THERMO ELECTRIC REFRIGERATION USING A PELTIER MODULE

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in

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by

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CERTIFICATE

This is to certify that this thesis entitled "**THERMO ELECTRIC REFRIGERATION USING A PELTIER MODULE**" is a bonafide record of the work done, in award of the degree of **Bachelor of Technology** in the department of **Mechanical Engineering,** Raghu Engineering College Dakamarri, Visakhapatnam.

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ABSTRACT

The global increasing demand for refrigeration in field of refrigeration air-conditioning, food preservation, vaccine storages, medical services, and cooling of electronic devices, led to consumption of more electricity and consequently more release of CO_2 all over the world which is contributing factor of global warming on climate change.

Thermoelectric refrigeration is new alternative because it can convert electricity into useful cooling. Thermo electric refrigeration uses the Peltier effect to create a heat flux between the junctions of two different types of materials. Also referred as Peltier cooler, in application, is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current.

The objectives of this study is design and develop a working thermoelectric refrigerator with an interior cooling volume of 1L that utilizes the Peltier effect to refrigerate and maintain a temperature less than ambient. Along with the peltier module we have provide certain other components such as heat sinks which account for heat transfer. We have checked for the feasibility of the volume which a single stage peltier module can handle and we have arrived at certain optimum conditions which have been presented further.

The design considerations which we have considered to be playing a key role are :

a) Heat transfer methods
b) Material properties
c) Geometry of the chamber

During the course of our tests we have seen the refrigerator reach temperatures below dew point and surface of the peltier module reaching freezing temperatures. The detailed analysis of our test results has been included further.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF NOATATIONS

The following symbols are used in this report:

W	Watt
m	meter
k	coefficient of thermal conductivity
K	Kelvin scale of temperature
^{0}C	Celsius scale of temperature
mm	Millimeter
J	current density
Q	Heat transfer rate
ΔT	Temperature grad

CHAPTER-1

INTRODUCTION

1.1 GENERAL

The term Refrigeration, as we all know is a process of removing heat from a low-temperature reservoir and transferring it to a high-temperature reservoir. The work of heat transfer is traditionally driven by mechanical means, but can also be driven by heat, magnetism, electricity, laser, or other means.

However, mechanical refrigeration technology has rapidly evolved in the last century. Refrigeration has had a large impact on industry, lifestyle and agriculture. The increase in demand for refrigeration globally is in the field of air-conditioning, food preservation, medical services, vaccine storages, and for electronic components temperature control.

In order to meet our requirements we use the conventional cooling systems. Conventional cooling systems (vapor compression system) such as those used in refrigerators utilize a compressor and a working fluid to transfer heat. Thermal energy is absorbed and released as the working fluid undergoes expansion and compression and changes phase from liquid to vapor and back, respectively. The main disadvantage of the system is the release of harmful gas like CO_2 all over the world which is a contributing factor of global warming on climate change.

Thermoelectric refrigeration is a new alternative method. This process makes use of semiconductor materials as a medium for heat transfer between the refrigeration space and the surroundings. Although thermoelectric refrigeration isn’t a latest development, because of its characteristics and its purpose they are only used in specific applications.

The complete analysis of this refrigeration technique and how we have achieved the objective had been included further.

1.2 HISTORY

Early study of Thermoelectricity dates back to 19^{th} century (1820-1920).

Thermoelectricity has been explained by

- Peltier effect
- Seebeck effect
- Thomson effect

Thomas Johann Seebeck was the first to make a study on thermo electrics in 1821. Followed by Jean Charles Athanase Peltier and William Thomson .The laws of these three scientists provide the basis of thermo electric refrigeration.

Thermoelectricity was actively studied for use in valuable technologies, primarily cooling as well as power generation for military as well as civilian uses when it was first developed. . The political and economic importance of such devices made advances more difficult and slow to publicize particularly between the Eastern European and Western countries. By the 1950's, generator efficiencies had reached 5% and cooling from ambient to below 0 C .Many thought thermoelectric would soon replace conventional heat engines and refrigeration and interest and research in thermoelectricity grew rapidly. However, by the end of the 1960's the pace of progress had slowed with some concerns over its performance and thus the research programs were dismantled.[2]

The research which has been carried out still is in use with very minimal modifications. This shows the extent to which the subject has been handled and publicized.

1.3 THERMO ELECTRIC REFRIGERATION

Thermoelectric refrigeration is the process of obtaining a temperature gradient by passing an electric current through a junction of two dissimilar metals. This is generally referred as peltier effect or thermoelectric effect. So to fabricate a thermo electric refrigerator using this principle we use a solid state device called peltier module.[1]

Fig 1.1 Peltier module

Our objective of fabricating a thermo electric refrigerator mainly functions on a peltier module.

1.3.1 PELTIER MODULE

Peltier module is a semiconductor device which produces a temperature difference on either side of its plates when subjected to a voltage. Heat from one side is absorbed and rejected to other side.

As a result, one side gets heated and other side gets cooled below room temperature. The side which is cooled below room temperature is our desired output which is used for refrigeration. The hot side is made to be in contact with a heat sink which effectively dissipates the heat evolved through forced convection of blowing air. This provides the basis for our project.

