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Experimentation on Solar Thermoelectric Module for Cooling and Heating

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Abstract: ***Now a day's energy conservation plays a major role in day to day life due to energy crisis. Thus a solution has to be given to utilize the heat energy dissipated to environment for the useful heating applications and conserve waste heat energy. The thermoelectric effect has been proven as a source of cooling and small power generation as defined by the Peltier-Seebeck effect. A novel idea of this is to utilize both heating and cooling effects generated by Thermo-Electric module so we have developed a system which will produce cooling effect without the use of mechanical devices and also this system does not require working fluids or any moving parts. Solar panel was used to power up thermoelectric modules (TE-12706 module) with the help of a battery in order to provide continuous power. The waste heat regeneration unit consisting of two parallel copper plates and a water channel with staggered fins was installed above the hot side of thermoelectric cooler (TEC) and a fan was installed in colder side for cooling purpose. The heat dissipated from the thermoelectric cooler can be removed by the cooling water such that the performance of the cooling module is elevated. The system was tested in different flow rates of water for effective utilization.***

Index Terms: ***Solar panel, TEC, Water channel, Green building.***

I. INTRODUCTION

Under the inevitable influence of the energy shortage and the rise of environmental awareness, promising energy sources to satisfy the world's growing energy demand has received increasing attention in the past several decades. By the twentieth century the now common thermoelectric module had begun to take shape [1-4]. A standard module consists of any number of thermocouples connected in series and sandwiched between two ceramic plates by applying a current to the module one ceramic plate is heated while the other is cooled as shown in figure 1. The direction of the current determines which plate is cooled. The number and size of the thermocouples as well as the materials

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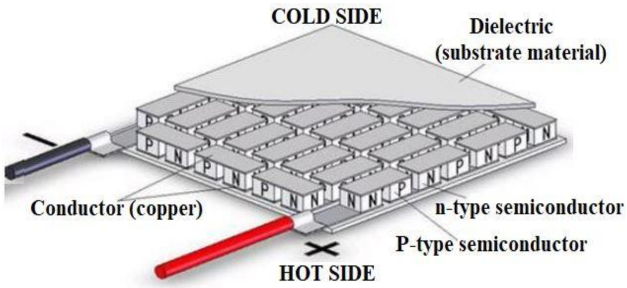

Fig. 1 Thermoelectric Module (TEC-12706)

used in the manufacturing determine the cooling capacity. For much of the twentieth century the technology of the thermoelectric module was limited to the military and aerospace industries. As with all technologies increased availability and a wider range of applications have driven prices down to the point where these modules are very affordable and found in a multitude of commercial products. Some of the more common applications include electronic cooling equipment, laboratory as well as medical equipment. The thermoelectric cooling uses the peltier effect to create a heat flux between the junctions of two different types of materials [5-8]. It is solid state active heat pumps which transfer heat from one side of the device to the other with consumption of electric power, depending on the direction of current. These can either be used for heating or cooling, although in practice the main application is cooling. Thermoelectric coolers has two sides when dc current flows through the device, thus one side gets cooler while other gets hotter. The hot side is attached to a heat sink so that it remains at ambient temperature, while the cooler side goes below room temperature. In our module we use water channel as heat sink, which is placed above the TEC hot side, water have high heat capacity value than air. Thus it removes more heat from module while much affecting its temperature [9-15]. Moreover water which gets hot can we use for other purpose, thus helps in energy saving.

II. PELTIRE EFFECT

Thermoelectric generator can also be used as a Peltier cooler as shown in figure 2. When voltage is applied across the device as a result difference in temperature will build up between the two sides. Then device operated as a cooler. 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 [16-18].

