

Design and Fabrication of Mini Refrigerator Using a Peltier Thermoelectric Module



G.A. Okorie¹, N. Faci¹ , P. U. Okorie^{2*}

¹Department of Mechanical Engineering, Ahmadu Bello University, Zaria – Nigeria

²Department of Electrical Engineering, Ahmadu Bello University, Zaria - Nigeria

ABSTRACT: A mini thermoelectric Peltier Refrigerator was designed and built in this study. The Peltier thermoelectric cell was attached in between an external heat sink and internal radiator that acted to remove heat from the internal space of refrigeration box to be conducted and removed to the ambient. To ensure the success of this study several criterions are to be satisfied such as portability, size and cost of the system. The design of the system is based on the principles of thermoelectric module (i.e. Peltier effect) to create a hot side and a cold side. Thermoelectric refrigeration work on the principle of seebeck effect in which the voltage is applied between two different combinations of metal and due to effect of seebeck the cooling and heating phenomena happens which can be used accordingly for different purposes. The cold side of the thermoelectric module is used for refrigeration purposes; provide cooling to the vaccine chamber. On the other hand, the heat from the hot side of the module is rejected to the surroundings with the help of a heat sink and fan assembly.

Key words: Thermoelectric refrigerator, thermoelectric, peltier device, CFCs, HCFCs

1. INTRODUCTION

Refrigeration is the process of heat removal in a space, thus providing and maintaining temperature below ambient temperature. Refrigeration provides temperature differential for processes like food preservation, food processing, storage applications etc. Another requirement of refrigeration is in developing scientific equipment and their operation under controlled environment to get reliable result.

Conventional cooling systems such as those used in refrigerators utilize a compressor and a working fluid to transfer heat. Thermal energy is absorbed and released as the working fluid undergoes expansion and compression and changes phase from liquid to vapor and back, respectively. Semiconductor thermoelectric coolers (also known as Peltier coolers) offer several advantages over conventional systems [1]. They are entirely solid-state devices, with no moving parts; this makes them rugged, reliable, and quiet. They use no ozone-depleting chlorofluorocarbons, potentially offering a more environmentally responsible alternative to conventional refrigeration. They can be extremely compact, much more so than compressor-based systems. Precise temperature control ($< \pm 0.1$ °C) can be achieved with Peltier coolers [2]. This conventional refrigeration systems uses Chloro-Fluoro-Carbons (CFCs) and Hydro Chloro-Fluoro-Carbons (HCFCs) as refrigerants. These CFCs and HCFCs are mainly responsible for environmental degradation such as Ozone layer depletion, global warming. As a result, there is need to develop clean refrigeration technology and hence

extensive research is happening in field of thermoelectric refrigeration.

The refrigeration engine is a heat engine that works in reverse. So, a heat engine takes heat from a place with a low temperature and dissipates that heat to a place with a high temperature. For this process to occur, the machine must do work. However, heat naturally only wants to flow from places of high temperature to places of low temperature. Heat cannot flow by itself from a place of low temperature to a place of high temperature. So, we need a tool that can do this by giving effort. That's how the cooling machine works where cold air is flowed to a place with a high temperature but with given effort. There are various types of cooling machines include refrigerators, air conditioners, PC coolers, and heat pumps. Refrigerator is one application of thermodynamics in which there is isolation of a system in a container with its environment. Refrigerators as earlier mentioned are used in many ways. With the development of the era, the refrigerator underwent changes after changes which used freon gas for cooling to become Freon less and it work effectively. This means that innovation from each technology is still carried out to find more effective and easy ways to achieve the same technology. Some of study even develop a refrigerator that can be carried anywhere. Thus, with this innovation people do not have to bother bringing

Received : December 13, 2023

Revised : February 5, 2024

Accepted : February 29, 2024

their large refrigerator to and fro. In addition, the development of a refrigerator that utilizes the Peltier effect of thermoelectric is also one of the innovations made to make a refrigerator.

Thermoelectric is one of the electronic components that is composed of a row of n and p type semiconductors which, when energized by DC electric current, has a hot temperature on one side and a cold temperature on the other side [3]. The cold side of the thermoelectric is used as a cooling material for the refrigerator. Several developments have been made using thermoelectric by combining them with heat sinks and fans on the hot side in order to obtain optimal cold temperatures [4]. There are also those who use a water block to cool the hot side of the thermoelectric to get optimal results [5].

