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Performance Evaluation of Pyramidal Slope Solar Still Integrated with PCM Thermal Storage

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Abstract : The pyramidal slope solar still is designed with thermal storage unit to increase the production rate of desalinated water. The paraffin wax is used as a storage material. The performance test is conducted for three days without and with phase change material (PCM). The experimental results observed that the still productivity yield increases due tomaximum radiant energy absorbed by the pyramidal slope and with PCM. The increased efficiency of desalinated water by using the paraffin as thermal energy storage material is 9.908%.
Keywords : Pyramidal slope, Solar still, Paraffin storage.

Introduction

Global potable water demand is expected to grow, particularly in areas where freshwater supplies is limited and also supply of it requires use of high amounts of non-renewable fossil fuels. Solar still is used for solar desalination process to process saline water and the evaporated low pressure steam condensed in the still roof surface is then collected in the condensate as the product. Due to day time availability of solar radiation, optimum design of still and thermal energy storage required to improve productivity of solar desalination. Arunkumar et al.[1] conducted an experimental study of various solar still designs of spherical, double basin, pyramidal, hemispherical, concentrator-coupled CPC tubular and with coupled with pyramid solar still. Results shows that the pyramid solar still gives the maximum amount of productivity due to the concentrator effect. Imad and Omar[2] has carried out an analysis of the effect of using different designs of solar stills on water distillation and the solar energy is the best alternative heating energy source. It is concluded that the use of solar water distillation promises to enhance the quality of life and to improve health standards in arid areas in Jordan. Abdul Jabbar[3] presented the article on the effect of cover tilt angle of the design of solar still on its productivity in different seasons and latitudes. Rajendra Prasad et al.[4] investigated a solar still with graphite filled silica gel. Atul Sharma et al.[5] carried out an experimental review on thermal energy storage with phase change materials (PCMs) and applications and found that it is focused on the available thermal energy storage technology with PCMs with different applications. This paper also presents the current research of PCM storage and various thermal properties of PCMs. The heat storage applications used as a part of solar water-heating systems, solar air heating systems, solar cooking, solar green house, space heating and cooling application for buildings. Janarthanan and Suresh[6] reviewed thermal storage with variety of phase change materials and its applications. Edwin and Joseph Sekhar[7] investigated a solar distillation system with 41% efficiencyMohammed Farid et al.[8] has carried out a review on phase change energy storage: materials and applications and concluded that Organic and inorganic compounds are the two most common groups of PCMs. Senthil and Cheralathan[9] reviewed the natural heat transfer methods in PCM. Murali and Mayilsamy[10] discussed about the PCM usage in solar water heating systems. From their view of literature presented above, the following are the major conclusion: Among the number of PCMs available paraffin wax is the best suited for solar desalination due to its non-corrosive nature and availability in large temperature range. Use of the pyramidal slope solar still increases the production rate of desalinated water. Black base helps in increase of absorbing heat from surrounding to the solar still. The production rate of desalinated water varies every month depending upon climatic season. Use of copper tube reduces corrosion effect.

Experimental description of solar still

Thepyramidal slop of solar still is made up of glass to absorb maximum radiant energy. The glass which has the following parameters such as single-glazed clear glass and it allows highest energy transmission compare to other glasses. Energy transmits in the form of conductance (K) & transmission (U) and It has higher SHGC and VT value. Thermal conductivity and transmission is directly proportional to daily range of temperature. The concrete base which is 0.6m approximately, hence avoid the diffused radiation (scattered from surrounding obstruction). And it has seated the black base to improve the productivity. The entire apparatus is made of glass having a transmissivity of above 80%. The glass still apparatus mounted above the black base is acted as a heat absorber. It absorbs the surrounding heat as well as still hear and emitting to the still to further evaporation process. Condensing collector: four 20mm semi-circle shaped PVC tubes arranged in a crossed manner acts as the collector cum condensing surface. The various design parameters of the still are compared and tabulated below,

