DESIGN AND FABRICATION OF PELTIER EFFECT COOLER

Thesis submitted for the undergraduate degree in Mechanical Engineering
at the
University of Central Punjab

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Session 2019-2023
Department of Mechanical Engineering,
University of Central Punjab, Lahore, Pakistan

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ABSTRACT

We are currently confronted with numerous challenges such as energy crises and environmental degradation caused by the escalating emission of carbon dioxide and depletion of the ozone layer. These issues have become a primary concern for both developed and developing nations. However, our project offers a solution that eliminates the need for refrigerants, compressors, or prime movers.

Our project focuses on showcasing the performance of a refrigeration system that utilizes the Peltier module. Thermoelectric modules play a crucial role in this refrigerator by providing thermoelectric cooling. The system comprises components such as the Peltier module, heat sink, battery, thermocol box, and others. Power consumption is a significant concern, but semiconductors present an excellent solution in addressing this issue. The Peltier module stands out as one of the best solutions for minimizing power consumption. In our project, we employ the Peltier module to cool one side while the other side becomes hot, dissipating heat into the environment with the assistance of fans. This results in a cooling effect without the use of greenhouse gases, contributing to a reduction in global warming typically associated with traditional refrigeration systems. The system operates on DC power and achieves a cooling temperature of up to 5°C. The inclusion of a charge controller ensures efficient system output. These advantages highlight the benefits of our system over conventional approaches. Notably, our system does not contain any moving parts, rendering it rugged and reliable. It can be highly compact, surpassing the size of compressors. Additionally, the system is portable and cost-effective. The incorporation of the Peltier module into our daily lives helps save electricity and reduce power consumption.

DEDICATION

To Allah S.W.T, The Most Gracious, The Most Merciful for His Guidance and Blessing.

Without His blessing, I may not get to where I stand today.

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LIST OF ABBREVIATIONS AND ACRONYMS

CEP	Complex Engineering Problem
CFC	Chlorofluorocarbon
COP	Coefficient of Performance
DC	Direct Current
EMF	Electromotive Force
PEC	Peltier Effect Cooling
TE	Thermo-Electric
TEC	Thermo-Electric Cooling
UN SDGs	United Nation’s Sustainable Development Goals

CHAPTER ONE: INTRODUCTION

1.1 Background History

Few decays before, new cooling devices introduced which were called semiconductor coolers that use the Peltier effect. A Thermo-Electric device called a Peltier module, based on semi-conductor heat pump that absorbs heat from one side and emits it from the other.

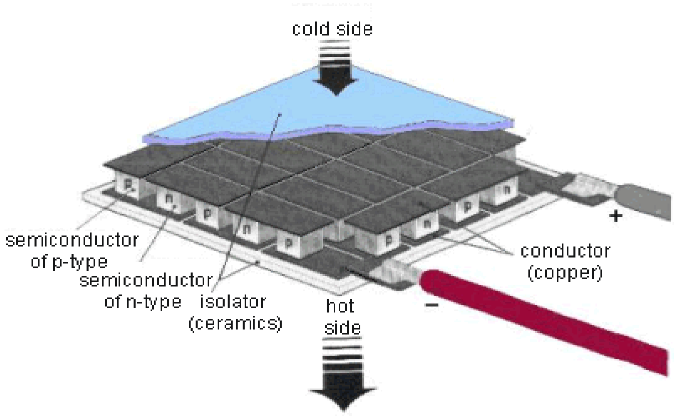

Figure 1. The PEC Module

In the 19th century, a watch-maker from France made a significant discovery known as the Peltier module. This module operates on a solid-state principle and utilizes different semiconductor materials, specifically P-type and N-type, to generate heat transfer. In the past, thermoelectric devices incorporating the Peltier module were employed in medical devices, sensor technology, and cooling integrated circuits. The performance of the Peltier module is typically assessed based on its heat dissipation capacity, heat dissipation characteristics, and the maximum temperature difference it can achieve given a specific DC voltage and applied current. Another notable feature of the Peltier module is its heat dissipation polarity, which changes when the direction of the applied current is altered. This means that the module has the ability to both cool and heat an object within the same setup, depending on the current polarity.

When using the Peltier module, it is essential to evaluate its heat dissipation rate based on the information provided in the module's data sheet, typically provided by the manufacturer such as TE Technology, Inc. The system must maintain a temperature difference to ensure proper heat dissipation and to uphold the module's COP (Coefficient of Performance) performance. Therefore, it is important to consider the development of heat sinks that meet the performance requirements for this project. Copper and aluminum are the primary materials used for heat sinks due to their high thermal conductivity and resistance properties.

While implementing Peltier cooling with copper or aluminum heat sinks may be costly for prototypes, this cooling method offers advantages over existing compressor-based cooling systems, making it a worthwhile consideration. This project includes a detailed analysis of the selection of the Peltier module and the heat sink. The prototype design of the project is based on the principle of air-to-air or liquid-air thermal cooling, aiming to effectively remove heat from the surrounding environment.

A thermoelectric concept is used in Peltier Effect. Our aim in this project is to design a cooling effect that is easy affordable by the user especially in Pakistan. A design purpose of this prototype is to limit the spaces that can refrigerate item i.e., food items on demand.

By using thermoelectric cooling in the prototype design, it increases a chance of heat dissipation by attaching heat sink that offers very less thermal resistance. An increase in temperature difference of Peltier system caused by failure of these mechanisms, which then reduces the capacity to pump heat and contributes to the general failure of the thermoelectric device.

By increasing of Population, the pollution is increasing at higher rate day by day. The Thermoelectric system is eco-friendly, compact in size consumes less energy so easily affordable by users as compare to compressor driven refrigerators. Both cooling systems are responsible for alarming. The main cause of global warming is the release of greenhouse gases into the atmosphere. Although research is ongoing, better alternatives to CFC refrigerants are still being sought. Therefore, it better to introduce other cooling resources other than conventional air conditioners, other products should be developed that can cool a person efficiently.

1.2 Problem Statement

This prototype is about designing of refrigeration system for small uses with a confined space that does not use conventional refrigerators (e.g., water or gas) as the thermal medium. The Peltier effect has solved the problems of energy consumption, vibration and maintenance. The Peltier effect can be effectively exploited on a microscopic level where other conventional cooling methods fail due to low or no power availability. It could be easily deployed in remote and rural areas where the best available power source is solar power.

1.3 Objective and Scope

Acknowledging the significance of this project and its eventual outcome is crucial. For this purpose, to describe the key point to achieve goal in this project is important. The scopes of work of this project are:

- Design and simulate the overall circuit for the thermoelectric cooling.
- Design and construct a prototype of a portable container having confined space which can heat or cool items as required.
- To assess the efficacy, efficiency, environmental impact, comfort, and convenience of the TEC, it is imperative to conduct tests.

