© 2016 IJEDR | Volume 4, Issue 2 | ISSN: 2321-9939

Thermoelectric Refrigeration System (Multistage) - A Review

[1]Deepak M. Bondre, [2]Vaibhav N. Deshpande
[1]BE Student, [2]Asst. Professor
Department of Mechanical engineering,
Lokmanya Tilak College of Engineering, Navi Mumbai, Mumbai, Maharashtra, India

***Abstract*: Effectiveness of single-stage thermoelectric refrigerator may decrease with increase in the temperature ratio of heat source and heat sink. This initiates development of various ways to improve coefficient of performance (COP) of the thermoelectric refrigeration system. One of the most effective method to improve the co-efficient of performance is improving effectively the dissipation of heat at the sink. This can be done by application various methods such as use of phase change materials, multi-stage combined thermoelectric refrigerator etc,**

***Index Terms:* Peltier-effect, See-back effect, Thermo-electric Refrigeration, Multi-stage**

I. INTRODUCTION

Global need of refrigeration is increased for food preservations, medical requirements, vaccine storage, cooling of electronic device, air conditioning of the space led consumption of more electricity. This causes ultimately more release of CO_2 , which helps in global warming. Considering these factors thermoelectric refrigeration offers several advantages over conventional refrigeration systems like vapor-compression refrigerators. This advantages can be shortlisted as free of moving parts, acoustically silent, reliable, and lightweight. But low efficiency and peak heat flux capabilities have restricted their use in wider applications. Peltier effect and Seeback effect were first observed in metals (1820s–1830s) , but the low thermoelectric performances of metal was the reason for failure of metals as Thermo-electric Refrigerator.Until 1950s development of semiconductor materials as Thermo-electric Refrigerator took place. This was possible due to small band gap, large Seeback coefficients, good electrical conductivities, and poor thermal conductivities, which makes semiconductor to have much bigger thermoelectric performances than the pure metals, thus revived the interest in this field.

Single stage thermoelectric refrigerator

This is simplest form of Thermoelectric refrigerator. It is made up of large number of P- and N-type semiconductor elements connected electrically in series and thermally in Parallel.

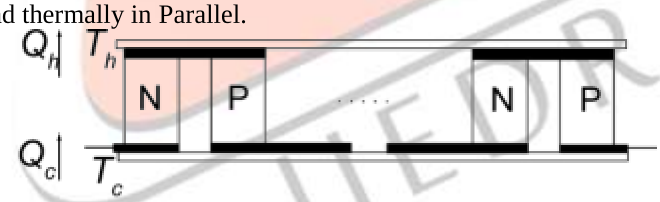

Fig. 1 Schematic diagram of a single-stage semiconductor thermoelectric refrigerator [1]

When electric current flows through thermoelectric material due to Peltier effect , heat flows in one direction as shown in figure 1. This causes surface at temperature ‘Tc’ be more cooled than surface at temperature ‘Th’ .As more current flows ‘Tc’ drops to sufficient value so that lower surface can be effectively used for refrigeration purpose.

A two-stage thermoelectric refrigerator

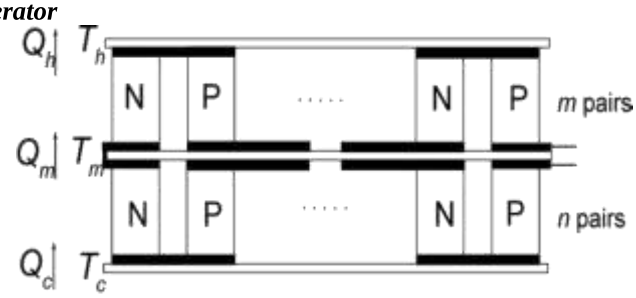

Fig. 2.Schematic diagram of a two-stage semiconductor thermoelectric refrigerator [1]

The performance of single stage thermoelectric refrigerator depends on how effectively heat is dissipated or absorbed from heat sink side. To improve heat dissipation rate on heat sink side one of the method use is multistaging of thermoelectric refrigerators . Figure 2 shows Two stage thermoelectric refrigerator . In two stage thermoelectric refrigerator value of temperature at cooled side that is ‘Tc’ is much more lower than that of single stage thermoelectric refrigerators. Hence by multistaging ‘Tc’ can be lowered significantly.

II. REVIEW OF SOME RESEARCHERS

Jincan Chena et al.,[1]:- According to non-equilibrium thermodynamics ,cycle models of single-stage and two-stage semiconductor thermoelectric refrigeration were experimentally investigated. By using the three important parameters which governs performance of thermoelectric refrigerator i.e. coefficient of performance (COP), the rate of refrigeration, and the power input, development of general expressions performances of the two-stage thermoelectric refrigeration system took placed. It was concluded that performance of thermoelectric refrigerator depends on temperature ratio of heat sink to cooled space. When this ratio is small, the maximum value of COP of a two-stage thermoelectric refrigeration system is larger than COP of a single-stage thermoelectric refrigeration system; however maximum rate of refrigeration is smaller than that of a single-stage thermoelectric refrigeration system. Hence it is convenient to use single stage thermoelectric refrigerator when ratio is small. When temperature ratio is large two stage thermoelectric refrigerator is observed to be superior than single stage by both parameters i.e. maximum value of COP and maximum rate of refrigeration.

