Design of Brackish Water Distillation using Cylyndrical and Square Types of Solar Radiation Absorbers Made of Galvanized Base for Coastal Communities

Dedy Nataniel Ully, Agus Laka, Bernadus Wuwur and Lukas Lantan
State Politeknk of Kupang, Adi Sucipto, Kupang, Indonesia

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Abstract: The availability of clean water for people living on the coast is an unsolved problem for various reasons. To meet the need for clean water consumption, people on the coast only rely on water from shallow wells that are contaminated with sea water, where it tastes brackish or salty and the quality is not guaranteed. Thus, it is necessary to apply appropriate technology in the form of distillation of brackish water into fresh water by utilizing solar energy. The specific purpose of this research is to apply appropriate technology in the form of a brackish water distillation device into fresh water in order to overcome the clean water crisis for coastal communities. This research was conducted using real experimental methods in the field and was carried out at 08:00 am to 04:00 pm with a volume of water in the distillation basin as much as 120 liters. The results showed that there was an increase in performance with the use of solar radiation absorbent plates. The square type solar radiation absorber can produce the highest efficiency of 21.63%, while the cylindrical type solar radiation absorber only produces an efficiency of 21.13%.

1 INTRODUCTION

The availability of clean water on the coast is an unsolved problem for various reasons. Residents who live on the coast are dominated by fishermen, so they have to choose to dig groundwater wells or buy tank water. To meet the needs of clean water consumption, people on the coast only rely on water from shallow wells that are contaminated with sea water, so that it tastes brackish or salty and the quality is not guaranteed. To overcome the problem of clean water, especially in coastal areas, it is necessary to apply appropriate technology in the form of brackish water distillation by utilizing solar energy as an energy source to assist the condensation process, so that this process is natural and environmentally friendly.

The purpose of this brackish water distillation is to separate the excess salt in brackish water with the help of a simple technology, namely solar powered brackish water distillation. To speed up the process of absorbing solar heat, it is equipped with a heat-absorbing plate made of galvanized material which is square and cylindrical. This is done to speed up the heating and condensation process and can test the performance of the two designs of installed solar radiation absorber plates.

Research on the development of brackish water distillation into clean water has been carried out by many previous researchers. In 2006 a research was conducted on desalination of brackish water to meet drinking water needs in coastal areas. This research was conducted with the aim of obtaining important technical data for design and for use at a factory scale. The research was conducted using real experimental methods in the field. From the research results, the system performance can work well (Siregar and Siegar, 2019).

Further research will be conducted on micro-scale reverse osmosis techno-economy analysis for the process of brackish water distillation. This research was conducted to obtain an economical design result for the distillation scale of 12 to 14%. From the results of the study showed that the evaluation based on NPV and IRR stated that it was feasible (Adami and Pudjiastuti, 2017).

Further research was conducted on modeling, optimization and simulation of various aspects of brackish water distillation for clean water needs. Distillation column modeling can help in predicting various parameters for the separation between salt

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and water elements. The optimal reflux ratio is highly dependent on the feed mole fraction, feed quality, relative volatility, and the separation factor being carried out (Kurkami,2017).

The next research is about the effect of temperature and operating time on the distillation process for aquades processing. This research was conducted with the aim of knowing the temperature and operating time of the volume of distilled water produced and to determine the efficiency of the performance of the distillation apparatus. This research was conducted using real experimental methods in the field. The results showed that the highest efficiency was 51, 30% and obtained a temperature of 145 ^{O} C (Sivieri and Teixeira, 2019).

Further research on the identification model of column distillation. This study aims to determine a suitable model for brackish water distillation. The results showed the feasibility of using a linear model to identify the dynamic equation of the distillation column (Widiasa and Yoshi, 2016).

The next research conducted is about the use of modeling technology for the process of distillation of brackish water to meet the needs of clean water. The purpose of this study is to identify whether this technology can be applied and developed for optimization and design purposes. The results of the study indicate that the model made is able to successfully describe the concentration and distribution during the distillation process (Widiasa and Kusumayanti, 2009).

Furthermore, research was conducted on experimental studies of the effect of tilt angle on seawater distillation equipment utilizing solar energy. The results showed that the greatest potential for solar radiation at 12.00 am was 908.712 W/m2. This is caused by the position of the sun perpendicular to the distillation apparatus. After doing research, the slope angle of 30 ^{O} is the most effective angle where the seawater temperature obtained is 73 ^{O} C at 12.30 am, the radiation heat transfer rate is 92.86 Watts per day and the fresh water produced is 650 ml (Honarparvar and Xhang, 2019).

The new contribution of this research is to overcome the clean water crisis in coastal areas by applying a simple technology, namely the distillation of brackish water into fresh water with the addition of square and cylindrical solar radiation absorber designs. This is done to speed up the process of distillation of brackish water, so that production capacity has increased.

