A Project Stage-II Report on

DESIGN AND DEVELOPMENT OF SOLAR BASED PELTIER REFRIGERATION SYSTEM

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have successfully completed the Project Stage – II entitled *"Design and Development of Solar Based Peltier Refrigeration System"* under my supervision, in the partial fulfillment of *Bachelor of Engineering - Mechanical Engineering* of Savitribai Phule Pune *University.*

Date: - 01/06/2023

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I express my immense pleasure and thankfulness to all the teachers and staff of the **Department of Mechanical Engineering of Smt. Kashibai Navale College of Engineering** for their co-operation and support.

Mr. Chougule Nishant Dilip Sign……………….

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ABSTRACT

A large distribution of people living in developing countries irrespective of areas where the major problem at present is lack of electrification to provide refrigeration. Grid power is presently unavailable and is not imagined in the divine future. Refrigeration systems driven by the thermal combustible organic material have efficiency about 35% in average and leads emission of greenhouse gas . Since, conventional electrically powered refrigeration system may not be much use in those areas, for basic applications such as food and drug preservation, alternative refrigeration system is required. Solar energy is confirmed to be an ideal source for a low temperature heating application. Three known sound out that use solar energy to produce refrigeration at temperature below $0^{o}C$ include solar i.e. photovoltaic (PV) operated refrigeration, absorption refrigeration and solar mechanical. Among these approaches, the photovoltaic (PV) system or solar thermal energy by using Thermoelectric Technology , the most feasible and appropriate means for portable systems irrespective to any location , can call as freezer on wheels.

Thus the refrigerator is eco-friendly, without fluorine pollution ,small volume, and absence of moving parts in system. Solar-powered refrigerators are typically used in off-grid locations where utilities provided AC power is not available, but we can implement these irrespective to several conditions to meet the future and utilize the conventional sources in vast possible ways. By this project we have archived the instance cooling and adequate coefficient of performance of the system to any locations easily. This project will serve the purpose of providing a portable refrigerator for medical team or emergency teams to carry things in remote areas and in areas where electricity supply is not reliable.

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1. INTRODUCTION

The Peltier Refrigerator is a mobile refrigerator that is powered using solar panels, fully collapsible to haul around anywhere, and completely weather resistant. Perfect for picnics at the park to keep your food fresh, keeping your brew skies chilled while listening to crunchy tunes at a music festival, or maybe you just can't go 10 minutes without eating a cheeseburger, so you haul around an entire refrigerator to fulfill your appetite so that your meat doesn't go bad.

You can charge the Peltier Refrigerator before you go out and if the sun goes down or you run out of sunlight, the battery will kick in and continue cooling your food/beverages/dead body until the sun is back, and better yet you can leave it outside all year long as it is weather proof.

A fridge, a freezer, a solar-powered wonder child called the Peltier Refrigerator . Portable for camping and sturdy and weather-resistant for transport or permanent outdoor installation, this wheeled powerhouse of food preservation.

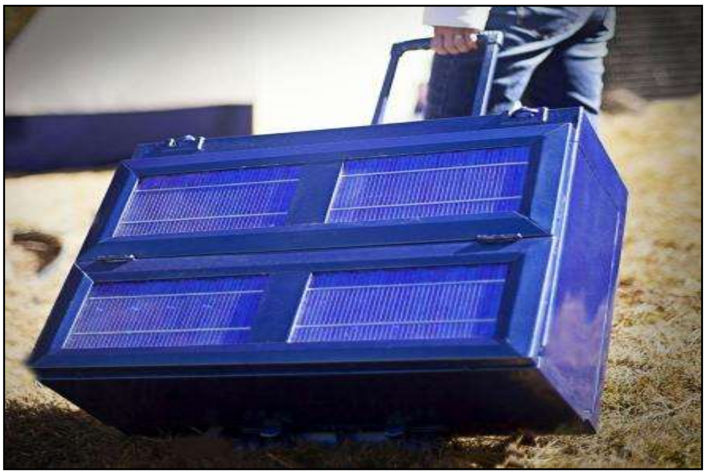

Figure 1 Portable Refrigerator

From the ancient age man always prefers to have cold water for drinking purpose. Also in India, our country the weather is too hot. Particularly in summer season, the normal water temperature in open space is 35 to 38°C. The water is not suitable for drinking purpose. The required temperature is at the most 250°C. Hence lowering down of the temperature is an essential task.

In old age there was space available to keep the earthen container also the houses were sheltered by the trees and bushes which were enough to lower down the water container temperature. Because in most of the situations the temperature depends upon the temperature of the flowing air.

The different water-cooling processes incorporated are since old age are as follows: -

Earthen pots Using ice:

Cooling of water in earthen pot is one of the earliest methods employed by men for cooling the water in their houses. Only in recent years, it has been put on sound footing thermodynamically. It is a process of adiabatic saturation of air when cooling of surface water on container is made to evaporate to cool with transfer of heat from water to the surroundings. The initial investment cost of such a system is low & the operation is simple & cheap. Simple evaporative cooling is achieved by direct contact of water particles & a moving air stream. The water may be sufficiently cooled by evaporative process to results a considerable degree of drinking comfort in climates of high dry-bulb temperatures associated with low relative humidity. The minimum outdoor temperature required for successful evaporative cooling is above 350 c & another requirement is a relatively low wet bulb temperature.

Although the evaporative cooling does not perform all the function of true water-conditioning, but it provides coolness by filtering heat & circulating the cooled air. From last century till now refrigeration has been one of the most important factors of our day-to-day life.

The current tendency of the first world is to look at renewable energy resources as a source of energy. This is done for the following two reasons; firstly, the lower quality of life due to air pollution and secondly, due to the pressure that the ever-increasing world population puts on our natural energy resources. From these two facts comes the realization that the natural energy resources available will not last indefinitely.

A conventional cooling system includes an evaporator, a compressor, and a condenser. In the evaporator the pressurized refrigerant goes through expansion, boiling and then evaporation. When the phase changes from liquid to gas heat energy is absorbed. Then the compressor recompresses the gas into a liquid and the condenser expels the gas to the ambient surroundings. A TE cooling system has similar subassemblies.

However, TE cooling is specifically the abstraction of heat from electronic components. Over the past four decades, improvement in the conversion efficiency has been marginal. The challenge has been the improvement in the performance of the thermo-couple materials, which could lead to a breakthrough in terms of the efficiency of the TE device.

Hence conventional refrigerators were invented which worked on refrigerant and thermodynamic cycle. Refrigeration serves human beings throughout their life. It has found tremendous application in manufacturer of ice, preservation of food and air conditioning. The basic idea is implementation of photovoltaic driven refrigerating system powered from direct current source or solar panel with a battery bank. It is different from conventional refrigeration system and based on Peltier effect. It uses Thermo-electric module which replace bulky parts in conventional refrigerator as there is no working fluid.

A developed model of commercial thermoelectric refrigerators with finned heat exchanger is established. The aim of this chapter is to present some fundamental aspects of the direct thermoelectric conversion. Thermoelectric systems are solid-state heat devices that either convert heat directly into electricity or transform electric power into thermal power for heating or cooling. Such devices are based on thermoelectric effects involving interactions between the flow of heat and electricity through solid bodies

These phenomena, called See beck effect and Peltier effect, can be used to generate electric power and heating or cooling. Solar energy is the lowest cost, competition free, universal source of energy as sunshine's throughout. And the theory existed in 1911; the materials available were not suitable for effective cooling. Metals have good electrical conduction but good thermal conductivity as well. This allowed for a very low COP (co-efficient of performance) of one per-cent due to the thermal conductivity of the metal from the hot side to the cold side of the TEC It was only since the 1950's with the discovery of semiconductors, that the COP was increased. Semiconductors had the same electrical conductivity as metals but much lower thermal conductivity. This provided for a much-improved COP of twenty percent. Typical material composition is alloys of the elements Bi, Cd, Sb, Te, Se and Zn.

This energy can be converted into useful electrical energy using photovoltaic technology. Thermo-electric refrigeration replaces the three main working parts with: a cold junction, a heat sink and a DC power source. The refrigerant in both liquid and vapour form is replaced by two dissimilar conductors. The cold junction (evaporator surface) becomes cold through absorption of energy by the electrons as they pass from one semiconductor to another, instead of energy absorption by the refrigerant as it changes from liquid to vapour. The compressor is replaced by a DC power source which pumps the electrons from one semiconductor to another. A heat sink replaces the conventional condenser fins, discharging the accumulated heat energy from the system. The difference between two refrigeration methods, then, is that a thermoelectric cooling system refrigerates without use of mechanical devices, except perhaps in the auxiliary sense, and without refrigerant.

2. LITERATURE REVIEW

2.1 Research papers

Awasti, M., & Mali, K. (2012). Design and Development of Thermoelectric Refrigerator. International Journal of Mechanical Engineering and Robotics Research (Volume No. 3). The retention time achieved was 52 min with the designed module in this project. To achieve a higher retention time, another alternative was incorporated. This consists of the additional heater on a heat sink.

