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A New Approach in Design and Fabrication of Passive Solar Still

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ABSTRACT: In this communication, an attempt has beenmade to find out the effect of blue metal stone on heat transfer coefficient for a passive single-slope distillation system in summer climatic condition. The experiments have been conducted on a south facing, single slope, solar still of 10° inclination of condensing cover, in summer climatic condition for 24 h on different five days for different three sizes of blue metal stone from 6mm to 20mm and this is finally compared by using the basin ,without any absorbing material.

KEYWORDS: Heat transfer coefficient, Absorbing material, solar radiation

I. INTRODUCTION

Solar desalination is a process of separation of pure water from saline or sea water by using solar energy.[1] The use of solar still is a cheap method of providing clean water. The solar assisted desalination system can be classified as: (i) passive (conventional) solar still and (ii) active (modified) solar still. The simple or conventional solar still consists of a black-painted copper or steel basin to receive solar radiation in which saline or sea water is kept. The basin is placed in a trapezoidal wooden box, which is covered by a glass cover at an angle between 10° - 25° to the horizontal to retain the solar thermal energy inside the still due to green house effect. That solar thermal energy is utilized to heat the saline or sea water. [2-3]The space between the basin and wooden box is packed with glass wool insulation to reduce the heat loss through the sides and bottom of the still. Due to the existence of phase equilibrium between the saline water surface and air space, the air just over the water surface will be saturated with water vapour corresponding to the water temperature. With the solar radiation incident on the saline water, its surface temperature increases which causes the increase of saturated pressure of water vapour near the water surface corresponding to the water temperature.[4-5] At that time the partial pressure of water vapour near the glass surface will be less as the temperature of the inner surface of the glass cover is lower than that of the water surface. The temperature difference between the water and inner glass surface causes the difference in partial pressures of water vapour which causes the transfer of water vapour from the basin water surface to glass surface and the condensation on the inner surface of the glass. The rate of evaporation of water vapour from the water surface depends on the rate of condensation of water vapour in the glass cover. Even in the areas of higher solar intensity, the annual performance of the still per square meter of aperture is limited to an average of about 2.5 - 3.0 L day $^{-1}$. Interest in the conventional solar still has been due to its simple design, construction and low operating and maintenance cost, mainly in remote areas with no electricity supply. However, its low productivity simulates and motivates the researchers to develop novel methods to enhance the still productivity. Numerous attempts have been made by many researchers to increase the rate of evaporation of water and utilize the maximum solar energy that strikes on the still to enhance the system efficiency which utilizes a minimum amount of still surface. The main objectives of this experimental study is, (i) to find the effect of different size of blue metal stone on the performance and the internal and external heat transfer of the single slope single basin solar distillation system.[6-8]

II. EXPERIMENTAL SETUP

Two single basin solar stills are fabricated and tested under field condition at the testing field of the School of Energy PSG College of technology, Coimbatore, Tamilnadu, India. The basin liner is made of galvanized iron sheet of 0.5 · 1 m^2 with maximum height of 288mm, and 1.4 mm thickness. The basin surfaces are painted with black paint to absorb the maximum amount of solar radiation incident on them. The condenser surface of the still is made of glass with 4mm thickness and angle of inclination is 10° with horizontal. There are certain specifications needed for the used glass cover in the still, and they are (a) Minimum amount of absorbed heat, (b) Minimum amount of reflection for solar radiation energy, (c) Maximum transmittance for solar radiation energy, and (d) high thermal resistance for heat loss from the basin to the ambient. [7]Glass covers have been framed with wood and sealed with silicon rubber which plays an important role to promote efficient operation as it can accommodate the expansion and contraction between dissimilar materials. A collecting trough made by G.I. sheet is used in the still to collect the distillate condensing on the inner surfaces of the glass covers and to pass the condensate to a collecting flask. Steel rule is fixed along with inside wall for measuring water depths.[8] The bottom and sides are insulated with 25mm thick thermocole and 12.5mm thick wood with thermal conductivity 0.015 W/mK and 0.055 W/mK respectively. The still technical specifications are shown in Table 1, and Fig.1. Fig 2, show the pictorial views of the various sizes absorbing materials.Fig 3 shows the snap shot of the experimental setup

