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"THERMOELECTRIC COOLER: AN APPLICATION OF THERMOELECTRICITY"

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ABSTRACT

This paper provides begins with the basic concepts of the thermoelectricity, its principal and application. The thermoelectricity encompasses with three effects, Seebeck effect, Peltier effect and Thomson effect. The purpose of this paper to review onone of the Peltier effect applications that is thermoelectric cooler. In conventional refrigeration systems there is use and discharge of Chloro Fluoro Carbons (CFCs) and Hydro Chlorofluorocarbons (HCFCs) as heat carrier fluid. These gases have harmful effect on the environment which results in research of new technologies that can overcome these effects. Thermoelectric device provides a promising solution to this environment deterioration and to energy crises also. Thermoelectric operated cooler provides a best alternative in refrigeration technology due to their distinct advantages over the conventional refrigeration systems. Coefficient of performance of the system will increases by using the thermoelectric effect. As the thermoelectric cooler also have some drawbacks, so many researchers are trying to overcome those by using different materials used in the current technology.

OBJECTIVES

- Description of thermoelectricity
- Introduction of Seebeck, Peltier and Thomson effects
- Understanding of Peltier Construction

- Description of thermoelectric cooler
- Applications of thermoelectric cooler
- Advantages of thermoelectric cooler

KEYWORDS

- Thermoelectric module
- Seebeck effect
- Peltier effect
- Thermoelectric cooler
- Mounting
- Clamping

INTRODUCTION

Thermoelectric field came into focus over the past decade due to the need for more efficient materials for electronic refrigeration and power generation. The thermoelectric phenomenon deals with the conversion of thermal energy into electrical energy and vice-versa. It was discovered and developed in Western Europe by academic scientists more than 180 years ago. Mainly three terms, Seebeck effect, Peltier effect, and Thomson effect encompasses the thermoelectric effect.

Thermoelectric module applications are implemented in different areas. Its applications can be categorised based on direction of energy conversion. The Seebeck effect is used for the conversion of temperature gradients to an electrical voltage while Peltier effect is used in the function of thermoelectric cooling devices.

Seebeck effect

In 1823 a Germen scientist, Thomas Johann Seebeck found that a closed circuit made up of dissimilar metals with junctions at different temperatures produced an electric current that would flow continuously and is known as Seebeck effect.

Seebeck effect is used in thermoelectric generators, which function like heat engines and is also used in spacecrafts as a source of producing electricity. Seebeck effect plays an important role in power plants as a role of energy recycler by converting waste heat into additional electrical power. It is also used in automobiles for increasing fuel efficiency as automotive thermoelectric generators. The thermometer made up using Seebeck effect are best known for its accuracy and its ability to measure temperatures quickly without changing the temperature of the thing being measured. Seebeck effect used in temperature measurement also. Thermocouples are often used to measure high temperatures while thermopiles use number of thermocouples connected in series or parallel for measurements of very small temperature difference. It has also been useful in obtaining the precise amplitude of sinusoidal waves. This has assisted in detection of the hyper frequency electrical power produced in a system and notifies the operators.

Peltier effect

In 1834, a French watchmaker and part time physicist, Jean Charles Athanase Peltier found thatwhen electric current is passed through a circuit consisting of two different conductors, a cooling and heating both effects are observed in different junctions. This change in temperatures at the junctions is called the Peltier effect. It can be used either for heating or for cooling, but cooling is the main application of Peltier effect.

Peltier module has been used in many applications such as thermoelectric generator, thermoelectric cooler, medical freezer, in modern PCR machines, for cooling computers and other electronic equipment. It is also used to support temperature – sensitive reactions. PE can be use to facilitate highly stable temperature controllers that either heats or cools. It can keep desired temperature within ±0.01 °C that is used for laser applications. thermoelectric dehumidifiers used to cool a surface and to extract water from the air is based on Peltier heat pump.

The **Thomson effect** is an extension of the Peltier–Seebeck model by Lord Kelvin in 1851. It defines the relationship between the current flowing in a single piece of material and the heat it absorbs or produces. It describes the heating or cooling of the current carrying conductor as the temperature rises.

PELTIER COOLER INSTALLATION

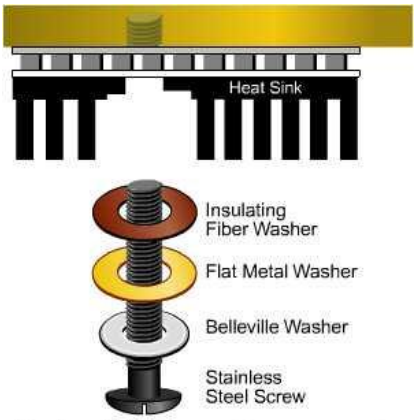
Installation techniques for Thermoelectric modules in a cooling system are very important. System designs and module installation include some factors which are:

- Shear strength is relatively low in thermoelectric modules. Also, it has high mechanical strength in compression mode. As it does not support mechanical structure, so the thermoelectric coolers should not be designed into this system
- To minimize thermal resistance the interfaces between system components should be parallel, clean and flat.
- Position of the wire leads is helpful in identifying the hot and cold sides of thermoelectric modules. Module face is the hot side of the model which is attached to the wires and it is in contact with heat sink.
- The object should be insulated to minimize heat loss when cooling below ambient. Fans should not be positioned so the air blow at cooled object directly, this is to reduce conductive loses.an effective moisture seal should be installed to prevent moisture entering in TE module and to reduce its thermal performance.

