THERMO ELECTERIC AIR CONDITIONING AN ALTERNATIVE TO CONVENTIONAL AIR CONDITIONING SYSTEM

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Abstract: Today's present HVAC system is very efficient and reliable but it has some demerits. It has been observed during the last two decades that the O layer is slowly destroyed because of the refrigerant (CFC and HFC) used for the refrigeration and air conditioning purposes. A single molecule of HFCs can destroy thousands of Ozone molecules, Even the percentage of HFC's are emitted into the atmosphere compared to CO2 is negligible but its global warming effect is few thousand times of CO. The effect of 100 gm of HFC's can destroy 0.5 tons of Ozone molecule. These HFC's once destroy O-layer; it takes lack of years to recover its thickness as it is formed by complex reactions.

Thus in order to tackle this problem thermoelectric phenomenon is taken into account to deal Thermoelectric cooling, commonly referred to as cooling technology using thermoelectric coolers (TECs), it has advantages of high reliability, no mechanical moving parts, compact in size and light in weight, and no working fluid. In addition, it possesses advantage that it can be powered by direct current (DC) electric sources and alternating current (AC) electric source

Index Terms – HVAC, HFC'S

I. INTRODUCTION

ii Thermoelectric phenomena is based on Peltier Effect which was proposed by Sir Jean Peltier in 1834 It states that "when an electric current flows across two dissimilar conductors, the junction of the conductors will either absorb or emit heat depending on the flow of the electric current. The heat blot up or released at the junction is proportional to the input electric current. The constant of proportionality is called the Peltier coefficient.

iii It use a very simple concept of running on a temperature difference and as long as this criteria is being fulfilled, energy is produced. The idea of thermoelectricity can be classified into 2 parts. Thermoelectric Coolers (TEC) and Thermoelectric Generators (TEG). There have been quite a few number of applications in the recent past and the number of applications are upcoming with time. Thermoelectrics has found its route into air conditioning systems, automobile applications, solar energy applications and many others.

iv Thermoelectric cooling: 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 relocates heat from one side of the device to the other, with consumption of electric energy depending on the orientation of the current. Such an gadget is also called a Peltier device, Peltier heat pump, solid state refrigerator, or thermoelectric cooler (TEC). They can be used either for heating or for refrigeration. Although in practice the main application is cooling. It can also be used as a temperature monitor that either heats or cools.

1.1 PROPOSED METHODOLOGY

The project used a structured system analysis and design methodology approach to achieve the project objectives. Block system analysis of the project is shown above (Figure 1.1) with the use of block diagram. TECs are sandwiched in between heat sinks. Glacial air is blown out from one end of the cold heat sinks. The TECs were powered by a power supply.

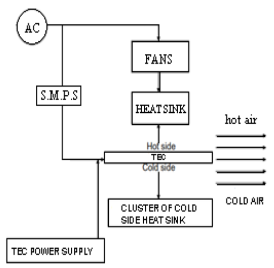

Figure 1.1 Block Diagram of Thermoelectric Setup

1.2 ORGANIZATION OF DISSERTATION

1.2.1 Operating Principle

Thermoelectric system operate by Peltier effect (which also goes by the more general name thermoelectric effect). The device has two sides, and when DC current flows through the device, it brings heat from one side to other, so that one side gets cooler while other gets hotter. The hot side is attached to a heat sink so that it remains at ambient temperature, while the cool side goes below room temperature. In some applications, multiple coolers can be cascaded together for lower temperature.in the fig 1.2 it shows the PN junctions used with hot side and cold side above is the hot side and below is the cold side it depends on the polarity of the current .

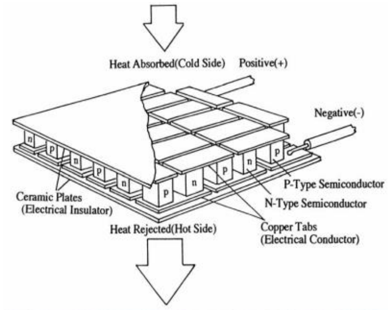

Figure.1.2 Peltier element schematic diagram [2]

1.2.2 Movement of electrons (Charge Carrier Diffusion):

In fig 1.3 diagram the movement of electrons and formation of holes on the n side is been shown as p junction is lesser in electrons n more in holes where as the n junction is having more electrons and less holes

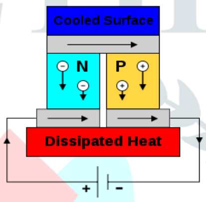

Figure.1.3 Circuit diagram for thermoelectric cooler

Same in fig 1.4 the same circuit can be used in generator so as to provide heat source as the time of heating
The same circuit configured as a generator.

