ENGINEERING
UNDERGRADUATE RESEARCH OFFICE

SURF SUMMER UNDERGRADUATE RESEARCH FELLOWSHIP

Single Phase Static Immersive Cooling of Cylindrical Battery Insight of Measuring Methods an Result

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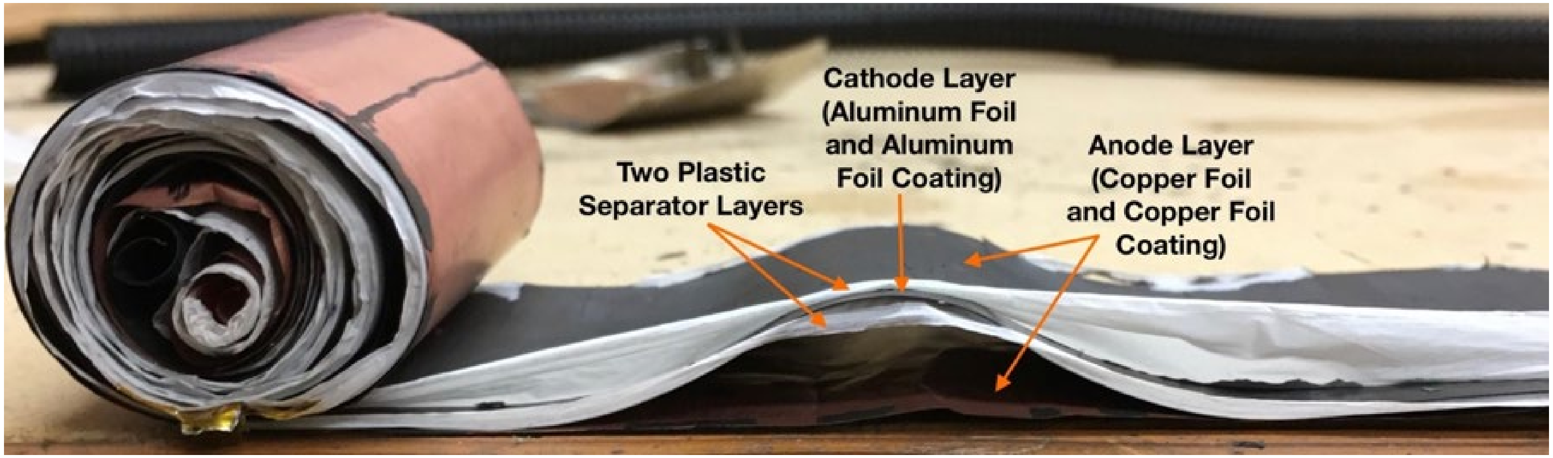
M TEC

IntroductionLi Battery Heat Generation

Sources of Heat:

- Cathode intercalation
- Anode intercalation
- electrical resistance within battery (IR drop)
- Collision between Li^+, electrolyte particles, and electrodes (activation / ohmic, & concentration polarization)

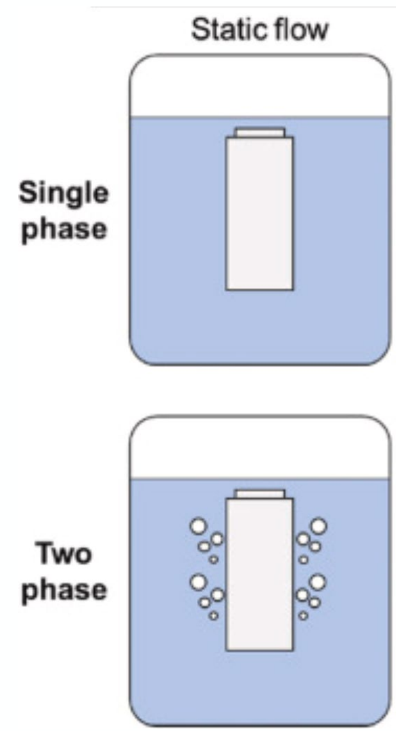
*Fire and Thermal Runaway Propagation Challenges in Electric Vehicles [1]



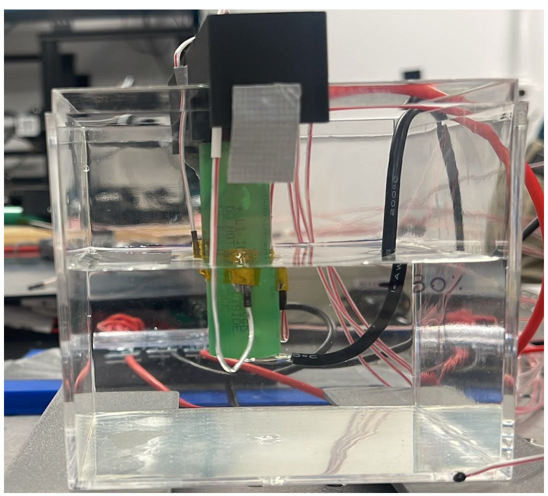
Radial thermal conductivity measurements of lithium-ion battery cells [2]

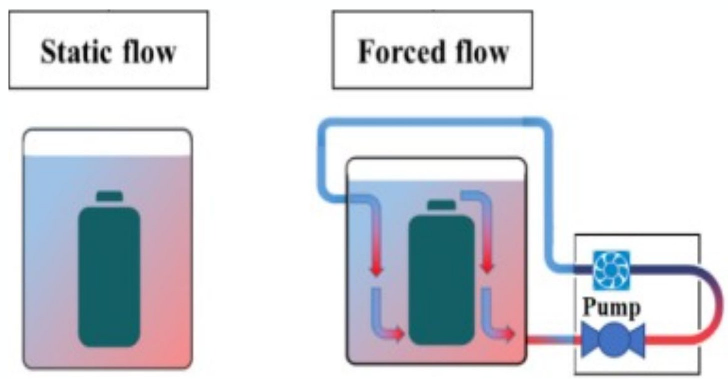
Introduction-Single Phase Static Direct Immersive Cooling

- **Single Phase:** Coolant remains as a single form
- **Static:** No external force is used to move the coolant
- **Direct:** Fluid is contacting the battery's body
- **Immersive Cooling:** parts of / whole battery is inside the coolant for heat transfer



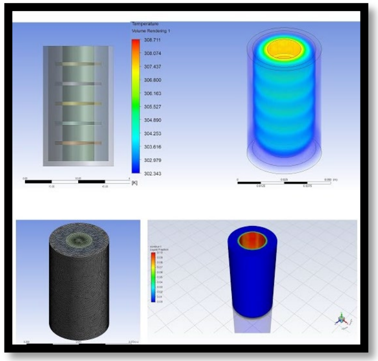
Immersion cooling for lithium-ion batteries – A Review [3]





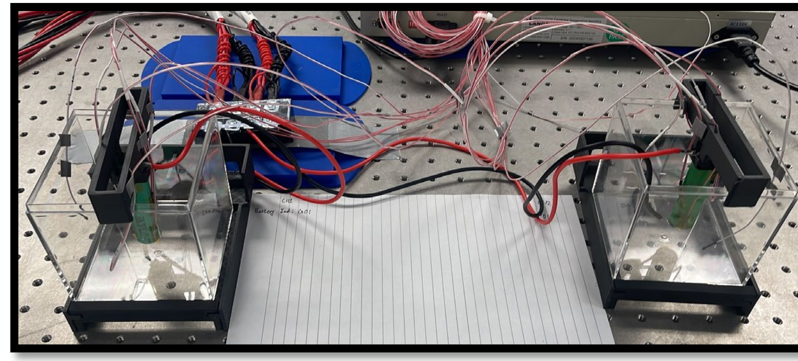
Performance evaluation of a hydrostatic flow immersion cooling system for high-current discharge Li-Ion Batteries [4]

Objective-Milestones & Current Agenda

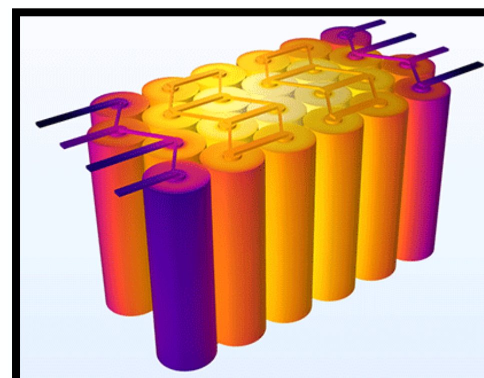


CFD simulation of Single Cell Lithium Ion Battery with fins, PCM & enclosure with heat generation [5]

1. Create Accurate Battery Model



2. Validate and Tune the Model with Experimental Data



How to accurately simulate batteries from detailed electrodes to the pack thermal management scale [6]

3. Use the model to optimize the battery configuration

Electric Vehicle Li-ion Battery Pack [7]

4. Validate the result from step 3

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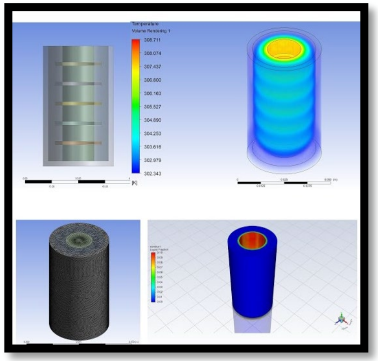

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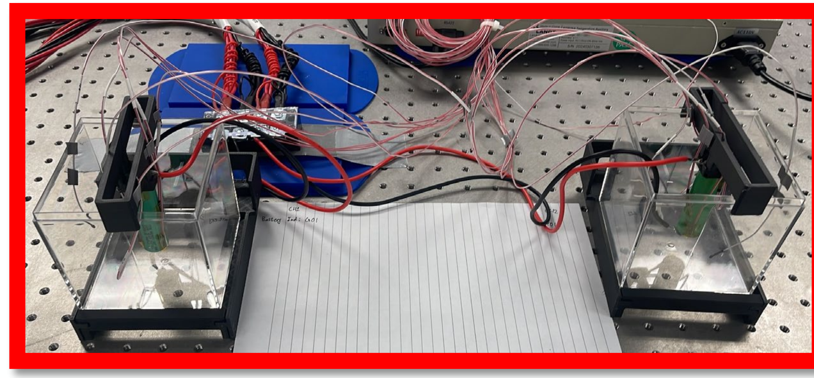
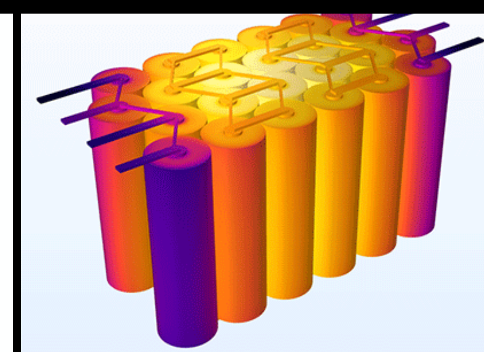


2. Validate and Tune the Model with Experimental Data

Main Objective for this SURF Research



How to accurately simulate batteries from detailed electrodes to the pack thermal management scale [6]

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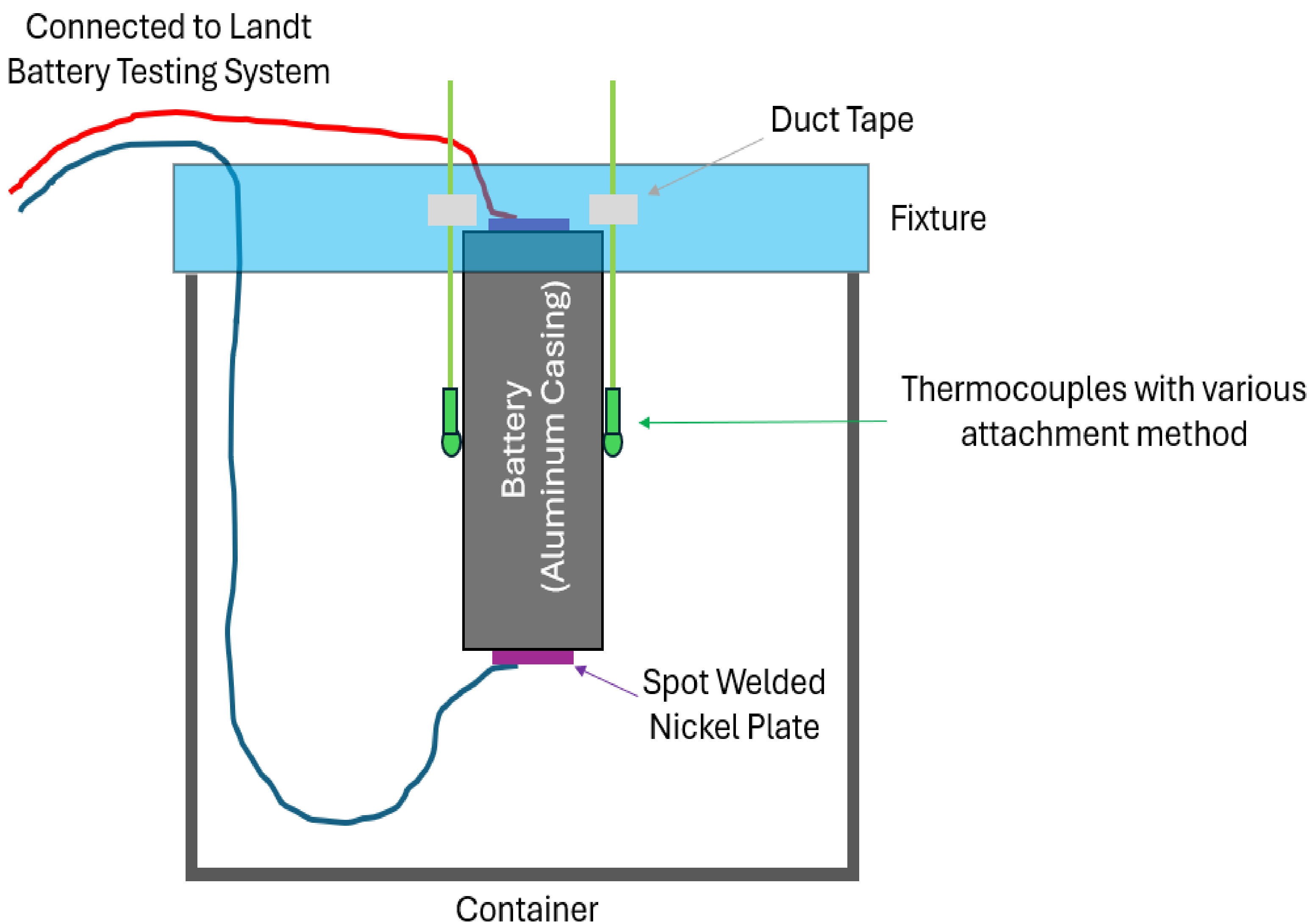
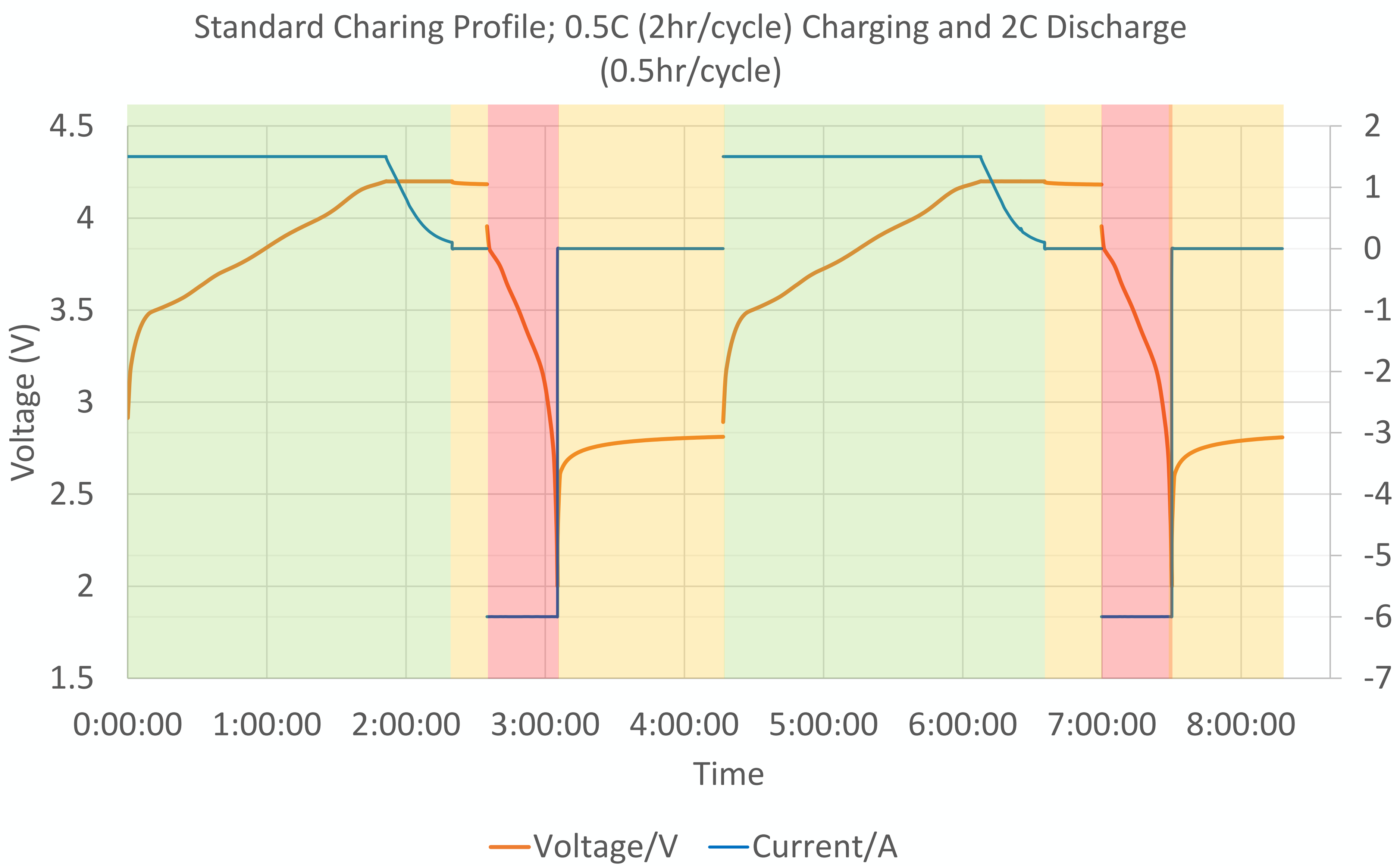
Method I. Preliminary Measurement