1.4 CEP Attributes

Following are the Attributes that align with our project:

Table 1

Complex Engineering Problem Attributes

WP1	**Depth of knowledge**	**WK3 – Engineering Fundamentals** **WK4 - Engineering Knowledge** **WK8 - Research Literature**
WP2	Range of conflicting requirements	Use of only locally available material Cost
WP3	Depth of analysis required	Peltier Effect Refrigeration
EP1	Consequences (Professional Competency)	Testing (Effect of ERV on cooling load and power consumption)

1.5 UN SGDs

Following are the UN SGDs attributes that align with our project:

- **3 Good Health and Well-Being**
- **7 Affordable and Clean Energy**

Figure 2. United Nation's Sustainable Development Goals

CHAPTER TWO: LITERATURE REVIEW

2.1 Importance of Peltier Device

The global energy crisis has long been a significant issue, especially with the growing demand for energy. There is a pressing need for appliances that consume less power to address this concern. Traditional appliances like refrigerators and heaters typically consume a substantial amount of energy, ranging from 200W to 1500W. To address this challenge, the proposed model is based on the utilization of the Peltier effect and specifically employs a Peltier module (TEC1-12706). This module enables cooling on one side and heating on the other, depending on the supplied voltage bias. Furthermore, to enhance heating efficiency, the concept of incorporating a Fresnel lens heat collector is introduced. As a result, a model is proposed that serves both heating and cooling purposes while significantly reducing energy consumption, aligning with the goal of energy conservation. [1]

A household refrigerator that utilizes thermoelectric technology to produce ice cubes. To design this refrigerator, they developed a computational model that solves equations related to thermoelectricity, heat transfer, and phase change. The model takes into account inputs such as temperature-dependent thermoelectric parameters and boundary conditions (room temperature and voltage supplied to the Peltier module). As outputs, the model provides temperature values for all components of the thermoelectric ice-maker as well as the amount of ice produced. [2]

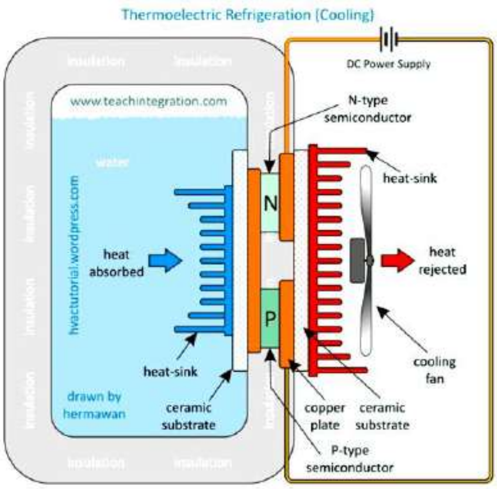

Figure 3. Thermoelectric Refrigeration

Several prototype thermoelectric refrigerators were analyzed, and their cooling capabilities were evaluated based on various factors including the coefficient of performance, heat-pumping capacity, and cooling rate. The coefficient of performance of a thermoelectric refrigerator was found to be around 0.3-0.5 when operating at a typical temperature of 5°C, with an ambient temperature of 25°C. Additionally, researchers investigated the potential enhancement of cooling performance by employing a realistic model and experimental data derived from their work. The results indicate that it is possible to improve the coefficient of performance by addressing issues such as module contact resistances, thermal interfaces, and the efficiency of heat exchangers. [3]

The challenges posed by global warming are addressed, emphasizing the growing demand for refrigeration in various fields such as air-conditioning, food preservation, vaccine storage, medical services, and cooling of electronic devices. This increased demand has resulted in higher electricity production and subsequently greater CO^2 emissions worldwide, contributing to climate change. To tackle this issue, thermoelectric refrigeration is presented as a promising alternative. It has the ability to convert wasted electricity into useful cooling, making it a valuable solution to current energy challenges. Thermoelectric refrigeration is particularly crucial for developing countries that require long-lasting and low-maintenance solutions. [4]

2.2 TEC Analysis

A compact and portable thermoelectric refrigerator powered by a Peltier element has been developed, built, and evaluated. The refrigerator box incorporates the Peltier element, along with fans placed on both sides. These conditions involve the ambient temperature and the voltages applied to both the fans and the Peltier element. The analysis focuses on the performance of the system under the obtained optimal conditions. [5]

An experimental study was conducted to examine the performance of a thermoelectric cooler box by testing different positions of the thermoelectric module. The cooling system of the cooler box included a TEC1-12706 thermoelectric module, a heat sink and fan, an inner heat sink, and a 360 ml water bottle. The thermoelectric module was positioned at the top of the cooler box to assess its impact on cooling efficiency. [6]

2.3 Solar Integration

A thermoelectric refrigeration system was designed and created, utilizing DC voltage generated by solar cells. An experimental investigation and analysis were carried out to evaluate its performance. The prototype consists of a thermoelectric module, an array of solar cells, a controller, a storage battery, and a rectifier. The system is designed to operate outdoors during the daytime using solar cells and the thermoelectric refrigerator, while during nighttime with access to AC power, it utilizes a storage battery, an AC rectifier, and the thermoelectric refrigerator. The experimental analysis primarily focused on assessing the unit's performance under sunny conditions. The examined refrigerator successfully maintains the temperature within the refrigerated space at 5-10°C, achieving a coefficient-of-performance (COP) of approximately 0.3 under the given conditions. [7]

A cost-effective thermoelectric refrigerator was designed and created to cater to the needs of people living in the desert region of Oman, where electricity is not readily available. To improve and expedite the heat transfer from the hot surface of the thermoelectric module, a finned surface (heat sink) was utilized. A cooling fan was employed to dissipate the heat from the hot side of the module into the surrounding environment. Based on the experimental data collected from running a single thermoelectric module, it was observed that a temperature difference of up to 26.6°C could be achieved at a current of 2.5 A and voltage of 3.7 V. The coefficient of performance (COP) of the refrigerator was calculated to be approximately 0.16. [8]

2.4 Use of TEC for Medical Purposes

A portable vaccine carrier box was designed, produced, and evaluated, incorporating a thermoelectric module and heat pipe. The cooling performance experienced a substantial improvement by utilizing the heat pipe as a heat sink on the hot side of the thermoelectric module. The vaccine carrier cabin achieved a minimum temperature of -10°C, indicating its capability to store vaccines at the desired temperature. [9]

2.5 Thermoelectric Beverage Chiller

Theoretical and practical examinations were performed on a thermoelectric beverage chiller, and a comparison was made between its cooling time and the cooling times of the freezer and cold compartments found in a standard household refrigerator. The findings revealed that in the freezer section of the refrigerator, the water temperature exhibited a linear decrease over time, while in the thermoelectric beverage chiller, the water temperature decreased exponentially as time advanced. [10]

2.6 Investigation on Small Scale

A practical investigation was carried out to evaluate the effectiveness of thermoelectric cooling devices designed for small-scale space conditioning applications in buildings. The researchers conducted a theoretical analysis to determine the optimal operational parameters, which were then applied in laboratory experiments. A TEC (thermoelectric cooling) unit was assembled and examined under controlled laboratory conditions. The findings indicated that by utilizing eight Ultra TEC modules, a maximum cooling capacity of 220W was achieved, with a coefficient of performance (COP) of 0.46. These outcomes were obtained with an input current of 4.8A for each module. [11].

