Evaporation Rate Progress Report

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2.671 GF Project

01

Objective Question + Motivation

Original Objective Question

How does plate temperature and relative humidity affect the drying rate of isopropyl alcohol?

Revised Objective Question

How do the temperature of a water-supporting surface and ambient relative humidity influence the rate of water evaporation?

Changes

- Exploring water-supporting surface temperature instead of air temperature

- Returned to water as the working fluid because the revised setup enables faster evaporation measurements while avoiding the increased fire risk associated with heating isopropyl alcohol

Motivation

- Moisture removal is critical in applications such as temperature control, dehydration, and rot prevention

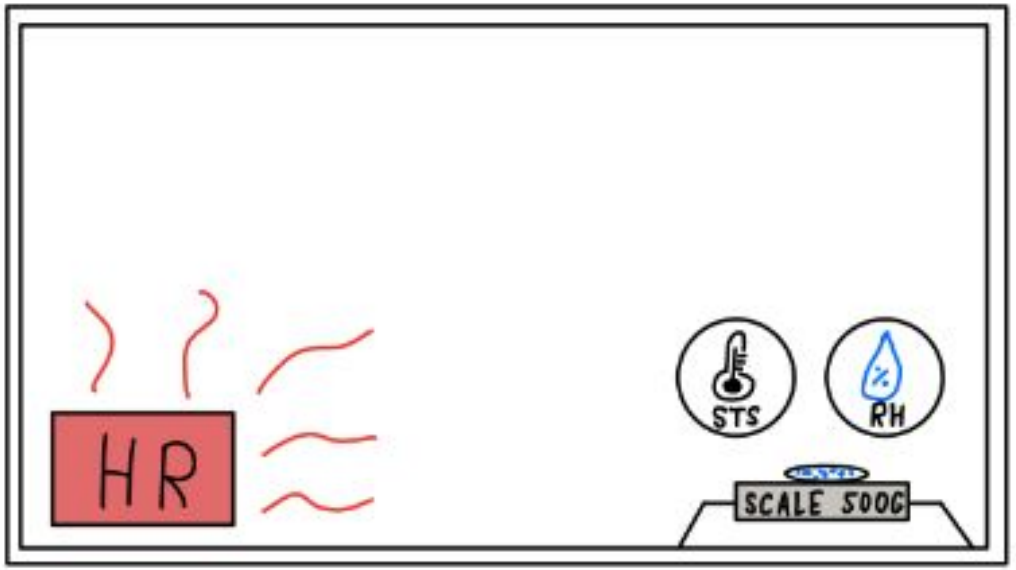
- Understanding how temperature and relative humidity affect water evaporation can help inform more energy-efficient drying processes, improve manufacturing efficiency, and support low-cost food preservation

