# Performance Review of Distillation Equipment Using An Evaporator

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***Abstract***

*In the framework of current energy savings, increased equipment efficiency is necessary to avoid wasting energy. It is well known that fossil-fueled energy continues to rise and is quickly exhausted, so we need alternative energy that is not rapidly depleted, energy is easily obtained. This equipment can be applied in the laboratory, pharmacy, hospital, etc. In the refining process in the laboratory, the results of the first distillation of distilled water are usually not used anymore as a high-value product; aquadest. Aquadest is water from the distillation process. The purpose of this research is to review the evaporator in the distillation equipment to obtain a product in the form of distilled water by examining the physical and chemical properties of distilled water. The method used in this design is the design of the structural and functional design. In the process of heating the water in the evaporator, the volume was varied. From the research, the performance of the equipment and aquabidest distilled water with energy consumption (SFC) is 1,1471597129 optimum kwh / kg of steam at the volume of 1 liter. The optimum time is at a temperature of 100$^0$C and in 1 hour, produces distilled water with levels TDS 9 mg/L and, a decent pH 6.12 used for practical purposes in the laboratory.*

***Keywords:*** *aquadest, chemical, condenser, distillation, evaporator.*

**Abstrak**

Dalam rangka penghematan energi saat ini, peningkatan efisiensi peralatan diperlukan untuk menghindari pemborosan energi. Sebagaimana diketahui energi berbahan bakar fosil terus meningkat dan cepat habis, sehingga diperlukan energi alternatif yang tidak cepat habis, dan energi yang mudah dijumpai. Peralatan ini dapat diaplikasikan di laboratorium, farmasi, rumah sakit, dll. Pada proses pemurnian di laboratorium, hasil penyulingan pertama air suling biasanya tidak digunakan lagi sebagai produk yang bernilai tinggi; akuades. Aquadest merupakan air hasil proses penyulingan. Tujuan dari penelitian ini adalah meninjau evaporator pada peralatan destilasi untuk memperoleh produk berupa air sulingan dengan mengkaji sifat fisik dan kimia air suling. Metode yang digunakan dalam perancangan ini adalah perancangan struktur dan perancangan fungsional. Pada proses pemanasan air di dalam evaporator volumenya divariasikan. Dari hasil penelitian, kinerja peralatan aquabidest dan aquabidest dengan konsumsi energi (SFC) optimum adalah 1,1471597129 kwh/kg steam pada volume 1 liter. Waktu optimum adalah pada suhu 100$^0$C dan dalam waktu 1 jam, menghasilkan aquades dengan kadar TDS 9 mg/L dan pH 6,12 yang layak digunakan untuk keperluan praktikum di laboratorium.

***Kata kunci :*** *aquades, kimia, kondensor, destilasi, evaporator*

## 1. Introduction

Renewable energy is a solution to the conventional energy crisis, including electrical energy. Electrical energy is an energy that is widely used in everyday life. Energy has been used since the past, and because of the energy crisis. The energy crisis, especially electricity, that occurred towards the end of the 20th century is a sign that the supply of electrical energy cannot keep up with the high rate of demand [1]. Nowadays, the manufacture of equipment relies heavily on electricity, including the manufacture of Aquadest distillation equipment which uses electrical energy. The distillation equipment it self is a

tool that applies several methods to produce clean and good water by stages or distillation. The water distillation equipment uses the concept of differences between boiling points and melting points of the chemicals that make up water. In this system, two processes occur, namely evaporation and condensation. The process of making distilled water begins when raw water is boiled at a temperature of around $100^0$C (water boiling point) using a boiler/heater. When the water temperature reaches boiling point, the water will evaporate. When water vapor comes into contact with an area with a low temperature, the water vapor will condense and fall as water droplets. This distiller is capable of producing distilled water through a distillation process that utilizes electrical energy and changes it into a mechanical distillation process [2].

These water droplets are then collected into distilled water. Aquadest is a vital ingredient in a laboratory. According to [3] the need for distilled water is very large because distilled water is the main solvent in practical activities in the laboratory. Clean water which comes from PDAM (Regional Drinking Water Company) is different from Aquadest. Clean water that comes from PDAM has gone through human treatment such as filtration and chlorination, but those process does not allow pure PDAM water to be clean because it is included in group B, odorless and tasteless. Aquadest and PDAM water certainly have different qualities and ion contents. Both are placed in an external electric field. The use of Aquadest is of course very important, especially in a laboratory environment.