Chetan Jangonda, K. P. (2016). Review of various Applications of Thermoelectric Module. Thermoelectric cooling added a new dimension to cooling. It has a major impact on a conventional cooling system. It is compact in size, no frictional elements are present, no coolant is required and the weight of the system is low.

D. Suman, p. H. (2020). Design and fabrication of thermoelectric refrigerator using peltier module. The efficiency and life of the Peltier refrigerator are maximized by using these water pockets and the temperature was controllable by changing the input voltage and current so we can maintain the things at the required temperature. Finally, it has been recorded the minimum temperature i.e., 2°c.

Jatin Patel, M. P. (2016). Improvement in the COP of Thermoelectric Cooler. This study experimentally investigates the performance of the single-stage and multistage TEC air-cooling module. It is quite easy to achieve a significant temperature difference in the single-stage TE module, but, the COP of the single-stage module is very less for domestic use. In the multistage TE module, it is possible to get the required COP as well as better thermal performance.

Kshitij Rokde, Mitali Patle, T. k. (2017). Peltier Based Eco-Friendly Smart Refrigerator for Rural Areas. The efficiency of the refrigerator can be increased by increasing the number of Peltier plate modules which will eventually help in decreasing the temperature in less time. The number of Peltier plate modules used can be calculated using the heat transfer formula.

2.2 History: -

From the ancient age man always prefers to have cold water for drinking purpose. Also in India, our country the weather is too hot. Particularly in summer season, the normal water temperature in open space is 35 to380 C. The water is not suitable for drinking purpose. The required temperature is at the most 250 C. Hence lowering down of the temperature is an essential task.

In old age there was ample space available to keep the earthen container also the houses were sheltered by the trees and bushes which were enough to lower down the water container temperature. Because in most of the situations the temperature was depending on the temperature of the flowing air.

The Peltier-effect has been now known for 180 years. But only recently has it developed more practical uses. Now it is not only indispensable to send a spaceship to Saturn and to speed up the central processing unit of your PC. You may even find one in your lunch box! In this module, you will do simple experiments with a small Peltier device. You will find out how the three different applications of the device are related. You will look at the flows of energy and realize analogies to quite different engines such as airplane engines and those in refrigerators. The history of thermoelectric effects shows how closely related science and technology are. And you will see that scientific development sometimes goes strange ways. All modern science is quantitative. It is not enough to know whether a device works "in principle" or if it might solve some practical problems. One has to show how well it works. Science is also a network of links between different fields, and this web needs quantitative knots to hold. You will therefore carry out quantitative measurements with Peltier devices.

The Peltier device is just one specific example of a thermal engine. All of these engines must comply with Carnot's law. We will check whether this is true or whether we have a perpetual mobile…

Usually, Peltier devices are applied as heat pumps. We will measure it's efficiency in this mode.

The energy flow diagram for thermal engines (TE) looks as follows:

• Energy flows into the engine as heat Q1 from a reservoir (called source) at the high temperature level T1.

• A part of this energy goes away as useful work W to a consumer.

• But there is always a part of (waste) heat Q2 that flows to a reservoir (called drain) that has the lower temperature level T2.

Because energy is conserved there must be: $Q1 = W + Q2$

2.3 Thermoelectric cooler: -

Since the cooling load of most typical battery compartments is not high, thermoelectric coolers are a possibility. These are systems where cooling is achieved electrically using the electromagnetic thermodynamics).

Although reliable, thermoelectric coolers are inefficient and not well-suited for remote outdoor cabinets.

In many cases, since cooling loads are not very high, flow through fans can be used to remove excessive heat and moisture build-up in the battery compartments. Fans can also be used for the thermal management of the compartment using thermal inertia.

Thermoelectric cooling relies fundamentally on the Peltier effect. Electrons passing through semiconductor materials with alternating conductive properties absorb ambient heat energy in order to travel through one of the materials and expend this energy as they travel through the other material.

Given the proper spatial arrangement, these materials can form a small module (about the size and shape of a saltine cracker) that will get hot on one side and cold on the other. Such thermoelectric modules alone would not be suitable for most cooling applications, but they are at the heart of any thermoelectric cooling

system. The addition of heat sinks, fans, fins, cold plates, liquid jackets, and the like allow thermo-electric devices to be built in the form of air conditioners, liquid

chillers, and cold plates

2.4 Comparison: conventional refrigeration: -

Because thermoelectric cooling is a form of solid-state refrigeration, it has the advantage of being compact and durable. A thermoelectric cooler uses no moving parts (except for some fans), and employs no fluids, eliminating the need for bulky piping and mechanical compressors used in vapor-cycle cooling systems.

Such sturdiness allows thermo-electric cooling to be used where conventional refrigeration would fail. In a current application, a thermo-electric cold plate cools radio equipment mounted in a fighter jet wingtip. The exacting size and weight requirements, as well as the extreme g forces in this unusual environment, rule out the use of conventional refrigeration. Thermoelectric devices also have the advantage of being able to maintain a much narrower temperature range than conventional refrigeration. They can maintain a target temperature to within $\pm 1°$ or better, while conventional refrigeration varies over several degrees.

Unfortunately, modules tend to be expensive, limiting their use in applications that call for more than 1 kW/h of cooling power. There are also limits to the maximum temperature differential that can be achieved between one side of a thermoelectric module and the other.

However, in applications requiring a higher. T, modules can be cascaded by stacking one module on top of another. When one module's cold side is another's hot side, some unusually cold temperatures can be achieved.

After the modules themselves, most thermoelectric devices made today are probably air conditioners. Thermoelectric air conditioning is used mostly in enclosure cooling applications, especially the cooling of electronic enclosures.

These air conditioners are usually

designed for mounting directly on the enclosure wall, in such a way that forms a tight seal between the air conditioner and the enclosure. Because of the solid-state nature of thermoelectric technology, these air conditioners do not exchange air or any other material between the enclosure and the ambient environment.

This can be an important advantage if delicate electronics or special materials must be kept safe in a dirty environment. Varying greatly in size, heat load, and ambient conditions, enclosures cooled by thermoelectric air conditioners include such diverse applications as environmental test chambers, galley refrigerators, and ATMs.

The cooling of computer electronics by this method is especially common, as is the cooling of individual computer chips by direct contact with tiny thermoelectric cold plates.

Thermoelectric air conditioners also suit hazardous environments, up to and including Class 1 Division 1. Such devices must be designed in such a way that they cannot cause an explosion, even when operating in an environment where explosive gases are present. (So, for example, such devices cannot use fans, be-cause the spinning fan blades could build an electric charge.)

2.5 Selection parameters

Because thermoelectric coolers are often used to cool enclosures, some selection media are organized around that application. Selection of a thermoelectric cooler depends on certain technical parameters. Specifically, the engineer needs to know the enclosure's surface area, desired enclosure temperature, ambient temperature, amount of insulation around the enclosure, and the active load inside the enclosure. As a practical matter, selection of a thermoelectric device these days is very simple. Most cooler manufacturers have free downloadable "sizing software" on their Web sites. After prompting the user for all the required data, these programs perform all the necessary calculations and recommend one or more suitable products.

Alternatively, thermoelectric devices can be selected through the use of performance curves. These curves describe heat-pumping capacity at different values of .T. Their use requires that the engineer already have some idea of the amount of heat to be transferred by the cooler. Not all manufacturers measure product performance in the same way, so take care when comparing data from different companies.

Whether selected through sizing software or by comparison of performance curves, the engineer will want to have some idea of where and how the thermoelectric cooler is to be attached to the application. For example, thermoelectric air conditioners mount directly onto an enclosure wall and depending on the particular air conditioner it may or may not intrude into the enclosed space.

Also, thermoelectric air conditioners can generally operate in any orientation, so except in the case of some liquid chillers, there is no such thing as upside-down or sideways thermoelectric technology. Because of this, a thermoelectric air conditioner could operate from the top, bottom, or any side of an enclosure.

Power requirements for thermoelectric devices vary greatly. While the modules themselves can only operate on dc, an air conditioner, liquid chiller, or cold plate can be made to use either dc or ac, and operable across a range of voltages and frequencies. Even if an unusual power situation exists, a thermoelectric de-vice can usually be adapted to it.

Watch out for ratings When comparing thermoelectric devices, it is important to be particularly aware of the desired temperature differential between the enclosure and the ambient temperature.

By convention, thermoelectric devices are usually rated at 0°. T, where the enclosure temperature is at equilibrium with the ambient temperature. Actual applications often call for a negative. T an enclosure made cooler than its surroundings. Less common are applications calling for above-ambient cooling, in which the desired enclosure temperature is hotter than the ambient temperature. Most of the time, this type of cooling is accomplished simply by opening the enclosure to the outside, or by installing a simple fan. However, if an application requires the enclosure remain sealed, and that it also remains above a certain temperature (above a dew point temperature, for example), then above-ambient active cooling may be called for.