*TIM: Thermal Interface Material

Result I. Preliminary Measurement



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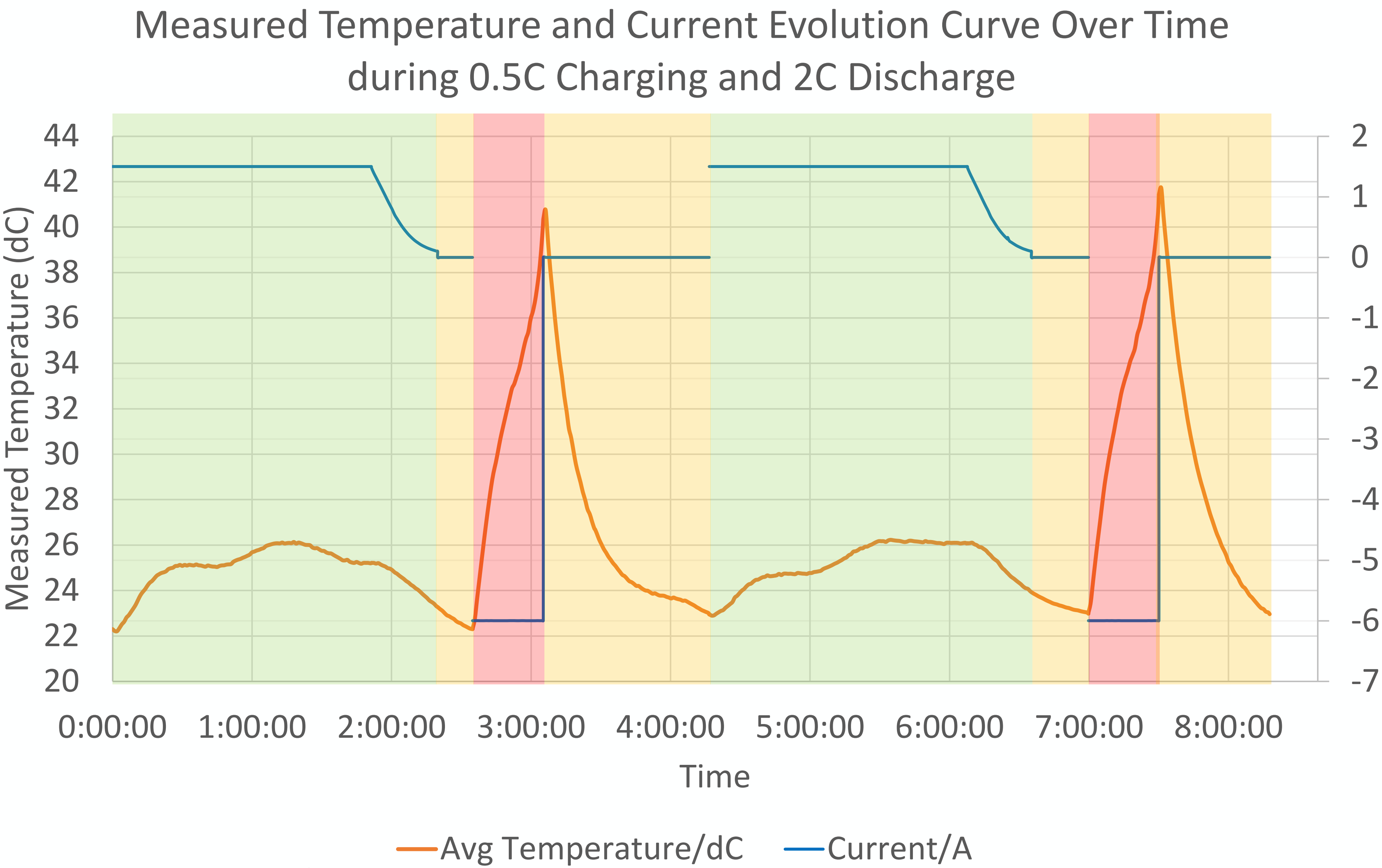

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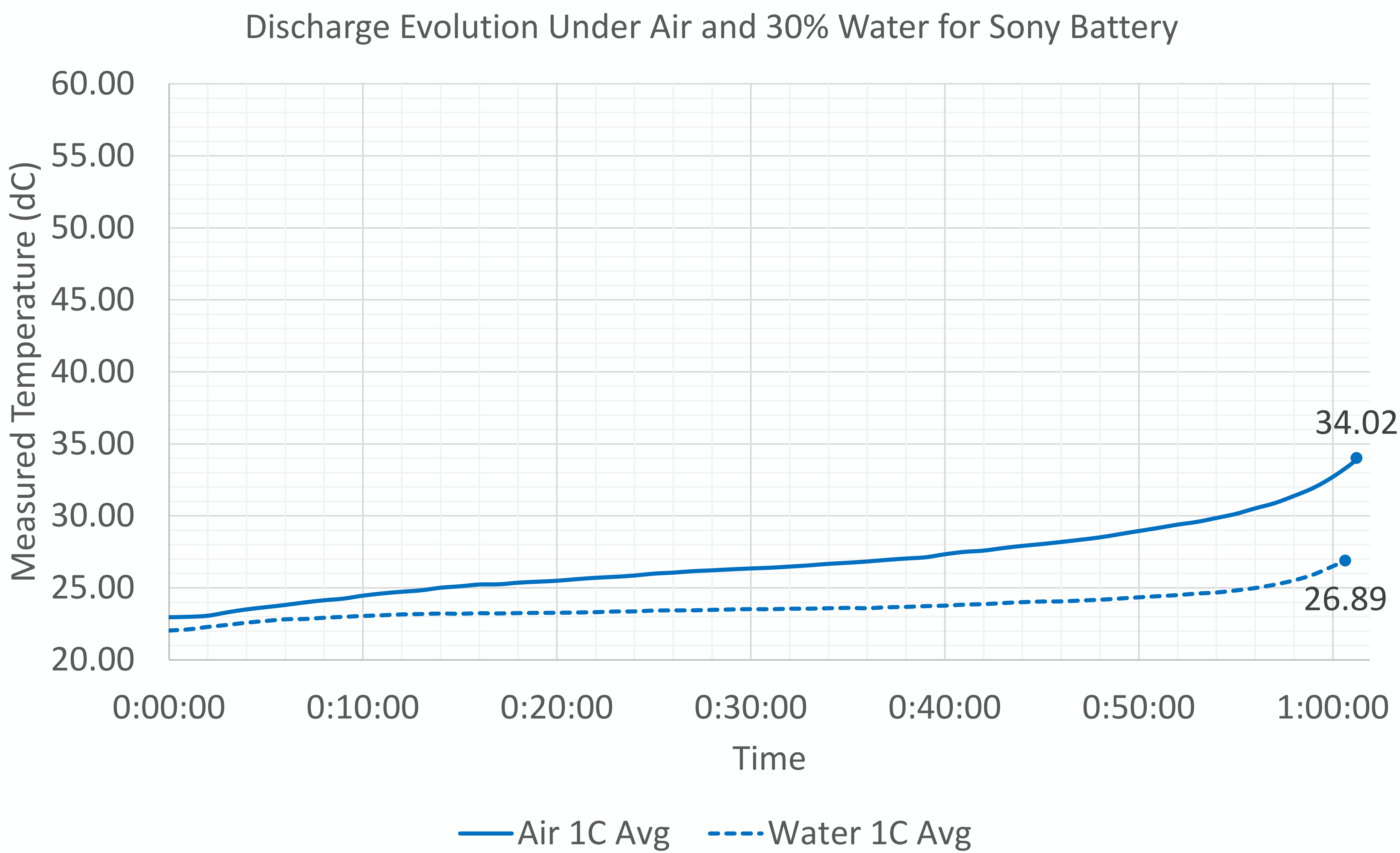

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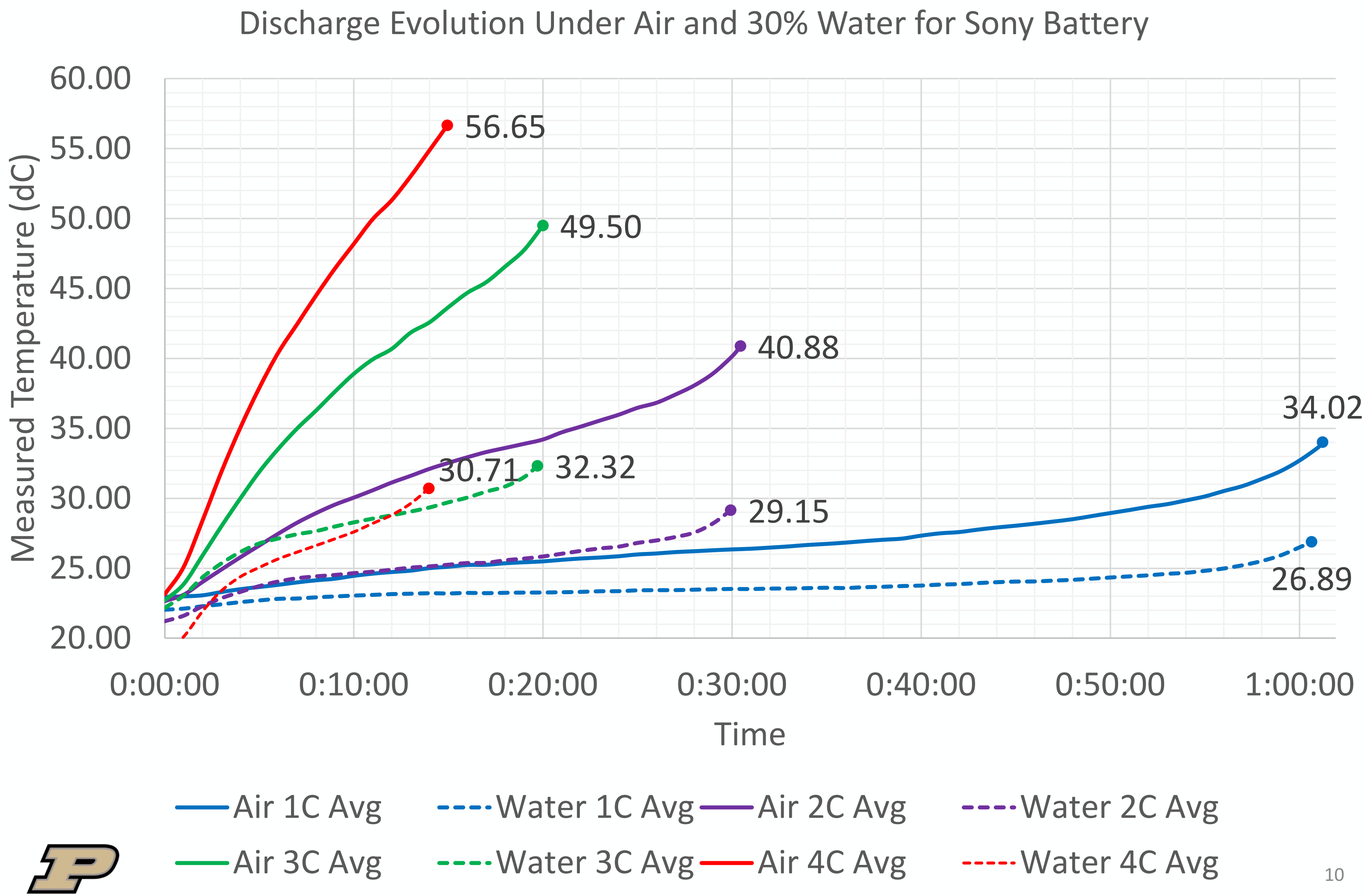

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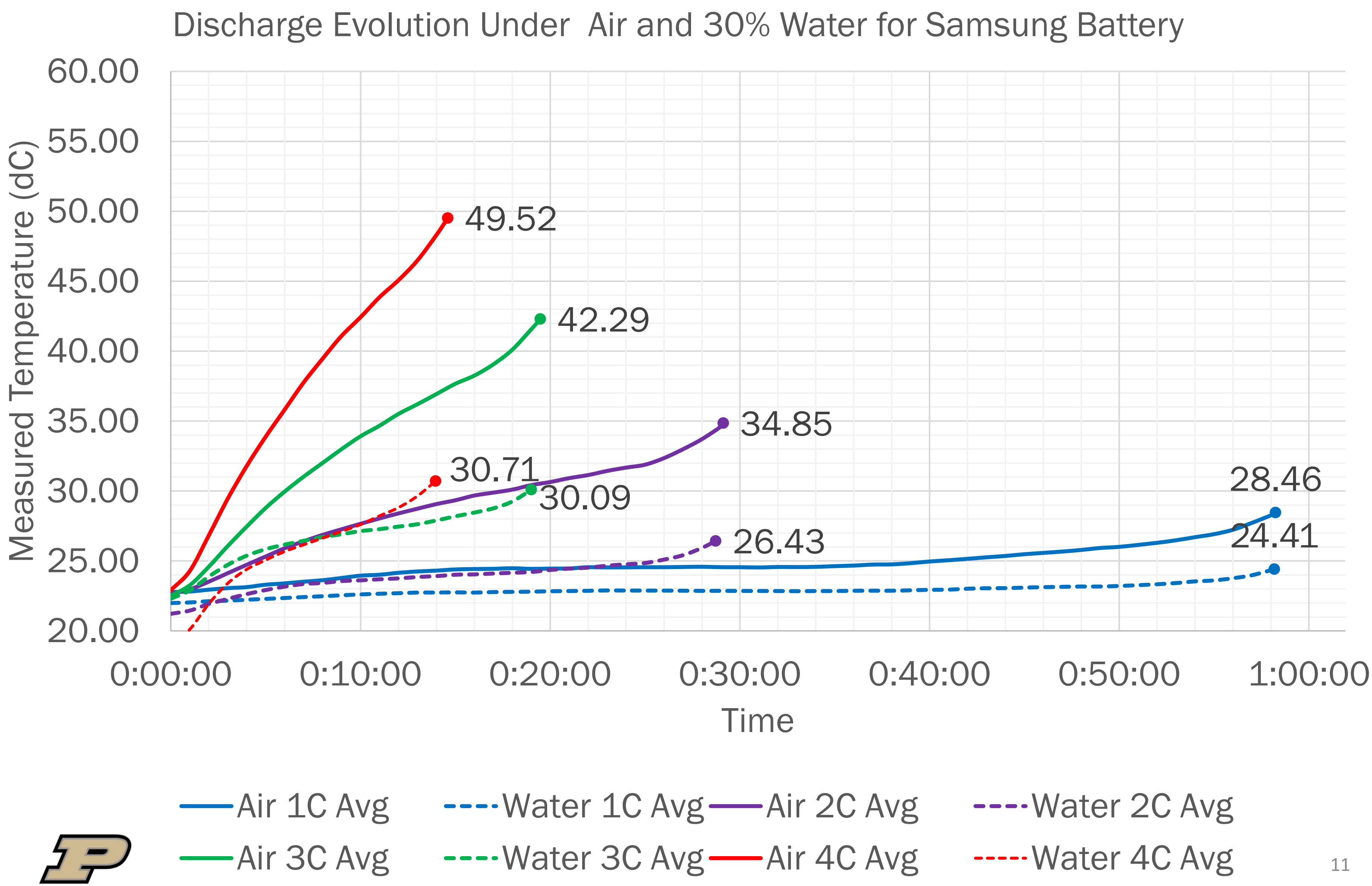

