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FABRICATION AND TESTING OF THERMOELECTRIC REFRIGERATION SYSTEM

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ABSTRACT

Advancement in technological field led to the most valuable invention i.e refrigeration and air conditioning system but its prolonged usage resulted in environmental problems that were catastrophic. Refrigerant used in the system such as CFC's, HFC's. HFC's caused serious environmental issues and giving rise to global warming. These refrigerants deplete the ozone layer that strains the ultraviolet rays coming to the earth's surface and there effect is for a longer period of time as these refrigerants stay in the atmosphere for as long as 18 years. A single molecule of HFC can destroy thousands of O3 molecules and that's why it has created a threat for the not only to maintain earth eco system stable but also to existence of earth. Even the percentage of HFCs are emitted into the atmosphere compared to CO2 is negligible but its global warming effect is few thousand times of CO2. The capacity of HFCs to increase in earth temperature 10% is contributed by HFC's only.

In recent years people are more inclined towards the usage of a compact and efficient refrigeration system that live upto their personal and environmental expectations. These led to the discovery and usage of thermo-electric cooling and heating system that can be a boon to the mankind TEC's emulates the performance of conventional refrigeration system in a considerable low cost.

KEYWORDS: Peltier Effect, Peltier Device, Radiator, Thermo-Electric Cooling

INTRODUCTION

Refrigeration is a process of removal of heat from a space where it is unwanted and transferring the same to the surrounding environment where it makes little or no difference.

Although a thermoelectric (TE) phenomenon was discovered more than 150 years ago, thermoelectric devices (TE coolers) have only been applied commercially during recent decades. For some time, commercial TECs have been developing in parallel with two mainstream directions of technical progress – electronics and photonics, particularly optoelectronics and laser techniques. Lately, a dramatic increase in the application of TE solutions in optoelectronic devices has been observed, such as diode lasers, super-luminescent diodes (SLD), various photo-detectors, diode pumped solid state lasers (DPSS), charge-coupled devices (CCDs), focal plane arrays (FPA) and others. The effect of heating or cooling at the junctions of two different conductors exposed to the current was named in honor of the French watchmaker Jean Peltier (1785–1845) who discovered it in 1834. It was found that if a current passes through the contacts of two dissimilar conductors in a circuit, a temperature differential appears between them. This briefly described phenomenon is the basis of thermoelectricity and is applied actively in the so-called thermoelectric cooling modules. Thermoelectric devices (thermoelectric modules) can convert electrical energy into a temperature gradient—this phenomena was discovered by Peltier in 1834. The application of this cooling or heating effect remained minimal until the development of semiconductor materials. With the advent of semiconductor materials bring the capability for a wide variety of practical thermoelectric refrigeration applications. Thermoelectric refrigeration is achieved when a direct current is passed through one or more pairs of n and p-type semiconductor materials. In the cooling mode, direct current passes from the n to p-type semiconductor material. The temperature of the interconnecting conductor decreases and heat is absorbed from the environment. This heat absorption from the environment (cooling) occurs when electrons pass from a low energy level in the p-type material through the interconnecting conductor to a higher energy level in the n-type material. The absorbed heat is transferred through the semiconductor materials by electron transport to the other end of the junction TH and liberated as the electrons return to a lower energy level in the p-type material. This phenomenon is called the Peltier effect. We studied working system of HVAC system and observe temperature and pressure in this system. Our aim is to introduce the new HVAC system using thermoelectric couple which shall overcome all the disadvantages of existing HVAC system. If this system comes in present HVAC system, then revolution will occur in the automotive sector. With population and pollution increasing at an alarming rate TEC (thermoelectric couple) system have come to rescue as these are environment friendly, compact and affordable. Conventional compressor run cooling devices have many drawbacks pertaining to energy efficiency and the use of CFC refrigerants. Both these factors indirectly point to the impending scenario of global warming. As most of the electricity generation relies on the coal power plants, which add greenhouse gases to the atmosphere is the major cause of global warming. Although researches are going on, better alternatives for the CFC refrigerants is still on the hunt. So instead of using conventional air conditioning systems, other products which can efficiently cool a person are to be devised. By using other efficient cooling mechanisms we can save the electricity bills and also control the greenhouse gases that are currently released into the atmosphere. Although Thermoelectric (TE) property was discovered about two centuries ago thermoelectric devices have only been commercialized during recent years. The applications of TE vary from small refrigerators and electronics package cooling to Avionic instrumentation illumination control and thermal imaging cameras. Lately a dramatic increase in the applications of TE coolers in the industry has been observed. It includes water chillers, cold plates, portable insulin coolers, portable beverage containers and etc.

