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Effect Of Absorber Material On The Performance Of Basin Type Solar Still With Multiple Floating Porous Absorbers

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Abstract: This paper presents an experimental work conducted atRewa (M.P.) (24'32"N, 81'18"E), in order to evaluate the effect of the absorber material on a modified single sloped basin type still. The modified still consisted of multiple porous blackenedjute absorbers floated on the basin water with the help of thermocol insulation and gives quicker start-up and higher yield due to low thermal inertia of the floating absorber and increased absorptivity of the evaporation surface. The performance of the still with the easily obtainable absorber materials such as jute fabric and cotton cloth was compared. It was observed that the floating porous absorber type still performed at higher operating temperatures and gave better yield with the jute fabric as compared to cotton cloth with around 12% better distillate output, since the absorptivity of jute cloth is better than cotton cloth. The experimental results were verified theoretically with the help of Dunkle's heat transfer relations. Higher values of heat transfer coefficients with jute fabric absorber were obtained.
Keywords:solar still, floating porous absorber, start-up, absorptivity, jute.

1. Introduction:

The continuingly decreasing fossil fuel reserves and day by day increasing petroleum product priceshave made it unavoidable for the man to think about the vastly abundant and free of cost solar energy and its applications. Also, to obtain potable water in many parts of the world is still a major problem. Solar still is a cheap and simple device to get pure water with the use of solar thermal energy which can be fabricated with the locally available materials by even unskilled person. Therefore, it is very suitable for the undeveloped and remote regions of the world where electric power is not available or scarce and even in the developed areas, where people have abundantly available sunlight and sufficient space to install the solar distillation units.

Even having all such attractive features, there is still required a lot of research and improvements to make solar distillation attractive. Several researchers have studied the effect of variousdesigns, operational and climatic parameters. Many designs and modifications of the solar still have been proposed. Heat and mass transfer relations for the conventional basin type solar still were developed by[1], with the help of which the glass cover temperature for a given ambient and basin water temperature could be calculated by trial and error method. [2]Sodha, M.S.,et al had investigated that, reduced air gap increased the performance of the still, since the lesser air mass gets saturated more rapidly and also the still operates by diffusion mass transfer due to smaller vapour length. [3]Rajvanshi, A.K. et al had studied the effect of black dye in deep basin still. He observed a 29% increase in the yield due to greater absorptivity caused by the dye. [4]Tiwari, G.N. et al had established that the glass cover inclination equal to the latitude of the place, receives sun rays normal to the cover all round the year. [5]Minasian,A.N. worked on a wick basin type solar still and got an improvement in the performance. [6]Abu-Hijleh increased the still performance by water film cooling of the glass cover. [7]Akash B.A. et al used different types of absorber materials like rubber mat, black dye and black ink and obtained an increase in the distillate yield by 35 to 60 percent. The effect of wind speed on some designs of solar still was investigated by El-Sebaii A.A[8]. The use of black rubber sheet and black gravel as storage media gave a daily distillate output of 3.5 Kg/m^2 as experimented by Nafey, A.S.[9] [10]Naim et al got an increase in the rate of evaporation by using charcoal particles as heat absorber medium. The sponge cubes were used in saline water by Abu- Hijleh et al[11] to increase the rate of evaporation. [12]Tiwari A.K. studied the effect of water depth on heat and mass transfer of a passive type solar still and observed the basin water depth varies inversely with the productivity. [13]Velmurugan V. et al increased the productivity of a solar still by integrating fins at the basin plate of the solar still. The effect on the performance of the solar still with PCM as storage material was studied by Sebaii, A.A.[4]. Tanaka Hiroshi[15] experimented with internal and external reflectors and observed an increase in the yield by 70 to 80 percent in the winter season, when the reflector was slightly inclined forward. [16]Eldalil Khaled M.S. observed an improvement in the still performance by using vibratory harmonic effect due to which the productivity increased to 5.85l/m^2 per day and average daily efficiency of 60%. A regenerative solar still was investigated by Sakthivel M.[17], in which jute cloth was used as energy storage medium and latent heat of condensation accumulated within the air gap was utilised. [18]Murugvel et al observed the effect of different wick materials with minimum water mass on the performance of a double sloped solar still. They found that, rectangular aluminium fins covered with black cotton cloth and arranged in lengthwise direction were more effective. [19]Omara Z.M. had conducted an experimental study and compared the performances of finned and corrugated stills with the conventional still at the same water depth and the same water quantity. The finned and the corrugated type stills performed better than the conventional type due to increased absorber surface area. [20]Srivastava Pankaj K. had investigated the adverse effect of the crookedness of the condensate channel and the effect of the scattering of incidentsunrays due to condensate dropletson the glass cover.Thecrookedness or a slight upward bend of the distillate channel or aminor obstruction of the channel due to a piece of putty or some matter may significantly alter the performance of the still, especially during the summer season and moreover in case of totally black linedstill, since the hotter inside still air causes rapid re-evaporation ofthe accumulateddistillate at the depressed part of the channel. [21]Srivastava Pankaj K. have developed a high performance modified basin type still with multiple floating porous absorbers. They conducted the theoretical and experimental analysis of the modified still and observed a 68% increase in the yield, whilst the application of a twin reflector booster gave a distillate gain of 79%.The present experimental work, deals with the investigation of the performance of the modified still with different glass cover thickness, 3mm. and 4mm. and different absorber materials such as jute fabric and cotton cloth. The results obtained theoretically from the Dunkle's relations were compared with the experimental values. Besides the convective and evaporative heat transfer coefficients for different variations have also been compared.

