorbed by basin liner
ε_g	Emissivity of glass cover
ε_w	Emissivity of basin water
ε_b	Emissivity of basin liner
ε_{eff}	Effective emissivity between water surface and glass cover
σ	Stefan–Boltzmann constant
μ_j	Fraction of solar flux having extinction coefficient
η_j	Extinction coefficient
η	Efficiency of solar still

q_{rga}	Radiative heat transfer from glass cover to ambient (W/ m^2)	**subscripts**	
q_{tga}	Total heat transfer from glass cover to ambient (W/ m^2)	a	ambient
q_{cbw}	Convective heat transfer from basin liner to water (W/ m^2)	g	Glass cover
q_{tba}	Total heat transfer from basin liner to ambient (W/ m^2)	w	Basin water
q_{ba}	Total heat transfer from bottom of basin to ambient (W/ m^2)	b	Basin liner

There are many Parameters that affect the evaporation rate, studying the effect of these parameters helped in increasing the evaporation rate. Hence, better yield. One of these parameters is the water depth; it was found out that the evaporation rate is inversely proportional to water depth. Abhay Agrawal & R.S. Rana [18] made an experimental and theoretical comparison of the daily output yield for different water depths from 2 cm and 10 cm. the experimental value for daily efficiency was around 41. 49% and 32.42% respectively. It is obvious that to achieve a higher efficiency of a solar still, heat loss should be minimized by adequate insulation. Khalifa & Hamood [19] studied experimentally the effect of insulation thickness on the productivity of solar still and developed a performance correlation for the effect of insulation on the productivity. Their study showed that the insulation thickness could influence the productivity of the still by over 80%.

In this paper, detailed experimental work is used to investigate the effect of a floating lid on productivity. The work is conducted in The Military Technical College (MTC), Cairo, Egypt. The paper is organized as follows: first, a physical model for a solar still with net dimensions of 1m*1m is constructed; then, theoretical analysis was conducted for the solar still; finally, the calculation methodology and results were introduced.

II.EXPERIMENTATIONs

A. Experimental setup

The solar still is designed and constructed to compare the productivity of the solar still with and without the floating lid. The experiment was conducted in Military Technical College (MTC), Cairo, Egypt (Latitude:30, Longitude:31). The solar still takes the design of a box with dimensions of 1.3m length, 1.1m breadth, and 0.9m height. the box was made of plywood with 0.05m thickness. It has four sides, two of these sides are rectangular and the other two are trapezoidal. The area available for water is 1m*1m. the basin has three holes one for feeding water, one for impure water outlet, and the third for distilled water output. All the holes have PVC pipes. The outside walls are insulated with glass wool with thermal conductivity k=0.035w/m K. The distillate channel is covered with polyester fabric with a slope of 1/10 to ease the flow of distilled water through the hole to reach the graduated flask insulated with the same material as still. The distilled water passes from the PVC pipe to the flask through a U-tube (act as a manometer) to prevent any air from entering the still. The condensing surface is a normal glass with a thickness of 8mm, emissivity =90%, reflectivity=6%, and absorptivity=4%. The glass is inclined at an angle of 30° which is equal to the latitude of Cairo. Silicon rubber was used to fill the gaps between plywood edges. The basin was coated with black painted polyester fabric (used for making banners) to enhance the absorptivity of solar radiation. Figure shows the design model for the solar still using Solidworks software and Figure shows the constructed physical model.

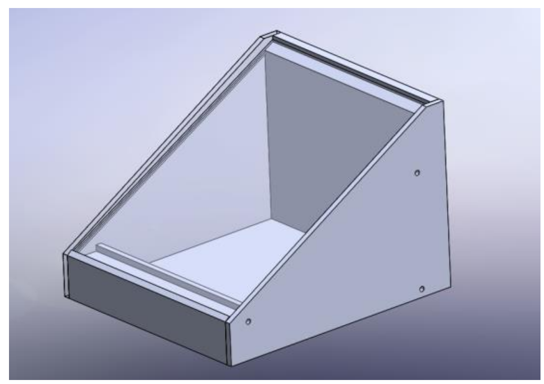

Figure 1 Solidworks model for the designed solar still

Figure 2 Photograph of the constructed solar still

B. Procedures

The experimental work was conducted for two cases; first, solar still without lid; second, solar still with lid afloat.

