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Design of solar still using Phase changing material as a storage medium

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Abstract - The only nearly inexhaustible sources of water are the oceans, which is of high salinity. However, the separation of salts from seawater requires large amounts of energy which, when produced from fossil fuels, can cause harm to the environment. Therefore, there is a need to employ environmentally friendly energy sources in order to desalinate seawater. In this project we designed a solar still (single basin double slope), which can be used for water desalination (removing salt content from water using solar energy). Probably, they are considered the best solution for water production in remote, arid to semi-arid, small communities, where fresh water is unavailable, however, the amount of distilled water produced per unit area is somewhat low in designed solar still which makes the solar still unacceptable in some instances. The purpose of this project is to study the effect of using phase change materials in a solar still, and thus enhance the productivity of water. In present work phase change material(Bitumen) is used to store the solar thermal energy in the form of latent heat, which can offer high storage capacity per unit volume and per unit mass and we can get heat in the night time for desalination. The efficiency of the solar still without PCM is about 25.19% and in presence of PCM (Bitumen) is 27.00%.

Index Terms: *Bitumen, Desalination, latent heat, PCM, Solar energy, Solar still,Thermal energy*

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1. Introduction

Solar distillation uses the heat of the sun directly in a simple piece of equipment to purify water. The equipment, commonly called as solar still, consists primarily of a shallow basin with a transparent glass cover. The sun heats the water in the basin, causing evaporation. Moisture rises, condenses on the cover and runs down into a collection trough, leaving behind the salts, minerals, and most other impurities.

This project focuses mainly on small-scale basin type solar stills as suppliers of potable water for families and other small users. In this study an attempt has been made to bring out a new kind of organic phase change material (Bitumen) for energy storage. The material used is refined bitumen of specific grade. In this work the system is fabricated using combination of PCM and water as the storage material. This system consists of solar still which is an equipment to perform the desalination (removing of salt form sea water) process and bitumen as phase change material.

Single-basin solar stills can be used for water desalination. Probably, they are considered the best solution for water production in remote, arid to semi-arid, small communities, where fresh water is unavailable, however, the amount of distilled water produced per unit area is somewhat low which makes the single-basin solar still unacceptable in some instances. The purpose of this paper is to study the effect of using phase change materials in a solar still, and thus enhance the productivity of water.

In present work phase change material is used to store the solar thermal energy in the form of latent heat, which can offer high storage capacity per unit volume and per unit mass and we can get heat in the night time for desalination. This phase changing material changes its phase from solid to liquid and store solar energy; during liquid to solid it will release absorbed solar energy.

1.1 Solar still operation

A solar still used for converting brackish/saline water into potable water using solar energy is called solar still. It consists of a shallow blackened basin of saline water covered with a sloping transparent roof. Solar radiation that passes through the transparent roof heats the water in the blackened basin, thus evaporating the water which gets condensed at underside of the glass and gets collected in the tray as distillate attached to the glass. In present project a phase changing material is placed at the bottom of the water tray which is in contact with the water tray at the bottom and helps in evaporation by liberating heat after sunset.

2. Experimental setup:

The present project consist as an equipment called solar still, which consist of a basin made up of tin of 0.54 m^2 area, having a length of 90cm and 60cm width with 30 cm height. Inside this basin another basin is placed with a distance of 8cm leaving a gap from bottom and sides and in between this gap an insulation material (glass wool) is placed to prevent loss of heat. The inner box is filled with phase changing material (PCM) with a thickness of 7cm, here the PCM used is Bitumen which will change their phase from solid to liquid during day time and liquid to solid in the night, above the PCM a 2, 4 and 6cm height of saline water is filled which will evaporate when gets heated by solar radiation. At the top of the basin a transparent glass is placed at an inclination of 23deg which is having a thick-

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ness of 3mm which will allow the solar radiation to enter into basin consisting of water. When water gets heated it starts evaporating and collects at the underside of the glass cover as vapors. This collected vapors move on to the condensate channel which is provided inside the basin. The basin also consists of one inlet at the rear end for water input and two outlets at front end to collect the water from two condensate channels. In addition to this certain important parameters are to measured simultaneously which are temperature, global solar radiation, wind speed and humidity and these are measured using thermometer, Pyranometer, anemometer respectively.

