Biomedical and Mechanical Engineering Journal (BIOMEJ)
e-ISSN: 2776-1983, p-ISSN: 2829-5242
Vol. 4, No.1, May 2024, pp 12-19

Cooling Machine Adapted Peltier Cooling Module TEC1-12706 to Understand Heat Transfer Application

R M Suares[1], I Maulana[1], Z. Ikhsanudin[1], A I Ghozali[1], A Dwi Yanto[1], R A Hafizh[1], A R Firmansah[1], M S Yudha[1], W Saputro[1], R D Issafira[1*]
[1]Department of Mechanical Engineering, Faculty of Engineering, University of Pembangunan Nasional Veteran Jawa Timur, 60294, Indonesia

*Corresponding e-mail: radissa.d.tm@upnjatim.ac.id

Abstract. This paper discusses the development of a simple refrigeration system that utilizes a PSU (Power Supply Unit), Peltier TEC1-12706 module, axial fan, and heatsink. This system is designed to provide an efficient solution for cooling limited spaces or electronic devices at an affordable cost. The PSU is used as the main electrical power source, while the Peltier module functions as the main cooling element that utilizes the thermoelectric effect. An axial fan is integrated to improve heat transfer, increase cooling efficiency, and maintain operational temperatures at desired levels. Heatsinks are used as an addition to the heat absorption and distribution process, ensuring optimal system performance. This research involves experimental testing to measure the system's ability to reduce temperatures and maintain operational stability. The experimental results show that data was obtained from the 5th minute to the 30th minute. The average temperature was 18.54˚C in the 5th minute, 16˚C in the 10th minute, 14.88˚C in the 15th minute, 14.88˚C in the 10th minute. in the 20th minute it was 14.34˚C, in the 25th minute it was 14˚C, and in the 30th minute it was 13.78˚C and obtained a maximum COP value of 0.702 and actual COP 0.212. This research contributes to the development of efficient and affordable cooling technology by utilizing components that are easy to access and apply.
Keyword: Cooling Box, Peltier TEC-12706, $COP_{maximum}$,COP_{actual}

1. Introduction

With today's increasingly rapid technological developments, refrigerants (cooling materials) on the market are required to be environmentally friendly, in addition to other necessary technical aspects. Especially in urban areas, refrigeration machines are equipment that can be found in almost every office, building and household. A cooling machine is an energy conversion machine that is used to transfer heat from low to high temperatures by increasing external performance. In clear terms, a cooling machine is equipment used in the process of cooling a material (fluid) so that it reaches the desired temperature and humidity, by absorbing heat from the material (fluid) that will be conditioned, or in other words absorbing heat (heat) from a cold reservoir. and given to the hot reservoir.

The cooling machine can function as a refrigerator, freezer, chiller both for air conditioning needs and to support the production process. Currently, vapor compression and absorption refrigeration types are widely used. In a cooling machine there are several main components, namely: evaporator, compressor, condenser, expansion device/capillary pipe, and refrigerant (Simamora and Hamidi, 2019). Refrigerant is the main working fluid in a refrigeration cycle whose job is to absorb heat at low temperature and pressure and remove heat at high temperature and pressure. There are various types of refrigerants used in vapor compression systems. The required refrigeration temperature is very

Biomedical and Mechanical Engineering Journal (BIOMEJ)
e-ISSN: 2776-1983, p-ISSN: 2829-5242
Vol. 4, No.1, May 2024, pp 12-19

determining in fluid selection. The refrigerants that are commonly used are those that include chlorinated fluoro carbons (CFC), also known as freons.