When selecting a thermoelectric cooler, engineers need to take care to not be misled by the device's rating. The amount of heat that a cooler removes depends in part on the temperature differential between the enclosure and the ambient environment. Any cooler with a performance rating given at 0°. T will achieve a higher performance rating at 20°C. T. So, care must be taken when comparing products to use the same rating point for each unit considered. Being rigorous and consistent will yield the most consistent and re-liable results.

3. PROBLEM DEFINITION

The Peltier Refrigerator liberates the convenience of industrial refrigeration from the limitations of your home. It runs off detachable solar panels which simultaneously charge the built-in battery.

The Product to have access to a fully functional refrigerator wherever and whenever, whether you are camping, tailgating, caught in a natural disaster or without power for days. The Peltier Refrigerator is equipped to perform like an industrial-strength refrigerator while being portable and accommodating, making it perfect for the outdoors person, the frugal minded and the utilitarian.

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 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. And it is the fundamental principal behind a thermo-electric system.

Figure 2 Portable systems

Using different metals produced cooling devices that had very poor co-efficient of performances (COP). This was because materials with high temperature conduction co-efficient were used partly because of excessive temperature conduction between the hot side and the cold side of the thermo-electric heat exchanger. Since the discovery of semiconductors, the co-efficient of performance of the TEC was drastically improved since materials could be used with low temperature conduction co-efficient but by doping it, the semiconductor could be made to conduct, exerting electrical conduction properties found in metal. The Peltier Refrigerator liberates the convenience of industrial refrigeration from the limitations of your home. It runs off of detachable solar panels which simultaneously charge the built-in battery.

4. OBJECTIVES OF PROJECT

- There are so many refrigerators available in market but they have their own limitations due to which they are they are not beneficial for special purposes.
- Our main objective in this project is to develop a low-cost portable solar powered refrigerator for special and small needs.
- The design should be simple and the size must be compact to carry.
- It should be light weight in nature and does not require any external power source for operation other than solar.
- It should be leaked proof and opened and closed by using powerful magnets for attending foldability.

5. SIGNIFICANCE OF PROJECT

5.1 Solving the Problem of Refrigeration

Every year people from all over the world experience power outages from heat and natural disasters. According to Independent US News and CBS News, $306 billion dollars were spent in 2017 on Natural Disasters in America. Much of that money went to food and vital medical supplies.

Whether you require extra area for keeping foods at home, or need to have chilly beverages anywhere you are going, a portable mini fridge is right for you. Portable fridges provide you with the opportunity to take pleasure in cold refreshments and also to bring perishable products whenever and wherever. You'll be able to bring it together with you anytime you need to have a hiking adventure or picnic along with your family and friends, or even devote it to your private utilization in your workplace.

In addition, to such purposes, investing in a portable refrigerator as well provides you with the opportunity to have several advantages. Given an array of mini fridges in the marketplace, it is very easy look for a portable mini fridge which matches your specific requirements and personal preferences. Extra Storage

Probably, the most impressive advantage you’re going to get from buying a mini refrigerator is actually the opportunity to get extra space for storage for chilling slices of meat, bottled drinks along with other food items. In case you are having troubles with the constrained quantity of foods you could place in your home freezer, use a transportable fridge for an extra place for keeping your preferred drinks as well as foods. The extra space for storage provided by portable fridges is, likewise, helpful if you want to defrost the fridge in your house. When you are experiencing trouble searching for a cold and dry spot for saving frozen treats and frozen slices of various meats each time you want to defrost the refrigerator, you may momentarily keep frozen products in your portable mini refrigerator while the home fridge defrosts.

Figure 3 Household Refrigerators

and taking all of them home. Having a mini fridge, also you can take pleasure in cool beverages on hot summer moments whenever you have to travel to your college or workplace. It is easy to carry the portable mini fridge everywhere you go.
Additional features:

If you think a portable mini fridge is only utilized to keep the food cold, then you thought wrong. They also have heaters on them to maintain food warm. If you’re traveling and desire to have warm meals awaiting you at the subsequent stop, you can simply ready the foodstuff in your home and put it inside the mini fridge where heating system choice can maintain the food warm and scrumptious. Additional capabilities which make portable small fridges very convenient are they happen to be compact to place in your boat or car.

6. METHODOLOGY

6.1 Thermoelectric Module working principle

A typical thermoelectric module is composed of two ceramic substrates that serve as a foundation and electrical insulation for P-type and N-type Bismuth Telluride dice that are connected electrically in series and thermally in parallel between the ceramics. The ceramics also serve as insulation between the module's internal electrical elements and a heat sink that must be in contact with the hot side as well as an object against the cold side surface. Electrically conductive materials, usually copper pads attached to the ceramics, maintain the electrical connections inside the module. Solder is most commonly used at the connection joints to enhance the electrical connections and hold the module together. Most modules have and even number of P-type and N-type dice and one of each sharing an electrical interconnection is known as, "a couple". While both P-type and N-type materials are alloys of Bismuth and Tellurium, both have different free electron densities at the same temperature. P-type dice are composed of material having a deficiency of electrons while N-type has an excess of electrons. As current (Ampere) flows up and down through the module it attempts to establish a new equilibrium within the materials. The current treats the P-type material as a hot junction needing to be cooled and the N-type as a cold junction needing to be heated. Since the material is actually at the same temperature, the result is that the hot side becomes hotter while the cold side becomes colder. The direction of the current will determine if a particular die cools down or heat up. In short, reversing the polarity will switch the hot and cold sides.

Thermoelectric modules are solid-state heat pumps that operate on the Peltier effect (see definitions). A thermoelectric module consists of an array of p- and n-type semiconductor elements that are heavily doped with electrical carriers. The elements are arranged into array that is electrically connected in series but thermally connected in parallel. This array is then affixed to two ceramic substrates, one on each side of the elements (see figure below).

The heat transfer occurs as electrons flow through one pair of p- and n-type elements (often referred to as a "couple") within the thermoelectric module. The p-type semiconductor is doped with certain atoms that have fewer electrons than necessary to complete the atomic bonds within the crystal lattice. When a voltage is applied, there is a tendency for conduction electrons to complete the atomic bonds.

When conduction electrons do this, they leave "holes" which essentially are atoms within the crystal lattice that now have local positive charges. Electrons are then continually dropping in and being bumped out of the holes and moving on to the next available hole. In effect, it is the holes that are acting as the electrical carriers. Now, electrons move much more easily in the copper conductors but not so easily in these micro conductors. When electrons leave the p-type and enter into the copper on the cold-side, holes are created in the p-type as the electrons jump out to a higher energy level to match the energy level of the electrons already moving in the copper. The extra energy to create these holes comes by absorbing heat. Meanwhile, the newly created holes travel downwards to the copper on the hot side. Electrons from the hot-side copper move into the p-type and drop into the holes, releasing the excess energy in the form of heat.

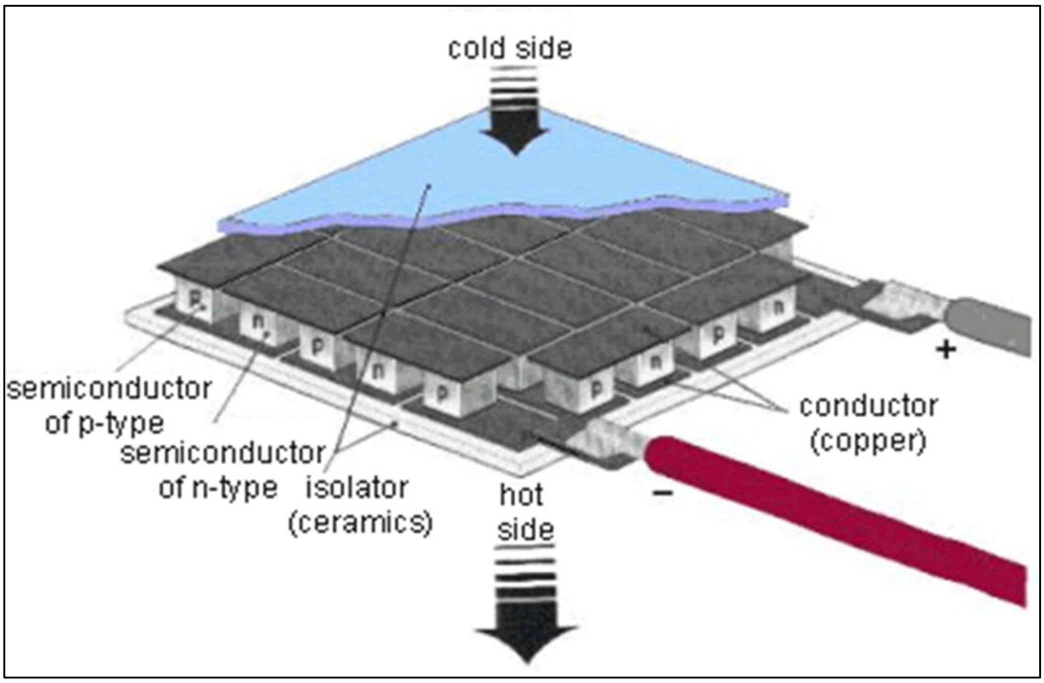

Figure 4 Peltier plate inner working

The n-type semiconductor is doped with atoms that provide more electrons than necessary to complete the atomic bonds within the crystal lattice. When a voltage is applied, these extra electrons are easily moved into the conduction band. However, additional energy is required to get the n-type electrons to match the energy level of the incoming electrons from the cold-side copper. The extra energy comes by absorbing heat. Finally, when the electrons leave the hot-side of the n-type, they once again can move freely in the copper. They drop down to a lower energy level, and release heat in the process.