Thermoelectric refrigeration works on principle of Peltier effect. Jean Peltier, a French physicist found the Peltier effect in 1834. It is reverse of Seebeck effect, which states that when voltage is applied across two junctions of dissimilar electrical conductors, heat is absorbed from one junction and heat is rejected at another junction. This is known as Peltier effect and this effect is attained in thermoelectric modules [6].

These thermoelectric modules consist of P-N type semiconducting materials. N-type material is doped such that it has excess number of electrons (which are required to complete perfect molecular lattice structure). P type material has deficiency of electrons resulting into holes. Excess electron in N-type material and holes in P-type materials are the carrier of heat energy in thermoelectric module [7]. So, the purpose of this experiment is to make a mini refrigerator by combining the heatsink and fan components to optimize cooling in the hot side of the Peltier. Thus, from the experiment, the good value coefficient of performance (COP) was obtained.

In the related area, several research papers have been published recently by many researchers to mention but few here, Tanami designing and constructing of mini refrigerator performance of the thermoelectric Peltier [5]. Dongare designed and developed thermoelectric refrigeration [8]. Gupta design and development of refrigerator for storage of food, vaccine, medical services and cooling electronic devices [9]. Abdelmessih designed a personal heating/cooling system using Peltier [10]. Thermoelectricity especially the Peltier concept useful for the refrigeration system [11]. Experimental study of mini cooler by using Peltier thermoelectric cell was developed by Rahman [4]. Ebong designed and implemented a solar powered mini refrigerator using thermoelectric cooler module and Vinarao developed a portable chest fridge using Peltier module [12] [13]. In this study, thermoelectric Peltier module was also utilized in the designing and fabricating of mini portable refrigerator and the performance was perfectly satisfactory and friendly used.

2. PROPOSED APPROACH

This section present step by step approach methods in implement the proposed work.

2.1 Description of the Thermoelectric Refrigerator

The thermoelectric refrigerator consists of parts such as the refrigeration box itself which has an outer geometry of 38.7cm x 36.7cm x 28.5cm and inner geometry of cold side radiator is 32cm x 30cm x 25cm; thereby creating an internal volume of 24Litres, Peltier module, heatsink, insulation, cooling fan, power supply, thermostat. In operation, the thermoelectric refrigerator cools down the refrigeration space due to the application of a DC current with the help of the power supply through to the Peltier module which works on DC current only, which then results in temperature difference between the cold side and hot side of the Peltier module. Whereby the heat in the refrigeration chamber is expedited from the system with the aid of the heat sink. The hot side of the Peltier module is connected to the heatsink and fan assembly, while the cold side is connected to the internal radiator which is an aluminum plate due to its good conductivity, the inner chamber will further be insulated with polyurethane foam sheets due to its good thermal properties. The thermostat will indicate the temperature difference in the refrigerated space, a rocker switch will be used to power on and off the refrigerator. Figure 1 present the isometric view of the deep freezer. The block diagram of the developed system is shown in Figure 2, has the following components, the supply power source which is connected to the high current 12V DC with heat sinks and a peltier module. There is a sensor and relay connected which is the temperature and humidity sensor and the output is the LCD to display the temperature and humidity.

Figure 3 shows the flow chart of the design system. The supply power source for the system to be operational should be adequate. The mini fridge will operate if the power source level is adequate enough and the switch is turned ON. This state will also be displayed on the LCD panel.

2.2 Design Considerations

In selecting the material most suited for the implementation of this research, the following conditions will be taken into consideration so as to achieve the best possible outcome:

2.2.1 Size of refrigeration space:

Alongside portability factor, the surface area to be cooled by the module is taken into consideration, in order to know the amount of heat load to be removed from the system by the Peltier module. A refrigeration chamber of 24Ls is to be cooled with the aid of the TEC1-12703 module and is strongly insulated to minimize heat loss to the ambient temperature.

2.2.2 Peltier module and arrangement:

Peltier modules are of various kinds based on their ratings and efficiency and the space to be cooled. Its arrangement also plays a vital role in its design, Peltier in series connection offers better temperature differential which makes it more efficient.

