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Experimental Study of Double Slope Solar Distillation with and without Effect of Latent Thermal Energy Storage

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Abstract - **Hygienic drinkable water is a basic necessity for man along with food and air. Fresh water is also required for agricultural and industrial purposes. Most water sources are contaminated by industrial waste, sewage and agricultural runoff. The higher growth rate in world population and industries resulted water in a large acceleration of demand for fresh water.**

The natural source can meet a limited demand and this leads to acute shortage of fresh water. Hence, there is an issue to essentially treat the salt and contaminated into purified water. There are several methods to convert impure water into potable water for drinking, but out of them thermal method is economically viable. In this paper experimentation were carried out on two different setups of double slope single basin solar still with and without thermal energy storage by phase change material.
Keywords: **Solar, Latent Heat, Paraffin Wax**

I. INTRODUCTION

A Solar still operates on the same principle of rain caused by evaporation and condensation. The water from the oceans evaporates, only to cool, condense, and return to earth as rain. When the water evaporates, it removes only pure water and leaves all contaminants behind. Solar stills copy this natural process. Solar still has a top cover made of glass, with an interior surface made of a waterproof membrane. This interior surface uses a blackened material to improve absorption of the sun's rays. Water to be cleaned is poured into the still to partially fill the basin.

The glass cover allows the solar radiation to pass into the still, which is mostly absorbed by the blackened base. The water begins to heat up and the moisture content of the air trapped between the water surface and Condensed water trickles down the inclined glass cover to an interior/exterior collection trough and out to a storage bottle. But efficiency of such normal solar still is poor and we never use benefit of such device after sunshine hour.

There are various techniques through which performance of solar still will improve out of them use of extended surface in solar still basin, blackening of inner surface, use of reflectors mirrors, sensible and latent energy storage, etc. In this experimentation separate test were carried out on the same capacity single basin double slope solar still with and without use of latent thermal energy storage.

II. THERMAL ENERGY STORAGE

Thermal energy storage (TES) is defined as the temporary holding of thermal energy in the form of hot or cold substances for later utilization. Energy demands vary on daily, weekly and seasonal bases. These demands can be matched with the help of TES systems that operate synergistically, and deals with the storage of energy by cooling, heating, melting, solidifying or vaporizing a material and the thermal energy becomes available when the process is reversed.

The main types of TES are sensible and latent. Sensible TES systems store energy by changing the temperature of the storage medium, which can be water, brine, rock, soil, etc. Latent TES systems store energy through phase change, e.g., cold storage water/ice and heat storage by melting paraffin waxes.

Fig.1 Paraffin Wax

A phase change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa. Properties of selected paraffin wax for thermal energy storage in solar still application.

TABLE 1 PROPERTIES OF PARAFFIN WAX

Properties	Values
Melting-point	50°C
latent heat	145 kJ/kg
Viscosity	1.9 mm²/s
Density	1.412 g/cm³
specific heat capacity – solid	2.1 kJ/kg-K
specific heat capacity – liquid	2.4kJ/kg-K
coefficient of thermal conduction – liquid	0.15W/m-K

III. LITERATURE REVIEW

Mohammed Farid and Faik Hamad (1993) [1] Efficiency of the still was found to be independent of solar radiation, however, an increased diffused radiation lead to slight decrease in its efficiency. Still productivity increases with the increase in ambient temperature and decrease in wind velocity.

Singh et al., (1995) [2] have been analyzed the orientation of the glass cover inclination for higher yield in a solar still. The effects of water depth on the hourly instantaneous cumulative and overall thermal efficiency and internal heat transfer coefficient have also been investigated.

El-Sebaii *et al*., (2000) [3] designed and fabricated a single slope single basin solar still with baffle suspended absorber (SBSSBA) as an alternate to external pre heater. Results concluded that the daily productivity of the SBSSBA is about 20% higher than that of the conventional still (SBSS).

El-Swify and Metias (2002) [4] induced the concept of planer reflector in a double exposure solar still. Still was theoretically analyzed and experimentally tested. It is found theoretically that the double exposure still gained much more daily energy than that of the ordinary one.