2. Experimental Setup and Procedure:

The experiments were conducted at Rewa (M.P.) with latitude and longitude of (24'32"N, 81'81"E). Two single sloped basin type solar stillsmade of wood were constructed, as shown in Fig.1 with the basin size of 0.8m x0.65meach and the cover slope[4] of 24^0, which is nearly equal to the latitude angle of Rewa.The glass cover was of ordinary window plane glass of 3mm. thickness.Both the stills were modified by floating the porous absorbers[21]as shown in Fig.2,with the help of nine thermocol pieces of dimension 0.79m x 0.07m x 0.025m, such that the basin was completely covered with the porous absorbers.In one of the stills, blackened jute fabric was used as absorber, whereas in the other, black cotton cloth was used.The water could be supplied through the feed pipe at the rear wall of the stillsand the thermocouple wires were inserted into the stills through a small opening at the rear wall. The distillate was collected in the glass graduated bottles. Initial basin water depth of 5cm. was kept in all the test runs. Hourly readings of the temperatures of the glass cover, porous absorber, basin water and the ambient air temperature were recorded with the help of multichannel digital temperature indicator connected to copper constantan thermocouples. Mercury thermometer was used to measure the ambient air temperature. The hourly variation of the solar intensity was recorded with the help of digital solar power meter, whereas the distillate could be measured directly from the graduated bottles.Both the stills were oriented in the north – south direction with the glass cover slope facing south. Before starting the tests, both the stills were checked for synchronisation. For this, both the stills were used as conventional basin type and there performances were observed simultaneously for five days, keeping them side by side. After confirming the equal performances of both the stills, the experiments with different absorber materials were conducted for another five days. The observations were recorded at hourly basis from 7am to 5pm and then at 7am the next day, in this way 24 hours observations were recorded which included the nocturnal output also.

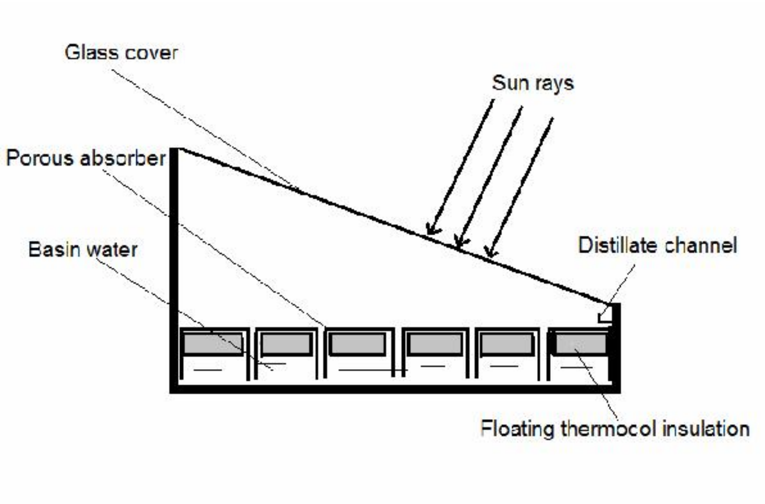

Fig.1 Construction of the modified still.