Since it is a solid state solid state there are no moving parts expect the blower to dissipate the heat to surroundings

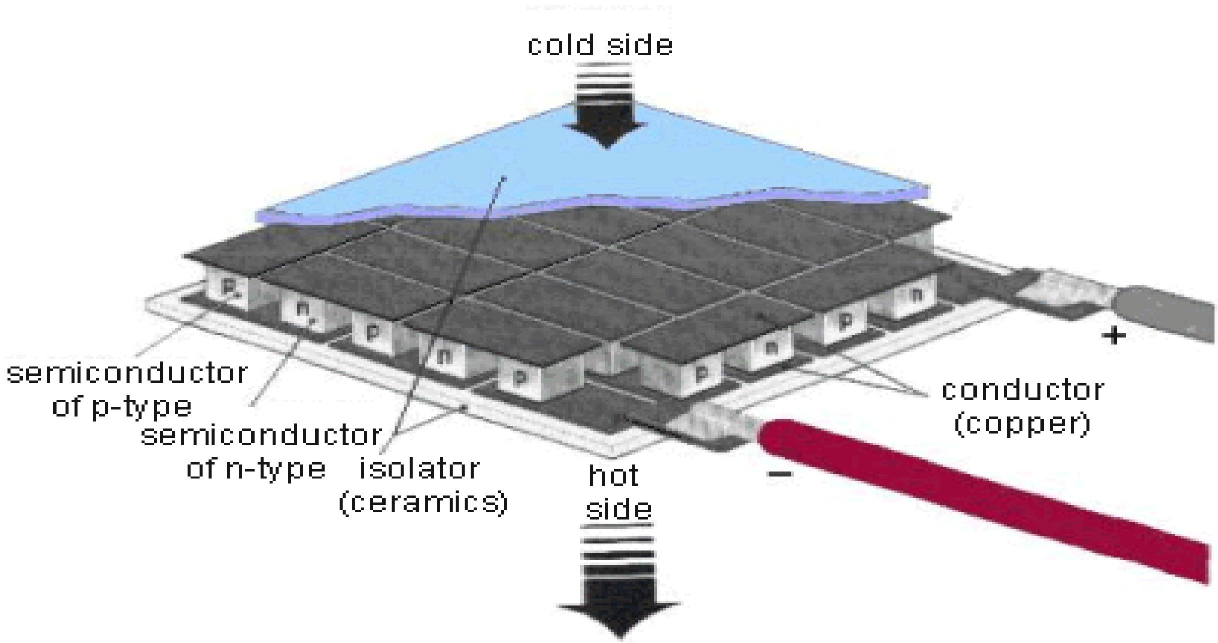


Fig 1.2 Exploded view of a peltier module

The peltier module essentially consists an assembly of p type and n type semiconductors arranged electrically in series and thermally in parallel. The semiconductor material used is bismuth telluride. This assembly has copper conductor and ceramic isolation over and below it.

When a D.C voltage is applied to the Module the positive and the negative charge carriers in the pellet assembly absorb heat sEnergy from one of the surface and reject it to the opposite surface. The surface where the Heat energy is absorbed is the cold side and the surface where the heat energy is dissipated is the hot side. A P type and an N type semiconductor assembly is sandwiched between the assembly are generally doped. The n type semiconductor has extra free electrons. The p type Semiconductors are positive charge carriers.

1.4 PROJECT OBJECTIVE AND OVERVIEW

Our prime objective was to refrigerate a small enclosed volume which is capable of attaining temperatures nearer to 10C using a peltier module as the medium and other aided components.

