# Design & Fabrication of Thermoelectric Year Round Heating and Cooling System

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*Abstract*— Many people studied and carried out research on thermoelectric heating and cooling system. Now a days conventional cooling system consist of refrigerants to generates cooling effects which results in emission of CFC (chlorofluorocarbon) and consumes more electricity. Hence the necessity of this project is to study and develop the heating and cooling system in winter and summer respectively along with water dispenser with the effective use of thermoelectric system. Facilitating the multiple use of Peltier module. Investigation the performance and efficiency of Air Conditioning and heating system along with cool water dispenser. Through this process we can provide system less maintenance and long life. To eliminate the emission of CFC (chlorofluorocarbon) and reduce power consumption.
***Keywords:*** CFC (chlorofluorocarbon), Heating and Cooling System

## I. Introduction

### A. *History and Development*

The present air conditioning system uses the refrigerant as a working fluid for producing cooling effect or removal of heat. By using these refrigerants, we get maximum output but one of the major disadvantages of these refrigerants is harmful gas emission and global warming. These problems can be overcome by using the alternate method of cooling and heating known as thermoelectric heating and cooling. In this system we use the thermoelectric modules (Peltier module) to produce cooling effect which works on Peltier effect.

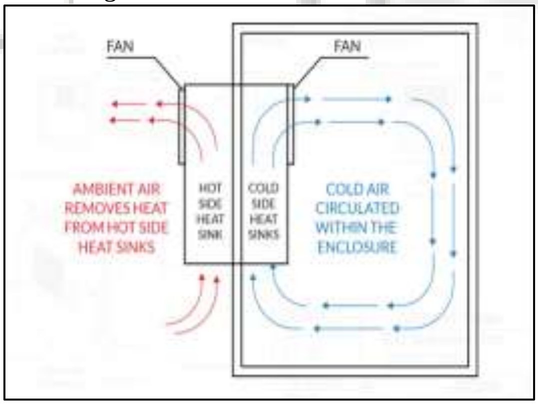


Fig. 1.1: Schematic arrangement of thermoelectric air conditioning system

The thermoelectric module has p-type and n-type semiconductors connected in series and covered by silicon bismuth coating. Direction of pumping transforms when reserves the polarity. The one side of module gets colder and another side get hotter simultaneously.

## II. Literature Review

It is examined by brooks samuel mann in the year 2006,that the study of thermoelectric began in 1882 ,when the German Physicist named as Thomas Johann seebeck noticed that a closed loop caused a compass needle to deflect when the two metals were held at different temperatures. This meant that an electric field was created between the two metals, thus inducing a magnetic field to deflect the needle. Although Peltier generally credited with the discovery of thermoelectric cooling, he did not fully understand the physics of the phenomenon. The full explanation was given four years later by Emil Lenz, who showed that a drop of water on a bismuth-antimony junction would freeze when electrical current was applied one way, and melt again when the current was reversed

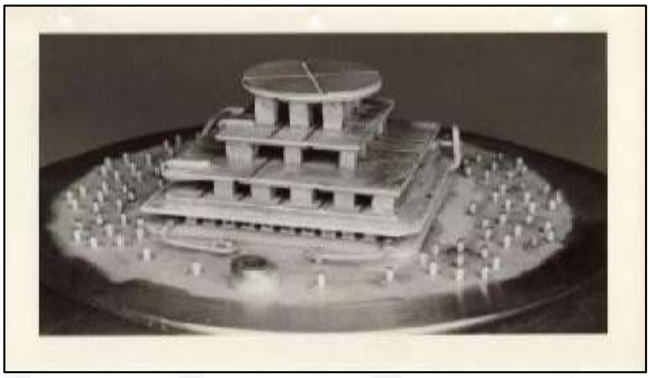

Fig. 1.2: The first idea of thermoelectric device

A. "Design, analysis and fabrication of thermoelectric cooling and heating system for water dispenser" R.S. Fayazahamed, S. Cyril Jain, K.L. Alagarasan, A. Balachandran, P. Balasubramani fabricated the model and the measurements were taken at room temperature. The chart below shows the temperature change of water with respect to time. The initial temperature of water was measured to be 27℃ at room temperature Around 12V 240 W dc power supply was used for the TEC modules. The sample test was carried to measure and to evaluate the change in temperature for every 5 minute which was for the duration of 30 minutes through the 5 liters of water on two reservoirs. The below table (A) shows the rise of temperature on the hot side heat exchanger. The temperature of water rises from 27℃ to 45℃. Another table (B) shows the fall of temperature on the cold side heat exchanger. The temperature of water falls from 27℃ to 17℃.

