ABSTRACT

The main purpose of this design and build an affordable solar thermoelectric refrigerator for the people living in remote parts of country where electricity is still not available but sunlight is an ultimate source of light. The refrigerator could be used to store perishable items and facilitate the transportation of medicines as well as biological material that must be stored at low temperatures to maintain effectiveness. The design of the solar-powered refrigerator is based on the principles of a thermoelectric module (i.e., Peltier effect) to create a hot side and a cold side. The cold side of the thermoelectric module is utilized for refrigeration purposes; provide cooling to the refrigerator space. On the other hand, the heat from the hot side of the module is rejected to ambient surroundings by using heat sinks and fans. The designed solar thermoelectric refrigerator was experimentally tested for the cooling purpose. The results indicated that the temperature of the refrigeration was reduced from 30.2°C to 15.8°C in approximately 35 min. The coefficient of performance of the refrigerator (COPR) was calculated and found to be about 0.23.

The intention of thermoelectric refrigerator is based on the opinion of a thermoelectric module which makes a hot side and a cold side. The cold side of thermoelectric module is used for refrigeration purpose to offer chilling to the refrigerator space on the further hand the warmth from the hot side of the module is rejected to ambient surrounding by using of heat sink and fan. The design of thermoelectric refrigerator was experimentally verified for the cooling persistence.

CHAPTER -1

1.0 INTRODUCTION

Thermoelectric coolers (TEC) are versatile temperature control devices. Among the many -profits provided by the TEC devices it can found the following:

-They don't have moving parts.

-They are used in applications where space limitations and reliability are paramount.

-They don't have CFC's.

-They may be used for heating or cooling by reversing the direction of current flow.

Presently, we are working in the development of a low-cost pollutant gas detector based on infrared optical absorption spectroscopy. We use a Bismuth telluride array of 64 pixels as sensor element, this array incorporate a TEC device. The TEC element is necessary because dark current characteristics of photoconductors have a big dependence on the temperature. In our case, if temperature increases 1^{o}C, around 298 K, then the Bismuth telluride dark resistance increases close to 3%. The variation of characteristics may be misunderstood as a variation of the concentration of pollutant gases.

Thermoelectric (TE) materials are able to directly convert the heat energy to the electrical energy and vice versa. The TE device generally produces less industry pollution, such as carbon gas, slag, and noise, during working than traditional energy industry. Therefore, it is a convenient and environmental-friendly choice for energy harvest andBismuth telluride (Bi_2Te_3) and its alloys have been regarded as one of the best TE materials due to their good thermoelectric figure of merit at the room temperature. However, the ZT value of bulk Bi_2Te_3 based materials was limited at 1 for decades until the application of nanotechnology in TE materials. In recent years, plenty of studies have demonstrated that the utilization of nanotechnology further improved the performance of Bi_2Te_3 based TE materials because the increased phonon scattering at the grain boundaries effectively decreases the thermal conductivity.

Since TE devices are very delicate to boundary and working conditions, correct choice of materials, geometry, and working conditions play acute role in creating the best TE technology for a specific requirement.

The coefficient of performance of compression refrigerators decrease with the decrease of its capacity. Therefore, when it is necessary to design a refrigerator for cooling a chamber of only a few liters capacity, thermoelectric cooling is always preferable. Also for controlling the temperature of small units, thermoelectric cooling has no competition from existing refrigerators of the conventional types. The importance of thermoelectric cooling can be best understood by examining other various advantages it offers over the conventional methods of refrigeration-

Refrigeration means deletion of heat from a body or space in order to carry it to a temperature lesser than those of the natural surrounds. In this framework, my topic, **Thermoelectric Refrigeration** aims at providing cooling effect by using thermoelectric effects rather than the more prevalent conventional methods like those using the ‘vapors compression cycle’ or the ‘gas compression cycle’. There are 5 thermoelectric effects and these are observed when a current is passed through a thermocouple whose junctions are at different temperatures. These phenomenon are the *Seeback effect*, the *Peltier effect*, the *Joulean effect*, the *transfer effect*, plus the *Thomson effect*. Thermoelectric refrigeration, also called "Peltier Effect", is a solid-state process of hotness transmission throughdivergent semiconductor ingredients. It is based on the thermoelectric effect known as ‘Peltier Effect‘ according to which if current is passed over a thermocouple, formerly the heat is engrossed at one connection of the thermocouple and progressive at the other connection. So by using the cold connection of the thermocouple as the evaporator, a heat sink as the condenser and a DC power source as the compressor of the refrigerator, cooling effect can be provided.

The coefficient of performance of compression refrigerators decrease with the decrease of its capacity. Therefore, when it is necessary to design a refrigerator for cooling a chamber of only a few liters capacity, thermoelectric cooling is always preferable. Also for controlling the temperature of small units, thermoelectric cooling has no competition from existing refrigerators of the conventional types. The importance of thermoelectric

cooling can be best understood by examining other various advantages it offers over the conventional methods of refrigeration-

- There is ease of interchanging the cooling and heating functions by reversing the direction of current in the thermocouple
- Thermoelectric systems are vibration less and have no moving parts. Hence there is no problem of wear and noise.
- There is no problem of containment and pollution because no refrigerant or chemical is used.
- Since there is no bulky equipment it provides ease of miniaturization for small capacity systems.
- The capacity can be controlled easily by varying the current and hence the amount of heat immersed or grown at the junctions.
- The system is highly reliable (with a life of > 250,000 hours)
- This system also has the capacity to operate under various values of gravity (including zero gravity) and in any position.

Thus, thermoelectric cooling has a great relevance in today’s time.

1.1HISTORY

The physical principles upon which modern thermoelectric coolers are based actually date back to the early 1800s, although commercial thermoelectric cooler modules were not available until almost 1960. The first important discovery relating to thermoelectricity occurred in 1821 when a German Scientist, Thomas Seebeck, found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals 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 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. Twenty years later, William Thomson later Lord Kelvin issued a compressible explanation of the Seebeck and Peltier effects and described their interrelationship. At the time however, these phenomenon were still considered to be more laboratory curiosities and were without practical application. In the 1930, Russian scientists began studying some of the earlier thermoelectric work in an effort to construct power generators for use at remote locations throughout the 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 thermoelectric refrigerators make use of modern semi-conductor technology whereby doped semi-conductor material takes the place of dissimilar metals used in early thermoelectric experiments.

I. SEEBECK EFFECT

Fig.1 Illustrate the Seebeck Effect.

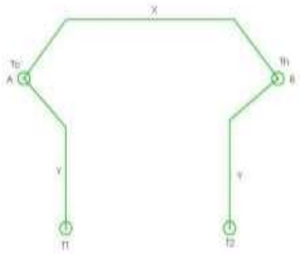


Fig. 1 Seebeck Effect

The thermocouple conductors are two dissimilar metals denoted as X and Y materials. With heat applied to the end
B of the thermocouple and the end A is cooled, a voltage will appear across terminals T_1 and T_2. This voltage is known as the Seebeck e.m.f.

II. PELTIER EFFECT

The Peltier effect bears the name of Jean-Charles Peltier, a French physicist who in 1834 discovered the calorific effect of an electrical current at the junction of two different metals. When a Current (I) is made to flow through the circuit, heat is evolved at the upper junction (T_2) and absorbed at the lower junction (T_1). The Peltier heat absorbed by the lower junction per unit time $\dot{Q}$ is equal to

$$\dot{Q} = \pi_{AB} I \qquad (1)$$

Where π_{AB} is the Peltier coefficient.

Peltier heat is reversible, when the direction of current is reversed; the Peltier heat is the same, but in opposite direction. Peltier coefficient depends on the temperature and materials of a junction. Fig. 1.2 Illustrates The Peltier Effect.

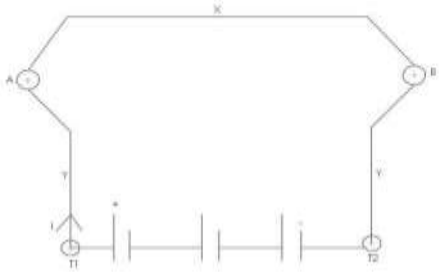


Fig. 1.2 Peltier Effect

If a voltage is applied to terminals T_1 and T_2, electric current (I) will flow in the circuit. As a result of the current flow, a slightly cooling effect will occur at thermocouple junction A where heat is expelled. Note that this effect will be reversed whereby a change in the direction of electric current flow will reverse the direction of heat flow.

III. THOMSON EFFECT

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 upon the direction of both the electric current and temperature gradient. This phenomenon, known as Thomson effect is of interest in respect to the principles involved but plays a negligible role in the operation of practical thermoelectric models.

1.2OBJECTIVES OF WORK

The objective of the proposed work is to present an analysis of the working of TE cooling refrigerators. Detail scope of this work includes:

- Explanation of the principles and working of thermoelectric refrigerator.

- Finding ways and methods to increase the proficiency of the thermoelectric cooling structures and suggesting ways for significant enhancement in the current performance of these devices by increasing the value of the *figure of merit*, Z. For this, discussion on new design techniques in this field which improve heat transfer is intended.
- Suggesting potential new materials which will have properties better suited to increase the value of the *figure of merit*. This also includes the following –

  a) Broad range of temperature over which Z is high for different materials.
- Reduction and improved performance of thermoelectric devices is covered.

1.3 THE REPORT LAY-OUT OF

A brief description of all the chapters is given below:

Chapter first gives a brief introduction of thermoelectric cooling and background in which it is explained what is thermoelectric cooling and what are Its advantages over the conventional means of refrigeration.

Chapter 2 explains the structure of a thermoelectric module, basic thermoelectric phenomenon and gives it's functioning. It also discusses the basic construction of a thermoelectric refrigerator.

Chapter 3 presents a mathematical analysis of the coefficient of presentation of a thermoelectric refrigerator and the several types of loads which it has to encounter.

Chapter 4 deals with various methods and configurations which help to increase the efficiency of the thermoelectric refrigerators. It also aims at increasing the measurement of performance of a thermoelectric refrigerator over the use of novel materials better suited for this purpose.

Chapter 5 presents the various applications and uses in which thermoelectric cooling is used at present. It also lists some of the new commercial products developed which can be bought off the shelf.

Finally Chapter 6 gives the result and conclusion based on the study and the scope of future development of thermoelectric cooling.

1.4 LITERATURE REVIEW

While doing a complete literature review, I came across many new developments in the field of solar thermoelectric refrigerator. Here I propose to present few of all the literatures that have been studied. The literature consist research papers mainly from the solar thermoelectric material and application of alternative of various material in thermoelectric refrigerator field. The literatures based on thermoelectric refrigerator are and the variations of efficiency to some parameters e.g. current flow, figure of merit (Z), temperature difference etc. are studied along with various workable materials. Below you can read some of the most influential material came across with observations and conclusions pointed out:

1. S.A Omer and D.G Infield, investigated in 1997 they present an improved theoretical model of a thermoelectric device which has been developed for geometrical optimization of the thermoelectric element legs and prediction of the performance of and optimum device in power generation mode .

