A comparative experimental testing in enhancement of the efficiency of pyramid solar still and hemispherical solar still

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Abstract

This work focused towards an experimental investigation by comparing the performance of two solar still such as pyramid solar still and hemispherical solar still. The comparative performance study is analyzed for same weather conditions with different design parameters. The same area is maintained for the both the solar stills as 1 m^2. The analysis is based on the distillate yield rate due to top cover structural arrangement of both the stills. Operational parameters such as ambient, inner, outer cover temperature, water, air and productivity have been predicted. The efficiencies of these solar stills conformed that the distilled water output of the hemispherical solar still was higher than the pyramid type solar still. Performance characteristic of the hemispherical solar still showed temperature at the water surface is closely related to the more incident radiation. The productivity is due to receiving the radiation from the top cover without any loss.

Keywords: *solar distillation, hemi spherical, pyramid, solar still, productivity*

1. Introduction

Solar still partially support man's needs of drinking water with free energy, simple and cheap technology and a clean environment, particularly in remote areas. Solar still, on the other hand act also natural disinfection devices that use natural solar ultra violet rays without any chemical addictives. Solar stills have demonstrated their stability when the weather conditions are suitable, the demand is not too large, sources of fresh water and fuel are not available or difficult to be transported and the technical capabilities of the users are limited. The use of solar energy in thermal desalination processes is one of the most promising applications of renewable energies to seawater desalination. The problem of low daily productivity of the solar stills triggered scientists to investigate various means of improving the stills productivity and thermal efficiency. A comparative study between the single effect and double effect absorption heat transformer systems used for seawater desalination was carried out. They reported that the energy efficiency of the double effect absorption heat transformer (DAHT) was higher than that of the single effect absorption heat transformer [1]. An analysis was also carried out in a double effect; active solar distillation unit by incorporating the effect of climatic and design parameters. The observation reported that there was a significant improvement in the performance for a minimum flow rate of water in the upper basin [2].

Similarly many attempts have been made to improve the performance of simple solar stills. Khalifa [3] made tests on forced and natural convection solar stills. Hiroshi Tanaka [4] analyzed the geometrical model to calculate the radiation reflected from an external reflector inclined backwards and then absorbed on to a basin linear of a basin type still. The performance of 'V' type solar still using a charcoal absorber and a boosting mirror [5]. Y.H. Zurigat and M.K Abu Arabi [6] studied the modeling and performance analysis of a regenerative solar distillation unit. Theoretical study was made on the effect of a cooling tower on a solar desalination system by Hichem Marmouch et al., [7].

An analytical study as well as thermal and economic comparisons between two solar still configurations: the pyramid and the single slope solar still were investigated. It was concluded that, the single slope solar still was found to be slightly more efficient and economic than the pyramid one [8]. The enhancement of the productivity of the two solar desalination systems such as single slope

and pyramid shaped. The results show that, the best average and maximum daily productivity are obtained from solar stills of single and pyramid shaped [9]. A simple transportable hemispherical solar still was designed and fabricated, and its performance was experimentally evaluated under Dhahran climatic conditions. It was found that the daily distilled water output from the still ranged from 2.8 to 5.71 l/m^2 day [10].

The present work reported as an experimental investigation by comparing the performance of two solar still such as pyramid and solar still and hemispherical solar still. The productivity rate, efficiency due to top cover design were estimated and compared for both the solar stills.

2. Fabrication details

2.1 Hemispherical solar still

A circular shape of water storage basin of the still is constructed with diameter 0.95 m of mild steel. The water storage basin is painted with black paint to increase the absorbtivity. The height of the water storage segment is 0.10 m collection segment. The water drainage segment is fixed at the inner perimeter of the basin wall. The still is filled with the water to a height of 0.05 m. The top hemispherical cover is made up of transparent acrylic sheet of 3 mm thickness with transmittance 88 %. Hemispherical cover of diameter 0.94 m and height 0.20 m is designed for the still. The outer box for the still is made up of wood of thickness 4 mm with the dimension 1.10 m x 1.10 m x 0.25 m. The bottom of the basin is filled with the sawdust up to the height of the 0.20 m. The sides of the basin are insulated with the glass wool. This insulation is made to reduce the conduction heat loss through the base and sides of the solar still. Figs. 1-2 show the schematic and pictorial view of hemispherical solar still.

