Advances in Social Science, Education and Humanities Research, volume 576
Proceedings of the 2nd International Conference on Science, Technology, and Modern Society (ICSTMS 2020)

# Concentrated Solar Power (CSP) Technology Uses Parabolic Reflectors for Seawater Desalination

Muhammad Amin*, Teuku Azuar Rizal, Syamsul Bahri Widodo, Fazri Amir, Diki Wijaya, Sudi Alperius Tumanggor
Department of Mechanical Engineering, Faculty of Engineering
Universitas Samudra
Langsa, Indonesia
*muhammadamin@unsam.ac.id

***Abstract*—The sun is an abundant and never-ending energy source, and the conversion is relatively easy, cheap, not influenced by economic, political conditions and pressures from developed countries. Langsa City receives an average annual solar radiation intensity of up to 600 W/m2. One way to get this massive amount of solar energy is by concentrating the radiation emitted by the sun to a single focal point, or better known as Concentrated Solar Power (CSP). This study aimed to utilize CSP technology using a parabolic reflector applied to the seawater desalination process. The parabolic reflector is made of an iron plate with a thickness of 0.5 mm, and 80 cm in diameter. The focal point distance is 50 cm. Many small mirrors are glued to the parabola's surface to fill the surface area of the parabola. This mirror serves to reflect sunlight to the focal point. The reflector is then mounted on a frame made of ½, ¾, and 1-inch steel. The frame is 1 x 1 x 1 m in dimension. The testing of the prototype was carried out for three days at different times. The temperature measurement at the focal point shows a maximum value of 147.3°C at a daily average solar radiation intensity of 500-600 W/m2. The freshwater product obtained from desalination using this parabolic reflector is 224 mL for an operational time of 8.5 hours.***

***Keywords*—concentrated solar power, parabolic reflector, desalination, seawater**

## I. INTRODUCTION

Fossil fuel resources have been beneficial; therefore, it is necessary to immediately find energy solutions to meet future energy needs and create future ones. The sun is an inexhaustible source of abundant energy. It is straightforward, cheap, and does not affect the economic, political, and pressure from more developed countries.

Langsa is one of the cities in Aceh, Indonesia. It is approximately 400 km from the city of Banda Aceh. It is also a tropical area that is always affected by monsoons, causing two distinct seasons: the rainy and dry seasons. Rain and heat usually occur randomly throughout the year. Despite frequent weather changes, the average annual rainfall ranges from 1500 mm to 3000 mm, with average air temperatures ranging from 28 – 32°C and average relative humidity of 75%, and the intensity of solar radiation reaches 600 $W/m^2$ on average. Based on this potential, it is possible to utilize solar energy for seawater desalination applications.

Radiation is an energy emitted by any object with a temperature above absolute zero and is the only form of energy that can propagate in the vacuum of outer space. The sun emits 56 x 1026 calories of energy every minute. From this energy, the earth receives 2.55 x 1018 calories or only ½ x 109 [1]. Some developing countries with relatively higher solar radiation, such as India, Egypt, Morocco, India, and Mexico, have begun to concentrate solar power for electricity. One example, India in 2014 has successfully installed solar power plants at 237,743 MW of total installed capacity [2].

One way to obtain a large amount of solar energy is to collect solar energy at a certain point, often known as Concentrated Solar Power (CSP). When collected at a predetermined point, the temperature obtained can reach 300$^o$C to 1000$^o$C or even higher [3]. This temperature indicates that the energy obtained can be used for various engineering applications, one of which is seawater desalination applications [4].

Commonly used CSP technologies include parabolic reflectors, electric towers, parabolic dishes, and using Fresnel Reflectors [5]. Among these technologies, parabolic reflectors are highly developed and often used. Its advantages include easy manufacture and compact size [6].

