Thermoelectric Air Cooling For Cars

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ABSTRACT

India is the second most populous country in the world with over 1.21billion people (estimated for April, 2011), more than sixth of the world's population. India is projected to be world's most populous country by 2025,surpassing china, its population exceeding 1.6 billion people by 2050.Comparing with the population there are 2.65 million cars sold in India as of march 2011.According to the society of Indian automotive manufacturer, annual car sales are projected to increase up to 5 million vehicles by 2015 and more than a 9 million by 2020.By 2050,the country is expected to top of the world in car volumes with approximately 611 million vehicles on the nation's roads.

The above data shows that, as the population increase the no. of vehicles also increase. Today, an automobile is a necessity for everyone. For a long or short journey people need car regard to the safety, environment and most important comfort. Owing to these reasons, many vehicles are equipped with heating, ventilating and air conditioning system. In today's world, no one feel comfortable in a vehicle without HVAC system. Therefore, HVAC becomes an integral part of human life. 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_3 –layer is slowly destroyed because of the refrigerant (CFC and HFC) used for the refrigeration and air – conditioning purposes. The common refrigerant used is HFC's which are leaked and slowly climb into the atmosphere. When they reach to O_3 layer they act on O_3 –molecules and the layer of O_3 is destroyed. A single molecule of HFC's can destroy thousand 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 HFC's are emitted into the atmosphere compared to CO_2 is negligible but its global warming effect is few thousand times of CO_2.The effect of 100 gm of HFC's can destroy 0.5 tons of O_3 molecule. These HFC's once destroy O_3-layer; it takes lack of years to recover its thickness as it is formed by complex reactions. This is because as HFC's comes in environment they remain in atmosphere for 18 years. The capacity of HFC's to increase in earth temperature 10% is contributed by HFC's only.(see reference)

Other demerits includes: - The compressor is driven by the crankshaft of the engine. So it consumes about 5 to10% power of the engine. This consequently reduces mileage of the vehicle. An Air conditioning system consumes as much as 8 h.p. with a unit capacity of 3 tons or 9072 kcal/hr. approximately .So, due to these the pickup of vehicle decreases. The cost of present HVAC system is very high; it may vary depending upon price and model of vehicle.

Maintenance and repairing cost of this system is very high. Each component of HVAC is very costly. This system occupies very large space in engine compartment and dashboard. In this system, if any component fails to perform well then the whole system either will not function properly or will not function at all. Instead of this, today's electronically and computer controlled HVAC system has a sensors. If somebody wants to start an AC system, but due to high power requirement of an engine, the AC system will not start and person will need to wait for the starting of the HVAC system.

As an mechanical engineer I am trying to overcome these demerits by replacing the existing HVAC system 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 of this project 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 are also performed using on car (Maruti Suzuki Zen). A simple temperature controller to interface with the cooling system has also been incorporated. Based on an analysis of sizing and design of the TEC air cooling for car, it can be deduced that the cooling system is indeed feasible. Readings taken during testing also testify to the fact that the TE cooling for car can lower the ambient temperature by 7 degree Celsius.

1. GENERAL TERMS

Symbol	Description	Units
A	Cross section area	m^2
A_b	Effective base Area of a heat sink	m^2
A_{fin}	Area of a Fin	m^2
C_p	Specific heat of air	J/kgK
D	Diameter of the channel	m
f	Darcy friction factor	N/A
h	Heat transfer coefficient	W/m^2K
H	Height of a channel	m

