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Productivity Enhancement of Solar Still Desalination by Different Methods of Glass Cooling and Water Depth Evaluation

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Abstract— Desalination of saline water by solar powered system is a practical and promising technology for producing potable water in the regions which suffer from water scarcity especially in arid areas and ships. A lot of research work is undertaken to improve the productivity of the solar still. The present study aims to improve the solar still performance, and to increase its productivity. Productivity of flash water in a solar still mainly depends on the temperature difference between the evaporative water surface and the condensing glass surface temperature for a given surface area. An attempt has been made to increase the temperature difference in the solar still by reducing the condensing surface temperature by applying different methods of glass cooling like that Without glass cooling with water, End cooling of glass with water, Parallel cooling of glass with water and Cross cooling of glass with water .The depth of saline water in the basin is varied and experiment has been conducted for each types. The productivity of flash water and thermal efficiency of solar still is high by the way of applying water cooling on transparent glass with compared to the without water cooling on transparent glass.

Keywords – desalination, solar still, different types of glass cooling.

I. Introduction

Solar desalination is the removing of salt from the saline water using solar energy. Desalination is one of mankind's earliest forms of water treatment, and it is still a popular treatment solution throughout the world today. Separation of salts from sea water requires lot of energy, which when produced from fossil fuel, can cause harm to the environment. The production of 1000 m3 per day of freshwater requires 10,000 tons of oil per year [1]. The condensation is higher when the condensing heat transfer from the glass and the evaporation heat transfer from the basin water are high. Heat transfer within the solar still mainly depends on the evaporative surface area and the temperature difference between the evaporative surface temperature and the condensing surface temperature [2]. In order to maximize the existing temperature difference between the water and the condensing surface, an attempt has been made to cool down the condensing surface by flowing water on the condensing surface [3]. The glass cover temperature is reduced by a film of cooling water continuously flowing over the glass. The productivity of water is high when depth of saline water is low [4].

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II. Methodologies

A. Experimental Setup

Fig.1 shows the photographs of double slope solar stills kept on platform. The experimental setup consists of a passive solar distillation unit with a glazing glass cover inclined at 15 degree having an area of each 1 x 0.5176 m. This tilted glass cover (4 mm thick) served as solar energy transmitter as well as a condensing surface for the vapor generated in the basin. To intercept the maximum isolation, the still was oriented in the East-West direction. Solar still basin, made up of galvanized iron sheet, has an effective area of $1m^2$. The basin of the distiller was blackened to increase the solar energy absorption. A distillate channel was provided at each end of the basin. For the collection of distillate output, a hole was drilled in each of the channels and plastic pipes were fixed through them with an adhesive.

