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Improving Productivity of Solar Energy Distillation Still For Sea Water

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***Abstract*— Solar thermal systems that produce potable water from salty water have been studied for quite some years, and the use of solar energy to produce potable water was known in ancient Egypt. Water distillation by using Solar still is provided with a cascade mesh material welded with on absorber sheet is designed and tested in the present investigation. The mesh material acts as a wick material on the absorbing surface to improve the productivity of the distilled water. In this study the effect of the type of the mesh material, the ambient temperature, the wind speed, cooling water flow rate over the glass cover and the flow rate of the feed salt water on the productivity of fresh water are investigated. The study indicated that the still provided with mesh material gives 17% more in the daily productivity than the conventional still. This improvement occurs with flow rate of feed salt water of 0.50 l/s, cooling water flow rate of 0.1 l/s over the glass cover and air gap constant of 40 mm.**

Keywords—: Solar still, Solar energy, Water distillation, Mesh material, and Wick material

I. INTRODUCTION

Ninety-seven percent of the earth's water mass lies in its oceans. Of the remaining 3 percent, 5/6 is brackish, leaving a mere 0.5 percent as fresh water. As a result, many people do not have access to adequate and inexpensive supplies of potable water. This leads to population concentration around existing water supplies, marginal health conditions, and a generally low standard of living.

Solar distillation uses the heat of the sun directly in a simple piece of equipment to purify water. The equipment, commonly called a solar still, consists primarily of a shallow basin with a transparent glass cover. The sun heats the water in the basin, causing evaporation. Moisture rises, condenses on the cover and runs down into a collection trough, leaving behind the salts, minerals, and most other impurities, including germs.

Although it can be rather expensive to build a solar still that is both effective and long-lasting, it can produce purified water at a reasonable cost if it is built, operated, and maintained properly.

This paper focuses mainly on small-scale tilt-type solar stills as suppliers of potable water for families and other small users.

Of all the solar still designs developed thus far, the basin-type continues to be the most economical.

Since 1942 as pointed out by Nebbia and Menozzi (1967) in their historical review for water desalination. The first large solar still was constructed in 1872 at Las Salinas in northern Chile, to provide fresh water from desert mines. Very little was made on solar distillation until the World War II, when it was applied to the production of fresh water for use in wartime emergency. Work on these devices decreased when World War II came to an end in 1945. In early 1950s many different schemes were tried. Solar stills of small size were constructed in Algeria. However, the experimental work done during active period of the 1950s and 1960s furnished an experimental data and an analytical basis for the design and prediction of performance of simple solar still as described by Dickinson and Cheremisinoff (1980).

A number of solar stills have been developed with the absorbing surface sloped at some fixed angle from the horizontal in the manner of water heaters. Ohahiro et al. (1996) investigated theoretically and experimentally study on effect of using tetrafluoroethylene wick in solar still. It was found that this method gives an increase in productivity of the distilled water. These findings showed that a wick tetrafluoroethylene could be used in a multi-wick solar still to increase its productivity. Bouchekima et al. (1998) presented experimental results obtained from a capillary film solar still installed in the south of Algeria used for groundwater distillation. It was found that the efficiency of the distiller increased with the increase in the inlet temperature of the saline water and with the increase in the intensity of solar radiation.

Kumar and Tiwari (1996) studied an active solar distillation system during the peak summer days. The system was made of fiber reinforced plastic equipped with a flat plate collector. The performance of single and double effect solar distillation unit with and without water flow over the glass cover was monitored. It was found that an active solar still with water flow over the cover gives the maximum yield

Recently, Abdel Whahab et al. (1996) studied the effect of using corrugated absorber surface and the tilt angle of the solar still cover on the heating characteristic and its suitability to obtain best performance for Cairo climate. It was found that using corrugated absorber surface of triangular shape increases the productivity of the solar stills at tilt angle of 36º for the still cover.

Atef Ghandour (2001) studied the best tilt angle was 33º with productivity 5.2 l/m^2 d and coefficient of performance 81.77 %.

