International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 07, July-2015

Experimental Analysis of Single Basin Single Slope Acrylic Solar Still with Fins

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***Abstract*—Scarcity for water exists in many countries even though three fourth of the earth is covered by water. The reason behind this is the rapid growth of industry and population worldwide. Solar still is the only efficient solution for water problem in hot climatic conditional areas where there is scarcity of water and electricity. Solar still is a very simple solar device that is used for converting the available brackish water (Salt water) into potable water. The aim of this project is to analyze the performance of single basin single slope solar still by using acrylic sheet as casing as it has very low thermal conductivity of 0.2 W/mk, it helps in retaining the heat inside the solar still. The Aluminium fins are used as heat storage material since it has a high thermal conductivity of 167 W/mk which helps in conducting more heat to the brackish water. The working of the solar still is that when the solar radiations from the sun enter inside the solar still through the glass cover of thickness 3 mm due to which the aluminium fin which has higher thermal conductivity gets heated and conducts heat to the brackish water due to which pure water evaporate into water vapour and condenses on the glass cover and then gets collected in the water collector and passed into the measuring beaker through the outlet tube. It was found out that about 505 ml of water is obtained by placing the solar still on a sunny day from 7.00 AM to 7.00 PM.**

Keywords—Condensation, Vaporization, Acrylic, Solar still, Heat storage material.

I. INTRODUCTION

Water is essential for all life forms on earth — human, plants, and animals. Water is one of the most abundant resources on earth, covering three fourths of the planet's surface. About 97% of the earth's water is salt water in the oceans and the remaining 3% (about 36 million km$^{3)}$ is fresh water contained in the polar region (in the form of ice), ground water, lakes and rivers, which supply most human and animal needs. Less than 1% fresh water is within human reach. Even this small fraction is believed to be adequate to support life and vegetation on earth. Nature itself provides most of the required fresh water, through hydrological cycle. A very large-scale process of solar distillation naturally produces fresh water. The essential features of this process are thus summarized as the production of vapours above the surface of the liquids, the transport of vapours by winds, the cooling of air–vapour mixture, condensation and precipitation. However, rapid industrial growth and a worldwide population explosion have resulted in a huge rise of demand for freshwater, both for household needs and for crops to produce adequate quantities of food. Added to this is the problem of the pollution of rivers and lakes by industrial wastes and the large amounts of sewage discharge. On a global scale, human–made pollution of natural sources of water is becoming one of the greatest causes of fresh water shortage.Then provision of freshwater is becoming an increasingly important issue in many areas of the world.

