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Thermoelectric Refrigeration System

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Abstract: *A thermoelectric refrigerator, also known as a thermoelectric cooler module or Peltier cooler, is an electric component made of semi-conductors that acts as a tiny heat pump. When a thermoelectric cooler module is powered by a low voltage direct current power source, heat is transferred from one side to the other. As a result, one module face will be cooled while the opposite face is heated at the same time. The same fundamental laws of thermodynamics govern both thermoelectric and mechanical refrigerators, and both refrigeration systems, despite their vastly different appearances, operate on the same principles.*

Keywords: Thermoelectric Refrigerator

I. INTRODUCTION

A thermoelectric refrigerator, also known as a thermoelectric cooler module or Peltier cooler, is an electric component made of semi-conductors that acts as a tiny heat pump. When a thermoelectric cooler module is powered by a low voltage direct current power source, heat is transferred from one side to the other. As a result, one module face will be cooled while the opposite face is heated at the same time. The same fundamental laws of thermodynamics govern both thermoelectric and mechanical refrigerators, and both refrigeration systems, despite their vastly different appearances, operate on the same principles. A compressor in a mechanical refrigeration unit boosts the pressure of a refrigerant and circulates it throughout the system. The refrigerant boils in the refrigerated chamber, and the refrigerant boils in the freezer chamber. The refrigerant boils in the chilled chamber, and while converting to a vapour, the refrigerant absorbs heat, making the chamber chilly. The heat absorbed in the chamber is transmitted to the condenser, where the condensing refrigerant transfers it to the atmosphere. A doped semi-conductor material replaces the refrigerant, the condenser is replaced by a finned heat sink, and the compressor is replaced by a Direct Current power source in a thermoelectric cooling system. Electrons travel through semi-conductor material when Direct Current power is applied to the thermoelectric cooler modules. Heat is absorbed by electron movement at the cold end of the semi- conductor material, transferred through the substance, and released at the hot end. Because the material's hot end is physically connected to a heat sink, heat is transported from the material to the heat sink and ultimately to the environment. A compressor and a working fluid are used in traditional cooling systems, such as those used in refrigerators, to transfer heat. Thermal energy is received and released as the working fluid expands and contracts, changing phases from liquid to vapour and back again. Compared to traditional systems, semiconductor thermoelectric coolers provide a number of advantages. They're solid-state devices with no moving components, so they're tough, dependable, and silent. They don't require ozone-depleting chlorofluorocarbons, making them a potentially greener alternative to traditional refrigeration. They can be far more compact than compressor-based systems. Peltier coolers can provide precise temperature control. In comparison to traditional refrigerators, their efficiency is low. As a result, they're used in medium-temperature cooling applications where their distinct advantages exceed their low efficiency. Although certain large-scale uses (on submarines and surface vessels) have been investigated, Peltier coolers are often utilized in areas where small size is needed and the cooling demands are not too great , such as for cooling electronic component. Whenever direct current passes through a pair of thermocouples with junctions maintained at different temperatures, three effects are observed

- Seebeck effect,
- Peltier effect,
- Thomson effect

II. LITERATURE REVIEW

Thermoelectric technology is currently making its way into the global market, particularly for applications requiring high-quality temperature control, such as precision medical and research devices. Furthermore, some thermoelectric applications are receiving economic interest because to their promising future possibilities. Many researchers designed a thermoelectric refrigerator system for this use, which has the following data.

[1] Design and development of thermoelectric refrigerator

"Mayank Awasthi" and "K V Mali" are the authors of this work. This paper will present an overview of the TER Cooling system, which was conceived and built to provide active cooling with the help of a single stage 12 V TE module. The cooling load estimations for the TER compartment under investigation were first given. In the environmental chamber, simulation testing validated the theoretical design parameters and showed the capability of supplying cooling using a single stage thermoelectric cooler. Because of its high current carrying capacity, thermoelectric refrigerators are not accessible on the open market and cannot maintain cooling in the event of a power failure. The retention time achieved was 52 minutes with the designed module in this project. In order to achieve the higher retention time, another alternative was incorporate. This consists the additional heater on heat sink. The highest retention time achieved was 57 minutes.

