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DESIGN, FABRICATION AND ANALYSIS OF THERMOELECTRIC REFRIGERATOR.

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Abstract Refrigeration is the process of removal of heat from a body at lower temperature and sending it to surroundings. The present day refrigeration devices use refrigerant gases like Freon's to do refrigeration which result in release of CFC sin to atmosphere which thereby result in depletion of ozone layer. But by using Thermo electric refrigeration this impact can be reduced. This project deals with design, fabrication and analysis of Thermo electric refrigerator. This refrigerator contains thermoelectric modules, Switched mode power supply equipment, Heat sinks, exhaust fans and temperature controlling switches. This project also includes the analysis of this refrigerator. Thermoelectric has a lot of scope in refrigeration, electric generators etc. This chapter recalls the general principles and main formulations useful in the study of thermoelectric coolers. Starting from the general heat diffusion equation, analytical expressions are introduced for the determination of cooling capacity and rate of heat rejection in steady-state conditions. When dealing with the whole refrigeration system, the limits of the steady-state analysis of the individual thermoelectric elements are pointed out, indicating the need for transient analysis supported by experimental evaluations. Then, the energy indicators are illustrated by considering the electrical power consumption, the thermal performance described by the dimension -less figure of merit, as well as the coefficient of performance. Furthermore, the main methods to enhance the thermoelectric cooler performance in refrigeration units are highlighted, with reference to highperformance materials, design aspects and temperature control systems. Finally, indications are reported on some applications of various thermoelectric refrigeration solutions,considering the technical aspects of the performance of these systems.

INTRODUCTION

Refrigeration is the process of heat removal from as pace in order to bring it to a lower temperature than surrounding temperature. In this context, "Peltier cooling module" which works on thermo electric refrigeration, aims to provide cooling by using thermoelectric effects rather than the more prevalent conventional methods like 'vapour compression cycle' or the 'vapour absorption cycle' There are three type so thermo electric effect. See beck effect, Peltier effect, Thomson effect. Peltier refrigerator works on the peltier effect which states that when voltage is applied across two junctions of dissimilar electrical conductors, heat is absorbed from one junction and heat is rejected at another junction.

Thermoelectric cooling uses the peltier effect to createa heat flux between the junctions of two different typesof materials. A pettier cooler, heater, or thermo electric 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 thermo electric cooler. It can be used either for heating or for cooling, although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools. Many researchers and companies are trying to develop peltier coolers that are cheap and efficient.

A Peltier cooler can also be used as a thermo electric 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 willbuild up between the two sides (the see beck effect).However, a well-designed peltier cooler will be mediocre thermoelectric generator and vice versa, due to different design and packaging requirements.

3. Methods to enhance the TEC performance in refrigeration units Some methods to enhance the TEC performance are-

- Development of thermoelectric materials with highperformance
- TEC design
- Thermal design
- Optimization of the internal temperature controller of the insulated compartment

- **Development of thermoelectric materials with high performance**

A thermoelectric refrigerator unit operates with COP typically less 0.5 due to the limited cooling temperature toΔT max f f i 20 K under the ambient temperature [20]. Figure 6 shows a comparison of the theoretical COP of a TEC with respect to household refrigerators [36]. Refrigerators with thermoelectric modules with materials based on alloys of Bi_2Te_3 have a COP about 1 [9] which is low enough to be competitive to the vapour-compression systems with COP = 2 ÷ 4 [37–39]. The low COP values of TECs are not considered a drawback. These systems are more suitable for a niche market sector (below 25 W) such as military and medical industries, in applications such as temperature stabilization of semiconductor lasers and vaccine cooling. Furthermore, they are also suitable for the civil market (e.g., portable refrigeration, car-seat cooler, high- quality bevel- age conservators). For these applications, the thermoelectric elements have the advantages that do not suffer vibrations and shocks.

