PERFORMANCE ANALYSIS OF SINGLE BASIN DOUBLE SLOPE SOLAR STILL USING PHASE CHANGE MATERIAL

[1]N. PARI, [2]Dr.R. KARTHIKEYAN
[1]Assistant Professor, [2]Professor
Department of Mechanical Engineering
Annamalai University, Annamalainagar, India

Abstract : Solar distillation is a promising method for the supply of freshwater to rural communities. Worldwide passive solar still is used for solar distillation plants due to its simplicity in construction and operation, low cost and however the yield is low. The pure water can be obtained by distillation in the simplest solar still. Various active methods have been adopted to increase the temperature of the basin so as to improve the productivity of solar still. Hot water from the collector can be store in storage tank while water in still is get evaporated due to solar radiation and then it will be condensed. This condense water can be used as for the drinking purpose. Hot water store in the tank can be used for the various domestic purposes as well as it can be used in night for desalination. This system gives high thermal efficiency

Keywords: **Desalination, Double sloped solar still, Phase change material**

I. INTRODUCTION

Energy is an essential factor for the social and economic development of the societies. Renewable energy is accepted as a key source for the future on this earth. The combined effects of the deflection of fossil fuels and the gradually emerging consciousness about environmental degradation have given the first priority to the use of renewable alternative energy resources in the 21st century. All of renewable, solar thermal energy is considered to be practically unlimited in the long term and is a very abundant resource in the world. Many conventional and non-unconventional techniques have been developed for purification of saline water. Among these water purification systems, solar distillation proves to be economical and eco-friendly technique. Mitesh Patel discussed People can remain a live for a several days without food, but cannot live for more than a week without water. We have all heard it said that we should drink a minimum of 8 glasses of water each day. However, drinking the minimum will only help maintain a minimum level of health [1]

Potable water is a basic necessity for man along with food and air. Fresh water is also required for agricultural and industrial purposes. Direct uses of water from sources like rivers, lakes, sea and underground water reservoirs are not always advisable, because of the presence of higher amount salt and harmful organisms. The higher growth rate in world population and industries resulted in a large escalation of demand for fresh water.[2] The natural source can meet a limited demand and this leads to acute shortage of fresh water. India's huge and growing population is putting a severe strain on all of the country's natural resources. Most water sources are contaminated by industrial waste, sewage and agricultural runoff. India has made progress in the supply of safe water to its people, but gross disparity in coverage exists across the country. The World Bank estimates that 21% of communicable diseases in India are related to unsafe water. In India, diarrhea alone causes more than 1600 deaths each day (John Briscoe 2005). Water is an essential for the maintenance of life and also the key to human's prosperity. In Solar distillation method, the brackish water is evaporated using solar energy, the steam is condensed and the final water is collected as potable water.[3]

Desalination or "Desalinization" refers to water treatment processes that remove salts from saline water or brackish water. Clean potable water is a basic necessity for man along with food and air. Fresh water is also required for agricultural and industrial purposes. The main sources of water are rivers, lakes and underground water reservoirs. However, direct uses of water from such sources are not always advisable, because of the presence of higher amount of salt and harmful organisms.[4] The higher growth rate in world population and industries resulted in a large escalation 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 a n issue to essentially treat the salt and contaminated water into purified Water

Simplest form of solar desalination plant is a solar still with shallow blackened basin of saline water covered and a sloped transparent roof. The solar radiation passes through the transparent roof, heats and evaporates the water. The water is cooled at the bottom surface of the roof and gets collected by the channel runs along the lower edge of transparent roof. Solar desalination method is a process of obtaining pure water from waste /brackish or saline water using solar energy. The instantaneous thermal efficiency of an active solar still has been presented by Tiwari *et al.*, [5] and inferred that the instantaneous thermal efficiency of the system decreases with an increase of collector area. The effect of coupling a flat-plate collector on the solar still productivity has been investigated experimentally by Badran and Al-Tahaineh [6].

Different methods are discussed to desalinate and purify the waste and salt water. Nowadays the small (8-10 liters/h) and medium (50-100 liters/h) range of RO desalination plants are popular in rural areas. They are available in affordable cost. But the peoples living in the village cannot afford to use these types of plants. Out of other different types of technologies available, the solar desalination using solar still is the cheap and simple process. It uses the solar energy and can be used in remote places where electricity and other conventional fuel are not available or costly. Hence to solve the water scarcity in villages and remote areas, the solar still is the best solution.

