Design and Fabrication of Thermo Electric Air-Cooler

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Abstract: Cooling may be defined as the process of achieving and maintaining a temperature below that of surrounding. Natural air cooler is available at low cost but the temperature reduced by that is very less. To get high reduction in temperature air conditioner is used. In regular air conditioning process the refrigerants used may cause environmental pollution because of production of CFC's, may cause health problems such as dizziness, headaches, irritation to eyes and other environmental effects. To reduce the environmental pollution and to obtain effective cooling as that of normal air conditioners, we bring up a new type of cooling method that is thermo-electric cooler using thermo electric cooling modules with no moving parts as in air-conditioners and without chlorofluorocarbons. The main objective of the present work is to design and fabricate thermoelectric air cooler in which water of 4.5 liters is used to cool air and produce cooling effect. It works with ample amount of power supply. The desired design is intended to provide a good alternative to Air Conditioners which consume sufficiently high power with very large initial investment. We can extend this design to commercial purpose by increasing the capacity of thermoelectric modules and size of equipment.

Keywords: Air-cooler, Air Conditioner, Thermoelectric cooler, Peltier effect

1. INTRODUCTION

A thermoelectric (TE) cooler, sometimes called a thermoelectric module or Peltier cooler, is a semiconductor-based electronic component that functions as a small heat pump. By applying a low voltage DC power source to a TE module, heat will be moved through the module from one side to the other. One module face, therefore, will be cooled while the opposite face simultaneously is heated. If a typical single-stage thermoelectric module was placed on a heat sink that was maintained at room temperature and the module was then connected to a suitable battery or other DC power source, the "cold" side of the module would cool down. At this point, the module would be pumping almost no heat and would have reached its maximum rated "Delta T (DT)." If heat was gradually added to the module's cold side, the cold side temperature would increase progressively until it eventually equaled the heat sink temperature. At this point the TE cooler would have attained its maximum rated "heat pumping capacity" (Q max). The Seebeck, Peltier, and Thomson Effects, together with several other phenomena, form the basis of functional thermoelectric modules.

The physical principles upon which modern thermoelectric coolers are based actually date back to the early 1800's, although commercial TE modules were not available until almost 1960. The first important discovery relating to thermoelectricity occurred in 1821 when a German scientist, Thomas Seebeck, found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals provided that the junctions of the metals were maintained at two different temperatures. In 1834, a French watchmaker and part time physicist, Jean Peltier, while investigating the "Seebeck Effect," found that there was an opposite phenomenon whereby thermal energy could be absorbed at one dissimilar metal junction and discharged at the other junction when an electric current flowed within the closed circuit. At the time, however, these phenomena were still considered to be mere laboratory curiosities and were without practical application. In the 1930's Russian scientists began studying some of the earlier thermoelectric work in an effort to construct power generators for use at remote locations throughout the country.

Huang B J et al. [1] designed a thermo electric cooler. An automatic test apparatus was designed and built to illustrate the testing. The performance test results of the module are used to determine the physical properties and derive an empirical relation for the performance of thermoelectric module. These results are then used in the system analysis of a thermoelectric cooler using a thermal network model. The thermal resistance of heat sink is chosen as one of the key parameters in the design of a thermoelectric cooler. The system simulation shows that there exists a cheapest heat sink for the design of a thermoelectric cooler. Wang Huajun et al. [2] developed a low Power Thermo electric cooling dehumidifier. From the experiments they found that the relative humidity experienced two accelerating stages and two decelerating stages. This phenomenon is related with the condensing behaviour of the cold side fin heat exchanger and also they found there is variation in...
COP by changing input power and they got COP of 0.32 and corresponding dehumidifying rate was 0.0097g/min when input power was kept at 6 watt. Dabhi J B, et al. [3] conducted experiments on thermo electric cooling system and found the following things which are considered in the design of thermo electric cooling system. They are 1. COP of the system increasing with increasing current up to certain limit and further it decreasing 2. The COP decreases with increase in input Power. 3. The COP decreases with increase in the Temperature difference by keeping the hot side temperature constant. Mayank Awasthi et al. [4] designed and developed a thermo electric cooler of 5L capacity and maintained temperature between 5°C to 25°C. Their intention is to store the vaccine, medicines, foods etc when electricity for long time is not available. They used a large battery to give power supply to the thermo electric refrigerator and they tested the equipment with different power sources. Onoroh Francis, et al. [5] developed a thermo electric refrigerator which is maintained at 4°C. Results from those tests show that COP which indicates the performance of a thermo electric system is a function of the temperature between the source and sink. For maximum efficiency the temperature difference is to be kept to the barest minimum. Rawat M K, et al. [6] designed a thermo electric of capacity 1L, temperature reduction of 11°C from 23°C ambient in 30 minutes and they got The COP of TE refrigerator as 0.1. Gaurav Maradwar [7] fabricated TE Refrigerator and tested in two methods i.e. with fans and without fans and concluded that the cooling effect is more in the TE refrigerator in which heat sink contain fans because of forced convection. Nilesh Varkute et al. [8] developed a Peltier operated air cooler coupled with a dehumidifier to achieve dual objective of dehumidification and sensible cooling. The work was aimed to perform the testing of Peltier for indoor cooling. The air cooling unit gives a cooling of up to 26°C.

