ISSN XXXX XXXX © 2017 IJESC

IJESC

Research Article Volume 7 Issue No.5

Performance Evaluation of Solar Based Thermoelectric Refrigerator

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Abstract:
The global increasing demand for refrigeration in field of refrigeration air-conditioning, food preservation, vaccine storages, medical services, and cooling of electronic devices, led to production of more electricity and consequently more release of CO2 all over the world which it is contributing factor of global warming on climate change. Thermoelectric refrigeration is new alternative because it can convert waste electricity into useful cooling, is expected to play an important role in meeting todays's energy challenges. Therefore, thermoelectric refrigeration is greatly needed, particularly for developing countries where long life and low maintenance are needed. The objectives of this study is design and develop a working thermoelectric refrigerator interior cooling volume of 4.5 L that utilizes the Peltier effect to refrigerate and maintain a selected temperature from 15 °C to 20 °C. The design requirements are to cool this volume to temperature within a time period of 6 hrs and provide retention of at least next half an hour. The design requirement, options available and the final design of Thermoelectric refrigerator for application are presented.

Keywords: Vaccine, Thermoelectric Refrigeration, Peltier Effect, module, Global Warming, Climatic Change

I. INTRODUCTION

Emisssions of greenhouse gases like CFC from domestic home appliances like AC and refrigerators has become a major concern these days. These appliances are not only high on CFC emissions but are bulky and consume high power on the other hand. World needs an alternative for the conventional refrigeration systems. Solar based thermoelectric cooling works on the principle of "Peltier Effect". "Peltier Effect" states that if current is passed through a thermocouple, then the heat is absorbed at one junction and liberated at other junction. So by using the cold junction as an evaporator, a heat sink as the condenser and solar charged DC power source as the compressor, cooling effect can be achieved. By solar energy, these refrigerators are able to keep perishable goods such as meat and dairy cool in hot season and are used to keep much needed vaccines at their appropriate temperature to avoid spoilage. The portable devices can be caused with simple components and are refrigerator beneficial for areas of the developing world electricity is unreliable or non-existent.

II. OBJECTIVES

Objective of this project is to design thermoelectric Refrigerator Utilize Peltier effect to refrigerate and maintain a specified temperature, perform temperature control in the range 15 °C to 20 °C. Interior cooled volume of 4.5 Liter and Retention for next half hour

III. DESIGN OF THERMOELECTRIC COMPONENTS

The design progressed through a series of steps. These steps were identification of the problem, analyze problem, brainstorm ideas, decide upon a design selection, and implement design. Redesign if necessary. The main design considerations were Heat Transfer Methods, Geometry and Materials. To design thermoelectric components we need to calculate heat load on refrigerator due to active, passive and air changing load, the total heat load is calculated for following specification mentioned in Table 1 and Environmental condition mentioned in Table 2.

Table. 1. Design calculation of thermoelectric water can cooler

Outside Dimension (mm)	Width (w)	260
	Length (l)	360
	Height (h)	240
Inside Dimension (mm)	Width (w)	140
	Length (l)	210
	Height (h)	150
Door Dimension(mm)	Width(w)	6
	Length(l)	285
	Height(h)	240
Note : Usable Volume	**4.5 Litres**	

Table.3. Inputs to Heat Load

S. No.	Parameters	Values
1.	Outside Temperature (Do) (°C)	43
2.	Inside Temperature (Di) (°C)	3
3.	Internal Fan Motor Wattage (W)	1
4.	Gasket Thickness (m)	0.01
5.	Gasket Height (m)	0.025
6.	Outside Material Thickness (m)	0.00028
7.	Inside Material Thickness (m)	0.00036
8.	M/C Area Top Temperature (°C)	48
9.	Inside Heat Transfer Coefficient (W/ m^2K)	10
10.	Outside Heat Transfer Coefficient (W/m^2K)	10
11.	Outside Material Thermal Conductivity HIPS (W/m^2K)	0.188
12.	Inside Material Thermal Conductivity HIPS (W/m^2K)	0.188
13.	Gasket Thermal Conductivity (W/m^2K)	0.07
14.	Heat Extender Material (W/m^2K)	373
15.	Top Foam Thickness (m)	0.025
16.	Foam Thermal Conductivity (W/m^2K)	0.1944

Using Tables 1 and 2 for the input the total heat load calculated as 33 Watts using standard conduction and convective heat transfer equations. the optimum foam thickness considering cost vs. heat load Figure 1 represent the 20 mm is optimum range of foam thickness.

