Physics DLP: Group 2

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The Problem: Horse Laminitis

Horse laminitis: The inflammation and damage of the tissue that separates the hoof and underlying hoof bone. It slowly deteriorates the hoof until the horse can no longer properly walk on it.

Modern literature suggests that while there is no cure, cold temperature treatment between 41–50 degrees fahrenheit can slow or halt its progression.

UIUC Animal Science Solution and Our Constraints

- Currently the UIUC Horse Farm treats their horses by dunking their hooves directly in an ice bath.
    - Issue with this solution is that it is not the correct temperature.
    - Horses can be uncomfortable due to the cold water on skin.
- Constraints
    - Must be low power
    - Must work outdoors
    - Must be comfortable for the horse

Proposal

- Our Proposal is an insulating wrap the keeps the horse leg temperature at 41–50 degrees fahrenheit
    - Cold enough to to treat laminitis
    - Warm enough not to bother the horse
    - Essentially a very bad wetsuit

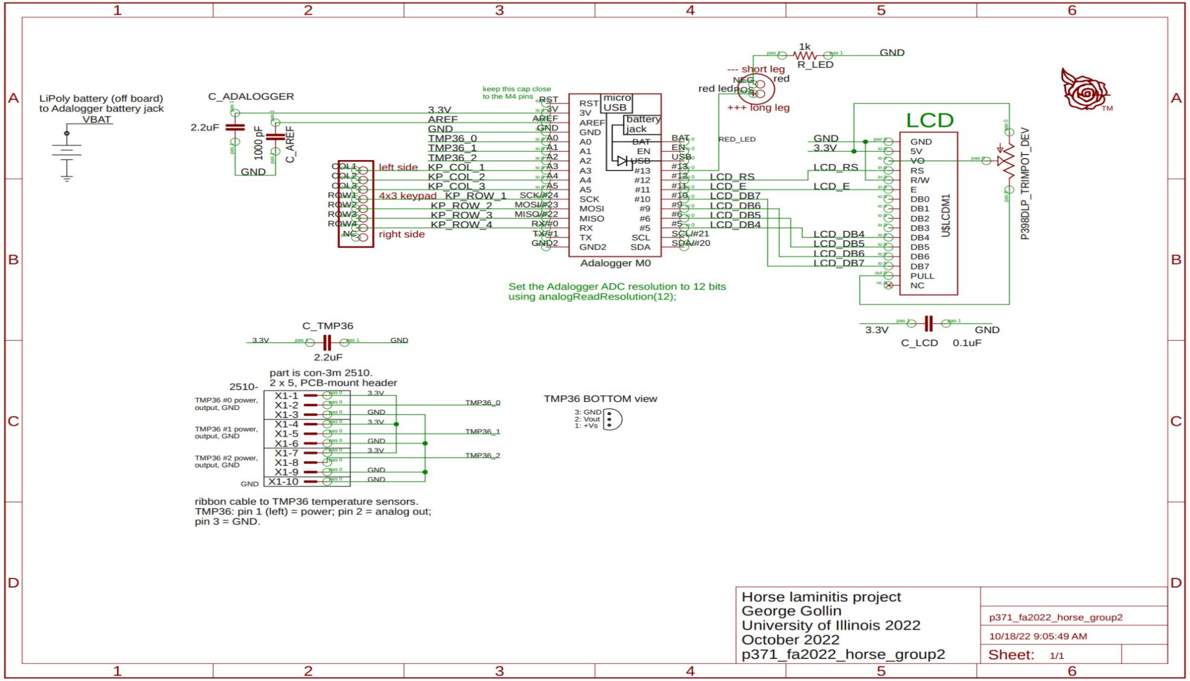
Aude Reubrecht Tinney Eventing / Rex Features

The suits, made by Australian company Hidez, are designed to help horses recover from travel and strenuous exercise.