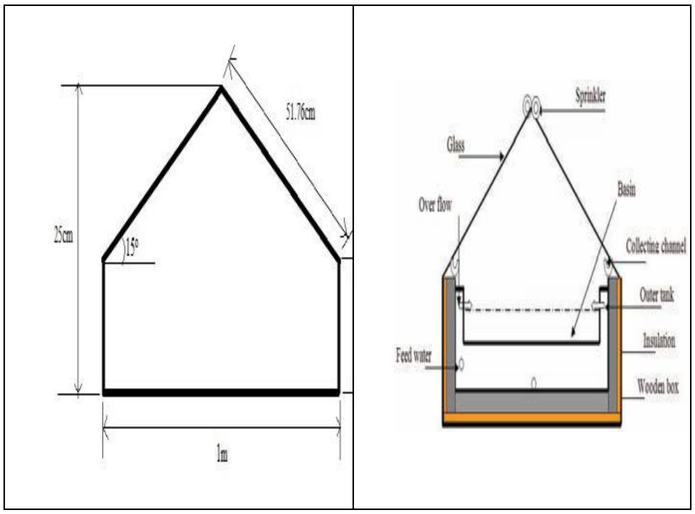

Fig.1 Double slope solar still

An inlet pipe and outlet pipe was provided at the top of the side wall of the still and at the bottom of the basin tray for feeding saline water into the basin and draining water from still for cleaning purpose, respectively. Rubber gasket was fixed all along the edges of the still. The glass panes of 4 mm thickness were used as covers for the still. All these arrangements are made to make the still air tight. A water tank is kept at a height of 2 m to supply cooling water, to cool down the glass covers as in the photograph. The basin water gets evaporated and condensed on the inner surface of glass cover. It runs down the lower edge of the glass cover. The distillate was collected in a bottle and then measured by a graduated cylinder. The system has the capability to collect distillates from two sides of the still (i.e. East and West sides). Thermometers were used to record different temperature, such as inside glass cover (T_g), water temperature (T_w) in the basin and ambient temperature (T_a). Apply the different ways of water cooling on the transparent glass in order to increase the productivity of flash water and study the effect of depth variation in solar still basin. The salt was added into the distilled water to convert salinity water.

B. Technical Specification Of Solar Still

Table 1 Technical specification of solar still

Specification	Dimension
Basin area	1 m^2
Glass area (total)	1.0277 m^2
Glass thickness	4mm
Number of glasses	2
Slope of glass	15°

Table 2 Thermal conductivity of materials

Materials	Thermal conductivity(W/m^2 $^{\circ}$C)
Galvanized iron sheet (black)	300
Transparent glass	0.8
Wood	0.04
Thermo coal	0.02

C. Different Methods Of Glass Cooling

- Without glass cooling with water
- End cooling of glass with water
- Parallel cooling of glass with water
- Cross cooling of glass with water

The Fig.2 shows that the production of flash water by method of without glass cooling with water in the double slope solar still. In this method, condensation of water vapours takes place by the air flowing on the transparent glass. Condensation rate dependent on the amount of air flow as well environmental condition.

The Fig.3, Fig.4 and Fig.5 show the production of flash water by methods of glass with water in the double slope solar still. In these methods, the water is flowing on the transparent glass in order to increase the rate condensation of water vapours at the bottom of glass and condensation takes place by the air flowing on the transparent glass as well as water.

Fig.2 Without glass cooling with water

Fig.3 End cooling of glass with water

Fig.4 Cross cooling of glass with water

Fig.5 Parallel cooling of glass with water

D.Procedure

Experiments were conducted at the Government College of Technology, Coimbatore, India. The Solar stills were constructed, and the experimental investigation regarding the different way of transparent glass cooling and effect of water depth on the still productivity was carried out. Because the Productivity of flash water in a solar still strongly depends on the temperature difference between the evaporative water surface temperature and the condensing surface temperature (bottom of glass). The accepted thermal performance which was achieved was due to the improved design parameters and optimized operational technique. The solar stills were properly oriented and directly exposed to the solar radiation. The initial investigations were carried out in May 2015; the negative aspects regarding the design and operational parameters were detected and treated. Each time the solar still was tested and compared at various depths (2cm, 3cm, and 4cm) of saline water in the solar basin. The remarkable results and visual observations during the initial investigations ware due to the accurate adjustments and calibrations. Based on these observations, the system of measurement was carefully established during the testing period; all the key quantities

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were carefully measured and recorded at a time interval of every 1hours. The measured parameters and quantities ware; the solar radiation intensity (I), the glass temperature (T_g), the basin water temperature (T_w), and the ambient air temperature (T_a), cold water temperature inlet (T_{ci}), cold water temperature outlet (T_{co}), productivity of fresh water (m_w) and mass flow rate of cold water. The rapid formation of a thin vapour film on the internal sides of the glass cover was clearly observed after 1hours of exposing the distiller to the solar radiation. The procedure was repeated for different glass cooling with various depths.