6.2 Working of Peltier Refrigerator

It is an equipment, which work on principle of conversion of solar energy into electrical energy. A solar cell is used to develop 14 V- & 0.71-amps current DC supply and 10 W. This electrical energy is stored in a battery which is of 12 volts DC supply which then supplies the power to transformer. The fan work as heat extractor, it removes heat from system and add to heat sink. During operation, DC current flows through the TEM causing heat to be transferred from one side of the TEC to the other, creating a cold and hot side. The COP for heating and cooling are different, because the heat reservoir of interest is different. The COP is the ratio of the heat removed from the cold reservoir to input work. However, for heating, the COP is the ratio of the heat removed from the cold reservoir plus the input work to the input work.

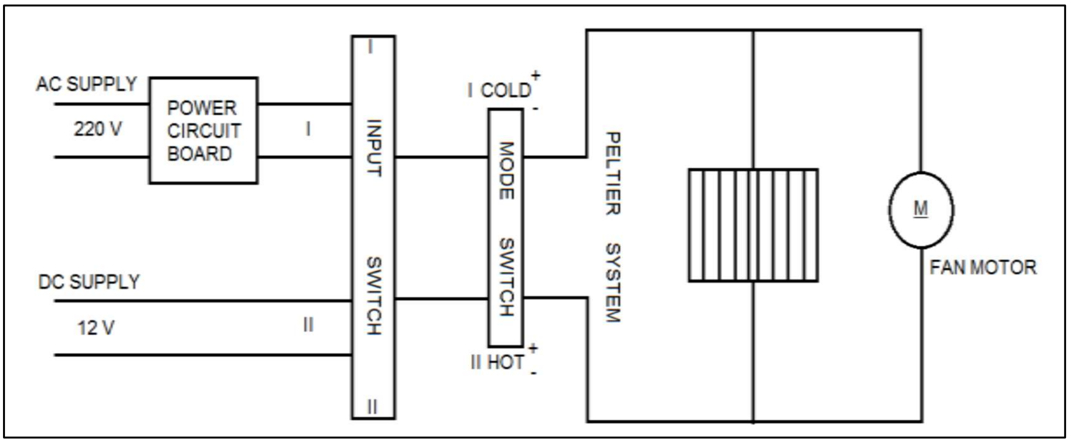

Figure 5. Electric Principal Diagram of Refrigeration Chamber

Since a TEC is a simple heat exchanger, it is also simple to install. To use a TEC as a high efficiency, reliable heat exchanger, a slightly more complex installation is required. The rest of this section will discuss these points.

6.3 Components

The construction setup of the refrigerator is as follows,

1. Thermo-electric module
2. Cooler box
3. Battery

4. Solar cell
5. Frame
6. Thermocouple

1.Thermo-electric module

A TE module is composed of two ceramic substrates that give foundation and also electrical insulation to p-type and n-type semiconductors. The TE module is composed of silicon bismuth semiconductor cause this pair gives the highest COP.

Specification:

1. Material used- Silicon - Bismuth
2. A = 0.04 x 0.04 = 0.0016 m^2
3. Number of p-n coupling = 127

Hot side temperature (°C)	25	50
Qmax (W)	50	57
Delta Tmax (°C)	66	75
Imax (A)	6.4	6.4
Vmax (V)	14.4	16.4
Module resistance (Ω)	1.98	2.30

Performance specification of TEC1-12706

Figure 6 TEC Module

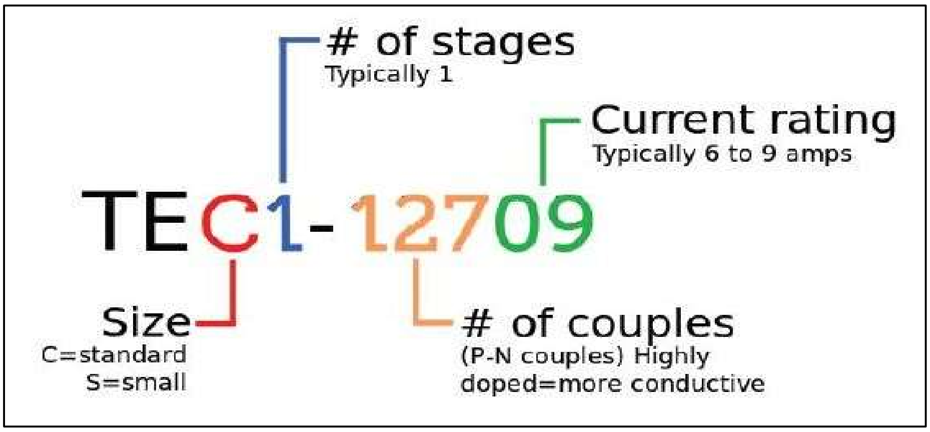

Figure 7 Explanation of number on tec

Performance Curve

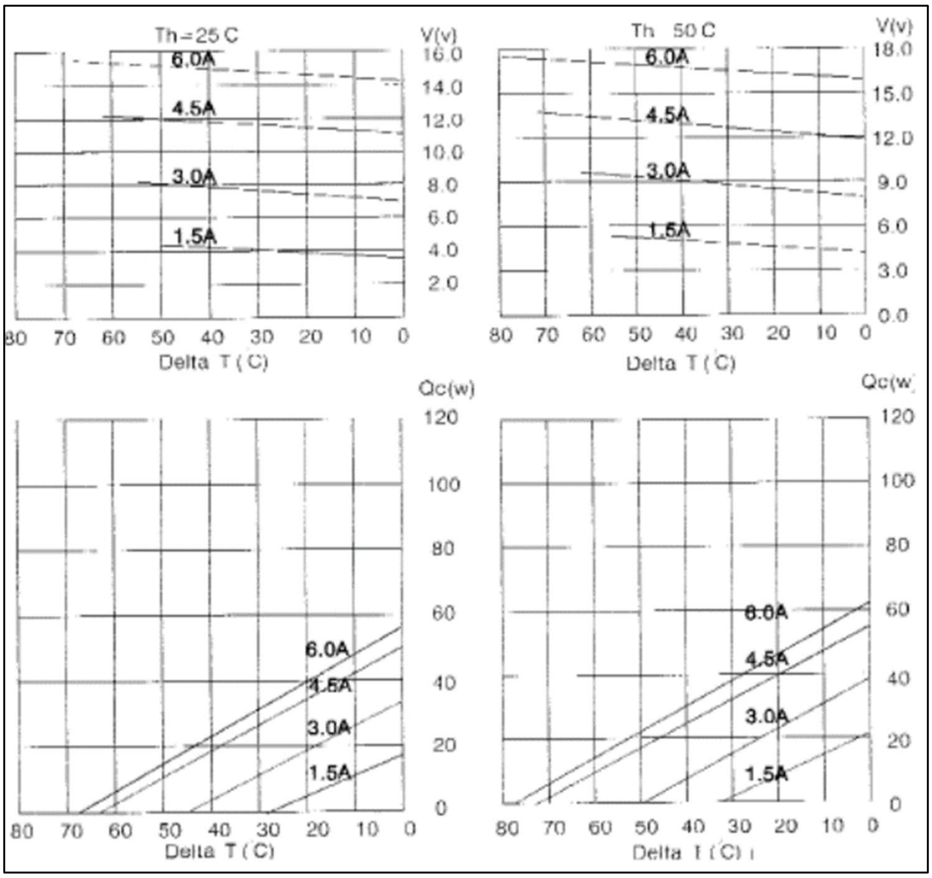

Figure 8 Performance Curve

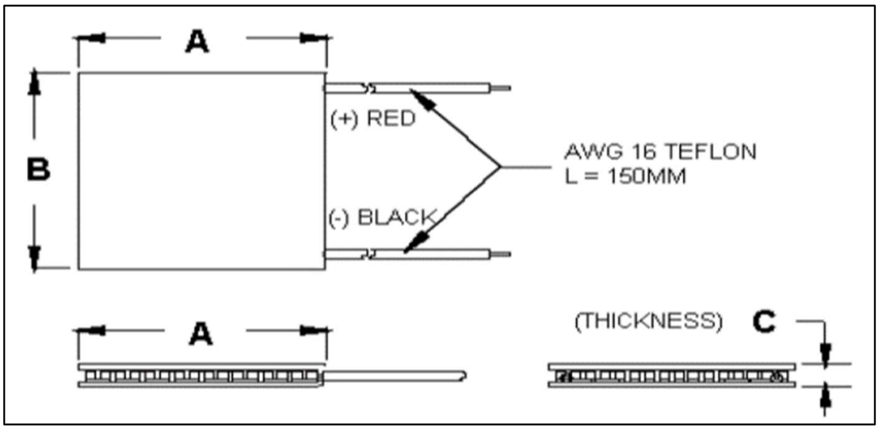

Figure 9 Dimension of tec

Where,

A = 40mm, B = 40mm, C = 3.9mm.

