Calorimetric Efficiency of Peltier Device

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1. Abstract
2. Theory
3. Challenges, Design, & Methodology
4. Data Redux & Analysis
5. Conclusion

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We measured the coefficient of performance for a Peltier device by running a known current through the device and tracking the amount of heat removed from a mass of water. The experimental COP will be compared to the nominal value listed by the manufacturer.

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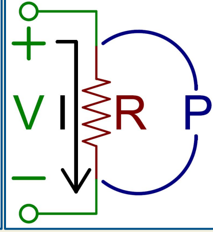
Theory– Peltier Effect (Reverse Seebeck Effect)



Electrical Power

$$P = I\,V$$

Heat Capacity Equation

$$Q = mc\Delta T$$

Electrical Work

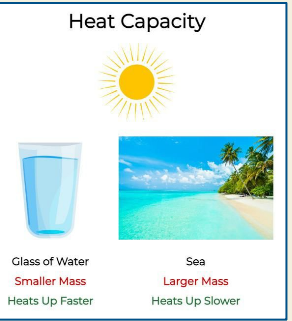
$$W = P\Delta t$$

Coefficient of Refrigerative Performance

$$COP = \frac{Q_{cold}}{W}$$

Fourier's Heat Law (Added in Error Analysis)

$$Q = \frac{k \cdot A \cdot \Delta T}{d}$$



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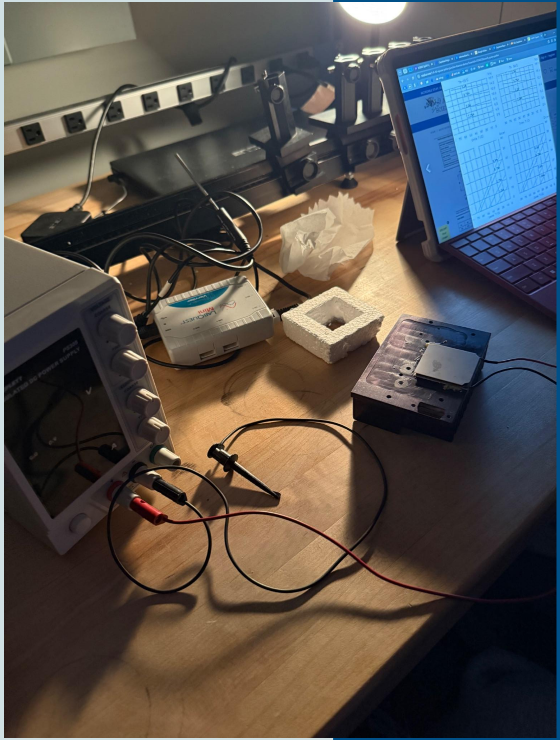
Challenges

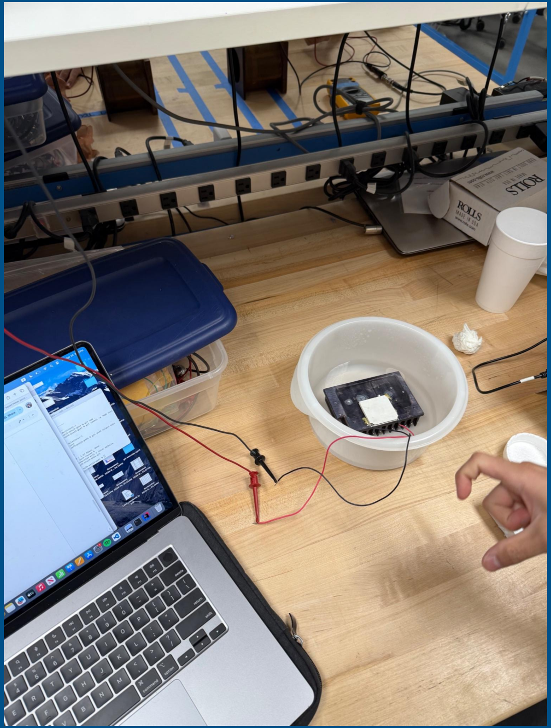
- Watertight?
- Heat transfer through bottom?
- Heat loss through adhesive?
- Dimensions for bottom?
  - Bigger? Smaller?
- How to stop heat from flowing back in?
  - Will Discuss more-developed a new setup after initial trials
- Initial trials were through an inconsistent power source (Voltage and Current fluctuated too much)

Final Design

Setup

With according adjustments...