Table1 production and thermal efficiency of double slope solar still when without water cooling of glass and end cooling of glass using water

Time	Without water cooling of glass						End cooling of glass					
	1cm depth		2cm depth		3cm depth		1cm depth		2cm depth		3cm depth	
	m_w	η_{th}	m_w	η_{th}	m_w	η_{th}	m_w	η_{th}	m_w	η_{th}	m_w	η_{th}
9 am	0.015	1.39	0.011	1.05	0.009	0.85	0.010	0.95	0.008	0.77	0.008	0.76
10 am	0.024	1.72	0.021	1.53	0.018	1.30	0.025	2.18	0.022	1.92	0.020	1.76
11 am	0.060	4.04	0.054	3.74	0.051	3.50	0.059	3.94	0.053	3.56	0.048	3.27
12 noon	0.108	7.06	0.093	6.14	0.09	5.93	0.098	6.38	0.093	6.07	0.095	6.28
1 pm	0.150	8.78	0.145	8.35	0.142	8.25	0.172	9.96	0.168	9.84	0.160	9.21
2 pm	0.252	16.25	0.246	15.64	0.244	15.74	0.286	17.37	0.279	15.98	0.265	15.34
3 pm	0.219	18.12	0.214	17.12	0.204	16.79	0.238	19.42	0.220	18.15	0.226	18.42
4 pm	0.205	23.19	0.198	22.61	0.197	22.64	0.211	23.04	0.195	21.78	0.191	22.11
5 pm	0.189	44.78	0.186	43.03	0.182	42.78	0.197	46.46	0.191	45.25	0.185	43.56
6 pm	0.140	57.76	0.130	55.04	0.125	53.70	0.131	58.65	0.129	56.19	0.122	54.57
	1.362		1.298		1.262		1.427		1.358		1.320	

Table1 production and thermal efficiency of double slope solar still when cross cooling of glass and parallel cooling of glass using water

Time	Cross cooling of glass						Parallel cooling of glass					
	1cm depth		2cm depth		3cm depth		1cm depth		2cm depth		3cm depth	
	m_w	η_{th}	m_w	η_{th}	m_w	η_{th}	m_w	η_{th}	m_w	η_{th}	m_w	η_{th}
9 am	0.010	0.89	0.007	0.64	0.008	0.74	0.008	0.76	0.007	0.65	0.006	0.58
10 am	0.027	2.19	0.024	1.93	0.022	1.72	0.029	2.42	0.024	2.03	0.022	1.98
11 am	0.058	3.94	0.057	3.91	0.055	3.73	0.060	4.42	0.056	4.19	0.052	3.49
12 noon	0.100	6.62	0.096	6.27	0.092	5.99	0.106	7.18	0.099	6.57	0.098	6.44
1 pm	0.180	10.59	0.174	9.54	0.172	9.28	0.186	10.83	0.171	9.72	0.169	9.47
2 pm	0.290	18.53	0.287	16.70	0.278	16.24	0.297	19.09	0.283	16.85	0.285	16.02
3 pm	0.250	20.16	0.238	19.08	0.223	17.87	0.254	20.91	0.236	19.15	0.221	17.75
4 pm	0.221	26.01	0.203	23.79	0.198	22.66	0.224	26.87	0.212	24.95	0.200	23.13
5 pm	0.196	45.42	0.182	44.47	0.182	42..88	0.195	46.87	0.193	46.86	0.192	45.49
6 pm	0.138	59.23	0.132	56.29	0.130	54.69	0.139	59.71	0.135	57.26	0.130	55.14
	1.470		1.400		1.360		1.498		1.416		1.375	

III. EXPERIMENTAL OBSERVATIONS

The temperatures of water, glass cover and water vapor were recorded with the help of calibrated copper constantan thermocouples in combination with a digital temperature indicator. The ambient temperature is measured by calibrated mercury thermometer. The distillate from the still was measured using measuring jar. The solar radiation on inclined plane facing east and west were measured using a pyranometer. The experiments of each type were carried out to study the effect of water depths (1cm, 2cm and 3cm) on the performance of double slope active solar stills.

IV. MATHEMATICAL CALCULATIONS

➢ Instantaneous thermal efficiency of active solar still The hourly yield can be obtained by adding yield obtained from east and west side as

$$W_w = \sum (m_{we} + m_{ww})$$

The values of m_w for different water depth during sunshine hours (9AM-6 PM) are given in Tables.