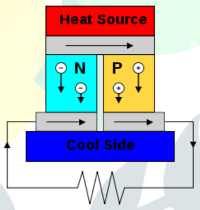

Figure.1.4 Circuit diagram for generator

In the diagram 1.4 the See-beck effect is described. The See-beck effect is formed by two things: charge-carrier diffusion and phonon drag. Charge carriers in the materials will diffuse when one end of a conductor is at a different temperature than the other. Hot carriers diffuse from the hot end to the cold end, since there is a lower density of hot carriers at the cold end of the conductor, and vice versa.

In the early phases thermocouples were metallic, but many more recently developed thermoelectric devices are made from alternating p-type and n-type semiconductor elements connected by metallic connectors. Semiconductor junctions are same in power generation devices, while metallic junctions are more common in temperature measurement. Charge passes through the n-type element, crosses a metallic interconnect, and passes into the p-type element. If a power source is provided, the thermoelectric device may act as a cooler by the Peltier effect explained below. Electrons in the n-type element move in the opposite direction of current and holes in the p-type element will move in the direction of current, both removing heat from one side of the device. When heat source is provided, the thermoelectric device work as a power generator. The heat source manages electrons in the n-type element toward the cooler region, creating a current through the circuit. Holes in the p-type element then ripple in the direction of the current. Therefore, thermal energy is transformed into electrical energy.

1.2.3 Working of thermoelectric module:

In 1834 Jean Peltier noted that when an electrical current is applied across the junction of two dissimilar metals, heat is removed from one of the metals and transferred to the other. This is the basis of the thermoelectric refrigeration. Thermoelectric modules are assembled from a series of small metal cubes of different exotic metals which are physically bonded together and connected electrically. When electrical current passes through the cube junctions, heat is shifted from one metal to the other. Solid-state thermoelectric modules are capable of transferring large quantities of heat when connected to heat absorbing device on one side and a heat dissipating device on the other. The internal aluminum cold plate fins blot up heat from the contents, (food and beverages), and the thermoelectric modules transfer it to heat dissipating fins on the heat sink. Here, a small fan helps to scatter the heat into the air. The only moving part is the small 12-voltt fan. Thermoelectric modules are too costly for normal domestic and commercial applications which run only on regular household current. They are ideally suited to recreational usages because they are lightweight, compact, and insensitive to motion or tilting, have no moving parts, and can work directly from 12-volts batteries.

In fig 1.5 the working of the thermoelectric module is shown. Thermoelectric modules are solid-state heat pumps that work on the Peltier effect. A thermoelectric module consists of an array of p- and n-type semiconductor elements that are extremely doped with electrical carriers. The elements are align into array that is electrically connected in series but thermally connected in parallel. This array is then attach to two ceramic substrates, one on each side of the elements. We can see in Fig 1.5 how the heat transfer occurs as electrons flow through one pair of p- and n-type elements (often referred to as a "couple") within the thermoelectric module:

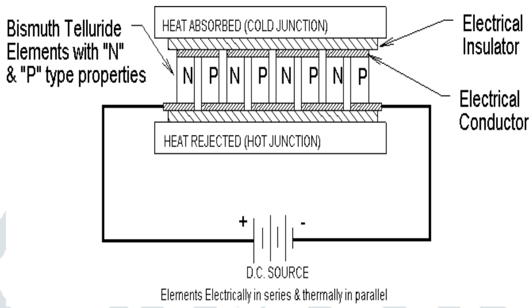

Figure.1.5 working of the thermoelectric cooler

Some benefits of using a TEC are:

- No moving parts so maintenance is recommend less frequently
- No chlorofluorocarbons
- Temperature controlled in between fractions of a degree can be maintained
- Adaptable shape (form factor); in particular, they can have a very small size
- Can be applied in environments that are smaller or more severe than conventional refrigeration
- Long life, with mean time between failures (MTBF) exceeding 100,000 hours
- Is controllable via changing the input voltage/current

Some disadvantages of using a TEC are:

[1] Only a limited amount of heat flux can be dissipated
[2] Relegated to applications with low heat flux
[3] Not as productive, in terms of coefficient of performance, as vapor-compression systems.

