Performance Enhancement Of Etc By Changing Water Film Thickness.

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Abstract – The vital demand of fresh water across the world lead researcher to look for solution. This experiment introduces a new design solar still system in which a traditional solar still is replaced by ETC. ETC as a solar desalination system provide a simple and economical solution. Water film thickness inside ETC changed (6mm and 8mm) to decide which one gives the highest thermal efficiency. Result showed that the ETC with water film thickness of 6 mm achieved the highest efficiency of 23% and the production of fresh water reaches up to 0.299 kg per day.

Keywords: ETC, Water film thickness, Performance enhancement, Desalination

1. Introduction

Recently, Fresh water demand around the world become vital. Water could be divided to two different categories salt water in oceans, fresh water that can be used by living creatures. Fresh water represents only 3% of the existing water in the earth [1]. So, Solar desalination system become more efficient due to the availability of the core of power source. The solar desalination system represents a simple and economical method to produce fresh water. This method depends on the concept of water evaporation and condensation. Sun rays used to evaporate brackish water, whereas the pollutions and impurities sediment stay in the bottom of the basin. Condensation process is required to get the fresh water [2].

Active and passive are the only two categories of solar desalination system. Radiation of the sun is the only power source in case of passive techniques, while there is another power source beside sun in active one [3]. The effect of many design of traditional solar still such as: single and double basin solar still were investigated before, furthermore additional information can be located in [4]. Results showed that the efficiency of reviewed designs ranged from 30% to 65% compared to single basin solar still, additionally, the productivity of fresh water did not exceed 5L/m^2 per day.

A new promising technique is Evacuated tube collector (ETC) and Flat plate collector (FPC) which is used as a complete solar still system or integrated with solar still [5]. The using of FPC integrated with solar still increased the production from 2.575 L/m^2 per day for a solar still only to 5.18 L/m^2 per day when integrated with FPC [6]. The solar still productivity increased 36% by coupling FPC [7]. In addition, FPC increased the production of solar still up to 24% compared to simple one [8]. A double slope solar still integrated with FPC has as high as productivity compared to single slope with FPC, and the production increased up to 51% [9].

ETC has more rewards compared to FPC for water heating purposes. ETC are well known for their higher efficiencies when compared to FPC. In FPC, sun rays are perpendicular to the collector only at noon and therefore a proportion of the sunlight striking the surface of the collector is likely always to be reflected. But in ETC, due to its cylindrical shape, the sun rays are perpendicular to the surface of the glass for most of the day. ETC greatly reduce the heat losses by means of vacuum present in the tubes[10]. ETC has a superiority over FPC due to its simplicity and low manufacturing cost and also evacuated tube solar collectors had better performance than flat plate solar collectors, in particular for high temperature operations[11] .

ETC integrated with single basin solar still was studied by [12]. Results showed that the fresh water production increased from 2.7 L/m^2 per day in case of single basin solar still to 5.1 L/m^2 per day in ETC integrated with single basin solar still. Also, the production cost of fresh water increased due to this enhancement [13]. The effect of changing ETC inclination angle in productivity was studied by [14]. Results showed that the productivity increased up to 70%, when the inclination angle of ETC and solar still glass cove were equaled.

Changing the depth of water inside basin of solar still integrated with ETC was studied by [15]. Results showed that at 2cm water depth the productivity increased up 45% with using ETC. Double basin solar still with and without ETC was studied by [16]. Result showed that the fresh water increased up to 56% with using ETC. The production of fresh water by using a different configuration of ETC integrated with solar still was introduced in [17], and the result showed that a significant increases in production because of ETC.

The performance of a solar still equipped with thermoelectric modules and ETC was experimentally studied by [18]. Results showed that the thermal efficiency increased up to 60% due to using ETC. Solar ETCs were used to heat the saline water and vacuum pump created vacuum conditions at system startup only [19]. The thermal efficiency increased up to 47.6%. A system consist of basin, 5 ETC thermosyphon heat pipe was studied by [20] to investigate it productivity. Results showed that a huge amount of heat was transferred from ETCs and het pipe to the solar still basin.

