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Performance Analysis of Active Solar Still with ETHP Solar Collator Attached as Natural Convection

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Abstract-This experimental study has been carried out to measure the effect of ETHP solar collector by natural convection on solar still. From this study it has been observed that the productivity of solar still has been increased with decreasing in water depth. Optimum value of water depth for solar still has been found 1cm. Also, the productivity has been increased with increasing the ETHP solar collector area from $0.1m^2$ to $.4m^2$. From the comparison in a same day, it has been observed that the ETHP solar collector Attached to the solar still gives more productivity as compared to the passive solar still.

Key words- passive, active, solar still, ETHP solar collector, solar radiation, productivity

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1. Introduction

Solar still is the best alternative solution to convert brackish water into the pure water. This research work has been carried out to measure the effect of ETHP solar collector by natural convection on the solar still. For this study Active and passive solar still has been fabricated and tested for a typical sunny days of March and April in 2014at ahmedabad, Gujarat, india. The optimum value of water depth for active solar still has been found from passive solar still results for maximum productivity at different water depth. For this optimum water depth collector area of ETHP solar collector has been increased and also measures the effect of increasing collector area in active solar still. After that both active solar still with $0.4m^2$ collector areas and passive solar still have been directly exposed to the sun in a same day to observe the effect of ETHP solar collector for same water depth and compare it to passive solar still for same day and same solar radiation.

Some research study has been carried out for this work as following

B.B. Sahooa et al. work is aimed at utilizing solar energy for removal of fluoride from drinking water by using a ‘‘solar still’’ because of Fluoride contaminated drinking water is a severe problem in many parts of the world because of fluoride-related health hazards, which are considered to be a major environmental problem today. A Tests have been conducted with the ‘‘solar still’’ to find out hourly output rate and ‘‘still efficiencies’’ with various test matrixes. It is observed that the distillate from ‘‘solar still’’ showed a fluoride reduction of 92–96%. Further, the efficiency of ‘‘solar still’’ got increased by 11% when capacity of water in the solar basin was raised from 10 to 20 L. Upon suitable modification of the solar basin with appropriate base liner and insulation, this efficiency of the ‘‘solar still’’ is found to be further increased by 6% with a 20L basin capacity. [1]

A.A. El-Sebaii et al. presented Transient mathematical models for an active single basin solar still (ASS) with and without a sensible storage material under the basin liner of the still. Sand is used as a storage material due to its availability. The flowing water temperature is assumed to vary with time and space coordinates. Analytical expressions are obtained for various temperatures of the still elements as well as for the temperature of sand. The performance of the still with and without storage is investigated by computer simulation using the climatic conditions of Jeddah (lat. 21° 42′ N, long. 39° 11′ E), Saudi Arabia. Effects of mass flow rate and thickness of the flowing water for different masses of the storage material on the daylight Pdl, overnight Pon and daily productivity Pd and efficiency ηd of the still are studied. The dependence of Pd and ηd on the thickness and thermal conductivity of the basin liner material is also investigated. It was found that Pd and ηd decrease as the mass of the storage material increases, due to the increased heat capacity of the storage material.[2]

Hiroshi Tanaka et al. present a theoretical analysis of a basin type solar still with internal and external reflectors. The external reflector is a flat plate that extends from the back wall of the still, and can presumably be inclined forwards or backwards according to the month. They have theoretically predicted the daily amount of distillate produced by the still throughout the year, which varies according to the inclination angle of both the glass cover and the external reflector, at 30°N latitude. We found the optimum external reflector inclination for each month for a still with a glass cover inclination of 10°–50°. The increase in the average daily amount of distillate throughout the year of a still with inclined external reflector with optimum inclination in addition to an internal reflector, compared to a conventional basin type still was predicted to be 29%, 43% or 67% when the glass cover inclination is 10°, 30° or 50°and the length of external reflector is half the still's length. [3]

Sangeeta Suneja, G.N. Tiwari works on transient analysis of a double basin solar still. They derived explicit expressions for the temperatures of various components of the inverted absorber double basin solar still and its efficiency. The effect of water depth in the lower basin on the performance of the system has been investigated comprehensively. For enunciation of the analytical results, numerical calculations have been made using meteorological parameters for a typical winter day in Delhi. It has been observed that the daily yield of an inverted absorber double basin solar still increases with the increase of water depth in the lower basin for a given water mass in the upper basin. [4]

Sangeeta Suneja, G.N. Tlwarl, S.N. Rai Presented an analysis of an inverted absorber double-effect solar still. Energy balance equations have been written, and analytical expressions for water and condensing cover temperatures and the hourly yield have been derived. Numerical computations have been carried out for a typical day in Delhi. The results thus obtained have been compared with those of the conventional double effect (double basin) solar still. It was observed that an inverted absorber solar still gives a higher output than the conventional double-effect one. [5]

