The Effect of The Capillarity on the Efficiency of Wick-Type Solar Energy Water Distillation

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Abstract. The low efficiency of the wick-type solar energy water distillation is due to the significant flow rate of contaminated water that will be distilled at the absorber. The flow rate of water in the absorber is generally regulated using a faucet. However, setting the water flow rate using a faucet is very difficult to produce a low water flow rate. This study examines a new method of regulating the flow rate of inlet water in wick-type solar energy water distillation using the capillarity method. The study was carried out experimentally using a distillation model with an absorber area of 0.54 m2 and a cover glass thickness of 3 mm. The water flow rate will be varied by varying the thickness of the absorber by 0.08 and 0.16 mm. The results showed that the inlet water flow method using the capillarity method could increase the efficiency of solar energy water distillation compared to solar energy water distillation by adjusting the inlet water flow rate using a faucet. The highest efficiency increase of 34.2 percent was obtained at a variation of 0.08 mm absorber thickness. Distillation of solar energy water is generally needed in remote areas where drinking water sources have been contaminated with contaminants that are harmful to health. Regulating incoming water using the capillarity method is a simple method that can be applied to the community, especially in remote areas.

Keywords: Capillarity, Wick-Type Solar Energy, Water Destilation

1 Introduction

Living things, especially humans, need water to survive. Water plays an important role in human life. However, currently potable water is becoming increasingly difficult to obtain. When viewed from a quality perspective, only about 0.03% of ready-to-consume drinking water is available [1]. This is of particular concern in remote areas.

Solar energy water distillation equipment is one of the solutions that can be used today. Distillation is used to purify water by absorbing heat from the sun as a heat source for the evaporation process. This tool is very suitable for use in tropical climates such as Indonesia. The potential for solar energy in Indonesia is very large, which is around 4.8 KWh/m2 or the equivalent of 112,000 GWp, but only around 10 MWp has been utilized [2].

The solar energy water distillation consists of an absorber plate and a cover glass. Water is evaporated by absorber plates which receive solar radiation directly. The steam will go to the cover glass. The temperature difference between the cover slip and the water vapor causes the water vapor to turn into dew. The condensation on the cover slip

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flows down into the reservoir. The condensed water that flows into the reservoir is the result of the distillation process.

The problem that occurs in solar energy water distillation is low productivity and efficiency [3]. This study aims to increase the productivity and efficiency of solar energy water distillation equipment by varying the absorber section [4]. This research will examine the effect of capillarity on the input and absorber surface. Bamboo tissue absorber was chosen because it has high absorption characteristics. The thickness of the tissue and black ink are used as the variables studied. There are 3 types of capillarity in fabrics, namely upward capillarity, horizontal capillarity and downward capillarity [5]. This research will discuss the effect of upward capillarity and downward capillarity on oblique type solar energy water distillation absorber on evaporation.

2 Method

2.1 Distillation Equipment Specifications

The design of the solar distillation apparatus used in this study is of the oblique type with the specifications (Table 1).

Table 1. Specifications of the oblique type solar distillation apparatus

Item		Specifications
Tool length	:	84 cm
Tool width	:	63.5 cm
Absorber length	:	75 cm
Absorber width	:	58 cm
Absorber thickness	:	0.08 mm – 0.16 mm
Glass thickness	:	0.3 cm
Tilt angle	:	15 °

2.2 Principle Of Capillarity

Capillarity is divided into three types; upward capillarity, horizontal plane capillarity and downward capillarity. In order to get the downward capillarity value on the fabric, it is necessary to have an upward capillarity value first. Whereas the capillarity of the horizontal plane is not affected by upward capillarity, but is affected by the length of the cloth. To determine the saturation present in the fabric, it is necessary to know the value of the liquid filling fraction so that it is more accurate to determine the moisture level in the media. The saturation value of the tissue can be calculated by equation [5]:

$$f = \frac{V_{fluid}}{V_{total}} \tag{1}$$

where, f is the tissue saturation, Vfluid is the volume fluid that is in the tissue (m3) and Vtotal is the tissue volume (m3). To count Vfluid on tissue can be calculated by equation [5]:

$$V_{fluiid} = \frac{(M_w - M_d)}{\rho} \tag{2}$$

where, Min is an absorbent tissue mass fluid, Md is the mass of dry tissue and r is the density fluid (g/cm3). For Vtotal can be calculated by multiplying the length, width and thickness of the tissue. To find out the flow rate on the tissue, equation [5] is used:

$$\frac{dV}{dt} = \frac{Ak}{L\mu}(\Delta P) \tag{3}$$

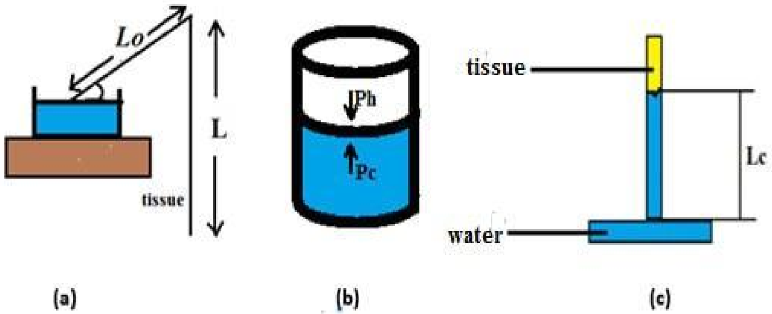

Fig. 1. (a) Length of fluid flow, (b) Pressure difference, (c) Length of fluid rise

Where dV/dt is the downflow discharge (cm3/second), k is the permeability of the fabric (darcy or cm2), A is a flow perpendicular to L, L is the flow length (cm), m is the viscosity of the fluid (dyne sec/cm2) and P is the difference between capillary pressure (Pc) with hydrostatic pressure (Ph). The downward flow velocity is also related to the volume of the absorber. Equation 3 can be substituted by the volume formula, where volume is the downward flow length multiplied by the absorber area. Lc is the length of the fluid rise in the tissue (the height at which capillary action stops and is in an equilibrium state), whereas L is the length of fluid flowing down the tissue. This equation can be simplified further to [5] :

$$\frac{dL}{dt} = \frac{\rho g k}{\mu}\left[\frac{L_c - L}{L}\right] \tag{4}$$

The efficiency of a solar energy water distillation apparatus (ɳ) is the ratio of the amount of energy used at a certain time interval. Solar energy distillation efficiency can be found using equation [6]:

$$ɳ = \frac{m \,.\, hfg}{Ac \,.G \,.\, dt} \tag{5}$$

where ɳ is the distillation efficiency, *m* is the result of distillation (kg), *hfg* is the latent heat of vaporization of water (kJ/kg), A_c is the area of the evaporation absorber (m^2), *G* is the solar radiation (W/m^2) and *t* is the irradiation time (s).

3 Results

After processing the data, the researchers compared the results of oblique distillation with conventional distillation for each variation. Data collection was carried out on different days for each variation. Fig. 2 shows a comparison of the distillation results of oblique and conventional water distillation under conditions of receiving the same solar energy and different variations.

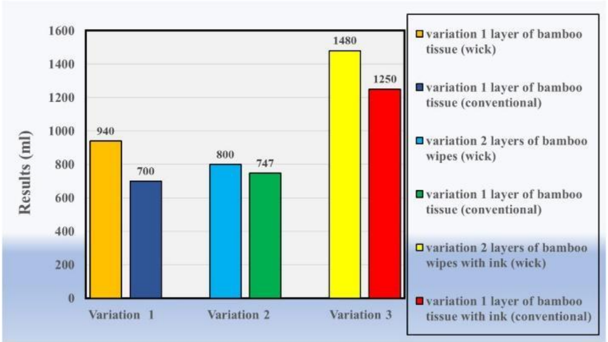

Fig. 2. Comparison of the results of each variation with the comparison

From the results of research that has been done, oblique wicking water distillation has better results than conventional oblique distillation. This proves that the use of the capillarity principle in oblique type distillation can increase the productivity of oblique type solar energy water distillation.

This is due to the mass the water contained in the tissue in the tilted distillation absorber is less than the mass of water present in conventional distillation. This can be explained using Equations (1) and (2). A small mass of water will cause water evaporation to take place quickly [7]. Equation (2) explains that the mass of water in variation 2 and variation 3 has a larger mass of water than variation 1. The 2-layer tissue has a mass fluid 2 times more than mass fluid on 1 layer. This causes the oblique axes distillation variation that uses 1 layer of bamboo tissue variation to have better evaporation than the conventional 1 layer bamboo tissue distillation, the highest yield increase compared to other variations with a value of 34.3%. The dryness of the absorber layer using a variation of 1 layer of bamboo tissue can be seen in Fig. 3.