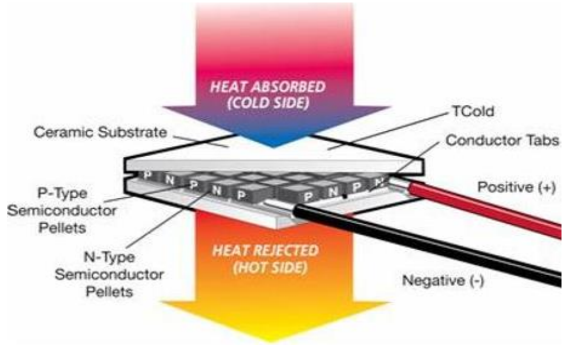

Fig. 2 Pettier Effect Principle

III. FABRICATION OF EXPERIMENTAL SETUP

The tested combined module is divided into four major components like solar cells, thermo electric cooler, waste heat regeneration unit and the measurement system as shown in Figure 3. Solar panel (silicon crystal type) has fixed above the cooling chamber at an inclination angle of 45°. Water channel made up of copper having 8 number of staggered fins plates are fixed inside the channel to increase heat remove rate. Hot side of TEC was fixed with heat sink. Cold side of TEC was attached with cooling chamber perfectly insulated from surrounding by thermocol [20-25]. The cold sides of TCE are used to cool indoor space of the cooling chamber. Two batteries were used to store the extra electricity produced during the day time and it can be used to supply electricity for driving the thermoelectric coolers during the night time or cloudy days. The solar panel is connected to battery and all the electricity to the TEC is provided by the battery. Cold water enters from one side and leaves from another side of water channel by taking waste heat produced by TEC. Thus heat is continuously removed by water from hot side of TEC. The temperature of hot and cold side of TEC (T_{tech}, T_{tecc}) was measured by probe type temperature reader. A pump (12 watt) was fixed near water tank which created a pressure difference needed for flow in the pipe network through water channel. A valve was installed near the pump to control the quantity of flow of water. Hot water leaving from heat sink enter into tank and it can be used for our specific purpose by tank outlet valve.

IV. COMPONENTS AND ITS SPECIFICATION

- TEC-12706:
  - Operational voltage: 12V DC
  - Current max: 6 Amp
  - Dimension: 40 x 40 x 3.5mm
- Solar cell: 15 volts (DC), 6 Amp.
- DC circuit: 12.5 volts, 7 amp
- DC power supply: 12volts, 6amp current, 6.5 Ah
- Temperature measuring device (tete-eltn-eca1474)
- Cooling chamber dimensions (Thermocol insulation): 20 x 15 x 15 cm
- Water channel: 10 x 7 x 2 cm
- Tank : 15 x 15x 30 cm

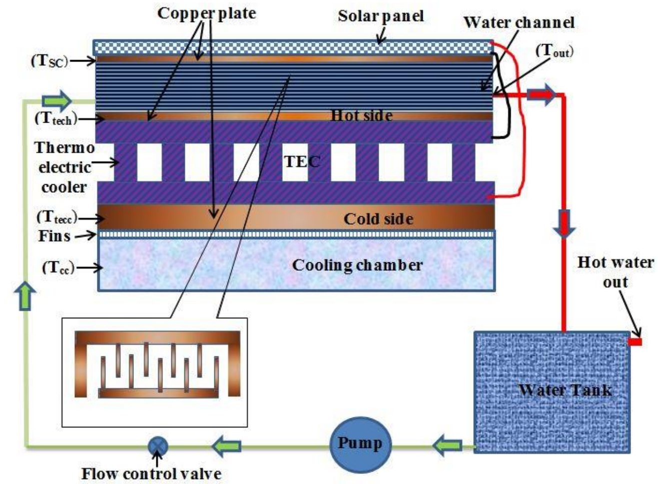

Fig. 3 Schematic of Experimental Setup for TEC

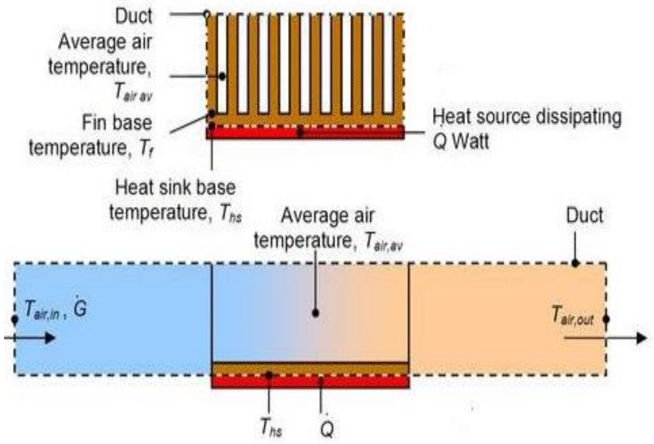

Fig. 4 Heat Sink for Heat Transfer

V. HEAT SINK (WATER CHANNEL)

Heat sink was a passive heat exchanger that cooled a device by dissipating heat into the surrounding medium as shown in figure 4. It was designed to maximize its surface area in contact with the cooling medium surrounding it, such as the water. Water flow rate, choice of material, protrusion design and surface treatment are factors that affect the performance of a heat sink.

