

# Review of Various Application of Thermoelectric Module

Chetan Jangonda<sup>1</sup>, Ketan Patil<sup>2</sup>, Avinash Kinikar<sup>3</sup>, Raviraj Bhokare<sup>4</sup>, M.D.Gavali<sup>5</sup>

B.E Student, Department of Mechanical Engineering, Shivaji University, Kolhapur, India <sup>1-2-3-4</sup>

Assistant Professor, Department of Mechanical Engineering, Shivaji University, Kolhapur, India <sup>5</sup>

**ABSTRACT:** In recent years, with the increase awareness towards environmental degradation due to the production, use and discharge of ChloroFluoro Carbons (CFCs) and Hydro Chlorofluorocarbons (HCFCs) as heat carrier fluids in conventional refrigeration systems has become a subject of great concern and resulted in extensive research into development of refrigeration technologies. Thermoelectric operated cooler provides a best alternative in refrigeration technology due to their distinct advantages. While using thermoelectric effect in system the COP of the system also increases. A brief introduction of thermoelectricity, principal of thermoelectric cooling and thermoelectric materials has been presented in this paper. The literature review of some research paper has been seen in this paper. The purpose of this paper to review on various application of thermoelectric phenomenon by using thermoelectric module technology. In this paper, we have also mention development on thermoelectric module based devices.

**KEYWORDS:** Thermoelectric module; Peltier effect; Thermoelectric generator; Thermoelectric dehumidifier

## I. INTRODUCTION

The first important discovery relating to thermoelectricity occurred in 1823 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. The Peltier effect was discovered in 1834 by a French watchmaker and part time physicist Jean Charles Athanase Peltier. Peltier found that the use of a current at an interface between two dissimilar materials results in the absorption of heat and release of heat at the subatomic level, this is a result of the different energy levels of materials, particularly n and p type materials. As electrons move from p type material to n type material, electrons jump to a higher energy state absorbing energy, in this case heat, from the surrounding area. The reverse is also true. As electrons move from n type material to p type material, electrons fall to a lower energy state releasing energy to the surrounding area.

The thermoelectric phenomenon deals with the conversion of thermal energy into electrical energy and vice-versa. When operating as an energy-generating device the thermoelectric device is termed a thermoelectric generator (TEG). The source of thermal energy manifests itself as a temperature difference across the TEG. When operating in a cooling or heating mode the thermoelectric device is termed a thermoelectric cooler (TEC). Similarly, the thermoelectric device produces heating or cooling that takes the form a heat flux which then induces a temperature difference across the TEC. Thermoelectric devices are solid-state mechanisms that are capable of producing these three effects without any intermediary fluids or processes. For power generation applications thermoelectric devices are used in automobiles as exhaust gas waste heat recovery devices where thermal energy is scavenged along the exhaust line of a vehicle and converted into useful electricity [2]. Solar thermoelectric generators capture incoming sunlight and convert solar thermal energy into electricity using thermoelectric principles. On the other hand, thermoelectric devices are widely implemented for heating, ventilation and air-conditioning (HVAC) purposes in vehicles. These take the form of thermoelectric air-conditioners and climate controlled seats that may potentially replace conventional compressor-based air-conditioning systems in automobiles [4]. The performances of a thermoelectric cooler are expressed as follows and are described in many handbooks and papers [4].

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

$$Q_c = \alpha n T_c I - \frac{1}{2}(I^2 R) - K(T_h - T_c) \tag{1}$$

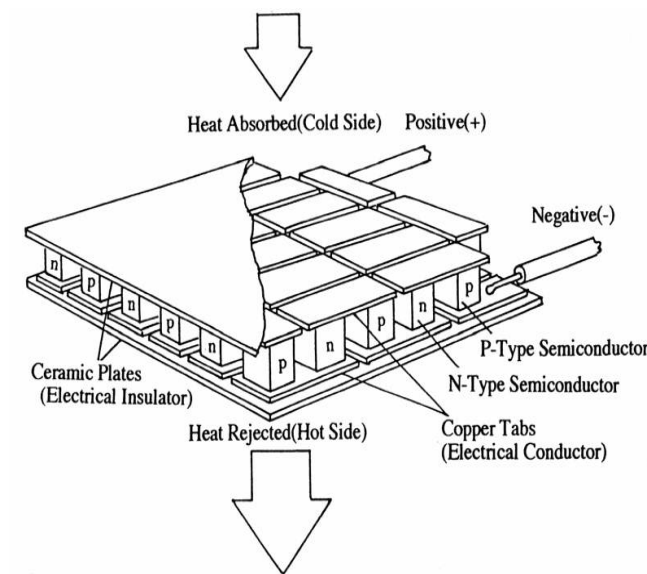
The overall rate of expenditure of electrical energy is given by