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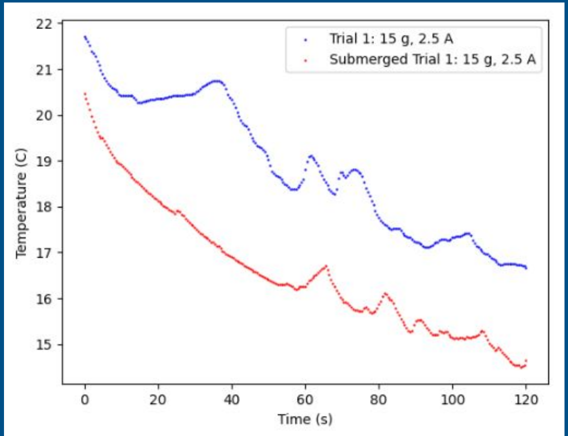
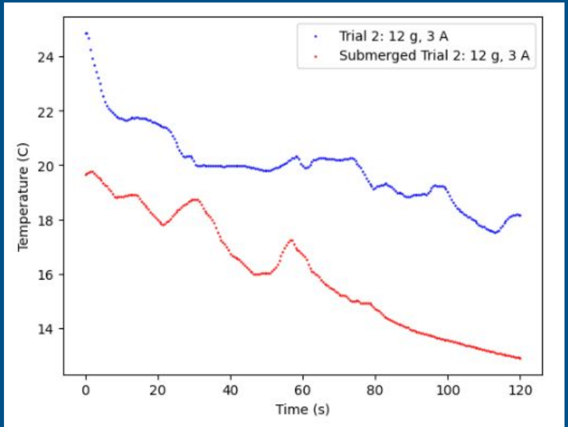
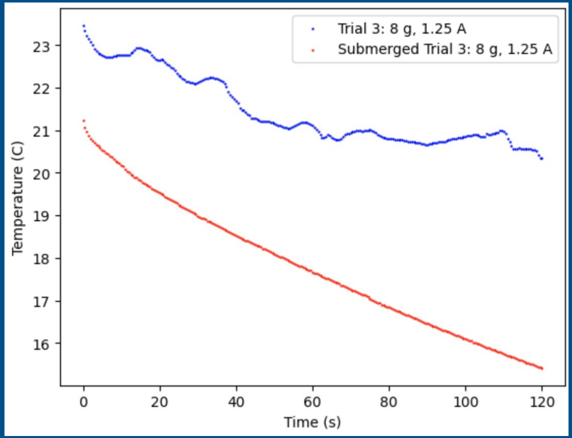
Data Taking

- Measure input Voltage and Current
- Measure Mass of Water

Data: T vs t







2 important trends!

Analysis

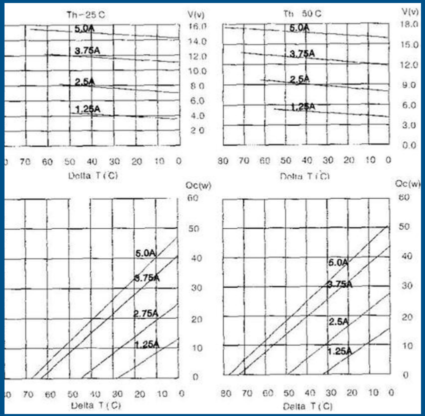
Let’s compare COP’s...

