Analyzing of Thermoelectric Refrigerator Performance

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Abstract

The refrigeration system of thermoelectric refrigerator (TER; 25 × 25 × 35 cm³) was fabricated by using a thermoelectric cooler (TEC; 4 × 4 cm²) and applied electrical power of 40 W. The TER has no cooling fan for the coldness circulates in the refrigerator. The temperature of TER was measured at ten points to check the cooling system. The current, differential temperature, time, and coefficient of performance (COP) were analyzed. TEC cold plate temperature (Tc) was decreased from 30 ºC to –4.2 ºC for 1 hr and continuously decreasing to –7.4 ºC for 24 hrs and 50 ºC for hot plate temperature (Th). The TER temperature was decreased from 30 ºC to 20 ºC in 1 hr and slowly decreasing temperature for 24 hrs. The maximum COP of TEC and TER were 3.0 and 0.65, respectively.

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Keywords: Thermoelectric refrigerator; Peltier effect; Cooling system

1. Introduction

Recently, the global increasing demand for refrigeration, e.g. air-conditioning, food preservation, vaccine storages, medical services, and cooling of electronic devices, led to production of more electricity and consequently more release of CO2 all over the world [1] which it is contributing factor of global warming on climate change. TER is new alternative because it can convert waste electricity into useful cooling, is expected to play an important role in meeting today’s energy challenges [2]. Therefore, TER are greatly needed [3], particularly for developing countries where long life and low maintenance are needed [4]-[7]. TER are applied of TEC with base on Peltier effect for removing heat by DC current applied across two dissimilar materials causes a temperature differential [8]. Since TEC can be analyzed by Joule heat, which is called heat rejection (Qh), from TEC hot side larger than the heat absorption (Qc), into TEC cold side. The general forms of heat absorption and heat rejection are presented as below.

\[ Q_c = \alpha IT_c - 0.5I^2R - \kappa (T_h - T_c) \]
\[ Q_h = \alpha I I_{th} + 0.5 I^2 R - \kappa_c (T_h - T_c) \]  

(2)

Where \( \alpha \) is the Seebeck coefficient (VK\(^{-1}\)), \( I \) is the electric current, \( T_c \) is the TEC cold side temperature, \( T_h \) is the TEC hot side temperature, \( R \) is the electrical resistant of the TEC material (\( \Omega \)) [9], and \( \kappa_c \) is the thermoelectric element thermal conductivity (Wm\(^{-1}\)K\(^{-1}\)) [10]. The COP of TEC and TER measurement are described with the following equations [11].

\[ COP = \frac{Q_c}{Q_h - Q_c} = \frac{T_c}{T_h - T_c} \]  

(3)

In this work, we are measurement for finding COP of TEC and TER from fabricated TER.

2. Methodology

2.1 Analyzing COP of TEC

The COP of TEC (TEC1-12705) is analyzed from measurement values compose of Volt, Amp and temperature etc, which TEC has performance specifications as shows in Fig. 1 [9]. The schematic for electric measurement is shows in Fig. 2. The \( Q_c \) of TEC is calculated by Eq. (1), where \( \alpha \) is 0.04224 VK\(^{-1}\), \( I \) is 1-3 A, \( R \) is 3.25 \( \Omega \), and \( \kappa_c \) is 0.495 Wm\(^{-1}\)K\(^{-1}\) [10].

![Fig. 1 The data performance specifications of TEC1-12075 [9]](image)

![Fig. 2 The schematic for electric values measuring](image)

2.2 Analyzing COP of TER

The most common type of TE application is a TEC designed to cool air in TER. The TER system in this research is fabricated by using a TEC1-12705, and without cooling fan in TER. This TER has dimension of 25 \( \times \) 25 \( \times \) 35 cm\(^3\) is designed as shows in Fig. 3(a). A TEC is mounted between cold side sink and a larger sink on the hot side of the
cooling system. This creates a cold surface on the substrate where heat is absorbed and a hot surface where heat is released similar to a heat pump. The circulating fan on the hot side then circulates ambient air between the sink's fins to absorb some of the collected heat. The heat dissipated on the hot side not only includes what is pumped from the box, but also the heat produced within the TEC itself. A rectangular fin heat exchanger in Fig. 3 (b) by used on the hot side of TEC was made of aluminium. The position of thermo couples for measure temperature in box is shown in Fig. 3 (b-d), where \( T_1 \) is fan before the cold heat sink temperature, \( T_2 \) is the temperature at midpoint of the inside wall of refrigerator door, \( T_3 \) is the temperature at midpoint of the right inside wall, \( T_4 \) is the temperature at midpoint of the left inside wall, \( T_5 \) is the temperature at midpoint of the lower inside wall, \( T_6 \) is the temperature at midpoint of the upper inside wall, \( T_7 \) is the temperature at midpoint of refrigerator box, \( T_8 \) is the ambient temperature, \( T_c \) is the TEC cold side temperature, and \( T_h \) is the TEC hot side temperature.

