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Experimental Investigations and Analysis of Thermoelectric Refrigerator with Multiple Peltier Modules

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ABSTRACT

As the conventional refrigeration system are large in size and consumes a lot of electrical energy which in terns leads to releases of more green-house gases for production of electricity which is major environmental concern nowadays. Thermo-electric refrigerators are compact and consume less electrical energy which supports use of renewable energy resources such as solar, tidal, wind power, etc. major applications of thermo-electric refrigerator are in medical storage systems, blood-tissue transfer and as a portable refrigerator.

KEYWORDS: *Thermo-electric cooling, Peltier effect.*

1. INTRODUCTION:

Conventional refrigerator has been used for more than two centuries but they has certain following limitations such as-

1. Conventional refrigerators consume large amount of electrical energy which leads to more consumptions of fossil fuel in order to meet the supply which leads to production of green-house gases as well as reduces density of Earth's core.
2. Traditional refrigerant uses Freon and CFC as refrigerant which causes thinning of Ozone layer which leads to passing of Ultra-Violet radiation from Sun to Earth's atmosphere.
3. In traditional refrigerators there is a tendency of leakage of refrigerant which canlead to ineffective cooling and polluting atmosphere.

Thomas seebeck found that the 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. Peltier effect was first discovered in 1834 by a French physicist Jean Charles Athanase Peltier . Peltier found opposite of Seebeck effect i.e. that the use of current at an interface between two dissimilar metals results in the absorption of heat and release of heat at subatomic level on two ends of metal joints this is a result of different energy levels in material's energy bands.

2. THERMO-ELECTRIC COOLER:

Peltier effect is the phenomenon to create a heat flux between the junctions of two different types of materials. Peltier module is consist of two side having opposite effect, one side gets cooler than ambient and other gets hotter. The effect is dependent upon the temperature difference between the two sides lesser the temperature difference higher will be cooling-heating effect and vice-versa.

3. PELTIER EFFECT:

It's a reverse of Seebeck effect which describes when the two dissimilar metals are brought in contact a voltage difference is established opposite to Seebeck effect inPeltier effect when voltage is applied to Peltier the temperature difference gets built since it has heating and cooling effect simultaneously it can be utilized for cooling or heating or both simultaneously.

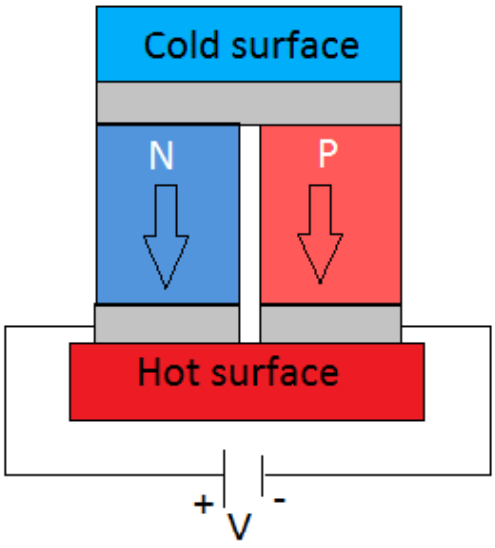


Fig. 1: Peltier Effect

4. WORKING PRINCIPLE:

Mainly in thermoelectric module a two dissimilar conductors are semiconductors as they can be doped and hence high carrier charge can be achieved commonly Bismuth telluride is used. As in fig.1 if the module is in reverse bias then the electron from P side will move towards N type semiconductor which means electron will move to high energy state thus absorbing heat from surrounding and on the other hand electron from N type semiconductor will move to positive terminal which will cause electron to jump in lower energy state thus releasing heat in surrounding.

Multiple couples are connected electrically in series and thermally in parallel the couples are separated from one another by ceramic.

The performance of Peltier module is greatly affected by the temperature difference between the two sides, to achieve very low temperature on cold side the hot side must be as cool as possible by means of heat sinks or other cooling systems.

