Design and Development of Thermoelectric Refrigerating System

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Thesis submitted to the Department of Mechanical Engineering, Sonargaon University in partial fulfillment of the requirements for the award of the degree of Bachelor of Science in Mechanical Engineering

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DECLARATION

We hereby, declare that the work presented in this project is the outcome of the investigation and research work performed by us under the supervision of M. I. Washif Rahman, Department of Mechanical Engineering, and Sonargaon University (SU). We also declare that no part of this project and thereof has been or is being submitted elsewhere for the award of any degree.

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TABLE OF CONTENTS

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"Authors"

Abstract

In the past the possibility of thermoelectric refrigeration has been considered, but all Attempts to produce a practical refrigerator have failed owing to lack of suitable Thermocouple materials. In this paper it is proposed that semiconductors should be used and the factors governing their selection are discussed. It is concluded that the semiconductors should be chosen with high mean atomic weights and that they should be prepared with thermoelectric powers lying between 200 and 300 μV°C.

The Inspect of ongoing progress in Science and Technology has created a variety of systems that can be used in producing of refrigeration effect with the use of thermo electric module and photovoltaic module for generation of energy which we further use for cooling & heating effect. The Most important utilization of the portable cooler is for the preservation of insulin in extreme conditions a thermo electric module is used instead of compressor so that it become portable, as it is based on the principle of palter effect is to create a heating side and a cooling side and also to maintain effectiveness.

Thermoelectric cooler is a solid-state heat pump which uses the component are available commercially. The thermoelectric refrigerator does not produce chlorofluorocarbon (CFC). It is pollutant free contains no liquids or gases, portable, compact, creates no vibration or noise because of the differences in the mechanics of the system. It is a prototype and its semiconductor materials, by palter effect, to provide instantaneous cooling or heating. It has the advantage of having no moving parts and thus maintenance free.

List of Tables:

List of Figures:

CHAPTER- 01
Introduction:

1.1 Background:

Brief History of Thermoelectric:

The manufacturing or process industry consumes vast amount of energy and around its half eventually lost as waste heat to the environment in the form of flue gases and radiant heat energy. There is a clear need to improve the situation by capturing at least some of the waste heat (harvesting) and converting it back into useful energy such as electricity to supply for instance small sensing electronic devices of the plant system, to increase the efficiency of system. Also, recuperating it, helps to reduce the emission which contributes to global warming. There are a lot of technologies which are being used to capture the waste heat; these different methods which are normally used to recover waste heat, differ each other with respect to the intensity of waste heat, for instance some of them are not adequate for low temperature, others require moving part to converts waste heat into useful energy, and others are not environmentally friendly. This study is focusing on thermoelectric generators, which use thermoelectric effects to produce power. This technology is an interesting one, for direct heat to power conversion. Thermoelectric generators present potential applications in the conversion of low-level thermal energy into electrical power. Especially in the case of waste heat recovery, it is unnecessary to consider the cost of the thermal energy input, and there are additional advantages, such as energy saving and emission reduction, so the low efficiency problem is no longer the most important issue that we have to take into account

[1]. Thermoelectric generators work even at low temperature applications, there are a renewable energy sources and do not produce noise. This project is focusing on the design, modelling and manufacturing thermoelectric generator for waste heat recovery applicable in local industries, by using comsol Multiphysics software as the tool. The design is based
on the shape of the chimney, environment and cost of manufacturing; cost is found by considering all materials used in process, this helps to give conclusion weather the system should be adopted in local processing industries.

Energy consumption is an important parameter which reflects the influence of a certain sector on the economic growth and environmental pollution of a region. Existing reports from different energy statistics agencies and show that both industrial activities and energy sectors (power stations, oil refineries, coke ovens, etc.) are the most energy consuming sectors worldwide and, consequently, the responsible for the release of large quantities of industrial waste heat (IWH) to the environment by means of hot exhaust gases, cooling media and heat lost from hot equipment surfaces and heated products. Recovering and reusing IWH would provide an attractive opportunity for a low-carbon and less costly energy resource. Moreover, reducing the environmental impact and costs could, at the same time, improve the competitiveness of the sector.

[2]. Nowadays, energy problems have become worldwide focuses. Several national problems, such as, energy security, energy prices, increasingly competitive global markets and stringent environmental emission regulations, are primary driving forces in the search for efficient, sustainable and economically viable technologies for energy conversion and utilization. The process industries of the chemicals, food and drinks, steels and iron, pulps and paper are substantial energy users, which represent more than 50% of the industrial energy usage. Hendricks and Choate reported that 33% of the manufacturing industrial energy was discharged directly to the atmosphere or cooling systems as waste heat, due to the fact that most industries were incapable of recycling excessive waste heat. Moreover, the global energy demand will increase by almost 35% by 2030 compared with the 2005s level or by up to 95% without the use of energy efficient technologies. Great efforts have been made in improving the energy conversion efficiency, but a considerable amount of energy is still wasted in forms of gas, liquid and solid, which requires large scope of waste energy recovery.

[3]. In the French industry, 75% of the final energy is used for thermal purposes such as furnaces, reactors, boilers and dryers. However, around 30% of this heat is assumed to be wasted in the form of discharged hot exhaust gas, cooling water and heated product. In metal and non-metallic mineral product manufacturing in the United States, 20-50% of the energy is lost as waste heat. In Turkey, in cement plants 51% of the overall heat of the process is unfortunately lost. The combustion of fossil fuels, which generates carbon dioxide emissions, is considered as the primary source of heat production in the industry

[4]. More than 80% of the total energy use in the Dutch industry involves the need for heat, either in fired furnaces or in the form of steam at different pressure levels, see Figure 1. Most of this heat is eventually released to the ambient atmosphere through cooling water, cooling towers, flue gasses, and other heat losses. We call this heat loss 'Industrial waste heat'. Large energy savings are possible, if this waste heat could be reused. The total industrial waste heat in the Netherlands is estimated at more than 250 PJ (PJ = Petajoule 1*1015J) per year.

[5]. For all the above-mentioned reasons, it is necessary to recover waste heat via capturing and reusing for heating or generating electrical or mechanical power in industrial processes. That way, the process efficiency will be increased, less fuel will be consumed and therefore less carbon dioxide will be emitted, the high and intermediate temperature waste can be directly utilized by driving steam turbine and gas turbine to generate electricity, but there are still difficulties in the utilization of waste heat in low-temperature range. Thermoelectricity (TE), which is directly generated electric energy from waste heat sources shows promising results in making vital contributions to reducing greenhouse gas emissions and providing cleaner forms of energy.

[6]. The Thermoelectric Generator (TEG) can be used to convert heat to electricity through the Seebeck effect as illustrated

Thermoelectric Effects - Early study of Thermoelectricity 1820-1920 In the 100 years before the world wars thermoelectricity was discovered and developed in western Europe by academic scientists, with much of the activity centered in Berlin.

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates a voltage when there is a different temperature on each side. Conversely when a voltage is applied to it, it creates a temperature difference (known as the Peltier effect). At atomic scale (specifically, charge carriers), an applied temperature gradient causes charged carriers in the material, whether they are electrons or electron holes, to diffuse from the hot side to the cold side, similar to a classical gas that expands when heated; hence, the thermally induced current.

This effect can be used to generate electricity, to measure temperature, to cool objects, or to heat them or cook them. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices make very convenient temperature controllers.

Traditionally, the term thermoelectric effect or thermoelectricity encompasses three separately identified effects, the Seebeck effect, the Peltier effect, and the Thomson effect. In many textbooks, thermoelectric effect may also be called the Peltier-Seebeck effect. This separation derives from the independent discoveries of French physicist Jean Charles Athanase Peltier and Estonian-German physicist Thomas Johann Seebeck. Joule heating, the heat that is generated whenever a voltage is applied across a resistive material, is somewhat related, though it is not generally termed a thermoelectric effect (and it is usually regarded as being a loss mechanism due to non-ideality in thermoelectric devices). The Peltier-See beck and Thomson effects can in principle be thermodynamically reversible, whereas Joule heating is not.

Seebeck Effect:

In 1821-3 Thomas Johann Seebeck found that a circuit made from two dissimilar metals, with junctions at different temperatures would deflect a compass magnet [1]. Seebeck initially believed this was due to magnetism induced by the temperature difference and thought it might be related to the Earth's magnetic field. However, it was quickly realized that a "Thermoelectric Force" induced an electrical current, which by Ampere’s law deflects 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.

Thermoelectric Refrigeration:

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. This effect is commonly used in camping and portable coolers and for cooling electronic components and small instruments.

Magnetic refrigeration:

Magnetic refrigeration, or adiabatic demagnetization, is a cooling technology based on the magnetocaloric effect, an intrinsic property of magnetic solids. The refrigerant is often a paramagnetic salt, such as cerium magnesium nitrate. The active magnetic dipoles in this case are those of the electron shells of the paramagnetic atoms.

A strong magnetic field is applied to the refrigerant, forcing its various magnetic dipoles to align and putting these degrees of freedom of the refrigerant into a state of lowered entropy. A heat sink then absorbs the heat released by the refrigerant due to its loss of entropy. Thermal contact with the heat sink is then broken so that the system is insulated, and the magnetic field is switched off. This increases the heat capacity of the refrigerant, thus decreasing its temperature below the temperature of the heat sink.

Because few materials exhibit the required properties at room temperature, applications have so far been limited to cryogenics and research.

