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Experimental Investigation on Pyramidal Solar Still for Indian Climate

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ABSTRACT

Solar stills are one of the most economical and effective water treatment process which uses the available low grade energy, solar radiation. The geographical location of the setup directly impacts the performance and the final output of the setup. In this regard, the geographical location i.e. latitude (17.83°N) is considered and the experimental setup has been built accordingly. The experimental analysis on Pyramidal solar still performed on two setups with glass inclinations of 17° and 30° by varying various productivity effecting parameters like working fluid composition, angle of tilt of collector and water temperature to increase the performance are discussed in the paper. The performance variation obtained by using a geyser aided heat exchanger is studied. The geyser is to simulate the effect of exhaust gases which can be used as an aid in the heating process. The *performance comparison between 17° and 30° inclination is also done.*

Keywords:—*Pyramidal Solar still, Angle of inclination, Salt concentration, Heat exchanger.*

I. INTRODUCTION

Solar energy is one of the renewable energy sources which meets the future energy requirements without creating impact like global warming and pollution. The conversion of solar energy into different forms has various applications. One among the many such applications is water distillation. Solar distillation is the method of converting non consumable water to drinkable water. Solar stills are the setups which are used for solar distillation. There are many designs of solar stills which can be adopted.

Out of the various designs of solar stills, the pyramidal solar still is a generally viable design for usage. A pyramidal glass solar still has been considered as more heat trapping is feasible. For same basin area, condensation in pyramid shape solar still is higher as condensing area in pyramid shape is higher than that of normal conventional Solar stills. So, on considering different performance affecting parameters [1, 2, 3, 4] like temperature of evaporation, angle of tilt, type of retaining material, working fluid, construction plan of solar still is made. There are various methods to increase the efficiency of the solar still. The method adopted here to increase the efficiency is by coupling the still with a geyser to simulate the effect of using exhaust gases.

1.1 Angle

Angle of glass cover has significant effect on performance of solar still. It effects the performance. The productivity of the solar still increases when an ideal angle of inclination is maintained. But higher angle of slope reduces the condensation rate. The angle is dependent on the latitude of the place. In this project the angle is taken as 17.83°, 30° it should ideally be equal or more than 10 of the latitude of area. (latitude of Hyderabad 17.38 degrees N)). [5, 6]

1.2 Absorbing Material

This is a major part of solar still. Because it absorbs the radiations from the sun, so heating of water is produced and Vapor is formed. It should be such that when radiation intensity is fissures must not be formed. The absorptivity of Aluminum is 0.1 to 0.44. The material used here is Aluminum. [7]

1.3 Thickness of glass

Higher the thickness higher the reflection of radiations. Thus it is optimum to use less glass thickness so that the reflections of solar radiations will below. [8,9]

1.4 Salt concentration

The salt concentration in the water does effect the evaporation rates in the cabin. The higher the concentration the lower the productivity of distilled water. As the soluble impurities increase, the temperature for vaporization increases. As a result the evaporation rate decreases.

1.5 Insulating material

Insulating materials used to reduce the heat loss from bottom, top, and sidewall of still and to maintain constant temperature inside the solar still. The insulating material is thermocol and it was surrounded by wood to decrease the heat transfer inside the still. Few of them are rock wool, charcoal, cotton, poured concrete, bricks, fiber, cardboard and slag wool etc. Insulating material used here is thermocol.

II. Design of the Pyramidal Solar Still

Design with collector area of 0.25m2 (0.5m × 0.5m) is presented as shown in figure. The still is filled with saline water to height of 0.15m. From the economic point of view, the solar still with thermocol has been used as an insulating material. In the view of eco-friendly material, saw dust would be a good alternative for thermocol. The water storage basin of the still is constructed with dimension 0.7m × 0.7m × 0.20m of wood and Aluminum.

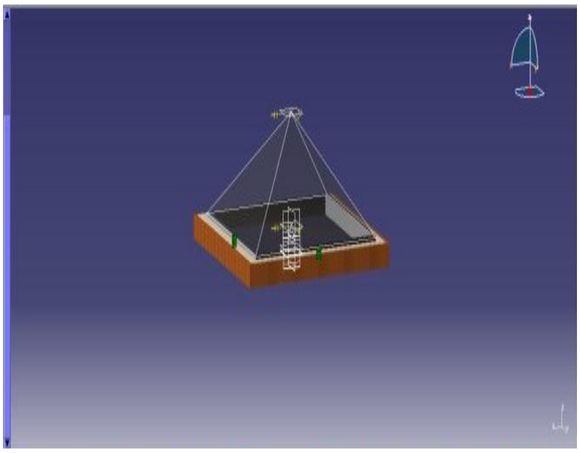

Figure: 1 CATIA V5 design of Solar still

III. Constructional Specifications of the Pyramidal Solar Still

The design is consisting a base area of 0.5 × 0.5 m2 absorber plate and height of 15cm. The absorber plate is provided with the insulation in order to avoid the radiation losses of around 4.5-5cm on all the sides. This insulation is provided with support made of outer wooden box with dimensions 70 × 70 × 20 cm. There is a glass thickness of 3mm. The angles of solar stills are 17.83 0, 300.

