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Assessment of wind loss coefficient for masonic solar still in winter climate

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ABSTRACT

Among all water desalination techniques, Solar still has been researcher’s domain with FRP, GI, and Plexiglas still materials.FRP solar still are being exploited for better performance and condensate (yield) with various modifications. In performance analysis, various heat transfer coefficients are quantified and correlated. In that connection, wind loss coefficient play vital role, as it decides yield of solar still. Since, induction of solar still, analysis of wind loss coefficient has been done with two major correlations viz. McAdam and Jurge But applicability of these two equations is in Solar Flat Plate Collectors. No separate correlation has been suggested for wind loss coefficient pertaining to solar still physics. An attempt is made to develop a correlation for wind loss for Masonic solar still. In this experiment, wind is simulated with blowers and pipe fixtures. The wind velocity of order 3.1m/s,2.8m/s and 1.8m/s is attended. The yaw angle is kept zero degree with glass cover of still. Hourly condensate and appropriate temperatures are measured. With least square techniques, multivariable exponential correlation of forced convection mode is put forth. Trials are conducted in December at Pune. (18.5°N) The operating parameters viz. water depth (5-6 mm) and still temperature (not more than 50°C) have been observed. During peak Sun shine, hourly yield of 180-200ml is being extracted from solar still. Comparative study is done with earlier established equations. In total analysis, need of new correlation for wind loss coefficient of solar still is justified.

Keywords— Forced Convection, Hourly Yield, Masonic Solar Still, Wind Loss Coefficient.

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I. INTRODUCTION

A conventional basin type solar still (CSS) has a thin layer of saline water in horizontal basin and transparent cover over that with one or two slopes. Saline water in the basin does get heat from solar radiation passing through the transparent cover and greenhouse effect. Saline water at the bottom of still basin gets vaporized. Flows upward and condenses when comes into contact with the cooler inner surface of the transparent cover. Pure water trickles down along the transparent cover and gets deposited in trough. Deposited pure water is termed as solar still yield.

The evaporation and condensation process takes place within the same chamber in a conventional solar still. In this total phenomenon, transparent cover gets heat from condensing vapour. In addition to that, transparent cover intercepts solar radiation and gets solar heat. Saline water from the basin also transfers heat to transparent cover by means of convection and radiation. In result of that temperature of transparent cover attains temperature more than ambient temperature.

On the basis of various modifications and modes of operation introduced in conventional solar still, solar stills are mainly classified as passive and active solar still. In active solar still, an extra thermal energy is fed into the basin in the form of preheated water. This preheated water offer more evaporation rate as compared to passive solar still. Extra evaporation provides more yield. The extra thermal energy in the form of preheated water can be made available from solar water heater or from any chemical, Industrial, agricultural processing thermal plant. For given set of design, the performance of solar still is influenced by climatic and operational parameters. The daily yield from any solar still depends on climatic parameters like solar intensity, wind velocity, ambient air temperature and operational parameters viz. absorbivity 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. REVIEW OF RESEARCH

The performance of solar still has been tested for different wind velocities, since 1961. If we consider varying wind velocity across transparent cover of solar still, it will definitely change the yield. In general, higher wind velocity over the transparent cover; higher is the convective heat loss. If heat loss is higher, more will be the temperature difference between basin saline water and transparent cover. Ultimately, higher will be the yield.

2.1International Status:

LÖf et al,.[1] developed that, the yield of solar still decreases with increase in wind velocity.

Cooper et al,[2] yield of solar still increases with increase in wind velocity.Farid and Fath et al,.[7]concluded, yield of solar still decreases with increase in wind velocity. ElSherbiny and Fath said in case of increase in wind speed from 0 to 8 m/s, decrease in yield is less than by 10%.

Toure and Meacham et al,.[8] predicted that when wind speed increases from 0 to 9 m/s the increase in yield is less than 10%.El-Sebaii, he predicted that, for different solar still designs, yield increases with increase in wind velocity. But at typical velocity increase in yield is insignificant; though there is further increase in wind velocity. This typical wind velocity is independent on the still shape and the mode of operation (active or passive) with some seasonal dependence.O.O.Bardan predicted that the yield of conventional solar still increases by 35%, as there is increase in the wind velocity from 2.7 to 5 m/s.V.Dimiri predicted that for active and passive solar still yield increases with increase in wind velocity. With wind velocity from 1 to 5 m/s yield of passive increases by 60-61% whereas for active 68-69%.

