Thermoelectric Air Cooling For Cars

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ABSTRACT— The existing HVAC system is replaced by newly emerging thermoelectric couple or cooler which works on peltier and seebeck effect. Thermoelectric cooling can be considered as one of the major applications of thermoelectric modules (TEM) or thermoelectric coolers (TEC). The main objective is to design a cooling system installed on a conventional blower of car AC. The idea of cooling is based on Peltier effect, as when a dc current flows through TE modules it generates a heat transfer and temperature difference across the ceramic substrates causing one side of the module to be cold and the other side to be hot. The purpose of the project 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. Testing and measurements is performed on car (Maruti 800).The temperature difference between inside air of car & outside ambient air is 7 °C

I. INTRODUCTION

The concept of air to air cooling by using thermoelectric effect may be efficient in comparison to the existing HVAC system for cars. Since air to air cooling working on thermoelectric effect is more effective in terms of producing cooling effect as compared to HVAC system and more efficient in terms of saving Petrol/Diesel.

Regarding Environment, such as global warming, ozone depletion, and a lack of energy efficiency, it is necessary to investigate alternative cooling technologies to the refrigeration that uses refrigerants. Thermoelectric cooling and heat pumping are alternatives that have recently attracted attention. Thermoelectric devices are solid-state devices in which electrons or holes equivalent to refrigerants in traditional vapor-compression systems carry electricity and thermal energy under an electric field. Therefore, they have many inherent, attractive features such as a long life and no moving parts, and they don't emit toxic gases, are lightweight, are low-maintenance, and are very reliable. In the past decade, there has been rapid development when it comes to the fundamental theory, materials, and devices related to thermoelectric. Nowadays, thermoelectric technology is making its way into the civil market, especially for applications that require high quality temperature control, such as precision instruments for medicine and research. Moreover, several thermoelectric applications are attracting commercial attention owing to their great prospects for the future, such as dehumidifiers, for domestic sectors, portable and domestic refrigerators, transports for perishable goods, etc.Thermoelectric cooling offers several advantages with respect to conventional vapor compression technology, since thermoelectric devices are more compact, free of noises and vibrations, provide high quality temperature control and require far less maintenance. 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. The design and development of this type of system will highlight the basic requirement of modifications in conventional system to reduce the consumption of fuel. The performance analysis of a system will definitely give the platform to modify the conventional system using Peltier effect.

Thermoelectric Refrigeration

The thermoelectric Refrigeration is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side. This effect can be used to generate electricity, measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as temperature controllers. The term "thermoelectric effect" encompasses three separately identified effects: the Seebeck effect, Peltier effect, and Thomson effect. The Peltier effect is the presence of heating or cooling at an electrified junction of two different conductors and is named after French physicist Jean Charles Athanase Peltier, who discovered it in 1834.

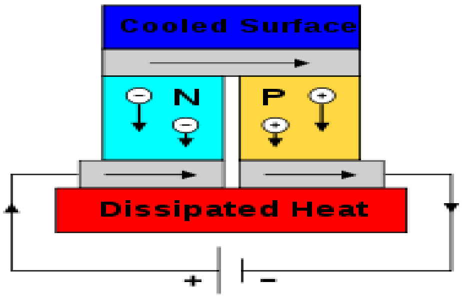


Fig.1 Peltier Effect

The Peltier effect can be used to create a refrigerator that is compact and has no circulating fluid or moving parts. Solid-state electrically-driven refrigerators (also named thermo-electric coolers, TEC) are based on the Peltier effect: when a DC current flows in a circuit formed by two dissimilar electrical conductors, some heat is absorbed at one junction and some more heat is released at the other junction, reversing the effects when reversing the sense of the current.

