DESIGN AND FABRICATION OF REFRIGERATION CUM HEATER USING PELTIER EFFECT TO KEEP FOOD AND DRINKING PRODUCTS

Harsh Rathod[1], Rahul Dodiya[2], Meet Amin[3], Dhaval Zanzrukiya[4], Prof Zankar Yadav [5]

The increasing demand for refrigeration in field of refrigeration air-conditioning, vaccine storages, medical services, and in cooling of electronic devices, A Thermoelectric module (TEM) is use as it is based on the principles of Peltier effect. The use of Peltier effect is to create a heating side and a cooling side and also to maintain effectiveness. Thermoelectric cooler (TEC) is a solid-state heat pump uses the semiconductor materials, by the principle of Peltier effect, to provide instantaneous cooling or heating. It has no moving parts and thus maintenance free. It is a pollution less project, made by using thermoelectric module. It supports for both heating and cooling in same time. Hence it proves to be very helpful. It is pollutant free-contains no liquids or gases, compact, creates no vibration or noise because of the difference in the mechanics of the system. The project has various applications like refrigeration purpose, for storing blood plasma, vaccines, and other medical and pharmaceutical supplies etc."

Keywords: Carbon dioxide, Thermoelectric, Thermoelectric cooler, Thermoelectric refrigerator, Thermoelectric heater.

INTRODUCTION

Conventional cooling systems used in refrigerators utilize a compressor and a working fluid to transfer heat. Thermal energy is absorbed from the cooling chamber and then it is released in the environment. The working fluid undergoes expansion & compression and changes its phase from liquid to vapor and vice-versa respectively.

Thermoelectric coolers (Peltier coolers) offer many advantages over conventional refrigeration systems. Thermoelectric coolers are entirely solid-state devices, with no moving parts; this makes them rugged, reliable, and quiet. This device does not use ozone depleting Chlorofluorocarbons, and it is potentially offering a more environment friendly and is a better alternative to conventional refrigeration. These devices are extremely compact, silent and easy to operate than the conventional compressor-based refrigeration systems. These devices can be extremely compact than the compressor-based systems. Precise temperature control (< ± 0.1 °C) can be achieved with Peltier coolers. However, their efficiency is low compared to conventional refrigerators. Thus, they are used in applications where their unique advantages balance their low efficiency. Peltier coolers are generally used in applications where small size is needed and the cooling demands are not too excessive, such as for cooling electronic components.

Objective of this project is to design thermoelectric Refrigerator cum heater by utilizing Peltier effect to refrigerate a compartment of 21.38 Liters and maintain it to a specified temperature, perform temperature control in the range 15 °C to 25 °C and Retention for next half hour.

The heat generated by the Peltier cooler/plates are also utilized in warming food items to temperature of 40 °C to 45 °C. There are products available in market where the thermoelectric cooling and heating is utilizing but not at same time so we design and fabricate a prototype which can cool & warm drinking products and food items.

PRINCIPLE

What is a Peltier effect?

Peltier effect was discovered in 1834 by the French physicist Jean-Charles-Athanase Peltier. He found that by the use of two dissimilar metals if current is passed between the junctions, the two junctions will create a temperature difference between them. One junction becomes hot and the other becomes cool. This is the basis on which our project works.by using Peltier effect we will make two different compartments to heat and cool food and drinking products.

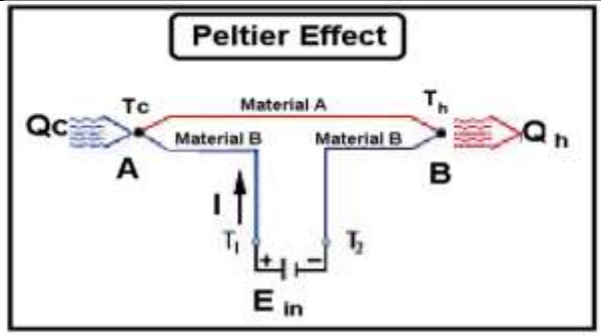

Fig 1.1 Peltier effect

What is a seeback effect?