Figure 4. Thermoelectric Cooler

2.7 Cooling Performance

The effectiveness of a thermoelectric ceiling cooling panel (TE-CCP) system, comprising 36 thermoelectric modules (TEM), in terms of cooling performance and thermal comfort, was assessed. In this system, the cold side of the TEM was attached to an aluminum ceiling panel to provide cooling to a test chamber with a volume of 4.5 m3. Heat dissipation was achieved by utilizing a copper heat exchanger that circulated cooling water on the hot side of the TEM modules. To determine thermal acceptability, the indoor environment was evaluated based on the 80% acceptability criteria specified in the ASHRAE Standard-55. Operating at a current flow of 1 A, the TE-CCP system demonstrated a cooling capacity of 201.6 W, resulting in a coefficient of performance (COP) of 0.82. The average indoor temperature was maintained at 27°C, and the indoor air velocity was recorded at 0.8 m/s, effectively meeting the acceptability criteria outlined in the ASHRAE Standard-55. [12]

2.8 Energy and Cost

Researchers carried out an experimental investigation to assess the effectiveness of thermoelectric cooling devices designed for small-scale space conditioning in buildings. They initially conducted a theoretical analysis to identify the most favorable operating conditions, which were then applied in laboratory testing. A TEC (thermoelectric cooling) unit was fabricated and examined within a controlled laboratory environment. The findings indicated that by utilizing eight Ultra TEC modules, the TEC unit achieved a maximum cooling capacity of 220W with a coefficient of performance (COP) of 0.46. These outcomes were obtained by supplying an input current of 4.8A to each module. [13]

CHAPTER THREE: RESEARCH DESIGN

In this chapter Design and work methodology, our plan to execute the procedure, material used their specifications section criteria and cost analyses are done.

3.1 Design and Fabrication Planning

The procedure and steps we are going to follow are as given:

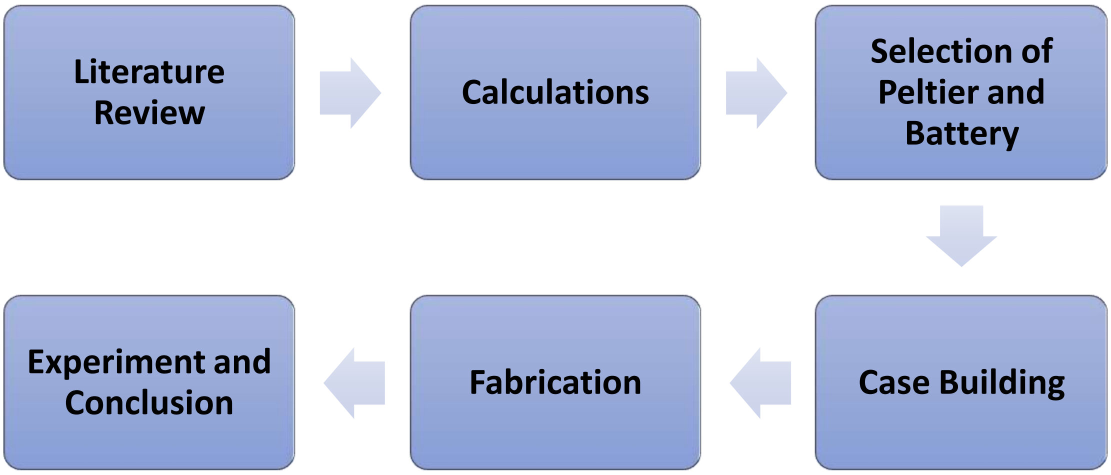

Figure 5. Design and Fabrication Plan

3.2 Mechanism used

3.2.1 Thermocouple

It is based on the Seebeck effect. According to the Seebeck effect, when two dissimilar metals are brought together to form two junctions, and when those junctions are held at different temperatures, an electromotive force is created that is directly proportional to temperature differential.

3.2.2 Peltier Effect

The converse of the Seebeck Effect refers to a phenomenon where the application of an electromotive force (E.M.F.) to two connected conductors generates an electric current. As these current passes through the junctions of the conductors, heat is released at one junction, resulting in cooling, while the other junction collects this heat.

3.3 Components

3.3.1 Peltier Device

These devices are employed to achieve controlled cooling or heating at a temperature below the surrounding environment. They operate based on the principle of the Peltier effect. Utilizing electrical energy, this device transfers heat from one side to another.

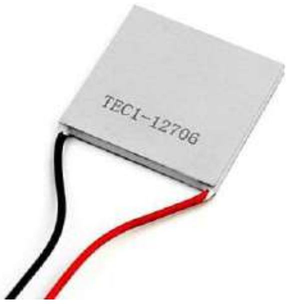

Figure 6. Peltier Device

3.3.2 DC Battery

This apparatus is utilized to induce fluid movement. It functions with the aid of a battery or alternative power supply. It incorporates vanes or blades that interact with the fluid. These components operate quietly and provide the flexibility to adjust the speed as needed.

Figure 7. DC Battery

3.3.3 Heat Sink

The purpose of this component is to move the warm air produced by this into the fluid medium, allowing the heat to be released from the system. A heat sink is commonly referred to as a heat reservoir as it absorbs a certain amount of heat from the system without significantly altering the temperature.

Figure 8. Heat Sink

3.3.4 DC Fan

This apparatus is utilized to generate a fluid motion. It functions through the utilization of a battery or another power supply. It contains vanes or blades that exert an effect on the fluid. These components operate quietly and provide the option to adjust the speed as needed.

Figure 9. DC Fan

3.3.5 Insulation Material

To optimize cooling, we have applied thermal insulation, such as thermocol or foam, to the device's sides. This reduces the risk of carbon dioxide and other greenhouse gases being released, which is a significant contributor to ozone depletion and other environmental issues.

Figure 10. Insulation Material

3.3.6 Temperature Sensor

A temperature sensor is an electronic device designed to measure the temperature of its surroundings. It converts the input data into electronic information, which can be used to record, monitor, or indicate any fluctuations in temperature.