A.A. El-Sebaii et al. Work to enhance the productivity of single basin solar stills especially during the night, a shallow solar pond (SSP) was coupled to the still. An analytical model for the various elements of the system (the pond and the still) was performed. Numerical calculations were carried out under Tanta prevailing weather conditions. The daily productivities of the active single basin solar still (ASBS) were found to be 5.740 and 1.830 (kg/m^2 day) with and without the SSP, respectively. The daily productivity P_d and efficiency η_d of the active still were found to decrease with increasing the thickness d_w and mass flow rate $\dot{m}$ of the water flowing over the basin liner of the still up to typical values of 0.030 m and 0.015 kg/s. [6]

Vimal Dimri, et al. works on effect of condensing cover material on yield. Numerical computations have been performed for a typical day in month of December, 2005 for the climatic condition of New Delhi. Compared to the passive solar still an active solar still have higher yield was observed. It produces larger temperature differences between water and glass cover. The parametric study has also been performed to find out the effects of various parameters, namely thickness of condensing cover collector absorbing surface, wind velocity and water depth of the still. It is observed that there is significant effect on daily yield due to change in the values of collector absorbing surface, wind velocity and water depth. [7]

2. Experimental Study of Solar Still

An active type solar still has been investigated in this study at Neharu Nagar, Ahmedabad (Latitude: 23°02'N, Longitude: 72° 54' E), Gujarat. In This Experimental Setup manufacturing a single basin in which the effect of active solar still was utilized in limited space. Basin was connected with Evacuated tube heat pipe solar collector as a natural convection system, which can work as an active solar still. The basin of the solar still was constructed from 20"gauge of galvanized iron sheet. The bottom and sides of the galvanized iron basin were well insulated by Thermocole insulation sheet. The thickness of insulation was 10mm in each side and it covered or supported by other galvanized iron sheet of 20"gauge. The thickness of the glass was 4mm, which is used as a condensing cover.

The glass was mounted at an angle of 15° to the horizontal to ensure that the condensate will run down on the glass up to the condensate-collecting channel. The channel was ended with small plastic pipe in order to drain the fresh water into external vessel or measuring flask. The absorbing coating of black oil painted on the inner surface of the basin. Which has the dimensions of 1 m^2 area, longer height of 400 mm and lower height of 130 mm. also the effective absorber area for solar still was 1 m^2.

There were three holes created in the solar still one for brackish water inlet, second for pure water outlet and third for draining dirty water outlet. After Manufacturing the Still it was painted with black Color from inner and outer side. In basin lower side nine holes were drilled and copper closed single ended tube used for the ETHP solar collector attached to the basin. The entire Solar still and ETHP solar collector was mounted on the stand. After completing paint the Measuring scale was fixed on the longer side wall of basin for measuring the water depth inside the basin with the help of solution.

Thermocouples were inserted from holes and located in different places of the still before fixing the glass cover. They record the different temperatures, and then thermocouple was inserted through inlet hole of fresh water. One thermocouple was placed at the Basin and measure the water temperature, Second was fixed to the inner side of glass cover and measures the glass cover temperature third one was placed on a steel bar to measure the vapour temperature inside still and last one is placed in the open air outside still to measure the ambient air temperature.

The Evacuated tube heat pipe solar collector as shown in Figure 5.2 was mounted at the 15° inclination with horizontal, 1700mm × 70 mm in tube dimension, Absorber surface area of 0.1m2, heat pipe was made from seamless copper tube of 8mm and absorber aluminum sun strip of 0.6mm, selective coating on the absorber surface is of aluminum nitride oxide (absorption a>0.92, Emission: e< 0.0), The glass tube was made of toughened borosilicate (thickness: 1.8mm, light transmittance: 91%), and can withstand hailstones of dia. 2” falling directly on them. The greatest advantage is that they can collect direct as well as diffused radiation, making them the ideal choice for those hot yet cloudy days.

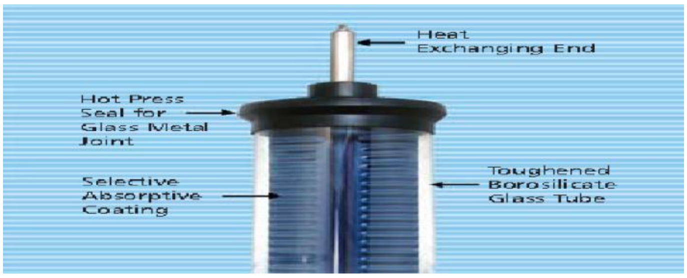

Fig.2.1. Evacuated Tube Heat Pipe (Mamata Energy)

The long side of the solar still is aligned in north-south direction. Schematic view of the solar still is shown in Figure 2.1. Photograph of This Experimental Setup shown in Figure 2.2,

Brackish water was taken with a galvanized pipe into the still. During the experiment the solar still was fed by brackish water and the maximum water depth was kept 2.5cm in the solar still. Experiment was carried on sunny days with variable collector area (0.1m2, 0.2m2, 0.3m2, 0.4m2) of solar collector at 1cm constant water depth. The temperatures of glass cover, ambient temperature, vapour temperature, inside water temperature of still and temperature of water outlet from ETHP solar collector was recorded. Thermocouples (J-type) were used to measure temperatures. Solar irradiation has been measured by solarimeter. Hourly collected distilled water was measured in measuring jar.