Our Technical Materials

- **Adafruit Feather M0 Adalogger**
  - Monitor sensors with Analog to Digital Converter
- **LCD**
  - Display information about setup and operation
- **Three TMP36 Analog Temperature Sensors**
  - Measure the temperature of water inside and outside of our insulating wrap
- **3x4 Keypad**
  - Start and stop recording
- **LED**
  - Replicate the smaller LED on the Adalogger
- **MicroSD Card**
  - Store data collected while recording

Our Schematic



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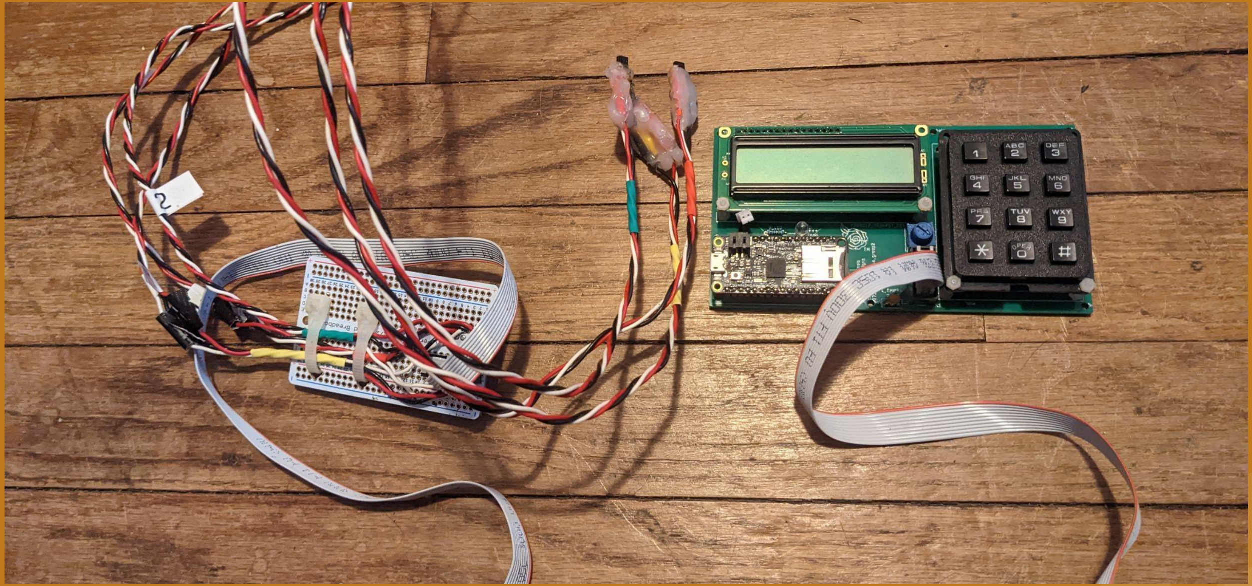
Our Device



Materials for Our Wrap

Made with the following materials.

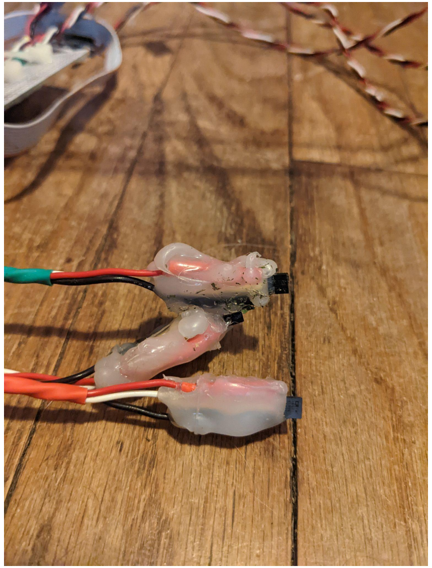
- Flexible styrofoam sheets (0.125” x 8” x 14”)
- 1” Polyester Belting
- 1” Velcro Tape
- Duct Tape

Our original design included 0.25” latex tubing to make a seal around the edge, but it was far too hard to work with. Instead we allowed water flow more freely.

Our Wrap/Set Up

Technical Issues: Water Damage

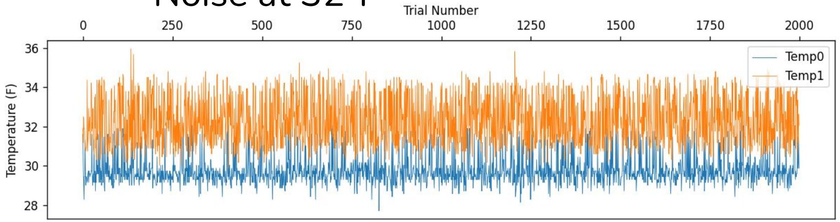
- In preliminary trials, we were experiencing issues with our temperature sensors being very strange and having awful readings
  - Reading very high temperature in ice water
- We suspected that water was somehow getting into the plastic casing.
- Confirmed the problem doesn't occur before the sensors goes into water.
- Hot glued the sensors to waterproof them, and the issue went away



