Application Of Peltier Effect In Producing Eco-friendly refrigerator

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Abstract

The objective of this project work is to develop portable thermoelectric refrigeration system capable of maintaining vaccine temperatures within 13 °C. The main system consisted of thermoelectric module as cooling generator along with insulated cabin, battery and charging unit. Thermoelectric elements perform the same cooling function as Freon-based vapour compression or absorption refrigerators. To ensure the success of this project several criteria's are to be satisfied such as portability, size and cost of the system. The design of the preservation is based on the principles of thermoelectric module (i.e. Peltier effect) to create a hot side and a cold side. The cold side of the thermoelectric module is used for refrigeration purposes; provide cooling to the vaccine chamber. On the other hand, the heat from the hot side of the module is rejected to the surroundings with the help of heat sinks and fans. After gathering experimental data's and necessary guidelines from research papers on the thermoelectric refrigeration systems, the initial design of the model was made. Based on the heat load calculations, the thermoelectric module is selected. The system was fabricated and was experimentally tested for the cooling purpose. The capability of the system to maintain the required temperature and the time for reaching the same were analysed. The results showed that the system can maintain the vaccine storage temperature within 13 °C under ambient temperature up to 30 °C with minimum power consumption of 64 Watt. The proposed thermoelectric module, to maintain the vaccine storage temperature, satisfied the design criteria.

I.INTRODUCTION

The conventional cooling systems are used now a days are requires the refrigerant whose phase change takes place in heat exchanging and compressor are required for the compression of the refrigerant. The compressor required more power and space. The refrigerant is also not eco-friendly and increases the global warming and the major cause of ozone layer depletion.

The mini Eco-friendly refrigerator is based on the PELTIER EFFECT and a thermoelectric device called Peltier device is used for the cooling purpose. In the MEF-Refrigerator there is no need of compressor and refrigerant. Semiconductor thermoelectric coolers (also known as Peltier coolers) off temperature control ($< \pm 0.1$ °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.

In the recent years, we are facing many problems such as energy crises and environment degradation due to increasing CO_2, HCFCs and CFCs emissions causing ozone layer depletion. It has become the primary concern to both developed and developing countries. As the conventional refrigeration systems consumes more electrical energy and release more hazardous gases such as CFCs which are of major environmental damage concern nowadays. Even coolants used are not eco-friendly and much more costly. In these types of refrigerators, there is a tendency of leakage of refrigerants which can lead to ineffective cooling, wastage of electric energy and polluting atmosphere. Thus, thermoelectric module is going to be one of the most effective, clean and environment friendly system. Thermoelectric module works on the principle of Peltier effect i.e, when a direct current is passed between two electrically dissimilar materials, heat is absorbed or liberated at the junction due to which one side of the Peltier plate gets cooled (the side inside the chamber)and the other side gets heated up(facing towards the atmosphere).The heat from the hotter side of the Peltier plate is absorbed by using heatsink(or along with fan)and heat is dissipated into the atmosphere.

An efficient alternative to this is an eco-friendly refrigerator which works on the principle of 'Thermoelectric effect' [1]. Thermoelectric devices are based on Peltier, Seebeck and Thomson effect which has gained major developments in recent period [2]. Semiconductor thermoelectric/peltier coolers possess several advantages over conventional Refrigeration systems. They are solidstate devices which are rugged and silent since there are no moving parts. They are very much environment friendly as no release of ozone depleting gases occurs during their working. Accurate temperature control (< ± 0.1 °C) can be achieved with Peltier coolers. Another important feature is its mobility, which increases its reliability in remote areas, especially during natural calamities. The device could be used to store perishable items and facilitate the transportation of medications as well as biological material that must be stored at low temperatures to maintain effectiveness.[3] However, they have low efficiency compared to conventional refrigerators. Hence, they are used in specific and crucial applications where their advantages overrule efficiency. Peltier coolers are mostly used in applications where small size is needed and the cooling demands are not too great, such as for cooling electronic components, preserving medicines etc [4].

only peltier plated and 12v power supply is provided to it from smps. The data is collected during this experimental setup and plotted the line graph with temperature variation at the cooler side versus the time taken to achieve it as shown in chart1.Initially temperature was at room temperature, after providing power supply the cooler side started getting cold and temperature went up to 18 degree for first 25 seconds. Later due to lack of proper coolant or heatsink to absorb heat from the hotter side of peltier plated and due less thickness, temperature started to pass from hotter side to cooler side of peltier plate. So, temperature went on rising and after 1 minute temperature at cooler side was 32 degrees