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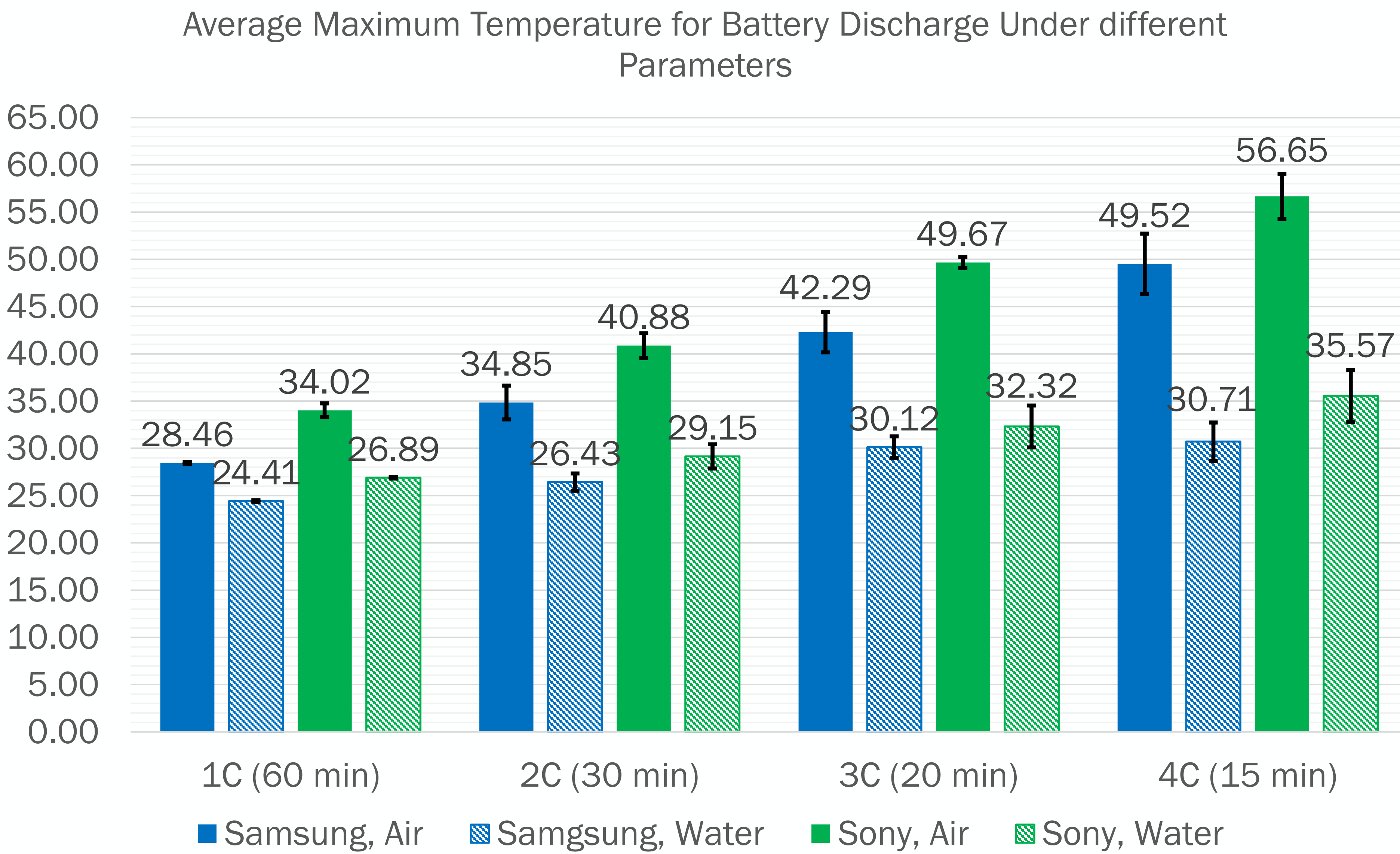

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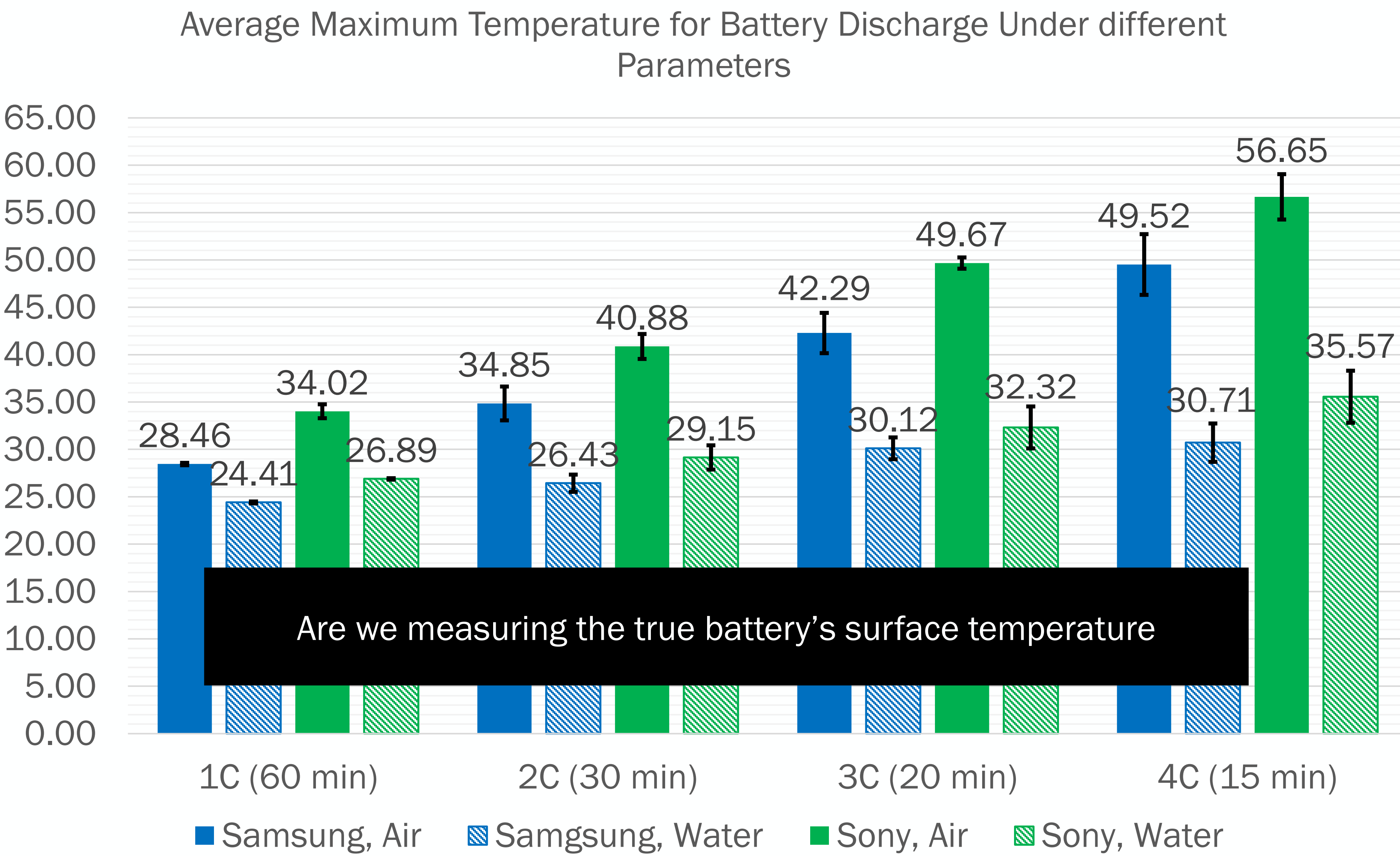


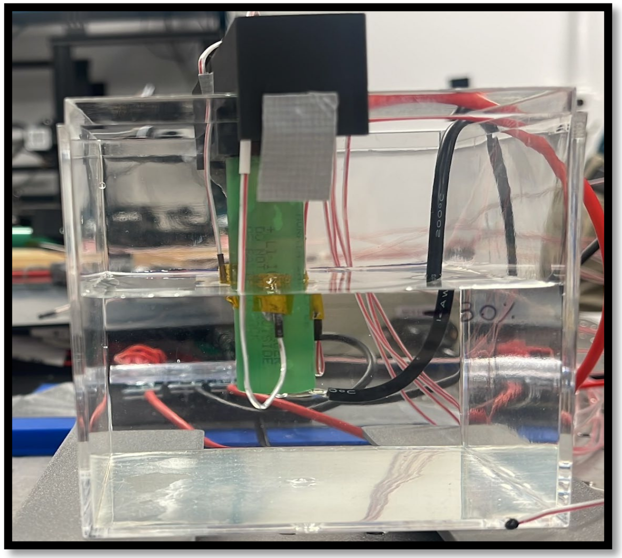
Are we measuring the true battery's surface temperature

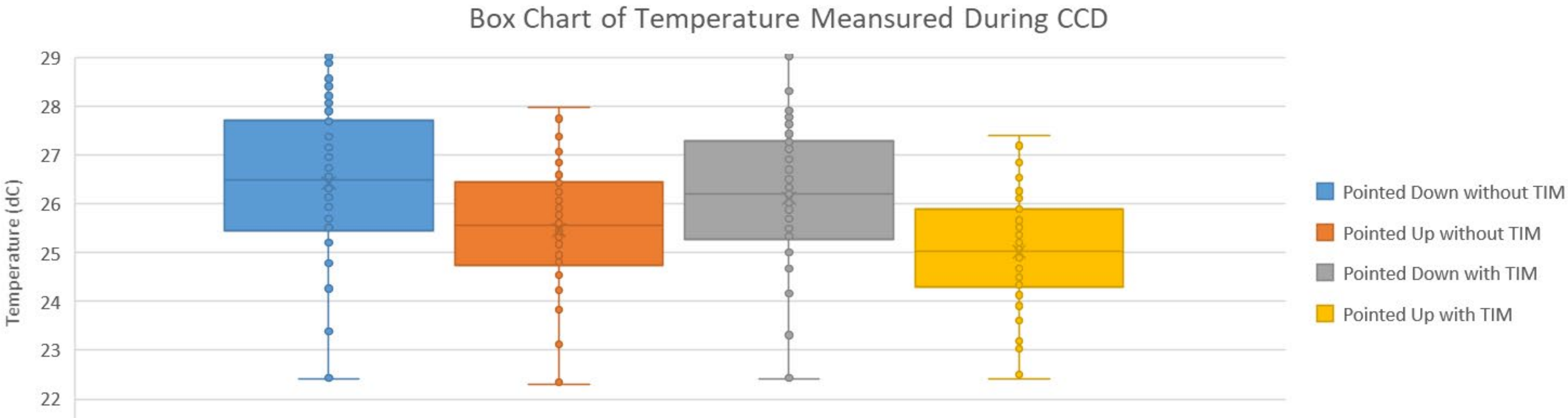
Objective II. Seeking Ideal Thermocouple Attachment Me

- **New Objective:** Identify the most accurate and precise measurement method

Pointed Down Without TIM

Pointed Up With TIM





*TIM: Thermal Interface Material

Method II. Validating Assumptions

Is the battery temp uniform on the same altitude?

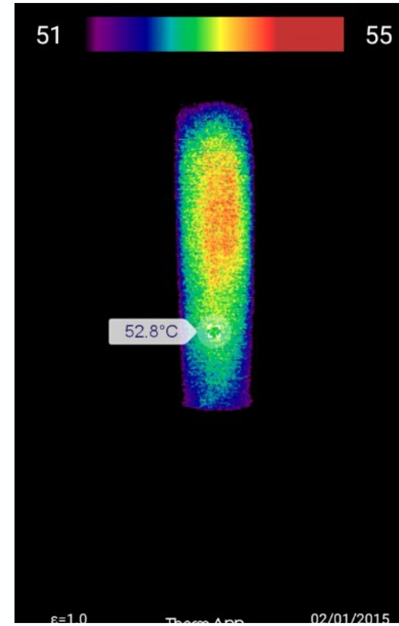
- IR Camara is used to validate the homogeneous horizontal heat generation

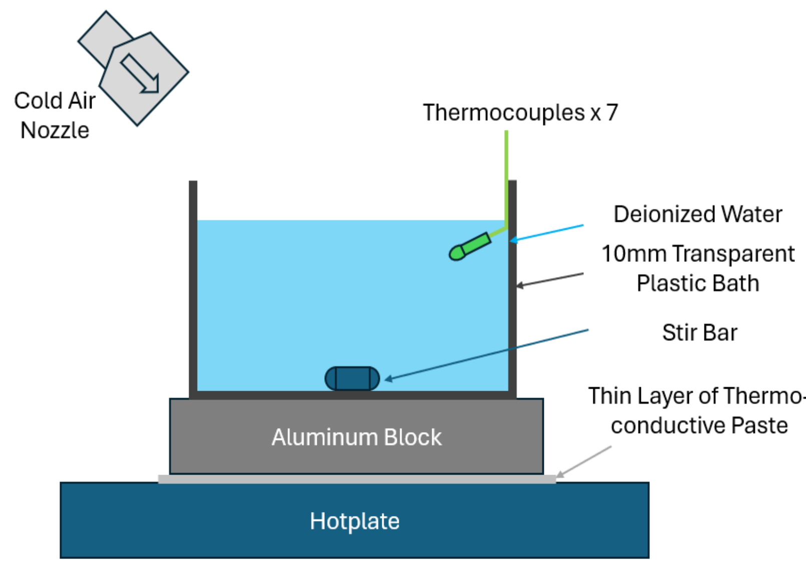
Are thermocouples calibrated?

- Water bath is used to validate the accuracy and precisions of the thermocouple

Are the thermal hotplate generating uniform temp?