1) solar still without lid afloat

The experiments were conducted for seven days of the summer season,2021 at Military Technical College (MTC), starting from (July 1^{st}) to (July 7^{th}). The solar still was placed in the south direction. Solar radiation intensity was measured by using a pyrometer. Wind velocity was taken from the website: timeanddate.com and these data were used in the theoretical calculation. Both water temperature and glass cover temperature were measured with Ni/Cr electric thermometer and were compared with the theoretical values. The water depth was set to be 3 cm at the beginning of each experimental day. The condensed water was collected in a graduated flask. The yield was considered every 24 hours starting at 7:00 am. The measured solar radiation intensity range was (0 to 990.8 w/m^2) and wind velocity was (0 to 7.78 m/s).

2) solar still with lid afloat

The experiments were conducted for six days starting from (July 8^{th}) to (July 13^{th}). A black fibrous lid was placed on the surface of the water. The black color to enhance the solar absorptivity. Also due to the porosity of the lid, the evaporative surface area of the still was increased. The collection of the distilled water was taken every 24 hours starting from 7:00 am. Solar radiation intensity range was taken as (0 to 989.7 w/m^2) and wind velocity was taken as (1.11 to 7.78 m/s).

III. THERMAL ENERGY CALCULATION

Thermal energy balance has been made for the solar still. The following assumptions are considered to simplify the analysis:

- The physical properties of water remain constant with changes in temperature.
- Water vapor and dry air are assumed to be ideal gases.
- The outer temperature of the glass equals the inner temperature of the glass.
- The still is assumed to be completely vapor leakage proof.

a. Energy balance equations glass cover, water mass, and basin linear [18]

1) Glass cover

The glass receives heat from internal and external sources by different methods, externally from the incident solar radiation and internally from basin water surface through three methods (convection, evaporation, and radiation) and reject the received heat to the atmosphere through two methods (convection and radiation).

$$\alpha'_g I(t) + q_{twg} = q_{tga} \quad (1)$$

Where,

$$q_{twg} = q_{cwg} + q_{ewg} + q_{rwg} \quad (2)$$

$$q_{tga} = q_{cga} + q_{rga} \quad (3)$$

$$\alpha'_g I(t) + h_{twg}\left(T_w - T_g\right) = h_{tga}\left(T_g - T_a\right) \quad (4)$$

2) Basin water

Basin water absorbs energy released from the basin liner and consumes it in two ways, some energy is stored in water due to its specific heat, and the rest is transferred to the glass cover through three methods (convection, evaporation, and radiation).

$$\alpha'_w I(t) + q_{cbw} = q_{twg} + m_w c_w (dT_w/dt) \quad (5)$$

$$\alpha'_w I(t) + h_{cbw}(T_b - T_w) = h_{twg}\left(T_W - T_g\right) + m_w c_w (dT_w/dt) \quad (6)$$

3) Basin liner

Basin linear absorbs heat energy from the solar radiation transmitted from the glass and releases this energy to basin water and the rest to the atmosphere by conduction and convection through walls of the still.

$$\alpha'_b I(t) = q_{cbw} + q_{tba} \quad (7)$$

$$\alpha'_b I(t) = h_{cbw}(T_b - T_w) + h_{tba}(T_b - T_a) \quad (8)$$

By solving eqn. (3.4,3.6,3.8) we get,

$$(dT_w/dt) + aT_w = f(t) \quad (9)$$

Where,

$a = U_L/(m_w c_w)$

$f(t) = M\, I(t) + a\, T_a$

$M = (\alpha'_{eff} h_{cbw})/m_w c_w (h_{cbw} + h_{tba})$

The solution of Eqn. (3.9) is

$$T_w = \left(\bar{f}(t)/a\right)(1 - e^{-at}) + Tw_0 e^{-at} \quad (10)$$

The hourly yield equals,

$$M_w = \left(h_{ewg}\left(T_w - T_g\right) * 3600/L_{ev}\right) * A_b \qquad (11)$$

The latent heat of evaporation is calculated by [20],

$$L_{ev} = (2501.67 - 2.389 * T_w) * 10^3 \quad J/Kg \qquad (12)$$

b. Solar still heat transfer analysis

There are mainly two types of heat transfers taking place in the process of solar still (Internal and external)

1) Internal heat transfer:

It occurs between the basin water surface and inner glass cover through three methods (convection, evaporation, and radiation)

First the convection heat transfer,

$$q_{cwg} = h_{cwg}(T_w - T_g) \qquad (13)$$

$$h_{cwg} = 0.884\left[\left(T_w - T_g\right) + \left(P_w - P_g\right)(T_w + 273)/(268.9 * 10^3 - P_w)\right]^{1/3} \qquad (14)$$

Empirical relation is given by Dunkle [21].

