Renewable and Sustainable Energy Reviews 78 (2017) 176–193

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The cooling techniques of the solar stills' glass covers – A review

Z.M. Omara[a,*], A.S. Abdullah[b,c], A.E. Kabeel[c], F.A. Essa[a]

[a] Faculty of Engineering, Kafrelsheikh University, Egypt
[b] Faculty of Engineering, Prince Sattam Bin Abdulaziz University, Saudi Arabia
[c] Faculty of Engineering, Tanta University, Egypt

ARTICLE INFO

Keywords:
Glass covers cooling
Solar still
Solar distillation
Review
Efficiency of solar still

ABSTRACT

The productivity of a solar still is influenced by the temperature difference between condensing and evaporating areas. Previous researches determined that increasing the difference between water–glass temperatures enhances the daily productivity of solar stills. To maintain this temperature difference high, fans, condensers, storing materials, reflectors, and the glass cover cooling were utilized. Continuous supply of air or water film over the glass cover leads to diminish the temperature of glass. Also, the cooling water film performs the important role of continuous self-cleaning of the glass cover. The presence of filth and dirt on the glass cover greatly diminishes the efficiency of still. Continuous cleaning of the glass cover keeps high levels of efficacy. In this regard, this paper aims to review the various methods of glass cover cooling used to enhance the performance of the solar stills. The cooling of glass covers is found to achieve a reduction in glass cover temperature in the range of 6–20 °C with an improvement in stills efficiency and productivity up to 15.5% and 20% maximum, respectively. It was concluded that for the tubular solar still with cooling air flow of glass cover, the daily productivity improved by approximately 32.8%, and improved by approximately 59% with cooling water flow more than the still without cooling.

1. Introduction

Solar distillation looks to be a promising process and an alternative way of providing small communities in islands and remote regions with potable water. Because of the solar energy is accessible in remote areas and most arid. Also, Solar stills are an ideal source of potable water for both agricultural aspects and domestic. The fresh water obtained will be of high quality and low quantity about 2–3 l/m^2 day [1]. The temperature difference between condensing and evaporating areas in the still influences on its daily distillate. Previous researches determined that increasing the water–glass temperature difference enhances the solar stills production. To maintain these temperature difference high, reflectors, storing materials, condensers, fans, and glass cover cooling were utilized. The present paper describes a comprehensive review for the modifications conducted on the solar stills to improve the thermal performance by cooling the glass covers. The temperature of glass cover can be reduced by cooling using water, air, combination between them, increasing area of condensation, and using condensers. Further, comparisons between the thermal performances and the improvements percentage of the productivity and efficiency of the solar stills due to glass cooling of different techniques by various investigators are presented.

This present paper gives the leading keys to the interested researchers to improve the solar still productivity using different techniques of glass covers' cooling. Likewise, it puts the researchers' feet on the present technology of improving the solar still regarding the related parameter of glass cover. Additionally, this paper helps the researchers to choose the optimized parameters referred to glass cover to get the best optimized productivity of solar still. Finally, this paper introduces some new scopes for future work on the glass cover cooling to enlarge the still yield.

Kalidasa et al. [2] concluded that to improve the daily productivity of solar stills, the rate of condensation should be improved. The rate of condensation can be improved by decreasing the temperature of glass cover. Inside the solar stills, the natural circulation of air mass is increased by keeping up the temperatures difference (ΔT) between basin water and glass [2]. In active solar stills, among the active methods utilized is the glass cooling and using the latent heat of condensation dissipated through the glass. The glass gains heat from vapor condensation on the inward surface and loses this heat to the atmospheric by radiation and convection. Ordinarily, the heat transfer from the glass to the atmospheric by radiation and convection are few, particularly at low speed of wind. So, the temperature of glass is high, and therefore the daily distillate of solar still is low. The glass cooling increases ΔT between basin water and glass, which improves the vaporization rate, giving higher distilled water of solar

* Corrresponding author.
E-mail address: zm_omara@yahoo.com (Z.M. Omara).

http://dx.doi.org/10.1016/j.rser.2017.04.085
Received 17 October 2016; Received in revised form 22 March 2017; Accepted 27 April 2017
1364-0321/

still. So, the glass temperature can be decreased by using cooling process. The cooling process can be accomplished by flowing air or flowing water above the glass.

Continuous water flowing or air above the glass cover leads to decrease the temperature of glass. In addition, the cooling water plays out the important function of continuous self-cleaning of the outer surface of the glass. The presence of filth and dirt on the glass cover greatly diminishes the still efficiency.

In addition, Bassam and Abu-Hijleh [3] proposed that a properly designed of flowing water above the glass could improve the still productivity, while a poor design may lead to reduce in a daily production of solar still [3], because of the cooling water diminished solar irradiation to the still.

The daily productivity of solar still is dependent on the saline water, the glass cover temperatures and the difference (ΔT) between them. Production of fresh water increases with a ΔT between the basin water and glass [4,5]. When ΔT was 6.0 °C, the distillate of water was 0.10 l/m^2 h, while the distillate of water was 0.850 l/m^2 h when ΔT was about 11.0 °C. For the same ΔT of 10 °C, a distillate of 0.8 l/m^2 h was acquired when the temperature of basin water was about 70.0 °C, while the distillate was about 0.10 l/m^2 h when the temperature of basin water was about 30 °C [4].

