ANALYSIS OF THE SOLAR STILL PRODUCTIVITY BY SIMILITUDE APPLICATIONS

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ABSTRACT

The aim of the present study is to develop mathematical analysis for common design solar still involving all ambient surrounding variables affecting its productivity and coefficient of performance. Two similar units of the solar stills were used namely: Control unit and cooled glass cover unit (cooled unit). The prediction equations for the productivity of the two studied units were reasonably accepted with coefficients of determinations ranged between 98-99%.

It was also found that the cooled unit has highest values of the productivity and coefficient of performance. The daily productivity and average coefficient of performance were 6.1655 kg/m², 59.52% for the cooled unit compared to 5.536 kg/m² and 52.19% for the control unit.

INTRODUCTION

Freich and Sommerfeld (1973) designed a wick-type collector – evaporator or distiller of a shallow depth. They reported that it has a production rate of 3.8-4.4 L/m².day, with an operational efficiency of about 40 to 46 %. Mostafa et. et. al. (1994) mentioned that the productivity of solar stills reaches its maximum value at an optimum cover slope. They added that the slope depends on the time of the year, the location of still, and the ambient conditions. An average slope of 20 to 25 degrees from the horizontal shows satisfactory results for a wide range of stills. Ernani (1996) studied a solar still versus solar evaporator. He concluded that, the distillation rate increases with increasing water temperature and temperature differences. Zabady (1997) mentioned that the total daily productivity decreases from 4646 to 4506, 4416 and 4323 cm³/m².day with brine depth increased from 0.5 to 1.0, 1.5 and 2 cm respectively. The nocturnal production increased from 835 to 850, 900 and 912 cm³/m² when brine depth increased from 0.5 to 1.0, 1.5 and 2 cm respectively. Abdel-Rahman (2009) reported that at a maximum recorded
value of solar intensity 825 w/m$^2$, and the corresponding air temperature of 40.7 °C, the maximum and minimum solar still productivity and the corresponding transpiration rate accomplished in September were 3196, 1910 g/m$^2$ and 2234, 1254 g/m$^2$ respectively. Tayel et. al. (2009) designed and evaluated four different units of solar stills namely: control unit, preheated unit, air blowing unit and air suction unit. They studied several parameters affecting the productivity of the solar still as: brine depth, slope angle of glass cover, feeding water and covering materials. They reported that the preheating unit has the highest productivity (6030cm$^3$/m$^2$. day) with brine depth of 0.0 2 m, slope angle of 20º.

**THEORITICAL APPROACH**

The first step in the similitude application is to define the most associated variables affecting the phenomena under investigation. The following are the pertinent and independent variables considered to affect the productivity of the solar still. Their units and dimensions are as follows:

<table>
<thead>
<tr>
<th>NO.</th>
<th>Symbol</th>
<th>Description</th>
<th>Dimension</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D</td>
<td>Productivity of the solar still</td>
<td>M L$^{-2}$ t$^{-1}$</td>
<td>kg/m$^2$.h</td>
</tr>
<tr>
<td>2</td>
<td>ΔP</td>
<td>Evaporation and condensation potential or the difference between partial pressure at glass cover temperature and water temperature</td>
<td>M L$^{-1}$ t$^{-2}$</td>
<td>kg m$^{-1}$ s$^{-2}$</td>
</tr>
<tr>
<td>3</td>
<td>I$_p$</td>
<td>Solar intensity</td>
<td>HL$^{-2}$ t$^{-1}$</td>
<td>W/m$^2$</td>
</tr>
<tr>
<td>4</td>
<td>Q$_{ec}$</td>
<td>Heat utilized in vaporizing water in the still</td>
<td>HL$^{-2}$ t$^{-1}$</td>
<td>W/m$^2$</td>
</tr>
<tr>
<td>5</td>
<td>ΔT$_{g-a}$</td>
<td>Temperature difference between glass cover and the ambient air.</td>
<td>θ</td>
<td>°K</td>
</tr>
<tr>
<td>6</td>
<td>U$_L$</td>
<td>Over all heat loss coefficient</td>
<td>HL$^{-2}$ t$^{-1}$ θ$^{-1}$</td>
<td>W/m$^2$°K</td>
</tr>
<tr>
<td>7</td>
<td>λ</td>
<td>Brine depth</td>
<td>L</td>
<td>m</td>
</tr>
<tr>
<td>8</td>
<td>φ</td>
<td>Elapsed time</td>
<td>t</td>
<td>h</td>
</tr>
<tr>
<td>9</td>
<td>Cos β</td>
<td>Glass cover tilt angle</td>
<td></td>
<td>dimensionless</td>
</tr>
</tbody>
</table>