2.2National Status:

G.N.Tiwari[11] had developed for passive solar stills only at low wind velocity of order 1m/s, there is considerable decrease in yield but at high wind velocity the yield almost remains constant. Aggrawal[9] predicted that For conventional passive solar still, increase in the velocity from 1 to 7 m/s increase in the yield is by11%.G.N.Tiwari had developed, If the wind velocity is increased from 1 to 8 m/s for Active solar still the yield increases by 45%

2.3 Conclusive Remark:

Based on critical review, we have concluded that, among all scientists, there is existence of controversial conclusions. Besides that, all conclusions are pertaining to their specific design of solar stills. Majority of research has been done with, McAdam or Jurge equations of wind loss coefficient. But at state of art, these equations are not for solar still physics. So doing research pertaining Masonic solar still, which is new design with new material poses interesting prospects. Further, an attempt can be made to develop a correlation for wind loss coefficient in exact applicability i.e. solar still. Environmental conditions in winter at Pune, India, can be a starting point in the research.

III.EXPERIMENTAL WORK

Fig1. Photograph of Masonic Solar Still

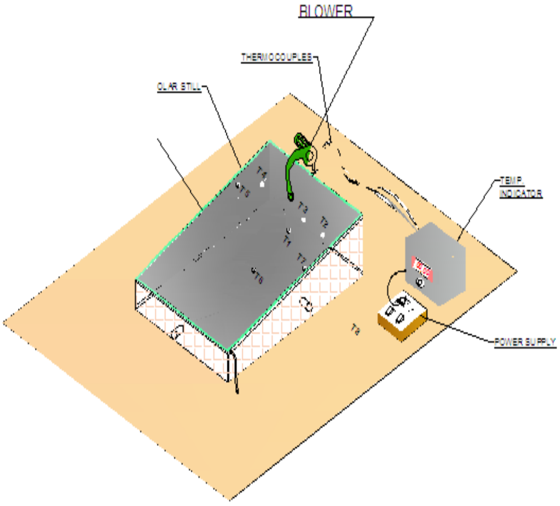

Fig 2.Schematic Diagram of Masonic Solar Still

Experimental set up consist of basin tank which is basic Masonic solar still and it has effective area of 1 m^2. The still is made of bricks, tiles, cement and concrete. It has a top cover of transparent glass (i.e. Ordinary glass), and the interior surface of its basin is black colored resin to enable absorption of solar radiations. The whole assembly was air tight made with help of Resin strips and sealed with silicon sealant. Fig.1/2 show, the different component and how it is assembled. We have used eight channel thermocouple for measuring the different temperature i.e. water basin temperature(T6), inner glass temperature(T5 & T7), Dry bulb temperature(T1), atmospheric temperature (T8)and outside glass temperature(T2,T3,T4). A plain transparent glass (i.e. Ordinary) of 4 mm thickness has used at the top, with an inclination of 18.5° from horizontal to ease the flow of condensate along the transparent inside surface of glass and maximum isolation of radiations. The low thickness of glass transmits up to 98% of solar radiation. Wind is replicated with air blower and PVC pipes. Anemometer is used to achieve the spectrum of velocity 3.1,2.8,1.8m/s. The replicated wind is applied to glass cover at top edge with zero yaw angles as shown in Fig.2.Reach of wind towards bottom edge of glass cover is also realized.

IV. OBSERVATION

4.1 Procedure for taking reading at hourly yield (Day time): For wind velocity 3.1m/s, first, fill up the 5 to 6 mm level of water in solar basin. Take temperature reading at 1.30 pm (for 1.30 pm to 2.30 pm).Measure the yield of water by using measuring flask. Then Take temperature reading at 2.30 pm (for 2.30 pm to 3.30 pm), also note down yield of water for that time. Measure ambient temperature (Ta/T_8) and inner glass temperature (Tig).Follow, the same procedure for next day for wind velocity 2.8 m/s and 1.8m/s**.**

Date	T1	T2	T3	T4	T5	T6	T7	T8	Wind Velocity (V)	Yield in ml	Time of day(pm)
25/12/2014	35	38	37	37	45	45	44	34	3.1	133	1.30-2.30
	37	38	37	37	46	46	43	35	3.1	136	2.30-3.30
26/12/2014	35	38	38	37	45	47	44	34	2.8	161	1.30-2.30
	36	36	36	36	44	45	41	33	2.8	133	2.30-3.30
27/12/2014	35	38	39	38	45	48	45	34	1.8	168	1.30-2.30
	38	38	38	38	47	49	44	34	1.8	165	2.30-3.30

