Performance Enhancement of Solar Still using Phase Change Material

[1]Prakash H. Vekariya, [2] Nisarg Merchant, [3]Dhananjay Nayak, [4] Prof. Bhaumik J Sheth
[1]Bachelor of Engineering, [2]Bachelor of Engineering, [3]Bachelor of Engineering, [4]Assistant Professor
[1]Mechanical Engineering Department,
[1]A.D. Patel Institute of Technology, Anand, India

Abstract: There is always a paucity of clean and pure drinking water in many developing countries. Water from different sources is often unsafe for drinking purpose (i.e. contains dissolved salts) and contains harmful bacteria and therefore, cannot be used for drinking purpose. There are many water frontier areas where seawater is in surplus quantity but drinkable water is not available in sufficient quantity. Major parts in India, particularly, village areas, coastal areas and many municipalities too, have a serious drinking water problem. Sufficient drinking water, at granted purity level, is inaccessible. Therefore, it is dire need of the society to manufacture certain purification systems which run on renewable energy. The project makes use of the latent heat of fusion of the PCM that is placed in the basin to continue desalination even after sunset. The PCM used was stearic acid having a melting point of 54 °C. The cooling effect is also explored for their effect on the single slope solar still productivity.

Index Terms **- Desalination, Solar stills, Solar energy storage, Phase change materials.**

I. INTRODUCTION

Due to degradation of environment and restricted fossil fuel resources, heavy attention is being given to renewable energy sources. Now a days effective research is made on solar energy. One of the simplest and primary applications of this energy is the convergence of solar radiation into heat. Solar irradiation can be broadly used for water heating in hot water systems, swimming pools as well as a supporting energy sources for central heating installations. In this case, solar radiation is converted into heat with the use of solar panel. Using the sun's energy to heat water is not a new idea. As along with food and air, human body needs water as importantly as previous two.

1.1 Principle of Solar Still

Solar still works on the principle of normal distillation. A solar still follows same procedure as rain water that is evaporation and condensation. Saline water is feed in the black paint coated basin of the solar still. This is enclosed in an air tight surface. A sloping transparent cover is provided at the top. Then solar radiations are allowed to fall on it. Solar radiation passes through the glass cover and is absorbed by the black surface. The distillator is designed so that an efficient amount of solar radiations gets trapped inside it. This increases the internal temperature of still resulting the saline water to evaporate leaving behind all the salt contents and harmful bacterias, etc. The resulting vapour rises and condenses as distilled water on the underside of the cover and is collected in the condensate channel due to the inclination provided to the glass covers.

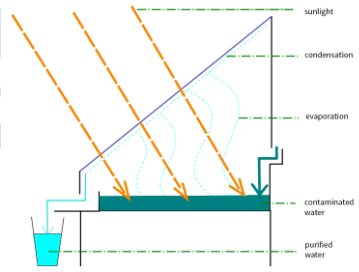


Figure 1 Principle of Solar Still

1.2 Phase Change Material (PCM)

Phase Change Material is material having the property of high heat of fusion, which melts and solidifies at a given point of temperature. It can store and release huge quantity of energy. Heat gets absorbed or released at the time of phase change of the substance. PCM materials are also known as Latent Heat Storage units.

1.3 Selection criteria for PCM

- Melting temperature should be at desired operating temperature range
- High latent heat of fusion per unit volume
- High specific heat, high density and high thermal conductivity
- High rate of crystal growth, so that the system can meet demands of heat recovery from the storage system
- Chemical stability
- No degradation after a large number of freeze/melt cycle
- Non-corrosiveness, non-toxic, non-flammable and non-explosive materials
- Low cost
- Availability

II. STEARIC ACID PROPERTIES (PCM)

CHARACTERISTIC	VALUE
Melting temperature (°C)	54
Specific heat (J/kg K)	Solid – 1590
Density (kg/m3)	Solid - 965 Liquid- 847
Thermal conductivity (W/m°C)	Solid- 0.29
Heat of fusion (J/kg)	1,69,000
Price (Rs. /kg)	250

Table 1: Stearic acid properties

III. FABRICATION OF SOLAR STILL

3.1 Apparatus used

- Measuring cylinder with a capacity of 2000 ml.
- Pen type thermometer
- Stearic acid crystals (n-Octadecanoic acid) ($CH_3(CH_2)_{16}COOH$))
- Steel containers with a capacity of 250 grams
- Black oil paint
- Black electrical tape
- Thermocole covering on measuring cylinder to prevent leakage
- Pyranometer (Solar radiation measuring instrument)

