Design and Experimental Analysis of Portable Refrigerator System

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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 can 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.*

1. 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.

Saidur. R, et al (2008) they have studied that, a thermoelectric refrigerator, which is develop in standalone photovoltaic system for domestic usage, has been presented in this paper. The work on efficiently running of the thermoelectric refrigerator the photovoltaic sizing required for with energy consumption 520Wh is including 4 solar modules of 5.7A, 17.5V and100W;along with this 4 lead acid batteries of 12V and 100Ah, a solar charge controller of 12A and 24V; and an inverter of 24V and 150W the researcher is . Rawat Manoj Kumar(2012) 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 ofgrid 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=0.5Imax (where I=2.0A & V= 5.5V) along with this work forced air convection heat dissipation shows in this paper

RawatManoj Kumaret al (2013), 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 Seeback 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%) . Vishnu Vardhan D et.al (2013) studied that thermoelectrical refrigerator which is commercial model with finned heat exchanger. 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 energy 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).

Rawat Manoj Kumar et al (2013) 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°C temperature reduction at zero load and 9°C at 100 ml water inside refrigeration space of developed thermoelectrical Refrigeration has been experimentally found with respect to 23°C 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

2. THERMOELECTRIC COOLING

In Thermoelectrical refrigeration system, the Peltier effect is the phenomenon of to generate 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).They can be used either for heating or for cooling 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 economically efficient.

2.1 Peltier effect

Thermoelectric generator purpose a Peltier cooler can also be used. 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.

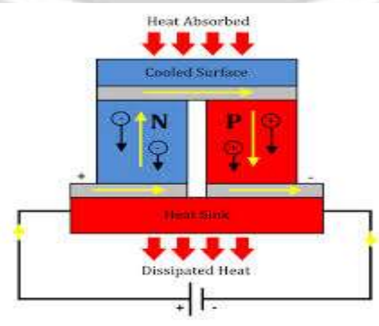


Fig 3.1 Peltier effect

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.

2.2 **Thermoelectric module**

As given thermoelectric module is combination of two special type ceramic materials that give strength to the foundation. These materials are connected in series for reference to electrically and parallel for reference to thermally between these ceramics material. These material also having function of providing insulation between the modules internal electrical elements and a heat sink that can be in contact with the hot side and object which is placed on the cold side. Copper pads material is used which is electrically conductive to maintain the electric connection inside the thermoelectrically modules attached on ceramics. To enhance electrical connection between the joint solder is used and connect module with one another.

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

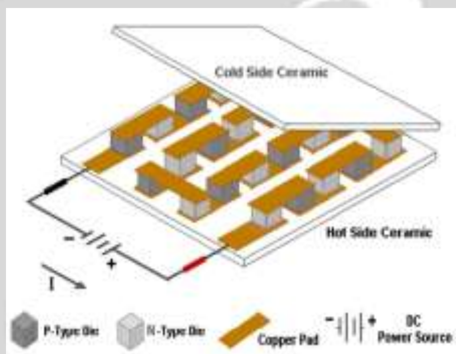


Fig 3.2 Thermoelectric module

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. 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, 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.

Specifications:

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

2.3 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 is in limit of extended to 100W/mK for heat transfer. This heat transfer is 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 attachfor 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.

3.0 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

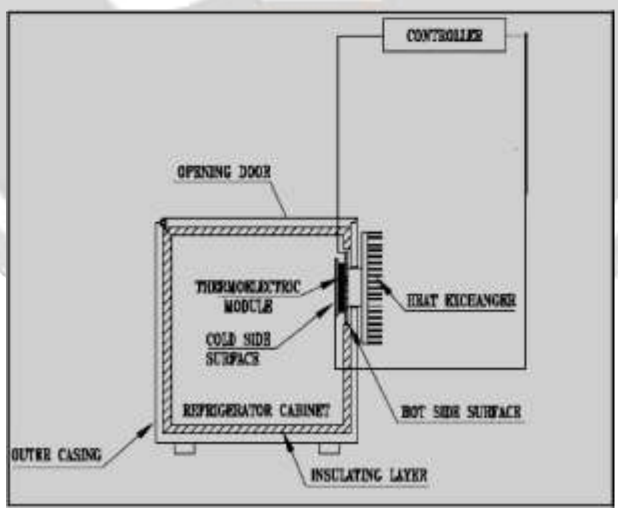


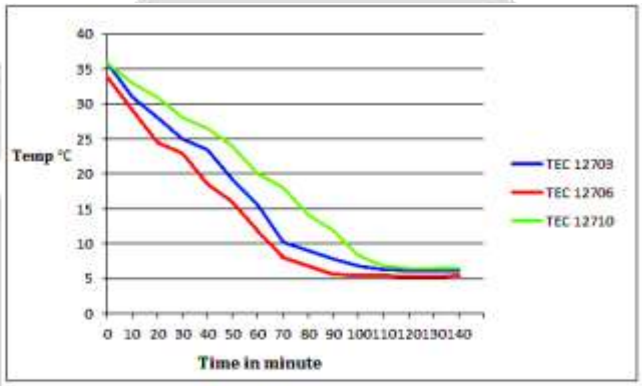
Fig 4.1 Experimental Setup Diagram

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.