VI. HEAT TRANSFER PRINCIPLE

Fourier's law of heat conduction represented that heat will be transfer from the higher temperature region to the lower temperature region. The rate at which heat is transferred by conduction, qk is proportional to the product of the temperature gradient and the cross-sectional area through which heat is transferred.

$$q_k = -kA\frac{dT}{dx} \quad (1)$$

According to low of conservation of energy in steady state condition is represented by Newton's law of cooling.

$$Q^{\cdot} = \dot{m}c_{p,in}(T_{air,out} - T_{air,in}) \quad (2)$$

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$$\dot{Q} = \frac{T_{hs} - T_{air,av}}{R_{hs}} \tag{3}$$

$$T_{air,av} = \frac{T_{air,in} - T_{air,out}}{2} \tag{4}$$

VII. EXPERIMENTAL RESULTS

Initially temperature on both sides TEC equal to room temperature, when power supplied from battery then temperature of one side goes up while that of other goes down. Heat transfer rate was low because no flow of water, thus temperature of cold side started rising. After that TEC model working will become inefficient due to low temperature difference. At zero flow rate temperatures in hot and cold side of TES as shown figure 5 and table 1.

Table 1 Temperatures of TEC, T_{amb} vs time when (Q = 0 ml/min)

Time (sec)	T_{tecc} (°C)	T_{tech} (°C)	T_{amb} (°C)
0	24	24	24
25	20	27	24
50	22	29	24
75	24	30	24
100	26	33	24

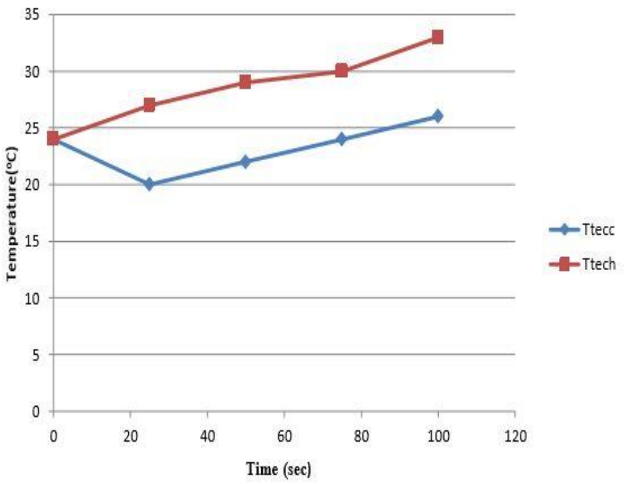

Fig. 5 Temperature of TEC *vs.* Time When Flow Rate Zero

Table 2 Temperatures of TEC, Tcc vs time (Q = 2500 ml/min)

Time (hr)	T_{tecc} (°C)	T_{tech} (°C)	T_{cc} (°C)
0	24	24	24
0.5	16	28	22
1.5	15	27	21
2.5	14	27	21
3.5	14	27	20

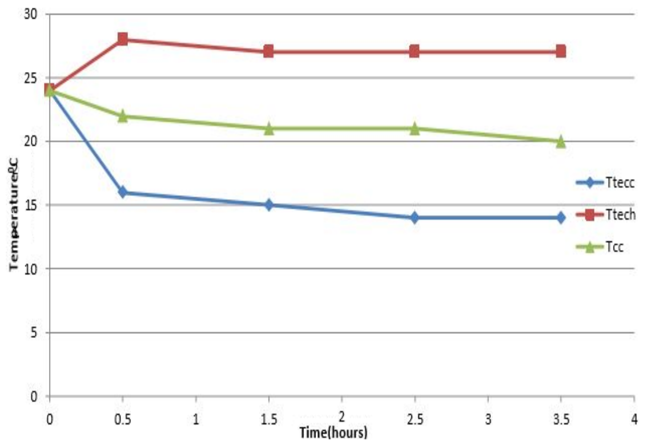

Fig. 6 Temperatures of TEC and Cooling Chamber with Water Flow Rate of 2500 ml/min.

As shown in figure initially temperature of hot side of TEC raises up to 28 °C while that of cold side decreases to 16 °C at time half hour, when ambient temperature is 24 °C and flow rate is 2500 ml/min. Water flows for long time in heat sink thus time will come when T_{tech} will in equilibrium (at 28oC) and same in cold side equilibrium T_{tecc} will 14 °C. In the experiment it is found that the temperature of cooling chamber is decreasing with time but rate of cooling is very low it is about 3°C per hour initially than decrease to 1 °C per hour after 3 to 4 hours decrease to 20°C than remains almost constant as shown in figure 6 and table 2.

