Thermoelectric Cooling device based on Peltier Effect

R.Mohanabalan, K. Sudhanthira, C Deepakraja
Assistant Professor, Department of Electrical & Electronics Engg; CMS College of Engineering and Technology Coimbatore, Tamilnadu, India

mohanabalan82@gmail.com, ksudhanthira85@gmail.com, deepakearly@gmail.com

***Abstract*—There are different kinds of refrigeration system available, have their own merits and demerits. The device is to create a mini refrigerator or cooler using thermoelectric cooler which used peltier technology. The cooler will be light in weight, portable and easy to operate and will keep a constant temperature throughout. This makes it ideal for storing and transporting medicines, vaccines, blood banks and lives human organs also. The device can also used in automobiles with 12V DC supply from the vehicles. The thermoelectric cooler is a new technique which has many advantages over conventional cooling technologies.**

Keywords—Refrigeration, Peltier effect, Thermoelectric cooling, Cooler, Mini fridge.

I. INTRODUCTION

Refrigeration is a process of moving heat from one location to another in controlled conditions. The work of heat transport is traditionally driven by mechanical work, but also can drive by heat, magnetism, electricity, laser or other means. Refrigeration has many applications, including but not limited to: household refrigerators, industrial freezers, cryogenics and air conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible but are otherwise similar to air conditioning units.

Refrigeration has had a large impact on industry, lifestyle, agriculture and settlement patterns. The idea of preserving food dates back to at least the ancient roman and Chinese empires. However, mechanical refrigeration technology has rapidly evolved in the last century, from the harvesting to temperature – controlled rail cars. In most developed countries, cities are heavily dependent upon refrigeration in supermarkets, in order to obtain their food for daily consumption. The increase in food sources has led to a larger concentration of agricultural sales coming from a smaller percentage of existing farms. Farms today have a much larger output per person in comparison to the late 1800s. This has resulted in new food sources available to entire populations, which has had a large impact on the nutrition of society.

Refrigeration is an essential requirement in various fields of medicine. It is required in hospitals, nursing homes, laboratories and clinical research organizations and also in the field of every medical research. Different types of refrigerators are available for medical use and these refrigerators provide suitable for medical refrigeration. The Various uses are in the blood bank, laboratory, medical stores, safe storage of vaccines, etc., and many more use.

The importance of thermoelectric cooling uses very advanced peltier cooling technology, which is a very advanced technology. The absence of compressor, liquid pumps, noise, toxic refrigerant gas, high volume equipment, etc., makes this technology highly acceptable in the medicals fields.

This system helps 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 from one side of the device to the other, with consumption of electric 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 cooling, although inpractice the main application is cooling. It can also be usedas temperature controller that either heats or cools.

II. EXISISTING METHODS

There are different types of refrigeration methods available now, each of them have got their own merits and demerits. Methods of refrigeration can be classified as non-cyclic, cyclic, thermoelectric and magnetic.

A. Cyclic Refrigeration

This system consists of refrigeration cycle, where heat is removed from a low temperature space and rejected to a high temperature sink with the help of external work, and its inverse the thermodynamic power cycle. In the cycle, heat is supplied from a high temperature source to engine, part of the heat being used to produce work and the rest being rejected to a low temperature sink. This satisfies the second law of thermodynamics.

A refrigeration cycle describes the changes that take place in the refrigerant as it alternately absorbs and rejects heat as it circulates through a refrigerator. It is also applied to heating, ventilation, and air conditioning HVACR works, when describing the process of refrigerant flow through an HAVACR unit, whether it is a package or split system. Heat naturally flows from hot to cold. Work is applied to cool a living space or storage volume by pumping heat from a lower temperature heat source in to a higher

temperature heat sink. Insulation is used to reduce the work and energy needed to achieve and maintain a lower temperature in the cooled space. The operating principleof the cycle was described mathematically by Sadi Carnot in 1824 as a heat engine.