Several researchers have studied CSP technology's structural design's performance problems using parabolic reflectors such as Lupfert et al.[7]. Padilla et al. have conducted and analyzed one-dimensional heat transfer in a satellite dish solar reflector and concluded that a 41.8% reduction in convective heat loss results in improved performance [8]. Edenburn conducted a performance study on a cylindrical parabolic collector and compared it theoretically with experimental results [9]. Naeeni and Yaghoubi have conducted a wind flow analysis on a CSP technology system using a parabolic reflector by changing the collector orientation with wind speeds of 2.5, 5, 10, and 15 m/s. The resulting force acting on the standard collector structure and the field pressure acting around the collector was 15-20 times lower than the

Copyright © 2021 The Authors. Published by Atlantis Press SARL.
This is an open access article distributed under the CC BY-NC 4.0 license -http://creativecommons.org/licenses/by-nc/4.0/.

collector opening area [10]. Rojas et al. conducted focus research on capillary systems in absorbent tubes to produce direct steam, used for many applications [11].

Seawater desalination is a process to convert seawater into freshwater [12]. The solar radiation energy desalination method is the most straightforward and most flexible because solar radiation energy can be found worldwide and can be used free of charge. Several studies that utilize solar radiation for seawater desalination applications, such as Arunkumar et al., research by utilizing solar radiation with the CSP system to produce fresh water 3,520 kg/$m^2$ paraffin can increase tool performance to 26% [13]. Sathyamurth et al. make a desalination tool in the form of a triangular pyramid that can produce 3.5 L/$m^2$.day, and if heat storage material is added, there is an increase in performance by 26% a freshwater product yield of 5.5 L/m2.day [14]. Kabeel et al. make desalination test equipment by making a dual system, namely 2 (two) solar collectors combined with a phase change material. The productivity of freshwater obtained is 9.36 L/$m^2$.day [15]. All three studies still manage their relatively low solar radiation, and this hindrance can be overcome by using a highly concentrated ratio concentrator such as a parabolic reflector [16]. Tambunan et al. researched the solar CSP system's utilization using a parabolic reflector for seawater desalination applications. The maximum temperature obtained from the results is 140 ºC which produces 516 ml of freshwater from a volume of 2 Liters of seawater. The results of this study are better than those without using a parabolic reflector [17]. Chaichan and Kazem carried out a distillation process with the CSP concept using a parabolic reflector combined with a phase change material. The results showed an increase in the productivity of the test equipment system up to 307.54%. [18].

Based on the literature review above, it raises the question, can the application of CSP technology using a parabolic reflector suitable for the climatic conditions of Langsa City? Based on the assumption that there are several similarities in solar radiation's potential and the tools used, it seems that CSP technology is very likely to be adopted, researched, and applied to seawater desalination. Considering that there are still around Langsa City that still lives in coastal areas and still lack freshwater, the options for implementing this technology are pretty promising.

This study aimed to utilize CSP technology using a parabolic reflector applied to the seawater desalination process.

## II. Methodology

### *A. Parabolic Reflector Test Equipment*

This study's test instrument is a set of desalination systems consisting of a parabola, frame, container for desalination of seawater, and bottles for freshwater reservoirs, as shown in Figure 1. The parabola was made from an iron plate with a thickness of 0.5 mm, a diameter of 80 cm, and 6 cm depth. The focal point distance is 5.5 cm. On the parabola's inner surface are arranged mirrors as reflectors of sunlight parallel to the reflector's surface area. The frame made of ½, ¾, and 1inch steel was supporting the parabolic reflector. Each frame has a length, width, and height of 1 x 1 x 1 m. The desalination container is made of aluminum in a box shape with dimensions 100 x 60 x 200 cm. At the top of the container (measuring cup), a cone-shaped glass is installed with a height of 100 cm.

Fig. 1. Seawater desalination test device with a parabolic reflector.

### *B. Methods*

This experimental research is carried out in the laboratory and Mechanical Engineering Study Program and the open field of the Faculty of Engineering, Universitas Samudra. The test was carried out from 09.00 am until 06.00 pm when solar radiation intensity is available. The intensity of solar radiation is simulated using the HOMER Energy application. Simultaneously, the temperature is measured using a k-type thermocouple connected directly using data acquisition and recorded by a computer. Apart from temperature, the humidity was also observed to determine the effect of moisture content in the air. The air humidity meter also uses RH Dht22, which an Arduino Mega 2560 controller controls. As the test sample, seawater was prepared separately. The variables measured in this study include ambient temperature, mirror surface temperature, focal point temperature, seawater temperature, the temperature in the seawater container as raw material for desalination, humidity, and freshwater production. Also, the purity of freshwater was measured using a Water Quality Meter.