4.2 Calculation:

$$hew == \frac{m y \times L}{(Tw - Tig)3600}$$

$$L = \sigma\left[(1 - 9.4779 \times 10^{-4} \times T_{ig}) + (1.3132 \times 10^{-7} \times T_{ig}^2) - (4.7974 \times 10^{-9} \times T_{ig}^3)\right]$$

$$hrw = 0.82 \times \sigma\,[(Tw + 273)^2 + (Tig + 273)^2]\,(Tw + Tig + 546)$$

$$hcw = w = 0.884\,[(Tw - Tig) + \frac{(Pw - Pci)(Tw + 273)}{(268.9 \times 10^3 - Pw)}]$$

$$p_w = exp[25.317 - \frac{5144}{(Tw+273)}]$$

$$p_{ci} = exp[25.317 - \frac{5144}{(Tig+273)}]$$

$$h_w = h_{ew} + h_{cw} + h_{rw}$$

$$\frac{1}{U} = \frac{L}{k} + \frac{1}{h_{rg}} + \frac{1}{h_{cg}}$$

$$\frac{1}{h_{rg}} == \frac{(Tg - Ta)}{(0.82 \times 5.67 \times 10^{-8})[(Tg + 273)^4 - (Tsky + 273)^4]}$$

$$T_{sky} = Ta - 6$$

While doing exhaustive calculations, we have come across various facts. The conventional way of calculation of yield with prevailing temperatures and wind loss equations could hardly match experimental results.

In all readings, theoretical yield and Mcadam's wind loss coefficient variance with experiment reading is of unacceptable order viz.50 to 900% and some time even more. So by giving highest priority to experiment, we have tried new equation for wind loss Coefficient

V. RESULT & DISCUSSION

By using least square technique method, we can calculate index value of a_0,a_1, and a_2 in that equation, $Nu = a_0 Re^m Pr^n$

Where,

$$\begin{bmatrix} n & \varepsilon x_{1i} & \varepsilon x_{2i} \\ \varepsilon x_{1i} & \varepsilon x_{1i}^2 & \varepsilon x_{1i}x_{2i} \\ \varepsilon x_{2i} & \varepsilon x_{1i}x_{2i} & \varepsilon x_{2i}^2 \end{bmatrix} \begin{bmatrix} loga_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \varepsilon y_i \\ \varepsilon x_{1i}y_i \\ \varepsilon x_{2i}y_i \end{bmatrix}$$

$$\begin{bmatrix} 6 & 31.066 & -0.829 \\ 31.066 & 160.259 & -4.298 \\ -0.829 & -4.298 & 0.1142 \end{bmatrix} \begin{bmatrix} loga_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} 20.13 \\ 104.05 \\ -2.783 \end{bmatrix}$$

x_{1i} = log Re

x_{2i} =log Pr

y_i =log$_{\text{yield}}$

After solving this matrix gets value of,

$a_0 = 35.042$

$m = 0.3177$

n= -1.1941

Now, $Nu = a_0 Re^m Pr^n$

Nu= 35.042 (Re)$^{0.3177}$× (Pr)$^{-1.1941}$

This correlation is valid for wind velocity range 1 to 4 m/s, on clear sunny day with still temperature not more than 50°C and depth of water 5-6mm

VI. CONCLUSION

Foremost conclusion we could draw that, rate of condensations increases with increase in wind velocity. The proportions of increments are 10% to 50%. Only magnitude of wind velocity is not the key of better yield but how effectively the wind cools the glass surface is of importance. Experiments shows that wind velocity of 1.8m/s could give more yields because it has cooled glass surface uniformly than other two velocities. So wind of higher magnitude without uniform cooling effects or less transversal coverage of any usage in regards of getting more condensation or yield. Secondly, we could conclude that effective condensation area of solar still is at distance of 30 to 40 % from top. So wind blowing from top with zero yaw angle and more transversal coverage increases the yield of solar still. Higher wind velocity and its more transversal coverage will set new yield values for solar still.

NOMENCLATURE

Symbol	Description
Pw	Partial pressure of water at basin temperature

Pci	Partial pressure at inner glass temperature
h_{ew}	Evaporative heat transfer coefficient at condensation
h_{rw}	Radiative heat transfer coefficient from basin water
h_{cw}	Convective heat transfer coefficient at Vaporization
h_{cg}	Convective heat transfer coefficient from glass surface
h_{rg}	Radiative heat transfer coefficient from Glass surface
σ	Stefan Boltzman constant
$\dot{m}y$	Yield in kilogram
U	Overall heat transfer coefficient
T_{sky}	Sky temperature at radiation
l	Characteristics Length, 4A/P
K	Thermal characteristics of Glass
T_{ig}	Inner Glass Temperature
T_8	Atmospheric temperature.
T_w	Water basin temperature
V	Wind velocity
Pr	Prandlt number.$\frac{cp\mu}{k}$
Re	Reynolds number$\frac{\rho VL}{\mu}$
hw	Wind heat Loss coefficient.
$\dot{m}$	Yield of water
Nu	Nusselt number,hl/K
A	Area
P	Perimeter

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