Table. Description of still

Description	Cuboidal pyramid
	Roof angle - 50
Length	20 inch
Breadth	20 inch
Still basin area	400 inch
Height(cube)	10 inch
Height(pyramidal)	14.4 inch
Still volume	15 litres
Depth of water- initial fill	5 cm

In the above tabulation clearly indicates the acting roof surface area of various roof angle and still shapes. The still performance optimized the shape as cuboidal because of the roof surface area is higher than the bottom one. The pyramidal solar still is used for the experimental in which is combined with the solar water heating. The inlet water for the solar water heating and the solar desalination is taken from the storage tank. In nature, solar desalination produces rain when solar radiation is absorbed by these and cause water to evaporate and cools down to its dew point, condensation occurs. This condensed water is collected by placing a condensate tube. This water can be used for drinking purpose. To measure the saline water and PCM temperature, thermocouples are used with the operating range of -250 to 400Celsius.The photographic view of experimental setup shown in figure 1.

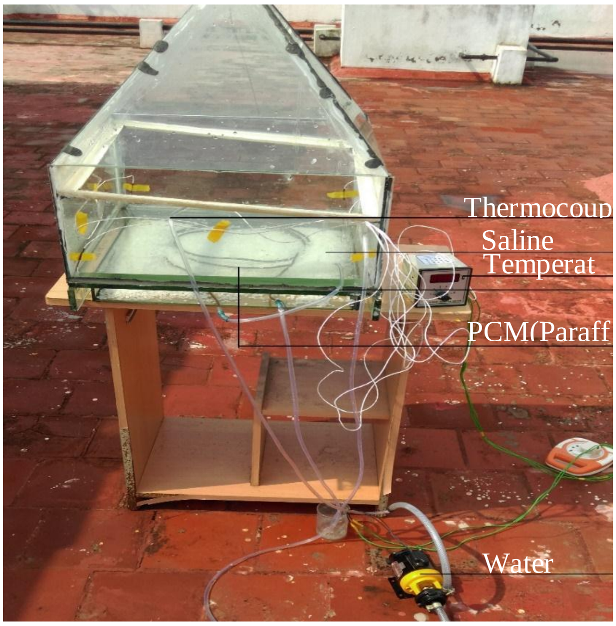

Fig.1 Photographic view of experimental setup

The condensate mass flow rate of desalinated water estimated by the following expression,

$$\dot{m} = \frac{q}{h_{fg}}$$

Where, h_{fg} is the enthalpy of saturated water and the evaporate heat transfer rate, q is calculated by the following equation, $q = h\left(T_w - T_g\right)$, The efficiency of the solar pyramidal still evaluated by the expression,

$$\text{Efficiency} = \frac{\text{Total yield collected with PCM} - \text{Total yield collected without PCM}}{(\text{Total yield without PCM})(100\%)}$$

Result and discussion

To investigate the new design of pyramidal slope solar still system, consider the hourly variations of solar irradiance and ambient temperature for the site. The experimental test is conducted for three days of 01 March 2016 to 06 March 2016. The water temperature and the amount of water desalinated is observed and discussed for a consecutive six days without and with Paraffin.In Fig. 2 shows that the saline water meantemperature variation without and with PCM. From the graphs it is inferred that the peak temperature is obtained between times 1 to 2pm at the range of 47℃ to 50℃ . And the graph with the PCM content has the maximum temperature range compared with the one without PCM.