I	Operating Current	A
L	Length of a fin or channel	m
L_c	Corrected length for a rectangular fin	m
$\dot{m}$	Mass flow rate of air	kg/s
N	Number of channels	N/A
P_c	Pressure drop in the circular duct	N/m^2
P_e	Electrical input power	W
P_r	Pressure drop in the rectangular channel	N/m^2
P_t	Total pressure drop	N/m^2
Q	Air flow rate	f^3/min
Q_c	Heat load absorbed by the cold side of TEC	W
Q_h	Amount of heat dissipated at the hot side of TEC	W
R	Thermal resistance	K/W
R_b	Base thermal resistance	K/W
R_f	Fin thermal resistance	K/W
R_t	Total Thermal resistance	K/W
r	Radius	m
t	Thickness of a fin	m
T	Temperature	°C
T_c	Cold side temperature	°C
T_h	Hot side temperature	°C
T_{in}	Inlet temperature	°C
T_{out}	Outlet temperature	°C
T_∞	Ambient temperature	°C
ΔT	Temperature difference	K
v	Velocity of the air	m/s
V	Operating Voltage	V
W	Spacing between a rectangular channel.	m
w	Width of a fin/heat sink	m
ρ	Density of air	kg/m^3

1.1 Keywords

CFC	Chloro fluro carbon
TE	Thermoelectric
TEC	Thermoelectric cooler
TEM	Thermoelectric module
TEA	Thermoelectric assembly

2. INTRODUCTION

My 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 commercialised 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.

3. 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.
5) To test HVAC using TEC for its effectiveness, efficiency, environment friendliness, comfort and convenience

4.1 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

1. Selection of the TECs
2. Selection of Fans and Heat sinks
3. DC power supply design with temperature control.
4. Prototype Assembly and Fabrication.
5. Temperature measurements for testing.
6. Power supply testing and troubleshooting.

4.2 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.

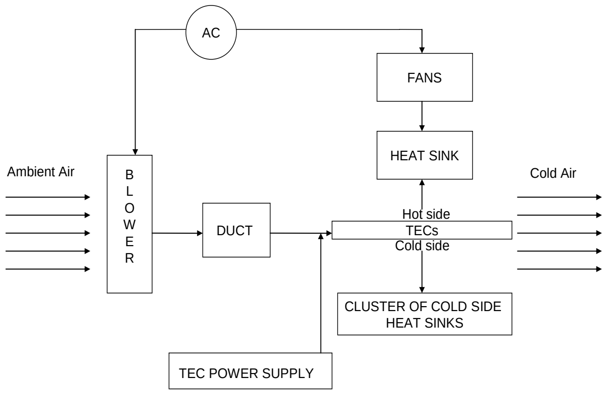

Figure 1: Block diagram of the thermoelectric cooled cooling fan.

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. 4 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.

4.3 Thermoelectric Module

A standard module consists of any number of thermocouples connected in series and sandwiched between two ceramic plates (See Figure 3). 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. 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 2.

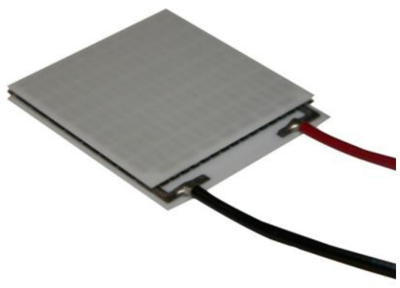

Figure 2: A typical single stage thermoelectric module.

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.

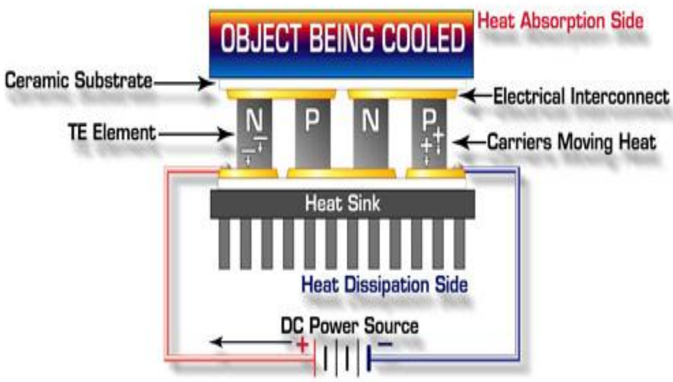

Figure 3: A Classic TE Module Assembly

Before staring to design a TEC cooling system the designer have to take note the following into consideration.