![Image](image1.png)

**Fig. 3 (a)** Outside and inside walls of the TER are made from stainless, (b, c and d) the position of thermo couples for measure temperature which 1-8 are \( T_1 \) to \( T_8 \), respectively.

### 3. Results and Discussion

#### 3.1 COP of TEC

The thermoelectric cooling was used electric power of 40 W. The TER without cooling fan for the coldness circulates in a refrigerator. The relationship of temperature and time were measured for finding temperature increases rate, difference temperature and calculation COP of TER. It results show that, the temperature inside refrigerator was decreased with increasing time. The inside temperature of TER was decreased rate of 1.1 °C/min in the time interval 0–20 minutes, the minimum temperature was -1.1 °C, COP about 0.6 for 2 hour as shown in Fig. 4.
Fig. 4 The relationship of (a) time and temperature and (b) current and $P$, $Q_c$, and COP, (c) the ice when minimum temperature -1.1 °C.

3.2 COP of TER

The relationship of time and temperatures of TER which was used the electrical power of 20, 30 and 40 W was shown in Fig. 5. Figure 5 (a-c) were shown the temperatures of $T_1$-$T_7$, cold side ($T_c$), and hot side ($T_h$) of electrical power 20, 30 and 40 W, and Fig. 5 (d-f) were showed the difference temperatures cold side ($T_c$), and hot side ($T_h$) of electrical power 20, 30 and 40 W, respectively.

Fig. 5 The relationship of time and temperatures of $T_1$ to $T_7$, $T_c$, and $T_h$ and difference temperature $T_h - T_c$ of (a-b), (c-d) and (e-f) are electrical power 20, 30 and 40 W, respectively.
The experimental results show that for an electrical power 20.0 W (voltage = 8 V, current = 2.5 A) input to the TEC, the heat (Q_h) transferred from a TEC from the base to the fin tip. Consequently, the temperature of the fin tip was thus gradually increased. The ventilation fan dissipates the heat to surrounding air. The fin temperature was rather constant when 30 minutes elapsed. T_h was approaching to 38 °C. The cold side temperature of the fin tip decreased gradually. The fin temperature was rather constant when 28 minutes elapsed. T_c was approaching to −2.5 °C, the temperature difference between hot side and cold side of TEC (ΔT = T_h−T_c) was equal to 40.5 °C. The ambient temperature was 27 °C. The temperature profiles of cold heat sink (T_1), the inside wall of TER (T_2 to T_6) at each wall, the midpoint of refrigerator box (T_7), TEC cold side, and TEC hot side. Experimental results show that for an electrical power 20.0 W (voltage = 8 V, current = 2.5 A) input to the TEC, the ambient temperature (T_8) was 27 °C. The fin temperature was rather constant when 30 minutes elapsed. T_h was approaching to 38 °C.

The temperature at midpoint of refrigerator box T_7 was 26.4 °C. The corresponding COP of refrigerator was about 0.26. Whenever changing electrical power from 20.0 W to 30.9 W (voltage = 10.3 V, current = 3.0 A) input to the TEC, the fin temperature was rather constant when 15 minutes elapsed. T_h and T_c were approaching to 45 °C and −3.5 °C respectively. The corresponding COP of TEC and COP of TER were about 6.57 and 0.21 respectively. Whenever changing electrical power from 30.9 W to 40.46 W (voltage = 11.56 V, current = 3.5 A) input to the TEC, the fin temperature was rather constant when 12 minutes elapsed. T_h and T_c were approaching to 50 °C and −4.2 °C respectively. The corresponding COP of TEC and COP of TER were about 6.05 and 0.22 respectively.

![COP of TEC profiles versus time.](image)

4. Conclusion

The TEC cold plate temperature inside TER was using the electric current of 3.5 A and then decreased temperature from 30 °C to −4.2 °C for 1 hr and continuous to −7.4 °C for 24 hrs. The TER was decreased from 30 °C to 20 °C for 1 hr and slowly decreasing temperature for 24 hrs. The maximum COP of TEC and TER were 3.0 and 0.65, respectively.

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