Fig 2.1: Solar still without PCM

Fig 2.2: Solar still with PCM

3. Methodology

All the experiments were conducted between the time periods of 09:00 to 17:00hrs when the solar still is without PCM and this time period is extended to two more hours' i.e. Up to 19:00hrs.when the PCM is used in the solar still, because to see the effect of PCM in solar still. This experiment will be conducted at NMAMIT energy park, NITTE. This site is $13^0$10'54''N and $74^0$56'10''E, with an altitude of around 265 feet. The climate is non-semi-arid and is characterized by heavy annual rainfall during rainy season and bright sunshine during winter and summer season. The annual global solar radiation is around 1801 kWh/m^2 and around 2722 hours of sunshine per year. The solar irradiance is monitored on PC system. Thermo couples were fixed to take the temperature of water, PCM, glass, insulation and ambient temperature. The experiment is conducted during the time period of 09:00 hrs to 17:00hrs in the absence of PCM. The 6 cm height water tray is filled with 2 cm of brackish or saline water. The above procedure is repeated for 4 and 6 cm height of water in tray.

4. Results and Discussion

The experiments were conducted for different thickness of water level i.e for 1,1.5 and 2 cm thickness in solar still without PCM and with PCM, to compare the results when the global radiation is similar during both the experiment.Fig 4.1 shows the comparison of global radiation which is nearly similar intensity for whole day.

fig 4.2 explains about output of water with respect to time and also shows the variation of output with respect to solar intensity. Fig 4.3 reveals that the efficiency of solar still with PCM is better than solar still without PCM. The temperature of the water, glass cover, ambient, insulation temperature and global radiation vs. time were taken from solar still when still is without and with PCM which is shown in fig 4.4 and 4.5 respectively. These graphs are plotted for 1.5 cm height of water level in the solar still. PCM temperature will be taken into account when PCM is used in solar still.

The efficiency of solar still is calculated by using this formula:

h=ML/IAT

Where;

M-Mass of the distilled output(ml/hr)
L-Latent heat of water (kg/kJ)
A-Absorber area (m^2)
T-Time (sec)
I-Global radiation (W/m^2)

Table 4.1 Comparison of global radiation on solar still with and without PCM for 1.5 cm water level depth

Time(hrs)	Global Radiation without PCM(W/m^2)	Global Radiation with PCM(W/m^2)
09:00	290	280
10:00	570	570
11:00	620	630
12:00	760	750
13:00	780	770
14:00	810	810
15:00	720	730