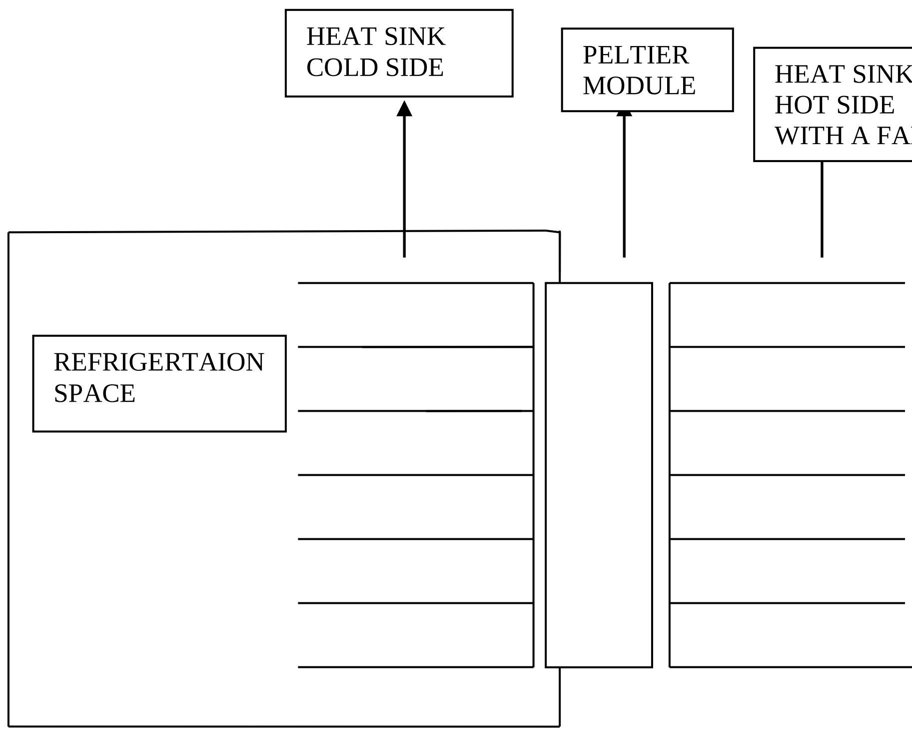


Fig 1.3 BLOCK DIAGRAM OF A THERMO ELECTRIC REFRIGERATOR

As mentioned previously a peltier module is capable of obtaining negative temperatures on one of its sides. The side that reaches negative temperatures along with a heat sink can be enclosed in a space which is well insulated. As a result the refrigeration space reaches temperatures well below ambient and acts as a refrigerator. The other side of the module is kept in contact with surroundings to dissipate the heat absorbed from the cold side using a heat sink and a fan.

1.5 GOVERNING LAWS

Thermo electric refrigeration works on the principle given by Seebeck, Peltier, Thomson

- **Seebeck effect**: Seebeck found that a circuit made from two dissimilar metals, with junctions at different temperatures would deflect a compass magnet .he found that a "Thermoelectric Force" induced an electrical current that deflected the magnet. More specifically, the temperature difference produces and electric potential (voltage) which can drive an electric current in a closed circuit. Today, this is known as the Seebeck effect. The voltage produced is proportional to the temperature difference between the two junctions. The proportionality constant (S or a) is known as the Seebeck coefficient, and often referred to as "thermopower"

- **Peltier effect:** When a current is made to flow through a junction between two conductors, A and B, heat may be generated or removed at the junction. The Peltier heat generated (Q) at the junction per unit time is

$$\dot{Q} = (\pi_A - \pi_B)I$$

Where π_A , π_B are constants of the plates, I is the current flowing.

The Peltier coefficients represent how much heat is carried per unit charge.

- **Thomson effect:** Heat is absorbed or produced when current flows in a material with a temperature gradient. The heat is proportional to both the electric current and the temperature gradient. The proportionality constant, known as the Thomson coefficient is related by thermodynamics to the Seebeck coefficient.

  If a current density **J** is passed through a homogeneous conductor, the Thomson effect predicts a heat production rate per unit volume **q** is

$$q = -kJ\,\Delta T$$

where **k** is Thomson coefficient

ΔT is temperature gradient produced.

1.6 ADVANTAGES AND DISADVANTAGES

- They are entirely solid-state devices, with no moving parts; this makes them rugged, reliable, and quiet.
- They use no ozone depleting chlorofluorocarbons, potentially offering a more environmentally responsible alternative to conventional refrigeration.
- They can be extremely compact, much more so than compressor-based systems. Precise temperature control (< ± 0.1 °C) can be achieved with Peltier coolers.

However, their efficiency is low compared to conventional refrigerators.
Thus, they are used in niche applications where their unique advantages outweigh their low efficiency. Although some large-scale applications have been considered (on submarines and surface vessels), Peltier coolers are generally used in applications where small size is needed and the cooling demands are not too great, such as for cooling electronic components.

1.7 APPLICATIONS

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 to extremely sophisticated temperature control systems in missiles and space vehicles.

Thermoelectric coolers generally may be considered for applications that require heat removal ranging from mill watts up to several thousand watts.

Large thermoelectric systems in the kilowatt range have been built in the past for specialized applications such as cooling within submarines and railroad cars.

Typical applications for thermoelectric modules include:

- Electronics package cooling
- Refrigeration systems (aircraft, automobile, , hotel, insulin, , pharmaceutical, RV)