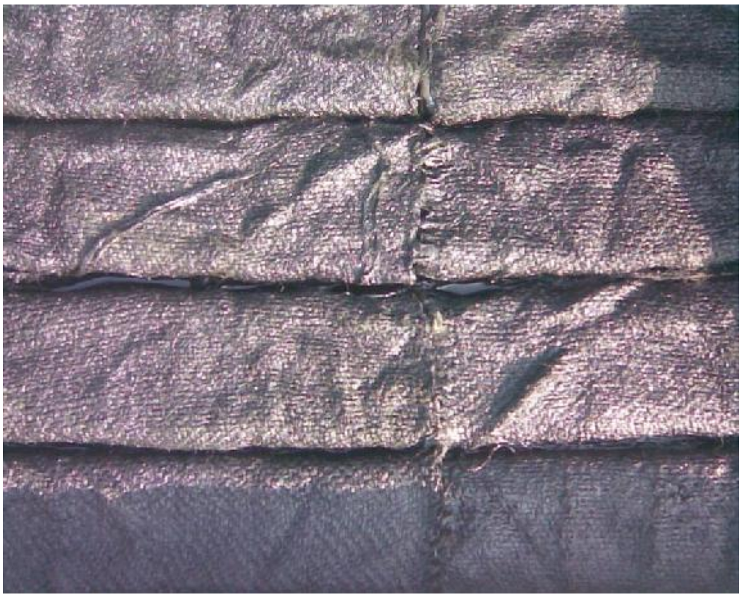

Fig.2 Porous absorbers of blackened jute fabric

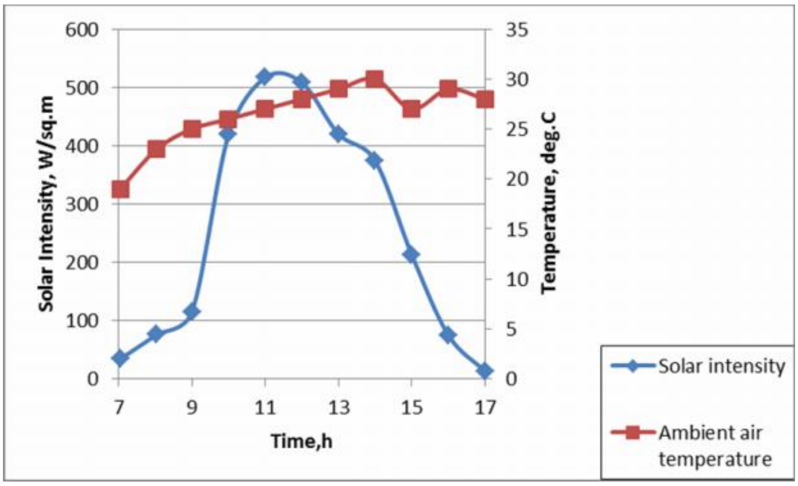

Fig.3 Hourly variation of Solar Intensity and Ambient air temperature.

3. Theoretical study: The evaporation of water within the still is dependent on the evaporative heat transfer coefficient, which is a function of convective heat transfer coefficient between the wet porous absorber surface and the glass cover. The convective heat transfer coefficient depends upon the difference between the absorbertemperature and glass cover temperature and the difference in partial pressure of water vapour between the porous absorber and the glass cover. The relations[1] for the coefficient of convective heat transfer and the evaporative heat transfer can be used to determine the distillate output[2,21].