■the currently available methods, this model takes into account the effect of all the parameter to contributing to heat transfer process associated with the thermoelectric device.

■The model is used for comparative evaluation of four thermoelectric modules.

■The model are compared with experimental data of the commercial thermoelectric module in power generation mode with temperature gradient consistent with those achievable.

■Difference in temperature of hot junction and cold junction gives good figure of merit and better performance.

2. J.G Vian, D. Astrain in 1999 investigate that the heat dissipation in thermoelectric devices by means of an element with phase change.

■They suggest an element with phase change and no moveable components has been developed in order ot improve the heat dissipation in application of TE.

■The result show that the heat is increase when the thickness of the wall is increase. They investigated system with this element it increase the efficiency of the system by 12 -18 % this is the total efficiency of the system.

3. In 2001 Y. J. Dai and R. Z Wang show experimental investigation and analysis on a thermoelectric refrigerator driven by solar cells has been conducted. The research interest focused on testing the system Performance under sunshine. They give various impact of electric current and impact of solar insolation rate. The conclusions show that the system have less weight and low cost, operation modes of the refrigerator used in daytime and nighttime were treated in different ways.

4. According to the studies conducted in 2001 by Hugh W. Hillhouse, Mark T. Tuominen suggested that the thermoelectric materials are main factor to increase efficiency in many case.

■while an increase inlet temperature thermoelectric materials to incrase in its thermal conductivity hence it leads to an overall increase in efficiency even to its maximum.

■ Similarly, while an increase in temperature flow rate leads to an increase in energy efficiency of the TE refrigerator.

■ The proposed materials for the thermoelectric module is generally suited for cooling propose hence have low Seebeck effect.

5.In 2005 A.K Pramanick and P.K Das give the construction and design of the thermoelectric device.

■For this they introduced three important dimensionless parameters are identified to designate poor Thomson effect; low thermal conductivity and low electrical resistivity of a good semiconductor.

■They also make it to be environment friendly for direct energy conversion especially the capacity of peltier and seebeck effect to dispense with the moving parts.

■The design prescription leads to the limit of maximum permissible length of any individual module of the cascaded thermocouple.

■In order to maintain a consistency with the standard notation of analysis prevailing in the literature they define the relationship between electrical resistance and resistivity; thermal conductance and conductivity of the thermoelectric element.

6.Sabah A. Abdul-Wahab proposed the design and experimental investigation of portable solar thermoelectric refrigerator in 2008.

■The main objective of this study is to design this system for the people who lives in desert and rural area where electric is still not available but solar energy is present in unlimited amount.

■The design is experimentally tested for cooling purpose.

■The result indicated that the temperature of the refrigerator was reduced from 27 to 5 °C in approx. 45 min.

■The refrigerator was designed based on the principle of a thermoelectric module to create a hot side and cold side.

7.FankaiMeng, Lingen Chen and Fengrui Sun in 2008 introduced the term two-stage thermoelectric refrigerator system.

■In this paper various graph are introduce between electrical current, and the coefficient of performance versus the working electrical current of the combined device are derived.

■The thermodynamic model of the combined device is built by using non-equilibrium thermodynamic theory.

■The optimum working currents corresponding to the maximum cooling load is larger than that corresponding to the maximum COP.

■The cooling load at maximum COP increase with the increase of total number of thermoelectric element pairs, while the cop at maximum cooling load is independent of the total number of thermoelectric electric element pairs

8. In 2013 Onoroh Francis, Itoje Harrison John give the performance evaluation of a thermoelectric refrigerator.

■The research focused on simulation of a TE refrigerator maintained at 4°C.

■The system consisted of the refrigeration chamber, thermoelectric modules, heat source and heat sink.

■The results show that the coefficient of performance which is a criterion of performance of such device is a junction of the temperature between the source and sink.

■For maximum efficiency the temperature difference is to be kept to the barest minimum.

9. Eun Soo proposed a new approach to optimize thermoelectric cooling modules in 2013.

■The one dimensional analytic model give the optimum current, which maximize the COP of a thermoelectric cooling module.

■In the model the optimum current, which maximizes the cop of a thermoelectric cooling module, is determined by the cooling capacity of a thermo-element, the hot and cold side temperatures.

■The thermal and electrical contact resistance and the properties of thermoelectric material, but not by the length of a thermo-element.

■The thermo-element can be easily obtained using the optimum current.

10,T. Hara, H. Azuma, H Shimizu H. Obora, Z. Abdin in 2013-14 theoretically analysis.

■Based on the analytical results they concluded the cuonanofluid could reduce the entropy generation by 4.34% and enhance the heat transfer coefficient by 22.15% theoretically compared to water as and absorbing fluid.

■It also has a small penalty in the pumping power by 1.58%.

11.In2014 Andrea Montecucco and Andrew R.Knox give accurate simulation of thermoelectric power generating systems.

■They observed that the waste heat can be recover in large scale of application in TE system by proper designing of the system.

■The useful heat rate and useful exergy rate have conflicting behavior in many cases.

■Solar irradiance considerably affects both the useful heat rate and useful exergy rate.

■High performance is based on appropriate solar irradiance.

■The optimum fluid inlet temperature varies, and it is mainly affected by heat loss.

After read all the paper that I used in my thesis I found that when the we want to increase the efficiency of the system we want to use the materials that have good figure of merit and having good thermal conductivity and provide better precaution that reduced the maximum temperature of the system and all these quality are found when I used the semiconductor bismuth telluride bulk thermoelectric device which is completely cover with ceramic layer and plastic jar which are made of good plastic after the use of these I found that my cop of system is less than the other system .

SUMMARY:

Objective:- 1. To fabricate an aluminum assembly container inside the Plastic Jar/Can suitable to store food stuff inside.

2. To make a space (at any one side of the above encloses) to fit PELTIER JUNCTION APPRATUS in this with no air gap remains open.

3. To fix a small exhaust air fan at the outer surface above the PELTIER junction apparatus.

4. To fabricate & assemble a 12 V DC Power supply to provide power Source for this whole set up and battery charging (optional).

5. To provide solar powered electrical energy (DC) Using Suitable Solar Modules (optional assembly)

6. To Connect a change over switch for polarity reversing for cooling & heating effect inside the enclose assembly.

Factors effecting performance of thermoelectric refrigerator

Performance of thermoelectric refrigerator can be effected by the net energy delivered for the delivered outlet temperature on a variable mass flow rate, These factors depend on various parameters such as thermodynamic and physical properties of material of construction, design of TE refrigerator etc

■Figure of merit ZT.

■Efficiency of the TE module.

■Temperature of the hot side and cold of the junction.

■Coefficient of performance of the system.

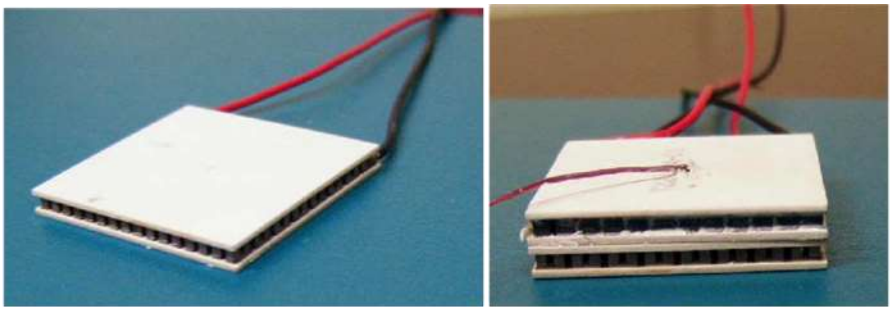
■Increase electrical conductivity and decrease thermal conductivity.

CHAPTER 2

STRUCTURE AND CONSTRUCTION

2.0 INTRODUCTION

Thermoelectric Refrigerator are compact state devices deficient touching parts, fluids or airs. The unpretentious laws of thermodynamics placed on to these procedures reasonable as they do to traditional heat drives, concentration refrigerators and additional devices concerning the conduction of heat energy. However, the construction and structural details of a TE module are quite different from normal refrigerators and requires a knowledge of materials and semiconductor technology in addition to heat transfer. Therefore, collection of the correct TE Refrigerator for a particular application needs an estimation of the whole system in which the refrigerator will be recycled.



(1) **(2)**

Fig 2.1 Component of thermoelectric module first one is single stage module and second is Two stage module

2.1 COMPARISON

Subsequently thermoelectric refrigerating systems are maximum when typically likened to conventional systems, possibly the optimum technique to demonstration the inconsistencies in these two refrigeration methods is to be designated the systems themselves. The unadventurous cooling system holds three essential parts these are - the evaporator, the compressor and the condenser. The evaporator or cold segment is the portion where the refrigerant is allowable to boil and vaporized. Totally this transformation of state from liquid to air, energy (heat) is captivated. The compressor performances as the refrigerant pump and recompresses the air. Hence the condenser emits the heat immersed at the evaporator plus the heat created all the way through compression, into the immediate area or ambient.

The thermoelectric refrigerator put away similar parts. On the hand the cold junction, the energy is immersed through electrons as they authorization from a minor energy level in the p-type semiconductor component, toward a higher energy level in the n-type semiconductor component. The power quantity supplies the energy to transfer the electrons from side to side of the structure. And at the hot junction, the energy is driven out to a heat sink by way of electrons transfer from a high energy level component (n-type) to a lower energy level component (p-type). Such as the electrons transfer from the p-type material to the n-type material from side to side an electrical connector, the electrons impediment to a higher energy state absorbing thermal energy (cold side). Continuing over and done with the structure of material, the electrons movement from the n-type material to the p-type material through an electrical connector, plummeting to a minor energy state and discharging energy as heat to the heat sink (hot side). The Thermoelectric module therefore use a couple of immovable junctions into which electrical energy is applied causing one junction to convert cold whereas the other converts hot.

2.2 THERMOELECTRIC MATERIALS

The semiconductor resources are N and P kind, and are so called becausewhichever they put away more electrons than necessary to comprehensive a perfect molecular matrix assembly (N-type) or not appropriate electrons to comprehensive a matrix arrangement (P-type). The further electrons in the N-type material and the holes left in the P-type material are called “carriers” and they are the intermediaries that move the heat energy from the cold to the hot assembly. Heat fascinated at the cold connection is pumped to the hot connection at a rate proportionate to carrier current transitory through the circuit and the number of pairs.

Table 2.1Figure of Merit for Different Materials

Material	Figure of merit (ZT)
Pb – Te	1.2 x 10^{-}3
Pb – Se	1.2 x 10^{-}3
Pb_2 – Te_3	1.2 x 10^{-}3
Bi_2 – Te_3	1.3 x 10^{-}3
(BiSb) $_2$ – Te_3	3.3 x 10^{-}3

Figure 2.1 shows how the material properties vary with carrier concentration. This fig. explains, qualitatively, that semiconductor materials maximize the figure of merit (Z).

