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Solar Operated Refrigeration System without Refrigerant

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Abstract:
The need for renewable energy sources is on the rise because of the acute energy crisis in the world today. India plans to produce 100 gig watts of solar power by the year 2022, whereas we have only realized 2.7 gig watts of our potential as of March 2015. Solar energy is a vital untapped resource in a tropical country like ours. The main hindrance for the penetration and reach of solar PV systems is their low efficiency and high capital cost. Our project essentially focuses on developing a solar photovoltaic cell based thermoelectric cooler which can function as the air conditioning system in automobiles. In doing so, we can restrict the fuel intake which is needed in the compressor in conventional automobile air conditioning systems. The main objective of our project is to design & make analysis of a Cooling system which utilizes non-conventional energy source (i.e. Solar Energy) with the help of Thermoelectric Module which works on the principle of the Peltier effect. This will be a suitable & affordable system for the people living in remote part of India where load shedding is a major problem. The major difference between the existing system & our system is that, our project works without use of mechanical device & without refrigerant too. As the module is compact in size one can design (i.e. shape, capacity) the system according to his requirement. It is an attempt has been made to conduct an experimental study on small scale solar operated thermoelectric Cooling system.

Keywords: Thermo-Electric Module, Peltier Effect, Solar Energy**,** Solar Cells, Coefficient of Performance.

I. INTRODUCTION:

Renewable & alternative non-conventional green energy technologies used for heat-pumping applications have shown real merits and received renewed interest in recent years especially in small scale portable heating applications. Solar-driven thermoelectric heat pumping is one of these innovative technologies [1]. Solar energy is the most low cost, competition free, universal source of energy as sunshine's throughout. This energy can be converted into useful electrical energy using photovoltaic technology. Thermoelectric refrigerator sometimes called a thermoelectric cooler module or Peltier cooler is a semiconductor based electric component that functions as a small heat pump. By applying a low voltage direct current (DC) power source to a thermoelectric cooler module, heat will be moved through the module from one side to the other. One module face, therefore, will be cooled while the opposite face simultaneously is heated. Both thermoelectric refrigerators and mechanical refrigerators are governed by the same fundamental laws of thermodynamics and both refrigeration systems; although considerably different in form, function in accordance with the same principles. In a mechanical refrigeration unit, a compressor raises the pressure of a refrigerant and circulates the refrigerant through the system. In the refrigerated chamber, the refrigerant boils and in the process of changing to a vapor, the refrigerant absorbs heat causing the chamber to become cold. The heat absorbed in the chamber is moved to the condenser where it is transferred to the environment from the condensing refrigerant. In a thermoelectric cooling system, a doped semi-conductor material essentially takes the place of the refrigerant, the condenser is replaced by a finned heat sink, and the compressor is replaced by a Direct Current (DC) power source. The application of Direct Current (1DC) power to the thermoelectric cooler modules causes electrons to move through the semi-conductor material. At the cold end of the semi-conductor material, heat is absorbed by the electron movement, moved through the material, and expelled at the hot end. Since the hot end of the material is physically attached to a heat sink, the heat is passed from the material to the heat sink and then in turn, transferred to the environment. The main objective of the heating & cooling system service is to be suitable for use by the people who live in the remote areas of country where load-shading is a major problem. The system can also be used for remote parts of the world or outer conditions where electric power supply is not readily available.

II. LITERATURE REVIEW

As we know that, the physical principles upon which modern thermoelectric coolers are based actually date back to the early 1800's, although commercial thermoelectric (TE) modules were not available until almost 1960. The first important discovery relating to thermoelectricity occurred in 1821 when a German scientist, Thomas Seebeck, found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals provided that the junctions of the metals were maintained at two different temperatures [3]. In 1834, a French watchmaker and part time physicist, Jean Peltier, while investigating the "Seebeck Effect," discovered the “Peltier Effect” and it is the fundamental principal behind a thermo-electric system [2]. There are a number of experimental and numerical studies that characterized the performance of TE heating and cooling systems. For example, Luo, et al[4] performed experiments and verified that a TEHP system is more efficient than an electrical heating device, for its heating coefficient reached more than 1.6 with suitable operating conditions. Riffat and Qiu[4] compared the performance of the thermoelectric air conditioner with two other types of domestic air conditioners, namely the vapor compression air-conditioner and the absorption air-conditioner. Bansal and

Martin [5] investigated and compared the performance characteristics of three domestic refrigerators, namely the vapor compression, the thermoelectric and the absorption refrigerators based on actual experimental data. Bansal and Martin [5] also reported that as the TE technology has advanced, the reliability and cost of TE cooling systems have changed favorably and at present TE systems are available for the domestic market at comparable prices. Min and Rowe [9] investigated a number of prototype TE-coolers and evaluated their performances in terms of the COP. Dai et al.[10] conducted an experimental investigation on a portable solar-TE refrigerator for small-scale remote applications or in areas where electric supply is unavailable. Their results showed that the unit can maintain the inside temperature at 5–10^{o}C, and have a COP of approximately 0.3.

