COMPARATIVE STUDY OF PASSIVE SOLAR STILL WITH TWO DIFFERENT CONDENSING COVER MATERIALS

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ABSTRACT

Present communication is an attempt to find out the effect of condensing cover material for a passive solar still. Glass and Poly-Carbonate (PC) sheets were used as condensing covers. Stills were experimented with 1.5 cm and 3 cm of water depth in the basin. The best productivity with glass cover was observed as 2.089 L/m^2/8hrs whereas it was only 1.106 L/m^2/8hrs with PC cover. There was 13.4% loss of efficiency for higher depth with glass cover whereas it was 55.69% for higher depth with PC cover. Convection was predominant in case of glass cover whereas evaporation was higher for PC cover. There was a 39.4% gain of efficiency in the case of glass cover having lower water depth whereas it was 69% higher for glass as compared to PC cover with higher depth.

Keywords: Condensing Cover Material, Desalination, Passive Solar Still, Poly Carbonate, Water Depth.

I. INTRODUCTION

The gap between demand and supply of potable water is high and to bridge it up, solar water distillation technique is gaining popularity for small scale demand. According to Howe [1] there is 30% cost reduction in producing fresh water by desalination as compared to the transportation of the same from some distant source. During the hot season, solar insolation is high and water is at its peak consumption. Thus, utilization of solar energy for fresh water production becomes a very convenient method and thereby making solar stills an attractive alternative of electricity based purifying systems.

The performance of a solar still is affected by three major factors – meteorological parameters, design parameters, operational parameters. Meteorological parameters are out of human control viz solar intensity, ambient temperature, wind velocity and humidity etc. But these have direct influence on the productivity of the solar still. So the designer has to be very cautious, while installing a solar still, regarding these parameters. Basin area, condensing cover thickness & its inclination manly constitute the design parameters these can be moderated as per the requirements. The depth of the water in the basin & orientation of still axis etc are clubbed under the head of operational parameters [2-4].

Condensing cover thickness & its inclination has been the pivotal focus of various research scholars [5-6]. But very limited churning on the material of the condensing cover was found [7]. Glass has been a unanimous choice for solar still. But glass is brittle and heavy. So somewhat it is difficult to deal with. It is reported that a bulk sale of plastic solar still on commercial basis was more successful than glass covers. Also, a wide comparison has been made between plastic and glass for solar still [8-10]. In the present work, authors have fabricated two identical, single basin, passive solar stills in the campus of Rajshree Institute of Management & Technology, Bareilly and used glass & polycarbonate as condensing cover. Stills were kept operative for all 24 hours and readings were recorded during the working hours only. Experiments were conducted on different days of February and March 2014. The best recorded values are being presented here.

II. MATERIALS & METHODS

Productivity of the solar still, predominantly, depends on the convection and evaporation phenomena inside the still. Since convection inside the still is governed by the temperature difference between condensing cover and water surface so it is the case of free convection and thus Nusselt's theory is applicable here. Dunkle [11] has given a direct approach to calculate the heat transfer coefficient under convection and evaporation process between parallel surfaces.

Convective heat transfer is given by:

$Q_{cw}=h_{cw}.A.(T_w-T_g)$

(1)

Where h_{cw} is convective heat transfer coefficient

$Nu=h_{cw}*L_v/ \lambda= C(Gr.Pr)^n$ (2)

Or, $h_{cw}=k.C.(Gr.Pr)^n/L_v$ (3)

Gr and Pr are the grashof's & Prandtl numbers respectively. The unknowns C and n constants, given in Eq.(2) can be determined by regression analysis using experimental data and following the Shukla and Rai model [12].

Evaporative heat transfer causes and contributes to water distillation. Thus mass of water distilled can be calculated by knowing the evaporative heat transfer rates:

$Q_{ew}=h_{ew}.A.(T_w-T_g)$

(4)

Where h_{ew} is known as evaporative heat transfer coefficient. It can be evaluated as:

$h_{ew}=Q_{ew}/(T_w-T_g)$

(5)

Alternatively,

$h_{ew}=.01623.h_{cw}.(P_w-P_g)/(T_w-T_g)$

(6)

$m_{ew}= Q_{ew}.A.t/\Delta h_v$

(7)

from eq (3), (4) and (5);

$m_{ew}=.01623.\lambda.A.t.(P_w-P_g).C(Gr.Pr)^n/\Delta h_v.L_v$

(8)

Efficiency of the still is a ratio of total amount of thermal energy utilized to get a certain amount of distilled water in a certain period to the energy supplied to the solar distillation unit during the same period.