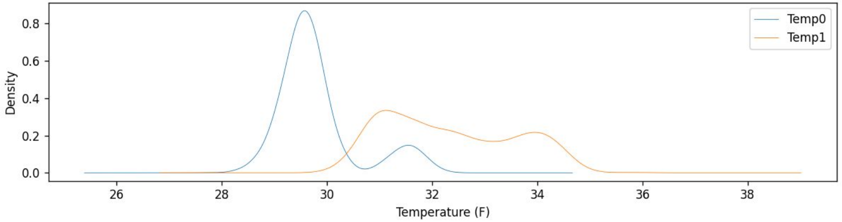
Technical Issues: Noise

- Temperature sensors were submerged in 32°F water and data collected as fast as possible (<1 sec).
- Measurement fluctuate by ±2.5°F for Temperature Sensor 0 and ±2.0°F for Temperature Sensor 1.
- Could not find an explanation for the differences
- If we averaged the temperature over 100s of readings, the impact noise was completely erased.

Noise at 32°F



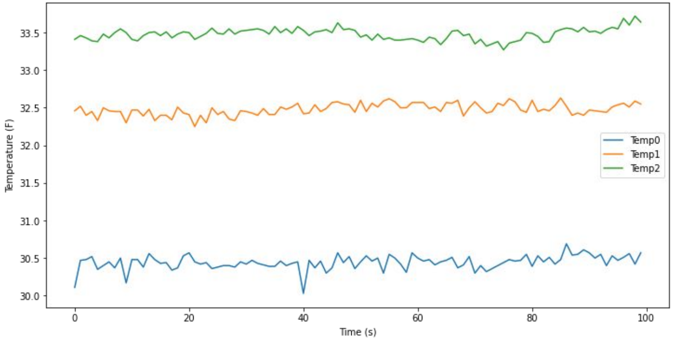
Density Estimates of Noise at 32°F



Technical Issues: Sensor Inaccuracy

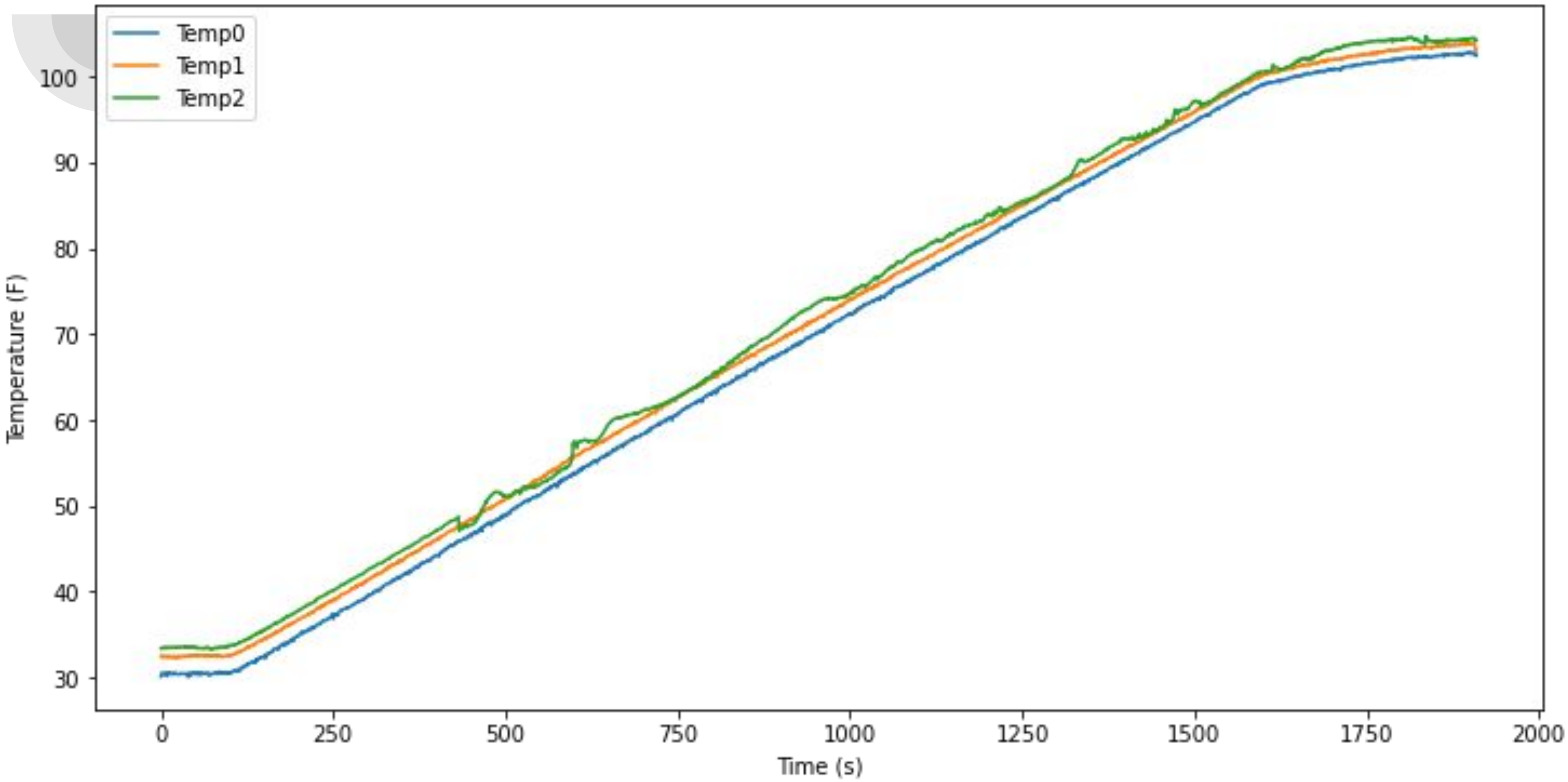
- Sensors have documented inaccuracy of ±3.6°F.
- Sensors were recorded in 32°F water.
- Averages over 100 second were calculated and offset were found.
- To find real temperature, corrections need to be added.
- Tested from 32°F to 100°F and offsets stayed constant
  - One of the three sensors would spontaneously start to wander. We removed it from our trials.