II. LITERATURE SURVEY

Tiwari et al. reduced the glass cover temperature by an intermittent flow of cooling water on the cover of single basin solar still. The glass cover temperature was slightly higher than the ambient temperature and the flowing water temperature over the glass cover remained of the same order as ambient temperature.[1] Lawrence et al. investigated the effect of heat capacity on the performance of solar still with water flow over the glass cover. Flowing water over the glass cover reduces the water temperature as well as glass temperature. Reduction in basin water temperature slightly reduces the evaporation rate. Reduction in glass temperature increases the condensation rate, due to which productivity of the still improved.[2] Bilal a. Akash, mousa s. Mohsen, omar osta, and yaser elayan have conducted experimental analysis by using absorbing black rubber mat, black ink and black dye. The still used in the study was a single-basin solar still with double slopes and an effective insulation area of 3 m. It was found by using absorbing black rubber mat the daily water productivity increased by 38%. Using black ink increased it by 45%. Black dye was the best absorbing material used in terms of water productivity. It resulted in an enhancement of about 60%.[3] Dr.s.shanmugam has conducted experimental analysis using single slope single basin solar still which is provided with a dripping arrangement to pour saline water drop by drop in the basin. The system has been tested with dripping of saline water and different energy absorbing materials like pebbles, black granite stones, and concrete stones. It has been found that the concrete stones in the basin with dripping of saline water to maintain least water depth have validated with the experimental results. Experiments were conducted in climate conditions of Chennai in Tamilnadu from February to October. The experimental result which use of absorbing materials high production rate in concrete stones with compared other energy absorbing materials.[4] Ehssan m.r. nassef , mohamed z.el-abd ,yahya a.el-tawil have studied the efficiency of a solar still. The basic idea of the work is to check the production of a simple still for solar distillation that has no moving parts and does not use any other source of energy. The still is basically a rectangular basin filled with black or blackened solid material that acts as the solar energy collector. Experiments were carried out during the months from May to August. The different materials used as collecting media are black plastic balls made of polyamide with different diameters, steel balls painted black with a diameter of 5mm and black or dark gravel with an average diameter of 6.4mm. The highest volume of distillate water was obtained with 4mm diameter black plastic balls, this rate was 4 m^3/m^2 per day with an average efficiency of 49%. It was also found that solids with high heat capacity gives better rates of distillation and higher efficiency in the afternoon hours. Finally the still was used for desalination of sea water and gave almost the same rate of production at the best conditions.[5] Dr. S. Shanmuga Priya 1 & Umair Iqbal Mahadi had analysed the performance of single basin solar still by using Ink and dye as heat storage materials and results were compared against distillation with both absorbing materials and found out that using dye in water gave better result as compared to ink.[6] Pankaj K. Srivastava1, S.K. Agrawal & Abhay Agrawal had analysed the performance of the still with the easily obtainable absorber materials such as jute fabric and cotton cloth was compared. It was observed that the floating porous absorber type still performed at higher operating temperatures and gave better yield with the jute fabric as compared to cotton cloth with around 12% better distillate output.[7] Abdullah, et al, mazen m. Abu-khader have conducted experimental analysis of single slope solar still using different types of absorbing materials to examine their effect on the yield of solar stills. These absorbing materials are of two types: coated and uncoated porous media (called metallic wiry sponges) and black volcanic rocks. Four identical solar stills were manufactured using locally available materials. The first three solar stills contain black coated and uncoated metallic wiry sponges made from steel quality AISI 430 type, and black rocks collected from Mafraq Area in north-eastern Jordan. The fourth still is used as reference still which contains no absorbing materials (only black painted basin). The results showed that the uncoated sponge has the highest water collection during day time, followed by the black rocks and then coated metallic wiry sponges. On the other hand, the overall average gain in the collected distilled water taking into the consideration the overnight water collections were 28%, 43% and 60% for coated and uncoated metallic wiry sponges and black rocks respectively.[8]

III. COMPONENTS OF THE SINGLE SLOPE SOLAR STILL

A. *Acrylic box*

The Acrylic box is the outer casing of the solar still, which acts as a thermal insulator helps in retaining the heat generated inside the acrylic box which leads to the increase in the rate of evaporation of the water which is poured into the solar still in the form of salt water or brackish water.

B. *Aluminium fins*

Aluminium fins is used as a heat storage material as it has thermal conductivity (160 W/m·K) and also good corrosion resistance. It's high thermal conductivity helps in conducting more heat to the salt water or brackish water and it's corrosion resistance helps in preventing it from corroding when placed in the salt water or brackish water.

C. *Glass cover*

The top cover of the acrylic box is taken as glass as it allows more amount of solar radiations to pass inside the solar still as it increases the absorption of solar radiations by the aluminium fins

D. K type thermocouples

The thermocouples are used to measure the variation of temperature of the Aluminium fins, water, water vapor, glass bottom surface and ambient temperature on hourly basis.

E. *Six point temperature indicator*

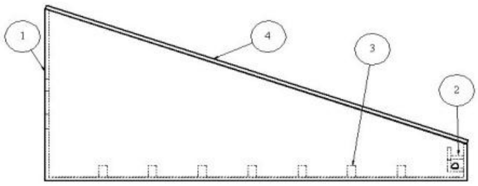
The six point temperature indicator is used for displaying six temperatures based on the location of the thermocouples which can be seen by adjusting the knob provided at the front.

