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Performance of Masonic Solar Still with Tube Type Internal Condenser in Summer Climate

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ABSTRACT

The worlds demand for potable water is increasing with growing population. Water desalination using solar energy is simple and echo friendly technique for water production from brackish and sea water. Solar still assures 2-3 litre per sq. meter per day on clear sunny day. FRP, G.I and other kind of single basin passive solar stills are being areas of research for enhancement of still productivity and performance. In our developed Masonic solar still, productivity is of a lot variance across days of winter and summer at Pune (18.5°N). Physics of vapour condensation in still, is natural convection heat transfer which dependence on difference between basin water temperature and inner temperature of condensing cover. In earlier research, difference of this temperature has been raised with internal condensers. In order to have better yield tube type internal condenser is fitted on back wall of still. Across days of summer, it has been observed that yield has been 800-900ml during peak Sun shine hours with still temperature reaching up to 55°C. The depth of water is 5-6mm and experimental procedure is followed. Further Spalding theory of mass transfer, analysis of still perused and variance in results are put forth. In accordance, with variance in result and readings, a new correlation pertaining to summer climate and still design has been suggested.

Keywords— Masonic solar still, Productivity, Spalding theory, Summer climate, Tube type internal condenser.

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I. INTRODUCTION

Fresh water availability is a basic human need. Water shortage is a worldwide problem, where 40% of the world population is suffering from water scarcity. Although 75 percent of the earth is covered with water, 97 % of Earth's water is too salty for us to use. 3% of Earth's water is fresh water. Only one third is accessible at the lakes and rivers. So the fact that 97% of the earth's surface is covered with saline water has been an important catalyst for developing water desalination technologies. The Gulf Region, the Middle East and North Africa are blessed with huge solar energy which is available in most of the calendar of the year. This abundant availability of solar power could be used effectively to produce fresh water by installing solar still plants and the water obtained could be used as a supplement to the existing water storage plants in these regions [1]. Distillation techniques utilizing solar energy have been known and used long time ago. The use of solar stills for producing fresh water dated back to the 16th century [2]. Solar stills use a relatively an easy and simple technique to \ produce distilled fresh water from brackish or sea water. It implements and simulates the greenhouse effect using the basic principles of heating, evaporation and condensation. It is easy to fabricate and require low maintenance demand [3].

Solar energy can be used to supply the energy required to heat water by making use of a solar still. A solar still operates on the same principle as that of rain formation: water from the ocean evaporates, then cools, condenses, and returns to earth as rainwater. When the water evaporates, only pure water vapor is formed while contaminants are left behind in the still basin and the distillate flows to the collection gutter by gravity. Solar stills have proven to be highly effective in providing safe drinking water. The quantity of water which we get as pure water is less from solar still. So different scientist are working in the field of improving the productivity of solar still.

A.Y.Hashim,J.M.AlAsadi,W.A.TahaAlramdhan[4] have studied different types of solar still with different shapes, angle of inclination and area and observe that solar still with symmetric double slope, the inclination angle of 45o and the lesser inner surface area (11645 cm2) gives best productivity. Husham M. Ahmed and Khalid A. Alfaylakawi[5] have studied the effect of wind speed and water sprinklers and observed that increase in the wind speed from an average natural value of 1.2 m/s to 3 m/s and 4.5 m/s increases the production rate by 8% and 15.5% respectively. Also cooling the glass cover using water sprinklers at preset intervals of 20 min and 10 minutes respectively increases the production rate by 15.7% and 31.8%. Ajeet Kumar Rai, Nirish Singh and VivekSachan[6] have studied the effect of cooling glass cover and observed that 17% gain in the distillate output due to cooled condensing water cover on glass. Hitesh N Panchal, Dr.P.K.Shah[7] have studied the effect of different glass thickness and pointed that the reducing glass cover thickness increases the distillate water output. And proposed that 4 mm glass cover thickness is most prominent thickness of solar still.Imad Al-Hayek, Omar O.Badran[8] have studied asymmetric still with mirror and symmetric still and found that the distilled water output of the asymmetrical greenhouse type solar still having mirrors on its inside walls was 20% higher than that of symmetric greenhouse type. Charles N.O.Kwach, Reccab M. Ochieng and Frederick N. Onyango[9] investigated some of the factors namely: wind speed and wind direction, angle of inclination of the cover, ambient temperature of the surrounding air, temperature of the water, and the internal cover temperature as well as the solar radiation and found out that their variations affect the efficiency of a single basin solar still considerably. JadhavMadhav V [10] have studied the comparison bet black granite basin solar still and iron solar still and observed that the productivity of distilled water was enhanced for black granite basin solar still as compared to iron steel basin solar still.