Figure 11. Digital Temperature Sensor

3.4 CAD Designs of Parts

3.4.1 Peltier Module

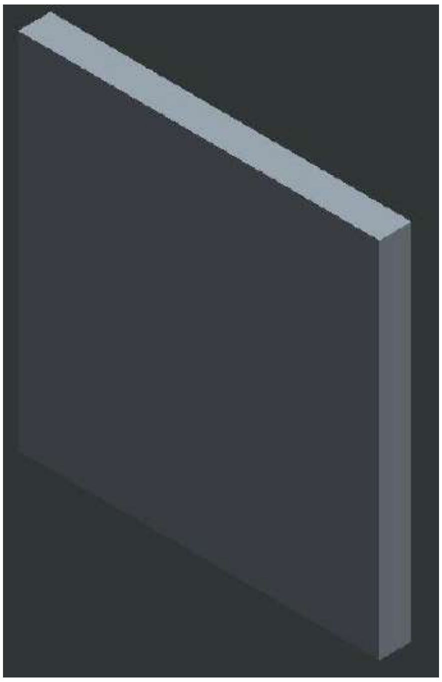

Figure 12. Peltier Module

3.4.2 DC Fan

Figure 13. DC Fan

3.4.3 Heat sink

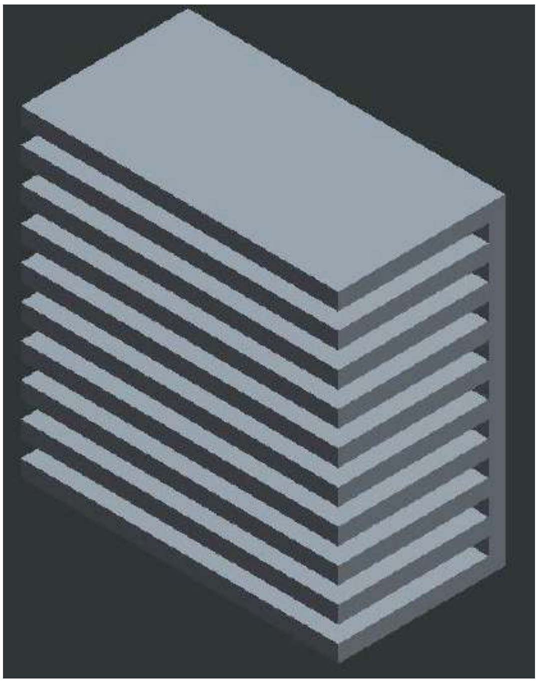

Figure 14. Heat sink

3.4.4 Upper Side

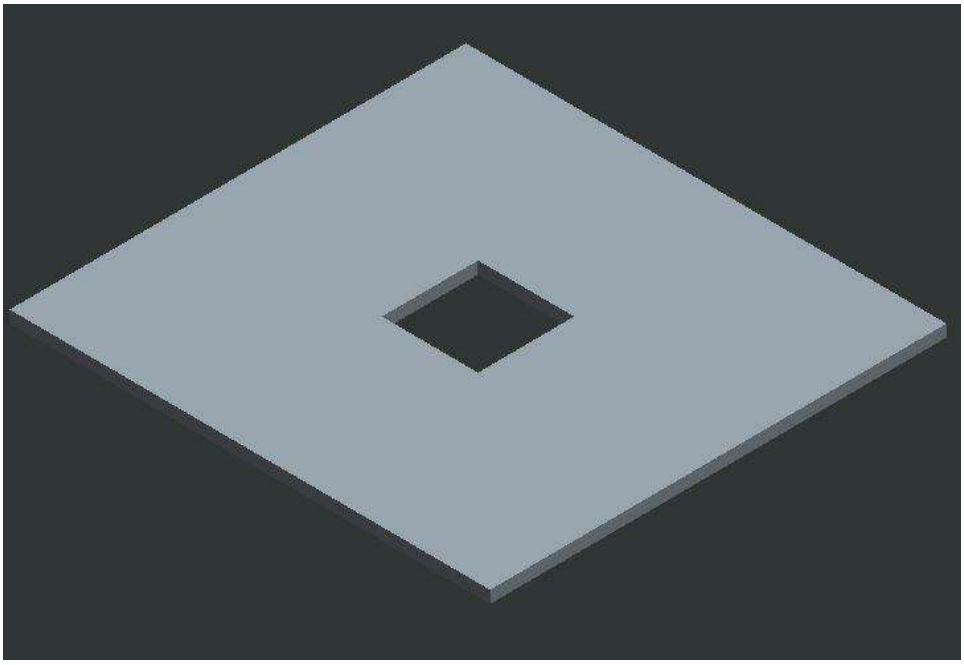

Figure 15. Upper Side

3.4.5 Lower Side

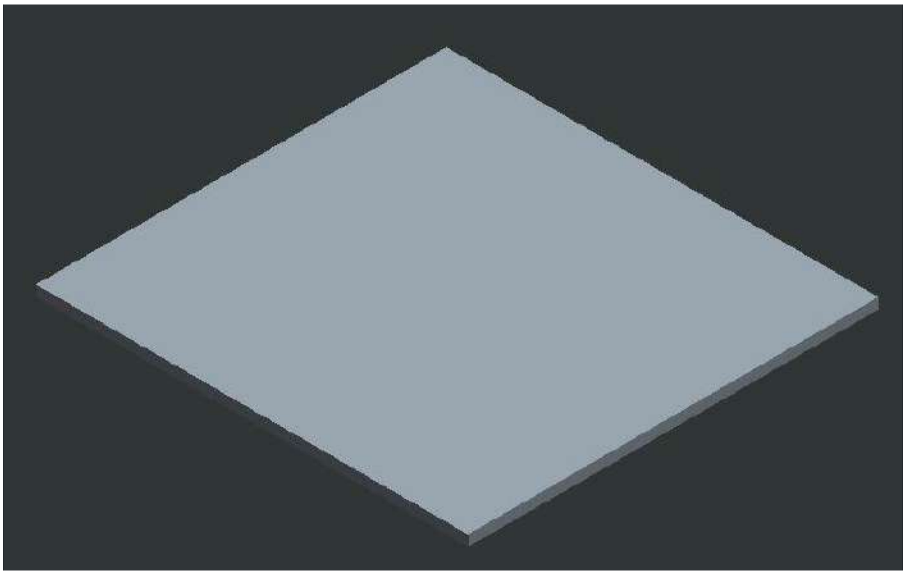

Figure 16. Lower Side

3.4.6 Right Side

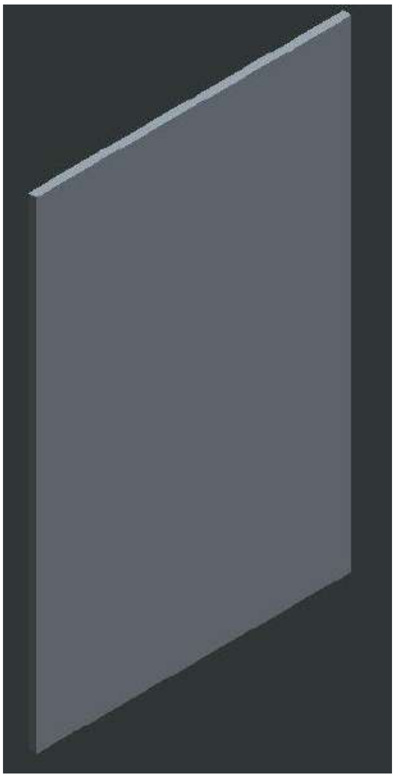

Figure 17. Right Side

3.4.7 Left Side

Figure 18. Left Side

3.4.8 Back Side

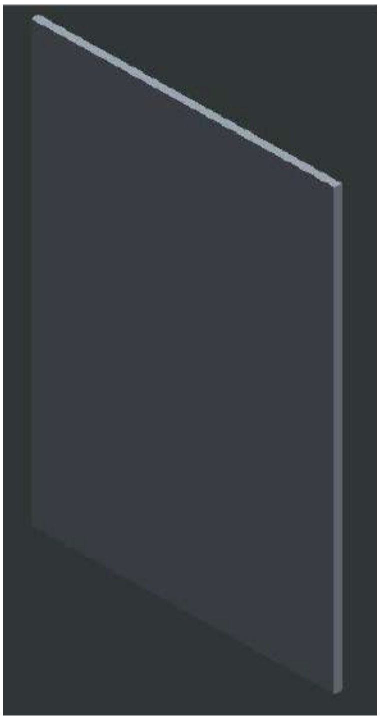

Figure 19. Back Side

3.4.9 Front Door

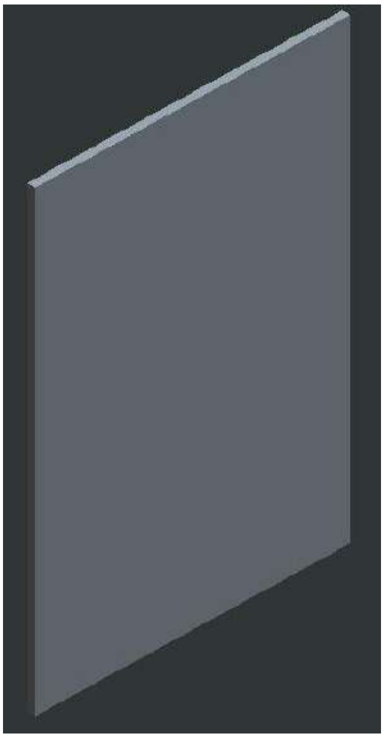

Figure 20. Front Side

3.4.10 Handle

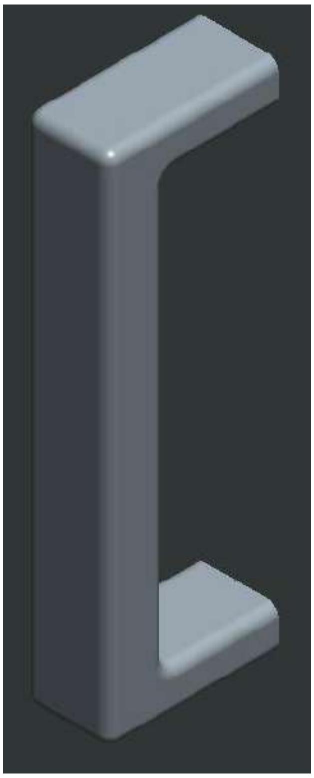

Figure 21. Handle

3.5 Assembly of Parts

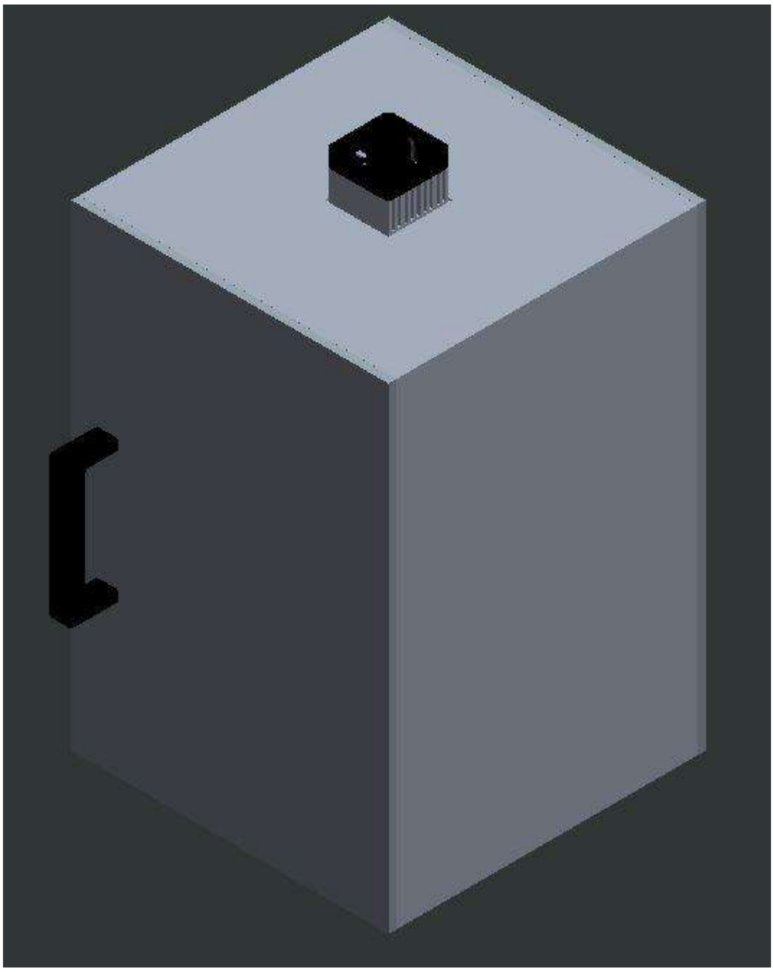

Figure 22. Assembly of Peltier Refrigerator

3.6 Extrude View of Assembly

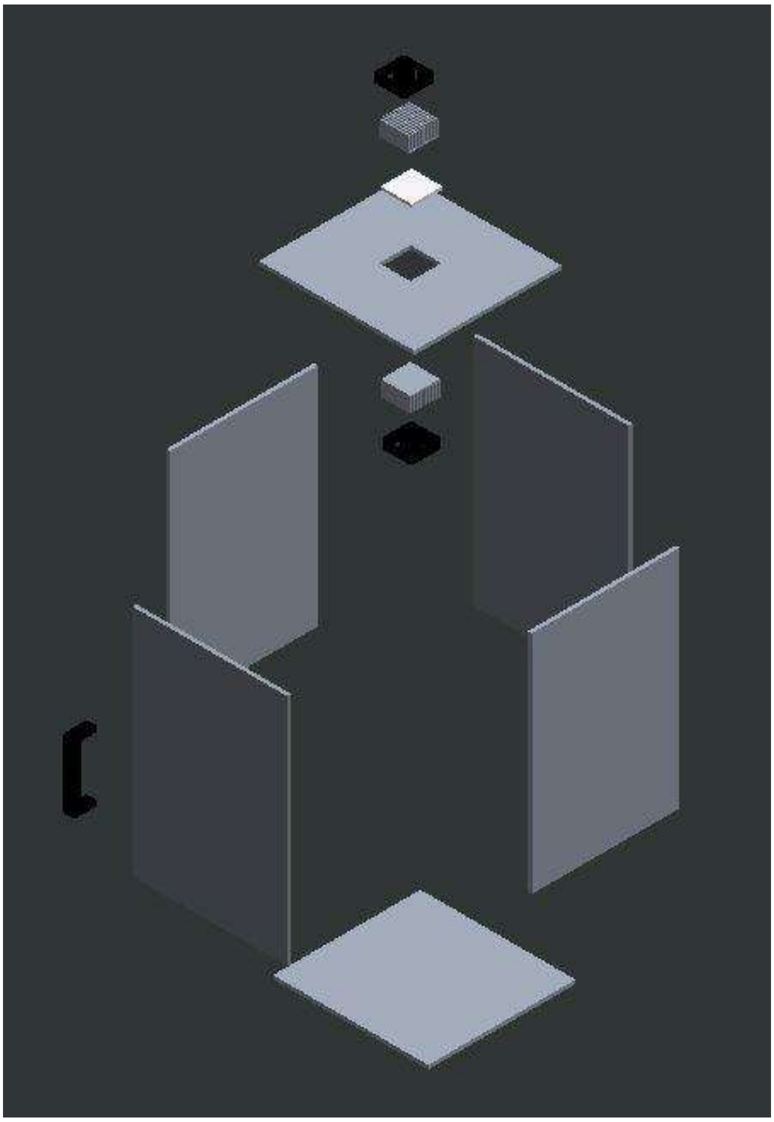

Figure 23. Extruded view of Assembly

CHAPTER FOUR: FINDINGS

4.1 Peltier Module

A Peltier Module, also known as a thermoelectric cooler or Sleuth, is a solid-state heat pump that utilizes the Peltier effect to transfer heat from one side of the device to the other when an electric current is applied. It was named after the French physicist Jean Charles Athanase Peltier, who discovered this phenomenon in 1834.

The Peltier effect is based on the principle that heat is either absorbed or released at the junction of two different conductors, depending on the direction of the electric current. The thermoelectric module of the Peltier device consists of two distinct types of semiconductors, typically n-type and p-type.

When the module is subjected to direct current, the current flows through the junction of the two semiconductor materials. As a result, heat is transferred from the cold side to the hot side of the module. This allows the Peltier device to function as a solid-state heat pump, providing heating or cooling depending on the direction of the electric current.

Figure 24. Peltier Module

4.1.1 Uses