The convective heat transfer between the wet porous absorber and the glass cover can be given as,

$$q_{cabg} = h_{cabg}(T_{ab} - T_g) \quad (3.1)$$

Where h_{cabg}isthe convective heat transfer coefficient which depends upon the difference in the temperatures and the partial pressures of the water at the absorber surface and glass cover surface and is given as,

$$h_{cabg} = 0.884\left[(T_{ab} - T_g) + \frac{(P_{ab} - P_g)T_{ab}}{(268.9 * 10^3 - P_{ab})}\right]^{1/3} \quad (3.2)$$

The evaporative heat transfer coefficient between the absorber surface and the glass cover depends upon the convective heat transfer and hence it can be obtained as,

$$h_{eabg} = \frac{0.01623 * h_{cabg}(P_{ab} - P_g)}{(T_{ab} - T_g)} \quad (3.3)$$

Hence, the evaporative heat transfer can be given as,

$$q_{eabg} = h_{eabg}(T_{ab} - T_g) \quad (3.4)$$

The amount of distillate per hour per square metre of the basin area can be obtained from the relation,

$$m_w = \frac{q_{eabg}}{h_{fg}} \quad (3.5)$$

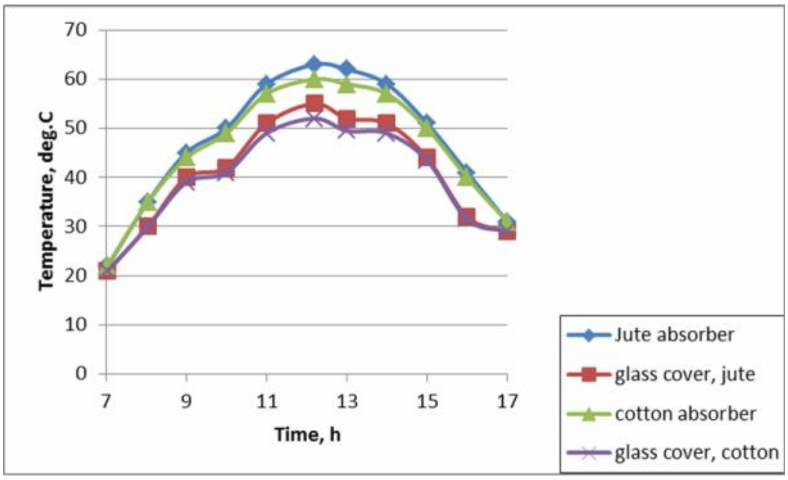

Fig. 4 Comparison of component temperatures for both the absorbers.

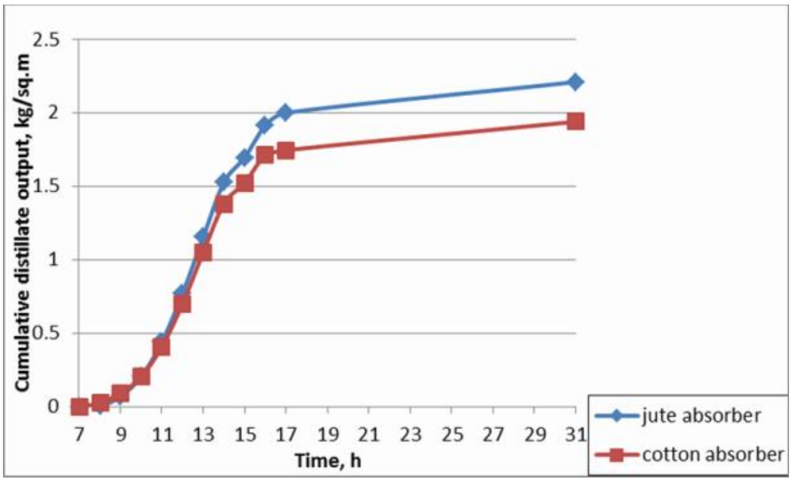

Fig.5 Cumulative outputs for 24 hrs. (7am to 7am)

