Performance Analysis of Electric Coolers TEC1-12706 and TEC1-12715 with Heatsinks at Semi-conductor Cooler Boxes

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Abstract. This cooler box is designed to assist humans in getting cold drinks when traveling long distances by car. Semi-conductor cooler box components consist of TEC1-12706 and TEC1-12715, styrofoam box with a size of 53 × 31 × 43 cm, copper and aluminum processor heatsinks, fans with 12V and 1A voltage, acrylic, and retaining bolts. The lowest temperature that can be achieved by TEC1-12706 and TEC1-12715 is 23.7 °C which is reached in 60 min. The efficiency possessed by TEC with a heatsink 77.8%. Maintenance for the semi-conductor cooler box is very easy by not using a voltage that exceeds 12 V and it is not expected to disassemble the cooling component circuit consisting of the heatsink and TEC.

Keywords: Thermo Electric Cooler · Heatsinks · Semiconductor · Performance

1 Introduction

The rapid development of technology and the Indonesian economy has an impact on the activities or habits of the Indonesian people are also developing. People tend to have the habit of frequently traveling somewhere, both near and far. When traveling near or far, humans will feel thirsty and need drinks, this is because the amount of water contained in the human body is 70% and water is the most abundant element in the human body.

Water has several characteristics based on temperature, namely boiling water (temperature 100 °C), hot hot water (temperature 60–80 °C), warm water (temperature 40–50 °C), cold water (temperature 28–32 °C), and water. Frozen (temperature 0–48 °C). Hot water and warm water are very suitable for humans to drink during the rainy season or cold weather, while cold water is very suitable for humans to drink during the dry season. However, most people prefer cold water to hot water and warm water, because cold water or cold drinks can accelerate human thirst and dehydration. To get cold water or drinks, humans need cooling devices that are able to cool drinks, such as refrigerators, conventional cooler boxes, and semi-conductor thermo electric cooler boxes.

The refrigerator can create and maintain a cool temperature for the drink. If humans carry a refrigerator when traveling near or far, it is very inefficient because the refrigerator has a large construction and requires quite a lot of electricity. This electric current cannot

H. P. Agustin et al. (Eds.): IJCSE 2022, AER 218, pp. 281–292, 2022.
https://doi.org/10.2991/978-94-6463-100-5_29

be met when we are on the way. In addition, the refrigerator also needs refrigerant to produce cold temperatures. These refrigerants can damage the ozone layer leading to global warming or global warming that is currently rampant.

In addition to the refrigerator, there is a conventional cooler box that can be the first alternative to get a cold drink if there is no refrigerator. Conventional cooling boxes are smaller than refrigerators and do not require electricity. Conventional cooling boxes can maintain low temperatures in cold drinks for several hours. However, conventional cooling boxes have the disadvantage of requiring the help of ice cubes to keep the drink cool. After the ice cubes melt, a few hours later the drink will not cool again. Therefore, people tend to find it difficult to carry a conventional cooling box because it is considered too space-consuming, heavy and ineffective. Semi-conductor thermo electric cooler box is the second right alternative as a replacement for conventional refrigerators and cooler boxes.

Thermoelectric cooling is an interesting technology to achieve active thermal management of electronic devices, integrated circuits, and micro motor mechanisms [1]. Such cooling systems are designed using semi-conductor materials operating under the Peltier effect [2], in addition Peltier effect is also used in the design and manufacture of isothermal micro calorimeters and PC processors [3, 4], heat flow compensation and thermal analysis [5]. Thermo electric cooler has a small and lightweight design that makes this tool can be carried anywhere this can be supplied with electricity from a car cigarette lighter, so that tool users do not have to worry about having trouble getting cold drinks when traveling long distances by car. On the thermoelectric cooler the heat flow is absorbed from the cold side of the TEC and transported to the hot side depending on the coefficient of the TEC. In practice, there are two effects namely Joule heat and conducted heat, preventing ideal conditions in real applications [6–9].

