

CONSTRUCTION AND PERFORMANCE TEST OF WATER COOLING SYSTEM USING PELTIER MODULE.

A Project
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A thesis report submitted to the department of Mechanical Engineering for the partial fulfilment of the award of degree of “Bachelor of Science in Mechanical Engineering.

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Declaration

This us hereby declared that this thesis or any parts of this thesis has not been submitted elsewhere for the award of any degree or diploma.

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Abstract

Water Cooling System is an emerging technology that utilizes the thermoelectric effect to achieve cooling without traditional refrigerants or mechanical compressors. Efficient cooling systems are crucial in various industries, from electronics and industrial processes to renewable energy and medical equipment. As the demand for higher-performance systems continues to grow, innovative solutions are needed to effectively dissipate heat and maintain optimal operating temperatures. This abstract provides an overview of the design, construction, and performance testing of water cooling system utilizing Peltier modules a project that addresses these pressing cooling challenges. By applying an electric current across dissimilar materials, a temperature difference is created, enabling heat absorption or release. This technology offers advantages such as compact size, silent operation, precise temperature control, and environmental friendliness. Applications range from residential to automotive and aerospace sectors, including cooling electronic components, small enclosures, car seats, and spacecraft. Challenges include lower cooling efficiency compared to conventional systems and higher initial costs. Ongoing research aims to enhance performance and cost-effectiveness, making Water cooling System amiable alternative for sustainable cooling solutions.

Table of Contents

	Page No
Declaration	i
Acknowledgement	ii
Abstract	iii
Table of Contents	iv
List of figures	v
Nomenclature	vi
 Chapter 1 Introduction	
1.1 General	1
1.2 Objectives:	2
 Chapter 2 Literature Review	
2.1 Background	3
2.2 Peltier module	5
2.3 Water Tank	6
2.4 Peltier cooling blocks	7
2.5 PVC Foam Board	8
2.6 Cooling Fan	9
2.7 Heat Sink	13
2.8 Circulating Pump	13
2.9 Thermal glue	15
2.10 Connecting Pipe	15
2.11 Power Supply (SMPS)	16
2.12 Reservoir Tank	18
2.13 Digital Thermometer	20
2.14 Glue Gun	22
2.15 Coolant	23
2.16 Silicon Gum	25
 Chapter 3 Methodology	
3.1 Working Process	28
3.2 Electrical Cycle	30
3.3 Mechanical Cycle	32
3.4 Schematic View of Our Project	35
 Chapter 4	
4.1 Temperature Analysis	36
4.2 Data Table	37
4.3 Graph of Temperature vs. Time	38

Chapter 5

5.1 Future scope of water cooling systems	39
5.2 Limitation	41
5.3 Cost analysis	41

Chapter 6

6.1 conclusion	43
6.2 Reference	44

List of figures

2.1 Peltier effects	3
2.2 Peltier module	5
2.3 Water Tank	6
2.4 Peltier cooling blocks	8
2.5 PVC Foam Board	9
2.6 Cooling Fan	11
2.7 Heat Sink	13
2.8 Circulating Pump	14
2.9 Thermal glue	15
2.10 Connecting Pipe	16
2.11 Power Supply (SMPS)	17
2.12 Reservoir Tank	18
2.13 Digital Thermometer	20
2.14 Glue Gun	22
2.15 Coolant	23
2.16 Silicon Glue	25

Chapter 3

3.1 Working Process	27
3.2 Electrical cycle	31
3.3 Mechanical Cycle	32
3.4 Schematic View of Our Project	35

Chapter 4

4.1 Data Table	37
4.2 Graph of Temperature vs. Time	38

Chapter 5

5.1 Table for cost analysis	42
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Nomenclature

- (a) LCD = Liquid crystal display
- (b) LED = Light Emitting diode
- (c) RTD = Resistance Temperature Detector
- (d) SMPS = Switched Mode Power Supply
- (e) PVC = Poly Vinyl Chloride
- (f) CPU = Central Processing Unit
- (g) GPU = Graphics processing unit
- (h) TIM = Thermal Interface Material
- (i) UV= Ultra violet
- (j) PCR = Polymerase Chain Reaction
- (h) GFS = Glass-Fused-to-Steel

Chapter 1

Introduction

1.1 General

Water Cooling systems rely on refrigerants and mechanical compressors to achieve cooling. However, concerns about environmental impact and energy efficiency have driven the exploration of alternative cooling technologies. Water Cooling System based on the thermoelectric effect, is a promising solution that offers potential advantages in terms of efficiency, compactness, and environmental friendliness. G. Pahl and W. Beitz [1]

In an era marked by the continuous evolution of technology and the increasing demand for high-performance systems, efficient cooling solutions have become paramount. The ability to dissipate heat effectively while maintaining optimal operating temperatures is a critical factor in ensuring the reliability and longevity of various devices and industrial processes. In this context, the project “Construction and Performance Testing of a Water Cooling System Using Peltier Modules” emerges as an innovative endeavor to explore and harness the potential of Peltier modules—a solid-state cooling technology.

The thermoelectric effect, also known as the Peltier effect, is the phenomenon where a temperature difference across a junction of dissimilar materials results in the generation of a voltage and the transfer of heat. In bottle type water cooling systems, this effect is harnessed to achieve cooling without the need for conventional refrigerants or moving parts.

The core component of a bottle type water cooling system is the thermoelectric module, consisting of multiple pairs of p-type and n-type semiconductor materials. When a direct current is applied to the module, heat is either absorbed from the surrounding environment or released depending on the direction of the current flow. This enables the system to create a cooling effect by absorbing heat from a desired space and dissipating it elsewhere.

Water cooling systems offer several advantages over traditional systems. Firstly, they have a compact and solid-state design, making them suitable for various applications where space is limited. They are also silent in operation since there are no mechanical components involved. Additionally, thermoelectric systems offer precise temperature control, allowing for better comfort and energy management. Moreover, they do not use refrigerants that contribute to ozone depletion or global warming, making them environmentally friendly. Gannon, Charles [3]

Despite these advantages, there are challenges associated with water cooling system. One significant challenge is the relatively low cooling efficiency compared to conventional refrigeration cooling technologies. The thermoelectric materials currently available have limited efficiency in converting electrical energy into cooling power. This results in higher energy consumption and limits their application in large-scale cooling systems. Furthermore, thermoelectric cooling systems tend to have higher initial costs, which can be a barrier to their widespread adoption.

To overcome these challenges, ongoing research and development efforts are focused on improving the performance and efficiency of thermoelectric materials, as well as optimizing system designs. Scientists and engineers are exploring advanced materials, such as nanostructure thermoelectric materials, and innovative approaches to enhance cooling efficiency. Additionally, efforts are being made to reduce manufacturing costs to make thermoelectric water cooling more economically viable.

In conclusion, Bottle Type water cooling system represents a promising alternative to traditional cooling systems. Its compactness, silent operation, precise temperature control, and eco-friendly nature make it an attractive option for various applications. Although challenges exist, ongoing advancements in materials and system optimization hold the potential for significant improvements in the efficiency and cost-effectiveness of thermoelectric air conditioning, paving the way for a more sustainable and efficient cooling technology.

1.2 Objectives:

The Objectives of the Project is given bellow:

- To Study about bottle type water cooling system.
- To know the construction of a bottle type water cooling system for research.
- To get the research result of the project.
- To Analyze the performance test of the project

Chapter 2

Literature Review

2.1 Background

In the relentless march of technological progress, our world has become defined by its ever-increasing capacity to generate heat. From the densely packed integrated circuits of our computers to the colossal machinery driving our industries, heat is the inevitable byproduct of power and performance. It's a challenge that transcends sectors, touching industries as diverse as electronics, manufacturing, renewable energy, and healthcare. In this context, cooling systems emerge as the unsung heroes, quietly working behind the scenes to ensure that our increasingly sophisticated and heat-generating systems can function optimally and reliably. The modern world runs on electricity, and the more powerful our electronic devices become, the more heat they generate. Consider the microprocessors that power our computers. As they become more powerful, with smaller transistors packed into the same silicon real estate, the density of electronic components on a single chip rises exponentially. The consequence is an astonishing concentration of heat in a tiny space. The same principle applies to graphics cards, servers, and even our Smartphone's. G. Pahl and W. Beitz [1]

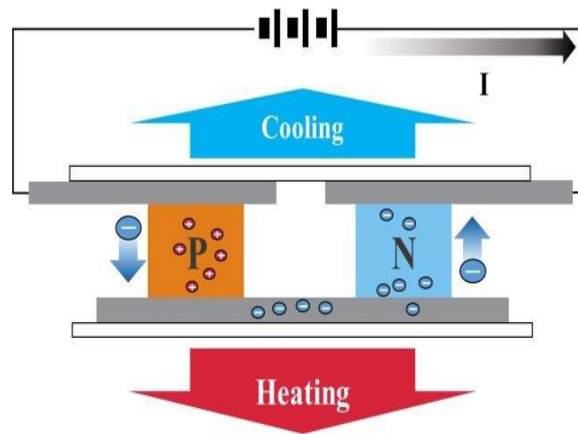


Figure: 2.1 Peltier effects

This phenomenon isn't confined to electronics alone. Across industries, machines and processes are becoming more energy-efficient, but they still generate substantial heat. Industrial processes such as metalworking, chemical manufacturing, and plastics molding rely on machinery that generates immense thermal loads. The renewable energy sector, which holds the promise of a greener future, faces its own thermal challenges. Solar panels absorb vast amounts of sunlight, converting it into electricity, but in the process, they heat up. Wind turbines, too, generate heat as they convert kinetic energy into electrical power.

In the realm of healthcare, precision cooling is a matter of life and death. Take magnetic resonance imaging (MRI) machines, for instance. These marvels of medical technology require

an ultra-stable operating environment with precise temperature control. Even slight fluctuations in temperature can result in distorted images and compromised diagnoses.

Combining the strengths of Peltier modules with liquid cooling systems presents an exciting frontier in cooling technology. Water cooling has already demonstrated superior thermal conductivity and efficiency compared to air cooling. By integrating Peltier modules into water cooling setups, we aim to harness the precise temperature control and heat transfer capabilities of Peltier technology while leveraging the thermal advantages of liquid cooling.

This project, “Construction and Performance Testing of a Water Cooling System Using Peltier Modules,” seeks to explore this innovative fusion of technologies. By designing, constructing, and rigorously testing water cooling system that incorporates Peltier modules, we aim to unlock a new level of cooling performance that can benefit a wide range of applications, from high-performance computing to industrial processes and beyond.