Mounting methods for thermoelectric modules are available. There are some mounting techniques which are possible.

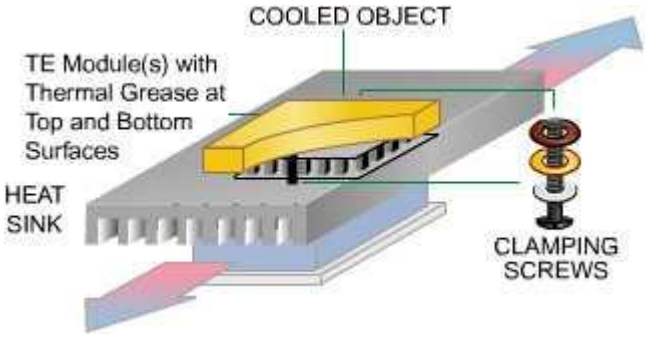
1. **Height Tolerance** - The two height tolerance values are defined +/-0.3mm (+/-0.010″) and +/-0.03mm (0.001″) in most of the thermoelectric cooling modules. +/-0.03mm (+/-0.001″) tolerance module is preferred as it provides slight cost advantage comparison to other.

2. **Clamping** - It is the most common mounting method where the article to be cooled between the flat surface and heat sink. Thermoelectric modules will be located between the machine or grind flat mounting surfaces. Mounting surfaces should be flat to within 1mm/m (0.001 in/in) to achieve optimum thermal performance. Height/ thickness has to be matched in the group of modules which are mounted between the given pair of mounting surfaces, overall thickness variation does not exceed 0.06mm (0.002″).



Typical Fastener Components

To provide uniform pressure on the modules, mounting screws should be arranged symmetrically. Smallest size screw has to be use to minimize heat loss through mounting screws. To remove all dirt, burrs, etc., mounting surfaces and clean the module. With a thin layer of thermal grease, coat the hot side of the module.



TE Module Installation Using the Clamping Method

On the heat sink place the module with hot side down in the desired location. Then gently push down the module and to squeeze out extra thermal grease apply back and forth turning motion. Sight resistance is being detected by continuing the downward pressure. Now this time coat the "cold" side of the module with thermal grease as explained above. Place the object for cooling in contact with cold side and squeeze out extra thermal grease. Using stainless steel screws and spring washers, bolt the heat sink and cooled object together. To maintain parallelism uniform pressure is applied on mounting surfaces. thermal performance may be reduced, or worse, the TE module(s) may be damaged if the uneven pressure is applied. To check whether the pressure is uniform, tighten all the screws using torque screwdriver. A small amount of grease is being squeezed out after first assemble clamped together. Repeat these steps after waiting for one hour and recheck the torque.

Formula:

$T=((S_a \times A)/N) \times K \times d$

where:

T = torque on each bolt

S_a = cycling 25-50 psi, static 50-75 psi.

A = total surface area of module(s)

N = in assembly they used number of bolts

K = torque coefficient (use K=0.2 for steel, K=0.15 for nylon)

d = nominal bolt diameter

For steel fasteners, we typically recommend either:

6-32 d=.138 in (.350 cm)

4-40 d=.112 in (.284 cm)

By 4-40 steel fasteners the torque is calculated for nine 9500/065/018 modules:

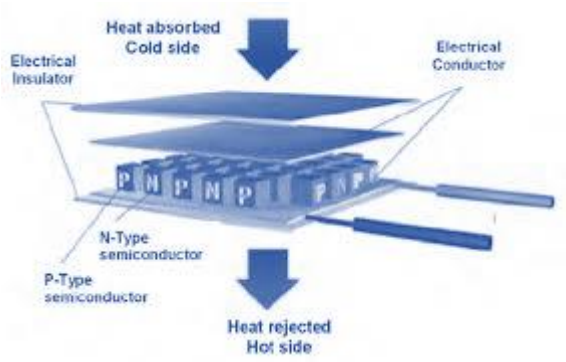
$T=((75 \text{ lbs/in.}^2 \times (.44'' \times .48'') \times 9)/4) \times 0.2 \times .112 \text{ in.} = 0.8 \text{ in-lbs.}$

THERMOELECTRIC COOLER

Thermoelectric cooling is a process of eliminating heat energy from a process by applying a constant voltage between two dissimilar semiconductors or electrical conductors. It is also known as "The Peltier Cooling" as it is based on the principle of Peltier effect. Although this technology is generally less efficient than the conventional refrigeration technology but its many other features like compact and lightweight in nature, relatively inexpensive than alternative technologies, reliability etc. made it so popular. TECs have a limited lifetime and their strength can be measured by their AC resistance. The high value of ACR indicates that TEC is getting old.

