International Journal of Emerging Engineering Research and Technology
Volume 2, Issue 7, October 2014, PP 240-247
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Experimental Analysis of Double Effect Type Solar Still Integrated with Liquid Flat Plate Collector

Nithin P. K.[1], Hraiharan.R[2]

[1]Department of ME, LBS College of Engineering, Kasaragod, India (Post Graduate Researcher)
[2]Department of ME, LBS College of Engineering, Kasaragod, India (Assistant Professor)

Abstract: *Solar energy has the greatest potential of all the sources of renewable energy. Solar energy is available in abundance and considered the easiest and cleanest means of tapping renewable energy. A device which will convert the dirty/ saline water in to pure/ potable water using the renewable source of energy called solar still. Solar still method of distillation is simple, cost effective and economically friendly. In this paper an experiment on fabricated double effect type solar still was conducted and results are analysed graphically.*

Keywords: *Double Effect Type Solar Still, Liquid Flat Plate Collector (LFPC), Internal and External Heat transfer.*

1. Introduction

Solar energy is available in abundance and considered the easiest and cleanest means of tapping renewable energy. All forms of energy on the earth are derived from sun. However, the more conventional forms of energy. No significant polluting effects. Only one percentage of earth's water is in a fresh, liquid state and nearly all of this is polluted by both diseases and toxic chemicals. For this reason, purification of water supplies is extremely important. A device which will convert the dirty/ saline water in to pure/ potable water using the renewable source of energy called solar still.

Solar still is an airtight basin that contains saline or contaminated water (ie feed water). It is enclosed by a transparent top cover, usually of glass or plastic, which allows incident solar radiation to pass through. The inner surface of the basin is usually blackened to increase the efficiency of system by absorbing more of the incident solar radiation. The feed water is heated up, starting to evaporate and subsequently condensed on the inside of the top cover, which is at lower temperature as it is in contact with the ambient air. The condensed water (ie. the distillate) flowing down the cover is collected in a collecting trough and then stored in a separate Basin. According to number of glass cover used solar still can be classified as two types – Single Effect Type and Double Effect Type.

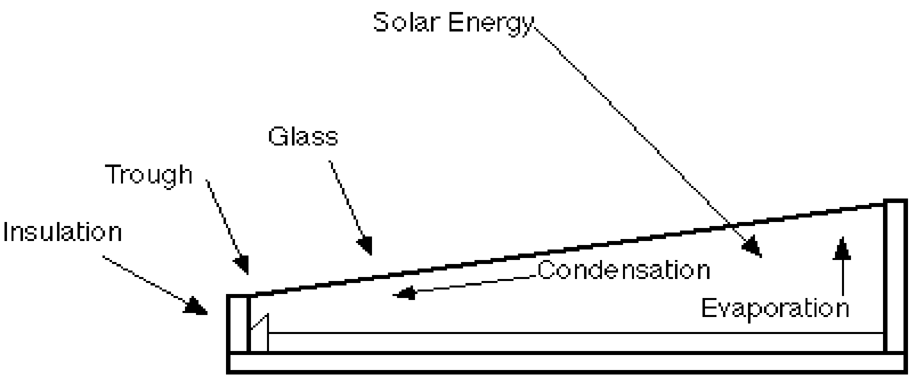

Fig1. *Single effect type solar still*

Single Effect Type is most common in conventional solar still. It generally consists of a basin with black bottom having trays for saline water with shallow depth. A transparent air tight glass or a plastic slanting cover encloses completely the space above the basin. Incident solar radiation passes through the transparent cover and is absorbed by black surface the still. Brackish water is then heated and water vapours, condenses over the cool interior surface of the transparent cover. Condensate flows down the glass and gets collected in troughs installed as outer frame of solar still. Distilled water is then transferred in to storage tank. The system is capable of purifying sea water with salinity of about 30,000 mg/litre. Production rate is about 3 litres/m2 /day in a well-designed still on a good sunny day.

Double Effect Type Solar Still consists of two storage basin type solar still with glass covers for both basins. The first basin glass cover is used as the base for the second basin with the advantage that heat of condensation of bottom basin can be used to heat the water on top basin, so that the output yield increases more than the single effect type solar still. In the case of double effect type solar still, upper and bottom solar still separated by slopped glass. Heat transfer between top glass and the basin water by evaporation and the heat transfer between top glass and bottom basin by radiation. Double Effect Type Solar Still has advantage of more amount of distilled water produced than the Single Effect Type.

