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Construction and Evaluation of Performance of a Refrigeration System Based on Thermoelectric Principles With The Use of Thermoelectric Cooling (Tec) Modules

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ABSTRACT A Thermoelectric Refrigerator works on the principle of Peltier effect- the presence of heating or cooling at an electrified junction of two different conductors. The production of heat at one junction and the absorption of heat at the other junction of a thermo electric module when current is passed around the thermocouple circuit, the heat produced is additional to the heat arising from the resistance of the wires. This effect is used to cool as well as warm the same chamber at required temperature point set by user with the use of thermostat. This system is supported by a radiator for better and fast heat transfer outside the chamber and cooling fans inside the chamber. A pump is also used to circulate the coolant between fluid blocks that are attached to modules & radiator. All the components are supported by a power supply unit which takes AC current 50hz, 230v and gives DC current suitable to each component.

KEY WORDS: Peltier coolers, Thermosiphon,TEC,

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 vapour and back, respectively. Semiconductor thermoelectric coolers (also known as Peltier coolers) offer several advantages over conventional systems. They are entirely solid-state devices, with no moving parts; this makes them rigid, reliable, and quiet. They use no ozone-depleting chlorofluorocarbons, potentially offering a more environmentally responsible alternative to conventional refrigeration. They can be extremely compact, much more so than compressor-based systems. Precise 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.

The objectives of this study is design and develop a working thermoelectric refrigerator interior cooling volume of 40L that utilizes the Peltier effect to maintain a selected temperature from 5 °C to 35 °C. The design requirements are to cool this volume to temperature within a time period of 3 hours and provide retention of at least next one hour. The design requirement, options available and the final design of thermoelectric refrigerator for application are presented.

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II. BASIC PRINCIPLES OF THERMOELECTRICS

Thermo electricity is based upon the following basic principles consideration of which is essential for the project Seebeck effect,Peltier effect,Thomson effect,Joule effect&Fourier effect

A Seebeck effect

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.

$$\Delta V \propto \Delta T$$

B. Peltier Effect 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.

C Thomson effect The Thompson effect governs the cooling and the heating of a material carrying a current and subjected to a temperature gradient. It states when an electric current is passed through a conductor having a temperature gradient over its length, heat will be either absorbed by or expelled from the conductor.

$$\frac{dQ}{dx} = \tau I \left[\frac{dT}{dx}\right]$$

D.Joule Effect

When electrical current I flows through a conductor of resistance R, there is dissipation of electrical energy. This is well known joule effect. The energy dissipated is given by;

$$Q_j = I^2 R$$

E. Fourier Effect

If the ends of any element are maintained at different temperatures, the heat transfer from the hot end to the cold end is related by; $Q_{COND} = U(T_h - T_c)$; $U = \frac{kA}{L}$

The cooling and heating effects due to thermoelectric effect are given by;

$$Q_c = \alpha_{ab} I T_c$$
$$Q_h = \alpha_{ab} I T_h$$

III. BASIC MECHANISM OF THERMOELECTRICS

A. Peltier structure A typical thermoelectric module consists of an array of Bismuth Telluride semiconductor pellets that have been carrier–either positive or negative–carries the majority of current. The pairs of P/N pellets are configured so that they are connected electrically in series, but thermally in parallel. Metalized ceramic substrates provide the platform for the pellets and the small conductive tabs that connect them.

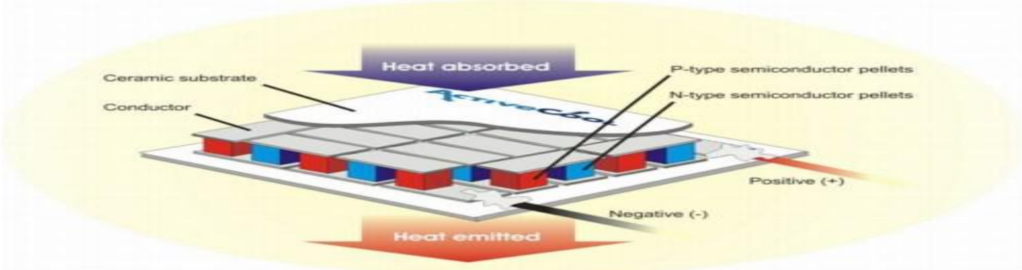

Figure 3.1.1 Peltier structure

The semiconductor in this examples N type (doped with electrons) therefore, the electrons move towards the positive end of the battery.

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When a p type semiconductor (doped with holes) is used instead, the holes move in a direction opposite the current flow. The heat is also transported in a direction opposite the current flow and in the direction of the holes. Essentially, the charge carriers dictate the direction of heat flow.