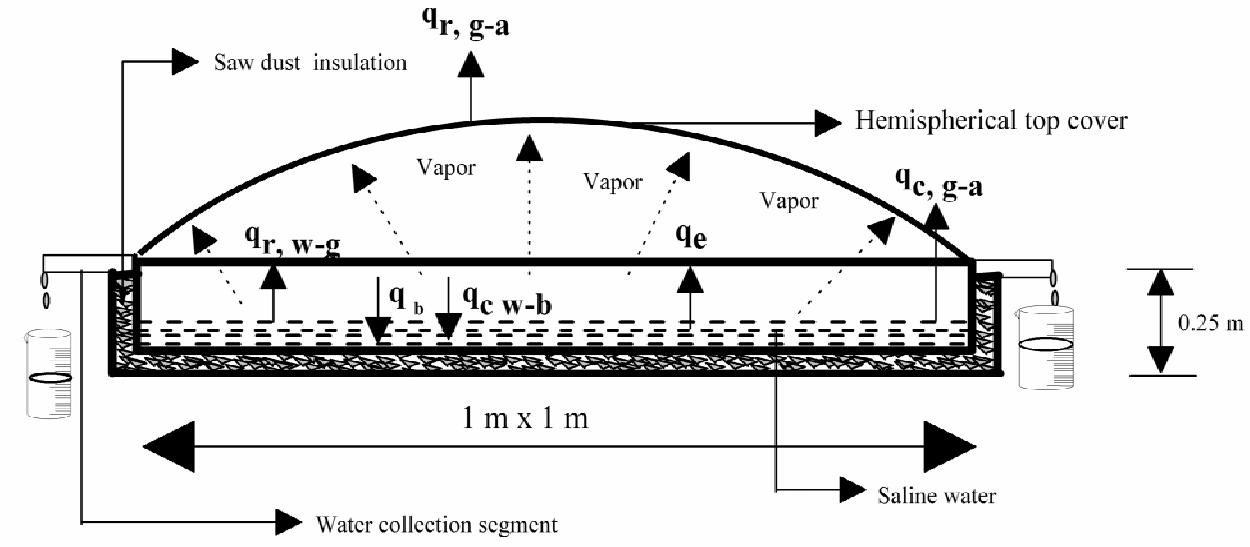

Fig. 1 Schematic view of the hemispherical solar still

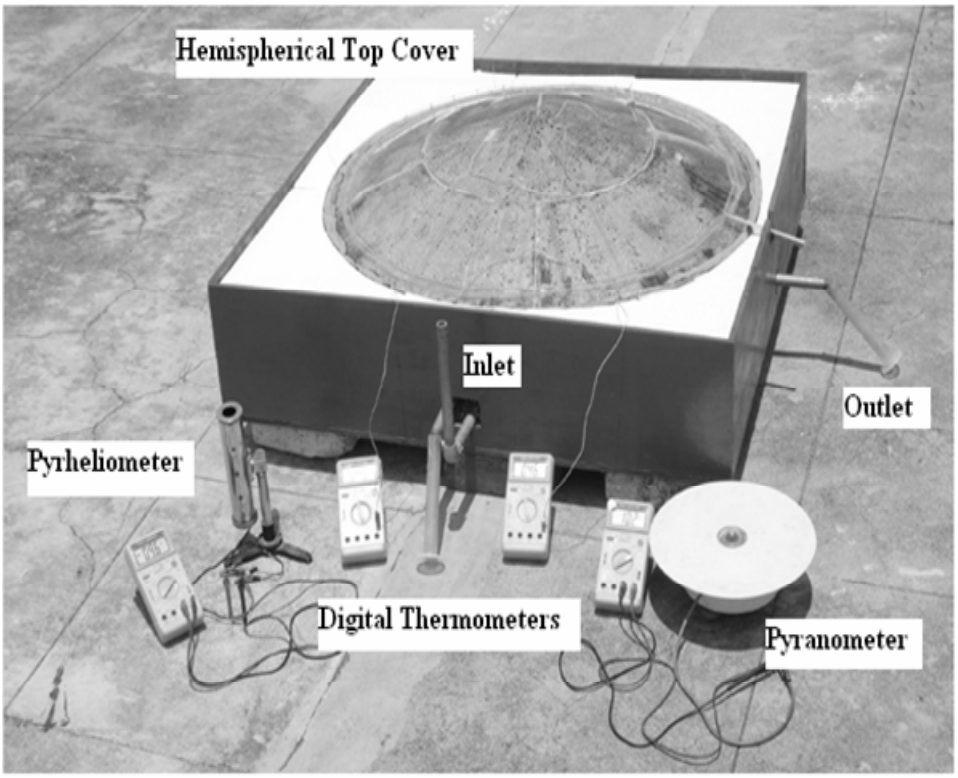

Fig. 2 Photographic view of the hemispherical solar still

2.2 Pyramid solar still

Pyramid acrylic solar still of area 1.10m x1.10m is designed. The still was filled with the water a height of 0.05m. The top of the system is covered by a glass with a height of 0.20m at the middle. It is tightened using bolts provided at the surface with cushion supports. The bottom of the still is insulated using sawdust. The water storage basin of the still are constructed with dimension 0.95m x 0.95m x 0.10m of mild steel. Water collection segment of dimension 0.10m x 0.05m x0.075m is provided at four sides of the basin walls. Outlet pipes are provided at four sides of the water collection segment. Water was poured to the basin by using the funnel through the inlet at outside the system. The pictorial view of pyramid solar still is shown in Figs. 3-4.