➢ The instantaneous thermal efficiency is defined as

$$\eta_{th} = ((m_w * L) / (A_b * I * 3600)) * 100$$

Where L is the latent heat of water vapour given by this equation

$$L = 2.4935*106*[1-(9.4779*10^{-4} Tw + 1.3132*10^{-7}*Tw^2 - 4.7974*10^{-9}*T_W^3)]$$

V. RESULT AND DISCUSSIONS

A. Comparison of flash water productivity with respect to time

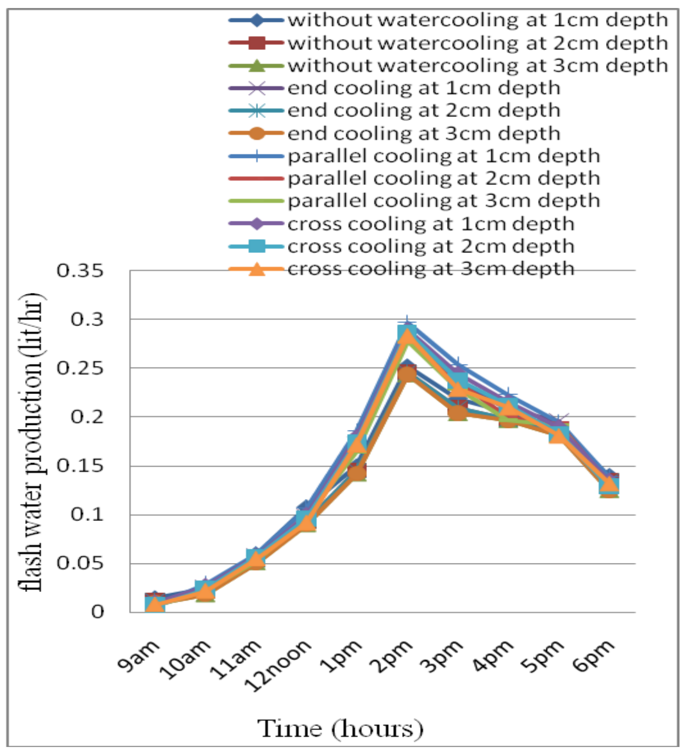

Fig.6 Comparison of flash water productivity at various depths with respect to time

The Fig.4.4 shows that the comparison of flash water productivity at various depths with respect to time. It shows that the productivity of flash water was high at 1cm water depth in the basin compared to others methods. The productivity has increased in the methods of glass cooling with water by minimum 4% and maximum 10% approximately when comparing to without cooling of glass. Productivity of flash water increment in the methods of glass cooling

- End cooling – 4.5% to 4.77% than without cooling
- Parallel cooling – 8.9% to 9.98% than without cooling and
- Cross cooling – 7.7% to 7.92% than without cooling

