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PRODUCTIVITY ENHANCEMENT OF SOLAR DESALINATION SYSTEM USING PARAFFIN WAX

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ABSTRACT

The experimental investigation of solar desalination without and with PCM thermal storage is examined. Solar still is designed with a single basin double slope with East-West orientation. The objective is to study the effect of thermal storage using paraffin wax as phase change material (PCM) in a solar still. The experiment is carried out for the different depth of water at 10, 20 and 30 mm in the basin with and without PCM. The productivity of water at the depth of 10 mm is greater than 20 mm and 30 mm. The productivity is increased to 11.6% and the peak yield is increased by 9.5% with PCM.

Key words: Solar still, Experimental performance, Thermal storage, Paraffin.

INTRODUCTION

There is a need to employ environmental friendly energy source to desalinate the seawater. Desalination is the process of removal of salt and impurities from the water. Kalidasa Murugavel et al.[1] carried out modeling of double slope solar still (DSSS) and reported with improved performance. Hitesh and Shah[2] studied the effect of different thickness glass cover on passive solar still. Three identical size solar stills having three different thickness of glass cover of 4 mm, 8 mm and 12 mm were used. A lower thickness of glass cover gives higher productivity. Sharma et al.[3] investigated a solar desalination and the effect of photocatalyst nickel sulphide on productivity of distilled water and its quality. Sethi and Dwivedi[4] carried out an exergy analysis of double slope active solar still under forced circulation mode. Several researchers[5-8] reviewed on phase change energy storage: materials and applications. Kaliappan et al.[9] experimentally investigated a single and double slope solar distillation system and the performance studied with different wick materials. The daily and night productivity of distilled water improved around 75% and 49.2% with

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double basin. Senthil and Cheralathan[10] reviewed the natural heat transfer methods in PCM. Gnanaraj and Ramachandran[11] enhanced the productivity of conventional solar still by adding with solar pond.

Based on the literature, use of single-glazed DSSS increases the production rate of desalinated water, and use of copper tubes reduces corrosion effects. The production rate of desalinated water varies every month depending upon the climatic season. The energy storage is required to optimize the performance and productivity of solar still. Among the various PCMs, paraffin is best suited for solar desalination due to its non-corrosive nature and availability in required temperature range. The investigation of the solar desalination integrated with PCM thermal storage was carried out and the results are reported in this work.

EXPERIMENTAL

Material and methods

A two galvanized iron basins, one of length 1500 mm and breadth 1000 mm is designed for operation, and the depth of the basin at the front and rear side is 100 mm and its uniform throughout the cross-section. The other one is a bigger basin of length 1540 mm, breadth 1040 mm and height 120 mm. The smaller basin in inserted in a bigger basin. The gap between two trays is maintained to be 20 mm by using small metal strips which are welded between two trays to hold them. This gap is provided to store PCM. The detailed experimental setup specifications are given in Table 1.

Table 1: Dimensions of double slope single basin

Description	**Size**
Length of basin	1.5 m
Breath of basin	1 m
Height of basin	100 mm
Thickness of basin	1.5 mm
Tilt angle of glass with horizontal plane	20°
Dimensions of glass	1×0.8 m^2
Thickness of glass	3 mm

Paraffin is used as a thermal storage material in the DSSS. The gap between two basins of galvanized iron is filled with 27 Kg of the paraffin and with melting temperature range of 55-60°C. Trays of the size 1500 x 1000 x 100 mm and 1540 x 1040 x 120 mm are fabricated. The inner sides of the tray are painted black. Three holes are provided on the sheet of the inner tray for inlet, drain, and outlet of water. The photographic view of still is shown in the Fig. 1.