5. METHODOLOGY:

To conduct experiment Cold side of Peltier consisting fan for fast cooling of chamber isfitted inside the chamber and hot side Heat sink have exhaust to surrounding, for measuring real time temperature of cold side a digital thermometer is fitted inside the cooling chamber.

Abbreviations –

α = *Seebeck coefficient*
K_m = *Peltier electrical conductance*
R_m = *Peltier electrical resistance*
Q_C = *Heat absorbed at cold side of Peltier*
Q_h = *Heat rejected at hot side of Peltier*
T_h = *Initial temperature of cooling chamber*
T_c = *Final temperature of cooling chamber*
V_{max}=*Peltier maximum voltage rating*
I_{max} = *Peltier maximum current rating*

Equations for Peltier coefficients-

$\alpha = V_{max} \div T_h$
$R_m = ((T_h - \Delta T_{max}) \times V_{max}) \div (T_h \times I_{max})$
$K_m = ((T_h - \Delta T_{max})(V_{max} \times I_{max})) \div (2\Delta T_{max} \times T_h)$

For measuring heat absorbed at cold side and heat rejected on hot side the following equations have been used-

Heat absorbed at cold side (RE)-
$Q_c = (\alpha \times I \times T_c) - ((I^2 \times R_m) \div 2) - (K_m(T_h - T_c))$

Heat rejected at hot side-
$Q_h = (\alpha \times I \times T_h) + ((I^2 \times R_m) \div 2) - (K_m(T_h - T_c))$

Work input-
$W = Q_h - Q_c$

6. COMPONENTS USED IN EXPERIMENTAL SETUP:

A. PELTIER MODULE:

The Peltier module used is TEC1-12706 as its operating conditions are feasible and it has moderate resistance and power input.

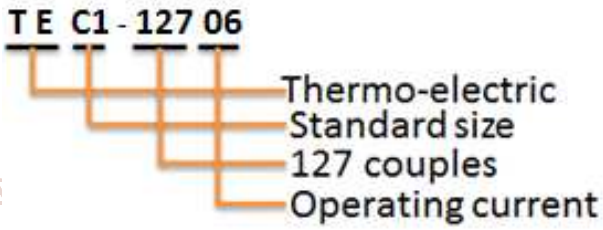


Fig. 2: Nomenclature of Peltier module

Fig. 3: Peltier module Specifications of TEC1-12706

Size 40x40x3.9 cubic mm, Weight 27g
I_{max} 6.4Amp, V_{max} 14.4V, R_m 1.98 Ohms Max temperature difference 68
Q_{max} (initially) 63 Watts

B. SMPS (SWITCHED MODE POWER SUPPLY):

The electronic power supply integrated with the switching regulator for converting AC supply into DC efficiently and consistently with desired output, called as switched mode power supply. It is used to achieve regulated DC output voltage from unregulated AC input source.

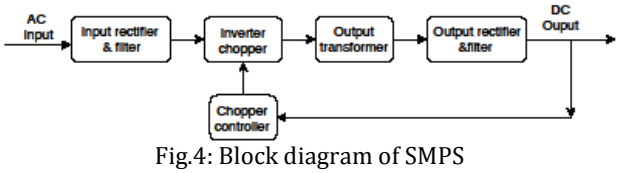


Fig.4: Block diagram of SMPS

Fig. 5: SMPS

Specification of SMPS-
Input Voltage : 100-270V AC
Output Voltage : 12V DC
Output Current : 10Amp
Power Factor : 0.95
Frequency Range : 47-67Hz

C. SUPPLY REGULATOR:

A supply regulator is device which is used in order to get steady, reliable output supply.

It acts as supply check for Peltier in order to prevent any overloading from abruption in supply and it also facilitates in providing a range of output supply within the max rating limit to perform experiments.

