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Design and Performance Evaluation of Thermoelectric Refrigerator

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***Abstract**: This study outlines the implementation of compressor less refrigerator with peltier module. Compared to conventional refrigeration systems thermoelectric refrigeration based on the Peltier effect, does not require any compressor, expansion valves, absorbers, condensers or solution pumps. Moreover, it does not require working fluids or any moving parts, which is friendly to the environment and results in an increase in reliability. It simply uses electrons rather than refrigerants as a heat carrier. Nowadays, thermoelectric refrigeration devices have a distinct place in medical applications, electronic applications, scientific equipment and other applications, where a high-precision temperature control is essential.*

The device is powered by a Non-conventional energy resource, here PV Cells. The difference between the existing methods and this model is that a thermoelectric cooling system refrigerates without use of mechanical devices (Conventional Condenser fins and Compressor) and without refrigerant too. Since the Peltier module is compact in size, refrigeration or heating system can be designed according to the user's requirements (in desired size and shape).

Keywords: Solar Panel, thermoelectric refrigeration and Thermoelectric Module.

I. INTRODUCTION

With the increase awareness towards environmental degradation due to the production, use and disposal of Chloro Fluoro Carbons (CFCs) and Hydro Chlorofluorocarbons (HCFCs) as heat carrier fluids in conventional refrigeration and air conditioning systems (Omer, Riffat, & Ma, Experimental investigation of a thermoelectric refrigeration system employing a phase change material integrated with thermal diode (thermosyphons), 2001).

Thermoelectric refrigeration is new alternative because it can convert waste electricity into useful cooling, is expected to play an important role in today's energy challenges. (Dhumal, Deshmukh, & Kulkarni, 2015) It does not require working fluids or any moving parts, which is friendly to the environment and it simply uses electrons rather than refrigerants as a heat carrier. Continuous efforts are given by researchers for development of thermo electric materials with increase figure of merit may provide potential commercial use of thermoelectric refrigeration system.

Thermoelectric systems are solid-state heat devices that either convert heat directly into electricity or transform electric power into thermal power for heating or cooling. (Xi, Luo, Fraisse, & G., 2007) They use no ozone depleting chlorofluorocarbons, potentially offering a more environmentally responsible alternative to conventional refrigeration. (Awasthi & Mali, 2012). Such systems works on Seebeck effect and Peltier effect which is based on thermoelectric effects involving interactions between the flow of heat and electricity through solid bodies. Solar energy is abundantly available and pollution free conventional energy available throughout. This energy can be converted into useful electric energy using photovoltaic technology. The steady state reduction of price per peak watt and simplicity with which the installed power can be increased by adding panels are attractive features of PV technology.

Thermoelectric refrigeration replaces the three main working parts with a cold junction, a heat sink and a DC power source. The refrigerant in both liquid and vapor form is replaced by two dissimilar conductors.

The cold junction (evaporator surface) becomes cold through absorption of energy by the electrons as they pass from one semiconductor to another instead of energy absorption by the refrigerant as it changes from liquid to vapor. The compressor is replaced by a DC power source which pumps the electrons from one semiconductor or another. A heat sink replaces the conventional condenser fins, discharging the accumulated heat energy from the system. The difference between two refrigeration methods is that a thermoelectric cooling system refrigerates without use of mechanical devices except perhaps in the auxiliary sense and without refrigerant.

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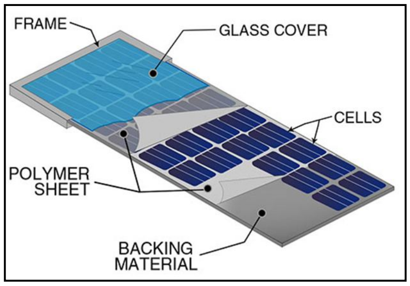
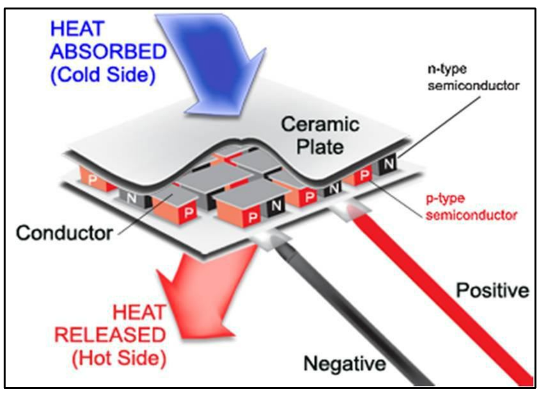
A. Principle Of Solar Power Generation

