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Design and Development of Eco-Friendly Refrigeration

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Abstract: The objective of this project work is to develop portable thermoelectric refrigeration system capable of maintaining temperatures between 8 °C and 13 °C. The main system consisted of thermoelectric module as cooling generator along with insulated cabin. Thermoelectric elements perform the same cooling function as Freon-based vapour compression or absorption refrigerators. To ensure the success of this project several criteria's are to be satisfied such as portability, size and cost of the system. The design of the preservation is based on the principles of thermoelectric module (i.e. Peltier effect) to create a hot side and a cold side. The cold side of the thermoelectric module is used for refrigeration purposes; provide cooling to the chamber. On the other hand, the heat from the hot side of the module is rejected to the surroundings with the help of heat sinks and fans. After gathering experimental data's and necessary guidelines from research papers on the thermoelectric refrigeration systems, the initial design of the model was made. Based on the heat load calculations, the thermoelectric module is selected. The system was fabricated and was experimentally tested for the cooling purpose. The capability of the system to maintain the required temperature and the time for reaching the same were analysed. The results showed that the system can maintain the storage temperature at 8°C and 13 °C under ambient temperature up to 30 °C with minimum power consumption of 64 Watt. The proposed thermoelectric module, to maintain the storage temperature, satisfied the design criteria.

Keywords: Peltier Module, Refrigeration

I. INTRODUCTION

The conventional cooling systems are used now a days are requiring the refrigerant whose phase change takes place in heat exchanging and compressor are required for the compression of the refrigerant. The compressor required more power and space. The refrigerant is also not eco-friendly and increases the global warming and the major cause of ozone layer depletion. The mini-Eco-friendly refrigerator is based on the PELTIER EFFECT and a thermoelectric device called Peltier device is used for the cooling purpose. In the MEF-Refrigerator there is no need of compressor and refrigerant. Semiconductor thermoelectric coolers (also known as Peltier coolers) off temperature control (< ± 0.1 °C) can be achieved with Peltier coolers. However, their efficiency is low compared to conventional refrigerators. Thus, they are used in niche applications where their unique advantages outweigh their low efficiency. Although some large-scale applications have been considered (on submarines and surface vessels), Peltier coolers are generally used in applications where small size is needed and the cooling demands are not too great, such as for cooling electronic components.

1.1 Objective of the Project:

- To understand the basic principal of the our project
- Describe the construction and working of various parts of our project
- Development of the working model of the our project
- To reduce time spent on this activity.
- To analyze the technology according to needs and capabilities.

II. LITERATURE REVIEW

1. Jonathan Michael Schoenfeld et at [1] in his thesis submitted on integration of a thermoelectric sub cooler in 2008. There are two general research areas focused on increasing TEC performance: materials Research on thermoelectric semiconductors and system level assembly and heat dissipation techniques. The former is focused on developing

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advanced thermoelectric materials with superior thermoelectric properties. The most important parameter of a thermoelectric semiconductor is the figure of merit, Z, which is given by α2/ (kρe). Each of these properties is temperature dependent so often the of merit will be given at a particular temperature in the dimensionless form, ZT. Increasing the figure of merit directly results in an increase in the optimum COP of a TEC. The most common thermoelectric semiconductor in today's TECs is Bismuth Telluride (Bi 2Te 3), which has a ZT of ~0.9 at 300 K. (2) Bass et al. (2004) [2] investigated the use of multi-layer quantum well (MLQW) thermoelectric in a cooling application. MLQW thermoelectric material is a composite of thin layers of alternating semiconductor material with differing electronic band gaps deposited on a substrate. In this way, the thermal and electrical conductivity of the material can be decoupled.

