PRESERVATION OF MEDICINES & VACCINES BY THERMOELECTRIC (PELTIER) REFRIGERATION UNIT IN BANGLADESH PERSPECTIVE

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January 2017

ACKNOWLEDGEMENT

First of all, we would like to express our sincere gratitude to Almighty Allah for all the knowledge that He has given to mankind and bestowing us health and patience to complete the work.

There are a good number of people that we would like to thank in assisting us in completion of our thesis. First, we would like to thank our supervisor, Maj Md. Faisal Kader, PhD; not only for supporting us unconditionally, but also for his enthusiastic advice and guidance in obtaining our degree.

We would like to extend our gratefulness to our Mechanical Engineering Department for providing financial support and specially our dean of Mechanical Engineering Department Brig. Gen. Lutfor Rahman for his efficient support and invaluable guidance.

We are grateful to Jahirul Islam and Tousif Islam for giving us ideas during construction process.

We are also grateful to Mr. Dibakor, lab instructor of ME, MIST for processing heatsink by CNC milling machine in his busy schedule.

We are also grateful to Lt Cdr KMR Sadi for his help in providing economical support.

Abstract

The increase in demand for refrigeration globally in the field of air-conditioning, food preservation, medical services, vaccine storages, and for electronic components temperature control, led to the production of more electricity and consequently more release of CO_2 all over the world leads to global warming and many climatic changes.

Thermoelectric refrigeration system is a new alternative because it can reduce the use of electricity to produce cooling effect and also meet today's energy challenges. Therefore, the need for thermoelectric refrigeration in developing countries is very high where long life and low maintenance are needed.

The refrigeration system of thermoelectric refrigerator (TER; $28 \times 23.5 \times 25\ cm^3$) was fabricated by using a thermoelectric cooler (TEC; $4 \times 4\ cm^2$) and applied electrical power of 57.7 W. The TER has cooling fan for the coldness circulates in the refrigerator. The current, differential temperature, time, and coefficient of performance (COP) were analyzed. TEC cold plate temperature (T_c) was decreased from 30 ºC to –4.2 ºC and 55 ºC for hot plate temperature (T_h). The TER temperature was decreased from 30 ºC to 19.5 ºC in 8 hrs. The maximum COP of TEC and TER were 3.0 and 0.55, respectively.

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Chapter 1

Introduction

Introduction

Thermoelectric are based on the Peltier Effect, The Peltier Effect is one of the three thermoelectric effects; the other two are known as the Seebeck Effect and Thomson Effect. Whereas the last two effects act on a single conductor, the Peltier Effect is a typical junction phenomenon.

Thermoelectric coolers are solid state heat pumps used in applications where temperature stabilization, temperature cycling, or cooling below ambient are required. There are many products using thermoelectric coolers, including CCD cameras (charge coupled device), laser diodes, microprocessors, blood analyzers and portable picnic coolers. This article discusses the theory behind the thermoelectric cooler, along with the thermal and electrical parameters involved.

1.1 Motivation

Greenhouse gas has been increasingly emitted globally due to the increasing demand for electricity, heating, refrigerating, air-conditioning, etc. In the last few decades, immense efforts have been made to explore and develop alternative technologies to meet the increasing demand for energy. Green technologies, such as solar photovoltaic, wind turbine, hydrogenation and biomass, have started to play an important role in tackling the energy and environment issues arising in this technology oriented world. These technologies have brought us the undeniable benefits due to their clean style of power generation, which, to some extent, contributes to lessening the environment related issues. However, the greenhouse gas emission during the manufacturing process of these technologies cannot be ignored especially when a large amount of them is required. As we are all deeply aware inside, the overall energy demand of the world has never stopped climbing. The effort in developing the current green technologies and exploring new energy technologies only switches the pressure from traditional power technologies to different technologies. Something has not been changed, which is the increasing demands for energy. Turning our head back, we would be over-whelmed by the way how the resources are consumed. It is excessive and highly inefficient. This makes us wonder the essential cause of all related issues of global energy which have been seizing our attentions intensively. It is not the technologies themselves that give birth to the worries and anxiousness that the world is loaded with. Instead, it is ourselves, who have been consuming our finite resources in an excessive and wasteful style. We must appreciate the beauty of simplicity and reconsider the necessity of energy usage in many areas. Being equally important, the energy efficiency also needs to be enhanced by improving the system efficiency and recovering waste heat. In this paper, the thermoelectric (TE) technology, one of many green technologies, is reviewed to demonstrate its potential in improving the energy efficiency and point a possible direction of alleviating our energy demand.

1.2 Objective

- The objective of this work is to develop a refrigeration system which will provide efficient cooling effect that is cheaper and energy saver than the existing refrigeration system.
- It has no moving parts that’s why its maintenance and repair cost is less.
- Vapor Compression refrigeration system uses mechanical energy whereas thermoelectric refrigeration system uses low power input for cooling.
- Its main objective is to ensure that countries like Bangladesh where electric power is a great problem can get the benefit of this refrigeration system.
- People of remote areas can get benefited by this system.
- We can also use the solar energy in case of low power input which is available throughout the year.
- Preservation of vaccine that need low temp cold storing will be easier by using this refrigeration system.
- To develop a refrigeration system which will not produce any greenhouse gases.

1.3 Historical Background

Although commercial thermoelectric modules were not available until almost 1960, the physical principles upon which modern thermoelectric coolers are based actually date back to the early 1800s.

The first important discovery relating to thermoelectricity occurred in 1821 when German scientist Thomas Seebeck found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals, provided that the junctions of the metals were maintained at two different temperatures. Seebeck did not actually comprehend the scientific basis for his discovery, however, and falsely assumed that flowing heat produced the same effect as flowing electric current.

In 1834, a French watchmaker and part-time physicist, Jean Peltier, while investigating the Seebeck Effect, found that there was an opposite phenomenon where by thermal energy could be absorbed at one dissimilar metal junction and discharged at the other junction when an electric current flowed within the closed circuit. Twenty years later, William Thomson (eventually known as Lord Kelvin) issued a comprehensive explanation of the Seebeck and Peltier Effects and described their relationship. At the time, however, these phenomena were still considered to be mere laboratory curiosities and were without practical application.

In the 1930s, Russian scientists began studying some of the earlier thermoelectric work in an effort to construct power generators for use at remote locations throughout their country. This Russian interest in thermoelectricity eventually caught the attention of the rest of the world and inspired the development of practical thermoelectric modules. Today's thermoelectric coolers make use of modern semiconductor technology in which doped semiconductor material takes the place of the dissimilar metals used in early thermoelectric experiments. The Seebeck, Peltier and Thomson effects, together with several other phenomena, form the basis of functional thermoelectric modules.

The works to create a large-volume domestic thermoelectric cooler started in the mid-1950-s in Leningrad, at the Institute of Semiconductors of the USSR Academy of Sciences and culminated in 1957 in manufacturing cooler prototype with air heat removal and chamber volume 91 liter (Fig.1) [1]. Afterwards, these developments did not advance due to low energy efficiency of thermopiles that made stationary thermoelectric coolers (hereinafter – STEC) noncompetitive as compared to compressor and even absorption counterparts. Thus, the half-century history of stationary thermoelectric coolers is actually reduced to 10-year period at the break of XX and XXI centuries, when the long-cherished dream of academician Ioffe’s followers of thermoelectric products entering our everyday life started to be reanimated and realized.

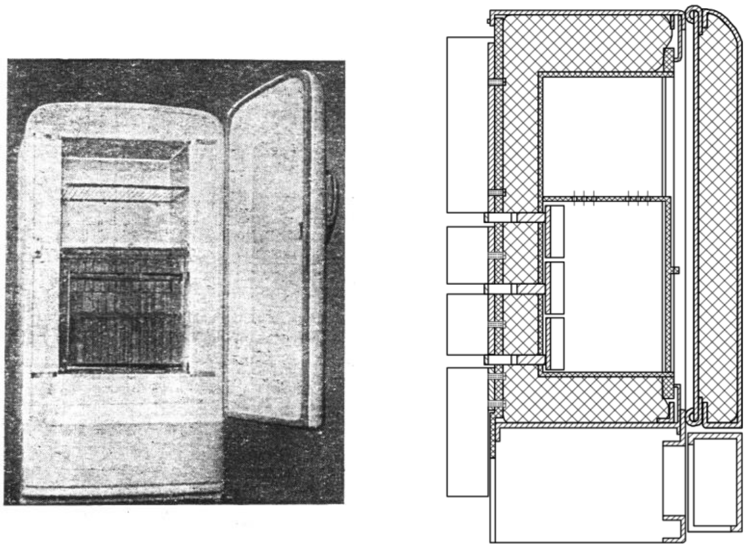


Figure1.3.1 -Appearance and circuit diagram of thermoelectric cooler of 1957 design.

On this background, separate developments of stationary thermoelectric coolers appeared periodically. The majority of them were created in the “Vesta” Research and Production Enterprise (Kyiv, Ukraine). The most successful developments include:

- Thermoelectric cooling cabinet for submarine galley [2]. The basic structural features of such a cooler are as follows: 160-liter internal chamber is made of stainless steel; the heat from the hot junctions of modules is removed by running water.
- Kitchen thermoelectric thermostat which is a support for a domestic cooler designed for storage of vegetables and fruit, and in heating mode – for drying mushrooms. Its chamber of net volume 70 liters is made as a drawer. A cooler weighing up to 100 kg can be mounted on the reinforced support frame. In this cooler, for the first time there were utilized heat pipes providing high uniformity of temperature field along the finned surface of the hot side heat exchanger, which allowed doing away with the use of fans.
- Thermoelectric 200-liter thermostat-bin for round-the-year storage of vegetables and fruit in the balconies and loggias. The device has 12 modules of MT3-18-39 type uniformly arranged on the rear and lateral chamber walls. Heat removal from the modules is realized by means of natural convection dictated by the open air operating conditions, but with no direct exposure to atmospheric precipitates. Located in the room, power supply and control unit automatically

Keeps the chamber temperature at 0...5ºC with a change in ambient air temperature in the range from -40 to +25ºC. At higher air temperatures, the chamber temperature is increased to 8...10ºC. The thermostat was mass produced in Russia in the 90-s. This product up to now is the largest of series stationary thermoelectric coolers and served as a prototype for creation of other thermostat designs, for example, of medical purpose.

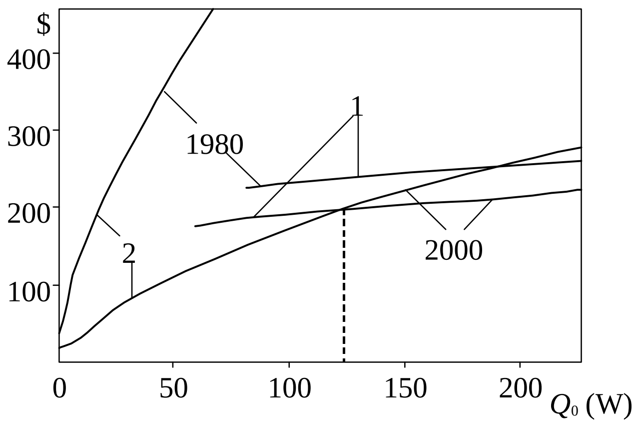


Figure 1.3.2-Qualitative dependences of cooling unit price on its cooling power in 1980 and 2000:
1 –compressor unit, 2 – thermoelectric unit.

Chapter 2

Literature Review

Literature Review

2.1 Cooling Techniques

To maintain optimal performance of PEs and prevent premature failure, adequate cooling is critical. Cooling techniques are usually classified into two groups, conventional and advanced cooling. Conventional cooling techniques commonly consist of forced air or natural convection and conduction. Advanced cooling techniques are comprised of new technologies and methodologies such as direct and indirect cooling, spray cooling, and cooling through the use of TE devices.

2.1.1 Conventional Cooling

Conventional cooling employs large heat sinks and fans as a means to cool. The reward from this type of cooling is simplicity. The PEs are attached to a heat sink with high thermal conductivity and fins as seen in Figure 1.1. The heat sink provides the expediting absorption, transferable, and removal of heat from the PEs. To boost the efficiency in the convection process, a fan is employed to circulate air along the heat sink fins. Increasing the cooling capacity of this system is as straightforward as intensifying the airflow either by obtaining a larger or higher-speed fan. The drawbacks to such a design are the low heat flux removal capacity, the development of hot spots, and the difficulties imposed by maintenance.

In the conventional cooling system, the heat is in effect directly transferred from the PEs to air. Air has a poor thermal conductivity, therefore limiting the heat flux removal capacity. This is the principal reason for the application of heat sinks. Heat sinks absorb the thermal energy from the PEs much more readily than air and distribute the heat through the use of fins that deliver large surface areas for convection to air.

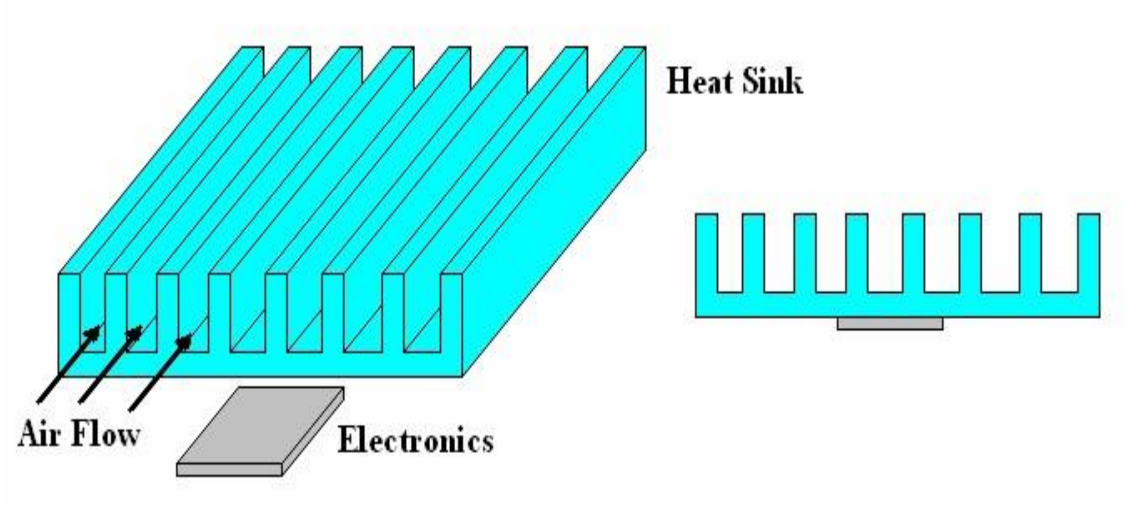


Figure 2.1.1.1 -Conventional cooling.

Due to the small size and resulting limited surface area of PEs, hot spots can generate at solder locations. The heat sink cannot make contact with the solder; hence cooling is not rendered to these locations. These hot spots can spur the growth of cracks and voids between the PEs and their interfaces and ultimately to the deformation and failure of the power electronic modules.

Since a fan is a dynamic component, maintenance is also a concern. Should the fan malfunction, the efficiency of the heat removal system would fall dramatically. This drop in cooling could elicit the overheating and failure of the PEs.

2.1.2 Advanced Cooling

As aforementioned, direct and indirect cooling, spray cooling, and the use of TE devices are classified as advanced cooling techniques. Direct, indirect, and spray cooling all adopt liquid as the cooling agent. TE devices do not draw on any form of cooling agent, but instead rely on several physical phenomena to cool.

2.1.2.1 Direct and Indirect Cooling

Indirect cooling uses a liquid as a cooling agent but does not permit the direct contact of the cooling agent and PEs. Instead, a thermal pathway, usually a metal with a high thermal conductivity, is furnished between the PEs and the cooling agent as seen in Figure. The benefits to indirect cooling relate to the cooling agent. Since the PEs do not come in contact with the cooling agent, the cooling agent can be any liquid. Water is the most commonly applied cooling agent in indirect cooling applications, thanks to its high thermal conductivity and environmental compatibility. The heat flux capacity of indirect cooling exceeds that of conventional cooling by a great margin as a result of the high thermalconductivity of water.