MATERIALS AND METHODS

1. Peltier Device

The Peltier device consists of pairs of P-type and N-type semi-conductor thermo element forming thermocouple which are connected electrically in series and thermally in parallel. The modules are considered to be highly reliable components due to their solid state construction. For most application they will provide long, trouble free service. In cooling application, an electrical current is supplied to the device, heat is pumped from one side to the other, and the result is that one side of the module becomes cold and the other side hot.

Figure 1: Peltier Module

2. Radiator

Radiator is used in this setup to dissipate heat from the coolant to keep it cool and to maintain an optimum temperature. At the inlet of the radiator, aluminum block is connected and pump is connected at the outlet which pumps cooled coolant through the aluminum block. The radiator contains a coolant that carries away the heat from radiator.

Figure 2: Radiator and Radiator Fan

3. Aluminium Block

Aluminium block has a dimension of 40mm X 40mm is attached at the hot side for the liquid cooling of Peltier. This is used for the liquid cooling of the Peltier module. It contains an inlet and outlet. At the inlet is attached a pump which circulated the cooled coolant coming out from radiator and the outlet is attached to the radiator.

Figure 3: Aluminum Block

Figure 4: Aluminum Heat Sink

4. Aluminum Heat Sink

A heat sink is a passive heat exchanger that transfers the heat by convection from the refrigeration chamber. This is connected at the cold side of the Peltier. They cool down to a temperature of about 0 C and air passing through them gets cooled up by convection and then is transferred to the chamber which in turn helps in bringing down the temperature of the chamber.

5. Coolant

Coolant used in this setup is a non amine based green colour coolant that has an excellent resistance on rust and corrosion and can be used for both ferrous and non ferrous radiators. Coolant passes through the aluminum block which is connected at the hot side of the Peltier device to dissipate heat from it.

6. Automatic Thermostat

It's an electronic device that measures the temperature and automatically controls the temperature of chamber in a desired range using relay operations.

7. SMPS

A switched-mode power supply (SMPS) is an 12V DC supply electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Ideally, a switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time. This higher power conversion efficiency is an important advantage of a switched mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor.

8. High Density Thermocol Chamber

High density thermocol chamber is used which acts a void in which the required temperature is maintained.

9. Circulating Pump

It facilitates the flow of coolant into the aluminum block and then to the radiators. It's a 12v electronic device that provides the force to the coolant to complete its flow that is from aluminium block inlet to the radiator outlet.

Thermoelectric Effect

When two dissimilar metals are joined together with some semi-conductor sandwiched between, and when electric current passes through these plates and temperature difference is established, i.e. one side becomes cold one side becomes hot. This effect is known as thermoelectric effect.

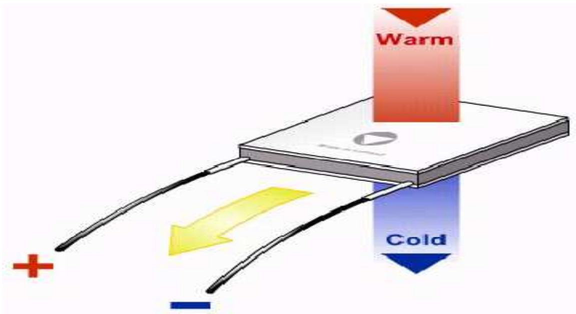


Figure 5: Thermoelectric Effect

Methodology

In this design we have fabricated a high density thermo cool chamber of 395mm height, 252mm depth and 385mm length, to the wall of the chamber is attached a Peltier of 12V 6A, an aluminum water block attached on the hot side of the Peltier, an aluminum heat sink on the cold side of the Peltier along with a delivery fan. Aluminum water block has an inlet and outlet which is connected to the radiator through delivery pipes. Through the delivery pipes flows the coolant which is used to dissipate the heat from the aluminum block which is due to the hot side of the Peltier. The delivery pipes are connected to the inlet and outlet of a radiator, the work of the radiator is to dissipate the heat into the atmosphere from the coolant. The outlet of the radiator consists of circulating pump which facilitates the flow of the coolant to the aluminum block. The power supply to the Peltier is provided by the Switched Mode Power Supply (SMPS) which helps in regulating the input voltage to the Peltier. Automatic thermostat with a digital indicator is used to indicate the temperature inside the chamber and that of the heat sink too.

