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A New Way of Getting Comfort by Using Peltier Comfort Conditioner

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Abstract: Air-conditioning is the process of controlling temperature, humidity, motion and purity of the atmospheric air in confined space. In the recent years have seen the increase in demand of air conditioning due to the global warming. Present air conditioning systems are work on VCR (vapour compression refrigeration) system & this system is expensive and have many other problems such as difficult to install, bulky system, required more space, Compressor is main component of VCR system which creates noise and vibrations. So, there is a need to find out the new system which can become an alternative to VCR system. After making the research survey on air conditioning technologies we got that Thermoelectric Cooling can become an alternative to VCR. So that in this work we have gone through the study of TEM, Validation of Thermoelectric Module & Fabrication of a prototype model for the experimental analysis of thermoelectric cooling (TEC) system to check its performance as compare to VCR system.

Keywords: VCR (vapour compression refrigeration), TEM (thermoelectric module), TEC (thermoelectric cooling)

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I. INTRODUCTION

Air conditioning is the process of removing heat and moisture from the interior of an occupied space, to improve the comfort of occupants. Air conditioning can be used in both domestic and commercial environments. This process is most commonly used to achieve a more comfortable interior environment, typically for humans and other animals, however, air conditioning is also used to cool/dehumidify rooms filled with heat-producing electronic devices, such as computer servers, power amplifiers, and even to display and store some delicate products, such as artwork.1902 Wills Havilland Carrier invented the first air conditioner to control the temperature and humidity of a printing company, marking the first-time effort taken to control the temperature of the surroundings. Present air conditioner installations mainly come in two types: window systems and split systems (these are further classified into mini-split and central systems). In everyday language, these are commonly referred to as window ACs and split ACs, respectively. Window air conditioner is the most commonly used air conditioner for single rooms. In this air conditioner all the components, namely the compressor, condenser, expansion valve or coil, evaporator and cooling coil are enclosed in a single box. This unit is fitted in a slot made in the wall of the room, or more commonly a window sill. The split air conditioner comprises of two parts: the outdoor unit and the indoor unit. The outdoor unit, fitted outside the room, houses components like the compressor, condenser and expansion valve. The indoor unit comprises the evaporator or cooling coil and the cooling fan. For this unit you don't have to make any slot in the wall of the room. Further, present day split units have aesthetic appeal and do not take up as much space as a window unit. A split air conditioner can be used to cool one or two rooms. Even though this system has some problems such as this system consist of many moving equipment's as like compressor and condenser. Due to the movement of the parts of these components they create vibrations and so that unnecessary noise is produce. That affects the human comfort. Also each moving components require periodic maintenance. The compressor and condenser are large in size so that they require more space to install also they make the system bulky. All the current AC system are refrigerant base and many refrigerant produce advertising effect on the environment such as ozone layer depletion. So to overcome these problems there is a need to find out the new system which can become an alternative to VCR system. After making the research survey on air conditioning technologies we got that Thermoelectric Cooling can become an alternative to VCR. So that in this work we have gone through the study of TEM, validation of Thermoelectric Module & fabrication of a prototype model for the experimental analysis of thermoelectric cooling (TEC) system to check its performance as compare to VCR system.

Thermoelectric Cooling:

Thermoelectric cooling is a way to remove thermal energy from a medium, device or component by applying a voltage of constant polarity to a junction between dissimilar electrical conductors or semiconductors. Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Such an instrument is also called a Peltier device, Peltier heat pump, solid state refrigerator, or thermoelectric cooler (TEC). It can be used either for heating or for cooling, although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools.

II. METHODOLOGY

A typical thermoelectric module is composed of two ceramic substrates that serve as a foundation and electrical insulation for P-type and N-type Bismuth Telluride dice that are connected electrically in series and thermally in parallel between the ceramics. The ceramics also serve as insulation between the module internal electrical elements and a heat sink that must be in contact with the hot side as well as an object against the cold side surface. Electrically conductive materials, usually copper pads attached to the ceramics, maintain the electrical connections inside the module. Solder is most commonly used at the connection joints to enhance the electrical connections and hold the module together. Most modules have and even number of P-type and N-type dice and one of each sharing an electrical interconnection is known as, "a couple". While both P-type and N-type materials are alloys of Bismuth and Tellurium, both have different free electron densities at the same temperature. P-type dice are composed of material having a deficiency of electrons while N-type has an excess of electrons. As current (Amperage) flows up and down through the module it attempts to establish a new equilibrium within the materials. The current treats the P-type material as a hot junction needing to be cooled and the N-type as a cold junction needing to be heated. Since the material is actually at the same temperature, the result is that the hot side becomes hotter while the cold side becomes colder. The direction of the current

Figure : TEM

Will determine if a particular die will cool down or heat up. In short, reversing the polarity will switch the hot and cold sides.

