# Design and Analysis of Thermo Electric Refrigerator

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# DESIGN AND ANALYSIS OF SOLAR THERMO ELECTRIC REFRIGERATOR

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**ABSTRACT:** - The design of the solar-powered refrigerator is based on the principles of a thermoelectric module (i.e., Peltier effect) to create a hot side and a cold side. The cold side of the thermoelectric module is utilized for refrigeration purposes; provide cooling to the refrigerator space. In this research a new way to be find out to improve COP. Thermoelectric couples are solid-state devices capable of generating electrical power from a temperature gradient, known as the Seebeck effect, or converting electrical energy into a temperature gradient, known as the Peltier effect.

**KEY-WORDS: -** Peltier Effect, Thermo Couple, COP, Cold and Hot Junction.

## Background

Thermoelectric solar refrigerator works on solar energy works on Peltier effect, which is unique from other types of Refrigerators which works on Conventional electric energy. The purpose is to improve the COP of the solar thermo electric refrigerator by modifying thermo electric module which can be used in the remote areas where electricity is not available or the people facing electric power fluctuations. So a modified solar thermo electric refrigerator which has optimal COP can solve this problem.

## Aim

The aim is to design a peltier module to improve the COP of the thermo electric refrigerator. In this research a new way to be find out to improve COP. Thermoelectric couples are solid-state devices capable of generating electrical power from a temperature gradient, known as the Seebeck effect, or converting electrical energy into a temperature gradient, known as the Peltier effect.

## Scope Of The Project

Thermoelectric devices achieved an importance in recent years as viable solutions for applications such as spot cooling of electronic components, remote power generation in space stations and satellites etc. These solid state thermoelectric devices are free from moving parts, having good reliability however their efficiency depends on the selection of materials. Such devices with higher efficiency can be implemented for refrigeration also. Actually the combination of Seebeck Effect and Peltier Effect is the absolute advent for such refrigeration. If heat from solar energy is provide as the input to this implementation the cooling will be the output. Surely this research work will be an idea for better refrigeration and becomes an effort to overcome the energy crisis by the means of refrigeration from waste heat. In the instruments like computers, laptops, dynamos and vehicles the low grade waste heat can be utilized for cooling and can also be recycled to improve their performances. To reduce the thermal conductivity the heat resistant membranes can also be used. In a large number of devices metallic blocks are used, which causes eddy currents due to non uniform magnetic fields. If these magnetic fields are synchronized to the thermo coupled devices then it is observed that the thermo emf will enhanced. This results to more cooling without any extra input. Such thermoelectric cooling devices can be applied to industries, buildings of hot regions and to the houses in summer. However, they require some modifications related to their size and the selection of materials but their cheapness, eco friendly nature, no cause to global warming are enough inputs to motivate the engineers for their implementations in almost all the suitable applications of daily life in near future.

### Selection of a component:

The major components of the solar thermoelectric refrigerator include thermoelectric module, solar cells, aluminum box, plastic plates, finned surface (or heat sink), and the cooling fan. In this study, 10 thermoelectric modules were used in the design of the refrigerator. Fig. 1 depicts one of the 10 modules that were used. Looking at Fig. 1, it can be seen that the module comes with two wires. Table 1 shows the specifications of the thermoelectric module used in this study. The electrical power generated by the solar cells was supplied to the thermoelectric refrigerator by means of the photovoltaic effect. The solar cells used in this study were manufactured by BP Solar and had the efficiency of 14% with size of 12.5 cm_ 12.5 cm. In addition, aluminum sheets were added to the sides of the cabinet of the refrigerator to evenly distribute the cold for a uniform temperature within the whole refrigerator. The plastic plates were used as thermal insulation for inhibiting the back flow of heat when operating in humid conditions. They also used to prevent any loss in the performance of the refrigerator to be affected by external heat which is important when refrigerator is used in hot conditions (e.g. Bedouin desert). The finned surface (i.e., heat sink) was used to enhance and increase the rate of heat transfer from the hot surface of the thermoelectric module so the heat will be discarded outside of the refrigerator. In order to maintain the efficiency of the thermal module, cooling fan was used to reject the heat from the hot side of the module to ambient surroundings