When the setup is supplied with AC supply the SMPS regulates the voltage that is to be supplied to the Peltier, when the current is supplied one side of the Peltier turns hot and one side cold due to thermoelectric effect. To the cold side of the Peltier is connected an aluminum heat sink to which a circulation fan is connected which supplies the cold air throughout the chamber and cools the chamber due to convection.

Area of Chamber = L × B × H = 385 mm × 252 mm × 395 mm.

= 0.385 m × 0.252 m × 0.395 m

= 0.038 m3

Experimental Procedure

The automatic thermostat records the temperature of the chamber and automatically cuts off the Peltier if the temperature exceeds or goes below the desired temperature. Temperature of the heat sink is recorded with a thermometer. Temperature of the chamber, coolant and heat sink is recorded at an interval of fifteen minutes.

Table 1: Temperature of the Surface of the Peltier Device When the Load is applied on the Setup

Load	Hot Side	`Cold Side
OFF	At room Temperature	At Room Temperature
ON	54°C(327K)	-16°C (256K)

Case 1

In this case the circulating fan is switched on and the temperature is recorded The temperature in chamber reaches upto 13°C and that of the heat sink upto -2°C.

Table 2: Air Circulation Fan is ON

S. No.	Time	Heat Sink Temperature (°C)	Chamber Temperature (°C)	Coolant Temperature (°C)
1	0 min	32	32	32
2	15 min	2	23	34
3	30 min	0	18	35
4	45 min	-1	16	37
5	60 min	-1	15	36
6	75 min	-2	14	37
7	90 min	-2	13	37

Case 2

In the second setup the circulating fan is switched off and the temperature is recorded. The temperature in chamber reaches upto 16°C and that of the heat sink upto -3°C.