To unique semiconductors are placed in parallel to each other and electrically in series. The semiconductors should be unique, one is n-type and another is p-type, as they have to be of different electron density. The semiconductors are joined with a thermally conducting plate on each side. A DC current will flow across the junction of the semiconductors while

applying a voltage to the free ends of the two semiconductors. This will cause the temperature difference. A thermoelectric cooler are connected side by side and is placed between two ceramic plates. The cooling capacity of the total unit is directly proportional to the number of thermoelectric cooler used in it.



APPLICATION OF THERMOELECTRIC COOLER

The thermoelectric coolers are applicable where heat removal is required. The range of heat can vary from mill watts to several thousand watts. Its application covers the wide area as it can be implemented in small equipments of daily life as well as in scientific field.

Industrial field

Thermoelectric cooler are used in many fields of industrial manufacturing. It is used in industrial electronics and telecommunications, mini refrigerators, military cabinets, laser equipment, thermoelectric air conditioners or coolers, automotive and more. It is used to cool computer components like chip, photon detectors used in astronomical telescopes, digital cameras, portable coolers, climate-controlled jackets etc. It can also cool a chip to well below ambient temperature.

Medical field

Thermoelectric cooling has widely used in medical field. Temperature effects are an important factor in treatment of many diseases of the human organism. Thermoelectric coolers are used in manufacturing of possible miniature and portable refrigerators for medicine and insulin storage as they are highly scalable in nature. The ability of thermoelectric cooler to maintain the precise and accurate temperature control prevents the

spoiling of vaccines, medicine, and experiments. It is also useful in many skin diseases treatment.

Consumer products

Peltier elements are commonly used in consumer products. For example, Peltier elements are used in small instruments, cooling electronic components and portable coolers. It is used as food and beverages chillers like wine coolers.

Scientific field

TECs are used in many scientific devices. They are common component in thermal cyclers and used in modern polymerase chain reaction (PCR) which requires frequent heating and cooling of the reaction.

During laser applications, laser wavelength may vary as the temperature of environment changes so to remain its wavelength remain constant, thermoelectric cooler are used that act as a temperature controller and to can maintain the stability of temperature within ±0.01 °C The effect of TEC is also used in satellites and spacecrafts to maintain the temperature difference that is caused due to the direct sunlight on one side of a craft.

It is used in fibre-optic applications, where the wavelength of a laser or a component is highly dependent on temperature, to maintain a constant temperature and stabilized the wavelength of the device. Many electronic equipment used in military field are cool by thermoelectric method.

ADVANTAGES OF THERMOELECTRIC COOLING

There are too many problems related to thermal management, the thermoelectric modules provide solutions using applications. Thermoelectric coolers are more advantageous over conventional cooling system as it has new dimension to cooling.

- Harmful gases are neither used nor generated by Peltier's module like Chloro Fluoro Carbons (CFCs) and Hydro chlorofluorocarbons (HCFCs) but they are used/ generated by conventional systems.
- Peltier module does not generate electrical noise and can be used in conjunction with sensitive electronic sensors, so it is quite in operation, but conventional system generates noise.

- DC power source used in Peltier system.
- Peltier module can control precise temperature by using proper closed loop circuit better than +/- 0.1°C.
- It has long life as the mean time between failures(MTBF) exceeds 100,000 hours.
- It is controllable through changing the input current/voltage. And pulse width modulation(PWM) used in many applications.
- It has no frictional elements in it so it is compact in size. And also the weight of the system is low and there is no coolant required.
- Its maintenance is free because there are no moving parts available.
- In conventional heat sink temperature must rise above ambient, but in Peltier's module, heat sink has ability to reduce the temperature below ambient value.
- It has the ability to heat and cool with the same module depending upon the polarity of applied DC power and eliminated the necessity of using two separate systems.
- It uses solid state construction, so it exhibits very high reliability.
- Thermoelectrical modules are used in zero gravity environments and in any orientation. So, in aerospace applications they are very popular.
- It is simple to install and reuses waste heat. Also, possible to be used in reversible mode.

CONCLUSION

The literature regarding the investigation of Thermoelectric air conditioner using different modules has been thoroughly reviewed. From the review of the pertinent literature presented above, it can be inferred that thermoelectric technology using different modules used for cooling as well as heating application has considerable attention.

The main disadvantages of thermoelectric coolers are that their efficiency is low and the cost is very high. Most of the companies and researchers are trying to create or develop Peltier coolers which are low in cost and also efficient.

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