From the literature review we can conclude that we can use thermo electric principle in refrigeration and air conditioning applications as alternative to the conventional refrigeration systems. But the COP of the thermo electric system is very less comparing to conventional systems. We can concentrate on thermo electric module materials to increase the COP of the system, by selecting the materials which have high figure of merit. In this work an attempt was made to design and fabricate a thermo electric air cooler of 4.5 litres capacity with 4 thermo electric modules to get reduced temperature up to 18°C which works like an air cooler.

2. EXPERIMENTAL TEST RIG

2.1 Working Principle

Working of TE cooler is same as that of normal cooler. In normal cooler water is circulated without cooling but in this TEcooler water is cooled by Thermo electric cooling module setup, this cooled water is circulated over the cooling pad with the help of a pump which is placed in the aluminium container, so that we can get the more cooling effect by circulating cooled water. In cooling pad cooling water and warm air coming from the atmosphere in indirect contact. In coling pad the heat is removed from the air and cooled air is blown to outside with the help of fans or blowers. Experimental setup shown in Fig. 1 consists of the following components: 1. Thermo Electric Module, 2. Heat Sink, 3. Insulating material, 4. Aluminium Sheet And Block, 5. Anabond Paste, 6. MS bracket, Grill, 7. DC fan, 8. PCB (Power circuit board), 9. Sleeves, 10. Screws, 11. Washer and Casserole.

![Thermo Electric Cooling System](image)

Fig. 1 Schematic Diagram of Thermo Electric Cooling System

2.2 ThermoElectric Module Selection

Selection of the proper TE Cooler for a specific application requires an evaluation of the total system in which the cooler will be used. For most applications it should be possible to use one of the standard module configurations while in certain cases a special design may be needed to meet stringent electrical, mechanical, or other requirements. Table 1 show the module specification which we have used in this project to construct TE cooler. It gives the details such as voltage, current, resistance of the module and power requirement and temperature difference of heat sink and cold side of the module.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>TEC 1 12706 MODULES</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q_{\text{MAX}}$</td>
<td>60 Watts</td>
</tr>
<tr>
<td>$T_{\text{MAX}}$</td>
<td>70°C</td>
</tr>
<tr>
<td>$I_{\text{MAX}}$</td>
<td>6.1 Amps</td>
</tr>
<tr>
<td>$V_{\text{MAX}}$</td>
<td>15.9 Volts</td>
</tr>
<tr>
<td>Resistance</td>
<td>2.05 Ohms</td>
</tr>
</tbody>
</table>

Table 1 Module Specifications
2.3 Other Components of Air-Cooler

The Table 2 shows the aluminium container designed for 4.5 lit capacities. It is made with aluminium because of its less weight and high thermal conductivity. Container is prepared with aluminium sheet of 1.2mm thick with the process of TIG welding. Module, Heat sink and DC fans are to be arranging to this container. For this purpose, 24.5 mm thick aluminium block is to be arranged at the bottom of the container.

Table 2 Specifications of Aluminium Container

<table>
<thead>
<tr>
<th>CAPACITY</th>
<th>4.5 LITRES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATERIAL</td>
<td>ALUMINIUM</td>
</tr>
<tr>
<td>SIZE</td>
<td>300X 100 X 150 (mm)</td>
</tr>
<tr>
<td>THICKNESS</td>
<td>1.2 mm</td>
</tr>
<tr>
<td>THERMAL CONDUCTIVITY</td>
<td>205 W/mk</td>
</tr>
</tbody>
</table>

The fabricated part of thermo electric cooler is shown in Fig. 2, which incorporates Aluminium container, Heat sink, TE Modules and fans and cooling pad and motor for pumping cool water. The specifications of the outer body are shown in the Table 2.

3. RESULTS AND DISCUSSION

To Design a thermo electric cooler the following procedure should be followed.