- IR Camara is used to validate homogeneous temperature across the top surface of the aluminum block

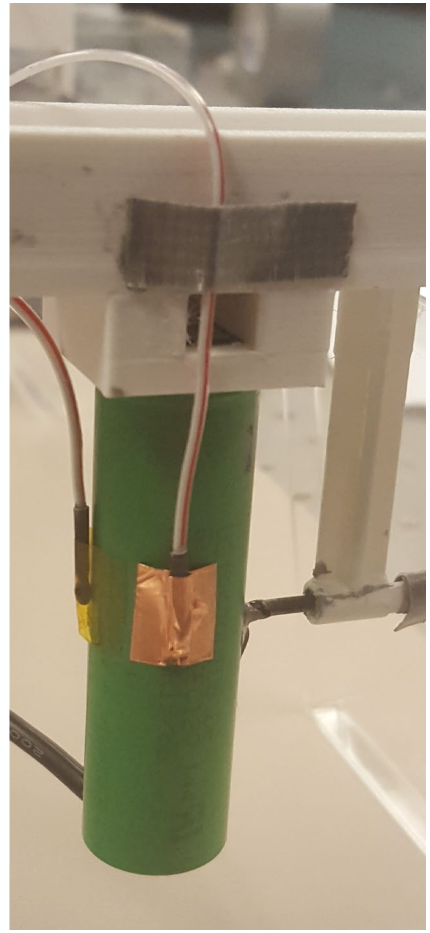




Result II. Is Battery Providing Uniform Temperature

Verified:

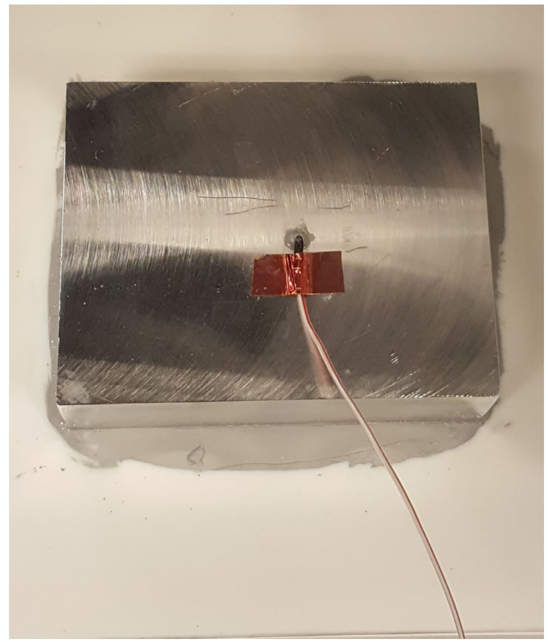
- Homogeneous horizontal heat generation of the battery

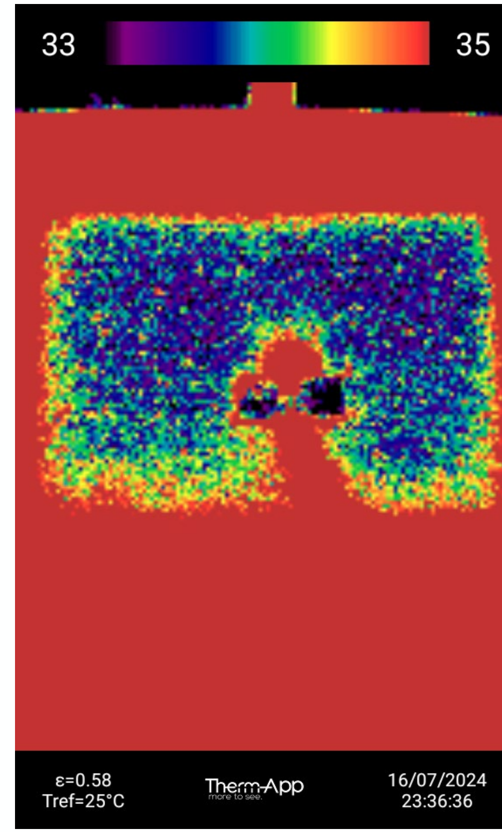


Result II. Is Test Bed Providing Uniform Temperature

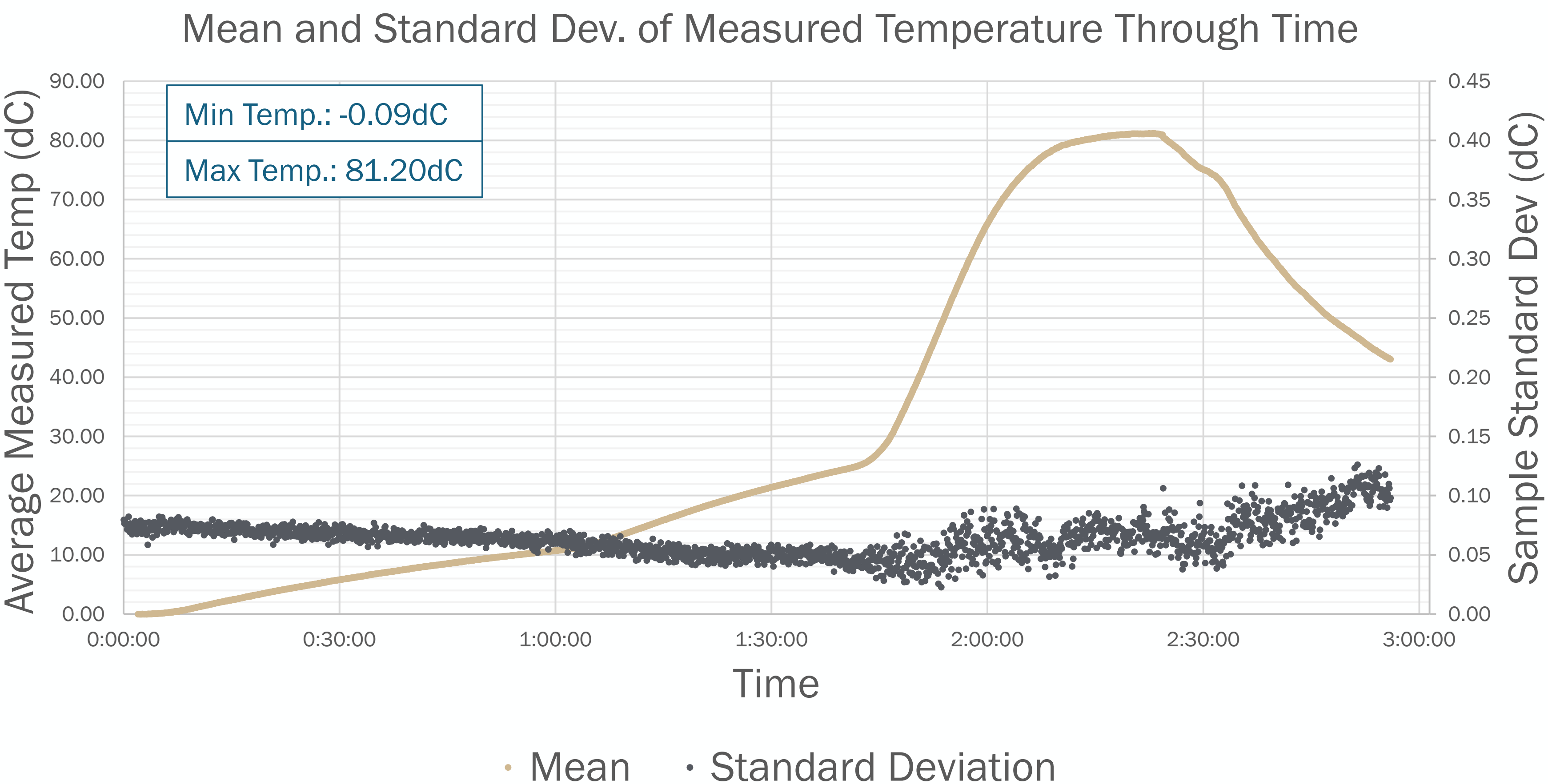
Verified:

- Homogeneous horizontal heat generation of the battery
- Homogeneous temperature across the aluminum block surface





Result II. Are Thermocouples Calibrated



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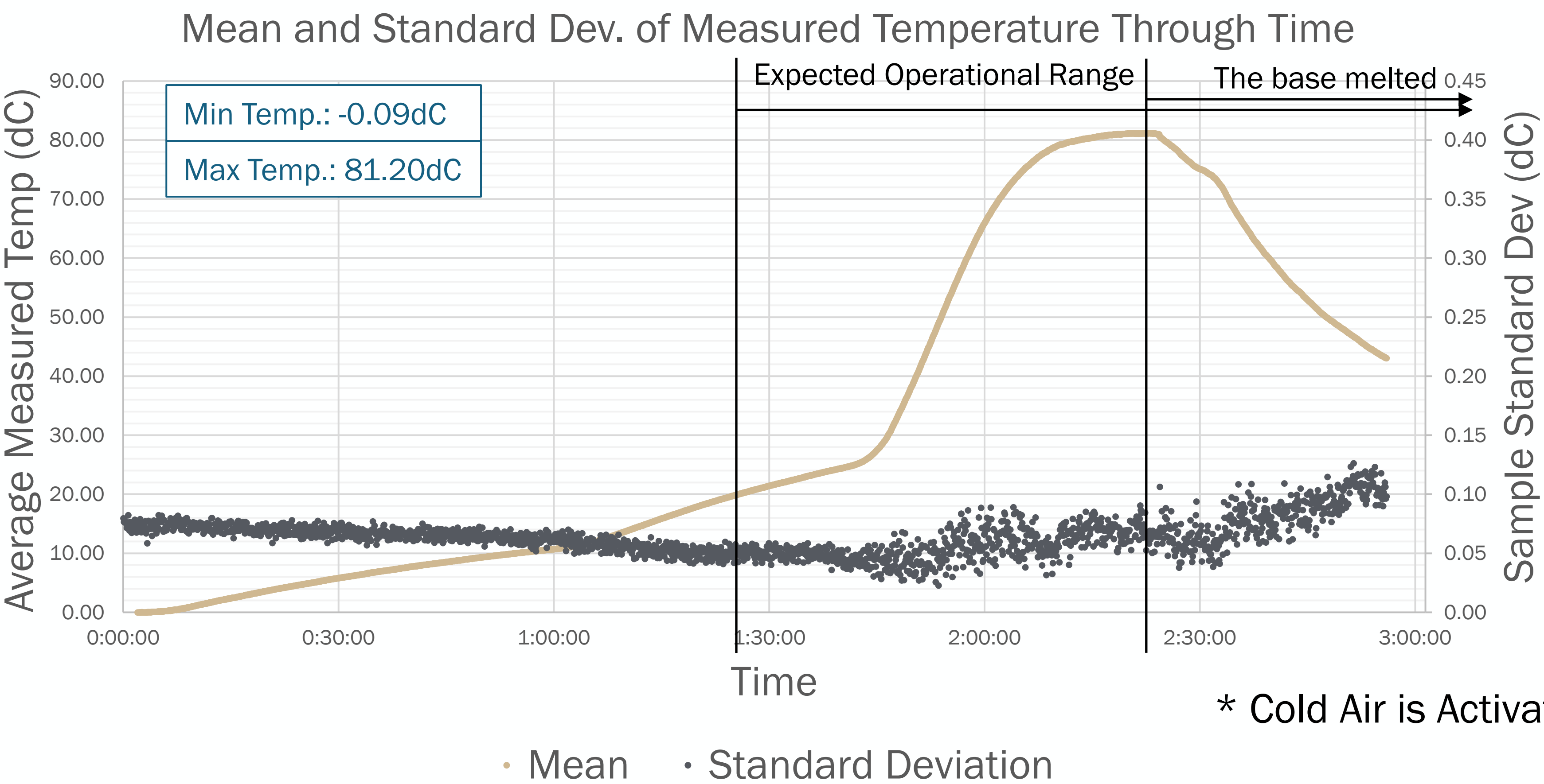

* Cold Air is Activated

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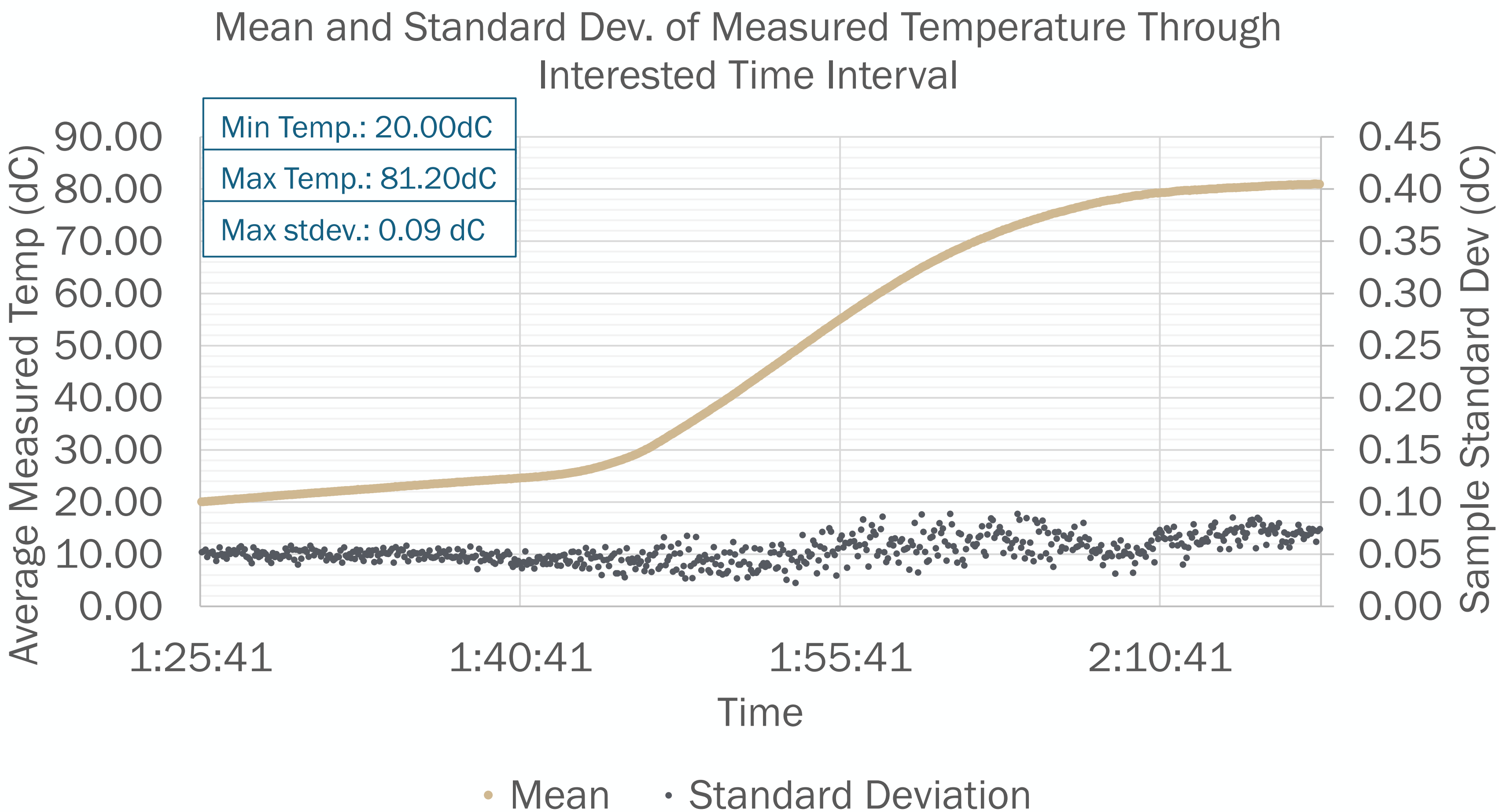