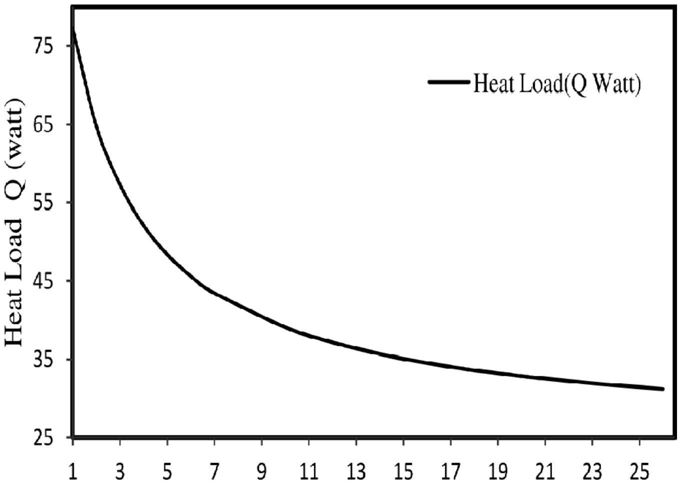

Figure.1. Heat Load vs. Foam Thickness

Heat Sink Design

In order to visualize the energy flow in the entire system, a thermal circuit is constructed, which is schematically shown in Figure 2. *Rc* and *Rh* and are the overall thermal resistances for the internal heat sink and external heat sink, respectively. The components of the air cooler are an internal heat sink, a thermoelectric module, and an external heat sink as shown in Figure 2 is the amount of heat transported at the internal heat sink, which is actually the design requirement (33Watts).

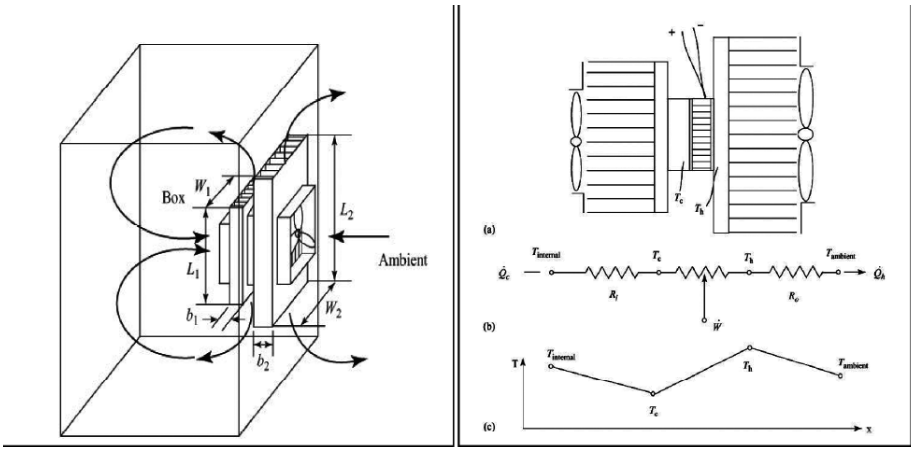

Figure.2. Air Flow of a Thermoelectric Air Cooler

Considering the dimension available at the machine area and various options keeping the weight, cost and manufacturing feasibility as the main consideration for selection for mounting of heat sink both at hot and cold side area Fin thickness of 1mm with profile length of 20 mm is selected.

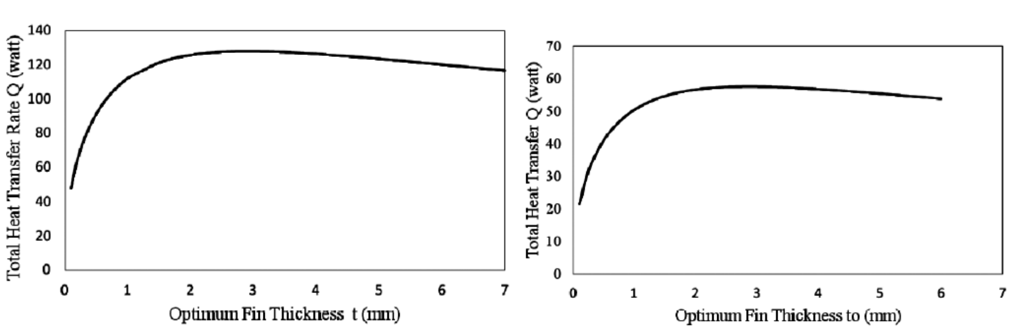

Figure.3. Total Heat Transfer (*Q*) vs. Optimum Fin Thickness (*to*) for Hot Side and Cold Side Fin

Thermoelectric Cell

Using Standard correlation available in handbooks the commercial available module with the calculated maximum performance is represented in Table 5.