The conductivity parameter is used to determine the quality of distilled water because conductivity produces a non-specific measure of ion content. According to [4] there are several distillation methods developed for water desalination technology, namely: simple distillation, single distillation, multiple effect distillation, multilevel distillation, vapor compression distillation, and the latest is the Renfro-distiller method. Apart from distillation methods which continue to develop, alternative energy is utilized in the process. Aquadest processing is alsobeing developed, as is done by using waste heat from power generating machines as an energy source. In a distillation equipment without modification, after passing through the condenser, the water will enter the heater as raw material for distilled water. When the water in the heater increases by a large amount, it will affect the water temperature in the heater as a whole. A decrease in the water temperature in the heater will affect the amount of water vapor produced, this is in line with [5] who says that the smaller the volume of feed water, the greater the efficiency, and the more steam produced will be. In a series of modified distillation equipment, the water temperature in the heater is not affected by the addition of water because the incoming water flow is very small. Distillation is a process that involves steam being turned into a liquid with the help of a condenser. In distillation, a mixture of substances is boiled until it evaporates, and this vapor is then cooled back into liquid form. Evaporation is a condition where a liquid changes to a vapor state. The evaporation of an evaporator itself can be calculated by knowing the absolute pressure that occurs in the evaporation chamber. Where the evaporation temperature is the temperature of saturated steam at absolute pressure [6]. In this process some of the water and solvent are evaporated to obtain a thick product. To use an evaporator, a condenser must not be missed out, the evaporator and condenser are two important components in the evaporation process, including the distillation equipment. On the other hand, the influence of wall thickness on the evaporator affects the equipment in heat absorption. In a study explained that evaporators made of glass materials with a smaller thickness can absorb heat energy faster [7].

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changes to a vapor state. The evaporation of an evaporator itself can be calculated by knowing the absolute pressure that occurs in the evaporation chamber. The evaporation temperature is the temperature of saturated steam at absolute pressure [6]. In a distillation equipment, the condenser is one of the components that converts steam into water or can be called a heat exchanger. By reducing the downstream pressure or reducing the absolute pressure in the condenser, the installation efficiency increases and the steam flow will decrease for a fixed installation output [8]. The challenge in making this Aquadest distillation equipment is to have a level of efficiency that needs to be known to optimize the performance of the tool so that it can work with maximum output without having to waste existing energy, so that energy savings can be made and produce small scale tools without wasting energy [3]. Energy-related problems have attracted the attention of many countries recently. Nearly 40 percent of carbon emissions are produced by the electricity sector, where the higher the electricity consumption, the higher the emissions produced [1]. Apart from that, making Aquadest, which is increasingly expensive, takes a long time because it does not apply the best possible energy efficiency. Waste of energy is certainly a serious problem, when energy is not used as efficiently as possible, it will cause waste. Improper use of electrical energy will cause harm to users. Therefore, in making an equipment that will be useful, we should calculate the energy and study alternative energy that will be used and wasted, so as to produce agood product for the Aquadest distillation equipment [9]. The use of equipment that involves energy should be planned well from the start, so that operating the tool is a necessity and not a waste [10]. So, in this research, the problem that will be discussed is, how much energy consumption is needed to evaporate water with variations in the volume of feed water used and then compare the physical and chemical properties of distilled water with established standard.

## 2. Literature Review

Distillation is a process that involves steam being turned into a liquid with the help of a condenser. In distillation, a mixture of substances is boiled until it evaporates, and this vapor is then cooled back into liquid form. Evaporation is a condition where a liquid changes to a vapor state.

The evaporation of an evaporator itself can be calculated by knowing the absolute pressure that occurs in the evaporation chamber. Where the evaporation temperature is the temperature of saturated steam at absolute pressure [6]. In this process, some of the water and solvent are evaporated to obtain a thick product. To use an evaporator, a condenser must not be missed since the evaporator and condenser are two important components in the evaporation process, including the distillation equipment. In a distillation equipment, the condenser is one of the components that converts steam into water or can be called a heat exchanger. By reducing the downstream pressure or reducing the absolute pressure in the condenser, the installation efficiency increases and the steam flow will decrease for a fixed installation output [8].