Experiments were carried out in month of March and April and amount of distilled water was weighted starting from 9am and until 5 pm.

Fig.2.2. Experimental Setup

3. Results and discussion

The experiment was carried out at the end of March and April. In the first Stage we take the results data of the Passive Solar Still at different water depth from 0.5cm, 1cm, 1.5cm, 2cm and 2.5cm. Solar radiation was measured by solar power meter in w/m^2, different temperatures has been measured by J-Type Thermocouples, which has been indicated the value of temperature in temperature indicator. From this results optimum water depth for the next active solar still has been taken 1cm and with this constant water depth effect of Number of ETHP – solar collector has been measured.

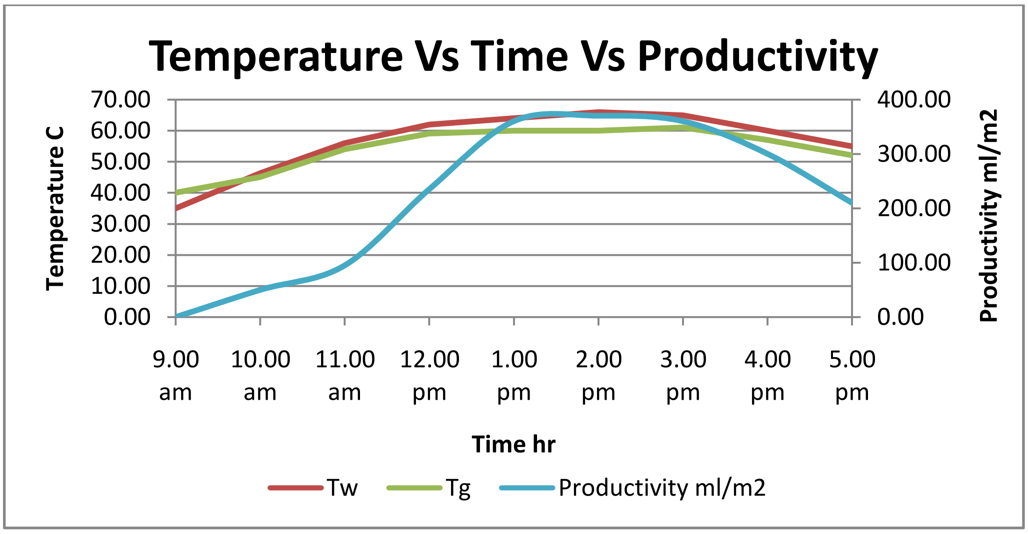

Fig. 3.1 Variations in Temperatures Vs Time Vs Productivity of solar still for 0.5 cm water depth

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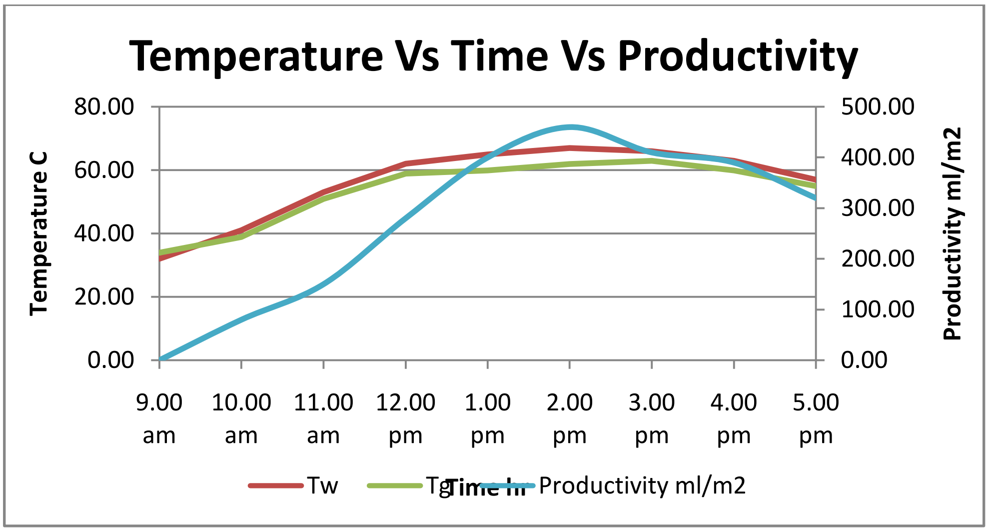