Thermoelectric conversion was discovered towards the end of the 19th century. Electrons are capable of carrying heat, as well as electricity. When a temperature difference exists between the two end faces of a thermoelectric material, many electrons will travel from the hot end face to the cold one. This phenomenon is known as the Seebeck effect and forms the basis on which the thermoelectric generation module was developed. As we are all aware, the global energy crisis is becoming worse and much emphasis is being placed on environment protection and the recovery of energy resources. These include waste heat from cooling water, exhaust gas, and steam power plants, amongst others. TEG modules are light and silent, have no moving parts and can convert recycled heat directly into electricity.

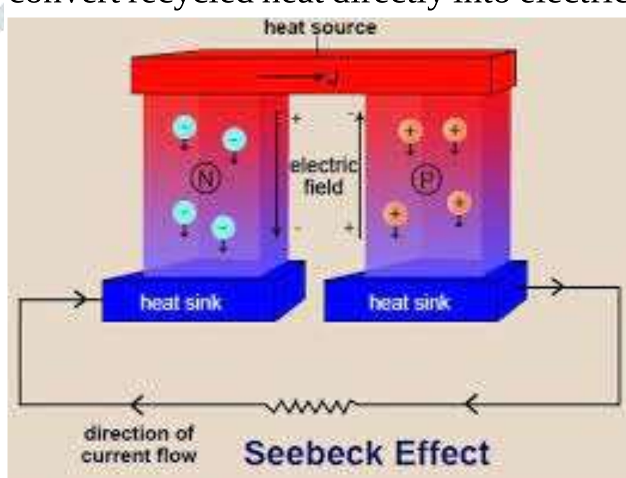

Fig. 1.2 Seeback Effect

MATERIAL REVIEW

Thermoelectric module is made of two different semiconducting materials, when a voltage of similar polarity and in appropriate direction applied through the connected junction generates cooling effect on one material and heating on other.

The compartments were made of thermocol as it is having low thermal conductivity and it is cheaper. Also, it is easy to use and can cut easily.

Four heat sinks and four fans are attached to the hot sides and additionally four fins are attached to the cold sides of thermoelectric module in order to increase heat transfer and system performance. There exists an optimum current & voltage for maximum coefficient of performance (COP) for a specific module and fixed hot or cold side temperatures.

According to the primary criterion of figure of merit

$$(Z = \frac{\alpha^2}{RK}),$$

a good thermoelectric material should have high Seebeck coefficient, high electrical conductivity, and low thermal conductivity. Commonly used thermoelectric materials are Bismuth Telluride (Bi_2Te_3), Lead Telluride (PbTe), Silicon Germanium (SiGe) and Cobalt Antimony ($CoSb_3$), among which Bi_2Te_3 is the most commonly used one. These materials usually process a ZT value (figure of merit at temperature) less than one. From 1960s to 1990s, developments in materials in the view of increasing ZT value was modest, but after the mid-1990s, by using nano structural engineering thermoelectric material efficiency is greatly improved. Thermoelectric materials such as primary bulk thermoelectric materials like skutterudites, clathrates and half-Heusler alloys, which are principally produced through doping method are developed but not exploited for commercial use.

The best commercial thermoelectric materials currently have ZT values around 1.0. The highest ZT value in research is about 3. Other best reported thermoelectric materials have figure-of-merit values of 1.2-2.2 at temperature range of 320-520^{0}C. It is estimated that thermoelectric coolers with ZT value of 1.0 operate at only 10% of Carnot efficiency. Some 30% of Carnot efficiency could be reached by a device with a ZT value of 4. However, increasing ZT to 4 has remained a formidable challenge. Bell also mentioned that if the average ZT reaches 2, domestic and commercial solid-state heating, ventilating and air-cooling systems using thermoelectric material would become practical.

CONSTRUCTION

The compartments of volume 21.38 Liters are fabricated using the thermocol sheet of 20mm. The refrigeration compartment is insulated from inside with the help of the aluminum tape so as to isolate the cooling compartment from the surroundings. The heating side compartment is covered with the aluminum tape. The thermoelectric module is sandwiched between two CPU heat sinks of different sizes using thermal paste to set a single unit. In total there are four such units are attached to the compartments and also for better heat dissipation fans on the hotter side fins are provided. As heat dissipation plays an important role in cooling too.