1.2.4 Features of thermoelectric cooler:

COMPACTNESS: Thermoelectric module are the most compact because of the small size of the cooling components- cooling module/ heat sink/ cold sink.
Weight: The weight is 1/3 to ½ as much as other units because of the lightweight cooling system- no heavy compressor.
Portability: They are the most portable because they are light enough to carry with one hand and are not affected by motion or tilting.
Price: They cost 20% - 40% less than equivalent sized compressor or absorption units available for recreational use.
Battery Drain: System has a minimum current drain on 12 volts of 5 amps. Compressor portables requires slightly more current when running but may average slightly less depending on thermostatic control settings. Absorption portables uses 6.5 to 7.5 amps when running and may average about 5 amps draw.

2. LITERATURE SURVEY

Increasing demand of consumer for handheld devices for higher functionality and reliability in low power hand held devices was an approach made to developing of handheld device that is thermoelectric cooler and heater. For this purpose insights from various reference books and research papers were taken.
1. The reality of a small house hold refrigerator [3] by P.K Bansal has described the design of the thermoelectric module, how it can be used for cooling of water and heating. Various books have provided different ways or design for fabrication of thermoelectric cooler

2.Saket Kumar, Ashutosh Gupta, Gaurav Yadav, Hemend Pal Singh[7] published research paper which stated the heating & cooling through Peltier Module is completely depends upon the point of contact and the material you are using.

3. P. Amaanath, K. Kalyani Radha [8] stated when DC power is applied to the TEC module, heat is moved from the cold surface to the hot surface. The direction in which the heat is pumped is directly related to the direction of the current. When the direction of the current is reversed, the direction in which the heat is pumped is also reversed.

4. Michael Gasik et al [9]:- 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. This system needs constant temperature range. The cooling system have no moving parts as thermoelectric cooling based on Peltier effect is used. We can directly apply to do cooling. The excessive and low grade heat is rejected to surrounding. This system is widely used in space system

5. Andrew B. Kustas et al [10]:- This research paper presents the application of thermoelectric cooling in fire fighter. Fire-fighter suffered physiological strain due to working environment. Some strain is produced due to presence in high temperature environment doing physical activity. Many fire fighter die because of external environment leads to increase internal body temperature as heat flows from high to low. Researcher suggested that external thermoelectric cooler can be provided with each fire fighter

3 Geometry-

In order to be used as portable device basically two shapes were initially considered, circular and rectangular. Circular shape has the largest volume to surface area ratio while for rectangle, doors could be easily attached and thermoelectric module and heat sink could be easily fastened. Then, keeping in a view its simplicity to build and insulation phenomenon rectangle shape was taken into consideration. The basic geometry is as shown in model. Later it was modified to and converted into two compartments.

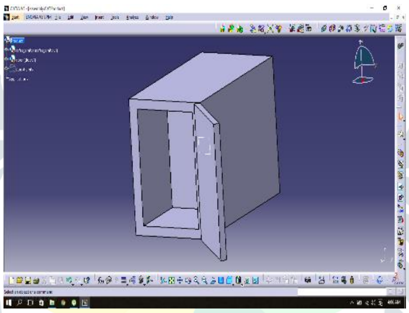

Figure 3.1 Basic CATIA modelling of our Thermoelectric system

3.1 Material:

We explored various materials for construction of the outer casing, insulation. The outer casing inside which two compartments would be made was made up of wood due to its ease to be able to cut and to drill.
While the part on the inner side was made up of Aluminum which is light in weight, has high conductivity and is easily available in low cost.

Figure 3.2. Aluminum block

3.2 Thermoelectric module:

The Thermoelectric module provided is as specified in design, one cold end is connected to the cold plate that is facing the cooling coil whereas the other end is connected to the heat sink.