Table 1 Technical specification of the solar still

Specification	Dimension
Basin area	0.5 m^2
Glass area	0.508m^2
Glass thickness	4mm
Number of glass	1
Slope of glass	10°

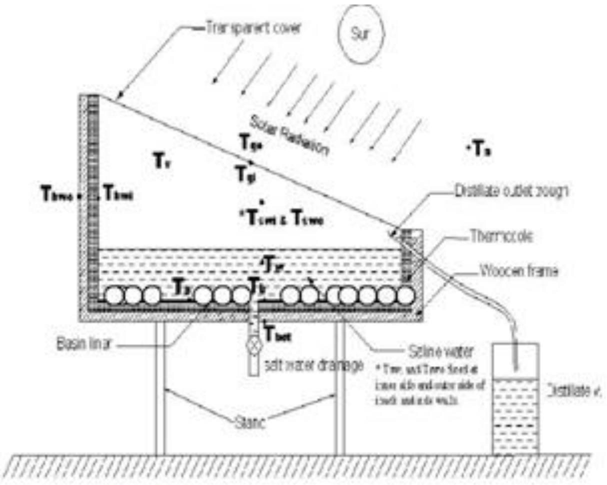

Figure 1 Schematic diagram ofexperimental setup

The experiments were performed in the April 2010 for typical five days has been referred in this paper being the probable hottest month of the year. The experiments were conducted on different five days in the campus of the PSG College of Technology Coimbatore, India for different three sizes of blue metal stone.[9]All experiments were started at 9 AM local time and lasted for 24 h. In each day experiment constant water depth of 30mm was used. During experimentation when switching over from one absorbing material to another the still was left idle, minimum for a day to attain steady state condition

Figure 2 pictorial views of blue metal stone invarious sizes of 6, 12,20mm

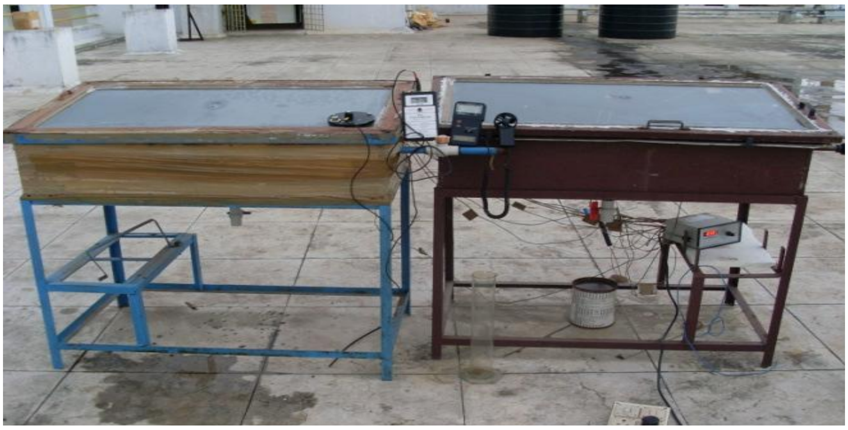

Figure 3 Experimental setup

Prior to start of the experiment for next absorbing material till the completion of experiments for all three absorbing material. The following parameters were measured every hour for a period of 24 h for fixed inclinations and for fixed water depth.

- Basin temperature

- Back wall temperature
- Side wall temperature

- Water temperature

- Glass temperature

- Moist air temperature

- Ambient temperature

- Air velocity
- Solar radiation

- Distillate output

Water, Basin, glass and vapor temperatures were recorded with the help of k-type thermocouples and a digital temperature indicator having a least count of 0.1°C. Solar radiation is measured using pyranometer and the wind velocity is measured using digital anemometer. And a 30mm steel rule is fixed inside wall used to measure water depth. And the readings were shown in table 2-5.[10]

III .THERMAL ANALYSIS OF SOLAR STILL

The performance analysis is achieved by energy balance of the still. Fig.3.1 shows the energy transfer processes for various components in the still, which have a direct effect on the output. For simplifying the analysis, the following assumptions are considered:

☐ The level of water in the basin is maintained constant level. [12-13]
☐ The condensation that occurs at the glass trough is a film type.
☐ The heat capacity of the glass cover, the absorbing material, and the insulation material are negligible. [14]
☐ No vapor leakage in the still;
☐ The heat capacity of the insulator (bottom and side of the still) is negligible.