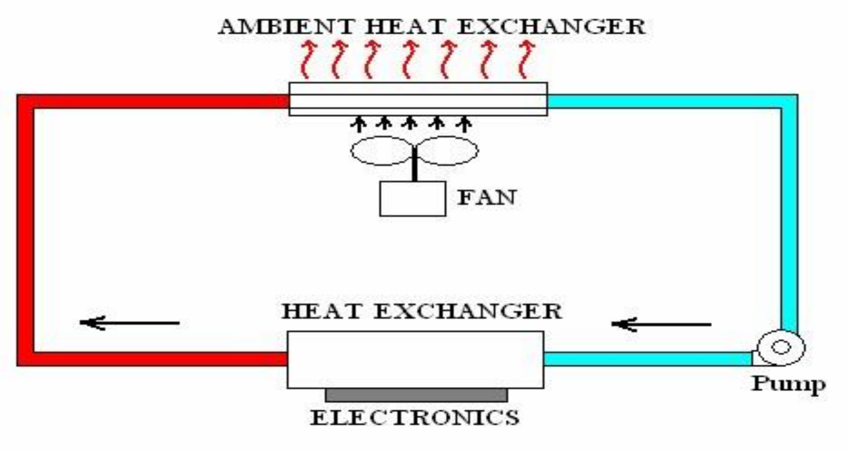


Figure 2.1.2.1.1 -Indirect cooling.

Unlike indirect cooling, direct cooling actually submerges the PEs in the cooling agent as seen in Figure. The lack of separation between the cooling agent and PEs allows for two-phase cooling. Two-phase cooling exploits two phases, liquid and vapor, to remove heat. Essentially, the PEs create a temperature gradient at the surface of the PEs within the cooling agent. The temperature rises from the heat produced by the PEs until the cooling agent begins to boil and convert to vapor. Once in vapor form, the vapor begins to rise due to buoyancy removing the heat from the PEs. As the vapor reaches the ambient surface, the vapor commences cooling. Finally, the vapor returns to the liquid phase completing the cycle.

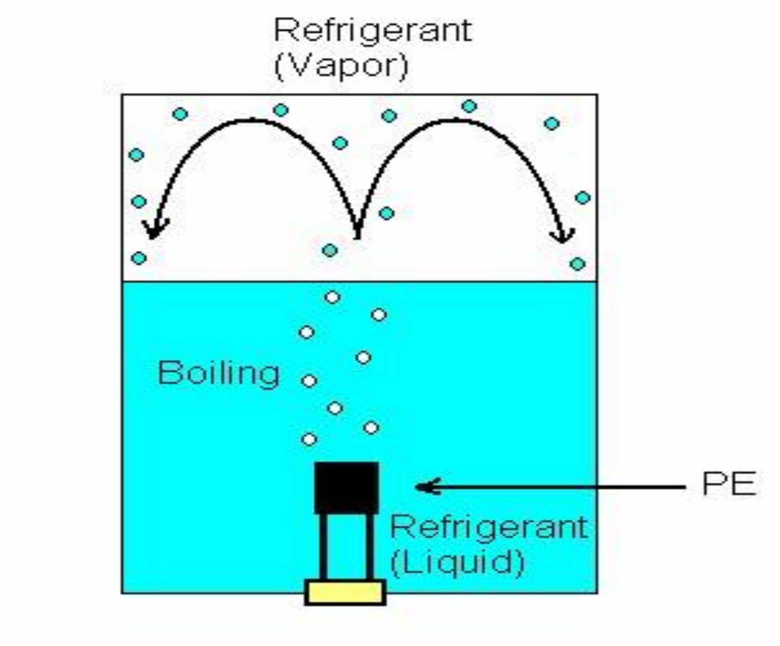


Figure 2.1.2.1.2-Direct cooling.

Two-phase cooling enables direct cooling to have a much greater overall heattransfer coefficient compared to that of indirect cooling. Therefore, direct cooling is capable of removing larger quantities of heat from a smaller volume. This gives direct cooling a distinct advantage over indirect cooling and conventional cooling in terms of cooling capacity. Direct cooling also does not suffer from hot spots since the entire circuit is submerged and is cooled. However, in order to use a cooling agent for two phase direct cooling, the cooling agent must have a high dielectric strength, be noncorrosive, and have a normal boiling point within 20-80°C.

2.1.2.2 Spray Cooling

Spray cooling, as the name implies, injects cooling agent through nozzles onto the PEs module as seen in Figure. The liquid droplets impinge on the surface and form a thin liquid film. Similar to direct cooling, heat from the PEs initiates boiling, which leads to evaporation of the cooling agent. The constant impingement by the spray forces convection of the cooling agent and contributes to cooling the PEs. The hot liquid and vapor cool in the ambient container and returns to the reservoir via a drain to repeat the cycle. The cooling agent frequently employed is water that is subcooled or at saturation temperature to provide more effective cooling. A thin protective layer is coated onto the PEs to protect against short circuits because water has a very low dielectric strength.

The asset of this type of cooling is the large heat flux capacity. Water as noted earlier has a large thermal conductivity allowing for considerable heat flux capacities.

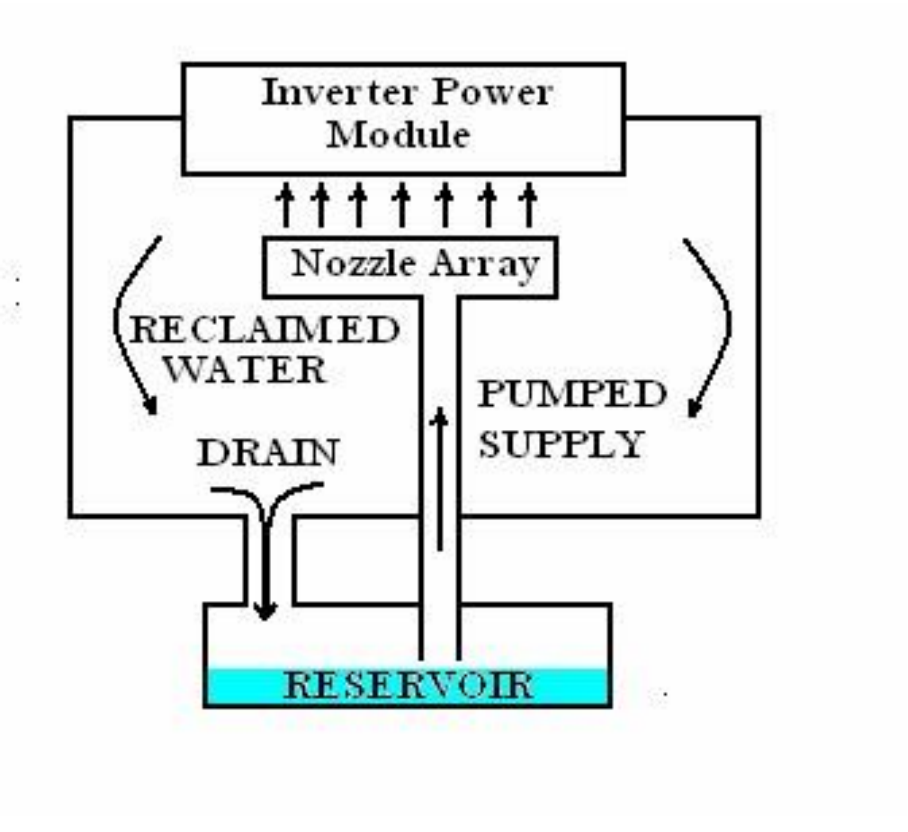


Figure 2.1.2.2.1 -Spray cooling.

Also, the PEs are under a constant barrage of liquid from the spray providing an abundant amount of convection.

The drawback to this cooling methodology is complexity. Spray generation is non-uniform, unpredictable, and varies from nozzle to nozzle. The system also necessitates energy to provide pressure for the nozzles reducing the efficiency of the system. Nevertheless, reported heat flux capacity values have exceeded direct and indirect cooling capacities.

2.1.2.3 Thermoelectric Device Cooling

TE devices are solid state devices that do not profit from the use of cooling.

Instead, TE devices draw on electrical energy along with several physical phenomena, the Seebeck, Peltier, and Thomson effects, to implement cooling. The figure imparts a generic view of the TE device commonly found on most manufacturer websites.

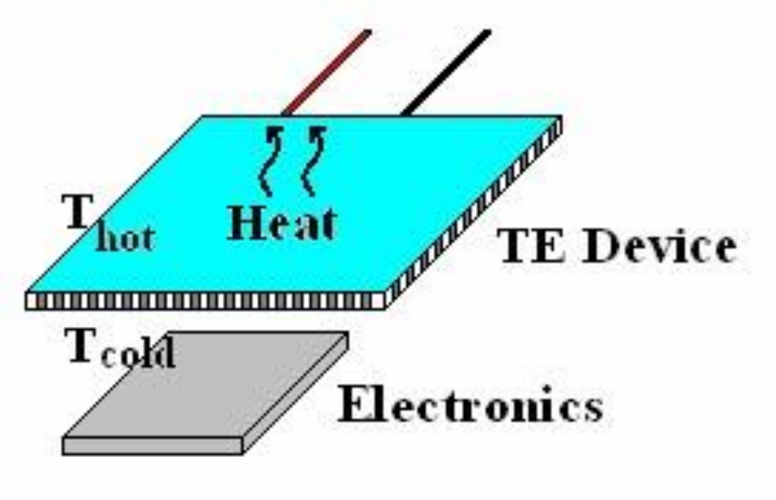


Figure 2.1.2.3.1-TE device.

Multiple justifications exist in exercising TE devices for cooling. TE devices are solid-state. Solid-state devices have no moving parts and as a result require no maintenance. TE devices do not depend on cooling agents. Consequently, TE devices do not necessitate refilling and containment of refrigerants. TE devices can cool below ambient temperatures. None of the aforementioned methods can cool under ambient without the application of a condenser. With a TE device, the temperature can be controlled to within fractions of a degree and can be maintained through utilizing the appropriate support circuitry. The other methods of cooling require feedback for control and must cycle between on and off in an attempt to preserve a specified temperature. TE coolers function in environments that are too severe, too sensitive, or too small for conventional refrigeration.

Despite the large number of assets that TE devices provide, several discouraging obstacles plague TEs. The maximum coefficient of performance (COP) for these devices falls off exponentially with change of temperature as seen in Figure 1.6. Thus, operation above temperature differences of 20 ^{o}C results in extremely low efficiencies. The COP is a gauge on the performance of a system through relating the input energy to the output cooling. TE devices also require a high thermally conductive material for heat dissipation at the interface. Without a thermally conductive material, the surface of the TE will heat/cool at a faster rate than the ambient air alone can absorb resulting in larger temperature variations across the device. These larger temperature variations not only induce lower efficiencies but can also bring about premature failure of the TE device.

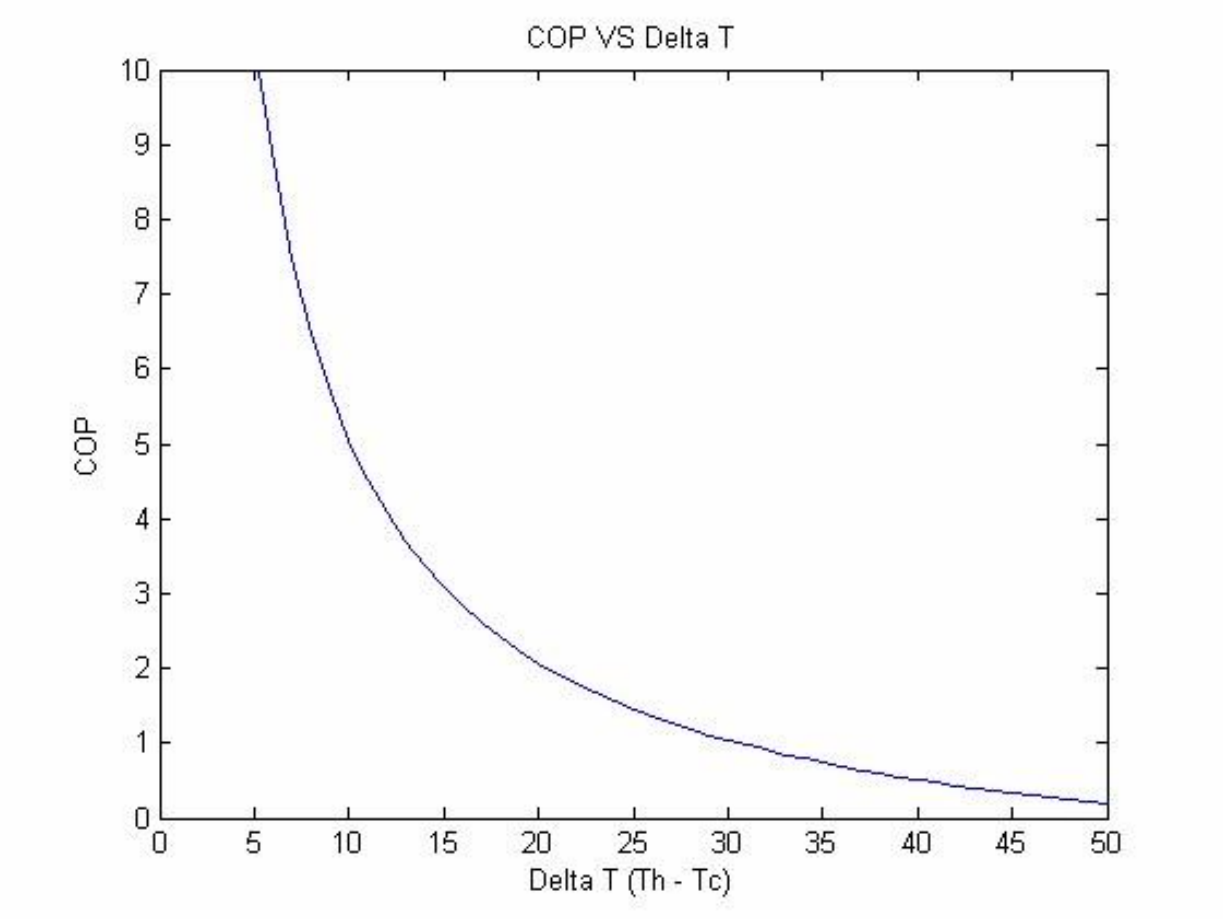


Figure 2.1.2.3.2-Coefficient of performance versus delta T

2.2 THERMOELECTIC BACKGROUND

In the previous chapter, the motivation and precedence in cooling with TEs has been discussed. To better understand the functionality of a TE device, a brief overview of the physical phenomena behind TE devices, Seebeck, Peltier, and Thomson Effects, are reviewed along with the architecture of a TE.

As previously mentioned, some of the key perks in the selection of TE devices are that the device is solid state, can be operated in any environment, has very accurate control, and can cool below ambient. These advantages currently determine the relevance of TE devices. In this chapter, multiple TE applications will be also be examined along with current and future TE technologies.

2.2.1 Physical Phenomena of TE Devices

Three physical phenomena, the Seebeck, Peltier, and Thomson effects are the foundation behind the operation of a TE device. Of these the Peltier effect is recognized as the dominant force that permits TE devices to function. For this reason, the nickname “Peltier cooler” is often bestowed to TE devices.