2. Techniques used for glass covers cooling

In basin solar stills, the heat of evaporation received by the glass gets lost to the surrounding mainly by radiation and convection. The convection and radiation losses are small, leading to an increase in the temperature of glass and reduction in ΔT between saline water and the glass cover. This adversely influences on evaporation rate and hence the daily distillate of still. Lower glass surface temperature increases the circulation of air inside the still which improves the evaporative and convective heat transfer between saline water and glass cover, also cooler glass inner surface enhances condensation, [6]. The temperature of glass can be decreased by cooling via water, air, combination between them, increasing area of condensation, and condensers. A comparison of various solar stills with glass cover cooling is showed in Table 1. They are compared based on locations, daily yield or efficiency improvement (%), and observations in experiment.

2.1. Cooling of glass covers via flowing water film

The main factor affects the daily productivity of the still is the temperature of glass cover. Decreasing the temperature of glass cover leads to improve the production rate. Water flowing above the glass cover shows a good effect on efficiency and daily productivity of the solar still. The temperature of glass cover is decreased, and the production output is increased by continuous or intermittent flow of raw cooling water on the cover. The glass cover temperature can be decreased by passing water above the single-glass cover or passing water between a double-glass cover.

2.1.1. Single-glass cover stills

Kaushal et al. [7] carried out an extensive review on solar stills and highlighted that the solar still efficiency increases by 20% when 1.3 mm cooling film thickness is introduced on a glass cover having a thickness of 5 mm. Significantly, the annual productivity depends on the water depth and condensing cover inclination.

2.1.1.1. Single slope solar still. Sherwood et al. [8] have represented heat transfer because of water evaporation connected with cooling. A Cross-sectional view of water film type solar still is appeared in Fig. 1. The still productivity was further increased by using a part of cooling water in the form of preheated makeup water into the basin of solar still. Their results indicated that proper utilize of film cooling parameters may enhance the efficiency of the still up to 20%.

The water film type of a solar still is simple in construction, an easy and cheap method for giving daily distillate. It comprises of a glass cover of 5 mm thick, thickness of cooling film 1.3 mm and a basin. The glass cover temperature can be reduced by flowing water film above the outer surface of glass cover. Mousa and Bassam [9] have focused in accomplishing high thermal efficiency with respect to ΔT between the saline water and glass, Fig. 2.

Tiwari and Bapeshwara [10] investigated the performance of conventional still with flow of water above the glass (Fig. 3). They concluded that by introducing a uniform water flow above the glass, the distillate output of the solar still was often doubled and it somewhat reduced with increasing the flowing water above the glass cover resulted of reduction in temperature of saline water of still.

Abu-Hijleh [11] used the cold water to minimize the glass cover temperature by producing a thin film over it as revealed from Fig. 4. Regarding to the combination way, the still efficiency was determined. For instance, the efficiency was enhanced by 6% by proper use of cooling, while, a decline of efficiency could be happened by the poor combination. The author concluded that the glass temperature and that of cooling water have approximately the same value. The parameters leading to the best productivity were 2×10^{-4} m as a thickness of the cooling film, 5×10^{-7} m^3/s as a volumetric flow rate of cooling water per unit width, and 2 m as a length of the glass cover.

Aneesh and Anil [12] designed and theoretically studied the single basin solar still top cover cooling using an air cooler for four various climatic zones in Indian plains. Fig. 5 shows a schematic graph of a basin still associated to a desert cooler. The authors additionally installed a desert (evaporative) cooler to cool the water that was run above the glass cover. A fixed flow rate of 1.5 m/s was used for the water. Two different cooling methodologies were followed: (1) the cold water from the evaporative cooler and (2) the cooling water at ambient temperature. The water that has been warmed by the glass cover was recirculated back to the air cooler. From the experimental results, they concluded that the increase in annual production was about 41.3–56.5% with water from the evaporative cooler, and the increase was about 30.1–21.8% with water at temperature of ambient.

Influence of heat capacity on the still efficiency with flowing water above the glass was studied by Lawrence et al. [13], Fig. 6. Results indicated that flowing water above the cover decreases the temperatures of saline water and glass. Reduction in temperature of basin water slightly decreases the rate of evaporation. Reduction in temperature of glass increases the rate of condensation, due to which production rate of the still enhanced. Because of flowing water above the glass in the cases without and with black dye present in the still, there are 7% and 10% increases in solar still efficiency.

Asphalt liner and sprinkler were adopted to improve the distillate of the single slope solar still by Badran [14]. The introduction of asphalt as basin liner increased the output by 29% when compared to the usage of black paint as the liner. The usage of sprinkler (cooling film) on the glass cover increased the temperature difference between glass and water which in turn contributed to 22% increase in output. It is also found that the distillate increases with a decrease in the depth of water and an increase in velocity of wind up to a typical velocity, and after that, it starts decreasing.

The higher operating temperature of the solar still leads to the higher rate of vaporization. This can be achieved by integrating an external heat source to the still. Additionally, this will lead the glass cover to receive more latent heat of evaporation. As a result, the glass-water temperature difference will decrease due to increasing the glass temperature, and hence, low distillate production because of the low