As we delve into the intricacies of this project, we embark on a journey to push the boundaries of cooling technology. The subsequent sections of this report will detail the design, construction, performance testing, and potential optimizations of our water cooling system. Through this endeavor, we aspire to contribute to the ever-evolving landscape of cooling solutions, where innovation meets the pressing needs of our heat-intensive world.

Apparatus Analysis:

2.2 Peltier module: The story of Peltier modules, also known as thermoelectric coolers (TECs), is a testament to the enduring quest for innovation and efficiency in the field of cooling technology. The history of Peltier modules can be traced back to the early 19th century, with the discovery of the thermoelectric effect by French physicist Jean Charles Athanase Peltier in 1834. **Discovery of the Thermoelectric Effect (1834):** Pelletier’s pioneering work unveiled what is now known as the Peltier effect, a fundamental thermoelectric phenomenon. He observed that when an electrical current passes through the junction of two dissimilar conductive materials, it causes one side of the junction to become cold while the other side becomes hot. This revelation laid the groundwork for the development of thermoelectric cooling technologies. Robin Roj[2]

Early Investigations and Applications (Late 19th Century): Pelletier’s discovery sparked scientific interest and further investigations into the properties of thermoelectric materials. Researchers explored the behavior of various materials, particularly bismuth and antimony alloys, which exhibited strong thermoelectric effects. These early studies contributed to the understanding of thermoelectricity and its potential applications.

World War II and Military Applications: The practical applications of thermoelectric technology gained momentum during World War II. Thermocouples, formed by connecting two dissimilar conductive materials, were employed for temperature measurement in military equipment. The need for compact and reliable cooling and heating solutions in military contexts spurred the development of thermoelectric cooling systems for various applications. Robin Roj[2]

Advancements in Materials (Mid-20th Century): Post-war developments in materials science led to the discovery of more efficient thermoelectric materials. Researchers identified materials with enhanced thermoelectric properties, including improved electrical conductivity and reduced thermal conductivity. These advances laid the foundation for the development of more efficient and practical thermoelectric devices, including Peltier modules.

Commercialization and Diverse Applications (Late 20th Century): The latter half of the 20th century witnessed the commercialization of Peltier modules and their integration into various industries. Peltier modules found applications in electronics cooling, where they were used to cool electronic components such as CPUs and GPUs. Their precise temperature control capabilities made them valuable in healthcare, with integration into medical equipment like MRI machines.

Renewed Interest and Contemporary Applications (21st Century): In the 21st century, a renewed interest in thermoelectric technologies emerged, driven by the demand for energy-efficient and sustainable solutions. Peltier modules found applications in renewable energy systems, efficiently cooling components like solar cells and thermoelectric generators. Their compact, solid-state nature made them suitable for aerospace applications, including cooling sensitive instruments on spacecraft.



Figure: 2.2 Peltier modules

Peltier modules offer several advantages such as compact size, silent operation, no moving parts, precise temperature control, and the ability to cool or heat localized areas. They find applications in various fields including electronics cooling, thermal management, temperature stabilization, portable refrigeration, medical devices, and energy-efficient systems. However,

they have lower efficiency compared to traditional refrigeration systems and are typically used for relatively small temperature differentials.

2.3 Water Tank: Bolted type water tanks, often referred to as bolted steel tanks, are an essential and widely-used solution for the storage of water in various applications. These tanks are constructed from individual steel panels that are manufactured with precision and then assembled on-site using high-strength bolts and gaskets. The use of durable materials and advanced coatings, such as galvanized steel or glass-fused-to-steel (GFS), ensures resistance to corrosion and extends the tank's lifespan, even in challenging environmental conditions.

One of the standout features of bolted type water tanks is their versatility and customization options. These tanks can be tailored to fit specific requirements, whether it's for residential, commercial, industrial, or municipal use. They come in various sizes, shapes, and capacities, making them adaptable to a wide range of site constraints and project needs. Gannon, Charles[3] Installation of bolted steel tanks is relatively straightforward and cost-effective, especially when compared to alternative water storage solutions. The bolted panel design allows for quick assembly and easy expansion or modification as storage requirements evolve over time.



Figure: 2.3 Water Tank

Moreover, these tanks require minimal maintenance, with routine inspections and occasional cleaning typically sufficient to ensure their continued performance.

Bolted type water tanks find application in diverse sectors. They serve as a vital component of municipal water supply systems, providing a reliable source of potable water for communities. Additionally, these tanks are instrumental in wastewater treatment plants, fire protection systems, industrial processes, agricultural irrigation, and more. Their durability, scalability, and

environmental compliance make them a trusted choice for safeguarding water resources and supporting critical infrastructure.

In conclusion, bolted type water tanks are a versatile, durable, and practical solution for water storage needs across various industries and applications. Their customizable design, ease of installation and resistance to corrosion make them a dependable choice for ensuring a consistent and safe water supply, whether for drinking, wastewater treatment, industrial processes, or agricultural use. These tanks play a pivotal role in water management and infrastructure development.

2.4 Peltier cooling block: A Peltier cooling block, also known as a thermoelectric cooling block, is a remarkable device that leverages the Peltier effect to achieve precise and efficient temperature control in various applications. This innovative technology combines the advantages of thermoelectric cooling with the compact form factor of a solid-state device, making it a valuable tool in industries ranging from electronics to healthcare.

At its core, a Peltier cooling block consists of one or more Peltier modules, which are semiconductor devices that exhibit the Peltier effect. When an electric current passes through a Peltier module, it creates a temperature differential across the module. One side of the module becomes cold, while the other side becomes hot. This bidirectional heat transfer capability allows Peltier cooling blocks to serve as both coolers and heaters, depending on the direction of the current. Taylor, R.A. [4]

The cold side of the Peltier cooling block is typically in direct contact with the target object or substance that requires cooling. This direct contact enables rapid and precise temperature control. Whether it's cooling sensitive electronic components, maintaining stable temperatures in medical equipment like PCR machines, or ensuring the optimal operating conditions for chemical reactions, Peltier cooling blocks offer a versatile and reliable solution.

One of the key advantages of Peltier cooling blocks is their ability to provide precise temperature control with minimal maintenance requirements. Unlike traditional cooling systems that rely on mechanical components like compressors and refrigerants, Peltier cooling blocks have no moving parts, making them robust and silent in operation. This inherent simplicity enhances their reliability and reduces the risk of system failures.

Moreover, Peltier cooling blocks are known for their compact and space-efficient design. Their solid-state nature and minimal footprint make them suitable for integration into various devices and systems where space constraints are a concern.

In summary, Peltier cooling blocks are a testament to the synergy between scientific discovery and practical application. By harnessing the principles of the Peltier effect, they provide precise and efficient temperature control in diverse industries and applications. As technology continues to advance, Peltier cooling blocks remain at the forefront of cooling solutions, offering a versatile and sustainable approach to temperature management.



Figure: 2.4 Peltier cooling blocks

Management in laboratory equipment, and beverage cooling devices. They offer advantages such as compact size, precise temperature control, and no moving parts. However, their cooling capacity is limited compared to traditional refrigeration systems, and their efficiency depends on factors such as ambient temperature and heat dissipation.

2.5 PVC Foam Board: Versatile and Durable Material for a Myriad of Applications

PVC foam board, also known as expanded PVC or Foamex, is a versatile and lightweight material widely used in various industries and applications. Composed of polyvinyl chloride (PVC) with added foaming agents, PVC foam board combines the durability of traditional PVC with the benefits of a foam core, making it a preferred choice for signage, construction, advertising, and creative projects. In this discussion, we will explore the key features, benefits, and applications of PVC foam boards. Xiong, Z., Zhang [5]

Composition and Structure:

- PVC foam boards are typically composed of a solid, closed-cell PVC sheet with a foamed core. This core provides excellent rigidity and insulation while reducing overall weight.

Advantages:

- **Lightweight:** One of the primary advantages of PVC foam boards is their lightweight nature. This makes them easy to handle, transport, and install, reducing labor and transportation costs.

- **Durable:** PVC foam boards are known for their durability and resistance to harsh weather conditions, moisture, chemicals, and UV radiation. This durability ensures a long service life, even in outdoor environments.
- **Versatility:** These boards are highly versatile and can be cut, shaped, and fabricated into various forms to suit specific project requirements.
- **Smooth Surface:** PVC foam boards have a smooth, consistent surface, which is ideal for printing, painting, or applying laminates and adhesives.
- **Fire-Resistant:** Many PVC foam boards are inherently fire-resistant, making them suitable for applications where fire safety is a concern.



Figure: 2.5 PVC Foam Board

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Applications of PVC Foam Board:

- **Signage and Graphics:** PVC foam boards are a popular choice for indoor and outdoor signage due to their smooth surface and ease of printing. They are often used for point-of-sale displays, exhibition stands, and promotional materials.
- **Construction:** In the construction industry, PVC foam boards are used for interior wall cladding, ceiling panels, and decorative trim due to their moisture resistance and ease of installation.
- **Advertising:** PVC foam boards serve as a substrate for advertising materials, including vinyl graphics, banners, and billboards.
- **Furniture and Cabinetry:** PVC foam boards are employed in the production of lightweight furniture, cabinets, and interior fixtures due to their durability and ease of fabrication.
- **Model Making:** Hobbyists and professionals use PVC foam boards for architectural models, prototypes, and dioramas because of their versatility and ability to hold intricate details.
- **Marine and Outdoor Applications:** PVC foam boards are used in marine settings for boat components, as they are resistant to saltwater and offer excellent weather ability.
- **Arts and Crafts:** PVC foam boards are a favorite among artists and crafters for their ease of cutting, painting, and gluing in creative projects.

Environmental Considerations:

- PVC foam boards are often recognized for their environmental friendliness. Many are recyclable and can be repurposed at the end of their lifecycle, reducing their environmental impact.

Customization and Printing:

- PVC foam boards readily accept printing, whether through direct UV printing, screen printing, or the application of adhesive vinyl graphics. Their smooth surface ensures vibrant and high-quality results.

In summary, PVC foam boards are a versatile and reliable material used in a diverse range of industries and applications. Their lightweight yet durable composition, along with resistance to harsh environmental conditions, makes them a preferred choice for signage, construction, advertising, furniture, and artistic projects. PVC foam boards have earned their reputation as a dependable material that combines form, function, and environmental considerations, making them a go-to solution for many professionals and hobbyists alike.

