# FABRICATION OF THERMOELECTRIC REFRIGERATION SYSTEM

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**ABSTRACT**

Thermoelectric refrigeration is one of the modern developments in the field of refrigeration systems. It is one of the method used for producing refrigeration effect. These devices are based on using Peltier and see beck effect. The use of Peltier effect is to create a heating side and a cooling side and also to maintain effectiveness.

The specifications for thermoelectric module should have parameters of cold side temperature, hot side temperature, operating current (I) and operating voltage (V), operating temperature difference, heat load.

It has no moving parts. Peltier effect is inverse of see beck effect. Materials used for the thermoelectric refrigeration is Peltier module, heat sink, batteries and temperature indicators.

Thermoelectric module is used instead of compressor. So it is portable, has no liquids, no gas and creates no vibration or noiseless. The use of Peltier module is to create heating on one side and cooling at other side.it is pollutant free does not contain chlorofluorocarbon (CFC). Our project aim is to determine coefficient of performance and efficiency using Peltier module in the refrigeration system.

## 1. INTRODUCTION:

Refrigeration term is used as cooling an object or area below the ambient temperature by process of removing heat. There are number of methods of achieving refrigeration and they are primarily classified into two categories: Cyclic method of refrigeration and Non-cyclic method of refrigeration. Cyclic process of refrigeration consists of vapour compression cycle, vapour absorption cycle, thermoelectric refrigeration, and gas refrigeration cycle. Non-cyclic refrigeration process consists of ice refrigeration and dry ice refrigeration cycle. Both thermoelectric coolers and refrigerators are governed by the laws of thermodynamics. In conventional refrigerator compressor plays an important role where as in thermoelectric unit module is important.

**Thermoelectric effects:**

Peltier effect:

The Peltier effect is the liberation of heat at one junction of thermocouple and absorption of heat at other junction, when electric current flows into it.

$$q \ \alpha \ I \qquad (1)$$

$$q = \pi ab \ I \qquad (2)$$

Seebeck effect:

Seebeck effect is based on the temperature. According to this effect, electro motive force (emf) is generated when two non-identical metals are maintained at different temperature.

$$\Delta E \ \alpha \ \Delta T \qquad (3)$$

$$E = \alpha \ \Delta T \qquad (4)$$

**Thomson effect:**

when electric current is passed through a conductor having a temperature gradient, heat will be either absorbed by or expelled from the conductor. It depends on the direction of both electric current and temperature gradient. This phenomenon is known as Thomson's effect.

**Parameters of a thermoelectric module:**

● **Cold side temperature:**

The object should place in direct contact with the cold side temperature of the module that required temperature will be considered as the cold side temperature. In this project the object is air, which has to be cooled when passes through heat sink.

● **Hot side temperature:**

The hot side temperature of the thermoelectric module mainly depends up on two factors. First factor is environmental temperature to which heat is been dissipated and the second most factor is the heat sink efficiency, which is placed between the hot side of thermoelectric module and the environment.

● **Cooling load:**

The most important parameter to select suitable thermoelectric module is cooling load, the amount of heat removed or absorbed by the cold side of the thermoelectric module. In this project Q is calculated.

$$Q = m\, c_p \Delta T$$

Where m = mass flow rate

Cp =specific heat

ΔT = Temperature difference

● **Temperature difference:**

Temperature difference is difference between the ambient temperature and cold side temperature of the module. ΔT is an important factor.

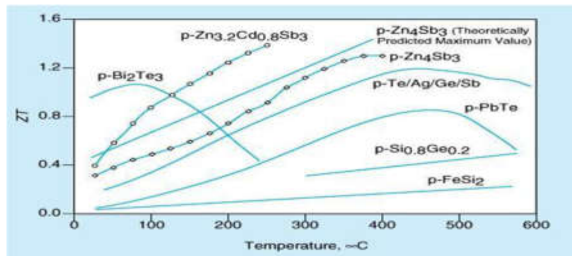
● **Operating current and Operating voltage:**

Power supply is given by the batteries or by house hold supply. DC current is important. Thermoelectric module is a direct current device. Thermoelectric power is the product of required voltage and current (p= IV).

- Heat load
- Temperature difference

**Materials used in thermoelectric module:**

There are many thermoelectric semi-conductor materials but mostly used semiconductors now-a-days is Bismuth telluride.




Temperature (vs) ZT values of thermoelectric materials

**Requirements for thermoelectric materials:**

- Narrow band gap semiconductors
- High mobility and low thermal conductivity.
- Complex structure
- Complex composition and should be anisotropic.