II. EXISTING METHODOLOGY

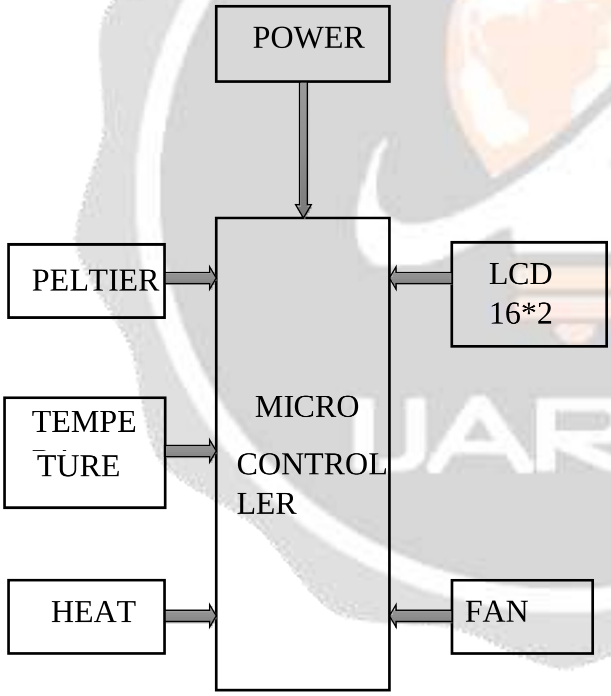

Fig 1: block diagram

The Peltier Effect is the basis on which a thermoelectric module operates: it involves the generation of a temperature difference due to an electric current passing through a nonhomogeneous conductor. Thermoelectric modules are made of two materials called p-type and n-type and are often made from a Bismuth Telluride semiconductor. When a DC voltage is applied to the module, one side absorbs heat (becomes cold) and the other side rejects heat (becomes hot). The cold side of a thermoelectric module can be used for cooling in a refrigerator and the hot side for warming. The rate of heat transfer through the module is directly related to the temperature difference across the two sides of the module and the temperature of the hot side of the module. Less heat will be transferred when the temperature difference across the module is high or the hot side temperature is relatively low. It is most desirable to have a low temperature difference across the two sides of the module and to have a high temperature on the hot side of the module. However, in order to freeze water, the temperatures of the hot and cold sides must be kept at extremes, which severely limit the amount of heat transfer that can occur through the thermoelectric module.

ATMEGA Controller: ATmega is an 8-bit high performance microcontroller of Atmel's Mega AVR family with low power consumption. Atmega is based on enhanced RISC (Reduced Instruction Set Computing, Know more about RISC and CISC Architecture) architecture with 131 powerful instructions. Most of the instructions execute in one machine cycle. Atmega can work on a maximum frequency of 16MHz.ATmega16 has 16 KB programmable flash memory, static RAM of 1 KB and EEPROM of 512 Bytes. The endurance cycle of flash memory and EEPROM is 10,000 and 100,000, respectively. ATmega16 is a 28-pin microcontroller. There are 17 I/O (input/output) lines which are divided into four 8-bit ports designated as PORTA, PORTB, PORTC and PORTD.ATmega16 has various in-built peripherals like USART, ADC, Analog Comparator, SPI, JTAG etc. Each I/O pin has an alternative task related to in-built peripherals.

Thermoelectric Module: A thermoelectric module is a circuit containing thermoelectric materials which generates electricity from heat directly. A thermoelectric module consists of two dissimilar thermoelectric materials joined at their ends: an n-type (negatively charged), and a p-type (positively charged) semiconductor. A direct electric current will flow in the circuit when there is a temperature difference between the ends of the materials. Generally, the current magnitude is directly proportional to the temperature difference.

Thermoelectric system Using thermoelectric modules, a thermoelectric system generates power by taking in heat from a source such as a hot exhaust flue. In order to do that, the system needs a large temperature gradient, which is not easy in real-world applications.

Peltier Effect: The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material. A Peltier module works based on the principle that 'if direct current is passed through two dissimilar metals then a potential difference will be developed across them and there will be cooling at one surface and heating at the opposite surface. A typical thermoelectric module consists of an array of Bismuth Telluride semiconductor pellets that have been "doped" so that one type of charge 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. When DC voltage is applied to the module, the positive and negative charge carriers in the pellet array absorb heat energy from one substrate surface and release it to the substrate at the opposite side. The surface where heat energy is absorbed becomes cold; the opposite surface where heat energy released becomes hot. Its operating voltage is about 12 V.