2.6 Cooling Fan: A cooling fan is an essential component when using a thermoelectric Peltier device for cooling applications. Thermoelectric Peltier devices operate on the principle of the Peltier effect, which enables the transfer of heat from one side of the device to the other when an electric current is applied. However, this process generates heat on the opposite side, requiring efficient heat dissipation. Sukesh Kumar[6]

A cooling fan serves the purpose of enhancing heat dissipation by facilitating airflow across the hot side of the Peltier device. The fan helps to remove the excess heat generated by the Peltier module and prevents overheating, ensuring optimal performance and longevity of the device. By directing a stream of air over the hot side, the fan aids in dissipating heat into the surrounding environment.

The fundamental principle behind cooling fans is convective cooling, which relies on the movement of air to remove heat. When an object, such as a computer processor or an industrial machine, generates heat during operation, a cooling fan is used to draw in ambient air and expel it over the hot components. This airflow enhances heat transfer, allowing the object to remain within safe temperature limits.



Figure: 2.6 Cooling Fan

Cooling fans are not only vital for electronics but also critical in many industrial processes and HVAC systems. In data centers, they prevent servers from overheating, ensuring uninterrupted operations. In automotive applications, cooling fans help regulate engine temperature. In manufacturing, they assist in keeping machinery cool during continuous operation, preventing costly downtime due to overheating.

As technology advances, so do cooling fan designs, with improvements in efficiency, noise reduction, and control mechanisms. Whether in your home computer or a massive industrial facility, cooling fans quietly work behind the scenes to maintain the temperature equilibrium of countless devices and systems. Their role in preventing overheating and ensuring reliable performance cannot be overstated.

Choosing an appropriate cooling fan is crucial to match the cooling requirements of the Peltier device. Factors such as airflow rate, static pressure, and noise level should be considered when selecting a fan. Additionally, the fan should be mounted securely to ensure effective heat transfer and proper airflow.

2.7 Heat Sink: A heat sink is a vital component when utilizing a thermoelectric Peltier device for cooling applications. A Peltier module operates by transferring heat from one side to the

other when an electric current is applied. However, this process generates heat on both the hot and cold sides of the module, necessitating efficient heat dissipation.

A heat sink is designed to maximize heat dissipation from the hot side of the Peltier module. It typically consists of a thermally conductive material with a large surface area and fins. The heat sink absorbs the heat generated by the Peltier module and dissipates it into the surrounding environment through conduction, convection, and radiation. ALAM, T. [7]

A heat sink is a crucial component in electronic devices and machinery designed to dissipate heat generated during operation. Its primary function is to maintain the temperature of electronic components within safe operating limits to ensure optimal performance and longevity.

Heat sinks are typically made from materials with high thermal conductivity, such as aluminum or copper, due to their ability to efficiently transfer heat away from the heat-generating component. The heat sink's design consists of fins or ridges that increase its surface area, allowing for better heat dissipation.

The heat sink's operation relies on the principle of thermal conduction. When an electronic component, like a CPU or GPU, generates heat during operation, it conducts the heat to the heat sink through a thermal interface material (TIM), such as thermal paste or a thermal pad. The heat sink then spreads this heat across its surface area, and the increased surface area facilitates the transfer of heat to the surrounding air. This process effectively cools down the component and prevents overheating.

Heat sinks come in various shapes and sizes, depending on the specific application and space constraints. Some heat sinks are compact and suitable for laptops and mobile devices, while others are large and designed for high-performance desktop computers or industrial machinery. Additionally, active cooling solutions, such as heat sink fans, can be added to further enhance heat dissipation by actively moving air across the heat sink's fins.

In summary, heat sinks play a critical role in maintaining the thermal stability of electronic devices. By efficiently dissipating heat generated by electronic components, they help prevent overheating, which can lead to reduced performance and even component failure. As technology continues to advance, heat sink designs and materials continue to evolve to meet the increasing thermal demands of modern electronics.

Choosing an appropriate heat sink involves considering factors such as the power dissipation of the Peltier module, size constraints, and thermal resistance. Proper installation and securing of the heat sink onto the hot side of the Peltier module are crucial for optimal heat transfer and overall cooling performance.

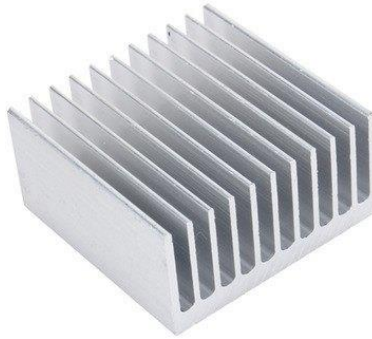


Figure: 2.7 Heat Sink

2.8 Circulating Pump: A circulating pump plays a crucial role in thermoelectric Peltier cooling systems by facilitating the movement of a cooling fluid through the system. Thermoelectric Peltier devices operate by transferring heat from one side to the other when an electric current is applied. To maximize the cooling efficiency, a circulating pump is used to actively circulate a coolant through the cold side of the Peltier module.

The circulating pump ensures that the coolant flows consistently, carrying away heat absorbed by the cold side of the Peltier module. By continuously circulating the coolant, the pump helps to maintain a stable and low temperature on the cold side, enhancing the overall cooling performance.

When choosing a circulating pump, factors such as flow rate, pressure capabilities, and compatibility with the coolant being used should be considered. The pump should be capable of providing sufficient flow and pressure to meet the cooling requirements of the Peltier system. Additionally, the pump should be reliable, durable, and designed for continuous operation.

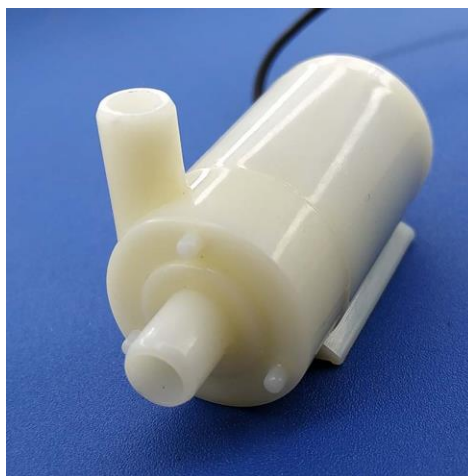


Figure: 2.8 Circulating Pump

Proper installation and integration of the circulating pump within the cooling system are essential. The pump should be connected to the coolant reservoir and the cold side of the Peltier module, ensuring a continuous flow of coolant and efficient heat transfer. S.Huancheng, L.Shusong. [8]

2.9 Thermal glue: Thermal glue, also known as thermal adhesive or thermal compound, is a specialized adhesive material designed to facilitate the efficient transfer of heat between two surfaces. Its primary purpose is to create a thermally conductive bond between heat-generating components, such as computer processors or semiconductor devices, and heat sinks or other cooling solutions, allowing for effective heat dissipation and temperature regulation.

Here are key aspects of thermal glue:

Thermal Conductivity: The most critical property of thermal glue is its high thermal conductivity. It ensures that heat generated by electronic components can flow through the adhesive and into the heat sink or cooling solution efficiently. Common materials used in thermal glue include ceramic particles, silver, or aluminum, which provide excellent thermal conductivity.

Bonding: Thermal glue forms a strong and secure bond between the component and the heat sink. This bond is crucial because it eliminates gaps and air pockets that can impede the transfer of heat. Proper application of thermal glue ensures maximum contact between the surfaces, optimizing heat transfer.

Insulation: While thermal glue conducts heat well, it also acts as an insulator for electrical conductivity. This prevents electrical shorts and damage to sensitive electronic components while maintaining effective thermal performance.

Applications: Thermal glue is commonly used in the assembly of electronic devices, such as CPUs, GPUs, power transistors, and LED lighting systems. It's also used in automotive electronics, industrial equipment, and aerospace applications, where maintaining precise temperature control is critical for reliable performance and longevity.

Types: There are various types of thermal glues available, including one-part and two-part formulations. One-part thermal glues are easier to apply but may require a curing period to achieve their full thermal conductivity. Two-part thermal glues often offer superior performance but require careful mixing before application. Narumanchi [9]

Paste vs. Pad: Thermal glue is available in different forms, including paste and pre-cut pads. Paste is applied manually and allows for precise customization, while pads offer convenience and consistency in applications where a pad shape is suitable.

In summary, thermal glue is a crucial component in electronics and other industries where efficient heat dissipation is essential. It ensures that electronic components can operate within their recommended temperature ranges, preventing overheating and potential damage. Advances in thermal glue formulations continue to enhance their performance, enabling modern electronic devices to deliver improved functionality and reliability.



Figure: 2.9 Thermal glue

Proper application of thermal glue involves cleaning and preparing the surfaces, applying an appropriate amount of adhesive, and allowing it to cure according to the manufacturer's instructions. It is essential to follow the recommended guidelines to achieve optimal thermal performance and secure attachment of the Peltier module.

2.10 Connecting Pipe: Rubber pipes, also known as rubber hoses, are flexible tubes made from rubber materials that are used for various applications. Rubber pipes offer flexibility, durability, and resistance to abrasion, chemicals, and weathering. Here are some common types of rubber pipes and their applications it is used to withstand the pressure and flow of water while maintaining flexibility. Miller[10]



Figure: 2.10 Connecting Pipe

Cable ties, also known as zip ties, are versatile fastening tools used to secure and organize cables, wires, and other objects. They are commonly made of nylon and consist of a flexible strap with a ratchet mechanism.

In conclusion, pipes are indispensable components of our modern infrastructure, facilitating the movement of essential resources and materials. Their diverse materials, types, and applications make them a critical element in various industries, ensuring the efficient and safe transfer of liquids, gases, and solids from one point to another. Proper selection, installation, and maintenance of pipes are vital for the functioning and longevity of any piping system.

2.11 Power Supply (SMPS): A Switched-Mode Power Supply (SMPS) is an electronic device that converts electrical power efficiently from one voltage or current level to another, typically from a higher voltage to a lower one. In your case, you are interested in a 12V SMPS power supply, which converts a higher input voltage into a stable 12V output voltage. Below, I'll provide an in-depth explanation of SMPS power supplies, their components, and their applications: L. Lorenz, G. Decoy [11]

Basic Principle of Operation:

- An SMPS operates on the principle of switching and regulation. It consists of a rectifier to convert AC (Alternating Current) into DC (Direct Current), a switching circuit, a transformer, and a rectifier again to regulate the output voltage.

Components of an SMPS:

- Rectifier: The input AC voltage is first rectified into a high-voltage DC using diodes.
- Switching Circuit: This is the heart of the SMPS. It includes a high-frequency oscillator or controller that rapidly switches the power to the transformer.
- Transformer: The transformer steps down the high-voltage DC into a lower voltage, which is rectified again.
- Rectifier (Output): The rectifier on the output side converts the stepped-down DC into a stable 12V DC.
- Filtering and Regulation: Capacitors and inductors are used for filtering and regulating the output voltage, ensuring it remains stable.