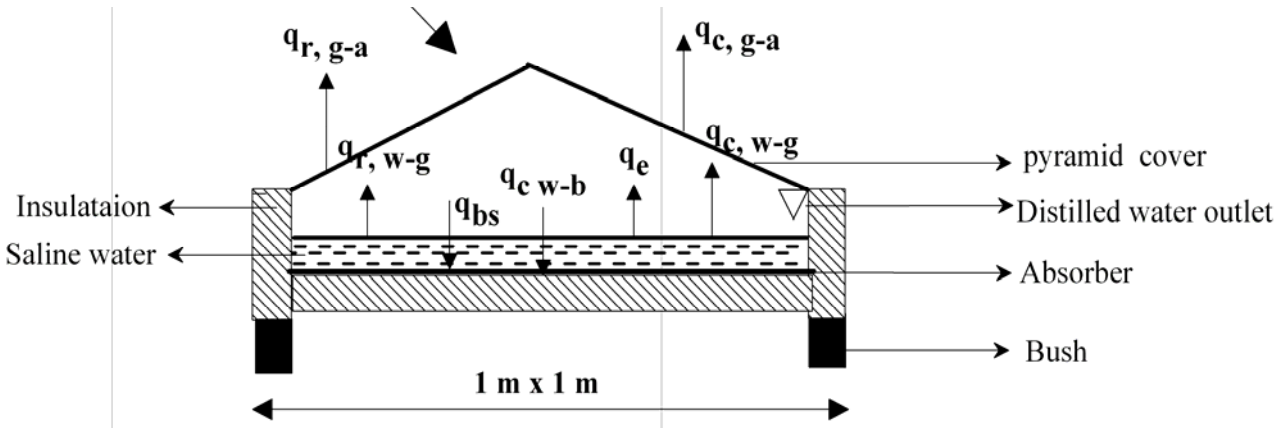

Fig. 3 Schematic view of the pyramid solar still

Fig. 4 Pictorial view of the pyramid solar still

3. Experimental setup

Measurements were performed in a pyramid and single slope solar still designed and installed at the solar energy laboratory, Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Coimbatore. The variations of water temperatures and glass temperatures of the still as well as the productivity with respect to time are recorded. The measurements are carried out by calibrated copper constantan thermocouples. The solar radiation is recorded with the help of pyranometer. The hourly productivity of the fresh water is collected through a measuring jar. The daily productivity is obtained as summation of day and night productivity.

4. Results and discussion

The experiments were conducted to investigate better performance in distillate yield by comparing the hemispherical and pyramid solar stills. The system was operated continuously for several clear sky days. The influence of climatic conditions and solar radiation, on the system in production of distillate yield is investigated. Fig. 5 represents the solar intensity measurement. The peak value during the experimental study shows maximum in the range of radiation received during 12 PM to 1 PM. Radiation received during this study is in the range of 450 W/m^2 as minimum to 1099.7 W/m^2 as maximum for both the experiments. The temperature variation at different parts of the still during the operation with respect to time is shown in Fig. 6. The solar radiation transmitted through the glass cover and heat up the basin water; hence, its temperature increases. One part of thermal energy would be transferred to the water and the other part would be conducted to the insulation material under the basin. At the beginning, water temperature is higher than the basin temperature. But in the evening, when the solar radiation decreases, water and air inside the still starts to cool down and water temperature curve falls down. On the other hand, temperatures of the basin liner and other elements of the still decrease slowly with respect to time due to decreasing of the ambient temperature. This causes a significant difference between basin and insulation temperatures during the night period. A small quantity of heat energy gained from the insulation in this period and keeps the basin water temperature high enough to produce fresh water. Because of the bottom insulation is made by low thermal conductivity material. This causes an enhancement of the still productivity, especially during the night period. Solar intensity has a major effect on the performance of the solar stills. A shadow effect creates a small amount of shadow to fall over the water surface

during in the morning time as well as in the evening time. This type of drawbacks is fully rectified by reducing the height of the basin as well as hemispherical shape top cover. Thus the shadow effect does not affect the rise in water temperature. Fig. 7 shows the variation of efficiency with respect to time. The maximum efficiency was calculated for a hemispherical solar still as 32.02% and 26.59% for a pyramid solar still. The yield rates of the two systems are shown in Fig. 8. It reveals that the productivity is more for hemispherical solar still. Because this type of still has a peculiar advantage such as, it receives the radiation from all the sides of the still. But in the pyramid solar still, the radiation may scattered due to the top edge.

