THE INFLUENCE OF GLASS COVER SHAPE ON CLEAN WATER PRODUCTIVITY ON SEAWATER DISTILLATION EQUIPMENT

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THE INFLUENCE OF GLASS COVER SHAPE ON CLEAN WATER PRODUCTIVITY ON SEAWATER DISTILLATION EQUIPMENT

玻璃蓋形狀對海水蒸餾設備清潔水生產率的影響

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Abstract

Current conditions of a lack of clean water, abundant seawater, and the ready availability of solar radiation energy contribute to the need to develop solar-powered seawater distillation technology. This research was conducted to determine the effect of the glass cover shape on the solar still distillation equipment productivity of clean water, and was carried out in May 2019 at the Faculty of Engineering, Sam Ratulangi University, Manado. The study used 100 cm long and 50 cm wide, a 3 mm thick glass cover angled at 17 degrees from the top of the basin. Observations were made with two treatments, including a one-sided glass cover and a two-sided glass cover. Temperature data were taken from the glass cover, water in the basin, solar radiation, and the clean water temperature every 10 minutes from 0805 to 1705 hrs. The results of the study show that more water is produced with a one-sided glass cover than with the two-sided cover. The average amount of clean water produced in a day was 2,393.3 ml with the one-sided cover and 2,265 ml with the two-sided glass cover. The one-sided glass cover had an efficiency of 68.27% and the two-sided glass cover had an efficiency of 62.50%.

Keywords: Distillation, Basin, Glass Cover, Solar Still

摘要 當前缺乏清潔水，豐富海水以及太陽能輻射能隨時可用的條件促使人們需要開發太陽能海水蒸餾技術。這項研究旨在確定玻璃罩形狀對太陽能蒸餾設備清潔水生產率的影響，該研究於 2019 年 5 月在萬鴉老山姆拉圖蘭吉大學工程學院進行。這項研究使用了 100 厘米長，50 厘米寬，一個 3 毫米厚的玻璃蓋，該玻璃蓋與盆的頂部成 17 度角。用兩種處理進行觀察，包括一側玻璃罩和兩側玻璃罩。溫度數據來自玻璃蓋，水池中的水，太陽輻射以及從 0805 到 1705 小時的每 10 分鐘的清潔水溫度。研究結果顯示，單面玻璃蓋產生的水比帶有雙面蓋。一天的平均清潔水量（帶側蓋）為 2.393.3 毫升，帶側玻璃蓋為 2.265 毫升。一側玻璃罩的效率為 68.27%，而兩側玻璃罩的效率為 62.50%

关键词: 蒸餾，水盆，玻璃蓋，太陽能蒸餾器

I. INTRODUCTION

Along with the development of human populations living number on Earth, they are very dependent on energy sources that exist on this earth. So, the more the population on earth is growing, the more it needs various energy sources to meet human needs.. To develop various technologies and result in greater energy needs, humans do research using existing energy sources, one of which is an abundance of renewable solar energy.

Solar energy is an inexpensive and environmentally friendly source of energy, although it has not been used to its full potential. One promising utilization of solar energy is seawater distillation, and this study explores the effect of the cover glass shape on clean water productivity in seawater refining equipment using a steel basin. It facilitates utilizing cheap and environmentally friendly solar energy to obtain clean water through seawater distillation, utilizing distillation using a steel basin.

A. The scope of the problem

The problem is as follows: What is the effect of cover glass shape on clean water production by seawater refining equipment?

The scope of the problem is limited to the following:

- The basin is made from 0.5 mm thick steel plate
- Data is collected in clear weather
- The study was conducted in the Sam Ratulangi University, Manado (UNSRAT) mechanical engineering parking area
- The heat transfer was assumed to occur in a one-dimensional state.

B. Writing Purpose

The purpose of this article is as follows:

- To calculate water efficiency and productivity, in this case, the water quantity produced by the seawater refining equipment using a steel basin;
- To describe the design of seawater distillation equipment;
- To serve as a data source for researchers and other planners in developing or designing seawater distillation equipment.

C. The Article Benefits

The benefits of this article are as follows:

- To determine how the glass cover shape on the seawater solar energy distillation equipment influences clean water production;
- To provide input and suggestions for solar energy utilization development, especially for seawater purification applications;
- To help solve the lack of clean water problems, especially in coastal areas.

D. Theoretical Basis

Seawater refining is the process of purifying seawater using a physical separation process between water and salt content by evaporating seawater and then cooling the resulting steam as freshwater. This seawater distillation process is carried out using a distillation device that undergoes a heat transfer process at the bottom of the distillation device which receives energy in the form of sunlight.

