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Cooling of Water using Peltier Effect

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Abstract: ***With climate change being a reality and temperatures soaring up, water at low temperature is a necessity everywhere. Since the means of cooling the water is not readily available to all sections of the society, an alternate method to do so is the need of the hour. A cooling system based on Peltier Effect uses very less power and is portable. It uses a very thin thermoelectric module through which the required heat transfer can be achieved.***

Keywords: Low Temperature, Heat Transfer, Thermodynamics, Alternate Cooling System, Peltier Effect, Thermoelectric Module.

I. Introduction

Low temperatures are a necessity everywhere around the world, in one respect or the other. Its usage varies from the storage of medicines to daily life matters such as drinking water. As technology has evolved, the ways of producing these low temperatures has changed too. From the harvesting of snow and ice to the air-conditioners and heat exchangers, we have indeed come a long way. However, every system has its own problems and ill effects attached to it. Thermoelectric cooling is a novel method that can be used to get the desired results with less harms.

First studies regarding thermoelectric cooling dates back to 1823 when it was found that an electric current would flow continuously in a circuit made up of two dissimilar metals if the junctions of these metals were maintained at two different temperatures. A German scientist, Thomas Seebeck, was the man behind this observation. Based on this concept, Jean Peltier discovered the reverse of this effect where a temperature difference would be produced if a constant current were passed through a similar circuit. It is on the principle of this discovery that the thermoelectric cooling works. Courtesy of further developments in the field by Emil Lenz and Altenkirch, it was known that this effect even has the potential to freeze water and that the thermoelectric materials need to have certain properties such as high Seebeck coefficient, high electrical conductivity, low thermal conductivity, etc. Moreover, the direction of the heat flow depends on the direction of applied electric current and the relative Seebeck coefficient of the two materials. Based on this, a Peltier module or thermoelectric module was designed that is a solid-state active heat pump which consist a number of p- and n- type semiconductor couples connected electrically in series and thermally in parallel are sandwiched between two thermally conductive and electrically insulated substrate.

Now, how can the low temperature that is produced on one side of the module be trapped to make use of it? Will the temperature from the hot side of the module not affect the cooling phenomenon? In what capacity should the modules be used for optimum results? How is thermoelectric cooling more advantageous than the conventional systems?

II. Material and Methodology

The goal was to supply power to the thermoelectric modules using an ac source by converting it into dc power. The modules in turn will cool a container wherein water will be filled and tests be done.

A circuit consisting of transformers, 5 in number, was designed to convert the available ac power to dc. There are five output terminals each having a maximum capacity of 10 amps at 12-volt dc current. This is achieved due to the circuit having five transformers connected separately. For extensive testing it was required that we should be able to vary the power input to the module to study it properly. This was made possible by the knobs attached to each of the terminals, which help us to vary the voltage from two to 12 in steps of two.

The modules are connected to the terminals of the transformer circuit as shown above. Switches are introduced in between the path to enable controlled cooling.

A container had to be fabricated of a material, which would easily conduct heat. Other requirements of the container include that it should be strong enough to bear the pressure of water that will be filled inside it, it should be easier to handle and, more importantly, it should have a flat surface for the modules to be mounted on. To achieve these objectives, we bought a thermocol box. At the bottom of the box, where the modules were to be attached, five slots were cut to place plates of such a material that can transfer the cold temperature of TE modules easily to the water inside the box. We chose copper as the material of the plates as it has one of the best thermal conductivities, is relatively cheaper than other high conductivity metals and is soft enough to be fabricated easily.

To this container, at one of the bottom corners, is fixed a small pipe to act as an outlet for water. A regulator is attached to the plastic pipe. To meet the requirements of the project the dimensions of the container were to be decided to ensure highest efficiency. We were looking for area that was only large enough to just fix the modules along with heat sinks. Similarly, the thickness of the copper should also be appropriate, thin enough to allow the process of heat transfer

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easily and thick enough for the surface to be rigid and flat. This was achieved by selecting a copper sheet of 0.5 mm for the bottom plates, where the modules were to be mounted. The base surface measures 8 inch by 10 inches.

