Water Desalination System using Parabolic Trough with Varying Glass Thickness

Elmer B. Dollera, Mark Chester F. Rey, Anjo R. De Jesus, Jiah M. Piloton, Rico R. Salem, Jr.

Abstract: ***Three quarters of the earth's surface is covered with water[1]. Based on a survey, with the world's population growing every year, the supply of usable water is not keeping enough with the required amount of water needed for survival. Nowadays, clean water has become a business which produces constraints when it comes to accessibility. Here in the Philippines, there are various diseases every year which relates to unsafe drinking water which may sometimes lead to death. The researchers want to know the effectivity of the assessed solar desalination system, how much desalinated water could this system provide and how long does it take for this amount to be produced in a given day. This study uses a parabolic trough which is the main means of harnessing solar energy and transferring this energy to the saltwater container which will heat up the pre-specified amount of saline water. The vapor will evaporate and the condensate will be trapped in the glass lid and routed to a desalinated water container. An evaluation is made to know the effective glass thickness for the device, the 3mm, 6mm and 10 mm thickness has been assessed and after the testing phase, it has been found out that the 10 mm glass thickness produced the optimum results. It is able to produce a liter of desalinated water out of 5000 mL of saline water. It is then observed that the 10mm glass thickness has the highest volume conversion efficiency of 23.10 % , followed by the 6mm glass thickness of 21.90% and the 3mm glass thickness of 17.30%.***

Keywords: condensation, desalination, glass thickness, seawater, solar desalination system

I. INTRODUCTION

Water is considered as the most important necessity of man. Three quarters of the earth's surface is covered with water[1] and yet, people are paying much money to obtain clean and potable drinking water. Nowadays, potable water has become a business which produces constraints when it comes to accessibility and supply. At some places, people are in scarce of potable water supply[2].

Here in the Philippines, some islands and places still don't have adequate supply of potable water. Many people resort in drinking unsafe tap water which eventually acquiring various diseases and even fatal death. Every year, this potable water supply problem, which relates to unsafe potable drinking water caused many harmful diseases that may bring many people to death. Desalination is not a new method. During the old times, people use evaporation to desalt the seawater[3]. Many designs of desalination process were done.

Solar stills are one of the most commonly used type for water desalination system. A study conducted by a group of researchers from Lebanon aimed to see if modifications made to the solar still will enhance the efficiency of the device. The researchers added a rotating drum inside covered with aluminum sheet to make it solar absorbing. This will provide a more heating effect on the brackish or saltwater depending on what will be used. As they run through with the experiment they have seen that adding modification to the solar still increases the evaporating effect of the device. As a result they concluded that solar still modification is good but one must take into account the cost-efficiency and the area available for the system to be placed.[4] Desalination or desalting is another method of increasing the supply of usable water. To most people, desalination means desalting seawater. By leaving salts, minerals, and other contaminants, it can raise the quantity of usable water.[5] Another method uses the principle of reverse osmosis. Instead of utilizing heat, this method uses pressure to remove salts and other minerals. Water molecules are forced through a special membrane under pressure leaving the minerals behind[5]. In this study, parabolic trough desalination equipment is being considered. The authors want to know the effectivity of this type of solar desalination system in obtaining safe and potable drinking water and how much water could this system provide in a given day. This study also aims to find out the optimum glass thickness that should be used in the system. The temperature of the container, the glass, the ambient and the focal point is being considered and observed. The glass thickness that has been assessed has an individual thickness of 10mm, 6mm and 3mm. The rate at which desalinated water would be produced is also observed, as part of the test and analysis of this paper. In order to be focused on this study, the researchers come up with a specific set of objectives:

- To design and fabricate a container with varying glass thickness.
- To determine the time taken to evaporate a specified volume of seawater to produce 250mL of desalinated water
- To compare the results obtained to the previous results gathered using statistical analysis in order to identify which is more efficient between the modifications being made and the original design
- To provide temperature data of the entire system.