Hiroshi Tanaka and Yasuhito (2007)[5] investigated outdoor experiments for vertical single-effect diffusion solar still and the proposed multiple-effect still has a very high rate of productivity in spite of its simple structure.

Selva kumar *et al*., (2008)[6] studied the thermal performance of "V" type basin solar still with charcoal absorber. The internal heat transfer and external heat transfer modes are studied. Performance ratio of the still, variation of Nusselt number (Nu), Grashof number (Gr) and heat transfer rates were also calculated.

Bharat Kumar Patil, Sanjay Dambal (2016) [7] the maximum productivity of a double slop single basin solar still is effective when paraffin wax is used. As the productivity of water is obtained in the month of April for paraffin wax is 1100ml. When compared to PCM the productivity is a bit low when black pebble was 954ml. But the productivity of water did not obtain without Paraffin wax nor is Black pebble found to be 795ml. This is comparatively low. The productivity of the still can be enhanced by varying the Declination angle and it is observed that as the solar radiation increases the temperature in the still also increases and as a result the productivity increases remarkably.

B. N. Subramanian (2016) [8] solar desalination is one of the most sustainable and attractive method employed to meet the supply of drinking water for remote areas at very reasonable cost. Heat loss is one of the major parameter affecting the productivity of the solar still. The objective of this study is to enhance the thermal performance and productivity of single basin solar still with integrated phase change material.

The important parameters affecting the performance of the still are analyzed theoretically. Effect of water depth in galvanized iron, aluminum and copper basin still and effect of mass of PCM in solar still were investigated. It was found that the productivity of still decreases with increase in water depth. The highest daily productivity of 1.39 kg/m^2 was obtained when the depth of water was maintained at 10 mm.

IV. METHODOLOGY AND EXPERIMENTATION

Two double slope single basin type solar still units are fabricated with same design parameters, and tested under field conditions. The experiments were conducted at the open terrace at SIT COE Yadrav, Maharashtra. Total 5 Lit waste water (Mud Water) can be used for experimentation. Total water depth for both set up is 1.5cm.

The glass and cover of solar still for both set up is sealed by cello tape to avoid loss of heat due to convection and radiation. The outer layer of both the solar still is insulated by thermacol and aluminium foil to avoid loss of het due to radiation. The output of distilled water is collected in two plastic bottles. Inner surface of both the stills are coated with black colour to improve the thermal performance.

The observations were taken for 7 hours starting from 10am to 5pm on without thermal energy storage setup and 10 hours from 10am to 8pm on with thermal energy storage set up. The global and diffused irradiances on horizontal and irradiances on inclined planes, the temperatures of the atmosphere, glass surface temp, basin water temp, and the masses of distilled water supplied and condensate collected were recorded every 1 hr.

Temperature and solar intensity was measured in every 1 hr with the help of digital temp meter and flux meter. And output of water in ml is measured by digital weight pan. Experiment was conducted on two different setup with and without TES and readings are recorded accordingly.

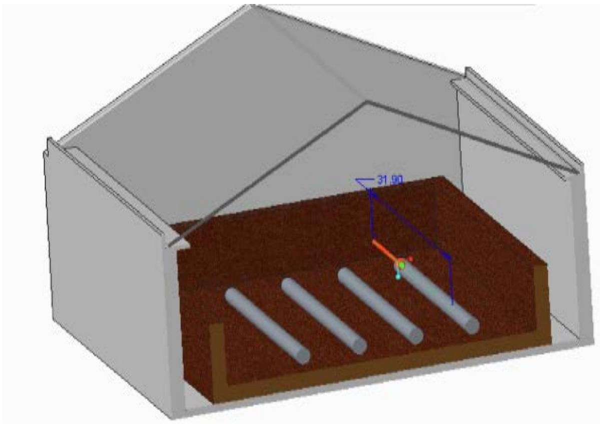

Fig.2 Experimental Setup

Comparison of experimental set up of solar still with and without PCM

TABLE 2 COMPARISON OF SOLAR STILL WITH AND WITHOUT PCM

Time (hr)	Weight of water added without PCM in kg	Weight of water added with PCM in kg
10am	0	0
11am	0.152	0.156
12pm	0.164	0.176
1pm	0.34	0.288
2pm	0.484	0.42
3pm	0.588	0.484
4pm	0.684	0.67
5pm	0.704	0.745
6pm	0.7	0.778
7pm	0.7	0.80
8pm	0.7	0.85
8:30pm	0.68	0.91