The experimental setup has 5 thermocouples set on it. All the thermocouples are then connected to a temperature indicator. The thermocouples are placed individually at five different places; in the water, over the aluminum surface, on both sides of the glass and inside the cabin (freely suspended).

Inlet and outlet points for water are given and also the slots for the heat exchanger to be inserted inside are also given. The experimental setup which has been used has been modified for further experimentation. A copper tubing has been placed in the cabin as a heat exchanger. The copper tubing is used a passage for hot water to flow in the cabinet. The water is heated by means of a geyser. [10, 11, 12]

Figure :2 Overview of experimental Setup

IV. Experimentation and Procedure

A pyramidal solar still for 30° and 17° glass inclination is constructed. Basin area of the conventional still is 0.25 m^2 (0.5m × 0.5m). High-side wall depth is 250mm. The still is made of Aluminum sheets. Also, the still is insulated from the bottom to the side walls with thermocol of 5cm thick to reduce the heat loss from the still to ambient. The insulation layer is supported by a wooden frame. The basin is covered with a clear glass sheet 3 mm thick inclined at 30° and 17° with horizontally, which is nearly equal to latitude of Hyderabad, India to maximize the amount of incident s olar radiation.[13]

Tests were conducted at VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, India, from 10:00 am to 4:00 pmamid April 2018. The surrounding temperature and the temperature of bowl plate, saline water, glass cover and distilled water are noted for every 60 minutes. The cumulative efficiency a mid the day is recorded. The concentration of the saline water in the solar stills is kept steady all through the experiment.

The experimental setup was put in open area, where sunlight was abundant. The experiment was carried out for a total of 5 days during the sun abundant hours of the day. The first day the experiment was conducted on the 30° experimental setup without mixing any salt. The temperatures of respective nodal areas are all then obtained by the thermocouples connected to the setup.

Figure 3: Formation of Droplets on the glass after condensation

V. Results and Discussions

The graphs below depict the temperature trends at various locations on the setup. The temperatures have been obtained by using thermocouples. The graphs below depict various trends for five various days. The figure 4 shows time and temperature comparison for a 30° setup for non brackish water and the graph 2 shows time and temperature comparison for a 30° setup with salt concentration.