There are 2 types of cooling machines, namely absorption cooling machines and vapor compression cycle cooling machines. Firstly, an absorption cooling machine is a method of cooling technique which in its operating cycle utilizes heat (heat) as a power source to drive the cooling cycle (heat-operated cycle). The main components of the absorption refrigeration cycle are the generator, condenser, expansion valve, evaporator, absorber, and circulation pump. Second, the vapor compression refrigeration machine works on the basis of the reverse Carnot cycle, with the working fluid circulating to form a closed cycle. The refrigeration cycle is the opposite of the Carnot cycle which requires work to transfer heat from a higher temperature. This machine uses a compressor to increase the pressure of the refrigerant vapor from the evaporator and then pushes it into the condenser so that it can be easily condensed. The actual vapor compression cycle is different from the standard (theoretical) cycle. This difference arises because of the assumptions set out in the standard cycle. In the actual cycle there is further heating of the refrigerant vapor which leaves the evaporator before entering the condenser. This further heating occurs due to the type of expansion equipment used or can also be due to heat absorption in the suction line between the evaporator and compressor. Likewise, the liquid refrigerant undergoes further cooling or undercooling before entering the expansion valve or capillary pipe. The above conditions are normal events and perform the desired function to ensure that all refrigerant entering the compressor or expansion device is 100% vapor or liquid.

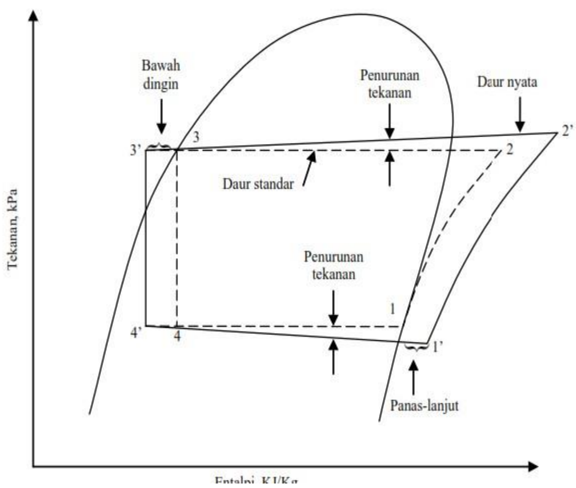


Figure 1. Comparison of actual cycle and standard cycle.

Line 4-1' shows the pressure drop that occurs in the refrigerant when it passes through the suction line from the evaporator to the compressor. Line 1-1' shows the occurrence of superheat in the refrigerant vapor which is indicated by the line that passes through the saturated vapor line. Process 1'-2' is the process of compressing refrigerant vapor in the compressor. In the theoretical cycle the compression process is assumed to be isentropic, which means there is no movement of fluid between the refrigerant and the cylinder wall. In reality, the process that occurs is neither isentropic nor polytropic. Line 2'-3 shows the pressure drop that occurs in the condenser pipes. Meanwhile, the 3-3' line shows the pressure that occurs in the liquid path (Irama and Sumadijhono; 2018). Thermoelectric technology is technology that works by converting thermal energy into electricity directly (thermoelectric generator), or vice versa, from electricity to produce cold (thermoelectric cooler).

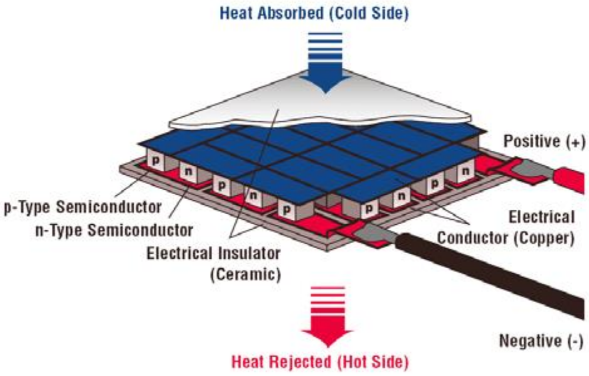


Figure 2. Flow of electrons from P type to N type

The Peltier effect phenomenon is when two metal wires with different materials (for example A and B) are given a different voltage, which will produce a temperature difference. The working principle of thermoelectric coolers is based on the Peltier effect, namely when DC current is applied to the Peltier element, one side of the Peltier element becomes cold (heat is absorbed) and the other side becomes hot (heat is released) (Ekopoetro, 2010). Coefficient of Performance To measure a cooling machine, parameters are used to measure the efficiency of the cooling machine. The coefficient of performance is the ratio between the cooling power produced (Qc) and the electrical power consumed (W) using the formula:

$$\text{COP(maks)} = \frac{\text{QL}}{QH - QL} = \frac{\text{TL}}{Th - TL}$$

Dimana :
COP = *Coefficient of Performance*
TL = Temperature inside Refrigerator
Th = Environment Temperature

$$\text{COP(aktual)} = \frac{\text{QL}}{W}$$

Q_L = Beban Pendinginan
W = Daya Masukan yang Digunakan (*termoelectric*)

2. Method

This project combines the construction of a simple cooler box with an investigation into its efficiency. A Peltier module is utilized to create a portable cooling system and calculate its Coefficient of Performance (COP). The procedure begins by gathering the necessary tools and materials, which conssist a Styrofoam box, Peltier cooler module, a heatsink to dissipate heat, an axial fan to facilitate airflow, a 12V power supply to energize the system, thermocouple for measuring both hot and cold side temperatures, and a recording tool like a spreadsheet for data collection.

Subsequently the Styrofoam box transform into a functional cooler. Using a cutting tool, a hole was made in one side of the box. The size of the opening is match with heatsink to securely mount it and allow for unobstructed airflow from the axial fan. The Peltier module positioned inside the box, with one side facing the interior, where the cooling to occur, and the other facing the outside environment. The heatsink will be attached to the exposed side of the Peltier module, responsible for drawing away heat generated during the cooling process. The design of cooler box shown on the figure 4 below.

Biomedical and Mechanical Engineering Journal (BIOMEJ)
e-ISSN: 2776-1983, p-ISSN: 2829-5242
Vol. 4, No.1, May 2024, pp 12-19

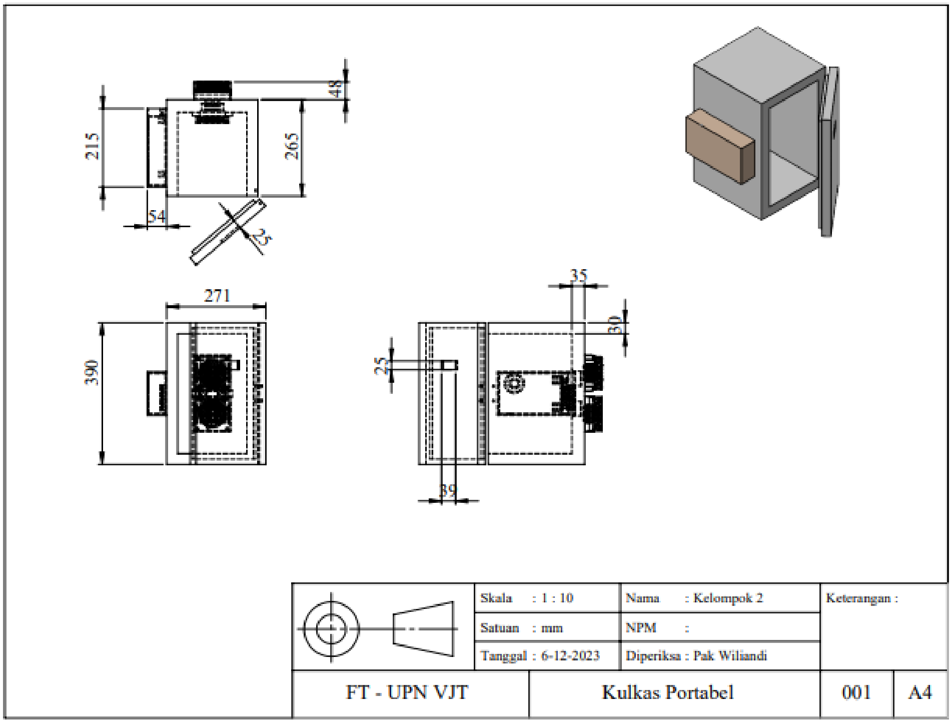
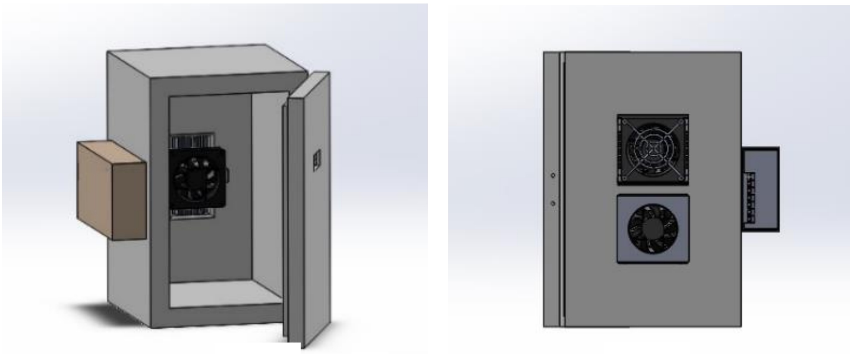