There are many uses for Peltier devices; it includes the following:

In electronic devices like CPU coolers, beverage coolers, and refrigerators, Peltier devices are frequently utilized as thermoelectric coolers. The device or the surrounding environment can be cooled by removing heat from the cold side by running an electric current through it.

In scientific and industrial applications, such as maintaining stable temperatures in laboratory equipment or thermal cycling in DNA amplification (PCR), Peltier devices can be used to precisely control temperatures.

4.2 DC Fan

An electronic device that uses direct current (DC) electricity to produce airflow and provide cooling is referred to as a DC fan. DC fans are regularly utilized in different applications where a solid and effective cooling arrangement is required. They come in various sizes, going from little fans for gadgets to bigger fans utilized in modern settings.

The activity of a DC fan is generally straightforward. At the point when DC power is provided to the fan, it stimulates the fan engine, which comprises of loops and magnets. The connection between the attractive field and the curls makes the engine shaft turn, driving the fan sharp edges to turn. Air is drawn in from one side of the fan and expelled from the other as the blades rotate, resulting in airflow.

Figure 25. DC Fan (12V)

4.2.1 Advantages of DC Fan

DC fans offer a few benefits over different kinds of fans, for example, AC fans:

Due to their lower power consumption, DC fans are well-known for their energy efficiency. This can be especially important in applications or devices that use batteries and are concerned about conserving energy.

Using pulse width modulation (PWM) techniques or adjusting the voltage, DC fans can be easily controlled to operate at various speeds. When cooling requirements are lower, this adaptability enables quieter operation and precise control of the airflow.

DC fans are available in a variety of sizes, including small form factors for laptops, gaming consoles, and other small electronic devices.