| Time (Min) | $T_h$ ($^0$C) |
|---|---|
| 0 | 27 |
| 5 | 31 |
| 10 | 34 |
| 15 | 37 |
| 20 | 40 |
| 25 | 42 |
| 30 | 54 |

Table 2.1. (A): The rise in hot side temperature ($T_h$) after every Five minutes.

| Time (Min) | Tc ($^0$C) |
|---|---|
| 0 | 27 |
| 5 | 25 |
| 10 | 23 |
| 15 | 21 |
| 20 | 19 |
| 25 | 18 |
| 30 | 17 |

Table 2.1 (B): The fall in cold side temperature (Tc) after every Five minutes.

B. "Study and Fabrication of Thermoelectric Air Cooling and Heating System" Prof. N. B. Totala, Prof. V. P. Desai, Rahul K. N. Singh, Debarshi Gangopadhyay, Mohd. Salman Mohd. Yaqub, Nikhil Sharad Jane says that, In present scenario, HVAC system (commonly used in the air conditioners) is very efficient and reliable but it has some demerits. It has been observed during the last two decades that the O3 layer is slowly destroyed because of the refrigerant (CFC and HFC) used for the refrigeration and air- conditioning purposes. These HFCs once destroy O3 layer; it takes hundreds of years to recover its thickness as it is formed by complex reactions. It is because the HCF present in the environment remains upto 18 years in the atmosphere. The capacity of HFCs to increase in earth temperature 10% is contributed by HFC's only. That leads to the emergence of finding an alternative of the conventional HVAC system, i.e. thermo-electric cooling and heating system.

C. "Design and Development of Thermoelectric Refrigerator" Dongare V.K, Kinare R.V2, Parkar M.H, Salunke R.P. Thermoelectric refrigeration is a advanced process which not only save the electric energy but also converts waste energy into useful cooling and is expected to play a vital role in setting an challenge. The main objective was to develop and design the performance of thermoelectric refrigerator, In interior cooling volume 18 L which uses petlier effect to refrigerate and maintain from 30°C to 22°C temperature. The task or challenge of designing thermoelectric refrigeration is to transform the volume of cooling to temperature within the time spam of 1 hr and also to adapt 0.2 to 0.6 COP range. One such unit is made. From this investigation following conclusions are made:
   1) The coefficient of performance of the system for TEC1-12706 is calculate from the average of reading.it is observed that COP of thermoelectric refrigerator using TEC1-12706 is less than COP of VCRS.
   2) Solar power can be used as power source to the system as it is renewable source of energy. The immensely decrease the working cost of the refrigerator and burden on the earth.
   3) Liquid cooling at hot side can be used to increase the refrigeration effect.
   4) Waste heat can be recovered using ducts for heating purpose.
   5) Number of Peltier modules or multistage Peltier modules can be used to increase the cooling effect.

The results of the project analysed and calculated by researchers of this project are following

| Sr. No | Parameters | Values |
|---|---|---|
| 1 | Max. Temperature difference in $^0$C | 22 |
| 2 | Time taken in minutes | 60 |
| 3 | $(COP)_{theoretical}$ | 0.4855 |
| 4 | $(COP)_{actual}$ | 0.3143 |

Table 2.2: Performance and results

D. "Thermoelectric Air Cooling for Cars" Manoj S. Raut, Dr. P. V. Walke investigated and made project work on thermoelectric air cooling for cars, they said that, as a mechanical engineer I am trying to overcome these demerits by replacing the current HVAC system by the materialised thermoelectric couple or cooler which runs through peltier and seebeck effect. which works on Peltier and Seebeck effect. The purpose of the paper is to make use of the cold side to cool the ambient air to a lower temperature, so that it can be used as a personal cooler.