In summary, a 12V SMPS power supply is a versatile electronic device that efficiently converts electrical power from a higher voltage to a stable 12V output. It finds widespread use in various applications, from consumer electronics to industrial equipment, due to its high efficiency, compact size, and reliability. Proper design and engineering are essential to ensure the safety and functionality of SMPS units in different applications.

The power supply is a crucial component in any electrical system, providing the necessary electrical energy to operate the device or equipment. In the context of thermoelectric air conditioning systems, the power supply plays a vital role in supplying the required electrical power to drive the thermoelectric modules.

The power supply for thermoelectric air conditioning systems typically converts the incoming alternating current (AC) power from the main power source to the direct current (DC) power needed by the thermoelectric modules. It must meet the voltage and current requirements specified by the manufacturer of the thermoelectric modules to ensure proper operation.

The power supply's capacity should be sufficient to handle the power demands of the system, including the thermoelectric modules and any additional components. It is important to select a power supply with an appropriate power rating to prevent overloading and ensure stable and reliable operation.

Efficiency is another crucial aspect to consider when choosing a power supply. A higher efficiency power supply converts electrical energy more effectively, minimizing wasted energy and reducing operating costs.

Furthermore, safety features such as overvoltage protection, over current protection, and short-circuit protection are essential to protect the system and prevent damage to components.



Figure: 2.11 Power Supply (SMPS)

Overall, selecting the right power supply is vital for the proper functioning, efficiency, and safety of thermoelectric air conditioning systems. Careful consideration of voltage and current requirements, power capacity, efficiency, and safety features will ensure optimal performance and reliability.

2.12 Reservoir Tank: In a thermoelectric air conditioning system, a reservoir tank and a pump are commonly used for circulating the coolant and facilitating the heat transfer process. Here's how they are typically incorporated:



Figure: 2.12 Reservoir Tank

The reservoir tank serves as a storage and expansion vessel for the coolant. It is usually located in a convenient position within the system, such as near the thermoelectric modules or the heat exchange components. The reservoir tank helps in maintaining the coolant level, allowing for expansion and contraction due to temperature variations. S. S. Bhavikatti [12]

The main functions of the reservoir tank include:

Coolant Storage: The reservoir tank holds an adequate amount of coolant, ensuring a continuous supply for the thermoelectric modules and other components. It helps to maintain the system's coolant level and prevents any interruptions due to insufficient coolant.

Thermal Stability: The reservoir tank assists in stabilizing the temperature of the coolant. As the coolant circulates through the system, it absorbs heat from the hot side of the thermoelectric Modules and releases heat at the cold side. The reservoir tank helps to balance the temperature fluctuations and maintain a consistent operating temperature.

Air Separation: The reservoir tank allows any entrapped air or gas bubbles within the coolant to rise to the top, facilitating their removal. This prevents air pockets from forming, which can reduce the efficiency of heat transfer in the system.

The pump in a thermoelectric air conditioning system is responsible for circulating the coolant between the thermoelectric modules and the heat exchange components. It provides the necessary flow rate to ensure efficient heat transfer and uniform cooling or heating across the system. The pump is typically placed in-line with the coolant flow path, either on the supply or return side.

The primary functions of the pump include:

Coolant Circulation: The pump creates a continuous flow of the coolant through the system, allowing it to absorb heat at the hot side and release heat at the cold side. This circulation helps in maintaining the desired cooling or heating effect.

Flow Control: The pump regulates the flow rate of the coolant, ensuring proper heat transfer and maintaining consistent performance. The flow rate is adjusted based on factors such as the system's cooling capacity, desired temperature differentials, and specific application requirements.

Pressure Enhancement: The pump helps to increase the pressure of the coolant, ensuring that it flows efficiently through the thermoelectric modules, heat exchangers, and other components. Adequate pressure is crucial for achieving optimal heat transfer and system performance.

It's important to select a reservoir tank and pump that are compatible with the coolant used in the system and capable of meeting the flow rate and pressure requirements. Proper sizing and installation of the reservoir tank and pump contribute to the overall effectiveness and efficiency of the thermoelectric air conditioning system.

A temperature meter, also known as a thermometer, is a device used to measure the temperature of an object or the environment. It typically consists of a temperature sensor and a display unit to provide a numerical or graphical representation of the temperature reading. There are various types of temperature meters available, each with its own principles of operation and applications. Here are a few common types:

Mercury-in-glass thermometer: This traditional thermometer consists of a glass tube filled with mercury. As the temperature changes, the mercury expands or contracts, causing it to rise or fall within the graduated scale on the tube. However, mercury thermometers are being phased out due to environmental concerns.

Digital thermometer: These thermometers use electronic sensors, such as thermocouples or resistance temperature detectors (RTDs), to measure temperature. The readings are then displayed digitally on an LCD or LED screen. Digital thermometers are commonly used in medical settings for measuring body temperature.

Infrared thermometer: Also known as non-contact thermometers, these devices measure temperature without direct contact. They use infrared radiation emitted by the object being measured and convert it into temperature readings. Infrared thermometers are useful for measuring the temperature of objects that are difficult or unsafe to touch, such as hot surfaces or moving machinery.

Thermocouple thermometer: Thermocouples consist of two different metal wires joined together at one end. When the junction is exposed to a temperature gradient, it generates a small voltage that is proportional to the temperature difference. Thermocouple thermometers use this principle to measure temperature across a wide range.

Resistance temperature detector (RTD): RTDs are temperature sensors made from pure metals, such as platinum, whose electrical resistance changes with temperature. RTDs offer high accuracy and stability and are commonly used in industrial applications where precise temperature measurements are required.

These are just a few examples of temperature meters available on the market. The choice of a temperature meter depends on the specific application, temperature range, accuracy requirements, and environmental conditions in which it will be used.

2.13 Digital thermometer: A digital thermometer is a type of temperature meter that utilizes electronic sensors and displays the temperature reading digitally on a screen. It has become increasingly popular due to its ease of use, accuracy, and quick response time. Digital thermometers are commonly used in various settings, including medical, culinary, industrial, and household applications. Miller AC, Singh [13]

Here are some key features and advantages of digital thermometers:

Accuracy: Digital thermometers can provide highly accurate temperature measurements. They are designed to display temperature readings with decimal points, allowing for precise monitoring and control.

Fast response time: Digital thermometers typically provide quick temperature readings, making them convenient for situations where immediate results are required. This is especially useful in medical applications, where rapid temperature assessment is crucial.

Easy-to-read display: Digital thermometers feature an LCD or LED display that shows the temperature reading in numerical form. The digital display makes it easy to read and interpret the temperature, eliminating the need for manual interpretation of a scale like in traditional thermometers.



Figure: 2.13 Digital thermometers

Memory and data storage: Some digital thermometers come with built-in memory or data storage capabilities. This allows users to record and review previous temperature readings, making it useful for tracking temperature trends over time.

Various probe options: Digital thermometers often come with interchangeable probes suitable for different applications. For instance, a digital thermometer for medical use may have a flexible probe for oral or rectal measurements, while a culinary thermometer may have a stainless-steel probe for food temperature measurements.

Non-contact options: Some digital thermometers incorporate infrared technology, enabling non-contact temperature measurements. These thermometers can measure the temperature of an object or a person's forehead without physical contact, making them hygienic and convenient for certain applications.

Alarm and alert features: Many digital thermometers have programmable alarm features that can be set to sound an alert when the temperature exceeds a certain threshold. This is particularly useful in medical settings or when monitoring temperature-sensitive processes.

It's important to follow the manufacturer's instructions for proper usage and calibration of digital thermometers to ensure accurate and reliable temperature measurements.

2.14 Glue Gun: A glue gun and glue sticks are an inseparable duo in the world of adhesives, offering a versatile and efficient way to bond various materials in a wide array of applications. These tools are a staple for both DIY enthusiasts and professionals, owing to their simplicity, reliability, and effectiveness. A glue gun is a handheld device designed to melt and dispense adhesive material, typically in the form of glue sticks. The operation of a glue gun is straightforward – it relies on heat to liquefy a solid glue stick, transforming it into a foldable adhesive. Users simply load a glue stick into the gun, activate the heating element, and then apply pressure on the trigger to dispense the molten glue through a nozzle. This intuitive mechanism makes glue guns user-friendly and accessible to individuals of all skill levels. One notable feature of glue guns is their ability to accommodate different types of glue sticks, thanks to adjustable temperature settings. This feature allows users to fine-tune the glue gun's performance to suit the specific requirements of their project. Brogly M. [14]

Low-temperature glue guns are ideal for delicate materials like foam, fabric, or paper, as they operate at lower temperatures, minimizing the risk of damage or burns. Conversely, high-temperature glue guns are tailored for more robust materials, such as wood, metal, and plastics, offering a stronger bond due to the higher operating temperatures. The applications of glue guns are diverse and far-reaching. Crafters often turn to them for a multitude of projects, including scrapbooking, model-making, and embellishing decorations. In the realm of home repair, glue guns are indispensable for mending broken household items like ceramics, plastic objects, and conducting minor wood repairs. DIY enthusiasts frequently rely on these tools for an extensive range of tasks, from constructing furniture to securing loose trim. Students and educators employ glue guns for school projects, presentations, and prototype creation. Even in packaging, glue guns play a role, sealing boxes and affixing labels securely and efficiently.

They are available in various sizes and diameters to fit different glue gun models, ensuring compatibility.

One of the primary advantages of glue sticks is their clean application. Unlike liquid adhesives, glue sticks remain solid until heated, preventing messy drips or spills. Moreover, they set quickly, allowing for efficient work on projects and repairs, reducing downtime. The bond they create is robust and durable when used with a suitable glue gun, making them reliable for a wide range of applications.

In conclusion, the combination of a glue gun and glue sticks forms an efficient and accessible adhesive solution for bonding materials in numerous applications. Their ease of use, speed, versatility, and minimal mess make them indispensable tools for crafters, DIY enthusiasts, professionals, and students alike. Whether you're embarking on a creative project, tackling home repairs, or engaging in industrial applications, the glue gun and glue stick duo is a go-to choice for reliable and effective adhesion.



Figure: 2.14 Glue Gun

Temperature control: Some glue guns have adjustable temperature settings, allowing you to choose between high and low heat. This feature is useful when working with different types of glue sticks or materials.

Trigger mechanism: Most glue guns have a trigger mechanism that controls the flow of the melted glue. Squeezing the trigger dispenses the glue, and releasing it stops the flow.