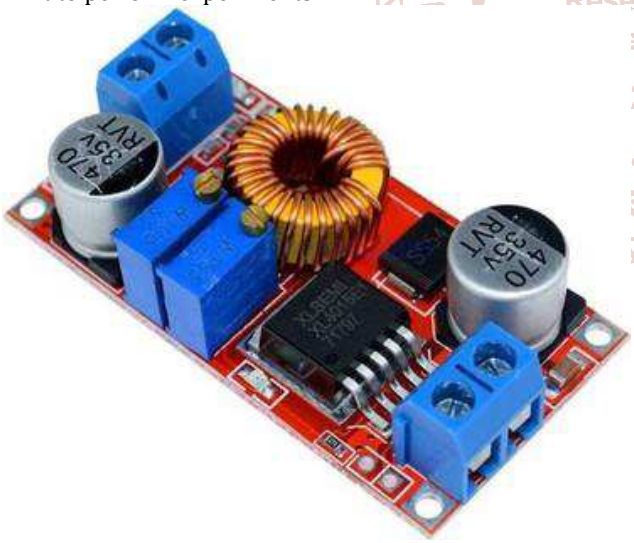


Fig. 6: Supply convertor

Specifications-
Output Voltage : 0.1-12V DC
Output Current : 0.1-5Amp

D. HEAT SINK:

It is an integral part of thermo-electric refrigerator which necessary for two reasons-

A. To remove the heat of hot side of Peltier to atmosphere.
B. To properly circulate the medium inside the cooling chamber to ensure fast response within the cooling chamber.

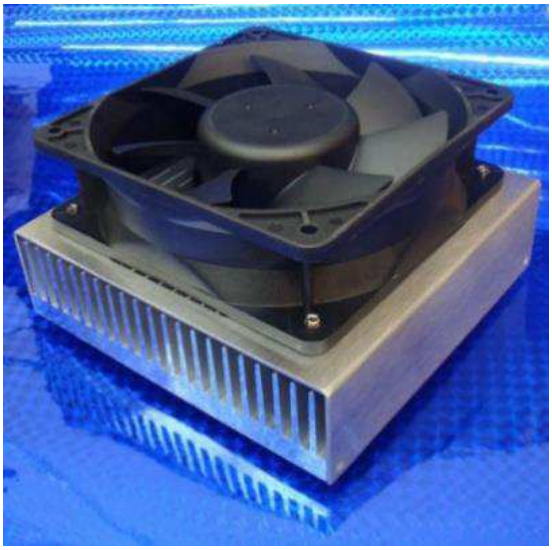


Fig. 7: Heat sink

E. DIGITAL THERMOMETER:

Digital thermometers are fast, accurate and easily portable they have permanent probe attached to it. The response time depends upon the type of sensor used it can be thermocouple type, resistance type, or thermistor type. We have used PM 10 model digital thermometer.

Fig. 8: Digital thermometer

7. EXPERIMENTAL SETUP:

Experimental setup is made of ply-wood (thermal conductivity: 0.13W/m-K at 25 degrees Celsius) and for insulation we have used the polystyrene foam (thermal conductivity: 0.033W/m-K at STP).

Fig. 9: Prototype (front view)

The prototype has two separate compartments, upper chamber has two Peltier module and lower chamber has three Peltier module.

Cooling space-
Upper chamber : 240x270x140cubic mm
Lower chamber : 240x270x330cubic mm

