Enhancing the Performance of Solar Refrigeration System

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Abstract: ***This paper present the possibility of enhancing the performance of Solar refrigeration system using Terracotta and Peltier effect. Thermoelectric modules are the key elements in this refrigerator for providing the thermoelectric cooling. The one side of the thermoelectric module gets cooled and provide refrigerating effect while the other side becomes hot and rejects the heat to the environment with the help of fans and fins. It will evidently reduce the burden on our ecological system by reducing the pollution caused by CFCs and other toxic components. By experimenting for 30 min every day for 12 days and the measured ambient temperature between 30^{0}C-38^{0}C, there is a significant decrease in the temperature inside the cabinet and it is measured between 25^{0}C-34^{0}C. The coefficient of performance so get after performing the test is between 0.2054-0.3547. The average coefficient of performance of the system was 0.3202 and there was a temperature difference of average 5^{0}C between ambient temperature and the temperature inside the cabinet.***

Keywords: Refrigeration, Terracotta, Peltier Effect, CFCs, Thermoelectric module, Coefficient of performance, convection.

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1. Introduction

Energy is vital for the progress and development of a nation’s economy. Energy shortages and variable power availability is responsible for society’s advancement. The systems are designed such that there will be no adverse effect on the environment. Energy saving and low environmental impact should be the primary targets for the systems designers and producers. Conventional Refrigeration and air conditioning consume enormous energy and uses Chlorofluorocarbons which causes ozone layer depletion. Solar refrigeration has been getting more and more attention. Solar refrigeration is one of the alternative technologies that use solar power in combination with peltier effect.

Solar energy is the natural source of energy. It is continuously available on the earth surface during the day time. As it is natural source of energy it doesn’t produce any harmful byproducts. Recently, solar energy has received interest as in attractive energy source for cooling systems, especially in places where electricity is expensive or in short supply. The solar energy is available in most areas and represents an important driving source of thermal energy systems . With the use of solar energy, usage of conventional energy sources and its peaks demand will be reduced.

Terracotta is a type of clay which has high porosity. The cabinet made up of terracotta provide natural cooling inside the cabinet. This material can be used to make refrigeration cabinet because of natural cooling.Through the bottom layer of the upper chamber, small droplets of waterfilter through a porous surface, which keep the Inner climate moist. As air circulated naturally or forcefully around the cabinet water evaporates through side walls which helps in reducing the inside temperature of the cabinet and thereby provides the cooling effect. Terracotta cabinet gives higher cooling effect in dry climate as compared to humid climate.

1.1 Thermoelectric solar powered refrigerator

Thermoelectric refrigerators (TECs), also known as Peltier refrigerators. They are solid-state heat pumps that utilize the theory of Peltier effect to remove heat. When the current is passed through the terminal one side of the module absorbs the heat result in decrease in temperature produces refrigerating effect whereas other side emits the heat which provide heating effect then the heat can be dissipated to the atmosphere through forced or natural convection. The principle of peltier effect is the inverse of the principle of seeback effect.

According to Seeback effect, When two different metals or semiconductors are kept at different temperature and both are connected at one junction then the voltage is developed on the other junction.

According to Peltier effect, It is a phenomena in which temperature difference can be measured between two different metals or semiconductors connected at one junction when the electric current is passed through the other junction. The principle is shown in fig 1.

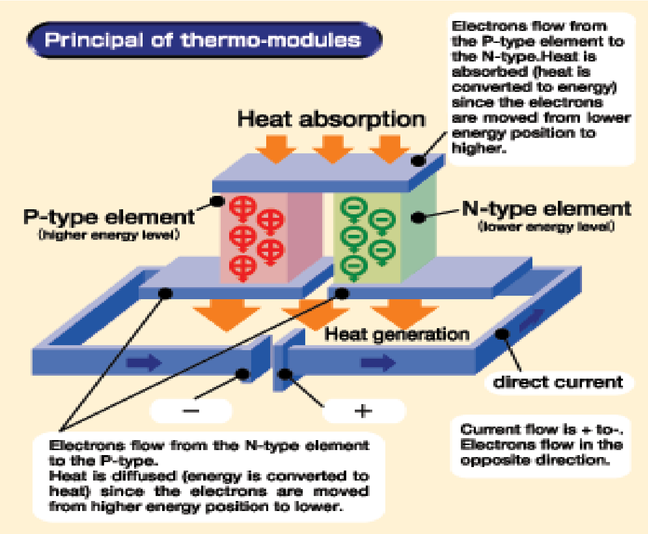

Figure 1: Principle of thermoelectric module

2. Materials and Methods

2.1 Materials

2.1.1 Thermoelectric module

Company: Nippon India ltd.
Model No: TEC1-12704T125
Voltage: 15.2 Volt
Current: 4 Ampere
Power: 60.8 Watts