02

Original Plan + Revisions

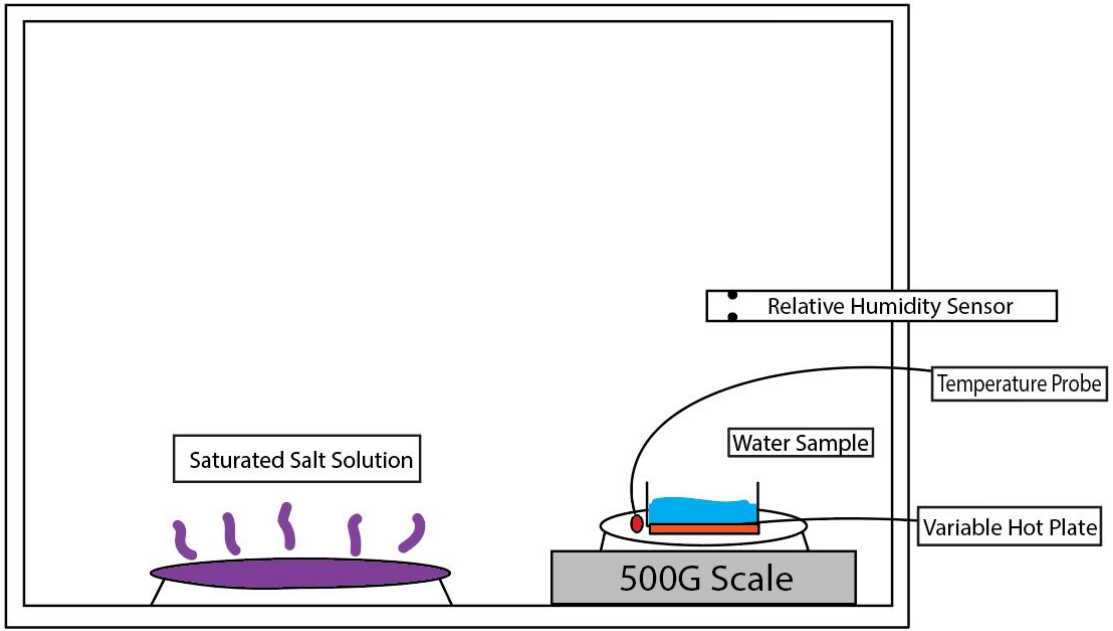
Original Set-Up

- Electric Resistive Heater to with closed loop temperature control to set air temperature
- Relative Humidity and Temperature Sensors
- Scale with water sample on it
- Closed Container
- Saturated Salt Solution for Humidity Control



Revised Set-Up

- Closed Container
- Saturated Salt Solutions for Humidity Control
- Relative Humidity Sensor
- Temperature Probe on Hot Plate/Water Sample interface
- Scale to measure mass change



Why These Changes?

Drying Times

Pilot tests showed that achieving a sufficiently wide range of air temperatures was difficult and would result in longer experiments. I therefore shifted to controlling the temperature of the water-supporting surface, which produced a more readily measurable change in evaporation rate during preliminary testing

Equipment

The 2.671 Lab had a variable hot plate in stock, while a closed loop space heater would have required purchasing

Digital Filtering

The scale's digital filtering produces a stable displayed reading but may obscure small, gradual mass changes. As a result, the current measurement setup may not have sufficient resolution to reliably quantify the water's mass loss over the duration of a trial.

Similar Question

Switching to a hot plate instead of air temperature control still answers the same question of what conditions have the greatest effect on water evaporation