**Fabrication of Peltier cooler:**

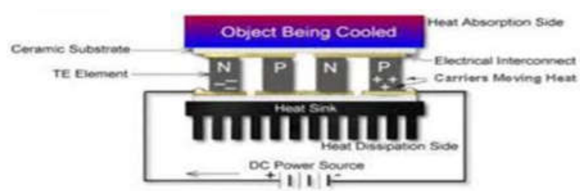



Fig 2.2 peltier module

**2.LITERATURE SURVEY**

S.Haidar researcher made a portable active solar still. He made effort to increase the productivity of still as compared to other convectional stills. Water sprinkling device along with thermoelectric cooler is added to improve performance of still. Plexiglas is used on the wall of portable solar still to make it unbreakable. He carried out this experiment in nine summer and winter days in Iran. But result took from both seasons were having a significant difference.

Michael Gasik the research paper present the functionally graduated material used for thermoelectric cooling of solar space power system. This system is designed to use natural resources such as intensive solar radiation approaching earth. The mirror arrangement is placed in the system which is at space.

Nandy Putra the research paper represents the thermoelectric cooling of an electrical equipment with the help of Nano fluids with heat pipe liquid block. As the technology is increasing the size of microprocessor is also increasing. It will give higher heat flux. In computer, central processing unit(CPU) is the heart of computer.

**3. WORKING PRINCIPLE**

Thermoelectric module is composed of two ceramic substance which acts as a foundation and electrical insulation for p type and n type which are connected electrically in series and thermally in parallel between plates.

Heat sink must be in contact with hot side as well as an object against cold side surface.

The working principle of the TE modules is based on Peltier effect which states that "If the DC electric current passes through the junction of two non-identical 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 Peltier effect is opposite to Seebeck effect in which, by applying temperature difference across the junction of two dissimilar semiconductor materials produces electric current.Thermo-Electric refrigeration is one of the recent development in the field of refrigeration.

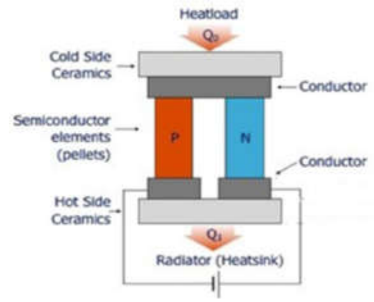



Fig : Peltier module semiconductors

Thermo-Electric refrigeration systems work based on the principle of Peltier effect, where electric current passes directly through the junction of two dissimilar semiconductor materials causes the junction either to cool down (absorbing heat) or warm up (rejecting heat) depending on direction of current. In thermoelectric refrigeration process the cooling effect is effectively used whereas the heat is dissipated to the environment. There is a note that energy conservation plays a vital role in day to day life due to energy crisis. Hence, a solution should be implemented to utilize the heat energy dissipated to environment for the useful heating applications and conserve waste heat energy. So there should be an aim to utilize both heating and cooling effects generated by Thermo-Electric module. Cooling effect can be used for storage purpose as well and the waste heat energy for heat storage and used as hot pack. The power is given to the connections as per the requirement by household appliances or by solar panels and batteries.

Thermoelectric aspect deals with the conversion of thermal energy into electric energy and the vice-versa. Then thermoelectric is operated in cooling or heating mode, it is termed as thermoelectric cooler and when operating as an energy generating device it is termed as thermoelectric generator. Thermoelectric devices are capable of producing these three effects without any intermediary processes or fluids.

**Applications of thermoelectric cooler**

- Electronic enclosures

- Laser Diodes
- Laboratory instruments
- Temperature baths
- Refrigerators
- Medical
- Aerospace
- Tele communications

## 4. METHODOLOGY

**Design analysis**

A system design method of thermoelectric cooler is developed in the present study.

The design calculation utilizes the performance curve of the thermoelectric module that is determined experimentally.

An automatic test apparatus was designed and built to illustrate the testing method.

The performance test results of the module are used to determine the physical properties and derive an empirical relation for the performance of thermoelectric module.

The thermal resistance of heat sink is chosen as one of the key parameters in the design of a thermoelectric cooler.

An optimal design of thermoelectric cooler at the conditions of optimal COP is also studied.

The optimal design can be made either on the basis of the maximum value of the optimal cooling capacity, or on the basis of the best heat sink technology available.