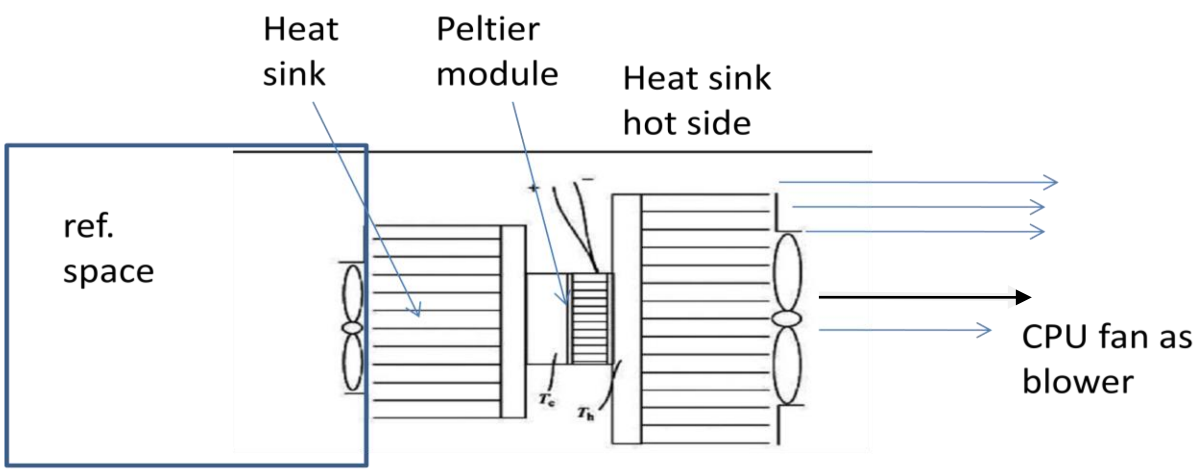
CHAPTER-2

DESIGN OF THERMOELECTRIC REFRIGERATOR

2.1 OBJECTIVE:

In this proposed work, the main aim is to develop a refrigeration system with a capacity of 1L of cooling chamber. It is necessary to design a system capable of maintaining the temperature of the materials between 10^0C to 15 ^{0}C for a long duration. The system is meant for outdoor use which makes better insulation mandatory. the design should be such that it can adaptable for refrigerating the chamber from ambient temperature to the required temperature.

2.2 WORKING OF THE SYSTEM

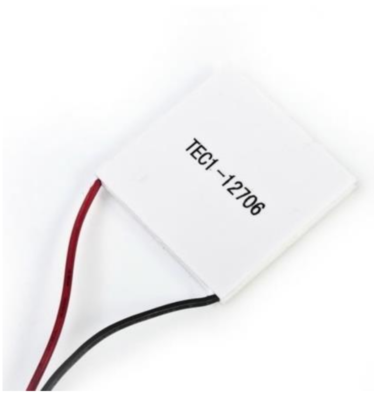


BLOCK DIAGRAM OF TER SYSTEM

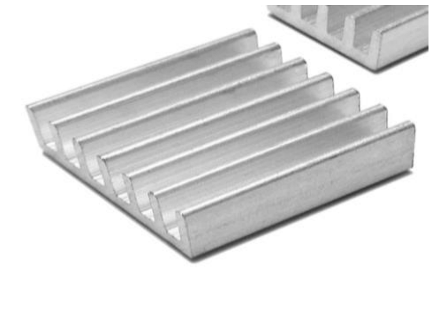
Fig 2.1

As shown above, a peltier module is sandwiched between two heat sinks. One heat sink is enclosed in an insulated refrigeration space. The other is left to ambient with a blower in conjunction to it. When a dc voltage is applied to it, the heat sink inside the enclosed space gets cooler and the other gets hotter. Since the cooler side is enclosed in a insulated space the system acts as a refrigerator and hence the desired result is achieved. The specifications of the components used and the design parameters are discussed further.

2.3 COMPONENT SPECIFICATIONS:



PELTIER MODULE



HEAT SINK

HEAT SINK WITH CPU FAN

CPU FAN

VOLTAGE CONVERTOR

Fig 2.2 COMPONENTS USED

Table 2.1 **SPECIFICATIONS**

COMPONENT	**SPECIFICATION**
PELTIER MODULE	TEC1-12706 12V 6A 92W(MAX) 4cm*4cm
CPU FAN FOR CONVECTION	12V
POWER SUPPLY USING VOLTAGE REGULATOR	I/P 220-240V A.C O/P 12V 10A D.C
HEAT SINK (COLD SIDE)	ALUMINIUM 4cm *4cm
POLY EURATHENE FOAM INSULATION WOOD FOR RIGIDITY	T>5mm

The components used are considered after looking at various design parameters

The need for the specifications mentioned above is mentioned in the design parameters.

2.4 DESIGN PARAMETERS

We have identified certain parameters greatly influence the working the refrigerator and hence have included their design considerations with utmost importance.

2.4.1 HEAT TRANSFER METHODS

Since the peltier module absorbs heat from one side to the other side, one sides gets hotter. If the heat is not rejected to surroundings at a quicker rate, then t might damage the peltier module. So heat transfer methods employed is of utmost importance.

There are several methods which can be employed to facilitate the transfer of heat from the surface of the thermoelectric refrigeration space to the surrounding.

These methods are described in the following three sections.

a)Natural convection,

b) Liquid cooled,

c)Forced convection

forced convection: The value co-efficient of thermal transfer (*K*) is 100W/mK for forced convection. Moreover by providing heat sinks the surface area for convection can be increased and by employing a CPU fan as a blower , forced convection can be achieved.