Fig. 3.2 Variations in Temperatures Vs Time Vs Productivity for 1 cm water depth

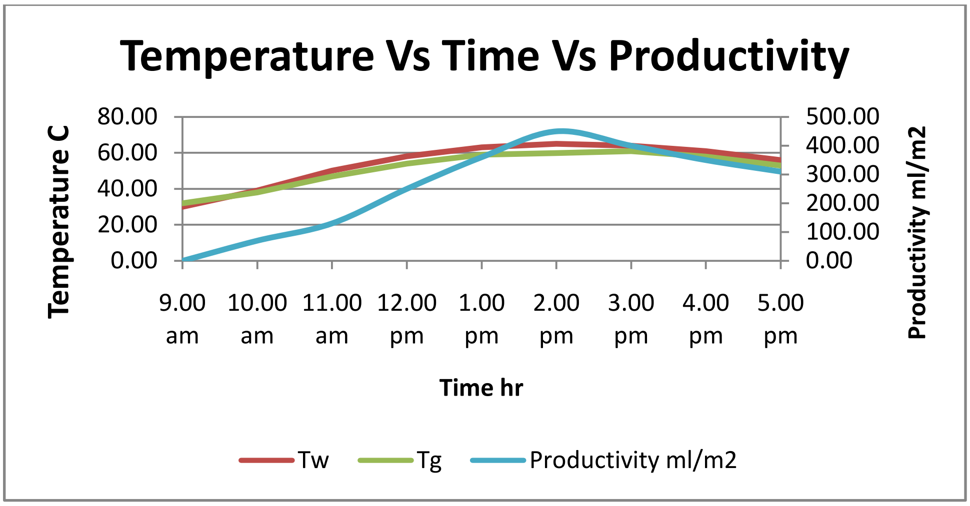

Fig. 3.3 Variations in Temperatures Vs Time Vs Productivity for 1.5 cm water depth

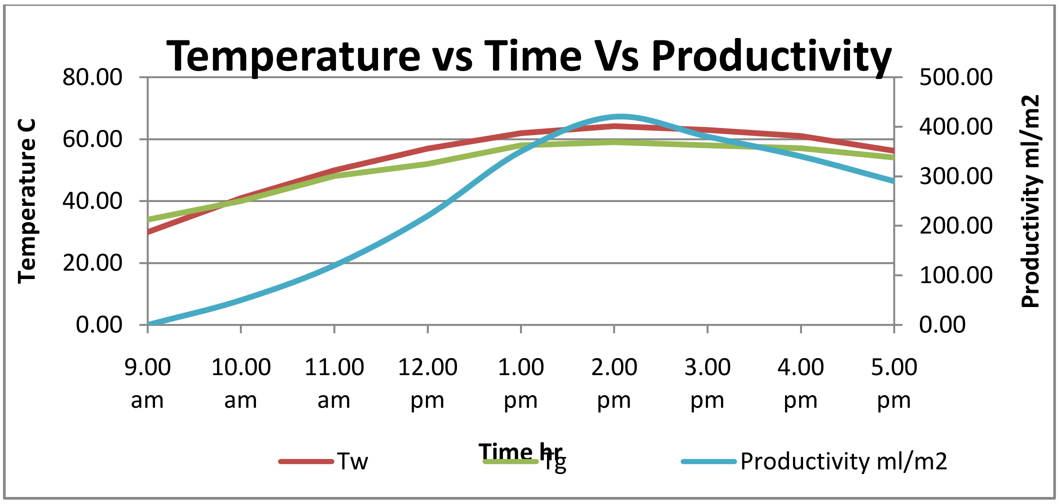

Fig. 3.4 Variations in Temperatures Vs Time Vs Productivity for 2 cm water depth

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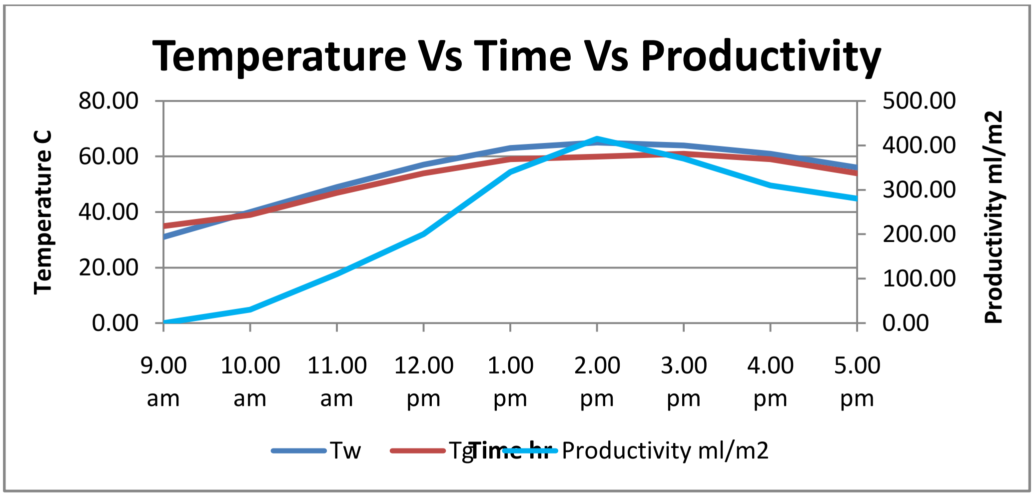