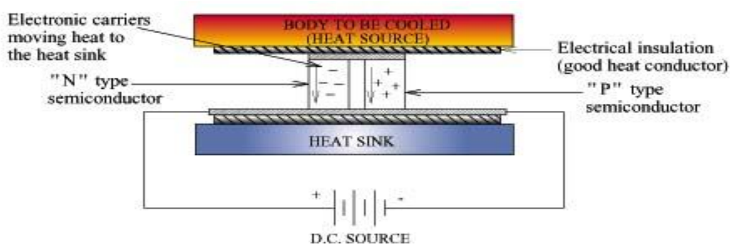
**Literature survey:**

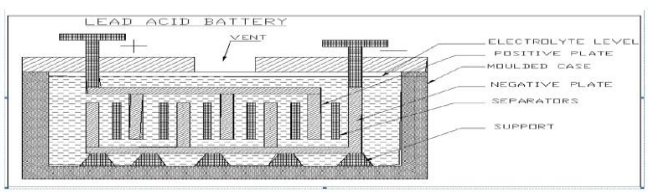
Prof. Vivek R. Gandhewar et al worked on Fabrication of Solar Operated Heating and Cooling System using Thermo-Electric Module. According to the authors, the electricity crisis is deemed to be the most faced technical drought. It's time to harness the renewable energy resources of the nature. Their project utilizes the solar energy to run a heating and cooling system. The author prime focuses on fabricating a thermoelectric system using solar energy. It is an eco-friendly Project, made by using thermoelectric module. Thus the authors conclude that solar energy systems must be implemented to overcome increasing electricity crisis. In order to utilize renewable energy, solar energy was integrated to power the thermoelectric module in order to drive the system. Furthermore, the solar thermoelectric cooling and heating system avoids any unnecessary electrical hazards and proves to be environment friendly.

Dr. Jovan Mitrovic (Ed.) worked on Heat Exchangers for Thermoelectric Devices. The author debates on the very fact that heat exchangers play an important role in the performance of thermal machines, namely, electric power generators, engines and refrigerators. Regarding thermoelectric, this influence is even higher, owing to the difficulty of transferring heat from the small surface area of a typical thermoelectric module to a bigger one. The authors have shown the major influence of the heat exchangers on the efficiency of thermoelectric devices, and according them this efficiency raises as the thermal resistances of both heat exchangers decreases. The optimization of finned dissipators used in thermoelectric refrigerators allows the reduction of their thermal resistances, which in turn increases the COP of these thermoelectric devices. However, finned dissipators do not represent the most efficient heat exchangers, since constriction thermal resistances restrict, to a great extent, the global thermal resistance of the dissipators.

Zhiting Tian, Sangyeop Lee et al worked on a paper in Comprehensive Review of Heat Transfer in Thermoelectric Materials and Devices and authors debate on the fundamental facet that the solid-state thermoelectric devices are currently used in applications ranging from thermocouple sensors to power generators in satellites, to portable air-conditioners and refrigerators. Efficient thermoelectric energy conversion critically depends on the performance of thermoelectric materials and devices. In this review, we discuss heat transfer in thermoelectric materials and devices, especially phonon engineering to reduce the lattice thermal conductivity of thermoelectric materials, which requires a fundamental understanding of nanoscale heat conduction physics

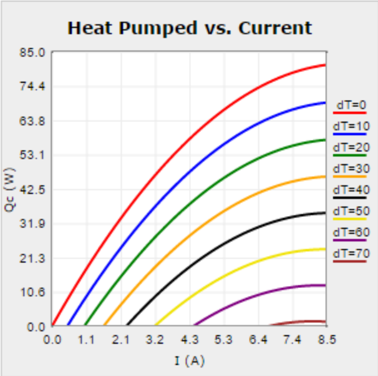
**Accessories considered, description and specifications:**

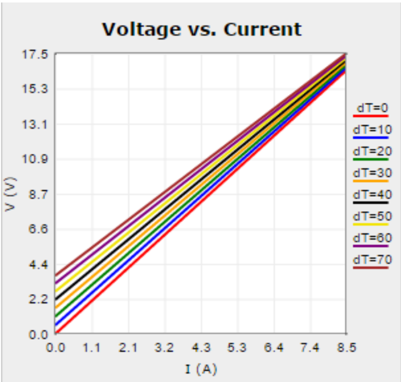


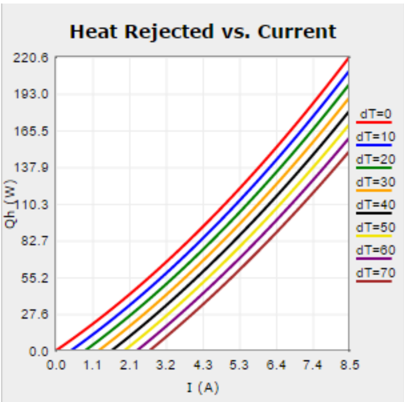



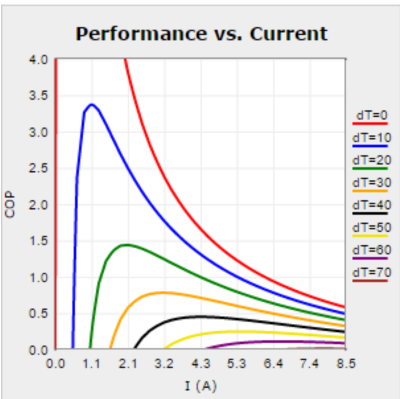

Lead Acid Battery

## Calculation and modeling:




Performance characteristics graphs

The cold function temperature Tc can be evaluated using the module formula with expression for maximum temperature difference

$$DT_{max} = \frac{S_m^2 \, T_c^2}{2\, R_m K_m}$$

It is essential to calculate the total heat energy of the cold junction which can be evaluated using the following expression

$$Qc = (S_m * T_c * I) - (0.5 * I^2 * R_m) - (K_m * DT)$$

The supply voltage which also termed

as the input voltage which is expressed

$$V_{in} = (S_m * DT) + (I * K_m)$$

With the supply voltage the power input to the function can be evaluated of as follows

