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Technical Specification Analysis Of Seawater Destillator Type Of Solar Water Heater With Variations

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Abstract – The existence of the Navy Post in the outer islands has problems in meeting the need for clean water, especially for drinking and eating due to the lack of water sources in those places. Distillation of seawater into freshwater is an alternative to overcome this by utilizing solar power which is an unlimited and environmentally friendly energy source. In this thesis, the writer carries out an analysis of the calculation of the effect of the angle of incidence and the area of the collector on the time required to produce 10 liters of distilled water with variations in the angle of incidence 0º, 5º, 10º, 15º, 20º, 25º, and 30º and with a variation of the collector area of 1.6 m². up to 10 m². From the results of the analysis, it was found that the angle of incidence 0º has the largest value in the absorption of solar intensity, which is 1297 W/m² and tends to decrease with the addition of the angle of incidence. Meanwhile, the time needed to produce 10 liters of distilled water with an area of 1.6 m² is 8.88 hours and is getting faster as the collector area increases.

Keywords – ***Distillation, Solar water heater, Collector.***

I. Introduction

Indonesia's geography is crossed by the equator with the condition of the sun shining throughout the year making sunlight an abundant natural resource. Based on data from the Ministry of Energy and Mineral Resources, solar radiation collected from 18 locations in Indonesia, solar radiation in western Indonesia is around 4.5 kWh/m2/day with a monthly variation of about 10% and for eastern Indonesia, it is around 5.1 kWh/m2 /day with a monthly variation of about 9%. Thus, the average solar radiation potential in Indonesia is around 4.8 kWh/m2/day with a monthly variation of around 9%.

The Navy as a State Agency which has the smallest unit in the form of the Navy Post (Posal), whose area of operation includes the coastal area, has a responsibility to the surrounding environment. This condition should be used to support government programs in energy and water saving in the region. One way that can be done is through the development of coastal villages by optimizing climatic and geographical conditions, namely by utilizing the distillation system of seawater into freshwater. The distillation system itself is the process of converting seawater into freshwater by utilizing solar heat.

In this paper, we will discuss the calculation of technical specifications in a simple distillation process that utilizes sunlight with the help of a standard solar collector with a parallel flow type in the process of making freshwater from seawater. This process works by utilizing sunlight that is absorbed by the collector so that the quantity of heat energy produced is greater. Furthermore, the absorption energy is used to heat the water until it evaporates, the water vapor is then condensed and flowed to a freshwater reservoir.

For the distillation system to work optimally, of course, it must meet certain specifications. In writing this thesis, we will analyze the technical specifications of the distillation system using a solar collector, while the data to be calculated is in the form of energy requirements, the volume of seawater to produce fresh water as much as 10 liters, and the intensity of the sun with variations in collector angles and variations in collector area. Determination of the number of 10 liters based on the basic needs of Posal personnel according to the Personnel Composition List (DSP) is 4 people with the total need for each personnel of 2.5 liters/day. Variations were made on the collector slope (0º, 5º, 10º, 15º, 20º, 25º, and 30º) and collector area (1.6 m², 2 m², 4 m², 6.4 m², 8 m², 10 m²).

II. Literature Review

2.1 Design Methodology

In one year, the earth revolves around the sun in an elliptical path. This elliptical plane forms an angle of 23.45° with the plane of the Earth's equator. When viewed from the earth, the position of the sun seems to be in the northern hemisphere and southern hemisphere for half a year alternately.