Second the evaporation heat transfer,

$$q_{ewg} = h_{ewg}(T_w - T_g) \qquad (15)$$

$$h_{ewg} = (16.28 * 10^{-3})h_{cwg}(P_w - P_g)/(T_w - T_g) \qquad (16)$$

Third the radiation heat transfer,

$$q_{rwg} = h_{rwg}(T_w - T_g) \qquad (17)$$

Also given by Stefan Boltzmann's equation,

$$q_{rwg} = \varepsilon_{eff}\sigma\left[(T_w + 273)^4 - (T_g + 273)^4\right] \qquad (18)$$

From Eqn. (3.17) and (3.18),

$$h_{rwg} = \varepsilon_{eff}\sigma\left[(T_w + 273)^4 - \left(T_g + 273\right)^4\right]/(T_w - T_g) \qquad (19)$$

Total internal heat transfer coefficients,

$$h_{twg} = h_{cwg} + h_{ewg} + h_{rwg} \qquad (20)$$

2) External heat transfer

External heat transfer is contributed by the top, bottom, and sides losses of the solar still.

Top heat losses

It occurs between the outer glass cover and the atmosphere through two methods (convection and radiation). Can be calculated by,

$$q_{tga} = q_{cga} + q_{rga} \qquad (3)$$

Where

$$q_{rga} = h_{rga}(T_g - T_{sky}) \qquad (21)$$

$$q_{rga} = \varepsilon_g\sigma\left[(T_g + 273)^4 - (T_{sky} + 273)^4\right] \qquad (22)$$

From equations (21) and (22)

$$h_{rga} = \varepsilon_g\sigma\left[\left(T_g + 273\right)^4 - \left(T_{sky} + 273\right)^4\right]/(T_g - T_{sky}) \qquad (23)$$

The sky temperature is estimated from [22]

$$T_{sky} = 0.0552 * T_a^{1.5} \qquad (24)$$

$$q_{cga} = h_{cga}(T_g - T_a) \qquad (25)$$

Where from [23]

$$h_{cga} = 2.8 + 3.0V_w \ if \ V_w \le 5 \ m/s \ \& \ 6.15 * (V_w)^{0.8} \ if \ V_w > 5 \ m/s \qquad (26)$$

$$h_{tga} = h_{cga} + h_{rga} \qquad (27)$$

Bottom and side heat losses

It occurs between the water in the basin and the outer atmosphere through the insulation on the sides and base through three methods (conduction, evaporation, and radiation). Can be calculated by,

$$q_{tba} = h_{tba}(T_b - T_a) \qquad (28)$$

The heat loss coefficient from basin liner to the atmosphere,

$$h_{tba} = [(L_i/K_i) + (1/h_{ba})]^{-1} \qquad (29)$$

Where,

$$h_{ba} = h_{rb} + h_{cba} \qquad (30)$$

Side heat loss,

$$h_{sa} = h_{tba} * (A_s/A_b) \qquad (31)$$

3) Solar radiation fractions [24]

Fraction by glass cover,

$$\alpha'_g = (1 - R_g)\alpha_g \qquad (32)$$

Fraction absorbed by water,

$$\alpha'_w = (1 - \alpha_g)(1 - R_g)(1 - R_w)\alpha_w \tag{33}$$

without attenuation factor

$$\alpha'_w = (1 - \alpha_g)(1 - R_g)(1 - R_w)\alpha_w * [1 - \sum \mu_j EXP(-\eta_j d_w)] \tag{34}$$

with attenuation factor

Where, $[1 - \sum \mu_j EXP(-\eta_j d_w)]$ is the attenuation factor depends on water depth [20].

$$T_{gi} = \alpha'_g I(t) + h_{twg} * T_w + U_{tga} * T_a / h_{twg} + U_{Tga} \tag{35}$$

Where U_{Tga} is calculated from,

$$U_{Tga} = (K_g / L_g * h_{tga}) / (K_g / L_g + h_{tga}) \tag{36}$$

And the partial vapor pressures from,

$$P_w = EXP\{25.317 - 5144/(T_w + 273)\} \tag{37}$$

$$P_g = EXP\{25.317 - 5144/(T_g + 273)\} \tag{38}$$

The overall heat transfer coefficients can be calculated from,

$$U_T = h_{twg} * U_{Tga} / h_{twg} + U_{Tga} \tag{39}$$

$$U_b = h_w * h_{ba} / h_w + h_{ba} \tag{40}$$

$$U_{ss} = (A_{ss}/A_b) U_b \tag{41}$$

$$U_L = U_b + U_t + U_{ss} \tag{42}$$

Table 2
Attenuation (Att.) factors for varying water depth

$d_w(m)$	Att. factor
0.02	0.6756
0.03	0.6441
0.04	0.6185
0.05	0.6124
0.06	0.5858
0.08	0.5648
0.10	0.5492

The above equations were set and solved by computer using excel software to get the yield.