II. LITERATURE REVIEW

Dudnik et.al. [1] Presented paper on "Production and Exploitation of Thermoelectric Air Conditioning System for Vehicles" he mentioned that In the paper, more than 10-year experience of thermoelectric devices batch manufacturing is described for the field of their obvious advantages. This field of application includes thermoelectric air conditioning systems which have shown their competitive advantage.When used in vehicles of elevated vibration where compressor equipment application is difficult because of leakage of refrigerant. Energy characteristics of air conditioners for tractors, excavators, tanks, locomotive driver's cabins and cranes are described. Thermoelectric (TE) air conditioners mechanical test data as well as operation experience in vehicles are presented. It is shown that consumption of tellurium, which is a strategic component for thermoelectric materials manufacturing, may be lowered to 40 grams per 1 kW of cooling. Generally, mass application of thermoelectric in automotive industry is limited by two reasons, namely relatively low efficiency of energy conversion and limited raw material resources for production of thermoelectric materials (TE). Nevertheless there is a field of application for thermoelectric cooling devices in vehicles where such products have obvious advantages as against compressor systems. This is the field of application for vehicles of elevated vibration conditions where thermoelectric air conditioners application is quite reasonable. The fact is that thermoelectric cooling devices on the base of compressor systems are unworkable because of compressor systems refilling has no economic sense due to refrigerant leaks and is sometimes impossible. Such vehicles of high mechanical load include tractors, excavators, cranes, tanks, and other military machines. TE air conditioners development and studies have started as early as 1960-s. The articles of French scientist J. G. Stockholm should be mentioned as the most systematic. In this article the 15 year manufacturing and operating experience of TE air conditioners for automotive industry is presented, namely for those fields of application where the application of compressor systems is impossible. The most important criterion for some power unit application on a vehicle is the effectiveness, which is expressed as ratio of cooling capacity (Q0) to power consumption (P) for cooling systems. It is the so called Coefficient of Performance.

The advantages of above described TE air conditioner are:

- Resistance to vibration and impact stress (single or repeated mechanical shocks of 500/20g; sinusoidal vibration with the range of 5-500 Hz and with vibration acceleration Range of 3g)
- Stability when careen and sway occur;
- High reliability;
- Ease of maintenance & operation;
- TE air conditioner workability at high ambient above +500C temperatures
- Fire safety and environmental friendliness;
- Independent switch-on and switch-off of every cooling unit;
- Bacterial protection for cooling plates

Riffat et.al. [2] presented paper on Thermoelectrics : A Review Of present And Potential Applications and they discussed that, Thermoelectric devices are solid state devices. They are reliable energy converters and have no noise or vibration as there are no mechanical moving parts. They have small size and are light in weight. As refrigerators, they are friendly to the environment as CFC gas or any other refrigerant gas is not used. Due to these advantages, the thermoelectric devices have found a large range of applications. In this paper, basic knowledge of the thermoelectric devices and an overview of these applications are given. The prospects of the applications of the thermoelectric devices are also discussed. 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 came 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. Fig. 1 is a diagram of a single pair consisting of n- and p-type semiconductor materials. In the cooling mode, direct current passes from the n- to p-type semiconductor material. The temperature Tc 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.A second phenomenon is also important in thermoelectric refrigeration. When a temperature differential is established between the hot and cold ends of the semiconductor material, a voltage is generated. This voltage is called the Seebeck voltage, and it is directly proportional to the temperature differential. The constant of proportionality is referred to as the Seebeck coefficient.

Gurevich et.al. [3] in their paper explained "Theory of Thermoelectric Cooling in Semiconductor Structures" A new approach is suggested to explain the Peltier effect. This approach is based on the idea of the occurrence of induced thermal diffusion fluxes in any non-uniform medium through which a D.C. electric current flows, in particular in a structure composed of two different uniform semiconductors. These induced thermal diffusion fluxes arise to compensate for the change in thermal fluxes carried out by an electric current (drift thermal fluxes) during their driving through the junction in accordance with the general Le Chatelier-Braun principle. The occurrence of these thermal diffusion fluxes leads to temperature non-uniformity in the structure and, as a result, to the junction's cooling or heating. The general heat balance equations are obtained. It is shown that only two sources of heat exist: the Joule source of heat, and the Thomson source of heat. They have commensurable magnitudes in the problem considered. There is no Peltier's source of heating or cooling present. The new equation for the Thomson heat is obtained and its physical interpretation is made. New boundary conditions for the heat balance equation are derived.