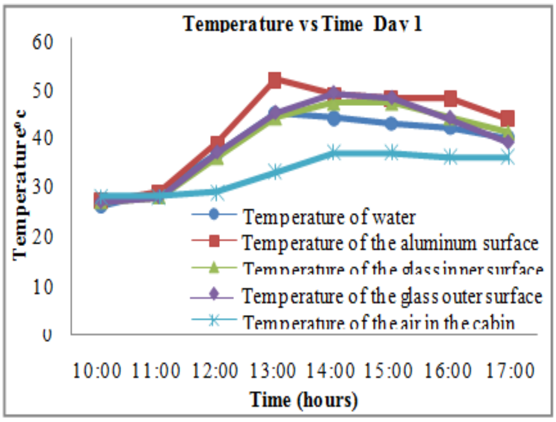

Figure: 4 Temperature vs. time for 30° set up without salt concentration

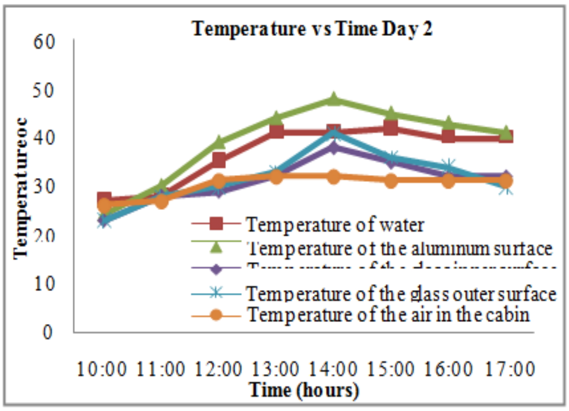

Figure: 5 Temperature vs. time for 30° set up with salt concentration

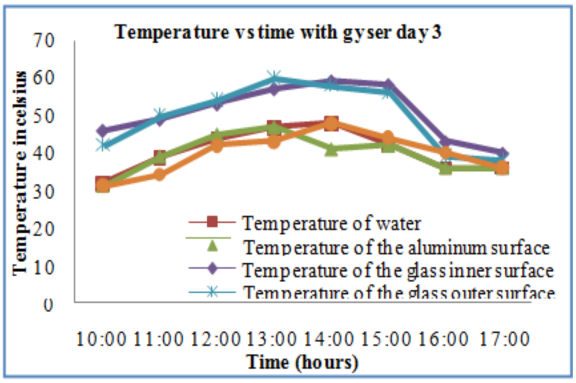

Figure: 6 Temperature vs. time for 30° set up with geyser

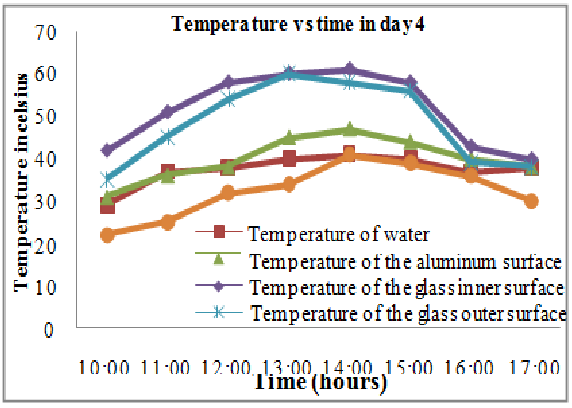

Figure: 7 Temperature vs. time for 17° set up without concentration

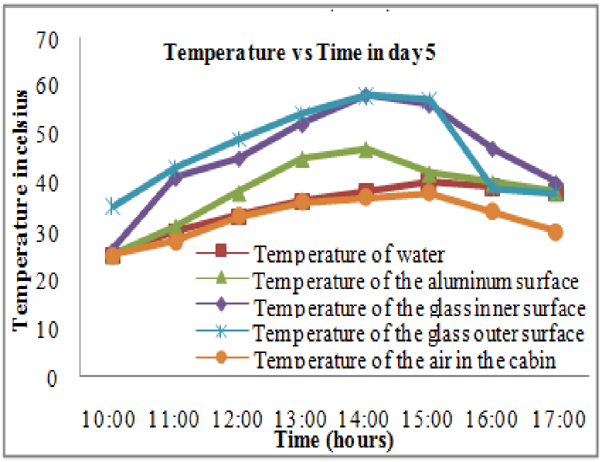

Figure: 8 Temperature vs. time for 17° setup with salt

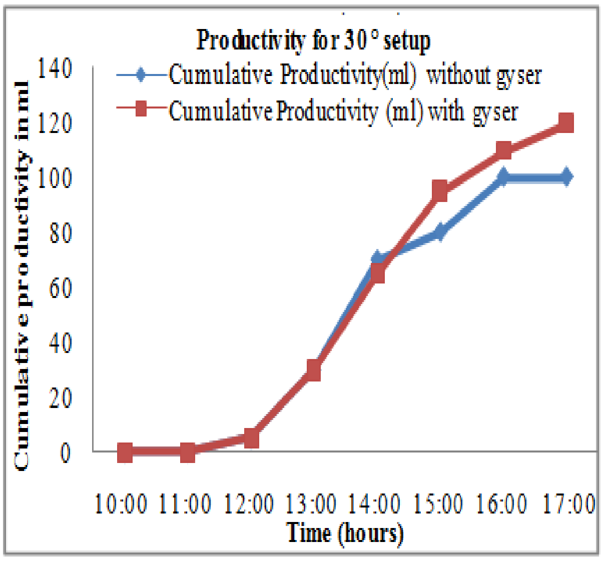

Figure 9: comparison of cumulative productivity between with concentration geyser and without geyser for 30° setup without concentration

Figure 6 is representing the temperature vs time with geyser for 30° inclination of the still. This geyser is kept instead of utilization of exhaust gas. Figure 7 and 8 are indicate the temperature vs time for 17° inclination of the still for with and without salt concentration. These graphs can indicate the purification of the mud or dust water.

The above all graphs are drawn between temperature vs time . Temperature of the water in the still are increased and decreased with the time. The energy fall on the still is also a function of time, that's why the temperature of the still is varied.

The overall productivity can be changed if an additional heat source is provided in the still. The below figures 9 and 10 shows us the comparison of cumulative productivity between with geyser and without geyser for both 30° and 17°. The salt concentration in the water has been maintained at zero.