03

Data Analysis

Structure

01 Set-up

Set Temperature
Set Humidity
Place Water Sample

02 Measure

Log mass of water vs time

03 Process

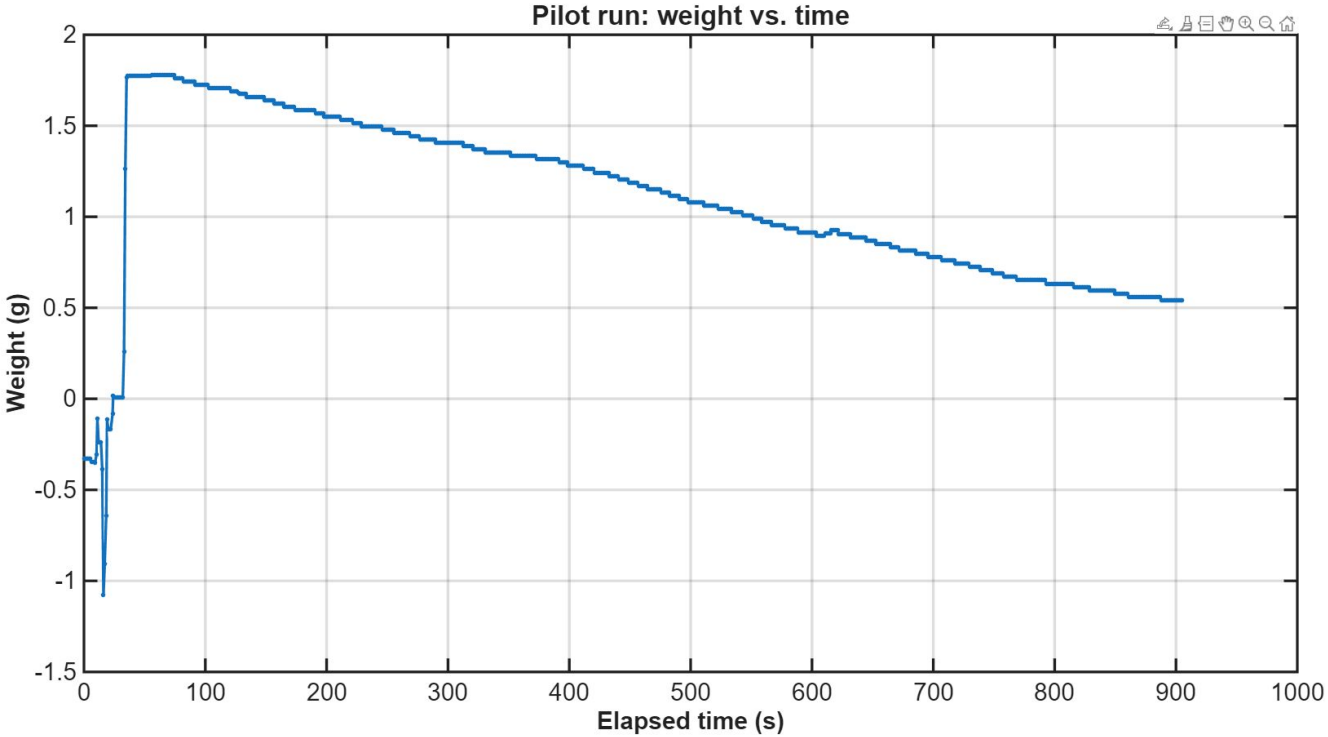
Truncate the beginning
Calculate slope

04 Plot τ for multiple trials

Run trial multiple times
Calculate τ for each trial by calculating the slope of a linear fit for the data

