EXPERIMENTAL INVESTIGATION OF THE SOLAR STILL WITH THE DIVERSE ABSORBER PLATE CONFIGURATIONS USING ENERGY STORING MATERIALS

by

Prabahar JEEVANANDAM[a*] and Balusamy THANGAVEL[b]

[a] Department of Mechanical Engineering, JCT College of Engineering, Pichanur, Coimbatore, Tamilnadu, India
[b] Department of Mechanical Engineering, Government College of Engineering, Salem, Tamilnadu, India

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Solar distillation is an economical and nature-friendly method used for the product of fresh water from the (mixing of salt water and fresh water) brackish water. Solar still performance depends mainly on the absorber plate conditions. Since all the solar radiation is mainly absorbed by the basin plate and the water present in the basin. In this experimental work, the performance of the basin plate is enhanced by using diverse basin plate configurations with energy storing materials like mild steel, black gravel, pebbles, sand, and cast iron. The basin plates and the energy storing materials increase the evaporation area and it will store the high heat during the sunshine hours and emitted the stored energy during the off shine hours to the system enhances the still productivity in the less solar radiations too. Here, the comparison has been made between the energy storing materials with flat absorber plate to the trapezoidal and the pin fin absorber plate with similar conditions. Through this experimentation process, we could conclude that trapezoidal basin plate with varied energy storing materials plays a predominant role in the production of distilled water than the flat and pin fin basin plates. On the other hand, black gravel gives good productive results compared to other energy storing materials used in this experiment for all basin plates. This will show the fulfilment of the basin plate and the productivity could be enhanced with different configurations of basin plates as well as incorporation of different energy repository materials

Keywords: *double slope solar still design, flat basin plate, pin fin basin plate, trapezoidal basin plate, energy storing materials, basin performance*

Introduction

With diverse population growth and development, energy crises play a main role in the world due to the increased birth rate and decreased death rate which leads to the high consumption and degradation of natural resources. Due to this, there is a serious reduction in the freshwater resources, in the current situation, this problem affects only the poor people all around the world due to the water scarcity and the wastage of water by the industries.

This leads to severe water scarcity around the world in the future and the sufferers are our future generations. In India, the population growth increases day by day. Although India has improved the availability of water there are other problems like water resources are highly polluted with both bio as well as chemical pollutants by sad all over the world over 21% of the

* Corresponding author, e-mail: jpkuku5050@gmail.com

disease mainly by water contaminated this is mainly because of lack of government planning, increased of population, corporate privatization-industrial and human waste, *etc.* Hence, many freshwater producing techniques have been introduced. Among them, solar distillation process plays a predominant role. This helps in the fresh water production economically and eco-friendly made this very opt for the fresh water production. Tiris *et al.* [1] described the effects on performance of the still using various absorber materials and correlated a relation between the yield, solar insolation for the charcoal and black paint absorbers. Saravankumar *et al.* [2] explained the present scenario of the solar still in and around the world along with the basic heat and mass transfer relation and the usage of fiber reinforced plastic in the condensing cover, brackish water, water demand, availability of fresh water and purification methods with the state of art background. El-Agouz [3] stated that there should be an optimum slope of the cover with respect to a location for the maximum yield.

The gap distance between the glass and the plate also minimum by the way of slope inclination and cooling of the covers are played a major role in the yield of distilled water. Yamunadevi *et al.* [4] computed that the yearly output considerably mainly depends on depth of water, the inclination angle for both passive and active solar stills and the yearly yield increases linearly for a certain water in an active solar still. Vivekanandan *et al.* [5] used the stepped solar still with the absorbing materials like the sponge, fins and pebbles for the enhancement in the production rate. Yoganandam *et al.* [6] experimentally proved that the efficiency of the solar still enhanced by large exposure area of the basin through stepped absorber plate with the flat plate collector. The energy storing materials also introduced in the trays to rise the evaporation rate. Pradeep Mohan Kumar *et al.* [7] proved that conventional solar still showed minimum efficiency as compared to stepped solar still with internal reflector. Ganeshan *et al.* [8] evaluated the transmittance of the solar radiation at still location and the enhancement of productivity through the presence of energy storing materials. Avudaiappan *et al.* [9] reviewed that the major factors affecting the productivity of solar still are solar intensity, wind velocity, temperature difference, the surface area of water, absorber plate area, the temperature of inlet water and glass. Godwin Antony *et al.* [10] experimentally studied the single basin solar still with a floating absorber aluminum sheet over the water surface which improves the output of the solar still than the conventional still. Kalidasa Murugavel *et al.* [11] experimentally used black granite stones as a storage medium shows an increment in the yield of the solar still. The project mainly focus is to raise the output of the solar still.