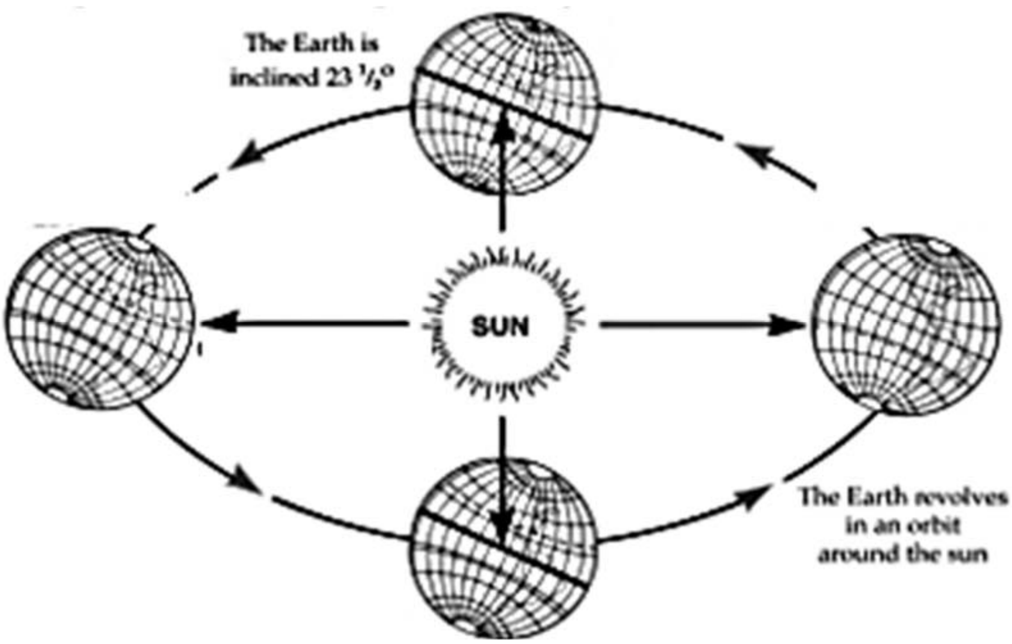

Figure 1. Earth's orbit around the sun

The solar constant is defined as the energy from the sun per unit time received by a unit of surface area perpendicular to the direction of propagation of radiation at the earth-sun average distance outside the earth's atmosphere. The amount is:

Gsc=1367 W/m2...(2.1)

The intensity of solar radiation emitted outside the Earth's atmosphere varies depending on the position of the sun concerning the earth on the day of observation. The magnitude of the intensity of solar radiation outside the Earth's atmosphere at any one time can be calculated by the equation:

$$Gon = Gsc\ (1+0.033\cos\frac{360n}{365})..........(2.2)$$

The rotation of the earth causes the position of the sun to the earth will change the angle of incidence of the sun on the collector plane in one day. This change in angle of incidence causes the value of solar radiation received by the collector to change with the time of observation in a day.

In addition, the angle of incidence of the sun on the collector plane is also influenced by several other angles which can be expressed in the equation:

$$\cos . = \sin\delta . \sin\Phi . \cos - \sin\delta . \cos . \sin . \cos + \cos . \cos\Phi . \cos . \cos + \cos . \sin\Phi . \sin\beta . \cos\gamma . \cos\omega + \cos\beta . \sin\gamma . \sin\omega \ldots\ldots\ldots\ldots(2.3)$$

2.2 Distillation

Distillation is another term for distillation, namely the process of heating a material at various temperatures, without contact with outside air to obtain certain results. Distillation is the change of material from liquid form to gaseous form through the process of heating the liquid, and then cooling the heating gas, to further collect condensed liquid droplets (Cammack, 2006). Salvato (1972) suggested that distillation is very useful for the conversion of seawater into freshwater.

Conversion of seawater into freshwater can be done by using artificial heat distillation, solar distillation, electrodialysis, osmosis, gas hydration, freezing, and others. Homig (1978) stated that for the manufacture of a distillation installation, the most important thing is that it must be non-corrosive, inexpensive, practical, and durable.

2.3 Heat Transfer

Heat transfer is heat energy that moves/flows caused by a temperature difference in the medium (1 medium) or between media. Thermal energy can move from a high-temperature medium to a low-temperature medium. There are 3 modes of heat energy transfer process (figure 2), namely:

a. Conduction

b. Convection

c. Radiation

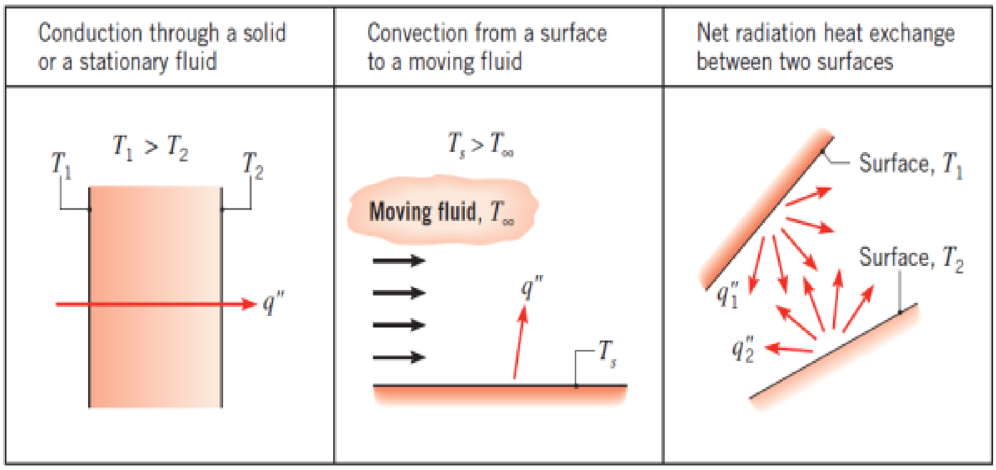

Figure 2. Modes of heat transfer by conduction, convection, and radiation

(Bergman, Theodore L. et al, 2011)