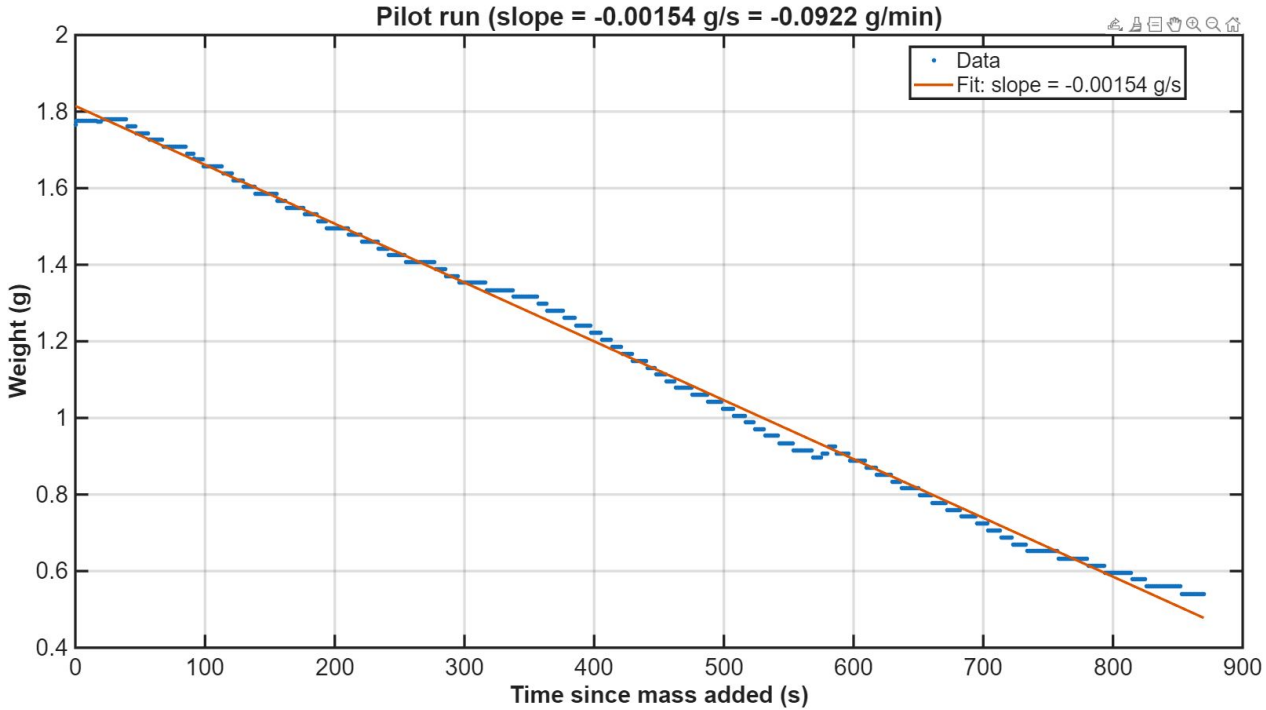
05 3D Plot τ x Temp x RH

Calculate τ at each condition
Plot surface



Raw Data Plot

Mass Water mass was recorded over approximately 15 minutes. Mass decreased approximately linearly with time, suggesting that the evaporation rate remained relatively constant during the measured interval recorded over ~15 minutes. $\frac{dm}{dt}$ appears approximately linear as expected

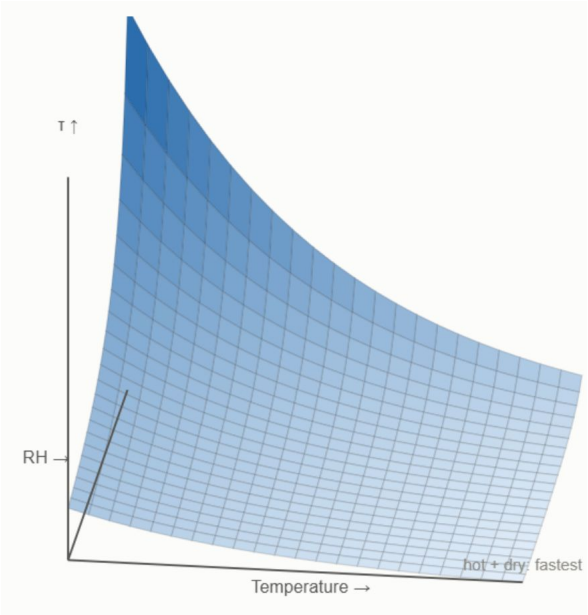


Processed Data Plot

Exclude the initial transient, plot the remaining mass measurements against time, and fit a linear regression to estimate the mass-loss rate from the slope

Next Steps

Measure the mass-loss rate at multiple surface temperatures and relative humidity levels, repeating each condition to quantify trial-to-trial variability. Use the resulting measurements to estimate uncertainty and generate a surface plot of evaporation rate as a function of temperature and relative humidity



Rough Sketch of what the final plot may look like

04

Risk

What has Gone Wrong

Scale Accuracy	• Scale struggles to register small changes in mass • The scale exhibits inconsistent readings, and the source of the measurement variability has not yet been identified
Humidity Control	• Saturated salt solution can buffer change in RH, but not prevent it. • Change in RH from water evaporation is significant
Water Container	• I originally tried using plastic containers to hold water sample, but they got melted by the heating pad
Heating Pad	• Temperature drops when water is added, making temperature harder to control

How it is Handled

Scale Accuracy	• Scale still works, but I intend to try another sensor such as the Dual-Range Force Sensor to see if it can give more accurate results
Humidity Control	• A larger chamber reduces the RH change caused by evaporation, although its humidity response will need to be validated.More salt may also work for measuring the low humidity range
Water Container	• I found a metal measuring cup which conducts heat much better
Heating Pad	• Measure using temperature when the water is in the container