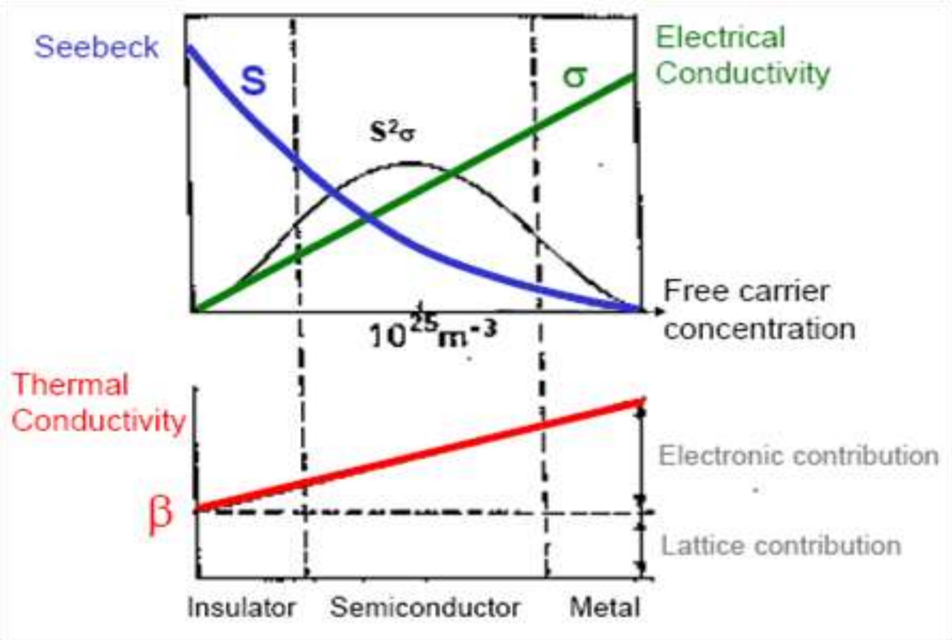


Figure.2.2 thermal conductivity of semiconductor

This figure also state that the thermal conductivity of semiconductor is increased when the temperature of is increased going on the further hand in metal the when thermal conductivity is decreased when the temperature is increased.

Material properties

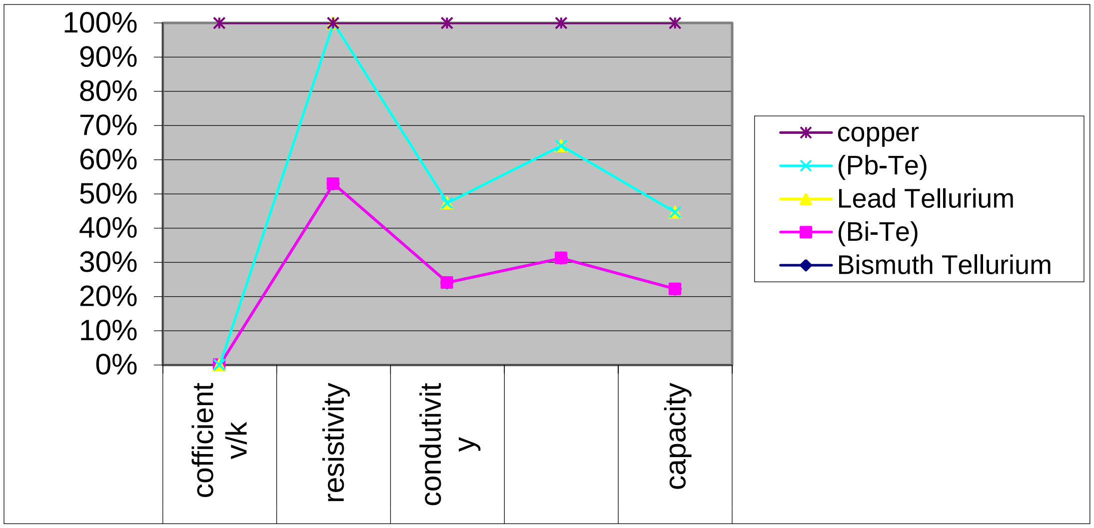


Fig. 2.3 Show the best one material from the given semiconductor

Noble thermoelectric semiconductor materials such for example bismuth telluride significantly obstruct unadventurous heat conduction starting hot to cold areas, however deliver anrelaxed flow for the carriers. In the calculation, these materials consume carriers by way of a volume for

Transferring more heat.

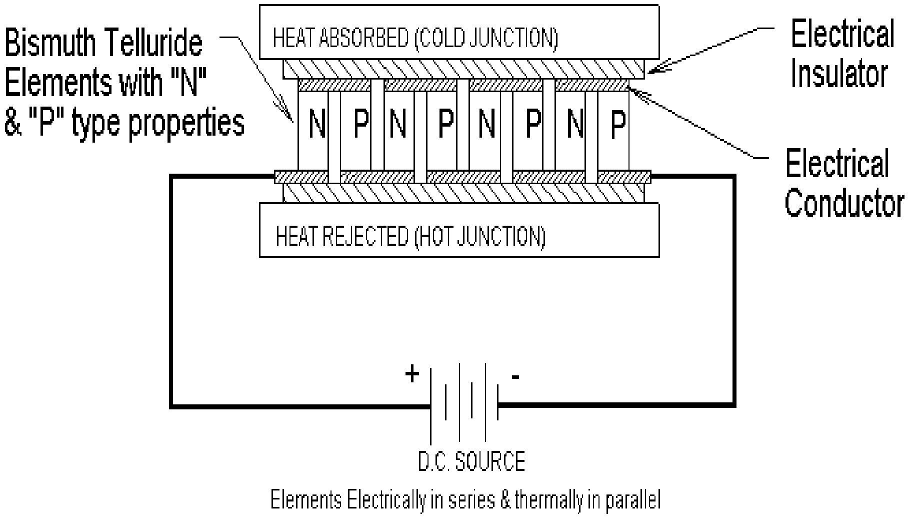


Figure 2.4: Thermoelectric module Assemblage

2.3 THERMOELECTRIC MODULE SELECTION

Selection of the proper thermoelectric module for a specific application requires an evaluation of the total system in which the refrigeration will be used. For most applications, it should be possible to use one of the standard module configurations while in certain cases a special design may be needed to meet stringent electrical, mechanical or other requirement. The overall cooling system is dynamic in nature and system performance is a function of several interrelated parameters. Before starting the actual thermoelectric module selection process, under listed questions must be answered. At what temperature must the cooled object be maintained? How much heat must be removed from the cold object? Is thermal response time important? What is the expected ambient temperature? What is the extraneous heat input (heat leak) into the system? How much space is available for the module and heat sink? What power is available? What is the expected approximate temperature of the heat sink during operation? Table 2 shows the average parameters for a 31 couple Bismuth telluride module at various temperatures and current.

Table II Parameters of Bismuth Telluride Moduleday the use of, couples are combined in the module (Fig. 2.2) where these are linked electrically in the series, and thermally in parallel.

S/N	TEMP. ^{0}C	∝ V/K	RM Ω	K W/K	RM Ω	K W/K
			9A	9A	15A	15A
1	0	0.0122 9	0.344 0	0.181 5	0.206 4	0.302 4
2	10	0.0125 7	0.363 4	0.182 8	0.218 0	0.304 7
3	20	0.0128 2	0.383 3	0.185 8	0.230 0	0.309 6
4	30	0.0130 4	0.403 5	0.190 5	0.242 1	0.317 6
5	40	0.0132 3	0.423 9	0.197 1	0.254 4	0.328 6

Parameters of bismuth telluride

Typically a module is the slightest component commercially accessible. Modules are existing in a great variety of sizes, shapes, operational currents, operational voltages and collections of heat thrusting capacity. The existent tendency, however, is in the direction of a higher number of pairs operating at lower currents. The user can be select the quantity, size or capacity of the module to fit the exact requirement deprived of paying for extra power.

In the typical domestic refrigerator, a cooling power of around 50 watt is needed. The thermo-elements are connected by flat strips of a good electrical conductor, e.g. copper or aluminum, so as to form a rectangular array. If the spaces among the elements are large they should be filled with a good thermal insulator, but if they are small this is unnecessary. The faces of the metal connectors are ground flat and are pressed against the flat surfaces of two large metal slabs to which fins are attached. It is important that the slabs should be electrically insulated from the metal connecting strips but the thermal interaction must be good. These metal slabs are drawn together by bolts arranged round their periphery.

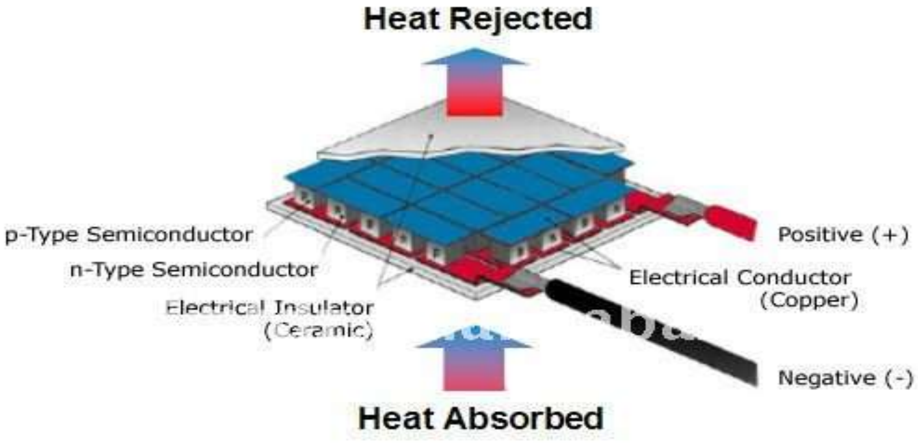


fig2.5Thermoelectric module

It should be the concentrating thought that the materials reject for the gathering component. The heat sink and the cold side of the system increasing surface should be complete out of materials that having a high thermal conductivity (for example, copper or aluminum) to the improvement in the heat transfer. On the other hand, insulation and assembly hardware would be prepared of materials that have a little thermal conductivity (for example, polyurethane foam and stainless steel) to moderate heat loss.

The fins attached to the hot face of the cooling unit are larger than those entering the cooled chamber. This is because the latter fins merely have to abstract heat from the chamber whereas the former have to pass this heat, as well as that developed in the thermocouples, on to the surroundings. Ideally the fins should be of sufficient area for the temperature of their bases to be insignificantly different from their respective ambient temperatures. However such fin areas are generally so large as to be economically impracticable and a balance must be drawn between the reduction of the fin sizes and the lowering of the temperature differences between the metal slabs and their surroundings

2.4 CONCLUDING RAMARKS

The whole cooling system is dynamic in environment and system presentation is a function of a number of interrelated considerations. As a result, it generally is essential to take into account each of the above factors and select the best module as per the requirements.

CHAPTER 3

APPLICATIONS OF THERMOELECTRIC COOLING

3.0 INTRODUCTION

Commercial devices based on thermoelectric materials have come up in a big way recently. In addition to the benefits thermoelectric offer over the conventional devices, commercial factors like decrease in production costs and significant opening of Consumer markets have helped it in a big way and the use of T.E. devices is increasing day by day.