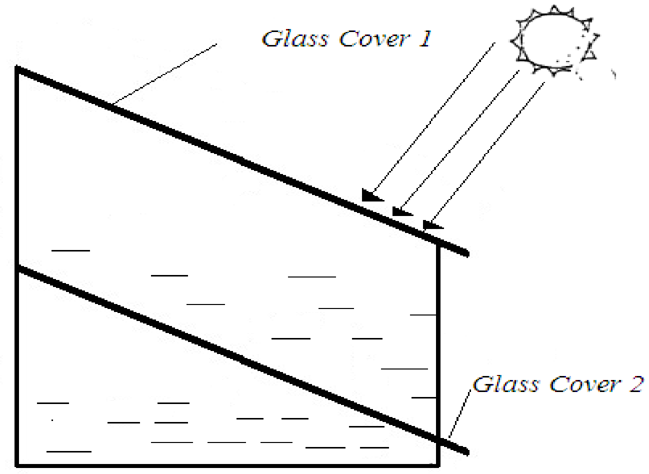

Fig2. *Double effect type Solar still*

2. Flat Plate Collector

A simple flat plate collector has a coated flat heat absorber plate with channels or tubing in contact with the plate for passage of working fluid. Transparent covers of glass sheet are placed on the upper side of absorber plate to reduce thermal losses. Thermal insulation is provided between the absorber plate and the casing. The panel is installed on a support structure. Flat plate collectors absorb both beam and diffuse components of radiant energy. Hence they can function without need for tracking the sun. Also they absorb energy even during cloudy and hazy atmosphere. In this experiment liquid flat plate collector consists of a toughened glass cover of thickness 5 mm. an absorber plate made up of copper having length 1m, width 0.5 m and thickness 1mm is placed 7cm below the glass cover. Absorber tubes (5 by 8 inch) made of copper is weld to the absorber plate placed at the top. The absorber surface reduces convection and radiation losses to the atmosphere and the back insulation to reduce the conduction losses. Set up consist total 7 numbers of copper tubes each of length 1m placed at 7cm from one another. These copper tubes are interconnected by using ‘T’ and ‘Elbow’ joints (12Tjoints and 2 Elbow joints). Provision is taken from first and last of copper tubes having a length of 0.15m and is integrated with holes of bottom basin of still. Aluminium foil of 0.5 cm is placed 1cm below the absorber tubes to reduce the bottom heat loss from the LFPC. Wood material insulation of thickness 2cm is provided at bottom and sides of collector to prevent heat losses. Figure shows FPC coupled with solar still, and most of the analysis of this study is concerned with this geometry. FPC is almost always mounted in a stationary position with an orientation optimized for the particular location for the time of year in which the solar device is intended to operate.

3. Experimental Setup

The experimental set up consists of a double slope solar still coupled with a flat plate collector. Solar still has a black painted FRP basin which is filled with brackish water. The flat plate collector is integrated with double slope solar still in such a way that the hot water from the collector plate under natural circulation mode lay out of experimental set up given in figure 4.1.

Fig 1. *Experimental Setup*

The double slope solar still is placed in north-south direction whereas the collector plate faces south inclined at 270.to receive maximum possible radiation. The collector plate absorbs solar energy and transfers energy to water flowing through tubes.

Solar still and flat plate collector are mounted on iron stands. Outdoor experiments are conducted in LBS, Kasaragod, Kerala starting from 16th April 2014 to 7th May 2014 at various water depths. Hourly ambient temperature, inner and outer glass cover temperature for the basins, solar intensity, and distillate yield are measured for 8 hours. Accumulated yield at night is measured at 8 am in the morning.

3.1. Working of the Solar Still

The set up consists of a double slope solar still integrated with flat plate collector. The basin liner inside the solar still which carries the water mass has two holes of 3 cm each. Two heat resistant Teflon pipes are joined to a flat plate collector through these holes. It consists of two separate holes of 3 cm size for the saline water entry and also consist two big holes for the collection of salt accumulated. Out of the Teflon pipes one acts as inlet pipe to flat plate collector and the other one is the outlet pipe of flat plate collector to the solar still.