2.1.2 Fan

Voltage: 12 Volt
Current: 0.4 Ampere
Power: 0.48 Watt
No. of fans: 02

2.1.3Solar Panel:

Name of company: PV solar
Dimensions of each solar cell: 40x40 mm
Maximum voltage: 0.5 Volt /cell
Maximum Current: 1.8 Ampere/cell
Power: 0.9 watt

2.1.4 Temperature measurement device

Temperature range: -20^{0}C to 50^{0}C

2.2 Method

Initially a cabinet (27”X15”X12”) of terracotta clay is manufactured. On the cabinet, required holes are made in order to place thermoelectric module fan and fin arrangement. Module is placed like sandwich between the two fans. Fan and fin arrangement provide forced convection which helps in dissipating heat from the one side of module and circulating cool air from the other side of module. All the components are arranged as shown in Fig 2 and the connections are made in parallel in order to distribute same voltage (12V) in all the components. Since the voltage output from solar panel is variable therefore solar panel is connected to batteries which supply constant voltage. In order to measure the cabinet temperature, temperature sensor is placed inside the cabinet. Then the temperature is measured after half hour and noted in a table.

The experiment is carried for 12 days, each day for half hour for better result.

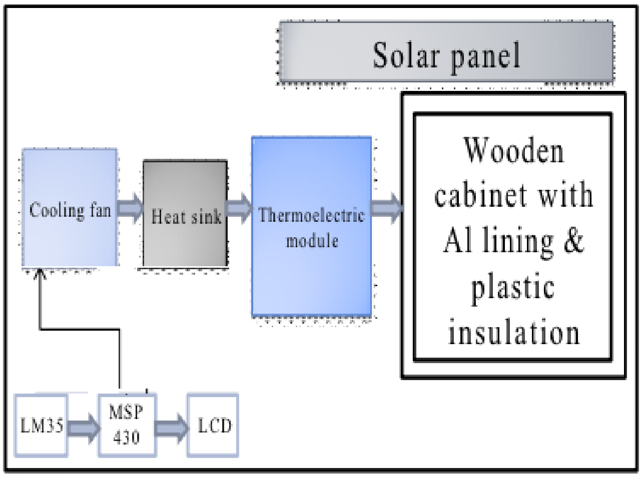

Figure 2: Arrangement of component

3. Calculations

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3.1 Cooling Capacity

Volume of water to be cooled: 1.36 liters
Cooling capacity required to cool 1.36 litres of water in 50 min from 27^{0}C to 5^{0}C:
Q=m*c*dT
Where,
m = mass of water to be refrigerated (in Kg)
c = Sp. Heat of Water (in J/Kg/Celsius)
dT = Temp. Difference (in Celsius)
Q= 1.36*4180*(27-5)
Q=125065.6 J
Heat rejected per second: 125065.6/3000 (in J/s or W) = 41.68W

3.2 Total power requirement

Total power used by fan = power X no of fan used
= 0.48x2
= 0.96 Watts

Total Power required for refrigerator
= power required for module + power required for heat sink & fans

= 60.8 + 0.96 Watts
= 61.76 watts

3.3 Solar panel configuration

No. of Solar cells needed ideally, Each Solar cell generate 1.8 watts (0.5Volt x 1.8 Amp)
No. of cells needed = 61.76 watts / 0.9 watts
= 68.22 = 70 units.

3.4 Calculation of COP

Coefficient of performance (COP) = (Heat removed from refrigerator /sec)
Power Input
Heat Removed (Q) = 40.1 watts or joules/sec
Power input = 61.76 watts or joules/sec
Coefficient of performance = 40.1/61.76 = 0.649

4. Results

The results for the COP, ambient temperature and cabinet temperature are in table 1 and Fig.3 gives the variation of COP with respect to days.

Day	Time (Sec)	Cabinet temperature (^{0}C)	Ambient temperature (^{0}C)	COP
1	1800	29.5	35.5	0.308
2	1800	29.6	36.6	0.359
3	1800	30.4	37.2	0.349
4	1800	34.1	38.1	0.2054
5	1800	29.4	36.3	0.3547
6	1800	26.9	33.5	0.3393
7	1800	29.4	36.2	0.349
8	1800	29.8	34.8	0.257
9	1800	25.6	30.9	0.2724
10	1800	28.5	35.2	0.3444
11	1800	29.8	36.7	0.3547
12	1800	27.2	34.0	0.3496