Nozzle options: Glue guns typically come with different nozzle sizes or shapes. The nozzle determines the pattern and thickness of the adhesive being dispensed. Some glue guns also offer interchangeable nozzles for specific applications.

2.15 Coolant: Engine coolant, often referred to as antifreeze, is a vital component in ensuring the smooth operation and longevity of your vehicle's engine. This essential fluid plays a crucial role in maintaining the engine's temperature and preventing it from overheating, especially in extreme weather conditions. In this article, we will explore the importance of engine coolant, its composition, functions, maintenance, and the consequences of neglecting this critical aspect of vehicle care. Shankar [15]

Composition of Engine Coolant:

Engine coolant is typically a mixture of water and antifreeze, with additional additives to enhance its performance. The most common antifreeze used is ethylene glycol, although propylene glycol is also an option, particularly in environmentally conscious applications. These



Figure: 2.15 Coolants

Glycol-based substances serve as the primary ingredient responsible for preventing freezing in cold temperatures and boiling in hot conditions.

Engine Coolant's Vital Functions:

- **Temperature Regulation:** The primary purpose of engine coolant is to control and stabilize the operating temperature of the engine. When the engine is running, it generates an immense amount of heat. If left unchecked, this heat could lead to severe engine damage. Coolant circulates through the engine and absorbs excess heat, preventing overheating and maintaining optimal operating temperatures.
- **Freeze Protection:** In cold climates, water within the engine can freeze, causing catastrophic damage. Engine coolant contains antifreeze, which lowers the freezing point of the mixture, protecting the engine from freezing even in frigid conditions.
- **Boil-Over Prevention:** In hot weather or during strenuous activities like towing heavy loads, the engine can reach high temperatures. Engine coolant raises the boiling point of

the water in the system, preventing it from evaporating and causing the engine to overheat.

- Corrosion Prevention: Engine coolant contains additives that inhibit corrosion and protect various engine components from rust and other forms of deterioration. This corrosion protection is essential for maintaining the longevity of the engine.

Maintenance of Engine Coolant:

Proper maintenance of engine coolant is crucial for the health of your vehicle's engine. Here are some essential steps to keep your coolant system in optimal condition:

- Regular Inspection: Check the coolant level regularly, especially before long trips or during seasonal changes. The coolant reservoir typically has a "minimum" and "maximum" marking to guide you.
- Top-Up or Replacement: If the coolant level is low, add a mixture of coolant and distilled water as needed. Consult your vehicle's owner's manual for the recommended coolant-to-water ratio.
- Flushing: Over time, engine coolant can become contaminated with rust, dirt, and other impurities. It's essential to flush the cooling system periodically, typically every 30,000 to 50,000 miles, depending on the manufacturer's recommendations.
- Coolant Type: Ensure that you use the correct type of coolant specified by your vehicle's manufacturer. Mixing different coolant types can lead to chemical reactions that could damage your engine.

Consequences of Neglect:

Neglecting your vehicle's engine coolant can have severe consequences, including:

- Overheating: Insufficient coolant can lead to engine overheating, potentially causing severe engine damage and costly repairs.
- Freezing: In cold weather, neglecting to use antifreeze or maintaining the proper coolant-to-water ratio can result in a frozen engine block, leading to engine cracks or damage.
- Corrosion: Failure to maintain the cooling system can result in corrosion, leading to leaks and other cooling system issues.
- Reduced Engine Efficiency: Inadequate cooling can cause reduced engine efficiency and power output, leading to decreased fuel economy and performance.

In conclusion, engine coolant is a critical component of your vehicle's cooling system, playing a pivotal role in maintaining engine health and performance. Regular inspection, proper maintenance, and using the correct coolant type are essential steps to ensure your engine operates at its best and lasts for years to come. Neglecting this vital fluid can result in costly repairs and vehicle downtime, so take the time to care for your engine coolant and, by extension, your vehicle's engine.

2.16 Silicon Glue: [16] Stark FO [16] Silicon glue, also known as silicone adhesive or sealant, is a versatile and widely used adhesive that offers numerous benefits across various industries and applications. Composed primarily of silicone polymers, silicon glue is prized for its

flexibility, durability, and resistance to extreme temperatures and environmental conditions. In this article, we will explore the characteristics, uses, advantages, and application tips for silicon glue.

Characteristics of Silicon Glue:

- **Flexibility:** Silicon glue remains pliable and flexible even after curing. This flexibility allows it to accommodate movements and vibrations without losing adhesion, making it suitable for applications that involve joint or surface movement.
- **Temperature Resistance:** One of silicon glue's outstanding features is its ability to withstand a wide range of temperatures. It can endure extreme heat, often exceeding 500°F (260°C), as well as sub-zero cold without losing its adhesive properties.
- **Water Resistance:** Silicon glue forms a watertight seal, making it ideal for applications where exposure to moisture or water is common, such as bathroom fixtures, aquariums, and outdoor projects.
- **Chemical Resistance:** It is highly resistant to chemicals, oils, and solvents, making it suitable for use in environments where exposure to these substances is likely.
- **Electrical Insulation:** Silicon glue can act as an electrical insulator, which is advantageous for sealing electrical connections and components.
-



Figure: 2.15 Silicon Glue

Common Uses of Silicon Glue:

- **Sealing and Bonding:** Silicon glue is commonly used for sealing gaps and joints in various materials, including glass, metal, plastic, and ceramics. It is an excellent choice for sealing around windows and doors in construction.
- **Automotive Applications:** It is used to create watertight seals in car windshields, sunroofs, and tail lights. Its resistance to temperature fluctuations makes it ideal for under-the-hood applications.
- **Plumbing and Bathroom Fixtures:** Silicon glue is frequently used to seal joints and connections in plumbing, such as sink and bathtub installations. Its water-resistant properties make it perfect for bathroom fixtures.

- **Electronics:** It is used in the assembly of electronic components, providing insulation and protection against moisture and dust.
- **Glass and Mirror Bonding:** Silicon glue adheres well to glass and is used for bonding glass panels and mirrors in both residential and commercial settings.
- **HVAC Systems:** In heating, ventilation, and air conditioning systems, silicon glue is used to seal ductwork and maintain airtight connections.

Advantages of Silicon Glue:

- **Durability:** Silicon glue maintains its adhesive properties over time, reducing the need for frequent reapplications.
- **Versatility:** Its ability to bond to a wide range of materials makes it a versatile choice for many applications.
- **Weather Resistance:** Silicon glue is UV resistant and can endure exposure to sunlight, rain, and harsh weather conditions without deteriorating.
- **Longevity:** Properly applied silicon glue can last for many years, contributing to the longevity and reliability of sealed components and structures.

Application Tips:

- **Surface Preparation:** Ensure that the surfaces to be bonded are clean, dry, and free from grease, dirt, and contaminants. Proper surface preparation is crucial for the adhesive to work effectively.
- **Use in Well-Ventilated Areas:** When working with silicon glue, ensure adequate ventilation to disperse any fumes emitted during curing.
- **Curing Time:** Silicon glue typically cures within 24 hours but may take longer in very humid conditions. Follow the manufacturer's instructions for the recommended curing time.
- **Storage:** Store silicon glue in a cool, dry place away from direct sunlight and extreme temperatures to extend its shelf life.

In conclusion, silicon glue is a versatile adhesive with a wide range of applications across various industries. Its flexibility, temperature resistance, and durability make it an invaluable tool for sealing, bonding, and protecting a multitude of materials and structures. Whether you're working on a DIY project at home or tackling complex industrial applications, silicon glue is a reliable choice for achieving strong, long-lasting bonds.

Chapter 3 Methodology

3.1 Working Process: A bottle-type water cooling system utilizing a Peltier module, also known as a thermoelectric cooler (TEC), is an innovative and efficient solution designed to rapidly cool beverages or small liquid containers. This technology leverages the thermoelectric effect to create a temperature gradient across a semiconductor material, enabling precise and controllable cooling without the need for refrigerants or traditional compressor-based cooling systems. In this comprehensive explanation, we will delve into the intricate working process of such a system, step by step, to provide a comprehensive understanding of its operation.

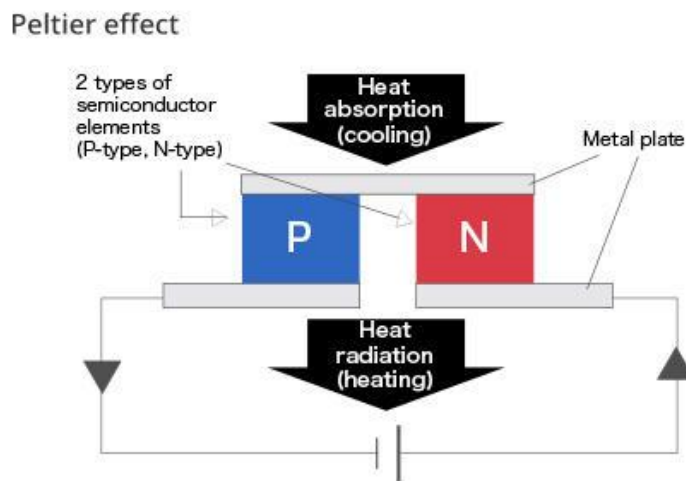


Figure: 3.1 Working Process

1. Components of the System:

To comprehend the working process of a bottle-type water cooling system using a Peltier module, it's essential to first understand its key components:

- **Peltier Module:** At the core of this system is the Peltier module, a solid-state device comprising two ceramic plates with semiconductor materials sandwiched between them. The Peltier module is designed to exploit the thermoelectric effect, which allows it to transfer heat from one side to the other when an electrical current is applied.
- **Heat Sink:** To efficiently dissipate the heat generated by the hot side of the Peltier module, a heat sink is employed. The heat sink typically features fin-like structures to maximize surface area and enhance heat dissipation.
- **Fan:** In many systems, a fan is integrated with the heat sink to further enhance heat dispersion. The fan blows air across the heat sink's fins, facilitating more efficient cooling.