Apparatus Risks

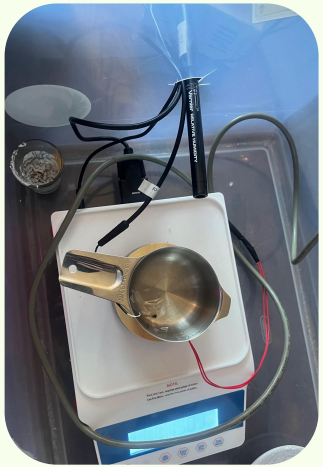
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Scale Temperature

Scale may get hotter which can lead to inaccurate measurements

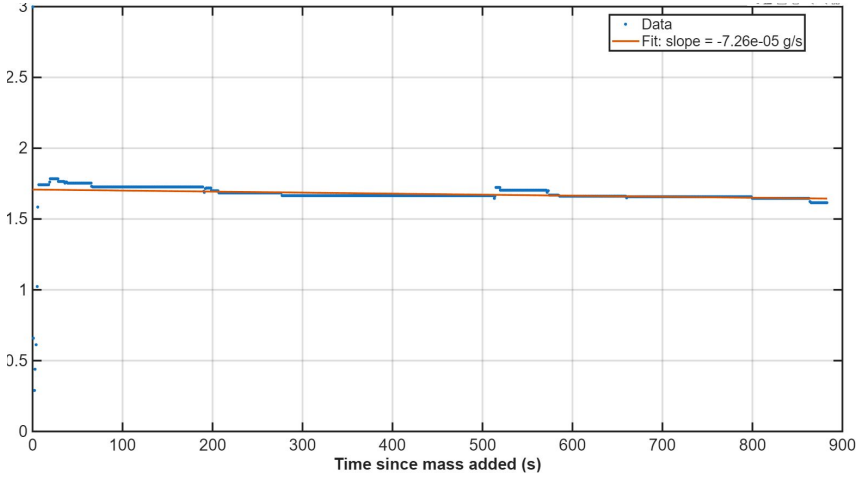
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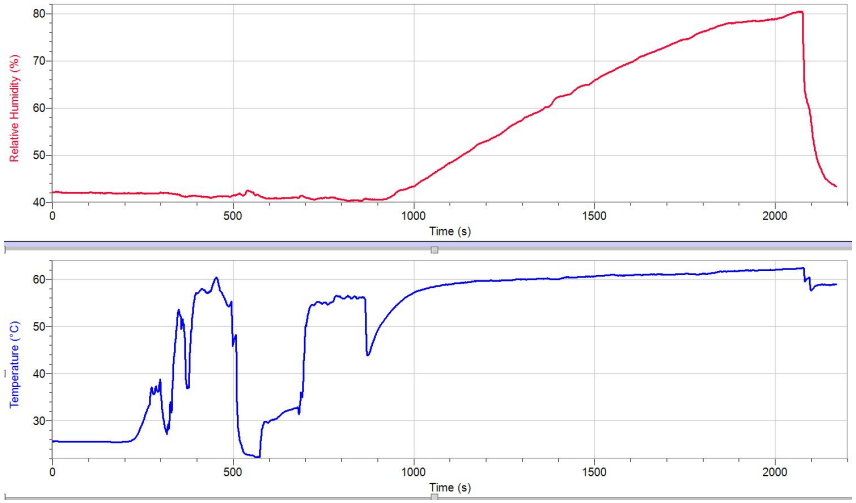