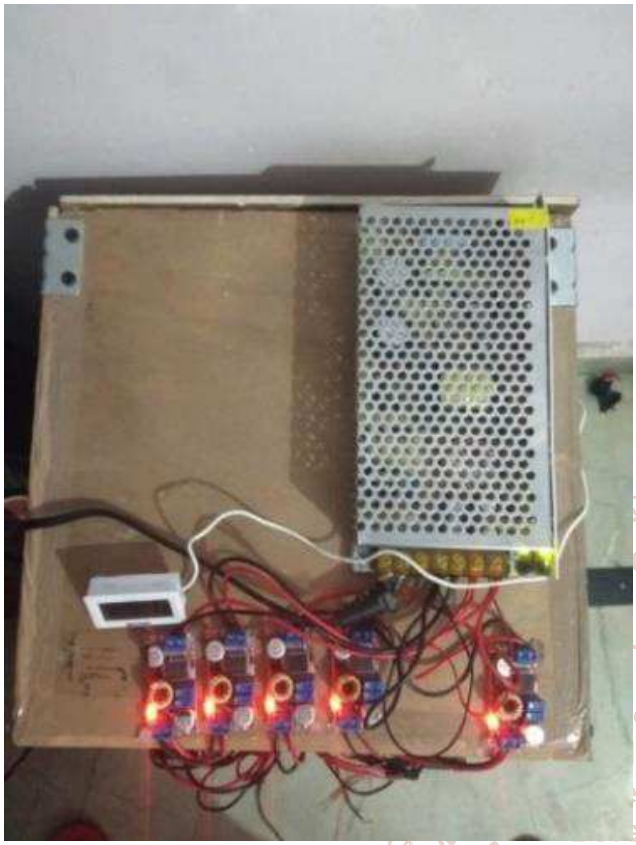


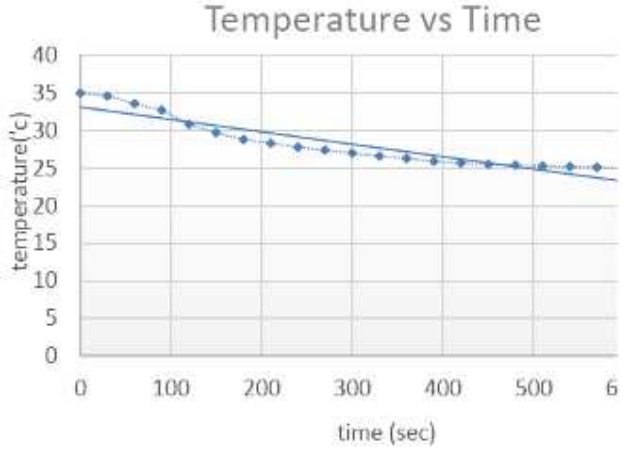
Fig. 10: Prototype (top view)

Peltier operating conditions-
Input voltage : 6V DC
Input current : 3Amp DC

8. RESULTS AND DISCUSSION:

Graph between temperatures of cooling space versus time has been shown below-

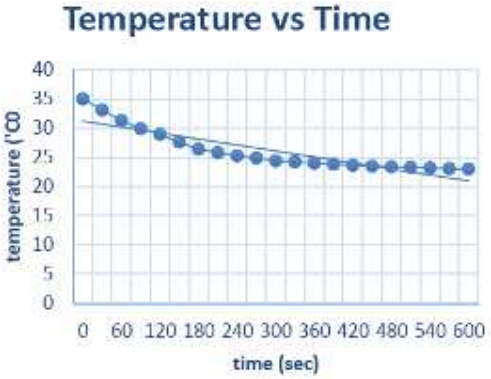
Graph no. 1: In upper chamber



Graph 1: Temperature vs Time graph of upper

In above graph, Two Peltier shows the temperature drop from 35 to 25 degrees Celsius over a time period of 10 min in upper chamber (240x270x140 cubic mm i.e. 9.07L).

Graph no.2: In lower chamber



Graph 2: Temperature vs Time graph of lower

In above graph, Three Peltier shows the temperature drop from 35 to 23 degrees Celsius over a time period of 10 min in lower chamber (240x270x330 i.e. 21.38L).

This shows the power increases significantly with an increase in no. of Peltiers module with heat sinks.

9. CONCLUSION AND FUTURE SCOPE:

The study of Thermo-electric refrigerator has been done successfully and the drop in temperature of 10 and 12 degrees has been observed in upper and lower chambers respectively in 10 minutes.

In context of its future scope, the performance of this scale refrigerator can be improved significantly by using efficient liquid cooling to lower the hot side temperature as low as possible.

The hot side exhaust can also be used as a hot blower.

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