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Experimental study on productivity of modified single-basin solar still with a flat plate absorber

V Ramanathan[1], **B Kanimozhi**[1], **V K Bhojwani**[2]

[1]Department of Mechanical Engineering, Sathyabama University, Chennai, India

[2]Department of Mechanical Engineering, J.S.P.M. College of Engineering, Pune, India

vramnathan.sae@sinhgad.edu

Abstract. Solar still is an apparatus which uses solar energyto producedistilled water from saline water.This can be used in remote areas effectively wherein electricity is not available.The output from a conventional single basin solar still is found to be very low. Hence research is required to increase the productivity of the conventional solar still. This work is an attempt to increase the productivity of solar still. A flat mica plate is embedded in the conventional solar still to augment evaporation of the water from the input saline water. The flat plate absorber is placed in such a way that it is parallel to the glass cover of the solar still so as to maximize the absorption of solar radiations. By this modification, the maximum temperature of the absorber plate achieved was 95°C in comparison to 67°C of the conventional solar still. Experimental results of modified solar still were compared with conventional solar still. It was found that distillate output increased by 25% with a flat plate absorber when compared to conventional still.

Keywords—Solar Still; Flat Plate Collector; Distillation.

1. Introduction

A major amount of water on earth is either in the form of seawater or icebergs in the Polar Regions. About97% of this water is in sea. Only 1% of the fresh water is within human reach. Even this small fraction of water is said to be sufficient to support human life. The hydrological cycle of nature is a very large-scale process of solar distillation which naturally produces fresh water in the form of rain. Thishydrological cyclecan be explained in short as a process of production of water vapours above the surface of the seawater and cooling of air-vapour mixture through condensation and precipitation. The basin type solar still mimics this natural hydrological process on a small scale.

Solar distillation usessolar energy as a source of heat energy for obtaining fresh water from salty, brackish or contaminated water. It is a slow distillation process which allows only pure water to evaporate from the basin and condensate beneath the glass cover, leaving all particulate contaminants behind. Solar stills are suitable only for regions where freshwater demand is less than 200 m^3/ day [1]. Amongst the various types of solar stills available, the single-basin still has been much studied by various authors worldwide. One of the main setbacks for this type of desalination device is low thermal efficiency and productivity [2].

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2. Historic Review

The solar distillation has been used by Arab alchemists as early as 1551. The French chemist Lavaosier has used wide glass lenses to concentrate solar rays to distillate water inside the flasks in 1862 [3]. The first known documented application of solar distillation was in the year 1872 at Las Salinas. It provided drinking water for animals used in nitrate mining [4]. Most of the solar stills have been built on a similar concept with some variations in geometry, materials, methods of construction and operations employed.

The thermal efficiency and productivity of the simple solar still has been improved by a number of both passive and active modifications. Various wick and porous materials were experimentally studied by Murugavel et al [5] for using in basin to improve the productivity. The results show that the still with black light cotton cloth as wick material is found to be more productive. The wick is a better option than porous materials for they maintain a thin water film which in turn improves the evaporation rate.

The performances of solar still with different sizes of sponges placed in the basin were studied by Bassam et al [6]. The productivity of the still was increased in the range of 18% to 273%. The optimal parameters were arrived at through series of experiments. However with increase in salinity, sponges were found to be less effective. Velmurugan et al [7] integrated fins at the basin of the still which resulted in productivity increase of the stillby 45.5%.

The surface heating of water mass was attempted by Valsaraj et al [8]. A perforated aluminum sheet is floated over the water surface. This sheet absorbs and dissipates the heat energy at surface of water layer. This prevents the whole water mass being heated by convection as in the normal still. The overall productivity was increased by 49.3 %.

The effect of suspended absorbers was investigated by Sebaii et al [9]. When aluminium plates were used it was found that the productivity increased by 20 % and 23% for mica plate as suspended absorber. The suspended absorber enables to increase the water mass contained in the basin thus increasing the nocturnal production of the still. Sahoo et al [10] studied the effect of blackened surface and insulation on the performance of a solar still. The efficiency of solar still got increased by 17% upon suitable modification of the solar basin with appropriate base liner and insulation.