$$W = \alpha n I(T_h - T_c) + I^2 \tag{2}$$

The coefficient of performance is defined as

$$COP = \frac{Q_c}{W} \tag{3}$$

## II. PELTIER CONSTRUCTION



**Figure No. 1: Working principle of thermoelectric module**

Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities. The semiconductors are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side. When a voltage is applied to the free ends of the two semiconductors there is a flow of DC current across the junction of the semiconductors causing a temperature difference. The side with the cooling plate absorbs heat which is then moved to the other side of the device where the heat sink is. TECs (Thermoelectric cooler) are typically connected side by side and sandwiched between two ceramic plates. The cooling ability of the total unit is then proportional to the number of Thermoelectric cooler in it. When two conductors are placed in electric contact, electrons flow out of the one in which the electrons are less bound, into the one where the electrons are more bound. The reason for this is a difference in the so-called Fermi level. Between the two conductors Fermi level represents the demarcation in energy within the conduction band of a metal, between the energy levels occupied by electrons and those that are unoccupied.

When two conductors with different Fermi levels make contact, electrons flow from the conductor with the higher level, until the change in electrostatic potential brings the two Fermi levels to the same value. (This electrostatic

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

potential is called the contact potential.). Current passing across the junction results in either a forward or reverse bias, resulting in a temperature gradient. If the temperature of the hotter junction (heat sink) is kept low by removing the generated heat, the temperature of the cold plate can be cooled by tens of degrees.

### III. FEATURES OF PELTIER MODULE

1. Peltier module can convert thermal energy into electricity, or when electricity is provided to the peltier module then absorption of heat(cool side) on one side and rejection of heat(hot side) on other side.
2. Conventional systems can use or generate harmful gasses like ChloroFluoro Carbons (CFCs) and Hydro Chlorofluorocarbons (HCFCs).The peltier module can't use or generate these harmful gasses.
3. The conventional refrigeration system can generate some noise during operation. The peltier module can't generate any noise during operation. It is quite in operation.
4. Peltier module can operate on DC power source.
5. By using proper closed loop circuit, the peltier module can control precise temperature.
6. Long life, with mean time between failures (MTBF) exceeding 100,000 hours.
7. Controllable via changing the input voltage/current.

#### A. General Mechanical Properties of Thermoelectric Material

Thermoelectric material has following mechanical properties.

**Table No. 1: Mechanical properties of thermoelectric material**

Material	Young's modulus	Fracture strength	Hardness	Fracture toughness
Skutterudite	133-140	35-85	-	1.1-1.8
Oxides	85-210	-	2.5-11.75	2.69-4.78
Antimonide	74	65	1.56	0.69
PbTe-based	54-55	28	0.98-1.27	-

There are different thermoelectric material are used like skutterudite, oxides, antimonide, PbTe based etc.each material has different mechanical properties. In above table mention the values of mechanical properties of each material, which is helpful during the selection of thermoelectric module.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

## IV. APPLICATION

Following are the application where peltier module has been used

- A. Thermoelectric generator
- B. Thermoelectric cooler
- C. Water condensation using thermoelectric cooler
- D. Medical Freezer

### A. Thermoelectric Generator

Thermoelectric generator or TEG (also called a Seebeck generator) is a solid state device that converts heat (temperature differences) directly into electrical energy through a phenomenon called the Seebeck effect (a form of thermoelectric effect). Thermoelectric generators function like heat engines, but are less bulky and have no moving parts. However, TEGs are typically more expensive and less efficient. Thermoelectric generators could be used in power plants in order to convert waste heat into additional electrical power and in automobiles as automotive thermoelectric generators (ATGs) to increase fuel efficiency. Another application is radioisotope thermoelectric generators which are used in space probes, which has the same mechanism but use radioisotopes to generate the required heat difference.

Thermoelectric generators can be applied in a variety of applications. Frequently, thermoelectric generators are used for low power remote applications or where bulkier but more efficient heat engines such as Stirling engines would not be possible. Unlike heat engines, the solid state electrical components typically used to perform thermal to electric energy conversion have no moving parts. The thermal to electric energy conversion can be performed using components that require no maintenance, have inherently high reliability, and can be used to construct generators with long service free lifetimes.