2.2.3 Efficient cooling of the host side:

When using thermoelectric modules, a great concern is efficient cooling for the hot side to avoid any concerns of

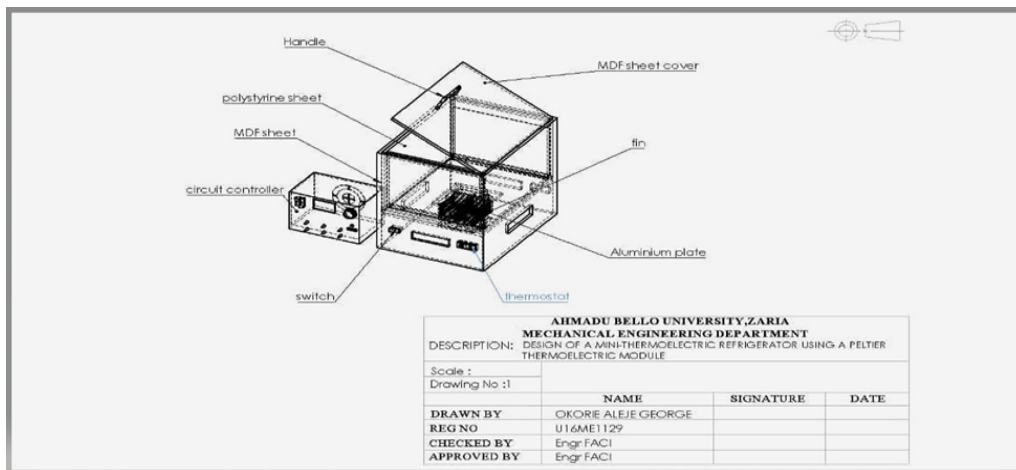


Fig. 1. Isometric view of deep freezer

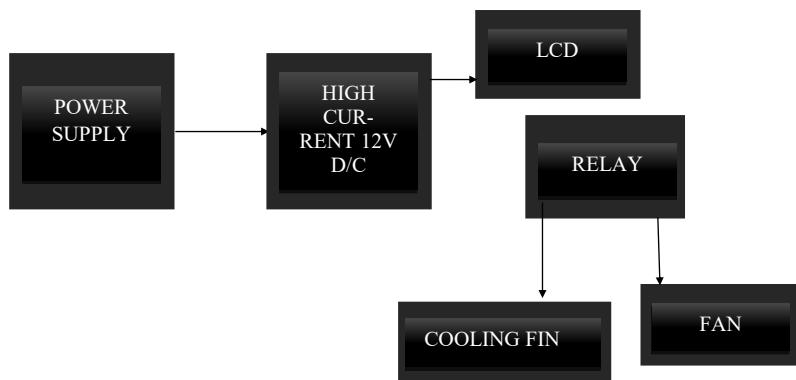


Fig. 2. Block Diagram of Thermoelectric Refrigeration System

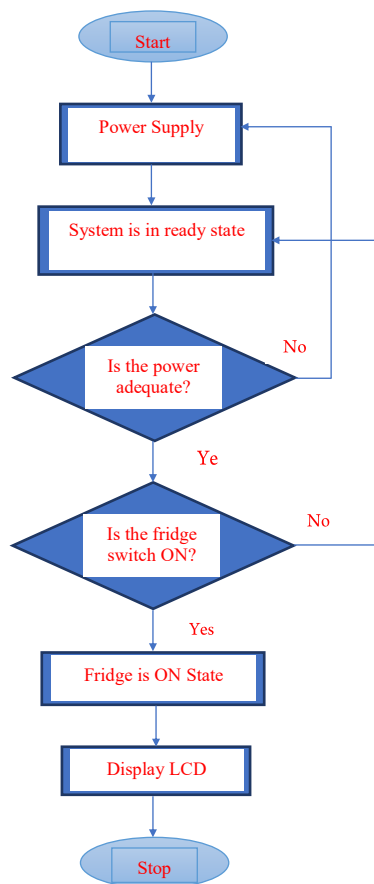


Fig. 3. Flow chart of the developed system

fire outbreak, also to ensure proper cooling of the cold side of the module. And cooling fan of 12V with speed of 2500rpm, 34.65CFM airflow mounted on the heatsink.

2.2.4 No leakages

In refrigeration, infiltration of air is as much as possible eliminated if not efficiency and performance of system is reduced. Also, when cooling is achieved and ice develops on melting, we don't want water trapped in the refrigerator or to contact the wood so a small duct for letting water out is incorporated in design.