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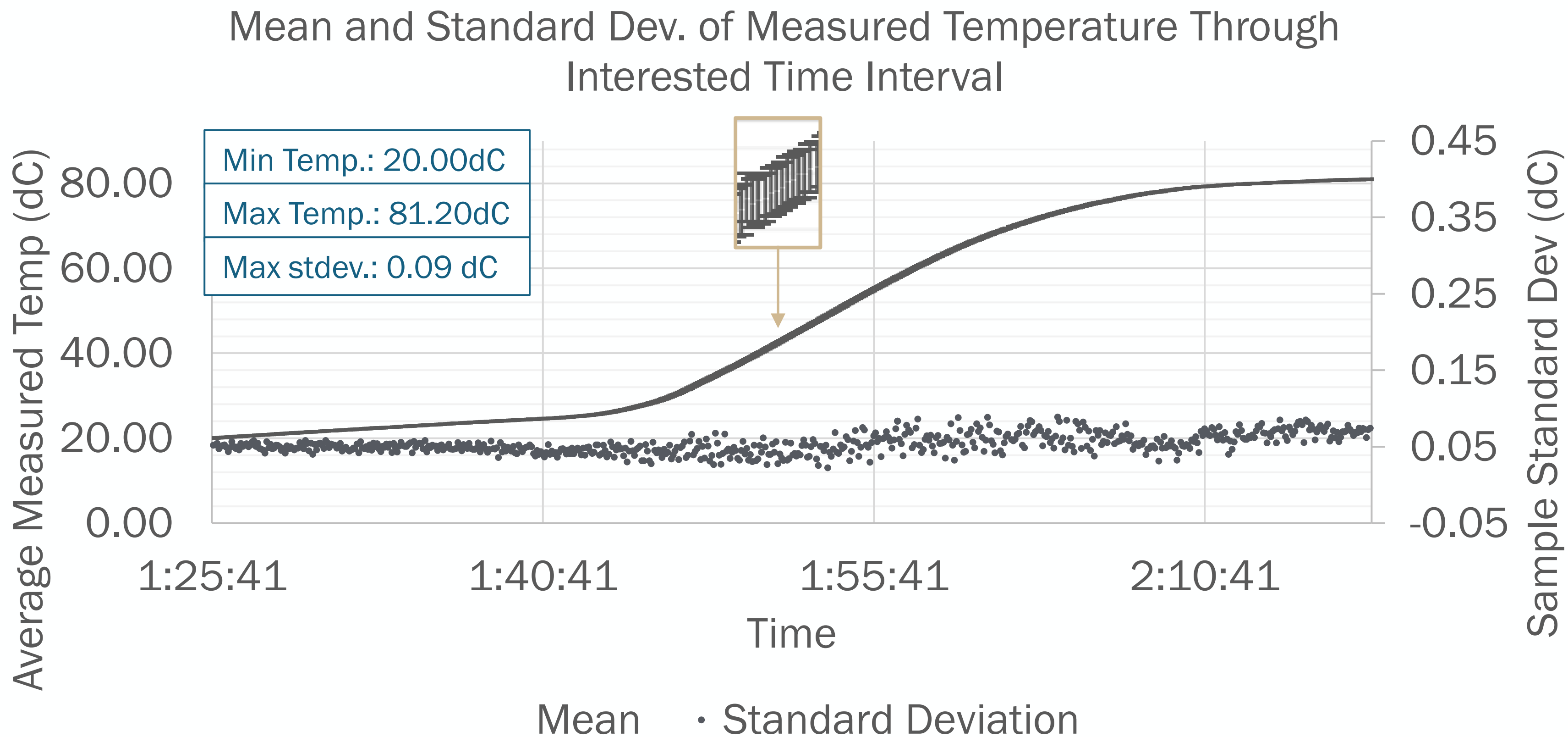
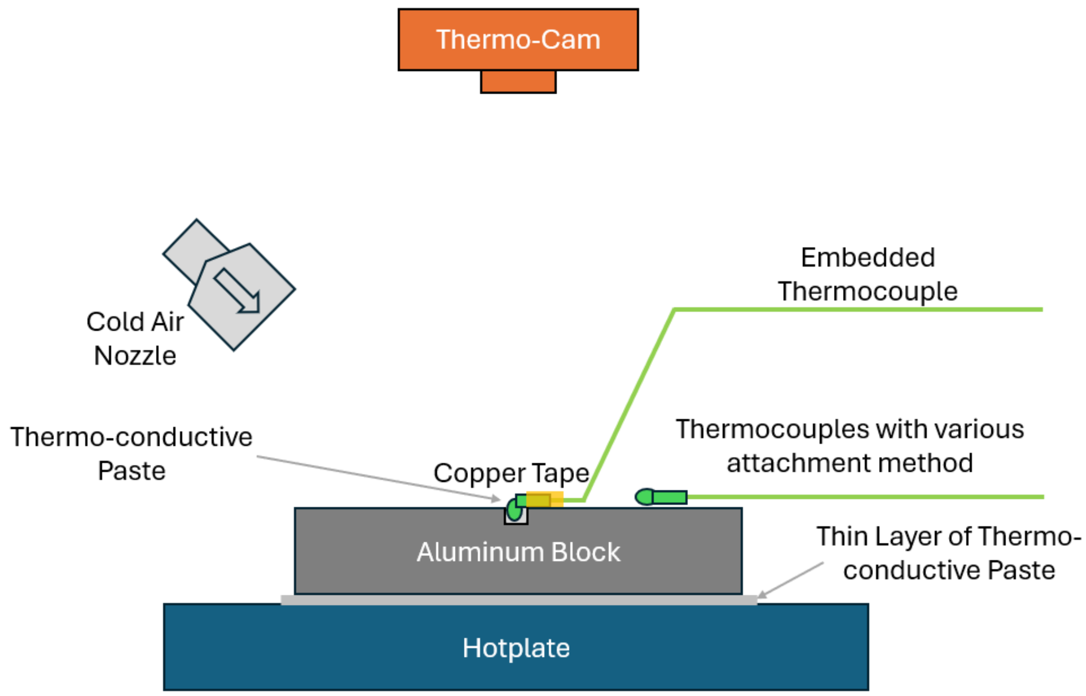
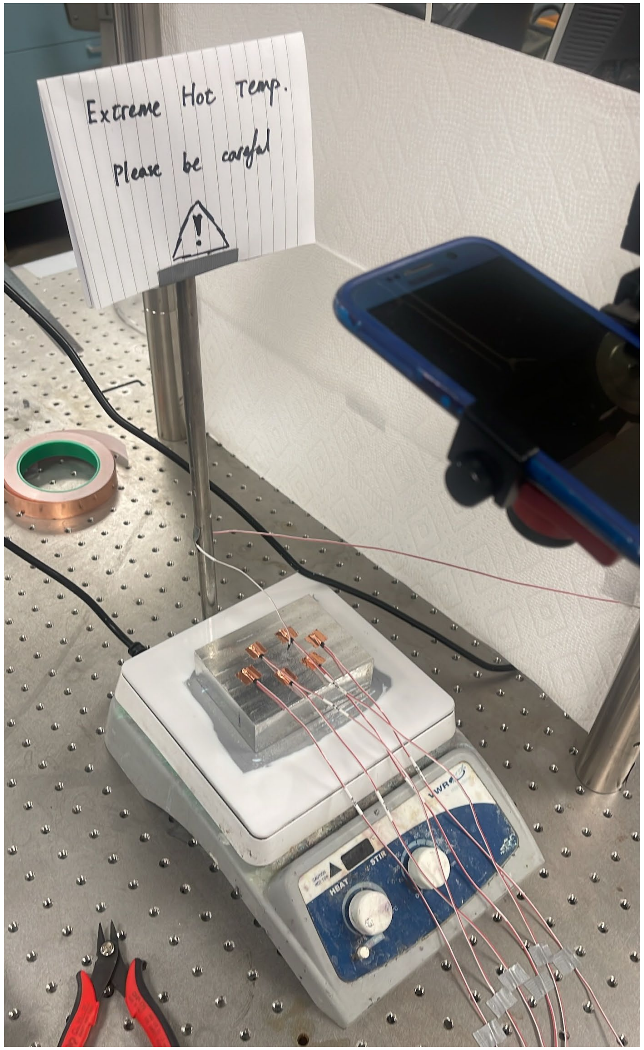


Assuming normal distribution, we have 95% confidence that the actual temperature is within ±0.176dC of the measured temperature

Method III. Finding Ideal Thermocouple attachment Meth

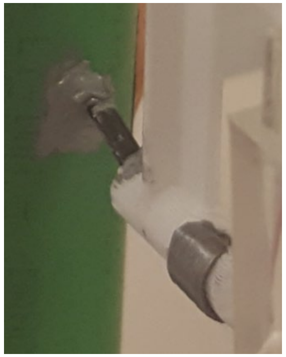




Method III. Finding Ideal Thermocouple attachment Meth

Kapton Tape without TIM

Kapton Tape with TIM



Perpendicular with TIM

Copper Tape without TIM

Copper Tape with TIM

Embedded Method &
Embedded with TIM

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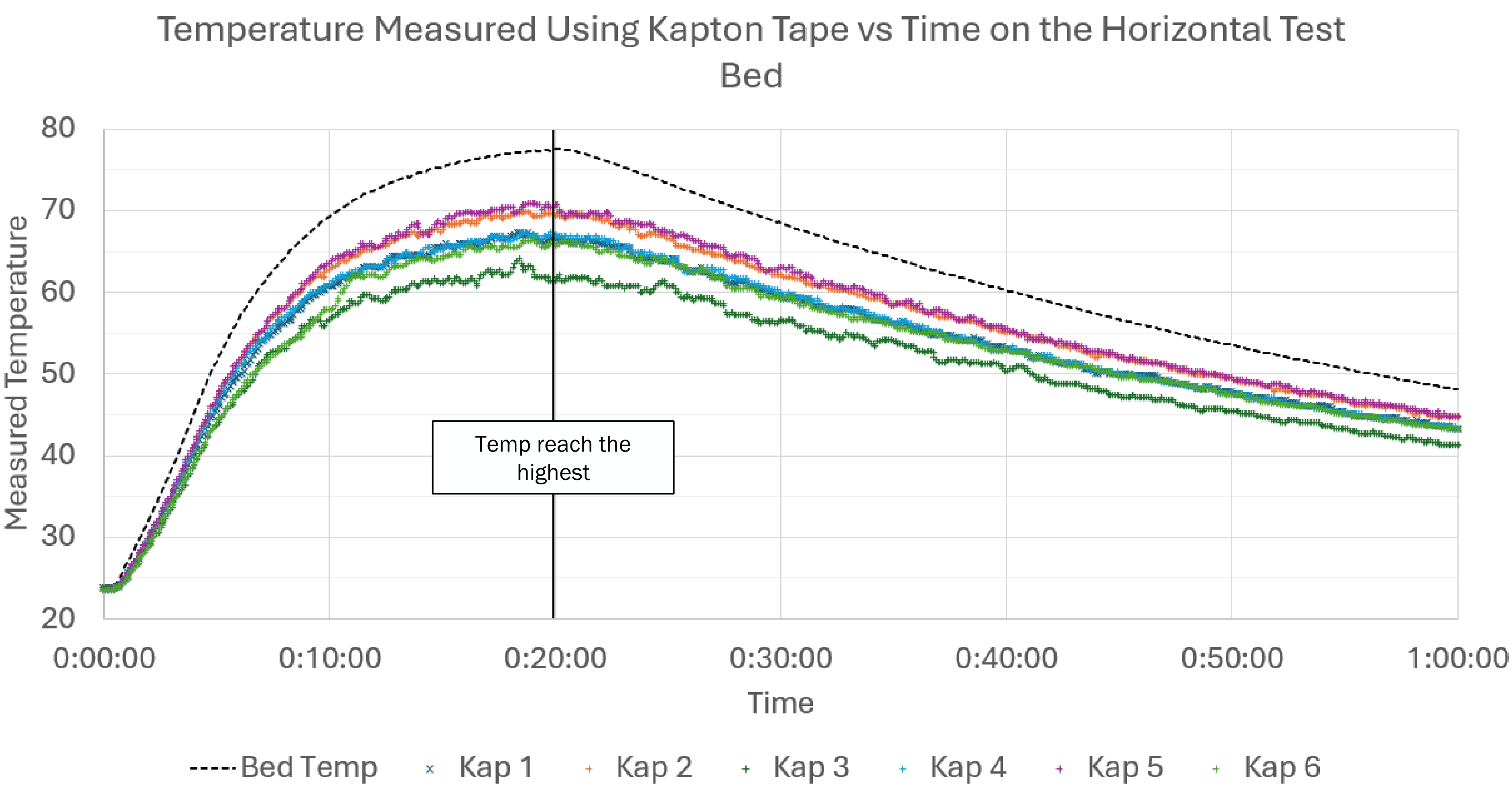
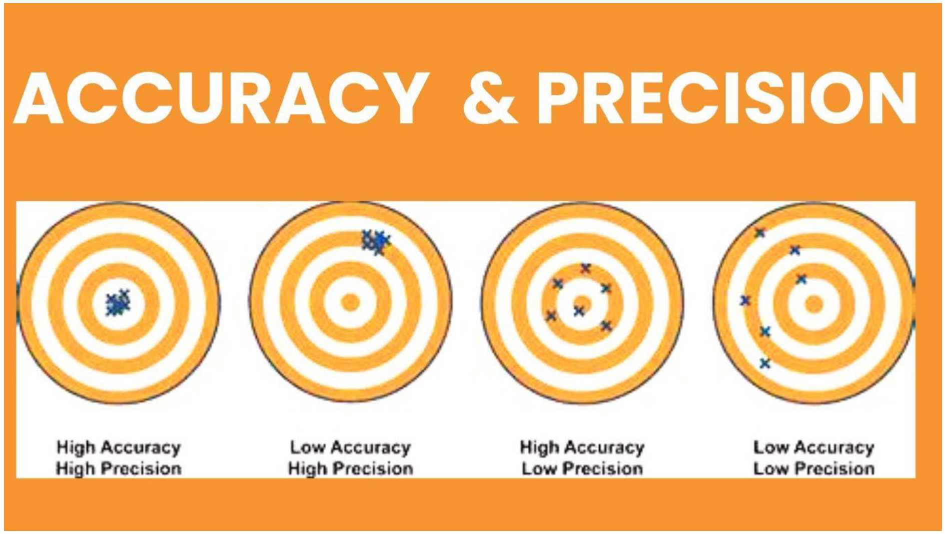
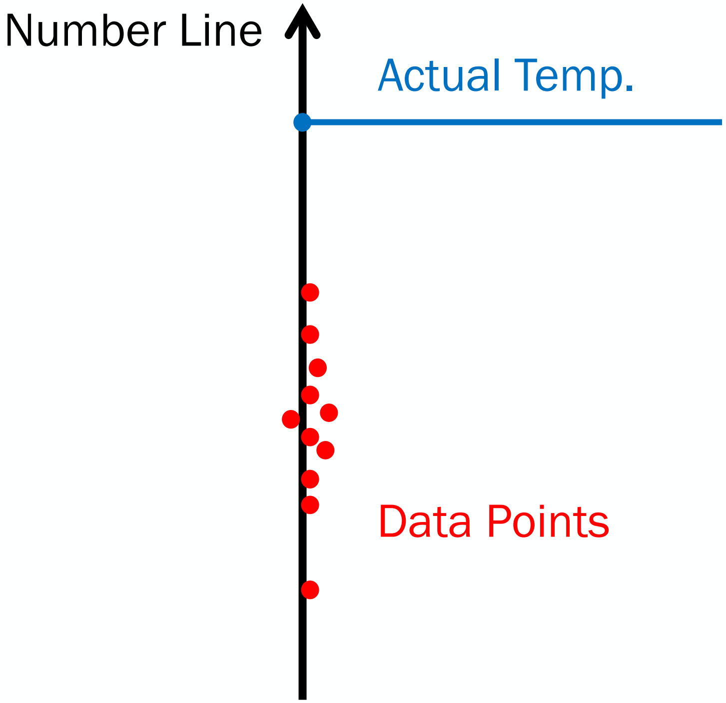


Method III. Finding Ideal Thermocouple attachment Meth

* Assume Normal Distribution



* What Are the Differences between Accuracy and Precision? [8]



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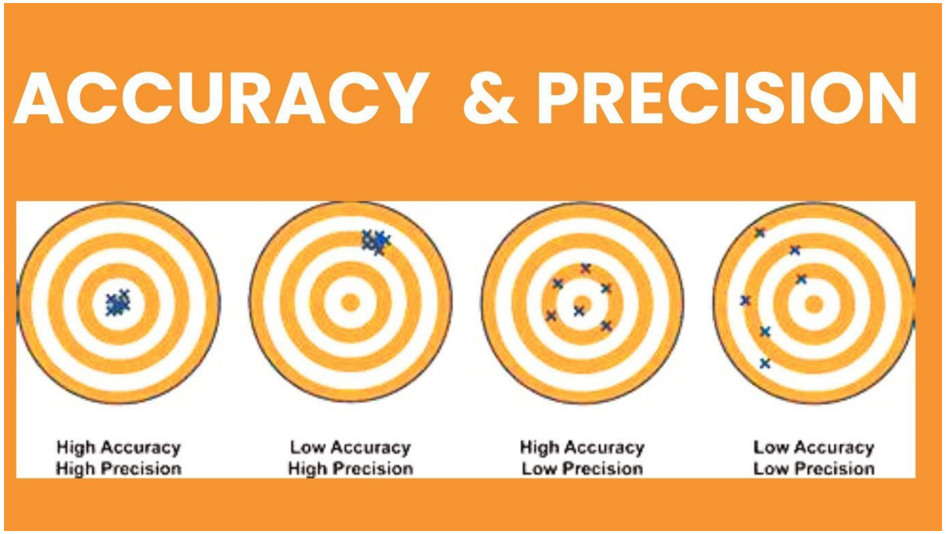

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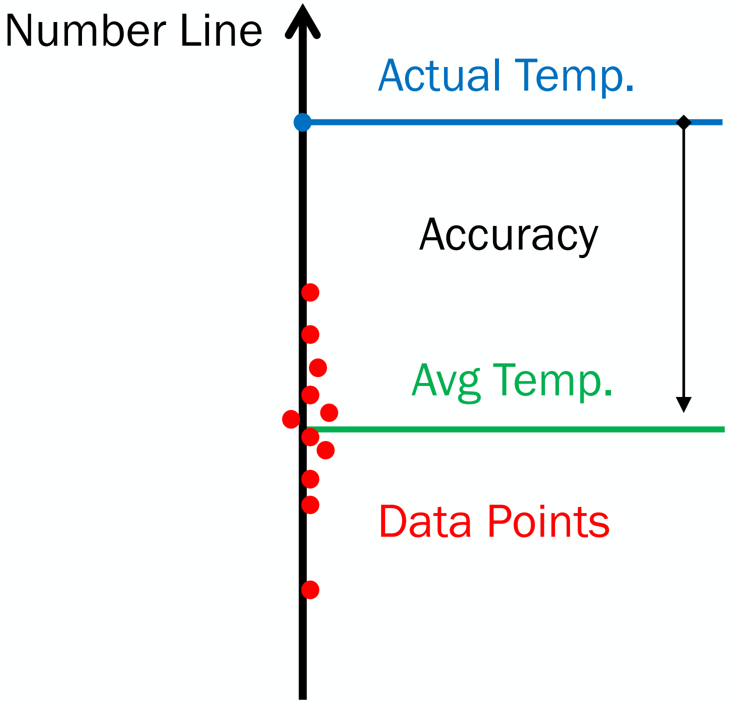