The analysis of these boundary conditions shows that the Peltier sources of heat are also absent at the junctions. It is shown that, in the general case, the thermoelectric cooling represents the superposition of two effects, the isothermal Peltier effect and the adiabatic Peltier effect. Both essentially depend on the junction surface thermal conductivity. The isothermal Peltier effect disappears in the limiting case of a very small surface thermal conductivity while the adiabatic Peltier effect disappears in the limiting case of a very large surface thermal conductivity. The dependence of thermoelectric cooling on the geometrical dimensions of the structure is discussed. It is shown that the thermoelectric cooling (heating) is a thermodynamically reversible process in the linear approximation of the electric current applied.

Riffat et.al. [4] has presented a paper on "Comparative Investigation of Thermoelectric Air Conditioners versus Vapour Compression and Absorption Air Conditioner" in this paper they explained concluded thermoelectric technology has been used practically in wide areas recently. The thermoelectric devices can act as coolers power generators or thermal energy sensors and are used in almost all the fields such as military, aerospace, instrument, biology, industrial or commercial product. The applications of small capacity thermoelectric coolers are widespread. The development of new thermoelectric materials with large quality could make a breakthrough on applications of the thermoelectric devices in various fields.

Project Objective

1. To study critically existing HVAC system for its advantage and disadvantages.
2. To explore various technological option to replace existing HVAC system.
3. To study TEC as a substitute for present HVAC System which will overcomes the all demerits of present HVAC system.
4. To fabricate working model of HVAC using TEC.To test HVAC using TEC for its effectiveness, efficiency environment friendliness, comfort & convenience.

1 Scope Of Project

Why Thermoelectric cooling for cars than HVAC.

Power loss – Compressor is driven by the crankshaft of the engine. It consumes 5 to 10% of engine power.

Fuel loss – Present HVAC System reduces the mileage of the vehicle.

Pick up decreases –An air conditioning system can consumes as much as 8 h.p. with a unit capacity of 3 tones or 9072 kcal/hr. approximately. So, due to these the pickup of vehicle decreases.

Electric loss –Battery provide 12V current to the blowers and electromagnetic clutch of compressor for engaging the compressor.

Cost – cost of present HVAC System is very high.

Hazardous refrigerant – HFC is quit hazardous for human body & ozone layer which leads to global warming.

Repairing cost – Repairing cost of HVAC System is very high.

Maintenance – Proper maintenance is very necessary because this system can affect human body & Environment.

Size –Present HVAC system required very large space in the engine compartment and dashboard.

Delicate system –if any component fails to perform well then the whole HVAC system will either not function properly or not function at all.

The project scope involves the following elements

Sizing and Designing of the cooling system

Selection of the TECs

Selection of Fans and Heat sinks

DC power supply design with temperature control.

Prototype Assembly and Fabrication.

Temperature measurements for testing.

Power supply testing and troubleshooting.

2 Proposed Approach And Method Implemented

The project implemented a structured system analysis and design methodology approach to achieve the project objectives. Block system analysis of the project is shown below (Figure 1) with the aid of a straightforward block diagram. Ambient air is blown out by the blower through a duct to the TECs. TECs are sandwiched in between heat sinks. Cold air is blown out from one end of the cold heat sinks. The TECs were powered by a power supply.

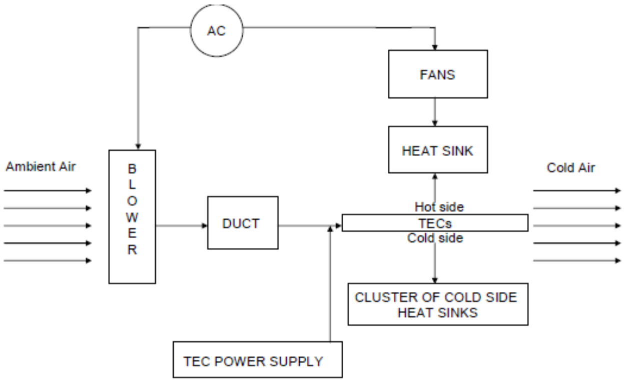


Fig.2 Block Diagram of thermoelectric air cooling system

The cooling system mainly consist of the following modules

Car Blower which acts as the primary source of air.