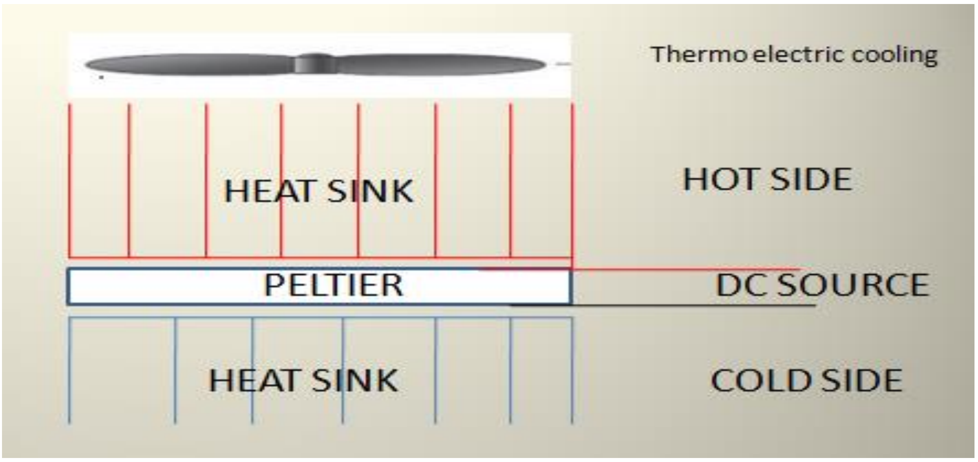


Fig 2.3 heat flow through in forced convection using heat sink

Natural convection : When the co-efficient of thermal transfer (*K*) was investigated, the *K* for natural convection was approximately 25 W/m K. the size of the heat sink for a natural convection apparatus would need to be 4 times that for a forced convection set-up.so for the geometry we use, natural convection becomes difficult.

Liquid cooled: additional accessories such a s pump is required if the hotter side is needed to be cooled for heat rejection. This arrangement would be superfluous since it is not as efficient as forced convection.

2.4.2 INSULATION MECHANICS:

Since the insulation plays a crucial role in maintaining temperature of the space, it has to be designed properly. The insulating material should be such that it shouldn't allow the ambient temperature to escape in. thermal conductivity becomes the criteria for the selection of the material for insulation.

MATERIAL	k (w/mk)
TIN WOOD	62 – 68 **0.12-0.04**
ALUMINIUM	205-249
STAINLESS STEEL	12 – 45
POLYEUREATHENE FOAM	**0.02**

Table 2.2 Thermal conductivity of various materials

Thermal conductivity depicts how much amount of heat flux escapes per unit time. So for the insulating material it should be low. Of all the materials that are available and affordable, wood and foam have the least thermal conductivity.

Geometry[7]

Two main geometries were considered for the device the first was a rectangle. The advantage of rectangle is its simplicity to build and insulate. A door can easily be attached to one of the sides. Finally any insulation, thermoelectric modules or heat sinks are easily fastened to the sides. The second choice for cooler geometry was a cylinder. The advantage found with this shape is that it has the largest volume to surface area ratio of the two designs considered. This is a good property when the objective is to minimize heat loss. But considering the simplicity to build and insulate rectangle box is considered.
The dimension of the rectangular box after analyzing the extent to which a peltier module can minimum hold is listed below.

Dimensions (in mm)	Width (w)	Length (l)	Height(h)	Vol enclosed
outer	150	180	170	4.5 L
inner	130	160	150	3 L

Table 2.3 insulation dimension

2.4.3 HEAT FLUX CALCULATIONS:

Now that we have identified the insulating material it is necessary to make certain analysis of performance of the material in keeping the space at required temperature. One such analysis is calculating the heat flux that exists. we have to identify the greatest temperature difference between the thermal load and the ambient environment that can occur.

We have used an insulation of wood and foam. The heat transfer from these materials is through conduction.

The assumptions that are considered are as follows:[4]

- Heat transfer is greatly influenced through conduction and then by convection.
- The conduction is assumed to be one dimensional and steady state
- The conduction follows fouriers law

Below is the scenario of one side of the insulating material when conduction takes place:

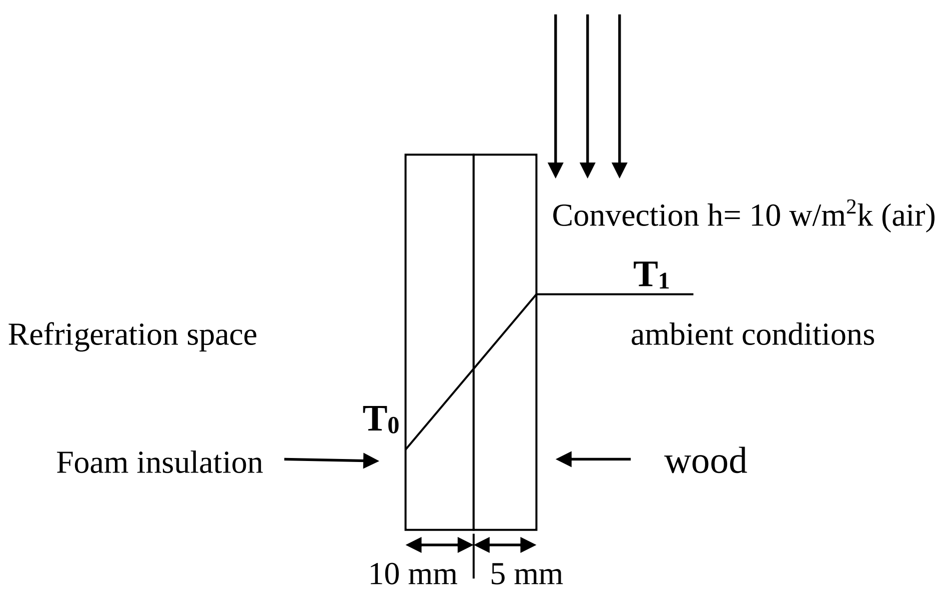


Fig 2.4 temp distribution

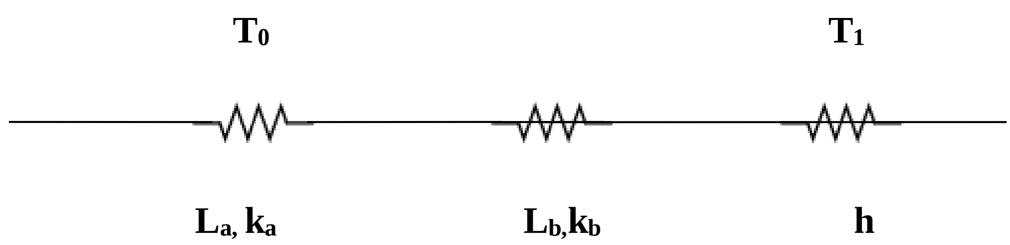
- **T_0=10^{0}C** and **T_1= 34^{0}C** are the temperatures at the inner surface of foam and outer surface of Wood (ambient) respectively
- let **L_a=10 mm**, **L_b=5mm** be the thickness of foam and wood respectively

- Let $\mathbf{k_a=0.02}$ **w/mk** and $\mathbf{k_b = 0.12}$ **W/mk** be the thermal conductivities of

  foam and wood respectively.

- Let **h** be the heat transfer coefficient of air which is experimentally found to be around **10W/m²k.**

The equivalent circuit can be represented analogous to thermal resistances as follows



.

The heat transfer rate per unit area is given by

$$\boxed{Q= \frac{T_1-T_0}{\left(\frac{L_a}{K_a} + \frac{L_b}{k_b} + \frac{1}{h}\right)}}$$

The heat transfer per unit area $\mathbf{Q = \dfrac{34-10\ K}{0.641\ K\ m^2/W}}$

$$= \mathbf{37.44\ W/m^2}$$

2.4.4 HEAT SINK DESIGN :

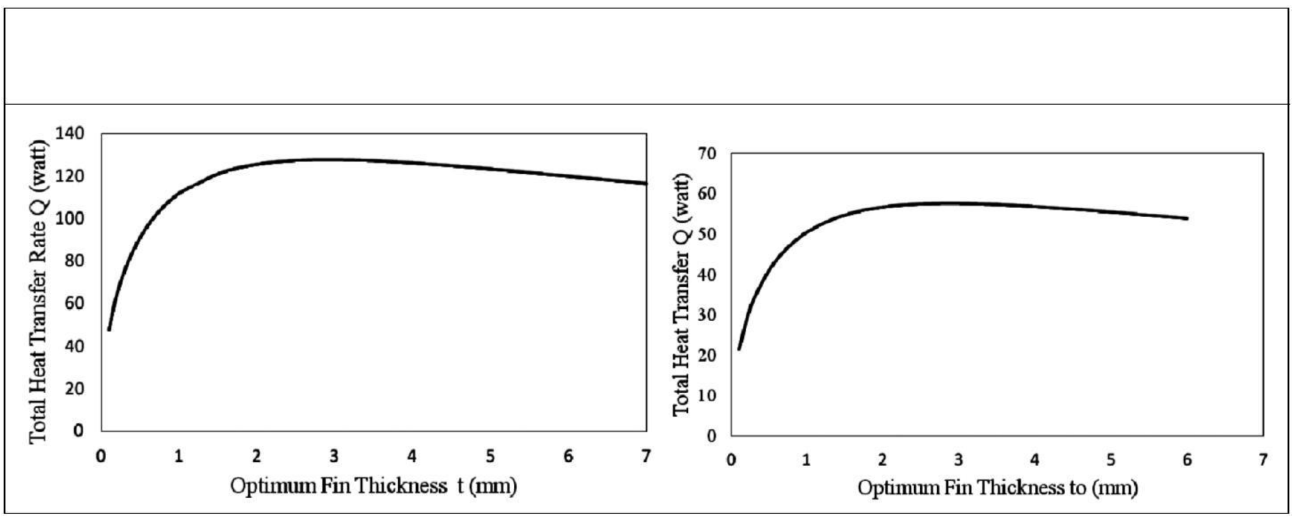
To dissipate the heat effectively heat sink is very much essential. Heat sink is made to be in contact with the peltier module using a thermal compound.

.

Again, the thermal conductivity plays a key factor in dissipating the heat.

For this purpose the material selected is **Aluminum** since its thermal conductivity is approximately 237 W/mk.

Considering the dimension available at the surface area and various options keeping the weight, cost and manufacturing feasibility as the main consideration for selection for mounting of heat sink both at hot and cold side area Fin thickness of 1mm with profile length of 20 mm is selected.



Graph 2.5 H.T rate v/s fin thickness[10]

The above graph depicts the performance of the heat sink with varying fin thickness. These graphs have been plotted experimentally by the sources. The graph clearly shows that heat transfer rate is maximum both on cold side and hot side when the fin thickness is about 1mm. These are still applicable to our case since the standard fin thickness that is prescribed for devices the size of a peltier is 1mm.

2.5 FABRICATION PROCESS:

Since the only fabrication that has to be done here is making a rectangular refrigeration space, there is not much machining work to do.