The cost of fresh water production was lowered to 0.0092 $/l by using ETC and thermosyphon. The performance of ETC was decreased by 60% when the glass tube transmission reduced from 0.98 (clean glass) to 0.6 (very dusty glass) [21]. A performance of a solar still integrated with ETC in natural mode was investigated by [22]. They claimed that the use of ETC increases the temperature of water as well as yield. Also, they mentioned that the use of ETC with 10 tubes is preferable than a single larger size ETC. A solar still integrated with ETC and heat pipe was experimentally studied by [23]. Result showed that there is an increase in efficiency due to heat pipe.

2. Description OF EXPERIMENTAL SETUP

The experiment was performed in Zagazig, Egypt (latitude: 30°35' N; longitude: 31°30' E and altitude of 16 m above mean sea level). The components of the system are an ETC connected to a condenser by a coupler. The material of two-glass tube is borosilicate glass and the composition of ETC in which the outer glass is clear glass to make the light rays passing through with minimum reflection. On the other hand, the inner glass is covered with a special selective coating (Al-N/Al) which features excellent solar radiation absorption and minimal reflection properties.

The top part of the two ETCs are attached together and the air contained in the space between glass layers was vacuumed. This was done to make an insulator when ETC exposed to high temperatures. The presented system (ETCs with condenser) was fitted on steel to make it fixed. This frame was attached with several reflectors to focus the sun rays on ETC and reducing the time required for heating. The brackish water was supplied by a tank which was installed in high place to ensure that smooth water flow without pumping power. The system layout is shown in Fig. 1.

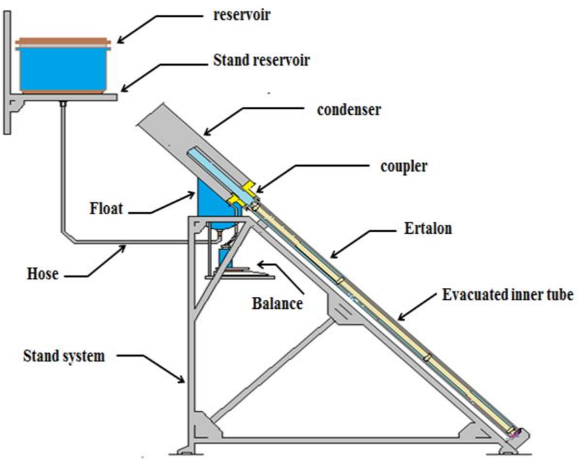

Fig. 1 Experimental Setup.

This system consists of t wo main the first part is ETC which have inner of 42 mm and outer diameters of 58 mm. The ETC length is 1800 mm. In addition, steel condenser is the second part which have a 600 mm length and 0.7 mm thickness. The condenser diameter is 160 mm. A plastic tank as shown in Fig. 2a used to fill the system with brackish water. Furthermore, A reservoir with scale as shown in Fig. 2b used to collect the fresh water and easily calculate the fresh water production.

(a) **(b)**

Fig. 2 Picture of brackish water tank and reservoir with scale.

3. Instrumentations

The major part of solar energy gained in Zagazig can be calm between 8:00 AM and 4:00 PM in summer. All the experiments were performed in the same time as previously mentioned of year 2019. The thermocouples type is T-type which used to measure temperature of the wall of the condenser. The thermocouples uncertainty is ±1°C. NI Compact DAQ with NI-9211 Module used for temperature measurement and recording with resolution of 0.01°C. PASCO Xplorer GLX which its uncertainty is ± 0.5 °C used to measure wind speed and ambient temperature, wind speed and direction as shown in Fig. 3. Also, PYR1307 pyranometer which its uncertainty is < 10 W/m^2 is used to measure the intensity of solar radiation and its place parallel to the ETC.

Fig. 3 PASCO Xplorer GLX and wind speed detector.

4. Parameters

The presented experiment, 6, and 8mm are the water film thickness WFT inside ETC. The material called ERTALON 66SA-C used to manufacture bars at several diameters to insert it inside the ETC to control the water thickness. The rings made from ERTALON were inserted between the ETC and ERTALON column to make sure the column was centered inside the ETC as shown in Fig. 4.