4.0 RESULT AND DISCUSSION:

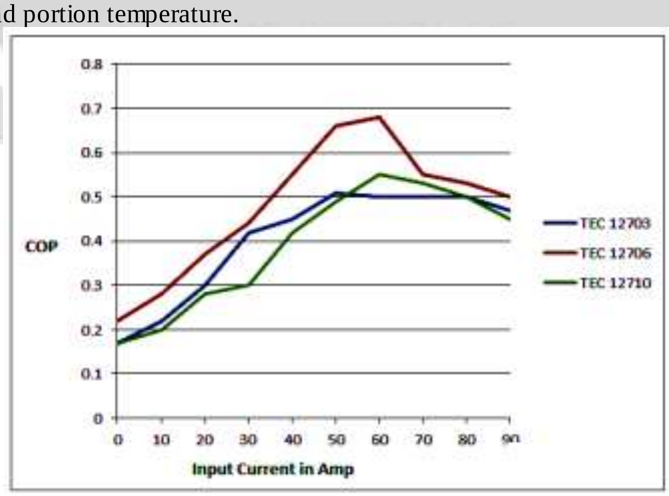
To increase C.O.P. there is lot of scope for developing material especially suitable for cooling purpose. By changing thermoelectrical material TEC 12703, TEC12706 and TEC 12710 performances of thermoelectric refrigerator is checked. As per the load condition on refrigerator, we can select the material TEC12703 on which we take readings of Current input, temperature with time and COP of refrigerant. 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 increases the time. The result on the material TEC12706 was better than remaining TEC 12710 andTEC 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.



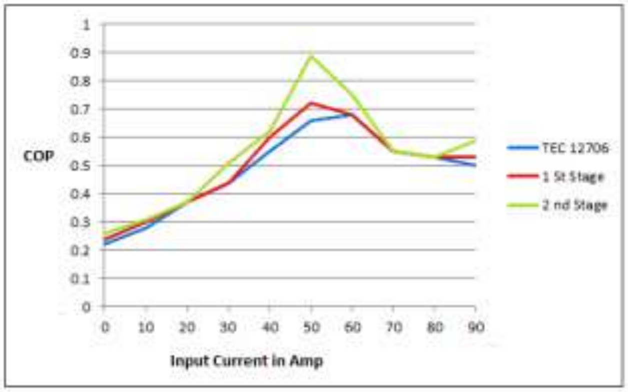
Graph 5.1: Variation of Temperature with Time.

.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.



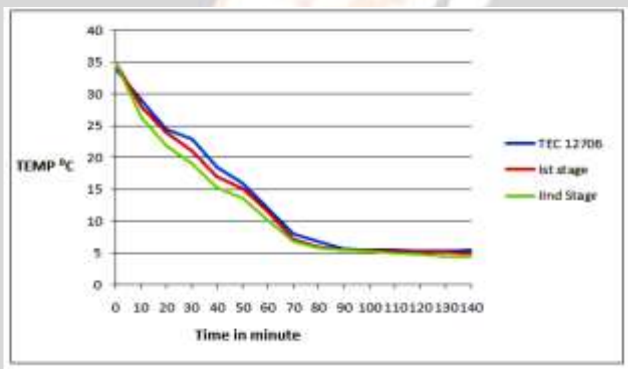
Graph 5.2: Variation of Cold Junction temperature with Input Current (Voltage)

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 multistage the portable refrigerator using TEC 12706 modules.



Graph 5.4 Variation of Temperature with Time (multistaging)

6.0 CONCLUSION:

Various ways of improving the coefficient of performance (COP) of the thermoelectric refrigeration system are as follow.

1] Using this thermo electrical refrigeration method Temperature was controllable via changing the input voltage or current. As per requirement, we can maintain the medicine as desired level of temperature.

2] The COP among threematerialsTEC 12706 having highest one and it is 0.65 for signal stage.

3] To improve the performance of the thermoelectric refrigeration system by multistage of the thermoelectric modules. For second multistage module the COP was 0.89 which is highest in experimentation. We can concluded that as number of stages increase the COP increases and Temperature at cold junction decreases

4] Although the COP of given system is varying in between 0.1 to 0.89. It is suitable for given application

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