TiMER
*Trends in Mechanical Engineering Research*

# ADDITION OF ALUMINIUM OXIDE NANO PARTICLES TO THE ABSORBER PLATE COATING TO INCREASE THE PRODUCTIVITY OF SOLAR DISTILLATION

Ni Ketut Caturwati[a,b*], Dwinanto Sukamto[a], Rizki Fauzi[a]

[a]Department of Mechanical Engineering, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon, Banten, Indonesia
[b]Energy Conversion Laboratory, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon, Banten, Indonesia
*Corresponding author: n4wati@untirta.ac.id

## Graphical abstract

| Test | Non | NP 10% | NP 15 % | NP 20% |
|---|---|---|---|---|
| 1 | 435 | 617 | 705 | 816 |
| 2 | 347 | 527 | 725 | 887 |
| 3 | 338 | 555 | 789 | 927 |
| 4 | 340 | 493 | 635 | 763 |
| 5 | 210 | 225 | 302 | 529 |
| average | 334 | 483,4 | 631,2 | 784,4 |

**Article history**
Received
*13 June 2023*
Received in revised form
*21 June 2023*
Accepted
*XB June 2023*
*Published*
*XB June 2023*

## Abstract

There are few areas in Indonesia still have unsuitable water due to water pollution and limited water resources. Distillation is an effective way to produce clean water which is free from impurities in the form of small solids, germs and bacteria. One type of distillation is a solar-based distillation. However, the use of these tools still has a low productivity. There are several ways to increase the productivity of solar distillation equipment, one is by adding thermal energy storage material in the form of aluminum oxide ($Al_2O_3$) nanoparticles. This study is used experimental method by comparing a solar distillation with the addition of $Al_2O_3$ nanoparticles on the absorber plate coating to the coating without the addition of $Al_2O_3$. The results showed that the addition of $Al_2O_3$ nanoparticles increased the productivity of solar distillation. The results showed the addition of heavy concentration of $Al_2O_3$ nano-particles: 10%; 15% and 20% increased the productivity by: 44.73%; 88.98% and 134.85%, it was compared without the addition of nanoparticles of absorber plate coating.

*Keywords:* Solar distillation; absorber plate coating; nanopartikel $Al_2O_3$

## Abstrak

Beberapa daerah di Indonesia masih memiliki air tidak layak pakai dikarenakan terjadinya pencemaran air dan terbatasnya sumber mata air. Distilasi merupakan cara yang efektif untuk menghasilkan air bersih yang terbebas dari kotoran berupa kuman dan bakteri. Salah satu jenis alat distilasi yaitu alat distilasi berbasis tenaga surya. Akan tetapi, penggunaan alat tersebut masih memiliki produktivitas alat yang cukup rendah. Ada beberapa cara untuk meningkatkan produktivitas alat distilasi tenaga surya yaitu salah satunya dengan cara menambahkan material thermal energy storage berupa nanopartikel aluminium oksida ($Al_2O_3$). Metode yang digunakan pada penelitian ini adalah metode eksperimental, yaitu dengan cara membandingkan alat distilasi tenaga surya dengan penambahan nano partikel $Al_2O3$ pada pelapis pelat absorber terhadap pelapis tanpa penambahan $Al_2O_3$. Hasil pengujian menunjukkan penambahan nanopartikel $Al_2O_3$ meningkatkan prodiuktivitas distilasi surya. Hasil pengujian menunjukkan penambahan konsentrasi berat nano-partikel $Al_2O_3$: 10%; 15% dan 20% meningkatkan produksi sebesar: 44,73% ; 88,98% dan 134,85% dibandingkan tanpa penambahan zat nano partikel pada pelapis pelat absorber.

*Kata kunci*: Distilasi surya; Pelapis absorber; Nanopartikel $Al_2O_3$
*Doi: http://dx.doi.org/10.62870/timer.v1i1.20455*

## 1.0 INTRODUCTION

Water is a very important natural resource for life on earth, especially human. Water is one of the main needs that supports the life of all living things on earth. Human need water not only for consumption or drinking, but also for various other needs such as cooking, bathing, washing and other aspects of life. Some of these water sources are obtained from lakes, seas, springs and rivers.