3.2. TEC design

TEC design involves the choice of number of thermocouples and thermo element length and is carried out by looking at the module parameters. For example, for domestic refrigeration the thermo element length optimization is strongly linked to COP, cooling capacity and material consumption. To improve COP and cooling capacity, the contact resistances, especially thermal contact resistance, must be reduced. In devices with long thermo elements, the COP is high, and the contact resistances have a little effect on the cooling capacity, while in devices with short thermo elements, the contact resistances have an increased influence on the cooling capacity; in particular, starting from a long thermo element and reducing its length, the cooling capacity increases up to a maximum value then it decreases sharply [20]. As mentioned above, the thermal performance of a TEC depends on the thermoelectric material properties which change with the TEC operating temperature. Some manufacturers use the maximum design parameters and the performance chart [43]. The performance chart takes ΔT and _Qc as inputs and determines the current and thus the voltage needed to produce the cooling effect. Another possibility is to consider voltage, current andΔT as known quantities (e.g. measured) in order to find _Qc. A key aspect of the use of the TEC performance chart is that the module parameters are considered to be known and unchanged for different devices, while actually these parameters change because of the outcomes of the manufacturing process. The design procedure illustrated in [43] is simplified by considering the thermal resistance of the heat sink as one of the key parameters, avoiding the heat transfer analysis of the heat sink.

3.3. Thermal design

Thermal design involves the determination of the heat sink geometry considering the thermal resistances and the optimization of the heat sink characteristic. The heat sink located on the hot side is useful to dissipate heat from the TEC system to the environment and is considered an important factor affecting the TEC performance. Therefore, to enhance the TEC performance, the heat sink must have a low thermal resistance (to be minimized). Important TEC efficiency improvements are obtained by optimization of the different types of heat exchangers at the hot side (water-air system with a cold plate, pump and fan coil, finned heat sink with fan, heat pipe with fan) . A normal heat sink uses fins to increase heat transfer surface. When the thermal resistance of the heat sink is computed, it is necessary to take into account an additional heat thermal resistance of the thermal grease applied to provide a good thermal contact between TEC and heat sink [45]. The design of the heat sinks is presented in [4], where some aspects useful to find the optimal heat sink geometry (fin thickness and position) are detailed. Sometimes at the hot side of TEC, thermal storage using phase change materials (PCMs) or a heat pipe heat exchanger may take the place of a heat sink with fins in order to reduce the temperature Tc of the TEC. For thermal storage, the heat sink is designed to have a high storage capacity to keep the sink temperature less than the junction temperature. In this case, PCMs are useful to improve the performance of the thermoelectric refrigerator. These high-energy-density materials have the advantage that the heat is transferred at constant temperature. In this case, Tc is constant during the phase change, so that _Qc and COP remain constant as well. For a conventional refrigerator, the utilization of a heat sink with fins at the cold side of the TEC supposes a fast Tc reduction until ΔTmax of the cooler is obtained, while using PCMs a slow reduction of the cold side temperature tillΔTmax is obtained. Furthermore, PCMs operate in a wide range of phase change temperatures, providing different alternatives to be used at the hot side and at the cold side of the TEC [46]. These materials are very suitable for different types of thermoelectric refrigerators for food (domestic refrigerators; refrigerators/freezers; hotel room minibar refrig- erators preferred for their silent operation; refrigerators for mobile homes, trucks, recreational vehicles, and cars; food service refrigerators for airborne application; and portable picnic coolers) as well as for medicine storage which need precise temperature control [8, 46]. Refrigerators based on PCMs exhibit useful storage capacity behavior in case of blackout, as they are able to limit the temperature variation during a blackout much more than other materials. The heat pipes are heat exchangers with very high thermal conductivity using ethanol or methanol as refrigerant water. They are used on the both sides of the TEC to dissipate both the cooling and waste heat to the heat sinks. If heat pipes with a thermo siphon are used at the hot side of the TEC, the waste heat is rejected to the environment by natural or forced convection. These systems have a low thermal resistance, leading to reduction of the temperature differential between the hot side temperature of the TEC and the environmental temperature. The heat pipes are used at the cold side of TEC to keep Tc constant during peak and Thermoelectric Refrigeration Principles off-electricity times [46, 47]. Two prototypes of thermoelectric refrigerator are described in [48], one with finned heat sink and the other one with a finned heat sink integrated in an aluminumthermosiphon in which phase change occurs. The thermo siphon depends on the specific latentheat at the phase change from vapour state to liquid state, useful to disperse the heat efficiently to the environment. The results of the experimental heat sink optimization demonstrated that the thermal resistance between the hot side of the TEC and the environment reduced with about 23.8% at 293 K environment temperature and 51.4% at 308 K, with respect to a commercial finned heat sink, and between 13.8% and 45% with respect to an optimized finned heat sink. Much more, the COP of this prototype is 26% at ambient temperature of 293 K, achieving 36.5% improvement at 303 K