2 RESEARCH METHODOLOGY

Research on the design of brackish water distillation using square and cylindrical solar radiation absorbers made of galvanized for coastal communities was carried out using real experimental methods, where observations on research objects were carried out in coastal areas that were young exposed to direct sunlight. Research was also carried out with the application of square and cylindrical solar radiation absorber designs to determine the highest performance of the two designs. Data collection was carried out at the same time for both radiation absorbent designs this sun. The data collection process was carried out from 8:00 am to 4:00 pm. Data collection is done every hour and is done repeatedly for three days, then look for the average value as valid data for analysis purposes.

The research instruments or installations regarding the use of square and cylindrical solar radiation absorbers to support the process of distillation of brackish water into clean water can be seen in Figure 1 and 2 below:

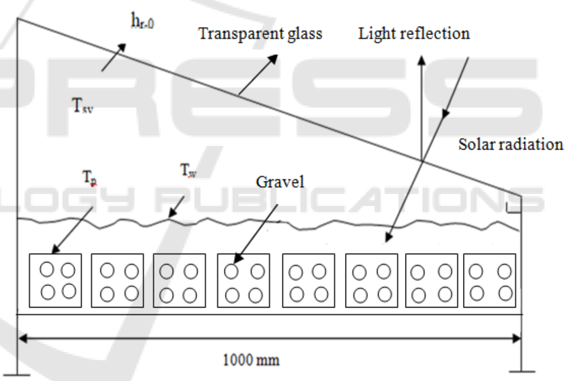

Figure 1: Installation of square type solar radiation absorber.

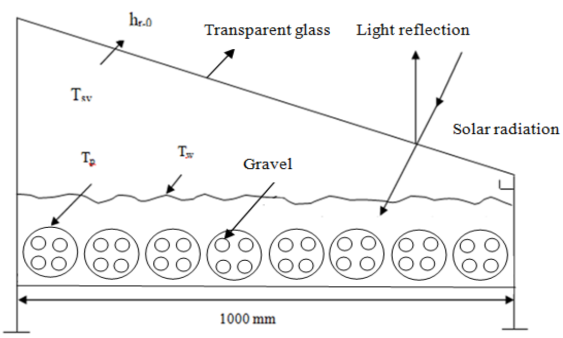

Figure 2: Cylinder type solar radiation absorber installation.

Caption:
IT = solar intensity (W / m^2).
qr, 1 = The rate of radiation heat transfer from the collector to the surface in the glass (Watt).
qc, 1 = Convection heat transfer rate from water vapor to the surface in the glass (Watt).
qc, w = The rate of convection heat transfer from water to water vapor (Watt).
Qk = Conduction heat transfer rate from the collector to the outer wall (Watt).
qr, O = The rate of radiation heat transfer from the glass to the environment (Watts).
qc, O = Convection heat transfer rate from the glass surface to the environment (Watt).
Ta = Environmental temperature (^{O} C).
Tw = water temperature (^{O} C).
Tc = glass surface temperature (^{O} C).
Tsv = Water vapor temperature (^{O} C).
Tp = Temperature of absorbent plate (^{O} C).

2.1 Distillation

Distillation is a method of separating liquids from their mixtures according to differences in boiling points or the ability of substances to evaporate. Distillation has a working principle that is when a substance in a solution does not evaporate equally, it means that the vapor of the solution will have different components from the original solution. If one of the substances evaporates, it means that the separation will occur completely. But if the two substances evaporate, the separation process occurs only partially but the distillate or product will have a richer precipitate of components than the original solution.

2.2 Heat Collector

Heat collector is a device that can accommodate heat which aims to prevent heat drastically. Various types of heat collectors have been widely used, including flat plate collectors, tubular heat collectors, flat plate collectors arranged with a certain slope, collectors with glass covers and collectors filled with water flow.

2.3 Radiation

Radiation can be defined as energy emitted in the form of particles or waves. Solar radiation can produce energy. The energy produced is used to boil the brackish water that flows from the brackish water tank. The power generated from solar radiation is calculated based on the equation:

$$P = e \,.\, \tau \,.\, T^4 \,.\, A \quad \text{(Watt)} \qquad (1)$$

Where :
P = Radiation power (Watt);
e = Emisivity coefficient;
τ = Constant Stefan Boltzman;
T = Absolute temperature (^{O} K);T
A = Cross-sectional area (m^2)

2.4 Convection

Convection is the transfer of heat accompanied by the movement of particles. Convection occurs in substances in the form of gases and liquids. In the distillation apparatus, heat transfer by convection occurs in the air between the glass and the space around the solar basin and in the evaporation of brackish water. The equation to calculate the power from convection is:

$$P = h \,.\, A \,.\, \Delta T \quad \text{(Watt)} \qquad (2)$$

Where :
P = Convection power (Watt);
h = Transfer rate;
A = Cross-sectional area (m^2).