Materials and method

Methodology

To achieve the objective, the certain modification is done on the simple solar distillation system. To enhance the productivity of the still, experiment is carried out in a single basin double slope solar still with varied designs of basin plates like flat basin plate, trapezoidal basin plate and pin fin basin plate with the different energy storing materials like mild steel, black gravel, pebbles, sand, cast iron individually with the water height of 0.5 cm. The basin condition is studied and the comparison has been made between the various energy storing materials with different basin plates.

Design and description of apparatus

Figure 1 shows the schematic view of the solar still with flat plate and fig. 2 shows the modified basin plates of trapezoidal and the pin fin basin plates with cross-sectional area of

1 m^2. The main difference from the flat plate to the other plates is its increase in surface area and their different design which have the protrusion height from the flat surface of the trapezoidal and pin fin are 1.5 cm and 2 cm, respectively. The simple still consists of: 1 – flat basin made of aluminum with black liner, 2 – transparent glass cover, 3 – condensate channel, 4 – sealant, 5 – insulation with wood and thermocol. The design consist of the slope angle of 20° makes the maximum amount of radiation which could be trapped inside the still through the transparent glass cover. The modified basin plates help to raise the heat transfer rate from plate to water due to its increased surface area. Solar radiation falling on the basin plate coated with black liner holds brackish water through transparent glass cover evaporates the water due to the temperature difference between the inner glass cover and the water in the solar still. The evaporated water get condensed in the inner side of the glass plate and get collected through the trough or condensate channel. To reduce the leakage of vapor from the system, the insulation is made from wood and thermocol in the system, fig. 3.

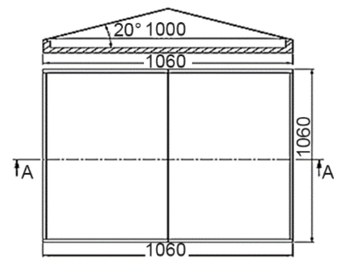

Figure 1. Schematic view of solar still with flat plate

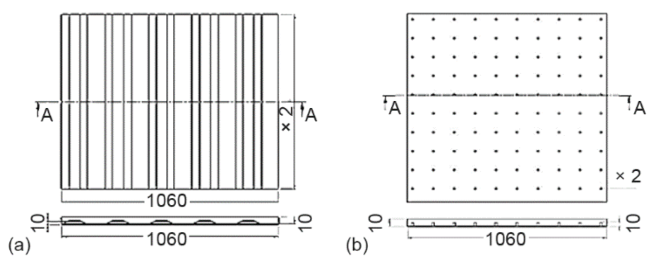

Figure 2. (a) Trapezoidal basin plate (b) pin fin basin plate [mm]

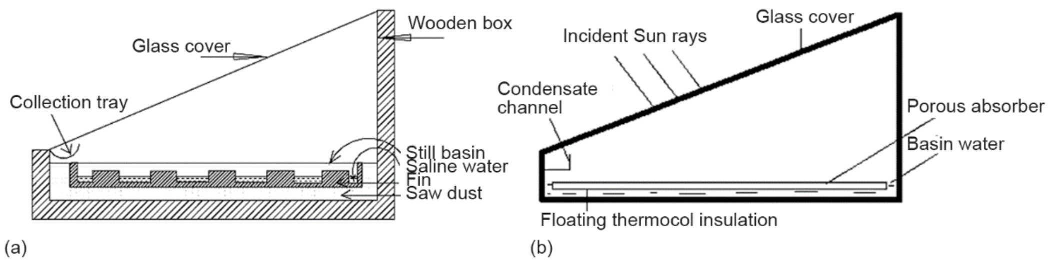

Figure 3. (a) Cross-sectional view of finned stills, (b) diagrammatic illustration of the stills with porous plates

Construction of the experimental set-up

The pictorial view of the experimental set-up and the diverse configurations of basin plates are shown in fig. 4, the one basin double slope solar still are made up of plywood which acts as an insulating medium. The still consist of basin plate, transparent glass cover, condensate channel and insulating materials. The transparent glass cover has an area of 1 m × 0.75 m with a slope angle of 20° with the minimum thickness of 4 mm. The basin plates are made up of aluminum with the thickness of 2 mm with the nominal area of 1 m^2 helps to hold the heat from the various modes. The condensate channel helps in the collection of the distilled water which is made of thick PVC pipes. The sealants are used for the protective layer around the still to reduce the leakage.