Shanmugasundaram Kandasamy et al [7] attempts have been made by researchers to investigate the effect of water depth in double-slope singlebasin solar still. A digital simulation method has been done for the productivity of a complicated still by Cooper [8], and the influence of more common variables such as water depth, wind velocity, still insulation, double glass cover, cover slope, and daily variability on the productivity has been investigated. Results of the simulation indicate that water depth and thermal insulation have little effect on the productivity at shallow water depth and that a double glass cover and high cover slopes are not justifiable.

Many researchers have used energy storage mediums in the solar still to improve the daily productivity. Nafey et al,[8] used black rubber and black gravel to enhance the productivity of the solar still. El-Sebaii et al [9] used baffle suspended absorber plate in the solar still to increase the productivity. Almost 20% gain in daily productivity was found by these researchers. Latent heat of phase change material is many orders higher than the specific heat of materials. Therefore PCM can share 2-3 times more heat or cold per volume or per mass as can be stored as sensible heat in water in a temperature interval of 20^0C [10].

II. MATERIALS AND METHODS

A single basin double slope solar still has been fabricated with mild steel plate as shown in figure 1. The overall size of the inner basin is 1 m × 0.84 m × 0.075m, and that of the outer basin is 2.3 m × 1m × 0.25 m. The gap between the inner and outer basin is packed with rice husk as insulation material. The top is covered with two glasses of thickness 4mm, inclined at 45^o on both sides, using wooden frame. The outer surfaces of the still are covered with glass wool and thermo cool insulation. The condensed water is collected in the V-shaped drainage provided below the glass lower edge of the still. The condensate collected is continuously drained through flexible hose and stored in a jar placed on the electronic weighing machine on both side of the still. A hole in the basin side wall allows inserting the thermocouples for the measurement of the basin water, still, and condensate temperature. To measure the basin temperature, four thermocouples were placed at the basin at different locations. Two thermocouples were dipped into the water the collecting drainage on either side. The hole is closed with insulating material to avoid the heat and vapor loss. thermocouple is exposed to atmosphere to measure e atmospheric temperature. This thermocouple is placed a shadow area to prevent the variation in temperature due to incidence of sun radiation on the thermocouple.

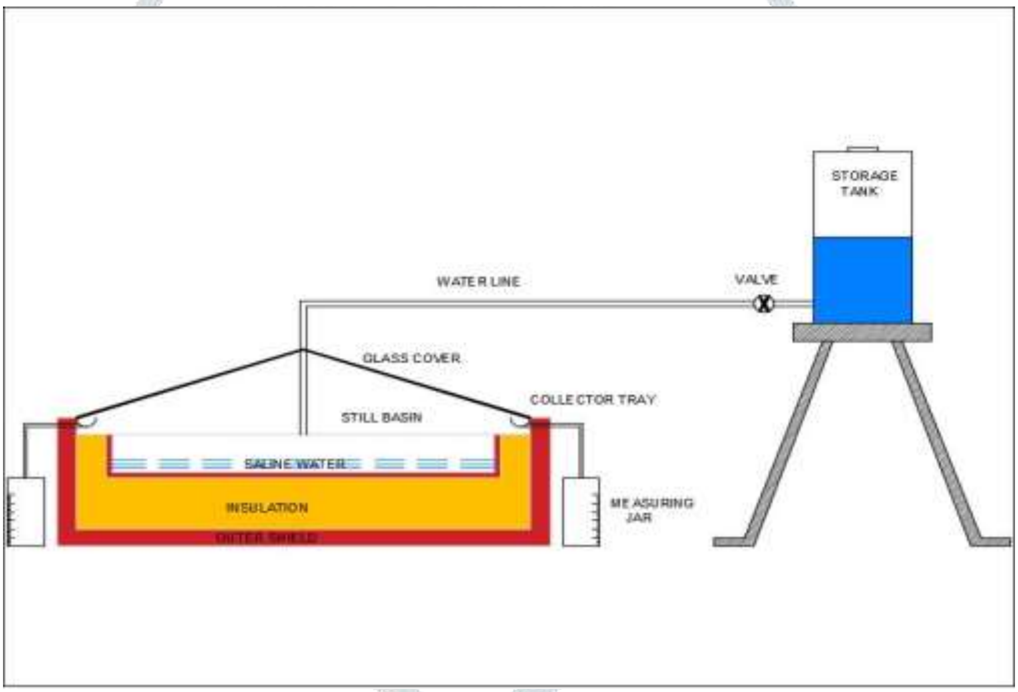

Figure 1 Schematic View of Single Basin Double Slope Solar Still

Phase Change Material is filled in the tubes and placed in the basin of the still. Tubes are made of aluminum to offer little resistance to the heat transfer between water and PCM. Tubes are of dia 10 mm and length as that of the basin inner side. Thermocouples were attached in different locations of the still to record the temperatures of inside glass cover, 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. The effect of use of phase change material is also studied by comparative analysis.

