Cooling and Heating of Refrigerator Jacket by Using Peltier Effect

G. Lavanya¹, S. Venkanteshwarlu², A. Nagaraju³, G. Prasanthi⁴

¹P.G. Research Scholar, Department of Mechanical Engineering, J.N.T.U.A College of Engineering, Ananthapuramu-515001, Andhra Pradesh, India
²Lecturer, Department of Mechanical Engineering, J.N.T.U.A College of Engineering, Ananthapuramu-515001, Andhra Pradesh, India
³Lecturer, Department of Mechanical Engineering, J.N.T.U.A College of Engineering, Ananthapuramu-515001, Andhra Pradesh, India
⁴Professor, Department of Mechanical Engineering, J.N.T.UA College of Engineering, Ananthapuramu-515001, Andhra Pradesh, India

ABSTRACT
This project outlines the implementation of photo voltaic driven cooling and heating system. Refrigerator jacket works according to the atmospheric conditions. If the atmosphere is cooler than the required condition, then it gives the amount of warmness to the human body, without causing any side effects and vice versa. Refrigerator jacket entirely depends upon the principle of “Peltier effect”. Refrigerator jacket simply uses electrons rather than refrigerants as a heat carrier. This cooling or heating system does not contain any moving parts like compressor or solution pumps and also it does not require any condenser, expansion valve, or absorber. So, its design is simple and easy to construct. In this project, the working model of jacket utilises the required thermo electric modules. The performance of this model is experimentally evaluated with copper cabinet. The present article explains about how Peltier cooler is used in jacket and its advantages over conventional cooling system. Refrigerator jacket reduces the use of convectional refrigeration system, therefore effect of skin cancer, ozone depletion potential, and global warming potential reduces. This jacket is compact in size and it is eco-friendly in nature. Because of all these reasons Peltier effect is used in refrigerator jacket. Function of jacket interface is to provide thermal efficiency and comfort to user. Peltier cooling module is used to cool fluids stored in reservoir. Thermal resistance and cooling jacket size slightly decrease the Peltier cooling capacity on human.

INTRODUCTION
Thermoelectric cooling is a method used for cooling purpose in various applications. It has good impact over conventional cooling system. Thermoelectric coolers are compact in size, no coolant is used in the system, no frictional element present in system, and weight of system is very less. The changing state between cooling device and heating device is easily controlled. Depending upon the requirement, thermoelectric coolers are used in various applications such as cooling of electronic equipment, thermoelectric refrigeration, space cooling with use of PCM, portable active solar still etc. Thermoelectric coolers are heat pumps that operate on Peltier effect. Research suggests that heating or cooling effect occurs when electric current passes through two conductors. When a voltage is applied to two ends of dissimilar material it will create difference. The temperature difference causes heat to flow according to Peltier effect. A basic thermoelectric cooler will consist of semiconductor elements (p-type & n-type) that work as two dissimilar conductors arranged in specific order. The layer of elements is soldered between two ceramics plates, placed electrically in series structure and thermally in parallel structure. decrease at that junction , resulting the absorption of heat from the surrounding. The heat is carried out through the transportation of electron and it will move from high state to low state. The pumping capacity of a cooler is directly proportional to the number of pairs of ‘n’ and ‘p’ type (couples). The ‘n’ and ‘p’ type semiconductor, usually Bismuth Telluride, is the most used material to achieve the Peltier effect because they are used for carrying out the heat. They also control the charge carrier type in the system.

THERMOELECTRIC COOLER
Basics of Thermoelectric Cooler
Thermoelectric refrigeration system is based upon the principle of thermoelectric effect. This effect is based on the following law:

Seebeck effect
When the two junctions of a thermocouple are maintained at distance, then the difference between the junctions is called
thermo electric emf which is of the order of a few micro-volts per degree temperature difference.

For small temperature difference between two junctions of materials A and B the open circuit voltage developed is proportional to the temperature difference and is given by

$$\Delta V = \alpha_{ab} \Delta T$$

**Peltier effect**

Thermoelectric coolers operate according to the Peltier effect. The effect creates a temperature difference by transferring heat between two electrical junctions. A voltage is applied across the joined conductors to create an electric current. When the current flows through the junctions of the two conductors, heat is removed at one junction and cooling occurs. Heat is deposited at the other junction. The main application of the Peltier effect is cooling. However the Peltier effect can also be used for heating or control of temperature. In every case, a DC voltage is required. Peltier found that

$$Q \propto I$$

Where, $Q$ = rate of heating or cooling

$I$ = current passing through the junction

**Thomson effect**

When material carrying current along temperature gradient, heat will be absorbed or expelled from conductor. It depends upon direction of both electric current & temperature gradient. According to Thomson effect.

**Heat Flow in Thermoelectric Module**

A pair of P-type and N-type semiconductor thermo element forming thermo couples which are connected electrically in series and thermally in parallel is known as thermoelectric module.
In N-type semiconductor, extra valence electrons are added. These electrons are repelled by the negative pole of the power supply and attracted by positive pole. Heat flow takes place in the direction of electron flow. In P-type semiconductors which are missing in the fourth valence electron, creates “Broken Bonds” (Holes) that are free to move. These “holes” are repelled by positive pole of power supply. Heat flow takes places in the direction of hole flow.