Operating Tips

- Max. Operating Temperature: 138oC
- Do not exceed Imax or Vmax when operating module.
- Please consult HB for moisture protection options (sealing).
- Life expectancy: 200,000 hours
- Failure rate based on long time testing: 0.2%.

3.Battery

The battery is an electrochemical converting chemical energy into electrical energy.

Figure 10 Battery

The main purpose of the battery is to provide a supply of current for operating the cranking motor and other electrical units.

Specification:

1. Voltage 12v
2. Current 7.2Ah

4.Solar cell

Figure 11 Solar Panel

The direct conversion of solar energy is carried out into electrical energy by conversion of light or other electromagnetic radiation into electricity.

1. The dimensions of the panel are-
    - Length – 48.5 cm,
    - Width – 35 cm.
2. Number of sub-cells used is 72
3. Dimension of the sub-cells is,
    - Length – 4.8 cm
    - Width – 4 cm.
4. Maximum power is 20 W
5. Voltage is 17 V
6. Current is 1.16 A

Solar cells collect light from the sun and turn it into electricity. They do this in the following way.

- Energy from the sun falls on a thin slice of a silicon-based material.
- This causes the silicon material to have more energy, the electrons in the material move around faster.
- Moving electrons create electricity.
- The heat energy makes the electric current flow from the silicon material.
- The greater the intensity of the sunlight the greater the amount of electricity produced.
- The output from a solar cell is at its greatest when the light hits the cell at right angles.
- The amount of electrical power generated is affected by the temperature around the solar cell.

5. Solar Cell Operation

Solar cells convert light energy into electrical energy either indirectly by first converting it into heat, or through a direct process known as the photovoltaic effect. The most common types of solar cells are based on the photovoltaic effect, which occurs when light falling on a two-layer semiconductor material produces a potential difference, or voltage, between the two layers. The voltage produced in the cell is capable of driving a current through an external electrical circuit that can be utilized to power electrical devices. This tutorial explores the basic concepts behind solar cell operation.

The tutorial initializes at an arbitrarily set "medium" photon intensity level, with photons randomly impacting the surface of the solar cell to generate free electrons. The released electrons complete a simple circuit containing two light bulbs that become illuminated when current flows through. In order to increase or decrease the photon flux, use the Photon Intensity slider to adjust the number of photons incident on the surface.

Today, the most common photovoltaic cells employ several layers of doped silicon, the same semiconductor material used to make computer chips. Their function depends upon the movement of charge-carrying entities between successive silicon layers. In pure silicon, when sufficient energy is added (for example, by heating), some electrons in the silicon atoms can break free from their bonds in the crystal, leaving behind a hole in an atom's electronic structure. These freed electrons move about randomly through the solid material searching for another hole with which to combine and release their excess energy. Functioning as free carriers, the electrons are capable of producing an electrical current, although in pure silicon there are so few of them that current levels would be insignificant. However, silicon can be modified by adding specific impurities that will either increase the number of free electrons (n-silicon), or the number of holes (missing electrons; also referred to as p-silicon). Because both holes and electrons are mobile within the fixed silicon crystalline lattice, they can combine to neutralize each other under the influence of an electrical potential. Silicon that has been doped in this manner has sufficient photosensitivity to be useful in photovoltaic applications.

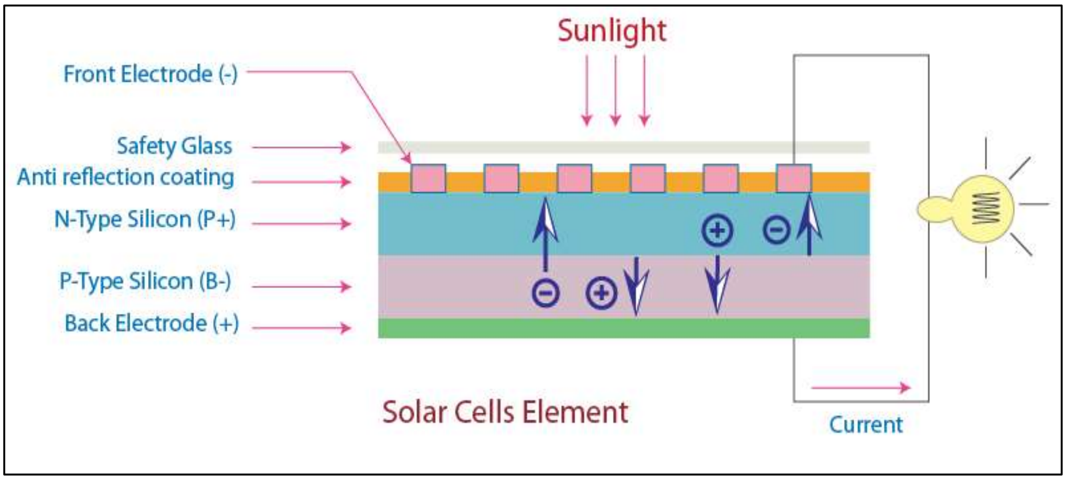

Figure 12 Working of solar

In a typical photovoltaic cell, two layers of doped silicon semiconductor are tightly bonded together (illustrated in Figure). One layer is modified to have excess free electrons (termed an n-layer), while the other layer is treated to have an excess of electron holes or vacancies (a p-layer). When the two dissimilar semiconductor layers are joined at a common boundary, the free electrons in the n-layer cross into the p-layer in an attempt to fill the electron holes. The combining of electrons and holes at the p-n junction creates a barrier that makes it increasingly difficult for additional electrons to cross. As the electrical imbalance reaches an equilibrium condition, a fixed electric field results across the boundary separating the two sides.

When light of an appropriate wavelength (and energy) strikes the layered cell and is absorbed, electrons are freed to travel randomly. Electrons close to the boundary (the p-n junction) can be swept across the junction by the fixed field. Because the electrons can easily cross the boundary, but cannot return in the other direction (against the field gradient), a charge imbalance results between the two semiconductor regions. Electrons being swept into the n-layer by the localized effects of the fixed field have a natural tendency to leave the layer in order to correct the charge imbalance. Towards this end, the electrons will follow another path if one is available. By providing an external circuit by which the electrons can return to the other layer, a current flow is produced that will continue as long as light strikes the solar cell. In the construction of a photovoltaic cell, metal contact layers are applied to the outer faces of the two semiconductor layers, and provide a path to the external circuit that connects the two layers. The final result is production of electrical power derived directly from the energy of light.

Converting Photons to Electrons, the solar cells that you see on calculators and satellites are photovoltaic cells or modules (modules are simply a group of cells electrically connected and packaged in one frame). Photovoltaic, as the word implies (photo = light, voltaic = electricity), convert sunlight directly into electricity. Once used almost exclusively in space, photovoltaic are used more and more in less exotic ways. They could even power your house. How do these devices work?

Photovoltaic (PV) cells are made of special materials called semiconductors such as silicon, which is currently the most commonly used. Basically, when light strikes the cell, a certain portion of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred to the semiconductor. The energy knocks electrons loose, allowing them to flow freely. PV cells also all have one or more electric fields that act to force electrons freed by light absorption to flow in a certain direction. This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, we can draw that current off to use externally. For example, the current can power a calculator. This current, together with the cell's voltage (which is a result of its built-in electric field or fields), defines the power (or wattage) that the solar cell can produce.

That's the basic process, but there's much more to it. Let's take a deeper look into one example of a PV cell: the single crystal silicon cell.

6.4 CAD Model

Procedure:

- The entire model has been designed with the help of designing software solid works.
- With the help of colour feature the colours are given to the entire model.

Cad model of the assembled project is designed on Solid works 2022 software.

SOLID MODELING:

The entire model has been designed with the help of designing software solid works.