### 2.1 Distillation Equipment:

1. Evaporator

A distilled kettle commonly called a tank function as a container for the combustion process which produces heat or steam from water. This distilled kettle is in the form of a cylinder or tube which has a smaller diameter than the height of the tank. This tank has a section/plate at the top and bottom to cover the tube. This tank has an electric heater to heat the water which will produce steam. From the top of the tank, a 3/8-inch copper pipe is installed to facilitate the entry of steam produced from the water. The kettle is made of stainless steel with a diameter of 10 cm and a height of 50 cm. The stainless-steel tube cover is welded so that steam does not leak so that maximum steam is produced. The energy required by the evaporator to convert water into steam is the sum of the energy for heating the water and the energy for evaporation. An evaporator is a device that functions to change part or all of a

solvent from a solution from liquid to vapor. The evaporator has two basic principles, namely to exchange heat and to separate the vapor formed from the liquid. There are several types of evaporators, according to their intended use and different shapes. This is because it depends on the amount or volume of liquid that you want to evaporate. The evaporation process can occur if:

1. There is energy (solar, heat carried by hot winds in the ground, heat in water),
2. There is a water source,
3. There is wind, to move air near the earth's surface.

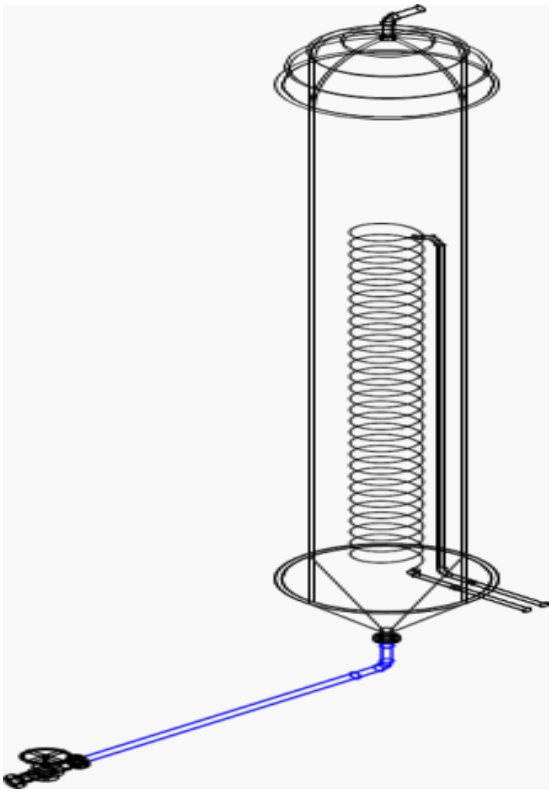

*Figure 1. Evaporator*

## 3. Method

### 3.1 Materials

The material used in this design was clean water (PDAM). PDAM water itself is different from aquadest, in which PDAM water has gone through human treatment such as filtering and chlorination, but this does not allow pure PDAM water to be clean because it is included in group B, odorless and tasteless.