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This study is also focused on the enhancement of the Solar Water Desalination System with varying glass thickness of the container being used. Changing the parabolic trough design is not included in the study. The data recorded are limited to the required time of producing 250 milliliters of desalinated water, the temperatures of the outer surface area of the container, the glass thickness and the focal point, the volume of desalinated water produced and the efficiency of the system. This project is tested at various near-shore places. In order to further understand the different concepts involved in the study of desalination system, topics on Thermodynamics and Heat Transfer subjects are considered. A thorough understanding on how to harness effectively the solar energy is also required to make this study feasible and possible. In terms of the process, a specific volume of saline water is filled in the container then the parabolic trough provides the primary heating source for the container so that evaporation takes place inside the container and the vapor given off by the saline water is trapped by the covering glass and the condensates that are formed by the glass are collected in the gutter before sliding down into the container which contains the produced desalinated water.

II. METHODOLOGY

In order to be guided with the study, the researchers followed a certain conceptual framework where the flow of the day to day activities are focused.

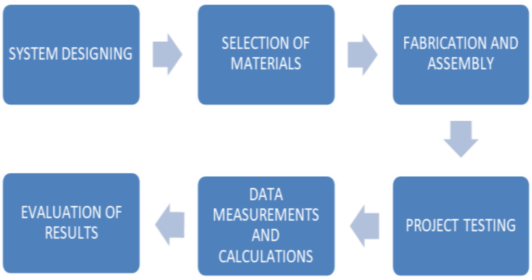

Fig. 1. Conceptual framework

Fig.1 shows the conceptual framework of this study that involves the system design, selection of materials, fabrication and assembly of the parabolic trough, testing of the project, data gathering and calculations, and finally, the evaluation of results.

A. System Design

With the gathered information of the researchers and the use of Computer Aided Drafting or CAD, the design of the system is developed and has made a prototype model of the whole system which served as guide in fabricating it. Based from the previous study done, the dimensions of the parabolic trough are already known and the focal point is said to be 51.49 cm from the center of the parabola[6].

B. Selection of Materials

The researchers selected the appropriate materials needed for their prototype. The container used for the saltwater is made up of a non-corrosive material and GI plane sheet metal. Support and sturdy stand is constructed to hold the parabolic trough in place and should be focused to the direction of the sun. Glass sealants were provided in order to minimize and eventually, eliminate the possibility of warm air leaking from the system. The amount of leaking warm air will cause a lot of heat absorbed by the trough from the energy of the sun. Materials used such as steel angle bars, bolts, galvanized iron metal sheet, steel flat bar, sealant, aluminum duct tape, thermal insulating film and assorted glass with frame.

C. Fabrication and Assembly

From the selection of materials, the fabrication of the prototype is made based from the system already designed using CAD. The fabrication of the trough is based from the dimensions used by the past researchers[6]. The design of the structure is retained but there was a modification when it comes to the glass lid part since it will be varied for the purpose of comparison.

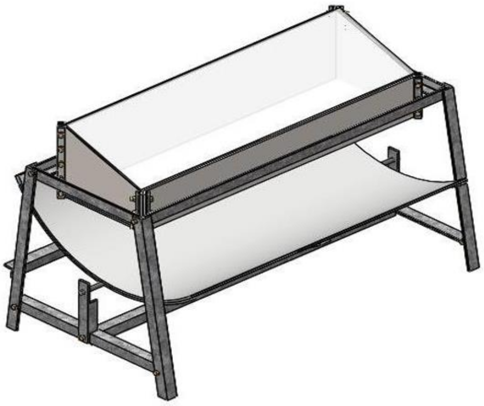

Fig. 2. Isometric view of the parabolic trough

Fig.2 shows the isometric view of the parabolic trough were the data of the collected condensate will be measured and assessed.

D. Data Gathering and Calculations

In the project testing, the researchers have to monitor the ambient, focal point, and the temperature of the glass in every 30-second interval for a duration of 60 minutes[7]. The researchers also must answer the objectives stated in the previous pages.

E. Evaluation of the Result

The evaluation of results was based from the efficiency done by the system. It had to produced output higher enough to be considered as more efficient design. It was then identified if the designed system was more efficient compared to the previous designed system. To calculate the efficiency of the system, the total volume of desalinated water divided by the total volume of the salt water, $\varepsilon =$ (100)x(volume of desalinated water)/(volume of saline water)

III. EXPERIMENTAL

The parabolic trough contains four main parts: the saline water container, the parabolic trough, the desalinated water container and the glass. In this study the glass has been the main focus since it is the goal of this system to determine the most productive glass thickness where volume of desalinated water is maximum.