- **Bottle Holder:** The bottle holder is specially designed to securely hold the beverage or liquid container in direct contact with the cold side of the Peltier module. This physical contact ensures efficient heat exchange between the liquid and the cooling surface.
- **Temperature Control System:** Some advanced systems include a temperature control mechanism that allows users to set and maintain the desired cooling level. This feature enables precise temperature regulation for different types of beverages.
- **Power Supply:** The system requires an electrical power supply to provide the necessary voltage and current to the Peltier module, enabling it to function effectively. Brogly [14]

2. The Cooling Process:

The cooling process of a bottle-type water cooling system using a Peltier module can be broken down into several key steps:

- **Power Application:** The process initiates when an electric current is applied to the Peltier module. The module is designed to be reversible, meaning it can change the direction of heat transfer by altering the polarity of the applied current. This feature enables it to function both as a cooler and a heater.
- **Heat Transfer:** As the electric current flows through the Peltier module, it creates a temperature differential between its two sides. One side becomes cold (the cold side), while the other side becomes hot (the hot side).
- **Contact with the Bottle:** The cold side of the Peltier module is placed in direct contact with the bottle or liquid container that requires cooling. The efficient heat transfer properties of the Peltier module ensure rapid cooling of the liquid inside the bottle.
- **Heat Dissipation:** Concurrently, the hot side of the Peltier module is in contact with the heat sink. If a fan is incorporated into the system, it aids in blowing air across the heat sink's fins, expelling the heat into the surrounding environment. This active cooling process prevents the hot side of the module from overheating and helps maintain the desired temperature gradient.
-
- **Rapid Cooling:** As the Peltier module continues to operate, heat is extracted from the liquid in the bottle, causing it to cool down rapidly. The rate of cooling can be precisely controlled by adjusting the amount of electrical current supplied to the module. This level of control allows users to achieve the desired temperature quickly and accurately.
- **Continual Operation:** The cooling process persists until the desired temperature is reached inside the bottle or container. Once the target temperature is achieved, the system is designed to maintain it consistently. As long as the power supply is active, the system will continue to operate, ensuring that the contents of the bottle remain chilled at the desired temperature.

3. Temperature Control and Regulation:

A significant advantage of this bottle-type water cooling system is its ability to provide precise temperature control and regulation. The temperature control system, if included in the setup, allows users to set and maintain the desired cooling level. This feature is particularly valuable when cooling different types of beverages that require specific serving temperatures. By

adjusting the electrical current supplied to the Peltier module, users can achieve and sustain the exact temperature they desire.

4. Shutdown and Energy Efficiency:

When the cooling process is no longer required, the system can be easily shut down by disconnecting the power supply. This results in the gradual warming of the liquid inside the bottle as the Peltier module ceases its cooling operation. The system is designed to be energy-efficient, as it only consumes electricity while actively cooling the liquid. This energy-conscious operation contributes to reduced power consumption and cost-effectiveness.

Seebeck Effect: The Seebeck effect is a crucial thermoelectric phenomenon wherein an electric voltage is generated when a temperature gradient exists across a conductor or semiconductor material. Conversely, when an electric current is passed through such a material, it can result in a temperature differential—a process often utilized in Peltier devices. In Peltier modules, this effect is employed for solid-state cooling or heating applications. When an electrical current flows through the junction of two dissimilar materials, it causes one side to absorb heat while the other side releases it, depending on the current direction. This technology is commonly used in portable refrigeration, temperature control, and precision cooling systems due to its efficiency and reliability.

3.2 Electrical Cycle

In this cycle lots of components are used, these are given below

1. Peltier Module
2. Electrical Pump Motor
3. Cooling Fan
4. Power Supply (SMPS)

An electrical cycle, equipped with components like a Peltier Module, Pump Motor, Cooling Fan, and Power Supply (SMPS), represents an innovative and efficient solution for cooling and temperature regulation in a variety of applications. This combination of components creates a versatile system capable of providing precise temperature control and cooling in various contexts. In this comprehensive explanation, we will explore the roles and functions of these key

Components within an electrical cycle.

1. Peltier Module:

- The Peltier Module, also known as a thermoelectric cooler (TEC), is a solid-state device with two ceramic plates sandwiching semiconductor materials. When an electrical current passes through the module, it induces the thermoelectric effect, causing one side to become cold while the other side heats up.
- Role: In the electrical cycle, the Peltier Module serves as the core component responsible for cooling. It can rapidly lower the temperature of a specific area or object placed in contact with its cold side, making it invaluable for precise cooling applications.

2. Pump Motor:

- The Pump Motor is an electric motor that drives a pump mechanism responsible for circulating a coolant or heat transfer fluid within the system. It ensures the efficient transfer of heat away from the hot side of the Peltier Module.
- Role: The Pump Motor plays a crucial role in maintaining the system's cooling efficiency by continuously circulating the cooling fluid. This circulation prevents the hot side of the Peltier Module from overheating, ensuring consistent and effective cooling.

3. Cooling Fan:

- A Cooling Fan is an essential component designed to dissipate heat generated during the operation of the system, primarily from the hot side of the Peltier Module. It expels hot air and assists in maintaining a suitable operating temperature.
- Role: The Cooling Fan enhances the heat dissipation process by blowing air over the heat sink and other components that may generate heat, such as the power supply. It contributes to overall system efficiency by keeping temperatures within acceptable limits.

4. Power Supply (SMPS):

- The Power Supply, often in the form of a Switched-Mode Power Supply (SMPS), provides the electrical energy required for the system's operation. It converts and regulates the incoming electrical power to meet the specific needs of the components.

Working Process of Electric Cycle:

Electrical Circuit

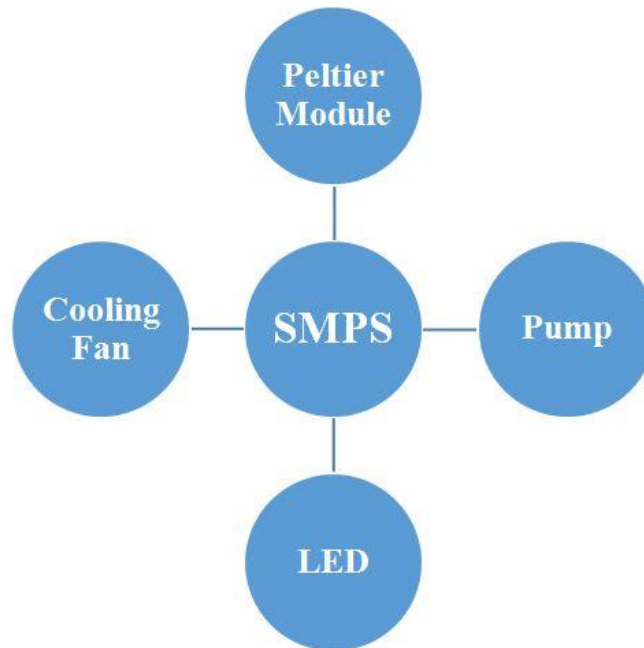


Figure: 3.2 Electrical cycles

The electrical cycle operates by using the Peltier Module to transfer heat from one side to the other. Here's how it works in conjunction with the other components:

- The Pump Motor circulates a cooling fluid through a loop that includes the hot side of the Peltier Module.
- As the electric current flows through the Peltier Module, it creates a temperature differential, with one side becoming cold and the other hot.
- The cold side of the Peltier Module is placed in direct contact with the area or object requiring cooling.
- Heat is absorbed from the target area and transferred to the hot side of the module.
- The Pump Motor ensures that the cooling fluid effectively carries away the heat from the hot side, preventing overheating.
- The Cooling Fan expels hot air from the system, maintaining suitable temperatures.
- The Power Supply provides the necessary electrical energy to all components, ensuring the entire system functions cohesively. V

Applications of Electric Cycle:

Electrical cycles equipped with these components find applications in various industries and contexts, including:

- **Electronic Cooling:** They are used to cool sensitive electronic components and circuits to prevent overheating and ensure optimal performance.
- **Food and Beverage:** These systems are employed for precise temperature control in food storage, transportation, and display units.
- **Medical Devices:** They are used in medical equipment such as incubators, thermal cycler machines, and laboratory instruments requiring temperature regulation.
- **Automotive:** Electrical cycles with Peltier Modules find use in cooling and temperature control for automotive applications, including seat coolers and beverage holders.
- **Environmental Control:** They are utilized for environmental testing and simulation, creating specific temperature conditions for research and development.

In conclusion, an electrical cycle equipped with a Peltier Module, Pump Motor, Cooling Fan, and Power Supply forms a versatile and efficient cooling and temperature control system. These components work in harmony to ensure precise cooling and heat transfer, making such systems invaluable in various industries, from electronics to healthcare and beyond. Their ability to maintain precise temperature control enhances the efficiency and reliability of many processes and applications.

3.3 Mechanical Cycle

Mechanical Components name is given bellow.

A mechanical cycle employing components like a Bottle, Water Valve, Cooling Block, Pump, and Reserve Tank represents a highly effective system designed for cooling and maintaining a steady supply of chilled water. This combination of components creates a versatile and dependable cooling system suitable for various applications. In this comprehensive explanation, we will explore the roles and functions of these key components within a mechanical cycle for water cooling

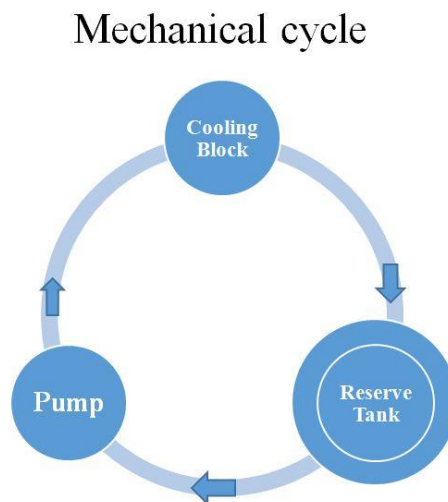


Figure: 3.3 Mechanical Cycles

Bottle:

- The Bottle serves as the central unit of the system. It contains the cooling elements, typically a refrigeration system or thermoelectric module, responsible for cooling the water.
- Role: The Water Cooler's primary function is to cool the water efficiently. It houses the cooling mechanism and ensures the water remains at a desired temperature.

Water Valve:

- The Water Valve is a control mechanism responsible for regulating the flow of water from the Bottle-Type Water Cooler to the Cooling Block. It can be manually operated or automated, depending on the system's design.
- Role: The Water Valve controls the flow of water into the cooling system, allowing for precise regulation of the cooling process. It determines the rate at which water enters the system.
- Role: The Bottle holds the initial supply of water, ensuring a consistent source for cooling. It feeds water to the Water Cooler for the cooling process to commence.

Cooling Block:

- The Cooling Block is a critical component designed to rapidly cool the incoming water. It typically consists of a metal or thermally conductive material with channels or fins for efficient heat exchange.
- Role: The Cooling Block is responsible for lowering the temperature of the incoming water as it passes through. It enhances the cooling efficiency of the system.