The no dimensional figure of merit of such composite materials has been determined experimentally to be as high as 3 or 4. Theoretical analysis predicted COPs as high as 5 at a ΔTm of 20 K. A TEC utilizing MLQW thermoelectric material is still under development. It can be expected that the additional manufacturing costs of such a module would be substantial. 20 Besides the obvious increase in optimum COP provided by such an improvement in thermoelectric properties, it has also been recognized that Tellurium, a main component in Bismuth Telluride, is becoming increasingly rare and expensive, which will eventually lead to a necessary replacement for thermoelectric materials. Further research is still required to develop nanotechnology thermoelectric, with the ultimate hurdle being the fabrication of a scaled-up module with an applicable cooling capacity. (3) Chain and Chen et al. (2005) investigated the use of a micro channel heat sink on a TE module used to cool a water tank. The micro channels were etched into a silicon wafer with a glass cover plate. Four micro channel heat exchangers were fabricated with a differing number of ports and hydraulic diameters (D h), from 89 ports at a D h of 65 μm to 44 ports at a D h of 150 μm. Water was pumped at flow rates ranging from 289 – 10,702 ml/h to remove the heat from the hot side of the module. The micro channel was placed on top of a 4 cm x 4 cm TE module. The lowest measured thermal resistance for the heat sink was 1.68 K/W. The authors suggested that the thermal resistance could be reduced to 0.5 K/W by increasing 6 the aspect ratio of the micro channel ports and by using a more conductive material like copper. (4) Webb et al. (1998) [4] investigated the use of a thermo siphon as the heat sink of a TE module used for electronics cooling. A porous aluminium surface was employed to enhance the boiling heat transfer in the evaporator. The condenser was constructed with internal micro fins to enhance condensation.

An experimental study was conducted with simulated heat loads typical of a thermoelectric module heat rejection. At 75 W a thermal resistance of 0.0505 K/W was calculated for a 45 mm square enhanced boiling surface. The authors also recognized that the thermal resistance decreased slightly with increasing heat flux. As the figure of merit continues to increase through a continued research effort, the use of thermo electrics for air cooling has become more feasible. (5) Riff at and Qui et al. (2005) [5] investigated TE air conditioning systems with an air- and water-cooled heat sink. A cylindrical heat sink was designed through the optimization of the interior fin length and pitch as well as fluid velocity. The cylindrical design could reduce heat exchanger volume and thermal resistance. An evaporative water "condenser" was suggested as 21 the outdoor unit, which would cool the circulated water down close to the wet bulb temperature through convective and evaporative cooling. It was shown that the thermal resistance of a water-cooled heat sink was significantly lower than an air-cooled heat sink, with values reported as low as 4.75 x 10-4 K/W for a cylinder with an outer surface area of 0.23 m 2.

An ideal COP of 1.8 was reported at a ΔTm of 20 K of merit of Z = 3.0 x 10 -3 K -1. Although possible, it would be difficult to fabricate a TE module on a curved surface as suggested. (6) Muhammad Khazratul development of small D.C. thermoelectric refrigerator et al [6] The refrigerator is one of the most innovative and important inventions of the twentieth century. The basic function of a domestic refrigerator is to preserve the quality of perishable food products. Several studies have shown that the quality of food products directly depends on temperature and air distribution inside the storage chambers. Hence, unsuitable temperatures and air velocities may cause food to undergo a premature deterioration. Even if the average temperature inside the refrigerator cabinet is adequate, uncontrolled rise or fall in local temperatures may affect the quality of food products. A device described as a "refrigerator" maintains a temperature a few degrees above the freezing point of water; a similar device which maintains a temperature below the freezing point of water is called a "freezer". The refrigerator is a relatively modern invention amongst kitchen appliances. It replaced the common icebox which had been placed outside for almost a century and a half prior and is sometimes still called by the original name "icebox". A typical household refrigerator is a combination refrigerator-freezer since it has a freezer compartment to make ice and to store frozen food. Today's refrigerators use much less energy as a result of using smaller and higher-efficiency motors and compressor, better insulation materials, larger coil surface areas, and better door seals.

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III. DEVELOPMENT OF THE PROJECT

3.1 Parts used in the Project

- ❖ Peltier Module
- ❖ Heat Sink
- ❖ Cooling fan
- ❖ Power Supply
- ❖ Wooden frame
- ❖ Thermo-coal

3.2 Diagram of the Project

3.3 Working of the Project:

In MEF-Refrigerator the Peltier device is used which works on Peltier effect PELTIER EFFECT: The Peltier effect occurs whenever electrical current flows through two dissimilar conductors, depending on the direction of current flow, the junction of the two conductors will either absorb or release heat The Seebeck Effect- is the reverse of the Peltier Effect. By applying heat to two different conductors a current can be generated. The Seebeck Coefficient is given by: Where is the electric field? A typical thermoelectric cooling component is shown. Bismuth telluride (a semiconductor) is sandwiched between two conductors, usually copper. A semiconductor (called a pellet) is used because they can be optimized for pumping heat and because the type of charge carriers within them can be chosen. The semiconductor in this examples N type (doped with electrons) therefore, the electrons move towards the positive end of the battery.

IV. ADVANTAGES AND APPLICATION OF THE PROJECT

4.1. Advantages of the Project:

Advantages of the project as per following like as:

❖ Thermoelectric devices are advantageous because they are reliable, light in weight, small, quiet, and inexpensive.