IV. OBJECTIVES:

1. To make a refrigeration system dependent on renewable energy resource
2. To provide refrigeration for the people living in remote part of India where load shading is a major problem.
3. To implement cooling with 12v dc cooler boxes.
4. Our system provides the refrigeration effect without the use of refrigerant and mechanical device too.

III. CONSTRUCTION:

Here this system heat or cool the product using thermo-electric-module. The construction set up for this system require following parts

1. Solar panel,
2. Insulated Box (2 chambers)
3. Charge controller,
4. Battery
5. Fins, thermistor,
6.Exaust fan, circuit kit
7. Thermoelectric module.
8. Metal (aluminum box, sheets)

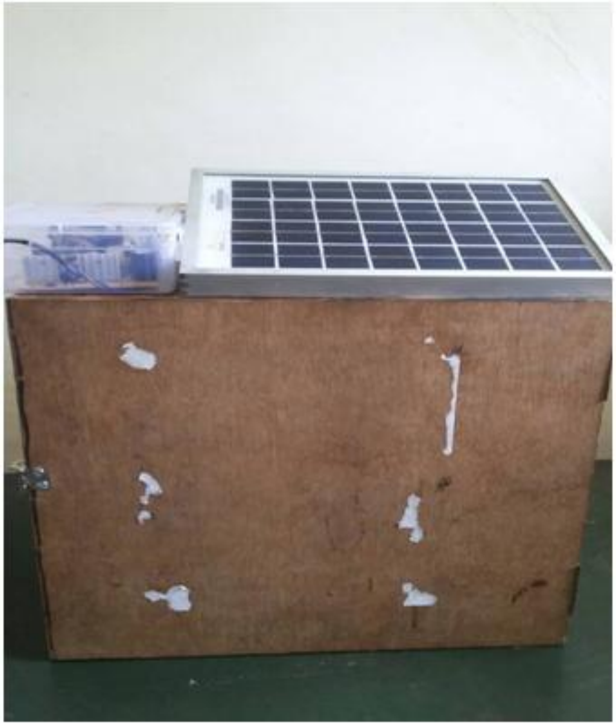


Figure.1.Fabricated Thermo- Electric Refrigerator system powered by solar energy

A. Thermoelectric Module

A typical thermoelectric module is composed of two ceramic substrates that serve as a foundation and electrical insulation for P-type and N-type Bismuth Telluride dice that are connected electrically in series and thermally in parallel between the ceramics. The ceramics also serve as insulation between the modules internal electrical elements and a heat sink that must be in contact with the hot side as well as an object against the cold side surface. Electrically conductive materials, usually copper pads attached to the ceramics, maintain the electrical connections inside the module. Solder is most commonly used at the connection joints to enhance the electrical connections and hold the module together [11]. Most modules have and even number of P-type and N-type dice and one of each sharing an electrical interconnection is known as, "a couple." [11]. While both P-type and N-type materials are alloys of Bismuth and Tellurium, both have different free electron densities at the same temperature. P-type dice are composed of material having a deficiency of electrons while N-type has an excess of electrons. As current flows up and down through the module it attempts to establish a new equilibrium within the materials. The current treats the P-type material as a hot junction needing to be cooled and the N-type as a cold junction needing to be heated. Since the material is actually at the same temperature, the result is that the hot side becomes hotter while the cold side becomes colder. The direction of the current will determine if a particular die will cool down or heat up. In short, reversing the polarity will switch the hot and cold sides

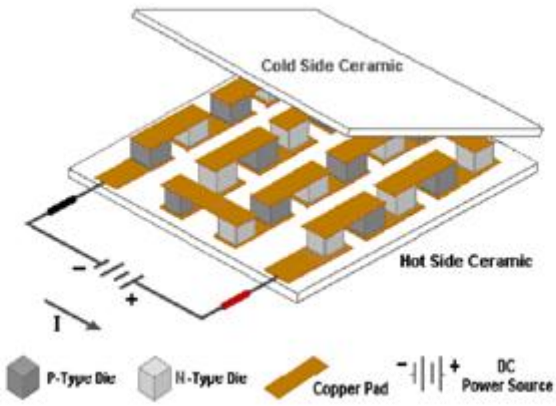


Figure.2. Internal construction of thermo- electric module (Adapted from ADVANCED THERMOELECTRIC · One Tara Boulevard · Nashua, NH 03062 · USA)

V. OPERATING PRINCIPLE OF THE THERMO-ELECTRIC MODULE PELTIER THOERY:

When DC voltage is applied to the module, the positive and negative charge carriers in the pellet array absorb heat energy from one substrate surface and release it to the substrate at the opposite side. The surface where heat energy is absorbed becomes cold; the opposite surface where heat energy is released becomes hot. Reversing the polarity will result in reversed hot and cold sides.