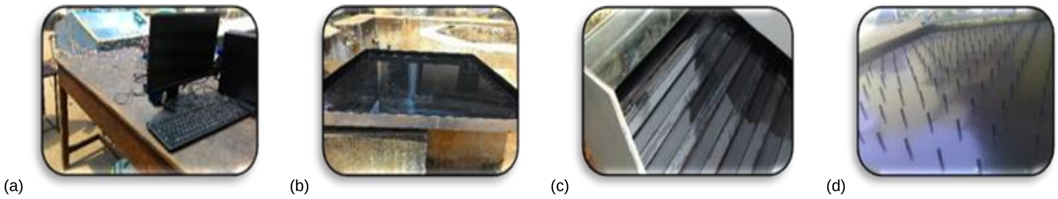

Figure 4. (a) Solar still with DAQ system, (b) flat plate, (c) trapezoidal plate, and (d) pin fin plate

Measuring instruments and devices

A data acquisition system (DAQ) was used to measure the temperatures of the glass cover, water, absorber plate, and vapor using the thermocouple connected to the PC-based measuring device which runs a software to record the various signals from the various thermocouples periodically at the particular instant. The DAQ records and stores the each temperature values in excel sheet at given regular interval. The accuracy of these T-type thermocouples is ±1 °C or ±0.75% with the measurement range of 0 °C to 260 °C. A multi thermometers are used to measure the dry bulb and wet bulb temperature which helps in calculating the ambient temperature. A pyranometeris used to measure the instantaneous solar irradiation at regular intervals of time manually with a slope angle of 20°.

Experimental procedure

The experiments were conducted during the months of March and April 2016 at the GCE, Salem, India with the latitude of 11.71°N, 78.08°E from 10 a. m. to 4 p. m. with the solar still facing south to the Sun. The basin plates with different designs like: flat basin plate, trapezoidal basin plate, pin fin basin plate is incorporated with energy storing materials like: mild steel, black gravel, pebbles, sand, and cast iron individually with the water depth of 0.5 cm is experimentally observed and the hourly yield is noted. Besides this, the solar intensity, temperatures in the glass, water, basin plate, and vapor are measured with five thermocouples attached in the solar still periodically, fig. 5.

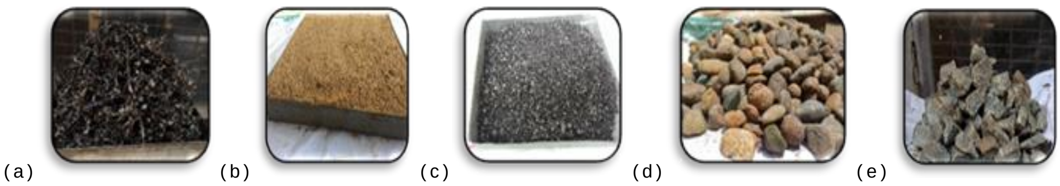

Figure 5. (a) mild steel, (b) sand, (c) cast iron, (d) pebbles, (e) black gravel

Results and discussion

Solar intensity with variation time

The solar intensity with variation time for different basin plates by various kind of storing materials is maintained at the depth of 0.5 cm is shown in fig. 6. The productivity of the solar still directly depends on the basin plate condition with respect to the amount of solar radiation falling over it. It is evident that the solar radiation for a particular day is unpredictable and due to this, the still productivity cannot be properly compared. Hence, the experiment has to be conducted in a similar climatic condition where the solar intensity could not have many deviations. The radiation in solar was steady increased from day time between 10 am to 2 pm proper sunshine and gradually decreases in the time of evening because of poor sunshine which are experimented. It was observed that the average maximum and minimum solar intent are measured manually by the means of pyrometer is about 1150 W/m^2 and 425 W/m^2, respectively.