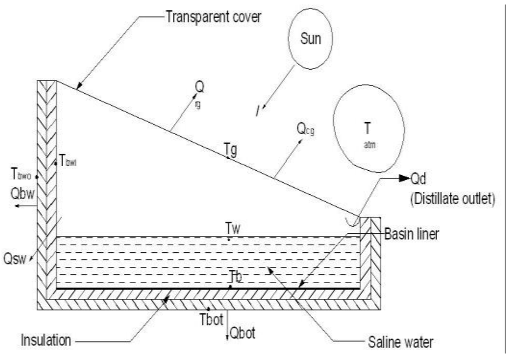

Figure 4 Various components of conventional singleslope solar still

We can obtain collecting efficiency of the still from writing energy balance equation for solar still, referring fig 1

$$I = Q_d + Q_{rg} + Q_{cg} + Q_{bw} + Q_{sw} + Q_{bot} \quad (1)$$

Q_d, the amount of heat taken by distilled water, the expression is

$$Q_d = m_w . h_{fg} \quad (2)$$

Where m_w, mass of output distilled water and h_{fg}, latent heat of evaporation of water = 2382×10^3 J/kg Q_{cg}, the convective heat transfer from glass to ambient is,

$$Q_{cg} = h_{cg} A_g (T_g - T_a) \quad (3)$$

Where, h_{cg}, convective heat transfer coefficient between glass material and ambient. It is mainly depends on wind velocity, the expression is,

$$h_{cg} = 2 + 3.8V \quad (4)$$

Where, Q_{rg} is the radiative heat transfer from glass to atmosphere, is equal to,

$$Q_{rg} = \varepsilon_g A_g \sigma (T_g^4 - T_s^4) \quad (5)$$

where ε_g, emissivity of the glass material, σ, A_g, surface area of glass exposed to atmosphere, Stefan Boltzmann constant, 5.67×10^{-8} K^{-4} , h_{rg}, radiation heat transfer coefficient between glass and air and T_s, sky temperature, is less than (such as 6°C) ambient temperature

Q_{bw}, the heat transfer from inside to atmosphere through back wall, the expression is,

$$Q_{bw} = A_{bw} * U * (T_{bwi} - T_a) \quad (6)$$

Where A_{bw} – Area of back wall,

U - Overall heat transfer coefficient Q_{sw}, the heat transfer from inside to atmosphere through side walls, the expression is,

$$Q_{sw} = A_{sw} * U * (T_{swi} - T_a) \quad (7)$$

Where A_{sw} – Area of side wall

Where Q_{bot} is the heat transfer rate from basin liner to atmosphere through bottom wall, and It is expressed with composite wall conduction equation, the expression is,