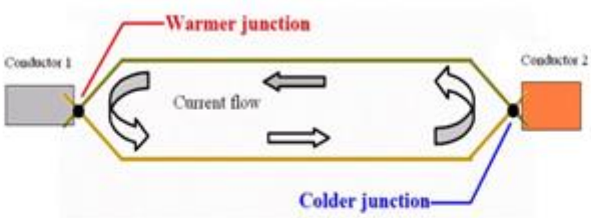
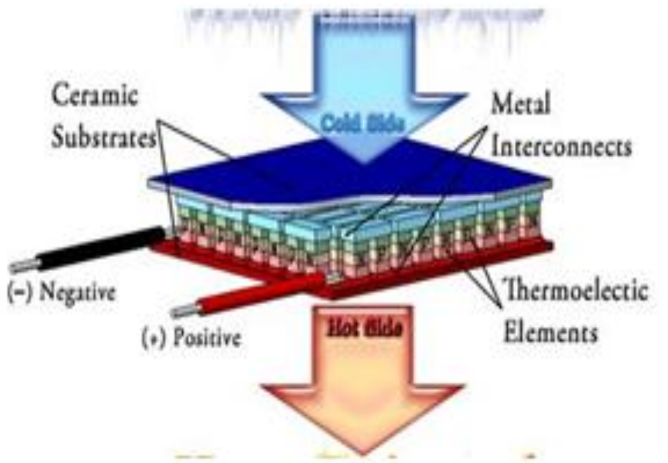


Figure.3.peltier theory:

The TEM operating principle is based on the Peltier effect. The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material 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. On the other hand, the heat from the hot side is utilized for heating purpose. In a thermo-electric heat exchanger the electrons acts as the heat carrier. The heat pumping action is therefore function of the quantity of electrons crossing over the p-n junction

Heat Absorbed



Heat Rejected

Figure.4. Operating principle of thermo-electric module (adapted from scientific and production firm module -ISO 9001)

VI. WORKING OF THERMOELECTRIC MODULE

Thermoelectric modules are solid-state heat pumps that operate on the Peltier effect (see definitions). A thermoelectric module consists of an array of p- and n-type semiconductor elements that are heavily doped with electrical carriers. The elements are arranged into array that is electrically connected in series but thermally connected in parallel. This array is then affixed to two ceramic substrates, one on each side of the elements (see figure below). Let's examine how the heat transfer occurs as electrons flow through one pair of p- and n-type elements (often referred to as a "couple") within the thermoelectric module:

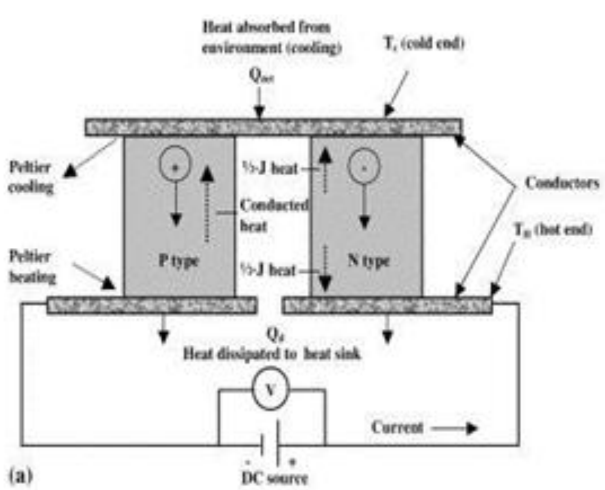


Figure.5. Schematic diagram of thermoelectric cooling

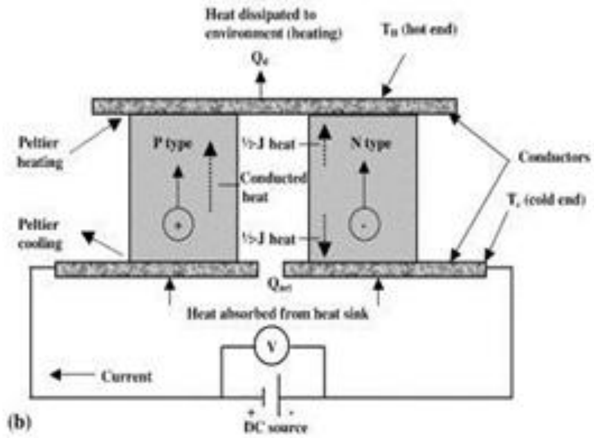


Figure.6. Schematic diagram of thermoelectric heating

Figure.7. Inner view of the system

The p-type semiconductor is doped with certain atoms that have fewer electrons than necessary to complete the atomic bonds within the crystal lattice. When a voltage is applied, there is a tendency for conduction electrons to complete the atomic bonds. When conduction electrons do this, they leave "holes" which essentially are atoms within the crystal lattice that now have local positive charges. Electrons are then continually dropping in and being bumped out of the holes and moving on to the next available hole [5]. In effect, it is the holes that are acting as the electrical carriers. Now, electrons move much more easily in the copper conductors but not so easily in the semiconductors. When electrons leave the p-type and enter into the copper on the cold-side, holes are created in the p-type as the electrons jump out to a higher energy level to match the energy level of the electrons already moving in the copper. The extra energy to create these holes comes by absorbing heat. Meanwhile, the newly created holes travel downwards to the copper on the hot side. Electrons from the hot-side copper move into the p-type and drop into the holes, releasing the excess energy in the form of heat. The n-type semiconductor is doped with atoms that provide more electrons than necessary to complete the atomic bonds within the crystal lattice. When a voltage is applied, these extra electrons are easily moved into the conduction band. However, additional energy is required to get the n-type electrons to match the energy level of the incoming electrons from the cold-side copper. The extra Energy comes by absorbing heat. Finally, when the electrons leave the hot-side of the n-type, they once again can move freely in the copper. They drop down to a lower energy level, and release heat in the process.

VII. RESULTS AND ANALYSIS

Sr.no.	*Time*		*Temperature*	
	Sec.	*Min.*	*°C*	*°F*
1.	0	0	30	86
2.	29	0:29	29	84.2
3.	40	0:40	28	82.4
4.	53	0:53	27	80.6
5.	68	1:08	26	78.8
6.	80	1:20	25	77
7.	89	1:29	24	75.2
8.	108	1:48	23	73.4
9.	120	2:00	22	71.6
10.	140	2:20	21	69.8
11.	157	2:37	20	68
12.	184	3:04	19	66.2
13.	204	3:24	18	64.4
14.	229	3:49	17	62.6
15.	268	4:28	16	60.8
16.	300	5:00	15	59
17.	357	5:57	14	57.2
18.	402	6:42	13	55.4
19.	477	7:57	12	53.6
20.	540	9:00	11	51.8
21.	657	10:57	10	50
22.	766	12:46	9	48.2
23.	994	16:34	8	46.4
23.	994	16:34	8	46.4