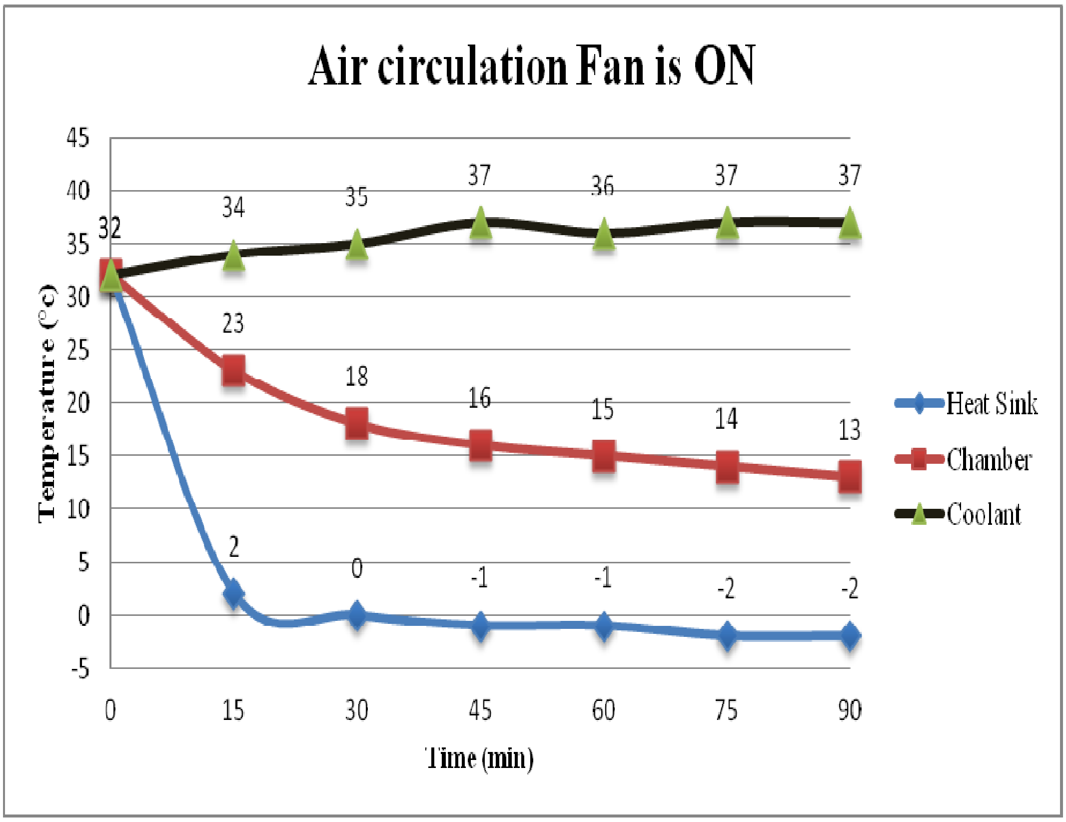
Table 3: Air Circulation Fan is OFF

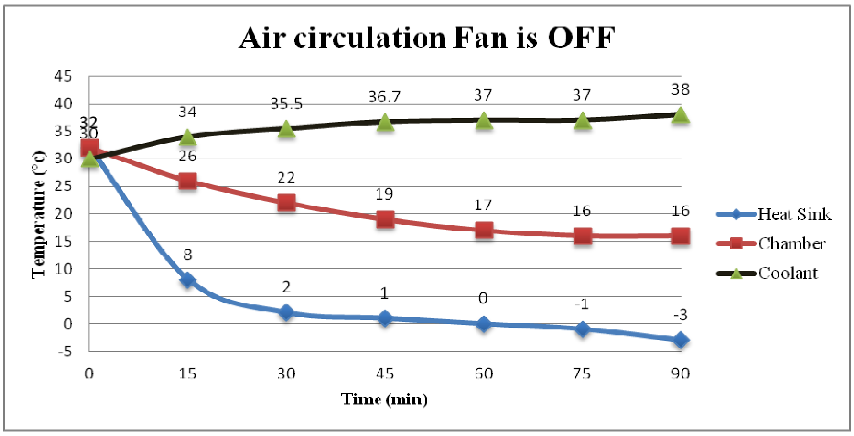
S. No.	Time	Heat Sink Temperature (°C)	Chamber Temperature (°C)	Coolant Temperature (°C)
1	0 min	32	32	30
2	15 min	08	26	34
3	30 min	02	22	35.5
4	45 min	01	19	36.7
5	60 min	00	17	37
6	75 min	-01	16	37
7	90 min	-03	16	38

RESULTS AND DISCUSIONS

The graph of fan ON condition shows that the chamber temperature reaches upto 13°C and that of the heat sink upto -2°C. Chamber temperature can be maintained constant after 90 minutes of continuous working of the TERS while coolant and heat sink temperature reduce very slightly after 30 minutes of continuous working of the TERS.

In fan OFF condition temperature reduces to 16°C from 32°C in chamber and heat sink temperature drops from 32°C to -3°C and coolant temperature rises 38°C from 32°C. Chamber and Coolant temperature reduces very negligible after 1 hour while heat sink temperature reduces very negligible after 30 minutes of continuous working of the TERS. Temperature reductions also depend upon the atmospheric conditions or outside temperature of the chamber.





CONCLUSIONS

A Thermoelectric refrigeration system (TERS) was designed and built which can be used for personal and industrial refrigeration purposes. It can also be used very effectively in car for cooling and warming purpose just by changing the polarity. One Peltier was used for achieving the cooling with a DC power supply through external power supply (SMPS). It had been shown from testing results that the refrigeration system is capable of cooling the air inside the chamber with the help of heat sink and air delivery fan working combined or heat sink working individually. TERS with fan ON condition is more capable of cooling the air inside the chamber as it reduces the temperature from 32°C to 13°C. Cooling stabilizes within one hour once the air delivery fan is turned ON (with an rpm of 200). The system can establish the set target temperature range that is 10°C-15°C. The prototype can be made more effective by using multiple TECs or by using a copper heat sink instead of an aluminum one. This refrigeration system can be used as more effectively as an air conditioning system for cooling automobiles (cars) by using multiple TECs and higher rpm fan or blower. Radiator of car can be used to cool the hot side thus by eliminating the cost of the model.

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