B. Method of Heat Transfer

Electrons can travel freely in the copper conductors but not so freely in the semiconductor. As the electrons leave the copper and enter the hot-side of the p-type, they must fill a "hole" in order to move through the p-type. When the electrons fill a hole, they drop down to a lower energy level and release heat in the process. As the electrons leave the copper and enter the hot-side of the p-type, they must fill a "hole" in order to move through the p-type. When the electrons fill a hole, they drop down to a lower energy level and release heat in the process. Next, the electrons move freely through the copper until they reach the cold side of the n-type semiconductor. When the electrons move into the n-type, they must bump up an energy level in order to move through the semiconductor. Heat is absorbed when this occurs. Finally, when the electrons leave the hot-side of the n-type, they can move freely in the copper. They drop down to a lower energy level and release heat in the process.

C. Electrically and thermally parallel multiple pellets

To increase heat transport, several p type or n type thermoelectric (TE) components can be hooked up in parallel. However, the device requires low voltage and therefore, a large current which is too great to be commercially practical.

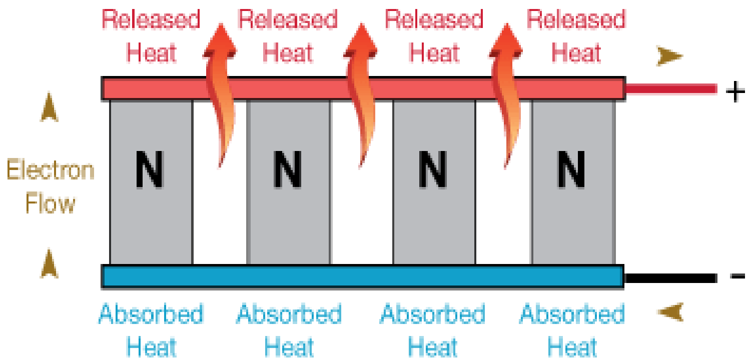

Figure 3.3.1 Electrically and thermally parallel multiple pellets

D. Thermally parallel and electrically in series multiple pellets

The TE components can be put in series but the heat transport abilities are diminished because the inter connections between the semiconductor creates thermal shorting.

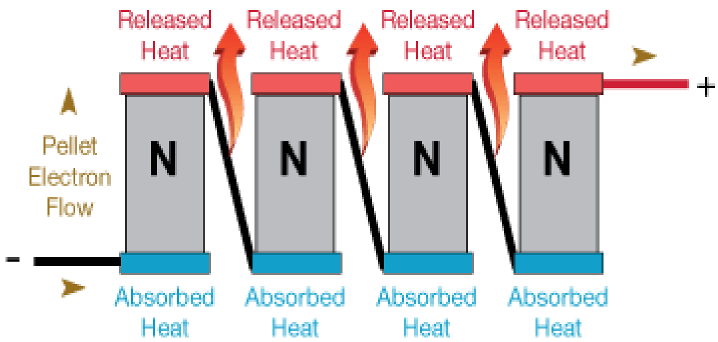

Figure 3.4.1 Thermally parallel and electrically in series multiple pellets

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E. n and p- type Peltiers

The most efficient configuration is where a p and n TE component is put electrically in series but thermally in parallel. The device to the right is called a couple. One side is attached to a heat source and the other a heat sink that convects the heat away. The side facing the heat source is considered the cold side and the side facing the heat sink the hot side. Between the heat generating device and the conductor must be an electrical insulator to prevent an electrical short circuit between the module and the heat source. The electrical insulator must also have a high thermal conductivity so that the temperature gradient between the source and the conductor is small. Ceramics like alumina are generally used for this purpose.

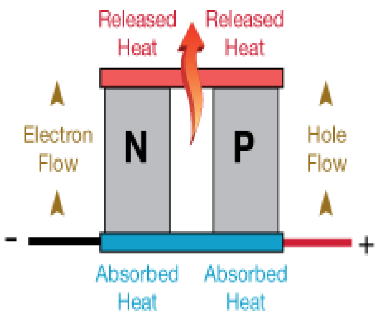

Figure 3.5.1 n and p- type Peltiers

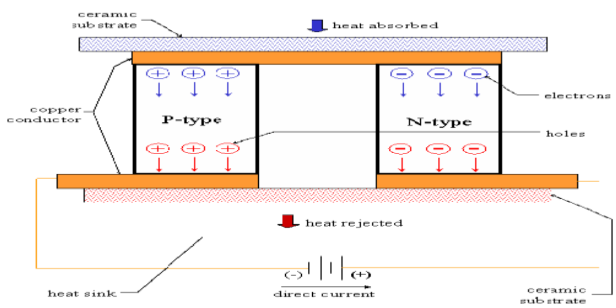

Figure 3.5.2 n and p- type peltiers current flow

IV. THERMOELECTRIC MATERIALS

A Thermoelectric materials

Semiconductors are the optimum choice of material to sandwich between two metal conductors because of the ability to control the semiconductors' charge carriers, as well as, increase the heat pumping ability. The most commonly used semiconductor for electronics cooling applications is Bi2Te3 because of its relatively high figure of merit. However, the performance of this material is still relatively low and alternate materials are being investigated with possibly better performance. Alternative materials include:

- Alternating thin film layers of Sb2Te3 and Bi2Te3.
- Lead telluride and its alloys.
- SiGe.
- Materials based on nanotechnology.

