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Thermoelectric Cooler

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Abstract: **This paper examines and presents the working of solar refrigerator based on thermo electric cooling and Peltier effect. Like other countries of GCC, the UAE realizes that it has to rely less on oil and gas and start to consider other sources of energy for power production. Solar energy has been one of the most important renewable resources of energy that has been lately used for generating electricity. But amount of electricity generated from these solar panel systems is not enough for efficiently controlling a device. The aim of my work here is to use this solar energy, not to generate electricity but to directly convert solar heat applied on one side of the surface of the thermo electric element into refrigeration effect on the other side, based on peltier effect and thermo electric cooling. The main principle of the solar refrigerator is to produce a positive and negative temperature effects on its either junctions by supplying an electrical voltage with extra heat available on the plate through solar heat to generate a cooling effect. Thermoelectric cooling systems have advantages over conventional cooling devices, such as compact in size, light in weight, high reliability, no mechanical moving parts and no working fluid.**

Keywords: **Solar energy, Thermo electric cooling, Peltier effect, Refrigeration.**

I. INTRODUCTION

Solar refrigerators are one of the latest advancements in modern world and its maximum applications are in transporting small elements/ medicines from one place to another where an only solar light is available to us and this solar heat is used to generate enhanced cooling effect on the other side of the thermo-electric element. The main principle of operation of our Solar Refrigerator is to produce a positive and negative temperature effects on its either junctions by supplying an electrical supply voltage to it and with extra heat available on the plate through solar heat to generate a cooling effect on the other side.

In industries, Solar Refrigerators are used for the storage of medicines and solar based cooling devices.The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice-versa. A thermoelectric device creates a 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 charge carriers in the material to diffuse from the hot side to the cold side, similar to a classical gas that expands when heated; hence inducing a thermal current.

This technology is far less commonly applied to refrigeration than vapor-compression refrigeration is. The main advantages of a thermo electric cooler (compared to a vapor-compression refrigerator) are its lack of moving parts or circulating liquid, and its small size and flexible shape (form factor). Its main disadvantage is that it cannot simultaneously have low cost and high power efficiency. Many researchers and companies are trying to develop thermo eclectic coolers that are both cheap and efficient.

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

II. COMPONENTS

A. Performance of thermoelectric elements:

Thermoelectric junctions are generally only around 5–10% as efficient as the ideal refrigerator (Carnot cycle), compared with 40–60% achieved by conventional compression cycle systems (reverse Rankine systems using compression/expansion). Due to the relatively low efficiency, thermoelectric cooling is generally only used in environments where the solid state nature (no moving parts, maintenance-free, compact size) outweighs pure efficiency.

Thermoelectric cooler performance is a function of ambient temperature, hot and cold side heat exchanger (heat sink) performance, thermal load, thermo electric module (thermopile) geometry, and thermo electric electrical parameters.

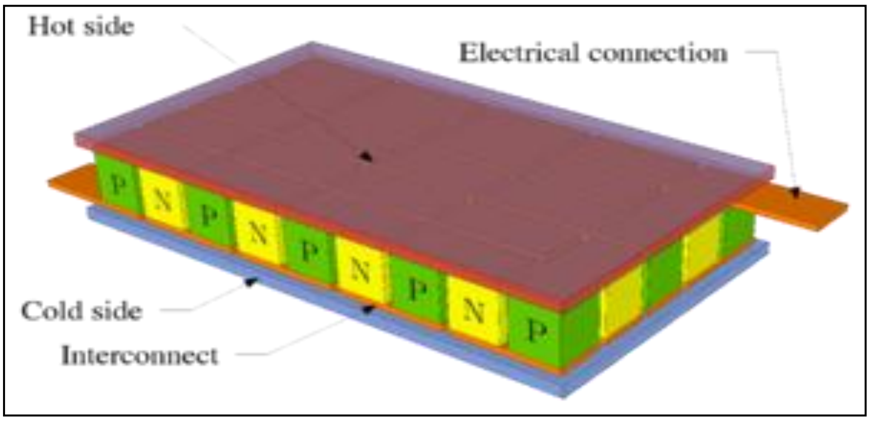

Fig.1: Thermo electric element schematic. Thermoelectric legs are thermally in parallel and electrically in series.