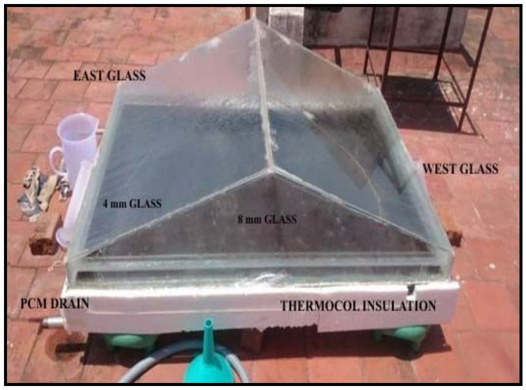

Fig. 1: Photographic view of DSSS

The fabrication is with transparent glass arrangement, to have the maximum strength of 8 mm thick transparent glass at boundaries. The upper cover of the basin is closed with 4 mm thick glass, so that maximum radiation is transmitted inside the basin. The glass to glass and metal to glass is attached to each other by silicone gel. A tray made of glass is attached to the base of the glass cover by silicone gel, with an inclination towards the collecting pipe, to collect the potable water that slides from the underside of the glass cover. Temperature is measured using K-type thermocouples and laboratory thermometer. Thermocouples are installed at the glass, water, PCM, chamber and outside for ambient temperature. Thermocouple reading is noted using 12 channel temperature indicator. Solar radiation data and wind speed data are collected at the site. The still is oriented in East-West direction to receive maximum radiation and the effect on wind speed and shadows are neglected. Bottom and all sides are insulated with thermos-wool having thermal conductivity is 0.03 W/mK.

Thermal performance of solar still and storage can have evaluated the following expressions. Heat absorbed (Q_W) by water calculated as below:

$$Q_W = m_W C_p \Delta T \quad \ldots(1)$$

Where m_W - the mass of water collected in kg. Average solar radiation received on still during summer day is 6.4 kWh/m^2/day (23.04 MJ m^{-2} day^{-1}) and 8 hours a day an average of 0.8kW/m^2. Heat absorbed by water evaluated as below:

$$Q_S = nq_s P.3600 \qquad \ldots(2)$$

Where n - the number of hours, q_s - the heat received by still and P is assuming only 30% of the radiation is absorbed by still.PCM is filled in the gap between the inner tray and outer tray at the bottom of the basin and amount heat stored by PCM calculated the expression:

$$Q_{PCM} = m_{PCM} C_{p,PCM} \Delta T + m_{PCM} LH \qquad \ldots(3)$$

Where m_{PCM} - mass of PCM, $C_{p,PCM}$ - the specific heat (2.2 kJ/kg K) and LH - the latent heat of vaporization of PCM and also 50% of the heat is lost considering convective losses through basin.

Instantaneous thermal efficiency is calculated and compared without PCM and with PCM. The following expression has used to calculate the instantaneous efficiency (η):

$$\eta = \frac{m_W L}{I A_b (\tau\alpha)} \qquad \ldots(4)$$

Where, A_b is the area of basin in square metre, I is the intensity of solar radiation in W/m^2, L is the latent heat of vaporization of PCM and $\tau\alpha$ is the absorptivity and transmissibility of glass.

RESULTS AND DISCUSSION

Outdoor experiments are conducted in single basin DSSS without PCM and with PCM at different depths of water 10 mm, 20 mm and 3 mm during 9.00-17.00 hrs in a day with the maximum intensity of solar irradiation and the temperature of water, glass, chamber and ambient temperature in every one-hour time interval are measured.

Figs. 2-4 show that the temperature of water always more than the chamber and all other temperatures. Both water temperature and chamber temperature vary in the same way. Peak temperature is observed between 13:00 and 14:00.