II. LITERATURE REVIEW

Research on solar stills has been conducted for some time and is used to support this research. M. Kobayashi [1] examined a solar still device to purify radioactive contaminated groundwater. J. Ahmadzedeh [2] describes the results of using water distillation equipment. Jackson and Van Bavel [3] proposed a simple distillation device consisting of a rectangular wooden plank that was covered with glass on the sides and top. A study by Foster and Cormier [4] found that distillation equipment of 2.6 m^2 in good weather of sufficient sunlight so that the distillation process runs well can produce 3 gallons of clean water per day with solar radiation of 2,306 KWh/m^2. The authors of paper [5] described a solar still that can operate day and night. Meinhart, Arter, Amerco, and Iqbal conducted a performance test on a solar still situated in an east-west orientation operating during the hours from 0800 to 1700.

A. Solar Radiation

The sun is a collection of gases with very high temperatures. According to Kreith and Kreider [6], the outermost layer of this gas mass has a temperature of 5,760 degrees Kelvin, interior temperature of 20 x 10 degrees Kelvin, and a radiation emission rate of 3.8×10^{23} kW. Only 1.7×10^{14} kW of radiation is emitted to Earth, which is 150 million km from the sun [7].

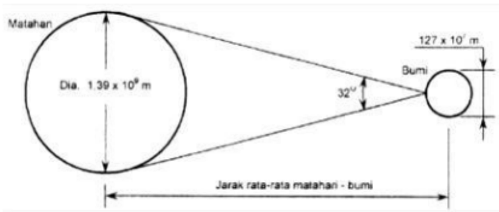

Figure 1. The Sun and Earth relationship
(Source: Duffie and Beckman, 1980.)

Solar Constant

According to Duffie and Beckman [7], the solar constant, *Ik*, is the solar radiation that falls perpendicular to a surface outside the Earth's atmosphere:

$$I_k = \frac{\sigma d_s^2 T^4}{4R^2} \qquad (2.3)$$

where:

Ik = solar constant

R = average distance between earth and sun = $1.5 x 10^{11}$ m

The solar constant (*Ik*) is used as a reference base to determine the solar radiation intensity that arrives at a surface before experiencing a decrease due to various factors that become obstacles on the way to Earth. A cover glass serves to reduce the heat loss from the absorber, as a gathering place for heated water vapor, and drain the condensation water into the reservoir through a channel. Solar still equipment cover glass generally is made of a transparent material such as glass or plastic. A good cover glass must have high transmissivity, absorptivity, and low reflectivity.

Transmittivity

According to Duffie and Beckman [7], transmissivity is very important in solar still equipment. This transmissivity can be reduced due to several things, namely: an increase in the angle of incidence that exceeds 45 degrees vertical, material thickness, iron content, and the type of material used on the cover glass.

Absorbivity

As Duffie and Beckman [7] assumed, radiation absorption in transparent media is explained by Bouger's law, which is based on the assumption that radiation absorbed by the local intensity with the distance from the radiation is evenly distributed and the distance of the radiation transfer is evenly distributed.

Reflectivity

Reflectivity in a transparent cover glass material depends on the refractive index and the angle of incidence formed between the incoming radiation and the perpendicular line that is transmitted on the surface.

The intensity of the Sun's Radiation in a Surface Field on Earth

As a result of the earth's tilted position of the vertical axis during rotation and revolution, the sun's rays with the equatorial plane form a declination angle whose magnitude changes from +23.450 in early summer (June 21) to -23.450 in early winter (December 21).

Solar Still Working Process

The operation of a solar is still, in principle, the same as rainwater - namely, the evaporation process. Water from the earth's surface is heated by sunlight, and evaporation occurs. This water vapor gathers and increases into a collection of water, which then cools, changing the water vapor into water droplets that fall back to the earth's surface in the form of rainwater. When the water evaporates, there is a release of the charge contained in the water. The working process of this solar still equipment is similar to the natural evaporation process, as shown in the picture below.

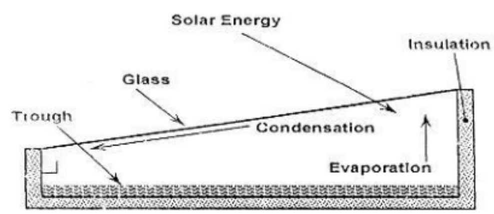

Figure 2. Solar Still Basin Type
(Source: Sol Aqua, 2001)

Solar Still Performance

There are generally four main parts of a solar still: cover glass, absorbent plates, insulators and condensate drain. For optimal solar efficiency of a solar still, the following factors must be considered:

1. Cover glass - The solar still performance will be affected by the amount of cover glass used, cover glass thickness, cover glass material, and cover glass treatment (coating and etching).
2. Absorbent plate - The solar still performance will be affected by the type of material and color of the absorbent plate.
3. Insulator - Insulator type and thickness will affect the solar still performance.

