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An Alternative To Conventional Refrigeration Method

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Abstract: This study introduces thermoelectric refrigeration, a radical non-conventional technique of refrigeration that is more efficient than current refrigeration technology. The TEC module and the components utilised in the refrigerator are investigated, and the coefficient of performance (COP) for single and multistage modules is calculated. It is concluded that by substituting a multistage TEC module for a single stage TEC module, the COP of the single stage TEC module can be enhanced.

1. Introduction

Because food is the most basic human requirement, humans devised refrigeration to keep our food and beverages safe from outside pollution. We have many sorts of refrigerators where this technique is performed, and we are all familiar with how these devices work. However, new technology has emerged that can be significantly more efficient than cyclic refrigeration: "THERMOELECTRIC REFRIGERATION."

PrakashPanwar [1], through his paper compels us to adopt renewable energy resources that are less expensive and have a lower environmental impact. The adoption of highly mechanised machines in the cooling and heating industries has had a significant impact on global energy consumption. This is causing major global warming, which is causing ozone layer depletion, rapid climate change, and temperature rise and decline in some parts of the world. Modern technology and companies are now being compelled to address such concerns.

N. Ortega [2] also raises these concerns and provides a solution to the situation.He emphasised the importance of harvesting solar energy for both commercial as well as non-commercial purpose. Vijay Kumar [3], statedthe application of desiccant wheel technology for solar powered air conditioning is a relatively new topic of attention. The basic ideas are described, and past experience is assessed. At Warwick, a briefing on the project Carbon-ammonia refrigerators driven by the heat of steam condensing in a thermosyphon heat pipe was given.

VahidVakiloroaya [4],has conducted an analysis and performance evaluation of a vapor-absorption cooling system that was totally driven by a renewable energy source, solar radiation, and does not require any water storage or auxiliary heat exchangers. To assure performance, the 6 kW Li-Br water system was built and tested.Their testing results demonstrate the proposed system's technological potential in meeting air-conditioning demand while directly addressing critical issues like power consumption and greenhouse gas emissions.

We attempted to provide a novel form of refrigeration that is more sustainable and efficient than the existing refrigeration methods now available. The publication is further divided into sections, with section 2 outlining the methodology and section 3 giving the findings of the trials. The drawn conclusion has finally been stated in section 4.

2. Methodology

2.1Thermoelectric effect

Thermoelectric effect is the direct conversion of temperature variations to electric voltage and vice versa. It includes three distinct effects: the Seebeck effect, the Peltier effect, and the Thomson effect.Seebeck effect is the conversion of heat directly into electricity at the junction of different electrical conductors, named after Baltic German physicist Thomas Johann Seebeck. The two junctions are kept at different temperatures and the voltage generates in the closed circuit. Alternatively in the Peltier effect the voltage difference at the junction creates a temperature difference between them.

QC or QH = □□x I = (□T) x I (1)

where, "β" is the differential Peltier coefficient between the two materials A and B (volts). "I" represents the current flow (Amperes). Q_C and Q_H are the rates of cooling and heating, respectively (watts).

Whereas the Thompson effect occurs when an electric current is carried through a conductor with a temperature gradient along its length, heat is either emitted or absorbed by the conductor. The direction of the electric current and the temperature gradient determine by whether the heat is absorbed or released.

2.3 Peltier effects on various semiconductors

When a voltage source is applied to an N-type semiconductor, electrons are dragged away by the negative pole and transferred to the positive pole; electrons at the Fermi level go towards the positive terminal, creating heat and holes. Heat is absorbed at the negative terminal and rejected near the positive terminal at the junction.

In case of when a direct current is passed through the circuit, the holes are attracted to the source's negative terminal. Holes are drawn to the negative terminal as heat is released. Holes in the conduction band absorb heat from the junction and migrate to the Fermi level due to the steady flow of current.Heat is absorbed at the junction near the positive terminal and rejected at the junction near the negative terminal in a P-type semiconductor.

A series circuit can be made by arranging N and P-type pellets in a "couple" and connecting them with a plated copper tab. This keeps all heat travelling in the same direction. By establishing the circuit depicted in fig.1, it is possible to emit heat to one side and receive heat from the other. We can also construct the thermoelectric module by connecting numerous p-n type semiconductors in a straight line.