$\eta_{oA} = [m_{ev}.\Delta h_v / I(t).A_b+ m_w.C_w.(T_{ini} - T_{amb})]x100$ (9)

III. EXPERIMENTAL SETUP & INSTRUMENTATION

Fig (1) shows the pictorial view of the fabricated stills. The basin area of the solar still is kept as 1 m^2 which is painted black to increase absorbvity. Condensing covers were inclined at the latitude angle of Bareilly and still axis is oriented due North-South (N-S) direction to receive the maximum possible solar radiation. The stills were experimented with two different depths of water inside the basin as 1.5 cm and 3 cm. The condensed water is collected in a galvanized iron channel fixed at the lower end side of both the condensing covers. The distillate collected is continuously drained through flexible hose and stored in a bottle. Solar Intensity was measured with TES 1333R Data-logging Solar Power Meter. K-type Copper-constantan thermocouple were used for measurement of water, cover, ambient and vapor temperatures. A Vane probe Mextech AM-4208 anemometer is employed over the stills to measure the wind velocity. The collected distillate yield has been measured using graduated cylinder with least count of 1ml.

Fig-1 Pictorial View of Set-Up **Fig-2 Instrumentation Details**

IV. RESULTS AND DISCUSSION

Fig (3) depicts the trends of solar insolation recorded during the different days of experimentation. It is clear from the graph that the best intensity was obtained during the experiments with glass cover at lower water depth.

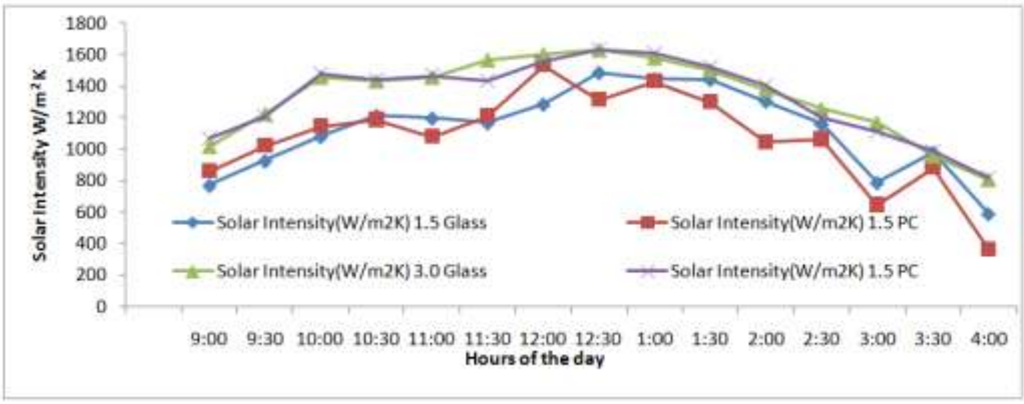

Fig-3: Variation of Solar Intensity During The Experimentation.

After the insolation, next important parameter is the ambient temperature during the course of work. The same has been plotted in fig (4). The plots indicate almost same variation of ambient temperature except for lower depth with PC as condensing cover.