The general relationship for the productivity of the solar still as a function of the associated independent variables can be expressed as:
D = F ( ΔP, I_p, Q_{ec}, ΔT, U_L, λ, φ, Cos β ) ...........................(1)

According to the Buckingham Pi-theorem, the number of dimensionless and independent quantities required to express a relationship among the variables in any phenomenon is equal to the number of quantities involved, minus the number of dimensions of those quantities Murphy (1950). In the present study nine quantities with five dimensions is involved. So, four dimensionless groups can be formed. The dimensional analysis yields the following relationship for both tested units:

\[
\frac{λD}{ΦΔp(3600)^2} = \left[ A \left( \frac{Q_{ec}}{I_p} \right) + C \right] \cos β
\]

\[
......................... \ldots.................(2)
\]

Where A and C are functions of π3. The value (3600)^2 is used as conversion factor of Δp to kg m^{-1} h^{-2}. It is notable that π2 represents the C.O.P of the solar still. π3= [U_LΔT_{g-a}/I_p] represents the ratio between heat losses and solar insolation. π_1 includes Δp that represents the potential of evaporation and condensation. π4 is a constant represents the view factor of sky, ground and surrounding with respect to cover tilt angle.

**MATERIALS AND METHODS**

In the present study two similar solar stills were used. The experimental part was carried out on the roof of the Agricultural Engineering Department Faculty of Agriculture Al-Azhar University Nacr City.

**Solar still construction:**

The solar still as shown in Fig.(1) is consists of an evaporator of four sides of galvanized iron sheet of 0.6 mm thick. The basin dimensions (evaporator) are 865x695 mm, the still was insulated from its bottom and sides by two layers 0.03m fpolyurethane and 0.016 m wood panels. The space above the basin is completely enclosed by a transparent cover tightly. The inside still base and sides are painted twice with a black paint. The outer surface of the glass cover for the cooled unit is surrounded by three sides of glass slices 30mm high, two ducts at the ends of the glass cover was made to allow cooling water to be easily collected and recycled. Saline water was distillated by the solar still and water was continuously fed.
Measuring instrumentations:
1 Thermocouples: Temperature were measured using type-K thermocouples, the output device includes a large 4-digits temperature reading display and electronic circuitry, the specifications of thermocouples are manufactured in U.S.A, model 8528-40, full accuracy 18-28°C and useful range 4-45°C

2 Graduated glass bottle: (1 litter) was used to measure the amount of distilled water.

3 Solar intensity device: A black and white pyranometer was constructed and tested by Ghanem (1989) and calibrated in the solar energy department, National research center, Giza Egypt. It was used for measuring the solar intensity in W/m².

4 Turbo meter: A turbo meter was used for measuring the wind speed in m/s, the meter is manufactured in U.S.A of measuring range: 0 – 44.8 m/s.

METHODS
1 Solar still energy balance
In the present work assuming steady state, the performance of the solar still can be described by energy balance that indicates conversion of the solar energy into useful energy gain, thermal losses and optical losses. The useful energy used in evaporation and condensation $Q_{ec}$ is equal to the difference between absorbed energy $Q_{abs}$ and energy losses. The thermal energy lost from the still to the surrounding by conduction, convection and infrared-radiation can be presented by the overall heat...
transfer coefficient " $U_L$ " times difference of the average value of water and steel temperature" $T_{ws}$" and the ambient air temperature " $T_a$' :

$$Q_{ec} = Q_{abs} \cdot U_L (T_{ws} - T_a) \quad \ldots \ldots \ldots \ldots \ldots \ldots (3)$$

2 Over-all heat transfer coefficient of the solar still

It is useful to develop the concept of over-all heat loss coefficient for the solar still to simplify the calculations. A thermal net work Fig.(2) was made to change the thermal loss in a similar electrical resistance around the basin to help in estimating the overall heat loss coefficient and the useful energy gain. Fig.(3) shows the equivalent thermal net work for the solar still. This method is considered the simplest one to evaluate the over-all heat loss coefficient for flat plate collectors as reported by Ria (1980) and applied by Shoukr et. al.(1986). The over-all heat transfer coefficient is the sum of top" $U_T$ " , back " $U_b$ "and edge " $U_E$ "losses respectively which can be represented as:

$$U_L = U_T + U_b + U_E \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (4)$$

2-1 Top loss coefficient $U_T$

Energy losses through the top of the still is essentially a result of convection and radiation between the basin, cover plate, radiation and convection due to ambient air and sky temperatures.

