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The Experiment of Producing Freshwater from the Air Using Thermoelectric Cooler for the Need of Drinking Water in a Lifeboat

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***Abstract*— A limitation of freshwater supply in a lifeboat during sea survival situation caused by a ship accident could endanger survivor's life. An availability of freshwater is critical for people to survive during search and rescue time. Therefore, it is very important to have a device that can produce freshwater continuously in a lifeboat. A capacity of the lifeboat is around for 20 people. In this research, four model of atmospheric water generator (AWG) namely Model I, Model II, Model III, and Model IV has been designed, fabricated, and tested. All models are tested for one hour with humid air flow is 20 cfm. The atmospheric condition is 78% relative humidity and 30 ^{0}C temperature. The cooling process in AWG device use a thermoelectric cooler (TEC). Based on the result of experiments, the Model IV atmospheric water generator has a best result. The Model IV can produce 53 mL/hr of freshwater. By using 6 sets of the Model IV AWG, a total 7.63 liter/day of freshwater could be produced in that lifeboat. The electricity power supply for those AWG is served by 4 solar panels which each produce 295 WP. The electricity energy from solar panels is saved in 9 power storages or batteries which each has 100 AH and 12 V voltage.**

Keywords— atmospheric water generator, freshwater, lifeboat, survival, thermoelectric cooler.

I. INTRODUCTION

Indonesia is known as the world's largest archipelago which consists of around 17,000 islands which span more than 5,000 km (around 3,200 miles) eastward from Sabang in northern Sumatra to Merauke in Irian Jaya. Ships in various types have a main role in logistics and transportation across the country. With such wide of waters territory, any ship accidents will be quite difficult and takes a long time to search and rescue.

Drinking water is essential for life or to survive, because it is useful for maintaining the body's metabolism and physiology. The human body consists of millions of cells and the most components of these cells are water, if cells were drained, it would contract and could not work properly. Similarly, water is a liquid extract from the human body such as tears, urine etc. When in the middle of the sea the existence of water that could be consumed by humans is very limited, because humans can only consume freshwater, not saltwater.

When a ship is having a major accident during its voyage, all passengers and crews would be embarked to lifeboats. Meanwhile, amount of freshwater in a lifeboat is very limited. Only a total of 1.5 liter of fresh water for each person the lifeboat is permitted to accommodate [1]. With uncertain-time for rescue during sea accidents, therefore an availability of fresh water in lifeboats will become very crucial. It is very important to have a device that can produce freshwater continuously. This is a problem what need to be solved.

An average of atmospheric relative humidity in Indonesia waters are between 70% - 85% as shown in Figure 1. It is very humid. Therefore, it is very possible to produce freshwater from atmospheric or free air. Based on a psychrometric chart, with a temperature 35 ^{0}C and 70% - 80% relative humidity, there is water (as vapor) potentially around 27 gram of water in 1 kg dry air in Indonesia atmosphere.

In the world, some efforts or researches are to be done in order to produce freshwater from free air or atmosphere. M.A.Munoz-Garcia et al [2] have done a research to establish the concept of moist air condensation as well as generation of water as harvesting water for young trees using Peltier plates that are powered by photovoltaic solar energy. Their research objective is to obtain the water required by some dry-climate woody crops to overcome their critical growing stage.

Meanwhile Aditya Nandy et al [3] has designed and tested their own AWG model which capable to convert atmospheric moisture directly into usable and even drinking water especially for people who lived in arid regions in India. They use three 40 W (3.5 A) Peltier coolers (TEC1) which each has a dimension of 4x4x0.8 cm and connected in parallel. The maximum temperature difference i.e. ΔT of 87°C. A 3000 rpm, 15x15cm (size of TEC1) fan that is capable of producing airflow of at most 500 cfm is used for circulation of the air. The heat sinks are made of aluminum and anodized. Activated carbon filter are used for water filtration. Two temperature sensors and a PIC16F872 or ATmega series microcontroller are used for temperature control. For a power supply to their AWG, a solar cell unit with 12 V rated output is used. The maximum output power is 120 W. Their AWG model can produce almost 1 Litre of condensed water per hour during the day light.