### B. Thermoelectric Cooler

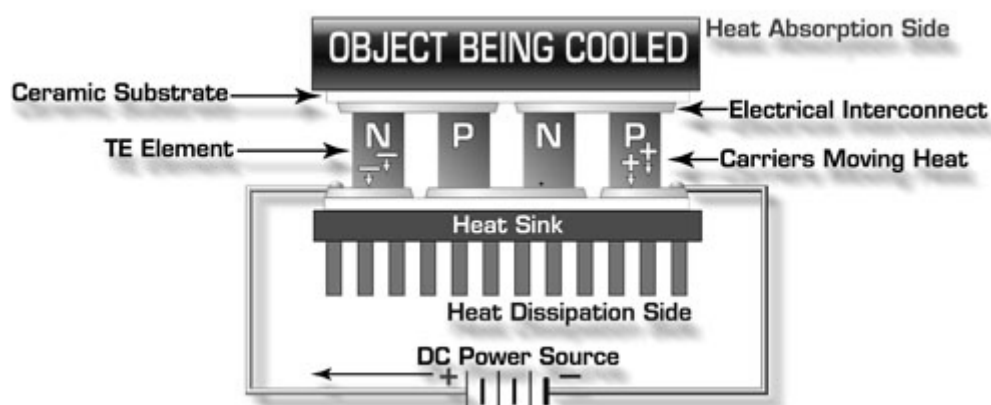


Figure No.2: Thermoelectric cooler

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Such an instrument is also called a Peltier device, Peltier heat pump, solid state refrigerator, or thermoelectric cooler (TEC). It can be used either for heating or for cooling [1]. Although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools.

This technology is far less commonly applied to refrigeration than vapour-compression refrigeration is. The primary advantages of a Peltier cooler compared to a vapour-compression refrigerator are its lack of moving parts or circulating liquid, very long life, invulnerability to leaks, small size and flexible shape. Its main disadvantage is high cost and poor power efficiency. Many researchers and companies are trying to develop Peltier coolers that are both cheap and efficient. (See thermoelectric materials.) A Peltier cooler can also be used as a thermoelectric generator. When operated as a cooler, a voltage is applied across the device, and as a result, a difference in temperature will build up between the two sides. When operated as a generator, one side of the device is heated to a temperature greater than the other side, and as a result, a difference in voltage will build up between the two sides (the Seebeck effect).

### C. Medical Freezer

Thermoelectric cooling is widely used in many areas of science and technology, in particular, in medicine. It is well known in medical practice that temperature effects are an important factor in treatment of many diseases of the human organism. To achieve low temperatures, systems with liquid nitrogen are used, which limits their use in hospitals significantly. In most cases such devices are bulky, without proper temperature control and thermal modes reproduction. Therefore, the use of thermal effects on the patient is confronted with some difficulties and is reduced mainly to the application of ice or hot water. The use of thermoelectric cooling can solve this problem, because it has several advantages, if compared to conventional techniques of thermal effects. Fundamental research on the application of thermoelectric cooling in medicine confirms the possibility of its practical application in such areas of medicine as cryotherapy, cryosurgery, ophthalmology, traumatology, neurosurgery, plastic surgery, gynecology, urology, oncology, dermatology etc [4]. Therefore, the development and improvement of thermoelectric medical devices for skin diseases treatment is of current importance.

### D. Thermoelectric Dehumidifier

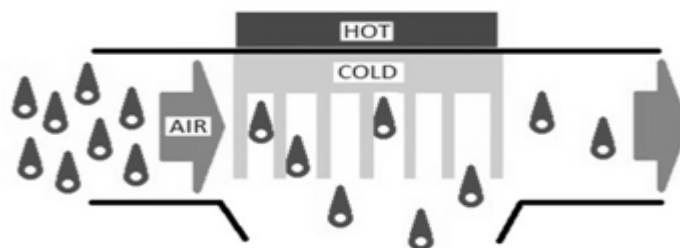


Figure No. 3: Thermoelectric dehumidifier

An additional key concern water scarcity is the water consumption during energy generation. Solar energy has the distinct advantage of low water consumption during its use-phase, making it ideal for installation in locations that have a highly variable or scarce freshwater supply. However, close attention was not paid to solar refrigeration until the energy crisis in 1970s,[5]. Research in a Peltier's cooling effect integrated with Photovoltaic (PV) also developed around that time [6], primarily for the cold chain project of the World Health Organization and the international Health