1. Calculation of product load
2. Cooling capacity of each module
3. No of modules required
4. Power input

3.1 Calculation of Product Load

To calculate product load we assumed that mass of water as 4.5 kg because tank capacity is 4.5 litres. And we assumed that atmospheric temperature as 40°C (313 K) and final temperature as 18°C (291 K) and also we assumed that cooling can be achieved in 60 minutes. The following formula should be used to calculate the product load.

\[ Q_p = M_w \times C_{pw} \times (T_2 - T_1)/t \]  

where,  

\[ Q_p = \text{Product load in watts} \]  
\[ M_w = \text{Mass flow rate in kg/sec} \]  
\[ C_{pw} = \text{Specific heat of water in J/kgK} \]  
\[ T_1 = \text{Initial temperature of atmosphere in Kelvin} \]  
\[ T_2 = \text{Final temperature of air in Kelvin} \]  
\[ t = \text{Expecting time taken for cooling} \]

3.2 Cooling Capacity per Module

TB-12706 Module is selected because this module is low cost and consume less power and easily available in the market. To calculate the number of modules required for cooling first of all we have to calculate the cooling capacity of each module of the selected module. The following formula should be used to calculate the cooling capacity of each module.

\[ Q_c = \left| \alpha_m T_c I - 0.5 I^2 R_m - K_m (T_2 - T_1) \right| \]  

To calculate \( \alpha_m \) value we have to calculate resistivity \( (\varepsilon) \) value. To calculate \( \varepsilon \) value we have to know the area and length of the module.

\[ \varepsilon = \frac{\rho L}{A}, \rho = 0.082 \text{ ohms} - \text{metre} \]

\[ Z = \frac{\alpha^2}{\varepsilon} \]

where,  

\[ Z = \text{Figure of merit} \]  
\[ \alpha = \text{Seebeck coefficient} \]  
\[ \varepsilon = \text{Resistivity of materials} = 0.085 \text{ ohms} - \text{metre} \]

\[ K = \text{thermal conductivity of materials} = 1.3 \text{ W/mk} \]

\[ Z = 0.85 \cdot \alpha^2 / 0.082 \cdot 1.3, \alpha = 0.09061 \]
The manufacturing data related to the values of I, R, K, δT is available in the KRYOTHERM CATLOUGE [8].

3.3 Coefficient of Performance (cop) of the Thermo Electric Cooler

The following formula should be used to calculate the power input. This gives how much power is consumed by one module.

\[
P = V \times I \]

where \( V \) = Voltage input in volts, \( I \) = current in amps

COP may be defined as the ratio of cooling capacity of the module to the power consumed by that module. The following formula should be used to calculate the COP of the cooler.

\[
COP = \frac{\text{Cooling capacity of each module}}{\text{Input power}}
\]

\[
COP = \frac{Q_C}{P}
\]

\[
COP = \frac{36.79}{72}
\]

\[
COP = 0.51
\]

The following formula should be used to calculate the no of modules required

\[
n = \frac{Q_P}{Q_C}
\]

\[
n = \frac{114.95}{36.79}
\]

\[
= 3.12 = 4
\]

where \( n \) = no of modules required

The thermo electric cooler is fabricated as per design and tested it. We have tested the thermo electric cooler by taking the readings as temperature reduction with time and we noted down the room temperature for every minute until the completion of test. The thermo electric cooler is tested for 30 minutes when initial atmospheric temperature was 34.3°C and pouring water temperature was at 29.6°C and we get the reduced temperature of 16.3°C.

4. CONCLUSION

A portable hybrid thermoelectric air cooling has been fabricated and tested. Temperature of air is reduced up to 16.3°C from atmospheric temperature 34.3°C. The system’s COP was 0.51. Therefore, the concept of applying TE to cool the water seems to be reliable and possible for commercial development. The power supply requirements for this system is 300 watts.

TE cooler has so many advantages like no moving parts, low power consumption and occupying less space. For example a conventional Air conditioning system consumes 1200 watts of energy for an hour where as our TE cooler consumes 300 watts of energy for an hour. So we can conclude that we can save 75% of energy consumption. The performance of the thermo electric module depends on the material used for thermo electric module. The Bismuth Telluride is the best material among the thermo electric materials using now a days. Experiment on this unit was conducted and studied at different conditions. Thermo electric evaporative cooling adds humidity but by maintaining a constant flow of outside air and maintaining right exhaust rate, high humidity levels can be avoided.

Power supply battery is used as source of power supply to the thermo electric system. A suitable solar power unit may be designed and the cooling of water made to work with solar power and other unconventional sources of energy, the cost of the system reduced and operational cost also reduced. We can use the Inductive charging also known as wireless charging uses an electromagnetic field to transfer energy between two objects. This is actually done with charging station. Energy is sent through inductive coupling to run the TE cooler. With this wireless electric system we can make TE cooler wireless and we can operate the system from distance.

REFERENCES