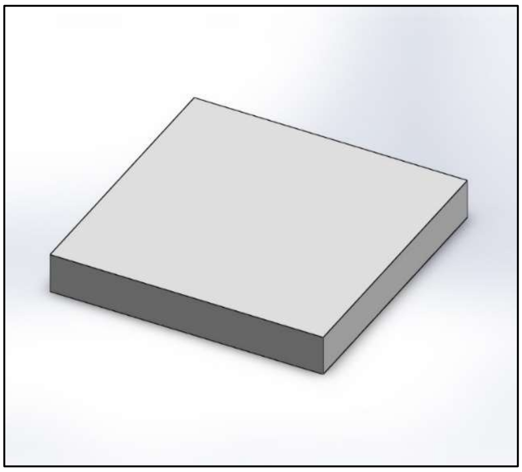

Figure 13 Peltier Module

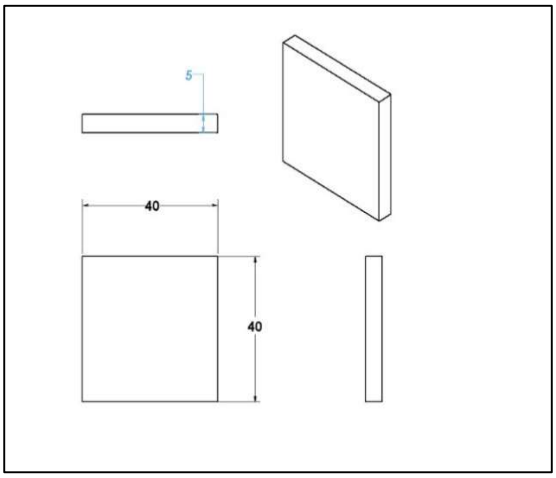

Figure 14 Drafting of Peltier module

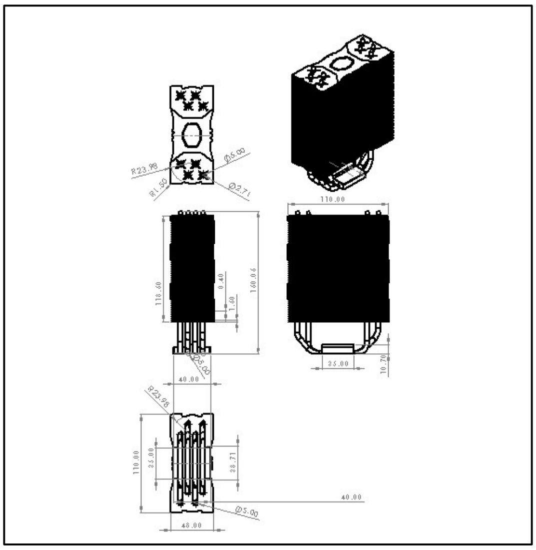

Figure 15 Drafting of heat sink assembly

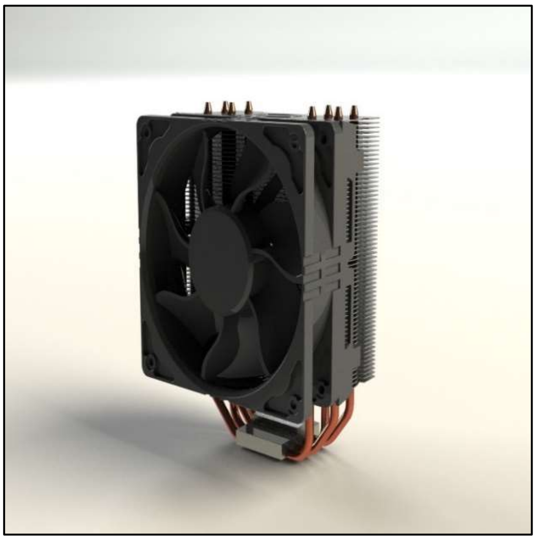

Figure 16 Heat Sink

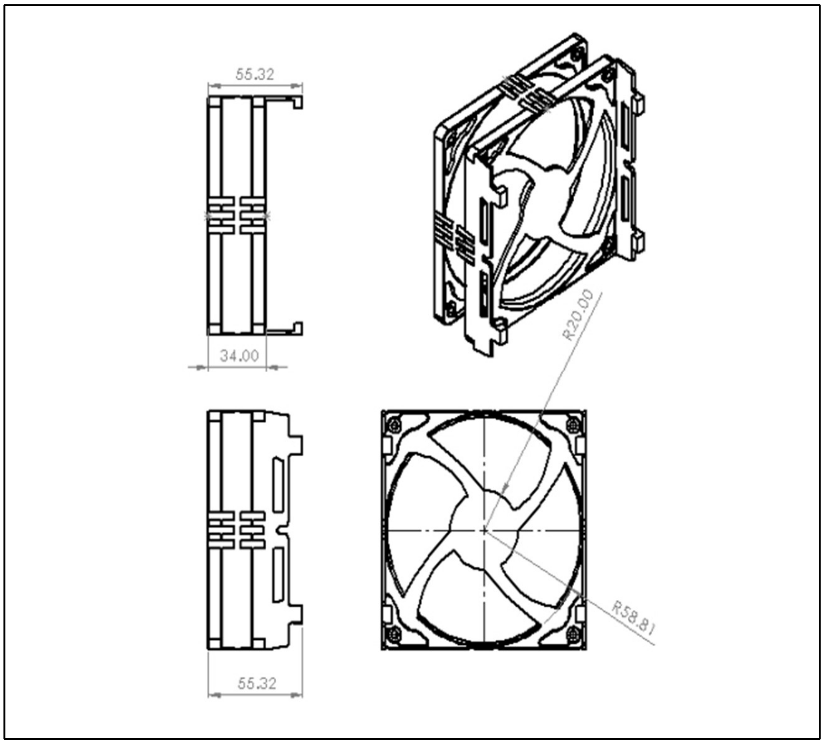

Figure 17 Drafting of fan

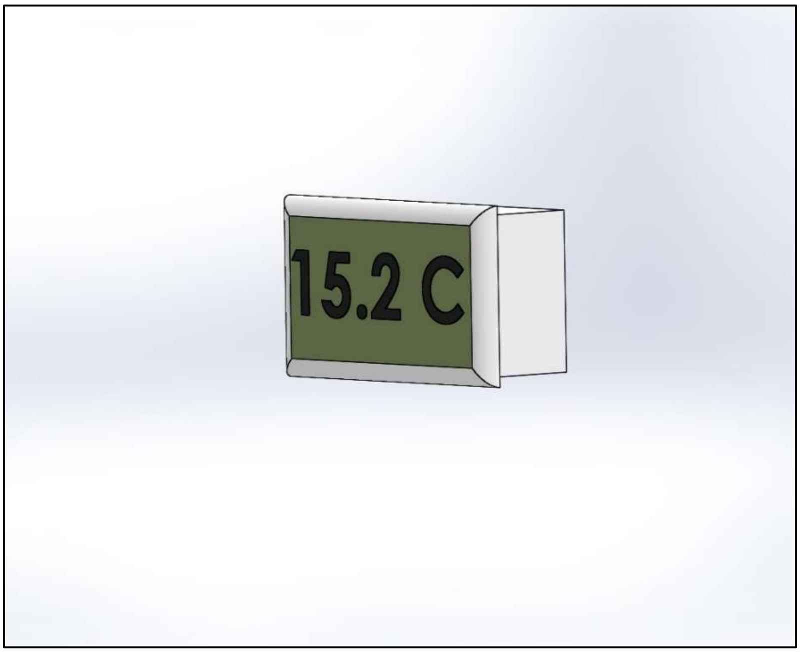

Figure 18 Temperature Sensor

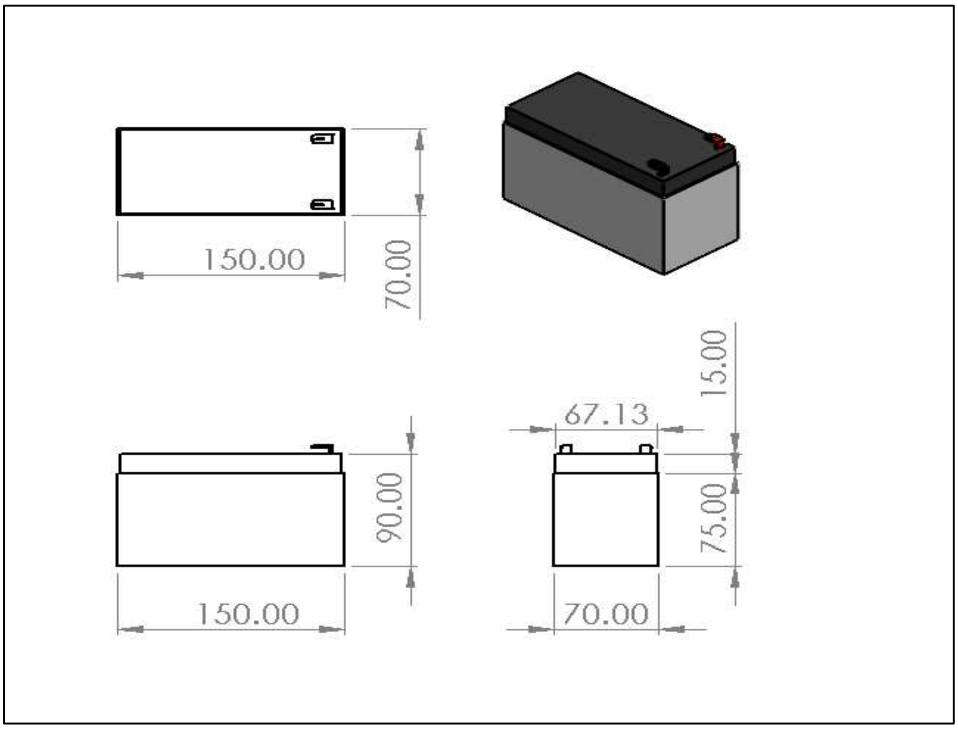

Figure 19 Battery

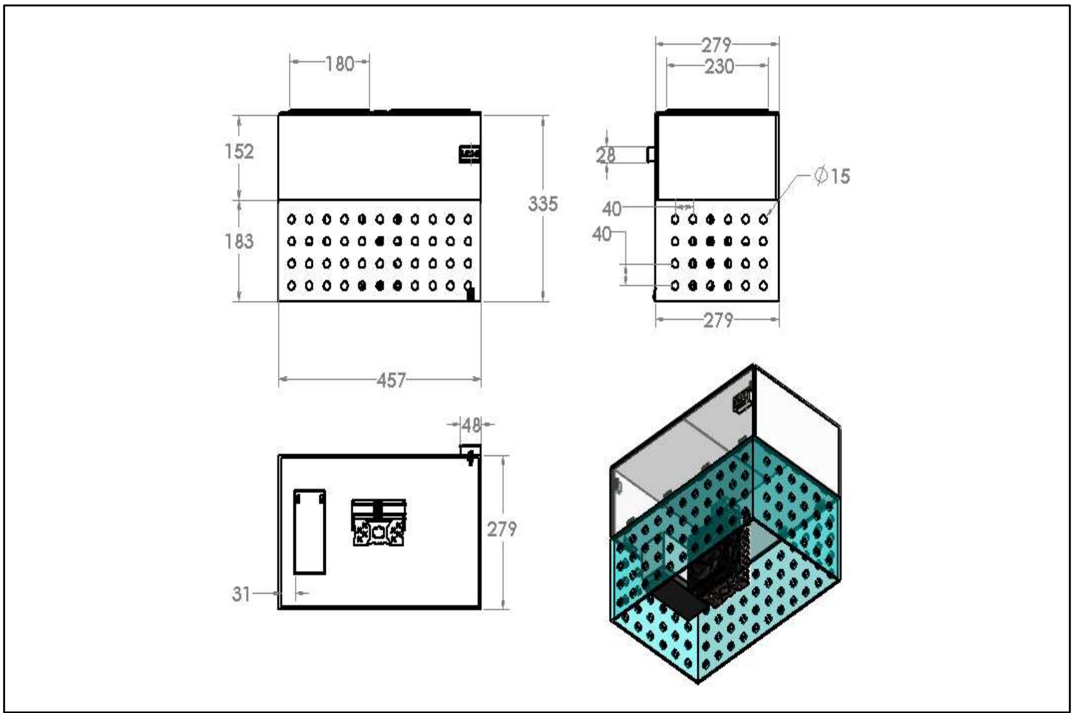

Figure 20 Drafting