$$Q_{bot} = A_b * U * (T_b - T_a) \quad (8)$$

Where A_b – Area of back wall

The overall efficiency of the solar still is

$$\eta_o = \frac{Q_d}{I} \qquad (9)$$

IV. OBSERVATION READING

Table 2 Without using any blue metal stone

S.NO	Time	I, W/m^2	Basin temperature (T$_b$)	Back wall temp (T$_{bi}$)	Side wall temp (T$_{si}$)	Glass temp (T$_g$)	Water temp T$_w$°C	Vapour temp T$_v$°C	Ambient temp T$_a$°C	Mass of Distilled water (m$_w$)	Wind Velocity (m/s)
1	9.00-10.00	495	34	37	38	39	32	44	26	0	0.09
2	10.00-11.00	605	38	44	40	45	37	50	28.2	0.06	0.07
3	11.00-12.00	710	49	56	49	53	49	62	32	0.1	0.05
4	12.00-13.00	890	54	62	55	58	54	66	34.4	0.14	0.09
5	13.00-14.00	850	60	69	63	63	59	68	35	0.13	1.1
6	14.00-15.00	785	65	75	72	61	66	73	33.2	0.17	1.2
7	15.00-16.00	690	61	74	76	59	68	70	31	0.23	0.03
8	16.00-17.00	520	58	69	78	54	66	66	30.9	0.14	0.06
	17.00-9.00									0.28	
Total										**1.25**	

Table 3 Using 12mm blue metal stone

S.NO	Time	I, W/m^2	Basin temperature (Tb)	Back wall temp (T$_{bi}$)	Side wall temp (T$_{si}$)	Glass temp (T$_g$)	Water temp T$_w$°C	Vapour temp T$_v$°C	Ambient temp T$_a$°C	Mass of Distilled water (m$_w$)	Wind Velocity (m/s)
1	9.00-10.00	500	31	37	36	38	34	43	25.9	0	0.05
2	10.00-11.00	630	36	46	38	47	35	50	29.6	0.08	1
3	11.00-12.00	730	45	59	50	53	52	64	32	0.12	0.08
4	12.00-13.00	870	55	65	54	58	54	67	34	0.15	0.06
5	13.00-14.00	845	62	74	65	60	59	72	35.7	0.17	0.04
6	14.00-15.00	769	68	81	73	59	69	74	32.4	0.18	0.07
7	15.00-16.00	683	63	78	75	55	72	71	30.9	0.21	1.3
8	16.00-17.00	505	60	76	78	50	67	68	28.9	0.15	0.04
	17.00-9.00									0.4	
Total										**1.46**	

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Table 4 Using 6mm blue metal stone

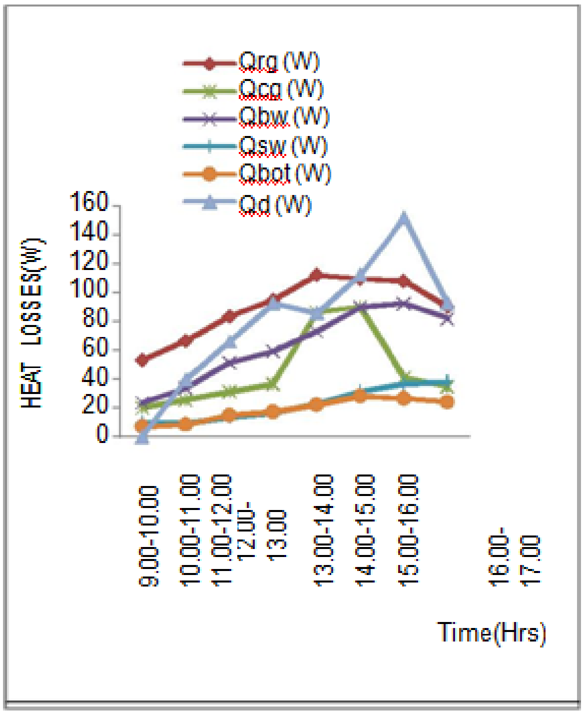
S.NO	**Time**	**I, W/m^2**	**Basin temperature (T_b)**	**Back wall temp (T_{bi})**	**Side wall temp (T_{si})**	**Glass temp (T_g)**	**Water temp** T_w°C	**Vapour temp** T_v°C	**Ambient temp** T_a°C	**Mass of Distilled water (m_w)**	**Wind Velocity (m/s)**
1	9.00-10.00	490	33	35	39	37	33	42	26.5	0	0.07
2	10.00-11.00	630	38	43	41	45	38	51	29	0.08	0.04
3	11.00-12.00	700	51	56	56	55	50	63	32.2	0.13	1.1
4	12.00-13.00	900	53	64	58	57	54	67	34.5	0.14	0.04
5	13.00-14.00	865	62	71	64	69	61	70	35.4	0.15	0.05
6	14.00-15.00	780	66	75	79	65	67	77	33.1	0.17	0.08
7	15.00-16.00	675	61	72	83	61	68	75	31.9	0.23	1.1
8	16.00-17.00	535	60	70	84	59	64	68	30.8	0.15	0.02
	17.00-9.00									0.37	
Total										**1.42**	