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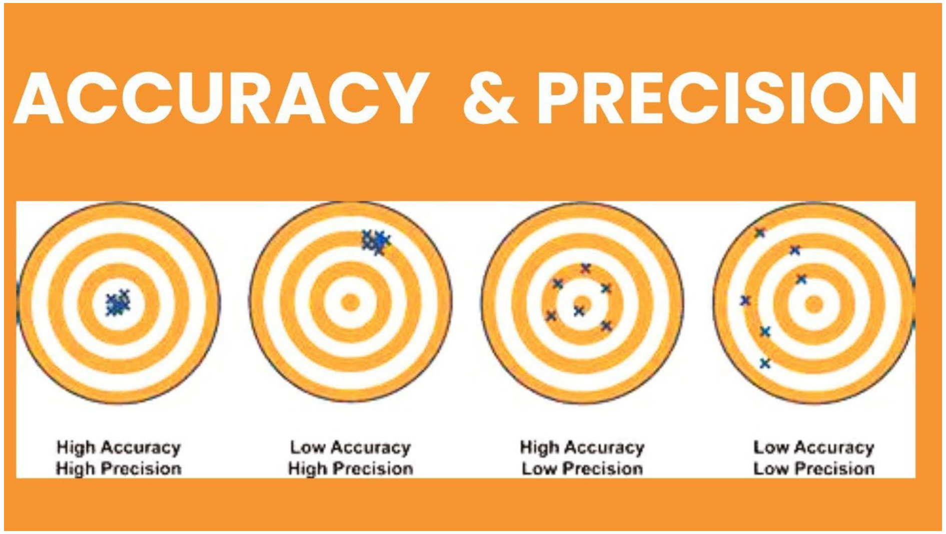

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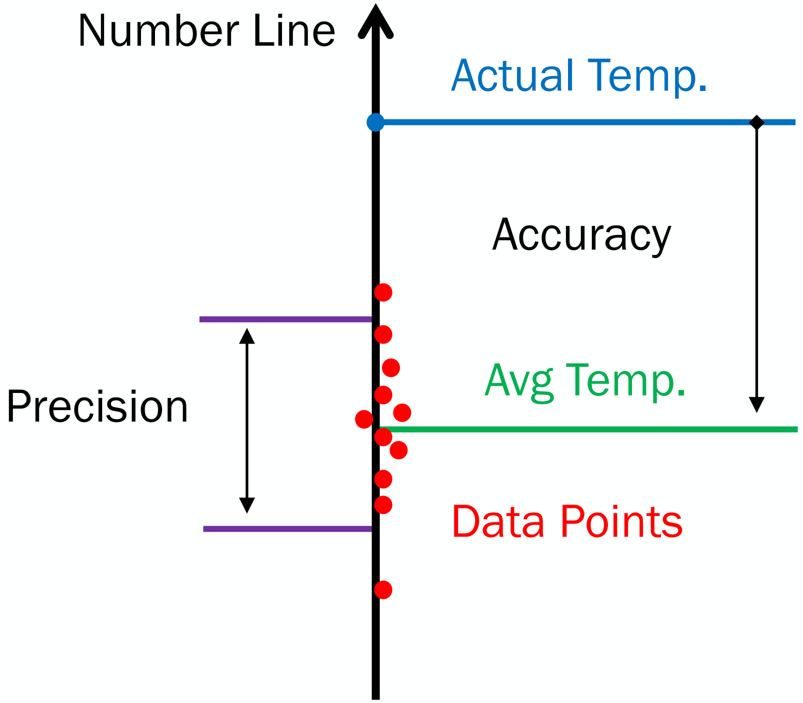
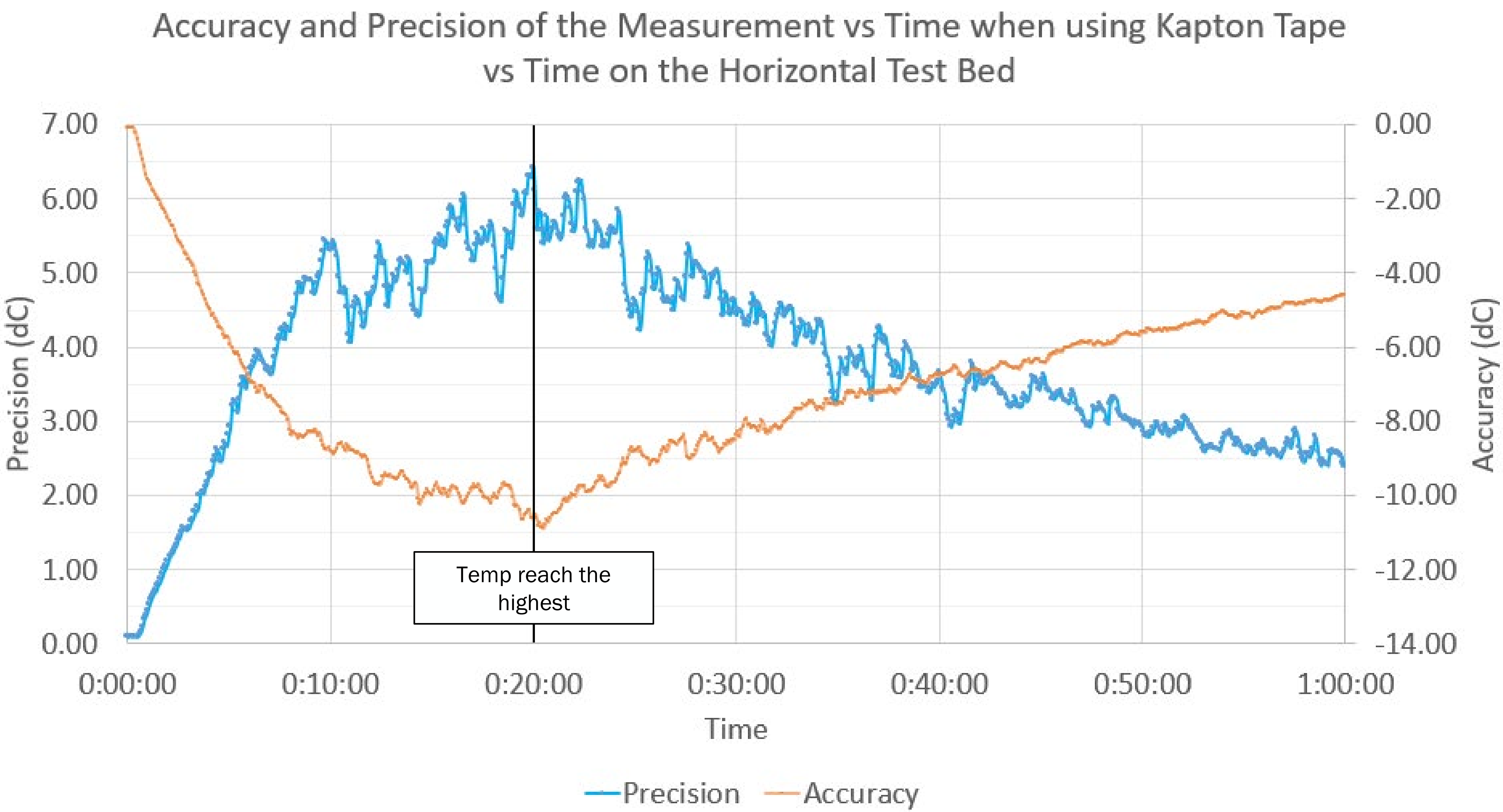


Result III. Finding Ideal Thermocouple attachment Metho



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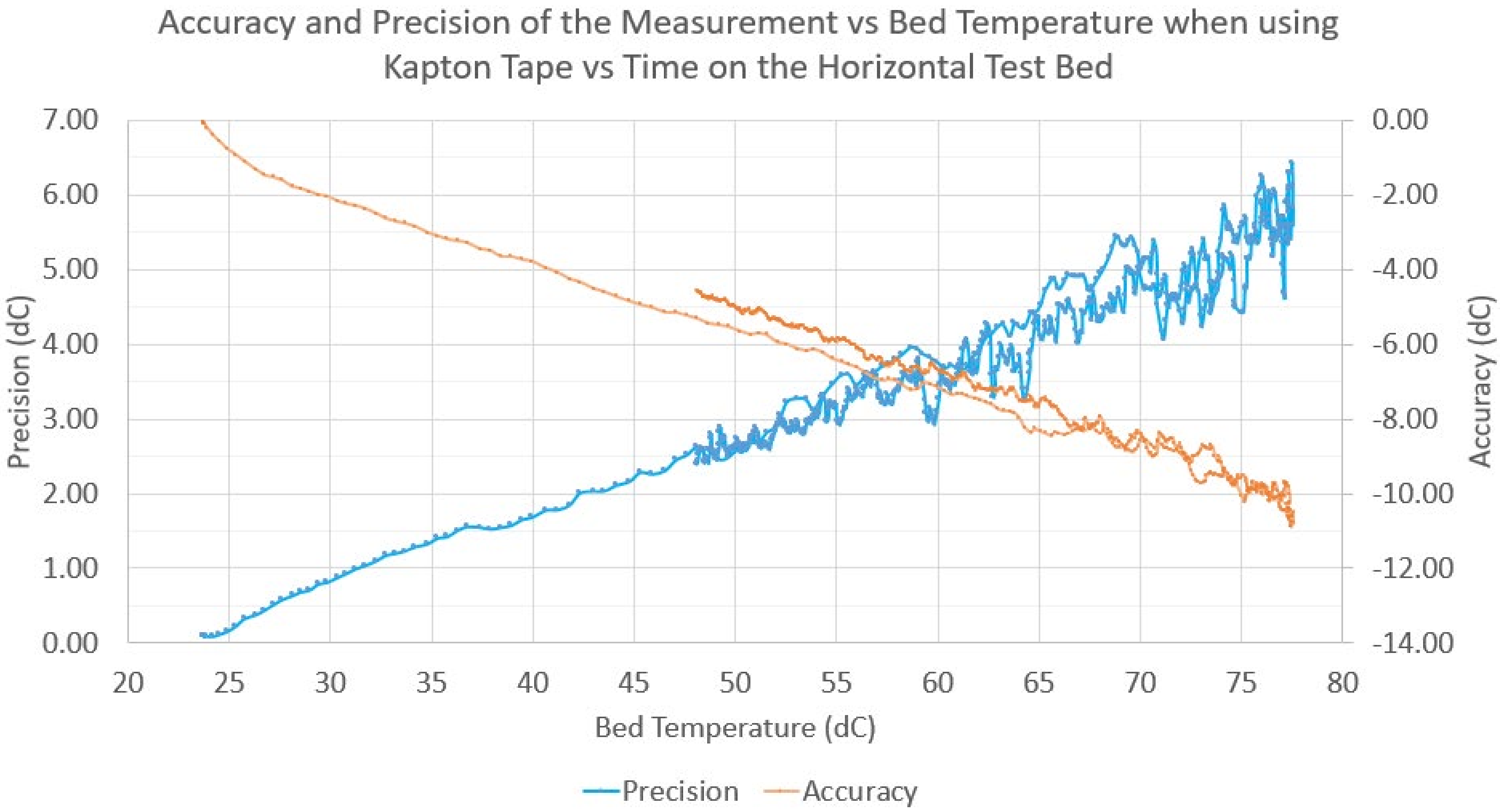

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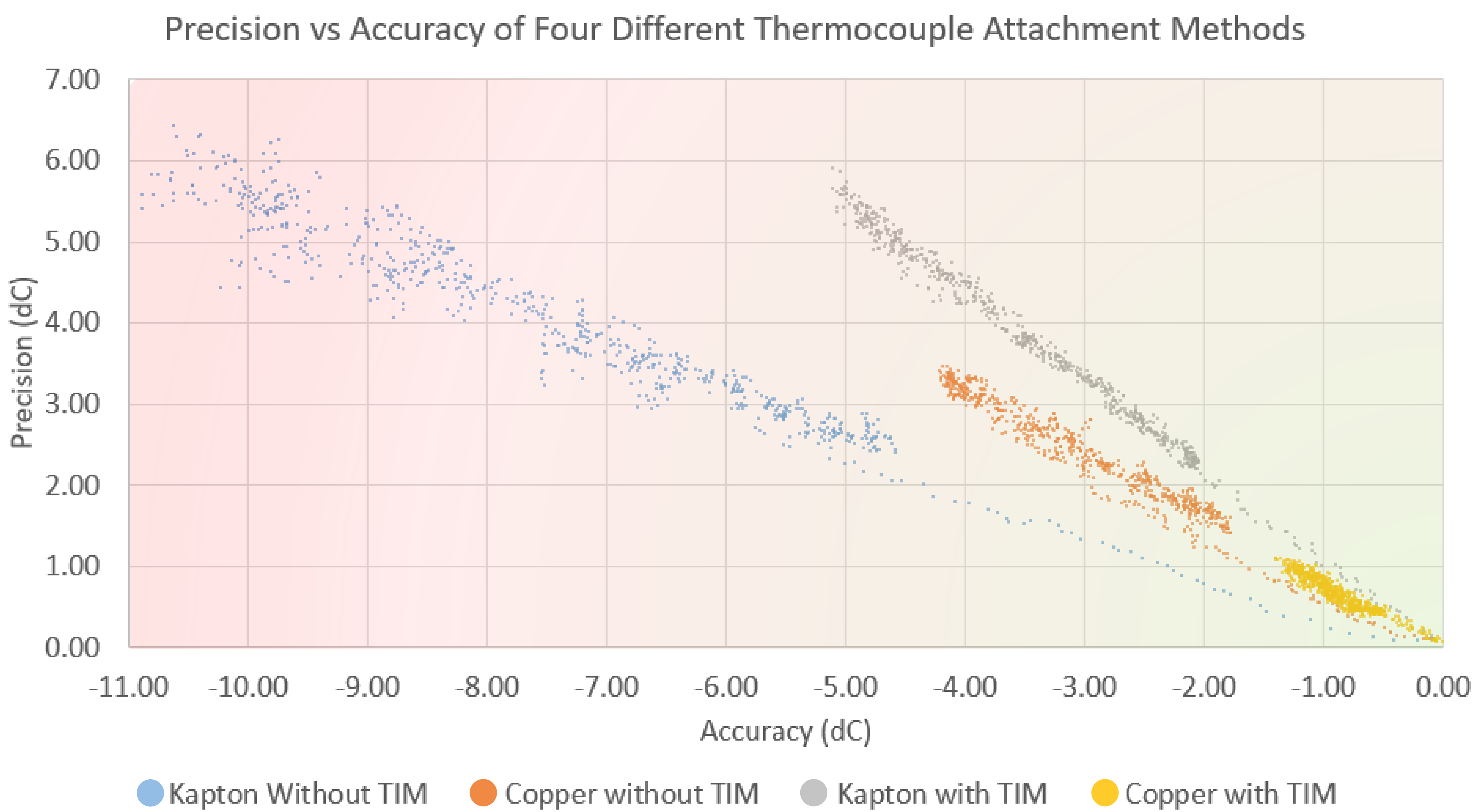
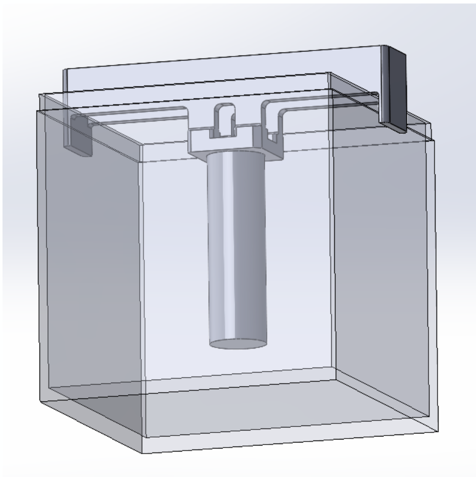
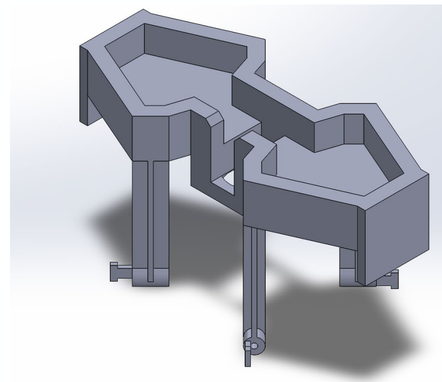
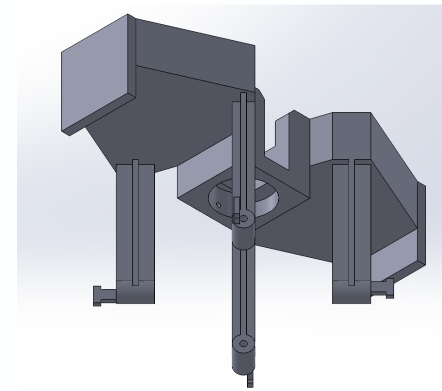
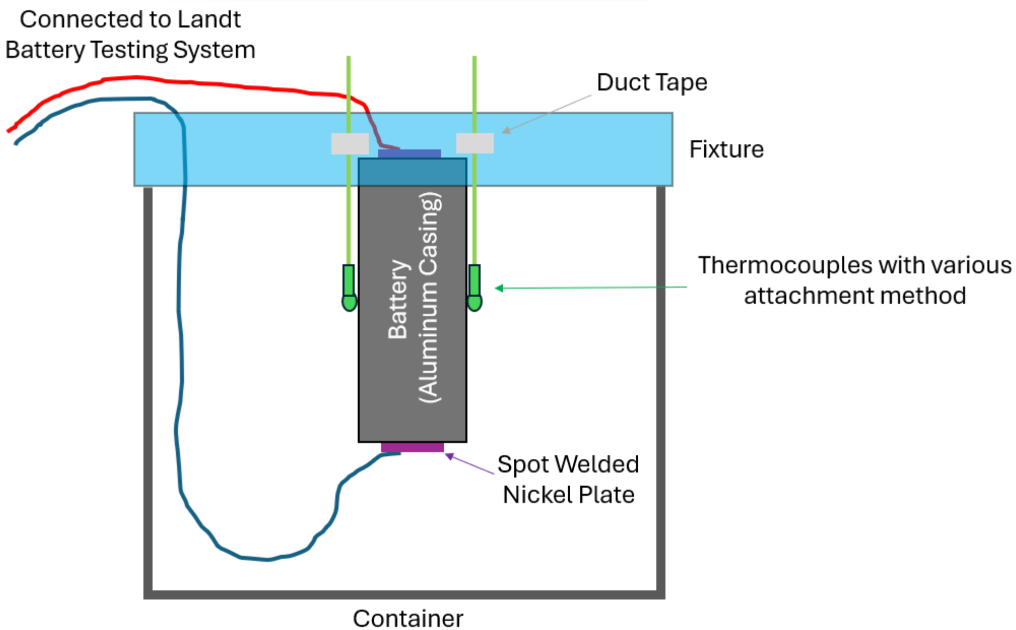