Figure 3. Cooling Box Dimension



(a) (b)

Figure 4. (a) Front (b) Sides

2.1 Electrical Connections and Power Up

The Peltier module comes with two wires representing the positive and negative terminals. The wires is connected to the 12V power supply, ensuring proper polarity to avoid malfunction. The heatsink and fan have separate power connections. Subsequently a cable and plug to connect the power supply to a standard wall outlet, providing the necessary electricity to power the system.

2.2 Data Acquisition: Putting the Cooler to the Test

It is crucial to allow the system to stabilize and reach thermal equilibrium before taking measurements. The experiment involves recording temperatures at specific intervals of 5, 10, 15, 20, 25, and 30 minutes. Two crucial sets of temperature readings are required: the cold side temperature inside the Styrofoam box, representing the cooling effect, and the hot side temperature measured on the heatsink. Thermocouple is utilized to ensure consistent placement for each reading for reliable data.

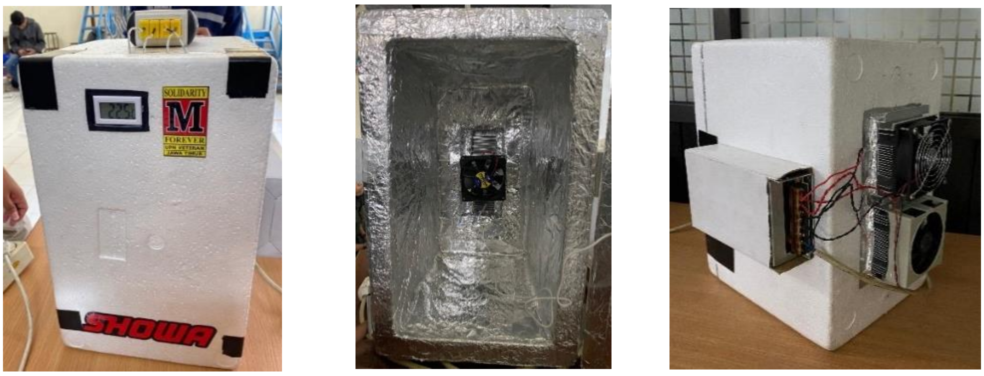
Biomedical and Mechanical Engineering Journal (BIOMEJ)
e-ISSN: 2776-1983, p-ISSN: 2829-5242
Vol. 4, No.1, May 2024, pp 12-19