The thermal paste also plays a vital role in conduction of heat from Peltier module to the aluminum heat sinks.

Additionally U.V lamp is also provided to sterilize the surface of the drinking products or any other food products in the refrigeration compartment. For sensing the temperature, temperature sensors are placed inside both the compartments.

Every component is connected through parallel connection. However, Power in all the fans and the Peltier modules are supplied from SMPS of power output of 12 volts and 30 amps. The SMPS input is 230-volt AC supply.

ANALYSIS

Geometric Characteristics

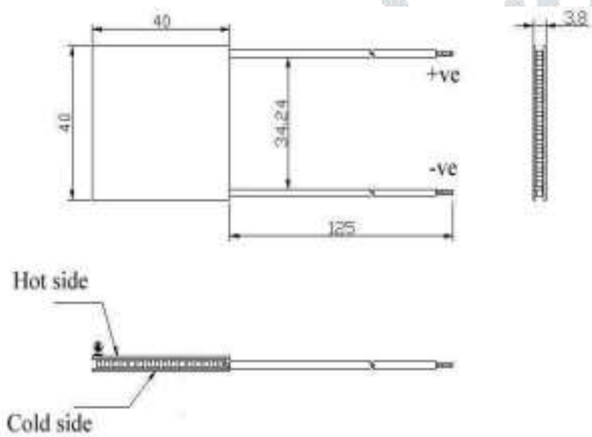

Fig 1.3 Plate dimensions

→Naming of the module

The Peltier module used in this project is TEC1-12706.