Measurements in 32°F water



Sensor	Mean Temperature (F)	Correction (F)
Temp0	30.44	+1.56
Temp1	32.48	-0.48
Temp2	33.48	-1.48

Temperature Sensors in Linearly Increasing Bath from 32–100°F



You can see sensor we removed wandering

Horse Setup

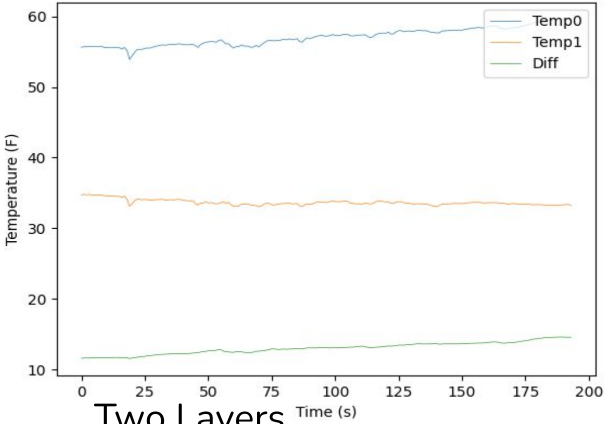
- A 5 gallon bucket was filled with ice packs and water.
- Temperature sensors were attached to the inside and outside of the wrap.
    - Temp0 inside and Temp1 outside
- The wrap was strapped to horse leg so that it covered the hoof and ankle.
- The horse leg was coaxed into the bucket.

Horse Trials

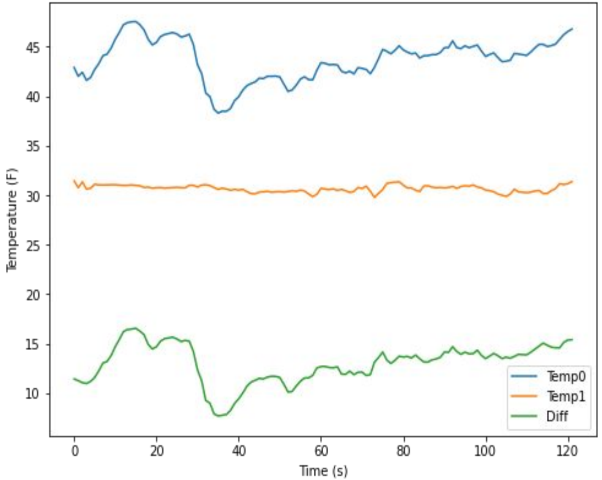
- Two trials were successfully completed (3 and 2 layers).
- The horse often knocked over the bucket requiring the trial be restarted.
- The process required a significant amount of time and patience.
- Preliminary analysis relieved we could stop at 2 layers.