3.4. Optimization of the internal temperature controller of the insulated compartment

The operating conditions of a thermoelectric refrigerator depend on parameters as environment temperature, humidity, lower set point of the internal temperature and difference between higher and lower set points of the internal temperature. In vapour- compression refrigerators, the internal temperature control inside the insulated compartment is generally inaccurate due to the multitude of start and stop cycles made by the compressor, leading to a temperature variation bigger than 8 C, with a negative effect on the quality of the food and on the conservation of the perishable food [50, 51]. This represents a drawback for these refrigerators compared with the thermoelectric refrigerators in which there are no start and stop cycles and the supply voltage gradually increases. However, overall the thermoelectric refrigerators are not competitive with vapour-compression refrigerators in terms of COP [10, 11, 48]. Most of the thermoelectric refrigerators have on/off control systems for the internal temperature. This control is critical in the period in which the TEC is switched off, because in this period, the heat stored in the heat sink connected to the hot terminal returns into the refrigerator compartment; in this way, the power consumption of the refrigerator increases and the COP decreases.

4. Thermoelectric refrigeration unit applications

In spite of their relatively low efficiency with respect to other refrigeration technologies, the TEC technologies are experiencing a period of development, with subsequent efficiency improvement and reduction of the manufacturing costs [52]. One of the drivers that have increased the interest in the development and use of TECs as refrigerators is the absence of environmental pollution in the TEC operation, in particular, the absence of chlorofluorocarbon (CFC) issues. The current trends towards replacement of CFCs consider good solutions with low global warming potential (GWP) using natural refrigerants like CO2 used at pressures much higher than traditional refrigerants [6, 53]. Further drivers to increase the TEC applications depend on positive aspects of the TECs such as low noise, possibility of operation in different positions, absence of mechanical vibrations, ease of transportation and possibility to obtain accurate temperature control. Today, thermoelectric refrigerators are the most significant applications at the commercial level. In addition to domestic refrigerators [10, 54, 60], other applications have been developed for food-related services, such as portable refrigerators [55–57], food expositors, refrigerators mounted on vehicles for perishable food transportation as well as low-power refrigerators for minibar, hotel room, offices, boats and aircraft services [8]. Further applications are available for the medical sector (vaccine transportation and instruments for blood coagulators, dew point sensors and others), for the military sector and for scientific devices subject to precise temperature control [58]. In addition, thermoelectric systems are found in the automobile industry for air conditioning or car-seat coolers [59] and in different applications to the microelectronics sector [60, 61]. Besides the applications mentioned above, the present trend towards the use of green energy raises the attention on the possibility of supplying the thermoelectric refrigerator through Thermoelectric Refrigeration Principles. Energy produced from renewable sources. The refrigerators powered by renewable sources may work in stand-alone of off-grid connection. To connect a thermoelectric refrigerator to the PV module in off-grid mode, the possibilities.