B. Comparison of thermal efficiency with respect to time

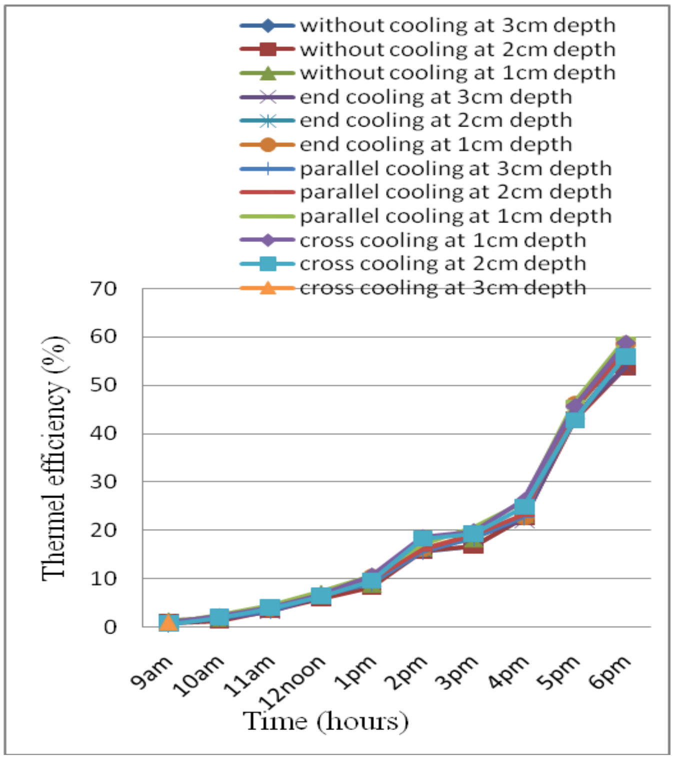

Fig.7 Comparison of thermal efficiency at various depths with respect to time

The Fig.4.8 shows that the comparison of thermal efficiency at various depths with respect to time. The thermal efficiency was low at 9AM because the production of flash water, solar intensity and temperature of the saline water in the basin are low at that time. But at 6PM the thermal efficiency high because the productivity and temperature of the saline water in the basin was high even though low solar radiation. The temperature of the water in the basin slightly increased from 9AM to 2PM, after which it get decreased as shown the figure 4.9. Thermal efficiency of parallel cooling was high compared to other methods by the reason it give the better condensation of water vapor at the bottom of glass. Always the productivity and thermal efficiency is high at minimum water depth in basin because the temperature of the water rises easily when depth was minimum. Thermal efficiency increment in the methods of glass cooling

- End cooling – 1.36 to1.55% than without cooling
- Parallel cooling – 2.68 to 3.21% than without cooling
- Cross cooling – 1.84 to 2.4% than without cooling

C. Comparison of evaporative water temperature

The methods of glass cooling, the saline water temperature affected due to the excess surface cooling by the reason the cooling water absorb some amount of solar radiation. So the flow rate cooling water should be controlled. Difference between the evaporative water surface temperature and condensation surface temperature (bottom of glass) increased up to 3^{o}C when applying water cooling on the transparent glass.

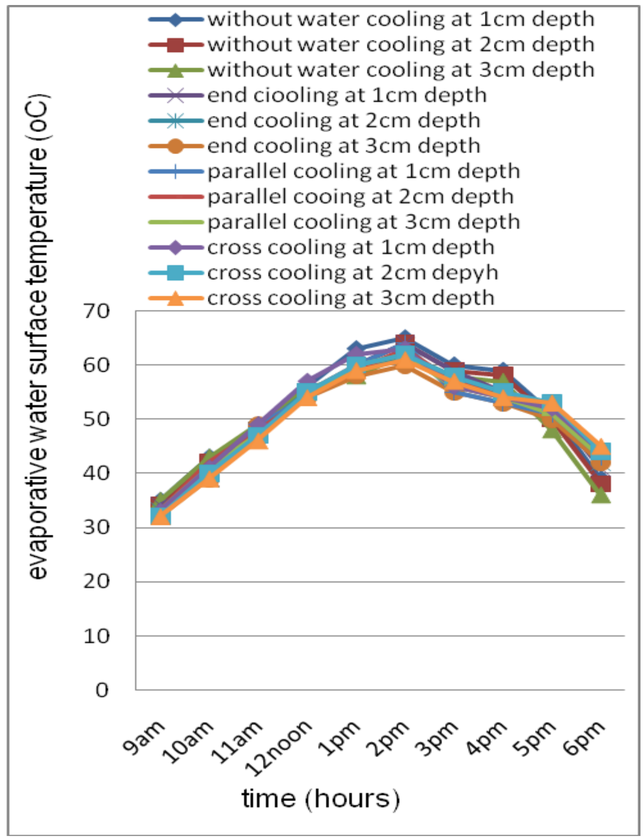

Fig.8 Evaporative water surface temperature vs time

VI. CONCLUSIONS

A simple method to enhance the solar still productivity and still efficiency was proposed. The water film cooling method is used to decrease the glass cover temperature in order to increase the rate of condensation. The difference between the evaporative water surface temperature and condensation surface temperature (bottom of glass) was increased up to 3°C when applying water cooling on the transparent glass. The depth of saline water in the basin was varied and experiment has been conducted for different methods of glass cooling using water and without water. The productivity of flash water and thermal efficiency of solar still was increased considerably in the methods of glass cooling especially in the parallel cooling of glass was high compared with the other methods.

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