2.2.1.1 Seebeck Effect

The conductors are two dissimilar metals denoted as material A and material B. The junction temperature at A is used as a reference and is maintained at a relatively cool temperature (T_C). The junction temperature at B is used as temperature higher than temperature T_C. With heat applied to junction B, a voltage (E_{out}) will appear across terminals T_1 and T_2 and hence an electric current would flow continuously in this closed circuit. This voltage as shown in Figure, known as the Seebeck EMF, can be expressed as

$$E_{out} = \alpha (T_H - T_C)$$

Where:

$\alpha = dE / dT = \alpha_A - \alpha_B$

α is the differential Seebeck coefficient or (thermo electric power coefficient) between the two materials, A and B, positive when the direction of electric current is same as the direction of thermal current, in volts per ^oK.

E_{out} is the output voltage in volts.

T_H and T_C are the hot and cold thermocouple temperatures, respectively, in ^oK.

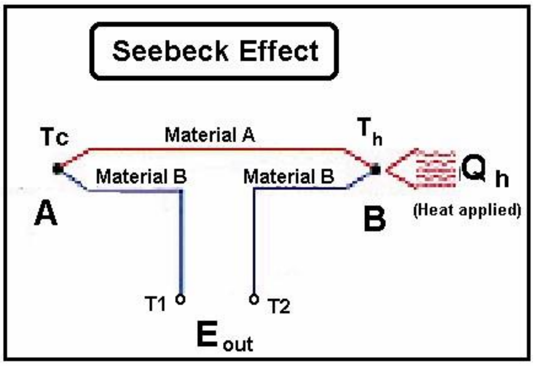


Figure 2.2.1.1.1-Seebeck effect

2.2.1.2 Peltier Effect

Peltier found there was an opposite phenomenon to the Seebeck Effect, whereby thermal energy could be absorbed at one dissimilar metal junction and discharged at the other junction when an electric current flowed within the closed circuit.

In Figure, the thermocouple circuit is modified to obtain a different configuration that illustrates the Peltier Effect, a phenomenon opposite that of the Seebeck Effect. If a voltage (E_{in}) is applied to terminals T_1 and T_2, an electrical current (I) will flow in the circuit. As a result of the current flow, a slight cooling effect (Q_C) will occur at thermocouple junction A (where heat is absorbed), and a heating effect (Q_H) will occur at junction B (where heat is expelled). Note that this effect may be reversed whereby a change in the direction of electric current flow will reverse the direction of heat flow. Joule heating, having a magnitude of I^2 x R (where R is the electrical resistance), also occurs in the conductors as a result of current flow. This Joule heating effect acts in opposition to the Peltier Effect and causes a net reduction of the available cooling. The Peltier effect can be expressed mathematically as

Q_C or $Q_H = \beta \times I$

$= (\alpha T) \times I$

Where:

β is the differential Peltier coefficient between the two materials A and B in volts.

I is the electric current flow in amperes.

Q_C and Q_H are the rates of cooling and heating, respectively, in watts.

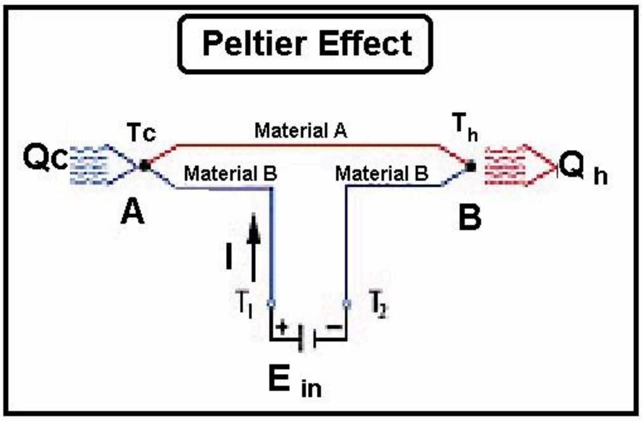


Figure 2.2.1.2.1-Peltier effect

Peltier coefficient β has important effect on Thermoelectric cooling asfollowing:

β <0 ; Negative Peltier coefficient

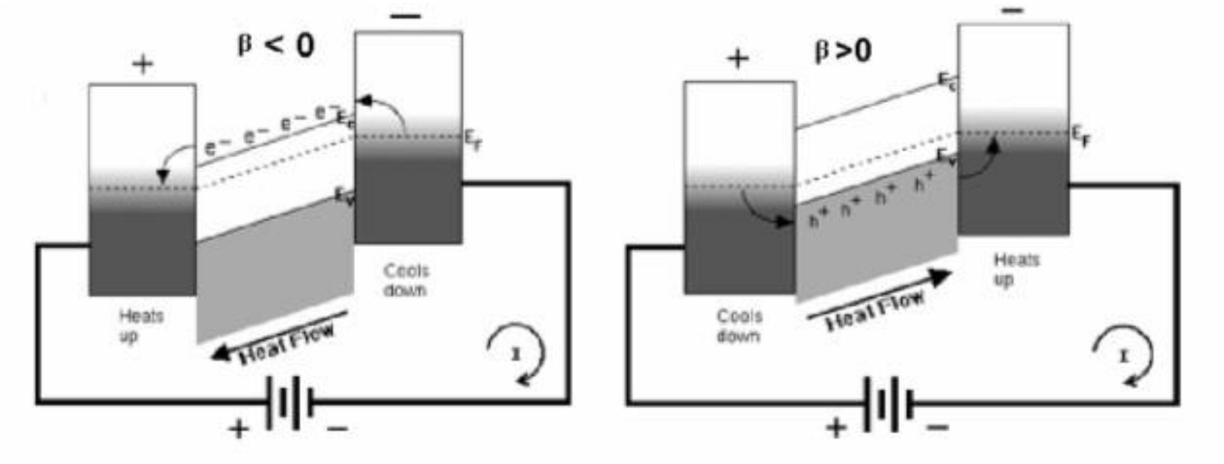
High energy electrons move from right to left.

Thermal current and electric current flow in opposite directions.

β >0 ; Positive Peltier coefficient

High energy holes move from left to right.

Thermal current and electric current flow in same direction



a) –vePeltier coefficient

b)+vePeltiercoefficient

Figure 2.2.1.2.2 -Effect of Peltier coefficient on cooling Process

2.2.1.3 Thomson Effect

William Thomson, who described the relationship between the two phenomena, later issued a more comprehensive explanation of the Seebeck and Peltier effects. When an electric current is passed through a conductor having a temperature gradient over its length, heat will be either absorbed by or expelled from the conductor. Whether heat is absorbed or expelled depends on the direction of both the electric current and temperature gradient. This phenomenon is known as the Thomson Effect.

2.3Areas of Application of Peltier Technology

Thermoelectric cooling technology is applied in areas requiring low level cooling and where energy efficiency is not a priority or using compressors is not feasible due to their size. Peltier-based coolers are ideal for campers or cars for active cooling of beverages and foods, thanks to their portability and option of directly plugging into a 12V electrical system. Thermocycler used for multiplying DNA sequences employs Peltier temperature control to achieve three different reaction temperatures in quick succession for this polymerase chain reaction. Due to their small size, Peltier elements can be used to cool scintillators in order to reduce the noise of the photodiodes. Unlike compressors whose operation relies on their position, Peltier modules are used to construct battery-operated mobile devices, such as refractometers, rheometers, viscometers, and density meters.

Since the amount of heat dissipated by Peltier elements is more than the amount that they can pump, they can be used to cool computer processors to a temperature below ambient temperature. Multistage Peltier modules are used in dew point mirror hygrometers and IR sensors, thanks to their ability to create a temperature difference of over 100k. Peltier technology is also suitable for heating and cooling of diffusion cloud chambers involved in the detection of particles such as positrons, electrons, and alpha radiation.

Peltier technology is also used in the cooled incubators involving incubation at or around ambient temperature (15 - 30°C), or in areas involving heat input, eliminating the technical complexity and drawbacks of a compressor system.

Applications for thermoelectric modules cover a wide spectrum of product areas. These include equipment used by military, medical, industrial, consumer, scientific/laboratory, and telecommunications organizations. Uses range from simple food and beverage coolers for an afternoon picnic to extremely sophisticated temperature control systems in missiles and space vehicles.

Unlike a simple heat sink, a thermoelectric cooler permits lowering the temperature of an object below ambient as well as stabilizing the temperature of objects which are subject to widely varying ambient conditions. A thermoelectric cooler is an active cooling module whereas a heat sink provides only passive cooling.

Thermoelectric coolers generally may be considered for applications that require heat removal ranging from milliwatts up to several thousand watts. Most single-stage TE coolers, including both high and low current modules, are capable of pumping a maximum of 3 to 6 watts per square centimeter (20 to 40 watts per square inch) of module surface area. Multiple modules mounted thermally in parallel may be used to increase total heat pump performance. Large thermoelectric systems in the kilowatt range have been built in the past for specialized applications such as cooling within submarines and railroad cars. Systems of this magnitude are now proving quite valuable in applications such as semiconductor manufacturing lines. The range of the application of thermoelectric module is vast in some other areas

Typical applications for thermoelectric modules include:

01. Avionics
02. Black box cooling
03. Calorimeters
04. CCD (Charged Couple Devices)
05. CID (Charge Induced Devices)
06. Cold chambers
07. Cold plates
08. Compact heat exchangers
09. Constant temperature baths
10. Dehumidifiers
11. Dew point hygrometers
12. Electronics package cooling
13. Electrophoresis cell coolers
14. Environmental analyzers
15. Heat density measurement
16. Ice point references
17. Immersion coolers
18. Integrated circuit cooling
19. Inertial guidance systems
20. Infrared calibration sources and black body references
21. Infrared detectors
22. Infrared seeking missiles
23. Laser collimators
24. Laser diode coolers
25. Long lasting cooling devices
26. Low noise amplifiers
27. Microprocessor cooling
28. Microtome stage coolers
29. NEMA enclosures
30. Night vision equipment
31. Osmometers
32. Parametric amplifiers
33. Photomultiplier tube housing
34. Power generators (small)
35. Precision device cooling (lasers and microprocessors)
36. Refrigerators and on-board refrigeration systems (aircraft, automobile, boat, hotel, insulin, 37.portable/picnic, pharmaceutical, RV)
38. Restaurant portion dispenser
39. Self-scanned arrays systems
40. Semiconductor wafer probes
41. Stir coolers
42. Thermal viewers and weapons sights
43. Thermal cycling devices (DNA and blood analyzers)
44. Thermostat calibrating baths

45. Tissue preparation and storage
46. Vidicon tube coolers
47. Wafer thermal characterization
48. Water and beverage coolers
49. Wet process temperature controller
50. Wine cabinets

Many advances in computer technology have been made possible by increases in the packaging density of electronics. These advances began with the introduction of the transistor in 1947 and continue today with ultra-large scale integration at the chip level coupled with multi-chip modules. The combination of increased power dissipation and increased packaging density led to substantial increases in chip and module heat flux over the past 40 years, particularly in high-end computers. During this time the challenge was to limit chip temperature rise above the ambient coolant temperature to ensure satisfactory circuit operation and reliability.

Throughout this period virtually all commercial computers were designed to operate at temperatures above ambient, generally in the range of 60° to 100°C. Researchers identified the advantages of operating electronics at low temperatures. These advantages include: faster semiconductor device switching; increased speed due to lower electrical resistance of interconnecting materials; and a reduction in thermally induced failures.

In 1997 IBM announced and shipped the RY5 S/390 mainframe, which uses a conventional refrigeration system to maintain chip temperatures below that of comparable air-cooled systems, but well above cryogenic temperatures. Since then there have been indications that other manufacturers may be developing refrigeration cooled computers.

The growing demand for energy throughout the world has caused great importance to be attached to the exploration of new sources of energy. Among the unconventional sources, solar energy is one of the most promising energy resources on earth and in space, because it is clean and inexhaustible.

Applications of solar thermoelectric generator are attractive.
The use of the sola thermoelectric generator usually combines a solar thermal collector with a thermoelectric generator which delivers the electric energy.

Thermoelectric power generation is based on a phenomenon called “Seebeck effect” discovered by Thomas Seebeck in 1821. When a temperature difference is established between the hot and cold junctions of two dissimilar materials (metals or semiconductors) a voltage is generated, i.e., Seebeck voltage. Generator operating based on Seebeck effect. Based on Seebeck effect, the heat supplied at the hot junction causes an electric current to flow in the circuit and electrical power is produced. Using the first-law of thermodynamics (energy conservation principle) the difference between QH and QL is the electrical power output. It should be noted that this power cycle intimately resembles the power cycle of a heat thus in this respect a thermoelectric power generator can be considered as a unique heat engine.

2.4 Medicine & Vaccine Preservation Conditions

A separate, secure and dedicated refrigerator should be available for medicines in services where there is a regular need for medicines to be stored between 2°C – 8°C.

In smaller services where the need for cold storage may only be, for example, for the occasional bottle of oral antibiotic or eye drops, medicines could be stored in a domestic fridge. Here medicines should be kept on a separate shelf in a lidded plastic container which will help in isolating the medicines from any other fridge items. The medicines container in the domestic fridge should not be accessible to service users.

Some medicines require storage at less than 15°C. Since most services do not have a cool room a refrigerator would probably provide appropriate storage for such products, provided that storage below 8ºC does not affect the medicine.

The requirement to store medicines at 25°C or below can usually be satisfied by room temperature storage. The requirement to monitor room temperatures is only an issue if the room appears to be “warm”. This might be the case, for example, if the room was next to the kitchen, contained a cupboard with a hot water tank, was consistently warmed by sunshine through a window etc.

If the main medicines room falls into this sort of situation, or if there is any doubt about the temperature of the room, it would be recommended that daily temperature readings are recorded for a sustained period (e.g. 2-3 months) to ascertain if the temperature is consistently above 25 degrees.

If the main storage area is found to be consistently above 25°C measures such as the introduction of an air conditioner should be implemented by the service in an attempt to control the problem.

While some medicines will be unaffected at temperatures consistently above 25°C, others, however, will not. If the service is in any doubt about which medicines may be affected they should contact their supplying pharmacist for advice.

Summary

- Storage conditions can influence the stability of medicines.
- Maximum and minimum temperatures over the previous 24 hours should be recorded daily in fridges used to store medicines between 2°C and 8°C.
- Temperatures should be recorded daily for any central medicines storage areas if there is any concern that the temperature is above 25°C.

2.5 Bangladesh Perspective

In Bangladesh, electricity supply is not sufficient to meet the required demand and refrigerators that are used in daily life, are one of the indispensable tools. So the thermoelectric refrigerator based on low power supply is very much effective to preserve different types of goods and food.

In another case there are many remote areas in Bangladesh where the preservation of essential medicines &vaccines is very difficult. Here we can implement the usage of thermoelectric refrigerator. For using the refrigerator unit, solar PV panels can be used as power source as there is enough sunshine. By the grace of it the necessity of electricity becomes less.

Low-income households face several economic and non-economic barriers hindering them from investing in electrical equipment. Typically, a low-income household should consume less energy than a high-income household as a higher income is likely to influence an increasing number of appliances and hence appliance energy usage. However, low-income households tend to choose household appliances that are less energy efficient because they are prone to choose products with lowest initial costs, which often are also of low quality and energy inefficient.

Although in our country there is less opportunity in technological sector, the system can be implemented effectively due to availability of required components like peltier module (thermoelectric module).

Chapter 3

Principle, Operation & Working Procedure

3.1 Thermoelectric Principle of Operation

The typical thermoelectric module is manufactured using two thin ceramic wafers with a series of P and N doped bismuth-telluride semiconductor material sandwiched between them as shown in Figure. The ceramic material on both sides of the thermoelectric adds rigidity and the necessary electrical insulation. The N type material has an excess of electrons, while the P type material has a deficit of electrons. One P and one N make up a couple, as shown in Figure. The thermoelectric couples are electrically in series and thermally in parallel. A thermoelectric module can contain one to several hundred couples.