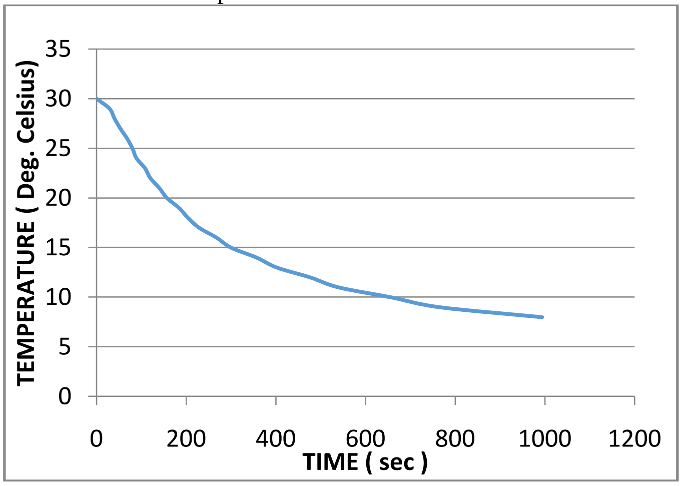
(1) Observation table:-1

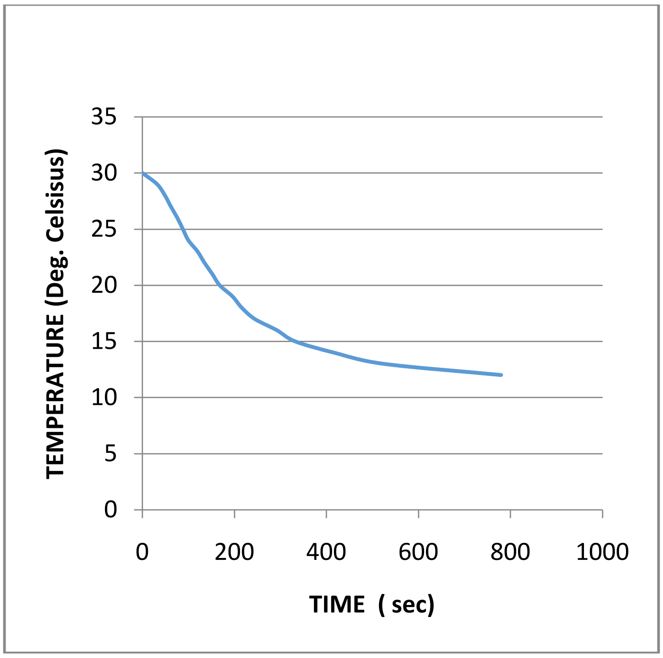
- Module used: TEC1-12709
- Compartment dimensions (mm): 260× 150 × 175 i.e., (Volume of 6825000mm^3).
- Temperature 30^{0}C

Sr.no.	**Time**		**Temperature**	
	Sec.	**Min.**	**°C**	**°F**
1.	0	0	30	86
2.	32	0:32	29	84.2
3.	49	0:49	28	82.4
4.	62	1:02	27	80.6
5.	76	1:16	26	78.8
6.	88	1:28	25	77
7.	100	1:40	24	75.2
8.	120	2:00	23	73.4
9.	135	2:15	22	71.6
10.	152	2:32	21	69.8
11.	168	2:48	20	68
12.	196	3:16	19	66.2
13.	216	3:36	18	64.4
14.	244	4:04	17	62.6
15.	292	4:52	16	60.8
16.	332	5:32	15	59
17.	416	6:56	14	57.2
18.	524	8:44	13	55.4
19.	780	13:00	12	53.6

2. Observation table:-2

- Module used: TEC1-12706
- Compartment dimensions (mm): 340× 140 × 340 i.e (Volume of 16184000mm^3)
- Room Temperature - 30°C





VI. ADVANTAGES

We believe that thermoelectric cooling offers a number of advantages over traditional refrigeration methods, as:

1. No moving parts, eliminating vibration, noise, and problems of wear.
2. No Freon's or other liquid or gaseous refrigerants required,
3. High reliability& durability - We guarantee 5 years hours of no failures,
4. Compact size and light weighted,
5. Relatively low cost and high effectiveness,
6. Eco-friendly C-pentane, CFC free insulation
7. Reversing the direction of current transforms the cooling unit into a heater.

DISADVANTAGE

1. C.O.P. is less as compared to conventional refrigeration system.
2. Suitable only for low cooling capacity.

LIMITATION

In rainy season it cannot be possible to charge battery due to irregular atmospheric condition as our project is totally based on solar energy. This is the limitation of our project, but this problem can be solved by giving direct electric supply.

APPLICATIONS OF SYSTEMS

1. Can be uses for remote place where electric supply is not available,
2. Medical field- Pharmaceutical industry, medicine and medical equipment storage, etc.
3. Military- storing of consumable goods in war affected zones, rural area, etc.
4. Dairy (milk) industry.
5. Mechanical industry.
6. Restaurant and hotel.
7. Vegetable, fish, fruit, beverage, etc. storage.
8. Electronic— miniature cooling units for incoming stages of highly sensitive receivers and amplifiers; coolers for high power generators, CCD cameras, vacuum and solid-state photo detectors and CPU coolers, etc

VII. FUTURE SCOPE

To build a real time model replacing both air conditioner & room heater in one system i.e. thermoelectric hot & cold room conditioner.

VIII. CONCLUSION

From this project we can conclude that without the use of Compressor and the Refrigerant It is possible to cool the system. There are several different types of cooling devices available to remove the heat from industrial enclosures as well as medical enclosures, but as the technology advances, thermoelectric cooling is emerging as a truly viable method that can be advantageous in the handling of certain small-to-medium applications. As the efficiency and effectiveness of thermoelectric cooling steadily increases, the benefits that it provides including self-contained, solid-state construction that eliminates the need for refrigerants or connections to chilled water supplies, superior flexibility and reduced maintenance costs through higher reliability will increase as well**.** it can use in ambulance for storing medical equipment can use in remote area for storing medicines, etc. Blood plasma and antibiotics are manufactured using a method called freeze drying.

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