B. TEC Construction:

TECs are constructed using two dissimilar semi-conductors, one n-type and the other p-type (they must be different because they need to have different electron densities in order for the effect to work). The two semiconductors are positioned thermally in parallel and joined at one end by a conducting cooling plate (typically of copper or aluminium). A voltage is applied to the free ends of two different conducting materials, resulting in a flow of electricity through the two semiconductors in series. The flow of DC current across the junction of the two semi-conductors creates a temperature difference. As a result of the temperature difference, Peltier cooling causes heat to be absorbed from the vicinity of the cooling plate, and to move to the other (heat sink) end of the device.

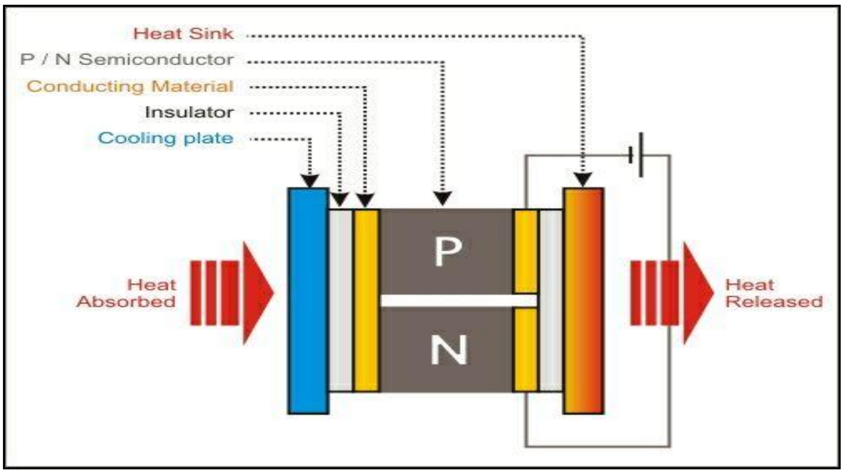

Fig.2: TEC inner view.

The heat is carried through the cooler by electron transport and released on the opposite ("hot") side as the electrons move from a high to low energy state. When the two materials are connected to each other by an electrical conductor, a new equilibrium of free electrons is established. Potential migration creates an electrical field across each of the connections. When current is subsequently forced through the unit, the attempt to maintain the new equilibrium causes the electrons at one connection to absorb energy, while those at the other connection release energy. In practice many TEC pairs (or couples), such as described above, are connected side-by-side, and sandwiched between two ceramic plates, in a single TEC unit.

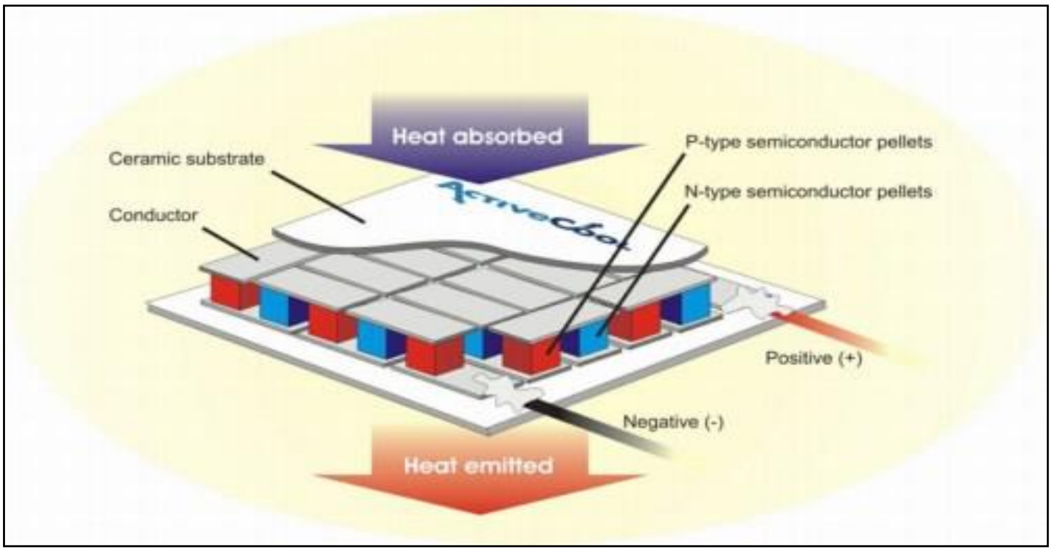

Fig.3: Working of a TEC.