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V.P. Joshi *et al* [4] also develop and experimentally investigate a thermoelectric fresh water generator based on the fundamental of Thermoelectric Cooling Effect by condensing the moisture from the ambient moist air. Experiments are carried out in order to study the effect of mass flow rate of moist air, electric current, humidity, and the effects of placing the internal heat sink on the amount of water condensed. They made a prototype of the generator consisting of a 0.7 m long cooling channel along with ten thermoelectric modules of dimension 4x4 cm each placed linearly in an array. An internal heat sinks of surface area 0.2 m^2 and length 0.65 m is placed on the cold side of the modules to enhance heat transfer rate. The experiments are carried out at 30 °C ambient temperature for ten hours running of each individual test. For studying the effect of mass flow rate of moist air on the amount of water condensate, electric current and humidity are kept constant at the maximum possible value of 1.5A and 90% relative humidity respectively and the mass flow rate is varied by varying the voltage of the axial fan from 1.5 V to 7.5 V at an interval of 1.5V. The mass flow rate at which the amount of water condensate is observed to be maximum, which is taken into consideration for studying the effects of electric current and humidity. For the effect of electric current, humidity is kept constant at 90% relative humidity and the current is varied as 0.5A, 0.8A, 1A, 1.3A, 1.5A. For the effect of humidity, electric current is kept constant at which the water condensate is observed to be maximum and the humidity is varied as 60%, 63%, 71%, 80%, 90%.

The observations from the experiments show that with the use of internal heat sink, the quantity of water generated per 10 hours increases by 81% as compared without internal heat sink. Electric current, air mass flow rate and humidity of moist air were varied to understand their impact on the quantity of water generated. Based upon the observed results, the quantity of water generated is directly proportional to all the three parameters.

Generally, people think that AWG units are more efficient only at coastal regions where the relative humidity is high. However, A. Bharath and K. Bargav [5] have done a research which the objective of their research is to obtain a specific temperature (dew point temperature) to condense water with the help of Peltier devices and aims at optimizing the AWG unit to be efficient at locations where humidity percentage is low. As a result of their research, it is concluded that 5 Peltiers are required for the atmospheric water generator at ambient temperature of 35 ^{0}C or higher and if relative humidity is nearer to 45% then the device will function well.

Thermoelectric cooler (TEC) uses the Peltier effect for the exchange of heat. S. Haidar *et al* [6] described the conversion of thermal energy into electrical energy (Seebeck effect) or electrical energy into thermal energy (Peltier effect) takes place with the help of thermo-electric devices. The electromotive force was generated when heating between two dissimilar metals takes place. The reverse operation was also possible. The transformation of heat from one side to another side was made possible by-passing electric current with the development of semiconductors. Figure 2 gives an illustration of a thermoelectric cooler's work.

Meanwhile, the performance of a Thermoelectric Refrigerator has been studied by G. Anbazhgan and R.Hariharan [7]. The performance of the refrigerator was experimentally under varying conditions of source and sinks temperature differences and input current. The system consisted of the refrigeration chamber, thermoelectric modules, heat source and heat sink and thermocouples. In their experiment, the cold space of the refrigerator is maintained at 13 ^{0}C, this also is the cold side temperature of the module. The heat sink temperature is maintained at 42 ^{0}C, to maintain the necessary temperature difference for heat transfer as the ambient temperature on a very hot day is been 30–35 ^{0}C. Results of their research show that the coefficient of performance (C.O.P.), which is a criterion of performance of such a device, is a function of the temperature difference between the source and sink. For maximum efficiency, the temperature difference should be maintained at the barest minimum temperature.

Hence, based on the problem which described above, in this research we try to design an atmospheric water generator which suitable for a lifeboat. Including its solar panel system as well as an electric source of the device.