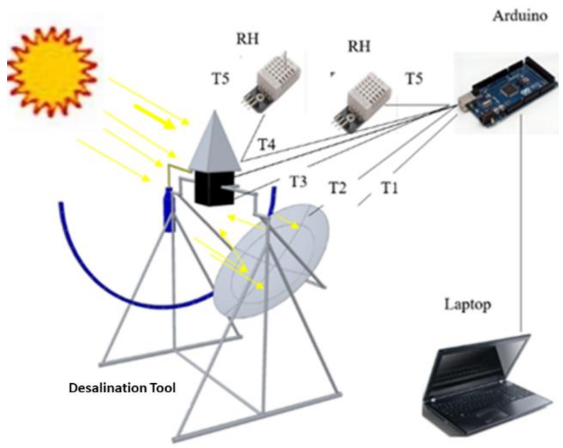


Fig. 2. Schematic of the test instrument.

Figure 2 illustrates the schematic of the test equipment where $T_1$ is the outside temperature, $T_2$ is the temperature of the parabolic reflector, $T_3$ is the temperature of the focal point, $T_4$ is the temperature of seawater, $T_5$ is the humidity of the air, and $T_6$ is the humidity in the tank. The tool works when the sunlight's energy hits the parabolic reflector and is concentrated towards the collector tank. The collector tank acts as a heat collector, and the seawater container delivers heat in the form of heat from outside into the tank. This process is known as conduction heat transfer. Seawater in the collector tank has increased in temperature due to heat energy transfer to the collector tank walls. The increase in seawater temperature in the tank from a low to a higher temperature is called convection heat transfer.

The increase in seawater temperature inside the tank has resulted in the evaporation of the seawater. The steam formed from the evaporation of seawater will move upwards and stick to the glass wall. Later on, it forms tiny water droplets, where the vapor will gradually become saturated to form droplets that will flow down the surface of the glass wall and continue to move along the water flow path and move toward the tube. The tube is connected to the drain system and sends the water to the measuring cup to determine the amount of freshwater formed.

This test is carried out for three days, at the same time on different days. After the implementation of the test is complete, a test instrument performance analysis is carried out.

The data analysis results are described in graphic form with the following format: graph comparison of solar radiation intensity to time, focal point temperature, seawater temperature, air humidity, and productivity of the amount of freshwater.

## III. Results and Discussions

### A. Solar Radiation Intensity

The intensity of solar radiation is essential because the sun is the only heat source used to test desalination devices. The intensity of solar radiation is critical because the sun is the only source of heat used to test desalination devices. The intensity of solar radiation is obtained using the HOMER energy software application by determining the coordinates of the research location. The research location is at the coordinates of 4°27.5' North Latitude, 97°56.3' East Longitude.

Data retrieval of solar radiation intensity is carried out from 00.00 am to 11.00 pm, carried out for three days. The first data collection was taken with a span of 1 hour. The data of solar radiation intensity is shown in Figure 3 and Figure 4 of the three figures. The average solar radiation intensity obtained is 500-600 W/m$^2$. On the first day, the weather was partly cloudy, so that it affected the freshwater yield. Meanwhile, on the second day, the weather was relatively sunny compared to the first day. As for the third day, the weather is cloudy and better than the first day.

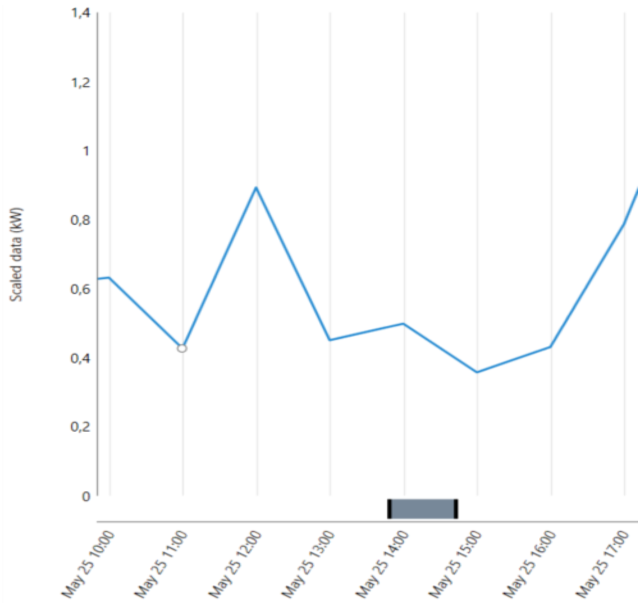


Fig. 3. The intensity of solar radiation during the first-day test.