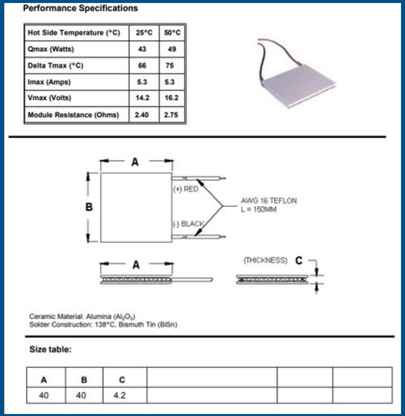
Trial #	Calculated COP
1	0.14 ± 0.02
2	0.10 ± 0.01
3	0.17 ± 0.05
1 (submerged)	0.17 ± 0.03
2 (submerged)	0.11 ± 0.02
3 (submerged)	0.34 ± 0.06

Analysis

Let's compare COP's...

Nominal COP ≅ 0.53 – 0.58




Performance Specifications

Hot Side Temperature (°C)	25°C	50°C
Qmax (Watts)	43	49
Delta Tmax (°C)	66	75
Imax (Amps)	5.3	5.3
Vmax (Volts)	14.2	16.2
Module Resistance (Ohms)	2.40	2.75

Ceramic Material: Alumina (Al_2O_3)
Solder Construction: 138°C, Bismuth Tin (BiSn)

Size table:

A	B	C			
40	40	4.2			

Potential Errors

- Non-constant voltage
- Imperfect contact between copper plate and device
- Non-uniform heat distribution in water
- Heat dissipated through gaps in lid
- **Heat dissipated through sides of device**
- Human error from shaking of hand when holding the LoggerPro Device
- Nonzero thermal conductivity of **styrofoam** (0.030 to 0.040 W/m·K), adhesive, and air

Accounting for Errors

Quantifiable and Qualitative Errors

PROPAGATION OF ERROR

- **General Formula**

  Suppose that y is related to n independent measured variables $\{X_1, X_2, \ldots, X_n\}$ by a functional representation:

  $$y = f(X_1, X_2, \cdots, X_n)$$

  Given the uncertainties of X's around some operating points:

  $$\{\bar{x}_1 \pm \Delta x_1, \bar{x}_2 \pm \Delta x_2, \cdots, \bar{x}_n \pm \Delta x_n\}$$

  The expected value of $\bar{y}$ and its uncertainty Δy are:

  $$\bar{y} = f(\bar{x}_1, \bar{x}_2, \cdots, \bar{x}_n)$$

  $$\Delta y = \sqrt{\left(\frac{\partial f}{\partial X_1}\Delta x_1\right)^2 + \left(\frac{\partial f}{\partial X_2}\Delta x_2\right)^2 + \cdots + \left(\frac{\partial f}{\partial X_n}\Delta x_n\right)^2}\Bigg|_{(\bar{x}_1, \bar{x}_2, \cdots, \bar{x}_n)}$$

$$Q = \frac{k \cdot A \cdot \Delta T}{d}$$

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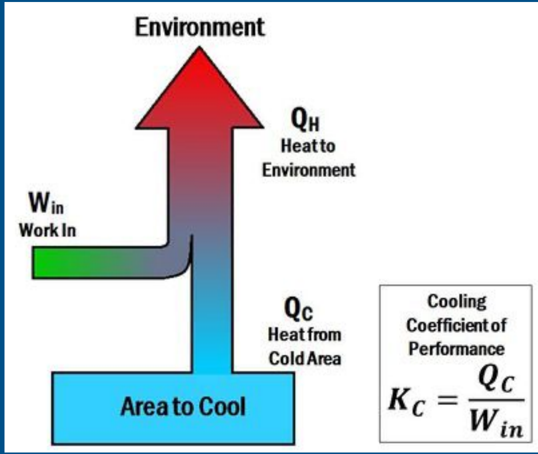
Conclusion/ Future Analysis



Our measured performance values of the Peltier device are consistently lower than the listed values. There are many sources of error, and the wear & tear of our device can not be ignored. However, the trends we saw make physical sense.

In the future, we could adjust our data for some of the quantifiable errors.