International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-3, February 2020

Design of Portable Conditioning Chamber with Peltier Element for Transfusion Blood Temperature

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Abstract: A research has been conducted on the design of conditioning chambers with Peltier elements aimed at controlling transfusion blood temperature and analyzing the control system that has been made. The working principle of the control system that is made is the temperature sensor will read the temperature in the chamber, if the temperature reads above 10 °C, the relay will light up and electricity will flow so that the Peltier cooler will work, if the temperature has reached 10 °C, then the relay will off and the electricity will stop to save energy. The relay will turn on again if the temperature rises above 10 °C. The results obtained from this experiment is the Peltier element can cool down for 30 minutes with variations in load 0 mL, 350 mL, 700 mL, 1050 mL, and 1400 mL in the temperature range of 2 °C to 10 °C.

Keywords : Chamber, peltier element, transfusion blood, portable.

I. INTRODUCTION

The quality of blood was determined by the term blood cold chain. The blood cold chain is a system of storing and distributing blood in the right temperature and condition range from the point of blood collection to the point of transfusion to the patient. The blood cold chain pays great attention to the temperature of storage and distribution of blood because inappropriate temperature conditions will have an effect on safety, successful efforts, and availability of blood [1].

Deviations in temperature ranges and specific conditions during blood storage and transport can cause changes in the survival of blood components, which can later reduce the clinical benefits. It can also increase the risk of bacterial proliferation in blood components during storage and potentially threaten the safety of transfusion reactions, such as septic shock, or even death. Damage to the blood cold chain causes waste and disposal of blood units, which can have a detrimental impact on the availability of blood for transfusion.[2].

Damage to the blood cold chain can be caused by several reasons. The most common reason is that the equipment used does not meet quality and safety standards, refrigerators are not suitable for blood storage - a common case in developing countries is the use of ordinary refrigerators and picnic boxes for blood storage - or equipment that is not maintained and repaired correctly [1].

Seeing how important the blood cold chain is in the process of storing and distributing blood, the authors see the urgency, in this case, to innovate to create a portable conditioning chamber that can be used for blood storage.

A. Blood and Blood Products

Blood and blood products have an important role in the world of health. Everyone may need a blood transfusion at any time under various conditions. For this reason, blood and blood product stocks must always be available at the Hospital Blood Bank is safe and quality guaranteed.

The planning, mobilization and preservation of blood donors, the supply of blood, the distribution of blood, and the medical treatment of giving blood to patients are health services in the effort of blood transfusion services. Blood transfusion services are facilitated by the Blood Transfusion Unit (BTU), which organizes blood donations, blood supply, and blood distribution [3].

The entire process carried out by the Blood Transfusion Unit from the organization of blood donations to the distribution of blood is carried out in a quality management system to guarantee the quality of blood from donors to blood recipients called the blood cold chain.

B. Blood Storage

Blood is a biological material that cannot be synthesized outside the body. Blood must be collected, handled, transported and stored according to the quality management system for the blood supply unit. The purpose of these things is to guarantee the quality and safety of blood while minimizing the potential for bacterial contamination.

One process that must be passed by blood before being transfused to recipients is transportation from the Hospital Blood Bank to the transfusion point. Facilities or containers used for the transportation of blood components must be able to maintain the desired temperature conditions for the expected period of transportation in a manner that is consistently qualified and validated by Regulation of the Minister of Health of Republic Indonesia Number 91 Year 2015.

Revised Manuscript Received on February 05, 2020.

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C. Thermoelectric Technology

Thermoelectric modules are energy converters consisting of several thermocouples which are electrically arranged in series and thermally arranged in parallel. The thermocouple itself consists of two different semiconductor materials, which produce a cooling effect (Peltier effect - Seebeck effect) when there is a potential difference that is precisely connected to the thermoelectric module. Thermoelectric modules generally have two cross-sections installed on two sides, namely the hot and cold side of the module, which serves to improve heat transfer and system performance [4].