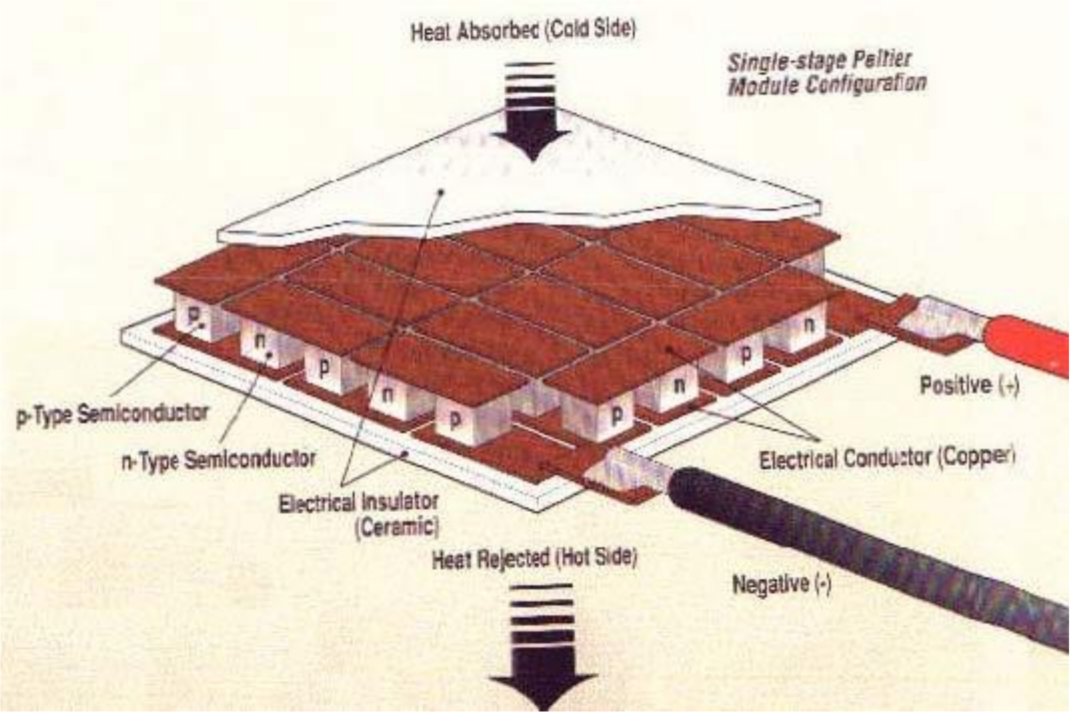


Figure 3.1.1-TEC Principle of operation

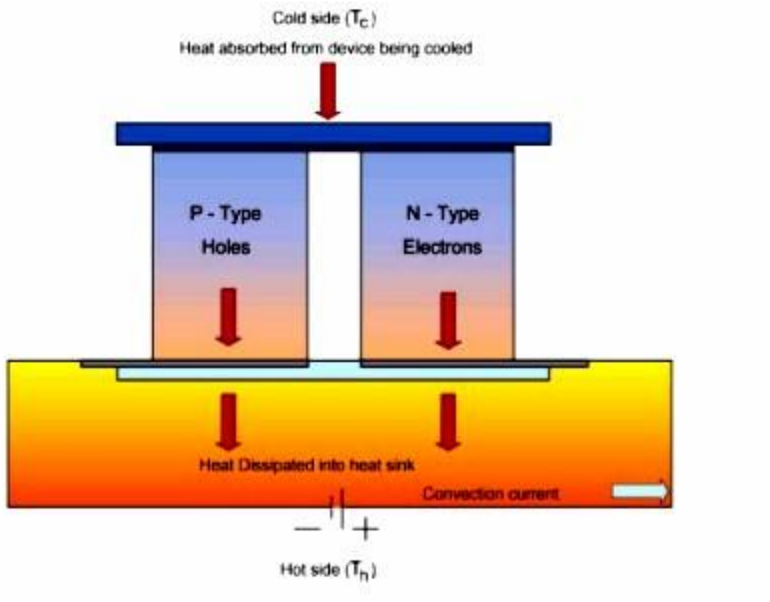


Figure 3.1.2-Cross section of a thermoelectric cooler

As the electrons move from the P type material to the N type material through an electrical connector, the electrons jump to a higher energy state absorbing thermal energy (cold side). Continuing through the lattice of material; the electrons flow from the N type material to the P type material through an electrical connector dropping to a lower energy state and releasing energy as heat to the heat sink (hot side).

Thermoelectric can be used to heat and to cool, depending on the direction of the current. In an application requiring both heating and cooling, the design should focus on the cooling mode. Using a thermoelectric in the heating mode is very efficient because all the internal heating (Joulian heat) and the load from the cold side is pumped to the hot side. This reduces the power needed to achieve the desired heating.

Recently, the global increasing demand for refrigeration, e.g. air-conditioning, food preservation, vaccine storages, medical services, and cooling of electronic devices, led to production of more electricity and consequently more release of CO_2 all over the world which it is contributing factor of global warming on climate change. TER is new alternative because it can convert waste electricity into useful cooling, is expected to play an important role in meeting today’s energy challenges. Therefore, TER are greatly needed, particularly for developing countries where long life and low maintenance are needed. TER are applied of TEC with base on Peltier effect for removing heat by DC current applied across two dissimilar materials causes a temperature differential. Since TEC can be analyzed by Joule heat, which is called heat rejection (Qh), from TEC hot side larger than the heat absorption (Qc), into TEC cold side. The general forms of heat absorption and heat rejection are presented as below.

$$Q_c = \alpha I T_c - 0.5 I^2 R - k_t (T_h - T_c) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .(1)$$

$$Q_h = \alpha I T_h - 0.5 I^2 R + k_t (T_h - T_c) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .(2)$$

Where Ị is the Seebeck coefficient (VK^{-1}), I is the electric current, Tc is the TEC cold side temperature, Th is the TEC hot side temperature, R is the electrical resistant of the TEC material, and Nt is the thermoelectric element thermal conductivity ($Wm^{-1}K^{-1}$). The COP of TEC and TER measurement are described with the following equations.

$$\mathrm{COP} = \frac{Qc}{Qh - Qc} = \frac{Tc}{Th - Tc} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

In this work, we are measurement for finding COP of TEC and TER from fabricated TER.

Co-efficient of performance:

The coefficient of performance is used to quantify the performance of refrigeration cycles. The symbol used for coefficient of performance is “COP” with a subscript “R,” for refrigeration. Just like the efficiency of power cycles, the COP is defined as the ratio of the desired output to the required input.

3.1.1 Controlling a Peltier System

Pulse width modulation involving control of the average current by the length of high frequency current pulses is used to control Peltier elements. Another commonly used method is voltage regulation. However, simple on-off control is recommended due to the possibility of reduced component life caused by the heavy load on the Peltier element. Peltier modules can be regulated by reversing the direction of the current, but reversing the polarity prior to equalizing the temperature in the Peltier element will expose the Peltier element to enormous thermal stress.

3.2 Advantages and Drawbacks of Peltier Systems

The following are the advantages of Peltier elements:

- Highly reliable, durable, and requires less maintenance as they do not contain moving components that are prone to wear
- Vibration and noise-free operation
- Lightweight and smaller footprint
- Low manufacturing cost
- Absence of refrigerants that are ozone depleting, thanks to the advanced control technology
- System function can be reversed by reversing the polarity

The following are the drawbacks of Peltier elements:

- Cold and hot sides are very close to each other, posing a challenge for efficient heat transfer from and to the module; large heat sinks with fans are used for this purpose.
- A Peltier module's performance relies on the required temperature difference. Complex multistage elements are required to achieve greater temperature differences.
- In Peltier elements, the current behaves a refrigerant in the cooling cycle and its flow influences the pumping capacity. Hence, the pumping capacity needs to compensate for the loss of power due to the irreversible conversion of the current into Joulean heat and the resulting heat loss on the cold side, prior to a net cooling capacity results. Therefore, it is necessary to accept a multiple of heat pumping capacity for power loss in Peltier systems.
- Conversely, in compressor systems, the cooling capacity is above the work to be invested by roughly two folds.

3.3 Comparison between Peltier technology & Compressor technology

"Peltier technology" was discovered by Athanase Peltier while observing the temperature difference between one side of a device and the other, depending on the direction of current. Only from recent advances in semiconductor materials has the full utilization of this technology been realized. The strength of Peltier technology lies in the scalability of its cooling elements, their location-independence, precision control, as well as vibration-free and noise-free operation.

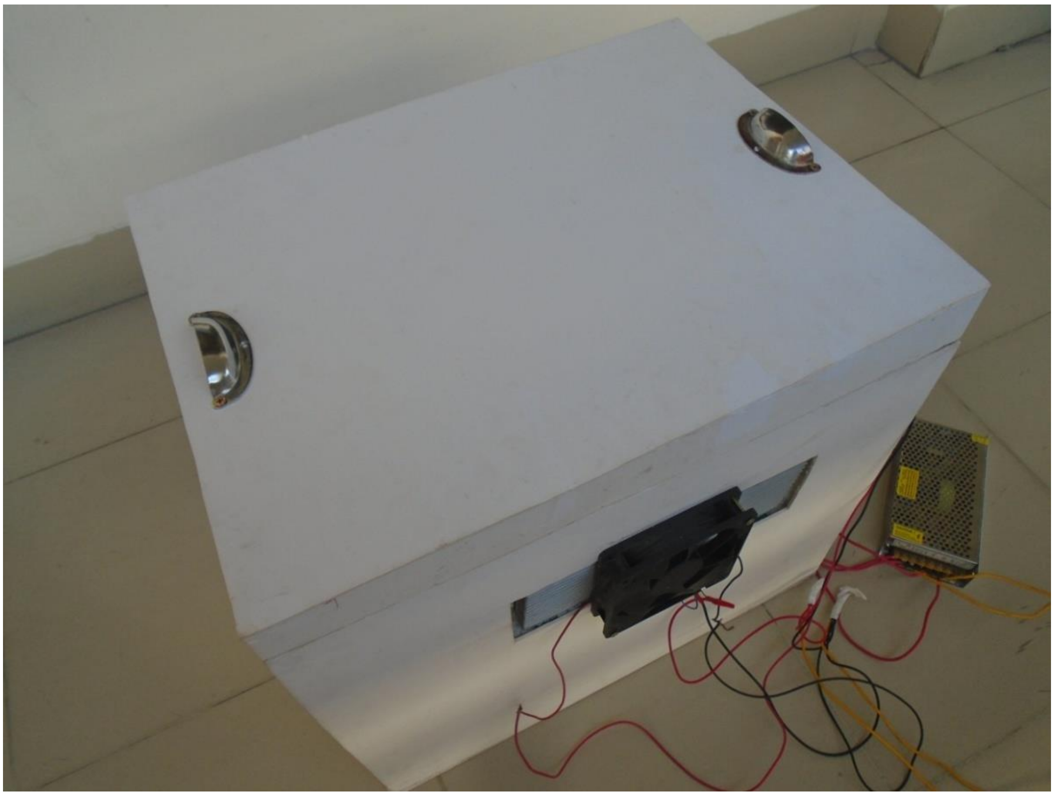
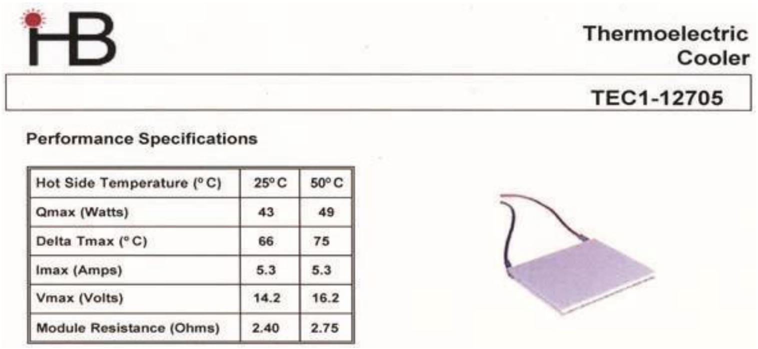


Figure 3.3.1-Setup view

3.4 Methodology

Analyzing COP of TEC

The COP of TEC (TEC1-12706) is analyzed from measurement values compose of Volt, Amp schematic for electric measurement is shows in the Fig. The Qc of TEC is calculated by Eq. (1), where Į is 0.04224 VK^{-1}, I is 1-3 A, R is 3.25 and Nt is 0.495$Wm^{-1}K^{-1}$.



Thermoelectric
Cooler

TEC1-12705

Performance Specifications

Hot Side Temperature (° C)	25° C	50° C
Qmax (Watts)	43	49
Delta Tmax (° C)	66	75
Imax (Amps)	5.3	5.3
Vmax (Volts)	14.2	16.2
Module Resistance (Ohms)	2.40	2.75

Figure3.4.1-The data performance specifications of TEC1-12706

Chapter 4

Installation & Procedure

Construction and Procedure

4.1Installation

Figure 4.1.1–Thermoelectric Refrigeration Unit Construction

To design a coolerbox, it is important to determine if the heat exchanger (fan) that is used to operate adequately under the designing conditions. For this project a TEC mechanical fan was used. In sizing the TEC (determining the heat rejection capability of the TEC, it was considered to be important to see if the manufacturer’s performance claims for the TEC were accurate.
This is important, because should the TEC be undersized, performance of the coolerbox under adverse conditions would suffer. Should the TEC be oversized, it would result in a high power consumption appliance.

A simulator (by heatsink, Peltier module, thermal paste, insulator, and fan) and a 12V variable DC power supply were constructed for this project. The intention was to see if the performance data on the TEC supplied by the manufacturers are measured under ideal conditions, thus resulting in elevated performance data that could lead to a poor heat exchange design due to undersizing.

The purpose of the power supply that was constructed was to provide enough current to the Peltier module, digital thermometer and the fans in the simulator.

Clamping

The most common mounting method involves clamping the thermoelectric module(s) between a heat sink and flat surface of the article to be cooled. This approach, as illustrated in Figure (6.1), usually is recommended for most applications and may be applied as follows:

a) Machine or grind flat the mounting surfaces between which the TE module(s) will be located. To achieve optimum thermal performance mounting surfaces should be flat to within 1mm/m (0.001 in/in).

b) If several TE modules are mounted between a given pair of mounting surfaces, all modules within the group must be matched in height/thickness so that the overall thickness variation does not exceed 0.06mm (0.002″). Module P/N with a “B” ending should be specified.

c) Mounting screws should be arranged in a symmetrical pattern relative to the module(s) so as to provide uniform pressure on the module(s) when the assembly is clamped together. To minimize heat loss through the mounting screws, it is desirable to use the smallest size screw that is practical for the mechanical system. For most applications, M3 or M3.5 (4-40 or 6-32) stainless steel screws will prove satisfactory. Alternately, nonmetallic fasteners can be used, e.g., nylon. Smaller screws may be used in conjunction with very small mechanical assemblies. Belleville spring washers or split lock-washers should be used under the head of each screw to maintain even pressure during the normal thermal expansion or contraction of system components.