Indonesia has been recognized internationally as an archipelagic country. The United Nations Convention on the Law of the Sea (UNCLOS) said that the total sea area owned by Indonesia is about 5.9 million km2. Because of it Indonesia has been named the largest archipelagic country in the world [10]. However, a few areas in Indonesia have unsufficient and unusable clean water. Many problems have arisen in several places, including clean water that is not able to use. These problems are due to limited water sources and water pollution. Limited water sources conditions make available water sources are not sufficient to meet the needs of the water to be used.

These are caused by several factors, namely the prolonged dry season or areas whose geographical location is hard to find water sources and reduced water sources due to human activities. In addition, other problems are caused by water pollution. In addition, other problems are caused by water pollution. Along with the development of the time, there are several ways that are often used to overcome the problem of polluted dirty water, the were distillation, boiling, filtering and others.

The distillation method is an effective way to produce clean water that is free from impurities in the form of small solids, germs and bacteria. Several distillation technologies have been developed, including Mechanical Vapor Compression (MVC), Multi Effect Distillation (MED), Multi-Stage Flash Distillation (MSF), Reverse Osmosis (RO), Thermal Vapor Compression (TVC) and Vacuum Desalination (VD). But some researchers say that the water distillation process using solar energy is the most efficient technology, eco-friendly, easy to maintain and inexpensive to manufacture [14].

Solar-based distillation is a method that utilizes solar energy to process dirty water into clean water by heating and evaporation in solar collectors. Solar water distillation equipment is generally shaped like a box or rectangle which is commonly called a distiller box.

There are 2 main components in a solar distillation equipment, there are a water bath (basin) and a cover glass. The water bath has the function of absorbing heat from the sun which then evaporates the water so that the water is separated from the contaminated substances. Meanwhile, the cover glass functions as a place for water vapor to condense so that it can produce clean water that can be used for household needs [9].

The utilization of solar water distillation equipment generally still has a relatively low productivity of clean water produced. There are several ways to increase productivity, there were by choosing the right location for carrying out the test, the material of the glass cover and its thickness, the water level used, the intensity of the sun, the ambient temperature and the wind speed.

Another way to improve the performance of this solar water distillation equipment is by adding thermal energy storage (TES) material which functions to store heat energy from the sun during the day and release this heat energy at night. By that way the distillation process takes place continuously for 24 hours [11].

Based on the explanation above, the researchers conducted research on the manufacture of a solar water distillation equipment by adding thermal energy storage material, it was aluminum oxide ($Al_2O_3$) nanoparticles with different weight concentration variations to produce clean water that ready to use.

This method is used to make a faster evaporation process of changing the temperature of the water in the distillation equipment. In this study, the absorber plate used was coated with black paint mixed with aluminum oxide ($Al_2O_3$) nanoparticles

### 1.2 Solar Distillation

Solar distillation is a distillation equipment that has been developed and is quite widely used by the public. This type of distillation uses solar radiation as the main energy source used to heat water. Of course this is an eco-friendly equipment because it does not use any fossil energy. However, the process is highly dependent on the weather.

There are three main components in a solar distillation equipment which can be seen in Figure 1. These include: a basin which functions as a raw water reservoir, a cover glass as a place for water vapor to gather and is a place for the condensation process to occur and a storage tank as a place for water from the distillation process.

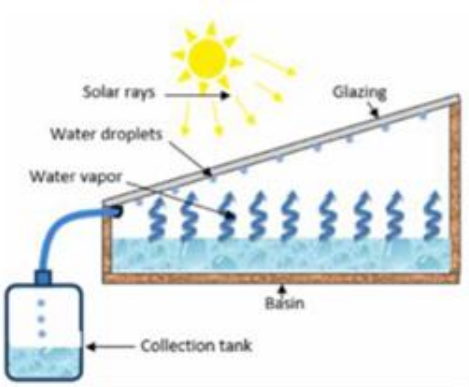


**Figure 1.** Single Slope Solar Distillation

### 1.3 Aluminum Oxide (Al2O3)

Aluminum oxide is an amphoteric oxide having the chemical formula $Al_2O_3$. Aluminum Oxide (Alumina) consists of the chemical compound aluminum and oxygen. Aluminum Oxide ($Al_2O_3$) is a solid material in the form of a chemical compound, insoluble in water, odorless and white in color. The thermophysical properties of aluminum oxide nanoparticles are shown in Table 1.