DC fans are suitable for applications that require quiet operation, such as audio equipment, home theaters, or office environments, as they generally produce less noise than AC fans.

4.3 DC Battery

DC Battery is a device that, when needed, converts chemical energy stored in electrical energy into electrical energy. It is a self-contained power source that can generate direct current (DC) electricity and is portable.

One or more electrochemical cells are connected to one another in a battery. Positive and negative electrodes, typically made of various metals or materials, are embedded in an electrolyte solution in each cell. A chemical reaction takes place within the cell when a load is connected to the battery. This reaction causes electrons to flow from the negative electrode (anode) to the positive electrode (cathode) through the external circuit, resulting in an electric current.

Figure 26. DC Battery (12V)

4.3.1 *Applications of DC Batteries*

DC batteries are frequently utilized in a variety of applications, including:

Batteries power a large number of compact electronic gadgets, including cell phones, PCs, tablets, cameras, and handheld gaming consoles. These batteries, which are typically lightweight and small, supply the power these devices require to function without a power source.
The starting battery, which provides power to start the engine, and the auxiliary battery, which supplies electricity to the vehicle's electrical systems (such as lights, radio, and power windows) when the engine is not running, are both essential components of automobiles.

Batteries are utilized in environmentally friendly power frameworks, like sunlight-based chargers and wind turbines, to store abundance power created during times of low interest or high creation. When demand exceeds supply, this stored energy can be released.

In the event of a power outage, UPS systems use batteries to provide backup power. Critical equipment like servers, computers, and the infrastructure for telecommunications are all provided with a continuous and uninterrupted supply of power thanks to these systems.