Number of Layers	Temperature (F)
3	60.27
2	46.16

Three Layers

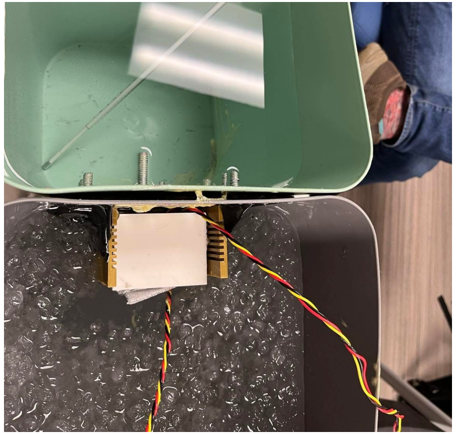


Two Layers



Lab Model Setup

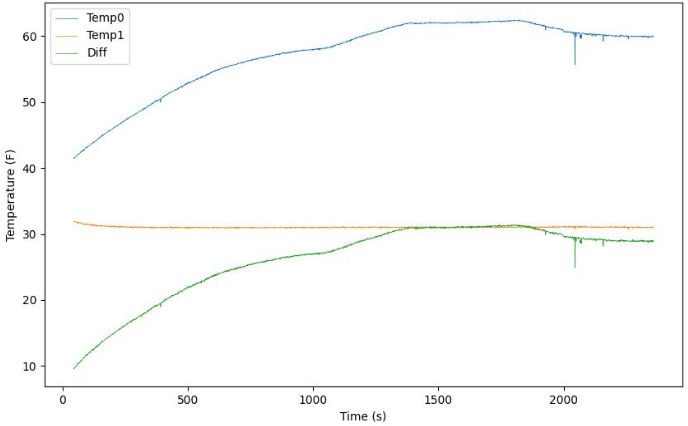
- Two plastic containers were attached together with thin Aluminum window.
- Cold side was chilled with Ice to 32°F with 3D-printed channel attached to window.
- Hot side was heated with an Immersion Circulator to 99°F, a normal temperature for a horse.
- Layers of foam inserted in channel with Temp Sensors on both sides to mimic the wrap.
- Missing the insulation of the horse hoof. That is tuned dynamically in the first trial.



Lab Trials

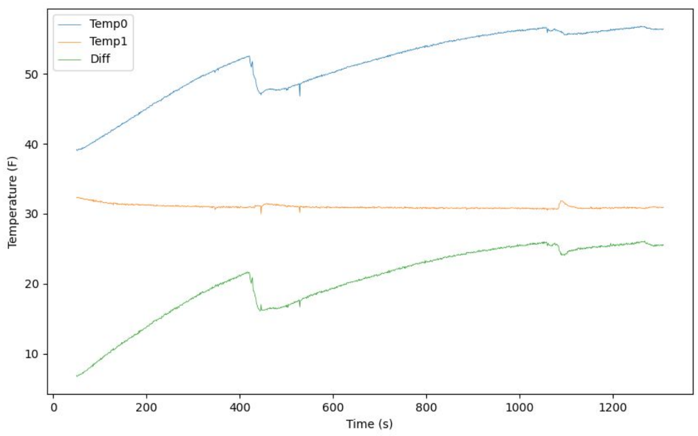
- First trial with 3 layers is to tuned the amount of hoof insulation (Shown in graph).
- Insulation is added to hot side until internal temperature nears the 60.27°F we found during the horse trial with 3 layers.
- With the proper amount of hoof insulation attached, subsequent trials with a varying number of layers were done.
- Also ran test with aluminum layer to understand effects of just convection in model.