Other methods:

Other methods of refrigeration include the air cycle machine used in aircraft; the vortex tube used for spot cooling, when compressed air is available; and thermoacoustic refrigeration using sound waves in a pressurized gas to drive heat transfer and heat exchange. Many Stirling cycle heat engines can be run backwards to act as a refrigerator, and therefore these engines have a niche use in cryogenics.

1.2 Aim:

Our main aim was to build electro-thermal refrigerator to get the proper cooling facility through Peltier modules without compressor and refrigerant.

1.3 Objective:

The objective of this thesis is to design and modeling a thermoelectric generator for waste heat recovery (module and heat exchanger) and calculate the optimum power with respect to optimum materials, by means of Consul Multiphasic software. input data are real waste heat values, from local industry which is 3B fiberglass company. Figure 3 shows purpose in the details, where the electricity can be produced when there is heat at one side and cold at the other side. the following points were considered to full fill the task:

1. Our main aim was to build electro-thermal refrigerator to get the proper cooling facility through Peltier modules without compressor and refrigerant gas coming out of the conventional cooling system.
2. The objective of the project is to develop thermoelectric cooling system.
3. 3. Reducing power consumption and saving electricity was also one of our Objectives.
4. Study how to use the waste heat as renewable energy sources
5. Application of Thermoelectric in industry for waste heat recovery
6. 3-D Modelling of the thermoelectric generator in Consul Multiphasic
7. Using Consul Multiphasic to optimize final module, considering cost per unity power

Thermoelectricity is based upon following basic principles:

Seebeck Effect 2. Peltier Effect 3. Thomson Effect 4. Joule Effect 5. Fourier Effect Seebeck Effect: In 1821, Thomas Seebeck found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals, if the junctions of the metals were maintained at two different temperatures

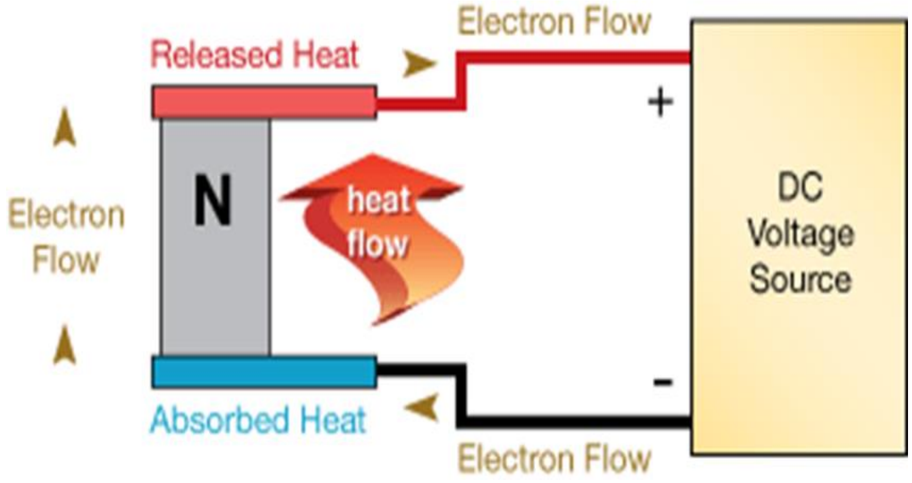


Fig 1.1: Thermoelectric refrigeration systems. [16]

Thermoelectric power supply generators are based on the Seebeck effect which is based on voltage generation along a conductor subjected to a gradient of temperature. When a temperature gradient is applied to a conductor, an electromotive force is produced. The voltage difference generated is proportional to the temperature difference across the thermoelectric module between the two junctions, the hot and the cold one. AV a AT Seebeck Effect: Seebeck Coefficient: - The Seebeck coefficient is defined as the ratio of the voltage difference to the temperature gradient. If the temperature difference AT between the two ends of a material is small, then the Seebeck coefficient of a material is defined as: aab = AV /AT aab=aa - ab aa & ab is the Seebeck Coefficient with units of Volts per Kelvin for metals A & B or P & N Peltier Effect: In 1834, a French watchmaker and part time physicist, Jean Peltier found that an electrical current would produce a temperature gradient at the junction of two dissimilar metals. The Peltier effect is the main contributor to all thermoelectric cooling applications. It is responsible for heat removal and heat absorbance. It states that when an electric current flows across two dissimilar conductors, the junction of the conductors will either absorb or emit heat depending on the flow of the electric current. The heat absorbed or released at the junction is proportional to the input electric current. The constant of proportionality is called the Peltier coefficient.

CHAPTER: 02
Review of Literature

2.1 Introduction:

Review of literature shows that though there are a good number of studies on Design & development of thermoelectric refrigerating system which operates without compressor and refrigerant in manufacturing organizations in many countries. Studies on Design & development of thermoelectric refrigerating system which operates without compressor and refrigerants in Bangladesh are rare to find. Among the previous study some of explained here.

This study reviews the recent advances of thermoelectric materials, modeling approaches, and applications. Thermoelectric cooling systems have advantages over conventional cooling devices, including compact in size, light in weight, high reliability, no mechanical moving parts, no working fluid, being powered by direct current, and easily switching between cooling and heating modes. In this study, historical development of thermoelectric cooling has been briefly introduced first. Next, the development of thermoelectric materials has been given and the achievements in past decade have been summarized. To improve thermoelectric cooling system's performance,

the modeling techniques have been described for both the thermoelement modeling and thermoelectric cooler (TEC) modeling including standard simplified energy equilibrium model, one- dimensional and three-dimensional models, and numerical compact model. Finally, the thermoelectric cooling applications have been reviewed in aspects of domestic refrigeration, electronic cooling, scientific application, and automobile air conditioning and seat temperature control, with summaries for the commercially available thermoelectric modules and thermoelectric refrigerators.

It is expected that this study will be beneficial to thermoelectric cooling system design, simulation, and analysis.

This paper deals with a review of the main research aspects concerning the formulation of the parameters indicating the characteristics and performance of thermoelectric cooling devices, with particular reference to a number of recent publications. The specific aspects addressed include some practical considerations referring to the thermoelectric figure of merit, the characterization of the cooling capacity, and the assessment of the coefficient of performance (COP). The contribution of this paper starts by categorizing the topics addressed by recent review papers, showing that these reviews generally had a wide focus and provided little specific details on thermoelectric cooling parameters and performance.

WASTE HEAT RECOVERY:

Industrial waste heat refers to energy that is generated in industrial processes without being put to practical use. Sources of waste heat include hot combustion gases discharged to the atmosphere, heated products exiting industrial processes, and heat transfer from hot equipment surfaces. The waste heat temperature is a key factor determining waste heat recovery feasibility. Waste heat temperatures can vary significantly, with cooling water returns having low temperatures around 100-200°F [40-90°C] and glass melting furnaces having flue temperatures above 2,400°F [1,320°C]. In order to enable heat transfer and recovery, it is necessary that the waste heat source temperature is higher than the heat sink temperature. Moreover, the magnitude of the temperature difference between the heat source and sink is an important determinant of waste heat's utility or "quality". The source and sink temperature difference influences a) the rate at which heat is transferred per unit surface area of heat exchanger, and b) the maximum theoretical efficiency of converting thermal from the heat source to another form of energy (i.e., mechanical or electrical). Finally, the temperature range has important ramifications for the selection of materials in heat exchanger designs [7] Waste heat to power (WHP) is the process of capturing heat discarded by an existing industrial process and using that heat to generate power (see Figure 4). Energy intensive industrial processes such as those occurring at refineries, steel mills, glass furnaces, and cement kilns all release hot exhaust gases and waste streams that can be harnessed with well-established technologies to generate electricity. The recovery of industrial waste heat for power is a 7 largely untapped type of combined heat and power (CHP), which is the use of a single fuel source to generate both thermal energy (heating or cooling) and electricity

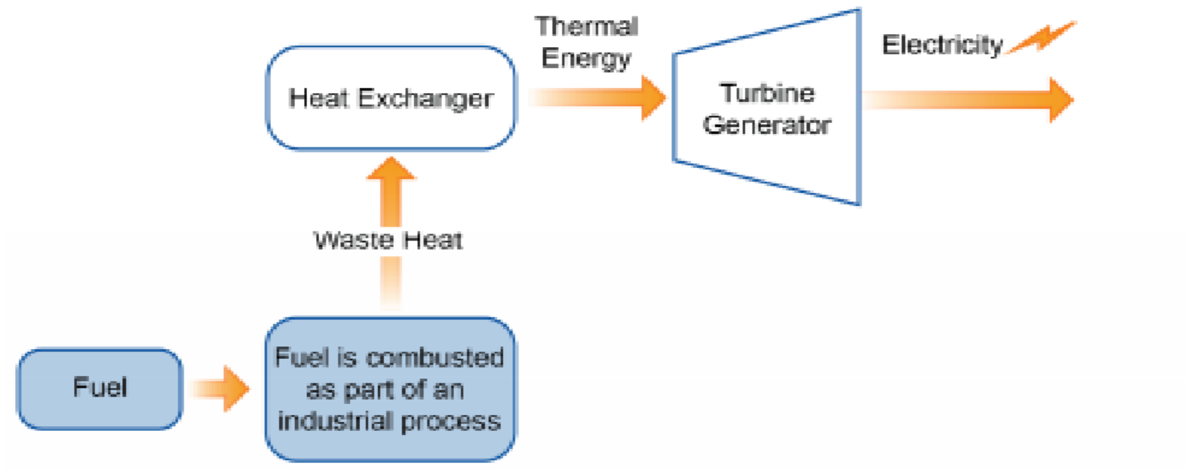


Fig 2.1: Waste Heat to Power Diagram. [17]