Methodology

The theoretical equations for the thermoelectric module performance include:

The voltage equation, $V = (TH - TL) + IR$ (1)

The input power equation, $P = (TH - TL) + I2$ (2)

The cooling capacity equation,

$QL = I\alpha TC - (TH - TL) - 0.5I2R$ (3)

The total heat rejection equation,

$QH = I\alpha TW - (TH - TL) + 0.5I2$ (4)

And COP is given by, $COP = QLP$ (5)

An important physical property for the thermoelectric module is the figure of merit Z which is given by,

$Z = \alpha 2$ (6)

The thermoelectric cooler can be designed at maximum COP or at maximum cooling capacity.

In many applications, the thermal efficiency is more important.

Thus, the design based on the maximum COP is adopted in the present study.

Goktun showed that heat transfer at a finite rate and electrical resistive losses are necessarily irreversible processes and unavoidable in a thermoelectric device.

It is shown that the internal and external irreversibility in a thermoelectric refrigerator may be characterized by a single parameter, named the device-design parameter.

The presence of this parameter in the equations for the refrigeration effect and the maximum input power shows that a real refrigerator has a smaller cooling capacity and needs more input power than an ideal refrigerator.

The heat flow rate from the low temperature reservoir at TL to the cold junction at Tc can be written as:

$QL = h(TL - TC)$ (7)

Similarly, on the high temperature side, the heat flow rate is:

$QH = h(TW - TH)$ (8)

Where h is the heat transfer coefficient,

A is the heat exchanger surface area

Tw and TH is the hot junction and sink temperatures respectively

Assuming all material properties, including the Seebeck coefficient (α), of the thermoelectric element is independent of temperature. A one-dimensional heat conduction analysis in the direction of current (I) flow yields the net rates of heat input and heat rejection as: From the first law of thermodynamics, the input power

$P$ is:

$P = QH - QL = (TW - TC) + I2$ (9)

According second law

$QHTW = S(QLTC)$

$with\ S < 1$ (10)

Substituting equations (7) & (8) into (10), S becomes,

$S = \beta(TW - TH)TC\ (TL - TC)TW$

Using equation (9) and dimensionless temperature ratio specified above, the cold junction ratio can be written as:

$TC = XTW$ (12)

Where,

$X = S\psi S + (1 - \psi\tau)$

with $\psi < X < 1$ (13)

Prime requirement of a TER is the optimum refrigeration effect, therefore optimizing $QL$ with respect to I yields:

$(I)opt = \alpha TWXR$ (14)

$\phi = (QL)\ (\alpha TW2)/2R$

$= X2 + 2(TH - TL)\ (ZTW2)$ (15)

$Pmax = W\ (\alpha TW)2/2R = 2X$

For β=0 and S=1, X approaches to ψ, then equation (15) reduces to the maximum refrigeration effect of TE refrigerator.

Thermoelectric devices can be characterized by single parameter X, named device-design parameter.

This parameter appears in both the equation for optimum refrigeration effect and maximum input power.

In order to get high values of X, S must be decreased for the values of β within the range of interest.

In order to get better the refrigeration effect, X must be increased.

**Load calculations:**

Thermocol box has a length 18.5cm,width 23.2cm, height of 22.5cm and it has a capacity of 5 litres.

Specifications of thermocol box:

Length=18.5

Width=23.2

Height=22.5

Volume=18.5*23.2*22.5=9657cm3

Capacity=5litres

Cooling capacity required=m*c*dt

=9.6*4.27*(29-23)

=245.952KJ

=68.12W

Module selection:

Number of modules required=cooling capacity required/cooling capacity of module

Cooling capacity of module=45W

Number of modules required=68.12/45=1.51

Hence 2 Peltier modules are required to obtain the required temperature inside the cold box.

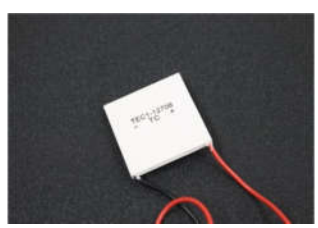
**Fabrication of thermoelectric device for cooling:**

**Experimental setup:**

The experimental setup consisting of

**a) Thermoelectric modules**

Thermoelectric modules for the selected box capacity of 5 litres, two thermoelectric modules are used in the fabrication inside the cold box. The cooling capacity of one module is 45W. The modules are placed opposite side of the box. Thermoelectric modules are available in wide varieties.