Fig. 3. Test rig for the water desalination

Fig. 3 shows the pictorial view of the parabolic trough. The parabolic trough will transmit the sun energy down to the bottom of the container. As a result, the saline water inside the container will heat up producing water vapor. The water vapor will then rise up to the glass panel due to the difference in density. The water vapor would be trapped by the glass and the glass, due to the cooler ambient temperature, will trigger the condensation process of the water vapor being trapped. The study spent a three-day testing period, one day is allotted for each glass thickness and the temperature of the system and the weather condition will also be considered.

A. Data gathering

This study is done by gathering the seawater from the sea, 1 kilometer from the seashore of the coastal village. and placed the collected seawater in the supplied and designed sea water container. The container, along with the parabolic trough, is then exposed directly to the sunlight for a period of 60 minutes. Data logger is used to record the temperature of the parabolic trough every 30-second interval.

The parabolic trough is used to transmit and absorb absorb the energy from the sun. The parabolic trough reflects some of the energy from the sun, some of the energy is absorbed by the parabolic trough and the rest is absorbed by the bottom portion of the container.

With the use of data logger, the temperature of the glass is recorded during the 60 minutes period[8]. By allowing the seawater gain heat in the container, and when it reached a certain temperature, vaporization process then takes place. The produced water vapor is trapped in the glass lid and as it condensed, it slides down to the gutters located on both ends of the glass lid and sorted in a separate container where the produced product or the desalinated water is stored. The volume of the collected desalinated water is then measured in volume and in the salinity values. The testing period of 60 minutes started by deploying the device to the area during hot and clear sky. Monitoring appearance of water vapor and other various parameters were observed during a 30-second interval and recording the gathered data in the prepared data sheet[9]. The level of desalinated water was also monitored from time to time to determine the rate of water production in the device.

IV. RESULT AND DISCUSSION

The data were based on the temperature data that was gathered during the three-day test period given a 30-second interval. The data was supported by statistical analysis to validate the soundness of the gathered data.

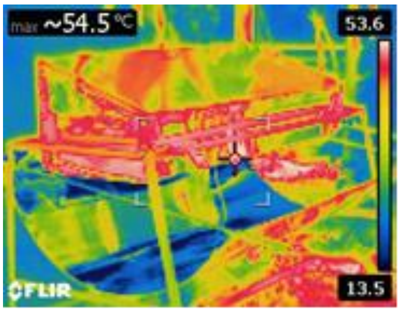

Fig.4. Thermal images for 3mm

Fig. 4 shows the solar thermal distribution absorbed by the parabolic through assembly. The hotter parts of the parabolic through assembly are colored coded with red while the cooler parts of the assembly were colored coded as blue.

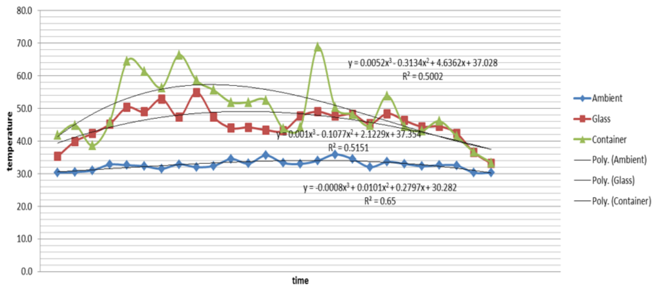

Fig. 5. Temperature profile for 3mm

The testing phase for the 3mm glass thickness was done during a hot and clear sky. This was also the main reason why there were large temperature values for the ambient temperature. The average temperatures for the ambient, glass temperature and container temperature were at 32.6 °C, 45.1 °C and 49.6 °C respectively.

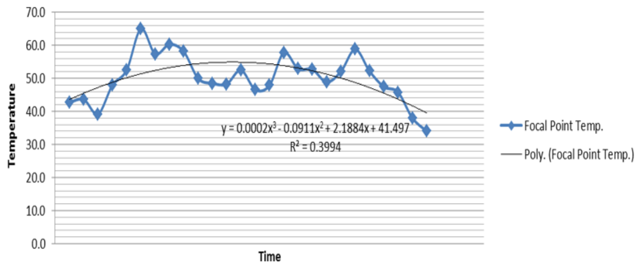

Fig. 6. Focal temperature for 3mm

Fig.6 shows the focal temperature for 3mm glass thickness. After necessary tabulations, Fig. 6 were plotted to show the behavior of the temperature profile at the focal point of the parabolic through. It contained the temperature data, the blue line corresponds to the focal temperature of the parabolic through. T

The equation that best fits the behavior of the temperature profile is best describe by the third degree equation of $y = 0.0002x^3 - 0.0911x^2 + 2.1884x + 41.497$. With this equation, the value of $R^2=0.3994$.