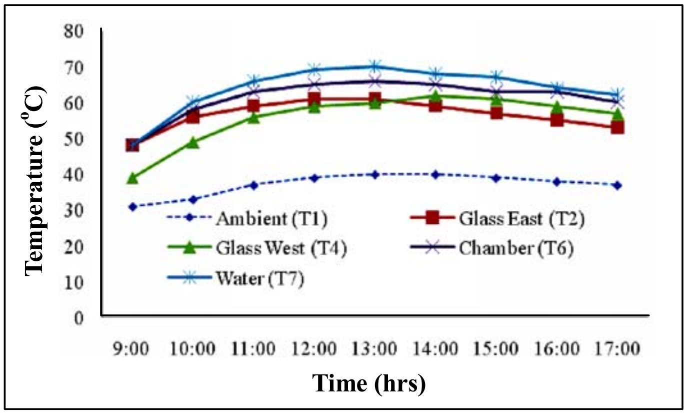

Fig. 2: Variation of temperature for 10 mm depth of water without PCM

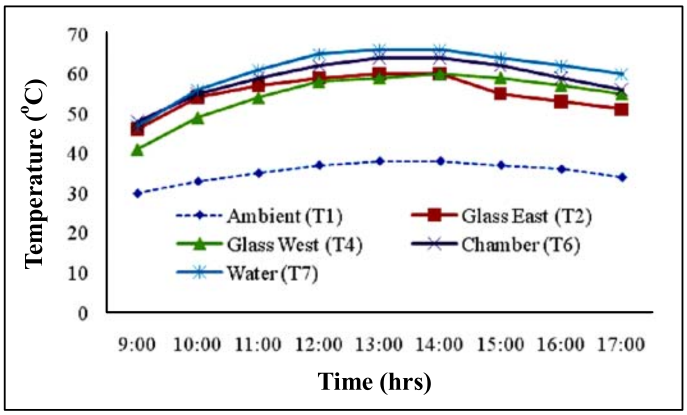

Fig. 3: Variation of temperature for 20 mm depth of water without PCM

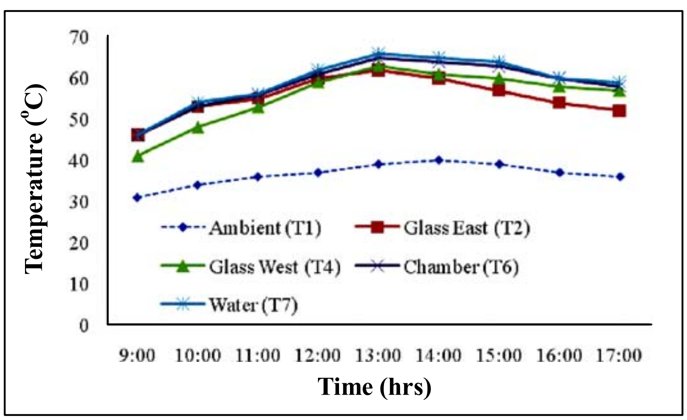

Fig. 4: Variation of temperature for 30 mm depth of water without PCM

Figs. 5-7 show that the PCM temperature tries to achieve water temperature. The chamber temperature is high when compared to chamber temperature without PCM. The slope of water temperature is not much variation when compared to without PCM.