Humidity Accuracy

Air is not getting mixed which may make humidity reading inaccurate

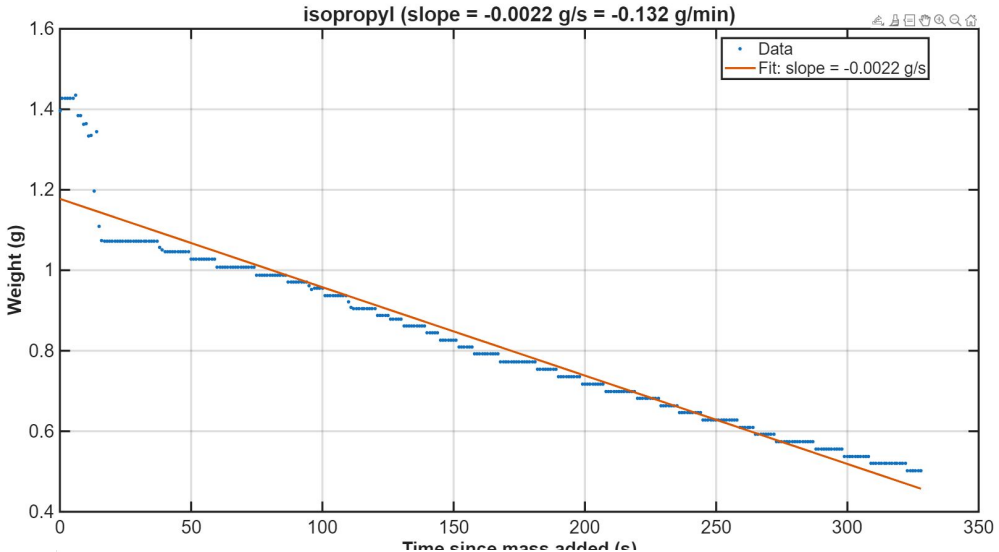
In a small closed container, mass change is too small to measure

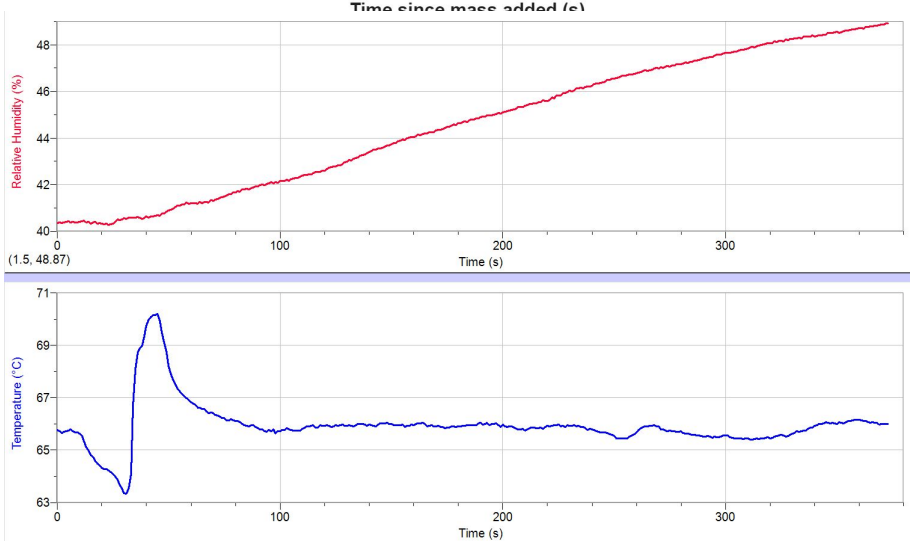




Using Isopropyl Alcohol instead of water gives more measurable results, but it brings with it a potential fire risk