2.3.1 Conduction Heat Transfer

Conduction heat transfer Conduction is the process by which heat flows from areas of high temperature to areas of lower temperature in one medium (solid, liquid, gas) or between different mediums that are in direct contact without any substantial molecular movement. The temperature of an element of a substance is proportional to the average kinetic energy of the molecules that make up that element. The transfer of energy is by diffusion (diffusion) of electrons that move rapidly from areas of high temperature to regions of lower temperature (eg metals).

The amount of conduction heat transfer rate can be expressed in the form of Heat Flux, q" with units of W/m2, i.e., heat transfer per unit area, whose direction is perpendicular to the area and its magnitude is proportional to the temperature gradient. In general, the value of heat transfer in the x-direction is:

$$q_n^{"} = -k\frac{dT}{dx} \text{..........} (2.4)$$

where k is a property called thermal conductivity in units and T is the temperature in Kelvin.$\frac{\mathbf{W}}{\mathbf{m.K}}$

In conduction heat transfer, there are different thermal resistances. The value of this thermal resistance depends on the material. Thermal resistance in conduction heat transfer can be expressed in the following equation.

$$R_{t,cond} = \frac{T_1 - T_2}{q_x} = \frac{L}{kA} \quad (2.5)$$

where L is the thickness of the material in meters that undergoes heat transfer and can be illustrated as in Figure 3.

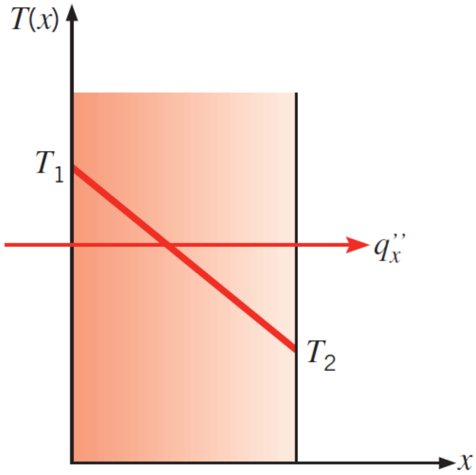

Figure 3. Relationship between coordinate system, heat flow direction, and temperature gradient in 1 dimension

(Bergman, Theodore L. et al, 2011)

2.3.2 Convection Heat Transfer

Convection heat energy transfer occurs between the surface and the moving fluid when there is a temperature difference between the two (figure 2.18). Convection heat transfer consists of two mechanisms, namely energy transfer caused by random molecular motion (diffusion) and macroscopic fluid motion in the boundary layer. Convection flow is influenced by several factors:

a. Horizontal or vertical flow.

b. Laminar or turbulent flow.

c. Flat or curved surface.

d. Type of fluid, liquid, or gas

e. Fluid properties such as viscosity, specific heat, etc.

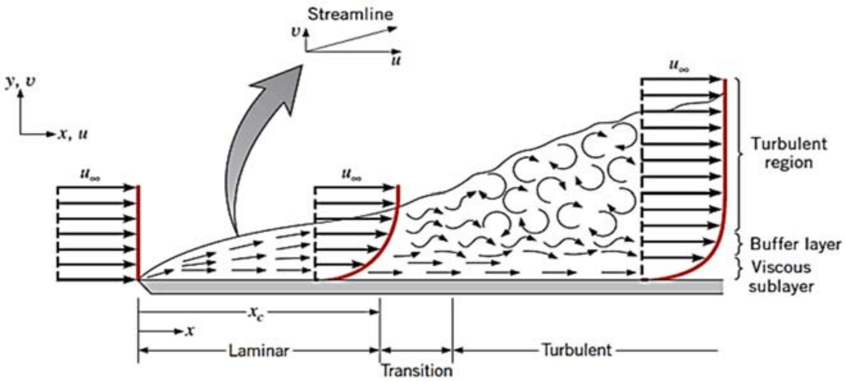

Figure 4. Boundary layer on convection displacement

(Bergman, Theodore L. et al, 2011).

Based on the nature of the fluid flow, convection heat energy transfer can be classified into two, namely forced convection and free convection. Forced convection is influenced by external factors such as blowers, pumps, etc. Meanwhile, free convection of fluid flow occurs solely due to differences in fluid density caused by differences in temperature or the influence of buoyancy forces.