2-1-1 Basin loss coefficient $R_1$

The convection heat losses can be evaluated according to Rai(1980) as follows:

$$h_{c_{w-g}} = 8.84 \times 10^{-4} \left( T_w - T_g \right) + \left( \frac{P_w - P_{wg}}{265 \times 10^4} \right) \left( T_w + 273 \right)^{\frac{1}{3}} \left( P_w - P_{wg} \right) \quad \ldots \ldots \ldots (5)$$

$$h_{r_{w-g}} = \frac{0.9 \sigma \left( T_w^4 - T_g^4 \right)}{T_w - T_g} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6)$$

Where

$h_{c_{w-g}}$ is the convection heat transfer coefficient between glass cover and brine water; W/m$^2$$^\circ$K,

$h_{r_{w-g}}$ is the radiation heat transfer coefficient between glass cover and brine water; W/m$^2$$^\circ$K,
T\textsubscript{w} : is brine water temperature; °K,
T\textsubscript{g} : is the glass cover temperature °K;
P\textsubscript{w} : is the partial pressure of water in P\textsubscript{a} at T\textsubscript{w} °C, .
P\textsubscript{wg} : is the partial pressure of water in P\textsubscript{a} at T\textsubscript{g} °C,
\(\sigma\) : is Stefan Boltzman 56.7x 10\textsuperscript{-9} W/m\textsuperscript{2}oK\textsuperscript{4}.

Both partial pressures are evaluated by regressing steam table data for the partial pressure as a function of temperature at a range of 20-75 °C for the present study as follows:

\[
P = 0.1483 T^3 - 8.4081T^2 + 341.34T - 2323.3 \quad (R^2 =1) \quad (7)
\]

Then, the loss resistance from the basin to the glass cover will be:

\[
R_1 = \frac{1}{(hc_{w-g} + hr_{w-g})} \quad \text{.................................................. (8)}
\]

2-1-2 Glass cover loss to surrounding \(R_2\)

The resistance from the glass cover to surrounding due to the wind blowing and radiation "hr\textsubscript{g-a}" W/m\textsuperscript{2}°K can be determined according to Duffie and Bechman(1980) as follows:

\[
hr_{g-a} = \varepsilon_c \sigma ( T_g^2 + T_a^2 ) ( T_g + T_s ) \quad \text{.................................................. (9)}
\]

Where:

\(\varepsilon_g\) : is the emittance of the glass cover;0.9 ,
T\textsubscript{s} : is the sky absolute temperature °K ,
T\textsubscript{a} : is the ambient air temperature, °K ,

The wind losses "h\textsubscript{w}" W/m\textsuperscript{2}°K can be evaluated according to Rai(1980):

\[
h_w = 5.7 + 3.8 V_w \quad \text{.................................................. (10)}
\]

\[
T_s = 0.0552 T_a^{1.5} \quad \text{.................................................. (11)}
\]

Then the top loss coefficient is:

\[
U_T = \frac{1}{R_1 + R_2} = \left[ \frac{1}{(hc_{w-g} + hr_{w-g})} + \frac{1}{(hc_{g-a} + h_w)} \right]^{-1} \quad \text{..........................(12)}
\]

2-2 Back loss coefficient \(U_b\)

The resistance to heat flow through the bottom of the steel plate is "R\textsubscript{3}"
which is covered by insulation can be determined as follows:
\[ R_3 = \frac{L_s}{k_s} \] ........(13)

Where "L_s=0.0006 m" is the thickness of the steel sheet constructing the basin and "k_s=48 W/m°K" is the thermal conductivity of that sheet.

Duffie and Beckman (1980) reported that the bottom resistance is due to insulation.