[2] Analysis of Thermoelectric Refrigerator with Finned Heat Exchanger

"F. Meng," "L. Chenard," and "F. Sun" are the authors of this paper. This study will provide an overview of both internal and external multi-irreversibility; a developed model of a commercial thermoelectric refrigerator with finned heat exchanger will be produced by integrating finite time thermodynamics with non-equilibrium thermodynamics. Physical qualities, geometrical dimensions, temperature parameters, and flow parameters are all included in the model. When the cooling temperature difference is 10 K, numerical studies and comparative investigation of the performance of a typical commercial water-cooling thermoelectric refrigerator, which consists of 127 thermoelectric elements, show that the maximum cooling load is 2.33 W and the maximum COP of the refrigerator is 0.54. The multi-irreversibility's decreased the maximum cooling load and the maximum COP by 34% and 26%, respectively. Their reversibility analysis shows that there are many factors causing irreversibility's. The thermal resistance of the heat convection between the heat exchanger and the cooling—water has the greatest effect on the device's performance, followed by heat leakage through the air gap of the thermoelectric module, ceramic plates, and thermal resistance of the heat exchanger base, with the thermal and electrical resistance of the conducting strips having the smallest effect. The length and cross-section area of the thermoelectric components can be optimized to improve the device's performance. The maximum cooling load and maximum COP are 95.89 % and 92.88 % of the performance limitations, respectively, when the heat exchanger base is three times the size of the thermoelectric refrigerator's ceramic plate. Not only can the model and calculation approach be used to anticipate the performance of thermoelectric refrigerators, but it can also be used to optimize the heat exchanger of thermoelectric refrigerators

[3] Design of Thermoelectric Refrigeration System "Jaspalsinh B. Dabhi," "Nimesh B. Parmar," and "Dr. Nirvesh S. Mehta" are the authors of this publication. This paper will provide an outline of the COP Increase, which occurs when the current is increased until it reaches a particular value, after which it declines. With increasing input power, the COP decreases. The COP decreases as the temperature difference increases.

[4] Performance Evaluation of a Thermoelectric Refrigerator Thermoelectric cooling has added a new dimension to the cooling challenge, and with the continuous desire for enhanced cooling technologies to improve performance, reliability, and operating cost, cooling may be considered a potential candidate. As a result, a thermoelectric refrigerator is constructed and simulated to keep the enclosure temperature at 4°C. The minimal temperature permissible module power, current equations supplied here can be used to undertake a trade-off analysis to see if thermoelectric argumentation is better than conventional approaches To use these equations, detailed information in terms of the parameters pertaining tothe thermoelectric module under consideration is required, average values of the parameters of Bismuth telluride (Bi2Te3) are used for analysis From the plot of C.O.P against current, the coefficient of performance of such devicesis 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 obtained for a temperature difference of 20oC.

[5] Developments of Thermoelectric Refrigeration "Manoj Kumar Rawat, Himadri Chattopadhyay, and Subhasis Neogi" are the authors of this study. This presentation will provide a comprehensive summary of the research efforts performed by many researchers in the design and development of innovative thermoelectric refrigeration and space conditioning systems. The benefits and cost- effectiveness of thermoelectric cooling systems over traditional cooling systems have also been discussed. At ideal operating circumstances, a temperature reduction of 11oC without any heat load and 9oC with 100 ml of water in refrigerated space at 23oC ambient temperature was found in the first 30 minutes. The designed experimental

thermoelectric refrigeration cabinet had a predicted COP of0.1. According to the available literature, thermoelectric cooling systems are only 5–15 percent as efficient as traditional compression cooling systems, which attain 40–60 percent efficiency. The figure of merit of the thermoelectric material and the efficiency of the heat exchange system are the main limiting factors. Researchers are working hard to produce greater figure of merit thermoelectric materials, which could lead to commercial applications of thermoelectric refrigeration and air conditioning. The compatibility of thermoelectric cooling systems with solar energy also makes them more practical and environmentally friendly.

[6] Design and CFD Analysis of Thermoelectric Cooling System

"V. Rajangam" and "M Venkataramanan" are the authors of this publication. This study will provide an overview of the thermoelectric cooling system design parameters. The goal of the experiment is to reach a temperature of 5 degrees Celsius. By providing suitable boundary conditions, an attempt was made to validate the experimental work with the CFD analysis. To achieve high performance, this work could be enhanced with alternative thermoelectric materials.