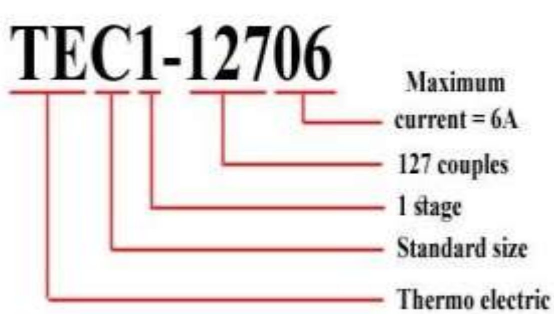

Fig 1.4 Plate specification

Performance curves at T_h = 27 ºC

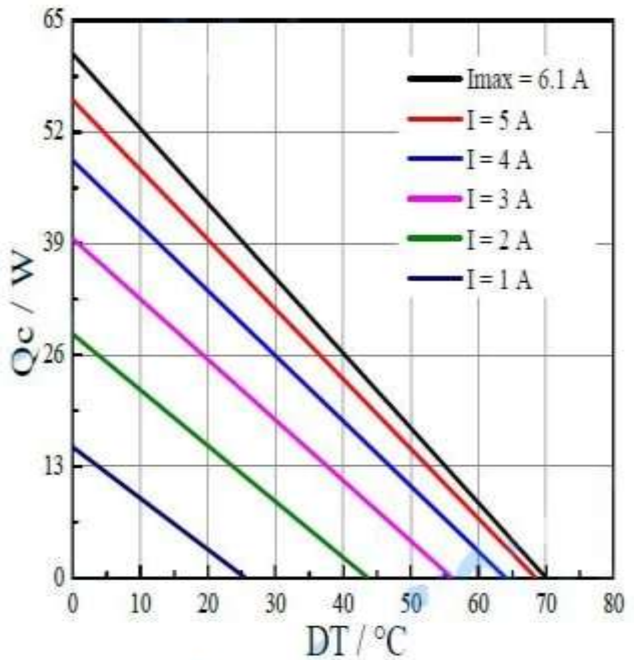

Fig 1.5 Standard performance graph $Q_c = f(DT)$

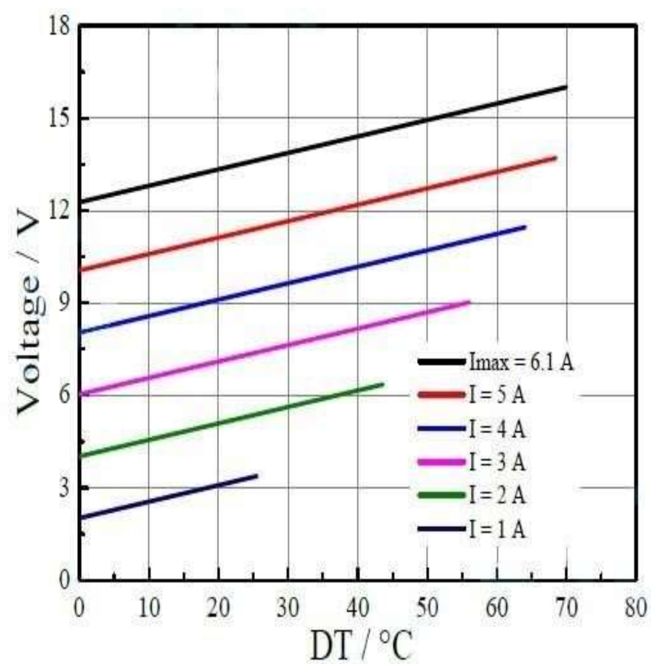

Fig 1.6 Standard performance graph V = f(DT)

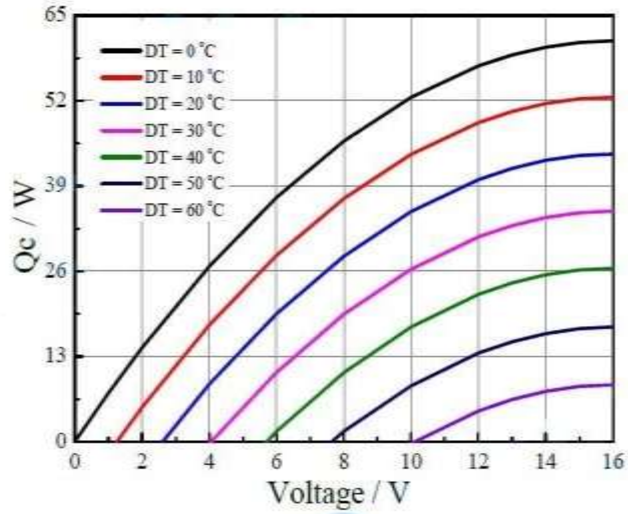

Fig 1.7 Standard performance graph $Q_c = f(V)$

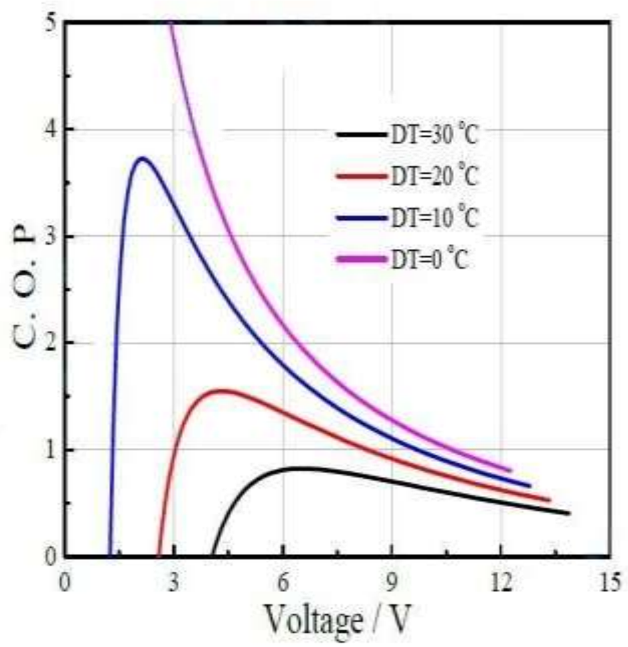

Fig 1.8 Standard performance graph COP = f(V)

FABRICATION

Components used in fabrication of this project are:

COMPONENTS	QUANTITY
Peltier module	4
CPU cooling fan	4
CPU heat sink	8
Thermal paste(10g)	1
SMPS (12V&30amps)	1
U.V. lamp	1
Thermocol sheet (25*80*2cms)	5
Aluminum tape	1
Aluminum foil	-
Connecting wires	-
Fevicol	-

Table 1.1

FABRICATION PROCEDURE

- Two thermocol box of inner cabin volume of 21.38 liters is made by thermocol sheets of 20mm each. The dimensions as follows 40*22*37 CMS.
- There are four slots of 40*40mm are made on one face of the cabin.
- All the inner faces of the cooling cabin have been taped with aluminum tape & foil to insulate it completely, so as to isolate the cooling cabin from the atmosphere.
- The thermo electric module is sandwiched between two CPU heat sinks of similar sizes using thermal paste to set a single unit. There is total 4 of such units are made.