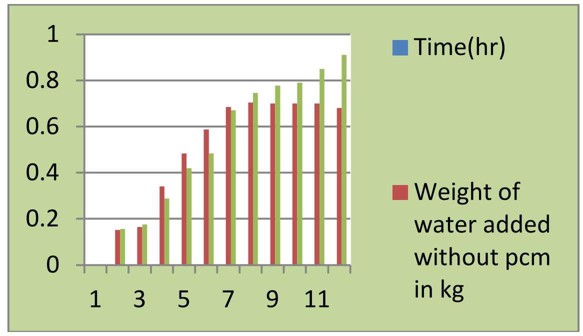

Fig.3 Time vs Weight of water

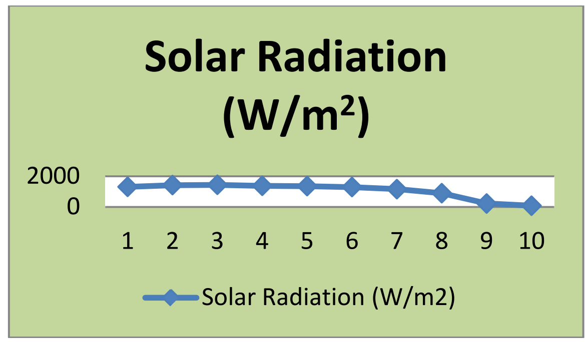

Fig.4 Time vs Solar Intensity

V. RESULT AND CONCLUSION

Heat transfer from the water surface to the glass (Q_{cw}) by convection through humid air in the upward direction is given by,

$Q_{cw}=h_{cw}\times A_w\times (T_w-T_g)$

TABLE 3 RATE OF HEAT TRANSFER

Time Hr	Water Temp ^{0}c	Glass Temp ^{0}c	Q (Rate Of Heat Transfer)
10 am	36.8	30.2	6979.5
11 am	40.8	35.4	5710.5
12 pm	55.3	38.1	18189
1 pm	59.1	40.8	19352.25
2 pm	59	41.1	18929.25
3 pm	56.3	41.2	15968.25
4 pm	52.7	41.2	12161.25
5 pm	47.2	36.3	11526.75
6 pm	40.5	31.8	9200.25
7 pm	40	31.6	9094.5
8:30 pm	39.2	30.2	8912.5

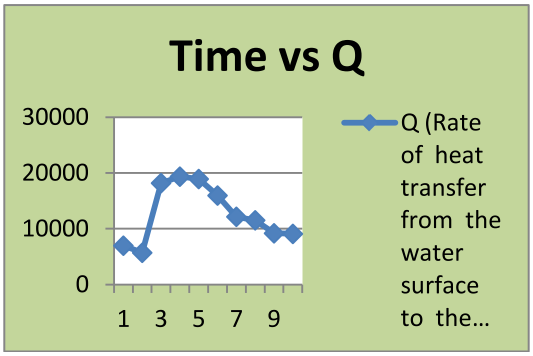

Fig.5 Time vs rate of heat transfer

From Experimentation it was observed that, solar still continues to produce the fresh water by converting mud water. The distillate production is said to be increased to 10-25% with PCM. The energy storage materials in the still store considerable amount of heat during noon hours and release the stored heat to the basin water in the late afternoon hours when radiation is low, and are found to influence the temperature of the solar still components considerably. Output of the conventional still is higher in the morning whereas the output of the energy storage material still is higher in the evening hours. The energy storage materials which are used in this investigation system are economically suitable for solar still to improve the output and efficiency. In this study, physical and chemical tests are performed on the water distilled from the solar stills. The distilled water from the solar stills was collected in a plastic bottle. For this purpose, two water samples (mud water and distilled water) are given to the Nikhil analytical laboratory, Sangli for water Potable test. After testing it is observed that distilled water is chemically and bacteriological safe i.e. potable

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