Heat Sink: There are several methods which can be employed to facilitate the transfer of heat from the surface of the thermoelectric to the surrounding. These methods are described in the following three sections. Natural convection, Liquid cooled, forced convection when the coefficient of thermal transfer (K)was investigated, the K for natural convection was approximately 25 W/mK. This value compared to 100W/mK for forced convection.

Liquid Crystal Display: A liquid crystal display or LCD draws its definition from its name itself. It is combination of two states of matter, the solid and the liquid. LCD uses a liquid crystal to produce a visible image.

III. PROPOSED METHODOLOGY

We have conducted different experiments setups for peltier plate for checking it's better perform and to study its nature of cooling effect.

5.1 1st Experimental setup

In this experimental setup we have just placed only peltier plated and 12v power supply is provided to it from smps. The data is collected during this experimental setup and plotted the line graph with temperature variation at the cooler side versus the time taken to achieve it as shown in chart1.Initially temperature was at room temperature, after providing power supply the cooler side started getting cold and temperature went up to 18 degree for first 25 seconds. Later due to lack of proper coolant or heatsink to absorb heat from the hotter side of peltier plated and due less thickness, temperature started to pass from hotter side to cooler side of peltier plate. So, temperature went on rising and after 1 minute temperature at cooler side was 32 degrees.

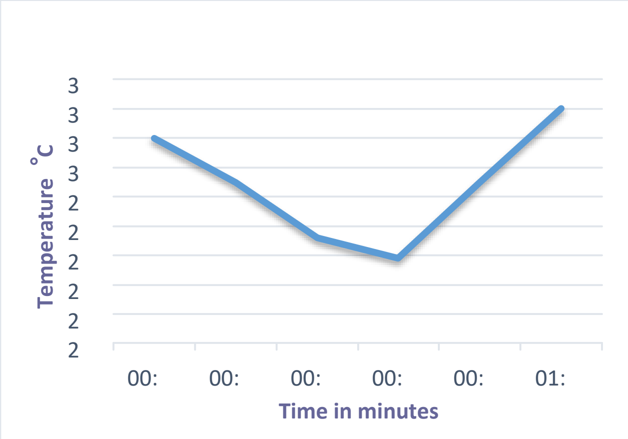

Chart -1: Peltier plate without heat sink

5.2 2nd Experimental setup

In this experiment setup we have used heat sink of small size of 36sqcm and attached it to hotter side of peltier plate with thermopaste. Initially when power supply was given to peltier plate, temperature at colder side of peltier plate was at room temperature of 31 degree Celsius. Later gradually temperature at the colder side peltier plate went on decreasing and lowest temperature achieved was 21.7 degree Celsius with in 1min and 50 seconds. Later due to problems as mentioned above, colder side of peltier started getting heated and by the end of 2 min 15 sec temperature at the colder side of peltier plate reached 35 degree Celsius. Even this setup was not effective for cooling the icabin.

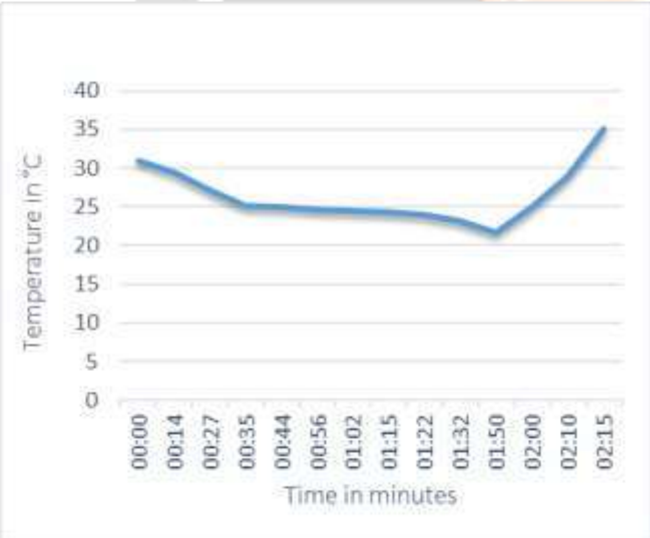

Chart -2: Peltier plate with small active heat sink

5.3 3rd Experimental setup

As the above experimental setup, here we used stationary water as coolant with passive heat sink of 36sqcm for achieving better results. The plot of line graph based on the temperature reading recorded during experiment setup with respect to time is show in chart-3. There was temperature of 31 degree Celsius present at the cold side of peltier plate before providing power supply to peltier plates. After providing power supply the temperature gradually went low when measured at the cold side of peltier plate. The minimum temperature recorded at the cold side of peltier plate was 18 degree Celsius after approximate of 3 minutes. Later when water got heated, once again temperature at the cold side of peltier plate went high. So, even this setup was not effective. We didn't use circulation water as coolant because that needed a motor to pump the water which is again wastage of power.