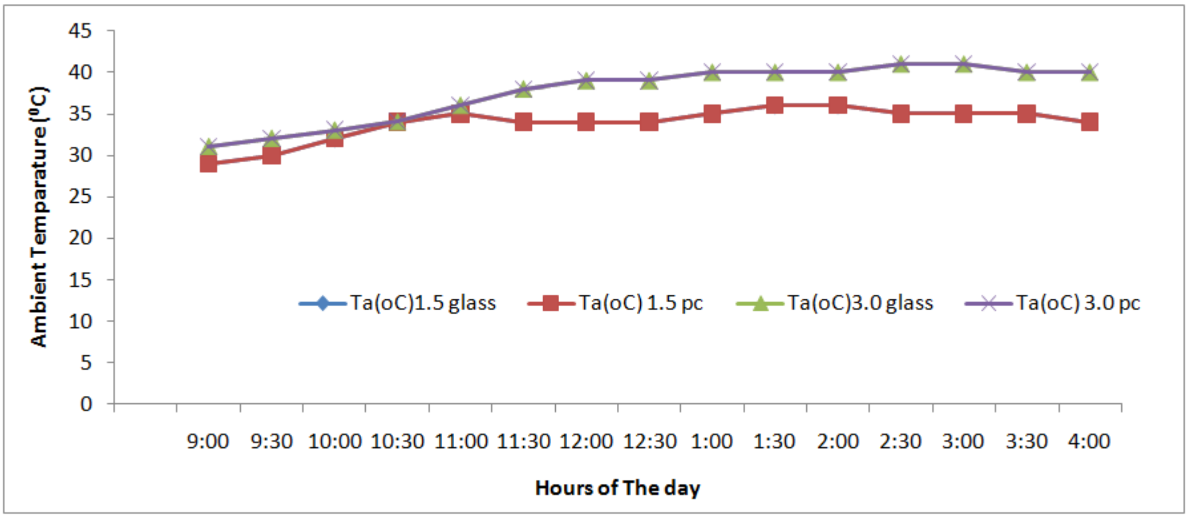

Fig-4: Variation of Ambient Temperature During The Experimentation.

Wind velocity caters a cooling effect by removing the heat from outer surface of condensing cover and thus it can greatly affect the productivity of the device by reducing the net temperature difference between water and condensing cover surface. Its variation has been shown in fig (5). The highest average value of wind velocity was recorded as 2.253 m/s on Glass cover with higher depth of water in the basin.

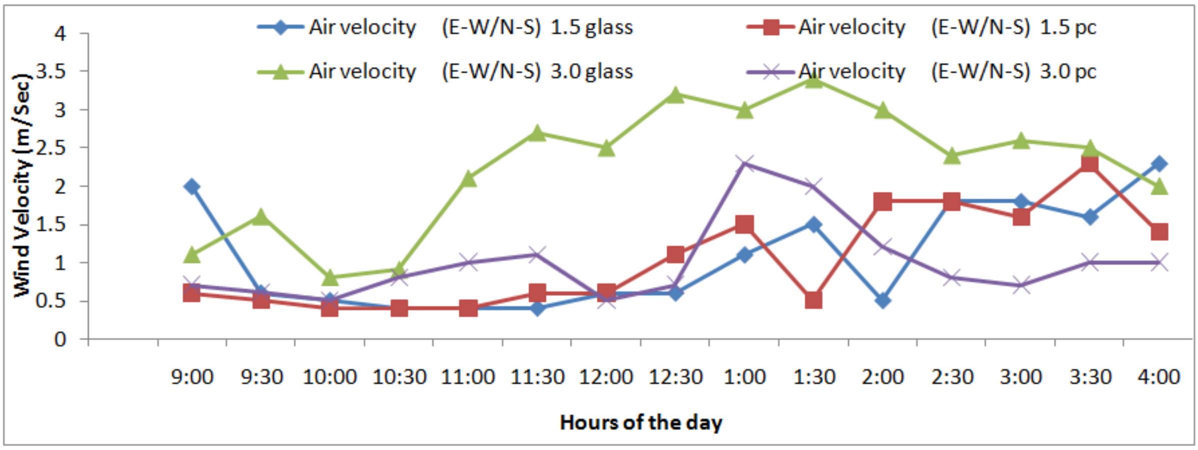

Fig-5: Variation of wind velocity during the experimentation.

Convective and evaporative heat transfer coefficients plotted in Fig (6a) and (6b). It is found that the major part of input energy fraction was being utilized to evaporate the water in case of PC condensing cover whereas convection was predominant in the case of glass cover.