Today, we face some significant environmental and energy problems such as global warming, urban heat island, and the precarious balance of world oil supply and demand. However, we have not yet found a satisfactory solution to these problems. Waste heat recovery is considered to be one of the best solutions because it can improve energy efficiency by converting heat exhausted from plants and machinery to electric power. This technology would also prevent atmospheric temperature increases caused by waste heat, and decrease fossil fuel consumption by recovering heat energy, thus also reducing CO2 emissions [9]. So far, today's electrical energy production is mostly affected by generators, based on electromagnetic induction. Reciprocating steam engines, internal combustion engines, and steam and gas turbines have been coupled with such generators in utilizing chemical heat sources such as oil, coal and natural gas and nuclear heat for the production of electrical energy. Renewable energy sources like geothermal energy, solar energy and biomass energy are also being added to the list of heat sources used in modern electric power plants. Furthermore, solar energy provides hydropower indirectly. All these power plants have, however, a common disadvantage; the conversion of thermal energy into electric energy is accomplished by the utilization of moving and wear-subjected machine equipment. Some of the most widely used waste heat recovery technologies are in figure 5. The system proposed for this study is to generates electric power by providing waste heat or unharnessed thermal 8 energy to built-in thermoelectric modules that can convert heat into electric power. The main advantages are the low maintenance requirement, the high modularity and the possibility of utilizing heat sources over a wide temperature range

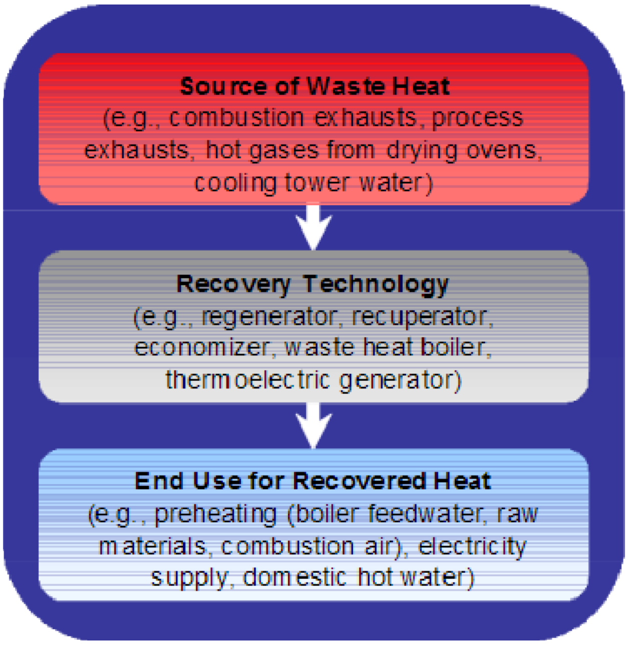


Fig 2.2: Heat recovery flowchart. [18]

2.2 Previous work and how they performed:

Jincan Chena et al. [11]: -
According to non-equilibrium thermodynamics, cycle models of single-stage and two-stage semiconductor thermoelectric refrigeration were experimentally investigated. By using the three important parameters which governs performance of thermoelectric refrigerator i.e. coefficient of performance (COP), the rate of refrigeration, and the power input, development of general expressions performances of the two-stage thermoelectric refrigeration system took placed. It was concluded that performance of thermoelectric refrigerator depends on temperature ratio of heat sink to cooled space. When this ratio is small, the maximum value of COP of a two-stage thermoelectric refrigeration system is larger than COP of a single-stage thermoelectric refrigeration system; however maximum rate of refrigeration is smaller than that of a single stage thermoelectric refrigeration system. Hence it is convenient to use single stage thermoelectric refrigerator when ratio is small. When temperature ratio is large two stage thermoelectric refrigerator is observed to be superior than single stage by both parameters i.e. maximum value of COP and maximum rate of refrigeration.

X.C. Xuan et al. [12]: -

In this paper Two stage thermoelectric refrigerator was investigated with two design configurations. Two configurations were pyramid style and cuboid style as shown in respective figures. In pyramid style configuration top side is being coldest as current is unidirectional. In cuboid style configuration current can be alternated causing top and bottom side to be switched between heating and cooling mode. To obtain optimization methods other multi stage designs can be used. The point of maximum cooling capacity and maximum COP both were taken into consideration while investigation for optimization for the two-stage TE coolers. It was concluded that value lies between 2.5-3 for both parameters that is optimum limit of ratio of number of thermo electric modules of two stages in pyramid style TE cooler and optimum limit of ratio of electric current between stages of cuboid style TE cooler. Maximum temperature difference of pyramid-style cooler is greater than single stage cooler.

Jun Luo et al., [13]: -

Using finite time Thermodynamics theory performance of a thermoelectric refrigeration system, with multielement was analyzed. To improve and maximize the cooling load and coefficient of performance (COP) optimization of the ratio of the heat transfer surface area of the high temperature side to the total heat transfer surface area of the heat exchangers was done. The analysis of number of parameters which affects optimum performance of Thermoelectric system was done parameters were number of thermoelectric refrigerating elements, the Seeback coefficients, internal heat conductance, the heat source temperature and internal electrical resistance. As well as the analysis of other parameters like influences of total heat transfer surface area and working electrical current on the optimum performance was done. They concluded that the cooling load and coefficient of performance (COP) of TE system is greatly influenced by total heat transfer surface area and working electrical current. These results can be used for designing and manufacturing of practical Thermoelectric refrigerators.

D. Astrain et al. [14]: -

In this paper a device using phase change material based on Thermosyphon principle was developed. This device was used and tested as a heat dissipater for hot side of TE cooler. Performance of TE cooler with this device was compared with TE cooler with conventional heat dissipater made up of fins. It was concluded that with the help of developed phase changing device it is possible to reduce thermal resistance between hot side of TE cooler and atmosphere up to 23.8% at 293 K ambient temperature and 51.4% at 308 K ambient temperature, compared to commercial finned heat sink. Decrease in thermal resistance ultimately causes heat to dissipate more effectively from heat sink of TE cooler, therefore improving the COP of TE cooler. At the same values of temperatures, it was observed that COP increases by

26% and 35% respectively.

Yuzhuo Pan, et al, [15]: -

Author of this paper designed and analyzed an Irreversible multi-couple thermoelectric refrigerator, which operates between two reservoirs maintained at constant temperature. Effect of other factors like external and internal irreversibility of thermoelectric refrigerator on performance was also studied. They have specified many important parameters which affects coefficient of performance (COP) of system. Results of obtained from experiments leads to knowledge of information about performance characteristics of real multicomplex thermoelectric refrigerator. This information may be used to manufacture and design thermoelectric refrigerator which will perform at its optimum level.

Hongxia Xi.et al, [16]: -

In this paper Author done survey on solar based driven Thermo electric technology. A brief history of development of solar based driven Thermo electric technology was presented. It's today's status and drawbacks present in current Technologies were reviewed. Applications, future scope, advantages over conventional technology where also discussed. In this paper they have discussed about two main modes, that are solar based thermoelectric power generation and refrigeration. Current status of both Technologies was described. Problems related to this technology and their possible solutions were presented. Ultimately these Technologies with some more development may lead to solve demand of Environment protection and energy conservation.

Suwit Jugsujinda et al, [17]: -

In this paper they have fabricated thermoelectric refrigerator using thermoelectric cooler. Thermoelectric refrigerator (25 × 25 × 35 cm3) and thermoelectric cooler (4 × 4 cm2). This system was applied to 40 W electric power without any cooling fan as heat dissipater at heat sink. They have measured temperature of this system at ten different points. It was concluded that these experiments result into temperature of cold side of thermoelectric cooler to be decreased from 30°C to -4.2°C for 1 hour and decreased to -7.4°C for 24 hours with heat plate temperature being 50 °C. Temperature of cold side of thermoelectric refrigerator decreased from 30°C to 20°C for 1 hour and decreased further in 24 hours. 3 and 2.5 are the maximum value of coefficient of performance (COP) of thermoelectric cooler and thermoelectric refrigerator respectively.

S.A. Omer et al, [18]: -

This paper presents some results of thermoelectric refrigeration system using phase change materials (PCM) integrated with thermosyphons. They investigated two models of thermoelectric refrigeration system, one with conventional finned devices as heat dissipater and other with phase change material (PCM) as heat dissipater. After results they have concluded that coefficient of performance (COP) and effectiveness of thermoelectric refrigeration system with Phase Change Material (PCM) is higher than conventional one. They have also compared thermoelectric refrigeration system of two kinds, one is using phase change materials (PCM) without thermal diode and other integrated with thermal diode (Thermosyphons). Results shows that thermosyphons used prevent leakage of heat during power off.

Overall, they have concluded system can be work with the help of renewable energies like solar energy producing electricity. It is suited for medicine and food storage.

Sujith G. et al. (2016), [19]: -
In this paper author design and fabricated the Thermoelectrical Refrigeration to cool a volume of 40L using principle of Peltier effect to cool and maintain temperature range of 5°C to 25°C and the project is used only for light heat load to lower its temperature to particular temperature. One of the advantages of this project is it takes low power to drive the refrigerator.