The daily yield from any solar still depends on climatic parameters like solar intensity, wind velocity, ambient air temperature and operational parameters viz. absorptivity of basin material, water depth, salt content of water mass, inclination of condensing cover, bottom and side wise insulation, back wall reflection etc. In totality, these parameters affect the temperature difference between water surface temperature in the basin and inner surface temperature of transparent cover. In this regards, if we employ more temperature difference, greater yield will be obtained.

II. SPALDINGS MASS TRANSFER THEORY FOR DISTILLATE OUTPUT

The bulk state of the mixture of air and water vapors in the solar still is referred to as G-state, while the mixture close to an evaporating surface (water surface) is referred to as S-state (Fig.1). It can be assumed that the saturation condition exists at S-state. A flux g* of the moist air at the G-state moves towards S-surface, induces mass flux $\dot{m}_w$ from the

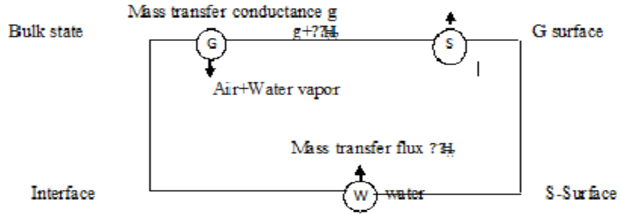

Fig1 Mass transfer mode (after kiatsiviroat et.al.1986, 1987)

S-surface and the total flux ($\dot{m}_w$ +g*) at the S-state moves through the G-Surface away from the interface. The flux g* is called the Reynolds flux or mass transfer conductance. An expression for g* with different orientations of the absorbing surface is given (after Indaba, 1984)

Orientation	**Nu**	**g*.H.Sc/ µf**	**Range**
Horizontal (θ=0)	$0.14(Gr.Sc)^{1/3}$	$0.54(Gr.Sc)^{1/4}$	$4.2 \times 10^5 < Gr < 4.2$

A. Limitations of Spalding Theory

In Spalding theory, wet bulb temperature and dry bulb temperature of air in still are to be measured before calculating theoretical yield i.e. distillate water. As per dry bulb temperature and wet bulb temperature concept it is not possible to measure both temperature inside the still basin, hence we have proposed two assumptions viz.wet bulb temperature can be adiabatic temperature and adiabatic temperature is equal to copper tube temperature. Secondly, dry bulb temperature is equal to basin water temperature.

III.EXPERIMENTATION

The water inside the basin is kept to 5mmheight..Different temperature is measure in the still hourly basis during 12 to 3pm which are the peak hours in summer climate in Pune (18.5°N) . The pure water is also measured with the help of measuring flask hourly. Here, we have used K-type thermocouple for measuring the different temperature inside the Masonic solar still. i.e. basin water temperature (Tb), Copper tube temperature (Tc), Interface temperature(T7), inner glass temperature(T8).

Fig.2 experimental Set Up:

Experimental set up consist of Basin tank which is basic Masonic solar still and it has effective area of 1 m2. The still is made of Bricks, tiles, Cement concrete so it is called as Masonic solar still.. It has a top cover of transparent glass of 4 mm thickness, with an inclination of 18.5° to horizontal. The low thickness of glass transmits up to 98% of solar radiation. Inner surfaces of still are made insulated by using tiles and to absorb maximum solar energy, internal area of still is covered with black Rexene. On the back side wall of Masonic solar still the copper tubes are mounted. The diameter of copper tube is 10mm. The continuous water supply has been provided to the copper tubes through the overhead water tank. Aluminum channel is provided on the three walls to collect the distilled water. Condensed water flowing through is collected outside the solar still in collecting tank (here we use plastic bottle) through the pipe inserted at end point. The whole assembly is made air tight.

IV. OBSERVATION

TABLE I

TEMPERETURE READINGS AND OBSERVATIONS

Sr. No.	Date	Tb	Tc	T7	T8	Y1	Y2
1	23/05/2015	54	49	49	50	260	356.96
2		55	51	54	53	275	188.09
3		55	52	54	53	280	143.67
4	24/05/2015	53	48	49	50	320	302.20
5		56	51	54	52	300	281.99
6		55	52	53	53	300	175.78
7	25/05/2015	53	49	49	50	290	248.90
8		55	51	53	52	270	222.83
9		54	52	53	53	340	97.20
10	26/05/2015	53	49	49	50	310	248.90
11		54	51	53	52	280	136.74
12		55	53	53	53	270	120.76
13	27/05/2015	54	49	48	51	280	363.11
14		54	51	53	54	270	145.45
15		55	52	53	53	260	175.78