The amount of heat flow in the above case is less, to increase heat flow join P- and N-type pellet and form a junction between them with copper tab. Free end of N- and P-type pellets connects to the positive voltage potential and negative side of voltage respectively.

Electrons flow continuously from negative pole of supply to positive pole of voltage supply, through N- and P-type semiconductors.

In the above series, circuit configuration keeps all the heat moving in the same direction through the pellets. When a positive DC voltage is applied to as shown in Fig. 6, electrons flow from the P-type to the N-type semiconductor. The temperature of cold side decreases as electron absorbs heat, until equilibrium reached.

**Fig. 4 Heat flow in thermoelectric module.**

In N-type semiconductor, extra valence electrons are added. These electrons are repelled by the negative pole of the power supply and attracted by positive pole. Heat flow takes place in the direction of electron flow. In P-type semiconductors which are missing in the fourth valence electron, creates “Broken Bonds” (Holes) that are free to move. These “holes” are repelled by positive pole of power supply. Heat flow takes places in the direction of hole flow.

The amount of heat flow in the above case is less, to increase heat flow join P- and N-type pellet and form a junction between them with copper tab. Free end of N- and P-type pellets connects to the positive voltage potential and negative side of voltage respectively.

**Fig. 5 Thermo electric principle.**

The purpose of jacket is to provide cooling mechanism. The thermoelectric cooler is used to chill water in the reservoir. Fig. 6 shows liquid jacket design. In the refrigerated jacket, line tube absorbs heat from human body. The liquid in lined tube is passed through expansion valve, where temperature and pressure of liquid reduces. This liquid is then transferred to the fluid reservoir. Thermoelectric cooler is used to absorb heat from liquid stored in reservoir and transfer to atmosphere, due to which the temperature of liquid stored in reservoir decreases and vice versa. This liquid is pumped and transferred through jacket line tube. This cycle is repeated.

**FINAL PROTOTYPE DESIGN**

Jacket interface and a cooling and heating module are main parts of the liquid cooling jacket. Jacket interface consists of conductive fabric jacket tubing and an insulating fabric. Water in jacket line tube is cooled by cooling module using
thermoelectric cooler, which absorb heat from liquid and transfer to atmosphere and vice versa. Thermoelectric cooling jacket shown in Fig. 7.

**Jacket Interface**

The main function of jacket interface is to provide the high thermal efficiency and comfort to user. Jacket interface consists of internal layer, tubing, and external layer. Internal layer is the first subcomponent of vest interface which has to be kept tight and comfortable to fit the user. The tubing was sewn on internal layer. The second subcomponent of vest interface is tubing, which is thermally conductive to circulate cool water throughout cooling vest. The tubing in vest extracts heat from body and transfer to fluid moving through it. External layer is the final subcomponent of the vest interface use to provide insulation to device. External layer is used to increase thermal efficiency.

**Cooling and Heating Module**

The heat dissipation assembly and the cooling reservoir are the main sub components of cooling module. Cooling module is used to cool the water store in reservoir. Cooling module is attached to thermal vest by an attachment clip. The cooling reservoir is used for extracting heat from the circulating water to and from the body jacket.
interface. The circulated water from jacket is circulated through reservoirs, which acts as heat exchanger. To increase the efficiency of system thermoelectric module is surrounded with insulating material.

In heat dissipation assembly, atmospheric air and working fluid are used to dissipate heat from cooling reservoir to atmosphere. Atmospheric air is drawn by fan to cool heat exchanger and water is circulated through heat dissipation assembly to cool heat exchanger.

RESULT AND DISCUSSION

The results in Table 1 are taken by using Peltier in the cooling jacket for both cooling and heating side and the number of trials is taken to provide proper cooling to the person who wears the cooling jacket after all the testing is conducted. The tabulated results shows that the cooling jacket is able to deliver a cooling air temperature of 18.3°C in static condition; these results are obtained in the period of 20 minute.

CONCLUSION

Thus the climate controlled wearable jacket monitors the extreme temperatures, controls, and provides tolerable temperature to the people who wear it using thermoelectric cooler module. The heat dissipated in this system is controlled at a maximum rate using a heat sink and a liquid pump. Thus the system eliminates the conventional methods of handling heat dissipation. The ultrathin thermo-electric cooler module is more affordable and provides needful solutions to the people making the system less complex, very less power consumption, small in size, and weight.

As thermo-electric cooler module works in Peltier cooling effect, the system can be implemented in wearable jacket that can provide tolerable and controlled temperature to the people wearing it. In the future, if the system is implemented in thin fabric designed jacket, this system would be a milestone in the field of wearable electronics for sure. The work can also be extended by using increased figure of merit Peltier modules and efficient heat exchange technology.

REFERENCES


**Statement of originality of work:** The manuscript has been read and approved by all the authors, the requirements for authorship have been met, and that each author believes that the manuscript represents honest and original work.

**Source of funding:** None

**Competing interest/Conflict of interests:** The author(s) have no competing interests for financial support, publication of this research, patents, and royalties through this collaborative research. All authors were equally involved in discussed research work. There is no financial conflict with the subject matter discussed in the manuscript.

**Disclaimer:** Any views expressed in this paper are those of the authors and do not reflect the official policy or position of the Department of Defense.