Bharat M. Jibhakate et al. (2016), [20]: -
The study show that a Thermoelectric Refrigeration model is design and fabricated in place of compressor and it is based on principle of Peltier effect to maintain effectiveness of both heating and cooling side also the simulation is done to on thermoelectric refrigeration to maintain it at 40°C. The designed is environmentally friendly also it has various applications in medical and pharmaceutical equipment's.

Sivakumar.N.et al. (2018), [21]:-
In the literature the author designed the Thermoelectric Refrigeration in place of prime movers, compressor or any type of refrigerant as this designed is applicable in such areas where the electricity not available and also environmentally friendly as CFC, CO_2 etc. produce in other refrigeration system. As per the experimental result on thermoelectric refrigeration the minimum temperature 15°C for cooling and maximum temperature 65°C for heating was obtained. Also, comparisons of results done on effect of cooling on AC and DC supply and COP of systems.

Mr. Swapnil B. Patond et al. (2015), [22]: -
In this research a thermoelectric module is designed to analysis the heating and cooling system by using solar energy and which is based on Peltier effect. This system is different from other refrigeration system where heating and cooling is done with the help of mechanical devices and by using refrigerants. Experimental study is done for small scale solar operated thermoelectric heating and cooling, the graph is plotted from obtained results from experiment for different metals, fruits & water to analyses the heating and cooling rates in various modes. This system is free from

maintenance.

In the literature the author fabricated a prototype of solar operated thermo electric cooling system based on Peltier effect and its working on solar photo voltage cell generated DC voltage. Through the experiments the performance parameter (heat absorption, energy supply and coefficient of friction) are analyzed the result show that the COP of the system increases with time interval. Through the system high COP on low cost obtained. It also having applications in Military and medical equipment.

Abhijith Raju et al. (2016) [23]: -

In this paper the authors objective is to design and develop solar operated thermoelectric refrigeration to produce small amount of refrigerating effect using solar energy this system is working on the principle of Peltier effect. Its results from experiments shows that the COP about 0.17 when the atmosphere temperature was 27°C and 500ml water kept inside the refrigerated space for 50 minutes it shows that the reduction of temperature from 27°C to 15°C. and through the results of experiment shows that the system work continuously if we full charged it with solar panel for 15 hours.

Recent development and application of thermoelectric generator and cooler Wei He, Gan Zhang, Xingxing Zhang, Jie Ji, Guiqiang Li, Xudong Zhao applied energy 143, 1-25, 2015 energy crisis and environment deterioration are two major problems for 21st century. Thermoelectric device is a promising solution for those two problems. This review begins with the basic concepts of the thermoelectric and discusses its recent material researches about the figure of merit. It also reports the recent applications of the thermoelectric generator, including the structure optimization which significantly affects the thermoelectric generator, the low temperature recovery, the heat resource and its application area. Then it reports the recent application of the thermoelectric cooler including the thermoelectric model and its application area. It ends with the discussion of the further research direction.

Thermoelectric cooler and thermoelectric generator devices: A review of present and potential applications, modeling and materials Seyed Mohsen Pourciau, Mohammad Hossein Ahmadi, Milad Sadeghzadeh, Soroush Moosavi, Fathollah Purnayan, Lingen Chen, Mohammad Arab Pour Yazdi, Ravinder Kumar Energy 186, 115849, 2019

Increasing the production of energy in line with industry development, transportation, and life quality improvement is an interesting topic needs to be addressed. Energy policymakers and researchers have aimed at energy management, particularly by improving energy systems performance. This review paper explains the rising interest of thermoelectric technology and applications. Nowadays, thermoelectric technology such as thermoelectric generators (TEGs) and thermoelectric cooling systems (TECs) provide heat loss recovery of thermodynamic units for power production of remote areas. Unlimited solar energy can also be employed for thermoelectric power production. This paper describes the principles of thermoelectricity and presents an explanation of current and upcoming materials. Developed models and various performed optimization of thermoelectric applications by using non-equilibrium thermodynamics and finite time thermodynamics are discussed as well. Additionally, a number of topical applications and energy resources are introduced. The main goal of this study is to give a clear overview of thermoelectric technology and applications.

Thermoelectric cooling technology applied in the field of electronic devices: Updated review on the parametric investigations and model developments Yang Cai, Yu Wang, Di Liu, Fu-Yun Zhao Applied Thermal Engineering 148, 238-255, 2019. In recent years, thermoelectric cooling technology (TECT) has emerged as one of high efficiency and low energy consumption methodologies for electronic cooling. This paper presented a comprehensive survey of TECT to show a complete foundation on the thermoelectric applications in electronic cooling. Thermoelectric physical parameters, consisting of Seebeck coefficient S, thermal conductivity K, and electric resistance R, are highly dependent on temperatures of thermoelectric heating and cooling sides and they have been simplified into constants when the thermoelectric cooling model was theoretically established. Furthermore, two systematical solution methodologies were proposed, i.e., the thermal resistance network and the effectiveness-number of transfer units, to describe the coefficient of performance (COP). Effects of cooling load, air temperature and all thermal conductance’s in heating side on the cooling performance have been attempted, regarding surface temperature of electronic devices and COP as evaluation indexes. Our analysis reveals that thermal control for electronics of high heat flux could be achieved by enhancing heat transfer in the hot side of thermoelectric system and increasing the numbers of thermoelectric coolers. Overall, governing parameters and modeling for practical applications have been presented, and the cooling potential of thermoelectric technology for electronic devices could be enhanced further.

Increasing the production of energy in line with industry development, transportation, and life quality improvement is an interesting topic needs to be addressed. Energy policymakers and researchers have aimed at energy management, particularly by improving energy systems performance. This review paper explains the rising interest of thermoelectric technology and applications. Nowadays, thermoelectric technology such as thermoelectric generators (TEGs) and thermoelectric cooling systems (TECs) provide heat loss recovery of thermodynamic units for power production of remote areas. Unlimited solar energy can also be employed for thermoelectric power production. This paper describes the principles of thermoelectricity and presents an explanation of current and upcoming materials. Developed models and various performed optimization of thermoelectric applications by using non-equilibrium thermodynamics and finite time thermodynamics are discussed as well. Additionally, a number of topical applications and energy resources are introduced. The main goal of this study is to give a clear overview of thermoelectric technology and applications.

2.3 Conclusion:

Refrigerator and air conditioners are the most energy consuming home appliances and for this reason many researchers had performed work to enhance performance of the refrigeration systems. Most of the research work done so far deals with an objective of low energy consumption and refrigeration effect enhancement. Thermoelectric refrigeration is one of the techniques used for producing refrigeration effect. Thermoelectric devices are developed based on Peltier and Seebeck effect which has experienced a major advances and developments in recent years. The coefficient of performance of the thermoelectric refrigeration is less when it is used alone, hence thermoelectric refrigeration is often used with other methods of refrigeration. This paper presents a review of some work been done on the thermoelectric refrigeration over the years. Some of the research and development work carried out by different researchers on TER system has been thoroughly reviewed in this paper. The study envelopes the various applications of TER system and development of devices. This paper summarizes the advancement in thermoelectric refrigeration, thermoelectric materials, design methodologies, application in domestic appliances and performance enhancement techniques based on the literature.

CHAPTER: 03
Methodology

3.1 Introduction:

Thermoelectric refrigeration technology is an electronic refrigeration technology with high efficiency and low energy consumption. Thermoelectric elements are characterized by compact structure, fast response, and integration of refrigeration and heating. The thermoelectric elements can be divided into two categories, one is a thermoelectric generator (TEG) based on Seebeck effect, which converts heat into electricity and uses waste heat as energy. The other is a thermoelectric cooler (TEC) based on Peltier effect, which converts electricity into heat for cooling and heating. The most direct representative is semiconductor refrigeration,

Based on the thermoelectric element’s characteristics, a large number of experiments and simulations have been done to prove feasibility of thermoelectric elements in BTMS. Alaoui [176] studied a BTMS based on Peltier thermoelectric elements, and measured discharge efficiency of a 60-Ah prismatic lithium-ion battery at different rates and temperatures. It was found that thermal response and energy consumption of the BTMS can meet the design requirements. Zhang [177] designed a BTMS using semiconductor refrigeration, simulated and analyzed it. The results showed that the BTMS had a good cooling effect under high temperature conditions.

At present, the research progress of thermoelectric elements refrigeration used for BTMS is still in its infancy, and there are still many problems to be solved in the development of this technology. Thermoelectric elements are used for BTMS, and there is still a lot of room to improve battery pack cooling performance. How to further optimize the thermoelectric elements-based BTMS is a problem that researchers need to solve. Low conversion efficiency and high material cost of thermoelectric elements are the major factors restricting their popularization. Optimizing TEC, and improving cooling performance of thermoelectric elements is the key of thermoelectric elements-based BTMS in the future development.

Heat Transfer Methods:

Geometry and Materials. Heat Transfer Methods There are several methods which can be employed to facilitate the transfer of heat from the surface of the thermoelectric to the surrounding. These methods are described in the following three sections.

