Performance of TEC Cooler Box using Water Cooling and Coolant

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Abstract: Research on cooler boxes using thermoelectrics has been widely carried out because of the advantages of these coolers which are easy to carry and environmentally friendly. The cooler box in this study measures 750 x 400 x 400 mm, using two thermoelectrics measuring 4 x 4 mm. The cooler box material is polyurethane, aluminum foil and plywood on the outside. The hot side of this cooler does not use fins and fans, but utilizes water cooling and coolant. Data collection is carried out to find the performance of the cooler box. The measurement data is the thermoelectric cold and hot side temperature data, the inside of the cooler box, the load and the environment. The performance of the water cooler and coolant will be compared to the performance of the cooler with air cooling. The room temperature that can be achieved by the cooler when using water and coolant as a cooler is 21.5°C and 19.9°C, respectively. And their respective performances are 0.41 and 0.31 for water and coolant.

1 INTRODUCTION

Research on thermoelectric coolers (TECs) is growing rapidly to date, because TECs are a promising future in other refrigeration applications. TEC is the most desirable alternative cooling technology and is possible to be developed because it is able to control temperature precisely in various applications and is able to overcome problems in size, weight, performance, noise and environment. TEC has the advantages of small size, silent operation, limited maintenance requirements, long life, no use of flammable or toxic refrigerants, possibility of use in various positions and flexibility of use through optimized control (Patel, 2016), (Atta, 2018) and (Enescu, 2018).

TEC applications have been applied in various fields such as electronic cooling, laser diodes, superconducting systems, food industry, medical equipment, military, biotechnology, telecommunications and HVAC for specific targets.

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For cooling small volumes of applications TEC is an alternative, where cooling requirements are not too high and low COP is not a real disadvantage.

Commonly, the hot side of thermoelectric cooled by fan, in this study the thermoelectric hot side cooled by water and coolant. The purpose of this research is to explain the design of thermoelectric based cooler box, to get thermal performance and effectiveness.

2 METHODOLOGY

2.1 Cooler Box Construction

This cooler box has dimensions 750 x 400 x 400 mm. Cooling box material consists of polyurethane coated aluminum foil and plywood. The thermoelectric used is TEC1 12706 with a size of 4 x 4 mm as many as 2 pieces, with specifications as shown in Figure 1 (Hebei 2010).

The heat dissipation process uses forced convection on the cold side of TEC, aluminum fins and fans and water blocks to cool the hot side of TEC. The water block will be filled with water for the first test and then filled with coolant. The schematic

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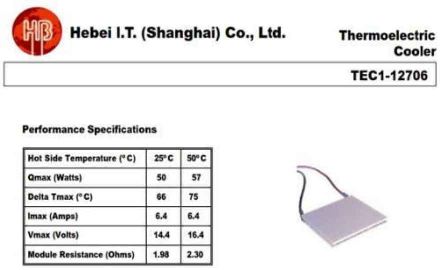
diagram of the cooler box test can be seen in Figure 2.
In this test the TEC working voltage and current are measured using a multimeter. The temperature of the cooler and the room was measured with the NI 9714 data acquisition instrument and the NI 9213 module.


Hebei I.T. (Shanghai) Co., Ltd.
Thermoelectric Cooler
TEC1-12706

Performance Specifications

Hot Side Temperature (°C)	25°C	50°C
Qmax (Watts)	50	57
Delta Tmax (°C)	66	75
Imax (Amps)	6.4	6.4
Vmax (Volts)	14.4	16.4
Module Resistance (Ohms)	1.98	2.30

Figure 1: Specification of TEC1-12706.

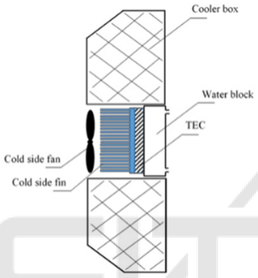


Figure 2: Cooler box test schematic diagram.

Based on the purpose of this cooler box testing, the first test was carried out in two test groups, namely testing the cooler with water cooling and coolant. The working voltage and current provided are the same, namely 12V and 6A.

2.2 COP Analyzing

2.2.1 TEC

TEC performance can be analyzed by finding the amount of heat absorbed on the cold side of the thermoelectric (Qc) and the amount of heat dissipated on the hot side of the thermoelectric. The amount of heat absorbed and the amount of heat dissipated (Qh), is expressed by the following formulas (Jugsujinda,2011):

$$Q_c = \alpha I T_c - 0.5 I^2 R - K_t (T_h - T_c) \quad (1)$$

$$Q_h = \alpha I T_h + 0.5 I^2 R - K_t (T_h - T_c) \quad (2)$$

Where α is Seebeck coefficient (VK^{-1}), Tc and Th are temperature of cold side and hot side of thermoelectric, respectively. By comparing the amount of heat absorbed to the difference between the amount of heat wasted and the amount of heat absorbed, TEC performance is expressed as follows (Zhao, 2014):

$$COP = \frac{Q_c}{Q_h - Q_c} = \frac{Q_c}{\alpha I (T_h - T_c) + I^2 R} = \frac{Q_c}{P} \quad (3)$$

Based on the TEC specifications, the Seebeck coefficient (α) = 0.0425 VK^{-1} and the thermal conductivity of the thermoelectric material (K_t) = 0.495 $Wm^{-1}K^{-1}$.