C. Heat Sink:

In electronic systems, a heat sink is a passive component that cools a device by dissipating heat into the surrounding air. Heat sinks are used to cool electronic components such as high-power semiconductor devices, and optoelectronic devices such as higher-power lasers and light emitting diodes (LEDs). Heat sinks are heat exchangers such as those used in refrigeration and air conditioning systems, or the radiator in an automobile.

A heat sink is designed to increase the surface area in contact with the cooling fluid surrounding it, such as the air. Approach air velocity, choice of material, fin (or other protrusion) design and surface treatment are some of the factors which affect the thermal performance of a heat sink. Heat sinks are used to cool computer central processing units or graphics processors. Heat sink attachment methods and thermal interface materials also affect the eventual die temperature of the integrated circuit. Thermal adhesive or thermal grease fills the air gap between the heat sink and device to improve its thermal performance. Theoretical, experimental and numerical methods can be used to determine a heat sink's thermal performance.

Basic heat sink heat transfer principle A heat sink is an object that transfers thermal energy from a higher temperature to a lower temperature fluid medium. The fluid medium is frequently air, but can also be water or in the case of heat exchangers, refrigerants and oil. If the fluid medium is water, the 'heat sink' is frequently called a cold plate. In thermodynamics a heat sink is a heat reservoir that can absorb an arbitrary amount of heat without significantly changing temperature. Practical heat sinks for electronic devices must have a temperature higher than the surroundings to transfer heat by convection, radiation, and conduction.

D. Thermal paste:

Heat sinks operate by conducting heat from the processor to the heat sink and then radiating it to the air. The better the transfer of heat between the two surfaces (the CPU and the heat sink metal) the better the cooling. Some processors come with heat sinks glued to them directly, ensuring a good transfer of heat between the processor and the heat sink.

Heat sinks that are attached using clips normally sit rather loosely on top of the processor. It may feel like it is attached securely, but there will be a gap between the CPU and the heat sink, and that gap of air them makes for poor heat transfer, even if it is very small. Air is a poor conductor of heat compared to most liquids or solids. To improve the thermal connection between the processor and heat sink, a special chemical called heat sink compound should be used. A thin layer of this is spread between the two, which greatly improves heat transfer and the cooling of the processor.

Heat sink compound is typically a white paste made from zinc oxide in a silicone base. Very little of the substance is needed, just enough to fill the gap between the CPU and heat sink.

E. Peltier plates and peltier effect:

Peltier thermo-elements are mainly made of semi conductive material with several P – N contacts.

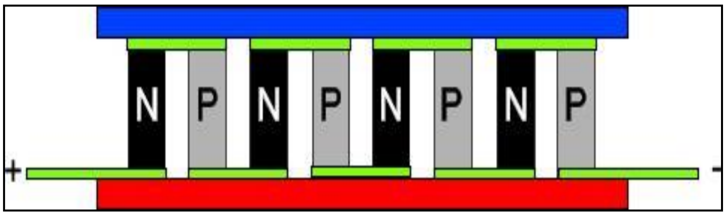

Fig.4: Internally connecter P-N contacts within a peltier TEC.

The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material. This phenomenon can be useful when it is necessary to transfer heat from one medium to another on a small scale. The Peltier effect is one of three types of thermoelectric effect; the other two are the Seebeck effect and the Thomson effect.

In a Peltier-effect device, the electrodes are typically made of a metal with excellent electrical conductivity. The semiconductor material between the electrodes creates two junctions between dissimilar materials, which, in turn, creates a pair of thermo couple voltage is applied to the electrodes to force electrical current through the semiconductor, thermal energy flows in the direction of the charge carriers. Peltier-effect devices are used for thermoelectric cooling in electronic equipment and computers when more conventional cooling methods are impractical.

The Peltier effect is the presence of heat at an electrified junction of two different metals and is named for French physicist Jean-Charles Peltier, who discovered it in 1834. When a current is made to flow through a junction composed of materials A and B, heat is generated at the upper junction at T_2, and absorbed at the lower junction at T_1. The Peltier heat $\dot{Q}$ absorbed by the lower junction per unit time is equal to $\dot{Q} = \Pi_{AB} I = (\Pi_B - \Pi_A)\, I,$

Where Π_{AB} is the Peltier coefficient for the thermocouple composed of materials A and B and Π_A (Π_B) is the Peltier coefficient of material A (B). Π varies with the material's temperature and its specific composition: p-type silicon typically has a positive Peltier coefficient below ~550 K, but n-type silicon is typically negative.