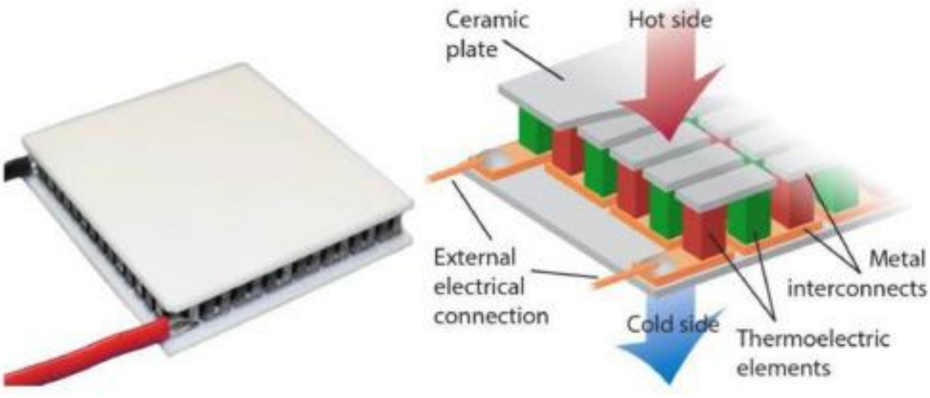


Fig 3.1: Picture of Thermoelectric elements. [19]

Natural convection, Liquid cooled, forced convection when the co-efficient of thermal transfer (K) was investigated, the K for natural convection was approximately 25 W/mk. This value compared to 100W/mk. for forced convection. Clearly the size of the heat sink for a natural convection apparatus would need to be 4 times that for a forced convection set-up

Geometry:

Two main geometries were considered for the device the first was a rectangle. The advantage of rectangle is its simplicity to build and insulate

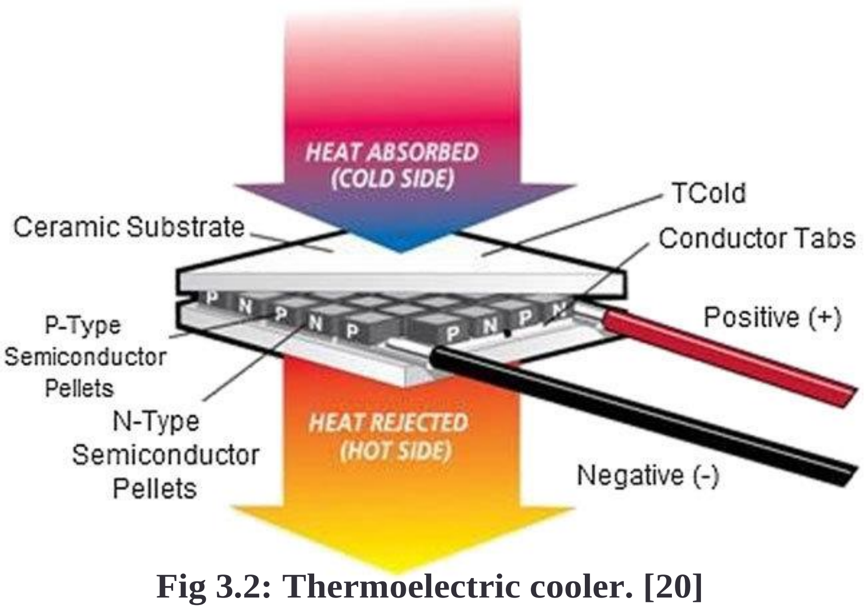


Fig 3.2: Thermoelectric cooler. [20]

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.

Material:

We explored three different materials for the construction of the outer casing and frame of the device. These were aluminum, stainless steel and Hips. High impact polystyrene is desirable as it has a low thermal conductivity. Building the device out of would make it very light, portable while maintaining rigidity is readily available and reasonably priced, is easy to cut and drill. The outer casing and container would be made by first making a positive mold and applying a cloth coated with resin.

Principle of thermoelectric Refrigerator:

Thermoelectric coolers operate according to the Peltier effect. The effect creates a temperature difference by transferring heat between two electrical junctions. A voltage is applied across joined conductors to create an electric current.

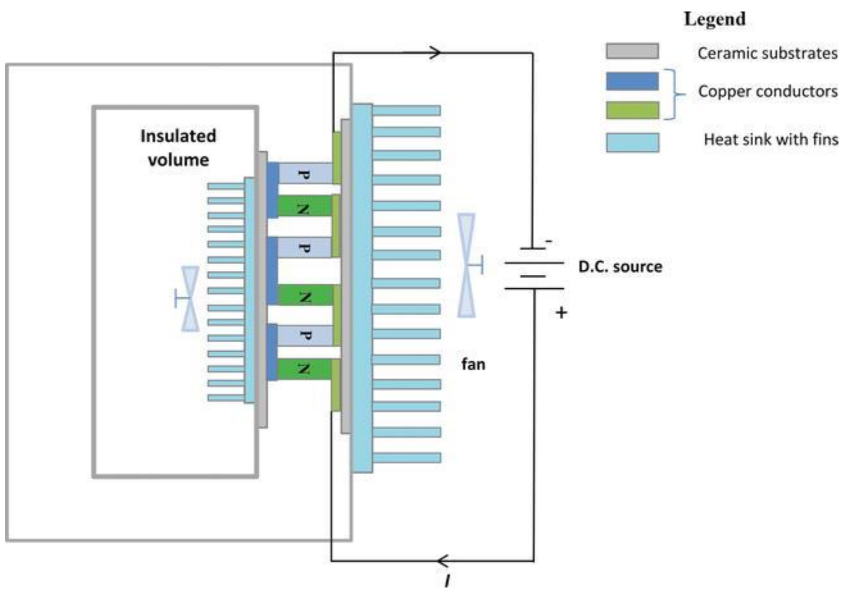


Fig 3.3: Thermoelectric Refrigerator. [21]

Thermoelectric coolers operate according to the Peltier effect. The effect creates a temperature difference by transferring heat between two electrical junctions. A voltage is applied across joined conductors to create an electric current.

<u>Circuit Diagram</u>:

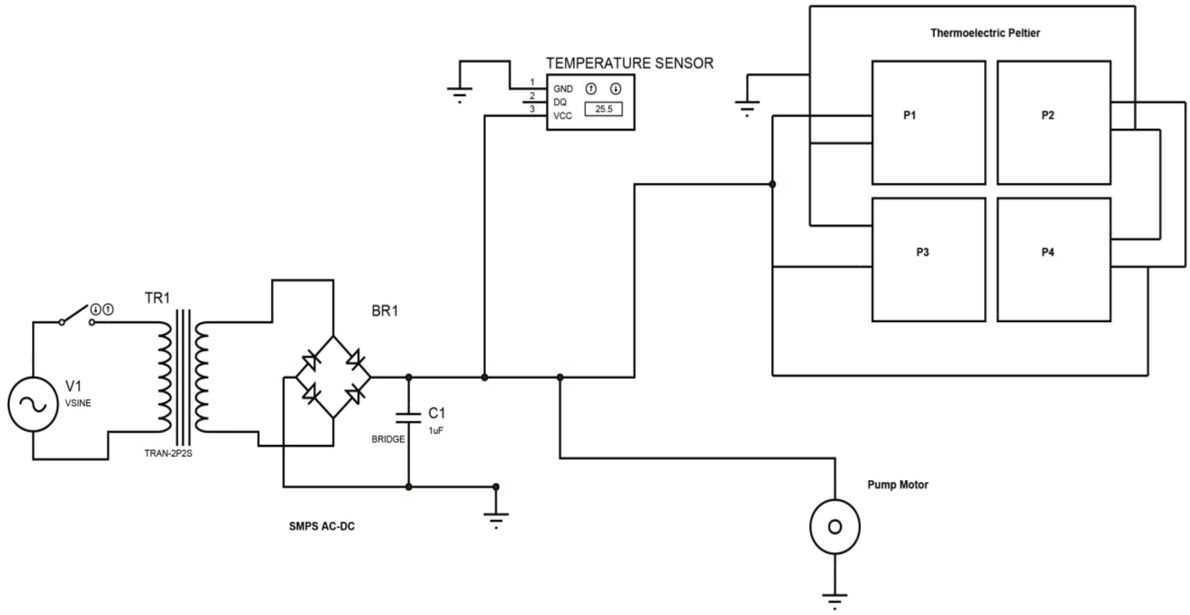


Fig 3.4: Thermoelectric Refrigerator System Circuit Diagram.

Table 3.1: Necessary Component for Thermoelectric Refrigerator Project.

1.	Peltier Module
2.	Dc 12 Volt Water Pump
3.	(SMPS)Dc Power Supply 12 Volt
4.	Water Block
5.	Thermal Paste
6.	Mini Radiator with Dc 12 Volt Cooling Fan
7.	Acrylic Sheet
8.	Temperature Sensor Etc.

Component Description with picture:

1. <u>Peltier Module</u>:

Peltier module (thermoelectric module) is a thermal control module that has both "warming" and "cooling" effects. By passing an electric current through the temperature. module, it is possible to change the surface temperature and keep it at the target temperature

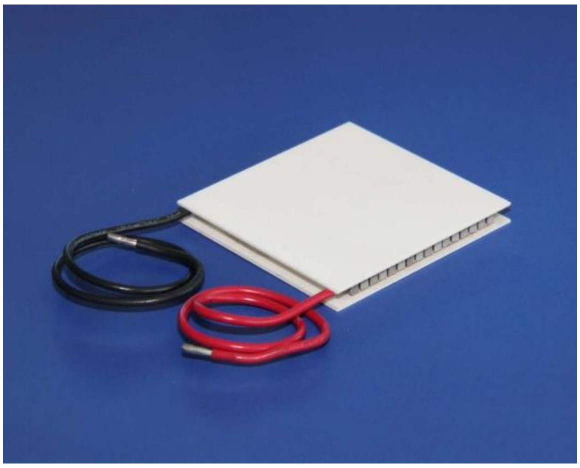


Fig 3.5: Picture of Peltier Module. [22]

2. Water Pump:

Brushed DC water pump is driven by a brushed motor. The alternating change of current direction of its coil is realized by the commutator and brushes that rotate along with the dc motor. As long as the motor rotates, the carbon brushes will wear out.