The previous research conducted by Permana (2017) was to design a semi-conductor cooling box that uses TEC1-12706 with water cooling. This semi-conductor cooling box can reach the lowest temperature of 11 °C reached in 30.2 min. The heat transfer rate generated by a semi-conductor cooling box with water cooling is greater than without the use of a water cooler [10]. However, this semi-conductor cooler box still has a complicated design and its performance is not optimal, so consumers are less interested in cooling semi-conductor boxes with water cooling. The semi-conductor cooling box designed using TEC1-12706 and TEC1-12715 with a heatsink is different from the semi-conductor cooling box that uses TEC1-12706 with water cooling. According to research by [11] Eight UltraTECs can produce cooling up to 220 W with a COP of 0.46 under an input current of 4.8 A for each module. Thermo-economic analysis shows that systems with PV panels can compete with equivalent systems without PV panels when PV costs drop to or lower than £1.25 per Watt [11]. Another important parameter to consider to improve the performance of thermoelectric devices is the electric thermo-foot geometry [12]. Some researchers [13] and [14] have studied the traditional rect- foot thermoelectric angle and compared the results using trapezoidal saccharine. It has been observed that electrical power and efficiency in TEG have increased when trapezoidal thermoelecstric legs are considered and the system is two-stage. Similarly, TEC can achieve lower temperatures and higher COP when trap-leg thermoelectric zoidal is used, or the area-to-length relationship of juvenile thermoelements is considered [15][16].

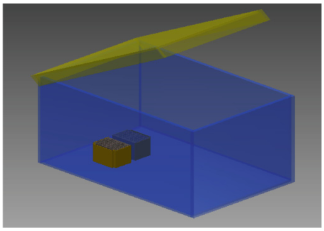

Fig. 1. Design of Semi-conductor Cooler Box

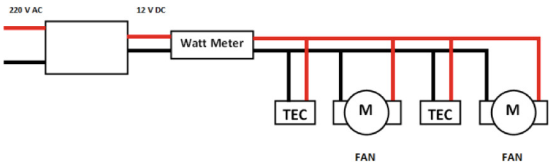

Fig. 2. Semi-conductor Cooler Box Electrical Circuit

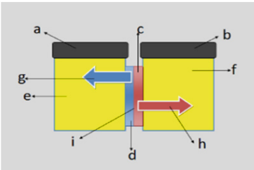

Fig. 3. Cooling System Components

2 Method

Semi-Conductor Cooler Box Electrical Design and Assembly In planning the mechanism of this semi-conductor cooler box concept, several main components are needed. This machine is made of several main components, namely the cooling unit and the body unit. The design drawing of this semi-conductor cooler box is as shown Fig. 1 and Fig. 2.

At this semi-conductor cooler box, an electric cooler is used in the form of TEC series TEC1-12706 TEC1-12715. All components are regulated by one thermo control which functions to regulate the entire performance of the tool components that use temperature as the setting variable main Components of Semi-Conductor Cooler Box. The main component parts of the semi-conductor cooler box are as follows:

1. Refrigeration Unit

   The Cooling Unit functions as a component that makes the cooler box cool. The Components of the Pending Unit consist of nine item as shown Fig. 3.

   Description of the cooling unit as on Fig. 3 are;

   a. Cool fan
   b. Hot fans

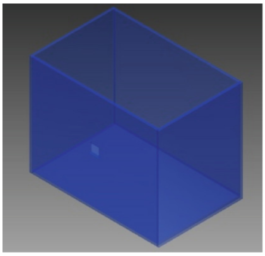

Fig. 4. Body Cooler Box and Cooler Box Cover

c. TEC1-12706
d. TEC1-12715
e. Copper cold side heatsink
f. Copper hot side heatsink
g. Cold transfer to heatsink
h. Heat transfer to heatsink
i. Liquid thermal paste

2. Body Unit

This unit body serves as a forum for research or learning. The unit body is made transparent (see-through) for easy viewing from the outside. The unit body material is made of acrylic measuring 57 × 37 × 45 cm. This acrylic material was chosen because it has a low thermal conductivity value of 0.19 W/mK, therefore the unit body can withstand cold better than the unit body made of glass. To determine the dimensions of the cooler box, the size according to the size on the market is used, because that size is the most effective measure. The unit body consists of the body and the cooler box lid. The 3D images and dimensions of the unit body as shown Fig. 4.

The way the Semi-conductor Cooler Box works is as follows:

1. Put the drink to be cooled into the cooler box and close it again.
2. Connect the power supply to a power source.
3. Set the temperature with a thermo control of
4. Turn on the power supply by pressing the switch, the TEC, Volt indicator and fan will light up. Then TEC will react on both sides.
5. Fans on the hot and cold sides turn on so that hot and cold transfer occurs on the heatsink.