Fluid Mechanics Overview - Reynolds number

The Reynolds number provides a relationship between the wind speed, the length of the cover glass, and the kinematic viscosity [5].

$$Re : \text{bilangan Reynold, } Re = \frac{u_{\infty} . l}{v}$$

where u = wind speed (m/sec)
l = cover glass length (m)
v = kinematic viscosity (m^2/sec)

Heat Transfer Basics

Heat transfer is defined as the process of energy transfer from one location to another due to temperature differences. Three heat transfer methods are usually classified: conduction, convection, and radiation.

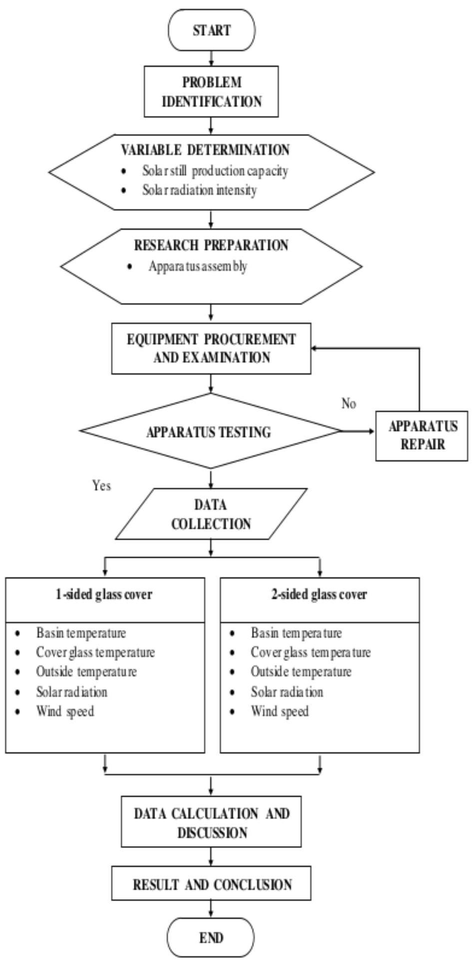

Figure 3. Research flow chart

1. *Conduction Heat Transfer*: Conduction is the process by which heat flows from areas of high temperature to lower temperatures in a medium (solid, liquid, or gas), or between two mediums that directly intersect.
2. *Convection Heat Transfer*. Convection heat transfer is the combined process of transferring work energy from heat conduction, energy storage, and combustion. Convection is very important as a mechanism of energy transfer between the surface of solid objects and a liquid or gas [6]
3. *Radiation Heat Transfer*. Radiation is the process by which heat flows from high-temperature objects to lower-temperature objects when the objects are separated in space, even if there is a vacuum between them.

III. METHODS/MATERIALS

This research was conducted directly on seawater distillation equipment, to determine the equipment's ability to produce clean water with changes in time and solar radiation intensity. The seawater distillation equipment is produced with the orientation, facing north, this is intended so that sunlight will hit the glass cover surface along the solar still from east to west.

A. Research Place and Time

Location: Mechanical Engineering parking lot UNSRAT

Time: May 2019

The city of Manado is located at 1.30 - 1.40 LU and 124.40 - 124.5 BT. This research was conducted in May 2019, because at that time, it was still in the dry season and the solar radiation intensity was quite high.

B. Materials

The seawater distillation equipment, the construction consists of several parts, namely:

1. Steel basin or steel container,
2. Styrofoam
3. Glass Cover.
4. Clean waterways
5. Dull black paint

C. Research procedure

The test was carried out in October 2007 for 6 days. Data collection is carried out starting from 08.05 to 16.05 with a data recording done every 10 minutes. Data collection was carried out simultaneously on both equipments, namely the equipment with one-sided form cover glass and the equipment with two-sided shape cover glass. In carrying out this test, data collection is carried out the:

1. Basin temperature

2. Cover glass temperature
3. Seawater temperature
4. Air ambient temperature
5. Momentary solar radiation
6. Wind velocity
7. Condensate water production

The whole set of research activities can be illustrated in a flowchart (Figure 3).

D. Data Processing

The processed data are presented in Figure 4.