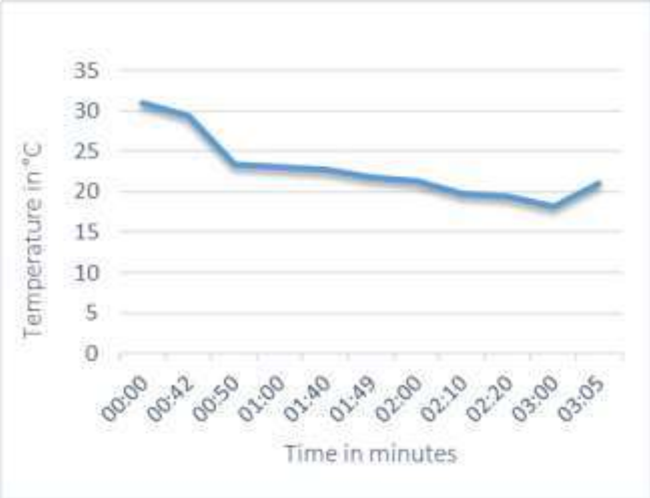

Chart-3: Peltier plate with heat sink and water coolant

5.4 4th Experimental setup

In this experimental setup we have used active heat sink of large size which is 81sqcm in area, large surface area for easy dissipation of heat to surrounding environment. Initially before providing power supply temperature at the cold side of peltier plate was 27 degree Celsius. Using the temperature reading obtained during experiment operation a plot of graph of temperature versus time taken to achieve that temperature is shown in chart-4. In this experimental setup the temperature went gradually low till 8 degree Celsius over period of 8 minutes and later it stayed constant at around 8 degrees Celsius itself. of the refrigerator can be increased by increasing the number of peltier plate module which will eventually help in decreasing the temperature in less time. Number of peltier plate modules used can be calculated using the heat transfer formul

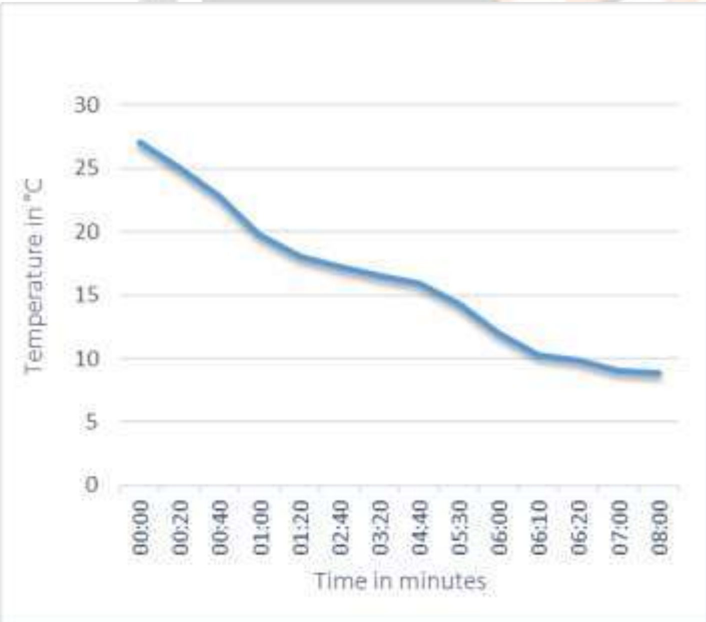

Chart -2: Peltier plate with large active heat sink

From all the different experimental results observation, 4th experimental setup was efficient and able to achieve lowest temperature among different experimental setups. So, for cooling insulated cabin we have used the 4th experimental setup.

IV. RESULTS

After building a insulated cabin with the help of thermocol of size 0.20meter height, 0.15meter width and 0.12meter breath which is equivalent to 3.6liters cabin. Pasting aluminum sheet inside the cabin for equal distribution of temperature inside the cabin. Two peltier plates with active sink attached to the hotter side of peltier plate was placed outside the cabin to dissipate heat to surrounding and passive heat sink was placed inside the cabin to lower the cabin temperature.