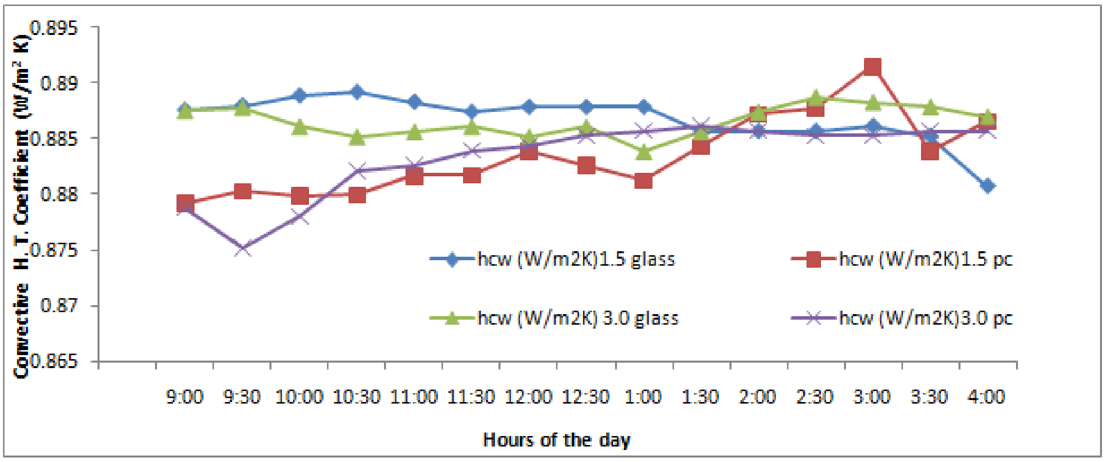

Fig-6a: Variation of convective heat transfer coefficient during the experimentation.

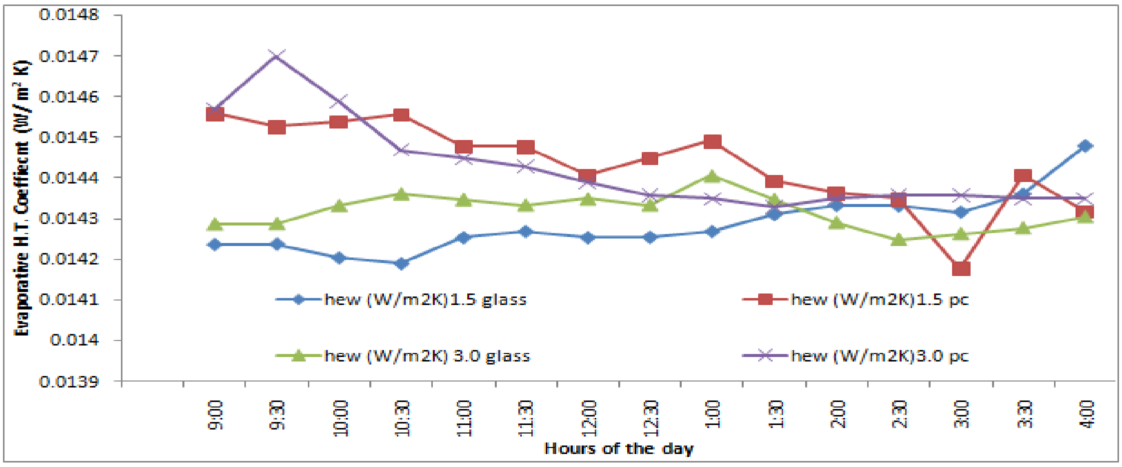

Fig-6b: Variation of evaporative heat transfer coefficient during the experimentation.

Fig (7) shows the trend of still productivity. The most consistent productivity was obtained with 1.5 cm of water depth having glass as condensing cover. It is also observed that the effect of condensing cover material is more prominent with higher water depth. With increase in the depth, the difference of productivity of both stills is higher. The best productivity with glass cover was observed as 2.089 L/m^2/8hrs whereas it was only 1.106 L/m^2/8hrs with PC cover

