Design and Development of a Portable Thermo-Electric Cooler Bottle

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Abstract: *There are several traditional refrigeration systems as we all know. This has resulted in serious issues with the usage and disposal of CFCs and HFCc, as well as the fact that they are not portable. As a result, an electronic device is required to maintain the inside temperature while also lowering the temperature to cool water and preserve perishable liquids. When compared to conventional cooling systems, a Peltier Effect water-cooling system has numerous advantages, including being tiny, portable, noiseless, environmentally benign, and cost-effective. The current study examines the performance characteristics of thermoelectric refrigerators in various scenarios. The hot side temperature rises when the applied voltage is raised, whereas the cold side temperature decreases. The heat absorbed by the cold side and the heat rejected by the hot side both increase as the applied voltage increases, but the "coefficient of performance" drops. Raising the heat sink fan speed improved system performance by increasing the amount of heat absorbed by the cold side and rejected by the hot side. The performance of the TE water cooling system is heavily influenced by the "initial water temperature". As a result, compared to traditional refrigeration with the same refrigerating effect, there will be less power usage and completely eco-friendly refrigeration.*

Keywords: Peltier Effect, Heat Sink, Coefficient of performance, Thermoelectric

I. INTRODUCTION

We now live in the hi-tech twenty-first century, with gadgets for everything. Food and drinks refrigeration and cooling has become a need in today's environment. Without good temperature management, fresh food would decay, drinks will be unsuitable for intake, and people will be unhappy. For these reasons, coolers are particularly handy for keeping food and drinks cool when away from home. Whether camping, picnic, on a road trip in a car people will utilise coolers to keep their food and drinks at the ideal desired temperature. One downside of conventional coolers is that they are only good insulators and do not provide any cooling. To keep the food and drinks chilled, ice must be placed in the cooler. While this is usually convenient and cost-effective, it would be preferable if there was a means to keep food and drinks refrigerated without the use of ice. In this case, a "thermoelectric cooler" (TEC) can aid. A TEC cools things without utilising ice, instead relying on electricity. Food and drinks might be refrigerated without the use of ice at any time with this application.

II. LITERATURE REVIEW

In this work, we looked at three different Peltier modules and tested their temperature performance over time when 12 V, 2A DC was supplied. The stress and contacting termination of the Ceramic plate are completely responsible for Peltier module cooling and heating. This Peltier module is a critical electronic component for energy conservation. This features a low power consumption and a high output.[1] The purpose of this research was to see how changing the thermal resistance and voltage of the hot- and cold-side heatsinks affected the performance of a TEC and the system performance evaluated using the presented equation. The results revealed that cop of tec cooling system affected by thermal resistance of "hot side and cold side" heat sinks. The method demonstrated in this paper may be valuable to designers or engineers who want to employ a thermoelectric cooler with heatsinks as a cooling device. Researchers can use the method to determine the ideal voltage and system attributes for a particular ambient temperature and heatsink thermal resistance.[2] A thermoelectric cooler box with TE positions was used to explore the effect of TE positions on cooler box performance. At the same power as the TE, the TE's placements were top (OT), bottom (OB), and wall (OW). Some observations are made based on the experimental data and analysis. With time, the cooling capacity reduces. The rate of conduction heat transfer rises over time. Although the trend of Qc with time has deteriorated for the OB's TE position, the overall heat transfer rate (Qc) decreases with observation duration. The TE and heat sink should be installed on the wall if possible.[3] This study demonstrates how the suggested model's parameters may be retrieved from manufacturer's data for both TEC and TEG devices. We looked at formulas for calculating various factors like as thermal conductivity, electrical thermal resistance, and the Seebeck Coefficient, as well as mathematical modelling.[4] This study examines the evolution of thermoelectric cooling over the last decade in terms of material advancements, modelling methodologies, and applications. Domestic refrigeration, electronic cooling, scientific uses, and car applications are among the most common thermoelectric cooling applications.[5] In this paper designed, built, and tested a thermoelectric cooler prototype. The experiment uses a Melcor shape thermoelectric module. The experiment was carried out at four distinct ambient temperatures (15, 21, 32, and 43 degrees Celsius). The findings revealed that a lower temperature can be achieved with improved prototyping.[6] Three alternative fin configurations were investigated in this study. The COP of the system was shown to increase as the fin length was increased. We also discovered that rectangular fin designs had the highest COP. As a result, for small-scale thermoelectric refrigerators, rectangular is preferred.[7] “Conduction and convection” heat transfer were explored for the suggested thermoelectric cooler box for uniformly distributed temperature. The experimental results demonstrated steady-state temperature distributions with observation time at various places of the layers, including the cold and hot areas. [8]

