



Design Aspects of Solar Powered Thermoelectric Module to Operate Refrigeration System

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ABSTRACT: The increase in the demand for refrigeration globally in the field of air-conditioning, food preservations, medical services, vaccine storages, and for electronic components temperature control led to the increased production of electricity and consequently an increase in the CO₂ concentration in the atmosphere which in turn leads to global warming and many more climatic changes. Thermoelectric refrigeration is a new alternative because it can reduce the use of electricity to produce cooling effect and also meet current energy challenges. Therefore, the need for thermoelectric refrigeration in developing countries is very high where long life and low maintenance are required. The objectives of this study is to develop a working thermoelectric refrigerator to cool a volume 5L cabin that utilizes the Peltier effect to cool and maintain a selected temperature range of 5⁰C to 25⁰C. The cooling chamber design integrates thermoelectric modules (TEMs), which operate on the Peltier effect to cool juicer down to nearly 18⁰C. Solar panel added advantage to provide the energy. The design and fabrication of solar powered thermoelectric refrigerator for required applications are presented.

KEYWORDS: Solar energy, Thermoelectric generator, heat sink, refrigeration unit etc

I. INTRODUCTION

Due to the increasing demand for refrigeration in various fields led to production of more electricity and consequently more release of harmful gases like CO₂ all over the world which are one of the contributing factors of global warming on climate change. Thermoelectric refrigeration is a new alternative method. The thermoelectric modules are made of semiconductor materials electrically connected in series configuration and thermally in parallel to create cold and hot surfaces thus creating a temperature gradient. Although they are less efficient than the vapour compression system, they are very light, low in cost, silent in operation, and are environmental friendly.

The objective of this project work is to develop a portable thermoelectric refrigeration system capable of maintaining vaccine temperatures between 8°C and 13°C. The main system consisted of thermoelectric module as cooling generator along with an insulated cabin, battery and a charging unit. Thermoelectric elements perform the same cooling function as Freon-based vapor 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 system 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.

II. LITERATURE REVIEW

Jonathan Michael Schoenfeld et al [1] in his thesis submitted on integration of a thermoelectric sub cooler in 2008. There are two general research areas focused on increasing TEC performance; materials Research on thermoelectric semiconductors and system level assembly and heat dissipation techniques. The former is focused on developing advanced thermoelectric materials with superior thermoelectric properties. The most important parameter of a thermoelectric semiconductor is the figure of merit, Z, which is given by $\alpha^2 / (\rho \kappa)$. Each of these properties is temperature dependent so often the figure of merit will be given at a particular temperature in the dimensionless form, ZT. Increasing the figure of merit

directly results in an increase in the optimum COP of a TEC. The most common thermoelectric semiconductor in today's TECs is Bismuth Telluride (Bi_2Te_3), which has a ZT of ~ 0.9 at 300 K.

Bass et al. (2004) [2] investigated the use of multi-layer quantum well (MLQW) thermo electrics in a cooling application. MLQW thermoelectric material is a composite of thin layers of alternating semiconductor material with differing electronic band gaps deposited on a substrate. In this way, the thermal and electrical conductivity of the material can be decoupled. The non-dimensional figure of merit of such composite materials has been determined experimentally to be as high as 3 or 4. Theoretical analysis predicted COPs as high as 5 at a ΔT_m of 20 K. A TEC utilizing MLQW thermoelectric material is still under development. It can be expected that the additional manufacturing costs of such a module would be substantial.

Chain and Chen et al. (2005) [3] investigated the use of a micro channel heat sink on a TE module used to cool a water tank. The micro channels were etched into a silicon wafer with a glass cover plate. Four micro channel heat exchangers were fabricated with a differing number of ports and hydraulic diameters (D_h), from 89 ports at a D_h of $65 \mu\text{m}$ to 44 ports at a D_h of $150 \mu\text{m}$. Water was pumped at flow rates ranging from 289 – 10,702 ml/h to remove the heat from the hot side of the module. The micro channel was placed on top of a 4 cm x 4 cm TE module. The lowest measured thermal resistance for the heat sink was 1.68 K/W. The authors suggested that the thermal resistance could be reduced to 0.5 K/W by increasing 6 the aspect ratio of the micro channel ports and by using a more conductive material like copper.

