EXPERIMENTAL STUDY OF DOUBLE SLOPE SOLAR STILL WITH ENERGY STORAGE MEDIUM

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ABSTRACT

An experimental study was conducted to enhance the productivity of double slope solar still by storage of thermal energy in day time with the help of phase change materials (PCM). We use paraffin wax as PCM. For this purpose two double slope solar still of same size are used in the experimental work. Overall 23% gain was observed when paraffin wax was used in solar still. An attempt has also been made to increase the conductivity of paraffin wax, which further increases the productivity of the still.

Key words: Double slope solar still, Paraffin wax, Al₂O₃.

INTRODUCTION

Nowadays, accessibility to drinking water is one of the main issues for human being. Drinking water is important not only for life, but also domestic, industrial and agricultural purposes. More than 75% of the earth has been covered with water, but only about 0.014% of global water can be used directly for drinking and industrial purposes. Solar still can utilized the solar radiation for producing fresh water. Solar still are low cost and fabricated easily, but they suffer from low productivity. Because of their advantage, researcher have conducts studies to enhance the solar still performance. Effective store the extra solar energy during the daytime and release it in particular time such as at night time to achieve the aim of time shift the phase change material (PCM) as the thermal energy storage medium is applied to solar still to enhance the energy storage capacity of the solar still in present study. in this case solar energy that reaches the solar absorber is absorbed and stored by the PCM. The paraffin wax with melting point 68 used as the PCM [1]. Although Water is one of the most abundant resources on Earth, covering approximately three-quarters of the planet's surface. About 97% of the Earth's water is salt water in the oceans. 3% of all fresh water is in ground water, lakes and rivers, which supply most of that needed by humans and animals. However, rapid industrial-growth and the population explosion world-wide have resulted in a large escalation of the demand for fresh water. Added to this is the problem of pollution of rivers and lakes by industrial
wastes and the large amounts of sewage discharged. On a global scale, man-made pollution of natural sources of water is becoming the single largest cause for fresh-water shortages. Besides the only inexhaustible sources of water are the oceans. Their main drawback, however, is the high salinity of such water. It would be attractive to tackle the water-shortage problem with desalination of this water, which may be mixed with brackish water increase the amount of fresh water and reduce the concentration of salts to around 500 ppm [2].

Solar distillation has been practiced for many generations. All desalination methods require fossil fuel or electrical energy but solar distillation is one of many processes that can be used to produce fresh water by using the heat of the sun directly in a simple equipment to purify water. The equipment, commonly called a solar still [3, 4]. In open environment solar still has to work under some parameters which tremendously affect its performance and productivity. These parameters can be divided in two categories, metrological parameters and non-metrological parameters. The former one, which cannot be controlled by human efforts, constitutes with solar intensity, wind velocity and ambient temperature whereas the later one, also known as controllable parameters, counts for water-glass temperature difference, free surface area of water, absorber plate area, temperature of inlet water, glass angle, still orientation and depth of water. In the present work, still orientation and depth of water has been selected as the variables for productivity analysis.

The performance prediction of a solar distillation unit mainly depends on accurate estimation of the basic internal heat and mass transfer relations. The oldest semi-empirical heat and mass transfer relation was given by Dunkle[5]. They have analyzed the effect of water depth on the performance of DSS. Due to intermittent nature of solar energy, distillate production is not continuous and night time production is almost nil. By using energy storage mediums, distillate may be produced during non-Sunshine hours. These energy storage systems may store heat energy in two ways (i) Sensible Heat (ii) Latent Heat. Thermal energy can be stored as a change in internal energy of a material as sensible heat, latent heat or combination of these two. In sensible heat storage (SHS), thermal energy is stored by raising the temperature of a solid or liquid. SHS utilizes the heat capacity and the change in temperature of the material during the process of charging and discharging of the medium the temperature. The amount of heat stored depends on the specific heat change and the amount of storage material [7].

Shukla et al[8] has recently developed a model, based on regression analysis, to determine the values of C and n using the experimental data obtained from the stills. This method uses both inner and outer glass cover temperatures to determine the expressions for internal heat transfer coefficient and does not impose any limitations.