X.C. Xuan et al., [2]:-In this paper Two stage thermoelectric refrigerator was investigated with two design configurations. Two configurations were pyramid style and cuboid style as shown in respective figures. In pyramid style configuration top side is being coldest as current is unidirectional. In cuboid style configuration current can be alternated causing top and bottom side to be switched between heating and cooling mode. To obtain optimization methods other multi stage designs can be used.

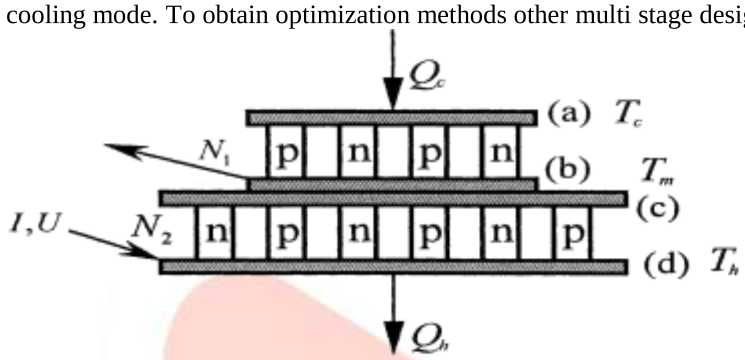

Fig. 1. Two-stage pyramid-style TE cooler.[2]

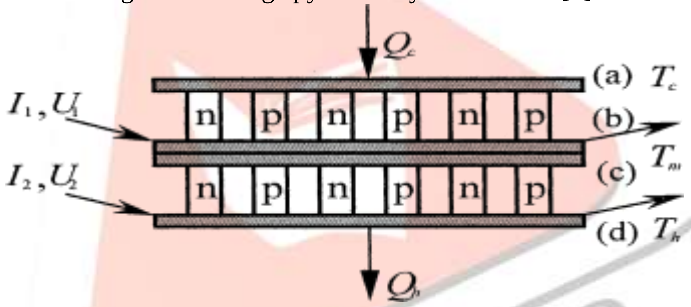

Fig. 2. Two-stage cuboid style TE cooler.[2]

The point of maximum cooling capacity and maximum COP both were taken into consideration while investigation for optimization for the two-stage TE coolers. It was concluded that value lies between 2.5-3 for both parameters that is optimum limit of ratio of number of thermo electric modules of two stages in pyramid style TE cooler and optimum limit of ratio of electric current between stages of cuboid style TE cooler. Maximum temperature difference of pyramid-style cooler is greater than single stage cooler.

Jun Luo et al., [3]:- Using finite time Thermodynamics theory performance of a thermoelectric refrigeration system, with multi-elements was analysed. To improve and maximise the cooling load and coefficient of performance (COP) optimisation of the ratio of the heat transfer surface area of the high temperature side to the total heat transfer surface area of the heat exchangers was done. The analysis of number of parameters which affects optimum performance of Thermoelectric system was done , parameters were number of thermoelectric refrigerating elements, the Seeback coefficients, internal heat conductance, the heat source temperature and internal electrical resistance. As well as the analysis of other parameters like influences of total heat transfer surface area and working electrical current on the optimum performance was done. They concluded that the cooling load and coefficient of performance (COP) of TE system is greatly influenced by total heat transfer surface area and working electrical current. These results can be used for designing and manufacturing of practical Thermoelectric refrigerators.

D. Astrain et al.,[4]:- In this paper a device using phase change material based on Thermosyphon principle was developed. This device was used and tested as a heat dissipater for hot side of TE cooler. Performance of TE cooler with this device was compared with TE cooler with conventional heat dissipater made up of fins. It was concluded that with the help of developed phase changing device it is possible to reduce thermal resistance between hot side of TE cooler and atmosphere up to 23.8% at 293 K ambient temperature and 51.4% at 308 K ambient temperature, compared to commercial finned heat sink . Decrease in thermal resistance ultimately causes heat to dissipate more effectively from heat sink of TE cooler, therefore improving the COP of TE cooler. At the same values of temperatures it was observed that COP increases by 26% and 35% respectively.

Yuzhuo Pan, et al, [5]:- Author of this paper designed and analyzed an Irreversible multi-couple thermoelectric refrigerator, which operates between two reservoirs maintained at constant temperature. Effect of other factors like external and internal irreversibility of thermoelectric refrigerator on performance was also studied. They have specified many important parameters which affects coefficient of performance (COP) of system. Results of obtained from experiments leads to knowledge of information about performance characteristics of real multi-couple thermoelectric refrigerator. This information may be used to manufacture and design thermoelectric refrigerator which will perform at its optimum level.