Fig 3.6: Dc 12 Volt Water Pump. [23]

3. Dc Power Supply:

The AC current runs through a coil, which creates a magnetic field. A second coil, with fewer turns of wire, is placed next to it. The magnetic field from the first coil creates an electric current in the second coil. Because there are fewer turns in the second coil, it creates lower-voltage AC electricity.

Fig 3.7: Picture of a Dc Power Supply 12 Volt.

4. Water Block:

Fig 3.8: Water Block. [24]

Water blocks are essential part of every liquid cooling loop. We are offering a wide variety of water blocks for almost every component.

5. Thermal Paste:

Thermal Paste - A silvery-gray substance that you apply to a processor before installing a cooling solution. It allows for an efficient transfer of heat from the IHS of the processor to the base plate or water block of the CPU cooler that is designed to dissipate that heat.

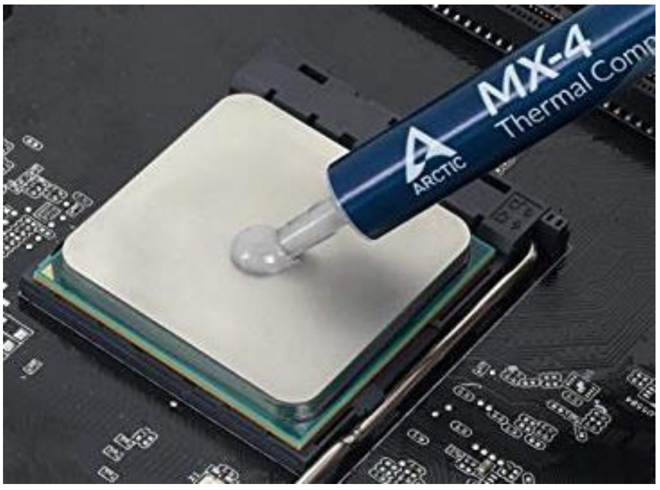


Fig 3.9: Thermal Paste. [25]

6. Mini Radiator with Cooling Fan:

Fig 3.10: Mini Radiator with Cooling Fan [26]

A DC ceiling fan works pretty much on the same principle as the DC motor. A DC motor uses an internal arrangement of magnets with opposing polarity. As current passes through the coil around this arrangement, a strong magnetic field is produced. This magnetic field then creates a torque that causes the motor to rotate

7. Acrylic Sheet:

Fig 3.11: Acrylic Sheet. [27]

Acrylic sheet is used in everything from windows and wall partitions to lighting fixtures and canopies. Acrylic for Transportation Applications- Acrylic is used throughout the transportation industry in instrument panels, windows, windshields, and mirrors.

8. Temperature Sensor:

Fig 3.12: Temperature sensor. [28]

How do temperature sensors work? They are devices to measure temperature readings through electrical signals. The sensor is made up of two metals, which generate electrical voltage or resistance once it notices a change in temperature.

DESIGN OF THERMOELECTRIC COMPONENTS:

The design progressed through a series of steps. These steps were identification of the problem, analyze problem, brainstorm ideas, decide upon a design selection, and implement design. Redesign if necessary.

3.2 Set Up Description with picture:

At first the structure of the fridge that is made by acrylic sheet. The acrylic sheet box is then lined with polyurethane foam then the inner part is again made of acrylic sheet wall.

Thermoelectric refrigerator in this project we have come out of the conventional refrigerant system and used Peltier module instead of compressor and refrigerant gas where aluminum water block has been used in the heated part of Peltier module and water is constantly circulating through the block.

Thermoelectric refrigerator in this project we have used the Audrina Controller to automatically turn on the combination of all Peltier modules after a certain period of time when the temperature inside the fridge exceeds 21 degrees.

Here given some picture for Refrigerator body making time:

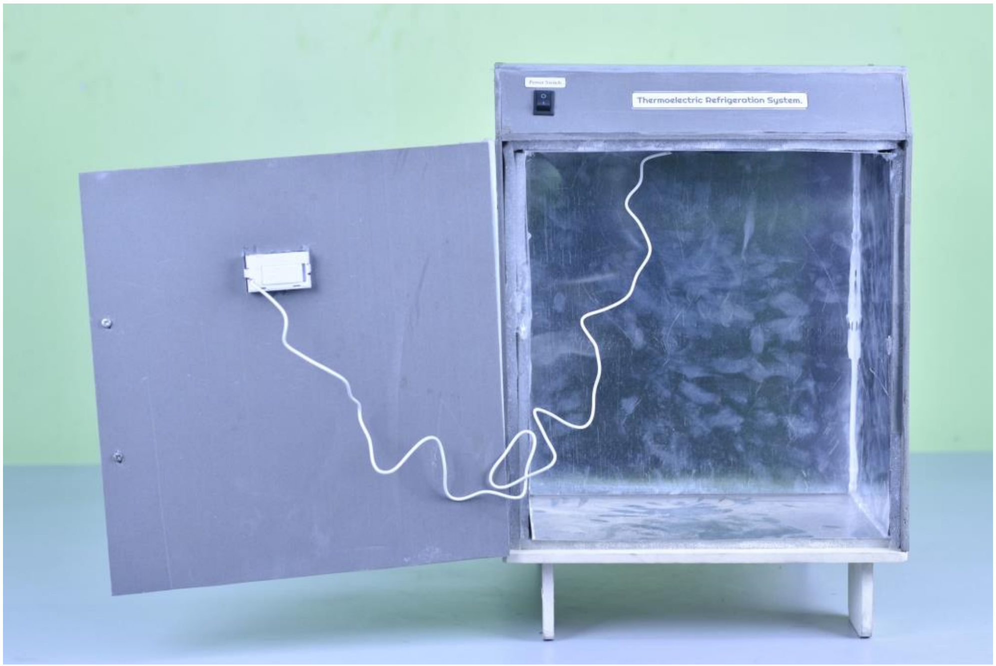


Fig 3.13: Picture of Refrigerator Body Opened the Door.

Fig 3.14: Picture of Full Setup of Refrigerator.

When the temperature inside the fridge drops to 12 degrees, the whole system will shut down automatically for 6 minutes. Our fridge will automatically turn on and off as the temperature rises and falls.

3.3 <u>Working and Data Collection</u>:

After completing all the activities of making the fridge, the data was collected to verify the performance of the fridge. The fridge was connected to a 12-volt power supply and the fridge turned on automatically then we saw through the temperature sensor that the temperature inside was slowly decreasing after 24 minutes the temperature is rises at 12.6 degrees. When the temperature is rises at 12.6 degrees Our system is turn off for 6 minutes, after 6 minutes it was seen that the temperature is reached at 20.5 degrees and again automatically whole system is turn on.

Thus, keeping the whole system running for 3 hours we observed that when the temperature drops to 12 degrees within a certain period of time our system automatically shuts down and when the temperature reaches 21 degrees then our system restarts again automatically

3.4 <u>Conclusion</u>:

The coefficient of performance of this refrigerator is much smaller than that of a conventional compressor-type refrigerator when the required cooling capacity is high, whereas the coefficient of performance of the conventional unit falls off rapidly.

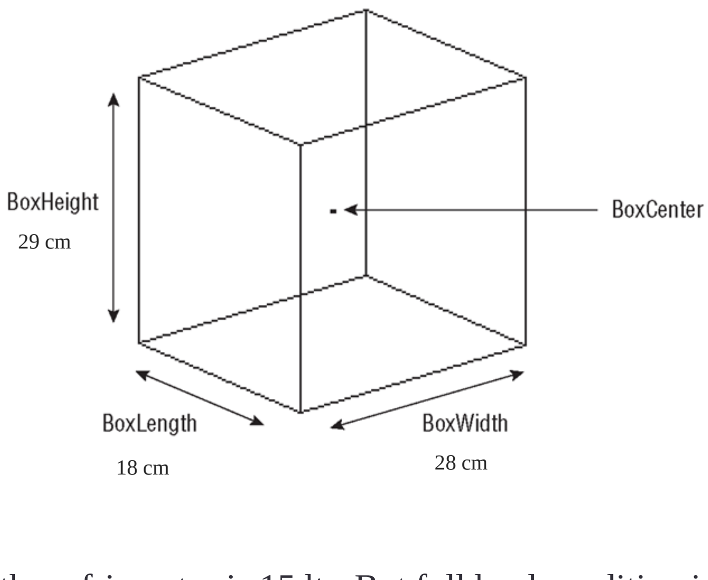
as the cooling capacity is decreased and that of thermo electric unit remains constant. Thus, a conventional refrigerator is preferred when the required cooling capacity is high and a thermoelectric refrigerator should be chosen when a low cooling capacity is needed. The cold side of the thermoelectric module was utilized for refrigeration purposes whereas the rejected heat from the hot side of the module was eliminated using heat sinks and fans. As the cooling units are of small size, silent, contains no liquids or gases, have no moving parts and have a long life. It is very simple to control the rate of cooling by adjustment of the current, the response to changes in the supply is very rapid, while reversal of the direction of the current transforms a cooling unit into a heater with a coefficient of performance in excess of unity i.e. a heat pump for oven. In this work, a portable compressor less refrigerator unit was fabricated and tested for the cooling purpose this is completely eco-friendly project Multipurpose and Portable.

