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THERMOELECTRIC COOLING SYSTEM USING PELTIER EFFECT

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Abstract: The continuous advancement in science and technology has led to the development of various systems capable of producing refrigeration effects. Conventional refrigerators commonly use refrigerants such as Ammonia and R12, which are harmful to the environment. This project proposes the development of compact cooling units designed for applications such as medicine storage in medical shops and hospitals, preservation of food for patients, and use in small pan-shops, hotel rooms, and guest houses. These units utilize thermoelectric modules based on the Peltier effect, thereby eliminating the need for harmful refrigerants and mechanical components like compressors and evaporators. This eco-friendly refrigeration approach not only helps in protecting the ozone layer but also reduces the overall cost of the refrigerator. The system is capable of effectively cooling a storage volume of up to 48 liters.

Keywords: Portable, Eco-Friendly, Thermoelectric Cooling, Peltier Effect, Refrigerant-Free

I. INTRODUCTION

The primary function of a refrigerator is to keep food cold and fresh for extended periods by slowing down the growth and activity of bacteria, which thrive less in cooler temperatures. As a result, refrigeration significantly reduces food spoilage. Various refrigeration systems are designed to achieve this cooling effect, one of which is thermoelectric cooling, which operates based on the Peltier Effect.

The main objective of our project is to generate a cooling effect using a Peltier Module. This approach eliminates the need for conventional mechanical components and harmful refrigerants commonly used in traditional refrigeration systems. By avoiding greenhouse gases and environmentally hazardous materials, thermoelectric refrigeration presents a more sustainable alternative.

This not only allows for efficient cooling but also supports environmentally friendly and compact refrigeration solutions.

Principal of Peltier Effect

The Peltier effect occurs when an electric current flows through a junction between two dissimilar conductive materials, causing heat to be either absorbed or released at the junctions. Specifically, one junction may heat up while the other cools down.

The amount of heat transferred depends on the Peltier coefficients of the materials involved and the magnitude of the electric current. This effect allows for the pumping of heat from one side of a thermoelectric device to the other, making it useful in applications where silent, compact, and reliable cooling is needed.

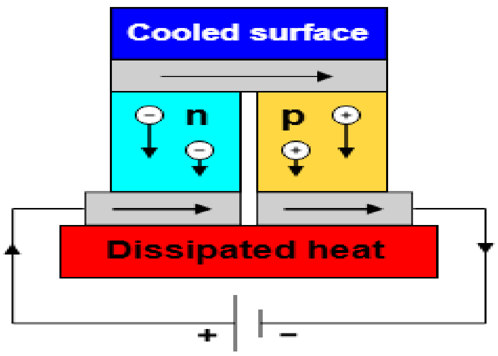

Fig: Peltier Effect

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II. LITERATURE REVIEW

Tarun Prasad Sonwani et al. (May 2020) [5]:
This study highlights the usefulness of a thermoelectric refrigeration system during travel, particularly for transporting medicines and maintaining the temperature of food items. The system ensures that the temperature of stored items remains stable throughout the journey.

Muhammad Fairuz Remeli et al., ICMER (2019) [6]:
The authors conducted a validated theoretical analysis to predict optimal parameters for thermoelectric coolers. These include selecting suitable heat sinks, determining appropriate cooler sizes, estimating cooling temperatures, and evaluating system performance through the coefficient of performance (COP).

Manish Nair and Brajesh Tripathi (April 2019) [7]:
This conference paper investigates the performance of thermoelectric refrigerators under two different conditions. The findings indicate reduced power consumption and an eco-friendly operation compared to conventional refrigeration systems, while delivering a comparable cooling effect.

Prof. Rajendra P. Patil et al. (May 2017) [4]:
This paper presents a comprehensive review of the developments in thermoelectric refrigeration (TER) systems. The study concludes that TER systems are a novel and promising alternative to conventional refrigeration technologies, due to their efficiency and environmental benefits.

Rakesh B. K. et al. (May 2016) [3]:
The system produced a cooling effect of approximately 12 W, demonstrating its potential for small-scale refrigeration applications.

III. SELECTION OF TEC MODULE

It is necessary to compute the cooling load Qc. The product of the water's mass flow rate, specific heat, and temperature differential yields the cooling load, or Qc. The heat sink, which is at room temperature, is connected to the hot side of a TEC Module for refrigeration applications. The temperature on the cold side falls below the surrounding air temperature. Multiple coolers can be staged or cascaded together for lower temperatures in certain applications, however this results in a significant decrease in overall efficiency (COP).

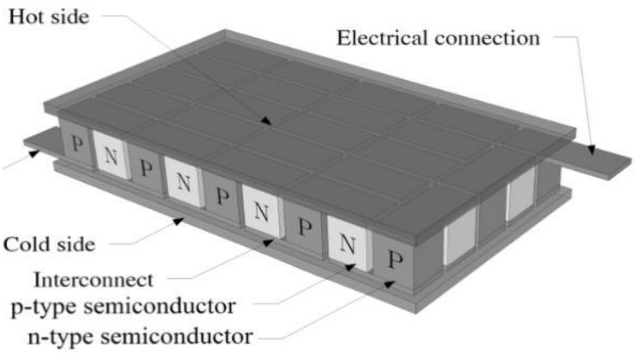
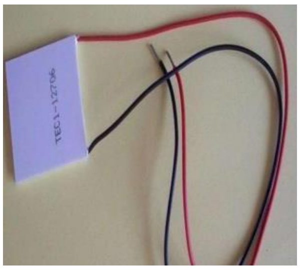


Fig: TEC Module

IV. COMPONENT REQUIREMENTS

1 Thermoelectric Module



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Material:
The TEC1-12706 module is made using Bismuth Telluride (Bi_2Te_3), which is the most commonly used material for thermoelectric modules, especially for near-room-temperature applications. This material is used for both P-type and N-type semiconductor legs.
Model Number Breakdown – TEC1-12706:
"127" indicates the number of thermocouples (or thermoelectric junctions), i.e., 127 pairs of P-type and N-type semiconductor elements.
"06" typically refers to the maximum current rating, which is about 6 Amps.