2.5 Conduction

Conduction is the transfer of heat through a substance without the movement of its particles. In the distillation apparatus, heat transfer by conduction occurs in the glass and copper pipes. The equation for calculating power from conduction is:

$$P = k \,.\, A \,.\, \frac{\Delta T}{d} \qquad (3)$$

Where :
k = Thermal conductivity of heat conductor;
A = Cross-sectional area (m^2);
ΔT = Temperature change (^{O} K);
d = Material thickness (m)

2.6 Heat Resistance

Heat resistance is the losses in the environment and panels of the solar vapor evaporation system.

Win resistance :
The equation of the wind resistance coefficient is shown in the equation:

$$h_{c\text{-}0} = 5{,}7 + 3{,}8.\, v \qquad (4)$$

Where :
$h_{c\text{-}0}$ = Wind resistance coefficient;
v =Local wind speed

External radiation resistance:
External radiation resistance is an obstacle caused by radiation reflected by the glass to the intensity of heat received from the sun.

$$hr_{-0} = \varepsilon_c \cdot \tau \left(T_g^{\,4} - T_{langit}^{\,4}\right) \qquad (5)$$

Where :

ε_c = Emisivity glass;

τ = Coefficient of Stefan Boltzman;

T_g = Glass surface temperature;

T_{sky} = Sky temperature 0,0552 ($Ta^{1,5}$).

2.6 Efficiency

The efficiency of the distillation apparatus is obtained from the equation:

$$\eta = \frac{T_w}{T_{desain}} \ x \ 100\ \% \qquad (6)$$

Where :

Tw = Brackish water temperature (^{O} C);

T_{desain} = Fresh water temperature (^{O} C).

The performance of the brackish water distillation design can be calculated using the following equation:

- Useful Energy Collektor

$$Q_U = Q_{In} - Q_{Out} \qquad (7)$$

$$Q_U = (\alpha \ . \ IT \ . \ A_c \ . \ \tau) \ . \ (U_L \ . \ A_c \ [(U_L. \ A_c \ . \ (T_P - T_A)]$$

- Useful Energy Distillation

$$Q_{u-d} = \frac{mk \ . \ h_{fg}}{t} \qquad (8)$$

- Efficiency of the Destillation

$$\eta_d = \frac{mk \ x \ h_{fg}}{A_c \ x \ I_T \ x \ t} x \ 100\ \% \qquad (9)$$

3 RESULT AND DISCUSSION

3.1 Result

Based on the test data in the field, data processing is carried out for further analysis based on its tendency, as shown in tables 1 and 2 below:

Table 1: Test results and data processing (square type).

Time	T_{sv} (^{O} C)	m_k (kg)	I_T (W/m ^{2})	Q_{U-d} (kW)	η_d (%)
08:00 am	26.10	0	533.42	0	0
09:00 am	35.43	0.129	688.84	0.086	13.91
10:00 am	38.16	0.175	785.02	0.117	16.61
11:00 am	42.66	0.217	853.32	0.144	18.84
12:00 am	43.10	0.259	887.67	0.172	21.63
01:00 pm	42.96	0.255	893.46	0.169	21.13
02:00 pm	39.16	0.209	878.08	0.139	17.69
03:00 pm	38.76	0.159	783.37	0.106	15.09
04:00 pm	37.33	0.138	723.46	0.092	14.20

Table 2: Test results and data processing (cylinder type).

Time	T_{sv} (^{O} C)	m_k (kg)	I_T (W/m^2)	Q_{U-d} (kW)	η_d (%)
08:00 am	25.86	0	533.42	0	0
09:00 am	30.93	0.087	688.84	0.058	9.46
10:00 am	33.75	0.126	785.02	0.084	11.99
11:00 am	35.65	0.166	853.32	0.111	14.51
12:00 am	36.00	0.207	887.67	0.138	17.39
01:00 pm	35.26	0.209	893.46	0.140	17.45
02:00 pm	35.53	0.167	878.08	0.112	14.18
03:00 pm	32.93	0.128	783.37	0.086	12.22
04:00 pm	31.90	0.108	723.46	0.072	11.17

3.2 Discussion

After doing the calculations as shown in the table of data processing results above, it is displayed in graphical form, so that it can be discussed based on existing trends. The discussion in question can be seen in Figures 2, 3, 4 and 5 below, namely:

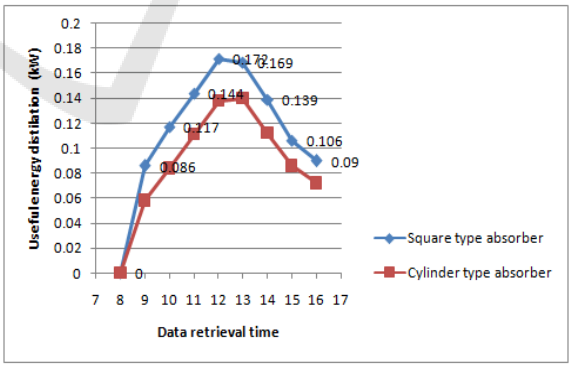

Figure 3: Graph of the correlation between time and distillation useful energy.

