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Flow rate analysis experiment on thermoelectric cooling

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Abstract

Currently, common cooling methods are related with refrigerants such as R-134a which are considered not totally environmentally friendly, so thermoelectric cooling had become a solution to the issue as it is a refrigerant free system. Thermoelectric cooling is based on the Peltier Effect takes place in the cooling or heating phase. Thermoelectric cooler module varies in type, some are made in an air to air configuration, and later types proved water cooled system to be more efficient. This experiment is about analyzing the effect of cooling water flow rate towards temperature drop in refrigeration compartment. The apparatus involved an insulated foam box with a water cooled thermoelectric module attached to the side. Water flow was regulated at different rates and temperature recordings were made to compare. The results shows that water flow rate have great effect onto the cooling performance. Further details had shown that there is a threshold of water flow rate which the thermoelectric module would start cooling down. This research is a guideline for other works that require the optimization of thermoelectric cooling system.

Keywords: Flow rate, Thermoelectric cooling, Peltier effect, Water cooling

1. Introduction

As thermoelectric cooling had become one of the method people use to cool down a system, the requirement of optimization is needed to enhance the system's performance. There had been numerous approach made by various researchers after the discovery by Thomas Seebeck and Jean Peltier in 1823 and 1834 respectively towards maximizing the performance of thermoelectric cooling or power generation. In this research, we will determine the effect of cooling water flow rate towards temperature drop scheme.

As there are effort towards optimizing thermoelectric module for cooling and heating, this research is focused on the flow rate study of thermoelectric module. Longer time interval would be involved in order for the cooling trends to be investigated. The study could reveal more about thermoelectric cooling optimization as the module used is a water cooled system. In 2010 Gurel A. had experimented the variation of thermoelectric heat removal with different flow rates. He had found that the rate of heat removal will increase as more water had been flown into the system [1]. In 2012 Chen W. had experimented about thermoelectric power generation, although the work is not directly related to cooling methods, but reports had been made toward water flow rate. It concluded that constant flow rate of water had been the optimum solution towards power consumption [2]. Also in the same year Git H. had conducted a preliminary study of thermoelectric heating and cooling, he developed a trend of cooling and heating with water flow rate variation. It showed that rate of water flow did not significantly have effect on cooling performance [3]. Other researchers had also made review and design evaluations regarding to thermoelectric cooler [4-5].

2. Materials and methods

2.1. Materials used and schematics

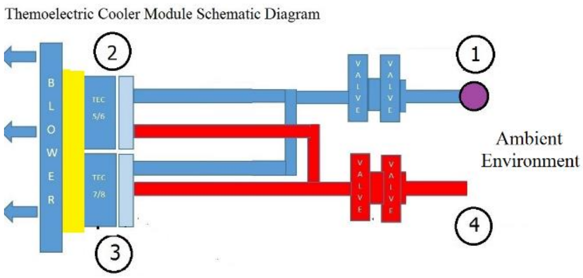

Figure 1 Schematic of the cooling module

Figure 1 had displayed the system configuration where the thermoelectric modules are placed through a foam box to replicate a closed and insulated space. Water will be pumped from a tap through a flow meter which would enter the operating module at point 1, as it will be travelling through

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Table 1 Temperature Data for Different Flow Rates

Temperature (°C)	Flow Rate (L/Hr)					
	100	**200**	**300**	**400**	**500**	**600**
Ambient Temperature	28.1	28.2	28.1	28.1	28.2	28.3
Interior Temperature	27.8	28.7	27.8	27.9	27.7	27.6
Inlet Water Temperature	27.6	27.5	27.5	27.5	27.4	27.4

Table 2 Equipment Specification

Item	Quantity – Specification
Thermoelectric Dimension TEC-12726 (2)	40mm x 40mm
Thermoelectric Dimension TEC-12710 (2)	50mm x 50mm
Total Output TEC-12726 Combined	480 Watts
Total Output TEC-12710 Combined	240 Watts
Hose Diameter	¾ Inches
Flow Rate Meter	Micronics Porta flow 300
Box Volume	40 Liters
Electricity Source	220V Outlet
Thermoelectric Power Supply	1100 W/ 96 A MAX

the piping and enters the water box for the heat transfer to occur at point 2 which is made due to the thermoelectric plates at point 3. Heat will be removed from the sink to the environment at point 4. Figure 2 and 3 displayed the experimental apparatus used.