2.3 Material Selection

In selection of the materials to be used, it was ensured that the thermoelectric refrigerator is easy to construct and affordable. The components are made from local materials and little or no training for the operation and maintenance. Polyurethane foam sheet was used for insulation of the refrigerator because of its good thermal properties, Aluminum has been selected for the internal radiator because of its availability, good machineability and also thermal properties

2.4 Design Analysis

The calculations of Heat transfer, power consumption and coefficient of performance (COP) of the system play the most important role in the design because on the results of these calculations and its correctness depends stability, safety and successful working of the whole refrigeration system. The Peltier is a dynamic device as the temperature difference across hot and cold side changes as current is passed through the device and the dissipation of the heat sink is observed

2.4.1 Peltier selection:

It was ensured that the appropriate TEC module has not only sufficient cooling capacity to maintain the proper temperature, but also meet the dimensional requirements imposed by the Refrigeration compartment. A module can be arbitrarily chosen by considering the geometrical constrain imposed due to the size of the cabin and also appears to have appropriate performance characteristics.

According to [14][15] the usefulness of thermoelectric materials for refrigeration is often characterized by the dimensionless product, ZT , of the thermoelectric value of merit Z and temperature T . The expression for the thermoelectric figure of merit is given by:

$$z = \frac{\alpha}{\rho K} \quad (1)$$

Where;

α = Seebeck coefficient

ρ = Electrical Resistivity

K = thermal conductivity

Low electrical resistivity and thermal conductivity are required for high value of merit. These values are temperature dependent therefore, the value of merit is temperature dependent.

Area of thermoelectric element is express in equation 2;

$$A_e = L_e \times B_e \quad (2)$$

Where;

B_e = Breadth of element

L_e = Length of element

Internal resistance of the couple is given in equation 3;

$$R_e = \frac{\rho L_e}{A_e} \quad (3)$$

Thermal conductance of couple and others relative characteristics are given in equations 4 - 10;

$$K_e = \frac{KA_e}{L_e} \quad (4)$$

$$Q_{co} = \frac{T_h - T_c \times A}{\frac{1}{h_o} + \frac{x_1}{k_{ply}} + \frac{x_2}{k_{PSF}} + \frac{x_3}{k_{Al}} + \frac{1}{h_i}} \quad (5)$$

Q_{co} = The external wall, the insulation, the internal wall, aluminum sheet material, heat transfer per unit area is defined as;

k_{MDF} = Thermal conductivity of MDF = 0.13W/mK

k_{PSF} = Thermal conductivity of Polyurethane foam sheet = 0.024W/mK

k_{Al} = Thermal conductivity of aluminum plate = 222 W/mK

h_i and h_o air = 10W/m²K

x_1, x_2, x_3 = Length of each material

$$Q_{inf} = \text{Infiltration rate} \times \text{Enthalpy change} \quad (6)$$

Q_{inf} = The amount of heat to be removed from refrigerated space due to infiltration or air change as a result of door opening

$$Q_p = M_a C p_a (T_2 - T_1) \quad (7)$$

Q_p = The total amount of heat to be removed from the products inside the refrigerated space is known as the product load;