16:00	590	600

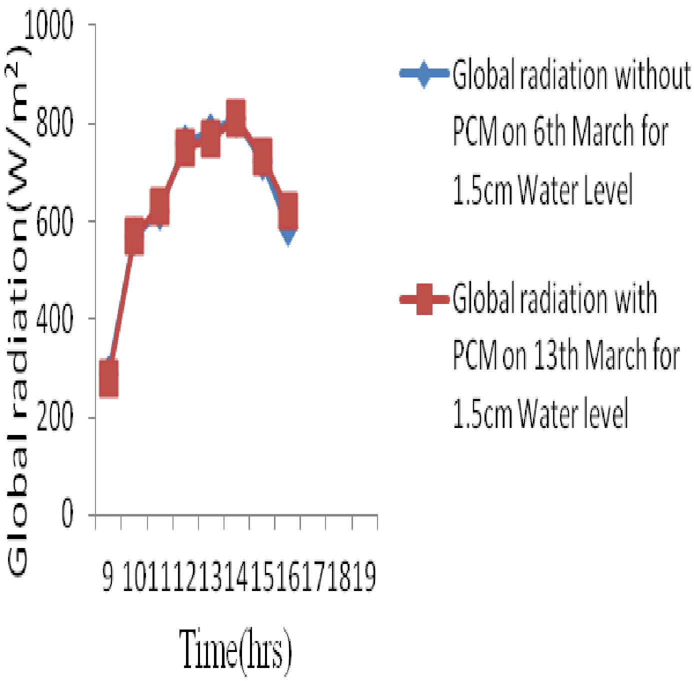

Fig 4.1: Comparison of Global radiation vs. Time (without and with PCM)

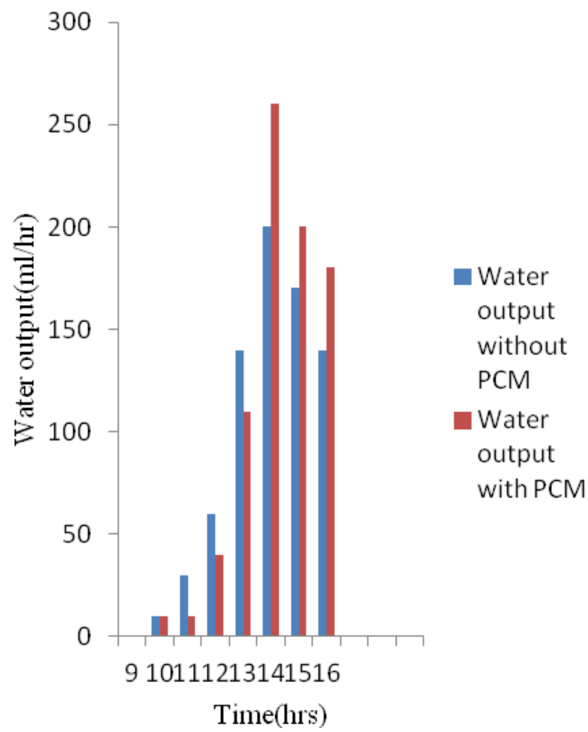

Fig 4.2: Water output vs. Time (without and with PCM)

Table 4.2: Comparison of distilled water output for with and without PCM

Time(hrs)	Water output without PCM for 1.5 cm (ml/hr)	Water output with PCM for 1.5 cm (ml/hr)
09:00	0	0
10:00	10	10
11:00	30	10
12:00	60	40
13:00	140	110
14:00	200	260
15:00	170	200
16:00	140	180

Table 4.3: Comparison of Efficiency with and without PCM

Time(hrs)	Efficiency without PCM solar still	Efficiency with PCM solar still
09:00	0	0
10:00	3.38	3.38
11:00	9.329	3.06
12:00	15.22	10.285
13:00	34.6	27.54
14:00	54.76	61.88
15:00	45.52	52.82
16:00	34.6	55.97

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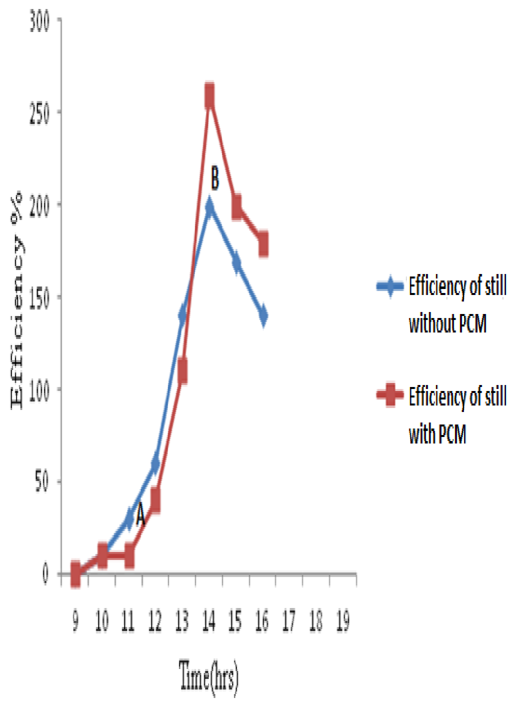

