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DETERMINE THE THERMAL EFFICIENCY OF A DISTILLED WATER EVAPORATOR BY UTILIZING CLEAN WATER AS THE RAW MATERIAL

Imaniah Sriwijayasih[1*], Eky Novianarenti[1], Tarikh Azis Ramadani[1], Rikky Leonard[1]

[1]Department of Marine Mechanical Engineering, Politeknik Perkapalan Negeri Surabaya, Surabaya, Indonesia

*Correspondence Author: imaniahsriwijayasih@ppns.ac.id

Abstract

Increasing the efficiency of equipment is a crucial factor to avoid wasting energy. It is known that fossil fuel energy continues to increase and runs out quickly. Alternative energy is needed that can be used sustainably and is easily available so as to mitigate the impact of fuel oil depletion. This research aims to design a distilled water evaporator that can be applied in all aspects of human life. The methods in this research are designing the equipment and calculating balance energy. The volume of water in the evaporator is used to evaluate the performance of the system. The results of the research indicate that it can be seen that the electrical thermal efficiency shows that the smaller the value of the feed water volume, The greater the electrical thermal efficiency (inversely proportional). The results prove that one indication is that the performance of the aquadest evaporator saves electrical energy in the heating and evaporation process of optimal water because the less feed, the faster the heating process. It can be seen that the energy consumption is spent on a volume of 3.5 Liters because the heating time is long compared to other variations in feed water volume, so the energy consumption is significant.

Keywords: evaporator, efficiency thermal, specific fuel combustion, sensible heat, latent sensible

1. Introduction

Indonesia is known for its tropical climate, affecting the seasons in this area, namely the dry and rainy seasons. The rainy season usually occurs from October to April and meets the water needs. Because it always rains every year. Water sources not only come from rainwater but also from river water. However, even if Indonesia has reserves of water sources in the form of river water, based on data, in December 2018, as many as 550 rivers located in Indonesia, 82% of them are in damaged or polluted states (Pratiwi et al., 2020). One other factor that influences environmental quality besides renewable energy is water. Water utilization is a challenge in itself for environmental balance as over exploitation of water sources leads to environmental degradation. The role of water is very important for most countries in the world to pay attention to improve the environment. Water is an important source of generating renewable energy, especially hydroelectric power. Water scarcity and increasing water pollution have attracted the attention of researchers from all over the world. Wastewater management is another problem and if it is not managed properly, it will cause groundwater pollution and also cause eutrophication (Majeed, 2019).

Water resources performance management which includes economic aspects of water and distribution networks was introduced in several countries including Morocco with 15 new methods introduced (Habib, 2020). In Algeria, individual demand for drinking water was at 120 l/inhabitant in 2011, and the estimated performance was at 55% in 2010 according to (Kherbache, 2019). Currently, the situation has apparently worsened with regard to the restrictions imposed on the distribution of drinking water throughout Algeria territory. Rationing has effectively marked the year 2021. In Jordan, green growth is allocated as a top national priority. Where this work is to study aspects of environmental sustainability, social development and inclusiveness of green economic growth as well as efficient use of resources. The result is oriented towards encouraging one of the six green economic sectors, namely waste and environmental pollution, which will soon be resolved (Shalamai, 2022). In Tunisia, policies in water management strategies came out as wasteful in resource management. The policy control program solution on water prices is implemented but social actions affect the economic order (Ali, 2022).

Data World Resources Institute (WRI) in the matter of the freshwater resources owned by each country in the world, Indonesia is ranked 51st with a high level of crisis risk (high 40-80% chance) (Jaan et al.,2020). Freshwater is a key resource for sustaining human life on earth. Supply of potable water requires energy and unfortunately most of the countries with minimal access to safe drinking water are also poor in terms of access to reliable energy grids (Simanjuntak, Zai and Tampubolon, 2021). In a laboratory, the need for clean water is a definite thing. Likewise, to make a solution or dissolve a material, we need air that is clean from other metals or what is usually called air distillation, or what we also know as distilled water. Aquadest or aqua distillation is water that has been purified, which has been released and still contains little or no iron, manganese, zinc, lime and the like. Aquadest or what is often called aqua distillation is pure water produced from a distillation process which contains almost no minerals. Aquadest is widely used, especially on a laboratory scale at universities (Wahyudi et al., 2017). Almost all chemical laboratories in Indonesia use distilled water as an ingredient to dissolve substances. It is known that distilled water is distilled water. The standard for distilled water itself is a normal pH of around 7, which means there is an equilibrium between H+ and OH-. Many terms are used to refer to aquadest. In Indonesian, some people call it pure water, distilled water (distillation water), some even call it denim water.