**b) Battery**

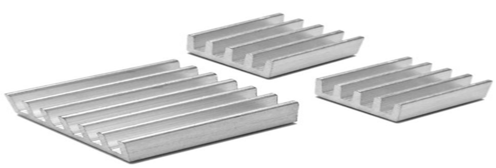
Batteries are the devices with DC electric energy in the form of chemical energy. In this system batteries are used for storage of excess solar energy converted into electrical energy. In this fabrication we use 12V 7AMP lead-acid battery.


**c) Thermocol box**

The dimensions of the thermocol box used in this project are 18.5*23.2*22.5cm and the capacity of the box is 5 litres.

**d) Heat sink**

A heat sink is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device temperature at optimal levels.



**e) Heatsink with fan:**

Heat sink with fan is mounted on the hot side surface of thermoelectric module and other is mounted on the cold side.

**f) Temperature indicator:**

Two temperature indicators are placed on the either sides of the cold box and the sensors emitted temperature is shown on the display.


**g) Insulation:**

A foam insulation material is used to reduce the heat losses to the surroundings around the two boxes. Thermocol board insulation is placed in between two boxes to eliminate the heat transfer from hot box to cold box through conduction.

**Assembly**:

- First check whether thermoelectric module is working or not and should find out the cool side and the hot side of the module by sending DC current through module.

- Thermal conductive paste is applied between hot module side and heat sink. A 12V DC fan connected to heat sink.

Fig :Prototype of thermoelectric refrigeration

- After mounting the module on the heatsink, it is placed inside the thermocol box such that heatsink fan is exposed to ambient temperature and other heat sink is pasted from inside of the box to cool side of the module.
- The batteries are placed under the boxes and connections are given accordingly such that battery

can supply power to modules and DC fan.

- Temperature indicators are placed inside the box to sense the coolness and values are noted.
- The battery used in this project is rechargeable.

**Experimentation:**

Experiments are conducted to analyse coefficient of performance (COP) and efficiency. The power supply from the battery is given to the system and reading of the temperature at different places of box are taken by placing temperature indicators near modules for every three minutes of time interval. The readings are tabulated and check for least temperature occur in box. After that the power is switched off. The tabulated values are plotted as temperature VS time.

In this experiment the heat sink is attached to the cold side of the module and the cold box is exposed to the environment.

Whereas hot box is closed and temperature indicators are placed inside the box and the values are noted.

**Observations (in ON conditions):**

Table 1: temperature values in thermocol box (ON condition) at one side

| Time | Temperature |
|---|---|
| 0 | 28 |
| 3 | 27.2 |
| 6 | 26.7 |
| 9 | 26 |
| 12 | 25.6 |
| 15 | 24.9 |
| 18 | 24.2 |
| 21 | 23.3 |

The values are tabulated for every 3minutes of time up to 21 minutes in the cold box at one side and the least temperature obtained is 23.3℃ at ambient temperature of 28℃.

Table 2: values in thermocol box at other side (ON condition)

| Time | Temperature |
|---|---|
| 0 | 28 |
| 3 | 27.1 |
| 6 | 26.8 |
| 9 | 26.1 |
| 12 | 25.5 |
| 15 | 24.7 |
| 18 | 24.9 |
| 21 | 23 |

Observations (OFF condition):

Table 3: values in thermocol box (OFF condition) at one side

| Time | Temperature |
|---|---|
| 21 | 23 |
| 18 | 23.8 |
| 15 | 24.5 |
| 12 | 25.8 |
| 9 | 26.6 |
| 6 | 27.9 |
| 3 | 31 |

Table 4: values in thermocol box at other side (OFF condition)

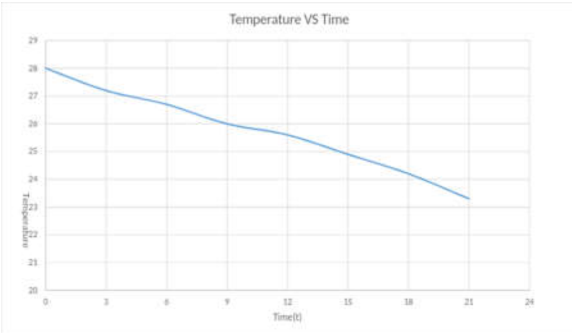
| Time | Temperature |
|---|---|
| 21 | 23 |
| 18 | 23.8 |
| 15 | 24.5 |
| 12 | 25.8 |
| 9 | 26.6 |
| 6 | 27.9 |
| 3 | 31 |