2.2.2 COP of Cooler Box

In this test the total power consumption of the cooler box must take into account the power consumption of the cold side fan, because the power consumption of the cooling side fan will turn into hot. This can be used as the main basis for determining the optimal operating conditions of this cooler. The calculation is as follows (Cengel, 1998) and (Mirmanto, 2009):

$$Q_c' = Q_l + Q_t + W_f \quad (4)$$

$$Q_l = m\, c_p\, \Delta T \quad (5)$$

$$Q_t = U\, A\, \Delta T \quad (6)$$

$$P' = P_c + P_f \quad (7)$$

where Q_l is heat load, Q_t is transmisi load, A is the total heat transfer surface of cooler box, U is the overall heat transfer coefficient. The overall heat transfer coefficient is calculated below:

$$U = \frac{1}{\frac{1}{h_{int}} + \frac{1}{k_{wall}} + \frac{1}{h_{ext}}} \quad (8)$$

3 RESULT AND DISCUSSION

The cooler box temperature phenomenon is shown in Figures 3 and 4. Temperature denoted by T_1-T_6, T_c, T_h, T_L, T_E represent the temperature of cooler box, thermoelectric cold side, thermoelectric hot side, cooled load, and environment, respectively.

The T_L, decreases from 0 to 355s, and then it gets nearly constant. The same phenomenon also found by previous researchers that used a fan as a thermoelectric hot side cooler (Jugsujinda, 2011) and (Mirmanto, 2009).

Based on Figure 5, the COP obtained by the cooler for cooling the hot side of the thermoelectric using water and coolant are 0.38 and 0.29, respectively. The COP obtained is still within the standard COP thermoelectric.

After one hour, cooling water on the hot side of the thermoelectric obtained T_c, T_h, T_L and COP of 26 ºC, 31 ºC and 25.4 ºC and 0.49, respectively. Cooling with coolant on the hot side of the thermoelectric obtained T_c, T_h, T_L and COP of 25.5 ºC, 31 ºC and 25.4 ºC and 0.48, respectively.

Finally, obtained COP 0.38 with water cooling when T_c, T_h, and T_L are 22.1 ºC, 39.3 ºC and 21.5 ºC, respectively. The COP of cooling with coolant on the hot side of the thermoelectric is 0.29 with T_c, T_h, T_L and COP of 16.9 ºC, 44 ºC and 19.9 ºC, respectively.

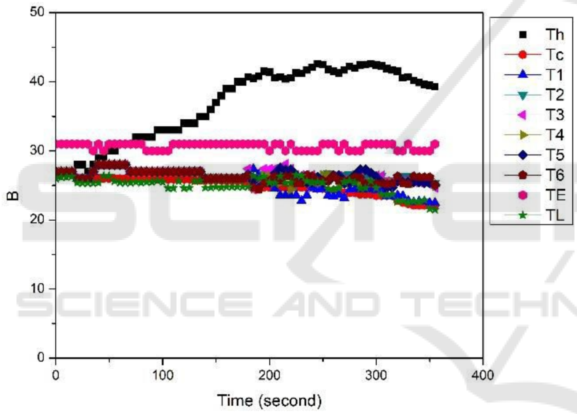


Figure 3: Temperature versus time trend with water cooling.

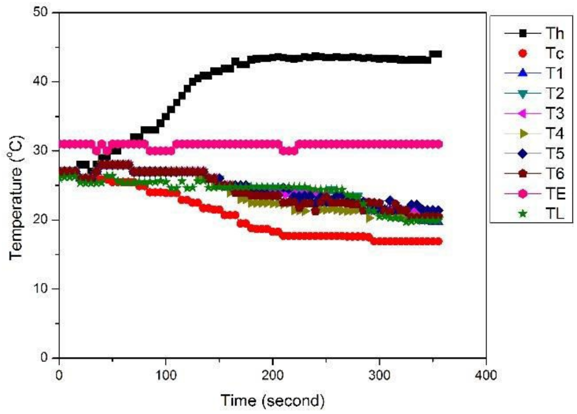


Figure 4: Temperature versus time trend with coolant.

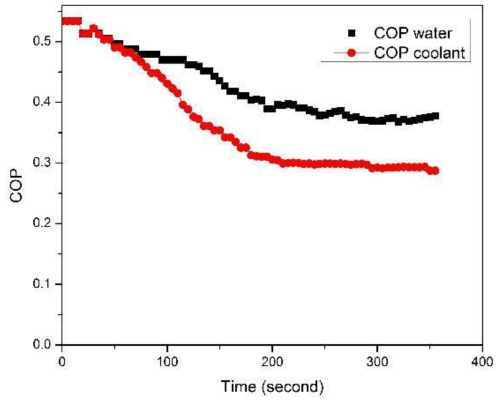


Figure 5: COP for cooling by water and coolant.

4 CONCLUSIONS

TEC cooling with water and coolant has similar temperature trend as cooling using fan. The cooling capacity decreases with the time. The conduction heat transfer rate increases with the time. The total heat transfer rate (Q) decreases with the observation time. The COP of the TEC cooler box is still within the allowed COP TEC, which is 0.3 It is necessary to regulate the flow of water and coolant in order to get better cooling.

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APPENDIX

Q_c = heat absorbed on the cold side
Q_h = heat dissipated on the hot side
Tc = temperature of cold side thermoelectric
Th = temperature of hot side thermoelectric