A plot of various p-type semiconductor figures of merit times temperature vs. temperature are shown. Within the temperature ranges concerned in electronics cooling (0-200^{0}C) Bi2Te3 performs the best.

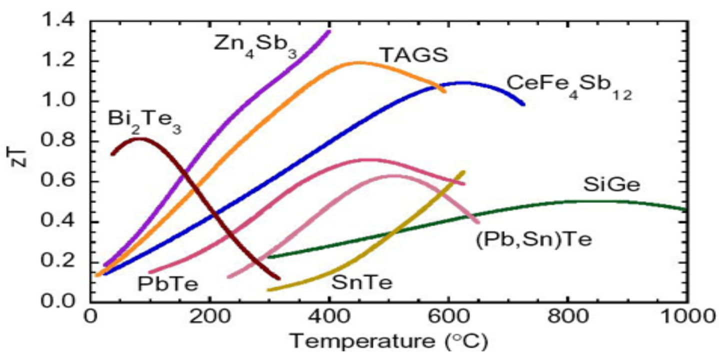

Figure 4.1 graph 1 Similar results are shown for n-type semiconductors below

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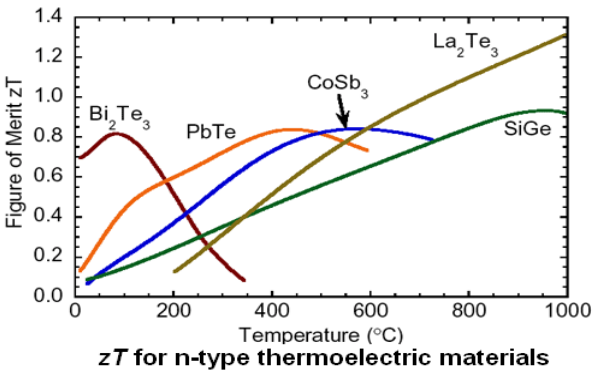

Figure 4.2 graph 2

B. Bi_2Te_3 Properties

Below is a plot of the figure of merit (Z), Seebeck coefficient, electrical resistivity, and thermal conductivity, as a function of temperature for Bi2Te3. Carrier concentration will alter the values below.

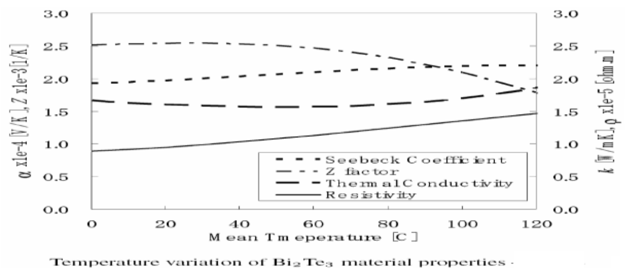

Figure 4.2.1 graph 3

Bi_2Te_3 figure of merit as a function of tellurium concentration is given below.

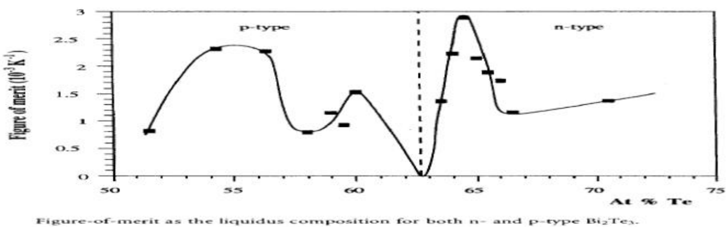

Figure 4.2.2 graph

Specification of TEC

Product	TEC-12706
Operational voltage	12V DC
Current max	6Amp
Voltage max	15.4V

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Power max	92.4
Power nominal	60
Couples	127
Dimensions	40×40×3.5 mm

V. DESIGN FOR THERMOSIPHON WATER COOLING SYSTEM

Thermosiphon is a cooling technique used in early automobile engines. In this system, circulation of water is obtained from the difference of densities of hot and the cold regions of cooling water. In this project this system consists of an Aluminium tank, a radiator and a cooling fan. The hot side of the TEC is attached to one side of the Al tank which contains water. The heat rejected from the TEC is absorbed by the coolant liquid, its density gets vary. This variation of density leads to the circulation of coolant in the system. The hot coolant which reaches the radiator is cooled by forced convention by the cooling fan in radiator. This system is provided outside the cooling space. The volume of coolant needed to dissipate the heat can be found by the equation, $Q = m C_p \Delta T$

Where Q is the amount of heat to be dissipated, m is the mass of water, C_p is the specific heat capacity of water and ΔT is the temperature difference.