III. FABRICATION

A. CAD MODEL

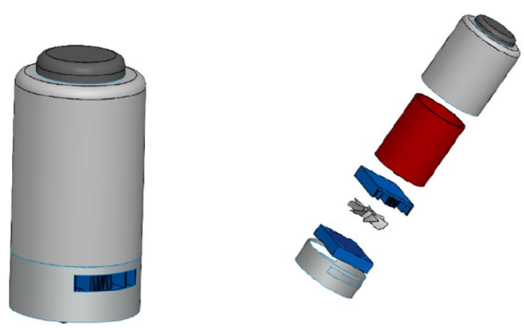

Fig -1: Basic Design of Bottle and Exploded view

B. CIRCUIT DIAGRAM

The following circuit consists of following components:

- AC source
- Charger AC-DC
- Voltage Regulator (VR)
- Relay Module (R)
- Connector (C)
- Peltier Module (P)
- Cooling Fan (F)
- Connecting Wires

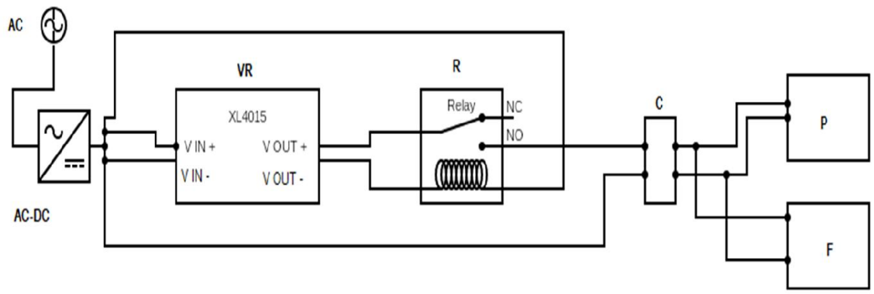

Fig -2: Circuit Diagram

IV. Methodology

Figure 3. shows a thermoelectric water-cooling system's experimental apparatus All of the components are included, including the heat sink, TEC, water container, fan, and power supply. A thermoelectric module TEC1-12715 was used in this research. There are 127 thermocouples in the thermoelectric module. It was placed between two ceramic plates and joined in series. When electricity is applied to the system, one “ceramic plate” becomes a heated plate, while the other becomes a “cooled plate”. Which plate is heated is determined by the current direction.

The thermoelectric modules were to be powered by a DC power supply. The modules will then chill a water-filled container before being tested. It was necessary to make a container made of a heat-conducting substance. With a diameter of 100 mm and a height of 150 mm, the container is cylindrical in shape (120mm). Thermal grease is used to adhere the container's base to the cold side of TE. To reduce heat loss, the water containers have been insulated. More amount of heat should be removed from the “hot side” for the best “TEC” performance. It consists of two parts: a 12-volt DC fan and a finned aluminum surface. To ensure adequate thermal contact, use correct thermal paste below the heat sink module's TEC settings. Aluminium was used to create it. The base has a volume of (100*95*50) mm3, and the fins have a length of (95mm), with a height and thickness of (25mm) and (1mm) accordingly 18 fins with a distance of 1.2 mm have been used on the heat sink's base. Below the heat sink is a 12V fan.

Fig -3: Experiment Setup

V. Observation

Table 1: Water Inlet Temp. 30 ˚C

No.	Time (min)	Tc ˚C	Current (Amp)	Voltage (Volts)	Atmospheric Temp. ˚C	Th ˚C
1	0	29.5	2	11.5	32.8	30
2	5	28	2	11.5	32.8	30.5
3	10	26.7	2	11.5	32.8	31

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4	15	25.6	2	11.5	32.8	31.5
5	20	25.1	2	11.5	32.8	32
6	25	24.2	2	11.5	32.8	34.4
7	30	23.6	2	11.5	32.8	34.5

We have taken further observation readings under different conditions for calculating the following: -

- Effect of water initial temperature
- Effect of voltage
- Effect of fan air speed

VI. CALCULATIONS

Theoretical Calculations

In this below calculation parameters calculated are: Energy supplied (W), "coefficient of performance" and cold side heat pumping rate (Q_L).

$$Q_L = \left[SIT_c - \frac{1}{2} I^2 R - K(T_{h\,-}T_c)\right]$$

= [0.0508*2*290 – 0.5*2^2*0.789 – 1.26(303-290)]

= -11.5 w (- sign denotes heat rejected)

Where values of fundamental parameters thermos-electric thermal conductivity (K), "thermo-electric Seebeck coefficient" (S) and "electrical resistance" (R) are calculated as follows: -

$$S = \frac{Vmax}{T_h}$$

$= 15.4/303$

= 0.051

$$R = \frac{V_{max}}{I_{max}} \frac{(T_h - \Delta T_{max})}{T_h}$$

$= 15.4/15 \ ((303 - 70))/303$

= 0.789

$$K = \frac{\Delta T_{max}}{I_{max}\, V_{max}} \frac{2\, T_h}{(T_h - \Delta T_{\max})}$$

$= 70/(15 * 15.4) \ (2 * 303)/((303 - 70))$

= 1.269

Qh is the amount of heat transported from the hotter side to the heat sink.:

$$Q_H = \left[SIT_c + \frac{1}{2} I^2 R - K(T_{h\,-}T_c)\right]$$

Where S is the "thermo- electric Seebeck coefficient", K is the TE "thermal conductivity" and R is "electrical resistance", Q_L is cold side heat pumping rate and Q_H is hot side heat pumping rate.