1. Duct which conveys the air from the blower to cluster of Al cold heat sinks.
2. One long heat sink is fitted to the hot side of TEC to absorb heat.
3. Aluminium heat sinks that are attached to the cold side.
4. Six TECs are sandwiched between cold and hot heat sinks.
5. An DC source which is used to power the fans and blower.(Car Battery)
6. Dc power supply is used to drive the TECs

A simple on off temperature controller is built in with the dc power supply.Thermoelectric Air Cooling For Cars To design a cooling system using thermoelectric cooler (TEC) one has to know the basics of thermoelectric effect, thermoelectric materials and thermoelectric cooling.Thermoelectric effect can be defined as the direct conversion of temperature difference to electric voltage and vice versa. Thermoelectric effect covers three different identified effects namely, the Seeback effect, Peltier effect and the Thomson effect.

A thermoelectric device will create a voltage when there is temperature difference on each side of the device. On the other hand when a when a voltage is applied to it, a temperature difference is created. The temperature difference is also known as Peltier effect. Thus TEC operates by the Peltier effect, which stimulates a difference in temperature when an electric current flows through a junction of two dissimilar materials.

A good thermoelectric cooling design is achieved using a TEC, which is solid state electrically driven heat exchanger. This depends on the polarity of the applied voltage. When TEC is used for cooling, it absorbs heat from the surface to be cooled and transfers the energy by conduction to the finned or liquid heat exchanger, which ultimately dissipates the waste heat to the surrounding ambient air by means of convection.

3. Thermoelectric Module

A standard module consists of any number of thermocouples connected in series and sandwiched between two ceramic plates (See Figure 2). By applying a current to the module one ceramic plate is heated while the other is cooled. The direction of the current determines which plate is cooled. The number and size of the thermocouples as well as the materials used in the manufacturing determine the cooling capacity. Cooling capacity varies from fractions of Watts up to many hundreds. Different types of TEC modules are single stage, two stage, three stage, four stage, center hole modules etc. A thermoelectric cooler has analogous parts. At the cold junction, energy (heat) is absorbed by electrons ,as they pass from p-type (low energy) semiconductor element, to the n-type semiconductor (high energy). The power supply provides the energy to move the electrons. At the hot junction, energy is expelled to a heat sink as electrons move from an n-type to a p-type. Figure 4 shows an illustration on the assembly of a Thermoelectric cooler.

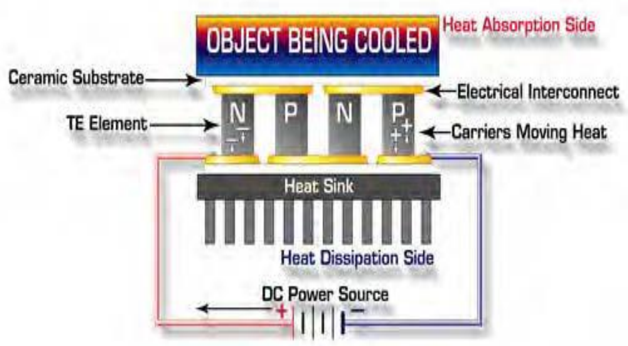


Fig. 3 A Classic TE Module Assembly

Single stage will be suitable for a wide range of cooling applications with low to high heat pumping capacities. A typical single stage is shown in Figure 3.

Fig. 4 A typical Single Stage Thermoelectric Module.

TEC can achieve temperature differences up to 70°C, or can transfer heat at a rate of 125 W. To achieve greater temperature differences (up to 131°C), select a multistage (cascaded) modules.

Before starting to design a TEC cooling system the designer have to take note the following considerations.