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A.E. Kabeel (2009) surfaces used for evaporation and condensation phenomenon play important roles in the performance of basin type solar still. A concave shaped wick surface increases the evaporation area due to the capillary effect. Results show that average distillate productivity in day time was 4.1 l/m^2 and a maximum instantaneous system efficiency of 45% and average daily efficiency of 30% were recorded. The maximum hourly yield was 0.5 l/h. m^2 after solar noon.

K. Kalidasa Murugavela et al. (2008) single basin solar still is a popular solar device used for converting available brackish or waste water into potable water. Because of its lower productivity, it is not popularly used. Numbers of works are under taken to improve the productivity of the still. The still productivity depends on parameters like solar radiation intensity, atmospheric temperature, basin water depth, glass cover material, thickness and its inclination, wind velocity and the heat capacity of the still. When compared with other parameters, the basin water depth is the main parameter that affects the performance of the still

H. M. Qiblawey (2008) show the use of solar energy in thermal desalination processes is one of the most promising applications of the renewable energies. Solar desalination can either be direct; use solar energy to produce distillate directly in the solar collector, or indirect; combining conventional desalination techniques, such as multistage flash desalination (MSF), vapor compression (VC), reverse osmosis (RO), membrane distillation (MD) and electrodialysis, with solar collectors for heat generation.

M. Sakthivel et al. (2010) show the effectiveness of the modification, theoretical still hourly yield from the basin water and from the jute cloth is calculated using model. Its performance is compared with the conventional still under the same climatic condition. It is also found that there is 9% deviation from the experimental result. It is found that cumulative still yield in the regenerative still with jute cloth increases approximately by 20% and efficiency increases by 8% with low cost for this modification as the jute cloth is very cheap and easily available

V. G. Gude and N. Nirmalakhandan (2010) using direct solar energy alone, the system could produce up to 7.5 L/day of freshwater per m^2 of evaporator area. With the addition of a photovoltaic panel area of 6 m^2, the system could produce up to 12 L/day of freshwater per m^2 of evaporator area, at efficiencies ranging from 65% to 90%.

V. G. Gude (2011) describes the theoretical rationale for a new low temperature phase-change desalination process, and six examples of applications to illustrate how this process can be engineered for sustainable desalination. In this process, brackish water is evaporated at near-ambient temperatures under near-vacuum pressures created by the barometric head without any mechanical energy input.

Alpesh Mehta et al. (2011) devised a model which will convert the dirty/saline water into pure/potable water using the renewable source of energy (i.e. solar energy). The basic modes of the heat transfer involved are radiation, convection and conduction. The results are obtained by evaporation of the dirty/saline water and fetching it out as pure/drinkable water. The designed model produces 1.5 liters of pure water from 14 liters of dirty water during six hours. The efficiency of plant is 64.37%. The TDS (Total Dissolved Solids) in the pure water is 81ppm.

Omar Badran (2011) the performance of active single slope solar still using different operational parameters is studied theoretically and compared with the experimental data for validation purposes, to find out best factors enhancing still productivity. The study concluded that active solar stills can be one of the options for enhancing the productivity of stills, while wind speed and insulation thickness can contribute to the enhancement of the overall yield.

T. Rajaseenivasan (2013) show that double basin double slope and single basin single slope stills have been fabricated and their performances were compared for various basin conditions. The outcome of the analysis presented is summarized as: Providing additional basin increases the total cost a little, but hugely increases the distillate. It is also noted that, provision of wick or porous or energy storing material in the basin increases the distillate output. Maximum water production is 3.58 l/day (5.68 l/m^2.day) for double basin still. Production increase is 85% for the same basin condition. Production increase is 169% when compared with minimum production condition of the single basin still.

Goosen, M. F. A. (2016) the use of alternative energy sources is essential to meet the growing demand for water desalination. Up till now, the expansion of renewable energy sources to run desalination processes at a larger scale is hampered by technical, economic, regulatory and environmental challenges. While medium-scale renewable energy driven desalination plants have been installed worldwide, many are connected to the electrical grid to assure a continuous energy supply for stable operation. This critical review paper focuses on integrated approaches in using renewable energy such as solar and geothermal technologies for water desalination. Innovative and sustainable desalination processes which are suitable for integrated renewable energy systems are also presented, along with the benefits of these technologies and their limitations.