Fig. 3.5 Variations in Temperatures Vs Time Vs Productivity for 2.5 cm water depth

Figure 3.1 to Figure 3.5 shows that the variation in productivity with increasing the temperature difference between water surface and inner surface of glass cover. From this result data it has been observed that the productivity of the solar still increased with increase in temperature difference between water surface and inner surface of condensing cover. The maximum temperature difference between water surface and inner surface of glass cover has been observed from 1:00pm to 2:00pm and similarly the maximum productivity has been observed in that time.

In the above experiment, when the depth of water was increasing the temperature difference between water and inner surface of condensing glass cover is decreased at this time productivity of the solar still gradually decreasing for 0.5 cm, 1 cm, 1.5 cm, 2 cm and 2.5 cm respectively. Maximum productivity of the solar still comes from 12:00 pm to 2:00 pm.

In this experiment we got maximum productivity with 1 cm water depth and lowest productivity at 2.5 cm of water depth.

So that, in the next stage for attaching a ETHP solar collector for Active solar still with natural convection the optimum value of water depth for the experiment taken as 1 cm.

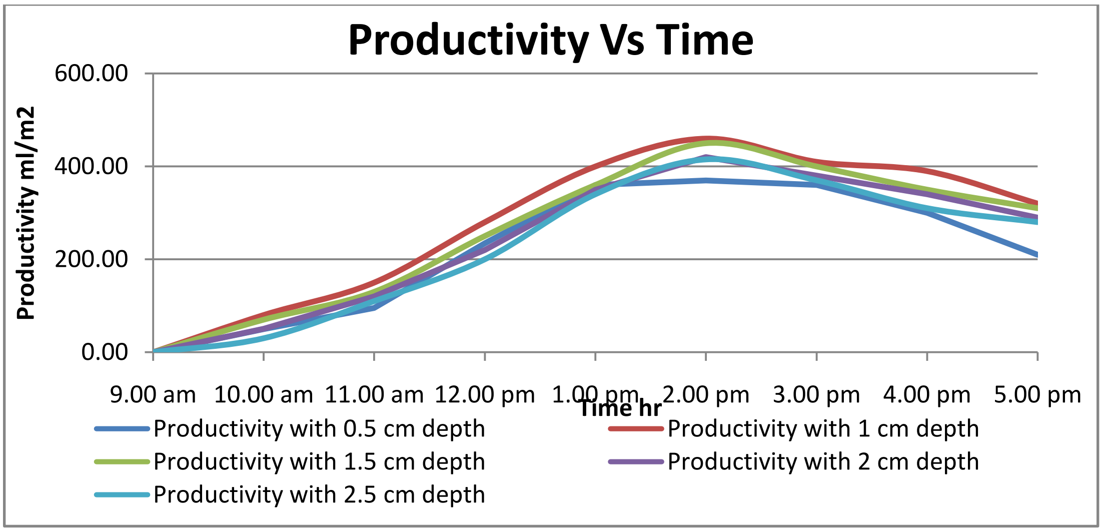

Fig. 3.6 Variations in Productivity Vs Time for different water depth in Passive Solar Still

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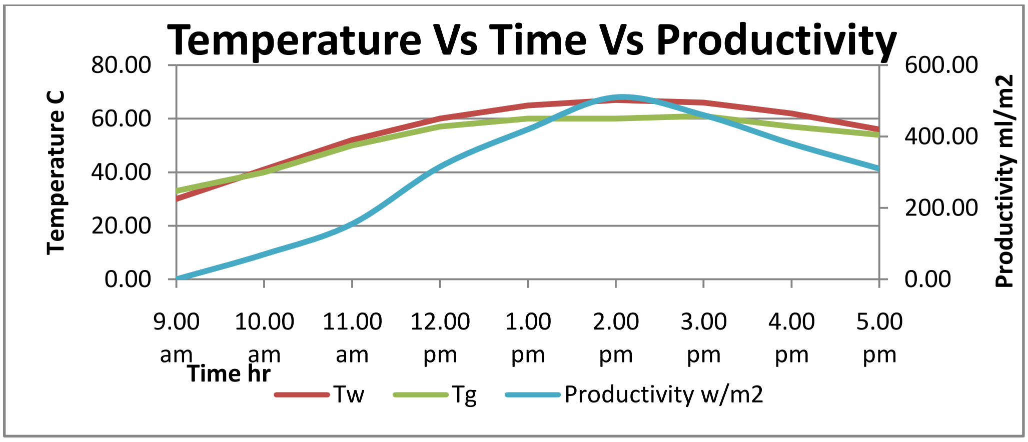