II. METHOD

In this research we designed and tested four models or prototypes of atmospheric water generators (AWG), namely Model I, Model II, Model III, and Model IV. Every model has improved or modified based on a test of the previous model. Hence a Model II is better than a Model I, and a Model IV is the best model. Improvements and modifications of the AWG model must be done in order to produce 1 Liter/day of freshwater as a target.

Modifications are made with considering a result of freshwater production during a test or an experiment. Some aspects or parameters are also observed. They are air flow and air quantity, kinds of material of heat sink and cold sink, using of heat pipe, and made of a cooling coil with water inside as a cooling fluid. That cooling water is circulated by a small water pump.

Each experiment has to be done for one hour with atmospheric conditions where a relative humidity is 78% and air temperature around 30 0C (a dew point is 26 0C). The quantity of humid air is 20 cfm supplied by one unit fan (DC 12 V; 0.075 A; 0.9 W). The thermoelectric cooler is TEC 120706 with 60 W. Meanwhile a fan heat sink has DC 12 V with 0.13 A, and 1.56 W. An electricity power for a water pump is 1.05 W. A material for heat pipe and cooling coil is copper. The Model IV configuration shown in Figure 3, and Figure 8 is the photograph of the Model IV AWG.

The photovoltaic is applied because it could be a really cost and effective solution for the lifeboat. PV systems can act as ideal subsidiary power sources because it produces electric power without the need of transferred gas or liquid fuel. PV systems also have no by-products such as gas emissions or noise, relatively low maintenance cost, limited or no use of mechanical moving parts, easy installation and fast replacement in case of aging or defectiveness, it can be placed in small surfaces such as roofs, walls, and superstructure,

Construction and PV placement design is an important issue because of the limited space to mount PV modules in a lifeboat. The PV modules must be exposed to sunlight in order to get higher power from PV. The higher the intensity of light received by PV module, the higher the power generated by PV module. The total weight of PV modules and battery must also be considered [8].

