WATER CONDENSATION GENERATOR BASED ON PELTIER COOLER MODULE

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ABSTRACT The current issue of global warming has resulted in many impacts. One of the most important impacts is the shortage of water in many areas around the world. Therefore, this paper focuses on the new technology to generate the water as the alternative solution of water destitution problem. The Water Condensation Generator (WCG) is the equipment having capability to generate water by making the condensation environment for vapor in normal atmosphere. The basic element of WCG includes the peltier cooler module, heat sink and cold sink (made from aluminum). From the principle of peltier, when we give the DC voltage to the peltier cooler module, the positive and negative charge carriers in the pellet array absorb heat energy from one substrate surface and release it to the substrate at the opposite side. The side where heat energy is absorbed becomes cold and the opposite side where heat energy is released becomes hot. We connect the cold sink with the cold surface and connect the heat sink in the hot surface of peltier cooler module. The heat sink serves transferred heat leaves the peltier cooler module with the fluid in motion. Consequently, when the temperature of surface of cold sink is lower than vapor saturation temperature, it begins the water condensation effect. At the current stage of WCG, the authors have implemented the real prototype of WCG and it can really generate the water. Although the amount of generated water is still little, this work provides the proof of new technique to be an alternative choice for generating water.

1. INTRODUCTION

This research aims to tackle water consumption in the areas of water shortage. At present, there are various methods of making water for human consumption such as making artificial (Bernaed A. & Wathana, 2000) turning seawater into fresh water (Knust, et al., 2013). The artificial rainmaking can make a lot of water but it also requires a high budget. The conversion seawater into freshwater must have seawater as a raw material. Thus, it cannot be implemented at far area from the coast.

The proposed research presents the new technique to generate the water from the condensation of vapor. The Nusselt's Film Theory is the theory of condensation on the surface of the object. Condensation occurs if a vapor is cooled below its saturation temperature (Holman, 2000). When the surface temperature of the object is reduced to the saturation temperature of the steam, it will cause condensation of water vapor on the surface of the object such as condensation in the evaporator of the air conditioning system (Chandra, 2010). However, the cooling system of air conditioning is still a process of complex systems. In contrast, the peltier module can create a cooling by a simpler and smaller than the air conditioning. The peltier Theory is shown in Fig. 1. When DC voltage is applied to the module, the positive and negative charge carriers in the pellet array absorb heat energy from one substrate surface and release it to the substrate at the opposite side. The surface where heat energy is absorbed becomes cold; the opposite surface where heat energy is released becomes hot. Reversing the polarity will result in the reversed hot and cold sides. Thus, just DC voltage is applied to the peltier module and then it is able to create cooling.

For this reason, the authors apply a peltier module for being a cold source of condensation effect. To apply a peltier module for industrial purpose is not a new idea. It was applied to many applications such as cooling systems ((Gupta et al., 2011), (Hirachan & Agonater, 2012), (Litvinovitch et al., 2010)), thermal sensors for detecting temperature difference (Dalola et al., 2009). However, there has not been any research so far to apply a peltier module directly for water production.

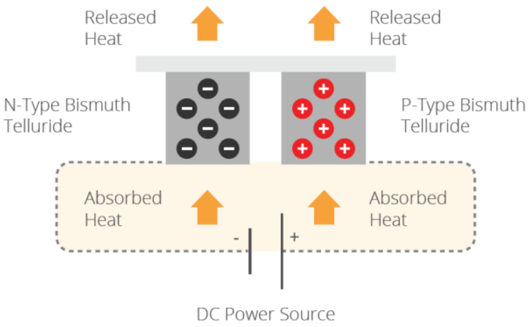

Fig. 1 Illustration of peltier effect

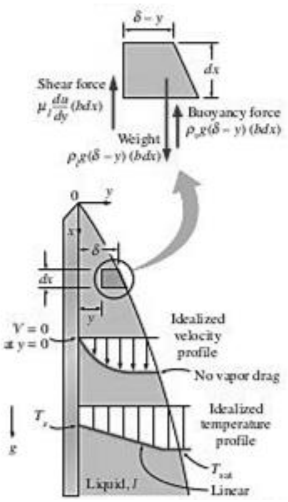

Fig. 2 film condensation on a vertical flat plate

2. ANALYSIS

2.1 The Nusselt's Film Theory (Holman, 2000)

From the Nusselt's film theory, it can consider a vertical flat plate exposed to a condensable vapor. If the temperature of plate is below the saturation temperature of the vapor, condensate will form on the surface and under the action of gravity will flow down the plate as shown in Fig 2.