**Table 1.** Physical properties of $Al_2O_3$ nanoparticles

| NO | *Properties* | *Value* |
|---|---|---|
| 1. | *Melting point (oC)* | ± 30 |
| 2. | *Therm Conductivity* (W/ m.K) | 40 |
| 3. | *The Spec Heat*, Cp (kJ/kg. k) | 0,88 |
| 4. | *Density* (kg/m3) | 3890 |
| 5. | *Purity* | 99% |
| 6. | *Color* | White |
| 7. | *Average particles size* | 3 nm |

## 2.0 METHODOLOGY

### 2.1 Research Method

The method used in this study is an experimental method to test a solar distillation equipment by mixing aluminum oxide ($Al_2O_3$) nanoparticles with black paint and applying it to the surface of the absorber plate with varying weight concentrations, there were 10; 15; 20% which will be compared with a conventional solar distillation equipment (without nanoparticles) under the same conditions and place. So that in the end it can be known the effect of using Aluminum Oxide ($Al_2O_3$) nanoparticles on the efficiency and productivity of solar water distillation results. The type of solar distillation equipment used is Single Slope Solar Distillation.

### 2.2 Data Collection Stage

there are steps that must be fulfilled as follows at the data collection stage.

1. Data collection was carried out 5 times or 5 days in clear weather conditions, with a duration of 8 hours from 09.00 s.d. 17.00 WIB. Where data collection is done every 5 minutes. The types of data to be retrieved are as follows.
   - Tg.i = Inside Glass Surface Temperature (°C)
   - Tg.o = Outer Glass Surface Temperature (°C)
   - Ta = Air Temperature in the Basin (°C)
   - Tw = Standard Water Temperature in the Basin (°C)
   - Te = Ambient Temperature (°C)
   - Is = Sunlight Intensity (W/m2)
2. Record the distilled water in a measuring cup every 1 hour.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Analysis of Test Result

The data from the distillation equipment test results are displayed in graphical form, based on these graphs it can be seen the effect of variations in the addition of $Al_2O_3$ nanoparticles mixed with black paint.

1. Water temperature in the Basin with the addition of 10% nanoparticles.

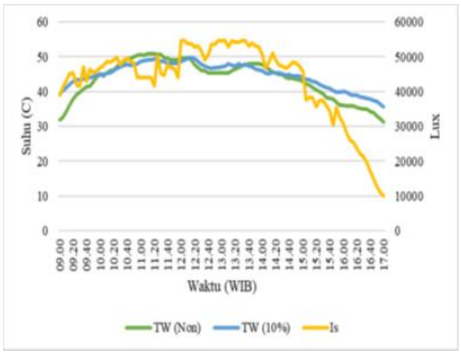


**Figure 2.** Graph of Basin Water Temperature without Nanoparticles and 10% Nanoparticles with Solar Radiation Intensity

Based on Figure 2 it can be seen that there is an effect of adding 10% $Al_2O_3$ nanoparticles to the raw water temperature.

It can be seen in the graph above that the increase and decrease in raw water temperature between the two distillations is relatively the same. It can also be seen that the raw water temperature starts at 31.8 - 39.15 °C and ends at 31.5 - 35.65 °C.

Based on Figure 2, the increase and decrease in raw water temperature with the addition of 10% nanoparticles and without the addition of nanoparticles is affected by the increase and decrease in the intensity of solar radiation received by the two equipments. the addition of 10% $Al_2O_3$ nanoparticles was better in influencing the raw water heating process compared to without the addition of $Al_2O_3$ nanoparticles because it was found that the average Tw 10% > Tw non, namely 44.74 °C and 43.59 °C.

2. Water temperature in the Basin with the addition of 15% nanoparticles.

Figure 3 explains the graph of the difference in the speed of heating raw water in the basin of the distillation equipment with the addition of 15% nanoparticles and without the addition of nanoparticles.

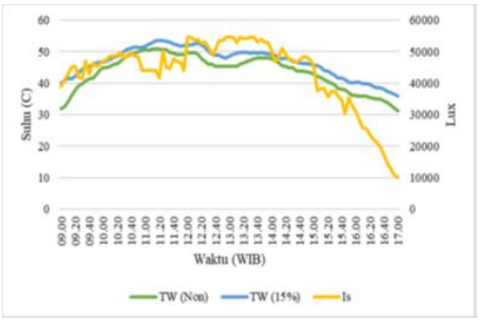


**Figure 3.** Graph of Basin Water Temperature without Nanoparticles and 15% Nanoparticles with Solar Radiation Intensity

It can be seen in the graph above that the raw water temperature starts at 31.8 - 40 °C and ends at 31.5 - 35.95 °C. The distillation apparatus with the addition of 15% nanoparticles increased faster in raw water heat compared to the distillation equipment without the addition of nanoparticles when the intensity of solar radiation entering the distillation equipment was of the same value.