2-3 Resistance due to insulation

The energy losses through the bottom of the solar still is represented by three resistances "R_4 ","R_5 " and "R_6 ". R_4 and R_5 are resistances due to insulation and R_6 is due to convection and radiation to the environment. Since R_4 and R_5 \gg R_6 we may neglect R_6 in calculations of the bottom loss coefficient as reported by Rai(1980). So, back loss coefficient "U_b" for the two layers of insulation, polyurethane and plywood of thickness and thermal conductivity of 0.03 m, 0.0245 W/m°K and 0.016 m, 0.12 W/m°K respectively, can be determined as follows:

\[ U_b = \frac{1}{1/U_b} = \frac{1}{(L_1/K_1)+(L_2/K_2)} \] .... (14)

2-4 Edge loss coefficient U_E

Rai (1980) reported that if the edge insulation thickness is kept equal to the bottom insulation thickness, the edge losses may be estimated by assuming one dimensional sideways heat flow around perimeter of the still. Shoukr et.al.(1986) mentioned that the evaluation of edge losses is very complicated. However, in well designed system, the edge losses should be small that it is not necessary to predict it with great accuracy.

\[ U_E = (U A) edge/ A_s \] ....(15)
Where \((U A)\) edge is edge loss coefficient multiplied by its area \(m^2\) and \(A_s\) is the solar still area \(m^2\).

3 Evaluation of heat flux by evaporation

The rate of heat flux due to vaporizing water within the solar still \(Q_{ec}\) W/m\(^2\) can be determined according to Mostafa et.al. (1994) as follows:

\[
Q_{ec} = 0.0061 \left( T_w - T_g \right) + \left( \frac{P_w - P_{wg}}{265 \times 10^3} - \frac{3}{T_w + 273} \right) \left( P_w - P_{wg} \right)^{\frac{1}{3}} \]

(16)

Where \(L_{HV}\) is the latent heat of vaporization of water kJ/kg which can be evaluated by regressing steam table data for the latent heat of vaporization as a function of temperatures within the range of 20-75 °C in the present study as follows:

\[
L_{HV} = -2.4124T + 2502.9 \quad \left( R^2 = 0.99 \right) \]

(17)

To study the effect of glass cover temperature on the productivity and coefficient of performance of the solar still, two similar solar stills were constructed. One of them was used as a control unit and the other was cooled by spraying water three times per hour on the upper surface of the glass cover to reduce its temperature. Brine depth of 0.02 m and 20 ° tilt angle of the glass cover were used as reported by Tayel et. al.(2009). Solar intensity, ambient air, glass cover, steel basin, water in the tank and cooling water temperatures were hourly recorded. Wind speed was continuously recorded and average values were used.

RESULTS AND DISCUSSIONS

3-1 Prediction equations:

In the present study Table (1) and (2) summarize calculations for and \(\pi_3\) for the cooled glass cover and control units. Figs.(4)and (5) showed justified relations between \(\pi_1\) and \(\pi_2\) at constant tilt angle of the glass cover i.e \(\cos \alpha = 0.9397\), constant brine depth \(L = 0.02\) m and elapsed time of one hour, for the cooled cover and control unit of the form:

\[
\frac{\lambda_D}{\phi \Delta p} = A \left( \frac{Q_{ec}}{I_P} \right) + C \cos \beta \quad \left( R^2 = 0.8 \right) \]

(18)

Where \(A\) and \(C\) parameters are functions of \(\pi_3 = \frac{U_1 \Delta T_{g,a}}{I_P}\), Figs (6) shows the best fit relations, which are for the cooled unit:

\[
A = 2.01 \times 10^{-14} \pi_3 + 4.475 \times 10^{-15} \quad \left( R^2 = 0.8 \right) \]

(19)

\[
C = 4.63 \times 10^{-12} \pi_3 + 6.17 \times 10^{-14} \quad \left( R^2 = 0.98 \right) \]

(20)
And for the control unit:
\[ A = -7.72 \times 10^{-15} \pi_3 + 1.39 \times 10^{-13} \quad (R^2 = 0.85) \quad \ldots \quad (21) \]
\[ C = 1.54 \times 10^{-12} \pi_3 + 1.543 \times 10^{-16} \quad (R^2 = 95) \quad \ldots \quad (22) \]

![Fig. (4) Effect of \( \pi_2 \) on \( \pi_1 \) for the cooled unit.](image)

![Fig. (5) Effect of \( \pi_2 \) on \( \pi_1 \) for the control unit.](image)