3. Results and Discussion:

Fig.3 shows the hourly variation of the solar intensity and ambient air temperature. Itcan be observed that the maximum solar intensity is at 12:00 noon, whereas the maximum ambient air temperature is at around 15:00 hrs. which can be attributed to the thermal inertia of the ambient air mass. Fig.4 shows the comparison of the component temperatures for both the stills with jute and cotton absorbers respectively. It can be observed that, the maximum temperature reached in case of the jute absorber is higher than that of cotton absorber, which is obviously due to greater surface roughness and hence greater absorptivity of jute fabric. The maximum temperature of jute absorber is 63^{o}C whereas that ofcotton absorber is 60^{o}C.Similarly the glass cover temperature for jute absorber are higher than that for cotton absorber, which is due to relatively greater heat and mass transfer from absorber to cover. But the absorber – cover difference in case of jute absorber still is slightly more than that of cotton absorberstill, mainly during the second half of the day, which is the reason for higher distillate output by about 12% for jute absorber still as shown in Fig.5 for cumulative output. Fig.6 and7 give a comparison of the hourly distillate outputs obtained experimentally and theoretically for cotton absorber and jute absorber respectively. It can be seen that a sound agreement is obtained between the experimental and the theoretical values. Fig. 8 and 9 give the comparison of hourly variation of evaporative heat transfer coefficient and production rate respectively for both types of absorbers. Due to reasons, already discussed, higher values are obtained for jute absorber.

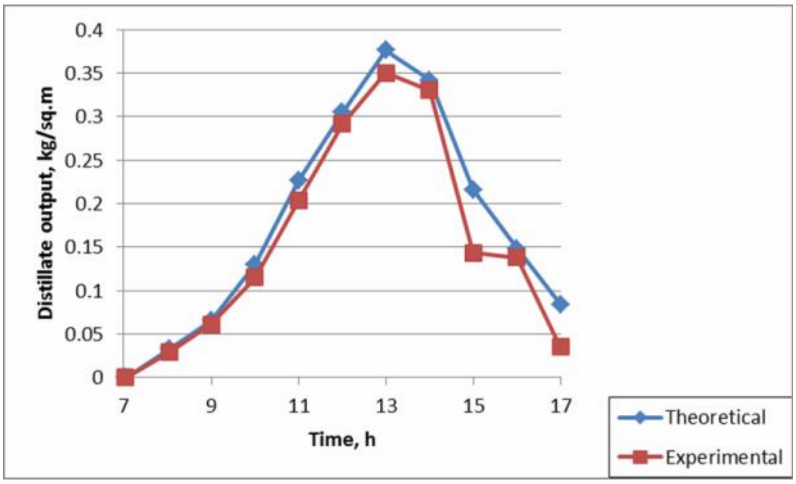

Fig.6 Comparison of theoretical and experimental hourly distillate output for cotton absorber

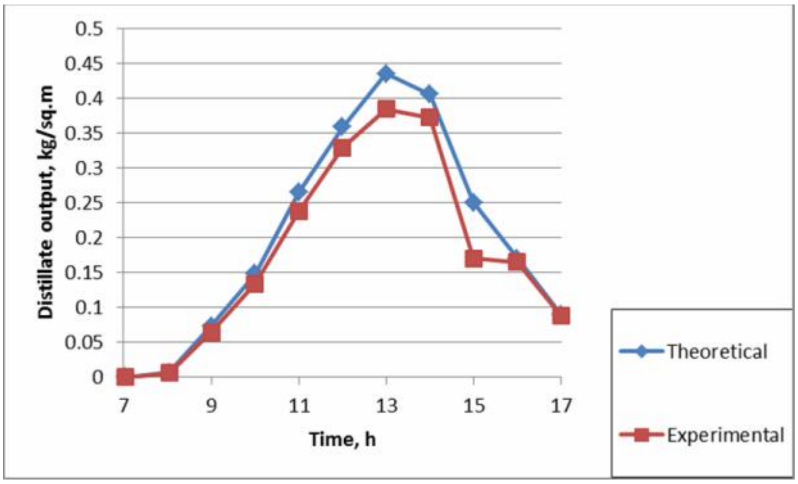

Fig.7 Comparison of theoretical and experimental hourly distillate for jute absorber.