1. Temperature to be maintained for the object that is to be cooled.
2. Heat to be removed from the cooled object.
3. Time required to attain the cooling after a DC power is applied.
4. Expected ambient temperature.
5. Space available for the module and hot side heat sink.
6. Expected temperature of hot side heat sink.
7. Power available for the TEC.
8. Controlling the temperature of the cooled object if necessary.

4 Parameters of a Thermoelectric Module

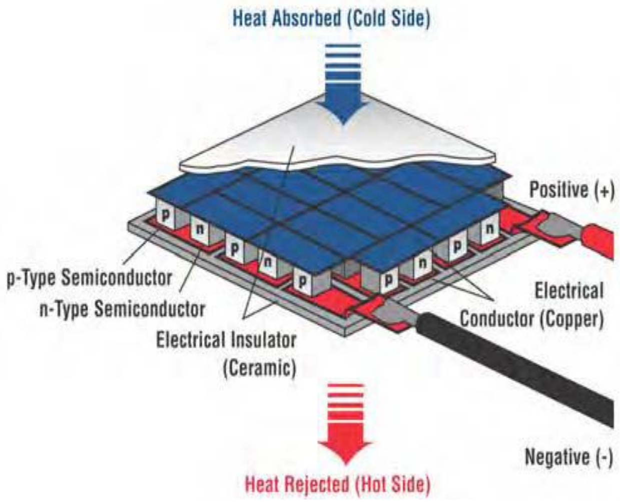


Fig. 5 A Cutaway of Thermoelectric Module

Parameters

1. Cold side temperature (T_c)
2. Hot side temperature (T_h)
3. Operating temperature difference (ΔT), which is the temperature difference between T_h and T_c.
4. Amount of heat to be absorbed at the TEC's cold surface. This can also be termed as heat load. It is represented as (Q_c) and the unit is Watts
5. Operating current (I) and operating voltage (V) of the TEC.

Specifications of thermoelectric air to air cooling system

Thermoelectric air to air cooling system is manufactured for experimental investigation purpose and accordingly the TEC Module with heat sink is designed.

Specification:
Blower = 80 watt, 2500 RPM
Rated Voltage = 12 volt
Centrifugal pump = 12 volt
Rated Voltage = 220 volts 50Hz
TEC Modules = 1Amp, 12Volts DC supply.

1.Thermoelectric Cooling Device with Heat Sink TEC1-12704 Description

The 127 couples, 40mmx40mm size module is a single stage module which is designed for cooling and heating up to 100 ^{O}C applications.

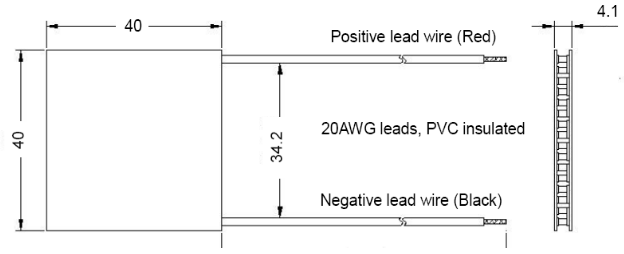


Fig 6 TEC dimensions

2. Heat Sink (hot side)

The absorbed heat by water from the TEC should be immediately dissipated to heat sink, is utilized for the same. the proper heat sink through which cold water being circulated. Hot side heat sinks is made from copper.

Fig.7 Hot side heat sink

3 Heat Sink (cold side)

The carry out cold air which is cooled by peltier plates, a rectangular aluminum heat sink is used.

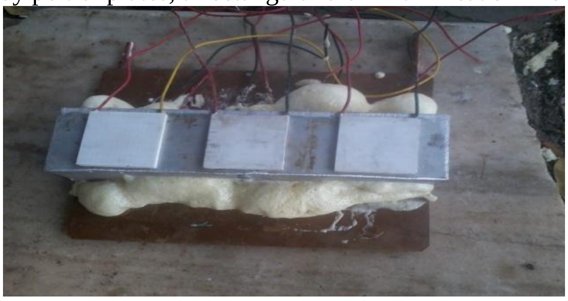


Fig.8 cold side Heat sink

4 Blower

Blower is one of the main parts of the thermoelectric air cooling system, which is having specifications of 80 watt and 2500 rpm. The blower is used as a primary source of air. The blower which is used is having a velocity of air from 50 m/sec to 100 m/sec. Blower is having stepped motor and having three speed controllers.