F. *PU tube and beaker*

The PU tube is used as a outlet tube for collection of the distilled water and also as a inlet tube for entry of the brackish water or salt water into the solar still. A beaker is used for measuring the amount of distilled water collected.

IV. FABRICATION

The Acrylic box is fabricated by pasting the acrylic sheets into the box as designed using a acrylic cement solvent, then the aluminium fins is placed inside the acrylic box, the aluminium fins is fabricated by welding the aluminium rods of diameter 10 mm and of length 15 mm on to surface of aluminium sheet of thickness 1 mm by gas welding such that 49 aluminium rods are equally spaced from each other and it is painted in black colour to enhance the heat absorption. The water collector is pasted on the lower side of the acrylic box with a inclination of 2º by using acrylic cement solvent, the water collector is in the form of L shape. A glass cover of thickness 5 mm is pasted on the top of the acrylic box with a inclination of 20º by using silicone paste. A hole of 20 mm is drilled and the inlet pipe is fitted in it and a hole of 10 mm is drilled and the outlet PU tube is fitted in it. A hole of 16 mm is drilled and the thermocouples are passed inside and placed at five different locations using m-seal and also m-seal is applied in the hole to make the solar still in airtight condition. Silicone paste is applied to all the edges to prevent the leakage of the water and the water vapour.



ITEM NO.	PART NUMBER
1	acrylic box
2	water collector
3	aluminium fin
4	glass cover

Figure 1. Schematic model of the solar still

V. WORKING

Single basin solar still consists of a basin with a black painted aluminum plate with fins. The solar still is enclosed by a transparent glass cover in such a way that it keeps the solar still airtight. The performance of the solar still depends mainly on solar intensity, wind velocity, ambient temperature, and water and glass temperature difference, free surface area of water, absorber plate area, and temperature of inlet water, glass angle and depth of water. The brackish or salt water is poured into the solar still through the inlet pipe of diameter of 20 mm and then closed by a air tight cap for maintained the solar still air tight so that the water vapour does not escape into the atmosphere. The solar still is placed such that the inclined top glass cover is facing the south direction so that more amount of solar radiations pass into the solar still. The solar still is made of Acrylic sheet which has a thermal conductivity of 0.2 W/mk helps in retaining the heat generated inside the solar still. The solar radiations start to enter into the solar still which leads to heating up of the aluminium fins. As aluminium has a thermal conductivity of 167 W/mk. It helps in conducting more amount of heat to the brackish water or salt water which leads to the evaporation of water. This water vapour starts to condense on the bottom surface of the glass due to the temperature difference between the water and glass. This condensed water starts to slide down on the bottom surface of the glass due to the 20^{o} inclination of the glass. This condensed water then gets collected in the water collector which is placed at a 2^{o} inclination for the distilled water to pass out through the outlet PU tube of diameter of 10 mm. This distilled water is collected in the beaker and then the amount of distilled water collected is measured.

The thermocouples are placed to read the temperature change of the Aluminium sheet, water, water vapour and glass bottom surface of the solar still and also ambient temperature with change in time. The thermocouples are passed into the solar still through the hole of diameter 10 mm which is closed by using M-seal.

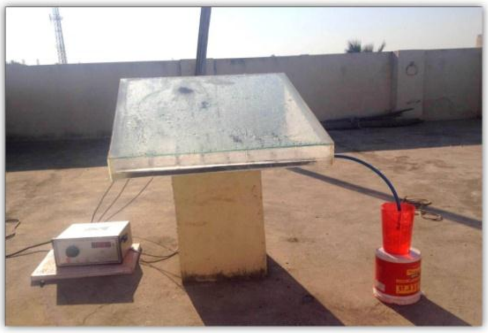


Figure 2. Final setup of single basin single slope acrylic solar still

VI. MERITS OF THE SOLAR STILL

- It is Pollution free.
- Source is free and renewable.
- It is Environmental friendly.
- The Solar still can be used for large scale desalination process as it is more economical and construction is simple.
- The cost of the production of the water will become cheaper than other water purification systems.
- Plenty of available sea water can be converted into potable water for the domestic use.