4.4 Temperature sensor

A device that measures and detects temperature variations in its environment is known as a temperature sensor. It is used in a lot of different places, like HVAC systems, medical equipment, industrial processes, weather monitoring, and consumer electronics. Temperature sensors are fundamental for observing and controlling temperature levels to guarantee ideal execution, security, and solace.

Figure 27. Dual Temperature Sensor

4.4.1 Types of temperature sensors

There are many different kinds of temperature sensors on the market, each with its own operating principle and features. The following are some typical kinds of temperature sensors

Thermocouples are made of two disparate metals joined toward one side to shape an intersection. At the point when the intersection is presented to a temperature slope, it creates a voltage corresponding to the temperature distinction. Due to their long lifespan, wide temperature range, and adaptability to a variety of environments, thermocouples are widely used.

RTDs are temperature sensors based on the idea that electrical resistance changes as temperature increases. Most of the time, they are made of pure metals like platinum, and their resistance goes up with temperature in a predictable way. Compared to thermocouples, RTDs have a limited temperature range but offer high accuracy and stability.

Thermistors are resistors that change their resistance significantly with temperature and are temperature-sensitive. Typically, they are made of semiconductor or ceramic materials. Thermistors are savvy and deal high responsiveness and exactness over a restricted temperature range.

Infrared sensors recognize temperature from a distance by estimating the warm radiation discharged by objects. They are suitable for applications like temperature monitoring in hazardous environments and thermal imaging cameras for non-contact temperature measurements.

4.5 Power Calculation

Peltier voltage = 12 V

Peltier current = 6 A

Peltier power (P_{pel}) = P = $V \times I$ = 12 x 6

= 72 W

DC Fan voltage = 12 V

DC Fan current = 0.15 A

Power (P_{fan}) = P = $V \times I$ = 12 x 0.15

= 1.8 W

Power for two fans = 2 (1.8) = 3.6 W

Total power consumption = $P_{pel} + P_{fan}$

= 72 W + 3.6 W

Total Power consumption (P_{Total}) = 75.6 W

4.6 Coefficient of Performance (COP)

The effectiveness of the Peltier component is determined by its COP. The Coefficient of Performance (COP) is determined by dividing the heat absorbed at the cold side Q_L by the input power P_{pel} of the Peltier element. The COP is in principle the efficiency of the Peltier element when cooling.

$$COP = \frac{Refrigerant\ effect}{Power} = \frac{Q_L}{W} \quad (1)$$

Peltier Module (TEC1-12706) specifications:

Seebeck Constant (α) = 0.01229 V/k

Thermal-Conductivity (K) =0.1815 W/k

Resistance (R) = 4 Ω

Current (I) = 6 A

Temperature on hot side (T_h) = 70 ℃

Temperature on cold side (T_c) = 12 ℃

Temperature difference (ΔT) = ($T_h - T_c$) = (70 - 12) = 58 ℃

$$Q_L = [\alpha \mathrm{I} T_c - \tfrac{1}{2} I^2 \mathrm{R} - \mathrm{k}\,(T_h - T_c)] \quad (2)$$

Q_L = $[0.1229 \times 6 \times 12 - \frac{1}{2} 6^2 \times 4 - 0.1815 \times 58]$

Q_L = 81.64 W

$$Q_H = [\alpha \mathrm{I} T_c + \tfrac{1}{2} I^2 \mathrm{R} - \mathrm{k}\,(T_h - T_c)] \quad (3)$$

Q_H = $[0.1229 \times 6 \times 12 + \frac{1}{2} 6^2 \times 4 - 0.1815 \times 58]$

Q_H = 62.35 W

$$\mathrm{COP} = \frac{\text{Refrigerant effect}}{\text{Power}} = \frac{\mathrm{Q_L}}{W} = \frac{81.64}{75.6}$$

COP = 1.07

4.7 Calculation

4.7.1 Cooling capacity

Cooling capacity (Q_c) = $P \times COP = 75.6 \times 1.07$

= 80.89 W

4.7.2 Operating Conditions

T_{out} (Outside temperature)	= 40 ℃
T_{in} (Inside temperature)	= 20 ℃
Voltage	= 12 V
Current	= 6 A
Peltier coefficient (α)	= 0.02117
Cooling capacity (Q_c)	= 80.89W

$Q_{C_{actual}}$ = $(T_{out} - T_{in})\, I \times \alpha$ = $(40 - 20) \times 6 \times 0.01229$

$Q_{C_{actual}}$ = 1.47 W

$$\Delta T = \frac{Q_{C_{actual}}}{I \times \alpha} = \frac{1.47}{6 \times 0.01229}$$

$\boldsymbol{\Delta T = 19.93\ ℃}$

Therefore, the temperature difference achieved by the Peltier effect cooler operating at $20\ ℃$ is approximately $19.93\ ℃$.

This means that the cold side temperature would be around $0.07\ ℃$ $(20\ ℃ - 19.93\ ℃)$ under these operating conditions.

4.8 Testing

Table 2

Testing no. 1

Sr. No.	Variation of Temperature (°C)	Starting Time (in Mins)	Temperature difference
1	38	00	-
2	35	10	3
3	32	20	3
4	30	30	2
5	28	40	2
6	26	50	2
7	25	60	1

The temperature dropped to 25°C from 38°C in 60 minutes.

(Inner running temperature is 25°C)

Table 3

Testing no. 2

Sr. No.	Variation of Temperature (°C)	Starting Time (in Mins)	Temperature difference
1	38	00	-
2	34	10	4
3	30	20	4
4	27	30	3
5	24	40	3
6	22	50	2
7	20	60	2

The temperature dropped to 20°C from 38°C in 60 minutes.

(Inner running temperature is 20°C)

4.9 Costing

Here is the table of costing based on our project.