V.RESULT

TABLE II

Date	Pc	W2	W1	Pb	W3	M1	M2	υ2	Gr	g*=y	Me	M
23/05/2015	0.1141	0.0801	0.078	0.1456	0.106	0.0724	0.0958	3.18E-10	236189540.7	0.0038	9.82E-05	**356.9634**
	0.1259	0.0896	0.0899	0.1528	0.1122	0.0825	0.1008	3.28E-10	45580926.6	0.0026	5.17E-05	**188.0956**
	0.1322	0.0947	0.0951	0.1528	0.1122	0.0868	0.1008	3.28E-10	45580926.6	0.0026	3.95E-05	**143.6703**
24/05/2015	0.1085	0.0757	0.0753	0.1388	0.1002	0.07	0.0911	3.18E-10	189531238.8	0.0036	8.31E-05	**302.2007**
	0.1259	0.0896	0.0905	0.1602	0.1187	0.083	0.1061	3.25E-10	91876650.7	0.003	7.75E-05	**281.9967**
	0.1322	0.0947	0.0946	0.1528	0.1122	0.0864	0.1008	3.28E-10	91161853.21	0.003	4.83E-05	**175.7866**
25/05/2015	0.1141	0.0801	0.0796	0.1388	0.1002	0.0737	0.0911	3.18E-10	189531238.8	0.0036	6.84E-05	**248.9055**
	0.1259	0.0896	0.09	0.1528	0.1122	0.0825	0.1008	3.25E-10	92156762.44	0.003	6.13E-05	**222.8343**
	0.1322	0.0947	0.0945	0.1456	0.106	0.0863	0.0958	3.28E-10	45720317.82	0.0026	2.67E-05	**97.20967**
26/05/2015	0.1141	0.0801	0.0796	0.1388	0.1002	0.0737	0.0911	3.18E-10	189531238.8	0.0036	6.84E-05	**248.9055**
	0.1259	0.0896	0.0899	0.1456	0.106	0.0825	0.0958	3.25E-10	46219293.7	0.0026	3.76E-05	**136.7474**
	0.1388	0.1002	0.1001	0.1528	0.1122	0.091	0.1008	3.28E-10	91161853.21	0.003	3.32E-05	**120.7657**
27/05/2015	0.1141	0.0801	0.0788	0.1456	0.106	0.073	0.0958	3.21E-10	280350715.8	0.004	9.99E-05	**363.1188**
	0.1259	0.0896	0.0888	0.1456	0.106	0.0816	0.0958	3.32E-10	45228080.26	0.0026	4E-05	**145.4557**
	0.1322	0.0947	0.0946	0.1528	0.1122	0.0864	0.1008	3.28E-10	91161853.21	0.003	4.83E-05	**175.7866**

VI.DISCUSSION

Based on results obtained, it can be seen that difference in experimental amount of distilled water and calculated amount of distilled water is in high propositions. It ranges from ±10%
to ±100 %. The reasons behind this are assumptions or design and architecture of Masonic solar still. In advocacy ofSpalding, we must get wet bulb and dry bulb temperature somehow or parameters which may be substitute these two otherwise we have to discard the theory. So we have tried copper tube temperature and basin water temperature as substitution.

VII.CONCLUSION

In total experiment, actual yield and temperatures in still are deciding factors. So by giving weightage to actual yield, we have followed regression analysis. With least square technique for same Gr and Sc, we have found new correlation for mass conductance as follows:

$$\frac{g* \times H \times SC}{\mu} = 0.16[Gr \times SC]^{1/3.3}$$

Suggested correlation is different from original at cofactor and index terms.

NOMENCLATURES

Tb - Average Basin Temperature in 0 C
Tc – Copper Tube Temperature in 0 C
T8 – Inner Glass Temperature in 0 C
T7 – Inter face Temperature in 0 C
Tb– Dry Bulb Temperature 0c
Y1 – Experimental Amount of Distilled Water (Yield) In Ml
Y2 – Calculated Amount of Distilled Water (Yield) In Ml
W1 - Humidity Ratio of Dry Air
W2 – Humidity Ratio at WBT
W3 – Humidity Ratio at Basin Temperature
Hg – Specific Enthalpy of Vapour
Hfg – Specific Enthalpy of Evaporation
Hf - Specific Enthalpy of Water
M1 –Mass Fraction in Bulk State
M2 –Mass Fraction at Interface State
B – Constant
B – Coefficient of Volumetric Expansion
µ - Dynamic Viscosity
ϱ – Kinematic Viscosity
Ʊ - Viscosity Ratio
Gr – Grashoff Number
Sc – Schmidt Number
g* - Mass conductance
Me – Distillate output in kg/m2.s
M – Distillate output in ml

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