3.1 USES

- Thermoelectric refrigerator is used in medical and medication equipment, spectroscopy systems, and several types of indicators, electrical equipment, portable refrigerators, chilled food and drink distributors, and drinking water coolers.
- Mandatory cooling devices with high consistency that appropriate into small places, powerful combined circuits in today's particular computers to employ thermoelectric coolers.
- With solid state high temperature pump that are utilize the Peltier effect, thermoelectric cooling devices are similarly below analysis for larger spaces such as passenger sections of wasting aircraft parked at the gate.

Amount of extra potential and current uses of thermoelectric cooling are:

Armed/Atmosphere

- Inertial management Systems, Night Visualization Equipment, Electrical Equipment Freezing, Cooled Individual Garments, Moveable Refrigerators**.**

Customer Goods

- Amusing Automobile Refrigerators, Movable Household Refrigerators, Handy Picnic Chillers, Wine and Alcoholic drink Keg Coolers, Accommodation Water Cleansers.

Workshop and Technical Equipment

- Infrared Indicators, Joined Circuit Coolers, Workshop Cold Plate ware, Cold Compartments, Ice Socket Orientation Baths, Dew point Hygrometers, Continuous Temperature Bathhouses, Thermostat Adjusting Baths, Laser Collimators.

Industrialized Equipments

- C Computer Microprocessors, Microprocessors and PC's in Arithmetic Regulator and Robotics, Medical Devices, Hypothermia Over-blankets, Pharmaceutical Refrigerators - Moveable and Immobile, Blood Analyzers, Tissue Research and Storage, Restaurant Apparatus, Cream and Butter Distributors.

Miscellaneous

- Hotel Apartment Refrigerators, Vehicle Mini – Refrigerators, Automobile Chair Cooler, Aircraft Drinking Water Coolers.

CHAPTER 4

METHODS TO IMPROVE C.O.P. OF TE REFRIGERATORS

4.0 INTRODUCTION

The performance of the thermoelectric cooling system is very closely related to the parameter$ZT_m$of the system. Conventional phase change systems have ZT_m of the order > 4. In contrast the value of ZT_m for thermoelectric cooling systems is comparatibly very low of the order of 1.

The value of ZT, however, can be increased by the use of novel methods in the fields of heat transfer, semiconductor technology, material technology and design of thermoelectric cooling systems. A number of new and emerging methods are Describe in the subsequent section.

4.1 MINIATURIZATION:

There are two fundamental issues related to miniaturization: [4]

a) Miniaturization allows one to use low cost and parallel semiconductor manufacturing technology to make thermal devices that would not be otherwise possible.

b) The heat transfer design of microdevices is very different from macroscopic ones since the proximity and size can have a strong influence on the magnitude of thermal transport and time scales. As the objects become smaller heat transfer characteristics change dramatically. For conductive and convective heat transfer what is important is the ratio of surface-to-volume *(A/V)***.** This factor increases with reducing length scale, L. The *thermal time constant,* Γ, of an object is given as $\Gamma = (rho)(C/h)(V/A)$.Assuming that $(rho)(C/h)$remains constant, the thermal time constant varies as 1/L. Hence, the thermal time constant can be extremely small, thus allowing fast thermal processes. The Reynolds number in flow scales with size, L, and hence flows tend towards laminar in small length scales. This makes heat transfer much more predictable. If the Nusselt number remains constant or largely unchanged, then the heat transfer coefficient, h, scales as 1/L. This makes convective heat transfer very efficient at small scales.

Factors	**Scaling**
Surface-to-Volume, A/V	1/L
Thermal Time Constant, τ	L
Reynolds Number, Re	L
Heat Transfer Coefficient, h	1/L

Table 4.1: Some Scaling Laws in Conduction and Convection

Thus, we see that as we go to the smaller scales, all of the above four factors tend to increase the efficiency of heat transfer. The better heat transfer, in turn, leads to an increase in the C.O.P. of the thermoelectric refrigeration systems.

4.2 SUPERLATTICES:

A new approach to increase ZT is to use superlattice structures to reduce *k*.

In heat conduction, a quantum of vibrational energy is called a phonon, and heat conduction can be studied as a transport of phonons. To increase ZT, strategies to reduce k and ρ simultaneously have been very difficult. For example, by making amorphous materials, one can reduce k by introducing many scattering sites for phonons and thereby reducing l. However, they also scatter electrons and thereby reduce ρ. Because at the fundamental level, heat conduction by phonons is a wave transport problem, wave effects are being used to alter heat conduction. One such approach is to fabricate a multi-layer structure containing extremely thin films of two alternating materials. Such a superlattice should have a period of 1-10 nm since the wavelength of phonons that dominate in heat conduction fall in this regime. Phonon wave interference effects in superlattices reduce the propagation speed of phonons and thereby reduce the effective thermal conductivity. Therefore, as the superlattice period thickness decreases, thermal resistance increases and the thermal conductivity goes on reducing with increasing number of such interfaces.

Using PbTe quantum wells and electron confinement to quantum wells with thickness ranging from 1.7 to 5.5 nm, a factor of 5 increase was found in Z relative to bulk PbTe of the same volume.

Thermal conductivity reduction in this manner is being used in thermoelectric devices to produce high-performance refrigerators.

4.3THERMOELECTRIC REFRIGERATION METHOD WORK FOR A PHASE CHANGE MATERIALS:-

The choice of a Heat Sink is essential to the on the whole process of the thermoelectric arrangement. Hence the Heat Sink must be deliberated to reduction the thermal resistance. On the other hand, the Heat Sink can be deliberated to have an enormous heat storage capacity, which would service out to keep the Sink temperature small comparative to the connection temperature. This concluding solution could be accomplished using a phase change material (PCM).

PCMs have the extended to be recognized as applicants for thermal storage systems, remaining to the high energy densities (MJ/m^3). The PCM materials absorb energy, initially because sensible heat, and then at the same time as the latent heat whereas the phase change temperature is extended. On this stage, the temperature remains unchanging up until the phase change is completed.

The PCMs are accessible with a large range of phase change temperatures, and thus may be functioned on both the cold and hot junctions of a TEC and for a collection of presentations and environments. In the selection of a PCM with appropriate passing temperature and huge storage space capacity, then the temperature difference across the thermoelectric module may be maintained at the low values, thus increasing the performance of the device. After an unadventurous heat sink is used on the cold side, the temperature of the cold connection drops quickly until the maximum possible temperature difference transversely TEC is reached. When the PCM is used, a huge quantity of the cooling energy is absorbed by the PCM, because a result of the cold side temperature drops more slowly than when PCM is not used; this is shown in the Figure 4.1. With these PCM, the temperature drops gradually at the start in looking forward of the temporary temperature is reached. All through the phase change procedure, the temperature of the refrigerationsystem is essentially persistent until the phase change method is completed. This helps to keep the temperature difference across the TEC to a minimum, therefore improving its performance.

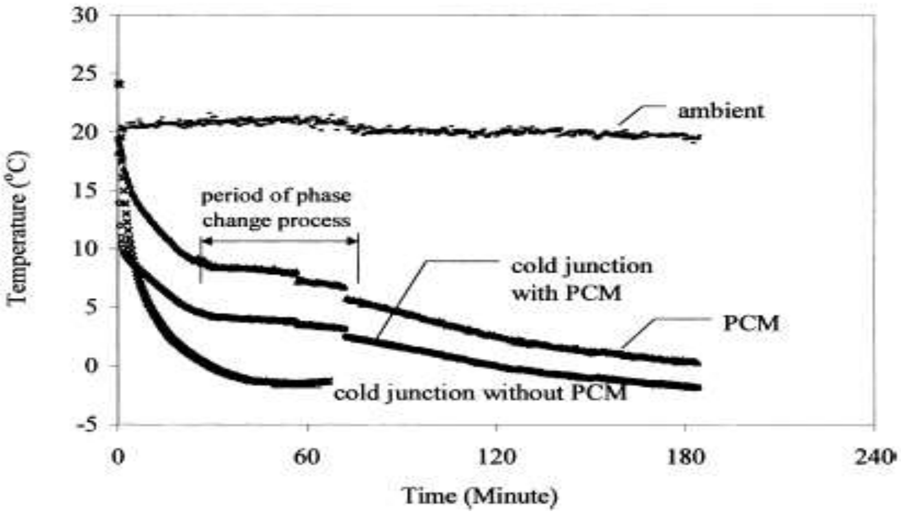


Figure 4.1: difference of the cold junction and the PCM temperatures from side to side the cooling technique for the tests with, and short of, PCM material

By use of a PCM provided a loading capacity, which maintenance to increase greatest loads and cooling losses through periods of door opening. The circumstance of electrical power is turned off for some reason, the refrigeration system employment PCM would have a storage capacity able of meeting the cooling load for a longer time. For example, as shown in Figure 4.2, Later than the electrical power was turned off, it take twice as long for the temperature in the cabinet with PCM to increase to the equal value as in the cabinet with no PCM.

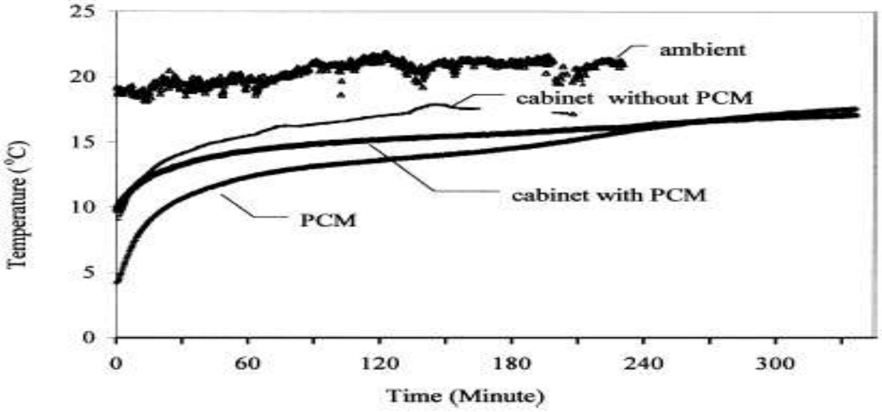
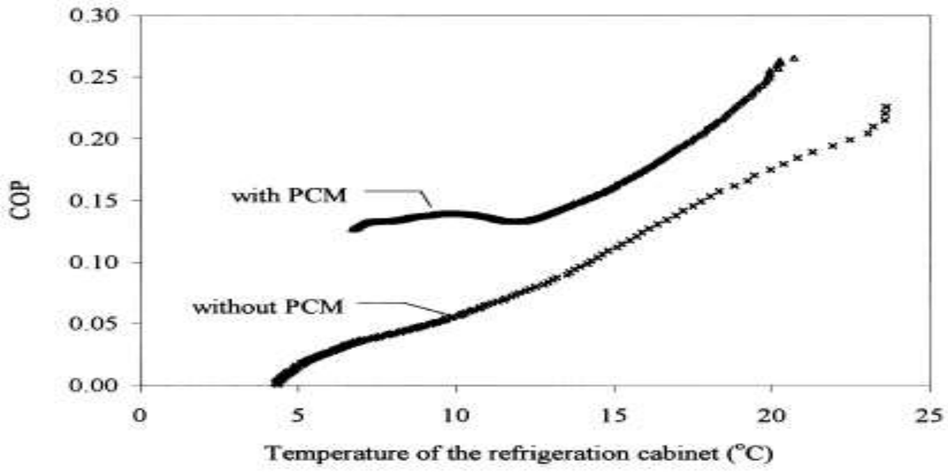


Figure 4.2: difference of cold junction and PCM temperatures for the test by, and without, PCM material, when the power was turned off.