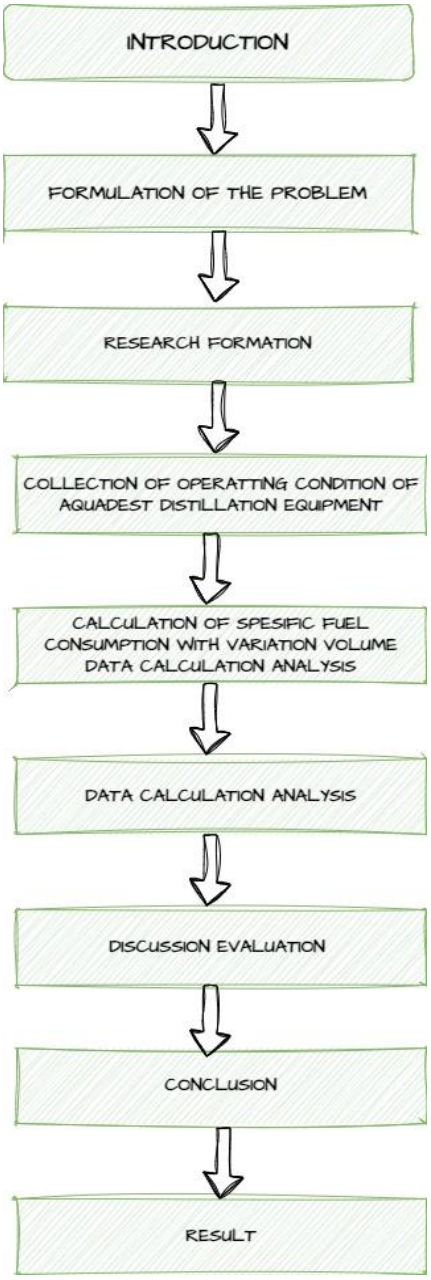


*Figure 2. Research diagram*

### Systematics Calculation

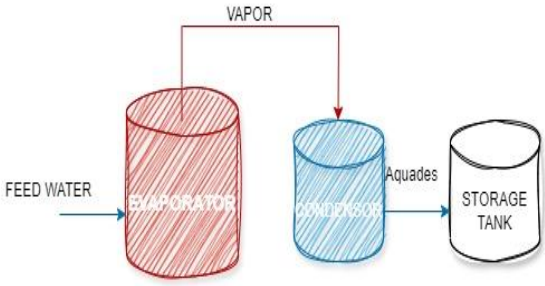


*Figure 3. Block Diagram of Aquadest Distillation Equipment*

There were 3 stages of doing systematics calculation; 1) water boiling, 2) analysis of the physical properties of aquadest, and 3) analysis of the chemical properties of aquadest. The first stage was water boiling. On this stage, firstly, prepared a set of water evaporation distillation equipment. After that, turned on the pump. Then, filled the evaporator with water with a volume of 1 liter. Next is turned on the heating element by setting the temperature to $100^0$C using the control panel. Then, measured the temperature of the steam and the temperature of the remaining water using a thermometer then condensed the steam. The amount of condensate was collected for 1 hour using a measuring cup. And repeat the experiment with varying feed water volume. The second stage was doing analysis of the physical properties of aquadest. To be able to do this analysis, firstly, prepared the TDS Meter. Then, turned on the TDS Meter by pressing the ON button. After that, dipped the electrode in the distilled water product obtained.

Next, recorded the TDS, conductivity and salinity values listed on the display. Then, turned off the TDS Meter by pressing the OFF button. And finally, washed the electrode with clean water and dry with tissue. The third stage was analysis of the chemical properties of aquadest. Firstly, calibrated the pH meter 632, and then installed the combination glass electrode on the pH meter 632. After that, attached the cable to the socket. Next was turning on the pH meter 632 by pressing the on/off button and pressing the pH button (do not press the u/mv button). Next, dipped the electrode in distilled water and measured the temperature of the solution and enter the temperature value on the pHmeter according to the distilled water temperature using the t/c button. Then, set up the “slope” button on scale 1. The next was pressing the "meas" button reads the pH on the display and setting the number on the display according to the pH of the distilled water using the "ucomp” button. And the last was pressing the "stand by" button, rinse the electrode with clean water and dry with atissue.

## 4. Results and Discussion

The evaporator which is designed from a modification of equipment usually used by industry for the solution of thickening process. It is done by releasing water from the solution through boiling in a vessel. Even though there was a chemistry laboratory in Shipbuilding Institute of Polytechnic Surabaya, no equipment produced aquadest in that laboratory. Therefore, the author used an evaporator with clean water as the raw material for the water boiling process. That process produced a high value product, namely aquadest. The amount of water vapor was an important thing to consider in the process of water boiling. The steam produced through the boiling process would be returned to feed, then absorbed by the condenser. In making the design of the aquadest equipment, research was carried out twice. The first observation used variations in the volume of feed water and the second observation analyzed the physical and chemical properties of distilled water. The results of these observations were in the following table.

***Table1. Observation data with variations in feed water volume in distilled water***

| Feed Water (liter) | $T_{in}$ ($^0$C) | $T_{vapor}$ ($^0$C) | Volume aquadest (liter/hour) | Power (watt/hour) |
|---|---|---|---|---|
| 1 | 28 | 88 | 0,451 | |
| 2 | 28 | 88 | 0,437 | |
| 2,5 | 28 | 88 | 0,389 | 500 |
| 3 | 28 | 88 | 0,367 | |
| 3,5 | 28 | 88 | 0,355 | |

The amount of steam for each variation in feed water volume was different. This was done so that ideal operating conditions could be determined. The evaporator design was 4 liters, however when the water was boiling, it did not reach 4 liters. This was done in order that boiled water was not wasted. In addition, set point was adjusted on the control panel because if the water is heated continuously, it will cause scale. Based on these data, specific fuel consumption calculated.

The results of specific fuel consumption calculation could be seen in the following table.