![Fig. (6) Evaluation of A and C parameters of the two studied units.](image)

**3-2 Productivity of the solar still**

Prediction equation for determining the productivity of the cooled cover unit can be presented as follows:

\[
D = \left[ 1.3 \times 10^{-5} \left( \frac{Q_{ec}}{I_p} \right) + 0.008 \left( \frac{U_L \Delta T_{E-a}}{I_p} \right) + 2.9 \times 10^{-6} \left( \frac{Q_{ec}}{I_p} \right) + 4 \times 10^{-4} \right] \Delta \rho \quad \ldots \quad (23)
\]

And for the control unit:

\[
D = \left[ -5 \times 10^{-5} \left( \frac{Q_{ec}}{I_p} \right) + 0.3 \left( \frac{U_L \Delta T_{E-a}}{I_p} \right) + 9 \times 10^{-5} \left( \frac{Q_{ec}}{I_p} \right) + 10^{-7} \right] \Delta \rho \quad \ldots \quad (24)
\]
Table (1) Evaluation of $\pi_1$, $\pi_2$ and $\pi_3$ for the cooled glass cover unit.

<table>
<thead>
<tr>
<th>$I_p$</th>
<th>$\Delta T_{g-v}$</th>
<th>$Q_{e}$</th>
<th>$\Delta P_{w-g}$</th>
<th>$U_L$</th>
<th>$\pi_1$</th>
<th>$\pi_2$</th>
<th>$\pi_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>W/m²</td>
<td>°K</td>
<td>W/m²</td>
<td>P_s</td>
<td>W/m².K</td>
<td>$\lambda D/\Delta \phi$</td>
<td>Q_e/ $I_p$ %</td>
<td>$U_L \Delta T_{g-v}$ / $I_p$</td>
</tr>
<tr>
<td>241</td>
<td>2.50</td>
<td>537</td>
<td>1074.2</td>
<td>1.02176</td>
<td>1.14x10⁻¹³</td>
<td>22.27</td>
<td>0.0106</td>
</tr>
<tr>
<td>320</td>
<td>7.74</td>
<td>150</td>
<td>2399.5</td>
<td>0.9874</td>
<td>1.44x10⁻¹³</td>
<td>46.95</td>
<td>0.0233</td>
</tr>
<tr>
<td>490</td>
<td>11.16</td>
<td>291</td>
<td>4244.9</td>
<td>0.9942</td>
<td>1.57x10⁻¹³</td>
<td>59.48</td>
<td>0.0226</td>
</tr>
<tr>
<td>770</td>
<td>19.27</td>
<td>596</td>
<td>8421.1</td>
<td>0.98582</td>
<td>1.67x10⁻¹³</td>
<td>77.44</td>
<td>0.0247</td>
</tr>
<tr>
<td>800</td>
<td>21.86</td>
<td>624</td>
<td>8835.6</td>
<td>0.98714</td>
<td>1.67x10⁻¹³</td>
<td>78.01</td>
<td>0.027</td>
</tr>
<tr>
<td>950</td>
<td>24.16</td>
<td>796</td>
<td>10840</td>
<td>0.89467</td>
<td>1.75x10⁻¹³</td>
<td>83.79</td>
<td>0.025</td>
</tr>
<tr>
<td>804</td>
<td>18.09</td>
<td>632</td>
<td>8838.3</td>
<td>0.9726</td>
<td>1.69x10⁻¹³</td>
<td>78.66</td>
<td>0.0222</td>
</tr>
<tr>
<td>765</td>
<td>19.18</td>
<td>596</td>
<td>8454.8</td>
<td>0.98769</td>
<td>1.67x10⁻¹³</td>
<td>77.97</td>
<td>0.0248</td>
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<tr>
<td>498</td>
<td>10.08</td>
<td>217</td>
<td>3440.7</td>
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<tr>
<td>315</td>
<td>5.10</td>
<td>85.4</td>
<td>1576.9</td>
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<td>1.24x10⁻¹³</td>
<td>27.10</td>
<td>0.016</td>
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<tr>
<td>Avg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>59.516</td>
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Table (2) Evaluation of $\pi_1$, $\pi_2$ and $\pi_3$ for the control unit.

