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Research Article

Experimental Investigation on Thermoelectric Refrigeration system (40 Watts at 30^{o}C ambient temperature)

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Abstract

In recent years, with the increase awareness towards use of CFCs and HCFCs refrigerants in conventional refrigeration systems has become a subject of great concern. Besides, these kinds of refrigeration systems having limitation of use of grid power and same cannot be utilized for remote applications. Thermoelectric cooling is an effective method to transfer heat from one side of the module to the other when a current is applied which works on Peltier effect. In this study, a thermoelectric refrigeration system (Q_{max} = 40 W) is experimentally investigated which is having a refrigeration space of water of 1 liter capacity. A heat sink assembly is used to increase heat dissipation rate from the hot side of module. The experimental results shows a temperature drop of 21^{o}C with 250 ml of water kept inside refrigeration space for 15 minutes with respect to 31^{o}C ambient temperature i.e. 69% decrease in the temperature of water with respect to ambient temperature. COP of the system is found to be 0.1. When the results are compared with the open literature it is concluded that the system has the potential for small capacity refrigeration applications such as biomedical applications, electronics cooling applications, aerospace applications etc.

Keywords: *Thermoelectric cooling, Peltier effect, Refrigeration, Peltier module, COP, Peltier cooler*

1. Introduction

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. Peltier effect states that when a current is made to flow through a junction between two conductors, heat is absorbed at one junction and rejected at other junction. The junction at which heat is absorbed is used of cooling applications.

Thermoelectric refrigerator sometimes called a thermoelectric cooler module or Peltier cooler is a semi-conductor 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. The face which will be cooled is used for cooling or refrigeration purpose. (M. Zeki Yilmazoglu, 2015)

Including the application of thermoelectric cooling in refrigeration there are many other applications of thermoelectric cooling where it can be used very effectively. The performance of thermoelectric cooling in temperature suited for down-hole measuring equipment is analyzed by Rohitha Weerasinghe (Rohitha Weerasinghe *et al*., 2017). Another application of thermoelectric cooling is cooling of photovoltaic panel. Kashif Irshad presented experimental and simulation investigation of a novel thermoelectric air duct system assisted with photovoltaic system for space cooling in Malaysian weather condition (Kashif Irshad *et al*., 2016). Anoother study included optimization of thermoelectric cooling technology for an active cooling of photovoltaic panel. Thermoelectric module (TEM) is attached at the back side of PV module for absorption of the heat generated in PV module by infrared spectrum (Aarti Kane *et al*., 2016).

This work includes the study of thermoelectric cooling system used for cooling or refrigeration purpose. A critical review of thermometric technology and its potential applications in refrigeration provided by Jaspalsinh B. Dabhi (Jaspalsinh B. Dabhi *et al*., 2014). In another study an experimental prototype of thermoelectric refrigeration system working on solar photo voltaic cells generated DC voltage is designed and developed. The developed experimental prototype having a refrigeration space of 1 liter capacity is refrigerated by four Peltier modules (Manoj Kumar Rawat *et al*., 2013).

2. Components

2.1 Thermoelectric plate

Thermoelectric coolers operate by the Peltier effect (which also goes by the more general

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name thermoelectric effect). The thermoelectric plate has two sides, and when DC current flows through the device, it brings heat from one side to the other, so that one side gets cooler while the other gets hotter. The hot side is attached to a heat sink so that it remains at ambient temperature, while the cool side goes below room temperature. The Thermoelectric module is of 40 mm × 40 mm as shown in Fig.1.

Fig.1 Thermoelectric plate

2.2 Heat sink

The heat sink usually made of aluminum, is in contact with the hot side of a thermoelectric module. When the positive and negative module leads are connected to the respective positive and negative terminals of a Direct Current (D.C) power source, heat will be rejected by the module's hot side, the heat sink expedites the removal of heat. Heat sink typically is intermediates stages in the heat removal process whereby heat flows into a heat sink and then is transferred to an external medium.

Fig.2 Heat sink with fins

2.3 Power supply (Battery)

Thermoelectric module is a Direct Current (D.C) device. Specified thermoelectric module performance is valid if a Direct Current (D.C) power supply is used. Figure 3 shows rechargeable battery of AKARI-plus for thermoelectric plate is used. It has specifications as 12V, 1.2 Ah. For driving the fan we use directly electricity. Also we use solar panel after charging it in solar energy.