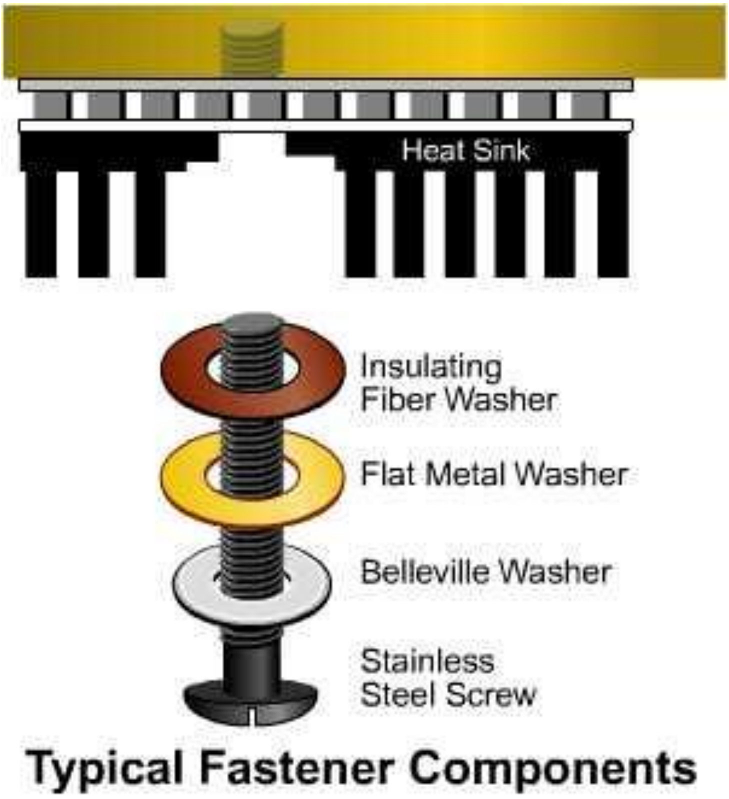


Figure 4.1.2 -Clamping

d) Clean the module(s) and mounting surfaces to ensure that all burrs, dirt, etc., have been removed.

e) Coat the “hot” side of the module(s) with a thin layer (typically 0.02mm / 0.001″ or less thickness) of thermally conductive grease and place the module, hot side down, on the heat sink in the desired location. Gently push down on the module and apply a back and forth turning motion to squeeze out excess thermal grease. Continue the combined downward pressure and turning motion until a slight resistance is detected. Ferrotec America recommends and stocks American Oil and Supply (AOS) type 400 product code 52032.

f) Coat the “cold” side of the module(s) with thermal grease as specified in step (e) above. Position and place the object to be cooled in contact with the cold side of the module(s). Squeeze out the excess thermal grease as previously described.

g) Bolt the heat sink and cooled object together using the stainless steel screws and spring washers. It is important to apply uniform pressure across the mounting surfaces so that good parallelism is maintained. If significantly uneven pressure is applied, thermal performance may be reduced, or worse, the TE module(s) may be damaged. To ensure that pressure is applied uniformly, first tighten all mounting screws finger tight starting with the center screw (if any). Using a torque screwdriver, gradually tighten each screw by moving from screw to screw in a crosswise pattern and increase torque in small increments. Continue the tightening procedure until the proper torque value is reached. Typical mounting pressure ranges from 25 – 100 psi depending on the application. If a torque screwdriver is not available, the correct torque value may be approximated by using the following procedure:

In a crosswise pattern, tighten the screws until they are “snug” but not actually tight. In the same crosswise pattern, tighten each screw approximately one quarter turn until the spring action of the washer can be felt.

h) A small additional amount of thermal grease normally is squeezed out soon after the assembly is first clamped together. In order to insure that the proper screw torque is maintained, wait a minimum of one hour and recheck the torque by repeating step (g) above.

i) CAUTION: Over-tightening of the clamping screws may result in bending or bowing of either the heat sink or cold object surface especially if these components are constructed of relatively thin material. Such bowing will, at best, reduce thermal performance and in severe cases may cause physical damage to system components. Bowing may be minimized by positioning the clamping screws close to the thermoelectric module(s) and by using moderately thick materials. However, if hot and/or cold surfaces are constructed of aluminum which is less than 6mm (0.25″) thick or copper which is less than 3.3mm (0.13″) thick, it may be necessary to apply screw torque of a lower value than specified in step (g) above.

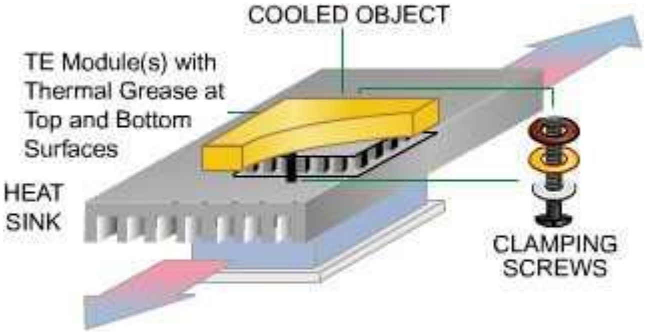


Figure 4.1.3-TE Module Installation Using the Clamping Method

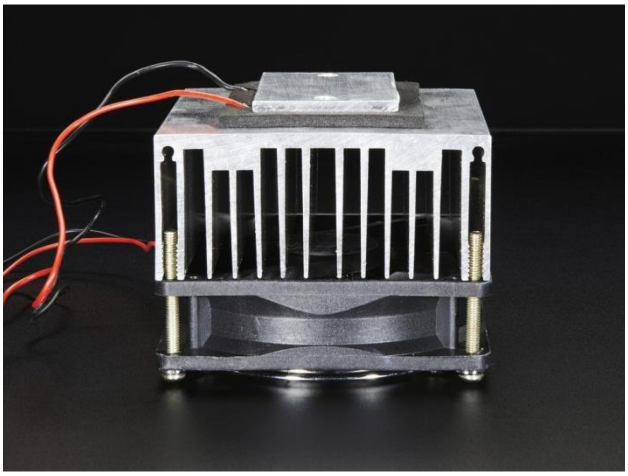


Figure 4.1.4– Cooling Unit

4.2 Components

1. Choosing a TEC Controller

The TEC controller is regulating the current supplied to the Peltier element, according to the desired temperature and the object temperature measured.

Meerstetter Engineering TEC Controller Products
TEC Controller Setup Guide – step by step guide helping you to set up your controller
TEC Controller Notes – information on how to connect accessories to the TEC controller
TEC Family User Manual (PDF) – detailed information on functionality of TEC controllers
Given the current I_{max} and voltage U_{max} of the Peltier element one has to select an appropriate TEC controller.

Based on I_{max} of the Peltier element you can select one of the following models from Meerstetter Engineering's TEC Family.

Single channel (stage) TEC controllers:

I < 4 A TEC-1091 (21 V)
4 - 10 A TEC-1089 (21 V)
10 - 16 A TEC-1090 (30 V)
Dual channel TEC controllers in parallel mode:

16 - 20 A TEC-1122 (21 V)
20 - 32 A TEC-1123 (30 V)

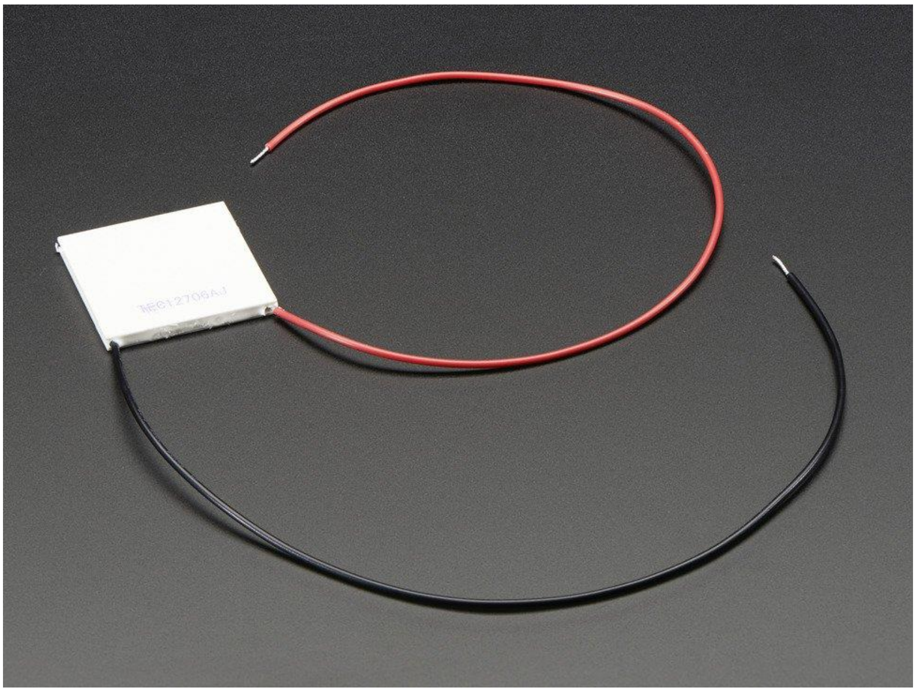


Figure 4.1.5-Peltier Module

The TEC module was selected by considering few factors such as dimensions, Q_C, power supply etc. The model number of the module is TEC1-12706. It is decided to select a TEC module which has a cooling power greater than the calculated cooling load. TEC1-12706 operates with an optimum voltage value of 12V. It has a maximum voltage of 15.4V. At 12V it draws and maximum DC current of 6 A. The nominal power rating or the cooling power is 60 W. It has a maximum operating temperature of 200^0C. ΔT of the TEC is 70 when hot side temperature is $25\ ^0C$. It had been decided to choose 6TECs of the same model so that when the power of all the 6 TEC modules are greater than the calculated cooling load. The minimum power rating for 6 TEC modules added together was more than the cooling load calculated. More number of TEC reduces the time required for cooling of a particular material.

2. Heat Sink

The heat sink absorbs the heat load at the warm side of the Peltier element and dissipates it to the surrounding air.

The heat sink has to be large enough, so that its temperature doesn't get too high. This is a point that shouldn't be underdesigned. On the other hand the heat sink has to fit into the application by its form and dimensions. Depending on your requirements a custom made heat sink or heat pipe might be a solution.

The thermal resistance is calculated by: $R_{th}Sink = \Delta T/P$
$R_{th}Sink$ = Thermal resistance of the heat sink [K/W]
ΔT = Temperature difference between the heat sink and the ambient air temperature [K]
P = Heat load to be absorbed [W]

The heat load P has to be assumed as heat load of the object plus heat load of the Peltier element due to losses.

As an example we assume P = 20 W. The temperature difference ΔT between the heat sink and the ambient temperature (25 °C) shall not be higher than 10 K. So $\Delta T = 10$ K.

$R_{th}Sink = \Delta T/P = 10 \text{ K} / 20 \text{ W} = 0.5 \text{ K/W}$ (minimum)

The smaller the thermal resistance $R_{th}Sink$ the bigger the heat sink. So we choose a heat sink with $R_{th}Sink$ smaller than 0.5 K/W.

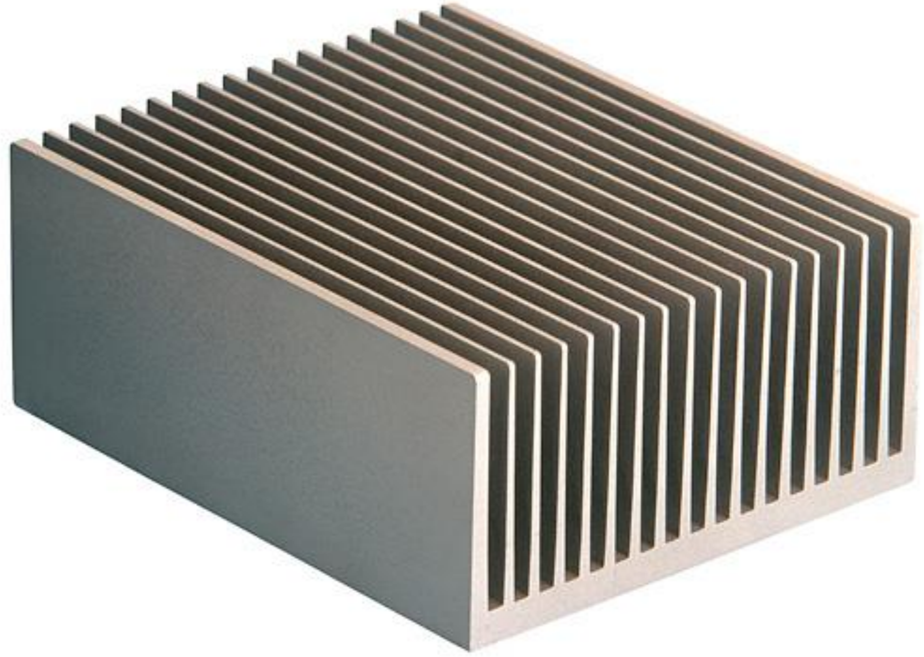


Figure 4.1.6– Heat sink

Rather than being a heat absorber that consumes heat by magic, a thermoelectric cooler is a heat pump which moves heat from one location to another. When electric power is applied to a TE module, one face becomes cold while the other is heated. In accordance with the laws of thermodynamics, heat from the (warmer) area being cooled will pass from the cold face to the hot face. To complete the thermal system, the hot face of the TE cooler must be attached to a suitable heat sink that is capable of dissipating both the heat pumped by the module and Joule heat created as a result of supplying electrical power to the module.

A heat sink is an integral part of a thermoelectric cooling system and its importance to total system performance must be emphasized. Since all operational characteristics of TE devices are related to heat sink temperature, heat sink selection and design should be considered carefully.

A perfect heat sink would be capable of absorbing an unlimited quantity of heat without exhibiting any increase in temperature. Since this is not possible in practice, the designer must select a heat sink that will have an acceptable temperature rise while handling the total heat flow from the TE device(s). The definition of an acceptable increase in heat sink temperature necessarily is dependent upon the specific application, but because a TE module’s heat pumping capability decreases with increasing temperature differential, it is highly desirable to minimize this value. A heat sink temperature rise of 5 to 15°C above ambient (or cooling fluid) is typical for many thermoelectric applications.

Several types of heat sinks are available including natural convection, forced convection, and liquid-cooled. Natural convection heat sinks may prove satisfactory for very low power applications especially when using small TE devices operating at 2 amperes or less. For the majority of applications, however, natural convection heat sinks will be unable to remove the required amount of heat from the system, and forced convection or liquid-cooled heat sinks will be needed.

Heat sink performance usually is specified in terms of thermal resistance (Q):

$$Q_s = \frac{T_s - T_a}{Q}$$

where:

Q_s = Thermal Resistance in Degrees C per Watt
T_s = Heat Sink Temperature in Degrees C
T_a = Ambient or Coolant Temperature in Degrees C
Q = Heat Input to Heat Sink in Watts

Each thermoelectric cooling application will have a unique heat sink requirement and frequently there will be various mechanical constraints that may complicate the overall design. Because each case is different, it is virtually impossible to suggest one heat sink configuration suitable for most situations. We have several off the shelf heat sinks and liquid heat exchangers appropriate for many applications but encourage you to contact our engineering department.

When combining thermoelectric cooling modules and heat sinks into a total thermal system, it normally is not necessary to take into account heat loss or temperature rise at the module to heat sink junctions. Module performance data presented herein already includes such losses based on the use of thermal grease at both hot and cold interfaces. When using commercially available heat sinks for thermoelectric cooler applications, it is important to be aware that some off-the-shelf units do not have adequate surface flatness. A flatness of 1mm/m (0.001 in/in) or better is recommended for satisfactory thermal performance and it may be necessary to perform an additional lapping, flycutting, or grinding operation to meet this flatness specification.

Natural Convection Heatsink: Natural convection heat sinks normally are useful only for low power applications where very little heat is involved. Although it is difficult to generalize, most natural convection heat sinks have a thermal resistance (Qs) greater than 0.5°C/watt and often exceeding 10°C/watt. A natural convection heat sink should be positioned so that (a) the long dimension of the fins is in the direction of normal air flow, vertical operation improves natural convection and (b) there are no significant physical obstructions to impede air flow. It also is important to consider that other heat generating components located near the heat sink may increase the ambient air temperature, thereby affecting overall performance.