3 Result and Discussion

3.1 Results of Semi-conductor Cooler Box Design Unit

In the design of this semi-conductor cooler box, there are two different Thermo-Electric Coolers (TEC) which function to cool the heatsink in the cooling system of the semi-conductor cooler box. In addition, in the design of this semi-conductor cooler box, there

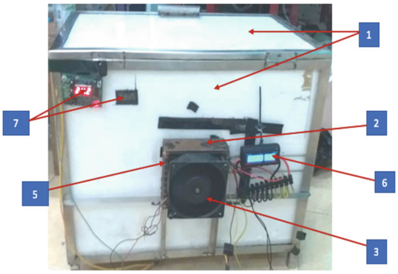

Fig. 5. Semi-Conductor Cooler Box with Heatsink

are also two different heatsinks, namely a heatsink made of copper (on the outside of the box) and a heatsink made of aluminum (on the inside of the box) as shown Fig. 5.

Here are the components of the Semi-Conductor Cooler Box:

1. Acrylic
2. Heatsink
3. Fan
4. Retaining Bolt
5. Thermo-Electric Cooler (TEC)
6. Volt Indicator
7. Thermometer

3.2 Testing the Conductor Heat Transfer Rate in the Cooler Box Cooling System

The test was carried out for 1 h and the temperature was recorded in the cooler box every 10 min. The timing is 1 h because that time corresponds to the time required for TEC to reach the lowest temperature according to TEC specifications. The initial temperature in the cooler box corresponds to the room temperature in general. The first heatsink used has dimensions of 4 × 8 × 1 cm and is made of copper material which has a thermal conductivity coefficient of 375 w/mK. The second heatsink used has dimensions and is made of aluminum which has a thermal conductivity coefficient of 205 w/mK. The following are the results of measurements that have been carried out on the heatsink as shown Table 1.

From the results of the measurement of the heat transfer rate above, the data obtained are the initial temperature of the semi-conductor cooler box of 32 °C at an electric voltage of 11.05 W and an electric current of 8.76 A. In the first 10 min, the temperature of the semi-conductor cooler box experienced a decrease of 5.4 °C so that the temperature changes to 26.6 °C. As in Fig. 5, in the next 10 min, the temperature of the cooler box semi-conductor decreases so that the temperature changes to 25.4 °C.

During 30 min of testing on the cooler box semi-conductor, the electric current of the cooler box decreased to 8.75 A and the final temperature decreased to 24.9 °C. In the next 10 min until the last 10 min, the final temperature drops little by little and the cooler box electric current remains stable at 8.75 A. In the last 10 min, the final temperature changes to 23.7 °C so that for 60 min of testing on the cooler it can be concluded that the semi-conductor cooler box has the coldest temperature of 23.7 °C.

Table 1. Test Results on Semi-Conductor Cooler Box

Time (minute)	T_0 (Start)	T_1 (Finish)	V (Voltage)	I (Electric Current)
10	32 °C	26,6 °C	11,05 W	8,76 A
20	32 °C	25,4 °C	11,05 W	8,76 A
30	32 °C	24,9 °C	11,05 W	8,75 A
40	32 °C	24,7 °C	11,05 W	8,75 A
50	32 °C	24,4 °C	11,05 W	8,75 A
60	32 °C	23,7 °C	11,05 W	8,75 A

These data can be used to calculate the conduction heat transfer rate based on the following equation:

$$Q = -kA \ dT/dx$$

Information: Q = Heat transfer rate (W) k = Thermal conductivity (W/mK) A = Surface area (cm2) dT = Temperature difference (°K) dx = Surface thickness (cm) From the measurements that have been made and the most recent data used to calculate the conduction heat transfer rate, because it is the most optimal performance of TEC and the following data are obtained:

1. Value of heat transfer rate (Q) at a time of 10 min with a temperature difference 32–26,6 °C = 5,4 °C:
   K = 205 w/mK
   A = 32 cm^2 = 0,32 m^2
   dT = 5,4 °C = 278,55 ˚K
   dX = 1 cm = 0,01 m
   Answer:
   Q = -kA dT/dx
   Q = -205 w/mK × 0,32 m^2 (278,55 ˚K /0,01 m)
   Q = 1.827.288 J = 1.827,29 kJ
   So, value of heat transfer rate (Q) at a time of 10 min with a temperature difference 5,4 °C = 1.827,29 kJ.
2. Value of heat transfer rate (Q) at a time of 20 min with a temperature difference 32-25,4 °C = 6,6 °C:
   K = 205 w/mK
   A = 32 cm = 0,32 m
   dT = 6,6 °C = 279,75˚K
   dX = 1 cm = 0,01 m
   Answer:
   Q = -kA dT/dx
   Q = -205 w/mK × 0,32 m^2 (279,75˚K /0,01 m)
   Q = 1.835.160 J = 1.835,16 kJ

So value of heat transfer rate (Q) at a time of 20 min with a temperature difference 6,6 °C = 1.835,16 kJ.