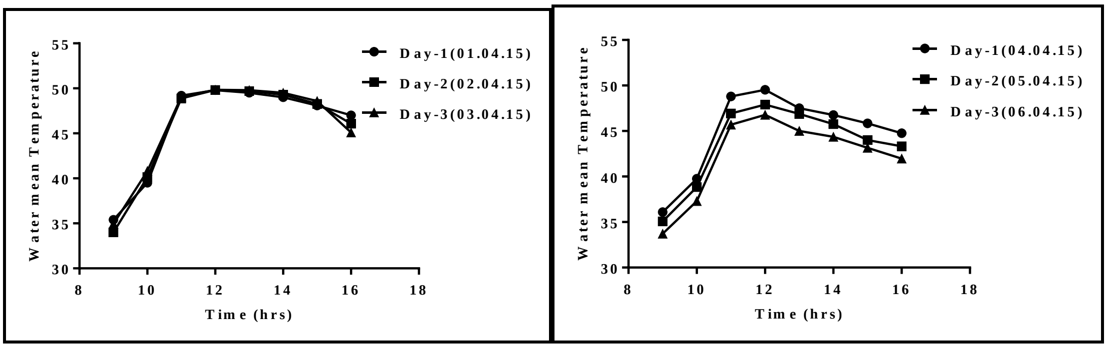

Fig. 2 Saline water mean temperature variation without and with PCM

In Fig. 3 shows that the desalinated water yield without and with PCM. From the graphs it is inferred that the desalinated water outlet is maximum between times 1 to 2pm at the range of 140ml to 150ml. And the graph with the PCM content has the maximum yield compared with the one without PCM.

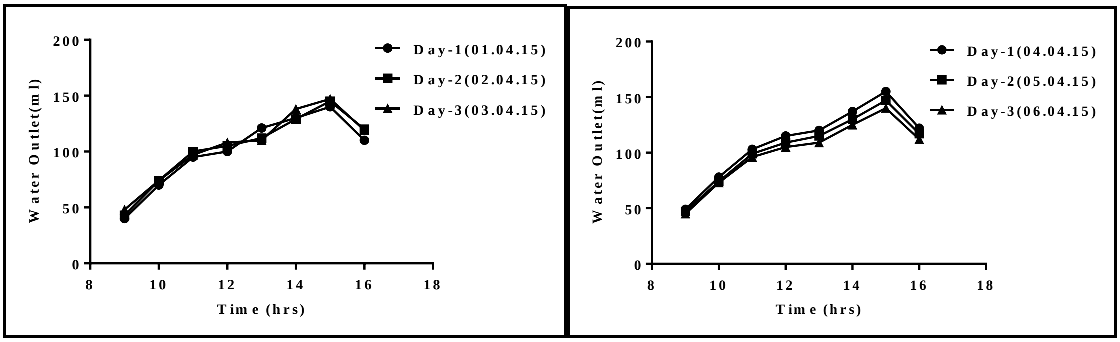

Fig. 3 Desalinated water yield without and with PCM

In Fig. 4 shows the solar radiation incident on the still and the saline water mean temperature on day1 from 09.00-16.00 hours. It is inferred that the maximum radiation is at noon and the maximum water outlet is at 15.00 hour, where the radiation gets decreased.

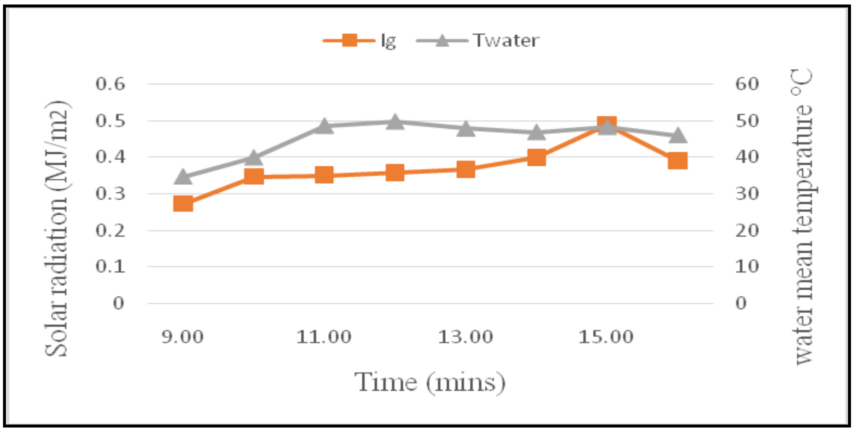

Fig.4 Effect of solar radiation incident and water temperature without PCM on 01 March 2015

The below graph Fig 4 shows the radiation vs water outlet on day2 from 10am to 4pm. It is inferred that the maximum radiation was at 1pm, the minimum radiation was at 11am and the maximum water outlet was at 3pm where the radiation got decreased.