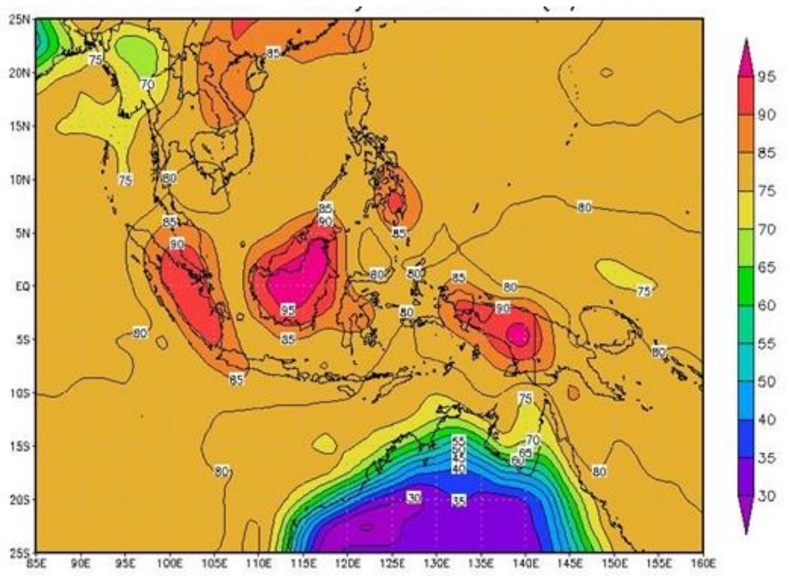

Figure 1. Relative Humidity in Indonesia

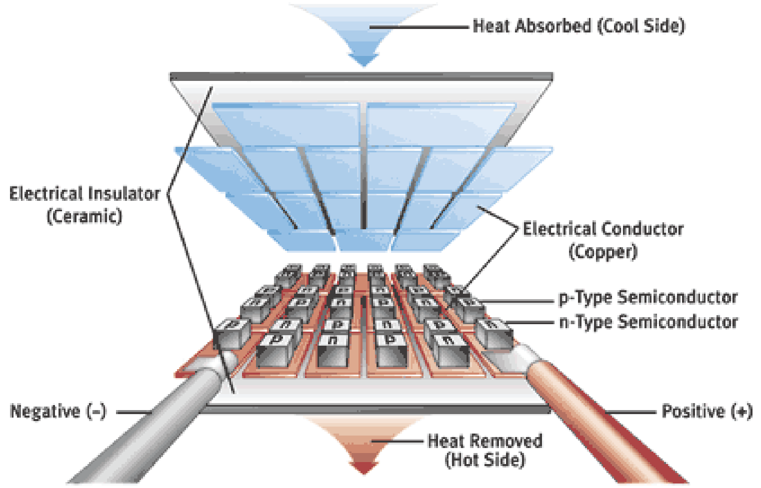

Figure 2. Thermoelectric cooler

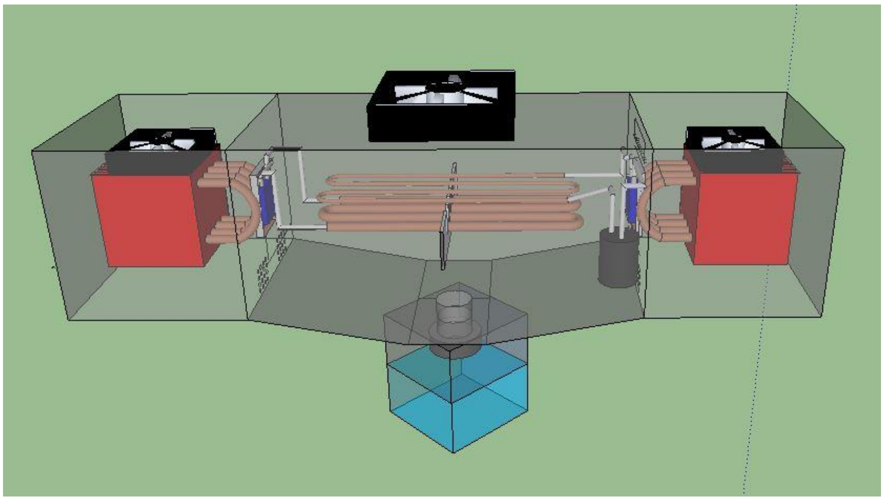

Figure 3. Design model

III. Results and Discussion

Based on the test results of four different AWG designed models, it is obtained one model *i.e.* Model IV which has a highest fresh water production. The Model IV can produce 53 mL/hour of freshwater. This model uses heat pipes to remove heat on the hot side of the TEC. The heat pipes work optimally as they cool the hot side of the TEC and keeps the temperature on the cold side of the TEC around 16 ^{0}C.

The cooling process on the TEC's heat side is also aided by the flow of cooled low-temperature air from cold side of the TEC. A cool air flows through some holes which made for its purpose. We design like that because of the TEC principle shows that while the temperature on the hot side getting lower, so then the temperature on the cold side will be lower as well. In the humid air catcher, the Model IV uses a copper cooling coil. The cooling coil connects one water block to another water block where a heat transfer process occurs. Cold freshwater in cooling coil is circulated by a pump. The water vapor in humid air that flows through the cooling coil then will be condensed becomes water droplets which then contained in the underneath bottle.

The length of the copper pipe as a cooling coil also affects an amount of freshwater obtained. This happens because the longer copper pipes then a surface area for cooling process also be increasing. And finally, the vapor in moist air will be condensed even greater. However, if the copper pipe becomes longer, it means that the volume of water in the pipe also increase. This situation makes a temperature of cooling water becomes a little bit higher and causing the condensation process to be slow. Therefore, it is necessary to find out an optimal surface area. The result of this can be looked at in Table 1 and Figure 4.

