Investigation of the Simultaneous Cooling and Heating Using a Thermoelectric Peltier †

Abdur Rehman Mazhar *, Ali Ubaid, Syed Muhammad Hamza Shah, Suhaib Masood and Muneeb Zafar Alvi

Department of Mechanical Engineering, College of Electrical & Mechanical Engineering CEME, National University of Sciences & Technology NUST, Islamabad 47301, Pakistan; aubaid.me41ceme@student.nust.edu.pk (A.U.); smhamza.me41ceme@student.nust.edu.pk (S.M.H.S.); suhaibmasood888@gmail.com (S.M.); mmueeb.me41ceme@student.nust.edu.pk (M.Z.A.)

* Correspondence: arehman.mazhar@cem.e.nust.edu.pk
† Presented at the Third International Conference on Advances in Mechanical Engineering 2023 (ICAME-23), Islamabad, Pakistan, 24 August 2023.

Abstract: Substitution of vapor compression refrigeration systems (VCRS) by using Thermoelectric Peltier offers numerous advantages. The Peltier effect is the inverse of the Seebeck effect: as a current flows between two dissimilar materials, it causes one side to grow hotter, making the other side cooler. This effect was experimentally exploited to simultaneously cool and heat water. In 60 min, 1 L of water was cooled from 40 °C to 16 °C and another liter heated from 25 °C to 45 °C. Power consumption was about 0.0828 kWh with a COP of 1.33, which can be enhanced using improved methods of heat dissipation on the Peltier device.

Keywords: Thermoelectric Peltier; HVAC; water dispenser

1. Introduction

The demand for efficient and eco-friendly cooling systems has led to the exploration of new refrigeration technologies. One such technology is the use of Thermoelectric Peltier’s, which operates on the principle of the Seebeck effect. Thermoelectric Peltier cooling systems do not require harmful refrigerants, making them more environmentally friendly without any mechanically moving parts in comparison to the status quo Vapor Compression Refrigeration System (VCRS). They can also potentially reduce energy consumption and improve efficiency by directly cooling or heating water without the need for a compressor or heat exchanger.

The primary objective of this project was to develop a prototype of a water refrigeration system using Thermoelectric Peltier’s. The prototype comprises an AC supply, Thermoelectric Peltiers, aluminum and copper heat sinks, thermal paste, a DC pump, pipes, and containers for water. The system is designed to operate on the principle of the Reverse Seebeck Effect, where a current is passed through the Thermoelectric Peltiers to create a temperature difference across its junctions [1]. The fins of the copper heat sink are submerged in one container containing hot water, while cold water is circulated through an aluminum heat sink block via pipes.

The use of a thermoelectric cooling system in this project is an important step towards developing sustainable and eco-friendly cooling technologies for drinking water. Traditional refrigeration systems rely on the use of harmful refrigerants, such as chlorofluorocarbons (CFCs) and mechanically moving parts, which have negative environmental impacts. The use of thermoelectric cooling systems reduces the reliance on harmful refrigerants and provides a more sustainable solution for cooling applications.

The thermoelectric cooling system has several potential applications in various fields, such as the food industry, medical settings, and research laboratories. It is also compact and with low noise, making it suitable for a variety of applications, including domestic,
industrial, and scientific settings [2]. The capital and operational cost of such a system is lower than a VCRS, with lower risks of refrigerant leakage and contamination, especially of drinkable water in this application involving close proximity with humans.

2. Methodology

A comprehensive literature review is primarily conducted for Thermoelectric Peltier applications for domestic applications [3].

Based on this literature review, it is clear that there is a major research gap in using Thermoelectric Peltiers for applications involving drinkable water. Additionally, there are limited studies investigating the effects of simultaneous heating and cooling with modified heat sinks attached to the device. This study aims to develop and test a Thermoelectric Peltier-based water dispenser for domestic use. This would be a competing technology for conventional VCRS-based water dispensers. Additionally, this paper and further linked papers of this study would serve as a guide to novice researchers interested in developing water refrigeration and purification systems using active carbon filtration and Thermoelectric Peltier technology.

An overview of the experimental setup is illustrated in Figure 1. Two compartments having a volume of 1 L are filled with water. The Thermoelectric Peltier device attached to a heat sink is placed in the left water compartment, as illustrated in Figure 2. The right compartment has a DC motor connected to a pump with pipes to circulate water to one side of the Peltier device placed in the left compartment. After operation, the system simultaneously heats the water in the right compartment whilst cooling the water in the left compartment using the Peltier effect. A Thermoelectric Peltier operates on the reverse Seebeck effect in which a temperature difference develops across the surface of the module when a DC current is applied to it. At a microscopic level, charge carriers in the material diffuse from the hot to the cold side of the module, creating a temperature gradient.

![Figure 1](image1.png)

**Figure 1.** Schematic of the assembly of the experimental setup with the AC-DC conversion kit, pump, and the heatsink attached to the Thermoelectric Peltier.

![Figure 2](image2.png)

**Figure 2.** Assembly of the heatsink and TEC1-12706 Thermoelectric Peltier.
The system is plugged into a normal domestic 220V AC switch with a conversion kit. A layout of a uniquely designed heat sink for this specific application and the structure of the Thermoelectric Peltier module TEC1-12706 is presented in Figure 2.

