

PERFORMANCE OF SOLAR STILL WITH A WICK CONCAVE EVAPORATION SURFACE

A. E. Kabeel

Mechanical Power Department, Faculty of Engineering,
Tanta University, Egypt
E-mail: kabeel6@hotmail.com

ABSTRACT

The amount of distillate water from a solar still depends on different parameters. The evaporative surface area and glass cover temperature are the most effective parameters. Increasing the surface area or decreasing the cover temperature will enhance the distillate output. In this work, a weir concave type solar still with four glass cover surfaces is studied experimentally. The main advantage of using four glass cover surface is to increase the amount of solar radiation falling on the evaporative surface. Most of the day time, there is a temperature difference between the four still glass sides and the evaporative surface which allow more vapor to condensate on the lower glass cover surface. Results have shown that the average distillate productivity during the day time is approximately 4 L/m² with a system efficiency of 0.38 at solar noon. It is higher than the conventional type solar still.

INTRODUCTION

The shortage of drinking water is expected to be the biggest problem of the world in this century due to unsustainable consumption rates and population growth. Pollution of fresh water resources (rivers, lakes and underground water) by industrial wastes has increased the problem.

The total amount of global water reserves is about 1.4 billion cubic kilometers. Oceans constitute about 97.5% of the total amount, and the remaining 2.5% fresh water is present in the atmosphere, surface water, polar ice and ground water. This means that only about 0.014% is directly available to human beings and other organisms [1]. Therefore, the development of new clean water sources is imperative. Desalination of sea and/or brackish water is an important alternative, since the only inexhaustible source of water is the ocean.

Solar desalination is suitable for remote, arid and semi-arid areas, where drinking water shortage is a major problem and solar radiation is high. These places mostly suffer also from energy shortage. The limitations of solar energy utilization for desalination are the high initial cost for renewable energy devices and intermittent nature of the solar radiation. Due to these limitations the present capacity of solar

desalination systems worldwide is only about 0.01% of the existing large-scale conventional desalination plants [2-3]. Therefore, efforts must be made to develop technologies, which will collect and use renewable energy more efficiently and cost effectively to provide clean drinking water. Besides, developing new technologies to store this energy for using it whenever it is not available is also required.

Solar stills are commonly used in arid coastal zones to provide low-cost fresh water from the sea. In the Northern Hemisphere, the still is placed due south with long axis facing East-West direction. Total daily output of the solar still decreases with increasing water depth, but overnight output increases with an increase in water depth, which contributes considerably towards the total daily output [4]. Solar stills are usually classified into two categories [5]: a single-effect type and a multi-effect type that reuses wasted latent heat from condensation [6]. The integration between flat plate solar collector and a solar still is classified into passive [7] and active [8] stills. Single-effect passive stills are composed of convectional basin, diffusion, wick and membrane types [9-10]. Using a still with cover cooling [11-12] and a still with a multi-effect type basin have been studied by H. Tanaka et al [13]. Complicated systems with a variety of solar stills are not applicable to desert technology. A tube-type solar still is proposed to integrate a conventional still and a water distribution network suitable to our concept of desert plantation. This still is directly set up on ground-like pipelines connecting brackish water or seawater pond [14].

However, various scientists have made attempts to maximize the daily yield per m^2/day in a single basin solar still in a passive mode [15]. From the previous work, it has been observed that the daily yield per m^2/day in the basin solar still mainly depends on the evaporative area and condensing surfaces. The objective of the present work is to study experimentally the performance of the weir concave type solar still at different days of the year.

EXPERIMENTAL SETUP

A concave type solar still is designed and constructed for the purpose of experimental work. Figure 1 shows a schematic diagram of the designed solar and a photograph of this solar still is shown in Fig. 2. The basin of the solar still is a concave with a square aperture of 1.2 m x 1.2 m. It is fabricated from iron steel 2 mm. thick. The bottom and sides of the basin are insulated by 10 cm thickness glass wool surrounded by a steel 2 mm thickness. The basin depth of concave surface is 30 cm. The weir takes the same shape of the concave surface and has a thickness of 5 cm covering the basin. The weir surface is painted black to absorb maximum solar radiation. The four sides of glass cover are of ordinary window glass of 3 mm thickness with a tilt angle of 45 degrees to the horizontal surface. The distillate water is collected by a galvanized iron channel fixed on the sides at the lower end of the glass cover and is taken out through a PVC pipe to two slight glasses as shown in the figure. The whole system is made vapor tight using silicone rubber as a sealant to prevent any vapor leakage.