Within the common, use of a PCM increases the performance of the thermoelectric refrigeration system, as shown in Figure 4.3. As be able to be seen, because the cold junction temperature remains constant through the phase change process, the rate of cooling is also constant, as is the COP of the refrigeration system.



<u>Fig 4.3: relationship b/w performance of thermoelectric refrigeration planning, with and without, PCM materials</u>

4.4 SEMICONDUCTORS FOR USE IN TE REFRIGERATORS:

The most excellent thermoelectric materials currently existing, compounds of doped Bi_2Te_3, contain $ZT \cong 1$ at the chamber temperature and reach maximum temperature differential of $\cong 82K$. A number of of the normally used conventional thermoelectric materials are follows as:-

- Bi_2Te_3, Bi_2Se_3 and Sb_2Te_3 ; ZnSb, PbTe and PbSe

The real meaning of a good thermoelectric is specified for the purpose of the material's dimensionless **figure of merit, Z,** where α is the **Seebeck coefficient,**σ the **electrical conductivity**, and k the **total thermal conductivity**. The high flexibility movers which is having the maximum electrical conductivity for a certain carrier thoughtfulness are most necessary, and generally the most hopeful materials have carrier applications of approximately 10^{19} carriers/cm^3. The most accomplished thermoelectric materials would achieved as a phonon-glass/electron crystal. The model of the **PGEC** material is that it would perform thermally as a glass (large phonon diffusion and thus low lattice thermal conductivity) and as an electronic crystal (little scattering for the electrons, thus excessive electrical conductivity).

TRANSFIGURATION-METAL PENTATELLURIDES

The electrical resistivity, *(ρ=1/σ)*, the thermo-power for simply crystals of the pentatelluride materials as a purpose of temperature (10 K<T<450 K) are shown in Figures. 4.4 and 4.5 for the materials *HfTe5* and *ZrTe5,* separately. The Organized maternal materials show only a single resistive transition highest, $T_P \approx 80$ K for $HfTe_5$ and $T_P \approx 145$ K for $ZrTe_5$. During addition, all displays a huge positive (p-type semiconductor) thermo-power ($\alpha \geq +125$ μV/K) approximately room temperature, which undergo a Modify to a large negative (n-type semiconductor) thermo-power ($\alpha \leq -125$ μV/K) near the resistivity peak temperature. These materials display thermo-power that is comparatively large above a wide range at lowest temperatures used for the equally n type ($T<T_P$) and p type ($T>T_P$). The great principles of thermo-power ($|\alpha| \approx 100$ μV/K) on temperatures lower than 245 K mark these materials are very encouraging for potential low-temperature uses.

In summary, a capable classes of materials, the conversion metal *Pentatelluride*, have been recognized for the achievable improvement as low-temperature thermoelectric materials. These materials, when properly doped, display very high power factors in the temperature gathering of 150 K<T<250 K.

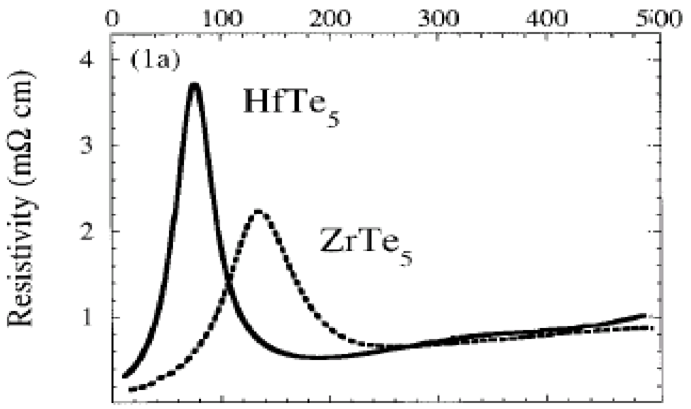


Figure 4.4 : Resistivity ρ as a purpose of temperature for $HfTe_5$ and $ZrTe_5$

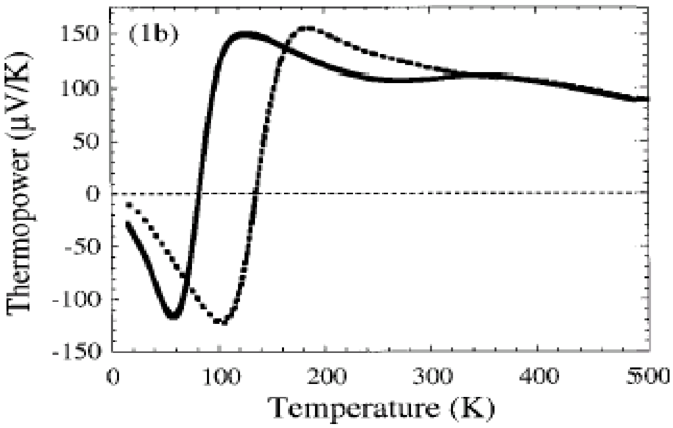


Figure 4.5: complete thermopower as a purpose of Temp. for $HfTe_5$ and $ZrTe_5$ [7]

4.5 CONCLUDING REMARKS

Methods like miniaturization and superlatives allow us to manipulate the thermal properties of materials which can have a strong influence on the performance of thermoelectric refrigeration devices. Use of PCMs, new materials with unusual electronic and thermal properties and other novel heat transfer designs significantly increase the C.O.P. of TE devices and thus need to be developed more vigorously.

CHAPTER 5

ANALYSIS OF THERMOELECTRIC COOLING

5.0 INTRODUCTION

In a TE, energy could be transported from the thermoelectric arrangement by three basic approaches: **conduction**, **convection**, and **radiation**. In the Dissimilarity and costing of various refrigeration systems requires a parameter which is applicable for all refrigerating machines. The performance of cooling machines is therefore expressed in terms of a non-dimensionless parameter called the **Coefficient of Performance (C.O.P.)** which is stated as the ratio of useful conclusion to work input.

5.1DESIGN

Every particular application where a thermoelectric cooler module or refrigerator is mandatory is characterized by a set of operation parameters, which dictate the necessity and accurate selection of the optional thermoelectric cooler type among a wide range of single and multi-stage thermoelectric cooler modules.

These parameters are:

Δt – Operating temperature difference
QC – Operating cooling capacity
I – Applied or available current
V - Terminal voltage

A. Specification of the Thermoelectric Refrigerator

The cold space of the refrigerator will be maintained at 30.2°C, this also is the cold side temperature of the module. The heat sink temperature will be maintained at 30.2◦C to maintain the necessary temperature difference for heat transfer as the ambient temperature on a very hot day is been 30 – 35◦C. Therefore the thermodynamic force property for the Peltier device is 36◦C. The maximum current to be drawn by the module is 9A.

B. Thermoelectric Cooler Module The thermoelectric cooler module material chosen is Bismuth telluride.

The properties of system Bismuth Telluride module are:

Seebeck coefficient (∞ m) = 0.01229 V/k

Module thermal conductance (Km) = 0.1815 W/k

Module resistance (Rm) = 0.344

C. Heat Load Analysis

The quantity of heat to be removed by the module comprises: Heat conduction through the walls of the cooling chamber Infiltration due to door openings.

The product load C1. Heat Conduction

The capacity of the refrigerated space is 36L. The materials of construction are:

The external wall, mild steel sheet material, the insulation, polyethane foam, the internal wall, aluminum sheet material. Heat transfer QCO per unit area is defined by

$$Q_{CO} = \frac{T_h - T_c}{\frac{1}{h_o} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3} + \frac{1}{h_i}}$$

C2. Infiltration due to Door Opening The amount of heat to be removed from the refrigerated space due to infiltration or air change due to door opening is given by [5]

Q_{INF} = Infiltration rate (L/s) x Enthalpy change (J/L)

From tables [5]

Infiltration rate = 3.74 L/s

Enthalpy change = 0.0709 J/L

C3. Product Load

The quantity of heat to be removed from the products inside the refrigerated space is known as the product load. The product load is estimated from the equivalent water contents of the products in the refrigerated space, since it has a higher specific heat capacity. Therefore, product load is defined as

$$Qp = M_w Cp_w (T_{w2} - T_{w1}) \qquad (6)$$

C4. Total Refrigeration Load

$$Q_T = Q_{co} + Q_{INF} + Qp \qquad (7)$$

D. Cooling Capacity per Module

The quantity of heat pumped by the module is obtained from [5]:

$$Q_C = \propto_M T_C I - \frac{1}{2} I^2 R_M - K_M (T_h - T_C) \qquad (8)$$

Fig. 3 shows the schematic diagram of the thermoelectric refrigerator.