Fig.9 Blower

5 Pump

We have selected the pump which is used for cleaning the wind shield of the car by sprinkling the water on it. And this pump is used to circulate water around the hot side heat sinks for cooling the hot side heat sinks so that we will get maximum cooling effect. Water temperature is atmospheric. Therefore the suitable pump available near to that power is 12 volt pump.

6 Condenser

Condenser is a one type of heat exchanger which exchanges heat from one fluid to another, we have selected the compact finned type heat exchanger in which cold water is flowing through the coil above which air will be circulated, by a fan for having forced convection.We have selected a condenser of tube diameter is 3/8, aluminum fins 9 inch* 9inch, 2 rows of fins in one inch.

Fig.10 condenser

7 Fan

We have selected a fan which is mounted on condenser for having forced convection. The fan is axial flow type, 12volts and 2150 RPM.

Fig.11 Fan

8 Water Sump

It is used to store the cold water. It is sump which is used in car for wiper water storage for sprinkling the water on windshield to clean the same.

Water Sump is having inlet and outlet ports, In order to circulate the water around hot side heat sinks to absorb the heat, inlet port for condenser and outlet port which is connected to hot side heat sinks. Rubber pipes are used to circulate the water to absorb the heat from hot side heat sinks.

9 Voltmeter Ammeter & Temperature Indicator

Fig.12 Display of Voltmeter, Ammeter &Temp. Indicator

Project set up actual photograph

Fig.13 Thermoelectric module fitted to the blower

Computation of cooling power

The amount of heat removed or the cooling power was determined before selection of the TEC. *Qc* which is the amount of heat absorbed was calculated using the equation ($Qc = m\ Cp\Delta T$). Mass flow rate (*m*) of air and is the product of density of air (ρ) and volume flow rate (*Q*). Density of air at 30 °*C* was taken as1.164 *kg* / *m*3 . *Q* was obtained by multiplying velocity of air pass through the rectangular duct of heat sinks and the cross section area of a heat sink. It is denoted by the equation ($Q = V \times A$). Velocity. air passing through the duct was measured using an anemometer and resulted in a reading of 2 *m* / *s*2 . Cross sectional area of the rectangular duct ($W \times H$) should calculate in *m*2 and the volume flow rate was in *m*3 / *s* . Specific heat of air (*Cp*) at 30 °*C* was taken as1007 *J* / *kgK* . ΔT is the difference between the ambient temperature and the temperature of the load to be cooled. It had been targeted to attain a temp of 23°*C* from the ambient temperature (30 °*C*). In other words the input temperature from the blower fan is 30 °*C* and the expected output is 23°*C*

$\Delta T = T_{in}\ Tout$ =30 °*C*-23 °*C* =7 °*C*

The amount of heat load(Qc) for cooling the air through the rectangular duct should calculate in W.

(Qc)=$m\ Cp\Delta T$=1.164*2*0.15*1007*7=246.15w

Cooling power=48*6=288w

TEC Selection

The TEC was selected considering few factors such as dimensions, Qc, power supply and etc.The idea was to select a TEC which has a cooling power greater than the calculated TEC. TEC1-12704 operates with an optimum voltage of 12V. It has maximum voltage of 15.4V. At 12V it draws and maximum DC current of 4 A. The minimum power rating or the cooling power is 37.7 W. The maximum power is 48W. It has a maximum operating temperature of 100°C. The charts from the TEC manufacture were also analysed while choosing the TEC. choose no.of TECs of the same model according to heat load.The power ratings of TES is higher than the calculated heat load. .

TECs cooling power > heat load(Qc)

Therefore 288w>246.15w

Project Results

Condition 1

In morning Hrs / Car in running condition .OutSide Temp is 28.9 in Degree Celsius..After Starting the TEC Cooling, within 30 min. the temp. inside the car are as follows.