Fig. 3.7 Variations in Temperature Vs Time Vs Productivity for 1 ETHP attached with 1cm water depth Active Solar Still

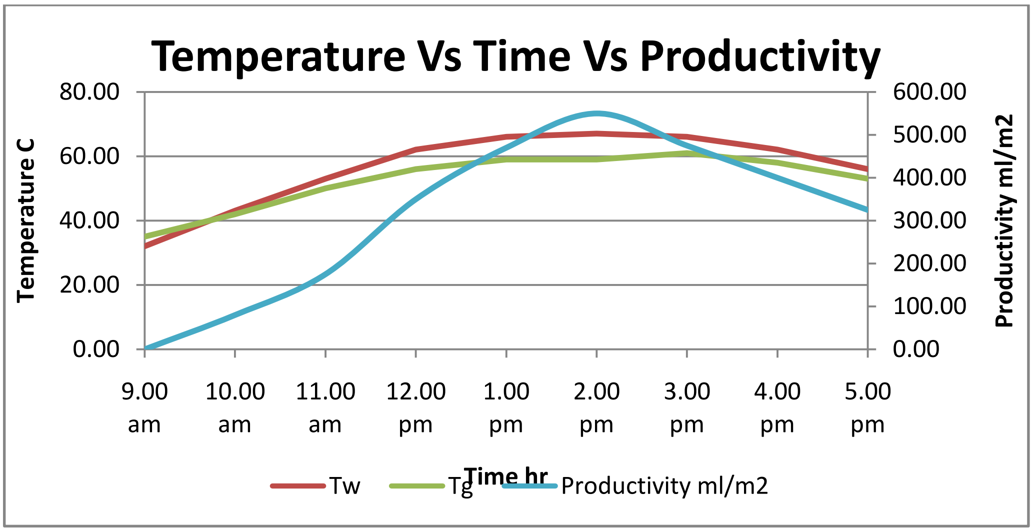

Fig. 3.8 Variations in Temperature Vs Time Vs Solar Radiation for 2 ETHP attached with 1cm water depth Active Solar Still

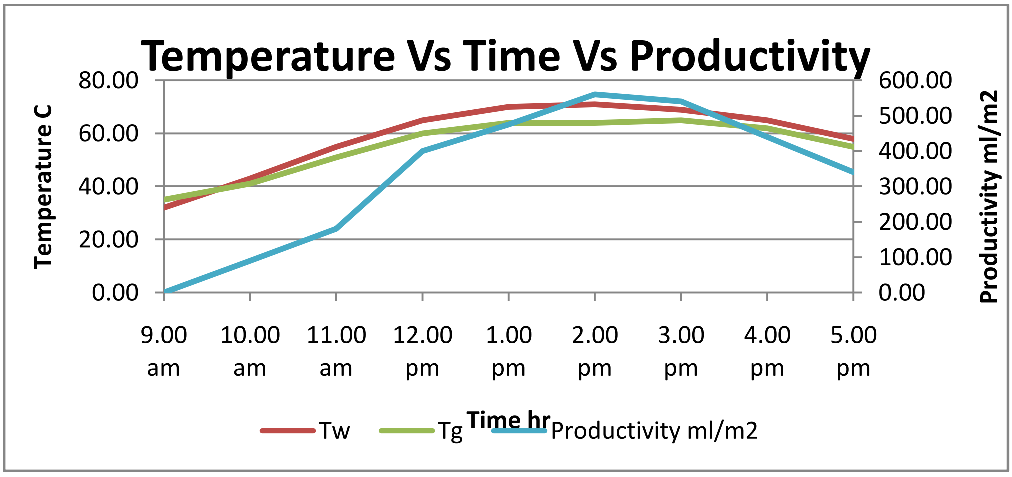

Fig. 3.9 Variations in Temperature Vs Time Vs Productivity for 3 ETHP attached with 1cm water depth Active Solar Still

