

Design, Fabrication and Testing of Refrigerator System by Using Peltier Effect

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Abstract: The present air conditioning system produces cooling effect by refrigerants like Freon, Ammonia, etc. using these refrigerants can get maximum output but one of the major disadvantages is harmful gas emission and global warming. These problem can be overcome by using thermoelectric modules (Peltier effect) air-conditioner and their by protecting the environment. The present paper deals with the study of Thermoelectric air conditioner using different modules is discussed. Thermoelectric cooling systems have advantages over conventional cooling devices, such as compact in size, light in weight, high reliability, no mechanical moving parts and no working fluid.

Keywords: Refrigerator System

I. INTRODUCTION

Refrigeration is the process of heat-removal from a space in order to bring it to a lower temperature than surrounding temperature. In this context, my seminar topic, "Peltier cooling module" which works on thermoelectric refrigeration, aims to provide cooling by using thermoelectric effects rather than the more prevalent conventional methods like vapour compression cycle" or the vapour absorption cycle". There are three types of thermoelectric effect: The Seebeck effect, the Peltier effect, the Thomson effect. From these three effects, Peltier cooler works on the Peltier effect; which states that when voltage is applied across two junctions of dissimilar electrical conductors, heat is absorbed from one junction and heat is rejected at another junction.

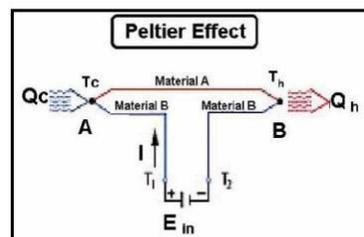
Peltier coolers are basically used as a cooling element in laser diodes, CCD cameras (charge coupled device), blood analyzers, portable picnic coolers laser diodes, microprocessors, blood analyzers and portable picnic coolers.

1.1 Thermoelectric Effect

The thermoelectric effect 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. The term "thermoelectric effect" encompasses three separately identified effects: the Seebeck effect, Peltier effect, and Thomson effect.

A. The Peltier Effect

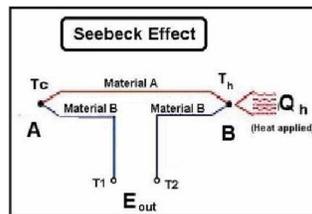
Peltier found there was an opposite phenomenon to the Seebeck Effect, whereby thermal energy could be absorbed at one dissimilar metal junction and discharged at the other junction when an electric current flowed within the closed circuit.



In Figure above, the circuit is modified to obtain a different configuration that illustrates the Peltier Effect, a phenomenon opposite that of the Seebeck Effect. If a voltage (E_{in}) is applied to terminals T1 and T2, an electrical current (I) will flow in the circuit. As a result of the current flow, a slight cooling effect (QC) will occur at thermocouple junction A (where heat is absorbed), and a heating effect (QH) will occur at junction B (where heat is expelled). Note that this effect may be reversed whereby a change in the direction of electric current flow will reverse the direction of heat flow.

B. The Seebeck effect

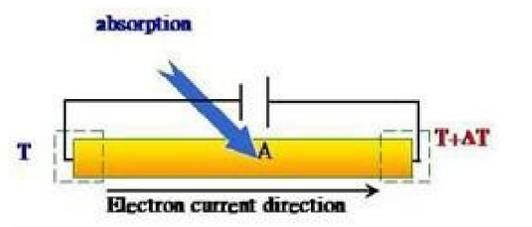
The Seebeck effect is the conversion of heat directly into electricity at the junction of dissimilar electrical conductors. It is named for the Baltic German physicist Thomas Johann Seebeck.



As shown in Figure, the conductors are two dissimilar metals denoted as material A and material B. The junction temperature at A is used as a reference and is maintained at a relatively cool temperature (T_C). The junction temperature at B is used as temperature higher than temperature T_C . With heat applied to junction B, a voltage (E_{out}) will appear across terminals T1 and T2 and hence an electric current would flow continuously in this closed circuit. This voltage is known as the Seebeck EMF, can be expressed as $E_{out} = \alpha (T_H - T_C)$

C. The Thomson Effect

As per the Thomson effect, when an electric current is passed through a conductor having a temperature gradient over its length, heat will be either absorbed by or expelled from the conductor. Whether heat is absorbed or expelled depends on the direction of both the electric current and temperature gradient. This phenomenon is known as the Thomson Effect.

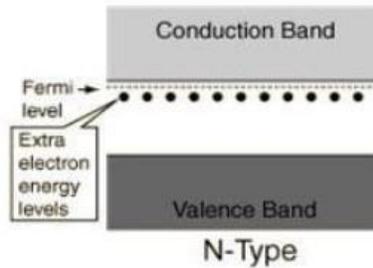


D. Working of Peltier Cooler

The Peltier effect occurs whenever electrical current flows through two dissimilar conductors; depending on the direction of current flow, the junction of the two conductors will either absorb or release heat. In the world of thermoelectric technology, semiconductors (usually Bismuth Telluride) are the material of choice for producing the Peltier effect because they can be more easily optimized for pumping heat. Using this type of material, a Peltier device (i.e., thermoelectric module) can be constructed in its simplest form around a single semiconductor “pellet” which is soldered to electrically-conductive material on each end (usually plated copper). In this configuration, the second dissimilar material required for the Peltier effect, is actually the copper connection paths to the power supply.