The effect of varied depths of water in the basin was studied. The depth of water influences the internal heat and mass transfer and thereby the productivity of the still[11]. The maximum distillate output was achieved with water depth in still basin 2 cm. The maximum efficiency of the experimental still varies from 10% to 34%. The results indicate that an increase in depth of basin water, still productivity decreases [12].Patel et al [13] utilized the different semi-conducting oxides like CuO, PbO_2 and MnO_2 as photo-catalysts. The overall efficiency of conventional basin type solar still got enhanced. Metal oxides not only improve the efficiency of the process but the rate of production of desalinated water was also increased.

Bassam et al [14] analysed the Effect of water emissivity on solar still efficiency. The use of dye resulted in minimal improvement in still efficiency. The reduction in the water emissivity will reduce the radiation heat transfer from water to glass. This resulted in a substantial improvement in still efficiency and offers great potential for solar still usage.

The literature survey points out that output can be increased by decreasing the losses, increasing the temperature difference between the evaporating and condensing surfaces, making use of latent heat of condensation, and maximizing the driving force for evaporation by increasing the heat sink capacity. These considerations usually increase the cost of the system, since they require use of more materials.

The still productivity depends on parameters like solar radiation intensity, atmospheric temperature, basin water depth, glass cover material, thickness and its inclination, wind velocity and the heat capacity of the still. Amongst the above parameters, the inclination of the absorber surface and depth of the basin water are the main parameters that affect the performance of the still.

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3. System Developement

In this work, a flat plate absorber plate (a mica plate of thickness 8 mm) was integrated to the basin of the still. The flat plate absorber was placed in such a way that it is parallel to the glass cover of the solar still so as to maximize the intensity solar radiations by reducing the angle of incidence. Depth of water on absorber is reduced for maximizing the absorption. This is achieved by supplying water on the absorber surface of solar still through a separate water tank by gravity. The primary objective of the work is to increase the productivity of single basin solar still with the help of low cost modifications.

The experimental investigations were performed using one of the simplest types of solar stills popularly known as asymmetric greenhouse type still (ASGHT). It has an effective area of 1 m^2. The frame is made of fiber reinforced plastic. It has a top cover of transparent glass, and the interior surface of its basin is blackened to enable absorption of solar energy to the maximum possible extent. The body is made of Fibre reinforced plastic, 3 mm thick; and shaped as an inclined box placed on a vertical mild steel stand. The whole assembly is air tight with help of rubber gasket and screws.

The unmodified still will be referred as conventional still henceforth. This conventional still serves as a standard for comparison with the modifications done in the solar still. The outputs of the two systems were compared to see the effect of the modification.

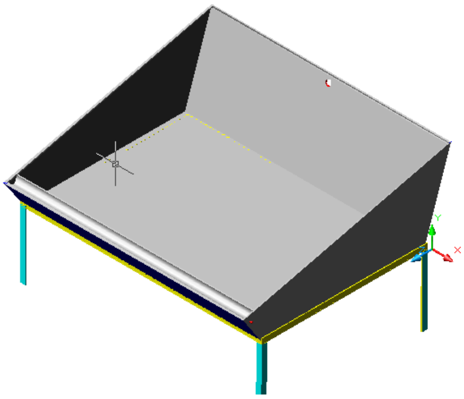


Figure. 1Conventional solar still

The conventional still is the still as in figure 1 is without any modification. Thermocouples were fixed at various points on the still to measure temperature. This still has served as the standard for comparison for the modified still.