The Peltier coefficients represent how much heat current is carried per unit charge through a given material. Since charge current must be continuous across a junction, the associated heat flow will develop a discontinuity if Π_A and Π_B are different. Depending on the magnitude of the current, heat must accumulate or deplete at the junction due to a non-zero divergence there caused by the carriers attempting to return to the equilibrium that existed before the current was applied by transferring energy from one connector to another. Individual couples can be connected in series to enhance the effect. Thermoelectric heat pumps exploit this phenomenon, as do thermoelectric cooling devices found in refrigerators

The Peltier effect can be used to create a refrigerator which is compact and has no circulating fluid or moving parts; such refrigerators are useful in applications where their advantages outweigh the disadvantage of their very low efficiency.

Peltier effect describes the temperature difference generated by EMF and is the reverse of See beck effect. Finally, the Thomson effect relates the reversible thermal gradient and EMF in a homogeneous conductor. Peltier thermo-element is a device that utilizes the peltier effect to implement a heat pump. A Peltier has a cold plate and a hot plate. Between those plates there are several thermo couples which are connected together. If voltage is applied to those wires, the cold plate will be cold and the hot plate...hot. The device is called a heat pump because it does not generate heat or cold, it just transfers heat from one plate to another, and thus the other plate is cooled. It is also called a thermo-electric cooler or TEC for short. Because TECs have several thermocouples, a lot of heat is transferred between the plates. Sometimes it can reach a temperature difference of 80 degrees Celsius or more.

F. Thermo electric effect and cooling:

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice-versa. A thermoelectric device creates a 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 charge carriers in the material to diffuse from the hot side to the cold side, similar to a classical gas that expands when heated; hence inducing a thermal current.

This effect can be used to generate electricity, measure temperature or change the temperature of objects. Thermoelectric devices are efficient temperature controllers because the direction of heating and cooling is determined by the polarity of the applied voltage.

Thermoelectric cooling uses the Peltier effect 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 electrical 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). The Peltier device is a heat pump i.e. when direct current runs through it, heat is transfered from one side to the other. Therefore it can be used either for heating or cooling (refrigeration), although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools.

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

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Peltier (thermoelectric) cooler performance is a function of ambient temperature, hot and cold side heat exchanger (heat sink) performance, thermal load, Peltier module (thermopile) geometry, and Peltier electrical parameter.

G. Solar panel:

A solar panel (also solar module, photovoltaic module or photovoltaic panel) is a packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications.

Because a single solar panel can produce only a limited amount of power, many installations contain several panels. A photovoltaic system typically includes an array of solar panels, an inverter, and sometimes a battery and interconnection wiring.

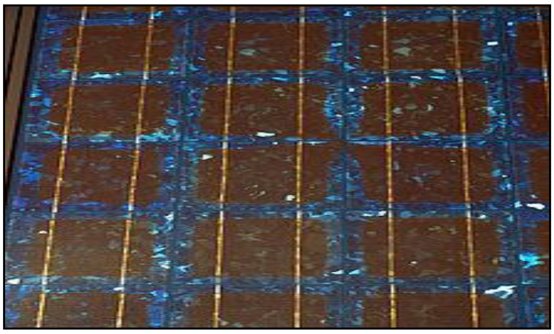

Fig.5: Polycrystalline PV cells connected in a solar panel.

III. WORKING OF THE REFRIGERATOR

The solar refrigerator is the refrigeration system that runs on the solar energy. The solar refrigerator comprises of all the traditional components like the compressor, condenser, expansion valve and the evaporator or the freezer. The power is supplied not by the domestic electrical supply system, but from the solar panel.

The solar system of the solar refrigerator comprises of the solar panel that collects the solar energy. The solar panels are fitted with photovoltaic cells that convert the solar energy into electrical energy and store it in the battery. During the normal running of the solar refrigerator the power is supplied directly by the solar panel, but when the output power of solar panels is less, the additional power is supplied by the battery. The battery is recharged when excess amount of power is produced by the solar panels.