From the above analysis for the available literature it can be concluded that the improving the productivity of distilled water from solar stills needs more investigations.

The objective of the present study is to carry out an experimental work to examine the effect of cascade steel mesh welded with galvanized steel sheet as a new type of the absorbing materials on the productivity of the distilled water. In the meantime, the study includes the effect of the following parameters:

A. Intensity of solar radiation.

B. Ambient temperature.

C. Flow rate of cooling water over the upper surface of the glass cover.

D. Flow rate of the salinity water distributed over the mesh material.

II. EXPERIMENTAL SETUP

Solar radiation enters the solar still unit and converts the water flowing over the absorber sheet to vapor. The vapor condenses on the bottom surface of the glass cover as fresh water flowing into the trough, allocated to the lower side of

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the glass cover inter the enclosure. The collected fresh water conducted outside to graduated bottle indicted the productivity by liter per hour. Fig. (1) Shows the layout of different components of the solar diffusion still, which is designed for the present study to obtain optimum operating conditions.

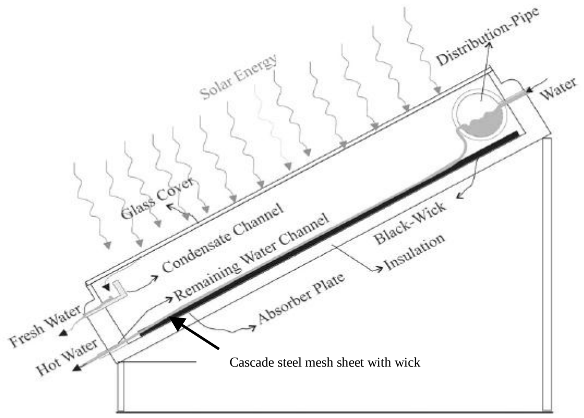

Fig. 1. Schematic diagram of the inclined solar still.

The four sides are rectangular; every two opposite sides have the same dimension. The evaporator basin is 141.0 cm x 73.0 cm, there are eight holes through the evaporator; two for outlets of distilled water, two for brine supply, two for air supply, one for vapor outlet to heat exchanger and the last one for thermocouples leads to pass through. The design details are illustrated the sunrays pass through the cover and are absorbed by the saline water and the black tray. As the water temperature increases, evaporation takes place from the surface of the water. Vapor condenses on the underside of the glass cover forming a film, which runs down to the trough that conducts the distilled water to the reservoir.

The distillation of saline water to recover potable water is accomplished by exposing thin layers of the saline water (usually in black shallow tray or basin to solar radiation, and condensing the water vapor produced).

The set length implemented after the theoretical investigation is 1.41 m long and the width of the set along the east-west directions is 0.71 m. that is made the area equal one meter square The still consists of galvanized steel sheet, metal box, single glass cover and insulation of 25 mm thickness of thermal conductivity of 0.036 w/m.k as given by Aboul-Enein et al. (2004) insulating the bottom and the sides of metal box to minimize heat losses. The steel sheet is black paint. A high penetration glass cover of 4 mm thickness is placed on the top of the box and fixed using rubber gasket to prevent vapor to leak. An insulated water tank of 225 liters volume is located on ground conducted with pump to raise the salinity water to the highest point of the solar still through an open pipe to distribute salinity water over the absorber sheet. The covers are made of special tempered sheet glasses manufactured in Dr. Greash Factory at 10th of Ramadan City (As the A.S.E. standard for Solar Energy instruments). By pass line with manual control valves used to regulate the flow rate of the salinity water to desired values as 0.35, 0.50 and 0.65 l/s. The solar still is fixed on a steel frame inclined to the horizontal by an angle of 33º (Atef Ghandour, 2001). Decrease the gab distance from 200 m to 40 mm to improve performance (Atef Ghandour, 2001). material welded with galvanized steel sheet acting totally as an absorber sheet. Four thermocouples along the absorber sheet inside the still, absorber sheet surface temperature, flowing salinity water temperature, vapor wet bulb temperature and vapor dry bulb temperature.