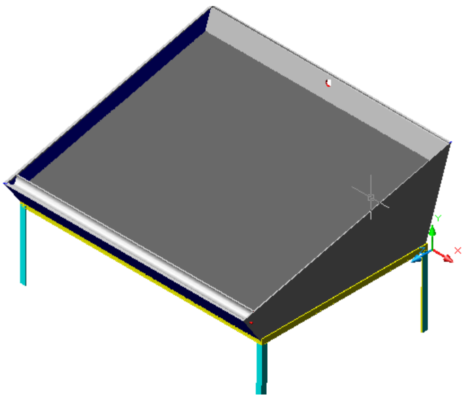


Figure. 2 Modified solar still

The modified still as shown in figure 2 is geometrically same as that of the conventional solar still. Modifications like inclusion of a flat plate absorber and continuous flow of inlet water were made in the conventional still.

A flat absorber surface parallel to the glass will increase the efficiency of the system. A mica sheet 940 mm x 980 mm size was placed within the still parallel to the glass surface. The mica sheet is light in

weight and can withstand up to 80-85^{o}C. The modified still is of active nature as against a passive conventional still. Here a reservoir of 20 liter capacity is used to store and supply saline water to the modified still. The reservoir is mounted on a level higher than solar still.
The flat plate introduced in to the system is the new absorber surface as against a basin in a conventional still. The K-Type thermocouples were placed in the as shown in figure 3 for conventional still and figure 4 for modified still.

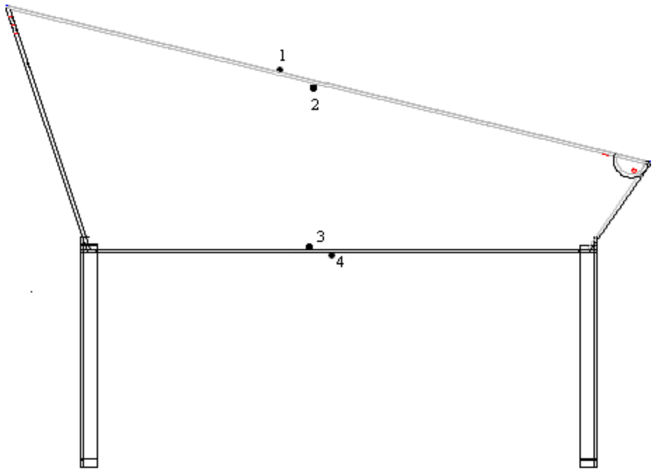


Figure. 3 Positioning of thermocouple in conventional still

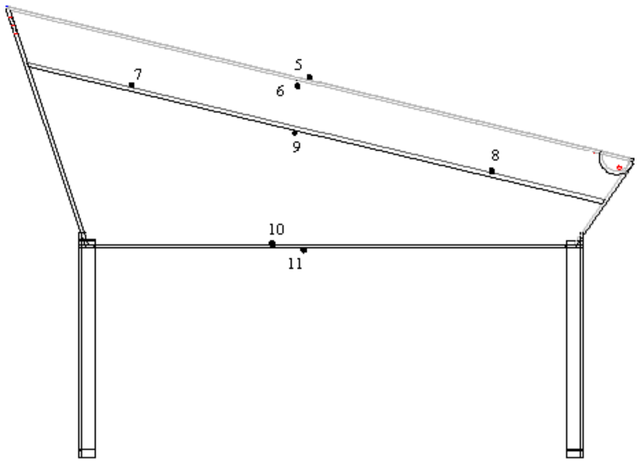
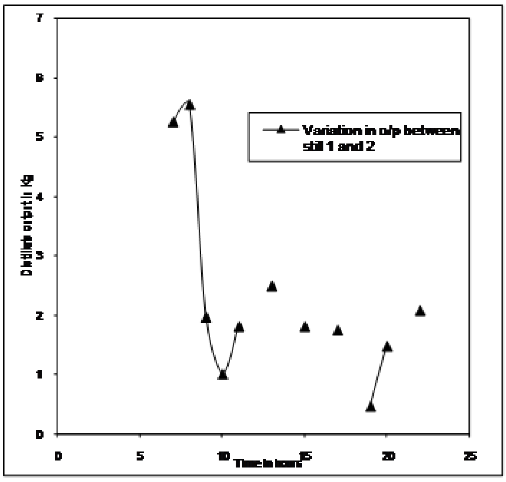