E. Peltier Cooling with N-type Semiconductor

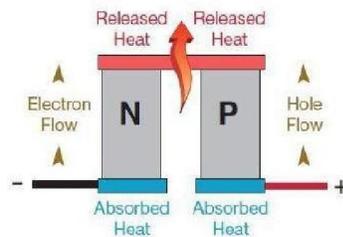
In Figure below, “N-type” semiconductor material is used to fabricate the pellet so that electrons (with a negative charge) will be the charge carrier employed to create the bulk of the Peltier effect. N-type semiconductor has an extra electron in its Fermi level (higher energy level).



With a DC voltage source connected as shown, electrons will be repelled by the negative pole and attracted by the positive pole of the supply; due to this attraction, electrons at Fermi level move towards positive terminal by releasing heat and creating the holes in the Fermi level. Now, due to continuous supply of current, electrons move from valance band (lower energy band) to Fermi level by absorbing energy from the junction. With the electrons flowing through the N-type material from bottom to top, heat is absorbed at the bottom junction and actively transferred to the top junction.

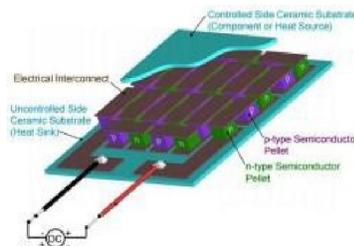
F. Peltier Cooling with P & N Type of Semiconductors

By arranging N and P-type pellets in a “couple” (see Figure) and forming a junction between them with a plated copper tab, it is possible to configure a series circuit which can keep all of the heat moving in the same direction. As shown in the illustration, with the free 8 (bottom) end of the P-type pellet connected to the positive voltage potential and the free (bottom) end of the N-type pellet similarly connected to the negative side of the voltage. As we have seen in previous section, for N-type of semiconductor, heat is absorbed from the junction near to the negative terminal and heat is releases at the junction near to the positive terminal. For P-type of semiconductor, heat is absorbed from the junction near to negative terminal.to positive terminal and released at the junction near to negative terminal.



G. Fabrication of Peltier Cooler

As we have seen in previous section, for producing thermoelectric effect couples of P and N type semiconductors are connected in series by metal plates. By doing this it absorbs the heat from one sideand releases the heat to another side. So, when solid state P-N materials are connected electrically in series and thermally in parallel it makes one thermoelectric unit as shown in Figure.



A typical TEC module comprises of two highly thermally conductive substrates (Al₂O₃, AlN, BeO) that serve as Hot/Cold plates. An array of p-type and n-type semiconductor (Bi₂Te₃, Sb₂Te₃, Bi₂Se₃, PbTe, Si-Ge) pellets are connected electrically in series sandwiched between the substrates. The device is normally attached to the coldside of the TEC module, and a heat sink which is required for enhanced heat dissipation is attached to the hot side. Solder is

normally used to connect the TEC elements onto the conducting pads of the substrates. The construction of a single stage thermoelectric module is shown in Figure.

H. Specification

I max.: 6.0A, Delta T max.: 152.6°F, Voltage:15.4V, Q max.: 51.4W, Number of couples: 127, Melcor type: CP1.4-127-06L, Dimensions: 1.6" x 1.6" x 0.15", Wire Lead Length: 8", Aluminium Heat Sink : 205W/Mk

II. GOVERNING EQUATIONS

7.1 Cooling Power

$$Q_1 = (\alpha_p - \alpha_n)IT_1 - (T_2 - T_1) * (K_p + K_n) - \frac{I^2(R_p + R_n)}{2}$$

7.2 Power Consumed

$$W = (\alpha_p - \alpha_n).I.(T_2 - T_1) + I^2.(R_p + R_n)$$

7.2 Coefficient of Performance

$$\therefore COP = \frac{((\alpha_p - \alpha_n)IT_1 - (T_2 - T_1) * (K_p + K_n) - \frac{I^2(R_p + R_n)}{2})}{((\alpha_p - \alpha_n).I.(T_2 - T_1) + I^2.(R_p + R_n))}$$

7.3 Maximum Cooling Power

$$Q_1 = (\alpha_p - \alpha_n)IT_1 - (T_2 - T_1) * (K_p + K_n) - \frac{I^2(R_p + R_n)}{2}$$

III. CONCLUSION

Since Peltier cooling is not efficient comparatively and due to its small size applications, it is not widely used. It found its application only in electronics cooling etc. But, we have seen that there is a huge scope of research in this field about thermoelectric materials, its fabrication, heat sink design etc. Researcher are working on reducing irreversibilities in the systems, because Peltier cooler has more potential which we can see from the vast difference between value of first law efficiency and second law efficiency.

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