III. RESULTS AND DISCUSSION

There are many factors affecting the productivity of the solar still as: Climatic variables, design parameters and operation techniques.

The major design parameters affecting the daily and annual productivity of solar still were the solar intensity, ambient temperature, wind speed, flow rate of water cooling over the upper side of glass cover, flow rate of saline water, saline water distribution over the absorber sheet, vapor tightness, distiller leakage, and salt concentration .

A. Effect of solar intensity and different temperatures on the solar still unit:

The experiments were conducted to study the effect of the solar radiation intensity and different temperatures along the daytime, on the solar still unit.

B. The Incident Solar Heat fluxes:

Plots for the incident solar radiation intensity (Is) versus, the daytime is presented. The solar intensity increasing as local time increased and reached its maximum value at noon, about 12 a.m. after that, it started to decrease, as the time increased.

In Fig (2) beginning at 9:00 a.m., the solar radiation intensity is about 9.5 W/m^2.

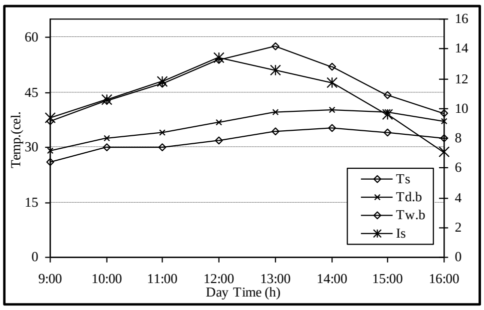

Fig. 2 Show solar intensity and different temperatures on the solar still unit

The solar intensity reached its peak value at 12:00 noon having the value of 15.7 W/m^2, while it started to decreased of 6.2 W/m^2 was observed at 16 p.m. The fluctuations shown, in the solar heat flux values, from one hour to another, were due to the instability of the weather conditions along the daytime. The solar heat flux is mainly affected by the appearance of clouds in the Sky. In addition to the above mentioned, there was a time lag during the measuring process, due to the relatively, large number of the measured points. This time lag affected the accuracy of the measured solar heat flux values.

The nature of the incident solar heat flux has significant effects on the thermal performance of the apparatus. The effect of the incident solar heat flux on the solar still surfaces (the black absorber sheet and glass cover surface) was observed.

C. Glass Cover Surface Temperatures:

The surface temperatures of the glass cover at the outside and inside surface are used to show the direction of the radiation solar energy, which is absorbed or reflected by the

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collector. The outside-inside temperature differences of the glass cover are relatively large. The outside surface temperature of the glass cover (Tgout) is almost lower than the inside surface temperature of the glass cover (Tgin) along the daytime, that is because of the greenhouse effect.

The temperatures of the glass cover surface, outside (Tgout) and inside surface (Tgin). The temperature versus, the daytime is presented in Fig (3).

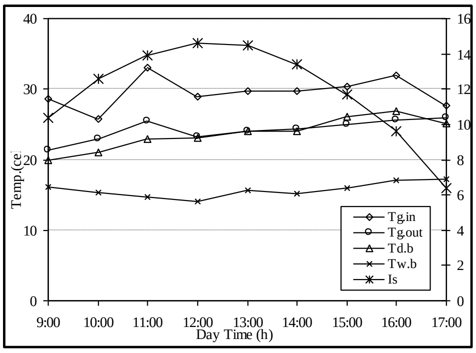

Fig. 3 Show the experimental results temperature without operating the water for solar intensity, (Is) ambient air (Tdb and Twb) and glass temperature degrees. (Tgin and Tgout)

D. Effect of cooling the upper side of the glass cover by water on temperatures and productivity:

Experiments investigated with cooling water observed that flow rate increase the productivity of the still, as shown in Fig. (4). Finally, for the previous experiments indicated that the productivity by using cooling of the upper surface of the glass cover is better than the solar still unit without cooling of the upper surface of the glass cover as shown in Fig. (5).