Figure 2 Photographic view of Single Basin Double Slope Solar Still

The measuring devices used in the system are as follows:

1. The thermocouples (type-k) coupled to digital thermometer with a range from 0 to 99.9°C with ±1°C accuracy is used to measure the temperatures of the various components of the still system.

2. The solar intensity was measured with the help of a calibrated pyranometer of least count of 2 mW/cm^2 (1mW/cm^2=10W/m^2). It is generally measured as the total solar radiation.

3. A 150 mm steel rule fixed inside wall is used to measure water level inside basin with least count of 0.5 mm

4. The distillate output was recorded with the help of a measuring cylindrical jar of least count 1 ml.

5. The ambient air velocity is measured with an electronic digital anemometer model of Lutron AM-4201. It has a least count of 0.1 m/s with 2% accuracy on the full-scale range of 0.2 – 40.0 m/s.

Table 1 Properties of Phase Change Material

Sl.No	Parameters	Paraffin Wax
1	Chemical formula	$C_{31}H_{64}$
2	Molar mass	785gm/mole
3	Appearance	White soft solid
4	Density	900kg/m^3
5	Boiling point	322C
6	Melting point	37C
7	Vapour pressure	0.2Kpa
8	Thermal conductivity	0.224 W/mk
9	Latent heat of fusion	251 J/kg
10	Cost	Rs 800

Figure 2 Paraffin Wax

Paraffin wax (or petroleum wax) is a soft colorless solid, derived from petroleum, coal or shale oil, that consists of a mixture of hydrocarbon molecules containing between twenty and forty carbon atoms. It is solid at room temperature and begins to melt above approximately 37 °C (99 °F), and its boiling point is above 370 °C (698 °F).[12] Common applications for paraffin wax include lubrication, electrical insulation, and candles; dyed paraffin wax can be made into crayons. It is distinct from kerosene and other petroleum products that are sometimes called paraffin Un-dyed, unscented paraffin candles are odorless and bluish-white. Paraffin wax was first created by Carl Reichenbach in Germany in 1830, and marked a major advancement in candle making technology, as it burned more cleanly and reliably than tallow candles and was cheaper to produce. In industrial applications, it is often useful to modify the crystal properties of the paraffin wax, typically by adding branching to the existing carbon backbone chain. The modification is usually done with additives, such as EVA copolymers, microcrystalline wax, or forms of polyethylene. The branched properties result in a modified paraffin with a higher viscosity, smaller crystalline structure, and modified functional properties. Pure paraffin wax is rarely used for carving original models for casting metal and other materials in the lost wax process, as it is relatively brittle at room temperature and presents the risks of chipping and breakage when worked. Soft and pliable waxes, like beeswax, may be preferred for such sculpture, but "investment casting waxes," often paraffin-based, are expressly formulated for the purpose. In a pathology laboratory, paraffin wax is used to impregnate tissue prior to sectioning thin samples of tissue. Water is removed from the tissue through ascending strengths of alcohol (75% to absolute) and the tissue is cleared in an organic solvent such as xylene. The tissue is then placed in paraffin wax for a number of hours and then set in a mold with wax to cool and solidify; sections are then cut on a microtome.

III. EXPERIMENTAL PROCEDURE

Experiments have been carried out at Department of Mechanical engineering, Annamalai University, Annamalainagar - 608001 (latitude 11° N, longitude 77° 52’ E), Tamilnadu, India. Observations have been made with regular intervals of 30 minutes. Solar radiation monitor and digital thermometer were used to measure intensity of the solar radiation and temperature of the ambient respectively.