Table 5 Using 20mm blue metal stone

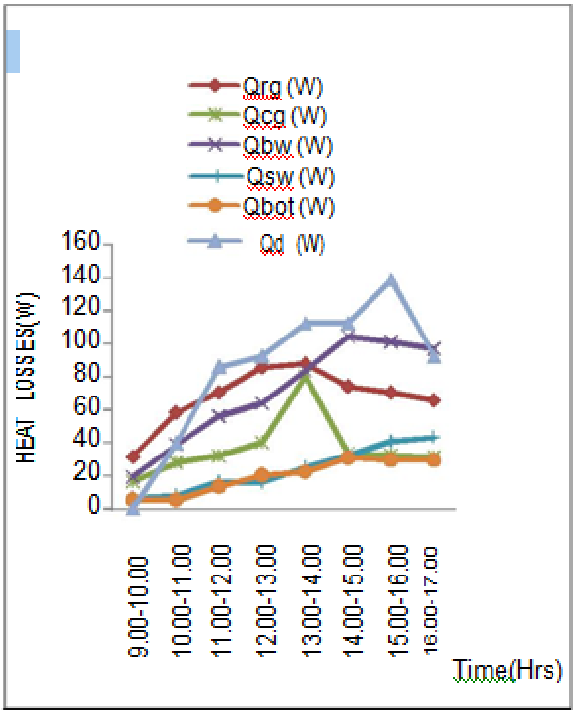
S.NO	**Time**	**I, W/m^2**	**Basin temperat re (T_b)**	**Back wall temp (T_{bi})**	**Side wall temp (T_{si})**	**Glass temp (T_g)**	**Water temp** T_w°C	**Vapour temp** T_v°C	**Ambient temp** T_a°C	**Mass of Distilled water (m_w)**	**Velocity (m/s)**
1	9.00-10.00	510	32	35	34	37	32	42	26	0	0.05
2	10.00-11.00	635	35	47	39	48	36	51	28.9	0.06	0.03
3	11.00-12.00	720	47	58	52	54	54	62	31.9	0.13	0.02
4	12.00-13.00	882	57	64	54	60	57	69	34.2	0.14	0.09
5	13.00-14.00	853	61	75	67	62	61	73	36	0.17	1.1
6	14.00-15.00	790	69	83	74	57	67	76	34.4	0.17	0.04
7	15.00-16.00	694	65	79	82	54	69	74	31.9	0.21	0.03
8	16.00-17.00	508	63	75	83	51	64	69	29.9	0.14	0.04
	17.00-9.00									0.32	
Total										**1.34**	

