Experimental analysis of thermoelectrical cooling system with various TEC materials

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Abstract— In the field of military and medical science there are refrigerators used to cool samples or specimens for preservation. They include refrigeration units for storing blood plasma and other blood products, as well as vaccines and other medical or pharmaceutical supplies. They differ from standard refrigerators used in homes or restaurant because they need to be very hygienic and completely reliable. However, in case of transportation of component from one place to another place there is no refrigeration system. Due to such problem, portable refrigeration system is to be used. Number of insulin have low temperature range and have very high cost such insulin should store at less temperature. In case of emergency transportation of insulin from medical to hospital, such system is used. It may be implementing in medical field. The present work consists of design and development of portable refrigeration system using thermoelectrical system on principle of peltier effect, which is economical for people.

***Keywords*:** Refrigeration, Thermoelectrical system, peltier effect.

I. INTRODUCTION

Refrigeration is the process of removing heat from a substance for lowering the temperature. Refrigeration is related to the demand for cooling foodstuffs and many other commodities as a normal part of commercial domestic life. By using vapor compression, absorption or thermoelectric refrigeration system refrigeration can be best alternative. In vapor compression Refrigeration, cooling systems such as those utilize a compressor and a working fluid as a refrigerant to transfer heat. Thermoelectric Cooling System has advantages over conventional systems. They are having no moving parts and in solid state, due to that they are reliable and easy in working principle. Thermoelectrical cooling system has easy to vary cooling effect by varying input Voltage and Current. Temperature control can be ± 0.1 °C in this system. By using three TEC modules like Bismuth telluride (12706), Lead telluride (12703) and silicon Alumina (12710) we can select optimize result material.

II. LITERATURE REVIEW

R. Saidur, H.H. Masjuki, M. Hasanuzzaman, T.M.I. Mahlia, C.Y. Tan, J.K. Ooi and P.H. Yoon they have studied that, the development stages and performance of a solar powered thermoelectric refrigerator. It is carried out by installing a conventional thermoelectric refrigerator in a standalone photovoltaic system for household usage. This photovoltaic driven refrigerator is powered by a field of solar panels, a battery bank, a solar charge controller, and an inverter. In this work the output power of the photovoltaic system and the capability of the battery bank are determined. A compact thermoelectric refrigerator of 22 watts is applied to be investigated in respect to cooling effect produced. To make the device portable, daytime use and night time use of the refrigerator are treated in different ways. The effect of door-opening upon the cooling temperature produced by the photovoltaic driven thermoelectric refrigerator is investigated too. In order to efficiently operate this solar powered refrigerator, the sizing of this stand-alone photovoltaic system and the optimum tilt angle of the photovoltaic array must firstly be determined to maximize the electricity generation for matching the load requirement. [1]

Manoj Kumar Rawat, LalGopal Das, Himadri Chattopadhyay and Subhasis Neogi they have studied that,the Researchers are continuously giving efforts for development of eco-friendly refrigeration technologies like thermoelectric, adsorption, magnetic and thermo acoustic refrigeration. These kinds of refrigeration systems having limitation of use of grid power and it cannot be utilized for remote applications. The experimental analysis of developed prototype of Thermoelectrical Refrigeration system shows that the performances were optimum for a given operating conditions $I=0.5I_{max}$ (where I=2.0A & V= 5.5V) along with this work forced air convection heat dissipation shows in this paper [2].

Manoj Kumar Rawat, Himadri Chattopadhyay, SubhasisNeogi they have studied that the research effort made by different researchers for design and development of thermoelectric refrigeration and space conditioning systems has been thoroughly reviewed in this paper. His work explained those thermoelectric cooling materials needed to have high Seebeck coefficients, good electrical conductivity to minimize Joule heating, and low thermal conductivity to reduce heat transfer from junctions to junctions. The calculated COP of developed experimental thermoelectric refrigeration cabinet was 0.1. The given work shows that thermoelectric cooling systems (5–15%) is less efficient conventional compression cooling system (40–60%) [3].