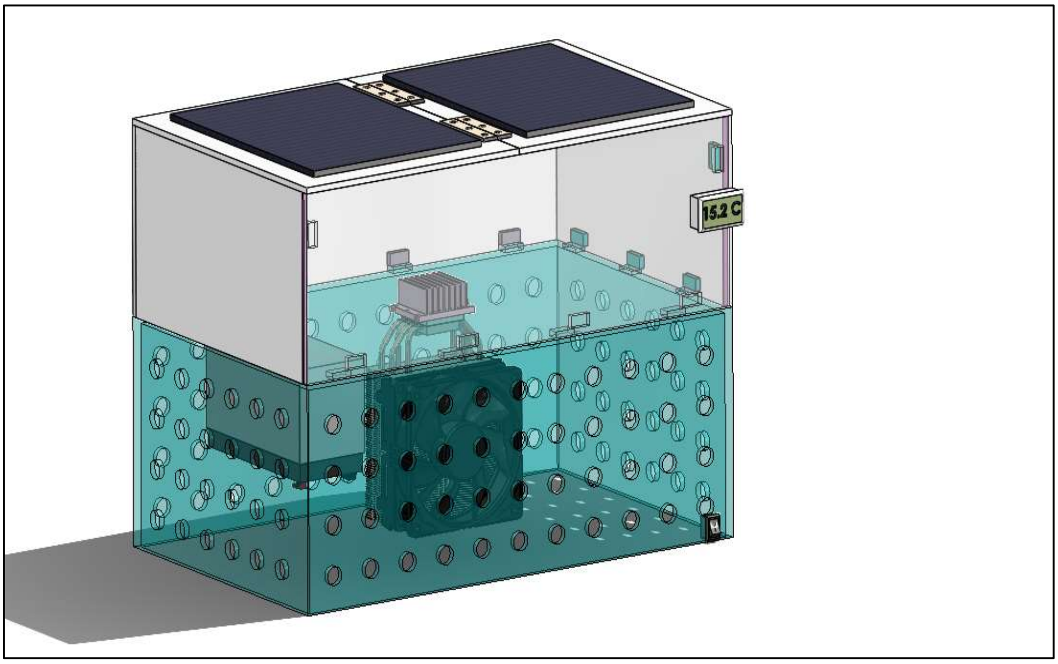

Figure 21 Isometric view

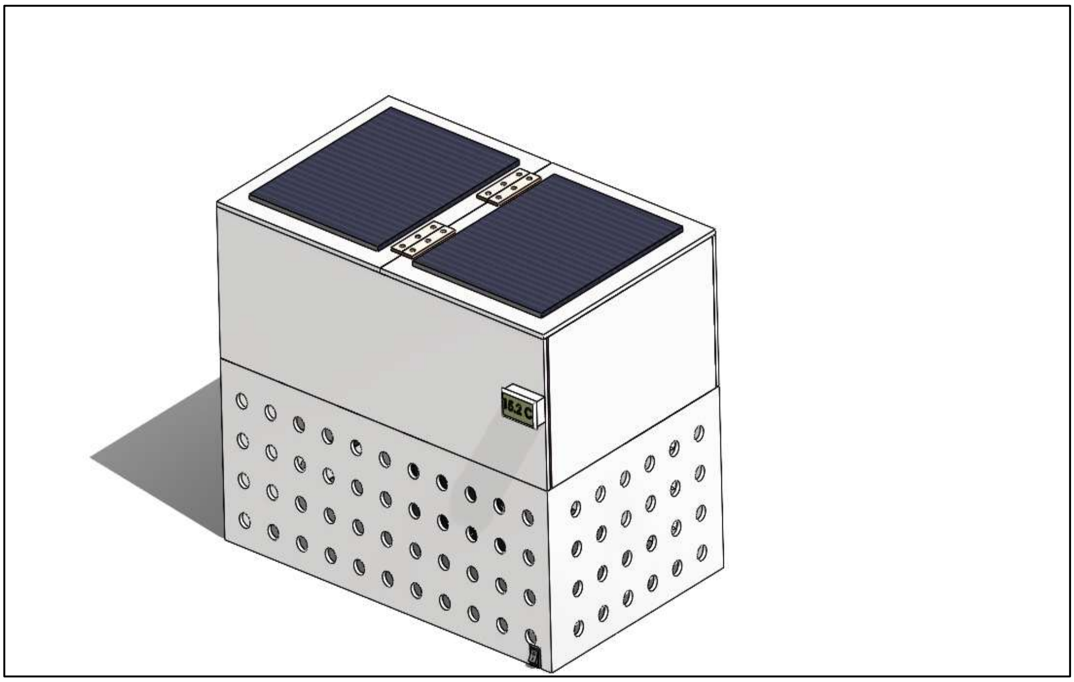

Figure 22 Final assembly

7. DESIGN CALCULATIONS

In this we calculate two types of load Heat absorbing load in the cabin and Heat rejection load through the outside Heat sink fan.

Volume = 450×150×275 = 18562500 millimeters^3 = 18 Liter

First, we have to calculate how much amount of power is required to absorb the heat of a 18 liter size of volume box at 35°coutside Temperature. So, there is a heat-absorbing load formula Q = m*Cp*(Th- Tc). so, we have to calculate Mass.