B. Thermoelectric Refrigeration

The thermoelectric cooling uses the peltier effect to create heat flux between the junctions of two types of material. This effect is commonly used in camping and portable coolers and for cooling electronic components and small instruments, medical purposes, etc.,

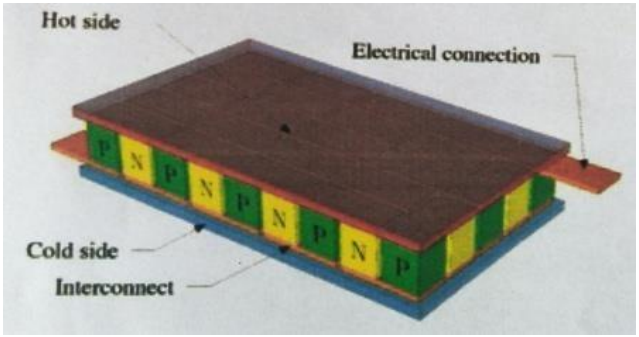

Fig. 2.1 Thermoelectric Refrigeration

C. Magnetic Refrigeration

The magnetic refrigeration is a cooling technology based on the magnetic caloric effect, an intrinsic property of magnetic solids. The refrigerant is often a paramagnetic salt, such as cerium magnesium nitrate. The active magnetic dipoles in this case are those of the electron shells of the paramagnetic atoms. A strong magnetic field is applied to the refrigerant forcing its various magnetic dipoles to align and putting these degrees of freedom of the refrigerant into a state of lowered entropy. A heat sink then absorbs the heat release by the refrigerant due to its loss of entropy. Thermal contact with heat sink is then broken so that the system is insulated and the magnetic field is switched off. This increases the heat capacity of the refrigerant thus decreasing its temperature below the temperature of the heat sink. Because a few materials exhibit the needed properties at room temperature, applications have so far been limited to cryogenics and research.

D. Other Methods

The other types of refrigeration includes air cycle machine used in aircraft, the vortex tube used for spot cooling, when compressed air is available and thermo acoustic system using sound waves n a pressurized gas to drive heat transfer and heat exchange; steam jet cooling popular in the early 1930s for air conditioning large buildings, thermo elastic cooling using a smart metal alloy stretching and relaxing. Many sterling cycle heat engines can be run backwards to act as a refrigerator and therefore these engines have a niche use in cryogenics.

III. PROPOSED WORK

This system used in conventional refrigerators pose a threat to the environment because of their ozone depletion potential and global warming potential. Despite the

inherent advantages, refrigeration had its problems. Refrigerants like sulfur dioxide and methyl chloride were causing people to die. Ammonia had an equally serious toxic effect if it leaked. Frigidaire discovered a new class of synthetic refrigerants called halocarbons in 1928. Then part of general motors, the company sewed up all the patents. The entire industry was allowed to use the patents and refrigeration technology switched to these new "safe" agents like Freon. Now, new refrigeration methods are getting in to practice like HFC based refrigerators and thermoelectric refrigerators. The latter is getting extensively advanced due to its flexibility and mobility. This field is a very fast growing sector and still needs much advancement as it is not much efficient when compared to conventional techniques.

A. Peltier Cooling

A voltage is applied to a device, it creates a temperature difference causing charged carriers in the material to diffuse from the hot to cold side, thus including a thermal current; also known as the peltier effect.

This effect can be used to change the temperature of a given object. In other words, a peltier device is a thermo electric heat pump; when direct current runs through it, heat or cold is created by the moving electrodes. Therefore, the device can be used for heating, cooling or as a temperature controller. The main advantage of a device are the lack of liquid in the cooling system and minimization of moving parts, as well as its small size and flexible shape ensuring multiple installation options. The peltier technology is highly suitable for compartment cooling, medical refrigeration, electronic device cooler, etc., and is often used in combination with passive or free cooling solutions to achieve optimum savings. Compartmentalized cooling of temperature sensitive components allows a higher temperature for the non- temperature sensitive components.

B. Working of Peltier Device

The thermoelectric cooler uses the peltier effect to create flux between the junction of two different types of materials. A

peltier cooler, heater, or thermoelectric heat pump is a solid state active heat pump which transfers heat form one side of device to other, with consumption of electrical energy, depending on the direction of current. Such an instrument is also called peltier device, peltier heat pump, solid state refrigerator or thermoelectric cooler. It can be used either for heating or cooling, although in practice the main application is cooling. It can also be used as a temperature controller that either heats orcools.

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice – versa. A thermoelectric device created 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 carriers in the material to diffuse from hot side to cold side.

This effect can be used to generate electricity, measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as temperature controllers. The device encompasses three separately identified effects: the Seebeck effect, peltier effect and Thomson effect.