❖ They will function in environments that are too severe, too sensitive, or too small for conventional refrigeration.

❖ These environmentally friendly devices offer precise temperature control, while requiring minimal maintenance because they have no moving parts.

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❖ Thermoelectric devices are most useful for small cooling jobs where a compressor based system would be impractical. These devices are also useful because they can heat as well as cool depending on the polarity of the power source.

4.3. Application of the Project:

❖ Thermoelectric cooling is used in medical and pharmaceutical equipment, spectroscopy systems, various types of detectors, electronic equipment, portable refrigerators, chilled food and beverage dispensers, and drinking water coolers.
❖ Requiring cooling devices with high reliability that fit into small spaces, powerful integrated circuits in today's personal computers also employ thermoelectric coolers.
❖ Using solid state heat pumps that utilize the Peltier effect, thermoelectric cooling devices are also under scrutiny for larger spaces such as passenger compartments of idling aircraft parked at the gate.
❖ Some of the other potential and current uses of thermoelectric cooling are:

❖ **Military/Aerospace**
❖ Inertial Guidance Systems, Night Vision Equipment, Electronic Equipment Cooling, Cooled Personal Garments, Portable Refrigerators**.**

❖ **Consumer Products**
❖ Recreational Vehicle Refrigerators, Mobile Home Refrigerators, Portable Picnic Coolers, Wine and Beer Keg Coolers, Residential Water Coolers/Purifiers.

❖ **Laboratory and Scientific Equipment**
❖ Infrared Detectors, Integrated Circuit Coolers, Laboratory Cold Plates, Cold Chambers, Ice Point Reference Baths, Dew point Hygrometers, Constant Temperature Baths, Thermostat Calibrating Baths, Laser Collimators.

❖ **Industrial Equipments**
❖ C Computer Microprocessors, Microprocessors and PC's in Numerical Control and Robotics, Medical Instruments, Hypothermia Blankets, Pharmaceutical Refrigerators - Portable and Stationary, Blood Analyzers, Tissue Preparation and Storage, Restaurant Equipment, Cream and Butter Dispensers.

❖ **Miscellaneous**
❖ Hotel Room Refrigerators, Automobile Mini – Refrigerators, Automobile Seat Cooler, Aircraft Drinking Water Coolers.

❖ Thermoelectric modules and systems have been extensively applied in numerous fields, handling cooling loads from milliwatts up to tens of kilowatts with temperature differences from almost zero to over 100 K. They offer advantages of no moving parts and good reliability, absence of noise and vibration, compactness and light weight. They have, however, lower COP and higher capital cost than vapour compression systems. To improve the COP, efficient heat transfer systems are required to reduce the temperature difference across the module. Current applications in the food sector include: hotel room (mini-bar) refrigerators; refrigerators for mobile homes, trucks, recreational vehicles and cars; portable picnic coolers; wine coolers; beverage can coolers; drinking water coolers.
❖ Other potential future applications include domestic and commercial refrigerators and freezers, and mobile refrigeration and cooling systems

4.4 Future Scope:

The project has covered almost all the requirements. Further requirements and improvements can easily be done since the as per requirements is mainly structured or modular in nature. Improvements can be appended by changing the existing modules.

The two main issues in thermoelectric refrigeration are the development of new materials with stronger Peltier effects and the application of these materials to real engineering problems such as refrigeration and control of process heat. The former issue is primarily the domain of physicists and materials scientists who test many materials looking for crystalline structures which combine high electrical conductivity with low thermal conductivity as well as a strong thermoelectric characteristic. The latter issue is of greatest concern to mechanical engineering where problems such as heat transfer between the module and cheap manufacture of modules are of concern. For refrigeration, unlike air-conditioning, the power consumption is relatively small, typically 50 Watts which means that the number of modules and their cost is also small.

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4.5 Conclusion:

We have been successful in designing a system that fulfils the proposed goals. However, we do realize the limitations of this system. The present design can be used only for maintaining a particular temperature. The system is unable to handle fluctuations in load. Extensive modifications need to be incorporated before it can be released for efficient field use. Thermoelectric refrigeration is one of the key areas where researchers have a keen interest. Some of the recent advancements in the area surpass some of the inherent demerits like adverse COP. Experimental results show that for fall of temperature from -200C to 00C without phase change material, takes 5.5 hours' time whereas the same by using phase change material it takes 14.5 hours' time.

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