CHAPTER: 04
Result Analysis:

4.1 Introduction:

Conventional cooling systems 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. Semiconductor thermoelectric coolers (also known as Peltier coolers) offer ISSN 2278 - 0149 www.ijmerr.com Vol. 1, No. 3, October 2012 © 2012 IJMERR. All Rights Reserved Int. J. Mech. Eng. & Rob. Res. 2012 1 Mechanical Department, Sinhgad College of Engineering, Vadgaon bk., Pune 411041, India. several advantages over conventional systems. They are entirely solid-state devices, with no moving parts; this makes them rugged, reliable, and quiet. They use no ozone depleting chlorofluorocarbons, potentially more environmentally responsible alternative to conventional offering a refrigeration. They can be extremely compact, much more so than compressor-based systems.

4.2 Refrigerator Capacity:



Inner volume of the refrigerator is 15 ltr. But full load condition is considered with 04 liter.

4.3 Data Table:

Table 4.1: Temperature variation with time

S/N	Condition	Time (Minutes)	No Load Condition	Half Load Condition	Full Load Condition
1.	When Surrounding Temp. is 24 °C	0	24.2	24.3	24.3
2.		5	16.3	17.2	18.4
3.		10	14.9	16.5	17.5
4.		15	13.9	16.1	17.0
5.		20	13.1	15.8	16.4
6.		25	12.4	15.1	15.9
7.		30	12.6	14.9	15.5

Design Graph:

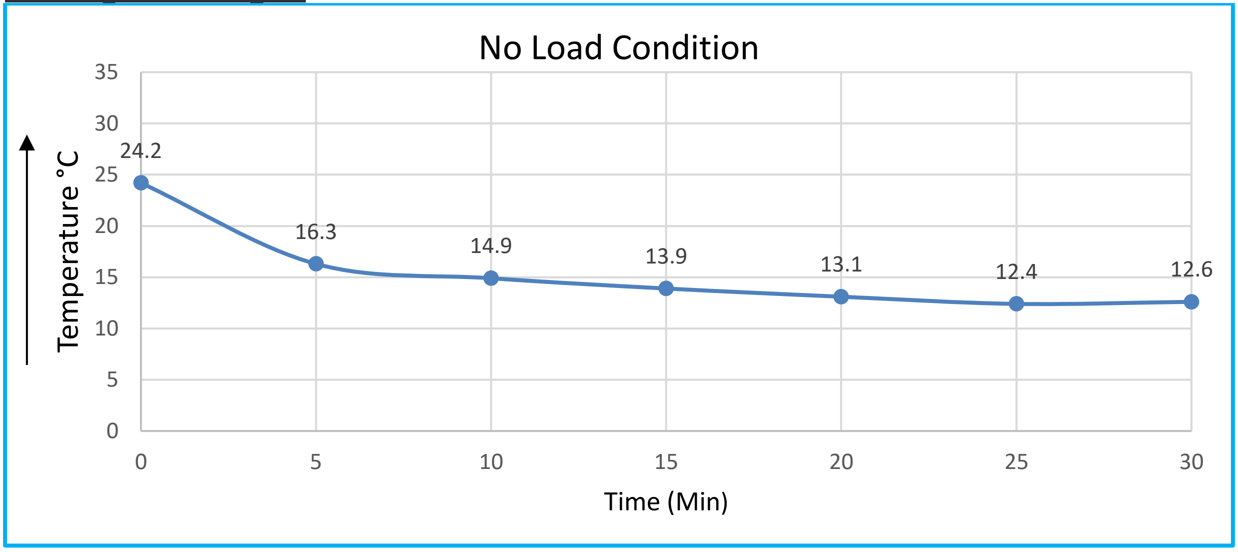


Fig 4.1: Graphs of temperature variation against time with no load.

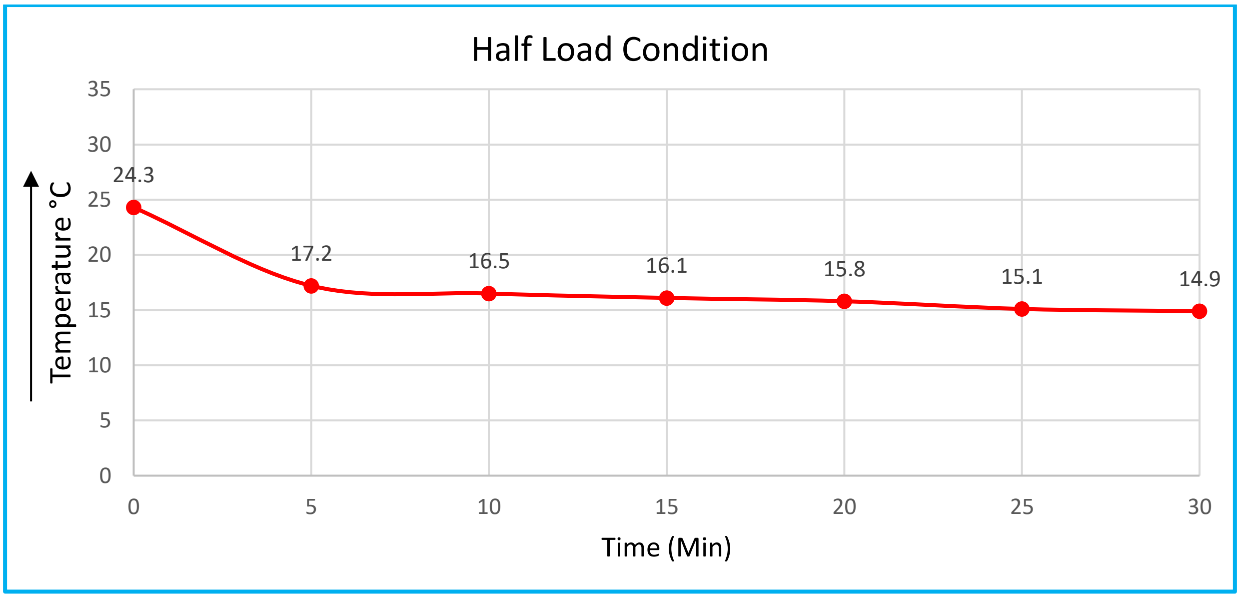


Fig 4.2: Graphs of temperature variation against time with half load.

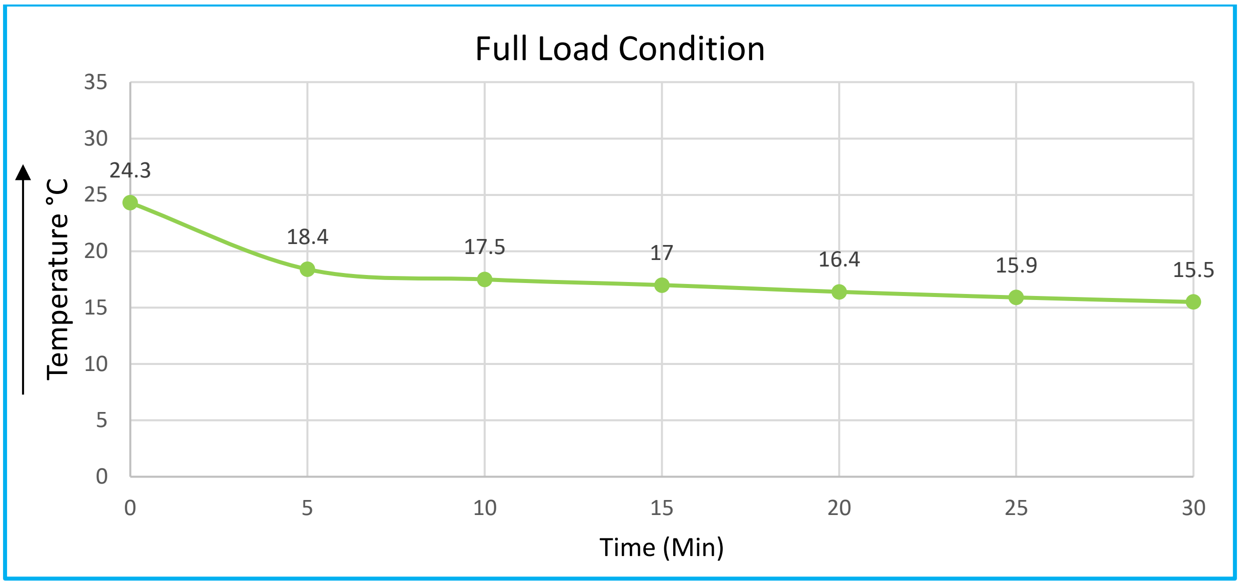


Fig 4.3: Graphs of temperature variation against time with full load.