3.2. Measured Parameters

Following major parameters were measured during the experiment

IT = total solar radiation (W/m2)

T1g = top glass cover temperature (0C)

T2g = bottom glass cover temperature (0C)

Tb1 = upper basin water temperature (0C)

Tb2 = bottom basin water temperature (0C)

Ta = ambient temperature (0C)

Tc = temperature of flat plate collector (0C)

m ew1 = volume of water collected in first basin (kg/m2)

m ew2 = volume of water collected in second basin (kg/m2)

3.3. Experimental Plan

Experiments are planned to conduct at the Mechanical Engineering Department block of LBSCE, Kasaragod during the months April and May. Experiments are conducted on the days which are selected in such a way that there should have clear sky conditions. The cloudy days present in these months are excluded. The experiments are conducted for different water depth at different time intervals of different days of April and May. For these experiments the condition for best performance of solar still is obtained in terms of yield. The selected days for conducting the experiments have similar pattern of global radiation.

1. EXPERIMENTAL RESULTS

Temperature distributions in the double effect type solar still are shown in Figure 2. The maximum yield of the solar still correlates very well with the temperature distribution of the solar still, where maximum temperature in the solar still occurs at around 1.00 pm with the highest temperature 47.60C for that of the bottom tray temperature and decreased for the upper tray temperature. From the graph plotted it is understood that minimum bottom water temperature of 39^{0}C occurs at 8.00 am. The temperature is minimum for first glass cover (340C), which is slightly greater than the ambient temperature. It is also observed that all the four temperature readings taken has higher value after 1.00 pm compared to the values before 1.00pm.

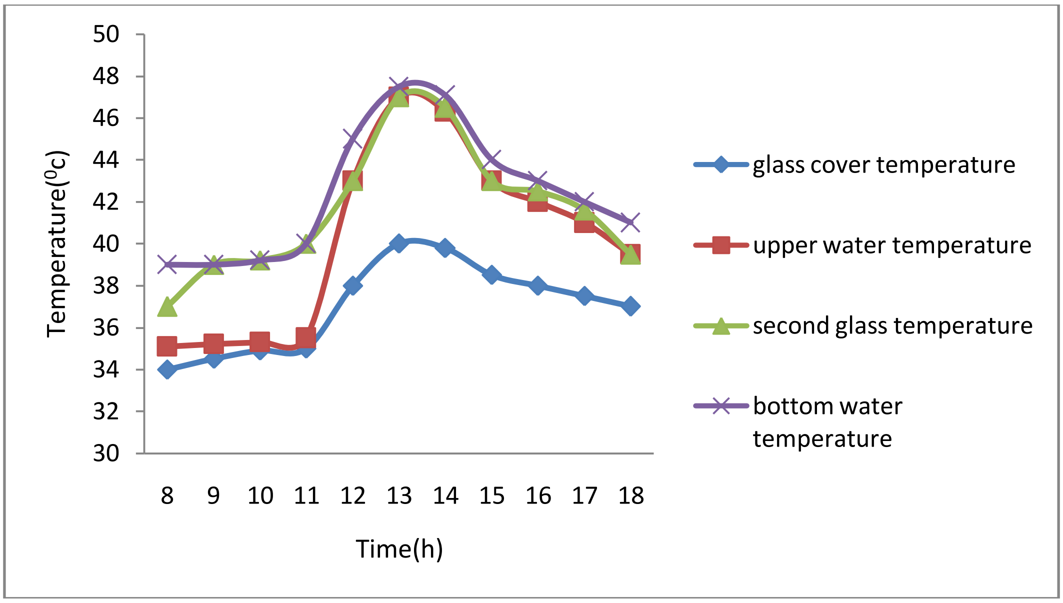

Fig2. *Temperature vs. time graph*

From Figure 3 it is clear that maximum still output occurs at 2.00pm having a value of 0.48kg/m2 h and has minimum of 0.01kg/m2 h corresponds to 8.00am. The still output increases gradually from 8.00am to 1.00pm and then get decreases to6.00pm.