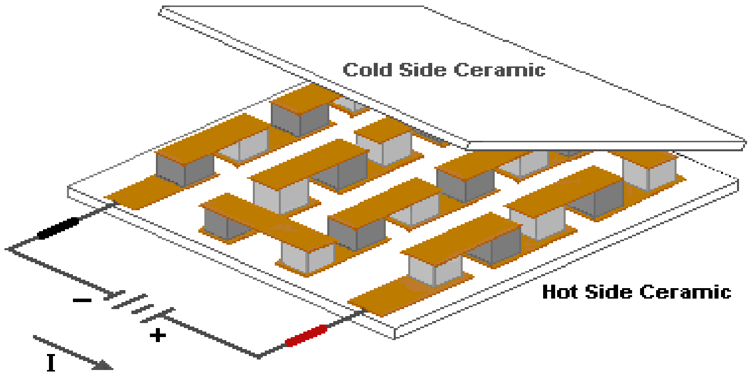
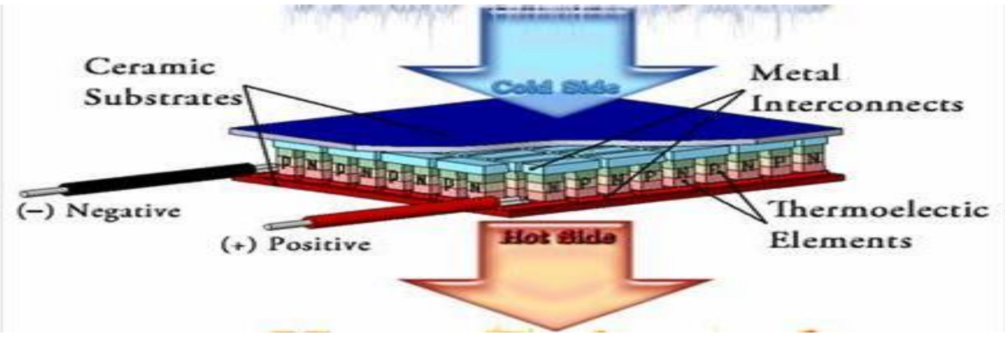


Figure: Internal Structure of TEM

Working principle of the Thermo-Electric Module

The TEM operating principle is based on the Peltier effect. The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material. One of the TEM sides is cooling and the other side is heating. When a thermoelectric module is used, you must support heat rejection from its hot side. If the temperature on the hot side is like the ambient temperature, then we can get the temperature on the cold side that is lower (tens of Kelvin degrees). The degree of the cooling is depended from the current value that is leaking through a thermoelectric module. In a thermo-electric heat exchanger, the electrons act as the heat carrier. The heat pumping action is therefore a function of the quantity of electrons crossing over the p-n junction .

Heat Absorbed



Heat Rejected

Figure: Operating Principle of TEM

Working of TEM

Thermoelectric modules are solid-state heat pumps that operate on the Peltier effect (see definitions). A thermoelectric module consists of an array of p- and n-type semiconductor elements that are heavily doped with electrical carriers. The elements are arranged into array that is electrically connected in series but thermally connected in parallel. This array is then fixed to two ceramic substrates, one on each side of the elements (as shown in figure). Let's examine how the heat transfer occurs as electrons flow through one pair of p- and n-type elements (often referred to as "couple") within the thermoelectric module.

