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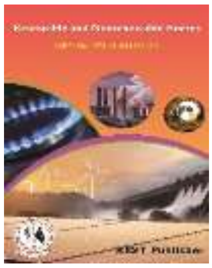

Fabrication of Thermo Electric Module for Cooling Applications Using Solar Energy

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Abstract: *Thermo-Electric refrigeration is one of the recent developments in the field of refrigeration. The development of semiconductor technology enhanced the feasibility of Thermo-Electric applications to greater extent. Thermo-Electric refrigeration systems were worked based on the principle of Peltier effect, where the passage of direct electric current through the junction of two dissimilar semiconductor materials causes the junction to either cool down (absorbing heat) or warm up (rejecting heat) depending on direction of current. Cooling effect can be used for storage (refrigeration) purpose of materials like vegetables and fruits. The power is given by solar energy for Thermo-Electric system for cooling applications instead of conventional electric power.*

Keywords: *Thermo-Electric Refrigeration, Peltier effect, solar energy, cold storage, Thermo-Electric module.*

1. INTRODUCTION

TER (Thermo Electric Refrigeration) modules were made up of two dissimilar metals that can be formed a junction in the 18th century. The developed TEC modules were comes into existence after the invention of semiconductor technology. The concept of See beck effect enhances the thermo electricity which was discovered by Thomas See beck, a German scientist in 1821. Another scientist named Jean Peltier found an opposite reaction to See- beck effect that was Peltier effect in 1834, which states that “the temperature difference occurs across the junction formed by two dissimilar conducting materials, when a direct electric Current flows through the junction”. The module also called as peltier module and it produces heat on one side and cooling effect on other side when a direct electric Current flows through it. This peltier effect can be used for refrigeration purpose. Applications for thermoelectric modules cover a wide spectrum of product areas. These include equipment used by military, medical, industrial, consumer, scientific/laboratory, and telecommunications organizations [1-3].

Operating principle: The operating principle of the TE modules is the peltier effect which states that “If the DC electric current flows through the junction of two dissimilar semiconductors, there is a temperature difference occurs across the junction”. The TE module produces cooling effect on one side and heating effect on other side when a DC current flows through the TE module. If the current direction changes, then the heating and cooling effects are also reversed means that the cooling effect occurs in place of heating effect and heating effect occurs in case of cooling effect. The TE module produces heating and cooling effects based on the current direction. The cooling effect and heating effects are also depending on the magnitude of DC current flows through the TE module. Formation of heat transfer occurs in the direction of current flow. By applying the current to the junction, then it transports heat from hot junction to cold junction [4-6]. The peltier effect is opposite to see beck effect in which, by applying temperature difference across the junction of two dissimilar semiconductor materials produces electric current.

