DESIGN, ANALYSIS AND DEVELOPMENT OF SELF COOLING BOTTLE OF 1L. CAPACITY

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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. The basic necessities of life, and for human comfort pure and chilled drinking water can be obtained just inside the bottle. A cooling system based on Thermo-Electric effect (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 and also maintaining it.

***Keywords* - Thermoelectric effect,Peltier effect,Peltier Module,Analysis of heat transfer,Stainless-steel bottle,copper bottle,Heat sink**.

I. INTRODUCTION

Today we live in the hi-tech 21st century where there are gadgets for everything from main stream to offbeat, just to make our lives easy, from a pen nip to a space shuttle, from automatic pizza ending machine to driverless car. One of the basic human needs is water and with the status of living is improved so much that chilled drinking water has become a necessity. For that refrigerators are used, but these refrigerators are quite bulky, heavy and not portable, and with advancement in technology, we have become lazy, that we need everything around us in handy manner, walking to the kitchen and getting a cold has also become a task, so why not design a bottle that cools itself.So the idea here is to cool the water in a small (compact) flask or bottle cooling it by using TEC module. The basic requirement here is electricity and water at normal room temperature.

II. LITERATURE REVIEW

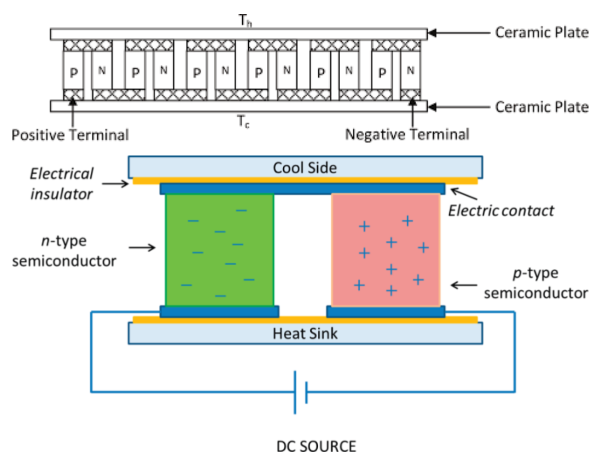
1. THERMOELECTRIC EFFECT

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa via a thermocouple.[1] A thermoelectric device creates voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, heat is transferred from one side to the other, creating a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side.

This effect can be used to generate electricity, measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as temperature controllers.

The term "thermoelectric effect" encompasses three separately identified effects: the Seebeck effect, Peltier effect, and Thomson effect. The Seebeck and Peltier effects are different manifestations of the same physical process; textbooks may refer to this process as the Peltier Seebeck effect (the separation derives from the independent discoveries by French physicist Jean Charles Athanase Peltier and Baltic German physicist Thomas Johann Seebeck). The Thomson effect is an extension of the Peltier–Seebeck model and is credited to Lord Kelvin.

2.PELTIER EFFECT



The Peltier effect is the presence of heating or cooling at an electrified junction of two different conductors and is named after French physicist Jean Charles Athanase Peltier, who discovered it in 1834. When a current is made to flow through a junction between two conductors, A and B, heat may be generated or removed at the junction. The Peltier heat generated at the junction per unit time is $Q = (\pi A + \pi B) I$

Where IIA and IIB are Peltier coefficients and I is the electric current (from A to B). The Peltier coefficients represent how much heat is carried per unit charge. Since charge current must be continuous across a junction, the associated heat flow will develop a discontinuity if π A and π B are different. The Peltier effect can be considered as the back-action counterpart to the Seebeck effect (analogous to the back-emf in magnetic induction): if a simple thermoelectric circuit is closed, then the Seebeck effect will drive a current, which in turn (by the Peltier effect) will always transfer heat from the hot to the cold junction. The close relationship between Peltier and Seebeck effects can be seen in the direct connection between their coefficients.

3. THERMOELECTRIC MATERIALS

Semiconductors are the optimum choice of material to sandwich between two metal conductors because of the ability to control the semiconductors' charge carriers, as well as, increase the heat pumping ability. ➢ The most commonly used semiconductor for electronics cooling applications is Bi2Te3,because of its relatively high figure of merit. However, the performance of this material is still relatively low and alternate materials are being investigated with possibly better performance.

4. MAJOR APPLICATIONS OF TE COOLERS

Include equipment used by military, medical, industrial, consumer,scientific/laboratory, and telecommunications organizations. Uses range from simple food and beverage coolers for an afternoon picnic to extremely sophisticated temperature control systems in missiles and space vehicles.

5. Why is TE Coolers Used for Cooling?

No moving parts make them very reliable; approximately 105 hrs. of operation at 100 degrees Celsius, longer for lower temps. Ideal when precise temperature control is required. Ability to lower temperature below ambient. Heat transport controlled by current input. Able to operate in any orientation. Compact size make them useful for applications where size or weight is a constraint. Ability to alternate between heating and cooling. Excellent cooling alternative to vapor compression coolers for systems that are sensitive to mechanical vibration.