Figure 2 Foam box for data collection with infrared gun installed for temperature measurements within the space

Figure 3 Thermoelectric module with water cooling system shown

2.2 Equations involved in work

Calculating for the power supply

$$P = I V \quad (1)$$

Where P = Power in Watts, I = Current in Ampere, V = Potential Difference in Volts Flow rate equation

$$Q = A V \quad (2)$$

Where Q = Volumetric Flow Rate, A= Cross sectional area, V = Flow Velocity.

As displayed in Table 1 and 2, it is seen that the experiment had been conducted in a small volume container to accelerate the cooling time in order to monitor difference in temperature easily. The flow rate meter ensures constant water flow during the measurement phase. Six trials had been run with different water flow rates. The discarded water are directed to be removed from the system.

3. Results and discussion

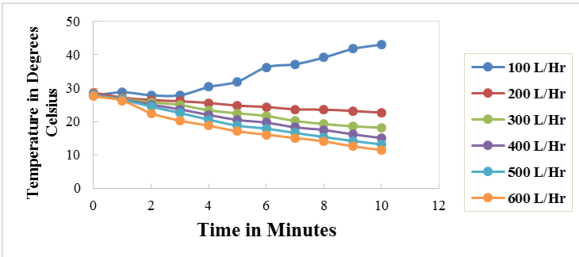

Figure 4 Temperature drop over time intervals with different water flow rate with no load

Figure 4 had displayed the results of the six trials made without any item inside the refrigeration compartment or having no load. The results resembled together between trial numbers 2 to 5. The first trial showed different pattern which proves that if the water flow rate is too low, the system will not work and the generated heat are reversed out of the module through the cold side of the thermoelectric plate. The system started to operate at a flow rate of approximately 200 liters per hour, displaying a cooling trend. In the last trial, the flow rate was increased to 600 liters per hour which is the maximum flow rate the system could take before leakage occur. Slightly more aggressive cooling trend had been found in the last trial as there are sudden temperature drop shown between minutes 1 to 2 when compared to other trials.

The experiment still have some further suggestion towards additional research. The system itself used a 3D printed water box which could withstand the flow of 600 liters per liter without leaking. The experiment could be pushed further if there are better design of the water box. The thermoelectric plate itself could also be improved by selecting a higher quality model which could boast more performance and should cool the system down faster and more efficiently.

4. Conclusion

This research had showed the different cooling trends of thermoelectric module upon different flow rate. It had been found that there is a threshold of water flow rate that the system could not operate under the point, and there should be a point where the flow rate cannot help extract more heat out of the system due to heat transfer properties. In actual application, the system should be able to withstand as much pressure as possible with the combination with good ventilation system as it is a closed system. The results are a guideline for other researchers in the field of thermoelectric research that are interested in making a water cooling system application.

5. Acknowledgements

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6. References

[1] Gurel AE, Ercan M. Cooling Performance Effects Of Thermoelectric Module Of Variable Water Flow Rates. Engineering Sciences 2010;5(4):573-578.

[2] Chen WH, Liao CY, Hung CI, Huang WL. Experimental study on thermoelectric modules for power generation at various operating conditions. Energy 2012;45(1):887-881.

[3] Git HM, Seng OK, Gilani S, Aris M. Preliminary Study of Thermoelectric System for Simultaneous Heating and Cooling. Asian Journal of Scientific Research 2013;6(3):528-536.

[4] Huang BJ, Chin CJ, Duang CL. A Design Method of Thermoelectric Cooler. International Journal of Refrigeration 2000;23(3):208-218.

[5] Riffat SB, Ma X. Thermoelectrics: A Review of Present and Potential Application. Applied Thermal Engineering; 2003;23(8):913-935.