Simple distillation is a separation technique to separate two or more liquid components that have large differences in boiling points. Apart from differences in boiling points, there are also differences in volatility, namely the tendency of a substance to become a gas. This distillation is carried out at normal atmospheric pressure. The main parts of the distillation apparatus are the heater and condenser/cooler. In the heater section there is a heating element which functions to boil raw water. In the cooling section there is a spiral that surrounds the hot water vapor. The spiral is filled with cold flowing water. The cooling water that flows through the distillation equipment will ultimately be left wasted because it is not possible to return it directly to the system because the water temperature is already high and it cannot be collected because there is no storage tank available (Marjuni, Minarto and Wahyono, 2021). The ratio of the distilled water produced to the water wasted is around 1:35, meaning that to produce 1 liter of distilled water, 35 L of PDAM water will be wasted. Several distillation methods have been developed for water desalination technology, such as simple distillation, single stage distillation, multiple effect distillation, multi-stage distillation, vapor compression distillation (Bahar, 2004) and Renfro-distiller system (Al Karaghouli, 2009; Saidur, 2011). Apart from the distillation process which continues to develop, the use of alternative energy in distilled water treatment also uses waste heat from generators as an energy source.

Laboratories in Higher Education have an important role as executors of its Tri Dharma which includes the functions of education, research, and community service. Every activity in the laboratory requires distilled water as a solvent and cleaners of various tools and materials. This fact leads to a high budget needed for the availability of the material in laboratory, so it is necessary to design the aquadest tool that is carried out using evaporation (evaporator) and condensation (condenser). An evaporator with an electric heater is important in designing an aquadest device because heating requires steam. This steam will be used as a distilled water product, which has been previously condensed with the help of a condenser. Apart from that, it is also closely related to the total amount of heat to evaporate the water obtained from the distilled water design. In this research, the problem that will be discussed is how much electrical thermal efficiency and electrical energy consumption is needed to evaporate water with variations in the volume of feed water used and also the design of aquadest distillation equipment can help the community in the development of science and technology, because with simple operations it can produce high value products.

2. Material and methods

2.1 Material

The material used in the design of aquadest is clean water (PDAM). Clean water (PDAM) is a substance that is used for daily needs and will become drinking water after being boiled first. As a limitation, clean water is water that complies with the requirements for a drinking water supply system, where the requirements in question are requirements in terms of water quality which includes physical, chemical, biological and radiological quality.

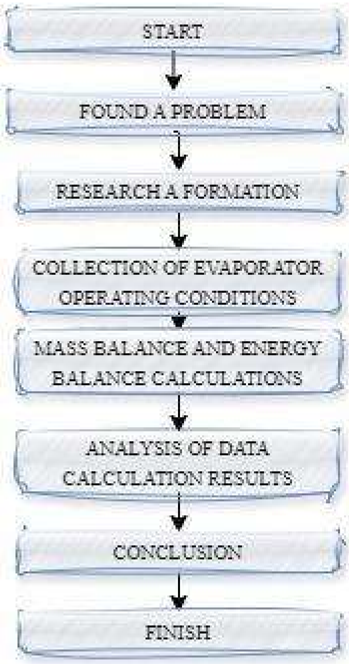

Figure 1. Research Diagram

2.2 Methods

The materials used in the design of the aquadest distillation equipment is Clean Water (PDAM). The apparatus created by Stainless Steel Evaporator Tube: 2 sized pieces. Ø 10 cm with tube height: 50 cm, tube thickness: 3 mm and also Stainless-Steel Condenser Tubes: 2 pieces measuring Ø 6 cm, tube height: 30 cm. The heater as a heating element made from Stainless Steel material with a size of Ø 0.64 cm, a heater height of 9 cm then a cooling element made from Stainless Steel material with a size of Ø 0.64 cm, a cooler height of 30 cm then a pump is used to circulate the fluid with the help of pipes and fittings.

