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Design & Fabrication of Portable Medical Refrigerator

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***Abstract-* For cooling small volume compartments, the thermoelectric systems have several advantages over the classic compressor refrigerators. Their priority is due to the active components in their design – Peltier modules which are chemically inactive, have no moving parts and do not practically need maintenance The thermoelectric cooling systems have the potential to meet the requirements for storing and transportation of vaccines and other medical solutions at low temperatures posed by the global pandemic of Covid-19. The electrical systems in the vehicles are excellent prerequisite for compatibility with the thermoelectric refrigerators requiring stable power supply. The aim of the present work was to design, realize and study a prototype of a small scale mobile thermoelectric cooling system for negative temperatures based on Peltier.**

***Keywords-* Thermoelectric, Cooling, Peltier, Refrigerator, Transport, Medical, Vaccines.**

I. INTRODUCTION

In rural areas, infectious diseases account for the majority of infant and young child fatalities and disabilities. Vaccination is the least expensive and most efficient method of preventing infectious diseases. Patients receive these vaccinations when they participate in routine immunisation programmes. The cold chain system is the most crucial component of these immunisation programmes. This system suggests that in order for a vaccine to remain effective, it must be stored and transported from the manufacturer to the patient at a specific temperature. All vaccines must be transported at specific, suitable temperatures because they lose their effectiveness if heated or frozen. It is obvious that using a vaccine that has lost its effectiveness is pointless.
According to the World Health Organisation (WHO), 50% of vaccines are lost or wasted before being used. The breakdown in the cold chain supply is one of the main causes of this problem. That is, vaccines that are temperature-sensitive must be kept at 2 to 8 degrees Celsius to maintain their effectiveness.
The most crucial equipment is working freezers and refrigerators in order to deliver vaccine to patients in a potent state. These cooling containers must be durable and have a way to power themselves because they will be used in remote areas without access to electricity.
The required temperature ranges for vaccines, insulin, and other medications are maintained using a variety of techniques. Refreezable ice/gel packs are one widely used technique for cooling down the intended chamber. These designs' cooling lifetimes are influenced by how long the packs remain frozen and how well the chamber is insulated. Although the cost is typically low, the system's dependability is a problem because it has poor temperature control, increasing the risk of vaccine wastage if exposed to temperature changes.
The development of small coolers capable of transporting vaccines, maintained in the proper temperature range, from the local health centre to the distant client is one way to address some of the wastage issues; this journey is referred to as the end stage of the cold chain.
For a range of medical uses, solid-state thermoelectric coolers employing the Peltier effect offer a reliable substitute for compressor refrigeration systems as there are far fewer moving parts that may require maintenance, no risks of refrigerant leakage, and a lighter, more compact size.
The purpose of the current study is to demonstrate and examine a small volume, portable cooler that is simple, inexpensive, and quick to make. This cooler allows for the short-term preservation of tiny quantities of vaccines while they are being transported.

II. THERMO-ELECTRIC COOLING SYSTEMS

On a global scale an important part of the electrical energy is consumed in the refrigeration and air conditioning sectors to keep food and pharmacy in a proper temperature. As a result, studies on the field of refrigeration are matter in the literature needs to be investigated. Vapor compression refrigeration cycles are widely utilized for these purposes, but there are many studies focused on Peltier thermoelectric devices and their performance to use in the field of refrigeration systems. Working principle of the vapor compression cycle and a sample fabricated Peltier unite are displayed below Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities. The alternating p & n-type semiconductor pillars are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side, usually ceramic removing the need for a separate insulator. When a voltage is applied to the free ends of the two semiconductors there is a flow of DC current across the junction of the semiconductors, causing a temperature difference. The side with the cooling plate absorbs heat which is then transported by the semiconductor to the other side of the device. The cooling ability of the total unit is then proportional to the total cross section of all the pillars, which are often connected in series electrically to reduce the current needed to practical levels. The length of the pillars is a balance between longer pillars, which will have a greater thermal resistance between the sides and allow a lower temperature to be reached but produce more resistive heating, and shorter pillars, which will have a greater electrical efficiency but let more heat leak from the hot to cold side by thermal conduction. For large temperature differences, longer pillars are far less efficient than stacking separate.