The principle of power generation behind solar cell consists of the utilization of the photovoltaic effect of semiconductors. When such a cell is exposed to light, electron-hole pairs are generated in proportion to the intensity of the light. Solar cells are made by bonding together p-type and n-type semiconductors .The negatively charged electrons move to the n type semiconductor while the positively charged holes move to the p-type semiconductor. They collect at both electrodes to form a potential. When the two electrodes are connected by a wire, a current flows and the electric power thus generated can be transferred to an outside application.



III. THERMOELECTRIC MODULE

It consists of two or more elements of n and p-type doped semiconductor material. That is connected electrically in series. These semiconductor materials are mounted between two ceramic substrates. In p-material charge carriers are holes and in n-material charge carriers are electrons. Both these p and n-type materials are made up of Bismuth Telluride. N-type material is doped in such a way that it will have an excess of electrons and P-type material is doped in such a way that it will have a deficiency of electrons. As the electron moves from the lower energy state i.e. from p-material to a higher energy state in i.e. n-material energy is absorbed which resulting in cooling effect. As the electron moves from the higher energy state i.e. from n-material to a lower energy state in i.e. p-material energy is released which resulting in heating effect



IV. THERMOELECTRIC MODULE PERFORMANCE SPECIFICATION

A. Model: TEC1-12706

T_h(ºC)	30	52	Hot side temperature
D_{Tmax}(ºC)	60	70	Temperature Difference between cold and hot side of the module when cooling capacity is zero at cold side
Umax(Voltage)	16	17.2	Voltage applied to the module at DTmax
Imax(amps)	6.0	6.0	DC current through the modules at DTmax
QCmax(Watts)	60	66.2	Cooling capacity at cold side of the module under DT=0 ºC
AC resistance(ohms)	1.8	2.0	The module resistance is tested under AC

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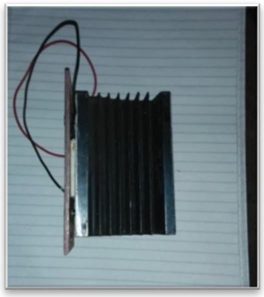
Heat sink = 90mm×90mm×25mm
Cooling fan = 90mm×90mm×25mm
Number of fins = 6



V. EXPERIMENTAL SET UP AND WORKING

Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). First use the equation editor to create the equation. Then select the "Equation" markup style. Press the tab key and write the equation number in parentheses. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Use parentheses to avoid ambiguities in denominators. Punctuate equations when they are part of a sentence, as in
The construction set up for this system requires following parts:-

A. Solar panel
B. Rectifier
C. Charge controller
D. Battery
E. Thermoelectric module
F. Heat sink
G. Cooling fan
H. Cooling and Heating compartment

(1)

Firstly constructing a cooling compartment of size 230 mm×155mm×155mm [L×W×H] made by using 1mm aluminum sheet. The cooling compartments and outside are separated by providing 30mm insulation in between them. Foam insulation is used as insulation. The overall outer surface of thermoelectric refrigerator is surrounded by metal sheet of aluminium .

Figure shows the thermoelectric refrigerator. Solar panel is the most important part of this system. Solar panel consists of a silicon semiconductor material when this material absorbs light energy it strikes atom to flow electron through the material. This flow of electron is known as electric current. This electric current is stored in the battery which connected to solar panel by means of wire and in between these there is a charge controller which restricts the flow of energy from battery to solar panel during night time or cloudy days.

From battery this electric current is supplied to thermoelectric module, cooling and exhaust fan. When an electric current is supplied to the module which present in cooling compartment then it will absorb the heat from component [liquid pouch] which placed in cooling compartment and liberate these heat to the atmosphere with the help of heat sink. So in this way cooling will take place inside the cooling compartment. Cooling fan is provided over the surface of heat sink which blows the air over the surface of heat sink in order to cool it.