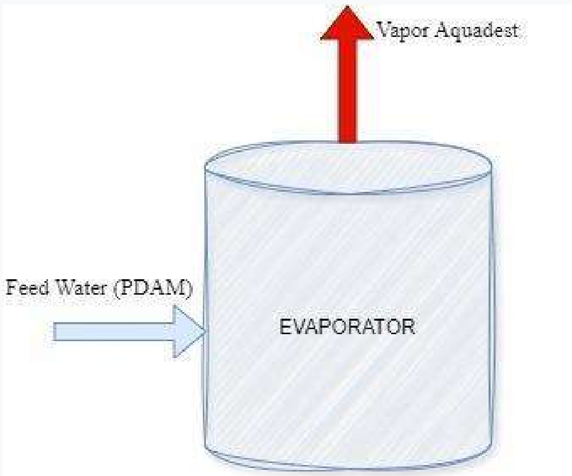

Figure 2. Distilled Water Evaporator

2.2.1 Energy Balance Calculations

A. Energy In Evaporator

1. Calculating the Sensible Heat of Incoming Feed (Q1) with a feed water volume of 3 liters/hour

$$Q1 = m.CP.\Delta t \quad (1)$$

$$CP = a + \frac{b}{2}(T2 + T1) + \frac{c}{3}(T2^2 + T2.T1 + T1^2) \quad (2)$$

2. Calculating Heat from a Heating Source (Electricity) (Q_2)

B. Energy Out Evaporator

1. Calculating the Sensible Heat of Outgoing Water Vapor (Q3)

$$Q3 = m.CP.\Delta t \quad (3)$$

$$CP = a + \frac{b}{2}(T2 + T1) + \frac{c}{3}(T2^2 + T2.T1 + T1^2) \quad (4)$$

2. Calculating Latent Heat of Vaporization (Q4)

$$Q4 = m.H \quad (5)$$

$$H = y1 + \frac{(x3-x1)}{(x2-x1)} X (y2 - y1) \quad (6)$$

3. Calculating Residual Water Sensible Heat (Q_5)

$$Q3 = m.CP.\Delta t \quad (7)$$

$$CP = a + \frac{b}{2}(T2 + T1) + \frac{c}{3}(T2^2 + T2.T1 + T1^2) \quad (8)$$

4. Calculating Conduction Heat in the Evaporator (Q6)

$$Q6 = \frac{(\Delta T)}{(R)} \quad (9)$$

5. Calculating Convection Heat in the Evaporator (Q7)

$$Q7 = h \; x \; A \; x \; (T2 - T1) \quad (10)$$

3. Results and discussion

Distilled water was made in this study using a distilled water evaporator and evaluated the performance of the system and the quality of the distilled water yield. The results of these observations are in the following Table 1.

Table 1. Observation data with variations in feed water volume in distilled water

Feed Water (liter)	$T_{Water\ in}$ (^{0}C)	T_{Vapor} (^{0}C)	Volume Aquadest (liter/hour)	$T_{Residue\ water}$ (^{0}C)	$T_{wall\ in\ evaporator}$ (^{0}C)	$T_{wall\ out\ evaporator}$ (^{0}C)	Time (minutes)	Power (watt/hour)
1	28	88	0,490	88	100	85	74	
2	28	88	0,390	88	100	85	5	
2,5	28	88	0,389	88	100	85	95	500
3	28	88	0,367	88	100	85	105	
3,5	28	88	0,355	88	100	85	110	

Increasing the feed water material in the system has a tendency to decrease the volume of distilled water and increase the process time. This is because the amount of heat added to the system is constant, but the amount of raw material is increasing. This causes the workload of the system to increase. This is in harmony with the increase in process time to produce the product. Based on these data, heat balance calculations are then carried out (Table 2). The results of the heat balance calculation can be seen in Table 2.

Table 2. Heat Balance for 1 Liter Feed Water Volume in the Evaporator

Component	***Input* (Kkal)**	***Percent* (%)**	***Output* (Kkal)**	***Percent* (%)**
Calculating the Sensible Heat of Incoming Feed Water	1,316922116	0,247750575		
Calculating the Sensible Heat of a heating source	530,2346667	99,75224943		
Calculating the Sensible Heat of outgoing water vapor			29,78513495	5,603432588
Calculating Latent Heat of Vaporization			259,2362272	48,76972107
Calculating Residual Water Sensible Heat			13,81910076	2,599766617
Calculating Conduction Heat in the Evaporator			0,012616975	0,002373613
Calculating Convection Heat in the Evaporator			0,000119607	$2,25015 \times 10^{-5}$
Heat Loss in the Evaporator			228,6983893	43,02468361
Total	531,5515888	100 %	531,5515888	100 %

The evaporator is designed from a modification of equipment that is usually used by industry for the solution thickening process, with the release of water from the solution through boiling in a vessel. The evaporator is an important part in the design of distilled water because it is used for the water boiling process and is a system that will indicate savings in the aquadest design.