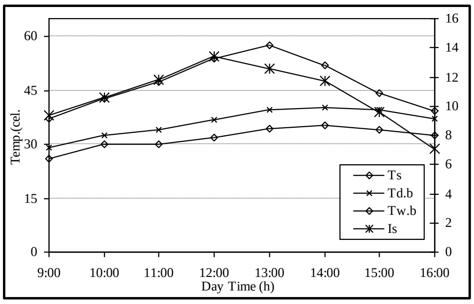

Fig. 4 Show the experimental results of temperatures and productivity without cooling glass cover.

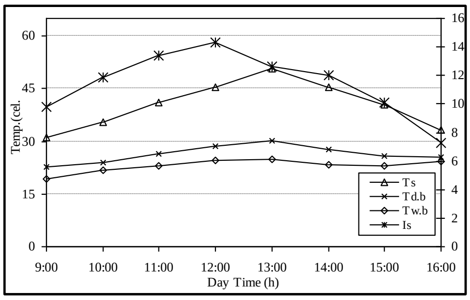

Fig. 5 Show the experimental results of temperatures and productivity with cooling water.

E. Effects of black flat plate and metallic mesh on the productivity:

A steel mesh used as a wick blackened material welded on the galvanized absorber sheet, to increase the thin film area of flowing saline water and enhance the evaporation rate of the vapor which will be condensed as fresh water.

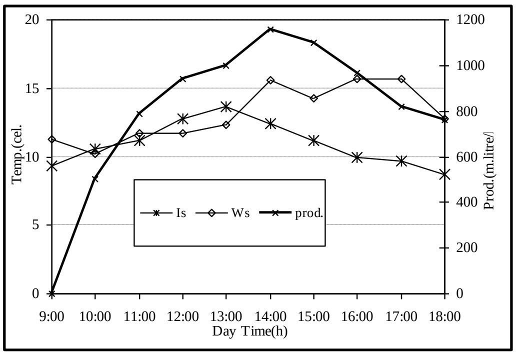

Fig. 6 Show the variation of the solar intensity "Is", W/m^2, ambient air temperatures (dry bulb and wet bulb), glass cover temperatures (upper side and lower side), temperatures inside the solar still, over mesh surface (wick) and flat plate surface (surface, water, dry bulb and wet bulb temperatures) and productivity of distilled water.

As shown from the comparison of Fig. (7), it's observed that the effect of absorber sheet with black cascade steel mesh is better than that, the effect of absorber sheet without black steel mesh.

The productivity improved from 5.2 l/m^2 d (Atef Ghandour 2001) to 8.1 l/m^2 d (the productivity increased about 35.8 %) in this study according to decrease the gab distance form 200 mm to 40 mm.

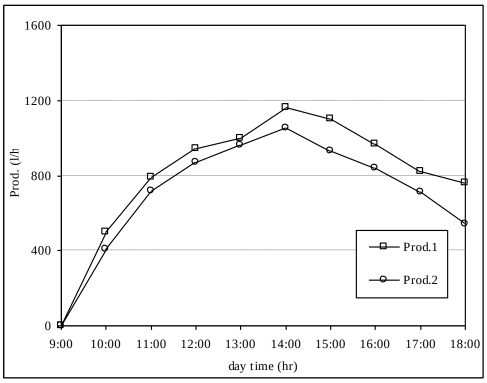

Fig. 7. effects of absorber sheet with and without mesh on the productivity

IV. CONCLUSION

From the experimental measurements and the calculations performed, the followings could be concluded:

The daily productivity increases with the increase of the solar radiation intensity for the same parameter.

By using of mesh sheet welded with the galvanized cascade steel sheet, the productivity is about 17% higher than the conventional absorber sheet.

The daily productivity of the modified solar still with cooling water of the upper side of glass cover flow rate (0.1 l/s) is about 13 % higher than that in natural air.

The overall improvement is 17.0 % higher than the conventional still when the mesh.

The daily productivity of the still with using (0.5 l/s) feed salinity water flow rate with (0.1 l/s) cooling water flow rate is highest value.

The productivity improved from 5.2 l/m^2 d (Atef Ghandour 2001) to 8.1 l/m^2 d (35.8 % increment) in this study according to decrease the gab distance form 200 mm to 40 mm.

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