M_a = Mass of air

$C p_a$ = Specific heat capacity of air

T_2 and T_1 = Temperature difference

$$Q_T = Q_{co} + Q_{inf} + Q_p \quad (8)$$

Q_T = Total refrigeration load

Q_{co} = Heat conductance through walls

Q_p = Product load

$$COP = \frac{Q_{cooling}}{P_{tec}} \quad (9)$$

COP = Coefficient of Performance

Table 1 Design Calculations

Initial Data	Calculations	Results
Outer geometry L = 0.387m B = 0.367m H = 0.285m	Area of Box (A) $A_o = L \times B = 0.387 \times 0.367$ $A_i = L \times B = 0.32 \times 0.30$	$A_o = 0.1420m$ $A_i = 0.096m$ $Vol_c = 0.024m^3 \sim 24l$
Inner geometry L = 0.32m B = 0.30m H = 0.25m	Volume of Cooling Chamber $Vol_c = L \times B \times H = 0.32 \times 0.30 \times 0.25$	
$T_h = 40^\circ C$ $T_c = 5^\circ C$ A = 0.1420m $x_1 = 0.016m$ $x_2 = 0.012m$ $x_3 = 0.0008m$ $k_{MDF} = 0.13W/mK$ $k_{PUF} = 0.024W/mK$ $k_{Al} = 222W/mK$ h_i and h_o air = 10W/m ² K Infiltration rate = 3.75 L/s Enthalpy change = 0.0708 J/L	Heat transfer through walls $Q_{co} = \frac{T_h - T_c \times A_o}{\frac{1}{h_o} + \frac{x_1}{k_{MDF}} + \frac{x_2}{k_{PUF}} + \frac{x_3}{k_{Al}} + \frac{1}{h_i}}$ $Q_{co} = \frac{(40^\circ C - 5^\circ C) \times 0.1420}{\frac{1}{10} + \frac{0.016}{0.13} + \frac{0.012}{0.024} + \frac{0.0008}{222} + \frac{1}{10}}$	$Q_{co} = 18.12W$ $Q_{inf} = 0.2655J/s$
$Q_{co} = 18.12W$ $Q_{inf} = 0.2655J/s$ $V_o = 12V$ $I_o = 3A$	Passive load through the walls, $Q_{co} = (6.04 + 6.04 + 6.04)$ $Q_{co} = (Q_{co1} + Q_{co2} + Q_{co3})$ $Q_{inf} = \text{Infiltration rate} \times \text{Enthalpy change}$ $Q_{inf} = 3.75 L/s \times 0.0708 J/L$	
	Total refrigeration load (Q_T) $Q_T = Q_{co} + Q_{inf}$ $Q_T = 18.12 + 0.2655$	$Q_T = 18.4W$ For Safety, $Q_T \approx 20W$ $Q_H = 56W$
	Total heat to be dissipated (Q_H) $Q_H = P_{tesc} + Q_T$ $Q_H = V_o \times I_o + Q_T$ $Q_H = 12 \times 3 + 20$	
$T_h = 40^\circ C$ $T_a = 25^\circ C$ $Q_T = 18.4W$ Airflow = 200LFM, Volumetric resistance: 150-250	Heat Sink $Vol_{heatsink} =$ Volumetric resistance/Thermal resistance $R_{ht} = \frac{T_h - T_a}{V_o \times I_o + Q_T}$ $R_{ht} = \frac{40^\circ C - 25^\circ C}{12 \times 3 + 18.4}$ $Volume_{heatsink} = \frac{200}{0.29}$	$R_{ht} = 0.29^\circ C/W$ $Vol_{hk} = 689.66Cm^3$
$P_{tesc} = 36W$ $Cp_a = 1005 J/kg$ Density = 1.2 kg/m ³ V = 0.024m ³ $T_2 = 29.5^\circ C$ $T_1 = 22.1^\circ C$ Fan input = 2.4W $\Delta T = 1080secs$	Coefficient of Performance (Cop) $Cop = \frac{Q_{cooling}}{P_o}$ $Q_{cooling} = \frac{Q_p}{\Delta T}$ $P_o = P_{tesc} + \text{Fan input}$ $P_o = V_o \times I_o + \text{Fan input}$ $P_o = 12 \times 3 + 2.4$ $M_a = \text{Density} \times \text{Volume}$ $M_a = 1.2 kg/m^3 \times 0.024 m^3$ $Q_p = M_a Cp_a (T_2 - T_1)$ $Q_p = 0.0288 \times 1005 (29.5 - 22.3)$ $Q_{cooling} = \frac{208.39J}{1080secs}$ $Cop = \frac{Q_{cooling}}{P_o} = \frac{0.19}{38.4}$	$P_o = 38.4W$ $M_a = 0.0288kg$ $Q_p = 81,646.5J$ $Q_{cooling} = 0.19W$ $Cop = 0.05$

$$Q_{cooling} = \frac{Q_p}{\Delta T} \tag{10}$$

2.4.2 Heat sink selection

The efficiency of the heat sink has a significant influence on the heat pumping capability of the thermoelectric module. The hot side of the module must interface with an efficient heat removal system in order to achieve a useful temperature differential across the thermoelectric module. Natural convection type, forced convection type, and liquid cooled are three of the most common variety of heat sinks. Thermal resistance varies among the different types and sizes of sinks in which natural convection being the least efficient and liquid cooled the most efficient. Most of thermoelectric cooling applications use forced convection heat sinks with thermal resistance values (R_{ht}) ranging from $0.10^{\circ}\text{C}/\text{W}$ to $0.50^{\circ}\text{C}/\text{W}$. Using the known values for T_a , V_o , I_o , and Q , R_{ht} is solved to determine if it is reasonable as expressed in equations (11 – 12) [16].