Table 3 Temperatures of TEC, T_{out} *vs.* flow rate varies from 0 to 2500 ml/min

Flow rate (ml/min)	T_{tecc} (°C)	T_{tech} (°C)	T_{out} (°C)
0	32	44	25
250	26	35	25
500	20	27	23
750	17	26	21
2000	15	25.5	20
2500	14	25	20

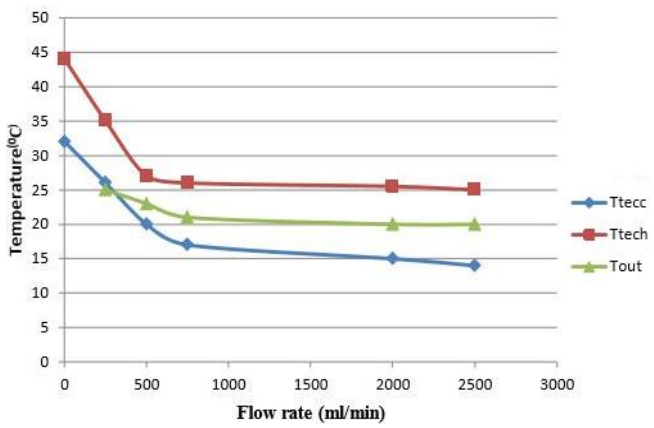

Fig. 7 Temperature of TEC, Tout *vs.* Flow Rate of Cooling Water ($T_{water\ in}$ = 19 °C)

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Through Flow control valve present near pump was controlled the flow of water. This is because water has high value of specific heat capacity as compare to air. From 500 to 750 ml/min temperature drop rate decrease after that it become almost constant. Because heat removal rate is depend upon the temperature difference between the hot and cold side of TEC. T_{tecc} decease when flow rate of water increase up to 750 ml/min and then become constant. Because temperature of cold side is depends upon the temperature of hot side of thermoelectric cooler. Minimum change in temperature of hot side was found after 750 ml/min. Due to this region constant temperature was found in cold side.

VIII. CONCLUSION

In this study a solar-driven thermoelectric cooling module with a waste heat regeneration unit was proposed and tested. Solar panel used to provide the electricity for thermoelectric cooler which was employed to absorb heat from the indoor space of the green building and then dissipated heat to the cooling water flowing in the regeneration channel. A model cooling chamber with the combined module had been built for testing the feasibility of this approach and experimental results were found during test model listed as follows:

- It noticed that the heat dissipated from the hot side of the thermoelectric cooler can also be efficiently removed by the cooling water to elevate the performance of the thermoelectric cooler.
- It found that without cooling water temperature of hot and cold side in TEC may be higher than 44 °C and 34 °C respectively.
- When cooling water allowed to flow through the heat regeneration water channel temperature of hot and cold side in TEC were reduced to 25 °C and 16 °C respectively.
- Additionally the waste heat rejected by TEC was utilized for water heating. Therefore, both air-conditioning and water heating demand can be satisfied without consuming any external energy source.
- Based on the model tests, it found that the present approach abled to produce a 10 oC temperature difference between the ambient temperature and the air temperature in the model house.
- It implies that combined module is capable of cooling down the indoor air of the model house.