Based on the experiments, the optimum surface area is 115 cm², with the average temperature on the cold side of the TEC is 4.1 ^{0}C. The quantity of freshwater that can be produced from moist air is 53 mL/hr. By the condition of an atmospheric air on Indonesian sea which generally has an average humidity ratio about 20.1 g_w / kg_{da}. Using the Model IV AWG that has a fan speed of 20 cfm, this model can produce 53 mL/hr of freshwater meanwhile amount of water (as a vapor) in atmosphere air flow is 689 mL/hr. It means that the efficiency of the Model IV AWG is only 7.7%.

Meanwhile from the calculation and design iteration, for lifeboat with a 6.73 m length and a 2.7 m width, the lifeboat can accommodate 4 solar panels which each produces 295 WP, and 9 power storages or batteries which each has 100 AH and 12 V voltage. Due to additional burden of this AWG system, so the capacity of the lifeboat should be reduced from 25 people previously without an AWG device to only 20 people. Hence, with the 1180 WP total availability of power that can be supplied by solar panels, that can be used to supply 6 set of AWGs for 24 hours. Figure 5, Figure 6, and Figure 7 show an arrangement of the AWG system in a lifeboat.

Table 1.
Water quantity obtained

No	Surface area of the pipe (cm²)	Temperature of the pipe (°C)	Water quantity obtained (ml/hr)
1	99	3,9	48
2	115	4,1	53
3	132	4,9	51