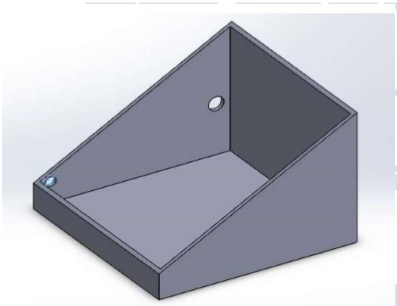


Figure 2: Auto cad model of solar still

3.2 Calculation for Design of Solar Still

Sr. No.	DESCRIPTION	Total Amount
1	Material of construction: High Density Moisture Resistance sheets	Rs 2500/-
2	Effective absorber area: 500x500 mm	
3	Overall dimensions: 500x500×380mm(H)	
4	Glazing Material and thickness: Glass sheet 4mm.	
5	Transitivity of glazing: 0.85	
6	Absorber material: Black Paint	
7	Water Holding capacity: 20 liters	
8	Sealing arrangement: Silicon Sealant	
9	Draining arrangement: Side drain	
10	Feeding arrangement: PVC pipe inlet / outlet	

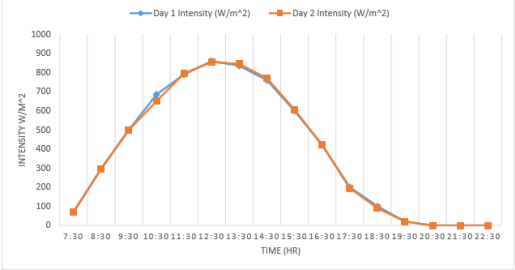
Table 2: Cost estimation of solar still

IV. EXPERIMENTATION AND RESULTS

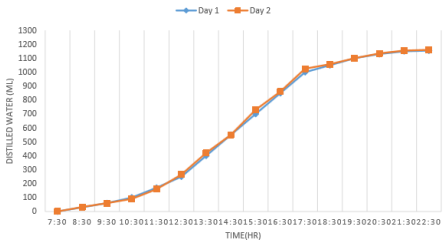
Figure 3 Actual Solar still and stearic acid containers as pcm material

4.1 functionality of solar still

The variation of the solar radiation between the solar stills for two days 24th and 25th march, received by an inclined glazing surface Θ=32° during the experimentation shown in Graph 1. The motto of this test was to make sure that solar still functioned properly, so that one can make sure that both the test dates intensities are identical, to compare the results of further test conducted in the experiment. From the graphs, one can clearly see that the both the days are identical. Therefore, one can add variations in the solar still and compare the readings to enhance the efficiency of the solar still.it was found that peak intensity conducted during the day 862 w/m^2 for day 1 and 857 w/m^2 for day 2.

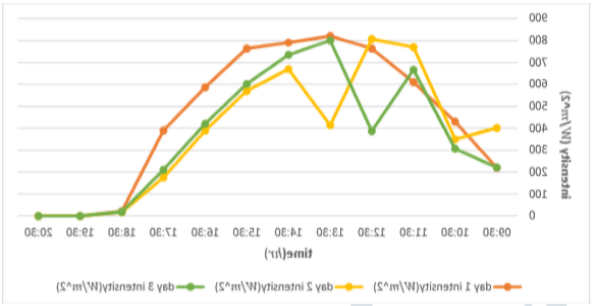


Graph 1 variation of intensity with time

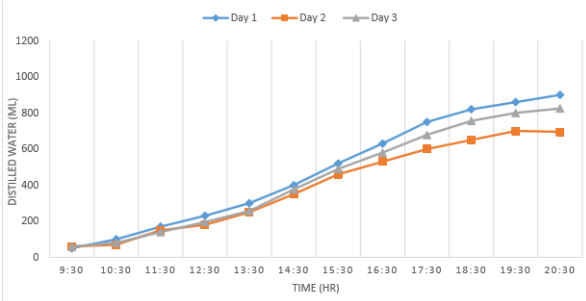


Graph 2 variation of distilled water productivity with time

4.2 Comparison of Reading of 3 Consecutive Days



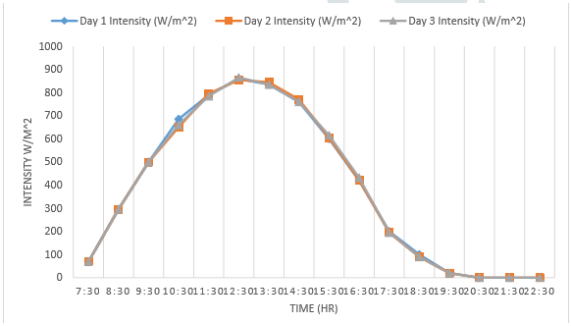
graph 3 variation of intensity with time



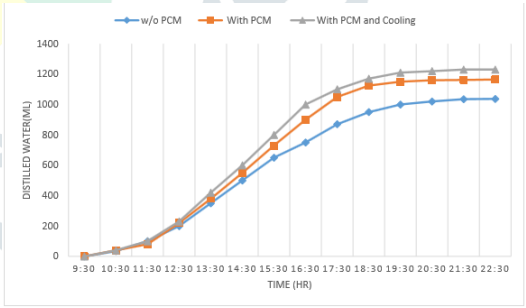
graph 4 variation of distilled water productivity with time

Graph 3 shows the difference in fresh water productivities with varying intensities on three consecutive days namely 17th ,18th ,19th march. Day 1 was observed to be very sunny with a maximum intensity of 821.1 w/m^2 and hence gives the total productivity of 1200ml.As day 2 turned out to be cloudy which caused a variation in solar intensity and hence the total productivity of 650ml.Day 3 showed a moderate weather with considerable variation of intensity which resulted in the output of 800ml.From the above reading of the solar intensity vs. time, it indicates that intensity is proportional to productivity.