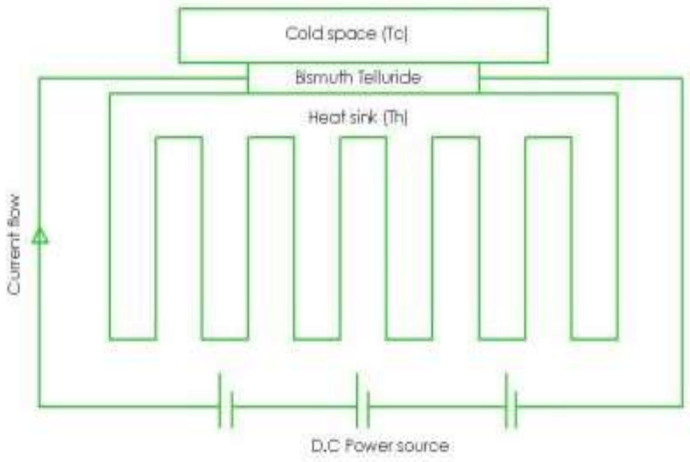


Fig. 5.1 Schematic of Thermoelectric Refrigerator

The minimum number of modules to be cascaded is obtained by:

$$n = Q_T/Q_c$$

E. Voltage Input to the Module

The input voltage to the module is obtained from [5]:

$$V_{IN} = \propto_M (T_h - T_C) + IR_M \qquad (9)$$

F. Electrical Power Input

The power required is obtained from the expression [5]

$$P = \propto_M I(T_h - T_C) + I^2 R_M \qquad (10)$$

G. Heat Rejected by the Module

The quantity of heat to be rejected by the module is obtained from [5]:

$$Q_R = \propto_M I(T_h - T_C) + I^2 R_M + \propto_M T_C I - \frac{1}{2} I^2 R_M - K_M (T_h - T_C) \qquad (11)$$

H. Coefficient of Performance of the System

The coefficient of performance of the thermoelectric cooler is obtained from:

$$C.O.P. = Q_c/P \qquad (12)$$

3.2 Energy and Entropy balance

The energy balance of a bulk thermoelectric device where an electric current and a heat current flow parallel from the P-leg to the N-leg depending on the direction of current in presence of an applied electric field, is given by

$$\rho C_p \frac{\partial T}{\partial t} = \Delta.\,(\lambda \Delta T) + \frac{J2}{\sigma} - J\tau\, T \qquad (1)$$

Lord Kelvin first proposed the quasi-thermodynamic method of the thermoelectric effects to prove the validity of relationships – $\tau = \frac{\pi}{T} - \frac{d\pi}{dT}$ and $\pi = \alpha T$ where τ is the Thompson coefficient, π is the peltier heat and α is the seebeck coefficient. Hence the gradient of peltier heat $\Delta\pi$ ($\Delta\pi_T + \frac{\partial\pi}{\partial T}$' ΔT) splits in to two parts: The first presents the heat effect even in the absence of temperature gradient and the second part indicates the heat effect due to a temperature gradient. Using equation (1),the energy balance of a thermoelectric element is written as

$$\rho C_p \frac{\partial T}{\partial t} = \Delta.\,(\lambda \Delta T) + \frac{J2}{\sigma} - JT\frac{\partial \alpha}{\partial T}.\,\Delta T + JT\Delta_{\alpha}\big|_{T} \qquad (2)$$

Following the Gibbs law and energy conservation within a control volume, the basic entropy balance equation can be expressed as

$$\frac{\partial(\rho s)}{\partial t} = \Delta\,.\,(-\frac{\lambda\Delta T}{T} + \alpha J) + [\frac{J2}{T\sigma} - \lambda\Delta T.\,\Delta(\frac{1}{T}) + J.\Delta_{\alpha}\big|_{T}] \qquad (3)$$

Where the first terms indicate the entropy flux J_s ($Wm^{-2}K^{-1}$) and the second terms are entropy generation S_{gen} ($Wm^{-3}k^{-1}$) and these are expressed as

$$J_s = -\frac{\lambda\Delta T}{T} + \alpha J \qquad (4)$$

$$S_{gen} = \frac{J2}{T\sigma} - \lambda\Delta T.\,\Delta(\frac{1}{T}) + J.\Delta_{\alpha}\big|_{T} \qquad (5)$$

With the boundary conditions indicated in Fig. 1(b), for thermoelectric legs of length L ($0 \le x \le L$), the one-dimensional energy balance equation for p- and n-legs becomes

$$(\rho C_p)\frac{\partial T(x,t)}{\partial t} = \lambda\frac{\partial 2\, T(x,t)}{\partial x2} + \frac{J2}{\sigma} - \tau J\,.\frac{\partial T(x,t)}{\partial t} \qquad (6)$$

Putting boundary conditions (at x=0, $T=T_L$ and x=L, $T=T_H$), the steady state analytical solution of Eq. (6) is written as $T = T_L + \frac{\rho J}{\tau}x + \frac{(DT - \frac{\rho J L}{\tau})}{(exp(\frac{\tau J}{\lambda}L) - 1)}(exp\left(\frac{\tau J}{\lambda}L\right) - 1)$

Where DT indicates the temperature difference between the hot and cold junctions, i.e., $DT = T_H - T_L$. Hence the temperature gradient along x direction is given by

$$\frac{dT}{dx} = \frac{\rho J}{\tau} + \exp\,(\frac{\tau J}{\lambda}x)\,[\frac{\left(DT - \frac{\rho J L}{\tau}\right)\frac{\tau J}{\lambda}}{(exp\left(\frac{\tau J}{\lambda}L\right) - 1)}]$$

$$-\lambda A\frac{dT}{dx} = -\frac{\lambda\rho I}{\tau} + \frac{\left(-\frac{\lambda A DT}{L} + \frac{\lambda\rho I}{\tau}\right)\frac{\tau I L}{\lambda A}}{(\exp(\frac{\tau I L}{\lambda A}\left(1 - \frac{x}{L}\right) - \exp\left(\frac{\tau I L x}{\lambda A L}\right))} \qquad (7)$$

Where I = JA . Defining Fourier heat $Q_F = \frac{\lambda ADT}{L}$, Joule heat $Q_J = \frac{\rho I2L}{A}$, Thompson heat $Q_T = I\tau DT$ and $\frac{QT}{QF} = \frac{I\tau DT}{\frac{\lambda ADT}{L}} = \frac{I\tau L}{\lambda A}$

Eq. (7) is written as

$$\lambda A\,\frac{dT}{dx} = \frac{\lambda\rho I}{\tau} + \frac{\left(-QF + \frac{\lambda\rho I}{\tau}\right)\frac{QT}{QF}}{\left(exp\left(\frac{QT}{QF}\left(1-\frac{x}{L}\right)\right) - \exp\left(-\frac{QTx}{QFL}\right)\right)} \tag{8}$$

At cold junction $(x = 0)$

$$-\lambda A\left.\frac{\mathrm{d}T}{\mathrm{d}x}\right|_{x=0} = -\frac{\lambda\rho I}{\tau} + \frac{\left(-Q_{\mathrm{F}} + \frac{\lambda\rho I}{\tau}\right)\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}}{\left(\exp\left(\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right) - 1\right)}$$
$$= \frac{\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}}{\left(\exp\left(\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right) - 1\right)}\left(-Q_{\mathrm{F}} + \frac{\lambda\rho I}{\tau}\right) - \frac{\lambda\rho I}{\tau}.$$

Using the expansion of $\frac{\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}}{\left(\exp\left(\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right)-1\right)}$

$$\frac{\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}}{\left(\exp\left(\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right) - 1\right)} = 1 - \frac{1}{2}\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}} + \frac{1}{6}\frac{1}{2}\left(\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right)^2 - \frac{1}{360}\frac{1}{2}\left(\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right)^4 + \cdots,$$

$$\left(-Q_{\mathrm{F}} + \frac{\lambda\rho I}{\tau}\right)\frac{\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}}{\left(\exp\left(\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right) - 1\right)}$$
$$= \left(-Q_{\mathrm{F}} + \frac{\lambda\rho I}{\tau}\right) \times 1 - \frac{1}{2}\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}} + \frac{1}{6}\frac{1}{2}\left(\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right)^2$$
$$- \frac{1}{360}\frac{1}{2}\left(\frac{Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right)^4 + \cdots$$

After rearranging,

$$-\lambda A\left.\frac{\mathrm{d}T}{\mathrm{d}x}\right|_{x=0} = \left[-Q_{\mathrm{F}} - \frac{1}{2}Q_{\mathrm{T}} - \frac{1}{2}Q_{\mathrm{J}}\right] + \frac{1}{6}\left[\frac{1}{2}\frac{Q_{\mathrm{T}}^2}{Q_{\mathrm{F}}} + \frac{1}{2}\frac{Q_{\mathrm{J}}Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right]$$
$$- \frac{1}{360}\left[\frac{1}{2}\frac{Q_{\mathrm{T}}^4}{Q_{\mathrm{F}}^3} + \frac{1}{2}\frac{Q_{\mathrm{J}}Q_{\mathrm{T}}^3}{Q_{\mathrm{F}}^3}\right] + \cdots,$$
$$-\lambda A\left.\frac{\mathrm{d}T}{\mathrm{d}x}\right|_{x=0} = \left[-Q_{\mathrm{F}} - \frac{1}{2}Q_{\mathrm{T}} - \frac{1}{2}Q_{\mathrm{J}}\right] + \frac{1}{6}\left[\frac{1}{2}\frac{Q_{\mathrm{T}}^2}{Q_{\mathrm{F}}} + \frac{1}{2}\frac{Q_{\mathrm{J}}Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right]. \tag{9}$$

Similarly at hot junction (removing all higher order terms)

$$-\lambda A \left.\frac{\mathrm{d}T}{\mathrm{d}x}\right|_{x=L} = \left[-Q_{\mathrm{F}} + \frac{1}{2}Q_{\mathrm{T}} + \frac{1}{2}Q_{\mathrm{J}}\right] + \frac{1}{6}\left[\frac{1}{2}\frac{Q_{\mathrm{T}}^{2}}{Q_{\mathrm{F}}} + \frac{1}{2}\frac{Q_{\mathrm{J}}Q_{\mathrm{T}}}{Q_{\mathrm{F}}}\right] \tag{10}$$

The higher order terms of Eqs. (9) and (10) indicate the interactions of Joule, Thompson and Fourier effects.

The transport of energy along the thermoelectric arm is

$$Q(x) = \alpha I T(x) - \lambda A \frac{dT}{dx},$$

$$Q(x) = \alpha I T(x) - \frac{\lambda \rho I}{\tau} + \frac{\left(-QF + \frac{\lambda \rho I}{\tau}\right)\frac{QT}{QF}}{(\exp(\frac{QT}{QF}\left(1 - \frac{x}{L}\right) - \exp(-\frac{QTx}{QFL}))} \tag{11}$$

The entropy flux along the thermoelectric arm is simply obtained by the ratio Q(x) to T(x), i.e.,

$$J_S\,(x) = \alpha I - \frac{\lambda \rho I}{\tau T(x)} + \frac{\left(-QF + \frac{\lambda \rho I}{\tau}\right)\frac{QT}{QF}}{(\exp(\frac{QT}{QF}\left(1 - \frac{x}{L}\right) - \exp(-\frac{QTx}{QFL}))}\frac{1}{T(x)} \tag{12}$$

Eq. (12) represents the entropy flow along the thermoelectric arm and captures the contributions of Peltier, Joule, Fourier and Thompson heats. Joule contribution extracts the entropy produced by the flow of current, Fourier heat also removes the flow of energy due to the transportation of heat from hot to cold junctions. The Thompson heat supplies the flow of entropy in the particles of the thermoelectric element, so the Thompson heat may be referred to as 'the specific heat of electricity'.

