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Portable Gravity-Assisted Thermoelectric Cooling Bottle: A Study on Copper-Based Passive Convection for Water Temperature Reduction

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Abstract

Portable cooling systems are traditionally dependent on compressor-based refrigerants or mechanical pumps, making them unsuitable for lightweight and off-grid applications. This study investigates a compact copper-based water-cooling bottle that integrates a thermoelectric cooling element (TEC) with a passive, gravity-driven convection mechanism. Experiments show a temperature reduction of 9.6 °C over 30 minutes under a 12 V, 3.1–3.2 A input, demonstrating the feasibility of low-power, portable cooling

Introduction

Portable cooling has become increasingly important in healthcare, sports, field sampling, and emergency scenarios. While thermoelectric devices based on the Peltier effect offer solid-state cooling, their efficiency is constrained by poor heat dissipation and the need for active fluid mixing. This study reports on a copper-based bottle with integrated TEC, designed to improve circulation using gravity-assisted convection.

System Architecture and Working Principle

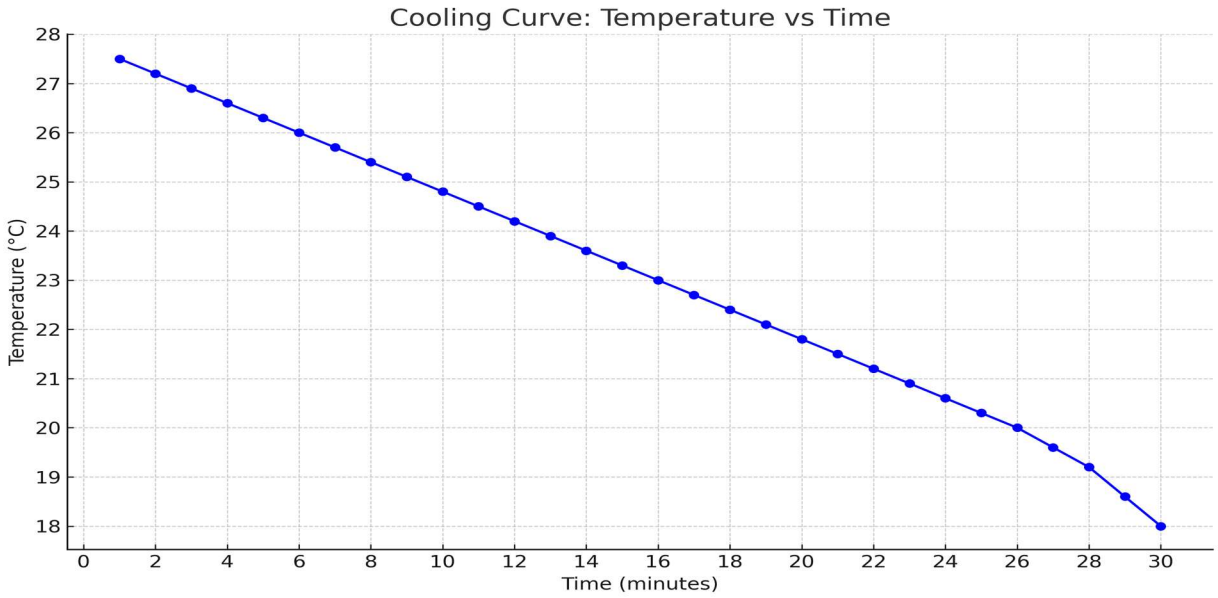
The system consists of a copper container, a TEC module at the top, a heat sink and fan, PVC foam insulation, and optional LiFePO4 battery. Its geometry enables gravity-driven convection, continuously cycling water without pumps.

Experimental Methodology

Power input: 12 V, 3.1–3.2 A. Initial temperature: 27.7°C. Measurements were recorded for 30 minutes. The dataset was obtained from experimental observations.

Experimental Cooling Data (Non-Battery Powered Model)

DC Voltage V_{in} = 12V, DC Current I_{in} = 3.1 A to 3.2A, Initial Temp. 27.7 °C											
Time (min.)	T (°C)	Time (min.)	T (°C)	Time (min.)	T (°C)	Time (min.)	T (°C)	Time (min.)	T (°C)	Time (min.)	T (°C)
1	27.5	6	26.0	11	24.5	16	23.0	21	21.5	26	20.0
2	27.2	7	25.7	12	24.2	17	22.7	22	21.2	27	19.6
3	26.9	8	25.4	13	23.9	18	22.4	23	20.9	28	19.2
4	26.6	9	25.1	14	23.6	19	22.1	24	20.6	29	18.6
5	26.3	10	24.8	15	23.3	20	21.8	25	20.3	30	18.1



Cooling is nonlinear: faster drop in the beginning, slower toward the end (as typical for thermal systems). Total drop: **27.7 °C → 18.1 °C = 9.6 °C** over 30 minutes. Figure 6: Temperature Drop Over 30 Minutes – Non-Battery Model

Results

The water temperature decreased from 27.7°C to 18.1°C in 30 minutes. The cooling curve follows an exponential decay pattern typical of Peltier systems.

Discussion

Advantages include no refrigerants, no pumps, high portability, and effective heat conduction due to copper. Limitations involve TEC efficiency and ambient heat ingress.

Conclusion

The copper-based gravity-assisted thermoelectric bottle provides efficient portable cooling without pumps or refrigerants. A 9.6°C temperature drop demonstrates its practical feasibility.

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