Energy Supplied (W) = $Q_H - Q_L$

= SI (T_h - T_L) + I^2R

= 0.0508*2(303-290) + (2*2*0.789)

= 32.62 w

The "coefficient of performance" of thermo-electric cooling system can be stated by:

$$C.O.P = \frac{Q_L}{Energy\ supplied\ (W)}$$

$C.O.P_{Theo}$ = 0.35

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Experimental Calculations

The problem here is to chill 0.30 litres of water in 1.5 hours from an initial temperature (Tin) to a final temperature (TfL). Assuming that the container is completely insulated. The amount of heat evacuated can be estimated as follows:

$$R_E = \frac{m * C_p * \Delta T}{t}$$

$$= \frac{0.3 * 4186 * 13}{90 * 60}$$

$$= 3.023 \text{ w}$$

The power supplied (W) can be calculated as

$$W = V * I$$

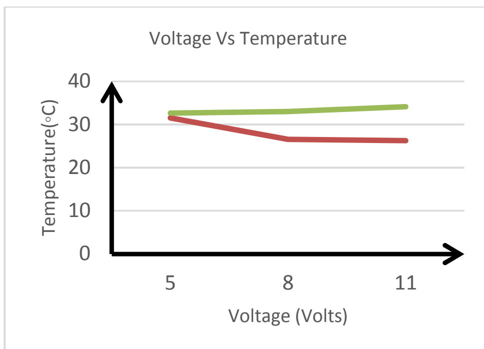
$$= 11.5*2$$

$$= 23 \text{ w}$$

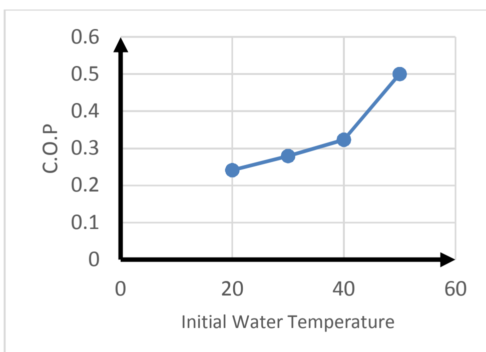
$$C.O.P_{Exp.} = \frac{RE}{w}$$

$$= 0.13$$

VII. Result and Discussion



Graph. - 1: Effect of voltage on temperature



Graph. - 2: Effect of initial water temp on COP

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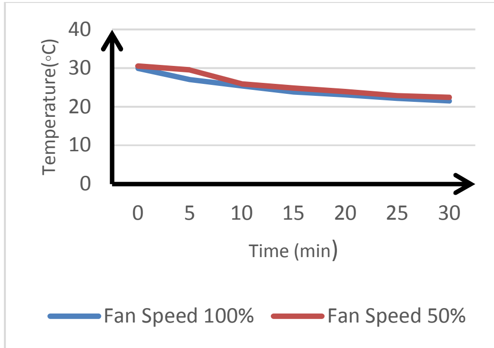
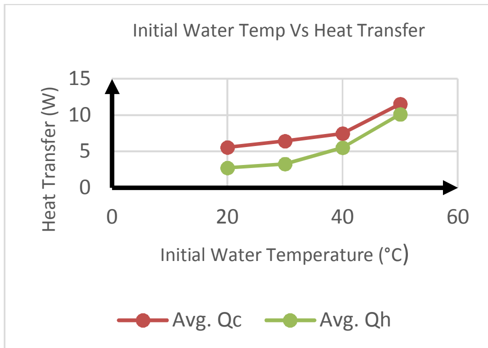


Graph - 3: Effect of fan air speed on temperature



Graph - 4: Effect of initial water temperature on heat transfer

From these graphs we can conclude that: -

- The cold side temperature drops as the applied voltage rises, whereas the hot side temperature rises.
- As the temperature of the intake water rises, so does the COP.
- It can be shown that raising the air speed lowers temperature measurements. values are lower for fan speed 100% as compared to values of fan speed 50%.
- The water temperature difference increases with increasing initial water temperature

VIII. CONCLUSION

The thermoelectric cooler's cooling properties are used in this work to create a thermally insulated cooler that can cool liquid to below surrounding temperature. Given that heat sink, it would be capable of dissipating all of the heat generated by the “thermoelectric coolers”. It was discovered that by leveraging a few key design characteristics, the heat sink's efficacy in dispersing heat may be improved. The conclusiveness of the heat sink to dissipate heat was revealed to be improved by increasing the “speed of air” going through the fins. Using the cooling capability of the thermoelectric coolers, the thermal modelling presented here indicated that 300 mL of liquid may be cooled.

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