2.3 Calculating COP: Unveiling Efficiency

COP expressed by the formula COP = Qc / W, which represents the efficiency of the cooling system. Here, Qc signifies the heat removed from the cold side (refrigeration effect), and W represents the electrical work input (power consumption). Calculating Qc requires some additional information, which are the specific heat capacity of the air inside the box and the volume of the box itself. With these values, along with the temperature difference between the initial and final readings on the cold side, we can estimate the amount of heat removed (Qc). The electrical work input (W) can be calculated by multiplying the voltage (12V) by the current (amps) drawn from the power supply. This information can be obtained using an ammeter connected in series with the Peltier module. By substituting the calculated values of Qc and W into the COP formula, the efficiency of the homemade cooler was determined.

3. Results and Discussion

The results of the design in this research can be seen in figures 7, 8 and 9. where the equipment used includes 2 peltiers, 4 headsinks, 3 fans, and 1 display thermometer which are designed to be connected to a power supply that is supplied with electricity for power needs. required. The results of observations of the cooler box temperature are shown in table 1 below.



(a) (b) (c)

Figure 5. (a) Front (b) Inside (c) Back Look of the Refrigeration System

Table 1 Temperature Testing within 25 minutes

Waktu	T1	T2	T3	T4	T5
5'	18,6	18,7	20,3	16,5	18,6
10'	16,3	15,6	18	13,9	16,2
15'	15,2	15	16,7	12,8	14,7
20'	14,7	14,5	16,1	12,2	14,2
25'	14,5	14,1	15,7	12,1	13,6
30'	14,3	13,4	15,5	11,8	13,9
Average	18,54	18,54	18,54	18,54	18,54

The variables used in the COP calculation can be seen below:

- Massa beban pendingin:
  1. Kipas = 0,085 kg
  2. *Heatsink* = 0,274 kg
  3. Total = 0,359 kg
- Cp
  1. Kipas = 1,67 KJ/kg K
  2. *Heatsink* = 0,87 KJ/kg K
  3. Total = 2,54 KJ/kg K
- Temperatur lingkungan $T_h = 28{,}6^oC$
- Suhu Terendah $T = 11{,}8^oC$

- Daya masuk yang digunakan W= 72 W

3.1 Data Calculations

Berdasarkan data yang didapatkan, dilakukan pengolahan data untuk mencari rata-rata temperature setuap 5 menit dalam 30 menit, yaitu pada menit ke-5, ke-10, ke-15, ke-20, ke-25, dan ke-30. Pengolahan data sebagai berikut :

Rumus suhu rata-rata

$$T_{rata\text{-}rata} = \frac{Suhu\ 1 + Suhu\ 2 + Suhu\ 3 + Suhu\ 4 + Suhu\ 5}{5}$$

1. Suhu rata-rata pada menit ke-5

$$5' = \frac{18{,}6+18{,}7 + 20{,}3 + 16{,}5 + 18{,}6}{5} = 18{,}54$$

2. Suhu rata-rata pada menit ke-10

$$10' = \frac{16{,}3 +15{,}6 + 18 + 13{,}9 + 16{,}2}{5} = 16$$

3. Suhu rata-rata pada menit ke-15

$$15' = \frac{15{,}2 +15 + 16{,}7 + 12{,}8 + 14{,}7}{5} = 14{,}88$$

4. Suhu rata-rata pada menit ke-20

$$20' = \frac{14{,}7 +14{,}5 + 16{,}1 + 12{,}2 + 14{,}2}{5} = 14{,}34$$

5. Suhu rata-rata pada menit ke-25

$$25' = \frac{14{,}5 +14{,}1 + 15{,}7 + 12{,}1 + 13{,}6}{5} = 14$$

6. Suhu rata-rata pada menit ke-30

$$30' = \frac{14{,}3 +13{,}4 + 15{,}5 + 11{,}8 + 13{,}9}{5} = 13{,}78$$

- Perhitungan Efisiensi

$$COP_{(maximal)} = \frac{11{,}8}{28{,}6 - 11{,}8} = 0{,}702$$

Sedangkan untuk perhitungan COP_{Aktual} dengan persamaan berikut:

$$Q_L = 0{,}359 \text{ kg x } 2{,}54 \frac{kj}{kg.k} \text{ x } 16{,}8\ °C$$

$$= 15{,}319$$

$$COP_{(aktual)} = \frac{15{,}319}{72\ W} = 0{,}212$$

Based on practical results on a cooling machine using a TEC1-12706 peltier, it produces an average of 18.54oC in the 5th minute, 16oC in the 10th minute, 14.88oC in the 15th minute, 14.88oC in the 20th minute. 14.34oC, at the 25th minute it was 14oC, and at the 30th minute it was 13.78oC. It can be seen in graph 4.1 that the average temperature decreases rapidly over time until it reaches the lowest average of 13.78oC. From the results of a 30 minute experiment on a cooling machine, the following average graph was obtained.

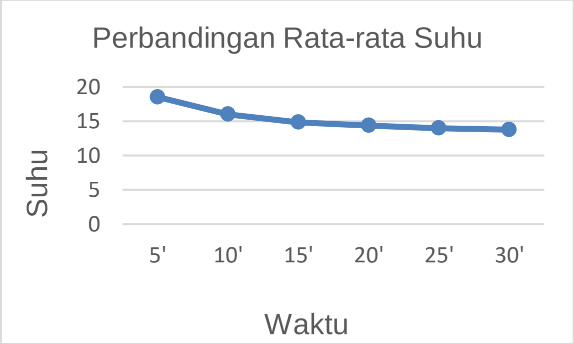


Figure 6. Comparison Graph of Average Temperatures for 30 minutes

As shown from the above, it can be explained that the average temperature decreases with time. The decrease in temperature that occurs in a refrigeration machine occurs because of the cycle that works, namely the thermodynamics that the system runs. In the average temperature observation results, the most important components for cooling are influenced by 2 peltiers, 2 heatsinks outside with dimensions of 98mm x 98mm x 25mm, 2 heatsinks inside with dimensions of 40mm x 60 mm x 18mm, 2 axial fans outside, 1 axial fan inside inside and aluminum foil in the refrigerator. The use of 2 peltiers to reduce the temperature of the refrigeration system more quickly is assisted by 2 heatsinks outside made of aluminum which have a high conductivity value and 2 axial fans outside to distribute the heat itself. 2 heatsinks inside and 1 axial fan in the refrigeration machine so that the cold spreads inside more quickly, there is also aluminum foil inside the refrigerator that binds and maintains the temperature inside the refrigerator. The volume of the refrigerator itself is not that large, therefore using 1 axial fan is sufficient.

Meanwhile, for data processing, the maximum COP value of the cooling machine received a value of 0.702. With this it can be concluded that the efficiency of the cooling machine is classified as less efficient. This is because more electrical energy is needed than the heat energy removed from the cooling machine room. The maximum COP value is influenced by several factors, including the temperature difference between the environment and the cooling machine and the efficiency of both the cooling machine components and the size of the cooling machine. Meanwhile, data processing on COPactual gets a value of 0.212, which makes the cooling machine also classified as inefficient. Because the higher the COP value, the better the performance of the cooling machine. The COP value depends on the electrical power, cooling time and the amount of heat drawn. With a maximum COP value of 0.702 and an Actual COP value of 0.212. Therefore, the cooling machine requires repairs and performance improvements until the cooling machine produces maximum performance.

According to Suryadi and Firmansyah (2020), the thing that influences the temperature reduction in the TECl-12706 peltier is the temperature in the room or surrounding environment. High room temperature and air humidity cause the performance of the cooling machine to be lower, so that the temperature drop in the cooling machine tends to take longer. Because the temperature of the room or surrounding environment influences the heat dissipation process produced by the hot side of the peltier. In addition, the way the cooling machine operates greatly influences the performance of the cooling machine. A cooling machine that operates with a heavy load can cause the cooling machine's performance to be lower. This is because a cooling machine that uses a cooling load has more heat that must be withdrawn from the cooling chamber compared to a cooling machine that does not use a cooling load.