4.3 Comparison with integration of PCM (1kg) with and without cooling



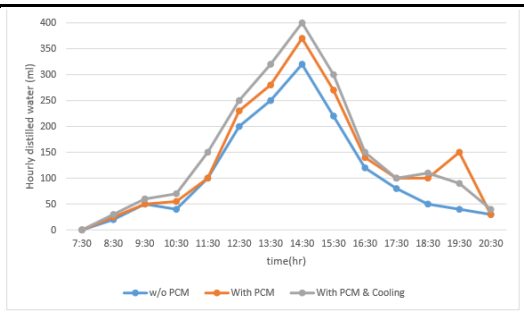
graph 5 variation of intensity with time



graph 6 variation of distilled water productivity with time

The variation of solar radiation between the solar stills for two days (30th and 31th March) with PCM (1kg), cooling and conventional solar still, during the experiment is shown in Graph 5. As one had compared in the previous graph, here also one make sure that both the test date's intensities are identical, to compare the results of further tests conducted in the experiment. From the graphs, one can clearly see that both the intensity of the two days is identical.

The variation of productivity of solar still with the application of PCM is compared with a conventional solar still. It is observed that for a conventional solar still, the total productivity is 1037ml for day1.After integrating it with 1kg of PCM, the total productivity is 1165ml. Therefore, there is an increase of 29.09% in the productivity of the solar still. The effect of pcm is observed after 6:30pm. During the 2nd day, the variation of productivity of solar still with PCM as well as cooling is compared to conventional solar still. The cooling is done by pouring water on the glass roof of the solar still.in this experiment one are cooling the solar still on hourly basis. The total productivity of solar still with PCM and cooling is 1230ml. There is an increase of 38.55% in the productivity of solar still when one adds pcm with cooling to the productivity of conventional solar still.



Graph 7 Variation of Hourly Distilled Water Productivity with Time

The hourly variation of distilled water during the experiment of the solar still for days is shown in graph 7. The maximum increase in the productivity is 100ml, observed at 2:30pm, for solar still when integrated with pcm and cooling on hourly basis.

V. CONCLUSION

In present work, the solar still integrated with phase change material is investigated. Stearic acid which has a melting point of 54 °C is used as the PCM. This provision helped to store the excess energy during day time and utilize in the night. The experimental results obtained for the performance of the solar still with and without PCM are obtained and analyzed. The effect of PCM was visible after 6:30pm in terms of productivity. To further enhance the efficiency of solar still, cooling of the top glass was carried out in fixed intervals. There is an increase of 38.55% in the productivity of solar still when one adds PCM with cooling to the productivity of conventional solar still. To check the effect of frequency of cooling the solar still, the productivity on hourly basis and half-hourly basis is also compared. When cooling effect is provided every half-hour, the total productivity is 1350 ml. Therefore, there is an increase of 23.39% in the productivity of the solar still. Then, from the mathematical model, the theoretical and practical values of the productivity was compared and analyzed, it's found that the maximum hourly distilled water obtained from the practical observation is found to be 28.8% less than the theoretical value obtained from mathematical modelling. The decrease in the hourly distilled water is attributed to various losses like leakage from sides of solar still, etc. Hence, the best arrangement according to our experiment is solar still integrated with pcm and cooling on half-hourly basis.

REFERENCES

[1] Vishwanath Kumar, Anil Kumar, Om Prakash, Ajay Kumar Kaviti. Solar stills system design. Renewable and Sustainable Energy Reviews 51(2015)153–181.

[2] P. Prakash, V. Velmurugan. Parameters influencing the productivity of solar stills. Renewable and Sustainable Energy Reviews 49(2015)585–609.

[3] T. Elango, K. Kalidasa Murugavel. The effect of the water depth on the productivity for single and double basin double slope glass solar stills. Desalination 359 (2015) 82–91.

[4] Tiwari, G.N., Lawrence, S.A., 1991. New heat and mass transfer relations for a solar still. Energy Convers. Manage. 31 (2), 201–203.

[5] Ravi Shankar Sathyamurthya, Nagarajan, Subramani, Vijayakumar, Mohammed Ashraf Ali.Kd. Effect of water mass on triangular pyramid solar still using phase change material as storage medium Energy Procedia 61 (2014) 2224 – 2228.