Additionally, details and specifications of the equipment are presented in Table 1.

### Table 1. Components and their specifications.

<table>
<thead>
<tr>
<th>Components</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC pump</td>
<td>12 V, 8 W, 10 L/m</td>
</tr>
<tr>
<td>Thermoelectric peltiers (TEC1-12706)</td>
<td>12 V, 4.4 A</td>
</tr>
<tr>
<td>Power supply</td>
<td>12 V, 30 A</td>
</tr>
<tr>
<td>Water block</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Thermoelectric peltiers (TEC1-12706)</td>
<td>Bismuth Telluride (Bi2Te3)</td>
</tr>
<tr>
<td>Heatsink</td>
<td>Copper</td>
</tr>
<tr>
<td>Pitch of the fins in the heatsink</td>
<td>2 mm</td>
</tr>
<tr>
<td>Number of fins</td>
<td>30</td>
</tr>
<tr>
<td>Water tanks</td>
<td>PETG (3D-printed)</td>
</tr>
<tr>
<td>Pipes</td>
<td>Polyethylene</td>
</tr>
</tbody>
</table>

### 3. Results and Analysis

During the cooling process, the initial temperature of the water is set to 40 °C. After cooling, the temperature successfully decreases to 16 °C in just a span of 60 minutes of continuous operation. For the heating process, the initial temperature is set to 25 °C, and through heating, the temperature is increased to 45 °C. Throughout the entire operation, the device consumed approximately 0.0828 kWh of energy. This corresponds to a change in temperature of approximately 0.3 °C/minute for both heating and cooling, which is a little below the value recorded in the literature primarily because of the fact that this study investigates simultaneous heating and cooling contrary to only one form of heat transfer found in the literature [3].

The Coefficient of Performance (COP) of the device is calculated to be around 1.3296, indicating that the device is efficient in converting energy simultaneously to produce a heating and cooling effect. This value of the COP is in line with results from the literature [3]. Had the calculation of the COP taken both effects into consideration, it would have been about 2.66. To further improve the performance of the device, the process could be refined with enhanced methods of heat dissipation. In the event of standalone heating and cooling, the COP improved further.

Figure 3 presents the variation of the cold and hot water temperature with time over the duration of the experiment. The variation is a linear process, as evident from Figure 3, with minor fluctuations due to reading variations of the thermocouples. Had the device operated for further time or with a heatsink having a higher fin pitch ratio, the plot would have asymptotically converged to the temperature of the Thermoelectric Peltier.

![Cooling Variation](image1)

![Heating Variation](image2)

**Figure 3.** Temperature variation in the cold and hot waters for the duration of the experiment.

A clear shortcoming of the Peltier not illustrated in these plots of Figure 3 is the fact that it heats up after 60 min of continuous operation, as observed in the literature as well [3].
This is similar to the heating of a compressor in a VCRS operating continuously. For this, three approaches are to be investigated in further studies of this project:

1. Usage of a more efficient and effective heat sink coupled with added passive heat dissipation technologies, probably with a higher fin pitch ratio.
2. Usage of cascaded Thermoelectric Peltier to minimize the load on a single device to provide a better-combined effect.
3. Usage of an automated time-limited operation of the Peltier using a PLC controller coupled with a variable input current supply. This approach is similar to the usage of variable speed compressors in modern VCRS.

A summary of the results of this experimental investigation is presented in Table 2:

<table>
<thead>
<tr>
<th>Control Parameters</th>
<th>Cooling Compartment</th>
<th>Heating Compartment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water stored</td>
<td>1 L</td>
<td>1 L</td>
</tr>
<tr>
<td>Initial Temperature</td>
<td>40 °C</td>
<td>25 °C</td>
</tr>
<tr>
<td>Final Temperature</td>
<td>16 °C</td>
<td>45 °C</td>
</tr>
<tr>
<td>Time taken</td>
<td>60 min</td>
<td>60 min</td>
</tr>
<tr>
<td>Flow rate through cooling block</td>
<td>10 L per minute</td>
<td>10 L per minute</td>
</tr>
</tbody>
</table>

4. Conclusions and Future Recommendations

In conclusion, the development of an innovative water refrigeration system employing Thermoelectric Peltiers represents a notable stride towards realizing a more sustainable and ecologically sound water dispenser as a competitor to VCRS-based dispensers. Furthermore, the system’s compact form factor and low acoustic emissions, along with a reasonable COP, contribute to its inherent appeal in domestic applications. Further work regarding the development of heatsinks, cascaded devices, and variable speed and time-based operation of the Peltier device is recommended.

Author Contributions: Conceptualization, A.R.M.; Methodology, A.U. and S.M.H.S.; Formal analysis, S.M. and M.Z.A.; Investigation, A.U. and S.M.H.S.; Resources, A.R.M.; Writing—original draft preparation, A.U., S.M.H.S., S.M. and M.Z.A.; Writing—review and editing, A.R.M.; Supervision, A.R.M.; Project administration, A.R.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.


Informed Consent Statement: Not Applicable.

Data Availability Statement: Not Applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References


Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.