IV. RESULT AND DISCUSSIONS

4.1 Solar Intensity

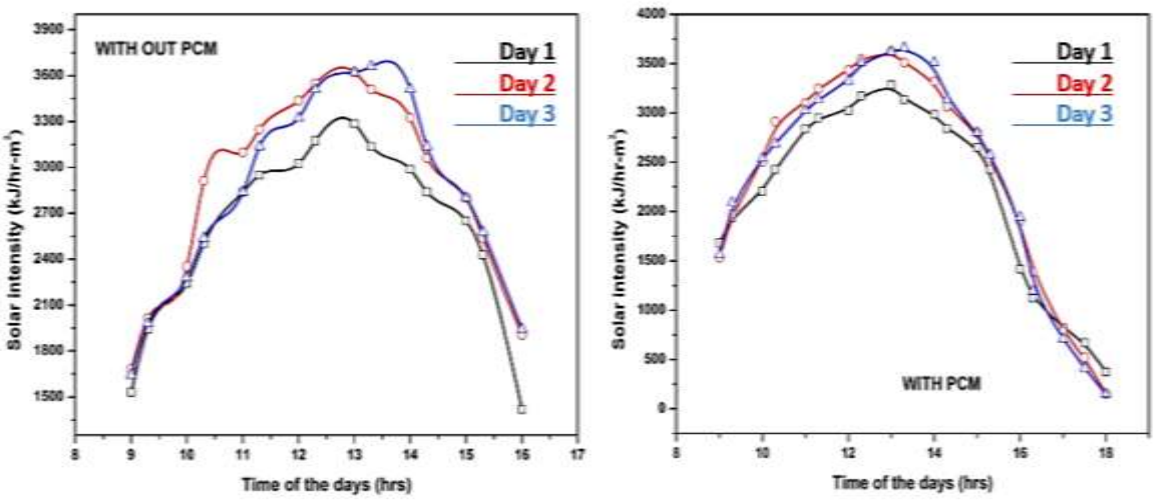

Figure 4 Solar Intensity with PCM and without PCM

The fig. 4 shows the solar intensity with local time day (hrs). The cumulative production at any time is higher for lower depth. The increase rate is higher during day time for lower depths. The overall solar intensity is only marginal for lower depths. For lower depth stills, the maximum amount of the solar intensity occurs during day time and during night the yield is minimum. For still with higher depths, the still continuously deliver water through entire night. The solar intensity compared to with PCM and without time 12^{o} clock increased to the solar intensity 3600 (kJ/hr –m^{2}).the with PCM day at 1^{o} clock day 3 increased to the solar intensity of with PCM.. they are continuously increased to the solar intensity of the solar still.