Vishnu Vardhan D et.al studied that developed model of commercial thermoelectric refrigerators with finned heat exchanger is established. The main objective of this paper is to present relation of the direct thermoelectric conversion.

Thermoelectric systems are solid-state heat devices that either convert heat directly into electricity or transform electric power into thermal power for heating or cooling is a thermoelectric systems or solid-state heat devices. This paper has evaluated the working of Peltier module for producing effective heating and cooling placed inside an aluminum cabinet. By using a temperature sensor inside the cabinet surface, we get the corresponding temperature values for each instant which are displayed in an LCD (Liquid crystal display) [4].

Manoj Kumar Rawat, Prasanta Kumar Sen, Himadri Chattopadhyay, Subhasis Neogi, they have studied that, the experimental results of developed prototype of Thermoelectrical Refrigeration system analyze that the performances were optimum for a given operating conditions $I=0.5I_{max}$ and forced air convection heat dissipation. An 11^0C temperature reduction at zero load and 9^0C at 100 ml water inside refrigeration space of developed thermoelectrical Refrigeration has been experimentally found with respect to 23^0C ambient temperature in 30 minutes. In addition, the calculated COP of thermoelectric refrigeration cabinet was 0.1. In addition, in this work, the developed thermoelectric refrigeration system gives optimum performance at 2.5A, 8V and the system can continuously work for 15 hours when battery is fully charged with solar panel [5].

III. THERMOELECTRIC COOLING

In Thermoelectrical refrigeration system, the Peltier effect is the phenomenon of to create a heat flux between the junctions of two different types of materials. A Peltier heater, cooler or thermoelectric heat pump is a solid-state active heat pump, which convert heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Such an instrument is also called a Peltier device, Peltier heat pump, solid-state refrigerator, or thermoelectric cooler (TEC).Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. They can be used either for heating or for cooling (refrigeration), although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools.

This technology is far less commonly applied to refrigeration than vapor-compression refrigeration. The main advantages of a Peltier cooler are its lack of moving parts or circulating liquid, near-infinite life and potential to avoid leaks, and its small size and flexible shape. Its main disadvantage is high cost and poor power efficiency. Many researchers and companies are trying to develop Peltier coolers that are both cheap and efficient [4].

3.1 Peltier effect

A Peltier cooler can also be used as a thermoelectric generator. When operated as a cooler, a voltage is applied across the device, and as a result, a difference in temperature will build up between the two sides.

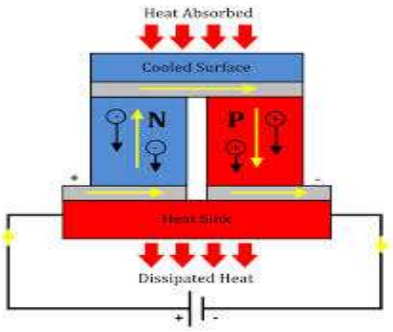


Fig 3.1 Peltier effect

When operated as a generator, one side of the device is heated to a temperature greater than the other side, and as a result, a difference in voltage will build up between the two sides.

3.2 Seebeck effect

When the two junctions of a pair of dissimilar metals are maintained at different temperatures, there is the generation of emf (electromotive force).He conducted a series of tests by varying the temperatures of the junctions of various combinations of a set of materials.

The emf output was found to be:

$\Delta E \alpha \Delta T$……………………………………. (1)

Where ΔE and ΔT the emf output and the temperature difference of the junctions. The phenomenon of generation of emf is called Seebeck effect

The proportionality constant of Eq.1is denoted by

$\alpha ab = \Delta E / \Delta T$…………………………..(2)

and is called Seebeck coefficient or the thermo electric power. It is to be noted that $\alpha_{ab}(\alpha_a - \alpha_b)$ is the coefficient for a pair of different metals (A and B or P and N or p and n).