Tuning Trial with 3 Layers

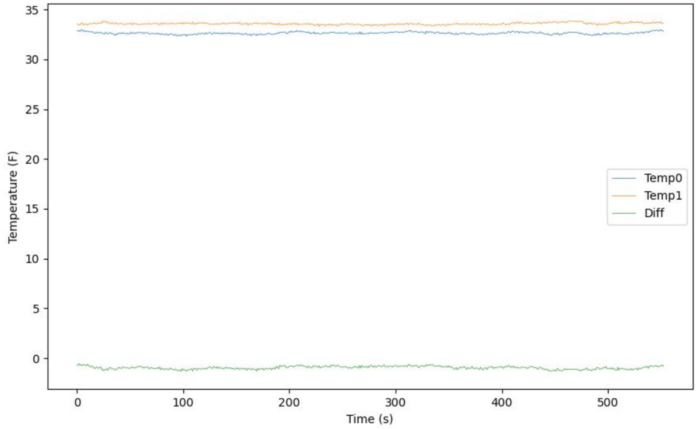


Number of Layers	Temperature (F)
3	61.49
2	58.10
1	52.44
0	34.26
Aluminum	45.71

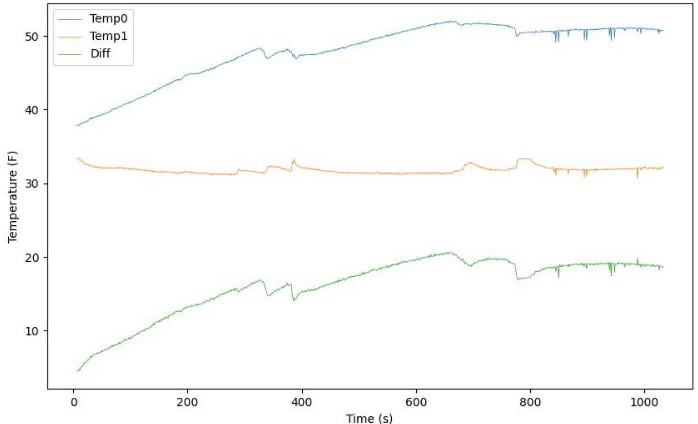
Trial with 2 Layers



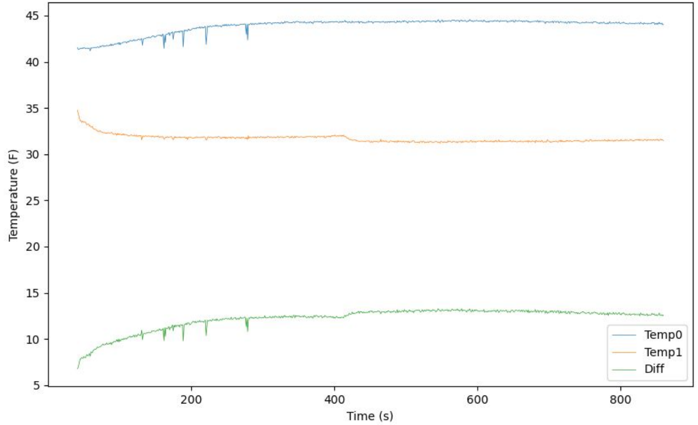
Trial with 0 Layers



Trial with 1 Layer

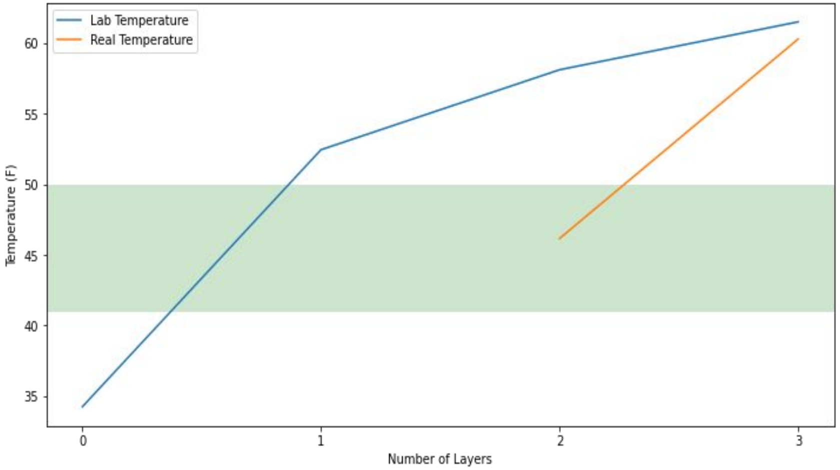


Trial with thin Aluminum Layer



Data Analysis

- Percent error at 3 layers is 2%.
- Percent error at 2 layers is 25%.
- Thermal equilibrium problems are not chaotic, so we know our model is incorrect.
- Test with aluminum has similar temperature to 2 layers in the horse trial, so we know the inaccuracy is most likely from a difference in convection.



Our Conclusion/Future Developments

- We found using two layers was the most optimal.
- We found our naive model does not accurately represent the problem.
- One avenue we can explore is accounting for the change in horse leg temperature.
- Another is ways to dynamically control the insulative properties of the wrap.
    - Heaters
    - Controlling flow of water
    - Physically deforming the wrap
    - Altering the viscosity
- The last direction is a more accurate model of problem.
    - Tuning both water flow and insulation of hoof in the model.

References

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