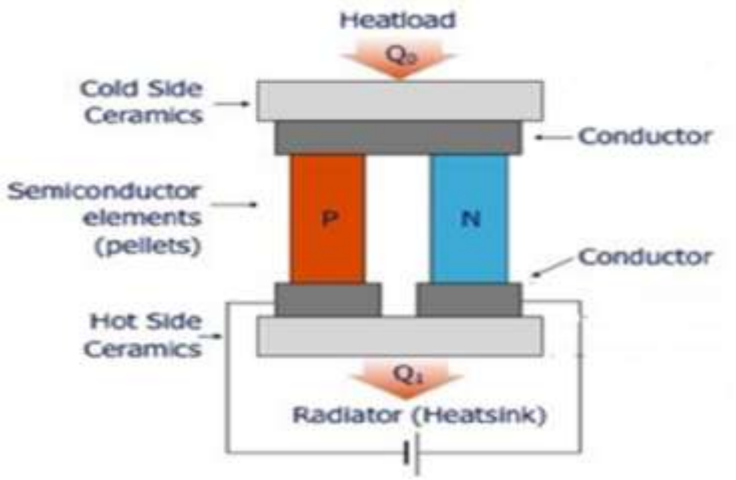

FIGURE 1. Operating principle of TE module

The average range in which temperature differ between the hot and cold surface of a TECM is between 64 and 67˚C. The compressor cooling system is compared to a TECM cooling system. The input power to both these systems is 60 W. Both systems pump 34 W of heat when the temperature difference (ΔT) between the hot and cold surfaces is 0˚C. This implies that the COP for both systems is the same at this point. As ΔT gradually increases, the heat pumping capability of the compressor system shows an advantage over the TECM system. The COP of the TECM system becomes less efficient than the compressor system with the increase in ΔT, because the compressor system has a much larger ΔT than the TECM system [7-10]. TE devices have many possible applications beyond cooling CPU chips. Among these applications are portable coolers, environmental control for optoelectronic equipment, and power generation in remote environments. Some consumer applications include a TE powered watch, a TE temperature-controlled vest, a Cannon digital camera, and a Coleman portable cooler [11]. Since the SIA roadmap suggests that by the year 2015 there is currently no known thermal solution to meet industry performance needs, have proposed TE refrigeration as a possible solution. Cryopreservation and storage of biological tissue are applications where precise temperature control and high cooling rates are necessary. In cryopreservation cells can be severely damaged if the cooling rate is not controlled precisely. For TE refrigeration, even with a current commercially available module, the cooling rate can exceed 7.6°C /s (under no heat load). TE modules can be utilized to generate electricity (Collamn et al 2). In a thermoelectric cooling system, a doped semiconductor material essentially takes the place of the liquid refrigerant, the condenser is replaced by a finned heat sink, and the compressor is replaced by a DC power source. The application of DC power to the thermoelectric module causes electrons to move through the semiconductor material. At the cold end (or "freezer side") of the semiconductor material, heat is absorbed by the electron movement, moved through the material, and expelled at the hot end. Since the hot end of the material is physically attached to a heat sink, the heat is passed from the material to the heat sink and then, in turn, transferred to the environment (AICTE project et al, 3). The main thrust of these studies is to design TE systems in order to eliminate or reduce losses in efficiency and performance. Simons, et al completed a case study using conventional off-the-shelf TE modules applied to a server application. Their conclusion was that current TE materials cannot provide large enough COP's to be competitive with conventional vapour compression refrigerators (Khartchenko et al 4). Baylin et al. [5] have designed and developed a thermoelectric refrigeration system powered by solar cells generated DC voltage and carried out experimental investigation and analysis. They developed a prototype which consists of a thermoelectric module, array of solar cell, controller, storage battery and rectifier. The system with solar cells and thermoelectric refrigerator is used for outside purpose in daytime and system with storage battery, AC rectifier and TER is used in night time when AC power is available. Experimental analysis on the unit was conducted mainly under sunshine conditions. The studied refrigerator can maintain the temperature in refrigerated space at 5–10ºC, and has a COP about 0.3 under given conditions. Summary: In the process of thermos electric refrigeration, the cooling effect was effectively used for cooling applications such as storage of vegetables, fruits etc... Due to energy crisis, it is important to conserve energy. The system is supplied by solar energy instead of conventional electric power by the solar panel and battery arrangements.

2. METHODOLOGY

Depending upon the load, the modules are selected. The proposed design of the system for cooling applications