Thermoelectric technology is a technology that works by converting thermal energy into electricity directly or vice versa, from electricity to thermal energy that can be felt in heat and cold. Thermoelectric coolers (thermoelectric coolers) are cooling devices that use Peltier elements in the system as heat pumps. The phenomenon of the Peltier effect arises from two metal wires with different materials and then given a voltage difference, it will produce a temperature difference. The difference in temperature produced will be proportional to the amount of direct current flowed so that later there will be a part that will absorb heat and there are parts that release heat. In addition, there will be other phenomena that will occur in two metals, namely the phenomenon of the Joule effect, the Fourier effect, the Seebeck effect, and the Thomson effect [5].

II. MATERIALS AND METHOD

A. Flowchart of Instrument Work

The research method used can be seen in the following Fig. 1.

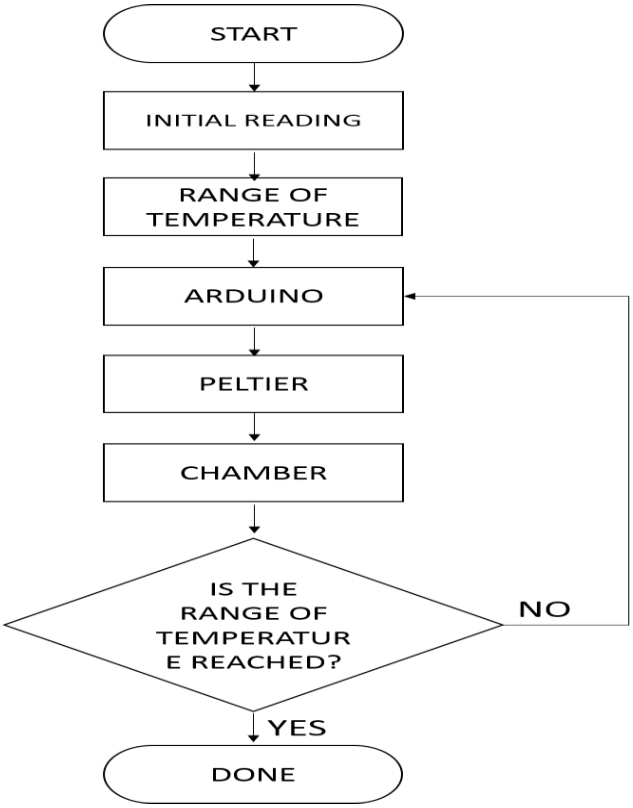

Fig. 1.Flowchart of instrument work.

B. Peltier Module Design

Fig. 2 shows the design of the Peltier module, which will be used as a cooling source for the chamber. Peltier elements are coated with thermal paste on each side, then affixed to the heatsink and cold sink. The thermal paste helps fill the Peltier pores so that the temperature transfer from the Peltier to the heatsink and cold sink is better. Peltier that has been connected to the power supply will then produce cold temperatures on one side, and hot temperatures on the other side. The temperature is forwarded to the cold sink on one side which serves as a conduit of cold temperature from the Peltier into the chamber, and on the other side of the Peltier, the temperature is transmitted to the heatsink which functions as a conduit of hot temperature and then discharged into the environment.

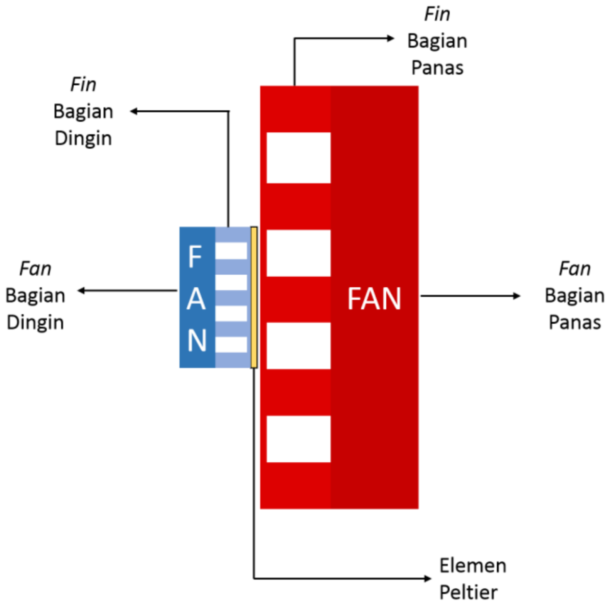

Fig. 2.Peltier module design.