IV. CALCULATION METHODOLOGY

A certain procedure must be followed to compute the hourly heat transfer coefficients, water temperature, glass temperature, and productivity.

1. First of all, water temperature, glass temperature, ambient temperature, solar radiation intensity, and wind velocity must be measured and use these values to evaluate the partial vapor pressures P_w & P_g equations (36) & (37), convection heat transfer coefficient h_{cwg} (14), evaporation heat transfer coefficient h_{ewg} (16), radiation heat transfer coefficient h_{rwg} (19) then deduce the total heat transfer coefficient h_{twg} (20).
2. Use the value of h_{twg} to get the value of overall heat transfer coefficients equations (38) to (41) from these values calculate the new value of T_w.
3. From evaporation heat transfer coefficient h_{ewg} calculate the hourly yield M_w (11).
4. From the value of T_w get a new value of T_g (34) and repeat the previous steps.

V. RESULTS AND DISCUSSION

the outputs of the experiment were recorded and compared with the theoretical values. First, Figure 4 shows the difference between the actual and the theoretical yield of the solar still and it shows that the average actual yield along these 7 days is about 52% of the theoretical yield. Figure 5 shows the difference between the actual and theoretical temperatures of both water and glass. Figure 6 shows the solar radiation intensity measured along the day. Second, with a floating lid for 6 days. After calculating the ratio between the actual and theoretical output yield of the first condition. The experimental output yield values of the second condition (with lid afloat) were compared with the ratio from the first condition to indicate the effect of the floating lid on the productivity of the solar still. It was found that the ratio increased to 58% with about 6% of the first condition.

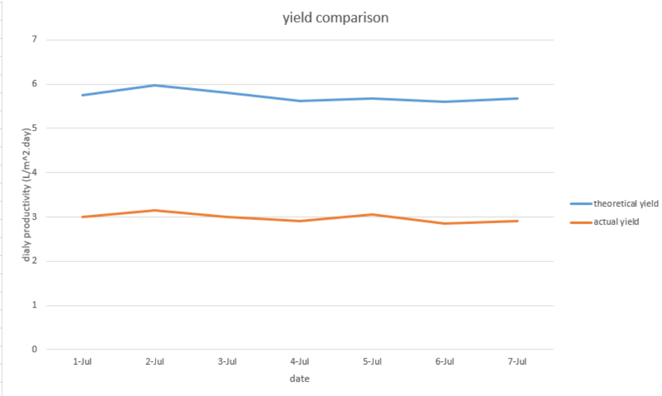

Figure 1 yield comparison without a lid on seven days from (July 1st to July 7th) shows that the actual yield is about 52% of the theoretical yield

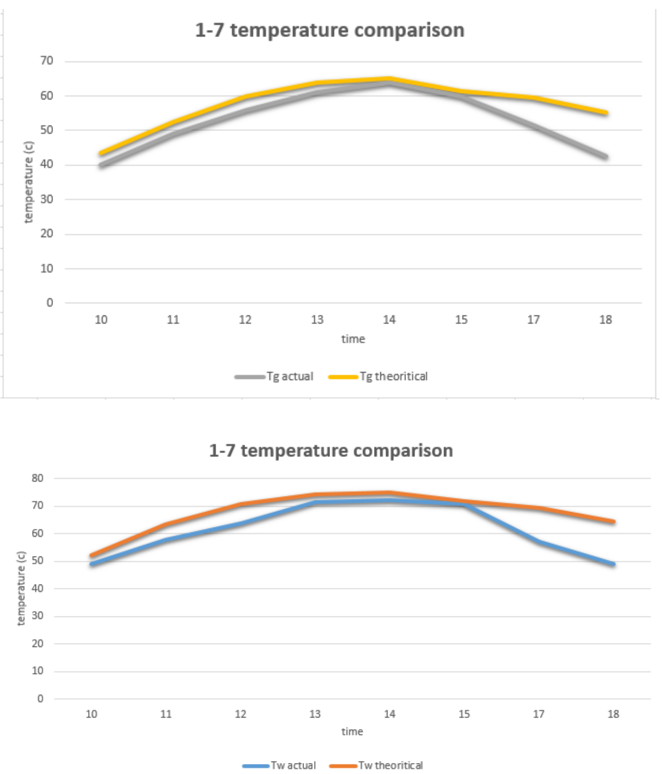

Figure 2 the temperature comparison between the actual and theoretical water and glass temperature on the first day of calculations (1-7-2021)