6. ADVANTAGES AND LIMITATIONS

--ADVANTAGES

➢Small size and light weight.
➢Compact and reliable.
➢Steady-state operation.
➢No moving parts and fluids.
➢Durable and maintenance-free.
➢Very long operation life.
➢Effective in spot cooling.
➢Environmentally friendly.
➢No chlorofluorocarbons.
➢Ability to heat and cool.
➢Work in any orientation.
➢Generate no electrical noise
➢Can powered directly by PV cells.

--LIMITATIONS

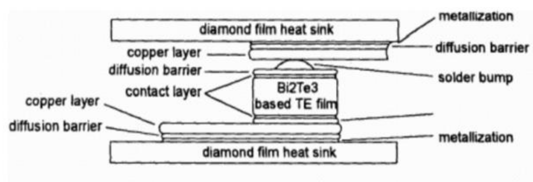
➢Able to dissipate limited amount of heat flux.
➢Lower COP as compared to VC systems.
➢Relegated to low heat flux applications.
➢More total heat to remove than without a TEC.

7. IMPROVING TE PERFORMANCE

Various methods have been used to improve the performance of TE coolers which are its major drawback.
Examples: thin film coolers or multistage (bulk) coolers.

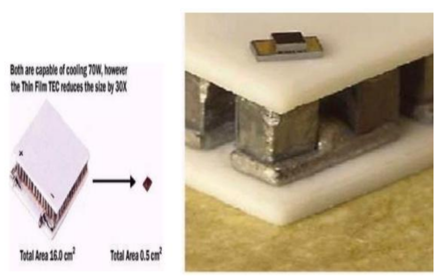
[A] THIN FILM COOLING

Thin films are material layers of about 1 micrometer thickness. Alternating layers of Sb_2Te_3 and Bi_2Te_3 are used to produce thin film TE coolers. An example is shown below where the highest power components are mounted on a diamond substrate which would be the top or cold side substrate of a thin film TE cooler. Power densities were reported to be above $100W/cm^2$.



Structure for a thin film thermoelectric device (adapted from Fleurial and Vandersande [9]).

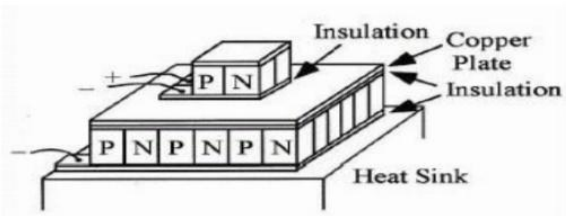
Thin film coolers considerably reduce the size of TE devices. Because the cooling density of a Peltier cooler is inversely proportional to its length, scaling to smaller size is desirable. A comparison of sizes are shown below.



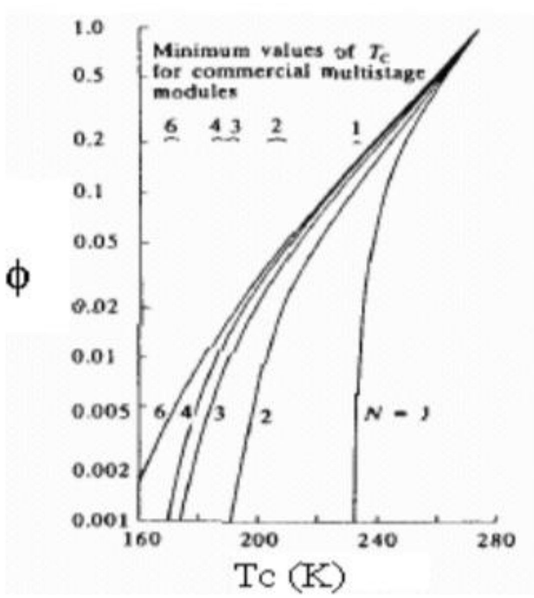
[B] MULTISTAGE COOLING

➢When the desired temperature differential between the cold and hot side cannot be obtained with a single stage module, or when the cold side temperature must be lower than a one stage cooler will allow, a multistage module may need to be applied.

➢ Multistage modules are essentially single stage modules stacked up in a vertical pyramid-shaped array (see next slide).
➢ As the number of stages increases, the minimum cold side temperature will decrease (Rowe, 1995).
➢ Also, increasing the number of stages increases the coefficient of performance for a given cold side temperature.



Increasing the number of stages increases the coefficient of performance for a given cold side temperature, as seen in the figure on the right.



The coefficient of performance of a multistage module is given by:

$$\phi = \left[\left(1 + \frac{1}{\phi'}\right)^{N} - 1\right]^{-1}$$

Where f' is the coefficient of performance of one stage of the module and N is the number of stages.

III. IMPLEMENTATION OF PROJECT WORK

EXPERIMENT -- 1

Aim: -To achieve cooling of water using TEC module.

Apparatus: -TEC module (TEC1-12706), heat sink with a cooling fan, water, copper glass, thermocol for insulation, digital thermometer, heat sink compound, 12 V vehicle battery.