V. VARIOUS HEAT LOSSES WITH RESPECT TO TIME

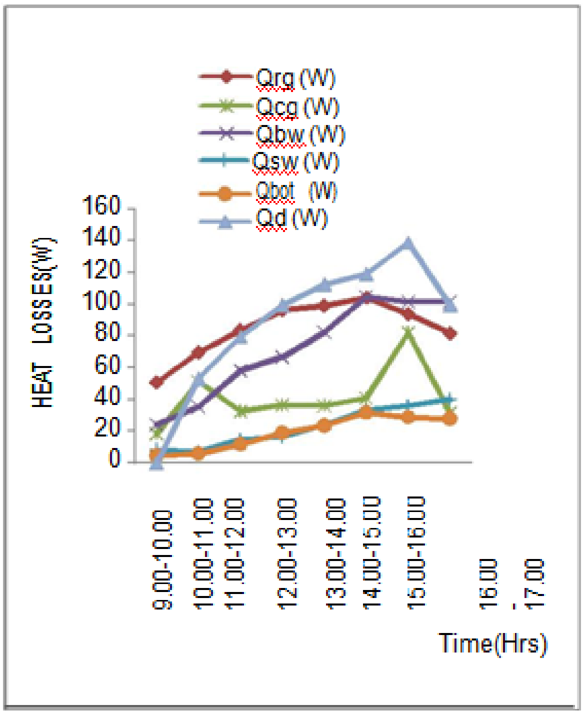
WITHOUT USING BLUE METAL STONE



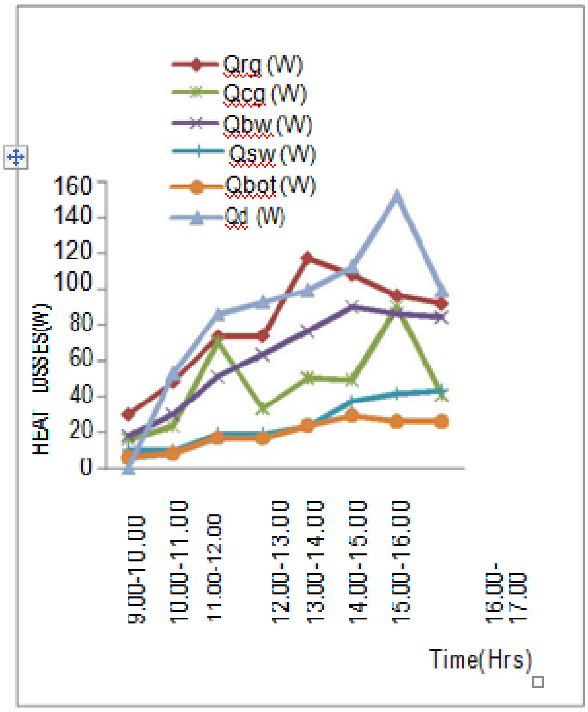
BY USING 12MM BLUE METAL STONE



BY USING 6MM BLUE METAL STONE



BY USING 20MM BLUE METAL STONE



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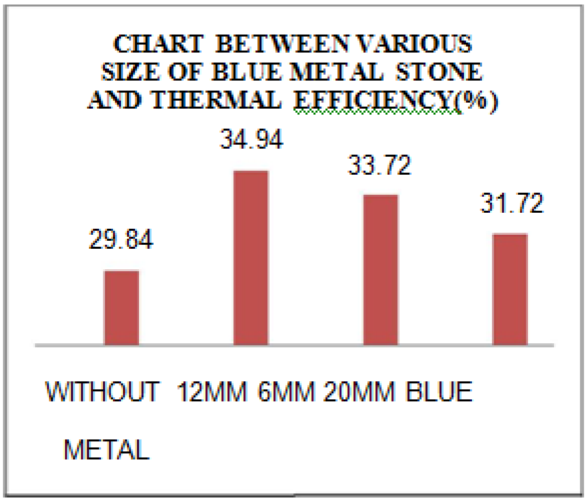
VI. RESULT AND CONCLUSION



The results and discussions for the behavior and performance of the solar desalination system presented here in the form of graphs and tables. Experiments have been conducted from 9:00 hrs to 17:00 hrs. Experiments are conducted by considering a wide range of parameters such as temperatures of basin water, temperature of glass cover, hourly yield, temperature of inside walls (back and side wall) and bottom side temperature. At this particular condition, experiments were conducted for a number of days, so that analysis and comparison could be done fairly under the same climatic condition and to get concurrent results.And the amount of energy required to produce the distilled water (Q_d) is very high in all cases during 3 o clock.The mass of distilled water produced during the off sunshine hours is more while using 12mm absorbing medium,this says that 12mm material has high latent heat storage and releases it during the half peak hours. Heat losses from water surface to ambient through side wall and heat loss from water surface to ambient through bottom surface(Qsw and Qbot) is similar in all cases. All the heat losses goes on increasing as the time varies. And in this its concluded that 12mm absorbing material has more thermal efficiency when compared with the other materials. This means that 12mm material is more effective in converting saline water into distilled output and this material has better heat storage capacity when compared with other materials.

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