Table 4

Costing

Sr. No.	Item	Quantity	Unit Cost (PKR)	Total Cost (PKR)
1	Peltier Module	2	600	1,200
2	Fan	3	700	2,100
3	Heatsink	2	600	1,200
4	Battery	1	2,000	2,000
5	Thermopore	1	2,000	2,000
6	Temperature Sensor	1	1,000	1,000
7	Box Manufacturing	1	7,000	7,000
8	Others	-	8,500	8,500
-	**Total**	**-**	**-**	**25,000/-**

The table represents the costing breakdown for various components and items used in a project. Each item is listed along with its quantity, unit cost in Pakistani Rupees (PKR), and the total cost. It provides a comprehensive understanding of the overall expenditure required for the project, which is **25,000 (PKR).**

Figure 28. Fabricated Box (Front)

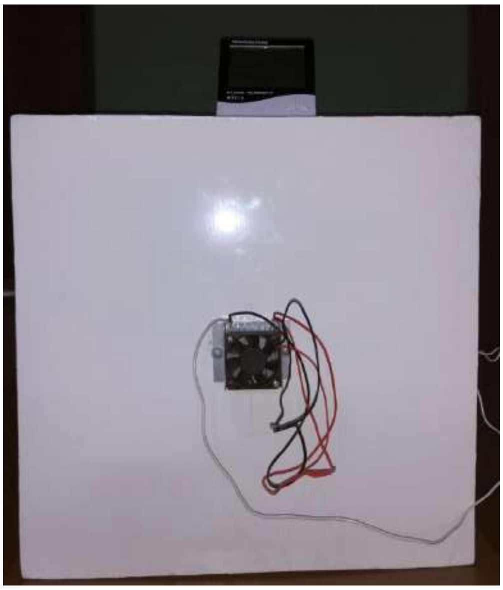

Figure 29. Fabricated Box (Back)

Figure 30. Inside View of Box

4.10 Results

The starting temperature at 00 minutes is 38°C.

- At 10 minutes, there is a decrease in temperature by 4°C, resulting in a temperature of 34°C. The temperature difference is calculated by subtracting the previous temperature (38°C) from the current temperature (34°C).

- At 20 minutes, there is another decrease in temperature by 4°C, resulting in a temperature of 30°C. The temperature difference is again 4°C, calculated by subtracting the previous temperature (34°C) from the current temperature (30°C).

- At 30 minutes, there is a further decrease in temperature by 3°C, resulting in a temperature of 27°C. The temperature difference is 3°C, calculated by subtracting the previous temperature (30°C) from the current temperature (27°C).

- At 40 minutes, there is a decrease in temperature by 3°C, resulting in a temperature of 24°C. The temperature difference is 3°C, calculated by subtracting the previous temperature (27°C) from the current temperature (24°C).

- At 50 minutes, there is a decrease in temperature by 2°C, resulting in a temperature of 22°C. The temperature difference is 2°C, calculated by subtracting the previous temperature (24°C) from the current temperature (22°C).

- At 60 minutes, there is another decrease in temperature by 2°C, resulting in a temperature of 20°C. The temperature difference is 2°C, calculated by subtracting the previous temperature (22°C) from the current temperature (20°C).

This data shows a gradual decrease in temperature over time, with consistent temperature differences of either 3°C or 2°C between each entry.

After conducting several rounds of testing, we ultimately succeeded in achieving the desired temperature of 20°C.

CHAPTER FIVE: DISCUSSION

Based on the testing table, we can observe the following:

The starting temperature of the cooler is 38°C at 00 minutes. This could be the initial condition before any cooling effect is applied.

As time progresses, there is a consistent decrease in temperature. This suggests that the Peltier effect cooler is effectively lowering the temperature.

The temperature difference column shows the change in temperature between each recorded time interval. The values indicate a gradual cooling effect, with a temperature difference of 4°C observed in the first two intervals, followed by 3°C and then 2°C for the subsequent intervals.

Based on this, we can infer that the Peltier effect cooler is successfully cooling the environment. The cooling effect seems to be consistent and progressive over time, as indicated by the decreasing temperatures and relatively stable temperature differences.

The performance of various prototype thermoelectric refrigerators was assessed, taking into account factors like the coefficient-of-performance, heat-pumping capacity, and cooling rate. At a standard temperature of 5°C and an ambient temperature of 25°C, the coefficient-of-performance of a thermoelectric refrigerator was observed to be around 0.3-0.5. [3]

The relevant literature on Peltier effect coolers reveals various studies that have investigated their design, performance, and applications. Common objectives in the literature include enhancing cooling efficiency, optimizing power consumption, and improving temperature stability. The project report aligns with these objectives and provides additional insights into the performance of Peltier effect coolers.

In terms of design and methodology, the project report describes the construction of the Peltier effect cooler. It is important to note that the literature has explored diverse designs, such as different arrangements of Peltier modules, heat sinks, and insulation materials.

The experimental results presented in our project report indicate a consistent temperature decrease over time, as reflected by the temperature variations and time intervals. This aligns with findings from similar studies in the literature.

Comparing the project's outcomes with those reported in the literature, the temperature differences observed in our project report are consistent with previous studies. The cooling effect is evident, as indicated by the decreasing temperatures over successive time intervals.

Our project report contributes valuable insights to the field of Peltier effect coolers. It highlights the feasibility of using Peltier modules to achieve temperature reduction, as observed in the consistent cooling effect demonstrated over time. The report serves as a starting point for future investigations, indicating the need for more comprehensive experiments to assess the performance and efficiency of the cooler under various conditions.

CHAPTER SIX: CONCLUTION AND FUTURE DIRECTION

This section presents the findings and conclusions derived from our project, along with an examination of the limitations encountered during the fabrication and testing phases. Additionally, it explores potential future directions that could be pursued to enhance the efficiency of our project.

6.1 Conclusion

This cooling system was designed and constructed using a thermoelectric air-cooling framework. The objective was to achieve air cooling using a DC power supply. The testing results demonstrated that the cooling system effectively cools the air within 60 minutes of operation, reaching the desired temperature. The TEC cooling design successfully reduced the ambient air temperature from 38°C to 20°C. The system was able to achieve a temperature difference of 20°C, meeting the project's target. This success indicates that the cooling system can be utilized in small household applications.

6.2 Limitations

Here is a brief summary of the limitations:

- Limited cooling capacity
- Long cooling time
- Unclear temperature stability
- Limited scalability
- Insufficient performance analysis
- Inadequate consideration of environmental impact

6.3 Future Directions

These are several potential future directions that can be explored to enhance the efficiency and capabilities of the Peltier.

Research and development efforts can focus on enhancing the cooling efficiency of Peltier effect coolers. This can involve optimizing the design of thermoelectric materials, improving heat dissipation techniques, and minimizing electrical losses.

Work can be done to increase the cooling capacity of Peltier effect coolers, allowing them to effectively cool larger or more demanding applications. This can involve advancements in thermoelectric material technology, module design, and electrical power management.

Addressing the high-power consumption of Peltier effect coolers is crucial. Future directions can explore strategies such as improving energy conversion efficiency, implementing advanced control algorithms for power management, and integrating energy-saving features into the cooler's design.

Incorporating smart features and capabilities into Peltier effect coolers can enable better monitoring, control, and optimization of cooling performance. This can include real-time temperature sensing, remote control options, and intelligent energy management systems.

While Peltier effect coolers are already used in various applications, there may be untapped areas where they can be effectively utilized. Future directions can involve exploring new industries and applications, such as medical devices, automotive cooling, aerospace systems, or renewable energy technologies.

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