3. Value of heat transfer rate (Q) at a time of 30 min with a temperature difference 32-24,9 °C = 7,1 °C:
   K = 205 w/mK
   A = 32 cm^2 = 0,32 m^2
   dT = 7,1 °C = 280,25˚K
   dX = 1 cm = 0,01 m
   Answer:
   Q = -kA dT/dx
   Q = -205 w/mK × 0,32 m^2 (280,25˚K /0,01 m)
   Q = 1.838.440J = 1.838,44kJ
   So, value of heat transfer rate (Q) at a time of 30 min with a temperature difference 7,1 °C = 1.838,44kJ.
4. Value of heat transfer rate (Q) at a time of 40 min with a temperature difference 32-24,7 °C = 7,3 °C:
   K = 205 w/mK
   A = 32 cm^2 = 0,32 m^2
   dT = 7,3 °C = 280,45˚K
   dX = 1 cm = 0,01 m
   Answer:
   Q = -kA dT/dx
   Q = -205 w/mK × 0,32 m^2 (280,45˚K /0,01 m)
   Q = 1.839.752J = 1.839,75kJ
   So, value of heat transfer rate (Q) at a time of 40 min with a temperature difference 7,3 °C = 1.839,75 kJ.
5. Value of heat transfer rate (Q) at a time of 50 min with a temperature difference 32-24,4 °C = 7,6 °C:
   k = 205 w/mK
   A = 32 cm^2 = 0,32 m^2
   dT = 7,6˚C = 280,75˚K
   dX = 1 cm = 0,01 m
   Answer:
   Q = -kA dT/dx
   Q = -205 w/mK × 0,32 m^2 (280,75˚K /0,01 m)
   Q = 1.841.720J = 1.841,72kJ
   So, value of heat transfer rate (Q) at a time of 30 min with a temperature difference 7,6 ˚C = 1.841,72kJ.
6. Value of heat transfer rate (Q) at a time of 30 min with a temperature difference 32-23,7 ˚C = 8,3˚C:
   K = 205 w/mK
   A = 32 cm^2 = 0,32 m^2
   dT = 8,3 °C = 281,45˚K
   dX = 1 cm = 0,01 m
   Jawab:
   Q = -kA dT/dx

Table 2. Calculation Results of Conduction Heat Transfer Rate

Time	k (W/mK)	A (m^2)	dT (^oK)	dx (m)	Q (KJ)
10 min	205	0.32	278.55	0.01	1827.29
20 min	205	0.32	278.55	0.01	1835.16
30 min	205	0.32	280.25	0.01	1838.44
40 min	205	0.32	280.45	0.01	1839.77
50 min	205	0.32	280.75	0.01	1841.72
60 min	205	0.32	281.45	0.01	1846.31

Table 3. Seeback Effect Coefficient Results

Temperature (T) °C	Voltage TEC (V) Volt	Coefficient of the seeback effect (α) V/°K
26.6 °C	11.05 W	0.037
25.4 °C	11.05 W	0.037
24.9 °C	11.05 W	0.037
24.7 °C	11.05 W	0.037
24.4 °C	11.05 W	0.037
23.7 °C	11.05 W	0.037

$Q = -205 \text{ w/mK} \times 0{,}32 \text{ m}^2 \; (281{,}45^\circ\text{K} / 0{,}01 \text{ m})$
$Q = 1.846.312 \text{ J} = 1.846{,}31 \text{ kJ}$
So, value of heat transfer rate (Q) at a time of 30 min with a temperature difference 8,3 °C is 1.846,31 kJ.

So, from the above calculation, it can be seen the results of the conduction heat transfer rate from the 10th minute to the 60th minute as shown in the following Table 2.

As can be seen in Table 2, the results of the calculation of the conduction heat transfer rate that occur show an increase from the 10th minute, namely 1,827.29 kJ to the 60th minute, which is 1,846.31 kJ.

3.3 Calculating the See Back Effect

The see back effect is a number that expresses the increase in the thermoelectric voltage for each unit of temperature difference between the two objects.