Thus, the average value of the heat transfer coefficient is

$$\bar{h} = 0.943\left[\frac{\rho(\rho-\rho_v)gh_{fg}k^3}{L\mu(T_s-T_w)}\right]^{1/4} \quad (1)$$

To calculate the Reynolds number, the mass flow may be related to the total heat transfer and the heat transfer coefficient by

$$q = \bar{h}A(T_s - T_W) = \dot{m}h_{fg} \quad (2)$$

$$\dot{m} = \frac{q}{h_{fg}} = \frac{\bar{h}A(T_s-T_W)}{h_{fg}} \quad (3)$$

From equation (1) and (3), the mass flow rate is

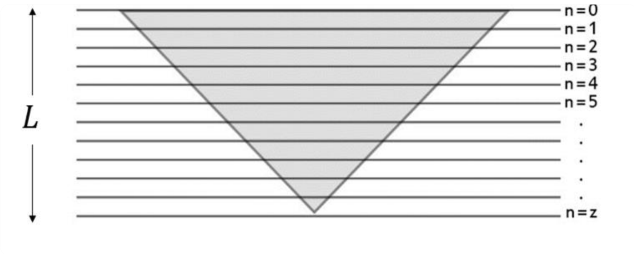

Fig. 3 film condensation on a vertical flat plate

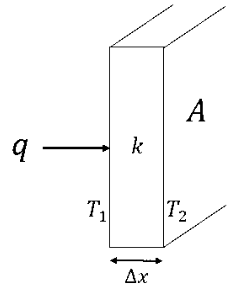

Fig. 4 volume for one dimensional heat conduction

$$\dot{m} = C\left[\frac{A^4k^3g\rho(\rho-\rho_v)(T_s-T_W)^3}{L\mu(h_{fg})^3}\right]^{1/4} \quad (4)$$

For this research, the cold sink is a pyramid shape. The surface is inclined at an angle $\emptyset$ with the horizontal plane. The net effect on the above analysis is to replace the gravitational force with its component parallel to the heat transfer surface.

$$\acute{g} = g\sin\emptyset \quad (5)$$

$$\dot{m} = C\left[\frac{A^4k^3g\sin\emptyset\,\rho(\rho-\rho_v)(T_s-T_W)^3}{L\mu(h_{fg})^3}\right]^{1/4} \quad (6)$$

The film condensation on a vertical flat plate is illustrated in Fig. 3. Each layer has the same width and the length of L is equally divided by z layers.

$$\sum_{n=0}^{z}\dot{m}_n = \dot{m}_0 + \dot{m}_1 + \dot{m}_3 + \cdots + \dot{m}_z$$

$$\sum_{n=0}^{z}\dot{m}_n = 2C\tan\theta\left[\frac{L^3k^3g\sin\emptyset}{z^3(h_{fg})^3}\rho(\rho-\rho_v)\right]^{1/4}\sum_{n=0}^{z}(L-nl)(T_{sat}-T_n)^{3/4} \quad (7)$$

2.2 Heat Transfer

The concept of heat transfer is introduced because it is used to realize the temperature of the surface. The relationships according to Fig. 4 are described as follows.

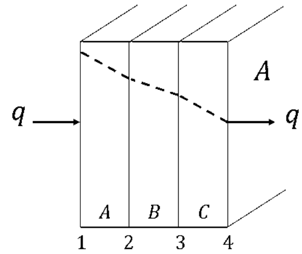

Fig. 5 multi-layered heat conduction

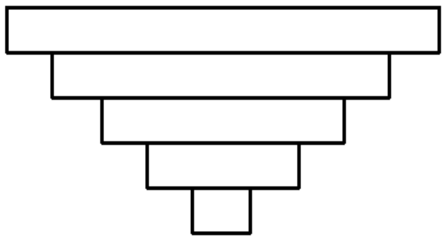

Fig. 6 multi-layer heat conduction of the pyramid shape

$$q = -\frac{kA}{\Delta x}(T_2 - T_1) \qquad (8)$$

$$T_1 - T_2 = \frac{q\Delta x}{kA} \qquad (9)$$

Then, for multi-layer heat conduction, the general equation of multi-layer conduction can be expressed as

$$T_{hot} - T_{cool} = q\left[\frac{\Delta x_1}{k_1A_1} + \frac{\Delta x_2}{k_2A_2} + \frac{\Delta x_3}{k_3A_3} + \cdots + \frac{\Delta x_n}{k_nA_n}\right] \qquad (10)$$