The maximum raw water temperature in the two equipments is 50.95 °C for the tool without the addition of nanoparticles and 53.55 °C for the tool with the addition of 15% nanoparticles at 11.20 WIB. This caused of the use of nanoparticles which are applied to absorber plates which play an important role in absorbing and storing heat from the sun so that it accelerates the process of heating raw water.

3. Water temperature in the Basin with the addition of 20% nanoparticles.

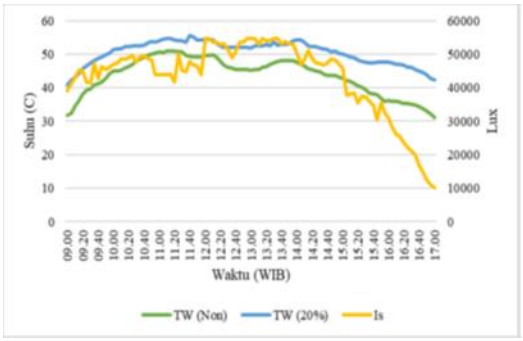


**Figure 4.** Graph of Basin Water Temperature without Nanoparticles and 20% Nanoparticles with Solar Radiation Intensity

Figure 4 explains the graph of the difference in the speed of heating raw water in the basin of the distillation equipment with the addition of 20% nanoparticles and without the addition of nanoparticles. In the graph above, it can be seen that the raw water temperature starts at 31.8 - 40.9 °C and ends at 31.5 - 42.25 °C.

The distillation equipment with the addition of 20% nanoparticles was clearly able to increase the raw water temperature better than the distillation equipment without the addition of nanoparticles when the intensity of solar radiation entering the distillation equipment was of the same value. The maximum raw water temperature for the two equipments is 50.95 oC for the tool without the addition of nanoparticles at 11.20 WIB and 55.55 oC for the tool with the addition of 20% nanoparticles at 11.40 WIB. It can be seen from the graph that the effective raw water heating process occurs between 09.00 s.d. at 14.00 WIB.

4. Ambient Temperature Against Sunlight Radiation Intensity

The relationship between ambient temperature and solar radiation intensity is shown in Figure 5. The highest environmental temperature reached 39.92 °C and the highest solar radiation intensity reached 54612.5 Lux which occurred at 12.00 WIB.

During 5 days reseach the average ambient temperature reached 36.67 °C and the average solar radiation intensity reached 43393.55 Lux. At 14.20 WIB to 17.00 WIB the intensity of solar radiation received by the distillation equipment began to decrease continuously, causing a decrease in the ambient temperature around the distillation equipment.

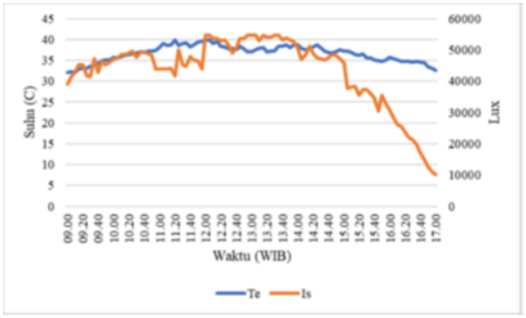


**Figure 5.** Graph of Environmental Temperature to Solar Radiation Intensity

5. Average Outside and Inside Glass Temperatures for Each Test Variation.

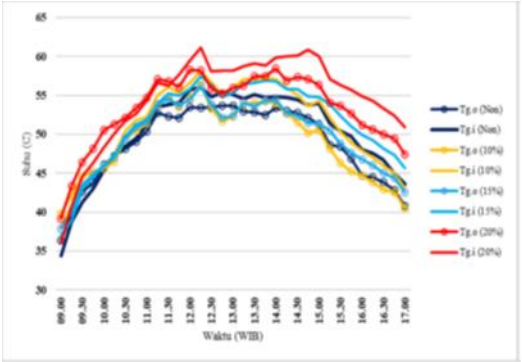


**Figure 6.** Graph of Comparison of Average Outside Glass and Inside Glass Temperatures for Each Test Variation

Figure 6 explains the comparison between the temperature of the outer glass and the inner glass in each test. At the beginning of the test it was seen