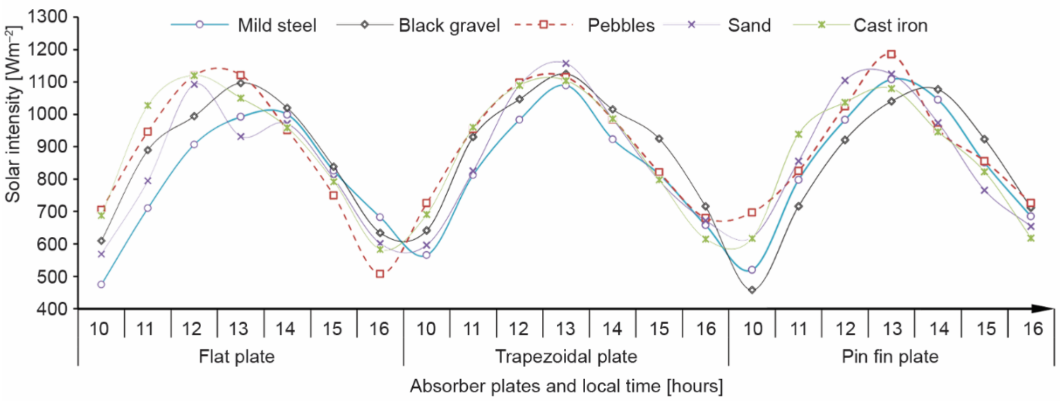

Figure 6. Variation of solar intensity with time

Variation of temperatures with parameter with respect to time

The temperature variations with parameter with respect to on continuously for every basin plates with the energy storing materials like mild steel, black gravel, pebbles, sand, and cast iron are measured and are plotted in figs. 7-9. From all these graphs, the vapor temperature and basin plate temperatures are always higher than the other temperatures involving in the system. In fig. 8, we could see that the basin and vapor heat are very much highly in the trapezoidal plate with black gravel compared to other energy storing materials in the same basin. The condensation takes place due to the striking of vapor to glass, the glass temperature very much less than the vapor which improves the production rate. Hence, the glass temperature is maintained, by spraying the water over the glass for every 15 minutes which helps the glass temperature to get reduce. This makes the glass temperature to be lesser than the minimum during the starting stage the temperatures of the system. From the graphs, we could see that all the initial temperatures.

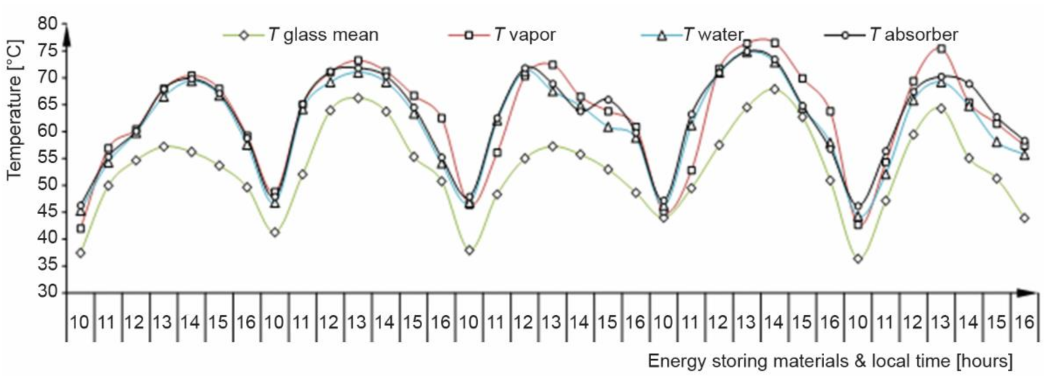

Figure 7. Variation of temperatures at glass, vapour, water, and absorber plates with time (flat basin plate)