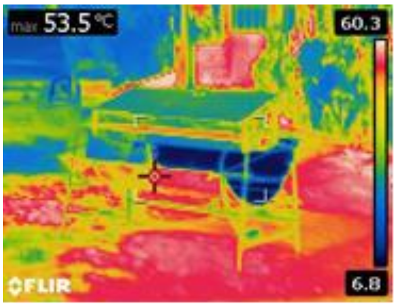

Fig.7. Thermal images for 6mm

Fig. 7 shows the thermal scanner images and it validated the temperature distribution across the parabolic through assembly. The parabolic through is colored blue in the thermal scanner which indicates that the parabolic through only absorbed minimum amount of the solar energy. The data further justifies that most of the solar energy strikes unto the parabolic through and reflected back to the provided sea water container.

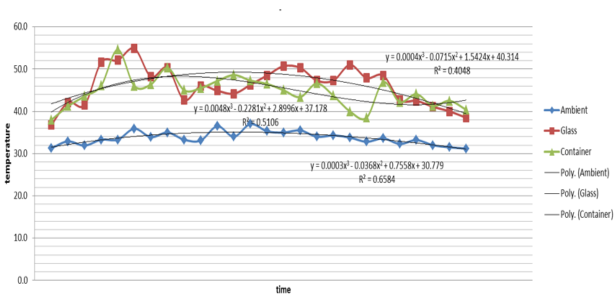

Fig.8. Temperature profile for 6mm

Fig. 8 shows the temperature profile for 6mm glass thickness. During the testing phase of the 6mm glass thickness, the weather condition was clear yet light to moderate winds prevailed, affecting the results of the experiment and the volume of desalinated water production. The average temperatures were 33.7 °C, 46.1 °C and 44.7 °C for the ambient temperature, glass temperature and water container temperature, respectively.

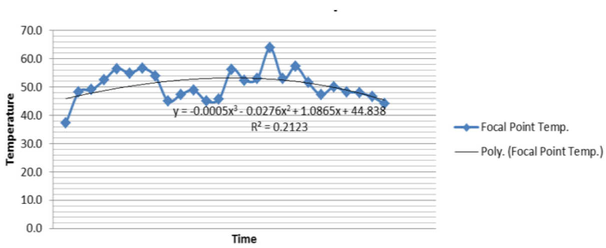

Fig.9. Focal temperature for 6mm

Fig.9 shows the focal temperature profile during the testing period for 6mm glass thickness. The focal point temperatures were plotted to show the behavior of the temperature profile at the focal point of the parabolic through. It contained the temperature data, the blue line corresponds to the focal temperature of the parabolic through while the black line represents the best fit equation. The equation that best fits the behavior of the temperature profile is best describe by the third degree equation of $y= 0.0005x^3 -0.0276x^2 +1.0865x + 44.838$. With this equation, the value of $R^2=0.2123$.

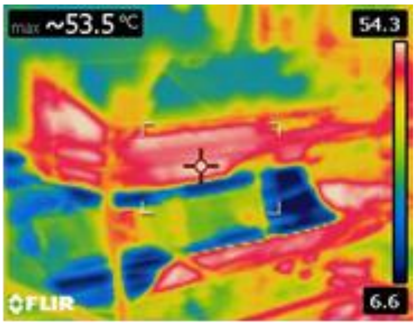

Fig.10. Thermal images for 10mm

Fig. 10 shows the thermal scanner images for 10mm glass thickness. The data further shows that most of the solar energy strikes unto the parabolic through and reflected back to the provided sea water container.

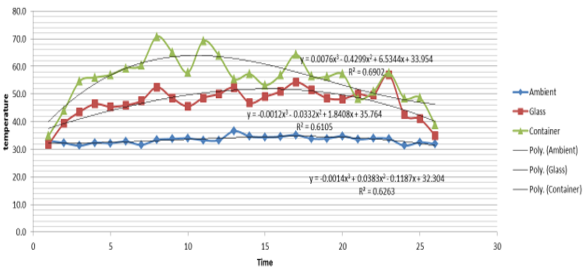

Fig. 11. Temperature profile for 10mm

Fig. 11 shows the temperature profile for 10mm glass thickness. During the testing phase of the 10mm glass thickness, the weather condition was hot and the sky is clear. For the 10 mm glass thickness, the average temperatures were 33.4 °C for the ambient temperature, 47.0 ºC for the glass and 55.5 ºC for the provided sea water container. The data above showed how the temperature varied with respect to the time. This is due to the effects of sunlight to the device.