3.3 Thermoelectric module:

A typical thermoelectric module is composed of two ceramic substance that serve as a foundation and electrical insulation for P-type and N-type Bismuth Telluride dice that are connected electrically in series and thermally in parallel between the ceramics. The ceramics also serve as insulation between the modules internal electrical elements and a heat sink that must be in contact with the hot side as well as an object against the cold side surface. Electrically conductive materials, usually copper pads attached to the ceramics, maintain the electrical connections inside the module. Solder is most commonly used at the connection joints to enhance the electrical connections and hold the module together.

Generally Thermoelectrical cooler identified by using following notification
TEC1-12706
Where C-Size C=Standard
S=Small
1- No of stages typically 1
127- No of couples (P-N couple)
Highly doped=more conductive

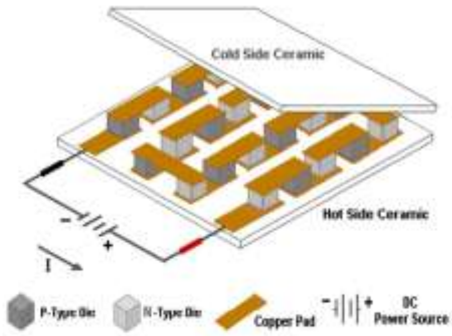


Figure 3.2 Thermoelectric module

Couple is term used in most modules as even number of P-type and N-type dice and one of each sharing an electrical interconnection. While both P-type and N-type materials are alloys of Bismuth and Tellurium, both have different free electron densities at the same temperature. Deficiency of electrons is in P-type dice, while N-type has an excess of electrons. As current flows up and down through the module, it attempts to establish a new equilibrium within the materials. The current treats the P-type material as a hot junction needing to be cooled and the N-type as a cold junction needing to be heated. Since the material is actually at the same temperature, the result is that the hot side becomes hotter while the cold side becomes colder. The direction of the current will determine if a particular die will cool down or heat up. In short reversing the polarity will switch the hot and cold sides.

The TEM operating working principle is based on the Peltier effect. The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material. One of the TEM sides is cooling and the other side is heating. When a TE module is used, you must support heat rejection from its hot side. If the temperature on the hot side is like the ambient temperature, then we can get the temperature on the cold side that is lower. According to current value that is, leaking through a thermoelectric module the degree of the cooling is depended. Electrons act as the heat carrier in a thermo-electric heat exchanger. The heat pumping action is actual function of the quantity of electrons crossing over the p-n junction [4].

Specifications:

Model: TEC1-12706(Bismuth)
Size: 40mm x 40mm x 4mm
Operates from 0~15.2V DC & 0~6A
Operates Temperature: -30^{0}C to 70^{0}C
Maximum power consumption: 91.2 Watts
Fitted with 6-inch

3.3 Design of Thermoelectric Components:

The design progressed through a number of steps. Identification of the problem, decides upon a design selection, brainstorm ideas, analyze problem, Redesign if necessary and implement design are the steps. Heat Transfer Methods, materials and Geometry is the main design considerations. This can used to facilitate the transfer of heat from the surface of the thermoelectric material to the Surrounding. Natural convection, Liquid cooled, Forced convection when the co-efficient of thermal transfer (K) was investigated, the K for natural convection was approximately 25 W/mK. This value increased up to 100W/mK for forced convection heat transfer. The size of the heat sink for a natural convection apparatus would need to be four times that for a forced convection set-up. The geometry of device is very important due to rectangle shape it is easy to build and insulated. On one side door is attach for communication of material with respect to material. .Finally, any insulation, thermoelectric modules or heat sinks are fastened to the sides. The second choice for cooler geometry was a cylinder. The advantage found with this shape is that it has the largest volume to surface area ratio of the two designs considered. This is a good property when the objective is to minimize heat loss. Insulate rectangle box is considered for the simplicity to build. Material we explored three different materials for the construction of the outer casing and frame of the device. These were aluminum and stainless steel. Low thermal conductivity material like high impact polystyrene is desirable Building the device out of would make it very light, portable while maintaining rigidity is readily available and reasonably priced, is easy to cut and drill. The outer casing and container would be made by first making a positive mold and applying a cloth coated with resin.