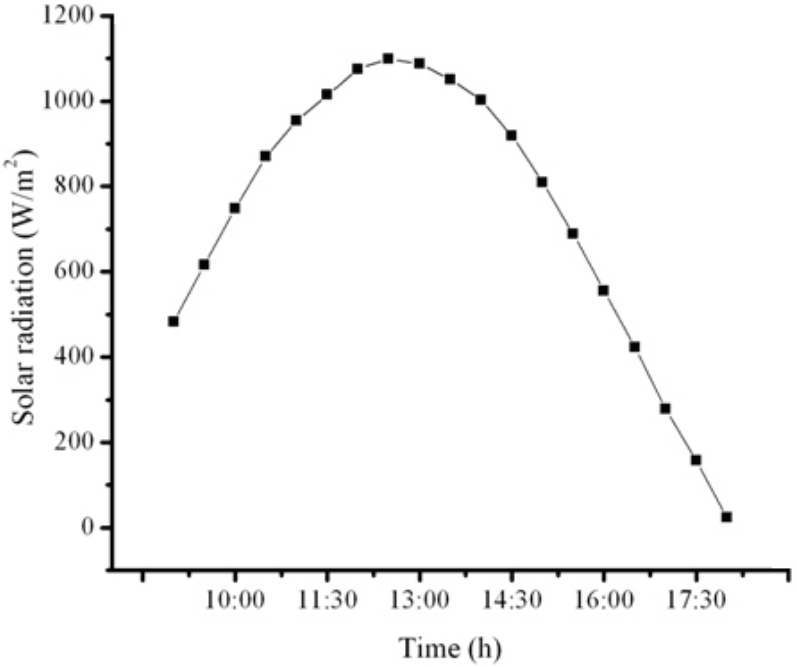

Fig. 5 Solar radiation intensity with respect to time

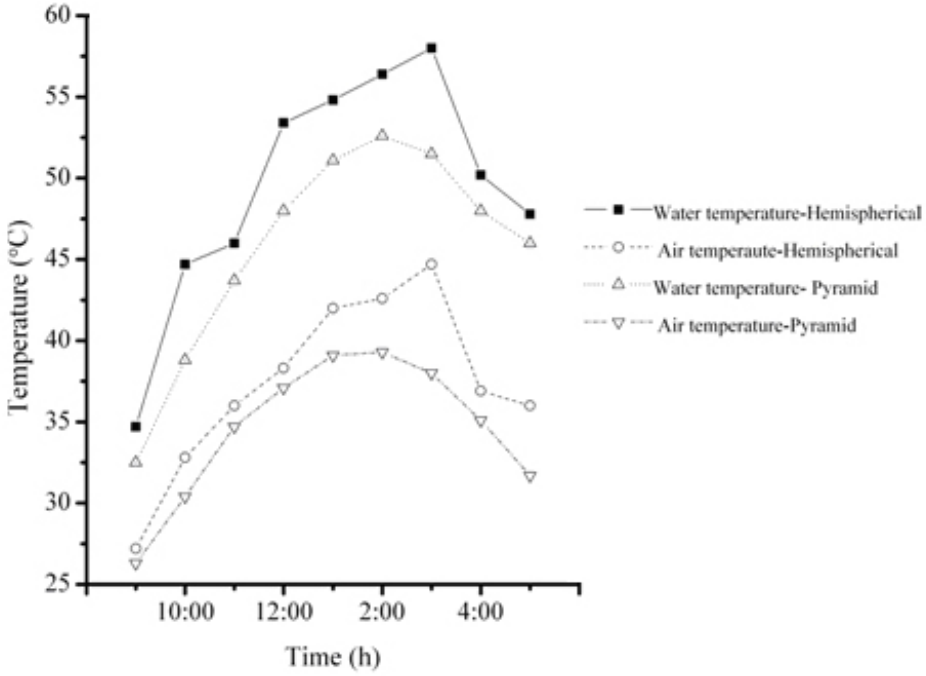

Fig. 6 Temperature profile of the systems

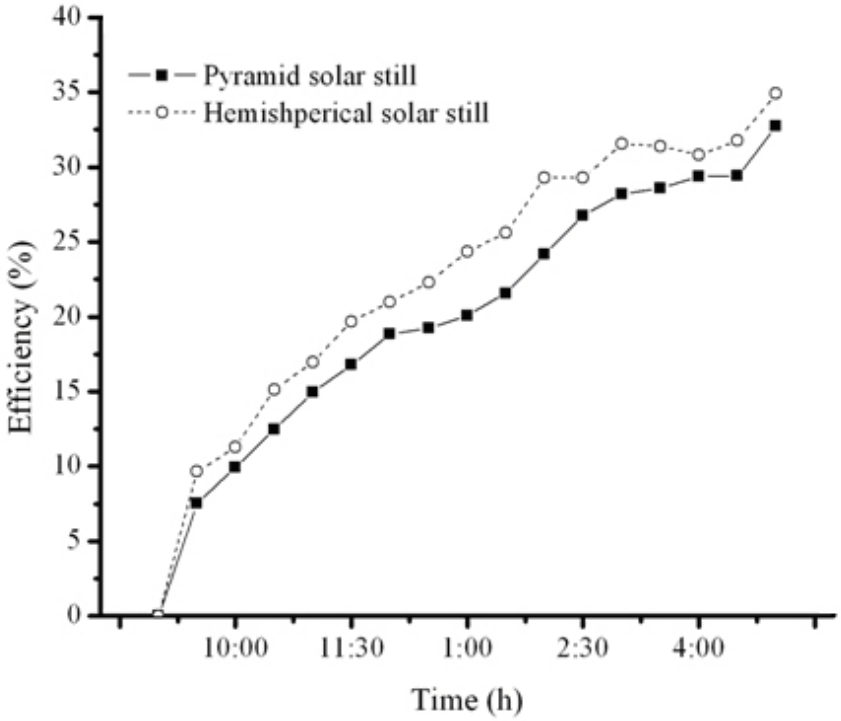

Fig. 7 Efficiency of the systems

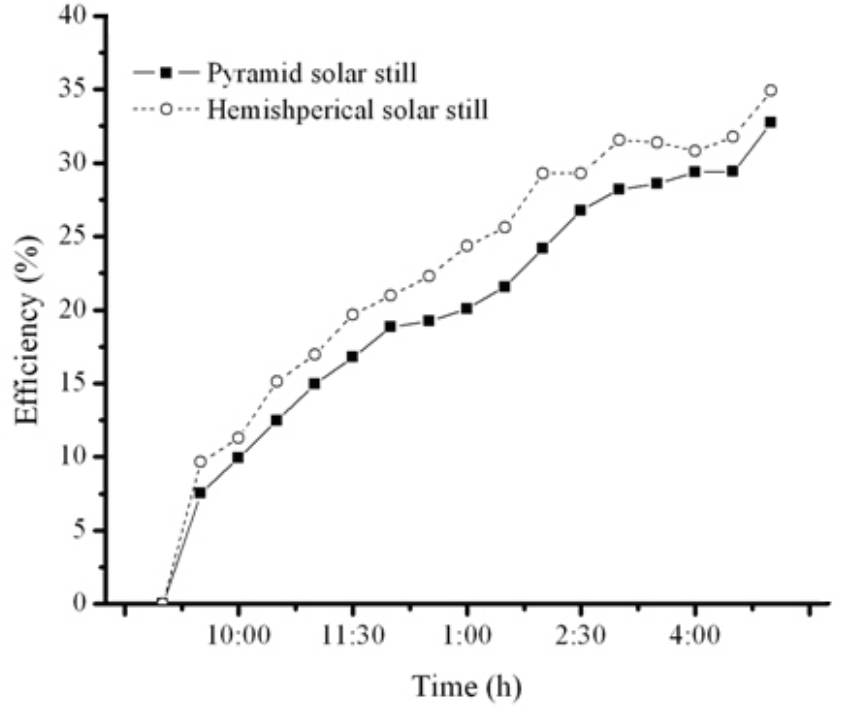

Fig. 8 Variation of yield with respect to time

5. Conclusion

A comparison is made between hemispherical and pyramid solar stills. These proposed stills are worked without practical difficulties. Both the stills are designed on the basis of top cover arrangement. Consequently, these stills provide very good water temperature rise. The differences between the evaporation and condensation rates are strongly varied due to top cover design. Because it produces change in vapor density at the water surface of the basin. A hemispherical and pyramid solar still was fabricated and tested. The daily production of the hemispherical solar still was about

3.3 l/m^2.day and its daily efficiency was about 32.02%. Similarly 2.73 l/m^2.day collected for pyramid solar still and its calculated efficiency 26.59%. The efficiency of the hemispherical solar still is more than the pyramid solar still. It concludes that the proposed experimental work can be identified that the large daily and hourly distillate yield rate production may be extracted from hemispherical solar still.

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