E. "Design and Fabrication of Thermoelectric Refrigerator with Thermosiphon System" Sujith G, Antony Varghese, Ashish Achankunju, Rejo Mathew, Renchi George, Vishnu V. the investigator of this project states that The increase in demand for refrigeration globally in the field of air-conditioning, food preservation, medical services, vaccine storages, and for electronic components The climatic change, caused by the increase in use of electric components which led production of increase in electricity and rise in $CO_2$ emission in the atmosphere which also causes Global Warming changes. The objectives of this study are to develop a working thermoelectric refrigerator to cool a volume of 40 L that utilizes the Peltier effect to cool and maintain a selected temperature range of 5 0C to 25 0C. The design requirements are to cool this volume to temperature within a short time and provide retention of at least next half an hour. The objectives of this paper is to design and develop a working thermoelectric refrigerator that utilizes the Peltier effect to refrigerate and maintain a temperature between 5$^0$C to 25$^0$C. The design requirements are to cool the volume to a temperature within a short time and provide retention of at least next half an hour. It is necessary to design a system capable of maintaining the temperature of the materials between 10$^0$C to 15$^0$C for a long duration.

## III. WORKING AND FABRICATION

Working of Peltier cooler: "N-type" semiconductor material is used to fabricate the pellet so that electrons (with a negative charge) will be the charge carrier employed to create the bulk of the Peltier effect. N-type semi-conductor has an extra electron in its Fermi level (higher energy level).

 

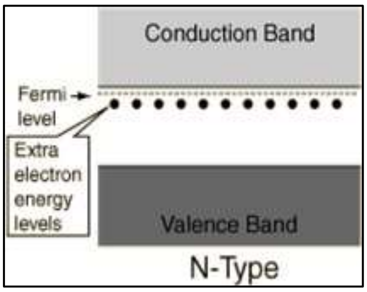


Fig. 3.1: N-type semiconductor Energy band diagram

So, we can say that, in Peltier cooler using N-type of semiconductor, heat is absorbed at the junction near negative terminal and heat is rejected at the junction near positive terminal.

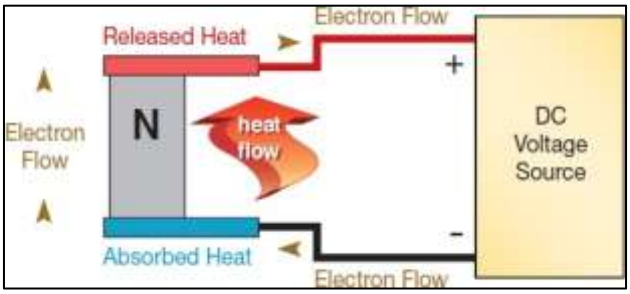


Fig. 3.2: Peltier cooling with N-type semiconductor

## A. *Peltier cooling with P-type semiconductor*

P-type semiconductors pellet's get employed in thermoelectrical industries. Fig.4.3 shows the energy band diagram of P-type semiconductor. The firm level(high energy level ) is where the holes are located.

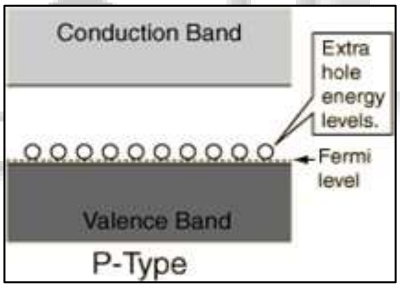


Fig. 3.3: P-type semiconductor Energy band diagram

Now, when DC current is applied through the circuit as shown in fig.4.4; holes get attracted towards negative terminal of source. The holes releases heat when moved on the negative terminal due to attraction.