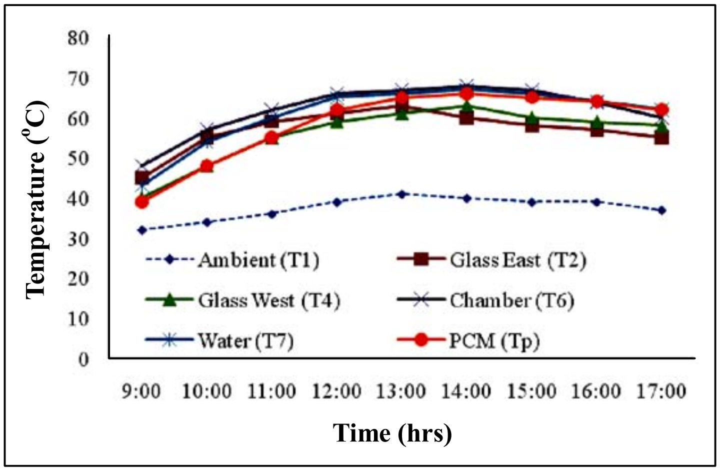

Fig. 5: Variation of temperature for 10mm depth of water with PCM

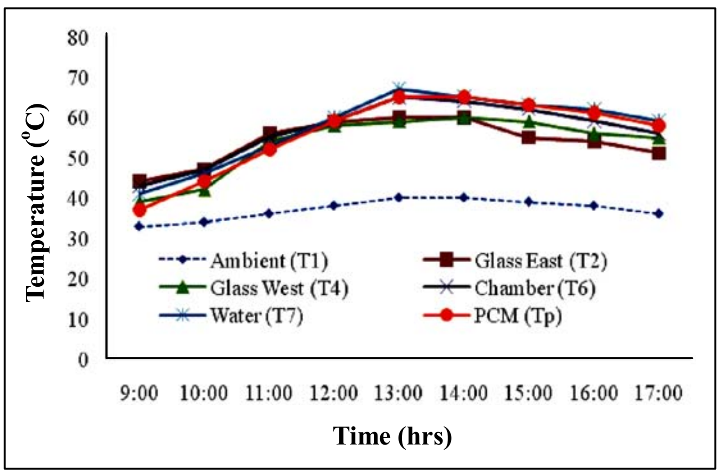

Fig. 6: Variation of temperature for 20 mm depth of water with PCM

Fig. 8 shows that the efficiency decreases till 12:00 because of PCM, after 12:00 the efficiency will increase. Drop in efficiency after 12:00 when PCM is used is far less when compared to without PCM. The total increase in efficiency is more when PCM is used.

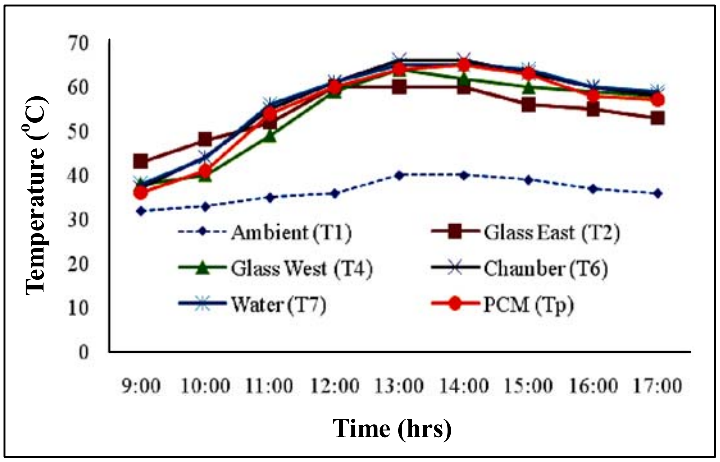

Fig. 7: Variation of temperature for 30 mm depth of water with PCM

As the efficiency is the function of temperature difference between glass and water as shown in Fig. 9, which is used to validate it. The temperature difference is taken as the difference of temperatures between water and individual glasses. From the results observed that both temperatures difference and efficiency change proportionally, but little deviation due to some factors like radiation and wind speed.

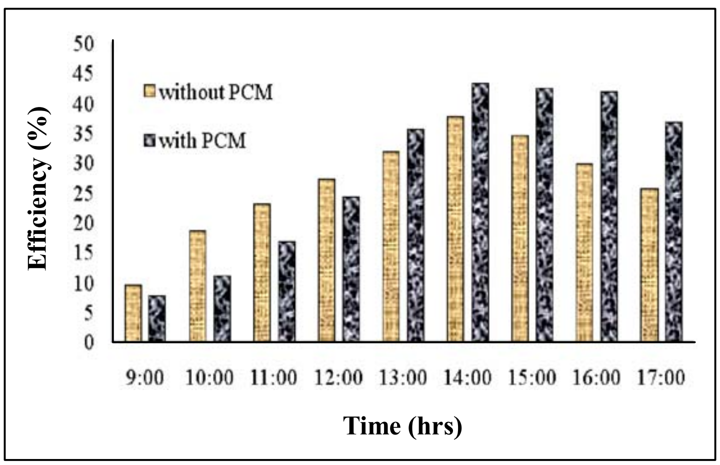

Fig. 8: Variation of instantaneous thermal efficiency with time

The overall efficiency between the different depth of water and with and without PCM, are compared. It is observed that, 10 mm depth has higher efficiency when compared to 20 mm and 30 mm. Finally, concluded that with the increase in depth of water efficiency drops and also observe that using PCM efficiency increased in all cases.