4.2 Absorber Plate Temperature

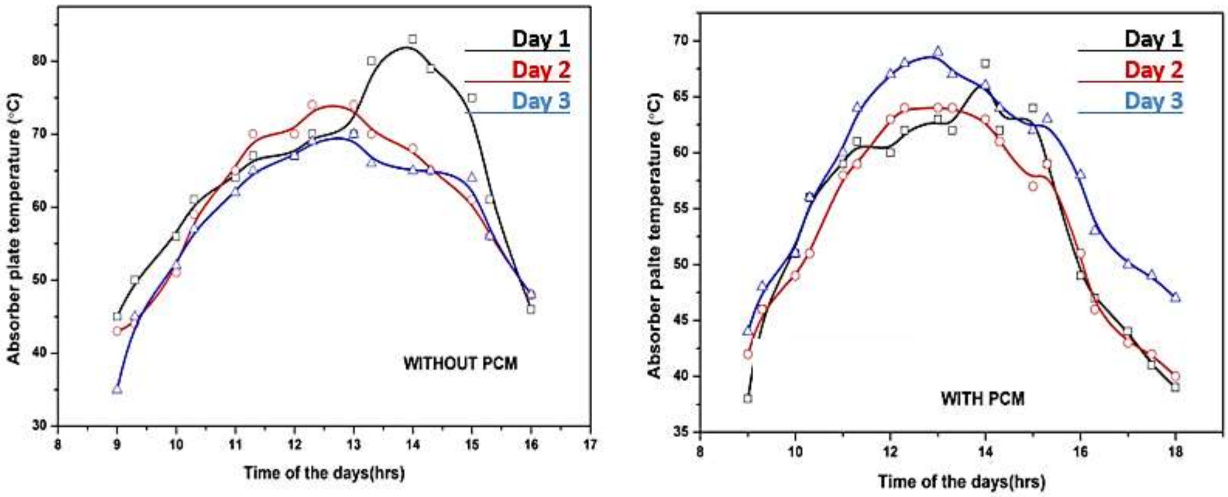

Figure 5 Absorber Plate Temperature with PCM and Without PCM

The figure 5 shows the absorber plate temperature with local time day (hrs). The cumulative absorber plate at any time is higher for lower depth. The increase rate is higher during day time for lower depths. The overall absorber plate is only marginal for lower depths. For lower depth stills, the maximum amount of the absorber plate occurs during day time and during night the yield is minimum. For still with higher depths, the still continuously deliver water through entire night. The absorber plate temperature compared to the with PCM and without PCM time 1^{o} clock increased to the absorber plate temperature 90^{0}C.the with PCM day at 2^{o} clock day 3 increased to the 70^{o}C absorber plate temperature of with PCM. they are continuously increased to the solar intensity of the solar still. When the compared to the single basin double slope solar still with phase change material of the solar still.

4.3 Distilled Water Temperature

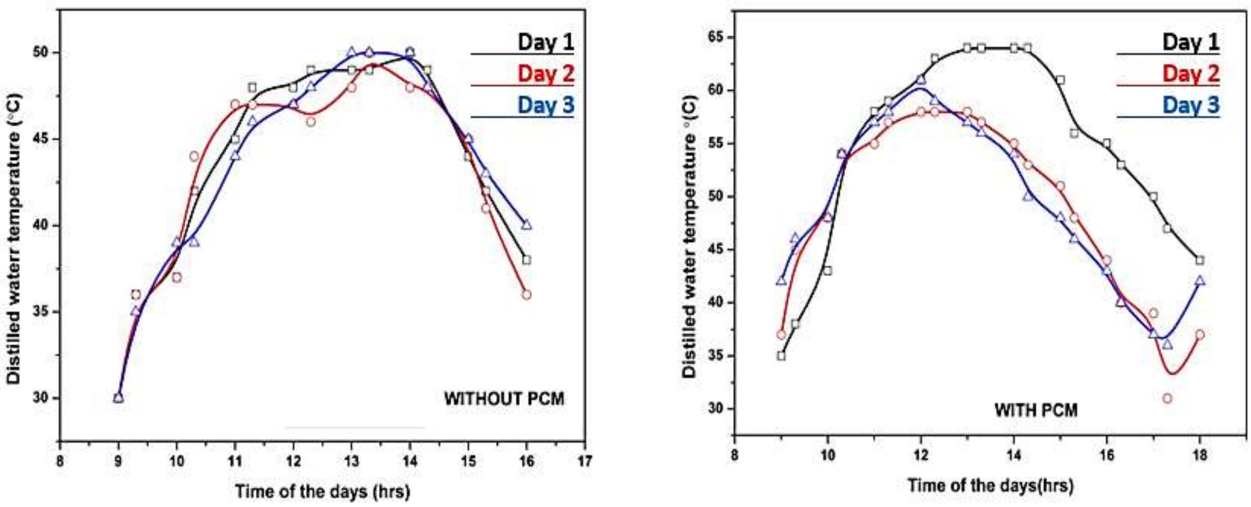

Figure 6 Distilled Water Temperature With PCM and Without PCM

The graph 6 shows distilled water temperature with local time day (hrs). The cumulative distilled water temperature at any time is higher for lower depth. The increase rate is higher during day time for lower depths. The overall distilled water temperature is only marginal for lower depths. For lower depth stills, the maximum amount of the distilled water temperature occurs during day time and during night the yield is minimum. For still with higher depths, the still continuously deliver water through entire night. The distilled water temperature compared to the with PCM and without PCM time 1 o clock increased to the distilled water temperature 35 ^{0}C.the with PCM day at 2^{o} clock day 3 increased to the 65^{o}C absorber plate temperature of with PCM. . the are continuously increased to the distiller water temperature of the solar still.