  Thermal paste plays a vital role in conduction of heat from Peltier module to the aluminum heat sinks.

- These units are placed in the cut slots with the CPU heat sinks facing in the interior of the both cabins.
- Also, CPU fans are fitted on the outer side of the heat sinks to have proper heat dissipation/rejection.
- Electrical connections are made and power is supplied from a SMPS of power output of 12V & 30amps.
- Additionally, square slots are also provided on the three walls of the heating cabin to have more ventilation in the cabin and thus providing more heat dissipation rate as heat transfer rate is also increased.

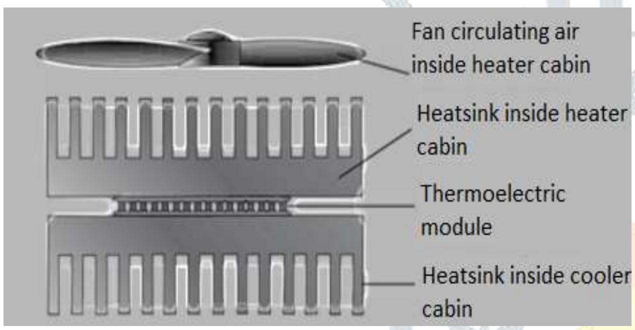

Fig 1.9 Heatsink-plate-fin assembly

BASIC CONCEPT DESIGN

For better understanding of different parts of our project first we made sketches on paper so we can understand different components of our project and get idea to how we will make project model.

DESIGNING IN PARAMETRIC SOFTWARE

For the design of the final product, we made a 3D model in SOLIDWORKS Software, in which we made different individual components and finally we put together different components.

To make a model, it is first necessary to make individual parts with the desired shape and dimensions containing in whole machine and then we need to assemble each of the parts together to make the final model.