<table>
<thead>
<tr>
<th>$I_p$</th>
<th>$\Delta T_{g-v}$</th>
<th>$Q_{e}$</th>
<th>$\Delta P_{w-g}$</th>
<th>$U_L$</th>
<th>$\pi_1$</th>
<th>$\pi_2$</th>
<th>$\pi_3$</th>
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<tbody>
<tr>
<td>W/m²</td>
<td>°K</td>
<td>W/m²</td>
<td>P_s</td>
<td>W/m².K</td>
<td>$\lambda D/\Delta \phi$</td>
<td>Q_e/ $I_p$ %</td>
<td>$U_L \Delta T_{g-v}$ / $I_p$</td>
</tr>
<tr>
<td>241</td>
<td>1.40</td>
<td>49.6</td>
<td>1016.5</td>
<td>1.0222</td>
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<td>15.86</td>
<td>243</td>
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<td>0.9956</td>
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<td>0.0322</td>
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<tr>
<td>770</td>
<td>24.27</td>
<td>536</td>
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<td>1.61x10⁻¹³</td>
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<td>76.49</td>
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<td>950</td>
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<td>24.09</td>
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<td>8490.4</td>
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<td>1.63x10⁻¹³</td>
<td>72.69</td>
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<td>21.75</td>
<td>0.0116</td>
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<tr>
<td>Avg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52.185</td>
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</table>

Fig(7) Predicted and observed productivity for the cooled unit

Fig(8) Predicted and observed productivity for the control unit

The observed and predicted productivities were evaluated and correlated to each other for the two tested units, Figs.(7) and (8). Prediction equations give reliable results for the still productivity of the two studied units. The coefficients of determinations were 0.98 and 0.99 for the cooled and control units respectively. Table(3) shows that, as the solar intensity increases partial pressure potential $\Delta P_{w-g}$, glass cover, water
Table (3) Solar intensity, \( I_p \), glass cover temperature \( T_g \), brine water temperature \( T_w \), partial pressure potential \( \Delta P_{w-g} \) and productivity for the two studied units.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cooled unit</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_p )</td>
<td>( T_g )</td>
<td>( T_w )</td>
</tr>
<tr>
<td>W/m(^2)</td>
<td>°C</td>
<td>°C</td>
</tr>
<tr>
<td>241</td>
<td>20.4</td>
<td>26</td>
</tr>
<tr>
<td>320</td>
<td>22.1</td>
<td>33</td>
</tr>
<tr>
<td>490</td>
<td>43</td>
<td>34</td>
</tr>
<tr>
<td>770</td>
<td>52</td>
<td>62</td>
</tr>
<tr>
<td>800</td>
<td>59.7</td>
<td>65</td>
</tr>
<tr>
<td>950</td>
<td>63</td>
<td>71.8</td>
</tr>
<tr>
<td>804</td>
<td>52.9</td>
<td>63.1</td>
</tr>
<tr>
<td>765</td>
<td>53</td>
<td>62.8</td>
</tr>
<tr>
<td>498</td>
<td>42.9</td>
<td>33</td>
</tr>
<tr>
<td>315</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>Avg.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The total daily productivity and average coefficient of performance were 6.1655 kg/m\(^2\), 59.52% for the cooled unit compared to 5.536 kg/m\(^2\) and 52.19% for the control unit. The maximum productivity, water temperature, temperature difference between water and glass cover, and partial pressure potential of 1.2304 kg/m\(^2\).h, 71.8°C, 8.8°C, and 10840 Pa for the cooled unit compared to 1.0529 kg/m\(^2\).h, 75°C, 7.5°C and 10529 Pa for the control unit.

**SUMMARY AND CONCLUSION**

The aim of the present study is to develop mathematical analysis for common design solar still involving all ambient surrounding variables affecting its productivity and coefficient of performance. Two similar units of the solar stills were used namely: Control unit and cooled glass cover unit (cooled unit). Similitude technique was used to develop prediction equations for these units. From the present study we can concluded that:

1- The prediction equations for the productivity of the two studied units were reasonably accepted with coefficients of determinations of 0.98 and 0.99 respectively. The predicted equations were of the form:

\[
D = \left[ \Lambda \left( \frac{Q_{ec}}{I_p} \right) + C \right] \left( \Phi \Delta P \right) \frac{\cos \beta}{\lambda}
\]
Where \( D \) is the productivity in \( \text{kg/m}^2\cdot\text{h} \), \( C \) and \( A \) are functions of \( \pi_3 \text{or}\ \left[U_L \Delta T_{g-a}/I_P\right] \) which are linearly justified, \( \phi \) time duration in hours, \( I_p \) solar intensity \( \text{W/m}^2 \), \( Q_{ec} \) the heat utilized in vaporizing water in the still \( \text{W/m}^2 \), \( U_L \) over-all heat loss coefficient in \( \text{W/m}^2\cdot\text{K} \), \( T_{g-a} \), temperature difference between ambient air and glass cover \( \text{°K} \), \( \Delta P_{w-g} \) partial pressure potential \( \text{kg/m}^2\cdot\text{s}^2 \), \( \lambda \) is a constant represents the view factor of sky, ground and surrounding with respect to cover tilt angle.

2- It was also found that the cooled unit has highest values of the productivity and coefficient of performance. The daily productivity and average coefficient of performance were 6.1655 \( \text{kg/m}^2 \), 59.52\% for the cooled unit compared to 5.536 \( \text{kg/m}^2 \) and 52.19\% for the control unit.

3- The maximum productivity, water temperature, temperature difference between water and glass cover, and partial pressure potential of 1.2304 \( \text{kg/m}^2\cdot\text{h} \), 71.8 \( \text{°C} \), 8.8 \( \text{°C} \), and 10840 \( \text{Pa} \) for the cooled unit compared to 1.0529 \( \text{kg/m}^2\cdot\text{h} \), 75 \( \text{°C} \), 7.5 \( \text{°C} \) and 10529 \( \text{Pa} \) for the control unit.

REFERENCES


**الملخص العربي**

تحليل أنتاجية مقطس شمسي باستخدام التحليل البعدى

د/ طارق حسين غانم

نظرًا لندرة المياه العربية في بعض الأماكن الساحلية لجمهورية مصر العربية؛ يعد استخدام الطاقة الشمسية كمصدر للطاقة النظيفة والمتجددة من أفضل الطرق وأفضلها لتوليد مياه البحر. ويهدف البحث إلى التوصل لنموذج رياضي يربط جميع المتغيرات المحيطة والداخلية بانتاجية مقطس شمسي ودراسة تأثير انخفاض درجة حرارة عطاؤه الشفاف أيضاً على انتاجية واداعه. استخدم لذلك نموذج مشتقين تصميمي حيث تبريد عطاء احدهم احدهم بالمااء ثلاث مرات كل ساعة وماسبق يمكننا استخلاص الأتى:

1. حقت المعادلات التي تم التوصل إليها نتائج مرضية في التنبؤ بانتاجية كلا المقططين

موضع الدراسة حيث تراوح معدل الارتباط بين 98% و 99% و كانت صوره المعادلات:

\[
D = \left[ A \left( \frac{Q_{ec}}{I_p} \right) + C \right] \left( \frac{\Delta T_{g,a}}{\Delta T_{g,a}} \right) \cos \theta \lambda
\]

حيث (D) هي الانتاجية جم/م² س، (A) و (C) مثال دوال في المجموعة الثالثة، (Q_{ec}) هي الحرارة المستفادة منها في التتبخير والتكييف (W/m² س)، (\Delta T_{g,a}) هو فرق الضغط الجزيئي عند درجة حرارة الحمول المائي والغازات الزجاجية بالكليات والكليات (W/m² س) في معمل الفقد الحراري الكليات (U), (\Delta T_{g,a}) هو فرق درجات الحرارة بين المحليات والغازات الزجاجية بالكليات (\beta), (\lambda) هي زاوية ميل الزجاج وهي 20° و (\cos \theta) هو عمق الحمول في المقطط بالمتر.

2. قدرت الانتاجية اليومية ومعدل الأداء بـ 1,125,632 جم/م² و 95% لالفم المبرد مقابل 52,632 جم/م² لوحدة المقارنة.

3. حقت تحلية الإنتاجية عند اقلي كمية اشعاع شمسي عندما كانت درجة حرارة الماء المالح وفرق درجة حرارة بين سطح الماء والمااء وكذلك فرق الضغط الجزيئي 1,320 جم/م² و 71,800 جم/م² يشكل للفكم المبرد مقابل 11,741 جم/م² و 75,110 جم/م² لوحدة المقارنة.

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