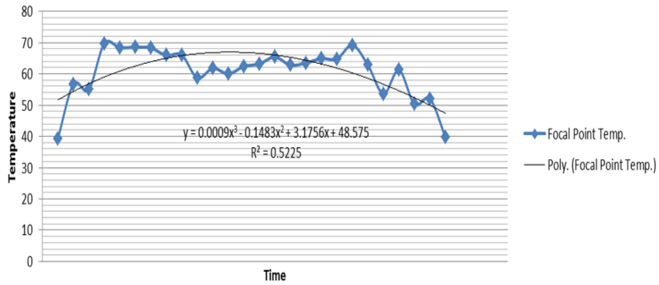

Fig. 12. Focal temperature for 10 mm

Fig.12 shows the focal temperature profile during the testing period for 10mm glass thickness. The equation that best fits the behavior of the temperature profile is best describe by the equation of $y=0.0009x^3-0.1483x^2+3.1756x+48.575$. With this equation, the value of $R^2=0.5225$. The focal temperatures that are presented in Fig. 6, Fig. 9, and Fig.12 were essentially important to understand the behavior of the temperature of the parabolic through.

The temperature of the sea water container is high enough to initiate vaporization of the sea water. This data will confirm that the parabolic through has a very effective application in reflecting the energy from the sun to the provided water container. The average temperatures for the 10mm, 6 mm and 3 mm were 60.5° C, 50.5 °C and 50.1 °C respectively.

Table 1. Volume flow rate of desalinated water

Glass Thickness, mm	Volume Flow Rate, mL/hr	Efficiency, % 1000mL
3.0	173	17.30
6.0	219	21.90
10.0	231	23.10

Table 1 shows the condensate volume flow rate of desalinated water. It is evident that the 10mm glass thickness has the highest conversion efficiency per 1000 milliliter of sea water. The 3mm glass provided a higher evaporation rate but because the 3mm has a higher temperature, it needed a lot of time to condensed the vaporized sea water.

The data above showed the various parameters gathered during the three- day test period having a 30-second interval. The statistical support showed the reliability of the data especially the value of R^2 , which shows the relationship of one value from the other value and the line along the graph showed the deviance of the value to the mean value of the data. The temperature data showed the peak temperatures and the time to which the temperature peaked, as observed the peak temperatures occur between 11:00am to 1:00pm. It also showed that starting at 4:00pm, the temperature of the parabolic trough starts to decrease. The decrease in temperature is a help in the rate to which the condensate will form for there would be a big change in temperature, enabling for the vapor to condense. The focal point temperature indicates the point to which the sun rays were focused with the help of the parabolic trough. The data also showed remarkably on the various weather conditions at various times which verified the rate at which the condensate was formed. The images of the device under the thermal scanner verified that the device can achieve higher temperatures.

V. CONCLUSION AND RECOMMENDATION

Heat energy is a very expensive commodity and waste heat recovery system is very important component in a successful industrial operation for the modern world[10}. From the data gathered and with the help of the answers of the specific objectives, the researchers found out that the 10mm glass thickness is the glass thickness that should be used for the solar desalination in order to provide the optimum output of desalinated water. It had been observed that due to the thickness of the glass being used, there was a big difference in the temperature of the parabolic through, which helped generate more condensate from the sea water container. The 10mm glass thickness also produced the most volume of desalinated water. The rate of production of desalinated water is around 250 milliliters in 2 hours or an average production rate of 125 mL/hour. For further research, the researchers recommend to use another alternative design of the parabolic trough material to enhance the collective effect. Have the collected desalinated water run through a potabililty test from a recognized testing agency to know if the desalinated water is safe for drinking. Finally, it is further recommended that a solar tracking device be installed in order to maximize the absorption of the solar energy. With the solar tracker mechanism, the direction of the sun and the solar energy is always available to the parabolic through at a maximum value at any given real time.

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