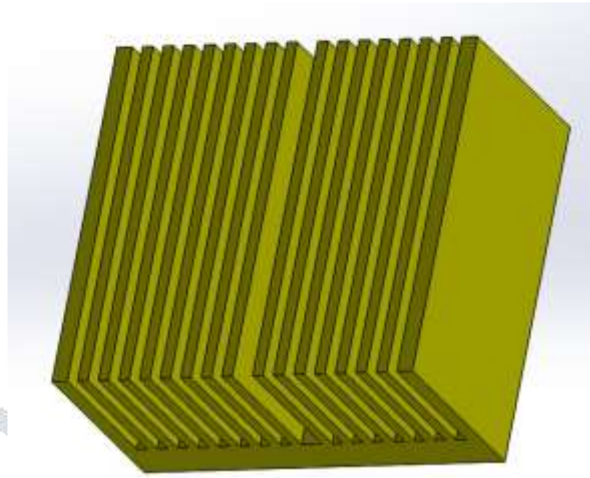

Fig 1.10 Heatsink

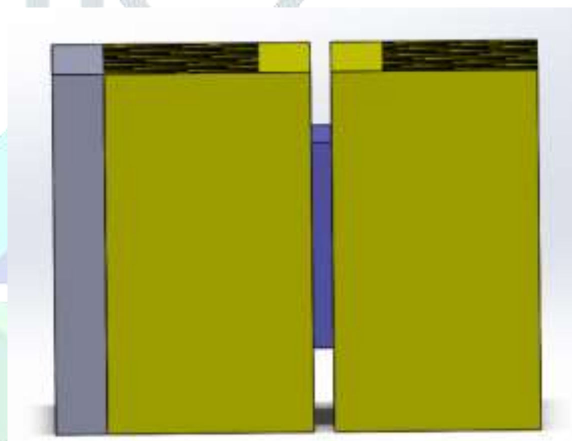

Fig 1.11 Heatsinks-plate-fan assembly

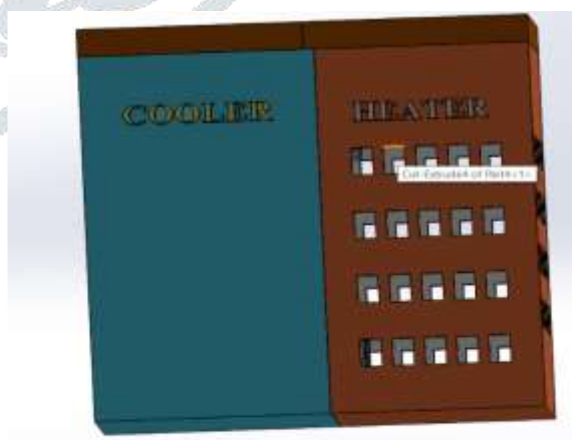

Fig 1.12 Final assembly

EXPERIMENTATION

Firstly, three plates & fans are operated and after that reading from heater and cooler are noted. And similarly, four plates & fans are operated and then readings are also noted from both the compartments/cabins.

Fig 1.13 Side view of model

Fig 1.14 Top view of model

Using 3 Peltier plate and using 4 Peltier plate

Observation with 3 Peltier plate			**Observation with 4 Peltier plate**		
Time (min)	**Cooling side Temperature (°C)**	**Heating side Temperature (°C)**	**Time(min)**	**Cooling side Temperature (°C)**	**Heating side Temperature (°C)**
10 min	30(°C)	30(°C)	10 min	32(°C)	34(°C)
20 min	28(°C)	34(°C)	20 min	30(°C)	37(°C)
30 min	26(°C)	36(°C)	30 min	28(°C)	39(°C)
40 min	25(°C)	38(°C)	40 min	25(°C)	40(°C)
50 min	23(°C)	40(°C)	50 min	22(°C)	42(°C)
60 min	20(°C)	40(°C)	60 min	18(°C)	44(°C)

Table 1.2

CALCULATION

Theoretical Calculations: -

- **Plate: -**

I= 25amp, V_{max}= 12V, T_H = 45 °C+273 = 318K

$\alpha_m = V_{max} / T_H = 12 / 318 = 0.03773$

$R_M = [(T_H - \Delta T_{max}) / T_H] [V_{max}/ I_{max}]$
= [(318-30)/ 318] [12/25]
= 0.4347Ω

$V_m = [(T_h - \Delta T_{max}) /2*\Delta T_{max}] * [V_{max} / (I_{max} *T_h)]$

= [(318 – 30)/ 2*30] * [12/(25*318)

= 0.007245 V

$Q_c = (\alpha_m*T_c*I) – (I^2*R_m/2) – V_m *(T_h-T_c)$

= (0.03773*288*25) – (25^2 *0.4347 /2) – 0.007245*(30)
= 135.59 watts

$W = \alpha_m * I *(T_H – T_c) + I^2R_m$
=0.03773 * 25 * 27 + $(25)^2$*0.5901
= 296.58 watts

COP = Q_c / W
= 135.59/298.58
= 0.45

- **Heat sink**

l=0.03m, b=0.07m, t=0.001m, k=205W/mk, h=50W/m^2K

Perimeter(P) = 2(t+b)
=2(0.001+0.07)
= 0.142m

Cross sectional area(A_c)= b*t

=0.07*0.001

=0.00007m^2

$m = \frac{\sqrt{hP}}{kAc}$
= √(50*0.142)/ (205*0.00007)
= 22.243

$Q_{fin} = \sqrt{hPkAc}(Tb - T\infty)\tanh(ml)$
= $\sqrt{(50)*0.142*205*0.00007}(45-33)$*tanh(22.24*0.03)