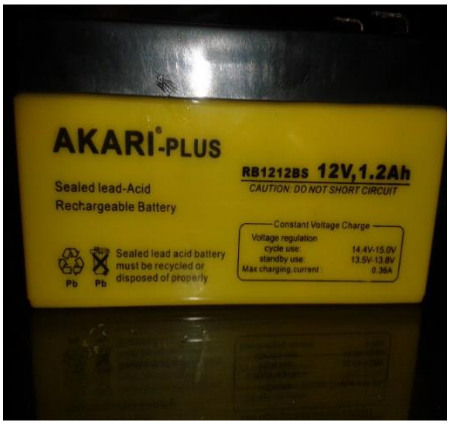

Fig.3 Power supply (Battery)

2.4 Fan

Fan is used to dissipate the hot air at the heat sink side. It provides the effect of forced convection. Fan with specifications of DC 12V and 0.16A id used as shown in Fig.4. The main function of the fan is to cool down the hot side as much early as possible.

Fig.4 Fan

2.5 Temperature sensor

Temperature sensors are used for measuring the temperature of cold side of the thermoelectric plate. In this work, we have used digital type of temperature sensor. The temperature range of sensor is -12°C to 80 °C.

3. Experimental setup and procedure

A thermoelectric refrigeration cabinet as shown in Fig. 6 with refrigeration space of 1 Liter has been developed with casing of polyvinyl chloride and for thermal insulation a polyurethane foam sheet has been provided inside the box to prevent the heat losses. Thermoelectric module has been used to reduce inside temperature of refrigeration space. Cold side of the thermoelectric plate is fixed in a plastic block and hot side of module is attached to the heat sink with fan assembly. The schematic of the experimental setup is shown in the Fig. 5.

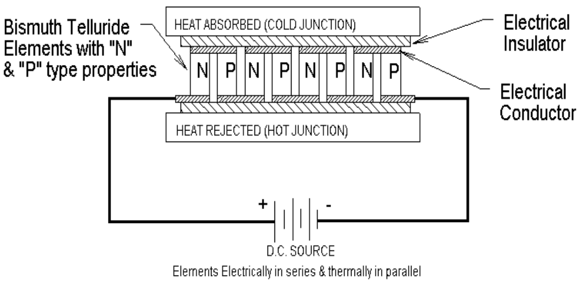

Fig.5 Schematic of Thermoelectric Refrigerator

The temperature sensor is used to measure the temperature of refrigerated space in which fluid is filled. The actual experimental setup is shown in Fig. 6.

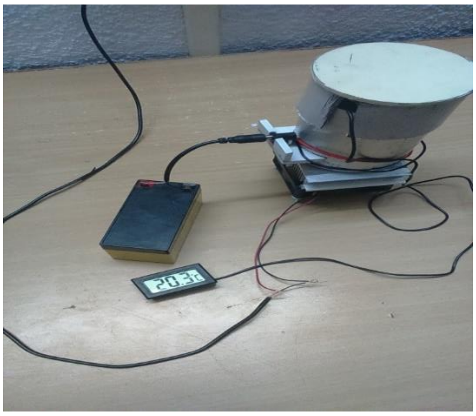

Fig.6 Experimental setup

3.1 Heat load calculation

The heat load is the heat released by a mass which is kept inside the cabinet during the cooling and is calculated by,

$$Q = \frac{mCp\Delta T}{dt}$$

Where,

$m \; = mass\ of\ fluid$, kg
$\Delta T = temperature\ decrease\ of\ fluid$, ^{o}C
$dt \; = total\ time\ span$
3.2 COP calculation

COP of thermoelectric refrigeration cabinet is calculated by,

$$COP = \frac{Q}{E}$$

Where, $E = total\ input\ elecrical\ energy$

4. Results and discussion

Table 1 Readings at constant time interval

Time (Sec)	Temperature (^{o}C)	Time (Sec)	Temperature (^{o}C)
30	30.6	480	16.5
60	28.7	510	15.3
90	25.0	540	14.6
120	24.1	570	13.8
150	23.9	600	12.6
180	23.6	630	11.2
210	23.0	660	10.8
240	22.7	690	10.2
270	22.3	720	9.9
300	21.8	750	9.5
330	21.1	780	10.1
360	20.8	810	10.8
390	19.7	840	11.4
420	19.1	870	12.0
450	17.3	900	13.3

Water is used for a cooling purpose in this work. The temperature of water at initial stage 30.6 ^{o}C. Readings were taken at a constant time interval of 30 seconds for 15 minutes as shown in the Table 1. Graph is plotted for variation in temperature of water with time interval of 30 seconds as shown in Fig. 7.