4.4 Distilled Water Output

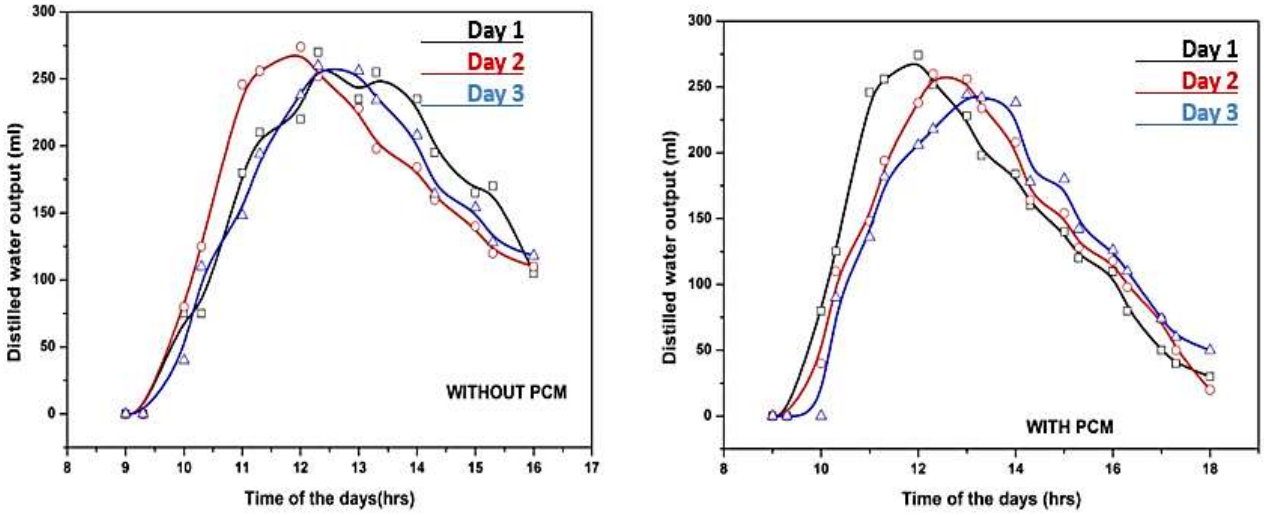

Figure 7 Distilled Water Output with PCM And Without PCM

Figure 7 shows the variation of daily yield with respect to all water depths. It is found that for a certain lower water depth (10 ml) of basin water, the yield per day is low and increases with depth and again starts decreasing beyond certain depth of basin water. that even though the still experienced a higher temperature difference for 250 ml water depth. This may be the reason for lower distilled water output in 300 mm water depth. It is observed that for a particular depth of water (200 ml), yield per day is maximum. A part from all energy transfer, unaccountable losses are noticed in the energy balance of the system, which may be due to the vapor leakage through gaskets, joints and sensible heat stored by the still components like basin liner, water, glass etc. The unaccounted losses are found quiet high in the higher water depths at 200, 250 and 300 ml, due to the higher heat storage capacity. The cumulative heat balances for the remaining experimental studies like effect of sponge liner, effect of coloured sponge liner etc, are found to be closely match with the 20 mm water depth study.

4.5 Glass Plate Temperature

Fig. 8 compares the glass plate temperature with the variation time of the days (hrs) with PCM and without PCM . Theoretically, water and glass temperatures are varying proportionally with glass plate temperature for all depths and for all ranges of radiation conditions. For higher depth of 2 cm, the distilled water output on water temperature. For 1 cm and 0.5 cm depths, the glass plate temperature reaches a maximum value just before the water temperature reaches the maximum value. After this point the day 2 at higher rate even though the water temperature increases considerably. Then the glass plate temperature decreases with the increase of water temperature for a short duration. During this period, the glass temperature slightly increases and remains almost constant. Then the production rate starts fall with the glass temperature. From around 8 am to 5 pm the water temperature is above 60 ºC and the glass temperature is above 45ºC for all depths. During this period the still production is having different relation with water and glass temperatures.