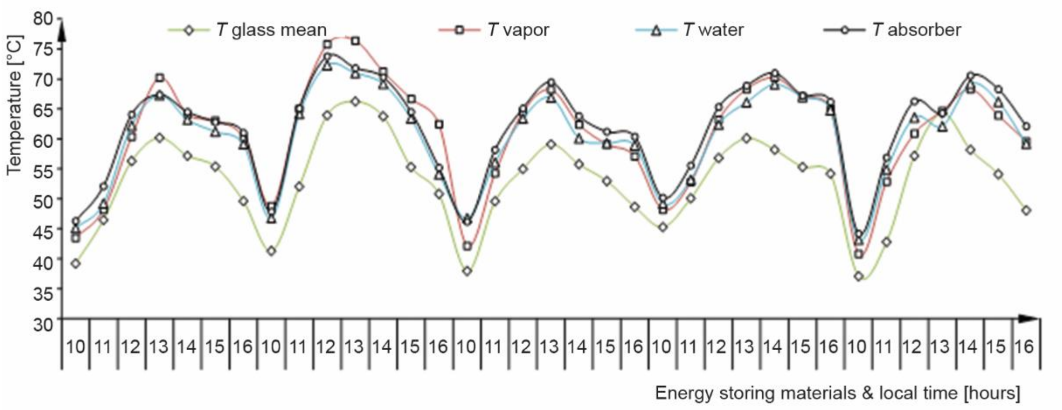

Figure 8. Variation of temperatures at glass, vapor, water, and absorber plates with time (trapezoidal basin plate)

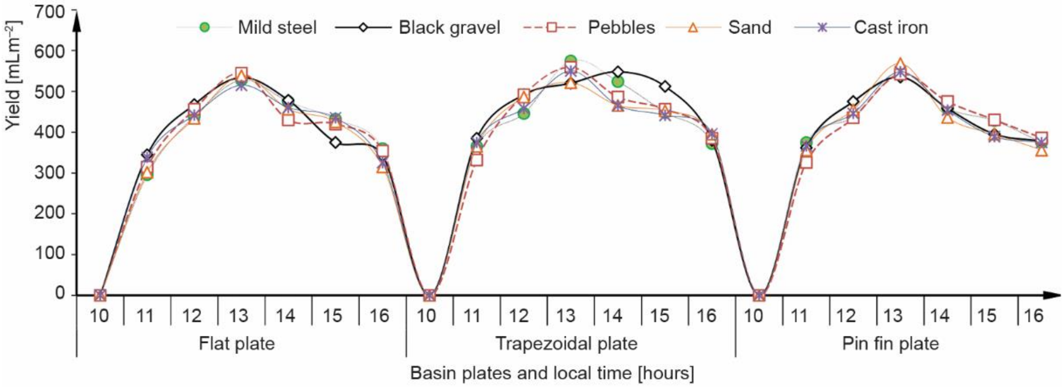

Figure 9. Variation of temperatures at glass, vapor, water, and absorber plates with time (pin fin basin plate)

Variation of depth, yield, and basin plates with varied energy storing materials with time

Solar still is monitor for every one hour. The production of condensate with time for different energy storing materials in the diverse basin plates is shown in fig. 10. From the graph it is clear that production was higher for lower water depths [5] and hence the still is maintained with 0.5 cm depth. The hourly yield productivity is high in the trapezoidal plate compared to the other two plates and it gives good productivity with all the energy storing materials especially black gravel. From fig. 10, we could understand that with the usage of energy storing materials in the still, the productivity is higher not only in the bright sunshine hours but also in the off shine hours.

The trapezoidal and the pin fin plate with different energy storing materials provide higher hourly productivity with respect to solar radiation when compared to the flat plate with same conditions. Also, it can be inferred that hourly production is increased in the evening hours due to the additional energy release from the energy storing materials which is stored during the bright sunshine hours.

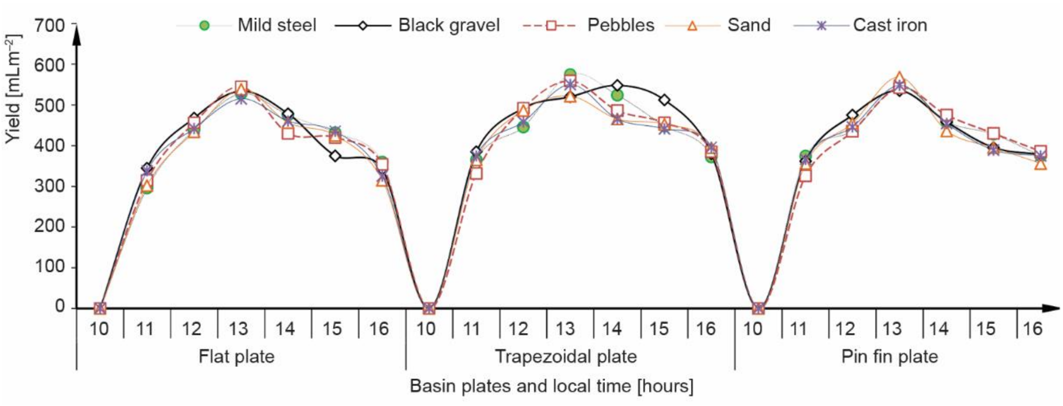

Figure 10. Variation of energy storing materials, yield, and basin plates with time