Fig. 4 Pictures of ERTALON columns inside the ETCs

5. Analysis

The main goal of this analysis is to study the performance of the presented system to estimate the thermal efficiency which is defined as a term used to prompt the performance of solar still. The thermal (daily) efficiency [5] of a desalination system can be expressed as:

$$\eta_{thermal} = \frac{m * h_{fg}}{E_G} \quad (1)$$

In which η is efficiency, m is the production in Kg, $h_{\_fg}$ is latent heat of water and equal $2260*10^3$ j/kg, EG is the sum solar radiation on the tube surface.

$$E_G = \sum I_g * P_A * time \quad (2)$$

Where, P_A is ETC projected area (m^2), Ig is solar radiation (w/ m^2) and Time: in sec (each 15 minutes).

6. Experimental RESULTS AND DISCUSSION

The film thickness of water in ETC was changed in the range of 6 to 8mm. Fig. 5shows this variation of the ambient temperature in ℃ and wind speed in m/s over the day. In that day, the temperature diverse from 29.5 to 35.9 ℃ and its average values is 33.2℃. The wind speed changed from 0.4 to 2.9 m/s with average values 1.6 m/s.

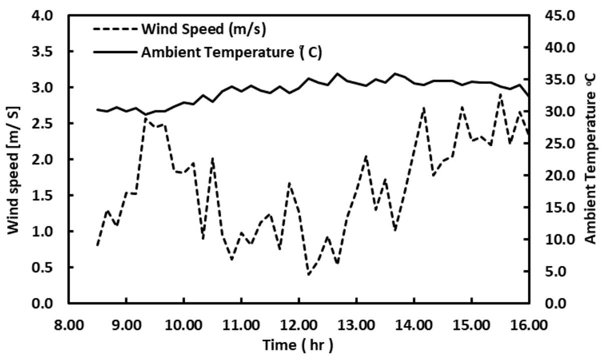

Fig. 5 The variation of the ambient temperature and wind speed in the water film thickness experiment.

Fig. 6 shows the distribution of the global inclined solar radiation (Ig). with a maximum value of 647w/m^2 which obtained between 13:00 hr and 14:00hr. The average value of global inclined solar radiation is 603.2 w/m^2. and obtained from collected data all over the day.

The distribution of the system's productivity over the day for the two the film thickness of water illustrated in Fig 7. As we can observe, the low intensity of radiation Leeds to lag in time between the systems start of production and solar cover removal of about 2.25 hours. The small values of solar radiation in that period of the year cause this phenomenon. It can be observed that the highest value of the rate of production of the system happens at the 6mm WFT with a value of 1.1 kg/m^2.hr at 13:00 hr.

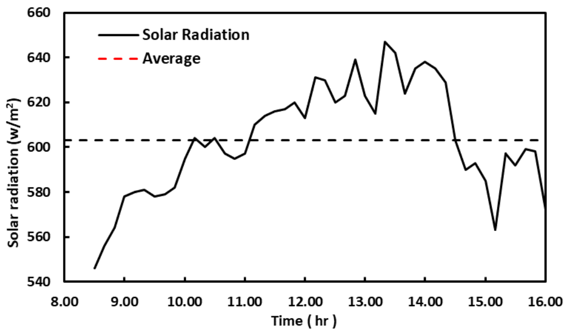

Fig. 6 The distribution of the global inclined solar radiation for the water film thickness experiment.

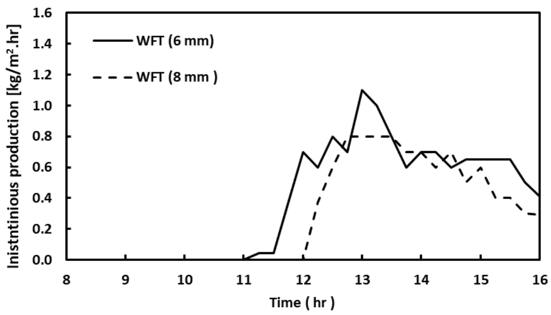

Fig. 7 The distribution of the systems productivity of the desalinate over the day for the water film thickness values of 6 and 8 mm.