REFERENCES

1. M. B. Dhawade, E. Mourya, A. Yadav, D. Samuel, S. A. Mohod, and V. N. Deshpande, "Review on portable solar thermoelectric refrigerator cum air cooler", International Journal of Advance Research in Science and Engineering, Vol. 4, 2015, pp. 44-58.
2. J. D. Francis, "Thermoelectric cooling and power generation", Science, Vol. 2, 2005, pp. 703-706.
3. S. M. Nivas, V. D. Vardhan, and K. Ramya, "Photovoltaic driven dual purpose thermoelectric refrigerator for rural india", International Journal of Advancements in Research and Technology, Vol. 2, 2013, pp. 111-116.
4. A. A. W. Sabah, A. Elkamel, A. M. A. Damkhi, and M. U. Chutani, "Design and experimental investigation of portable solar thermoelectric refrigerator", Renewable Energy, 2009, pp. 30- 34.
5. M. K. Rawat, P. K. Sen, H. Chattopadhyay, and S. Neogi, "Development and experimental study of solar powered thermoelectric system", International Journal of Engineering Research and Applications, Vol. 3, 2013, pp. 2543-2547.
6. S. S. Khode, P. Kale, and C. Gandhile, "Review on application of thermoelectric peltier module in cooling and power generating technology", International Journal of Engineering and Technical Research, Vol. 3, 2015, pp. 71-74.
7. D. Astrain, and J. G. Vian, "Computational model for refrigerators based on peltier effect application", Applied Thermal Engineering, Vol. 25, 2005, pp. 149-162.
8. J. L. Christian, and J. R. Barbosa, "Thermodynamic comparison of peltier, stirling, and vapor compression portable coolers", Applied Energy, Vol. 9, 2011, pp.51-5.
9. R. S. Bharj, and S. Kumar, "Experimental study of power reduction from cold storage by using VFD", International Journal of Research in Management, Science & Technology, Vol. 4, 2016, pp. 1-5.
10. S. Kumar, and R. S. Bharj, "Design for Solar Hybrid Mobile Multipurpose Cold Storage system", International Journal of Technical Research & Science, Vol. 1, 2016, pp. 289-294.
11. H. Mousazadeh, A. Keyhani, A. Javadi, H. Mobli, K. Abrinia, and A. Sharifi, "A review of principle and sun-tracking methods for maximizing solar systems output", Renewable and Sustainable Energy Reviews, Vol. 13, 2009, pp. 13-18.
12. M. Toivola, L. Peltokorpi, J. Halme, and P. Lund, "Regenerative effects by temperature variations in dye-sensitized solar cells", Solar Energy Materials & Solar Cells, Vol. 91, 2007, pp. 17-33.
13. E. Radziemska , "The effect of temperature on the power drop in crystalline silicon solar cells", Renewable Energy, Vol. 28, 2003, pp. 2-8.
14. R. S. Bharj, and S. Kumar, "Energy Efficient Hybrid Solar System for Cold Storage in Remote Areas", International Journal of Engineering Research & Technology, Vol. 4, 2015, pp. 315-318.
15. Y. Y. Hsiao, W. C. Chang, and S. L. Chen, "A mathematic model of thermoelectric module with applications on waste heat recovery from automobile engine", Energy, Vol. 35, 2010, pp. 14-17.
16. S. A. A. Wahab, A. Elkamel, A. M. A. Damkhi, I. A. A. Habsi, H. A. Rubaiey, and A. A. Battashi, "Solar thermoelectric refrigeration systems", International J. Energy Technology and Policy, Vol. 7, 2009, pp. 127-136.
17. B. Shreekar, and M. Vedachary, "Implementation of solar fridge with fast chilling application with temperature monitoring using LPC2148", International Journal of Advanced Research and Innovation, Vol. 2, 2013.
18. M. Awasthi, and K. V. Mali, "Design and development of thermoelectric refrigerator", International journal of mechanical engineering & robotics research, Vol. 1, 2015, pp. 15-20.
19. A. kumar, and K. Venkatesswarlu, "Implementation of solar fridge with fast chilling applications", International Journal Management and Research, Vol. 2, 2015, pp. 24-28.
20. C. H. Cheng, S. Y. Huang, and T. C. Cheng, "A three-dimensional theoretical model for predicting transient thermal behaviour of thermoelectric coolers", International Journal of Heat and Mass Transfer, Vol. 53, 2010, pp. 01-07.
21. M. Kubo, M. Shinoda, T. Furuhata, and K. Kitagawa, "Optimization of the incision size and cold-end temperature of a thermoelectric device", Energy, Vol. 30, 2005, pp. 21-26.
22. D. R. Myers, "Solar radiation modeling and measurements for renewable energy applications: data and model quality", Energy, Vol. 30, 2005, pp. 15-17.
23. R.S. Bharj, S. Kumar, and R. Kumar, "Study on solar hybrid system for cold storage", International Journal of Research in Management, Science & Technology, Vol. 3, 2015, pp. 71-74.
24. Y. j. Dai, R. Z. Wang, and L. Ni, "Expr. Investigation on a thermo-electric refrigerator driven by solar cells", Renew Energy, Vol. 28, 2003, pp. 49-55.
25. V. S. Umesh, P. K. Jhavar, and G. R. Seloskar, "Thermoelectric Refrigeration by Using Solar Energy for Domestic Appliance", International Journal of Research in Advent Technology, Vol. 3, 2015, pp. 72-75.

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