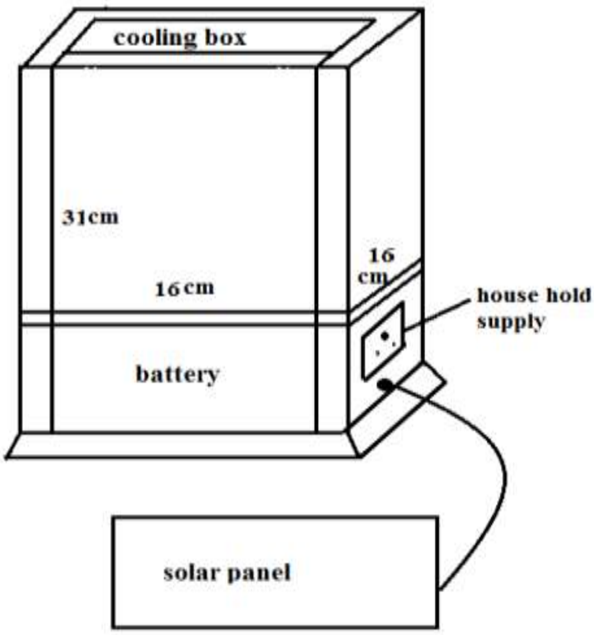

FIGURE 2. Proposed model design

Load calculations:

Specifications of aluminium box

Length = 16cm

Width = 16cm

Height =31cm

Volume =16*16*31 =7936cm^3

Capacity =7.936lit

Cooling capacity required =m*c*dt (1)

=7.9*4.27*(31-12)

=640KJ

=178.03W

Module selection:

Number of modules= $\frac{\text{Cooling capacitu required}}{\text{Cooling capacity of module}}$(2)

Cooling capacity of module =45W

Number of modules required $=\frac{178.03}{45}=3.95$

Hence 4 peltier modules are required to obtain the temperature of 12^{o}C inside the cold box.

3. EXPERIMENTAL SETUP

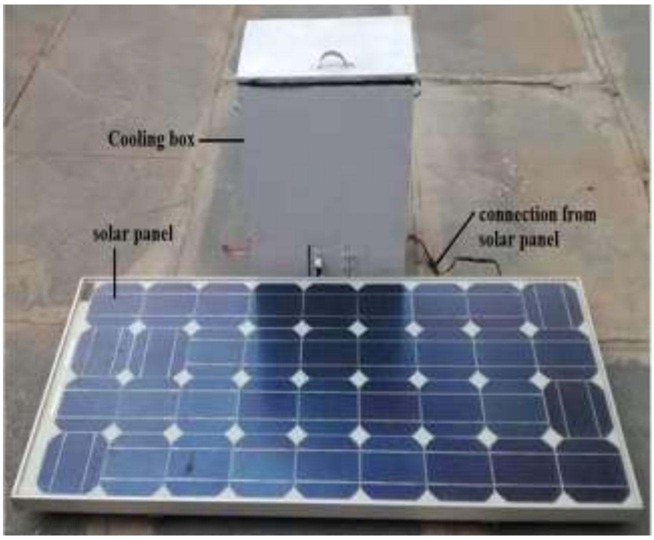

FIGURE 3. Fabricated Thermo Electric Refrigerator system powered by solar energy

The experimental set up consisting of:

- Thermo electric modules
- Solar panel
- Battery
- Metal (aluminium boxes)
- Insulation

A. Thermo Electric modules: For the selected box capacity of 7.9 lit, four Thermo Electric modules are used in the fabrication to obtain 12ºC inside the cold box. The cooling capacity of one module is 45W. The hot side surface of module is mounting on heat sink.

B. Solar panel: Solar pane converts light energy into electrical energy. One square meter of fixed array kept facing south yields nearly 0.5 KWh of electrical energy on a normal sunny day. Here we use a 50 W solar panel with output of 16 V.

C. Battery: Batteries are the devices which stores DC electrical energy in form of chemical energy. In these systems batteries are used for storage of excess solar energy converted into electrical energy. In this fabrication we use a 12 V lead-acid battery.

D. Metal (aluminium boxes): The aluminium box dimensions used in this project are 16*16*31 cm and the capacity of the box is 7.9 lit.

E. Insulation: A black foam insulation material of thickness of 14mm is used to reduce the heat losses to the surroundings around the box.

Experimentation: Experiments are conducted to analyse the COP. The power supply from the battery which is charged by solar panel is given to system and temperature readings inside the box are taking by placing the thermo couple inside the box for every 10 minutes of time. The readings are tabulated and check for least temperatures occur in cold. After that the power is switch OFFand checks for the storage time of the box and readings are taken. The tabulated values are plotted as temperature vs time for power ON and OFF conditions.