As a result of the variation of the evaporation rate and wind speed which used to control the rate of condensation, the system performance makes asynchronous productivity of the yield for the different values of the WFT. As a result, these systems can be judged using the cumulative productivity over the day. The difference of the cumulative yield among the two WFT values is shown in Fig. 8. Results showed that, the 6mm WFT gives the highest productivity of 0.299 kg in the experiment day. This behavior mentions to the water heat capacity. This in turn rises the rate of water evaporation and as a result, rises the rate of water condensation and the desalinate productivity.

The evaporation rate enhanced by core inserts inside the evacuated tube as the heat is absorbed by a smaller thickness of water (smaller heat capacity) leading to high rate of evaporation. The unsteady behavior of the system leads to unstable performance of evaporation and condensation, and because of the low rate of intensity of solar radiation, the instantaneous efficiency may lead to miss information. Thus, the system overall performance is judged through the over day efficiency. The over day efficiency of the systems is illustrated in Fig. 9. This figure indicates that the water film thickness 6 mm has the highest efficiency.

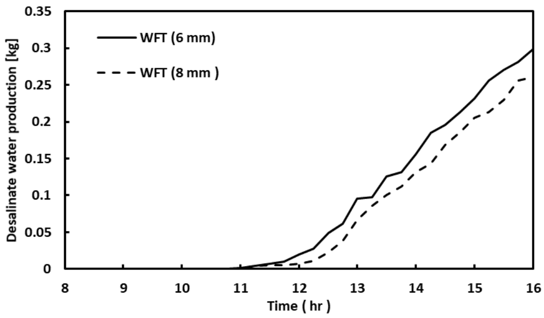

Fig. 8 The variation of the systems desalinates water production for the water film thickness values of 6 and 8 mm.

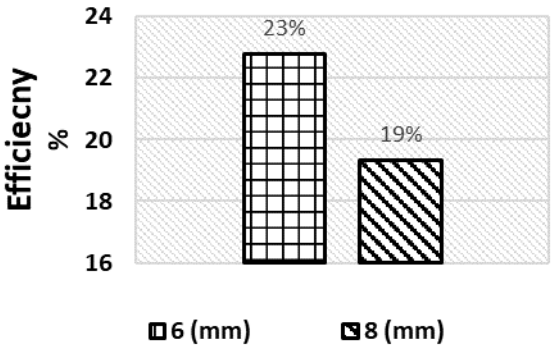

Fig. 9 system's efficiency variation according to WFT.

7. Conclusion

- The values of WFT tested are 6 and 8mm.
- Result showed that the WFT 6mm gives the maximum productivity of 0.299 kg in that day.
- The system efficiency of different values of WFT are 19% and 23% at 8mm and 6mm respectively.
- The lowest value of WFT has the highest value of system efficiency.
- This behavior refers to the smaller heat capacity of water with smaller WFT.

This in turn increases the evaporation rate of the water and as a result, increases the condensation rate and the desalinate productivity.

References

1. K. Vinoth Kumar and R. Kasturi Bai, ‘Performance study on solar still with enhanced condensation’, Desalination, vol. 230, no. 1–3, pp. 51–61, 2008.
2. V. Velmurugan and K. Srithar, ‘Performance analysis of solar stills based on various factors affecting the productivity - A review’, Renew. Sustain. Energy Rev., vol. 15, no. 2, pp. 1294–1304, 2011.
3. A. Kaushal and Varun, ‘Solar stills: A review’, Renew. Sustain. Energy Rev., vol. 14, no. 1, pp. 446–453, 2010.
4. P. Durkaieswaran and K. K. Murugavel, ‘Various special designs of single basin passive solar still – A review’, Renew. Sustain. Energy Rev., vol. 49, pp. 1048–1060, 2015.
5. M. B. Shafii, S. J. Mamouri, M. M. Lotfi, and H. J. Mosleh, ‘A modified solar desalination system using evacuated tube collector’, Desalination, vol. 396, pp. 30–38, 2016.
6. and S. Tiris, C., Tiris M., Erdalli, Y., ‘Experimental studies on a solar still coupled with a flat plate collector and a single basin still’, Energy Convers. Manag., vol. 39, no. 8, pp. 853–856, 1998.
7. A. A. Badran, A. A. Al-Hallaq, I. A. Eyal Salman, and M. Z. Odat, ‘A solar still augmented with a flat-plate collector’, Desalination, vol. 172, no. 3, pp. 227–234, 2005.
8. S. N. RAI and G. N. T I W A R I, ‘Single basin solar still coupled with flat plate collector’, Energy Convers. Manag., vol. 23, no. 3, pp. 145–149, 1983.
9. V. K. Dwivedi and G. N. Tiwari, ‘Experimental validation of thermal model of a double slope active solar still under natural circulation mode’, Desalination, vol. 250, no. 1, pp. 49–55, 2010.
10. K. Sampathkumar, T. V Arjunan, and P. Senthilkumar, ‘Single Basin Solar Still Coupled with Evacuated Tubes - Thermal Modeling and Experimental Validation’, vol. 12, pp. 53–66, 2011.