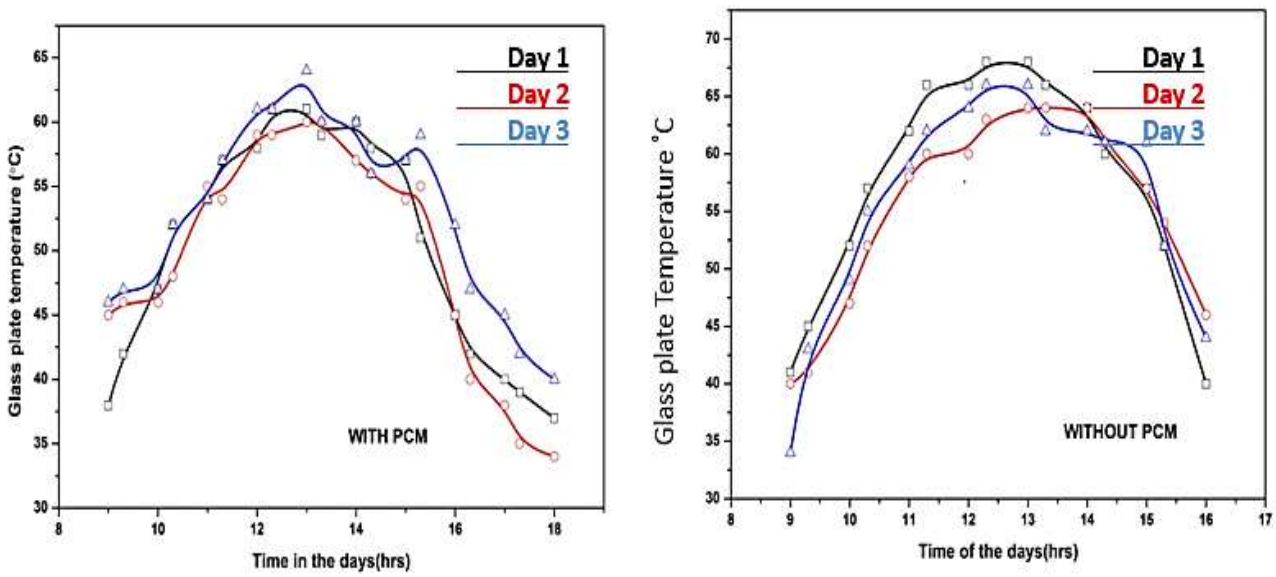

Figure 8 Glass Plate Temperature with PCM And Without PCM

4.6 Efficiency

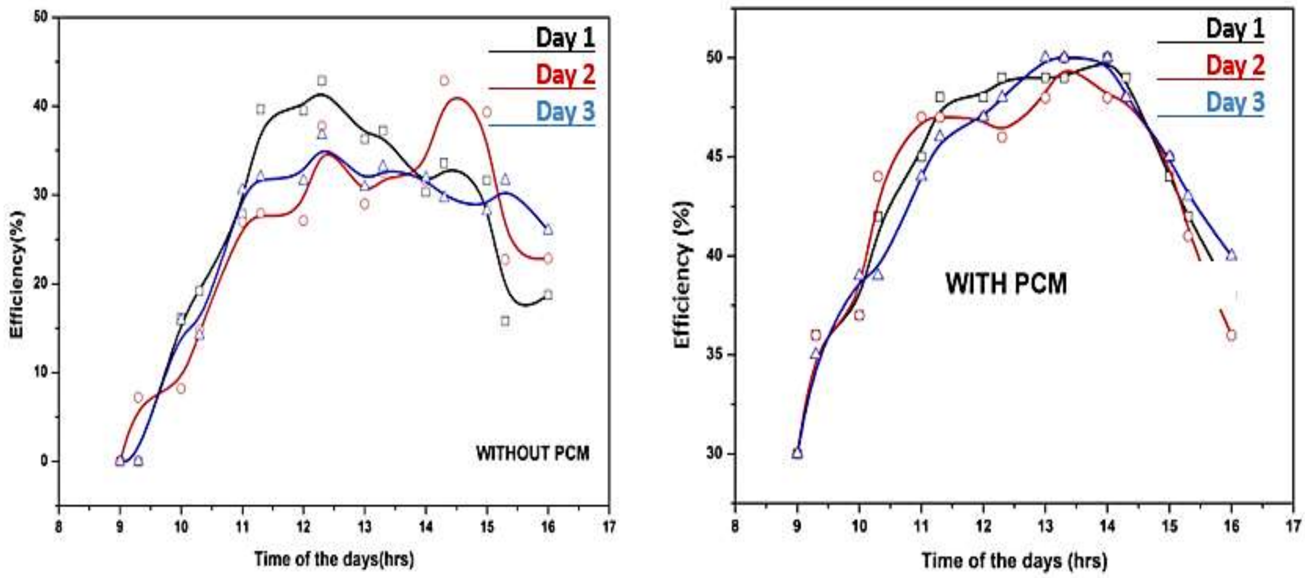

Figure 9 Efficiency with PCM And Without PCM

When the solar still is assumed as constant and the radiation on the horizontal basin area is taken as the input energy, the predicted overall efficiency of the still is 55.4%. The actual efficiency based on the energy on horizontal plane is 18.1%. When the radiation on the covers is taken as input energy to the still, the efficiency based on the energy on the cover is 48.5%. The actual efficiency based on this energy as input is 21%. the energy transmitted through the cover is taken as input for the still, the efficiency of the evaporation and condensation process is 59.6%. For actual still the efficiency based on the energy transmitted is 25.7%. The theoretical and actual efficiencies based on radiation energy on the covers are close (48.5%and 21 %). Efficiency based on the radiation on the covers indicates the real performance of the still. The following table compares different types of efficiencies of the still

