Peltier and seebeck efficacy of hot and cold air system for portable O-REF (oven & refrigerator) application

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ABSTRACT – The main motivation in using Peltier Module is due to the uniqueness of producing hot and cold air at the same time besides able to generate electricity using Seebeck Effect. The generating system theoretically can recycle the heat loss to produce additional electricity for other usage. The efficacy of this system tested using two types of experimental using Peltier and Seebeck Effect. Both experimental is conducted using 3 specific volumes; 1) $1000cm^3$; 2) $4000cm^3$; and 3) $9000cm^3$. As a result, temperature for heating and cooling systems achieve around $14 – 56^oC$ while the voltage generated around 12V in 50 minutes.

1. INTRODUCTION

Thermoelectric refrigeration is achieved when a direct current is passed through one or more pairs of n- and p-type of semiconductor materials. Figure 1 is a diagram of a single pair consisting of n- and p-type semiconductor materials. In the cooling mode, direct current is allowed to passes through n and p junction of a semiconductor material. The temperature, denoted as T_C (Cold Temperature) of the interconnecting conductor is decreased while heat is absorbed from the environment. This heat absorption from the environment (cooling) occurs when electrons pass from a low energy level in the p-type material through the interconnecting conductor to a higher energy level in the n-type material. The absorbed heat is transferred through the semiconductor materials through electrons to the other end of the junction, denoted as T_H (Hot Temperature) where the electron are liberated once it return to a lower energy level in the p-type material. This phenomenon is called the Peltier effect [1-3].

A second phenomenon is also important in thermoelectric refrigeration known as Seebeck Effect. When a temperature differential is established between the hot and cold ends of the semiconductor material, a voltage is generated. This voltage is called the Seebeck voltage, and it is directly proportional to the temperature differential. The constant of proportionality is referred to as the Seebeck coefficient.

The Peltier effect is controlled by the Peltier coefficient, defined as the product of Seebeck coefficient of the semiconductor material and the absolute temperature. The Peltier coefficient relates to a cooling effect as current passes through the semiconductor junction n to p, and a heating effect when current passes through p to n junction, as shown in Figure 1. Reversing the direction of the current reverses the temperature of the hot and cold ends [2].
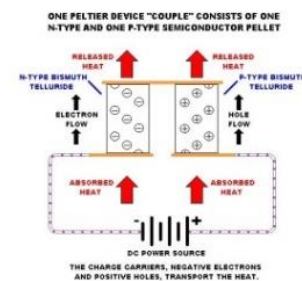

Figure 1 Schematic of thermoelectric module operation for cooling and heating.

2. METHODOLOGY

The Peltier effect is being measured using several volumes which are 1000 cm³, 4000 cm³ and 9000 cm³ by making partition on the area of the product as shown in Figure 2. The Peltier cells inside is cold so small heat sink unit is mounted at the cold side of the Peltier cells to increase the rate of releasing heat outside of unit. Heat sink is simulated using Comsole Multiphysics to study the fin arrangement in order to optimize heat transfer area [4-5]. The blower fan attach to the heat sink has the role to distribute the cold air equally at maximum rate in the container.

Figure 2 Portable O-REF System.

The temperature of the Peltier cell inside is high so small heat sink is mounted on top of the hot side of the Peltier cells to increase absorption rate of heat from the unit. The blower fan attach to the heat sink has the role to distribute the hot air equally at maximum rate within

the container. The other function of the blower fan is to circulate the hot air so that the hot temperature within the within the container remains hot.

By generating the hot and cold temperature, the heat transfer occur in the system can be used for generating current using Seebeck Effect that when the junctions of two different metals are maintained at different temperature, the emf is produced in the circuit. Thermoelectric power generation (TEG) devices typically use special semiconductor materials, which are optimized for the Seebeck Effect.