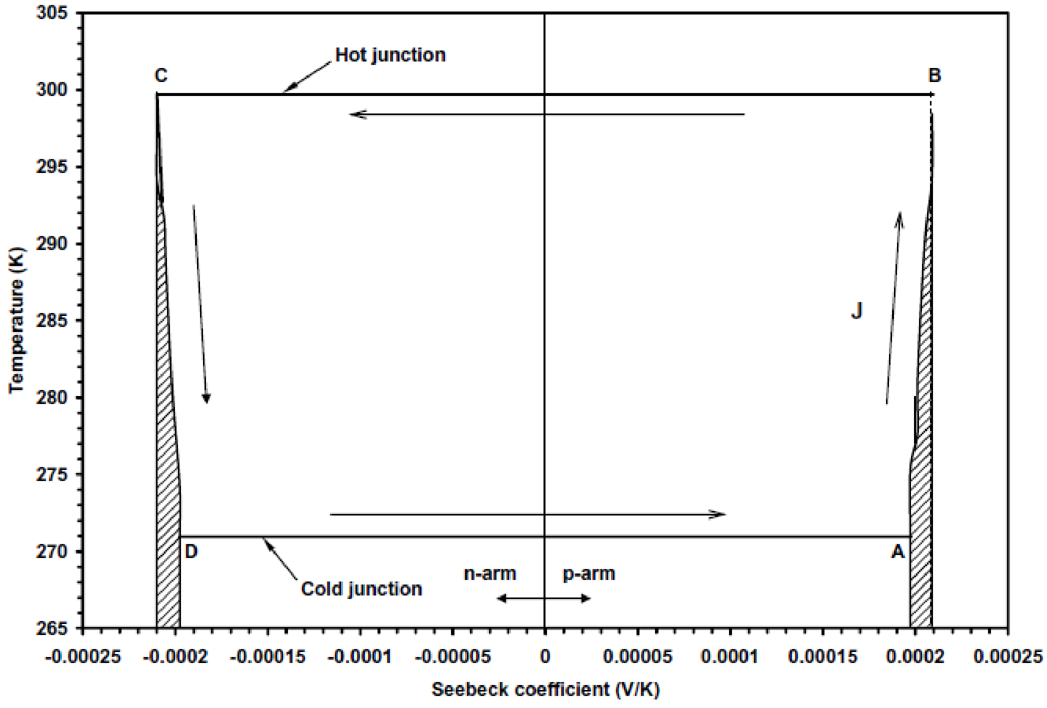


Fig.5.2temp. v/s seebeckcoefficent

5.3 CONCLUDING REMARKS

Proper design of a T.E. cooling system requires that various types of loads be properly accounted for and incorporated. It is through the above mathematical process only that we will be able to achieve the C.O.P. as required for any given design.

CHAPTER 6

CONCLUSIONS AND SCOPE FOR FUTURE DEVELOPMENT

6.1 POTENTIAL RESEARCH SCOPE IN MATERIALS FIELD:

- Tolerance to repeated temperature cycling.
- Broad range of temperature over which ZT is high.
- Low cost.
- Weight, volume and vibration concerns.

6.2Experimental work

Design of Solar Thermoelectric Refrigerator

SPECIFICATION

Volume:- 15litres

Voltage: - DC 12V; AC 100-240V

Power consumption:

DC: Cold mode: 58W+/-20%; Hot mode: 46W+/-20% AC: Cold mode: 72W+/-20%;Hot mode: 60W+/-20%

Cooling capacity: - 14.4°C-15°C below ambient temperature

Heating capacity: +60°C

Insulation:

adopts thermoelectric technology (peltier system)solid polyurethane foam with CFC-free

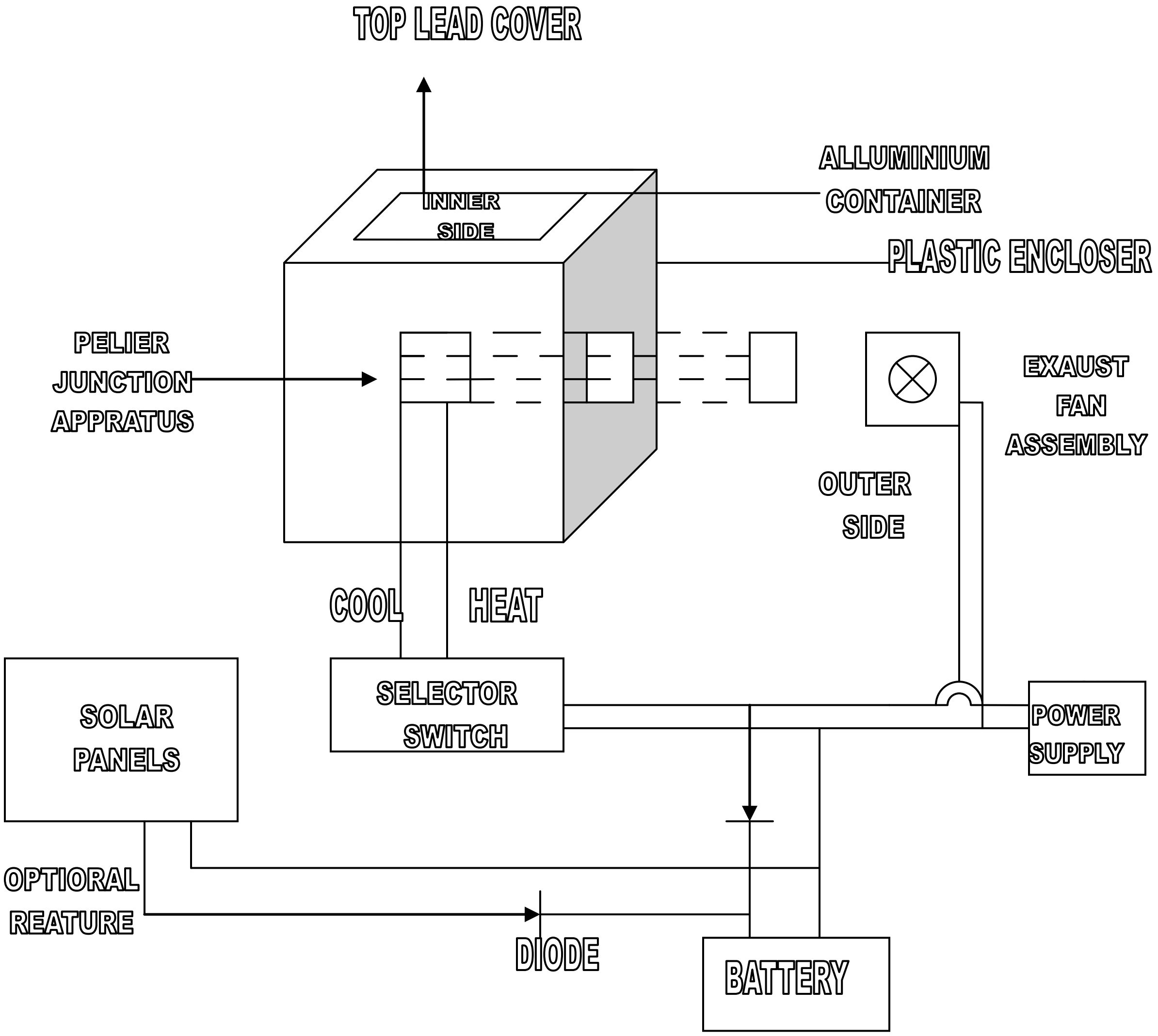
Features:

ONE peltiers are fixed in the box so that it can cool.

Specification of Thermoelectric module 6.1

S NO.	**SPECIFICATION**	**VALUES**
1	MAX. CURRENT (A)	2.6 A
2	MAX. VOLTAGE (V)	3.8 V
3	MAX. POWER (W)	5.2W
4	DELTA T MAX. °C	60°C
5	DIMENSION (L,B,H)	250MM,200MM,350MM
6	NO OF COUPLE N	6

6.1BLOCK DIAGRAM OF THERMOELECTRIC REFRIGERATOR



Experimental test of thermoelectric module

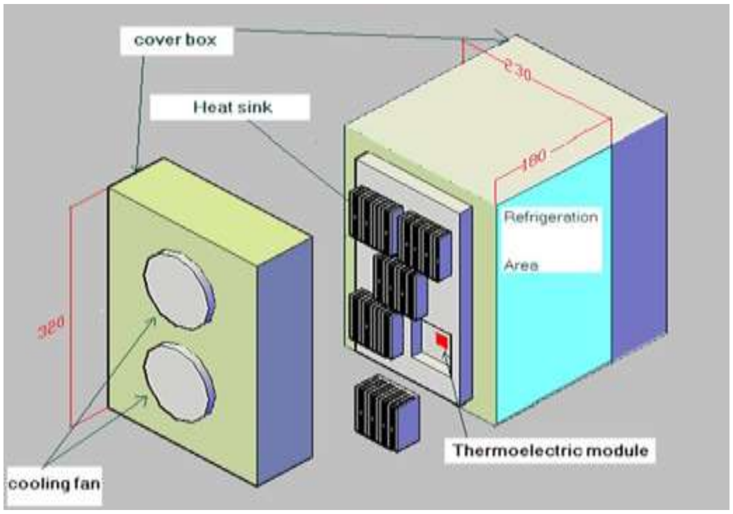


Fig.6.2(From encyclopedia)Thermoelectric

Fig 1 illustrate all component as connected together in testing the operation of the thermoelectric module. The red wire of the module was connected with positive power supply and black wire of module was connected with negative power supply. Due to this method of wire connection, the lower surface of the module become hot side of module, while the other side of the module become cold. The cold side of thermoelectric module is used for refrigeration work and the hot side to be set outside. The temperature of hot and cold side of thermoelectric module were measured by thermocouple wire which were connected to the side of module one end of the thermocouple was connected to hot side of module and other one to the cold side of the module.

6.3 Running status of Thermoelectric module

The thermocouple was connected to a data logger so the electric current was Converted and recorded in temperature unit. The hot side of the thermoelectric module was attached to heat sink where as the cold side of thermoelectric module was used to cool the refrigerator cabinet. The heat sink released the heat more efficiently out into the atmosphere. The back side of the heat sink was connected with the fan that was used mainly to help in rejecting the extra heat out into the atmosphere.

Fig.6.4 **running status of Thermoelectric Refrigeration**

The experimental data collected from running one thermoelectric module I fig1,fig2, and fig3. Fig1 indicate that using the thermoelectric module make it possible to achieve temperature difference up to 14.4 °C that was obtained when the current was 2.6A and voltage was 3.8V.

Configuration of thermoelectric refrigerator

In this section an experimental investigation and performance analysis on TE refrigerator was conducted. Figure 4 and fig.5 show cross-section of refrigerator fig.4 also show the dimension of the refrigerator. It can be seen that manufactured prototype had a base of 250mm, 300mm and height 350mm.

In the designed TE refrigerator 6 module unit were used, three unit of TE module were placed on one side of refrigerator and other three were placed on opposite side of refrigerator.