ADAVANTAGES

COMPACT SIZE: Very little space is required by the cooling system. The thermoelectric module is the size of a matchbook.
LOWER PRICE: 20% to 40% less expensive than compressor or absorption units.
LOW BATTERY: Averages approximately 4.5 amps - less than your cars headlights.
PERFORMANCE: Thermoelectric coolers maintain "cool" temperatures in ambientes up to 90 degrees F.
HEATING OPTION: Thermoelectric can be operated in heating mode for a short period.
SAFETY: No open flames, propane, or toxic refrigerants used.
RELIABILITY: Thermoelectric have a 40-year proven track record in military, aerospace, laboratory, and no of consumer applications.
EASY SERVICE: Most parts are easily replaced by the end-user with a screw driver.
LOWMAINTENANCE: The only maintenance required with any thermoelectric unit is periodic "dusting" and Vacuuming to ensure good heat dissipation.

V. CONCLUSION

This peltier refrigerator is more reliable than other portable refrigerators. It is cost efficient and ecofriendly which is the most wanted requirement of today's era. By controlling the temperature range of the cooling unit, it can be used in various sectors like for in the rural areas where dairy products need a lot of attention, near the coasts from where the marine edibles need to be transported to the market area, medical area for storing blood and pharmaceuticals. The efficiency of the refrigerator can be increased by increasing the number of peltier plate module which will eventually help in decreasing the temperature in less time. Number of peltier plate modules used can be calculated using the heat transfer formula.

VI. REFERENCES

[1] C J Mole, D V Foster, R A Feranchak, "Thermoelectric Cooling Technology," in IEEE Transactions on Industry Applications, vol. IA-8, no. 2, pp. 108-125, March 1972

[2] R. Sharma, "Peltier Effect Based Solar Powered Air Conditioning System," International Conference on Computational Intelligence, Modelling and Simulation, pp. 288-292, 2009

[3] Gastelo-Roque, José & Morales-Acevedo, Arturo, "Design of a photovoltaic system using thermoelectric Peltier cooling for vaccines refrigeration", IEEE MIT Undergraduate Research Technology Conference, 2017.

[4] Linlin Cao, Jitian Han, Lian Duan, and Chong H, "Design and Experiment Study of a

New Thermoelectric Cooling Helmet," In Proceedings of the 10th International

Symposium on Heating, Ventilation and Air Conditioning, pp.1426–1432, 2017, China

[5] Ajeet Gared, Abdurrahman, Babita K Varghese, Amit Jain, "Thermoelectric

Refrigerator: A Novel Potential Green Technology," International Journal of Engineering Trends and Technology, Vol 35, No 14, 2016

[6] A. Jose, A. D'souza, S. Dandekar, J. Karamchandani and P. Kulkarni, "Air conditioner using Peltier module," International Conference on Technologies for Sustainable Development (ICTSD), Mumbai, pp. 1-4. 2015

[7] Shuwang Chen, Jun Zuo and Dan Xie, "Design of solar power semiconductor refrigerator," 2010 8th World Congress on Intelligent Control and Automation, Jinan, pp. 419-423, 2010

[8] N. B. Totala, Prof. V. P. Desai, Rahul K. N. Singh, Debarshi Gangopadhyay, Mohd.

Salman Mohd. Yaqub, Nikhil Sharad Jane, "Study and Fabrication of Thermoelectric Air Cooling and Heating System", International Journal of Engineering Inventions pp. 2319-6491 Volume 4, Issue 2, 2014

[9] Palash Nakhate , Niraj Pawaskar , Purva Vatamwar , Saurabh Kalambe, "Ecofriendly refrigerator using peltier effect", International Journal of Research In Science & Engineering pp 2394-8280, 2017

[10] Sabah A. Abdul-Wahab , Ali Elkamel b, Ali M. AlDamkhi , Hilal S. Al-Rubai'ey, Abdulaziz K. Al-Battashi , Muhammad U. Chutani, "Design and experimental

investigation of portable solar thermoelectric refrigerator", International Journal for

Renewable Energy, Volume 34, Issue 1, pp 30-34, 2009

[11] Jonathan Michael Schoenfeld, Master of Science,2008 "Computational Model for Refrigerators Based on Peltier Effect Application", Applied Thermal Engineering, Vol. 25, No. 13, pp. 3149-3162.

[12] Bass et al. (2004), "Multi-layer quantum well (MLQW) thermo electrics in a cooling application" International journal of research in aeronautical and mechanical engineering ISSN (online): 2321-3051.