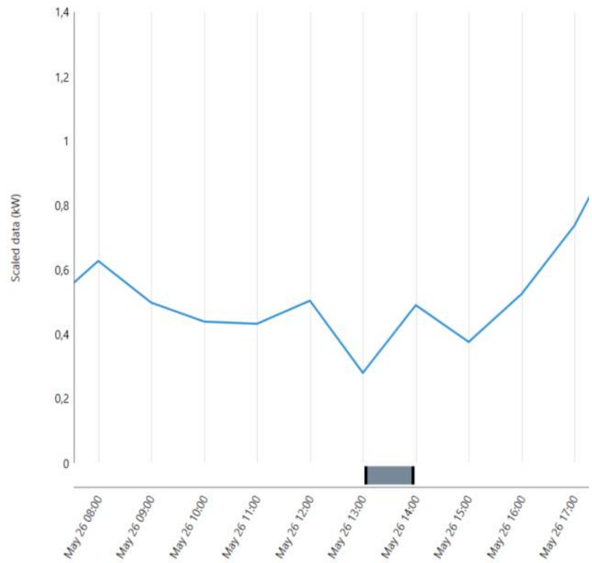


Fig. 4. The intensity of solar radiation during the second-day test.

### B. Performance of Seawater Desalination Test Equipment

The test results on the first day are shown in Figure 5. The test was carried out from 10.00 am up to 4.30 pm with a time of 6.5 hours. The result is that the highest temperature is obtained from the parabolic reflector (temperature of the focal point), ranging from 35-44.5 $^oC$. The temperature of the focal point obtained was minimal compared to some studies due to the cloudy weather. On the other hand, the seawater temperature is stable between 36 - 44 $^oC$, and the humidity in the desalination container is around 98-100%. The freshwater yield for the first day obtained from this test device is 32 ml.

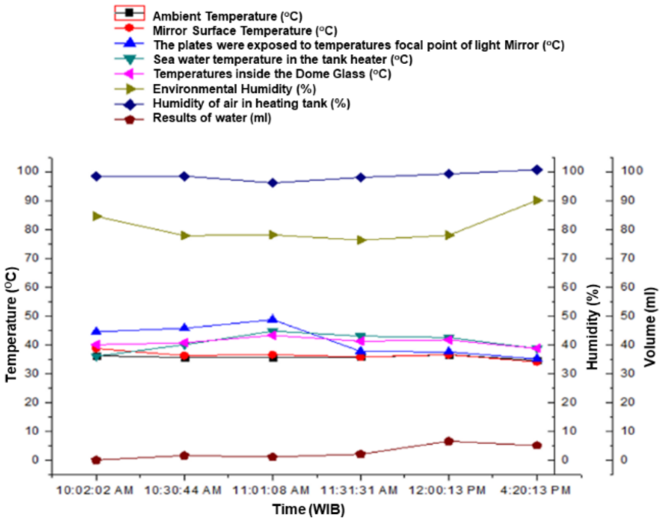


Fig. 5. First-day test results.

Figure 6 shows the second day of testing results, which was carried out for 8.5 hours starting at 08.00 am until 04.30 pm; the weather conditions when testing was relatively sunny. The maximum temperature of the focal point during the test was 147.3 °C. The seawater temperature in the desalination container reaches 93.8 °C; meanwhile, the ambient temperature averages 36 °C. The yield of freshwater obtained on the second day was 224 ml.