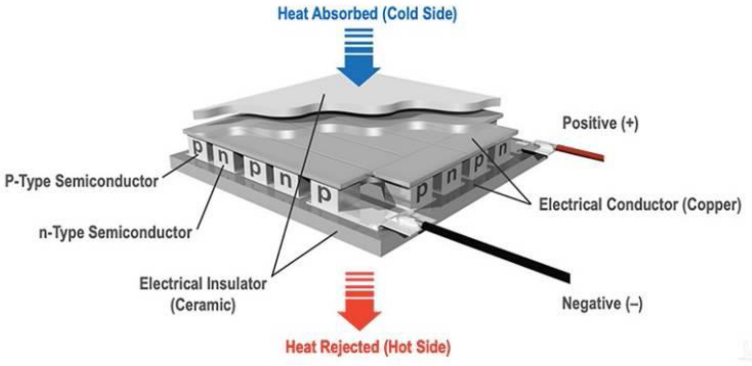

Fig. 1 Peltier module cross-section.

A refrigerator is a device which is used to removal of heat from a substance or space in order to maintain it to a particular temperature level (lower than the natural surroundings). A portable refrigerator aims at providing cooling effect by using Peltier effect. In the Peltier effect current is passed through a thermocouple, and then the heat is absorbed at cold junction of the thermocouple and liberated at the hot junction. So by using the cold junction of the thermocouple as the evaporator, a hot junction as the condenser and a DC power source as the compressor of the refrigerator, cooling effect can be provided. A Peltier effect refrigerator has

analogous parts. At the cold junction, energy is absorbed by electrons as they pass from a low energy level in the p-type semiconductor element, to a higher energy level in the n-type semiconductor element. The power supply provides the energy to move the electrons through the system. At the hot junction, energy is expelled to a heat sink as electrons move from a high energy level element (n-type) to a lower energy level element (p-type). As the electrons move from the p-type material to the n-type material through an electrical connector, the electrons jump to a higher energy state absorbing thermal energy.

III. DESIGN METHODOLOGY

This paper focuses on conceptual development of a device to store vaccines in last mile delivery for specific temperature range, which can work standalone, have good portability.
In analyzing the root of the problem, the approach should be to design a device which can powered with both 12V DC supply & 230V AC Supply. Charging ports of cars, two-wheelers can be used to powered the device in transportation.
The vaccine cold box was designed to proceed with this study. The factors that should be considered in the design process are as follows:

- Design of structure which can be easily transported.
- Build low-cost design.
- Have temperature controlling and monitoring system.
- Build a portable light-weight box.
- Can be powered through Cars & two-wheelers charging port.

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IV. MATERIALS USED

Materials used are as follows:

- **Thermoelectric Peltier Module (TEC1-12706)**
  TEC 12706 peltier unit is used. This unit works on 12 Volts DC power supply and draws Maximum current of 3.4 amps. The power rating of this unit is 40 watt.

Fig. 2 Peltier module

- **Temperature Controller (Thermostat)**
  For temperature control we have used Thermostat (W1209). Thermostats are devices that sense the temperature of a system so that the temperature is maintained at the desired set point or near to it. W1209 thermostat module has a temperature sensor, keys, LED display, relay and requires DC 12V power supply. NTC temperature sensor allows the module to intelligently control varied electrical devices based on the temperature. NTC thermistor has a negative temperature coefficient, which means the resistance decreases with increasing temperature.

Fig. 3 Thermostat

- **Heat Sink**
  A heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium with the help of fan mounted over it. The heat sink is generally made up of aluminum.

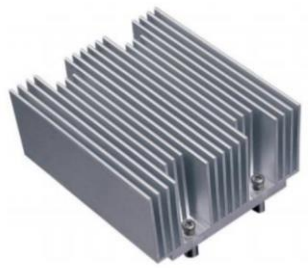

Fig. 4 Heatsink

- **Cooling fans**
  We are using two cooling fans respectively mount on each heatsink. Main purpose of cooling fan to dissipate heat by forced convection. One fan is of 9 inches and another one is of 4 inch which works on 12V DC supply and draws 0.18 amps each. The power consumption of each fan is 2.1 watts.