Moreover, thermocol would acts a very good insulator, thus protecting the inside space from the hotter atmosphere, effectively.

Thermoelectric modules work best when the heat developed on the opposite side of the cold plate is dissipated from it effectively. Moreover, there is a chance that the module is damaged due to excessive heat accumulation. To dissipate this heat a heat sink is to be attached to the hot side of the module. The heat sink we have used is the one, which is used typically in CPU's of the computers.

It consists of two parts; one is a 12-volt dc fan and the other an aluminium finned surface. Both the parts are held together using four long screws. Five of such heat sinks were used to dissipate the heat from the five modules that were going to be used.

Since the fan is a dc type and the power available is in ac, we had to make use of a converter for the fans to work. This was an 'LED Driver', which converts the available 220-volt ac into 12-volt dc with one amp as maximum current. So, five such drivers were used to run the five fans.

The air gaps present in the interface of the module and heat sink, module, and container hamper the efficiency of the module, as air is not a very good conductor of heat. This hurdle was dealt with by applying a thermal paste between the surfaces. After the thermal paste is applied the two surfaces are wrung together to ensure proper thermal contact.

III. Results and Tables

Our observations during the experiment and the results we got are discussed in the following section.

Test 1.

The following observations were made for the first test.

Atmospheric temperature = 35 °C
Initial temperature of water = 33 °C
Time interval = 10 minutes
No. of modules = 4
Volume of water = 500 ml

S. No.	Input Voltage	Temperature of Water (°C)	θT (°C)
1	2	32	1
2	4	30	2
3	6	28	2
4	8	25	3
5	10	22	3

Table 1: Test 1
where θT denotes the temperature difference created in the time interval when a certain voltage was applied.

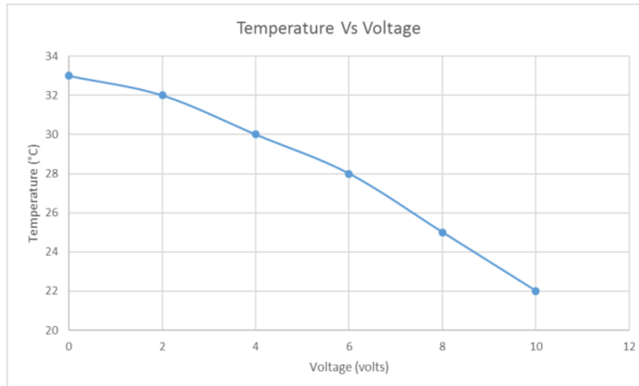

Figure 1: Result graph for test 1

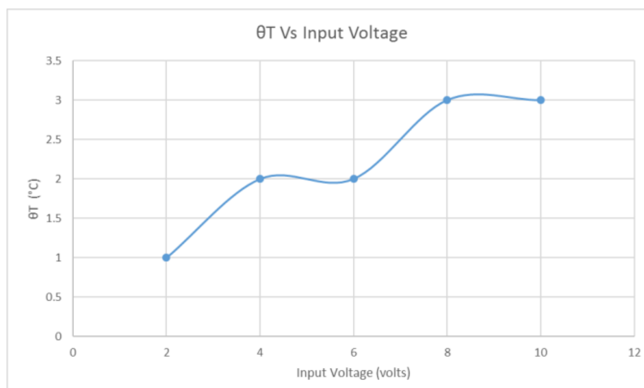

Figure 2: Result graph of test 1

The temperature of the water comes down as I increase the applied voltage to the modules.

Test 2.
The following observations were made for the second test.

