DESIGN, FABRICATION AND TESTING OF A MODIFIED SINGLE SLOPE SOLAR STILL

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ABSTRACT

In the present work a single slope single basin solar still was designed fabricated, and its performance was tested in the Allahabad climatic conditions. An effort is also made to find the effect of condensing cover material on the performance of solar still. It was found that over the hours of experimental testing that the condensing cover made up of glass gives 64% more distillate than the condensing cover made up of polyvinyl chloride. Cost calculations are also performed to find the payback period of the system.

Keywords: Slope Solar Still, heat transfer coefficients.

INTRODUCTION

A solar still is a device by which distilled or portable water can be produced from saline water, such as seawater brackish water. Solar still are normally used to provide a small scale of portable water needed in remote isolated location, where there is plenty of solar energy source of saline water are available [1].

A conventional basin type solar still is simply an air tight basin that contains a shallow layer of saline water, a sloped top cover of a transparent material usually glass to solar radiation and side metal frame walls[2]. Solar distillation is a technology with a long history. The first known-application of solar stills was in 1872. When a still at Laslina on the northern deserts of Chile started its three decades of operation to supply a mining community with drinking water. Most stills built and studies since then have been based on the same principles, though many variations in geometry, materials, methods of construction, and operation have been incorporated [3]. The cost of building and operating a conventional still is relatively low compared to those involving sophisticated designs. However, the conventional or standard basin type solar still [5-8] proven to have a low thermal efficiency.
with low daily distillate productivity [4]. The efficiency and yield of the conventional solar still depend on different factors: the design and functionality of the still, location, weather conditions, etc. [5]. Their low thermal efficiency is due to the considerable shadow caused by the walls of the basin that tend to decrease the absorption of solar radiation that could have been used for water distillation process. In order to improve the performance of conventional solar stills, several other designs have been developed, such as the double-basin type [6], multi-basin [7,8], inverted trickle [9], multi-effect [10], regenerative [11], with reflectors [12]. Kalogirou [13] presented an excellent review on various types of passive and active solar stills. Among these types are the single-slope with passive condenser, double condensing chamber solar still, vertical solar, and conical solar still. In this paper, a modification in design of a single slope solar still is presented and its performance is evaluated in Allahabad climatic condition. The condensing cover made-up of glass cover is replaced with a PVC material.

**Design of the solar still**

The photograph of the modified single slope solar still are shown in figure 1. The still mainly consists of the basin and absorber plate carrying the saline water, the cover, and the support structure as shown in Fig.1. The basin of the still (tray) and absorber plate, and the collector were all fabricated using Galvanized Iron. The basin contains the absorber aluminium plate which has a surface area of 1×1 m². A hole with diameter of approximately 30 mm was drilled into the tray to provide accessibility of saline water into the basin during initial filling and bottom section of basin was insulated to reduce thermal losses to the surroundings. The absorber was coated with black paint to maximize absorption of the incident solar radiation on the basin. The two different condensing covers, located on the top of the solar still unit, was made of two different material(a) A glass cover and (b)A transparent PVC sheet. The side walls are made of using two 5 mm thick glass plates separated by 2 cm air gap. The side walls are made of glass to capture more diffuse radiation and the air gap is provided to minimize heat loss from sides. The distillate output from the still was frequently collected using a plastic container placed under the nozzle outlet part of the collector.

![Fig 1 photograph of the modified design single slope solar still](image-url)
Test site meteorological environment

The new single slope solar still was tested under Allahabad (25°45' N, 81°85'E) climatic condition in typical summer month. Allahabad is characterized by two distinct seasons: a very hot season (March–June) and cold season (November -February). The hot months are typically characterized by high solar insolation. The hot months average temperature of Allahabad range from 30°C to 43°C. The cold month’s average temperature range from 3°C to 14°C.

Experimental Procedure

Experiments were conducted at Allahabad (U.P.), India (25°28’N, 81°54’E) in the month of April. The condensing cover of the single sloped still was kept with their glass covers facing south, so as to obtain maximum radiation throughout the day. Initially 2 cm basin water depth was taken. Readings of solar intensity, ambient air temperature and the temperature of basin water, glass cover, inside air were recorded. Hourly and daily distillate output was measured directly from the graduated bottles. Two different sets of experiments were conducted. These were (1) Performance of still with condensing cover made of glass and (2) Performance of the still with condensing cover made of PVC. Copper – constantan thermocouples were installed and used to measure the temperature of water, condensing cover, basin, atmosphere and anemometer used to measure wind speed.

RESULTS AND DISCUSSION

Numbers of experiments were conducted on every set of experiment. Typical results of the variation of the ambient temperature, cover temperature, saline water temperature and basin temperatutes during representative days of testing are shown in fig.4. At the start in the early morning and at the end in the evening the basin water temperatures and glass cover temperatures of both the still match very closely, but the difference increases and attains maximum value in the afternoon. This difference in the time for the maximum values of solar radiation and that of basin water temperature is due to the higher thermal inertia of the basin water mass. Fig .2 shows the solar intensity on particular day 15-03-2013. The maximum intensity of 1060 w/m² is received at 13:00 hrs.

Fig.2 Variation in solar intensity on 15-03-2013

Fig .3 shows the wind speed on particular day of 15-03-2013. The maximum wind speed of 1.1 m/s is observed at 11:30 hrs.
Fig. 3 Variation in wind speed on 15-03-2013

Fig. 4 shows the temperature of glass, water, atmosphere and basin. Initially at 8:30 hrs glass temperature is higher than water temperature.

Fig. 4 Variation of temperature with time

Fig. 5 shows convective heat transfer coefficient for Present model and Dunkle model. The maximum value of Convective heat transfer coefficient for Present model is obtained at 4:30 in the evening time.

Fig. 5 Variation of convective Heat Transfer Coefficient
Fig. 6 shows evaporative heat transfer coefficient for present model and Dunkle model. Evaporative heat transfer coefficient for present model is higher than Dunkle model.

![Fig. 6 Variation in Evaporative heat transfer coefficient](image)

Fig. 6 Variation in Evaporative heat transfer coefficient

Fig. 7 shows the variations in theoretical distillate and experimental distillate.

![Fig. 7 Comparison of theoretical and experimental distillate yield](image)

Fig. 7 Comparison of theoretical and experimental distillate yield

Fig. 8. The Total daily distillate yield from the still as a function of daytime during the four days of testing.

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Cost estimation

Typically, in designing a solar still for a primary application to provide a small scale of portable water needed in remote isolated location, the objective is to maintain the cost minimal.

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<th>Component</th>
<th>Cost (Rs)</th>
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<tr>
<td>G.I. basin</td>
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<tr>
<td>Glass(5mm thickness)</td>
<td>4700</td>
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<tr>
<td>Support legs</td>
<td>600</td>
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<td>Coating &amp;primer</td>
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Cost estimation for various component used in the in-house fabrication of the single slope solar still is given in Table1. The cost of the single slope still glass is Rs 4700. The cost of labour work was estimated Rs 700. The total cost of the fabricated still, including labour, was approximately Rs 10600. It should be noted that the solar still here was fabricated for research purpose and not for commercial use. It is expected that the cost would significantly decrease if a large number of still are fabricated for commercial purpose. With zero maintenance cost the payback period will be less than one year.

CONCLUSIONS

In this work, a modified single slope solar still was designed, fabricated and experimentally tested during daytime for six days under outdoors of Allahabad climatic conditions. It was found that over the hours of testing in data, the daily distillate produced from the still ranged from approximately 2.25 litre of absorber area. The daily efficiency of the still reached as high as 39%. The payback period is less than one year.

REFERENCES