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

4.4 Parameters of a Thermoelectric Module

Once it is decided that thermoelectric cooler is to be considered for cooling system, the next step is to select the thermoelectric module or cooler that can satisfy a particular set of requirements. Modules are available in great variety of sizes, shapes, operating currents, operating voltages and ranges of heat pumping capacity. The minimum specifications for finding an appropriate TEC by the designer must be based on the following parameters. The cutaway of a TEC is shown in Figure 4.

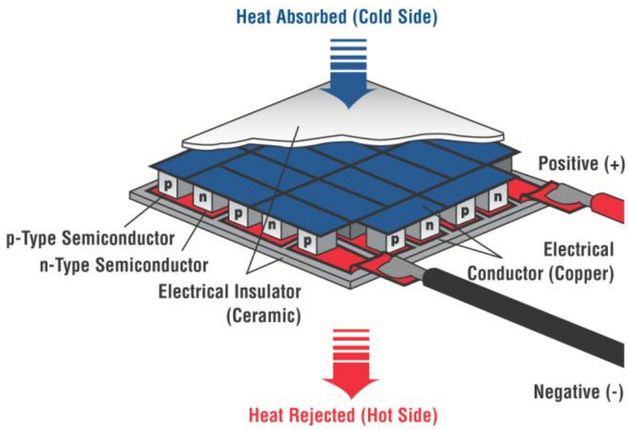

Figure 4: A Cutaway of Thermoelectric Module

- Cold side temperature (T_c)
- Hot side temperature (T_h)
- Operating temperature difference (ΔT), which is the temperature difference between T_h and T_c.
- 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
- Operating current (I) and operating voltage (V) of the TEC.

4.5 Cold Side Temperature

If the object to be cooled is in direct contact with the cold surface of the TEC, the required temperature can be considered the temperature of the cold side of TEC (T_c).Here in this project the object is air inside the car, which has to be cooled when passed through a cluster of four

Aluminium heat sinks. It is discussed in detail in the next chapter. The aim is to cool the air flowing through the heat sinks. When this type of system is employed the cold side temperature of the TEC is needed to be several time colder than the ultimate desired temperature of the air.

Hot side temperature The hot side temperature (T_h) is mainly based on the two factors. First parameter is the temperature of the ambient air in environment to which the heat is been rejected. Second factor is the efficiency of the heat sink that is between the hot side of TEC and the ambient.

4.6 Temperature Difference

The two temperatures T_c and T_h and the difference between them ΔT is a very important factor. ΔT has to be accurately determined if the cooling system is expected to be operating as desired. The following equation shows the actual ΔT.

$$\Delta T = T_h - T_c$$

Actual ΔT is not same as the system ΔT. Actual ΔT is the difference between the hot and cold side of the TEC. On the other hand system ΔT is the temperature difference between the ambient temperature and temperature of the load to be cooled. Figure 5 illustrates a relationship of a classic temperature summary across a thermoelectric system.

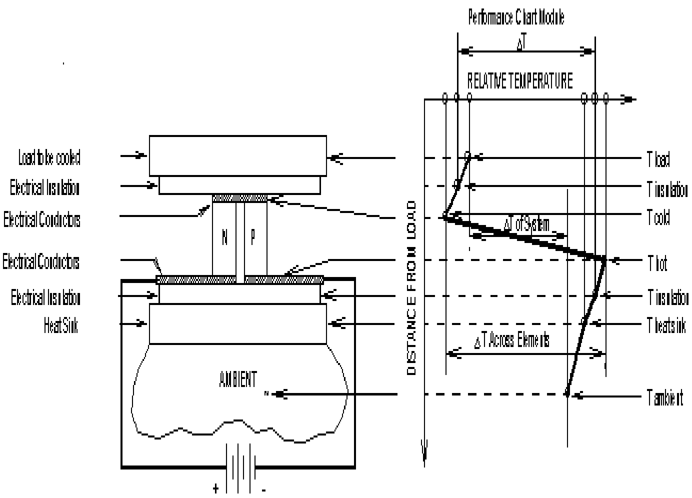

Figure 5: Characteristics temperature of relationship in a TEC

4.7 Cooling Load

The most difficult and important factor to be accurately calculated for a TEC is the amount of heat to be removed or absorbed (Q_c) by the cold side of the TEC. In this project Q_c 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 ΔT in the difference between the inlet temperature and outlet temperature of the cooling system. The mathematical equation for Q_c is as shown below.