Atmospheric temperature = 35 °C
Initial temperature of water = 33 °C
Time interval = 10 minutes
Input voltage = 10 volts
Volume of water = 500 ml

S. No.	No. of Modules	Temperature of Water (°C)	θT (°C)
1	1	33	0

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2	2	30	3
3	3	27	3
4	4	22	4

Table 2: Test 2

Where θT denotes the temperature difference created in the time interval when a certain number of modules was switched on.

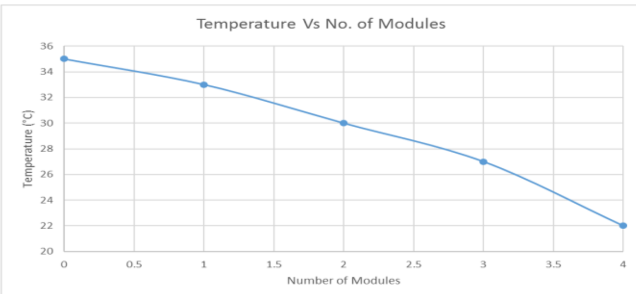

Figure 3: Result graph for Test 2

Here also, there is an evident cooling effect because of the increase in the number of modules.

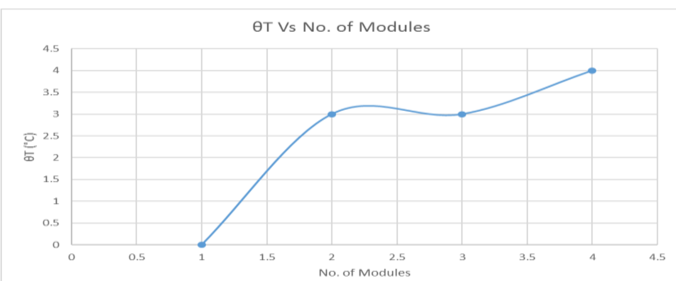

Figure 4: Result graph for test 2

Test 3.
The following observations were made for the third test.
Atmospheric temperature = 34 °C
Number of modules used = 5
Input Voltage = 10 volts

Temperature of Water (°C)	**Time (minutes)**
33	0
32	0.3
31	0.7
30	1.1
29	1.6
28	2.3
27	3.1
26	3.9
25	4.8
24	5.7
23	6.7
22	7.6
21	8.9
20	11.2

Table 3: Test 3

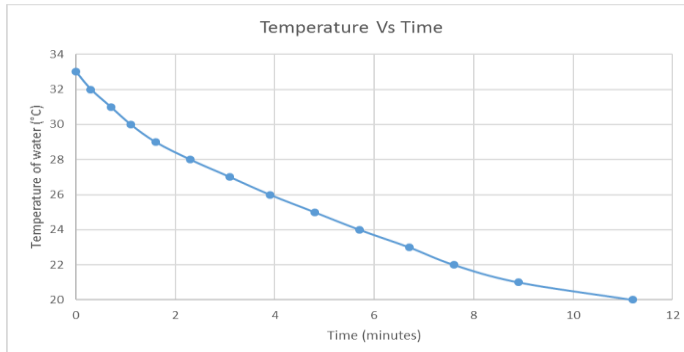

Figure 5: Result graph of test 3

We can very clearly observe that temperature of the water comes down as the time increases for which the modules are kept switched on. It is also seen that initially the water temperature is reduces faster than in the latter stages.

IV. Conclusion

Thermoelectric refrigeration is a noiseless method of doing so and, above it eco-friendly. The various tests that we have conducted made us to believe that TE modules are best suited for minor applications and efficient for the same too. As can be seen in the third test, its effects come to surface clearly after some time. There still can be an improvement in the performance of the module if heat sinks required are made and manufactured according to the dimensions of the module. The one's we are using now, CPU fans, are reliable but not perfect. Another room for improvement can be find in the making of the container in which efforts can be made to increase the ratio of area of the container covered by the modules to the area that is not. Overall, there is room for the module to perform even better than it is doing now. It holds the future of refrigeration needs for all small applications.

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