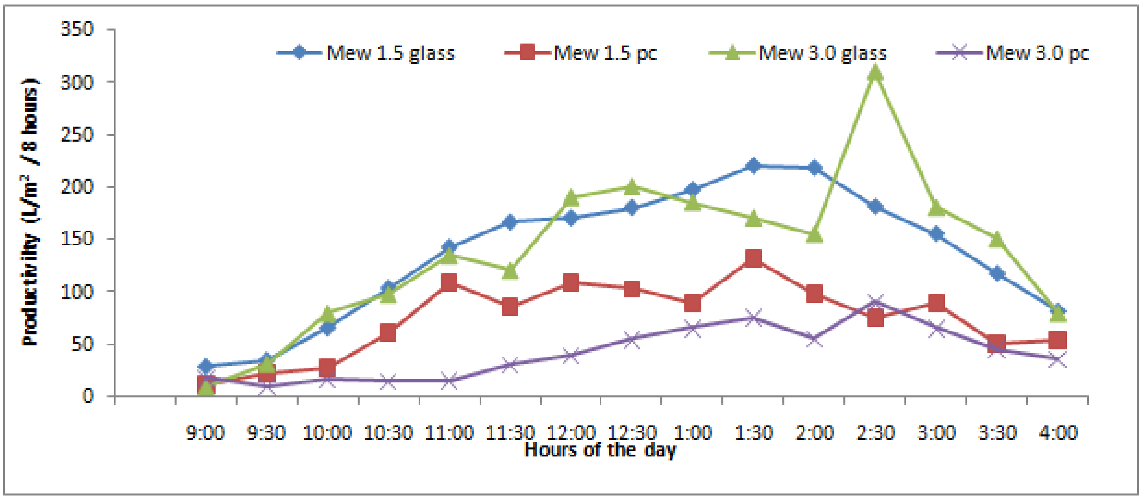

Fig-7: Variation of measured productivity during the experimentation.

Instantaneous efficiency of still with glass cover was found 27.6% at lower depth and it was 23.9% for higher depth whereas it was found 16.7% and 7.4% in case of PC cover for lower and higher depth respectively.

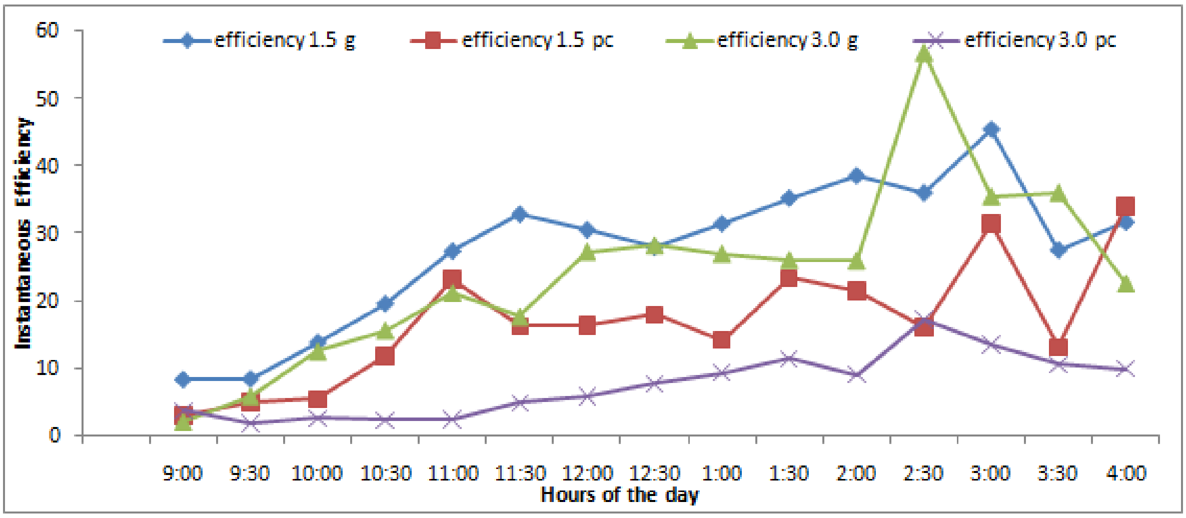

Fig-8: Variation of instantaneous efficiency of both the stills during the experimentation.

V. CONCLUSION

It is found that no much exercise is done on the material of condensing covers for a passive solar still. Authors have executed the same thought selecting glass & PC covers having two different depths of water in the basin. On the basis of this experimental study it is concluded that Glass cover has shown 47% gain in productivity as compared to PC cover. The rate of evaporation was better in case of PC cover. So there is a room of improvement for the convection phenomena in this case. Role of meteorological parameter was studied and it is found that the wind velocity should not exceed more than 2 m/s. This study helps the designers to select the better cover material as well as optimum water depth for the passive solar still. It is suggested to vary the thickness of PC so as to match up with the performance of glass cover. Some other available materials like poly vinyl chloride, acrylic etc. may, also, be exercised for better comparison.

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