Fig. 5 Cooling Fan

- **Thermal Grease**
- **Switch Mode Power Supply (SMPS)**
- **Battery**
- **PWM Controller**
- **Insulated cooling chamber**
- **Multimeter**
- **Composite Sheet for fabrication.**

V. SYSTEM DESIGN AND FABRICATION

Thermocol insulated box is used for cooling chamber, as thermocol is light in weight and it has good thermal insulation property also it is also an economic source of insulation. Customised made heat sinks are attached to Peltier module from both the sides for good thermal dissipation. Small heat sink is attached on cold side of the peltier module and small cooling fan is attached on it to increase the thermal dissipation. Large heat sink is attached on hot side of peltier module and big cooling fan is employed on it to get good heat dissipation on hot side of peltier. High thermal conductance paste is used to reduce the contact thermal resistance in each surface of thermoelectric module. The cool side heat sink is installed inside the cooling chamber to get refrigeration effect in cooling chamber. SMPS power supply is chosen as it is having good efficiency as compared to transformers. Circuit connections are made and thermostat is attached in circuit, temperature sensor probe is placed inside cooling chamber to take temperature reading by thermostat.

Table 1 – Characteristics of Peltier module, heatsinks & fans.

Specification	Characteristics
Peltier Module	TEC-12706 , 40mm × 40mm ×40mm
Cold side heat-sink	40mm × 60mm × 30mm (Aluminium)
Cold side fan	40mm × 40mm × 20mm
Hot side heat-sink	100mm ×100mm × 40mm (Aluminium)
Hot side fan	80 mm × 80mm × 30mm

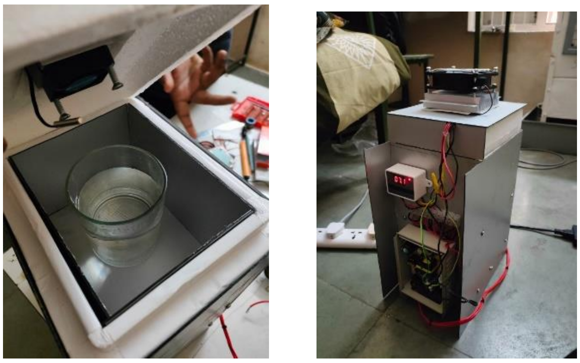

Fig. 6 Cooling Chamber

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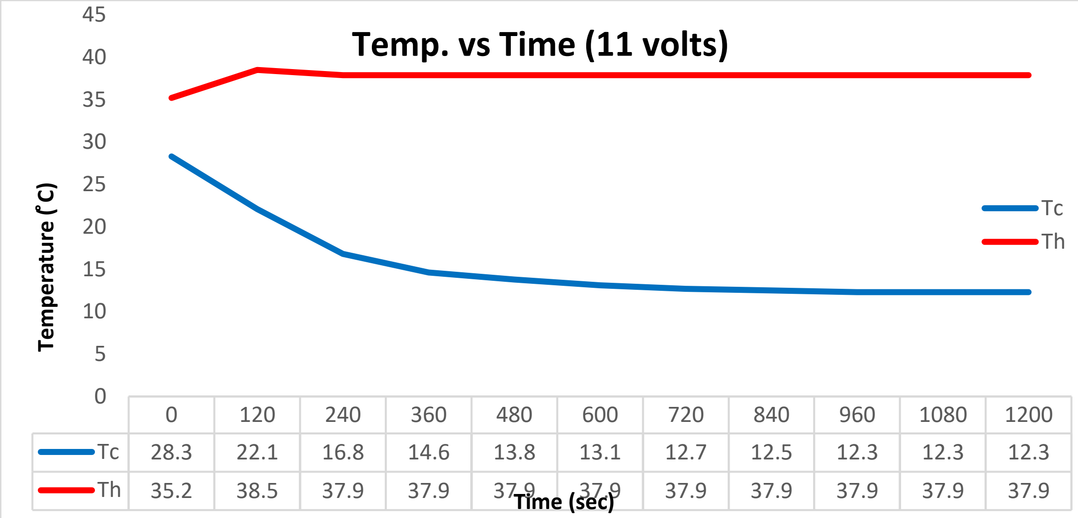
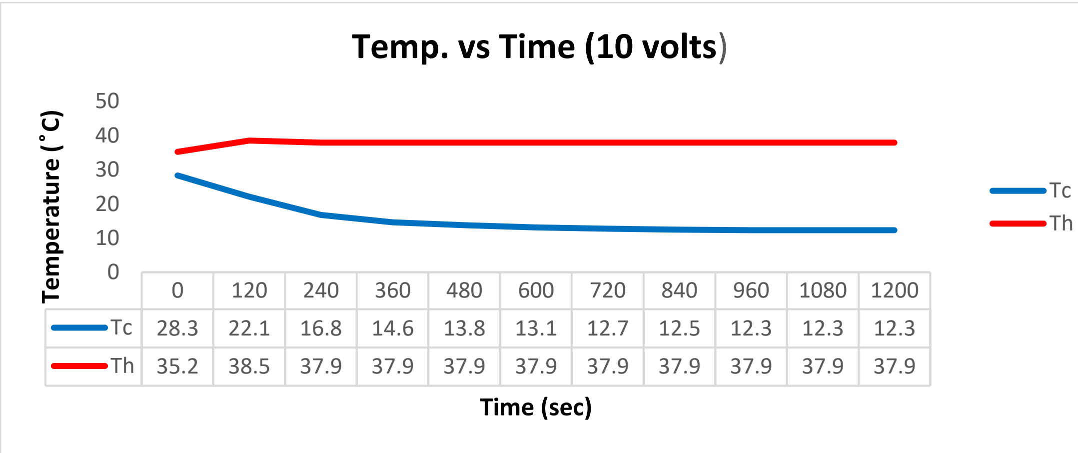
VI. RESULTS