$$Q_c = \dot{m} C_p \Delta T$$

4.8 Thermoelectric Assembly - Heat Sinks

Thermoelectric Assemblies (TEAs) are cooling or heating systems attached to the hot side of the TEC to transfer heat by air, liquid or conduction. TEAs which dissipate heat from the hot side use heat exchangers. TEC requires heat exchangers or heat sinks and will be damaged if operated without one. The two ΔTs, actual ΔT and system ΔT (section 3.2.1) depend on the heat sinks fitted at the hot sides or cold sides of TEC. The thermal resistances of the heat sinks could vary the ΔT across the TEC for a set ambient temperature and cooling load temperature. Therefore the thermal resistance of the heat sinks could increase the current flowing through the TEC. The three basic types of heat sinks are: forced convective, natural convective and liquid cooled, where liquid cooled is the most effective. The typical allowances for ΔT at the hot side heat sink of a TEC are

1. 10 to 15 $^\circ C$ for a forced air cooling system with fins.- Forced convection
2. 20 to 40 $^\circ C$ for cooling using free convection - Natural convection.
3. 2 to 5 $^\circ C$ for cooling using liquid heat exchangers - Liquid cooled.

There are several different types of heat exchangers available in the market. As far this project is concerned a forced convection type of heat sink was be used based on the ΔT. Figure 6 shows a forced convection hot side heat sink attached with a fan. The air blows towards the heat sink from the fan will cool down the temperature of heat sink.

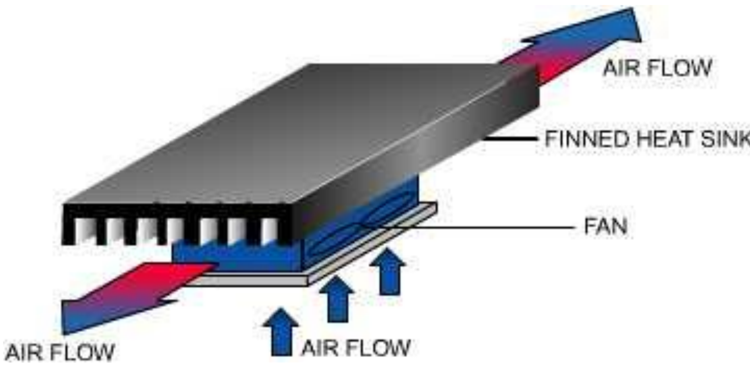

Figure 6: Forced convection heat sink system

The main heat sink parameter for the selection process is its thermal resistance. Heat sink resistance can be termed as the measure of the capability of the sink to dissipate the applied heat. The equation is as follows.

$$R = \frac{T_h - T_\infty}{Q_h}$$

R is the thermal resistance (in ^0C /W or K/W) and T_h, T_∞ is the hot side temperature and ambient temperature respectively. Q_h is the heat load into the heat sink which is the sum of TEC power P_e and heat absorbed.

$$Q_h = Q_c + P_e$$

The goal of a heat sink design is to lessen the thermal resistance. It can be attained through exposed surface area of the heat sink. It may also require forced air or liquid cooling. The following Figure 8 shows a simple thermal schematic of a forced convective heat sink.

Typical values of heat sink thermal resistance for natural convection range is from 0.5°C/W to 5°C/W, where as for forced convection is from 0.02°C/W to 0.5°C/W, and water cooled is from 0.005°C/W to 0.15°C/W. Most of the thermoelectric cooling requires forced convection or water cooled heat sinks. In this project force convective heat sink is used for the design of the cooling system.