Changing fluids would make my testing much faster



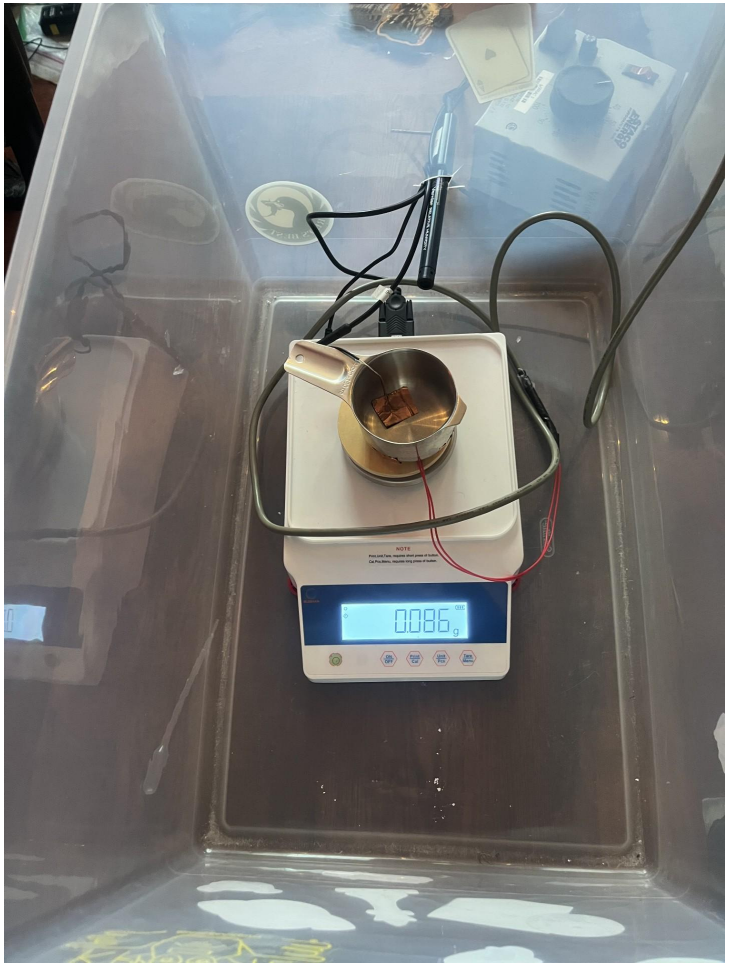


Future Needs

- Should I switch from water to isopropyl alcohol to obtain more measurable mass-loss rates, and how should I evaluate the associated safety risks?
- How can I improve the stability of my saturated salt solutions and maintain more consistent relative humidity throughout each trial?
- What could be causing the scale's inconsistent readings, and how can I determine whether an alternative sensor would provide more reliable measurements?
- How should I quantify and visualize uncertainty in my final response surface, including variability between repeated trials and uncertainty in the fitted evaporation rates?

Trial Photos

- Set up Humidity Sensor
- Scale
- Heating Platform
- Thermal Probe
- Set Humidity