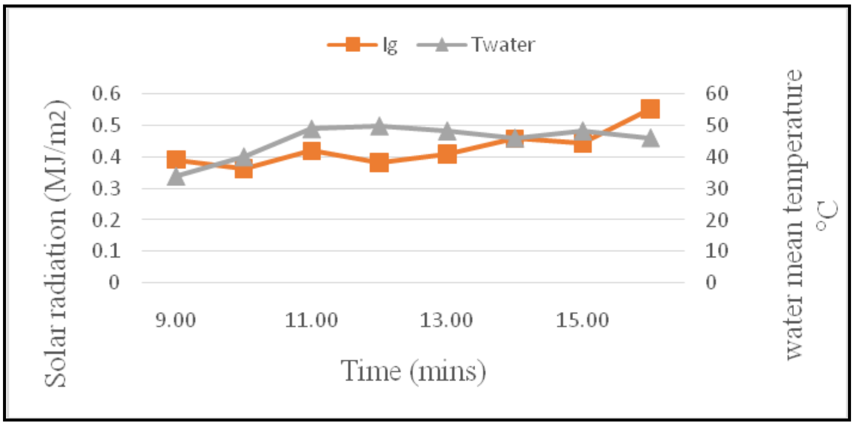

Fig. 5 Effect of solar radiation incident and water temperature without PCM on 02 March 2015

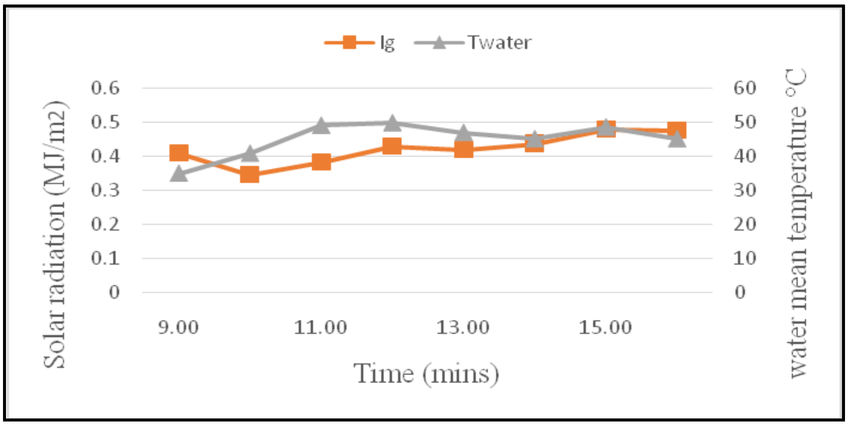

Fig. 6 Effect of solar radiation incident and water temperature without PCM on 03 March 2015

The above graph shows the radiation versus water outlet on day3 (03 March 2015) from 10am to 4pm. It is inferred that the radiation was on a gradual path by reaching its peak at 1pm and the maximum water outlet was at 3pm where the radiation was gradually decreasing.

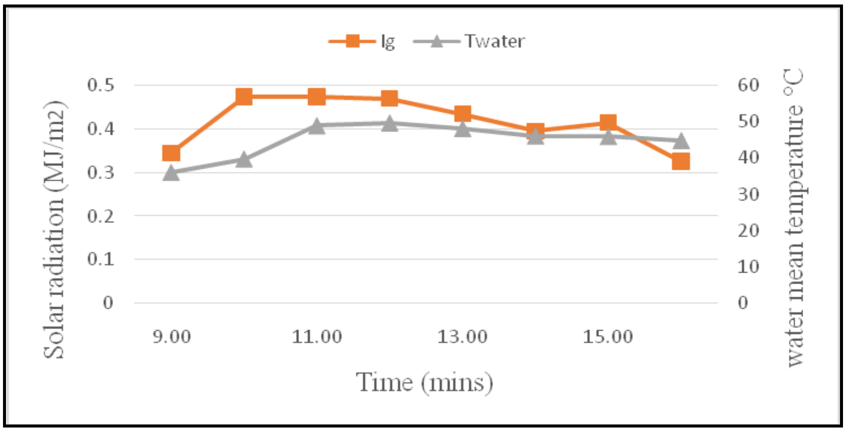

Fig. 7 Effect of solar radiation incident and water temperature with PCM on 04 March 2015

The above graph Fig. 7 shows the radiation versus water outlet on day4 (04 March 2015) from 10am to 4pm. It is inferred that the radiation started on a high note and gradually increased with the maximum between 12noon to 2pm and the maximum water outlet was at 3pm where the radiation was on a decreasing note.