Coefficient of Performance

The Coefficient of performance (COP) of a thermoelectric module which is the thermal efficiency must be considered for a TE system. The selection of TEC will also be based on the COP factor. COP is the ratio of the thermal output power and the electrical input power of the TEC. COP can be calculated by dividing the amount of heat absorbed at the cold side to the input power.

$$COP = \frac{Q_C}{P_e}$$

Power Supply and Temperature Control

Power supply and temperature control are two added items that must be considered wisely for a successful TE system. TEC is a direct current device. The quality of the DC current is important. Current and voltage of a TEC can be determined by the charts provided by the manufacturer. TEC's power is the product of required voltage and current. (P = IV).

Temperature control is generally categorized into two groups. One is open loop or manual and the other is closed loop or automatic. For cooling systems normally cold side is used as basis of control. The controlled temperature is compared to the ambient temperature. An on-off or a control using thermostat is the simplest and easiest techniques to control the temperature of a TEC.

5 THERMOELECTRIC COOLING FOR CAR DESIGN

The thermoelectric cooling fan design was preformed based on certain mechanical and electrical calculations. The fan's design was compromised on the availability of parts in the market and budget of the project. The prototype assembly starts with a main fan which is used to blow the ambient air through a circular duct (Appendix A.1).The duct is attached to the blower fan and leads towards a group of four heat sinks. The air which is passed through the duct goes into the cluster of four heat sinks which are united together. These heat sinks acts as a channel for the air to pass through. There are six TECs that are sandwiched between a long black heat sink and the bunch of four heat sinks. TEC cold side or the bottom side rests on the group of four heat sinks. The hot side or the top sides of the TECs are fastened together with the long heat sink. The TECs were installed between the heat sinks using thermal grease, which increases the thermal conductivity by balancing irregular surface of the heat sinks. When the TECs are in operation cold side of the TEC cools down the heat sink channel. Air which is coming out from the channel (i.e. cold side heat sinks H1, H2, H3, H4) is chilled air which is lower than the ambient. The cold side heat sinks rests on a wooden base (Appendix E, Figure E.2). There are two fans fitted on top of the hot side heat sink. They blow air towards the hot heat sink to cool it down when the TECs are in operation. The hot air is channeled away from the user using panels (Appendix E Figure E.3).The whole assembly of the cold side heat sinks, hot side heat sink, TECs and the wooden base are fitted tightly with the help of metal clips. These metal clips are tightened together with screws and nuts. The whole assembly is enclosed with sheets or panels.

5.1 Computation of cooling power

The amount of heat removed or the cooling power was determined before selection of the TEC. Q_c which is the amount of heat absorbed was calculated using the equation ($Q_c = \dot{m} C_p \Delta T$). Mass flow rate ($\dot{m}$) of air and is the product of density of air (ρ) and volume flow rate (Q). Density of air at $30\ °C$ was taken as $1.164\ kg/m^3$. 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 of the air passing through the duct was measured using an anemometer and resulted in a reading of $5 m/s^2$. Cross sectional area of the rectangular duct ($W \times H$) was calculated as $0.0054128 m^2$ and the volume flow rate was $0.02706 m^3/s$. Specific heat of air (C_p) at $30\ °C$ was taken as $1007\ J/kgK$. As discussed in section 3.2.3 the system 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 $23°C$ form the ambient temperature ($30\ °C$). In other words the input temperature from the blower fan is $30\ °C$ and the expected output is $23°C$

$$\Delta T = T_{in} - T_{out} = 30°C - 23°C = 7 K$$

The amount of heat load for cooling the air through the rectangular duct was calculated as $222\ W$. Please refer Appendix B.1 for detailed calculations on cooling load.

5.2 TEC Selection

The TEC was selected considering few factors such as dimensions, Qc, power supply and etc. The model of TECs used in this project was manufactured in China by Hebei I.T (Shangai) Co. Ltd. (Datasheet and Charts in Appendix G). The model no. of the module is TEC1-12704.