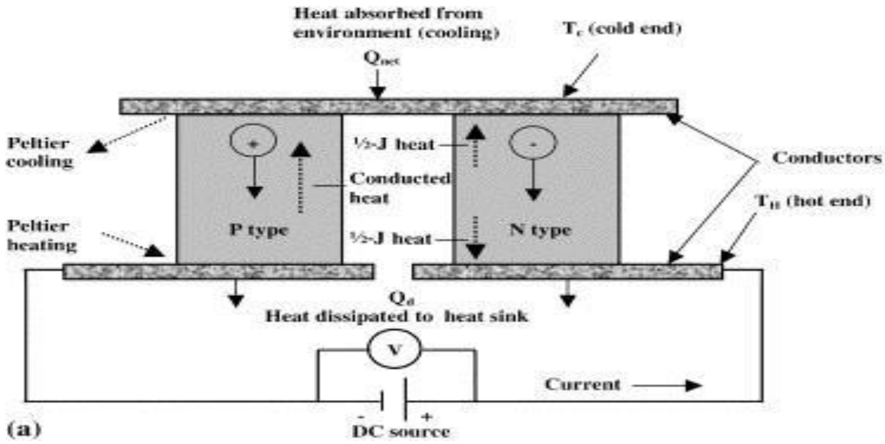


Figure : Schematic Diagram of TE Cooling

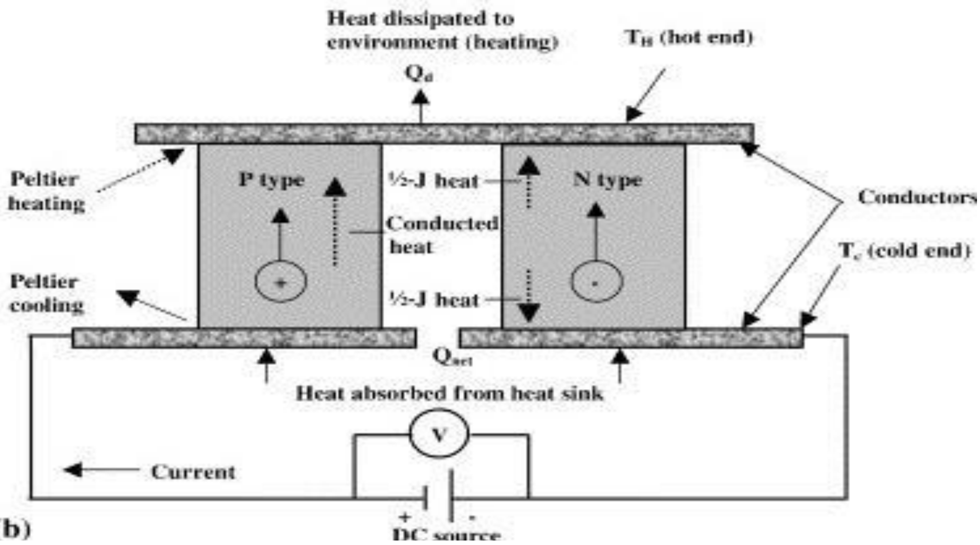


Figure : Schematic Diagram of TE Heating

The p-type semiconductor is doped with certain atoms that have fewer electrons than necessary to complete the atomic bonds within the crystal lattice. When a voltage is applied, there is a tendency for conduction electrons to complete the atomic bonds. When conduction electrons do this, they leave “holes” which essentially are atoms within the crystal lattice that now have local positive charges. Electrons are then continually dropping in and being bumped out of the holes and moving on to the next available hole. In effect, it is the holes that are acting as the electrical carriers. Now, electrons move much more easily in the copper conductors but not so easily in the semiconductors. When electrons leave the p-type and enter into the copper on the cold-side, holes are created in the p-type as the electrons jump out to a higher energy level to match the energy level of the electrons already moving in the copper. The extra energy to create these holes comes by absorbing heat. Meanwhile, the newly created holes travel downwards to the copper on the hot side. Electrons from the hot-side copper move into the p-type and drop into the holes, releasing the excess energy in the form of heat. The n-type semiconductor is doped with atoms that provide more electrons than necessary to complete the atomic bonds within the crystal lattice. When a voltage is applied, these extra electrons are easily moved into the conduction band. However, additional energy is required to get the n-type electrons to match the energy level of the incoming electrons from the cold-side copper. The extra energy comes by absorbing heat. Finally, when the electrons leave the hot-side of the n-type, they once again can move freely in the copper. They drop down to a lower energy level, and release heat in the process. A single-stage TEC will typically produce a maximal temperature difference of 70 °C between its hot and cold sides. The more heat moved using a TEC, the less efficient it becomes, because the TEC needs to dissipate both the heat being moved and the heat it generates itself from its own power consumption. The amount of heat that can be absorbed is proportional to the current and time.