IV. EXPERIMENTATION

The construction set up for this system require following parts:-

1. Charge controller
2. Thermoelectric module
3. Exhaust fan
4. Cabinet
5. Battery bank
6. Relay switch
7. Variable voltage Regulator
8. Temperature sensor

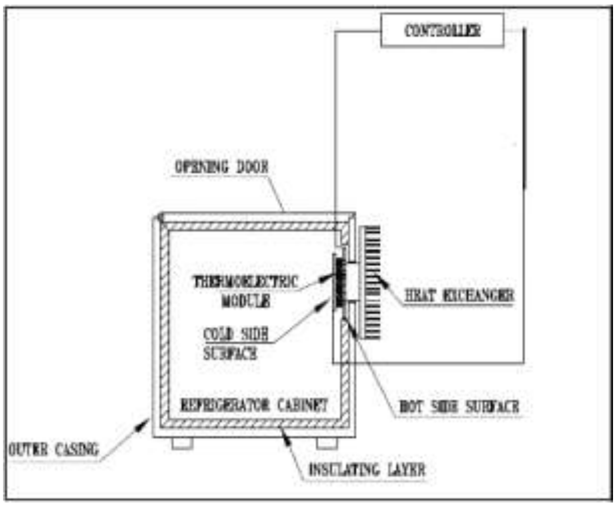


Figure 4.1 Experimental Setup Diagram

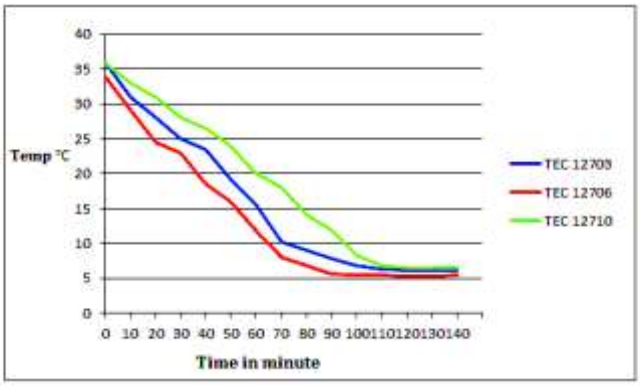
When a wire, a current flows and the electric power connect the two electrodes thus generated is transferred to battery banks connected to it charge controller is used to supply constant current to batteries. From battery, the supply is given to the thermoelectric module, which produces refrigeration effect in the cabinet using peltier effect. So required refrigeration effect can be obtained by supplying voltage from battery [5]

Figure 4.2 Actual setup of Refrigerator

V. RESULT AND DISCUSSION

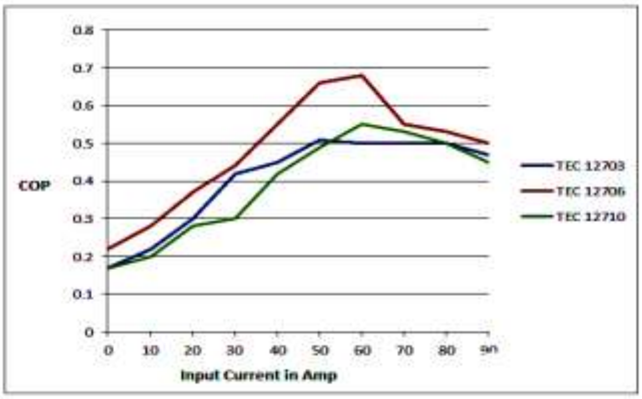
To increase C.O.P. there is lot of scope for developing material especially suitable for cooling purpose. By changing thermoelectrical material TEC 12703, TEC12706 and TEC 12710 performances of thermoelectric refrigerator is checked. As per the load condition on refrigerator, we can select the material TEC12703 on which we take readings of Current input, temperature with time and COP of refrigerator. These readings can take place on changing material to TEC12706 and TEC 12710 and performance evaluated.