$$R_{ht} = \frac{T_h - T_a}{V_o \times I_o + Q_T} \tag{11}$$

R_{ht} = Thermal resistance of heatsink in $^{\circ}\text{C}$ temperature rise per Watt dissipated

$Volume_{heatsink} = \frac{\text{Volumetric resistance}(Cm^3 \text{ } ^{\circ}\text{C}/\text{W})}{\text{Thermal resistance } (^{\circ}\text{C}/\text{W})}$ (3.12)

$$Q_H = P_{tec} + Q_T \tag{12}$$

Q_H = Total heat to be dissipated from system

P_{tec} = Power of Peltier module

2.4.3 Design assumptions

1. Temperature to be maintained inside Cabin $T_c = 5^{\circ}\text{C}$
2. Outside temperature or ambient temperature $T_a = 25^{\circ}\text{C}$
3. Temperature difference between the cabin walls = $25 - 5 = 20^{\circ}\text{C}$
4. The rise of temperature of the heat sink to be not more than about 15°C above ambient. This would give a thermoelectric module hot side temperature of about 40°C . Therefore, $T_h = 25^{\circ}\text{C} + 15^{\circ}\text{C} = 40^{\circ}\text{C}$

Table 1 present the design calculations, while Tables 2 – 4 presents specification of the cooling fan, an approximate range of volumetric resistance and specification of model respectively.

Table 2 Specification of cooling fan

Brand:	Intel E97379-003
Voltage:	12V
Imax (A):	0.20A
Dimensions:	8.7cm x 8.7cm x 1.87cm
Speed:	2500rpm
Air Flow:	34.65CFM

Table 3 Range of volumetric resistance

Available Airflow (LFM)	Volumetric Resistance ($\text{cm}^3 \text{ } ^{\circ}\text{C}/\text{W}$)
NC	500 – 800
200	150 – 250
500	80 – 150
1000	50 – 80

The TEC module was selected by considering few factors such as dimensions, Q_T , power supply etc. The model number of the module is TEC1-12703. It is decided to select a TEC module which has a cooling power greater than the calculated cooling load. TEC1-12703 operates with an optimum voltage value of 12V. It has a maximum voltage of 15.4V. At 12V it draws a maximum DC current of 3A. The nominal power rating or the cooling power is 60 W. It has a maximum operating temperature of 200°C as shown in Table 4.

Table 4 Specification of module

Peltier model (TEC1-12703)	Description
Maximum current, Imax	3A
Maximum voltage, Vmax	15.4V
Qmax	60 W
Maximum temperature difference, ΔT_{max}	200°C
Number of the thermocouples, n	127
Material	Ceramic/Bismuth Telluride
Thickness	0.0038 m
Length	0.04 m
Width	0.04 m
Seebeck coefficient (α)	$\alpha_p = 2.2 \times 10^{-4} \text{ V/K}$ $\alpha_n = 2.2 \times 10^{-4} \text{ V/K}$
Electrical resistivity (ρ)	$\rho_p = 1.2 \times 10^{-2} \text{ cm}$ $\rho_n = 1.2 \times 10^{-2} \text{ cm}$
Thermal conductivity (k)	$K_p = 1.62 \times 10^{-2} \text{ W/cmK}$ $K_n = 1.62 \times 10^{-2} \text{ W/cmK}$

2.5 Construction Implementation

Figure 4 present the detail construction implementation of the proposed mini refrigerator.

The design for the experimental system is described below. The cooling chamber is designed to a size of 38.7cm in length, 36.cm in width and 28.5cm in height. This provides a 24 liters cooling space. The outside walls are made of plank material while the walls of the cooling chamber are made of white aluminum sheet. This enables the temperature of the chamber to be uniform. Separating the outside and inside wall is a polyfoam insulated material to



Fig. 4. Image (Isometric view) of Fabricated Deep Freezer

to prevent external heat from entering the refrigerator so that the refrigeration process should not be affected. Below the cooling chamber is a space designed to house the battery and the charge controller. The door which is made of the same materials as the walls of the refrigerator also has rubber bands at the terminals. This enables it to have solid contact with refrigerator wall to which it is in contact. The rubber bands also seal the air spaces and prevent the ambient air or heat from entering the cooling chamber.