Working Principle:
The module works on the Peltier Effect — when DC current flows through the module, it causes heat to move from one side of the module to the other:
One side becomes cold (used for cooling),
The other side becomes hot (must be heat-sinked effectively to maintain performance).

2. Heat Sink with Fan:

Heatsink Size = 85.4x68.3x41.5mm
Fan size = 70 x 70 x 25 mm
Fan speed = 3300 ± 10% RPM
Bearing type = Porous bearing
Rated voltage = 12V DC
Noise = 19dBA (min)

3. Insulating Materials
-To reduce the overall production cost of the final product, more affordable materials were selected for the project. The three materials used are Polystyrene, Mild Steel Sheet, and Glass Fiber, with their respective properties detailed in Table 5.2.
-To achieve a cooling temperature of 200 K in the refrigerator unit, a Peltier module is employed in conjunction with a fan-equipped heat sink to effectively dissipate heat and maintain system performance.

Fig: Insulating Materials

4. Thermal Paste (Thermal Grease)
1)Viscosity=250 Ns/m² ,Indicates the thickness and flow resistance of the paste. High viscosity helps it stay in place.
2)Specific Gravity=2.77 (at 25°C),Denotes the density compared to water. A higher value means it's relatively dense.
3)Thermal Conductivity= 2.9 W/m·K ,Measures the ability to conduct heat. A higher value allows better heat transfer.

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4)Thermal Resistance=17 mm²·K/W,Represents the material's resistance to heat flow. Lower is better for cooling performance.
5)Operating Temperature=-50°C to +120°C ,The temperature range within which the paste remains effective and stable.

5)Specification of TEC

-PRODUCT= TEC-12706
-OPERATIONAL VOLTAGE = 12V DC
-CURRENT MAX = 6 Amp
-VOLTAGE MAX = 15.4 V
-POWER MAX= 92.4
-POWER NOMINAL= 60
-COUPLES= 127

V. RESULT

An analysis The cold side of the thermoelectric module (TEC-12706) was used to cool the interior of the refrigerator cabin, and temperature changes were monitored using a digital thermometer. To facilitate effective heat dissipation, the hot side of the module was mounted onto an aluminum heat sink with a fan to enhance thermal transfer.

A system cool-down test was performed to validate the refrigerator's functionality. During this experiment, the temperature inside the cabin was recorded over a period of time after the system was powered on. The test demonstrated a noticeable decrease in internal temperature, confirming that the thermoelectric module was effectively transferring heat from the cold side to the heat sink on the hot side. The results verify the operational capability of the thermoelectric refrigerator under the given conditions.

VI. CONCLUSION

The refrigerator cabin was successfully cooled using a thermoelectric refrigeration system incorporating three TEC (thermoelectric cooling) modules, each consuming 72 W of power. Thermoelectric refrigeration has demonstrated cost-effectiveness for applications operating within a temperature range of 25°C to 500°C, particularly when managing light and steady thermal loads. The system's performance can be further enhanced by adopting a cascaded module configuration, thereby extending its operational range.

Experimental results from the cool-down test indicate a Coefficient of Performance (C.O.P.) of 1.5. This value suggests room for improvement, particularly through enhanced fabrication techniques and improved thermal insulation. Furthermore, the system's portability and low maintenance requirements make it highly suitable for integration with renewable energy sources, enabling its use in off-grid or remote areas. This makes the thermoelectric refrigerator an effective solution for cooling electronic components and other low-load applications in resource-limited settings.

REFERENCES

[1]. Sujith G, Antony Varghese, Ashish Achankunju, Rejo Mathew, Renchi George, Vishnu V, "Design and Fabrication of Thermoelectric Refrigerator with Thermosiphon System", Volume- 2, Issue-4, April 2016.
[2]. Manish Nair and Brajesh Tripati, Conference: International Conference on Cutting Edge Technologies "Project: Experimental Studies on Thermoelectric Refrigeration", Greater Noida, UP.
[3]. Tarun Prasad Sonwani, Ashish Kumar, Gulab Chand Sahu, Kundan Lal Sahu, "Thermoelectric Refrigerator Using Peltier module", Volume: 07 Issue: 05, May 2020
[4]. Manoj Kumar Rawat, "A review on developments of thermoelectric refrigeration and air conditioning systems: a novel potential green refrigeration and air conditioning technology", Feb 2013, Int. Journal, ISSN 2250-2459, PP 362-367.
[5]. Prof. Rajendra. P. Patil, Pradhyumna Suryawanshi, Akshay Pawar, Avdhoot Pawar "thermoelectric refrigeration using peltier effect", IJESTR, May 2017,