The amount of heat gained or lost by a sample (q) can be calculated using the equation q = mcΔT, where m is the mass of the sample, c is the specific heat, and ΔT is the temperature change

Mass = Density * volume = 1000*0.018 = 18 kg

Q = m*Cp*(Tamb -Tc) = 18 x 4.186 (35 -15) = 1506.96 kJ = 418 watt-hr or for 5 hr 418/5 = 83.6 watt

So, we required a total 83-watt heat-absorbing load in a 18 cubic meter volume box to reach 15°c in 83 watts we select 2 Peltier each Peltier would take 40 watts of load to cool up to 15°c

7.1 Selection of Material

A. Peltier

Above calculation of cabin load for per Peltier, we required 80 watts and 12v dc supply 6.66 amperes current for this amount of power we select TEC1-12706 Module Peltier that characteristic is

Table 1 Peltier Characteristics

Hot side Temperature °C	25	50
Qmax (watts)	50	57
Delta Tmax (°C)	66	75
Imax (Amps)	6.4	6.4
Vmax (Volts)	14.4	16.4
Module Resistance (Ohms)	1.98	2.30

B . Selection of Battery

For 83 watt amount of load we required a battery to run this load hence we calculate capacity of battery.

Power calculation = Voltage Load * Current Load = 12 x 7.5 = 90 watt

Battery capacity = total load / battery voltage = 80/12 = 6.66 Ah

We select 7.5 Ah battery to run this refrigerator to charge the battery.

Solar panel watt is 6 watt total

90 wat /6 watt = 15 hrs

The output power of solar panel = 6W

Total power generated by solar panel = 6 watt = 14 v x 2.33 amp

A) Determining the TEC Hot Side Temperature

The' heat sink is used. to dissipate the heat pumped by the TEC, in addition to the heat dissipated internally by the TEC, to the surroundings (which may be air or liquid). To do this, the heat sink will be warmer than the surroundings. It is thus important to keep heat sink temperature as close as possible to ambient temperature.
The thermal resistance (efficiency) of a heat sink is measured, as the temperature rise of the hot side above ambient, per Watt of power dissipated into the heat sink. Therefore, the TEC hot side temperature may be estimated by multiplying the thermal resistance of the heat sink by the amount of heat dissipated at the hot side of the TEC Three types of hot side TEC-to-air heat exchangers are usually used:

• heat sink with natural convection,
• heat sink with forced convection,
• liquid cooling with forced convection.

The choice depends on the requirements and constraints of each application. Typical performance values of 20°_ to O.5°C/W can be expected for natural convection, 0.5°C to 0.02°C/W for forced convection, and 0.02° to 0.0^{0}C/W for liquid cooling. Limiting the rise of the TEC hot side temperature to SOC to IS0C above the surroundings is usually practical due to AT (64°q between the hot side and the cold side.
For maximum reliability, it is important that the hot side temperature of standard Tees be kept below 85°C For this project water cooling was used. Cape Heat Exchange PTY (Ltd)!9, assisted in the design of the water-to-air heat exchanger. They used their experience to design the liquid radiator, using existing automotive designed cooling tubes. This is of great advantage, since a new tube design would have been costly.

B) Determining the TEC Cold Side Temperature

The temperature required at the cold side of the TEC is a very important factor. Here it should be checked if single stage could be used or if a very low cold side temperature is required; a double stage or triple stage TEC could be used. The necessity to determine a suitable hot side temperature would be influenced by the temperature difference between the hot side and cold side of the TEC (see Annexure B on sizing a TEq.

7.2 COST ESTIMATION

Cost estimation may be defined as the process of forecasting the expenses that must be incurred to manufacture a product. These expenses take into a consideration all expenditure involved in a design and manufacturing with all related services facilities such as pattern making, tool, making as well as a portion of the general administrative and selling costs.

PURPOSE OF COST ESTIMATING:

1. To determine the selling price of a product for a quotation or contract so as to ensure a reasonable profit to the company.
2. Check the quotation supplied by vendors.
3. Determine the most economical process or material to manufacture the product.
4. To determine standards of production performance that may be used to control the cost.

i) Raw material cost: -

It includes the material in the form of the Material supplied by the “Steel authority of India limited” and ‘Indian aluminium co.,’ as the round bars, angles, square rods, plates along with the strip material form. We have to search for the suitable available material as per the requirement of designed safe values. We have searched the material as follows: -

Hence the cost of the raw material is as follows: -

7.2.1 RAW MATERIAL & STANDARD MATERIAL

SR.NO.	NAME OF THE COMPONENT	MATERIAL	QTY	COST
1	BODY	ACRALYC	1	2500
2	MAGNET	NDFEB	20	900
3	PELTIER MODULE	SI BE	1	700
4	SOLAR PANNEL	POLY CRYSTALLINE 10 WATT	2	600
5	TEMPERATURE INDICATOR	STD TEMP -5 TO 70 DEGREE	1	500
6	BATTERY	STD 12 V DC	1	2000
7	HEAT PIPE COOLING MODULE	STD	1	3500
8	CHARGING SOCKET	STD	1	20
9	SWITCH	STD	1	75
10	NUT BOLT	STD	1	10
11	HEAT SINK	AL	1	310
12	CHARGER	STD	1	350
13	WIRES	CU	3 M	80
14	ADHESIVE	STD	1	50
15	CHARGER	STD	1	750
	TOTAL			12345

Table 2 Raw material cost

7.2.2 DIRECT LABOUR COST: -

SR. NO.	OPERATION	HOURS	RATE / LABOUR	AMOUNT
1.	Drilling	7	100	700
2.	Laser cutting	0.5	2000	1000
3.	Grinding	1	60	60
4.	Tapping	1	40	40
5.	Cutting	1	40	40
6.	Assembly	5	100	500
			TOTAL	2340/-

Table 3 Labour cost

7.2.3 INDIRECT COST

Project report cost = 2000/-

TOTAL INDIRECT COST = 2000/-

7.2.4 TOTAL COST

Raw Material Cost + STD Parts Cost + Direct Labour Cost +Indirect Cost

Total cost of project is done in table

TOTAL COST	AMOUNT
A	12345
B	2340
C	2000
Total cost of project	16685

Table 4 Final cost

7.3 Results and discussion

Sr No.	Time (min)	Cold temperature (^0C)
1	0	36
2	1	25
3	1.5	21
4	2	18
5	2.5	17
6	3	15
7	4	14
8	5	13
9	6	11.5
10	7	10.5

Table 5 Test Results

The temperature was stable after 7 minutes of running.

8. SCHEDULE

8.1 Activity Chart

Months/ Activity	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
A												
B												
C												
D												
E												
F												
G												
H												
I												
J												

Table 6 Time activity chart

8.2 ACTIVITIES

- A= Topic finalization
- B= Literature Review
- C= Formulation of Problem
- D= Parametric analysis
- E=Development of CAD models of system
- F= Purchasing of components
- G= Manufacturing
- H= Assembly and Testing
- I= Results and Conclusion
- J= Report Writing

9. ADVANTAGES, DISADVANTAGES AND APPLICATION

9.1 ADVANTAGES

1. Light weight and compact for very small heat loads.
2. No CFC gases or refrigerant are used for cooling.
3. No moving parts, eliminating vibration, noise, and problems of wear.
4. Reversing the direction of current transforms the cooling unit into a heater.
5. Operates in any orientation.
6. Not affected by gravity or vibration.
7. Very low-cost device for cooling in small appliances.
8. Precision temperature control capability.
9. It can be used in drought affected areas.
10. Solar operation makes it more economical and environment friendly.

9.2 DISADVANTAGES

1. Limited to very small refrigeration loads due to size compaction.

2. Not suitable for higher refrigeration use due to poor efficiency.

3. Thermo-electric modules become very heavy and bulky as the refrigeration capacity increases.

9.3 APPLICATIONS

1. Medical field and ambulance- Pharmaceutical industry.

2. In Military, rural area, etc.

3. Dairy (milk) industry.

4. Mechanical industry.

5. Scientific and research Laboratory.

6. Restaurant and hotel.

7. Vegetable, fish, fruit, beverage storage. Etc.

10. CONCLUSION AND FUTURE SCOPE

10.1 CONCLUSION

The following concluding notes have been made based on the experimental study shows below:

- The lowest temperature reached to 10.5°C for the cooling while the highest temperature was obtained at 65°C for heating.
- Using solar based refrigerator as an alternative of using compressor operated refrigerator has many benefits such as saving the environment, cost, and health.
- The thermoelectric effect devices used as heat pumps, coolers, thermal energy sensors.
- The major challenge faced in Thermoelectric cooling is the lower coefficient of performance, exclusively in large capacity systems.
- Study different thermoelectric materials are essential to enhance the thermoelectric cooler coefficient of performance.

10.2 FUTURE SCOPE

Though refrigerator is working successfully to its full capacity, still there are many changes and improvements to be made so that it is more user-friendly and cultivated in nature. Some changes are as follows:

- By increasing the number of Peltier modules and keeping the size of refrigerator unchanged and decrease the temperature inside the box.
- similar process can be used for heating purpose also , if we add the heating side of the refrigerator chamber inside system.
- By increasing the volume of refrigerator the capacity can be varied.
- Efficiency can be increased by choosing better insulation material.
- The use of this refrigerator can also implement in Four Wheeler by installing it at the time of manufacturing of vehicle

11. REFERENCE

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