VII. RESULTS

- The Aluminium temperature, water temperature, glass bottom surface temperature, vapour temperature, and ambient temperature are taken in hourly basis on a sunny day from morning 7.00 AM to evening 7.00 PM.
- Graph is drawn to depict the change in temperature at different locations with respect to the time.
- Totally six graphs are drawn to depict the relation with respect to the time period and the ambient temperature, Aluminum temperature, Water temperature, water vapour temperature, glass bottom surface temperature and distilled water collected.
- Totally about 505 ml of distilled water is obtained in one day for 2 litre of brackish water poured into the solar still which has a cross sectional area of $.25m^3$.
- A large amount of distilled water is obtained between the time period of 11.00 AM and 2.00 PM as most of the solar radiations pass into the glass thus increasing the temperature of the aluminum fins which leads to the increase in the amount of heat conduction to the brackish water or salt water.
- A maximum of 80 ml of distilled water is obtained during the time period of 12.00 PM to 1.00 PM. It is clear that the amount of distilled water

obtained depends mainly on the solar intensity and the material used for heat absorption purpose.

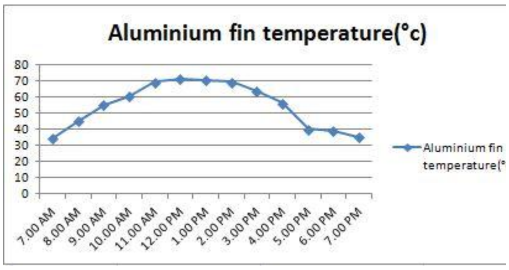


Figure 3. Time Vs Aluminium Temperature Graph

From fig 3 we can see the graph which shows the variation of the temperature of the aluminium fin which is used as a heat absorbing material in Celsius and the time in hours. This graph is plotted based on the experimental analysis carried out on a shiny day between 7.00 AM and 7.00 PM. The temperature of the Aluminium fin is found to be maximum at 12.00 PM and found out to be the almost same with a small variation between 11.00 AM and 2.00 PM.

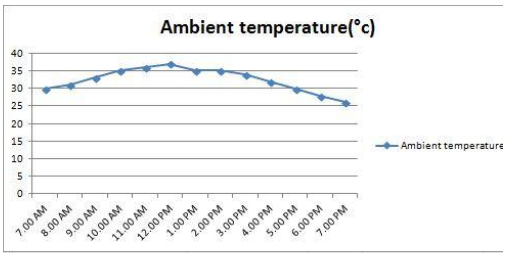


Figure 4. Time Vs Ambient Temperature Graph

From fig 4 we can see the graph which shows the variation of the ambient temperature in Celsius and the time in hours. This graph is plotted based on the experimental analysis carried out on a shiny day between 7.00 AM and 7.00 PM. The ambient temperature is found to be maximum at 11.00 PM and 12.00 PM and found out to be the almost same with a small variation between 1.00 PM and 4.00 PM.

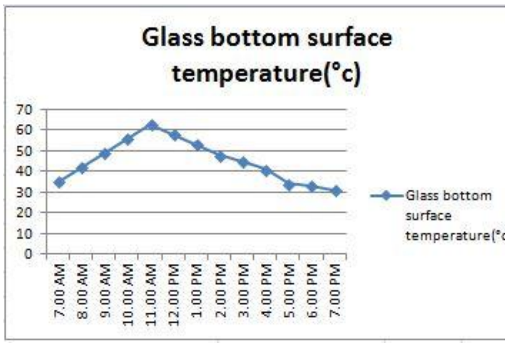


Figure 5. Time Vs Glass Bottom Surface Temperature Graph

From fig 5 we can see the graph which shows the variation of the temperature of the glass bottom surface in Celsius and the time in hours. This graph is plotted based on the experimental analysis carried out on a shiny day between 7.00 AM and 7.00 PM. The temperature of the glass bottom surface is found to be maximum at 11.00 PM and found out to be a narrow increase in the temperature form 7.00 AM to 11.00 PM and a narrow drop in the temperature from 11.00 AM to 5.00 PM.