C. Chamber Design

Fig. 3 shows the design of the instrument. Arduino Uno works as a microcontroller that regulates the overall working of the tool. Initially, the temperature inside the chamber will be read by the temperature sensor. Then the temperature sensor will provide an input signal to the relay connected to Arduino Uno. If the reading of temperature above the desired setpoint, the relay will turn on so that electricity can flow and make the Peltier work. The temperature sensor will continue to provide temperature readings every 1 second. When the temperature reaches the setpoint, the sensor will give a signal to the relay to disconnect the electricity so that the Peltier no longer gets electricity and stops working. The process continues to repeat as a closed-loop until the power supply is turned off.

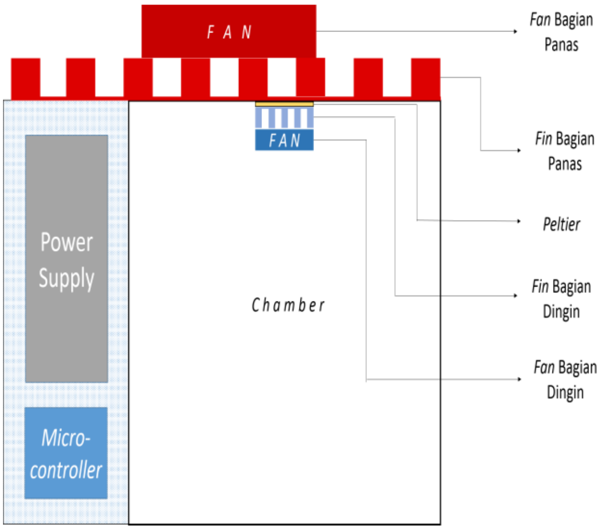

Fig. 3.Instrument design.

Fig. 4 shows the design of the top view and Fig. 5. shows the design of the side view. The inside of the chamber will be designed from acrylic with a thickness of 1 mm. The dimensions of the inner chamber measuring 21.4 cm x 20 cm x 24.2 cm for length, width, and height so as to produce a volume size of the inner chamber is 10.35 L. Temperature inside the chamber so that it does not easily come out into the environment, also withstand temperature and bacterial contamination from outside the chamber. The dimensions of the outer chamber are 30 cm x 20.7 cm x 24.2 cm for length, width and height. Arduino Uno, batteries, and relays will be placed between the acrylic chamber and the styrofoam chamber.

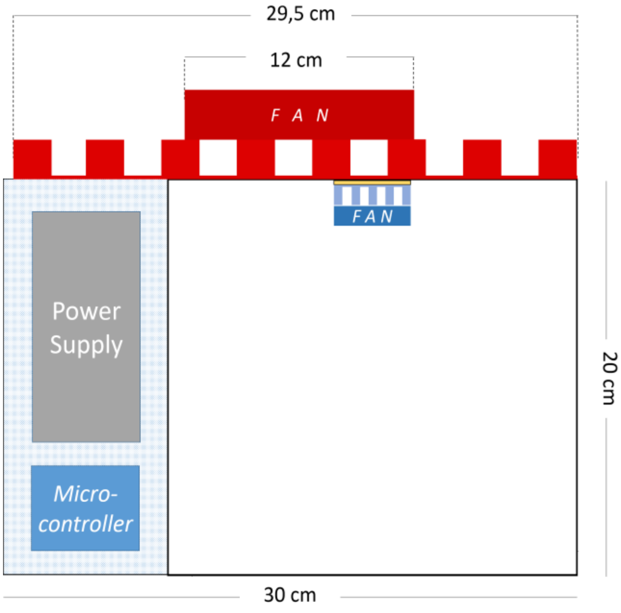

Fig. 4.Top view of instrument design

Meanwhile, the Peltier module that has been designed along with the heatsink and cold sink is placed between the inside and outside of the acrylic chamber. The side that produces cold will point into the chamber, while the side that produces heat will lead to the environment. This is done to isolate hot and cold temperatures according to their needs.