Consider the pyramid shape with multi-layer conduction of square flat, yields

$$T_n = T_{peltier} + \frac{ql}{4k\tan^2\theta}\sum_{n=1}^{n}\frac{1}{(L-nl)^2} \qquad (11)$$

From the equation (7) and (11), the equation of mass flow rate of the pyramid shape is expressed by

$$\sum_{n=0}^{z}\dot{m}_n = 2C\tan\theta\left[\frac{L^3k^3g\sin\emptyset}{z^3\left(h_{fg}\right)^3}\rho(\rho-\rho_v)\right]^{1/4} \cdot \sum_{n=0}^{z}(L-nl)\left[T_{sat} - \left(T_{peltier} + \frac{ql}{4k\tan^2\theta}\sum_{n=1}^{n}\frac{1}{(L-nl)^2}\right)\right]^{3/4} \qquad (12)$$

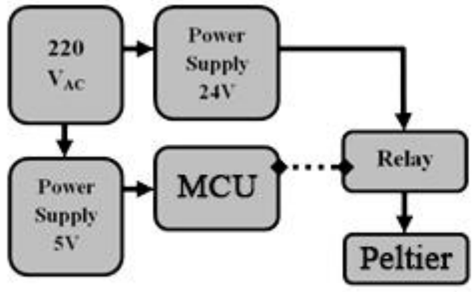

Fig. 7 block diagram of WCG

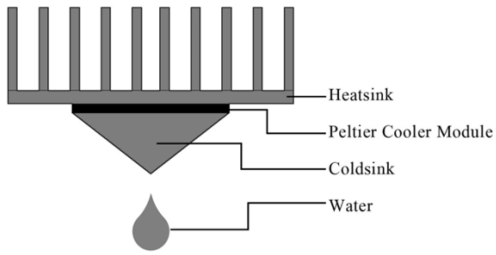

Fig. 8 The coldsink configuration of WCG

3. EXPERIMENT

3.1 Hardware Design

The block diagram shown in Fig 7 provides the guideline of the water condensation generator. There are many components including power supply 5V and 24V, MCU (microcontroller unit), relay and peltier module. The power supply 5V is a power source of MCU and the power supply 24V is a power source of peltier module. There is also relay for ON-OFF power into the peltier module. All processing and the relay action are controlled by MCU.

3.2 Experimental setup

Fig 8 presents the configuration of WCG. The basic element of WCG includes the peltier cooler module, heat sink and cold sink (made from aluminum). From the principle of peltier, when we give the DC voltage to the peltier cooler module, the positive and negative charge carriers in the pellet array absorb heat energy from one substrate surface and release it to the substrate at the opposite side. The side where heat energy is absorbed becomes cold and the opposite side where heat energy is released becomes hot.

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Fig. 9 Photograph of WCG prototype

Table 1 the amount of water are produced in one hour

Relay On (min)	Relay Off (min)	Water (ml/hr.)
1	1	7
2	1	8
3	1	12
4	1	15
5	1	15
6	1	13
7	1	12
8	1	12

4. RESULT AND DISCUSSION

The authors controlled the duty cycle of peltier cooler module. When the relay turns on, the peltier cooler module will be work on. As a result, the condensation process is occurred at the cold sink and, when the relay turns off, the water will flow from the top to the bottom of cold sink by the force of earth gravity. We fix the time of relay off at only 1 minute and set the time of relay on at 1-8 minutes as presented in Table 1.

The results of water condensation generator show the new insight of producing water.

5. CONCLUSION AND FUTUER WORK

The Water Condensation Generator can really generate the water by condensing the vapor around peltier surface. However, the current amount of water is still little which the authors will maximize the results by controlling the duty cycle of peltier cooler module or shape design of the cold sink.

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