C.Seebeck Effect

This effect is the conversion of heat directly into electricity at the junction of different types of wire. It is named after the Baltic German Physicist Thomas Johann Seebeck, who in 1821 discovered that a compass needle would be deflected by a closed loop formed by two different metals joined in two places, with a temperature difference between the joints. This was because the electron energy levels in each metal shifted differently and a voltage difference between the junctions created an electric current and therefore a magnetic field around the wires. See beck did not recognize there was an electric current involve, so he called the phenomenon "thermo magnetic effect" Danish Physicist Hans Christian Orsted rectified the oversight and coined the term "thermoelectricity".

The see beck effect is a classic example of electromotive force and leads to measurable current or voltages in the same way as any other emf. Electromotive forces modify Ohm's law by generating currents even in the absence of voltage differences. The see beck coefficients generally vary as function of temperature and depend strongly on the composition of the conductor. A metal of unknown sample that is locally heated to the probe temperature. It is used commercially to identify metal alloys. Thermocouples in series form a thermopile. Thermoelectric generators are used for creating from heat differentials.

D.Peltier Effect

The effect is the presence of heating or cooling at an electrified junction of two different conductors and is named after French Physicist Jean Charles Athanasius Peltier, who discovered it in 1834. When a current is made to flow through a junction between two conductors, A and B, heat may be generated or removed at the junction. The peltier heat generated at the junction per unit time is Q=(IIA – IIB)I, where, IIA is the peltier coefficient of conductor A and B and I is the electric current from A to B. The total heat generated is not determined by the peltier effect alone, at it may also influenced by joule heating and thermal gradient effects.

The effect represents how much heat is carried per unit charge. Since charge current must be continuous across a junction, the associated heat flow will develop a discontinuity if IIA and IIB are different. The peltier effect can be considered as the back action counterpart to the see back effect. If a simple thermoelectric circuit is closed then the see beck effect will drive a current, which in turn transfer heat from the hot to cold junction. A typical peltier heat pump device involves multiple junctions in series, through which a current is driven. Some of the junctions lose heat due to the peltier effect,

while others gain heat. Thermoelectric heat pumps exploit this phenomenon, as do thermoelectric cooling devices found in refrigerators.

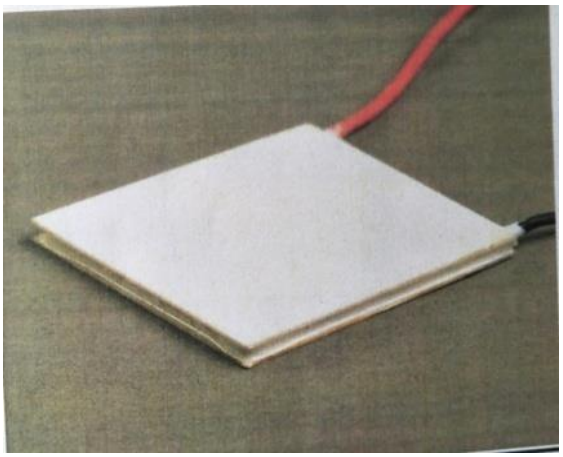

Fig.3.1 Peltier Device

E. Thomson Effect

In different materials, the see beck coefficient is not constant in temperature, and so a special gradient in temperature can result in a gradient in the see back coefficient. If a current is driven through this gradient, then a continuous version of the peltier effect will occur. It describes the heating or cooling of a current carrying conductor with a temperature gradient.