Free convection in fluid flow occurs solely because of differences in fluid density caused by temperature differences. When the plate is heated, a free convection boundary layer is formed. At the wall the velocity is zero because there is a no-slip condition, it increases continuously until it reaches a maximum value, and then decreases again to zero at the edge of the boundary layer, because free steam conditions do not exist in a free convection system., see figure 4. The initial development of the boundary layer is laminar, but on the fluid properties and the temperature difference between the wall and the environment, eddies are formed from the transition to the turbulent layer. The rate of convection heat transfer can be found by Newton's law of cooling, namely:

$q = hA(T_s - T_\infty)$…….. (2.6)

2.3.3 Radiation Heat Transfer

Radiation is the process by which heat flows from an object with a higher temperature to an object with a lower temperature when the objects are separated in space, even if there is a vacuum between them. All objects emit radiant heat continuously. The intensity of the emission depends on the temperature and the nature of the surface. Radiant energy travels at the speed of light (3x108 m/s) and its symptoms resemble light radiation. According to electromagnetic theory, light radiation and thermal radiation differ only in their respective wavelengths. This radiant energy field is emitted as electromagnetic waves. So radiant heat transfer does not require a medium such as conduction and convection heat transfer (figure 2.23). Radiant heat transfer will be more effective if it occurs in a vacuum chamber.

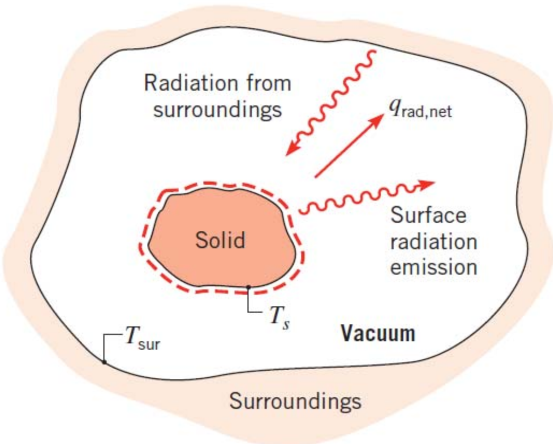

Figure 5. Radiation exchange

(Bergman, Theodore L. et al, 2011).

The radiation emitted by a surface is expressed by Stefan Boltzman's Law, with the equation:

$E_b = \sigma T_s^4$……... (2.7)

2.4 Solar Water Heater

Solar collectors can be defined as a heat transfer system that produces heat energy by utilizing solar radiation as the main energy source. When sunlight hits the absorber in the solar collector, some of the light will be reflected in the environment, while most of it will be absorbed and converted into heat energy, then the heat is transferred to the fluid circulating in the solar collector to be used for various applications. In general, solar collectors are divided into 2, namely flat plate collectors and concentrator collectors.

In general, flat plate collectors are used for indoor heating, air conditioning, and industrial heating processes. (Duffie, 1991). This type is designed for applications requiring thermal energy at temperatures below 100°C. The specifications of this type can be seen from its absorber which is a flat plate made of material with high thermal conductivity and coated with black paint. Flat plate collectors take advantage of direct and scattered (beam and diffuse) solar radiation, require no solar tracking, and require little maintenance. Supporting components found in flat plate collectors include; transparent cover, absorber, insulation, and framework.

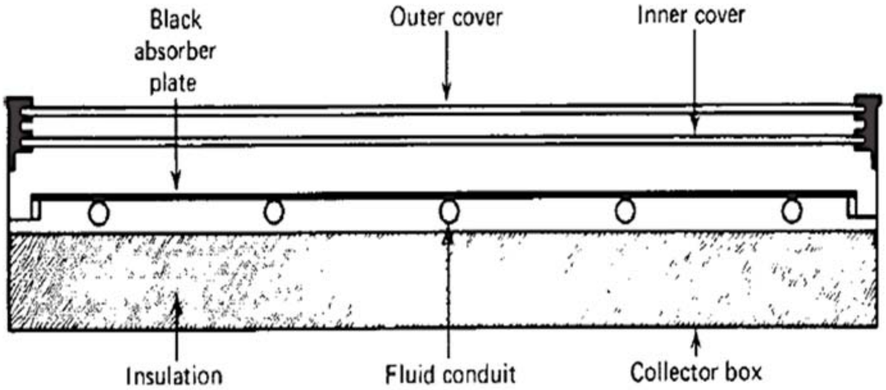

Figure 6. Flat plate solar collector

(Duffie, John A., and William; 2013)

III. Results And Discussion

3.1 Solar Intensity Data

We obtained data on the solar intensity from observations made by one of the BMKG observation stations in the Kalianget area, Madura. The data we obtained are shown in the table below.