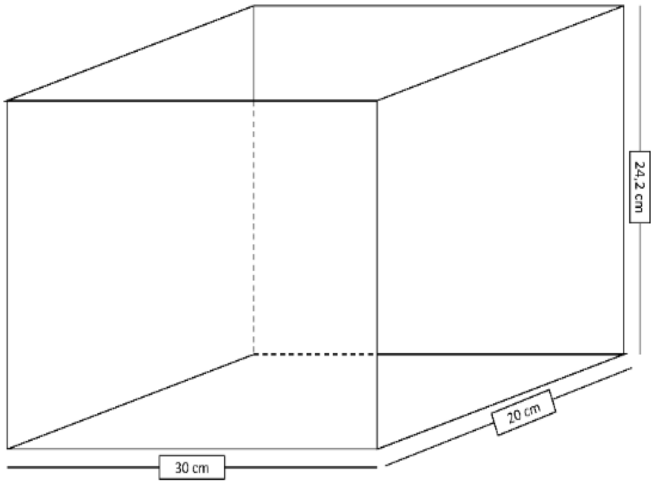

Fig. 5.Side view of instrument design.

D. Temperature Sensor Design

The temperature sensor used in this study is the DS18B20 sensor. This temperature sensor operates at a voltage of 3.0 V to 5.5 V, has a reading measurement range of -50 ºC to 125 ºC with an accuracy value of ± 0.5 ºC in the range of -10 ºC to 85 ºC. Communication of the temperature sensor to Arduino uses 3 pins connected to a 5 volt VCC, ground, and a digital pin 10. Then the sensor programming is done using a programming language that supports Arduino. The temperature sensor readings will be displayed on the LCD which is also connected to Arduino. The DS18B20 sensor circuit can be seen in Fig. 6.

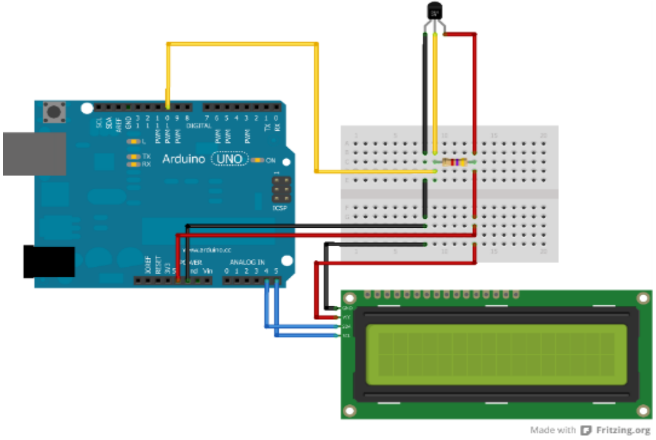

Fig. 6.Temperature Sensor Circuit.

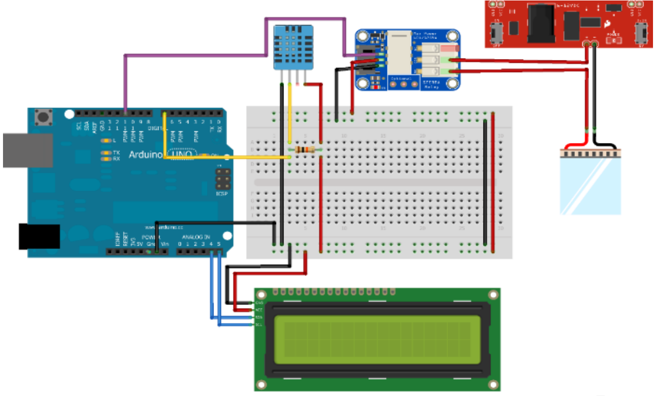

Fig. 7.System Circuit.

Overall, the system circuit is shown in Fig. 7. Initially, the temperature reading inside the chamber will be read by the DS18B20 temperature sensor. Then the sensor will provide the reading input to the Arduino Uno microcontroller via digital pin number 7.