Time(min)	Temp.inside car
5	25.8
10	24.3
15	23.4
20	22.5
25	21.8
30	21.5

Condition 2

In afternoon hours when car runing on road , OutSide Temp is 41 Degree Celsius.After Starting the TEC Cooling, within 30 min ,temp. inside the car is as follows

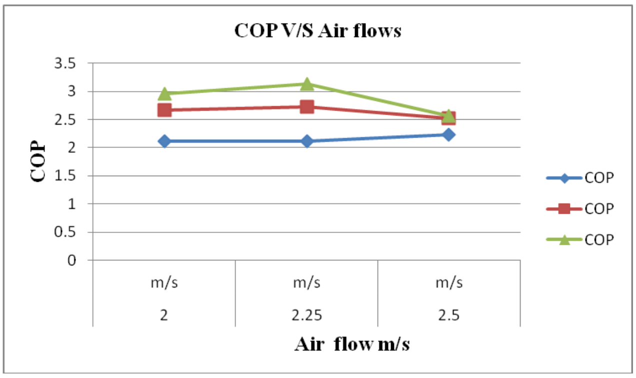
Time(min)	Temp.inside car
5	38.5
10	37.7
15	36.9
20	35.6
25	34.5
30	34

Condition 3

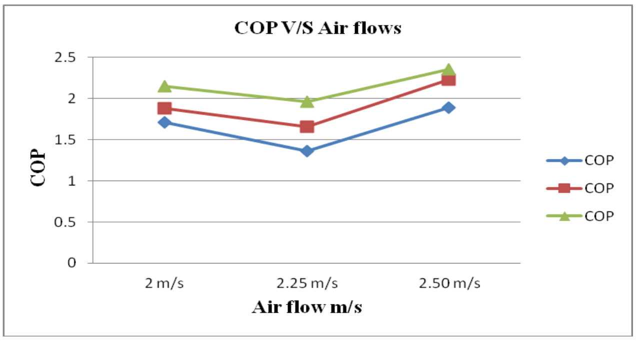
In Evening Hour Driving when OutSide Temp is 27 Degree Celsius.After Starting the TEC Cooling, within 30 min ,temp. inside the car is as follows

Time(min)	Temp.inside car
5	24.1
10	23
15	22.1
20	21.3
25	20.2
30	19

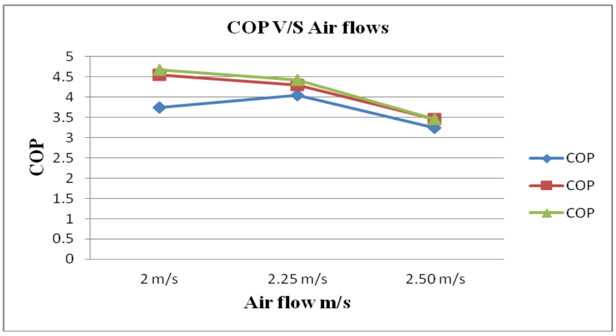
Observations for COP, Air Flow Rate at Morning.



Observations for COP, Air Flow Rate at Afternoon



Observations for COP, Air Flow Rate at Evening



III. CONCLUSION

A Thermoelectric Air cooling for car prototype is designed and built which can be used for personal cooling inside the car. Six TECs were used for achieving the cooling with a DC power supply through car battery. It had been shown from testing results that the cooling system is capable of cooling the air when recirculation the air inside the car with the help of blower. TEC cooling designed is able to cool an ambient air. Cooling stabilizes within five minutes, once the blower is turned ON. The system can attain a temperature difference of set target which was 7°C. By observations and different graphs plotted we can conclude that, The thermoelectric air cooling system produces better cooling effect if air flow rates should be kept at minimum. The COP of the system is higher at lower rates of air. The thermoelectric cooling device performance depends upon the ambient temperature, lower the ambient temperature, higher the cooling rate of the TEC module. At lower flow rates of air the system gives good cooling effect because a large amount of heat transfer will takes place at low rates of air.

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