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Organizations Specifically for rural areas [7]. Solar cells were used to power small TE operated fridges [5]. Experimental investigation and relevant analysis on a solar cell driven, thermoelectric refrigerator has been conducted. The main components of the solar PV/battery thermoelectric dehumidifying system are the PV cell (including the PV array, the storage battery and the Controller), the thermoelectric refrigeration system and the cooled object (e.g., a cooling box). The PV array is installed outdoors and the storage battery stores the excess electricity produced during sunshine periods. This stored energy is used for running the system during the night. There are specially designed lead-acid batteries suitable for deep discharge cycles occurring in PV systems. The controller is an electronic device, which controls the system operation according to the state of charge of the battery. Its main duty is to protect the battery against excessive charging or discharging. For the Solar-driven thermoelectric systems, the performance of whole system are the COP of the thermoelectric refrigeration system and the PV efficiency [5]. Proposed an effective heat rejection method for the hot side of thermoelectric modules to enhance the performance of a laboratory thermoelectric refrigerator and its solar power supply Compared with thermoelectric refrigerators and solar-driven thermoelectric refrigerators, fewer thermoelectric air-conditionings and solar-driven thermoelectric dehumidifiers are reported. The service temperature is generally 15-20°C for an air-conditioner system and 2-6°C for the a dehumidifier so the cooling capacity required is higher than a refrigerator system and energy removed from the cooling side has a low potential useful energy.

## V. LITERATURE REVIEW

In thermoelectric refrigeration system all mechanical part are eliminated and it replaced by thermoelectric module. The developed experimental investigation having a refrigeration load of 0.5 litter capacity is refrigerated by using two number of Peltier module (TEC 1-12706) and Heat sink fan assembly used to increase heat dissipation rate from hot side of peltier module. Experiments were conducted on developed prototype and mathematical model of thermoelectric refrigeration system and results obtained a temperature reduction of 24<sup>0</sup> C in 7 minutes with respect to 32<sup>0</sup>C ambient temperature. The coefficient of performance of thermoelectric Refrigeration system was calculated and found to be about 0.35 to 0.69 Thermo electrical analysis results have indicated that under given condition, there are optimal allocation ratio of the total thermal conductance that can maximize that TEC cooling capacity and COP respectively [11].

In this research researcher made thermoelectric space cooling system with the use of phase change material. Integrated thermoelectric cooling system with PCM is used for space cooling purpose. The function of Phase change material is to store cold thermal energy in night as cold side and it is used to reduce temperature of thermoelectric module in day period. A model based on thermoelectric space cooling system with PCM using numeric calculations is based on two working type. One is the removal of heat to surrounding with the help of air water heat exchanger and other one is to pass heat to shell and tube. Use of Phase change material increases the efficiency of the system [3]. The efficiency of the system increases with the overall increase in COP by 56%. The daytime cooling requirement of thermoelectric module can be fulfilled by this experiment.

Fire-fighter has suffered physiological strain due to working environment. Some strain is produced due to presence in high temperature environment doing physical activity. Many fire fighter die because of external environment leads to increase internal body temperature as heat flows from high to low. Researcher suggested that external thermoelectric cooler provided with each fire fighter , so in presence of high temperature environment the external temperature will affect in less quantity and internal body temperature will remain normal[9]. The TEC will be in portable form. The thermoelectric cooler is in form of closed loop system carrying water. This will reduce the temperature and maintain body temperature. The use of this cooler is easy and efficiency is good.

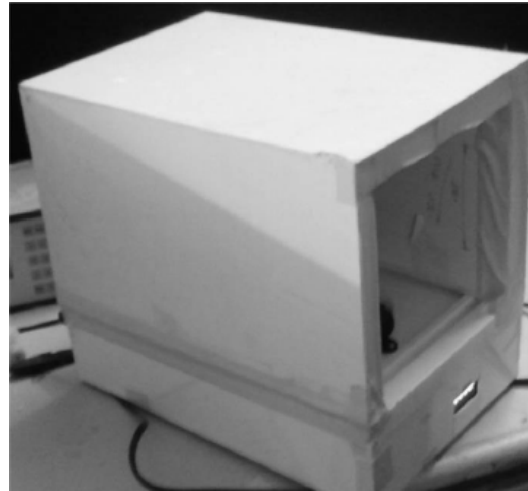
When the value of COP is greater than 1 then we can achieve heat removal rate of 250 W. successful heat removal rate for 160W having COP 0.6 has been achieved during test.