Table 1. Solar Intensity Value

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	id_record	ID Station	Date Time	RR	WS AVG	WS MAX	WD AVG	TT AIR MAX	TT AIR AV(	TT AIR MIN	RH_AVG	PP AIR	SR AVG	SR MAX
2														
3	STA2144 2	STA2144	01/09/2019 07.00	0	0	0	0	0	0	0	0	0	0	0
4	STA2144 2	STA2144	01/09/2019 08.00	82,05,00	3	4,06	148,05	28,06	28,03	28,03	69,06	1012,05	503,09	520,01
5	STA2144 2	STA2144	01/09/2019 09.00	89	2	3,08	143,04	29,05	29,02	29,01	66,03	1012,09	710,01	726,04
6	STA2144 2	STA2144	01/09/2019 10.00	140	3	5	165,09	29,03	29,01	29	67,09	1012,04	784,03	890,03
7	STA2144 2	STA2144	01/09/2019 11.00	156,05,00	3	4,09	85,06	30,08	30,05	30,03	62,08	1010,09	939	940,06
8	STA2144 2	STA2144	01/09/2019 12.00	164,05,00	4	5	91	31,01	30,09	30,09	61,04	1010,07	932,02	936,03
9	STA2144 2	STA2144	01/09/2019 13.00	205,05,00	4	6,05	83,08	30,08	30,05	30,03	63,02	1009,06	867,04	874,01
10	STA2144 2	STA2144	01/09/2019 14.00	215	4	6,01	81,02	30,07	30,02	30	62,04	1008,06	729	738,06
11	STA2144 2	STA2144	01/09/2019 15.00	216	4	6,02	94,05	30,02	30,01	30	64,01	1008,05	534,04,00	551,06
12	STA2144 2	STA2144	01/09/2019 16.00	217	4	5,05	89,07	29,03	29,01	29	64,08	1008,07	295,01,00	312,05
13	STA2144 2	STA2144	01/09/2019 17.00	218	3	4	89	28,03	28,01	28,01	71	1009	30	34,01
14	STA2144 2	STA2144	01/09/2019 18.00	225	5	5,05	101,01	27,05	27,05	27,05	72,03	1009,04	0,03	0,05
15	STA2144 2	STA2144	01/09/2019 19.00	232	2	3,09	106	27,01	27	27	77,07	1010	0,03	0,05
16	STA2144 2	STA2144	01/09/2019 20.00	242	2	3,04	112,03	26,09	26,08	26,08	79,06	1010,06	0,05	0,05
17	STA2144 2	STA2144	01/09/2019 21.00	255,05,00	4	4,09	110,01	27,01	27	27	79,08	1010,08	0,04	0,05
18	STA2144 2	STA2144	01/09/2019 22.00	313,05,00	6	6,06	121	26,07	26,07	26,07	78,04	1011	0,05	0,05
19	STA2144 2	STA2144	01/09/2019 23.00	326,05,00	4	5,08	115,06	26,05	26,05	26,05	77,03	1011	0,05	0,05
20	STA2144 2	STA2144	01/09/2019 24.00	0	4	4,07	89,01	26,06	26,04	26,03	74,07	1010,05	0,05	0,05

3.2 Data Collection

a. Seawater mass

$$\text{Msw} = \frac{10kg}{(100\% - 9{,}2\%)} = 11.01 \text{ kg}$$

b. Find the total energy needed

$$E_{1-2} = \text{msw x Cp x (Tfo} - \text{Tfi)}$$

$$= 3.292.731 \text{ J}$$

$$E_{2-3} = msw\ x\ hv$$

$$= 24.810.572{,}69 \text{ J}$$

$$\text{Et} = 28.103.303{,}69 \text{ J}$$

c. Finding the Average Heat Absorbed (S)

$$\text{S} = \text{Gm x } \tau\text{c x } \alpha\text{p}$$

$$= 557.15 \text{ W/m2}$$

d. Mfind the Overall Heat Transfer value

1) Finding the coefficient of radiation and forced convection due to wind in the cover

$$\text{hwind} = 5{,}7 + 3{,}8\,(4{,}01) = 20{,}938 \text{ W/m}^2\text{K}$$

2) Finding the Conduction Coefficient of Cover

$$hco = 0{,}84 \frac{\text{W}}{\text{m}^2\text{K}} \text{ x } 1{,}97 \text{ m2 / } 0{,}004 \text{ m2}$$