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 200°C. ΔT of the TEC are 68 when hot side temperature is 25 $^{\circ}C$. The charts from the TEC manufacture were also analysed while choosing the TEC. It had been decided to choose 6 TECs of the same model so that when the power of all the 6 TECs is higher than the calculated cooling loaad. The minimum power rating for 6 TECs added together was more than the cooling load calculated. So it was acceptable to select the

$$37.7W \times 6 = 226W > 222W$$

The electrical power supplied to the TEC must be higher than the combined power rating of the six TECs and it also depends on the arrangement of the TEC.

5.3 TEC Arrangement

The ambient air blown from the blower is channelled into goes a group of four heat sinks which acts a rectangular duct as discussed earlier. It was decided to remove maximum amount heat from the point when the air started to enter the first heat sink. Keeping that in mind the first heat sink was installed with two TECs in series and the second one also was installed with another two TECs in series. This will help to remove more heat from of the air when air enters the duct. The third and fourth heat sinks were installed with one TEC each and they were connected in series also. All the two series connected TECs were connected in parallel. Figure 8 illustrates a top view of the connection of TECs as explained above. The arrow indicates direction of air flow

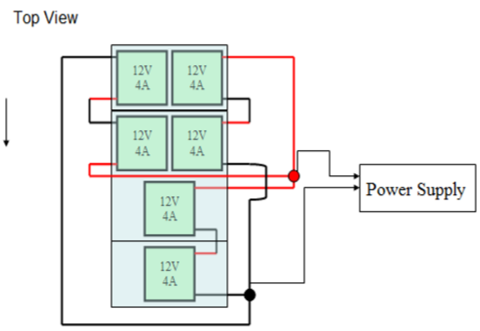

Figure 7: Layout of the TECs

Each of the TEC will be acting as loads. In other words the layout above can also be termed as three parallel groups of two TECs in series electrically. Figure 12 shows simpler redrawn electrical connection of the TECs.

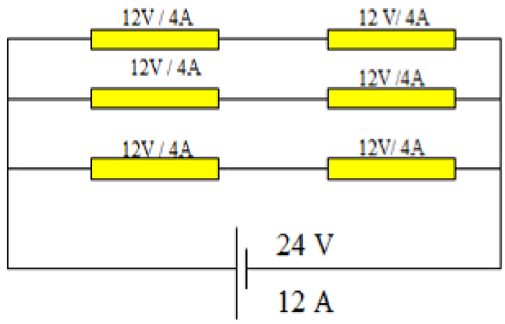

Figure 8: Electrical connection of the TECs

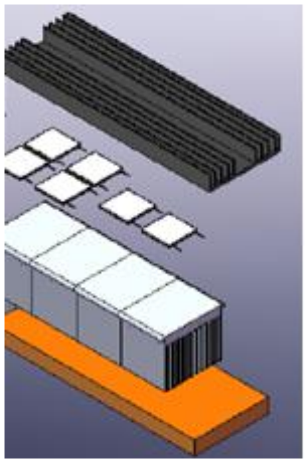

Figure 9: Arrangement of TEC

Total required current and voltage for the all the joined TE modules are 12A and 24V respectively. Therefore a 300W power supply was enough for the cooling system. The electrical power input was greater than cooling power of the TECs and also higher than the calculated Qc. ($300W > 226W > 222W$).

5.4 Selection of Heat sink

There were two different types of heat sink used for this project. One sort was for the cold side and another for hot side. The initial idea of the project was to use a hollow cylinder as duct to channel air, instead of heat sink on the cold side of the TEC. Initial testing after the proposal stage with hollow cylinder, did not work out well. This was because there of less heat transfer within the cylinder and the air coming out was not cold enough. So the decision was made to use to heat sinks which acts a rectangular duct to channel air. A total of four similar kinds of heat sinks (9Y692 A00-00) were used. .Each heat sinks have 20 fins which helped to dissipate coldness fast enough from TECs cold side.