The experimental setup is suitably instrumented to measure the temperatures at different points of the still, total solar radiation and the amount of distillate. The temperatures have been measured using copper constantan thermocouples which were connected to a digital temperature indicator. Solar radiation intensity is measured instantaneously by recording the short circuit D.C. current of a calibrated solar cell using a digital multimeter.

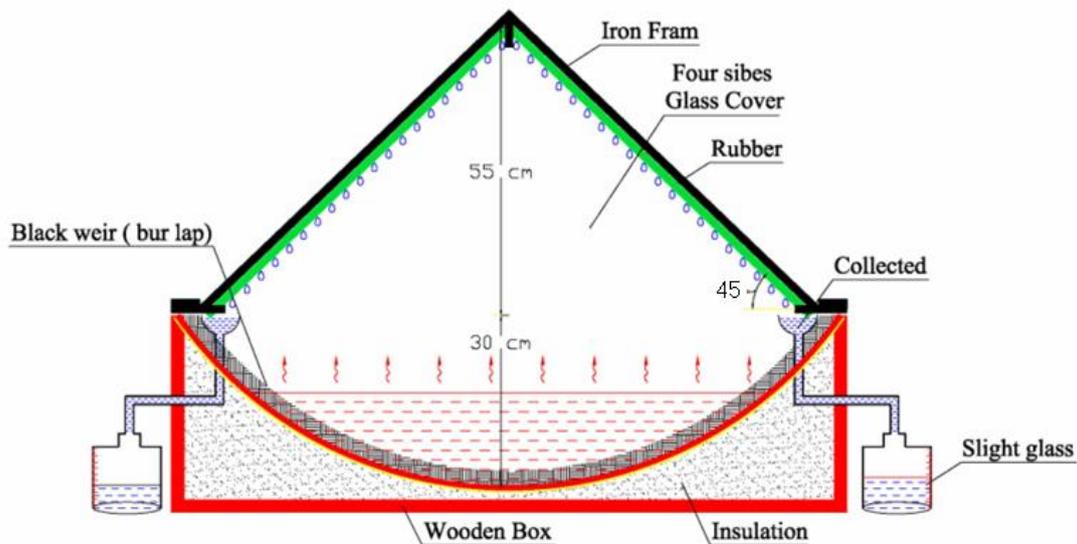


Fig. 1. Layout of the experimental setup



Fig. 2. A photograph of the experimental solar still

EXPERIMENTAL PROCEDURE

The experimental tests of this work were conducted at the Faculty of Engineering, Tanta University, Egypt during the period from 31/5 to 31/7/2007. During that period, all of the Egyptian climatic conditions (solar radiation, ambient temperature and wind velocity) were encountered. All the experiments are conducted on the best possible clear days for a water depth of 10 cm in the basin.

Each experiment is conducted in one day, during which the following measurements have been recorded:

- Brine mean temperature.
- Glass cover temperatures at the four sides.
- distillate output in slight glass
- Total solar radiation intensity.
- Ambient air temperature.
- Wind speed.

The experimental data were collected at regular intervals of 1 hour, starting from about 9 a.m. to the sunset (The data are recorded to 12 p.m. in some days). However, the accumulated productivity during the 24 hours has also been measured in each experiment.

The efficiency of solar still η is calculated from the following relation:

$$\eta = \frac{q_{ev}}{H} = \frac{m_{ev}L}{H} \quad (1)$$

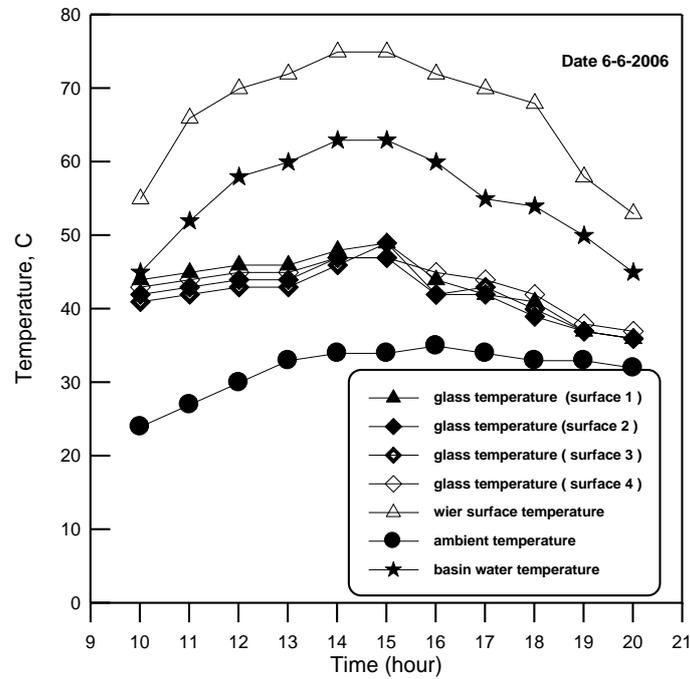
Where:

- q_{ev} is the heat of evaporation
- m_{ev} is the mass of evaporated vapor
- H is the total solar radiation fall upon the still surface
- L is the latent heat of evaporation

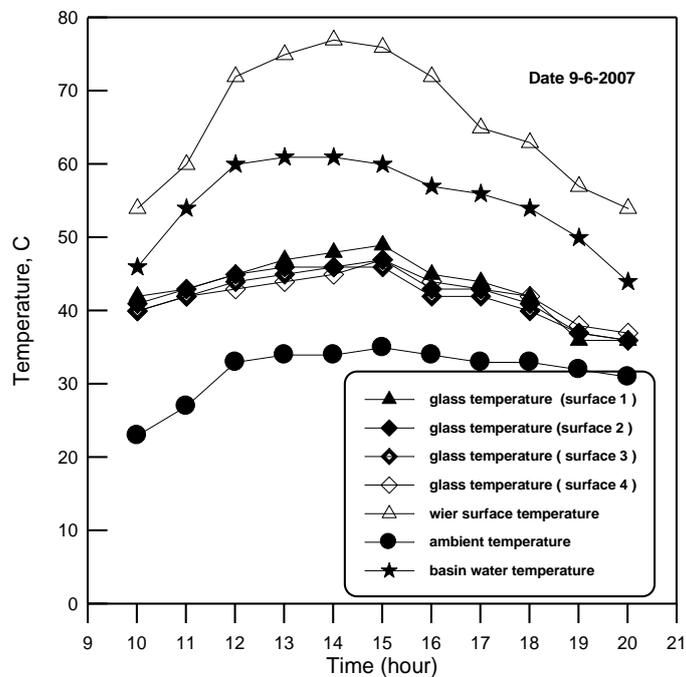
EXPERIMENTAL RESULTS

The experimental work was performed on the solar still during two months of the year (June and July 2007) for several days. The experimental data presented in the following analysis are chosen for some clear sky days as the example. The hourly temperature variation of the four glass sides, basin water, surface and ambient air during the day time is shown in Fig. 3. It can be observed that the temperatures at all points increase with time till maximum value at about 13 hour afternoon and then decrease again.

The temperature difference between the glass cover for all sides and the water is kept up to late afternoon. This temperature difference helps the vapor to condensate on the lower glass surface and hence condensing more vapors and hence increasing the collected water.



(3-a)



(3-b)

Fig. 3. Hourly variation of temperatures during the day

Figure 4 shows the variation of distillate output and total solar radiation intensity during the day time. The amount of total solar radiation incident on the still surface depends on the time of the day. The solar radiation varies along the hours after sunrise till a maximum value at mid day then decreases. These solar radiation data are used to calculate the solar still efficiency. These figures indicate that the effect of solar radiation intensity on still productivity is pronounced.