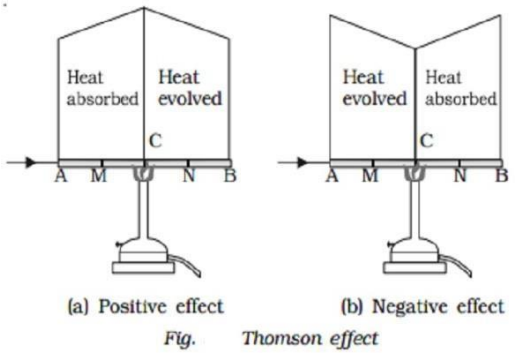

Fig. Thomson effect

Fig.3.2 Thomson Effect

If the material is not in steady state, a complete description needs to include dynamic effects such a relating to electrical capacitance, inductance and heat capacity. The thermoelectric effects lie beyond the scope of equilibrium thermodynamics. They necessarily involve continuing flows of energy. At least, they involve three bodies or thermodynamic subsystems, arranged in particular way, along with a metals and their junction region. The junction region is an in homogeneous body, assumed to be stable, not suffering amalgamation by diffusion of matter. The surroundings are arranged to maintain two temperature reservoirs and two electric reservoirs. For an imagined, but not actually possible, thermodynamic equilibrium, heat transfer from the hot reservoir to cold reservoir would need to be prevented by a specifically matching voltage difference maintained by the electric reservoirs and the electric current would need to be zero. In fact, for a steady state, there must be at least some heat transfer or some non-zero electric current. The two modes of energy transfer as heat and by electric current, can be distinguished when there are three distinct bodies and distinct arrangement of surroundings,. But in the case of continuous variation in the media, heat transfer and thermodynamic work cannot be uniquely distinguished. This is more complicated than the often considered thermodynamic processes, in which just two respectively homogeneous subsystems are connected.

IV. HARDWARE IMPLEMENTATION

The first phase is to setup the TEC device with the heat sinks and cooling fans. For that, the heat sink of 11cm length is drilled and fan is mounted on one side. The TEC device us then placed in the middle of the heat sink. The other side of the TEC is covered with two sided tape. Then after applying a thin layer of thermal paste on the other side of TEC, the small heat sink is placed over it. Over that, the small cooling fan is placed and the nuts are fastened so as to keep this as block. The connection leads are grouped to a side and left free for connecting the supply.

Now, the thermo coal box at one side and insert the TEC device block into it, with the cooling side facing inwards. Next, the SMPS power supply and thermostatic relay on the box. The power supply unit is fixed on a side of the box with the double sided adhesive tape. The temperature control relay is also placed adjacent to the power supply with the help of glue. The sensor probe of the relay is placed inside the box. The plastic junction box is mountedat a side of the box with glue.

Finally, the wire of device as per circuit is connected and it is enclosed with the junction box and switch is also connected. The vehicle power adapter is also connected with main power supply and its connection lead is placed on the box in a convenient place on the box.

V. CONCLUSION AND FUTURE SCOPE

The importance of refrigeration in modern world is very crucial. The role played by refrigeration in clinical and medical field is very vital. If we fail to maintain proper field is very refrigeration in medical supplies, it will result in many fatal problems. Advancements will always be there in this field and our project. "Thermoelectric Cooler" is one such advancement towards this sector.

The device of thermoelectric cooler can be developed and further enhanced and advanced to get optimum results. This device has a commercial future as it is relevant in medical and military sector. Many things have to be kept in mind if such future production is done.

We have to provide sufficient thermal insulation for the cooling block; the heat sinks of both sides have to be separated by special heat insulating components like poly urethane or expanded polystyrene. The bounding between heat sinks is also to be done by heat insulating materials like HPDE. The nut and bolt system will always allow heat to pass into the internal chamber.

The storage box or body of the cooler is to be designed with fiber glass filled with polystyrene or other optimum thermal insulators. Single stage peltier cooling are not much efficient, so multistage thermoelectric cooling device have to be used or parallel usage of single stage TEC device have to be adopted. This paper helped us to have proficient

knowledge in the field of refrigeration and importance ofelectric energy in this technology.

REFERENCES

[1] Ashtoush Gupta, Gaurav yadav, Hemender Pal Singh, "Peltier Module for Refrigeration and Heating using Embedded System", International Conference onRecent developments in control, Automation and Power Engineering, 2015.
[2] Yifei Li, Xin Hu, Victor Rocha Fortado, " A Cooling method based on Thermoelectric Effect – Peltier Cooling System", 5th International Conference on Mechanical, Control and Computer Engineering, 2020.
[3] Rohit Sharma, Vivek Kumar Sehgal, Nitin, Abhinav Thakur, " Peltier Effect based Solar Powered Air conditioning System", International Conference on Computational intelligence, Modelling and Simulation, 2009.
[4] M.Kalimuthu, R.Subhashini, U.Mohammed Al Rashid, " Peltier based Temperature Controlled Smart mini Refrigerator", International Conference on electrical, electronics, Communication, Computing and Automation, 2021.
[5] Muhammed Alia Rahman, Arif Widyatama, Akmal Irfan Majid, " Peltier Thermoelectric Refrigeration system as the future cold storage System for Indonesia: A Review", 5th International Conference on Science and Technology, 2019.
[6]