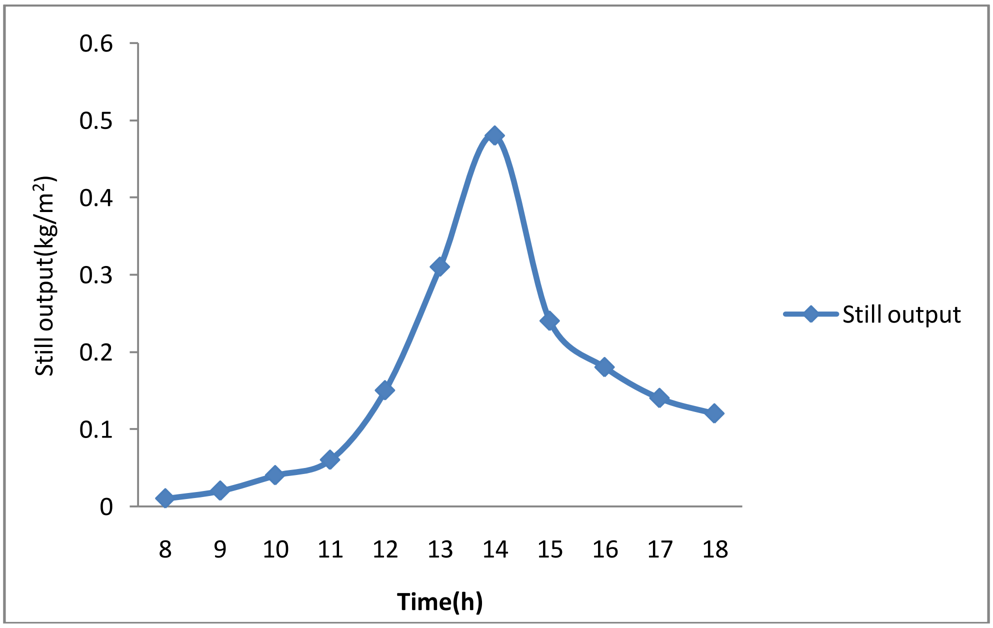

Fig3. *Still output vs. time graph*

The hourly water yield at different time interval of the double effect solar still is shown in figure 7.3. It can be seen from the figure that the maximum yield of 0.502kg/m2 of double effect type solar still occur at 2.00 pm. The difference of contributions between the two trays is significant during the peak period of production of the still with the first tray producing 70% of the total yield at 2.00pm. The maximum yield of the solar still correlates very well with the temperature distributions of the solar still, where the maximum temperatures in the still occur at around 1.00 pm. With the highest temperature observed for the bottom tray compared to the upper one. The temperature is minimum for both the tray at 8.00am and it gradually decreases after 1.00pm and have closer value with respect to one another.

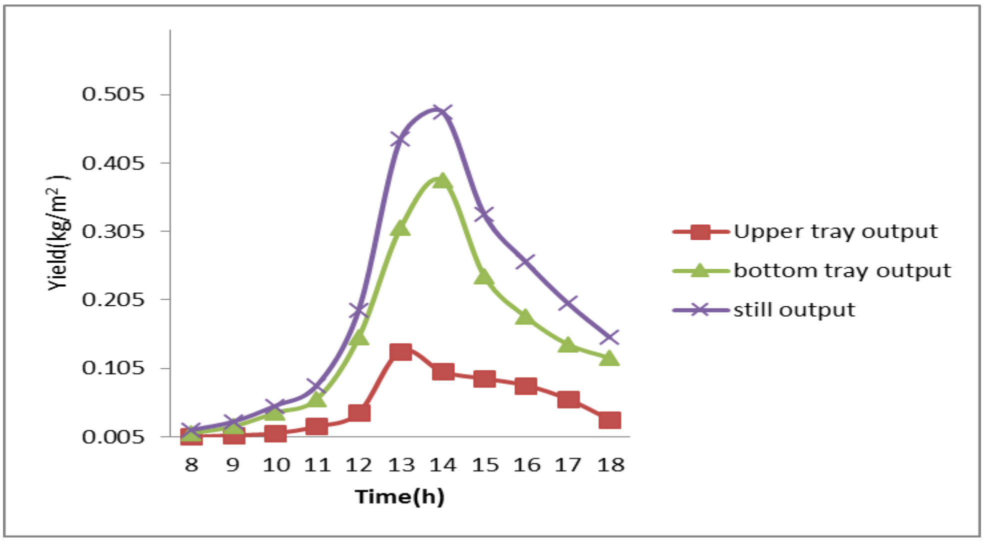

Fig4. *Still yield vs. time graph*

Figure 5 shows the average daily output of the double effect type solar still when the cover tilt is at optimum angle of 270. The experiment was conducted at six days of two different months (April and May). The maximum solar still yield occurs in April, where the intensity of radiation is also maximum compared to May. The still output for April is maximum for an output of 5.2kg/m2 d and for May is about 4kg/m2 d.