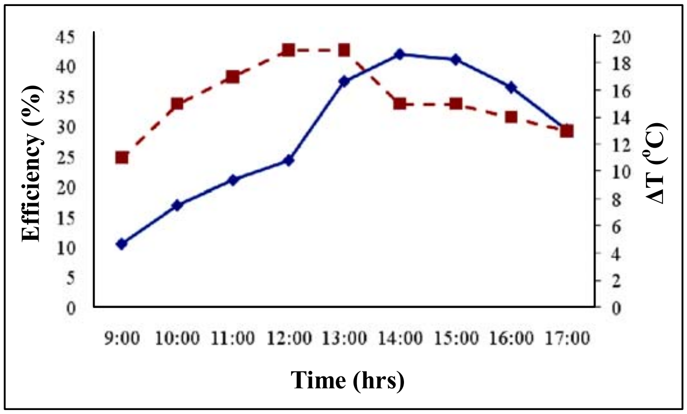

Fig. 9: Variation of temperature and efficiency

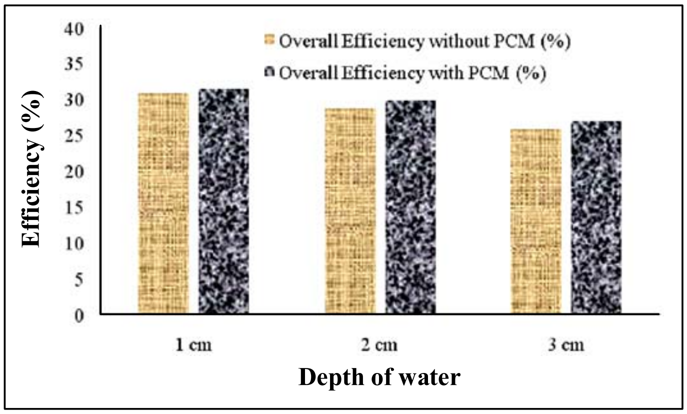

Fig. 10: Variation of depth of water on efficiency

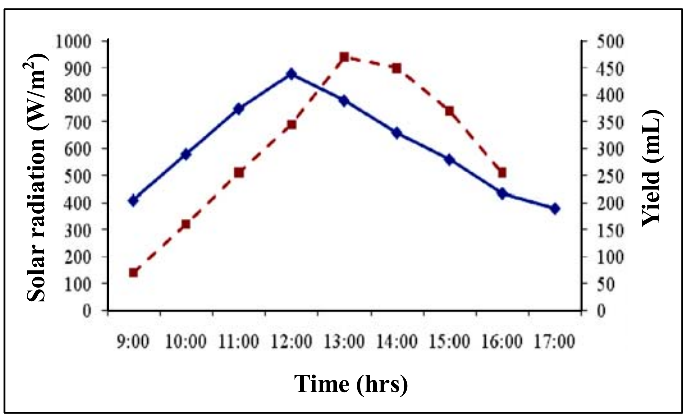

Fig. 11: Radiation intensity and yield on 10 mm depth of water without PCM

Fig. 11 shows that the solar intensity increases, yield also increases in all cases. From the experiments resulted that the solar intensity is almost maximum between 12:00 hrs - 13:00 hrs, whereas yield is maximum between 13:00 hrs - 14:00 hrs in all cases.

CONCLUSION

An improvement of productivity is achieved at the depth of water in the basin as 10 mm (15 litres of water) when compared to the depth of water at 20 mm and 30 mm. If the depth decreases, the productivity increases.

The productivity is increased by 11.6% with addition of PCM at an optimal depth of 10 mm in the basin. The peak yield of the still is increased by 9.75% with PCM.

The productivity is the function of the difference between the glass temperature and water temperature. The depth of water in the basin had the significant effect on the yield of the solar still and productivity increased that the increase in ambient temperature, solar intensity and increasing the temperature difference between glass and water. The possibility of increasing the water productivity could be reached by lowering the water depths in the basin.

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