The program on Arduino is made to turn on the relay when the temperature inside the chamber does not match the setpoint and turns off the relay when the setpoint has been reached. The relay is connected to the Peltier on the normally open pin. That is, under normal circumstances, the Peltier will not have contact with resources and cooling will not be carried out by the Peltier. If the DS18B20 sensor reads the temperature inside the chamber outside the setpoint, the relay will turn on so that the power source and Peltier will be connected to each other so that the Peltier can cool. The process will continue until the resource is removed from the circuit.

III. RESULTS AND DISCUSSION

A. Temperature Sensor Calibration

Temperature sensor calibration is done so that the temperature sensor reading results can detect the value accurately. Data is collected by comparing the reading value on the temperature sensor with the reading value on the standard temperature sensor. Data was collected 10 times at each measurement point. The temperature sensor calibration data can be seen in the following Table I.

Table- I: Calibration

Cal. Point (ºC)	STD Reading (ºC)	UUT (ºC)	Correction (ºC)	Uncertainty (ºC)	Coverage Factor (k)
-20	-20,52	-20,72	0,2	0,28	2
0	0,27	-0,06	0,33	0,28	2
2	1,49	1,2	0,29	0,28	2
5	4,52	4,26	0,26	0,28	2
8	7,52	7,26	0,26	0,28	2
10	9,52	9,25	0,27	0,28	2
15	14,52	14,19	0,33	0,28	2
20	19,5	19,19	0,31	0,28	2
Environmental Condition					
Temperature			(25 ± 1,2) ºC		
Humidity			(63 ± 5) ºC		

B. System Testing

Testing room temperature conditioning system is done by taking data for 1 hour with a time interval of 5 minutes. The desired temperature in the chamber is in the range of 2 °C to 10 °C. Performing variations in load on the chamber. When the temperature sensor detects a temperature of more than 10 ºC, the relay will ignite and flow an electric current to the Peltier element, so that the Peltier element will work to produce heat discharged into the environment aided by a heatsink and fan, and also produces cold which is used as a cooler in the chamber. When the temperature has reached 10 ºC, the relay will turn off to save electricity usage. The relay will turn on again if the temperature exceeds the expected temperature range.

The results obtained in this first experiment have not been able to meet the expected temperature range of 2 °C to 10 °C. The conditioning chamber test results are shown in Table II.

Table- II: First Testing

No.	Time (min)	Temperature (°C)		
		0 mL	*350 mL*	*700 mL*
1	0	27.90	27.59	26.97
2	5	21.17	18.81	18.31
3	10	19.68	18.31	18.07
4	15	18.87	17.69	17.82
5	20	17.51	17.63	18.07
6	25	17.82	17.51	18.50
7	30	17.19	17.38	18.43
8	35	18.37	17.13	18.37
9	40	17.51	17.19	18.07
10	45	16.94	17.19	18.43
11	50	17.32	17.44	18.31
12	55	17.32	17.51	18.13
13	60	16.82	17.38	17.57

In the form of graphs, data from the results of testing tools can be seen as in Table III and Fig. 8.

Table- III: Second Testing

Time (min)	Temperature (°C)				
	0 mL	*350 mL*	*700 mL*	*1050 mL*	*1400 mL*
0	28.09	31.88	26.59	30.27	32.20
1	18.62	18.13	13.32	16.20	21.61
2	10.98	9.58	9.40	7.45	12.87
3	8.01	9.33	9.46	7.95	8.96
4	9.77	9.40	9.33	7.89	9.58
5	8.39	9.40	8.96	7.89	8.65
6	9.52	8.77	8.77	8.32	9.52
7	8.65	8.32	8.83	8.77	8.39
8	9.58	7.95	8.39	9.27	9.46
9	8.71	8.26	8.20	9.33	8.14
10	9.52	8.14	8.14	9.33	9.33
11	8.51	7.95	8.14	9.33	8.14
12	9.65	8.14	8.20	9.33	9.21
13	8.45	8.39	7.95	9.21	8.58
14	9.27	8.58	8.07	9.08	9.08
15	8.07	8.71	8.71	9.02	9.02
16	9.08	8.96	8.20	8.90	8.90
17	8.71	9.15	8.07	8.58	9.27
18	8.90	9.21	8.51	8.51	8.71
19	9.21	9.33	8.90	8.20	9.40