Hongxia Xi.et al, [6]:- In this paper Author done survey on solar based driven Thermo electric technology. A brief history of development of solar based driven Thermo electric technology was presented. It's today's status and drawbacks present in current Technologies were reviewed. Applications, future scope, advantages over conventional technology where also discussed. In this paper they have discussed about two main modes, that are solar based thermoelectric power generation and refrigeration. Current status of both Technologies was described. Problems related to this technology and there possible solutions were presented. Ultimately these Technologies with some more development may lead to solve demand of Environment protection and energy conservation.

Suwit Jugsujinda et al, [7]:- In this paper they have fabricated thermoelectric refrigerator using thermoelectric cooler. Thermoelectric refrigerator (25 × 25 × 35 cm^3) and thermoelectric cooler (4 × 4 cm^2). This system was applied to 40 W electric power without any cooling fan as heat dissipater at heat sink. They have measured temperature of this system at ten different points. It was concluded that these experiments results into temperature of cold side of thermoelectric cooler to be decreased from 30°C to -4.2°C for 1 hour and decreased to -7.4°C for 24 hours with heat plate temperature being 50 °C. Temperature of cold side of thermoelectric refrigerator decreased from 30°C to 20°C for 1 hour and decreased further in 24 hours. 3 and 2.5 are the maximum value of coefficient of performance (COP) of thermoelectric cooler and thermoelectric refrigerator respectively.

S.A.Omer et al, [8]:- This paper presents some results of thermoelectric refrigeration system using phase change materials (PCM) integrated with thermosyphones. They investigated two models of thermoelectric refrigeration system, one with conventional finned devices as heat dissipater and other with phase change material (PCM) as heat dissipater. After results they have concluded that coefficient of performance (COP) and effectiveness of thermoelectric refrigeration system with Phase Change Material (PCM) is higher than conventional one. They have also compared thermoelectric refrigeration system of two kinds, one is using phase change materials (PCM) without thermal diode and other integrated with thermal diode (Thermosyphones). Results shows that thermosyphones used prevent leakage of heat during power off. Overall they have concluded system can be work with the help of renewable energies like solar energy producing electricity. It is suited for medicine and food storage.

III. CONCLUSION

Different methods of improving COP of thermoelectric refrigeration system were listed out in this review. The cooling load and coefficient of performance (COP) of TE system is greatly influenced by total heat transfer surface area and working electrical current.Many researchers proposed many different methods for improvement of performance of Thermoelectric cooler on basis of respective theories. It was concluded that effectively dissipating heat at the sink is most effective way to improve coefficient of performance (COP). . It is convenient to use to use single stage thermoelectric refrigerator when temperature ratio is small and multi stage thermoelectric refrigerator when temperature ratio is large. Dissipation of heat at sink can be improved with the help of PCM (Phase Change Material). Using Multi stages instead of single stage of TE cooler is also an effective way to improve performance. There is large scope for successful development of solar energy based Thermoelectric coolers.

REFERENCES

[1] Jincan Chen, Yinghui Zhou, Hongjie Wang, Jin T. Wang: " Comparison of the optimal performance of single- and two-stage thermoelectric refrigeration systems" Applied Energy 73 (2002) 285–298

[2] X.C. Xuan,K.C.Ng,C.Yap,H.T.Chua: "Optimization of two-stage thermoelectric coolers with two design configurations" Energy Conversion and Management 43 (2002) 2041–2052

[3] Jun Luo,Lingen Chen,Fengrui Sun,Chih Wu: "Optimum allocation of heat transfer surface area for cooling load and COP optimization of a thermoelectric refrigerator" Energy Conversion and Management 44 (2003) 3197–3206

[4] D.Astrain,J.G.Vian,M.Domınguez: "Increase of COP in the thermoelectric refrigeration by the optimization of heat dissipation" Applied Thermal Engineering 23 (2003) 2183–2200

[5] Yuzhuo Pan, Bihong Lin, Jincan Chen,: "Performance analysis and parametric optimal design of an irreversible multi-couple thermoelectric refrigerator under various operating conditions" Applied Energy 84 (2007) 882–892

[6] Hongxia Xi, Lingai Luo, Gilles Fraisse: "Development and applications of solar-based thermoelectric technologies" Renewable and Sustainable Energy Reviews 11 (2007) 923–936

[7] Suwit Jugsujinda, Athorn Vora-ud, Tosawat Seetawan: "Analysing of Thermoelectric Refrigerator Performance" Procedia Engineering 8 (2011) 154–159

[8] S.A.Omar,S.B.Raffit,Xiaoli Ma: "experimental investigation of thermoelectric refrigeration system employing a phase change material integrated with thermal diode (thermosyphons)"Applied thermal Engineering 21(2001)1265-1271