- the refrigerator is directly powered by the PV panel (the main components are the PV panel, the battery bank, the battery charge controller and the refrigerator)

- the refrigerator is indirectly powered by the PV panel (the main components are the PV panel, the battery bank, the inverter for AC grid connection and the AC-supplied refrigerator). Solar-driven thermoelectric refrigerators are of two types, namely, PV- battery thermoelectric systems and PV-PCM thermoelectric systems. The performance of the PV-battery thermoelectric systems depends on the intensity of solar radiation and temperature difference at the hot and cold sides of the TEC. In the case of PV- PCM thermoelectric systems, the PV is directly connected to the TECs having PCMs fixed at the cold side to replace the battery. Thermal storages have generally restricted capacity, and to improve this in some applications, the thermoelectric units use PCM integrated with thermal diodes

Field Experience

Experiments are conducted to analyses the COP. The power supply from the battery eliminator is given to system and readings of temperatures at different places are taken by placing the thermocouples near modules, at center and outside the heat sink for every 10 minutes of time. The readings are tabulated and check for least temperatures occur in cabin and maximum temperatures occur at the outside heat sink. After that the power is switch OFF and checks for the storage times of the cabin and readings are taken. The tabulated values are plotted as temperature vs time for power ON and OFF conditions.

3. Construction

The cabin of volume 21 lit. is fabricated using galvanized sheets and polyurethane foam(puff). The inner surface of the cabin is insulated completely using puff (3.8mm) so as to isolate the cooling cabin from the atmosphere. The thermoelectric module is sandwiched between two CPU heat sinks of different sizes using thermal paste to set a single unit. Thermal paste plays a vital role in conduction of heat from Peltier module to the aluminum heat sinks. One such unit is made. These units are placed in the cut slots with the smaller CPU heat sink facing the interior of the cooling cabin and the larger CPU heat sink on the outside of the cabin to establish greater heat rejection. Additionally fans are fitted on the inner and outer side of the heat sinks. Electrical connections are made and power is supplied from a 12V battery eliminator. K type thermocouples are placed inside the cabin and outside the heat sink to record the temperatures. Separate control panel containing dc eliminator switches and temperature indicator is made for taking readings.

LITERATURE SURVEY:

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 cuboids style as shown in respective figures. In pyramid style configuration top side is being coldest as current is unidirectional. In cuboids 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. 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 multielements was analysed. To improve and maximize 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 multicouple thermoelectric refrigerator. This information may be used to manufacture and design thermoelectric refrigerator which will perform at its optimum level.

OBJECTIVES:

1. To make a complete mechanical device: The idea is to make a device which does not use any electrical power so that it is fully independent of its electricity.
2. To make a device which is suitable economical for small Scale industries: taking in to consideration the cost factor this device is suitable for small scale as well as large scale industries.
3. Taking safety as a prime consideration: This device is safer in all aspects.
4. To build a device which can do various operations like glass handling and fork lift.

SUMMARY OF REVIEW:-

1. The Coefficient of performance of the system for TEC1 calculated from the average of readings. It is observed that COP of Thermoelectric refrigeration using TEC1 is lesser than COP of VCRS.
2. Solar power can be used as power source to the system as it is a renewable source of energy. This immensely decreases the working cost of the refrigerator and burden on the earth.
3. Liquid cooling at hot side can be used to increase the refrigeration effect.
4. Waste heat can be recovered using ducts for heating purpose,
5. Number of Peltier modules or multistage Peltier modules can be used to increase the cooling effect. We feel the project that we have done has a good future scope in any engineering industry. The main constraint of this device is the high initial cost but has low operating costs. Savings resulting from the use of this device will make it pay for itself with in short period of time& it can be a great companion in any engineering industry dealing with rusted and unused metals. The device affords plenty of scope for modifications, further improvements & operational efficiency, which should make it commercially available &attractive. If taken up for commercial production and marketed properly, we are sure it will be accepted in the industry. It has plenty of scope if the device is made larger in size so that the capacity of shearing the metals is more and it can be used in the factory premises.