From the graph above, it can be seen that the value of useful energy has increased with increasing data collection time. At 9.00 am to 12.00 am there was a linear increase, this happened because the intensity of solar radiation also increased from time to time until the maximum occurred at 12.00 am. Furthermore, at

1.00 pm to 4.00 pm continued to decline. The value of this useful energy is strongly influenced by the amount of intensity of solar radiation that reflects its light onto the glass surface, so that condensation occurs and produces a certain amount of water vapor with a certain condensate mass.

From the graph, it can be seen that the square type solar radiation absorber can produce better useful energy, when compared to the cylindrical type solar radiation absorber. This happens because the area of the square type of solar radiation absorber is larger than the cylindrical type of solar radiation absorber. The square-type solar radiation absorber can produce the maximum useful energy of 0.1728 kW, while the cylinder-type solar radiation absorber only produces 0.140 kW of useful energy, both of which occur at 12.00 am.

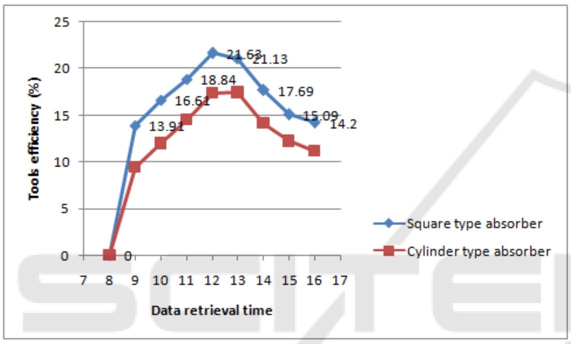

Figure 4: Graph of the correlation between time and distillation equipment efficiency.

Based on the graph above, it can be seen that the efficiency value has increased along with the increase in data collection time. The increase in efficiency value linearly occurred at 9.00 am to 12.00 am. Furthermore, the efficiency value decreased from 1.00 pm to 4.00 pm. The efficiency value is strongly influenced by the mass value of the condensate, the water vapor produced from the distillation process, the size of the distillation surface area, the value of the intensity of solar radiation and the time it takes.

From the graph, it can be seen that the square type solar radiation absorber can produce the maximum efficiency value when compared to the cylindrical type solar radiation absorber. This happens because the cross-sectional area of the absorber, the mass of condensate and the resulting condensation temperature are larger, when compared to the results obtained from the cylindrical type of solar radiation absorber.

The square type solar radiation absorber can produce a maximum efficiency value of 21.63%, while the cylindrical type solar radiation absorber only produces a maximum efficiency of 17.45%. Both the highest efficiency values occurred at 12.00 am, this happened because the highest intensity of solar radiation occurred at 12.00 am when data collection was carried out.

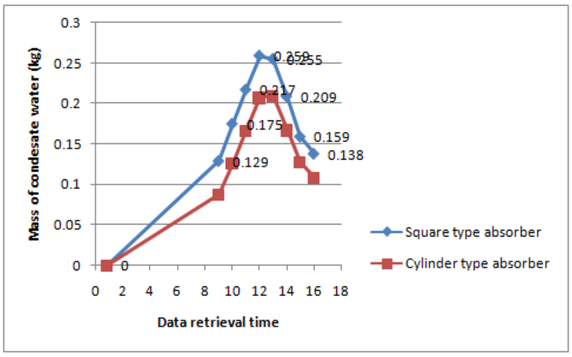

Figure 5: Graph of the correlation between time and condensate.

Based on the graph above, it can be seen that the mass of condensate produced from the distillation process has increased with increasing data collection time. The increase in condensate mass value linearly occurred at 9.00 am and then decreased from 2.00 pm to 4.00 pm. From the graph, it can be seen that the square type solar radiation absorber can produce a larger condensate mass when compared to the cylindrical type solar radiation absorber. The maximum condensate mass value produced by the square type solar radiation absorber is 0.259 kg, while the solar radiation absorber only produces a condensate mass of 0.209 kg, both of which occurred at 12.00 am.

4 CONCLUSIONS

Based on the results of the discussion above, several conclusions can be drawn, including:

The square type solar radiation absorber can produce useful energy, the efficiency and mass of the condensate is greater, when compared to the cylindrical type solar radiation absorber.

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