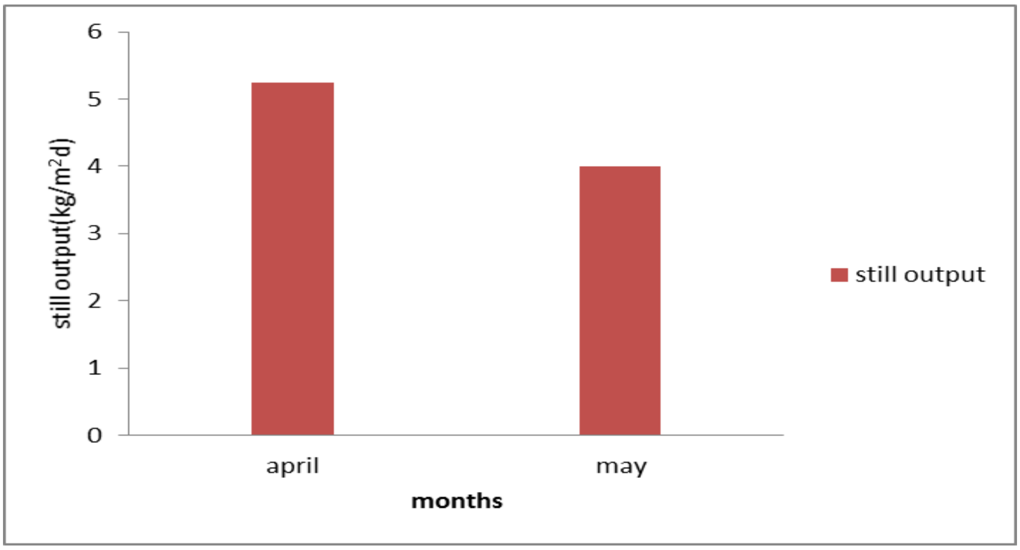

Fig5. *Still output vs. month*

Figure 6 shows the effect of varying bottom water basin depth while maintaining the upper water tray at a fixed depth. For a water depth of less than 0.05m, varying the depth of bottom tray tends to give the maximum yield in the double effect type solar still. This is due to the shallow depth which increases the evaporation from both the trays and hence increases the yield. As the depth of water varies beyond 0.05m varying the depth in the bottom tray tend to result in a lower still yield.