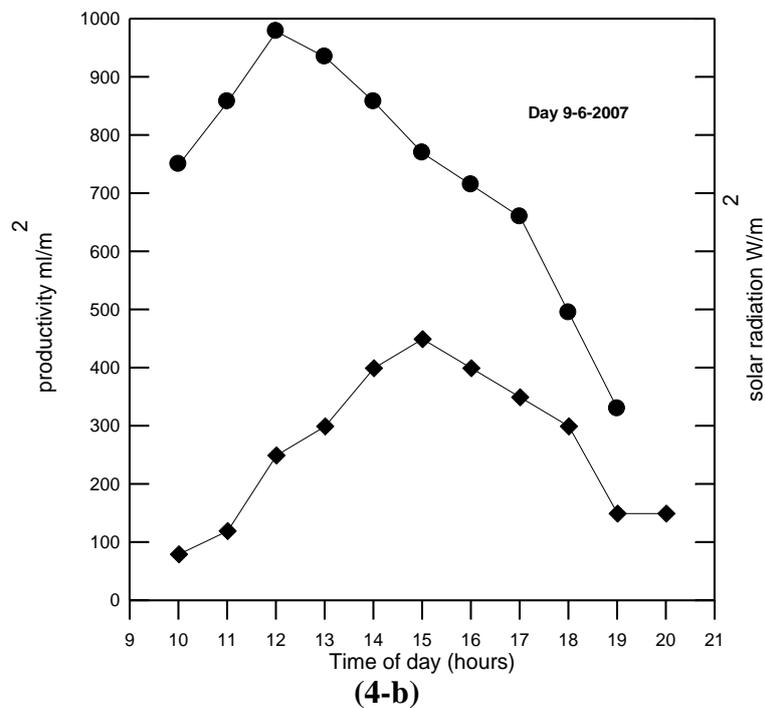
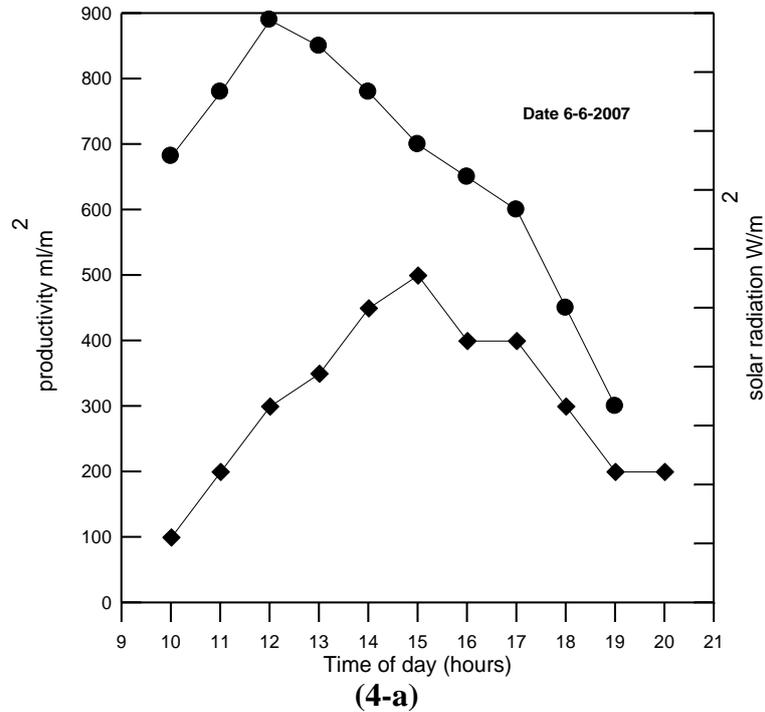
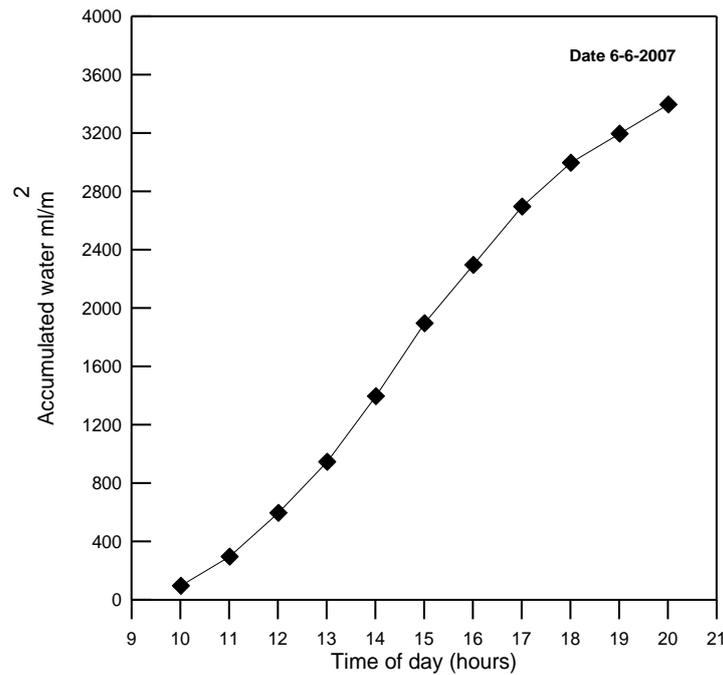