**Comparison of thermoelectric refrigeration with normal refrigeration**:

| s.no | Criteria | Thermoelectric refrigerator | Normal refrigerator |
|---|---|---|---|
| 1 | Cooling method | Non-cyclic refrigeration | Vapour compression cycle. |
| 2 | Components | Thermoelectric module | Compressor, condenser, evaporators |
| 3 | Cop | Less | High |
| 4 | Power consumption | 12-56volts | 220volts |
| 5 | Main advantage | portable | Not portable |

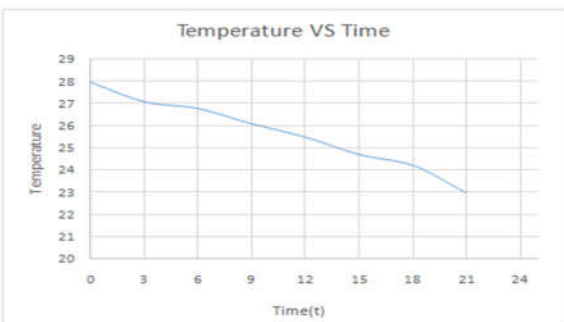
**Results and Discussion**

From experimentation we observed that there is decrease in temperature up to 6 to 7°c.



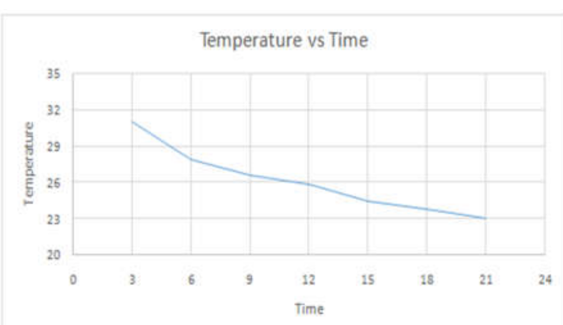

Graph 1 Temperature values inside the cold box (vs) time in thermocol box in ON condition.

Temperature values inside the cold box vs time are plotted as shown in the figure. The readings are tabulated for every 3minutes up to 21minutes.The temperature obtained inside the cold box at one end is $23.3^{o}$c at one side when the ambient temperature is $28^{o}$ c.



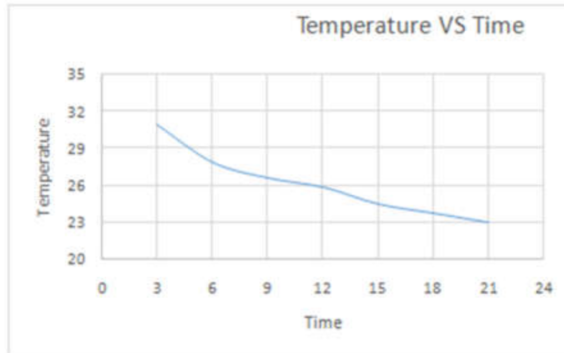

Graph 2 Temperature values inside the cold box (VS) time in power ON condition

The temperature values inside the cold box vs time are plotted as shown in figure. The temperature readings are taken inside the cold box at ambient temperature of $28^{o}$c for every 3 minutes up to 21 minutes $23^{o}$c at other side.




Graph3: Temperature values inside the cold box(VS) Time at power OFF condition.

Temperature values are plotted against time at power off condition and values are plotted for every 3minutes.




Graph4: Temperature values inside the cold box (VS)Time at power off condition

Temperature values are plotted against time for every 3minutes and values are tabulated.

**Calculations:**

Tcold $= 23^{o}$c

Tam $= 29^{o}$c

Thermal conductivity of the thermocol = 0.0427W/MC

Dimensions of the box = 18.5*23.2*22.

Tsink =15c

Temperature difference = (29 + Ta)-Tcold

= (29+15)-23

$=21^{o}$c

Using newton's law of cooling

Q= mcp (Tam- Tcold)

= 8*4180(29-23)

= 200640J

Electrical power (p) = 12V*7AMPH

= 12V*7

= 84WH

1WH=3600J

= 84*3600J

=302400

Now COP= Q/P

= 200640/302493

= 0.66349

**Conclusion:**

Thermoelectric refrigeration is designed which able to an ambient temperature from 29° c to 23° c. All the components of this project are tested individually.

We came to know that Coefficient of performance is less compared to normal compressor type refrigerator. So, conventional refrigerators are preferred when required high cooling capacity.

It is small in size, silent, contains no liquid, no gas and have no moving parts and have a long life.

There is a huge research in this field about thermoelectric materials, its fabrication, heat sink designs etc. But due to small size it found its applications in electronics cooling etc. It is not widely used and not efficient compared to conventional.

Hence this is completely pollutant free and portable project.

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