Pump:

- The Pump is an electric or mechanical device responsible for moving water from the Cooling Block to the Reserve Tank. It provides the necessary force to circulate the chilled water.
- Role: The Pump ensures that the chilled water is distributed efficiently throughout the system. It maintains the flow and circulation of cold water, preventing stagnation.

Reserve Tank:

- The Reserve Tank is a secondary container for storing the chilled water. It is typically larger than the Bottle and serves as a reservoir of cold water that can be accessed as needed.

- Role: The Reserve Tank stores the chilled water and ensures a continuous supply is readily available. It acts as a backup reservoir in case of increased demand or when the Bottle needs replenishing.

Working Process Mechanical Cycle:

The mechanical cycle operates by cycling water through the various components, creating a continuous supply of chilled water. Here's how it works in conjunction with the key components mentioned:

- Water from the Bottle is directed through the Water Valve, which regulates the flow into the Cooling Block.
- As the water enters the Cooling Block, it comes into contact with the cold surfaces or channels within the block. Heat is rapidly exchanged, causing the water temperature to drop significantly.
- The chilled water is then pumped by the Pump from the Cooling Block into the Reserve Tank. The Pump ensures a continuous flow of cold water.
- The Reserve Tank stores the chilled water and serves as a supply source for various applications, such as cooling equipment, beverages, or any process requiring cold water.
- The cycle repeats as long as there is a demand for chilled water. Water is drawn from the Reserve Tank, passes through the Cooling Block for additional cooling if needed, and is then returned to the Reserve Tank.

Applications of Mechanical Cycle:

Mechanical cycles equipped with these components find applications in various contexts and industries, including:

- Office Water Coolers: These systems are commonly found in office settings, providing employees with access to chilled water for drinking and hydration.
- Home Water Dispensers: Mechanical cycles are used in household water dispensers, ensuring that chilled water is readily available for drinking or cooking.
- Industrial Cooling: They are employed in industrial settings to cool equipment, machinery, and processes that generate heat during operation.
- Commercial Refrigeration: These systems are used in commercial refrigeration units to maintain low temperatures for food storage and preservation.
- Laboratory and Scientific Applications: Mechanical cycles find use in laboratories and scientific research, providing precise temperature control for experiments and testing.
- Agriculture: These systems are used in agriculture for cooling irrigation water and maintaining optimal conditions in greenhouses.

In conclusion, a mechanical cycle equipped with a Bottle-Type Water Cooler, Water Valve, Bottle, Cooling Block, Pump, and Reserve Tank forms a versatile and reliable cooling system. These components work together seamlessly to provide a continuous supply of chilled water, ensuring efficient and dependable cooling when needed. The ability to regulate and store chilled

water makes such systems invaluable in diverse industries and contexts, contributing to improved hydration, equipment cooling, and temperature-sensitive processes.

3.4 Schematic View of the Project



Figure: 3.4 Schematic View of the Project

The final view of our project's water cooling system showcases a well-executed and efficient cooling solution. The system is designed to maintain optimal temperature levels in various applications, ensuring the longevity and performance of equipment while conserving energy. Key features include a robust water circulation system, high-quality heat exchangers, and precise temperature controls.

The system's components are neatly organized, with clear labeling and easy access for maintenance. Safety measures, such as pressure relief valves and temperature sensors, are in place to prevent any potential issues. The cooling towers or radiators are efficiently dissipating heat, and the water flow is well-balanced throughout the system.

Overall, the final view of our water cooling system demonstrates a successful project, meeting performance and safety requirements while promoting energy efficiency and equipment reliability.

Chapter 4

Result

4.1 Temperature Analysis: The table provides temperature analysis data for a specific scenario. It records temperature changes over time, showcasing a gradual decrease. The initial temperature in Sl. No. 1 was 28°C, and it decreased to 27°C over 2 minutes. Similarly, in Sl. No. 2, the temperature dropped from 27°C to 26°C in 5 minutes, followed by a decrease from 26°C to 25°C over 8 minutes in Sl. No. 3. Finally, in Sl. No. 4, the temperature reduced from 25°C to 24°C in 12 minutes. Consistently reduced the temperature. This data might be valuable for various applications, such as process monitoring, climate studies, or quality control in manufacturing processes. H. Lee [17]

Our cooling temperature analysis project. Our team worked tirelessly to gather and analyze data, and their dedication ensured the success of this endeavor. Special thanks go to our research partners whose insights and expertise significantly enhanced the quality of our findings. Moreover, I am grateful for the availability of research tools and resources that facilitated our analysis. This project was a collaborative effort, and I am genuinely thankful for the contributions of everyone involved, as well as the support from our mentors and colleagues throughout the process.

The provided dataset offers a detailed insight into the cooling process of a substance over a set duration of time. Each data point is marked with a serial number, the initial temperature in degrees Celsius (°C), the final temperature in °C, and the time it took for the substance to transition from the initial to the final temperature in seconds (s).

Upon careful analysis of the data, several noteworthy trends and patterns emerge, shedding light on the substance's cooling behavior. The dataset demonstrates a clear and consistent cooling process, where the initial temperature progressively decreases from 35°C to 27°C, marking a systematic cooling trend. Additionally, the time intervals between successive measurements gradually increase, indicating that the duration over which the cooling process is monitored extends with each subsequent data point.

To gain a deeper understanding of the cooling process, it is essential to calculate the rate of cooling. The rate of cooling quantifies how quickly the substance is losing heat and can be determined by computing the temperature difference between consecutive data points and dividing it by the corresponding time interval.

sensitive processes operate within desired parameters, and safeguarding the quality and integrity of products that are sensitive to temperature fluctuations.

In industrial settings, such data is instrumental in the design and operation of cooling systems for machinery and equipment. It helps in preventing overheating and maintaining the efficiency and longevity of critical components. In scientific experiments, the rate of cooling data can provide insights into the thermodynamic properties of substances and aid in conducting controlled experiments.

Furthermore, in food and beverage industries, precise temperature control is vital for product quality and safety. Understanding the rate of cooling allows for the development of efficient cooling processes to meet stringent regulatory requirements.

In conclusion, the dataset underlines a systematic and gradual cooling process of a substance over time. The consistent decrease in temperature, coupled with the increasing time intervals between measurements, offers valuable insights into the substance's thermal characteristics. This type of data analysis holds significant relevance in fields where temperature control is paramount, impacting manufacturing, research, and quality assurance, as it facilitates informed decision-making to enhance process efficiency and product quality while ensuring compliance with temperature-related standards and regulations.

4.2 Data Table

SL Number	Initial temperature(°C)	Final temperature(°C)	Time(Min)
1	35	34	0.56
2	34	33	1.40
3	33	32	2.25
4	32	31	4.35
5	31	30	5.40
6	30	29	6.22
7	29	28	7.13
8	28	27	8.42

Figure: 4.1 Data Table

Upon calculating the rates of cooling, it becomes apparent that the cooling process is gradual, with only marginal temperature changes occurring over the observed time intervals. This observation suggests that the substance possesses a substantial thermal mass or that the environment in which it is cooling has limited heat dissipation capacity. In practical terms, this may imply that achieving rapid cooling or maintaining precise temperature control in such conditions could be challenging.

Understanding the rate of cooling is of paramount importance in various industries and scientific applications. It plays a pivotal role in optimizing cooling systems, ensuring that temperature-

4.3 Graph of Time vs Temperature:

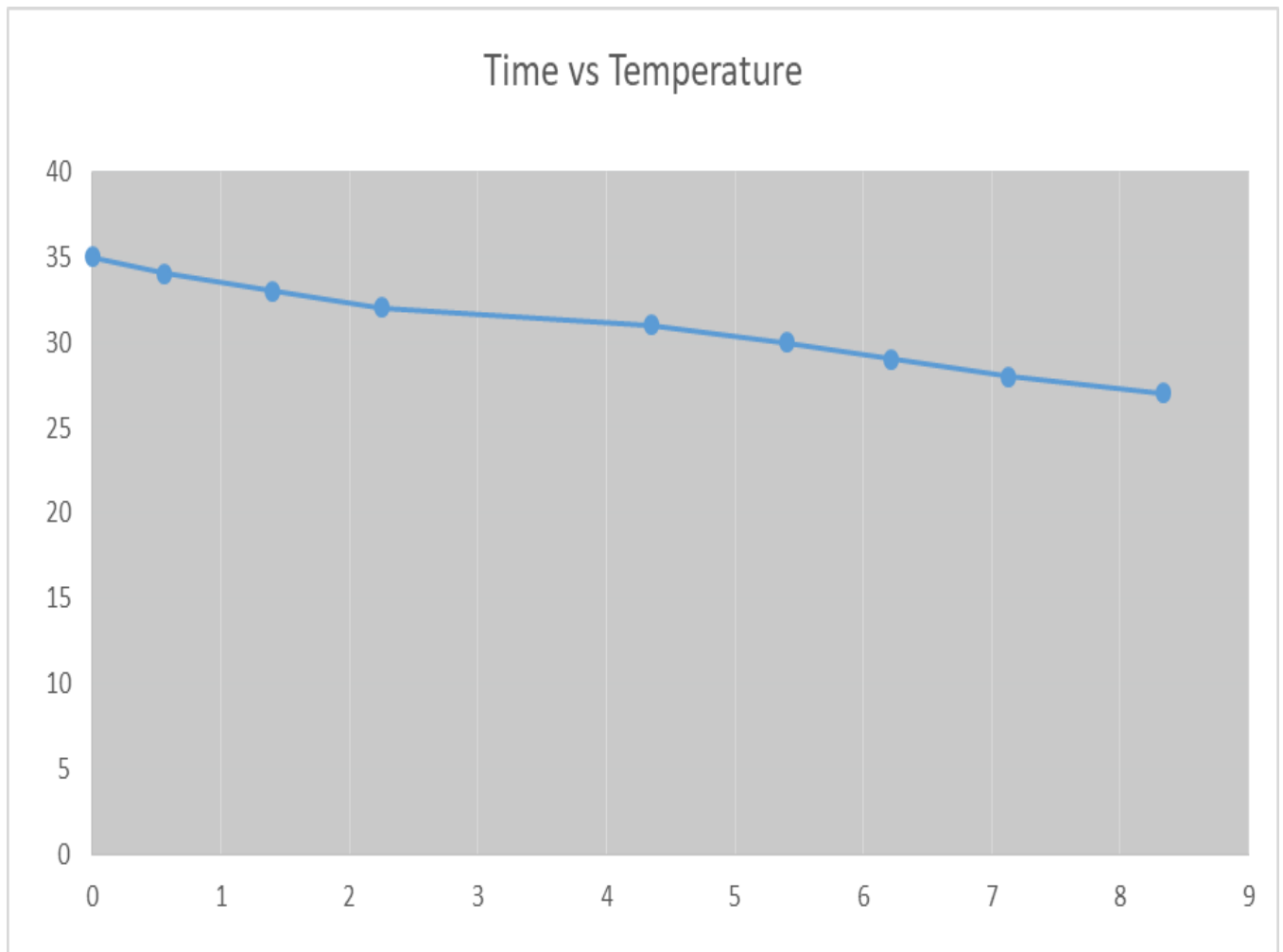


Figure: 4.2 Graph of Time vs Temperature

Chapter 5

Future scope of Peltier Module

5.1 Future scope of water cooling systems: The future of water cooling systems promises exciting advancements and innovations as technology continues to evolve and industries seek more efficient and sustainable solutions for managing heat. Here, we'll explore some recommendations for the future of water cooling systems, considering trends in technology and environmental concerns. H. Lee [18]