Forced Convection Heatsink: Probably the most common heat-sinking method used with thermoelectric coolers is forced convection. When compared to natural convection heat sinks, substantially better performance can be realized. The thermal resistance of quality forced convection systems typically falls within a range of 0.02 to 0.5°C/watt. Many standard heat sink extrusions are available that, when coupled with a suitable fan, may be used to form the basis of a complete cooling assembly. Cooling air may be supplied from a fan or blower and may either be passed totally through the length of the heat sink or may be directed at the center of the fins and pass out both open ends. This second air flow pattern, illustrated in Figure (5.l), generally provides the best performance since the air blown into the face of the heat sink creates greater turbulence resulting in improved heat transfer. For optimum performance, the housing of an axial fan should be mounted a distance of 8-20mm (0.31-0.75″) from the fins. Other configurations may be considered depending on the application.

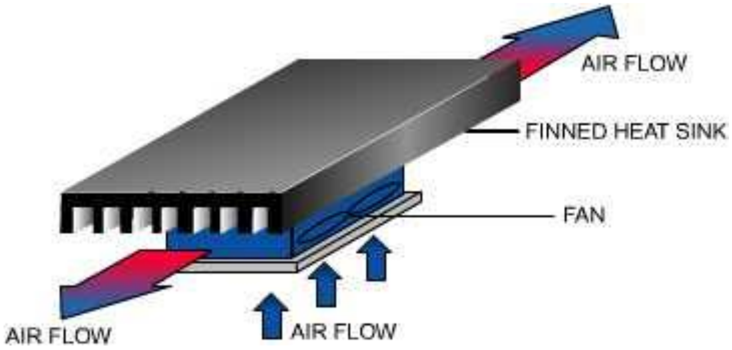


Figure 4.1.7-Forced Convection Heat Sink System Showing Preferred Air Flow

The thermal resistance of heat sink extrusions often is specified at an air flow rate stated in terms of velocity whereas the output of most fans is given in terms of volume. The conversion from volume to velocity is:

Velocity = Volume / Cross-sectional Area of Air Passage
or: Linear Feet per Minute = Cubic Feet per Minute / Area in Square Feet
or: Linear Meters per Minute = Cubic Meters per Minute / Area in Square Meters

3. Fan

The fan is used to ventilate the heat sink and to avoid the temperature of the heat sink getting too high.

Up to 2 fans can be directly connected and controlled by the TEC controller.

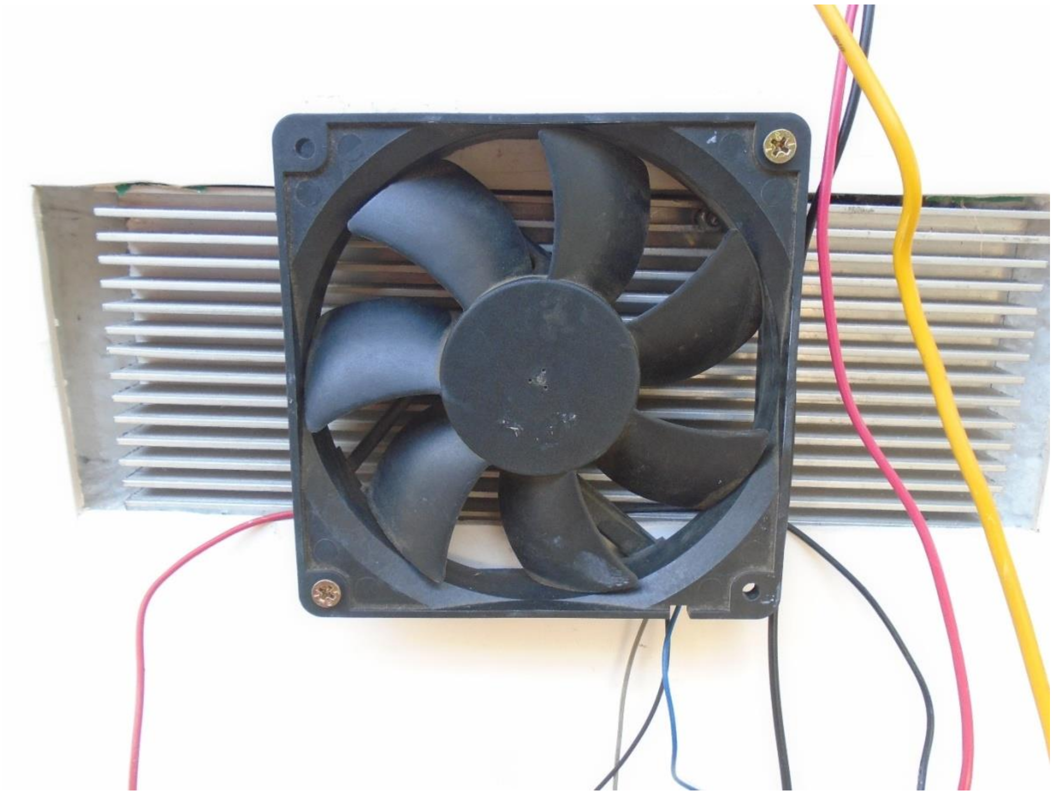


Figure 4.1.8–Fan

4. Digital thermocouple thermometer

   A thermocouple is an electrical device consisting of two dissimilar conductors forming electrical junctions at differing temperatures. A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Thermocouples are a widely used type of temperature sensor.

Figure 4.1.9-Digital temperature sensor

5. Thermal paste

Thermal grease (also called CPU grease, heat paste, heat sink compound, heat sink paste, thermal compound, thermal gel, thermal interface material, or thermal paste) is a kind of thermally conductive (but usually electrically insulating) compound, which is commonly used as an interface between heat sinks and heat sources (e.g., high-power semiconductor devices). The main role of thermal grease is to eliminate air gaps or spaces (which act as thermal insulator) from the interface area so as to maximize heat transfer. Thermal grease is an example of a Thermal interface material.

Figure 4.1.10-Thermal paste

6. A.C to D.C Converter / Battery

Thermoelectric coolers operate directly from DC power suitable power sources can range from batteries to simple unregulated “brute force” DC power supplies to extremely sophisticated closed-loop temperature control systems. A thermoelectric cooling module is a low-impedance semiconductor device that presents a resistive load to its power source. Due to the nature of the Bismuth Telluride material, modules exhibit a positive resistance temperature coefficient of approximately 0.5 percent per degree C based on average module temperature. For many noncritical applications, a lightly filtered conventional battery charger may provide adequate power for a TE cooler provided that the AC ripple is not excessive. Simple temperature control may be obtained through the use of a standard thermostat or by means of a variable-output DC power supply used to adjust the input power level to the TE device. In applications where the thermal load is reasonably constant, a manually adjustable DC power supply often will provide temperature control on the order of +/- 1°C over a period of several hours or more. Where precise temperature control is required, a closed-loop (feedback) system generally is used whereby the input current level or duty cycle of the thermoelectric device is automatically controlled. With such a system, temperature control to +/- 0.1°C may be readily achieved and much tighter control is not unusual.

Power supply ripple filtering normally is of less importance for thermoelectric devices than for typical electronic applications. However we recommend limiting power supply ripple to a maximum of 10 percent with a preferred value being < 5%.

Multistage cooling and low-level signal detection are two applications which may require lower values of power supply ripple. In the case of multistage thermoelectric devices, achieving a large temperature differential is the typical goal, and a ripple component of less than two percent may be necessary to maximize module performance. In situations where very low level signals must be detected and/or measured, even though the TE module itself is electrically quiet, the presence of an AC ripple signal within the module and wire leads may be unsatisfactory. The acceptable level of power supply ripple for such applications will have to be determined on a case-by-case basis.

Figure illustrates a simple power supply capable of driving a 71-couple, 6-ampere module. This circuit features a bridge rectifier configuration and capacitive-input filter. With suitable component changes, a full-wave-center-tap rectifier could be used and/or a filter choke added ahead of the capacitor. A switching power supply, having a size and weight advantage over a comparable linear unit, also is appropriate for powering thermoelectric devices.

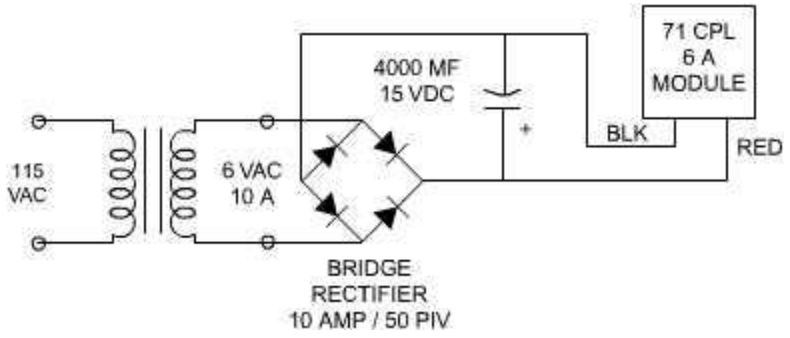


Figure 4.1.11- Simple Power Supply to Drive a 71-Couple, 6-Ampere TE Module

A typical analog closed-loop temperature controller is illustrated in Figure. This system is capable of closely controlling and maintaining the temperature of an object and will automatically correct for temperature variations by means of the feedback loop. Many variations of this system are possible including adaptation to digital and/or computer control.

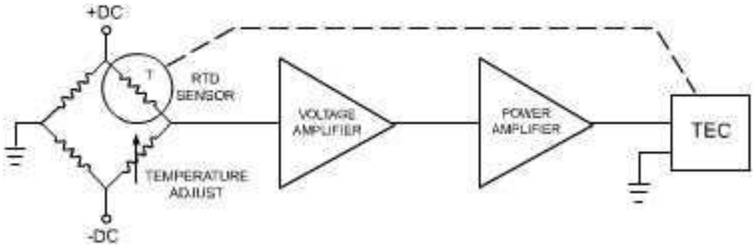


Figure 4.1.12-Block Diagram of a Typical Closed-Loop Temperature Controller

Figure 4.1.13- 12V 1.5A Adapter

Figure 4.1.14–12V D.C battery

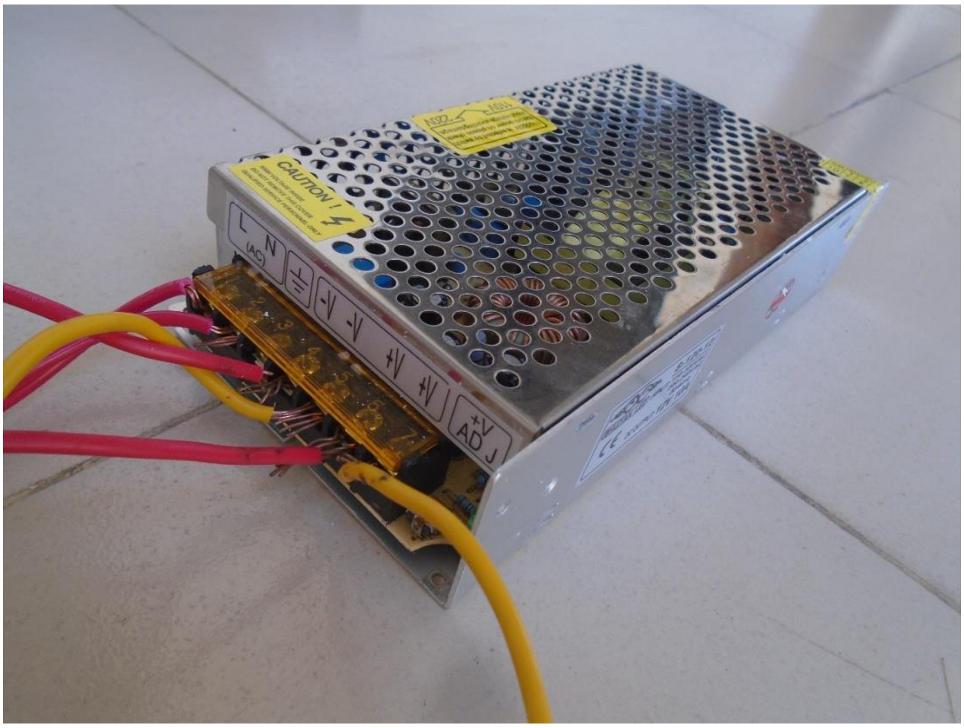


Figure 4.1.15–12V 5.2A Power Supply (A.C to D.C)

7. Refrigeration box

Refrigeration box was made by expanded polystyrene slabs (EPS), aluminium sheets and plastic sheets.

8. Insulation

EPS slabs with 7cm thickness which is having a density of 30kg/m^3 were used to obtain the required thermal insulation. For the selected expanded polystyrene foams the mechanical resistance varies from 0.4 to 1.1 kg/cm^2. There are various grades of foams available with density varies from 10 to 33 kg/m^3, and also with thermal conductivities that are lowered with the increase in density. Outside body of the frame was further insulated with plastic sheets of 3mm thickness. Inside of the walls were covered with aluminium sheets

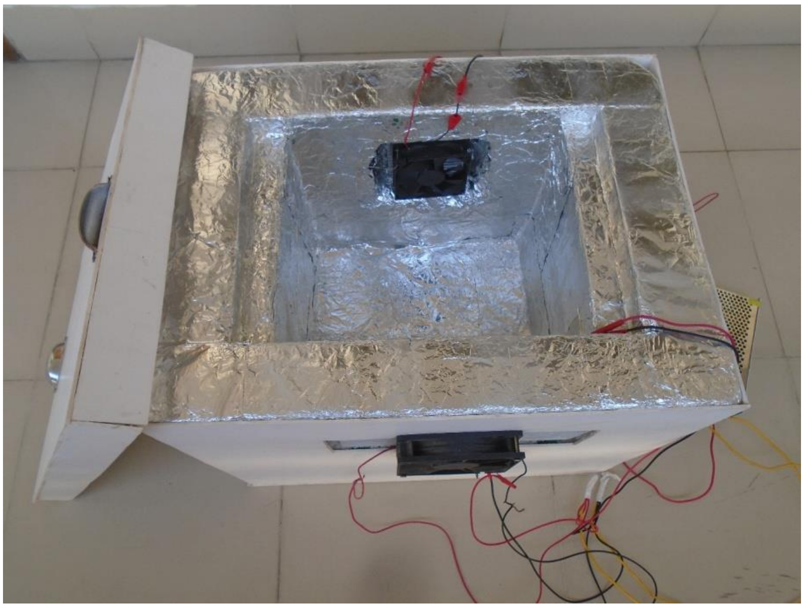


Figure 4.1.16–Refrigeration box

4.3 Method of Testing

A TEC was sandwiched between the hot side and the cold side heat exchanger and pressure was applied. The exposed side of the cold side heat exchanger was covered so that it sat cocooned in polystyrene. Only oneside of the cold side aluminium block was exposed to air. This side was the side onwhich the TEC would be connected. The hot side was exposed to ambient air temperature, as would be the case in the prototype coolerbox, and aluminium oxide paste was applied on the contact surfaces to improve the heat transfer. This set-up simulates as accurately as possible the application conditions in the cooler box.

4.4 Procedure

The test procedure was conducted as follows:

1. The hot side temperature of the heatsink was adjusted at 25°C and allowed to settle.
2. Slowly the temperature of the inner side of the cooler box started decreasing.
3. The TEC input current was adjusted between 0.5A to 6.5A.
4. The temperature was monitored until it stabilized and then it was recorded for both the hot side and cold side of the TEC.
5. The TEC input voltage was also recorded as well as the cold side temperature.
6. The following were calculated:
a. Voltage converter (mini transformer) input power
b. TEC input power
c. The temperatures of the cold side and hot side of the TEC & TER
d. The COP was then calculated (COP = $T_c/\Delta T$)
e. The temperature difference was calculated as $\Delta T = T_{hot} - T_{cold}$.
7. The coldside temperatures were measured18℃, 19.5℃ and 20℃in August and the temperatures measured in December were 17.5℃, 18℃, 19℃.

Chapter 5

Datas, Calculations, Graphs& Result

Data Collected in August, 2016

Experimental data 01:

Voltage:12 volt(DC),Current flow:1.5 amp,Room temperature: 28°C.