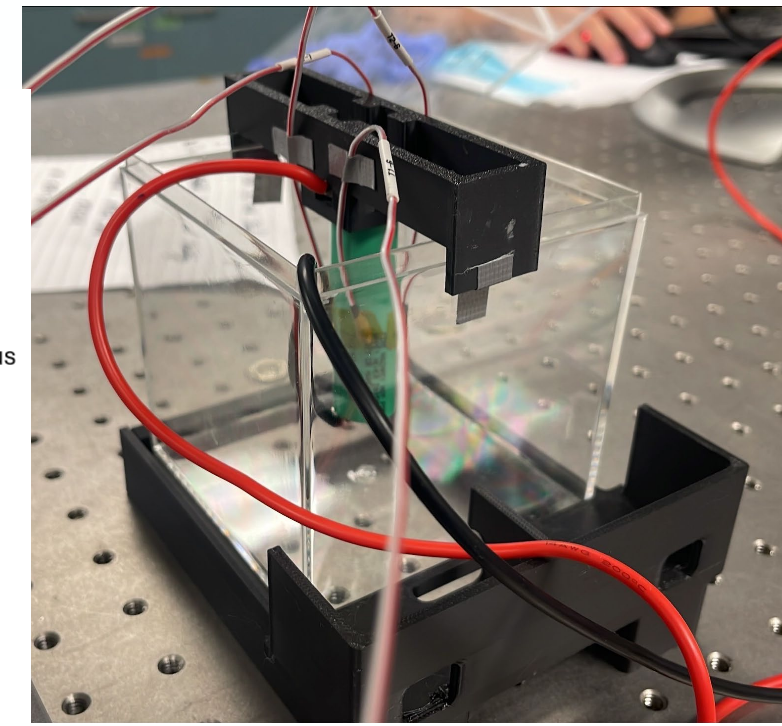
Method IV. Finding Ideal Thermocouple attachment Met



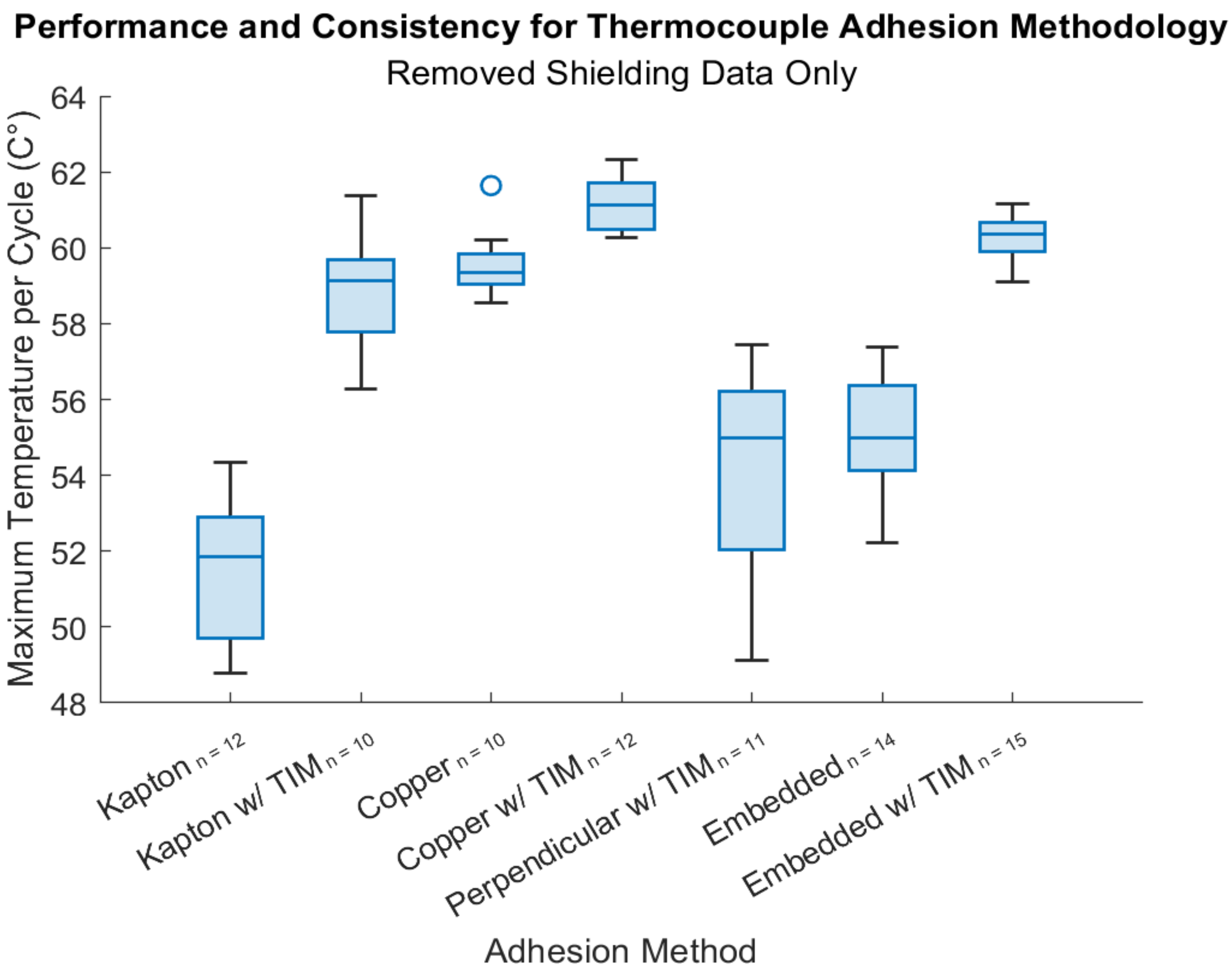








Method IV: Finding Ideal Thermocouple attachment Method



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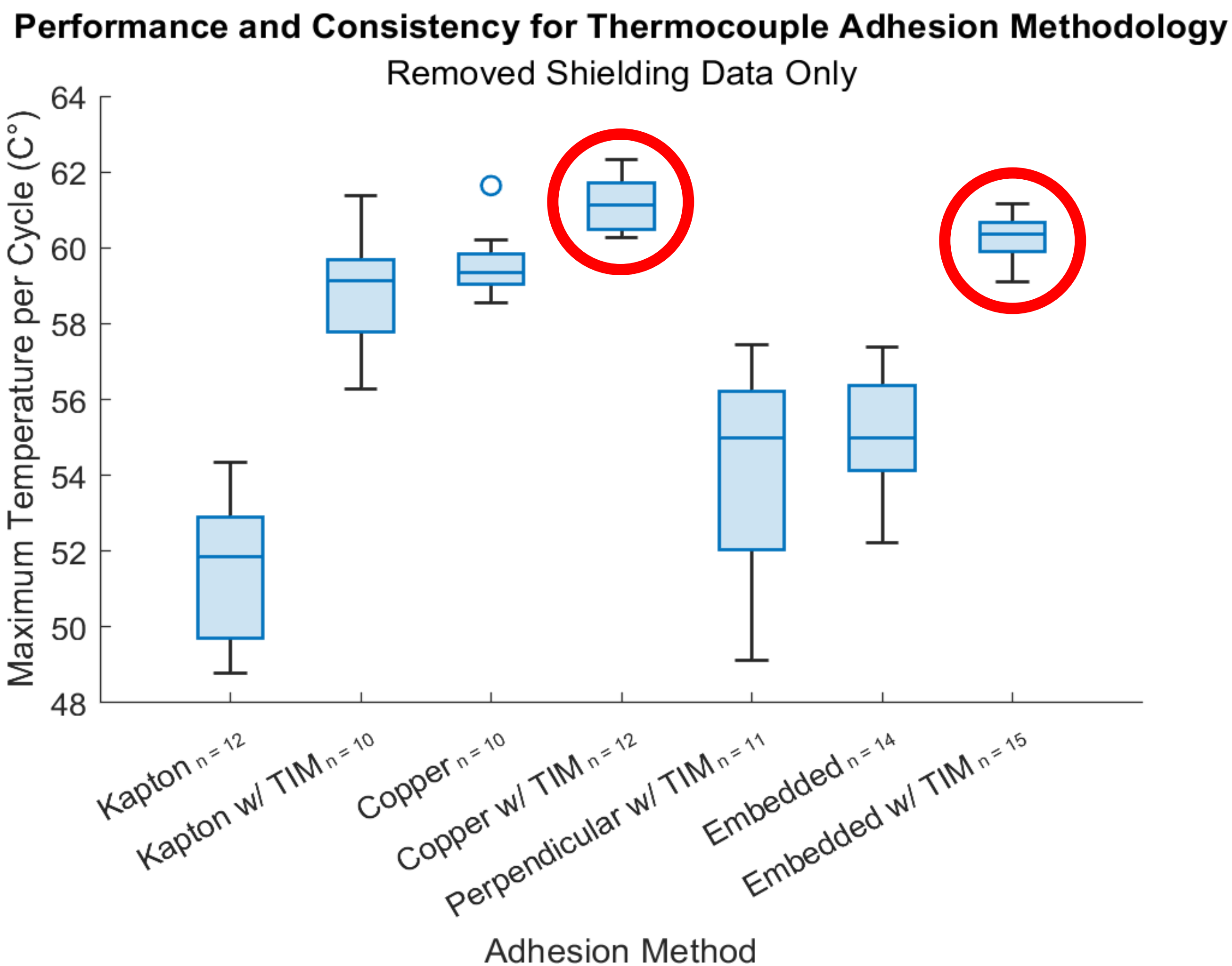
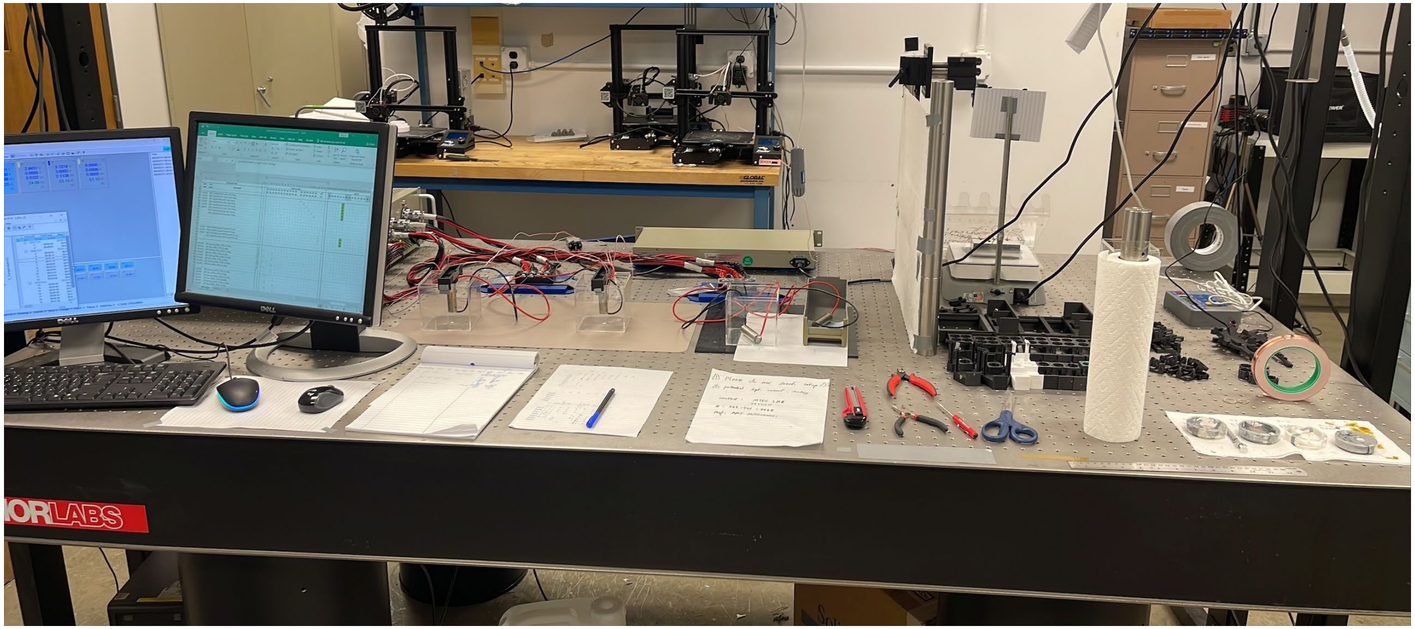
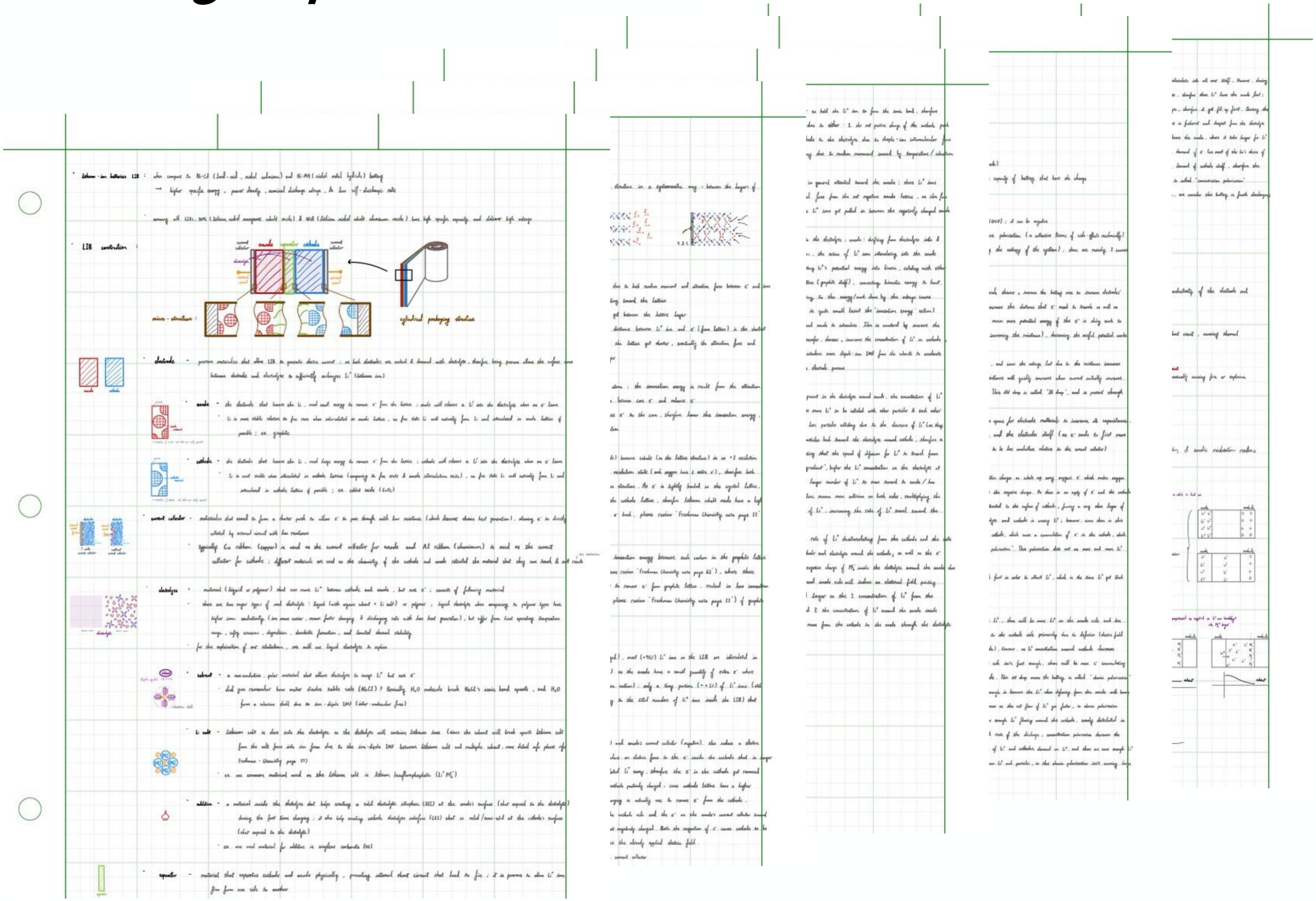