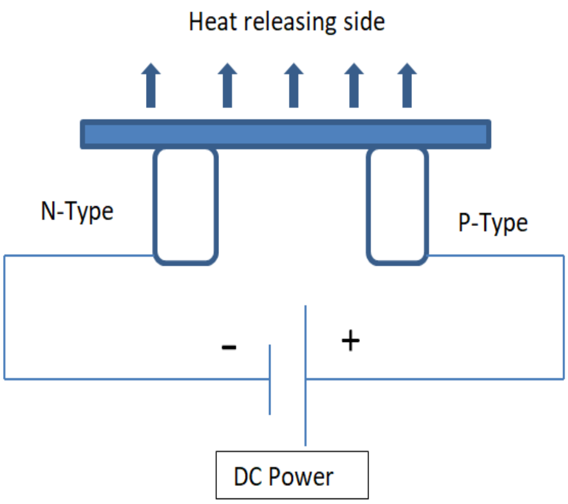

Figure 1. Couple arrangement of N and P-type pellets

2.4 Co-efficient of Performance (COP)

The coefficient of performance (COP) is defined as the ratio of the desired result to the input used to obtain that effect. In refrigeration this desired effect is the heat extracted (or temperature difference) and for the purpose there consumption of power. These thermoelectric junctions have around 1/4th the COP when compared to Vapour Compression Refrigeration (VCR) and they give around 10% -15% efficiency of an ideal Carnot Cycle Refrigeration, compared to 40-60% on a normal compression-cycle system. COP of the single stage TEC is lower than that of the VCR and multistage TEC.

$$\text{COP} = \frac{\text{cooling Capacity (Q)}}{\text{Power Consumption (W)}} \tag{2}$$

2.5Component

2.5.1 Thermoelectric Module (TEM):

It is the main component of the refrigeration as these are the Peltier effect-powered solid-state heat pumps. The two dissimilar conductors are doped in ceramic coating, which generates the cooling effect.

2.5.2 Heat Sink and Heat sink Fan

A heat sink is a component that functions as a heat exchanger, transferring heat produced by an electric or mechanical device into a liquid coolant in motion. The transferred heat flows with the coolant, allowing temperature adjustment of the device. And, similar to the fan, the heat sink itself might become hot; therefore this device is installed on top of it to keep the good convection.

2.5.3 Thermometer: For Output Display

The thermometer is required to determine the current temperature of this equipment. So, we utilise a digital thermometer to determine the temperature within the refrigerated chamber. It has a probe that is inserted within the chamber and senses the temperature, which is then displayed on the digital display.

2.5.4 Power source and thermal box

Power source is utilised to power the refrigeration process by sending current to the TEM and heat sink fans. The thermal box can be formed of any material that will maintain the efficacy of the refrigeration. The effectiveness is also affected by the casing material.

2.6 Specification of the refrigerator

We used the TEM module (model TEC1-12706/12715) for our investigation. The maximum voltage supply was around 15.4V, and the maximum current was approximately 4.5A. We were able to accomplish maximum cooling of 92W using a typical voltage of 12V battery with an internal resistance of 2.00 Ohm +/- 5%.

3. Result

From experimental results, we discovered that the COP of the TEC module can be increased. Reference values are taken from Refrigeration and Air Conditioning by Arora **[5]** for the experiment. Energy supplied can be calculated from formula:

$$\text{Energy supplied} = S.I.\,(T_h - T_c) + I.I.R \tag{3}$$

Heat absorption is given by:

$$Q_L = -\left[SIT_c - \frac{1}{2}\,.\,I.\,I.\,R - k(T_h - T_c)\right] = 58.21185 \tag{4}$$

From the 1st law of thermodynamic we get the work done as Q_H - Q_L which gives-

$$W = SI(T_h - T_c) + I.I.R = 103.13395 \quad (5)$$

From (2) we get COP for the single-stage TEC module which is equal to 0.564.

We applied multistage TEC to enhance the COP of the TEC module. We used the same criteria as in the single stage case for this reason. Using equation 4 and 5, the values of $Q_L$and W are found to be 68.74455 and 56.57515 Joules, respectively. Equation (2) yields a COP of 1.22, which is higher than the single-stage TEC modules, so we may use the multi-stage to produce a larger COP if necessary.

4. Conclusion

The modules described in this work provide simplified spot-cooling to provide accurate temperature control while preserving the peak performance of any device in which they are employed.It has the ability to replace the current cooling refrigerators since it can address both cooling and heating problems. This is an entirely environmentally beneficial project system that, if it were to be launched with all necessary equipment, would be recognised by the entire globe. It is an ideal replacement for conventional refrigeration, with advantages such as noiseless operation, the lack of flammable and hazardous refrigerants, and the greatest ability to be employed in moveable solutions and flexibility of usage due to its optimised control.

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