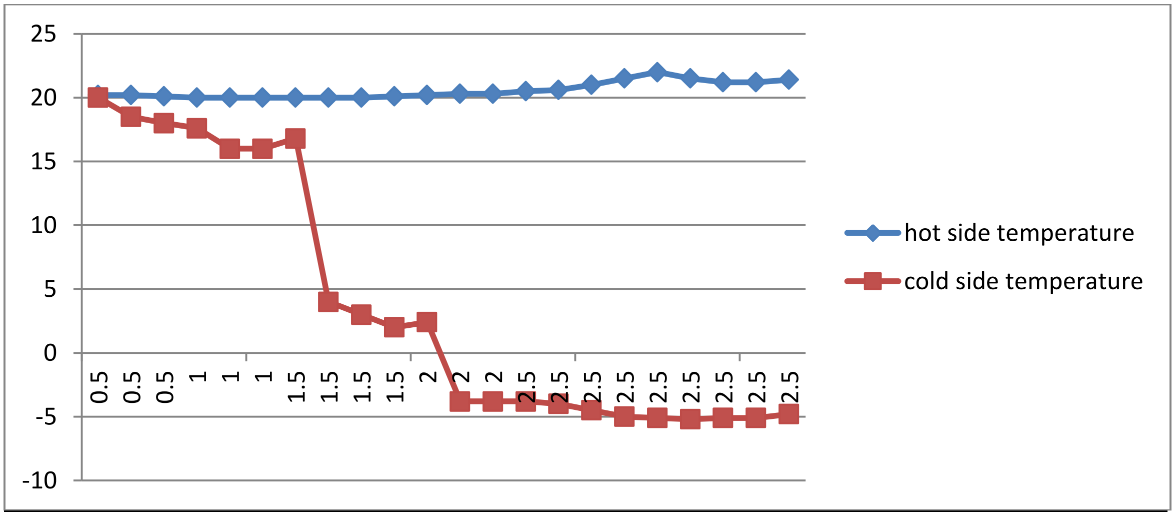
Result obtained form the experiment6.2

S NO.	CURRENT	VOLTAGE	HOT SIDE	COLD	TIME	CHANGE

	(A)	(V)	TEMP(°C)	SIDE TEMP(°C)	(MINTS)	IN TEMP(ΔT)
1	0	0	30.2	30.2	0	0
2	0.5	1.2	30	28.6	5	1.4
3	1	2	29.6	27.5	10	2.1
4	1.6	2.8	29.4	26.2	15	3.2
5	2	3.2	29.8	25.4	20	4.4
6	2.5	3.8	30 30.2 30.4 30.6	22.2 21.2 18.6 15.2	25 30 32 35	7.8 9 11.8 14.4

In the given fig the temperature between hot side temperature and cold side temperature is considered. When the hot side temperature is increase the other side temperature decrease

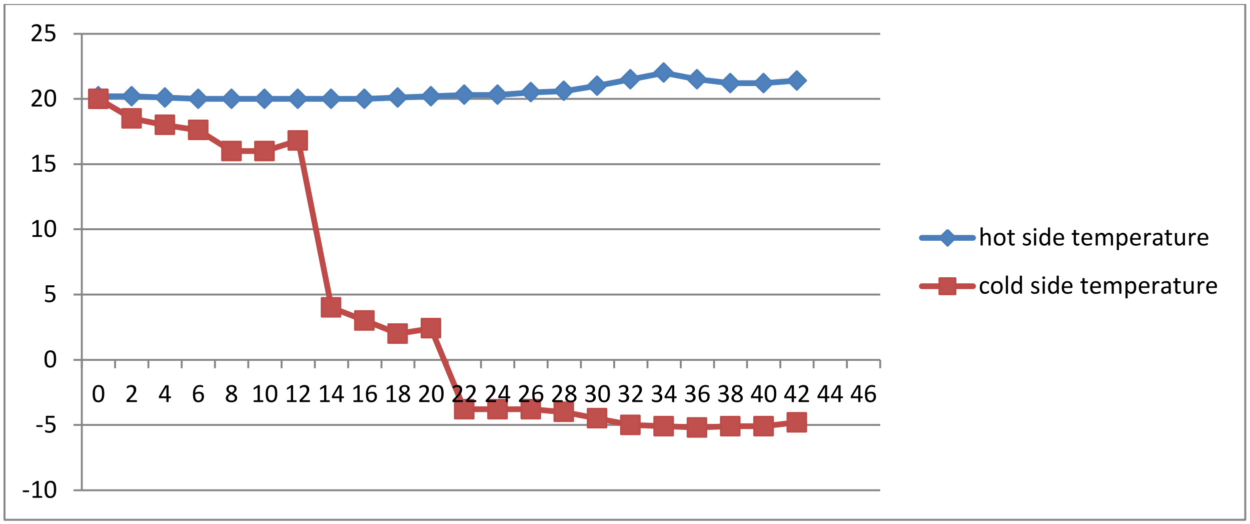
Hence cold side temperature is totally Depend on the hot side temperature.



6.5 Temperature (°C) versus Current (A) of Thermoelectric module

The temperature is also depend on the current value that is increase slowly with maximum temperature increase with 0 to 2.6 A. hence the temperature is increase the cold side temperature is increase.

In the next figure the temperature v/s time is drawn. In this figure when the time is increase the temperature is also with time. The maximum time taken by the system is around 40 mints. And it give voltage of 3.8 V. the temperature change between the hot side and the cold side is about14.4$_0$ C. due to this change in temperature the cop become high.



6.6 Temperature (°C) versus Time (min.) of Thermoelectric module

EXAMPLE

Below is an example, which shows how the coefficient of performance of the refrigerator (COPR) was calculated. It was assumed that the refrigerator used to cool a 0.5 L canned drink from 30.2oC to 15.8oC in 35 min. In these calculations, it was assumed that the properties of canned drinks are the same as those of water (density = 1kg/L and C = 4.18KJ/Kg).

V = 0.5 L canned drink.

Cools from 30.2°C to 15°C

In 35 min (time)

Calculate COP_R =

COP_R = Qcooling / Win

m = ΦV

m = 1 (kg/L) 0.5 (L) = 0.5 kg

Qcooling = m c ΔT =0.5 ×4180×14.4= 30096 J

Qcooling = Qcooling / Δt = 30096/60× 40 = 14.33W

Win = IV = 2.6 × 3.8×6= 60 J

COP_{R} = 12.54 /60 = 0.23

RESULT

When the design of the solar thermoelectric refrigerator was tested it was found that the inner temperature of the refrigeration area was reduced from 30.2 to 15.8°C
The result is show that when the temperature of the hot side is increase hence the temperature of the cold side is decrease w.r.t time. Hence due to this the coefficient of performance of the system is increase as 0.23

6.3 CONCLUSIONS AND SCOPE FOR FUTURE DEVELOPMENT

When we find out that our cop is greater that the cop as tested in above which is 0.16 and our cop is 0.23 with six peltier .This show that our design of thermoelectric refrigerator is useful in various applications. The system which we compare using 10 module and the cop is around 0.16 which is less than the cop that is given by our system because in our system we using just 6 thermoelectric module.
The experimental result taken by 10 module system. The temperature change in this system is around 26 °C. and cop is 0.16.
The thermodynamic model is also used to run any system with the help of solar energy and it free form any error . these all show that the design is useful for various purpose .

A new dimension has been added to the cooling challenge by reduction of temperatures using thermoelectric, with the continued demand for improved cooling technology to enhance performance, reliability and reduction in operating cost, a thermoelectric cooling may be considered a potential candidate. Thus a thermoelectric refrigerator is designed to maintain the temperature of enclosure at appro.14^{o}C. The minimum temperature, allowable module power, current equations presented here provide a useful means to perform trade-off analysis to assess whether or not thermoelectric argumentation will be advantageous over conventional techniques. To use these equations, detailed information in terms of the parameters pertaining to the thermoelectric module under consideration is required, average values of the parameters of Bismuth telluride (Bi_2Te_3) are used for analysis. From the plot of C.O.P against current, the coefficient of performance of such devices is dependent on the temperature difference between the hot and cold side of the module, for maximum C.O.P, the temperature is kept to the barest minimum which is also a function of the ambient condition or room temperature, a figure of 1.3 is obtained for a temperature difference of 15^oC.

In this work, thermoelectric refrigerator unit was fabricated and tested for the cooling purpose. The refrigerator was designed based on the principle of a thermoelectric module to create a hot side and cold side. The cold side of the thermoelectric module was utilized for refrigeration purposes whereas the rejected heat from the hot side of the module was removed using heat sinks and fans. In order to utilize renewable energy, solar energy was integrated to power the thermoelectric module in order to drive the refrigerator. Moreover, the solar thermoelectric refrigerator avoids any unnecessary electrical hazards and provides a very environmentally friendly product. In this regard, the solar thermoelectric refrigerator does not produce chlorofluorocarbon (CFC), which is believed to cause depletion of the atmospheric ozone layer. In addition, there will be no vibration or noise because of the difference in the mechanics of the system. In addition the rejected heat from the solar thermoelectric refrigerator is negligible when compared to the rejected heat from conventional refrigerators. Hence, the solar thermoelectric refrigerator would be less harmful to the environment. Several tests were carried out with the prototype to determine the minimum temperature that a refrigerated object could be reached.

The energy efficiency of solar thermoelectric refrigerators, based on currently available materials and technology, was still lower than its compressor counterparts. Nevertheless, a marketable solarthermoelectric refrigerator would be made with an acceptable performance through some improvements. For example, further improvement in the COP may be possible through improvingmodule contact-resistance, thermal interfaces and heat sinks. In addition, this could be achieved by including more modules in order to cover a greater surface area of the refrigeration box.Thermoelectric and thermoelectric cooling are being studied exhaustively for the past several years and various conclusions have been conceived regarding the efficient functioning of thermoelectric refrigerators.

FUTURE WORK

There are sufficiently of instructions that future work could take. This would involve a much broader selection of TE modules to test best geometry conditions. Second, one is to increase the COP of the system by using various alloy of bismuth telluride. If this can be done the optimum points would be removed positively. This one would also be located of notice to this investigator to study the generation side of TE devices. Now closing, there is sufficiently of area for intelligent design with TE technology. There are many ways in which TE devices could be useful to solve real world problems is practically unlimited. Finally, the ZT value at the different temperatures should be measured scientifically in the future work.

REFRENCES

1.S.A Omer and D.G Infield, investigated in 1997 they present an improved theoretical model of a thermoelectric device.

2.J.G Vian, D. Astrain in 1999 investigate that the heat dissipation in thermoelectric devices by means of an element with phase change.

3. In 2001 Y. J. Dai and R. Z Wang show experimental investigation and analysis on a thermoelectric refrigerator driven by solar cells has been conducted.

4. According to the studies conducted in 2001 by Hugh W. Hillhouse, Mark T. Tuominen suggested that the thermoelectric materials are main factor to increase efficiency in many case.

5.In 2005 A.K Pramanick and P.K Das give the construction and design of the thermoelectric device.

6.Sabah A. Abdul-Wahab proposed the design and experimental investigation of portable solar thermoelectric refrigerator in 2008.

7.FankaiMeng, Lingen Chen and Fengrui Sun in 2008 introduced the term two-stage thermoelectric refrigerator system.

8. In 2013 Onoroh Francis, Itoje Harrison John give the performance evaluation of a thermoelectric refrigerator.

9. Eun Soo proposed a new approach to optimize thermoelectric cooling modules in 2013.

10,T. Hara, H. Azuma, H Shimizu H. Obora, Z. Abdin in 2013-14 theoretically analysis.

11.In2014 Andrea Montecucco and Andrew R.Knox give accurate simulation of thermoelectric power generating systems.