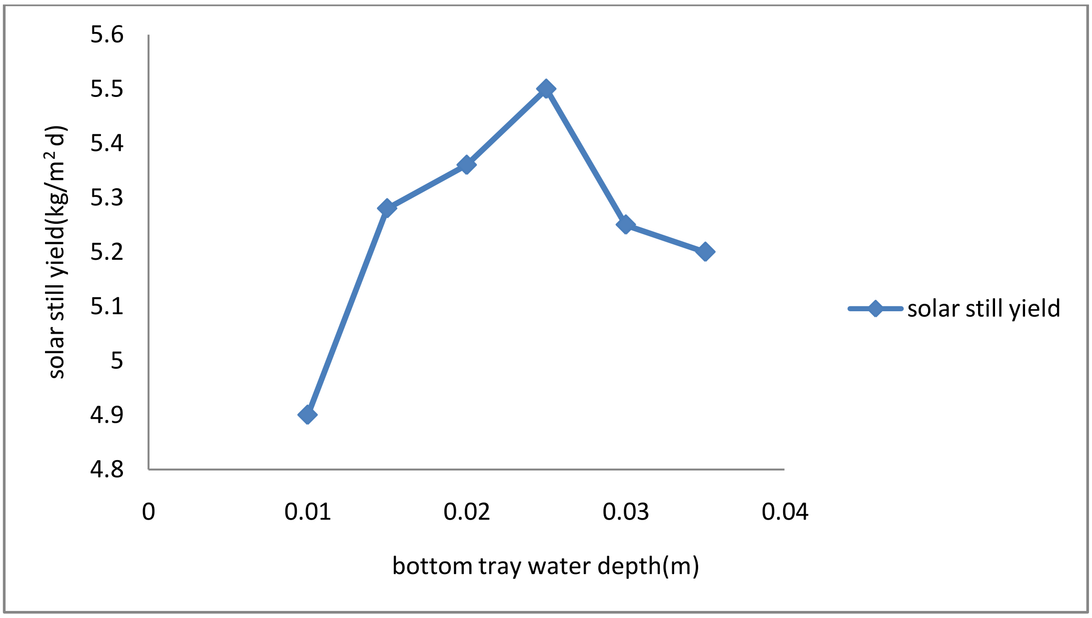

Fig6. *Solar still yield vs. water depth*

Figure 7 shows the effect of predicted solar radiation intensity at different time intervals during the month of April 2014 and May 2014. From the graph it is shown that maximum solar intensity of 699.78 W/m2 occurs at 12 pm. But the maximum solar still yield occurs at 2pm. The difference is due to the time lag of the system.

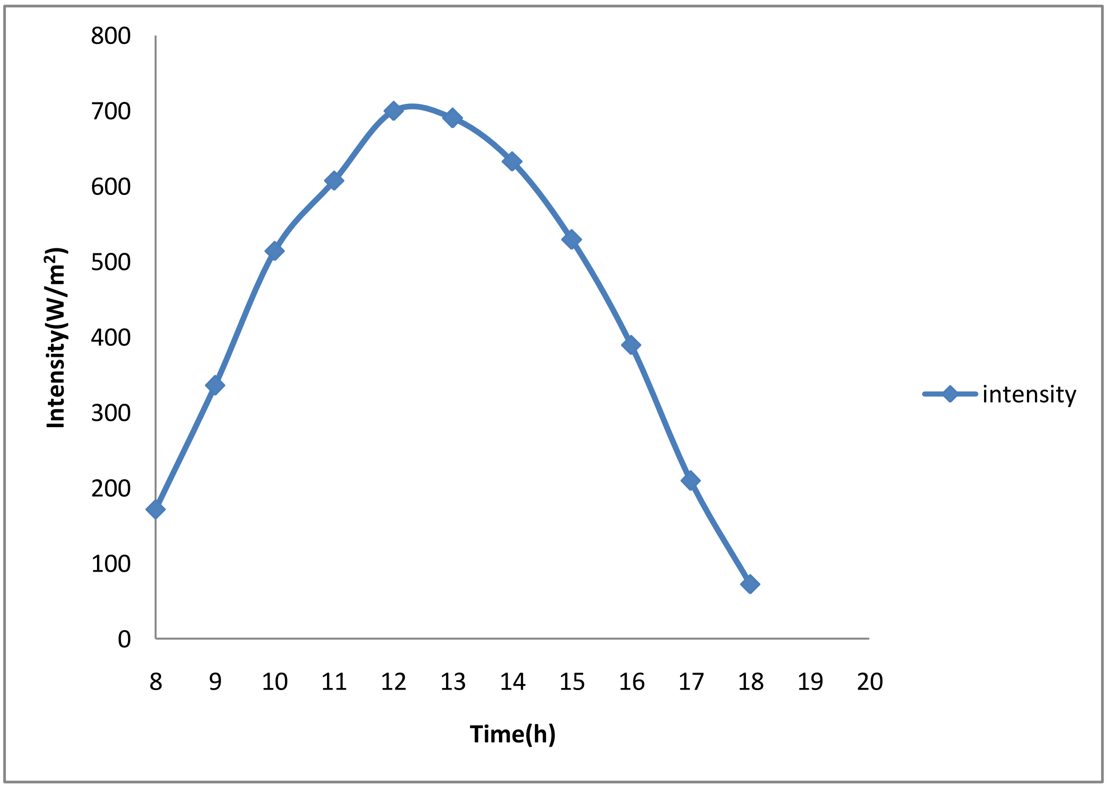

Fig 7. *Solar intensity vs. time*

Figure 8 shows the effect of intensity of solar radiation on still output. From the graph it is observed that solar intensity reaches its maximum value at 12.00 pm, while still output reaches its maximum at 2.00 pm. After that both suddenly get decreased.