$$= 413{,}7 \text{ W/m}^2\text{K}$$

3) Finding the Radiation Coefficient In the Evaporator

$$hrad = \frac{\sigma(T2^2 + T1^2)(T2 + T1)}{\frac{1}{\varepsilon 1} + \frac{1}{\varepsilon 2} - 1}$$

$$= 0{,}2582 \text{ W/m}^2\text{K}$$

4) Finding the Convection Coefficient In Evaporator

$$hc = Nu\,.K/L$$

$$= 64{,}38\ W/m^2K$$

5) Finding the coefficient of forced convection in the tube

$$hco = Nu\,.K/L$$

$$= 272{,}22 \text{W/m}^2\text{K}$$

$$\text{U} = 1/(1/\text{hw} + 1/\text{hco} + 1/(\text{hr} + \text{hc})\text{evaporator})$$

$$U = 1/(1/20{,}938 + 1/413{,}7 + 1/(0{,}258 + 1902{,}95))$$
$$= 15{,}126\ \mathrm{W/m^2K}$$

e. Looking for Qusefull

$$Qu = Ac \times (S - U\,(Tfi - Ta))$$
$$= 1077{,}68\ \mathrm{Watt}$$

f. Finding the Time It Takes

$$t\ total = E/Qu$$
$$= 7{,}24\ jam$$

g. Looking for Collector Efficiency

$$\eta = \frac{Quse\ full}{Ac.Gt} \times 100\%$$
$$= 83{,}8\%$$

In the same way, the time needed to produce 10 liters of distilled water with different area variations can be found so that the following results are obtained:

Table 2. Calculation results with area variance

Collector (m^2)	Collector Efficiency (%)	Time (Hour)	Overheat Transfer (W/m^2, K)	Sencible Time (Hour)	Evaporation Time (Hour)
1	2	3	4	5	6
1,6	83,898	8,869	15,0035	1,039	7,83
2	83,886	7,244	15,127	0,849	6,395
4	83,857	3,623	15,408	0,425	3,199
6,4	83,845	2,219	15,521	0,26	1,959
8	83,842	1,812	15,553	0,212	1,599
10	83,839	1,449	15,583	0,169	1,279

3.3 Results Analysis

From the calculations that have been carried out above, several things can be analyzed, including the following:

a. Relationship of Theoretical G to Time with Variation of Angle of Incident.

There is a difference in the value of solar intensity between theoretical and actual, this can be due to differences in weather conditions at that time. The theoretical intensity value can be obtained with the assumption that the weather is sunny and there are no obstacles. The theoretically highest solar intensity is 1297 W/m², while the actual value is 936 W/m², the value is obtained at the same hour, namely at 12.00 WIB. The actual solar intensity has a lower value due to several factors, including the presence of a barrier between solar radiation and the measuring instrument, the influence of the wind around the measuring instrument, and also the ambient temperature.

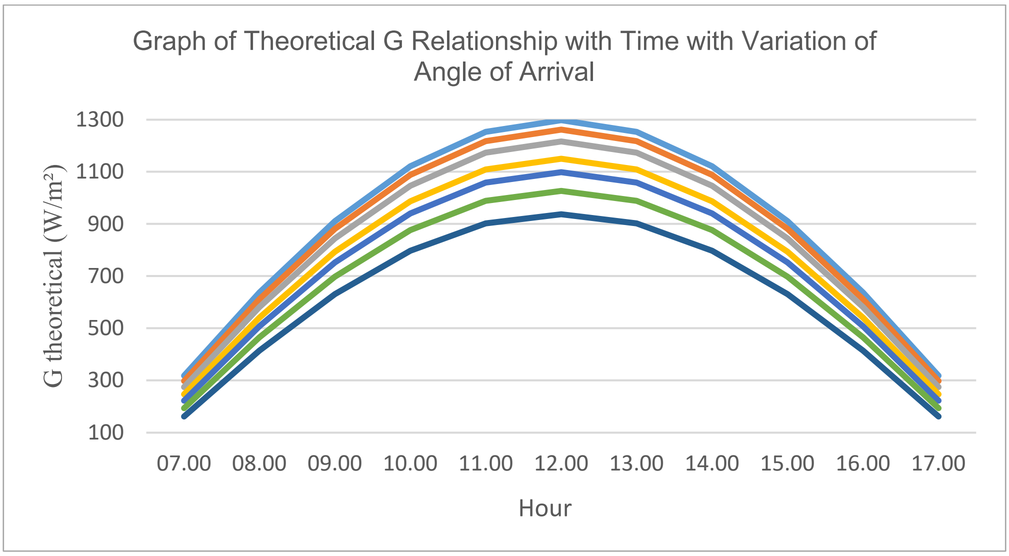

Figure 7. Graph of Theoretical G Relationship with Time with Variation of Angle of Arrival