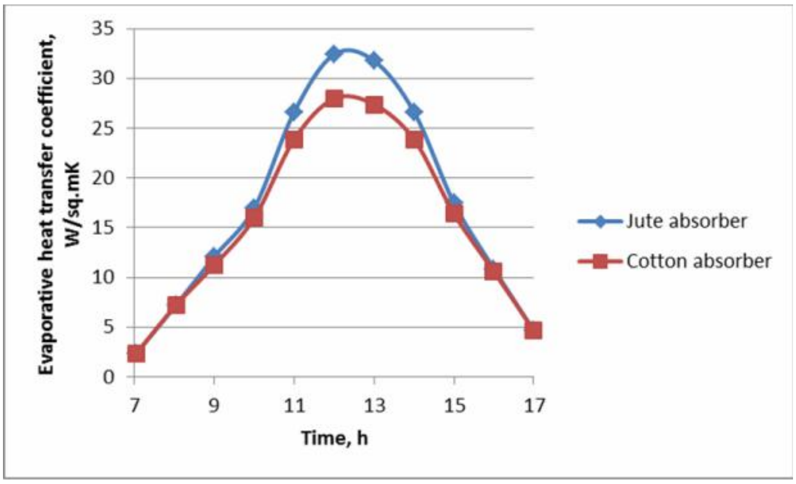

Fig.8 Comparison of hourly variation of evaporative heat transfer.

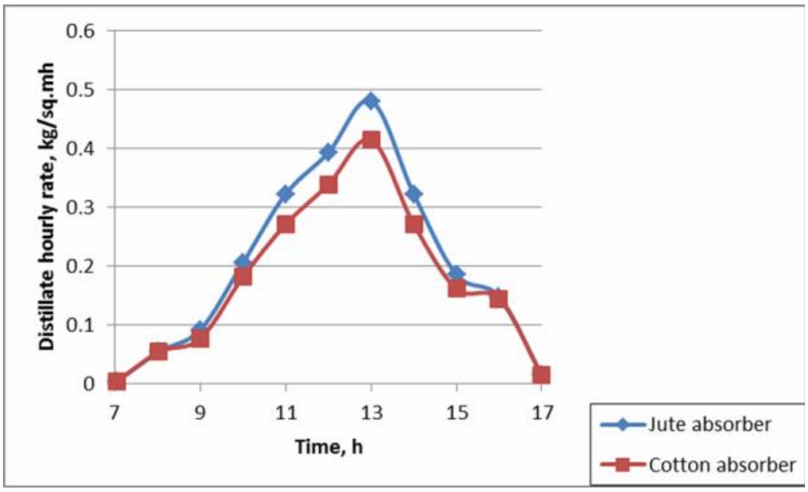

Fig.9 Comparison of hourly distillate production rate.

5. Conclusions:

From the results obtained experimentally and theoretically, it can be concluded that the jute fabric due to better absorptivity is a better material for the floating porous absorber. Besides it is easily available and much cheaper than cotton fabric.

Nomenclatures:

T_a Ambient temperature, K
T_{ab} Floating porous absorber temperature,K
T_g Glass cover temperature,K
M_w Distillate output, kg
p_{ab} Partial pressure of water vapour at T_{ab}, mm of mercury
p_g Partial pressure of water vapour at T_g, mm of mercury
q_{cabg} Convective heat transfer from floating absorber to glass cover, W/m^2
q_{eabg} Evaporative heat transfer from floating absorber to glass cover, W/m^2

Subscripts:

a ambient air
ab floating absorber
g glass cover

Appendix:

$h_{fg} = 3044205.5 - 1679.1109T_{ab} - 1.14258T_{ab}^2$

$$p = 165960.72X10^{-[x(a+bx+cx^3)/T(1+dx)]}$$

Where,

$x = 647.27 - T, \quad a = 3.2437814, \quad b = 5.86826 \, X \, 10^{-3},$
$c = 1.1702379 \, X \, 10^{-8} \text{ and } d = 2.1878462 \, X \, 10^{-3}$

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