By referring to Peltier electric generating calculation, the potential electricity generated by the Peltier device can be calculated by,

$$V = \alpha(T_h - T_c) \tag{1}$$

Where

V = Thermoelectric material figure of merit
α = Seebeck coefficient
T_h = Temperature at hot side
T_c = Temperature at cold side

The Seebeck coefficient can be calculated by,

$$\alpha = \frac{\overline{x}V}{\overline{x}T} \tag{2}$$

Where

$\overline{x}V$ = average voltage generated
$\overline{x}T$ = average temperature difference

The magnitudes of voltage generated are affected by the temperature difference 1 °C across the Peltier device, as stated the Seebeck effect. Material with high Seebeck effect is the main factor to increase the efficiency of the Peltier device.

3. RESULTS AND DISCUSSION

Generally, from the result obtained as shown in Figure 3 that the system can achieve about 14°C for cold system and about 56°C for hot system which enables it for operating in both conditions. From the result, it shows that The Peltier devices itself is dominant to hot temperature, apart from this to spreading the hot temperature within the container is faster compare to cold temperature.

For the Seebeck operation, the data used to use the temperature difference from small container generate the Seebeck coefficient, α=302 mV/ °C. Table 1 shows the relationship between temperature differences with Seebeck coefficient.

According to the result, it shows that the calculated and measured voltages are almost the same that makes this system able to generate power in order to recharging back the battery.

4. CONCLUSIONS

In conclusion, Portable OREF System can be used in dual mode operation, heating and cooling also can generate electricity using heat transfer occur in the system. This system achieves minimum temperature 14°C and maximum around 56°C and maximum voltage occur in 50 minutes.
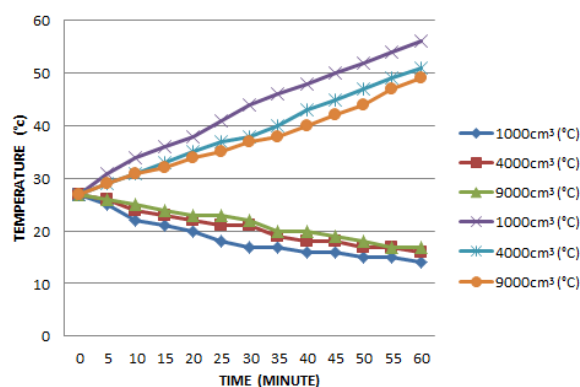

Figure 3 Graph temperature versus time for hot and cold testing in an hour.

Table 1 Result from Seebeck coefficient, α.

Time (min)	$T_{Difference}$ (°C)	$V_{Calculated}$ (V)	$V_{Measured}$ (V)
5	6	1.81	1.67
10	12	3.62	2.84
15	15	4.53	4.16
20	18	5.44	5.37
25	23	6.95	6.08
30	27	8.15	7.59
35	29	8.76	8.36
40	32	9.66	9.76
45	34	10.27	11.24
50	37	11.17	12.24
55	39	11.78	12.76
60	42	12.68	12.76

REFERENCES

[1] S.B. Riffat and X. Ma, "Thermoelectrics: a review of present and potential applications." *Applied Thermal Engineering*, vol. 23(8), pp. 913-935. 2003.

[2] S. Mukhopadhyay, S.P. Datta, et al. "Performance of an off-board test rig for an automotive air conditioning system." *International Journal Of Air-Conditioning And Refrigeration*, vol. 21(03), 2014.

[3] X. Gou, H. Xiao, et al. "Modeling, experimental study and optimization on low-temperature waste heat thermoelectric generator system." *Applied Energy*, vol.87(10), pp. 3131-3136, 2010.

[4] K.A.M. Annuar, F.S. Ismail, M.H. Harun and M.F. M.A. Halim, "Inline pin fin heat sink model and thermal performance analysis for central processing unit," in *Proceedings of Mechanical Engineering Research Day 2015*, 2015, pp. 35-36.

[5] K.A.M. Annuar, M.F.M A. Halim, F.S. Ismail, M. Zahari, S.H. Johari and M.H. Harun, "Thermal analysis of staggered pin fin heat sink for central processing unit" *Australian Journal of Basic and Applied Sciences*, vol.9(19), pp. 68-73, 2015.