Four groups of different voltage conditions were studied- Condition 1: 11V ; Condition 2: 10V; Condition 3: 9V ; Conditon 4: 8V. Temperature vs Time Graph on Different Voltages -



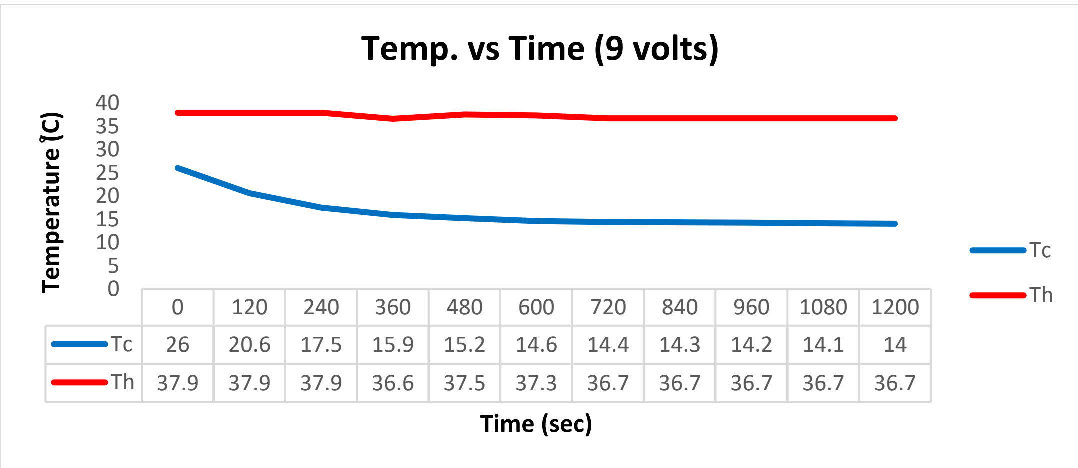
	0	120	240	360	480	600	720	840	960	1080	1200
Tc	28.3	22.1	16.8	14.6	13.8	13.1	12.7	12.5	12.3	12.3	12.3
Th	35.2	38.5	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9

Fig. 7 Temperature vs Time graph at 11V



	0	120	240	360	480	600	720	840	960	1080	1200
Tc	28.3	22.1	16.8	14.6	13.8	13.1	12.7	12.5	12.3	12.3	12.3
Th	35.2	38.5	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9