In this project heat sinks (hot side and cold side) operate by conducting heat or coldness from the TEC to the heat sink and then radiating to air. A better the transfer of coldness between the two surfaces, the better the cooling will be. When the heat sinks were attached the TECs, there will be uneven surfaces or gaps. The gap will cause for poor heat transfer, even if it is negligible. To improve the thermal connection between the TECs and the heat sinks a chemical compound was used. The heat sink compound, typically a white paste made form zinc oxide in a silicone base ensures a good transfer of heat between the modules and the heat sinks.

Hot Side heat sink

The hot side heat sink used in the project was a single long one installed on the top side of the TECs. (Appendix E, Figure E-7). As discussed in section 3.3, thermal resistance of a heat sink is an important factor while designing a system. Appendix B.2 shows a detailed calculation for the thermal resistance required for a suitable heat sink. Thermal resistance found using the equation $R_t = \frac{(T_h - T_\infty)}{Q_h}$ was $0.038 K/W$. Therefore a forced convection heat sink had to be used.

When selecting hot side heat sink for the project other factors such as dimension to fit into the whole assembly, budget and availability were also taken to consideration. The heat sink was bought from a local shop and there was no thermal resistance or datasheets available for the product. The alternative was to calculate R_t from the resistance of the unfinned area (R_b) and the resistance offered by the fins (R_f). Since both of these resistances are acting in parallel, total resistance was found using the equation $\frac{1}{R_t} = \frac{1}{R_b} + \frac{1}{R_f}$. The detailed calculations were attached in Appendix B.2. The calculated value was $0.0145 K/W$.

The calculated thermal resistance of the heat sink was lesser than the required. But when considered the dimensions of the cooling system the selected heat sink was very apt. A drawback expected was overheating of heat sink. However bigger fans were installed to cool the hot side heat sink to overcome this.

6 RESULTS AND DISCUSSIONS

Following Are The Detailed Experimental Result Carried Out On Maruti Zen At Different Condiion With SingleRider .

FITMENT IN CAR (MARUTI ZEN)
INSIDE THE CAR

Fig:- 10: Pictures Of Actual prototype Model fitted inside car

6.1 Condition 1:-

In Morning hrs when car parked under shade. OutSide Temp is 32 Degree Celsius After Starting the TEC Cooling within 20 achieved 25 Degree Celsius inside the car.

6.2 Condition 2:-

In morning Hrs / Car in running condition runing the TC system achieved 26 Degres within30 min. (Outside Temp was 32)

Time (Min)	Temperature Inside Car
3	32
6	31.9
9	31.5
12	30.8
18	30.2
21	29.9
24	29.1
27	28.5
30	28

6.3 Condition 3:-

In Afternoon Hours in running condition outside temp was 43 .Results obtained was not so encouraging.

OUTSIDE TEMP =43DEGREE CELCIUS

In This temperature. Results were disappointing especially when car is running in HOT /Torturing Sunlight.It seems the System Will not effective at or above 40 degree.

Time (Min)	Temperature Inside Car
0	40
5	40
10	39.7
15	39.3
20	39.1
25	39.1
30	39

6.4 Condition 4 :- IN AFTERNOON HOURS WHEN CAR RUNING ON ROAD –with CAR HVAC reduced temp inside car to 30 degree and then Switch over to TEC Cooling.

Time (Min)	Temperature Inside Car heat
0	30
5	29.6
10	28.6
15	28.1
20	27.5
25	26..8
30	26

By this I reduced temp inside the car to 30 Degree by using HVAC and then switch over to TEC air cooling .For another 30 Minutes car Inside temperature maintained at 25 with thermoelectric but after that temperature again Starts to rising

1.5 Condition 5 :- IN NIGHT HOURS DRIVING (When Temp 28 degree)In Night Driving Results obtained are very encouraging , within 20 min system archived 25 Degree and maintained further.