Table 5: Model Number for TER		Dimensions	
Module: Model TEC1-127-06L			
*Q*max	51.4 Watts	Width	40mm
*I*max	6 Amp	Length	40mm
*V*max	15.4 V	Thickness	3.8 mm
*T*max	67 °C		
Number of Thermocouple	127		

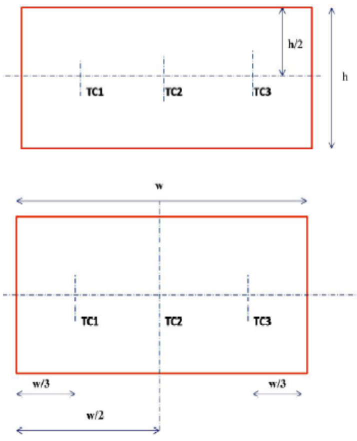

Figure.4. Build of TEC Thermocouple

IV. EXPERIMENTATION

This presents the detailed information of instruments, working procedure, operating parameters of thermoelectric cooler.

Experimental test facility

The test facility is used to test cooling performance, Energy measurements of Refrigerators and Freezers based on National and International standards in an environmentally Controlled chambers. This lab has NABL Accreditation capable of testing cooling performance, Energy measurements of Refrigerators and Freezer based on National and International Standards in environmentally controlled chambers.

Thermocouple Set-Up

The thermocouple of □15 mm □ 15 mm dimension is installed in TEC as per Figure 5 below:

Test procedure

The following test procedure is followed during the testing of:
The cabinet, with all compartment doors, pans, and grilles open, is to have been electrically disconnected for at least 16hours in an ambient temperature of (43 °C,32 °C or 21 °C) immediately preceding the start of the test.

- The cabinet, with all compartment doors, pans, and grilles open, is to have been electrically disconnected for at least 16 hours in an ambient temperature of (43 °C, 32 °C or 21 °C) immediately preceding the start of the test.
- During the test, all refrigerating system controls (thermostats, automatic defrost controls, etc.) are to be electrically inactivated (if necessary) to insure a continuous operation of the regrigerant motor-compressor assembly.
- Test rooms and Measuring Instruments shall meet the requirements as per ISO15502:2007/Au/Nzs 4474.1.2007.
- Start the Unit once the product reaches the temperature of ambient condition.
- To observe the lowest" compartment temperatures attained at the end of the specified test period of 6 hours.
- The retention time is calculated from the time the product reaches 20 °C to the time taken to reach ambient condition when
tested at 32 °C.

V. RESULTS AND DISCUSSION

To verify the above system design analysis, we designed and built a prototype thermoelectric cooler and perform an experiment. The picture built of the thermo-electric cooler is shown in Figure 6. The thermoelectric module is used for the experiment.

(a) Cabinet **(b) Sandwich of Fan ,Heat Sink and Module**

Figure 5: Prototype of Thermoelectric Cooler

COOLING RATE TEST DATA

The test was conducted at different ambient 21 °C, 15 °C, 32 °C and 43 °C represented in Figure 7. The temperature vary from 15 °C to 20 °C with temperature variation within the TEC is less than 1 °C as this was the proto sample with improvement in prototyping we can achieve even lower temperature.

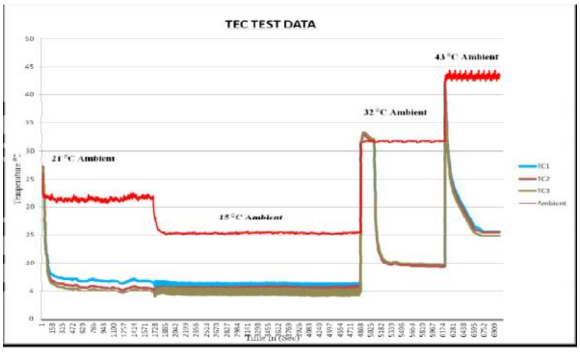

Figure.6. Data at Various Ambient Conditions

VI. CONCLUSION AND FUTURE SCOPE

The objective project is to achieve the long term cooling in case of power failure for refrigerator. A TER Cooling system is has been designed and developed to provide active cooling with help of single stage 12 V TE module is used to provide adequate cooling. First the cooling load calculations for this TER compartment considered under study were presented. Simulation tests in laboratory have validated the theoretical design parameters and established the feasibility of providing cooling with single stage thermoelectric cooler was tested in the environmental chamber. As TER not available in open market which we can retain cooling at case of power outage due to high current carrying capacity.

VII. FUTURE SCOPE

With recent development taking place in field of thermoelectric and nanoscience different thermoelectric material with figure of merit ZT more than 1 with high temperature difference to be explored this will further help to reduce the temperature, current below and can also perform better at higher ambient conditions. To improve the power retention in this thermoelectric cooler sandwich heater needs to be explored with quick switching mechanism from thermoelectric cell off state of heater to on state, so that temperature drop in thermoelectric cell can be reduced.

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