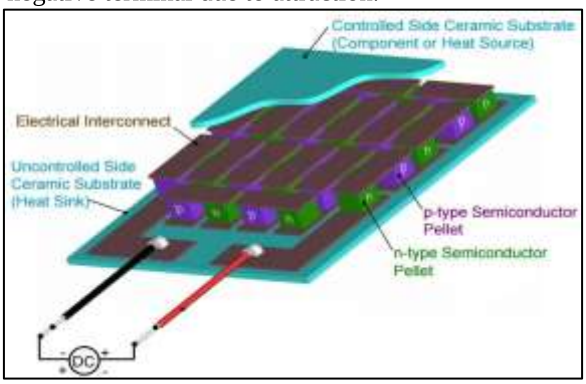


Fig. 3.4: Peltier cooling with P-type semiconductor

So, we can say that, in Peltier cooler using P-type of semiconductor, heat is absorbed at the junction near positive terminal and heat is rejected at the junction near negative terminal.

## B. *Peltier cooling with P & N type of semiconductors*

To arrange a series circuit,the N and P-type pallets are kept together in a couple and are intersected with a platted copper tab, which can keep all of the heat moving in the same direction.

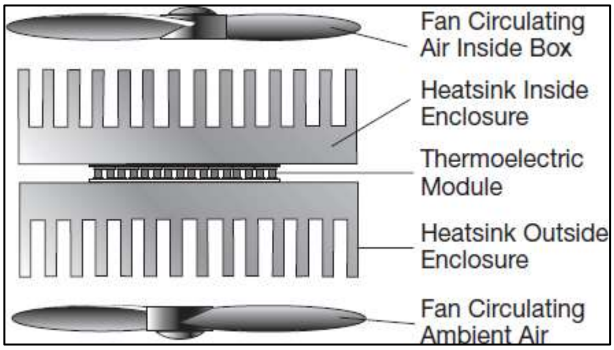


Fig. 3.5: Peltier cooling by couple of N & P Semiconductor

By arranging the circuit as like in fig.3.5, it is possible to release heat to the one side and absorb from another side. Using these special properties of the TE "couple", it is possible to team many pellets together in rectangular arrays to create practical thermoelectric modules as in Figure 3.6

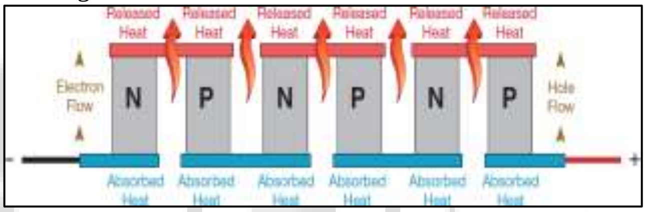


Fig. 3.6: Peltier cooling by multiple pallets

## C. *Fabrication of Peltier cooler*

As we have seen in previous section, for producing thermoelectric effect couples of P and N type semiconductors are connected in series by metal plates. Which helps in absorbing the heat from one side and relasing heat from another side.

So, when solid state P-N materials are connected electrically in series and thermally in parallel it makes one thermoelectric unit as shown in Fig 3.7.

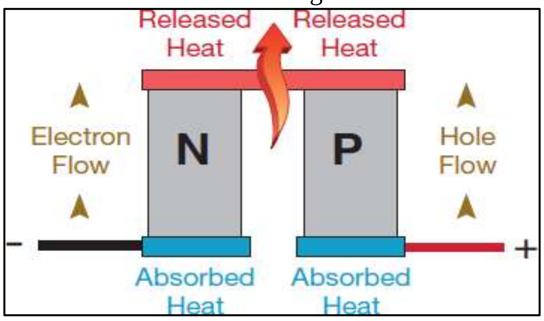


Fig. 3.7: Fabrication of Peltier module

The device is normally attached to the cold side of the TEC module, and a heat sink which is required for enhanced heat dissipation is attached to the hot side. The construction of a single stage thermoelectric module is shown in fig.4.7 The fan circulates ambient air which is located on hot side as it sinks fins to absorb the collected heat. Note that the hot side includes the depraved air which is pumped from the box and also the heat produced under the peltier device.