=2.2328watts

Effectiveness (ε)

$$\varepsilon = \frac{Qfin}{Q}$$

$$\varepsilon = \frac{\sqrt{kP}}{hAc} * \tanh(ml)$$

$$\varepsilon = 91.19 * .5831$$

$$\varepsilon = 53.177$$

Fin efficiency

$$\dot{\eta}f = \frac{Qfin}{Qmax}$$

$$= \frac{tanhml}{ml}$$

$= \frac{0.5831}{0.6672}$

$= 0.87400$

$= 87\%$

Overall fin efficiency

$A_t = A_b + NA_c$

$= 0.0049+(10*0.00007)$

$= 0.0056m^2$

$$ή = 1 - NAf\frac{1-ήf}{At}$$

$$= 1 - \frac{10(0.00007)(1-0.87)}{0.0056}$$

$= 1 - 0.01625$

$= 0.9837$

$ή = 98.37\%$

Actual calculation: -

$F_{22} + F_{21} = 1$
$F_{22} = 0$ (flat plate)
; $F_{21} = 1$

A_1 = plate dimensions
= 0.40*0.40 =0.16m^2
A_2 = wall dimensions
= 0.36*0.33 = 0.11m^2

By reciprocity eqation
$F_{12} A_1 = F_{21} A_2$
$F_{12} = F_{21} A_2 / A_1$
= 1*0.11 / 0.16
= 0.68

$\varepsilon1 = 0.94$

$\varepsilon2 = 0.60$

$Q_{rad} = \frac{\sigma(T1^4 - T2^4)}{\frac{1-\varepsilon1}{A1\varepsilon1}+\frac{1}{A1\,F12}+\frac{1-\varepsilon2}{A2\varepsilon2}}$ = 3.3911watts

Internal dimensions of cabin→
l=0.36m , b= 0.18m & h= 0.33m

FOR COOLING LOAD(Q_C) calculation,

For transmission load,

U(thermocol) = 3.3W/m^2K
T_{out} = 33 °C
T_{store} = 18 °C
A = 2(lb+bh+lh) = 0.486m^2

$Q = U*A*(T_{out} - T_{store})$
= 3.3*0.486 * (33-18)
= 24.057 watts

For product load,

m =6kg
C_p = 4.2kj/kg K
T_{enter} = 30 °C
T_{store} = 18 °C
$Q = m*C_p*(T_{enter} - T_{store})/3600$
= (6*4.2 * 12) / 3600
= 105 watts

For equipment load,

Fans =1

Wattage = 1.8watts

Q=fans*wattage
=1*1.8
= 1.8watts

Total cooling load(Q_c) = Transmission load + Product load +Equipment load
= 130.857 watts

Actual COP = Q_c / W
= 130.857 / 296.58
= 0.43

RESULT

- Input voltage and current – 12volt & 30 amp
- After performing experiment

i. Heating side maximum temperature is 45°C
ii. Cooling chamber minimum temperature is 18°C

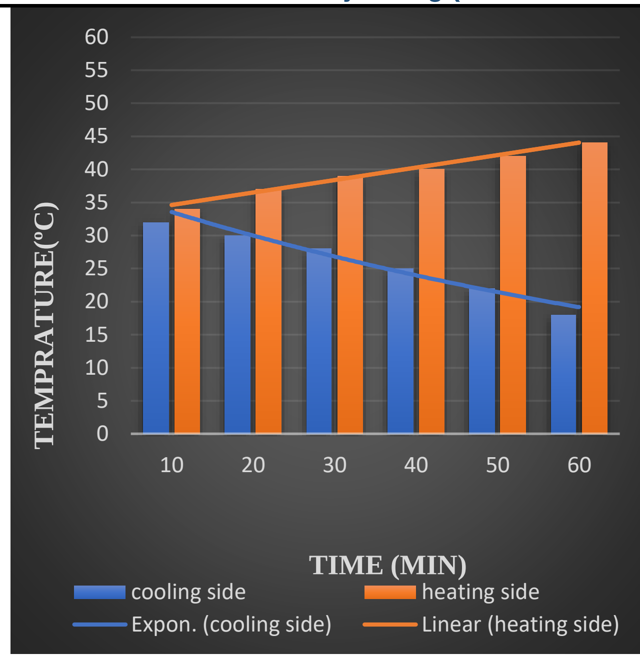

Fig 1.15 Temperature(°C) vs time(min) graph

From result table and graphs, it can be concluded that as time goes on increasing, the temperature inside the cooler cabin falls down gradually and rises gradually on the heater cabin.