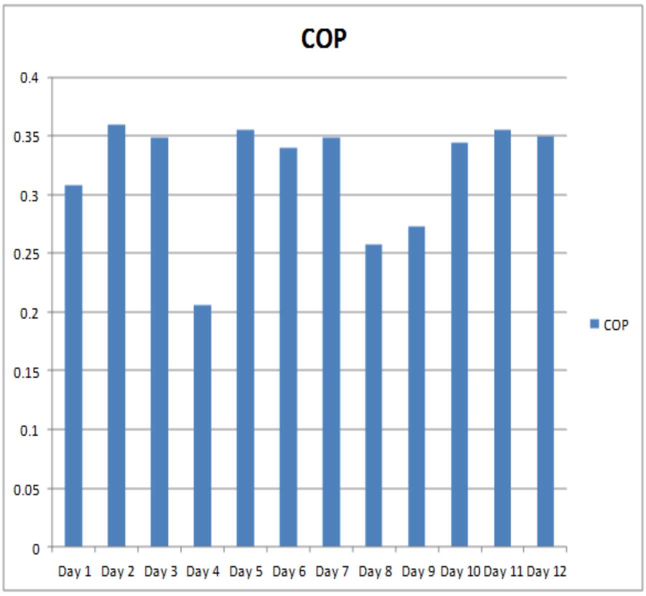

Figure 3: Variation of COP with respect to days

5. Conclusion

We have innovatively combined two principles of cooling i.e. terracotta clay and Peltier Effect to develop a whole new concept of refrigeration working on a renewable source of energy.

- COP attained is 0.3202
- We have been able to achieve our primary objective of developing a thermo-electric solar powered refrigerator with a COP (0.3202) considerably higher than that attained in the previous research (COP 0.161) [3] done in the same field.
- The Fig.3 histogram shows the comparison between the COP attained in this research work and the COP attained during the most recent previous research.

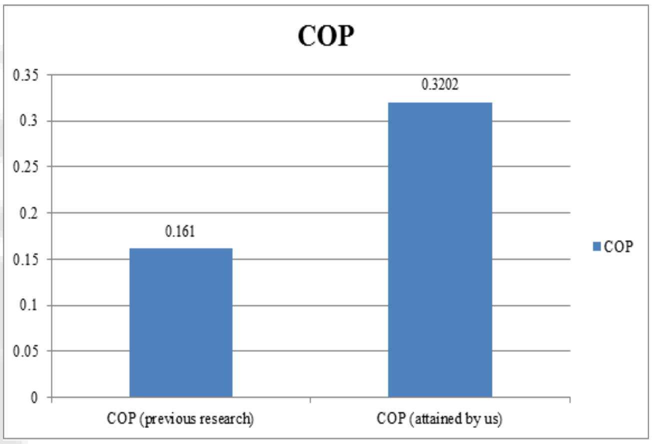

Figure 3: Comparison b/w COP

References

[1] Sabah A. Abdul Wahab and Ali Elkamel, "Design and experimental investigation of portable solar thermoelectric refrigerator", Sultan Qaboos University, College of Engineering, 2009.
[2] Quinghai Luo, WeiliGu and Yanjin Wang, "Thermodynamic Comparison between thermoelectric refrigerator and compression ones", School of urban construction, University of South China, 2011
[3] http://www.computer.org/csdl/proceedings/cdciem/2011/4350/00/4350a321.pdf
[4] Mouna Hamed, Ali Fellah and Ammar Ben Brahim, "Performance evaluation of a thermoelectric refrigerator with dynamic simulation", University of Gabes, Engineers National School, Applied Thermodynamic Research unit, gabes, Tunisia, 2011.
[5] Marc Hodes,"Optimal design of thermoelectric refrigerators embedded in a thermal resistance network" IEEE, March 2012.
[6] www.mitticool.in
[7] Thermal design and analog representation Of a thermoelectric refrigerator, Gerard Rezek+, Associate Member, IEEE https://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=1136411

[8] Thermoelectric cooling device YE. A. Kolenko http://www.researchgate.net/publication/235028194_THERMOELECTRIC_COOLING_DEVICS
[9] Solar thermoelectric generators based on advanced thermoelectric materials
[10] http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=1190345
[11] Free Convection Heat transfer Thermoelectric Refrigerators. By I. I. Sochard *Emerson Research Laboratories*
[12] Silver Spring, Maryland
[13] Overview of Solid-State Thermoelectric Refrigerators and Possible Applications to On-Chip Thermal Management
[14] By Jeff Sharp, Jim Bierschenk, and Hylan B. Lyon.
[15] Effect of coupled heat and mass transfer on the performance of adsorptive solar refrigerator using the pair activated carbon/methanol. By Wassila Chekirou, Nahman boukheit, Tahar kerbache.
[16] System optimization of hot water concentrate solar thermoelectric generation *Kazuaki Yazawa and Ali Shakouri*
[17] University of California Santa Cruz; USA.
[18] www.sunsolarelectric.com
[19] www.en.wikipedia.org

Author Profile

Sanchit Kumar Gupta has completed B.E. in the field of mechanical engineering from Maharashtra Institute of Technology, Pune, India. He has interest in the field of finite element analysis, computational fluid dynamics, Aerospace engineering. He has worked in the SAE- BAJA MIT team for 4 years.