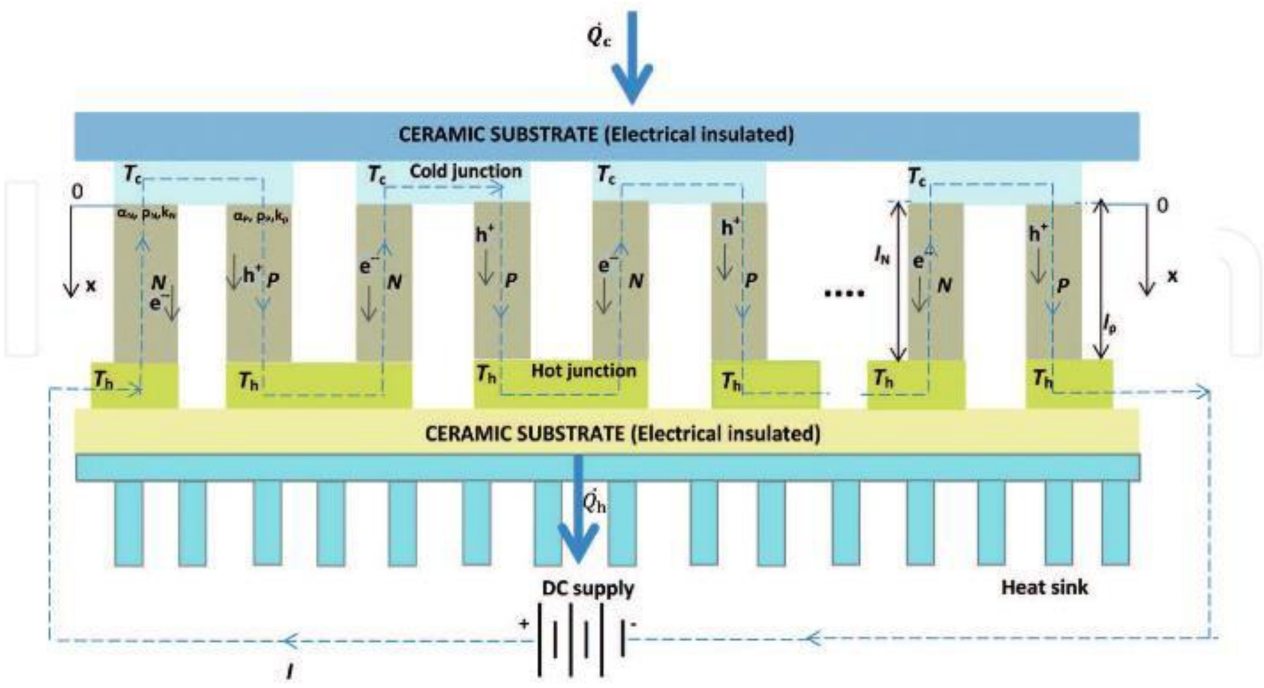

Figure 2. Schematic of a thermoelectric module (TEM) operating in cooling mode.