CONCLUSION

Currently the refrigeration system is extensively used as a cooling agent but it consumes lots of electricity and releases various types of gases like CO_2, CO which is harmful to the atmosphere and produce global warming and climate change. This paper covers all the relevant concerns for the design of refrigeration system using the peltier device. Bases on the experiment the points and conclusion can also be drawn out such as multistage modules can give much better COP we have achieved and also looking at the compact construction this can be utilized at different places for various applications.

Solar power can be used as power source to the system as it is a renewable source of energy. This immensely decreases the working cost of the refrigerator and burden on the earth.

FUTURE SCOPE

- This system can be further improved by installing thermo sensor which can be programmed using Arduino board, to vary the power supply within specified range of temperature.
- Our concepts can be used in many ways in future. This product can be modified by using solar, battery etc. according to the requirement. This product can also serve as an A/C & heater simultaneously and water cooler & heater can also be made out of it by doing slight modification. So indeed it will be very much beneficial for people in society.
- Solar power can be used as power source to the system as it is a renewable source of energy. This immensely decreases the working cost of the refrigerator and burden on the earth.

REFERENCES:

1) United States Patent Childress
   - William H. Childress
   - Portable thermoelectric heating and cooling device
   - Link: https://patents.google.com/patent/US7059137B2/en

2) International Journal of Advanced Research in Computer Science and Software Engineering, Volume 7, Issue 5, May 2017
   - Kshitij Rokde, Mitali Patle, Tushar Kalamdar, Radha Gulhane, Rahul Hiware
   - Peltier Based Eco-Friendly Smart Refrigerator for Rural Areas.
   - Link:https://www.researchgate.net/publication/318930958_Peltier_Based_Eco-Friendly_Smart_Refrigerator_for_Rural_Areas

3) International Research Journal of Engineering and Technology (IRJET)
   - Dongare V.K, Kinare R.V, Parkar M.H, Salunke R.P
   - Design and Development of Thermoelectric Refrigerator
   - Link: https://www.sciencedirect.com/science/article/pii/B9780128184134000119

4) International Journal of Scientific Development and Research - IJSDR
   - Rakesh B K, Anuj Shayan, Mithun Sharma M N, Mohan M, Vinay Karthik
   - Study, Analysis and Fabrication of Thermoelectric Cooling System.
   - Link: https://www.ijsdr.org/viewpaperforall.php?paper=IJSDR1605065

5) International Journal of mechanical engineering and robotics research
   - Design and Development of Thermoelectric Refrigerator‖
   - Mayank Awasthi and K.V Mali,
   - Link: http://www.ijmerr.com/uploadfile/2015/0409/20150409025007549.pdf

6) International Journal of Scientific & Engineering Research Volume 9, Issue 5, May-2018 ISSN,

- Prashant Kamble, Vinay Nikam, Akshay Bhagit, Madan Jagtap, Prasad Agivale
- Fabrication of thermoelectric cooler
- Link:- https://www.ijser.org/researchpaper/Fabrication-of-thermoelectric-cooler.pdf

7) International Journal of Emerging Technologies in Engineering Research (IJETER)
Volume 6, Issue 4, April (2018)

- S.Vijayarengan, R.Sooriyaraj, G.Vinithraj C.Venkatesan
- Design and fabrication of thermoelectric solar refrigerator

8) Research Gate

- Afdhal Kurniawan Mainil, Muktafa Akmal, Azridjal Aziz
- Portable thermoelectric cooler box performance with variation of input power and cooling load
- Link: http://www.researchgate.net/publication/328127916

9) United States Patent

- Hatho M. George, Hookcreek Blvd.,Rosedale
- Portable thermoelectric cooling and heating appliance device and method of using

10) Journal of Emerging Technologies and Innovative Research

- S Indumati, Pappuri Hazarathaiah, Y Ashok Kumar Reddy and Sk Riyaz Basha
- Design of Solar Based Thermo Electric Refrigeration System
- Link: https://www.jetir.org/view?paper=JETIR1902799