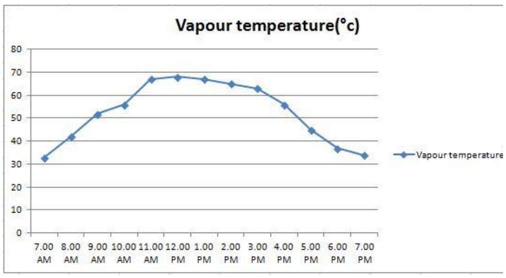


Figure 6. Time Vs Water Vapour Temperature Graph

From fig 6 we can see the graph which shows the variation of the temperature of the water vapour in Celsius and the time in hours. This graph is plotted based on the experimental analysis carried out on a shiny day between 7.00 AM and 7.00 PM. The temperature of the water vapour is found to be maximum at 12.00 PM and found out to be the almost same with a small variation between 11.00 AM and 3.00 PM.

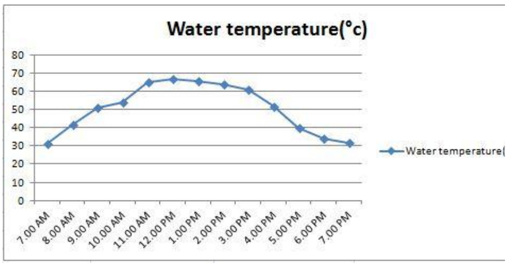


Figure 7. Time Vs Water Temperature Graph

From fig 7 we can see the graph which shows the variation of the temperature of the salt water which is poured into the solar still for distilling it in Celsius and the time in hours. This graph is plotted based on the experimental analysis carried out on a shiny day between 7.00 AM and 7.00 PM. The temperature of the salt water is found to be maximum at 12.00 PM and found out to be the almost same with a small variation between 11.00 AM and 12.00 PM then it keeps decreasing as the temperature of the Aluminium fin is also decreasing..

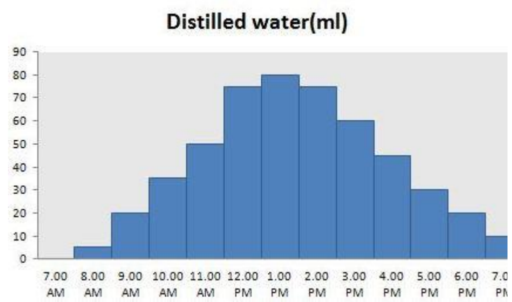


Figure 8. Time Vs Distilled water Temperature Graph

From fig 8 we can see the bar chart which shows the variation of the distilled water collected in ml and the time in hours. This graph is plotted based on the experimental analysis carried out on a shiny day between 7.00 AM and 7.00 PM. The distilled water collected is found to be maximum at 1.00 PM and found out to be the almost same with a small variation between 12.00 PM and 2.00 PM.

VIII. CONCLUSION

On performing the experimental analysis the results obtained from our solar still was 505ml per $0.25m^2$ per day. On comparing with the results obtained by Ehssan M.R. Nassef, Mohamed Z.El-Abd, Yahya A.El-Tawil with reference to the paper published on the Study on the performance of solar still[5], the results obtained by them was 640 ml per m^2 per day. We found out that the amount of distilled water collected was about 505ml per $0.25m^2$ per day(i.e.2020ml per m^2) which was found to be better than the results obtained by them and also the performance of our solar still is found out to be better than the those designed by Bilal a. Akash, mousa s. Mohsen, omar osta, and yaser elayan with reference to the paper published on Experimental evaluation of a single-basin solar still using different absorbing materials[3], the results obtained by them was 3600, 3200, 3000 ml per $3m^2$ per day for dye, matt and ink respectively as the results we have obtained was about 505ml per $0.25m^2$ per day(i.e.6060ml per $3m^2$ per day)

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