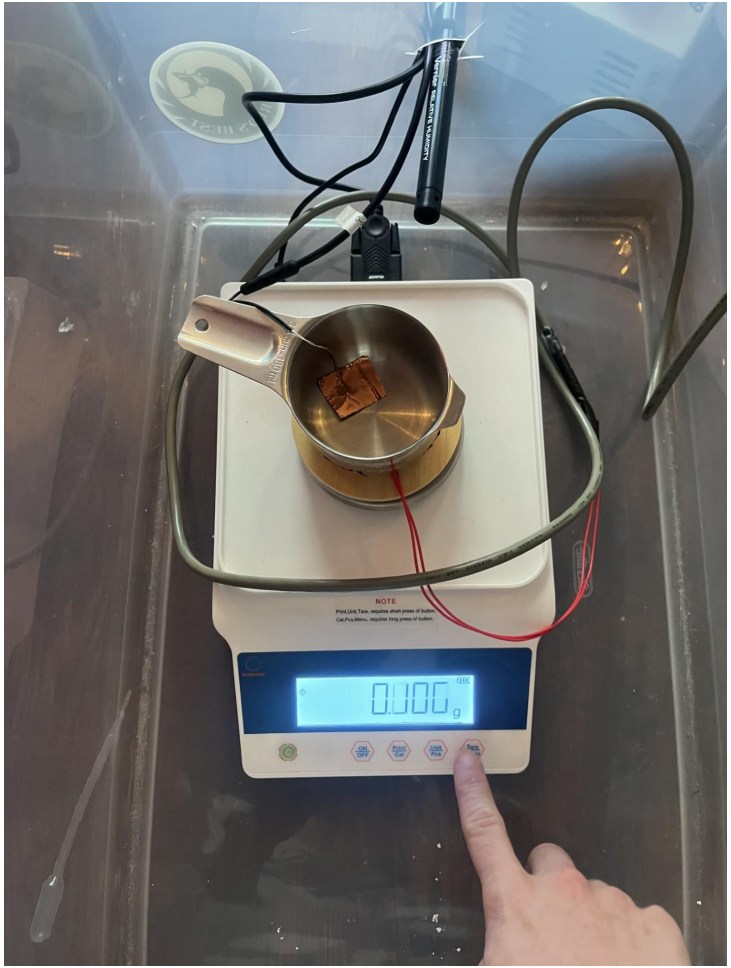
Trial Photos

- Set Variable Transformer to control Temperature



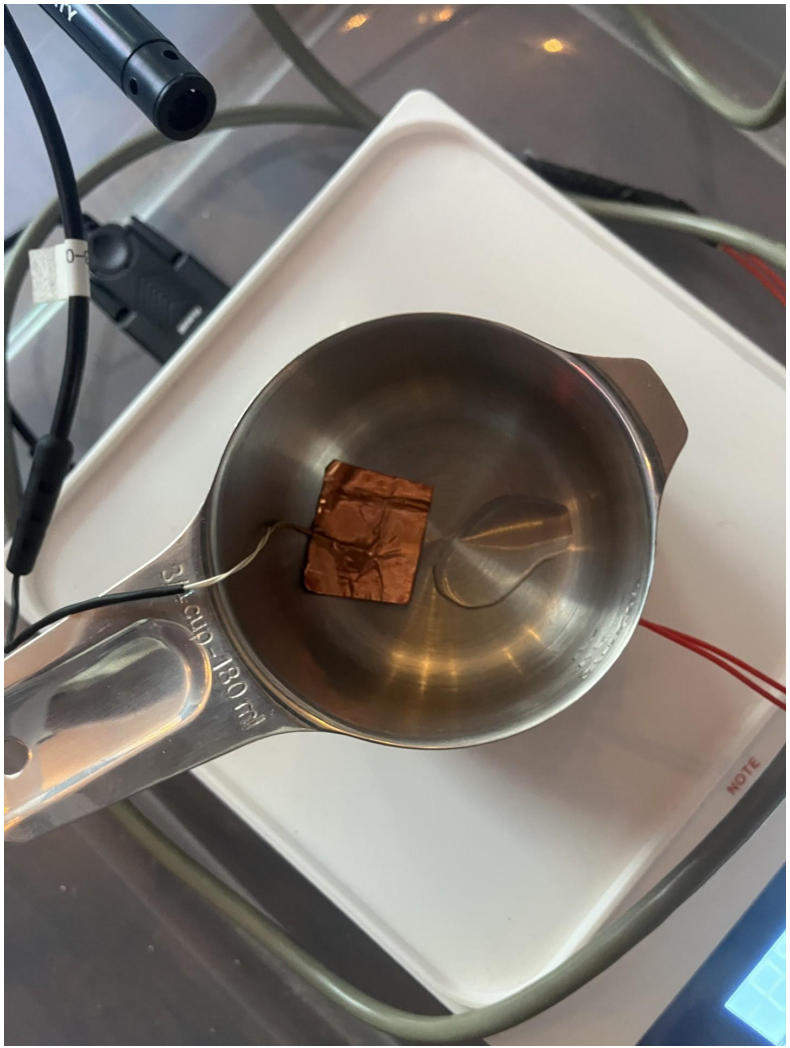
Trial Photos

- Zero the Scale



Trial Photos

- Add sample of water



Trial Photos

- Watch the RH and Temperature to check for unexpected changes