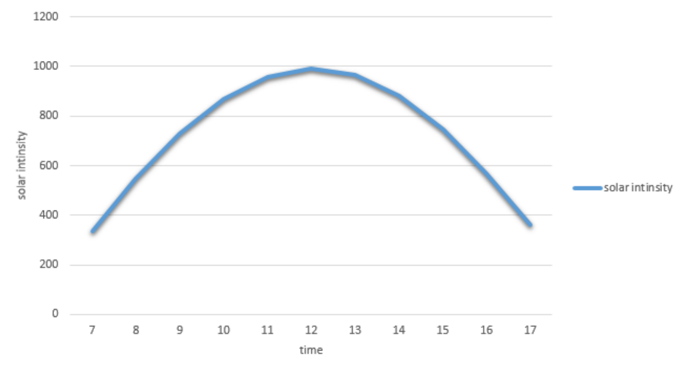

Figure 3 solar intensity taken by pyranometer on the first day of calculations (1-7-2021)

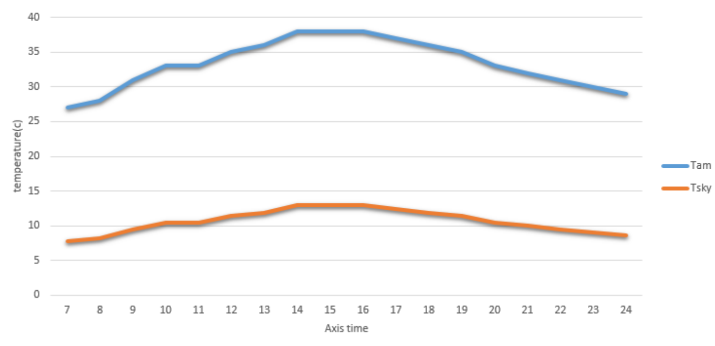

Figure 4 ambient& sky temperature from the website for the first day of calculations (1-7-2021)

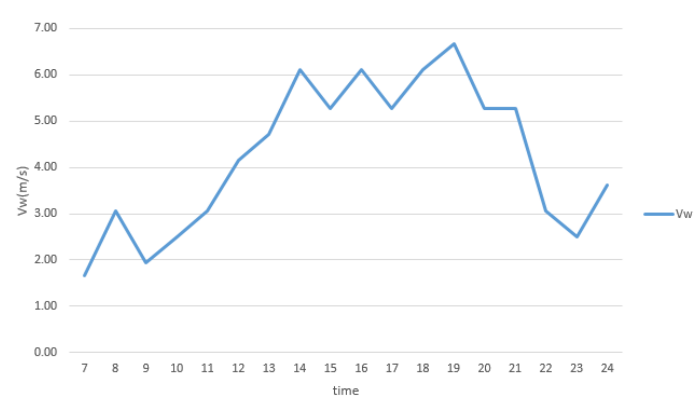

Figure 5 wind velocity from the website for the first day of calculations (1-7-2021)

Table 3
Design parameters

parameters	Numerical values
Basin area, A_b	$1m^2$
Glass absorptivity, $\propto_g$	0.04
Glass reflectivity, R_g	0.06
Glass emissivity, ε_g	0.9
Water reflectivity, R_w	0.05
Water emissivity, ε_w	0.95
Water heat capacity, c_w	4180 J/kg K
Time, t	3600 s
Thickness of glass cover, L_g	0.008m
Glass thermal conductivity, k_g	1.03 W/m K
Thickness of insulation, L_i	0.02m
Insulation thermal conductivity, k_i	0.035 w/m K
Stefan Boltzmann's constant, σ	$5.6697*10^{-8}$ w/$m^2.K^4$
h_w	250 W/m^2 K
Water depth, d	0.03m
h_{ba}	2.8 W/m^2 $°C$
h_{cbw}	250 W/m^2 $°C$ (summer) 200 W/m^2 $°C$ (winter)

VI. CONCLUSION

The single slope solar still was fabricated and investigated. Different parameters as glass temperature, water temperature, and output yield were measured and compared with the theoretically calculated values. Also, this work shows the effect of placing a floating lid (black fibrous lid) which is porous material on the output yield of the solar still. The output yield of the still with a floating lid was compared with the ratio of the experimental and theoretical output yield. It was found that :

1. the output without a lid was 52% of the theoretical output.
2. the output with lid was 58% from the theoretical output.
3. Placing a porous material (black fibrous lid) on the surface of the water increased the productivity by 6% of the regular output.
4. the porous material works as a heat absorber and increases the evaporative area of water because of the surface area of water balls that pass throw the holes of the material by capillary effect.

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