Need of Testing & Validation of TEM

Many times, the TEM doesn’t take the current and voltage in actual use as per the specification recommended by manufacturer, also not produce the temperature difference between the hot and cool side of it as much as that is specified by the manufacturer. So that the TEM cannot able to produce desire cooling effect. We are using TE12706 TEM for our analysis of thermoelectric cooling system. Manufacturer specified that this module takes 12V 6 Amp current and produce 75 temperature difference between hot and cool side of it, when the hot side is at 50°C that means when the hot side of TEM is maintain at 50°C the cold side will be at -25°C.To design the proper thermoelectric cooling system, we need the actual data regarding to the TEM so that we are going to test the TEM. In the work of testing and validation of TEM we are going to check the max current that can be taken by the TEM and also the temperature difference between the hot and cool side of it, when the supply of 12V 30 Amp is provide to this TEM (TE12706). For this purpose, we are going to maintain the temperature of hot side of TEM by using three cooling methods that’s air cooling, water cooling & evaporative cooling.

Experimental Setup:

The hot side of the TEM is maintain at the constant temperature by using three different methods this are air cooling, water cooling & evaporative cooling. The experimental setup requires for this method are quite different from each other that are as follows.

Air Cooling

Figure: Hot fins are cold by air

III. Construction

The image shows the experimental setup use for maintaining the temperature of hot side of TEM by using air cooling. The setup consists of TEM, Heat sinks, Fan, Adopter, Temperature sensor, Multi meter & Anemometer.The Heat sinks are connected to the hot as well as cool side of the TEM as shown in the image. The heat sink connected to the hot side are big in size as compare to the heat sink connected to the cool side, because to get more area for transmission of heat from hot side to the atmosphere. The axial fan is use to circulate the atmospheric air over the hot sink. The fan and the TEM is connected to the power adopter which provide DC supply of 12V 30 Amp.

Working:

When the DC power supply is turn on one side of the TEM become cool and another one become hot.Because of that the temperature of heat sink of cool side start falling below the ambient temperature and that of the hot side start increasing above the ambient temperature. So that the cool side heat sink become cool and that of hot side become hot.In this experiment the hot side of the TEM is maintain a constant temperature by circulating the atmospheric air over the heat sink (fins) of hot side of the TEM. When the atmospheric air is come in contact with the surface area of the hot side heat sink the heat is reject to the air from the heat sink because of the temperature difference between them. So that the heat sink of hot side of TEM is maintain at the constant temperature above the ambient temperature and that of cold side maintain at the temperature below the ambient temperature.

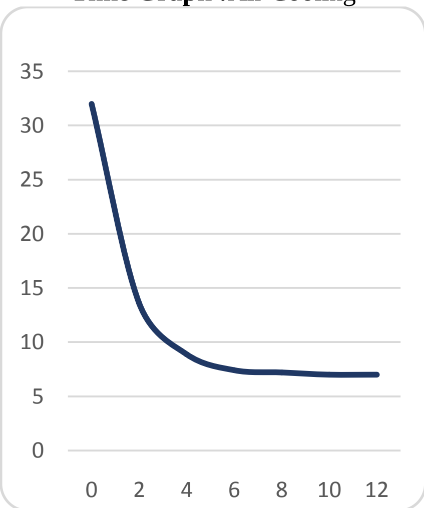
IV. Performance Evaluation

In this experiment the hot side of peltier module is cold by atmospheric air flowing at constant rate of 603.18 cm^3/sec. We have got reading of the temperature as mention in the table (A). "Tc" is cold side temperature and "Th" is the hot side temperature.The graph (A) is plot by using these readings. the graph illustrates the temperature drop in the cold side of thermoelectric module it consists of temperature. on y-axis (ºC) and time (minute) on x- axis.At the beginning the whole setup is at 32 ºC so as cold side after turning on the system the temperature of cold side start abating rapidly up to 6 min and after that it verging on 7ºC.The hot side temperature is rises45.7ºC in 12 minutes.