Volume of water = 6.199×10^{-6} m^3 i.e., 6.199×10^{-6} m^3 of water is needed to remove 385W of heat.

Fabrication of the Cabin

Cabin Walls- The rectangular double walled cabin is made using hylam sheets of 3mm thickness. The Designed dimension (40cm x 40cm x 40cm), of the cabin is obtained by performing suitable operations on the sheet. All the sheets and insulating material within the sheets are aided by aluminium foiled lining. Rubber beading for the door way is given to prevent the heat leakage, To prevent radiation heat transfer and to give better surface finish, the outside of the cabin is also aided by further lining.

Insulation- Thermocol slabs with 5 mm thickness which is having a density of $10 kg/m^3$ were used to obtain the required thermal insulation. The slabs having a thermal conductivity of 0.08 W/mK, were pasted inside walls of the cabin. A rubber beading is provided to prevent leakage at the door.

Performance of the thermoelectric refrigerator The active heat load is expressed as the equivalent cooling power that the unit will need to provide when the sample at ambient temperature is placed in the container. It was decided that two litre of water at room temperature took as the test sample .When the designed thermoelectric refrigerator was tested, it was found that the inner temperature of the refrigeration area was reduced from 33.1 ˚C to 13.2 ˚C in approximately 450min. Coefficient of performance of the refrigerator (COP_R) was calculated. Water is used in place of vaccine for taking measurements and calculation. In these calculations, the properties of water are (density = 1 kg/L and C_p = 4187J/kg).V = 2.0 L.

Coefficient of performance of the refrigerator (COP) is

$$COP_R = \frac{Q_{cooling}}{W_{input}}$$

$Q = m C_p \Delta T$

Mass of coolant, m = density x volume = 2 kg

Total heat removed from the coolant = 166642.6 J

$$Q_{cooling} = \frac{Q}{\Delta T} = \frac{166642.6}{450 \times 60} = 6.17W$$

Power given to the system for working,

$$W_{iput} = (V \times I) + fan\ input = (12 \times 4) + 2 = 50W$$

Coefficient of performance of this refrigeration system is given by,

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$$COP = \frac{Q_{cooling}}{W_{input}} = \frac{6.17}{50} = 0.124$$

COP of this refrigerator system is lower than conventional refrigerator. This is because the efficiency of thermoelectric modules is usually four times lesser than that of vapour compression system. And the heat leakage is also detected through doors; this too reduces the efficiency of the system. To increase heat transport, several p type or n type thermoelectric components can be hooked up in parallel.

VI. 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 light heat load to lower its temperature to 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. This is one of the advantageous project which uses low power to drive refrigerator. This project work has provided us an excellent opportunity and experience, to use our limited knowledge. 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. Cascaded module architecture has defined new limits for its application. Moreover recent breakthrough in organic molecules as a thermoelectric material assure an excellent future for TER. Integration of renewable energy as power source this refrigerator can be used for remote rural places where there is no electric supply.

REFERENCES

[1] Manoj S. Raut, Dr.P. V. Walke, "Thermoelectric Air Cooling For Cars", International Journal of Engineering Science and Technology (IJEST), Vol. 4 No.05 May 2012 ,ISSN : 0975-5462.

[2] Mr. Swapnil B. Patond," Experimental Analysis of Solar Operated Thermo-Electric Heating and Cooling System", International Journal of Engineering Trends and Technology (IJETT) – Volume 20 Number 3 – Feb 2015 , ISSN: 2231-5381.

[3] MayankAwasthi and K V Mali, "Design and development of thermoelectric refrigerator", Int. J. Mech. Eng. & Rob. Res. 2012, Vol. 1, No. 3, October 2012, ISSN 2278 – 0149.

[4] Sabah A. Abdul-Wahab , Ali Elkamel b, Ali M. Al-Damkhi , Hilal S. Al-Rubai'ey, Abdulaziz K. Al-Battashi , Muhammad U. Chutani (2009), Design and experimental investigation of portable solar thermoelectric refrigerator;An International Journal for Renewable Energy.

[5] Dai YJ, Wang RZ, Ni L;. Experimental investigation and analysis on a thermoelectric refrigerator driven by solar cells. Sol Energy Mater Sol Cells 2003.