that Tg.o > Tg.i, then when approaching 12.00 WIB the temperature of the inner glass began to increase compared to the temperature of the outer glass because the temperature in the basin began to increase. So that the value of Tg.o < Tg.i continues until the afternoon. When Tg.o < Tg.i, the evaporation process occurs and water dew appears on the inner glass surface or a condensation process occurs. The more heavy concentration of nanoparticles added to the distillation equipment, the higher the temperature of the glass, both the outer glass and the inner glass.

### 3.2 Distillation Equipment Productivity

The following is the total productivity of water distilled per day from a solar distillation equipment using aluminum oxide ($Al_2O_3$) nanoparticles mixed with black paint with variations in weight concentration, namely 10; 15; 20% and a distillation equipment that does not use nanoparticles for 24 hours, from 09:00 WIB to. at 09:00 WIB the next day.

**Table 2.** Distilled volume (ml)

| Test | Non | NP 10% | NP 15 % | NP 20% |
|---|---|---|---|---|
| 1 | 435 | 617 | 705 | 816 |
| 2 | 347 | 527 | 725 | 887 |
| 3 | 338 | 555 | 789 | 927 |
| 4 | 340 | 493 | 635 | 763 |
| 5 | 210 | 225 | 302 | 529 |
| average | 334 | 483,4 | 631,2 | 784,4 |

The average value obtained from the distillate volume in Table 2 is used to obtain the value of the increased distillate volume in each test. The following is a table of increasing the average volume of clean water produced by a distillation equipment without nanoparticles and a distillation equipment with the addition of nanoparticles.

**Table 3.** The increasing of distillate volume in a distillation equipment without nanoparticles and a distillation equipment with the addition of nanoparticles

| No | % NP | Non (ml) | NP (ml) | Beda (ml) | % |
|---|---|---|---|---|---|
| 1 | 10 | 334 | 483,4 | 149,4 | 44,73 |
| 2 | 15 | 334 | 631,2 | 297,2 | 88,98 |
| 3 | 20 | 334 | 784,4 | 450,4 | 134,85 |

## 4.0 CONCLUSION

Based the research on a solar distillation equipment with the addition of $Al_2O_3$ nanoparticles and a solar distillation equipment without the addition of Al2O3 nanoparticles, the conclusions can be drawn as follows:

1. Based on the results of experiments carried out that the use of $Al_2O_3$ nanoparticles has an effect on accelerating the process of heating raw water and storing heat during the day then releasing it at night. This is proven when the condensation process is still going on at night and sometimes the results of the distillate at night are more than during the day.
2. Based on the results of experiments, single-tilt solar distillation equipment with the addition of $Al_2O_3$ nanoparticles using a weight concentration of 10 ; 15 ; 20% successively increased in equipment productivity, namely 44.73% ; 88.98% ; 134.85% compared to the distillation equipment without the addition of $Al_2O_3$ nanoparticles.

## References

[1] Aprizki, E., Rokhmat, M., & Wibowo, E. 2018. Analisis Pengaruh Kemiringan Sudut Atap Kaca Dan Penambahan Cermin Pada Alas Basin Terhadap Laju Penguapan Air Garam Dalam Distilator Tenaga Surya. eProceedings of Engineering, 5(3).

[2] Astawa, K., Sucipta, M., & Negara, I. P. G. A. 2011. Analisa Performansi Destilasi Air Laut Tenaga Surya Menggunakan Penyerap Radiasi Surya Tipe Bergelombang Berbahan Dasar Beton. J. Ilm. Tek. Mesin Cakra M, 5(1), 7-13.

[3] Benoudina, B., Attia, M. E. H., Driss, Z., Afzal, A., Manokar, A. M., & Sathyamurthy, R. 2021. Enhancing the solar still output using micro/nanoparticles of aluminum oxide at different concentrations: an experimental study, energy, exergy and economic analysis. Sustainable Materials and Technologies, 29, e00291.

[4] Dewantara, I. G. Y., Suyitno, B. M., & Lesmana, I. G. E. 2018. Desalinasi air laut berbasis energi surya sebagai alternatif penyediaan air bersih. Jurnal Teknik Mesin (JTM), 7(1), 1-4.