Fig. 8 Temperature vs Time graph at 10V



	0	120	240	360	480	600	720	840	960	1080	1200
Tc	26	20.6	17.5	15.9	15.2	14.6	14.4	14.3	14.2	14.1	14
Th	37.9	37.9	37.9	36.6	37.5	37.3	36.7	36.7	36.7	36.7	36.7

Fig. 9 Temperature vs Time graph at 9V

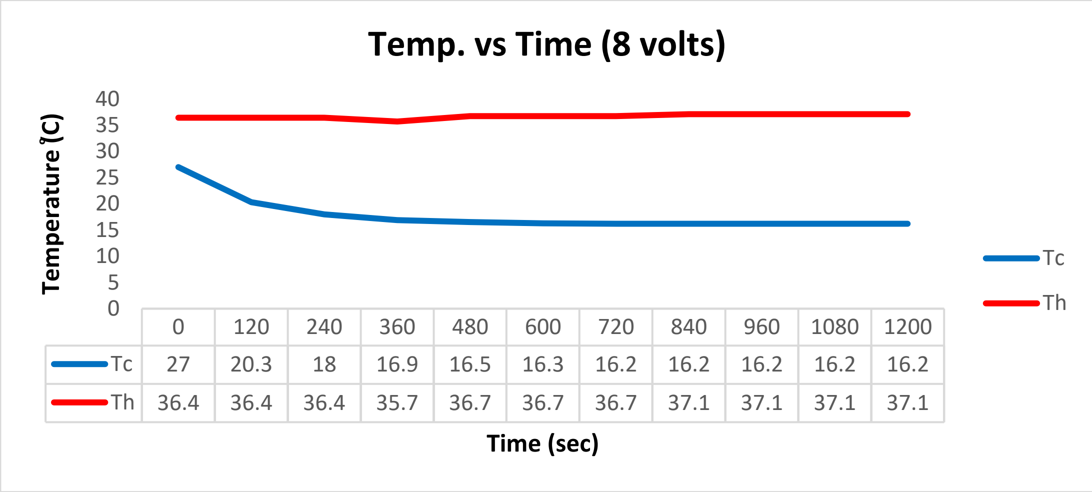


Fig. 7 Temperature vs Time graph at 8V

The testing of the prototype was done and observations were made. The minimum temperature reached was around 7˚C.

Table 2 - Results

Particular	Specification
Voltage	12 V
Current	3.5 A
Power	42 W
Min. Temperature	7ºC
Weight	2.5 Kg
Dimensions	200mm * 300mm * 150mm

VII. ADVANTAGES

Some major advantages of our designed portable vaccine refrigerator include -

- Desired temperature can be maintained.
- Economical and easy on budget.
- Lightweight and can be carried out easily.
- Portable and mobile, which makes it easy to use.
- Environment friendly due to no uses of gases.
- Safe and easy to use because of features.

VIII. DISCUSSION AND CONCLUSION

The testing of the prototype was done and observations were made. The minimum temperature reached was 7ºC. Total power consumption was around 42 watts.

To get a more optimal temperature, it is necessary to add a seal and a better heat insulator on the inner walls around the cooler because there is still cold air leaking out through the walls of the cooler.

The system is lightweight and compact and of low electric energy consumption. The design allows reaching temperature upto 7ºC within the cooled compartment. For the measuring and recording the results from the studies, modern intelligent gauges were used. providing possibility for convenient transportation of vaccines and other medical consumables as well as samples to remote mountain and rural areas, the refrigerator can be used in transportation for cooling of various medical items.

IX. FUTURE SCOPE

There are some drawbacks to using Peltier modules in cooling systems. First off, Peltier modules perform with low efficiency when compared to other systems like vapour compression or vapour absorption. Second, an effective heat sink is required to maintain the hotter side below air temperature in order to produce a temperature difference over the two faces of the module. The available heat sinks, however, are either expensive or not very effective. Thirdly, while there are many cheaper modules on the market, the better and more effective ones are more expensive and less long-lasting. Therefore, future developments ought to concentrate on fixing these flaws. The Power supply given to the box can be provided with solar power control which will increase the efficiency of cooling. The performance of Peltier cooling systems can be improved despite the fact that they are pollution-free, quiet, small, and low maintenance.

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