They designed and built a prototype thermoelectric cooler and perform an experiment. The picture built of the thermo-electric cooler is shown in Figure 4. The thermoelectric module form melcor is used for the experiment.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016



**Figure No.4: Prototype Thermoelectric cooler [10]**

The test was conducted at different ambient 21 °C, 15 °C, 32 °C and 43 °C , The temperature vary from 15 °C to 5 °C with temperature variation within the TEC is less than 1 °C as this was the proto sample with improvement in prototyping we can achieve even lower temperature[10].

Researcher made a portable active solar still. He made effort to increase the productivity of still as compared to other convectional stills. water sprinkling device along with thermoelectric cooler is added to improve performance of still. Plexiglas is used on the wall of portable solar still to make it unbreakable. He carried out this experiment in nine summer and winter days in Iran. But result took from both seasons were having a significant difference. The temperature of air and intensity of solar radiation was more in summer as compared to winter season. The efficiency of a portable solar still was in more in summer as compared to winter. The portability function gives significant impact on solar still as compared to other conventional type of solar stills. The experiment shows that intensity of solar radiation have a major impact on a productivity of a portable solar still. When experiment was carried out in 9 days, at 2-3 pm researcher got constant intensity of radiation along with increasing ambient temperature and decreasing velocity of air is obtained. This region got the maximum productivity of portable active solar still[8].

## VI. CONCLUSION

- The available literature shows that thermoelectric cooling systems are generally only around 5–15% as efficient compared to 40–60% achieved by conventional compression cooling system.
- From the above data we can conclude that Thermoelectric cooling added a new dimension to cooling. It has major impact over conventional cooling system. It is compact in size, no frictional elements are present, no coolant is required and weight of the system is low.
- 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. Many researchers try to improve the COP of the thermoelectric air-conditioner using different material.
- The temperature vary from 15 °C to 5 °C with temperature variation within the Thermoelectric cooler is less than 1 °C as this was the proto sample with improvement in prototyping we can achieve even lower temperature.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

## REFERENCES

- [1]. B.J. Huang, C.J. Chin and C.L. Duang:-“A design method of thermoelectric cooler”, International journal of Refrigeration, 23, pp.208-218, 2000.
- [2]. Taylor, R.A., Solbrekken, G., “Comprehensive system-level optimization of thermoelectric devices for electronic cooling applications”, Components and Packaging Technologies, IEEE Transactions on (Volume: 31, Issue: 1).
- [3] Study of a thermoelectric space cooling system integrated with phase change material Gang Tan Applied Thermal Engineering 86, 187-198, 2015.
- [4] L.I. Anatyhuk, R.R. Kobylansky, Yu.M. Mocherniuk, Thermoelectric Device for skin treatment, Journal of Thermoelectricity no.4, 2009, pp.86-92.
- [5] Wijngaards, D.L., S.H. Kong, M. Bartek and R.F. Wolffenbuttel, “Design and fabrication of on-chip integrated poly-SiGe and poly-Si Peltier devices”. Sensors and Actuators, 85:pp. 316-323, 2000.
- [6]. Sofrata, H., 1984. “Solar Thermoelectric Cooling System”. In: S.W. James, B.H. Khoshaim, R. Mallory and A. Meiners, Editors: Solar Buildings. Missouri: Midwest Research Institute, pp: 59-76.
- [7]. Eltawil, M. and D. Samuel, “Performance and economic evaluation of solar photovoltaic powered Cooling system for potato storage”. Agricultural Engineering International: the CIGR Ejournal. Manuscript EE 07 008, IX, 2007.
- [8]. J.A. Esfahani, N.Rahbar & M.Lavvaf, “Utilization of thermoelectric cooling in a portable active solar still — an experimental study on winter days Desalination” 269, pp. 198–205, 2011.
- [9]. Smith, D.L., Horn, G., Goldstein, E., and Petruzello, S.J. “Firefighter Fatalities and Injuries: The Role of Heat Stress and PPE,” Firefighter Life Safety Research Center, Illinois Fire Service Institute, University of Illinois at Urbana-Champaign, July 2008.
- [10]. Mayank Awasthi, “Development of thermoelectric refrigerator”, vol.1, No.3, pp.389-399, 2012.
- [11]. Sofrata H. “Heat rejection alternatives for thermoelectric refrigerators”. Energy Conversion and Management; 37(3):pp.269–80, 1996.