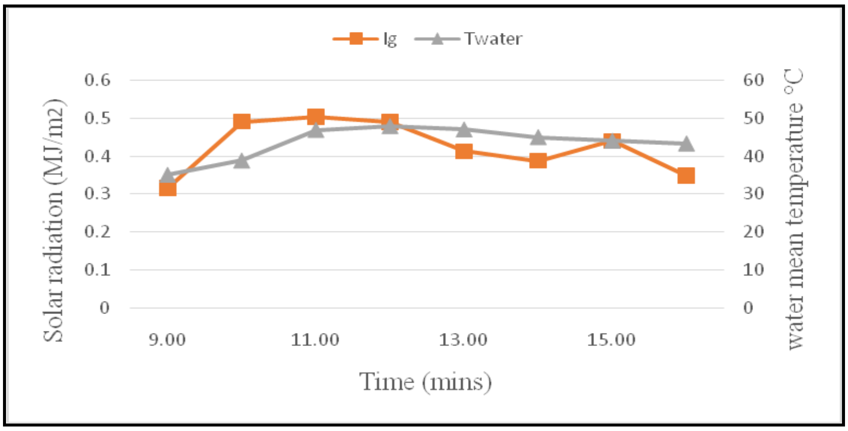

Fig. 8 Effect of solar radiation incident and water temperature with PCM on 05 March 2015

In Fig. 8 shows that Effect of solar radiation incident variation on the still water temperature with PCM on day5 from 10.00-16.00. The radiation emitted same as the previous day and the maximum water yield is at 15.00-16.00 hour.

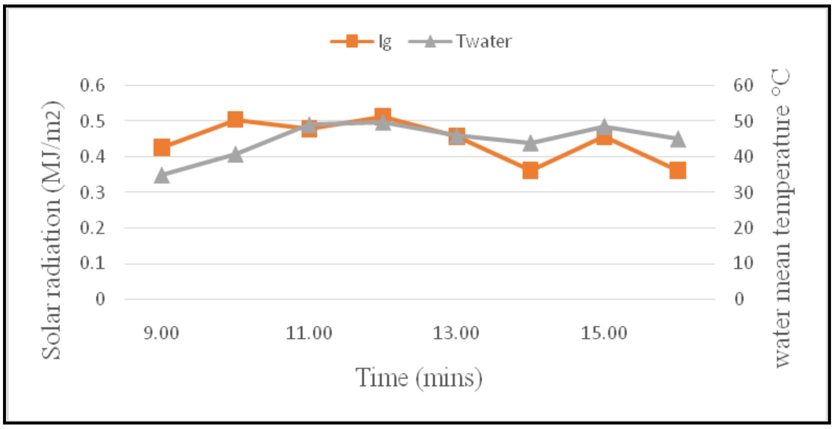

Fig. 9 Effect of solar radiation incident and water temperature with PCM on 05 March 2015

Effect of solar radiation incident variation on the still water temperature with PCM as shown in Fig. 9.It is observed that the radiation on this particular day got more deviation and the maximum is obtained on two spots and the maximum yield is at 15.00-16.00 hour.

Conclusion

This project concluded onincorporation of Phase Change Materials effectively to store thermal energy during day. PCM melts and stores energy in the form of sensible and latent heat. The stored energy releases to the water flowing in the copper tube and maintains the temperature of water. PCM which has high latent heat storage capacity and high diffusivity helps us in better productivity of desalinated water. The amount of desalinated water was more with PCM as compared to that without PCM. The percentage increase efficiency by using the PCM as energy storage material was found to be around 10%.

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