III. EXPERIMENTAL SETUP

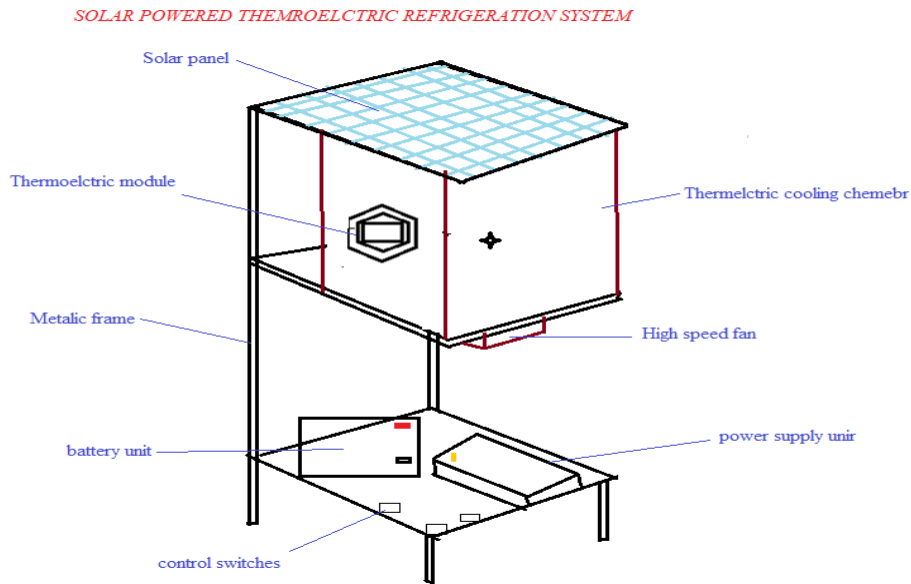




Figure 1: Thermoelectric refrigerator

IV. DESIGN PROCEDURE

The TEG module was selected by considering factors such as dimensions, heat load Q_c , power supply etc. The model number of the module is TEC1-12706. It is decided to select a TEG module which has a cooling power greater than the calculated cooling load. TEC1-12706 operates with an optimum voltage value of 12V. It has a maximum voltage of 15.4V. At 12V it draws a maximum DC current of 6 A. The nominal power rating or the cooling power is 60 W. It has a maximum operating temperature of 200 °C. ΔT of the TEG is 68 when hot side temperature is 25 °C. It had been decided to choose 1 TEGs of the same model so that when the power of 1 TEC modules are greater than the calculated cooling load. The minimum power rating for 1 TEG modules added together was more than the cooling load calculated. More number of TEG reduces the time required for cooling of a particular material.

- **Specification of TEG**

Table 1 : Specifications of TEG

Product	TEC-12706
Operational voltage	12V DC
Current max	6 Amp
Voltage max	15.4 V
Power max	92.4
Power nominal	60
Couples	127
Dimensions	40 x 40 x 3.5 mm



V. PERFORMANCE OF THE THERMOELECTRIC REFRIGERATOR

The active heat load is expressed as the equivalent cooling power that the unit will require to provide when the sample at ambient temperature is placed in the container. It was decided that two liters of water at room temperature was taken 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 vaccines for taking measurements and calculation. In these calculations, the properties of water are (density = 1 kg/L and $C_p = 4187$ J/kg). $V = 2.0$ L.

Coefficient of performance of the refrigerator (COP_R) was calculated,

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

$$Q = m C_p \Delta T$$

Mass of water, $m = \text{density} \times \text{volume} = 2$ kg

Total heat removed from the water = 166642.6 J

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

Power given to the system for working,

$$W_{IN} = V \times I + \text{fan input}$$

$$= 12 \times 4 + 2$$

$$= 50 \text{ W}$$

Coefficient of performance of this refrigeration system is given by,

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

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.

VI. CONCLUSION

A solar powered portable Cooling/refrigeration system was fabricated using thermoelectric module & electric control unit & tested for the cooling purposes. The system is self powered & can be used in isolated & a remote parts of the country where load-shading is a major problem. The important aspect to be noted is that it is a onetime investment and it is free from maintenance. 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 maintaining a particular temperature. The system is unable to handle fluctuations in load. Extensive modifications are needed to be incorporated before it can be released for efficient field use.

Further improvement in the efficiency of the system may be possible through improving module contact-resistance & thermal interfaces. This could be achieved by installing more modules in order to cover a greater surface area of the system.

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