$$P_{in} = V_{in} * I$$

The total heat energy of the hot function can be evaluated as a function of the input power of the total heat generation at the cold function which can be expressed as

$$Q_H = P_{in} + Q_c$$

Finally the coefficient of performance using the peltier can be numerically calculated as

$$COP = \frac{Q_c}{P_{in}}$$

## Modification

The above proposed method using a 127 couple Peltier module yields a COP of 0.31. But the performance at this value is at the cost of a total supply voltage of 182.85 V and a power dissipation of 182W. This module is satisfactory under the expense of supply voltage and the power dissipation. Hence a necessary modification to the PN junction module is required in order to increase the COP with affordable supply voltage and power input which makes the refrigeration at reduced rate of power consumption. From the calculations it can be seen that the COP has increased from 0.31 to 0.91 which is a 34% increase in the overall performance of the module.

The maximum current

$$I_{max} = 8.5 \text{ amp}$$

The maximum voltage

$$V_{max} = 17.5 \text{ V}$$

The maximum work done or heat generation

$$Q_{max} = 80W$$

The maximum differential temperature

$$DT_{max} = 72\ °C = 345K$$

Thermal module resistance

$$R_m = 1.6\ \Omega$$

Seebeck module coefficient

$$S_m = 1.25 \text{ V/K}$$

Internal module resistance or thermal conditioning

$$K_m = 0.476\ W/K$$

The hot Junction temperature

$$T_h = 300 \text{ K}$$

$$T_c^2 = \frac{DT_{max}\, 2\, R_m K_m}{S_m^2}$$

$$= \frac{345*2*13.6*0.476}{1.5625}$$

$$T_c = 155K$$

Hence the difference in temperature can be given as

$$DT = T_H - T_c = 300\text{-}155$$

$$= 145 \text{ k}$$

$$DT = 145 \text{ K}$$

$$Qc = (S_m*T_c*I) - (0.5*I^2*R_m) - (K_m*DT)$$

$$Qc = 57 \text{ W}$$

$$V_{in} = (S_m*DT) + (I*K_m)$$

$$V_{in} = 182.85 \text{ V}$$

$$P_{in} = V_{in} *I$$

$$P_{in} = 182 \text{ W}$$

$$Q_H = P_{in} + Q_c$$

$$= (182+57)$$

$$Q_H = 239 \text{ W}$$

$$COP = \frac{Q_c}{P_{in}}$$

$$= \frac{57}{182}$$

$$COP = 0.313$$

The necessary modification are as follows.

The maximum current

$$I_{max} = 8.5 \text{ amp}$$

The maximum voltage

$$V_{max} = 17.5 \text{ V}$$

The maximum work done or heat generation

$$Q_{max} = 80W$$

The maximum differential temperature

$$DT_{max} = 72\ °C = 345K$$

Thermal module resistance

$$R_m = 2.509\ \Omega$$

Seebeck module coefficient

$$S_m = 1.25 \text{ V/K}$$

Internal module resistance or thermal conditioning

$$K_m = 0.471\ W/K$$

The hot function temperature

$$T_h = 300 \text{ K}$$

The cold function temperature Tc can be evaluated using the module formula with expression for maximum temperature difference

$$T_c^2 = \frac{DT_{max}\,2\,R_m K_m}{S_m^2}$$

$$= \frac{345*2*13.6*0.476}{1.5625}$$

$$T_C = 155K$$

Hence the difference in temperature can be given as

$$DT = T_H - T_c = 300\text{-}155$$

$$DT = 145\ K$$

It is essential to calculate the total heat energy of the cold junction which can be evaluated using the following expression

$$Q_c = (S_m * T_c * I) - (0.5 * I^2 * R_m) - (K_m * DT)$$

$$= (1.25*155*8.5) - (0.5*2.059*8.5^2) - (0.471*145)$$

$$Q_c = 1504.195\ W$$

The supply voltage which also termed as the input voltage which is expressed

$$V_{in} = (S_m * DT) + (I * K_m)$$

$$= (1.25*145) + (8.5*1.6)$$

$$V_{in} = 194.85\ V$$

With the supply voltage the power input to the function can be evaluated of as follows

$$P_{in} = V_{in} * I$$

$$= 194.85 * 8.5$$

$$P_{in} = 1656.22\ W$$

The total heat energy of the hot function can be evaluated as a function of the input power of the total heat generation at the cold function which can be expressed as

$$Q_H = P_{in} + Q_c$$

$$= (1656.22 + 1504.195)$$

$$Q_H = 3160.415\ W$$

Finally the coefficient of performance using the peltier can be numerically calculated as

COP=0 .91

**Conclusion:**

The past results indicated that the temperature of the refrigeration was reduced from 27 °C to 5°C in approximately 44 min. The coefficient of performance of the refrigerator (COP) was calculated and found to be about 0.16. A Peltier module from Ferrotech is being used along with 127 couple, 8.5 amps, PN Junction. Initially the COP has to be found to be 0.31 at the expense of the extreme power consumption. After suitable modification in the couple and the junction the COP has to be found to be 0.91 which is at desirable power consumption and effective refrigeration.

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