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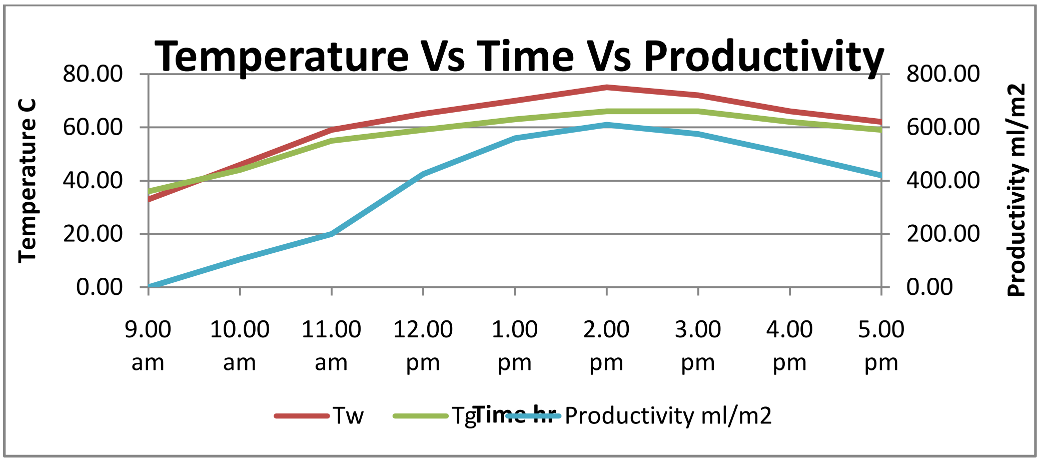

Fig. 3.10 Variations in Temperature Vs Time Vs Productivity for 4 ETHP attached with 1cm water depth Active Solar Still

Figure 3.6 to Figure 3.10 shows that the hourly productivity of distilled water in relation to various temperature between 9:00am to 5:00pm. So from Figure 3.10 the maximum productivity in active solar still has been observed at 2:00pm for 1, 2, 3, and 4 ETHP solar collectors attached. From this observation of experiment 9:00am to 5:00pm hour of the day the temperature difference between water of basin inner surface of glass cover was 9:00am and maximum at the 2:00pm. After peak value the ambient temperature will reduce and solar radiation also reduced.

So for that temperature of water in the basin and glass cover also decreases. From the part of this study it has been observed that the temperature difference between basin water and inner surface of glass cover of the still will increase then the productivity of the active solar still increase. After the peak value of productive output the productivity was continuously decreases.

But, when the ETHP solar collector area increases temperature of basin water also increases. So the productivity is increases.

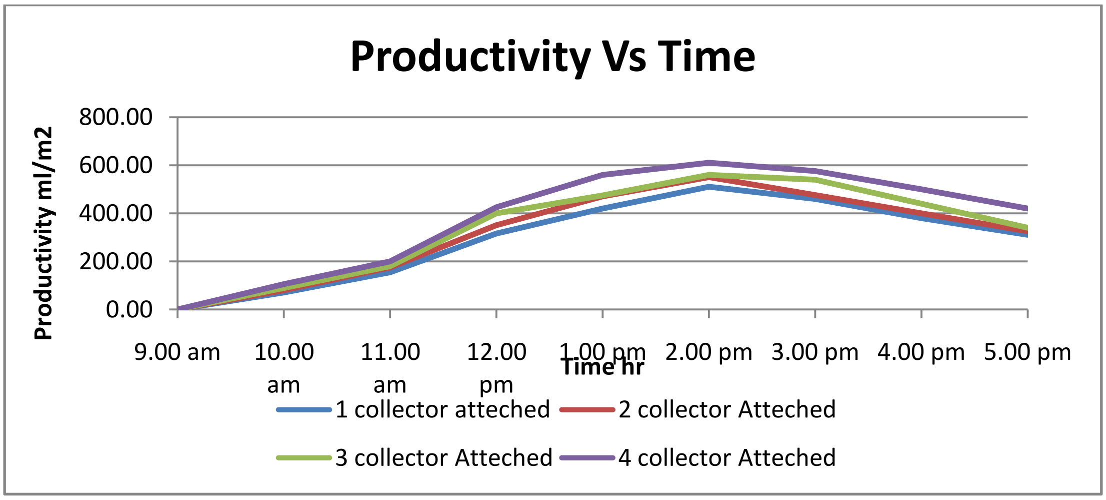

Fig. 3.11 Variations in productivity Vs Time for increasing solar collector area in active solar still

Figure 3.11 shows that the productivity variation with respected to the time for collector area increased from $0.1m^2$ to $0.4m^2$. From this figure it has been observed that the productivity of active solar still increased with increasing the collector area and decreasing with decreasing in solar radiation.