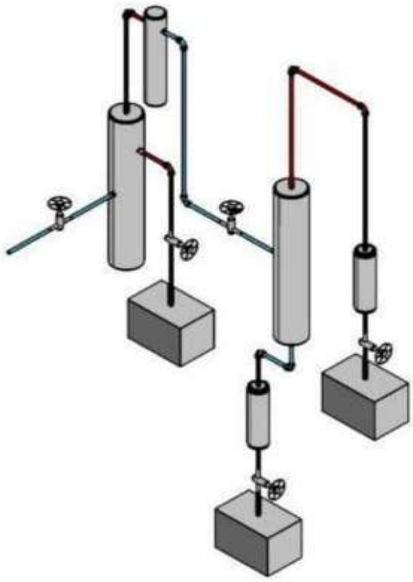

Figure 3. Prototype a Distilled Water Using an Evaporator

The evaporator is an important system in designing aquadest, it will evaluate the performance or capability of boiling air using an electric heater and its energy consumption which is the efficiency of the system. System efficiency will be influenced by the volume of feed air. The air feed volume will determine the optimal operating conditions of the evaporator in determining the consumption of electrical energy used. In designing the aquadest evaporator, it is designed to be 4 liters and set the set point to a temperature of 100^0C because if the air is heated continuously, it will cause the system to rust, while the electrical energy supplied is large, namely 500 watts/hour.

So, the air feed volume is varied using 5 variations so that the boiling air is not wasted and the efficiency and electrical energy consumption can be seen.

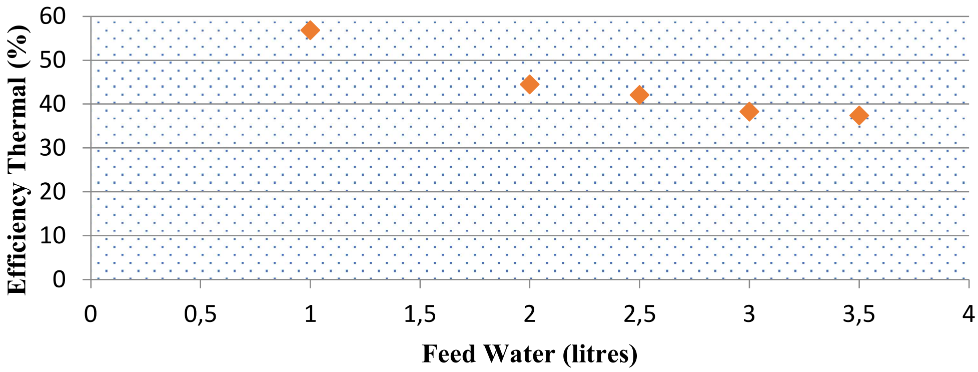

Figure 4. Graph of Feed Water Volume vs Electrical Thermal Efficiency

From figure 4, It can be seen that the electrical thermal efficiency shows that the smaller the value of the feed water volume, the greater the electrical thermal efficiency (inversely proportional). The result shows that one indication is that the performance of the aquadest evaporator saves electrical energy in the heating and evaporation process of optimal water because the less feed, the faster the heating process, and the greater the amount of steam produced in one hour of operation.

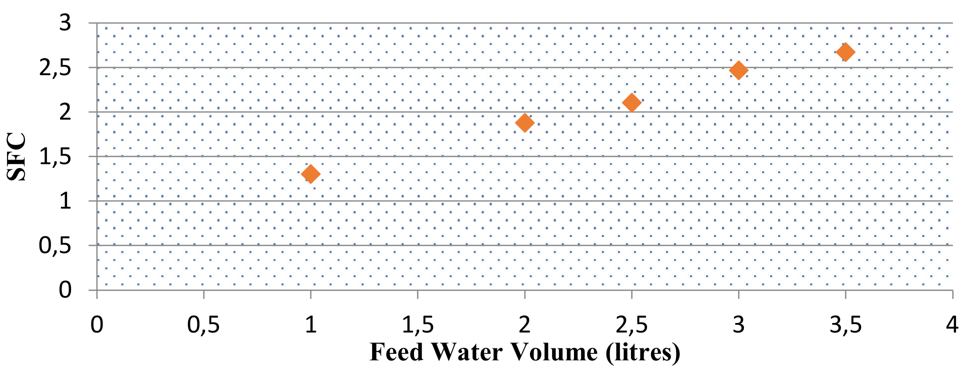

Figure 5. Graph of Feed Water Volume vs SFC

From figure 5, It can also be seen that the energy consumption consumed at a volume of 3.5 liters is due to the long heating time compared to other feed water volume variations, so the energy consumption is large. SFC has an increasing tendency in harmony with increasing feed water volume.

4. Conclusion

From the results of research on aquadest evaporator equipment, it can be concluded that the smaller the volume of feed water, the greater the efficiency. This is because the heating process is fast so that the large amount of steam produced in one hour of operation can be seen from the graph. So, the performance of the aquadest tool can save electrical energy at a volume of 1 liter and consume a lot of electrical energy at a volume of 3.5 liters. From the evaporator research process, in the process of boiling the heated water the set point is set so that when the water reaches 100^0C the electric heater will turn off and the feed water volume is varied 5 times to see the consumption of electrical energy used and also in the distilled water analysis it is best to replace the pipe with stainless steel pipe because using stainless steel pipes will not corrode and is environmentally friendly

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