4. RESULTS AND DISCUSSIONS

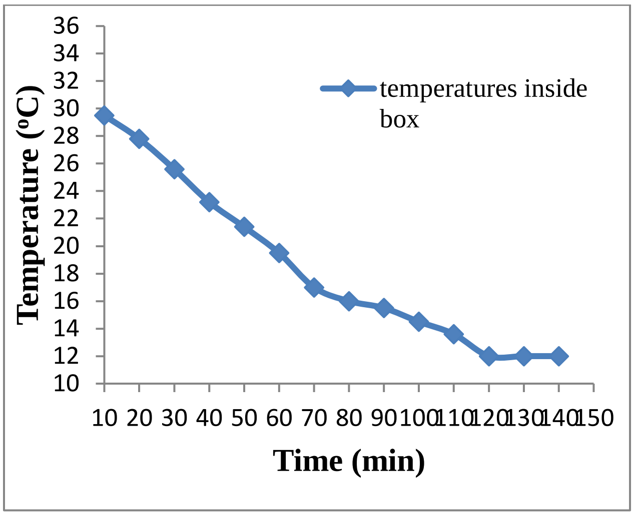

FIGURE 4. Temperature values inside the cold box (Vs) time at power ON condition

The temperature values (ºC) inside the cold box Vs the time (min) are plotted as shown in Fig.4 at power ON condition. The temperature readings are taken inside the cold box at ambient temperature of 34ºC for every 10 minutes up to 150 minutes. The minimum temperature inside the cold boxis12ºC.

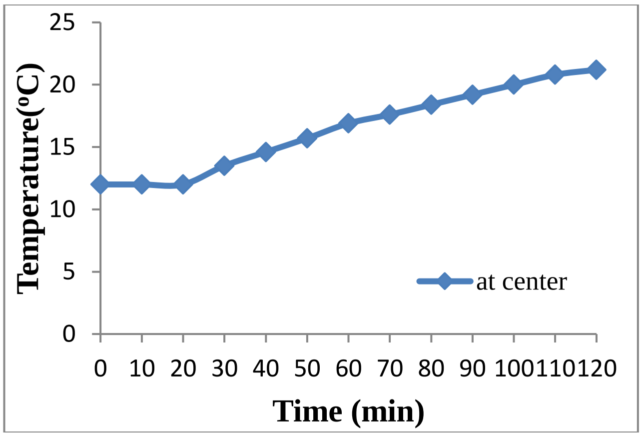

FIGURE 5. Temperature values inside the cold box (Vs) time at power OFF condition

The temperature values (ºC) inside the cold box Vs the time (min) are plotted as shown in Fig.5 at power OFF condition. The temperature readings are taken inside the cold box at ambient temperature of 34ºC for every 10 minutes up to 120 minutes. Up to 20 minutes we can maintain the same temperature of 12ºC inside the cold box.

5. CALCULATIONS

Heat absorbed inside the cold side box (Q_{abs})is the convective heat transfer inside cold box as shown in Eq.3.

Convective heat transfer inside the box (Q_{abs}) $=h*A*\Delta T$ (3)

Where h= Free convective heat transfer coefficient of air = 24 W/m^2K

A = Area inside the cold box= 0.0496m^2

ΔT= Temperature difference

Input power given (Q_{in}) = 160 W

Heat absorbed inside the cold box (Q_{abs})= 40 W

COP (Coefficient of Performance) = Q_{abs}/Q_{inp}(4)

= 0.25

6. CONCLUSION

A portable Thermo Electric system for cooling applications has been fabricated. The temperature inside the cod box obtained is 12ºC. The COP of TER (Thermo Electric Refrigeration) system is 0.25. The cooling effect used for storage purpose of materials like medicine, vegetables, fruits, etc.... Hence the fabricated TER (Thermo Electric Refrigeration) powered by solar energy is utilized for cooling applications.

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