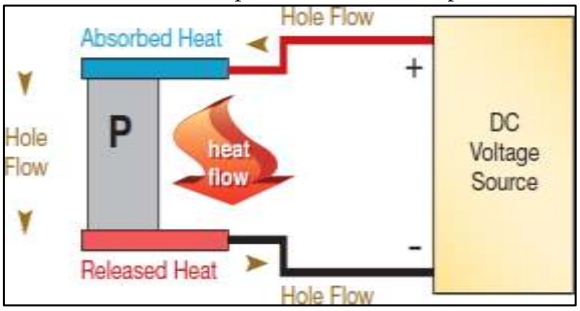


Fig. 3.8: Configuration of air-to-air thermoelectric cooler

Using a Peltier device which draws 4.1 amps at 10.4 V, the hot side of the system will have to dissipate the 25 watts from the thermal load plus the 42.6 watts it takes to power the TE module (for a total of 67.6 watts). By engaging hot side sink and fan by an thermal resistance of 0.148°C/W. The hot side sink's temperature rise upto 10°C and above ambient. It should be noted that, to achieve the 17° C drop between the box temperature and ambient, we had to create a 30° C (54°F) temperature difference across the Peltier device.

## IV. Material Selection

### A. TEC1-12706 Module

A thermoelectric cooling (TEC) mode is also said as semiconductor based. electronic component that function as a small heat pump. By applying DC power source to TEC heat will be transferred from one side of the module to the other. It creates a cold and hot side.

| Model Number | TEC1-12706 |
|---|---|
| Voltage | 12 V |
| Vmax | 15.4 V |
| Imax | 6 Amp |
| Qmax | 92 W |
| Internal Resistance | 1.98 Ohm +/- 10% |
| Dimensions | 40mm x 40mm x 3.6mm |
| Type | Cooling Cells |
| Quantity | 4 No.s |

Table 4.1: Specification Table of TEC1-12706

### B. Heat Sink

Aluminum alloys are most common material for heat sink because of their higher thermal conductivity values.

| Heat sink material | Aluminum |
|---|---|
| Color | Silver + Black Oxidation |
| Size | 105 mm x 105 mm x 40 mm |
| Thermal Resistance | 0.3 K/W |
| Weight | 420 gms |
| Quantity | 2 No.s |

Table 4.2: Specification Table of Aluminium Heat Sink

High Power Extruded Heat sinks designed for high power semi-conductor and thermoelectric applications Compact Machined thermal interface for excellent heat transfer designed for industry standard fans assemble.

### C. Cooling Fan

A Fan is a device which is used to carry the heat from one side to another. It cools the particular area by taking away the hot air away from that particular area. In thermo electric cooling process the fan is used on both sides i.e. cold and hot side. In thermoelectric cooling fins are also attached to the fans for more efficient cooling.

### D. Power Supply (ATX PC power Supply)

A circuit controller is an electric device. As we know the TEC module is operated or requires DC power supply hence circuit controller is used here to convert AC supply into DC. This circuit controller is ATX PC power supply. The specification of particular power supply used in this project is given below in tabulated form.

| Model | Classic-450 |
|---|---|
| Input Voltage | 220V 4A 50Hz |
| Output Voltage | 12 V |
| Output Current | 28 Amp |
| Manufacturer | Intex |
| Quantity | 1 No.s |

Table 4.2: Specification Table of Power Supply

### E. Spiral Copper Tube

In this project we used spiral copper tube to circulate normal drinking water through tubes to obtain cool water for drinking in summer condition. The tube is fabricated in spiral shape in order to place it in front of cool side of heat sink. The specification of this spiral tube is mentioned in below table along with its image.

| Material | Copper |
|---|---|
| Tube OD | 6 mm |
| Tube ID | 5 mm |
| Thickness | 0.5 mm |
| Spiral OD | 100 mm |
| Tube Length | 800 mm |
| Quantity | 1 No.s |

Table 4.3: Specification Table of Spiral copper Tube

### F. Temperature Sensor (LM35)

LM35 is a precision IC temperature sensor with its output proportional to the temperature and is integrated circuit sensor. LM 35 controls the linear temperature sensors which is calibrated in kelvin and it's not necessary to abstract the output with a large constant voltage.