The figure above shows that the angle of incidence 0º has the highest solar intensity value compared to other variations of the angle of incidence (5, 10, 15, 20, 25, 30º). The highest intensity value at 0º angle is 1297 W/m² while at other angles from the largest, respectively, are 1261.9 W/m², 1216,6 W/m², 1150.1 W/m², 1098.6 W/m², 1026.8 W/m², and 937.5 W/m². The angle of incidence is very influential on the ability of the collector to absorb the received solar intensity.

b. Area Effect Collector of Overall Heat Transfer

The figure below shows the relationship between U (overall heat transfer) to the collector area, this value affects Qu (usable heat). The graph below shows that the value of U is directly proportional to the collector area. So that the larger the collector area, the greater the U value, but the U value is inversely proportional to the Qu value, this can affect the time required to produce distilled water

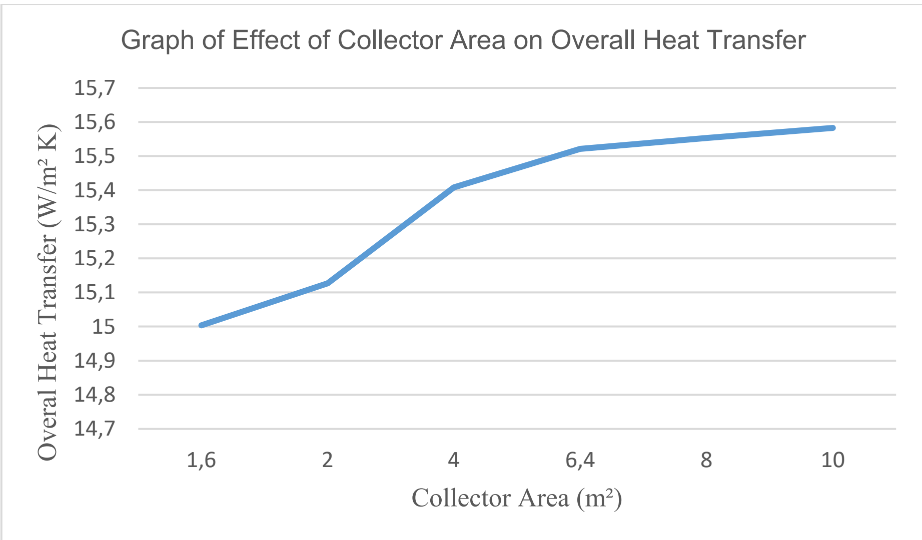

Figure 8. Relationship Graph Overall Heat Transfer Against Collector Area

c. Area Effect Collector against Sensible Process Time and Evaporation

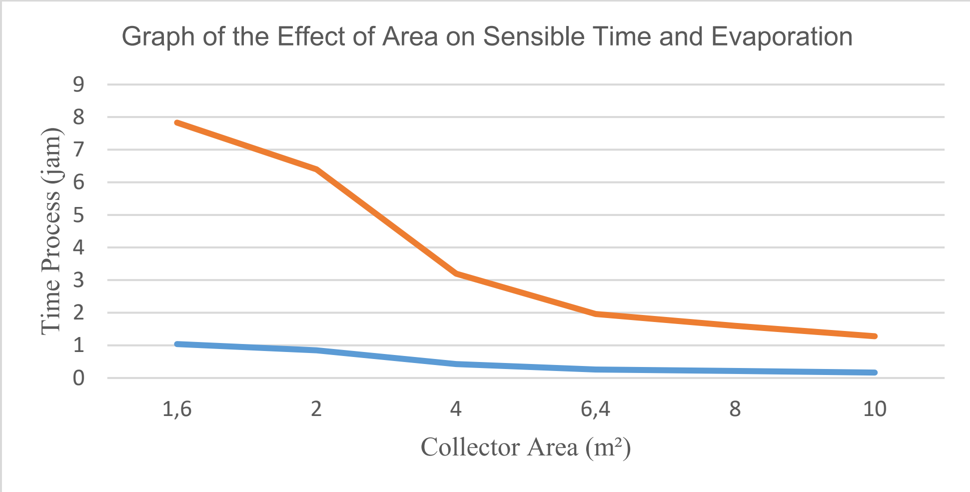

Figure 9. Graph of the Effect of Area on Time *Sensible and Evaporative*

The graph above is a graph that shows the relationship between evaporation time on variations in the collector area. The evaporation time on the solar collector can be expressed in the equation, where E is the energy required during the evaporation process and Qu is the useful heat generated by the collector. Because the value of t is inversely proportional to the value of Qu, then the relationship t is inversely proportional to Ac.$t = \frac{E}{Qu}$