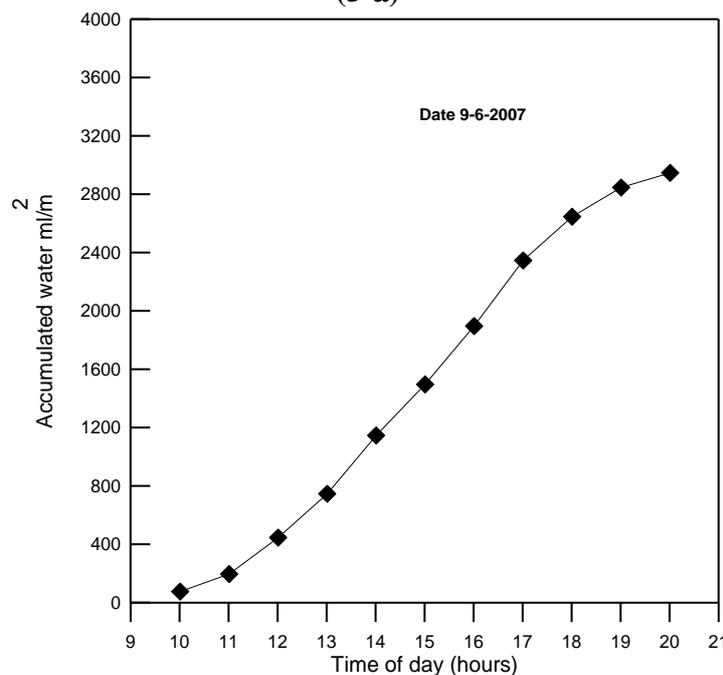
Fig. (4) Hourly variation of distillate output and radiation intensity during the day

The distillate output of the solar still varies as the total solar radiation intensity with about 2 hours delay. It increases up to a maximum value at 3 p.m. and then decreases with time. The maximum yield reached is about 500 ml/m^2 .

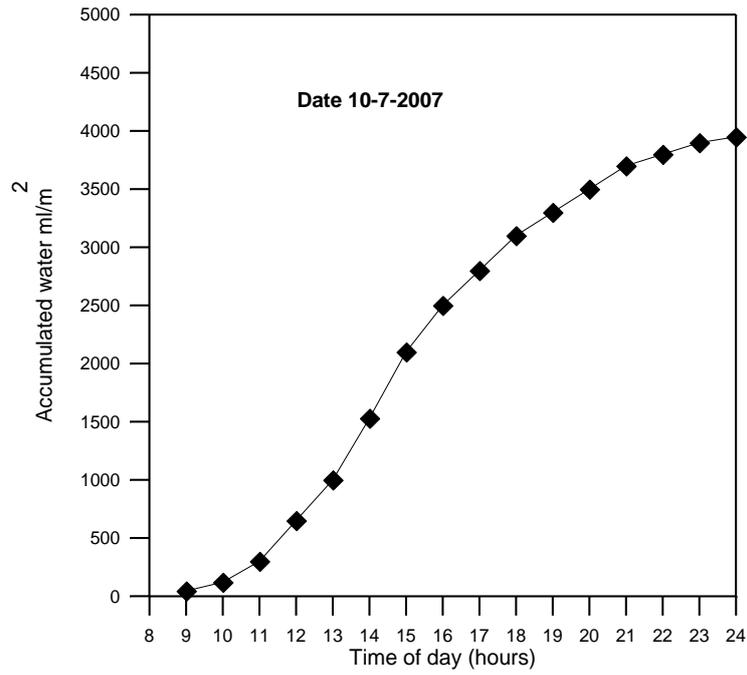
Variations of the accumulated distillate during the day for different days are shown in Fig. 5. The accumulated water reached 3600 ml/m^2 at 20 hr for day 6-6-2007 and 2800 ml/m^2 for day 9-6-2007. The total accumulated water after 24 hr operation reached 4000 ml/m^2 .