11. G. L. Morrison, I. Budihardjo, and M. Behnia, 'Water-in-glass evacuated tube solar water heaters', Sol. Energy, vol. 76, no. 1–3, pp. 135–140, 2004.
12. P. S. K. Sampathkumar, T.V. Arjunan, 'Single Basin Solar Still Coupled with Evacuated Tubes - Thermal Modeling and Experimental Validation', Int. energy J., vol. 12, no. 1, pp. 53–66, 2011.
13. Z. M. Omara, M. A. Eltawil, and E. A. ElNashar, 'A new hybrid desalination system using wicks/solar still and evacuated solar water heater', Desalination, vol. 325, pp. 56–64, 2013.
14. G. S. Praveen T Hunashikatti, KR Suresh, B Prathima, 'Development of desalination unit using solar still coupled with evacuated tubes for domestic use in rural areas.', Curr. Sci., vol. 107, no. 10, 2014.
15. M. Agrawal and L. P. Nema, 'Experimental works on Solar distil combined to EGT (Evacuated Glass Tube) By means of an air as unimportant Fluid', Int. J. Eng. Dev. Res., vol. 4, no. 4, pp. 2321–9939, 2016.
16. H. N. Panchal, 'Enhancement of distillate output of double basin solar still with vacuum tubes', J.
17. S. Yadav, H. Manchanda, M. Kumar, R. Kumar, and R. Scholar, 'Stepped and Evacuated Tube Collector Coupled Solar Stills: a Comprehensive Review', no. 4, pp. 2394–0697, 2017.
18. M. B. Shafii, M. Shahmohamadi, M. Faegh, and H. Sadrhosseini, 'Examination of a novel solar still equipped with evacuated tube collectors and thermoelectric modules', Desalination, vol. 382, pp. 21–27, 2016.
19. M. J. Abbaspour, M. Faegh, and M. B. Shafii, 'Experimental examination of a natural vacuum desalination system integrated with evacuated tube collectors', Desalination, vol. 467, no. June, pp. 79–85, 2019.
20. S. J. Mamouri, H. G. Derami, M. Ghiasi, M. B. Shafii, and Z. Shiee, 'Experimental investigation of the effect of using thermosyphon heat pipes and vacuum glass on the performance of solar still', Energy, vol. 75, pp. 501–507, 2014.
21. A. M. El-Nashar, 'Seasonal effect of dust deposition on a field of evacuated tube collectors on the performance of a solar desalination plant', Desalination, vol. 239, no. 1–3, pp. 66–81, Apr. 2009.
22. R. V. Singh, S. Kumar, M. M. Hasan, M. E. Khan, and G. N. Tiwari, 'Performance of a solar still integrated with evacuated tube collector in natural mode', Desalination, vol. 318, pp. 25–33, 2013.
23. M. B. Elsheniti, A. Kotb, and O. Elsamni, 'Thermal performance of a heat-pipe evacuated-tube solar collector at high inlet temperatures', Appl. Therm. Eng., vol. 154, no. October 2018, pp. 315–325, 2019.