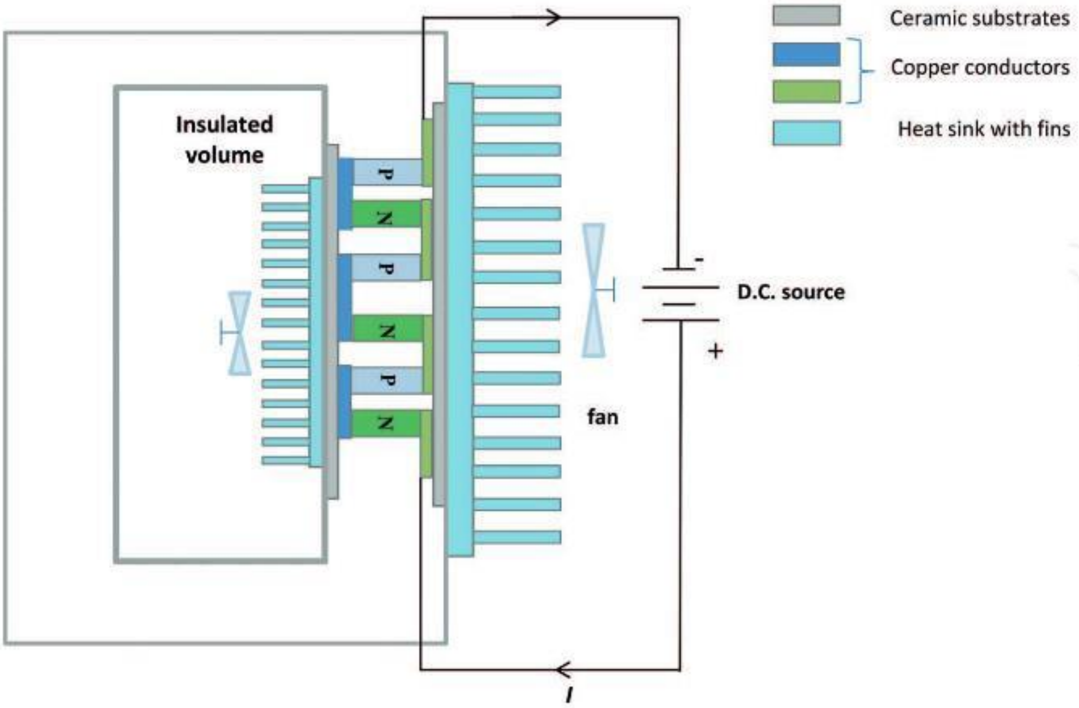

Figure 3. Schematic of a TEM used for the refrigeration unit.

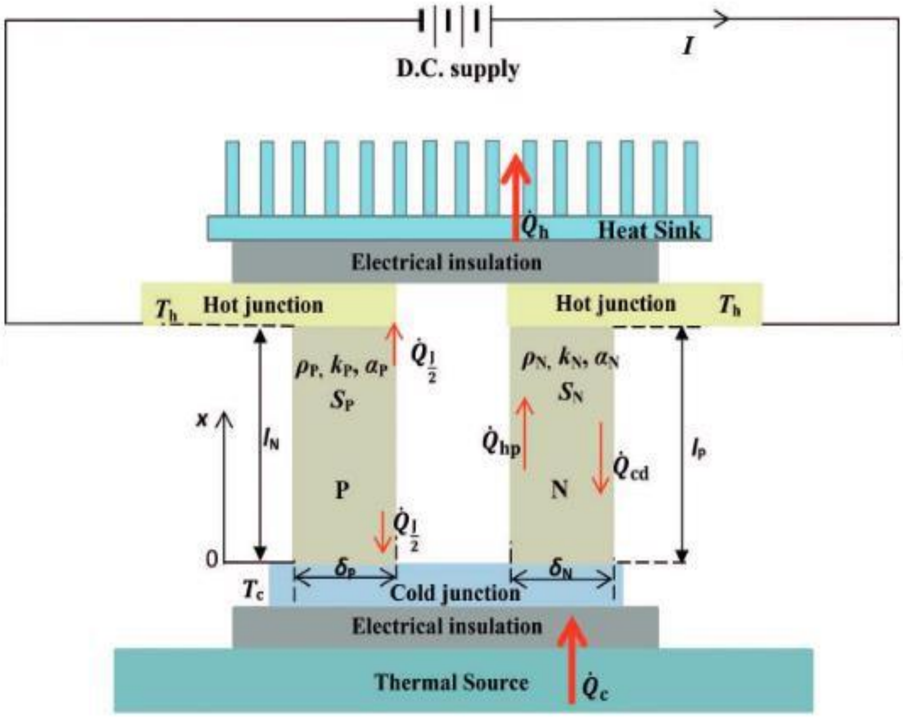

Figure 4. Schematic of a TEC (geometric elements and material properties).

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