**EXPERIMENTAL SET-UP**

The experimental setup consists of a passive solar distillation unit with a glazing glass cover inclined at $26^\circ$. Since the geographical location of Allahabad lays $26^\circ$ in northern hemisphere thus it is justified to take same inclination for glass covers to receive maximum insolation. This tilted glass cover of 3 mm thickness, served as solar energy transmitter as well as a condensing surface for the vapor generated in the basin Basin having area of $0.04\text{m} \times 0.096\text{m}$ is made up of Galvanized Iron has an effective area of $0.72\text{m}^2$. 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 (Araldite). 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. All these arrangements are made to make the still air tight. 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. South & North sides). A provision was made to fill the PCM beneath the basin. An aluminum tray was designed and fabricated with same size as that of the basin liner. Thermocouples were located in different places of the still. They record different temperature, such as glass cover, PCM and water temperature in the basin and ambient temperature. All experimental data are used to obtain the internal heat and mass transfer coefficient for double slope solar still.

**Fig. 1: Photograph of double slope solar still**

**PROCEDURE**

The experiments were conducted on different days in the campus of the Sam Higgiinbottom Institute of Agriculture Technology and Sciences Deemed University, Allahabad, India. All experiments were started at 08.30 AM local time and lasted 5.00 pm. Waterglass and vapour temperature were recorded with the help of calibrated copper constant thermocouples and a digital temperature indicator having a least count of 1°C. The ambient temperature is measured by calibrated mercury (ZEAL) thermometer having a least count 1°C. The distillate output was recorded with the help of a measure cylinder of least count 1 ml. The solar intensity was measured with the help of calibrated colorimeter of least count 1 ml. The solar intensity was measured with the help of a calibrated solarimeter of a least count of 1 (mW/cm²). The hourly variation of all above mentioned parameters were used to evaluate average values of each for further numerical computation.
RESULTS AND DISCUSSION

Fig.2: Variation of solar intensity with time on different days

Variation of solar intensity falling on the south and north side glass covers of the double slope solar still for a particular day (6-10-3) is shown in fig.2. It is observed that the solar intensity falling through south side glass cover is higher till 01:00 hrs. Maximum value is observed around 11:00 hrs on south glass cover.

Fig.3: Variation of wind velocity with time on different days
Shows the Variation of wind Velocity with Time of testing the double slopes in solar still in particular day (6-10-3) is shown in fig.3. PCM=2.5Kg & Al₂O₃ =0.25 kg and without PCM The maximum wind Velocity is 1.5 m/s at 12:00 PM

Fig.4: Variation of temperature with time on different days

Fig shows the Variation of temperature with time on different days(6-10-3) the temperature of water with PCM and Al₂O₃ is higher than PCM and without PCM. Higher temperature difference between water and condensing cover more productivity

Fig.5: Variation of productivity with time on different days
Shows the Variation of Productivity with Time of testing the double slops in solar still in pcm=2.5 Kg & Al₂O₃ =0.25 kg and without PCM. The maximum distillate in the day 6/3/2014 for south and north is 198 ml at 1:30 PM and the maximum distillate in the day 10/3/2014 for south and north is 230 ml at 2:00 PM. The maximum distillate in the day 3/3/2014 for south and north is 197 ml at 1:00 PM and total distillate in day 6 march is 2321 ml and total distillate in day 10 march is 2471 ml and the total distillate in day 3 march is 2202 ml.

Fig. 6. Variation of night distillate with different days (3-6-10) march

Fig. 7. Variations of convective heat transfer coefficient $h_{cw}$ with time on different days
CONCLUSION

An experimental work has been performed on the two similar double slope solar stills. One solar still is filled with phase change material in the basin and water tray is kept over it. Experimental results showed that nocturnal productivity of solar still with PCM was 42% higher than that of solar still without PCM. Daytime productivity of solar still with PCM was 5.4% higher than that of without PCM. When 10% Al$_2$O$_3$ is used in the PCM to enhance it's thermal conductivity, a further 12% rise of daily productivity is recorded.

REFERENCES


AUTHOR’S DETAIL

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