Graph 5.1 shows that the temperature of the cold junction was decrease as increase the time. The result on the material TEC12706 was better than remaining TEC 12710 and TEC 12703. The desired temperature will be set in the device, the temperature of the object was decrease and achieve the desired temperature and maintain the level of temperature. The time required two attained lowest possible tempature of medical application using this material is TEC 12703 is 104 minutes ,TEC 12706 is 90 minutes and TEC 12710 is 110 minutes. The reason behind that is flow of electrons in material.



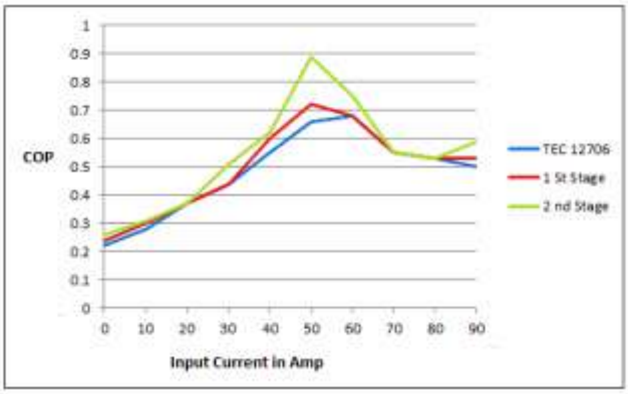
Graph 5.1:Variation of Temperaturewith Time

.Graph 5.2 shows that in the peltier cooler the input current is increases the cold junction temperature was decrease. The result obtained on input current and COP as follow .The maximum COP obtained for material TEC 12706 as compared to material TEC 12710and TEC 12710 at given current input. The main reason behind that is due to increase in voltage ,the current increase hence module more heat is being transferred at the hot end portion that results in lower the cold end portion temperature.



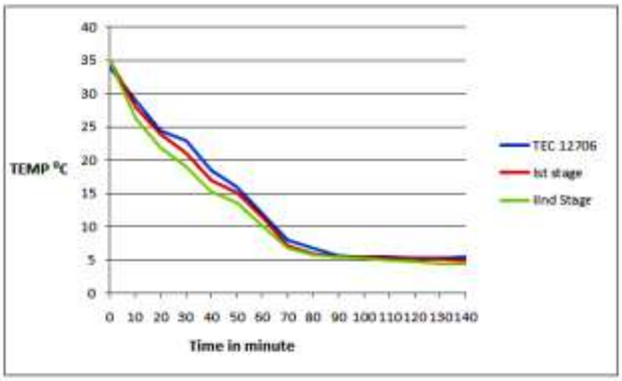
Graph 5.2: Variation of Cold Junction Temperature with Input Current (Voltage)

As the material TEC 12706 shows good result hence further improve performance of portable refrigerator multistaging of TEC 12706 can be done. In multistaging the result was taken in two way first was using two modules and second is using combination of three modules. Multistaging shows following result regarding to achieve the lowest possible temperature range in Graph 5.3. In following observation the second multistaging gives highest COP that is 0.89.



Graph 5.3 variation of COP with staging

The result obtained on the temperature and time scale is as follow in Graph 5.4 for multistaging the portable refrigerator using TEC 12706 modules.



Graph 5.4 Variation of Temperaturewith Time (multistaging)

VI. CONCLUSION

Various ways of improving the coefficient of performance (COP) of the thermoelectric refrigeration system. Using this thermo electrical refrigeration method temperature was controllable via changing the input voltage or current. The COP among three materials Bismuth telluride, Lead telluride and silicon Alumina experimentally it is found that bismuth telluride have better performance over other two. We can conclude that as number of stages increases the COP increases and temperature at cold junction decreases. Instead of using vapor compression refrigerator, thermoelectric refrigerator is applied due to its lower starting power, environmental friendliness, and noiselessness. The performance of this refrigerator can be improved by adding insulation to the refrigerator's body as well as improving its heat exchanger efficiency.

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