The output supply of the batteries and the solar panel is DC with voltage of about 12volts. A typical solar system produces 300W or 600W of power depending upon the size of the desired refrigerator. The voltage regulator is connected to the battery to convert the low voltage DC supply to high voltage AC supply to run the compressor. It is advantageous to use the AC supply compressor since it can run on domestic electrical supply also. Some of the solar refrigerators use compressors that can run directly on DC supply. The electric supply then from the battery goes to the thermo electric cooling peltier plates and a hot and cold region is formed. Our desired result (cooling) can be observed in the cold region and the heat produced in the heat sink is removed by a fan.

A. Experimental setup:

A Solar panel is connected with a diode (to prevent back current) which is further connected to a 12 volt battery. A metal cavity is made which is covered by thermocol to maximize the cooling effect. Below the thermocol, there are thermo electric cooling plates which are connected to the battery. Thermal paste is applied between TEC's and thermocol. Battery is also connected with a measuring device (which shows the temperature drop) and an exhaust fan (in the heat sink to remove the heat produced).

Fig.6: Experimental setup.

IV. CONCLUSION

A. Advantages over existing cooling systems:

The advantages of the solar refrigerator are similar to the ones offered by the other solar energy devices. The solar energy is available freely, abundantly and is a clean source of energy. One of additional advantage is that the excess power produced by the solar refrigerator can be used for the other domestic purposes. The solar refrigerators can be very useful in far off remote places where there is no continuous supply of electricity. In Maruata village, located on Mexican Pacific Coast, the fishermen use solar refrigerator for keeping the fish fresh.

Air Cooling, Oil Cooling, Water cooling are some of the techniques that have been implemented in commercial transformers for reducing the heat loss thereby increasing the transformer efficiency and life. Due to some of the disadvantages of such coolants like slow effects, bulky material requirement, large space coverage and cost, thermoelectric effect cooling can be devised and used for the same. This fundamental difference gives solid-state thermoelectric coolers the following advantages over compressors:

a. No moving parts. Therefore they require little or no maintenance. Ideal for cooling parts that may be sensitive to mechanical vibration.
b. No refrigerants such as potentially harmful CFCs are used hence they are environment friendly.
c. Enables reduced low-noise operation of cooling fans, while providing greater cooling power.
d. Suitable for manufacture in very small sizes, therefore ideal for use in the field of microelectronics.
e. They are lightweight and have a long life.
f. Thermo electric coolers can be controlled (by voltage / current).
g. It is small in size and is dynamic in response.
h. Can provide cooling below ambient temperature.

B. Disadvantages:

The disadvantage of the solar refrigerator is that the production of power is not uniform since solar energy is not available throughout the day and it also changes in intensity during various times of the year. Hence, it can be used only in places where solar energy is available throughout the year. The other major disadvantage of the solar refrigerator is the size of the solar collector occupying large areas of the home. To produce power sufficient for the refrigerator, big solar panels are required which will occupy a large area.

A number of solar refrigerators have been developed, and are being used successfully. However, the technology has not been developed to the stage for carrying out commercial production of the solar refrigerators. There are few companies like Haier and Vestfrost which manufacture solar refrigerators, but high costs of the solar equipments, their low efficiency and their large sizes have not made them a popular choice yet.

C. Applications:

Numerous applications on refrigeration and cooling can be mentioned on this latest technique. Some of practical implementation of the same has been mentioned below:

a. Thermo-electric coolers
b. Increasing efficiency of various electrical devices by efficient heat sinking
c. Solar Based Refrigerators Design
d. Thermoelectric AC
e. Waste Heat Utilization System Design for Refrigeration
f. For Cooling Car Seats
g. For Cool Satellites And Space Craft
h. For Making Humidifiers
i. For Laser Cooling
j. Car Batteries
k. For military Purpose where fast and compact cooling required, since it can operate from 12 V batteries or from solar power directly.
l. For Cooling sleeping pads for hotter surface area.
m. It can also act as dehumidifier for extracting water from air, suitable for water deficient areas such as desert.

D. Inference:

A conclusion reached on the basis of reasoning is that the thermoelectric effect may help to provide an environmental friendly way of producing energy. Countries in GCC have abundant solar power and it can be best used with this ideology. This setup can be used for car roof tops to keep the car cool when parked outside in Sun. The cooling effect can be acquired inside and the heat can be released in atmosphere.

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