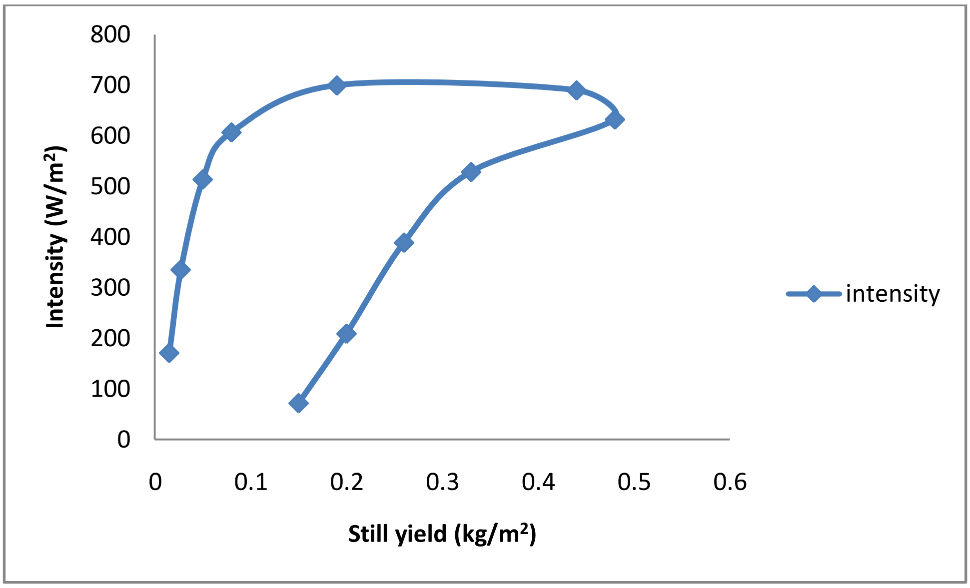

Fig8. *Solar intensity vs. still yield*

1. CONCLUSIONS

The operation of the double effect type solar distillation system coupled with a flat plate collector has been investigated experimentally. Comparison of the output between upper and bottom tray was studied. Comparison of still yield at different months (April and May) was also plotted at different time intervals. Experiments were conducted at different water depths. It is observed that the still output is greater from bottom tray compared to top one in the climatic conditions of Kasaragod. While taking time readings on both the glass bottom basin glass cover has got higher temperature than the upper basin water. Hence evaporation rate is higher in bottom still which leads to more output from bottom basin.

From Temperature vs. Time graph, it is observed that maximum temperature occurs at bottom glass cover than the upper one, since the heat from the liquid flat plate collector is distributed entirely in the bottom glass cover. Bottom water temperature is higher than the upper water temperature, since the bottom basin is directly coupled to the liquid flat plate collector. Maximum temperature occurs 1.00 pm for both upper and bottom basin. From still yield vs. time graph it is observed that still output is maximum at 2.00 pm and then decreases towards 6.00 pm. But the intensity of radiation is maximum at 12.00 pm. Difference between these two is due to the time lag for heat transfer within the system. Output from the bottom tray is greater compared to the output from the top one, since the bottom tray is directly coupled to the liquid flat plate collector and hence the maximum heat transmission. It was also observed that intensity of radiation is maximum for April month than May. So the output is also maximum for April.

For a water depth of less than 0.05 m, varying the depth of bottom tray tends to give the maximum yield which is due to the shallow depth increases the evaporation from both the trays and hence increases yield. The optimum water depth is found to be 0.025 m corresponds to the maximum solar still yield. Form still yield vs. intensity graph, it is found that still yield is directly proportional to the intensity of solar radiation. Theoretical value of still output is 3.15kg/m2 and the actual value obtained from observation is 2.64kg/m2. The difference may be due to minor leakage.

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AUTHORS' BIOGRAPHY

Nithin P. K. is presently doing M Tech in Thermal and Fluids Engineering at LBS College of Engineering, Kasaragod.

Hariharan.R is currently working as Assistant professor in Mechanical Engineering Department, LBS College of Engineering, Kasaragod.