Working: - connect fan and peltier module to the battery, apply heat sink compound on both the sides of the TEC module connect the hot side to the heat sink and cold side to the copper glass, now water is filled in the glass.

Atmospheric temp.:- 34.6 oC

Initial water temp.:- 30.5 oC

Water volume:- 250ml

Satisfactory temp. of cool water from fridge:- 18

Temp (ºC)	Time Min.
30.5	0
29.8	1
28.5	2
27.8	3
27.5	4
27.2	5
26.9	6
26.5	7
26.3	8
25.9	9
25.5	10
25.2	11
24.9	12
24.6	13
24.2	14
23.9	15
23.6	16
23.2	17
22.9	18
22.5	19
22.3	20
22.0	21
21.7	22
21.3	23
21.0	24
20.6	25
20.3	26
20.1	27
19.9	28
19.5	29
19.2	30
18.9	31
18.5	32
18.2	33
18.0	34

Conclusion: - after 34 min satisfactory cool temp. of water was achieved.

EXPERIMENT -- 2

Aim:- To achieve cooling of water using TEC module.

Apparatus:- TEC module (TEC1-12706), heat sink with a cooling fan, water, plastic glass mounted on a thin copper plate, digital thermometer, heat sink compound, 12 V vehicle battery.

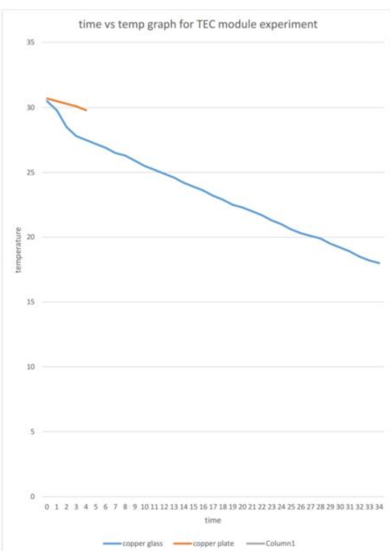
Working: - connect fan and peltier module to the battery, apply heat sink compound on both the sides of the TEC module connect the hot side to the heat sink and cold side to the copper plate, now water is filled in the plastic glass.

Atmospheric temp.:- 33.5 oC

Initial water temp:- 30 oC

Temp (°C)	Time Min
30.7	0
30.5	1
30.3	2
30.1	3
29.8	4

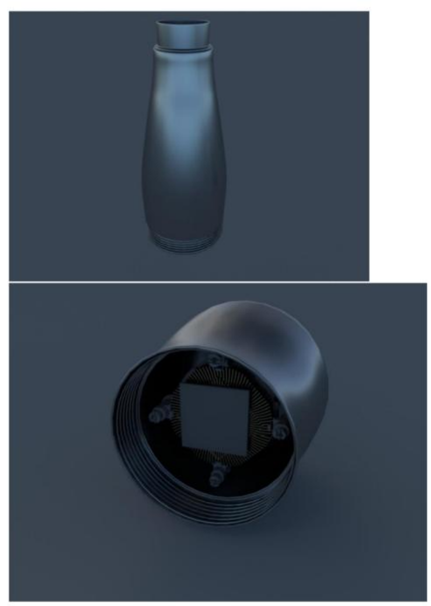
Conclusion:- even after 4 min no satisfactory results were obtained so we stopped it.

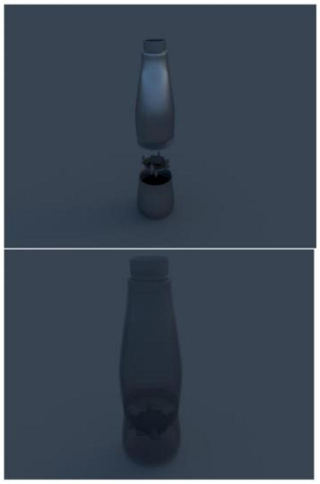


∗ **Images of apparatus while performing the experiment**

IV. PROTOTYPE DESIGN

1. BASIC DESIGN OF OUR SYSTEM





❖ Following are the components of our product

1. Thermally insulated copper Flask with insulated bottom

2. Thermo-electric Cooler (peltier module)

3. Heat sink with cooling Fan

4. Power adaptor

5. Heat sink compound (thermal paste)

2. WORKING

When the power is supplied the water inside the copper bottle stars to cool, With the help of TEC and the heat is continuously dissipated outside the heat sink with help of fan Capacity(60W).

• Reason to use a copper flask is that its thermal conductivity is maximum and by insulating it we can store the cooled water for a long time.

• And with the use of heat sink and fan the cooling of water is done on a fast rate and more efficiently.

V. CONCLUSION

From the performed experiments it concluded that copper flask is better for cooling of water instead of a copper plate.

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. 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.

Further application of heating too can be incorporated in the same system but by reversing the polarity the efficiency of TEC module decreases.

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