[5] Kabeel, A. E., Sathyamurthy, R., Sharshir, S. W., Muthumanokar, A., Panchal, H., Prakash, N., ... & El Kady, M. S. 2019. Effect of water depth on a novel absorber plate of pyramid solar still coated with TiO2 nano black paint. Journal of cleaner production, 213, 185-191.

[6] Kii, O. A. 2015. Rancang Bangun Sistem Distilasi Air Laut Tenaga Surya Tipe Double Slope Dengan Penambahan Pelat Absorber Bentuk Gelombang Segitiga Dan Reflektor Internal (Doctoral dissertation, Institut Teknologi Sepuluh Nopember).

[7] Panchal, H., Nurdiyanto, H., Sadasivuni, K. K., Hishan, S. S., Essa, F. A., Khalid, M., ... & Shanmugan, S. 2021. Experimental investigation on the yield of solar still using manganese oxide nanoparticles coated absorber. Case Studies in Thermal Engineering, 25, 100905.

[8] Pratama, A. W., Nurdiana, J., & Meicahayanti, I. 2017. Pengaruh perbedaan jenis plat penyerap kaca dan papan mika terhadap kualitas dan kuantitas air minum pada proses destilasi energi tenaga surya. In Prosiding Seminar Nasional Teknologi, Inovasi dan Aplikasi di Lingkungan Tropis (Vol. 1, No. 1, pp. 3540).

[9] Pratama, F. X. R. K. 2015. Destilator Air Energi Termal Surya Jenis Konvensional Menggunakan Pendingin Air Dengan Kaca Ganda. Skripsi. Sarjana Universitas Sanata Dharma Yogyakarta.

[10] Putra, R. A., Pauzi, G. A., & Surtono, A. 2018. Rancang Bangun Alat Destilasi Air Laut dengan Metode Ketinggian

Permukaan Air Selalu Sama Menggunakan Energi Matahari. Jurnal Teori dan Aplikasi Fisika, 6(1), 101108.

[11] Saputra, E. T., Caturwati, N. K., & Rosyadi, I. 2021. Pengaruh Massa PCM (Phase Change Material) Terhadap Produktivitas dan Efisiensi Alat Destilasi Tenaga Surya Menggunakan PCM Jenis Lauric Acid Sebagai Penyimpan Panas. Eksergi: Jurnal Teknik Energi, 17(3), 201-212.

[12] Shalaby, S. M., El-Bialy, E., & El-Sebaii, A. A. 2016. An experimental investigation of a v-corrugated absorber single-basin solar still using PCM. Desalination, 398, 247-255.

[13] Shoeibi, S., Kargarsharifabad, H., & Rahbar, N. 2021. Effects of nano-enhanced phase change material and nano-coated on the performance of solar stills. Journal of Energy Storage, 42, 103061.

[14] Siregar, M. A., Damanik, W. S., & Lubis, S. 2021. Analisa Energi pada Alat Desalinasi Air Laut Tenaga Surya Model Lereng Tunggal. Rekayasa Mesin, 12(1), 193-201.

[15] UDARA, B., & MARKUS, D. D. S. 2015. Membandingkan Unjuk Kerja Alat Destilasi Air Energi Surya Jenis Absorber Kain Menggunakan Kaca Tunggal Berpendingin Air Dengan Berpendingin Udara. Skripsi. Sarjana Universitas Sanata Dharma Yogyakarta.

[16] Yudiyanto, E. 2018. DISTILASI AIR LAUT TENAGA SURYA DENGAN KONSENTRATOR LENSA FRESNEL. TURBULEN Jurnal Teknik Mesin, 1(2).

[17] Yusuf, Y. (2020). Productivity of Solar Distillation in Indonesia using Sodium Thiosulfate Penta-hydrate as Thermal Energy Storage. Technium, 2(5), 1-10.

[18] Yusuf, Y., Rosyadi, I., & Almarwan, A. F. 2020. COMPARISON OF THE EFFECTIVENESS OF 45˚ AND 60˚ COVER ANGLE ON THE PRODUCTION OF CLEAN WATER ON DOUBLE SLOPE SOLAR DISTILATIONS (Perbandingan Efektivitas Sudut Penutup 450 dan 600 pada Double Slope Solar Destilasi Sebagai Penyedia Air Bersih). Journal of Renewable Energy & Mechanics (REM), 3(2), 59-70