Figure.3.3 Thermoelectric module

3.3 Selection of Peltier Modules for Above Configuration

Operating Voltage**:** maximum 15.4V. Potential may be applied either way. The only difference is the sides which heat up and cool down.
Rating: maximum 6 amps
Power: maximum 51.4 watts
Temperature difference**:** maximum 59 degree C at an ambient
Temperature of 30 ºC and with no load.
Number of p-n junctions: 127
Footprint: 4 cm x 4 cm (A*B)
Thickness**:** 4mm (H)
Weight: 28 grams

3.4 Switch Mode Power Supply (SMPS)

A switched-mode power supply (SMPS) is an electronic circuit that transform power using switching devices that are turned on and off at high frequencies, and storage components such as inductors or capacitors to provide power when the switching device is in its non-conduction state.

Advantages of switched-mode power supplies:

Fig. 1. Higher efficiency of 68% to 90%
Fig. 2. Regulated and reliable outputs regardless of variations in input voltage
Fig. 3. Small size and lighter
Fig. 4. Flexible technology
Fig. 5. High power density

Disadvantages:

- Generates electromagnetic interference
- Complex circuit design
- Expensive compared to linear supplies

Switched-mode power supplies are used to power the variety of gadgets such as computers, sensitive electronics, battery-operated devices and other equipment requiring high efficiency.

Figure.3.4 Assembled SMPS integrated with fan and heat sink

3.5 Cooling Fan

The aluminum heat sink fan is a cooling device that works on its own to efficiently draw heat away from the components into its large surface area to transfer cooler air into its fin-like aluminum structure. This cooling device used in unison with all the major components of the computer.

Fig 3.5 Heat sink and Cooling fan arrangement

Specifications:
Current (amp): 0.1 A
Speed (rpm) = 2200
Airflow (cfm) = 150
Power: 1 watt
Volt = 12 V

4. DESIGN AND CALCULATIONS

4.1 Heat generated by TEC

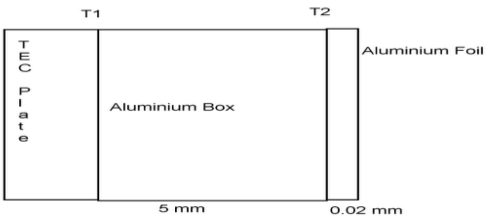

Figure 4.1 Heat transfer from TEC plate

Assumptions

1. Heat Transfer is in only one direction.
2. Both Aluminum block and aluminum foil is treated as one element as k=constant and Area=constant.

$Q= KA (T_1-T_2)/ x$

Where,
k= thermal conductivity of aluminum (205 W/mk)
A= cross sectional area (0.016 mm^2)
T_1 = Temperature generated by TEC plate.
T_2= Temperature at foil surface
x = Thickness of aluminum block and foil. ($2.02 * 10^{-3}$)
Q = heat capacity of TEC
Now, putting values in
$Q= KA (T_1-T_2)/ x$
Q = 40 W

4.2 Cooling Load Calculations:

The most difficult and important factor to be accurately calculated for a TEC is the amount of heat to be removed or absorbed (Qc) by the cold side of the TEC. In this project Qc was calculated by finding the product of finding the product of mass flow rate of air, specific heat of air and temperature difference. Here the temperature difference system in the difference between the inlet temperature and outlet temperature of the cooling system. The mathematical equation for Q c is shown as,

$Qc = mCp\Delta T$
Now,
Volume = 20*8*15 = 2400 cm^3 = 2.4 liters
Cooling capacity required = m * Cp * dt
= 2.4 *4.2* (30-15)
= 153.72 KJ
= 153.72/3.6 = 42.7 Watts

Module Selection - Since cooling capacity of our module is 45 KW, we can use TEC- 12706.To produce temperature of 16 ^{0}C inside the box we use 1 TEC.

Coefficient of Performance Calculations: [13]

C.O.P. = m * Cp * dt / (t*60).
= 2.4*4.21* (30-16) / (5*60)
= 0.4736

5. Performance

A single-stage TEC will typically produce a maximum temperature difference of 60°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, as well as the heat it generates itself from its own power consumption. The amount of heat that can be blot up is proportional to the current and time.