Basin plates with time, fig. 11, cumulative production of energy storing materials with diverse basin plates with energy storing materials provides a good participation in the distillate production compared to that of other basin plates with the same condition. Also, there is a higher productivity with black gravel combination. Then the pin fin basin plate also compared with the flat plate with different energy storing materials which gives an increase in productivity of 3.4%, 4.1%, 3.07%, 3.6%, and 3.3% with mild steel, black gravel, pebbles, sand, and cast iron, respectively. Figure 11 also notifies that there is an increment in the still productivity when the black gravel combines with all basin plates.

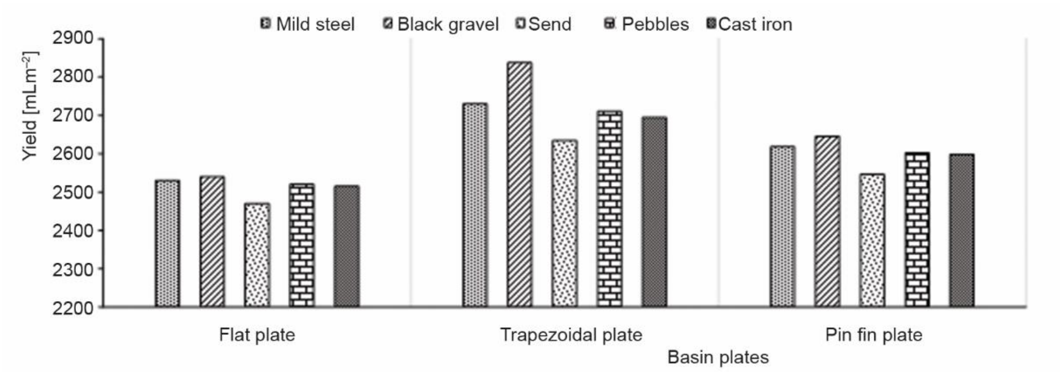

Figure 11. Cumulative production of energy storing materials with diverse basin plates

The rate of evaporation varies due to variation in the amount of water mass in the still and due to this, sum of all production becomes various in each case. The main criteria which increase the productivity in the trapezoidal and pin fin with different energy storing materials are due to the increase in the exposure area and the thickness of the plates and the capacity of materials added to the system. This leads to the increase in the heat transfer rate. Due to this excess energy release from the exposure area, the efficiency of the basin plate gets improved which gradual the productivity of the still. The cumulative production mainly depends on the solar radiation, in this set-up is increased due to the presence of absorbed or stored energy from the energy storing materials, and is often released when there is a temperature drop in the system.

Conclusions

In this experimental study, the energy storing materials like mild steel, black gravel, pebbles, sand, and cast iron is placed in the different basin plate configurations like flat basin plate, trapezoidal basin plate and pin fin basin plate individually, is introduced in the solar still with the minimum depth of 0.5 cm. Then the results are obtained with respect to the basin plate performance in addition to the energy storing materials and based on the effectiveness of each energy storing materials. From the observations, the trapezoidal basin plate with black gravel gives a maximum increase in the productivity of 11.6% with black gravel and 7.9%, 6.6%, 7.5%, and 7.1% with mild steel, sand, pebbles, and cast iron, respectively, when compared to the flat plate basin with same conditions. Then the pin fins basin plate with mild steel, black gravel, pebbles, sand, and cast iron gives an increase in productivity of 3.4%, 4.1%, 3.07%, 3.6%, and 3.3%, respectively, to the flat plate with same conditions. Hence, usage of energy storing materials and different plate configurations enhances the overall production of the still through the increment of productivity even during the off shine hours (i. e. evening). Through this experimentation, we could come to the conclusion that trapezoidal basin plate with varied energy storing materials plays a predominant role in the production of distilled water than the flat and pin fin basin plates. On the other hand, black gravel gives good productive results compared to other energy storing materials because of its good heat storing and releasing capacity.

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