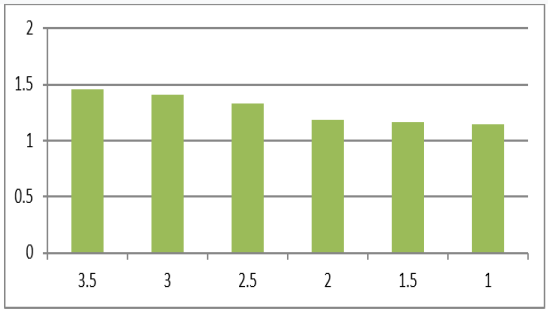


*Figure 4. Sfc and volume*

From graph 2. It could be seen that the energy consumption was spent on a volume of 3.5 liters because the heating time was longer compared to other feed water volume variations. So that the energy consumption was larger. A low SFC value had high efficiency and a high SFC value had low efficiency. This condition showed that the higher the SFC value on the evaporator, the lower the efficiency of the system. Aquadest would speed up the resin working process, so that the machine could be used quickly. It would not cause rust on the material, would not easily crust, and would not easily grow moss. Thereby, it could simplify the production process and save maintenance costs. This research used sources water, namely clean water to be processed into distilled water using a distillation process. Then distilled water were analyzed to determine their quality. The analysis carried out includes TDS, pH, etc.

*Table 2. Properties Of Aquadest*

| Unit | Aquadest |
|---|---|
| Conductivity (µ S/cm) | < 25 |
| TDS (ppm) | 1 – 10 |
| pH | 5 -7 |
| BM (Kg/mol) | 18 |
| Boiling Point ($^0$C) | 100 |
| Freezing Point ($^0$C) | 0 |
| Smell | Odorless |
| Color | Colorless |
| Flavor | Tasteless |

*Source: Sarjoni, 2003: 241*

*Table 3. Analysis of the Properties of Aquadest Produced*

| NO | Characteristics | Results | Methode |
|---|---|---|---|
| 1 | Smell | Odorless | Organoleptik |
| 2 | Color | Colorless | Platinum Cobalt |
| 4 | Flavor | Tasteless | Organoleptik |
| 5 | Ph | 6,12 | Potensiometri |
| 6 | TDS (ppm) | 9 | Potensiometri |
| 7 | Boiling Point ($^0$C) | 100 | - |
| 8 | Freezing Point ($^0$C) | 0 | - |
| 9 | Temperature($^0$C) | 28 | - |
| 10 | Salinity (%) | 0 | - |

The evaporator and condenser were designed from a modification of equipment usually used by industry for the solution thickening process. It was done by releasing water from the solution through boiling in a vessel. Condenser and evaporator coils were *responsible for directly carrying out the heat exchange process*. The evaporator was an important thing in aquadest design because it was used for the water boiling process and as a system that would indicate savings in aquadest design. While the condenser was designed to change the vapor phase to liquid. So, the evaporator and condenser processes were interconnected. The evaporator was an important system in designing aquadest. It would review its performance or ability in boiling water to see the physical properties produced from aquadest and whether it complied with standardization or not. The use of materials from which the evaporator was made, played a very important role in the results of aquadest because it determined the quality of the water. It also affected the physical and chemical properties of distilled water. From the research results, the properties of distilled water were the same as the standard and the production of distilled water at the PPNS Laboratory. The similarities were because the pipes used were stainless steel pipes so they would not rust if used continuously.

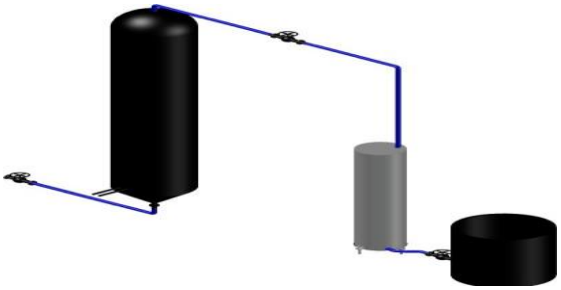

*Figure 5. Prototype a Distilled Water Using an Evaporator*

## 5. Conclusions

From the research that has been carried out, it is concluded that the results of distilled water are having good quality since it was done in a distillation equipment that was assembled with optimum temperature. The performance of the equipment and aquabidest distilled water with energy consumption (SFC) was 1,1471597129 optimum kwh / kg of steam at the volume of 1 liter. And the optimum time was at a temperature of $100^0$C and 1 hour, produced distilled water with levels TDS 9 mg/L, decent pH 6.12 used for practical purposes in laboratory. Suggestions needed to improve the quality of distilled water requires processing initial water before the distillation process, such as: coagulation, flocculation followed by filtration to remove high dissolved solids content in water bait.

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