W=*Pit*

Where, P is the Peltier Coefficient, I is the current, and t is the time required. The Peltier Coefficient is dependent on temperature and the materials the TEC is made of Thermoelectric junctions are about four times less productive in refrigeration applications than conventional means (they offer around 10-15% productivity of the Carnot cycle refrigerator compared with 40–60% achieved by traditional compression cycle systems (reverse Rankine systems using compression/expansion).Due to this lower efficiency, thermoelectric cooling is generally used in environments where the solid state nature (no moving parts, maintenance, compact size, and orientation insensitivity) outweighs pure efficiency.

Requirements for Thermoelectric materials
1. Constricted band-gap semiconductors because of room temperature operation
2. Heavy elements because of their high portability and low thermal conductivity
3. Large unit cell, complex structure
4. Highly anisotropic or highly symmetric

Common thermoelectric materials used as semi-conductors comprises bismuth telluride, lead telluride, silicon germanium, and bismuth-antimony alloys. Of this bismuth telluride is the mostly used? New high-productive materials for thermoelectric cooling are being actively researched.

5.1. Typical applications for TEC module include:
1. Thermoelectric cooler
2. Laser diodes
3. Laboratory instruments
4. Temperature baths
5. Electronic enclosures
6 .Refrigerators

5.2. Efficiency of Thermoelectric module

The COP depends on the heat load, input power, and the required temperature difference. Usually, the COP is between 0.3 and 0.7 for single-stage applications. However, COPs more than 1.0 can be attained especially when the module is pumping against a positive temperature difference (that is, when the module is removing heat from an object that is warmer than the ambient).

6. PROCEDURE OF EXPERIMENTATION:

- Start TEC module supply.
- Put in the load to be heated or cooled.
- Measure the temperature
- Measure the temperature after certain intervals
- Plot a graph and see where does graph stabilizes.

6.1. OBSERVATION TABLE

Initial Temperature = 32 ^{0} C

Sr. no	Container volume (ml)	Time(Min.)	Final Temperature	ΔT
1	200	60	23.4	8.6
2	200	55	24.2	7.8
3	200	50	25	7
4	200	45	25.9	6.1
5	200	40	26.8	5.2
6	200	35	27.7	4.3
7	200	30	28.2	3.8
8	200	25	29	3
9	200	20	30.7	1.3
10	200	15	31.2	0.8

Table 6.1Observation Table for Cooling

Sr. no	Container volume (ml)	Time(Min.)	Final Temperature	ΔT
1	200	60	47.02	15.02
2	200	55	46.4	13.4
3	200	50	45.9	13.9
4	200	45	45.2	13.2
5	200	40	44.1	12.1
6	200	35	42.2	10.2
7	200	30	39.9	7.99
8	200	25	38.1	6.1
9	200	20	35.9	3.9
10	200	15	34.1	2.1

Table 6.2 Observation table for Heating

CONCLUSION

The objective was to find an alternative for the use of conventional refrigeration system to minimize the power consumption and effluents caused by the hydrocarbon compounds. This we have achieved the desired results by the use of Peltier effect. Cooling system is has been designed and developed to provide active cooling with help of single stage 12 V TE module is used to provide adequate cooling. First the cooling load calculations for this TER compartment considered under study were presented. Establishment of the feasibility of providing cooling with single stage thermoelectric cooler which makes it more versatile, and it was also used for heating of the water by using the heat from heat reservoir and there was rise in temperature of water that is the difference in temp in a very less time.

Thus our aim is to design and manufacture low cost efficient system in which it would able to achieve both cooling and heating effect at the same time with less amount of power input, without any moving parts and which does not affect our environment by emitted harmful gases.

FUTURE SCOPE:

I. The effect of TEC plate deteriorate with time. Hence measure should be taken to improve the system so that the thermoelectric effect would be constant with respect to time.
II. To optimize the design of the system to improve its efficiency.
III. In order to increase the COP the temperature difference maintained at hot side of the TEC plate and cold side of the TEC plate should increase. This can be achieved by utilizing effective heat dissipation system.
IV. To improve the COP of the system, multistage of thermoelectric module can be done.
V. The system can be powered by solar panel.

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