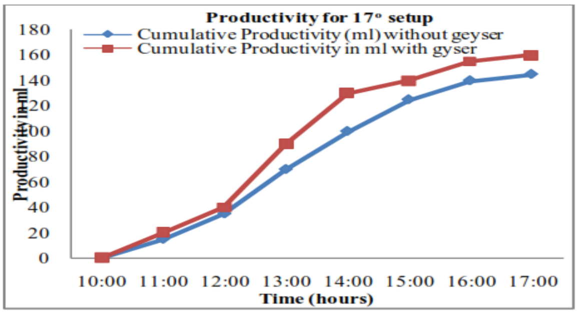

Figure 10: comparison of cumulative productivity between with geyser and without geyser for 17° setup without concentration

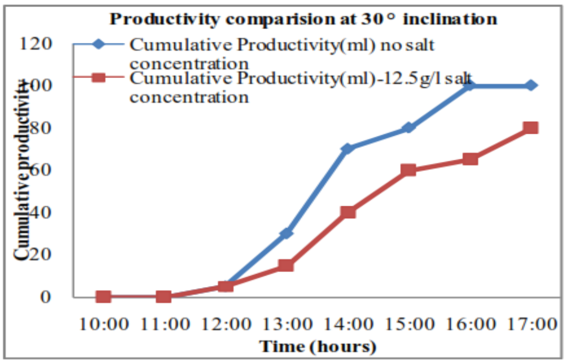

Figure 11: Productivity comparisons with salt and without concentration for 30° setup

The rate of evaporation and condensation both change when the s alt concentration is altered. The figure 12 and 13 below show the productivity comparison with and without salt concentration at two different angles namely 30° and 17°.

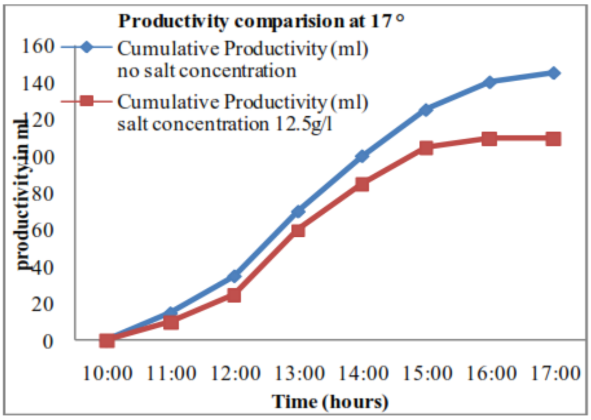

Figure 12: Productivity comparison with salt and without salt

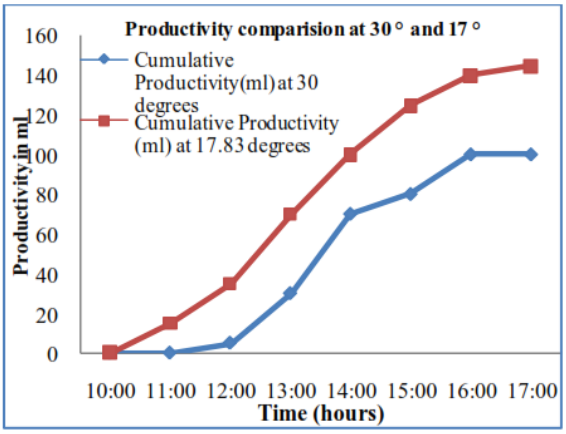

Figure 13: Comparison of productivity (ml) between the concentration for 17° setup 30°

The overall productivity which is obtained after the conduction of experiment in both the 30°and 17°setups has been studied. The below graph is drawn between productivity and time.

VI. CONCLUSION

After conducting the experiment, it is evident fro m the results that the inclination of 17º is more efficient in terms of productivity. Thus maximum a mount of sunlight can be utilized and maximum heat energy can be harvested. However, further reduction of angle may not be feasible as the condensed droplets may drip down fro m the glass even before they s tart sliding down into the collector.

The concentration of the salt dissolved in the water, does play an important role in determining the distilled water output. Pure water without any salt took the least amount of time to evaporate and condense. On increasing the salt concentration the time needed to convert the solution into vapor increases considerably. On general terms, the vaporization temperature increases with increase in dissolved substances. So, upon studying the experimental results, we can infer that the lesser the salt concentration the faster the evaporation occurs.

In order to increase the performance, a heat exchanger has been engaged. As mo re heat is given to the water the vaporization takes place quickly thereby increasing productivity. An inference which can be drawn from the experiment is that using an external heat source like exhaust gases can increase the productivity. Distillation can also be done during the s un-less hours.

On a whole a pyramidal solar still is an effective way to produce distilled water in hot regions, marine and coastal regions. If the key performances are consistently varied, then the overall productivity shall increase.

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