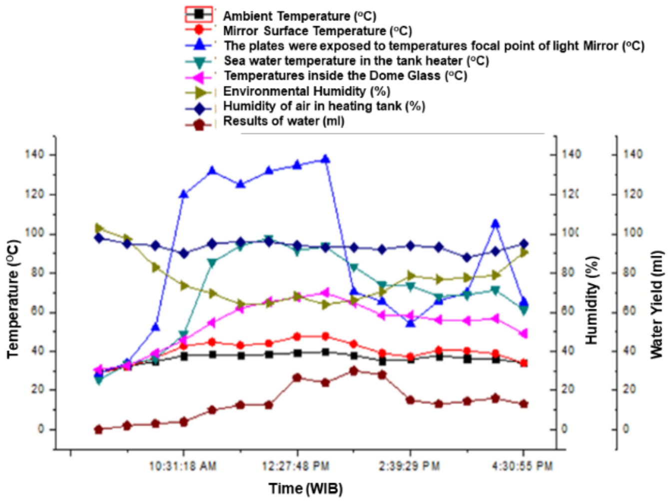


Fig. 6. Day two-test results.

Figure 7 shows the desalination test results on the third day, where the data is recorded for 9 hours from 08.00 am to 05.00 pm. During the test, the weather conditions were relatively sunny from morning to noon and turned cloudy by late afternoon. The maximum temperature of the focal point when tested was 94.8 °C. The temperature of seawater in the desalination container reaches 67 °C. Meanwhile, the average ambient temperature is 35 °C. The freshwater production for the second day obtained from this device is 109 ml.

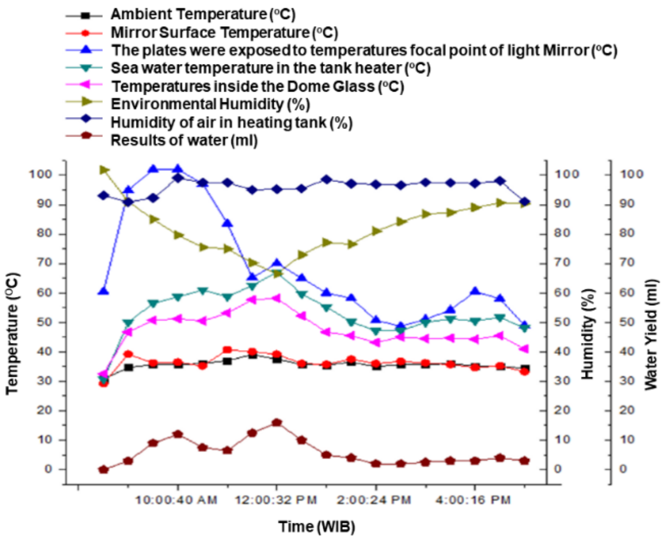


Fig. 7. Third-day test results.

## *C. Discussion*

A concave mirror causes the solar radiation to focus on the desalination container and heat the seawater, causing an increase in temperature, which encourages water evaporation in the container. The water vapor will rise to the top, and the temperature will naturally drop and condense. The saturated dew descends and flows through the pipe leading into the reservoir. The amount of freshwater produced from the three tests showed different results. Most freshwater production was taking place on the third day of testing, which was 224 mL. Testing the salinity of water produced from desalination with a parabolic reflector compared to water processed by a Reverse Osmosis (R.O.) based desalination device showed a relatively similar salinity value, namely 0.13 part per thousand (ppt).

In principle, research on seawater desalination using CSP technology depends on the researcher's test equipment's dimensions and several engineering models. Kabeel [19] uses a parabolic concentrator cylinder coupled with a phase change material and can produce fresh water up to 10.6 L/m$^2$ days.

# IV. Conclusions

From the results of this study, it can be concluded that CSP technology with parabolic reflectors has succeeded in reaching heating temperatures above 100°C. These results indicate that this tool is feasible to be developed for seawater desalination. The total amount of fresh water produced from seawater's desalination using this parabolic reflector is 224 mL.

# References


[1] P. Alamdari, O. Nematollahi, and A. A. Alemrajabi, "Solar energy potentials in Iran: A review," Renew. Sustain. Energy Rev., vol. 21, pp. 778–788, May 2013.

[2] V.K. Jebasingh and G.M.J. Herbert, "A review of solar parabolic trough collector," Renew. Sustain. Energy Rev., vol. 54, pp. 1085–1091, Feb. 2016.