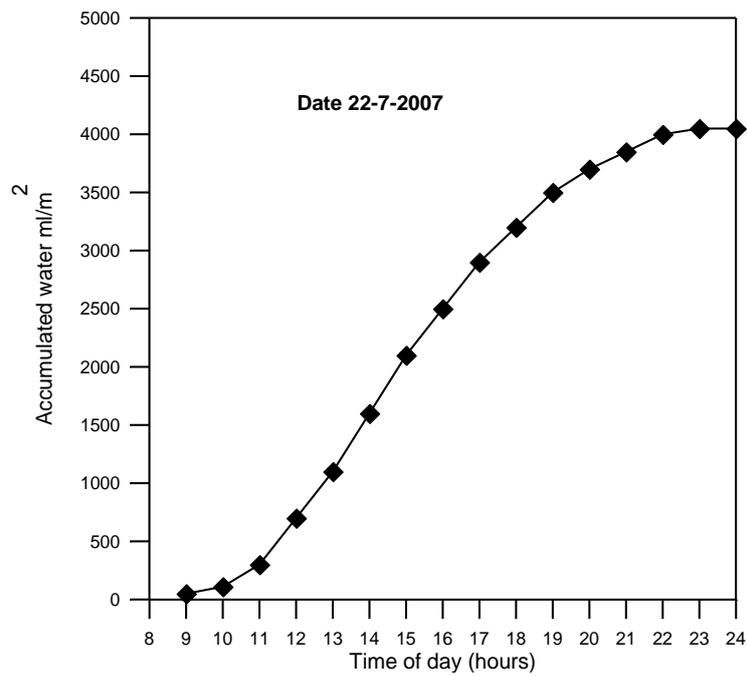
(5-a)



(5-b)



(5-c)



(5-d)

Fig. (5) Variation of the accumulated distillate water during the day

The variations of present solar still efficiency and conventional type solar still during the day time are shown in Figure 6. It can be seen that the efficiency of the concave

wick solar still reached 0.38. It is always higher than the conventional type solar still [16].

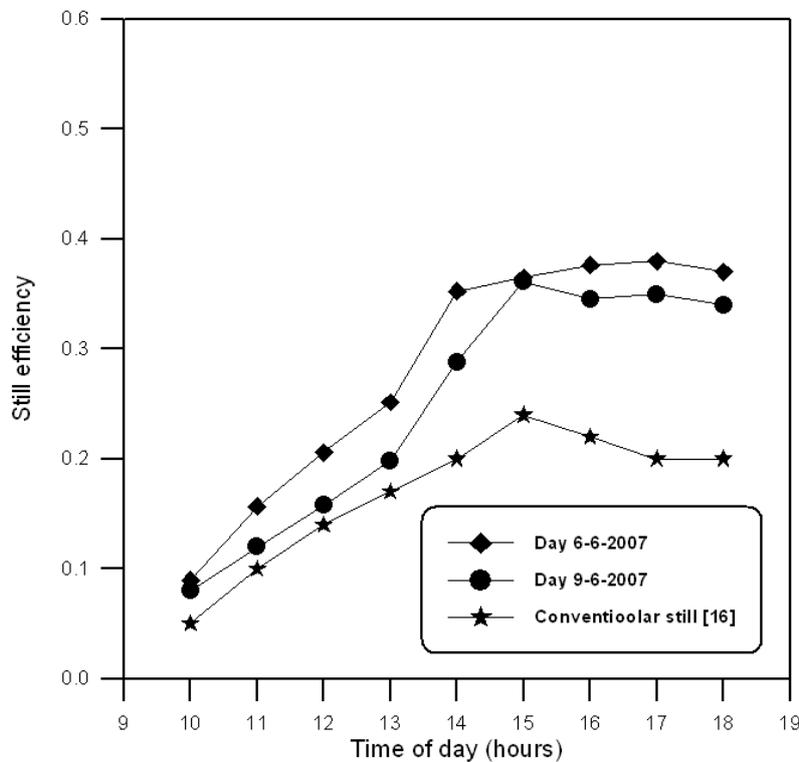


Fig. (6) Variation of the present solar still efficiency and conventional type

CONCLUSIONS

Based on the results obtained from the experimental work, the following can be concluded:

- 1- The temperature of the four glass cover surface is not equally specially till afternoon.
- 2- The average distillate productivity of the proposed still during the 24 hours time is about 4 L/m^2 .
- 3- The proposed solar still efficiency is 0.38 at solar noon. It is higher than the conventional type solar still.

In order to complete the whole picture of the present study, a future work is proposed in the following points:

- 1- Studying the system theoretical performance.
- 2- Studying the system at different glass tilt angles.
- 3- Studying the system at different water depth in the still basin.

REFERENCES

- 1- Bendfeld, J., Broker, Ch., Menne, K., Ortjohann, E., Temme, L., Vob, J., and Carvallo, P.C.M., 1998, "Design of a PV-powered reverse osmosis plant for desalination of brackish water," Proceedings of 2nd World Conference and Exhibition on Photovoltaic Solar Energy Conversion, Vienna, Austria, pp. 3075-3077.
- 2- Delyannis, E. and Belessiotis, V., 2001, "Solar energy and desalination," in Advances in solar energy, An annual review of research and development, Goswami, D.Y. (Ed.), 14, American Solar Energy Society, Inc, Boulder, Colorado, pp. 287-330.
- 3- Saleh -Khrabsheh, Theoretical and experimental analysis of water desalination system using low grade solar heat, Ph.D. dissertation Graduate school of the University of Florid, 2003.
- 4- Aboul-Enein S., El-Sebaili A.A., El-Bialy E. Investigation of a single-basin solar still with deep basins. Renewable Energy 1998; 14(1-4) 299-305.
- 5- H.E.S. Fath, Desalination, Solar distillation: a promising alternative for water provision with free energy, simple technology and a clean environment, 116 (1998) 45–56.
- 6- S. Toyama, M. Nakamura, K. Murase and H.M. Salah, Experimental and numerical analysis of a tube-type networked solar still for desert technology, Bull. Nagoya University, 43, (1990) 1-53.
- 7- G.N. Tiwari and M.A. Noor, "Characteristics of solar stills," Int. J. Solar Energy, 18 (1996) 147–171.
- 8- S. Kumar and G.N. Tiwari, Optimization of collector and basin areas for a higher yield for active solar stills, Desalination, 116 (1998) 1–9.
- 9- K. Murase, S. Komiyama, A. Ikeya and Y. Furukawa, Development of Multi-effect Membrane Solar Distillator, Bull. Soc. Sea Water Sci., 54 (2000) 30–36.
- 10- Kazuo Murase, Hiroshi Tobata, Masayuki Ishikawa and Shigeki Toyama, Experimental and numerical analysis of a tube-type networked solar still for desert technology Desalination, 190 (2006) 137-146.
- 11- M. Abu-Arabi, Y. Zurigat, H. Al-Hinai and S. Al-Hiddabi, Modeling and performance analysis of a solar desalination unit with double-glass cover cooling, Desalination, 143 (2002) 173–182.
- 12- B.A.K. Abu-Hijleh, Enhanced solar still performance using water film cooling of the glass cover, Desalination, 107 (1996) 235-244.
- 13- H. Tanaka, T. Nosoko and T. Nagata, A highly productive basin-type-multiple-effect coupled solar still, Desalination, 130 (2000) 279-293.
- 14- Kazuo M., Hiroshi T., Masayuki I., and Shigeki T., Experimental and numerical analysis of a tube-type networked solar still for desert technology, Desalination 190 (2006) 137-146.

- 15- M.K. Phadatare, and S.K. Verma, Development in solar still: A review, *Renewable and Sustainable Energy Reviews*, 2007.
- 16- Zeinab S. A., and Ashraf Lasheen, Experimental and theoretical study of a solar desalination system in Cairo, Egypt, *Desalination* 217, 2007, 52-64.