V. CONCLUSION

In this project, Single basin Double Slope Solar still with basin area of 1 m^2 absorber plate are fabricated and is compared with Double slope solar still with pcm.
From the experimental results several conclusions are obtained, which are as follows:

❖ The energy storage materials have a good capacity to capture solar energy during day as well as night-time due to the phenomenon of energy storage.

❖ Energy storage materials have also good impact during the higher sunshine hours for the energy storage purpose.

❖ Conventional solar still with materials enhances the performance.

It is observed that the use of PCM in the basin of the still increases the daily productivity by 12.7%. Day time distillate output increases by 9.4% and night time distillate output increases by 21.7% for the same total daily solar intensity. Energy efficiency of the solar still increases by 12.42% and exergy efficiency increases by 40% when paraffin wax is used as energy storage medium in the still.

REFERENCE

[1] Tiwari, G. N., Kumar, S., Sharma, P.B., and Emran Khan, M., "Instantaneous thermal efficiency of an active solar still",Applied thermal engineering,Vol.16, pp.189-192,1996.
[2] Badran, O. O., and Al-Tahaineh, H. A., "The effect of flat-plate collector on the solar still productivity", Desalination, Vol.183, pp.137-142, 2005.
[3] Velmurugan, V., and Srithar, K., "Solar still integrated with a mini solar pond: analytical simulation and experimental validation", Desalination, Vol.216, pp.232-241, 2007.
[4] El-Sebaii, A. A., Ramadan, M. R. I., Aboul-Enein, S., and Salem, N., "Thermal performance of a single-basin solar still integrated with a shallow solar pond", Energy Conversion and Management, Vol.49, pp.2839-2848, 2008.
[5] Thermo-hydraulic simulation of a solar distillation system under pseudo steady-state conditions , K. Voropoulos, E. Delyannis, and V. Belessiotis Desalination 107 (1996) 45-51
[6] Experimental study of the basin type solar still under local climate conditions, Bilal A. Akash, Mousa S. Mohsen, Waleed Nayfeh., .Energy Conversion & Management 41 (2000) 883-890
[7] Experimental Investigation of the behavior of solar still coupled with hot water storage tank.K.Voropolous,E.Mathioulakis,V.Belessiotis., Desalination 156(2003) 315-322

[8] Mitesh I Patel, P M Meena and Sunil Inkia "Experimental Investigation On Single Slope double Basin Active Solar Still Coupled With Evacuated Glass Tubes" International Journal of Advanced Engineering Research and Studies IJAERS/Vol. I/ Issue I/October-December, 2011/4-9

[9] K. Shanmugasundaram, B. Janarthanan "Performance Analysis of the Single Basin Double Slope Solar Still Integrated With Shallow Solar Pond" International Journal of Innovative Research in Science,Engineering and TechnologyVol. 2, Issue 10, October 2013

[10] Shobha.B.S, Vilas Watwe and Rajesh .A.M "Performance Evaluation of A Solar Still Coupled to an Evacuated Tube Collector type Solar Water Heater" International Journal of Innovations in Engineering and Technology (IJIET) Vol. 1 Issue 1 June 2012

[11] Tiwari, G. N., Kumar, S., Sharma, P.B., and Emran Khan, M., "Instantaneous thermal efficiency of an active solar still", Applied thermal engineering,Vol.16, pp.189-192,1996.

[12] Badran, O. O., and Al-Tahaineh, H. A., "The effect of flat-plate collector on the solar still productivity", Desalination, Vol.183, pp.137-142, 2005.

[13] Shanmugasundaram Kandasamy*, Manikandan Vellingiri, Shanmugan Sengottain and Janarthanan Balasundaram Performance correlation for single-basin double-slope solar still Kandasamy et al. International Journal of Energy and Environmental Engineering 2013, 4:4