[3] L.E. Doman, "World energy demand and economic outlook Macroeconomic assumptions Liquid fuels Natural gas Transportation sector Energy-related carbon dioxide emissions The following also contributed to the production of the IEO2013 report," 2013.

[4] K. Hamza, U. Gandhi, and K. Saitou, "Optimization of Parabolic Heliostat Focal Lengths in a Mini-Tower Solar Concentrator System," in Volume 5: 37th Design Automation Conference, Parts A and B, 2011, pp. 359–366.

[5] H.L. Zhang, J. Baeyens, J. Degrève, and G. Cacères, "Concentrated solar power plants: Review and design methodology," Renew. Sustain. Energy Rev., vol. 22, pp. 466–481, Jun. 2013.

[6] A. Barua, S. Chakraborti, D. Paul, and P. Das, "Analysis Of Concentrated Solar Power Technologies' Feasibility, Selection And Promotional Strategy For Bangladesh," J. Mech. Eng., vol. 44, no. 2, pp. 112–116, Jan. 2015.

[7] B. Wu, R. Reddy, and R. Rogers, "Solar energy: the power to choose," In Proceedings of Solar Forum, 2001.

[8] R.V. Padilla, G. Demirkaya, D.Y. Goswami, E. Stefanakos, and M.M. Rahman, "Heat transfer analysis of parabolic trough solar receiver," Appl. Energy, vol. 88, no. 12, pp. 5097–5110, Dec. 2011.

[9] M.W. Edenburn, "Performance analysis of a cylindrical parabolic focusing collector and comparison with experimental results," Sol. Energy, vol. 18, no. 5, pp. 437–444, Jan. 1976.

[10] N. Naeeni and M. Yaghoubi, "Analysis of wind flow around a parabolic collector (1) fluid flow," Renew. Energy, vol. 32, no. 11, pp. 1898–1916, Sep. 2007.

[11] M.E. Rojas, M.C. de Andrés, and L. González, "Designing capillary systems to enhance heat transfer in LS3 parabolic trough collectors for direct steam generation (DSG)," Sol. Energy, vol. 82, no. 1, pp. 53–60, Jan. 2008.

[12] A.D. Khawaji, I.K. Kutubkhanah, and J.-M. Wie, "Advances in seawater desalination technologies," Desalination, vol. 221, no. 1–3, pp. 47–69, Mar. 2008.

[13] T. Arunkumar, D. Denkenberger, A. Ahsan, and R. Jayaprakash, "The augmentation of distillate yield by using concentrator coupled solar still with phase change material," Desalination, vol. 314, pp. 189–192, Apr. 2013.

[14] R. Sathyamurthy, P.K. Nagarajan, J. Subramani, D. Vijayakumar, and K. Mohammed Ashraf Ali, "Effect of Water Mass on Triangular Pyramid Solar Still Using Phase Change Material as Storage Medium," Energy Procedia, vol. 61, no. 61, pp. 2224–2228, 2014.

[15] A.E. Kabeel, M. Abdelgaied, and M. Mahgoub, "The performance of a modified solar still using hot air injection and PCM," Desalination, vol. 379, pp. 102–107, Feb. 2016.

[16] C.M and A. Yadav, "Water desalination system using solar heat: A review," Renew. Sustain. Energy Rev., vol. 67, pp. 1308–1330, Jan. 2017.

[17] F.S. Tambunan, M. Edisar, and J.M., “Destilasi Air Laut Menggunakan Pemanas Matahari Dengan Reflektor Cermin Cekung,” J. Online Mhs. Fak. Mat. dan Ilmu Pengetah. Alam Univ. Riau, vol. 2, no. 1, pp. 116–122, 2015.

[18] M.T. Chaichan and H.A. Kazem, "Water solar distiller productivity enhancement using concentrating solar water heater and phase change material (PCM)," Case Stud. Therm. Eng., vol. 5, pp. 151–159, Mar. 2015.

[19] A.E. Kabeel and M. Abdelgaied, "Observational study of modified solar still coupled with oil serpentine loop from cylindrical parabolic concentrator and phase changing material under basin," Sol. Energy, vol. 144, pp. 71–78, Mar. 2017.