### G. Water Pump

To circulate water through copper tube we require water pumping device hence in this project we also used a water pump. The pump is powered by electricity which is obtained from same ATX PC power Supply.

| Manufacture | Aishang China |
|---|---|
| Voltage | 5 V DC |
| Current | 0.3 A |
| Power | 1.5 W |
| Head | 2 m |
| Flow | 11 Lit/hr |
| Quantity | 1 No.s |

Table 5.7: Specification Table of water Pump

### H. Voltage Controller for Fan Speed Regulation

Voltage Regulator Adjustable (LM2596): LM2596 is a regulator adjustable for the voltage regulator and also which is a monolithic integrated circuit designed for handy and convenient step-down switching regulator (back converter). It is capable of driving a 3.0 A load with excellent line and load regulation.

| Model | LM2596 |
|---|---|
| Input Voltage | 12V DC |
| Output Voltage | 7-12V |
| Output Current | 2.5 A Max |

Table 5.8: Specification Table of Voltage Regulator (LM2596)

### I. LCD (Liquid Crystal Display):

LCD screen is an electronic display module and find a wide range of applications. The 16*2 LCD display is designed in such a way that it is used as commonly as in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs.

### J. ATMEGA328 Microcontroller

The Boot program can use any interface to download the application program in the Application Flash memory. The software in the book flash sections only works when the application flash section is updated.

## V. Calculations

Now, we calculated Total Power required to run or operate whole assembly in order to calculate power consumption.

Let's calculate power required for Peltier module first. From specification table of TEC module, we have,

$$V = 12\ V \text{ and } I = 6\ A$$
$$P = V \times I$$
$$P = 12 \times 6$$
$$= 72 \text{ Watt}$$

Here we used four TEC modules so,

$$\text{Total Power required for Four TEC Module} = 72 \times 4 = 288 \text{ Watt}$$

Now, Power required for Cooling Fans. Again, from specification table of cooling fan, we have,

$$V = 12\ V \text{ and } I = 1.92\ A$$
$$P = 12 \times 1.92 = 23.04 \text{ Watt}$$

We used two cooling Fans hence,

$$\text{Total Power of Fans} = 2 \times 23.04 = 46.08 \text{ Watt}$$

Power required for Water Pump

$$\text{For Pump } V = 5\ V \text{ and } I = 0.3\ A$$
$$P = 5 \times 0.3 = 1.5 \text{ Watt}$$

But these are the separate values of power required. To calculate total power consumed by the device we have to add all of these.

$$\text{Hence } P_{Total} = \text{TEC Modules Power} + \text{Cooling Fans Power} + \text{Water Pump Power}$$
$$= 288 + 46.08 + 1.5$$
$$= 335.58 \text{ Watt}$$

So, the total Power consumed by the device is near about 335.6 Watt which is less as compared to the conventional air conditioning system.

## VI. Conclusion & Future Scope

### A. Conclusion

We have been successful in designing a system that fulfils the proposed goals. It is predicted that the system has limitations. The current design is only useful to cool/lower down from heat load to normal temperature. Before releasing the present design the updations are needed to incorporated. This is one of the advantageous project which uses low power to drive the system. This project work has provided us an excellent opportunity and experience, to use our limited knowledge. Thermoelectric heating and cooling are one of the key areas where researchers have a keen interest to reduce chlorofluorocarbons (CFC's) and seeking for alternative HVAC system. Moreover, recent breakthrough in organic molecules as a thermoelectric material assure an excellent future for thermoelectric heating and cooling system. For effective use of thermoelectric heating and cooling the integration of renewable energy power source could be used in backward areas where there is no electric energy used.

### B. Future Scope

Recent breakthrough in organic molecules as a thermoelectric material assure an excellent future for thermoelectric heating and cooling system. Further advanced research in thermoelectric heating and cooling system will replace current HVAC system for small capacity units likes small houses, offices, passenger cars etc. Moreover, in future we can use solar energy to operate heating and cooling system which is based on thermoelectric heating and cooling system. The use of solar energy (renewable energy) may results in saving of electricity and conservation of non-renewable energy resources which are used to produce electricity.

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