- **Enhanced Energy Efficiency:** Future water cooling systems should prioritize energy efficiency. This can be achieved through the use of advanced materials, improved pump and heat exchanger designs, and smart control systems. Energy-efficient cooling systems not only reduce operational costs but also have a lower environmental impact by consuming less electricity.
- **Integration of Renewable Energy Sources:** To further reduce the environmental footprint, future water cooling systems should explore the integration of renewable energy sources such as solar or wind power. This would enable cooling systems to operate using clean energy, reducing greenhouse gas emissions associated with electricity generation.
- **Heat Recovery:** Water cooling systems can be designed to recover waste heat and repurpose it for other applications, such as heating buildings or providing hot water. This concept, known as combined heat and power (CHP) or cogeneration, enhances the overall efficiency of energy use.
- **Advanced Cooling Fluids:** Research into advanced cooling fluids can lead to coolants that are not only better at heat transfer but are also more environmentally friendly. Innovative coolants with improved thermal properties can enhance the overall performance of water cooling systems.
- **Compact and Modular Designs:** Smaller, more modular water cooling systems can offer greater flexibility and scalability. This is particularly important in data centers and industrial applications where space is limited. Modular designs allow for easier expansion and maintenance.
- **Predictive Maintenance:** Implementing predictive maintenance through the use of sensors and data analytics can help identify potential issues in water cooling systems before they lead to failures. This can reduce downtime and extend the lifespan of equipment.
- **Water Recycling and Treatment:** Future water cooling systems should focus on efficient water use and responsible water management. Technologies for water recycling and treatment within the cooling system can minimize water consumption and environmental impact.

- **Improved Corrosion Resistance:** Enhancing the corrosion resistance of components within the water cooling system, especially in industrial applications, can lead to longer service life and reduced maintenance requirements.
- **AI and Machine Learning Integration:** Artificial intelligence and machine learning algorithms can optimize the operation of water cooling systems by continuously analyzing data from sensors and adjusting cooling parameters in real-time for maximum efficiency.
- **Sustainable Materials:** The use of sustainable and environmentally friendly materials in the construction of water cooling system components, such as heat exchangers and pipes, can further reduce the system's ecological footprint.
- **Edge Computing Cooling:** With the growing adoption of edge computing, which involves processing data closer to its source, water cooling systems tailored for smaller, distributed data centers and edge computing facilities will be in demand. These systems should be energy-efficient and compact. A. Attar [19]
- **Thermal Energy Storage:** Integration of thermal energy storage systems with water cooling can help shift cooling loads to off-peak hours, reducing electricity costs and easing the burden on the electrical grid.

In conclusion, the future of water cooling systems lies in a combination of technological advancements, sustainability efforts, and smart design. As industries continue to prioritize energy efficiency and environmental responsibility, water cooling systems will play a critical role in achieving these goals. By embracing innovative materials, renewable energy sources, and advanced control systems, water cooling systems of the future will not only provide effective heat management but also contribute to a more sustainable and eco-friendly world.

The future of water cooling systems is poised for innovation and efficiency enhancements. Advancements in materials and design will lead to more compact and modular systems, enabling flexible integration in various applications, from data centers to industrial processes. Smart, AI-driven controls will optimize cooling, minimizing energy consumption and environmental impact. Enhanced corrosion resistance and sustainable materials will prolong system lifespan. Integration with renewable energy sources will reduce carbon footprints. As technology evolves, water cooling systems will continue to play a vital role in maintaining temperature-sensitive processes while contributing to sustainability goals through improved energy efficiency and eco-friendly practices.

5.2 Limitation: Peltier modules are not able to withstand large tension or shear forces between the heat sink and the cold plate and may break if such forces are applied. In most applications, the heat sink and the object to be cooled are clamped together with the Peltier module in between. Can't provide low temperatures below 10°C. Not very energy-efficient compared to compressor-

based systems although control technology means cooling can be more accurately measured than with a compressor, so these systems can be energy-efficient for small temperature gradients.

With the high development of science and technology, in the environment of advocating energy conservation and environmental protection, thermoelectric semiconductor refrigeration / heating chip and its air conditioning system have made great progress in the field of industrial air conditioning with its unique technical advantages. Compared with the traditional industrial air conditioner, the control system of Tec semiconductor industrial air conditioner is simpler.

- It is not used with Freon and other refrigerant, and it has no adverse effect on the environment.
- Small and light weight.
- Very sensitive to temperature.
- Without vibration and noise, it can work at any angle and zero gravity state.
- Because all of them are solid-state based structures, the thermal and electrical coolers have high reliability.

5.3 Cost analysis:

Let's calculate the total cost of our Project and Research in TK:

Sl no	Components	Price in TK
1	Peltier Module	360
2	Cooling Block	350
3	Cooling fan	200
4	Heat sink	250
5	Connecting Pipe	100
6	Switched-Mode Power supply	850
7	Digital Thermometer	400
8	PVC Board	200
9	Circulating Pump	120
10	Reserve Tank	500
11	Glue Gun	300
12	Super glue	200
13	Silicon Gum	300
14	Wire	90
15	Jar	90

Sl no	Components	Price in TK
16	Water Tape	90
17	Water Pot	100
18	LED	50
19	Coolant	500
Total Cost		4,600

Fig: 5.1 Table for cost analysis.

Chapter 6

Conclusion & Reference

6.1 Conclusion

In conclusion, the bottle type water cooling project aims to explore and implement a cooling or heating system based on the thermoelectric effect. The project involves the use of thermoelectric modules, a power supply, control system, heat dissipation components, and a coolant circulation system. R. DM [20]

Water cooling systems offer advantages such as compact size, quiet operation, and environmental friendliness due to the absence of refrigerants. However, they generally have lower efficiency compared to traditional vapor compression systems. The project's success relies on thorough research and understanding of thermoelectric materials, system design, and optimization techniques.

The key components of the thermoelectric air conditioning system, such as the thermoelectric modules, power supply, control system, reservoir tank, and pump, play vital roles in achieving effective cooling or heating. The control system monitors and regulates the temperature and current flow to optimize the system's performance.

The project's success also depends on proper sizing and integration of components, selection of appropriate materials, and implementation of efficient heat dissipation techniques. Additionally, considerations such as system safety, reliability, and cost-effectiveness should be addressed during the project's development.

By successfully implementing the thermoelectric air conditioning system and addressing its limitations, the project can contribute to advancements in energy-efficient and environmentally friendly cooling or heating solutions.

6.1 Reference

- [1] G. Pahl and W. Beitz, Engineering Design A Systematic Approach. London: Springer, 1995.
- [2] Robin Roj, Nils Kate's brink, "Investigation on the Application of Different Air-Cooling-Systems in a Thermoelectric Setup", Quick-Ohm Küpper & Co. GmbH, Unterdahl 24B, 42349 Wuppertal, Germany, 2015
- [3] Gannon, Charles E. Rumors of War and Infernal Machines: Liverpool University Press, 2003.
- [4] Taylor, R.A.; Solbrekken, G.L. (2008). "Comprehensive system-level optimization of thermoelectric devices for electronic cooling applications". IEEE Transactions on Components and Packaging Technologies.
- [5] Xiong, Z., Zhang, L., Ma, S., Yang, Y., Zhang, C., Tang, Z. And Zhu, J. (2013). Journal of Carbohydrate Polymers.
- [6] Sukesh Kumar, Dr.V.N Bartaria, CFD modelling and simulation of axial fan for application in air-cooled heat exchanger (2017)
- [7] ALAM, T., SAINI, R. P., and SAINI, J. S. (2014). , Energy Conversion and Management. 81, 374-383.
- [8] S.Huancheng, L.Shusong.1002-3364(2003)09-0057- 03, 2003
- [9] Narumanchi, Sreekant; Mihalic, Mark; Kelly, Kenneth; Easley, Gary (2008).
- [10] Miller, Rex; Miller, Mark Richard (2004). (10th Ed.). Wiley Publishing, Inc.
- [11] L. Lorenz, G. Decoy, A. Knapp and M. Mars, "COOLMOST™ - "A new milestone in high voltage Power MOS", Siemens AG, Semiconductor Division, Ballast. 73, 81541 Munich, Germany
- [12] S. S. Bhavikatti, "Design Of R.C.C. Structural Elements, Volume 1", new age international publications, new Delhi, 2005

- [13] Miller AC, Singh I, Koehler E, Polygene PM. A Smartphone-driven thermometer application for real-time population- and individual-level influenza surveillance. *Clan Infect Dies* 2018; 67:388–97.
- [14] Brogly M., PhD Thesis, University de Haute-Alsace, Mulhouse, France, (1993).
- [15] Shankar, S., et al., Investigations on the tribological behaviour, toxicity, and biodegradability of kapok oil bio-lubricant blended with (SAE20W40) mineral oil. *Biomass Conversion and Biorefinery*, 2021: p. 1-13
- [16] Stark FO, Falender JR, Wright AP. Silicones. In: Wilkinson G, Stone FGA, Abel EW, editors. *Comprehensive organometallic chemistry*, vol. 2. Oxford: Pergamon Press, 1982. p. 305–63.
- [17] H. Lee, *Thermoelectric- Design and Materials*, John Wiley and Sons, 2016.
- [18] H. Lee, *Thermal Design: Heat Sinks, Thermoelectric, Heat Pipes, Compact Heat Exchangers, and Solar Cells*, Hoboken: John Wiley & Sons, Inc., 2010.
- [19] A. Attar, "Studying the Optimum Design of Automotive Thermoelectric Air Conditioning," Kalamazoo, 2015.
- [20] R. DM. *Thermoelectric Handbook: Macro to Nano*, 2006.