20	8.77	9.15	9.08	8.01	8.58
21	9.27	8.51	9.21	7.89	9.46
22	8.90	8.07	9.46	8.01	8.39
23	9.21	8.32	9.02	9.02	9.33
24	8.71	8.63	9.27	9.46	8.14
25	9.27	8.96	9.21	9.33	9.15
26	8.90	8.77	9.21	9.27	8.45
27	8.51	9.27	9.27	9.15	8.96
28	8.90	9.27	9.27	8.90	9.02
29	8.20	8.90	9.21	8.65	8.71
30	9.02	8.07	9.33	8.26	9.27

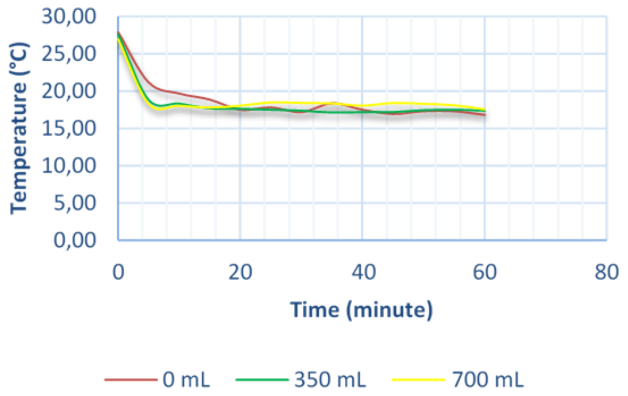

Fig. 8.System Circuit.

Then, after an evaluation and trial error, the second experiment gives better results because the temperature produced by the Peltier element has reached the set point.

In this experiment, the device was developed by adding one fan to the heatsink with a rotational speed of 2500 RPM. The results of the second test on the conditioning chamber are shown in Table III.

In the form of graphs, data from the results of testing tools can be seen in Fig. 9.

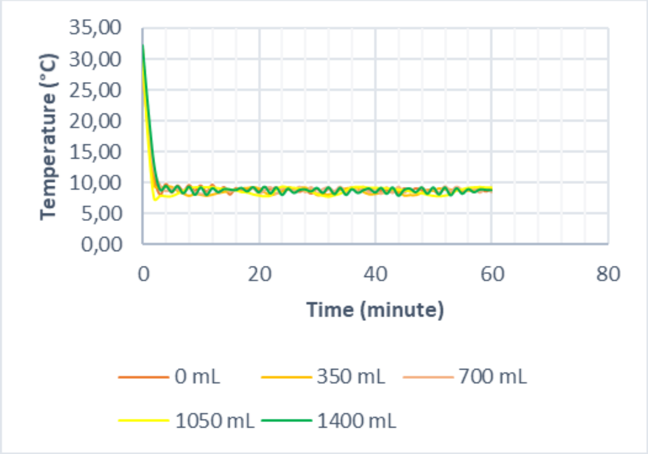

Fig. 9.System Circuit.

Overall on the second data collection, the cooler can reach the expected temperature range for each load in the chamber. The difference made to the system is the addition of a fan on the heatsink so that it produces a more optimal cooling process.

IV. CONCLUSION

The manufacture of a portable conditioning chamber for conditioning the transfusion blood temperature with the Peltier element was successfully carried out. The control system works when the temperature sensor detects a value <10 °C by activating the relay so that electricity from the power source flows to the Peltier element so that cooling is carried out. If the cooling temperature has reached the expected temperature range from 2 °C until 10 °C, the controller will give the relay off instructions so that the electricity from the power source to the Peltier element is cut off.

ACKNOWLEDGMENT

Thank you for Lembaga Penelitian dan Pengabdian kepada Masyarakat (LPPM) Universitas Nasional and my collegues in Faculty of Engineering and Science, Universitas Nasional.

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