Table 1:

Time	Temperature(°C)
9:00 AM	28
9:30 AM	26
10:00 AM	25
10:30 AM	25
11:00 AM	24
11:30 AM	23
12:00 PM	23
12:30 PM	22
01:00 PM	22
01:30 PM	21

Graph: 01

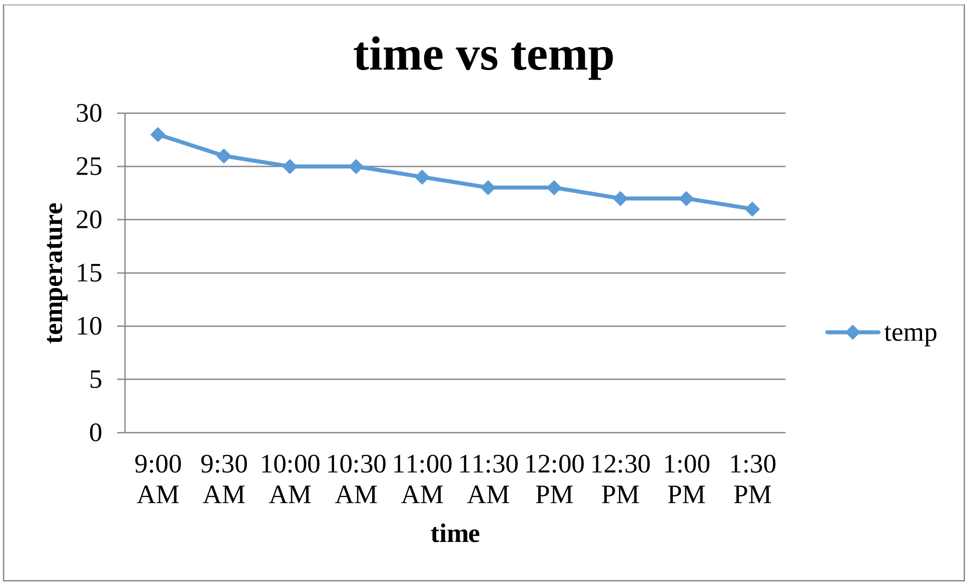


Figure 5.1.1 –Time vs. Temp graph for Voltage:12 volt(DC),Current flow: 1.5 amp

Calculation: 01

Formula used:

$Q_c = \alpha I T_c - 0.5 I^2 R - k_t(T_h - T_c)$
$Q_h = \alpha I T_h - 0.5 I^2 R + k_t(T_h - T_c)$

Here,
Q_c =Total heat in cold side
Q_h =Total heat in hot side
Co-efficient of Performance, COP $=\frac{Qc}{Qh-Qc}$ ....equation 1

Here,
Cold side temperature, T_c =18°C
Hot side temperature, T_h=56°C

Resistance, R=$\frac{2\rho L}{A}$
Here,
L=Length of the heat sink
A=cross sectional area of the surface
Now putting the values into equation 1 we get,

COP $=\frac{Tc}{Th-Tc}$

$=\frac{18}{56-18}$

=0.4736

Experimental data: 02

Voltage: 11.1volt (DC), Current flow: 5.2amp, Room temperature 30°C.

Table 2:

Time	Temperature(°C)
9:00 AM	30
9:30 AM	28
10:00 AM	26
10:30 AM	25
11:00 AM	24
11:30 AM	23
12:00 PM	23
12:30 PM	22
01:00 PM	22
01:30 PM	21
02:00 PM	21
02:30 PM	20.5
03:00 PM	20
03:30 PM	20
04:00 PM	19.5
04:30 PM	19
05:30 PM	19

Graph 2:

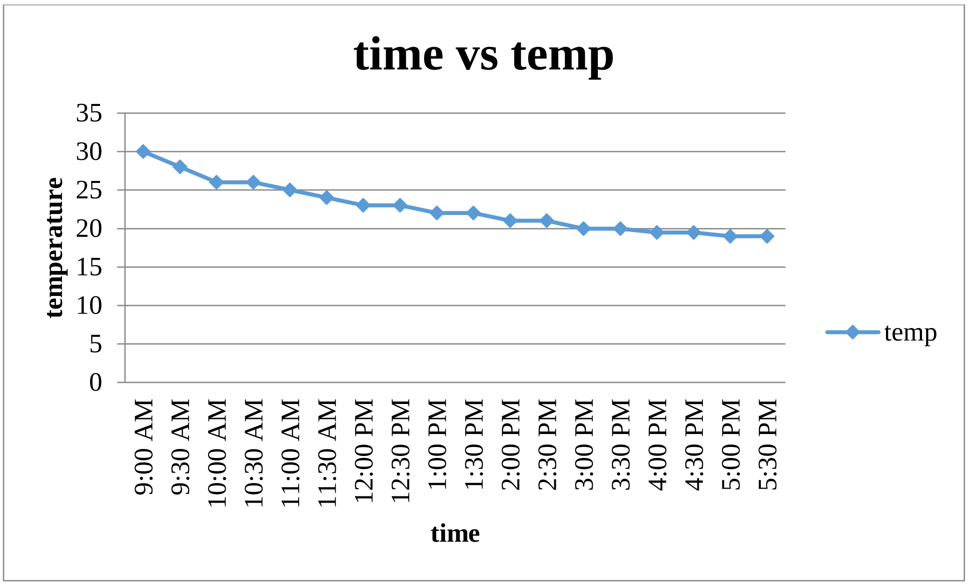


Figure 5.1.2 –Time vs. Temp graph for Voltage: 11.1volt (DC), Current flow: 5.2amp,

Calculation: 02

Formula used:

$Q_c = \alpha I T_c - 0.5 I^2 R - k_t(T_h - T_c)$
$Q_h = \alpha I T_h - 0.5 I^2 R + k_t(T_h - T_c)$

Here,
Q_c =Total heat in cold side
Q_h =Total heat in hot side
Co-efficient of Performance, COP=$\frac{Qc}{Qh-Qc}$ ....equation 1
Here,
Cold side temperature, T_c =19°C
Hot side temperature, T_h =54°C

Resistance, R =$\frac{2\rho L}{A}$
Here,
L=Length of the heat sink
A=cross sectional area of the surface
Now putting the values into equation 1 we get,

COP =$\frac{Tc}{Th-Tc}$

=$\frac{19}{54-19}$

=0.5428

Experimental data: 03

Voltage; 12volt (DC), current flow: 6.5amp (Battery), Room temperature: 29°C

Table 3:

Time	Temperature(°C)
11:30 AM	29
12:00 PM	27
12:30 PM	26
01:00 PM	25
01:30 PM	24
02:00 PM	23
02:30 PM	22
03:00 PM	21
03:30 PM	20.5
04:00 PM	20

Graph 3:

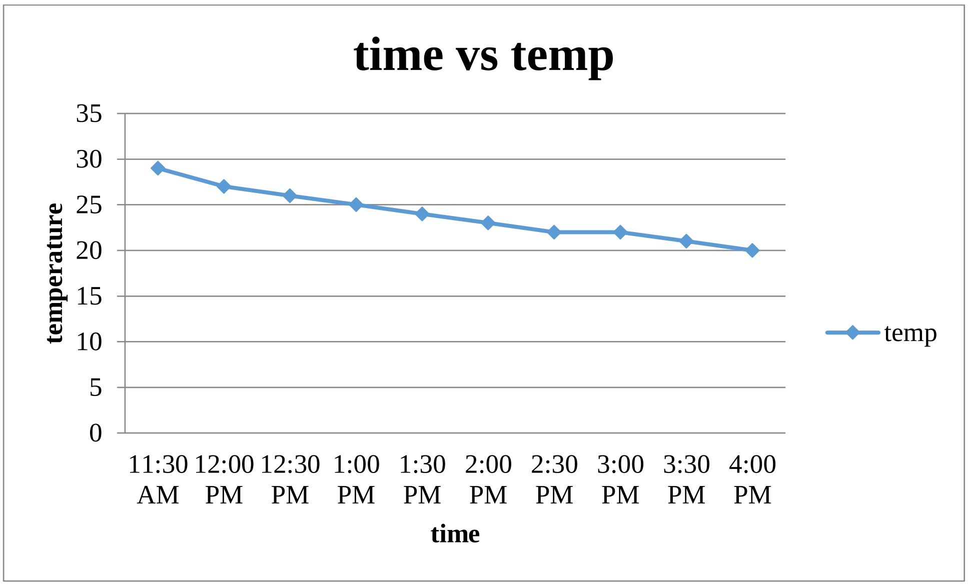


Figure 5.1.3: Time vs. Temp graph for Voltage; 12volt (DC), current flow: 6.5amps (Battery)

Calculation: 03

Formula used:

$Q_c = \alpha I T_c - 0.5 I^2 R - k_t(T_h - T_c)$
$Q_h = \alpha I T_h - 0.5 I^2 R + k_t(T_h - T_c)$

Here,
Q_c =Total heat in cold side
Q_h =Total heat in hot side
Co-efficient of Performance, COP $= \frac{Qc}{Qh - Qc}$ ……………..equation 1

Here,
Cold side temperature, T_c =20°C
Hot side temperature, T_h=52°C

Resistance, R $= \frac{2\rho L}{A}$

Here,
L=Length of the heat sink
A=cross sectional area of the surface
Now putting the values into equation 1 we get,

COP $= \frac{Tc}{Th - Tc}$

$= \frac{20}{52-20}$

=0.625

Data Collected in December, 2016

Experiment 04:

Voltage: 12volt (DC), Current flow: 1.5amp, Room temperature: 23°C.

Table: 04

Time	Temperature
9:00 AM	23
9:30 AM	23
10:00 AM	22
10:30 AM	22
11:00 AM	21.5
11:30 AM	21.5
12:00 PM	21
12:30 PM	20
01:00 PM	20
01:30 PM	19.5

Graph: 04

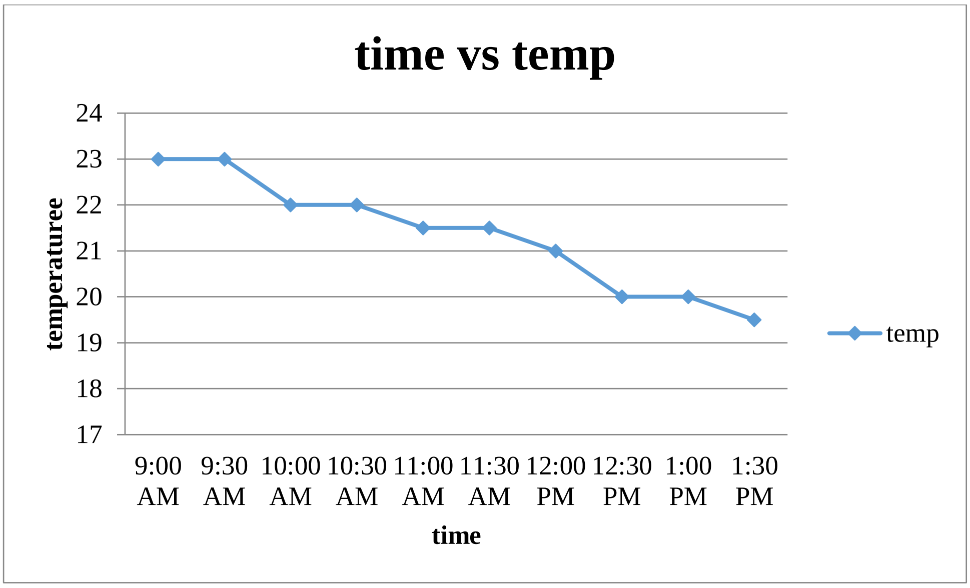


Figure 5.1.4: Time vs. Temp Graph for Voltage: 12volt (DC), Current flow: 1.5 amp

Calculation: 04

Formula used:

$Q_c = \alpha I T_c - 0.5 I^2 R - k_t(T_h - T_c)$
$Q_h = \alpha I T_h - 0.5 I^2 R + k_t(T_h - T_c)$

Here,
Q_c =Total heat in cold side
Q_h =Total heat in hot side
Co-efficient of Performance, COP=$\frac{Qc}{Qh-Qc}$ ……………..equation 1

Here,
Cold side temperature, T_c =19.5°C
Hot side temperature, T_h=51°C

Resistance, R=$\frac{2\rho L}{A}$

Here,
L=Length of the heat sink
A=cross sectional area of the surface
Now putting the values into equation 1 we get,

$$COP = \frac{Tc}{Th-Tc}$$

$$= \frac{19.5}{51-19.5}$$

$$=0.619$$

Experiment 05:

Voltage: 11.1volt (DC), Current flow: 5.2amp, Room temperature 24°C.

Table 05:

Time	Temperature
9:00 AM	24
9:30 AM	24
10:00 AM	23
10:30 AM	23
11:00 AM	22
11:30 AM	21
12:00 PM	21
12:30 PM	20.5
01:00 PM	20
01:30 PM	19.5
02:00 PM	19.5
02:30 PM	19
03:00 PM	18
03:30 PM	17.5

Graph 05:

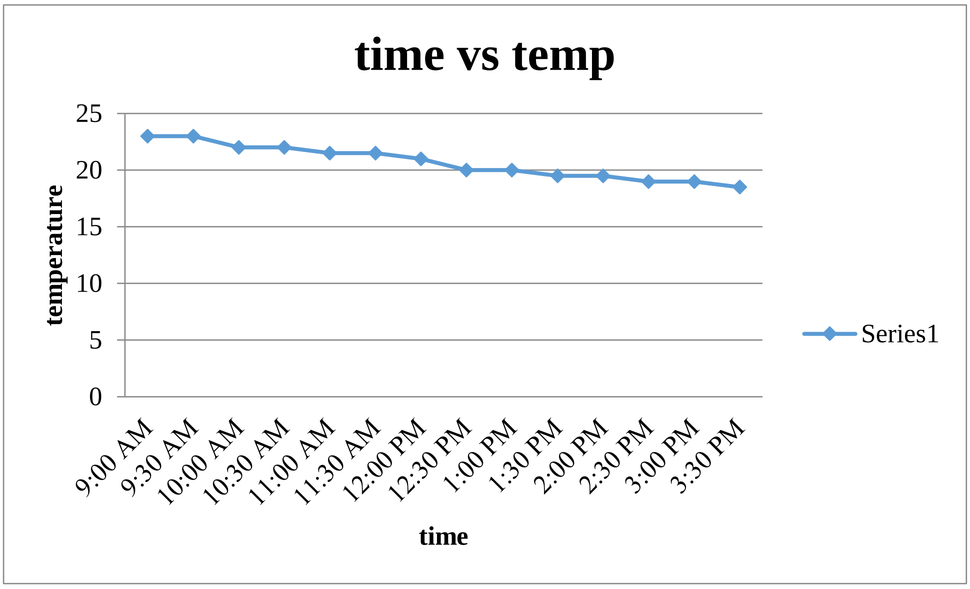


Figure 5.1.5: Time vs. Temp graph for Voltage: 11.1volt (DC), Current flow: 5.2amp

Calculation: 05

Formula used:

$Q_c = \alpha I T_c - 0.5 I^2 R - k_t(T_h - T_c)$
$Q_h = \alpha I T_h - 0.5 I^2 R + k_t(T_h - T_c)$

Here,
Q_c =Total heat in cold side
Q_h =Total heat in hot side
Co-efficient of Performance, COP=$\frac{Qc}{Qh-Qc}$ ....equation 1

Here,
Cold side temperature, T_c =17.5°C
Hot side temperature, T_h=52°C

Resistance, R=$\frac{2\rho L}{A}$
Here,
L=Length of the heat sink
A=cross sectional area of the surface
Now putting the values into equation 1 we get,

$$\text{COP} = \frac{Tc}{Th-Tc}$$

$$= \frac{17.5}{52-17.5}$$

$$=0.507$$

Experiment 06:

Voltage; 12 volt (DC), current flow: 6.5 amp (Battery), Room temperature: 24°C

Table: 06

Time	Temperature
10:30 AM	24
11:00 AM	23
11:30 AM	22
12:00 PM	21.5
12:30 PM	21
01:00 PM	20
01:30 PM	20
02:00 PM	19.5
02:30 PM	19
03:00 PM	19
03:30 PM	18

Graph 06:

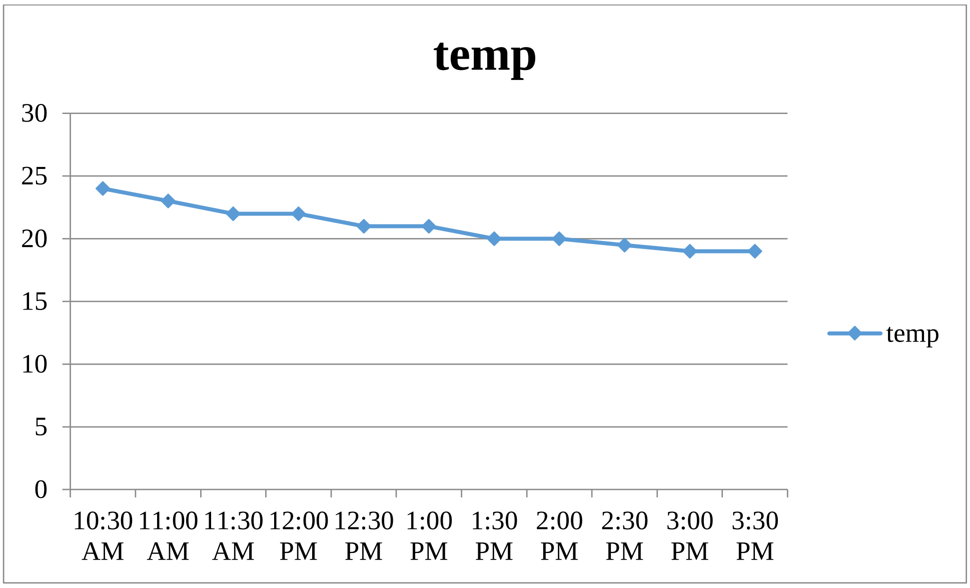


Figure 5.1.6 –Time vs. Temp graph for Voltage; 12 volt (DC), current flow: 6.5 amps (Battery)

Calculation: 06

Formula used:

$Q_c = \alpha I T_c - 0.5 I^2 R - k_t(T_h - T_c)$
$Q_h = \alpha I T_h - 0.5 I^2 R + k_t(T_h - T_c)$

Here,
Q_c =Total heat in cold side
Q_h =Total heat in hot side
Co-efficient of Performance, COP=$\frac{Qc}{Qh-Qc}$ ……………equation 1

Here,
Cold side temperature, T_c =18°C
Hot side temperature, T_h =49°C

Resistance, R=$\frac{2\rho L}{A}$
Here,
L=Length of the heat sink
A=cross sectional area of the surface

Now putting the values into equation 1 we get,

$$COP = \frac{Tc}{Th-Tc}$$

$$= \frac{18}{49-18}$$

$$=0.58$$

Result

COP of this refrigerator system is lower than conventional refrigerator. This is because the efficiency of thermoelectric modules is usually four times lesser than that of vapor compression system. And the heat leakage is also detected through doors; this too reduces the efficiency of the system.

Chapter 6

Limitations, Conclusion & Future Scope

6.1 Limitations

We had to face different problematic situations during the analysis. All the conditions were not always suitable for the proper results. From the results we calculated and by comparing results with ideal system we were able to find out our faults and drawbacks of the path we followed.

Few of them are:

- Due to lack of availability, we could not use thick Aluminium sheets for making a leakage proof & compact unit, so aluminium foil paper was used.
- The data were collected in inexperienced manner.
- In some cases the data were not collected in equal time interval.
- Well-equipped laboratory was not available.
- The appropriate operating temperature and pressure of the Peltier module were not monitored.
- We used three different input sources; thus there was variation of input to the module that's why the module got less efficient.
- We could have used better compacted structure but as wooden structure is not preferred for refrigeration system (it gets wet or absorbs vapor), we used thick polystyrene slabs and outside frame was made by 2mm plastic sheets for further compactness.
- If there was higher current input than 6A (from the battery we used was 7.5A), the Peltier module would got less efficient. So we had to change the Peltier module near about 3 or 4 times for better reading.

6.2 Recommendations

- For better efficiency the micro-control based unit such as Nano NADS intelligent temperature sensor can be used. As the Peltier module has an efficiency of 2%, which is very low. That's why all the COP, we calculated were very low. The intelligent temperature sensor will cut off power supply if the temperature is low enough such as 6℃; then if the operational temperature is 10℃, when the temperature raises to 10℃ then the power supply connects automatically to lessen the system temperature. Thus it will lessen the load on the module and increase lifetime. So the efficiency of the module increases.
- Thick aluminium sheets can be used in the place aluminium foil paper for better compactness and usefulness.
- The Peltier modules we used were from the local markets of Bangladesh. For better performance of the modules it is recommended to order online from a recognized online shop.
- For better insulation between the hot and cold side of the module high quality insulator is recommended.

- Water cooling is also recommended for faster cooling of the hot side. For this the heat sink should be set in an angle and a mini water pump should be set for the continuous flow of water.
- Appropriate channels for proper air-circulation is highly recommended.
- Sometimes water forms in the refrigeration unit, so a path for passing out the water is also recommended.
- As we know there is sufficient average daily sunshine in Bangladesh, so for the rural or remote areas of Bangladesh Solar PV panels can be used as the power source for this system. This technology might become little costly for installation but can be useful for adequate power supply as solar cells have an efficiency of near about 30-40%. As we know Bangladesh has adopted a renewable energy policy to generate 10% of its energy from renewable sources by 2020.

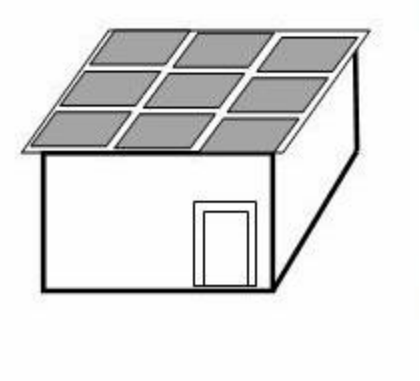


Figure 6.2.1- The Schematic diagram of a mini cold storage with solar PV panels at the roof top.

Conclusion & Future Scope

6.3 Conclusion:

We have been successful in designing a system that fulfils the proposed goals. However we do realize the limitations of this system. The present design can be used only for light heat load to lower its temperature to a particular temperature. The system is unable to handle fluctuations in load. Extensive modifications need to be incorporated before it can be released for efficient field use. This is one of the advantageous project which uses low power to drive refrigerator. This project work has provided us an excellent opportunity and experience, to use our limited knowledge. Thermoelectric refrigeration is one of the key areas where researchers have a keen interest. Some of the recent advancements in the area surpass some of the inherent demerits like adverse COP. By using temperature controlling thermostat we can increase the efficiency of the Peltier module as when it reaches, for example 17℃ the power automatically turns off supplying to the module; then when the temperature starts increasing and reaches at 19℃ the power supply to the module starts. Thus it increases the lifetime of the Peltier module. Again Cascaded module architecture has defined new limits for its application. Moreover recent breakthrough in organic molecules as a thermoelectric material assure an excellent future for TER. Integration of renewable energy (Solar energy) as power source for this refrigerator can be used for remote rural places where there is no electric supply.

6.4 Future Scope:

Thermoelectric materials convert heat into electricity and vice versa. They have no moving parts and release no pollutants into the environment. A few niche markets have used them for decades to cool electrical parts or generate power. Researchers have considered using thermoelectric-based refrigerators to replace current heat-pump-based refrigerators that compress and expand a refrigerant such as Freon.

The energy conversion efficiency, or Coefficient of Performance (COP) of thermoelectric cooling devices, is determined by thermoelectric figure-of-merit, commonly denoted by ZT. The highest ZT to date is reported in Bi_2Te_3/Sb_2Te_3 and PbSeTe/PbTe superlattice thin films. Coolers based on such materials typically have a COP of ~2, which is lower than the COP of 3-4 vapor compression refrigerators. However, there is no known theoretical impediment to significant increases in thermoelectric energy conversion efficiency, and given a breakthrough in materials, thermoelectric technology might offer the possibility of a safe, efficient, and affordable alternative to fluorocarbon compression equipments.

The use of thermoelectric devices and systems has been limited by their relative low energy conversion efficiency. Present commercial thermoelectric devices operate at about 10% of Carnot efficiency, whereas the efficiency of a compressor-based refrigerator increases with size: a kitchen refrigerator operates at about 30% of Carnot efficiency and the largest air conditioners for big buildings operate near 90%.

Today’s thermoelectric devices are particularly useful when the efficiency is a less important issue than small size, low weight, or high reliability. For example, thermoelectric devices are suited for situations where the heat load is small (say, <25W) or the temperature lift is small (say <10C) or the variation of the heat load is large (e.g., train passenger cabin). It is important to note that the COP of thermoelectric coolers increases significantly with decreasing the temperature lift.

- Instead of utilizing a full-fledged thermoelectric cooling system, it is possible to use a thermoelectric heat pump to improve the performance of an existing vapor compression system, so called “hybrid system.” For example, a hybrid vapor compression – thermoelectric cooler systems could use thermoelectric heat pumps to enhance the outlet subcooling of a condenser, in which thermoelectric heat pumps operate at small ΔT and high COP. Theoretical analysis predicted the cooling capacity and COP of the hybrid system could be significantly improved.

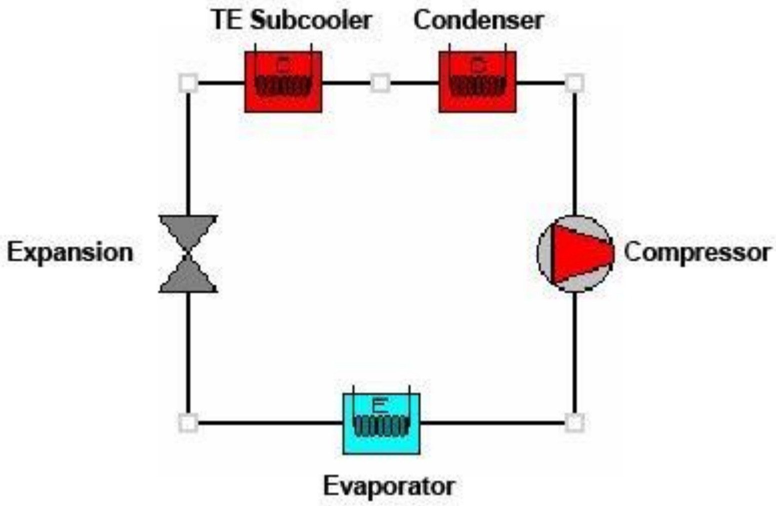


Figure 6.4.1- Hybrid system

Thermoelectric heat pumps could operate at very high COP (possibly COP>6)under the condition of small temperature lift. They would provide a high COP boost to conventional refrigerating systems.

The thermoelectric subcooler is modeled as additional component that provides a given temperature lift. The simulation results are shown below
The important findings from the studies are listed below:

- A theoretical maximum improvement of 16.2% in COP can be achieved. The corresponding increase in cooling capacity is about 20%.
- A theoretical maximum improvement of 35% in capacity can be achieved, without change in COP.
- No increase in the size of the heat exchangers in the system.
- The economic aspects of coupling a thermoelectric device with a conventional vapor compression system remain to be investigated.

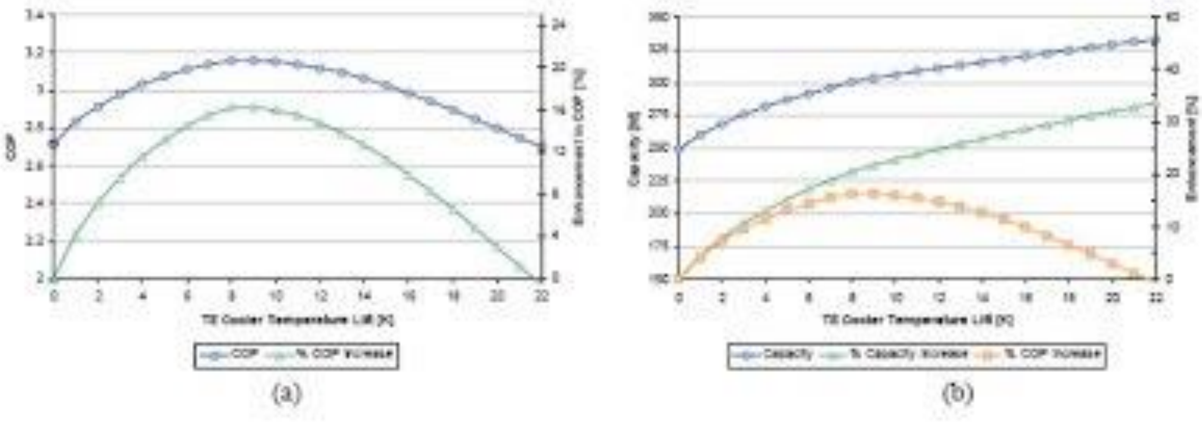


Figure 6.4.2– System simulation results for COP and cooling capacity in a hybrid vapor compression refrigeration system.

- High Reliability: Thermoelectric coolers possess high reliability. Depending on the conditions of application, the lifetime of thermoelectric coolers is in the range of 100,000 to 200,000 hours

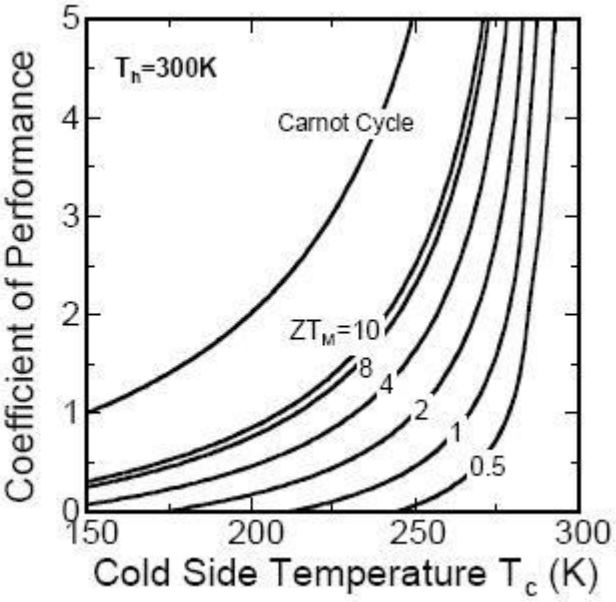


Figure 6.4.3 –COP vs Temp graph

Thermoelectric coolers are solid state heat pumps used in applications where temperature stabilization, temperature cycling, or cooling below ambient are required. There are many products using thermoelectric coolers, including CCD cameras (charge coupled device), laser diodes, microprocessors, blood analyzers and portable picnic coolers.

Replacing Freon in AC and refrigerators would be a big part of reducing greenhouse gases. Freon refrigerant gas was banned from vehicular air conditioning systems in the mid 1990’s to prevent Ozone Layer depletion. R134-a refrigerant gas was universally adopted as the replacement However R134-a has 1,300 times* the global warming potential of CO_2. The European Union is prohibiting use of R134-a in cars for

- New models in 2011
- All new cars in 2017

Thermoelectric devices achieved an importance in recent years as viable solutions for applications such as spot cooling of electronic components, remote power generation in space stations and satellites etc.

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