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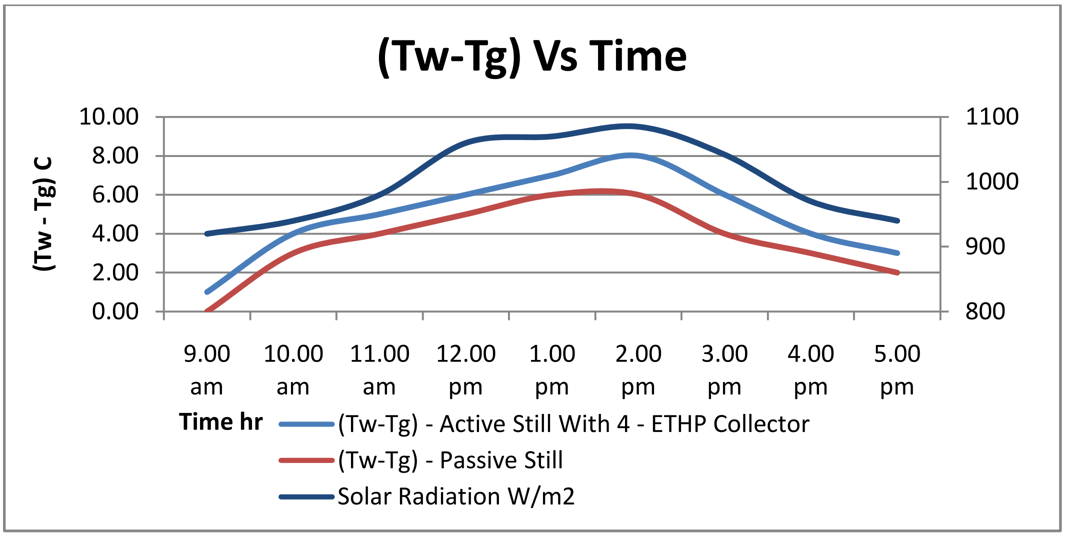

Fig. 3.12 Variation in Temperature difference between water surface and glass cover with solar radiation and time for a same day.

Figure 3.12 shows that the increment in temperature difference between water surface and inner surface of glass cover of active solar still with 0.4m^2 of solar collector area and passive solar sill for same water depth and for same solar radiation during a single day. From this study it has been observed that the active solar still with natural convection by 0.4m^2 solar collectors attached to the basin have higher temperature difference as compared to the passive solar still.

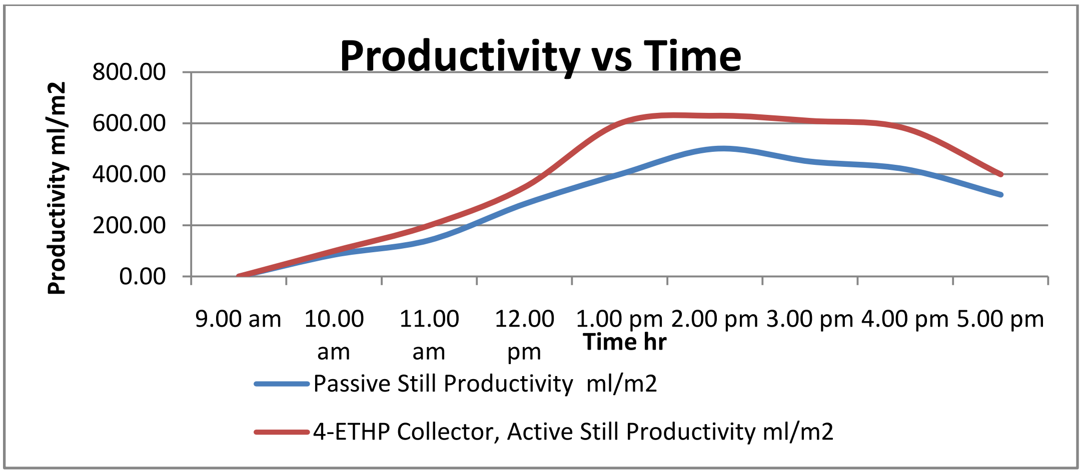

Fig. 3.13 variations in Productivity Vs time for active and passive solar still for same day.

From this Figure 3.13 it has been observed that the productivity of active solar still is higher as compared to the passive solar still for a same water depth and for a same solar radiation during a same day. Maximum productivity for both systems has been observed during 1:00pm to 2:00pm.

Conclusion

This Experimental study has been carried out to increase the productivity of solar still with high effective solar collectors and from this experiment it has been observed that active solar still with ETHP solar collector have higher productivity as compared to the Passive solar still. Also, productivity of solar still has been increased with decrease in water depth. Optimum value of water depth to go for active solar still was 1cm. The productivity of Active solar still has been increased with increasing solar collector area. For the same day and same solar radiation active solar still with ETHP solar collector have higher productivity as compared to passive solar still.

Scope of Thesis Work

To measure the effect of ETHP solar collectors attached with force circulation of water to the solar still and compare it's results with natural circulation and with passive solar still.

To measure the effect of ETHP solar collector on Active solar still and compare its results to the different collectors attached to the active solar still such as flat plate collector, evacuated pipe collector, etc.

Measure the effect of ETHP solar collector in Multi stage solar still.

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