Future Direction

- Complete Testing different Battery's Measurement
- Construct battery simulator to access accurate performance of thermocouples
- Innovate better thermocouple attachment methods (ex. Silicon)
- Compare battery measurement with IR camara in air
- Devise fixtures or tools that assist attaching the thermocouples



Learning Experience



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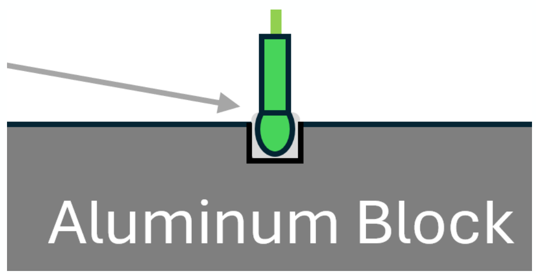
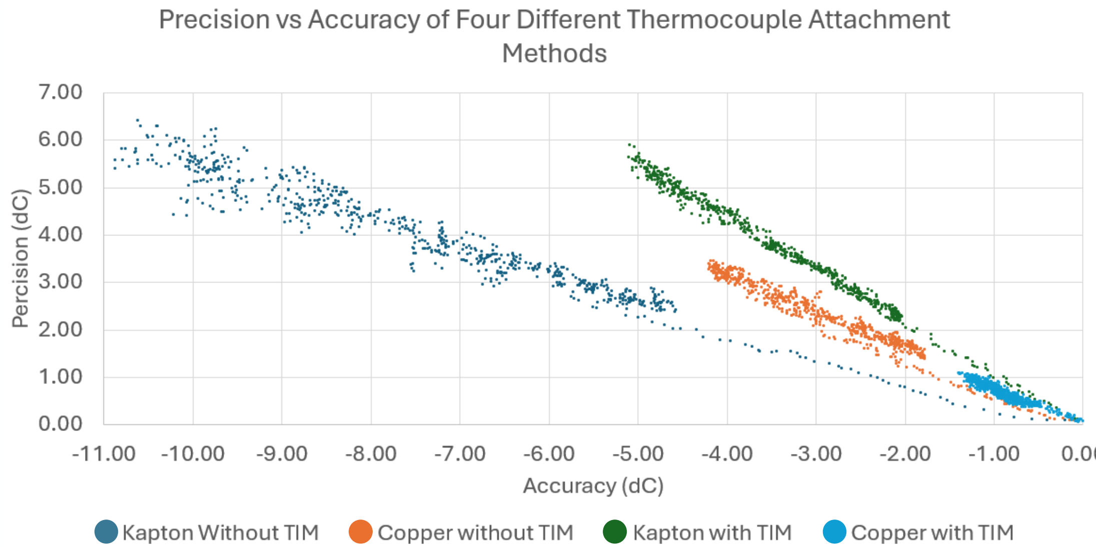
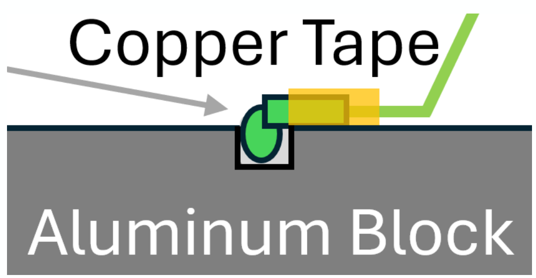


Old Method





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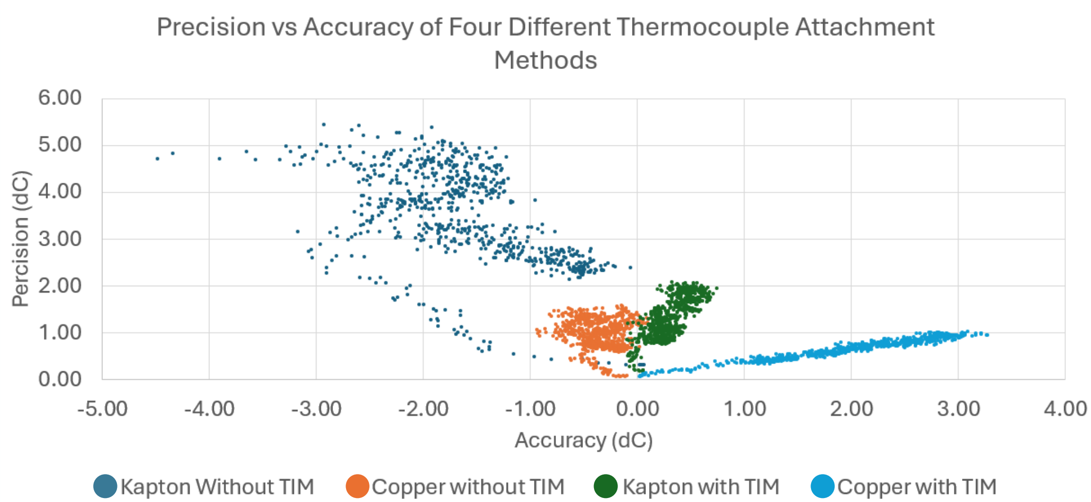

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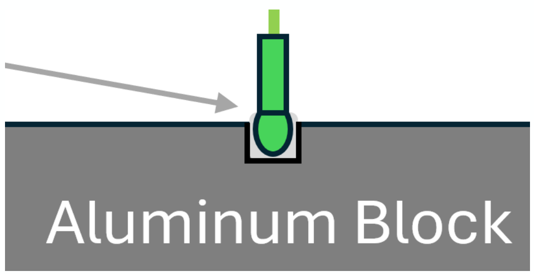

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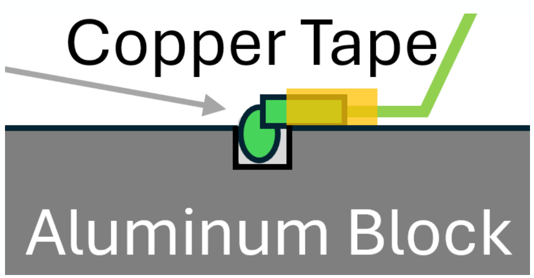

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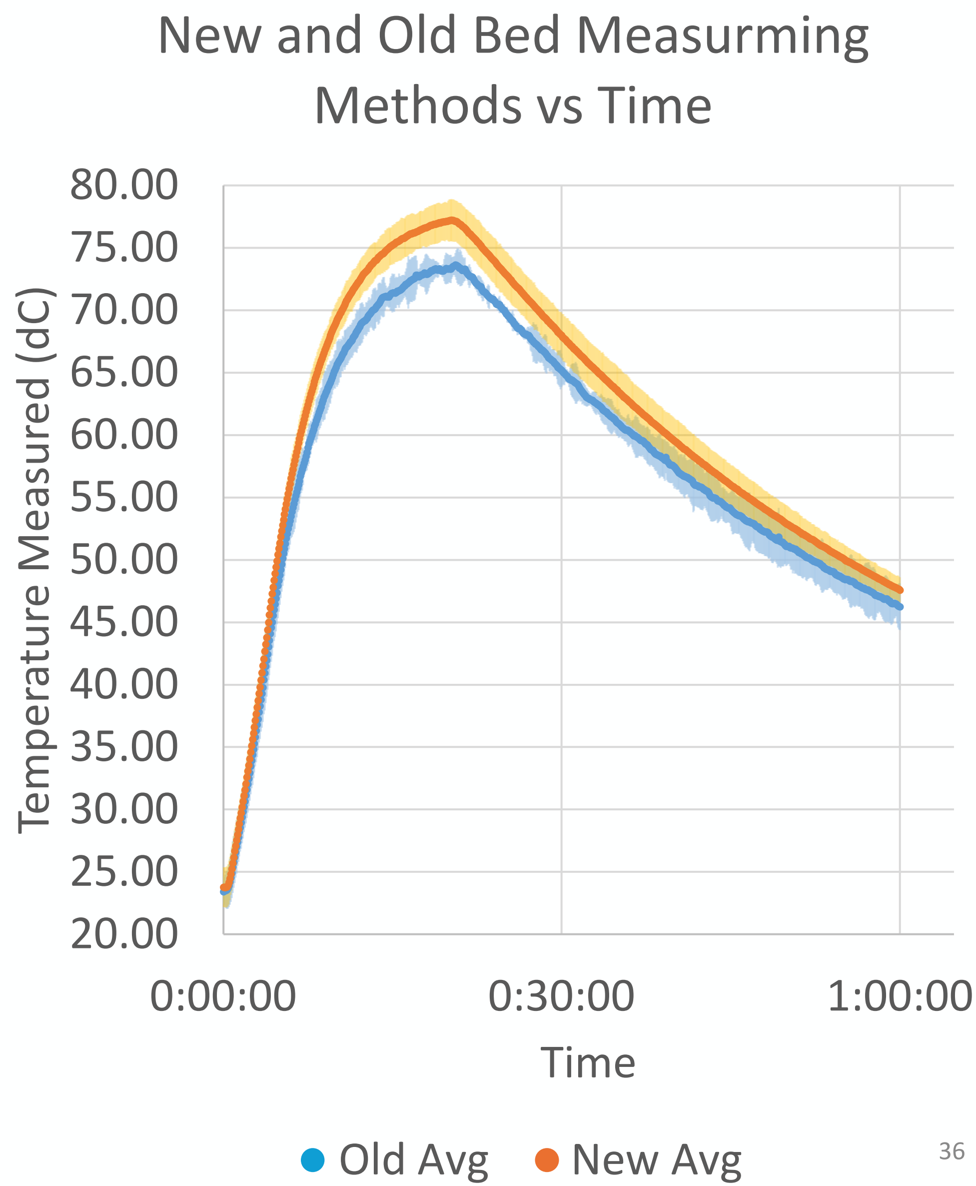

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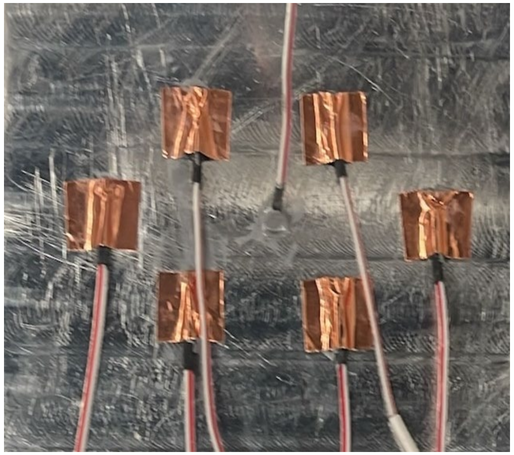

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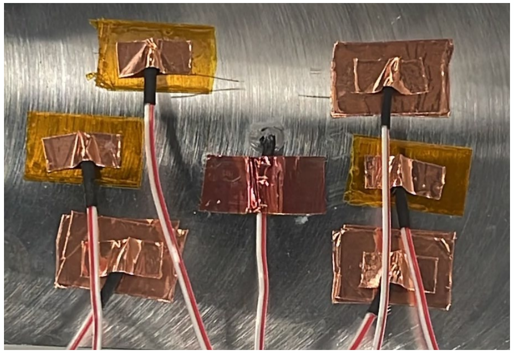

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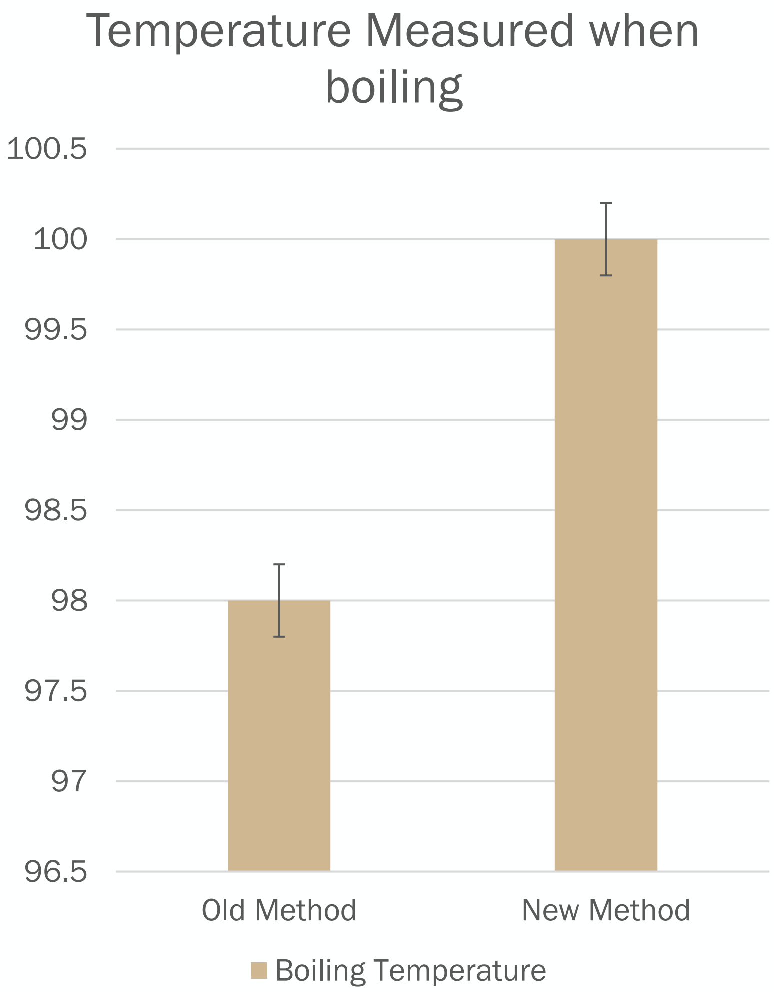

Acknowledgement

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- Sincerely appreciate the time and effort Sameep Shah invested on detailly explaining how Li battery works.
- Highly appreciate for this summer fellowship opportunity provided by Purdue EURO department.
- This material is based upon work supported by the National Science Foundation under Grant No. 2143043.
- We would like to acknowledge the support from our collaborators from battery innovation center (BIC) and Valvoline.

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Q & A

Thank You

Reference

[1] “Fire and thermal runaway propagation challenges in electric vehicles: What we recommend,” UL Research Institutes, https://ul.org/news/fire-and-thermal-runaway-propagation-challenges-electric-vehicles-what-we-recommend (accessed Jul. 25, 2024).

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