As can be seen in Table 3 of the calculation results to find the coefficient of the seeback effect in the 10th to the 60th minute with a final temperature value that decreases or reaches a cold temperature which has a difference value or decreases slightly in the next 10 min, the resulting seeback effect coefficient the same is 0.037V/°K.

Table 4. Data for Calculating Heat Absorbed TEC

Time	α (V/°K)	I (A)	Th (°K)	*Tc* (°K)	Ø (°K/W)	R (Ω)
10 min	0.037	8.76	299.75	278.55	1.1	1.26
20 min	0.037	8.76	298.55	278.85	1.1	1.26
30 min	0.037	8.75	298.05	280.25	1.1	1.26
40 min	0.037	8.75	297.85	280.45	1.1	1.26
50 min	0.037	8.75	297.55	280.75	1.1	1.26
60 min	0.037	8.75	296.85	281.45	1.1	1.26

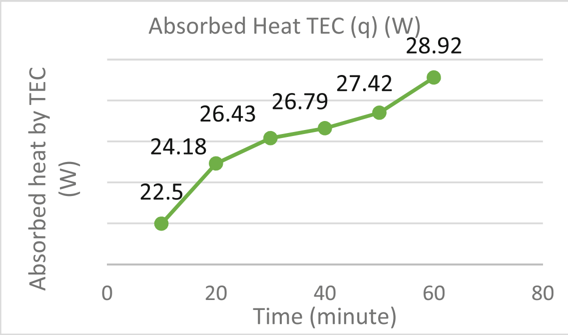

Fig. 6. Absorbed Heat by TEC

3.4 Calculating the Heat Absorbed TEC

As seen in Fig. 6 from the calculation of the heat absorbed by TEC in the 60th minute to reach a temperature of 296.85 °K, the heat absorbed is 28.92 W.

3.5 Calculating the Heat Released by TEC

So, it can be seen in Fig. 7 from the calculation of the heat released by TEC in the 60 min with an initial temperature of 296.85 K, the heat released is 130.51 W.

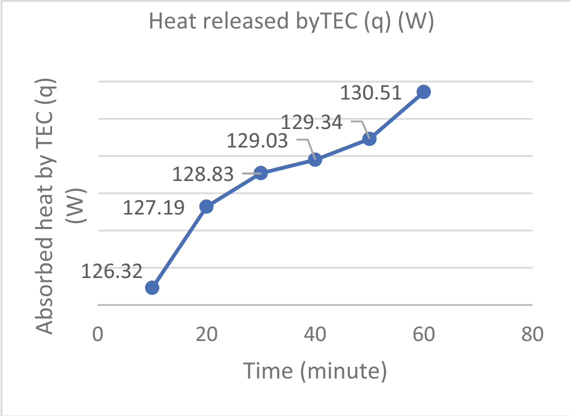

Fig. 7. Heat relased by TEC

3.5.1 Calculating Cooler Box Efficiency

Q2 is the heat absorbed by the TEC and Q1 is the heat released by the TEC. Where Q1 and Q2 taken are Q1 and Q2 at the last minute. As can be seen in Table 4 the calorific value absorbed at minute 60 is 28.92 W and in Table 4 the heat value released at minute 60 is 130.51 W. So to determine the efficiency of the cooler box, it can be calculated as follows:

$$\begin{aligned}\eta &= \frac{Q1 - Q2}{Q1} \times 100\% \\ &= \frac{130.51 - 29.92}{130.51} \times 100\% \\ &= 0.778 \times 100\% \\ &= 77.8\%\end{aligned}$$

The efficiency possessed by TEC with a heatsink is 77.8%. This is because the calorific value released and the heat removed by TEC do not have a significant difference. The longer the cooling process is carried out, the more optimal the temperature in the cooled cooler box, so as to produce better cooler box efficiency.

4 Conclusion

The lowest temperature that can be achieved by TEC1-12706 and TEC1-12715 is 23.7 °C which is reached in 60 min. The efficiency possessed by TEC with a heatsink 77.8%. TEC1-12706 and TEC1-12715 can lower temperature well, so this cooler box is very efficient for use on long trips by using a car during the weather hot. A higher temperature drop is possible by adding the core of the cooling system. This can be used as study material or consideration for future research.

Authors' Contributions. All authors contributed in this manuscript. HNS as writer. IMA and KUB contribute to collecting data and source. MC and WDK contribute to correcting. DVW contribute to final editing.

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