To fabricate the refrigeration space :

- Cutting and gluing of a 5mm thick wooden slabs
- Joining the wooden slabs to create the outer chamber.
- Cutting and gluing foam board as per the dimensions to the wooden chamber have been performed

  Also thermal compound which ensures a perfect contact between the module and the heat sinks has been used. Since it acts as an adhesive it is considered as a part of fabrication.

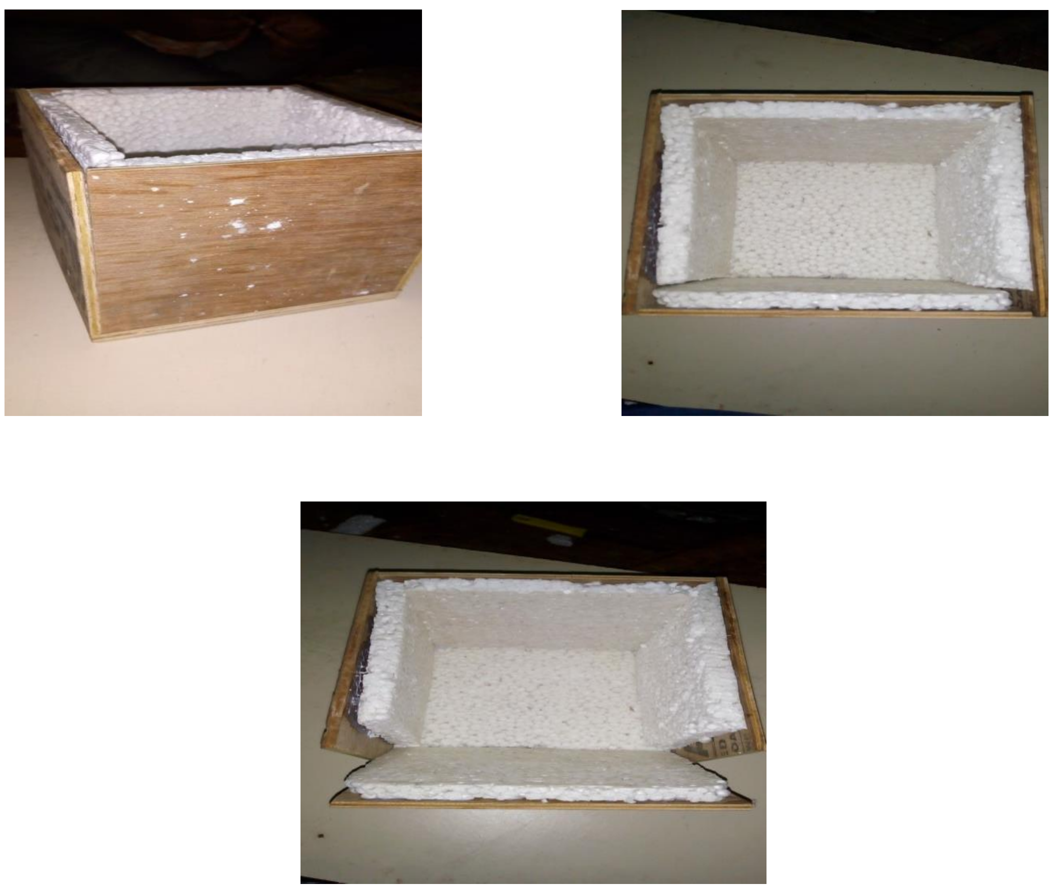


Fig 2.6 views of the cham

CHAPTER-3

RESULTS AND CONCLUSION

3.1 TEST RESULTS:

The test was conducted at different ambient 24^0C, 27°C, 32 °C represented . The temperature varied from 15 °C to 10 °C within the refrigeration space. The temperature sensing device has an accuracy of 1^0C. The readings were taken after a time period of 27 min.

Table 3.1 test results data

Ambient temperature($T_1{}^0$ C)	Cold side peltier temperature (T_c)	Hot side peltier temperature (T_h)	Refrigeration space temperature (T_0)
32	6.7	57.7	16.8
27	5.8	55.1	17
24	5	56.9	12

- The peltier module consistently reached a temperature of 6^0C and the system temperature reached a temperature of 15^0C most of the times.
- The above results are arrived at after a number of iterations and tests at the same conditions of surrounding temperature.

Table 3.2 Temperature gradient of the module

Ambient conditions	Peltier temp gradient **ΔT** = (T_h- T_c)
32	51
27	49.3
24	51.9

The temperature gradient produced between the sides of the peltier was nearly 51^0C.

The main disadvantage that lies with the peltier is that the proportional variance of temperature gradient is higher at lower electric currents and lower at higher electrical currents.[11]. The manufacturers specification of max temp difference is given below

Table 3.3 manufacturer specification

^{Q}max	51.4	Dimensions	
^{I}max	6 Amp	Width	40 mm
^{V}max	15.4 V	Length	40 mm
^{T}max	***67 °C***	Thickness	3.8 mm

On comparing the temperature achieved was 10^{0}C short of what the manufacturer has specified. So from this it can be inferred that the peltier module did work according to its capacity and also its performance depends on the voltage and ambient conditions provided.