4. Conclusion

In observations from the results of data collection, data was obtained from the 5th minute to the 30th minute. The average temperature at the 5th minute was 18.54˚C, at the 10th minute it was 16˚C, at the 15th minute it was 14.88˚C , in the 20th minute it was 14.34˚C, in the 25th minute it was 14˚C, and in the 30th minute it was 13.78˚C. Factors that influence engine performance and temperature decrease over time are due to the cooling engine working more optimally in low environmental temperatures, the use of aluminum foil on the inside of the refrigerator so that it is able to bind and maintain the temperature, the use of 2 peltiers so that the temperature of the refrigeration system decreases more quickly , and the use of 1 axial fan in the refrigeration machine so that the cold spreads inside more quickly.

From the results of data processing, the results obtained from the maximum COP were 0.702 and the actual COP was 0.212. With a value lower than 1, it indicates that the cooling machine used during the practicum requires more electrical energy to operate the cooling machine compared to the heat drawn from the space being cooled. So, it can be interpreted that the efficiency of the refrigerator engine's performance is not efficient.

References

[1] E. Enny, “Optimalisasi Penggunaan Alat Praktikum Power Supply Switching dengan Menggunakan Topologi Half Bridge Konverter sebagai Alat Bantu Praktikum Elektronika Analog,” Optim. Pengguna. Alat Prakt. Power Supply Switch. dengan Menggunakan Topol. Half Bridg. Konvert. sebagai Alat Bantu Prakt. Elektron. Analog, vol. 12, no. 1, pp. 1–8, 2018.

[2] E. P. Sitohang, D. J. Mamahit, and N. S. Tulung, “Rancang Bangun Catu Daya Dc Menggunakan Mikrokontroler Atmega 8535,” J. Tek. Elektro dan Komput., 2018.

[3] Ekopoetro, JE, 2010. Studi Teknologi Termoelektrik Sebagai Upaya Konservasi Energi pada BTS. Seminar Universitas Indonesia: Jakarta, Indonesia.

[4] E. P. Sitohang, D. J. Mamahit, and N. S. Tulung, “Rancang Bangun Catu Daya Dc Menggunakan Mikrokontroler Atmega 8535,” J. Tek. Elektro dan Komput., 2018.

[5] Gandhi, Frima dan Yusfi, Meqorry. Perancangan Sistem Pendingin Air Menggunakan Elemen Peltier Berbasis Mikrokontroler ATmega8535, Jurnal Fisika Unand Vol. 5, No. 1 (2016), p.35-41.

[6] Rokhimi, I. and Pujayanto (2017) ‘Alat Peraga Pembelajaran Laju Hantaran Kalor Konduksi’, Prosiding Seminar Nasional Fisika dan Pendidikan Fisika, 6(1), pp. 270– 274.

[7] Salim, A. A., & Indarto, B. (2018). Studi Eksperimental Karakterisasi Elemen Termoelektrik Peltier Tipe TEC. JEECAE (Journal of Electrical, Electronics, Control, and Automotive Engineering), 3(1), 179-182.

[8] Y. Meqorry, P. Wilka, Derisma. Rancang Bangun Sistem Kontrol Temperatur untuk Proses Pendinginan Menggunakan Termoelektrik. Prosiding bidang Fisika Semirata 2015 Bidang MIPA BKS-PTN Barat Universitas Tanjungpura Pontianak (2015), p. 194–203.

[9] Simamora H., Hamidi N. 2019. Pengaruh Jumlah Termoelektrik Terhadap Kinerja Dari Mesin Pendingin Kombinasi Termoelektrik Dan Evaporative Cooling. Malang. Universitas Brawijaya.