Figure. 4 Positioning of thermocouple in modified solar still

4. Experimental outcome

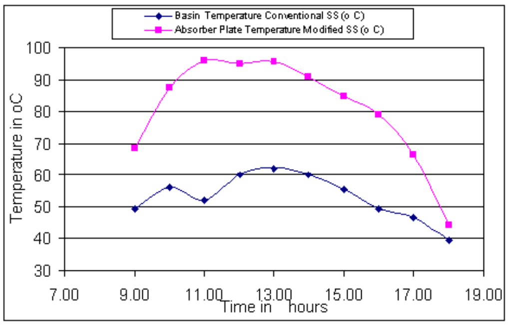
The main objective of this present work is to improve the distillate output. The modified system is tested for its performance. The conventional system serves as a standard to quantify the performance of the modified still. Both the stills were tested simultaneously under the same conditions. The experiments were conducted in actual outdoor conditions. The observations were recorded for the cover temperatures, basin water temperatures, plate surface temperatures, wind velocity, and ambient temperature.
Both the stills were supplied with 20 liters of water at same initial temperature and quality. In the conventional still, the water is filled at once in the basin trough before the experiment is started. In the modified still, 20 liters of water was filled in the water reservoir. The flow rate of the water entering the modified still can be fine adjusted using the control valve fitted to the base of reservoir. The

readings were recorded at an interval of one-hour. The distillates from both the stills were measured on hourly basis. The anemometer reading and pyranometer reading were recorded.
Initially the Standardisation of both the solar stills is done before any modification to ensure uniformity. Both the stills were subjected to the same conditions during the standardization test. The outputs of the two systems were measured and compared. Both the stills have shown nearly the same performance and variation in output is well within 2% as seen in graph.1.



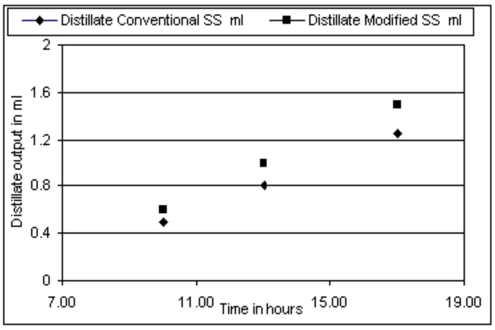
Graph.1 Standardisation of solar stills

The mica sheet is embedded in a solar still to make a modified still. This modified still is then tested against the conventional still.
From graph.2 it is noted that the maximum temperatures in a modified still is 95.5 0C on the flat absorber plate as against 67 0C in the basin trough of conventional still.



Graph.2 Temperature Plot of Conventional Still and Modified still

The distillate output of the modified solar still is increased by 25% conventional still as can be seen in graph.3



Graph 3. Distillate Output plot of Conventional Still and Modified Still

5. Conclusion

The modified solar still has an increased output by 25% compared to the conventional still. The increase in Thermal efficiency can be attributed to the following factors

1. The absorber plate is parallel to the glass surface and also approximately equal to the latitude of this place resulting in absorption of maximum solar radiations
2. Reduction in cavity volume between the absorber surface and glass surface: This led to enhancement of mass transfer i.e. more evaporation and condensation.
3. The water drained from the absorber plate gets accumulated in the basin. This further increases the heat mass capacity of modified still and enables condensation in nighttime also.
4. Due to accumulated water, the underneath of the absorber plate is not directly exposed to atmospheric temperature but to temperature of the vapor. This reduces the heat loss at the underside of absorber plate compared to the conventional still.

Thus it can be concluded that with the above simple modifications made in the solar still, it is possible to improve the output of the system significantly.

In this experimental work it is observed that the distribution of water is not uniform in the bare absorber plate. Although higher operating temperatures were achieved, a proportional increase in productivity was not achieved. The root cause of the problem was uneven distribution of water over the absorber surface. To overcome this problem the textile materials like jute, cotton cloth can be spread water over the absorber plate.

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