Fig 4.3 Comparison of efficiency in solar still with and without PCM

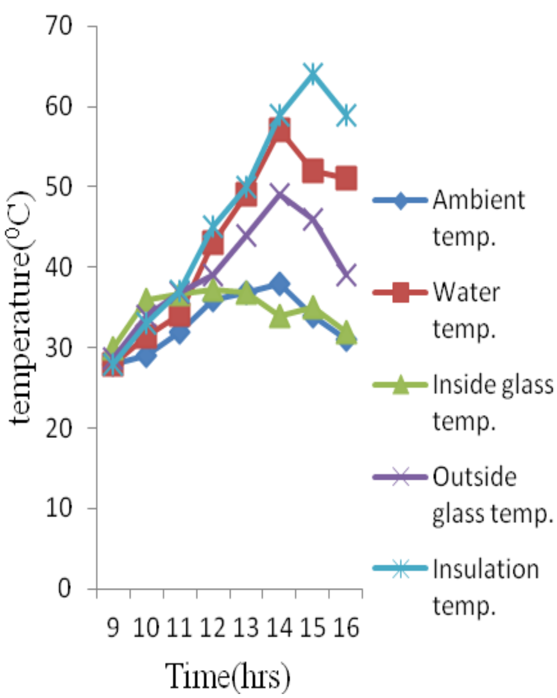

Fig 4.4 Variation of different temperatures in solar still without PCM

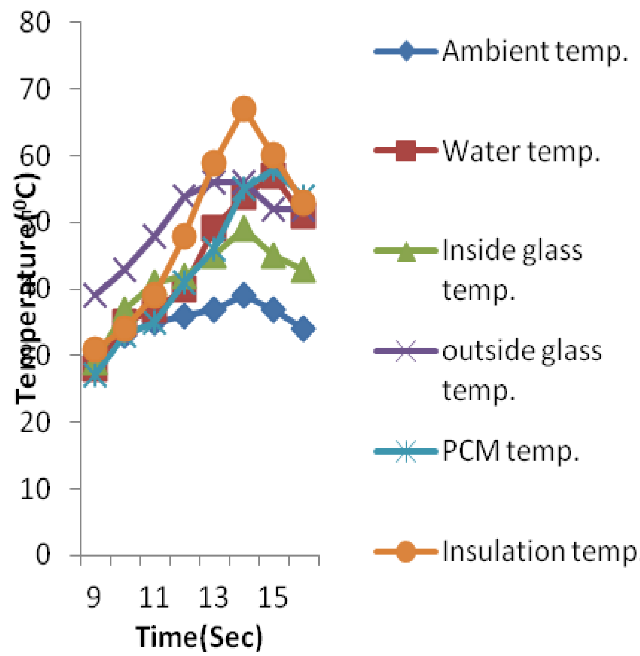

Fig 4.5: Variation of different Temperaturesin solar still with PCM for 1.5cm of water depth

Conclusions

The purpose of this work is to evaluate the increase in the productivity of the solar still by using phase changing material (PCM) as a storage medium.
Based on the experiment conducted and discussion carried out, the following conclusions are drawn.

1) The use of PCM as storage material in solar still results in increased distilled water output of about 2% with 1.5 cm of water depth and 1.96 % for 2 cm water depth

2) The efficiency with PCM is found to be 27% compared to 25.19 % efficiency of still without PCM.

3) The optimal water depth for both types of solar is found to be 1.5 cm.

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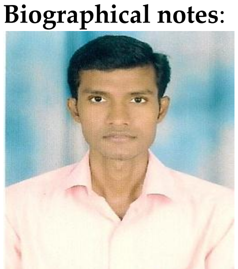

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