The Peltier module is electrically connected to the power source using cables. At the bottom base of the refrigerator, there are two hubs for connecting a module. A toggle switch is also provided at the front, to either connect or disconnect the system from the supply. Inside the chamber is a 12V LED lamp to indicate the system is powered.

3. RESULT AND DISCUSSION

An experimental performance analysis on fabricated thermoelectric refrigerator was conducted. The cold end (evaporator) of the thermoelectric module was used in the system to cool the refrigerator cabin and a digital thermostat is used to measure the temperature. The hot end (condenser) is attached to a heat sink for heat rejection. In order to validate the performance of the system cool down experiment was conducted on the system.

3.1 Cool Down Test

For analyzing the performance of system, water load is considered as the active heat load to the system. Deep freezer was tested when empty. The cabin temperature at 29.5°C was tested before switching ON the system. The temperature at every 2min interval was tabulated. The readings were recorded for 18mins. The Figure 5 shows the variation of temperature with time in the given setup.

Even though the conventional system is mainly designed to maintain a fixed temperature, the above cool

down experiment has proved that the system can be adapted for sensible cooling also. The lower steady temperature was attained around 22.3°C at a time of 18 minutes. It took about 18 minutes to attain the same from 29.5°C (ambient temperature). The Table 5 shows the result of the given setup for the cool down test of the cabin with time.

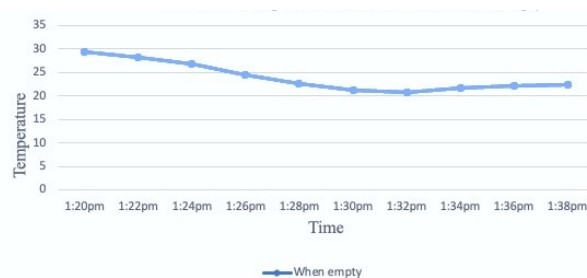


Fig. 5. Variation of Temperature with time when empty

Table 5 Result of cool down test

Time	Temperature Cabin Test (empty) °C
1:20pm	29.5
1:22pm	28.2
1:24pm	26.8
1:26pm	24.5
1:28pm	22.6
1:30pm	21.2
1:32pm	20.8
1:34pm	21.7
1:36pm	22.1
1:38pm	22.3

3.2 Performance of the Thermoelectric Refrigerator

The active heat load is expressed as the equivalent cooling power that the unit will need to provide when the sample at ambient temperature is placed in the container. It was decided that air at room temperature (when compartment is empty) took as the test sample. When the designed thermoelectric refrigerator was tested, it was found that the inner temperature of the refrigeration area was reduced from 29.5°C to 22.3°C in approximately 18mins. Coefficient of performance of the refrigerator (COP) was calculated using equations (7, 9 & 10). In these calculations, the properties of air are (density = 1.2 kg/m³ and CP = 1005 J/kg), V = 0.024 m³. Coefficient of performance (COP) was calculated to be 0.05.

4. CONCLUSION

A mini-Peltier cooler was fabricated by using a thermoelectric Peltier cell coupled with fan-cooled heat sinks. The use of Peltier thermoelectric module has the big potential to replace the oversized conventional vapor refrigeration in designing a mini cooler for specific applications. A 24litres chamber was designed that utilizes the Peltier effect for cooling. The thermoelectric refrigerator was constructed to regulate its temperature between 5-25°C with the aid of an XH-W3001 temperature controller connected with the peltier element, heatsink and fan assembly and a 12V power supply which all acted to aid in the cooling of the designed 24litres chamber which was made from medium density fiber board (outer body), polyurethane foam (insulation) and aluminum sheet (refrigeration chamber). Performance evaluation was carried out on the refrigeration system air acted as the test sample as. The properties of air are (density = 1.2 kg/m³, CP = 1005 J/kg) and V = 0.024 m³. The minimum temperature reached was found to be 22.3 °C from a temperature of 29.5°C and Coefficient of performance (COP) was calculated to be 0.005.