Temperature

Time (min)	Tc (ºc)	Th (ºc)
0	32	32
2	13.6	44.8
4	8.9	45
6	7.4	45.1
8	7.2	45.2
10	7	45.3
12	7	45.7

Time Graph : Air Cooling

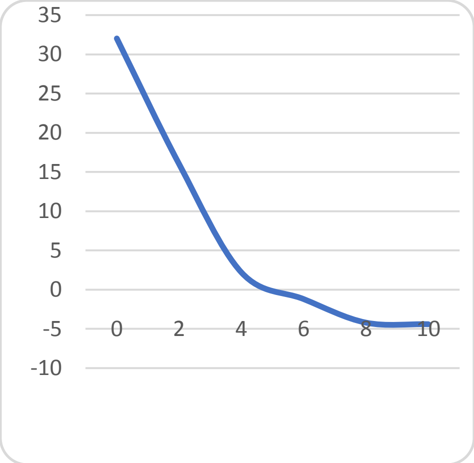


On the other hand hot side of peltier module is cold by1-literwater which is at 32 ºC. We have got reading of the temperature as mention in the table (B). "Tc" is cold side temperature and "Th" is the hot side temperature.The graph (B) illustrate the temperature drop in cold side of thermoelectric module. Water cooled system is use to absorb the heat from hot side.At the beginning at whole setup is at 32 ºC and the cold side is also at 32 ºC and temperature start abating very rapidly until 4 min and after that it shows fluctuations in temperature range.Maximum temperature drop of cold side is -4.4 ºC in 10 minutes and the water temperature rises to 37ºC.

Temperature

Time	Tc (ºc)
0	32
2	16
4	2.2
6	-1.2
8	-4.2
10	-4.4

Time Graph: water cooling



V. CALCULATIONS

i) Energy require for one module:
The module required 12 v and 3 amp current therefore power required will be 36 w.
ii) Cooling capacity of one module:

$$\frac{\text{Heat Absorbed}}{\text{Time}} = \frac{367}{3600} = 0.1 \text{ j/s}$$

iii) Water consumption:
It is observed that to cool the hot side of one peltire module 100 ml per hour water required.
Design of actual TEC cooling system:
This design is made to cool the room of 4×4×4 m^3volume from 35 ºc to 22 ºc by taking the reference of result of cooling experiment performed on the prototype of TEC system. We have considered that the room blank and it. Haven't any heat producing equipment inside it and also no human being is present in the room.
Volume of room = 64m^3
Initial temperature of room = 35 ºc
Desire cooling temperature = 22 ºc
No of TE12706 Module required for cooling = 500
Density of air = 1.1459 kg/m^3
Specific heat of air =1.0067kj/kg k
It observed that in experiment performed on the prototype of TEC system. The Cooling capacity of TE12706 module = 0.1 kg/s
Calculation of heat load:
Mass of air = Density of air × Volume of room
= 1.1459 × 64
= 73.33 kg
Heat load = m × cp × Δt
= 73.33 × 1.0067 × (35 - 22)
= 959 kJ

= 960 kJ
= 960000 J
Time require to cool the room = heat load ÷ cooling capacity of 500 module
= 960000 ÷ (0.1×500)
= 19200/sec
= 19200 ÷ 3600 = 5.33 hour
So, the room of 64 m^3volumes require 5 hour 19 minutes to cool down it from 35 °c to 22 °c by using 500 TEC modules.

VI. RESULT

The graph illustrates the performance TEC module. It consists of temp. on y-axis and time on x-axis. Simultaneously we are showing the temperature of hot fins and box/prototype box temperature. As we can clearly see the temperature drop in the box is very quick in beginning and after some time it start abating and nearly get constant on 22 °c. On the other hand, the temperature of hot fins is nearly constant at 34 °with slight up and down during the working. The system is capable of taking the temperature 22 °c around the human comfort which is general requirement/expectations of air-cooling system.

VII. CONCLUSION

From this work it is observed that the thermo electric cooling system take more time to produce cooling effect so that we have to run the system for more time so that it consumes more energy. This system is best for low scale application. If we are increasing the capacity of the system, we required a greater number of module and the size of the component of the system is too increases, also hot side of the TEM produce more heat so to maintain the temperature of hot side of TEM we required huge cooling system with more water. Electricity consumption is also more for such system. That makes the system inefficient and impractical.TEC system is more convenient for small scale application, it is suitable for cooling of complicated structure system as like electrical and computer components. Due to the large size components VCR system cannot as suitable as TEC system for the small working space. There is a need of further improvement in TEC technology for the wide application of it.

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