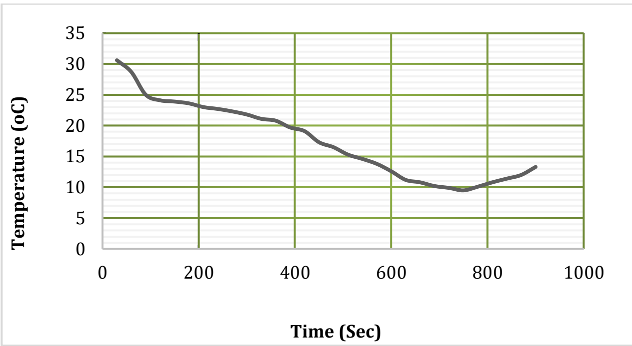

Fig.7 Variation in temperature of water for a constant time interval

It is observed from the graph that the temperature of water decreases with the time. The percentage decrease in temperature is 68.95% with respect to the ambient temperature. After one point the temperature of water goes on increasing. This happens because the Joule heating effect and Fourier heat conduction effect dominate Peltier effect as the thickness of thermoelectric plate is very small (approx. 4 mm). This reduces the cooling effect at cold side of the module. When the results are compared with the open literature it is found that there is a 24% increase in temperature drop of water for same operating parameters.

Conclusions

The experimental result of thermoelectric refrigeration system shows that the performances were great for a given operating conditions and forced air convection heat dissipation. A 21°C temperature reduction at 250 ml of water inside refrigeration space of thermoelectric refrigeration system has been experimentally found with respect to 31°C ambient temperature in 15 minutes. It is calculated that there is a 69% of decrease in temperature with respect to the ambient temperature. When the result is compared with open literature it is found that there is a 24% increase in temperature drop of water for same operating parameters. The COP of the system is found to be 0.1 which is slightly better than the open literatures reviewed. Also it has been experimentally found that the developed thermoelectric system can work for 6 hours continuously when battery is fully charged with solar panel.

It can be concluded that thermoelectric refrigerators are greatly needed, particularly for developing countries and remote areas, where long life, low maintenance and clean environment are needed. Further the performance of thermoelectric refrigeration system can be improved with use of increased figure of merit of Peltier modules and efficient heat dissipation technology.

References

Kashif Irshad, Khairul Habib, Firdaus Basrawi, Bidyut Baran Saha, (2017), Study of a thermoelectric air duct system assisted by photovoltaic wall for space cooling in tropical climate, *Energy,* 119, 504-522.

Manoj Kumar Rawat, Prasanta Kumar Sen, Himadri Chattopadhyay, Subhasis Neogi, (2013), Development and Experimental study of Solar Powered Thermoelectric Refrigeration system, *International Journal of Engineering Research and Applications,* Vol.3, Issue 4, pp.2543-2547.

Aarti Kane, Vishal Verma, Bhim Singh, (2016), Optimization of thermoelectric cooling technology for an active cooling of photovoltaic panel, *Renewable and Sustainable Energy Reviews.*

Dinesh S. Borkar, Sunil V. Prayagi, Jayashree Gotmare, (2014), Performance Evaluation of Photovoltaic Solar Panel using Thermoelectric Cooling, *International Journal of Engineering Research,* Vol.3, Issue 9, pp.536-539.

Manoj Kumar Rawat, Himandri Chattopadhyay, Subhasis Neogi, (2013), A review on developments of thermoelectric refrigeration and air conditioning systems: A novel potential green refrigeration and air conditioning technology, *International Journal of Emerging Techonology and Advanced Engineering,* Vol.3, Issue3, pp.362-367.

Rohitha Weerasinghe, Thomas Hughes, (2017), Numerical and experimental investigation of thermoelectric cooling in down-hole measuring tools: Case study, *Case studies in Thermal Engineering,* 16.

Jaspalsinh B. Dabhi, Nimesh B. Parmar, Nirvesh S. Mehta, (2012), Consideration for design of thermoelectric refrigeration system, *International Journal of Advanced Research and Studies,* Vol.1, Issue 2, pp.259-261.

M. Zeki Yilmazoglu, (2015), Experimental and Numerical investigation of prototype thermoelectric heating and cooling unit, *Energy and Buildings,* 15.

Anthony M. Pettes, Marc S. Hodes, Kenneth E. Goodson, (2009), Optimized thermoelectric refrigeration in the presence of thermal boundary resistance, *IEEE transactions on Advanced Packaging,* Vol.32, No. 2, pp.423-430.

Manoj Kumar Rawat, Lal Gopal Das, Himandri Chattopadhyay, Subhasis Neogi, (2012), An experimental investigation on thermoelectric refrigeration system: A potential green refrigeration technology, *Journal of Environmental Research and Development,* Vol.6, No. 4, pp.1059-1065.