AUTHOR INFORMATION

Corresponding Author

*Email: puokorie@abu.edu.ng

ORCID

P.U. Okorie : 0000-0002-7166-6745

N. Faci : 0009-0007-6576-0739

REFERENCES

- [1] Harivardhanreddy, B., Harivardhanreddy, M., Prashanth, M., & Amoodi, S. M. (2018). Design and Analysis of Solar Refrigeration Using Peltier Plate.
- [2] Yadav, H., Srivastav, D., Kumar, G., Yadav, A. K., & Goswami, A. (2019). Experimental investigations and analysis of thermoelectric refrigerator with multiple peltier modules. *Int. J. Trend Sci. Res. Dev*, 3, 1337-1340.
- [3] Ivanov, K., Aleksandrov, A., & Belovski, I. (2019). Synthesis and Study on Waste Heat Thermoelectric Generator. In 2019 II International Conference on High Technology for Sustainable Development (HiTech) (pp. 1-4). IEEE.
- [4] Remeli, Muhammad Fairuz, Nurfarah Ezzah Bakaruddin, Syahar Shawal, Hazran Husin, Muhammad Fauzi Othman, and Baljit Singh. "Experimental study of a mini cooler by using Peltier thermoelectric cell." In IOP Conference Series: Materials Science and Engineering, vol. 788, no. 1, p. 012076. IOP Publishing, 2020.
- [5] Tamami, F., Doyan, A., Ayub, S., & Hudha, L. S. (2022). Designing and constructing mini refrigerator with thermoelectric module. In *Journal of Physics: Conference Series* (Vol. 2165, No. 1, p. 012032). IOP Publishing.
- [6] Suryawanshi, D., Pokharkar, N., Pokale, V., & Walgude, A. (2016). Design and Fabrication of Thermoelectric Refrigerator for Liquid Cooling by Automatic Temperature Micro-Controller. *International Journal of Science Technology & Engineering*, 3, 21-27.
- [7] Wang, X., Suwardi, A., Lim, S. L., Wei, F., & Xu, J. (2020). Transparent flexible thin-film p-n junction thermoelectric module. *NPJ Flexible Electronics*, 4(1), 19.
- [8] Dongare, V. K., Kinare, R. V., Parkar, M. H., & Salunke, R. P. (2018). Design and development of thermoelectric refrigerator. *International Research Journal of Engineering and Technology*, 5(4).
- [9] Gupta, Satya Prakash, Sanjeev Kumar Soni, Aamir Siddique, Afzal Ali, Tauqueer Alam, Sahzad Ansari, and Zeeshan Ali. "Design and development of thermoelectric refrigerator." *Invertis Journal of Renewable Energy* 8, no. 4 (2018): 194-196.
- [10] Abdelmessih, A., Alvarez, A., Gonzalez, J., Gooch, T., Gutierrez, A., Magana, K., ... & van Haaster, J. (2020, October). Personal Heating/Cooling System Using Peltier. In *International Electronic Packaging Technical Conference and Exhibition* (Vol. 84041, p. V001T05A004). American Society of Mechanical Engineers.
- [11] Ab Rahman, R., Mohamad, M. A. H., Kaamin, M., Batcha, M. F. M., Mazlan, M. D. A., Rosli, M. L., & Aziz, M. A. A. C. (2022). Experimental study of Peltier -Based Thermoelectric Cooling Box System. *Journal of Advanced Research in Applied Mechanics*, 94(1), 1-6.
- [12] Ebong, D. N., Kaze, C. V. A., & Ngouateu, A. P. (2022). Design and implementation of solar powered mini refrigerator using thermoelectric cooler module. In *E3S Web of Conferences* (Vol. 354, p. 01007). EDP Sciences.
- [13] Vinarao, R. C. D. (2022). Design and Development of Portable Chest Fridge Using Peltier Module. *The Vector: International Journal of Emerging Science, Technology and Management (IJESTM)*, 31(1).
- [14] Zoui, M. A., Bentouba, S., Stocholm, J. G., & Bourouis, M. (2020). A review on thermoelectric generators: Progress and applications. *Energies*, 13(14), 3606.

- [15] Chen, J., Li, K., Liu, C., Li, M., Lv, Y., Jia, L., & Jiang, S. (2017). Enhanced efficiency of thermoelectric generator by optimizing mechanical and electrical structures. *Energies*, 10(9), 1329.
- [16] Praveen, B., Pranay, S., Jhabarmal, S., Mechanical, R. P. B. A., & Group, and O. Institutions. (2018). Fabrication of Portable Solar Thermo Electric Refrigerator by Liquid Cooling. *Int J Sci Resin Sci Technol*, 4, 248-255.



This article is licensed under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).