VI. OBSERVATION TABLE

Time [min]	Cooling compartment temperature [˚C]	Hot side temperature [˚C]
0	33.2	33.2
5	31.2	35
10	31.0	38
15	29.6	38.6
20	29.2	40.3
25	28.3	40.6
30	28.1	41.2
35	28.0	41.6
40	27.6	41.6
45	27.1	42.4
50	26.8	43.5
55	26.3	44.6
60	26.1	45.2
65	26.2	46.3
70	25.4	46.8
75	25.2	47.2
80	25.0	47.4
85	24.2	47.3
90	23.4	47.6

VII. CALCULATION

When the designed solar thermoelectric refrigerator was tested, it was found that the inner temperature of the refrigeration area was reduced from 44˚C to 15˚C in approximately 90 min, a difference of 18.2˚C. Below is an example, which shows how the coefficient of performance of the refrigerator [COP] was calculated. The refrigerator is used to cool a 0.3Liter of water from 33.2˚C to 15˚C in approximately 90 min.

Properties of water are:-

Density = 1000 Kg/m³

Specific heat = 4.186 KJ/KgK

Mass of water,

$M = \rho \times V$

$= 1000 \times 0.286 \times 0.001$

$= 0.286$ Kg

Cooling capacity

$Qc = Mw \times Cp \times \Delta T$

$= 0.286 \times 4186 \times [47.6-23.4]$

$= 28972.1432$ J

$$Qc = \frac{28972.1432}{\text{Time}}$$

$$= \frac{28972.1432}{90 \times 60}$$

$= 5.24$ W

Work input

W = Number of Batteries × V × I

$= 2 \times 12 \times 1.2$

$= 28.8$ W

Coefficient of Performance

COP = Q / W

$$= \frac{5.24}{28.8}$$

$= 0.184$

VIII. ADVANTAGES

A. No Refrigerants and mechanical parts
B. Noise less operation
C. No danger of ozone depletion
D. High reliability
E. Used in remote places
F. Relatively low cost and high effectiveness

IX. APPLICATION

A. It can be uses as remote place where electric supply is not available.
B. In food preservation
C. In storage of medical instruments
D. Military applications

X. CONCLUSION

In this work, a portable solar thermoelectric refrigerator unit was fabricated and tested for the cooling purpose. The refrigerator was designed based on the principle of a thermoelectric module to create a hot side and cold side. The cold side of the thermoelectric module was utilized for refrigeration purposes whereas the rejected heat from the hot side of the module was eliminated using heat sinks and fans is used for heating purpose. In order to utilize renewable energy, solar energy was integrated to power the thermoelectric module in order to drive the refrigerator. Furthermore, the solar thermoelectric refrigerator avoids any unnecessary electrical hazards and provides very environmentally friendly product. In this regard, the solar thermoelectric refrigerator does not produce chlorofluorocarbon [CFC], which is believed to cause depletion of the atmospheric ozone layer. In addition, there will be no vibration or noise because of the difference in the mechanics of the system. In addition the rejected heat from the solar thermoelectric refrigerator is negligible when compared to the rejected heat from conventional refrigerators. Hence, the solar thermoelectric refrigerator would be less harmful to the environment. A 0.3L of water was used as the refrigerated object in these tests. Experiment and analysis on the prototype were conducted mainly under sunny outdoor conditions. It was found that the system performance was strongly dependent on the intensity of solar insulation and the temperature difference of hot and cold sides between the thermoelectric modules. The maximum temperature difference under outdoor conditions was found to be 18.2˚C.

The energy efficiency of solar thermoelectric refrigerators, based on currently available materials and technology, was still lower than its compressor counterparts. Nevertheless, a marketable solar thermoelectric refrigerator would be made with an acceptable performance through some improvements. For example, further improvement in the COP may be possible through improving module contact-resistance, thermal interfaces and heat sinks. In addition, this could be achieved by including more modules in order to cover a greater surface area of the refrigeration box.

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