3.1.1 DEW POINT RESULT:

Dew point is the temperature to which air must be cooled to become saturated with water vapor. In other words , The dew point temperature is the temperature at which the air can no longer "hold" all of the water vapor which is mixed with it, and some of the water vapor must condense into liquid water. The dew point is always lower than (or equal to) the air

This generally happens when air comes into contact with a surface colder than itself. The water will condense on the surface at that instance. In our case since the peltier module reaches temperature reaches well below ambient, at some temperature the peltier would reach the dew point temperature and thus condensation would take place.

In order to measure the dew point temperature , humidity forms a necessary criteria. The water vapor content in the air is humidity. So at higher humidity dew point temperatures are nearer to ambient since the water vapor content would be more.

The peltier module which we have employed did reach dew point temperatures with ease as the conditions were humid. The detailed analysis of dew point is shown in the table.

Table 3.4 Dew point data[5]

Place	Day	Temperature	Rel humidity	Dew point
Visakhapatnam	17 Oct	34^0 C	51 %	22.11
Visakhapatnam	15 Oct	$31\ ^0$C	67 %	24.86
Visakhapatnam	10 Oct	$26\ ^0$C	80%	22.28

The test has been conducted in some part of the day since humidity doesn’t remain the same all throughout the day. The conditions mentioned above when the test has been conducted. The condensation took place on the surface of the peltier module that resulted in water droplets accumulating over the surface of the peltier module.

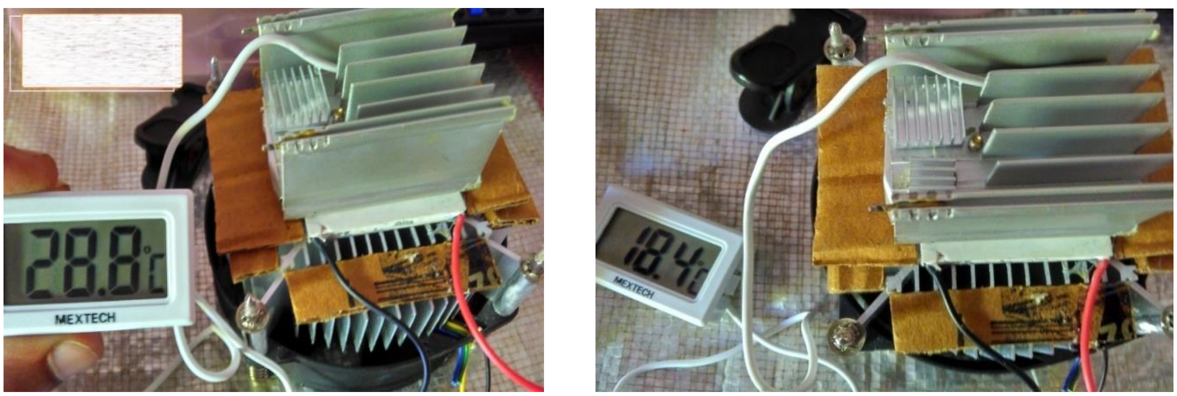


FIG 3.1 PELTIER MODULE AT DEW POINT

3.2 CONLUSION

The Peltier refrigeration is a compact and simple way of attaining temperatures below surroundings temperatures. the temperatures obtained in tests clearly indicated that reaching temperatures below 0 c is possible using a peltier module. In fact when cold side of the peltier was left open ice flakes were developed on the surface. Owing to damage, We have immediately withdrew the analysis further .

Using a peltier refrigeration space of a volume 1L we have achieved desired cooling that we mentioned in the objective. Our test results though not accurate but approximate justifies that.

The peltier refrigeration can be extended in its operation using a temperature regulating unit in order to prevent the space from reaching negative temperatures.

The thermo electric refrigerator has been insulated well with foam and wood and thus our deviations of heat rates calculations have been nullified. Testing the device at different ambient conditions helped us to analyze Its performance under varying conditions. The results obtained can be taken as the output of a simulated environment and can be used to extend the study in fabricating a space with more capacity, higher temperature gradient, more efficient heat sinks and upgrade in performance of other related parameters.

3.3 THE FUTURE:

Whatever may be the reason why thermoelectric study went on a decline post world war, now the time has come to salvage the past and proceed further. The research facilities available now are more advanced and will advance a lot in coming years. Thorough research in this age old concept of thermoelectricity may well pave the way in replacing the conventional vapor refrigeration systems.

The disadvantages of vapor compression system may not be of a huge concern now but in the future , all other varying factors such as climate, global warming etc would have impact on the systems usage and eventually would raise doubts on its functioning and eventually would demand a modification or replacement.

With recent development taking place in field of thermoelectric and Nanoscience different thermoelectric material with high temperature difference need to be explored. This will further help to reduce the temperature, current below and can also perform better at higher ambient conditions.

The feasibility of using cascaded peltier arrangement and increasing their efficiency is one huge challenge ahead that requires a solution. Different applications that include biomedical, electrical as well as mechanical, thermal sciences would direly need thermo electric refrigeration modified and more effective. Nevertheless, thermo electric refrigeration is a important field of study that may well open the unknown secrets that are still alien .

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