Figure 9. also explains the relationship between area and time to reach the saturated liquid state (from the initial temperature to the saturation temperature) at a temperature of 102°C and explains the relationship between area and time for saturated steam conditions (from saturated liquid to saturated steam).

d. Effect of AreaCollector on Efficiency and Total Time

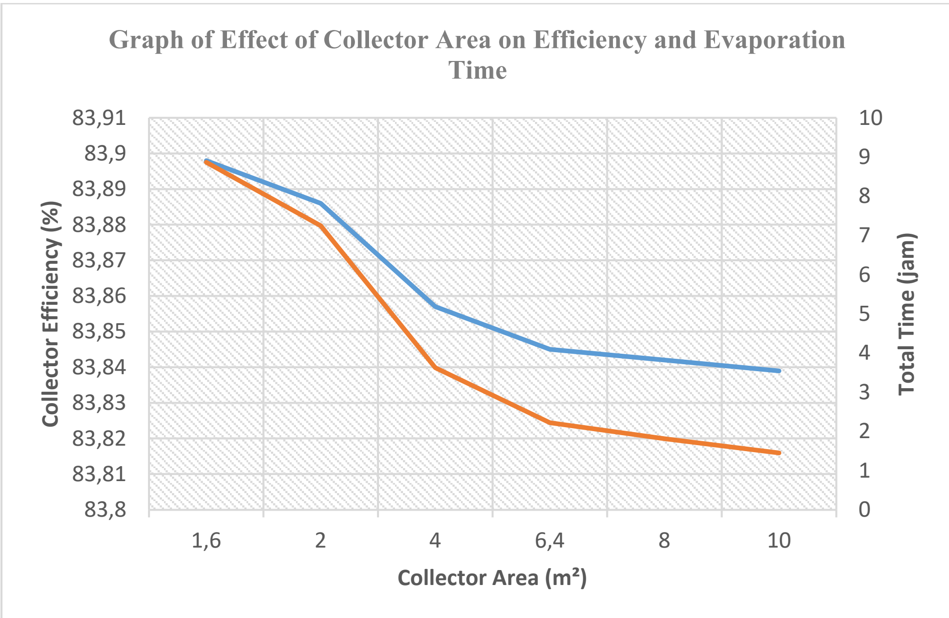

Figure 10. Area Effect Graph Grafik Collector on Efficiency and Total Time

The following graph shows the effect of collector area on efficiency and total time. The efficiency in question is process efficiency and does not include system efficiency (pumps, etc.) which are made the same. While the total time is the accumulation of the time required for the sensible process (boiling) with the evaporation time.

From the graph above, it can be seen that the relationship between the collector area varies from 1.6 m2 to 12.8 m2 to efficiency. The wider the collector field, the lower efficiency is obtained. Efficiency values range from 83.898% to 83.839%. With the same range of collector variations, the effect on the total time required for the distillation process can also be known. The graph shows that the larger the collector area, the faster the total time needed to produce the same volume of pure water, which is 10 liters.

IV. Conclusion

In the analysis of calculations from some of the data in the seawater distillation process above, the following conclusions are obtained:

a. The value of solar radiation received by the collector is influenced by the angle of inclination of the collector and in the analysis of this calculation, it is found that the horizontal collector position (0°) has the highest solar radiation yield with the maximum absorbed solar intensity value of 1297.7 W/m² while the radiation yield is 1297.7 W/m². The lowest solar energy is obtained from the collector with a slope of 30°, which is 937.5 W/m².

b.Variations in the collector area affect the speed of the boiling and evaporation processes in the collector, wherein the analysis of this calculation it is obtained that a graph that decreases or the wider the collector area will speed up the total process time. The collector efficiency value also decreases with the addition of the collector area with a range of 83.898% to 83.839%. So, it can be concluded that the collector area is inversely proportional to the efficiency and the total time required for the system to produce distilled water. To produce 10 liters of distilled water, the fastest time was obtained at an area of 10 m² of 1.45 hours while the longest time was obtained at an area of 1.6 m² of 8.88 hours.

Future Work

a. In this thesis only theoretical calculations are carried out, it is recommended to carry out experiments so that the data obtained are more accurate.

b. Continuing this research by adding variations in the form of mass flow rate ($\dot{m}$).

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