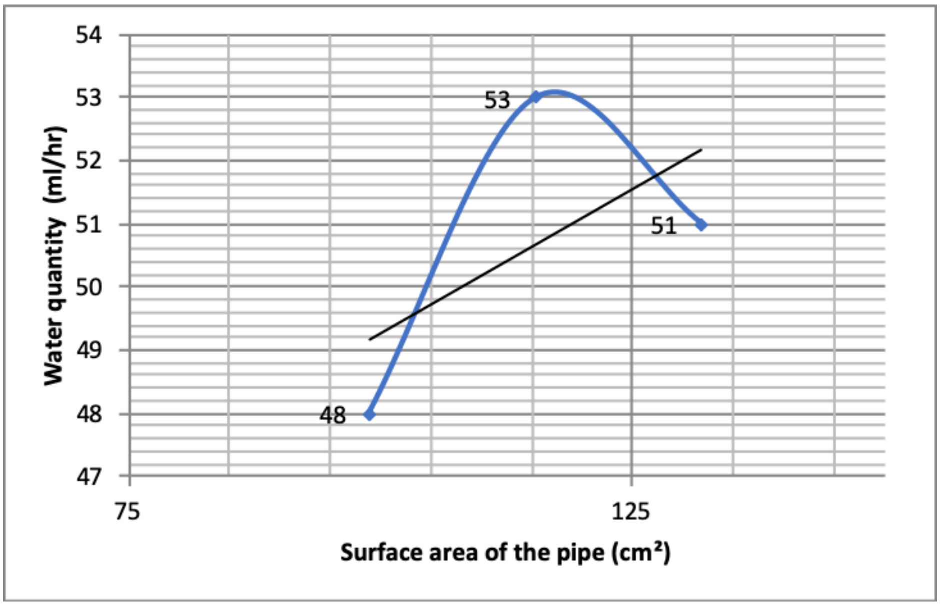

Figure 4. Chart of water quantity obtained

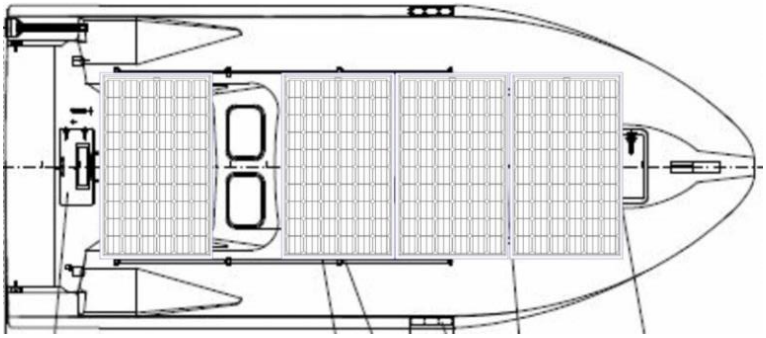

Figure 5. Solar panel arrangement on a lifeboat

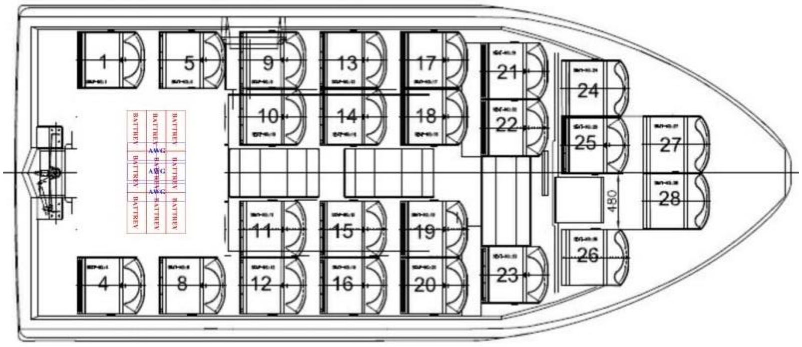

Figure 6. AWG & batteries arrangement in a lifeboat

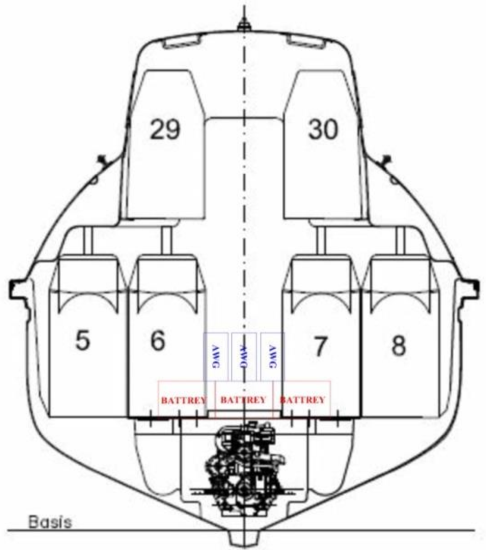

Figure 7. AWG & batteries in a lifeboat

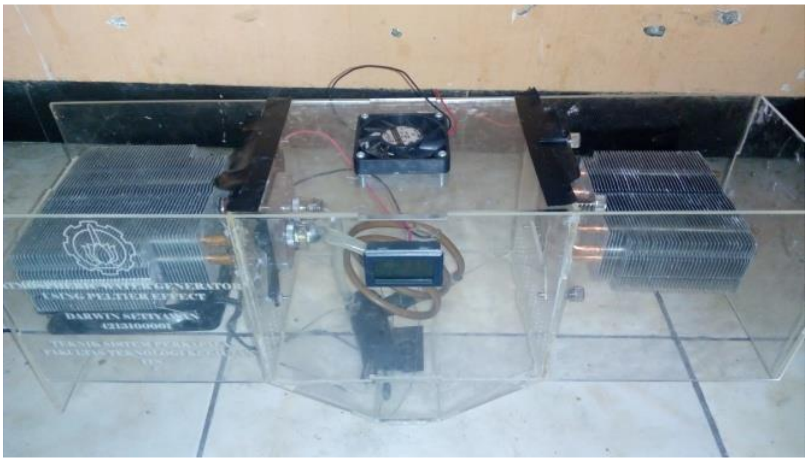

Figure 8. The model iv atmospheric water generator

IV. CONCLUSION

The research has succeeded in designing and testing the model of atmospheric water generator which suitable for a lifeboat. The Model IV configuration gives the best result compare other models. By using 6 set of the Model IV AWG, a total 7.63 liter/day of freshwater can be produced in that lifeboat. This could give a hope for survivors in the lifeboat during search and rescue time.

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