Time (Min)	Temperature Inside Car
2	28.5
4	28.3
6	28.9
8	27.8
10	26.4
12	26.3
14	26.1
16	25.8
18	25.4
20	25

7 CONCLUSIONS AND FURTHER WORK

7.1 Conclusions

A Thermoelectric Air cooling for car prototype was designed and built which can be used for personal cooling insie 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 recirculating the air inside the car with the help of blower.TEC cooling designed was able to cool an ambient air temperature from32 °C to 25.8 °C . Cooling stabilizes within three minutes once the blower is turned ON. The system can attain a temperature difference of set target which was 7 °C . Accomplishing the set target establish the success of the project. All the components in the project had been tested individually and the results were found to be positive

7.2 Further Work

The prototype can be made compact by selecting as single TEC of higher power (.i.e. of 200W or more). It can be done by choosing a better cold side heat sink that has twisted channels or pipes for circulating the air for a longer time. As an alternative for normal axial fan used in this project, if a blower fans is selected, the cooling system would provide better airflow.Even as shown in the appended figure we can mount no of TEC cooling in Roof, Floor , Seat ,Door, front dashboard with proper insulation . Well-known TEC brands (.i.e. Melcor, FerroTEC etc) must be chosen if there is only one high power TEC selected for the cooling system. Bigger hot side heat sink has to be selected accurately based its calculated thermal resistances for best cooling efficiency. With a single TEC, one hot side and a cold side heat sink a smaller personal TEC cooler which gives comfort can be fabricated and can be installed on roof for individual cooling

By changing the airflow and some mechanical or electronics section modification, the TEC air cooling for car can be used for heating applications too.

8 REFERENCES

Bartlett, S & Sukuse L, 2007, *Design and build an air conditioned helmet using thermoelectric devices,* Final Year Project, University of Adelaide

[1] Buist, RJ & Streitwieser, GD March 16-18,1988, *The thermoelectricly cooled helmet,* The Seventeenth International Thermoelectric Conference, Arlington, Texas.

[2] Bulat, L & Nekhoroshev, Y 2003, *Thermoelectric cooling-heating unit for thermostatic body of pickup refrigerated trucks,* 22nd international conference on thermoelectrics.

[3] Harrington, SS 2009, *Thermoelectric air cooling device,* Patent Application Publication, US Patent Number 5623828.

[4] Harvie, MR 2005, *Personal cooling and heating system,* Patent Application Publication, US Patent Number 6915641.

[5] Hyeung,SC, Sangkook, Y & Kwang-il, W 2007, *Development of a temperature-controlled car-seat system utilizing thermoelectric device,* Applied Thermal Engineering, pp 2841-2849.

[6] Koetzsch, J & Madden, M 2009, *Thermoelectric cooling for industrial enclosures,* Rittal White Paper 304, pp 1-6.

[7] Larid 2009, *Thermoelectric AssembliModules for Industrial Applications,* Application Note, Larid Technologies.

[8] Lauwers, W & Angleo, SD 2009, *The Cooling VestEvaporative Cooling,* Final Year Degree Project, Worcester polytechnic institute.

[9] Marlow Industries, *Thermoelectric Cooling systems Design* Guide, pp -11, Dallas, Texas.

[10] Melcor 2010, *Thermoelectric Handbook,* Laird Technologies.

[11] McStravick, M et.al 2009, *Medical travel pack with cooling System,* Patent Application Publication, US Patent Number 49845A1.

[12] Rowe, DM & Bhandari CM 2000, *Modern thermoelectrics*. Reston Publishing, USA.

[13] Rowe, DM 1995, *CRC handbook of thermoelectrics*. Boca Raton, FL: CRC Press.

[14] Rowe, DM 2006, *Thermoelectrics Handbook: Macro to Nano*. Boca Raton, FL: CRCPress.

[15] ST Microelectronics 2004, *300W Secondary Controlled Two switch forward converter with L5991A*, AN1621 Application Note.

[16] Tan, FL & Fok, SC 2008, *Metho.*