[7] Performance Evaluation of a Thermoelectric Refrigerator

Onoroh Francis, Chukuneke Jeremiah Lekwuwa, and Itoje Harrison John are the authors of this paper. This paper gives an overview of a thermoelectric refrigerator, also known as a thermoelectric cooler module or Peltier cooler, which is a semiconductor-based electric component that functions as a small heat pump. When a thermoelectric cooler module is powered by a low voltage direct current (DC) power source, heat is transferred from one side to the other [1]. As a result, one module face will be cooled while the opposite face is heated at the same time. The same fundamental laws of thermodynamics govern both thermoelectric and mechanical refrigerators, and both refrigeration systems, despite their vastly different appearances, operate on the same principles. A compressor in a mechanical refrigeration unit boosts the pressure of a refrigerant and circulates it throughout the system. The refrigerant boils in the chilled chamber, and while converting to a vapour, the refrigerant absorbs heat, making the chamber chilly. The heat absorbed in the chamber is transmitted to the condenser, where the condensing refrigerant transfers it to the atmosphere. A doped semi- conductor material replaces the refrigerant, the condenser is replaced by a finned heat sink, and the compressor is replaced by a Direct Current (DC) power source in a thermoelectric cooling system. Electrons travel via semi-conductor material when Direct Current (DC) electricity is applied to the thermoelectric cooler modules. Heat is absorbed by electron movement at the cold end of the semi-conductor material, transferred through the substance, and released at the hot end. Because the material's hot end is physically connected to a heat sink, heat is transported from the material to the heat sink and ultimately to the environment

III. MATERIAL SELECTION

Initially, we consider three potential materials for the cabinet's construction. Aluminum, wood, and plastic polymer are the three (PP material). We chose wood over the other two materials because it has a lower thermal conductivity than Al and provides a better insulating effect and rigid support than PP. The cabinet's exterior sheet is made of wood, while the internal compartment is constructed of PP, which is beneficial because it has a low thermal conductivity. In between these two materials one insulating material is used named as glass wool. The main function of this glass woolmaterial is to prevent heat exchange between surrounding and inner portion of cabinet.

Sr. No.	Material	Thermal conductivity (w/mk)
1	Aluminum	202
2	Stainless Steel	43
3	Wood	1.11
4	Plastic polymer	0.0049

We chose wood sheets for the cabinet's construction and plastic polymer for the interior insulation. We started by cutting the wood sheet for the interior cabinet according to the design calculations and putting it together. It is made with a large volume of 23 litres and parameters that must be met during the assembly of all units. We use plastic polymer sheet as an insulating material and cut it to fit the dimensions for a better cooling effect. We employ air foil paper that is adhered to a plastic polymer sheet to reduce heat loss.

Then we proceed to the production of the outside cabinet, in which we cut the wood sheet to the dimensions set in the design calculation, taking into account the insulation between the inner and exterior cabinet. It assembles the inner and outer cabinets in a right manner and insulates them with polyurethane foam to reduce heat loss from the inner cabinet, which has a lower temperature than the ambient temperature. We chose polyurethane since it is a better insulator for our application.

To assemble the heat sink, fan, and module, we cut a square hole from the outer cabinet to the inner cabinet that is the same size as the heat sink. One item, consisting of the heat sink, module, and fan, is assembled and installed in the cabinet with the square holes. Thermal grease is placed between the heat sink and the module to improve contact. The entire unit is screwed to the cabinet. Because it converts AC current to DC current, we employ a DC power supply as a switch mode power supply (SMPS). The module is powered by a DC power source with a 6 amp and 12 volt current, while the fan is powered by a DC power supply with a 0.6 amp and 12 volt current. Blower is used to dissipate heat from the hot side of the heat sink, which runs on DC current as well. All units are connected to SMPS through wire and SMPS is connected to main power supply through wire.

VIII. CONCLUSION

We examine the introduction of our project as well as the impact of global warming caused by the vapour absorption and vapour compression cycle, and as a result, we create a thermoelectric refrigerator with three modules. This idea uses thermoelectric refrigeration to provide an alternative method of cooling the bottles. It can reach temperatures of (Ti= °c) on the chilly side. We talked about how the project works, the materials required to make the cabinet, and the components we'll be using in our project, as well as how this project will function efficiently. We also designed a cabinet and purchased the required module, fans, and heat sinks to ensure that our system is properly cooled. When we ran our system with trip time, we received the best results. We have a better cooling impact if we trip our system for a while. As time passes, the module's performance deteriorates. When we trip the module, however, the module's performance restarts, resulting in a better cooling effect. So, if we employ an automatic tripping system, the refrigerator's performance will improve as well. We talked about why we use thermoelectric refrigerators and how little of an impact they have on global warming. We also consider how to improve the cooling impact and reduce the prior remedies that occurred in the TER system.

Consider the future potential of thermoelectric refrigerators. If we use our TER system, pollutants such as CFC, HCFC, and CO2 will not escape into the atmosphere, thereby reducing global warming. We will also learn how to reduce the impact of global warming, making this system environmentally friendly.

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