Fig. 3. shows the drying phenomenon that occurs in the oblique distillation absorber with a variation of 1 layer of bamboo tissue. The dryness is caused by the evaporation process being faster than the mass of water entering the absorber surface. The thinner the absorber layer of the tissue used, the smaller the water flow rate on the surface of the absorber.

In this research, there are three principles of capillarity. The axis absorbs water from the water channel to the surface of the absorber where an upward capillary process occurs. On the surface of the absorber, the bamboo tissue distributes water to all areas, this process causes the three principles of capillary action to occur simultaneously. On the surface of the absorber, downward capillarity has an important role which is directly proportional to the solar energy water distillation apparatus which has a tilt angle of

15°. The water flow on the surface of the absorber flows downward constantly (downward).

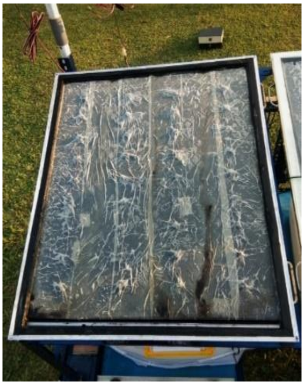

Fig. 3. Dryness in the wicking oblique distillation absorber with a variation of 1 layer of bamboo tissue

Equation (3), explains that the downward flow (downward) has a large discharge, the thicker the tissue layer used. This study uses the same material, so that the overall variable values occur constantly and are only differentiated by tissue thickness. The dryness of the absorber tissue using a variation of 1 layer of bamboo tissue is caused by a small flow rate which is not proportional to the evaporation that occurs. This incident resulted in dryness of the absorber.

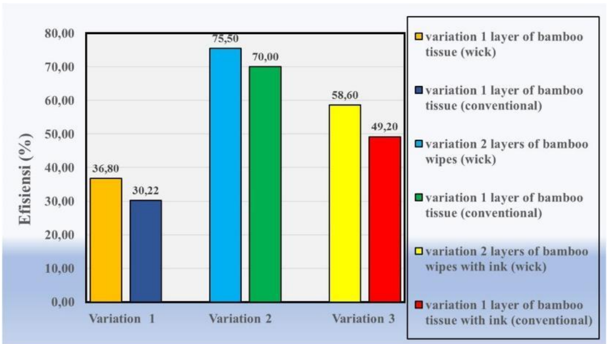

Fig. 4. Comparison of efficiency in each variation

Apart from being caused by the different downward capillary flow discharge, this is also caused by the different thickness of the absorber. This phenomenon is caused by the downward flow velocity. In Equation (4), it can be interpreted that the downward capillary flow rate has a constant value for the same type of wick material. In this research value LC and L have the same length and are not affected by the area or thickness of the axes. L is the length of the bamboo tissue on the absorber surface. LC is the height of the fluid that rises to the surface of the axis, so that variations of 1 layer of bamboo wipes and 2 layers of bamboo wipes in wick distillation have the same downward capillary flow rate value but have different debits.

Fig. 4 shows a comparison of the efficiency of oblique oblique distillation with conventional oblique distillation. This comparison was made for each variation of absorber thickness and the addition of black ink using Equation (5). The highest efficiency increase occurred in variation 1 with a value of 21.8%.

4 Conclusion

Based on the research that has been done on the effect of capillarity on the thickness of the absorber of bamboo tissue in oblique distillation, the following conclusions are drawn:

1. The use of the capillary method is able to increase the performance of oblique type water distillation compared to conventional oblique type water distillation. The greatest increase in efficiency occurred in the tilt type solar distillation of 21.8% from the conventional tilt type solar energy water distillation.
2. The thickness of the bamboo wipes can affect the performance of oblique type solar energy water distillation. The thicker the bamboo tissue layer on the absorber can make the mass of water in the absorber increase, so it can slow evaporation. The flow rate is directly proportional to the thickness of the absorber in the capillarity method, while the flow rate is constant in the thickness of the absorber in the capillarity method.

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