Time	Temperature (°C)				Ambient Temperature (°C)	Instantaneous Radiation (Watt/m²)
	Glass I	Basin I	Glass II	Basin II		
8:05	30	31	30	31	28	722,8662
8:15	32	31	31	31	29	805,058
8:25	34	32	33	33	30	850,3688
8:35	36	35	36	35	30	848,2613
8:45	38	37	37	36	30	854,5838
8:55	40	39	39	37	30	872,4974
9:05	41	40	40	39	31	887,2497
9:15	42	41	41	40	31	912,5395
9:25	44	42	43	41	31	922,0232
9:35	45	44	44	43	31	936,7756
9:45	46	46	45	44	31	952,5817
9:55	47	47	47	45	31	975,764
10:05	49	48	49	47	32	939,9368
10:15	51	50	51	49	32	1025,29
10:25	54	52	54	51	32	1044,257
10:35	55	56	57	54	32	926,2381
10:45	56	58	59	57	32	1076,923
10:55	58	60	61	59	33	1126,449
11:05	60	62	64	61	33	1145,416
11:15	63	65	68	64	33	1162,276
11:25	67	68	70	68	33	1199,157
11:35	69	69	72	70	33	1229,715
11:45	71	70	74	72	34	1250,79
11:55	73	73	75	74	34	1269,758
12:05	75	75	76	75	34	1276,08
12:15	77	77	78	76	34	1268,704
12:25	79	79	77	78	34	1246,575
12:35	78	83	76	77	34	1207,587
12:45	76	80	74	78	33	1174,921
12:55	75	84	73	81	33	1200,211
13:05	73	86	73	78	33	1184,405
13:15	70	80	71	76	33	1162,276
13:25	68	79	70	75	33	1142,255
13:35	65	79	65	73	33	1120,126
13:45	63	78	59	70	33	822,9715
13:55	60	74	60	69	33	1091,675
14:05	59	72	58	68	33	1061,117
14:15	57	69	56	67	33	1034,773
14:25	54	68	53	66	33	810,3267
14:35	50	68	50	64	32	985,2476
14:45	45	65	47	63	32	966,2803
14:55	43	64	45	61	32	714,4362
15:05	42	63	43	59	32	721,8124
15:15	42	60	41	54	32	740,7798
15:25	41	57	41	54	31	735,5111
15:35	40	57	40	53	31	707,0601
15:45	39	54	39	50	31	697,5764
15:55	39	50	38	43	31	625,922
16:05	39	50	38	48	31	385,6691
16:15	39	48	37	47	30	325,6059
16:25	39	48	37	47	30	261,3277
16:35	37	48	36	46	30	197,0495
16:45	36	47	36	45	29	169,6523
16:55	34	47	34	45	29	167,5448
17:05	34	46	33	43	29	128,5564

Figure 4. Processed data

IV. Results and Discussion

Observations were made in May 2019, data began to be taken at 08.05 hours to 17.05 hours with the results obtained varying each day.

A. The sun intensity during the observation

The solar intensity measuring data during the test is the solar intensity value received by the pyranometer and recorded every 10 minutes and it could be seen that there is a measure of results difference (Figure 5). This difference is due to moving clouds sometimes blocking the sun's rays.

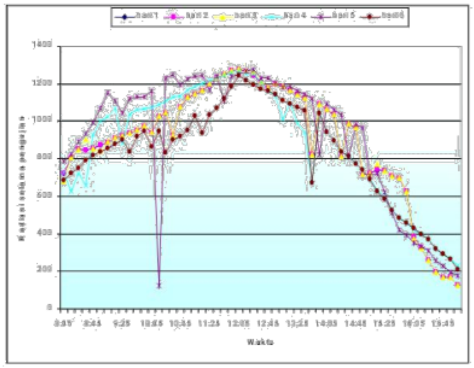

Figure 5. Sun intensity dring the observation

The picture above displays variation in the intensity of solar radiation; beginning at 08.05, it rises slowly, peaking between 11:25 and 12:25, then gradually diminishes until 16.05.

The effect of one-sided glass covers vs two-sided. Data analysis shows that in the distiller with a one-sided glass cover, condensation produces, on average, about 2.393.3 ml/day more water than a distiller with a two-sided glass cover, which averages about 2.265 ml/ day. This is because the single-sided glass cover's larger surface area receives more solar energy and wind, resulting in higher levels of condensation, thus producing more water. Further analysis of both distillers' output indicates an efficiency of about 68.27% for the one-sided glass cover and 62.50% for the two-sided.

B. Solar Radiation Intensity Effects

Evaporation occurs when the distiller's basin absorbs heat from solar radiation, which raises the temperature of the seawater. Solar radiation intensity varies throughout the day, which affects the amount of condensation in the basin. The more intense the solar radiation, the more energy gets transmitted to the basin's absorber plate, which increases the rate of evaporation.

C. Wind Speed Effects

Raising the evaporation rate can intensify steam pressure on the seawater's surface. Because the difference in pressure between the steam on the surface and near the glass cover is greater, the heat transfers to the glass cover at a higher rate.

Conclusion

Findings from the research conducted indicate that, first, the efficiency of the distiller basin with the one-sided glass cover is approximately 68 percent. Second, water condensation from this type of basin averages 2,393.3 ml per day. Third, solar radiation intensity increases the distiller's output. Raising the seawater temperature increases the rate of evaporation, creating more steam in the basin.

As this research continues, more accurate results are obtainable by implementing the use of better distillation equipment, e.g. units with copper-plated basins. Additionally, placing rain shields over the glass covers and bottoms will prevent cracks.

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