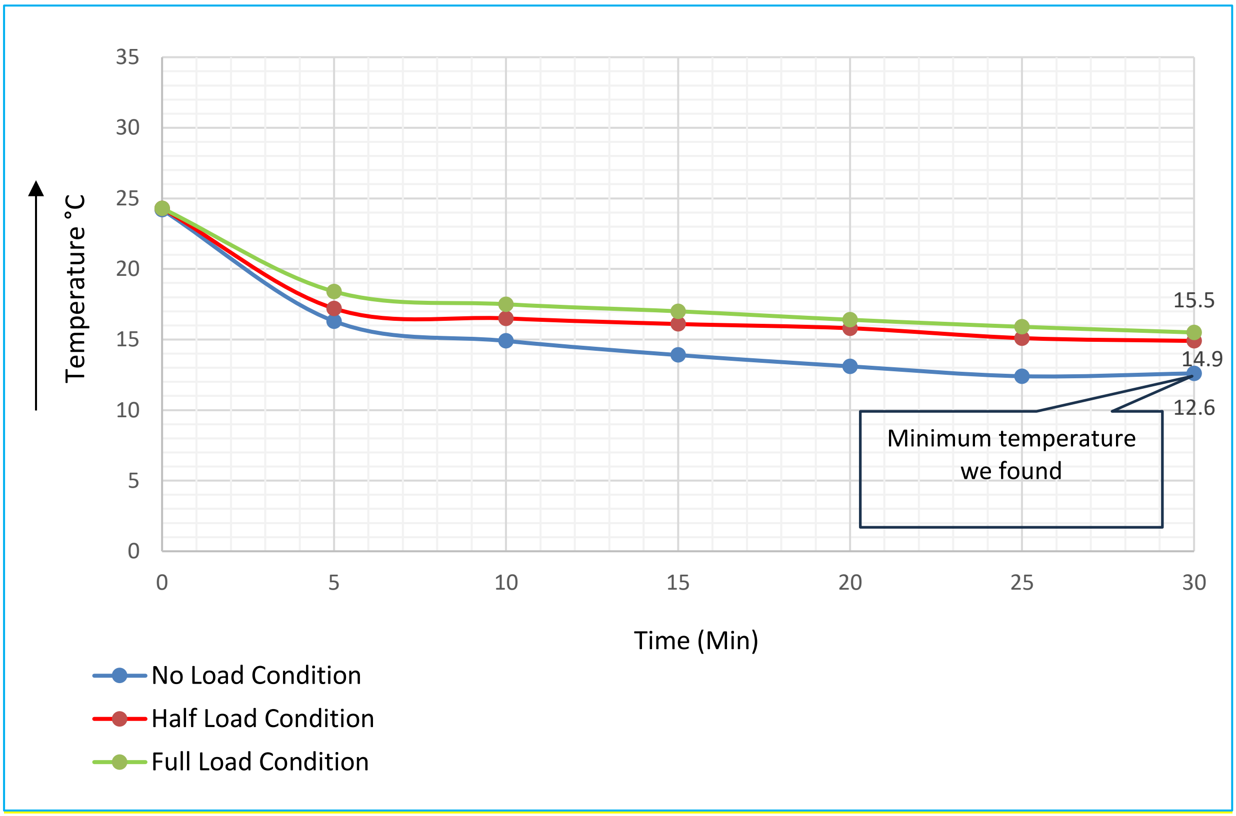


Fig 4.4: A Graphs of temperature variation against time.

4.3 Analysis of the result:

By analysis temperature variation chart, we set the program in Arduino 30 minutes our cooling system is continue and 5 minutes it is stop. This system will be repeated. Table 4.1 shows the data collected in two sequences while keeping the electric circuit on for some time and then current supply off for few minutes (approximately 5 minutes) to save electricity cost.

Fig 4.4 shows the graphical representation of the refrigeration process. It observed that in first running condition for 30 minutes the temperature falls up to 12°C. After 30 minutes no further decrease of the temperature occurs. So, the system keeps shut off for 6 minutes and observed that the temperature again goes up to 24°C. Again, we keep running the system for another 30 minutes with half load condition and the temperature falls up to 15°C. Again, we keep the system in off position for another 5 minutes and found the temperature rises up to 24°C. Again, we keep running the system for another 30 minutes with full load condition and the temperature falls up to 16°C. So, on optimization. off operation cycles will be 30 minutes (on) and 5 minutes (off) for process.

4.4 Conclusion:

The objective project is to achieve the long-term cooling in case of power failure for refrigerator. A TER Cooling system is has been designed and developed to provide active cooling with help of single stage 12 V TE module is used to provide adequate cooling. First the cooling load calculations for this TER compartment considered under study were presented. Simulation tests in laboratory have validated the theoretical design parameters and established the feasibility of providing cooling with single stage thermoelectric cooler was tested in the environmental chamber. As TER not available in open market which we can retain cooling at case of power outage due to high current carrying capacity. The retention time achieved was 52 min with the designed module in this project.

CHAPTER: 05

Recommendation and Conclusion:

Recommendation:

5.1 Introduction:

Refrigeration means removal of heat from a substance or space in order to bring it to a temperature lower than those of the natural surroundings. Thermoelectric cooling is a way to remove thermal energy from a medium, device or component by applying a voltage of constant polarity to a junction.

Between dissimilar electrical conductors or semiconductors. Thermoelectric refrigeration provides cooling effect by using thermoelectric effect i.e. Peltier effect rather than the more prevalent conventional methods like those using the 'vapor compression cycle' or the 'gas compression cycle'. Thermoelectric refrigeration finds applications in electronic systems and computers to cool sensitive components such as power amplifiers and microprocessors. Ter can also be used in a satellite or space application to control the extreme temperatures that occur in components on the sunlit side and to warm the components on the dark side. In scientific applications like digital cameras and charge-Coupled devices (CCDs) TER is used to minimize thermal noise, thereby optimizing the sensitivity and image contrast. The coefficient of performance (COP) of compression refrigerators decreases with the decrease in its capacity. Therefore, when it is necessary to design a low-capacity refrigerator, TER is always preferable. Also, better control over the space temperature is the major advantage of the TER. Hence, ter is good option for food preservation applications & amp; cooling of pharmaceutical products. Thermoelectric refrigerators (TEMS) offer several advantages over vapor-compression refrigerators. They are free of moving parts, acoustically silent, reliable and light-weight. Their low efficiency and peak heat flux capabilities have precluded their use in more widespread applications. Optimization of thermoelectric pellet geometry can help, but past work in this area has neglected the impact of thermal and electrical contact resistances. The present work extends a previous one-dimensional TEM model to account for a thermal boundary resistance and is appropriate for the common situation where an air-cooled heat sink is attached to a TEM. The model also accounts for the impact of electrical contact resistance at the TEM interconnects. The pellet geometry is optimized with the target of either maximum performance or efficiency for an arbitrary value of thermal boundary resistance for varying values of the temperature difference across the unit, the pellet Seebeck coefficient, and the contact resistances. The model predicts that when the thermal contact conductance is decreased by a factor of ten, the peak heat removal capability is reduced by at least 10 percent. Furthermore, when the interconnect electrical resistance rises above a factor of ten larger than the pellet electrical resistance, the maximum heat removal capability for a given pellet height is reduced by at least 20 percent and the maximum coefficient of performance at low Ku-∞o u /(NK), values is reduced by at least 50 percent.

5.2 Limitation:

Our project was so small that it was not for big commercial operations. And also, low coefficient of performance. We cannot decrease less than 12 temperatures. Utilizing thermoelectric refrigerator system is increasing in many industrial applications due to its advantages. Heat rejection from cold side of a pettier module is a substantial parameter to improve conversion efficiency of the module. One of the easy-to-use cooling approaches is using direct current (DC) fans. This study investigates a self- cooling (TER) system, where the cooling fans consume a fraction of power generated by the TERS. Critical design parameters are studied to reach maximum net power by utilizing suitable operating conditions of the cooling fans. Moreover, performance of the TER system, supplying electrical power required for both external user and the cooling fans, is explored experimentally. This paper studies, for the first time, effect of electrical input power of the cooling fans, coupled with the TERS, on performance of the self-powered energy harvesting system. Results of this work demonstrate that, feasibility of utilization of the cooling fans is strongly related to thermal boundary conditions and electrical load resistance applied on the coupled electric circuit of the TERS. Moreover, the results show a minimum inlet water flow temperature and a minimum external load resistance are required in self- cooling system to provide a net power more than without using the cooling fans.

Future Recommendation:

With recent development taking place in field of thermoelectric and Nano science different thermoelectric material with figure of merit ZT more than 1 with high temperature difference to be explored this will further help to reduce the temperature, current below and can also perform better at higher ambient conditions.
To improve the power retention in this thermoelectric cooler sandwich heater needs to be explored with quick switching mechanism from thermoelectric cell off state of heater to on state, so that temperature drop in thermoelectric cell can be reduced.

Conclusion:

This paper reviews the developments in TER system over the years. This study on the thermoelectric refrigeration emphasize that the TER system is a novel refrigeration system which will be a better alternative for conventional refrigeration system. The research and development work carried out by different researchers on TER system has been thoroughly reviewed in this paper. The study of this seminar spreads over the application of TER system and various technologies used with the same. This seminar summarizes the Advancement in thermoelectric refrigeration, thermoelectric materials, recent Modeling approaches, application in domestic appliances and various technologies. This paper also concludes that, to achieve better COP & Temperature control we can combine TER with other refrigeration systems. For example, combining VCR & amp; TER systems reduce the energy consumption, gives high COP & good temperature control within the refrigerated area. Hence It is better to have such hybrid systems & devices to reduce total energy consumption

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